WINGECARRIBEE SHIRE COUNCIL

Nattai Ponds Catchment

Floodplain Risk Management Study & Draft Plan

Final Report

Volume 1 of 2: Report Text & Appendices

Revision 3
December 2019

Catchment Simulation Solutions

Nattai Ponds Catchment

Floodplain Risk Management Study

Final Report

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Overview

The Nattai Ponds catchment is located within the Wingecarribee Shire Council LGA on the Southern Highlands of New South Wales and occupies a total area of 7.9 km^2. The catchment comprises a mix of urbanised and rural land uses and includes the suburbs of Renwick, Balaclava and Braemar, the eastern sections of Mittagong as well as Willow Vale. 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 flooding problems, Wingecarribee Shire Council commisioned Catchment Simulation Solutions to prepare a Floodplain Risk Management Study and Plan for the area. The primary goal of the project was to quantify the nature and extent of the existing flooding problem and evaluate options that could be potentially implemented to manage the existing, future and continuing flood risk.

The 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 *'Nattai Ponds Flood Study'* (Catchment Simulation Solutions, 2016). The models were updated as part of the current study including application of the revised hydrologic procedures outlined in the 2016 version of Australian Rainfall and Runoff.

The outputs from the flood simulations were used to quantify the potential impact of flooding on people, vehicles and property across the catchment for existing as well as potential future catchment conditions. The outcomes of the modelling determined that:

- 1 property would likely experience above floor flooding in a 10% AEP flood. During a 1% AEP flood, 6 properties are predicted to experience above floor inundation and during the probable maximum flood (PMF), over 100 properties are likely to experience above floor inundation.
- A number of roadways are predicted to be cut by floodwaters during the 1% AEP flood. This includes Inkerman Road, Scarlet Street and Braemar Avenue. During the PMF, the

Old Hume Highway, Hume Motorway and Bong Bong Road are also predicted to be cut by floodwaters.

- The average annual flood damage cost for existing catchment conditions would be about $21,000. Properties located in the following areas are expected to suffer the highest flood damage costs:
  - Biggera Street, Braemar;
  - Inkerman Road and Scarlett Street, Balaclava;
  - Braemar Industrial Area;

Impacts of Future Catchment Development

Future development across the catchment 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 a minimum of 5 to 10% across most areas and peak flood levels/depths are predicted to increase by over 0.2 metres at some locations. The increases in flood flows, levels and depths are predicted to increase existing average annual flood damages costs by around $2,000 per annum.

Impacts of Climate Change

Increases in rainfall associated with climate change also has the potential to increase the existing flood risk. More specifically:

- A 14% increase in rainfall will likely result in an additional 5 properties being exposed to above floor flooding during a 1% AEP flood. This is expected to cause an additional $358,000 worth of damage across the catchment during a 1% AEP flood (a 122% increase in damages relative to existing conditions)
- A 34% increase in rainfall is predicted to result in 9 additional properties being exposed to above floor flooding inundation during a 1% AEP flood and result in an additional $603,000 worth of damage across the catchment (a 206% increase in damages relative to existing conditions).

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. 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

Based upon the outcomes of the detailed evaluation, the options outlined in **Table 1** are recommended for implementation to assist in better managing the existing, future and continuing flood risk across the catchment. This Floodplain Risk Management Study is accompanied by a Floodplain Risk Management Plan (FRMP). The FRMP provides a consolidated overview of each of the recommended flood risk management options, including likely costs, implementation schedules and implementation responsibility.

Several other options were also identified as being beneficial in better managing the flood risk. However, they were found to afford little financial benefits and are, therefore, not recommended as part of the Plan. However, Council could look to implement these options as part of its capital works program in the future. These options include:

- Upgrading of the stormwater system between Biggera Street and Old Hume Highway (near the Old Pot Factory) (FM5)
- Enlargement of the existing channels in the vicinity of Inkerman Road and Scarlet Street (FM12)
- Upgrade of Inkerman Road and Scarlet Street (RM7)

It is also advised that Council monitors flooding in the Inkerman Road and Scarlet Street area during future storm events.

Draft 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 draft Floodplain Risk Management Plan for the Nattai Ponds 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 48**.

It is expected that implementation of the plan will have a capital cost of approximately $420,000. In addition to the capital costs, some options will require an investment in time from various agencies including Wingecarribee Shire Council and the State Emergency Service in addition to monetary contributions.

It needs to be recognised that implementation of the flood modification options will not eliminate the potential for flooding within the Nattai Ponds 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 these aimed to reduce 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.

Table 1 Recommended Floodplain Risk Management Options for the Nattai Ponds catchment

#	Option Description	Report Section	Cost	Implementation Responsibility	Priority
Flood Modification Options					
FM8	Elevate railway embankment near Biggera Street	7.4.1	$370,000	Council & OEH	Medium
FM9	Enlarge drainage channels adjacent to Braemar industrial area	7.5.1	$50,000	Council & OEH	Medium
Property Modification Options					
PM1	LEP Amendments	8.2	Council Time	Council	High
PM2	DCP Amendments	8.2.2	Council Time	Council	High
PM3	Update Section 10.7 certificate information	8.2.3	Council Time	Council	High
Response Modification Options					
RM1	Local Flood Plan Updates	9.2.1	SES Time	SES	High
RM2	Community Education	9.2.2	Council & SES Time	Council & SES	High
RM3	Make property level flood information available	9.2.3	Council	Council	High
RM4	Encourage the community to develop household Flood Plans	9.2.4	Council & SES Time	SES / Individual Residents	High
RM5	Encourage the community to develop business Flood Plans	9.2.4	Council & SES Time	SES / Individual Business Owners	High
RM6	Develop a safe on-site refuge policy	9.2.5	Council & SES Time	Council	Medium
Options for Reducing the Future Flood Risk					
Fut1	Onsite Detention Policy	10.2	Council Time	Council	High
Fut2	Do not increase future development densities in flood constrained land	10.3	Council Time	Council	High

1 INTRODUCTION

1.1 Background

The Nattai Ponds catchment is located in the Southern Highlands of New South Wales and occupies a total area of 7.9 km^2. The extent of the catchment is shown in **Figure 1**.

The catchment originates near the intersection of Range Road and Old South Road at Mittagong and drains in a north-easterly direction through the suburbs of Renwick, Balaclava and Braemar. It continues to drain in a northerly direction beneath the Hume Highway and into Sheepwash Creek which, in turn, drains into the Nattai River. The eastern sections of Mittagong as well as the suburb of Willow Vale also fall within the Nattai Ponds catchment.

The main watercourse that drains through the catchment has no formal name according to the Geographical Names Board of NSW. Previous investigations have referred to it as the 'Nattai Rivulet' and 'Nattai Ponds Creek'. For the purposes of this investigation, it shall be referred to as the main watercourse.

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 has been experienced on several occasions in the past, particularly across properties fronting Inkerman Road, Scarlet Street and Braemar Avenue.

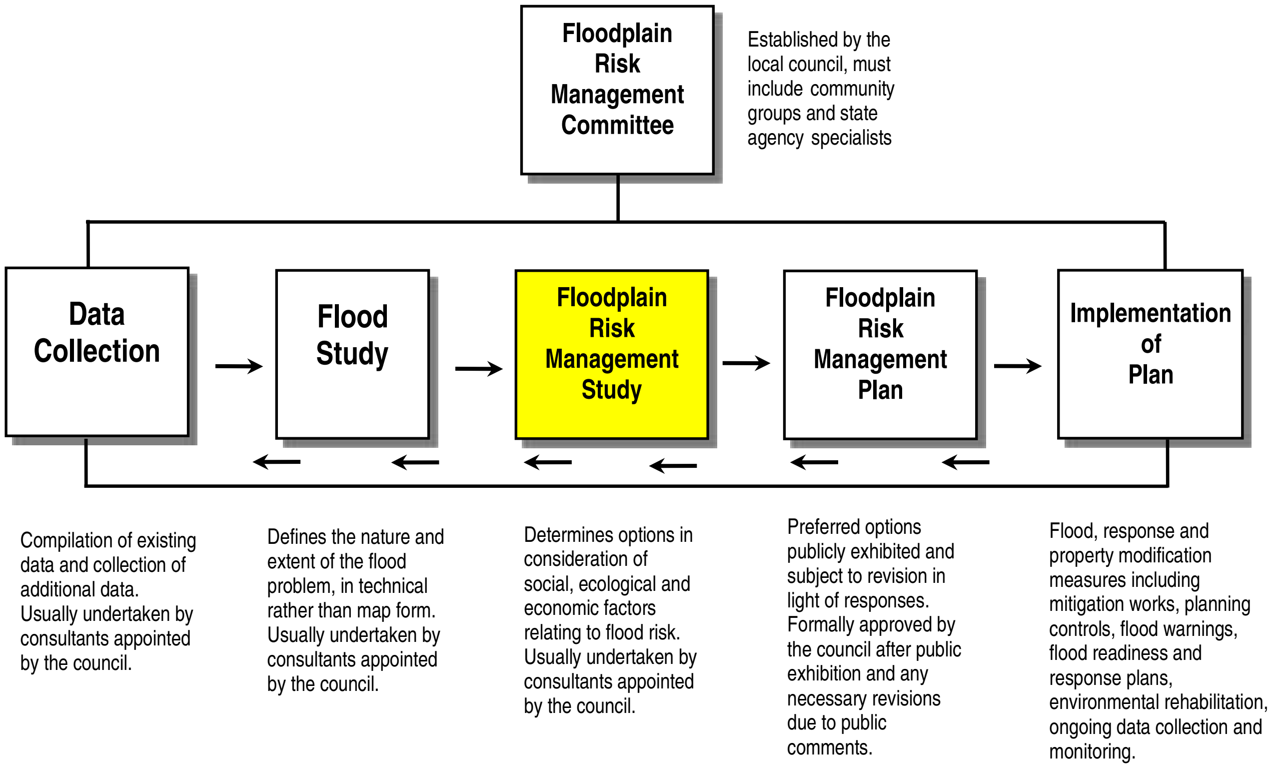
In recognition of the existing and potential future flooding problems, Wingecarribee Shire Council commisioned Catchment Simulation Solutions to prepare this Floodplain Risk Management Study and Plan for the catchment.

1.2 The Floodplain Risk Management Process

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

Under the Policy, the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Local Government in its floodplain management responsibilities.

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



Stages 1 and 2 of the process were previously completed culminating in the preparation of the *'Nattai Ponds Flood Study'* (Catchment Simulation Solutions, 2016).

Wingecarribee Shire Council engaged Catchment Simulation Solutions to prepare the *Nattai Ponds Floodplain Risk Management Study*, which represent Stage 3 of the floodplain risk management process outlined above. The aim of the Floodplain Risk Management Study is to identify, assess and compare various options for managing the flood risk across the catchment. The outcomes from the Floodplain Risk Management Study were subsequently used to inform the *Floodplain Risk Management Plan* for the Nattai Ponds catchment, which is documented in Section 11 of this report.

Technical and financial support for the project was provided by the NSW Government's Floodplain Management Program.

1.3 Report Structure

The following report forms the Floodplain Risk Management Study and Plan for the Nattai Ponds catchment. It has been divided into the following sections:

- Section 2 - Catchment Information: Provides general information regarding the catchment, including the history of flooding and previous 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 – Current Emergency Management Protocols: provides an overview of emergency management measures that are currently implemented across the catchment to assist in managing the flood risk. Opportunities to improve these existing protocols are also discussed.
- Section 6 – Options for Managing the Flood Risk: Outlines options that could be potentially implemented to manage the existing, future and continuing flood risk across the study area, including what options were ultimately selected for detailed assessment.
- Sections 7 to 10: discusses the outcomes of the detailed assessment of a range of flood, property and response modification measures that could be potentially employed to manage the existing, future and continuing flood risk across the catchment.

2 CATCHMENT INFORMATION

2.1 Catchment Description

The Nattai Ponds catchment is located in the Southern Highlands of New South Wales and occupies a total area of 7.9 km^2. The extent of the catchment is shown in **Figure 1**.

The catchment originates near the intersection of Range Road and Old South Road at Mittagong and drains in a north-easterly direction through Renwick, Balaclava and Braemar. It continues to drain in a northerly direction beneath the Hume Highway and ultimately into Sheepwash Creek which, in turn, drains into the Nattai River. The eastern sections of Mittagong, as well as the suburb of Willow Vale, also fall within the Nattai Ponds catchment.

The catchment comprises a mix of residential, commercial and industrial land uses as well as areas of open space. Over the past decade several new developments, including the Renwick and Nattai Ponds subdivisions, have increased the level of urbanisation. The upstream portion of the catchment is largely rural land and is predominantly undeveloped.

The catchment is drained primarily by natural watercourses. The location of all open channel/watercourses is shown by the blue lines in **Figure 1**. The main watercourse that drains through the catchment has no formal name according to the Geographical Names Board of NSW. Previous investigations have referred to it as the "Nattai Rivulet" and "Nattai Ponds Creek". For the purposes of this investigation, it is referred to as the "main watercourse".

As shown in **Figure 1**, the urbanised sections of the catchment are also drained by a stormwater system which carries local catchment runoff into the watercourses via a network of stormwater pipes, pits, open channels and culverts (refer to pink lines in **Figure 1**).

A number of flood detention basins have been constructed across the catchment to offset potential increases in runoff associated with new development areas, most notably the Renwick and Nattai Ponds subdivisions. A total of seven (7) basins were identified within the Renwick subdivision and two (2) basins were identified within the Nattai Ponds subdivision.

During periods of heavy rainfall across the catchment, there is potential for flooding to occur as a result of major watercourses overtopping their banks, as well as from overland flooding when the capacity of the stormwater system is exceeded. Flooding across the catchment has been experienced in February 2007, August 2014 and most recently during the August 2015 "East Coast Low" event. On these occasions flooding was experienced across the catchment but was a particular issue across areas of the catchment located between the downstream end of the Renwick development and Braemar Avenue, including properties fronting Inkerman Road, Scarlet Street and Braemar Avenue.

A Digital Elevation Model (DEM) showing ground surface elevations across the study area is shown in **Figure 2**. This DEM is based on Light Detection and Ranging (LiDAR) data that was collected across the southern highlands area in April 2014 by the NSW Government's Land and Property Information department. **Figure 2** shows that ground surface elevations vary between 750 mAHD near the intersection of Range Road and Old South Road down to 590 mAHD near the Hume Highway. Although the upstream sections of the catchment are quite steep, the topography "flattens" considerably downstream of Bong Bong Road.

2.2 Past Studies

The most recent flood study for the area is the *'Nattai Ponds Flood Study'* (Catchment Simulation Solutions, 2016). This study provides the most contemporary description of flood behaviour across the Nattai Ponds 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 Renwick Sustainable Village Project, Mittagong – Flood Study (2006)

The *'Renwick Sustainable Village Project, Mittagong - Flood Study'* (December 2006), was prepared by Bewsher Consulting for Landcom to quantify the potential hydrologic and hydraulic impacts associated with subdividing and developing the Renwick urban area for residential uses. The extent of the Renwick subdivision that was considered as part of the study is shown in **Figure 2**.

The study included the development of a hydrologic and hydraulic computer model of the catchment draining through the Renwick area. The hydrologic model was developed using the XP-RAFTS software and the hydraulic model was developed using the TUFLOW software. The computer models were used to simulate flood behaviour across the catchment for "existing" (i.e., pre-Renwick) as well as post-subdivision conditions.

Flood maps were produced from the model outputs showing peak floodwater levels and depths across the study area. The outputs from the TUFLOW model indicated considerable inundation across the area, particularly in the vicinity of Inkerman Road and Scarlett Street for both existing as well as post-development conditions. The study also determined that increases in runoff rates and volumes could be suitably managed by employing an appropriately design water management system primarily comprising of detention basins.

It is noted that the western sections of the subdivision are largely complete and construction across the eastern sections of the subdivision is underway. Accordingly, "current" (i.e., 2018/2019) catchment conditions fall somewhere between the "existing" and "post-development" conditions documented in the 2006 report.

2.2.2 Flood Impact Assessment – Lot 117 DP 659149 and Lot 8 DP 144854 Old Hume Highway, Braemar (2011)

Southeast Engineering and Environmental prepared the *'Flood Impact Assessment - Lot 117 DP 659149 and Lot 8 DP 1044854 Old Hume Highway, Braemar'* to quantify the potential flood impacts associated with the development of two lots located between the Old Hume Highway and railway line for residential purposes. The area is now referred to as the 'Nattai Ponds' subdivision.

The study included the development of a hydrologic computer model of the catchment draining to the development site. The hydrologic model was developed using the XP-RAFTS software (XP Software, 2009). A hydraulic computer model of the main watercourse was also developed using the HEC-RAS software.

The analysis determined that development of the area would likely increase peak 1% AEP flood levels. However, these flood level impacts were contained within the development site and minimal impacts were predicted upstream and downstream of the site.

This report includes a detailed description of how water moves across the site, including the potential contribution of flows from a subcatchment located on the western side of the Old Hume Highway. However, it is noted that the hydrologic/hydraulic analysis completed as part of this study did not incorporate the contribution of flows from this subcatchment. This was later determined to be a limitation and a more detailed hydraulic assessment was requested by Council. Accordingly, an addendum was subsequently submitted that included the results from more detailed 2-dimensional hydraulic modelling to better simulate the contribution of overland flows from the south and from the west of the site. The updated TUFLOW modelling outputs confirm the complex flow patterns across this area, including the contribution of flows from the western side of the Old Hume Highway.

2.2.3 Renwick Estate Flood Assessment (2017)

The 'Renwick Estate Flood Assessment' was prepared by Catchment Simulation Solutions on behalf of Wingecarribee Shire Council after a number of downstream residents (particularly those adjoining Inkerman Road and Scarlet Street) indicated that the frequency and severity of flooding has increased since the Renwick subdivision was developed.

In response to these concerns, Wingecarribee Shire Council engaged Catchment Simulation Solutions to undertake a hydrologic and hydraulic analysis to investigate the potential impacts of the current and anticipated development of the Renwick subdivision on pre-Renwick (i.e., historic) peak flows and flood levels during the 20%, 10% and 1% AEP flood events.

The assessment quantified peak flows and flood levels/depths for three separate development scenarios. This included:

- <u>Historic Conditions</u>: This scenario aims to reflect catchment conditions immediately prior to the development of the Renwick subdivision (circa 2010);
- <u>Existing Conditions</u>: This scenario aims to reflect catchment conditions after development of the western sections of the Renwick subdivision (circa 2016).

- Future Conditions: This scenario aims to reflect ultimate development of Renwick. This includes development of both the western (already developed) and eastern (to be developed in the near future) sections of the subdivision.

The modelling of these scenarios was completed using the XP-RAFTS and TUFLOW models that were originally developed as part of the Nattai Ponds Flood Study. The XP-RAFTS model was updated to reflect each of the three catchment development conditions (including existing and proposed detention basins).

Three separate TUFLOW models were also developed to reflect the three different development scenarios listed above. The historic and existing scenario models used actual terrain and land use information (i.e., historic aerials and LiDAR/contour information). The future development scenario was informed by design plans prepared by JMD Development Consultants between 2014 and 2017.

Peak flow estimates were extracted from the TUFLOW hydraulic model results at a number of locations downstream of the Renwick subdivision. These results indicated that peak flows downstream of the Renwick subdivision will increase relative to historic conditions under both existing and future scenarios for both the 20% and 10% AEP events. Increases during the 1% AEP are also predicted under existing conditions, however, under future conditions, peak flows are predicted to decrease as a result of inclusion of detention basins.

Peak flood levels are also predicted to be impacted under the existing and future scenarios with increases in peak flood level predicted during the 20% and 10% AEP events for properties downstream of the Renwick subdivision (although the increases are typically less than 0.05 metres). During the 1% AEP, increases of less than 0.03 metres are predicted under existing conditions, however, under future conditions (i.e., with detention basins), reductions in flood level are predicted downstream of the subdivision.

The increases in flood flows and flood level that are predicted for the 20% and 10% AEP events are considered minor and fall within the limits of variability of hydraulic flood models.

2.2.4 Braemar Avenue Culvert, Braemar – Flood Impact Assessment (2018)

The *'Nattai Ponds Flood Study'* (CSS, 2016) found that Braemar Avenue (adjacent to the Old Hume Highway) is subject to relatively frequent overtopping. More specifically, the flood study determined that during the 20% AEP event, Braemar Avenue would be inundated to a depth of 0.35m (increasing to over 1.7m during the PMF). Accordingly, it is unlikely that vehicular access along Braemar Avenue would be possible during any of the simulated design floods events including and greater than the 20% AEP flood.

In recognition of the flood liability of this roadway, Wingecarribee Shire Council proposed to remove the five 600mm diameter culvert crossings, and replace it with five 2.4 metre (wide) x 1.8 metre (high) box culverts. Channel modification works were also proposed upstream and downstream of the structure to cater for the increased height of the new culverts relative to the old ones.

Catchment Simulation Solutions completed a flood impact assessment on behalf of Council to determine the impact that the new Braemar Ave culvert is likely to have on flood behaviour in the area. The flood modelling was completed using the TUFLOW flood model that was originally developed as part of the 'Nattai Ponds Flood Study'.

The TUFLOW model was updated to include the proposed culvert and modifications to the channel upstream and downstream of the culvert. A 50% blockage allowance was assigned to the proposed culverts based upon guidance in the 2016 version of Australian Rainfall & Runoff. The updated TUFLOW model was used to simulate the 20% AEP flood with the upgraded culvert/channel in place.

The assessment determined that the proposed culvert upgrade is predicted to afford some notable reductions in flood levels upstream as well as downstream of Braemar Ave and Braemar Ave would remain trafficable during the 20% AEP flood. Some increases in flood level are anticipated, but they are contained to the main channel and are not predicted to adversely impact on any existing properties.

At the time this study was being prepared, Wingecarribee Shire Council were about to commence the culvert upgrade works. Therefore, it is considered that the "proposed" scenario that was considered as part of this assessment, will reflect current catchment conditions in the immediate future and the upgraded culvert should be included in all flood analysis completed as part of the current study.

2.3 Environment

2.3.1 Vegetation

As discussed, the Nattai Ponds catchment is a mix of rural, residential, commercial and industrial land. In particular, the upstream portion of the catchment is largely rural and predominantly undeveloped, while the downstream section of the catchment is more developed.

Council's vegetation mapping is shown on **Figure 3**. Significant native vegetation remains across the catchment, particularly within the central and northern areas of the catchment. This includes "pockets" of vegetation between developed areas in the catchment. The vegetation communities occupy about 1.8 km^2 of the 7.8 km^2 catchment area (approximately 22%).

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

2.3.2 Heritage

There are thirteen heritage items within the Nattai Ponds catchment. The extent of the heritage areas is shown on **Figure 3** and documented in **Table 2**.

Table 2 Summary of Heritage Conservation Areas

ID	Site Name
A	Picton-Mittagong Loop Line railway line
B	Braemar Lodge
C	Poplars Restaurant Inn
D	Kamilaroi (part of Braemar Garden World)
E	Former Renwick Institution
F	“Wandevan” house
G	Suttor Cottage
H	Goodlet Cottage
I	“Challoner Cottage”
J	Cutter’s Inn
K	Willow Run wells, barn and outbuildings
L	Kennerton Green garden
M	Old South Rd

There are also twenty-six 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 2.**

Table 3 Summary of Aboriginal Heritage Sites

ID	Site Name
1	Braemar, HCA23
2	Braemar, HCA22
3	Braemar, HCA20
4	Braemar, HCA21
5	Willow Vale VCL_GDG01
6	Braemar, HCA25
7	Braemar, HCA18
8	Braemar, HCA19
9	Braemar Garden World 1
10	BIF1 (BRAEMAR ISOLATED FIND 1) 11 duplicate of 52-1-0311
11	BIF2 (BRAEMAR ISOLATED FIND 2) 1 duplicate of 52-1-0312
12	Renwick 1
13	Renwick 5
14	TA(3) Mittagong
15	TA(6) Mittagong
16	TA(2) Mittagong
17	TA(7) Mittagong
18	TA(4) Mittagong

ID	Site Name
19	TA(1) Mittagong
20	TA(5) Mittagong
21	Renwick 2
22	Renwick 4
23	Renwick 3
24	Colo Street 1

2.4 Demographics

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

In this regard, the Australian Bureau of Statistics (ABS) provides a range of information for the villages within the Nattai Ponds catchments that was collected as part of the 2016 census. A summary of pertinent information extracted from the ABS website (http://www.abs.gov.au/) is provided in **Table 4**.

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

- Approximately 2,500 people reside in the Nattai Ponds catchment (noting that most of the Mittagong urban area is located outside of the catchment). However, this population is likely to increase significantly in the future as a result of the Renwick and Nattai Ponds subdivisions.
- Approximately 38% of the population would be considered more vulnerable to the impacts of flooding (i.e., people under the age of 15 or over the age of 65). The median age of residents within the area is 42.
- The majority of households only speak English at home. However, there are a limited number of households that also speak Mandarin, Greek, French, German, Italian, Spanish, Nepali, Dutch, Samoan, Korean, Japanese, Afrikaans, Croatian, Polish, Hindi and Turkish.
- 88% of households have an internet connection.
- The average household within the catchment typically has 2 or more people, and at least one motor vehicle.

Table 4 Summary of Catchment Demographics

Statistic			Balaclava	Braemar	Mittagong	Renwick	Willow Vale
Population Statistics	Total population		496	447	5,767	573	717
Population Statistics	Age	Median	42	33	48	39	46
Population Statistics	Age	<15 years of age	20%	23%	16%	20%	17%
Population Statistics	Age	>65 years of age	17%	12%	28%	16%	20%
Population Statistics	Education	Year 12 or equivalent	12%	13%	11%	11%	13%
Population Statistics	Education	Year 10 or equivalent	13%	16%	13%	11%	14%
Population Statistics	Education	Did not Complete Year 10	9%	6%	8%	5%	8%
Dwelling Statistics	Motor Vehicles	Dwellings with no vehicles	0%	2%	6%	2%	0%
Dwelling Statistics	Motor Vehicles	Dwellings with ≥ 1 vehicle	92%	96%	89%	97%	99%
Dwelling Statistics		Average persons per dwelling	2.7	2.8	1.7	2	2.2
Dwelling Statistics		Proportion of unpaid volunteers	18%	16%	23%	22%	18%
Dwelling Statistics	Language spoke at home	Speaks English only	78%	88%	87%	89%	89%
Dwelling Statistics	Language spoke at home	Speaks other language:	9%	14%	8%	12%	10%
Dwelling Statistics	Dwelling Type	Separate house	100%	95%	86%	100%	99%
Dwelling Statistics	Dwelling Type	Semi-detached, row or terrace house, townhouse	0	0%	7%	0%	0%
Dwelling Statistics	Dwelling Type	Flat, unit or apartment:	0	5%	5%	0%	1%
Dwelling Statistics	Dwelling Type	Other dwelling (cabin, caravan):	0%	0%	2%	0%	0%
Internet Statistics	Type of Internet Connection	No Internet connection	16%	10%	18%	2%	2%
Internet Statistics	Type of Internet Connection	Internet connection	82%	88%	79%	98%	93%
Internet Statistics	Type of Internet Connection	Internet connection not stated	2%	2%	3%	0%	2%

2.5 Community Consultation

2.5.1 Overview

Wingecarribee Shire recognises that the community is an important part in the development of the floodplain risk management study and plan for the Nattai Ponds 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 study;
- Identify community concerns and attitudes;
- Gather information from the community; and
- Develop and maintain community confidence in the study results.

A summary of the outcomes of the consultation that was completed with the community is summarised below.

2.5.2 Flood Study (2016)

A community information brochure and questionnaire was prepared and distributed to 414 households and businesses within the Nattai Ponds catchment.

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 whether residents could identify any historic flood marks. A total of 68 questionnaire responses were received, providing a questionnaire response rate of 16%.

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

- The majority of respondents have lived in the Nattai Ponds catchment for over 15 years. The average length of residence was about 20 years.
- 36% of the respondents indicated that they have experienced some sort of flood impact.
- The flooding impacts were typically associated with inundation of front/back yards. However, five respondents indicated that they have had their house or business inundated during past floods.
- Flooding problems were reported in the vicinity of:
    - Biggera Street
    - Bunya Close
    - Rush Lane
    - Railway Parade
    - Inkerman Road.
- A number of respondents indicated that Braemar Avenue experienced regular inundation.
- The majority of respondents considered that the flooding problems are primarily associated with:

- lack of stormwater facilities (kerb & gutter, stormwater pits and pipes)
- existing drainage facilities having inadequate capacity
- increases in runoff from new developments (e.g., Renwick).

2.5.3 Floodplain Risk Management Study

Community Questionnaire

A questionnaire was distributed to 164 households and businesses during the initial stage of the project to understand the types of flooding impacts that the community has experienced, how people would respond during future floods and what key objectives potential flood risk management measures should focus on. A copy of the questionnaire is included in **Appendix A**.

A total of 29 questionnaire responses were received and a summary of all questionnaire responses is provided in **Appendix A** in **Tables A1** to **A3**.

Most of the responses included addresses enabling spatial interpretation of the questionnaire responses. **Figure A1** in **Appendix A** shows the spatial distribution of reported flood impacts. **Figure A2** in **Appendix A** shows the spatial distribution of how people will likely respond during future floods with regard to evacuation.

The responses to the questionnaire indicate that:

- 16 of the 34 respondents (47%) have experienced some form of inundation or disruption as a result of flooding. The location and types of flood impacts that were reported are shown in **Figure A1**. The most common type of flood impact was reported was access being lost due to inundation of roadways followed by inundation of garages/sheds. Two respondents also reported above flood inundation of their house.
- It was found that 38% of respondents indicated they would remain at home and only 24% indicated they would evacuate (refer **to Figure A2**). 18% of respondents were unsure of how they would respond during a future flood.
- The primary reasons for people choosing to remain at home were the cost/inconvenience/discomfort of evacuation and feeling that their house could not be flooded. It was later determined that two of the properties that felt they could not be flooded were contained within the PMF extent; one in a low hazard area and another in a high hazard area.
- For those intending to evacuate, safety of their family was the overriding concern.

In terms of options for better managing/mitigating the flood risk, most of the suggested flood risk management options were supported by the community. However, the following options were ranked highest by the community:

- Stormwater upgrades
- Regular maintenance and clearing of creeks
- Debris control structures to prevent blockage of culverts/bridges
- Flood forecasting/warning system
- Development/planning controls

Although most of the suggested options were supported by the community, the following options were the least favoured by the community:

- Voluntary house raising
- Voluntary flood proofing
- Voluntary house purchase

Public Exhibition

The final draft 'Nattai Ponds Floodplain Risk Management Study & Plan' was placed on public exhibition at Moss Vale, Bowral and Mittagong libraries, as well as the Wingecarribee Shire Council Civic Centre from 3 June 2019 to 6 August 2019. A digital version of the final draft report was also available on the Wingecarribee Shire Council's website during the exhibition period. The public exhibition provided the opportunity for the community and key stakeholders to review the final draft report and provide feedback on the report content.

A total of six submissions were received during the exhibition period. A summary of the submissions that were received is provided in **Appendix G**. Also included in **Appendix G** are responses to each submission.

The actions that were taken to address the submissions did not alter the overall outcomes documented in the final draft report. However, an additional culvert upgrade option was investigated and the outcomes of the evaluation is provided in Section 7.6.1. A combined detention basin scenario was also explored, and the outcomes of this evaluation is provided in Section 7.2.5.

3 DEFINING THE FLOOD RISK

3.1 Overview

In order to identify and evaluate potential options for managing the flood risk, it is first important to have an understanding of the nature and extent of the existing flood risk. This is typically achieved through the preparation of a flood study, which provides information on key flood characteristics (e.g., flood depths, levels and velocities) for a range of floods up to and including the Probable Maximum Flood. Wingecarribee Shire Council commissioned the *'Nattai Ponds 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. It also describes the nature and extent of the potential future flood risk by quantifying the potential impacts that climate change as well as future catchment development may have on flood behaviour.

3.2 Existing Flood Behaviour

3.2.1 Overview

The *'Nattai Ponds Flood Study'* (2016) was prepared by Catchment Simulation Solutions on behalf of Wingecarribee Shire Council to define design flood behaviour across the Nattai Ponds catchment for a range of design floods.

A hydrologic model of the Nattai Ponds catchment as well as a hydraulic model of the main watercourses was developed as part of the flood study. The hydrologic model was developed using the XP-RAFTS software and the hydraulic model was developed using the TUFLOW software.

The XP-RAFTS and TUFLOW models were calibrated to the February 2007, August 2014 and August 2015 events. The calibrated models were subsequently used to simulate the design 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP floods as well as the PMF. The design flood simulations included a full representation of the Renwick subdivision based upon design plans provided by Council (only the western sections of the subdivision were being developed at the time the flood study was being prepared).

The outputs from the design flood simulation were used to prepare a range of flood maps. These included maps showing floodwater depths, levels and velocities. Flood hazard and hydraulic category maps were also prepared.

Overall, the XP-RAFTS and TUFLOW models and the associated outputs generated as part of this flood study are considered to represent the best available tools for defining design flood behaviour across the Nattai Ponds catchment and will serve as a suitable basis for defining the existing flood risk as part of the current study.

However, since the completion of the flood study, some changes have occurred within the catchment that were not reflected in the flood study models. Therefore, it was considered necessary to updates the models to ensure they provided the best possible representation of contemporary flood behaviour.

In addition, a revised flood estimation guideline was released after publication of the flood study. The guideline is referred to as *'Australian Rainfall and Runoff – A Guide to Flood Estimation"* (Geoscience Australia, 2016) and aims to provide improved estimates of flood behaviour. Accordingly, it was considered prudent to apply the updated flood estimation procedures across the Nattai Ponds catchment.

Further discussion on the model updates that were completed, and the outcomes of the revised design flood simulations are presented in the following sections.

3.2.2 Model Updates

The most notable modification that has occurred since the flood study was completed is the upgrade of the culvert under Braemar Avenue. Accordingly, the original TUFLOW model was updated to include a representation of the new Braemar Avenue culvert and channel modifications based upon the design plans discussed in Section 2.2.6.

As discussed, a representation of the Renwick subdivision was included in the 2016 Flood Study model based upon design plans only. Updated digital terrain and stormwater network information was provided for this floodplain risk management study to allow an improved representation of the Renwick subdivision in the TUFLOW model.

3.2.3 Australian Rainfall & Runoff 2016 Assessment

Flood Behaviour across the Wingecarribee Shire Council LGA for the past three decades has been defined based upon guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia) (referred to herein as ARR1987). This included the '*'Nattai Ponds 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, investigations were completed to determine the impact that the revised hydrologic procedures may have on design flood estimates across the catchment.

The outcomes of the assessment are presented in **Appendix B**. The assessment determined that application of ARR2016 hydrologic procedures to the Nattai Ponds catchment is predicted to generate lower peak discharges across all design floods up to and including the 1% AEP event relative to ARR1987. This is predicted to also result in a reduction in design flood levels across the catchment relative to ARR1987. The differences are primarily a result of the lower ARR2016 design rainfall depths and, to a lesser extent, higher "burst" rainfall losses.

Although there are concerns that adopting lower design discharges and flood levels could underestimate the flood risk across the catchment, available information for the area indicates that the more regionalised ARR2016 input information is more reliable than the generalised ARR1987 inputs. Accordingly, it was considered that application of ARR2016 procedures as part of the Nattai Ponds FPRMS will provide an improved representation of design flood behaviour relative to the ARR1987 procedures.

Accordingly, the results that are presented in the following sections reflect the updated ARR2016 procedures.

3.2.4 Floodwater Levels, Depths and Velocities

The XP-RAFTS model was used to simulate the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP floods based upon ARR2016 hydrology. The PMF was also simulated. Peak design discharges for each design flood simulation are presented in **Appendix B**.

The hydrographs from the XP-RAFTS model were subsequently applied to the TUFLOW model. Peak floodwater depths, levels and velocity vectors were extracted from the results of the revised modelling and are presented in **Figures 4.1** to **11.8** inclusive.

Peak flood levels were also extracted from the results of the modelling at key locations throughout the Nattai Ponds catchment and are presented in **Table 3**. The location identification (ID) numbers can also be referenced by the yellow points in **Plate 1** as well as in **Figures 4.1** to **11.8** inclusive.

It should be noted that the primary objective of the study is to define the nature and extent of the flooding problem across the Nattai Ponds catchment. Therefore, there is a need to distinguish between areas of significant inundation depths and those areas subject to negligible inundation. In this regard, only areas exposed to an inundation depth of greater than 0.1 metres are shown in **Figures 4.1** to **11.8**. In some cases, this can result in a discontinuous inundation surface. However, it needs to be recognised that these isolated "puddles" are linked by areas of shallow flow.

The results presented in **Figures 4.1** to **11.8** shows that:

- Flood behaviour across the Nattai Ponds catchment is typically characterised by relatively shallow depths of inundation (i.e., < 0.3 metres). However, more significant depths are predicted along and immediately adjacent to designated waterways.
- Several sections of the catchment are predicted to be exposed to more significant floodwater depths and velocities. This includes:
  - Inkerman Road
  - Scarlet Street
  - Upstream of the railway line

Figures 11.1 to **11.8** also show a notable "breakout" of flow from the Old Hume Highway across the Nattai Ponds subdivision and into the main watercourse that is not evident during more frequent floods. Shallow, but notable flooding is also evident in the vicinity of Railway Parade and Biggera Street.

The 2016 flood study also predicted frequent overtopping of Braemar Ave (overtopping was predicted in the 20% AEP event). However, with the upgraded Braemar Ave culvert, the revised modelling shows that Braemar Ave is predicted to remain flood free during events up to and including the 5% AEP flood (overtopping depths during the 2% AEP event are predicted to be less than 0.1 m).

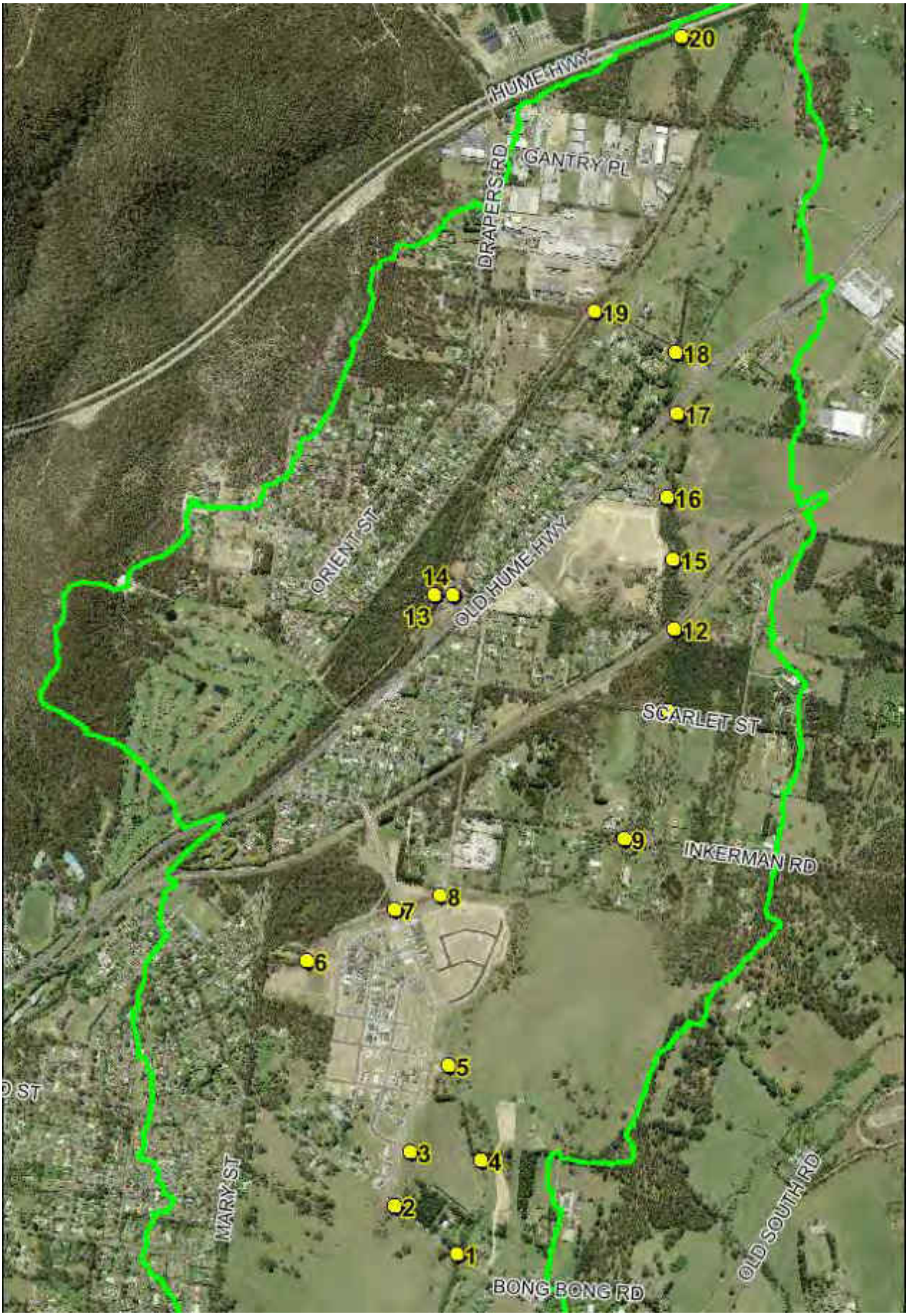


Plate 1 Flood Level Comparison Point Locations

Table 5 Peak Design Water Level

ID	Location	Peak Water Level *(mAHD)*							
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	U/S Bong Bong Rd Channel 55	628.01	628.06	628.12	628.17	628.23	628.28	628.34	628.70
2	U/S Bong Bong Rd Channel 54	622.56	622.62	622.67	622.71	622.75	622.80	622.85	623.27
3	U/S Guthawah Way	617.70	617.78	617.88	617.99	618.07	618.11	618.22	619.45
4	U/S Emergency Access Channel 55	620.36	620.41	620.46	620.51	620.56	620.61	620.66	621.20
5	U/S Oldfield Rd	615.09	615.37	615.72	616.26	616.50	616.63	616.76	617.69
6	U/S Renwick Footbridge	614.43	614.47	614.53	614.57	614.62	614.69	614.74	615.30
7	U/S Renwick Dr	609.50	609.57	609.65	609.74	609.81	609.92	610.04	611.63
8	U/S Cardigan St	608.18	608.23	608.30	608.38	608.45	608.49	608.57	609.75
9	U/S Inkerman Rd	604.52	604.58	604.64	604.69	604.73	604.79	604.87	605.55
10	U/S Inkerman Rd Tributary	603.45	603.50	603.57	603.61	603.67	603.73	603.81	604.56
11	U/S Scarlet St	600.72	600.73	600.75	600.77	600.80	600.83	600.88	602.97
12	U/S Railway	599.18	599.26	599.36	599.46	599.56	599.65	599.78	602.88
13	U/S Railway Culvert Braemar	615.34	615.38	615.46	615.52	615.58	615.65	615.69	615.96
14	U/S Biggera St	611.38	611.38	611.40	611.43	611.47	611.53	611.60	612.05
15	U/S Isedale Rd	596.81	596.95	597.14	597.34	597.64	598.09	598.28	599.13
16	U/S Lot 117 Access	595.51	595.64	595.81	596.03	596.26	596.74	597.13	598.00
17	U/S Old Hume Highway	594.46	594.60	594.82	595.07	595.25	595.43	595.73	596.83
18	U/S Braemar Av	592.96	593.10	593.25	593.40	593.51	593.67	593.74	594.22
19	U/S Braemar Av, Willowvale	597.88	597.92	597.96	598.01	598.04	598.09	598.14	598.60
20	U/S Hume Highway	587.48	587.69	587.87	588.12	588.37	588.59	589.09	592.05

refer to Figures 4.1 to 11.8 for Location ID

3.2.5 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, 2014).

Provisional hazard categories were prepared as part of the *'Nattai Ponds Flood Study' (2016)* based on criteria contained in Appendix L of the *'Floodplain Development Manual'* (2005) (FDM). Hazard categories were also mapped as part of the current study in accordance with the FDM as Council currently uses this information to assist in defining flood risk precincts (refer to Section 3.4). The resulting hazard maps for the 10% AEP, 0.5% AEP and 1% AEP floods as well as the PMF are shown in **Figures 12.1** to **15.8** inclusive.

It was noted that more contemporary flood hazard vulnerability curves have been published in the Australian Institute for Disaster Resilience's (AIDR) *'Technical Flood Risk Management Guideline: Flood Hazard'* (2014). The hazard curves are reproduced in **Plate 2** and are also described in **Table 6**. As shown in **Plate 2**, the hazard curves assess the potential vulnerability of people (for differing physical abilities), cars and structures based upon the depth and velocity of floodwaters at a particular location. Accordingly, this guideline is considered to provide a more detailed understanding of the potential flood hazard and it was considered valuable to also prepare flood hazard mapping in accordance with this guideline.

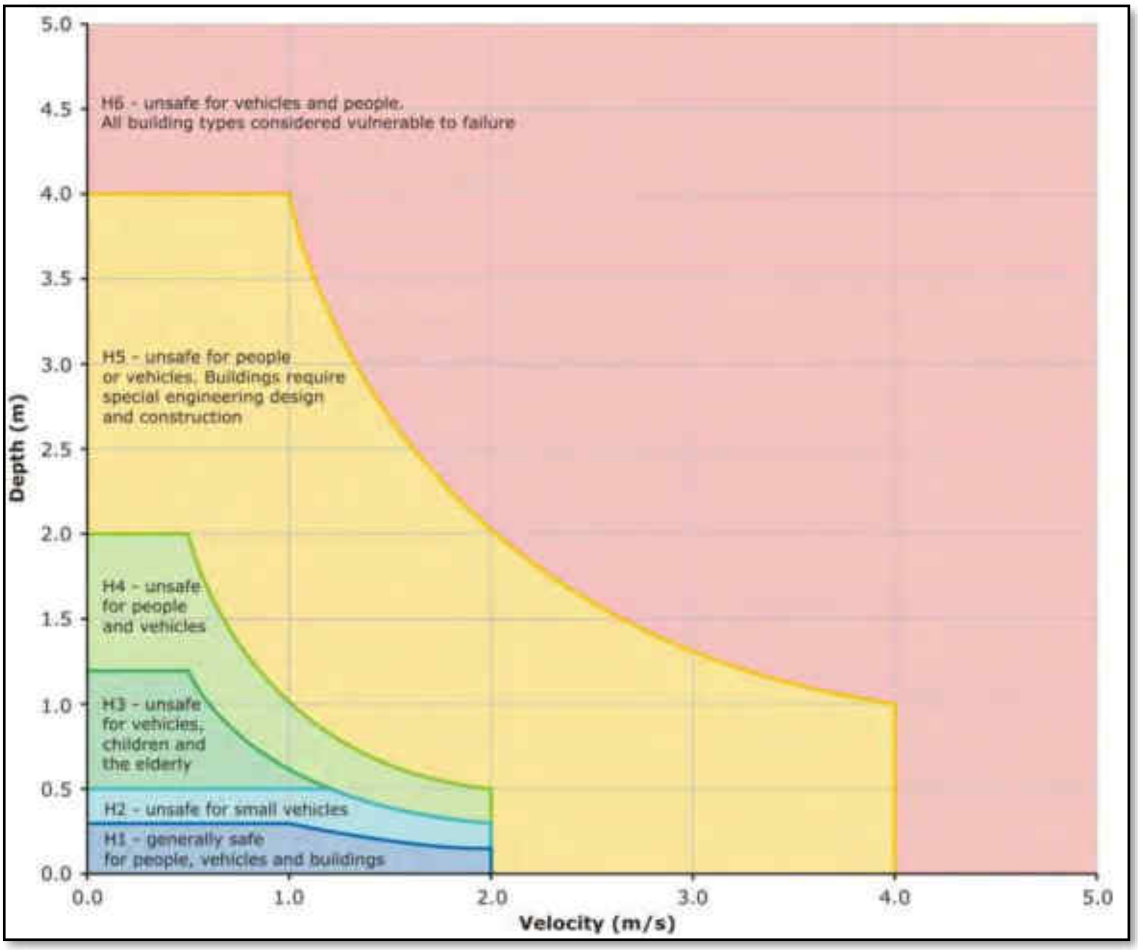


Plate 2 Flood Hazard Vulnerability Curves (AIDR, 2014)

Table 6 Description of Adopted Flood Hazard Categories (Australian Government, 2014)

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

The resulting "national" hazard category maps are included in **Appendix D** as **Figures D1.1** to **D4.8**.

The FDM and national hazard category mapping indicates that the high hazard areas typically coincide with defined waterways. Very few habitable areas are predicted to be exposed to a significant flood hazard during events up to and including the 1% AEP event. Nevertheless, several roadways (including the Old Hume Highway) are predicted to be high hazard areas at the peak of the PMF.

3.2.6 Hydraulic Categories

Hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour and highlights areas that should be retained for the conveyance and storage of floodwaters (failure to do so will likely have an adverse impact on existing flood behaviour).

Criteria for defining hydraulic categories across the Nattai Ponds catchment were previously established as part of the *'Nattai Ponds Flood Study'* (Catchment Simulation Solutions, 2016) and are summarised in **Table 7**. The flood study included various analyses to confirm the suitability of these criteria (e.g., encroachment analysis to confirm floodway extents). Therefore, these criteria were considered appropriate for application as part of the current study.

The resulting hydraulic category maps for the 10 % and 1% AEP floods as well as the PMF are shown in **Figures 16.1** to **18.8** inclusive.

The hydraulic category maps show that floodways are typically contained in close proximity to each of the main watercourses during events up to and including the 1% AEP. However, some roadways would likely function as floodways at the peak of the PMF (this includes the Old Hume Highway). A significant floodway area extends from the Renwick subdivision downstream to the Hume Highway. This floodway area encompasses several existing residential buildings, most notably near Inkerman Road and Scarlet Street.

Table 7 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Qualitative Description	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.	• V x D > 0.25 m^2/s
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.	• Not floodway and depth ≥0.15 m
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.	• Not floodway and depth <0.15 m

NOTES: V = Velocity, D = Depth
Hydraulic categories were only applied to areas subject to inundation (i.e., D > 0.1m)
**The adopted criteria were developed specifically for the Nattai Ponds catchment only and may not be appropriate for any other areas.*

3.2.7 Flood Emergency Response Precincts

In an effort to understand the potential emergency response requirements across different sections of the floodplain, flood emergency response precinct (ERP) classifications were prepared in accordance with the flow chart shown in **Plate 3** (Australian Emergency Management Institute, 2014). The ERP classifications can be used to provide an indication of areas which may be inundated and/or isolated during floods. This information, in turn, can be used to quantify the type of emergency response that may be required across different sections of the floodplain during future floods. This information can be useful in emergency response planning.

Each lot within the Nattai Ponds catchment was classified based upon the ERP flow chart for the 5% AEP, 2% AEP and 1% AEP floods 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" by the depth of inundation (a 0.2 m depth threshold was used to define a "cut" road).
- Whether evacuation routes continuously rise out of the floodplain.
- Whether properties become inundated.

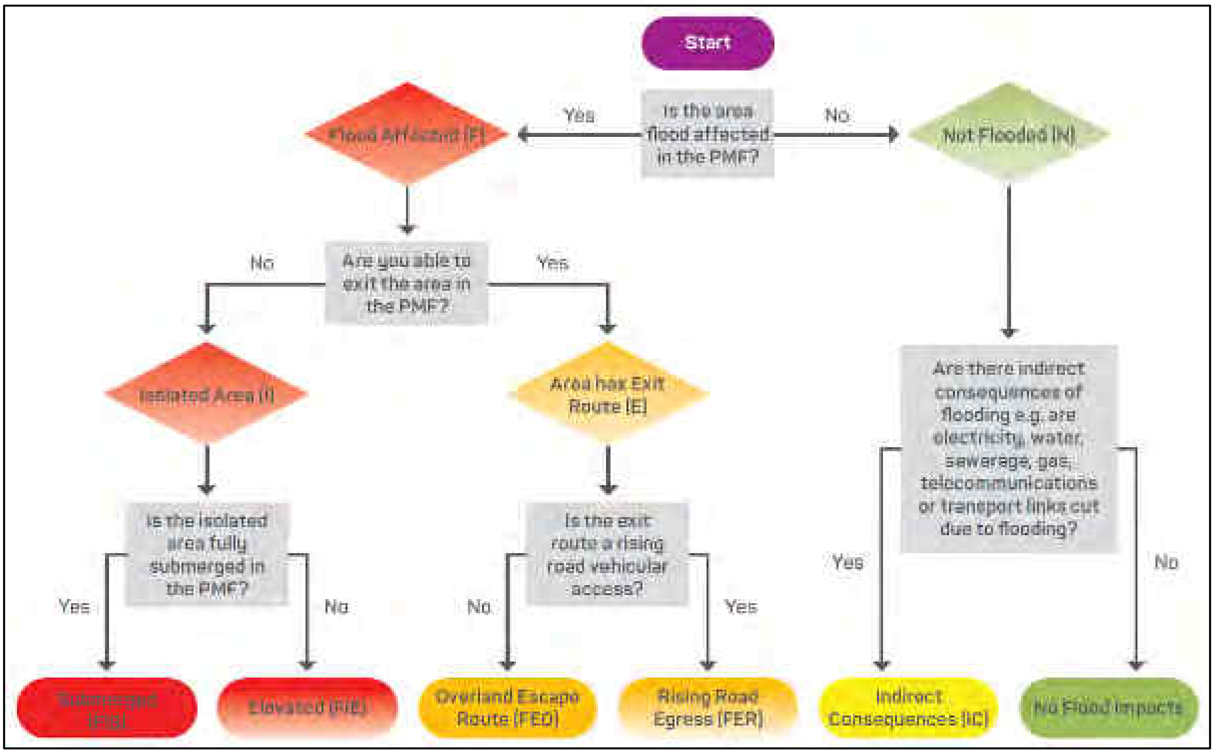


Plate 3 Flow Chart for Determining Flood Emergency Response Classifications (AEMI, 2014).

The resulting ERP classifications for the 5% AEP, 2% AEP and 1% AEP flood, as well as the PMF, are provided in **Figures 19.1** to **22.8** inclusive. A range of other datasets were also generated as part of the classification process to assist Council and the SES. This includes roadway overtopping locations, which are discussed in more detail in Section 3.3.2.

Figures 21.1 to **21.8** show that during the 1% AEP flood, the most common ERP classification is "Rising Road Egress", which indicates that evacuation routes grade up and out of the floodwaters. However, there are some "flooded isolated submerged" areas (i.e., low flood islands) and "flooded isolated elevated" areas, which indicates that evacuation routes are likely to be cut during floods. This includes properties fronting Scarlet Street and Inkerman Road as well as some properties adjoining Railway Terrace, Biggera Street and the Old Hume Highway.

Figures 22.1 to **22.8** show that during the PMF, the number of "flooded isolated submerged" and "flooded isolated elevated" areas increase significantly. Accordingly, if a particularly large flood was to occur, there is potential for a very large number of lots to become isolated. The sheer number of these "flooded isolated submerged" lots during the PMF (683 lots) and the limited warning times (as indicated by the "time road first cut") means that it is unlikely emergency services will be able to offer assistance.

3.3 Impacts of Flooding on the Community

The results of the design flood modelling show that:

- Flooding across the Nattai Ponds catchment can occur as a result of major watercourses overtopping their banks as well as from overland flooding when the capacity of the stormwater system is exceeded.
- Flooding can occur as a result of a variety of different storm durations. However, a storm duration of less than 2 hours typically produces the critical flood conditions across most of the catchment.
- Flood behaviour across the Nattai Ponds catchment is typically characterised by relatively shallow depths of inundation (i.e., < 0.3 metres). However, more significant depths are predicted along and immediately adjacent to designated waterways.
- A number of properties are predicted to be inundated during the 1% AEP flood. These are mainly limited to rural residential land, however, some urban properties in the Willow Vale/Braemar areas are also impacted. The Braemar industrial area is also predicted to be impacted at the peak of the 1% AEP flood.
- The relatively shallow depths of inundation result in the majority of the floodplain being exposed to a low flood hazard. However, several sections of the catchment are predicted to be exposed to more significant floodwater depths and velocities and, consequently, a high flood hazard during large events. This includes Inkerman Road and Scarlet Street:

Further detailed discussion on the impact of flooding on people, property, key infrastructure and transportation routes within the catchment is provided below.

3.3.1 Key Infrastructure

The Nattai Ponds 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. Therefore, it is important to understand the potential vulnerability of these facilities during a range of floods.

Critical and vulnerable facilities located within the Nattai Ponds catchment are summarised below. A discussion on the impacts of flooding on each facility is provided below and is also summarised in **Table 8**.

- **Schools**:
  - ***Tangara* School** (Bong Bong Road, Renwick): the school buildings are not predicted to be inundated during any design flood up to and including the PMF. However, access to and from the school may be cut during large floods due to overtopping of Bong Bong Road.
  - ***Highlands School*** (Bong Bong Road, Mittagong): The school lies on the catchment boundary. It is not predicted to be impacted during any of the design floods up to and including the PMF.
- **Fire Stations**: There are no fire stations located within the catchment;
- **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;

Table 8 Impact of Flooding on Key and Vulnerable Facilities

Key Infrastructure		1% AEP Flood		PMF	
		Inundated?	Access Cut?	Inundated?	Access Cut?
Fire Stations		There are no fire stations located within the catchment			
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	*Tangara* (Bong Bong Road, Renwick)		☑		☑
	Highlands School (Bong Bong Road, Mittagong)				

3.3.2 Transportation Links

There are several major roadways within the Nattai Ponds catchment which may be required for evacuation or emergency services access during floods. It is important to understand the impacts of flooding on these roads 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 3.2.7. The roadway overtopping locations are shown as yellow dots in **Figures 19.1** to **22.8**. Also included are labels describing the amount of time it takes for the roads to be inundated relative to the onset of rainfall (green label) and the total duration of roadway inundation (red label). Accordingly, this provides information describing the amount of warning time that would typically be available and how long the roadway would be cut by floodwaters after inundation first occurs.

With regard to the impact of floods on major roadways in the catchment, the roadway inundation information indicates that (also refer **Table 9**):

Table 9 Impact of Flooding on Key Transportation Links

Roadway	Access Cut During 20% AEP Flood?	Access Cut During 1% AEP Flood?	Access Cut During PMF?
Bong Bong Road			☑
Inkerman Road	☑	☑	☑
Scarlet Street	☑	☑	☑
Old Hume Highway (northbound lanes)			☑
Braemar Avenue		☑	☑
Hume Highway			☑

- ***Bong Bong Road:*** Bong Bong Road is predicted to experience inundation during all of the design floods. This ranges from 0.1m during the 20% AEP flood and 0.25m during the 1% AEP flood to more than 0.5 metres during the PMF. Accordingly, the road would likely remain trafficable for emergency vehicles during smaller floods, but access would be cut during events greater than the 1% AEP flood.
- ***Inkerman Road:*** Inkerman Road is predicted to be inundated during all of the simulated design floods. Depths of inundation are predicted to range from 0.2m during the 20% AEP event to ~1.3 m during the PMF. Accordingly, it is unlikely that vehicular access along Inkerman Road would be possible during events greater than the 20% AEP event. This is likely to results in a number of rural residential properties becoming isolated.
- ***Scarlet Street:*** Scarlet Street is predicted to be inundated during all of the simulated design floods. Depths of inundation are predicted to range from 0.25m during the 20% AEP event, 0.4m in the 1% AEP event, and 2.5 m during the PMF. Accordingly, it is unlikely that vehicular access along Scarlet Street would be possible during events greater than the 20% AEP event. This would result in a number of rural residential properties becoming isolated.
- ***Old Hume Highway***: The Old Hume Highway is predicted to experience inundation from local overland flow in the vicinity of Rush Lane and Isedale Road. Depths along the Northbound carriageway vary from less than 0.1m in the 20% AEP event to 0.2m in the 1% AEP event and 0.8m in the PMF. The highway would remain trafficable in events up to and including the 1% AEP for emergency vehicles. The PMF is predicted to overtop the Old Hume Highway adjacent to Braemar Avenue with depths across the roadway being about 1 metre.
- ***Braemar Avenue:*** The upgrades of the Braemar Avenue culverts are predicted to afford some notable improvements to the frequency of overtopping of Braemar Avenue. Previously, Braemar Avenue was predicted to be overtopped in events as frequent as the 20% AEP event. However, with the upgraded culverts, the roadway is predicted to remain trafficable during events up to and including the 2% AEP flood. Depths of 0.2m are predicted in a 1% AEP flood and 0.45m depths are predicted in a 0.2% AEP flood. Depths of ~1m are predicted during the PMF. Accordingly, vehicular access along Braemar Avenue would not be possible during events greater than the 1% AEP flood. Adjacent to the Braemar Avenue industrial area, depths of 0.3m are predicted in the 1% AEP event with almost 0.8m of water extending across the roadway during the PMF.

Therefore, this section of Braemar Avenue is predicted to be trafficable for emergency vehicles in events up to and including the 1% AEP flood.

- ***Hume Highway***: The Hume Highway is predicted to remain "flood free" during all events except the PMF. Depths across the highway during the PMF are predicted to exceed 0.5 metres. Accordingly, the Hume Highway is only predicted to be cut during very large floods.

It should be noted that under no circumstances should vehicles attempt to drive through floodwaters regardless of the floodwater depth of the type of vehicle they are driving.

3.3.3 The Cost of Flooding

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

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

- Residential properties
- Commercial/Industrial properties
- Infrastructure

As part of the damage cost calculations, the number of properties subject to above floor inundation was calculated. This information is summarised in **Table 10**. The number of properties subject to property damage (even if above floor flooding is not predicted) are also provided in **Table 10**. This includes damage to external items such as fences, sheds and garages. 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 **Figures 29.1** to **29.8** inclusive.

Table 10 shows that above floor inundation is not predicted to occur across any residential or commercial/industrial properties until the 10% AEP flood. During the 1% AEP event, 7 residential properties are predicted to suffer flood damage (six of which are predicted to experience above floor inundation). During the PMF, over 100 properties are predicted to be inundated above floor level.

The damage estimates for each design flood are summarised in **Table 11** for existing conditions. It indicates that if a 1% AEP flood was to occur, just under $300,000 worth of damage could be expected. Most of the damage would be incurred across residential properties.

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for each property. The AAD takes into consideration the frequency of a particular event occurring and the damage incurred during that event to estimate the average damage that is likely to occur each year, on average. The AAD for the Nattai Ponds catchment was determined to be **$21,176**. Accordingly, if the "status quo" was maintained, residents and business owners within the catchment as well as infrastructure providers, such as Council, would likely be subject to cumulative flood damage costs of around $21,000 per annum (on average).

Table 10 Number of Properties Subject to Above Floor Inundation and Property Damage

Flood Event	Residential		Commercial		Industrial		Total Number	
	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation
20% AEP	0	0	0	0	0	0	0	0
10% AEP	1	1	0	0	0	0	1	1
5% AEP	2	1	0	0	0	0	2	1
2% AEP	3	2	0	0	0	0	3	2
1% AEP	7	5	0	0	1	1	8	6
0.5% AEP	10	8	0	0	3	3	13	11
0.2% AEP	14	12	0	0	3	3	17	15
PMF	120	91	5	5	13	13	138	109

Table 11 Summary of Flood Damages for Existing Conditions

Flood Damage Component	Flood Damages (2018 dollars)							
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Residential	0	11,859	23,718	63,678	231,553	452,567	565,260	4,483,613
Commercial	0	0	0	0	0	0	0	210,290
Industrial	0	0	0	0	23,620	114,008	214,340	4,479,461
Infrastructure	0	1,779	3,558	9,552	38,276	84,986	116,940	1,376,005
TOTAL	0	13,638	27,276	73,230	293,449	651,561	896,540	10,549,369
Average Annual Damage (AAD)	**21,176**							

3.4 Flood Risk Precincts

Wingecarribee Shire Council have a suite of Development Control Plans (DCPs) that outline Council's requirements for development on all floodplains within the Local Government Area. This includes the Nattai Ponds catchment. Further discussion on the DCPs are included in Section 4.3.2.

Section A5.3.2 of the DCPs introduces the concept of "Flood Risk Precincts", which subdivides the floodplain accordingly to the potential flood hazard/risk. This flood risk precinct classification, in turn, determines what flood-related development controls are applicable for a particular parcel of land. The four flood risk precincts that are documented in the DCPs are summarised in **Table 12**.

Table 12 Flood Risk Precinct Definitions

Flood Risk Precinct	Description
High	This Precinct contains that land below the 1% AEP flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. The high flood risk precinct is where high flood damages, potential risk to life, and evacuation problems would be anticipated or development would significantly and adversely affect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.
Medium	This Precinct contains that land below the 1% AEP flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
Fringe-Low	This Precinct contains that land between the extents of the 1% AEP flood and the 1% AEP flood plus 0.5m in elevation (being a freeboard). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
Low	This Precinct contains that land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within any of the above Flood Risk Precincts. The Low Flood Risk Precinct is where risk of damages is low for most land uses and most land uses would be unrestricted within this precinct.

To aid Council in defining the spatial extent of each flood risk precinct across the Nattai Ponds catchment, a Flood Risk Precinct map was prepared based on the outcomes of the design flood simulations and hazard mapping. The flood risk precinct maps are shown in **Figures 30.1** to **30.8** inclusive.

3.5 Impacts of Future Catchment Development

The Nattai Ponds catchment includes significant areas that are currently undeveloped. However, some of these areas do have the potential to be developed in the future based upon current land use zonings defined in the Wingecarribee LEP 2010. A representation of some of this development that will occur in the immediate future (e.g., Renwick, east of the main watercourse) was included as part of the 'base' flood results.

Nevertheless, there are sections of the catchment where there is potential for further, new development to occur and this was not included in the 'base" simulations. 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. In addition, Wingecarribee Shire Council strategic planners were consulted to identify areas that have the potential to be rezoned in the future to promote further urban development. The extent of the land that was identified as having the potential for future urban development is shown on **Figure 23**.

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 13**).

Table 13 Adopted land use information for future development assessment

Future Land Use Zone	% of Catchment	Zone Description	Composition	Impervious	Pervious "n"
R2	7.5	Low Density Residential	50% building, 25% grass, 20% concrete, 5% trees	75%	0.026
R5	1.4	Large Lot Residential	30% building, 35% grass, 20% concrete, 15% trees	50%	0.030
IN1	3.0	General Industrial	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018
B1	0.1	Business Zone	70% building, 15% concrete, 10% car park, 5% grass	95%	0.018
SP3	0.4	Special Purpose Zone (Tourist Use)	60% building, 15% concrete, 20% car park, 5% grass	95%	0.018

The updated impervious and pervious "n" values were applied to an updated "ultimate catchment development" version of the XP-RAFTS model. The updated model was used to re-simulate the 20% AEP, 1% AEP and 0.5% AEP storms under potential future catchment development conditions. Peak discharges extracted from the results of the revised hydrologic assessment are presented in **Appendix E**. Peak 20% AEP, 1% AEP and 0.5% AEP discharges for current catchment development conditions are also included in **Appendix E** for comparison.

The discharge comparison indicates that the future catchment development is predicted to generate localised increases in peak design discharges. At the 15 focus locations within the catchment, the following average changes in peak design discharges are predicted:

- 20% AEP Event: Discharges are predicted to increase by 8%,
- 1% AEP Event: Discharges are predicted to increase by 4.9%,
- 0.5% AEP Event: Discharges are predicted to increase by 4.5%.

However, more significant increases (>200%) are predicted immediately downstream of some of the future development areas. Accordingly, although large increases in design discharges are not anticipated at the catchment scale, significant localised increases may still occur in the immediate vicinity of future development areas.

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).

Peak floodwater depths, levels and velocity vectors for the 20%, 1% and 0.5% AEP events were extracted from the results of the future catchment development modelling and are presented in **Figures 24.1** to **26.8** inclusive.

Updated flood hazard mapping was also prepared for the 1%AEP event based on the future catchment development simulation. The hazard map is presented in **Figure 27**.

It was also considered important to identify areas that should be retained in the future for the conveyance of flood flows and the temporary storage of floodwaters. In this regard, updated hydraulic category mapping was also prepared and is presented in **Figure 28**.

Flood level difference mapping was also 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 4**, **Plate 5**, and **Plate 6** for the 20%, 1% and 0.5% AEP events respectively.

Plate 4 indicates that in the 20% AEP flood, future development is predicted to generate localised increases in flood levels of up to 0.15 metres. However, these are mainly contained to the immediate vicinity of the future development areas. The most significant increases across existing development areas are predicted to occur along Inkerman Road (0.05 metres), upstream of the Old Hume Highway (0.04 metres), and within industrial properties on Gantry Place (0.12 metres).

The flood level differences shown in **Plate 5** indicate that during the 1% AEP event, future development is predicted to generate flood level increases of up to 0.22 metres. The most significant increases across existing development areas are predicted within the watercourse in the western arm of the Renwick subdivision (0.02 metres), within properties between Inkerman Road and Scarlet Street (0.04 - 0.06 metres), properties east of Beresford Street (0.05 metres), and within industrial properties on Gantry Place (0.13 metres).

Plate 6 shows that in the 0.5% AEP event, future development is predicted to generate localised increases in flood levels of up to 0.23 metres The most significant increases across existing development areas are predicted within the watercourse in the western arm of the Renwick subdivision (0.04 metres), within properties between Inkerman Road and Scarlet Street (0.04 metres), properties east of Beresford Street (0.06 metres), and within industrial properties on Gantry Place (0.15 metres).

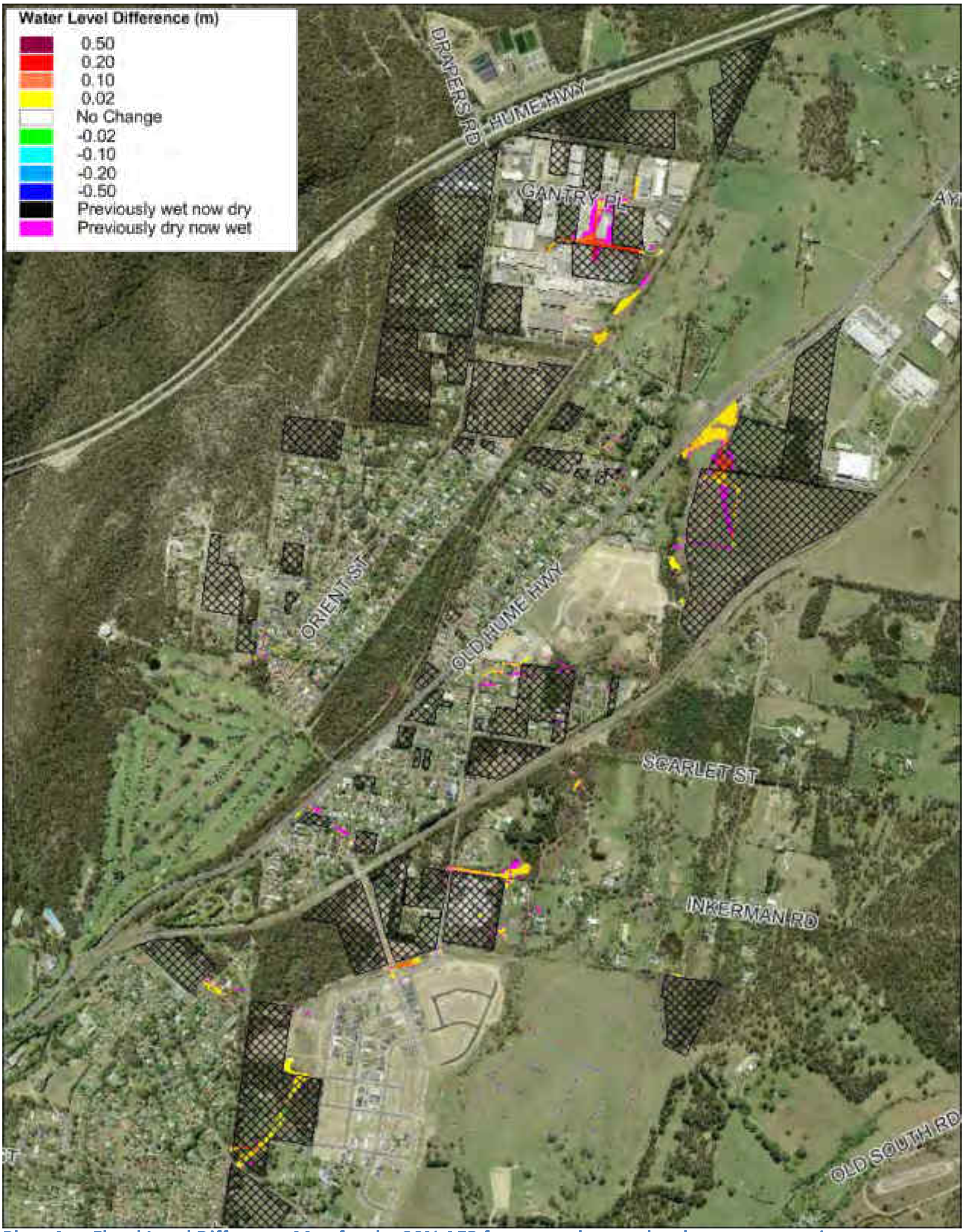


Plate 4 Flood Level Difference Map for the 20% AEP future catchment development scenario

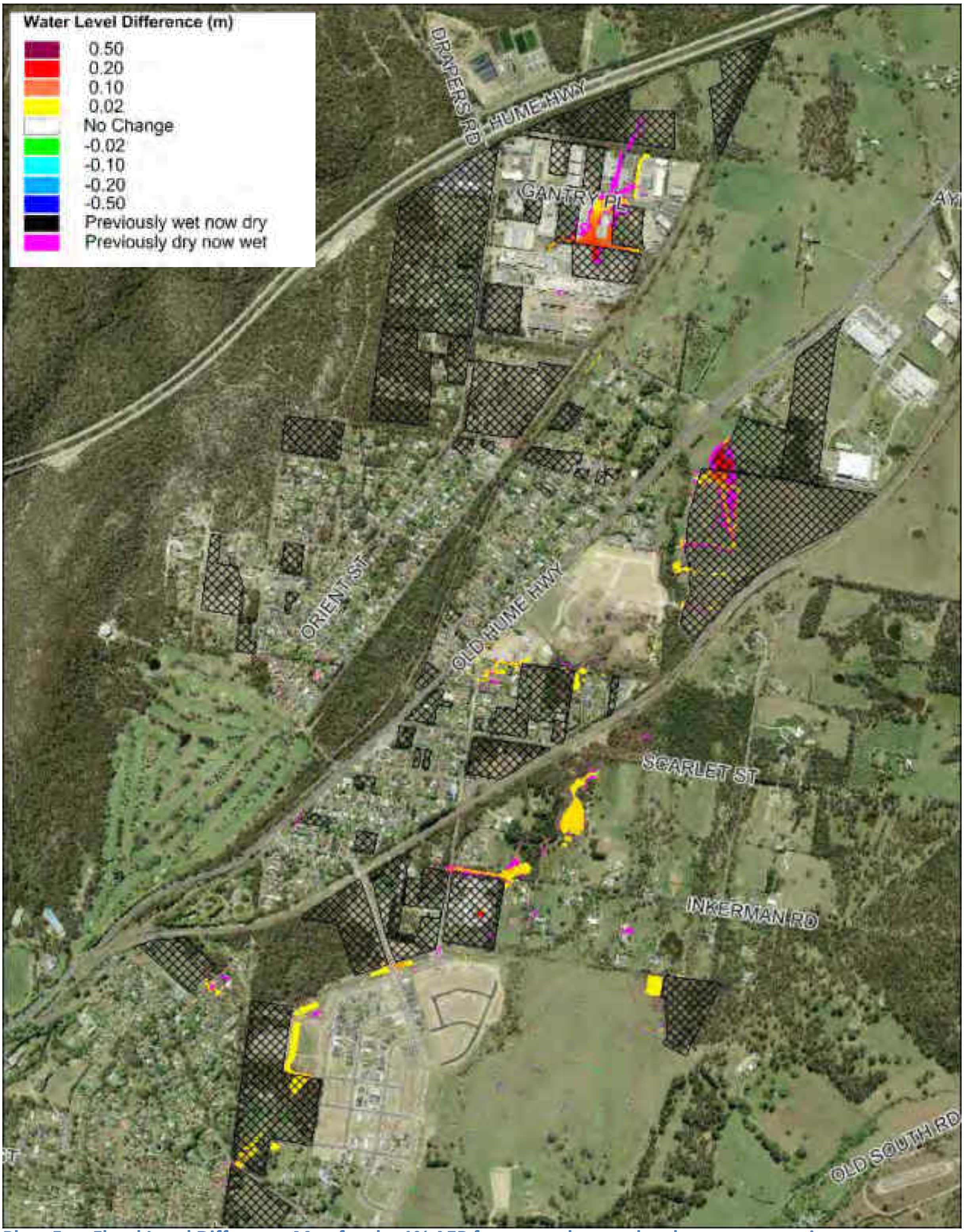


Plate 5 Flood Level Difference Map for the 1% AEP future catchment development scenario

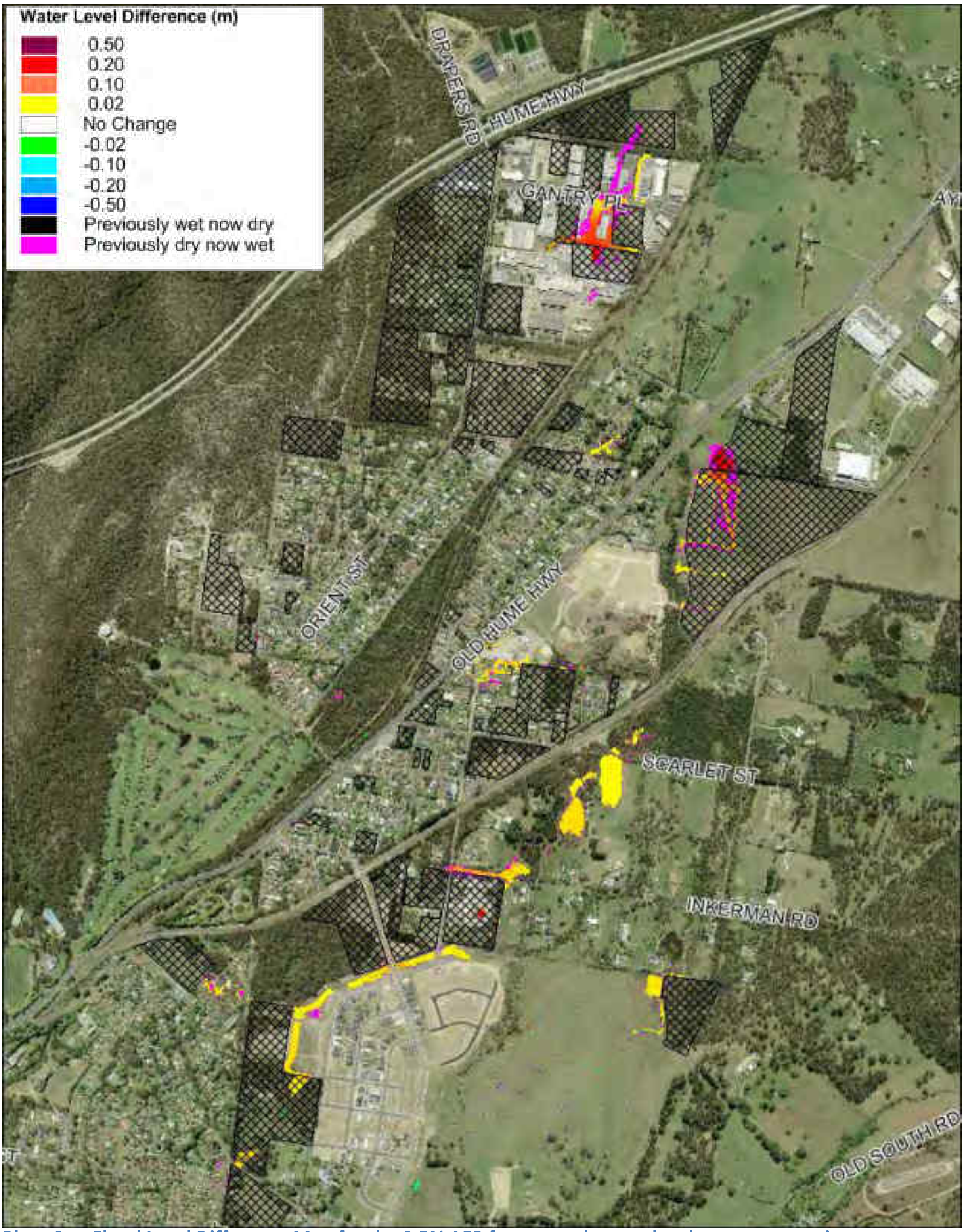


Plate 6 Flood Level Difference Map for the 0.5% AEP future catchment development scenario

A revised damage assessment was also completed to determine the impacts that potential future development may have on existing flood damage estimates. The future average annual damage (AAD) estimates were compare to the "existing" AAD estimates (refer Section 3.3.3) and this determined that future catchment development has the potential to increase AAD by just over $2,000.

A review of the revised flood damage estimates shows that a total of 8 buildings are predicted to be exposed to an increase in flood damage as a result of future catchment development. The properties are shown in **Plate 7**. As shown in **Plate 7**, the increase in AAD across residential properties between Biggera Street and the Old Hume Highway is predicted to be relatively small (i.e., <$100 per property). However, more significant increases are anticipated across industrial properties in Gantry Place.

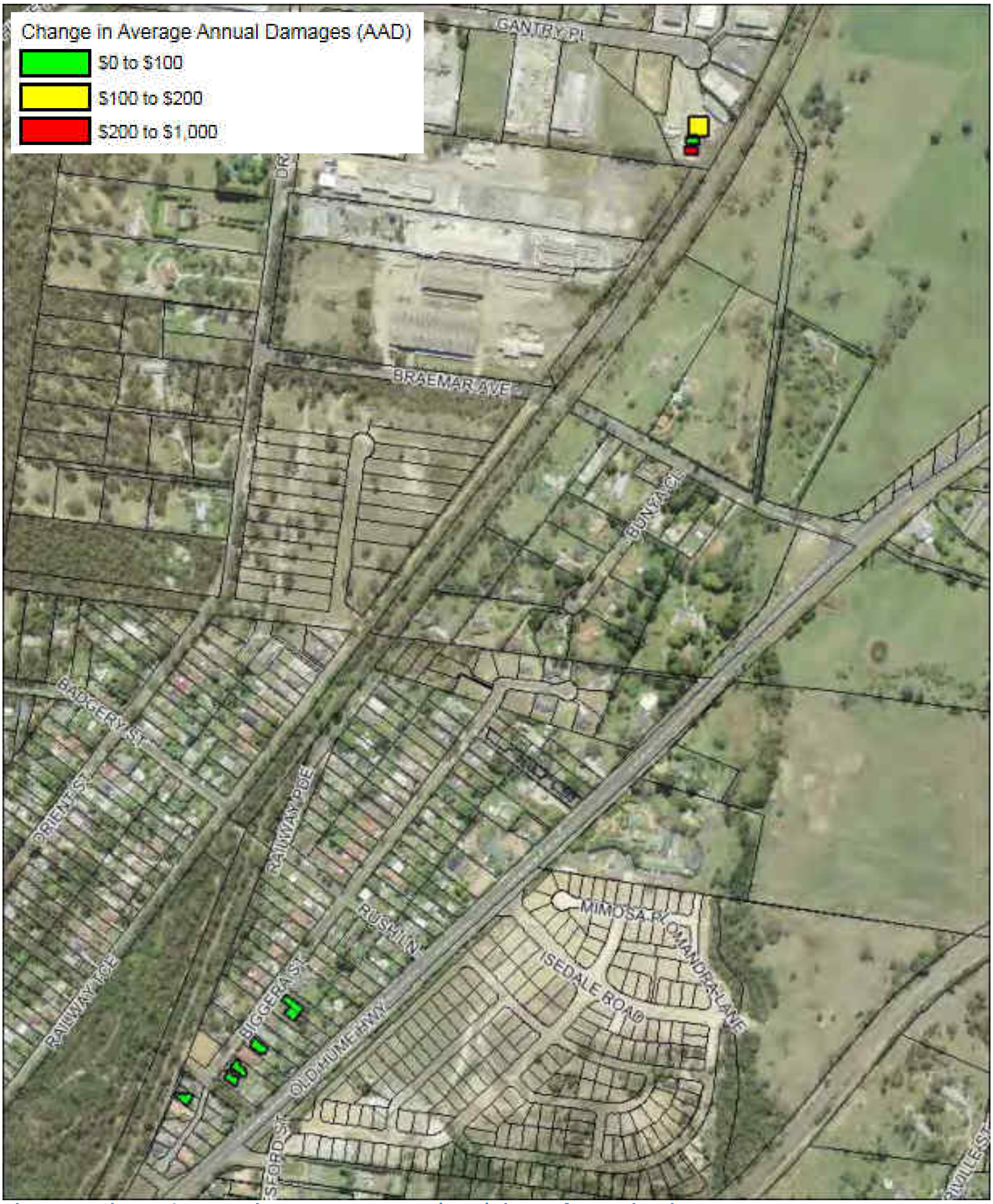


Plate 7 Change in Annual Average Damages (AAD) due to future development

Accordingly, future catchment development does have the potential to cause localised increases in flood discharges and levels. This has the potential to increase the flood exposure and flood damage potential across some existing properties. The most significant adverse impacts are predicted across industrial properties in Gantry place.

3.6 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 rainfall intensities in the future.

Although there is considerable uncertainty associated with the impact that climate change may have on rainfall, it was considered important to provide an assessment of the potential impact that climate change induced rainfall intensity increases may have on the current flood risk across the study area. In this regard, the results of the 0.5% AEP and 0.2% AEP flood were compared to the results from the 1% AEP flood to gain an appreciation of the impacts of the rainfall intensity increases. The 0.5% AEP rainfall reflects a 14% increase relative to current 1% AEP rainfall intensities, whiles the 0.2% AEP rainfall reflects a 34% increase relative to current 1% AEP rainfall intensities.

Flood level difference mapping was prepared to quantify the impacts that a 14% and 34% increase in rainfall would have on current 1% AEP flood level estimates. The difference mapping was prepared by subtracting the peak 1% AEP flood levels from the 0.5% and 0.2% AEP flood levels. The difference mapping is presented in **Plate 8** and **Plate 8**.

Plate 8 and **Plate 8** show that rainfall increases will likely increase current 1% AEP flood level estimates across most of the catchment, although the most notable increases are concentrated along defined watercourses. A 14% increase in rainfall is predicted to increase 1% AEP flood levels by over 0.3 metres at the Oldfield Road Basin and upstream of the Old Hume Highway, and 0.1 metres upstream of the main railway bridge crossing. The 34% increase in rainfall is predicted to increase existing 1% AEP flood levels by 0.9 metres at the Oldfield Road Basin, 0.6 metres upstream of the Old Hume Highway, and over 0.2 metres upstream of the main railway bridge crossing.

A comparison of the number of properties subject to above floor flooding (previously shown in **Table 10**) indicates that a 14% increase in rainfall is likely to result in an additional 5 properties being exposed to above floor flooding during a 1% AEP flood. A 34% increase in rainfall is predicted to result in 9 additional properties being exposed to above floor flooding. **Table 11** indicates that a 14% increase in rainfall is expected to cause an additional $358,000 worth of damage during a 1% AEP flood (a 122% increase in damages relative to existing conditions), and a 34% increase in rainfall is predicted to result in an additional $603,000 worth of damage (a 206% increase in damages relative to existing conditions).

Accordingly, the outcomes of the assessment show that increases in rainfall associated with climate change have the potential to produce a significant increase in the severity of flooding and the associated flood damage costs across the catchment.

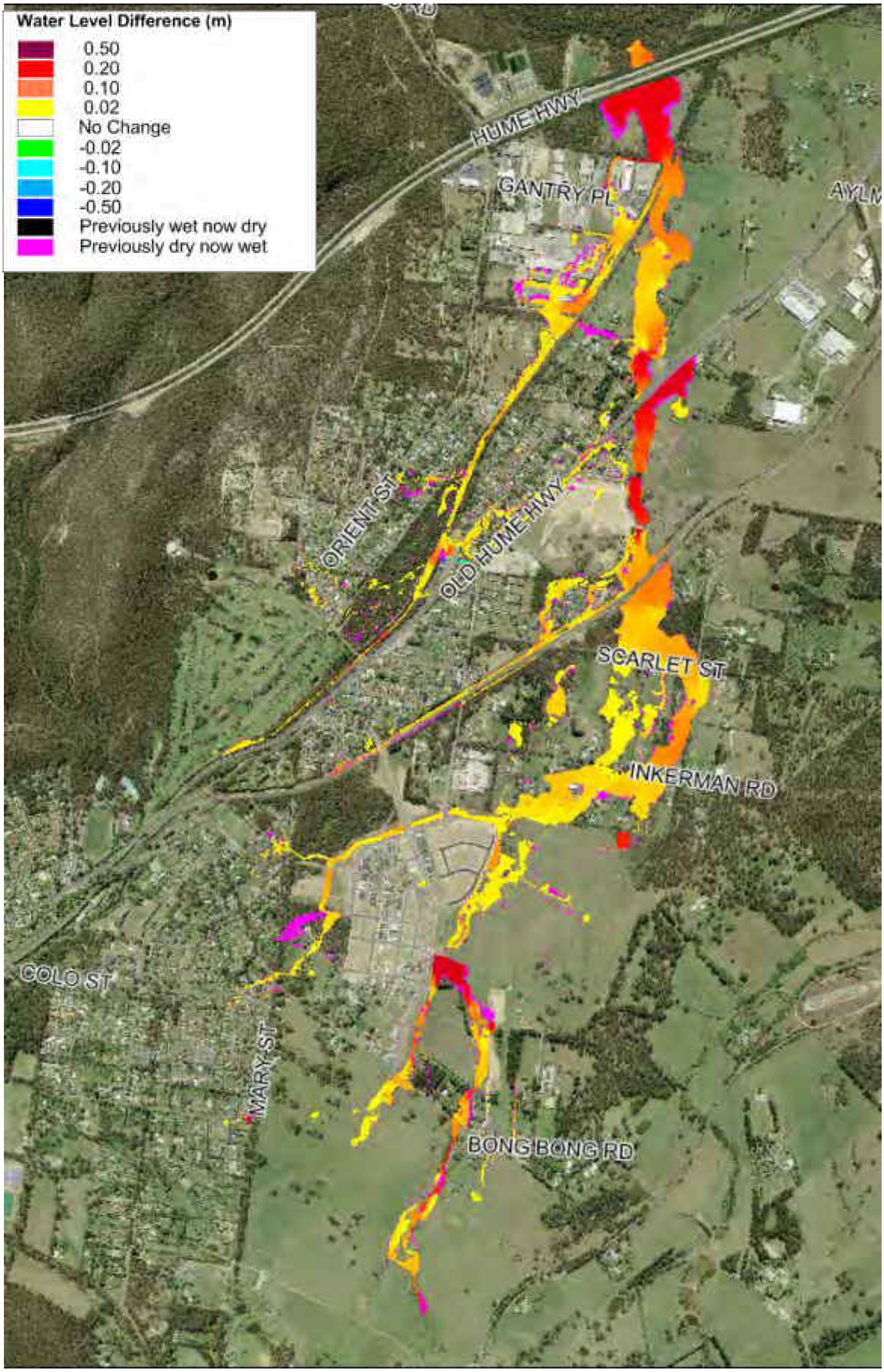


Plate 8 Flood level difference map for 0.5%AEP against 1%AEP

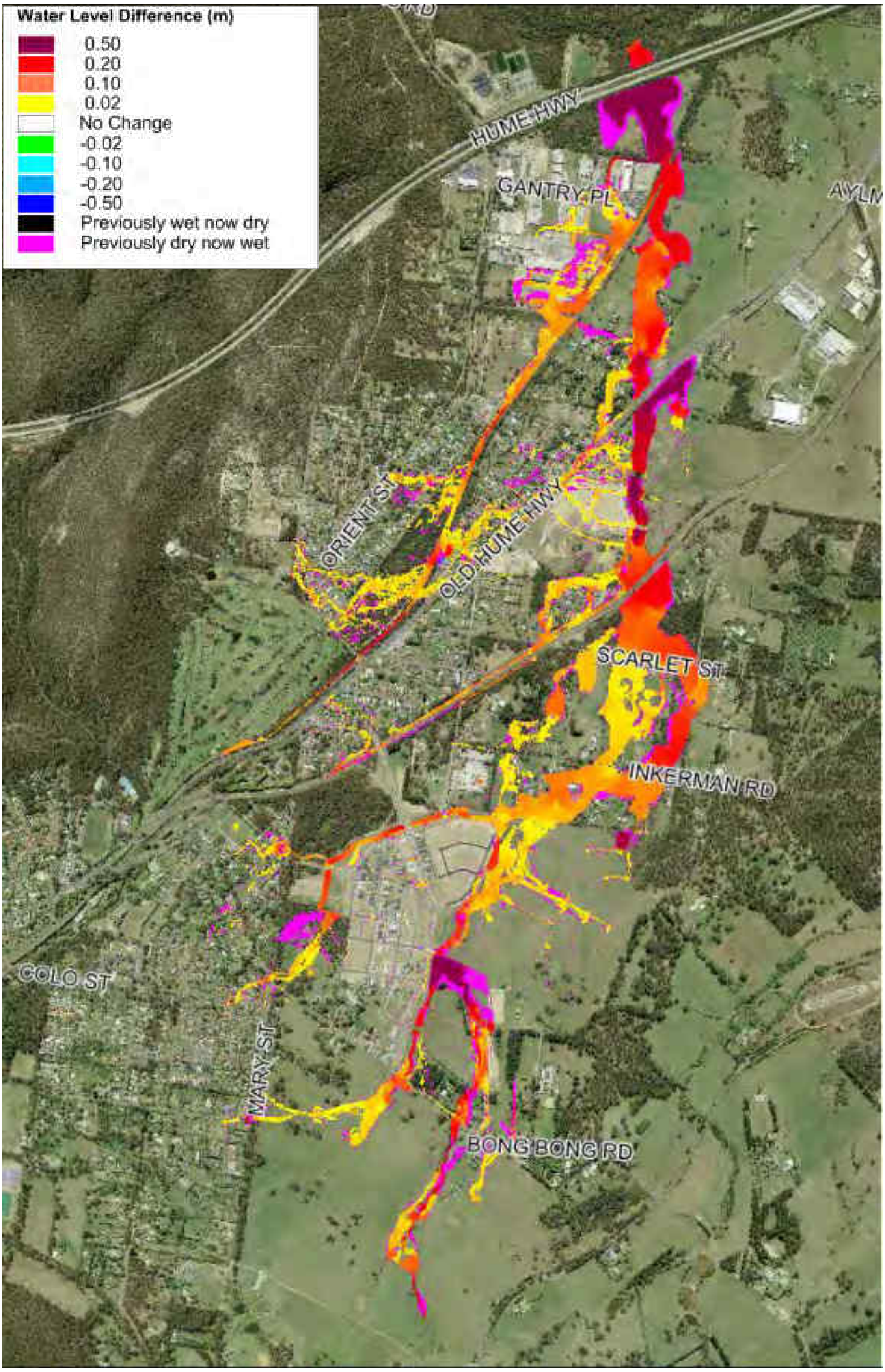


Plate 9 Flood level difference map for 0.2%AEP against 1%AEP

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 Wingecarribee Shire Council Local Government Area. Where appropriate, recommendations for ways in which Council's planning documents could be modified to better manage the existing and future flood risk are provided.

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" (described in more detail in Section 4.3.1) 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 described in Section 4.3.1.

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

- Flood actions;
- Elevation requirements;
- Foundation and footing requirements;
- Requirements for enclosures below the flood hazard level;
- Requirements for structural connections;
- Material requirements;
- Requirements for utilities; and
- Requirements for occupant egress.

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

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

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

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

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

In the NSW planning system, the BCA takes on importance for complying development under the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (see Section 4.2.1). Currently, certain development on the floodplain is also required to satisfy the requirements of the BCA under Mittagong DCP 2017 and Northern Villages DCP 2017. The Building Circular also indicates that following development approval, an application for a construction certificate (CC) will require assessment of compliance with the BCA.

4.2 State Provisions

4.2.1 State Environmental Planning Policies

State Environmental Planning Policies or SEPPs are the highest level of planning instrument and generally prevail over Local Environmental Plans (discussed in Section 4.3.1).

SEPP (Exempt and Complying Development Codes) 2008

State Environmental Planning Policy (Exempt and Complying Development Codes) 2008 (the *Codes SEPP*) defines development which is exempt from obtaining development consent and other development which does not require development consent if it complies with certain criteria. The Codes SEPP is aimed at simplifying the development application process for relatively small, low risk developments.

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 Local Environmental Plan (LEP) or Development Control Plans (DCP). Exempt development is not permitted on flood control lots, but some complying development is permitted.

Clause 3.5 of the Codes SEPP states that complying development is permitted on flood control lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a flood storage area, floodway area, flow path, high hazard area or high risk area. The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability (up to the PMF if on-site refuge is proposed)[1], flood affectation, access, and car parking (see **Plate 10** on the following page).

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 following maps have been prepared as part of the study:

- 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. A map was prepared to identify these areas (refer to **Figure 31**) based upon the following assumptions:
- floodway or flood storage during the 1% AEP flood (based upon **Figure 17.1** to **Figure 17.8**).
- exposed to a high flood hazard during the 1% AEP flood (based upon **Figure 13.1** to **Figure 13.8**).

[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.

- function as a major flow path (a velocity depth product of > 0.4 m^2/s was used for this purpose).
- A high risk area was defined as an area that becomes isolated early in a flood and then becomes inundated (i.e., flooded isolated submerged emergency response classification).
- land that is a flood control lot. This will reflect the standards set in the LEP and DCP, which shape the flood planning area. Draft mapping of the flood planning area and flood control lots was completed as part of the current floodplain risk management study (refer to Section 4.3.1).

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

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

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 Wingecarribee LEP 2010) as being a floodway or high flooding hazard.

As outlined previously, floodway and/or high flood hazard areas in the Nattai Ponds catchment are typically contained in close proximity to each of the main watercourses during events up to and including the 1% AEP. Accordingly, this policy could apply to much of the land beyond the main watercourses.

4.2.2 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 Section 9.1 (formally Section 117) of the EP&A Act. It requires councils to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy as set out in the 'NSW Floodplain Development Manual' (NSW Government, 2005). It requires provisions in a Local Environmental Plan on flood prone land to be commensurate with the flood hazard of that land. In particular, a planning proposal must not contain provisions that:

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

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

The question as to whether flood behaviour across the Nattai Ponds catchment warrants the imposition of flood related development controls above the residential flood planning level is considered in Section 4.3.1.

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) prescribes 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 "low risk" areas above the flood planning level, unless exceptional circumstances have been granted), information describing the flood affectation of the land would not be indicated under Section 10.7(2). A lot that is a flood control lot is a prescribed matter for the purpose of a certificate under section 10.7(2).

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

Inclusion of a planning certificate containing information prescribed under Section 10.7(2) is a mandatory part of the property conveyancing process in NSW. The conveyancing process does not mandate the inclusion of information under Section 10.7(5) but any purchaser may request such information be provided (typically requiring payment of a fee to the issuing council). Council may like to consider including Section 10.7(5) information with Section 10.7(2) information at no charge as a means of helping prospective property owners to better understand their flood exposure, particularly during rare floods, such as the PMF.

As a minimum, the updated design flood information generated as part of the current study should be included on Section 10.7 certificates moving forward to ensure the most up-to-date information is distributed for properties located within the Nattai Ponds catchment.

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 Manual). 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 advocates a merit approach for development decisions in the floodplain, taking into account social, economic, ecological and flooding considerations. The primary responsibility for management of flood risk rests with local councils. The Manual assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

Guideline on Development Controls on Low Flood Risk Areas, 2007

The *Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual* (the Guideline) was issued on 31 January 2007 as part of Planning Circular PS 07-003 at the same time as the Section 9.1 Direction described previously in Section 4.2.2. 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, 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 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.

Further discussion on whether an application for exceptional circumstances may be required for the Nattai Ponds catchment is provided in Section 4.3.1.

4.3 Local Provisions

In NSW, local government councils are responsible for managing their flood risk. A Local Environmental Plan (LEP) is used to establish what land uses are permissible and/or prohibited on land within the Local Government Area (LGA) and sets out high level flood planning objectives and requirements.

A DCP sets the standards, controls and regulations that apply when carrying out development or building work on land within a specified LGA. Wingecarribee Shire Council have a suite of DCPs, each applying to just one locality or zoning. The DCPs relevant to the Nattai Ponds catchment are:

- Northern Villages DCP: for the townships of Balaclava, Braemar (excluding the industrial area) and Willow Vale;
- Industrial Lands DCP: for the industrial area of Braemar;
- Mittagong DCP: for the townships of Mittagong and Renwick.

Council undertook a review of some provisions within the DCPs during 2017. The current set of DCPs came into effect on 29 November 2017.

4.3.1 Wingecarribee Local Environmental Plan 2010

Wingecarribee Local Environmental Plan 2010 (Wingecarribee LEP 2010) outlines the zoning of land, what development is allowed in each land use zone and any special provisions applying to land. Wingecarribee 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 include any flood mapping for the Nattai Ponds catchment.

Flood planning and floodplain risk management are addressed in Clause 7.9. This is reproduced in **Plate 11**. Clause 7.9 relates to land within the Flood Planning Area (FPA) (i.e., land at or below the flood planning level (FPL)), and other land at or below the FPL. The FPL is defined in Wingecarribee LEP 2010 as 'the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 metre freeboard'.

7.9 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 climate change,

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

(2) This clause applies to:

(a) land that is shown as "Flood Planning Area" on the Flood Planning Area Map, and,

(b) other land at or below the flood planning level.

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

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

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

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

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

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

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

(5) In this clause:

Flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 meters freeboard.

Flood Planning Area Map means the | **Wingecarribee Local Environmental Plan 2010 Flood Planning Area Map**.

Plate 11 Extract from Wingecarribee LEP 2010 Clause 7.9 (Note: version dated 20 April 2018)

The appropriateness of the Wingecarribee LEP 2010 for managing flood risk in the Nattai Ponds catchment is considered under the following headings:

- Suitability of Current Zoning;
- Flood planning area; and
- Need for 'Exceptional Circumstances'.

Suitability of Current LEP 2010 Zoning

The current land zoning within the Nattai Ponds catchment is presented in **Figure 32**. It shows that areas of the catchment located north of the Old Hume Highway primarily comprises a mix of "IN1" (General Industrial), "RU2" (Rural Landscape), "RU4" (Rural Small Holdings), "R5" (Large Lot Residential), R2" (Low Density Residential), "E2" (Environmental Conservation) and "E3" (Environmental Management).

Areas south of the Old Hume Highway predominantly comprises "RU2" (Rural Landscape), "RU4" (Rural Small Holdings), "R2" (Low Density Residential) and "E3" (Environmental Management), with scattered areas of "R3" (Medium Density Residential), "R5" (Large Lot Residential) and "E2" (Environmental Conservation). There are also small pockets of "B1" (Neighbourhood Centre) within the catchment. The Hume Highway and railway line are zoned "SP2" (Infrastructure), while the Old Hume Highway is zoned "SP3" (Tourist).

The suitability of the current land use zoning and potential flood constraints was assessed using information contained in the Australian Institute of Disaster Resilience handbook titled *'Flood Information to Support Land-Use Planning'* (2017). This document subdivides flood-liable land into one of four Flood Planning Constraint Categories (FPCC) (each with a number of subcategories) to provide advice about the relative degree and type of flood-related development constraints that apply in different areas of the floodplain.

The FPCC are summarised in **Table 14**. **Table 14** also summarises how the categories are defined along with the associated planning implication/considerations. In general, a FPCC categorisation of "1" implies a more flood constrained section of land relative to FPCC category "2", and so on.

Table 14 Flood Planning Constraint Categories (AIDR, 2017)

FPCC	Sub-Category	Constraint	Implications	Consideration
1	A	Flow conveyance and storage areas in the DFE	Development or changes to topography within flow conveyance areas and flood storages areas affect flood behaviour, which will alter flow depth or velocity in other areas of the floodplain. Changes can negatively affect the existing community and other property	The majority of developments and uses have adverse impacts on flood behaviour. Consider limiting uses and development to those compatible with maintaining flood function
	B	H6 hazard in the DFE	Hazardous conditions considered unsafe for vehicles and people. All building types are considered vulnerable to structural failure	The majority of developments and uses are vulnerable to failure in this flood hazard category. Consider limiting developments and uses to those that are compatible with flood hazard H6
2	A	Flow conveyance area in events larger than the DFE	Flow conveyance areas may develop during an event larger than the DFE. People and buildings in these areas may be affected by flowing and dangerous floodwaters	Consider compatibility of developments and users with rare flood flows in this area
	B	H5 hazard in the DFE	Hazardous conditions are considered unsafe for vehicles and people, and all buildings are vulnerable to structural damage	Many uses and developments will be vulnerable to flood hazard. Consider limiting new uses to those compatible with flood hazard H5. Consider treatments such as filling (where this will not affect flood behaviour) to reduce the hazard to a level that allows standard development conditions to be applied. Alternatively, consider a requirement for special development conditions
	C	Isolated and submerged areas (low flood island or low trapped perimeter in 1%AEP event)	Area becomes isolated by floodwater or impassable terrain, with loss of evacuation route to the community evacuation location. The area will become fully submerged with no flood-free land in an extreme event, with ramifications for those who have not evacuated and are unable to be rescued	Consequences of isolation and inundation can be severe. Consider the consequences of: • evacuation difficulty or inundation of the area on the development and its users, which may include limitations on land use, or on land use that has occupants who are more vulnerable to disruption and loss • the development on emergency management planning for the existing community, including the need for additional treatments • the development on community flood recovery • disruption or loss of the development on the users and wider community

FPCC	Sub-Category	Constraint	Implications	Consideration
	D	Isolated but not submerged areas (high flood island or high trapped perimeter in 1%AEP event)	Area becomes isolated by floodwater or impassable terrain, with loss of an evacuation route to a community evacuation location. The area has some land elevated above the extreme flood level. Those not evacuated may be isolated with limited or no services, and will need rescue or resupply until floods recede and roads are passable	Some developments and their users may be vulnerable to disruption or loss. Consider: • the consequences of disruption or loss of the development on the users and the wider community • limiting land use, or land use that has occupants who are more vulnerable to disruption and loss • additional emergency management treatment requirements • issues associated with the level of support required during a flood, particularly for long-duration flood events
	E	H6 hazard in events rarer than the DFE	Hazardous conditions may develop in an event rarer than the DFE, which may have implications for the development and its occupants	Consider the need for additional development conditions to reduce the effect of flooding on the development and its occupants
3	-	Outside FPCC 2 but generally below the DFE plus freeboard	Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings that meet building standards unlikely because of flooding	Standard land-use and development controls aimed at reducing damage and the exposure of the development to flooding in the DFE are likely to be suitable. Consider the need for additional conditions for emergency response facilities, key community infrastructure and vulnerable users
4	-	Outside of FPCC 3 but within the PMF extent	Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users

The categories use a “Defined Flood Event” (DFE), which is analogous to the “planning flood” (i.e., 1% AEP event). It also requires consideration of flood impacts in events rarer than the DFE. The 0.2% AEP event was selected for this purpose.

The information contained in **Table 14** was used with the flood modelling outputs (most notably the flood hazard, hydraulic category and emergency response mapping) to prepare the FPCC map shown in **Figure 33**. Also included on **Figure 33** are the current land use zones to gain an appreciation for how the current zoning aligns with the FPCC. The proportion of each land zone that fall within each FPCC was also extracted and is presented in **Table 15**.

The FPCC categories presented in **Figure 33** show that current land use zones are broadly compatible with the level of flood constraints. More specifically, the majority of the residential land use zonings are located outside of the more highly constrained land (i.e., FPCC 1) and, in most cases, are located outside of the PMF extent (as defined by the FPCC 4)

It is noted that a portion of the industrial area that adjoins Braemar Avenue falls within FPCC 1A and 2A. These categorisations indicate that any flow obstructions have the potential to impact on flood behaviour during the 1% AEP (and larger). Therefore, care will need to be exercised if any new/redevelopment occurs in this area to ensure existing flow paths and storage areas are retained. For example, any filling or buildings that would serve to obstruct flow or remove storage volume should be avoided and the potential to install "open" fencing could be explored.

Table 15 Land use zones falling within each Flood Planning Constraint Category

Zone	Flood Planning Constraint Category									
	1		2					3	4	Not Impacted
	A	B	A	B	C	D	E			
B1	0%	0%	0%	0%	0%	0%	0%	1%	0%	99%
E2	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
E3	1%	0%	0%	0%	0%	0%	0%	2%	0%	97%
IN1	15%	0%	12%	0%	0%	0%	0%	5%	6%	62%
R2	6%	0%	7%	0%	0%	0%	0%	7%	2%	78%
R3	1%	0%	10%	0%	0%	0%	0%	8%	0%	81%
R5	4%	0%	3%	0%	0%	1%	0%	3%	2%	89%
RE1	1%	0%	0%	0%	0%	0%	0%	1%	0%	97%
RU2	7%	0%	7%	0%	0%	0%	0%	1%	2%	84%
RU4	20%	0%	12%	0%	0%	3%	0%	2%	4%	59%
SP2	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
SP3	6%	0%	9%	0%	0%	0%	0%	1%	1%	82%

Apart from the location noted above, the LEP zoning appears to be broadly appropriate with regard to the flood constraints. That is, there is no obvious need for modification to the current LEP zones. Nevertheless, intensification of land uses below the flood planning level should be discouraged.

Flood Planning Area

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

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

As noted previously, the FPL is defined in Wingecarribee LEP 2010 as 'the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 metre freeboard'. This is consistent with the 'Floodplain Development Manual' (NSW Government, 2015), which suggests that a flood planning level consisting of the 1% AEP flood plus a 0.5 metre freeboard will generally be appropriate for new residential development unless exceptional circumstance exist. This "standard" is also echoed by the 'Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual' (Department of Planning, 2007) which states that "…*unless there are exceptional circumstances, councils should adopt the 100 year flood as the FPL for residential development"*.

The freeboard can be considered as a "factor of safety" that is used to cater for uncertainties in the estimation of the planning flood. An assessment of the suitability of Council's 0.5 metre freeboard requirement was completed as part of the *'Nattai Ponds Flood Study'* (2016). This assessment drew on the results of various sensitivity simulations and determined that an allowance of 0.4 metre would suitably account for modelling uncertainty along mainstream flooding areas. Accordingly, the adoption of a 0.5 metre freeboard would make an allowance for modelling uncertainty of up to 0.4 metres and at least a 0.1 metre allowance for areas of "other" uncertainty that cannot be explicitly represented in the modelling (e.g., wind and wave action). Therefore, it is considered that the 0.5 metre freeboard is suitable for application across areas subject to mainstream flooding.

The 0.5 metre freeboard was added to the peak design 1% AEP flood levels to develop a flood planning level layer. The flood planning level layer was extended laterally until the flood planning level encountered higher terrain. This formed the flood planning area for the catchment. The flood planning area is shown in **Figure 34**. Flood planning level contours are also included on **Figure 34**.

Need for 'Exceptional Circumstances'

An assessment was completed to determine if and where 'exceptional circumstances' may be appropriate for flood related development controls on residential development on land outside of the FPA. Exceptional circumstance may be triggered when there is an unacceptably high flood risk above and beyond the FPL/FPA. This was completed by determining if there were any H6 hazard areas during the PMF in areas located beyond the FPA.

Plate 12 shows locations outside of FPA where the hazard is predicted to reach H6 during the PMF (refer yellow areas). As shown in **Plate 12**, there are some areas where the PMF hazard is predicted to reach H6 outside of the FPA. But the areas are small and, with the exception of one industrial property, are not predicted to extend across areas currently zoned for habitable development. As a result, it is considered that application of appropriate development controls within the FPA should be sufficient to manage the flood risk.

However, the PMF hazard categories at the peak of the PMF are significant across some locations. As a result, consideration should be given to placing controls on development in this area to ensure that buildings are designed to withstand the floodwater forces during the PMF. Further discussion on this topic is provided in the following section.

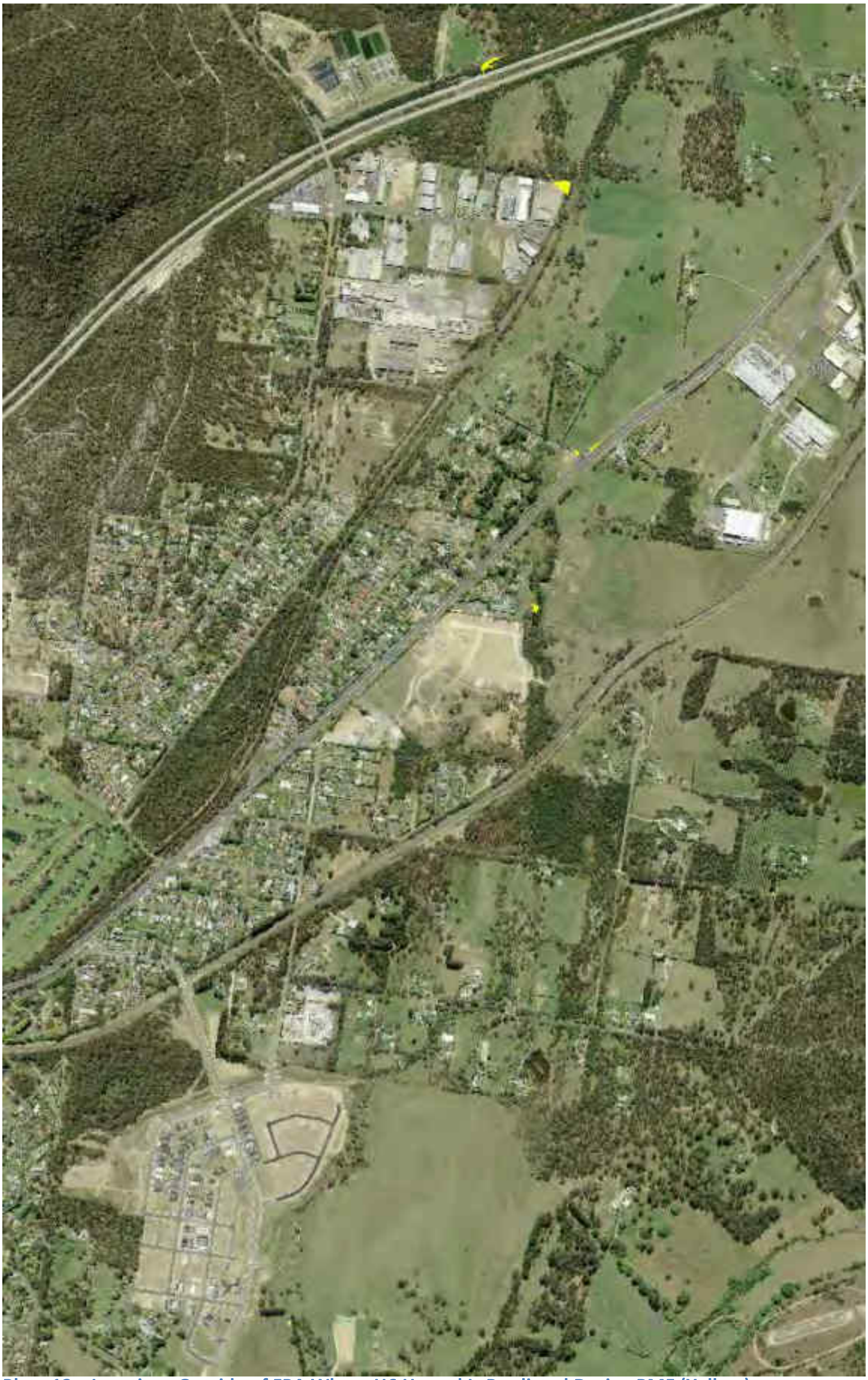


Plate 12 Locations Outside of FPA Where H6 Hazard Is Predicted During PMF (Yellow)

Suggested Modifications to LEP

It is recommended that the flood planning area maps are removed from the LEP, and made available to the public on councils' website, and/or through other means. There is current, and future proposed development in this catchment, as well as other parts of the LGA, which will modify the flood behavior in that area, and may result in changes to the flood planning area. If the flood planning area mapping is removed from the LEP and provided as a stand-alone suite of information, council will be able to update the information as required, with minimal time delays. If the flood planning area mapping remains as part of the LEP mapping, then council would need to go through a formal LEP review process every time updated or new flooding information was provided, which is a lengthy process, and most likely would need to be updated again as more additional flood information would become available for another area in the LGA. As these updates to the flood planning information occur, council will be able to update the flood planning area maps immediately, ensuring that the most current and up to date flood information is available to the public.

As discussed, the current Wingecarribee Shire Council LEP includes the additional local provision of clause 7.9 for flood planning. This clause applies to land that is shown on the flood planning area map. The flood planning area is defined as the 100 year ARI plus a 0.5 meter freeboard on the flood planning area map. Currently land between the flood planning area and the extent of the floodplain (i.e. PMF) are not indicated on any flood map or in any development or planning guidelines, and as such, development controls cannot apply to these areas.

An additional clause should be added to the LEP related to the low flood risk precincts identified in the DCP. This clause is referred to as "Floodplain Risk Management" in LEPs in other LGA's. This clause would relate to the areas between the flood planning area and the edge of the low flood risk precinct, as stated in the current DCP. The objective of identifying these areas and applying development controls is related to evacuation and emergency response issues for land subject to flooding in events greater than the flood planning level, as well as protecting the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

Removing the flood planning area map from the LEP, as recommended above, will not alter the relationship between the flood planning clauses of the LEP and the flood planning area and floodplain risk management areas indicated on the maps. The flood extent information would still be indicated on the maps, however these maps would not be embedded within the LEP, they would be provided and accessed as standalone documents, and as such, could be updated as frequently as required. The maps would still be referred to as "flood planning maps".

4.3.2 Mittagong Development Control Plan 2017 and Northern Villages Development Control Plan 2017

The *Mittagong Development Control Plan 2017* (Mittagong DCP 2017) applies to all land zoned for residential and business uses within the localities of Mittagong and Welby. Land under an Industrial zoning in or around Mittagong and Welby is covered under the Industrial Land Development Control Plan 2017 (refer to Section 4.2.3).

The *Northern Villages Development Control Plan 2017* (Northern Villages DCP 2017) applies to all land zoned "R2" (Low Density Residential), "R5" (Large Lot Residential), "B1" (Neighbourhood Centre) and "B2" (Local Centre in the villages of Aylmerton, Balaclava, Balmoral, Braemar, Colo Vale, Hill Top, Willow Vale and Yerrinbool). Other land zonings within these localities are covered under the *Rural Lands Development Control Plan 2017*, *Rural Living Development Control Plan 2017* and *Industrial Lands Development Control Plan 2017*.

"Section 5" (Flood Liable Land) of the Mittagong DCP 2017 and "Section 5" (Flood Liable Land) of the Northern Villages DCP 2017 outline the general development controls relating to the management of flood risk. These sections discuss the appropriateness of the controls for development on flood liable land to manage overland flow inundation and mainstream flood risks in the Nattai Ponds catchment. "Section 5" (Flood Liable Land) of the Mittagong DCP 2017 and the Northern Villages DCP 2017 are reviewed below.

Flood Risk Precincts

The flood risk management controls defined within the Mittagong DCP 2017 and Northern Villages DCP apply to all land within the Mittagong and Northern Villages that is affected by flooding, that is all land that lies within a flood risk precinct.

"Flood Risk Precincts" are used to grade the severity of the flood risk and determine what development types are permissible across different sections of the floodplain. As noted in Section 3.4, the DCP includes four flood risk precinct classifications:

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

The adopted flood risk precinct categories are convenient for aligning with the Floodplain Development Manual and the Codes SEPP 2008. For this reason, no changes to this classification system are considered necessary.

Land Use Categories

The land use categories discussed in relation to the flood risk management controls within the DCP include 'Critical Uses and Facilities'; 'Sensitive Uses and Facilities'; 'Residential'; 'Commercial or Industrial'; 'Recreation and non-urban' and 'Concessional development' (i.e., additions or alterations). These development types are suitably defined in Section A5.3.3 of the DCPs, however they do not relate specifically to the land use zoning specified in the Wingecarribee LEP 2010.

Risk Compatibility Categories

The Mittagong DCP 2017 and Northern Villages DCP 2017 provide a list of compatible development and flood related development controls for properties in each Flood Risk Precinct (FRP) via a "flood plain matrix". The matrix includes three categories, one of which is applied to each land use/FRP combination:

- Development is permitted with no flood related development controls

- Development is permitted with flood related development controls (refer to numbered prescriptive criteria below)
- Development is not permitted

A summary of the permitted development types within each FRP are illustrated in **Table 16**.

Table 16 Permissible Development Types within each Flood Risk Precinct.

Flood Risk Precincts	Development Type					
	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development
Low Flood Risk	Not Permitted	Permitted with Controls	Permitted without Controls	Permitted without Controls	Permitted without Controls	Permitted without Controls
Low-Fringe Flood Risk	Not Permitted	Permitted with Controls	Permitted with Controls	Permitted with Controls	Permitted with Controls	Permitted with Controls
Medium Flood Risk	Not Permitted	Not Permitted	Permitted with Controls	Permitted with Controls	Permitted with Controls	Permitted with Controls
High Flood Risk	Not Permitted	Not Permitted	Not Permitted	Not Permitted	Permitted with Controls	Permitted with Controls

Permitted without Controls | Permitted with Controls | Not Permitted

No flood-related development controls apply for all land uses in the Low FRP except for 'Critical Uses' (where no development is permitted) and 'Sensitive Uses'. Flood-related development controls do apply for many land uses in the Low Fringe and Medium FRP. Development within the High FRP is only permissible for non-urban development types and concessional development. The land uses are considered to be compatible with the FRP and no modifications are consideration necessary in this regard.

It was noted that the quality of the text in Figure A4.2 of the DCP was poor making some text difficult to read. Therefore, provision of a higher resolution or larger size version is recommended.

Prescriptive Controls for General Development (A5.4)

The prescriptive controls for general development include compliance with the requirements of the flood plain matrix (Figure A4.2) of the DCPs. The controls include:

- **Minimum Floor Level:** Habitable floor levels for residential, commercial and industrial development are to be no lower than 1% AEP flood level plus freeboard. As noted in Section 4.3.1, a 0.5 metre freeboard is considered to be appropriate for the Nattai Ponds catchment. Non-habitable floor levels should also be greater than the than 1% AEP flood level plus freeboard where possible or otherwise no lower than the 20% AEP flood level plus freeboard. The minimum floor level for sensitive uses and facilities must be no lower than the PMF level. This is considered to be appropriate given the potential vulnerability of occupants of these facilities and/or the important role that they may play in emergency response during floods.
- **Building Component:** The DCPs require all structures to have flood compatible building components below the 1% AEP flood level plus 0.5m freeboard and a list of flood compatible materials is provided in Figure A4.4 of the DCPs. This is consistent with the requirement in the Codes SEPP. Sensitive land uses require flood compatible building

materials to be provided up to the level of the PMF. No modifications are considered necessary.

- **Structural Soundness:** The DCPs require all structures to be built to withstand forces of floodwater, debris and buoyancy up to and including the 1% AEP flood plus freeboard or the PMF (sensitive land uses only). The need to extend the structural soundness requirements to include the PMF for other development types should be considered where refuge-in-place is the preferred evacuation strategy (discussed in more detail under 'evacuation').
- **Flood Effects:** The DCPs outline that any proposed development shall not increase flood effects elsewhere, having regard to loss of flood storage, changes in flood levels and velocities and the cumulative impact of multiple potential developments. This control is fairly standard. However, it is not clear if this requirement applies to all potential floods (i.e., up to and including the PMF) or is applicable to a specific flood (e.g., 1% AEP flood). It is considered that the 1% AEP flood is suitable for assessing the potential impacts of most development types. However, consideration of the impacts during the PMF would be beneficial for sensitive facilities. Therefore, Council could give consideration to modifying this section of Figure A4.2 to provide specific advice on what floods need to be considered as part of the impact assessment.
- **Car Parking and Driveway Access:** Car parking controls are important given the ease with which vehicles can become buoyant and become floating debris with potential to block culverts and pose environmental hazards. The DCP requires carports and garages with less than 3 cars to be no lower than the 20% AEP flood level plus freeboard. In areas of overland flow where inundation depths are typically shallow, an option to provide carports or garages 300mm above the ground level could be provided.
- **Evacuation:** The potential for evacuation across some sections of the catchment may be limited owing to the short warning times (i.e., less than 1 hour before some roads are cut). The DCP does include a requirement for most development types to provide a refuge area above the PMF level or a minimum of 20% of the gross floor levels to be above the PMF level, which may allow for safe refuge in place if evacuation cannot be achieved. However, in order to ensure the safety of occupants, it is considered that the 'structural soundness' requirements of the DCP will need to be modified so that the structures are designed to withstand the forces of floodwater during all events up to and including the PMF.

Controls for Fencing (A5.5)

Fencing can have a significant impact on flood flows. Ideally, fencing should not impede the flow of floodwaters so as to result in additional flood impacts on surrounding land and should be able to withstand flooding or to collapse in a controlled manner to prevent a 'wave' causing additional problems downstream.

The DCP largely address these requirements by requiring permeable/opening fencing in High FRP areas. Brick or masonry (i.e., impervious) type fence is generally not be permitted. This is considered to be appropriate although it is recognised that maintaining fencing controls can be difficult.

5 EXISTING EMERGENCY MANAGEMENT PROTOCOLS

The following chapter outlines current emergency management strategies for the Nattai Ponds catchment.

5.1 Wingecarribee Shire Local Flood Plan

The *Wingecarribee Shire Local Flood Plan* (NSW SES, 2013) (LFP) sets out procedures to follow before, during and after a flood including who is responsible for each of these activities within the Wingecarribee Shire area. A summary of pertinent components of the LFP for the Nattai Ponds catchment are provided in **Table 17.**

Volume 1 of the LFP was last updated in November 2013. It details organisational responsibilities for managing flooding hazards, and sets out tasks related to the preparedness, response and recovery phases of disaster management. There is scope for minor refinement, for example, to add one or more sites for active reconnaissance during floods, but noting the challenges for active reconnaissance given the likelihood of fast rising and falling floodwaters.

Volume 2 of the LFP was last updated in May 2007. This volume is in need of an update, both to align the structure and contents with the new NSW SES LFP template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. In particular, it currently says very little about flooding risks from local overland flow catchments including the Nattai Ponds catchment.

Volume 3 of the LFP was last updated in May 2007. It describes response arrangements including flood warning systems and evacuation protocols. The section is relatively vague with respect to when warnings and evacuation orders should be issued and, therefore, needs updating. The volume should also include a list of gauges to be monitored prior to and during flooding (although it is noted that there are no gauges within the Nattai Ponds catchment and very limited warning time). The list of media outlets should be reviewed (Annex C). Additionally, Annex F and G should also be checked for currency using the latest flood studies and floodplain risk management studies and plans. The maps should be updated to include new development within the Nattai Ponds catchment. Finally, considerable effort is needed to provide the detail consistent with the new SES LFP template.

As the SES is the agency responsible for flood emergency management, it is recommended that they undertake the suggested updates to the LFP based upon the recommendations documented in this study.

Table 17 Comments on Current Wingecarribee Shire Local Flood Plan

Section	Description	Comment
Volume 1		
1.5.21	Responsibilities of Roads and Maritime Services	The list of roads for which RMS exercises responsibility should be included
3.8.4	List of problem areas for active reconnaissance during flooding	The list currently does not include a site for the Nattai Ponds Catchment. One potentially appropriate site is the Old Hume Highway which would be representative of the whole catchment flooding, however this is downstream of most development and flooding may occur upstream prior to the main watercourses rising at Old Hume Highway. Another potential location may be at Bong Bong Road, which is located further upstream. The speed with which flooding in the Nattai Ponds catchments tend to rise and fall may preclude active reconnaissance.
3.18.42	List of evacuation centres	While there is a local evacuation centre at Mittagong (Mittagong RSL Club), it is likely that much of the residential area within the Nattai Ponds catchment will be cut at Bong Bong Road, Renwick Dr and the Old Hume Highway. Additionally, it is highly likely that the evacuation centre would be cut off by coincident flooding of the Nattai River. There are currently no appropriate public buildings within or adjacent to the catchment that could be used for evacuation centres. However, the Tangara School or Highlands School (both on Bong Bong Road, Renwick) could potentially be utilised.
Volume 2 Hazard and Risk in Wingecarribee		
5	Extreme Flooding	Information in the Nattai Ponds Flood Study and this FRMS should be used to describe what happens in floods rarer than the 1% AEP event in the Nattai Ponds catchment.
Annexure B	Effects of Flooding on the Community	Currently there is no description of Flooding on the Community for the Nattai Ponds Catchment. Suggested text is included below. In addition, maps of potential flooding should be included in the Local Flood Plan. **Nattai Ponds** The Nattai Ponds catchment includes the eastern fringes of Mittagong as well as Renwick, Balaclava and Braemar. Inundation from the various watercourse can cut many local roads as well as major roads including the Old Hume Highway. Given the high likelihood of coincident flooding in the Nattai River, it is likely that in extreme floods that the

<table>
<tr><th>Section</th><th>Description</th><th>Comment</th></tr>
<tr><td></td><td></td><td>Nattai Ponds catchment area would be cut off from the main section of Mittagong.

Flooding within Nattai Ponds catchment can occur relatively quickly from the onset of rainfall. Flooding typically will have a high rate of rise and subside relatively quickly once rainfall has ceased. Therefore, the warning time available for evacuation will be minimal, and the duration of isolation is likely to be only a few hours.

Available information indicates the following locations are prone to relatively frequency flooding:
1) Inkerman Road
2) Scarlet Street
3) Braemar Avenue

A series of design floods have been modelled as part of the Nattai Ponds Floodplain Risk Management Study and Plan. The table below indicates the number of buildings with over-floor flooding at the various design flood levels.
<table>
<tr><td>Annual Exceedance Probability (Annual Return Interval)</td><td>Number of houses with over-floor flooding</td><td>Total number of buildings with over-flood flooding</td></tr>
<tr><td>20% (1 in 5 year ARI flood)</td><td>0</td><td>0</td></tr>
<tr><td>10% (1 in 10 year ARI flood)</td><td>1</td><td>1</td></tr>
<tr><td>2% (1 in 50 year ARI flood)</td><td>3</td><td>3</td></tr>
<tr><td>1% (1 in 100 year ARI flood)</td><td>7</td><td>8</td></tr>
<tr><td>Probable Maximum Flood</td><td>38</td><td>125</td></tr>
</table>

The Nattai Ponds Floodplain Risk Management Study did not identify any critical infrastructure (such as hospitals, nursing homes, school etc) at risk of flooding.</td></tr>
<tr><td colspan="3">Volume 3 SES Response Arrangements</td></tr>
<tr><td>Annex C</td><td>Dissemination of SES Flood Bulletins</td><td>The list of media outlets for warning dissemination needs to be reviewed.</td></tr>
<tr><td>Annex D</td><td>Template Evacuation Warning Message</td><td>The template message should be updated to fit with areas that do not have a quantified flood warning and therefore rely on other warning products such as severe weather warnings or flood watches.</td></tr>
</table>

Section	Description	Comment
		Similarly, additional template warnings should also be prepared for short form communications such as the emergency alert system and social media.
Annex E	SES Dam Failure Arrangements	Not relevant to the Nattai Ponds catchment.
Annex G	Roads Subject to Flooding	The list of roads should be updated based on information contained in emergency response classification mapping (i.e., **Figures 19.1** to **22.8**). Also, other regional roads that have potential to be cut should also be included.
Maps	Maps	The maps should be updated to include new development areas within Mittagong
Missing Information		Volume 3 is also missing a number of key components, particularly: - A list of gauges that should be monitored during flood operations - A breakdown of the local SES response arrangements (e.g. sectors) and response strategies

5.2 Emergency Services' Capability

As of 2018, the Wingecarribee SES unit had a volunteer membership of 100 with the local headquarters based in Etheridge Street, Mittagong (approximately 3km west of the Nattai Ponds catchment). There is also potential to call in out-of-area units to supplement local resources. Discussion with the SES deputy local controller indicates that these resources are sufficient to manage the flood risk across the LGA.

However, given the size of the at-risk communities in the LGA, and the speed with which flash flooding can occur, adverse consequences are likely to occur across the Nattai Ponds 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 seeking 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. <u>Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome</u>.

However, AFAC recognises that evacuating too late may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters. 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 a 'on-site refuge' strategy include:

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

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

5.3.2 Nattai Ponds Practice

The current Wingecarribee Local Flood Plan proposes evacuation as the primary strategy. As discussed in Section 3.2, it is likely that flooding will be occurring and large parts of the catchment isolated prior to the effective mobilisation of the emergency services, therefore the delivery of timely evacuation warnings and orders is unlikely to be achievable. While evacuation is the primary and preferred strategy, the Local Flood Plan contains no details on how this may be enacted and currently lists no evacuation centres for the Nattai Ponds catchment.

On-site refuge is potentially a pragmatic approach for the majority of the catchment, given:

- The worst flooding occurs as a result of short storms with the 2-hour storm being critical in most locations. 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 for non-specific areas is likely to be socially unsustainable. Attempting to evacuate as flooding manifests itself may expose evacuees to adverse conditions such as heavy rainfall, hail, lightning, strong winds and the risk from debris, falling trees or power lines;

- Roads may be cut less than 30 minutes after the commencement of a storm, leaving very little opportunity for evacuation triggered by environmental cues;
- Roadways may be impassable for approximately 2 hours, which means a relatively short period of isolation;
- The national hazard mapping (refer Appendix D) indicates the maximum hazard during the 1% AEP flood is most often H1–H3, which is not unsafe for adults or buildings. However, more extensive areas would be exposed to a hazard classification of at least H5 hazard during the PMF event which would be unsafe for people and buildings may be susceptible to failure if they are not specifically designed to withstand the forces of the floodwaters (refer discussion on structural soundness included in Section 4.3.2);
- Estimated depths of above-floor inundation even in the PMF are less than 1.2 metres for almost all buildings in the database, with the exception of six buildings. Depths greater than 1.2 metres are considered unsafe for adults (see **Plate 2**);

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

- People whose prior medical condition means any isolation from medical help cannot be tolerated should evacuate prior to flooding.
- Sites where the national hazard rating exceeds H4 during the PMF could be unsafe for buildings and their occupants (e.g., properties near Inkerman Road and Scarlet Street).

An on-site refuge strategy requires that people know their risk exposure and plan how to respond in addition to building/construction requirements. 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.

If the NSW SES wishes to maintain an evacuation strategy for the Nattai Ponds area, then significant work needs to be undertaken to ensure that evacuation can be successfully achieved. This includes at a minimum:

- The identification of appropriate evacuation centres. With different areas of the catchment potentially isolated from each other, several evacuation centres are required to prevent evacuees from entering flood waters in an attempt to reach the evacuation centre. There are no obvious candidates for evacuation centres within much of the catchment, with the exception of Tangara School at Renwick, as most of the isolated areas are small residential subdivisions or rural residential areas with no public buildings.
- Given the relatively small population at risk and the short duration of flooding, there would be minimal requirements for space and supplies at evacuation centres. It is also likely that a significant proportion of the population at risk will evacuate to private residences such as family and friends, further reducing the potential requirements of local evacuation centres.
- The positioning of emergency services in each isolated section of the catchment to assist with evacuation. If an evacuation is enacted, it is likely that in each of the isolated sections of the catchments that there will be occupants that require assistance from emergency services to evacuate. Therefore, it is important that there are emergency

service personnel located within each of the isolated sections prior to the access becoming cut.

6 OPTIONS FOR MANAGING THE FLOOD RISK

6.1 General

As outlined in Section 3, a number of properties across the Nattai Ponds catchment are predicted to be exposed to a significant flood risk and/or significant financial impacts during floods within the catchment. Accordingly, the following chapters outline options that could be implemented to better manage the 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 or 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. However, they can also be designed to mitigate potential increases in flood risk associated with future catchment development.
- **Property Modification Options**: refers to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties is typically used to manage existing flood risk while planning measures (e.g., land use/development controls) are employed to manage future flood risk.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public responds before, during and after a flood. Response modification measures are the key measures employed to manage the continuing flood risk.

6.2.2 Options Considered as Part of Current Study

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

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

The list of options that was initially compiled is summarised in **Table 18**.

It was not considered feasible to undertake a detailed assessment of all options in **Table 18**. 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 19** and the outcomes of the assessment are provided in **Table 20**.

Table 18 Initial List of Options Considered for Managing the Flood Risk

	Flood Modification Options	Property Modification Options	Response Modification Options
Above Ground Storages	Modification to the Oldfield Road, Renwick Detention Basin outlet configuration	Voluntary purchase of select properties	Community education strategy
	Modification of main railway bridge to allow railway embankment to serve as detention basin	Voluntary raising of select residential properties	Installation of gates at roadway low points to prevent vehicular access during floods
	Detention Basin upstream of Bong Bong Road (at one or both crossing locations)	Voluntary flood proofing of select properties	Install flood depth indicators at roadway low points
	Create detention basin near railway line & Braemar Ave	Updates to LEP	Local flood plan updates
	Create new detention basin downstream of Renwick	Updates to DCP	Flash flood warning/forecasting system
	Create new detention basin south of Connolly Cl at Renwick	Updates to Section 10.7 certificates	Upgrade of Inkerman Rd and Scarlet St to allow better access/evacuation
Drainage Upgrades	Upgrade stormwater system in industrial area		Upgrade/Raise Biggera St to allow better access/evacuation
	Upgrade main railway culvert/bridge to take more flow during the PMF		Make property level flood information available
	Upgrade stormwater system between Biggera St and Old Hume Highway (near The Old Pot Factory)		Encourage preparation of household flood emergency response plans
	Blockage of railway culvert adjacent to Biggera Street		Encourage preparation of business flood emergency response plans
	Blockage of railway culvert adjacent to Railway Pde		Develop a safe on-site refuge policy
	Upgrade of culverts at western end of Biggera St		
	Install kerb & guttering and new stormwater system in Biggera St & along the Old Hume Highway between Beresford St and Braemar Ave		
Earthworks	Construction of swale on southern boundary of the Nattai Ponds Estate		

Flood Modification Options		Property Modification Options	Response Modification Options
	Construction of swale between eastern end of Southwood Pl and culvert crossing of Mary St		
	Swale enlargement or levee at rear of Gantry Pl Industrial Area		
	Elevate railway embankment near Biggera St		
	Levee near Braemar Ave industrial area		
Channel Modification	Creek maintenance / removal of dense vegetation		
	Enlarge Old Hume Highway Roadside swales		
	Create formalised channel on western side of railway embankment		
	Construction of channel through properties on Inkerman Rd and Scarlet St to concentrate flows and limit nuisance inundation		

Table 19 Adopted Evaluation Criteria and Scoring System for Relative Assessment of Flood Risk Management Options

Score:	**Change in Flood Levels/Extents**	**Economic Feasibility**	**Environmental Impacts**	**Emergency Response**	**Technical Feasibility**	**Community Acceptance**
-2	Significant increases in levels/extents	Cost much higher than reduction in flood damages	Significant impacts	Significant disbenefit to emergency services	Significant technical challenges	Majority of community opposed
-1	Minor increases in levels/extents	Cost slightly higher than reduction in flood damages	Minor impacts	Slight disbenefit to emergency services	Some technical challenges	Some opposed
0	Negligible changes in levels/extents	Cost and reduction in flood damages roughly equal	No impacts	No impact on emergency services	Minor technical challenges	Neutral
+1	Minor reductions in levels/extents	Reduction in flood damages slightly higher than cost	Some benefits	Slight benefit to emergency services	Negligible technical challenges	Some support
+2	Significant reductions in levels/extents	Reduction in flood damages much higher than cost	Significant benefits	Significant benefit to emergency services	No technical challenges	Majority of community support

Table 20 Relative Assessment of Initial List of Flood Risk Management Options

	Potential Measures	Evaluation Criteria / Score						
		Change in Flood Levels / Extents	Economic Feasibility	Environmental Impacts	Emergency Response	Technical Feasibility	Community Acceptance	Overall Score
Flood Modifications Option	Modification to the Oldfield Road, Renwick Detention Basin outlet configuration	1	0	0	1	-1	2	3
	Create new detention basin near railway line & Braemar Ave	1	0	0	1	0	1	3
	Create formalised channel on western side of railway embankment	1	1	-1	1	0	0	2
	Create new detention basin upstream of Bong Bong Road (at one or both crossing locations)	1	-1	-1	1	0	1	1
	Create new detention basin downstream of Renwick	1	-1	-1	1	-1	2	1
	Enlarge drainage channels adjacent industrial area	1	-1	0	1	-1	1	1
	Upgrade stormwater system between Biggera St and Old Hume Highway (near The Old Pot Factory)	1	-1	0	1	-1	1	1
	Blockage of railway culvert adjacent to Biggera Street	1	-1	0	1	0	0	1
	Install kerb & guttering and new stormwater system in Biggera St & Old Hume Highway	1	-2	0	1	0	1	1
	Elevate railway embankment near Biggera St	1	1	-1	0	0	0	1
	Enlarge Old Hume Highway Roadside swales	1	1	-1	1	-1	0	1
	Construction of channel through properties on Inkerman Rd and Scarlet St	2	-1	-2	0	1	1	1

	Potential Measures	Evaluation Criteria / Score						
		Change in Flood Levels / Extents	Economic Feasibility	Environmental Impacts	Emergency Response	Technical Feasibility	Community Acceptance	Overall Score
	Blockage of railway culvert adjacent to Railway Pde	1	-1	0	0	0	0	0
	Upgrade stormwater system in industrial area	1	-1	0	0	0	0	0
	Upgrade of culverts at western end of Biggera St	0	-2	0	1	0	1	0
	Construction of swale on southern boundary of the Nattai Ponds Estate	1	-1	-1	0	0	1	0
	Creek maintenance / removal of dense vegetation	1	-1	-2	1	-1	1	-1
	Modification of railway bridge to allow railway embankment to serve as detention basin	1	-1	0	0	-2	1	-1
	Create new detention basin south of Connolly Cl at Renwick	0	-2	-1	1	-1	2	-1
	Construction of swale between eastern end of Southwood Pl and culvert crossing of Mary St	1	-1	-1	0	-1	1	-1
	Levee near Braemar Ave industrial area	1	-1	-1	0	0	0	-1
	Upgrade second railway culvert to take more flow during the PMF	1	-2	0	0	-2	1	-2
Property Modificati	Updates to DCP	0	1	0	1	2	1	5
	Voluntary purchase of select properties	0	-2	1	2	1	-1	1

	Potential Measures	Evaluation Criteria / Score						
		Change in Flood Levels / Extents	Economic Feasibility	Environmental Impacts	Emergency Response	Technical Feasibility	Community Acceptance	Overall Score
	Voluntary raising of select residential properties	0	-1	0	1	1	0	1
	Voluntary flood proofing of select properties	0	-1	0	0	1	-1	-1
Response Modification Options	Local flood plan updates	0	1	0	2	1	2	6
	Community education strategy	0	-1	0	2	1	1	3
	Develop a safe on-site refuge policy	0	1	0	1	0	1	3
	Make property level flood information available	0	0	0	1	0	1	2
	Prepare household flood emergency response plans	0	0	0	1	0	1	2
	Prepare business flood emergency response plans	0	0	0	1	0	1	2
	Upgrade of Inkerman Rd and Scarlet St to allow better access/evacuation	0	-2	0	2	-1	2	1
	Install flood depth indicators at roadway low points	0	-1	0	1	0	0	0
	Upgrade/Raise Biggera St to allow better access/evacuation	0	-2	-1	2	-1	1	-1
	Installation of gates at roadway low points to prevent vehicular access during floods	0	-2	0	2	-1	-1	-2
	Flash flood warning/forecasting system	0	-2	0	1	-2	1	-2

As shown in **Table 20,** each measure was evaluated against six criteria. The expected performance of each measure against each criterion was scored between 2 (significant positive impact) and -2 (significant negative impact).

The relative scores were subsequently summed to provide an overall score for each option and enable a means of comparing the different options as well as provide an initial assessment of whether specific options would provide a net positive outcome. The options listed in **Table 20** are grouped according to whether they are a flood modification, property modification or response modification option and are then sorted from highest overall score to lowest overall score. Those options with a net positive score are shaded in blue.

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

6.3 Flood Risk Management Options Assessed in Detail

Based upon the qualitative assessment presented in in **Table 20**, the options listed in **Table 21** were selected for detailed assessment.

6.3.1 Detailed Options Assessment Approach

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

As outlined in the previous section, an assessment of each potential option was completed to provide an initial appraisal of the likely feasibility of each option (**Table 20**). However, as part of the detailed option assessment, it was considered important to provide a quantitative assessment of the advantages and disadvantages of each option. In this regard, each flood and property modification option was evaluated against the following criteria, where sufficient information was available:

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

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

Table 21 Options Selected for Detailed Investigations

	Option ID	Flood Modification Options	Option ID	Property Modification Options	Option ID	Response Modification Options
Above Ground Storages	FM1	Modification to the Oldfield Road, Renwick Detention Basin outlet configuration	PM1	Updates to LEP	RM1	Local flood plan updates
	FM2	Create new detention basin near railway line & Braemar Ave	PM2	Updates to DCP	RM2	Community education strategy
	FM3	Create new detention Basin upstream of Bong Bong Road	PM3	Updates to Section 10.7 certificates	RM3	Make property level flood information available
	FM4	Create new detention basin downstream of Renwick	PM4	Voluntary house raising	RM4	Prepare household flood emergency response plans
Drainage Upgrades	FM5	Upgrade stormwater system between Biggera St and Old Hume Highway (near The Old Pot Factory)	PM5	Voluntary house purchase of select properties	RM5	Prepare business flood emergency response plans
	FM6	Blockage of railway culvert adjacent to Biggera Street			RM6	Shelter-in-place strategy
	FM7	Install kerb & guttering and new stormwater system in Biggera St & Old Hume Highway			RM7	Upgrade of Inkerman Rd and Scarlet St to allow better access/evacuation
Earthworks	FM8	Elevate railway embankment near Biggera St				
Channel Modifications	FM9	Enlarge drainage channels adjacent industrial area				
	FM10	Create formalised channel on western side of railway embankment				
	FM11	Enlarge Old Hume Highway Roadside swales				
	FM12	Construction of upgraded culvert / channel through properties on Inkerman Rd and Scarlet St				

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

Change in Flood Levels/Extents

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

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

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

Economic Feasibility

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

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

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

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

Environmental Impacts

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

Emergency Response Impacts

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

Technical Feasibility

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

6.4 Future Catchment Development

As discussed in Section 3.5, future catchment development has the potential to increase the existing flood risk across parts of the catchment. Accordingly, it will be necessary to implement mitigation measures as part of these future developments to ensure the developments themselves as well as existing properties are not adversely impacted as a result of this future development.

Options for specifically mitigating the potential future flood risk (e.g., on-site detention) are discussed in more detail in Chapter 10.

However, there is also potential for the options that have been identified to help manage the existing flood risk to also afford benefits in reducing the potential future flood risk (e.g., regional detention basins). Where an option had the potential to afford benefits under future catchment conditions, it was assessed hydraulically for both existing conditions as well as potential future catchment conditions.

6.5 Summary

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

- Flood Modification Options: Chapter 7.

- Property Modification Options: Chapter 8.
- Response Modification Options: Chapter 9.
- Options for Managing the Potential Future Flood Risk: Chapter 10

7 FLOOD MODIFICATION OPTIONS

7.1 Introduction

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

Flood modification options considered as part of the study included:

- Above-ground storages (Section 7.2);
- Drainage upgrades (Section 7.3);
- Earthworks (Section 7.4); and,
- Channel modifications (Section 7.5).

As discussed in Section 6.3.1, the hydraulic benefits of each flood modification option were assessed by including the option in the hydraulic 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 change in the number of properties subject to above floor inundation was also quantified for each option and is included in **Table 22**. Negative numbers indicate a reduction in the number of properties exposed to above floor inundation while positive numbers indicate an increase in the number of properties subject to above floor inundation.

Cost estimates for each option were also prepared and are included in **Table 21**. **Table 23** also summarises the predicted reduction in flood damage costs if the option was implemented along with the associated benefit-cost ratio.

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

Table 22 Change in Number of Properties Subject to Above Floor Flooding for Each Flood Modification Option

Flood Event	Change in Number of Properties with Above Floor Inundation											
	Above-ground Storages				Drainage Upgrades			Earthworks	Channel Modifications			
	Modifications to Oldfield Rd detention basin outlet (FM1)	Detention basin near railway line and Braemar Ave (FM2)	Detention Basin upstream of Bong Bong Road (FM3)	Create new detention basin downstream of Renwick (FM4)	Upgrade stormwater system between Biggera St & Old Hume Hwy (FM5)	Blockage of railway culvert adjacent to Biggera Street (FM6)	Install kerb & guttering and new stormwater system in Biggera St & Old Hume Highway (FM7)	Elevate railway embankment near Biggera Street (FM8)	Enlarge drainage channels adjacent industrial area (FM9)	Create formalised channel on western side of railway (FM10)	Enlarge Old Hume Highway roadside swales (FM11)	Enlargement of channels through properties on Inkerman Rd and Scarlet St (FM12)
20% AEP	0	0	0	0	0	0	0	0	0	0	0	0
5% AEP	0	0	0	0	0	0	-1	-2	0	-2	0	0
1% AEP	0	-1	0	0	0	0	-3	-7	-1	-7	0	0
PMF	0	-1	0	0	1	0	-1	-13	0	-7	-1	0

Table 23 Economic Assessment for Flood Modification Options

Option		Cost	Total Damage for Existing Conditions	Total Damage with Option in Place	Reduction in Damage with Option in Place	Benefit-Cost Ratio
Above-ground storages	Modifications to the Oldfield Road detention basin outlet configuration (FM1)	$100,000	$263,949	$263,949	$0	0.00
	Detention basin near railway line and Braemar Avenue (FM2)	$320,000		$242,050	$21,899	0.07
	Detention basin upstream of Bong Bong Road (FM3)	$190,000		$263,949	$0	0.00
	Create new detention basin downstream of Renwick (FM4)	$60,000		Not calculated		
Drainage Upgrades	Upgrade stormwater system between Biggera Street and Old Hume Highway (FM5)	$150,000		$263,725	$224	0.00
	Blockage of railway culvert adjacent to Biggera Street (FM6)	-		Not calculated		
	Install kerb & guttering and new stormwater system in Biggera Street and Old Hume Highway (FM7)	$1,400,000		$217,484	$46,465	0.04
Earthworks	Elevate railway embankment near Biggera Street (FM8)	$370,000		$201,298	$62,651	0.17
Channel Modifications	Enlarge drainage channels adjacent industrial area (FM9)	$50,000		$249,988	$22,961	0.46
	Create formalised channel on western side of railway embankment (FM10)	$450,000		$224,695	$39,254	0.09
	Enlarge Old Hume Highway roadside swales (FM11)	$180,000		$262,896	$1,053	0.01
	Enlargement of channels through properties on Inkerman Rd and Scarlet St (FM12)	$300,000		$263,949	$0	0.00

7.2 Above-Ground Storages

7.2.1 Modification to the Oldfield Road, Renwick Detention Basin Outlet Configuration (FM1)

Areas downstream of the Renwick subdivision (most notably properties fronting Inkerman Road and Scarlet Street) are particularly susceptible to flooding and residents of this area have reported more frequent inundation since the subdivision was developed. As part of the Renwick subdivision, a number of flood detention basins were approved and implemented as part of the development approval process to ensure post development flows do not exceed those from existing conditions.

The Oldfield Road detention basin is the most significant storage basin in the Renwick subdivision. It is formed by the roadway embankment of Oldfield Road and a BEBO arch culvert that allows for the controlled release of flow beneath Oldfield Road. The outcomes of hydrologic modelling determined that this basin will suitably attenuate flows during large floods. However, the BEBO arch culvert comprises a significant base width which provides little attenuation of flows during smaller events where most of the flow is contained to the main channel. Accordingly, it is likely that the performance of the basin could be improved during more frequent events by modifying the outlet/creek configuration to provide greater attenuation during lower flow events.

Key modifications proposed as part of this option are shown in **Figure 35** and would include:

- A low-level weir and low flow culvert will be placed immediately upstream of the BEBO arch culvert. This will attenuate flows during smaller events but will still allow flows to pass over the weir during larger events so as not to impact on the performance of the existing arch culvert.
- Minor excavation upstream of the weir and lowering of the permanent water level to provide increased storage volume.

It is expected that the construction of the weir, installation of the new culvert and reconfiguration of the area upstream of the weir will have a capital cost of approximately $100,000. A detailed breakdown of the cost estimate is provided in **Appendix F**.

The TUFLOW computer model that was used to define existing flood behaviour across the catchment was updated to include the modified Oldfield Road basin configuration. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 13** and **Plate 14**.

Plate 13 shows that at the peak of the 20% AEP event, flood level decreases (typically around 0.04 metres) are predicted to extend downstream of the basin to the Hume Highway. Accordingly, the suggested modifications do have a minor beneficial flood impact across Inkerman Road and Scarlet Street during more frequent floods.

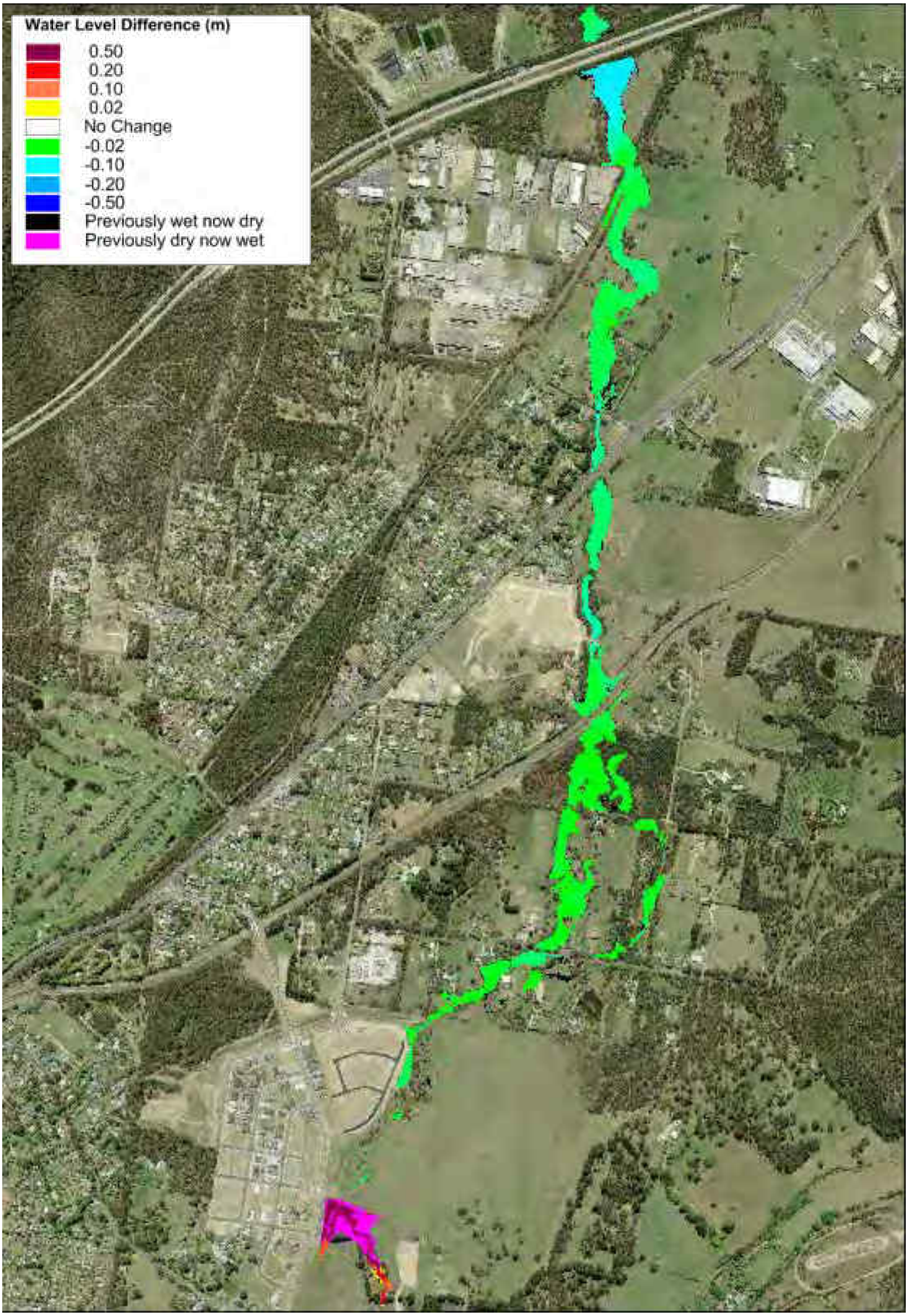


Plate 13 20% AEP Flood Level Difference Map for Oldfield Road Basin Modifications (FM1)

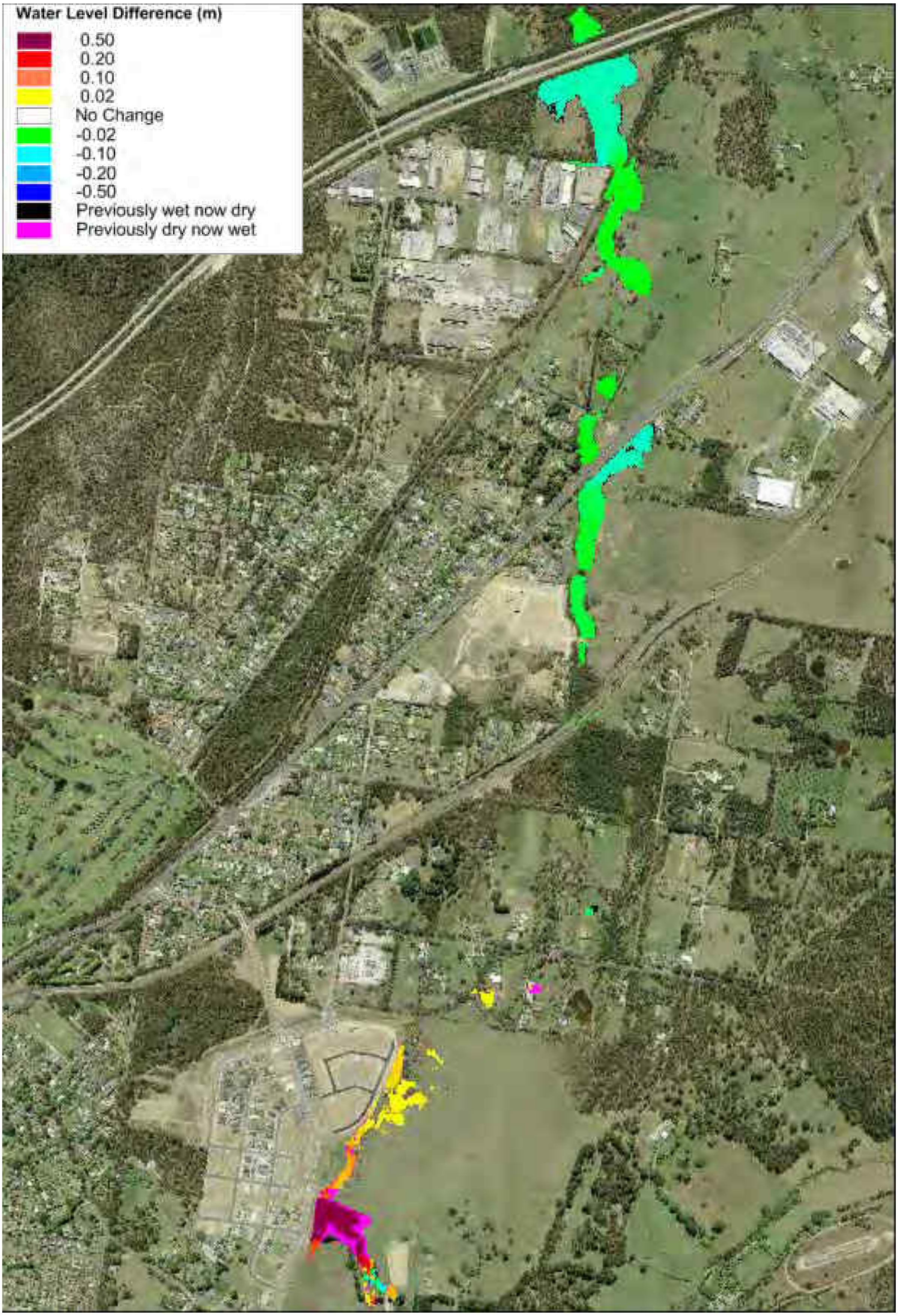


Plate 14 1% AEP Flood Level Difference Map for Oldfield Road Basin Modifications (FM1)

Plate 14 shows that during the 1% AEP flood, localised flood level reductions are predicted in the vicinity of the Old Hume Highway. However, negligible changes in flood levels are predicted in the vicinity of Inkerman Road and Scarlet Street.

The results of the revised flood simulations also indicate that the modified basin would not reduce the number of buildings subject to above floor inundation during the 20% or 1% AEP events. A revised damages assessment was also completed based on the results of the revised flood simulations. This determined that implementation of the modified Oldfield Road basin would not generate a reduction in flood damages. This yields a preliminary BCR of zero.

Although this option does not afford significant benefits during larger events, it does have the potential to afford hydraulic benefits during the more frequent "nuisance" floods that have been commonly reported by local residents in Inkerman Road and Scarlet Street. The results of the existing flood modelling confirm that Scarlet Street and Inkerman Road are predicted to be cut by floodwaters during events as frequent as the 20% AEP flood. A review of the flood hazard results indicates that although both roads would still be inundated during a 20% AEP flood if the basin was implemented, the depth and velocity of floodwaters would be sufficiently low to allow vehicular and pedestrian access. The flood level reductions are also sufficient to provide an additional 5-10 minutes of time before inundation of each road commences and would begin to recede 5-10 minutes earlier. Therefore, implementation of the option would provide a small amount of additional evacuation time.

As this option does not afford any significant hydraulic and financial benefits and only minor emergency response benefits, it is not recommended for implementation.

Recommendation: Not recommended for implementation

7.2.2 Detention Basin Near Railway Line and Braemar Avenue (FM2)

Existing Catchment Conditions

Currently, flood flows travelling on the western side of the railway line pond upstream of Braemar Ave. A small culvert passes under Braemar Ave near the industrial area that restricts flow and this allows the road embankment to act as a flood storage area. However, during large flood events, the ponded water overtops Braemar Ave at the low point in the roadway and is directed into adjoining industrial properties (e.g., AusTruss, Rocla).

This option would look to raise Braemar Ave and areas adjacent to the railway line to allow a higher level of storage to be achieved upstream of Braemar Ave. The culvert passing under Braemar Ave would also be upgraded to allow additional flows to pass under Braemar Ave and ensure additional storage volume is available at the peak of the flood. The features of this option are shown in **Figure 36**.

As shown in **Figure 36**, the additional storage "footprint" would primarily inundate an area of grass with some trees. However, given the temporary nature of the inundation and slow-moving nature of the water, no adverse environmental impacts to these are considered likely.

It is expected that this option will have a capital cost of approximately $320,000. A detailed breakdown of the cost estimate is provided in **Appendix F**.

The TUFLOW computer model was updated to include the proposed works included in **Figure 36**. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 15** and **Plate 16**.

Plate 15 shows that during the 20% AEP event, flood levels are predicted to increase by over 1 metre to the south of Braemar Avenue. However, flood levels and inundation extents to the north of Braemar Avenue are predicted to decrease significantly, with flood level reductions of over half a metre and inundation of the industrial properties effectively eliminated.

Plate 16 shows similar flood level and extent impacts during the 1% AEP flood. Again, flood levels are predicted to increase by over 1 metre to the south of Braemar Ave. However, there is predicted to be a commensurate reduction in flood level of over 1 metre across the industrial properties to the north of Braemar Ave. Inundation across most of these adjoining industrial properties is also predicted to be eliminated during the 1% AEP flood.

It is noted that the flood level increases do extend into an approved residential subdivision located on the western side of the railway line. These lots are not currently developed. However, it is likely that they will be developed in the future. Therefore, there may be a need to undertake additional earthworks in these areas to ensure these properties are not adversely impacted by the change in flood behaviour or, alternatively, purchase sections of this land, which would add to the overall implementation cost.

The results of the revised flood simulations also indicate that implementation of this option would result in 1 fewer property being inundated above floor level in the 1% AEP flood and PMF. A revised damages assessment was also completed based on the results of the revised flood simulations. This determined that implementation of the works would reduce flood damage costs by approximately $22,000 over the design life of the basin (i.e., 50 years). This yields a preliminary BCR of just under 0.1. Therefore, the costs of implementing the option are predicted to outweigh the reductions in flood damage costs.

The reduced inundation depths and extents, as well as reduced frequency of inundation of Braemar Ave will afford some improvements to evacuation potential from Braemar and Willow Vale towards the Old Hume Highway. More specifically, inundation of Braemar Ave is currently predicted during events as frequent as the 20% AEP flood and during the 1% AEP flood, “H3” hazard conditions are predicted indicating vehicles, children and the elderly would be subject to dangerous conditions. With this option in place, Braemar Avenue is predicted to remain “flood free” during events up to and including the 1%AEP flood. Accordingly, the frequency with which Braemar Avenue is overtopped will be significantly reduced with this option in place. This, in turn, will likely reduce the frequency with which vehicles may attempt to drive through floodwaters, which is considered to be a significant benefit from a risk to life perspective.

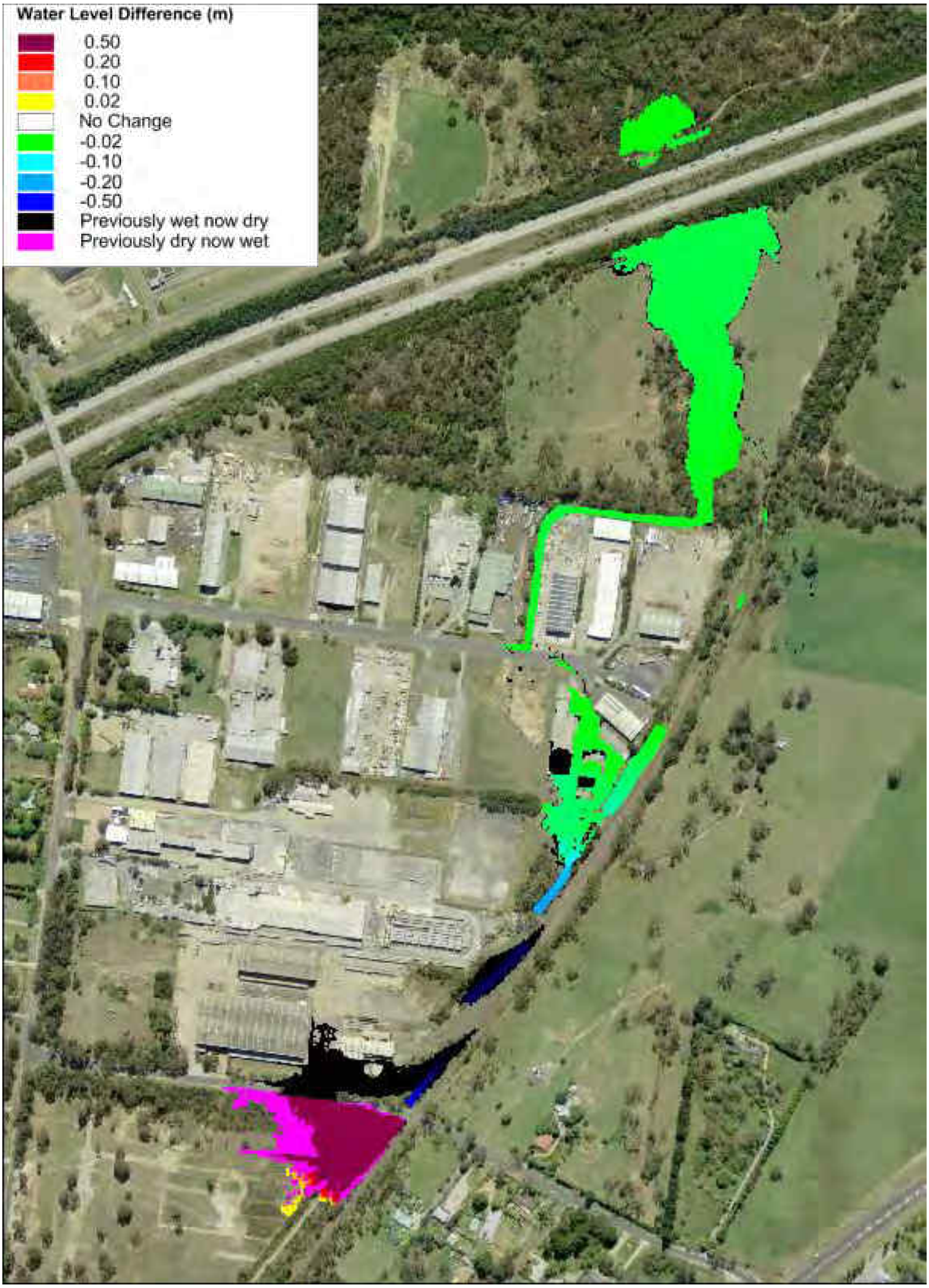


Plate 15 20% AEP Flood Level Difference Map for FM2

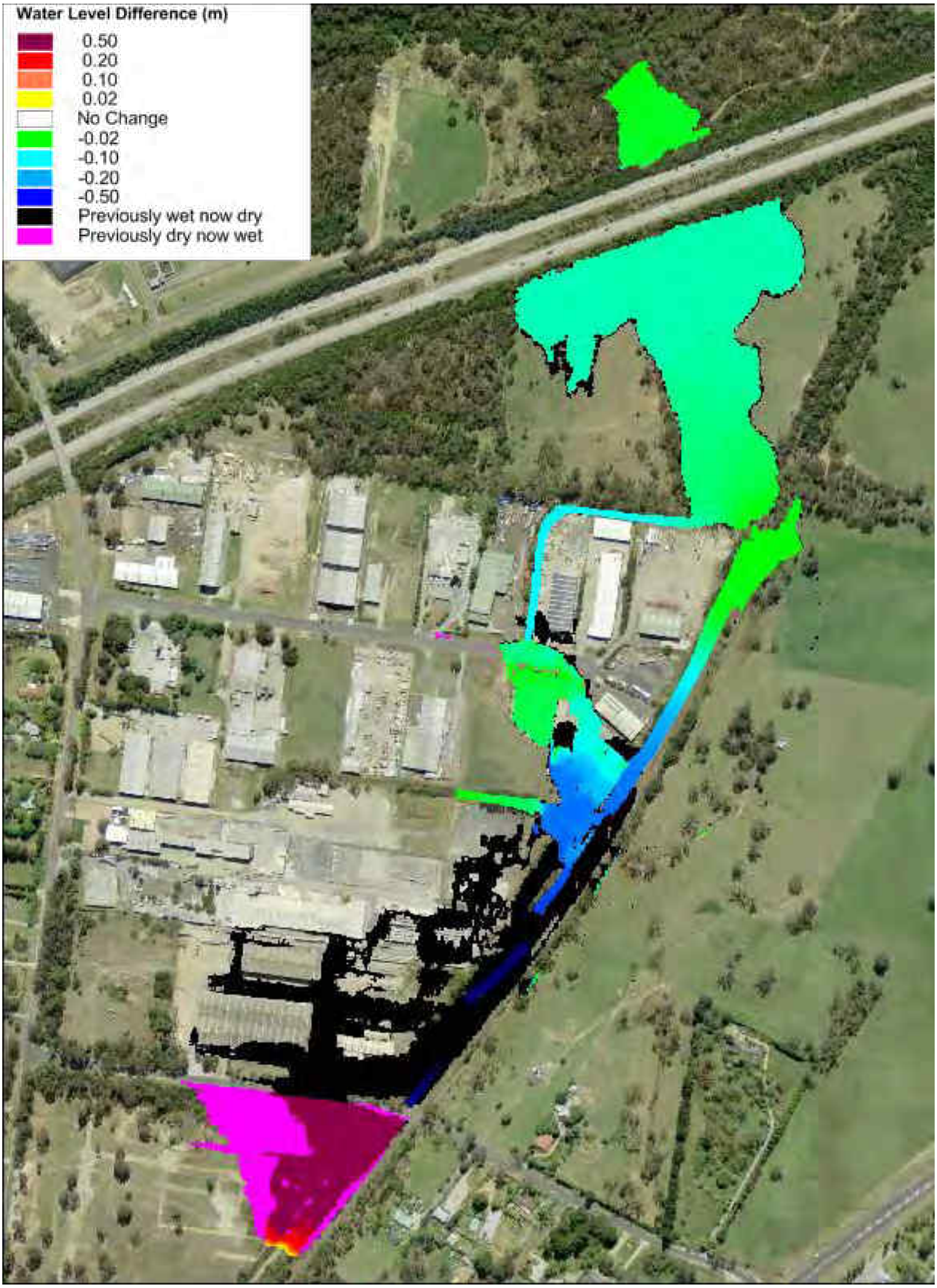


Plate 16 1% AEP Flood Level Difference Map for FM2

The basin will be constructed on private property and detailed consultation with the landholders will be required. This may require the purchase of some land from the private land holder, which could add significantly to the implementation cost.

Additionally, some of the proposed works would occur in close proximity to the railway line. It is currently unclear whether the ARTC would permit the use of the railway embankment as water storage structure. Therefore, as a minimum, consultation with ARTC will be required.

Any works along Braemar Avenue also has the potential to disrupt local traffic and the proposed works are located in proximity to vegetation communities. Therefore, there are several factors that would make this option more difficult to implement relative to some of the other options

Although several industrial properties are predicted to benefit from this option, the overall financial benefits do not appear to be sufficient to support implementation of this option in isolation. However, it could be considered for implementation in conjunction with some of the other options that are predicted to benefit upstream areas but generate adverse flood impacts across this industrial area (for example, the option discussed in Section 7.4.1).

Future Catchment Conditions

As described in Section 3.5, future development does have the potential to further increase the existing flood risk across the catchment. This includes sections of the Braemar industrial area. Therefore, the inclusion of the Braemar Avenue Basin has the potential to mitigate some of the adverse impacts that are predicted under future development conditions.

The potential hydraulic benefits afforded by the Braemar Avenue Basin was quantified by updating and undertaking additional TUFLOW model simulations under future catchment conditions with the basin in place.

The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 17** and **Plate 18**. The difference maps were prepared by subtracting peak flood levels for existing catchment conditions from peak future catchment flood levels with the basin in place (to verify if the works would mitigate the adverse flood impacts that are predicted with future catchment development).

Plate 17 and **Plate 18** shows that inclusion of the basin is predicted to improve the future flooding scenario by reducing some of the flood level impacts across the industrial area. However, it is not predicted to eliminate them completely as it would still result in increases in flood levels across multiple industrial properties during the 20% AEP and 1% AEP floods. This is associated with much of the potential future development within the industrial area being located downstream of the basin.

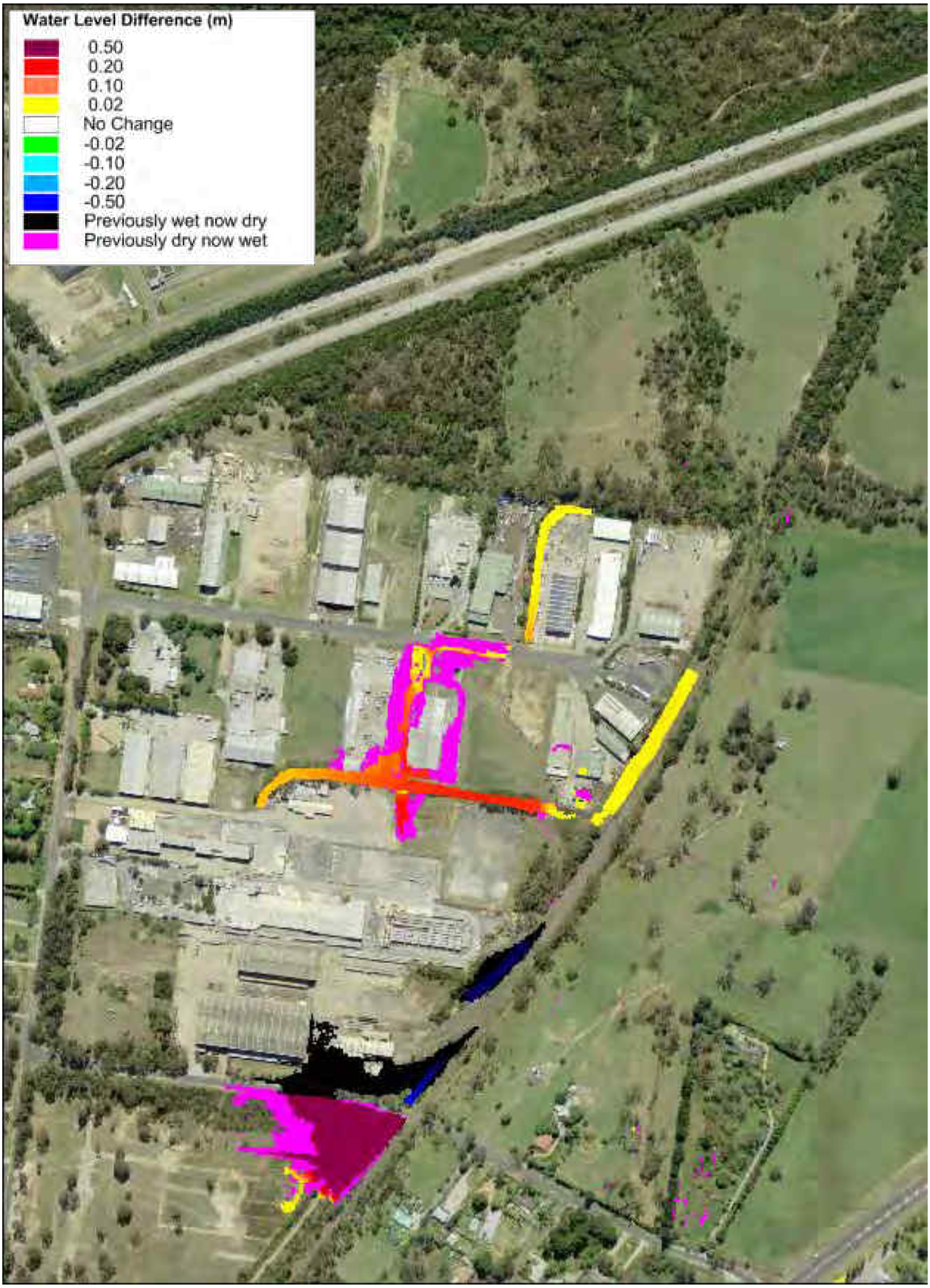


Plate 17 20% AEP Flood Level Difference Map for FM2 under Future Catchment Conditions

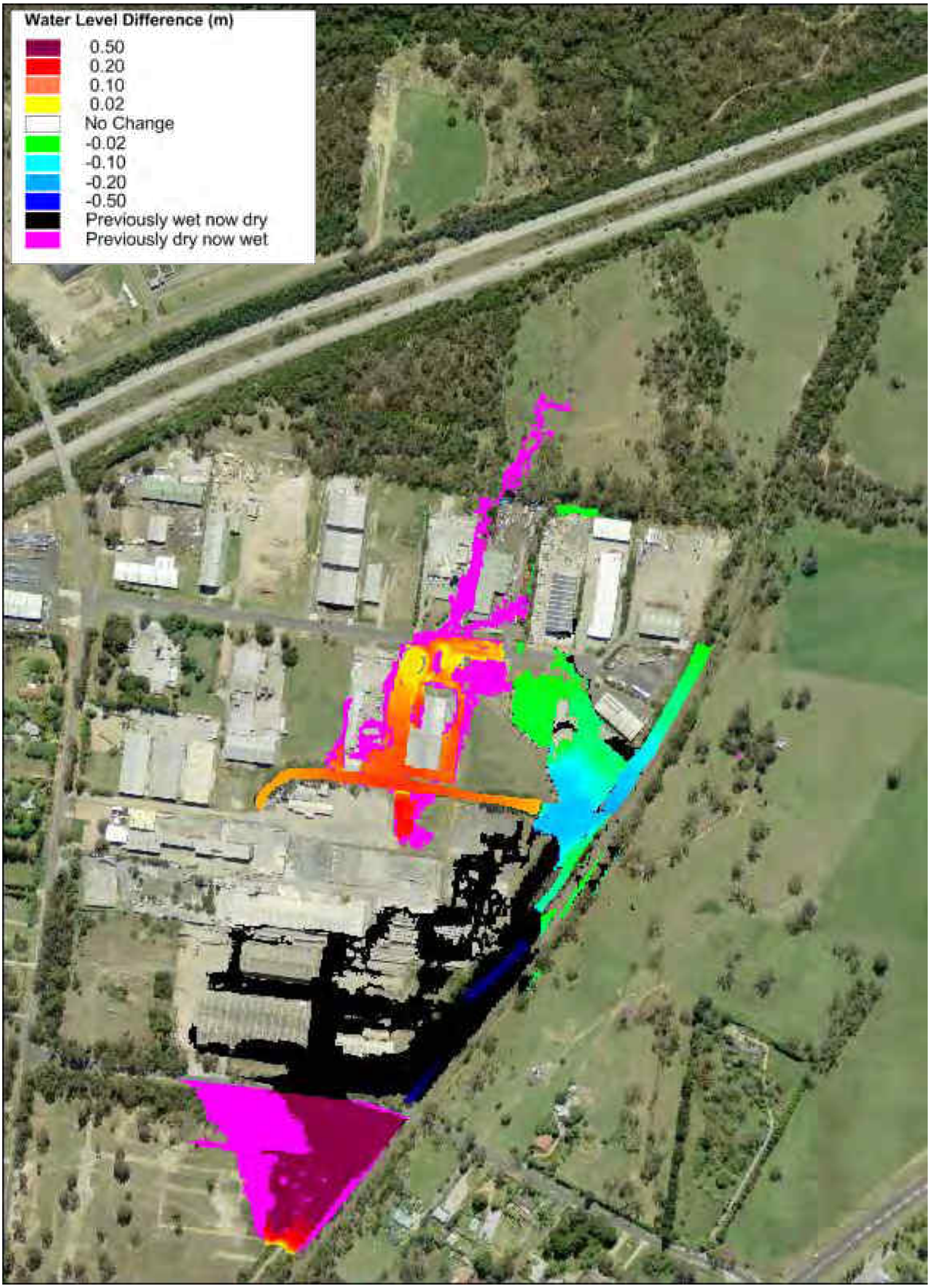


Plate 18 1% AEP Flood Level Difference Map for FM2 under Future Catchment Conditions

Therefore, this option does not appear to be suitable for completely off-setting the impacts of future catchment development if implemented in isolation. If future catchment development impacts are to be fully mitigated, it will be necessary to supplement this option to ensure no adverse impacts on other properties. If a combined option is found to mitigate the future flood impacts, it may open opportunities for other funding mechanisms (i.e., Section 7.10 & 7.11) to assist in funding the combined option.

Recommendation: Not recommended for implementation in isolation. May be considered for implementation in conjunction with other options to assist in managing the existing and potential future flood risk.

7.2.3 Detention Basin Upstream of Bong Bong Road (FM3)

As previously stated, properties on Inkerman Road and Scarlet Street are particularly susceptible to flooding. Therefore, implementation of a new detention basin upstream of Bong Bong Road was investigated to assist in reducing the frequency and severity of inundation across this area. The suggested basin configuration is shown in **Figure 37**. As shown in **Figure 37**, a dual level outlet is suggested to help ensure the basin can attenuate flows during both frequent and more severe floods.

The TUFLOW computer model that was used to define existing flood behaviour across the catchment was updated to include the detention basin. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 19** and **Plate 20.**

Plate 19 shows that during the 20% AEP flood, small reductions in flood levels are anticipated downstream of Bong Bong Road. However, the magnitude of the reductions is typically less than 0.05 metres. More extensive flood level reductions are predicted during the 1% AEP flood (refer **Plate 20**), however, the reductions are also predicted to be less than 0.05 metres across most areas. Therefore, the hydraulic benefits of this option do not appear to be significant.

The results of the revised flood simulations indicate that the basin would not reduce the number of properties exposed to above floor inundation during any of the simulated design floods.

An approximate cost of implementing the basin will be approximately $190,000. A breakdown of the cost estimate is provided in **Appendix F**.

A revised damages assessment was also completed based on the results of the revised flood simulations. This determined that implementation of the basin was not predicted to reduce existing flood damage costs. This yields a preliminary BCR of zero.

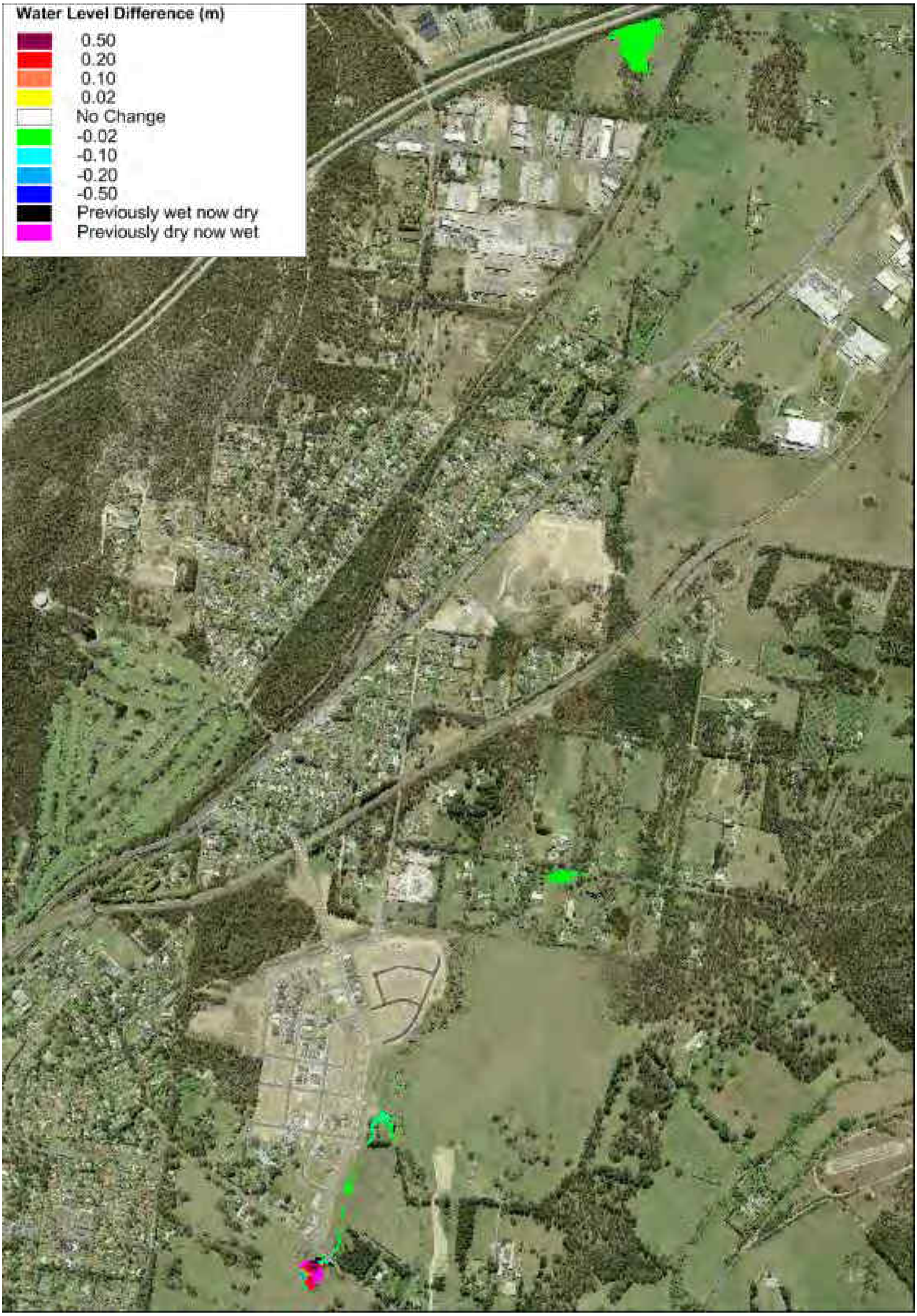


Plate 19 20% AEP Flood Level Difference Map for FM3

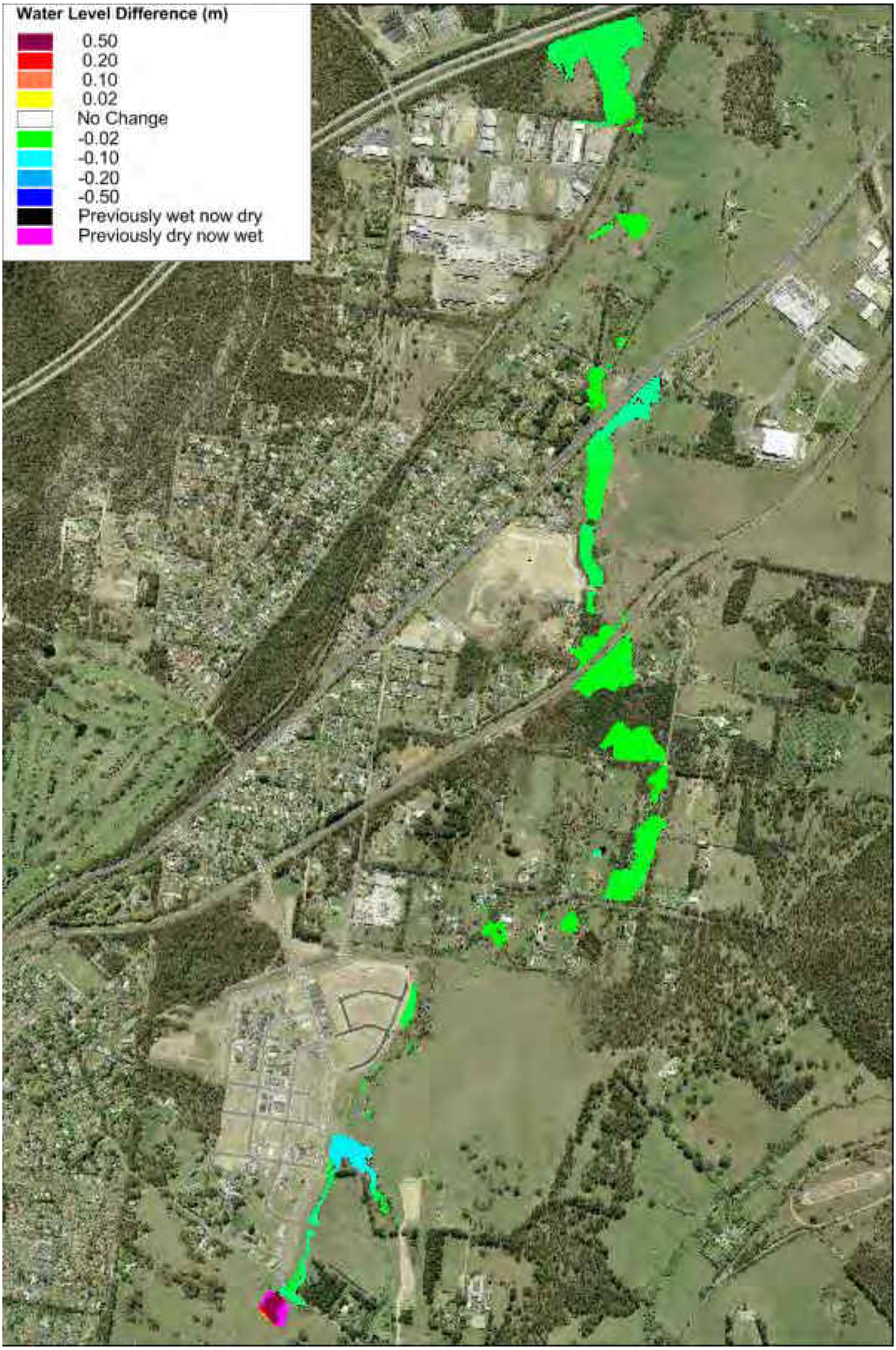


Plate 20 1% AEP Flood Level Difference Map for FM3

Overall, this option is not recommended for implementation due to the lack of significant hydraulic and economic benefits.

Recommendation: Not recommended for implementation

7.2.4 Detention Basin Downstream of Renwick (FM4)

This option is also intended to reduce the existing flood exposure across Inkerman Road and Scarlet Street properties. The option would involve the construction of a new detention basin at the downstream end of the Renwick subdivision. The proposed location and features of the basin is shown in **Figure 38**.

As shown in **Figure 38**, the basin would be located to the east of the main creek line and perform as an offline basin. Once flows exceed the capacity of the channel they will spill into the overbank area and the basin will begin to fill. An outlet culvert would allow the basin to drain slowly during and after a major rainfall event.

It is expected that the construction of the basin will have a capital cost of $60,000. A breakdown of the cost estimate is provided in **Appendix F**.

The TUFLOW computer model that was used to define existing flood behaviour was updated to include the proposed basin. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 21** and **Plate 22.**

Plate 21 shows that in the 20% AEP flood, flood level decreases are predicted to extend downstream of the basin to Scarlet Street, with typical decreases of 0.02 metres. **Plate 21** also shows that the basin redirects some additional flow across some residential properties. Therefore, the predicted reductions in flood levels across some properties are coupled with increases in flood levels across other properties.

Plate 22 shows that during the 1% AEP flood, some increases are predicted within the basin footprint of up to 1.5 metres. However, negligible reductions in flood levels are predicted downstream of the basin.

The results of the revised flood simulations also indicate that the modified basin would not reduce the severity of over floor flooding to any properties during the 20% or 1% AEP events. Similarly, no significant reductions in flood damages is anticipated with this option. Accordingly, this option has a preliminary BCR of zero.

The lack of significant hydraulic and financial benefits associated with this option makes it difficult to support for implementation.

Recommendation: Not recommended for implementation

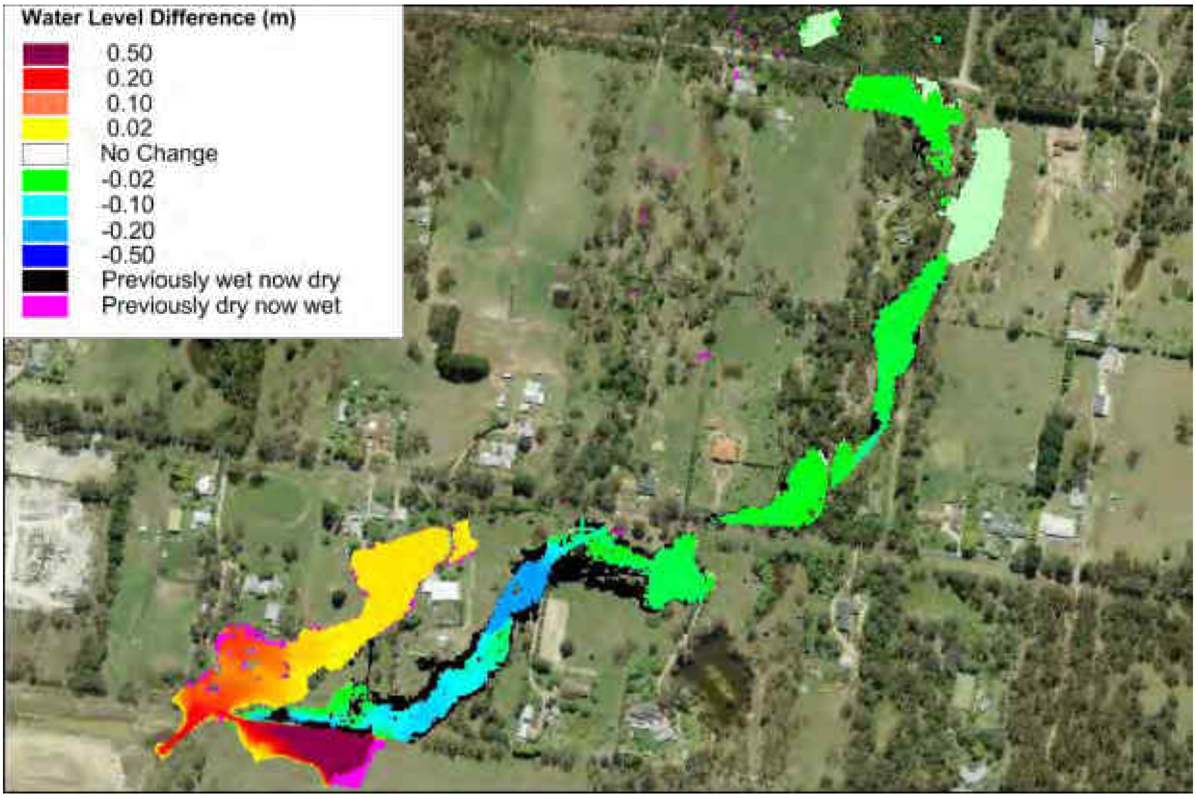


Plate 21 20% AEP Flood Level Difference Map for FM4

Plate 22 1% AEP Flood Level Difference Map for FM4

7.2.5 Basins at Bong Bong Road, Oldfield Avenue and Downstream of Renwick (FM1, FM3 & FM4)

A combined basin option was also was explored. This included the Bong Bong Road Basin (FM3), together with the Oldfield Avenue basin (FM1) and the basin downstream of Renwick (FM4).

The TUFLOW model was updated to include the combined option and was used to re-simulate each design flood. Flood level difference mapping was prepared to assess the impact of the combined basin option and is presented in **Plate 23** and **Plate 24**.

The flood level difference mapping in **Plate 23** and **Plate 24** indicates that the combined basin option is predicted to afford flood level reductions from Bong Bong Road all the way down to the Hume Highway. However, the flood level reductions are generally contained in close proximity to the main waterways. The hydraulic benefits (i.e., flood level reductions) are generally more significant during the more frequent floods (e.g., 20% AEP) and reduce as the magnitude of the flood increases.

Plate 23 shows that during the 20% AEP flood, the most significant flood level reductions are predicted within properties located at 45-53 Inkerman Road. Flood level reductions of up to 0.15 metres are predicted within these properties. The flood level reductions are sufficient to result in 51 Inkerman Road becoming effectively "flood free" during the 20% AEP flood. The flood level reductions across other Inkerman Road and Scarlet Street properties are typically less than 0.05 metres.

Plate 24 shows that during the 1% AEP flood, the flood level reductions across Inkerman Road and Scarlet Street properties are more modest with most properties predicted to experience flood level reductions of no greater than 0.02 metres. The flood level reductions further downstream (e.g., upstream of the Hume Highway) are more substantial and approach 0.1 metres.

The cost to implement the combined basins option would be approximately $350,000.

Revised flood damage calculations were prepared from the results of the TUFLOW model simulations. This showed a total reduction in flood damage costs of just over $4,000 over the next 50 years. Therefore, the benefit cost ratio of the combined basins option is predicted to be well under 0.1.

The low BCR combined with the relatively small hydraulic benefits means that the combined basin option is not recommended for implementation.

Recommendation: Not recommended for implementation

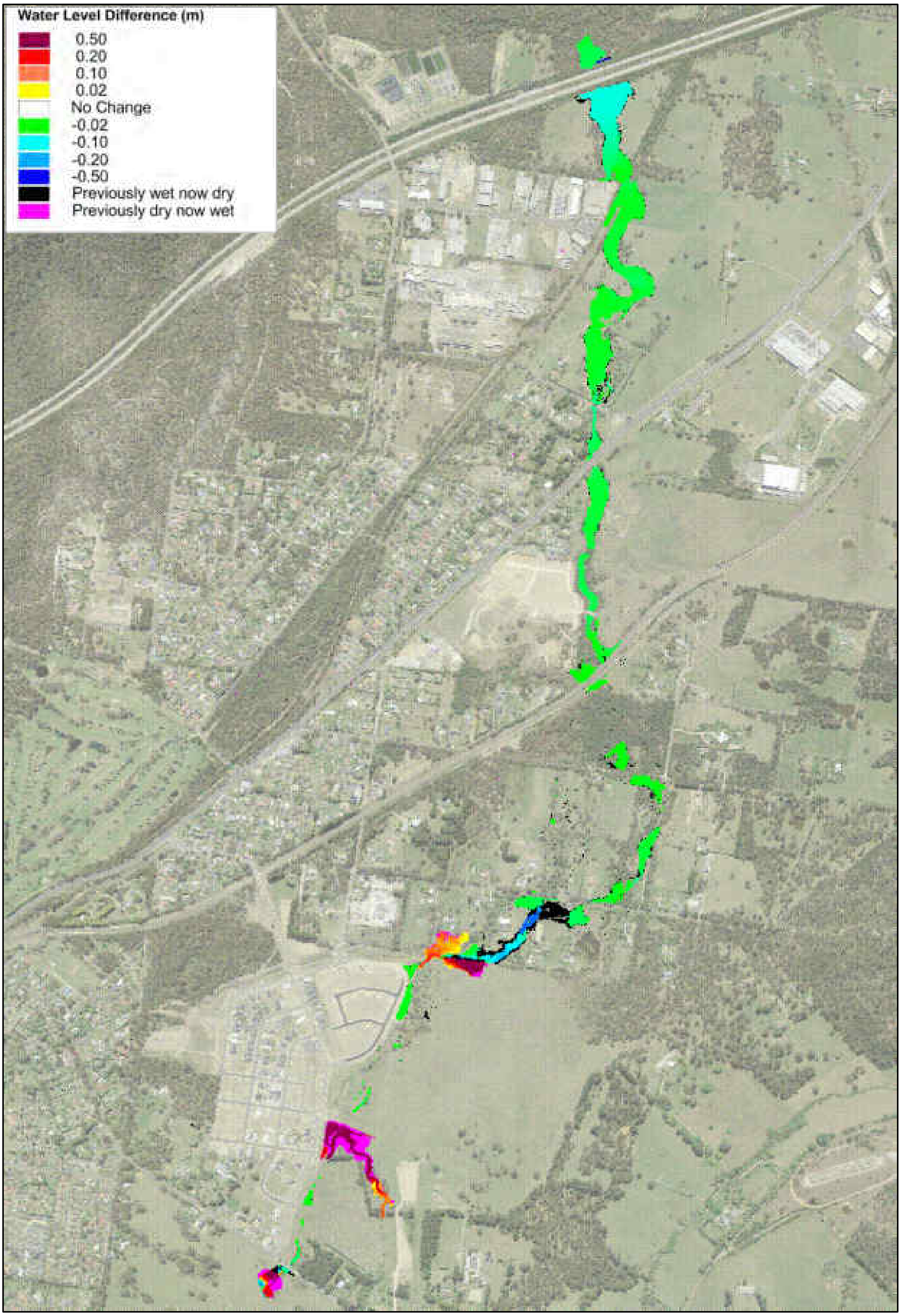


Plate 23 20% AEP Flood Level Difference Map for FM1, FM3 & FM4

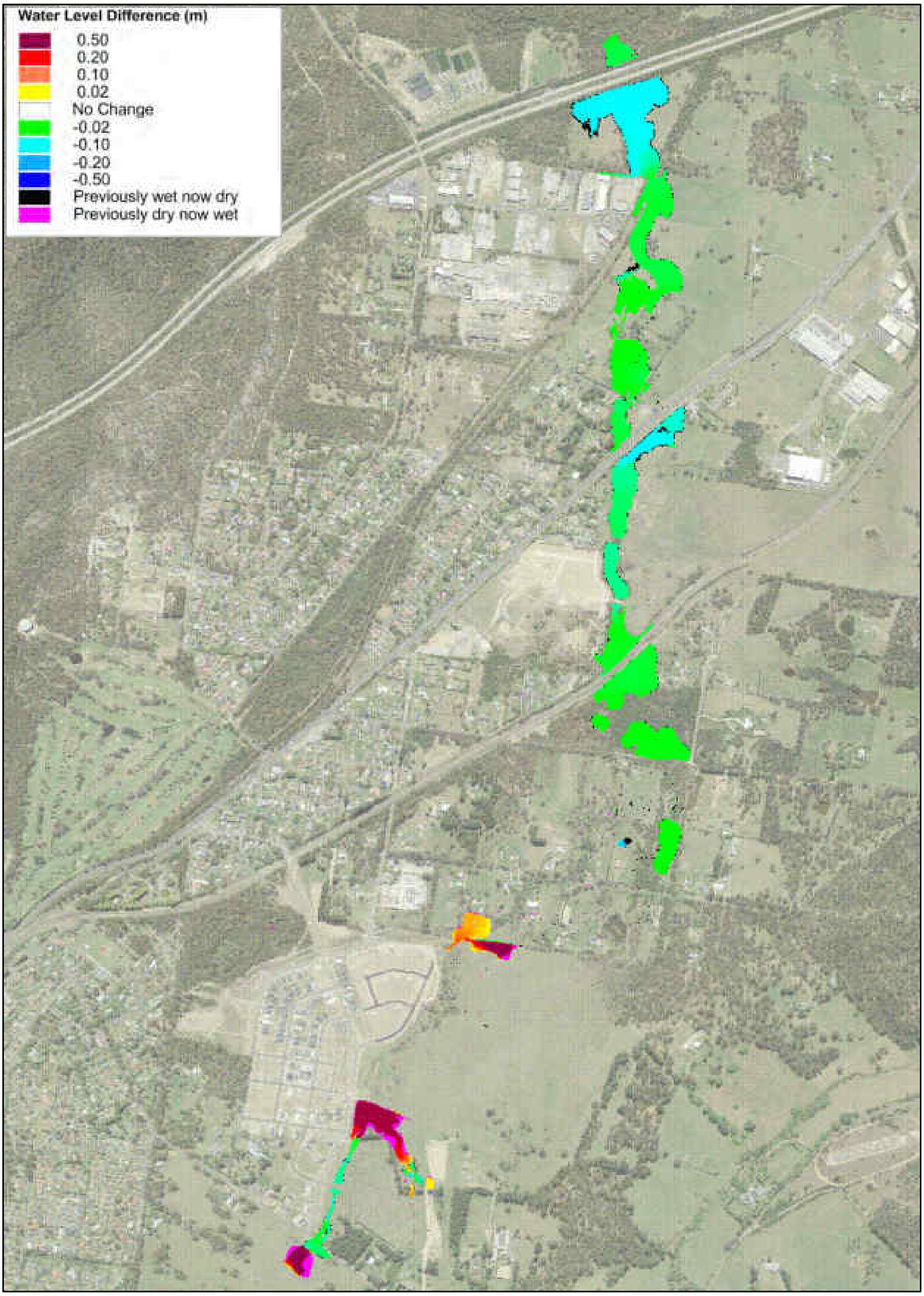


Plate 24 1% AEP Flood Level Difference Map for FM1, FM3 & FM4

7.3 Drainage Upgrades

7.3.1 Upgrade Stormwater System between Biggera Street and Old Hume Highway (near the Old Pot Factory) (FM5)

Currently, runoff along Biggera St is conveyed along roadside swales. In areas north of Rush Lane, ponding occurs outside number 41 and 43 Biggera St. During frequent events the ponded water is able to enter the stormwater system and is conveyed below ground. In larger flood events, the capacity of this stormwater system is exceeded, and flow enters the adjoining properties. Overland flow continues to move through the site of the Old Pot Factory towards the Old Hume Highway.

This option looks to increase the capacity of the stormwater system between Biggera St and the Old Hume Highway thereby reducing the extent and frequency of inundation in this area. The proposed features of the stormwater system upgrades are shown in **Figure 39**.

As shown in **Figure 39**, the existing 0.3m diameter pipes will be replaced with a 0.6m diameter pipe from Biggera St to the rear of number 43 Biggera St, after which it will be upgraded to a 0.75m pipe as it traverses through the Old Pot Factory, and then a 0.9m pipe near the Old Hume Highway where it will discharge into an existing roadside swale. Stormwater inlets at Biggera Street will also be enlarged and some minor local earthworks conducted to improve the inflow efficiency to the new pit.

It is expected that the upgrade works will have a capital cost of $150,000. A breakdown of the cost estimate is provided in **Appendix F**. It is noted that Council may need to acquire an easement that has not been taken into account in the cost estimate.

The TUFLOW computer model that was used to define existing flood behaviour was updated to include the stormwater upgrades. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 20** and **Plate 21**.

Plate 20 shows that at the peak of the 20% AEP event, flood level reductions of up to 0.2 metres are predicted across the rear yards of number 41 and 43 Biggera St. **Plate 21** shows that during the 1% AEP, flood level reductions of up to 0.18 metres are predicted in the rear of these properties. Reductions of up to 0.05 metres are also predicted within the Old Pot Factory site.

Although **Plate 20** and **Plate 21** indicate some significant reductions in peak 20% and 1 % AEP flood level, these decreases are fairly localised and do not extend across any buildings. As a result, only minor reductions in flood damages are predicted (i.e., damage reductions of $200 over the next 50 years). This yields a preliminary BCR of less than 0.01. Therefore, the costs of implementing the option are predicted to far outweigh the reductions in flood damage costs.

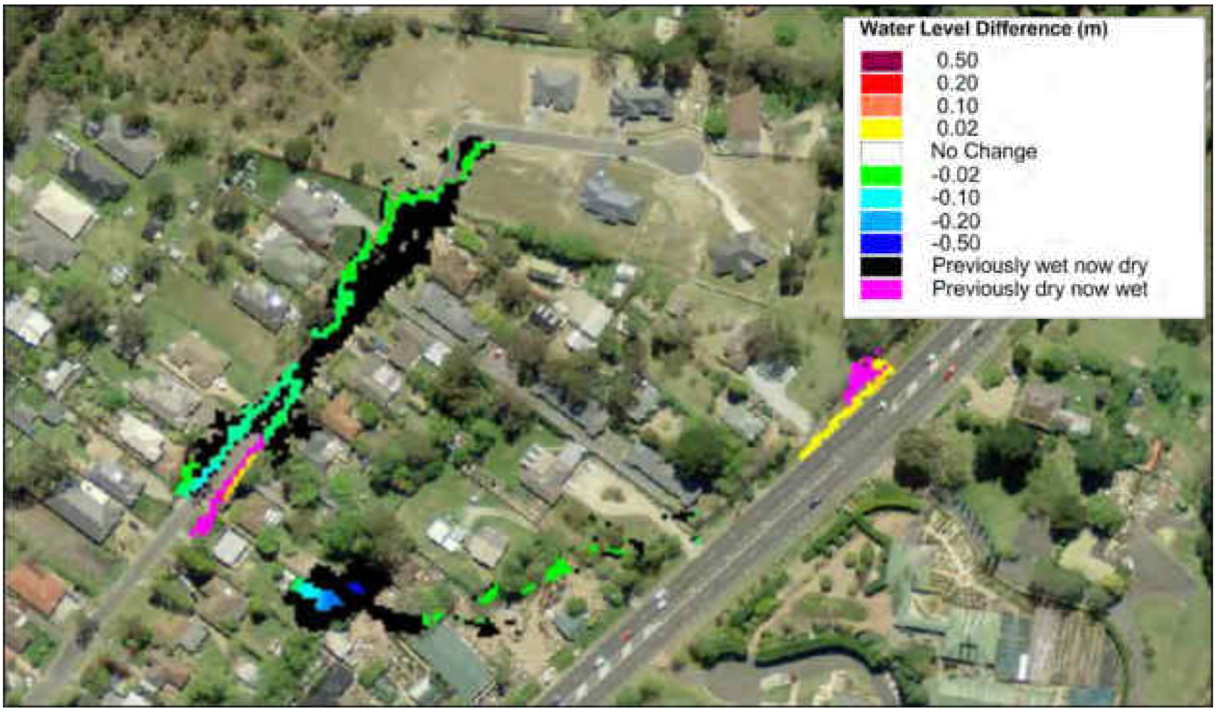


Plate 25 20% AEP Flood Level Difference Map for FM5

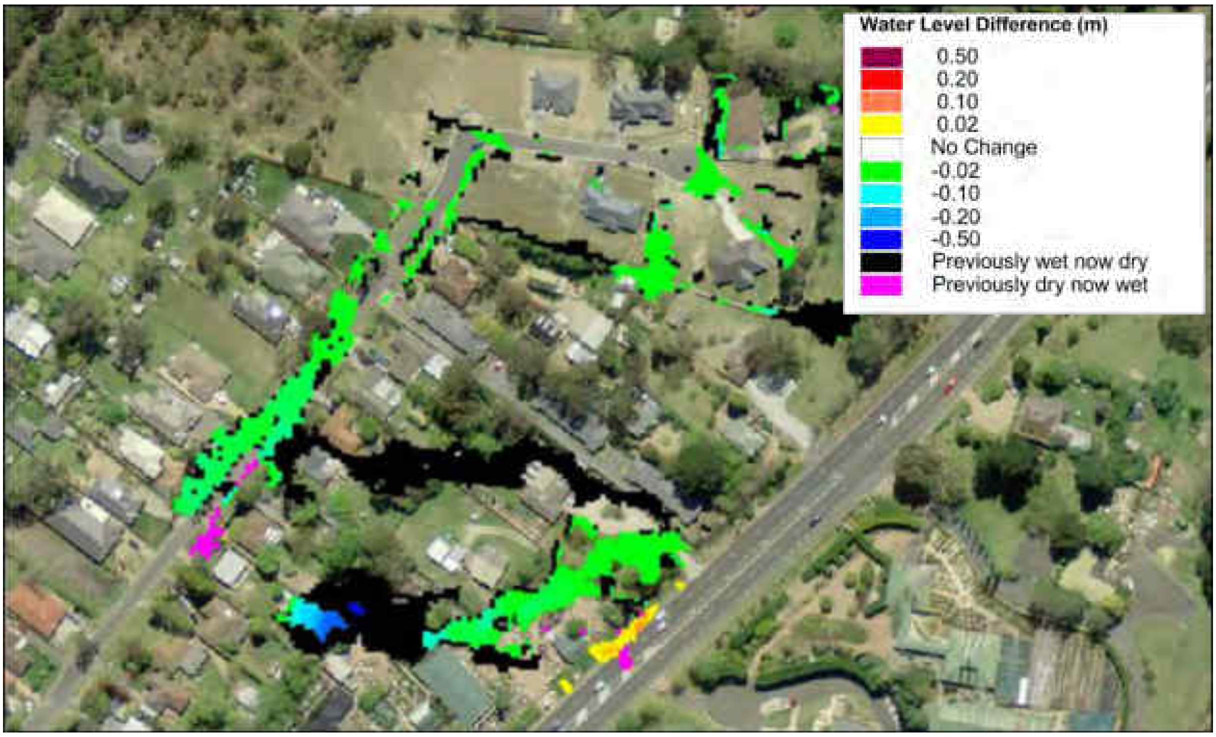


Plate 26 1% AEP Flood Level Difference Map for FM5

Given the low BCR, this option is difficult to support as part of the current study. Nevertheless, it does afford some benefits across an area that is known to be subject to inundation problems. Therefore, Council could include the stormwater upgrades within its Capital Works Program for implementation (along with the potential to install kerb and gutter in the area).

Recommendation: Not recommended for implementation through the Floodplain risk Management Study. However, it could be implemented as part of Council's capital works program

7.3.2 Blockage of Railway Culvert Adjacent to Biggera Street (FM6)

The southernmost portion of Biggera Street experiences inundation as a result of water moving from the western side of the railway to the eastern side via an arch culvert under the railway embankment.

This option looks at the potential benefits of permanently blocking the arch culvert so that flow is retained on the western side of the railway. The location of the arch culvert is shown in **Figure 40.**

The TUFLOW computer model was updated to represent complete blockage of the railway culvert. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 27** and **Plate 28**.

Plate 27 shows that during the 20% AEP event, flood level reductions of up to 0.3 metres are predicted within the channel on the eastern side of the railway. There are predicted to be associated increases in flood level of up to 0.2 metres on the westerns side of the railway. These increases are sufficient to overtop the railway further to the north of the culvert crossing resulting in an increase in flood level of between 0.03 and 0.06 metres across a large number of properties on Biggera Street.

Plate 28 also shows that during the 1% AEP, reductions in flood levels are again predicted within the channel. However, increases in existing flood levels are predicted within Biggera Street properties (increases of over 0.08 metres are predicted across most of these properties). Accordingly, the adverse flood impacts are predicted to be more expansive/significant than the beneficial flood impacts across a limited number of properties.

As the reductions in flood levels and inundation extents are contained to the channel during each design floods, this option was not considered further as it was unlikely to yield any reduction in flood damage costs across residential properties.

Recommendation: Not recommended for implementation

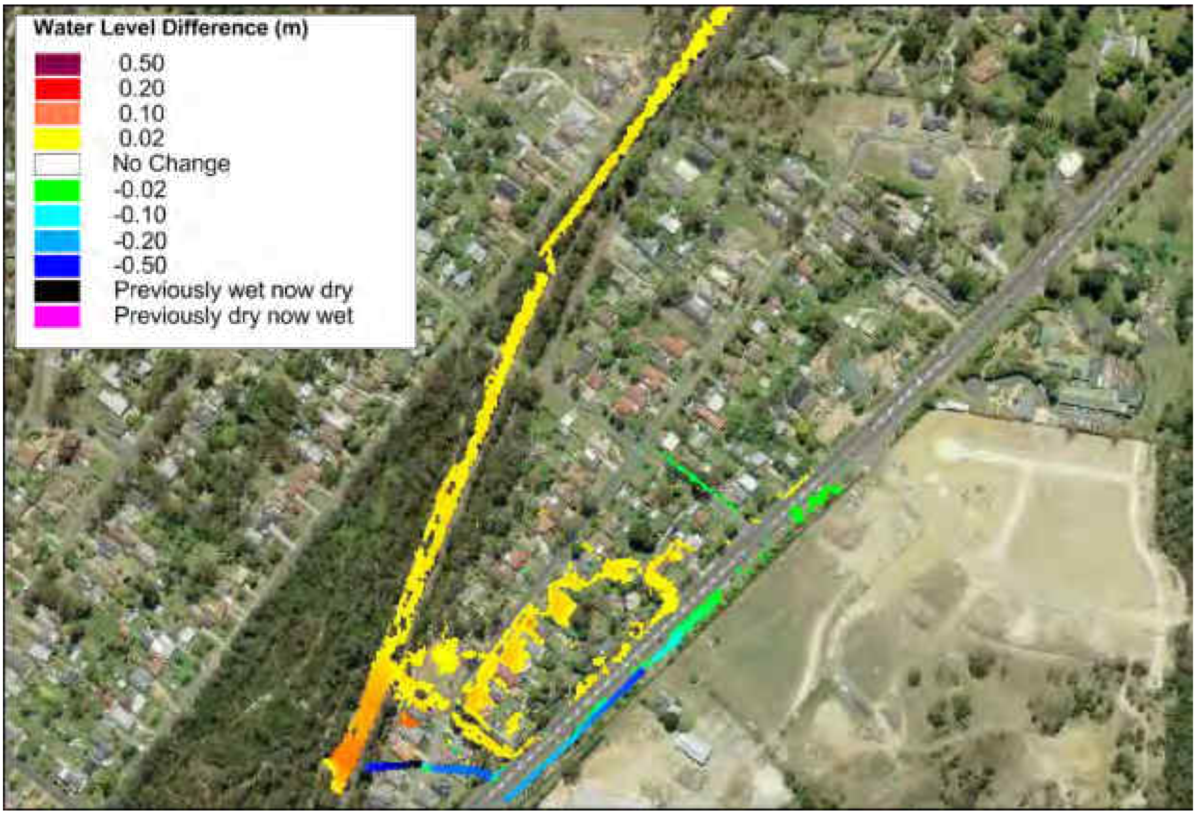


Plate 27 20% AEP Flood Level Difference Map for FM6

Plate 28 1% AEP Flood Level Difference Map for FM6

7.3.3 Install Kerb and Guttering and New Stormwater System in Biggera St & Old Hume Highway (FM7)

As discussed, runoff is currently conveyed along Biggera St via roadside swales. Once the capacity of this swale is exceeded, flow moves through a large number of properties in a south-easterly direction towards the Old Hume Highway.

This option looks at the installation of formalised kerb and guttering as well as the inclusion of a new subsurface stormwater system along the length of Biggera St to connect into recent upgrades along Rush Lane. The works would also involve the installation of stormwater infrastructure on the western side of the Old Hume Highway between Beresford Street and the main channel to accept the additional flow from the upstream stormwater system and better handle local flows off the Old Hume Highway. The location of the sugegsted works are shown in **Figure 41.**

The TUFLOW computer model was updated to include the proposed works. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 29** and **Plate 30**.

Plate 29 shows that some notable reductions in peak 20% AEP flood levels and reduced extents are predicted across a number of residential properties on Biggera Street and the Old Hume Highway, as well as typical decreases of 0.07 metres across part-sections of The Old Hume Highway south of Rush Lane. Some flood level decreases of 0.04 metres are also predicted on Isedale Road and along the eastern side of the Old Hume Highway, as well as decreases of 0.03 metres in the rear of properties at 68 – 82 Old Hume Highway. Flood level increases of between 0.03 and 0.08 metres are predicted along Rush Lane and the western side of the Old Hume Highway, however these are primarily due to the increases ground surface elevation resultant from filling of the roadside swales to accommodate the proposed subsurface stormwater system.

Plate 30 shows that flood level reductions are also predicted across a number of residential properties during the 1% AEP flood. Unfortunately, the kerb and guttering is predicted to redirect overland flow across a number of properties to the immediately south of Rush Lane. Although the increase in flood levels are not particularly large (i.e., less than 0.1 metres in most cases), they are sufficient to push additional water into a number of properties. Similar decreases to the 20% AEP occur along the Old Hume Highway and in the rear of properties at 68-82 Old Hume Highway.

It is expected that the installation of the stormwater infrastructure and kerb and gutter will have a capital cost of approximately $1,400,000. A detailed breakdown of the cost estimate is provided in **Appendix F**.

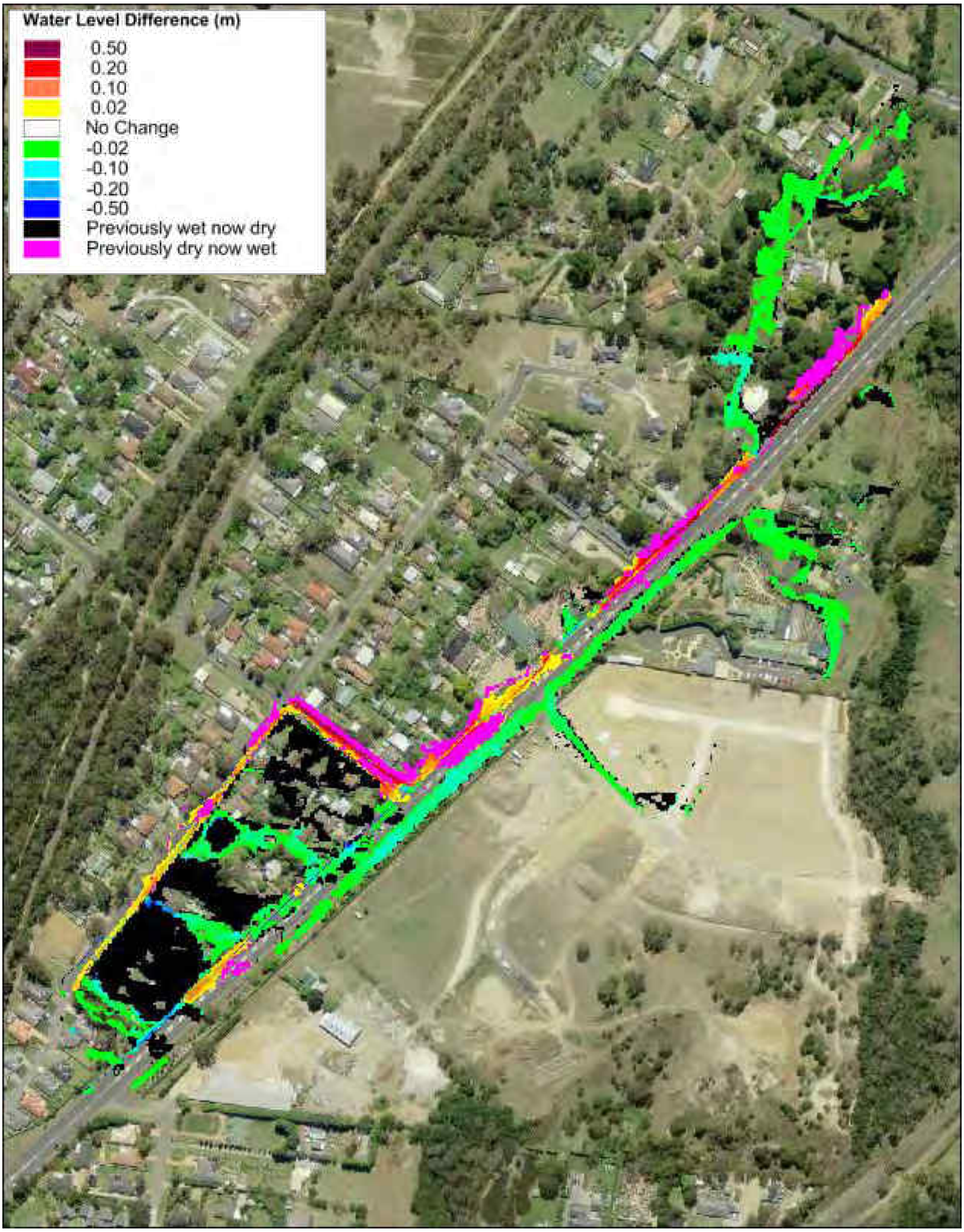


Plate 29 20% AEP Flood Level Difference Map for FM7

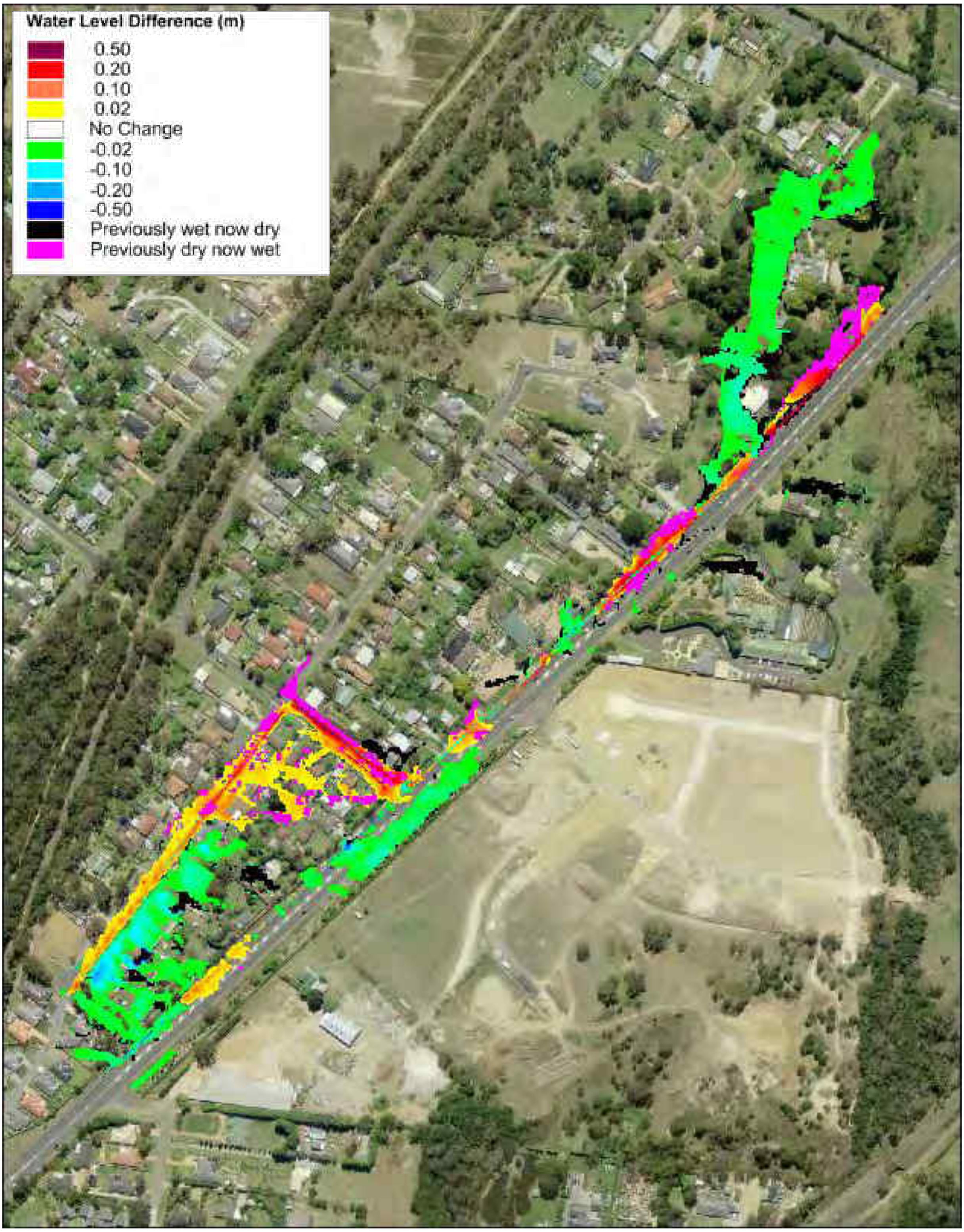


Plate 30 1% AEP Flood Level Difference Map for FM7

A revised damages assessment was also completed on the results of the revised flood simulations. The implementation of the works is predicted to reduce flood damage costs by approximately $50,000 over the design life of the works (i.e., 50 years). This yields a preliminary BCR of 0.04. Therefore, the costs of implementing the option are predicted to outweigh the reductions in flood damage costs. It should be noted that the benefits of this option include the already completed works on Rush Lane, however the costs of this work have not been included, providing for a greater reported benefit.

Given the low BCR and the adverse impacts to a number of properties during large floods, this option is not recommended for implementation through the Floodplain Risk Management process, however partial works could be considered as part of the Council capital works program.

Recommendation: Not recommended for implementation through the Floodplain Risk Management process. Could be considered as part of Council's capital works program.

7.4 Earthworks

7.4.1 Elevate Railway Embankment Near Biggera Street (FM8)

Existing Catchment Conditions

As discussed, the southern-most portion of Biggera Street is predicted to be inundated as a result of water moving from the western side of the railway line to the eastern side. Although a proportion of this flow is directed through an arch culvert, the remainder is predicted to enter the Biggera Street properties by overtopping the railway line further to the north.

This option involves elevating the railway embankment (or adding an elevated "bund" adjacent to the railway embankment) to reduce the potential for overtopping and keeping flood flows on the western side of the railway embankment. However, initial flood simulations showed this option, when implemented in isolation, would increase the flood affectation across a number of properties further to the north. Therefore, it will also be necessary to block an existing railway culvert near Railway Parade and implement the detention basin at Braemar Avenue discussed in Section 7.2.2 to offset these adverse impacts. The location of the proposed works for this option are shown in **Figure 42.**

The TUFLOW computer model was updated to include this option and the updated model was used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 31** and **Plate 32**.

Plate 31 shows that in the 20% AEP flood, a significant number of properties between the railway, Gascoigne St, Biggera St, the Old Hume Highway and Rush Lane are predicted to be "flood free" as a result of this option. Flood level reductions of up to 0.4 metres are predicted in the swale alongside the Old Hume Highway, however, decreases of less than 0.1 metres are most common. Decreases in flood level are predicted to extend across Railway Parade properties as well as across the Nattai Ponds subdivision. Increases in flood level are predicted on the western side of the railway line and extend downstream to Braemar Ave (thus the need to implement the detention basin at this location to ensure no adverse impacts across adjoining industrial properties).

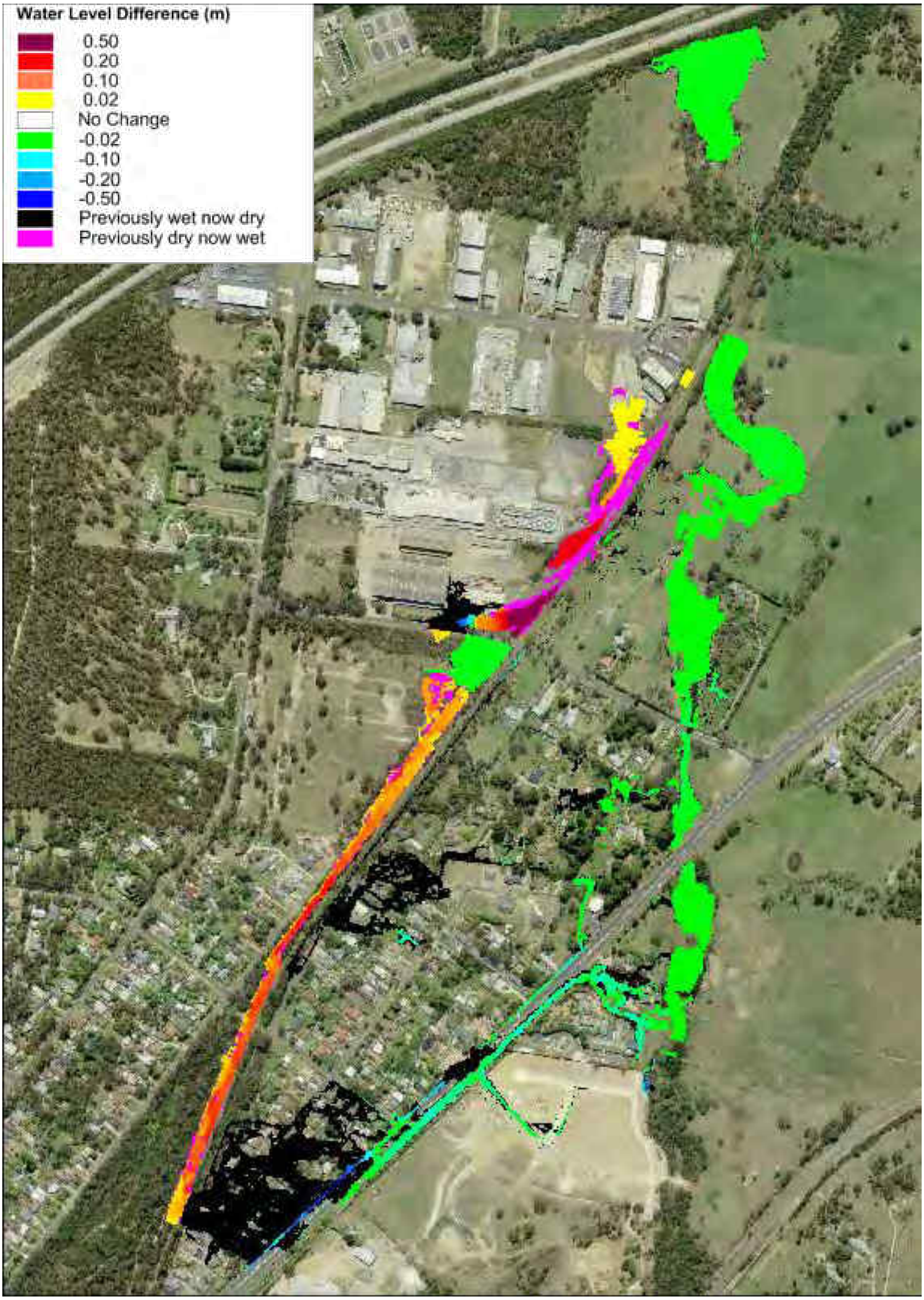


Plate 31 20% AEP Flood Level Difference Map for FM8

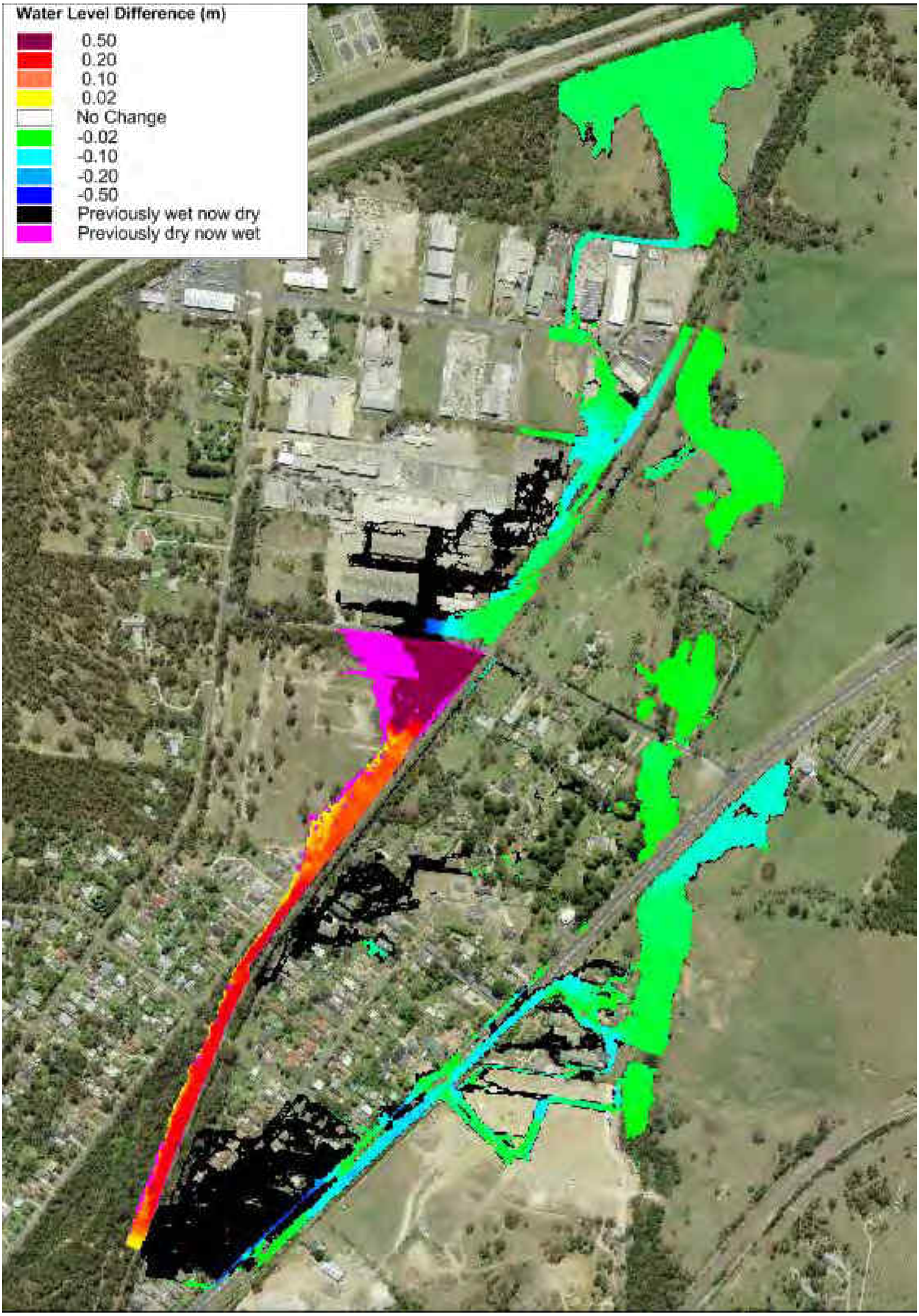


Plate 32 1% AEP Flood Level Difference Map for FM8

Plate 32 shows similar flood impacts during the 1% AEP flood. Typical reductions in flood level along the Old Hume Highway are predicted to be about 0.15 metres. Decreases of up to 0.05 metres are anticipated within the main creek channel. Increases are again predicted on the western side of the railway and these increases extend into the Braemar Ave Basin. However, providing the basin is implemented, decreases of about 0.05 metres are predicted across the downstream industrial properties.

It is expected that this option would have a total capital cost of approximately $370,000. A breakdown of the cost estimate is provided in **Appendix F**.

A revised damages assessment was completed based on the results of the revised flood simulations. The implementation of the works is predicted to reduce flood damage costs by approximately $63,000 over the design life of the basin (i.e., 50 years). This yields a preliminary BCR of 0.2. Therefore, the costs of implementing the option are higher than the predicted reduction in flood damages.

Overall, this option is predicted to afford some significant improvements to the existing flood affectation across a number of properties located between the railway line and Old Hume Highway. It would also reduce the frequency with which the railway line would be cut by floodwaters and provide a significant improvement to the level of service of this important infrastructure service.

It is currently unclear whether the ARTC would permit the use of the railway embankment to contain water on the western side of the railway embankment. Therefore, as a minimum, consultation with ARTC will be required.

It is noted that funding through the NSW State Government's Floodplain Management Grants program will only be provided for options that target the existing flood risk across properties constructed prior to 1986 (the Floodplain Development Manual was first gazetted in 1986. As a result, properties constructed after this date should have been constructed in accordance with the principles of the manual). A review of existing housing stock in the area that would benefit from this option indicates that roughly 25% of the housing stock was constructed prior to 1986 while the remaining 75% was constructed after 1986. Therefore, only 25% of the total implementation cost of this option will likely be eligible for funding by the state government. However, discussions could be held with ARTC to assist with funding due to the improvements that this option would afford the railway line (i.e., reduced frequency of the railway line being cut by water).

The major negative of this option is the poor benefit-cost ratio. The major cost component of this option is the Braemar Ave detention basin. Therefore, it is likely the economic viability of this option could be improved if a more cost-effective basin option is developed. Assuming a suitable basin design can be developed, there is sufficient evidence to support further detailed investigations and potential implementation of this option. Alternatively, a modified version of this option could be considered in conjunction with the railway channel option discussed in Section 7.5.2. Discussions could be held with Australian Rail Track Corporation (ARTC) to gain their support for the works with potential for some financial contribution given the improvement that this option affords the local rail network.

Future Catchment Conditions

As discussed in Section 3.5, future development does have the potential to increase the existing flood risk across the catchment. This includes a number of residential properties adjoining Biggera Street as well as the Braemar industrial area. As this option is predicted to afford reductions in flood levels/extents across many of the same properties, the potential for this option to mitigate the impacts of future catchment development were explored.

The potential hydraulic benefits afforded by the railway embankment raising and Braemar detention basin under future catchment conditions was quantified by undertaking additional future catchment simulations with the option in place. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 33** and **Plate 34**. The difference maps were prepared by subtracting peak flood levels for existing catchment conditions from peak future catchment flood levels with the embankment raising and basin in place (to verify if the works would mitigate the adverse flood impacts that are predicted with future catchment development).

Plate 33 and **Plate 34** shows that the railway embankment raising and basin effectively eliminates inundation during floods up to and including the 1% AEP flood across Biggera Street properties. Accordingly, the embankment raising appears to be a reasonable option for reducing the potential future flood risk across these residential properties. However, the difference maps also show that this option is not predicted to fully mitigate the predicted flood impacts across the Braemar industrial area (although it is noted that this option does afford benefits extending downstream of the Nattai Ponds subdivision).

Although the suggested works are not predicted to fully offset the impacts associated with future catchment development, they may assist in reducing the future flood risk. Therefore, there may be scope to partly fund this option by preparing a suitable developer contributions plan. However, a detailed review of the modelling results determined that the option is not predicted to offset the anticipated increase in flood levels associated with future catchment development. As a result, the potential for developer contributions to help fund the option is considered to be limited.

As it currently stands, this option would need to be supplemented with other options (e.g., Option FM9) to assist in fully mitigating the potential future flood risk. However, it does afford some notable benefits in reducing the existing risk. If a more cost-effective version of this option could be developed and/or additional funding opportunities can be secured, this option or a modified version of this option is recommended for implementation.

Recommendation: Not recommended at this time. However, further detailed investigations are recommended to determine if a more cost-effective option and/or additional funding sources can be secured

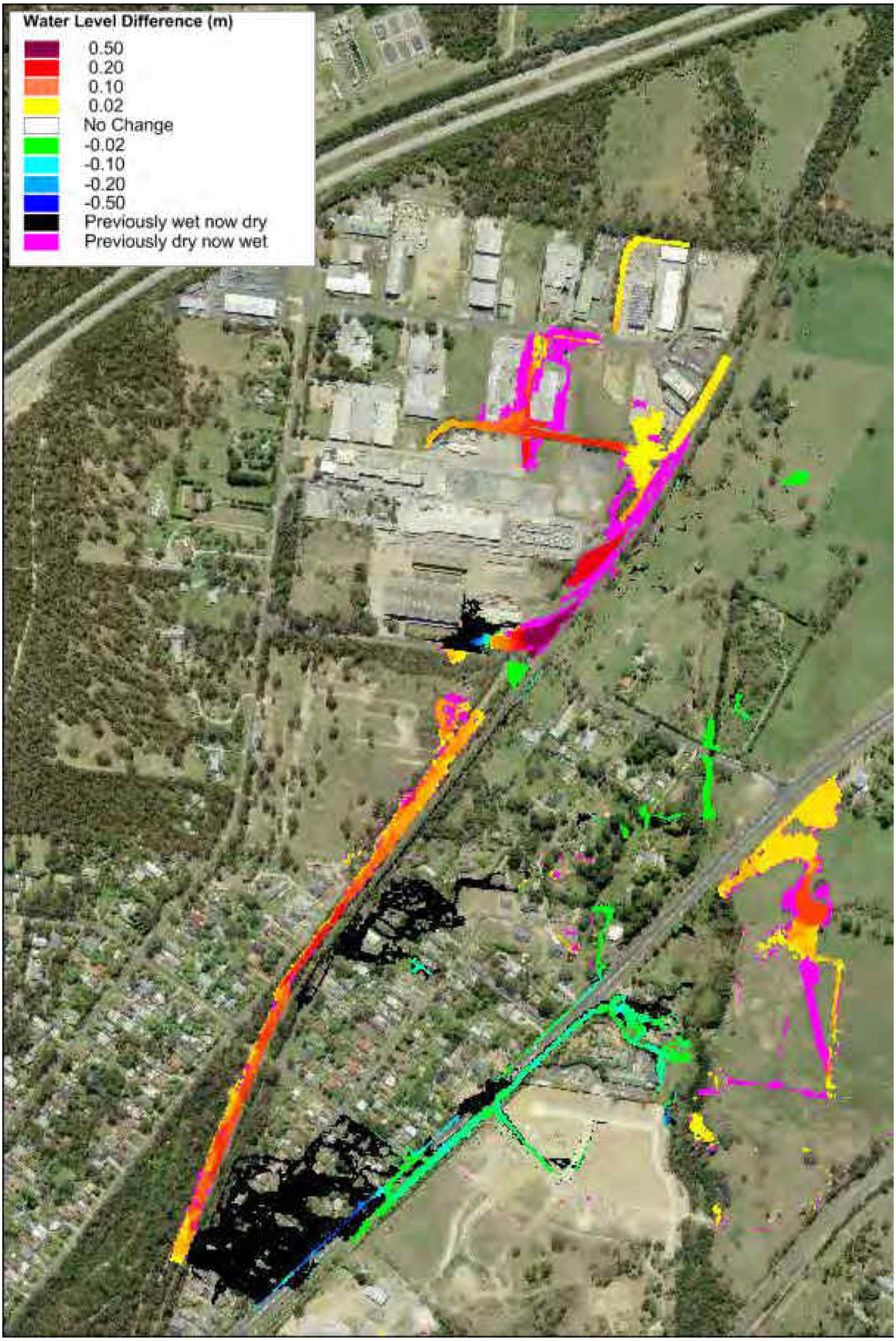


Plate 33 20% AEP Flood Level Difference Map for FM8 under Future Catchment Conditions

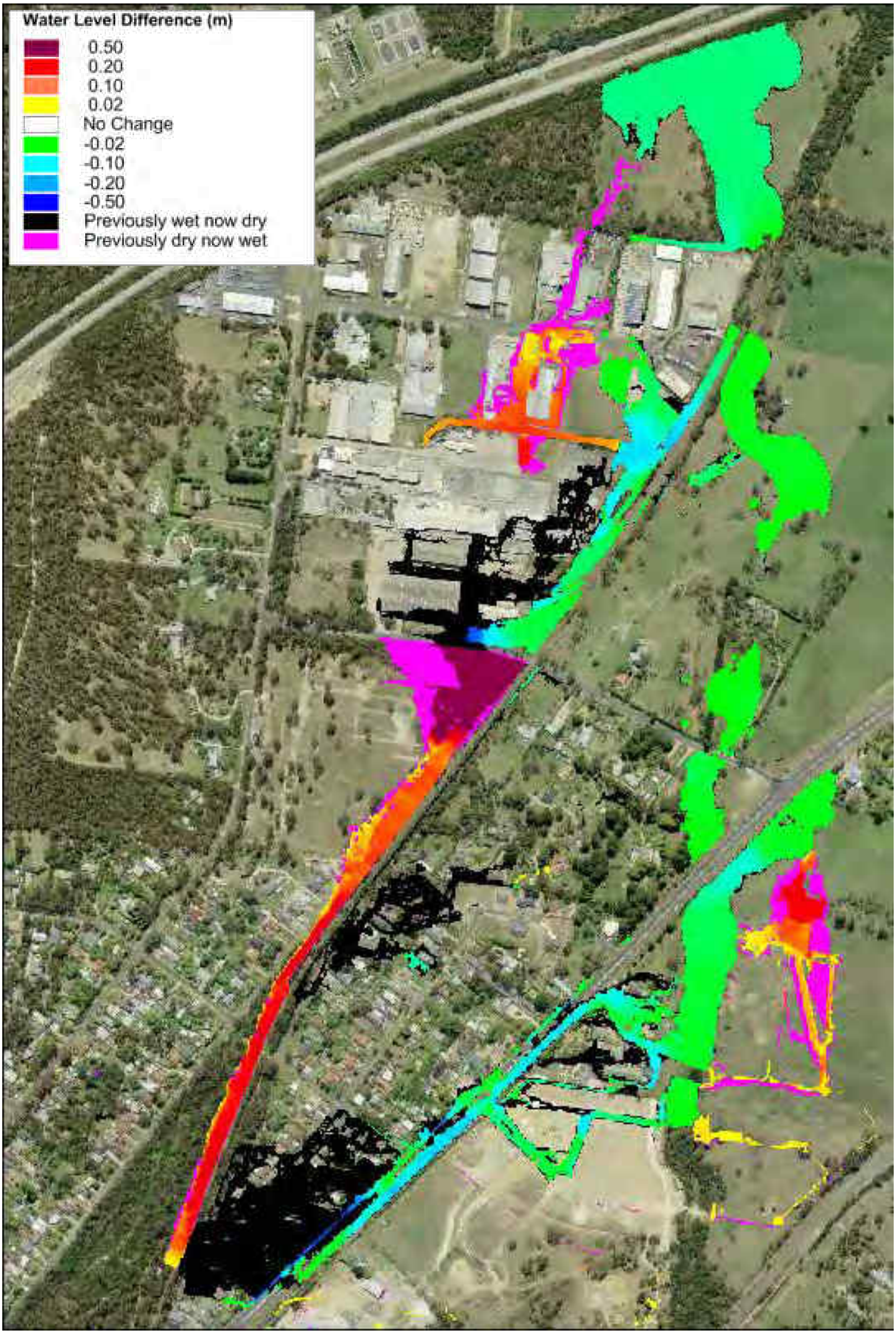


Plate 34 1% AEP Flood Level Difference Map for FM8 under Future Catchment Conditions

7.5 Channel Modifications

7.5.1 Enlarge Drainage Channels Adjacent to Braemar Industrial Area (FM9)

Existing Catchment Conditions

The Braemar Industrial Area is vulnerable to inundation as a result of the capacity of the local stormwater system being exceeded as well as from water overtopping the banks of the various open drainage channels in the area. There are open drainage channels along the western side of the railway line, as well as along the rear of industrial properties on the southern side of Gantry Place. Properties located adjacent to these channels are particularly susceptible to inundation in relatively minor flood events (e.g., 20% AEP). This option would aim to provide additional flow carrying capacity within these channels by enlarging them, as well as increasing the embankment height in locations where the bank is commonly overtopped (the typical increase in embankment height is predicted to be about 0.2 metres). The embankment crest level was set to be just above the peak level of the 1% AEP flood (i.e., negligible freeboard was provided).

The extent of the proposed channel and bank works is shown in **Figure 43.**

The TUFLOW computer model was updated to include the channel enlargement and bank raising. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 35** and **Plate 36**.

Plate 35 and **Plate 36** shows that the channel enlargement is predicted to generated flood level increases within the channels during each design flood (up to 0.2 metres). However, reductions in flood levels and extents are predicted across a number of Gantry Place industrial properties. Therefore, this option does appear to have notable positive flood benefits.

It is expected that the proposed works will have a capital cost of approximately $50,000. A breakdown of the cost estimate is provided in **Appendix F**.

A revised damages assessment was also completed based on the results of the revised flood simulations. This showed that implementation of the works is predicted to reduce flood damage costs by approximately $23,000 over next 50 years. This yields a preliminary BCR of about 0.5. Therefore, the costs of implementing the option are more than the anticipated economic benefits. However, despite the BCR being less than 1, this option affords one of the higher BCR of all of the options considered as part of the study. As the implementation cost is approximate only, more detailed investigations may yield a slightly lower cost estimate which would improve the economic viability of this option.

It should also be noted that State Government funding through the Floodplain Management Program focusses on the reduction of private and public loss, with less priority placed on reducing commercial losses. Accordingly, it is likely that Council would need to fund this option themselves or find alternate funding sources. The expected capital expenditure is not considered substantial and so the cost should not be considered as a limiting factor.

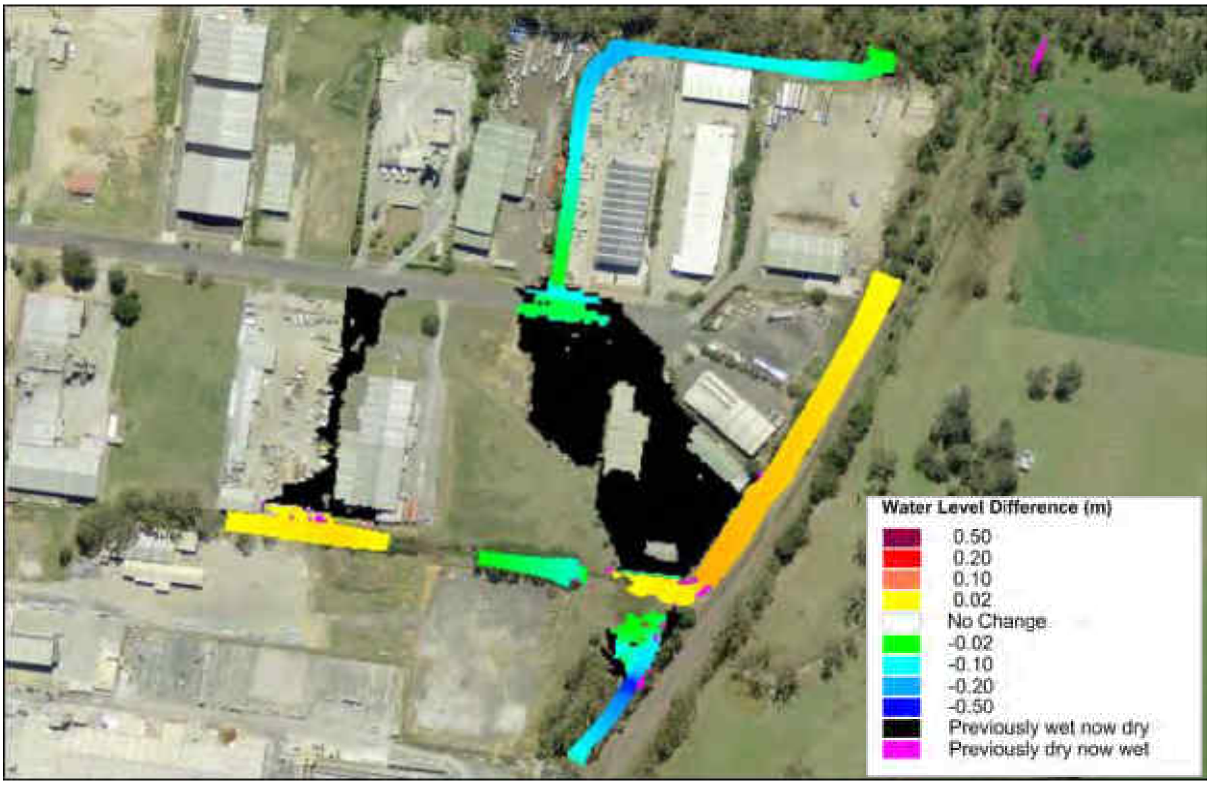


Plate 35 20% AEP Flood Level Difference Map for FM9

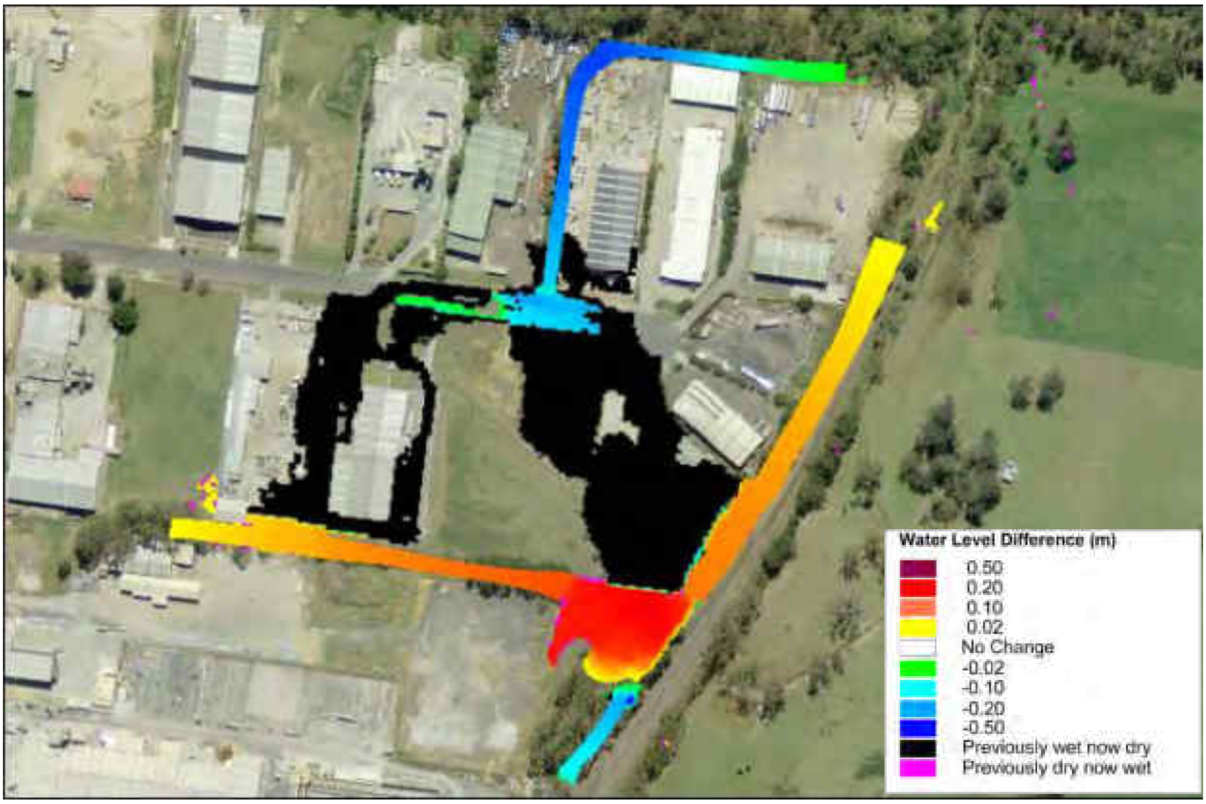


Plate 36 1% AEP Flood Level Difference Map for FM9

Community and landholder consultation would also need to be completed as the proposed works would primarily occur on private property. This may require acquisition of an easement for the proposed works, which would add to the implementation costs.

Overall, it is recommended that detailed investigation and design plans are prepared to aid a more precise scope of works and cost estimate for this option. If these investigations confirm a reasonable capital cost, it is recommended that Council proceed with implementation of this option.

Future Catchment Conditions

As discussed in Section 3.5 and 7.4.1, future development does have the potential to increase the existing flood risk across the Braemar industrial area. Enlargement of the drainage channels may assist in mitigating the adverse impacts that are predicted under future development conditions. Therefore, the potential hydraulic benefits afforded by the channel modifications was quantified by undertaking additional TUFLOW model simulations under future catchment conditions with the channel modifications in place.

The TUFLOW computer model was updated to include the channel enlargement and bank raising. However, as future development will likely involve some filling to elevate industrial buildings above the peak 1% AEP flood level, the location and size of the channel was altered slightly from the 'existing' conditions assessment to reflect potential future filling of the industrial land.

The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 37** and **Plate 38**. The difference maps were prepared by subtracting peak flood levels for existing catchment conditions from peak future catchment flood levels with the channel modifications in place (to verify if the channel modifications could suitably mitigate the adverse impacts that are predicted under future catchment conditions).

Plate 37 and **Plate 38** shows that the channel enlargement is predicted to generated flood level increases of more than 0.3 metres within the open channels during each design flood. However, reductions in flood levels and extents are predicted across a number of Gantry Place industrial properties, even with the increased flows associated with future development in the upstream catchment. Therefore, this option not only provides benefits under existing development conditions but will also help to ensure the flood risk does not increase in the future as a result of further development.

It is anticipated that the flood level reductions will extend across both existing development as well as future development areas. Therefore, part funding for this option could be sourced through developer contributions (i.e., Section 7.11 & 7.12 Contributions Plan). A review of the industrial properties that would benefit from this option indicate that around 70% of the benefitted area comprises existing development and the remaining 30% comprises currently vacant land that may be developed in the future. Therefore, up to 30% of the implementation cost of this option could potentially be sourced through developer contributions.

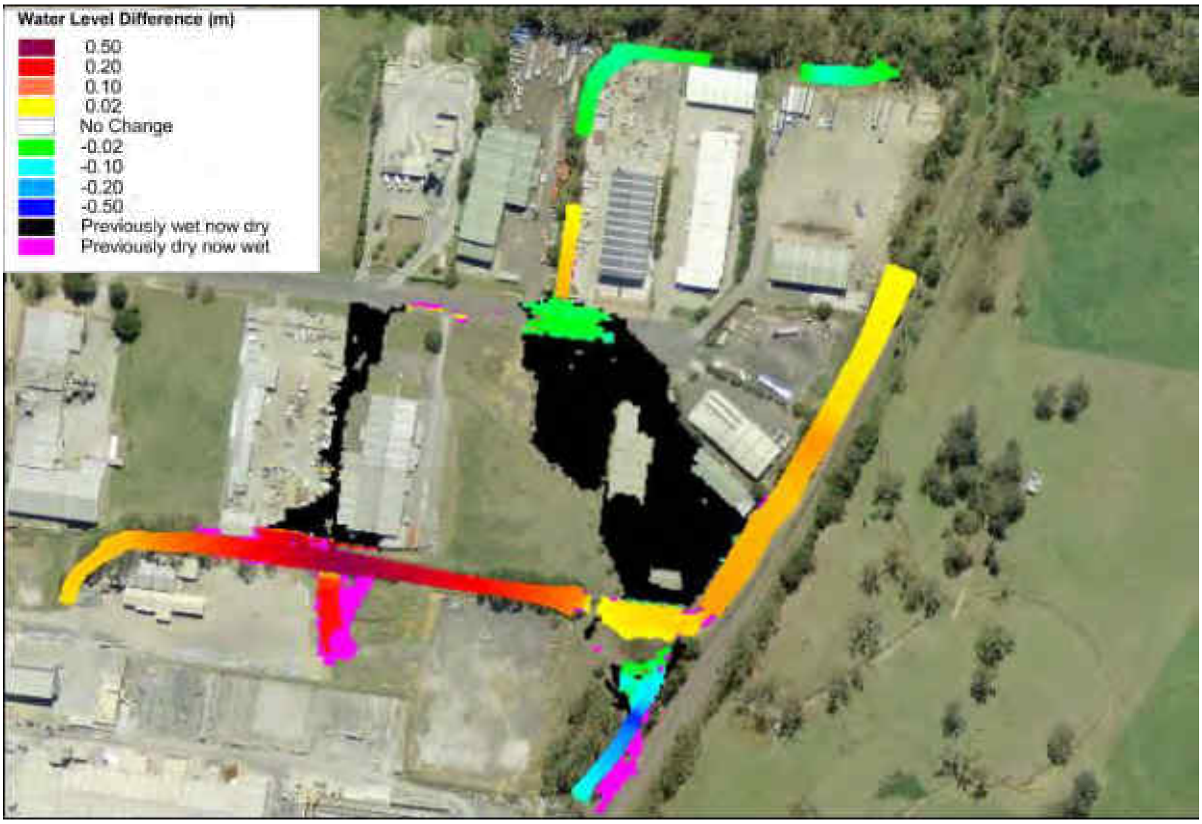


Plate 37 20% AEP Flood Level Difference Map for FM9 under Future Catchment Conditions

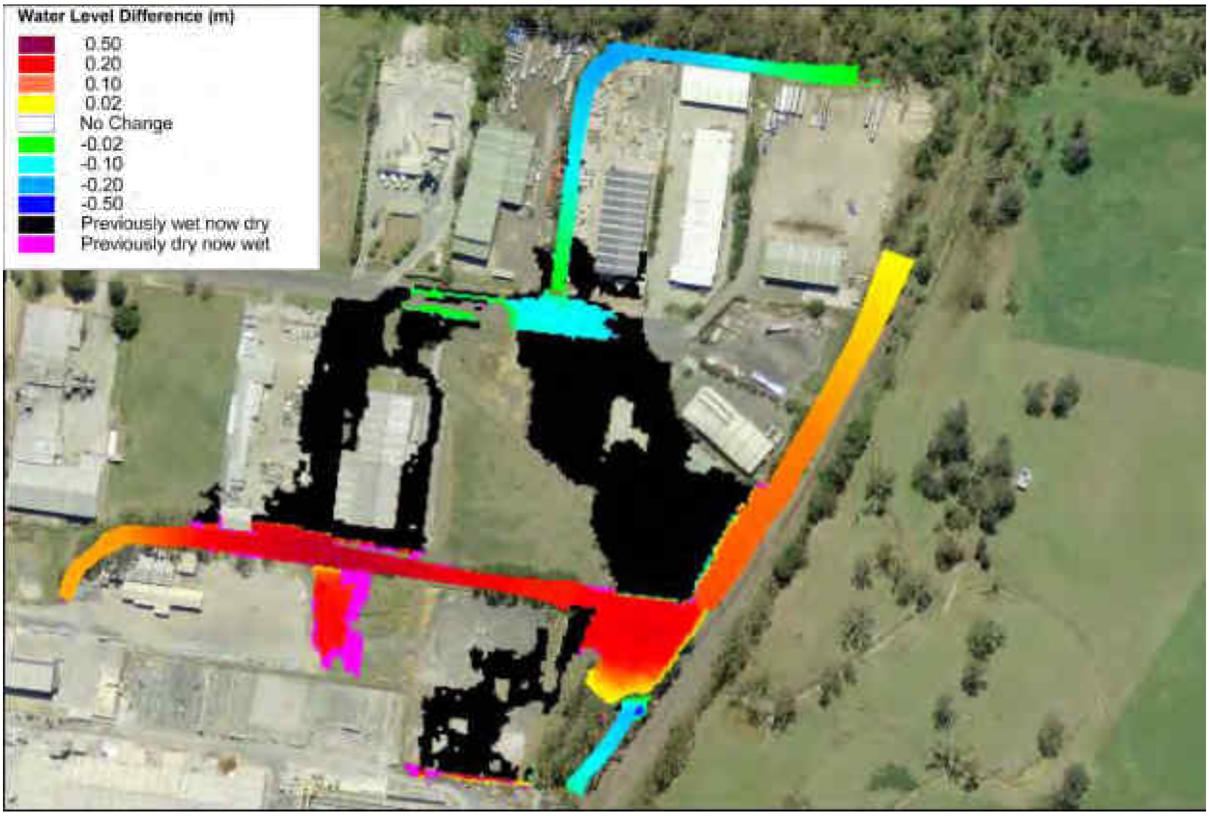


Plate 38 1% AEP Flood Level Difference Map for FM9 under Future Catchment Conditions

It is recommended that Council proceed with more detailed investigations to refine the concept design presented in this report and gain a better understanding of the scope of works, particularly in relation to land ownership. Once these detailed investigations are complete, a refined cost estimate can be prepared, and developer contribution requirements can be determined and incorporated into the Section 7.11/7.12 Plan for the catchment. There may also be potential to couple this option with FM8 to assist in reducing the future flood risk across the vast majority of the catchment.

Recommendation: Recommended for further detailed investigation and pending the outcomes of these investigations, potential implementation

7.5.2 Create Formalised Channel on Western Side of Railway Embankment (FM10)

The intention of this option is similar to the elevated railway embankment option discussed in Section 7.4.1. This option would look to achieve this by creating a formalised channel on the western side of the railway line to assist in carrying additional flow on the western side of the railway line.

This option would require the removal of existing vegetation beside the railway line, and excavation of several high points in the terrain to create a constant "downslope" grade. The excavated area would then need to be stabilised to avoid erosion. Some alterations to the railway culvert near Railway Parade would also be required. The Braemar Ave detention basin would also need to be incorporated as part of this option to ensure that downstream industrial properties are not adversely impacted. The location of the proposed works for this option are shown in **Figure 44.**

The TUFLOW computer model was updated to include this option and the updated model was used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 39** and **Plate 40.**

Plate 39 and **Plate 40** shows that the hydraulic performance of this option is similar to the railway embankment option detailed in Section 7.4.1. That is, notable reductions in levels and extents are predicted across multiple properties between the railway line and Old Home Highway. However, this option is more "hydraulically efficient" so the flood level reductions on the eastern side of the railway are more significant and flood level increases on the western side of the railway are not as substantial. However, the improved efficiency is predicted to result in more substantial flood level impacts across industrial properties north of Braemar Avenue during the 20% AEP flood (although the increases are not predicted to extend across any existing buildings).

It is expected that the required works would have a capital cost of approximately $450,000. A breakdown of the cost estimate is provided in **Appendix F**.

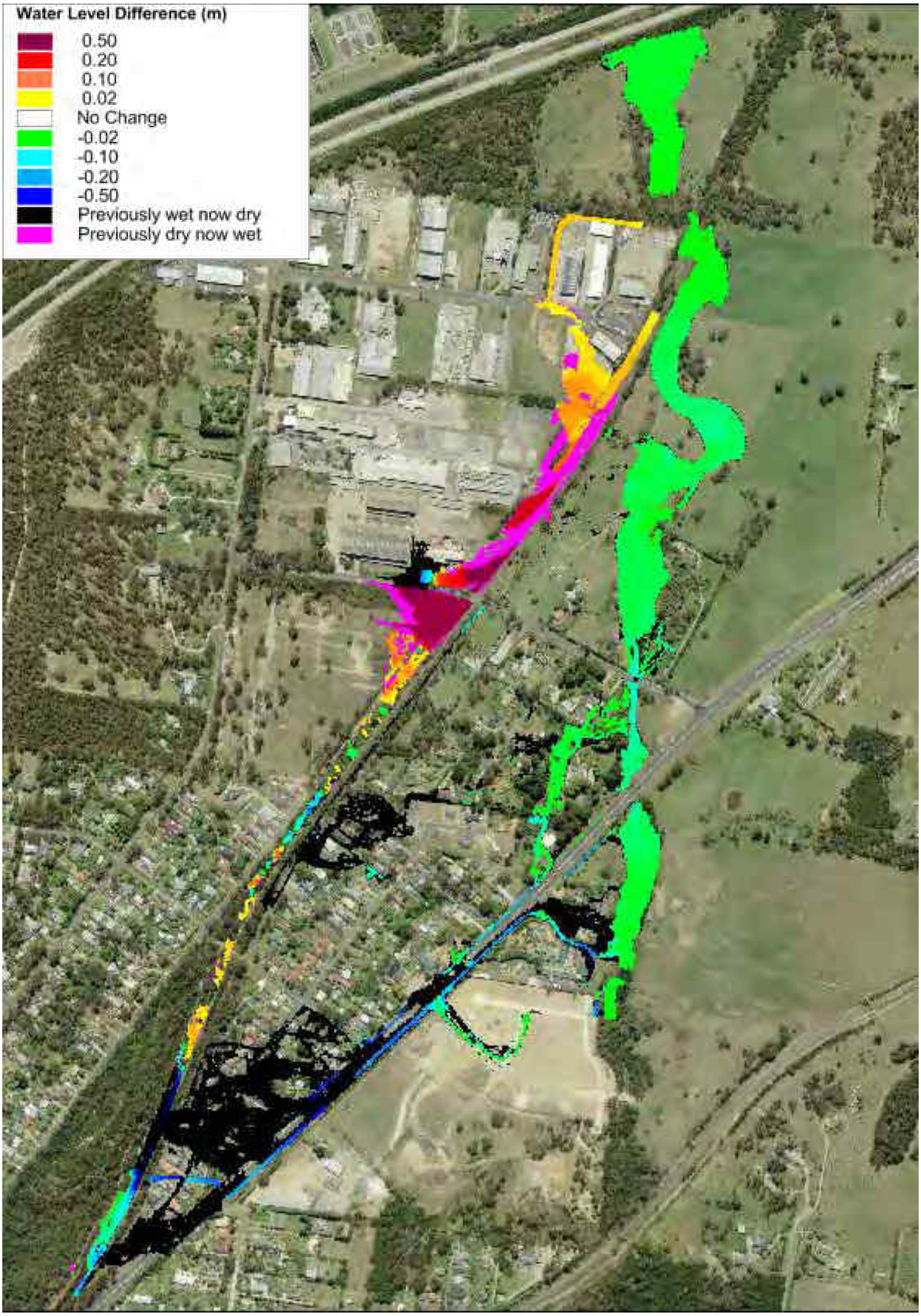


Plate 39 20% AEP Flood Level Difference Map for FM10

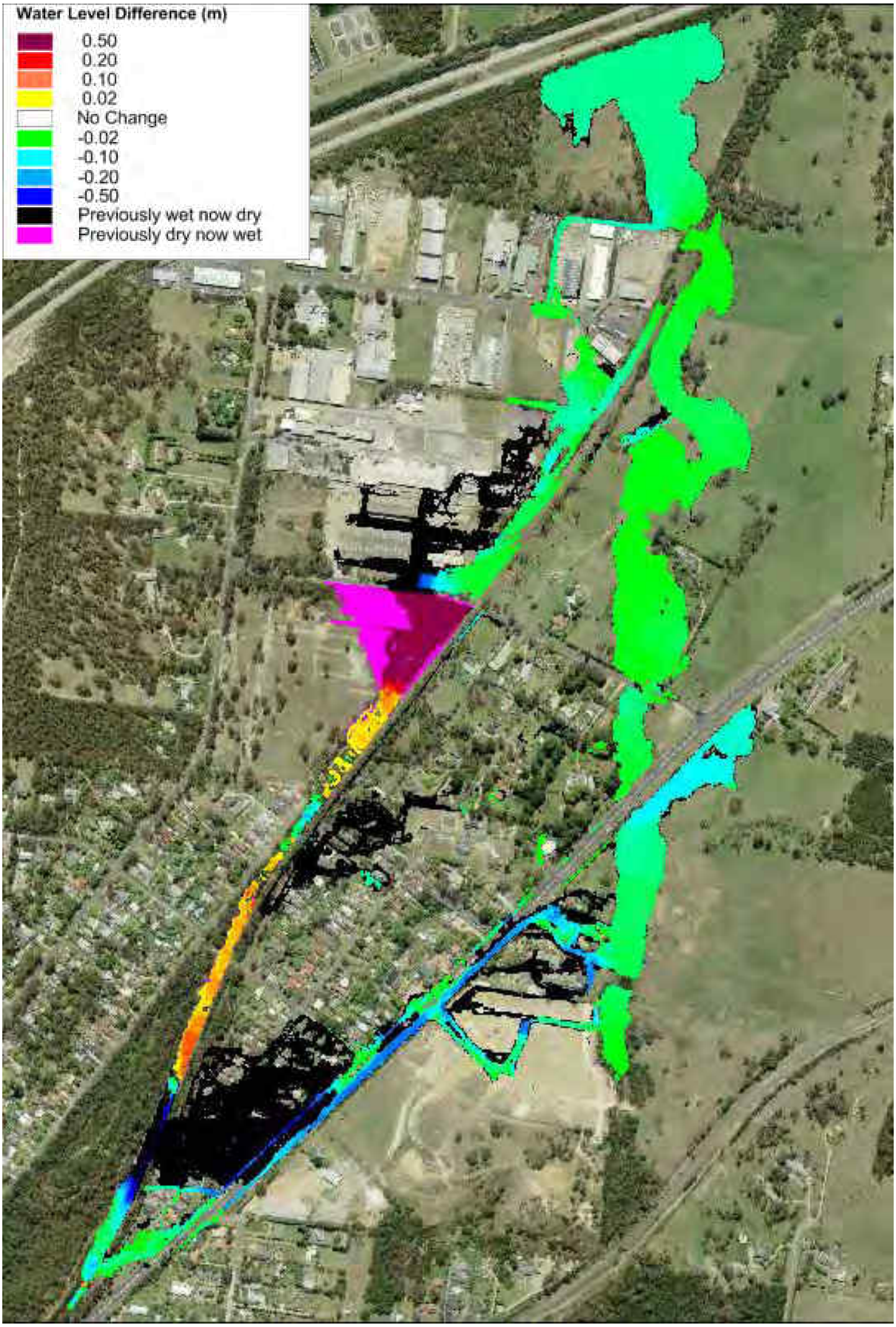


Plate 40 1% AEP Flood Level Difference Map for FM10

A revised damages assessment was also completed based on the results of the revised flood simulations. This showed flood damage costs would likely reduce by approximately $40,000 over the design life of the basin (i.e., 50 years). This yields a preliminary BCR of 0.1. Therefore, this option does not appear to afford a significant positive impact.

Overall, the relatively high capital cost and low BCR make this option difficult to support from a financial view. However, it does afford some notable hydraulic benefits. As discussed, in Section 7.4.1, a hybrid option incorporating elevation of the railway embankment in conjunction with regrading of some areas on the western side of the railway could be implemented and would likely yield similar hydraulic benefits at a reduced cost.

Recommendation: A modified version of this option would be looked at in conjunction with the Railway Embankment Elevation option discussed in Section 7.4.1

7.5.3 Enlarge Old Hume Highway Roadside Swales (FM11)

Inundation of the Amber Tiles and Lydie de Bray Antiques sites on the Old Hume Highway are predicted in relatively frequent floods (e.g., 20% AEP). Although flood depths are not particularly high, the frequency of inundation is considered problematic. As such, opportunities to enlarge the roadside swale on the eastern side of the Old Hume Highway (north of the Lydie de Bray Antiques site) was investigated in an attempt to improve the conveyance capacity and reduce existing flood levels. Some upgrades to the stormwater system immediately upstream of the swale were also considered necessary to fully charge the stormwater system and direct additional flows to the larger swale. The location of the proposed works are shown in **Figure 45.**

The TUFLOW computer model was updated to include the upgrades shown in **Figure 45** and the updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods are provided in **Plate 41** and **Plate 42.**

Plate 41 shows that in the 20% AEP flood, decreases of up to 0.07 metres are predicted within the Amber Tiles site. Parts of the antiques site that were previously inundated are predicted to be dry. Flood level increases are predicted within the roadside swale, however, the increases are localised and do not extend across any habitable areas. **Plate 42** shows that similar flood level impacts are predicted during the 1% AEP flood (i.e., small reductions in levels across the Amber Tiles and antiques site and flood level increases in the swale).

It is expected that the required works would have a capital cost of about $180,000. A breakdown of the cost estimate is provided in **Appendix F**.

A revised damages assessment was also completed based on the results of the revised flood simulations. The implementation of the works is predicted to reduce flood damage costs by approximately $1,000 over the next 50 years. This yields a preliminary BCR of less than 0.05.

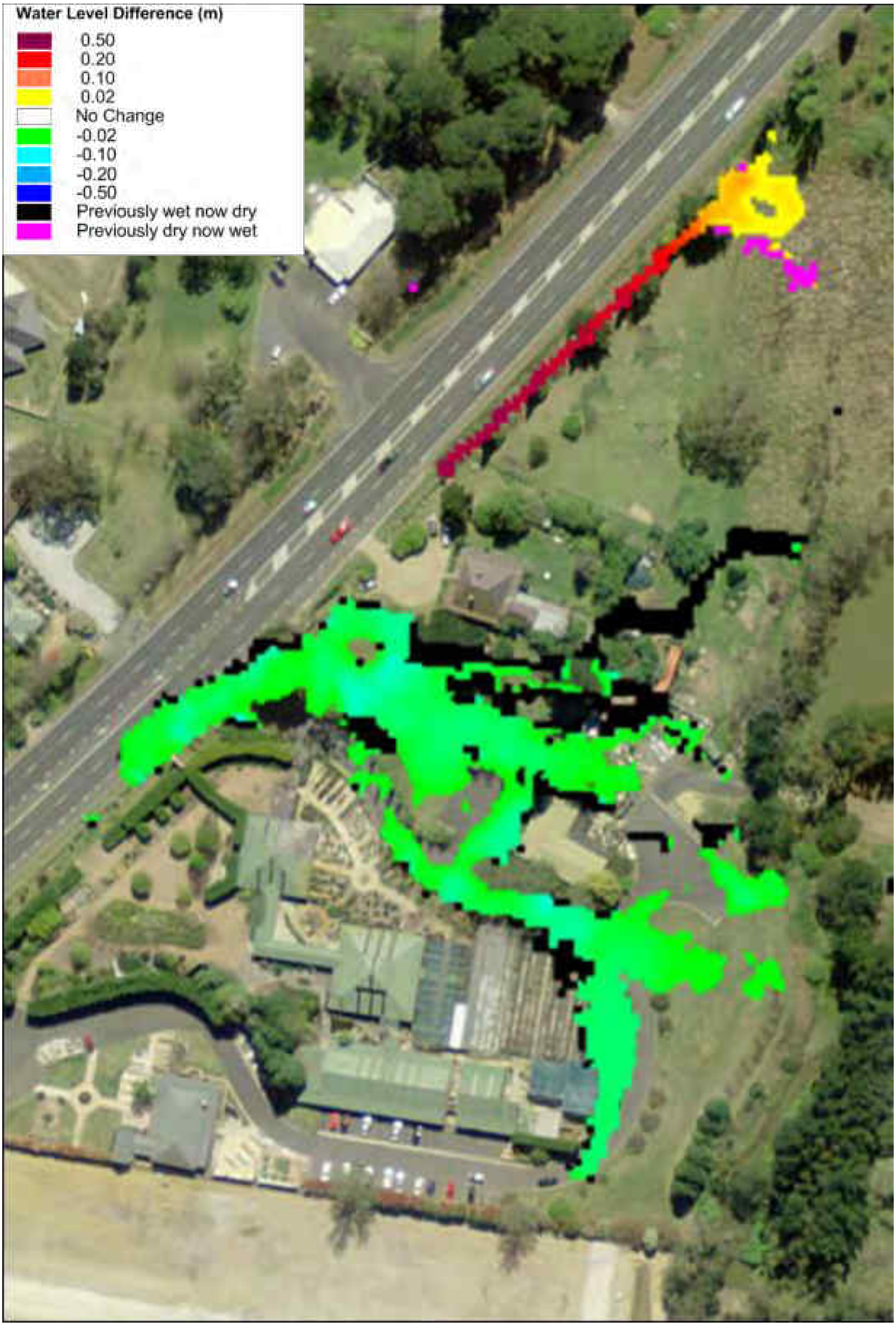


Plate 41 20% AEP Flood Level Difference Map for FM11

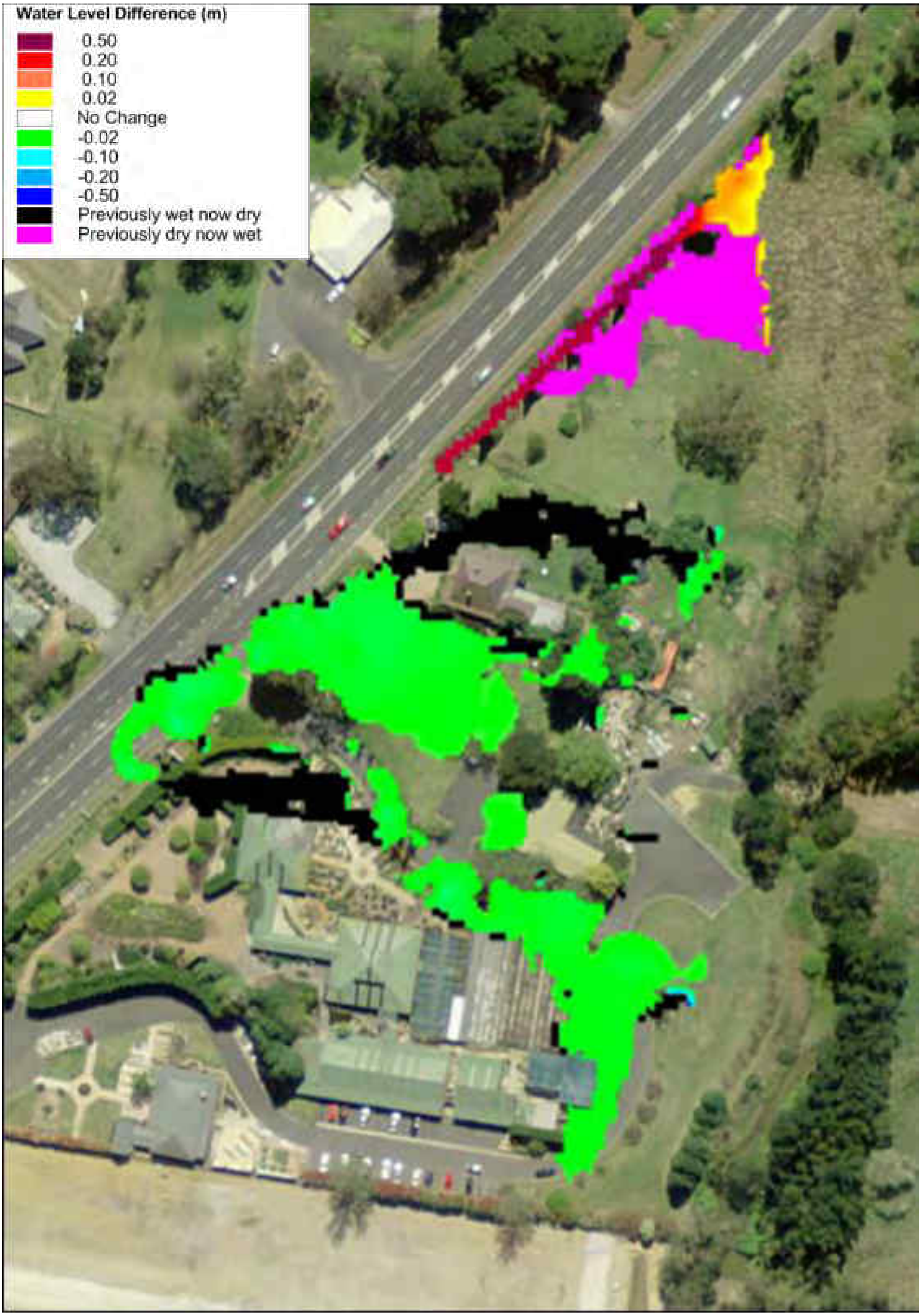


Plate 42 1% AEP Flood Level Difference Map for FM11

The relatively poor economic performance of this option and relatively small hydraulic benefits make this option difficult to support.

However, given the localised nature of flood impacts, Council could consider working with the land owners/occupiers of these sites to keep vulnerable areas free of debris/clear to minimise potential for flood damages. This could be initiated through the preparation of a business flood plan, which is discussed in more detail in Section 9.2.4. Discussions could be potentially held with RMS to gauge their interest in assisting to fund any drainage upgrades along this roadway corridor.

Recommendation: Not recommended for implementation

7.5.4 Enlarge Existing Channels Through Properties on Inkerman Rd and Scarlet St (FM12)

As discussed, properties on Inkerman Road and Scarlet Street experience relatively frequent inundation. Although the inundation during more frequent rainfall events is considered to be "nuisance" flooding, there is the potential for dangerous conditions to form in larger flood events where significant proportions of the properties are classified as floodway and inundation of roadways/isolation of properties is predicted to occur.

This option looked at the potential benefits of enlarging the size of the existing channels (i.e., widening and deepening the existing channels) to provide additional "in channel" conveyance capacity. The channel enlargement focused on enlarging channel segments that were discontinuous/disjointed and in areas where there where large, but relatively shallow, inundation extents. The location where channel enlargement works were identified are shown in **Figure 46.**

The TUFLOW computer model was updated to include the channel enlargements shown in **Figure 46** and the updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods with this option in place are provided in **Plate 43** and **Plate 44.**

Plate 43 shows that during the 20% AEP flood, flood level decreases of between 0.03 and 0.2 metres are predicted across multiple properties in the vicinity of Scarlet Street and Inkerman Road, with some areas adjacent to the channels now "free" from inundation. However, most of the flood level reductions occur in close proximity to the channels and are not sufficient to extend across existing dwellings. No notable flood level increases are predicted throughout the study area during the 20% AEP flood.

Plate 44 shows flood level reductions during the 1% AEP flood extending across a similar area relative to the 20% AEP flood, although the magnitude of the reductions is not as substantial. **Plate 44** also shows that the channel enlargement is predicted to generate flood level increases of 0.07 metres immediately downstream of Scarlet St and increases of up to 0.03 metres near the Nattai Ponds subdivision as well as upstream of the Old Hume Highway. These increases are not predicted to impact on any existing development.

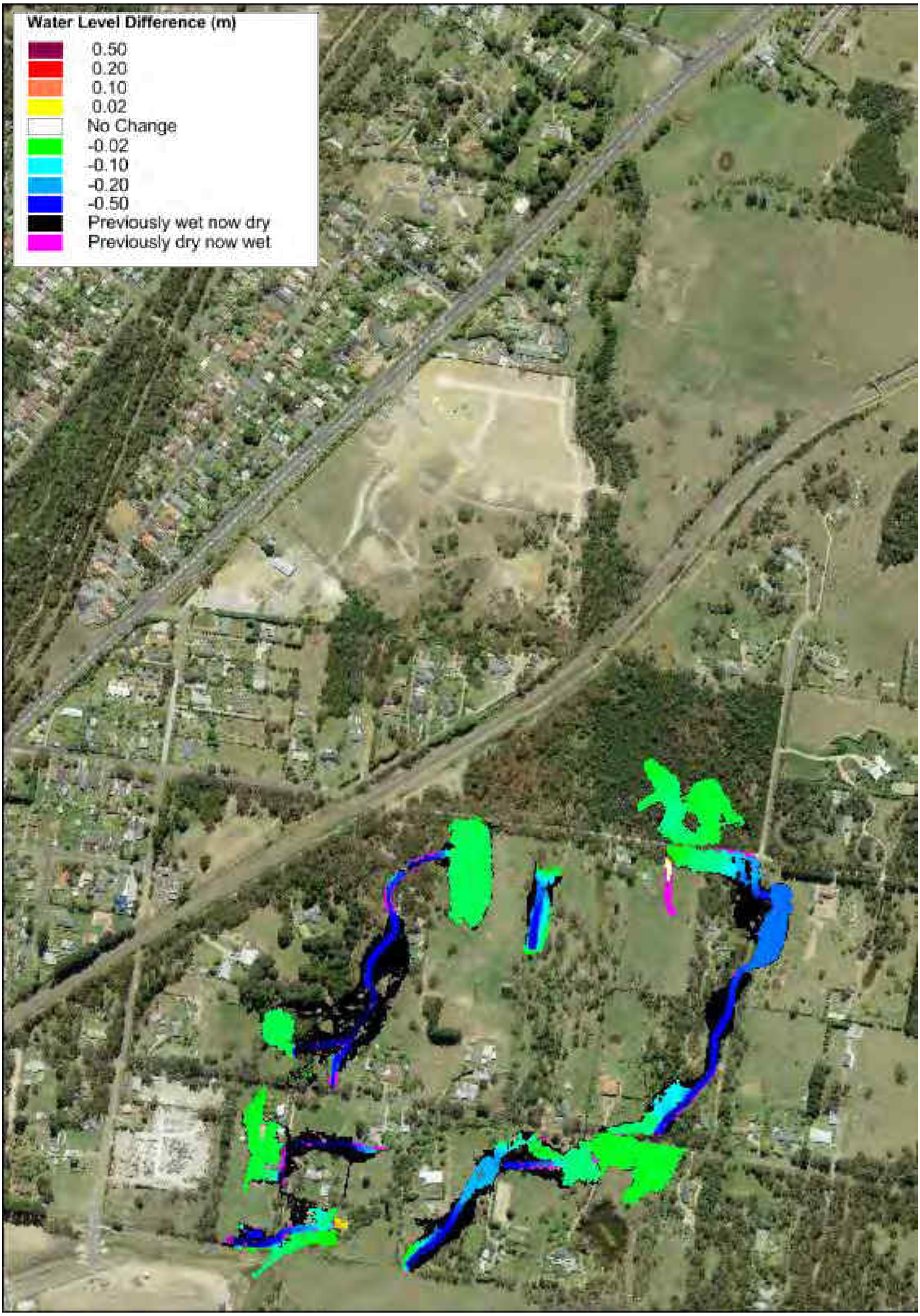


Plate 43 20% AEP Flood Level Difference Map for FM12

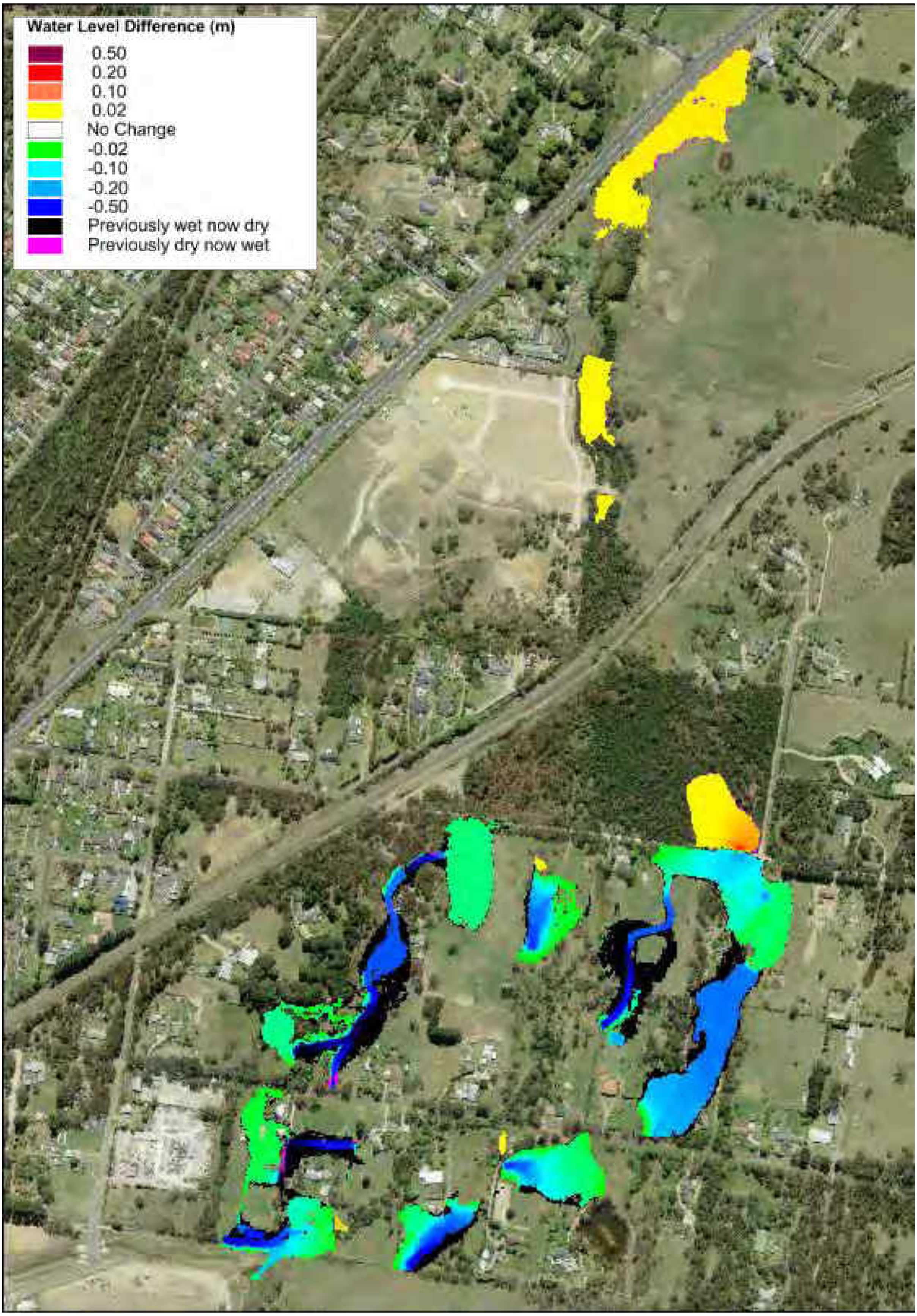


Plate 44 1% AEP Flood Level Difference Map for FM12

It is expected that the suggested works would have a capital cost of about $300,000. A breakdown of the cost estimate is provided in **Appendix F**.

A revised flood damages assessment was completed based upon the results of the hydraulic modelling with the channel enlargement in place. This determined that the enlargement is not predicted to reduce existing flood damages. This is associated with the flood level reductions being primarily contained to the main channels. As a result, this option is predicted to have preliminary BCR of 0.0. The poor economic performance makes this option difficult to support through the Floodplain Risk Management process. Accordingly, the potential for state government funding to help implement this option is considered to be limited.

However, it is noted that the channel enlargement does afford flood level reductions across many of the problematic Inkerman Road and Scarlet Street properties while, at the same time, generating negligible adverse flood impacts. As a result, local landowners may still consider there to be benefits in enlarging the channels running through their respective properties even if local or state government funding cannot be secured. In such circumstances, the local land owners could be given the authority to carry out the channel enlargement and maintain the channels at their own cost. Accordingly, it is recommended that Council undertake initial investigations to determine if such authority could be granted (subject to other considerations such as bank stability and water quality requirements for category 3 riparian land) and whether at least part funding could be provided to assist land owners with the implementation costs. If these investigations are favourable, Council could initiate discussions with the local land owners to confirm their willingness to contribute to the implementation of the option.

Recommendation: Not recommended for implementation under the Floodplain Risk Management process. However, Council could investigate potential for individual property owners to implement the channel enlargement within their respective properties.

7.6 Miscellaneous Options

7.6.1 Upgraded Scarlet Street Culvert (FM13)

As part of the public exhibition of the final draft report, Inkerman Road and Scarlet Street residents requested that the potential benefits of upgrading the main Scarlet Street crossing be explored as part of the final report. Therefore, an option involving upgrading the existing culvert (which provided a waterway opening that is approximately 1.2m high and 4.5m wide) with a 3 cell 1.2m high by 4.5m wide culvert (i.e., tripling the size/capacity of the current structure) was investigated. In addition to the upgraded culvert, the main channel was also widening to ensure it could accommodate the additional flows from the upgraded culverts. The channel widening extended approximately 30 metres upstream of Scarlet Street to a point 130 metres downstream of Scarlet Street. Some slight adjustment of the channel invert was also completed to better “tie in” with the upgraded culverts.

The TUFLOW computer model was updated to include the culvert and channel enlargement and the updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods with this option in place are provided in **Plate 45** and **Plate 46.**

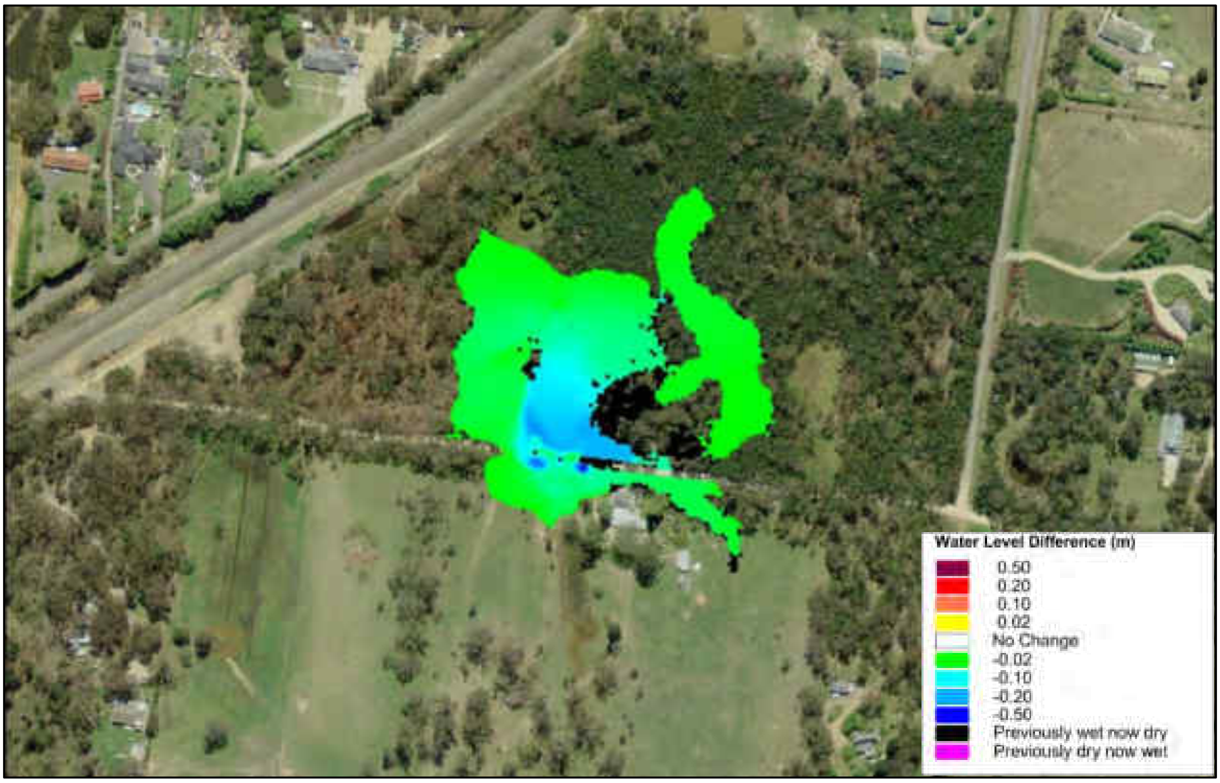


Plate 45 20% AEP Flood Level Difference Map for FM13

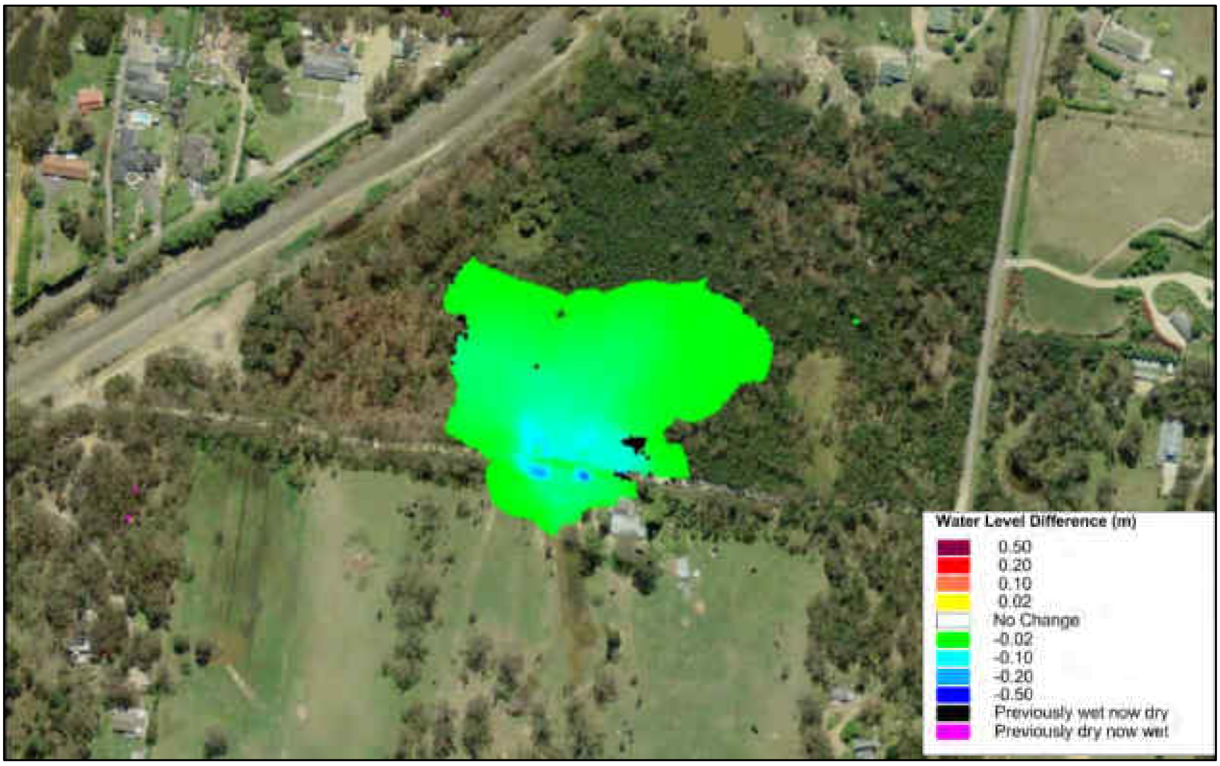


Plate 46 1% AEP Flood Level Difference Map for FM13

Plate 45 shows that during the 20% AEP flood, localised flood level decreases of up to 0.3 metres are predicted in the immediate vicinity of the Scarlet Street culvert. However, the flood level reductions are most commonly less than 0.05 metres across the adjoining properties.

Plate 46 shows flood level reductions during the 1% AEP flood extending across a similar area relative to the 20% AEP flood, although the magnitude of the reductions are not as substantial. More specifically, flood level reductions are not predicted to exceed 0.2 metres during the 1% AEP flood, and like the 20% AEP flood, the flood level reductions are most commonly less than 0.05 metres.

A revised flood damages assessment was completed based upon the results of the hydraulic modelling with the culvert upgrade and channel modifications in place. This determined that the modifications are predicted to produce flood damage reductions of less than $10,000 over the next 50 years. Any culvert upgrade works will cost well in excess of this damage reduction value. As a result, the BCR will be well below 1 and is not likely to secure funding support through the Floodplain Risk Management process.

As a result of the poor financial performance, the option is not recommended for implementation as part of the current study. However, it could be considered in the longer term as part of Council's capital works program should resources be available.

Recommendation: Not recommended for implementation

7.7 Recommendations

The following flood mitigation options are recommended for further consideration to assist in managing the existing and future flood risk across the Nattai Ponds catchment:

- Elevating the rail embankment and/or creating a formal channel on the western side of the railway (assuming a cost-effective option for mitigating adverse flood impacts across industrial area can be found) (FM8 or FM10);
- Enlarge drainage channels adjacent to industrial area (FM9)

In addition, upgrading of the stormwater system between Biggera Street and Old Hume Highway (near the Old Pot Factory) (FM5) could be explored as part of Council's capital work program. Enlargement of the existing channels in the vicinity of Inkerman Road and Scarlet Street could also be investigated (FM12), however, it is likely that this will need to be at least partly funded by the individual landowners.

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.

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

8.2 Planning Modifications

8.2.1 Changes to Wingecarribee Shire Council LEP (PM1)

A review of the Wingecarribee Shire Council LEP (2010) was completed and the outcomes of this review are summarised in Section 4.3.1. As discussed in Section 4.3.1, it is recommended that any future updates of the LEP consider the following changes:

- Remove the flood planning area maps from the LEP and make these maps available to the public on council's website, and/or through other means. This will help to ensure that council will be able to update the flood planning area maps immediately, ensuring that the most current and up to date flood information is available to the public.
- Include an additional "Floodplain Risk Management" clause in the LEP which would would relate to the areas between the flood planning area and the edge of the low flood risk precinct, as stated in the current DCP.

Recommendations: Amend Wingecarribee Shire Council LEP considering the detailed review presented in Section 4.3.1 of this report.

8.2.2 Changes to Mittagong DCP and Northern Villages DCP (PM2)

A review of the relevant clauses of Mittagong DCP 2017 and Northern Villages DCP 2017 was completed and a detailed discussion on the outcomes of this review are documented in Section 4.3.2. As discussed, it is recommended that any future updates of these DCPs consider the following changes:

- Extend the 'structural soundness' requirements so that structures within the floodplain are designed to withstand the forces of floodwater during all events up to and including the PMF for other development types. This control currently only applies to sensitive land uses where refuge-in-place may be necessary if early evacuation is not completed.
- Consider modifying Figure A4.2 of the DCPs to provide specific advice on what floods need to be considered as part of the impact assessment.

- In areas of overland flow where inundation depths are typically shallow, an option to provide carports or garages 300mm above the ground level could be provided.

Recommendations: Amend Mittagong and Northern Villages DCP considering the detailed review presented in Section 4.3.2 of this report.

8.2.3 Update Section 10.7 Certificate Information (PM3)

It is recommended that Council update Section 10.7 certificates to reference the updated design flood information generated as part of the current study. This will help to ensure the most up-to-date information is available and used for properties located within the Nattai Ponds catchment.

This needs to be implemented with the other changes identified in the preceding sections of this report regarding the updating of the LEP and DCP flood mapping information to include all food constraints up to and including the PMF, as indicated as flow flood risk precinct in Council's DCP.

Recommendations: Updated Section 10.7 certificate to reference updated design flood information generated as part of the current study.

8.3 Modification Options for Individual Properties

8.3.1 Voluntary House Raising (PM4)

Voluntary house raising (VHR) is a well-established method of reducing the frequency, depth and duration of above floor inundation. VHR can be a suitable measure for reducing the flood damage for individual dwellings or can be used as a compensatory measure where other flood mitigation works are predicted to adversely impact on flood behaviour across individual dwellings. An example of house raising is provided in **Plate 47**.

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

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

- Subject to frequent above floor inundation. In this regard, properties that were predicted to be inundated above floor level during events more frequent than the 1% AEP flood; and,
- Low flood hazard area at the peak of the 1% AEP event;

Plate 47 Examples of houses before (top image), during (middle image) and after (bottom image) house raising (photos courtesy of Fairfield City Council)

The outcomes of this assessment are shown on **Plate 48**.

The information presented in **Plate 48** shows that the majority of buildings subject to frequent above floor inundation are not located within low flood hazard areas. Only two properties were identified that meet the identified criteria (shown in pink in **Plate 48**). Further inspection of these properties showed they were brick buildings on a concrete slab so are not suitable for house raising. Therefore, there are no existing residential buildings located within the Nattai Ponds catchment that are considered eligible for voluntary house raising.

Recommendation: not recommended for implementation

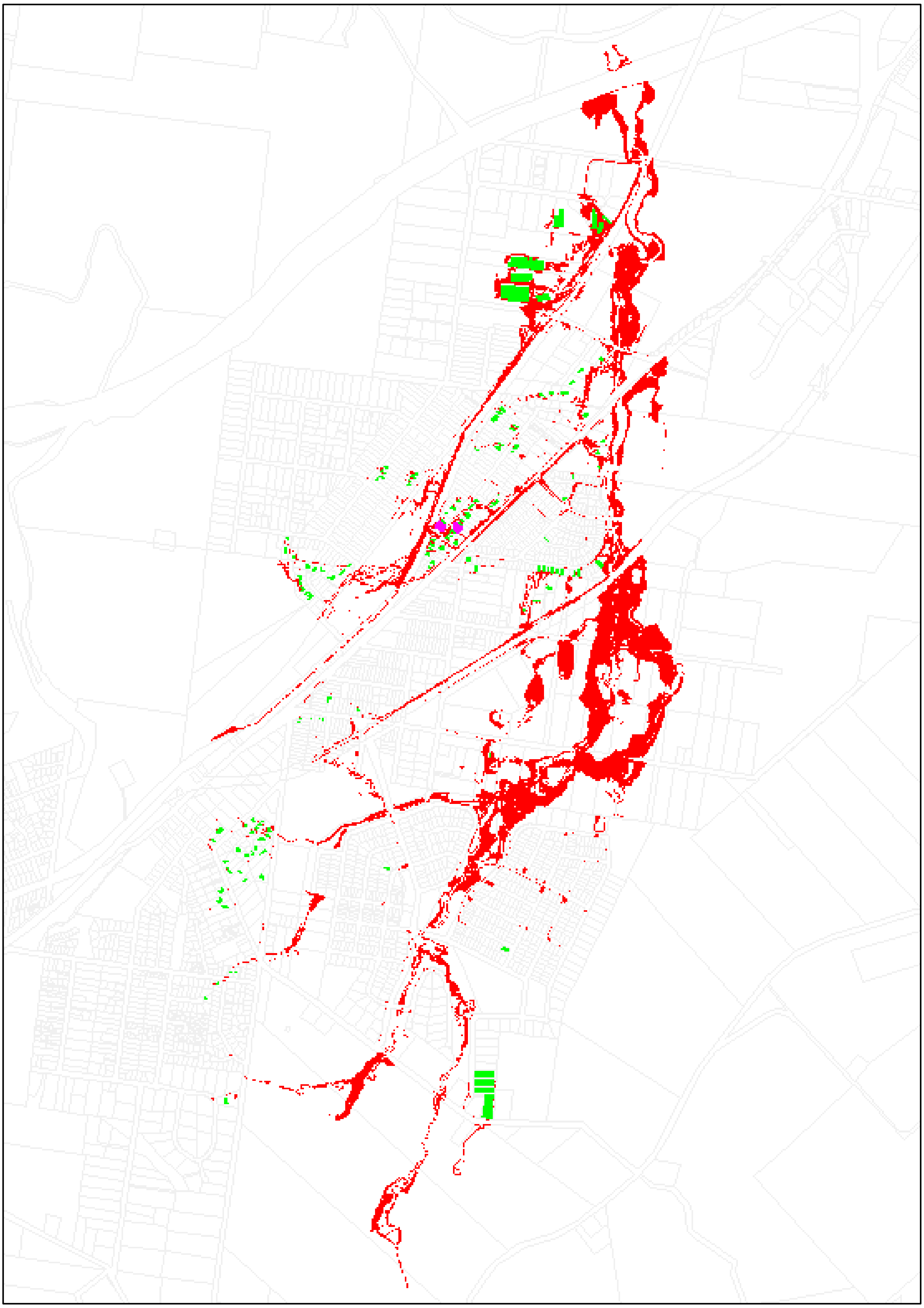


Plate 48 1% AEP low hazard areas (red) and buildings subject to frequent above floor inundation (green)

8.3.2 Voluntary House Purchase (PM5)

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 hazard.

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

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

- High flood hazard areas; and
- Floodway areas.

The outcomes of this assessment are presented in **Plate 49**. **Plate 49** shows that there are no residential properties within the Nattai Ponds catchment that would fall within a floodway or high hazard area at the peak of the 1% AEP flood. Therefore, there are no buildings in the catchment that are considered eligible for VHP.

Recommendation: not recommended for implementation

8.4 Recommendations

The following property modification options have been evaluated as part of the study and are consider viable for further consideration to assist in managing the future flood risk across the Nattai Ponds catchment:

- LEP Amendments;
- DCP Amendments; and,
- Update Section 10.7 Certificate Information.

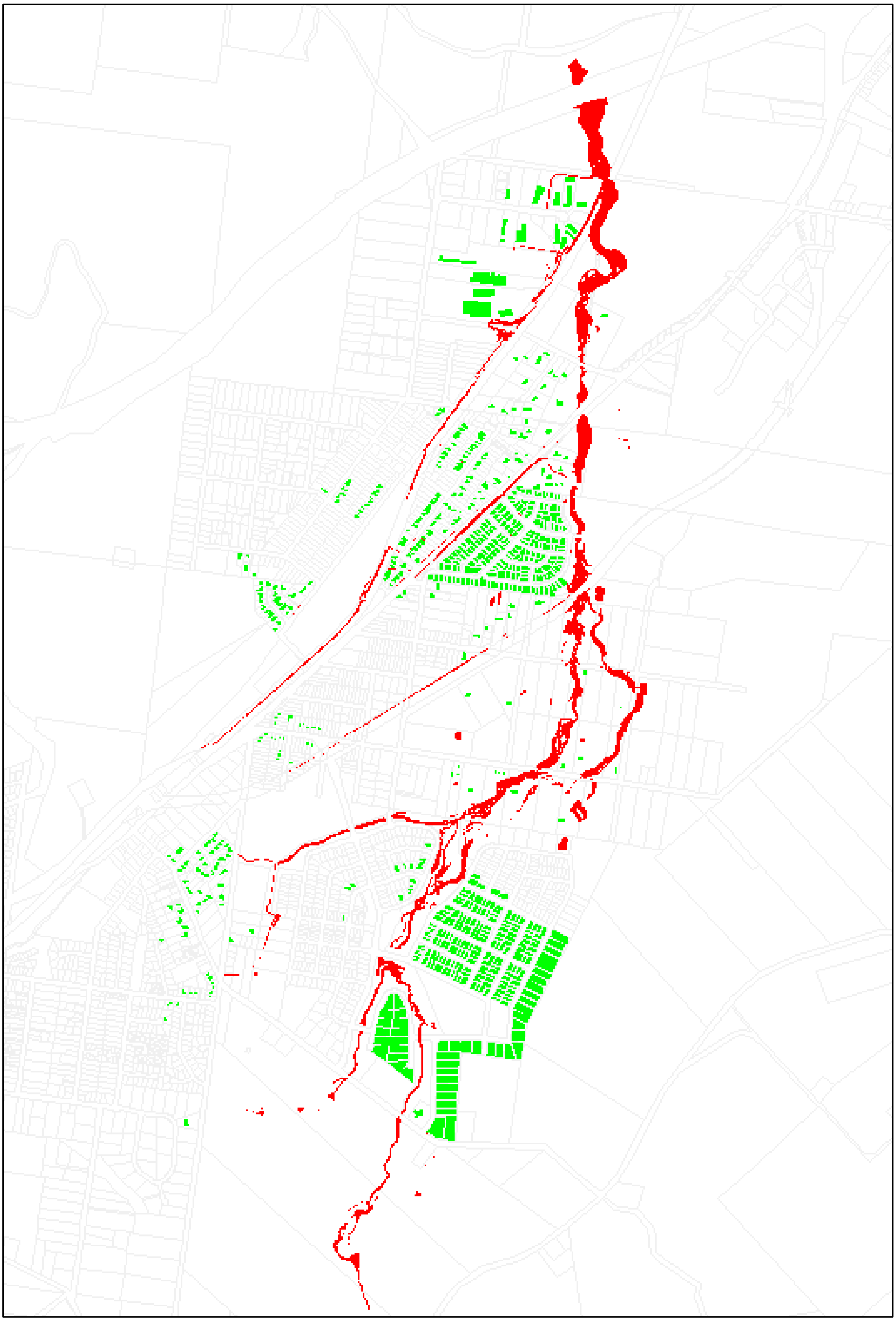


Plate 49 1% AEP high hazard/floodway areas (red) and building footprints (green)

9 RESPONSE MODIFICATION OPTIONS

9.1 Introduction

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

Response modifications options considered as part of the study include:

- Emergency response planning (i.e., planning before a flood);
- Options to improve emergency response during a flood; and
- Options to aid in post-flood recovery.

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

9.2 Emergency Response Planning

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

9.2.1 Local Flood Plan Updates (RM1)

The *Wingecarribee Shire Local Flood Plan* (NSW SES, 2013) (LFP) was reviewed as part of the current study and the outcomes of this review are summarised in **Table 17** in Section 5.1. This review identified areas of the LFP requiring revision, especially to Volume 2, which needs to align with the structure and contents of the new NSW SES LFP template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. 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.

As the SES is the agency responsible for flood emergency management, it is recommended that they undertake the suggested updates to the LFP based upon the recommendations documented in this study.

Recommendations: Update Wingecarribee Shire Local Flood Plan based upon in Table 17 in Section 5.1 of this report

9.2.2 Community Education Strategy (RM2)

An effective community education program is often the most effective emergency response planning strategy as it allows individuals to become more self-sufficient and less reliant on emergency services.

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

Although the population contained within the Nattai Ponds catchment is not particularly large, it is unlikely that the local SES unit has sufficient resources to assist all “at risk” properties within this catchment as well as adjoining catchments. Even if SES resources can be deployed, the “flashy” nature of flooding within the catchment may mean that roads will already be cut by the time the SES arrive. This emphasises the importance of the at-risk communities being equipped to respond appropriately to flooding without reliance on the emergency services.

A community survey conducted for this floodplain risk management study indicated that 38% of respondents would remain at home and 18% of respondents were unsure of how they would respond during a future flood. Some members of the community did not believe their house could be flooded, including the residents of two properties that are contained within the PMF extent; one in a low hazard area and another in a high hazard area. This highlights the need for community education activities to ensure the community better understands their flood risk/exposure and knows how to respond during future floods.

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

First, whatever approaches are implemented to increase community flood resilience in the catchment should be congruent with initiatives throughout the Wingecarribee Shire LGA to ensure a consistent and strategic rather than an ad hoc approach to community flood education. A first step could be to audit flood education initiatives recommended and those that were implemented in the LGA over the past 5-10 years. A second step would be to commission robust social research to form a new baseline of current levels of flood awareness and readiness, including any discernible spatial differences across this large and geographically diverse LGA. Then, new initiatives could be pursued, and their effectiveness tested, based on a solid evidence base.

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

From the flood hazard assessments and the outcomes of the community questionnaire, a number of key messages need to be disseminated to people in the Nattai Ponds catchment study area:

- “Never drive, ride, walk or play in floodwaters.” The need to continue broadcasting this message is suggested by the knowledge that motorists in Australia continue to lose their lives when attempting to cross floodwaters, and by the dangers posed by inundation of roads in the study area. Messages could also provide technical information to dissuade drivers from crossing flooded roads, such as the depths at which cars float Messages could also target the motivations for crossing water, such as by encouraging childcare centres and schools to advise parents during storms or floods that their children are safe. In catchments with stormwater drains, it is vitally important to include “play” in the message, recognising that young lives have been lost during storms when youths get in trouble in rapidly flooding culverts and drains.
- “One day a bigger, faster flood will happen than what anyone has ever seen. Council has modelled what these floods might be like. Learn whether your house/business could be flooded in an extreme flood. Identify whether it’s safe for you to stay or whether you need to evacuate before flooding. Plan ahead to keep your family/staff safe”. A message such as this is important because of the high proportion of respondents to the questionnaire who indicated they would shelter-in-place rather than evacuate. While such a response might have worked for the relatively small historical floods people have observed, it could lead to disaster in an extreme flood.
- “The safest place to be in a flood is away from the floodwaters. Therefore, early evacuation is recommended. However, if early evacuation is not completed it may be safer to stay than to attempt to evacuate late.” The potential depths of above-floor inundation for dwellings in the study area are typically lower than potential depths on roadways, which in combination with high flow velocities and adverse weather conditions could lead to highly hazardous driving conditions. Also, the duration of local catchment flooding is relatively short, lending itself to messaging such as “Wait a few hours”.

For this study area, there are some “hot spots” of flood risk exposure (Section 3.2.4) where site-specific campaign/projects (e.g. SES door-knocking or “meet the street” type events) may be warranted to convey the flood risk and to help residents plan for how they could best prepare and respond to flooding.

It is also suggested that the SES could prepare Floodsafe documents for the local area to provide general flood education information. The documents could be developed to be generic enough to cover not just the Nattai Ponds catchment, but also other similar catchment areas, such as the Nattai Creek and Gibbergunyah Creek catchments.

Recommendations: Develop local Floodsafe documents, develop educational messages targeting dangerous behaviours and undertake localised and tailored education campaigns for high hazard areas

9.2.3 Make Property Level Flood Information Available (RM3)

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

Advancements in flood modelling software and associated spatial datasets have significantly enhanced the quantity and quality of information from flood studies and floodplain risk management studies available at the property level. Council makes components of flood and floodplain risk management studies available via their website. However, this is considered to be relatively limited in nature and the information that is provided can be difficult to navigate down to the "property level".

A more extensive library of flood mapping covering the full range of potential design floods would provide local residents and business owners with a more comprehensive understanding of the potential impacts of flooding on their property. Alternatively, the existing flood extent information could be provided on an online mapping webpage to make it easier for the community to find all flood mapping in a single place and could include design flood depths, hydraulic hazard, information describing when and where access to individual properties will be cut as well as special risk factors such as the location of "low flood islands". This however might require additional Council resources and training to answer inquiries about what this information means and how it could be used to assist in the preparation of property-level flood response plans (discussed in Section 9.2.4).

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

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

A flood information portal would aim to provide information that will allow property owners to understand their existing flood risk which can "feed" into the preparation of personalised flood plans.

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

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

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

Recommendations: Make available additional flood information at a property scale, including flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform flood emergency plans

9.2.4 Flood Emergency Response Plans

Home Flood Plan Preparation (RM4)

It is unlikely that many private dwellings within the floodplain have formal flood emergency response plans. Accordingly, the preparation of home flood plans is encouraged as a way of making the broader community more "flood aware" and allowing the community to be more proactive during future floods and less reliant on emergency services. The plan should set out protocols to follow by the household before, during and after a flood to help mitigate damages and the potential for risk to life at the property level.

The SES has developed an online Home Emergency Plan website that can guide home owners through the development of the plan:
http://www.seshomeemergencyplan.com.au/index.php

Implementation of this option will require innovative approaches to persuade residents to plan ahead for floods. It is considered that the most effective method, albeit a labour-intensive method, will be via direct outreach from the NSW SES to particular residents. The SES could, with Council's assistance, host "flood planning mornings". Council could staff the meetings with laptops enabling the inspection of flood risks at property scales (booking times might be required to ensure adequate resources are made available), and SES personnel could then help homeowners translate that information into effective home emergency plans. Prior to these public information sessions, there would need to be an acceptance from official stakeholders that on-site refuge may be acceptable and even preferred at some sites (and is generally preferred by residents, especially those caring for animals), rather than a general insistence upon evacuation.

Recommendations: Host meetings to promote the preparation of Home Emergency Plans

Business Flood Plan Preparation (RM5)

Businesses across flood liable sections of the catchment would also benefit from flood plans. The plans set out protocols to follow by the business before, during and after a flood to help mitigate damages and the potential for risk to life at the property level.

As for private home flood plans, Council should be able to provide significant information describing the flood risk at the property scale based on the outputs from this study including the potential frequency and depth of inundation as well which roadways will be cut and the likely duration of any isolation.

The SES has developed a Business FloodSafe Toolkit to assist with the preparation of Business FloodSafe plans. These can be completed either online or as a hardcopy (see http://www.floodsafe.com.au/what-floodsafe-means-for-you/business).

A SES Business Breakfast could be hosted to promote the development of Business FloodSafe Plans, with sufficient Council and SES staff present to help guide business owners through the process. A follow up audit/breakfast could then be completed at a later date (say, 6 months later) to ensure that the FloodSafe plans have been developed/updated.

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

Recommendations: Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans

9.2.5 Develop a Safe On-site Refuge Policy (RM6)

The potential for evacuation across some sections of the catchment may be limited owing to the short warning times (i.e., less than 1 hour before some roads are cut). The DCP does include a requirement for most development types to provide a refuge area above the PMF level or a minimum of 20% of the gross floor levels to be above the PMF level, which may allow for safe onsite refuge / shelter in place if evacuation cannot be achieved.

The NSW SES also recognises this, and while its preferred flood emergency response strategy remains for people to evacuate it has stated:

"NSW SES has recognised that in an existing flash flood context, and only in that context, causing residents to attempt to evacuate at the time of flash flooding is occurring, could be a serious risk to life. Only in areas where urban redevelopment cannot be prevented under existing planning policy, it has therefore been proposed that the DCP for any new or redeveloped dwelling will require an internal refuge area above the level of the PMF." (Opper and Toniato 2008)

This statement illustrates the NSW SES support for internal refuge during a flash flood in situations where it would be more dangerous to attempt to evacuate. It also recognises that any new development or redevelopment which is permissible under existing zoning in such locations should provide a safe location for sheltering during a flood. What it does not support is the rezoning of land in flash flood environments to allow more people to occupy the land and rely upon "Sheltering-In-Place" (SIP) as the primary means of keeping those people safe during a flood.

NSW SES cites the following risks of SIP (Opper et al. 2011):

- *Floodwater reaching the place of shelter (unless the shelter is above the PMF level);*
- *Structural collapse of the building that is providing the place of shelter (unless the building 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 inundation first occurs);*
- *People's mobility (not being able to reach the highest part of the building);*
- *People's personal safety (fire and accident); and*
- *People's health (pre-existing condition or sudden onset e.g. heart attack)*.

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.

As the Nattai Ponds has no flood warning system and any advance warning that is provided would likely be insufficient to undertake an evacuation, it is proposed that a shelter in place (SIP) policy be developed which tries to strike a balance between decreasing the risk to individuals in the floodplain and increasing the number of individuals at risk in the floodplain. It is taking a risk-based approach to this by considering the probability, hazard, and duration of flooding in determining where in the floodplain SIP is an appropriate flood emergency response. The policy will look at what types of developments would not be appropriate for SIP, and where it may be appropriate for particular features to be incorporated into developments.

As mentioned, flood hazard is an important input component into making the decision as to whether SIP is an appropriate response method. Hazard categories published by Australian Institute for Disaster Resilience's (AIDR) *'Technical Flood Risk Management Guideline: Flood Hazard'* (2014) consider the safety of vehicles, pedestrians and building stability and are documented in Section 3.2.5. A comprehensive structural analysis of all houses located within the catchment has not been completed as part of the current study. However, the hazard mapping shows that most of the existing buildings within the catchment would likely remain structurally stable during in all floods up to the PMF based upon hazard mapping only (i.e., not be subject to a H5 or H6 hazard category – refer **Plate 50**). However, it should be noted that part sections of two properties within the Nattai Ponds subdivision would be exposed to H5 or H6 hazard conditions (refer **Plate 51**). In addition, over 120 dwellings are predicted to experience above floor flooding during a PMF and in a 1% AEP flood, 6 properties would likely experience above floor flooding.

The above statistics indicate that sheltering in place in many of the existing dwellings during particularly large floods can be problematic as there would be a lack of a "flood free" refuge area. This problem can be reduced through implementation of development controls to ensure a flood free refuge is provided above the peak levels of the PMF as new development and redevelopment occurs.

It is recommended to develop an on-site refuge strategy to be implemented with appropriate guidance from the NSW SES and the community where it is appropriate to do so (i.e., in areas where the structural stability of buildings can be ensured during the PMF). Council should also seek guidance on structural requirements for such buildings for inclusion in the DCP. Council and SES could also work with owners and occupiers of land where onsite refuge may be feasible to ensure safe occupation of these premises during floods.

Recommendations: Develop an on-site refuge strategy with appropriate guidance from the NSW SES and the community and update DCP to ensure structural adequacy of such refuges during the PMF

9.3 Evacuation Upgrades

9.3.1 Upgrade of Inkerman Rd and Scarlet St (RM7)

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).

Inkerman Road and Scarlet Street are predicted to experience relatively frequent inundation (i.e., both roads are predicted to be cut in events as frequent as the 20% AEP flood). Accordingly, this option investigated the potential to elevate these roads in an effort to reduce the frequency of roadway inundation and, therefore, the frequency that motorists may be tempted to drive through floodwaters.

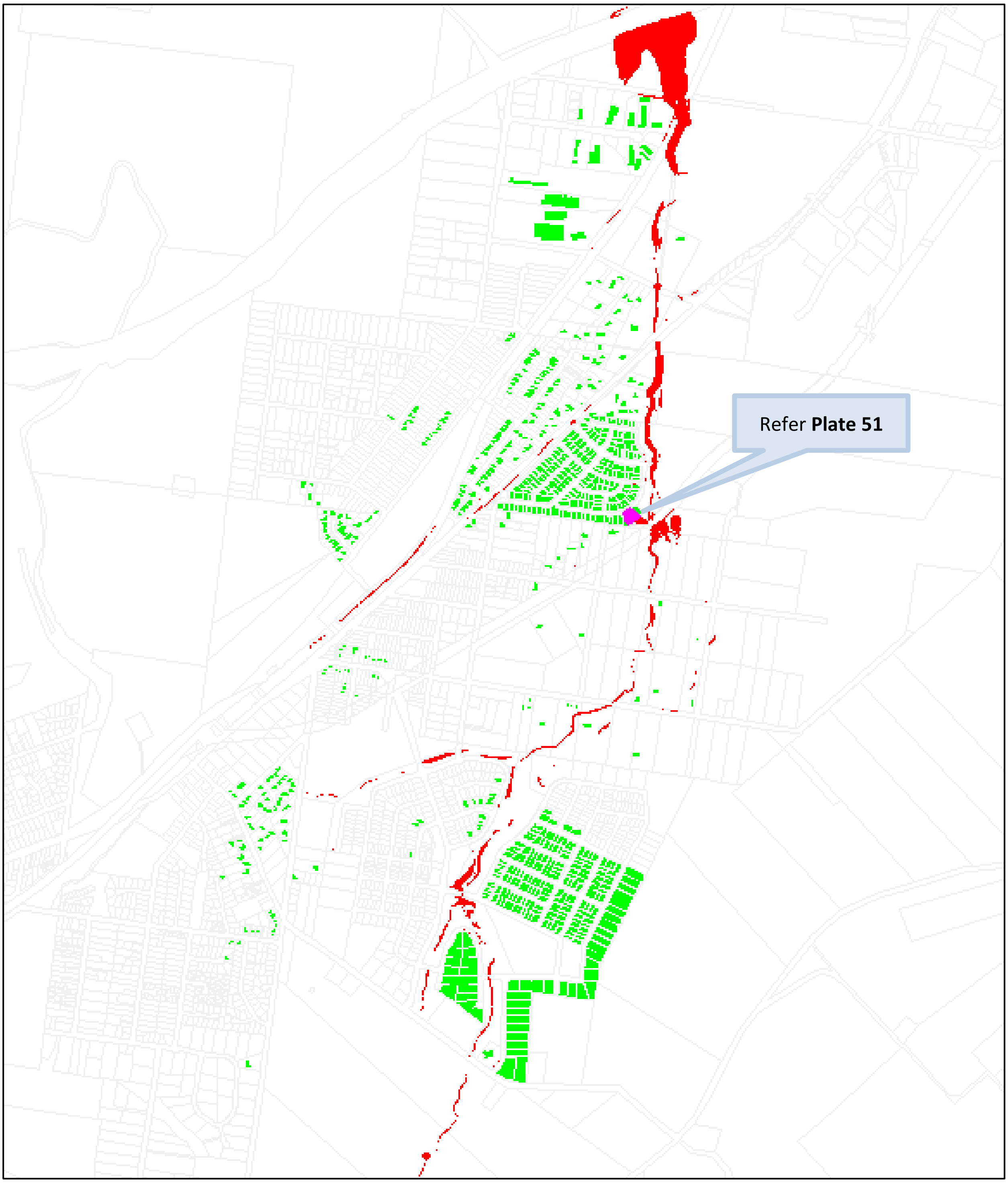


Plate 50 PMF H5 or H6 areas (red) with buildings not subject to H5 or H6 (green) and buildings exposed to H5 or H6 (purple)

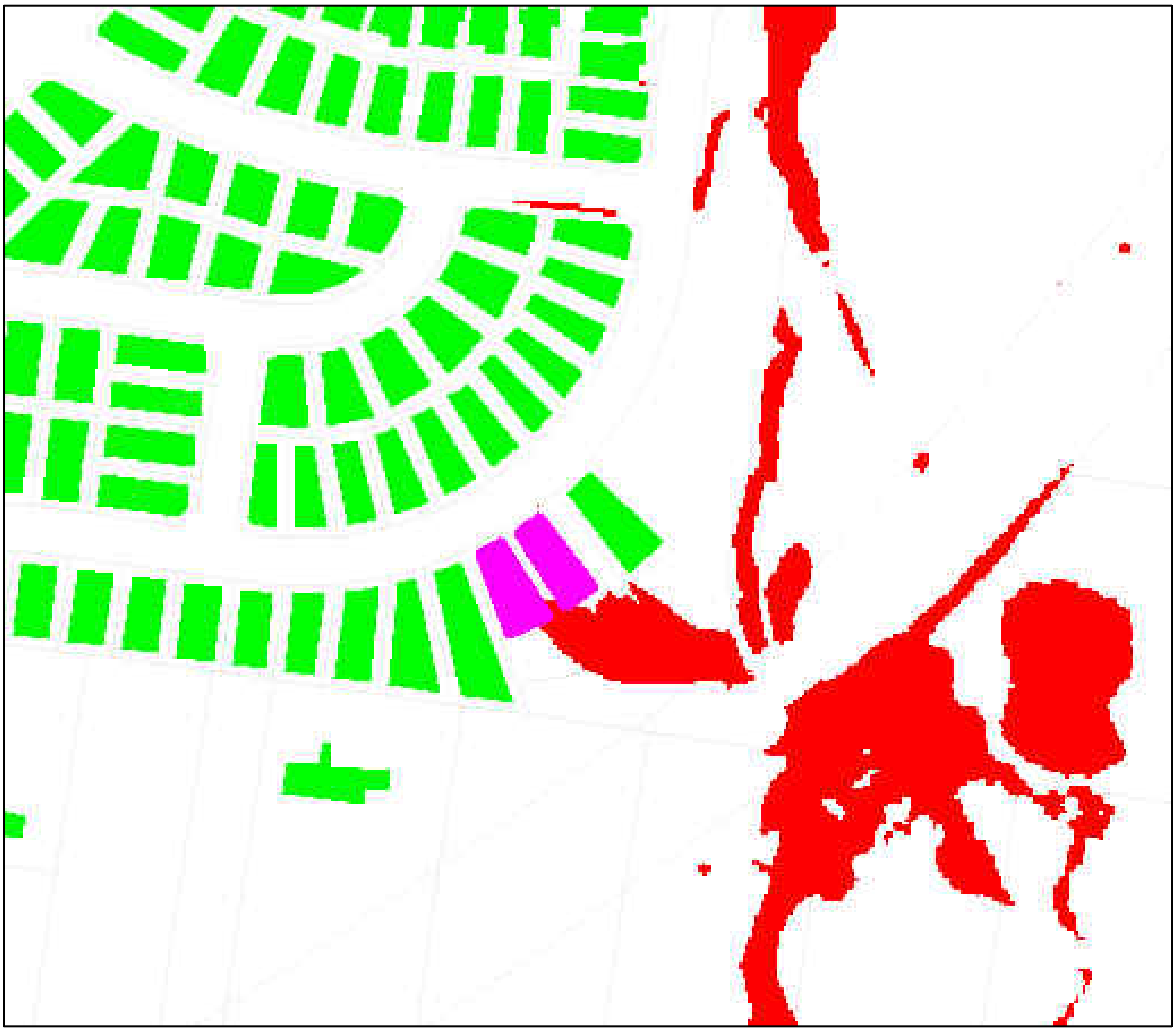


Plate 51 PMF H5 or H6 areas (red) with buildings not subject to H5 or H6 (green) and building subject to H5 or H6 (purple) at the peak of the PMF

This option involves elevating the lower-lying sections of Inkerman Road and Scarlet Street to ensure they remain "flood free" during events up to and including the 1%AEP event. This would involve elevating the existing road surfaces by about 0.3 metres. The option would also require the installation of new culverts and upgrades of existing culverts to ensure that flood levels do not increase upstream of the roadways as a result of the higher road embankments. The location of the proposed works for this option are shown in **Figure 47.**

The TUFLOW computer model was updated to include this option and the updated model was used to re-simulate each design flood. Peak floodwater level difference maps for the 20% and 1% AEP floods with this option in place are provided in **Plate 52** and **Plate 53**.

Plate 52 shows that during the 20% AEP flood, flood level decreases of between 0.1 and 0.4 metres are predicted along the eastern tributary as a result of the additional drainage infrastructure. However, the following flood level increases are also predicted:

- Flood level increase of up to 0.03 metres are predicted roughly mid-way between Inkerman Rd and Scarlet St within the western tributary.

- Flood level increases of around 0.05 metres are predicted upstream of Scarlet St and adjacent to the railway line.
- Flood level increases of between 0.03 and 0.07 metres are predicted downstream of Scarlet St.

Plate 52 also indicates that each roadway surface would remain dry during the 20%AEP event providing flood free access to properties during frequent floods.

Plate 53 shows that flood level impacts during the 1% AEP event similar to the 20% AEP however, they are more localised. The majority of the roadway surface is predicted to remain dry during the 1% AEP flood although some very shallow inundation (i.e., <0.1 metres) was predicted across some sections of each road indicating that further refinement of the roadway surface elevations may be required if flood free access is desired during all floods up to and including the 1% AEP event.

It is expected that this option would have a total capital cost of approximately $1.8 million. Much of this cost is associated with the new and upgraded drainage infrastructure. A breakdown of the cost estimate is provided in **Appendix F**.

As the flood level impacts are predicted to be contained in close proximity to each roadway, this option is not predicted to reduce flood damages across existing properties. As a result, this option is anticipated to comprise a BCR of 0.

Overall, this option is predicted to afford some localised flood level improvements. It is also predicted to afford some more significant improvements in the level of service afforded by the roadways by reducing the frequency and magnitude of roadway overtopping. Accordingly, the roadway improvements will likely reduce the frequency with which local residents may be tempted to drive through floodwaters and reduce requirements on SES staff to arrange resupply and/or rescue. Accordingly, the emergency response benefits of this option are significant.

The major negative of this option is the significant capital cost and the lack of associated economic benefits (BCR = 0). As a result, this option is not recommended for implementation as part of the Floodplain Risk Management process. However, Council may like to consider implementing this option (or a variation of this option) should roadway upgrades in these areas be earmarked in the future as part of Council's capital works program.

Recommendation: Not recommended for implementation as part of the Floodplain Risk Management process. However, Council may consider implementing the option as part of the capital works program.

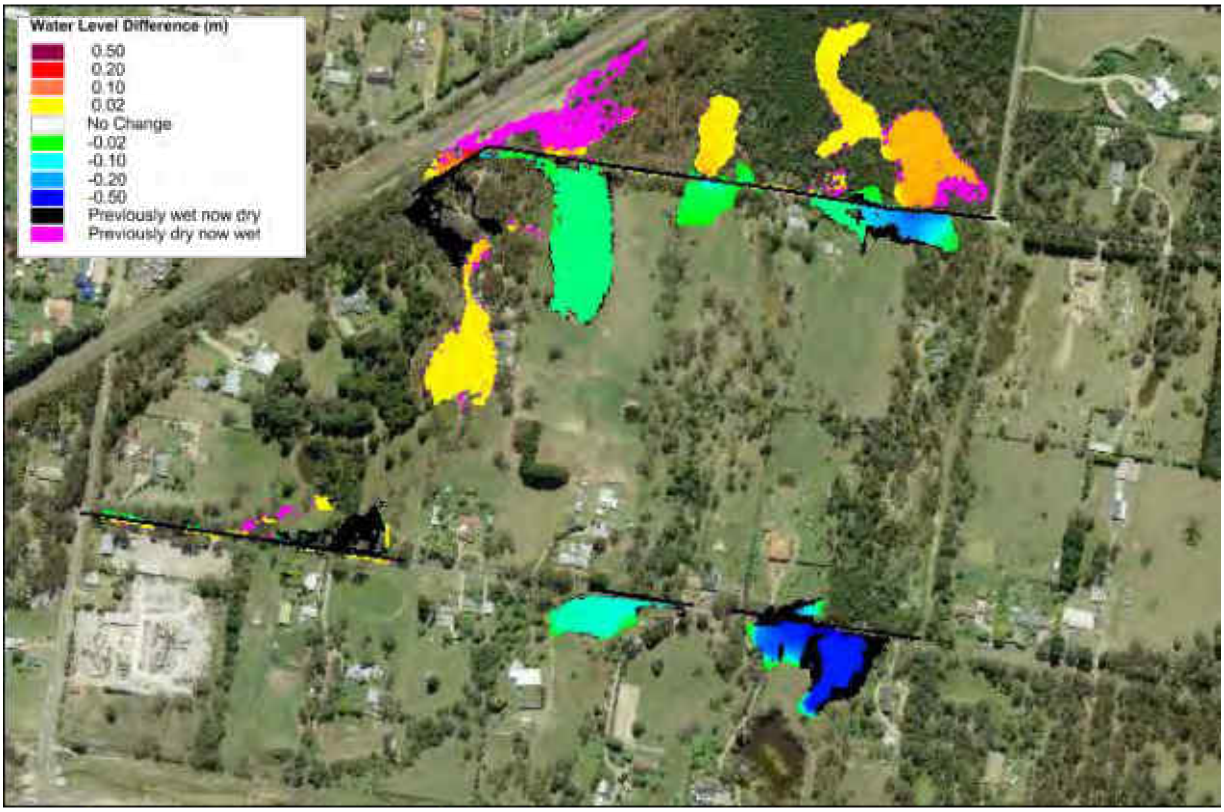


Plate 52 20% AEP Flood Level Difference Map for RM7

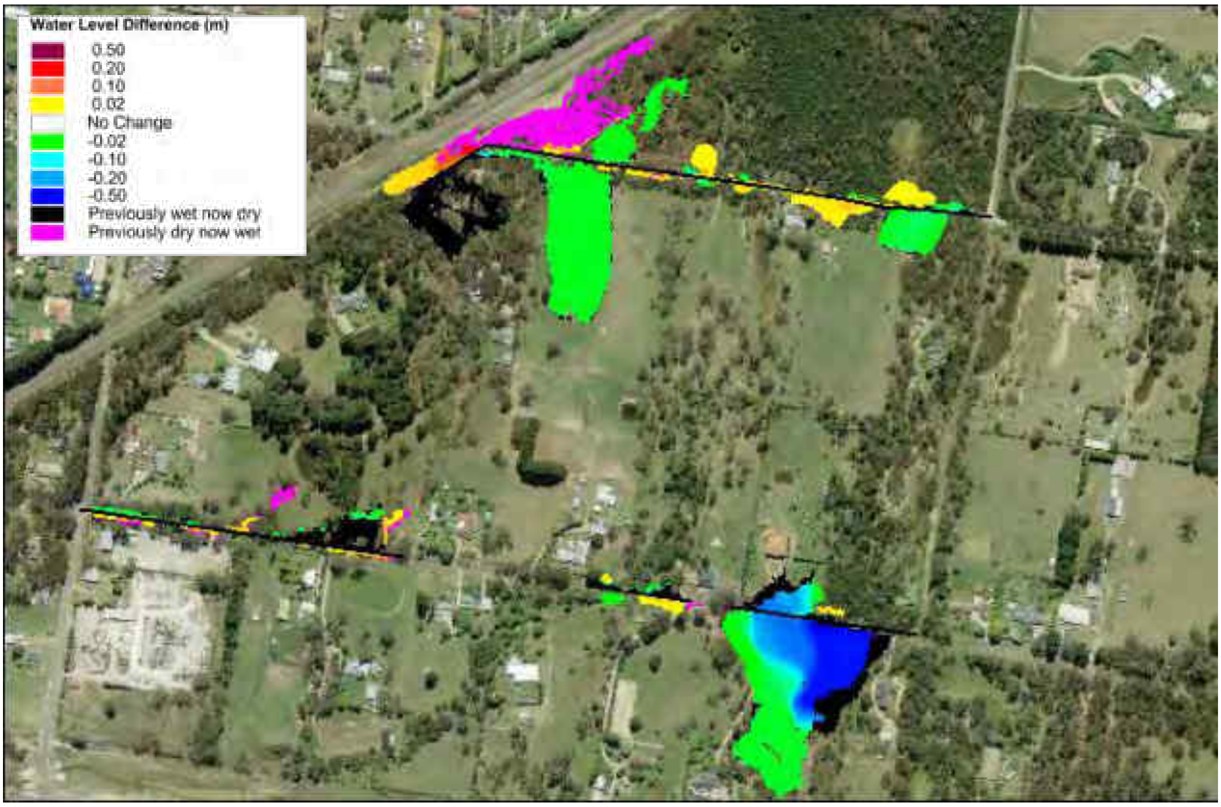


Plate 53 1% AEP Flood Level Difference Map for RM7

9.4 Options to Aid in Post-Flood Recovery

9.4.1 Recovery Planning

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

It is also suggested that additional, specific items could be included in the LFP to further assist emergency services and the community to expedite post-flood recovery, including:

- Council to ensure vital facilities such as water and sewer are restored/operational;
- Council to aid in removing waste and debris as part of clean-up activities;
- Appropriate agencies to ensure vital utilities such as power and gas are restored/operational;
- Appropriate agencies to offer welfare assistance and counselling services; and
- Various agencies to record post-flood information to assist in future updates/calibration of flood models and flood studies.

Council could also supply the most up-to-date flood information to these infrastructure agencies such as water, gas and electricity so that their future planning for infrastructure adequately caters for the flood constraints of the area.

It is noted that not all of the Nattai Ponds catchment area are covered under the "sewer coverage areas" mapping. It is recommended that any sewer works in the future are constructed out of the floodplain, where practical, so that they can remain operational during and after a flood.

Recommendation: Look to update Local Flood Plan to reflect additional flood recovery responsibilities for various agencies

9.4.2 Flood Insurance

Flood insurance is now available for residential, commercial and industrial buildings as part of most home and contents insurance policies. Flood insurance can also be taken out on public infrastructure and buildings.

Although flood insurance does not reduce the potential for flood damage nor reduce the residual flood risk, it can help in post-flood recovery by providing financial assistance to offset flood damage costs.

The cost of flood insurance varies significantly, based on a range of factors, including:

- The likelihood of flooding
- Expected depth of flooding across insured building (refer to **Plate 54**)
- the size and the floor level of the house

- the material used to build the house

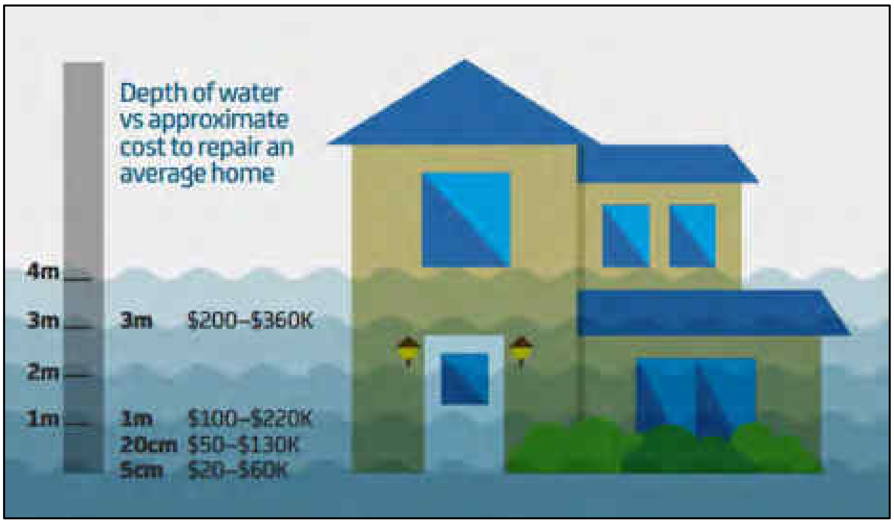


Plate 54 Examples of Repair Costs Versus Depth of Above Floor Inundation Used by Insurance Companies to Estimate Premiums (NRMA, 2015)

Buildings with a high likelihood of flooding and/or high flood damage potential will face higher insurance premiums. Owners of such properties, who would benefit most from flood insurance, may find the premiums unaffordable.

Nevertheless, flood insurance should be considered by property owners in high risk areas, where a single large flood may result in an unaffordable loss through damage to contents or the loss of the building itself (refer to **Plate 54**). Council could assist property owners as part of this process by providing property level flood information (refer to Section 9.2.3), so property owners can understand their flood risk and the potential financial implications of a significant flood. Based on this, the property owners can make an informed decision on the need to acquire flood insurance. Assuming flood insurance is desired by the property owners, the property level flood information could also be used to assist in negotiating premiums with insurance companies.

Recommendation: Individual property owners should consider flood insurance. Council can assist property owners by providing property specific flood information.

9.5 Recommendations

The following response modification options have been evaluated as part of the study and are considered viable for further consideration to assist in managing the existing and future flood risk across the Nattai Ponds catchment:

- Local Flood Plan Updates:
  - Update the Local Flood Plan, especially to incorporate flood behaviour and risk exposure information for the Nattai Ponds catchment (NSW SES); and,

  - Amend the Local Flood Plan to reflect additional flood recovery responsibilities for various agencies (NSW SES).
- Community Education:
  - Conduct an audit of flood education initiatives recommended (and potentially implemented) in the LGA over the past 5-10 years (NSW SES, Council);
  - Commission a baseline survey of community flood awareness and readiness, to inform an ongoing strategic approach to community flood education (Council);
  - Expand the type of flood information made available on spatial data platforms, with appropriate resources to explain the meaning of the data (Council);
  - Continue to disseminate messages about the dangers of entering or playing in floodwater (NSW SES);
  - Consider targeted messages to convey that staying may be safer than attempting to evacuate late (NSW SES); and,
  - Consider site-specific community outreach to recognised flooding “hot spots” (NSW SES, Council).
- Encourage the community to develop their own household/business Flood Plans.
- Develop a safe on-site refuge policy with associated development controls.

In addition, upgrading Inkerman Road and Scarlet Street (as well as the associated drainage infrastructure) could be explored in the future as part of Council’s capital work program.

10 Options for Managing the Potential Future Flood Risk

10.1 Overview

As described in Section 3.5, future development across the Nattai Ponds catchment is predicted to increase peak design flows and flood levels across part sections of the catchment. As a result, future development has the potential to increase the existing flood risk across the catchment.

Some of the flood modification options discussed in Section 7 are predicted to provide assistance in reducing the potential adverse impacts associated with future catchment development. However, as some of these options will require a significant capital investment, additional site-specific measures were investigated as a means of providing a more cost-effective option for ensuring the existing flood risk is not increased as a result of future development.

In this regard, an on-site detention (OSD) policy was explored. Further discussion on the outcomes of this assessment are presented below.

10.2 On-Site Detention Policy (Fut1)

Section D5.22 of Wingecarribee Shire Council's *'Development Design Specification, D5 – Stormwater Drainage Design'* (2003) specifies a maximum flow for the 10% AEP flood as being limited to 0.04l/s/m^2 (400l/s/ha) for discharge to kerb and gutter. The 1% AEP discharge is to be limited to that of pre-development conditions. In addition, Council's policy requires consideration of the capacity of the downstream system.

This requirement to ensure future development discharges do not exceed existing discharges is fairly standard across most local government areas and will help to ensure that the existing flooding problem is not increased in the future. The main limitations of this approach are:

- Modelling is frequently required to demonstrate future discharges are not predicted to increase as a result of the development. This can add to the overall cost of the development, particularly for isolated, single lot developments.
- It fails to consider the impacts that cumulative catchment development may have (including changes in timing of runoff).

To overcome these limitations, a number of Council's across New South Wales have implemented a more generic on-site detention (OSD) policy that negates the need to undertake additional modelling. Typically, an OSD policy stipulates the following requirements:

- The maximum allowable discharge from the site under future conditions (referred to as the permissible site discharge or PSD); and,
- The required volume of the onsite storage (referred to as the Site Storage Requirement or SSR).

To quantify the OSD requirements that would need to be enforced to ensure cumulative future flood impacts are suitably mitigated, the XP-RAFTS model that was developed to quantify potential future catchment runoff was updated to include a permissible site discharge (PSD) and site storage requirement (SSR). PSD and SSR values were initially populated based on typical values documented in OSD policies for other Councils. These values were iteratively refined until peak future discharges were reduced to existing levels and the onsite storages provided sufficient storage volume to fully contain all events up to and including the 1% AEP event.

The OSD requirements were broken down based upon LEP zones as the level of imperviousness is likely to vary considerably (e.g., industrial areas are likely to have considerably more impervious surfaces relative to residential areas). It was determined that if future development was implemented with the OSD values shown in **Table 24**, OSD would ensure the future flood risk is not increased above existing levels.

Table 24 Required OSD Parameters for the Nattai Ponds catchment

LEP Zone	**Maximum Permissible Site Discharge** (l/s/ha)	**Minimum Site Storage Requirement** (m^3/ha)
Residential R2 (development areas >5000m^2 or developments in close proximity to other existing developments – refer **Figure 48**)	110	260
Residential R5 (development areas >5000m^2 or developments in close proximity to other existing development – refer **Figure 48**)	90	370
Industrial IN1 / Business B1	90	480

There are two exceptions to the OSD requirements shown in **Table 24**. These include:

- Isolated residential subdivisions with an area of 5000m^2 or less. It was determined that isolated smaller developments on this scale were not sufficient to generate a significant adverse flood impact and, therefore, OSD was not required. However, in areas where there are multiple individual lots/developments in close proximity, the cumulative impact was determined to be significant and OSD would be required;
- Industrial areas located at the very north of the study area (i.e., north of Government Road to the Hume Motorway and east of Government Road to the Old Hume Highway). Inclusion of OSD in these areas would serve to delay runoff, thereby increasing existing discharges and levels across the downstream sections of the catchment

The location of potential future development areas is shown in **Figure 48**. The future development areas are colour coded according to whether OSD is required based upon the exceptions outlined above.

Peak design discharges for future catchment conditions with the recommended OSD requirements in place were extracted from the XP-RAFTS model and are tabulated in **Appendix E**. Peak design discharges for existing catchment conditions as well as future development catchment conditions without OSD are also included in **Appendix E** for comparison purposes.

The results provided in **Appendix E** show that implementation of the suggested OSD requirements will ensure future catchment discharges are not increased across most of the catchment. Localised increases are predicted in some areas even with the OSD implemented. However, the increases are typically less than 3% and were not sufficient to produce significant adverse impacts on existing flood levels. Accordingly, implementation of the OSD requirements outlined above is considered to be sufficient to ensure that future catchment development will not increase the existing flood risk.

The potential to implement varying OSD requirements based upon developable area (e.g., 1 lot versus 6 lot developments) was also investigated. However, negligible changes in the OSD requirements shown in **Table 24** were observed. Therefore, it is considered that these OSD requirements can be applied to developments of most sizes (as discussed, OSD will not be required for some developments).

It is recommended that future development within the Nattai Ponds catchment implement appropriate OSD consistent with the parameters documented above for those development areas identified in **Figure 48**. If future developments wish to deviate from these parameters, they should be supported with suitable calculations/modelling to demonstrate that the development will not adversely impact on flooding and drainage problems elsewhere in the catchment. This will require catchment-scale modelling to demonstrate that the change in runoff volume and timing of runoff from the proposed development will not increase peak discharges at any location downstream of the development site.

It is noted that it may be difficult for Council to enforce OSD for individual lots despite the potential for these individual developments to cumulatively impact on flood behaviour. In such cases, Council may need to use contributions from these developments to fund stormwater upgrades and/or regional detention basins.

Some examples of application of the recommended OSD policy are outlined below using standard lot sizes for R2 and R5 areas within the Nattai Ponds catchment.

Typical R2 zoned lot sizes across the catchment vary between 700 and 900 m^2. If we assume that future lot sizes will be 800m^2, and the lot is located in close proximity to a number of other lots that will be developed, the PSD and SSR requirements would be:
- <u>Maximum Permissible Site Discharge</u>: 0.08 ha x 110l/s/ha = 0.0088 m^3/s (or 8.8l/s) ***PER LOT***
- <u>Minimum Site Storage Requirement:</u> 260m^3 x 0.08ha = 20.8m^3 (or 20,800 l) ***PER LOT***

Therefore, if a ~1m deep detention area was provided in each R2 lot, it would occupy an area or about 20 m^2 (i.e., <3% of the total lot area). This could be potential incorporated as a landscape feature in the front or back yard and would only be "activated" during significant rainfall events.

A common lot size in R5 zoned areas within the catchment is around 2500m^2. If we assume that future lot sizes will be 2500m^2, and the lot is located in close proximity to a number of other lots that will be developed, the PSD and SSR requirements would be:
- Maximum Permissible Site Discharge: 0.25 ha x 90l/s/ha = 0.0225 m^3/s (or 22.5l/s) ***PER LOT***
- Minimum Site Storage Requirement: 370m^3 x 0.25ha = 92.5m^3 (or 92,500 l) ***PER LOT***

Again, if we assume a ~1 metre deep detention area was provided in each R5 lot, it would occupy an area or about 90 m^2. This equates to less than 4% of the total lot area.

If more than one lot is being developed (e.g., a multi-lot subdivision in excess of 5000m^2), it may be more efficient to include one "regional" detention area rather than individual detention areas for each lot. For example, if an existing 5575 m^2 block located within an R2 zoning was subdivided into six 930 m^2 lots, the following parameters would apply.
- Maximum Permissible Site Discharge: 0.5575 ha x 110l/s/ha = 0.061 m3/s (or 61.33l/s)
- Minimum Site Storage Requirement: 260 m^3 x 0.5575ha = 145 m^3

If we assume a single, ~1 metre deep detention area was provided, it would occupy an area of about 150 m^2. Therefore, around 150 m^2 of the total subdivision area could be set aside for the detention area, leaving the six lots to occupy the remaining area. This would result in the average lot size being 905 m^2 rather than 930 m^2.

Therefore, provision of an above ground detention area that satisfies the stipulated SSR, should not result in a significant loss in developable area.

Overall, it is recommended that Council implement an OSD policy for the Nattai Ponds catchment in accordance with the recommendations contained in this report.

Recommendation: Council to implement an OSD policy for all future development within the Nattai Ponds catchment in accordance with the following requirements:

Residential R2 Zoning (development areas > 5000m^2 or developments in close proximity to other future developments)**:**
- Maximum permissible site discharge (PSD) = 110l/s/ha
- Minimum site storage requirement (SSR) = 260m^3/ha.

Residential R5 Zoning (development areas > 5000m^2 or developments in close proximity to other future developments)**:**
- Maximum permissible site discharge (PSD) = 90l/s/ha
- Minimum site storage requirement (SSR) = 370m^3/ha.

Industrial IN1 / Business B1 Zoning:
- Maximum permissible site discharge (PSD) = 90l/s/ha
- Minimum site storage requirement (SSR) = 480m^3/ha.

10.3 Do not increase development densities in flood constrained lands (Fut2)

The current study looked at the appropriateness of the current land use zonings in the flood constrained lands within the Nattai Creek catchment. This review demonstrated that the current land use zonings are generally appropriate given the flood constraints on each lot within the catchment. Future planning and development should ensure that these zonings, or development standards or permissible uses within each zone, are not changed to facilitate increased densities within the flood prone areas.

Recommendation: Ensure development densities do not increase in flood constrained land.

11 DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

11.1 Introduction

The draft Floodplain Risk Management Plan sets out a preferred set of options that can be implemented to better manage the flood risk across the Nattai Ponds catchment. It also outlines responsibilities for the implementation of each option along with cost estimates and funding opportunities. This Draft 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.

11.2 Recommended Options

The options that are recommended for implementation as part of the draft Nattai Ponds Floodplain Risk Management Plan are summarised in **Table 25** and are also shown in **Figure 49**. 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, 9 and 10 of this report.

Several other options were also identified as being beneficial in better managing the flood risk. However, they were found to afford little financial benefits and are, therefore, not recommended as part of the Plan. However, Council could look to implement these options as part of its capital works program in the future. These options include:

- Upgrading of the stormwater system between Biggera Street and Old Hume Highway (near the Old Pot Factory) (FM5)
- Enlargement of the existing channels in the vicinity of Inkerman Road and Scarlet Street (FM12)
- Upgrade of Inkerman Road and Scarlet Street (RM7)

11.3 Plan Implementation

11.3.1 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:

<u>High Priority Options:</u>

- PM1: LEP Amendments
- PM2: DCP Amendments
- PM3: Update Section 10.7 certificate information
- RM1: Local Flood Plan Updates

- RM2: Community Education Strategy
- RM3: Make property level flood information available
- RM4: Encourage the community to develop household Flood Plans
- RM5: Encourage the community to develop business Flood Plans
- RM6: Develop a safe on-site refuge policy
- Fut1: Onsite detention policy
- Fut2: Do not increase development densities in flood constrained lands

Medium Priority Options:

- FM8: Elevate railway embankment near Biggera Street
- FM9: Enlarge drainage channels adjacent to Braemar industrial area

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

11.3.2 Costs and Funding

The total capital cost to implement the structural components of the Plan is expected to be about $420,000. In addition to the capital costs, some options will require an investment in time from various agencies including Wingecarribee Shire 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. Furthermore, the NSW Government's Floodplain Management Grants are targeted at managing the risk to residential properties and are generally not awarded to manage the flood risk to commercial and industrial properties (e.g., industrial channel widening).

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

11.3.3 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 25**, 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 25 Nattai Ponds 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								
FM8	Elevate railway embankment near Biggera Street	7.4.1	Council & OEH	$370,000	0.2	Medium	5+ years	Recommended for implementation if a more cost-effective detention basin option can be developed and/or part funding can be secured through ARTC and developer contributions.
FM9	Enlarge drainage channels adjacent industrial area	7.5.1	Council & OEH	$50,000	0.7	Medium	2 years	Recommended for further detailed investigation and pending the outcomes of these investigations, implementation
Property Modification Options								
PM1	LEP Amendments	8.2.1	Council	Council Time	-	High	3 years	Amend Wingecarribee Shire Council LEP considering the detailed review presented in Section 4.3.1 of the Nattai Ponds FRMS
PM2	DCP Amendments	8.2.2	Council	Council Time	-	High	2 years	Amend Mittagong and Northern Villages DCP considering the detailed review presented in Section 4.3.2 of the Nattai Ponds FRMS
PM3	Update Section 10.7 certificate information	8.2.3	Council	Council Time	-	High	<1 year	Update Section 10.7 certificates to reference updated flood information produced as part of current study

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
Response Modification Options								
RM1	Local Flood Plan Updates	9.2.1	SES	SES Time	-	High	2 years	Update Wingecarribee Shire Local Flood Plan to align with new SES LFP template and to incorporate new flood intelligence
RM2	Community Education	9.2.2	Council & SES	Council & SES Time	-	High	1-2 years	Develop local floodsafe documents and educational messages targeting dangerous behaviours such as driving through floodwaters
RM3	Make property level flood information available	9.2.3	Council	Council	-	High	1 year	Make available additional flood information at a property scale, such flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform individual flood emergency plans.
RM4	Encourage the community to develop household Flood Plans	9.2.4	SES / Individual Residents	Council & SES Time	-	High	2 years	Host meetings to promote the preparation of Home Emergency Plans
RM5	Encourage the community to develop business Flood Plans	9.2.4	SES / Individual Business Owners	Council & SES Time	-	High	2 years	Host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans
RM6	Develop a safe on-site refuge policy	9.2.5	Council	Council & SES Time	-	Medium	2 years	Develop an on-site refuge strategy with appropriate guidance from the NSW SES and the community and

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
								update development controls to ensure structural adequacy of such refuges
Options for Reducing the Future Flood Risk								
Fut1	Onsite Detention Policy	10.2	Council	Council Time	-	High	1 year	Implement an OSD policy for lots identified in **Figure 48** in accordance with the following requirements: • <u>R2 Zoning:</u> - Maximum permissible site discharge (PSD) = 110l/s/ha - Minimum site storage requirement (SSR) = 260m^3/ha. • <u>R5 Zoning:</u> - Maximum permissible site discharge (PSD) = 90l/s/ha - Minimum site storage requirement (SSR) = 370m^3/ha. • <u>IN1 / B1 Zoning:</u> - Maximum permissible site discharge (PSD) = 90l/s/ha - Minimum site storage requirement (SSR) = 480m^3/ha.
Fut2	Do not increase future development densities in flood constrained land	10.3	Council	Council Time	-	High	1 year	

12 REFERENCES

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13 Glossary

acid sulphate soils — are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.

annual exceedance probability (AEP) — the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. Eg, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).

Australian Height Datum (AHD) — a common national surface level datum approximately corresponding to mean sea level.

average annual damage (AAD) — depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

average recurrence interval (ARI) — the long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

caravan and moveable home parks — caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the Local Governments Act.

catchment — the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

consent authority — the council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify

a Minister or public authority (other than a council), or the Director General of OEH, as having the function to determine an application.

development is defined in Part 4 of the Environmental Planning and Assessment Act (*EP&A Act*).

infill development: refers to development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN) a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

ESD Ecologically Sustainable Development (ESD) using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act, 1993. The use of sustainability and sustainable in this manual relate to ESD.

effective warning time The time available after receiving advice of an impending flood and before floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

flash flooding flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	the remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	is synonymous with flood prone land, i.e., land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
flood planning area	the area of land below the FPL and thus subject to flood related development controls.
flood planning levels (FPLs)	are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for

floodplain risk management purposes, as determined in management studies and incorporated in management plans.

flood proofing a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.

flood readiness Readiness is an ability to react within the effective warning time.

flood risk potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

existing flood risk**:** the risk a community is exposed to as a result of its location on the floodplain.

future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.

continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L of the *Floodplain Development Manual* (*2005*).
historical flood	a flood which has actually occurred.
hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	councils have discretion in determining whether urban drainage problems are associated with major or local drainage. Major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flowpaths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical / computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach

the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.

minor, moderate and major flooding

Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood.

minor flooding: Causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: Low lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: Appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures

measures that modify either the flood, the property or the response to flooding.

peak discharge

the maximum discharge occurring during a flood event.

probable maximum flood (PMF)

the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

probable maximum precipitation (PMP)

the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability	A statistical measure of the expected chance of flooding (*see annual exceedance probability*).
risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	a plan prepared by a registered surveyor.
TUFLOW	is a 1-dimensional and 2-dimensional flood simulation software. It simulates the complex movement of floodwaters across a particular area of interest using mathematical approximations to derive information on floodwater depths, velocities and levels.
velocity	the speed or rate of motion (*distance per unit of time, e.g., metres per second*) in a specific direction at which the flood waters are moving.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	the horizontal distance in the direction of wind over which wind waves are generated.
XP-RAFTS	is a non-linear runoff routing software. It incorporates subcatchment information such as area, slope, roughness and percentage impervious and is used to simulate the transformation of historic or design rainfall into runoff (i.e., discharge hydrographs).

APPENDIX A

COMMUNITY CONSULTATION

9. TO ASSIST US IN DEVELOPING A SHORT LIST OF POTENTIAL FLOOD RISK REDUCTION MEASURES, PLEASE RATE THE FOLLOWING OPTIONS

Flood Modification Options:

Flood Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Flood detention basins						
Levees						
Stormwater upgrades						
Channel realignment						
Enlarging channel						
Regular maintenance and clearing of the creek						
Culvert/bridge upgrades						
Debris control structures to prevent blockage of culverts/bridges						

Property Modification Options

Property Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Voluntary house raising						
Voluntary flood proofing						
Voluntary house purchase						
Development/planning controls						
Rainwater tanks						

Response Modification Options: are options aimed at improving the way emergency

Response Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Flood forecasting / warning system						
Boom gates / signs at roadway overtopping points						
SES local flood plan updates						
Community education						
Upgrade evacuation routes						

Nattai Ponds
Floodplain Risk Management Study & Plan

Community Questionnaire

The following questionnaire should only take around 10 minutes to complete. The responses that you provide will help Wingecarribee Shire Council understand how best to reduce the impact of flooding on the community. Once complete, please return the questionnaire via email or mail by **27 July 2018**. Alternatively, if you have internet access, an online version of the questionnaire can be completed at: https://nattaiponds.fprms.com.au/

CONTACT DETAILS

Please provide your address to help us identify where floods have been (or haven't been) problematic. It would also be helpful to have a means of contacting you if required. Your contact details will remain confidential at all times.

Name: ______________________________

Address: ______________________________

____

Phone No. ______________________________

Email: ______________________________

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

☐ Yes ☐ No

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

☐ Residential

☐ Commerical

☐ Industrial

☐ Other (Please specify:______________________________)

How long have you lived at this property? __________years

2. HAVE YOU EXPERIENCED PREVIOUS FLOODS IN THIS AREA?

☐ Yes

☐ No

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

Tick all that apply:

☐ flooding over main building floor

☐ flooding of garage/sheds

☐ lost access due to flooding of roads

☐ sewerage system was not working at our property

☐ other (Please specify: ______________________________)

☐ not applicable / not affected

4. DO YOU KNOW IF YOUR HOUSE / BUSINESS HAS A RISK OF BEING FLOODED?

Tick one:

☐ Yes, I know my house/business could be flooded

☐ Yes , I know my house/business cannot be flooded

☐ No I don't know/I'm not sure whether my house/business could be flooded

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

Tick one:

☐ evacuate early to an official evacuation centre

☐ evacuate elsewhere – please describe: ______________________

☐ remain at my house

☐ other – please describe ______________________________

☐ don't know/not sure

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

Please select all factors that would apply:

☐ discomfort/inconvenience/cost of being isolated by floodwater

☐ need for uninterrupted access to medical facilities

☐ safety of our family

☐ other – please describe ______________________________

☐ not applicable (I intend to remain at my house)

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

Please select all factors that would apply:

☐ discomfort/inconvenience/cost of evacuating

☐ need to care for animals

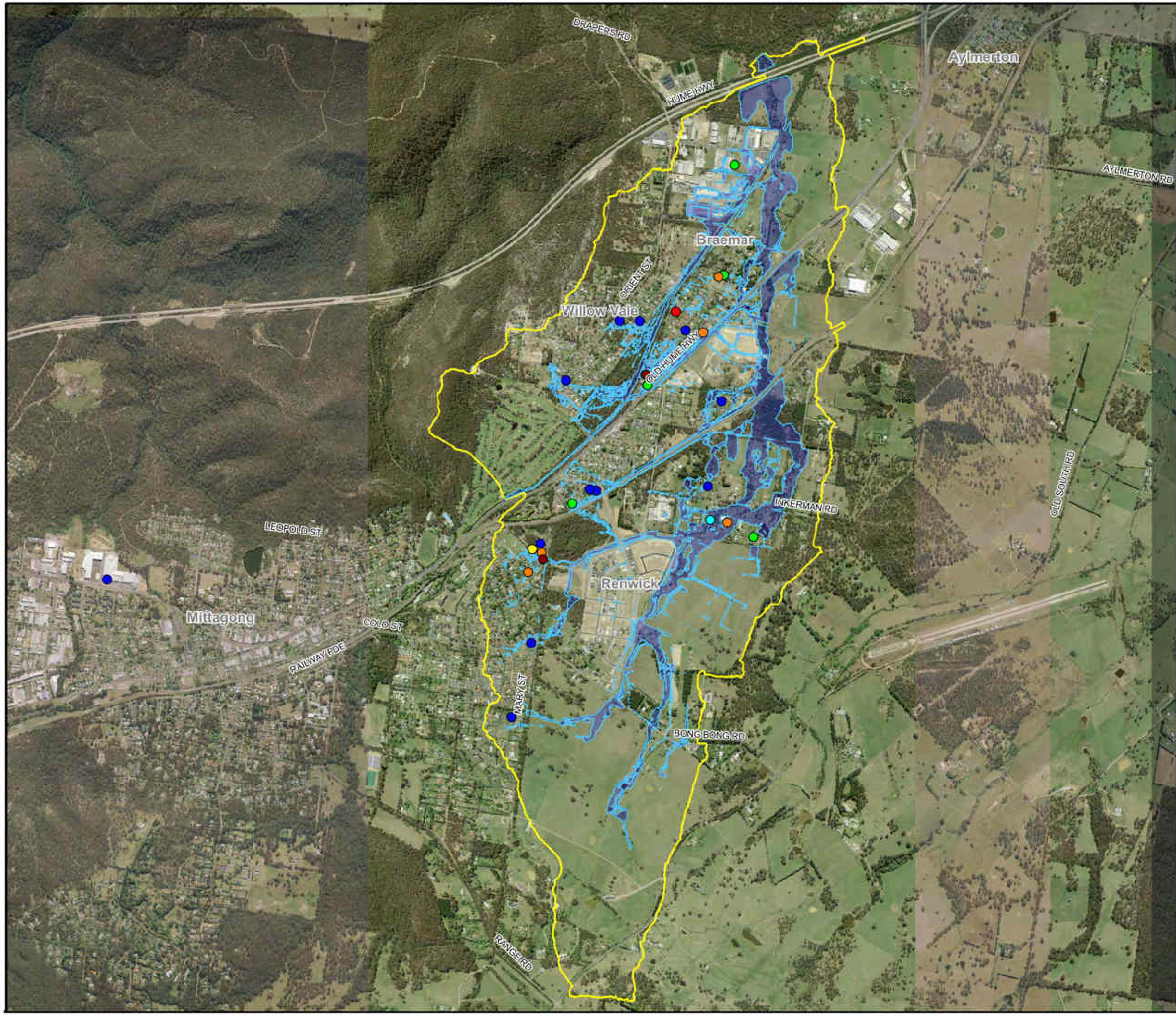
☐ my house cannot be flooded and we can cope with isolation

☐ concern for security of my property if I evacuate

☐ other – please describe ______________________________

☐ not applicable (I intend to evacuate from my house)

8. A LIST OF POTENTIAL OPTIONS FOR MANAGING THE FLOOD RISK IS PROVIDED ON THE NEXT PAGE. IF YOU HAVE ANY OTHER SUGGESTIONS FOR REDUCING FLOODING PROBLEMS, PLEASE DESCRIBE BELOW.



WINGECARRIBEE SHIRE COUNCIL

LEGEND

1% AEP Flood Extent

Q3 - How were you affected by flooding?

- Flooding Over Main Building
- Flooding of Garages / Sheds
- Flooding of Garden / Backyard
- Sewage System Was Not Working at Our Property
- Lost Access Due to Flooding of Roads
- Other
- Not Flood Affected

Notes:

Aerial photograph date: May 2014

N
W E
S

Scale 1:22,000 (at A3)

0 0.5 1.0 Km

Figure A1: Spatial Distribution of Historic Flood Impacts

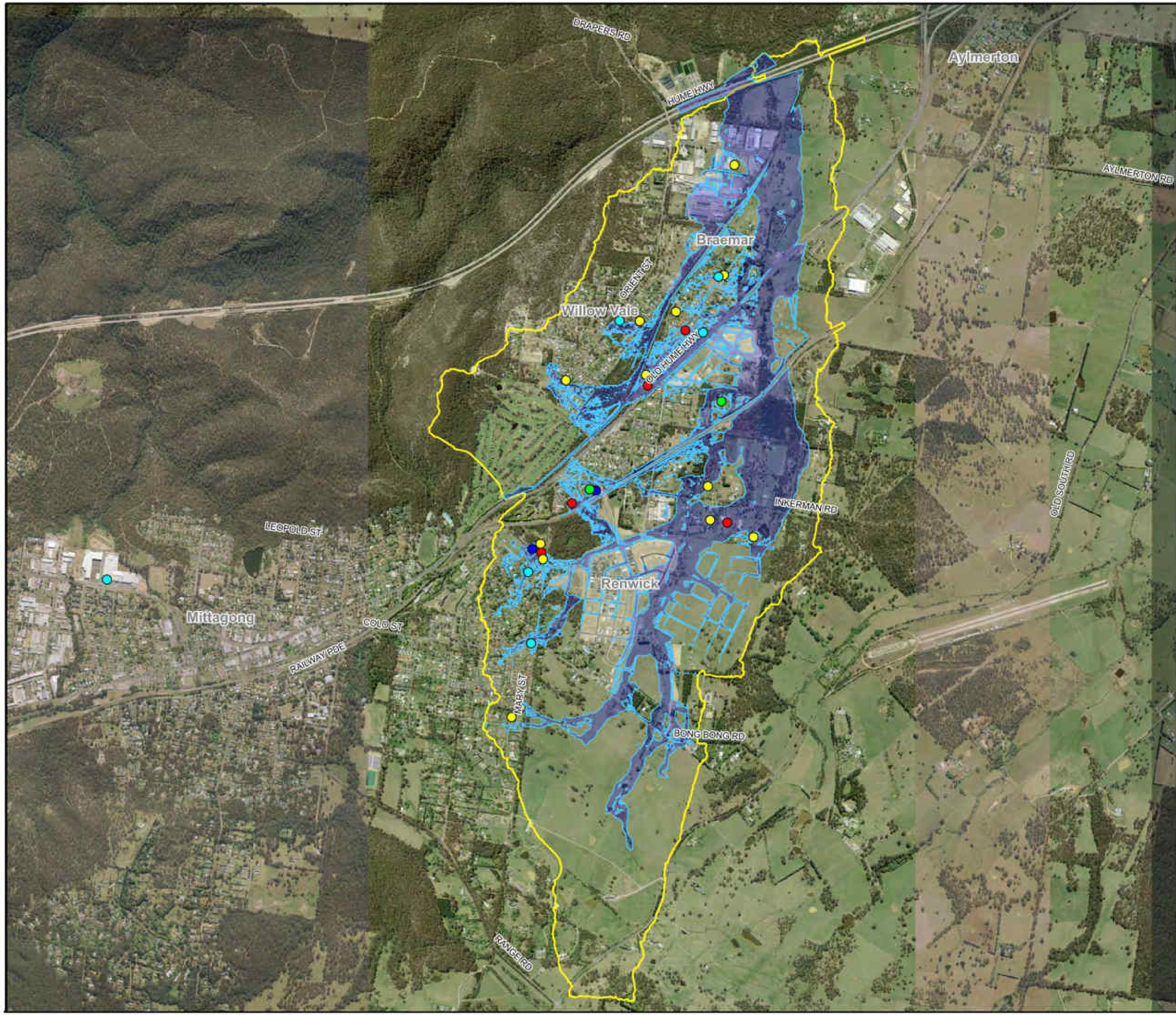
Prepared By:

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

File Name: FigA1 - Historic Flood Impacts.wor

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?		
								Type of Flood Impact								
	Residential	Commerical	Industrial	Other	How long have you lived/ worked at this property? (years)	Yes	No	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	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				30+		x						x		x	
2	x				6	x			x	x		x				x
3	x						x						x	x		
4	x						x						x			x
5	x				20	x					x			x		
6	x				4	x						x		x		
7	x					x						x				x
8	x					x							x		x	
9	x				40								x			x
10	x				15	x				x				x		
11	x				17.5	x			x							x
12	x				16	x		x	x	x		x		x		
13	x				18		x						x		x	
14	x			Rural	11	x			x			x				x
15	x				30	x							x		x	
16			x		28	x				x						x
17	x				23		x						x			x
18	x				9	x						x			x	
19	x				23	x				x		x				x
20	x				11	x				x				x		
21	x				22	x		x	x					x		
22	x				20		x						x			x
23	x				18		x						x		x	
24	x				7	x				x				x		
25	x				3		x						x			x
26	x				15	x				x						x
27	x				18		x						x			x
28	x				20		x						x		x	
29	x				10	x			x	x				x		



WINGECARRIBEE SHIRE COUNCIL

LEGEND

PMF Flood Extent

Q5 - How do you anticipate you would respond in a future flood in this area?

- Don't Know / Not Sure
- Remain at My House
- Evacuate Elsewhere
- Evacuate Early to an Official Evacuation Centre
- Other

Notes:

Aerial photograph date: May 2014

N W E S

Scale 1:22,000 (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 do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you?					If you are likely to remain at your house, what factors are most important to you?					
	Evacuate early to an official evacuation centre	Evacuate elsewhere	Remain at my house	Other	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	Not applicable (I intend to remain at my house)	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	Not applicable (I intend to evacuate from my house)
1										x					x	
2				x	x	x		x	x		x	x		x		
3	x					x	x	x			x	x		x		
4		x		x		x		x				x				
5				x		x					x					
6			x	x		x	x	x						x	x	
7			x							x				x		
8			x							x			x			
9			x							x			x			
10			x							x	x			x		
11	x							x			x					
12	x					x			x							x
13			x							x			x			
14					x				x						x	
15			x							x			x			
16			x	x		x					x					
17					x	x					x					
18			x						x				x			
19			x					x			x					
20					x											
21			x					x			x					
22	x							x					x			
23			x													
24					x			x			x					
25	x							x								
26					x						x					
27		x		x				x								
28			x										x			
29	x															

Table A3 - Feedback on Potential Flood Risk Mitigation Measures

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																	
	Flood modification options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.								Property modification options: Refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings to flooding.					Response modification options: Are options aimed at improving the way emergency services and the general public responds before, during and after a flood.				
	Flood detention basins	Levees	Stormwater upgrades	Channel realignment	Enlarging channel	Regular maintenance and clearing of the creek	Culvert/bridge upgrades	Debris control structures to prevent blockage of culverts/bridges	Voluntary house raising	Voluntary flood proofing	Voluntary house purchase	Development/planning controls	Rainwater tanks	Flood forecasting / warning system	Boom gates / signs at roadway overtopping points	SES local flood plan updates	Community education	Upgrade evacuation routes
1																		
2	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
3	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
4	Against	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Against	Against	Neutral	Support	Support	Support	Support	Support	Support	Support
5			Support	Support	Support											Support		
6			Strongly Support	Strongly Support		Strongly Support		Strongly Support			Strongly Support			Strongly Support				Strongly Support
7	Support	Support	Support	Support		Support	Support	Strongly Support	Neutral	Neutral	Support	Unsure	Strongly Support	Support	Support	Support	Support	Support
8	Neutral	Neutral	Support		Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Neutral	Support	Support	Support	Support	Support
9	Strongly Support	Support	Strongly Support	Support	Support	Strongly Support	Support	Support	Support	Neutral	Against	Strongly Support	Support	Support	Strongly Support	Support	Support	Support
10	Strongly Against	Strongly Against	Strongly Support	s	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support
11	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
12	Against	Neutral	Strongly Support			Strongly Support	Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
13		Support	Support											Strongly Support		Strongly Support	Strongly Support	
14	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support								Strongly Support		
15	Support	Neutral	Support	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Neutral			Support	Support	Support

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																	
	Flood modification options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.								**Property modification options: Refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings to flooding.**					**Response modification options: Are options aimed at improving the way emergency services and the general public responds before, during and after a flood.**				
	Flood detention basins	**Levees**	**Stormwater upgrades**	**Channel realignment**	**Enlarging channel**	**Regular maintenance and clearing of the creek**	**Culvert/bridge upgrades**	**Debris control structures to prevent blockage of culverts/bridges**	**Voluntary house raising**	**Voluntary flood proofing**	**Voluntary house purchase**	**Development/planning controls**	**Rainwater tanks**	**Flood forecasting / warning system**	**Boom gates / signs at roadway overtopping points**	**SES local flood plan updates**	**Community education**	**Upgrade evacuation routes**
16	Neutral	Against		Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Support	Support	Neutral	Against	Neutral	Neutral	Support	Support	Support	Neutral
17						Strongly Support		Strongly Support				Strongly Support	Strongly Support	Strongly Support		Strongly Support		Strongly Support
18	Strongly Support	Support	Support	Neutral	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Against	Against	Against	Neutral	Support	Strongly Support	Support	Support	Support
19	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Support	Unsure	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
20	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Neutral	Against	Strongly Support	Neutral	Strongly Support	Support	Support	Support	Strongly Support
21	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Neutral	Against	Against	Against	Strongly Support	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Support
22	Strongly Support	Support	Unsure	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Support	Support	Strongly Support	Strongly Support
23																		
24	Unsure	Unsure	Support	Strongly Support	Strongly Support	Unsure	Unsure	Support	Unsure	Unsure	Unsure	Unsure	Unsure	Neutral	Against	Neutral	Against	Against
25	Support	Neutral	Strongly Support	Neutral	Neutral	Strongly Support	Support	Strongly Support	Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support
26	Support		Strongly Support			Strongly Support	Strongly Support	Strongly Support	Unsure	Support	Against	Support	Support	Support	Support			
27	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Neutral	Neutral	Neutral	Neutral	Neutral
28	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
29			Strongly Support	Strongly Support	Strongly Support	Strongly Support		Strongly Support				Strongly Support		Strongly Support				

APPENDIX B

ARR2016 ASSESSMENT

1 ARR2016 AND ARR1987 HYDROLOGIC AND HYDRAULIC ASSESSMENT

1.1 Overview

Flood Behaviour across the Wingecarribee Shire Council LGA for the past three decades has been defined based upon guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia) (referred to herein as ARR1987). This included the 'Nattai Ponds Flood Study' (CSS, 2016).

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, investigations were completed to determine the impact that the revised hydrologic procedures may have on design flood estimates across the Nattai Ponds catchments. The ultimate 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 Nattai Ponds 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 on 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%, 10%, 5%, 2% 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 'Nattai Ponds Flood Study' (CSS, 2016), determined that the 120-minute storm duration produced the highest 1% AEP flood levels across the majority of the catchment. 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 IFD Parameters for the Nattai Ponds Catchment from ARR1987 and ARR2016

Design Rainfall Depths (mm)										
Duration	20% AEP		10% AEP		5% AEP		2% AEP		1% AEP	
	ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016
5 min	11.2	9.9	12.7	11.9	14.6	13.9	17.2	16.8	19.2	19.1
10 min	17.2	15.8	19.5	19.0	22.5	22.2	26.5	26.8	29.6	30.5
15 min	21.6	19.6	24.5	23.5	28.4	27.6	33.4	33.2	37.2	37.8
30 min	30.8	26.1	35.0	31.2	40.4	36.6	47.7	44.1	53.2	50.3
1 hour	41.9	33.0	47.7	39.4	55.3	46.0	65.3	55.4	72.9	63.1
2 hour	55.3	42.3	63.0	50.2	73.2	58.3	86.6	69.8	96.9	79.1
3 hour	64.4	50.0	73.5	59.1	85.5	68.5	101	81.5	114	91.9
6 hour	83.3	69.0	95.4	81.6	111	94.2	132	111	148	124
12 hour	109	98.1	125	117	146	135	174	158	196	176
24 hour	145	136	166	165	194	193	231	227	259	253
48 hour	191	176	218	216	254	259	302	309	338	347
72 hour	217	194	248	241	289	291	343	351	384	397

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%, 10%, 5%, 2% 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. The rainfall comparison shows that:

- As the severity of the event reduces, the magnitude of the differences increases. For example, the differences between ARR1987 and ARR2016 rainfall depths is more significant in the 20% AEP event then the 1% AEP event.
- The 2% AEP 10-minute, 1% AEP 10 and 15 minute and 5%, 2% and 1% AEP 48 and 72-hour storms were the only instance where the ARR2016 rainfall depths were larger than the equivalent ARR1987 rainfall depths.

- The biggest difference between ARR1987 and ARR2016 rainfall depths occurs for storm durations between 1 and 6 hours (i.e., the storm durations that were determined to be most often critical across the Nattai Ponds catchment). For these durations, the ARR2016 rainfall depths are typically 20% lower 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 Pervious Surfaces:
  - Initial Loss = 10 mm
  - Continuing Loss Rates = 2.5 mm/hour
- ARR1987 Rainfall Losses for Impervious Surfaces:
  - Initial Loss = 1 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 Nattai Ponds catchment is provided at the end of this Appendix.

The data hub rainfall loss information for the Nattai Ponds catchment indicate a rural initial loss of 39mm and rural continuing loss rate of 4.6mm/hr. 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 (39mm 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 = 23.4mm – 3.2mm

  Burst initial loss = 20.2mm

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	10% AEP	5% AEP	2% AEP	1% AEP
<1	22.3	22.2	22.2	22.6	22.9
1	22.3	22.2	22.2	22.6	22.9
2	22	21.5	21.1	20.6	20.2
3	19.3	18.6	17.9	18.7	19.3
6	8.6	2.6	0	3.5	8.6
12	10.5	6.5	2.7	0.6	0
24	17.2	13.8	10.6	6.2	2.9

As shown in **Table 2**, the ARR2016 pervious burst loss varies between 0 mm and 22.9 mm with a value of between 20 and 22 mm for the most commonly critical storm duration of 2 hours. Therefore, the ARR2016 pervious burst loss is typically higher than the 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 preburst rainfall. This yielded an impervious burst loss of 0mm 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 Nattai Ponds catchment indicate a rural continuing loss rate of 4.6mm/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 'Nattai Ponds 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.

Rainfall Loss Validation

As outlined above, the rainfall losses for impervious sections of the catchment as well as the continuing loss rate for pervious sections of the catchment are essentially identical between ARR2016 and ARR1987. However, the ARR2016 pervious burst loss is typically larger as the ARR1987 pervious initial loss. Therefore, additional investigations were completed to confirm the reliability of the calculated ARR2016 rainfall losses.

Firstly, the initial rainfall losses that were adopted as part of the 'Nattai Ponds Flood Study' calibration simulations were reviewed. This review determined that initial losses of between 10 and 15 mm were adopted as part of these calibration simulations. To assist in determining whether the higher ARR2016 burst losses would adversely impact on the calibration results, the calibration events were re-run with the initial rainfall losses increased by 10mm (i.e., the initial rainfall losses were increased from 10-15mm up to 20-25mm to closely align with the ARR2016 burst losses). The revised XP-RAFTS simulations results were reviewed, and this review determined that increasing the initial loses altered the peak discharge by less than 0.2% for the 2007 and 2014 events and about 1% for the 2015 event, on average. Accordingly, the calibration results are relatively insensitive to changes in the initial rainfall losses and adopting the higher ARR2016 burst losses would not adversely impact on calibration outcomes. Accordingly, this indicates that the ARR2016 burst losses are not unreasonable.

The Phase 4 report of Australian Rainfall and Runoff, Project 6 was also reviewed to confirm the suitability of the ARR2016 rainfall losses. This report details the gauged catchments that were used to derive the regionalised rainfall loss values across Australia. The most spatially, geographically and topographically similar catchments to the Nattai Ponds study area that were analysed as part of Project 6 include:

- O'Hares Creek at Wedderburn (located east of Campbelltown, approximately 50 km north-east from the Nattai Ponds catchment):
  - Rural Storm Loss = 60 mm
  - Rural continuing loss rate = 1.6 mm/hr
- Butmaroo Creek at Butmaroo (located east of Bungendore, approximately 110 km south-west from the Nattai Ponds catchment);
  - Rural Storm Loss = 40 mm
  - Rural continuing loss rate = 2.6 mm/hr

Although the Nattai Ponds catchment is located a significant distance from each of these catchments, it is evident that the rural storm loss for Nattai Ponds of 39 mm closely aligns with the calculated storm loss for the Butmaroo Creek catchment (i.e., 40mm) and is lower than the calculated storm loss for the O'Hares Creek catchment (i.e., 60 mm). Accordingly, it is considered that the ARR2016 storm loss of 39 mm is reasonable and more closely aligns with calculated loss values for the region relative to the ARR1987 initial rainfall loss of 10 mm. It is noted that ARR1987 provides a range of initial loss values for catchments in Eastern NSW. Although the 'Nattai Ponds Flood Study' adopted an initial loss of 10mm, initial losses of up to 30mm could be employed under ARR1987. However, the calculated losses from the Project 6 document still exceed the upper initial loss bound provided under ARR1987. Therefore, it is considered that the ARR2016 burst rainfall losses are more reliable relative to the ARR1987 initial losses.

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 Nattai Ponds 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 were 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 subcatchment 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 and are presented at the end of this Appendix.

In general, the critical storm durations across the study area varied between 90 and 120 minutes. The 90 minute 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 'Nattai Ponds 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 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 15 "focus" locations throughout the catchment were also extracted and are presented in **Table 3**. The focus locations are shown in **Plate 1**.

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.

Table 3 ARR2016 and ARR1987 Peak Design Discharges at Focus Locations

Location	XP-RAFTS ID	Peak Discharge (m^3/s)					
		20%AEP		5%AEP		1%AEP	
		ARR1987	ARR2016	ARR1987	ARR2016	ARR1987	ARR2016
Eastern Crossing of Bong Bong Road	1.05	9.24	4.24	14.63	6.69	20.68	11.92
Oldfield Road	_junc_21	20.17	10.22	31.82	15.44	45.19	26.25
Downstream of Renwick Development	19.10	23.72	13.28	36.36	19.06	51.08	29.98
Inkerman Road	19.11	24.29	12.76	37.28	19.58	52.41	30.63
Scarlet St	_junc_44	24.72	13.13	37.97	20.2	53.51	34.46
Upstream of Railway Crossing	US_Rail	33.42	19.01	51.19	29.02	72.25	45.24
Upstream of Old Hume Highway	US_OHH	37.54	22.09	56.65	32.7	79.81	50.97
Braemar Road	_junc_80	40.88	24.9	60.93	36.22	85.26	55.13
Downstream of Industrial Area	_junc_85	53.39	32.88	79.96	49.34	112.4	72.84
Western Crossing of Bong Bong Road	6.05	6.5	3.17	10.33	4.98	14.78	8.78
Bong Bong Road and Mary Street	_junc_133	2.1	1.09	3.06	1.51	4.19	2.26
Renwick Drive	19.07	6.7	4.17	10.53	6.56	15.23	10.03
Inkerman Road Downstream of Renwick East	_junc_38	6.58	4.58	9.28	6.47	12.28	9.24
Industrial Railway	58.07	6.33	3.55	9.93	5.43	14.36	9.21
Braemar Avenue at Industrial Areas	_junc_88	9.85	5.17	15.69	8.56	22.97	14.53

Box plots for the 1%AEP event were also prepared for the 15 focus locations shown in **Plate 1** 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 AEPs and subcatchments, the critical ARR2016 discharges are lower than the critical ARR1987 discharges.

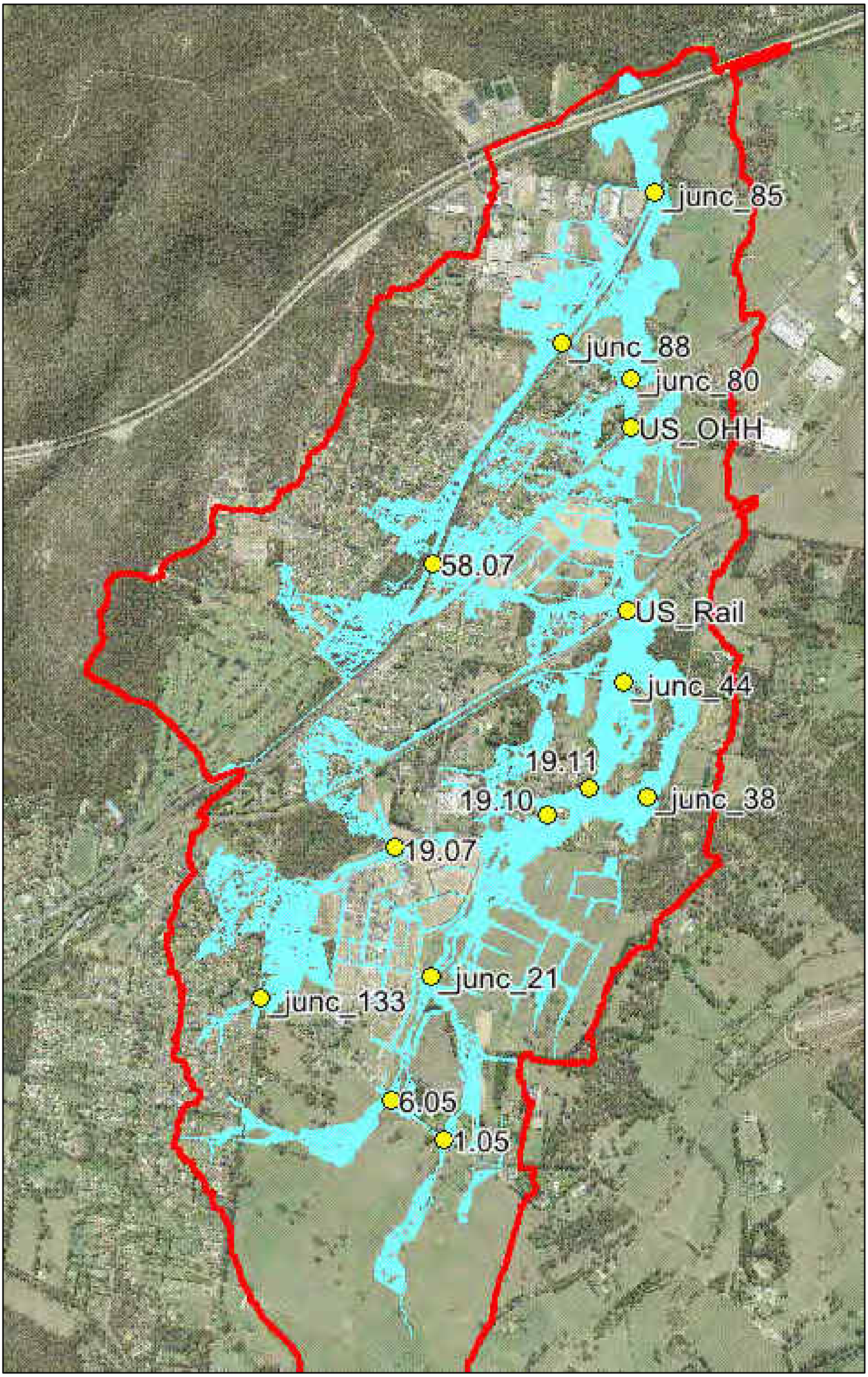


Plate 1 “Focus” locations (yellow) selected for critical duration & temporal pattern analysis

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

- 20% AEP: ARR2016 discharges are 42% lower than ARR1987 discharges
- 5% AEP: ARR2016 discharges are 42% lower than ARR1987 discharges
- 1% AEP: ARR2016 discharges are 34% lower 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 Nattai Ponds 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 Nattai Ponds catchment. To gain an understanding of how these reductions may impacts 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

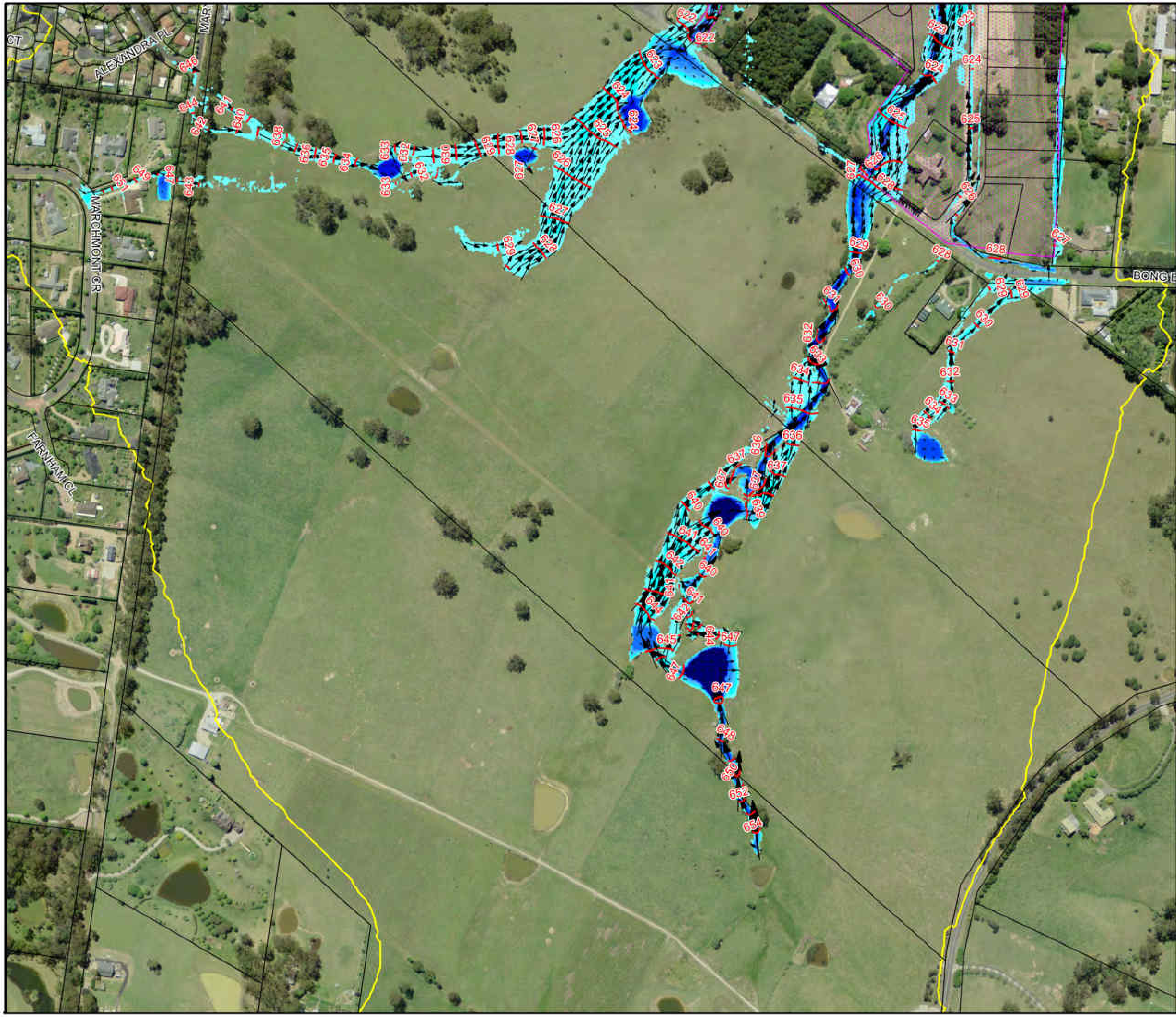
Australian Rainfall & Runoff 1987

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, levels and velocities were extracted from the enveloped results and are presented in **Figure B1.1** to **B1.8**.

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



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m): 0.1, 0.2, 0.3, 0.5, 1.0, 2.0, 3.0

Velocity Vector (m/s): 0.5 m/s, 1 m/s, 2 m/s

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B1.1: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

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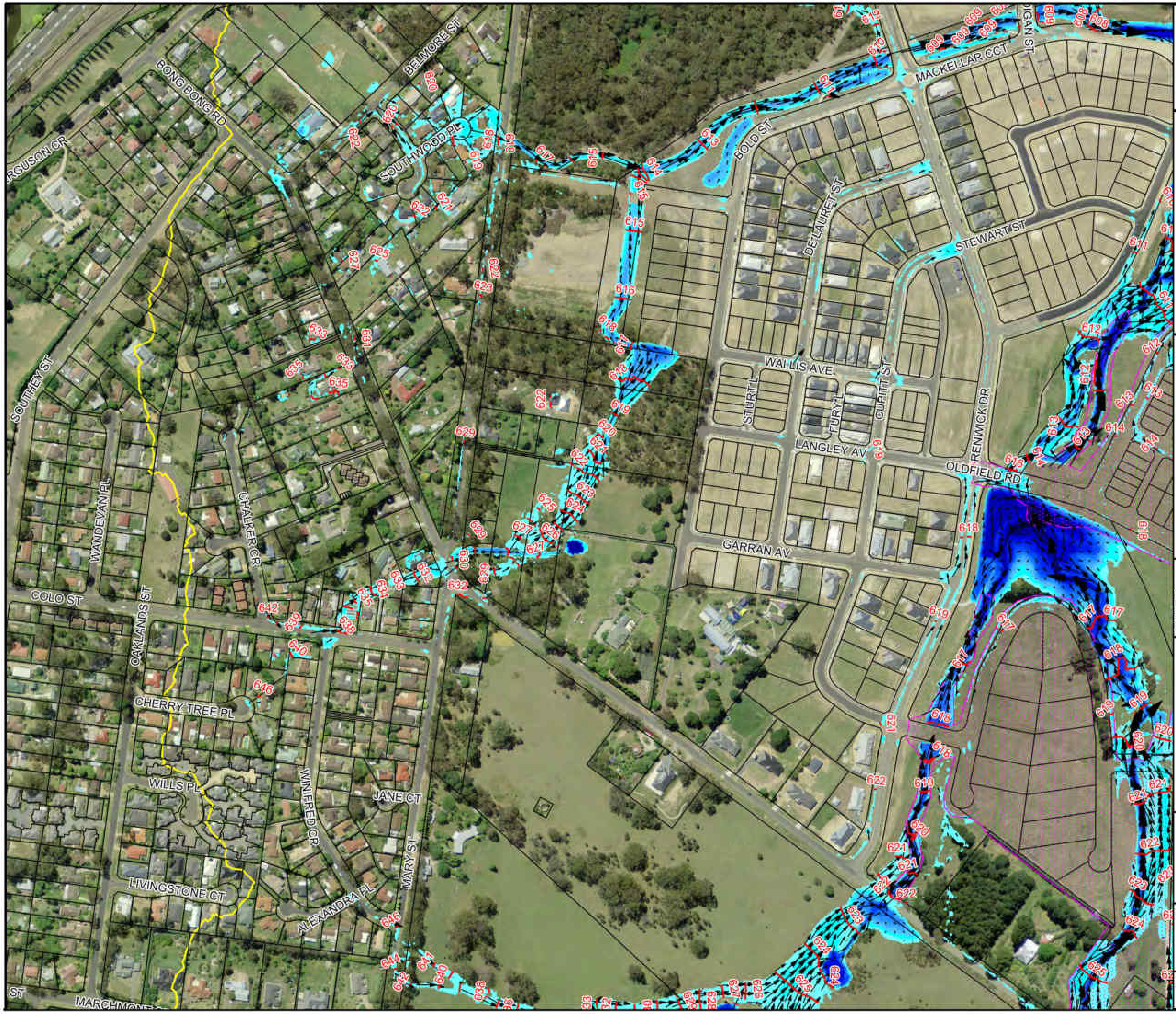
File Name: FigB1.1 - 1% AEP ARR1987 Depths, Levels and Velocities.wor



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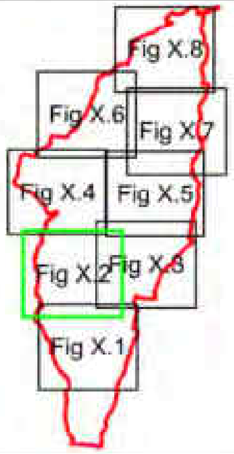

LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B1.2: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

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File Name: FigB1.2 - 1% AEP ARR1987 Depths, Levels and Velocities.wor

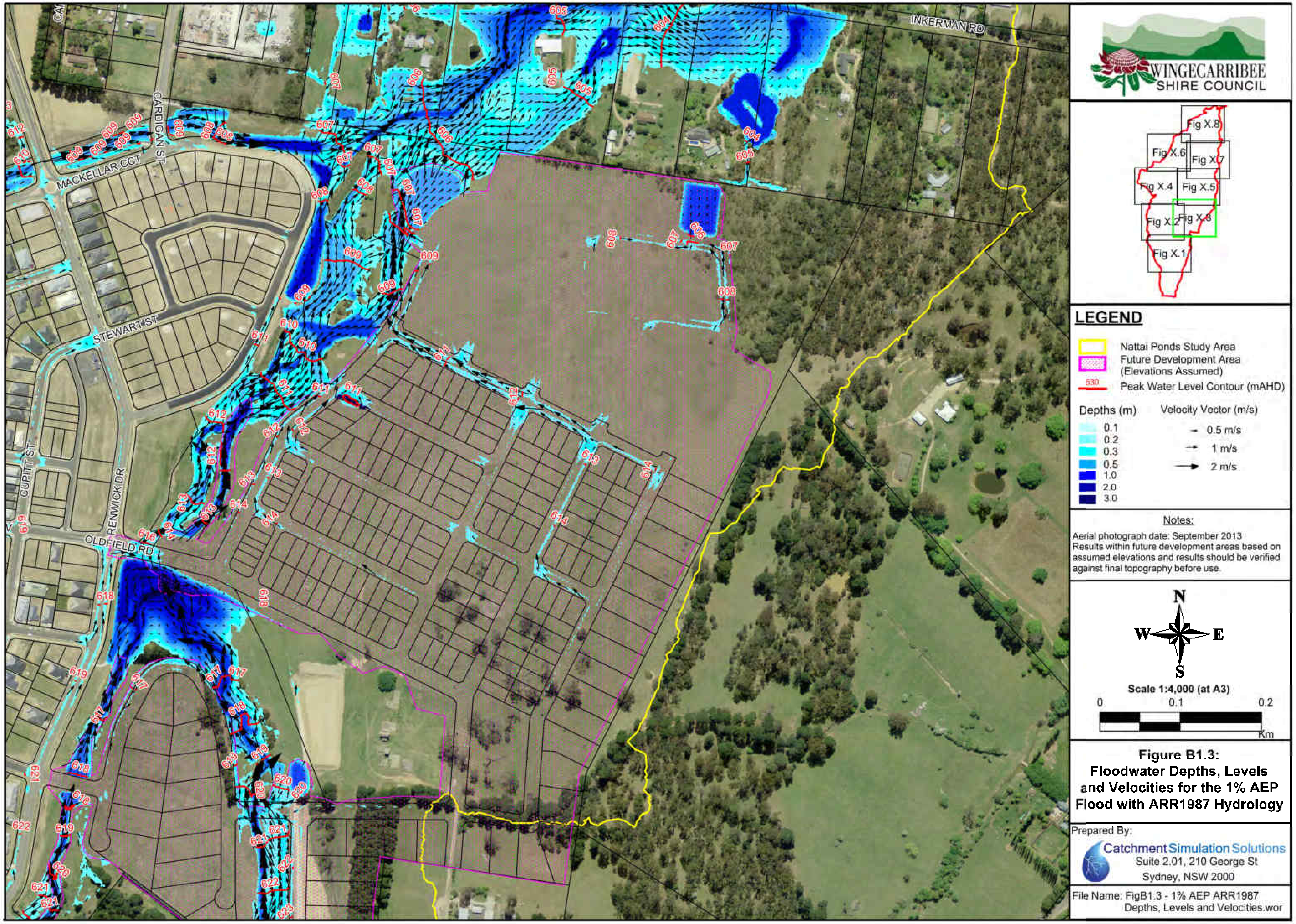
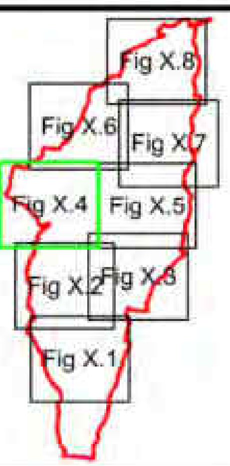


Figure B1.3: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B1.4: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

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Suite 2.01, 210 George St
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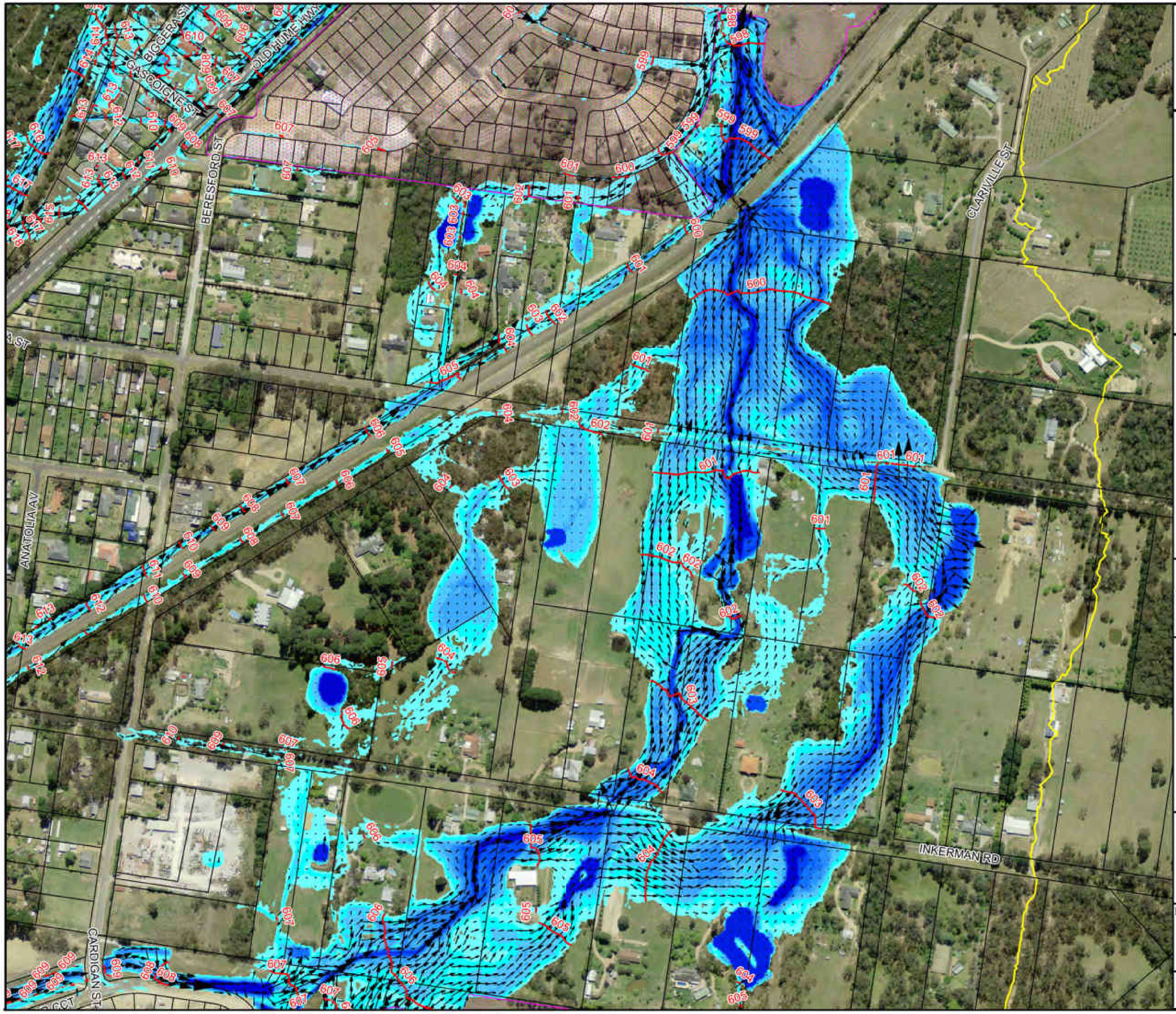
File Name: FigB1.4 - 1% AEP ARR1987 Depths, Levels and Velocities.wor



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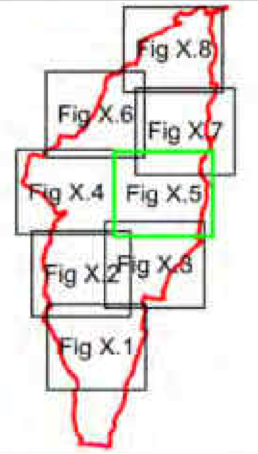

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B1.5: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

Prepared By:
Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: FigB1.5 - 1% AEP ARR1987 Depths, Levels and Velocities.wor

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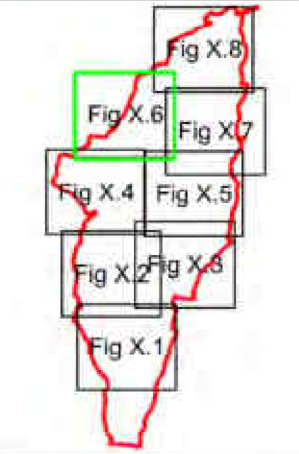

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B1.6: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

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

File Name: FigB1.6 - 1% AEP ARR1987 Depths, Levels and Velocities.wor

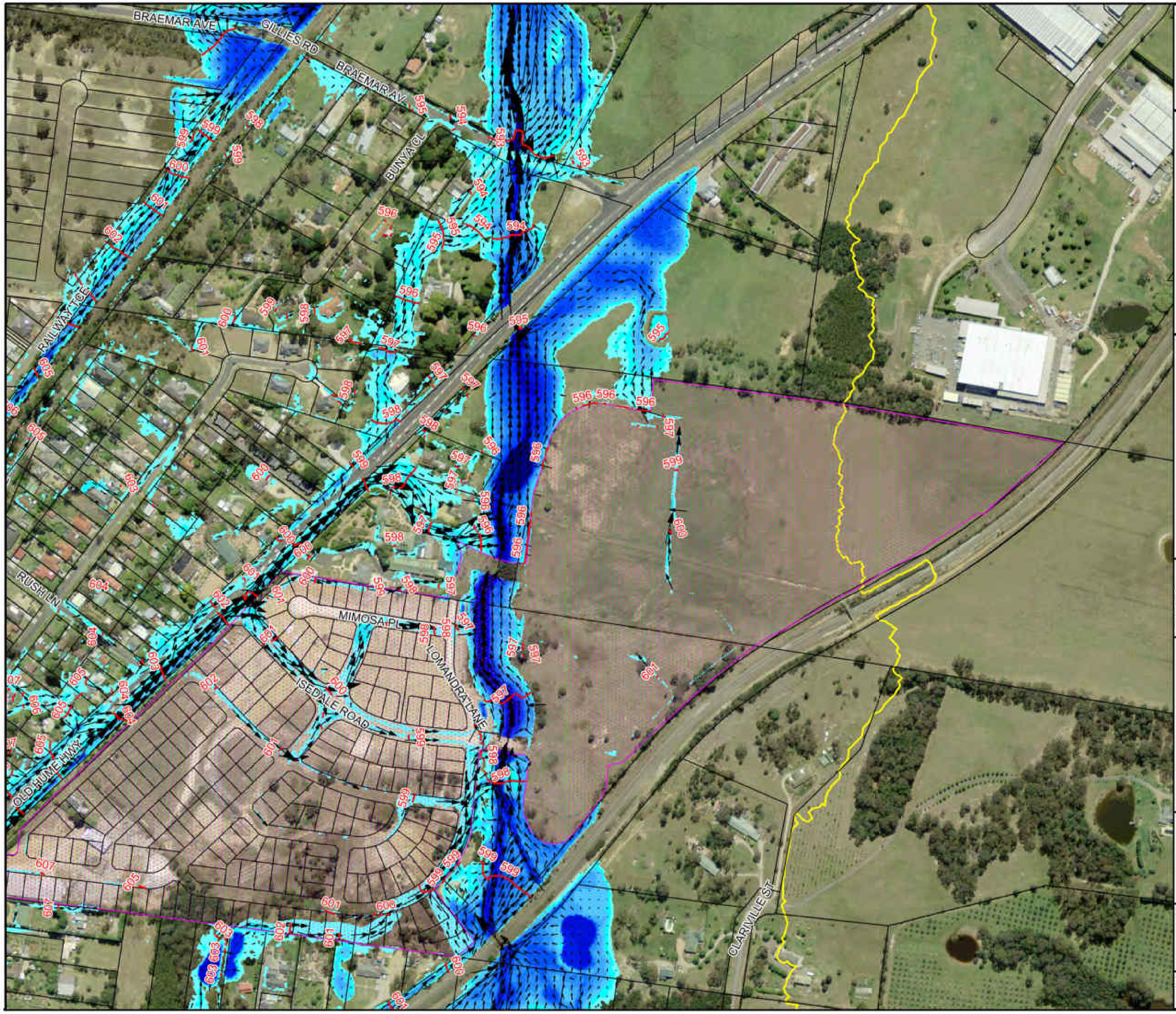

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Fig X.8
Fig X.6
Fig X.7
Fig X.4
Fig X.5
Fig X.2
Fig X.3
Fig X.1

LEGEND

Nattai Ponds Study Area
Future Development Area (Elevations Assumed)
Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

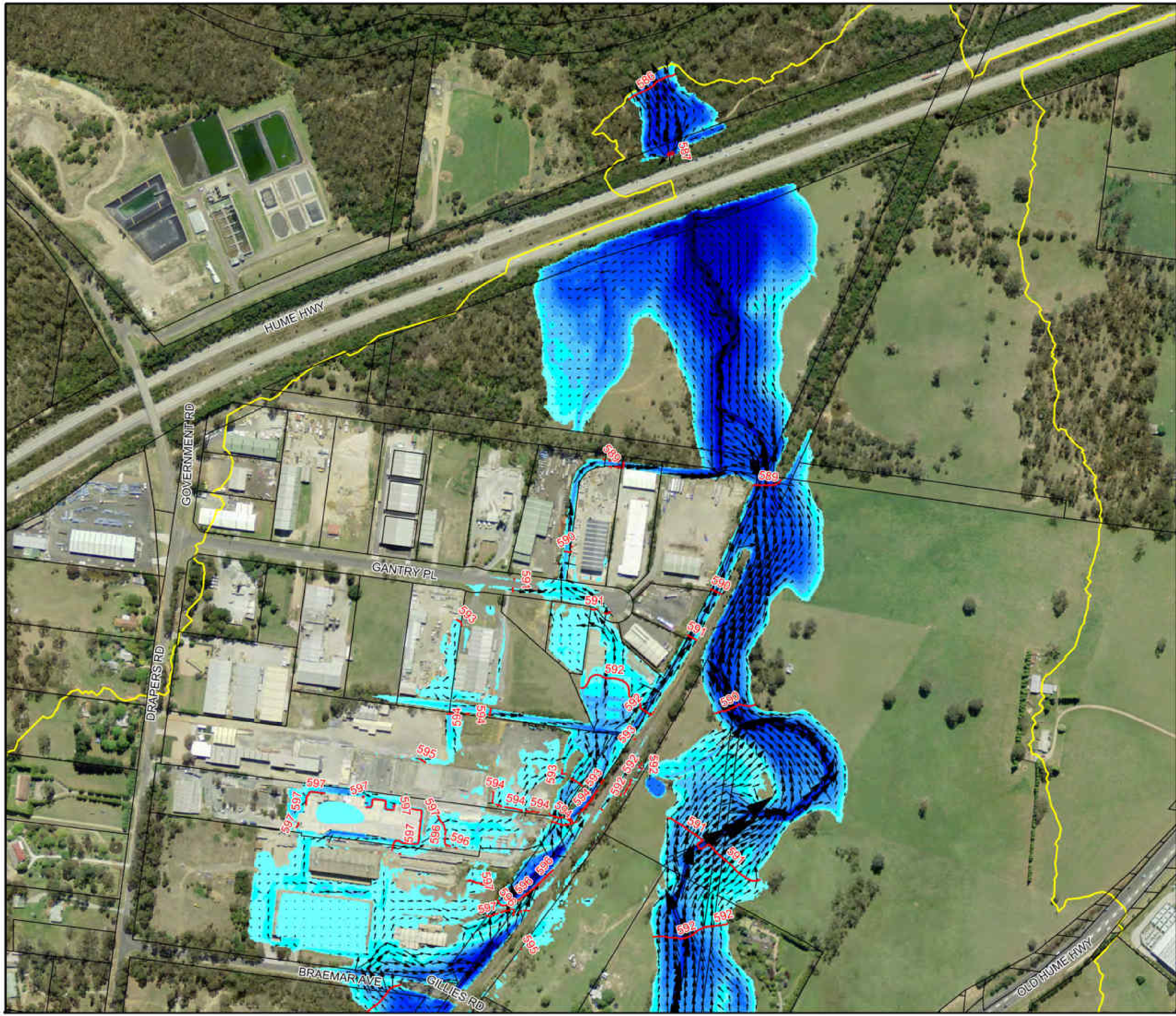
N
W E
S

Scale 1:4,000 (at A3)
0 0.1 0.2
Km

Figure B1.7: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

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

File Name: FigB1.7 - 1% AEP ARR1987 Depths, Levels and Velocities.wor



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LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B1.8: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR1987 Hydrology

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

File Name: FigB1.8 - 1% AEP ARR1987 Depths, Levels and Velocities.wor

temporal patterns when considering all subcatchments in the XP-RAFTS model. More specifically, 30 unique critical storms were identified for the 1% AEP flood.

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. A total of 15 focus locations were identified and are shown in **Plate 1**.

Once the assessment of critical durations and temporal patterns was reduced from every subcatchments (i.e., 188 locations) down to 15 focus locations, the number of unique durations and temporal patterns was significantly reduced (less than 10 unique combinations). 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. The peak discharges generated by the most common critical durations and temporal patterns were compared against the peak discharges generated by the "actual" critical durations and temporal patterns for each subcatchment to determine the difference in peak discharge that would results from using a reduced set of durations and temporal patterns. A preference was given to adopting durations and temporal patterns that produced a peak discharge slightly higher than the "critical" discharge in preference to a lower discharge to ensure a conservative estimate of flood behaviour was being provided.

The durations and temporal patterns are summarised in **Table 4**. The resulting discharges based on the reduced set of temporal patterns and storm durations at each XP-RAFTS model subcatchment are tabulated at the end of this Appendix.

Table 4 Adopted temporal patterns and storm durations for hydraulic analysis

Design Storm	Storm Duration / Temporal Pattern ID					
	10 mins	15 mins	60 mins	120 mins	270 mins	360 mins
20% AEP	4386				4711	4739
5% AEP		4410				4731
1% AEP	4363		4405	4618		

The peak discharges summarised at the end of this Appendix show that the peak discharges generated by the adopted/reduced set of durations and temporal patterns are typically higher than the "actual" discharges (i.e., discharges based upon the full set of temporal patterns and durations). However, in most cases, the differences in peak discharges are less than 2% (the average difference for the 1% AEP event was determined to be 1.2%). Therefore, although adopting a reduced set of durations and temporal patterns is providing conservative ARR2016 discharge estimates, the discharges are not significantly inflated. Therefore, it is considered that the reduced set of durations and temporal patterns is reasonable for application to the hydraulic model as part of the ARR2016 analysis.

The TUFLOW model was subsequently used to simulate design flood behaviour for the design 1% AEP event with the reduced set of ARR2016 storms. The results of each of the individual storm simulations were combined into a final design flood envelope. Peak floodwater depths, levels and velocities were extracted from the enveloped results and are presented in **Figures B2.1** to **B2.8**.

Discussion on Flood Impacts

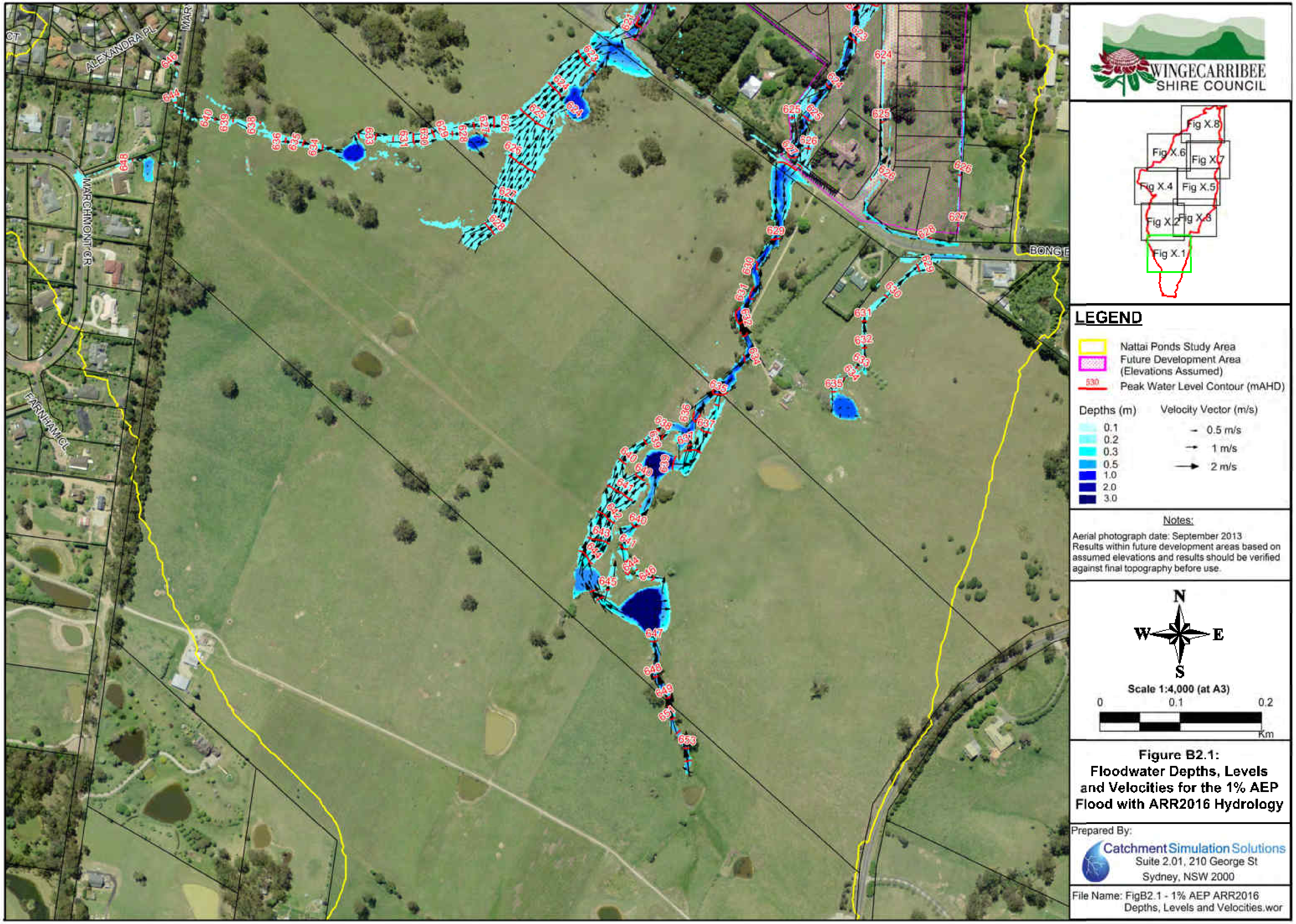
Difference mapping was also prepared to quantify the differences in peak 1% AEP flood levels and extents associated with adopting ARR2016 versus ARR1987 hydrology. The difference map was prepared by subtracting peak water levels generated as part of the ARR2016 model runs from the ARR1987 model runs. This creates a contour map of predicted changes in flood levels and extents. The flood level difference mapping is provided in **Figures B3.1** to **B3.8**. 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 B3.1** to **B3.8** 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. However, the flood level differences approach 0.5 metres in the vicinity of major hydraulic controls, such as the railway line and Hume Highway.

1.5 Conclusion and Recommendation

Application of ARR2016 hydrologic procedures to the Nattai Ponds catchment is predicted to generate lower peak discharges across all design floods up to and including the 1% AEP event relative to ARR1987. This is predicted to also result in a reduction in design flood levels across the catchment relative to ARR1987. The differences are primarily a result of the lower ARR2016 design rainfall depths and, to a lesser extent, higher "burst" rainfall losses.

Although there are concerns that adopting lower design discharges and flood levels could underestimate the flood risk across the catchment, available information for the area indicates that the more regionalised ARR2016 input information is more reliable than the generalised ARR1987 inputs. Accordingly, it is considered that application of ARR2016 procedures as part of the Nattai Ponds FPRMS will provide an improved representation of design flood behaviour relative to the ARR1987 procedures.



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LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 630 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B2.1: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

Prepared By:
Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: FigB2.1 - 1% AEP ARR2016 Depths, Levels and Velocities.wor

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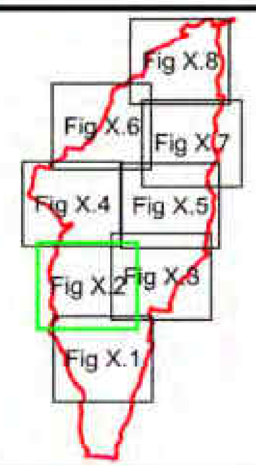


LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m): 0.1, 0.2, 0.3, 0.5, 1.0, 2.0, 3.0

Velocity Vector (m/s): 0.5 m/s, 1 m/s, 2 m/s

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

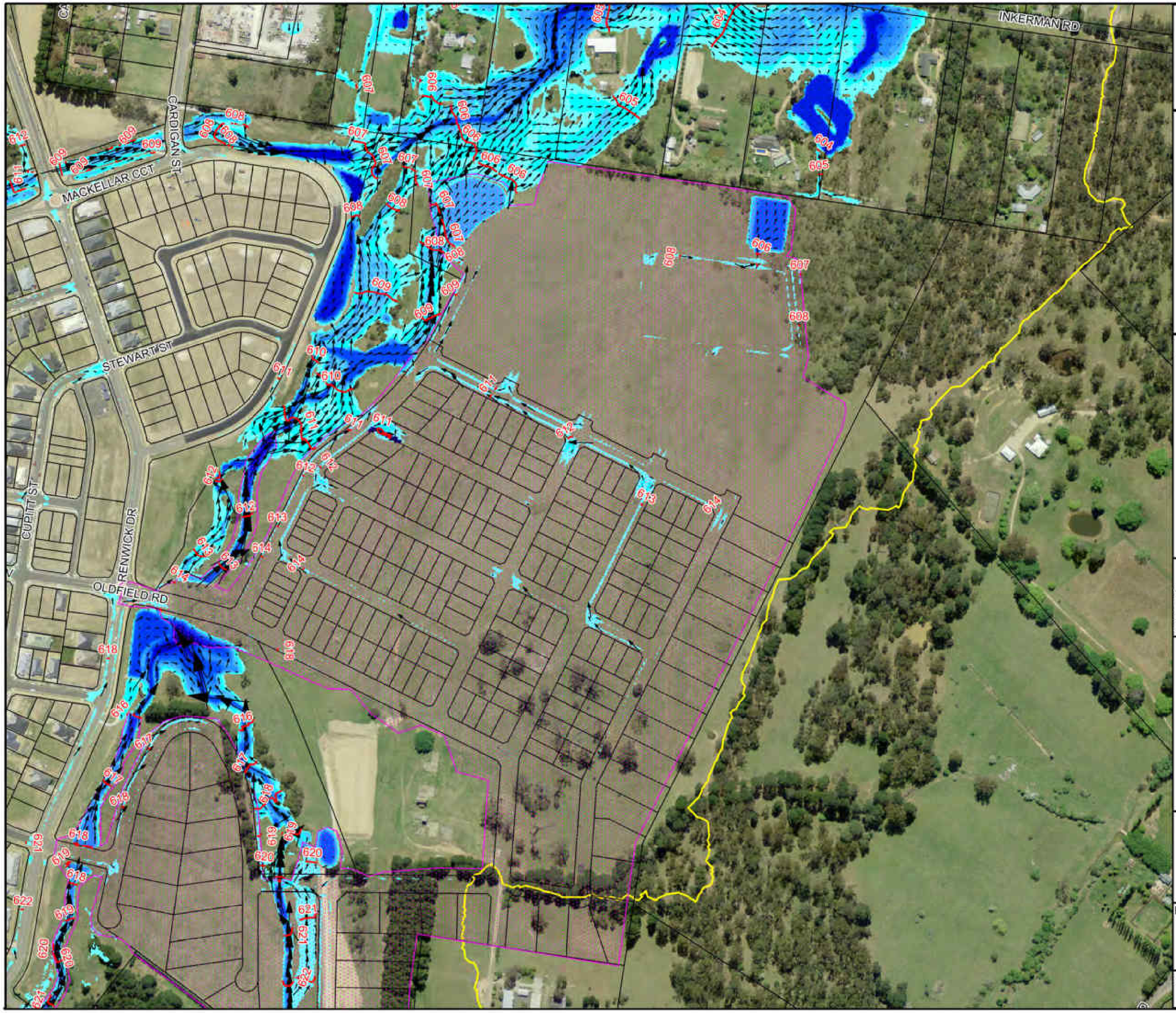
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

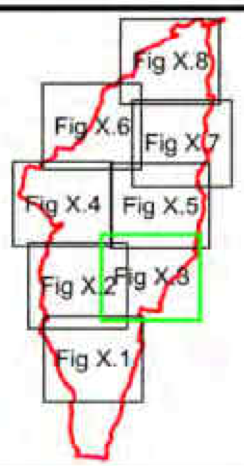
Figure B2.2: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

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

File Name: FigB2.2 - 1% AEP ARR2016 Depths, Levels and Velocities.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B2.3: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

Prepared By:

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

File Name: FigB2.3 - 1% AEP ARR2016 Depths, Levels and Velocities.wor

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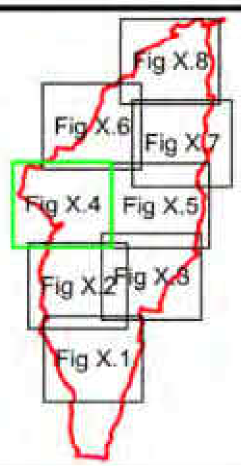


LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

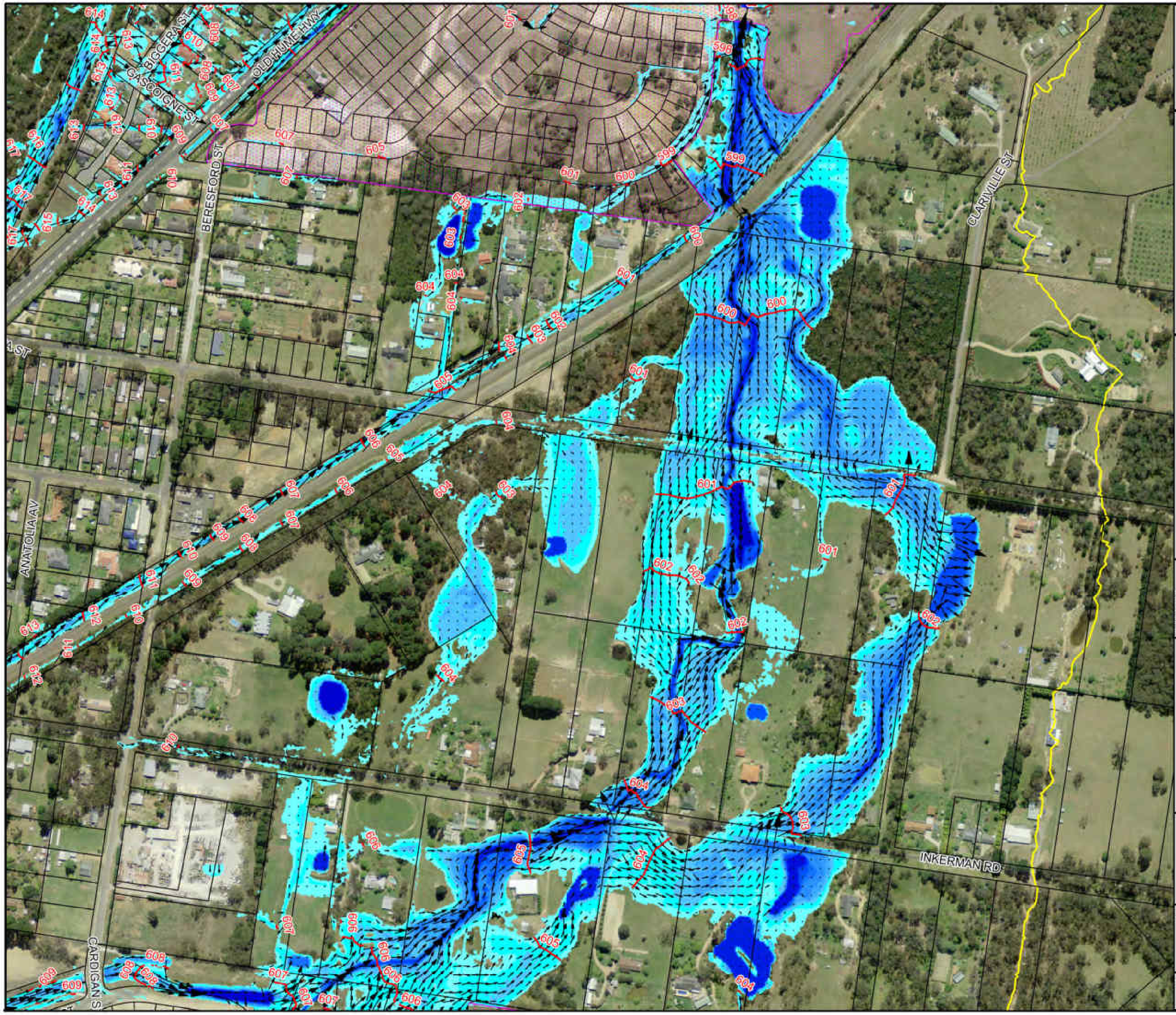
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B2.4: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

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

File Name: FigB2.4 - 1% AEP ARR2016 Depths, Levels and Velocities.wor



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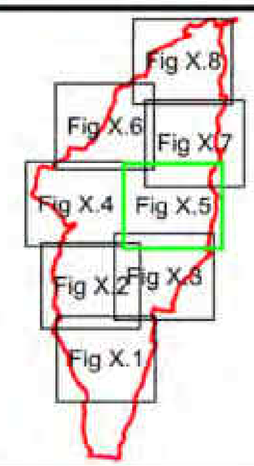

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B2.5: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

Prepared By:

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

File Name: FigB2.5 - 1% AEP ARR2016 Depths, Levels and Velocities.wor

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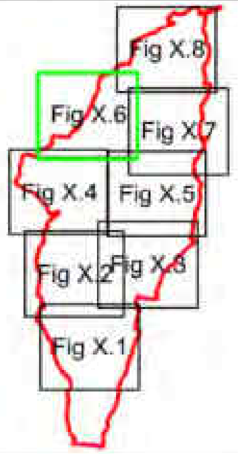

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B2.6: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

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

File Name: FigB2.6 - 1% AEP ARR2016 Depths, Levels and Velocities.wor

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Fig X.8
Fig X.6
Fig X.7
Fig X.4
Fig X.5
Fig X.2
Fig X.3
Fig X.1

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)
- 530 Peak Water Level Contour (mAHD)

Depths (m)	Velocity Vector (m/s)
0.1	0.5 m/s
0.2	1 m/s
0.3	2 m/s
0.5	
1.0	
2.0	
3.0	

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2
Km

Figure B2.7: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

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

File Name: FigB2.7 - 1% AEP ARR2016 Depths, Levels and Velocities.wor

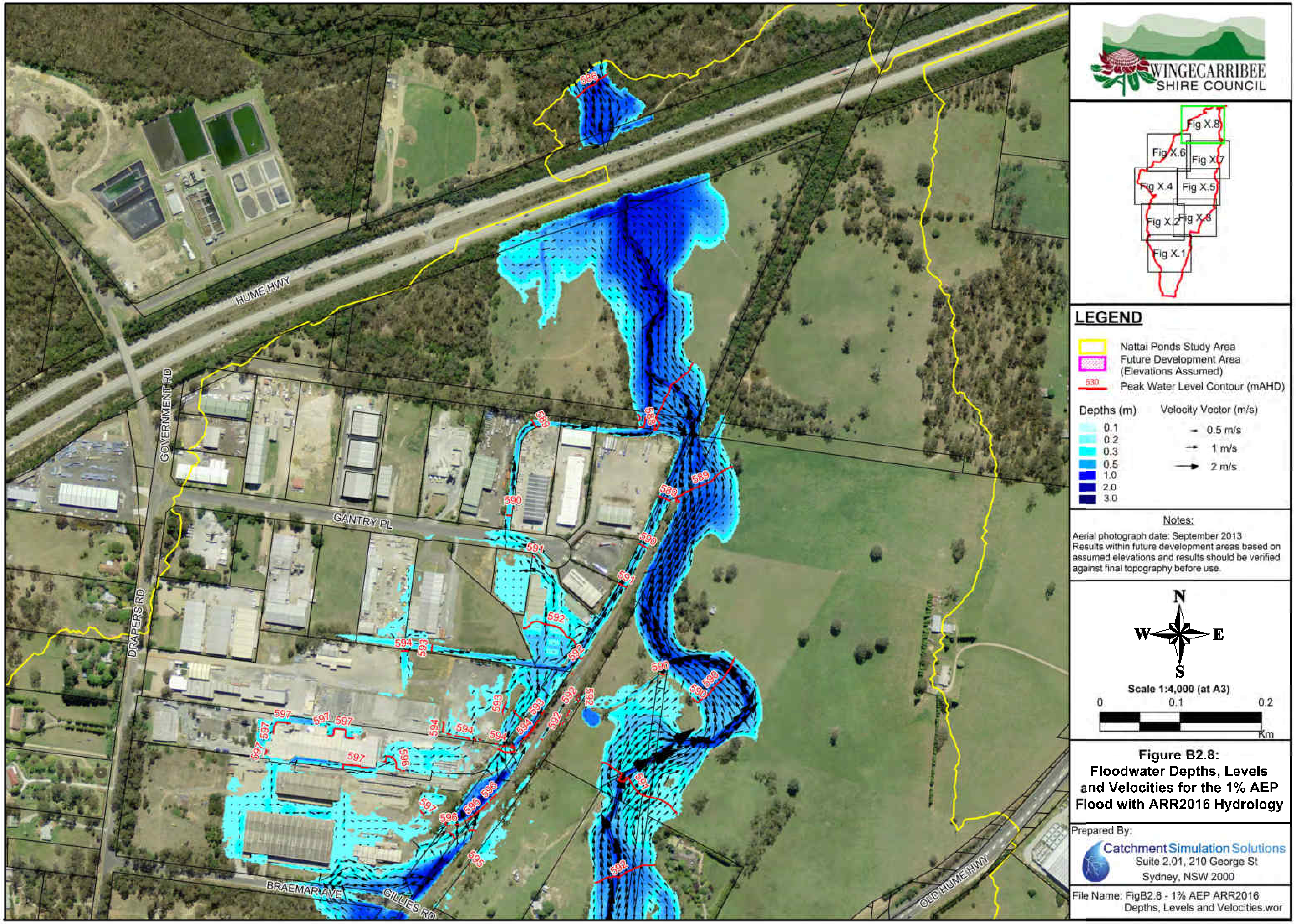

Figure B2.8: Floodwater Depths, Levels and Velocities for the 1% AEP Flood with ARR2016 Hydrology

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LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B3.1: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

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

File Name: FigB3.1 - 1% AEP ARR1987 and ARR2016 FL Diff.wor

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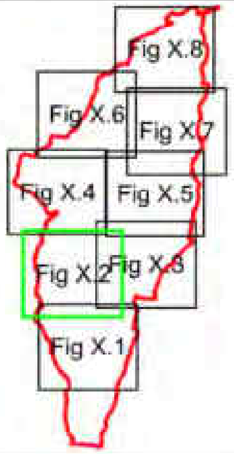


LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

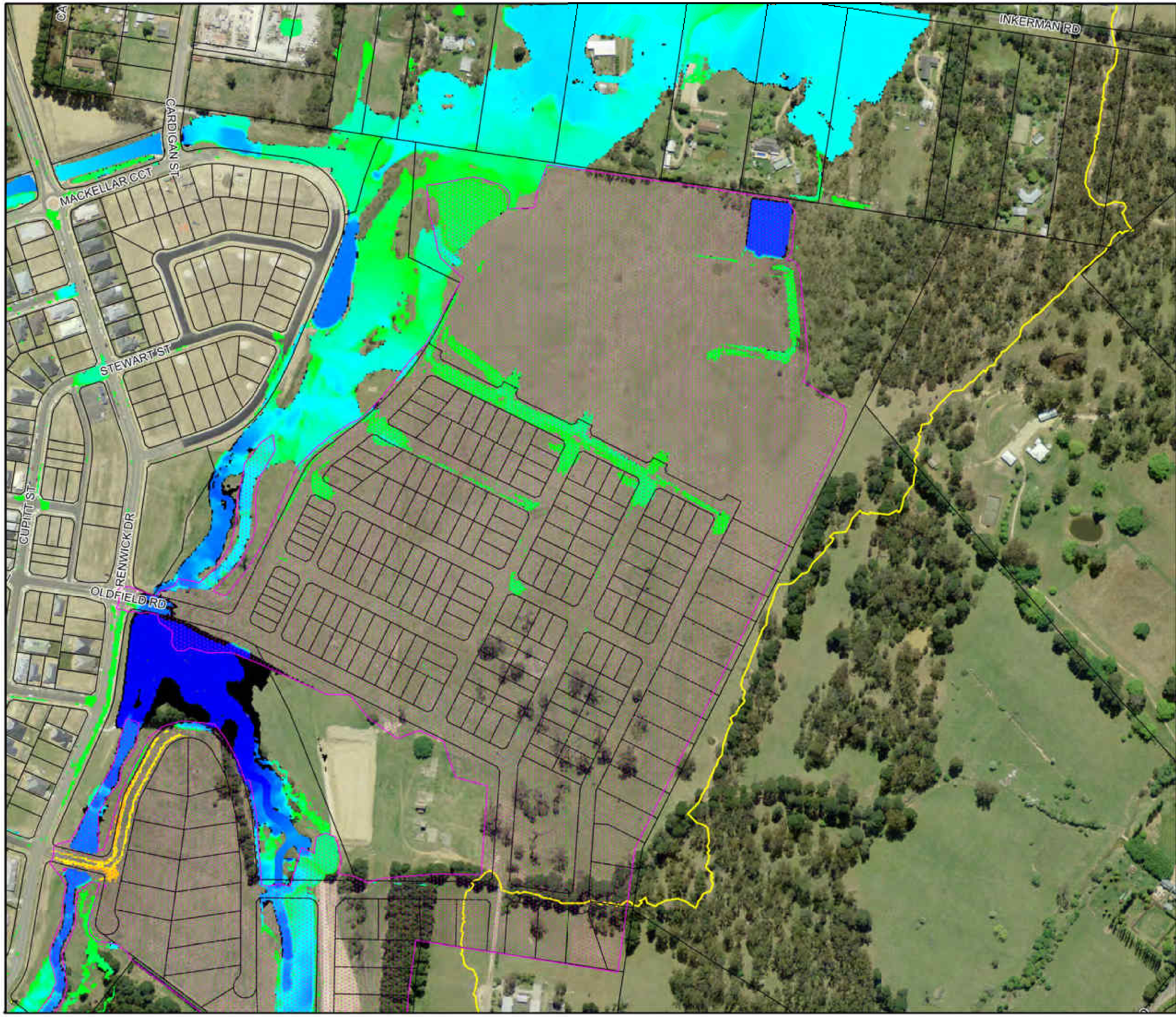
0 0.1 0.2 Km

Figure B3.2: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

Prepared By:

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

File Name: FigB3.2 - 1% AEP ARR1987 and ARR2016 FL Diff.wor



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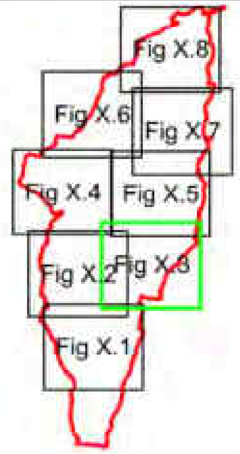

LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2
Km

Figure B3.3: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

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

File Name: FigB3.3 - 1% AEP ARR1987 and ARR2016 FL Diff.wor

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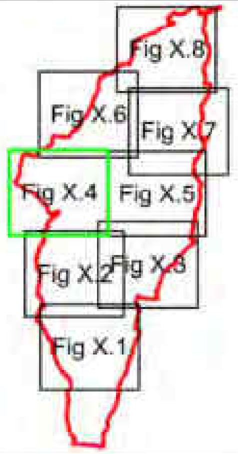


LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

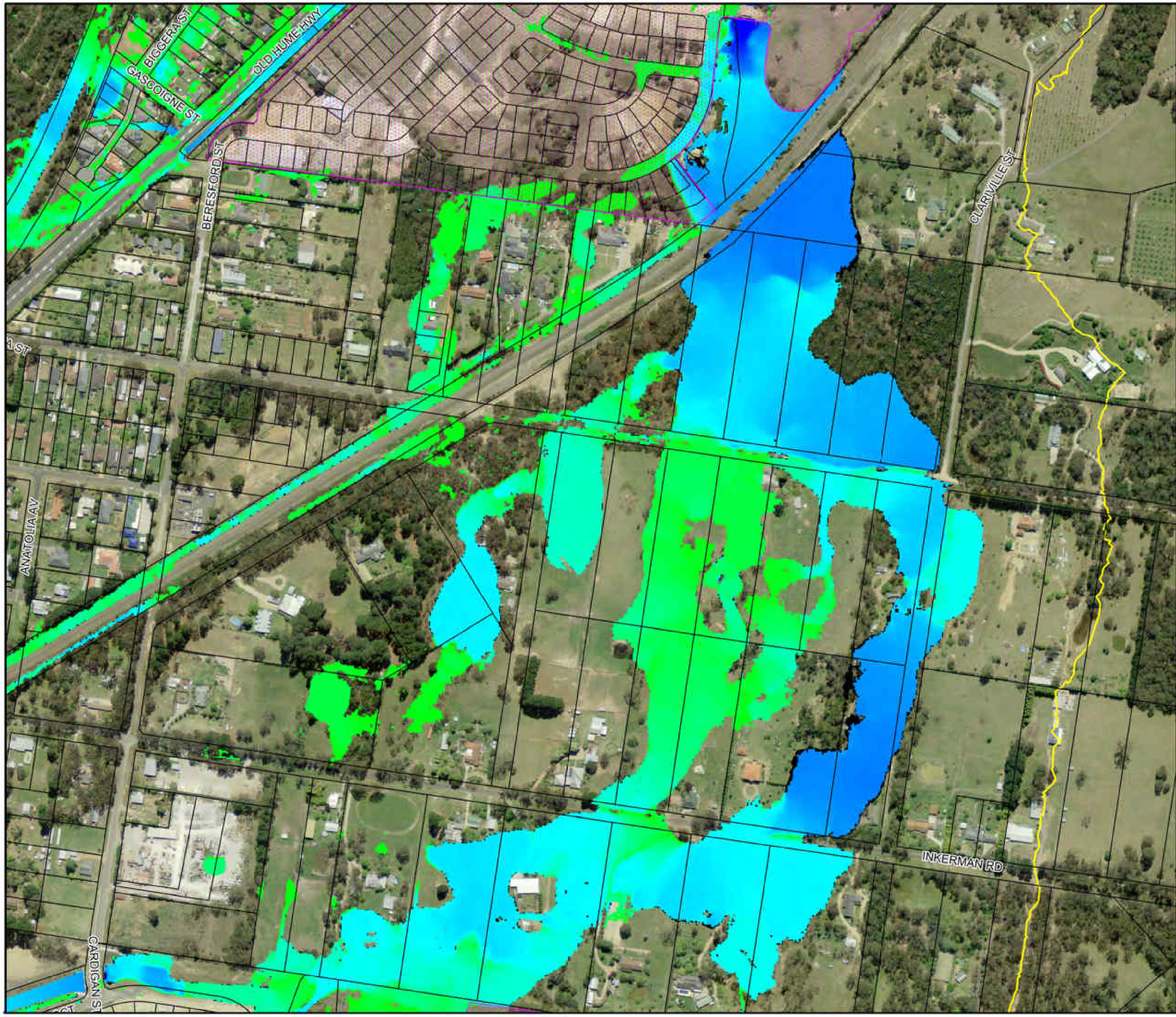
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B3.4: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

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

File Name: FigB3.4 - 1% AEP ARR1987 and ARR2016 FL Diff.wor



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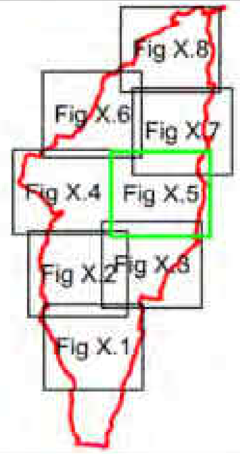


LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

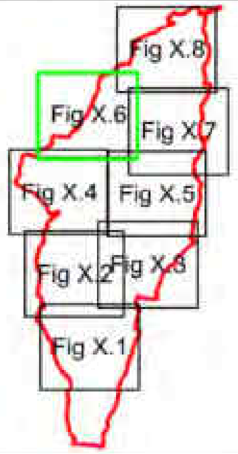
0 0.1 0.2 Km

Figure B3.5: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

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

File Name: FigB3.5 - 1% AEP ARR1987 and ARR2016 FL Diff.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

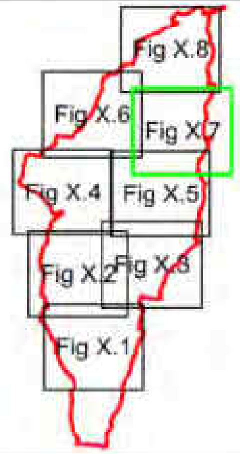
0 0.1 0.2 Km

Figure B3.6: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

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

File Name: FigB3.6 - 1% AEP ARR1987 and ARR2016 FL Diff.wor

Wingecarribee Shire Council



LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2
Km

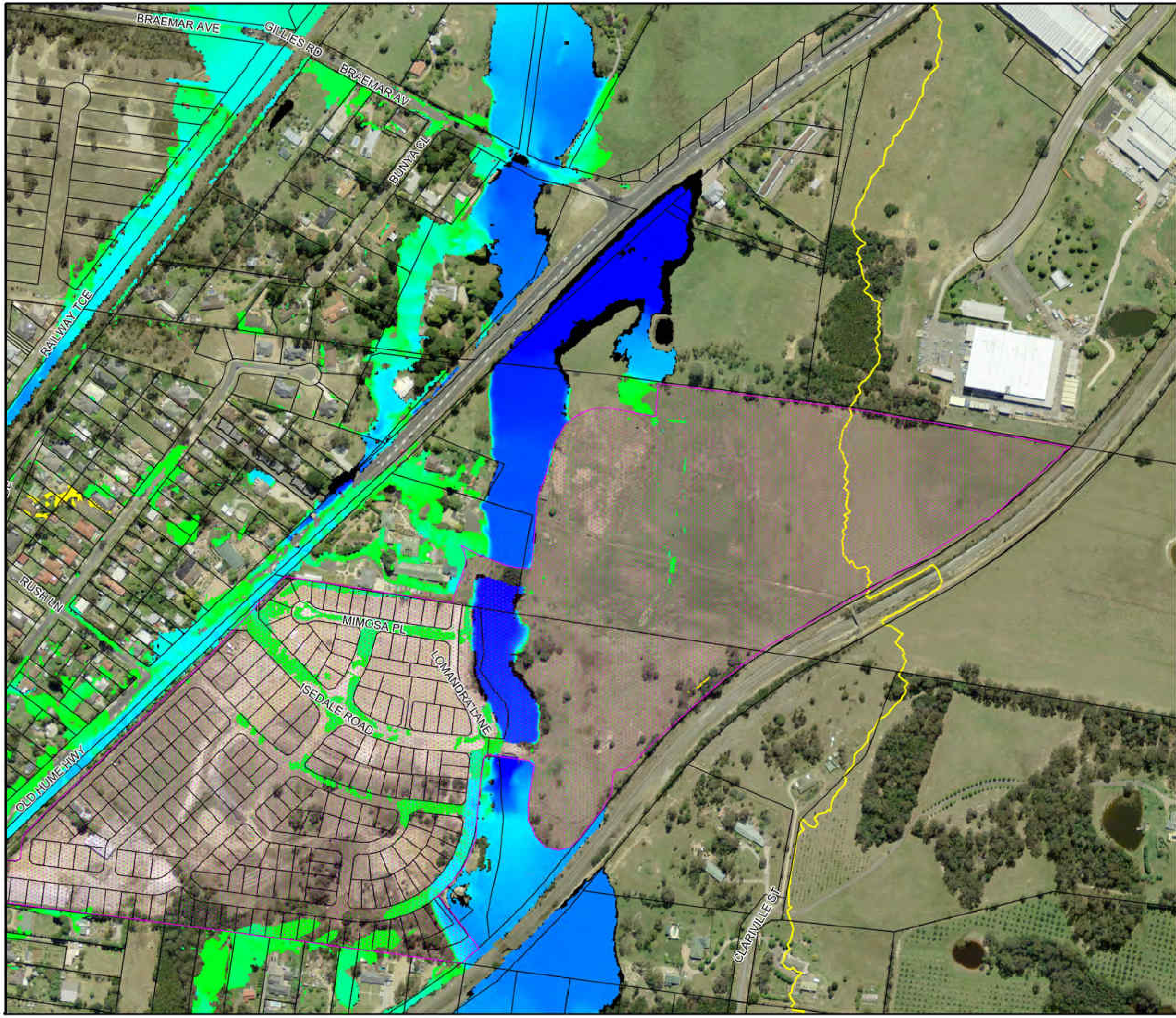


Figure B3.7: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

Prepared By:
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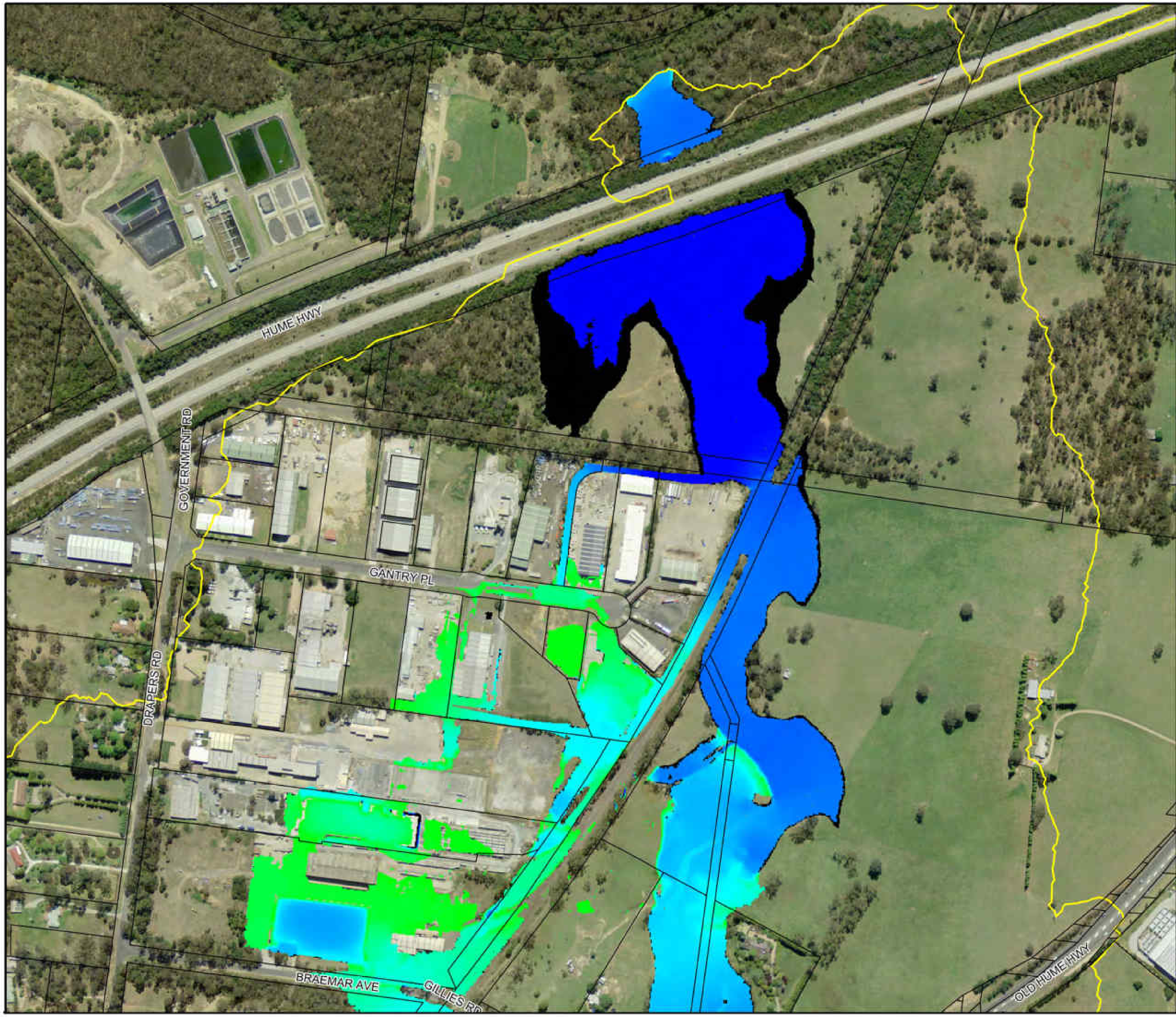
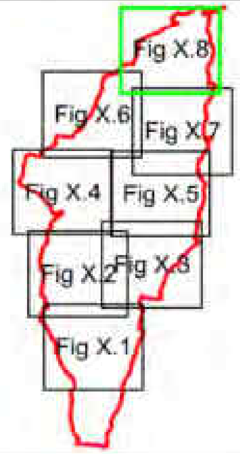
File Name: FigB3.7 - 1% AEP ARR1987 and ARR2016 FL Diff.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Water Level Difference (m)

- 0.50
- 0.20
- 0.10
- 0.02
- No Change
- -0.02
- -0.10
- -0.20
- -0.50
- Previously wet now dry
- Previously dry now wet

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B3.8: Floodwater Levels Differences between 1%AEP ARR1987 and ARR2016 Hydrology

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

File Name: FigB3.8 - 1% AEP ARR1987 and ARR2016 FL Diff.wor

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.

ARR2016 Data Hub Download

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	150.474
Latitude	-34.441
Selected Regions	
Storm Losses	
Temporal Patterns	
Areal Temporal Patterns	

Region Information

Data Category	Region
River Region	Hawkesbury River
ARF Parameters	SE Coast
Temporal Patterns	East Coast South

Data

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	32.0
Storm Initial Losses (mm)	39.0
Storm Continuing Losses (mm/h)	4.6

Layer Info

Time Accessed	24 August 2018 07:47AM
Version	2016_v1

Temporal Patterns

code	ECsouth
Label	East Coast South

Layer Info

Time Accessed	24 August 2018 07:47AM
Version	2016_v2

Areal Temporal Patterns

code	ECsouth
arealabel	East Coast South

Layer Info

Time Accessed	24 August 2018 07:47AM
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	24 August 2018 07:47AM

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)	1.1 (0.044)	1.1 (0.034)	1.2 (0.030)	1.2 (0.026)	0.8 (0.015)	0.5 (0.008)
90 (1.5)	1.3 (0.046)	1.7 (0.044)	1.9 (0.042)	2.1 (0.040)	1.5 (0.024)	1.0 (0.015)
120 (2.0)	0.8 (0.025)	1.4 (0.034)	1.9 (0.037)	2.3 (0.039)	2.8 (0.040)	3.2 (0.041)
180 (3.0)	3.1 (0.082)	4.1 (0.082)	4.8 (0.081)	5.5 (0.080)	4.7 (0.057)	4.1 (0.044)
360 (6.0)	5.6 (0.110)	14.8 (0.214)	20.8 (0.255)	26.6 (0.282)	19.9 (0.179)	14.8 (0.120)
720 (12.0)	7.0 (0.099)	12.9 (0.132)	16.9 (0.145)	20.7 (0.153)	22.8 (0.144)	24.3 (0.138)
1080 (18.0)	5.5 (0.064)	11.4 (0.095)	15.3 (0.106)	19.0 (0.114)	22.7 (0.115)	25.4 (0.116)
1440 (24.0)	1.2 (0.012)	6.2 (0.046)	9.6 (0.058)	12.8 (0.066)	17.2 (0.076)	20.5 (0.081)
2160 (36.0)	0.5 (0.004)	2.5 (0.015)	3.8 (0.019)	5.1 (0.022)	6.7 (0.024)	8.0 (0.026)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.8 (0.003)	1.5 (0.004)
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	24 August 2018 07:47AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
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	24 August 2018 07:47AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	1.0 (0.014)	1.6 (0.020)	2.2 (0.024)	1.0 (0.009)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.002)	0.8 (0.003)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
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

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Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	22.1 (0.905)	19.5 (0.591)	17.9 (0.453)	16.3 (0.353)	16.6 (0.299)	16.8 (0.266)
90 (1.5)	16.5 (0.585)	20.3 (0.535)	22.9 (0.506)	25.3 (0.481)	23.8 (0.376)	22.6 (0.315)
120 (2.0)	15.5 (0.492)	25.6 (0.604)	32.2 (0.641)	38.6 (0.662)	37.2 (0.533)	36.2 (0.457)
180 (3.0)	33.9 (0.911)	43.1 (0.863)	49.2 (0.833)	55.1 (0.805)	50.9 (0.624)	47.7 (0.519)
360 (6.0)	43.0 (0.846)	61.8 (0.895)	74.2 (0.909)	86.1 (0.915)	89.2 (0.804)	91.5 (0.737)
720 (12.0)	28.9 (0.409)	43.4 (0.442)	52.9 (0.453)	62.1 (0.459)	69.3 (0.437)	74.6 (0.424)
1080 (18.0)	30.3 (0.358)	46.3 (0.387)	56.9 (0.396)	67.0 (0.401)	70.8 (0.361)	73.5 (0.337)
1440 (24.0)	16.1 (0.169)	28.9 (0.212)	37.4 (0.227)	45.5 (0.235)	61.4 (0.270)	73.4 (0.290)
2160 (36.0)	12.7 (0.115)	23.6 (0.147)	30.8 (0.157)	37.8 (0.163)	43.1 (0.157)	47.0 (0.153)
2880 (48.0)	1.7 (0.014)	6.8 (0.039)	10.2 (0.047)	13.5 (0.052)	15.9 (0.052)	17.8 (0.051)
4320 (72.0)	0.0 (0.000)	0.4 (0.002)	0.7 (0.003)	1.0 (0.003)	17.7 (0.050)	30.2 (0.076)

Layer Info

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Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	107.7 (4.417)	82.7 (2.505)	66.2 (1.681)	50.4 (1.095)	61.5 (1.109)	69.8 (1.106)
90 (1.5)	55.4 (1.965)	86.8 (2.283)	107.6 (2.380)	127.5 (2.422)	98.4 (1.556)	76.6 (1.066)
120 (2.0)	70.7 (2.245)	100.0 (2.363)	119.5 (2.379)	138.1 (2.367)	132.8 (1.901)	128.8 (1.628)
180 (3.0)	91.2 (2.454)	110.4 (2.209)	123.0 (2.081)	135.2 (1.975)	124.6 (1.529)	116.7 (1.270)
360 (6.0)	79.9 (1.571)	104.4 (1.512)	120.6 (1.478)	136.2 (1.446)	146.6 (1.321)	154.5 (1.244)
720 (12.0)	61.7 (0.873)	87.9 (0.895)	105.2 (0.900)	121.8 (0.901)	136.1 (0.859)	146.9 (0.833)
1080 (18.0)	60.6 (0.714)	86.3 (0.721)	103.3 (0.719)	119.7 (0.715)	132.2 (0.673)	141.5 (0.649)
1440 (24.0)	48.6 (0.509)	74.7 (0.547)	92.0 (0.557)	108.5 (0.561)	117.3 (0.516)	123.8 (0.489)
2160 (36.0)	37.4 (0.339)	51.6 (0.322)	61.0 (0.311)	70.0 (0.301)	92.6 (0.337)	109.5 (0.356)
2880 (48.0)	14.7 (0.123)	31.1 (0.177)	42.0 (0.194)	52.4 (0.202)	66.4 (0.215)	76.8 (0.222)
4320 (72.0)	11.8 (0.090)	22.6 (0.117)	29.8 (0.123)	36.6 (0.126)	72.6 (0.207)	99.5 (0.251)

Layer Info

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Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

XP-RAFTS RESULTS

ARR2016 Results for 20% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4386 for the 10 minute duration	TP 4711 for the 4.5 hour duration	TP 4739 for the 6 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
1.01	270	2749	0.50	0.50	0.11	0.50	0.10	0.50	0.48	0.50	0.00	0.0%
1.02	270	4711	0.96	0.89	0.26	0.90	0.30	0.90	0.84	0.90	0.00	0.0%
1.03	270	4711	1.96	1.82	0.53	1.83	0.57	1.83	1.70	1.83	0.00	0.0%
1.04	270	4711	3.90	3.64	1.02	3.68	1.07	3.68	3.36	3.68	0.00	0.0%
1.05	270	2749	4.44	4.24	1.11	4.24	1.12	4.24	3.95	4.24	0.00	0.0%
1.06	270	2749	4.57	4.38	1.13	4.39	1.12	4.37	4.05	4.37	-0.02	-0.5%
1.07	270	2749	6.19	6.11	1.40	6.20	1.98	6.02	5.70	6.02	-0.18	-2.9%
1.08	270	2749	10.26	10.21	2.20	10.40	3.82	10.03	9.64	10.03	-0.37	-3.6%
1.09	270	2749	10.73	10.79	2.24	11.01	4.64	10.57	10.20	10.57	-0.44	-4.0%
1.1	10	4386	0.62	0.60	0.06	0.60	0.60	0.30	0.40	0.60	0.00	0.0%
1.11	10	4386	4.74	4.62	0.35	4.70	4.70	2.69	2.89	4.70	0.00	0.0%
1.12	10	4386	4.75	4.64	0.35	4.71	4.71	2.89	3.13	4.71	0.00	0.0%
1.13	10	4386	4.75	4.64	0.35	4.71	4.71	2.99	3.28	4.71	0.00	0.0%
1.14	360	4739	18.00	17.41	2.97	18.34	8.49	17.40	18.34	18.34	0.00	0.0%
1.15	360	4739	18.83	18.17	3.11	19.19	8.49	18.20	19.19	19.19	0.00	0.0%
1.16	360	4739	19.23	18.54	3.19	19.61	8.49	18.60	19.61	19.61	0.00	0.0%
1.17	360	4739	19.53	18.85	3.25	19.97	8.49	18.90	19.97	19.97	0.00	0.0%
1.18	360	4739	19.73	19.07	3.30	20.20	8.49	19.08	20.20	20.20	0.00	0.0%
1.19	360	4739	20.15	19.53	3.37	20.67	8.49	19.52	20.67	20.67	0.00	0.0%
1.2	360	4739	20.49	19.90	3.44	21.09	8.49	19.84	21.09	21.09	0.00	0.0%
1.21	360	4739	23.41	23.00	3.74	24.44	8.87	22.72	24.44	24.44	0.00	0.0%
1.22	360	4739	24.20	23.81	3.87	25.32	8.92	23.43	25.32	25.32	0.00	0.0%
1.23	360	4739	25.01	24.65	4.00	26.22	8.92	24.19	26.22	26.22	0.00	0.0%
1.24	360	4739	25.47	25.11	4.08	26.73	8.92	24.61	26.73	26.73	0.00	0.0%
1.25	360	4740	31.44	30.86	5.34	32.91	11.10	30.01	33.20	33.20	0.29	0.9%
1.26	360	4740	32.38	31.85	5.48	33.92	11.10	30.87	34.23	34.23	0.31	0.9%
2.01	120	4643	0.14	0.13	0.06	0.13	0.03	0.11	0.10	0.11	-0.02	-15.4%
2.02	120	4643	0.56	0.50	0.23	0.54	0.19	0.45	0.41	0.45	-0.09	-16.7%
3.01	120	4643	0.33	0.31	0.11	0.32	0.23	0.29	0.26	0.29	-0.03	-9.4%
3.02	270	4711	1.45	1.36	0.38	1.38	0.44	1.38	1.24	1.38	0.00	0.0%
3.03	270	4711	1.86	1.75	0.48	1.77	0.53	1.77	1.59	1.77	0.00	0.0%
4.01	270	4711	0.58	0.53	0.16	0.54	0.19	0.54	0.48	0.54	0.00	0.0%
5.01	270	4711	0.46	0.45	0.11	0.45	0.08	0.45	0.42	0.45	0.00	0.0%
5.02	360	4734	0.94	0.92	0.20	0.92	0.14	0.93	0.91	0.93	0.01	1.1%
5.03	360	4739	1.53	1.54	0.31	1.54	1.25	1.45	1.54	1.54	0.00	0.0%
6.01	270	4711	0.82	0.80	0.18	0.80	0.10	0.80	0.76	0.80	0.00	0.0%
6.02	270	4711	1.09	1.06	0.24	1.07	0.11	1.07	1.00	1.07	0.00	0.0%
6.03	270	4711	1.63	1.59	0.37	1.60	0.17	1.60	1.49	1.60	0.00	0.0%
6.04	270	4711	2.80	2.71	0.64	2.72	0.98	2.72	2.55	2.72	0.00	0.0%
6.05	270	4711	3.25	3.16	0.74	3.17	1.04	3.17	2.99	3.17	0.00	0.0%
6.06	270	2749	3.48	3.42	0.76	3.44	1.38	3.41	3.24	3.41	-0.03	-0.9%
6.07	270	2749	4.06	4.02	0.86	4.06	2.04	3.98	3.85	3.98	-0.08	-2.0%
7.01	270	4711	0.37	0.36	0.08	0.36	0.06	0.36	0.35	0.36	0.00	0.0%
8.01	120	4645	0.23	0.22	0.08	0.24	0.21	0.19	0.18	0.21	-0.03	-12.5%
8.02	120	4643	0.90	0.87	0.25	0.87	0.79	0.83	0.78	0.83	-0.04	-4.6%
8.03	270	4711	1.15	1.11	0.27	1.11	0.81	1.11	1.05	1.11	0.00	0.0%
9.01	10	4386	0.40	0.39	0.04	0.40	0.40	0.29	0.26	0.40	0.00	0.0%
10.01	360	4734	0.29	0.28	0.06	0.28	0.06	0.29	0.27	0.29	0.01	3.6%
11.01	10	4386	0.35	0.34	0.03	0.35	0.35	0.28	0.29	0.35	0.00	0.0%
11.02	10	4386	0.81	0.79	0.08	0.80	0.80	0.62	0.61	0.80	0.00	0.0%
12.01	10	4386	0.28	0.27	0.03	0.28	0.28	0.18	0.18	0.28	0.00	0.0%
13.01	10	4386	0.22	0.22	0.02	0.23	0.23	0.13	0.13	0.23	0.00	0.0%
14.01	10	4386	1.09	1.05	0.11	1.08	1.08	0.48	0.46	1.08	0.00	0.0%
15.01	10	4386	1.77	1.71	0.17	1.75	1.75	0.77	0.73	1.75	0.00	0.0%
15.02	10	4386	2.33	2.24	0.23	2.29	2.29	1.09	1.07	2.29	0.00	0.0%
15.03	10	4386	4.13	3.99	0.39	4.03	4.03	1.98	1.99	4.03	0.00	0.0%
15.04	10	4386	4.17	4.02	0.39	4.07	4.07	2.12	2.13	4.07	0.00	0.0%
16.01	10	4386	1.71	1.64	0.17	1.67	1.67	0.59	0.58	1.67	0.00	0.0%
17.01	360	4740	0.18	0.17	0.03	0.17	0.07	0.17	0.19	0.19	0.02	11.8%
18.01	360	4734	0.11	0.11	0.02	0.11	0.01	0.11	0.11	0.11	0.00	0.0%
19.01	10	4386	0.51	0.49	0.06	0.51	0.51	0.27	0.26	0.51	0.00	0.0%
19.02	10	4386	0.86	0.84	0.09	0.86	0.86	0.53	0.49	0.86	0.00	0.0%
19.03	120	4642	1.20	1.14	0.39	1.18	1.18	1.04	0.95	1.18	0.00	0.0%
19.04	270	2749	1.41	1.33	0.36	1.35	1.23	1.31	1.30	1.31	-0.04	-3.0%
19.05	270	2749	1.58	1.50	0.39	1.53	1.36	1.48	1.47	1.48	-0.05	-3.3%
19.06	360	4740	2.91	2.93	0.63	3.08	2.50	2.74	2.78	2.78	-0.30	-9.7%
19.07	360	4740	4.06	4.10	0.82	4.17	3.27	3.70	4.03	4.03	-0.14	-3.4%
19.08	540	4771	1.55	1.56	0.10	1.56	0.53	1.46	1.50	1.50	-0.06	-3.8%
19.09	540	4776	1.67	1.68	0.12	1.69	0.56	1.57	1.63	1.63	-0.06	-3.6%
19.1	270	2749	12.72	12.84	2.35	13.28	5.18	12.40	12.40	12.40	-0.88	-6.6%
19.11	360	4739	13.03	12.68	2.31	12.76	5.18	12.72	12.76	12.76	0.00	0.0%
19.12	360	4739	13.22	12.87	2.34	12.98	5.18	12.90	12.98	12.98	0.00	0.0%
20.01	10	4387	0.20	0.20	0.02	0.20	0.21	0.11	0.10	0.21	0.01	5.0%
21.01	10	4386	0.22	0.22	0.02	0.22	0.22	0.14	0.13	0.22	0.00	0.0%
22.01	270	4711	0.19	0.18	0.04	0.18	0.04	0.18	0.17	0.18	0.00	0.0%
23.01	120	4642	0.08	0.07	0.03	0.07	0.07	0.07	0.07	0.07	0.00	0.0%
24.01	10	4387	0.19	0.19	0.02	0.19	0.20	0.16	0.15	0.20	0.01	5.3%
24.02	10	4386	0.25	0.24	0.02	0.25	0.25	0.19	0.19	0.25	0.00	0.0%
24.03	10	4386	0.45	0.43	0.04	0.44	0.44	0.39	0.40	0.44	0.00	0.0%
24.04	10	4386	1.01	0.98	0.10	0.98	0.98	0.93	0.93	0.98	0.00	0.0%
24.05	10	4386	1.25	1.21	0.12	1.22	1.22	1.18	1.19	1.22	0.00	0.0%
25.01	360	4734	0.16	0.15	0.03	0.16	0.12	0.14	0.17	0.17	0.01	6.3%
26.01	10	4386	0.23	0.23	0.02	0.24	0.24	0.18	0.17	0.24	0.00	0.0%
26.02	120	4643	0.46	0.44	0.14	0.45	0.45	0.42	0.39	0.45	0.00	0.0%
27.01	120	4643	0.18	0.17	0.05	0.18	0.16	0.16	0.15	0.16	-0.02	-11.1%
28.01	10	4387	0.18	0.17	0.02	0.18	0.19	0.16	0.17	0.19	0.01	5.6%
29.01	10	4386	0.07	0.07	0.01	0.07	0.07	0.06	0.06	0.07	0.00	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4386 for the 10 minute duration	TP 4711 for the 4.5 hour duration	TP 4739 for the 6 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
30.01	360	4740	0.23	0.22	0.03	0.23	0.13	0.22	0.25	0.25	0.02	8.7%
31.01	10	4386	0.21	0.20	0.02	0.21	0.21	0.15	0.15	0.21	0.00	0.0%
31.02	10	4386	0.57	0.56	0.05	0.57	0.57	0.39	0.46	0.57	0.00	0.0%
31.03	10	4386	0.69	0.67	0.07	0.69	0.69	0.54	0.72	0.72	0.03	4.3%
32.01	360	4740	0.12	0.12	0.01	0.12	0.12	0.12	0.12	0.12	0.00	0.0%
33.01	10	4384	0.19	0.19	0.00	0.19	0.19	0.12	0.12	0.19	0.00	0.0%
34.01	360	4739	0.15	0.15	0.02	0.15	0.06	0.15	0.15	0.15	0.00	0.0%
35.01	10	4386	0.10	0.10	0.01	0.10	0.10	0.08	0.07	0.10	0.00	0.0%
35.02	10	4386	0.38	0.37	0.04	0.38	0.38	0.23	0.21	0.38	0.00	0.0%
35.03	10	4386	0.63	0.61	0.06	0.62	0.62	0.38	0.35	0.62	0.00	0.0%
35.04	10	4386	0.77	0.76	0.05	0.77	0.77	0.56	0.55	0.77	0.00	0.0%
35.05	360	4740	0.50	0.49	0.08	0.52	0.32	0.49	0.53	0.53	0.01	1.9%
35.06	360	4740	0.49	0.48	0.06	0.50	0.22	0.49	0.53	0.53	0.03	6.0%
36.01	10	4386	0.23	0.23	0.02	0.23	0.23	0.11	0.10	0.23	0.00	0.0%
37.01	10	4386	0.09	0.09	0.01	0.09	0.09	0.04	0.04	0.09	0.00	0.0%
38.01	270	2749	0.11	0.11	0.03	0.11	0.08	0.11	0.10	0.11	0.00	0.0%
39.01	360	4740	0.30	0.28	0.05	0.29	0.12	0.28	0.34	0.34	0.05	17.2%
40.01	10	4382	0.13	0.13	0.01	0.13	0.14	0.07	0.06	0.14	0.01	7.7%
40.02	10	4386	0.26	0.25	0.03	0.26	0.26	0.15	0.15	0.26	0.00	0.0%
40.03	10	4386	0.72	0.69	0.07	0.70	0.70	0.46	0.48	0.70	0.00	0.0%
40.04	10	4386	1.03	1.00	0.07	1.02	1.02	0.70	0.72	1.02	0.00	0.0%
40.05	10	4386	1.37	1.36	0.07	1.36	1.36	1.02	1.10	1.36	0.00	0.0%
40.06	10	4387	1.48	1.46	0.08	1.47	1.49	1.14	1.26	1.49	0.02	0.0%
41.01	10	4386	0.26	0.25	0.02	0.26	0.26	0.17	0.16	0.26	0.00	0.0%
42.01	10	4386	0.31	0.30	0.03	0.30	0.30	0.22	0.20	0.30	0.00	0.0%
43.01	10	4386	0.09	0.08	0.01	0.08	0.08	0.06	0.07	0.08	0.00	0.0%
44.01	360	4732	0.14	0.12	0.03	0.12	0.09	0.12	0.15	0.15	0.03	25.0%
44.02	360	4734	0.25	0.23	0.05	0.24	0.23	0.22	0.28	0.28	0.04	16.7%
44.03	360	4734	0.38	0.35	0.07	0.36	0.27	0.34	0.41	0.41	0.05	13.9%
44.04	360	4737	0.63	0.60	0.12	0.60	0.38	0.52	0.66	0.66	0.06	10.0%
45.01	10	4386	0.10	0.10	0.01	0.10	0.10	0.07	0.08	0.10	0.00	0.0%
46.01	360	4737	0.15	0.14	0.03	0.15	0.05	0.12	0.16	0.16	0.01	6.7%
47.01	360	4740	0.09	0.08	0.02	0.08	0.03	0.08	0.10	0.10	0.02	25.0%
48.01	360	4740	0.20	0.20	0.04	0.20	0.12	0.18	0.18	0.18	-0.02	-10.0%
48.02	360	4740	0.43	0.42	0.08	0.43	0.25	0.35	0.45	0.45	0.02	4.7%
49.01	360	4734	0.22	0.21	0.04	0.21	0.15	0.20	0.24	0.24	0.03	14.3%
50.01	360	4740	0.27	0.25	0.05	0.26	0.16	0.25	0.31	0.31	0.05	19.2%
51.01	10	4386	0.09	0.09	0.01	0.09	0.09	0.07	0.08	0.09	0.00	0.0%
52.01	10	4386	0.34	0.33	0.03	0.34	0.34	0.27	0.36	0.36	0.02	5.9%
52.02	10	4386	0.84	0.81	0.08	0.82	0.82	0.42	0.52	0.82	0.00	0.0%
53.01	10	4386	0.34	0.33	0.03	0.34	0.34	0.11	0.11	0.34	0.00	0.0%
53.02	10	4386	1.09	1.05	0.11	1.06	1.06	0.36	0.36	1.06	0.00	0.0%
53.03	10	4388	1.44	1.40	0.12	1.40	1.40	0.50	0.48	1.40	0.00	0.0%
54.01	10	4386	0.47	0.45	0.05	0.46	0.46	0.15	0.15	0.46	0.00	0.0%
55.01	10	4386	0.38	0.36	0.04	0.37	0.37	0.12	0.13	0.37	0.00	0.0%
56.01	10	4386	0.36	0.35	0.03	0.36	0.36	0.14	0.13	0.36	0.00	0.0%
57.01	10	4386	0.46	0.44	0.05	0.45	0.45	0.26	0.26	0.45	0.00	0.0%
57.02	10	4387	0.61	0.60	0.04	0.60	0.60	0.33	0.34	0.60	0.00	0.0%
57.03	10	4382	0.69	0.70	0.04	0.70	0.72	0.38	0.39	0.72	0.02	2.9%
58.01	360	4740	0.55	0.53	0.10	0.55	0.01	0.54	0.59	0.59	0.04	7.3%
58.02	360	4739	0.71	0.71	0.14	0.73	0.07	0.67	0.73	0.73	0.00	0.0%
58.03	360	4739	0.89	0.89	0.17	0.91	0.12	0.85	0.91	0.91	0.00	0.0%
58.04	360	4739	1.71	1.69	0.33	1.71	0.29	1.64	1.71	1.71	0.00	0.0%
58.05	360	4739	2.45	2.41	0.49	2.46	0.42	2.36	2.46	2.46	0.00	0.0%
58.06	360	4739	2.46	2.42	0.49	2.47	0.43	2.38	2.47	2.47	0.00	0.0%
58.07	360	4739	3.52	3.49	0.69	3.55	1.09	3.43	3.55	3.55	0.00	0.0%
58.08	270	2749	1.35	1.35	0.02	1.35	1.10	1.35	1.35	1.35	0.00	0.0%
58.09	270	2749	1.81	1.79	0.13	1.81	1.52	1.76	1.80	1.80	-0.01	-0.6%
58.1	270	2749	2.04	2.02	0.19	2.06	1.69	1.98	2.05	2.05	-0.01	-0.5%
58.11	270	2749	2.25	2.22	0.23	2.28	1.70	2.16	2.27	2.27	-0.01	-0.4%
59.01	360	4739	0.41	0.40	0.08	0.42	0.12	0.40	0.42	0.42	0.00	0.0%
59.02	360	4739	0.68	0.66	0.14	0.67	0.14	0.66	0.67	0.67	0.00	0.0%
60.01	270	4711	0.24	0.23	0.05	0.24	0.06	0.24	0.22	0.24	0.00	0.0%
60.02	360	4739	0.66	0.65	0.13	0.67	0.08	0.63	0.67	0.67	0.00	0.0%
61.01	120	4643	0.15	0.15	0.04	0.16	0.12	0.15	0.13	0.15	-0.01	-6.3%
61.02	120	4643	0.50	0.47	0.15	0.51	0.39	0.47	0.42	0.47	-0.04	-7.8%
61.03	270	4711	0.86	0.82	0.21	0.83	0.66	0.83	0.76	0.83	0.00	0.0%
61.04	270	2749	1.20	1.16	0.28	1.18	0.90	1.14	1.14	1.14	-0.04	-3.4%
62.01	270	4711	0.23	0.21	0.06	0.21	0.14	0.21	0.20	0.21	0.00	0.0%
63.01	270	4711	0.15	0.14	0.03	0.15	0.05	0.15	0.14	0.15	0.00	0.0%
64.01	120	4643	0.05	0.05	0.01	0.05	0.03	0.05	0.04	0.05	0.00	0.0%
65.01	10	4382	0.13	0.12	0.01	0.12	0.13	0.12	0.12	0.13	0.01	8.3%
65.02	10	4386	0.23	0.22	0.02	0.23	0.23	0.20	0.19	0.23	0.00	0.0%
66.01	120	4642	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	-0.01	-50.0%
67.01	10	4386	0.31	0.30	0.03	0.31	0.31	0.19	0.20	0.31	0.00	0.0%
68.01	10	4387	0.16	0.16	0.02	0.16	0.16	0.10	0.12	0.16	0.00	0.0%
69.01	10	4386	0.18	0.17	0.02	0.18	0.18	0.09	0.09	0.18	0.00	0.0%
69.02	10	4386	0.27	0.27	0.03	0.27	0.27	0.15	0.15	0.27	0.00	0.0%
70.01	10	4386	0.28	0.27	0.03	0.27	0.27	0.15	0.19	0.27	0.00	0.0%
71.01	10	4386	1.44	1.38	0.15	1.40	1.40	0.59	0.62	1.40	0.00	0.0%
71.02	10	4386	1.76	1.69	0.18	1.72	1.72	0.90	1.00	1.72	0.00	0.0%
72.01	360	4734	0.31	0.30	0.06	0.31	0.28	0.26	0.33	0.33	0.02	6.5%
73.01	10	4386	0.13	0.13	0.01	0.13	0.13	0.09	0.12	0.13	0.00	0.0%
73.02	10	4386	0.27	0.26	0.03	0.26	0.26	0.21	0.27	0.27	0.01	3.8%
73.03	360	4734	0.49	0.44	0.11	0.45	0.44	0.42	0.54	0.54	0.09	20.0%
74.01	360	4734	0.08	0.08	0.02	0.08	0.05	0.07	0.09	0.09	0.01	12.5%
75.01	10	4386	0.06	0.05	0.01	0.05	0.05	0.04	0.05	0.05	0.00	0.0%
76.01	360	4740	0.42	0.39	0.08	0.40	0.11	0.39	0.46	0.46	0.06	15.0%
77.01	360	4740	0.48	0.44	0.09	0.45	0.04	0.43	0.54	0.54	0.09	20.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4386 for the 10 minute duration	TP 4711 for the 4.5 hour duration	TP 4739 for the 6 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
78.01	10	4382	0.11	0.11	0.01	0.11	0.12	0.06	0.06	0.12	0.01	9.1%
78.02	360	4739	2.39	2.36	0.72	2.45	0.16	2.28	2.45	2.45	0.00	0.0%
78.03	270	4706	3.36	3.24	0.91	3.30	1.35	3.19	3.46	3.46	0.16	4.8%
78.04	270	4706	3.64	3.52	0.96	3.56	1.74	3.49	3.75	3.75	0.19	5.3%
78.05	270	4706	3.85	3.72	0.99	3.73	1.93	3.69	3.97	3.97	0.24	6.4%
78.06	360	4739	4.97	4.87	1.14	5.25	2.39	4.78	5.25	5.25	0.00	0.0%
78.07	360	4740	6.19	6.03	1.36	6.50	2.61	5.99	6.55	6.55	0.05	0.8%
79.01	120	4645	0.25	0.25	0.08	0.26	0.25	0.21	0.19	0.25	-0.01	-3.8%
79.02	120	4643	0.50	0.48	0.16	0.48	0.47	0.44	0.40	0.47	-0.01	-2.1%
79.03	120	4643	0.65	0.62	0.20	0.63	0.62	0.58	0.54	0.62	-0.01	-1.6%
80.01	120	4643	0.16	0.15	0.05	0.15	0.17	0.14	0.13	0.17	0.02	13.3%
81.01	120	4642	0.06	0.05	0.02	0.06	0.05	0.04	0.04	0.05	-0.01	-16.7%
82.01	10	4386	0.25	0.24	0.02	0.25	0.25	0.17	0.15	0.25	0.00	0.0%
82.02	10	4386	0.39	0.37	0.04	0.38	0.38	0.31	0.29	0.38	0.00	0.0%
82.03	10	4386	0.65	0.63	0.06	0.64	0.64	0.52	0.49	0.64	0.00	0.0%
83.01	10	4387	0.22	0.22	0.02	0.22	0.22	0.16	0.15	0.22	0.00	0.0%
84.01	10	4382	0.18	0.18	0.02	0.18	0.19	0.13	0.12	0.19	0.01	5.6%
84.02	10	4386	0.43	0.42	0.04	0.43	0.43	0.31	0.29	0.43	0.00	0.0%
85.01	10	4382	0.11	0.11	0.01	0.11	0.12	0.08	0.06	0.12	0.01	9.1%
86.01	10	4382	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.0%
86.02	10	4386	0.20	0.19	0.02	0.19	0.19	0.11	0.11	0.19	0.00	0.0%
87.01	120	4643	0.04	0.04	0.01	0.04	0.03	0.04	0.03	0.04	0.00	0.0%
88.01	10	4386	0.33	0.32	0.04	0.33	0.33	0.24	0.23	0.33	0.00	0.0%
88.02	10	4386	0.46	0.45	0.05	0.46	0.46	0.39	0.37	0.46	0.00	0.0%
88.03	360	4734	0.81	0.80	0.17	0.80	0.59	0.72	0.83	0.83	0.03	3.8%
88.04	360	4740	1.13	1.08	0.22	1.09	0.66	1.00	1.20	1.20	0.11	10.1%
89.01	360	4740	0.26	0.26	0.05	0.27	0.07	0.25	0.27	0.27	0.00	0.0%
89.02	360	4734	0.87	0.83	0.15	0.84	0.77	0.78	0.95	0.95	0.11	13.1%
89.03	10	4388	1.37	1.35	0.13	1.35	1.28	1.15	1.39	1.39	0.04	3.0%
90.01	360	4740	0.26	0.25	0.05	0.26	0.08	0.25	0.29	0.29	0.03	11.5%
91.01	10	4386	0.41	0.40	0.04	0.41	0.41	0.24	0.25	0.41	0.00	0.0%
92.01	10	4386	0.49	0.48	0.04	0.49	0.49	0.28	0.28	0.49	0.00	0.0%
92.02	10	4386	0.76	0.73	0.07	0.75	0.75	0.45	0.47	0.75	0.00	0.0%
_junc_116	270	4711	0.38	0.36	0.10	0.36	0.24	0.36	0.33	0.36	0.00	0.0%
_junc_123	10	4386	1.72	1.65	0.18	1.68	1.68	0.86	0.96	1.68	0.00	0.0%
_junc_125	360	4739	24.57	24.18	3.92	25.71	8.92	23.79	25.71	25.71	0.00	0.0%
_junc_126	360	4740	0.71	0.67	0.13	0.68	0.39	0.61	0.75	0.75	0.07	10.3%
_junc_130	270	4711	3.07	2.99	0.69	3.00	1.03	3.00	2.82	3.00	0.00	0.0%
_junc_133	10	4386	1.11	1.07	0.11	1.09	1.09	0.73	0.68	1.09	0.00	0.0%
_junc_135	10	4386	0.33	0.33	0.03	0.34	0.34	0.19	0.18	0.34	0.00	0.0%
_junc_136	10	4386	0.47	0.46	0.04	0.47	0.47	0.27	0.25	0.47	0.00	0.0%
_junc_138	10	4386	3.99	3.84	0.40	3.88	3.88	1.67	1.62	3.88	0.00	0.0%
_junc_142	10	4388	1.20	1.19	0.12	1.19	1.13	1.00	1.20	1.20	0.01	0.8%
_junc_150	270	4706	2.82	2.70	0.80	2.71	0.73	2.68	2.89	2.89	0.18	6.6%
_junc_151	10	4386	1.08	1.04	0.11	1.05	1.05	0.98	0.99	1.05	0.00	0.0%
_junc_158	360	4740	0.41	0.40	0.08	0.41	0.25	0.34	0.43	0.43	0.02	4.9%
_junc_162	270	4711	0.20	0.19	0.05	0.20	0.09	0.20	0.19	0.20	0.00	0.0%
_junc_19	10	4386	0.71	0.69	0.07	0.71	0.71	0.38	0.36	0.71	0.00	0.0%
_junc_21	270	2749	10.12	10.05	2.17	10.22	3.81	9.87	9.48	9.87	-0.35	-3.4%
_junc_28	360	4740	2.80	2.81	0.61	2.97	2.50	2.64	2.66	2.66	-0.31	-10.4%
_junc_29	270	2749	0.85	0.81	0.21	0.81	0.81	0.80	0.78	0.81	0.00	0.0%
_junc_30	10	4387	0.18	0.17	0.02	0.18	0.19	0.16	0.17	0.19	0.01	5.6%
_junc_32	270	2749	0.36	0.35	0.08	0.36	0.35	0.34	0.35	0.35	-0.01	-2.8%
_junc_37	270	2749	12.98	13.13	2.38	13.60	5.18	12.67	12.70	12.70	-0.90	-6.6%
_junc_38	10	4386	4.67	4.52	0.37	4.58	4.58	2.50	2.65	4.58	0.00	0.0%
_junc_40	10	4386	0.96	0.92	0.10	0.93	0.93	0.62	0.64	0.93	0.00	0.0%
_junc_41	360	4739	1.57	1.55	0.30	1.58	0.25	1.50	1.58	1.58	0.00	0.0%
_junc_42	10	4388	1.30	1.27	0.10	1.28	1.25	0.92	0.93	1.25	-0.03	-2.3%
_junc_44	360	4739	13.36	13.00	2.36	13.13	5.18	13.02	13.13	13.13	0.00	0.0%
_junc_47	360	4734	1.89	1.88	0.38	1.88	1.84	1.62	1.92	1.92	0.04	2.1%
_junc_50	10	4382	0.14	0.13	0.01	0.13	0.14	0.13	0.13	0.14	0.01	7.7%
_junc_59	360	4739	19.20	18.50	3.18	19.57	8.49	18.57	19.57	19.57	0.00	0.0%
_junc_64	270	2749	1.56	1.54	0.07	1.55	1.33	1.54	1.54	1.54	-0.01	-0.6%
_junc_68	120	4645	0.31	0.30	0.11	0.32	0.30	0.25	0.23	0.30	-0.02	-6.3%
_junc_69	360	4739	19.79	19.14	3.31	20.28	8.49	19.15	20.28	20.28	0.00	0.0%
_junc_71	270	2749	1.97	1.94	0.17	1.97	1.69	1.91	1.96	1.96	-0.01	-0.5%
_junc_74	270	2749	2.22	2.18	0.23	2.24	1.70	2.12	2.23	2.23	-0.01	-0.4%
_junc_76	360	4739	20.45	19.87	3.43	21.06	8.49	19.81	21.06	21.06	0.00	0.0%
_junc_80	360	4739	23.82	23.43	3.80	24.90	8.92	23.11	24.90	24.90	0.00	0.0%
_junc_81	360	4734	0.33	0.30	0.08	0.31	0.30	0.29	0.36	0.36	0.05	16.1%
_junc_84	360	4739	25.46	25.11	4.08	26.73	8.92	24.61	26.73	26.73	0.00	0.0%
_junc_85	360	4740	31.41	30.83	5.33	32.88	11.10	29.99	33.17	33.17	0.29	0.9%
_junc_86	360	4740	31.76	31.22	5.38	33.28	11.10	30.30	33.53	33.53	0.25	0.8%
_junc_88	360	4739	4.89	4.80	1.12	5.17	2.39	4.70	5.17	5.17	0.00	0.0%
_junc_91	360	4740	6.12	5.96	1.34	6.42	2.61	5.92	6.47	6.47	0.05	0.8%
US_OHH	360	4739	21.26	20.77	3.58	22.09	8.49	20.60	22.09	22.09	0.00	0.0%
US_Rail	360	4739	18.65	18.01	3.08	19.01	8.49	18.01	19.01	19.01	0.00	0.0%

Average Difference (All Subcatchments)	**0.00**	**0.88%**
Average Difference (Focus Locations)	**-0.07**	**-0.65%**

ARR2016 Results for 10% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)				Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4410 for the 15 minute duration	TP 4628 for the 2 hour duration	TP 4731 for the 6 hour duration	TP 4678 for the 6 hour duration			
			Average	Median	Standard Dev	Adopted						m^3/s	%
1.01	360	4731	0.65	0.65	0.16	0.67	0.11	0.62	0.67	0.61	0.67	0.00	0.0%
1.02	120	4628	1.25	1.09	0.35	1.15	0.36	1.15	1.29	1.10	1.29	0.14	12.2%
1.03	120	4628	2.55	2.23	0.73	2.36	0.68	2.36	2.62	2.25	2.62	0.26	11.0%
1.04	120	4628	5.11	4.51	1.46	4.75	1.32	4.75	5.11	4.52	5.11	0.36	7.6%
1.05	120	4628	5.75	5.13	1.53	5.43	1.36	5.43	5.85	5.28	5.85	0.42	7.7%
1.06	120	4628	5.89	5.28	1.54	5.60	1.38	5.60	5.98	5.43	5.98	0.38	6.8%
1.07	360	4731	7.94	7.66	2.09	7.74	2.58	7.66	7.74	7.55	7.74	0.00	0.0%
1.08	360	4731	13.32	12.88	3.42	13.00	4.84	12.85	13.00	12.69	13.00	0.00	0.0%
1.09	360	4672	13.95	13.41	3.59	13.47	6.09	13.40	13.36	13.32	13.40	-0.07	-0.5%
1.1	15	4410	0.73	0.73	0.08	0.73	0.73	0.37	0.64	0.59	0.73	0.00	0.0%
1.11	10	4378	5.54	5.44	0.37	5.50	5.68	3.38	4.18	3.70	5.68	0.18	3.3%
1.12	10	4373	5.55	5.44	0.37	5.50	5.73	3.61	4.48	4.02	5.73	0.23	4.2%
1.13	15	4410	5.55	5.53	0.52	5.73	5.73	3.72	4.67	4.22	5.73	0.00	0.0%
1.14	360	4678	23.77	23.68	4.71	23.76	11.59	20.84	23.60	23.76	23.76	0.00	0.0%
1.15	360	4678	24.85	24.77	4.84	24.92	11.60	21.59	24.61	24.92	24.92	0.00	0.0%
1.16	360	4678	25.37	25.27	4.90	25.48	11.61	21.91	25.06	25.48	25.48	0.00	0.0%
1.17	360	4678	25.68	25.51	4.88	25.81	11.62	22.01	25.21	25.81	25.81	0.00	0.0%
1.18	360	4678	25.90	25.69	4.90	26.04	11.62	22.10	25.34	26.04	26.04	0.00	0.0%
1.19	360	4678	26.40	26.08	4.93	26.54	11.64	22.33	25.63	26.54	26.54	0.00	0.0%
1.2	360	4678	26.82	26.43	4.98	26.93	11.64	22.58	25.92	26.93	26.93	0.00	0.0%
1.21	360	4678	30.35	29.86	5.37	30.19	11.99	25.08	29.18	30.19	30.19	0.00	0.0%
1.22	360	4678	31.46	31.00	5.50	31.32	12.00	25.72	30.31	31.32	31.32	0.00	0.0%
1.23	360	4678	32.60	32.14	5.68	32.44	12.02	26.43	31.46	32.44	32.44	0.00	0.0%
1.24	360	4678	33.23	32.79	5.78	33.06	12.02	26.81	32.09	33.06	33.06	0.00	0.0%
1.25	360	4678	41.80	41.24	7.85	41.67	14.17	33.08	40.69	41.67	41.67	0.00	0.0%
1.26	360	4678	43.12	42.67	7.99	43.09	14.19	33.87	41.87	43.09	43.09	0.00	0.0%
2.01	120	4628	0.18	0.14	0.06	0.15	0.03	0.15	0.16	0.14	0.16	0.01	6.7%
2.02	120	4628	0.72	0.59	0.25	0.61	0.20	0.61	0.68	0.56	0.68	0.07	11.5%
3.01	120	4628	0.42	0.36	0.14	0.36	0.26	0.36	0.41	0.35	0.41	0.05	13.9%
3.02	120	4628	1.94	1.70	0.56	1.77	0.53	1.77	1.92	1.68	1.92	0.15	8.5%
3.03	120	4628	2.46	2.19	0.70	2.29	0.62	2.29	2.45	2.17	2.45	0.16	7.0%
4.01	120	4628	0.78	0.67	0.23	0.70	0.20	0.70	0.77	0.66	0.77	0.07	10.0%
5.01	120	4628	0.60	0.55	0.14	0.57	0.09	0.57	0.62	0.56	0.62	0.05	8.8%
5.02	360	4731	1.24	1.23	0.30	1.28	0.16	1.17	1.28	1.17	1.28	0.00	0.0%
5.03	360	4731	2.00	2.02	0.45	2.13	1.59	1.78	2.13	1.91	2.13	0.00	0.0%
6.01	360	4731	1.07	1.06	0.28	1.09	0.11	1.03	1.09	1.00	1.09	0.00	0.0%
6.02	360	4731	1.42	1.41	0.37	1.46	0.13	1.36	1.46	1.34	1.46	0.00	0.0%
6.03	360	4731	2.13	2.12	0.56	2.18	0.20	2.04	2.18	1.99	2.18	0.00	0.0%
6.04	360	4731	3.62	3.62	0.95	3.75	1.15	3.43	3.75	3.37	3.75	0.00	0.0%
6.05	360	4731	4.23	4.21	1.12	4.36	1.21	4.01	4.36	3.93	4.36	0.00	0.0%
6.06	360	4731	4.53	4.48	1.18	4.60	1.54	4.31	4.60	4.25	4.60	0.00	0.0%
6.07	360	4731	5.30	5.17	1.35	5.28	2.22	5.04	5.28	5.00	5.28	0.00	0.0%
7.01	360	4731	0.48	0.48	0.13	0.50	0.07	0.46	0.50	0.45	0.50	0.00	0.0%
8.01	120	4628	0.28	0.24	0.08	0.24	0.24	0.24	0.27	0.22	0.27	0.03	12.5%
8.02	120	4626	1.17	1.06	0.32	1.08	0.93	1.05	1.18	1.00	1.18	0.10	9.3%
8.03	120	4626	1.52	1.39	0.40	1.40	0.95	1.39	1.55	1.36	1.55	0.15	10.7%
9.01	10	4373	0.48	0.46	0.06	0.46	0.47	0.37	0.41	0.34	0.47	0.01	2.2%
10.01	360	4731	0.38	0.37	0.10	0.39	0.07	0.36	0.39	0.36	0.39	0.00	0.0%
11.01	15	4410	0.41	0.40	0.04	0.41	0.41	0.32	0.40	0.35	0.41	0.00	0.0%
11.02	15	4410	0.95	0.95	0.10	0.96	0.96	0.76	0.88	0.75	0.96	0.00	0.0%
12.01	15	4410	0.32	0.32	0.04	0.32	0.32	0.23	0.25	0.22	0.32	0.00	0.0%
13.01	10	4373	0.26	0.25	0.02	0.26	0.26	0.18	0.19	0.16	0.26	0.00	0.0%
14.01	15	4410	1.29	1.28	0.15	1.29	1.29	0.63	0.69	0.59	1.29	0.00	0.0%
15.01	15	4410	2.06	2.03	0.25	2.05	2.05	1.02	1.12	0.95	2.05	0.00	0.0%
15.02	15	4410	2.74	2.71	0.31	2.73	2.73	1.40	1.57	1.37	2.73	0.00	0.0%
15.03	15	4410	4.85	4.84	0.50	4.88	4.88	2.56	2.91	2.52	4.88	0.00	0.0%
15.04	15	4410	4.89	4.88	0.50	4.92	4.92	2.70	3.11	2.69	4.92	0.00	0.0%
16.01	15	4410	2.00	1.99	0.21	2.01	2.01	0.82	0.86	0.75	2.01	0.00	0.0%
17.01	360	4731	0.24	0.24	0.05	0.25	0.08	0.20	0.25	0.24	0.25	0.00	0.0%
18.01	360	4731	0.15	0.14	0.03	0.15	0.01	0.14	0.15	0.14	0.15	0.00	0.0%
19.01	10	4372	0.60	0.57	0.07	0.57	0.58	0.37	0.39	0.32	0.58	0.01	1.8%
19.02	15	4410	1.01	0.99	0.13	1.00	1.00	0.71	0.76	0.63	1.00	0.00	0.0%
19.03	120	4626	1.53	1.37	0.43	1.39	1.40	1.35	1.49	1.23	1.49	0.10	7.2%
19.04	120	4626	1.83	1.66	0.46	1.70	1.45	1.63	1.93	1.66	1.93	0.23	13.5%
19.05	120	4626	2.04	1.87	0.49	1.88	1.57	1.86	2.15	1.89	2.15	0.27	14.4%
19.06	360	4730	3.71	3.74	0.86	3.94	2.99	3.38	4.04	3.54	4.04	0.10	2.5%
19.07	360	4730	5.18	5.37	1.04	5.60	3.82	4.52	5.69	5.14	5.69	0.09	1.6%
19.08	360	4660	1.88	1.88	0.06	1.89	0.63	1.36	1.88	2.01	2.01	0.12	6.3%
19.09	360	4660	2.05	2.05	0.07	2.05	0.67	1.50	2.07	2.19	2.19	0.14	6.8%
19.1	360	4678	16.50	16.22	3.57	16.24	6.86	15.40	16.19	16.24	16.24	0.00	0.0%
19.11	360	4678	16.93	16.63	3.65	16.69	6.86	15.75	16.58	16.69	16.69	0.00	0.0%
19.12	360	4678	17.19	16.91	3.67	16.99	6.86	15.91	16.84	16.99	16.99	0.00	0.0%
20.01	10	4373	0.23	0.22	0.02	0.23	0.22	0.16	0.16	0.13	0.22	-0.01	-4.3%
21.01	10	4373	0.26	0.25	0.03	0.25	0.25	0.19	0.21	0.17	0.25	0.00	0.0%
22.01	360	4731	0.24	0.24	0.06	0.25	0.05	0.23	0.25	0.23	0.25	0.00	0.0%
23.01	120	4626	0.10	0.09	0.03	0.09	0.08	0.08	0.10	0.08	0.10	0.01	11.1%
24.01	10	4372	0.22	0.22	0.02	0.22	0.21	0.19	0.23	0.20	0.23	0.01	4.5%
24.02	10	4378	0.28	0.28	0.02	0.28	0.28	0.24	0.27	0.23	0.28	0.00	0.0%
24.03	120	4626	0.52	0.50	0.11	0.52	0.52	0.46	0.56	0.50	0.56	0.04	7.7%
24.04	120	4626	1.28	1.18	0.29	1.22	1.21	1.14	1.37	1.18	1.37	0.15	12.3%
24.05	120	4626	1.60	1.50	0.36	1.55	1.48	1.42	1.73	1.50	1.73	0.18	11.6%
25.01	360	4731	0.21	0.21	0.04	0.22	0.13	0.17	0.22	0.20	0.22	0.00	0.0%
26.01	10	4373	0.27	0.26	0.03	0.27	0.27	0.23	0.26	0.21	0.27	0.00	0.0%
26.02	120	4626	0.60	0.54	0.16	0.54	0.51	0.54	0.60	0.50	0.60	0.06	11.1%
27.01	120	4628	0.23	0.20	0.06	0.21	0.16	0.21	0.23	0.20	0.23	0.02	9.5%
28.01	360	4731	0.22	0.22	0.05	0.23	0.20	0.20	0.23	0.21	0.23	0.00	0.0%
29.01	15	4410	0.09	0.08	0.01	0.08	0.08	0.07	0.08	0.07	0.08	0.00	0.0%
30.01	360	4672	0.27	0.28	0.03	0.28	0.18	0.25	0.28	0.28	0.28	0.00	0.0%
31.01	10	4373	0.24	0.23	0.02	0.24	0.24	0.18	0.21	0.18	0.24	0.00	0.0%
31.02	10	4378	0.66	0.65	0.06	0.66	0.65	0.45	0.64	0.58	0.65	-0.01	-1.5%
31.03	360	4678	0.88	0.92	0.13	0.94	0.80	0.62	0.99	0.94	0.99	0.05	5.3%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)				Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s) Average	Median	Standard Dev	Adopted	TP 4410 for the 15 minute duration	TP 4628 for the 2 hour duration	TP 4731 for the 6 hour duration	TP 4678 for the 6 hour duration		m^3/s	%
32.01	360	4731	0.16	0.17	0.03	0.17	0.12	0.14	0.17	0.17	0.17	0.00	0.0%
33.01	10	4375	0.20	0.20	0.00	0.20	0.20	0.16	0.17	0.15	0.20	0.00	0.0%
34.01	360	4672	0.17	0.18	0.02	0.18	0.07	0.17	0.18	0.18	0.18	0.00	0.0%
35.01	10	4372	0.12	0.12	0.01	0.12	0.12	0.10	0.12	0.10	0.12	0.00	0.0%
35.02	15	4410	0.44	0.43	0.05	0.44	0.44	0.31	0.34	0.27	0.44	0.00	0.0%
35.03	15	4410	0.73	0.72	0.08	0.73	0.73	0.51	0.56	0.45	0.73	0.00	0.0%
35.04	10	4378	0.90	0.88	0.07	0.89	0.90	0.71	0.82	0.70	0.90	0.01	1.1%
35.05	360	4731	0.66	0.66	0.12	0.66	0.40	0.59	0.66	0.65	0.66	0.00	0.0%
35.06	360	4730	0.62	0.64	0.07	0.65	0.28	0.52	0.62	0.66	0.66	0.01	1.5%
36.01	15	4410	0.26	0.26	0.03	0.26	0.26	0.15	0.16	0.13	0.26	0.00	0.0%
37.01	15	4415	0.11	0.11	0.01	0.11	0.11	0.06	0.06	0.05	0.11	0.00	0.0%
38.01	120	4626	0.14	0.14	0.03	0.14	0.10	0.13	0.15	0.13	0.15	0.01	7.1%
39.01	360	4660	0.41	0.42	0.08	0.42	0.14	0.31	0.44	0.41	0.44	0.02	4.8%
40.01	10	4372	0.16	0.15	0.02	0.16	0.15	0.09	0.10	0.08	0.15	-0.01	-6.3%
40.02	15	4410	0.30	0.30	0.04	0.30	0.30	0.19	0.22	0.19	0.30	0.00	0.0%
40.03	15	4410	0.85	0.84	0.09	0.85	0.85	0.55	0.68	0.59	0.85	0.00	0.0%
40.04	10	4378	1.21	1.18	0.09	1.19	1.21	0.87	1.01	0.89	1.21	0.02	1.7%
40.05	10	4372	1.63	1.61	0.05	1.62	1.68	1.25	1.54	1.38	1.68	0.06	3.7%
40.06	10	4372	1.75	1.72	0.08	1.72	1.88	1.39	1.75	1.58	1.88	0.16	0.0%
41.01	15	4410	0.30	0.30	0.04	0.30	0.30	0.22	0.23	0.19	0.30	0.00	0.0%
42.01	15	4410	0.37	0.37	0.05	0.37	0.37	0.27	0.30	0.26	0.37	0.00	0.0%
43.01	15	4410	0.11	0.11	0.01	0.11	0.11	0.06	0.10	0.09	0.11	0.00	0.0%
44.01	360	4678	0.18	0.19	0.03	0.19	0.11	0.14	0.20	0.19	0.20	0.01	5.3%
44.02	360	4660	0.34	0.35	0.06	0.36	0.29	0.26	0.37	0.34	0.37	0.01	2.8%
44.03	360	4731	0.50	0.52	0.09	0.54	0.33	0.40	0.54	0.51	0.54	0.00	0.0%
44.04	360	4725	0.87	0.89	0.12	0.91	0.43	0.59	0.97	0.97	0.97	0.06	6.6%
45.01	15	4410	0.12	0.12	0.02	0.12	0.12	0.08	0.11	0.10	0.12	0.00	0.0%
46.01	360	4591	0.21	0.22	0.03	0.23	0.06	0.12	0.23	0.23	0.23	0.00	0.0%
47.01	360	4660	0.13	0.13	0.02	0.14	0.04	0.10	0.14	0.13	0.14	0.00	0.0%
48.01	360	4696	0.28	0.28	0.03	0.28	0.15	0.14	0.32	0.32	0.32	0.04	14.3%
48.02	360	4725	0.58	0.61	0.08	0.63	0.30	0.40	0.66	0.64	0.66	0.03	4.8%
49.01	360	4731	0.29	0.30	0.06	0.31	0.16	0.24	0.31	0.29	0.31	0.00	0.0%
50.01	360	4660	0.37	0.38	0.06	0.38	0.18	0.28	0.40	0.37	0.40	0.02	5.3%
51.01	15	4410	0.11	0.11	0.01	0.11	0.11	0.08	0.13	0.11	0.13	0.02	18.2%
52.01	360	4678	0.44	0.47	0.07	0.47	0.39	0.28	0.51	0.47	0.51	0.04	8.5%
52.02	15	4408	0.99	0.99	0.09	0.99	1.01	0.52	0.76	0.69	1.01	0.02	2.0%
53.01	15	4410	0.40	0.39	0.04	0.40	0.40	0.17	0.17	0.14	0.40	0.00	0.0%
53.02	15	4410	1.29	1.29	0.13	1.30	1.30	0.54	0.55	0.47	1.30	0.00	0.0%
53.03	15	4416	1.67	1.68	0.14	1.68	1.70	0.72	0.73	0.61	1.70	0.02	1.2%
54.01	15	4410	0.56	0.56	0.07	0.56	0.56	0.23	0.22	0.19	0.56	0.00	0.0%
55.01	15	4410	0.46	0.45	0.06	0.46	0.46	0.19	0.19	0.16	0.46	0.00	0.0%
56.01	10	4373	0.42	0.41	0.04	0.41	0.41	0.19	0.20	0.17	0.41	0.00	0.0%
57.01	15	4410	0.54	0.54	0.06	0.54	0.54	0.33	0.38	0.33	0.54	0.00	0.0%
57.02	10	4373	0.73	0.70	0.06	0.70	0.74	0.42	0.48	0.42	0.74	0.04	5.7%
57.03	10	4372	0.86	0.85	0.06	0.85	0.86	0.50	0.56	0.49	0.86	0.01	1.2%
58.01	360	4731	0.75	0.74	0.16	0.76	0.01	0.66	0.76	0.74	0.76	0.00	0.0%
58.02	360	4731	0.94	0.95	0.21	0.97	0.08	0.83	0.97	0.92	0.97	0.00	0.0%
58.03	360	4731	1.18	1.18	0.26	1.21	0.14	1.06	1.21	1.15	1.21	0.00	0.0%
58.04	360	4731	2.26	2.25	0.53	2.31	0.33	2.08	2.31	2.18	2.31	0.00	0.0%
58.05	360	4731	3.26	3.22	0.77	3.29	0.48	2.99	3.29	3.15	3.29	0.00	0.0%
58.06	360	4731	3.27	3.23	0.77	3.30	0.48	3.01	3.30	3.16	3.30	0.00	0.0%
58.07	360	4731	4.66	4.58	1.09	4.60	1.39	4.32	4.60	4.56	4.60	0.00	0.0%
58.08	120	4626	1.38	1.38	0.03	1.39	1.36	1.37	1.37	1.36	1.37	-0.02	-1.4%
58.09	120	4626	1.97	1.98	0.16	2.02	1.80	1.86	2.02	1.93	2.02	0.00	0.0%
58.1	120	4626	2.27	2.28	0.22	2.33	2.01	2.12	2.35	2.24	2.35	0.02	0.9%
58.11	360	4730	2.53	2.57	0.25	2.63	2.12	2.35	2.66	2.52	2.66	0.03	1.1%
59.01	360	4731	0.56	0.55	0.13	0.57	0.13	0.51	0.57	0.53	0.57	0.00	0.0%
59.02	360	4731	0.90	0.89	0.22	0.92	0.14	0.84	0.92	0.86	0.92	0.00	0.0%
60.01	360	4731	0.31	0.31	0.08	0.32	0.07	0.30	0.32	0.29	0.32	0.00	0.0%
60.02	360	4731	0.88	0.87	0.21	0.90	0.09	0.80	0.90	0.84	0.90	0.00	0.0%
61.01	120	4628	0.20	0.18	0.05	0.19	0.12	0.19	0.20	0.17	0.20	0.01	5.3%
61.02	120	4628	0.66	0.59	0.19	0.59	0.40	0.59	0.65	0.56	0.65	0.06	10.2%
61.03	120	4628	1.12	1.01	0.28	1.04	0.75	1.04	1.12	1.00	1.12	0.08	7.7%
61.04	360	4731	1.54	1.57	0.36	1.65	1.05	1.42	1.65	1.49	1.65	0.00	0.0%
62.01	120	4628	0.30	0.26	0.09	0.27	0.14	0.27	0.30	0.26	0.30	0.03	11.1%
63.01	360	4731	0.19	0.19	0.05	0.20	0.06	0.18	0.20	0.18	0.20	0.00	0.0%
64.01	120	4626	0.07	0.06	0.02	0.06	0.04	0.06	0.07	0.06	0.07	0.01	16.7%
65.01	120	4626	0.16	0.16	0.03	0.17	0.14	0.15	0.17	0.14	0.17	0.00	0.0%
65.02	120	4626	0.28	0.26	0.07	0.28	0.27	0.25	0.27	0.23	0.27	-0.01	-3.6%
66.01	60	4475	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	-0.01	-50.0%
67.01	15	4410	0.36	0.36	0.04	0.36	0.36	0.23	0.28	0.25	0.36	0.00	0.0%
68.01	10	4373	0.19	0.18	0.02	0.19	0.18	0.13	0.18	0.16	0.18	-0.01	-5.3%
69.01	10	4373	0.21	0.20	0.02	0.20	0.20	0.11	0.14	0.12	0.20	0.00	0.0%
69.02	15	4410	0.32	0.32	0.04	0.32	0.32	0.18	0.22	0.19	0.32	0.00	0.0%
70.01	15	4410	0.32	0.32	0.04	0.32	0.32	0.18	0.26	0.23	0.32	0.00	0.0%
71.01	15	4410	1.71	1.69	0.21	1.71	1.71	0.78	0.91	0.80	1.71	0.00	0.0%
71.02	15	4410	2.08	2.06	0.25	2.08	2.08	1.13	1.41	1.26	2.08	0.00	0.0%
72.01	360	4660	0.41	0.42	0.07	0.43	0.33	0.32	0.43	0.40	0.43	0.00	0.0%
73.01	10	4373	0.15	0.15	0.02	0.15	0.15	0.11	0.17	0.15	0.17	0.02	13.3%
73.02	360	4660	0.33	0.34	0.06	0.35	0.31	0.25	0.37	0.34	0.37	0.02	5.7%
73.03	360	4660	0.66	0.68	0.11	0.69	0.54	0.49	0.74	0.68	0.74	0.05	7.2%
74.01	360	4730	0.12	0.12	0.03	0.13	0.06	0.10	0.13	0.12	0.13	0.00	0.0%
75.01	15	4410	0.07	0.07	0.01	0.07	0.07	0.05	0.07	0.07	0.07	0.00	0.0%
76.01	360	4731	0.57	0.58	0.12	0.60	0.12	0.48	0.60	0.57	0.60	0.00	0.0%
77.01	360	4678	0.67	0.70	0.11	0.70	0.05	0.47	0.71	0.70	0.71	0.01	1.4%
78.01	10	4372	0.13	0.12	0.01	0.13	0.12	0.08	0.09	0.07	0.12	-0.01	-7.7%
78.02	360	4731	3.59	3.51	1.12	3.53	0.27	3.20	3.53	3.50	3.53	0.00	0.0%
78.03	360	4731	4.88	4.83	1.40	4.87	1.67	4.38	4.87	4.79	4.87	0.00	0.0%
78.04	360	4731	5.24	5.20	1.46	5.23	2.06	4.71	5.23	5.17	5.23	0.00	0.0%
78.05	360	4731	5.53	5.48	1.52	5.51	2.26	4.96	5.51	5.44	5.51	0.00	0.0%
78.06	360	4731	7.13	7.10	1.83	7.16	2.81	6.22	7.16	7.04	7.16	0.00	0.0%
78.07	360	4678	8.72	8.60	2.10	8.64	3.82	7.52	8.57	8.64	8.64	0.00	0.0%
79.01	120	4628	0.31	0.27	0.09	0.27	0.28	0.27	0.30	0.25	0.30	0.03	11.1%
79.02	120	4628	0.65	0.57	0.18	0.57	0.57	0.57	0.62	0.53	0.62	0.05	8.8%

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	Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s): TP 4410 for the 15 minute duration	TP 4628 for the 2 hour duration	TP 4731 for the 6 hour duration	TP 4678 for the 6 hour duration	Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted: m^3/s	%
79.03	120	4626	0.84	0.75	0.23	0.75	0.76	0.74	0.82	0.69	0.82	0.07	9.3%
80.01	120	4626	0.21	0.18	0.06	0.19	0.17	0.19	0.20	0.17	0.20	0.01	5.3%
81.01	120	4628	0.07	0.06	0.02	0.06	0.06	0.06	0.07	0.05	0.07	0.01	16.7%
82.01	10	4373	0.29	0.28	0.03	0.28	0.29	0.23	0.25	0.21	0.29	0.01	3.6%
82.02	120	4626	0.47	0.42	0.13	0.43	0.46	0.40	0.44	0.36	0.46	0.03	7.0%
82.03	120	4626	0.76	0.69	0.20	0.71	0.76	0.67	0.76	0.64	0.76	0.05	7.0%
83.01	10	4373	0.26	0.25	0.03	0.25	0.25	0.22	0.24	0.19	0.25	0.00	0.0%
84.01	10	4372	0.21	0.20	0.02	0.20	0.20	0.17	0.18	0.15	0.20	0.00	0.0%
84.02	10	4373	0.50	0.48	0.05	0.49	0.49	0.39	0.45	0.36	0.49	0.00	0.0%
85.01	10	4372	0.14	0.13	0.02	0.13	0.13	0.10	0.11	0.09	0.13	0.00	0.0%
86.01	10	4372	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.0%
86.02	15	4410	0.23	0.22	0.03	0.22	0.22	0.15	0.17	0.14	0.22	0.00	0.0%
87.01	120	4626	0.06	0.05	0.02	0.05	0.04	0.05	0.05	0.04	0.05	0.00	0.0%
88.01	15	4410	0.39	0.38	0.05	0.39	0.39	0.30	0.33	0.28	0.39	0.00	0.0%
88.02	120	4626	0.55	0.51	0.13	0.53	0.52	0.49	0.55	0.48	0.55	0.02	3.8%
88.03	360	4731	1.06	1.10	0.22	1.14	0.68	0.88	1.14	1.05	1.14	0.00	0.0%
88.04	360	4731	1.52	1.57	0.30	1.62	0.76	1.22	1.62	1.53	1.62	0.00	0.0%
89.01	360	4731	0.35	0.34	0.08	0.35	0.08	0.31	0.35	0.33	0.35	0.00	0.0%
89.02	360	4660	1.16	1.18	0.21	1.21	0.98	0.92	1.23	1.17	1.23	0.02	1.7%
89.03	360	4660	1.71	1.76	0.31	1.83	1.65	1.37	1.84	1.70	1.84	0.01	0.5%
90.01	360	4731	0.36	0.36	0.08	0.37	0.10	0.30	0.37	0.35	0.37	0.00	0.0%
91.01	10	4373	0.47	0.46	0.04	0.47	0.47	0.29	0.35	0.31	0.47	0.00	0.0%
92.01	15	4410	0.56	0.55	0.06	0.56	0.56	0.34	0.40	0.34	0.56	0.00	0.0%
92.02	15	4410	0.88	0.87	0.09	0.88	0.88	0.54	0.66	0.57	0.88	0.00	0.0%
_junc_116	120	4628	0.50	0.44	0.14	0.46	0.26	0.46	0.50	0.43	0.50	0.04	8.7%
_junc_123	15	4410	2.03	2.01	0.24	2.03	2.03	1.07	1.35	1.19	2.03	0.00	0.0%
_junc_125	360	4678	31.97	31.49	5.60	31.78	12.01	26.05	30.81	31.78	31.78	0.00	0.0%
_junc_126	360	4678	0.95	0.99	0.14	1.02	0.47	0.68	1.06	1.02	1.06	0.04	3.9%
_junc_130	360	4731	4.00	3.98	1.05	4.13	1.20	3.78	4.13	3.72	4.13	0.00	0.0%
_junc_133	15	4410	1.30	1.28	0.16	1.29	1.29	0.99	1.07	0.88	1.29	0.00	0.0%
_junc_135	10	4373	0.39	0.37	0.04	0.38	0.38	0.26	0.28	0.22	0.38	0.00	0.0%
_junc_136	15	4410	0.54	0.53	0.06	0.54	0.54	0.37	0.40	0.32	0.54	0.00	0.0%
_junc_138	15	4410	4.69	4.68	0.49	4.71	4.71	2.21	2.43	2.10	4.71	0.00	0.0%
_junc_142	360	4660	1.47	1.52	0.27	1.57	1.44	1.17	1.59	1.47	1.59	0.02	1.3%
_junc_150	360	4731	4.16	4.09	1.24	4.10	0.91	3.72	4.10	4.08	4.10	0.00	0.0%
_junc_151	120	4626	1.35	1.25	0.31	1.30	1.28	1.20	1.45	1.25	1.45	0.15	11.5%
_junc_158	360	4725	0.56	0.58	0.07	0.59	0.30	0.38	0.63	0.61	0.63	0.04	6.8%
_junc_162	120	4628	0.26	0.23	0.06	0.24	0.10	0.24	0.27	0.24	0.27	0.03	12.5%
_junc_19	10	4373	0.83	0.80	0.09	0.80	0.81	0.53	0.55	0.46	0.81	0.01	1.3%
_junc_21	360	4731	13.12	12.70	3.38	12.82	4.75	12.67	12.82	12.49	12.82	0.00	0.0%
_junc_28	120	4626	3.57	3.30	0.80	3.34	2.99	3.26	3.88	3.38	3.88	0.54	16.2%
_junc_29	120	4626	1.12	1.02	0.28	1.05	0.99	0.99	1.17	1.00	1.17	0.12	11.4%
_junc_30	360	4731	0.22	0.22	0.05	0.23	0.20	0.20	0.23	0.21	0.23	0.00	0.0%
_junc_32	360	4730	0.45	0.46	0.09	0.49	0.41	0.40	0.50	0.44	0.50	0.01	2.0%
_junc_37	360	4678	16.87	16.57	3.64	16.62	6.86	15.69	16.52	16.62	16.62	0.00	0.0%
_junc_38	10	4378	5.45	5.31	0.36	5.36	5.57	3.17	3.89	3.40	5.57	0.21	3.9%
_junc_40	15	4410	1.13	1.12	0.12	1.13	1.13	0.77	0.91	0.78	1.13	0.00	0.0%
_junc_41	360	4731	2.08	2.07	0.48	2.14	0.28	1.90	2.14	2.01	2.14	0.00	0.0%
_junc_42	10	4377	1.51	1.49	0.06	1.50	1.52	1.12	1.33	1.15	1.52	0.02	1.3%
_junc_44	360	4678	17.38	17.12	3.69	17.21	6.86	16.03	17.03	17.21	17.21	0.00	0.0%
_junc_47	360	4660	2.46	2.56	0.41	2.58	2.27	1.94	2.72	2.54	2.72	0.14	5.4%
_junc_50	120	4626	0.18	0.17	0.04	0.18	0.15	0.16	0.18	0.15	0.18	0.00	0.0%
_junc_59	360	4678	25.32	25.23	4.89	25.44	11.61	21.87	25.02	25.44	25.44	0.00	0.0%
_junc_64	120	4625	1.66	1.65	0.09	1.67	1.59	1.60	1.66	1.60	1.66	-0.01	-0.6%
_junc_68	120	4628	0.38	0.33	0.12	0.33	0.34	0.33	0.37	0.31	0.37	0.04	12.1%
_junc_69	360	4678	25.96	25.74	4.90	26.11	11.62	22.10	25.37	26.11	26.11	0.00	0.0%
_junc_71	120	4625	2.19	2.20	0.21	2.25	1.99	2.03	2.25	2.13	2.25	0.00	0.0%
_junc_74	360	4730	2.49	2.52	0.24	2.58	2.09	2.30	2.61	2.47	2.61	0.03	1.2%
_junc_76	360	4678	26.78	26.39	4.98	26.89	11.64	22.55	25.88	26.89	26.89	0.00	0.0%
_junc_80	360	4678	30.93	30.45	5.45	30.74	12.00	25.42	29.74	30.74	30.74	0.00	0.0%
_junc_81	360	4660	0.45	0.47	0.08	0.48	0.38	0.34	0.50	0.45	0.50	0.02	4.2%
_junc_84	360	4678	33.22	32.78	5.78	33.06	12.02	26.81	32.09	33.06	33.06	0.00	0.0%
_junc_85	360	4678	41.77	41.21	7.85	41.64	14.17	33.05	40.66	41.64	41.64	0.00	0.0%
_junc_86	360	4678	42.24	41.73	7.91	42.13	14.18	33.35	41.06	42.13	42.13	0.00	0.0%
_junc_88	360	4731	7.03	7.01	1.81	7.08	2.80	6.14	7.08	6.94	7.08	0.00	0.0%
_junc_91	360	4678	8.63	8.53	2.09	8.55	3.81	7.45	8.51	8.55	8.55	0.00	0.0%
US_OHH	360	4678	27.82	27.42	5.13	27.84	11.65	23.13	26.59	27.84	27.84	0.00	0.0%
US_Rail	360	4678	24.62	24.56	4.81	24.69	11.60	21.45	24.43	24.69	24.69	0.00	0.0%

	m^3/s	%
Average Difference (All Subcatchments)	**0.03**	**2.19%**
Average Difference (Focus Locations)	**0.04**	**0.83%**

ARR2016 Results for 5% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s) Average	Median	Standard Dev	Adopted	TP 4410 for the 15 minute duration	TP 4628 for the 2 hour duration	TP 4731 for the 6 hour duration		m^3/s	%
1.01	120	4628	0.80	0.76	0.17	0.77	0.13	0.77	0.80	0.80	0.03	3.9%
1.02	120	4628	1.55	1.36	0.43	1.41	0.44	1.41	1.53	1.53	0.12	8.5%
1.03	120	4628	3.17	2.79	0.89	2.90	0.80	2.90	3.10	3.10	0.20	6.9%
1.04	120	4628	6.35	5.66	1.78	5.78	1.55	5.78	6.05	6.05	0.27	4.7%
1.05	120	4628	7.17	6.51	1.90	6.69	1.64	6.69	6.93	6.93	0.24	3.6%
1.06	120	4628	7.35	6.72	1.92	6.91	1.67	6.91	7.08	7.08	0.17	2.5%
1.07	120	4625	9.69	9.18	2.27	9.36	3.03	9.53	9.17	9.53	0.17	1.8%
1.08	180	4658	16.07	15.38	3.25	15.69	5.67	15.69	15.40	15.69	0.00	0.0%
1.09	180	4658	16.85	16.20	3.41	16.64	7.20	16.64	15.83	16.64	0.00	0.0%
1.1	15	4410	0.86	0.86	0.09	0.86	0.86	0.86	0.77	0.86	0.00	0.0%
1.11	15	4381	6.50	6.49	0.59	6.61	6.69	6.61	4.93	6.69	0.08	1.2%
1.12	15	4381	6.57	6.54	0.59	6.70	6.76	6.70	5.28	6.76	0.06	0.9%
1.13	15	4381	6.58	6.56	0.59	6.73	6.78	6.73	5.49	6.78	0.05	0.7%
1.14	360	4678	28.25	27.89	5.78	27.92	13.79	27.92	27.86	27.92	0.00	0.0%
1.15	360	4678	29.54	29.18	5.95	29.30	13.88	29.30	29.05	29.30	0.00	0.0%
1.16	360	4678	30.16	29.77	6.03	29.95	13.93	29.95	29.57	29.95	0.00	0.0%
1.17	360	4678	30.55	30.04	6.06	30.33	13.99	30.33	29.74	30.33	0.00	0.0%
1.18	360	4678	30.81	30.26	6.08	30.60	14.03	30.60	29.90	30.60	0.00	0.0%
1.19	360	4678	31.41	30.97	6.13	31.19	14.08	31.19	30.23	31.19	0.00	0.0%
1.2	360	4678	31.94	31.50	6.25	31.64	14.14	31.64	30.56	31.64	0.00	0.0%
1.21	360	4672	35.93	35.37	6.83	35.49	14.96	35.49	34.05	35.49	0.00	0.0%
1.22	360	4672	37.27	36.72	7.01	36.85	15.04	36.85	35.40	36.85	0.00	0.0%
1.23	360	4672	38.63	38.09	7.24	38.27	15.13	38.27	36.75	38.27	0.00	0.0%
1.24	360	4672	39.38	38.85	7.36	39.07	15.17	39.07	37.48	39.07	0.00	0.0%
1.25	360	4672	49.84	49.19	9.90	49.38	16.90	49.38	47.85	49.38	0.00	0.0%
1.26	360	4672	51.42	50.91	10.08	51.16	17.00	51.16	49.25	51.16	0.00	0.0%
2.01	60	4565	0.23	0.23	0.06	0.24	0.05	0.24	0.19	0.24	0.00	0.0%
2.02	60	4565	0.94	0.91	0.24	0.94	0.27	0.94	0.81	0.94	0.00	0.0%
3.01	120	4623	0.52	0.44	0.17	0.45	0.30	0.44	0.49	0.49	0.04	8.9%
3.02	120	4628	2.40	2.12	0.69	2.13	0.64	2.13	2.28	2.28	0.15	7.0%
3.03	120	4628	3.07	2.75	0.85	2.76	0.73	2.76	2.92	2.92	0.16	5.8%
4.01	120	4628	0.96	0.83	0.28	0.84	0.28	0.84	0.91	0.91	0.07	8.3%
5.01	90	4593	0.75	0.74	0.17	0.76	0.13	0.76	0.73	0.76	0.00	0.0%
5.02	120	4628	1.50	1.44	0.32	1.47	0.22	1.47	1.52	1.52	0.05	3.4%
5.03	120	4626	2.42	2.31	0.44	2.32	1.87	2.31	2.51	2.51	0.19	8.2%
6.01	90	4593	1.32	1.31	0.28	1.36	0.22	1.36	1.30	1.36	0.00	0.0%
6.02	120	4628	1.77	1.65	0.44	1.67	0.28	1.67	1.74	1.74	0.07	4.2%
6.03	90	4593	2.64	2.62	0.59	2.70	0.38	2.70	2.60	2.70	0.00	0.0%
6.04	120	4628	4.55	4.20	1.14	4.26	1.34	4.26	4.48	4.48	0.22	5.2%
6.05	120	4628	5.28	4.91	1.31	4.98	1.43	4.98	5.20	5.20	0.22	4.4%
6.06	120	4628	5.60	5.28	1.33	5.37	1.82	5.37	5.48	5.48	0.11	2.0%
6.07	120	4628	6.46	6.19	1.41	6.29	2.61	6.29	6.29	6.29	0.00	0.0%
7.01	120	4628	0.60	0.57	0.14	0.58	0.10	0.58	0.60	0.60	0.02	3.4%
8.01	60	4475	0.34	0.32	0.07	0.32	0.29	0.32	0.31	0.32	0.00	0.0%
8.02	120	4628	1.46	1.30	0.39	1.31	1.09	1.31	1.40	1.40	0.09	6.9%
8.03	120	4628	1.91	1.72	0.49	1.75	1.11	1.75	1.86	1.86	0.11	6.3%
9.01	10	4372	0.56	0.54	0.06	0.54	0.55	0.54	0.48	0.55	0.01	1.9%
10.01	120	4628	0.47	0.44	0.11	0.45	0.09	0.45	0.47	0.47	0.02	4.4%
11.01	120	4626	0.49	0.48	0.10	0.52	0.48	0.44	0.47	0.48	-0.04	-7.7%
11.02	15	4416	1.13	1.14	0.11	1.15	1.13	1.15	1.04	1.15	0.00	0.0%
12.01	15	4415	0.38	0.38	0.04	0.38	0.38	0.38	0.30	0.38	0.00	0.0%
13.01	15	4410	0.30	0.30	0.04	0.30	0.30	0.30	0.23	0.30	0.00	0.0%
14.01	15	4410	1.52	1.51	0.19	1.52	1.52	1.52	0.81	1.52	0.00	0.0%
15.01	15	4410	2.41	2.39	0.28	2.41	2.41	2.41	1.31	2.41	0.00	0.0%
15.02	15	4410	3.22	3.20	0.36	3.21	3.21	3.21	1.85	3.21	0.00	0.0%
15.03	15	4410	5.70	5.71	0.58	5.74	5.74	5.74	3.41	5.74	0.00	0.0%
15.04	15	4410	5.75	5.76	0.57	5.79	5.79	5.79	3.63	5.79	0.00	0.0%
16.01	15	4410	2.35	2.34	0.25	2.36	2.36	2.36	1.00	2.36	0.00	0.0%
17.01	360	4731	0.29	0.29	0.06	0.29	0.09	0.29	0.29	0.29	0.00	0.0%
18.01	360	4731	0.17	0.17	0.04	0.17	0.03	0.17	0.17	0.17	0.00	0.0%
19.01	10	4372	0.70	0.67	0.08	0.68	0.68	0.68	0.45	0.68	0.00	0.0%
19.02	10	4373	1.19	1.15	0.12	1.16	1.17	1.16	0.90	1.17	0.01	0.9%
19.03	120	4626	1.86	1.63	0.52	1.63	1.64	1.62	1.75	1.75	0.12	7.4%
19.04	120	4626	2.30	2.07	0.57	2.09	1.70	2.05	2.29	2.29	0.20	9.6%
19.05	120	4628	2.56	2.32	0.60	2.33	1.84	2.33	2.54	2.54	0.21	9.0%
19.06	120	4628	4.64	4.27	1.01	4.27	3.52	4.27	4.75	4.75	0.48	11.2%
19.07	360	4730	6.12	6.28	1.26	6.56	4.51	6.56	6.60	6.60	0.04	0.6%
19.08	360	4660	2.11	2.11	0.06	2.11	0.70	2.11	2.11	2.11	0.00	0.0%
19.09	360	4731	2.31	2.32	0.07	2.32	0.77	2.32	2.32	2.32	0.00	0.0%
19.1	360	4731	19.51	19.06	4.27	19.06	8.08	19.06	19.06	19.06	0.00	0.0%
19.11	360	4678	20.04	19.54	4.39	19.58	8.12	19.58	19.51	19.58	0.00	0.0%
19.12	360	4678	20.35	19.88	4.43	19.94	8.14	19.94	19.82	19.94	0.00	0.0%
20.01	15	4410	0.27	0.26	0.03	0.27	0.27	0.27	0.20	0.27	0.00	0.0%
21.01	15	4410	0.30	0.29	0.04	0.30	0.30	0.30	0.24	0.30	0.00	0.0%
22.01	90	4593	0.30	0.30	0.07	0.31	0.06	0.31	0.29	0.31	0.00	0.0%
23.01	120	4626	0.13	0.11	0.04	0.11	0.10	0.11	0.12	0.12	0.01	9.1%
24.01	120	4626	0.27	0.25	0.06	0.26	0.25	0.24	0.25	0.25	-0.01	-3.8%
24.02	120	4626	0.33	0.31	0.08	0.32	0.33	0.29	0.32	0.33	0.01	3.1%
24.03	120	4626	0.65	0.62	0.14	0.65	0.61	0.59	0.66	0.66	0.01	1.5%
24.04	120	4626	1.59	1.45	0.36	1.48	1.41	1.43	1.61	1.61	0.13	8.8%
24.05	120	4626	1.99	1.85	0.44	1.90	1.74	1.80	2.02	2.02	0.12	6.3%
25.01	360	4731	0.25	0.25	0.05	0.26	0.15	0.26	0.26	0.26	0.00	0.0%
26.01	120	4626	0.32	0.28	0.09	0.28	0.32	0.27	0.30	0.32	0.04	14.3%
26.02	120	4628	0.74	0.64	0.20	0.65	0.60	0.65	0.71	0.71	0.06	9.2%
27.01	120	4628	0.28	0.25	0.08	0.25	0.19	0.25	0.27	0.27	0.02	8.0%
28.01	120	4626	0.27	0.26	0.05	0.28	0.24	0.25	0.27	0.27	-0.01	-3.6%
29.01	10	4372	0.10	0.10	0.01	0.10	0.10	0.10	0.09	0.10	0.00	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s) Average	Median	Standard Dev	Adopted	TP 4410 for the 15 minute duration	TP 4628 for the 2 hour duration	TP 4731 for the 6 hour duration		m^3/s	%
30.01	360	4730	0.31	0.31	0.04	0.31	0.20	0.31	0.29	0.31	0.00	0.0%
31.01	15	4410	0.28	0.28	0.03	0.28	0.28	0.28	0.25	0.28	0.00	0.0%
31.02	15	4410	0.77	0.76	0.08	0.77	0.77	0.77	0.76	0.77	0.00	0.0%
31.03	360	4678	1.07	1.11	0.17	1.12	0.94	1.12	1.19	1.19	0.07	6.3%
32.01	360	4731	0.19	0.19	0.03	0.19	0.14	0.19	0.19	0.19	0.00	0.0%
33.01	10	4376	0.21	0.21	0.00	0.21	0.21	0.21	0.19	0.21	0.00	0.0%
34.01	180	4662	0.19	0.19	0.02	0.19	0.08	0.19	0.19	0.19	0.00	0.0%
35.01	120	4626	0.15	0.14	0.04	0.14	0.14	0.14	0.14	0.14	0.00	0.0%
35.02	15	4410	0.51	0.50	0.06	0.51	0.51	0.51	0.40	0.51	0.00	0.0%
35.03	15	4410	0.85	0.85	0.10	0.86	0.86	0.86	0.67	0.86	0.00	0.0%
35.04	10	4378	1.04	1.01	0.08	1.03	1.06	1.03	0.97	1.06	0.03	2.9%
35.05	360	4731	0.76	0.77	0.14	0.77	0.48	0.77	0.77	0.77	0.00	0.0%
35.06	360	4730	0.71	0.73	0.08	0.74	0.30	0.74	0.70	0.74	0.00	0.0%
36.01	15	4410	0.31	0.31	0.04	0.31	0.31	0.31	0.20	0.31	0.00	0.0%
37.01	15	4410	0.13	0.13	0.02	0.13	0.13	0.13	0.07	0.13	0.00	0.0%
38.01	120	4626	0.18	0.17	0.04	0.17	0.12	0.17	0.17	0.17	0.00	0.0%
39.01	360	4731	0.50	0.52	0.10	0.53	0.17	0.53	0.53	0.53	0.00	0.0%
40.01	10	4372	0.19	0.18	0.02	0.18	0.17	0.18	0.11	0.18	0.00	0.0%
40.02	15	4410	0.36	0.35	0.04	0.35	0.35	0.35	0.27	0.35	0.00	0.0%
40.03	15	4415	1.00	1.00	0.11	1.00	0.99	1.00	0.80	1.00	0.00	0.0%
40.04	10	4378	1.42	1.38	0.10	1.39	1.43	1.39	1.20	1.43	0.04	2.9%
40.05	10	4372	1.91	1.88	0.06	1.89	1.99	1.89	1.82	1.99	0.10	5.3%
40.06	15	4408	2.06	2.06	0.16	2.07	2.20	2.07	2.07	2.20	0.13	0.0%
41.01	15	4410	0.35	0.35	0.05	0.35	0.35	0.35	0.28	0.35	0.00	0.0%
42.01	15	4410	0.44	0.44	0.06	0.44	0.44	0.44	0.36	0.44	0.00	0.0%
43.01	15	4410	0.13	0.12	0.02	0.12	0.12	0.12	0.12	0.12	0.00	0.0%
44.01	360	4660	0.22	0.23	0.04	0.23	0.13	0.23	0.23	0.23	0.00	0.0%
44.02	360	4731	0.40	0.41	0.08	0.43	0.34	0.43	0.43	0.43	0.00	0.0%
44.03	360	4731	0.60	0.61	0.12	0.63	0.38	0.63	0.63	0.63	0.00	0.0%
44.04	360	4678	1.07	1.13	0.16	1.16	0.51	1.16	1.17	1.17	0.01	0.9%
45.01	10	4372	0.15	0.14	0.02	0.14	0.14	0.14	0.14	0.14	0.00	0.0%
46.01	360	4678	0.25	0.27	0.03	0.27	0.07	0.27	0.27	0.27	0.00	0.0%
47.01	360	4731	0.15	0.16	0.03	0.16	0.05	0.16	0.16	0.16	0.00	0.0%
48.01	360	4696	0.35	0.34	0.04	0.35	0.17	0.35	0.40	0.40	0.05	14.3%
48.02	360	4678	0.71	0.75	0.10	0.78	0.35	0.78	0.79	0.79	0.01	1.3%
49.01	360	4731	0.35	0.35	0.07	0.36	0.18	0.36	0.36	0.36	0.00	0.0%
50.01	360	4731	0.45	0.46	0.09	0.48	0.21	0.48	0.48	0.48	0.00	0.0%
51.01	15	4415	0.13	0.13	0.02	0.13	0.13	0.13	0.15	0.15	0.02	15.4%
52.01	360	4678	0.54	0.55	0.09	0.56	0.47	0.56	0.61	0.61	0.05	8.9%
52.02	15	4415	1.17	1.17	0.11	1.18	1.19	1.18	0.91	1.19	0.01	0.8%
53.01	15	4381	0.47	0.47	0.05	0.47	0.47	0.47	0.19	0.47	0.00	0.0%
53.02	15	4415	1.51	1.51	0.15	1.51	1.53	1.51	0.64	1.53	0.02	1.3%
53.03	15	4416	1.97	1.98	0.16	1.98	1.99	1.98	0.85	1.99	0.01	0.5%
54.01	15	4410	0.66	0.65	0.08	0.65	0.65	0.65	0.26	0.65	0.00	0.0%
55.01	15	4410	0.54	0.54	0.07	0.54	0.54	0.54	0.22	0.54	0.00	0.0%
56.01	15	4410	0.48	0.47	0.05	0.48	0.48	0.48	0.25	0.48	0.00	0.0%
57.01	15	4410	0.64	0.63	0.08	0.63	0.63	0.63	0.44	0.63	0.00	0.0%
57.02	10	4372	0.86	0.82	0.08	0.83	0.87	0.83	0.57	0.87	0.04	4.8%
57.03	10	4372	1.03	1.01	0.07	1.02	1.01	1.02	0.65	1.02	0.00	0.0%
58.01	360	4731	0.90	0.88	0.21	0.90	0.07	0.90	0.90	0.90	0.00	0.0%
58.02	360	4731	1.12	1.12	0.26	1.15	0.11	1.15	1.15	1.15	0.00	0.0%
58.03	360	4731	1.41	1.40	0.33	1.44	0.16	1.44	1.44	1.44	0.00	0.0%
58.04	360	4731	2.71	2.67	0.65	2.74	0.39	2.74	2.74	2.74	0.00	0.0%
58.05	360	4731	3.90	3.83	0.94	3.89	0.56	3.89	3.89	3.89	0.00	0.0%
58.06	360	4731	3.92	3.85	0.95	3.91	0.57	3.91	3.91	3.91	0.00	0.0%
58.07	360	4731	5.58	5.40	1.33	5.43	1.64	5.43	5.43	5.43	0.00	0.0%
58.08	120	4626	1.41	1.41	0.04	1.42	1.38	1.40	1.41	1.41	-0.01	-0.7%
58.09	120	4625	2.16	2.15	0.18	2.20	1.95	2.07	2.14	2.14	-0.06	-2.7%
58.1	120	4625	2.56	2.55	0.25	2.62	2.23	2.43	2.55	2.55	-0.07	-2.7%
58.11	120	4626	2.88	2.85	0.31	2.94	2.50	2.73	2.89	2.89	-0.05	-1.7%
59.01	120	4628	0.67	0.64	0.12	0.66	0.14	0.66	0.68	0.68	0.02	3.0%
59.02	120	4628	1.09	1.05	0.21	1.07	0.18	1.07	1.10	1.10	0.03	2.8%
60.01	90	4593	0.40	0.39	0.10	0.40	0.08	0.40	0.39	0.40	0.00	0.0%
60.02	360	4731	1.06	1.04	0.25	1.07	0.13	1.07	1.07	1.07	0.00	0.0%
61.01	120	4628	0.25	0.22	0.07	0.22	0.14	0.22	0.24	0.24	0.02	9.1%
61.02	120	4628	0.82	0.71	0.23	0.71	0.47	0.71	0.77	0.77	0.06	8.5%
61.03	120	4628	1.38	1.24	0.35	1.25	0.87	1.25	1.32	1.32	0.07	5.6%
61.04	120	4628	1.91	1.71	0.45	1.75	1.22	1.75	1.94	1.94	0.19	10.9%
62.01	120	4628	0.37	0.33	0.11	0.33	0.16	0.33	0.35	0.35	0.02	6.1%
63.01	120	4628	0.23	0.22	0.05	0.22	0.07	0.22	0.23	0.23	0.01	4.5%
64.01	120	4628	0.09	0.08	0.03	0.08	0.05	0.08	0.08	0.08	0.00	0.0%
65.01	120	4626	0.20	0.19	0.04	0.19	0.17	0.18	0.20	0.20	0.01	5.3%
65.02	120	4626	0.34	0.32	0.08	0.32	0.31	0.30	0.33	0.33	0.01	3.1%
66.01	60	4475	0.02	0.02	0.01	0.03	0.02	0.03	0.02	0.03	0.00	0.0%
67.01	15	4410	0.42	0.42	0.05	0.42	0.42	0.42	0.32	0.42	0.00	0.0%
68.01	10	4373	0.22	0.22	0.02	0.22	0.22	0.22	0.20	0.22	0.00	0.0%
69.01	15	4410	0.24	0.24	0.03	0.24	0.24	0.24	0.16	0.24	0.00	0.0%
69.02	15	4410	0.38	0.37	0.04	0.38	0.38	0.38	0.28	0.38	0.00	0.0%
70.01	15	4410	0.38	0.37	0.05	0.37	0.37	0.37	0.30	0.37	0.00	0.0%
71.01	15	4410	2.01	1.98	0.24	2.00	2.00	2.00	1.08	2.00	0.00	0.0%
71.02	15	4410	2.45	2.42	0.29	2.44	2.44	2.44	1.68	2.44	0.00	0.0%
72.01	360	4731	0.49	0.50	0.10	0.52	0.38	0.52	0.52	0.52	0.00	0.0%
73.01	10	4373	0.18	0.18	0.02	0.18	0.18	0.18	0.19	0.19	0.01	5.6%
73.02	360	4731	0.39	0.41	0.07	0.43	0.37	0.43	0.43	0.43	0.00	0.0%
73.03	360	4660	0.78	0.82	0.13	0.84	0.64	0.84	0.85	0.85	0.01	1.2%
74.01	120	4626	0.14	0.14	0.02	0.14	0.08	0.13	0.15	0.15	0.01	7.1%
75.01	15	4410	0.08	0.08	0.01	0.08	0.08	0.08	0.09	0.09	0.01	12.5%
76.01	360	4731	0.69	0.68	0.15	0.70	0.14	0.70	0.70	0.70	0.00	0.0%
77.01	360	4660	0.81	0.83	0.14	0.83	0.07	0.83	0.83	0.83	0.00	0.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s) Average	Median	Standard Dev	Adopted	TP 4410 for the 15 minute duration	TP 4628 for the 2 hour duration	TP 4731 for the 6 hour duration		m^3/s	%
78.01	10	4372	0.15	0.14	0.02	0.15	0.14	0.15	0.11	0.15	0.00	0.0%
78.02	360	4731	4.54	4.37	1.37	4.39	0.55	4.39	4.39	4.39	0.00	0.0%
78.03	360	4731	6.06	5.91	1.70	5.96	1.96	5.96	5.96	5.96	0.00	0.0%
78.04	360	4731	6.49	6.33	1.79	6.36	2.43	6.36	6.36	6.36	0.00	0.0%
78.05	360	4731	6.84	6.67	1.86	6.70	2.67	6.70	6.70	6.70	0.00	0.0%
78.06	360	4731	8.75	8.60	2.25	8.66	3.35	8.66	8.66	8.66	0.00	0.0%
78.07	360	4678	10.67	10.36	2.62	10.40	4.53	10.40	10.33	10.40	0.00	0.0%
79.01	120	4628	0.38	0.32	0.12	0.32	0.33	0.32	0.36	0.36	0.04	12.5%
79.02	120	4628	0.79	0.67	0.23	0.68	0.67	0.68	0.73	0.73	0.05	7.4%
79.03	120	4628	1.02	0.88	0.29	0.89	0.90	0.89	0.96	0.96	0.07	7.9%
80.01	120	4628	0.25	0.21	0.07	0.22	0.20	0.22	0.24	0.24	0.02	9.1%
81.01	60	4565	0.09	0.09	0.03	0.09	0.07	0.09	0.08	0.09	0.00	0.0%
82.01	60	4475	0.34	0.34	0.08	0.34	0.34	0.34	0.29	0.34	0.00	0.0%
82.02	120	4628	0.56	0.48	0.16	0.48	0.54	0.48	0.52	0.54	0.06	12.5%
82.03	120	4626	0.92	0.81	0.25	0.81	0.89	0.80	0.90	0.90	0.09	11.1%
83.01	15	4410	0.30	0.29	0.04	0.30	0.30	0.30	0.27	0.30	0.00	0.0%
84.01	10	4373	0.24	0.23	0.02	0.24	0.24	0.24	0.21	0.24	0.00	0.0%
84.02	15	4410	0.58	0.57	0.07	0.58	0.58	0.58	0.53	0.58	0.00	0.0%
85.01	10	4372	0.16	0.15	0.02	0.16	0.15	0.16	0.13	0.16	0.00	0.0%
86.01	60	4475	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.0%
86.02	15	4410	0.26	0.26	0.03	0.27	0.27	0.27	0.20	0.27	0.00	0.0%
87.01	120	4628	0.07	0.06	0.02	0.06	0.04	0.06	0.06	0.06	0.00	0.0%
88.01	15	4410	0.46	0.45	0.07	0.46	0.46	0.46	0.39	0.46	0.00	0.0%
88.02	120	4626	0.68	0.62	0.17	0.64	0.62	0.60	0.64	0.64	0.00	0.0%
88.03	360	4731	1.26	1.29	0.27	1.34	0.81	1.34	1.34	1.34	0.00	0.0%
88.04	360	4731	1.82	1.85	0.38	1.91	0.89	1.91	1.91	1.91	0.00	0.0%
89.01	360	4731	0.42	0.41	0.10	0.42	0.09	0.42	0.42	0.42	0.00	0.0%
89.02	360	4731	1.40	1.42	0.28	1.47	1.15	1.47	1.47	1.47	0.00	0.0%
89.03	360	4731	2.05	2.09	0.40	2.17	1.93	2.17	2.17	2.17	0.00	0.0%
90.01	360	4731	0.44	0.43	0.10	0.44	0.12	0.44	0.44	0.44	0.00	0.0%
91.01	15	4410	0.55	0.55	0.06	0.55	0.55	0.55	0.41	0.55	0.00	0.0%
92.01	15	4410	0.66	0.66	0.07	0.66	0.66	0.66	0.47	0.66	0.00	0.0%
92.02	15	4410	1.04	1.04	0.11	1.04	1.04	1.04	0.77	1.04	0.00	0.0%
_junc_116	120	4628	0.62	0.54	0.18	0.55	0.30	0.55	0.59	0.59	0.04	7.3%
_junc_123	15	4410	2.39	2.36	0.28	2.38	2.38	2.38	1.61	2.38	0.00	0.0%
_junc_125	360	4672	37.88	37.32	7.13	37.50	15.09	37.50	36.00	37.50	0.00	0.0%
_junc_126	360	4678	1.16	1.19	0.18	1.22	0.56	1.22	1.26	1.26	0.04	3.3%
_junc_130	120	4628	5.00	4.64	1.24	4.71	1.41	4.71	4.92	4.92	0.21	4.5%
_junc_133	15	4415	1.53	1.51	0.18	1.51	1.51	1.51	1.26	1.51	0.00	0.0%
_junc_135	15	4410	0.46	0.45	0.06	0.45	0.45	0.45	0.34	0.45	0.00	0.0%
_junc_136	15	4410	0.63	0.62	0.08	0.63	0.63	0.63	0.48	0.63	0.00	0.0%
_junc_138	15	4410	5.51	5.52	0.57	5.54	5.54	5.54	2.85	5.54	0.00	0.0%
_junc_142	360	4731	1.77	1.81	0.35	1.88	1.69	1.88	1.88	1.88	0.00	0.0%
_junc_150	360	4731	5.21	5.03	1.52	5.05	1.27	5.05	5.05	5.05	0.00	0.0%
_junc_151	120	4626	1.68	1.55	0.38	1.58	1.50	1.52	1.70	1.70	0.12	7.6%
_junc_158	360	4678	0.68	0.72	0.09	0.75	0.36	0.75	0.76	0.76	0.01	1.3%
_junc_162	120	4628	0.32	0.29	0.08	0.30	0.12	0.30	0.31	0.31	0.01	3.3%
_junc_19	10	4372	0.97	0.93	0.11	0.94	0.95	0.94	0.65	0.95	0.01	1.1%
_junc_21	180	4658	15.84	15.16	3.20	15.44	5.56	15.44	15.20	15.44	0.00	0.0%
_junc_28	120	4628	4.48	4.11	0.99	4.11	3.51	4.11	4.56	4.56	0.45	10.9%
_junc_29	120	4626	1.38	1.25	0.33	1.26	1.16	1.23	1.36	1.36	0.10	7.9%
_junc_30	120	4626	0.27	0.26	0.05	0.28	0.24	0.25	0.27	0.27	-0.01	-3.6%
_junc_32	120	4626	0.56	0.54	0.11	0.56	0.48	0.50	0.57	0.57	0.01	1.8%
_junc_37	360	4678	19.96	19.47	4.37	19.50	8.11	19.50	19.44	19.50	0.00	0.0%
_junc_38	15	4381	6.40	6.40	0.59	6.47	6.55	6.47	4.59	6.55	0.08	1.2%
_junc_40	15	4381	1.33	1.34	0.14	1.35	1.33	1.35	1.08	1.35	0.00	0.0%
_junc_41	360	4731	2.49	2.46	0.59	2.54	0.33	2.54	2.54	2.54	0.00	0.0%
_junc_42	10	4377	1.77	1.75	0.07	1.76	1.79	1.76	1.55	1.79	0.03	1.7%
_junc_44	360	4678	20.58	20.12	4.45	20.20	8.15	20.20	20.05	20.20	0.00	0.0%
_junc_47	360	4660	2.96	3.09	0.53	3.16	2.69	3.16	3.24	3.24	0.08	2.5%
_junc_50	120	4626	0.22	0.21	0.05	0.21	0.17	0.20	0.21	0.21	0.00	0.0%
_junc_59	360	4678	30.11	29.72	6.02	29.90	13.93	29.90	29.53	29.90	0.00	0.0%
_junc_64	120	4625	1.75	1.74	0.11	1.77	1.67	1.69	1.73	1.73	-0.04	-2.3%
_junc_68	60	4475	0.47	0.44	0.10	0.44	0.40	0.44	0.42	0.44	0.00	0.0%
_junc_69	360	4678	30.89	30.36	6.07	30.68	14.05	30.68	29.93	30.68	0.00	0.0%
_junc_71	120	4625	2.44	2.43	0.25	2.49	2.20	2.30	2.42	2.42	-0.07	-2.8%
_junc_74	120	4626	2.82	2.80	0.30	2.89	2.46	2.67	2.83	2.83	-0.06	-2.1%
_junc_76	360	4678	31.88	31.44	6.24	31.60	14.13	31.60	30.53	31.60	0.00	0.0%
_junc_80	360	4672	36.62	36.06	6.94	36.22	15.01	36.22	34.72	36.22	0.00	0.0%
_junc_81	360	4731	0.53	0.55	0.10	0.57	0.44	0.57	0.57	0.57	0.00	0.0%
_junc_84	360	4672	39.38	38.85	7.36	39.06	15.17	39.06	37.48	39.06	0.00	0.0%
_junc_85	360	4672	49.80	49.15	9.89	49.34	16.90	49.34	47.82	49.34	0.00	0.0%
_junc_86	360	4672	50.36	49.77	9.96	50.01	16.95	50.01	48.28	50.01	0.00	0.0%
_junc_88	360	4731	8.63	8.48	2.23	8.56	3.33	8.56	8.56	8.56	0.00	0.0%
_junc_91	360	4678	10.56	10.28	2.60	10.30	4.51	10.30	10.27	10.30	0.00	0.0%
US_OHH	360	4678	33.18	32.70	6.53	32.70	14.21	32.70	31.34	32.70	0.00	0.0%
US_Rail	360	4678	29.27	28.93	5.91	29.02	13.85	29.02	28.84	29.02	0.00	0.0%

Average Difference (All Subcatchments)	**0.03**	**1.76%**
Average Difference (Focus Locations)	**0.04**	**0.66%**

ARR2016 Results for 2% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4531 for the 45 minute duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
1.01	120	4618	1.06	1.07	0.25	1.09	0.18	0.97	1.09	1.09	0.00	0.0%
1.02	45	4531	1.98	2.01	0.31	2.06	0.54	2.06	1.92	2.06	0.00	0.0%
1.03	45	4531	4.12	4.20	0.63	4.24	1.02	4.24	3.85	4.24	0.00	0.0%
1.04	45	4531	8.35	8.52	1.11	8.60	1.92	8.60	7.74	8.60	0.00	0.0%
1.05	60	4558	9.31	9.38	1.50	9.39	2.01	9.46	8.80	9.46	0.07	0.7%
1.06	60	4405	9.52	9.61	1.51	9.63	2.03	9.62	9.00	9.62	-0.01	-0.1%
1.07	120	4611	12.84	13.49	2.83	14.29	3.65	12.01	12.69	12.69	-1.60	-11.2%
1.08	120	4611	21.56	22.29	4.75	22.92	6.31	19.22	21.65	21.65	-1.27	-5.5%
1.09	120	4611	22.37	22.95	4.90	23.62	8.13	19.71	22.28	22.28	-1.34	-5.7%
1.1	10	4363	1.06	1.08	0.10	1.10	1.10	0.62	0.82	1.10	0.00	0.0%
1.11	10	4363	8.07	8.09	0.54	8.28	8.28	5.24	6.41	8.28	0.00	0.0%
1.12	10	4363	8.11	8.13	0.56	8.35	8.35	5.53	6.75	8.35	0.00	0.0%
1.13	10	4363	8.12	8.14	0.56	8.36	8.36	5.67	7.03	8.36	0.00	0.0%
1.14	120	4618	34.33	35.03	6.30	36.97	14.22	27.36	36.97	36.97	0.00	0.0%
1.15	120	4618	35.71	36.32	6.47	38.49	14.29	28.15	38.49	38.49	0.00	0.0%
1.16	120	4618	36.41	37.00	6.53	39.35	14.31	28.49	39.35	39.35	0.00	0.0%
1.17	120	4618	36.81	37.45	6.47	40.02	14.35	28.57	40.02	40.02	0.00	0.0%
1.18	720	4443	37.20	34.57	11.67	36.33	14.38	28.64	40.28	40.28	3.95	10.9%
1.19	720	4443	38.09	35.29	11.90	36.98	14.41	28.89	40.81	40.81	3.83	10.4%
1.2	720	4443	38.74	35.87	12.10	37.55	14.45	29.16	41.58	41.58	4.03	10.7%
1.21	720	4443	43.26	40.06	13.04	41.85	15.07	31.78	45.72	45.72	3.87	9.2%
1.22	720	4443	44.94	41.63	13.49	43.49	15.14	32.48	47.25	47.25	3.76	8.6%
1.23	720	4443	46.60	43.18	13.97	45.12	15.21	33.22	48.84	48.84	3.72	8.2%
1.24	720	4443	47.51	44.03	14.24	45.99	15.24	33.63	49.72	49.72	3.73	8.1%
1.25	720	4443	59.77	56.13	18.08	59.69	19.33	39.73	63.59	63.59	3.90	6.5%
1.26	720	4443	61.75	57.89	18.63	61.44	19.39	40.54	65.18	65.18	3.74	6.1%
2.01	45	4528	0.31	0.31	0.06	0.32	0.05	0.31	0.23	0.31	-0.01	-3.1%
2.02	45	4528	1.26	1.27	0.23	1.28	0.33	1.27	1.03	1.27	-0.01	-0.8%
3.01	45	4531	0.71	0.72	0.11	0.74	0.41	0.74	0.71	0.74	0.00	0.0%
3.02	45	4531	3.20	3.29	0.40	3.34	0.80	3.34	2.99	3.34	0.00	0.0%
3.03	60	4405	4.09	4.12	0.71	4.13	0.94	4.19	3.81	4.19	0.06	1.5%
4.01	45	4531	1.29	1.33	0.18	1.36	0.33	1.36	1.18	1.36	0.00	0.0%
5.01	60	4558	0.99	0.99	0.15	1.00	0.15	0.96	0.96	0.96	-0.04	-4.0%
5.02	120	4618	2.00	2.01	0.46	2.06	0.25	1.81	2.06	2.06	0.00	0.0%
5.03	120	4618	3.14	3.17	0.66	3.41	2.28	2.69	3.41	3.41	0.00	0.0%
6.01	120	4611	1.75	1.78	0.41	1.81	0.18	1.65	1.74	1.74	-0.07	-3.9%
6.02	60	4558	2.34	2.33	0.34	2.36	0.21	2.28	2.29	2.29	-0.07	-3.0%
6.03	120	4611	3.49	3.59	0.82	3.78	0.32	3.39	3.42	3.42	-0.36	-9.5%
6.04	60	4558	5.94	5.96	0.85	6.04	1.80	5.89	5.83	5.89	-0.15	-2.5%
6.05	120	4611	6.93	7.20	1.64	7.63	1.90	6.80	6.78	6.80	-0.83	-10.9%
6.06	120	4611	7.40	7.60	1.72	7.98	2.44	7.08	7.21	7.21	-0.77	-9.6%
6.07	120	4611	8.62	8.85	1.98	9.03	3.45	7.89	8.66	8.66	-0.37	-4.1%
7.01	120	4611	0.79	0.80	0.19	0.81	0.12	0.74	0.79	0.79	-0.02	-2.5%
8.01	45	4535	0.45	0.45	0.08	0.47	0.38	0.47	0.45	0.47	0.00	0.0%
8.02	60	4557	1.87	1.91	0.29	1.93	1.45	1.94	1.94	1.94	0.01	0.5%
8.03	60	4558	2.45	2.48	0.36	2.48	1.48	2.50	2.49	2.50	0.02	0.8%
9.01	10	4363	0.71	0.72	0.07	0.76	0.76	0.71	0.74	0.76	0.00	0.0%
10.01	120	4618	0.63	0.63	0.15	0.64	0.12	0.59	0.64	0.64	0.00	0.0%
11.01	120	4618	0.62	0.64	0.12	0.68	0.63	0.54	0.68	0.68	0.00	0.0%
11.02	10	4368	1.38	1.41	0.12	1.41	1.40	1.28	1.43	1.43	0.02	1.4%
12.01	10	4363	0.47	0.47	0.04	0.48	0.48	0.36	0.42	0.48	0.00	0.0%
13.01	10	4363	0.38	0.38	0.04	0.40	0.40	0.33	0.35	0.40	0.00	0.0%
14.01	10	4363	1.91	1.93	0.18	2.01	2.01	1.07	1.31	2.01	0.00	0.0%
15.01	10	4363	3.02	3.05	0.28	3.14	3.14	1.72	2.12	3.14	0.00	0.0%
15.02	10	4363	4.00	4.06	0.37	4.15	4.15	2.30	2.91	4.15	0.00	0.0%
15.03	10	4363	7.03	7.15	0.63	7.23	7.23	4.22	5.21	7.23	0.00	0.0%
15.04	10	4363	7.10	7.21	0.62	7.30	7.30	4.37	5.42	7.30	0.00	0.0%
16.01	10	4363	2.91	2.96	0.27	3.01	3.01	1.54	1.78	3.01	0.00	0.0%
17.01	120	4614	0.36	0.35	0.08	0.36	0.14	0.26	0.42	0.42	0.06	16.7%
18.01	120	4618	0.22	0.22	0.05	0.24	0.03	0.19	0.24	0.24	0.00	0.0%
19.01	10	4363	0.89	0.89	0.09	0.95	0.95	0.68	0.73	0.95	0.00	0.0%
19.02	10	4363	1.50	1.51	0.14	1.58	1.58	1.30	1.36	1.58	0.00	0.0%
19.03	60	4559	2.40	2.38	0.35	2.44	2.14	2.47	2.50	2.50	0.06	2.5%
19.04	120	4611	2.90	3.15	0.62	3.33	2.23	2.87	2.97	2.97	-0.36	-10.8%
19.05	120	4611	3.25	3.47	0.70	3.66	2.43	3.14	3.28	3.28	-0.38	-10.4%
19.06	120	4611	5.91	6.18	1.24	6.30	4.46	5.57	6.08	6.08	-0.22	-3.5%
19.07	120	4618	7.83	8.06	1.50	8.28	5.66	6.89	8.28	8.28	0.00	0.0%
19.08	720	4787	2.37	2.39	0.18	2.39	0.69	1.45	1.89	1.89	-0.50	-20.9%
19.09	720	4787	2.61	2.59	0.21	2.60	0.77	1.64	2.11	2.11	-0.49	-18.8%
19.1	120	4611	25.05	25.60	5.00	25.91	8.84	21.93	25.28	25.28	-0.63	-2.4%
19.11	120	4611	25.65	26.17	5.11	26.41	8.87	22.33	25.92	25.92	-0.49	-1.9%
19.12	120	4611	25.96	26.45	5.13	26.63	8.88	22.50	26.27	26.27	-0.36	-1.4%
20.01	20	4367	0.35	0.34	0.06	0.35	0.36	0.30	0.31	0.36	0.01	2.9%
21.01	10	4363	0.38	0.38	0.04	0.40	0.40	0.35	0.35	0.40	0.00	0.0%
22.01	60	4558	0.40	0.40	0.06	0.41	0.08	0.39	0.39	0.39	-0.02	-4.9%
23.01	60	4559	0.17	0.17	0.03	0.17	0.14	0.17	0.18	0.18	0.01	5.9%
24.01	120	4611	0.33	0.35	0.07	0.35	0.34	0.31	0.35	0.35	0.00	0.0%
24.02	10	4363	0.41	0.41	0.04	0.42	0.42	0.40	0.43	0.43	0.01	2.4%
24.03	120	4618	0.81	0.87	0.15	0.88	0.77	0.75	0.88	0.88	0.00	0.0%
24.04	120	4611	1.97	2.11	0.40	2.19	1.75	1.92	2.04	2.04	-0.15	-6.8%
24.05	120	4611	2.50	2.65	0.51	2.68	2.16	2.39	2.63	2.63	-0.05	-1.9%
25.01	120	4614	0.31	0.29	0.06	0.30	0.22	0.24	0.35	0.35	0.05	16.7%
26.01	60	4559	0.41	0.41	0.06	0.42	0.43	0.42	0.44	0.44	0.02	4.8%
26.02	60	4557	0.95	0.96	0.14	0.98	0.79	0.97	0.97	0.97	-0.01	-1.0%
27.01	60	4557	0.37	0.37	0.06	0.37	0.26	0.38	0.37	0.38	0.01	2.7%
28.01	120	4614	0.34	0.35	0.07	0.36	0.31	0.29	0.37	0.37	0.01	2.8%
29.01	10	4366	0.13	0.13	0.01	0.14	0.15	0.11	0.13	0.15	0.01	7.1%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4531 for the 45 minute duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
30.01	720	4654	0.36	0.33	0.09	0.33	0.22	0.29	0.39	0.39	0.06	18.2%
31.01	10	4363	0.35	0.35	0.03	0.37	0.37	0.28	0.33	0.37	0.00	0.0%
31.02	10	4363	0.95	0.96	0.09	0.98	0.98	0.71	1.00	1.00	0.02	2.0%
31.03	360	4694	1.28	1.33	0.26	1.33	1.20	0.93	1.44	1.44	0.11	8.3%
32.01	120	4614	0.22	0.22	0.02	0.23	0.15	0.21	0.24	0.24	0.01	4.3%
33.01	10	4357	0.23	0.23	0.00	0.23	0.23	0.22	0.22	0.23	0.00	0.0%
34.01	720	4443	0.22	0.19	0.05	0.19	0.09	0.19	0.23	0.23	0.04	21.1%
35.01	60	4559	0.19	0.19	0.03	0.20	0.20	0.20	0.21	0.21	0.01	5.0%
35.02	10	4363	0.65	0.65	0.06	0.68	0.68	0.59	0.62	0.68	0.00	0.0%
35.03	10	4363	1.06	1.08	0.10	1.10	1.10	0.93	1.00	1.10	0.00	0.0%
35.04	10	4363	1.31	1.32	0.09	1.36	1.36	1.20	1.31	1.36	0.00	0.0%
35.05	120	4614	0.90	0.91	0.11	0.95	0.50	0.82	0.96	0.96	0.01	1.1%
35.06	360	4529	0.77	0.79	0.08	0.81	0.29	0.62	0.79	0.79	-0.02	-2.5%
36.01	10	4363	0.39	0.39	0.04	0.41	0.41	0.28	0.32	0.41	0.00	0.0%
37.01	10	4363	0.16	0.16	0.02	0.17	0.17	0.09	0.11	0.17	0.00	0.0%
38.01	120	4618	0.22	0.23	0.05	0.23	0.15	0.21	0.23	0.23	0.00	0.0%
39.01	120	4614	0.61	0.59	0.11	0.61	0.23	0.40	0.72	0.72	0.11	18.0%
40.01	10	4363	0.23	0.23	0.02	0.24	0.24	0.16	0.18	0.24	0.00	0.0%
40.02	10	4363	0.45	0.45	0.04	0.47	0.47	0.34	0.40	0.47	0.00	0.0%
40.03	10	4363	1.24	1.26	0.11	1.28	1.28	0.91	1.11	1.28	0.00	0.0%
40.04	10	4363	1.77	1.78	0.12	1.82	1.82	1.42	1.66	1.82	0.00	0.0%
40.05	10	4363	2.34	2.33	0.09	2.37	2.37	1.94	2.34	2.37	0.00	0.0%
40.06	10	4363	2.56	2.55	0.14	2.64	2.64	2.10	2.66	2.66	0.02	0.0%
41.01	10	4363	0.45	0.45	0.05	0.48	0.48	0.37	0.41	0.48	0.00	0.0%
42.01	10	4363	0.56	0.56	0.06	0.59	0.59	0.44	0.52	0.59	0.00	0.0%
43.01	10	4363	0.16	0.16	0.02	0.17	0.17	0.10	0.16	0.17	0.00	0.0%
44.01	360	4694	0.26	0.26	0.05	0.26	0.18	0.19	0.31	0.31	0.05	19.2%
44.02	120	4614	0.49	0.47	0.09	0.48	0.46	0.37	0.58	0.58	0.10	20.8%
44.03	120	4614	0.73	0.70	0.14	0.72	0.53	0.56	0.86	0.86	0.14	19.4%
44.04	360	4694	1.27	1.31	0.23	1.31	0.70	0.74	1.27	1.27	-0.04	-3.1%
45.01	10	4366	0.19	0.19	0.02	0.20	0.20	0.12	0.18	0.20	0.00	0.0%
46.01	720	4654	0.29	0.27	0.08	0.28	0.08	0.16	0.28	0.28	0.00	0.0%
47.01	120	4614	0.18	0.18	0.03	0.18	0.06	0.14	0.21	0.21	0.03	16.7%
48.01	360	4694	0.41	0.41	0.07	0.43	0.22	0.20	0.32	0.32	-0.11	-25.6%
48.02	360	4587	0.86	0.88	0.15	0.88	0.47	0.56	0.90	0.90	0.02	2.3%
49.01	120	4614	0.44	0.42	0.10	0.44	0.25	0.32	0.53	0.53	0.09	20.5%
50.01	120	4614	0.55	0.54	0.10	0.56	0.28	0.36	0.65	0.65	0.09	16.1%
51.01	10	4363	0.17	0.17	0.02	0.18	0.18	0.13	0.18	0.18	0.00	0.0%
52.01	360	4694	0.64	0.66	0.13	0.67	0.59	0.45	0.74	0.74	0.07	10.4%
52.02	10	4363	1.45	1.47	0.12	1.47	1.47	0.84	1.09	1.47	0.00	0.0%
53.01	10	4363	0.59	0.59	0.06	0.62	0.62	0.33	0.35	0.62	0.00	0.0%
53.02	10	4363	1.86	1.89	0.17	1.90	1.90	1.06	1.17	1.90	0.00	0.0%
53.03	10	4365	2.46	2.50	0.18	2.51	2.49	1.38	1.48	2.49	-0.02	-0.8%
54.01	10	4363	0.84	0.84	0.08	0.88	0.88	0.48	0.50	0.88	0.00	0.0%
55.01	10	4363	0.69	0.69	0.07	0.73	0.73	0.40	0.40	0.73	0.00	0.0%
56.01	10	4363	0.59	0.60	0.05	0.61	0.61	0.33	0.41	0.61	0.00	0.0%
57.01	10	4363	0.80	0.81	0.08	0.85	0.85	0.52	0.64	0.85	0.00	0.0%
57.02	10	4366	1.08	1.07	0.09	1.11	1.15	0.65	0.78	1.15	0.04	3.6%
57.03	10	4356	1.26	1.25	0.10	1.25	1.34	0.81	0.88	1.34	0.09	7.2%
58.01	120	4614	1.13	1.09	0.24	1.18	0.05	0.82	1.30	1.30	0.12	10.2%
58.02	120	4614	1.43	1.41	0.29	1.55	0.13	1.16	1.59	1.59	0.04	2.6%
58.03	120	4618	1.81	1.80	0.38	1.98	0.22	1.48	1.98	1.98	0.00	0.0%
58.04	120	4618	3.55	3.53	0.77	3.80	0.53	2.98	3.80	3.80	0.00	0.0%
58.05	120	4618	5.11	5.08	1.09	5.46	0.74	4.27	5.46	5.46	0.00	0.0%
58.06	120	4618	5.13	5.10	1.10	5.48	0.76	4.29	5.48	5.48	0.00	0.0%
58.07	120	4618	7.30	7.36	1.50	7.82	1.81	6.05	7.82	7.82	0.00	0.0%
58.08	120	4499	1.45	1.47	0.04	1.47	1.42	1.45	1.47	1.47	0.00	0.0%
58.09	120	4611	2.35	2.40	0.19	2.41	2.18	2.23	2.45	2.45	0.04	1.7%
58.1	120	4611	2.86	2.93	0.27	2.94	2.53	2.65	3.00	3.00	0.06	2.0%
58.11	120	4611	3.27	3.36	0.34	3.37	2.58	2.96	3.44	3.44	0.07	2.1%
59.01	120	4618	0.88	0.87	0.20	0.95	0.21	0.74	0.95	0.95	0.00	0.0%
59.02	120	4618	1.45	1.44	0.33	1.54	0.23	1.25	1.54	1.54	0.00	0.0%
60.01	60	4558	0.53	0.53	0.08	0.54	0.11	0.54	0.51	0.54	0.00	0.0%
60.02	120	4618	1.39	1.40	0.31	1.50	0.15	1.18	1.50	1.50	0.00	0.0%
61.01	60	4557	0.32	0.33	0.06	0.33	0.19	0.34	0.32	0.34	0.01	3.0%
61.02	45	4535	1.06	1.08	0.15	1.12	0.66	1.13	1.06	1.13	0.01	0.9%
61.03	60	4405	1.80	1.83	0.27	1.84	1.18	1.81	1.75	1.81	-0.03	-1.6%
61.04	120	4611	2.44	2.56	0.55	2.65	1.61	2.40	2.48	2.48	-0.17	-6.4%
62.01	45	4531	0.50	0.50	0.07	0.52	0.23	0.52	0.48	0.52	0.00	0.0%
63.01	120	4618	0.30	0.31	0.07	0.31	0.10	0.29	0.31	0.31	0.00	0.0%
64.01	45	4535	0.12	0.12	0.02	0.13	0.06	0.13	0.13	0.13	0.00	0.0%
65.01	120	4611	0.25	0.26	0.05	0.26	0.23	0.23	0.26	0.26	0.00	0.0%
65.02	120	4499	0.42	0.47	0.09	0.48	0.41	0.42	0.46	0.46	-0.02	-4.2%
66.01	25	4462	0.03	0.03	0.00	0.03	0.02	0.03	0.03	0.03	0.00	0.0%
67.01	10	4363	0.53	0.54	0.06	0.55	0.55	0.35	0.45	0.55	0.00	0.0%
68.01	10	4363	0.28	0.28	0.02	0.29	0.29	0.21	0.26	0.29	0.00	0.0%
69.01	10	4363	0.30	0.30	0.03	0.31	0.31	0.21	0.26	0.31	0.00	0.0%
69.02	10	4363	0.47	0.47	0.04	0.48	0.48	0.33	0.38	0.48	0.00	0.0%
70.01	10	4363	0.47	0.47	0.04	0.49	0.49	0.30	0.39	0.49	0.00	0.0%
71.01	10	4363	2.51	2.53	0.22	2.60	2.60	1.36	1.63	2.60	0.00	0.0%
71.02	10	4363	3.05	3.07	0.26	3.15	3.15	1.81	2.25	3.15	0.00	0.0%
72.01	120	4614	0.61	0.58	0.12	0.60	0.50	0.47	0.73	0.73	0.13	21.7%
73.01	10	4363	0.23	0.23	0.02	0.24	0.24	0.19	0.24	0.24	0.00	0.0%
73.02	120	4614	0.48	0.46	0.07	0.47	0.47	0.38	0.55	0.55	0.08	17.0%
73.03	120	4614	0.93	0.90	0.14	0.92	0.81	0.72	1.07	1.07	0.15	16.3%
74.01	120	4614	0.17	0.16	0.03	0.18	0.11	0.14	0.20	0.20	0.02	11.1%
75.01	10	4363	0.11	0.11	0.01	0.11	0.11	0.08	0.13	0.13	0.02	18.2%
76.01	120	4614	0.85	0.81	0.18	0.85	0.20	0.63	1.00	1.00	0.15	17.6%
77.01	360	4694	0.95	0.98	0.22	0.99	0.09	0.54	1.08	1.08	0.09	9.1%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4531 for the 45 minute duration	TP 4618 for the 2 hour duration		m^3/s	%
			Average	Median	Standard Dev	Adopted						
78.01	10	4366	0.18	0.18	0.02	0.19	0.20	0.17	0.16	0.20	0.01	5.3%
78.02	120	4618	6.30	6.35	1.53	6.87	0.75	4.94	6.87	6.87	0.00	0.0%
78.03	120	4618	8.25	8.33	1.89	8.97	2.56	6.48	8.97	8.97	0.00	0.0%
78.04	120	4618	8.81	8.85	2.01	9.49	3.11	6.96	9.49	9.49	0.00	0.0%
78.05	120	4618	9.20	9.22	2.09	9.88	3.35	7.29	9.88	9.88	0.00	0.0%
78.06	120	4618	11.42	11.35	2.50	12.35	4.09	8.81	12.35	12.35	0.00	0.0%
78.07	120	4614	13.65	13.46	2.81	14.75	4.48	10.26	14.93	14.93	0.18	1.2%
79.01	60	4559	0.51	0.50	0.08	0.52	0.45	0.53	0.52	0.53	0.01	1.9%
79.02	60	4559	1.04	1.04	0.16	1.08	0.87	1.07	1.04	1.07	-0.01	-0.9%
79.03	60	4559	1.33	1.35	0.21	1.39	1.15	1.38	1.35	1.38	-0.01	-0.7%
80.01	60	4559	0.32	0.32	0.05	0.33	0.28	0.33	0.32	0.33	0.00	0.0%
81.01	45	4528	0.12	0.12	0.02	0.12	0.10	0.12	0.11	0.12	0.00	0.0%
82.01	20	4367	0.45	0.44	0.07	0.44	0.46	0.44	0.42	0.46	0.02	4.5%
82.02	60	4559	0.72	0.70	0.10	0.72	0.69	0.74	0.73	0.74	0.02	2.8%
82.03	60	4559	1.17	1.15	0.16	1.18	1.17	1.20	1.19	1.20	0.02	1.7%
83.01	60	4559	0.39	0.39	0.06	0.39	0.40	0.40	0.41	0.41	0.02	5.1%
84.01	10	4363	0.30	0.30	0.03	0.32	0.32	0.27	0.30	0.32	0.00	0.0%
84.02	10	4363	0.73	0.74	0.06	0.77	0.77	0.69	0.75	0.77	0.00	0.0%
85.01	10	4366	0.20	0.20	0.02	0.21	0.21	0.20	0.21	0.21	0.00	0.0%
86.01	30	4457	0.02	0.02	0.00	0.02	0.02	0.02	0.02	0.02	0.00	0.0%
86.02	10	4363	0.33	0.33	0.03	0.34	0.34	0.26	0.31	0.34	0.00	0.0%
87.01	45	4531	0.10	0.10	0.02	0.10	0.06	0.10	0.10	0.10	0.00	0.0%
88.01	10	4363	0.59	0.59	0.06	0.63	0.63	0.54	0.58	0.63	0.00	0.0%
88.02	120	4611	0.84	0.92	0.19	0.94	0.85	0.85	0.90	0.90	-0.04	-4.3%
88.03	120	4614	1.63	1.62	0.32	1.74	1.08	1.36	1.81	1.81	0.07	4.0%
88.04	120	4614	2.26	2.17	0.43	2.33	1.19	1.75	2.56	2.56	0.23	9.9%
89.01	120	4614	0.55	0.54	0.12	0.61	0.13	0.43	0.61	0.61	0.00	0.0%
89.02	120	4614	1.72	1.63	0.34	1.69	1.35	1.27	2.02	2.02	0.33	19.5%
89.03	120	4614	2.55	2.40	0.49	2.49	2.34	1.97	2.97	2.97	0.48	19.3%
90.01	120	4614	0.55	0.53	0.12	0.56	0.16	0.39	0.64	0.64	0.08	14.3%
91.01	10	4363	0.68	0.69	0.06	0.70	0.70	0.46	0.57	0.70	0.00	0.0%
92.01	10	4363	0.81	0.82	0.07	0.83	0.83	0.55	0.68	0.83	0.00	0.0%
92.02	10	4363	1.27	1.30	0.12	1.31	1.31	0.84	1.05	1.31	0.00	0.0%
_junc_116	60	4557	0.82	0.84	0.14	0.84	0.42	0.86	0.80	0.86	0.02	2.4%
_junc_123	10	4363	2.97	3.00	0.25	3.07	3.07	1.75	2.17	3.07	0.00	0.0%
_junc_125	720	4443	45.68	42.34	13.71	44.28	15.18	32.82	47.98	47.98	3.70	8.4%
_junc_126	360	4406	1.39	1.43	0.27	1.44	0.73	0.89	1.52	1.52	0.08	5.6%
_junc_130	120	4611	6.55	6.80	1.55	7.19	1.88	6.44	6.42	6.44	-0.75	-10.4%
_junc_133	10	4363	1.91	1.92	0.17	1.98	1.98	1.82	1.89	1.98	0.00	0.0%
_junc_135	10	4363	0.58	0.58	0.06	0.61	0.61	0.49	0.53	0.61	0.00	0.0%
_junc_136	10	4363	0.80	0.80	0.07	0.83	0.83	0.68	0.73	0.83	0.00	0.0%
_junc_138	10	4363	6.80	6.92	0.63	6.99	6.99	3.84	4.67	6.99	0.00	0.0%
_junc_142	120	4614	2.21	2.08	0.43	2.16	2.05	1.72	2.59	2.59	0.43	19.9%
_junc_150	120	4618	7.18	7.27	1.67	7.87	1.72	5.58	7.87	7.87	0.00	0.0%
_junc_151	120	4611	2.09	2.24	0.43	2.30	1.87	2.04	2.17	2.17	-0.13	-5.7%
_junc_158	360	4694	0.82	0.84	0.14	0.84	0.47	0.52	0.85	0.85	0.01	1.2%
_junc_162	120	4611	0.41	0.43	0.10	0.45	0.17	0.41	0.42	0.42	-0.03	-6.7%
_junc_19	10	4363	1.23	1.23	0.12	1.31	1.31	0.97	1.03	1.31	0.00	0.0%
_junc_21	120	4611	21.29	22.02	4.70	22.69	6.28	19.01	21.35	21.35	-1.34	-5.9%
_junc_28	120	4611	5.68	5.97	1.21	6.12	4.45	5.41	5.82	5.82	-0.30	-4.9%
_junc_29	120	4499	1.72	1.87	0.37	1.96	1.44	1.72	1.78	1.78	-0.18	-9.2%
_junc_30	120	4614	0.34	0.35	0.07	0.36	0.31	0.29	0.37	0.37	0.01	2.8%
_junc_32	120	4614	0.71	0.74	0.13	0.75	0.61	0.64	0.77	0.77	0.02	2.7%
_junc_37	120	4611	25.56	26.09	5.09	26.33	8.86	22.25	25.85	25.85	-0.48	-1.8%
_junc_38	10	4363	7.94	7.99	0.57	8.10	8.10	4.99	6.10	8.10	0.00	0.0%
_junc_40	10	4363	1.64	1.67	0.15	1.69	1.69	1.29	1.50	1.69	0.00	0.0%
_junc_41	120	4618	3.26	3.24	0.70	3.52	0.46	2.71	3.52	3.52	0.00	0.0%
_junc_42	10	4361	2.20	2.20	0.13	2.22	2.19	1.82	2.10	2.19	-0.03	-1.4%
_junc_44	120	4611	26.17	26.65	5.14	26.79	8.89	22.63	26.52	26.52	-0.27	-1.0%
_junc_47	120	4614	3.60	3.61	0.63	3.68	3.24	2.81	3.89	3.89	0.21	5.7%
_junc_50	120	4611	0.27	0.29	0.06	0.30	0.25	0.26	0.28	0.28	-0.02	-6.7%
_junc_59	120	4618	36.35	36.94	6.52	39.28	14.31	28.47	39.28	39.28	0.00	0.0%
_junc_64	15	4397	1.86	1.82	0.13	1.82	1.78	1.80	1.91	1.91	0.09	4.9%
_junc_68	45	4535	0.62	0.62	0.11	0.65	0.55	0.65	0.63	0.65	0.00	0.0%
_junc_69	720	4443	37.33	34.67	11.70	36.41	14.39	28.65	40.33	40.33	3.92	10.8%
_junc_71	120	4611	2.69	2.76	0.25	2.78	2.51	2.55	2.83	2.83	0.05	1.8%
_junc_74	120	4611	3.19	3.25	0.33	3.27	2.57	2.89	3.38	3.38	0.11	3.4%
_junc_76	720	4443	38.68	35.81	12.09	37.50	14.44	29.14	41.52	41.52	4.02	10.7%
_junc_80	720	4443	44.14	40.89	13.28	42.75	15.12	32.14	46.52	46.52	3.77	8.8%
_junc_81	120	4614	0.65	0.62	0.11	0.63	0.56	0.53	0.75	0.75	0.12	19.0%
_junc_84	720	4443	47.50	44.02	14.23	45.99	15.24	33.63	49.72	49.72	3.73	8.1%
_junc_85	720	4443	59.72	56.08	18.07	59.64	19.32	39.70	63.55	63.55	3.91	6.6%
_junc_86	720	4443	60.43	56.70	18.27	60.29	19.36	39.99	64.07	64.07	3.78	6.3%
_junc_88	120	4618	11.30	11.23	2.48	12.22	4.08	8.75	12.22	12.22	0.00	0.0%
_junc_91	120	4614	13.54	13.36	2.80	14.64	4.47	10.19	14.81	14.81	0.17	1.2%
US_OHH	720	4443	40.22	37.11	12.54	38.74	14.50	29.77	42.82	42.82	4.08	10.5%
US_Rail	120	4618	35.41	36.05	6.44	38.18	14.27	28.01	38.18	38.18	0.00	0.0%

Average Difference (All Subcatchments)	**0.22**	**1.82%**
Average Difference (Focus Locations)	**0.59**	**0.33%**

ARR2016 Results for 1% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4405 for the 1 hour duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
1.01	60	4558	1.30	1.29	0.17	1.31	0.24	1.27	1.24	1.27	-0.04	-3.1%
1.02	45	4531	2.50	2.53	0.39	2.55	0.66	2.42	2.23	2.42	-0.13	-5.1%
1.03	45	4528	5.19	5.25	0.79	5.27	1.23	5.02	4.54	5.02	-0.25	-4.7%
1.04	45	4528	10.57	10.74	1.50	10.75	2.40	10.31	9.17	10.31	-0.44	-4.1%
1.05	45	4528	11.73	11.90	1.51	11.92	2.53	11.62	10.44	11.62	-0.30	-2.5%
1.06	45	4528	11.95	12.11	1.51	12.14	2.54	11.95	10.76	11.95	-0.19	-1.6%
1.07	60	4405	15.68	15.68	2.04	15.99	4.11	15.99	14.63	15.99	0.00	0.0%
1.08	60	4405	26.29	26.42	3.40	26.56	7.18	26.56	24.84	26.56	0.00	0.0%
1.09	60	4405	27.24	27.15	3.27	27.29	9.23	27.29	25.57	27.29	0.00	0.0%
1.1	10	4363	1.22	1.24	0.12	1.26	1.26	0.84	1.00	1.26	0.00	0.0%
1.11	10	4363	9.22	9.26	0.63	9.46	9.46	7.49	7.73	9.46	0.00	0.0%
1.12	10	4363	9.28	9.31	0.65	9.53	9.53	7.93	8.19	9.53	0.00	0.0%
1.13	10	4363	9.30	9.33	0.65	9.55	9.55	8.15	8.41	9.55	0.00	0.0%
1.14	120	4618	41.04	42.99	7.53	43.50	16.59	38.07	43.50	43.50	0.00	0.0%
1.15	120	4618	42.75	44.75	7.74	45.68	16.73	39.37	45.68	45.68	0.00	0.0%
1.16	120	4618	43.59	45.65	7.83	46.85	16.80	39.92	46.85	46.85	0.00	0.0%
1.17	120	4618	44.03	46.19	7.81	47.68	16.88	40.05	47.68	47.68	0.00	0.0%
1.18	120	4618	44.33	46.46	7.81	47.97	16.93	40.21	47.97	47.97	0.00	0.0%
1.19	120	4618	45.00	47.09	7.81	48.59	17.02	40.56	48.59	48.59	0.00	0.0%
1.2	120	4618	45.61	47.78	7.85	49.50	17.10	40.97	49.50	49.50	0.00	0.0%
1.21	120	4618	50.00	52.02	8.05	54.17	18.45	44.33	54.17	54.17	0.00	0.0%
1.22	120	4618	51.63	53.61	8.23	56.02	18.58	45.52	56.02	56.02	0.00	0.0%
1.23	120	4499	53.29	55.27	8.37	57.90	18.73	46.75	57.91	57.91	0.01	0.0%
1.24	120	4499	54.24	56.13	8.45	58.77	18.81	47.44	58.97	58.97	0.20	0.3%
1.25	120	4499	68.24	68.29	10.55	72.88	22.83	58.75	75.81	75.81	2.93	4.0%
1.26	120	4499	70.21	70.20	10.63	74.61	22.97	60.04	77.82	77.82	3.21	4.3%
2.01	45	4528	0.38	0.37	0.07	0.39	0.09	0.32	0.27	0.32	-0.07	-17.9%
2.02	45	4528	1.56	1.53	0.26	1.58	0.42	1.37	1.18	1.37	-0.21	-13.3%
3.01	45	4531	0.89	0.89	0.14	0.90	0.47	0.89	0.81	0.89	-0.01	-1.1%
3.02	45	4531	4.08	4.13	0.57	4.17	0.97	3.97	3.50	3.97	-0.20	-4.8%
3.03	45	4528	5.19	5.28	0.68	5.28	1.12	5.08	4.45	5.08	-0.20	-3.8%
4.01	45	4531	1.64	1.66	0.25	1.68	0.41	1.58	1.38	1.58	-0.10	-6.0%
5.01	60	4558	1.23	1.23	0.19	1.25	0.22	1.21	1.10	1.21	-0.04	-3.2%
5.02	60	4558	2.43	2.42	0.32	2.46	0.38	2.39	2.36	2.39	-0.07	-2.8%
5.03	120	4618	3.74	3.87	0.79	3.95	2.61	3.59	3.95	3.95	0.00	0.0%
6.01	60	4558	2.17	2.17	0.30	2.20	0.32	2.14	2.01	2.14	-0.06	-2.7%
6.02	60	4558	2.92	2.92	0.44	2.95	0.43	2.89	2.63	2.89	-0.06	-2.0%
6.03	60	4558	4.37	4.36	0.66	4.39	0.63	4.32	3.91	4.32	-0.07	-1.6%
6.04	60	4405	7.42	7.50	1.15	7.53	2.04	7.53	6.89	7.53	0.00	0.0%
6.05	60	4405	8.65	8.74	1.31	8.78	2.16	8.78	8.00	8.78	0.00	0.0%
6.06	60	4405	9.18	9.31	1.31	9.35	2.77	9.35	8.54	9.35	0.00	0.0%
6.07	60	4405	10.55	10.73	1.38	10.79	3.94	10.79	9.92	10.79	0.00	0.0%
7.01	60	4558	0.99	0.98	0.15	1.01	0.16	0.97	0.91	0.97	-0.04	-4.0%
8.01	45	4531	0.57	0.57	0.10	0.58	0.44	0.59	0.53	0.59	0.01	1.7%
8.02	45	4531	2.34	2.36	0.34	2.44	1.64	2.46	2.29	2.46	0.02	0.8%
8.03	60	4405	3.06	3.12	0.49	3.20	1.69	3.20	2.97	3.20	0.00	0.0%
9.01	30	4503	0.85	0.84	0.08	0.84	0.87	0.92	0.87	0.92	0.08	9.5%
10.01	60	4558	0.78	0.77	0.11	0.78	0.13	0.77	0.73	0.77	-0.01	-1.3%
11.01	120	4611	0.74	0.80	0.14	0.81	0.73	0.77	0.80	0.80	-0.01	-1.2%
11.02	20	4367	1.68	1.65	0.30	1.71	1.60	1.75	1.76	1.76	0.05	2.9%
12.01	10	4363	0.54	0.55	0.05	0.56	0.56	0.50	0.51	0.56	0.00	0.0%
13.01	20	4367	0.45	0.44	0.07	0.46	0.47	0.43	0.40	0.47	0.01	2.2%
14.01	10	4363	2.18	2.19	0.19	2.27	2.27	1.51	1.57	2.27	0.00	0.0%
15.01	10	4363	3.44	3.47	0.31	3.58	3.58	2.42	2.47	3.58	0.00	0.0%
15.02	10	4363	4.56	4.63	0.42	4.73	4.73	3.31	3.46	4.73	0.00	0.0%
15.03	10	4363	8.03	8.17	0.73	8.26	8.26	5.97	6.21	8.26	0.00	0.0%
15.04	10	4363	8.11	8.24	0.72	8.33	8.33	6.25	6.49	8.33	0.00	0.0%
16.01	10	4363	3.32	3.36	0.30	3.40	3.40	1.96	2.07	3.40	0.00	0.0%
17.01	120	4614	0.44	0.42	0.10	0.45	0.15	0.38	0.51	0.51	0.06	13.3%
18.01	120	4618	0.27	0.27	0.06	0.28	0.04	0.26	0.28	0.28	0.00	0.0%
19.01	10	4363	1.02	1.01	0.09	1.08	1.08	0.91	0.85	1.08	0.00	0.0%
19.02	10	4363	1.71	1.72	0.15	1.80	1.80	1.67	1.58	1.80	0.00	0.0%
19.03	45	4531	2.97	2.97	0.47	3.07	2.43	3.15	2.94	3.15	0.08	2.6%
19.04	60	4559	3.56	3.57	0.49	3.66	2.52	3.76	3.58	3.76	0.10	2.7%
19.05	60	4559	3.99	4.02	0.55	4.13	2.75	4.20	3.96	4.20	0.07	1.7%
19.06	60	4405	7.10	7.20	0.96	7.32	5.07	7.32	7.05	7.32	0.00	0.0%
19.07	120	4611	9.38	9.87	1.84	10.03	6.45	9.18	9.71	9.71	-0.32	-3.2%
19.08	720	4787	2.57	2.61	0.20	2.62	0.79	1.76	2.10	2.10	-0.52	-19.8%
19.09	720	4747	2.84	2.85	0.23	2.87	0.87	1.98	2.35	2.35	-0.52	-18.1%
19.1	60	4405	29.91	29.85	3.31	29.98	10.02	29.98	28.98	29.98	0.00	0.0%
19.11	60	4405	30.57	30.50	3.32	30.63	10.09	30.63	29.73	30.63	0.00	0.0%
19.12	120	4611	30.86	32.21	5.99	34.26	10.11	30.91	30.16	30.91	-3.35	-9.8%
20.01	20	4433	0.43	0.41	0.06	0.42	0.41	0.36	0.35	0.41	-0.01	-2.4%
21.01	20	4367	0.46	0.45	0.07	0.45	0.46	0.44	0.41	0.46	0.01	2.2%
22.01	60	4405	0.51	0.51	0.08	0.51	0.09	0.51	0.46	0.51	0.00	0.0%
23.01	45	4531	0.21	0.21	0.03	0.22	0.16	0.21	0.20	0.21	-0.01	-4.5%
24.01	60	4558	0.40	0.40	0.05	0.40	0.39	0.43	0.43	0.43	0.03	7.5%
24.02	60	4559	0.49	0.49	0.06	0.49	0.48	0.52	0.52	0.52	0.03	6.1%
24.03	120	4499	0.97	1.05	0.19	1.08	0.88	0.99	1.02	1.02	-0.06	-5.6%
24.04	60	4559	2.38	2.39	0.30	2.43	1.99	2.51	2.43	2.51	0.08	3.3%
24.05	60	4559	2.98	3.02	0.38	3.06	2.45	3.13	3.10	3.13	0.07	2.3%
25.01	120	4614	0.37	0.36	0.07	0.38	0.25	0.32	0.43	0.43	0.05	13.2%
26.01	60	4559	0.51	0.50	0.08	0.51	0.49	0.55	0.52	0.55	0.04	7.8%
26.02	60	4559	1.18	1.17	0.18	1.21	0.91	1.25	1.15	1.25	0.04	3.3%
27.01	45	4531	0.47	0.47	0.07	0.49	0.30	0.49	0.44	0.49	0.00	0.0%
28.01	120	4618	0.41	0.43	0.08	0.44	0.36	0.40	0.44	0.44	0.00	0.0%
29.01	60	4559	0.16	0.15	0.02	0.16	0.17	0.18	0.17	0.18	0.02	12.5%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4405 for the 1 hour duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
30.01	120	4499	0.41	0.42	0.05	0.44	0.25	0.36	0.46	0.46	0.02	4.5%
31.01	10	4363	0.41	0.41	0.04	0.42	0.42	0.39	0.40	0.42	0.00	0.0%
31.02	10	4363	1.08	1.10	0.10	1.12	1.12	0.99	1.18	1.18	0.06	5.4%
31.03	120	4614	1.54	1.47	0.23	1.51	1.37	1.29	1.77	1.77	0.26	17.2%
32.01	120	4614	0.25	0.25	0.02	0.26	0.17	0.25	0.27	0.27	0.01	3.8%
33.01	60	4360	0.25	0.25	0.01	0.25	0.24	0.24	0.24	0.24	-0.01	-4.0%
34.01	120	4499	0.24	0.25	0.03	0.26	0.11	0.22	0.27	0.27	0.01	3.8%
35.01	45	4531	0.24	0.24	0.04	0.25	0.22	0.25	0.24	0.25	0.00	0.0%
35.02	20	4367	0.77	0.75	0.12	0.76	0.77	0.74	0.70	0.77	0.01	1.3%
35.03	10	4363	1.22	1.23	0.12	1.26	1.26	1.19	1.14	1.26	0.00	0.0%
35.04	10	4363	1.50	1.51	0.11	1.55	1.55	1.59	1.54	1.59	0.04	2.6%
35.05	120	4614	1.02	1.03	0.12	1.10	0.57	0.96	1.11	1.11	0.01	0.9%
35.06	120	4499	0.83	0.84	0.03	0.85	0.35	0.77	0.85	0.85	0.00	0.0%
36.01	10	4363	0.45	0.46	0.05	0.48	0.48	0.36	0.35	0.48	0.00	0.0%
37.01	10	4363	0.18	0.18	0.02	0.19	0.19	0.14	0.13	0.19	0.00	0.0%
38.01	60	4405	0.26	0.27	0.03	0.27	0.18	0.27	0.26	0.27	0.00	0.0%
39.01	120	4614	0.73	0.70	0.14	0.73	0.26	0.64	0.86	0.86	0.13	17.8%
40.01	10	4363	0.26	0.26	0.02	0.27	0.27	0.22	0.22	0.27	0.00	0.0%
40.02	10	4363	0.51	0.51	0.04	0.53	0.53	0.47	0.47	0.53	0.00	0.0%
40.03	10	4363	1.42	1.44	0.13	1.45	1.45	1.31	1.37	1.45	0.00	0.0%
40.04	10	4363	2.01	2.03	0.14	2.07	2.07	2.01	2.05	2.07	0.00	0.0%
40.05	10	4363	2.68	2.67	0.10	2.71	2.71	2.72	2.71	2.72	0.01	0.4%
40.06	120	4611	3.01	3.19	0.56	3.28	3.03	3.01	3.10	3.10	-0.18	0.0%
41.01	10	4363	0.52	0.52	0.05	0.55	0.55	0.50	0.49	0.55	0.00	0.0%
42.01	10	4363	0.65	0.65	0.06	0.68	0.68	0.63	0.63	0.68	0.00	0.0%
43.01	10	4363	0.18	0.18	0.02	0.19	0.19	0.15	0.18	0.19	0.00	0.0%
44.01	120	4614	0.31	0.31	0.05	0.32	0.21	0.24	0.36	0.36	0.04	12.5%
44.02	120	4614	0.60	0.59	0.10	0.61	0.53	0.54	0.68	0.68	0.07	11.5%
44.03	120	4614	0.89	0.86	0.16	0.92	0.60	0.76	1.02	1.02	0.10	10.9%
44.04	360	4694	1.43	1.46	0.25	1.49	0.79	1.07	1.58	1.58	0.09	6.0%
45.01	10	4363	0.21	0.21	0.02	0.22	0.22	0.19	0.20	0.22	0.00	0.0%
46.01	720	4654	0.34	0.31	0.09	0.32	0.10	0.21	0.35	0.35	0.03	9.4%
47.01	120	4614	0.22	0.21	0.04	0.22	0.07	0.19	0.25	0.25	0.03	13.6%
48.01	720	4785	0.47	0.43	0.11	0.44	0.26	0.27	0.40	0.40	-0.04	-9.1%
48.02	360	4694	0.98	0.98	0.17	1.01	0.53	0.74	1.09	1.09	0.08	7.9%
49.01	120	4614	0.54	0.52	0.11	0.58	0.29	0.46	0.63	0.63	0.05	8.6%
50.01	120	4614	0.66	0.63	0.12	0.66	0.32	0.56	0.77	0.77	0.11	16.7%
51.01	120	4614	0.20	0.20	0.03	0.20	0.21	0.20	0.22	0.22	0.02	10.0%
52.01	120	4614	0.77	0.75	0.10	0.76	0.67	0.63	0.88	0.88	0.12	15.8%
52.02	10	4363	1.66	1.68	0.15	1.69	1.69	1.18	1.29	1.69	0.00	0.0%
53.01	10	4363	0.68	0.69	0.07	0.71	0.71	0.40	0.40	0.71	0.00	0.0%
53.02	10	4368	2.12	2.16	0.19	2.17	2.17	1.32	1.32	2.17	0.00	0.0%
53.03	10	4365	2.81	2.84	0.21	2.86	2.84	1.68	1.68	2.84	-0.02	-0.7%
54.01	10	4363	0.96	0.97	0.09	1.02	1.02	0.59	0.56	1.02	0.00	0.0%
55.01	10	4363	0.79	0.79	0.08	0.84	0.84	0.50	0.46	0.84	0.00	0.0%
56.01	10	4363	0.68	0.69	0.06	0.70	0.70	0.46	0.47	0.70	0.00	0.0%
57.01	10	4363	0.93	0.93	0.09	0.98	0.98	0.74	0.77	0.98	0.00	0.0%
57.02	10	4366	1.24	1.23	0.10	1.27	1.31	0.92	0.96	1.31	0.04	3.1%
57.03	10	4356	1.46	1.44	0.11	1.45	1.55	1.05	1.07	1.55	0.10	6.9%
58.01	120	4614	1.37	1.36	0.28	1.50	0.12	1.27	1.51	1.51	0.01	0.7%
58.02	120	4618	1.73	1.77	0.35	1.86	0.19	1.62	1.86	1.86	0.00	0.0%
58.03	120	4618	2.19	2.25	0.45	2.31	0.25	2.06	2.31	2.31	0.00	0.0%
58.04	120	4611	4.26	4.40	0.91	4.40	0.60	4.15	4.40	4.40	0.00	0.0%
58.05	120	4618	6.12	6.32	1.30	6.32	0.85	5.98	6.32	6.32	0.00	0.0%
58.06	120	4618	6.15	6.34	1.30	6.35	0.87	6.01	6.35	6.35	0.00	0.0%
58.07	120	4611	8.76	9.16	1.79	9.21	2.13	8.56	9.12	9.12	-0.09	-1.0%
58.08	60	4360	1.49	1.48	0.03	1.49	1.44	1.51	1.51	1.51	0.02	1.3%
58.09	120	4618	2.55	2.64	0.23	2.65	2.33	2.59	2.65	2.65	0.00	0.0%
58.1	120	4614	3.16	3.29	0.33	3.30	2.74	3.20	3.28	3.28	-0.02	-0.6%
58.11	120	4614	3.66	3.81	0.42	3.84	2.81	3.67	3.79	3.79	-0.05	-1.3%
59.01	120	4618	1.05	1.08	0.23	1.10	0.23	1.05	1.10	1.10	0.00	0.0%
59.02	60	4558	1.74	1.75	0.20	1.76	0.29	1.74	1.76	1.76	0.00	0.0%
60.01	60	4558	0.67	0.66	0.11	0.66	0.13	0.65	0.61	0.65	-0.01	-1.5%
60.02	120	4611	1.67	1.73	0.36	1.73	0.25	1.66	1.73	1.73	0.00	0.0%
61.01	45	4531	0.41	0.41	0.06	0.43	0.22	0.42	0.38	0.42	-0.01	-2.3%
61.02	45	4531	1.35	1.36	0.20	1.41	0.75	1.39	1.27	1.39	-0.02	-1.4%
61.03	45	4531	2.25	2.29	0.27	2.33	1.35	2.32	2.11	2.32	-0.01	-0.4%
61.04	60	4405	2.99	3.03	0.45	3.08	1.83	3.08	2.89	3.08	0.00	0.0%
62.01	45	4531	0.63	0.64	0.09	0.66	0.26	0.65	0.59	0.65	-0.01	-1.5%
63.01	60	4558	0.38	0.37	0.06	0.38	0.12	0.37	0.35	0.37	-0.01	-2.6%
64.01	45	4531	0.15	0.15	0.02	0.16	0.07	0.16	0.15	0.16	0.00	0.0%
65.01	60	4557	0.29	0.30	0.03	0.30	0.26	0.31	0.31	0.31	0.01	3.3%
65.02	60	4559	0.51	0.51	0.06	0.52	0.46	0.55	0.54	0.55	0.03	5.8%
66.01	20	4433	0.04	0.04	0.00	0.04	0.02	0.03	0.03	0.03	-0.01	-25.0%
67.01	10	4363	0.61	0.62	0.06	0.64	0.64	0.50	0.53	0.64	0.00	0.0%
68.01	10	4363	0.31	0.32	0.03	0.33	0.33	0.30	0.31	0.33	0.00	0.0%
69.01	10	4363	0.34	0.34	0.03	0.35	0.35	0.29	0.30	0.35	0.00	0.0%
69.02	10	4363	0.53	0.54	0.05	0.55	0.55	0.44	0.46	0.55	0.00	0.0%
70.01	10	4363	0.53	0.54	0.04	0.54	0.54	0.42	0.47	0.54	0.00	0.0%
71.01	10	4363	2.85	2.88	0.26	2.95	2.95	1.86	1.96	2.95	0.00	0.0%
71.02	10	4363	3.45	3.49	0.31	3.57	3.57	2.63	2.76	3.57	0.00	0.0%
72.01	120	4614	0.75	0.73	0.13	0.77	0.58	0.65	0.86	0.86	0.09	11.7%
73.01	10	4363	0.26	0.26	0.02	0.27	0.27	0.25	0.30	0.30	0.03	11.1%
73.02	120	4614	0.57	0.55	0.09	0.57	0.53	0.52	0.66	0.66	0.09	15.8%
73.03	120	4614	1.12	1.07	0.18	1.12	0.92	0.98	1.30	1.30	0.18	16.1%
74.01	120	4614	0.21	0.21	0.04	0.22	0.12	0.19	0.23	0.23	0.01	4.5%
75.01	90	4585	0.13	0.13	0.02	0.14	0.13	0.11	0.15	0.15	0.01	7.1%
76.01	120	4614	1.03	0.99	0.21	1.11	0.22	0.95	1.18	1.18	0.07	6.3%
77.01	120	4614	1.13	1.13	0.17	1.18	0.11	0.87	1.31	1.31	0.13	11.0%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4405 for the 1 hour duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
78.01	20	4433	0.24	0.23	0.03	0.23	0.22	0.20	0.20	0.22	-0.01	-4.3%
78.02	120	4618	7.81	8.21	1.84	8.24	1.03	7.58	8.24	8.24	0.00	0.0%
78.03	120	4618	10.11	10.54	2.28	10.68	3.09	9.88	10.68	10.68	0.00	0.0%
78.04	120	4618	10.79	11.17	2.43	11.29	3.75	10.44	11.29	11.29	0.00	0.0%
78.05	120	4618	11.26	11.62	2.52	11.73	3.95	10.85	11.73	11.73	0.00	0.0%
78.06	120	4618	13.95	14.25	2.99	14.69	4.79	13.08	14.69	14.69	0.00	0.0%
78.07	120	4618	16.67	17.09	3.38	17.96	5.16	15.31	17.96	17.96	0.00	0.0%
79.01	45	4531	0.64	0.64	0.11	0.66	0.52	0.67	0.61	0.67	0.01	1.5%
79.02	45	4531	1.31	1.31	0.21	1.33	1.00	1.37	1.23	1.37	0.04	3.0%
79.03	45	4531	1.67	1.68	0.26	1.72	1.31	1.74	1.60	1.74	0.02	1.2%
80.01	45	4531	0.40	0.40	0.06	0.41	0.32	0.42	0.38	0.42	0.01	2.4%
81.01	25	4462	0.16	0.15	0.02	0.16	0.11	0.14	0.13	0.14	-0.02	-12.5%
82.01	30	4503	0.56	0.55	0.06	0.55	0.52	0.54	0.49	0.54	-0.01	-1.8%
82.02	45	4531	0.89	0.88	0.14	0.90	0.79	0.93	0.86	0.93	0.03	3.3%
82.03	45	4531	1.44	1.44	0.22	1.47	1.34	1.52	1.42	1.52	0.05	3.4%
83.01	45	4531	0.48	0.48	0.08	0.49	0.46	0.51	0.47	0.51	0.02	4.1%
84.01	20	4359	0.35	0.35	0.06	0.36	0.36	0.37	0.36	0.37	0.01	2.8%
84.02	60	4559	0.84	0.82	0.11	0.84	0.87	0.90	0.88	0.90	0.06	7.1%
85.01	20	4429	0.24	0.23	0.04	0.23	0.23	0.25	0.23	0.25	0.02	8.7%
86.01	20	4433	0.02	0.02	0.00	0.02	0.02	0.02	0.02	0.02	0.00	0.0%
86.02	10	4363	0.38	0.39	0.04	0.39	0.39	0.35	0.35	0.39	0.00	0.0%
87.01	45	4531	0.12	0.13	0.02	0.13	0.06	0.13	0.11	0.13	0.00	0.0%
88.01	10	4363	0.67	0.67	0.06	0.72	0.72	0.73	0.71	0.73	0.01	1.4%
88.02	60	4559	1.05	1.06	0.14	1.08	0.97	1.13	1.11	1.13	0.05	4.6%
88.03	120	4618	1.96	2.06	0.38	2.13	1.24	1.85	2.13	2.13	0.00	0.0%
88.04	120	4614	2.75	2.78	0.52	2.97	1.36	2.47	3.06	3.06	0.09	3.0%
89.01	120	4618	0.67	0.67	0.14	0.71	0.14	0.66	0.71	0.71	0.00	0.0%
89.02	120	4614	2.09	2.01	0.40	2.15	1.55	1.81	2.38	2.38	0.23	10.7%
89.03	120	4614	3.10	3.02	0.58	3.21	2.67	2.65	3.52	3.52	0.31	9.7%
90.01	120	4614	0.67	0.65	0.13	0.71	0.18	0.62	0.75	0.75	0.04	5.6%
91.01	10	4363	0.77	0.79	0.07	0.80	0.80	0.64	0.67	0.80	0.00	0.0%
92.01	10	4363	0.94	0.95	0.09	0.97	0.97	0.80	0.83	0.97	0.00	0.0%
92.02	10	4363	1.46	1.48	0.13	1.49	1.49	1.20	1.26	1.49	0.00	0.0%
_junc_116	45	4531	1.04	1.05	0.15	1.08	0.48	1.07	0.97	1.07	-0.01	-0.9%
_junc_123	10	4363	3.38	3.41	0.30	3.49	3.49	2.50	2.65	3.49	0.00	0.0%
_junc_125	120	4618	52.34	54.33	8.29	56.85	18.66	46.06	56.85	56.85	0.00	0.0%
_junc_126	120	4614	1.58	1.53	0.27	1.57	0.83	1.29	1.84	1.84	0.27	17.2%
_junc_130	60	4405	8.18	8.26	1.24	8.29	2.13	8.29	7.59	8.29	0.00	0.0%
_junc_133	20	4367	2.32	2.25	0.38	2.26	2.25	2.32	2.19	2.32	0.06	2.7%
_junc_135	20	4367	0.67	0.66	0.11	0.68	0.70	0.61	0.59	0.70	0.02	2.9%
_junc_136	10	4363	0.91	0.91	0.08	0.95	0.95	0.87	0.83	0.95	0.00	0.0%
_junc_138	10	4363	7.76	7.90	0.72	7.97	7.97	5.28	5.52	7.97	0.00	0.0%
_junc_142	120	4614	2.69	2.63	0.51	2.79	2.35	2.30	3.06	3.06	0.27	9.7%
_junc_150	120	4618	8.86	9.30	2.03	9.40	2.11	8.65	9.40	9.40	0.00	0.0%
_junc_151	60	4559	2.53	2.54	0.33	2.59	2.12	2.68	2.60	2.68	0.09	3.5%
_junc_158	360	4694	0.93	0.94	0.16	0.96	0.53	0.71	1.03	1.03	0.07	7.3%
_junc_162	60	4405	0.52	0.52	0.08	0.52	0.19	0.52	0.50	0.52	0.00	0.0%
_junc_19	10	4363	1.41	1.40	0.13	1.49	1.49	1.27	1.20	1.49	0.00	0.0%
_junc_21	60	4405	25.98	26.11	3.39	26.25	7.14	26.25	24.48	26.25	0.00	0.0%
_junc_28	60	4405	6.87	6.96	0.94	7.10	5.06	7.10	6.83	7.10	0.00	0.0%
_junc_29	60	4559	2.12	2.11	0.28	2.15	1.65	2.24	2.14	2.24	0.09	4.2%
_junc_30	120	4618	0.41	0.43	0.08	0.44	0.36	0.40	0.44	0.44	0.00	0.0%
_junc_32	120	4611	0.85	0.91	0.16	0.92	0.70	0.84	0.91	0.91	-0.01	-1.1%
_junc_37	60	4405	30.47	30.41	3.32	30.54	10.07	30.54	29.63	30.54	0.00	0.0%
_junc_38	10	4363	9.07	9.13	0.65	9.24	9.24	7.08	7.31	9.24	0.00	0.0%
_junc_40	10	4368	1.88	1.92	0.17	1.92	1.92	1.81	1.86	1.92	0.00	0.0%
_junc_41	120	4618	3.91	4.03	0.84	4.07	0.51	3.81	4.07	4.07	0.00	0.0%
_junc_42	10	4354	2.51	2.50	0.15	2.52	2.48	2.47	2.48	2.48	-0.04	-1.6%
_junc_44	120	4611	31.13	32.46	6.02	34.46	10.13	31.11	30.46	31.11	-3.35	-9.7%
_junc_47	120	4618	4.35	4.50	0.75	4.62	3.72	4.07	4.62	4.62	0.00	0.0%
_junc_50	60	4559	0.32	0.32	0.04	0.33	0.28	0.34	0.34	0.34	0.01	3.0%
_junc_59	120	4618	43.52	45.58	7.82	46.76	16.79	39.87	46.76	46.76	0.00	0.0%
_junc_64	20	4371	2.00	2.00	0.09	2.01	1.88	2.01	2.04	2.04	0.03	1.5%
_junc_68	45	4531	0.79	0.78	0.13	0.79	0.62	0.82	0.74	0.82	0.03	3.8%
_junc_69	120	4618	44.40	46.53	7.80	48.03	16.95	40.22	48.03	48.03	0.00	0.0%
_junc_71	20	4371	2.98	2.99	0.28	3.06	2.71	3.03	3.11	3.11	0.05	1.6%
_junc_74	120	4618	3.56	3.71	0.40	3.71	2.79	3.56	3.71	3.71	0.00	0.0%
_junc_76	120	4618	45.56	47.73	7.85	49.44	17.07	40.93	49.44	49.44	0.00	0.0%
_junc_80	120	4618	50.84	52.85	8.14	55.13	18.53	44.96	55.13	55.13	0.00	0.0%
_junc_81	120	4614	0.78	0.76	0.13	0.78	0.63	0.71	0.90	0.90	0.12	15.4%
_junc_84	120	4499	54.24	56.12	8.45	58.77	18.81	47.44	58.97	58.97	0.20	0.3%
_junc_85	120	4499	68.19	68.25	10.54	72.84	22.82	58.72	75.76	75.76	2.92	4.0%
_junc_86	120	4499	68.87	68.87	10.55	73.37	22.89	59.16	76.42	76.42	3.05	4.2%
_junc_88	120	4618	13.79	14.10	2.98	14.53	4.77	12.95	14.53	14.53	0.00	0.0%
_junc_91	120	4618	16.55	16.97	3.38	17.82	5.14	15.22	17.82	17.82	0.00	0.0%
US_OHH	120	4618	47.00	49.09	7.92	50.97	17.21	41.85	50.97	50.97	0.00	0.0%
US_Rail	120	4618	42.38	44.39	7.70	45.24	16.69	39.10	45.24	45.24	0.00	0.0%

Average Difference (All Subcatchments)	**0.03**	**1.23%**
Average Difference (Focus Locations)	**-0.05**	**-0.47%**

ARR2016 Results for 0.5% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
1.01	60	4558	1.62	1.60	0.25	1.62	0.36	1.65	1.43	1.65	0.03	1.9%
1.02	45	4531	3.13	3.13	0.46	3.13	1.03	3.12	2.62	3.12	-0.01	-0.3%
1.03	45	4528	6.50	6.48	0.93	6.56	1.94	6.56	5.34	6.56	0.00	0.0%
1.04	45	4528	13.26	13.33	1.80	13.55	3.75	13.55	10.71	13.55	0.00	0.0%
1.05	45	4528	14.77	14.89	1.87	15.13	4.01	15.13	12.31	15.13	0.00	0.0%
1.06	45	4528	15.07	15.17	1.85	15.42	4.05	15.42	12.68	15.42	0.00	0.0%
1.07	60	4405	19.65	19.20	2.56	19.56	4.85	19.83	17.26	19.83	0.27	1.4%
1.08	60	4405	32.83	32.26	4.35	32.42	8.39	33.26	28.53	33.26	0.84	2.6%
1.09	60	4558	34.05	33.30	4.17	33.31	10.58	34.18	29.80	34.18	0.87	2.6%
1.1	10	4363	1.40	1.42	0.13	1.45	1.45	0.94	1.21	1.45	0.00	0.0%
1.11	10	4363	10.58	10.65	0.73	10.82	10.82	8.29	9.38	10.82	0.00	0.0%
1.12	10	4363	10.68	10.73	0.75	10.91	10.91	8.80	9.97	10.91	0.00	0.0%
1.13	10	4363	10.71	10.77	0.75	10.95	10.95	9.04	10.26	10.95	0.00	0.0%
1.14	60	4558	49.23	47.94	3.53	48.25	19.60	46.73	51.16	51.16	2.91	6.0%
1.15	120	4611	51.03	54.48	9.19	55.10	19.89	48.14	53.86	53.86	-1.24	-2.3%
1.16	120	4611	52.02	55.59	9.30	55.90	20.01	48.75	55.27	55.27	-0.63	-1.1%
1.17	120	4618	52.51	56.20	9.23	56.23	20.16	48.85	56.23	56.23	0.00	0.0%
1.18	120	4618	52.89	56.51	9.20	56.57	20.24	49.00	56.57	56.57	0.00	0.0%
1.19	120	4618	53.68	57.20	9.17	57.29	20.37	49.35	57.29	57.29	0.00	0.0%
1.2	120	4618	54.37	57.99	9.23	58.33	20.53	49.75	58.33	58.33	0.00	0.0%
1.21	120	4618	59.38	62.75	9.48	63.52	22.39	53.24	63.52	63.52	0.00	0.0%
1.22	120	4618	61.38	64.72	9.70	65.76	22.62	54.53	65.76	65.76	0.00	0.0%
1.23	120	4499	63.39	66.53	9.85	67.64	22.94	55.83	67.98	67.98	0.34	0.5%
1.24	120	4499	64.52	67.54	9.93	68.66	23.09	56.57	69.27	69.27	0.61	0.9%
1.25	120	4499	81.69	82.62	12.53	85.55	27.17	67.22	89.91	89.91	4.36	5.1%
1.26	120	4499	83.96	84.70	12.71	87.53	27.47	68.61	92.30	92.30	4.77	5.4%
2.01	25	4464	0.50	0.50	0.05	0.51	0.17	0.50	0.31	0.50	-0.01	-2.0%
2.02	30	4502	1.92	1.94	0.22	1.97	0.63	1.97	1.35	1.97	0.00	0.0%
3.01	45	4528	1.11	1.09	0.16	1.10	0.54	1.10	0.92	1.10	0.00	0.0%
3.02	45	4528	5.12	5.17	0.71	5.22	1.47	5.22	4.05	5.22	0.00	0.0%
3.03	45	4528	6.52	6.59	0.84	6.71	1.76	6.71	5.17	6.71	0.00	0.0%
4.01	45	4528	2.05	2.06	0.29	2.09	0.62	2.09	1.59	2.09	0.00	0.0%
5.01	45	4531	1.57	1.59	0.18	1.61	0.34	1.59	1.30	1.59	-0.02	-1.2%
5.02	60	4558	3.03	2.99	0.44	3.03	0.63	3.06	2.72	3.06	0.03	1.0%
5.03	60	4558	4.56	4.55	0.53	4.60	2.98	4.39	4.55	4.55	-0.05	-1.1%
6.01	45	4528	2.69	2.77	0.25	2.77	0.58	2.77	2.33	2.77	0.00	0.0%
6.02	45	4531	3.65	3.74	0.39	3.74	0.76	3.74	3.09	3.74	0.00	0.0%
6.03	45	4528	5.47	5.58	0.58	5.61	1.14	5.61	4.63	5.61	0.00	0.0%
6.04	45	4531	9.33	9.46	1.07	9.52	2.75	9.40	8.14	9.40	-0.12	-1.3%
6.05	45	4528	10.86	11.03	1.21	11.04	3.07	11.04	9.44	11.04	0.00	0.0%
6.06	45	4528	11.45	11.60	1.16	11.68	3.15	11.68	10.10	11.68	0.00	0.0%
6.07	60	4405	13.09	13.09	1.83	13.28	4.53	13.48	11.66	13.48	0.20	1.5%
7.01	45	4531	1.24	1.27	0.12	1.27	0.28	1.25	1.06	1.25	-0.02	-1.6%
8.01	30	4503	0.72	0.72	0.06	0.72	0.50	0.74	0.62	0.74	0.02	2.8%
8.02	45	4531	2.93	2.94	0.42	2.98	1.87	2.89	2.69	2.89	-0.09	-3.0%
8.03	45	4531	3.84	3.88	0.51	3.92	1.91	3.84	3.50	3.84	-0.08	-2.0%
9.01	30	4503	1.08	1.05	0.11	1.06	0.99	1.05	1.00	1.05	-0.01	-0.9%
10.01	45	4531	0.97	1.00	0.10	1.01	0.24	1.00	0.84	1.00	-0.01	-1.0%
11.01	60	4559	0.90	0.89	0.10	0.90	0.84	0.81	0.96	0.96	0.06	6.7%
11.02	20	4367	2.05	1.98	0.34	2.00	1.83	1.90	2.09	2.09	0.09	4.5%
12.01	10	4363	0.63	0.64	0.06	0.65	0.65	0.53	0.61	0.65	0.00	0.0%
13.01	20	4433	0.55	0.52	0.09	0.52	0.54	0.50	0.46	0.54	0.02	3.8%
14.01	10	4363	2.48	2.51	0.21	2.56	2.56	1.69	1.81	2.56	0.00	0.0%
15.01	10	4363	3.94	4.01	0.35	4.08	4.08	2.69	2.93	4.08	0.00	0.0%
15.02	10	4363	5.22	5.30	0.47	5.39	5.39	3.58	4.12	5.39	0.00	0.0%
15.03	10	4363	9.21	9.37	0.82	9.42	9.42	6.52	7.43	9.42	0.00	0.0%
15.04	10	4363	9.30	9.46	0.82	9.51	9.51	6.81	7.79	9.51	0.00	0.0%
16.01	10	4363	3.81	3.87	0.37	3.94	3.94	2.22	2.41	3.94	0.00	0.0%
17.01	90	4532	0.54	0.55	0.07	0.55	0.16	0.45	0.60	0.60	0.05	9.1%
18.01	60	4558	0.34	0.33	0.04	0.33	0.06	0.33	0.32	0.33	0.00	0.0%
19.01	10	4363	1.17	1.18	0.10	1.23	1.23	1.07	1.00	1.23	0.00	0.0%
19.02	20	4433	2.09	2.01	0.32	2.01	2.04	2.02	1.82	2.04	0.03	1.5%
19.03	45	4528	3.70	3.68	0.53	3.69	2.75	3.69	3.42	3.69	0.00	0.0%
19.04	45	4531	4.41	4.41	0.61	4.43	2.86	4.38	4.21	4.38	-0.05	-1.1%
19.05	60	4559	4.93	4.85	0.70	5.04	3.11	4.96	4.67	4.96	-0.08	-1.6%
19.06	60	4405	8.85	8.86	1.22	9.12	5.77	8.82	8.41	8.82	-0.30	-3.3%
19.07	60	4405	11.27	11.33	1.39	11.52	7.38	11.12	11.31	11.31	-0.21	-1.8%
19.08	720	4787	2.84	2.88	0.20	2.90	0.96	1.85	2.32	2.32	-0.58	-20.0%
19.09	720	4787	3.13	3.14	0.26	3.16	1.06	2.08	2.62	2.62	-0.54	-17.1%
19.1	60	4405	37.08	36.35	4.22	36.39	11.47	36.99	33.18	36.99	0.60	1.6%
19.11	60	4405	37.94	37.20	4.24	37.21	11.61	37.77	34.26	37.77	0.56	1.5%
19.12	60	4405	38.32	37.58	4.24	37.59	11.66	38.08	34.91	38.08	0.49	1.3%
20.01	20	4433	0.53	0.52	0.08	0.53	0.47	0.49	0.39	0.49	-0.04	-7.5%
21.01	20	4433	0.56	0.54	0.08	0.55	0.53	0.54	0.47	0.54	-0.01	-1.8%
22.01	45	4531	0.64	0.66	0.08	0.66	0.17	0.65	0.56	0.65	-0.01	-1.5%
23.01	45	4531	0.26	0.26	0.04	0.26	0.17	0.26	0.22	0.26	0.00	0.0%
24.01	60	4559	0.50	0.50	0.07	0.51	0.45	0.46	0.52	0.52	0.01	2.0%
24.02	60	4559	0.61	0.60	0.08	0.62	0.56	0.59	0.62	0.62	0.00	0.0%
24.03	60	4559	1.17	1.16	0.14	1.18	1.01	1.10	1.20	1.20	0.02	1.7%
24.04	60	4559	2.95	2.92	0.39	3.00	2.27	2.88	2.91	2.91	-0.09	-3.0%
24.05	60	4559	3.72	3.72	0.49	3.81	2.81	3.59	3.71	3.71	-0.10	-2.6%
25.01	120	4614	0.45	0.46	0.09	0.49	0.28	0.37	0.50	0.50	0.01	2.0%
26.01	30	4503	0.64	0.63	0.05	0.63	0.56	0.63	0.61	0.63	0.00	0.0%
26.02	45	4531	1.49	1.50	0.22	1.51	1.05	1.49	1.35	1.49	-0.02	-1.3%
27.01	45	4531	0.59	0.59	0.09	0.59	0.33	0.59	0.52	0.59	0.00	0.0%
28.01	60	4558	0.50	0.49	0.06	0.50	0.41	0.45	0.52	0.52	0.02	4.0%
29.01	60	4559	0.19	0.19	0.02	0.19	0.18	0.18	0.20	0.20	0.01	5.3%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s) Average	Median	Standard Dev	Adopted	TP 4363 for the 10 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration		m^3/s	%
30.01	120	4499	0.49	0.49	0.05	0.50	0.27	0.43	0.52	0.52	0.02	4.0%
31.01	20	4371	0.47	0.47	0.08	0.48	0.49	0.41	0.49	0.49	0.01	2.1%
31.02	120	4614	1.25	1.30	0.20	1.33	1.28	1.06	1.38	1.38	0.05	3.8%
31.03	120	4614	1.85	1.78	0.29	1.86	1.57	1.39	2.11	2.11	0.25	13.4%
32.01	60	4405	0.28	0.28	0.01	0.28	0.19	0.27	0.29	0.29	0.01	3.6%
33.01	45	4527	0.27	0.27	0.00	0.27	0.25	0.27	0.26	0.27	0.00	0.0%
34.01	120	4499	0.28	0.28	0.02	0.29	0.12	0.25	0.30	0.30	0.01	3.4%
35.01	30	4457	0.30	0.29	0.03	0.29	0.25	0.29	0.27	0.29	0.00	0.0%
35.02	20	4433	0.97	0.93	0.14	0.94	0.88	0.93	0.80	0.93	-0.01	-1.1%
35.03	20	4367	1.48	1.45	0.20	1.48	1.45	1.41	1.31	1.45	-0.03	-2.0%
35.04	60	4559	1.86	1.86	0.25	1.87	1.77	1.85	1.83	1.85	-0.02	-1.1%
35.05	60	4558	1.15	1.15	0.04	1.15	0.65	1.13	1.23	1.23	0.08	7.0%
35.06	120	4431	0.85	0.85	0.00	0.85	0.42	0.82	0.85	0.85	0.00	0.0%
36.01	20	4367	0.53	0.52	0.09	0.54	0.55	0.46	0.40	0.55	0.01	1.9%
37.01	10	4363	0.21	0.21	0.02	0.22	0.22	0.15	0.16	0.22	0.00	0.0%
38.01	60	4557	0.33	0.33	0.04	0.34	0.20	0.32	0.32	0.32	-0.02	-5.9%
39.01	90	4532	0.89	0.90	0.10	0.91	0.29	0.71	1.02	1.02	0.11	12.1%
40.01	10	4363	0.30	0.30	0.03	0.31	0.31	0.25	0.25	0.31	0.00	0.0%
40.02	10	4363	0.58	0.59	0.05	0.60	0.60	0.52	0.55	0.60	0.00	0.0%
40.03	10	4368	1.64	1.66	0.14	1.67	1.65	1.39	1.64	1.65	-0.02	-1.2%
40.04	20	4359	2.32	2.27	0.41	2.36	2.36	2.17	2.44	2.44	0.08	3.4%
40.05	60	4360	3.24	3.26	0.33	3.26	3.10	3.04	3.27	3.27	0.01	0.3%
40.06	60	4559	3.62	3.63	0.35	3.66	3.48	3.40	3.65	3.65	-0.01	0.0%
41.01	20	4367	0.60	0.59	0.10	0.60	0.63	0.54	0.57	0.63	0.03	5.0%
42.01	10	4363	0.75	0.76	0.07	0.79	0.79	0.66	0.75	0.79	0.00	0.0%
43.01	10	4363	0.21	0.21	0.02	0.22	0.22	0.16	0.21	0.22	0.00	0.0%
44.01	120	4614	0.38	0.37	0.07	0.39	0.23	0.27	0.44	0.44	0.05	12.8%
44.02	120	4614	0.72	0.73	0.12	0.76	0.60	0.58	0.81	0.81	0.05	6.6%
44.03	120	4614	1.08	1.08	0.20	1.16	0.68	0.89	1.21	1.21	0.05	4.3%
44.04	120	4614	1.71	1.66	0.26	1.71	0.90	1.27	1.92	1.92	0.21	12.3%
45.01	10	4363	0.24	0.24	0.02	0.25	0.25	0.20	0.24	0.25	0.00	0.0%
46.01	120	4614	0.40	0.41	0.04	0.42	0.11	0.24	0.46	0.46	0.04	9.5%
47.01	120	4614	0.26	0.25	0.05	0.28	0.07	0.22	0.30	0.30	0.02	7.1%
48.01	360	4694	0.56	0.56	0.09	0.58	0.30	0.29	0.54	0.54	-0.04	-6.9%
48.02	120	4614	1.16	1.12	0.18	1.15	0.61	0.89	1.33	1.33	0.18	15.7%
49.01	90	4584	0.66	0.66	0.08	0.67	0.33	0.57	0.73	0.73	0.06	9.0%
50.01	120	4614	0.80	0.77	0.14	0.83	0.36	0.63	0.91	0.91	0.08	9.6%
51.01	120	4614	0.23	0.25	0.04	0.25	0.23	0.20	0.26	0.26	0.01	4.0%
52.01	120	4614	0.93	0.89	0.14	0.93	0.78	0.67	1.07	1.07	0.14	15.1%
52.02	10	4363	1.90	1.94	0.18	1.94	1.94	1.32	1.53	1.94	0.00	0.0%
53.01	10	4363	0.78	0.79	0.07	0.82	0.82	0.50	0.46	0.82	0.00	0.0%
53.02	10	4368	2.43	2.47	0.21	2.48	2.46	1.57	1.50	2.46	-0.02	-0.8%
53.03	10	4365	3.20	3.24	0.23	3.25	3.22	2.10	1.93	3.22	-0.03	-0.9%
54.01	10	4363	1.11	1.12	0.10	1.17	1.17	0.68	0.65	1.17	0.00	0.0%
55.01	10	4363	0.92	0.92	0.09	0.97	0.97	0.57	0.54	0.97	0.00	0.0%
56.01	10	4363	0.78	0.79	0.07	0.81	0.81	0.52	0.54	0.81	0.00	0.0%
57.01	10	4363	1.07	1.08	0.10	1.12	1.12	0.80	0.94	1.12	0.00	0.0%
57.02	10	4366	1.42	1.41	0.11	1.46	1.51	1.05	1.15	1.51	0.05	3.4%
57.03	10	4356	1.67	1.66	0.12	1.68	1.78	1.23	1.29	1.78	0.10	6.0%
58.01	120	4618	1.66	1.69	0.34	1.78	0.24	1.48	1.78	1.78	0.00	0.0%
58.02	120	4611	2.08	2.19	0.44	2.21	0.37	1.97	2.17	2.17	-0.04	-1.8%
58.03	60	4558	2.63	2.63	0.30	2.65	0.48	2.55	2.69	2.69	0.04	1.5%
58.04	60	4558	5.25	5.24	0.63	5.28	1.04	5.11	5.09	5.11	-0.17	-3.2%
58.05	60	4558	7.54	7.52	0.88	7.59	1.44	7.34	7.31	7.34	-0.25	-3.3%
58.06	60	4558	7.57	7.56	0.88	7.62	1.44	7.37	7.33	7.37	-0.25	-3.3%
58.07	60	4405	10.64	10.70	1.18	10.73	2.61	10.48	10.60	10.60	-0.13	-1.2%
58.08	20	4433	1.54	1.54	0.02	1.55	1.47	1.53	1.54	1.54	-0.01	-0.6%
58.09	20	4367	2.84	2.83	0.24	2.89	2.51	2.70	2.93	2.93	0.04	1.4%
58.1	120	4618	3.51	3.67	0.41	3.68	3.01	3.39	3.68	3.68	0.00	0.0%
58.11	120	4499	4.10	4.28	0.52	4.30	3.26	3.91	4.26	4.26	-0.04	-0.9%
59.01	60	4558	1.32	1.31	0.16	1.33	0.33	1.29	1.26	1.29	-0.04	-3.0%
59.02	60	4558	2.18	2.17	0.27	2.20	0.49	2.14	2.03	2.14	-0.06	-2.7%
60.01	45	4531	0.84	0.85	0.10	0.86	0.22	0.85	0.70	0.85	-0.01	-1.2%
60.02	60	4558	2.06	2.06	0.25	2.08	0.41	2.03	1.99	2.03	-0.05	-2.4%
61.01	45	4531	0.52	0.52	0.08	0.53	0.25	0.52	0.44	0.52	-0.01	-1.9%
61.02	45	4531	1.70	1.69	0.26	1.70	0.85	1.69	1.48	1.69	-0.01	-0.6%
61.03	45	4531	2.85	2.89	0.38	2.92	1.54	2.87	2.49	2.87	-0.05	-1.7%
61.04	45	4531	3.76	3.81	0.47	3.86	2.09	3.75	3.42	3.75	-0.11	-2.8%
62.01	45	4531	0.79	0.79	0.11	0.79	0.31	0.79	0.68	0.79	0.00	0.0%
63.01	45	4531	0.48	0.49	0.06	0.50	0.14	0.48	0.43	0.48	-0.02	-4.0%
64.01	45	4531	0.19	0.19	0.03	0.19	0.09	0.19	0.17	0.19	0.00	0.0%
65.01	60	4559	0.37	0.37	0.05	0.37	0.29	0.34	0.38	0.38	0.01	2.7%
65.02	60	4559	0.63	0.63	0.08	0.63	0.52	0.61	0.64	0.64	0.01	1.6%
66.01	20	4433	0.05	0.05	0.01	0.05	0.03	0.05	0.04	0.05	0.00	0.0%
67.01	10	4363	0.71	0.72	0.07	0.74	0.74	0.55	0.64	0.74	0.00	0.0%
68.01	20	4359	0.36	0.36	0.06	0.37	0.38	0.31	0.37	0.38	0.01	2.7%
69.01	10	4363	0.39	0.40	0.04	0.41	0.41	0.32	0.34	0.41	0.00	0.0%
69.02	10	4363	0.61	0.62	0.06	0.64	0.64	0.49	0.55	0.64	0.00	0.0%
70.01	10	4368	0.61	0.62	0.05	0.62	0.61	0.47	0.56	0.61	-0.01	-1.6%
71.01	10	4363	3.26	3.30	0.30	3.39	3.39	2.09	2.30	3.39	0.00	0.0%
71.02	10	4363	3.94	4.00	0.36	4.08	4.08	2.91	3.32	4.08	0.00	0.0%
72.01	120	4614	0.90	0.93	0.16	0.97	0.68	0.74	1.00	1.00	0.03	3.1%
73.01	120	4614	0.31	0.32	0.05	0.33	0.30	0.26	0.35	0.35	0.02	6.1%
73.02	120	4614	0.69	0.68	0.11	0.70	0.60	0.56	0.79	0.79	0.09	12.9%
73.03	120	4614	1.35	1.30	0.23	1.36	1.04	1.04	1.57	1.57	0.21	15.4%
74.01	120	4618	0.25	0.26	0.05	0.27	0.14	0.21	0.27	0.27	0.00	0.0%
75.01	90	4585	0.16	0.16	0.02	0.16	0.15	0.14	0.17	0.17	0.01	6.3%
76.01	90	4532	1.24	1.25	0.17	1.26	0.30	1.11	1.36	1.36	0.10	7.9%
77.01	120	4614	1.36	1.36	0.23	1.44	0.21	0.98	1.59	1.59	0.15	10.4%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
78.01	20	4433	0.29	0.29	0.04	0.29	0.25	0.27	0.23	0.27	-0.02	-6.9%
78.02	60	4405	9.71	9.77	1.20	9.80	1.55	9.50	9.80	9.80	0.00	0.0%
78.03	60	4405	12.54	12.53	1.58	12.58	3.74	12.31	12.63	12.63	0.05	0.4%
78.04	60	4558	13.38	13.34	1.64	13.40	4.53	13.07	13.33	13.33	-0.07	-0.5%
78.05	60	4558	13.94	13.87	1.67	13.97	4.78	13.57	13.85	13.85	-0.12	-0.9%
78.06	60	4558	17.00	16.89	1.80	17.10	5.89	16.21	17.36	17.36	0.26	1.5%
78.07	120	4618	20.25	21.26	4.02	21.30	6.43	18.81	21.30	21.30	0.00	0.0%
79.01	30	4503	0.80	0.80	0.06	0.81	0.59	0.81	0.72	0.81	0.00	0.0%
79.02	45	4528	1.63	1.61	0.23	1.64	1.13	1.64	1.44	1.64	0.00	0.0%
79.03	45	4531	2.08	2.07	0.31	2.08	1.50	2.06	1.86	2.06	-0.02	-1.0%
80.01	45	4531	0.50	0.49	0.08	0.49	0.36	0.49	0.45	0.49	0.00	0.0%
81.01	20	4433	0.20	0.20	0.02	0.20	0.13	0.19	0.15	0.19	-0.01	-5.0%
82.01	20	4433	0.71	0.69	0.10	0.70	0.60	0.72	0.56	0.72	0.02	2.9%
82.02	30	4503	1.13	1.10	0.10	1.11	0.90	1.13	1.01	1.13	0.02	1.8%
82.03	45	4528	1.82	1.81	0.27	1.84	1.53	1.84	1.68	1.84	0.00	0.0%
83.01	30	4503	0.61	0.60	0.06	0.60	0.53	0.61	0.55	0.61	0.01	1.7%
84.01	20	4433	0.42	0.41	0.07	0.41	0.42	0.39	0.43	0.43	0.02	4.9%
84.02	20	4433	1.06	1.01	0.17	1.02	0.99	1.00	1.03	1.03	0.01	1.0%
85.01	20	4433	0.30	0.29	0.04	0.29	0.26	0.30	0.26	0.30	0.01	3.4%
86.01	20	4433	0.03	0.03	0.00	0.03	0.02	0.03	0.02	0.03	0.00	0.0%
86.02	20	4367	0.45	0.44	0.08	0.46	0.45	0.39	0.41	0.45	-0.01	-2.2%
87.01	45	4528	0.16	0.15	0.02	0.16	0.08	0.16	0.14	0.16	0.00	0.0%
88.01	30	4503	0.83	0.82	0.08	0.82	0.82	0.79	0.83	0.83	0.01	1.2%
88.02	60	4559	1.31	1.29	0.19	1.33	1.11	1.24	1.31	1.31	-0.02	-1.5%
88.03	120	4611	2.34	2.53	0.46	2.57	1.42	2.19	2.48	2.48	-0.09	-3.5%
88.04	120	4618	3.31	3.48	0.62	3.58	1.55	2.93	3.58	3.58	0.00	0.0%
89.01	60	4405	0.82	0.81	0.10	0.82	0.21	0.79	0.82	0.82	0.00	0.0%
89.02	120	4614	2.52	2.55	0.46	2.73	1.79	2.11	2.80	2.80	0.07	2.6%
89.03	120	4614	3.73	3.87	0.67	4.09	3.07	3.12	4.12	4.12	0.03	0.7%
90.01	90	4532	0.80	0.80	0.11	0.81	0.21	0.70	0.87	0.87	0.06	7.4%
91.01	10	4363	0.90	0.91	0.08	0.91	0.91	0.69	0.83	0.91	0.00	0.0%
92.01	10	4363	1.09	1.11	0.10	1.12	1.12	0.85	1.01	1.12	0.00	0.0%
92.02	10	4363	1.67	1.70	0.15	1.71	1.71	1.27	1.52	1.71	0.00	0.0%
_junc_116	45	4531	1.31	1.32	0.20	1.32	0.55	1.31	1.13	1.31	-0.01	-0.8%
_junc_123	10	4363	3.88	3.94	0.34	3.99	3.99	2.78	3.20	3.99	0.00	0.0%
_junc_125	120	4499	62.24	65.49	9.75	66.56	22.79	55.08	66.71	66.71	0.15	0.2%
_junc_126	120	4614	1.93	1.87	0.33	1.95	0.95	1.50	2.22	2.22	0.27	13.8%
_junc_130	45	4531	10.26	10.41	1.14	10.43	2.92	10.39	8.94	10.39	-0.04	-0.4%
_junc_133	20	4433	2.88	2.74	0.44	2.80	2.55	2.78	2.51	2.78	-0.02	-0.7%
_junc_135	20	4433	0.83	0.79	0.13	0.80	0.80	0.75	0.67	0.80	0.00	0.0%
_junc_136	20	4433	1.14	1.10	0.17	1.11	1.09	1.06	0.96	1.09	-0.02	-1.8%
_junc_138	10	4363	8.89	9.04	0.79	9.09	9.09	5.81	6.53	9.09	0.00	0.0%
_junc_142	120	4614	3.24	3.36	0.59	3.54	2.69	2.71	3.58	3.58	0.04	1.1%
_junc_150	60	4405	10.98	11.04	1.35	11.14	2.59	10.71	11.15	11.15	0.01	0.1%
_junc_151	60	4559	3.13	3.10	0.41	3.19	2.42	3.05	3.08	3.08	-0.11	-3.4%
_junc_158	360	4694	1.11	1.12	0.19	1.15	0.61	0.85	1.26	1.26	0.11	9.6%
_junc_162	45	4531	0.67	0.67	0.09	0.69	0.21	0.66	0.59	0.66	-0.03	-4.3%
_junc_19	20	4433	1.69	1.63	0.27	1.63	1.70	1.56	1.38	1.70	0.07	4.3%
_junc_21	60	4405	32.42	31.87	4.33	32.03	8.34	32.90	28.14	32.90	0.87	2.7%
_junc_28	60	4405	8.55	8.55	1.19	8.83	5.74	8.52	8.12	8.52	-0.31	-3.5%
_junc_29	45	4531	2.62	2.62	0.37	2.67	1.88	2.56	2.54	2.56	-0.11	-4.1%
_junc_30	60	4558	0.50	0.49	0.06	0.50	0.41	0.45	0.52	0.52	0.02	4.0%
_junc_32	60	4559	1.01	1.01	0.12	1.03	0.81	0.92	1.05	1.05	0.02	1.9%
_junc_37	60	4405	37.80	37.07	4.23	37.09	11.58	37.63	34.08	37.63	0.54	1.5%
_junc_38	10	4363	10.40	10.48	0.74	10.56	10.56	7.82	8.81	10.56	0.00	0.0%
_junc_40	20	4359	2.19	2.14	0.41	2.23	2.18	1.93	2.21	2.21	-0.02	-0.9%
_junc_41	60	4558	4.81	4.80	0.57	4.83	0.95	4.69	4.71	4.71	-0.12	-2.5%
_junc_42	60	4360	2.95	2.96	0.33	2.99	2.83	2.73	2.97	2.97	-0.02	-0.7%
_junc_44	60	4405	38.58	37.84	4.24	37.85	11.69	38.30	35.35	38.30	0.45	1.2%
_junc_47	120	4618	5.22	5.46	0.90	5.47	4.29	4.64	5.47	5.47	0.00	0.0%
_junc_50	60	4559	0.40	0.40	0.05	0.41	0.32	0.37	0.41	0.41	0.00	0.0%
_junc_59	120	4611	51.94	55.50	9.29	55.83	20.00	48.69	55.16	55.16	-0.67	-1.2%
_junc_64	20	4359	2.21	2.20	0.15	2.24	1.99	2.08	2.19	2.19	-0.05	-2.2%
_junc_68	30	4503	0.99	0.98	0.08	0.99	0.71	1.00	0.87	1.00	0.01	1.0%
_junc_69	120	4618	52.98	56.57	9.18	56.63	20.27	49.00	56.63	56.63	0.00	0.0%
_junc_71	20	4367	3.40	3.39	0.35	3.47	2.97	3.17	3.48	3.48	0.01	0.3%
_junc_74	120	4499	3.99	4.16	0.49	4.19	3.23	3.76	4.15	4.15	-0.04	-1.0%
_junc_76	120	4618	54.32	57.94	9.23	58.26	20.50	49.72	58.26	58.26	0.00	0.0%
_junc_80	120	4618	60.41	63.77	9.60	64.64	22.51	53.91	64.64	64.64	0.00	0.0%
_junc_81	120	4614	0.94	0.94	0.16	0.98	0.72	0.75	1.06	1.06	0.08	8.2%
_junc_84	120	4499	64.52	67.54	9.94	68.66	23.09	56.57	69.26	69.26	0.60	0.9%
_junc_85	120	4499	81.63	82.58	12.53	85.51	27.16	67.18	89.85	89.85	4.34	5.1%
_junc_86	120	4499	82.39	83.22	12.56	86.09	27.31	67.63	90.62	90.62	4.53	5.3%
_junc_88	60	4558	16.84	16.73	1.81	16.95	5.86	16.09	17.17	17.17	0.22	1.3%
_junc_91	120	4618	20.10	21.10	4.01	21.15	6.40	18.70	21.15	21.15	0.00	0.0%
US_OHH	120	4618	56.07	59.53	9.31	60.02	20.80	50.69	60.02	60.02	0.00	0.0%
US_Rail	120	4611	50.61	54.04	9.14	54.72	19.81	47.85	53.35	53.35	-1.37	-2.5%

Average Difference (All Subcatchments)	**0.09**	**0.90%**
Average Difference (Focus Locations)	**0.39**	**0.64%**

ARR2016 Results for 0.2% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration		m^3/s	%
			Average	Median	Standard Dev	Adopted						
1.01	45	4531	2.16	2.19	0.23	2.20	0.62	2.19	1.75	2.19	-0.01	-0.5%
1.02	45	4528	4.07	4.00	0.54	4.05	1.66	4.05	3.17	4.05	0.00	0.0%
1.03	45	4528	8.44	8.30	1.08	8.51	3.32	8.51	6.46	8.51	0.00	0.0%
1.04	45	4528	17.14	16.93	2.05	17.48	6.45	17.48	12.92	17.48	0.00	0.0%
1.05	45	4528	19.21	19.12	2.21	19.73	6.91	19.73	14.93	19.73	0.00	0.0%
1.06	45	4528	19.62	19.50	2.17	20.13	7.02	20.13	15.38	20.13	0.00	0.0%
1.07	45	4528	25.61	25.57	2.18	26.65	8.47	26.65	20.98	26.65	0.00	0.0%
1.08	45	4533	42.72	43.25	3.22	44.63	13.03	44.78	34.40	44.78	0.15	0.3%
1.09	45	4533	44.04	44.36	2.95	45.67	13.38	45.91	36.00	45.91	0.24	0.5%
1.1	10	4363	1.69	1.72	0.15	1.73	1.73	1.19	1.55	1.73	0.00	0.0%
1.11	10	4363	12.70	12.82	0.89	12.83	12.83	10.85	11.63	12.83	0.00	0.0%
1.12	10	4363	12.88	12.99	0.91	13.01	13.01	11.58	12.38	13.01	0.00	0.0%
1.13	10	4363	12.94	13.06	0.91	13.08	13.08	11.92	12.78	13.08	0.00	0.0%
1.14	60	4558	63.98	62.29	4.64	62.95	24.59	62.22	62.10	62.22	-0.73	-1.2%
1.15	60	4558	66.27	64.60	4.63	65.26	25.14	64.17	65.42	65.42	0.16	0.2%
1.16	60	4558	67.28	65.61	4.60	66.26	25.38	64.99	67.16	67.16	0.90	1.4%
1.17	60	4558	67.51	65.82	4.52	66.46	25.60	65.10	68.34	68.34	1.88	2.8%
1.18	60	4558	67.78	66.12	4.49	66.72	25.74	65.29	68.73	68.73	2.01	3.0%
1.19	60	4558	68.34	66.86	4.43	67.26	25.98	65.69	69.60	69.60	2.34	3.5%
1.2	60	4558	68.97	67.62	4.37	67.86	26.24	66.16	70.81	70.81	2.95	4.3%
1.21	60	4360	73.84	72.91	4.17	73.16	28.55	70.27	76.74	76.74	3.58	4.9%
1.22	60	4360	75.93	75.05	4.12	75.39	28.98	71.99	79.72	79.72	4.33	5.7%
1.23	60	4360	78.04	77.19	4.03	77.62	29.52	73.65	82.74	82.74	5.12	6.6%
1.24	120	4618	79.39	83.79	12.34	84.37	29.81	74.62	84.37	84.37	0.00	0.0%
1.25	90	4532	101.05	101.81	9.56	103.25	35.56	89.77	109.42	109.42	6.17	6.0%
1.26	90	4532	103.81	104.43	9.44	105.93	36.10	91.59	112.41	112.41	6.48	6.1%
2.01	25	4462	0.65	0.66	0.09	0.67	0.28	0.61	0.38	0.61	-0.06	-9.0%
2.02	25	4464	2.60	2.60	0.29	2.63	1.12	2.53	1.61	2.53	-0.10	-3.8%
3.01	25	4462	1.42	1.40	0.11	1.43	0.72	1.45	1.09	1.45	0.02	1.4%
3.02	45	4528	6.57	6.48	0.77	6.71	2.45	6.71	4.88	6.71	0.00	0.0%
3.03	45	4528	8.38	8.32	0.95	8.61	3.02	8.61	6.21	8.61	0.00	0.0%
4.01	45	4528	2.62	2.55	0.32	2.66	1.04	2.66	1.92	2.66	0.00	0.0%
5.01	45	4528	2.06	2.08	0.25	2.09	0.62	2.09	1.57	2.09	0.00	0.0%
5.02	45	4528	4.04	4.10	0.43	4.11	1.10	4.11	3.27	4.11	0.00	0.0%
5.03	60	4558	5.96	5.95	0.77	5.96	3.54	5.99	5.41	5.99	0.03	0.5%
6.01	45	4528	3.55	3.59	0.37	3.59	1.00	3.59	2.78	3.59	0.00	0.0%
6.02	45	4528	4.77	4.81	0.54	4.83	1.37	4.83	3.70	4.83	0.00	0.0%
6.03	45	4528	7.14	7.21	0.79	7.31	2.05	7.31	5.56	7.31	0.00	0.0%
6.04	45	4528	12.17	12.24	1.41	12.38	4.36	12.38	9.82	12.38	0.00	0.0%
6.05	45	4528	14.19	14.27	1.60	14.50	4.90	14.50	11.39	14.50	0.00	0.0%
6.06	45	4528	15.00	15.08	1.57	15.42	5.06	15.42	12.21	15.42	0.00	0.0%
6.07	45	4528	17.15	17.42	1.59	17.85	5.85	17.85	14.09	17.85	0.00	0.0%
7.01	45	4528	1.64	1.65	0.19	1.66	0.45	1.66	1.29	1.66	0.00	0.0%
8.01	25	4460	0.95	0.93	0.10	0.93	0.60	0.95	0.75	0.95	0.02	2.2%
8.02	45	4528	3.81	3.77	0.49	3.83	2.19	3.83	3.23	3.83	0.00	0.0%
8.03	45	4528	5.01	4.98	0.62	5.03	2.38	5.03	4.24	5.03	0.00	0.0%
9.01	20	4433	1.41	1.37	0.20	1.40	1.16	1.40	1.17	1.40	0.00	0.0%
10.01	45	4528	1.29	1.30	0.14	1.30	0.37	1.30	1.04	1.30	0.00	0.0%
11.01	60	4559	1.17	1.16	0.13	1.17	1.01	1.08	1.17	1.17	0.00	0.0%
11.02	20	4433	2.69	2.56	0.40	2.61	2.16	2.56	2.54	2.56	-0.05	-1.9%
12.01	20	4371	0.79	0.78	0.14	0.81	0.78	0.70	0.75	0.78	-0.03	-3.7%
13.01	20	4433	0.71	0.68	0.10	0.69	0.64	0.67	0.55	0.67	-0.02	-2.9%
14.01	10	4363	2.95	3.00	0.25	3.02	3.02	2.12	2.17	3.02	0.00	0.0%
15.01	10	4363	4.69	4.76	0.39	4.77	4.77	3.42	3.50	4.77	0.00	0.0%
15.02	10	4363	6.19	6.29	0.53	6.33	6.33	4.59	4.96	6.33	0.00	0.0%
15.03	10	4365	11.02	11.15	0.91	11.22	11.09	8.38	9.00	11.09	-0.13	-1.2%
15.04	10	4365	11.15	11.28	0.92	11.34	11.21	8.79	9.45	11.21	-0.13	-1.1%
16.01	10	4363	4.58	4.65	0.44	4.75	4.75	2.75	2.88	4.75	0.00	0.0%
17.01	60	4405	0.68	0.69	0.06	0.69	0.24	0.65	0.72	0.72	0.03	4.3%
18.01	45	4528	0.45	0.45	0.04	0.45	0.12	0.45	0.39	0.45	0.00	0.0%
19.01	20	4433	1.52	1.45	0.24	1.46	1.45	1.36	1.19	1.45	-0.01	-0.7%
19.02	20	4433	2.75	2.63	0.39	2.67	2.40	2.62	2.16	2.62	-0.05	-1.9%
19.03	30	4503	4.89	4.80	0.45	4.83	3.23	4.95	4.06	4.95	0.12	2.5%
19.04	45	4528	5.78	5.76	0.72	5.89	3.37	5.89	5.14	5.89	0.00	0.0%
19.05	45	4528	6.48	6.46	0.77	6.66	3.70	6.66	5.69	6.66	0.00	0.0%
19.06	45	4528	11.62	11.66	1.45	11.70	6.86	11.70	10.36	11.70	0.00	0.0%
19.07	45	4528	14.67	14.71	1.64	14.78	8.84	14.78	13.57	14.78	0.00	0.0%
19.08	720	4787	3.21	3.26	0.21	3.29	1.20	2.12	2.62	2.62	-0.67	-20.4%
19.09	720	4787	3.55	3.57	0.27	3.60	1.34	2.40	2.96	2.96	-0.64	-17.8%
19.1	60	4558	47.40	45.61	5.49	46.03	15.16	49.25	39.96	49.25	3.22	7.0%
19.11	60	4558	48.55	46.71	5.50	47.18	15.40	50.28	41.32	50.28	3.10	6.6%
19.12	60	4558	49.11	47.26	5.50	47.74	15.50	50.75	42.14	50.75	3.01	6.3%
20.01	20	4433	0.70	0.69	0.10	0.69	0.56	0.61	0.46	0.61	-0.08	-11.6%
21.01	20	4433	0.75	0.72	0.10	0.73	0.63	0.71	0.56	0.71	-0.02	-2.7%
22.01	45	4528	0.85	0.85	0.11	0.86	0.26	0.86	0.66	0.86	0.00	0.0%
23.01	30	4503	0.33	0.33	0.03	0.33	0.20	0.33	0.26	0.33	0.00	0.0%
24.01	45	4531	0.65	0.66	0.09	0.68	0.54	0.64	0.64	0.64	-0.04	-5.9%
24.02	45	4531	0.80	0.80	0.11	0.81	0.67	0.79	0.76	0.79	-0.02	-2.5%
24.03	60	4559	1.54	1.53	0.18	1.56	1.19	1.48	1.50	1.50	-0.06	-3.8%
24.04	45	4531	3.86	3.85	0.49	3.86	2.70	3.84	3.57	3.84	-0.02	-0.5%
24.05	45	4531	4.85	4.86	0.64	4.93	3.33	4.78	4.55	4.78	-0.15	-3.0%
25.01	90	4532	0.58	0.57	0.08	0.58	0.33	0.54	0.61	0.61	0.03	5.2%
26.01	30	4503	0.86	0.84	0.08	0.85	0.67	0.86	0.73	0.86	0.01	1.2%
26.02	45	4528	1.94	1.91	0.23	1.98	1.24	1.98	1.62	1.98	0.00	0.0%
27.01	30	4503	0.77	0.76	0.06	0.77	0.41	0.77	0.64	0.77	0.00	0.0%
28.01	60	4559	0.66	0.67	0.08	0.68	0.50	0.64	0.66	0.66	-0.02	-2.9%
29.01	20	4433	0.25	0.24	0.04	0.24	0.21	0.24	0.22	0.24	0.00	0.0%

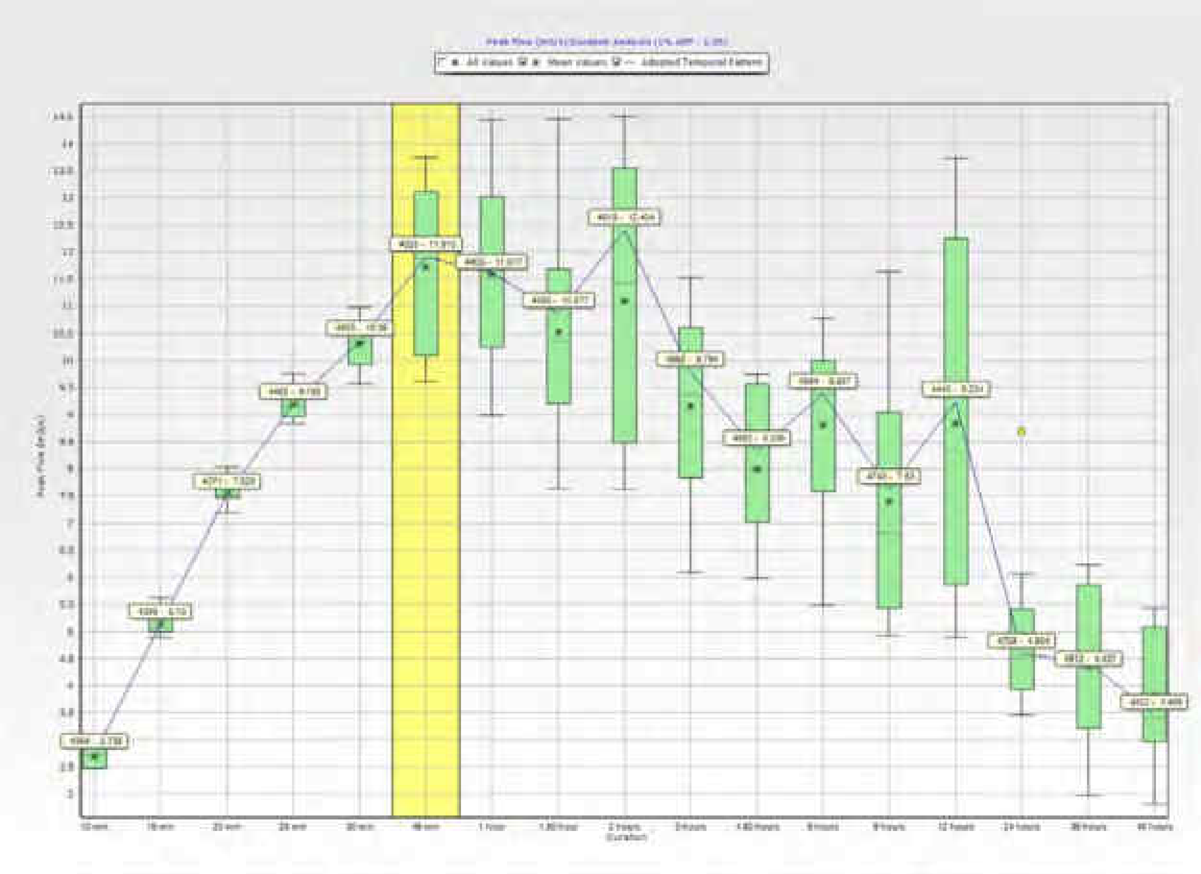
Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration		m^3/s	%
			Average	Median	Standard Dev	Adopted						
30.01	120	4499	0.57	0.57	0.05	0.59	0.29	0.53	0.62	0.62	0.03	5.1%
31.01	20	4367	0.60	0.58	0.10	0.59	0.59	0.54	0.60	0.60	0.01	1.7%
31.02	90	4584	1.56	1.57	0.22	1.59	1.51	1.40	1.68	1.68	0.09	5.7%
31.03	120	4614	2.33	2.35	0.36	2.43	1.85	1.91	2.63	2.63	0.20	8.2%
32.01	60	4558	0.32	0.32	0.01	0.32	0.21	0.31	0.33	0.33	0.01	3.1%
33.01	45	4533	0.30	0.30	0.00	0.30	0.27	0.30	0.30	0.30	0.00	0.0%
34.01	120	4499	0.33	0.33	0.02	0.33	0.16	0.30	0.34	0.34	0.01	3.0%
35.01	30	4503	0.39	0.38	0.04	0.38	0.29	0.38	0.32	0.38	0.00	0.0%
35.02	20	4433	1.25	1.20	0.18	1.22	1.05	1.18	0.95	1.18	-0.04	-3.3%
35.03	20	4433	1.91	1.82	0.26	1.85	1.72	1.82	1.56	1.82	-0.03	-1.6%
35.04	45	4528	2.43	2.42	0.32	2.46	2.11	2.46	2.26	2.46	0.00	0.0%
35.05	60	4558	1.35	1.34	0.04	1.34	0.79	1.32	1.41	1.41	0.07	5.2%
35.06	720	4443	0.85	0.85	0.00	0.85	0.53	0.85	0.85	0.85	0.00	0.0%
36.01	20	4367	0.68	0.65	0.11	0.65	0.66	0.57	0.47	0.66	0.01	1.5%
37.01	10	4363	0.25	0.26	0.02	0.26	0.26	0.20	0.20	0.26	0.00	0.0%
38.01	45	4531	0.43	0.43	0.05	0.45	0.23	0.43	0.40	0.43	-0.02	-4.4%
39.01	90	4532	1.13	1.14	0.14	1.14	0.40	1.01	1.24	1.24	0.10	8.8%
40.01	20	4367	0.37	0.36	0.06	0.37	0.37	0.32	0.30	0.37	0.00	0.0%
40.02	20	4367	0.74	0.73	0.12	0.74	0.70	0.66	0.65	0.70	-0.04	-5.4%
40.03	20	4359	2.04	2.00	0.35	2.07	1.95	1.84	2.01	2.01	-0.06	-2.9%
40.04	20	4367	2.99	2.96	0.47	3.05	2.80	2.90	2.97	2.97	-0.08	-2.6%
40.05	60	4559	4.16	4.16	0.45	4.18	3.69	4.10	4.02	4.10	-0.08	-1.9%
40.06	60	4559	4.65	4.64	0.48	4.69	4.14	4.57	4.48	4.57	-0.12	0.0%
41.01	20	4433	0.78	0.75	0.12	0.75	0.75	0.74	0.69	0.75	0.00	0.0%
42.01	20	4367	0.96	0.93	0.16	0.93	0.94	0.92	0.92	0.94	0.01	1.1%
43.01	10	4363	0.25	0.25	0.02	0.25	0.25	0.23	0.26	0.26	0.01	4.0%
44.01	90	4532	0.49	0.49	0.06	0.50	0.27	0.39	0.56	0.56	0.06	12.0%
44.02	90	4532	0.91	0.91	0.12	0.92	0.69	0.79	1.00	1.00	0.08	8.7%
44.03	90	4532	1.36	1.35	0.19	1.36	0.79	1.22	1.48	1.48	0.12	8.8%
44.04	120	4614	2.18	2.12	0.34	2.24	1.07	1.77	2.42	2.42	0.18	8.0%
45.01	20	4367	0.30	0.29	0.05	0.29	0.29	0.26	0.30	0.30	0.01	3.4%
46.01	120	4614	0.53	0.54	0.06	0.56	0.14	0.34	0.61	0.61	0.05	8.9%
47.01	90	4532	0.33	0.34	0.04	0.34	0.10	0.30	0.37	0.37	0.03	8.8%
48.01	180	4599	0.70	0.71	0.08	0.71	0.35	0.39	0.71	0.71	0.00	0.0%
48.02	120	4614	1.49	1.46	0.23	1.56	0.71	1.22	1.66	1.66	0.10	6.4%
49.01	90	4584	0.82	0.81	0.12	0.81	0.40	0.77	0.87	0.87	0.06	7.4%
50.01	90	4532	1.02	1.02	0.12	1.02	0.44	0.88	1.12	1.12	0.10	9.8%
51.01	20	4433	0.29	0.28	0.05	0.28	0.27	0.27	0.31	0.31	0.03	10.7%
52.01	90	4585	1.16	1.18	0.12	1.19	0.94	0.93	1.34	1.34	0.15	12.6%
52.02	10	4363	2.27	2.31	0.21	2.32	2.32	1.68	1.89	2.32	0.00	0.0%
53.01	10	4363	0.94	0.95	0.09	0.99	0.99	0.59	0.55	0.99	0.00	0.0%
53.02	10	4365	2.91	2.95	0.25	2.97	2.93	1.90	1.76	2.93	-0.04	-1.3%
53.03	10	4365	3.81	3.84	0.28	3.86	3.82	2.55	2.28	3.82	-0.04	-1.0%
54.01	10	4363	1.33	1.35	0.12	1.37	1.37	0.81	0.77	1.37	0.00	0.0%
55.01	10	4363	1.10	1.11	0.09	1.14	1.14	0.68	0.64	1.14	0.00	0.0%
56.01	10	4363	0.94	0.96	0.09	0.97	0.97	0.64	0.66	0.97	0.00	0.0%
57.01	10	4363	1.29	1.31	0.11	1.32	1.32	1.08	1.16	1.32	0.00	0.0%
57.02	10	4366	1.67	1.66	0.12	1.72	1.77	1.39	1.42	1.77	0.05	2.9%
57.03	10	4356	1.99	1.98	0.13	2.00	2.11	1.62	1.57	2.11	0.11	5.5%
58.01	60	4558	2.18	2.18	0.21	2.19	0.44	2.12	2.12	2.12	-0.07	-3.2%
58.02	60	4558	2.72	2.71	0.31	2.73	0.66	2.74	2.60	2.74	0.01	0.4%
58.03	60	4558	3.47	3.46	0.41	3.48	0.85	3.52	3.21	3.52	0.04	1.1%
58.04	45	4528	6.85	6.96	0.62	7.01	1.72	7.01	6.07	7.01	0.00	0.0%
58.05	60	4558	9.84	9.77	1.26	9.80	2.43	9.99	8.73	9.99	0.19	1.9%
58.06	60	4558	9.88	9.81	1.27	9.84	2.45	10.03	8.76	10.03	0.19	1.9%
58.07	60	4405	13.89	13.80	1.71	13.89	3.69	14.12	12.69	14.12	0.23	1.7%
58.08	20	4433	1.63	1.62	0.06	1.63	1.52	1.60	1.60	1.60	-0.03	-1.8%
58.09	20	4367	3.29	3.28	0.32	3.33	2.81	3.12	3.32	3.32	-0.01	-0.3%
58.1	20	4359	4.17	4.15	0.45	4.25	3.42	4.01	4.25	4.25	0.00	0.0%
58.11	60	4360	4.87	4.87	0.35	4.91	3.77	4.70	4.98	4.98	0.07	1.4%
59.01	60	4558	1.72	1.69	0.24	1.71	0.52	1.75	1.50	1.75	0.04	2.3%
59.02	45	4528	2.86	2.90	0.25	2.90	0.79	2.90	2.42	2.90	0.00	0.0%
60.01	45	4528	1.11	1.11	0.13	1.12	0.35	1.12	0.84	1.12	0.00	0.0%
60.02	60	4558	2.69	2.65	0.37	2.66	0.70	2.73	2.38	2.73	0.07	2.6%
61.01	45	4528	0.68	0.66	0.09	0.68	0.34	0.68	0.55	0.68	0.00	0.0%
61.02	45	4528	2.20	2.14	0.29	2.20	1.13	2.20	1.77	2.20	0.00	0.0%
61.03	45	4528	3.74	3.72	0.47	3.79	1.82	3.79	2.98	3.79	0.00	0.0%
61.04	45	4528	4.95	4.95	0.62	4.98	2.47	4.98	4.17	4.98	0.00	0.0%
62.01	45	4528	1.03	1.01	0.14	1.03	0.45	1.03	0.81	1.03	0.00	0.0%
63.01	45	4528	0.64	0.64	0.08	0.64	0.22	0.64	0.54	0.64	0.00	0.0%
64.01	45	4528	0.24	0.24	0.03	0.24	0.11	0.24	0.19	0.24	0.00	0.0%
65.01	60	4559	0.48	0.47	0.07	0.49	0.35	0.46	0.47	0.47	-0.02	-4.1%
65.02	30	4503	0.82	0.80	0.07	0.80	0.62	0.80	0.76	0.80	0.00	0.0%
66.01	20	4433	0.07	0.06	0.01	0.07	0.04	0.05	0.04	0.05	-0.02	-28.6%
67.01	10	4363	0.86	0.88	0.08	0.89	0.89	0.71	0.81	0.89	0.00	0.0%
68.01	20	4367	0.45	0.44	0.08	0.45	0.45	0.41	0.47	0.47	0.02	4.4%
69.01	10	4363	0.48	0.49	0.04	0.50	0.50	0.41	0.41	0.50	0.00	0.0%
69.02	10	4363	0.74	0.75	0.07	0.77	0.77	0.64	0.67	0.77	0.00	0.0%
70.01	10	4365	0.73	0.75	0.06	0.75	0.74	0.59	0.69	0.74	-0.01	-1.3%
71.01	10	4363	3.89	3.95	0.35	4.02	4.02	2.59	2.85	4.02	0.00	0.0%
71.02	10	4363	4.73	4.81	0.40	4.84	4.84	3.72	4.14	4.84	0.00	0.0%
72.01	90	4532	1.13	1.13	0.16	1.13	0.81	1.01	1.21	1.21	0.08	7.1%
73.01	90	4532	0.39	0.39	0.05	0.39	0.37	0.34	0.42	0.42	0.03	7.7%
73.02	90	4532	0.87	0.87	0.11	0.88	0.71	0.72	0.97	0.97	0.09	10.2%
73.03	90	4532	1.71	1.72	0.20	1.73	1.24	1.41	1.94	1.94	0.21	12.1%
74.01	60	4405	0.31	0.31	0.03	0.32	0.17	0.29	0.32	0.32	0.00	0.0%
75.01	90	4584	0.19	0.19	0.03	0.20	0.18	0.18	0.21	0.21	0.01	5.0%
76.01	60	4405	1.61	1.60	0.15	1.60	0.45	1.52	1.64	1.64	0.04	2.5%
77.01	90	4532	1.75	1.79	0.18	1.80	0.32	1.38	2.01	2.01	0.21	11.7%

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns						Peak Discharge for the Reduced Set of Durations and Temporal Patterns (m^3/s)			Max of the Reduced Set (m^3/s)	Difference between the Reduced Set and Adopted	
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)				TP 4363 for the 10 minute duration	TP 4528 for the 45 minute duration	TP 4618 for the 2 hour duration			
			Average	Median	Standard Dev	Adopted					m^3/s	%
78.01	20	4433	0.38	0.37	0.06	0.38	0.29	0.34	0.26	0.34	-0.04	-10.5%
78.02	60	4405	13.07	12.99	1.74	13.09	2.54	13.25	12.00	13.25	0.16	1.2%
78.03	60	4558	16.60	16.44	2.17	16.47	4.76	16.89	15.42	16.89	0.42	2.6%
78.04	60	4558	17.67	17.44	2.22	17.59	5.76	17.85	16.24	17.85	0.26	1.5%
78.05	60	4558	18.39	18.12	2.26	18.33	6.12	18.53	16.86	18.53	0.20	1.1%
78.06	60	4558	22.44	22.18	2.45	22.42	7.72	22.20	21.14	22.20	-0.22	-1.0%
78.07	60	4558	26.58	26.30	2.51	26.34	8.59	25.90	26.04	26.04	-0.30	-1.1%
79.01	25	4462	1.05	1.03	0.11	1.04	0.69	1.06	0.84	1.06	0.02	1.9%
79.02	30	4402	2.11	2.12	0.19	2.14	1.32	2.17	1.72	2.17	0.03	1.4%
79.03	45	4528	2.70	2.66	0.35	2.75	1.77	2.75	2.22	2.75	0.00	0.0%
80.01	30	4402	0.67	0.67	0.05	0.67	0.43	0.68	0.54	0.68	0.01	1.5%
81.01	20	4433	0.26	0.26	0.03	0.26	0.15	0.24	0.18	0.24	-0.02	-7.7%
82.01	20	4433	0.98	0.96	0.13	0.97	0.70	0.90	0.68	0.90	-0.07	-7.2%
82.02	20	4433	1.49	1.46	0.18	1.48	1.05	1.48	1.21	1.48	0.00	0.0%
82.03	30	4402	2.42	2.38	0.24	2.39	1.80	2.45	2.03	2.45	0.06	2.5%
83.01	30	4503	0.81	0.79	0.09	0.79	0.63	0.82	0.66	0.82	0.03	3.8%
84.01	30	4503	0.54	0.53	0.05	0.53	0.50	0.53	0.52	0.53	0.00	0.0%
84.02	20	4433	1.35	1.30	0.20	1.32	1.16	1.31	1.24	1.31	-0.01	-0.8%
85.01	20	4433	0.39	0.39	0.06	0.39	0.31	0.38	0.31	0.38	-0.01	-2.6%
86.01	20	4433	0.04	0.04	0.01	0.04	0.03	0.03	0.03	0.03	-0.01	-25.0%
86.02	20	4367	0.56	0.55	0.09	0.56	0.55	0.51	0.49	0.55	-0.01	-1.8%
87.01	45	4528	0.20	0.19	0.02	0.20	0.09	0.20	0.16	0.20	0.00	0.0%
88.01	20	4433	1.11	1.06	0.16	1.08	0.96	1.07	0.98	1.07	-0.01	-0.9%
88.02	30	4503	1.72	1.70	0.12	1.71	1.30	1.70	1.58	1.70	-0.01	-0.6%
88.03	60	4405	3.01	3.03	0.37	3.07	1.68	2.96	3.00	3.00	-0.07	-2.3%
88.04	60	4405	4.15	4.19	0.44	4.19	1.85	4.04	4.32	4.32	0.13	3.1%
89.01	60	4558	1.08	1.06	0.13	1.08	0.30	1.08	0.97	1.08	0.00	0.0%
89.02	90	4532	3.14	3.14	0.42	3.16	2.13	2.91	3.41	3.41	0.25	7.9%
89.03	90	4532	4.66	4.62	0.63	4.64	3.63	4.31	4.99	4.99	0.35	7.5%
90.01	60	4558	1.04	1.04	0.10	1.05	0.32	1.00	1.06	1.06	0.01	1.0%
91.01	10	4365	1.10	1.11	0.09	1.12	1.11	0.91	1.05	1.11	-0.01	-0.9%
92.01	10	4365	1.33	1.34	0.11	1.35	1.33	1.15	1.24	1.33	-0.02	-1.5%
92.02	10	4368	2.00	2.04	0.17	2.05	2.03	1.69	1.90	2.03	-0.02	-1.0%
_junc_116	45	4528	1.70	1.67	0.22	1.71	0.79	1.71	1.36	1.71	0.00	0.0%
_junc_123	10	4368	4.66	4.73	0.39	4.74	4.72	3.54	3.97	4.72	-0.02	-0.4%
_junc_125	60	4360	76.83	75.97	4.05	76.38	29.29	72.67	81.07	81.07	4.69	6.1%
_junc_126	120	4614	2.46	2.45	0.42	2.65	1.10	2.08	2.76	2.76	0.11	4.2%
_junc_130	45	4528	13.41	13.48	1.52	13.68	4.68	13.68	10.78	13.68	0.00	0.0%
_junc_133	20	4433	3.81	3.67	0.52	3.72	3.00	3.65	2.98	3.65	-0.07	-1.9%
_junc_135	20	4433	1.06	1.01	0.16	1.03	0.95	0.96	0.79	0.96	-0.07	-6.8%
_junc_136	20	4433	1.47	1.40	0.21	1.42	1.30	1.36	1.14	1.36	-0.06	-4.2%
_junc_138	10	4368	10.57	10.75	0.90	10.81	10.69	7.34	7.81	10.69	-0.12	-1.1%
_junc_142	90	4584	4.03	4.01	0.56	4.02	3.19	3.73	4.33	4.33	0.31	7.7%
_junc_150	60	4405	14.66	14.57	1.92	14.67	3.43	14.83	13.64	14.83	0.16	1.1%
_junc_151	45	4531	4.09	4.08	0.52	4.11	2.87	4.06	3.77	4.06	-0.05	-1.2%
_junc_158	120	4614	1.42	1.39	0.21	1.47	0.71	1.16	1.58	1.58	0.11	7.5%
_junc_162	45	4528	0.87	0.88	0.11	0.88	0.34	0.88	0.72	0.88	0.00	0.0%
_junc_19	20	4433	2.22	2.12	0.33	2.15	2.01	1.97	1.65	2.01	-0.14	-6.5%
_junc_21	45	4533	42.20	42.76	3.24	44.15	12.91	44.27	33.91	44.27	0.12	0.3%
_junc_28	45	4528	11.23	11.27	1.40	11.35	6.81	11.35	9.98	11.35	0.00	0.0%
_junc_29	45	4528	3.44	3.43	0.45	3.44	2.22	3.44	3.12	3.44	0.00	0.0%
_junc_30	60	4559	0.66	0.67	0.08	0.68	0.50	0.64	0.66	0.66	-0.02	-2.9%
_junc_32	60	4559	1.34	1.35	0.16	1.37	0.96	1.27	1.31	1.31	-0.06	-4.4%
_junc_37	60	4558	48.37	46.54	5.50	47.00	15.35	50.11	41.10	50.11	3.11	6.6%
_junc_38	10	4365	12.45	12.54	0.90	12.59	12.48	10.15	10.90	12.48	-0.11	-0.9%
_junc_40	20	4367	2.81	2.78	0.47	2.87	2.57	2.59	2.69	2.69	-0.18	-6.3%
_junc_41	60	4558	6.28	6.22	0.82	6.27	1.55	6.42	5.63	6.42	0.15	2.4%
_junc_42	45	4531	3.76	3.75	0.51	3.81	3.38	3.71	3.64	3.71	-0.10	-2.6%
_junc_44	60	4558	49.48	47.62	5.51	48.10	15.57	51.06	42.74	51.06	2.96	6.2%
_junc_47	60	4559	6.54	6.61	0.61	6.72	5.12	6.28	6.72	6.72	0.00	0.0%
_junc_50	60	4559	0.52	0.51	0.07	0.52	0.37	0.50	0.50	0.50	-0.02	-3.8%
_junc_59	60	4558	67.19	65.52	4.61	66.18	25.36	64.92	67.03	67.03	0.85	1.3%
_junc_64	20	4359	2.47	2.46	0.22	2.50	2.18	2.31	2.41	2.41	-0.09	-3.6%
_junc_68	20	4433	1.31	1.28	0.15	1.29	0.84	1.30	1.03	1.30	0.01	0.8%
_junc_69	60	4558	67.81	66.19	4.48	66.74	25.77	65.29	68.81	68.81	2.07	3.1%
_junc_71	20	4367	4.03	4.01	0.45	4.10	3.37	3.73	3.99	3.99	-0.11	-2.7%
_junc_74	60	4360	4.71	4.71	0.33	4.75	3.73	4.50	4.84	4.84	0.09	1.9%
_junc_76	60	4558	68.93	67.56	4.37	67.82	26.20	66.13	70.73	70.73	2.91	4.3%
_junc_80	60	4360	74.93	74.03	4.14	74.35	28.78	71.16	78.23	78.23	3.88	5.2%
_junc_81	90	4532	1.18	1.17	0.15	1.18	0.85	1.01	1.29	1.29	0.11	9.3%
_junc_84	120	4618	79.38	83.79	12.34	84.37	29.81	74.62	84.37	84.37	0.00	0.0%
_junc_85	90	4532	100.99	101.75	9.57	103.18	35.53	89.73	109.35	109.35	6.17	6.0%
_junc_86	90	4532	101.87	102.52	9.47	104.03	35.78	90.26	110.24	110.24	6.21	6.0%
_junc_88	60	4558	22.22	21.97	2.46	22.22	7.70	22.02	20.91	22.02	-0.20	-0.9%
_junc_91	60	4558	26.41	26.13	2.50	26.18	8.54	25.74	25.87	25.87	-0.31	-1.2%
US_OHH	60	4360	70.52	69.39	4.30	69.40	26.69	67.41	72.83	72.83	3.43	4.9%
US_Rail	60	4558	65.83	64.16	4.65	64.82	24.98	63.80	64.82	64.82	0.00	0.0%

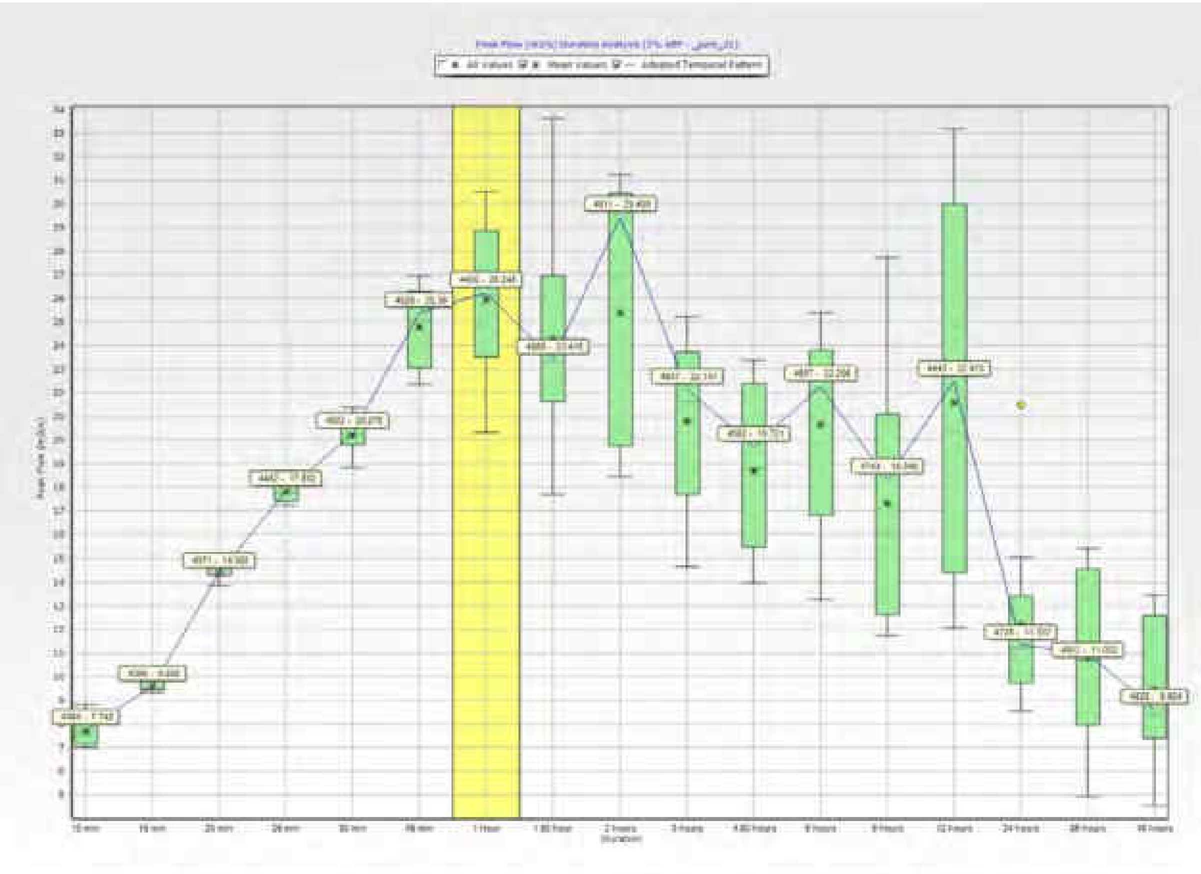
Average Difference (All Subcatchments)	**0.32**	**0.64%**
Average Difference (Focus Locations)	**1.62**	**2.44%**

ARR2016 Box Plots

1% AEP ARR2016 Box Plot for Eastern Crossing of Bong Bong Road

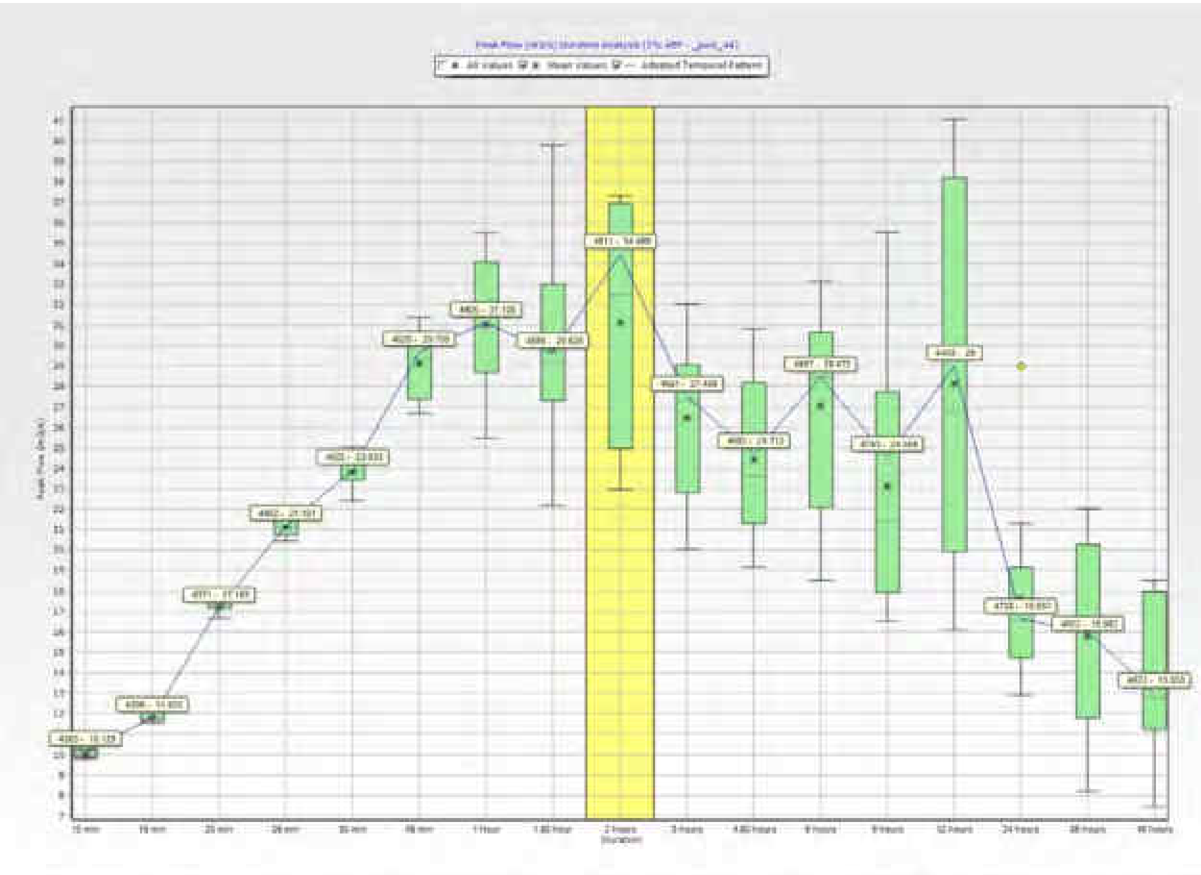


1% AEP ARR2016 Box Plot for Oldfield Road

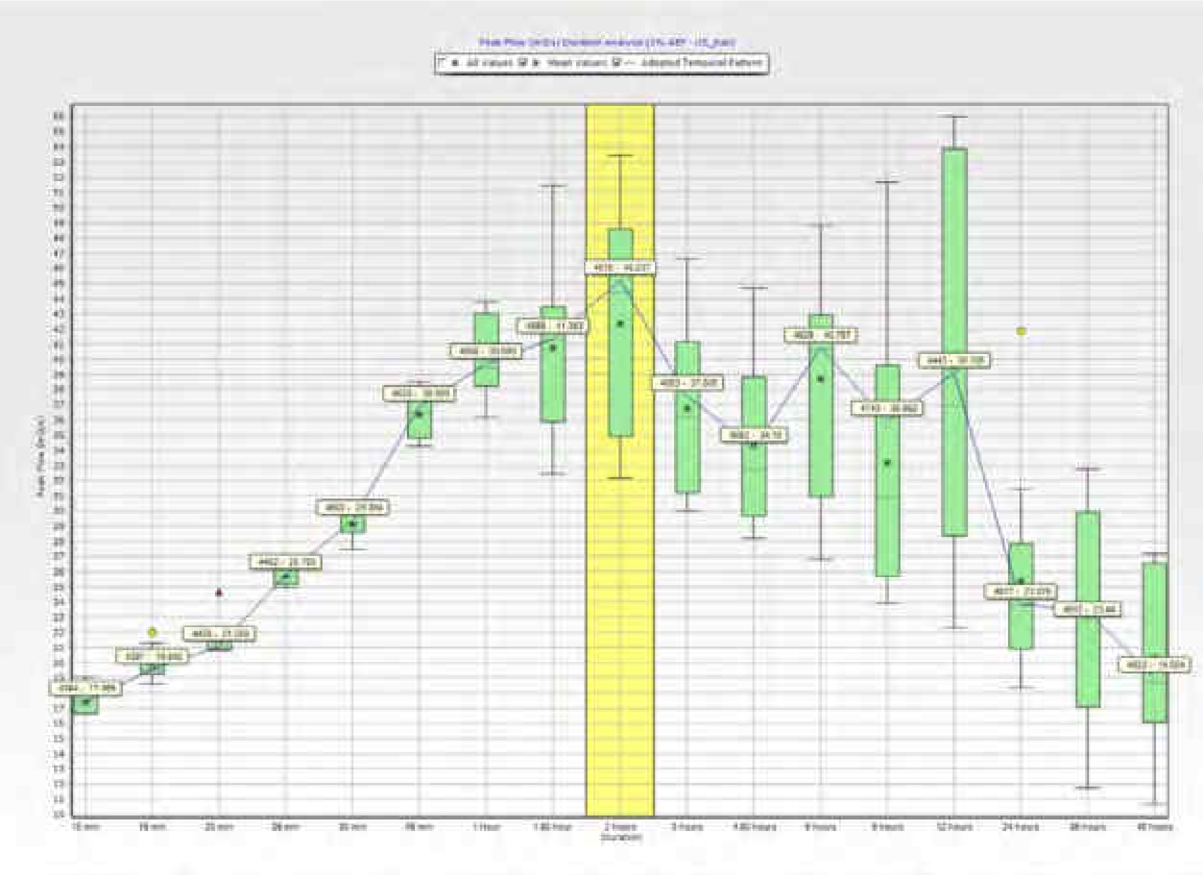


1% AEP ARR2016 Box Plot for Downstream of Renwick

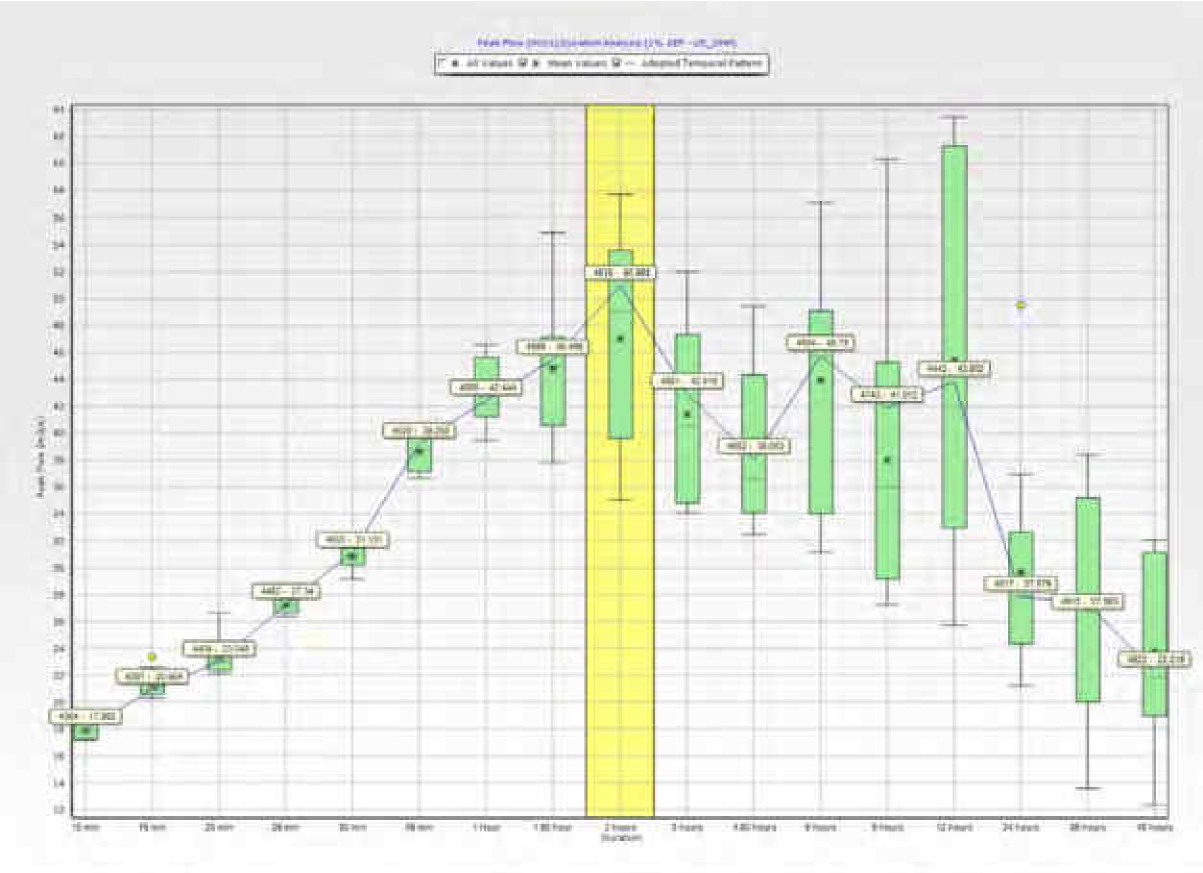
1% AEP ARR2016 Box Plot for Scarlet Street



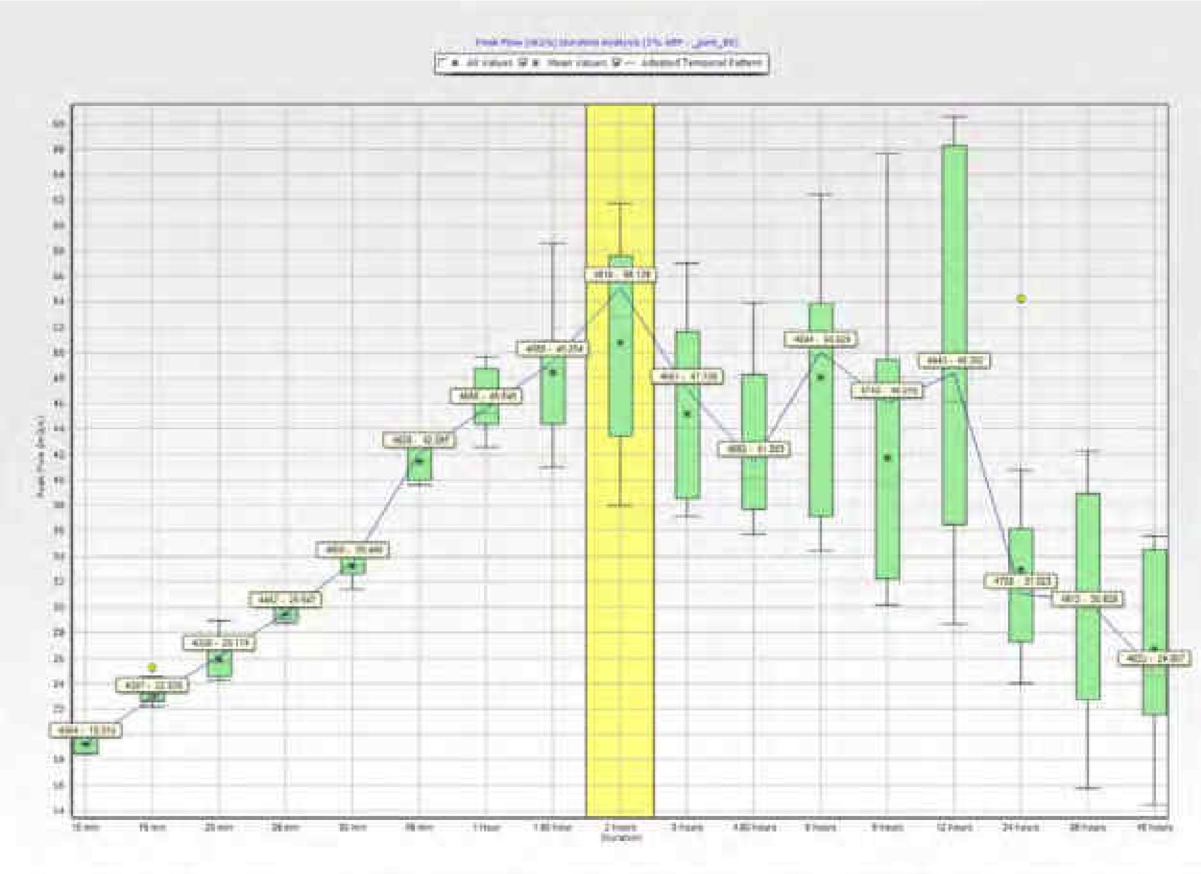
1% AEP ARR2016 Box Plot for Railway Crossing



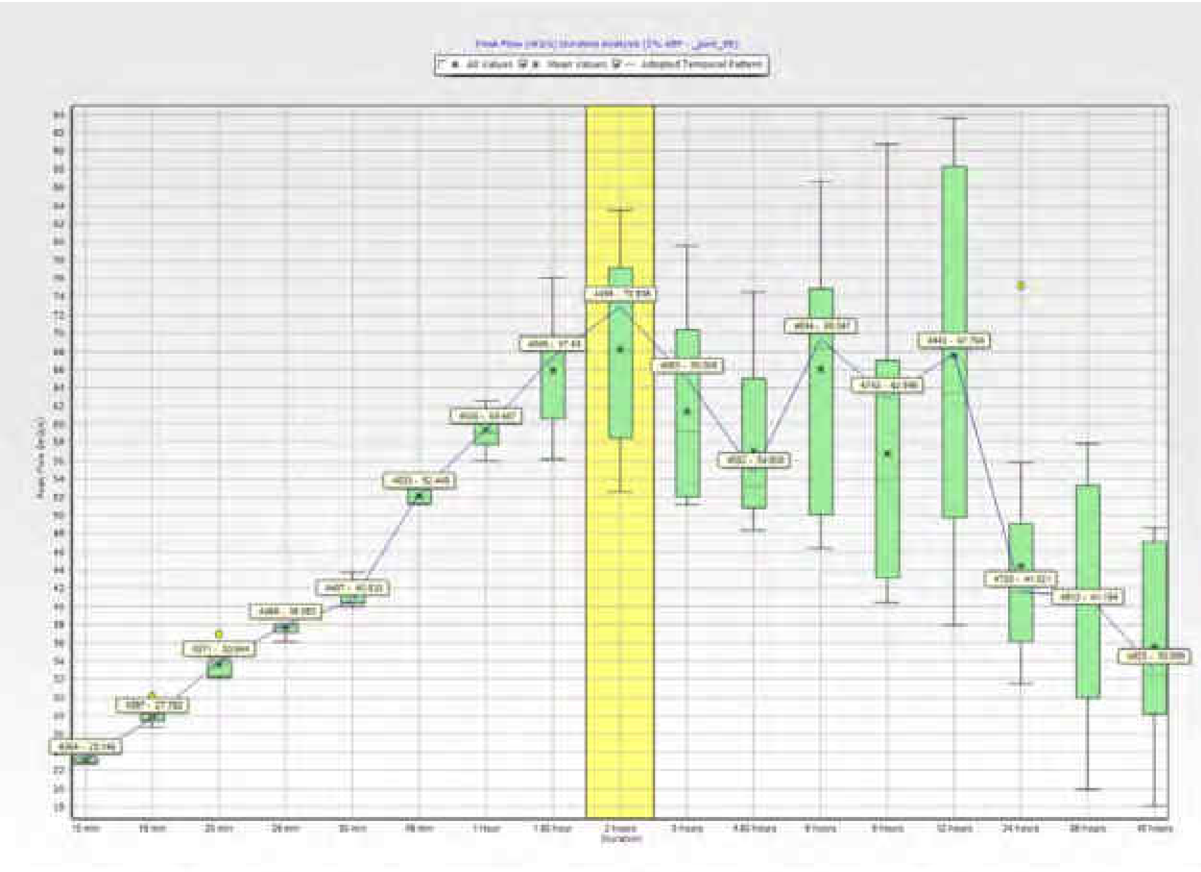
1% AEP ARR2016 Box Plot for Old Hume Highway



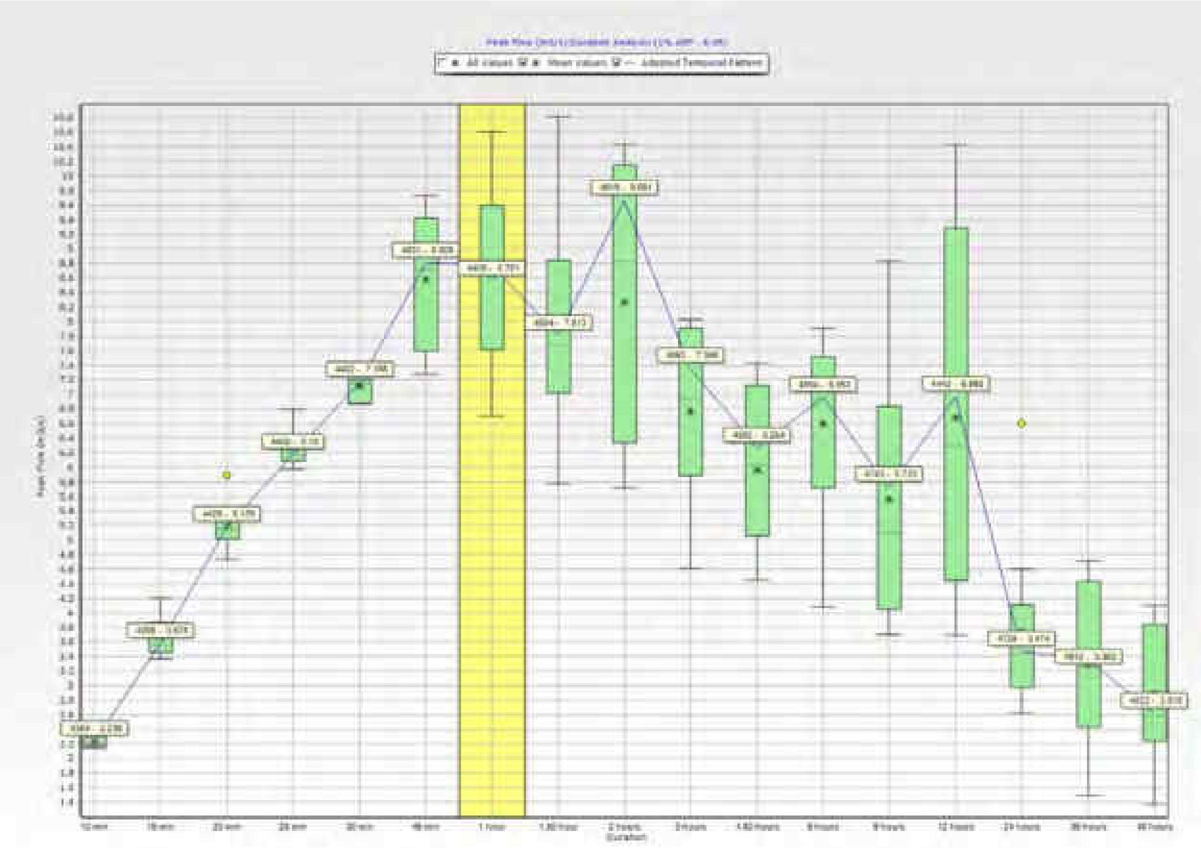
1% AEP ARR2016 Box Plot for Braemar Road



1% AEP ARR2016 Box Plot for Downstream of Industrial Area

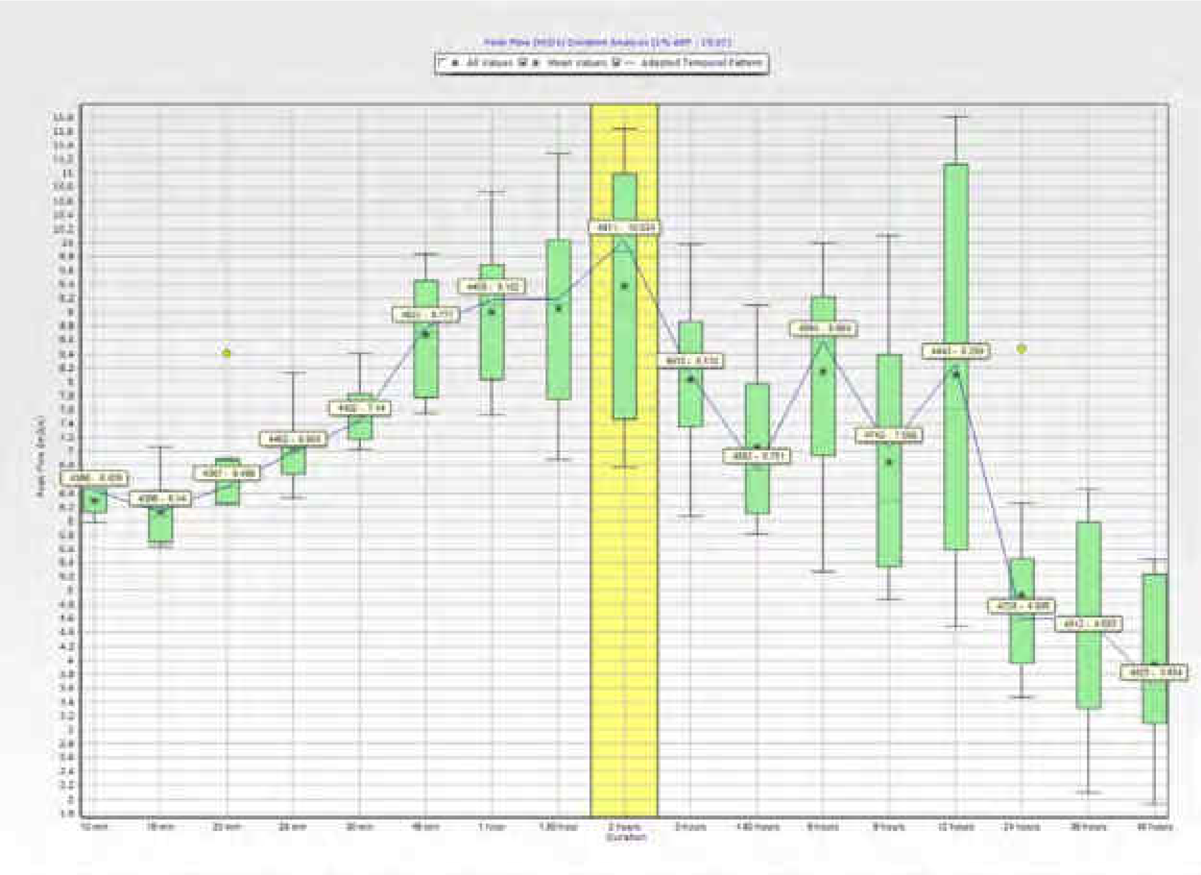


1% AEP ARR2016 Box Plot for Western Crossing of Bong Bong Road

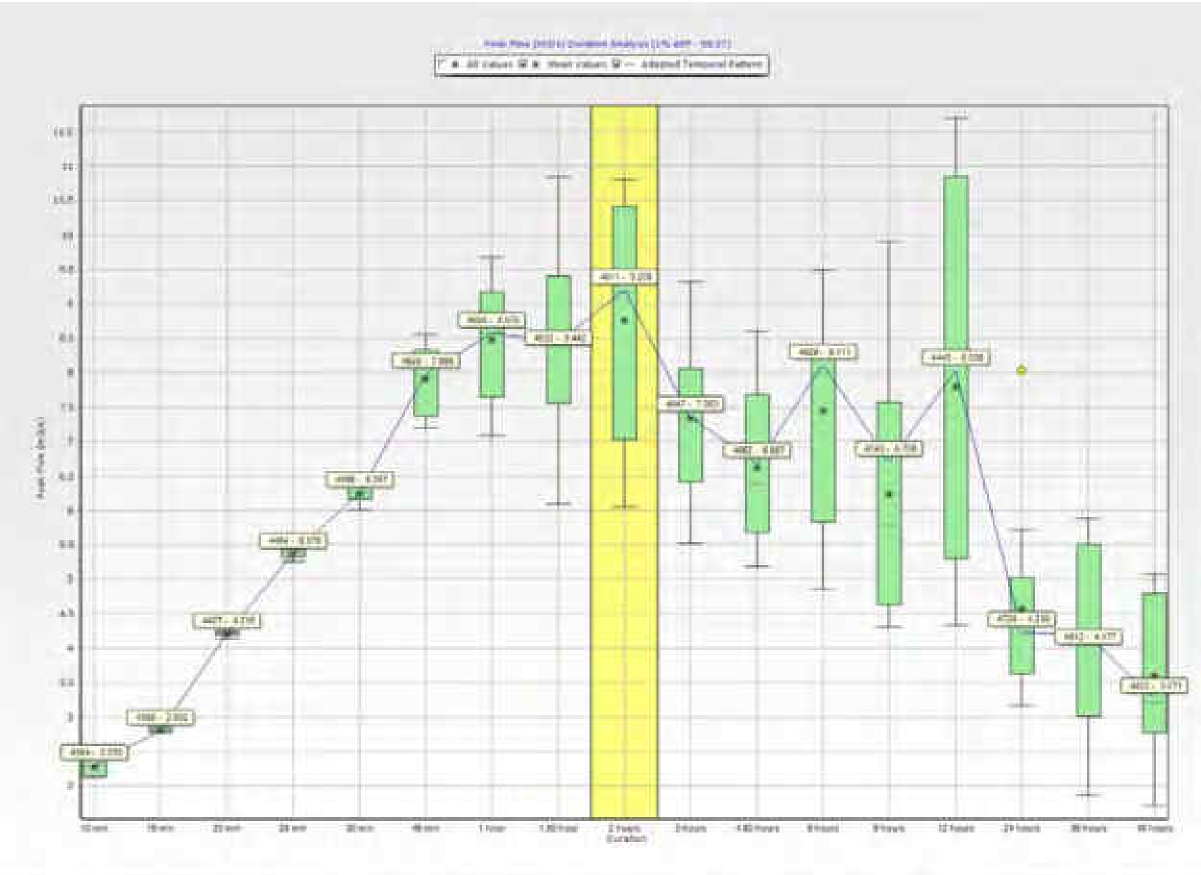


1% AEP ARR2016 Box Plot for Bong Bong Road & Mary Street

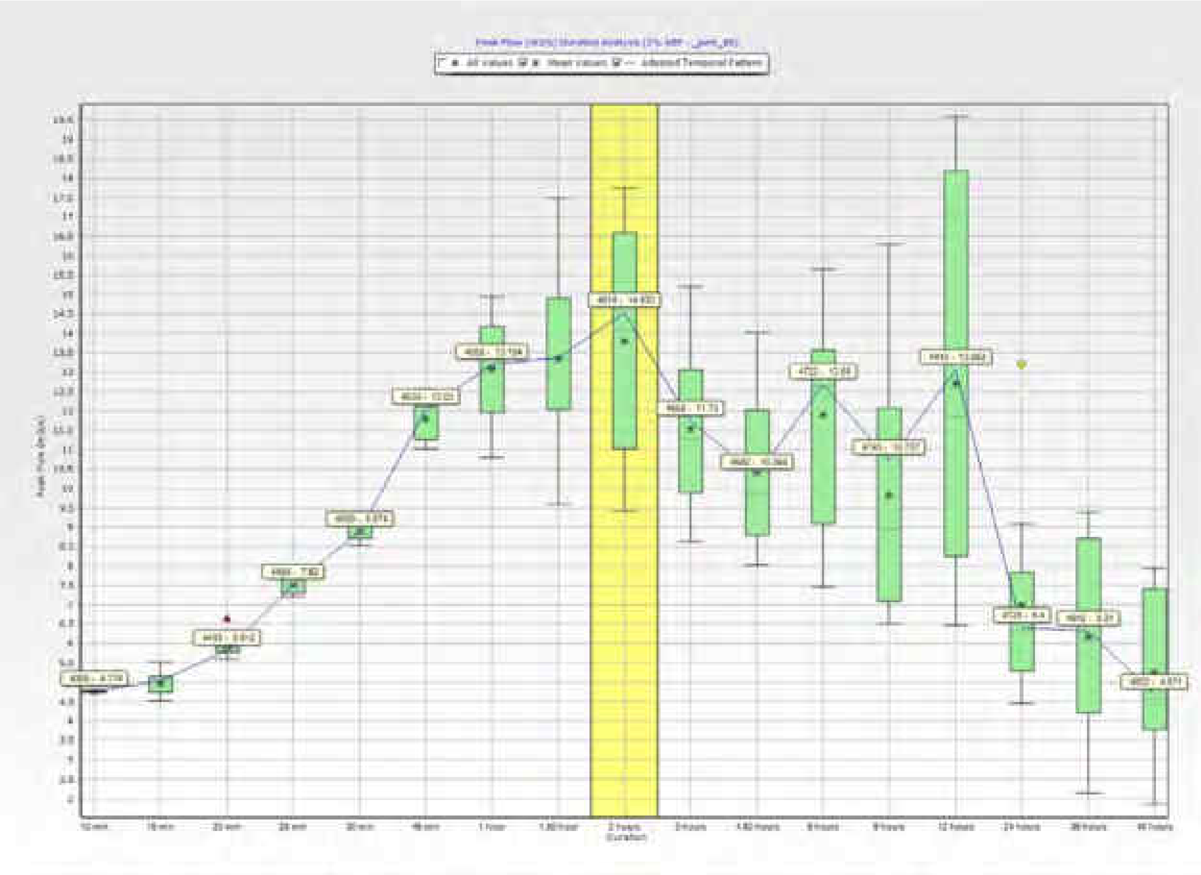
1% AEP ARR2016 Box Plot for Renwick Drive



1% AEP ARR2016 Box Plot for Industrial Railway



1% AEP ARR2016 Box Plot for Braemar Avenue at Industrial Area



APPENDIX C

FLOOD DAMAGES CALCULATIONS

Catchment Simulation Solutions

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

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

C1 Flood Damage Cost Calculations

1.1 Property Database

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

- Generic property type (i.e., residential, commercial or industrial);
- Building floor level – refer to the following sections for floor level estimation technique;
- Building floor area;
- Residential building type (i.e., two storey, single level high set or single level low set);
- Commercial or industrial property contents value (low, medium or high value).

The information contained in the property database was used with the design flood level information and depth-damage curves to establish a flood damage estimate for each building located within the Nattai Ponds catchment for each design flood. Further information on how the depth-damage curves were derived and how the flood damage estimates were prepared is presented below.

1.1.1 Building Floor Levels

It is necessary to have information describing the floor level of every building within the PMF extent to enable flood damage estimates for each building to be prepare. For this study, the floor levels were estimated using the following approach:

1. Google Street View was used to estimate how high the floor level of each building was elevated above the adjoining ground;
2. The ground level at the point where the floor height was estimated was extracted from the available LiDAR data;
3. The floor level was subsequently estimated by adding the floor height (calculated in step 1) to the ground elevation (calculated in step 2).

1.2 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.

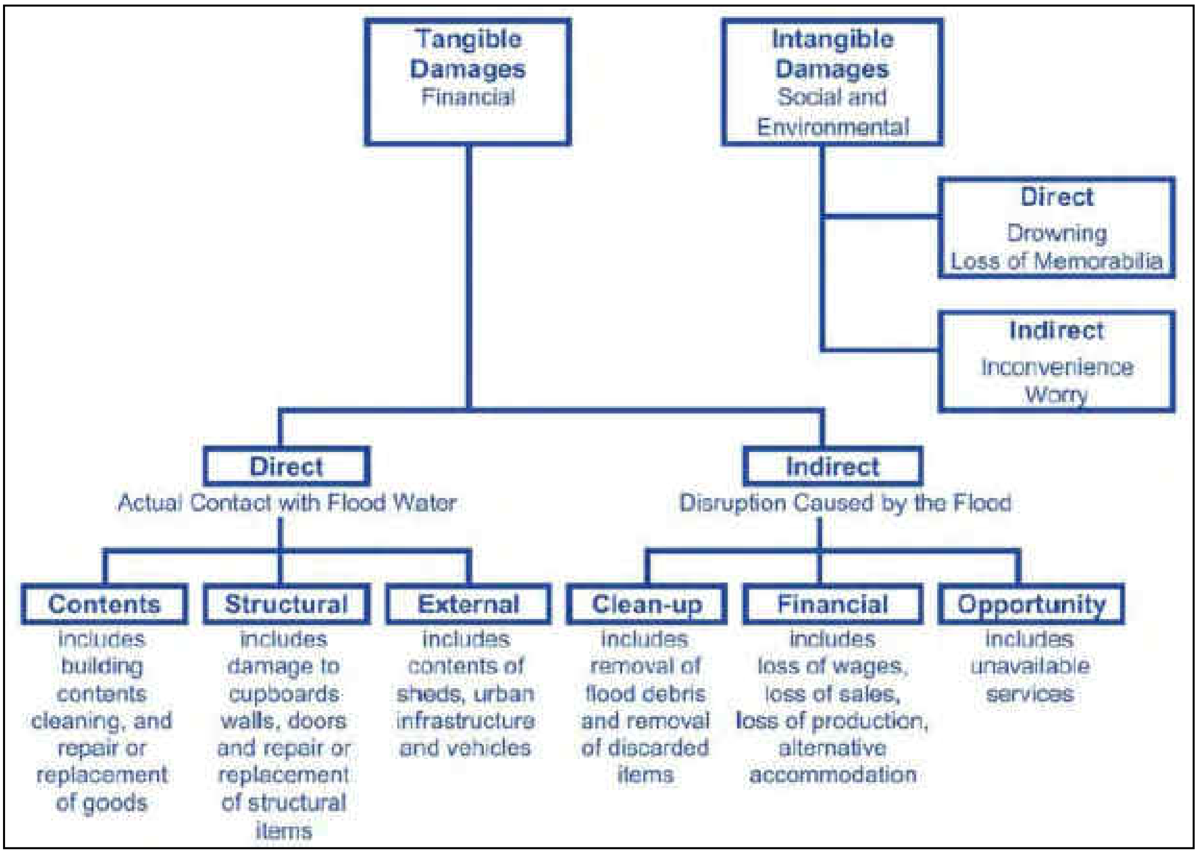


Plate 1 Flood Damage Categories (NSW Government, 2005)

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by waters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with water coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific 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 the tangible damages costs were estimated is presented in the following sections.

1.2.1 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 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).

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 Nattai Ponds catchment 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.

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 default 'single storey high set' damage curves commenced at -5 metres, which was considered to be too high for the catchment. In order to verify this, single storey high set building floor levels within the PMF extent were compared against the minimum ground elevation within each lot (i.e., the minimum elevation within each lot at which inundation will first occur). This determined that the median difference between the building floor level and minimum ground level within the corresponding lot was ~1.5 metres. Accordingly, the 'single-storey high set' damage curves were adjusted so that damage commenced when the flood level was less than 1.5 metres below the floor level.

The building floor area serves as one of the residential damage curve inputs. Building areas for each residential building in the catchment were calculated using GIS. This determined that the median floor area was ~240 m^2. Accordingly, this area was adopted for the flood damage curves.

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

1.2.2 Commercial and Industrial Properties

Commercial

Unlike residential flood damage calculations, there are no standard damage curves available for estimating commercial flood damages in NSW. Commercial property types include offices, retailers and shops.

To help ensure consistency with commercial flood damage estimates derived for other catchments within the Wingecarribee LGA, depth-damage curves developed as part of the *'Bowral Floodplain Risk Management Study and Plan'* (Bewsher Consulting, 2004) were used to define commercial flood damages for the Nattai Ponds catchment. However, depth-damage curves were updated from 2004 dollars to 2018 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS) before application to the Nattai Ponds catchment.

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007

PROJECT	DETAILS	DATE	JOB No.
Nattai Ponds	Residential Damages (240m2)	16/07/2018	xx

BUILDINGS

Regional Cost Variation Factor	1.03	*From Rawlinsons*					
Post late 2001 adjustments	1.77	*Changes in AWE see AWE Stats Worksheet*					
Post Flood Inflation Factor	1.00	*1.0*		*to*	*1.5*		
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*					
	Regional City			*Regional Town*			
	Houses Affected		*Factor*	*Houses Affected*			*Factor*
Small scale impact	*<*	*50*	*1.00*	*<*	*10*		*1.00*
Medium scale impacts in Regional City		*100*	*1.20*		*30*		*1.30*
Large scale impacts in Regional City	*>*	*150*	*1.40*	*>*	*50*		*1.50*
Typical Duration of Immersion	1	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	240	m^2		*240 m^2 is Base*			
Building Size Adjustment	1.0						
Total Building Adjustment Factor	**1.55**						

CONTENTS

Average Contents Relevant to Site	$ 60,000	*Base for 240 m^2 house*	*$ 60,000*		
Post late 2001 adjustments	1.77	*From above*			
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration*		*long duration*
Sub-Total Adjustment Factor	1.33	*Suggested range*	*0.75*	*to*	*0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*			
Effective Warning Time	0	hour			
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor			
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*			
Total Contents Adjustment Factor AFD <= TTBH	**1.33**	AFD = Above Floor Depth			
Total Contents Adjustment Factor AFD > TTBH	**1.33**				

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.77	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	1	weeks
Additional accommodation costs /Loss of Rent	$ 600	*$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

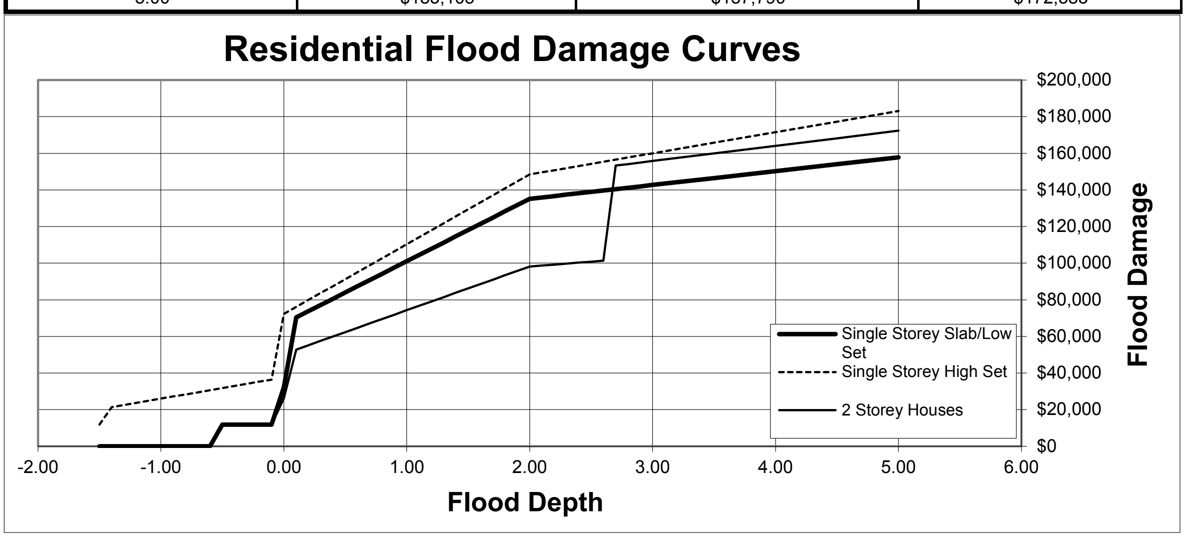
AFD = Above Floor Depth

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	-1.50	m		
Validity Limits	AFD	less than or equal to			6	m
Contents	20000	+	20000		x	AFD
Contents with GST	AFD	greater than			0	
Validity Limits	AFD	less than or equal to			2	

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve 0.1 m

	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses
Type	1	2	3
AFD from Modelling	Damage	Damage	Damage
-5.00	$0	$0	$0
-1.50	$11,859	$0	$0
-1.40	$21,390	$0	$0
-1.30	$22,545	$0	$0
-1.20	$23,701	$0	$0
-1.10	$24,856	$0	$0
-1.00	$26,011	$0	$0
-0.90	$27,166	$0	$0
-0.80	$28,321	$0	$0
-0.70	$29,476	$0	$0
-0.60	$30,631	$0	$0
-0.50	$31,786	$11,859	$11,859
-0.40	$32,941	$11,859	$11,859
-0.30	$34,096	$11,859	$11,859
-0.20	$35,251	$11,859	$11,859
-0.10	$36,406	$11,859	$11,859
0.00	$72,253	$32,258	$26,138
0.10	$76,063	$70,360	$52,810
0.20	$79,873	$73,770	$55,196
0.30	$83,683	$77,179	$57,583
0.40	$87,493	$80,589	$59,970
0.50	$91,303	$83,999	$62,357
0.60	$95,113	$87,409	$64,744
0.70	$98,923	$90,819	$67,131
0.80	$102,733	$94,228	$69,518
0.90	$106,543	$97,638	$71,904
1.00	$110,353	$101,048	$74,291
1.10	$114,163	$104,458	$76,678
1.20	$117,973	$107,867	$79,065
1.30	$121,783	$111,277	$81,452
1.40	$125,593	$114,687	$83,839
1.50	$129,403	$118,097	$86,226
1.60	$133,214	$121,507	$88,612
1.70	$137,024	$124,916	$90,999
1.80	$140,834	$128,326	$93,386
1.90	$144,644	$131,736	$95,773
2.00	$148,454	$135,146	$98,160
2.10	$149,609	$135,901	$98,688
2.20	$150,764	$136,655	$99,217
2.30	$151,919	$137,410	$99,745
2.40	$153,074	$138,165	$100,273
2.50	$154,229	$138,920	$100,802
2.60	$155,384	$139,675	$101,330
2.70	$156,539	$140,429	$153,286
2.80	$157,694	$141,184	$154,117
2.90	$158,849	$141,939	$154,947
3.00	$160,004	$142,694	$155,777
3.50	$165,779	$146,468	$159,929
4.00	$171,554	$150,242	$164,080
4.50	$177,330	$154,016	$168,231
5.00	$183,105	$157,790	$172,383



Each commercial property was classified according to the value of the contents (i.e., low, medium and high damage potential). This is intended to reflect the fact that the damage incurred across commercial properties is likely to be directly related to the value of its contents. **Table 1** provides a summary of the different commercial property types and the associated contents value that each would fall under.

Table 1 Content Value Categories for Commercial Property Types

Low Value Contents	Medium Value Contents	High Value Contents
Small cafes	Food stores	Electrical shops
Florists	Grocers	Chemists
Offices	Corner stores / mixed business	Shoe Shops
Consulting rooms	Take away food	Clothing stores
Post office	Cake shops	Bottle shops
Pet shops	Hairdressers	Bookshops
Churches	Banks	Newsagents
Launderettes	Dry cleaners	Sporting goods
Public halls	Professions (e.g., solicitors)	Furniture
	Small hardware	DVD rental
	Small retail	Kitchenware
		Restaurants
		Schools

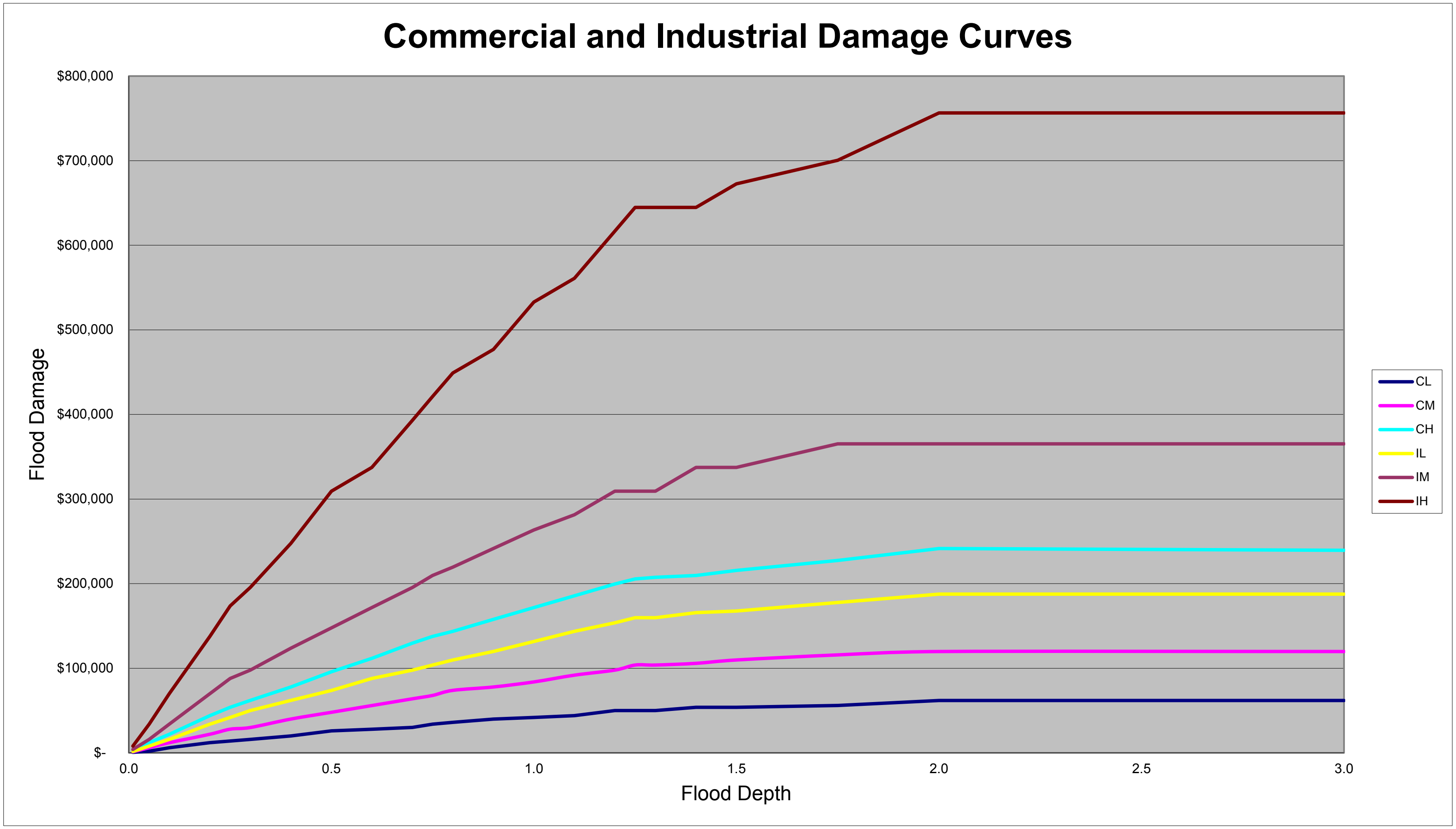
The adopted commercial depth-damage curves are presented on the following page.

The *'Bowral Floodplain Risk Management Study and Plan'* (Bewsher Consulting, 2004a) included an allowance for indirect commercial damage costs to account for clean-up costs, loss of income while clean-up occurs etc. The indirect damage cost was estimates at 50% of the direct damage costs. To ensure consistency with this previous study, the same factor was maintained in the current study.

Industrial

As for commercial properties, no standard depth-damage curves are available for industrial properties (e.g., warehouses, automotive repairs) in NSW. The industrial depth-damage curves developed for the *'Bowral Floodplain Risk Management Study and Plan'* (Bewsher Consulting, 2004) were considered appropriate for use within the Nattai Ponds catchment.

As with commercial properties, the industrial properties must be classified according to the value of the building contents (i.e., low, medium and high value). **Table 2** provides a summary of the different industrial property types and the associated contents value that each would fall under. The final industrial depth-damage curves are presented on the following page.



Commercial and Industrial Damage Curves
Flood Damage
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$-
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Flood Depth
CL
CM
CH
IL
IM
IH

As with commercial properties, indirect flood damage costs for industrial properties were calculated as 50% of direct costs in line with the approach adopted for the *'Bowral Floodplain Risk Management Study and Plan'* (Bewsher Consulting, 2004).

Table 2 Content Value Categories for Industrial Property Types

Low Value Contents	Medium Value Contents	High Value Contents
Automotive repairs	Equipment hire	Smash repairs
Sand, gravel & cement	Food distribution	Panel beating
Storage	Leather & upholstery	Car yard sales
Transport & couriers	Carpet warehouses	Vehicle showrooms
Paving & landscaping	Agricultural equipment	Service stations
Fuel depots	Truck yards	
Council & Governments depots	Vacant factories	
Chemical storage		
Pool products		
Sale yards		
Plumbing supplies		

1.2.3 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, electricity and telephone. Infrastructure damage has been estimated at 15% of the total direct residential, commercial and industrial damages. This value was extracted from the *'Bowral Floodplain Risk Management Study and Plan'* (Bewsher Consulting, 2004).

1.2.4 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 Nattai Ponds catchment 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 made to the flood damage curves.

1.3 Summary of Inundation Costs

1.3.1 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 levels for each building.

The number of buildings that are predicted to be subject to above floor flooding are summarised in **Table 8**. The number of properties that are predicted to suffer damage (this may or may not include above floor inundation) are also summarised in **Table 8**. This shows that above floor inundation could be expected during a 10% AEP flood. During a 1% AEP flood, 6 properties are predicted to experience above floor flooding

Table 3 Number of Properties Subject to Above Floor Inundation and Property Damage

Flood Event	Residential		Commercial		Industrial		Total Number	
	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation
20% AEP	0	0	0	0	0	0	0	0
10% AEP	1	1	0	0	0	0	1	1
5% AEP	2	1	0	0	0	0	2	1
2% AEP	3	2	0	0	0	0	3	2
1% AEP	7	5	0	0	1	1	7	6
0.5% AEP	10	8	0	0	3	3	10	11
0.2% AEP	14	12	0	0	3	3	14	15
PMF	120	91	5	5	13	13	120	109

The individual property damage estimates were subsequently summed with calculated infrastructure damage to calculate the total flood damages for each design event. Calculated flood damages for each design flood are summarised in **Table 3**.

Table 4 Summary of Flood Damages for Existing Conditions

Flood Damage Component	Flood Damages (2018 dollars)							
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Residential	0	11,859	23,718	63,678	231,553	452,567	565,260	4,483,613
Commercial	0	0	0	0	0	0	0	210,290
Industrial	0	0	0	0	23,620	114,008	214,340	4,479,461
Infrastructure	0	1,779	3,558	9,552	38,276	84,986	116,940	1,376,005
TOTAL	0	13,638	27,276	73,230	293,449	651,561	896,540	10,549,369
Average Annual Damage (AAD)	**21,176**							

The results presented in **Table 3** shows that a 1% AEP flood has the potential to cause just under $300,000 dollars of damages.

1.3.2 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). The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe.

The AAD for the Nattai Ponds catchment was determined to be $21,176.

1.4 Limitations of Damage Costs

The damage costs presented in this document are based on the best information that was available at the time this report was prepared. However, the estimates do not take into account future fluctuations in property and asset values. Therefore, the damage estimates should only be considered an approximation.

References

- Bewsher Consulting (2004) *Bowral Floodplain Risk Management Study*. Prepared for Wingecarribee Shire Council.
- Resources and Mines, Natural (2002). *Guidance on the Assessment of Tangible Flood Damages*

Appendix D

National Flood Hazard Categories

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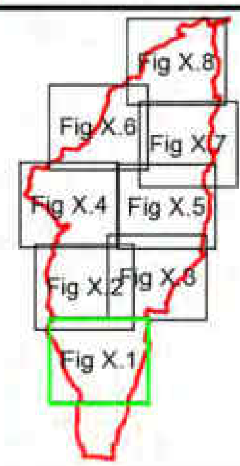

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Appendix D1.1: 10% AEP National Flood Hazard

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

File Name: 10% AEP Flood Hazard.wor

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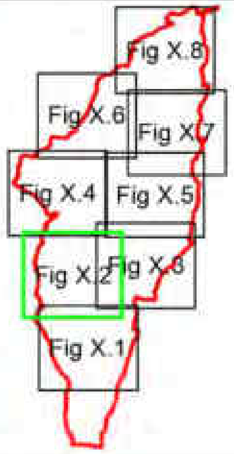


LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

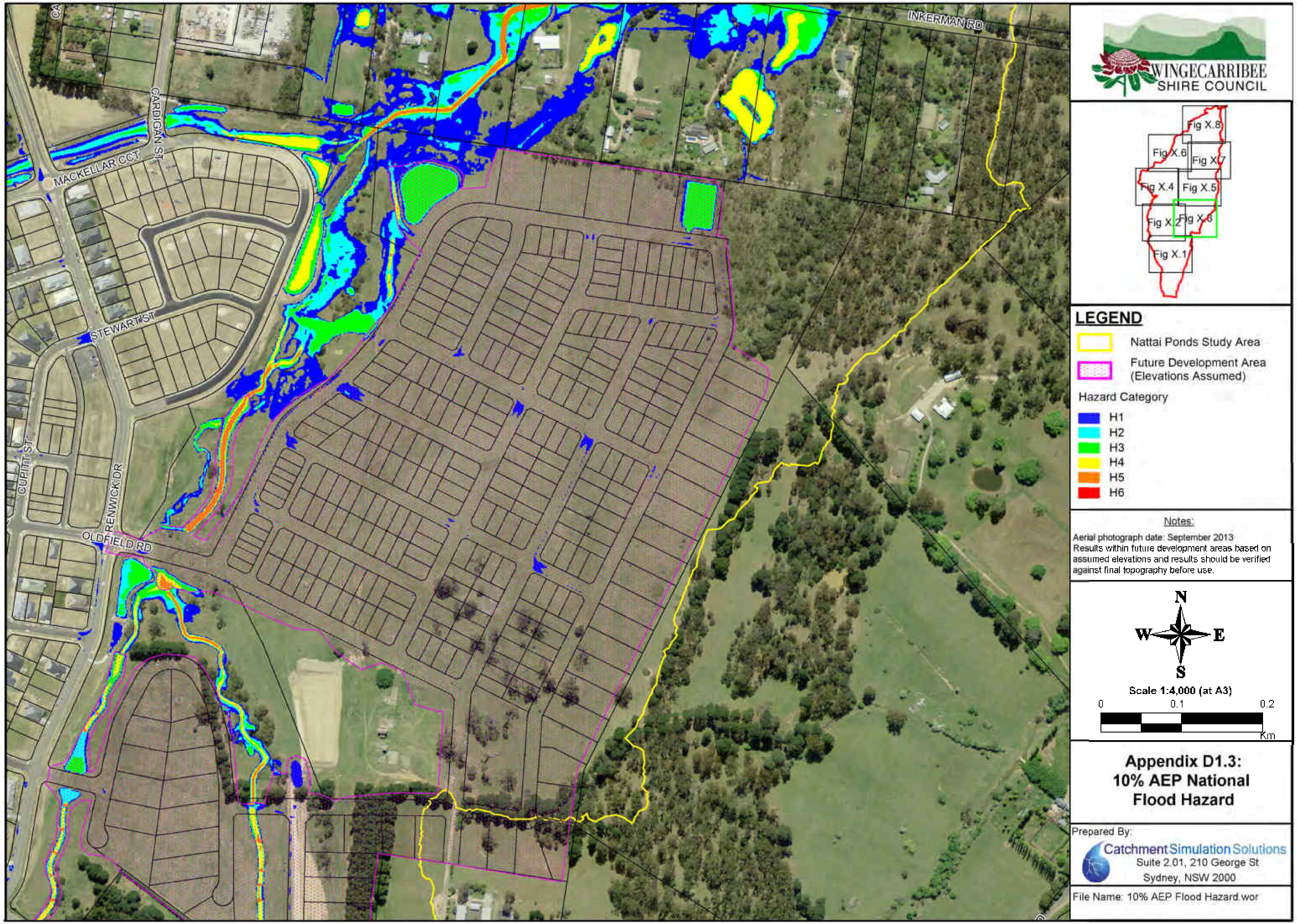
0 0.1 0.2 Km

Appendix D1.2: 10% AEP National Flood Hazard

Prepared By:

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

File Name: 10% AEP Flood Hazard.wor



Appendix D1.3: 10% AEP National Flood Hazard

Prepared By:

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

File Name: 10% AEP Flood Hazard.wor

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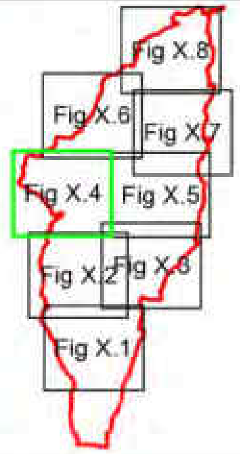


LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

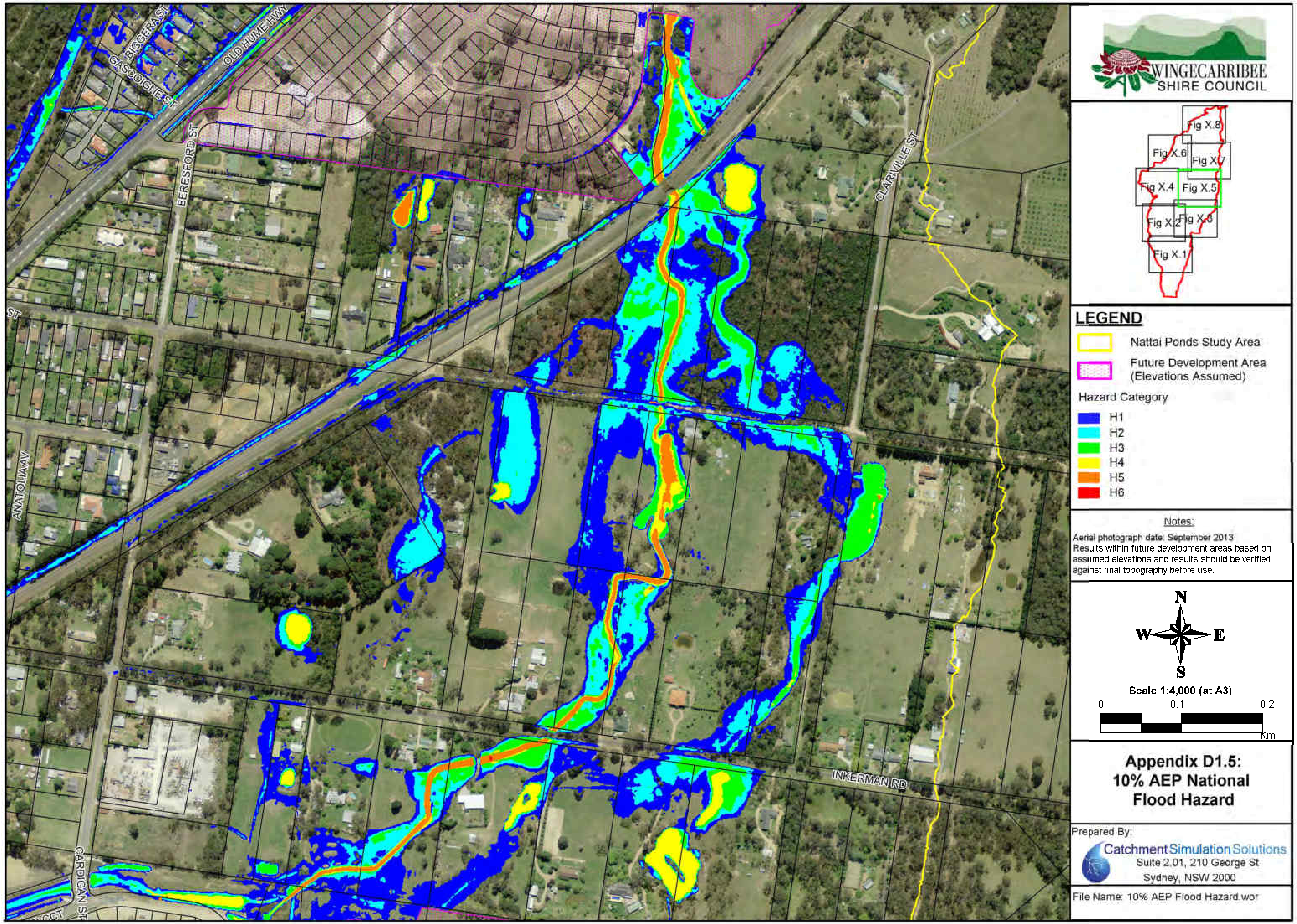
Scale 1:4,000 (at A3)

0 0.1 0.2
Km

Appendix D1.4: 10% AEP National Flood Hazard

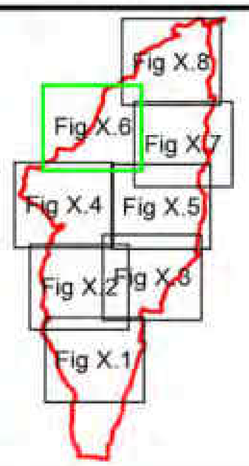
Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: 10% AEP Flood Hazard.wor



BIGGERA ST
GASCOIGNE ST
OLD HUME HWY
BERESFORD ST
CLARVILLE ST
ANATOLIA AV
INKERMAN RD
CARDIGAN ST
WINGECARRIBEE SHIRE COUNCIL
Fig X.8
Fig X.6
Fig X.7
Fig X.4
Fig X.5
Fig X.2
Fig X.3
Fig X.1
LEGEND
Nattai Ponds Study Area
Future Development Area (Elevations Assumed)
Hazard Category
H1
H2
H3
H4
H5
H6
Notes:
Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.
N
W
E
S
Scale 1:4,000 (at A3)
0
0.1
0.2
Km
Appendix D1.5: 10% AEP National Flood Hazard
Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000
File Name: 10% AEP Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2
Km

Appendix D1.6:
10% AEP National Flood Hazard

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

File Name: 10% AEP Flood Hazard.wor

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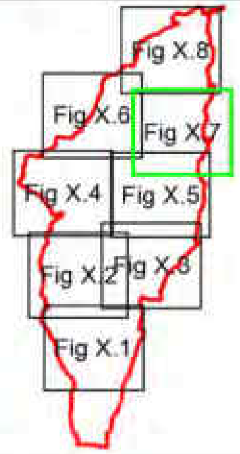


LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

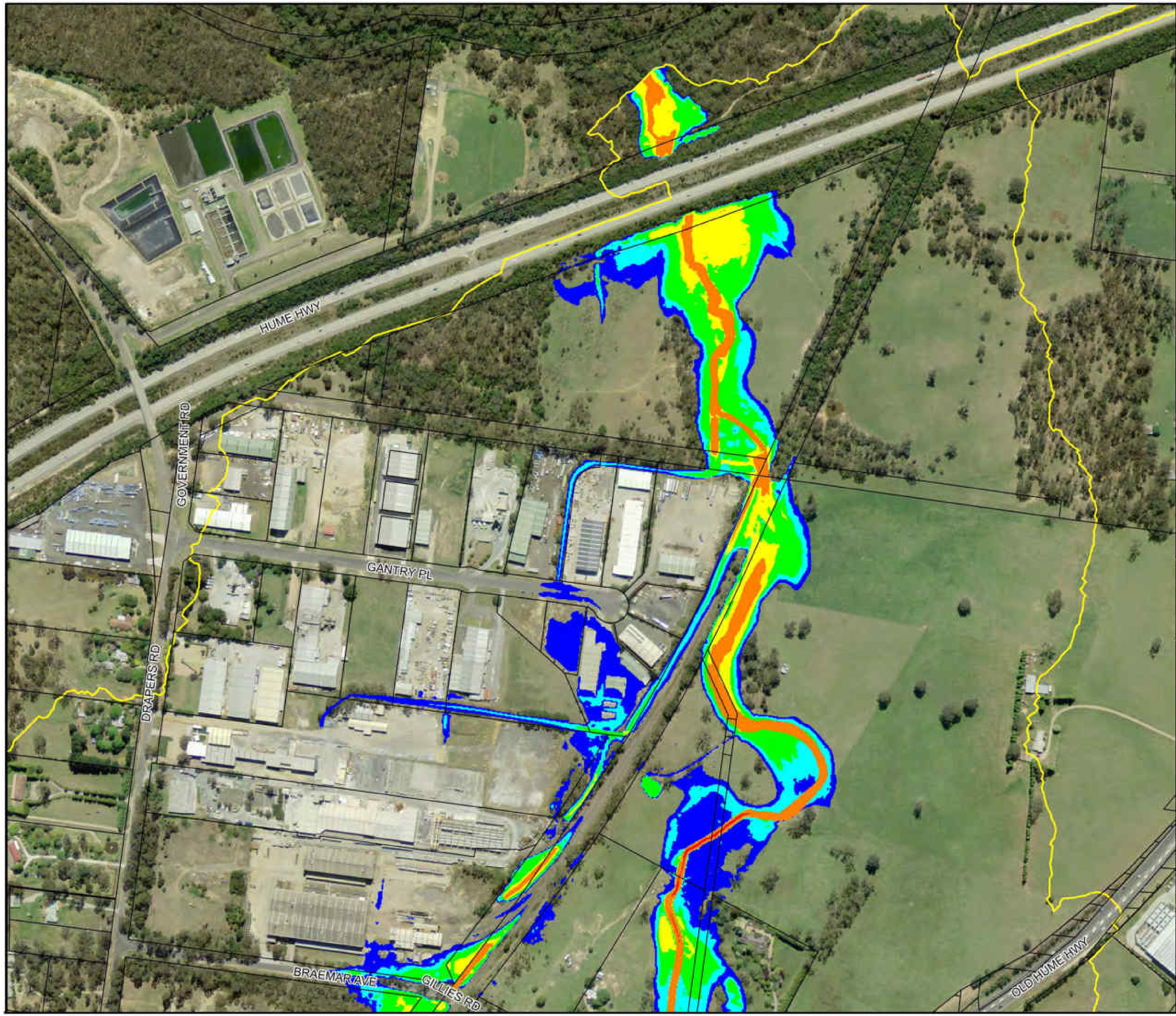
Scale 1:4,000 (at A3)

0 0.1 0.2
Km

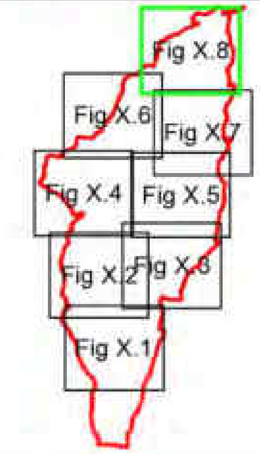
Appendix D1.7: 10% AEP National Flood Hazard

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

File Name: 10% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

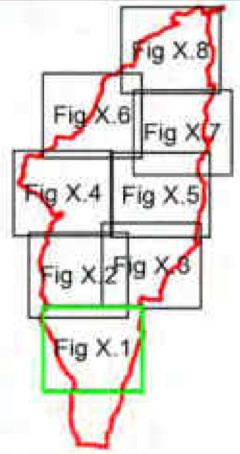
0 0.1 0.2 Km

Appendix D1.8: 10% AEP National Flood Hazard

Prepared By:

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

File Name: 10% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Appendix D2.1: 1% AEP National Flood Hazard

Prepared By:

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

File Name: 1% AEP Flood Hazard.wor

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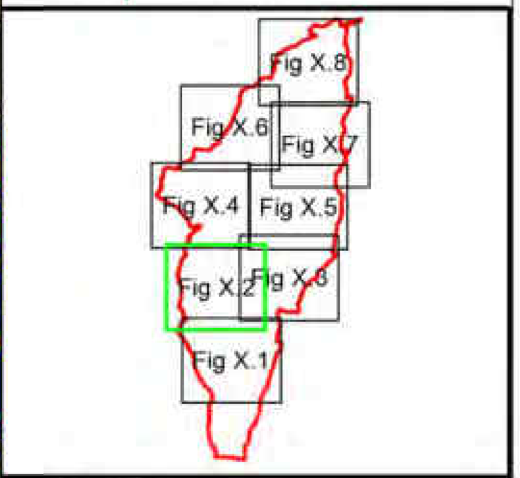


LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

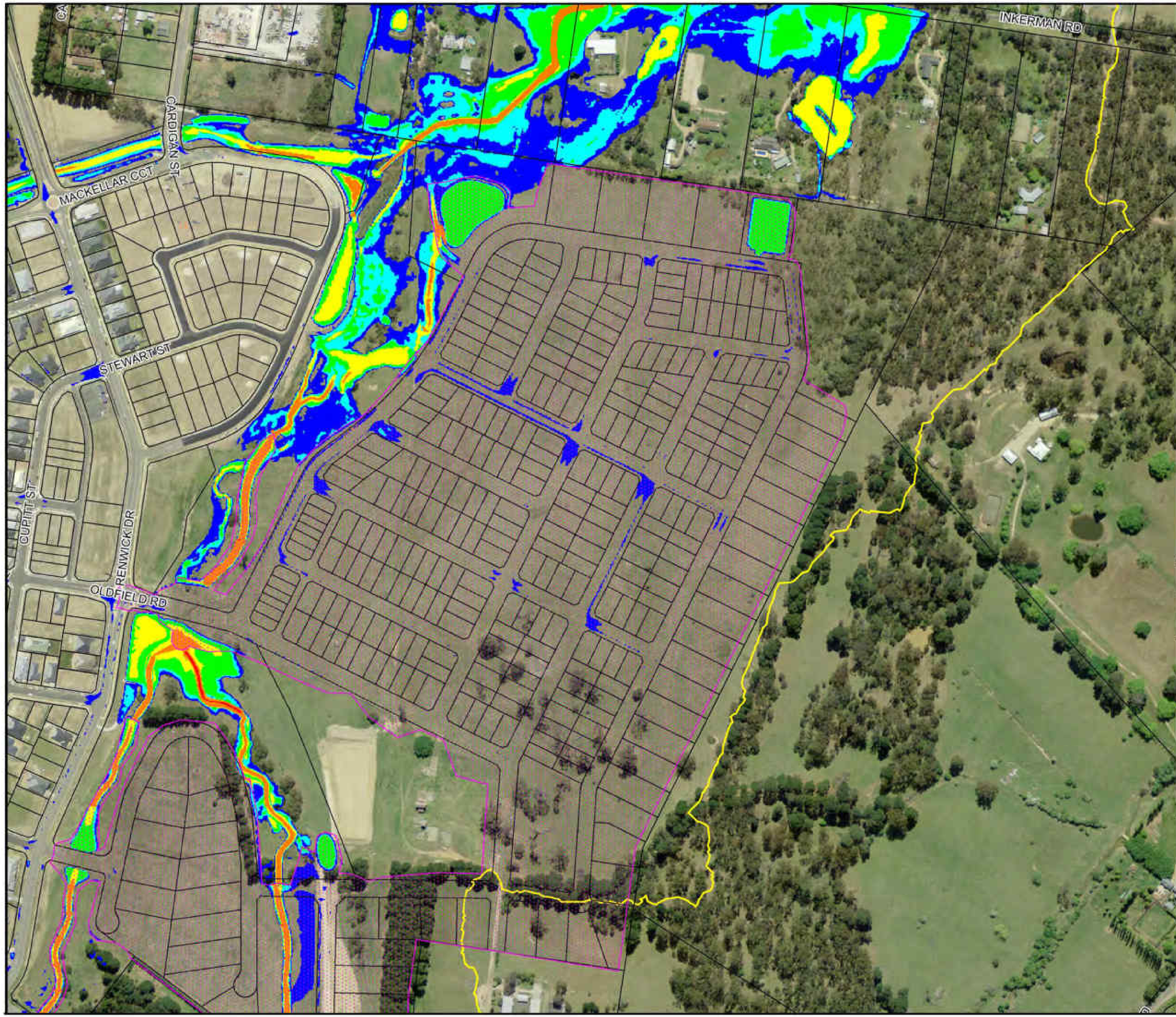
0 0.1 0.2 Km

Appendix D2.2: 1% AEP National Flood Hazard

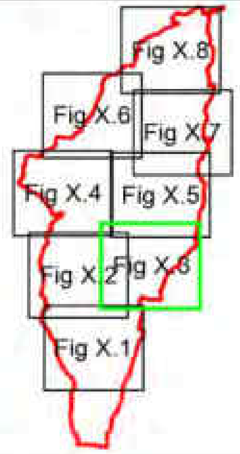
Prepared By:

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

File Name: 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

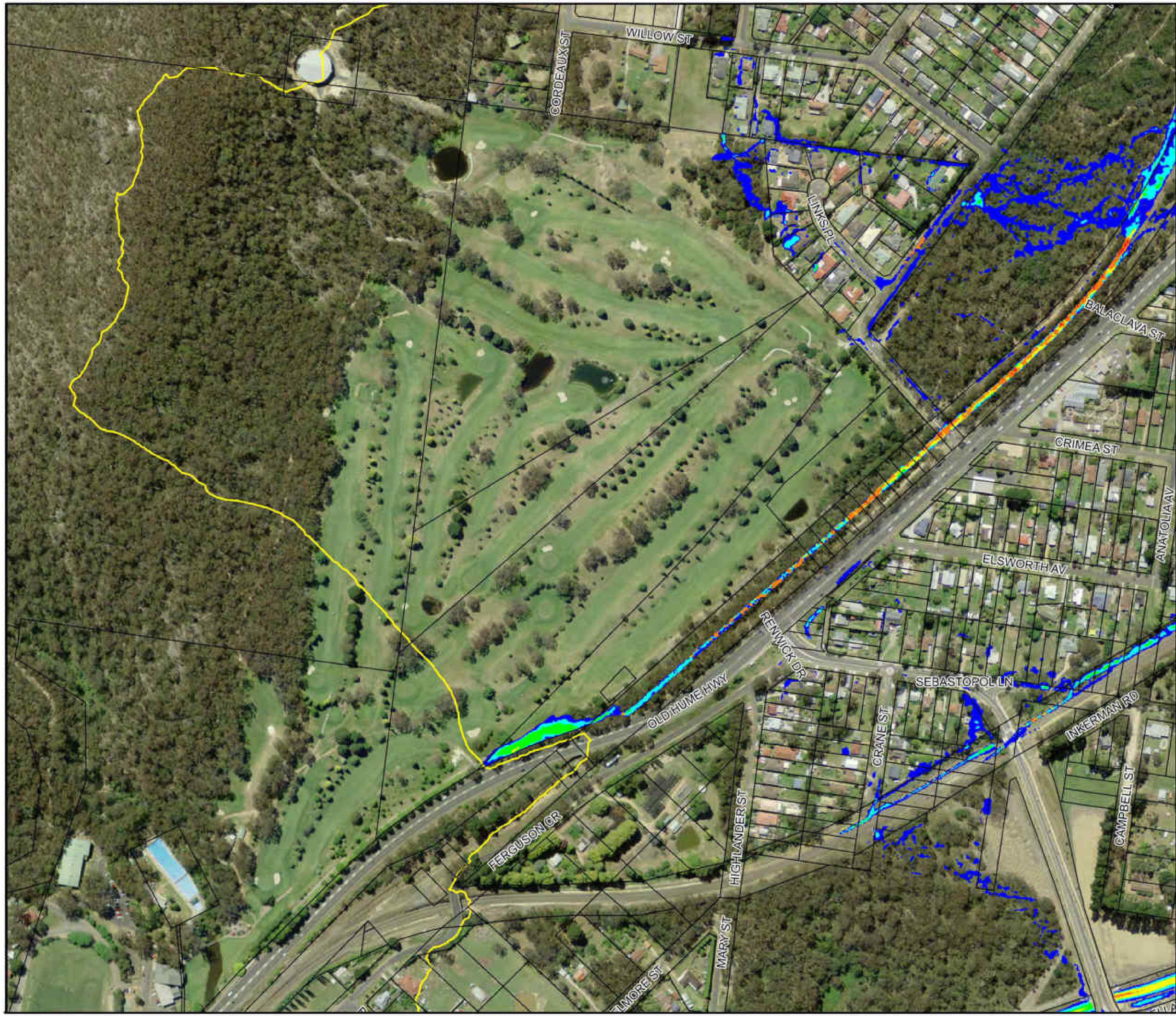
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

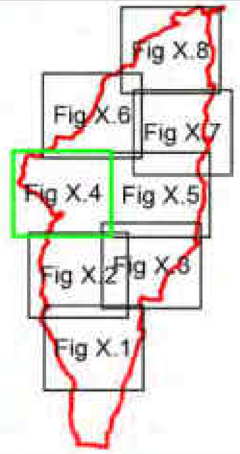
Appendix D2.3: 1% AEP National Flood Hazard

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

File Name: 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

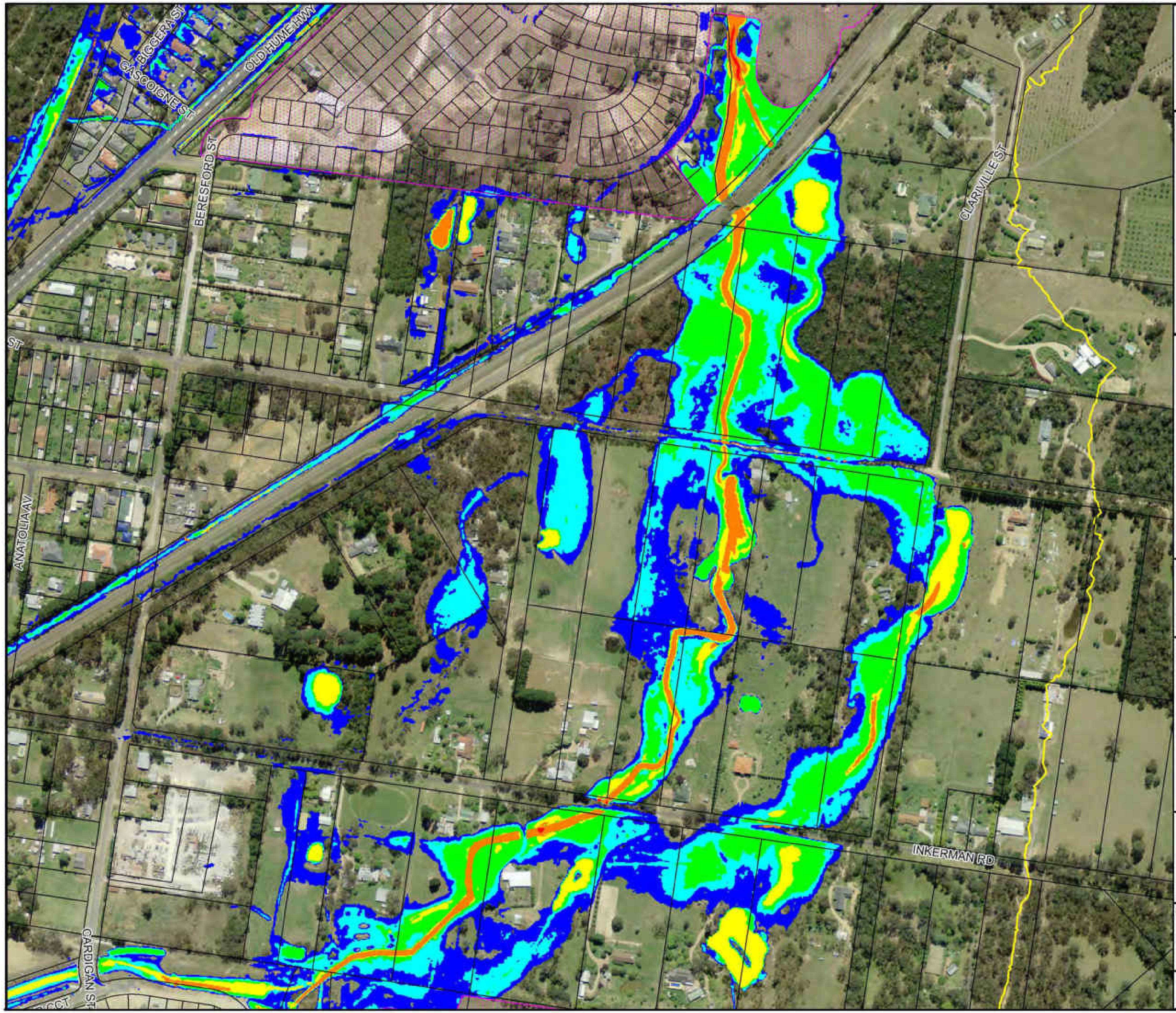
Scale 1:4,000 (at A3)

0 0.1 0.2
Km

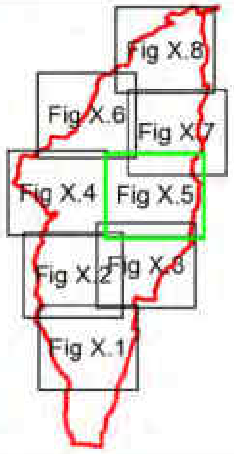
Appendix D2.4: 1% AEP National Flood Hazard

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

File Name: 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

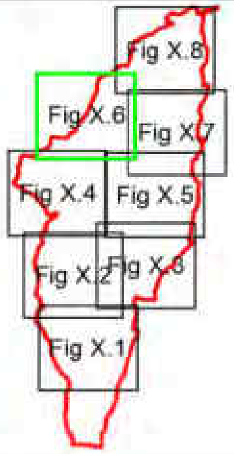
Appendix D2.5: 1% AEP National Flood Hazard

Prepared By:

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

File Name: 1% AEP Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

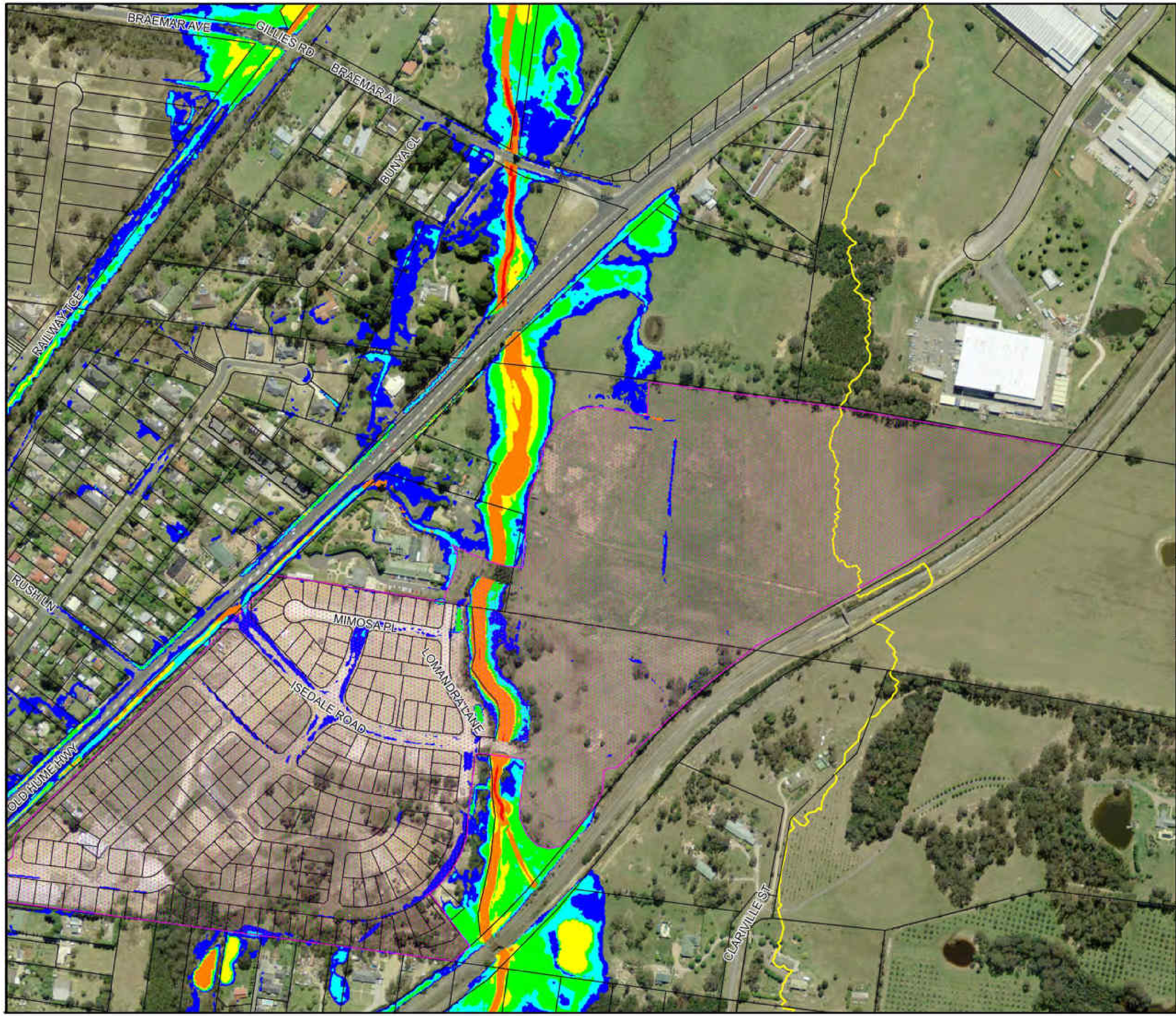
0 0.1 0.2 Km

Appendix D2.6:
1% AEP National Flood Hazard

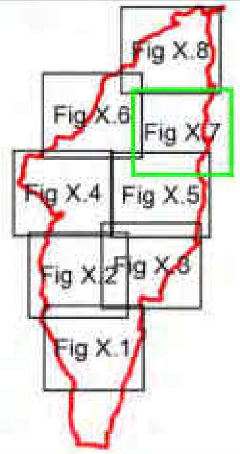
Prepared By:

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

File Name: 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

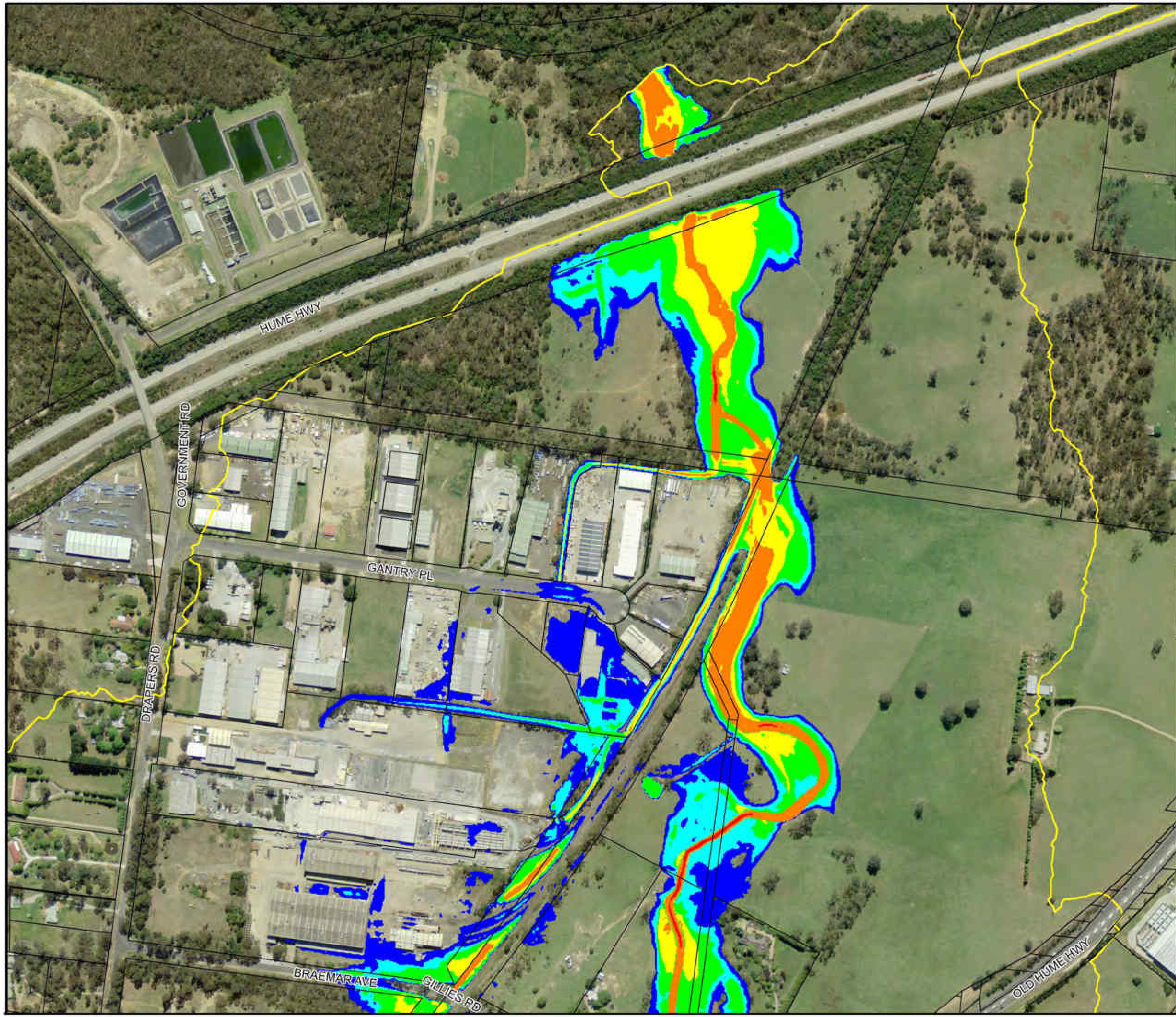
0 0.1 0.2 Km

Appendix D2.7: 1% AEP National Flood Hazard

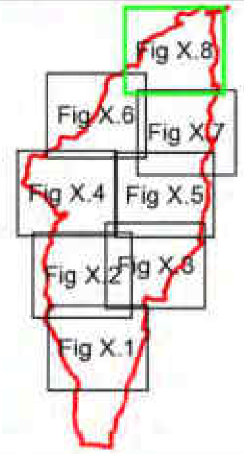
Prepared By:

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

File Name: 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

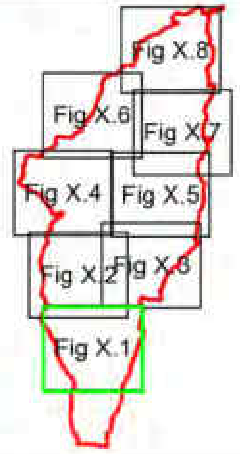
0 0.1 0.2 Km

Appendix D2.8: 1% AEP National Flood Hazard

Prepared By:

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

File Name: 1% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

Scale 1:4,000 (at A3)

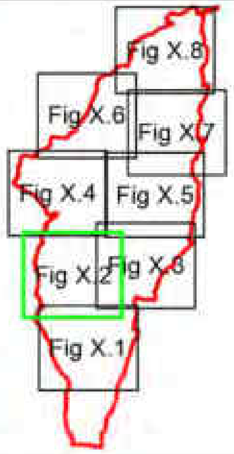
0 0.1 0.2 Km

Appendix D3.1:
0.5% AEP National Flood Hazard

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

File Name: 0.5% AEP Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

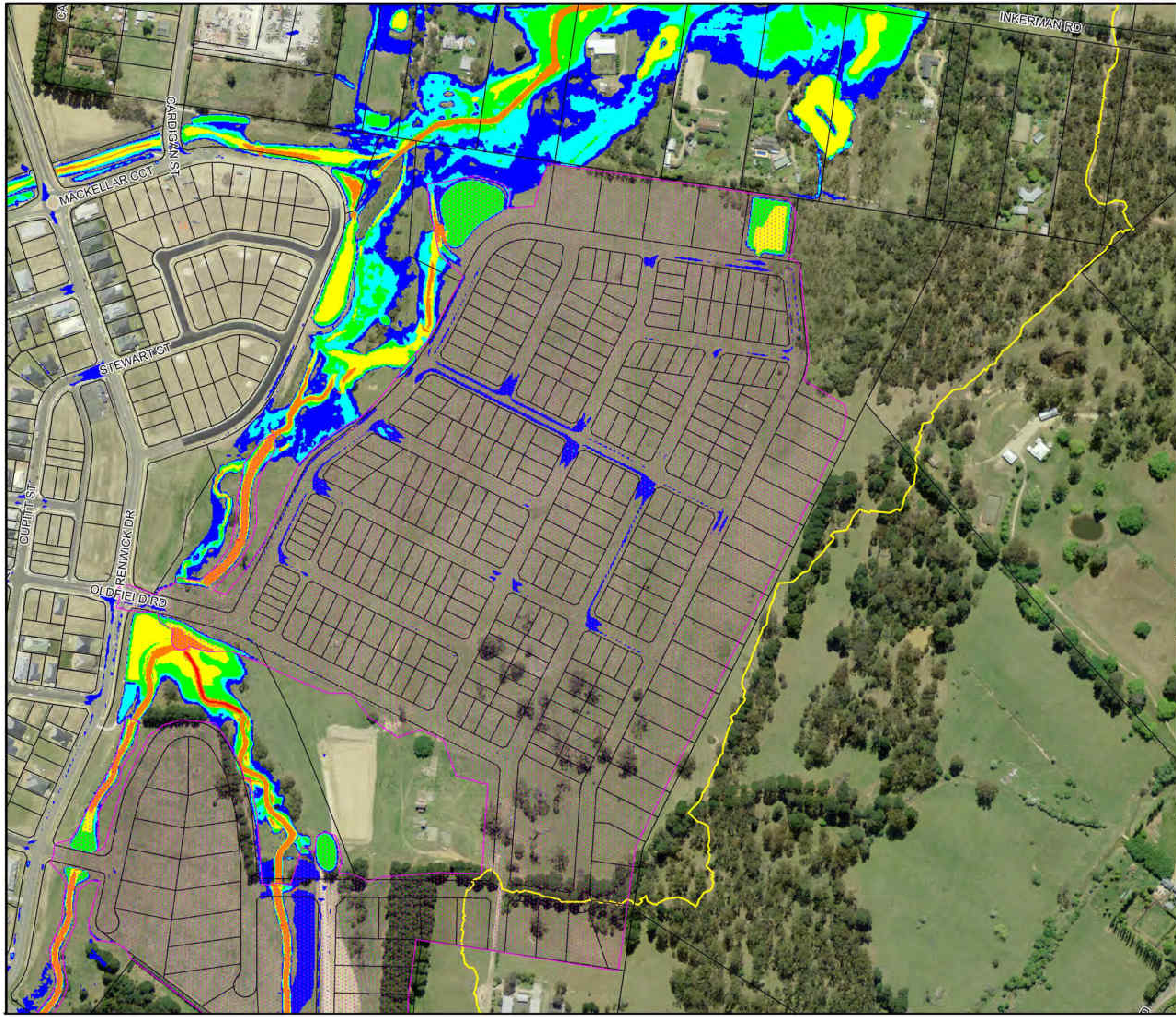
0 0.1 0.2 Km

Appendix D3.2: 0.5% AEP National Flood Hazard

Prepared By:

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

File Name: 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

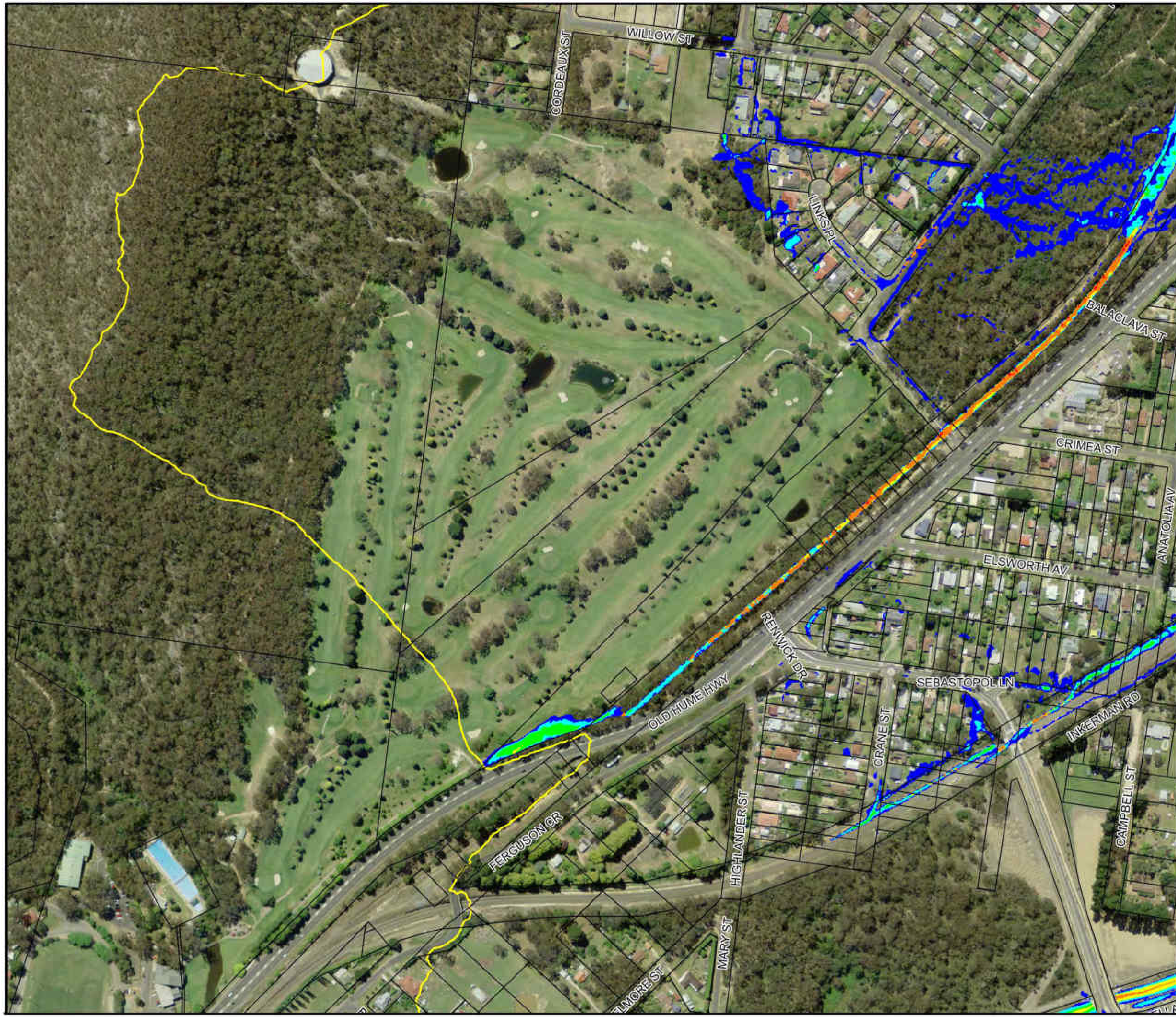
0 0.1 0.2 Km

Appendix D3.3: 0.5% AEP National Flood Hazard

Prepared By:

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

File Name: 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

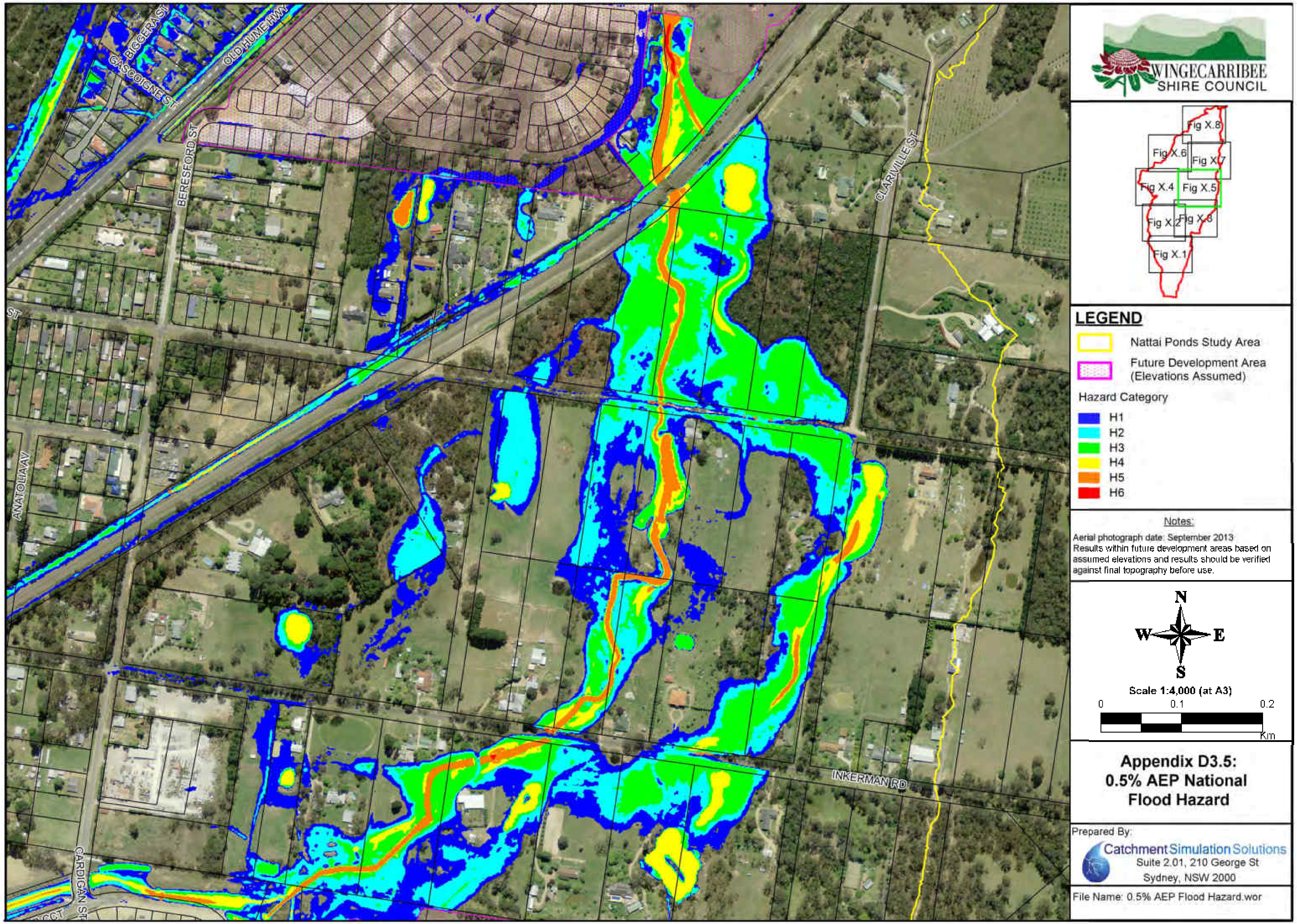
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Appendix D3.4: 0.5% AEP National Flood Hazard

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

File Name: 0.5% AEP Flood Hazard.wor


BIGGERA ST
GASCOIGNE ST
OLD HUME HWY
BERESFORD ST
ST
CLARIVILLE ST
ANATOLIA AV
INKERMAN RD
CARDIGAN ST
WINGECARRIBEE
SHIRE COUNCIL
Fig X.8
Fig X.6
Fig X.7
Fig X.4
Fig X.5
Fig X.2
Fig X.3
Fig X.1
LEGEND
Nattai Ponds Study Area
Future Development Area
(Elevations Assumed)
Hazard Category
H1
H2
H3
H4
H5
H6
Notes:
Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.
N
W
E
S
Scale 1:4,000 (at A3)
0
0.1
0.2
Km
Appendix D3.5:
0.5% AEP National
Flood Hazard
Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000
File Name: 0.5% AEP Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL

LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

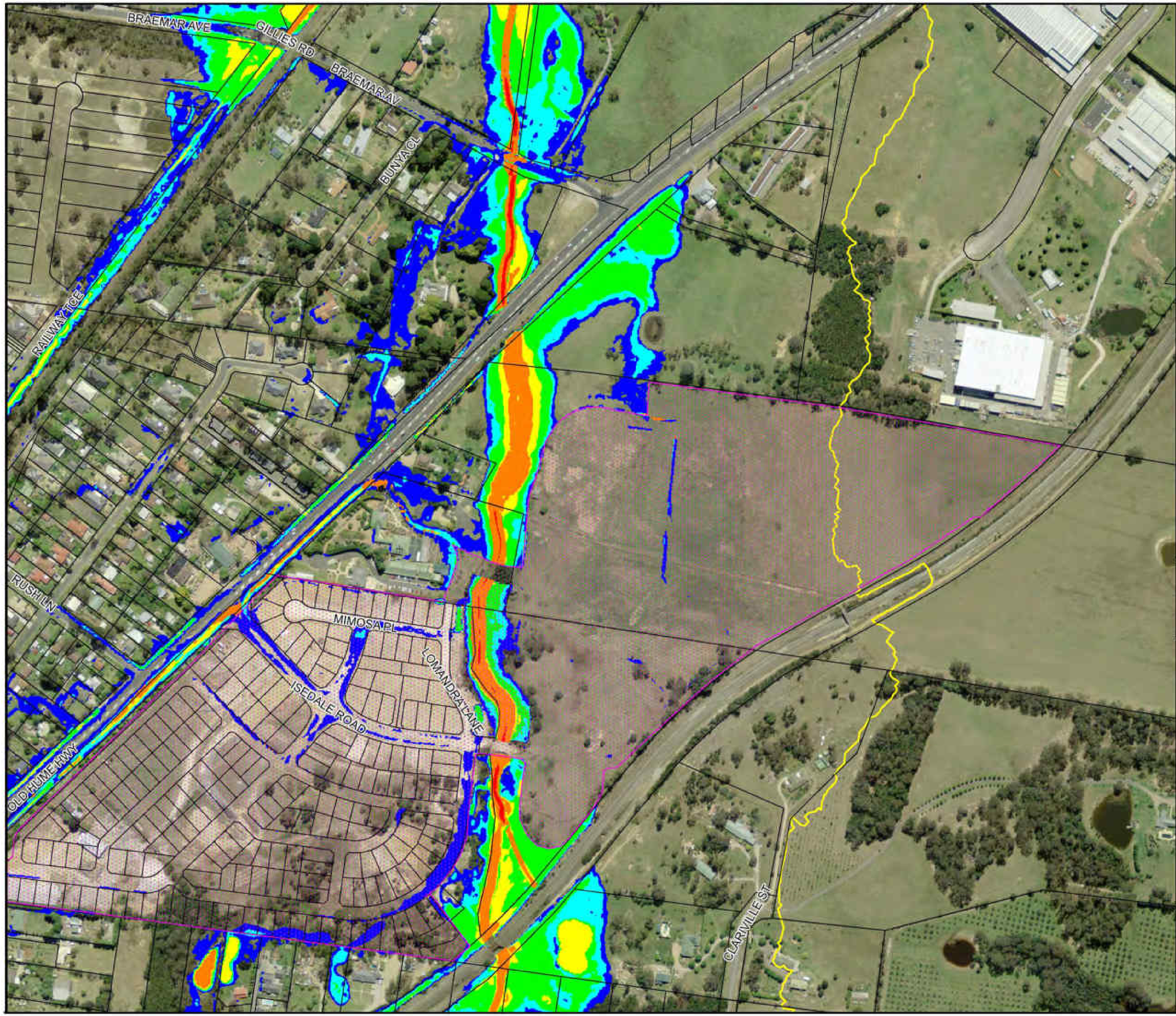
Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

Appendix D3.6: 0.5% AEP National Flood Hazard

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

File Name: 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL

LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

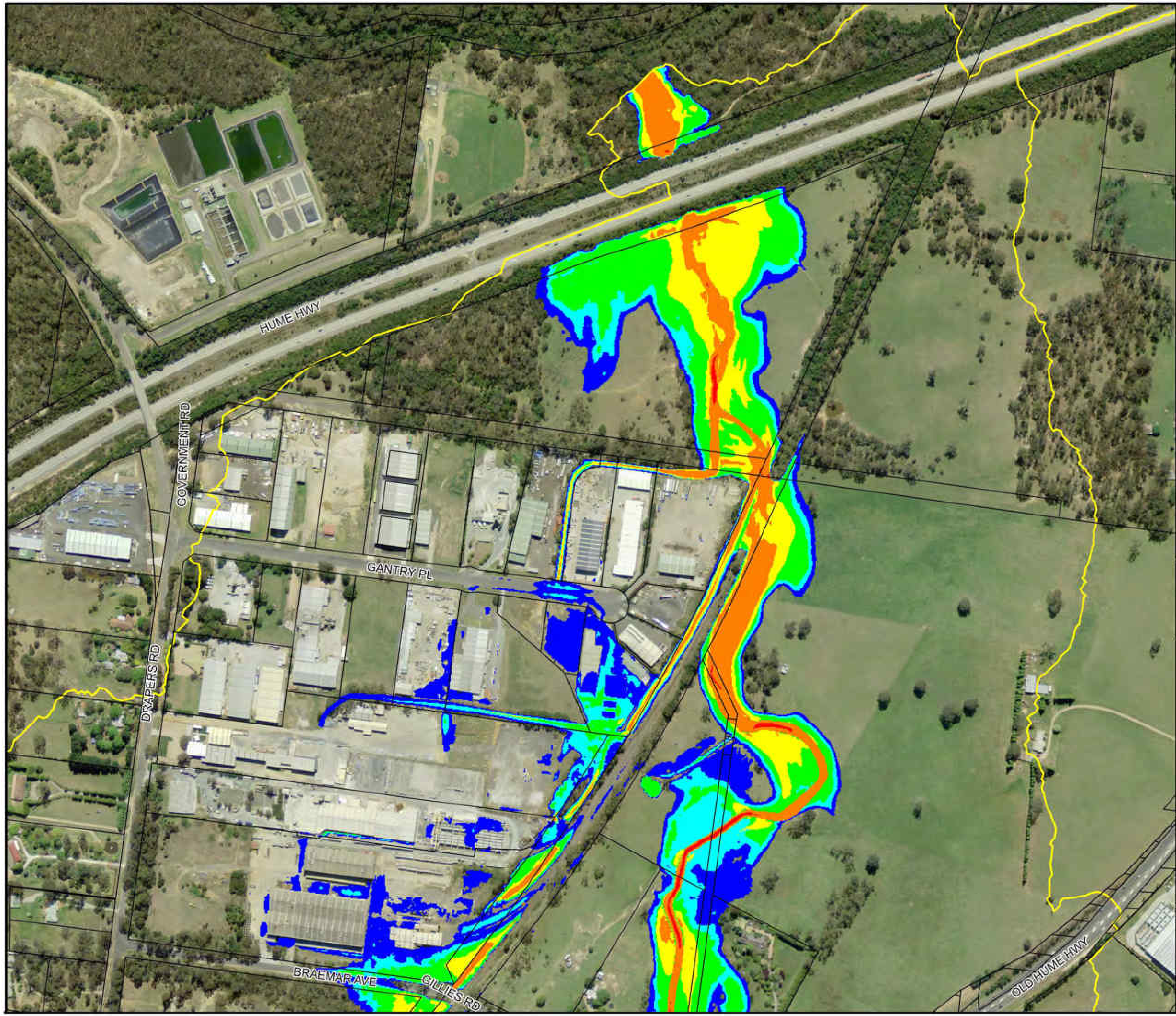
0 0.1 0.2 Km

Appendix D3.7: 0.5% AEP National Flood Hazard

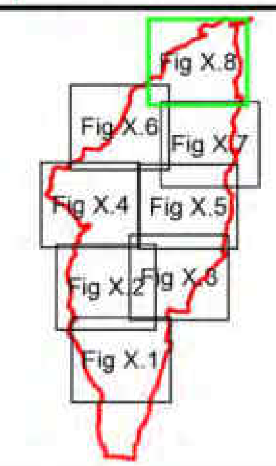
Prepared By:

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

File Name: 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

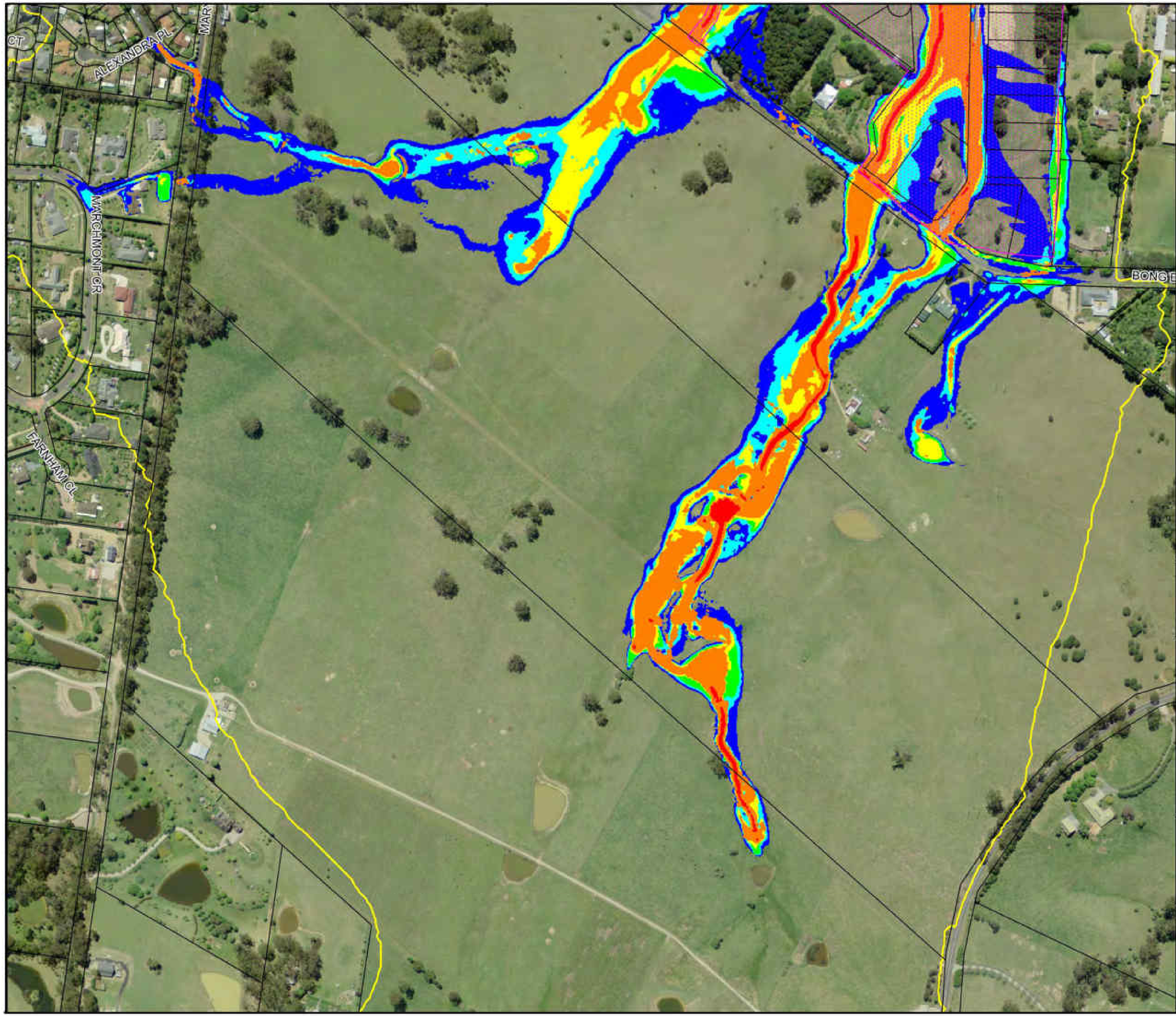
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

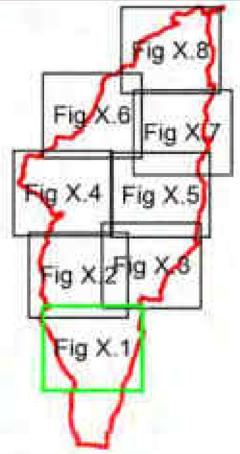
Appendix D3.8: 0.5% AEP National Flood Hazard

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

File Name: 0.5% AEP Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

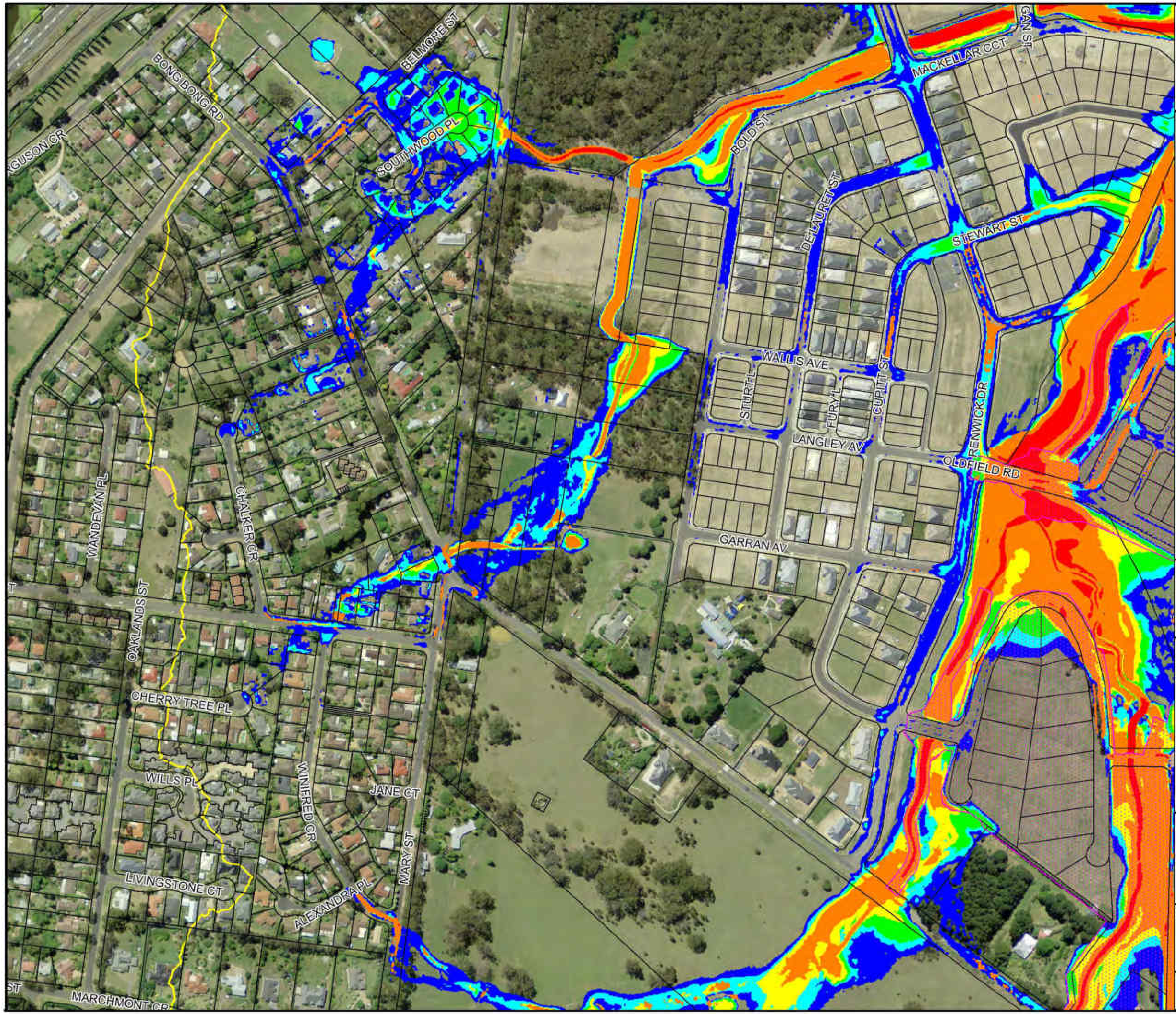
0 0.1 0.2 Km

Appendix D4.1: PMF National Flood Hazard

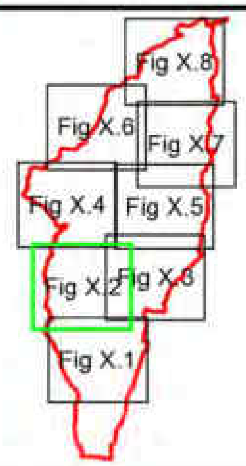
Prepared By:

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

File Name: PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

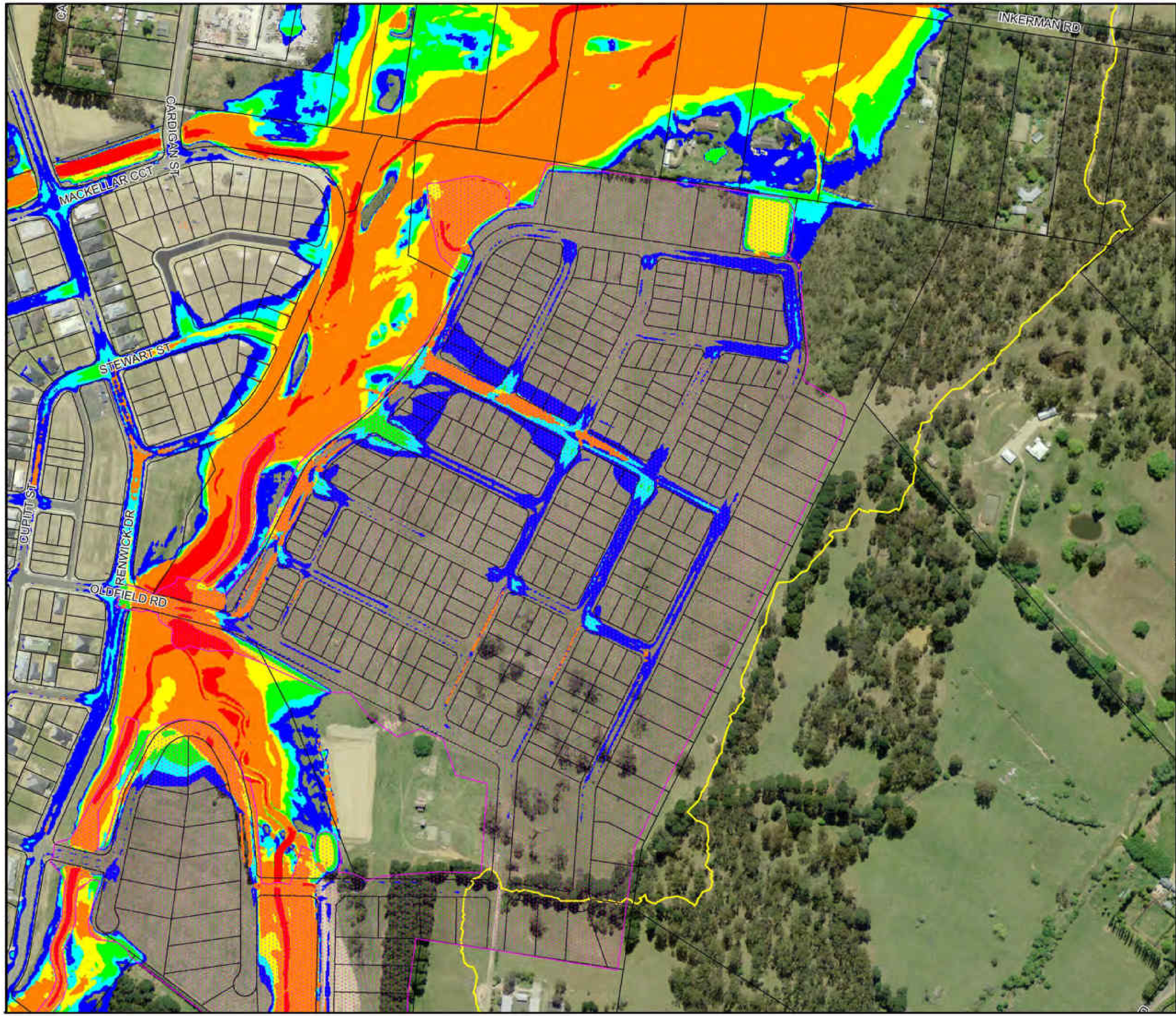
0 0.1 0.2 Km

Appendix D4.2: PMF National Flood Hazard

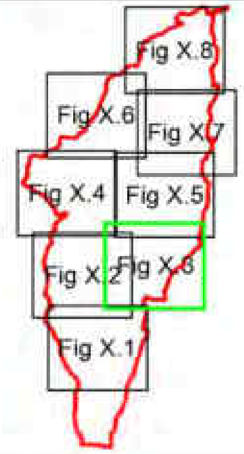
Prepared By:

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

File Name: PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

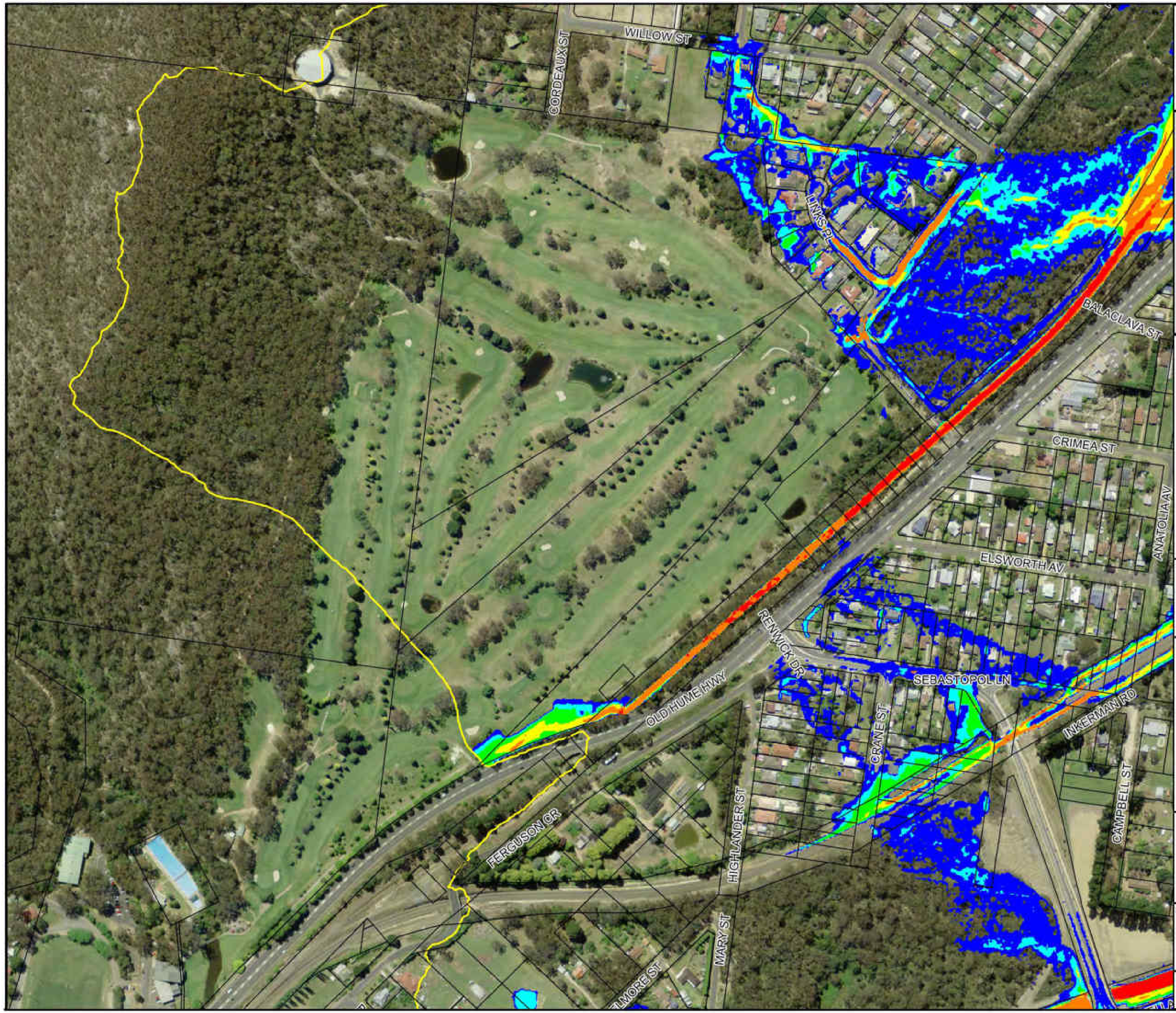
0 0.1 0.2 Km

Appendix D4.3: PMF National Flood Hazard

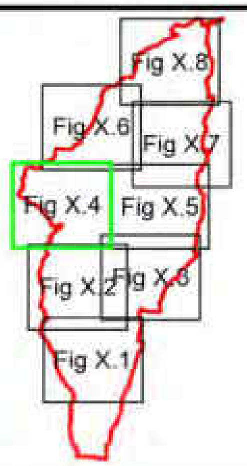
Prepared By:

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

File Name: PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

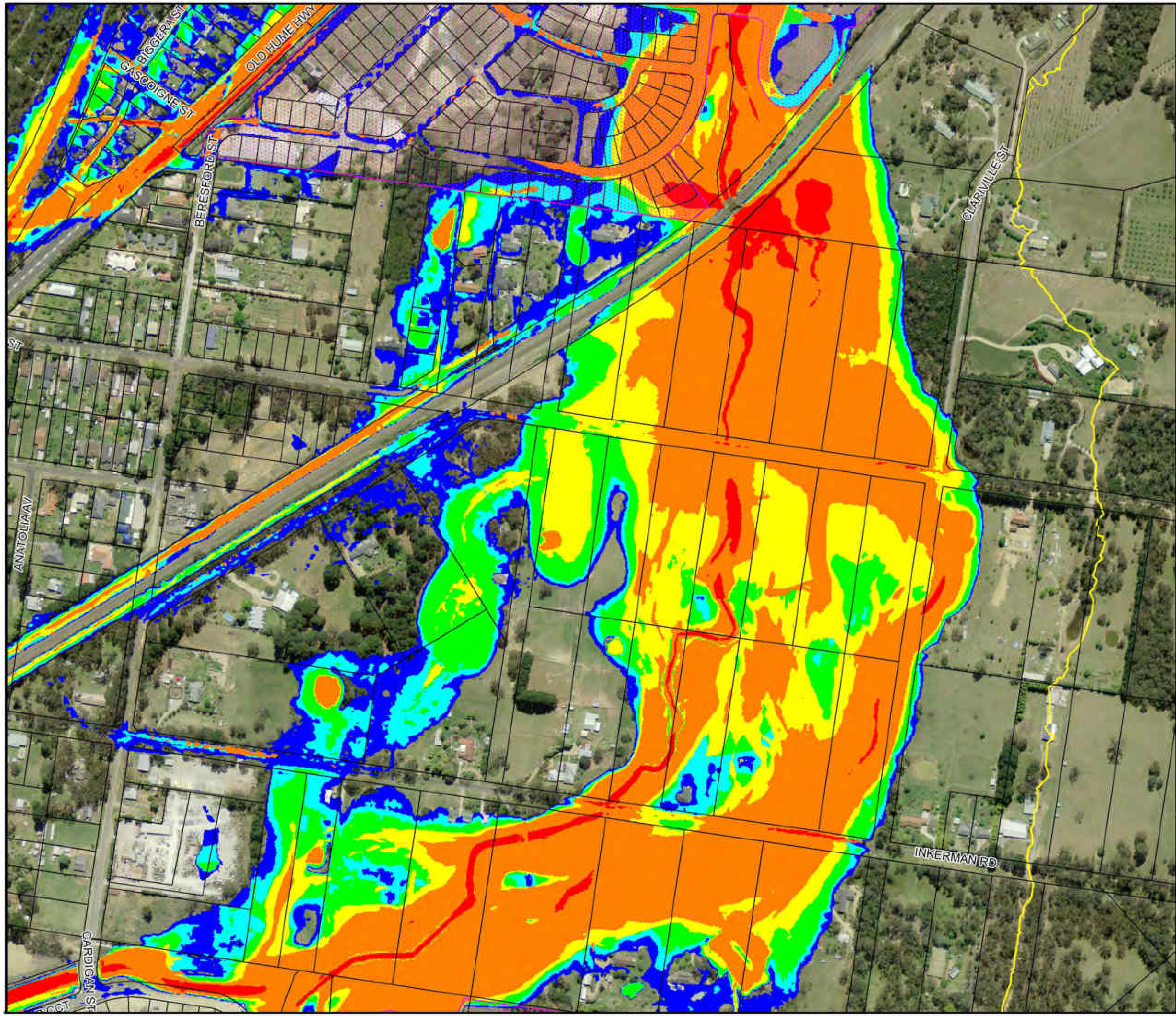
Scale 1:4,000 (at A3)

0 0.1 0.2
Km

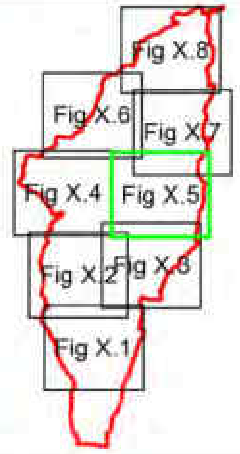
Appendix D4.4: PMF National Flood Hazard

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

File Name: PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

- Nattai Ponds Study Area
- Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

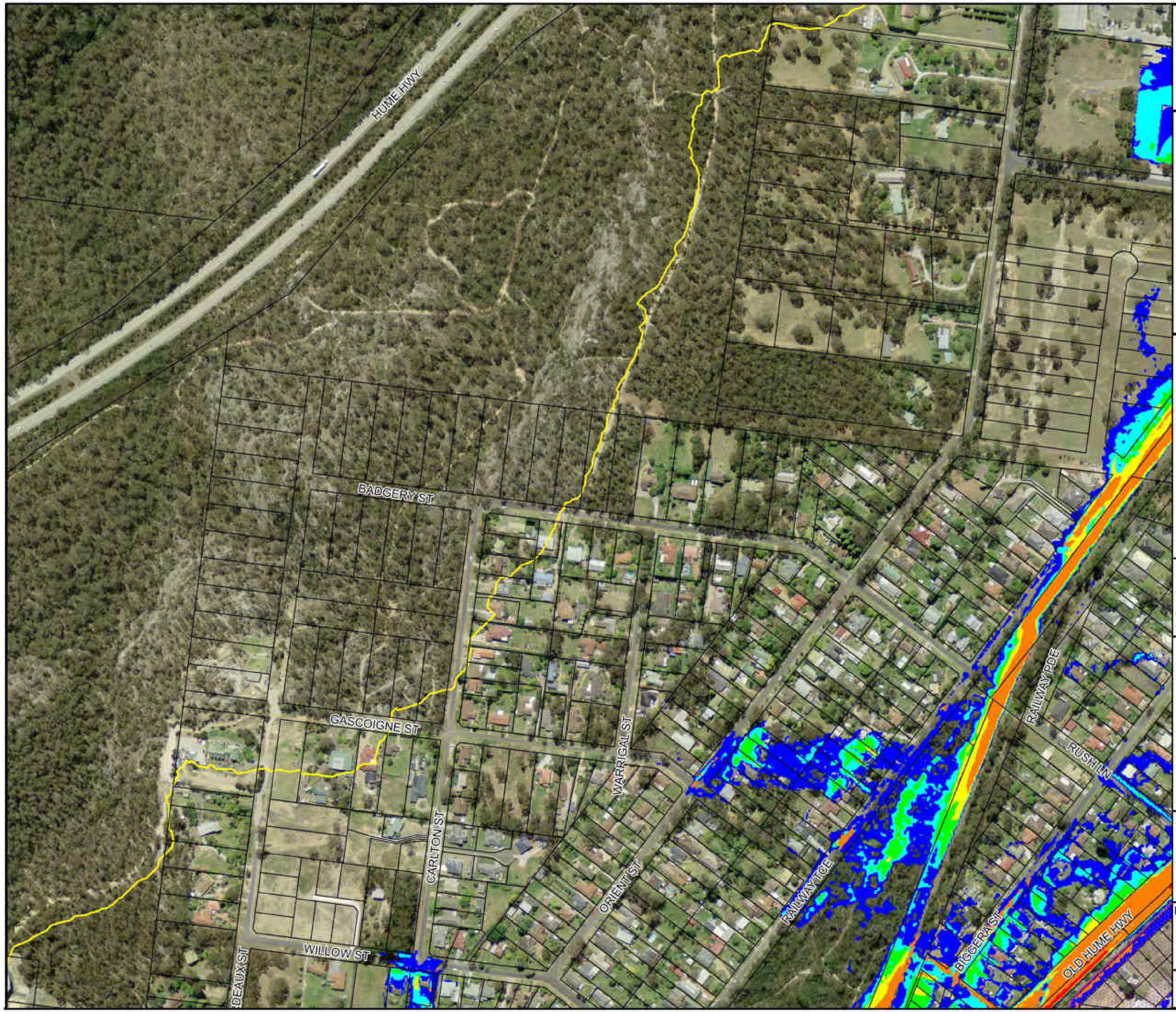
Scale 1:4,000 (at A3)

0 0.1 0.2 Km

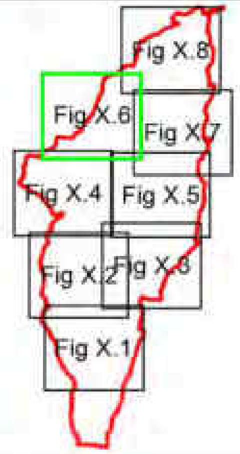
Appendix D4.5: PMF National Flood Hazard

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

File Name: PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013

Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N W E S

Scale 1:4,000 (at A3)

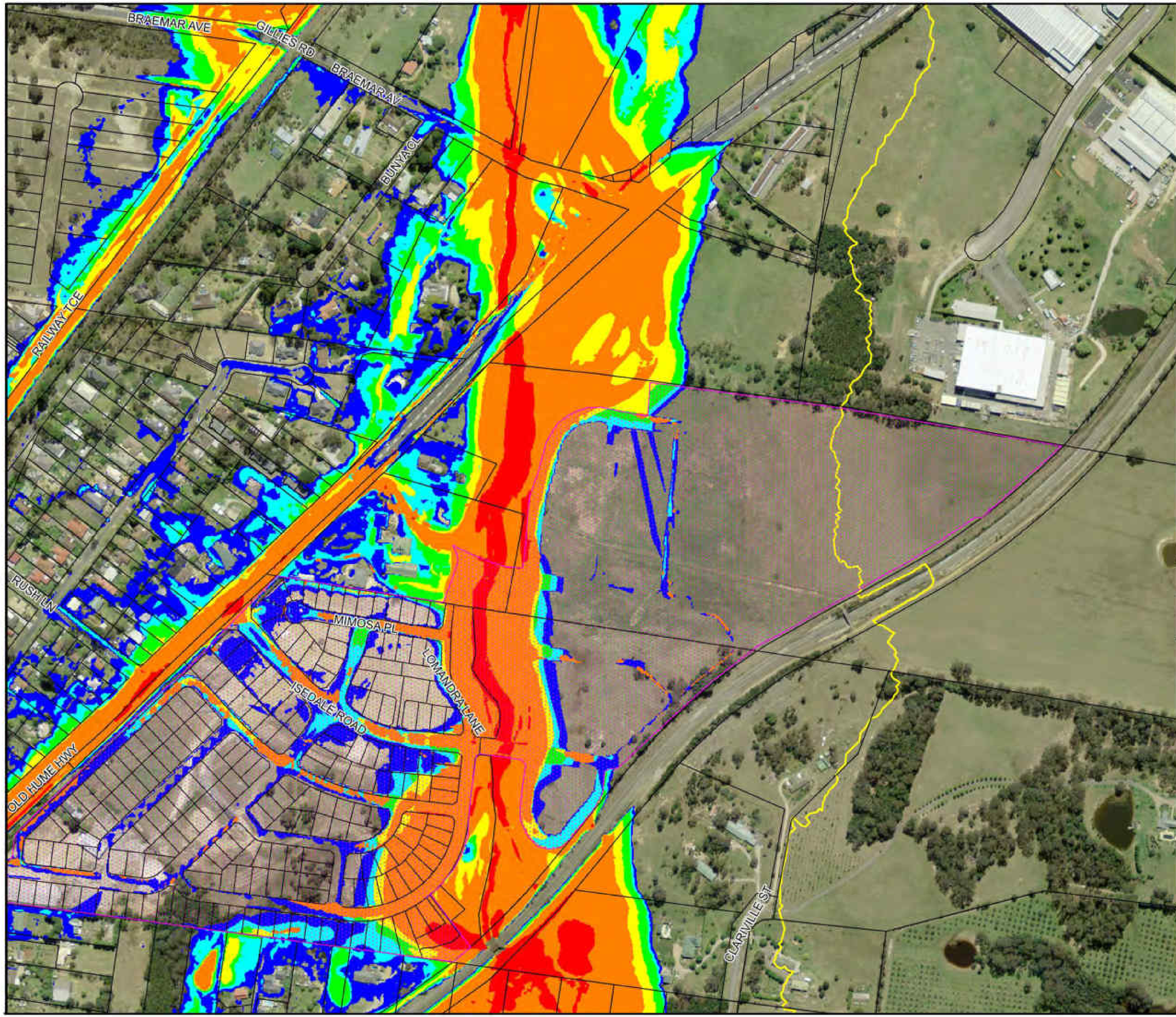
0 0.1 0.2 Km

Appendix D4.6: PMF National Flood Hazard

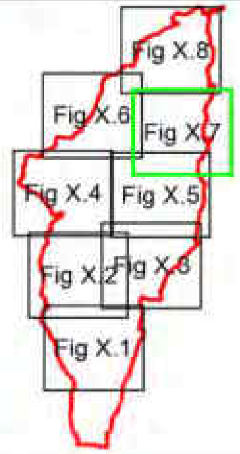
Prepared By:

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

File Name: PMF Flood Hazard.wor



WINGECARRIBEE SHIRE COUNCIL



LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2
Km

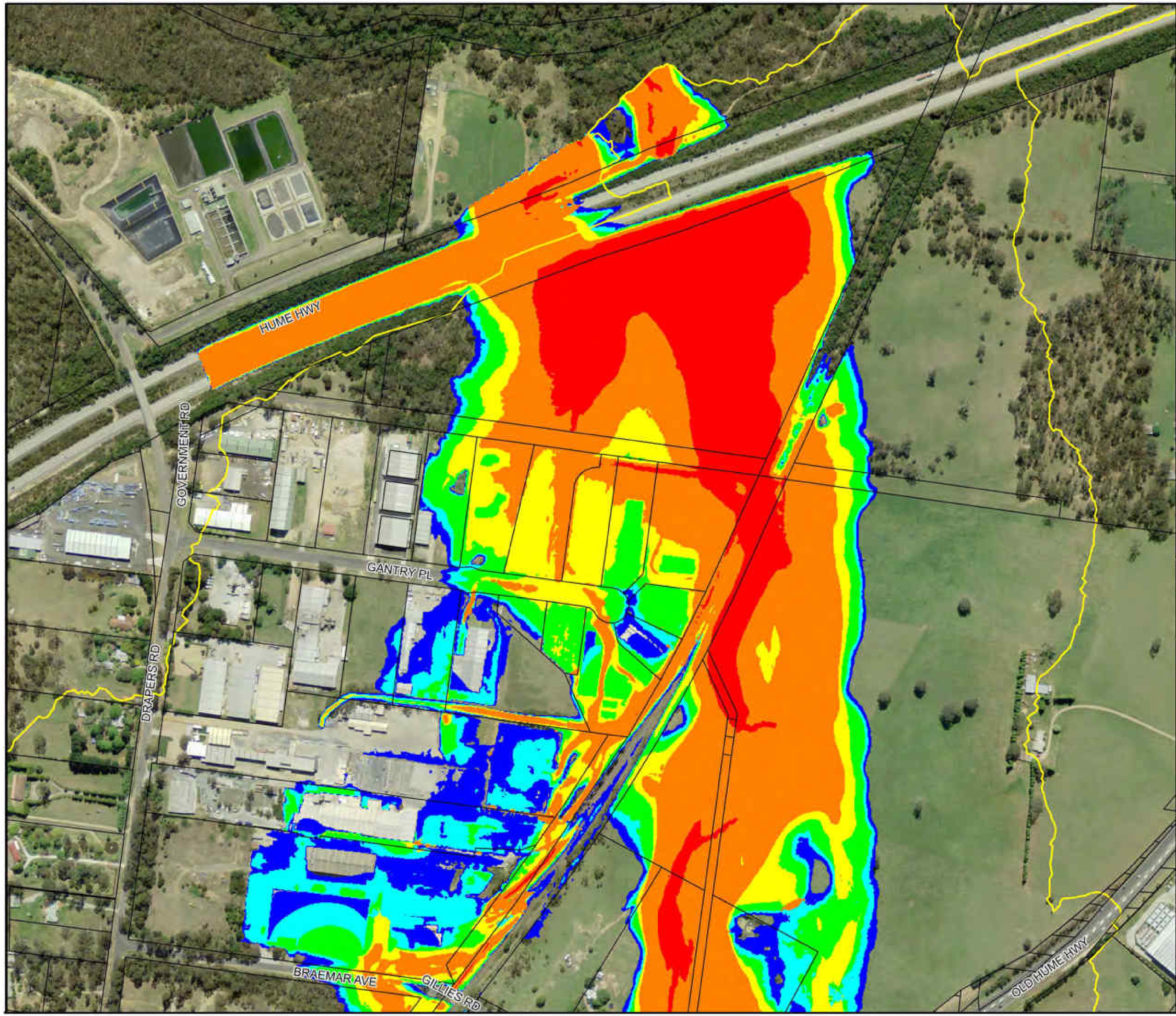
Appendix D4.7: PMF National Flood Hazard

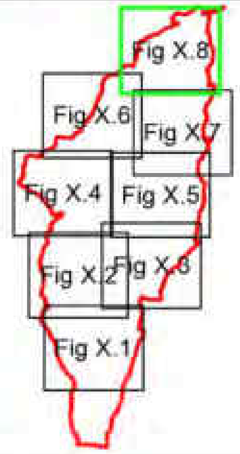
Prepared By:

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

File Name: PMF Flood Hazard.wor

WINGECARRIBEE SHIRE COUNCIL





LEGEND

Nattai Ponds Study Area

Future Development Area (Elevations Assumed)

Hazard Category

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: September 2013
Results within future development areas based on assumed elevations and results should be verified against final topography before use.

N
W E
S

Scale 1:4,000 (at A3)

0 0.1 0.2
Km

Appendix D4.8: PMF National Flood Hazard

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

File Name: PMF Flood Hazard.wor

APPENDIX E

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 without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
1.01	0.50	0.50	0.0%	0.50	0.0%
1.02	0.90	0.90	0.0%	0.90	0.0%
1.03	1.83	1.83	0.0%	1.83	0.0%
1.04	3.68	3.68	0.0%	3.68	0.0%
1.05	4.24	4.24	0.0%	4.24	0.0%
1.06	4.37	4.37	0.0%	4.37	0.0%
1.07	6.02	6.02	0.0%	6.02	0.0%
1.08	10.03	10.02	-0.1%	10.02	-0.1%
1.09	10.57	10.56	-0.1%	10.56	-0.1%
1.1	0.60	0.60	0.0%	0.60	0.0%
1.11	4.70	5.07	8.0%	4.66	-0.8%
1.12	4.71	5.09	8.0%	4.67	-0.8%
1.13	4.71	5.09	8.0%	4.67	-0.8%
1.14	18.34	18.66	1.7%	18.64	1.6%
1.15	19.19	19.50	1.7%	19.49	1.6%
1.16	19.61	20.01	2.0%	19.92	1.6%
1.17	19.97	20.45	2.4%	20.31	1.7%
1.18	20.20	20.67	2.3%	20.54	1.7%
1.19	20.67	21.16	2.4%	21.05	1.8%
1.2	21.09	21.61	2.5%	21.46	1.7%
1.21	24.44	25.56	4.6%	25.17	3.0%
1.22	25.32	26.43	4.4%	26.04	2.9%
1.23	26.22	27.34	4.2%	26.94	2.8%
1.24	26.73	27.82	4.1%	27.43	2.6%
1.25	33.19	34.54	4.1%	34.22	3.1%
1.26	34.23	35.50	3.7%	35.47	3.6%
2.01	0.11	0.11	0.0%	0.11	0.0%
2.02	0.45	0.45	0.0%	0.45	0.0%
3.01	0.29	0.29	0.0%	0.29	0.0%
3.02	1.38	1.38	0.0%	1.38	0.0%
3.03	1.77	1.77	0.0%	1.77	0.0%
4.01	0.54	0.54	0.0%	0.54	0.0%
5.01	0.45	0.45	0.0%	0.45	0.0%
5.02	0.93	0.93	0.0%	0.93	0.0%
5.03	1.54	1.54	0.0%	1.54	0.0%
6.01	0.80	0.80	0.0%	0.80	0.0%
6.02	1.07	1.07	0.0%	1.07	0.0%
6.03	1.59	1.60	0.1%	1.60	0.1%
6.04	2.72	2.72	0.1%	2.73	0.3%
6.05	3.17	3.20	0.8%	3.21	1.3%
6.06	3.41	3.43	0.7%	3.45	1.1%
6.07	3.98	4.03	1.4%	4.03	1.4%
7.01	0.36	0.36	0.0%	0.36	0.0%
8.01	0.22	0.22	0.0%	0.22	0.0%
8.02	0.83	0.83	0.1%	0.83	0.1%
8.03	1.11	1.14	2.4%	1.13	1.4%
9.01	0.40	0.40	0.0%	0.40	0.0%
10.01	0.28	0.86	204.7%	0.38	33.4%
11.01	0.35	0.35	0.0%	0.35	0.0%
11.02	0.80	0.80	0.0%	0.80	0.0%
12.01	0.28	0.28	0.0%	0.28	0.0%
13.01	0.23	0.23	0.0%	0.23	0.0%
14.01	1.08	1.08	0.0%	1.08	0.0%

Future Development Results for the 20% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
15.01	1.75	1.75	0.0%	1.75	0.0%
15.02	2.29	2.42	5.9%	2.17	-5.2%
15.03	4.03	4.40	9.4%	3.99	-0.9%
15.04	4.07	4.45	9.2%	4.04	-0.9%
16.01	1.67	1.67	0.0%	1.67	0.0%
17.01	0.20	0.32	62.5%	0.22	10.1%
18.01	0.11	0.11	0.0%	0.11	0.0%
19.01	0.51	0.51	0.0%	0.51	0.0%
19.02	0.86	0.86	0.0%	0.86	0.0%
19.03	1.18	2.05	74.3%	1.24	5.0%
19.04	1.31	3.19	144.3%	1.42	9.0%
19.05	1.48	3.73	152.7%	1.57	6.3%
19.06	2.78	5.44	95.5%	2.86	2.8%
19.07	4.03	6.82	69.2%	4.11	1.9%
19.08	4.15	7.01	68.7%	4.23	1.7%
19.09	1.63	1.72	5.6%	1.70	4.5%
19.1	12.40	12.60	1.6%	12.56	1.3%
19.11	12.76	12.89	1.0%	12.86	0.8%
19.12	12.98	13.11	1.0%	13.08	0.8%
20.01	0.20	0.20	0.0%	0.20	0.0%
21.01	0.22	0.34	52.9%	0.15	-35.1%
22.01	0.18	0.73	298.2%	0.17	-6.9%
23.01	0.07	0.07	0.0%	0.07	0.0%
24.01	0.20	0.20	0.0%	0.20	0.0%
24.02	0.25	0.25	0.0%	0.25	0.0%
24.03	0.44	0.91	107.7%	0.40	-8.8%
24.04	0.98	1.47	49.4%	0.94	-4.2%
24.05	1.22	1.74	43.5%	1.20	-1.6%
25.01	0.17	0.58	246.2%	0.17	1.5%
26.01	0.24	0.24	0.0%	0.24	0.0%
26.02	0.45	0.45	0.0%	0.45	0.0%
27.01	0.16	0.16	0.0%	0.16	0.0%
28.01	0.18	0.18	0.0%	0.18	0.0%
29.01	0.07	0.07	0.0%	0.07	0.0%
30.01	0.38	0.39	2.7%	0.39	2.7%
31.01	0.21	0.21	0.0%	0.21	0.0%
31.02	0.57	0.57	0.0%	0.57	0.0%
31.03	0.71	1.31	84.2%	1.01	41.5%
32.01	0.33	0.33	0.0%	0.33	0.0%
33.01	0.25	0.25	0.0%	0.25	0.0%
34.01	0.18	0.51	183.1%	0.21	16.5%
35.01	0.10	0.10	0.0%	0.10	0.0%
35.02	0.38	0.38	0.0%	0.38	0.0%
35.03	0.62	0.62	0.0%	0.62	0.0%
35.04	0.77	0.77	0.0%	0.77	0.0%
35.05	0.78	0.78	0.0%	0.78	0.0%
35.06	0.64	0.64	0.0%	0.64	0.0%
36.01	0.23	0.23	0.0%	0.23	0.0%
37.01	0.09	0.09	0.0%	0.09	0.0%
38.01	0.11	0.11	0.0%	0.11	0.0%
39.01	0.34	0.89	165.0%	0.45	34.5%
40.01	0.14	0.14	0.0%	0.14	0.0%
40.02	0.26	0.27	3.9%	0.27	3.9%

Future Development Results for the 20% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
40.03	0.70	0.84	20.9%	0.68	-2.8%
40.04	1.02	1.21	18.8%	0.80	-21.4%
40.05	1.36	2.01	47.7%	1.14	-16.2%
40.06	1.49	2.18	46.5%	1.30	-12.8%
41.01	0.26	0.30	16.2%	0.16	-38.5%
42.01	0.30	0.39	28.3%	0.21	-30.8%
43.01	0.08	0.11	25.9%	0.11	33.7%
44.01	0.15	3.00	1880.0%	0.16	2.9%
44.02	0.27	0.93	241.3%	0.29	4.5%
44.03	0.41	0.97	138.3%	0.42	3.0%
44.04	0.66	1.08	63.0%	0.67	1.9%
45.01	0.10	0.19	85.5%	0.11	12.8%
46.01	0.16	0.16	0.0%	0.16	0.0%
47.01	0.11	0.11	0.0%	0.11	0.0%
48.01	0.19	0.19	0.0%	0.19	0.0%
48.02	0.45	0.45	0.7%	0.45	0.7%
49.01	0.24	0.24	0.0%	0.24	0.0%
50.01	0.30	0.30	0.0%	0.30	0.0%
51.01	0.09	0.10	10.7%	0.10	10.7%
52.01	0.36	1.20	234.3%	0.56	57.2%
52.02	0.81	1.67	104.9%	1.00	22.6%
53.01	0.34	0.34	0.0%	0.34	0.0%
53.02	1.06	1.06	0.0%	1.06	0.0%
53.03	1.40	1.40	0.0%	1.40	0.0%
54.01	0.46	0.46	0.0%	0.46	0.0%
55.01	0.37	0.37	0.0%	0.37	0.0%
56.01	0.36	0.36	0.0%	0.36	0.0%
57.01	0.45	0.90	102.4%	0.25	-44.7%
57.02	0.60	1.06	75.9%	0.32	-46.9%
57.03	0.72	1.12	56.7%	0.37	-47.8%
58.01	0.59	0.59	0.0%	0.59	0.0%
58.02	0.73	0.73	0.0%	0.73	0.0%
58.03	0.91	0.91	0.0%	0.91	0.0%
58.04	1.71	1.71	0.0%	1.71	0.0%
58.05	2.46	2.46	0.0%	2.46	0.0%
58.06	2.47	2.47	0.0%	2.47	0.0%
58.07	3.55	3.59	0.9%	3.59	0.9%
58.08	1.35	1.39	2.9%	1.35	0.3%
58.09	1.80	1.87	3.4%	1.81	0.4%
58.1	2.05	2.06	0.4%	2.06	0.4%
58.11	2.27	2.29	0.8%	2.29	0.8%
59.01	0.42	0.42	0.0%	0.42	0.0%
59.02	0.67	0.67	0.0%	0.67	0.0%
60.01	0.24	0.24	0.0%	0.24	0.0%
60.02	0.67	0.67	0.0%	0.67	0.0%
61.01	0.15	0.15	1.3%	0.15	1.3%
61.02	0.47	0.86	83.5%	0.53	13.1%
61.03	0.83	1.25	51.5%	0.87	5.1%
61.04	1.14	1.49	30.5%	1.19	3.7%
62.01	0.21	0.57	164.7%	0.24	13.4%
63.01	0.15	0.15	1.3%	0.15	1.3%
64.01	0.05	0.14	182.9%	0.06	18.4%
65.01	0.13	0.13	0.0%	0.13	0.0%

Future Development Results for the 20% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
65.02	0.23	0.23	0.0%	0.23	0.0%
66.01	0.01	0.01	0.0%	0.01	0.0%
67.01	0.31	0.39	28.0%	0.25	-19.4%
68.01	0.16	0.16	0.0%	0.16	0.0%
69.01	0.18	0.18	0.0%	0.18	0.0%
69.02	0.27	0.27	0.0%	0.27	0.0%
70.01	0.27	0.41	49.8%	0.27	-2.0%
71.01	1.40	3.85	175.7%	0.97	-30.6%
71.02	1.72	4.81	180.5%	1.35	-21.2%
72.01	0.33	1.00	204.0%	0.34	2.0%
73.01	0.13	0.29	122.8%	0.16	20.5%
73.02	0.27	0.46	70.7%	0.32	18.1%
73.03	0.54	0.66	23.7%	0.55	3.0%
74.01	0.09	0.09	0.7%	0.09	0.7%
75.01	0.05	0.10	87.6%	0.06	6.3%
76.01	0.45	0.46	0.1%	0.46	0.1%
77.01	0.55	0.57	5.2%	0.57	5.2%
78.01	0.11	0.11	0.0%	0.11	0.0%
78.02	2.45	2.49	1.3%	2.49	1.3%
78.03	3.46	3.50	1.3%	3.51	1.3%
78.04	3.75	3.79	1.2%	3.79	1.2%
78.05	3.97	4.02	1.3%	4.03	1.4%
78.06	5.25	5.36	2.0%	5.38	2.4%
78.07	6.55	7.10	8.4%	6.82	4.1%
79.01	0.25	0.37	50.0%	0.24	-0.7%
79.02	0.47	0.59	26.9%	0.46	-2.2%
79.03	0.62	0.75	20.2%	0.61	-1.1%
80.01	0.16	0.16	0.0%	0.16	0.0%
81.01	0.05	0.05	5.2%	0.05	5.2%
82.01	0.25	0.29	18.5%	0.17	-32.1%
82.02	0.38	0.42	12.2%	0.31	-17.0%
82.03	0.64	0.69	8.5%	0.57	-11.5%
83.01	0.22	0.23	3.7%	0.23	3.7%
84.01	0.18	0.18	0.0%	0.18	0.0%
84.02	0.43	0.43	0.0%	0.43	0.0%
85.01	0.12	0.12	0.0%	0.12	0.0%
86.01	0.01	0.01	0.0%	0.01	0.0%
86.02	0.19	0.21	5.5%	0.21	5.5%
87.01	0.04	0.11	169.8%	0.06	50.1%
88.01	0.33	0.36	8.8%	0.36	8.8%
88.02	0.46	0.53	16.5%	0.53	16.5%
88.03	0.83	1.24	48.3%	0.89	6.8%
88.04	1.20	1.94	61.1%	1.31	9.0%
89.01	0.27	0.83	209.8%	0.30	10.0%
89.02	0.94	3.45	265.0%	0.96	1.5%
89.03	1.38	4.46	222.1%	1.39	0.2%
90.01	0.29	1.51	421.6%	0.28	-2.4%
91.01	0.41	0.75	83.6%	0.25	-39.3%
92.01	0.49	0.85	74.7%	0.27	-44.9%
92.02	0.75	1.13	50.5%	0.46	-38.8%
_junc_116	0.36	0.71	97.3%	0.39	8.5%
_junc_123	1.67	4.77	185.0%	1.31	-22.0%
_junc_125	25.71	26.83	4.3%	26.44	2.8%

Future Development Results for the 20% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
_junc_126	0.75	0.75	0.4%	0.75	0.4%
_junc_130	3.00	3.02	0.8%	3.04	1.3%
_junc_133	1.09	1.20	10.0%	1.05	-3.4%
_junc_135	0.34	0.34	0.0%	0.34	0.0%
_junc_136	0.47	0.47	0.0%	0.47	0.0%
_junc_138	3.88	4.01	3.5%	3.76	-3.1%
_junc_142	1.20	4.05	237.8%	1.20	0.3%
_junc_150	2.89	2.93	1.3%	2.93	1.3%
_junc_151	1.05	1.53	46.4%	0.99	-5.1%
_junc_158	0.43	0.43	0.0%	0.43	0.0%
_junc_162	0.20	0.21	7.2%	0.20	4.0%
_junc_19	0.71	0.71	0.0%	0.71	0.0%
_junc_21	9.87	9.87	-0.1%	9.86	-0.1%
_junc_28	2.66	5.43	104.4%	2.75	3.4%
_junc_29	0.81	1.28	58.8%	0.82	1.2%
_junc_30	0.18	0.18	0.0%	0.18	0.0%
_junc_32	0.35	0.82	133.8%	0.35	0.7%
_junc_37	12.70	12.84	1.1%	12.81	0.8%
_junc_38	4.58	4.96	8.2%	4.55	-0.8%
_junc_40	0.93	1.12	20.7%	0.71	-23.4%
_junc_41	1.58	1.58	0.0%	1.58	0.0%
_junc_42	1.25	1.51	20.7%	0.93	-25.7%
_junc_44	13.13	13.26	1.0%	13.23	0.8%
_junc_47	1.92	3.17	65.3%	1.97	2.6%
_junc_50	0.14	0.14	0.0%	0.14	0.0%
_junc_59	19.57	19.97	2.0%	19.89	1.6%
_junc_64	1.54	1.68	9.0%	1.55	0.5%
_junc_68	0.30	0.42	42.3%	0.27	-7.3%
_junc_69	20.28	20.74	2.3%	20.61	1.6%
_junc_71	1.96	2.04	3.8%	1.97	0.4%
_junc_74	2.23	2.25	0.8%	2.25	0.9%
_junc_76	21.06	21.57	2.5%	21.42	1.7%
_junc_80	24.90	26.02	4.5%	25.63	2.9%
_junc_81	0.36	0.52	44.2%	0.38	4.7%
_junc_84	26.73	27.81	4.1%	27.42	2.6%
_junc_85	33.17	34.51	4.1%	34.19	3.1%
_junc_86	33.53	34.91	4.1%	34.61	3.2%
_junc_88	5.17	5.27	1.9%	5.30	2.5%
_junc_91	6.47	7.09	9.6%	6.75	4.3%
US_OHH	22.09	23.21	5.1%	22.81	3.2%
US_Rail	19.01	19.33	1.7%	19.32	1.6%

Future Development Results for the 1% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
1.01	1.27	1.27	0.0%	1.27	0.0%
1.02	2.42	2.42	0.0%	2.42	0.0%
1.03	5.01	5.01	0.0%	5.01	0.0%
1.04	10.31	10.31	0.0%	10.31	0.0%
1.05	11.62	11.62	0.0%	11.62	0.0%
1.06	11.95	11.95	0.0%	11.95	0.0%
1.07	15.99	15.99	0.0%	15.99	0.0%
1.08	26.55	26.46	-0.4%	26.53	-0.1%
1.09	27.29	27.19	-0.4%	27.26	-0.1%
1.1	1.26	1.26	0.0%	1.26	0.0%
1.11	9.46	10.23	8.1%	8.77	-7.3%
1.12	9.53	10.27	7.8%	8.88	-6.8%
1.13	9.55	10.30	7.8%	8.90	-6.8%
1.14	43.50	44.26	1.7%	43.89	0.9%
1.15	45.68	46.48	1.7%	46.09	0.9%
1.16	46.85	47.91	2.3%	47.33	1.0%
1.17	47.68	48.81	2.4%	48.19	1.1%
1.18	47.97	49.06	2.3%	48.64	1.4%
1.19	48.59	49.42	1.7%	49.46	1.8%
1.2	49.50	50.40	1.8%	50.19	1.4%
1.21	54.17	55.92	3.2%	55.96	3.3%
1.22	56.02	57.89	3.3%	57.74	3.1%
1.23	57.91	59.97	3.6%	59.63	3.0%
1.24	58.97	61.03	3.5%	60.60	2.8%
1.25	75.81	78.04	2.9%	77.43	2.1%
1.26	77.81	79.47	2.1%	79.74	2.5%
2.01	0.32	0.32	0.0%	0.32	0.0%
2.02	1.37	1.37	0.0%	1.37	0.0%
3.01	0.89	0.89	0.0%	0.89	0.0%
3.02	3.97	3.97	0.0%	3.97	0.0%
3.03	5.08	5.08	0.0%	5.08	0.0%
4.01	1.58	1.58	0.0%	1.58	0.0%
5.01	1.21	1.21	0.0%	1.21	0.0%
5.02	2.39	2.39	0.0%	2.39	0.0%
5.03	3.95	3.95	0.0%	3.95	0.0%
6.01	2.14	2.14	0.0%	2.14	0.0%
6.02	2.88	2.88	0.0%	2.88	0.0%
6.03	4.33	4.34	0.1%	4.34	0.1%
6.04	7.53	7.55	0.2%	7.54	0.1%
6.05	8.78	8.75	-0.4%	8.79	0.0%
6.06	9.35	9.31	-0.4%	9.35	0.0%
6.07	10.79	10.76	-0.3%	10.79	0.0%
7.01	0.96	0.96	0.0%	0.96	0.0%
8.01	0.59	0.59	0.0%	0.59	0.0%
8.02	2.46	2.47	0.1%	2.47	0.1%
8.03	3.20	3.21	0.4%	3.23	0.9%
9.01	0.92	0.92	0.0%	0.92	0.0%
10.01	0.76	1.84	140.3%	0.76	-0.6%
11.01	0.80	0.80	0.0%	0.80	0.0%
11.02	1.76	1.76	0.0%	1.76	0.0%
12.01	0.56	0.56	0.0%	0.56	0.0%
13.01	0.47	0.47	0.0%	0.47	0.0%
14.01	2.27	2.27	0.0%	2.27	0.0%

Future Development Results for the 1% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
15.01	3.58	3.58	0.0%	3.58	0.0%
15.02	4.73	5.00	5.8%	4.00	-15.4%
15.03	8.26	9.02	9.3%	7.55	-8.5%
15.04	8.33	9.10	9.2%	7.63	-8.4%
16.01	3.40	3.40	0.0%	3.40	0.0%
17.01	0.52	0.71	37.9%	0.53	2.4%
18.01	0.28	0.28	0.0%	0.28	0.0%
19.01	1.08	1.08	0.0%	1.08	0.0%
19.02	1.80	1.80	0.0%	1.80	0.0%
19.03	3.15	4.20	33.3%	2.92	-7.2%
19.04	3.76	6.52	73.3%	3.68	-2.2%
19.05	4.20	7.63	81.8%	4.03	-3.9%
19.06	7.32	11.12	51.8%	7.26	-0.9%
19.07	9.71	13.57	39.7%	9.52	-2.0%
19.08	9.99	13.83	38.4%	9.80	-1.9%
19.09	2.36	2.51	6.5%	2.42	2.9%
19.1	29.98	30.21	0.8%	30.10	0.4%
19.11	30.63	30.64	0.0%	30.70	0.3%
19.12	30.91	30.92	0.0%	30.98	0.3%
20.01	0.41	0.41	0.0%	0.41	0.0%
21.01	0.46	0.74	59.7%	0.33	-29.0%
22.01	0.51	1.54	198.5%	0.37	-27.2%
23.01	0.21	0.21	0.0%	0.21	0.0%
24.01	0.43	0.43	0.0%	0.43	0.0%
24.02	0.52	0.52	0.0%	0.52	0.0%
24.03	1.02	1.81	77.3%	0.99	-3.1%
24.04	2.52	2.94	16.8%	2.53	0.4%
24.05	3.13	3.53	12.7%	3.18	1.4%
25.01	0.43	1.15	169.4%	0.36	-15.5%
26.01	0.55	0.55	0.0%	0.55	0.0%
26.02	1.25	1.25	0.0%	1.25	0.0%
27.01	0.49	0.49	0.0%	0.49	0.0%
28.01	0.44	0.44	0.0%	0.44	0.0%
29.01	0.17	0.17	0.0%	0.17	0.0%
30.01	0.77	0.79	2.4%	0.79	2.4%
31.01	0.42	0.42	0.0%	0.42	0.0%
31.02	1.18	1.18	0.0%	1.18	0.0%
31.03	1.77	2.67	50.5%	2.00	12.7%
32.01	0.68	0.68	0.0%	0.68	0.0%
33.01	0.54	0.54	0.0%	0.54	0.0%
34.01	0.49	1.13	132.5%	0.44	-8.7%
35.01	0.25	0.25	0.0%	0.25	0.0%
35.02	0.77	0.77	0.0%	0.77	0.0%
35.03	1.26	1.26	0.0%	1.26	0.0%
35.04	1.59	1.59	0.0%	1.59	0.0%
35.05	1.64	1.64	0.0%	1.64	0.0%
35.06	1.39	1.39	0.0%	1.39	0.0%
36.01	0.48	0.48	0.0%	0.48	0.0%
37.01	0.19	0.19	0.0%	0.19	0.0%
38.01	0.27	0.27	0.0%	0.27	0.0%
39.01	0.86	1.90	122.1%	0.96	11.6%
40.01	0.27	0.27	0.0%	0.27	0.0%
40.02	0.53	0.55	3.5%	0.55	3.5%

Future Development Results for the 1% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
40.03	1.45	1.76	21.5%	1.49	2.4%
40.04	2.07	2.49	20.0%	2.19	5.9%
40.05	2.72	3.93	44.4%	3.02	10.9%
40.06	3.10	4.34	40.0%	3.35	8.0%
41.01	0.55	0.66	20.9%	0.52	-6.1%
42.01	0.68	0.88	28.0%	0.69	0.5%
43.01	0.19	0.24	22.1%	0.19	-4.1%
44.01	0.36	3.00	722.1%	0.31	-13.7%
44.02	0.68	1.95	185.3%	0.65	-4.7%
44.03	1.02	2.02	98.0%	0.99	-3.1%
44.04	1.58	2.22	40.8%	1.58	0.1%
45.01	0.22	0.38	72.6%	0.21	-4.9%
46.01	0.35	0.35	0.0%	0.35	0.0%
47.01	0.26	0.26	0.0%	0.26	0.0%
48.01	0.41	0.41	0.0%	0.41	0.0%
48.02	1.09	1.09	0.3%	1.09	0.3%
49.01	0.63	0.63	0.0%	0.63	0.0%
50.01	0.77	0.77	0.0%	0.77	0.0%
51.01	0.22	0.23	4.2%	0.23	4.2%
52.01	0.89	2.52	183.8%	0.95	7.2%
52.02	1.69	3.44	103.7%	1.53	-9.2%
53.01	0.71	0.71	0.0%	0.71	0.0%
53.02	2.16	2.16	0.0%	2.16	0.0%
53.03	2.83	2.83	0.0%	2.83	0.0%
54.01	1.02	1.02	0.0%	1.02	0.0%
55.01	0.84	0.84	0.0%	0.84	0.0%
56.01	0.69	0.69	0.0%	0.69	0.0%
57.01	0.98	1.84	88.4%	0.52	-46.6%
57.02	1.32	2.18	65.7%	0.70	-46.8%
57.03	1.55	2.41	55.8%	0.83	-46.2%
58.01	1.52	1.52	0.0%	1.52	0.0%
58.02	1.86	1.86	0.0%	1.86	0.0%
58.03	2.31	2.31	0.0%	2.31	0.0%
58.04	4.40	4.40	0.0%	4.40	0.0%
58.05	6.32	6.32	0.0%	6.32	0.0%
58.06	6.35	6.35	0.0%	6.35	0.0%
58.07	9.12	9.19	0.8%	9.13	0.1%
58.08	1.51	1.54	1.9%	1.54	1.9%
58.09	2.65	2.74	3.5%	2.74	3.5%
58.1	3.28	3.37	2.8%	3.37	2.8%
58.11	3.79	3.91	3.2%	3.91	3.2%
59.01	1.10	1.10	0.0%	1.10	0.0%
59.02	1.77	1.77	0.0%	1.77	0.0%
60.01	0.66	0.66	0.0%	0.66	0.0%
60.02	1.73	1.73	0.0%	1.73	0.0%
61.01	0.42	0.44	4.4%	0.44	4.4%
61.02	1.39	1.77	26.8%	1.33	-4.5%
61.03	2.32	2.59	12.0%	2.24	-3.1%
61.04	3.08	3.31	7.5%	3.01	-2.3%
62.01	0.65	1.20	85.3%	0.57	-12.3%
63.01	0.37	0.38	3.1%	0.38	3.1%
64.01	0.16	0.28	76.5%	0.19	21.7%
65.01	0.31	0.31	0.0%	0.31	0.0%

Future Development Results for the 1% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
65.02	0.55	0.55	0.0%	0.55	0.0%
66.01	0.03	0.03	0.0%	0.03	0.0%
67.01	0.64	0.80	24.7%	0.59	-8.1%
68.01	0.33	0.33	0.0%	0.33	0.0%
69.01	0.35	0.35	0.0%	0.35	0.0%
69.02	0.55	0.55	0.0%	0.55	0.0%
70.01	0.54	0.81	49.7%	0.55	2.1%
71.01	2.95	7.90	167.4%	1.98	-33.0%
71.02	3.57	10.06	181.9%	2.83	-20.6%
72.01	0.85	2.08	143.6%	0.75	-12.3%
73.01	0.30	0.58	93.9%	0.31	5.6%
73.02	0.67	0.92	38.1%	0.70	5.2%
73.03	1.30	1.36	5.0%	1.35	3.9%
74.01	0.23	0.23	1.1%	0.23	1.1%
75.01	0.15	0.22	54.3%	0.16	8.3%
76.01	1.17	1.17	0.1%	1.17	0.1%
77.01	1.31	1.39	6.4%	1.39	6.4%
78.01	0.22	0.22	0.0%	0.22	0.0%
78.02	8.24	8.31	0.8%	8.25	0.1%
78.03	10.68	10.74	0.6%	10.71	0.3%
78.04	11.29	11.33	0.4%	11.32	0.3%
78.05	11.73	11.71	-0.2%	11.76	0.2%
78.06	14.69	15.17	3.3%	14.91	1.5%
78.07	17.96	18.67	4.0%	17.78	-1.0%
79.01	0.68	0.79	16.6%	0.66	-2.2%
79.02	1.37	1.41	3.4%	1.32	-3.5%
79.03	1.75	1.78	2.2%	1.71	-2.1%
80.01	0.42	0.42	0.0%	0.42	0.0%
81.01	0.14	0.15	1.2%	0.15	1.2%
82.01	0.54	0.63	17.2%	0.51	-5.4%
82.02	0.93	0.95	2.0%	0.88	-5.1%
82.03	1.52	1.55	1.6%	1.46	-4.0%
83.01	0.51	0.51	0.7%	0.51	0.7%
84.01	0.36	0.36	0.0%	0.36	0.0%
84.02	0.90	0.90	0.0%	0.90	0.0%
85.01	0.24	0.24	0.0%	0.24	0.0%
86.01	0.02	0.02	0.0%	0.02	0.0%
86.02	0.39	0.42	6.6%	0.42	6.6%
87.01	0.13	0.22	65.3%	0.15	12.9%
88.01	0.73	0.78	7.3%	0.78	7.3%
88.02	1.13	1.18	4.9%	1.18	4.9%
88.03	2.13	2.58	21.2%	2.21	3.7%
88.04	3.06	3.92	28.2%	3.16	3.3%
89.01	0.71	1.76	148.8%	0.69	-3.2%
89.02	2.39	7.07	196.0%	1.95	-18.5%
89.03	3.52	8.84	151.0%	2.87	-18.5%
90.01	0.75	3.07	309.2%	0.54	-27.9%
91.01	0.80	1.59	99.1%	0.54	-32.8%
92.01	0.97	1.77	83.3%	0.58	-40.2%
92.02	1.49	2.34	57.2%	1.06	-28.8%
_junc_116	1.07	1.48	38.8%	1.00	-6.2%
_junc_123	3.49	9.98	186.2%	2.73	-21.8%
_junc_125	56.85	58.84	3.5%	58.57	3.0%

Future Development Results for the 1% AEP Event

	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
_junc_126	1.84	1.85	0.5%	1.85	0.5%
_junc_130	8.29	8.26	-0.4%	8.30	0.0%
_junc_133	2.32	2.45	5.5%	2.20	-5.0%
_junc_135	0.70	0.70	0.0%	0.70	0.0%
_junc_136	0.95	0.95	0.0%	0.95	0.0%
_junc_138	7.97	8.25	3.4%	7.24	-9.1%
_junc_142	3.06	8.12	165.3%	2.47	-19.4%
_junc_150	9.40	9.49	0.9%	9.42	0.2%
_junc_151	2.67	3.07	14.9%	2.68	0.4%
_junc_158	1.03	1.03	0.0%	1.03	0.0%
_junc_162	0.52	0.57	9.4%	0.55	5.0%
_junc_19	1.49	1.49	0.0%	1.49	0.0%
_junc_21	26.25	26.15	-0.4%	26.22	-0.1%
_junc_28	7.10	11.11	56.4%	7.03	-1.0%
_junc_29	2.24	2.58	15.1%	2.24	-0.1%
_junc_30	0.44	0.44	0.0%	0.44	0.0%
_junc_32	0.90	1.63	80.9%	0.85	-6.1%
_junc_37	30.54	30.55	0.0%	30.60	0.2%
_junc_38	9.24	10.01	8.3%	8.56	-7.4%
_junc_40	1.91	2.33	21.7%	2.00	4.6%
_junc_41	4.07	4.07	0.0%	4.07	0.0%
_junc_42	2.48	3.01	21.3%	2.68	8.1%
_junc_44	31.11	31.12	0.0%	31.19	0.3%
_junc_47	4.61	6.36	37.8%	4.72	2.2%
_junc_50	0.34	0.34	0.0%	0.34	0.0%
_junc_59	46.76	47.82	2.3%	47.24	1.0%
_junc_64	2.04	2.13	4.3%	2.13	4.3%
_junc_68	0.82	0.90	10.1%	0.79	-3.5%
_junc_69	48.03	49.11	2.3%	48.69	1.4%
_junc_71	3.11	3.20	3.0%	3.20	3.0%
_junc_74	3.71	3.81	2.7%	3.81	2.7%
_junc_76	49.44	50.33	1.8%	50.12	1.4%
_junc_80	55.12	56.97	3.4%	56.86	3.1%
_junc_81	0.90	1.04	15.9%	0.93	4.2%
_junc_84	58.97	61.03	3.5%	60.60	2.8%
_junc_85	75.76	78.00	3.0%	77.38	2.1%
_junc_86	76.42	78.57	2.8%	78.13	2.2%
_junc_88	14.53	14.99	3.2%	14.75	1.5%
_junc_91	17.82	18.54	4.0%	17.69	-0.8%
US_OHH	50.97	51.90	1.8%	52.84	3.7%
US_Rail	45.24	46.06	1.8%	45.67	0.9%

Future Development Results for the 0.5% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
1.01	1.65	1.65	0.0%	1.65	0.0%
1.02	3.12	3.12	0.0%	3.12	0.0%
1.03	6.56	6.56	0.0%	6.56	0.0%
1.04	13.55	13.55	0.0%	13.55	0.0%
1.05	15.13	15.13	0.0%	15.13	0.0%
1.06	15.42	15.42	0.0%	15.42	0.0%
1.07	19.83	19.83	0.0%	19.83	0.0%
1.08	33.26	33.21	-0.1%	33.17	-0.3%
1.09	34.18	34.14	-0.1%	34.09	-0.3%
1.1	1.45	1.45	0.0%	1.45	0.0%
1.11	10.82	11.70	8.1%	9.94	-8.1%
1.12	10.91	11.78	7.9%	10.10	-7.4%
1.13	10.95	11.81	7.9%	10.14	-7.4%
1.14	51.16	51.89	1.4%	51.12	-0.1%
1.15	53.86	54.57	1.3%	53.80	-0.1%
1.16	55.27	56.25	1.8%	55.19	-0.2%
1.17	56.23	57.30	1.9%	56.12	-0.2%
1.18	56.57	57.58	1.8%	56.59	0.0%
1.19	57.29	57.99	1.2%	57.46	0.3%
1.2	58.33	59.10	1.3%	58.27	-0.1%
1.21	63.52	65.86	3.7%	64.69	1.8%
1.22	65.76	68.27	3.8%	66.92	1.8%
1.23	67.97	70.72	4.0%	69.19	1.8%
1.24	69.27	71.97	3.9%	70.35	1.6%
1.25	89.91	92.52	2.9%	90.58	0.7%
1.26	92.30	94.23	2.1%	93.39	1.2%
2.01	0.50	0.50	0.0%	0.50	0.0%
2.02	1.97	1.97	0.0%	1.97	0.0%
3.01	1.10	1.10	0.0%	1.10	0.0%
3.02	5.22	5.22	0.0%	5.22	0.0%
3.03	6.71	6.71	0.0%	6.71	0.0%
4.01	2.09	2.09	0.0%	2.09	0.0%
5.01	1.58	1.58	0.0%	1.58	0.0%
5.02	3.06	3.06	0.0%	3.06	0.0%
5.03	4.55	4.55	0.0%	4.55	0.0%
6.01	2.77	2.77	0.0%	2.77	0.0%
6.02	3.73	3.73	0.0%	3.73	0.0%
6.03	5.60	5.61	0.0%	5.61	0.0%
6.04	9.40	9.41	0.1%	9.41	0.1%
6.05	11.04	10.99	-0.5%	10.94	-0.9%
6.06	11.68	11.63	-0.4%	11.59	-0.8%
6.07	13.48	13.45	-0.2%	13.42	-0.4%
7.01	1.26	1.26	0.0%	1.26	0.0%
8.01	0.74	0.74	0.0%	0.74	0.0%
8.02	2.90	2.90	0.1%	2.90	0.1%
8.03	3.84	3.85	0.2%	3.84	0.1%
9.01	1.05	1.05	0.0%	1.05	0.0%
10.01	1.00	2.12	112.4%	0.89	-10.3%
11.01	0.96	0.96	0.0%	0.96	0.0%
11.02	2.09	2.09	0.0%	2.09	0.0%
12.01	0.65	0.65	0.0%	0.65	0.0%
13.01	0.54	0.54	0.0%	0.54	0.0%
14.01	2.56	2.56	0.0%	2.56	0.0%

Future Development Results for the 0.5% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
15.01	4.08	4.08	0.0%	4.08	0.0%
15.02	5.39	5.71	5.8%	4.50	-16.6%
15.03	9.42	10.29	9.3%	8.53	-9.4%
15.04	9.51	10.39	9.2%	8.62	-9.3%
16.01	3.94	3.94	0.0%	3.94	0.0%
17.01	0.60	0.82	35.9%	0.59	-1.3%
18.01	0.33	0.33	0.0%	0.33	0.0%
19.01	1.23	1.23	0.0%	1.23	0.0%
19.02	2.04	2.04	0.0%	2.04	0.0%
19.03	3.69	4.76	28.9%	3.50	-5.2%
19.04	4.39	7.46	70.2%	4.33	-1.4%
19.05	4.96	8.73	76.0%	4.75	-4.3%
19.06	8.82	12.70	44.1%	8.61	-2.4%
19.07	11.31	15.52	37.2%	11.26	-0.5%
19.08	11.61	15.79	36.0%	11.59	-0.3%
19.09	2.62	2.77	5.9%	2.67	2.1%
19.1	36.99	37.31	0.9%	36.98	0.0%
19.11	37.77	37.84	0.2%	37.96	0.5%
19.12	38.08	38.15	0.2%	38.27	0.5%
20.01	0.49	0.49	0.0%	0.49	0.0%
21.01	0.54	0.84	56.7%	0.41	-23.4%
22.01	0.65	1.76	170.0%	0.46	-29.1%
23.01	0.25	0.25	0.0%	0.25	0.0%
24.01	0.52	0.52	0.0%	0.52	0.0%
24.02	0.62	0.62	0.0%	0.62	0.0%
24.03	1.20	2.07	72.1%	1.13	-5.6%
24.04	2.90	3.34	15.2%	2.91	0.3%
24.05	3.70	4.15	12.0%	3.67	-1.0%
25.01	0.51	1.31	158.9%	0.41	-19.6%
26.01	0.63	0.63	0.0%	0.63	0.0%
26.02	1.48	1.48	0.0%	1.48	0.0%
27.01	0.59	0.59	0.0%	0.59	0.0%
28.01	0.52	0.52	0.0%	0.52	0.0%
29.01	0.20	0.20	0.0%	0.20	0.0%
30.01	0.93	0.94	0.8%	0.94	0.8%
31.01	0.49	0.49	0.0%	0.49	0.0%
31.02	1.38	1.38	0.0%	1.38	0.0%
31.03	2.11	3.06	44.7%	2.32	9.7%
32.01	0.79	0.79	0.0%	0.79	0.0%
33.01	0.62	0.62	0.0%	0.62	0.0%
34.01	0.60	1.28	113.7%	0.59	-1.1%
35.01	0.29	0.29	0.0%	0.29	0.0%
35.02	0.93	0.93	0.0%	0.93	0.0%
35.03	1.45	1.45	0.0%	1.45	0.0%
35.04	1.85	1.85	0.0%	1.85	0.0%
35.05	1.91	1.91	0.0%	1.91	0.0%
35.06	1.56	1.56	0.0%	1.56	0.0%
36.01	0.55	0.55	0.0%	0.55	0.0%
37.01	0.22	0.22	0.0%	0.22	0.0%
38.01	0.32	0.32	0.0%	0.32	0.0%
39.01	1.02	2.17	111.8%	1.04	1.5%
40.01	0.31	0.31	0.0%	0.31	0.0%
40.02	0.60	0.62	3.4%	0.62	3.4%

Future Development Results for the 0.5% AEP Event

	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
40.03	1.66	2.01	21.3%	1.54	-7.3%
40.04	2.44	2.83	16.2%	2.19	-10.1%
40.05	3.27	4.49	37.5%	3.23	-1.2%
40.06	3.64	4.97	36.3%	3.58	-1.8%
41.01	0.63	0.76	20.5%	0.48	-24.5%
42.01	0.79	1.01	28.0%	0.63	-20.6%
43.01	0.22	0.27	20.9%	0.22	-2.1%
44.01	0.44	3.00	576.0%	0.35	-21.2%
44.02	0.81	2.22	173.2%	0.72	-11.3%
44.03	1.21	2.30	89.7%	1.12	-7.6%
44.04	1.92	2.54	32.1%	1.86	-2.9%
45.01	0.25	0.45	80.4%	0.23	-8.6%
46.01	0.45	0.45	0.0%	0.45	0.0%
47.01	0.30	0.30	0.0%	0.30	0.0%
48.01	0.54	0.54	0.0%	0.54	0.0%
48.02	1.33	1.33	0.3%	1.33	0.3%
49.01	0.73	0.73	0.0%	0.73	0.0%
50.01	0.91	0.91	0.0%	0.91	0.0%
51.01	0.26	0.26	0.9%	0.26	0.9%
52.01	1.07	2.86	167.0%	1.05	-2.4%
52.02	1.94	3.92	101.8%	1.68	-13.6%
53.01	0.82	0.82	0.0%	0.82	0.0%
53.02	2.46	2.46	0.0%	2.46	0.0%
53.03	3.22	3.22	0.0%	3.22	0.0%
54.01	1.16	1.16	0.0%	1.16	0.0%
55.01	0.97	0.97	0.0%	0.97	0.0%
56.01	0.81	0.81	0.0%	0.81	0.0%
57.01	1.12	2.14	91.0%	0.63	-44.1%
57.02	1.50	2.52	67.9%	0.82	-45.3%
57.03	1.78	2.80	57.5%	0.96	-46.0%
58.01	1.78	1.78	0.0%	1.78	0.0%
58.02	2.17	2.17	0.0%	2.17	0.0%
58.03	2.69	2.69	0.0%	2.69	0.0%
58.04	5.11	5.11	0.0%	5.11	0.0%
58.05	7.34	7.34	0.0%	7.34	0.0%
58.06	7.37	7.37	0.0%	7.37	0.0%
58.07	10.60	10.68	0.7%	10.55	-0.5%
58.08	1.54	1.57	1.9%	1.57	1.9%
58.09	2.93	3.03	3.5%	2.87	-1.9%
58.1	3.68	3.78	2.7%	3.59	-2.4%
58.11	4.26	4.42	3.8%	4.22	-1.0%
59.01	1.28	1.28	0.0%	1.28	0.0%
59.02	2.14	2.14	0.0%	2.14	0.0%
60.01	0.85	0.85	0.0%	0.85	0.0%
60.02	2.03	2.03	0.0%	2.03	0.0%
61.01	0.52	0.53	0.9%	0.53	0.9%
61.02	1.69	2.01	19.3%	1.59	-5.6%
61.03	2.87	2.99	4.2%	2.76	-3.8%
61.04	3.75	3.82	1.8%	3.64	-2.9%
62.01	0.79	1.37	73.1%	0.69	-12.7%
63.01	0.48	0.48	0.7%	0.48	0.7%
64.01	0.19	0.32	67.4%	0.17	-12.1%
65.01	0.38	0.38	0.0%	0.38	0.0%

Future Development Results for the 0.5% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
65.02	0.64	0.64	0.0%	0.64	0.0%
66.01	0.05	0.05	0.0%	0.05	0.0%
67.01	0.74	0.93	24.8%	0.60	-19.0%
68.01	0.38	0.38	0.0%	0.38	0.0%
69.01	0.41	0.41	0.0%	0.41	0.0%
69.02	0.64	0.64	0.0%	0.64	0.0%
70.01	0.61	0.92	51.0%	0.55	-10.0%
71.01	3.39	9.13	169.6%	2.22	-34.3%
71.02	4.08	11.55	183.2%	3.20	-21.6%
72.01	1.00	2.33	133.7%	0.85	-14.6%
73.01	0.35	0.67	93.9%	0.34	-1.2%
73.02	0.79	1.05	33.4%	0.80	1.5%
73.03	1.56	1.63	4.1%	1.59	1.7%
74.01	0.27	0.27	1.0%	0.27	1.0%
75.01	0.17	0.25	50.7%	0.15	-9.4%
76.01	1.36	1.36	0.1%	1.36	0.1%
77.01	1.59	1.66	4.7%	1.66	4.7%
78.01	0.27	0.27	0.0%	0.27	0.0%
78.02	9.80	9.87	0.7%	9.74	-0.6%
78.03	12.63	12.69	0.5%	12.61	-0.1%
78.04	13.34	13.38	0.3%	13.32	-0.1%
78.05	13.85	13.87	0.1%	13.88	0.2%
78.06	17.36	17.95	3.4%	17.45	0.5%
78.07	21.30	22.02	3.4%	20.70	-2.8%
79.01	0.81	0.90	10.9%	0.77	-4.2%
79.02	1.64	1.71	4.5%	1.62	-1.2%
79.03	2.06	2.11	2.5%	2.06	0.0%
80.01	0.49	0.49	0.0%	0.49	0.0%
81.01	0.19	0.20	0.9%	0.20	0.9%
82.01	0.72	0.73	1.4%	0.62	-14.1%
82.02	1.13	1.14	0.9%	1.05	-7.1%
82.03	1.84	1.85	0.8%	1.75	-4.6%
83.01	0.61	0.61	0.8%	0.61	0.8%
84.01	0.43	0.43	0.0%	0.43	0.0%
84.02	1.03	1.03	0.0%	1.03	0.0%
85.01	0.30	0.30	0.0%	0.30	0.0%
86.01	0.03	0.03	0.0%	0.03	0.0%
86.02	0.45	0.48	6.9%	0.48	6.9%
87.01	0.16	0.24	56.5%	0.13	-18.1%
88.01	0.83	0.89	7.3%	0.89	7.3%
88.02	1.31	1.36	3.6%	1.36	3.6%
88.03	2.48	2.97	19.5%	2.57	3.4%
88.04	3.58	4.48	25.0%	3.55	-0.8%
89.01	0.81	2.03	148.7%	0.85	4.4%
89.02	2.80	8.11	189.8%	2.24	-19.8%
89.03	4.12	10.14	145.9%	3.27	-20.8%
90.01	0.87	3.54	304.8%	0.62	-29.4%
91.01	0.91	1.81	98.1%	0.61	-33.8%
92.01	1.12	2.01	79.5%	0.69	-38.4%
92.02	1.71	2.66	55.5%	1.22	-28.7%
_junc_116	1.31	1.69	28.7%	1.22	-7.3%
_junc_123	3.99	11.46	187.4%	3.08	-22.8%
_junc_125	66.71	69.38	4.0%	67.91	1.8%

Future Development Results for the 0.5% AEP Event					
	Existing Development Conditions	Future Development Conditions			
Subcatchment ID	Existing Discharge (m^3/s)	Discharge without OSD (m^3/s)	Difference to Existing (%)	Discharge with OSD (m^3/s)	Difference to Existing (%)
_junc_126	2.22	2.23	0.5%	2.23	0.5%
_junc_130	10.39	10.34	-0.5%	10.30	-0.9%
_junc_133	2.78	2.84	2.1%	2.66	-4.2%
_junc_135	0.80	0.80	0.0%	0.80	0.0%
_junc_136	1.09	1.09	0.0%	1.09	0.0%
_junc_138	9.09	9.40	3.5%	8.19	-9.8%
_junc_142	3.57	9.30	160.2%	2.82	-21.2%
_junc_150	11.15	11.23	0.7%	11.11	-0.4%
_junc_151	3.08	3.51	14.3%	3.08	0.3%
_junc_158	1.27	1.27	0.0%	1.27	0.0%
_junc_162	0.66	0.66	-0.1%	0.63	-4.0%
_junc_19	1.70	1.70	0.0%	1.70	0.0%
_junc_21	32.90	32.86	-0.1%	32.81	-0.3%
_junc_28	8.53	12.69	48.9%	8.32	-2.4%
_junc_29	2.57	2.96	15.3%	2.59	0.9%
_junc_30	0.52	0.52	0.0%	0.52	0.0%
_junc_32	1.05	1.87	77.2%	0.97	-7.8%
_junc_37	37.63	37.71	0.2%	37.83	0.5%
_junc_38	10.55	11.43	8.3%	9.69	-8.2%
_junc_40	2.21	2.65	20.0%	1.93	-12.7%
_junc_41	4.72	4.72	0.0%	4.72	0.0%
_junc_42	2.97	3.44	15.6%	2.82	-5.3%
_junc_44	38.30	38.37	0.2%	38.49	0.5%
_junc_47	5.47	7.27	33.0%	5.39	-1.4%
_junc_50	0.41	0.41	0.0%	0.41	0.0%
_junc_59	55.16	56.14	1.8%	55.08	-0.2%
_junc_64	2.19	2.28	4.2%	2.11	-3.8%
_junc_68	1.00	1.08	7.4%	0.95	-5.7%
_junc_69	56.63	57.64	1.8%	56.65	0.0%
_junc_71	3.48	3.58	2.9%	3.38	-2.6%
_junc_74	4.14	4.31	4.0%	4.14	-0.1%
_junc_76	58.26	59.03	1.3%	58.20	-0.1%
_junc_80	64.64	67.11	3.8%	65.79	1.8%
_junc_81	1.06	1.19	12.5%	1.07	1.4%
_junc_84	69.27	71.96	3.9%	70.35	1.6%
_junc_85	89.85	92.47	2.9%	90.51	0.7%
_junc_86	90.61	93.14	2.8%	91.43	0.9%
_junc_88	17.17	17.73	3.3%	17.27	0.6%
_junc_91	21.15	21.87	3.4%	20.57	-2.8%
US_OHH	60.02	61.41	2.3%	61.23	2.0%
US_Rail	53.35	54.09	1.4%	53.31	-0.1%

Appendix F

Cost Estimates

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Modifications to the Oldfield Road detention basin outlet configuration (FM1)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$7,638**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	275	16.50	$4,538
2		**EARTHWORKS AND SAFETY PROVISIONS**				**$40,856**
	2.01	Excavate ground over site to reduce levels for Basin invert and deposit in heaps within 500m - light soil	m3	572	21.9	$12,527
	2.02	Labour forming sloping edge to Embankment of Basin	m	275	2.65	$729
	2.03	Construction of weir using concrete/sandstone blocks (Keystone system retaining wall - 1 -3m high)	m2	80	345	$27,600
3		**DRAINAGE INFRASTRUCTURE**				**$19,835**
	3.01	1.2m RCP (Class 2) Basin High Flow Outlets	m	5	807	$4,035
	3.02	Trash Rack and inlet/outlet headwall supply and installed	each	2	6,900	$13,800
	3.03	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000.00	$2,000
4		**LANDSCAPING AND POST TREATMENT**				**$304**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	950	0.32	$304
					SUBTOTAL	**$68,632**
5		**DETAILED DESIGN**				**$8,000**
	5.01	Detailed design plans (Allowance)				$8,000
6		**PROJECT MANAGEMENT**				**$6,863**
	6.01	Supervision, Project Management etc (10%)				$6,863
7		**OTHER CONTINGENCIES**				**$20,590**
	7.01	General (30%)				$20,590
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$100,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Detention basin near railway line and Braemar Avenue (FM2)	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

Reg. Index: 1

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$46,845**
1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
1.02	QA & ITP	Lump sum	1	500	$500
1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
1.04	OHS&R Plan	Lump sum	1	800	$800
1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	530	16.50	$8,745
1.06	Traffic/Pedestrian Management Plan, diversions, traffic controllers	Lump sum	1	30,000	$30,000
1.07	Land/Easement Acquisition	Lump sum	1	5,000	$5,000
2	**EARTHWORKS AND SAFETY PROVISIONS**				**$100,779**
2.01	Excavate roadway, base and ground above existing pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench >2m deep in soft rock)	m3	73	219	$16,083
2.02	Fill for elevating Braemar Avenue - consolidated (General Filling) and carted to site (Council supplied)	m3	2895	19.00	$55,005
2.03	Fill for Embankment adjacent Railway line - consolidated (General Filling) and carted to site (Council supplied)	m3	229	19.00	$4,351
2.04	Labour forming sloping edge to Braemar Ave/Railway Embankment into Basin	m	630	2.65	$1,670
2.05	Concrete paved spillway across top of embankment to Braemar Ave roadway surface	m	50	65.40	$3,270
2.06	Guardrail (galvanised steel, double corrugated guard rail with bolts and splice plates) along roadway edge adjacent steep basin sloping edge	m	170	120.00	$20,400
3	**DRAINAGE INFRASTRUCTURE**				**$23,786**
3.01	Dispose of extracted existing pipe (recyclable material)	m	18	20	$360
3.02	New basin outlet - 1.2m RCP (Class 2) Culvert under Braemar Road	m	18	807	$14,526
3.03	Trash Rack and inlet/outlet headwall supply and installed	each	1	6,900	$6,900
3.04	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000	$2,000
4	**ROADWORKS**				**$92,500**
4.01	Install new pavement (suburban road with in-situ concrete kerbs - 6m wide) along Brarmar Ave	m	250	370.00	$92,500
5	**LANDSCAPING AND POST TREATMENT**				**$768**
5.01	Sprayed Grass Seed Compound Hydro Mulch	m2	2400	0.32	$768
				SUBTOTAL	**$264,678**
6	**DETAILED DESIGN**				**$7,000**
6.01	Detailed design plans (Allowance)				$7,000
7	**PROJECT MANAGEMENT**				**$26,468**
7.01	Supervision, Project Management etc (10%)				$26,468
8	**OTHER CONTINGENCIES**				**$26,468**
8.01	General (10%)				$26,468
				TOTAL at 7% NPV (Rounded to nearest $10,000)	**$320,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Detention basin upstream of Bong Bong Road (FM3)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$40,278**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	132	16.50	$2,178
	1.06	Traffic/Pedestrian Management Plan, diversions, traffic controllers	Lump sum	1	30,000	$30,000
	1.07	Land/Easement Acquisition	Lump sum	1	5,000	$5,000
2		**EARTHWORKS AND SAFETY PROVISIONS**				**$79,651**
	2.02	Excavate ground for Basin invert and heap to form basin embankment (excavate over site to reduce levels in light soil)	m3	3608	21.9	$79,015
	2.02	Labour forming sloping edge to Embankment of Basin	m	240	2.65	$636
3		**DRAINAGE INFRASTRUCTURE**				**$39,305**
	3.01	0.6m RCP (Class 2) Basin Low Flow Outlet	m	9	231	$2,079
	3.02	1.2m RCP (Class 2) Basin High Flow Outlets	m	18	807	$14,526
	3.03	Trash Rack and inlet/outlet headwall supply and installed	each	3	6,900	$20,700
	3.04	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000.00	$2,000
4		**LANDSCAPING AND POST TREATMENT**				**$1,952**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	6100	0.32	$1,952
					SUBTOTAL	**$161,186**
5		**PROJECT MANAGEMENT**				**$16,119**
	5.01	Supervision, Project Management etc (10%)				$16,119
6		**OTHER CONTINGENCIES**				**$16,119**
	6.01	General (10%)				$16,119
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$190,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Create new detention basin downstream of Renwick (FM4)	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$5,988**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	175	16.50	$2,888
2		**EARTHWORKS AND SAFETY PROVISIONS**				**$20,061**
	2.01	Excavate channel within proosed storage area of basin (excavate to lower levels and deposit in heaps within 500m - light soil)	m3	389	21.90	$8,519
	2.02	Placement, forming and compaction of edge of basin embankment to required height (using excavated fill)	m3	231	48.20	$11,134
	2.03	Labour forming sloping edge to Embankment of Basin	m	154	2.65	$408
3		**DRAINAGE INFRASTRUCTURE**				**$21,575**
	3.01	0.6m RCP (Class 2) Basin Low Flow Outlet	m	25	231	$5,775
	3.02	Trash Rack and inlet/outlet headwall supply and installed	each	2	6,900	$13,800
	3.03	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000	$2,000
4		**LANDSCAPING AND POST TREATMENT**				**$640**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	2000	0.32	$640
					SUBTOTAL	**$48,264**
5		**DETAILED DESIGN**				**$7,000**
	5.01	Detailed design plans (Allowance)				$7,000
6		**PROJECT MANAGEMENT**				**$4,826**
	6.01	Supervision, Project Management etc (10%)				$4,826
7		**OTHER CONTINGENCIES**				**$4,826**
	7.01	General (10%)				$4,826
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$60,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Upgrade stormwater system between Biggera Street and Old Hume Highway (FM5)	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,892**
	1.01	Site Establishment (allowance only)	Lump sum	1	5,000	$5,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around distrurbed portion of site (non-trench)	m	48	16.50	$792
	1.06	Traffic/Pedestrian Management Plan, diversions, traffic controllers	Lump sum	1	4,000	$4,000
2		**EARTHWORKS**				**$27,798**
	2.01	Excavate ground above existing pipe (including backfilling/compaction) (trench of 1.2 x new pipe width) (Excavate trench 1-2m deep in light soil)	m3	450	57.4	$25,830
	2.02	Form roadside swale above new stormwater pipes	m3	49	40	$1,968
3		**DRAINAGE INFRASTRUCTURE**				**$84,309**
	3.01	Dispose of extracted existing pipe (recyclable material)	m	170	20	$3,400
	3.02	0.6m RCP (Class 2)	m	71	231	$16,401
	3.03	0.75m RCP (Class 2)	m	38	386	$14,668
	3.04	0.825m RCP (Class 2)	m	25	510	$12,750
	3.05	0.9m RCP (Class 2)	m	37	550	$20,350
	3.06	Grated Inlet (6.5m2) - square precast concrete pit and Class D cast iron gully grating	No.	3	4,464	$13,392
	3.07	Kerb inlet with grate & 3.8m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	1	3,348	$3,348
4		**LANDSCAPING AND POST TREATMENT**				**$128**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	400	0.32	$128
					SUBTOTAL	**$124,127**
5		**DETAILED DESIGN**				**$5,000**
	5.01	Detailed design plans (Allowance)				$5,000
6		**PROJECT MANAGEMENT**				**$12,413**
	6.01	Supervision, Project Management etc (10%)				$12,413
7		**OTHER CONTINGENCIES**				**$12,413**
	7.01	General (10%)				$12,413
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$150,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Install kerb & guttering and new stormwater system in Biggera Street and along Old Hume Highway (FM6)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$25,450**
	1.01	Site Establishment (allowance only)	Lump sum	1	4,000	$4,000
	1.02	QA & ITP	Lump sum	1	2,000	$2,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	2,000	$2,000
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site (100m at a time, reuse for next section)	m	100	16.50	$1,650
	1.06	Traffic/Pedestrian Management Plan, diversions, traffic controllers	Lump sum	1	15,000	$15,000
2		**EARTHWORKS**				**$172,350**
	2.01	Excavate ground along alignment of new stormwater system (including backfilling/compaction) (trench of 1.2 x new pipe width) (Excavate trench 1-2m deep in soil)	m3	2730	57.4	$156,716
	2.02	Form area behind kerb (excavation in light soil)	m3	310	50.40	$15,634
3		**DRAINAGE INFRASTRUCTURE**				**$855,874**
	3.01	0.375m RCP (Class 2)	m	76	142	$10,683
	3.02	0.45m RCP (Class 2)	m	99	192	$19,016
	3.03	0.525m RCP (Class 2)	m	263	205	$53,813
	3.04	0.6m RCP (Class 2)	m	151	231	$34,881
	3.05	0.75m RCP (Class 2)	m	58	386	$22,388
	3.06	0.9m RCP (Class 2)	m	100	550	$55,165
	3.07	1.2m RCP (Class 2)	m	18	807	$14,526
	3.08	1.35m RCP (Class 2)	m	112	1,056	$118,272
	3.09	1.5m RCP (Class 2)	m	220	1,200	$264,000
	3.1	1.65m RCP (Class 2)	m	115	1,436	$165,140
	3.11	Kerb inlet with grate & 2.4m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating	No.	41	2,390	$97,990
4		**ROADWORKS**				**$97,456**
	4.01	Install Kerb and Gutter - cast in-situ concrete 150x150mm kerb and gutter on Biggera St and along the Old Hume Highway	m	1177	82.80	$97,456
5		**LANDSCAPING AND POST TREATMENT**				**$809**
	5.01	Sprayed Grass Seed Compound Hydro Mulch	m2	2528	0.32	$809
					SUBTOTAL	**$1,151,938**
6		**DETAILED DESIGN**				**$20,000**
	6.01	Detailed design plans (Allowance)				$20,000
7		**PROJECT MANAGEMENT**				**$115,194**
	7.01	Supervision, Project Management etc (10%)				$115,194
8		**OTHER CONTINGENCIES**				**$115,194**
	8.01	General (10%)				$115,194
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$1,400,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Blockage of railway culvert adjacent to Biggera Street (FM7)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$300**
1.01	Site Establishment (allowance only)	Lump sum	1	100	$100
1.02	QA & ITP	Lump sum	1	200	$200
2	**DRAINAGE INFRASTRUCTURE**				**$400**
2.01	Plate over culvert to constrict flow to west of railway embankment	Lump sum	1	400	$400
				SUBTOTAL	**$700**
3	**PROJECT MANAGEMENT**				**$300**
3.01	Supervision, Project Management etc				$300
4	**OTHER CONTINGENCIES**				**$400**
4.01	General				$400
		TOTAL at 7% NPV (Rounded to nearest $1,000)			**$1,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Elevate railway embankment near Biggera Street (FM8)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$5,575**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	150	16.50	$2,475
2		**EARTHWORKS AND BULK VEGETATION CLEARING/MULCHING**				**$13,341**
	2.01	Clear of vegetation and cart away (Medium vegetation)	m2	980	0.53	$519
	2.02	Place and compact Fill adjacent railway embankment to create elevated area	m3	266	48.20	$12,821
3		**DRAINAGE INFRASTRUCTURE**				**$400**
	3.01	Plate over culvert to constrict flow to west of railway embankment	Lump sum	1	400	$400
4		**LANDSCAPING AND POST TREATMENT**				**$314**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	980	0.32	$314
5		**BRAEMAR AVENUE BASIN WORKS** (Total without contingencies)	Lump sum	1	291,146	**$291,146**
					SUBTOTAL	**$310,775**
6		**DETAILED DESIGN**				**$2,000**
	6.01	Detailed design plans (Allowance)				$2,000
7		**PROJECT MANAGEMENT**				**$31,077**
	7.01	Supervision, Project Management etc (10%)				$31,077
8		**OTHER CONTINGENCIES**				**$31,077**
	8.01	General (10%)				$31,077
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$370,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Enlarge drainage channels adjacent industrial area (FM9)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$15,070**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Detailed Site Investigation (geotechnical and site specific investigations)	Lump sum	1	10,000	$10,000
	1.06	Erosion and Sediment control within enlarged channels - Jute Mesh (temporary use until grass takes hold - biodegradable)	m2	2463	0.80	$1,970
2		**EARTHWORKS AND BULK VEGETATION CLEARING/MULCHING**				**$11,877**
	2.01	Clear vegetation and cart away (Medium vegetation - not including grass)	m2	1200	0.53	$636
	2.02	Excavate channels to enlarge (excavate over site to reduce levels and deposit in heaps within 500m - light soil)	m3	267	21.90	$5,847
	2.03	Purchase of appropriate fill for embankment works (sourced locally)	m3	267	12.00	$3,204
	2.04	Placement, forming and compaction of edge of banks to required height (using appropriate fill)	m3	267	8.20	$2,189
3		**LANDSCAPING AND POST TREATMENT**				**$960**
	3.01	Sprayed Grass Seed Compound Hydro Mulch (Enlarged Channels and Edge of Bank)	m2	3000	0.32	$960
					SUBTOTAL	**$27,907**
4		**DETAILED DESIGN PLANS**				**$10,000**
	4.01	Detailed design plans (Allowance)				$10,000
5		**PROJECT MANAGEMENT**				**$8,372**
	5.01	Supervision, Project Management etc (30%)				$8,372
6		**OTHER CONTINGENCIES**				**$5,581**
	6.01	General (20%)				$5,581
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$50,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Create formalised channel on western side of railway embankment (FM10)	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$13,420**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control adjacent watercourses - Jute Mesh (temporary use until grass takes hold - biodegradable)	m2	12900	0.80	$10,320
2		**EARTHWORKS AND BULK VEGETATION CLEARING/MULCHING**				**$62,025**
	2.01	Clear of vegetation and cart away (Medium vegetation)	m2	12900	0.53	$6,837
	2.02	Excavate channels to enlarge (excavate over site to reduce levels and deposit in heaps within 500m - light soil)	m3	2520	21.90	$55,188
3		**DRAINAGE INFRASTRUCTURE**				**$400**
	3.01	Plate over culvert to constrict flow to the new channel	Lump sum	1	400	$400
4		**LANDSCAPING AND POST TREATMENT**				**$4,128**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	12900	0.32	$4,128
5		**BRAEMAR AVENUE BASIN WORKS** (Total without contingencies)	Lump sum	1	291,146	**$291,146**
					SUBTOTAL	**$371,119**
6		**DETAILED DESIGN**				**$9,000**
	6.01	Detailed design plans (Allowance)				$9,000
7		**PROJECT MANAGEMENT**				**$37,112**
	7.01	Supervision, Project Management etc (10%)				$37,112
8		**OTHER CONTINGENCIES**				**$37,112**
	8.01	General (10%)				$37,112
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$450,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Enlarge Old Hume Highway roadside swales (FM11)	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,854**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
	1.04	OHS&R Plan	Lump sum	1	800	$800
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	76	16.50	$1,254
	1.06	Traffic/Pedestrian Management Plan, diversions, traffic controllers	Lump sum	1	5,000	$5,000
2		**EARTHWORKS**				**#REF!**
	2.01	Excavate roadway, base and ground above existing pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench 1-2m deep in soft rock)	m3	234	219	$51,246
	2.02	Clear of vegetation and cart away (Medium vegetation - not including grass)	m2	200	0.53	$106
	2.03	Excavate roadside swale to enlarge (excavate trenches not exceeding 1m deep and deposit in heaps within 500m - light soil)	m3	165	#REF!	#REF!
3		**DRAINAGE INFRASTRUCTURE**				**#REF!**
	3.01	Dispose of extracted existing pipe (recyclable material)	m	104	20	$2,080
	3.02	0.9m RCP (Class 2)	m	16	550	$8,800
	3.03	1.05m RCP (Class 2)	m	89	#REF!	#REF!
	3.04	Kerb inlet with grate & 4.2m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	2	4,464	$8,928
4		**LANDSCAPING AND POST TREATMENT**				**$64**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	200	0.32	$64
					SUBTOTAL	**#REF!**
5		**DETAILED DESIGN**				**$2,000**
	5.01	Detailed design plans (Allowance)				$2,000
6		**PROJECT MANAGEMENT**				**#REF!**
	6.01	Supervision, Project Management etc (10%)				#REF!
7		**OTHER CONTINGENCIES**				**#REF!**
	7.01	General (10%)				#REF!
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**#REF!**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Channelisation through properties on Inkerman Rd and Scarlet St (FM12)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$6,150**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	QA & ITP	Lump sum	1	500	$500
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	2,000	$2,000
	1.04	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site (reused)	m	100	16.50	$1,650
2		**EARTHWORKS AND BULK VEGETATION CLEARING/MULCHING**				**$229,114**
	2.01	Clear of vegetation and cart away (Medium vegetation)	m2	36195	0.53	$19,183
	2.02	Excavate to reduce levels and deposit, spread and level within 1km in light soil	m3	24130	8.70	$209,931
4		**LANDSCAPING AND POST TREATMENT**				**$11,582**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	36195	0.32	$11,582
					SUBTOTAL	**$246,847**
6		**DETAILED DESIGN**				**$2,000**
	6.01	Detailed design plans (Allowance)				$2,000
7		**PROJECT MANAGEMENT**				**$24,685**
	7.01	Supervision, Project Management etc (10%)				$24,685
8		**OTHER CONTINGENCIES**				**$24,685**
	8.01	General (10%)				$24,685
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$300,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Raising Inkerman Rd and Scarlet St (RM7)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

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

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Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$20,278**
1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
1.02	QA & ITP	Lump sum	1	500	$500
1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	800	$800
1.04	OHS&R Plan	Lump sum	1	800	$800
1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	132	16.50	$2,178
1.06	Traffic/Pedestrian Management Plan, diversions, traffic controllers	Lump sum	1	15,000	$15,000
2	**EARTHWORKS**				**$80,131**
2.01	Excavate roadway along alignment of new drainage infrastructure (including backfilling/compaction) (trench of 1.2 x new pipe width x average 1.5m deep) (Excavate trench 1-2m deep in soil)	m3	1396	57.4	$80,131
3	**ROADWORKS**				**$661,030**
3.01	Take up existing roadway surface	m2	7392	26	$192,192
3.02	Fill to reprofile roadway (crushed rock/blue metal) (300mm already accounted for in basecourse)	m3	594	107	$63,756
3.03	Install new pavement (40mm thick hot mix bitumen over new 300mm crushed rock/blue metal basecourse)	m2	7392	55	$405,082
4	**DRAINAGE INFRASTRUCTURE**				**$762,013**
4.01	0.45m RCP (Class 2)	m	18	192	$3,370
4.02	Headwall for 0.45m RCP	each	4	555	$2,220
4.03	0.525m RCP (Class 2)	m	43	205	$8,856
4.04	Headwall for 0.525m RCP	each	8	600	$4,800
4.05	0.6m RCP (Class 2)	m	55	231	$12,590
4.06	Headwall for 0.6m RCP	each	10	801	$8,010
4.07	0.75m RCP (Class 2)	m	41	386	$15,749
4.08	Headwall for 0.75m RCP	each	8	1,315	$10,520
4.09	0.6m x 0.4m RCBC (Class 2)	m	177	457	$80,752
4.1	Headwall for 0.6m x 0.4m RCBC	each	24	1,315	$31,560
4.11	0.8m x 0.3m RCBC (Class 2)	m	20	457	$9,323
4.12	Headwall for 0.8m x 0.3m RCBC	each	2	1,315	$2,630
4.13	1.2m x 1.2m RCBC (Class 2)	m	13	1,420	$17,750
4.14	Headwall for 1.2m x 1.2m RCBC	each	2	1,800	$3,600
4.15	2.4m x 1.2m RCBC (Class 2)	m	227	2130	$483,084
4.16	Headwall for 2.4m x 1.2m	each	28	2400	$67,200
				SUBTOTAL	**$1,523,452**
5	**PROJECT MANAGEMENT**				**$152,345**
5.01	Supervision, Project Management etc (10%)				$152,345
6	**OTHER CONTINGENCIES**				**$152,345**
6.01	General (10%)				$152,345
			TOTAL at 7% NPV (Rounded to nearest $10,000)		**$1,830,000**

Appendix G

Public Exhibition Comments & Responses

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
1 & 2	Disappointed no recommendation for remediation of flooding across Inkerman Rd and Scarlet St. Believes that Renwick subdivision, raising of Scarlet St and raising of railway service road have caused the problems. Flow along creek obstructed by Scarlet St and culverts are under-sized. Channel downstream of Scarlet St is also too small. Water also ponds where raised railway service road acts as a "dam". Study does not offer practical solutions and places burden on landholders. Would like discussion of options in an open forum before any works are implemented.	An additional option was investigated involving increasing the capacity of the culvert crossing Scarlet St (ie tripling structure size) and widening the main channel upstream and downstream of Scarlet St (the channel modifications extended ~130m downstream of Scarlet Street. The hydraulic assessment indicated flood levels reduce by approximately 0.05 metres in the immediate vicinity of Scarlet Street, but the benefits are marginal further away from the upgraded culvert. The outcomes of a sensitivity analysis completed for the flood study indicates that flood levels in this area could vary by well in excess of 0.05 metres as a result of culvert blockage indicating the hydraulic benefits are negligible. An economic assessment indicates that there would be some small reductions in damages in the immediate vicinity of Scarlet Street (i.e., less than $10,000 over the next 50 years). However, this reduction would not be sufficient to offset the implementation costs of this option .The benefit cost ratio of this option would be so low, that when compared to all other applications state wide for OEH funding, it would be unlikely to ever attract a grant offer. Council considers such projects through its annual budget process. Upgrading culverts and roads are assessed and prioritised based on several factors, such as the reduction of flooding. Due to limited resources, and the breadth of current priorities in the capital works program, it is unlikely that this project would be included in the capital works program. Specific assessment of the impacts of the Renwick development was completed as part of a separate investigation by Catchment Simulation Solutions in October 2017. This study predicted peak flows and flood levels will: • increase by <50 mm for more frequent, minor storm events (5 and 10 year events) • decrease by 50 - 100mm for major storm events (100-year events). The slight increases observed for the 5 and 10 year events are within the allowable variations of the model (ie +/-150mm) and do not flood more properties or cause any worsening of the flooding situation.

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
3	Believe waterway has changed over time, significant silt and debris in creek from Renwick. Does not believe the flood damages to be correct, stating it's based on 2007 numbers, and external damage is under represented for their situation. Would like bespoke calculation for their lots (Inkerman Rd, Scarlet St). Believe inadequacy of Renwick stormwater management. Impediment to flow at Scarlet St based on 2 separate actions of Council - sewer riser under the railway bridge and sealing/raising of Scarlet St.	The floodplain risk management study is intended to examine flooding associated with historical, contemporary and future conditions to allow selection of the optimum mix of measures which will allow council to manage flood related risk to the existing and future communities. So while the process analyses the potential impacts of changes to catchment conditions over time, the primary focus is on the magnitude of impacts and the efficacy of management options in developed areas which exhibit risk.. The models used in the analyses are calibrated to reproduce historical flood behaviour when sufficient data on historical rainfall, catchment conditions and flood impacts is available. The models are then adjusted to reflect contemporary and potential future conditions for the design flood analyses. This allows council to determine the optimum mix of measures to deal with contemporary and potential future flood risk into the future. In this regard council notes that, historical flood photos show that properties downstream of Renwick used to flood before the Renwick development was commenced. It was also shown in the Bewsher Study of December 2006. The flood damage calculations are based on OEH guidelines and are adjusted to reflect current day dollars. The damage calculation approach is standardised to allow floodplain risk management projects from across the state to be compared. However, it is acknowledged that this may underestimate damages on larger, rural residential properties. Therefore, we completed a damages "sensitivity assessment" to provide a more detailed assessment of damages across the Scarlet Street and Inkerman Road properties. This included damages to sheds as well as all fences. The assessment determined that the existing flood damages would increase from $261,000 to just over $400,000 over a 50 year period. Although this is a notable increase in flood damages estimates, the benefit cost ratio is still well below the target of 1.0 which is required to attract OEH funding. For example, • the benefit cost ratio for the “combined basins” options (ie Options FM1, FM3 and FM4) is predicted to increase from 0.01 to 0.07 • the benefit cost ratio for the channel enlargement between Inkerman Road and Scarlet Street (ie Option FM12) increased but was still less than 0.1 .

<table>
<tr><th>SUBMISSION</th><th>SUBMISSION COMMENTS</th><th>RESPONSE TO SUBMISSION</th></tr>
<tr><td></td><td></td><td>Erosion and deposition of silt and debris within the creeks cannot be explicitly represented in the flood model (creek details are based on survey of the creek at the time the study was prepared). However, these comments will be acknowledged in the final report.

The sewer main under the railway bridge was installed in 2001. This gravity main is under ground and does not contribute to flooding issues.

Regarding stormwater flow at Scarlet St, an additional option was investigated involving increasing the capacity of the culvert crossing (ie tripling structure size) and widening the main channel upstream and downstream of Scarlet St (the channel modifications extended ~130m downstream of Scarlet Street.

The hydraulic assessment indicated flood levels reduce by approximately 0.05 metres in the immediate vicinity of Scarlet Street, but the benefits are marginal further away from the upgraded culvert.

An economic assessment indicates that there would be some small reductions in damages in the immediate vicinity of Scarlet Street (i.e., less than $10,000 over the next 50 years). However, this reduction would not be nearly sufficient to offset the implementation costs of this option. Therefore, this option would not attract OEH funding.</td></tr>
<tr><td>4</td><td>Flooding increased due to Renwick. Too much water directed into small creek system now. Paddock holding water as Scarlet St has been raised and a lack of drainage provided. Allow more flow at culvert near Jordan's property and enlargement of pipe at back of their paddock to remediate problems.</td><td>Specific assessment of the impacts of the Renwick development was completed as part of a separate investigation by Catchment Simulation Solutions in October 2017. This study predicted peak flows and flood levels will:

• increase by <50 mm for more frequent, minor storm events (5 and 10 year events)
• decrease by 50 - 100mm for major storm events (100-year events).

The slight increases observed for the 5 and 10 year events are within the allowable variations of the model (i.e., +/-150mm) and do not flood more properties or cause any worsening of the flooding situation.

An additional option was investigated involving increasing the capacity of the culvert crossing Scarlet St (i.e., tripling structure size) and widening the main channel ((the channel modifications extended ~130m downstream of Scarlet Street.</td></tr>
</table>

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
		The hydraulic assessment indicated flood levels reduce by approximately 0.05 metres in the immediate vicinity of Scarlet Street, but the benefits are marginal further away from the upgraded culvert. However, no properties are flooded to floor level in a 1% AEP flood event An economic assessment indicates that there would be some small reductions in damages in the immediate vicinity of Scarlet Street (i.e., less than $10,000 over the next 50 years). However, this reduction would not be nearly sufficient to offset the implementation costs of this option. The benefit cost ratio of this option would be so low, that when compared to all other applications state wide for OEH funding, it would be unlikely to ever attract a grant offer.
5	Flooding has worsened due to Renwick. Raises concerns about stream mapping and a different flowpath than that shown in figure. Only 2 detention basins in Stage 2 when Stage 1 had more. Creek experiencing more erosion and undermining, trees falling into channel. Disappointing no additional storage provided since Renwick developed. Unreasonable to expect property owners to do works to enlarge channels on their property. Council should explore options to alleviate increased stormwater runoff for downstream residents (FM1, FM3 and FM4 in combination?).	Specific assessment of the impacts of the Renwick development was completed as part of a separate investigation by Catchment Simulation Solutions in October 2017. This study predicted peak flows and flood levels will: • in increase by <50 mm for more frequent, minor storm events (5 and 10 year events) • decrease by 50 - 100mm for major storm events (100-year events). The slight increases observed for the 5 and 10 year events are within the allowable variations of the model (ie +/-150mm) and do not flood more properties or cause any worsening of the flooding situation. The stream alignment on Figure 1 in the report is based on Council GIS data derived from topographic maps. However, it is visual only and is not used to inform the flood modelling which is based on a detailed terrain model (based on LiDAR survey). Erosion of creeks cannot be explicitly represented in the flood model (creek details are based on survey at the time the study was prepared). An additional option was investigated involving increasing the capacity of the culvert crossing Scarlet St (ie tripling structure size) and widening the main channel ((the channel modifications extended ~130m downstream of Scarlet Street.

SUBMISSION	SUBMISSION COMMENTS	RESPONSE TO SUBMISSION
		The hydraulic assessment indicated flood levels reduce by approximately 0.05 metres in the immediate vicinity of Scarlet Street, but the benefits are marginal further away from the upgraded culvert. However, no properties are flooded to floor level in a 1% AEP flood event An economic assessment indicates that there would be some small reductions in damages in the immediate vicinity of Scarlet Street (i.e., less than $10,000 over the next 50 years). However, this reduction would not be nearly sufficient to offset the implementation costs of this option. The benefit cost ratio of this option would be so low, that when compared to all other applications state wide for OEH funding, it would be unlikely to ever attract a grant offer. A combined basin option (i.e., FM1, FM3 & FM4) was considered. This demonstrated flood level reductions of up to 0.15m extending along most of the main creek line (i.e., from Bong Bong Rd downstream to the Hume Highway). However, even with the revised damages assessment, the benefit cost ratio was not predicted to exceed 0.1. That is, the implementation cost is still predicted to outweigh the financial benefits of this option. No floor level flooding occurs for the 100 year flood event without flood modification measures.
6	Scarlet St regraded and raised each time (up to 50cm with sealing). New culvert was installed, but too high, so only allows some flow. Would like correct positioning and levels of the culverts.	An additional option was investigated involving increasing the capacity of the culvert crossing Scarlet St (ie tripling structure size) and widening the main channel ((the channel modifications extended ~130m downstream of Scarlet Street. The hydraulic assessment indicated flood levels reduce by approximately 0.05 metres in the immediate vicinity of Scarlet Street, but the benefits are marginal further away from the upgraded culvert. However, no properties are flooded to floor level in a 1% AEP flood event An economic assessment indicates that there would be some small reductions in damages in the immediate vicinity of Scarlet Street (i.e., less than $10,000 over the next 50 years). However, this reduction would not be nearly sufficient to offset the implementation costs of this option. The benefit cost ratio of this option would be so low, that when compared to all other funding applications state wide for OEH funding, it would be unlikely to ever attract a grant offer.