Paddington Floodplain Risk Management Study and Draft Plan

Final Report

Revision 5
July 2019

Catchment Simulation Solutions

Paddington Floodplain Risk Management Study and Draft Plan

REVISION / REVIEW HISTORY

Revision #	Description	Prepared by	Reviewed by
1	Draft report	D. Tetley	C. Ryan
2	Final draft report	D. Fedczyna	D. Tetley
3	Final draft report incorporating updates to address comments received during public exhibition	D. Tetley	C. Ryan
4	Final report	D. Tetley	C. Ryan
5	Final report including updates to address upper catchment consultation outcomes	D. Tetley	C. Ryan

DISTRIBUTION

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1	Woollahra Municipal Council	12/07/2017	PDF
2	Woollahra Municipal Council	13/04/2018	PDF
3	Woollahra Municipal Council	15/10/2018	PDF
4	Woollahra Municipal Council	6/11/2018	PDF
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Executive Summary

Overview

The suburb of Paddington is located within the Woollahra Municipal Council Local Government Area (LGA) and is home to a mix of residential and commercial land uses as well as open space and sporting facilities. As shown in **Figure ES1** on the following page, Paddington falls within the Rushcutters Bay catchment.

The majority of Paddington is drained by a sub-surface stormwater pipe system. During most frequent rainfall events, the stormwater system has sufficient capacity to carry the stormwater runoff below ground into open channels located west of Glenmore Road. The open channel conveys that runoff beneath New South Head Road and into Rushcutters Bay.

However, during periods of heavy rainfall there is potential for the capacity of the stormwater system to be exceeded, leading to overland flooding. There is also potential for the floodwaters to overtop the banks of the open channels, leading to inundation of the adjoining floodplain. Overland flooding has caused disruption and inconvenience to residents and business owners across Paddington during past rainfall events. During particularly severe rainfall events there is also potential for property damage to be incurred as well as a risk to life.

In recognition of the flooding problems confronting Paddington, Woollahra Municipal Council has prepared 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 provide a high-level evaluation of options that could be potentially implemented to better manage the flood risk.

The Existing Flooding Problem

The extent of the existing flooding problem was quantified using a computer flood model of the Rushcutters Bay catchment. The computer model was validated against historic flood information for three historic floods (including the August 2015 flood) and was also used to simulate a range of design floods. The August 2015 flood model validation map for the upper Paddington catchment is shown in **Figure ES2** as well as **Figure G2** which is enclosed in **Appendix G**.

Peak floodwater depths were extracted from the results of the flood model for the 20% AEP (1 in 5 year average recurrence interval (ARI)) flood, 5% AEP (1 in 20 year ARI) flood, 1% AEP (1 in 100 year ARI) flood and probable maximum flood (i.e., the largest flood that could occur) and are presented in **Figures ES3** to **ES6**.

The outputs from the design flood simulations were used to quantify the impact that flooding is likely to have on people and property across Paddington for a range of different floods. The outcomes of the flood modelling determined that:

- Some parts of the stormwater system only have sufficient capacity to carry a 1 in 1 year flow. As a result, overland flooding could be expected in some areas at least once a year.
- 190 properties are predicted to be exposed to above floor inundation during a 1% AEP flood.
- During the probable maximum flood, over 500 properties are predicted to be flooded above floor.

A flood damage assessment was completed as part of the study and determined that the average annual cost of flooding would be $5.9 million if the “status quo” was maintained.

The assessment ultimately determined that the following areas across Paddington are likely to experience significant property damage, risk to life and/or evacuation difficulties during significant rainfall events:

- Spicer Lane;
- Tara Street;
- Jersey Road;
- Forbes Street;
- Sutherland Ave;
- Harris Street;
- Hampden Street;
- Cecil Street and Cecil Lane;
- Cascade Street/Glenmore Road;
- Boundary Street;
- Goodhope Street; and,
- Brown Street/Neild Avenue.

In addition, low points within the following streets across the upper Paddington catchment are predicted to be exposed to significant inundation depths:

- George Street;
- Victoria Street;
- Elizabeth Place;
- Elizabeth Street;
- Underwood Street;
- Dudley Street;
- Hargrave Street;
- Hargrave Lane; and
- Sutherland Street.

Options for Reducing the Existing Floodplain Problem

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

- Flood Modification Options: Chapter 5.
- Property Modification Options: Chapter 6.
- Response Modification Options: Chapter 7.

Draft Floodplain Risk Management Plan

Based upon the outcomes of the detailed evaluation, the options outlined below are recommended for implementation as part of the draft Floodplain Risk Management Plan for Paddington. The options are also shown on **Figure ES7**.

Further detailed information on each option including costs, implementation schedules and funding opportunities is provided in Chapter 8.

High Priority Options:

- Cecil Street flood mitigation measures;
- George Street to Cascade Street drainage upgrades (Option B);
- Re-grading/roadworks in Hopetoun Lane/Paddington Street;
- Harris Street drainage upgrade;
- Glenmore Road regrading;
- Various community education activities including:
  - Develop educational messages targeting dangerous behaviours (e.g., driving through floodwaters).
  - Update Council website to include catchment specific flood information.
  - Undertake discussions with the Paddington Society to disseminate flood information.
  - Continue to develop social media platforms for flood safe messaging.
- Reviewing and updating Council's drainage maintenance program.

Medium Priority Options:

- Trumper Park floodway;
- Forbes Street to Harris Street Drainage Upgrades;
- Ocean Street and Tara Street Drainage Upgrade;
- Development Control Plan (DCP) modifications;
- CCTV inspections of potential drainage "bottlenecks".

Low Priority Options:

- Flood insurance (Council could also assist property owners by providing property specific flood information to assist in negotiating insurance premiums).

It is expected that implementation of the plan will have a capital cost of approximately $16 million spread across a 10-year period. In addition to the capital costs, some options will incur ongoing maintenance costs. Many of the options will also require a significant investment in time from various agencies including Woollahra Council and the State Emergency Service which are not accounted for in the overall cost estimate.

If the structural options (e.g., floodway and drainage upgrades) are implemented, it is expected that the number of properties exposed to above floor flooding during a 1% AEP flood would reduce by 70 and cumulative flood damages would be reduced by around $23 million over the next 50 years.

However, it is important to understand that implementation of the structural options will reduce the flood risk, it will not remove it completely. Therefore, it is important to implement the remaining, non-structural options to help ensure the flood damage potential is minimised across future development and re-development areas and ensure the continuing flood risk is minimised during particularly severe floods.

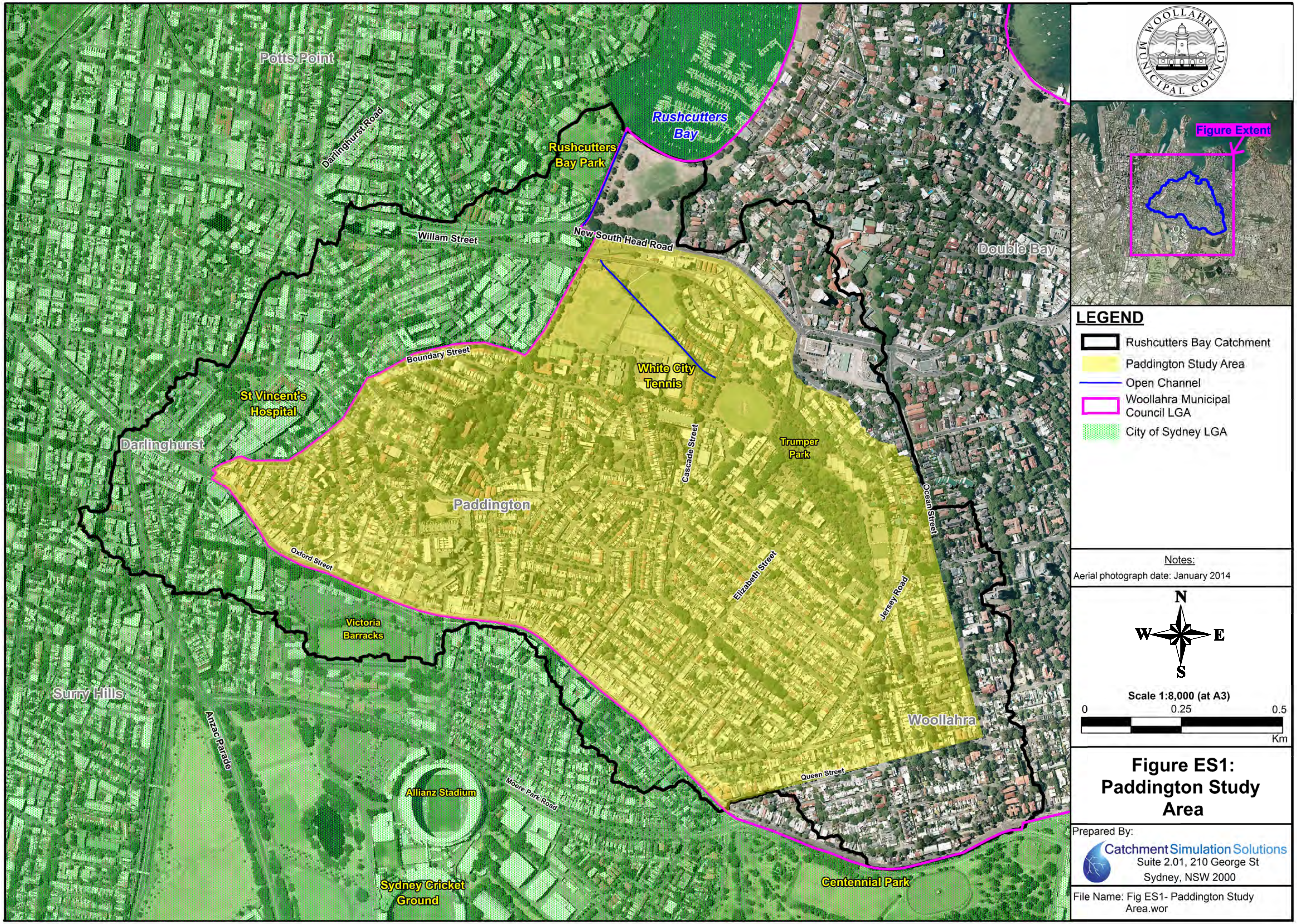
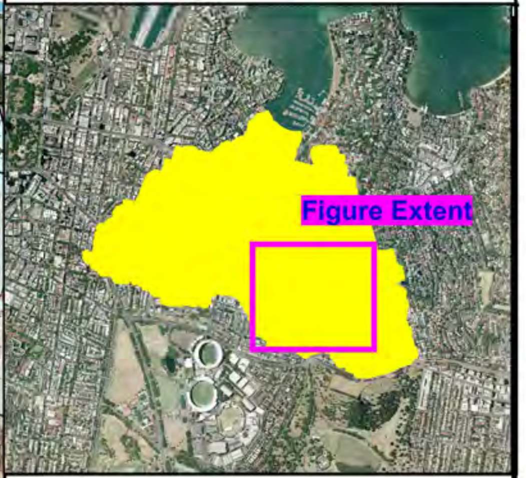


Figure ES1: Paddington Study Area



LEGEND

Reported Flood Depth (metres) — Simulated Flood Depth (metres)

August 2015 Flood Simulated Depths (metres)

- < 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:2,700 (at A3)

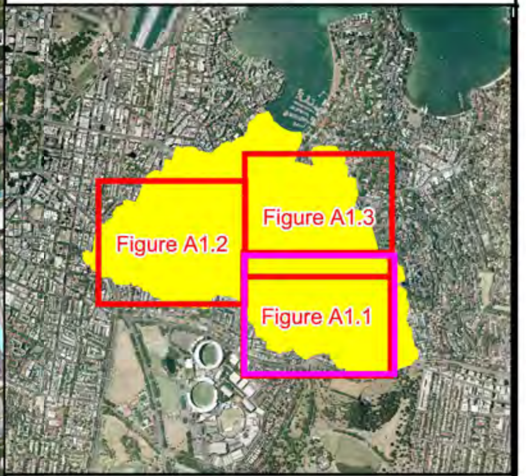
0 0.08 0.16 Km

Figure ES2: Reported Upper Paddington Catchment Questionnaire Depths for August 2015 Flood

Prepared By:

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

File Name: Fig ES2 - Reported Upper Paddington Catch Depths vs Aug 2015.wor



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LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

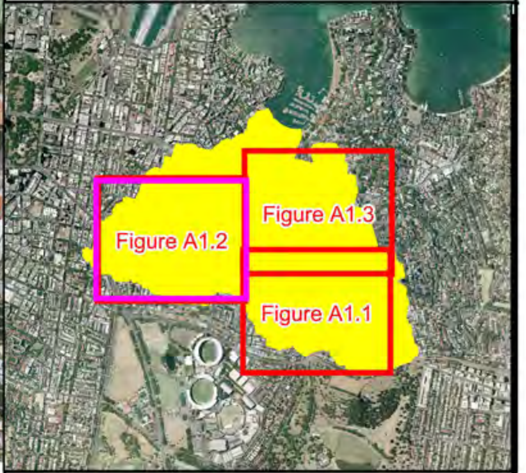
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure ES3.1: Peak Floodwater Depths for the 20% AEP Flood

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

File Name: Fig ES3.1 - Peak Floodwater Depths for the 20% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure ES3.2:
Peak Floodwater Depths for the 20% AEP Flood

Prepared By:
Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: Fig ES3.2 - Peak Floodwater Depths for the 20% AEP Flood.wor

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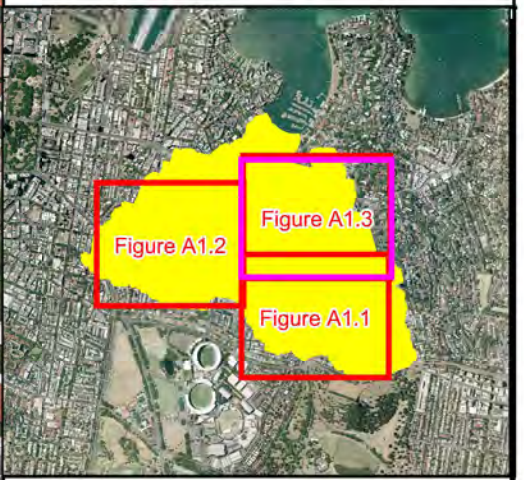


LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

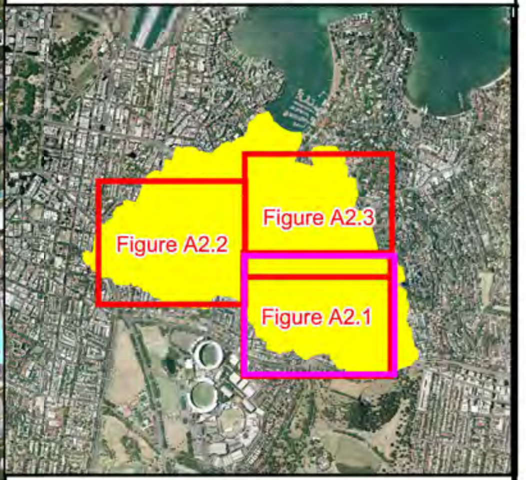
N
W E
S

Scale 1:3,000 (at A3)
0 0.1 0.2
Km

Figure ES3.3: Peak Floodwater Depths for the 20% AEP Flood

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

File Name: Fig ES3.3 - Peak Floodwater Depths for the 20% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

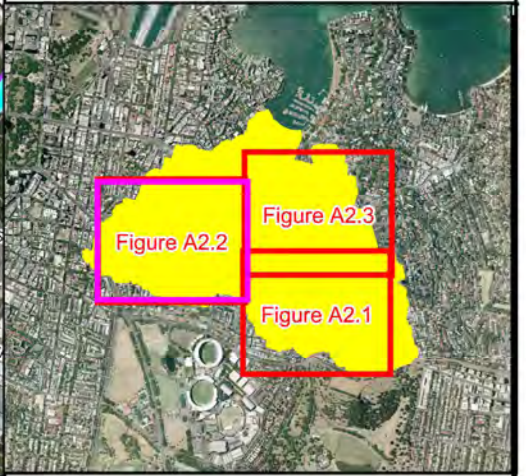
N W E S

Scale 1:3,000 (at A3)
0 0.1 0.2 Km

Figure ES4.1: Peak Floodwater Depths for the 5% AEP Flood

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

File Name: Fig ES4.1 - Peak Floodwater Depths for the 5% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

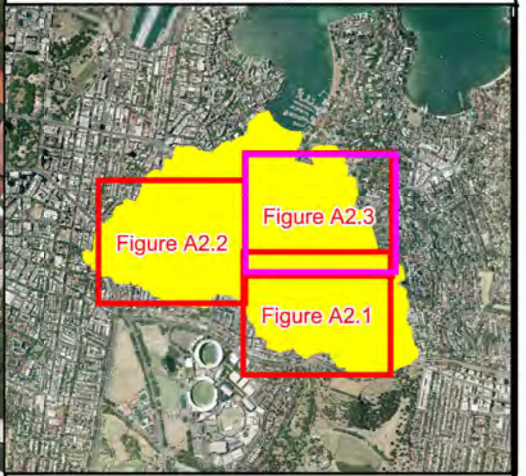
0 0.1 0.2 Km

Figure ES4.2: Peak Floodwater Depths for the 5% AEP Flood

Prepared By:

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

File Name: Fig ES4.2 - Peak Floodwater Depths for the 5% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
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Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure ES4.3: Peak Floodwater Depths for the 5% AEP Flood

Prepared By:
Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: Fig ES4.3 - Peak Floodwater Depths for the 5% AEP Flood.wor

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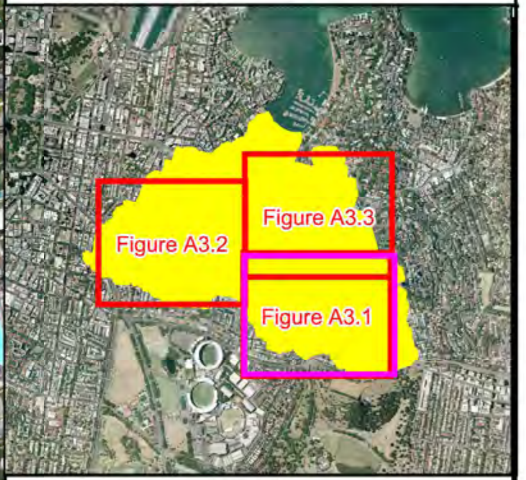


LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

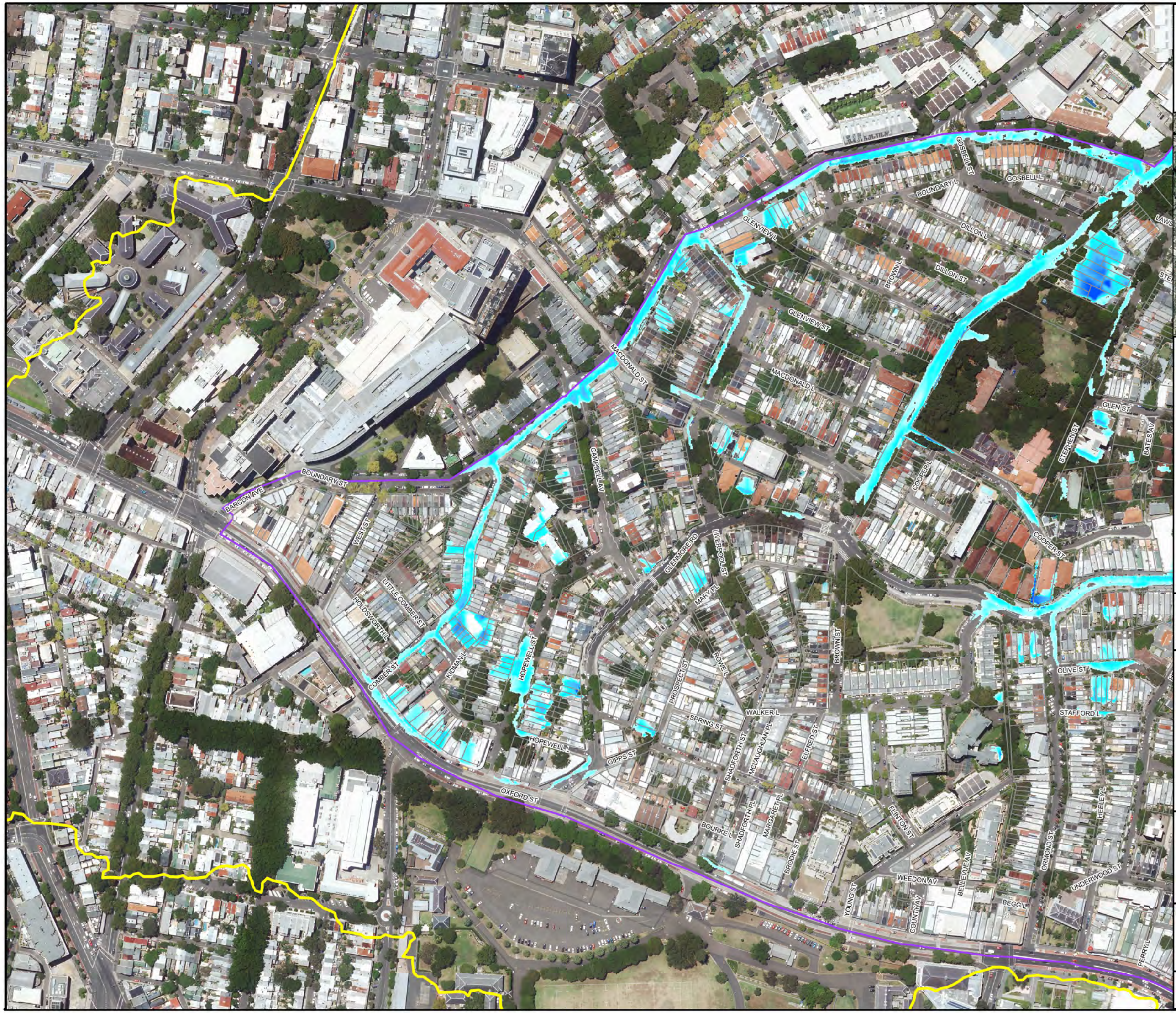
Scale 1:3,000 (at A3)

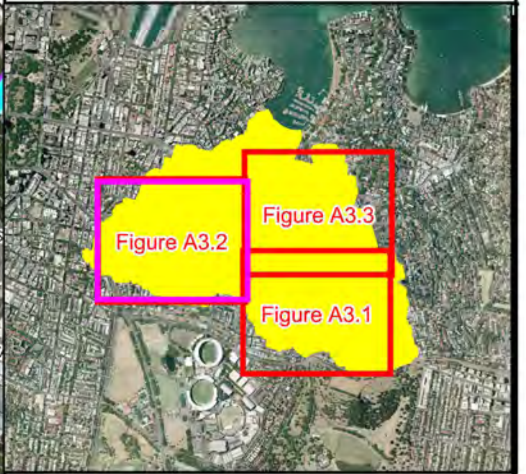
0 0.1 0.2 Km

Figure ES5.1: Peak Floodwater Depths for the 1% AEP Flood

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

File Name: Fig ES5.1 - Peak Floodwater Depths for the 1% AEP Flood.wor





LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

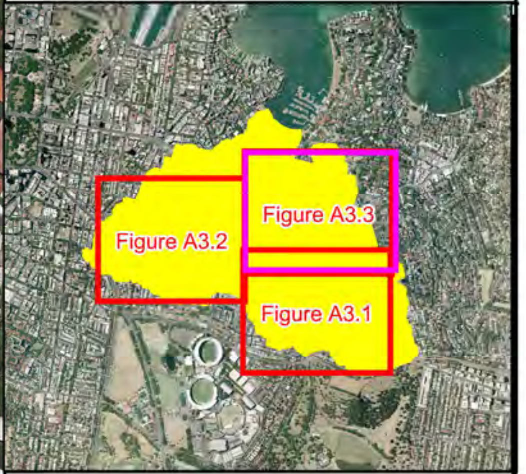
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure ES5.2: Peak Floodwater Depths for the 1% AEP Flood

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

File Name: Fig ES5.2 - Peak Floodwater Depths for the 1% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)

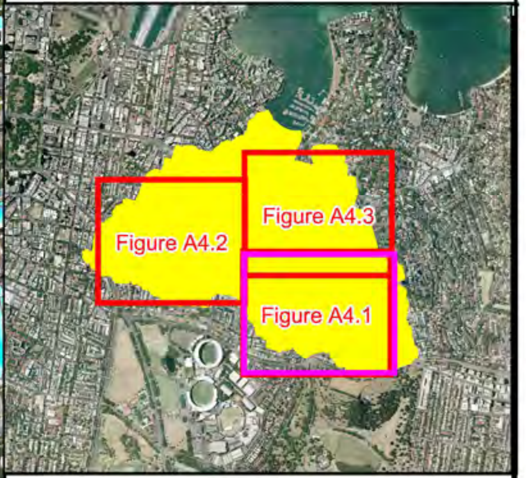
0 0.1 0.2
Km

Figure ES5.3: Peak Floodwater Depths for the 1% AEP Flood

Prepared By:

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

File Name: Fig ES5.3 - Peak Floodwater Depths for the 1% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure ES6.1: Peak Floodwater Depths for the PMF

Prepared By:

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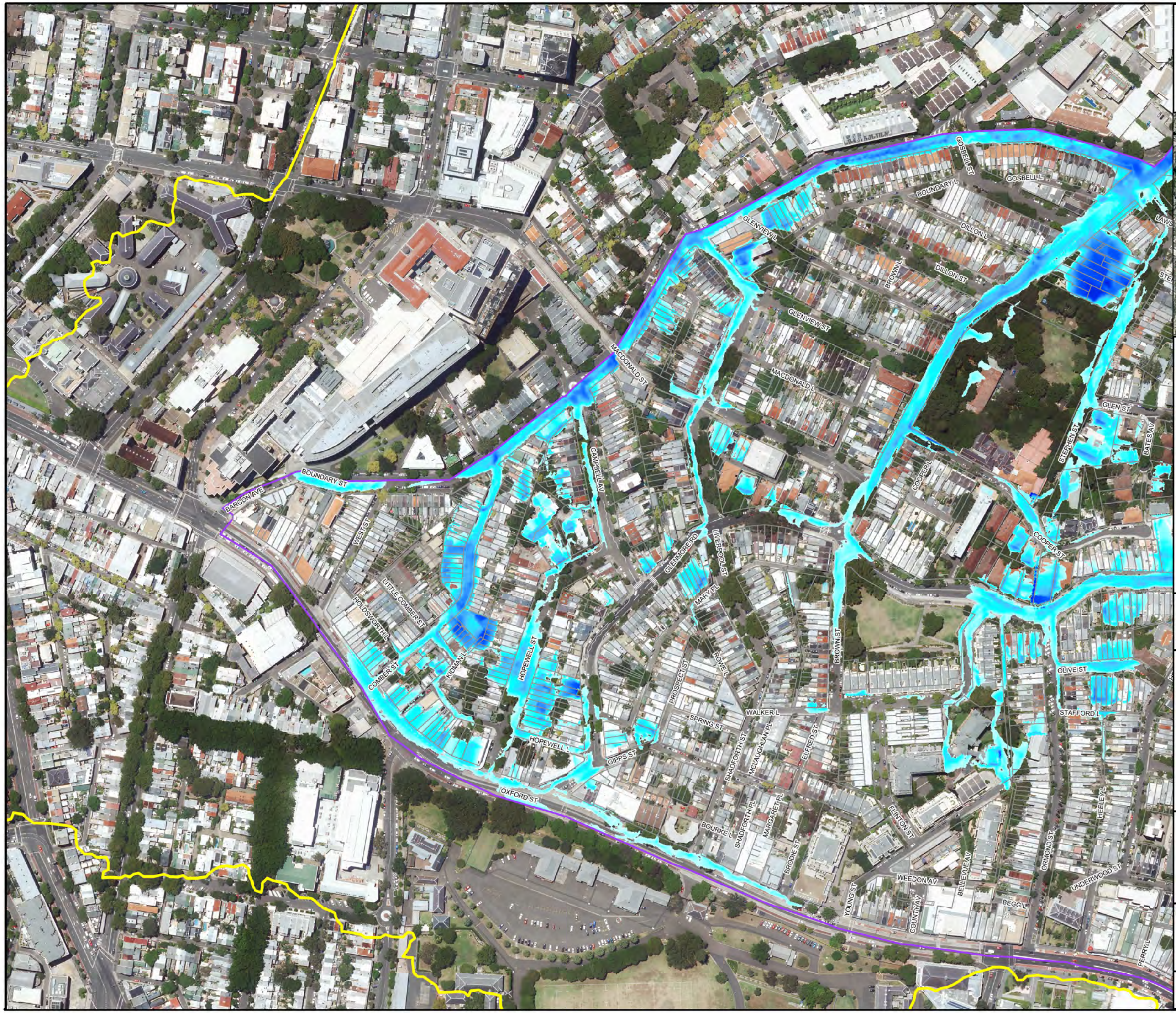
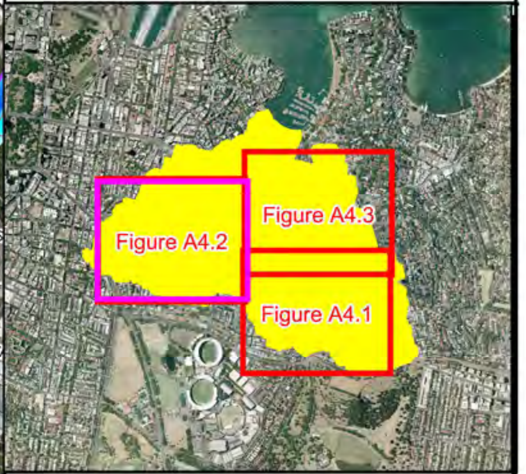
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig ES6.1 - Peak Floodwater Depths for the PMF.wor





LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)

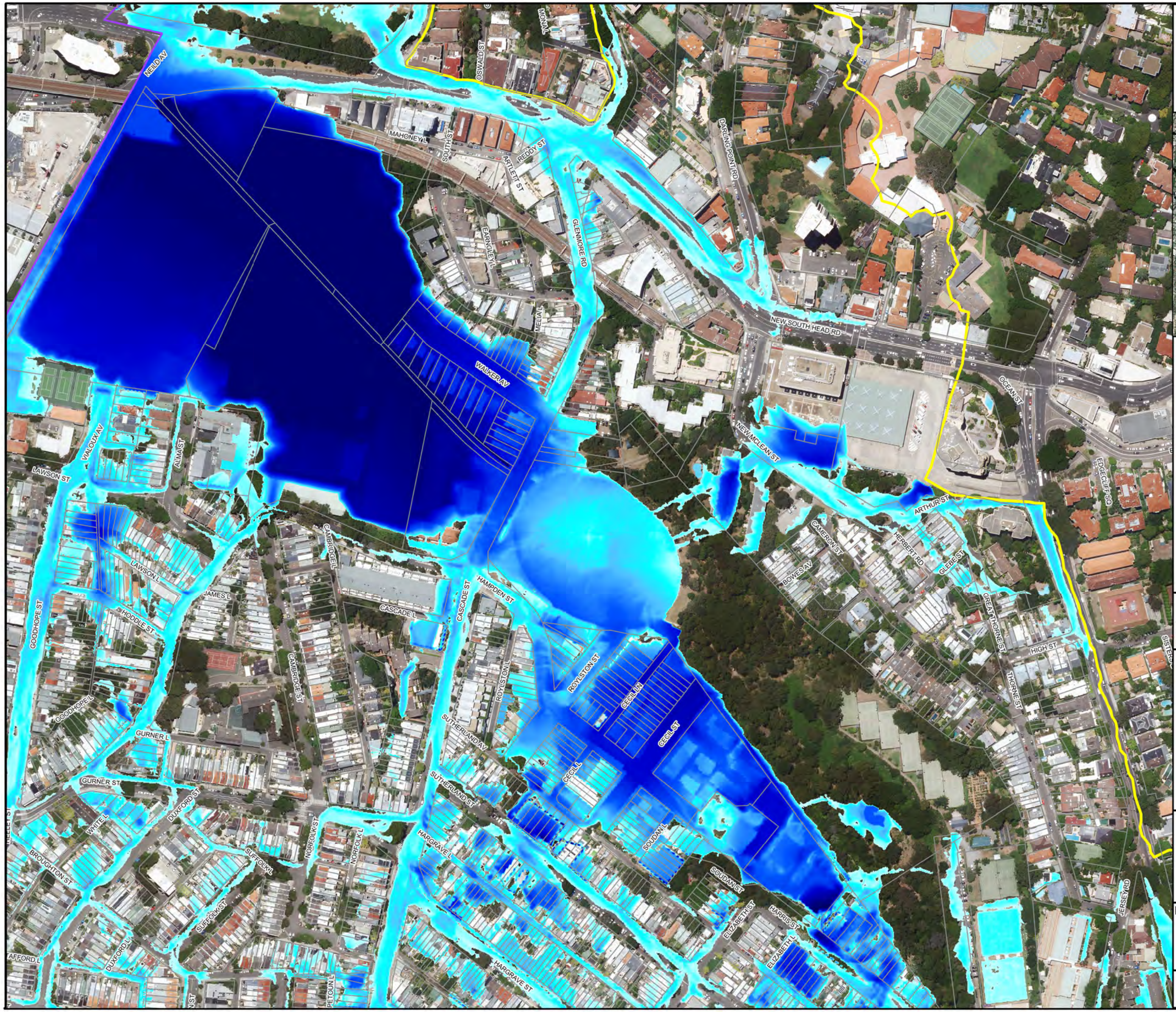
0 0.1 0.2
Km

Figure ES6.2: Peak Floodwater Depths for the PMF

Prepared By:

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

File Name: Fig ES6.2 - Peak Floodwater Depths for the PMF.wor



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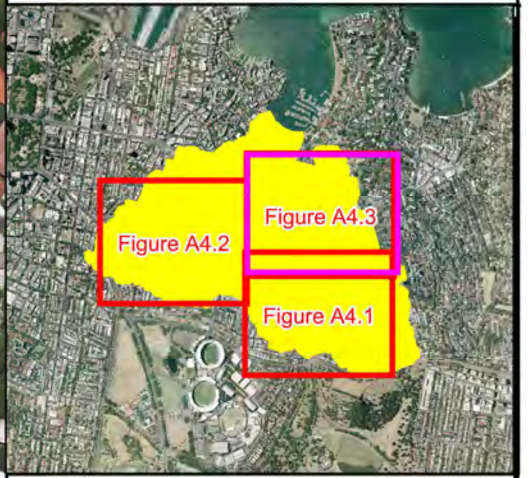

LEGEND

Depths (m)

- 0.1
- 0.2
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- 2.0
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N
W E
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Scale 1:3,000 (at A3)

0 0.1 0.2
Km

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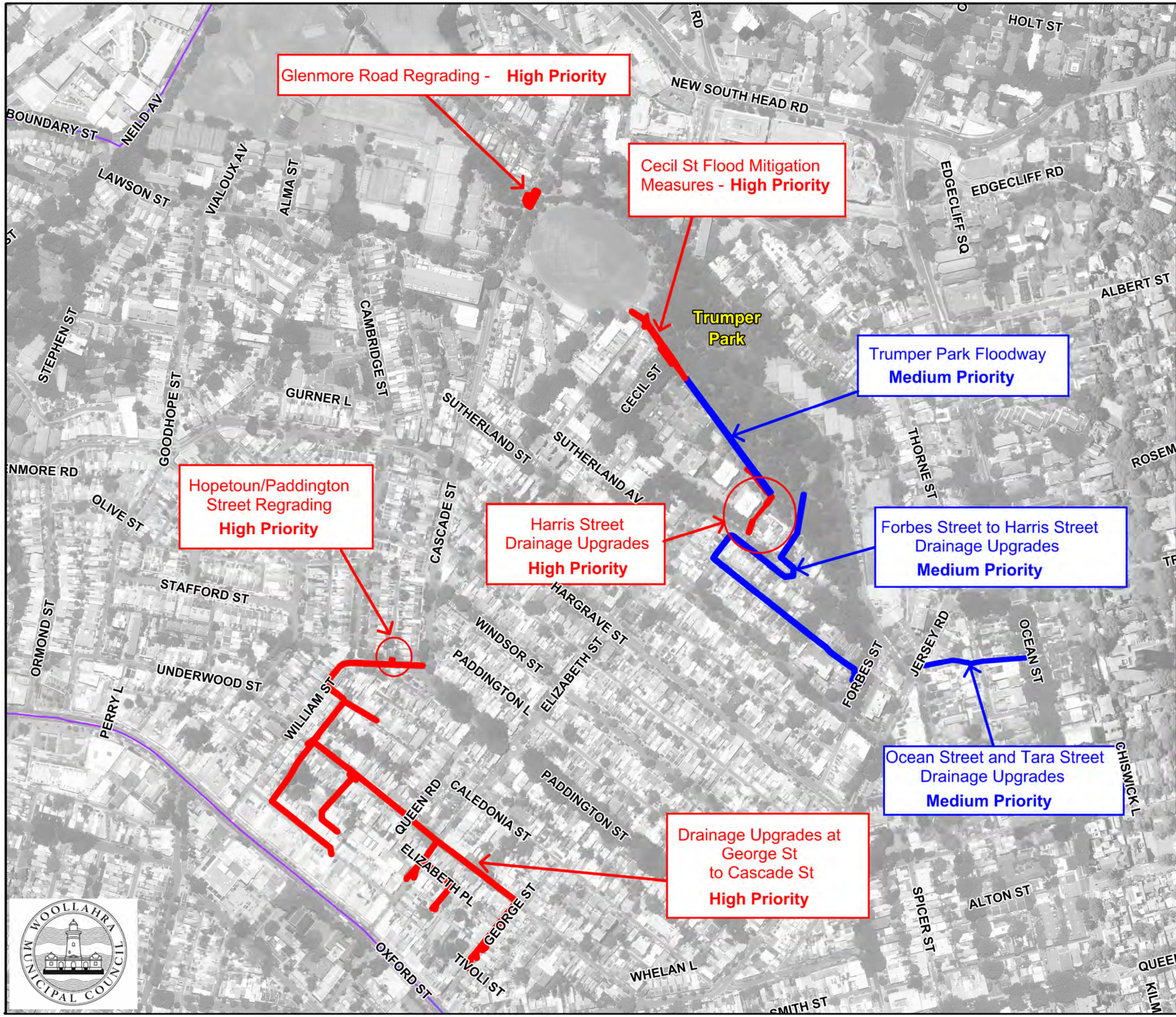


Option

High Priority Options:

- Cecil Street Flood Mitigation Measures
- George Street to Cascade Street drainage upgrades
- Regrading/roadworks in Hopetoun Lane/Paddington Street
- Harris Street drainage upgrade
- Glenmore Road Regrading
- Various community education activities including holding community meetings to promote preparation of flood plans and develop strategies to discourage dangerous behaviour
- Update Council website to include catchment specific flood information
- Reviewing and updating Council's drainage maintenance program

Medium Priority Options:

- Trumper Park floodway
- Forbes Street to Harris Street Drainage Upgrades
- Ocean Street and Tara Street Drainage Upgrades
- Development Control Plan (DCP) modifications
- CCTV inspections of potential drainage "bottlenecks"

Low Priority Options:

- Flood insurance (Council could also assist property owners by providing property specific flood information to assist in negotiating insurance premiums)

Figure ES7: Draft Paddington Floodplain Risk Management Plan

1 INTRODUCTION

1.1 Background

The suburb of Paddington is located within the Woollahra Municipal Council Local Government Area (LGA) and is home to a mix of residential and commercial land uses as well as open space and sporting facilities (e.g., White City tennis complex). The catchment is also home to critical facilities, such as St Vincent's Hospital (although the Hospital is located just outside of the Woollahra LGA). The extent of the Paddington catchment is shown in **Figure 1** (enclosed in **Appendix A**) and forms part of the larger Rushcutters Bay catchment.

The urbanised sections of the Paddington catchment are typically drained by a sub-surface stormwater pipe system. During most frequent rainfall events, the stormwater system has enough capacity to carry the stormwater runoff below ground into open channels located west of Glenmore Road. The open channel conveys that runoff beneath New South Head Road and into Rushcutters Bay.

However, during periods of heavy rainfall there is potential for the capacity of the stormwater system to be exceeded, leading to overland flooding. There is also potential for the floodwaters to overtop the banks of the open channels, leading to inundation of the adjoining floodplain. Overland flooding has caused disruption and inconvenience to residents and business owners across Paddington during past rainfall events. During particularly severe rainfall events there is also potential for property damage to be incurred as well as a risk to life.

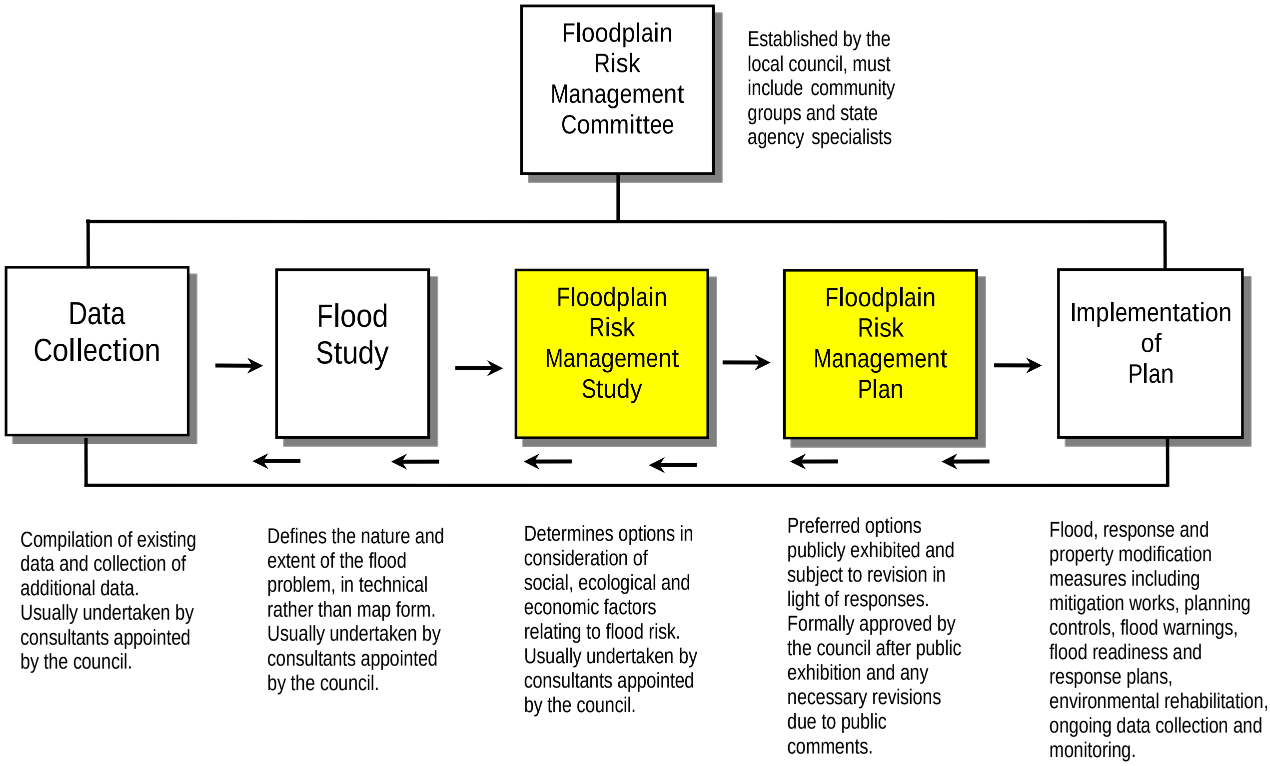
In recognition of the flooding problems confronting the Paddington catchment, Woollahra Municipal Council resolved to prepare a Floodplain Risk Management Study and Plan for the catchment.

1.2 The Floodplain Risk Management Process

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

Under the Policy, the management of flood liable land is 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 *"Paddington Flood Study"* (Catchment Simulation Solutions, 2016).

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

1.3 Report Structure

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

- Section 2 - Background Information: Provides general information regarding the study area including the history of flooding;
- Section 3 – The Existing Flooding Problem: 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.

- Sections 4 to 7: discusses the merits 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
- Section 8 – Draft Floodplain Risk Management Plan: provides a preferred list of options that are considered appropriate for adoption by Council to manage the flood risk.

2 Background Information

2.1 Study Background

A Floodplain Risk Management Study and Plan was previously prepared for the Rushcutters Bay catchment (WMAwater, 2016). However, this previous study focussed on flooding across the lower sections of the Rushcutters Bay catchment where "mainstream" flooding was the most prevalent flooding mechanism.

The Rushcutters Bay Floodplain Risk Management Plan recommended a number of measures that could be implemented to help manage the risk of flooding across the lower catchment. Several of these measures have since been implemented, the most notable of which is the construction of a new overland flow path from the northern end of Cecil Lane to Trumper Oval and extensive earthworks across Trumper Oval itself.

The Rushcutters Bay Floodplain Risk Management Study and Plan also noted that the identification of overland flooding problems and the assessment of mitigation options across the upper catchment was hampered by the lack of a suitable 2-dimensional hydraulic model of the area. Accordingly, the evaluation of the potential mitigation options across the upper catchment areas was largely based on a qualitative assessment. In recognition of this limitation, the study recommended that a new 2-dimensional flood model of the upper catchment should be prepared as part of a detailed flood study and floodplain risk management study dedicated to the upper catchment areas (i.e., Paddington).

Based on this recommendation, Council engaged Catchment Simulation Solutions to prepare a Flood Study and Floodplain Risk Management Study that aimed to define the nature and extent of the existing flooding probable across Paddington and identify potential options for managing any identified flooding problems. The "Paddington Flood Study" was prepared in 2016 and documents key flooding characteristics across Paddington for a range of historic and design floods. Further information on the flood study is provided in Section 3.2.1.

During the course of the study, several properties within the lower catchment suffered significant damage during at least two significant rainfall events. Therefore, it was evident that a significant flooding problem remained across the lower catchment despite the flood risk mitigation measures that have previously been implemented. Therefore, Woollahra Municipal Council requested that the study area be extended to also include the lower catchment area so that further opportunities for flood risk reduction measures could be explored.

2.2 Catchment Description

Paddington is a suburb located in the inner-east of Sydney that is located within the Woollahra Municipal Council Local Government Area (LGA) and covers an area of 2.5 km^2. It comprises a mix of residential and commercial land uses as well as open space and sporting facilities and is home to over 12,000 people (Australian Bureau of Statistics, 2017). The extent of the

Paddington study area is shown in **Figure 1**. As shown in **Figure 1**, Paddington forms part of the larger Rushcutters Bay catchment.

The Paddington area was originally inhabited by the Cadigal people. European settlement commenced in the 1820's but it was not until the late 1800's and early 1900's that Paddington experienced rapid growth and was largely "built out" (Paddington Society, 2017). It was during this period that the Victorian terrace style housing that Paddington is renowned for became prominent. Much of the character of Paddington lies in its preservation of historic architecture with many homes, streets and buildings recognised as being of National and State significance from a heritage perspective (Paddington Society, 2017). This heritage status does limit the extent of modifications that can be completed to the built environment (as may be desired to implement flood risk reduction measures).

As development progressed across the catchment, many of the natural gullies and waterways that historically drained runoff into Rushcutters Bay were built over and replaced by stormwater pipes. The stormwater pipes were typically designed to "European standards" and do not reflect contemporary design standards. Moreover, the significant increase in impervious surfaces that has occurred since European settlement has resulted in an increase in runoff volume, which further reduces the "design" capacity of the existing stormwater system. Ownership of the drainage system is shared between Sydney Water (who owns and maintains the main trunk drainage system) and Woollahra Council (who owns and maintains the smaller pipes that feed into the trunk drainage system).

2.3 Flood History

Paddington has a significant history of flooding. Notable flooding across the catchment has occurred at the following times:

- November 1984;
- January 1989;
- March 1989;
- January 1991;
- April 2012;
- April 2015;
- August 2015; and,
- February 2017.

The available rainfall information for these events indicates that significant flooding typically occurs as a result of relatively short duration, high intensity rainfall events. This type of storm system is most typically associated with thunder storms.

A selection of photographs and videos of historic floods across Paddington were also provided by Council staff and the community as part of the community consultation. The majority of the videos/photos were for floods that occurred in April 2012, April 2015 and August 2015. The photographs as well as a selection of "still images" from the videos are reproduced in **Plate 1** to **Plate 12**.

The images show a variety of different flooding mechanisms across the study area, including:

- Deeper "ponded" water contained within localised depressions (**Plate 1, Plate 4** and **Plate 12**).
- Flooding from a surcharging stormwater pit in the lower catchment (**Plate 2**);
- Shallow but fast moving water that is largely contained within the roadway but extending onto the adjoining footpath across the steeper sections of the catchment (**Plate 3, Plate 6**, **Plate 8** and **Plate 9**); and,
- Water cascading down stairs (**Plate 11**)

Plate 1 Flooding in Victoria Street, Paddington on 6 January 1989 (WMAwater, 2013)

Plate 2 Surcharging stormwater pit in Hampden Street during April 2012 flood

Plate 3 Flooding along Paddington Street during April 2015 flood

Plate 4 Flooding around 8 Hampden Street during April 2015 flood

Plate 5 Intersection of New South Head Road and Neild Ave during August 2015 event

Plate 6 Brown Street during August 2015 event

Plate 7 Fast moving water outside of 4 Harris Street during August 2015 event

Plate 8 Boundary St (near Glenview St) during August 2015 event

Plate 9 Comber St looking towards Boundary St during August 2015 event

Plate 10 **Jersey Road during August 2015 event**

Plate **11** **Water cascading down stairs between Forbes St and Sutherland Ave during August 2015 event**

Plate **12** **Floodwater in George Street**

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 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 1**.

Table 1 Summary of Catchment Demographics

Population Statistics		Median Age		35
Population Statistics	Education	Year 12 or equivalent		75%
Population Statistics	Education	Year 10 or equivalent		85%
Population Statistics	Education	Did not Complete Year 10		2%
Population Statistics	Address Continuity	Same usual address 1 year ago as in 2011		67%
Population Statistics	Address Continuity	Same usual address 5 years ago as in 2011		38%
Dwelling Statistics		Dwellings with a motor vehicle		77%
Dwelling Statistics		Average persons per dwelling		2.1
Dwelling Statistics	Language spoke at home	Speaks English only		89%
Dwelling Statistics	Language spoke at home	Speaks other language:		11%
Dwelling Statistics	Occupier Status	Separate house		7%
Dwelling Statistics	Occupier Status	Semi-detached, row or terrace house, townhouse	1 storey	5%
Dwelling Statistics	Occupier Status	Semi-detached, row or terrace house, townhouse	2 or more storeys	65%
Dwelling Statistics	Occupier Status	Flat, unit or apartment:		22%
Dwelling Statistics	Occupier Status	Other dwelling (cabin, caravan):		<1%
Internet Statistics	Type of Internet Connection	No Internet connection		1%
Internet Statistics	Type of Internet Connection	Broadband		89%
Internet Statistics	Type of Internet Connection	Dial-up		1%
Internet Statistics	Type of Internet Connection	Other		7%
Internet Statistics	Type of Internet Connection	Internet connection not stated		2%

The information presented in **Table 1** shows that:

- The median age of residents within the catchment is 35 years old.
- English is spoken in the majority of households (92%).
- 99% of households have an internet connection.

- 21% of dwellings do not have access to a motor vehicle.
- 73% of residential dwellings are semi-detached, row or terrace style housing. Of those, the majority (94%) have at least two storeys.
- The temporary population is limited with no caravan parks and only a limited number of hotels and guest houses providing accommodation options. However, there are a large number of rental properties were long term tenure might be more limited.

2.5 Community Consultation

Several community consultation devices were developed as part of the study to inform the community about the study and to obtain information from the community about their past flooding experiences. Further information on each of these consultation devices is provided below.

Website

A flood study website was established for the duration of the study. The website address is: http://paddington.floodstudy.com.au/

The website was developed to provide the community with detailed information about the study and provides a chance for the community to ask questions and complete an online questionnaire (this online questionnaire was identical to the questionnaire distributed to residents and business owners, as discussed below).

During the course of the study, the website was visited over 634 times by 450 unique users.

Community Information Brochure and Questionnaire

In 2015, a community information brochure and questionnaire were prepared and distributed to potentially flood liable households and businesses within the Paddington study area. The brochure and questionnaire were subsequently mailed out to all properties and owners of properties falling within the PMF extent. This resulted in the brochure and questionnaire being sent to 740 households and businesses.

The questionnaire sought information from the community regarding whether they had experienced flooding, the nature of flood behaviour, if roads and houses were inundated and whether residents could identify any historic flood marks. A total of 114 questionnaire responses were received.

The responses to the questionnaire indicate that:

- The majority of respondents have lived in or around the catchment for at least 15 years. Accordingly, most respondents would have been living in the area when the 2015 floods occurred. However, only a limited number of respondents are likely to have experience the 1989 and 1991 events.
- 45% of respondents have experienced some form of disruption as a result of flooding in the study area. This ranges from traffic disruptions through to garages and homes/businesses being inundated.
- The following streets/areas were identified by several respondents as being particularly susceptible to flooding problems:
  -> Cecil Street, Cecil Lane, Roylston Street and Hampden Street;

-> Jersey Road, Forbes Street, Sutherland Ave and Harris Street;
-> Cascade Street and Glenmore Road;
-> Boundary Street and Neild Avenue;
-> George Street, Elizabeth Place and Elizabeth Street.

A number of respondents also provided photos of past floods. A selection of these photographs are presented in Section 2.3.

Public Exhibition

The draft Floodplain Risk Management Study report was exhibited from 20 June 2018 to 27 July 2018. Letters were sent out to all property owners and occupiers within flood affected sections of the study area advertising the public exhibition. A total of 7,992 letters were sent out to property owners and 4,287 were sent out to residents/occupiers.

A total of 28 submissions were received during the exhibition period. All comments were collated and reviewed and, where necessary, updates were made to the draft report.

A summary of the comments and associated responses/actions are provided in **Appendix F**.

Additional Upper Catchment Consultation

Further consultation with upper Paddington catchment residents was undertaken in early 2019 to address concerns raised by residents during the public exhibition of the draft Floodplain Risk Management Study report and during subsequent Floodplain Risk Management and Environmental Planning Committee meetings.

The upper Paddington catchment was defined as the area generally bounded by Oxford Street to the south, Jersey Road to the east, Quarry Street, Harris Street and Sutherland Avenue to the north and Cascade Street, Hopetoun Street and William Street to the west.

A total of 2779 letters and surveys were distributed to property owners and residents in the upper catchment. The goal of the questionnaire was to secure information from the community regarding their past flooding experience including information on historic floods that could be used to validate the performance of the TUFLOW flood model. A copy of the questionnaire that was distributed to the upper catchment residents is included in **Appendix G**.

A total of 295 questionnaire responses were received. A summary of each questionnaire response is included in **Appendix G**. The spatial distribution of questionnaire respondents is also shown in **Figure G1**, which is also enclosed in **Appendix G**. The response locations shown in **Figure G1** are also colour coded according to whether flooding has been experienced at each location.

The responses to the questionnaire indicate that:

- Seventy respondents (i.e., 24%) reported that they had been impacted by flooding;
- The most commonly reported flooding impact was water covering roadways. However, a significant number of respondents also reported above floor flooding resulting in damage to buildings and contents. Rising damp was also a commonly reported problem.

- The area between George Street and Elizabeth Street, in particular, was identified as a flooding "hot spot".
- Historic flood information was provided for a number of past rainfall events. The August 2015 flood was the most reported historic flood.

To validate the performance of the TUFLOW model, the historic flood information provided as part of the questionnaire responses were compared against simulated water depths generated by the flood model for the August 2015 flood. This comparison is presented in **Figure G2**, which is also enclosed in **Appendix G**. Also included in **Figure G2** is historic flood information for the August 2015 flood from a previous questionnaire that was distributed as part of the Paddington Flood Study.

The comparison provided in **Figure G2**, shows that the simulated water depths (i.e., the water depths predicted by the flood model) are typically within 0.1 metres of the flood depths reported by the questionnaire respondents. It should be noted that an exact replication cannot be expected owning to localised differences in modelling assumptions (e.g., blockage of stormwater inlets). Overall, the comparison included in **Figure G2** shows the flood model is providing a reasonable reproduction of the community's experiences during the August 2015 flood.

Community briefing workshop for upper Paddington catchment residents

A community briefing was also held at the Woollahra library in May 2019. The briefing provided an opportunity for Council and Catchment Simulation Solutions to summarise the outcomes of the additional model validation and also provided an opportunity for the community to ask any questions regarding the study. A copy of the PowerPoint presentation that formed the basis for the briefing is enclosed in **Appendix G**.

As part of the community briefing it was uncovered that the community may have misinterpreted some of the mapping that was included in the draft report. More specifically, the flood level difference mapping was being interpreted as floodwater depth mapping and was the primary reason the residents felt the modelling results did not reflect their experiences. As a result of this, a copy of the floodwater depth mapping was subsequently included as part of the executive summary rather than in **Appendix A** of the report to help overcome the misinterpretation of results.

Overall, the outcomes of the upper catchment consultation confirmed that the flood modelling completed as part of the current study provided a good reproduction of the community's flooding experiences and served as a reasonable basis for assessing the potential benefits of a range of potential flood risk mitigation measures.

3 THE EXISTING FLOODING PROBLEM

3.1 Overview

In order to identify and evaluate potential options for managing the flood risk, it is first important to have an understanding of the nature and extent of the existing flood risk. This is typically achieved through the preparation of a flood study, which provides information on key flood characteristics (e.g., flood depths, levels and velocities) for a range of floods up to and including the Probable Maximum Flood. Woollahra Municipal Council commissioned the *'Paddington 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 flooding problem are provided in the following sections.

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

3.2 Existing Flood Behaviour

3.2.1 Previous Flood Studies

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

- Rushcutters Bay Catchment Flood Study (Webb, McKeown & Associates, 2007);
- Rushcutters Bay Floodplain Risk Management Study (WMAwater, 2012);
- Rushcutters Bay Flood Study (WMAwater, 2016) (for The City of Sydney Council);
- Rushcutters Bay Catchment Floodplain Risk Management Study and Plan (WMAwater, 2016) (for The City of Sydney Council);

Although the Paddington catchment is fully contained within the Rushcutters Bay catchment, the previous studies only considered flooding across the lower sections of the catchment (i.e., downstream of Lawson Street, Glenmore Road and Hampden Street). Accordingly, the potential flooding problem across the upper sections of Paddington was not defined as part of these previous studies.

More recently, Woollahra Municipal Council commissioned the *'Paddington Flood Study'* (Catchment Simulation Solutions, 2016) to provide an improved description of existing flood behaviour across the full extent of Paddington. As part of the *'Paddington Flood Study'*, hydrologic (i.e., rainfall-runoff) processes were defined using a DRAINS model previously developed as part of the *'Rushcutters Bay Catchment Flood Study'* (Web, McKeown &

Associates, 2007). A two-dimensional hydraulic computer model was developed using the TUFLOW software and was used to simulate the movement of floodwaters across Paddington. The TUFLOW model was developed to include a full representation of the stormwater drainage system as well as a representation of the movement of overland flows once the capacity of the stormwater system was exceeded.

The TUFLOW model that was developed for the flood study was calibrated/verified using historic rainfall and flood marks for floods that occurred in 1989, 1991 and 2015. The model was subsequently used to simulate the 1 exceedance per year event as well as the 20%, 10%, 5% and 1% AEP events as well as the Probable Maximum Flood (PMF). The following conclusions were determined from the results of the investigation:

- Flooding across Paddington generally occurs as a result of the capacity of the stormwater system being exceeded following heavy rainfall in the catchment leading to "overland" flooding.
- The trunk drainage system was determined to have limited capacity (less than a 1 in 1 year capacity in some instances). Accordingly, overland flooding is predicted to occur relatively frequently.
- Overland flooding typically occurs as result of relatively short duration, high intensity rainfall bursts. This type of storm system is most typically associated with thunder storms. The critical storm duration for those areas subject to significant overland flooding was determined to be 1.5 hours.
- Although a number of properties are predicted to be inundated during each of the simulated design floods, the depths of inundation across the upper catchment areas are typically shallow. As a result, most areas are subject to a low provisional flood hazard during the 1% AEP flood (the high hazard areas are primarily restricted to roadways).
- At the peak of the 1% AEP flood, approximately 1,300 properties (out of 5,366 contained within the catchment) are predicted to experience depths of inundation that exceed 0.1 metres. The areas that are most significantly impacted by floodwaters include:
    - Spicer Lane;
    - Jersey Road;
    - Forbes Street;
    - Sutherland Ave;
    - Harris Street;
    - Hampden Street;
    - Cecil Street and Cecil Lane;
    - low points in Victoria Street, Underwood Street, Dudley Street, Hargrave Street, Hargrave Lane and Sutherland Street;
    - Cascade Street/Glenmore Road;
    - Boundary Street;
    - Goodhope Street;
    - Brown Street/Neild Avenue.

Overall, it is considered that the information presented in the *'Paddington Flood Study'* provides the best contemporary description of flood behaviour for Paddington. Therefore, the results that are presented in the following sections are based on the information generated as part of this flood study

3.2.2 Floodwater Depths and Velocities

Floodwater depths and velocities were extracted from the TUFLOW modelling results documented in the 'Paddington Flood Study' and were used to prepare a series of maps describing design flood behaviour across Paddington. The depth maps are presented in **Figures A1** to **A4** in **Appendix A** and the velocity maps are presented in **Figures A5** to **A8** in **Appendix A**.

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

- The upstream sections of the catchment are characterised by relatively shallow, but fast moving water. The majority of the flow across the upstream sections of the catchment is contained within roadways. However, there are some locations where water is predicted to overtop gutters and flow through adjoining properties. This includes areas adjoining "sag" points in Jersey Road, Victoria Street, Underwood Street, Dudley Street, Hargrave Street, Hargrave Lane and Sutherland Street. Floodwaters travelling along roadways is commonly predicted to exceed 2 m/s during the 1% AEP flood.
- The downstream sections of the catchment (downstream of Harris Street & Hampden Street) is characterised by deeper and slower moving water. This is associated with the comparatively flat topography and some significant overland flow impediments (e.g., northern end of Cecil Street). Floodwater depths of over 1 metre are predicted during the 1% AEP flood across some sections of the lower catchment.

The results of the 1 exceedance per year event also predict overland flow across some sections of the catchment. This indicates that the stormwater system has less than a 1 year capacity across some sections of the catchment. Therefore, during particularly severe rainfall events across the catchment, the majority of runoff would be conveyed overland. Further information regarding the stormwater system capacity is provided below.

3.2.3 Stormwater System Capacity

The TUFLOW model produces information describing the amount of water flowing into each stormwater pit and through each stormwater pipe. This includes information describing which pipes are flowing completely full during each design flood. This information can be used to provide an assessment of the capacity of each pit and pipe in the stormwater system. In doing so, it allows identification of where stormwater capacity constraints may exist across the catchment.

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

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

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

The resulting stormwater capacity maps are presented in **Figure A9**. As shown in **Figure A9**, the pit and pipe capacities are colour coded based on the nominal capacity that was calculated for each element of the stormwater system. Furthermore, different symbols have been applied to each pit to define whether the pit first "fails" via ponding depth or surcharge.

The information presented in **Figure A9** shows that the capacity of the system varies considerably across the catchment. Some sections of the stormwater system have less than a 1 year capacity while other sections of the stormwater system are able to convey flows in excess of the 1% AEP event.

In general, the major trunk drainage lines where flows are concentrated appear to have a capacity of less than the 20% AEP event. **Figure A9** also indicates that the pipe capacity rather than pit capacity appears to be the limiting factor in the performance of the stormwater system.

However, it should be noted that the stormwater capacity estimates are not definitive as the capacity will vary depending on factors such as blockage, the capacity of the stormwater inlets and features that cannot be fully represented in the flood model (e.g., precise representation of kerb and guttering).

3.2.4 Flood Emergency Response Precincts

In an effort to understand the potential emergency response requirements across different sections of the study area, flood emergency response precinct (ERP) classifications were prepared. The ERP classifications can be used to provide an indication of areas which may be inundated or may be isolated during floods. This information, in turn, can be used to quantify the type of emergency response that may be required across different sections of the floodplain during future floods. This information can be useful in emergency response planning.

The ERP classifications were prepared based upon information contained in the Australian Institute of Disaster Resilience's Guideline 7-2: 'Flood Emergency Response Classification of the Floodplain' (2017). This involved delineating the catchment into emergency response classifications based upon the flow chart presented in **Plate 13.**

Each allotment within the Paddington catchment was classified based upon the ERP flow chart (refer to **Plate 13**) for the 1% AEP flood as well as the PMF. This was completed using the TUFLOW model results, digital elevation model and a road network GIS layer in conjunction with proprietary software that considered the following factors:

- Whether evacuation routes/roadways get "cut off" and the depth of inundation (a 0.2m depth threshold was used to define a "cut" road);
- Whether evacuation routes continuously rise out of the floodplain;
- Whether an allotment gets inundated during the nominated design flood and whether evacuation routes are cut, or the lot becomes completely surrounded (i.e., isolated) by water before inundation;

- If evacuation by car was not possible, whether evacuation by walking was possible (a 0.5 metre depth threshold was used to define when a route could not be traversed by walking).

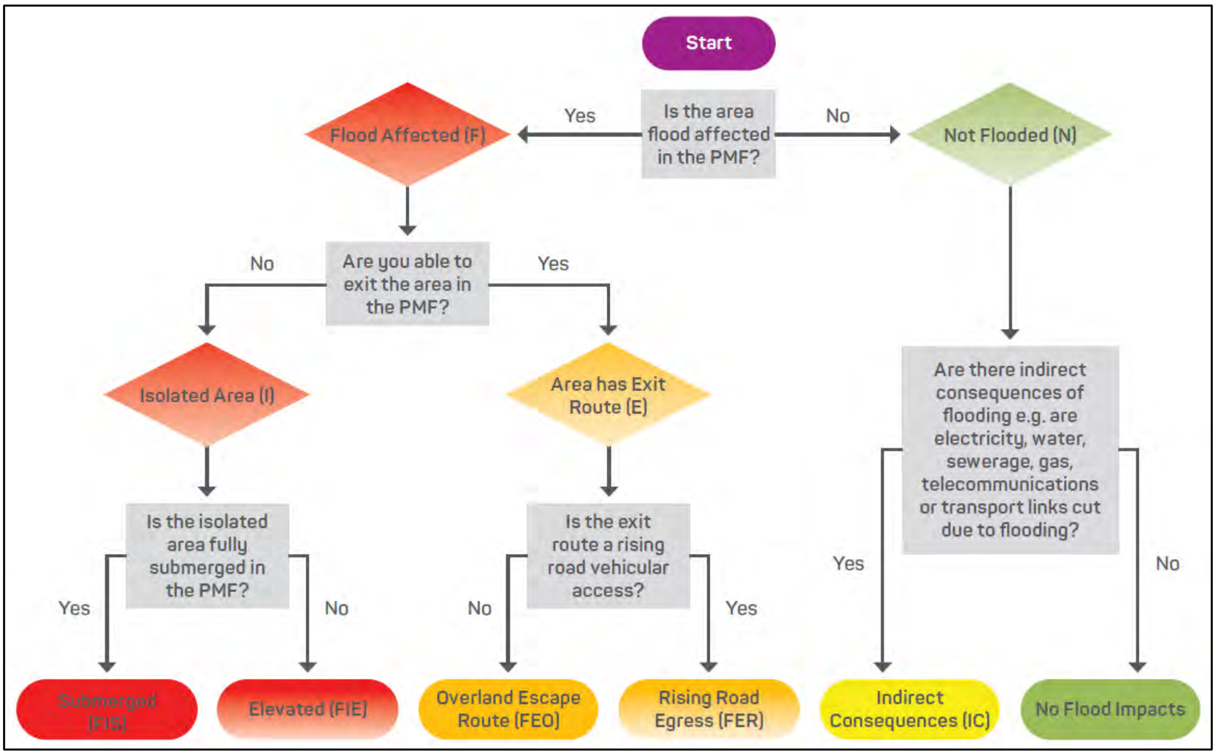


Plate 13 Flow Chart for Determining Flood Emergency Response Classifications (AIDR, 2017).

The resulting ERP classifications for the 1% AEP flood as well as the PMF are provided in **Figures A10** and **A11**. A range of other datasets were also generated as part of the classification process to assist emergency services. This includes the locations were roadways first become cut by floodwaters, the time at which the roadways first become cut and the length of time the roadways are cut. This roadway inundation information is also presented in **Figures A10** and **A11**

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. The provisional flood hazard at a particular area of a floodplain can be established from Figure L2 of the *'Floodplain Development Manual'* (NSW Government, 2005).

Figure L2 in the *'Floodplain Development Manual'* (NSW Government, 2005) divides hazard into two categories, namely high and low. It also includes a "transition zone" between the low and high hazard categories. Sections of the floodplain located in the "transition zone" may be classified as either high or low depending on site conditions or the nature of any proposed development.

In general, those areas subject to a low flood hazard can, if necessary, be evacuated by trucks and able-bodied adults would have little difficulty wading to safety (NOTE: evacuation by car may not be possible). Those areas of the floodplain exposed to a high flood hazard would have difficulty evacuating by trucks, there is potential for structural damage to buildings and there is possible danger to personal safety (i.e., evacuation by wading may not be possible).

The TUFLOW hydraulic software was used to automatically calculate the variation in provisional flood hazard across Paddington based on the criteria shown in Figure L2.

The provisional hazard categories only provide an appraisal of the potential hazard associated with the depth and velocity of floodwaters. The determination of true hazard categories requires the consideration of a number of additional factors to determine the potential vulnerability of the community during specific floods. These factors include (NSW Government, 2005):

- Size of the flood;
- Effective warning time;
- Flood awareness;
- Rate of rise of floodwaters;
- Duration of flooding; and
- Potential for evacuation.

To provide an understanding of the true flood hazard categories, the ERP classifications were combined with the provisional hazard categories. It was considered that the ERP classifications provided a reasonable assessment of the "other" emergency response factors that influence flood hazard, including the potential for isolation and evacuation difficulties.

In general, the provisional hazard categories were retained in the true hazard mapping. However, the provisional "transition" flood hazard was changed to "high" based on the limited flood warning time and rapid rate of rise of water across the area. In addition, the low provisional hazard was changed to a high hazard when it was identified as being "isolated" as part of the ERP classification (due to the flood liability of the land in conjunction with potential evacuation difficulties).

The hazard mapping for the 1% AEP flood as well as the PMF is presented in **Figures A12** and **A13**.

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 14** and are also described in **Table 2**. As shown in **Plate 14**, 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.

The resulting "national" hazard category maps are included in **Appendix E** as **Figures E1** to **E2** inclusive.

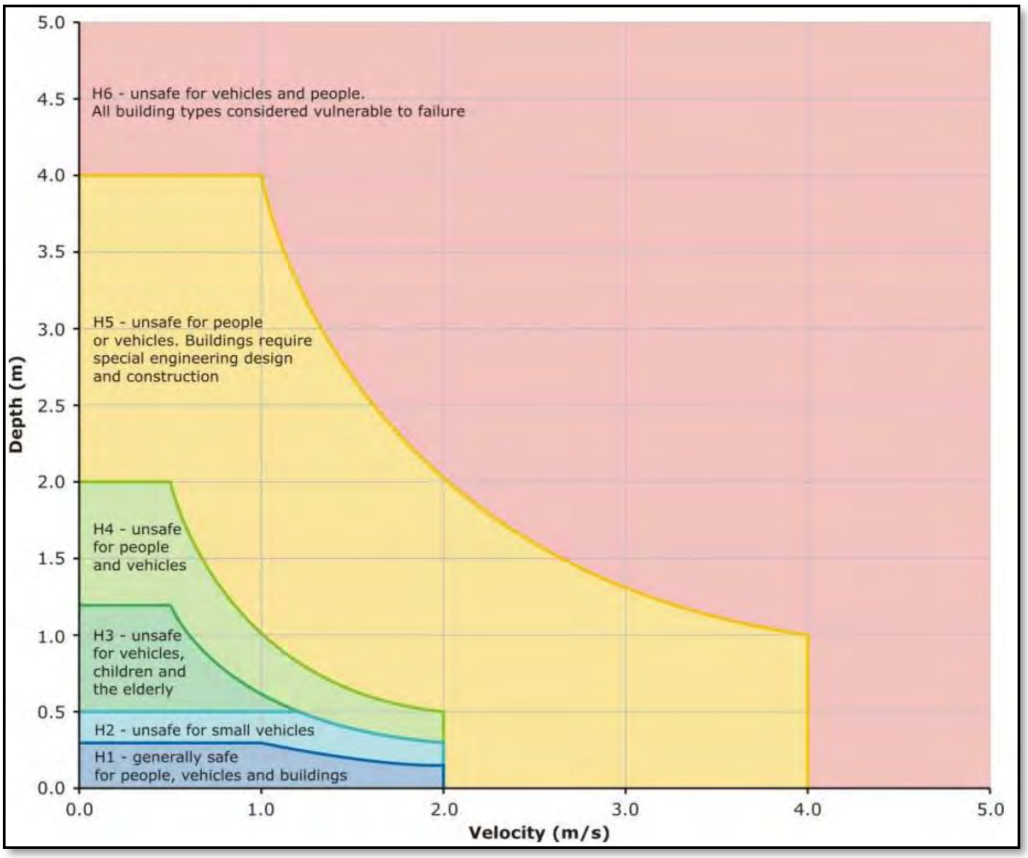


Plate 14 Flood hazard vulnerability curves (AIDR, 2014)

Table 2 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.

3.2.6 Hydraulic Categories

The NSW Government's *'Floodplain Development Manual'* (NSW Government, 2005) recommends subdividing flood prone areas according to the hydraulic categories presented in **Table 3**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour and highlights areas that should be retained for the conveyance of floodwaters.

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

Criteria for establishing hydraulic categories for Paddington were previously derived as part of the *'Paddington Flood Study'*. These criteria were reviewed as part of the current study and were determined to be suitable. The criteria are reproduced in **Table 3**.

Table 3 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Definition	Adopted Criteria*
Floodway	• Those areas where a significant volume of water flows during floods • Often aligned with obvious natural channels and drainage depressions • They are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	Velocity x Depth > 0.3
Flood Storage	• Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	Velocity x Depth < 0.3 and Depths > 0.5 metres
Flood Fringe	• The remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • Development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	Areas that are not floodway or flood storage

The hydraulic category maps that were developed based upon the criteria listed in **Table 3** for the 1% AEP flood and PMF are shown in **Figures A14** and **A15**.

3.2.7 Flood Risk Precincts

Woollahra City Council uses "flood risk precincts" to assess the flood risk of a site and the suitability of different development types. The precincts have been devised based on the flood hazard categorisation in the 1% AEP event (refer to Section 3.2.8) as well as the PMF extent. The *Woollahra Development Control Plan 2015* defines the flood risk precincts as follows:

- **High Flood Risk Precinct:** All land where high hazard conditions occur during a 1% AEP flood; where safe evacuation routes cannot be provided and flood refuge areas are required; and all floodways;
- **Medium Flood Risk Precinct:** All land that is inundated by the 1% AEP flood that is not classified as high risk; areas on the edge of the identified 1% AEP floodplain where the topography provides low hazard rated excavation routes.
- **Low Flood Risk Precinct:** Land within the floodplain that is above the 1% AEP flood but below the extent of the PMF.

The definitions provided above were used as the basis for preparing flood risk precinct mapping which is shown in **Figure A16**. **Figure A16** shows that majority of the upper catchment would fall under the low or medium flood risk precinct. Those areas of high flood risk are generally contained along roadways, although there are some notable high flood risk areas north of Sutherland Avenue as well as along an overland flow path stretching from Hargrave Street north towards Hampden Street.

3.2.8 Impact of Flooding on Vulnerable Facilities

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

A list of vulnerable facilities across Paddington are summarised in **Table 4** .**Table 4** also summarises if the facility is predicted to be subject to property inundation as well as above floor inundation.

Table 4 shows that several vulnerable/critical facilities are predicted to be subject to property inundation. Therefore, access to/from some of these facilities may not be possible during floods within the catchment. However, none of the facilities are predicted to be exposed to above floor inundation during any of the design floods. Therefore, although the facilities may be isolated during floods (i.e., access to or from the facilities may be cut), the floodwaters are likely to subside quickly, and any occupants of these facilities should be able to safely shelter in a place until such time.

Table 4 Impact of Flooding on Vulnerable Facilities

Vulnerable Facility		20% AEP Flood		5% AEP Flood		1% AEP Flood		PMF	
		Property Flooded	Above Floor Flooding	Property Flooded	Above Floor Flooding	Property Flooded	Above Floor Flooding	Property Flooded	Above Floor Flooding
Aged Care	Presbyterian Aged Care	☑		☑		☑		☑	
	ARV and Goodwin Village	☑		☑		☑		☑	
	Friends Home Care Nursing								
Child Care	KU Peter Pan Paddington Preschool								
	SDN Paddington Children's Education& Care Centre							☑	
Ambulance	Paddington Ambulance Station								
Fire Station	Fire & Rescue NSW Darlinghurst Fire Station								
	Fire & Rescue NSW Woollahra Fire Station								
School	Sydney Grammar School Edgecliff Preparatory	☑		☑		☑		☑	
	Glenmore Road Public School							☑	
Police Station	Paddington Police Station								
Doctors	Eastern Suburbs Medical Service	☑		☑		☑		☑	
	Doctor Maree Bellamy								
	Gould B M								
	Van Park								

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 Paddington catchment. A detailed description of the approach used to establish the flood damage cost estimates is provided in **Appendix B**.

As outlined in **Appendix B**, 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 5**.

Table 5 Number of Properties Subject to Above Floor Inundation

Flood Event	Number of buildings incurring damage		
	Residential	Commercial/ Industrial	Total Number
1 exceedance per year	15	1	16
20% AEP	79	3	82
10% AEP	101	7	108
5% AEP	124	9	133
1% AEP	161	13	174
PMF	483	49	532

Table 6 Summary of Flood Damage Costs for Existing Conditions

Flood Event	**Flood Damages** ($ millions)		
	Residential	Commercial/ Industrial	Total Damages
1 exceedance per year	2.08	0.08	2.15
20% AEP	4.63	0.31	4.94
10% AEP	5.94	0.63	6.57
5% AEP	7.33	0.81	8.14
1% AEP	9.39	1.02	10.41
PMF	30.03	6.97	37.01

The final flood damage estimates for each design floods are summarised in **Table 6** for existing topographic and development conditions. It indicates that if a 1% AEP flood was to occur, over $10 million worth of damage could be expected. The majority of the damage is predicted to occur across residential properties where 161 properties are predicted to suffer above floor inundation.

The highest flood damage costs are predicted to occur in the lower parts of the catchment. This includes properties in Cecil Street, Cecil Lane, Hampden St and Glenmore Road.

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

The individual AAD estimates for each property and asset were also summed to provide an estimate of the total damage likely to be incurred across the study area on an annual basis for existing topographic and development conditions. The AAD for Paddington was determined to be **$5.9 million**. Accordingly, if the "status quo" was maintained, residents and business owners within the catchment as well as infrastructure providers, such as Council, would likely be subject to cumulative flood damage costs of approximately $5.9 million per annum (on average).

3.4 Summary of Flooding "Trouble Spots"

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

- low points in George Street, Victoria Street, Elizabeth Street, Elizabeth Place, Underwood Street, Dudley Street, Hargrave Street, Hargrave Lane and Sutherland Street;
- Spicer Lane;
- Tara Street;
- Jersey Road;
- Forbes Street;
- Sutherland Ave;
- Harris Street;
- Hampden Street;
- Cecil Street and Cecil Lane;
- Cascade Street/Glenmore Road
- Boundary Street;
- Goodhope Street;
- Brown Street / Neild Avenue.

It should be noted that the nature of flooding across the local catchment is complex and cannot be fully represented in any computer flood model. Nevertheless, it is considered that the results from the modelling are suitable for identifying where there are significant inundation problems and provides a suitable tool for evaluating the potential hydraulic benefits of structural flood risk mitigation measures.

4 OPTIONS FOR MANAGING THE FLOOD RISK

4.1 General

As outlined in Section 3, a number of existing properties across Paddington are predicted to be exposed to a significant flood risk and/or significant financial impacts during floods within the catchment. Accordingly, the following sections outline options that could be potentially implemented to better manage this flood risk.

4.2 Potential Options for Managing the Flooding Risk

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

- **Flood Modification Options**: are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across flood liable areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk. Flood Modification Options are discussed in Section 5.
- **Property Modification Options**: refers to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties is typically used to manage existing flood risk while planning measures (e.g., land use/development controls) are employed to manage future flood risk. Property Modification Options are discussed in Section 6.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public responds before, during and after a flood. Response modification measures are the key measures employed to manage the continuing flood risk. Response Modification Options are discussed in Section 7.

4.3 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.

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

- Hydraulic impacts
- Change in number of buildings inundated above floor level
- Financial feasibility

- Environmental impacts
- Emergency responses impacts
- Technical feasibility

Further details on each of these evaluation criteria is presented below. The scoring system that was used to rank each option against these criteria is also provided in **Table 7**.

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.

4.3.1 Hydraulic Impacts

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 of each flood modification option, the TUFLOW hydraulic model that was used to define existing flood behaviour as part of the *'Paddington Flood Study'* 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.

If an option showed no net positive flood impact, no further assessment of the option was completed (i.e., the evaluation criteria listed below were not considered further).

4.3.2 Change in Number of Buildings Inundated Above Floor Level

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

4.3.3 Financial 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.

Table 7 Adopted Evaluation Criteria and Scoring System for Assessment of Flood Risk Management Options

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

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.

4.3.4 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.

4.3.5 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.

4.3.6 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.

4.4 Summary

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

- Flood Modification Options: Chapter 5.
- Property Modification Options: Chapter 6.
- Response Modification Options: Chapter 7.

5 Flood Modification Options

5.1 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:

- Detention Basins
- Channel Modifications
- Drainage Upgrades

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

It should be noted that all designs presented in the following section are conceptual in nature only. If the concept designs are determined to be feasible, each option will be subject to more detailed design that will take into consideration items such as aesthetics (a particularly important consideration for the area).

5.2 Detention Basins

5.2.1 General

Detention basins are structures that reduce downstream discharges by temporarily storing flows from the upstream catchment. They can be implemented on small scales (e.g., for individual development sites) through to large scales, where they approximate dams. An example of a detention basin is provided in **Plate 15**.

Plate 15 Example of a Flood Detention Basin (MECA, 2017)

The primary limitation associated with implementing a detention basin in a "built up" catchment like Paddington is the lack of open space (detention basins typically require a significant land area/storage volume to provide a significant reduction in flows). Nevertheless, opportunities to implement detention basins across existing areas of open space were explored and are documented in the following sections.

5.2.2 Moncur Reserve Detention Basin

Currently, floodwaters from the low point in Morrell Street flow into Moncur Reserve via a narrow pedestrian opening which is set between two masonry walls. Areas downstream of Moncur Reserve, most notably Spicer Lane and Jersey Road, are predicted to be subject to significant inundation during most design floods.

A possible flood mitigation measure for this area would involve the creation of a formal overland flow path from Morrell Street into Moncur Reserve and works within the park to create a detention basin to reduce flows into Spicer Lane.

The *'Rushcutters Floodplain Risk Management Study and Plan'* (*WMA, 2012*), previously investigated the implementation of a detention basins at this location. It was estimated that the available volume in the Reserve could be between 500 and 1,500 m^3 depending on whether the area is maintained for public use or the area is fenced and solely used for stormwater detention. The 2012 study estimated the volume of overland flow at this site as 9,500 m^3 in a 10% AEP event and 16,300 m^3 in a 1% AEP event. Therefore, the 2012 study determined that the effectiveness of constructing a detention basin within the reserve would be minimal as:

- The available storage is around 10 times less than the overland flow volume
- Any reduction of the peak flow will only benefit properties locally but have limited impact to properties downstream due to inflows from other subcatchments.

Based upon these factors, this option was not pursued as part of the 2012 study. However, a modified version of this option has been investigated as part of the current study to confirm the hydraulic benefits afforded by this option.

The revised basin configuration is illustrated in **Plate 16** and would include the following components:

- Regrading of Morrell Street to create a new "sag" point at the entrance to Moncur Park. This will include widening of the existing entrance to the park to allow more water into the park.
- Excavation of park down to an elevation of 52.8 mAHD
- Construction of basin wall (earth embankment) at 55 mAHD
- Construction of spillway at 54.5 mAHD to direct basin overflows into Spicer Lane
- Upgrade of existing pipe from basin to Jersey Road (from 0.45m diameter to 0.75m diameter)
- Installation of new stormwater pit in basin to serve as low flow outlet

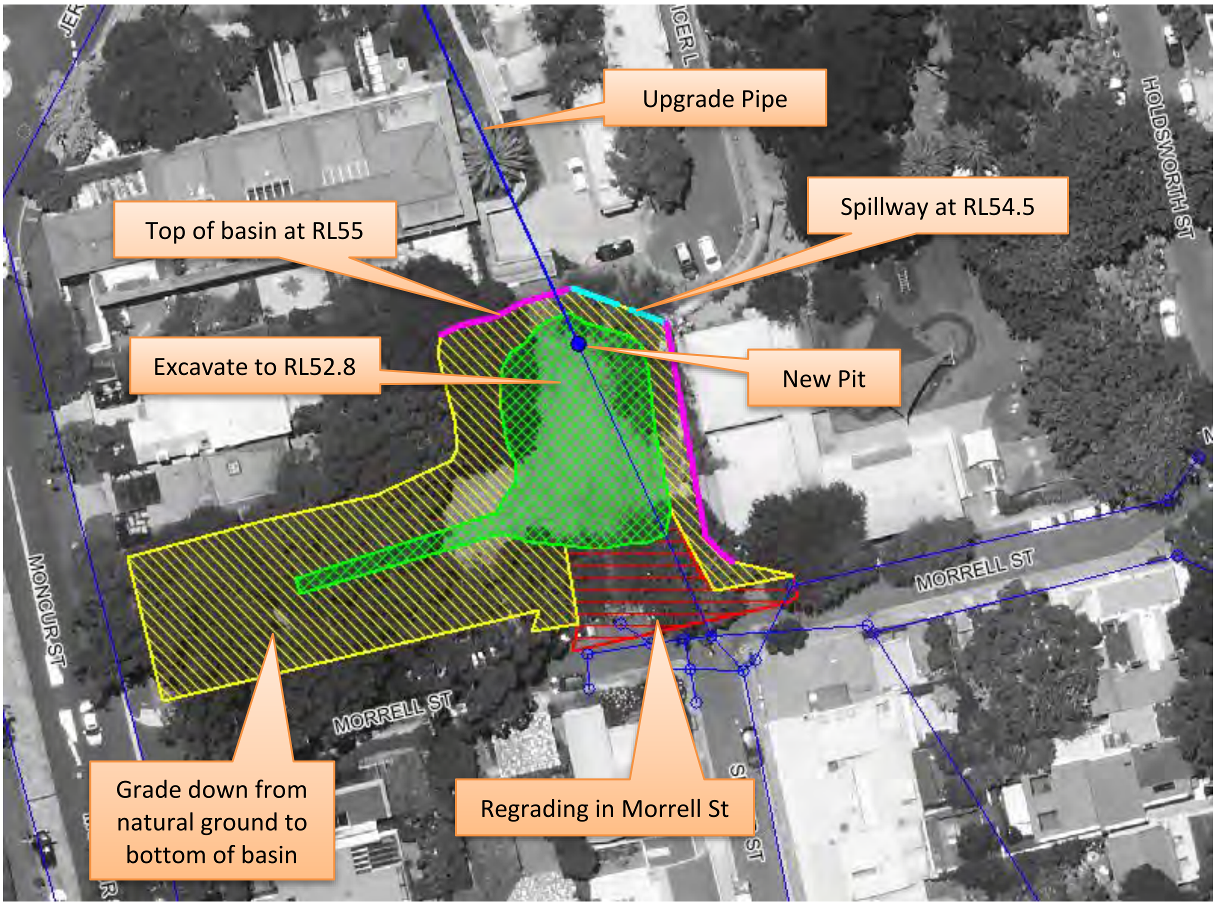


Plate 16 Design Concept for Moncur Reserve Detention Basin

The hydraulic benefits of the detention basin were quantified by including the basin in the TUFLOW model and re-simulating each of the design floods. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 17** and **Plate 18**.

Plate 17 and **Plate 18** show that the Moncur Reserve detention basin is predicted to generate reductions in peak 20% and 1% AEP flood levels within the roadways of Morrell Street and Spicer Lane, as well as properties fronting these roadways. Some minor decreases in peak flood levels are also predicted further downstream of the basin, around Jersey Road and Sutherland Street.

Most notably, at the peak of the 20% AEP flood the most significant peak flood level reductions of up to 0.4 metres are experienced within 2 Spicer Lane, downstream of the proposed detention basin. Decreases in peak 20% AEP flood levels are also predicted upstream of the basin within the roadway of Morrell Street.

At the peak of the 1% AEP flood reductions of up to 0.4 metres occur within the roadway of Morrell Street. Peak 1% AEP flood level reductions of up to 0.2 metres are predicted to occur within properties on Morrell Street.

The cost to implement the basin is estimated to be in the order of $1.4 million. A detailed breakdown of costs is provided in **Appendix C**.

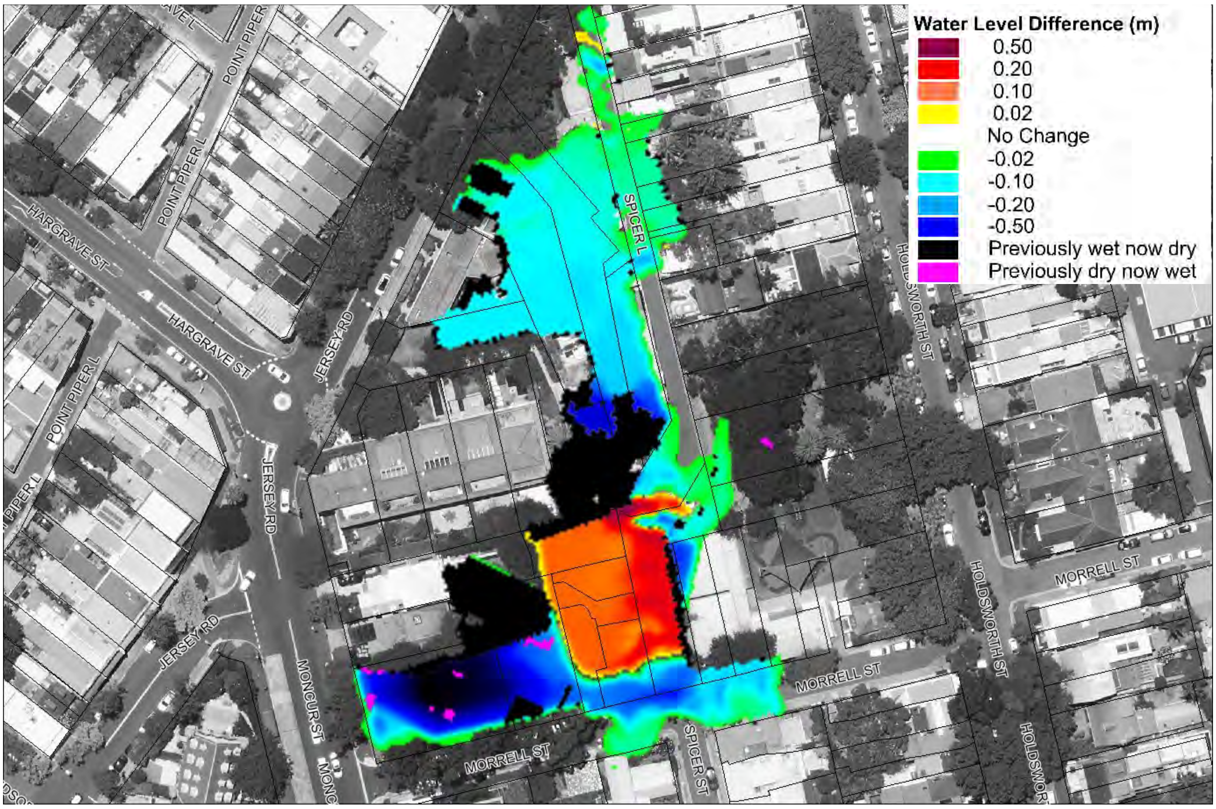


Plate 17 Peak 20% AEP Flood Level Difference Mapping for Moncur Reserve Detention Basin

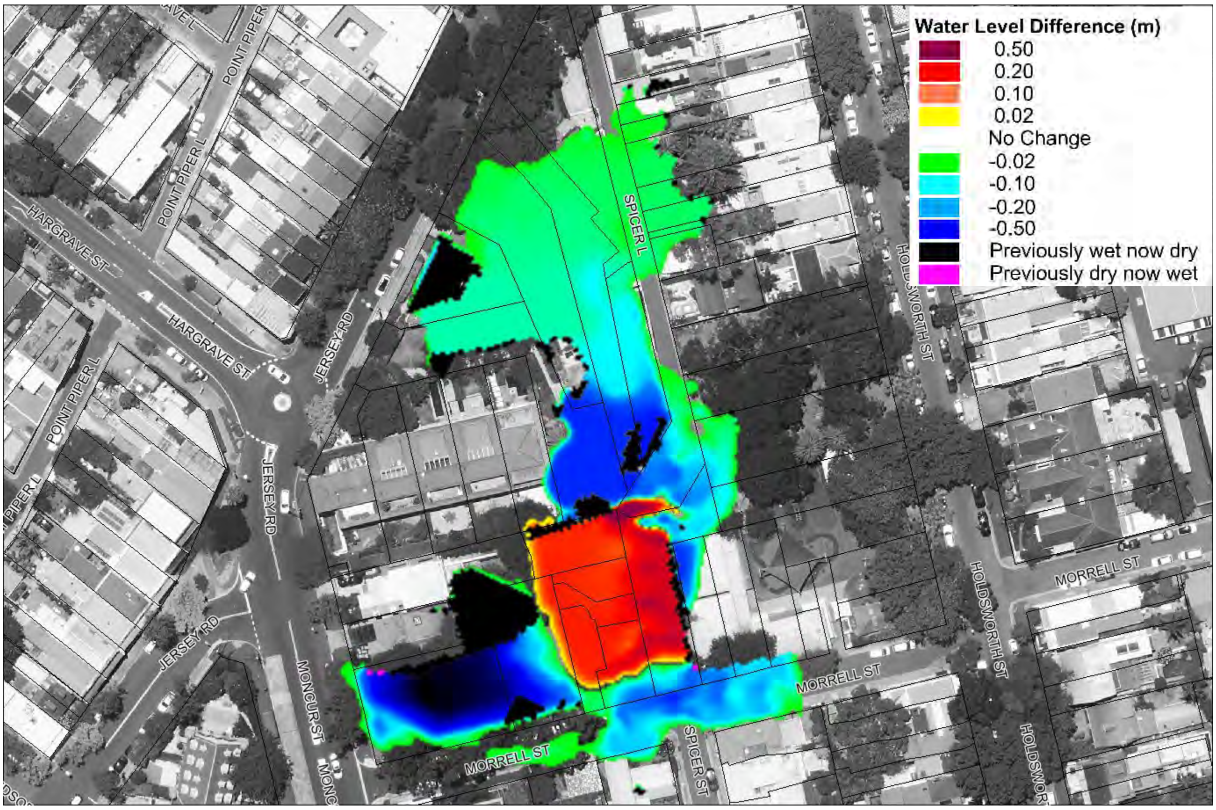


Plate 18 Peak 1% AEP Flood Level Difference Mapping for Moncur Reserve Detention Basin

The potential financial benefit associated with implementation of the detention basin was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the basin in place. The outcomes of the revised damages assessment determined that the detention basin would reduce total flood damage costs by about $1.9 million over the 50-year design life of the basin. This yielded a preliminary benefit-cost ratio of 1.4. Accordingly, the financial benefits of implementing the basin outweigh the costs.

The implementation of the basin may provide an improvement to emergency management as the basin would likely reduce the extent and depth of inundation across downstream properties and may increase the available warning time. However, it needs to be acknowledged that if the basin fails, there is likely to be a significant increase in flood risk and emergency response requirements.

The primary disadvantage associated with this option is the reduction in public amenity that would be afforded by this option. More specifically, the regrading would significantly increase grades across most sections of the park which will reduce accessibility and the potential to use this area for passive and active recreation activities. Given the highly urbanised nature of the catchment, a reduction in "usable" open space is unlikely to be supported by the local community. Therefore, despite the reductions in flood levels that are afforded by this option and the high benefit-cost, this option may be difficult to support from a public amenity/community acceptance perspective. Further consultation with the community is recommended before proceeding further with this option.

It is also likely that removal of some existing trees would be needed to implement the basin. Therefore, this option does have the potential to negatively impact on the existing environment.

Opportunities to regrade Morrel Street and redirect more flows into the park could still be explored in the short term.

Recommendation: Not recommended for implementation at this time. If there is demonstrated community support then the project will be re-examined.

5.2.3 Dillon Reserve Detention Basin

The *'Rushcutters Floodplain Risk Management Study and Plan'* (*WMA, 2012*), previously investigated the option of a Dillon Reserve basin and preliminary calculations were completed to ascertain the effectiveness of a basin at this location. The option would involve the creation of an overland flow path from Neild Street and/or Stephen Street into Dillon Reserve and works within the park to create a detention basin to control the downstream runoff.

The 2012 Study estimated that the available volume in the Reserve could be between 500 and 1500 m^3 depending on if the area is maintained for public use (side slopes 6:1, maximum depth of 1 m) or the area is fenced and solely used for stormwater detention (vertical walls, depth 1.5 m). The estimated volume of overland flow at this site, along Stephen Street and Neild Avenue is 3600 m^3 in a 10% AEP event and 7000 m^3 in a 1% AEP event.

It was determined that the effectiveness of the area for detention may be beneficial for a 10% AEP event if the maximum volume is achieved, however this would require high vertical retaining walls and would restrict any dual purpose recreational use. For events greater than the 10% AEP the basin would be less effective. Significant changes to the recreational activities would be required to construct a basin within the site and would likely receive community opposition. Furthermore, existing development to the south of the reserve would limit the ability to create a formal overland flow path into the reserve.

Therefore, this option was not considered further as part of this Floodplain Risk Management Study and Plan.

Recommendation: Not recommended for implementation.

5.2.4 Forbes Street

The results of the TUFLOW modelling indicate that at the peak of the 1% AEP flood, floodwaters overtop the western kerb of Forbes Street and flow down the pedestrian stairway and/or over the rock wall between Forbes Street and Sutherland Avenue. There is also historic evidence of significant overland flows from Forbes Street cascading down into Sutherland Avenue (refer to **Plate 11**).

Therefore, opportunities were explored to undertake localised road regrading and kerb works to create a small "detention area" for floodwaters to reduce or prevent floodwaters from Forbes Street overtopping the kerb and draining into Sutherland Avenue. The design concept for this option is presented in **Plate 19**.

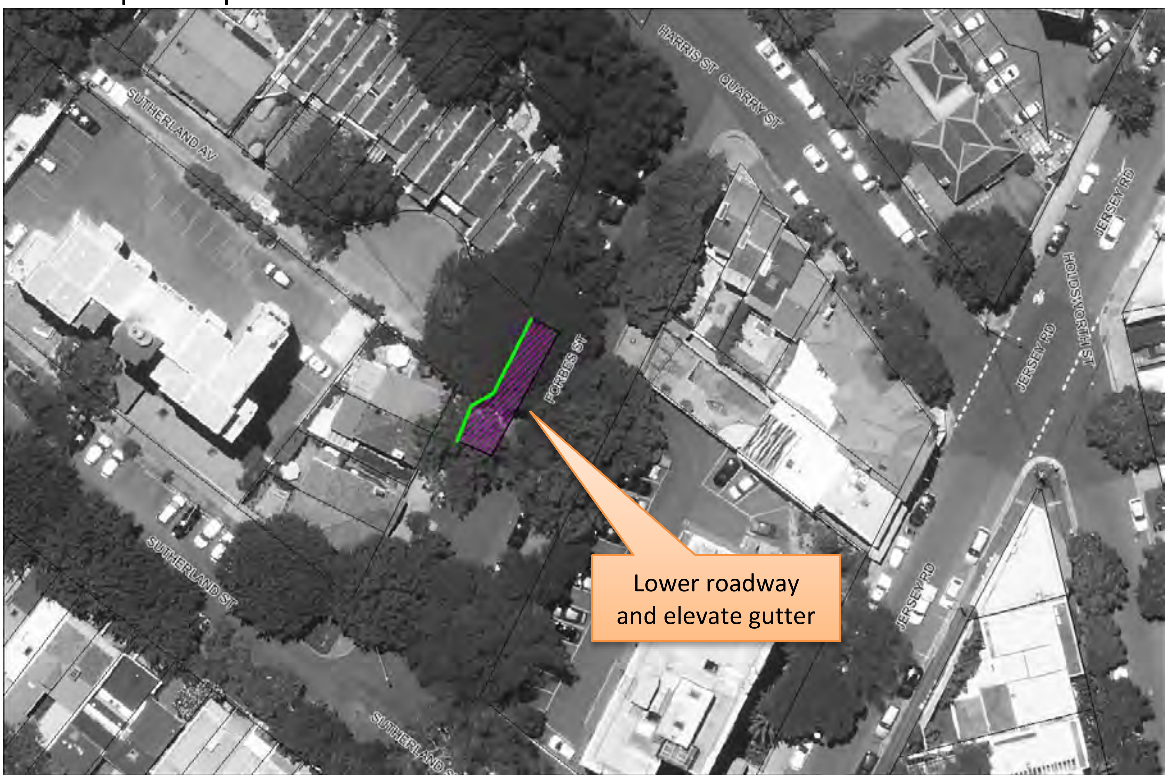


Plate 19 Design concept for Forbes Street Basin

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 20** and **Plate 21**.

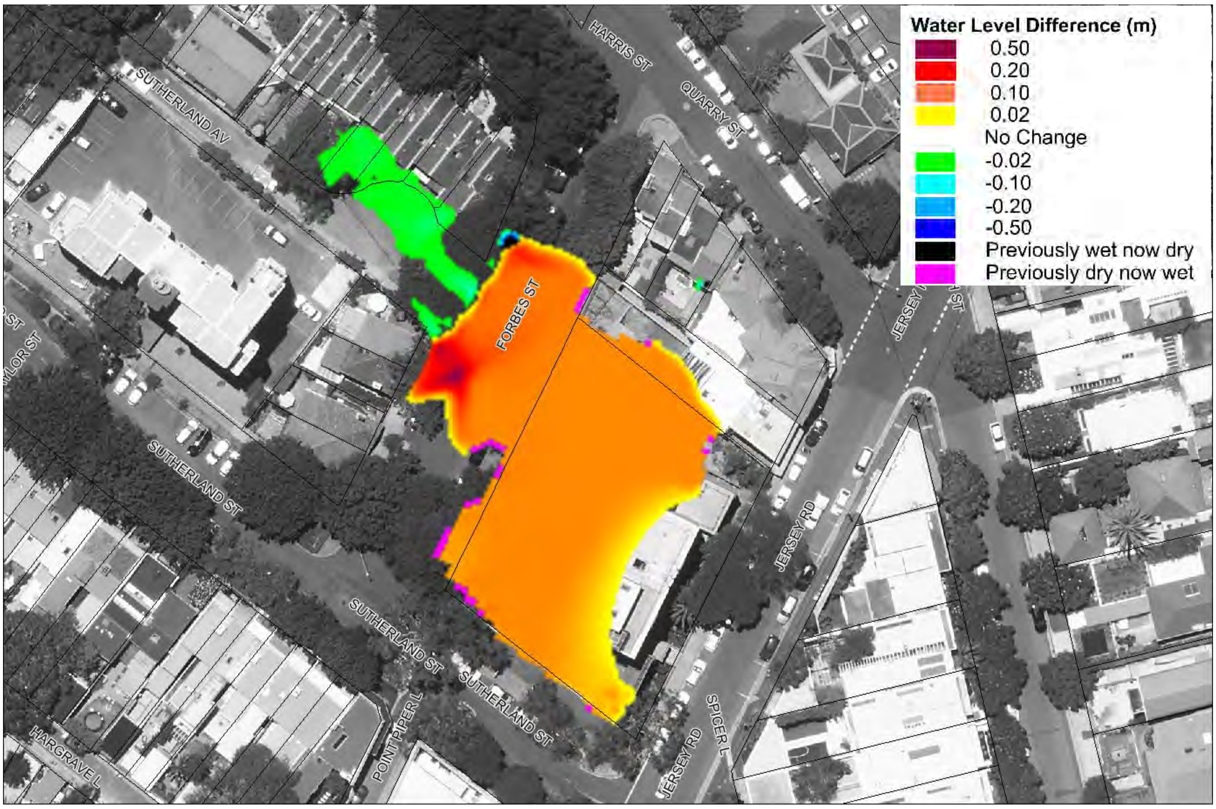


Plate 20 Peak 20% AEP Flood Level Difference Mapping for Forbes Street Basin

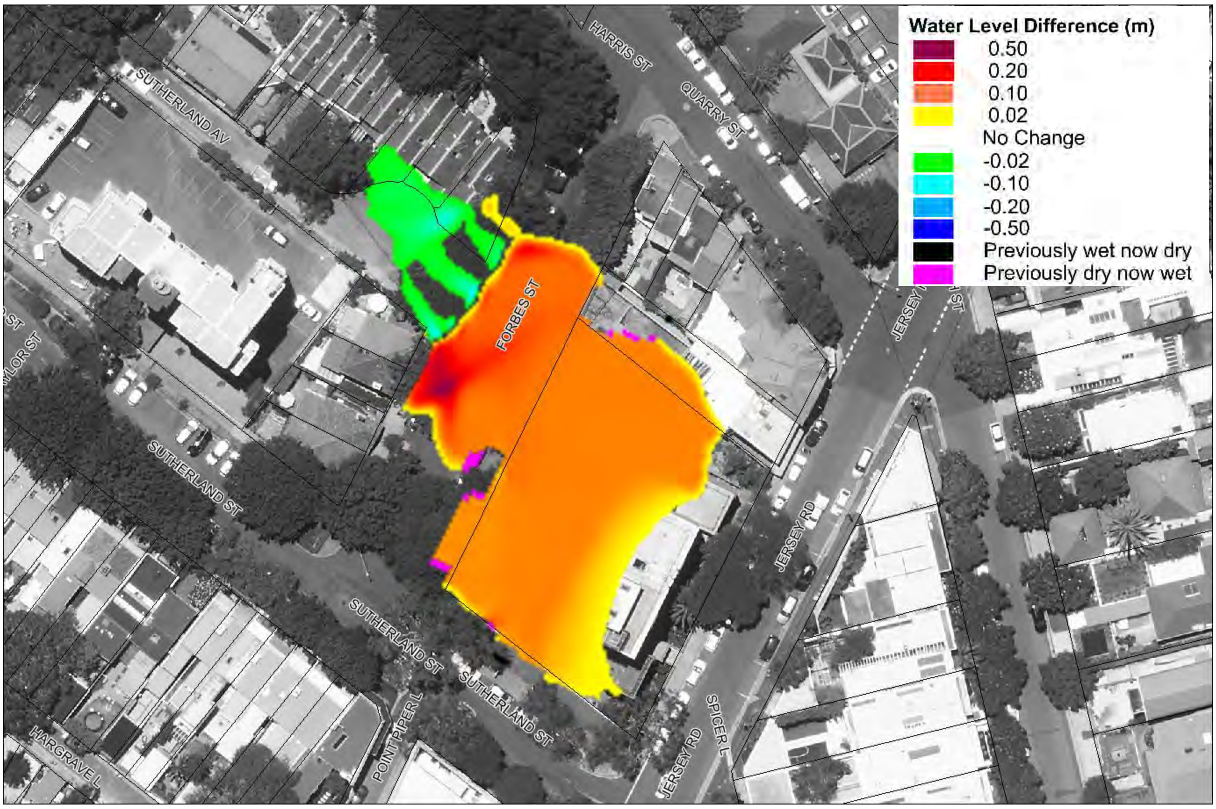


Plate 21 Peak 1% AEP Flood Level Difference Mapping for Forbes Street Basin

Plate 20 and **Plate 21** show that the roadworks in Forbes Street are predicted to generate reductions in peak 20% and 1% AEP flood levels of up to 0.05 and 0.08 metres, respectively.

However, the difference mapping does indicate significant increases in peak 20% and 1% AEP flood levels of 0.5 meters within the property at 8 Forbes Street. Increases are also predicted within other residential properties, such as 6 Forbes Street and 212 Jersey Road, and the Forbes Street roadway itself. During the 1% AEP flood, increases in peak flood levels of up to 0.2 metres are also predicted downstream of the proposed works, within residential properties located at western end of Sutherland Avenue.

Although this option affords some minor benefits to some properties along Sutherland Avenue, it is predicted to worsen the flood impacts across a number of properties in Forbes Street/Jersey Road. Therefore, this option is not recommended for implementation.

Recommendation: Not recommended for implementation.

5.2.5 Mini Detention Throughout Catchment

Feedback received from the community indicated that there may be some benefit in installing multiple small detention storages throughout the catchment to reduce flooding downstream during significant flood events (rather than bigger basins at discrete locations). This option was considered based on the results of the flood modelling as well as suggestions provided by the community.

The criteria used to determine suitable locations was limited to areas of existing open space that could be excavated, underground storage installed, and surface reinstated to its original purpose. To provide a benefit, the area of open space would need to be located near an overland flow path or existing stormwater infrastructure to allow water to be readily distributed to the storage area. Locations which could provide some minor above ground storage were also considered (e.g., the end of cul-de-sacs). The underground storages would be "offline" storages that would only be utilised once the capacity of the existing pipe system is exceeded.

Locations that were identified based upon the criteria outlined above are shown in **Plate 22** and includes.

- Grassed open space at the intersection of Elizabeth St and Windsor St (25m^3 underground storage below open space connected to adjacent stormwater system);
- A reserve at the intersection of Cascade St and Sutherland St (22m^3 underground storage and above ground storage were considered feasible);
- The cul-de-sacs of Roylston St (14m^3) and Cecil St (23m^3) where storage would be installed beneath the roadway surface and flows stored before draining to the existing stormwater system; and
- Open space within the 4-8 Hampden St premises where underground storage (75m^3) could be provided.

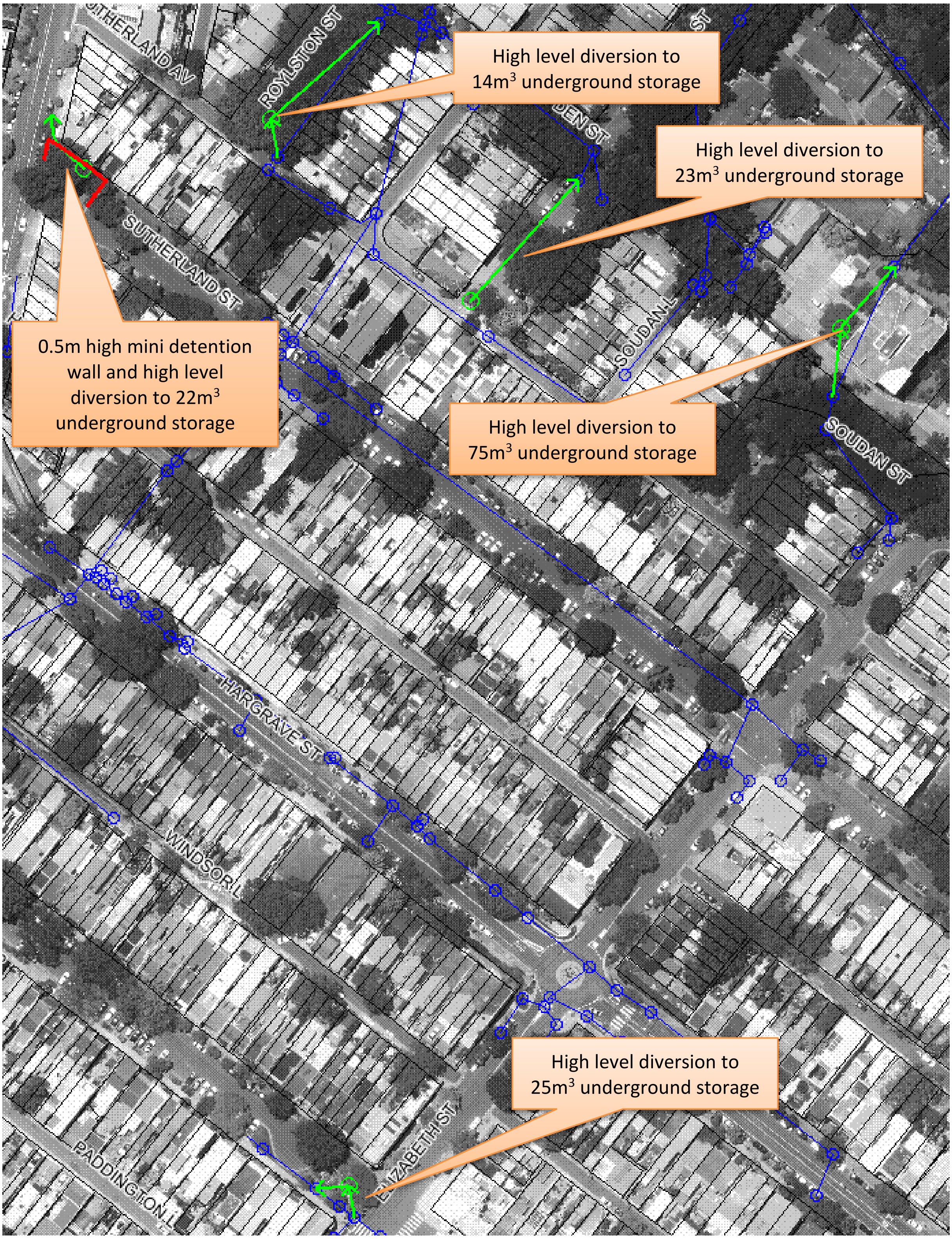


Plate 22 Design concept for Mini Detention Basins

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place was prepared and are presented in **Plate 23** and **Plate 24.**

Plate 23 Peak 20% AEP Flood Level Difference Mapping for Mini Detention Throughout Catchment

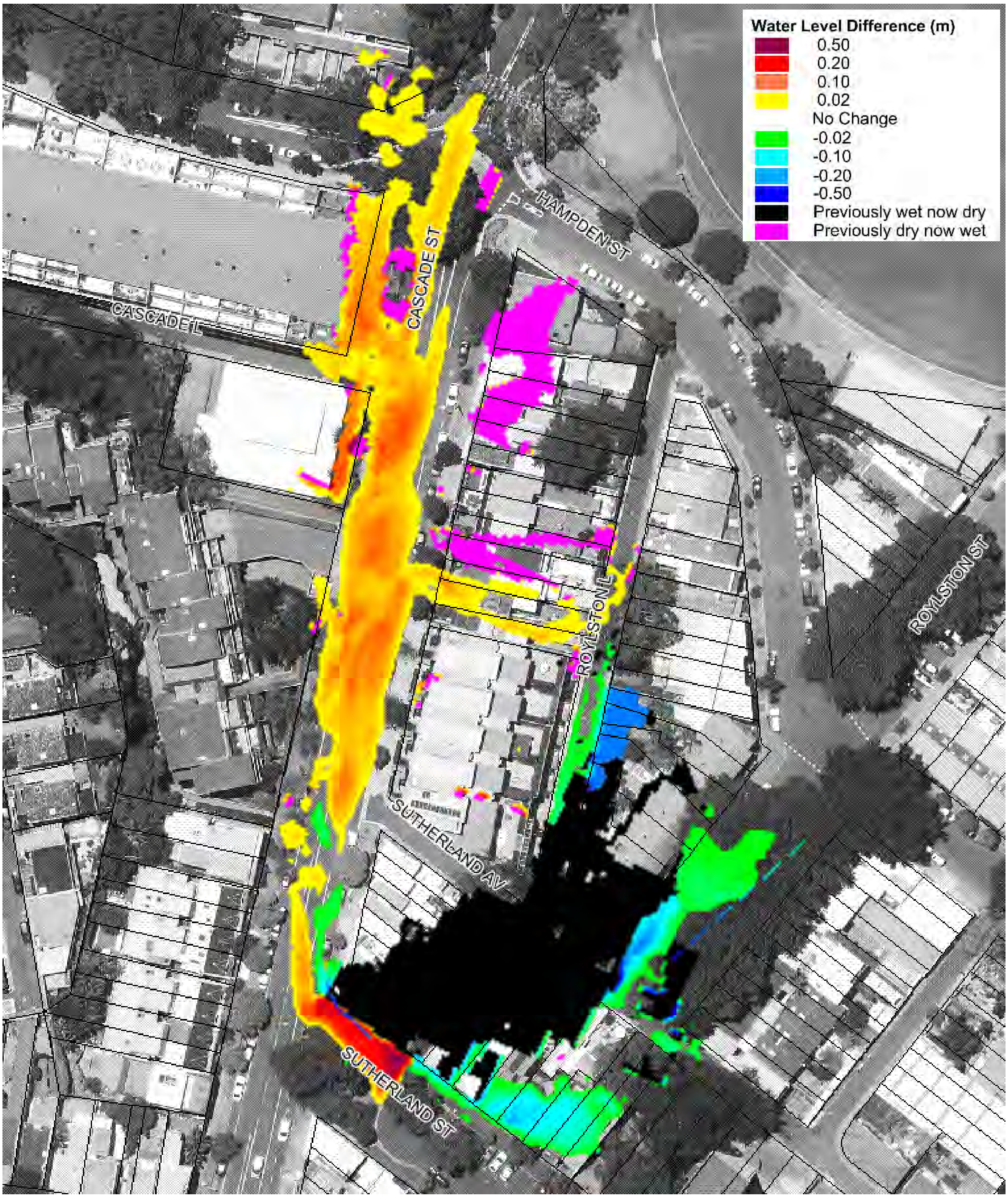


Plate 24 Peak 1% AEP Flood Level Difference Mapping for Mini Detention Throughout Catchment Option

The difference mapping showed that the underground storage did not afford any significant hydraulic benefits. This is considered to be a function of the limited capacity of the existing drainage system. As a result, water is directed into each storage early during each flood resulting in each of the storage being "full" by the time the peak of the flood arrives (i.e., negligible reduction in flood peaks.

Plate 23 and **Plate 24** show that the earthworks associated with the above ground storage at the intersection of Sutherland St and Cascade St does provide some benefit to a number of properties located immediately downstream of the proposed works. Reductions in peak 20% and 1% AEP flood levels of up to 0.2 metres are predicted.

However, the difference mapping does indicate increases in peak 20% and 1% AEP flood levels of over 0.1 meters within properties between Cascade St and Roylston Lane. Increases are also predicted on Cascade St, particularly near the corner of Glenmore Road.

Although this option affords some minor benefits to some properties along Sutherland Avenue, it is predicted to worsen the flood impacts across a number of properties between Cascade St and Roylston Lane. Additionally, the effectiveness of the underground storage is limited by the low efficiency of the existing drainage network. Therefore, this option is not recommended for implementation.

Recommendation: Not recommended for implementation.

5.2.6 Elizabeth Place Below Ground Detention

This option would involve the installation of an underground storage tank in an existing open space at the rear of 436 to 444 Oxford Street. The goal of the tank would be to capture all runoff from the catchment located upstream of George Street, thereby reducing flood levels within George Street itself as well as areas downstream of George Street. This option would also require installation of additional and upgraded stormwater pits and pipes in George Street and between George Street and the tank to provide sufficient capacity to convey runoff from George Street into the storage tank. The suggested location of the underground storage tank and the extent of the drainage upgrades is shown in **Plate 25.**

Initial model simulations were completed to confirm the required tank volume to store all runoff during rainfall events up to and including the 1% AEP flood. This determined the required tank volume would need to be 2,250m^3 (i.e., approximately the same size as an Olympic swimming pool). Assuming the tank occupies the "footprint" shown in **Plate 25**, this would require a 4.5 metre deep storage to be provided. The significant depth would mean the system could not operate under gravity and a pump would need to be installed to drain the tank following each rainfall event. It is envisaged that the area above the tank would be landscaped and would provide an area of common open space.

To confirm the impact that the underground storage tank would have on existing flood behaviour, the TUFLOW flood model was updated to include a representation of the tank and associated stormwater modifications. The updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place was prepared and are presented in **Plate 26** and **Plate 27.**

The difference mapping shows that the underground storage tank is predicted to reduce peak 20% and 1% AEP flood levels at the low point on George Street by approximately 0.4 metres. **Plate 26** and **Plate 27** shows that the storage tank also provides benefits to a number of properties located downstream of the proposed works. This includes flood level reductions of up to 0.15 metres during the 20% flood and flood level reductions approaching 0.2 metres during the 1% AEP flood. However, the benefits of the option gradually diminish moving downstream as additional catchment areas contribute runoff to the main flow path. Minimal flood level reductions are afforded downstream of Paddington and Cascade Streets.

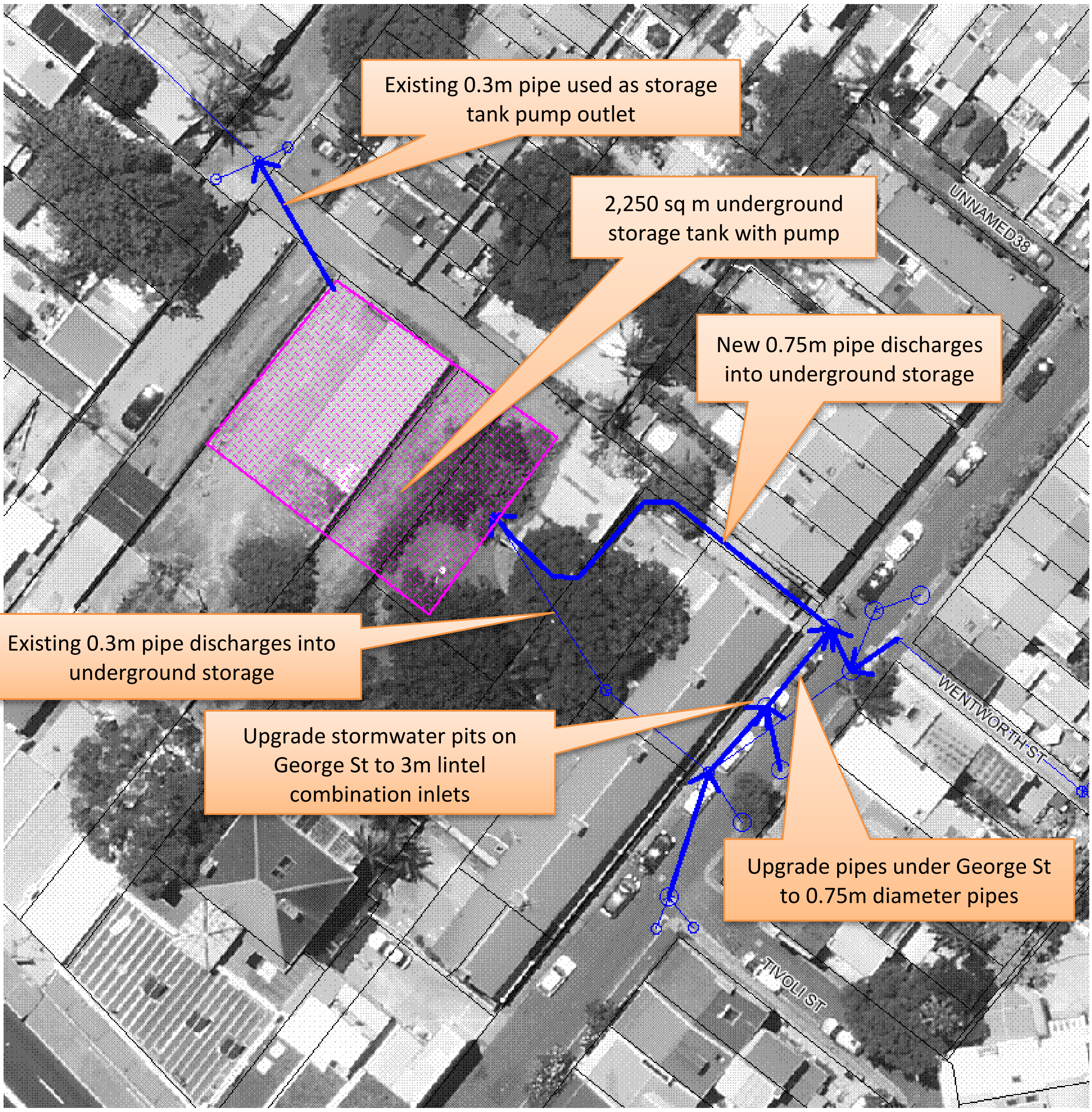


Plate 25 Design concept for Elizabeth Place Below Ground Detention

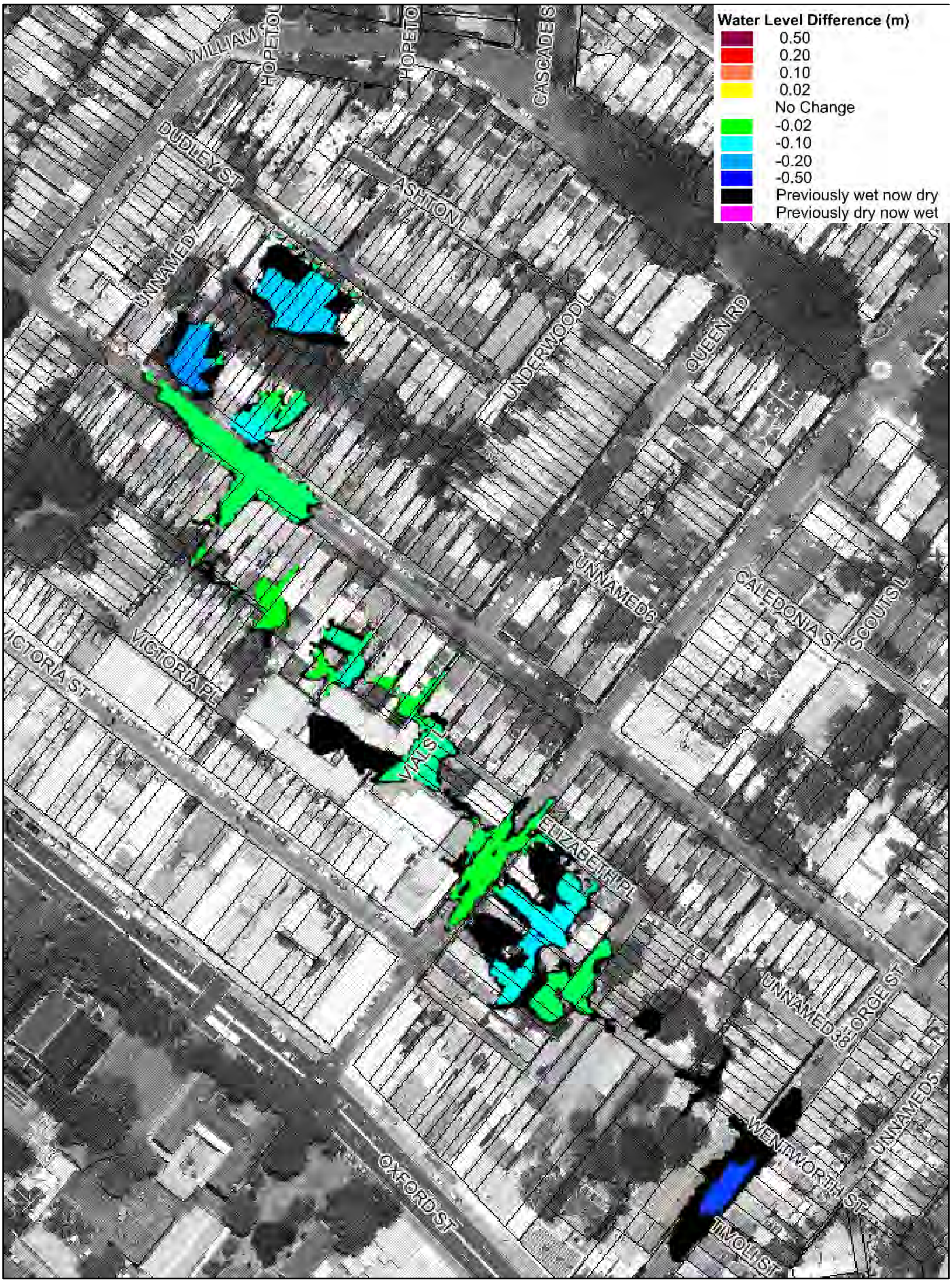


Plate 26 Peak 20% AEP Flood Level Difference Mapping for Elizabeth Place Below Ground Detention

Plate 27 Peak 1% AEP Flood Level Difference Mapping for Elizabeth Place Below Ground Detention

As shown in **Plate 25**, the underground storage tank would need to be installed on private property. In addition, the new stormwater pipes would need to be installed through private property. Accordingly, coordination and support from each of the landowners would need to be secured in order for this option to proceed. It is likely that the land required for the installation of the tank would need to be purchased from each of the landowners, which will significantly add to the overall implementation cost of the option.

The cost to implement the underground storage is estimated to be over $13 million. Accordingly, the capital cost of this option is substantial. A significant proportion of this cost is associated with the land acquisition, which has been estimated based on the current average market rate for the area. A detailed breakdown of the cost is provided in **Appendix C**.

The potential financial benefit associated with implementation of the underground storage was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the storage in place. The outcomes of the revised damages assessment determined that this option would reduce total flood damage costs by approximately $5.9 million over the 50-year design life. This yielded a preliminary benefit-cost ratio of 0.4. Accordingly, the financial benefits of implementing this option are not predicted to outweigh the costs.

As alternate storage tank option involving installation of a smaller tank that operated under gravity was also explored (maximum storage depth of 1.5m). However, this was found to "fill" during the early stages of most rainfall events and, as a result, provided only small reductions in flood levels (i.e., less than 0.1 metres). Furthermore, the overall implementation costs would not reduce significantly as the land acquisition costs would remain essentially unchanged. Accordingly, this option was not pursued further.

Overall, this option does afford hydraulic and flood damage reduction benefits across a number of properties located between George Street and Cascade Street. However, the high implementation cost and low benefit cost ratio limits the viability of this option. Furthermore, there are other options for this area that would provide improved economic performance and greater hydraulic benefits. Accordingly, it is recommended that the drainage upgrade option discussed in Section 5.5.8 be pursued in preference to this option.

Recommendation: Not recommended for implementation.

5.3 Channel Modifications

5.3.1 General

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

- Removal of vegetation
- Removal of blockages
- Construction of auxiliary flow paths
- Channel widening/deepening

A discussion on potential channel modifications that could be implemented across Paddington are discussed below.

5.3.2 Sutherland Avenue Overland Flow Path

The area between Sutherland Avenue and Harris Street is predicted to be exposed to a significant flood risk. The flood risk is primarily associated by the steep slopes across the area, which are predicted to produce significant flow velocities during the larger design floods.

It was noted that there is an existing park located at 49-51 Sutherland Avenue. The park currently provides a pedestrian connection from Sutherland Avenue to the eastern end of Harris Street (refer to **Plate 28**). Therefore, there may be an opportunity to create an overland flow path through this park to redirect floodwaters that currently discharge through properties in Sutherland Avenue.

Plate 28 Park at 49-51 Sutherland Avenue (Google, 2017)

A design concept for the overland flow path is provided in **Plate 29**. As shown in **Plate 29**, this option would involve regrading in Sutherland Avenue to capture and divert overland flow into the park as well as regrading through the park to prevent water from spilling across adjoining properties. A new 450mm diameter pipe and pit is also proposed to capture low flows.

The hydraulic impacts of this option were quantified by including the option in the TUFLOW model and using the model to re-simulate design flood behaviour with the new floodway in place. Floodwater difference mapping was prepared from the results of the modelling for the 20% and 1% AEP events and is presented in **Plate 30** and **Plate 31**.

Plate 30 and **Plate 31** show that the Sutherland Avenue overland flow path is predicted to generate reductions in peak 20% and 1% AEP flood levels across a number of properties along Sutherland Avenue (up to 0.4 metres and 0.3 metres, respectively).

However, the difference mapping also indicates significant increases in peak 20% and 1% AEP flood levels at some locations. In particular, increases in peak flood level of up to 0.3 metres are predicted across some existing properties in Harris Street.

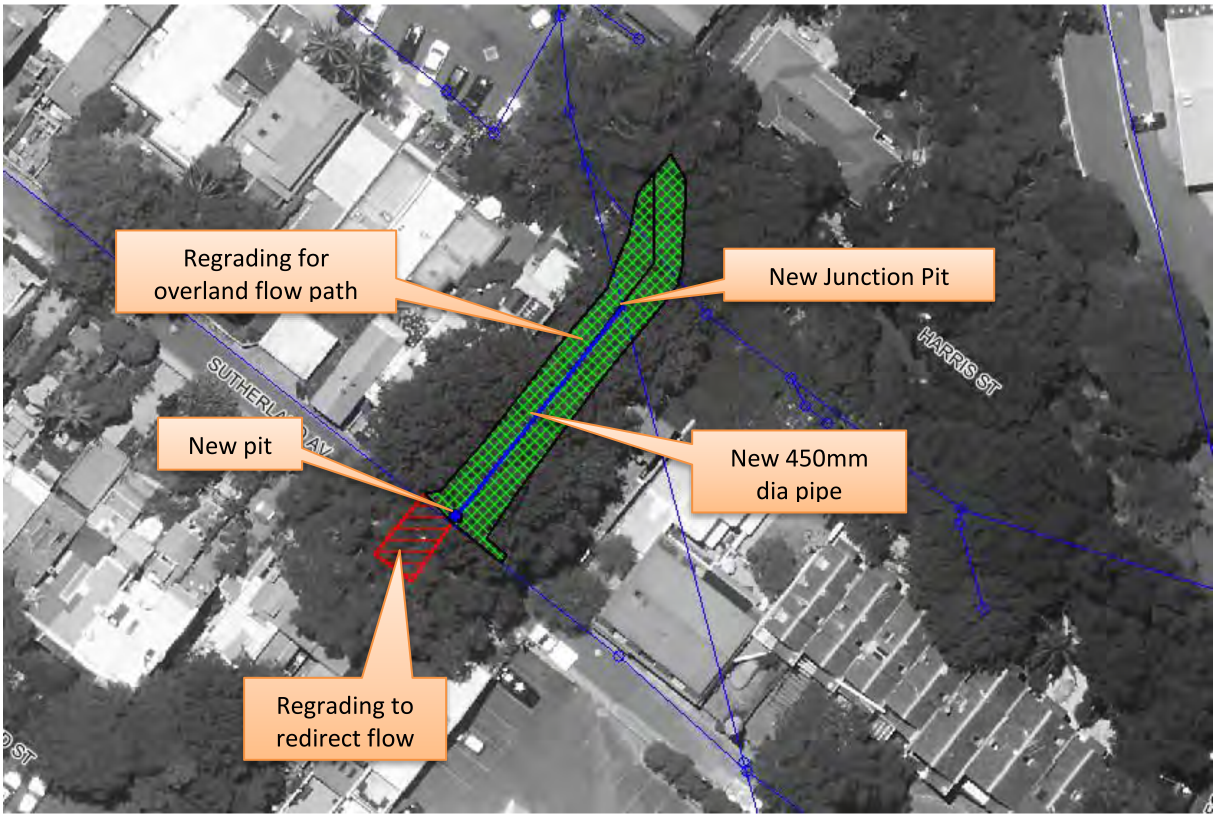


Plate 29 Design concept for Sutherland Avenue Overland Flow Path

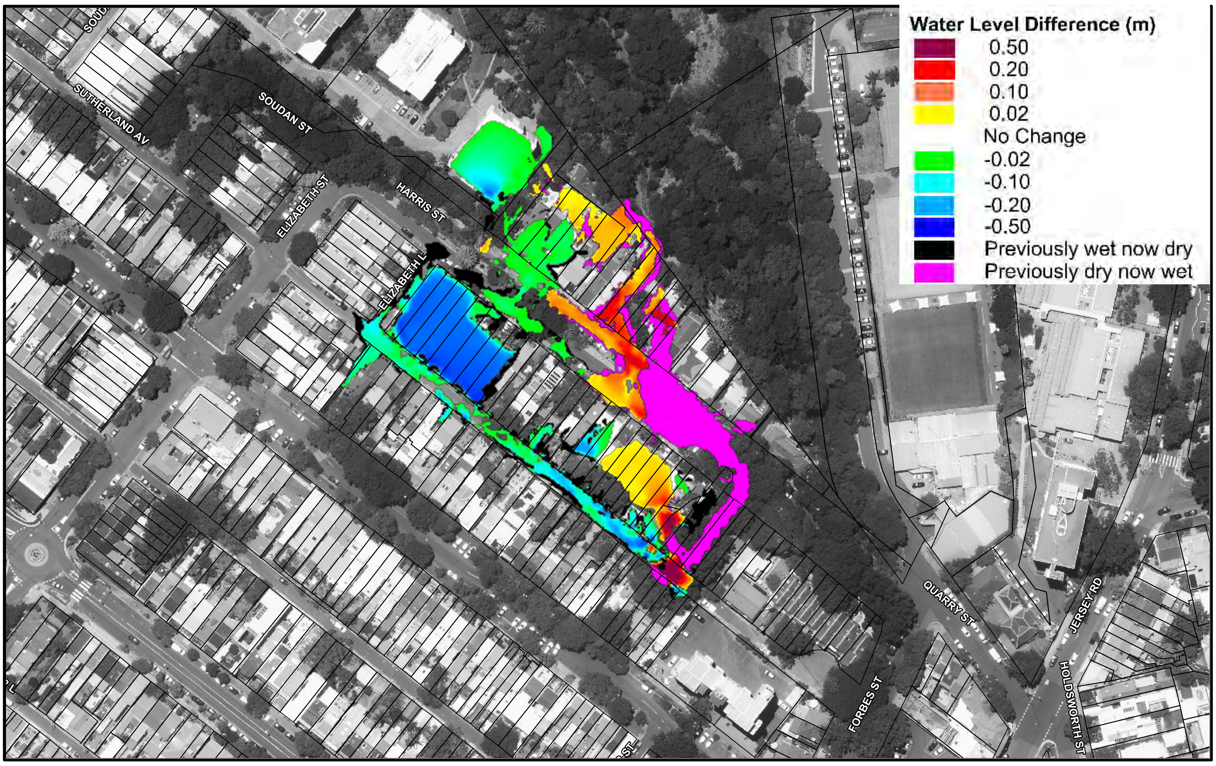


Plate 30 Peak 20% AEP Flood Level Difference Mapping for Sutherland Avenue Overland Flowpath

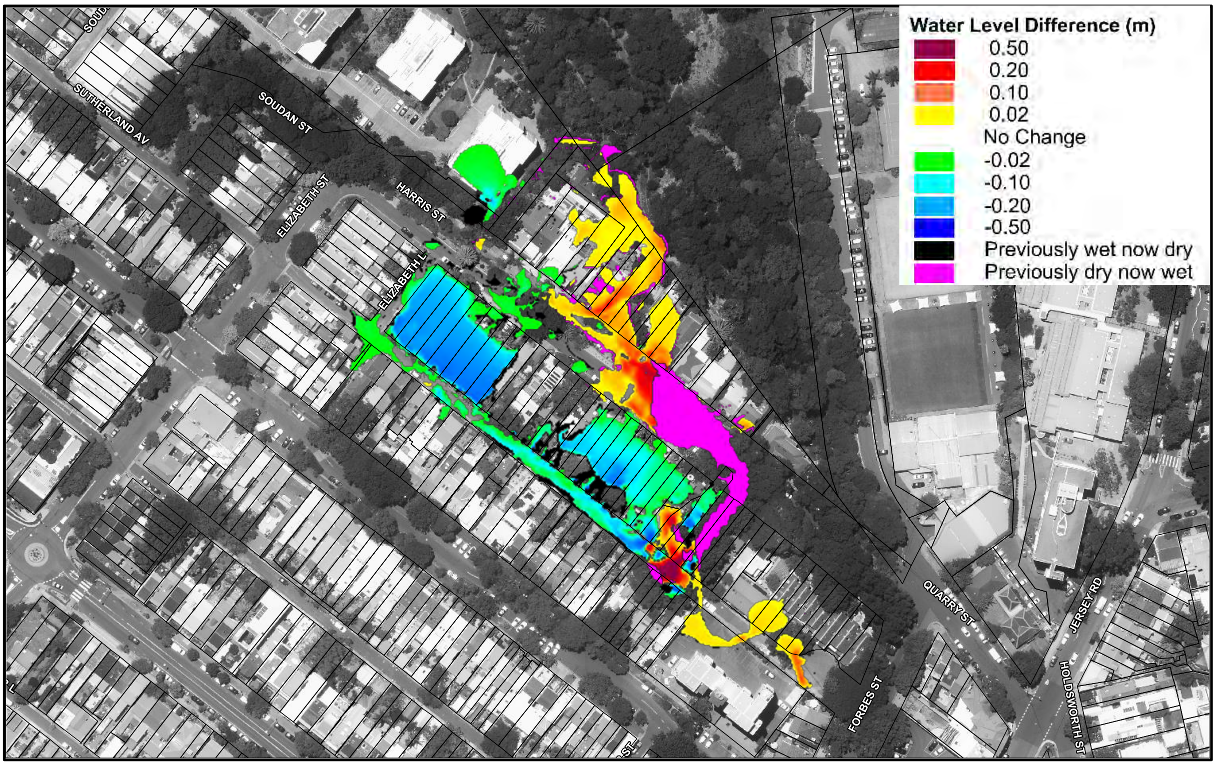


Plate 31 Peak 1% AEP Flood Level Difference Mapping for Sutherland Avenue Overland Flowpath

Therefore, although this option affords some benefits to properties along Sutherland Avenue, it is predicted to worsen existing flooding within a number of properties along Harris Street. Therefore, this option was not considered further and is not recommended for implementation.

Recommendation: Not recommended for implementation.

5.3.3 Cecil Street Flood Mitigation Measures

Properties adjoining Cecil Street and Cecil Lane are arguably the most significantly impacted by flooding in Paddington. Although previous mitigation works at the northern end of Cecil Lane and Trumper Oval have reduced flooding impacts in this area, a significant flood risk remains. The primary cause of the residual flood risk is a major topographic flow obstruction near the northern end of Cecil Street.

There are a number of options that could be potentially implemented to assist in reducing the existing flood risk in Cecil Street. These include:

- Floodway between Cecil Street and Trumper Oval
- Culvert between Cecil Street and Trumper Oval
- Flood proofing individual flood affected properties in Cecil Street.

An investigation into the feasibility and potential benefits of the floodway and culvert was undertaken. Floodwater difference mappings were prepared from the results of the modelling of the Cecil Street Floodway and Cecil Street Culvert options for the 1% AEP event and are presented in **Plate 32** and **Plate 33** respectively.

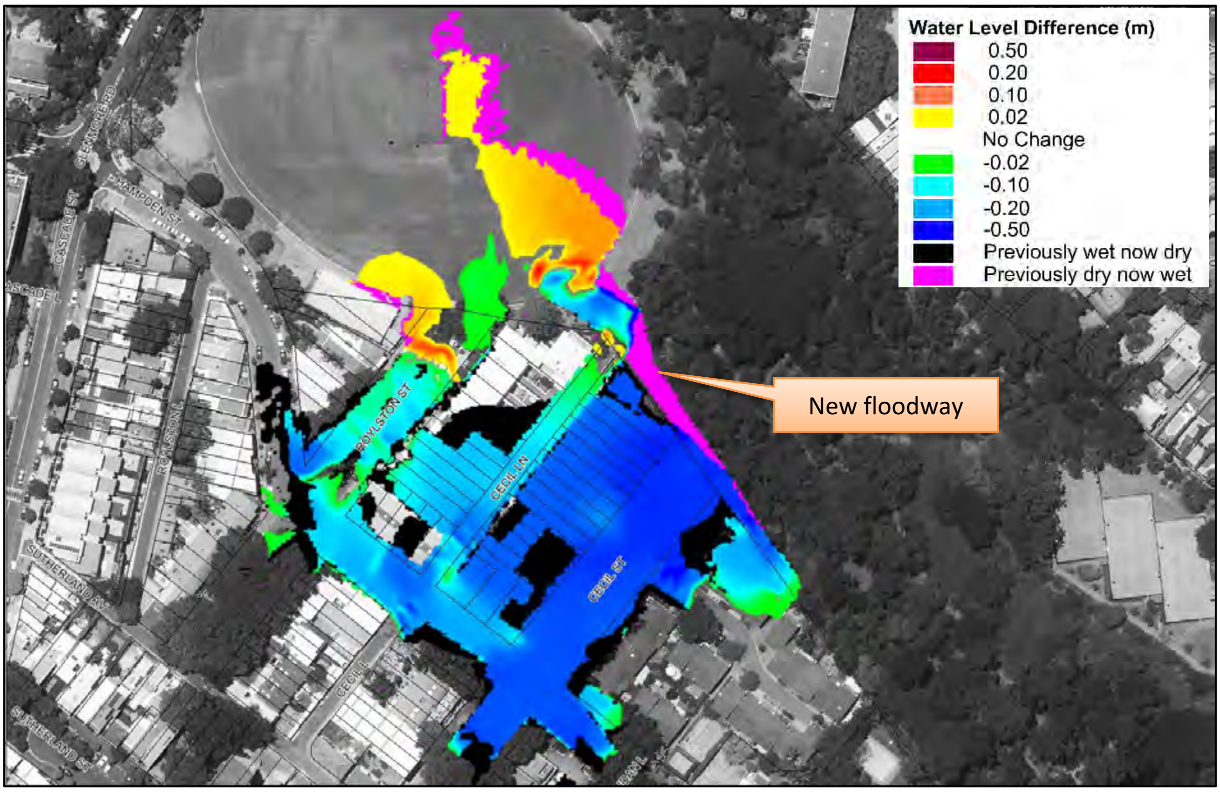


Plate 32 Example of Peak 1% AEP Flood Level Difference Mapping for the Cecil Street Floodway

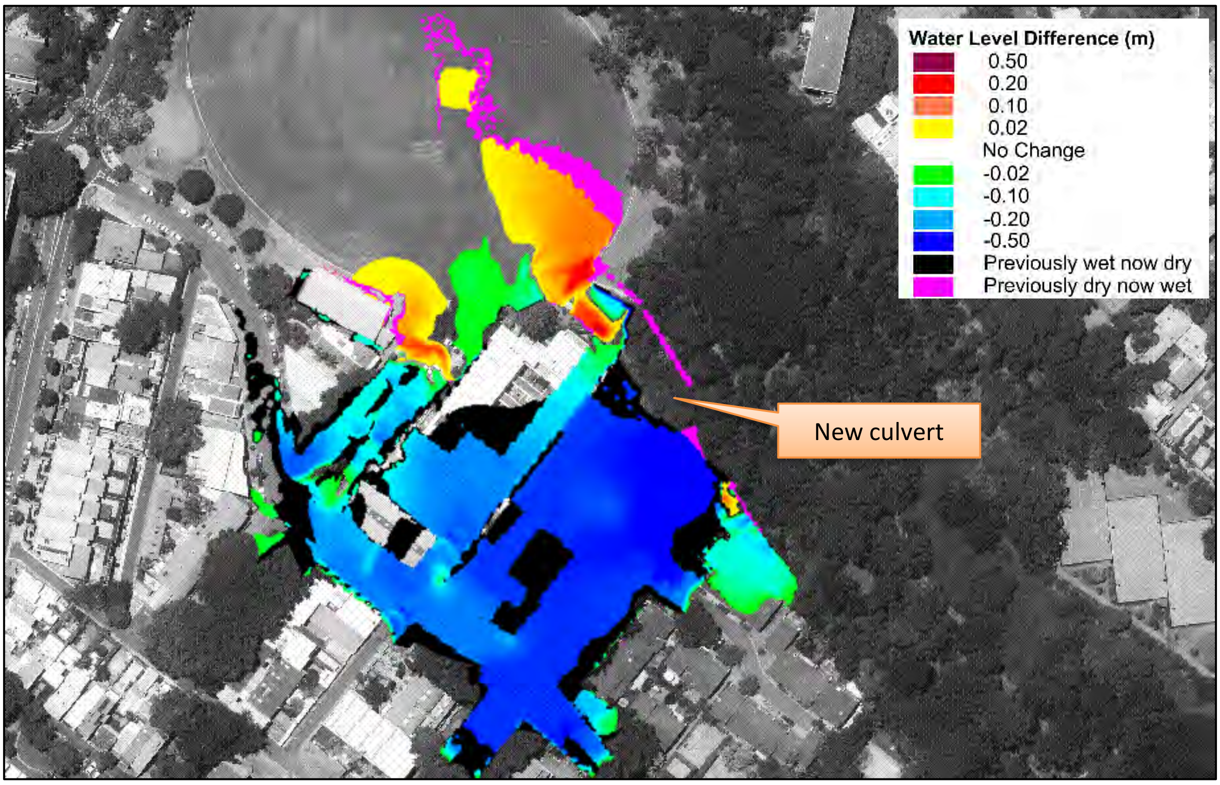


Plate 33 Example of Peak 1% AEP Flood Level Difference Mapping for the Cecil Street Culvert option

This preliminary assessment indicated that both of these options are predicted to reduce flood levels along the northern sections of Cecil St and reduced the number of properties in Cecil Street predicted to experience over floor flooding during all design events. Accordingly, the hydraulic benefits of the options are significant and either of the options is considered worth pursuing.

A resident did note that a manhole cover located at the northern end of Cecil Lane frequently gets "blown off" during rainfall events leading to damage of adjoining properties. It is recommended that options for overcoming this problem be explored as part of the Cecil Street works.

Given the complex nature of these options and their potential impacts on Trumper Park, trees/vegetation and on the streetscape of Cecil Street, multiple designs were developed, and hydraulic analysis of each design was undertaken outside of this study. Each option yielded a positive benefit cost ratio indicating that these options are worth implementing. It is recommended that detailed design plans be prepared for the preferred option.

Recommendation: Recommended for implementation.

5.3.4 Trumper Park Floodway

This option would look to create a floodway extending south from Cecil Street to provide additional conveyance capacity through Trumper Park. This would aim to reduce the frequency of water spilling through the apartment buildings located at 4-8 Hampden Street. However, it should be noted that the ultimate Trumper Park Floodway design would be dependent on the design of the Cecil Street flood mitigation measures as it would be an extension of the Cecil Street Floodway or Box-Culvert option described in Section 5.3.3.

The design concept for this option is provided in **Plate 34**. The concept is identical to the Cecil Street floodway; however, the upstream channel regrading would extend a further 170 metres upstream. It is envisaged that this channel would comprise a rectangular cross-section with a width of at least 3 metres and a depth of at least 0.5 metres. This would likely necessitate a retaining wall on the northern side of the channel.

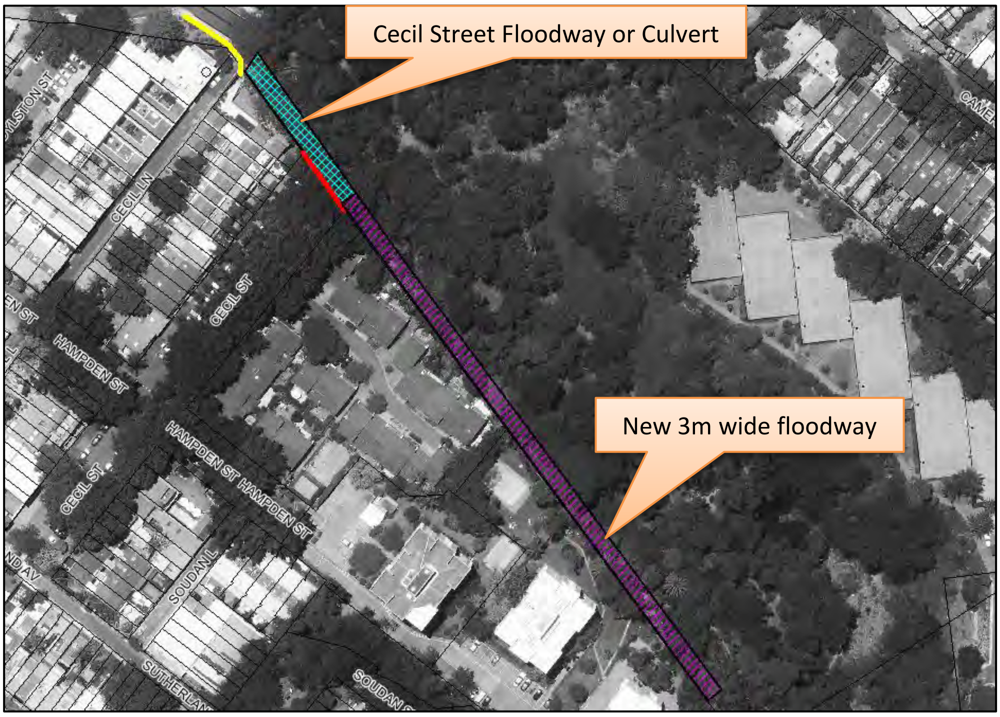


Plate 34 Design concept for Trumper Park Floodway (purple hatched area)

The Trumper Park floodway was included in the TUFLOW model and was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option were prepared and are presented in **Plate 35** and **Plate 36**.

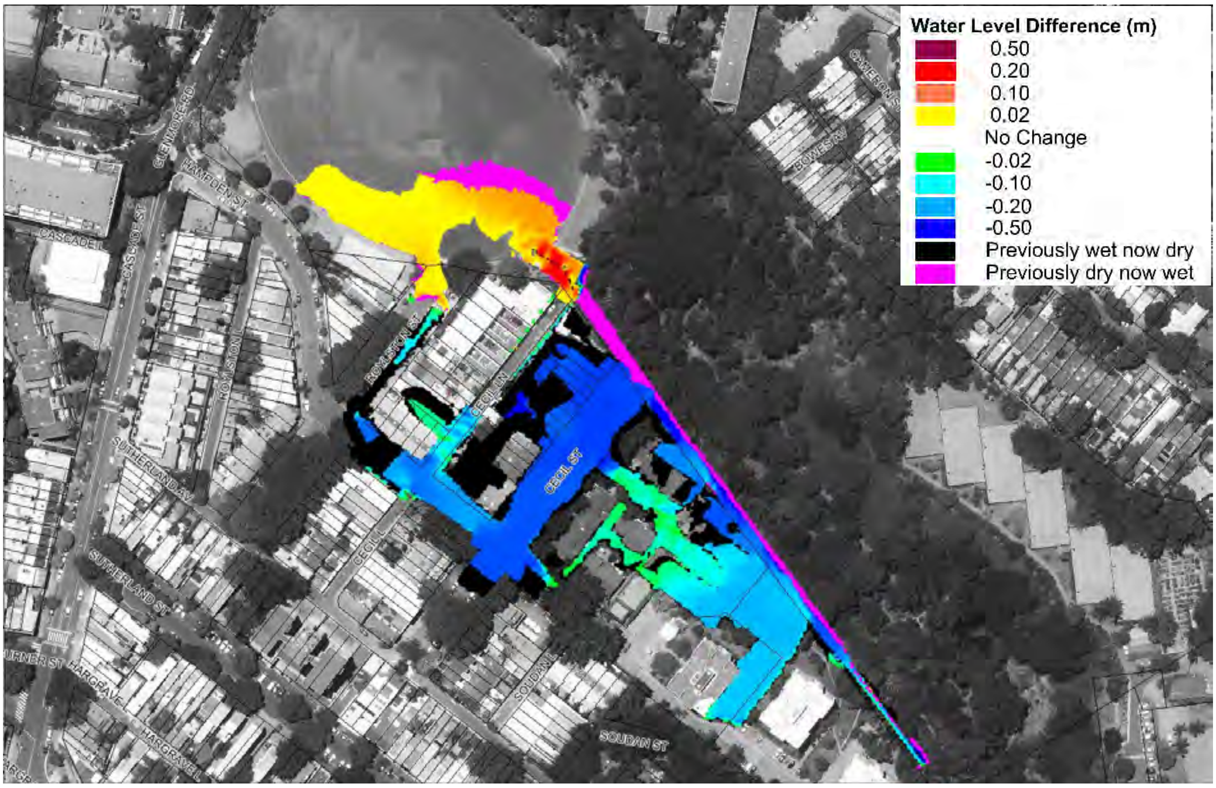


Plate 35 Peak 20% AEP Flood Level Difference Mapping for Trumper Park Floodway

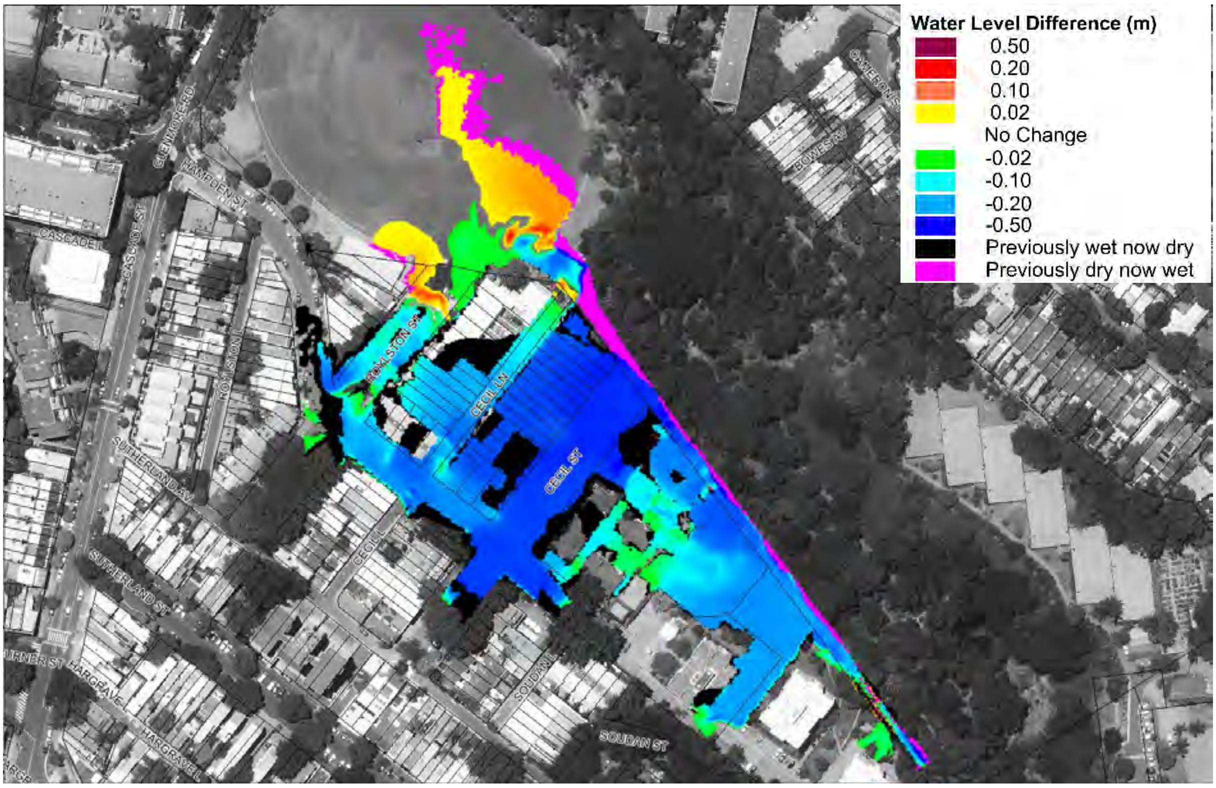


Plate 36 Peak 1% AEP Flood Level Difference Mapping for Trumper Park Floodway

Plate 35 and **Plate 36** show that the Trumper Park floodway is predicted to generate similar reductions in flood level to the Cecil Street floodway across Cecil Street, Cecil Lane and Hampden Street. However, the Trumper Park floodway would afford greater flood level reductions across properties located upstream of Cecil Street. More specifically, flood level reductions of between 0.1 and 0.4 metres are predicted across properties located at 21 Cecil Street as well as 4-8 Hampden Street.

The difference mapping shows flood level increase across part sections of Trumper Oval, Cecil Lane and Royalston Street. However, these flood level increases are contained to the roadways/oval and are not predicted to extend across any existing residential properties.

The reductions in flood levels are predicted to result in 14 fewer properties being exposed to above floor inundation during the 20% AEP flood (4 more than the Cecil Street floodway) and 11 fewer properties during 1% AEP flood (2 more than the Cecil Street floodway).

A cost estimate for the Trumper Park floodway was prepared and is enclosed in **Appendix C**. This indicates that construction of the floodway is expected to cost about $240,000 (this assumes construction commences immediately after completion of the Cecil St Flood Mitigation Works to reduce site disestablishment/reestablishment costs).

The potential financial benefit associated with the regrading was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the Trumper Park floodway as well as the Cecil Street floodway in place. The outcomes of the economic assessment yielded a benefit cost ratio of much greater than 1. Accordingly, the financial benefits of implementing this option are predicted to be significantly higher than the costs.

Removal of some trees and vegetation may be required within Trumper Park to construct the floodway. Therefore, there is potential for this option to have a small negative impact on the environment.

Overall, the high benefit-cost ratio coupled with significant reductions in flood levels and number of properties exposed to above floor inundation indicate this option is worth implementing. However, it is recommended that the Cecil Street Floodway is implemented first before the additional channel upgrades associated with the Trumper Park floodway are completed.

Recommendation: Recommended for further investigation and implementation following completion of the Cecil Street mitigation measures.

5.3.5 Channel Widening Downstream of Glenmore Road

Properties adjoining the open channel downstream of Glenmore Road have reported inundation on several occasions including significant damage to property immediately adjoining the channel. Several residents suggested that the channel is undersized and suggested that the channel should be widening to increase the flow carrying capacity and reduce the frequency of overtopping of the channel banks.

The design concept for this option is presented in **Plate 37** and would involve increasing the width of the existing concrete channel downstream of Glenmore Road from 4 metres to 8 metres. The only major constraint to this widening is existing tennis courts located within the White City complex. Some minor regrading at the "sag" point" in Glenmore Road is also recommended as part of this option to assist in more readily directing flow from the roadway and flow path from Trumper Oval into the widened channel.

Plate 37 Design concept for channel widening downstream of Glenmore Road

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 38** and **Plate 39**.

Plate 38 and **Plate 39** show that the amplification of the channel downstream of Glenmore Road is predicted to result in reductions in peak 20% and 1% AEP flood levels more than 0.5 metres along the channel. However, the reductions in flood levels across adjoining residential properties is less significant (i.e., less than 0.1 metres).

Due to the relatively minor reductions in flood levels and the significant cost associated with implementing this option, channel widening downstream of Glenmore Road is not recommended for implementation.

Recommendation: Not recommended for implementation

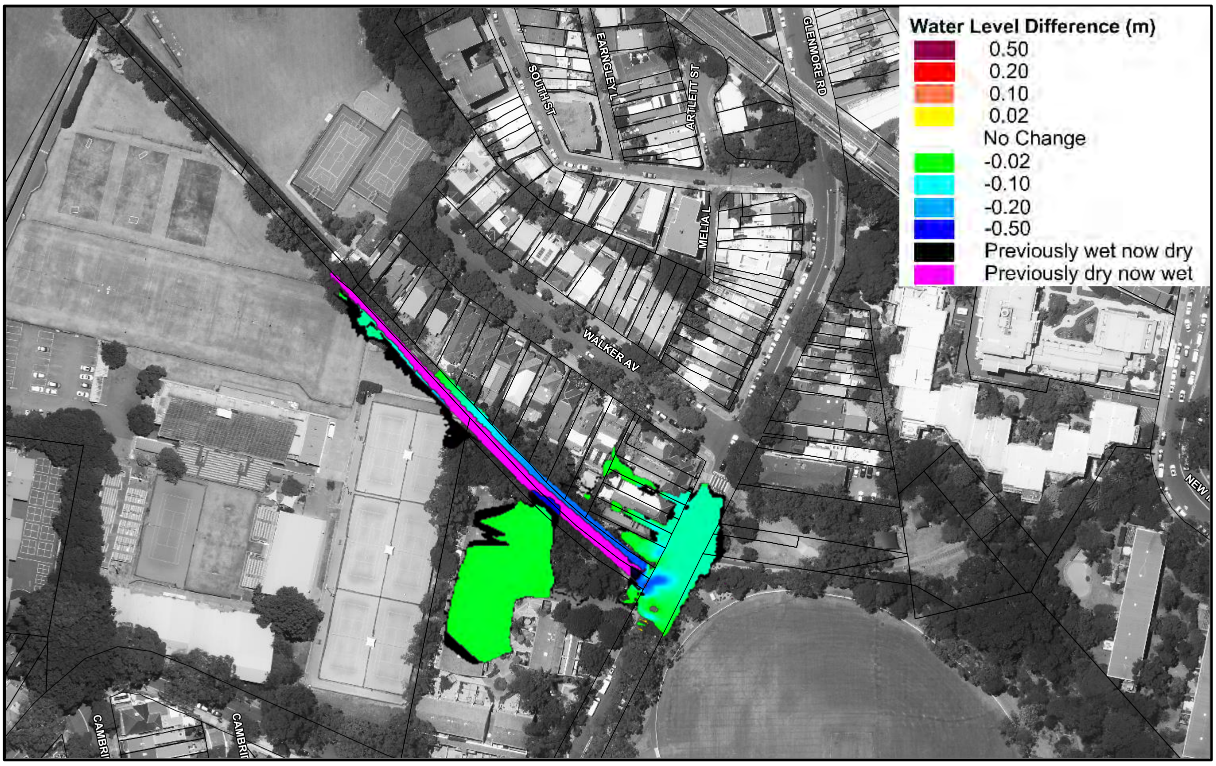


Plate 38 Peak 20% AEP Flood Level Difference Mapping for the Channel Widening

Plate 39 Peak 1% AEP Flood Level Difference Mapping for the Channel Widening

5.4 Roadworks/Regrading

5.4.1 General

In general, flows during frequent rainfall events are captured in the stormwater system and conveyed below ground and ultimately into Ruschutters Creek. During more significant rainfall events, the capacity of the stormwater system will be exceeded leading to overland flows along roadways and potentially through properties. As discussed in Section 3.2.3, some sections of stormwater system have less than a 1 year capacity. Consequently, overland flooding is predicted to occur relatively frequently.

As discussed in the previous section, there are limited opportunities for providing dedicated channels/flow paths for conveying overland flow. However, it may be possible to complete regrading of roadways across part sections of the catchment in an effort to contain more flow within the roadways and reduce the potential for overland flow through properties.
A discussion on potential regrading opportunities are provided in the following sections.

5.4.2 Tara Street

Investigations were completed to determine the feasibility of redirecting flow from a low point in Tara Street northwards towards Trelawney Street and onto Jersey Road through local regrading. However, the roadway levels rise from approximately 56.7m AHD to 57.4 m AHD over the 60 metres from the low point in Tara Street to the intersection of Tara and Trelawney Streets.

The significant roadworks required to provide a flow path from the low point in Tara Street to Trelawney Street would result in significant cost and disruption to local residents, particularly in terms of access/egress from properties during construction. It may also create access difficulties from Tara Street into the several garages with street frontage.

Therefore, this option was not considered further as part of this study.

Recommendation: Not recommended for implementation.

5.4.3 Trumper Park Flow Diversion

Runoff from elevated sections of Trumper Park currently drains along the internal roadway/pathway system to the northern end of Cecil Street. This runoff can also carry debris which can lead to blockage of the existing stormwater inlets in Cecil Street, thereby reducing the stormwater system capacity and increasing flood levels.

The Trumper Park Flow Diversion would aim to regrade some of the internal roadways and pathways to redirect flow towards the north-eastern side of Trumper Oval. The design concept for this option shown in **Plate 40**.

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 41** and **Plate 42**.

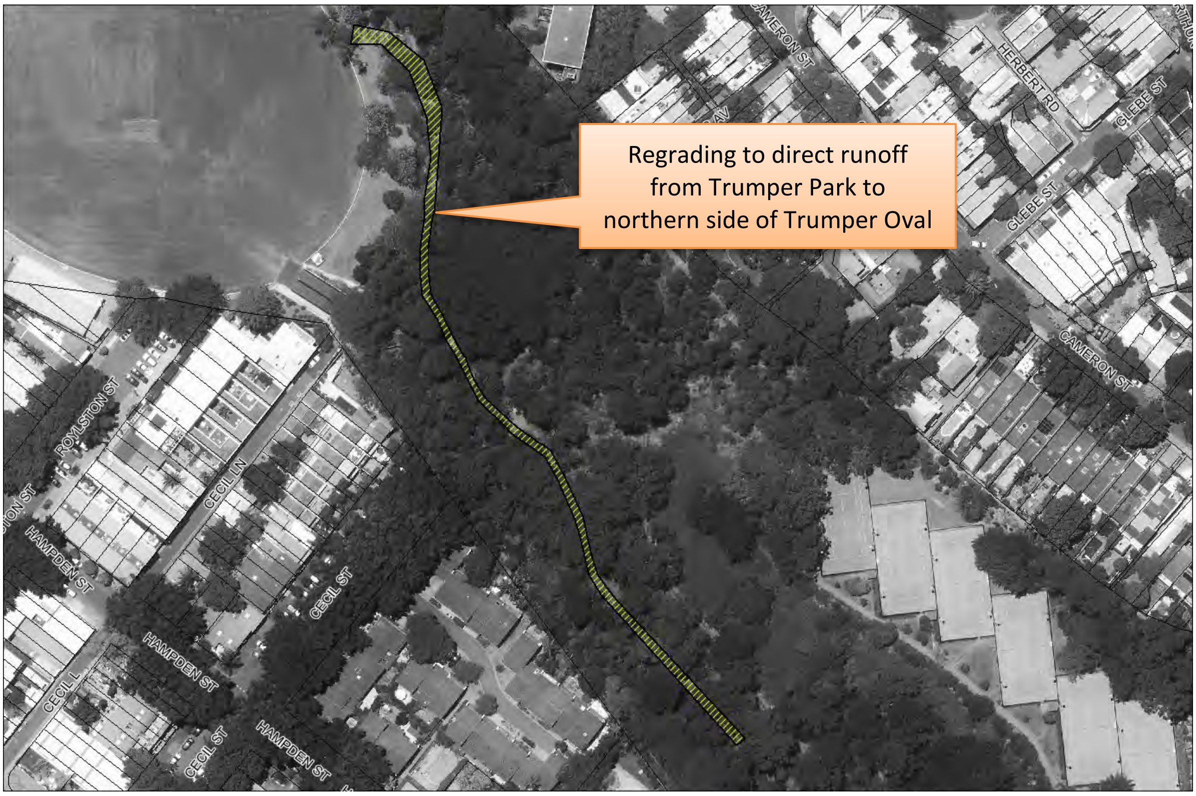


Plate 40 Design Concept for Trumper Park Flow Diversion

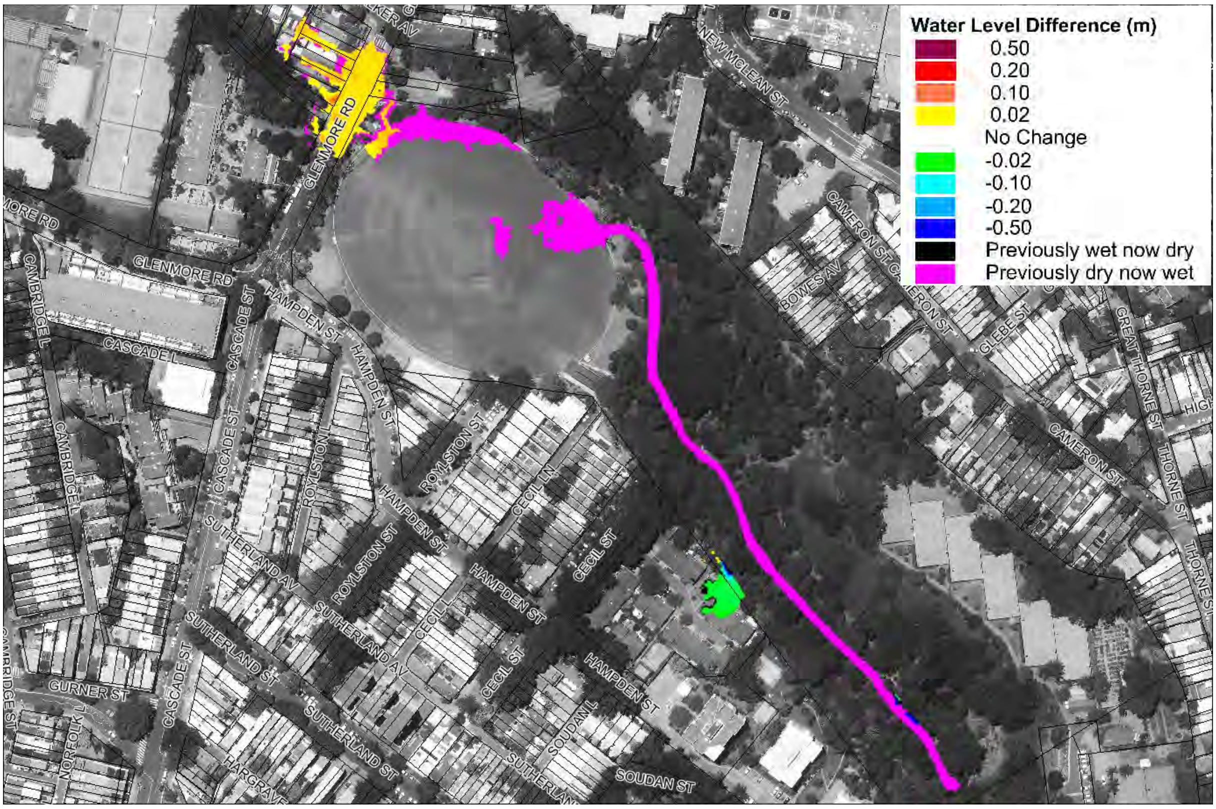


Plate 41 Peak 20% AEP Flood Level Difference Mapping for the Trumper Park Flow Diversion

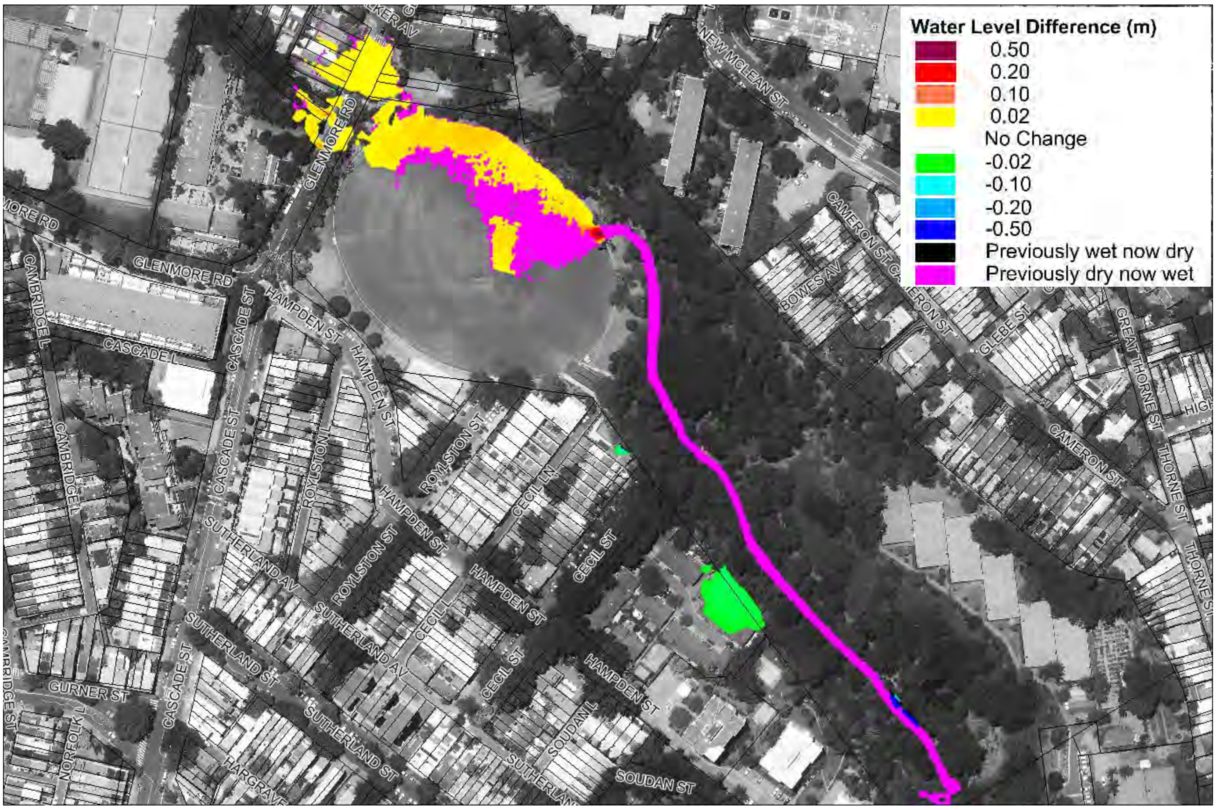


Plate 42 Peak 1% AEP Flood Level Difference Mapping for the Trumper Park Flow Diversion

Plate 41 and **Plate 42** show that the regrading will result in minor localised reductions in peak 20% and 1% AEP flood levels of up to 0.05 metres within the residential property at 17-23 Cecil Street. The lack of significant flood level reductions in the Cecil Street area is primarily associated with the Trumper Park subcatchment only forming a relatively small part of the overall catchment draining to the northern end of Cecil Street (the overall catchment draining to this area extends south to Oxford Street). Therefore, the re-direction of flows from Trumper Park to the northern side of Trumper Oval only provides a relatively small reduction in runoff leading to relatively small reductions in flood level.

Plate 41 and **Plate 42** also shows that this option would increase peak flood levels across the northern side of Trumper Oval. These increases are also predicted to extend across several properties fronting Glenmore Road. Increases in flood levels of up to 0.05 metres are predicted across these properties during the 20% AEP flood.

Due to the Trumper Park flow diversion only affording a small, localised reduction in flood levels across Cecil Lane and increasing flood levels across Glenmore Road, this option was not considered further as part of this study.

Recommendation: Not recommended for implementation.

5.4.4 Harris Street

Overland flow from a significant upstream catchment currently drains into the lower section of Harris Street. The lower section of the Harris Street roadway currently falls to the north towards existing residential properties. Therefore, the potential to regrade Harris Street to direct away from these properties was investigated.

The design concept for this option is presented in **Plate 43** and includes regrading of Harris Street down towards the south and elevating the gutter to reduce the frequency of gutter overtopping and improve the flow carrying capacity of the roadway.

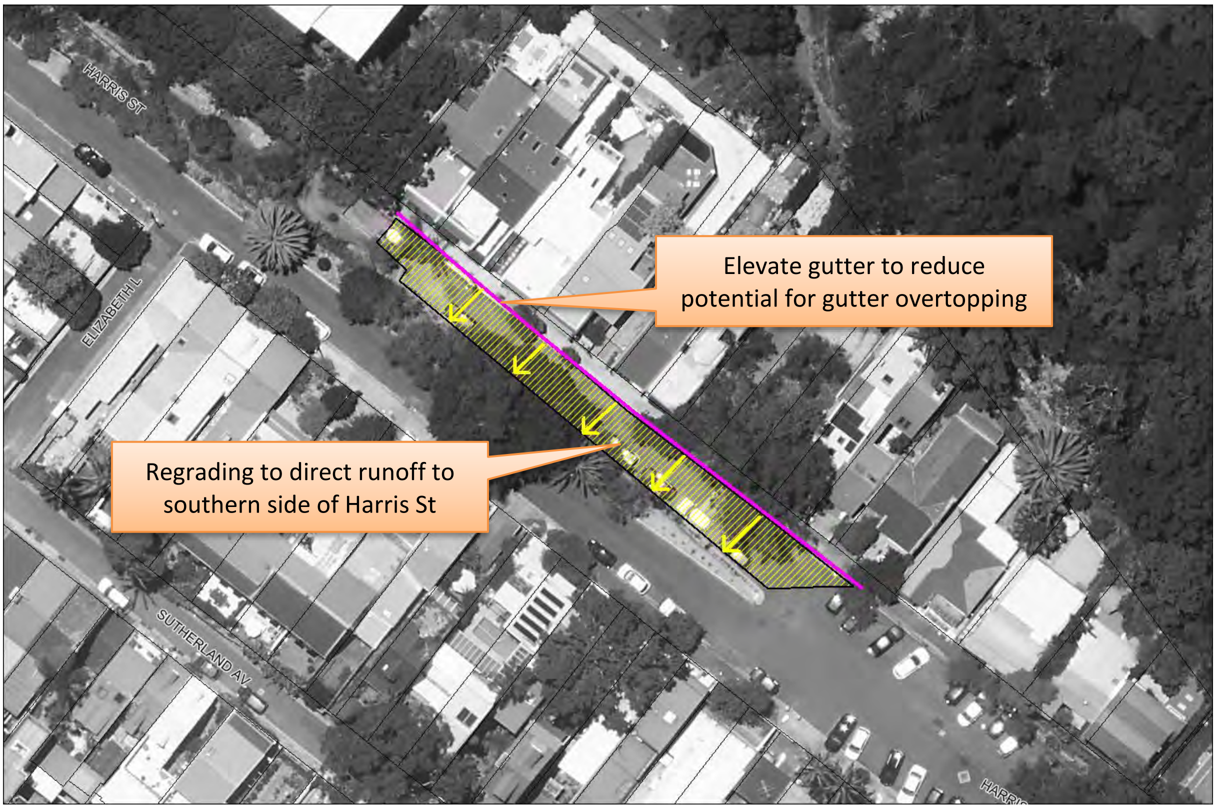


Plate 43 Design Concept for Harris Street Regrading

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 44** and **Plate 45**.

The difference mapping shows that this option does afford some notable reductions in flood levels during the 20% and 1% AEP floods for properties located from 12 to 18 Harris Street. Localised decreases in flood level of up to 0.2 metres are predicted at some locations during both the 20% and 1% AEP events.

However, **Plate 44** and **Plate 45** also show that the regrading would direct more flows to the detention basin located at the western end of Harris Street. This is predicted to increase peak 20% and 1% AEP flood levels within the front section of 4 to 12 Harris Street by up to 0.08 metres. 1% AEP flood level increases of up to 0.1 metres are also predicted to extend into 8 Hampden Road.

There is potential for these flood level increases to be offset by potential drainage upgrades in Harris Street (refer to 5.5.4). However, until such upgrades are implemented, this option is not recommended.

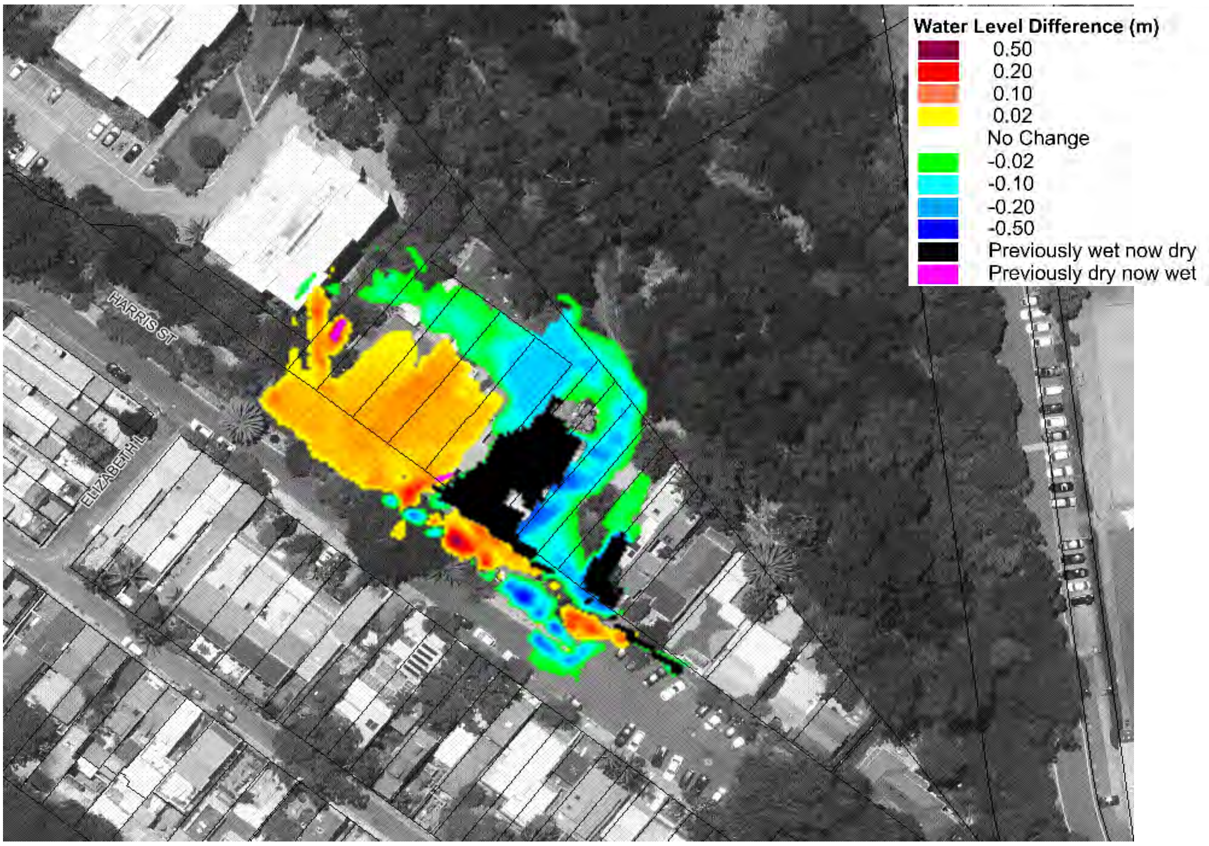


Plate 44 Peak 20% AEP Flood Level Difference Mapping for Harris Street Roadworks

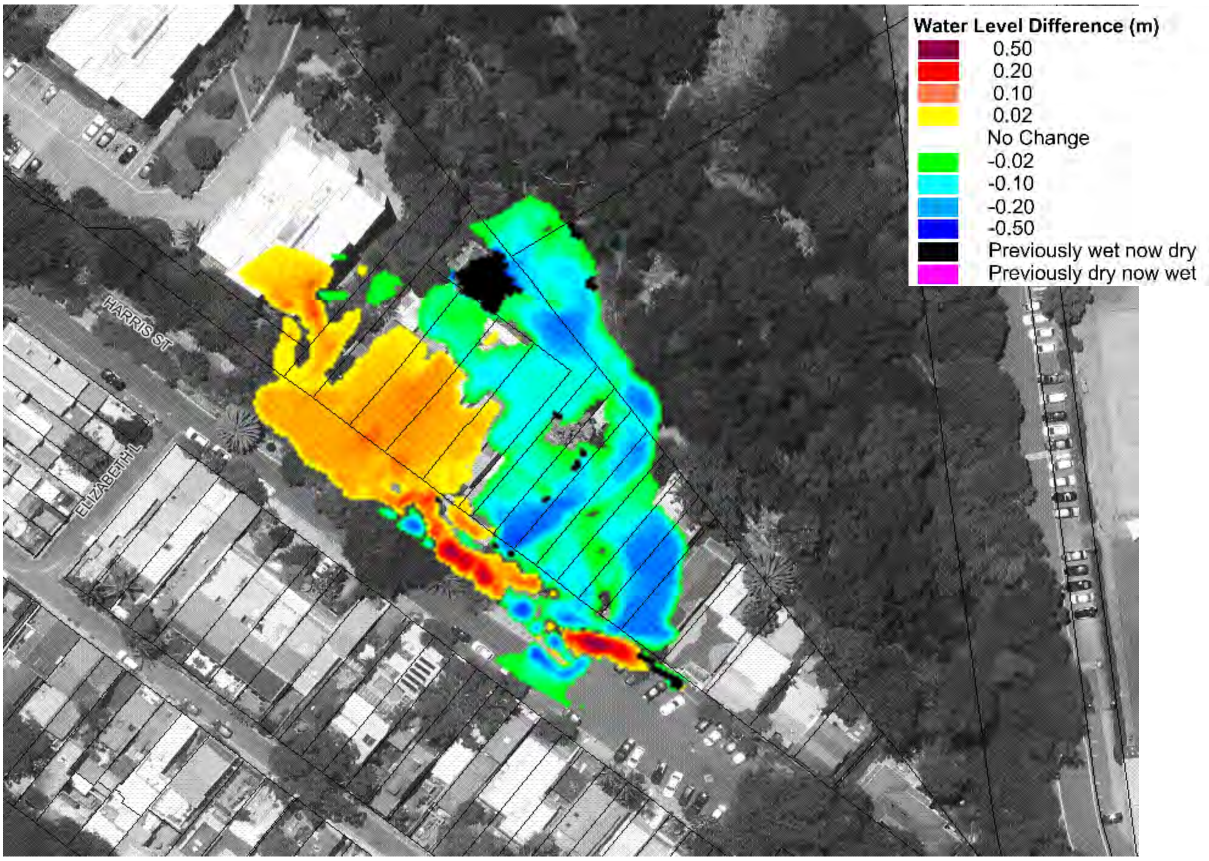


Plate 45 Peak 1% AEP Flood Level Difference Mapping for Harris Street Roadworks

Recommendation: Not recommended for implementation in isolation. Could be implemented following Harris Street drainage upgrades (subject to further investigations)

5.4.5 Hopetoun Lane/Paddington Street

During relatively frequent rainfall events, water travelling down William Street and Paddington Street is predicted to discharge into Hopetoun Lane and inundate a number of residential properties. Therefore, opportunities for regrading of Hopetoun Lane near its intersection with Paddington Street were explored to contain flow within Paddington Street.

A design concept for this option is presented in **Plate 46** and would involve elevating Hopetoun Lane by approximately 0.15 m. This could take the form of a speed hump and dish drain similar to that provided in nearby Hopetoun Street (refer to **Plate 47**).

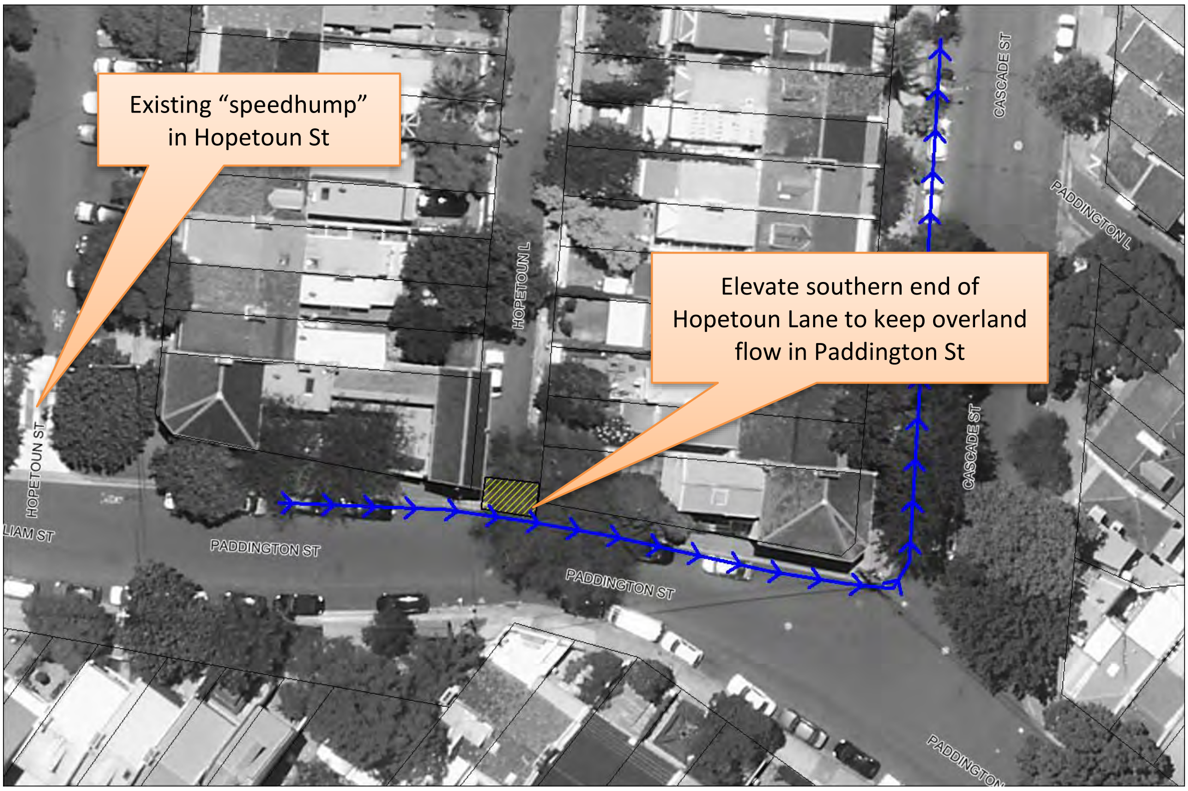


Plate 46 Design Concept for Hopetoun Lane / Paddington Street Regrading

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 48** and **Plate 49**.

Plate 48 and **Plate 49** show that the speedbump and associated roadworks at the southern end of Hopetoun Lane are effective in diverting flow that drains northwards along Hopetoun Lane under existing conditions, so that it now drains along the Cascade Street roadway.

As shown in **Plate 48**, during the 20% AEP flood this option is predicted to significantly reduce the flood exposure to residential properties at 30 to 44 Cascade Street. During the 1% AEP flood, peak flood level reductions of up to about 0.3 metres are predicted across properties at 26 to 40 Cascade Street.

Plate 47 Example of existing "speed hump" in Hopetoun Street that keeps water in Paddington Street (Google, 2017)

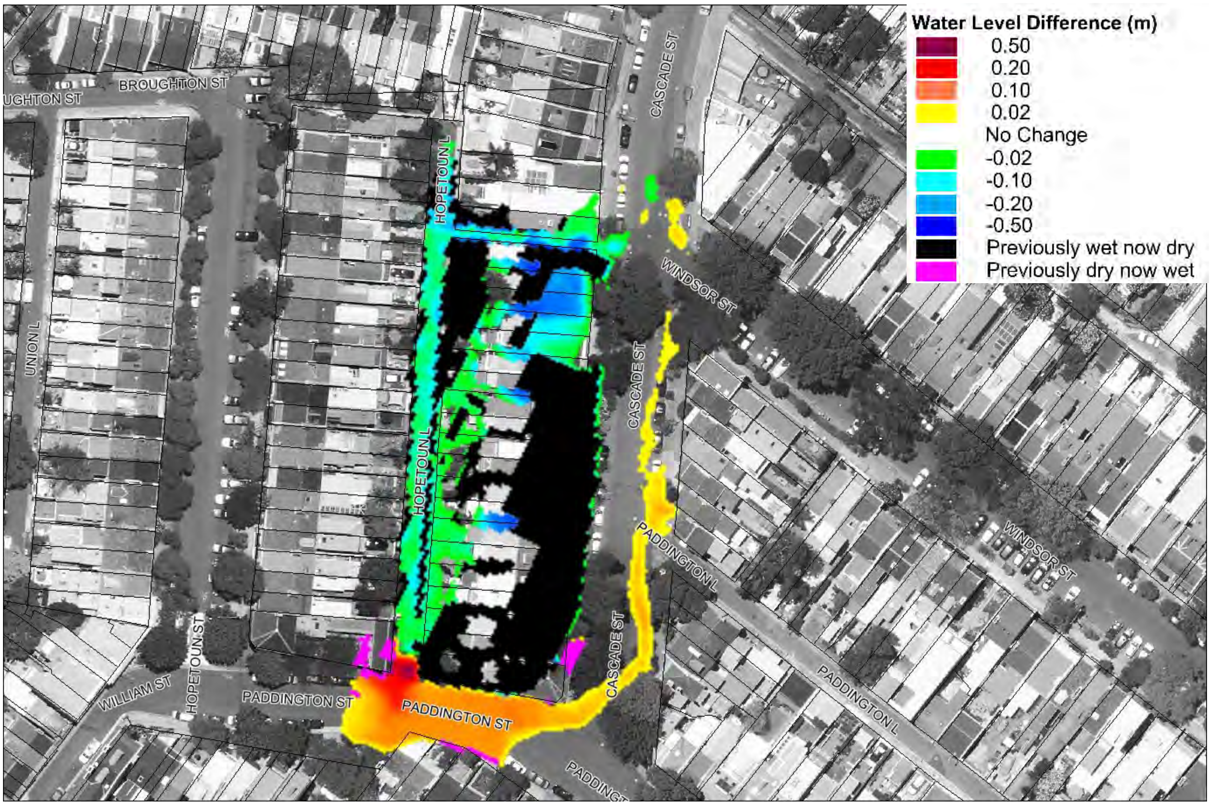


Plate 48 Peak 20% AEP Flood Level Difference Mapping for Hopetoun Lane Regrading

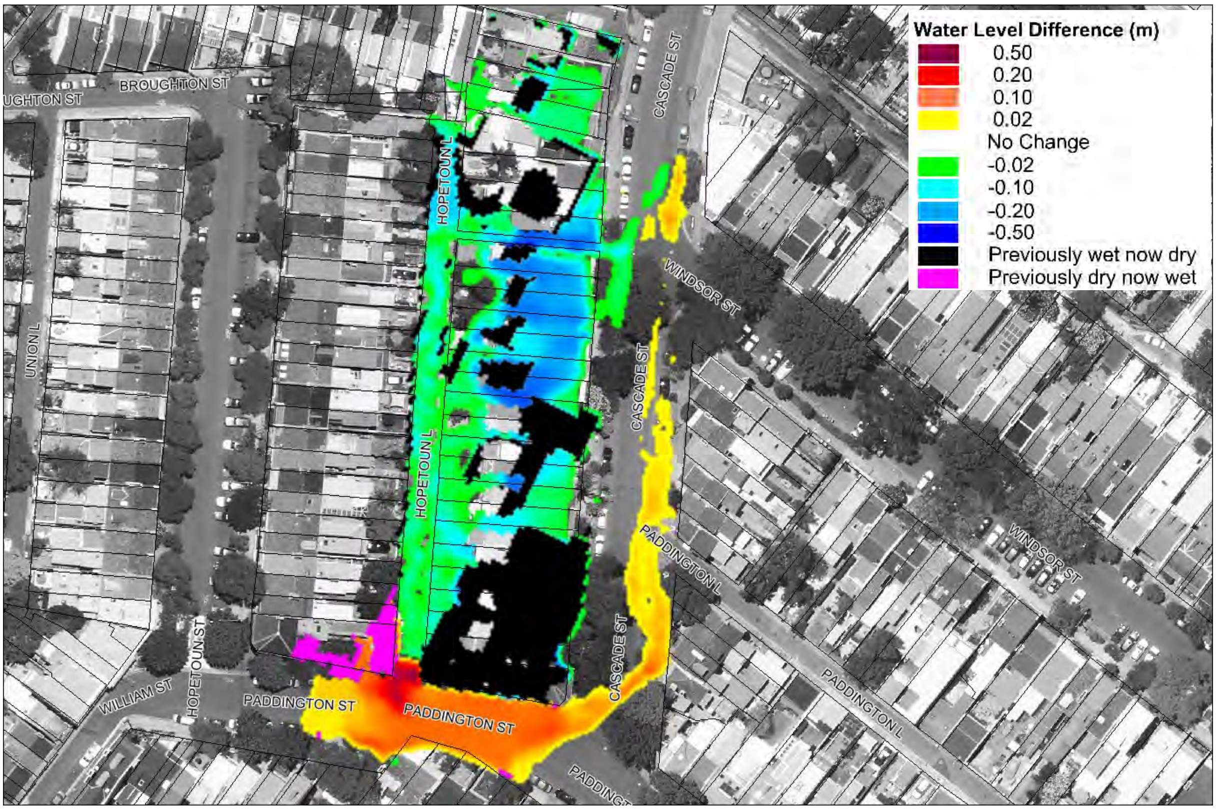


Plate 49 Peak 1% AEP Flood Level Difference Mapping for Hopetoun Lane Regrading

Increases in peak flood levels within Paddington Street and Cascade Street of up to 0.3 metres are predicted during both the 20% and 1% AEP floods. However, these increases are not predicted to impact on any adjoining properties.

The cost to implement the regrading is estimated to be about $40,000. A detailed breakdown of costs is provided in **Appendix C**.

The potential financial benefit associated with the regrading was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the basin in place. The outcomes of the revised damages assessment determined that the regrading would reduce total flood damage costs by over $1 million over the 50-year design life. This yielded a preliminary benefit-cost ratio of about 25. Accordingly, the financial benefits of implementing this option are predicted to be significant.

Furthermore, the results of the hydraulic modelling show that 4 fewer properties are predicted to be exposed to above floor inundation during the 20% AEP flood and 8 fewer properties are predicted to be inundated above floor during the 1% AEP flood.

Overall, it is considered that regrading near the intersection of Hopetoun Lane and Paddington Street affords some significant benefits for a relatively small financial outlay. Therefore, this option is recommended for implementation.

Recommendation: Recommended for implementation

5.4.6 Hargrave Street/Cascade Street

Floodwaters currently drain north along Cascade Street and some runoff then diverts east along Hargrave Street and "ponds" at the low point in front of 10 Hargrave Street. During larger events, water is predicted to overtop the gutter and inundate surrounding properties.

Therefore, the potential to undertake regrading at the western end of Hargrave Street to keep overland flow in Cascade Street was investigated. The location of the potential regrading is shown in **Plate 50**. This would likely take the form of a pedestrian 'speed' hump with a dish drain similar to that previously illustrated in **Plate 47**.

Plate 50 Design Concept for Hargrave Street Regrading

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 51** and **Plate 52**.

Plate 51 and **Plate 52** show that the regrading at the western end of Hargrave will divert a large proportion of the overland flow that currently drains eastwards along Hargrave Street further northwards along Cascade Street.

During the 20% AEP flood, this option is predicted to significantly reduce existing flood levels at 2A Hargrave Street and 25A Cascade Street that are predicted to be inundated under existing flood conditions. Reductions in peak 20% AEP flood levels of up to 0.22 metres are also predicted within residential properties between Hargrave Street and Hargrave Lane.

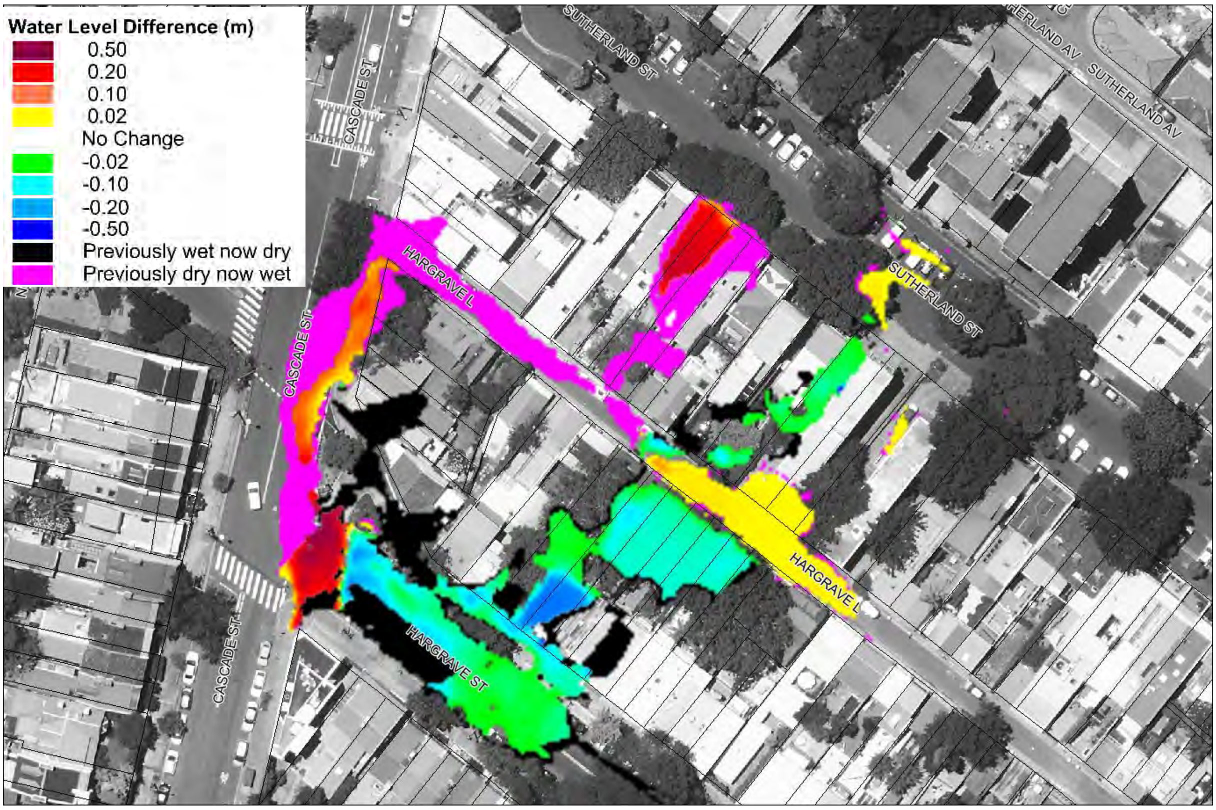


Plate 51 Peak 20% AEP Flood Level Difference Mapping for Hargrave Street Regrading

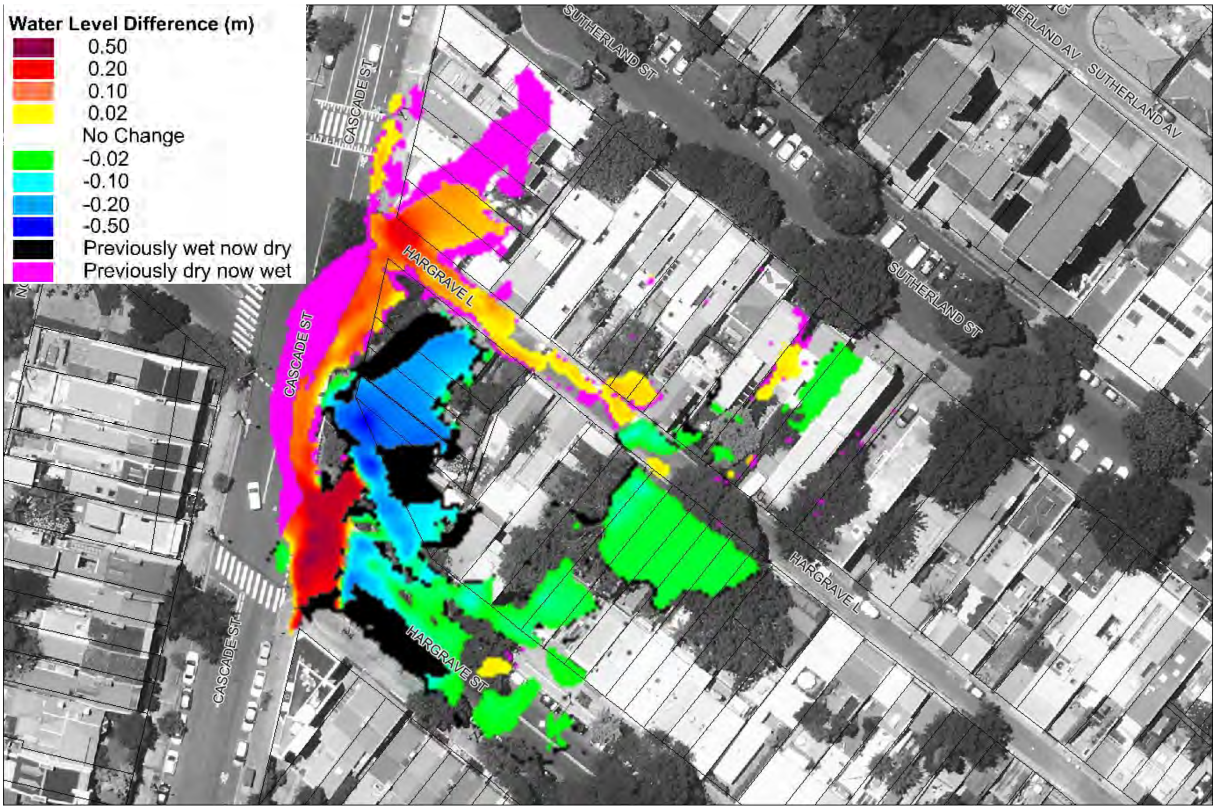


Plate 52 Peak 1% AEP Flood Level Difference Mapping for Hargrave Street Regrading

During the 1% AEP flood, peak flood level reductions of up to about 0.36 metres are predicted across properties at 2A Hargrave Street and 25A to 29 Cascade Street. Reductions in peak 1% AEP flood levels of up to about 0.2 metres are also predicted within residential properties between Hargrave Street and Hargrave Lane.

However, the topography across this area eventually redirects the overflow from Paddington Street into the western end of Hargrave Lane and Sutherland Street. This is predicted to increase peak 20% AEP flood levels across these areas by up to 0.36 metres. During, the 1% AEP flood, increases up to 0.27 metres are predicted within 37 to 45 Cascade Street.

Although this option affords benefits to some properties along Hargrave Street, Hargrave Lane and Cascade Street, it is predicted to increase the flood levels across an equivalent number of other properties in this area. Therefore, this option is not recommended for implementation.

Recommendation: Not recommended for implementation.

5.4.7 Comber Street

There are very low kerb heights along Comber Street. It may be possible to raise kerb heights to reduce the frequency of water overtopping the gutter. However, the benefit of this measure would be localised and would afford no benefits to downstream properties. Therefore, this option was not considered further in isolation.

Stormwater upgrades are likely to provide a better solution in this area. If stormwater upgrades in this area are pursued, opportunities to increase the kerb heights or regrade the roadway could be explored as part of the works.

Recommendation: Not recommended for implementation in isolation. But could be explored in conjunction with stormwater upgrades.

5.4.8 Glenmore Road

Glenmore Road is predicted to be subject to relatively frequent inundation, particularly near its "sag" point that adjoins the open channel. However, the sag point is actually located closer to an existing residential property located at 420 Glenmore Road. As a result, water tends to "pond" at this location and spill into existing properties in this area. Therefore, this option looked at regrading of Glenmore Road to create a new, lower "sag" point immediately adjacent to the existing open channel. This would be supplemented with lowering of the existing kerb and pathway between the roadway and channel to allow water to more readily discharge from Glenmore Road into the channel. The design concept for this option is provided in **Plate 53**.

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 54** and **Plate 55**.

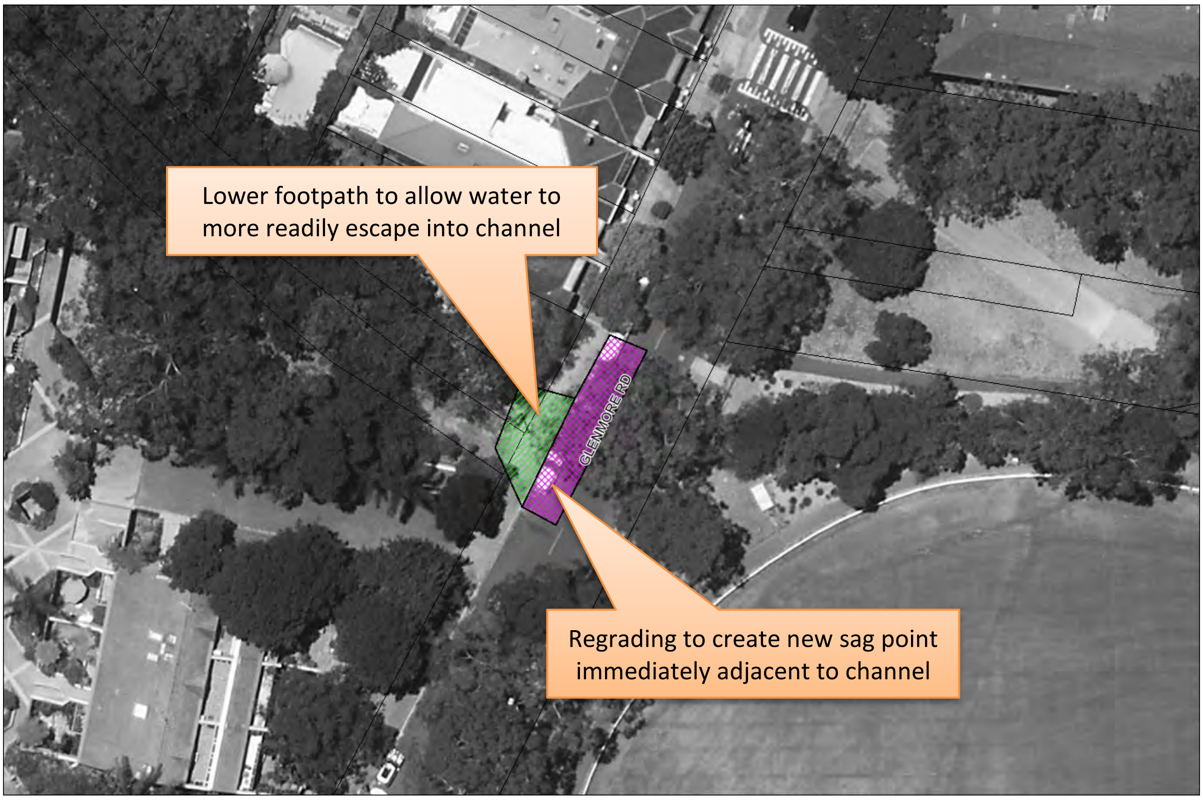


Plate 53 Design Concept for Glenmore Road Regrading

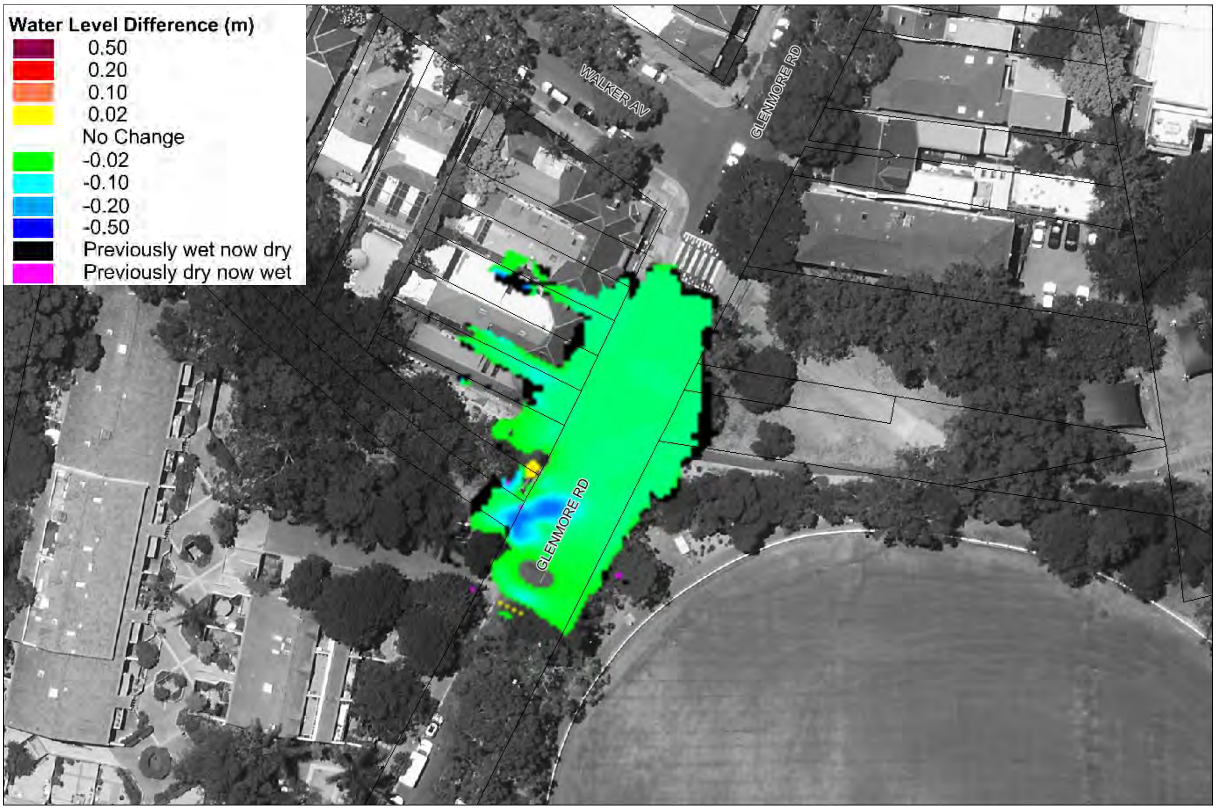


Plate 54 Peak 20% AEP Flood Level Difference Mapping for Glenmore Roadworks

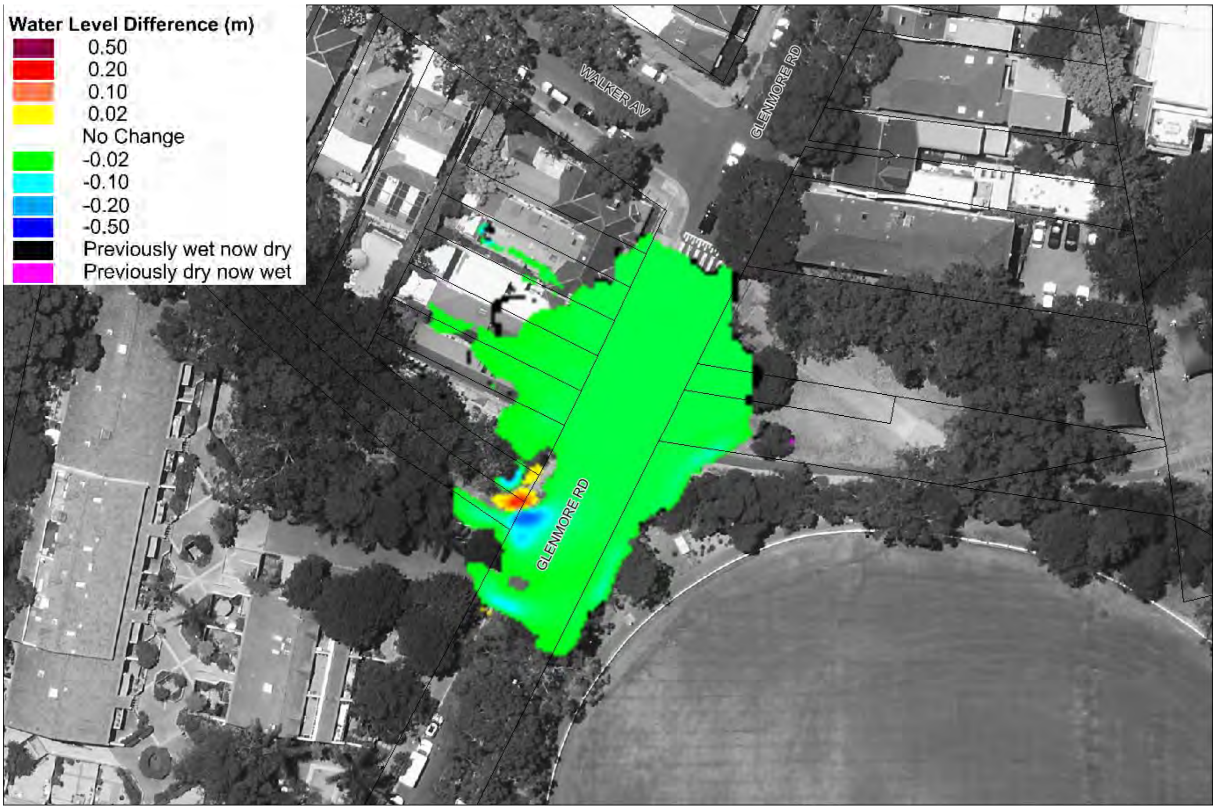


Plate 55 Peak 1% AEP Flood Level Difference Mapping for Glenmore Roadworks

Plate 54 and **Plate 55** show that the roadworks on Glenmore Road are predicted to generate reductions in peak 20% and 1% AEP flood levels of up to 0.16 and 0.15 metres, respectively, within properties along Glenmore Road. Reductions in peak 20% and 1% AEP flood levels of up to about 0.2 metres are predicted within Glenmore Road itself. However, the results of the modelling indicate that these flood level reductions are not sufficient to reduce the potential for above floor inundation during the 1% AEP flood.

Plate 54 and **Plate 55** shows that some localised increases in flood level are also predicted with this option. However, these increases are contained within the open channel.

A cost estimate for the option was prepared and is included in **Appendix C**. This determined that the total cost to implement this option would be about $50,000.

The revised modelling results were used as a basis for undertaking a revised flood damage assessment. This determined that the regrading is predicted to reduce the total flood damage over a 50-year time frame by $40,000. Therefore, the benefit-cost ratio for this option was determined to be 0.8. This indicates that the costs are only slightly higher than the benefits associated with this option. When this is coupled with intangible costs, it is argued that the benefit-cost ratio may be more than 1.

The reductions in flood levels afforded by this option are not sufficient to reduce the number of properties subject to above floor inundation. However, given the relatively frequent inundation in this area, any reduction in flood levels is considered beneficial. Therefore, it is considered that this option may be worth implementing given the relatively low cost of implementation.

Recommendation: Recommended for implementation.

5.4.9 George Street/Elizabeth Street

Across the upper catchment area, floodwaters currently drain from the southern end of Jersey Road north-west towards the low point in Oxford Street. However, a proportion of the runoff from Oxford Street is directed into Elizabeth Street and George Street. This results in significant inundation depths within each roadway with floodwaters also extending into adjoining properties.

This option explored the potential to undertake regrading at the southern ends of Elizabeth and George Streets to retain more overland flow within Oxford Street. The location of the potential regrading is shown in **Plate 56**. This would likely take the form of a pedestrian 'speed' hump with a dish drain similar to that previously illustrated in **Plate 47**.

The TUFLOW model was updated to include a representation of the regrading and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping was prepared for the 20% and 1% AEP events with this option in place and are presented in **Plate 57** and **Plate 58**.

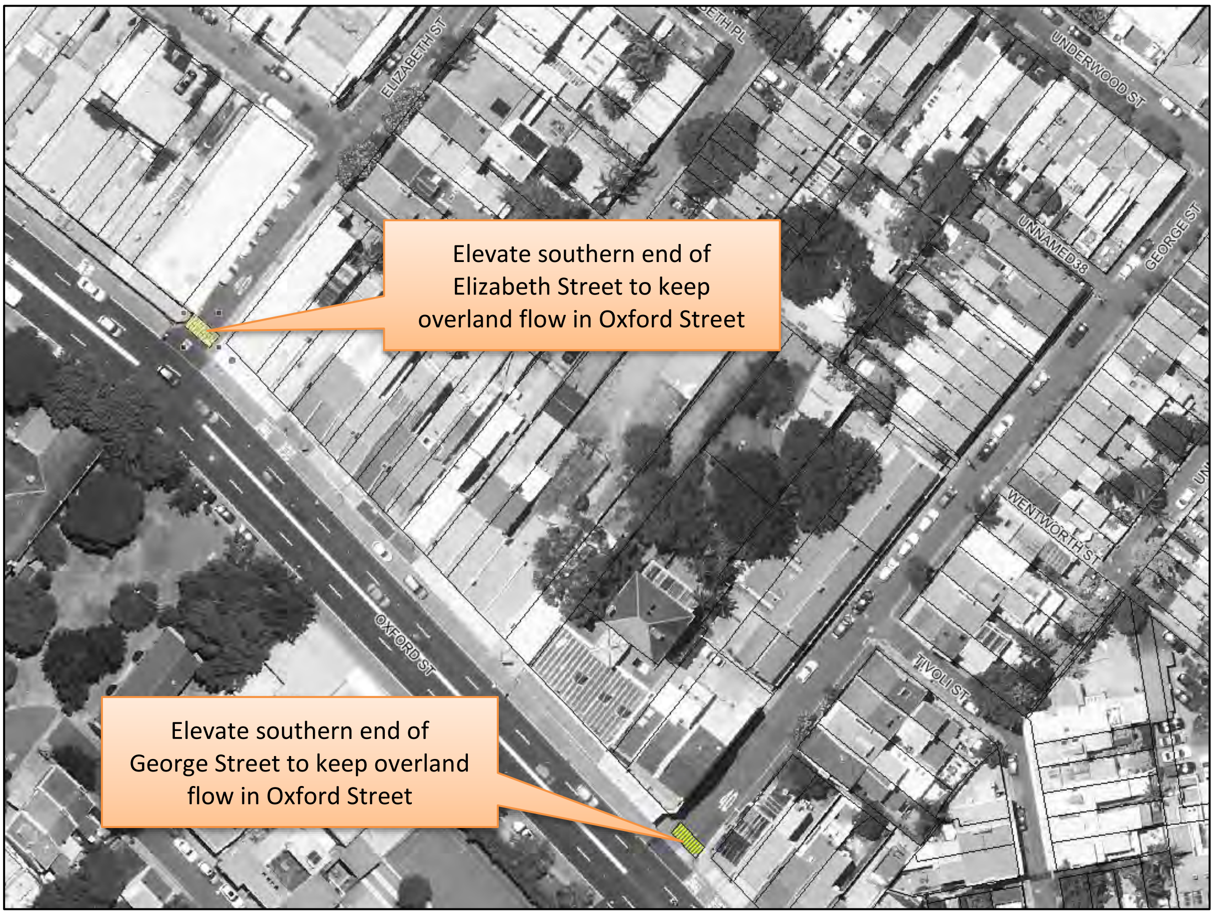


Plate 56 Design Concept for George Street and Elizabeth Street Regrading

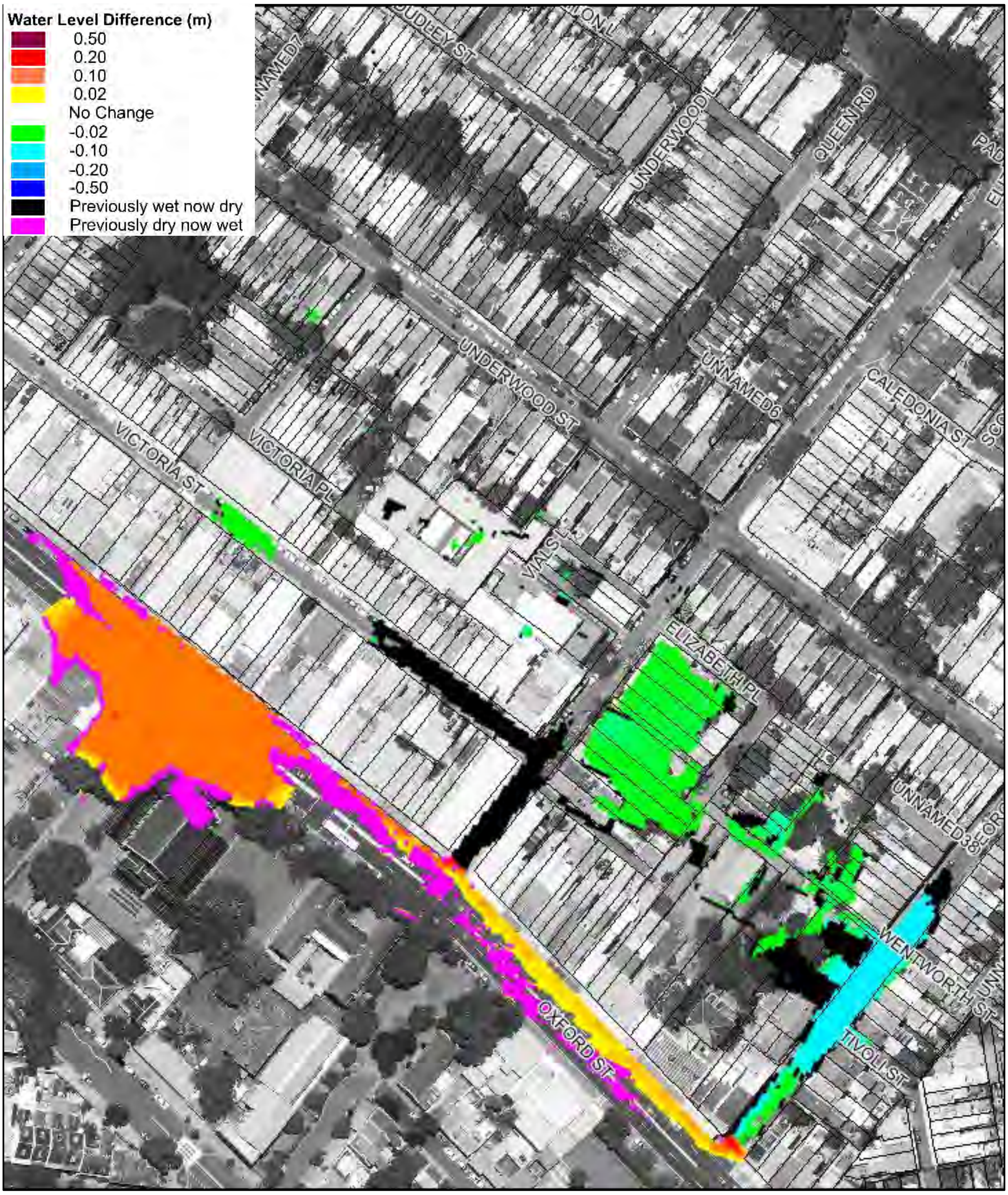


Plate 57 Peak 20% AEP Flood Level Difference Mapping for George Street/Elizabeth Street Roadworks

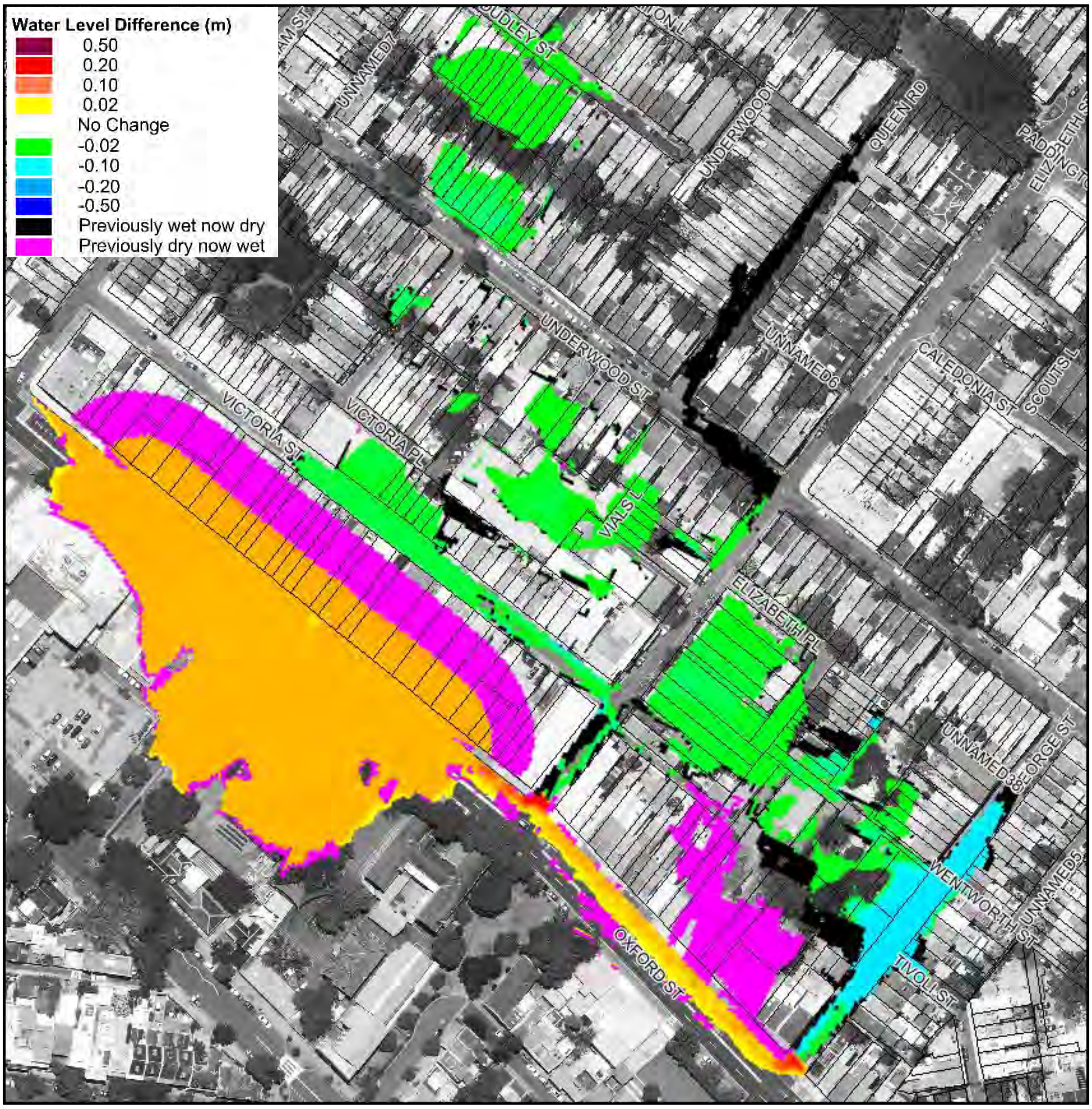


Plate 58 Peak 1% AEP Flood Level Difference Mapping for George Street/Elizabeth Street Roadworks

Plate 57 and **Plate 58** show that the regrading is predicted to generate reductions in peak 20% and 1% AEP flood levels within George Street of up to 0.15 metres. The regrading is also predicted to reduce flood levels along Victoria Street and Elizabeth Street during the 20% AEP flood. The flood level reductions are also predicted to extend down to Underwood Street during the 1% AEP flood (although the reductions at this location are less than 0.05 metres).

However, **Plate 57** and **Plate 58** also show that the additional water that is directed along Oxford Street as a result of the regrading is predicted to increase flood levels at the low point in Oxford Street. Peak flood levels are predicted to increase at this location by between 0.1 and 0.2 metres during the 1% and 20% AEP floods. As a result, this option would increase the flood risk in Oxford Street.

Although this option affords benefits to properties along George Street, Elizabeth Street Victoria Street and Underwood Street, it is predicted to increase flood levels across Oxford

Street properties. Any option that is seen to increase the flood risk across any properties regardless of the benefits it may afford across other areas will not be supported by the state government. Therefore, this option is not recommended for implementation.

Recommendation: Not recommended for implementation.

5.5 Drainage Upgrades

5.5.1 General

As discussed in Section 3.2.3, the TUFLOW model developed as part of the "Paddington Flood Study" (CSS, 2016) was used to simulate the conveyance of runoff via the stormwater drainage system, as well as the movement of overland flows once the capacity of the stormwater system was exceeded. The results of the modelling determined that flooding across the upper sections of Paddington generally occurs as a result of the capacity of the stormwater system being exceeded leading to 'overland' flooding.

Figure A9 presents the stormwater capacity mapping for Paddington and indicates that the capacity of the system varies considerably across the catchment. Some sections of the stormwater system have less than a 1 year capacity and the major trunk drainage lines where flows are concentrated appear to have a capacity of less than the 20% AEP event. **Figure A9** also indicates that the pipe capacity rather than pit capacity appears to be the limiting factor in the performance of the stormwater system.

Council's *Asset Management Strategy 2011-2021 (2011)* guides the activities and decision making of the organisation with regard to the management of Council's infrastructure assets, including drainage assets, within the Woollahra LGA. It defines the replacement of drainage pipes with pipes of greater capacity as "Capital Upgrade" expenditure.

Furthermore, Council's *Stormwater Asset Management Plan (2011)* indicates the priorities of Council with regard to the upgrade or renewal of drainage assets. Specifically, the Plan specifies that the highest priority be given to those elements of the network where there is a capacity issue resulting in unacceptable overland flow flooding within private property.

On this basis, a number of potential drainage upgrades have been investigated with the aim of improving the flow carrying capacity of the underground drainage network, thereby reducing the depth, extent and velocity of overland flows and meeting the principals documented in Council's *Stormwater Asset Management Plan*. These upgrades may include:

- Increasing the size of pipes.
- Extending the current system to include new pipes.
- Inclusion of new inlet pits to capture additional flow, particularly at low points in roadways where ponding occurs.

Proposed upgrades considered as part of this Floodplain Risk Management Study and Plan are detailed in the following sections.

5.5.2 Ocean Street and Tara Street

The current drainage system in Tara Street and Ocean Street comprises stormwater pits on both sides of the road at the roadway "sag" points. There are 4 pits in Tara Street and 3 pits in Ocean Street. The pits collect flow from the low point in each roadway and conveys it via a 375mm diameter pipe system down to Jersey Road where it joins a 600mm diameter pipe system. The results of the TUFLOW modelling predict that the pipes from Ocean Street to Jersey Road are full during a 1 exceedance per year (EY) flood.

Therefore, opportunities to upgrade the existing drainage system were explored. The drainage upgrades that were investigated are shown in **Plate 59** include the following works:

- Upgrade existing pits at the low point in Tara Street to include 3m lintels.
- Increase existing 375mm pipe to 750mm pipe between Ocean Street and Tara Street and Tara Street to Jersey Road.

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 60** and **Plate 61**.

Plate 60 and **Plate 61** show that this option is effective in reducing the flood risk to properties in this area during both the 20% and 1% AEP floods. Specifically, reductions in peak 20% and 1% AEP flood levels of up to about 0.2 metres are predicted across a number of properties located between Ocean Street and Jersey Road. This is predicted to reduce the number of properties exposed to above floor flooding by 2 in the 20% AEP flood and 3 during the 1% AEP flood. Accordingly, there is a significant hydraulic benefit associated with this option.

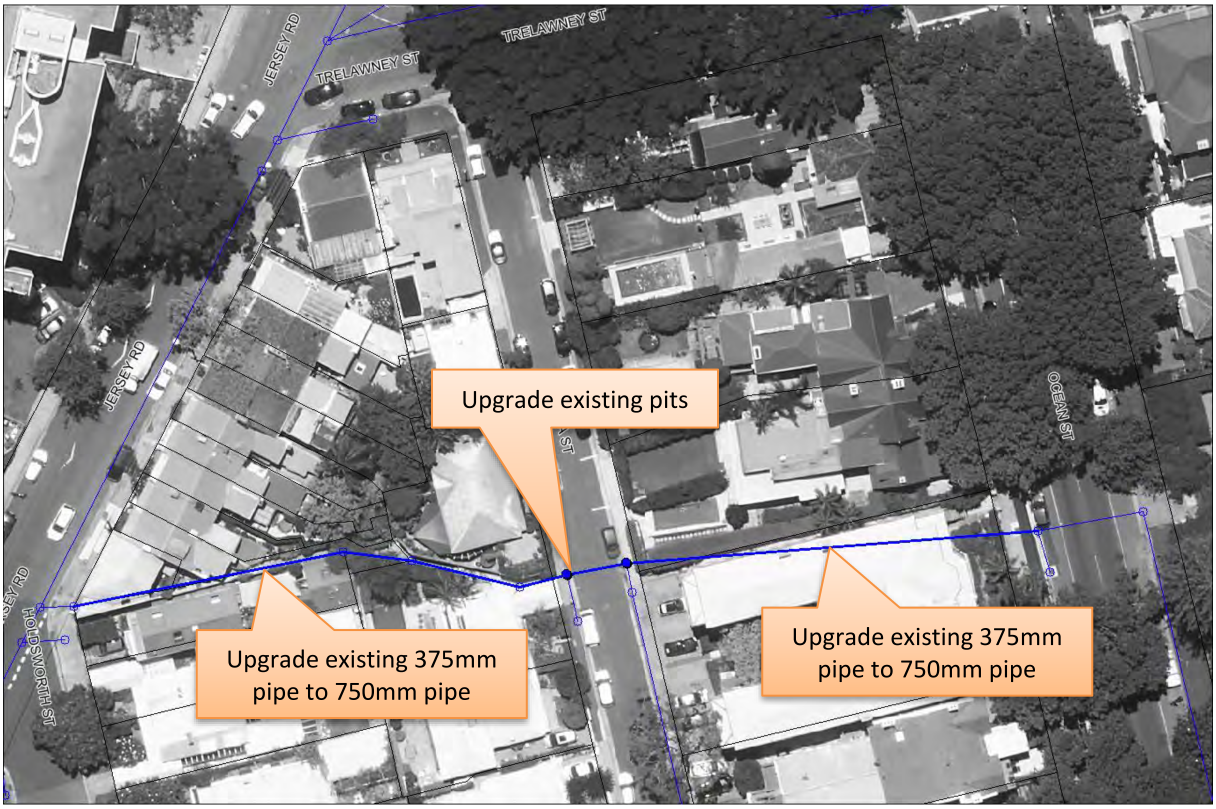


Plate 59 Design Concept for Ocean Street and Tara Street Drainage Upgrades

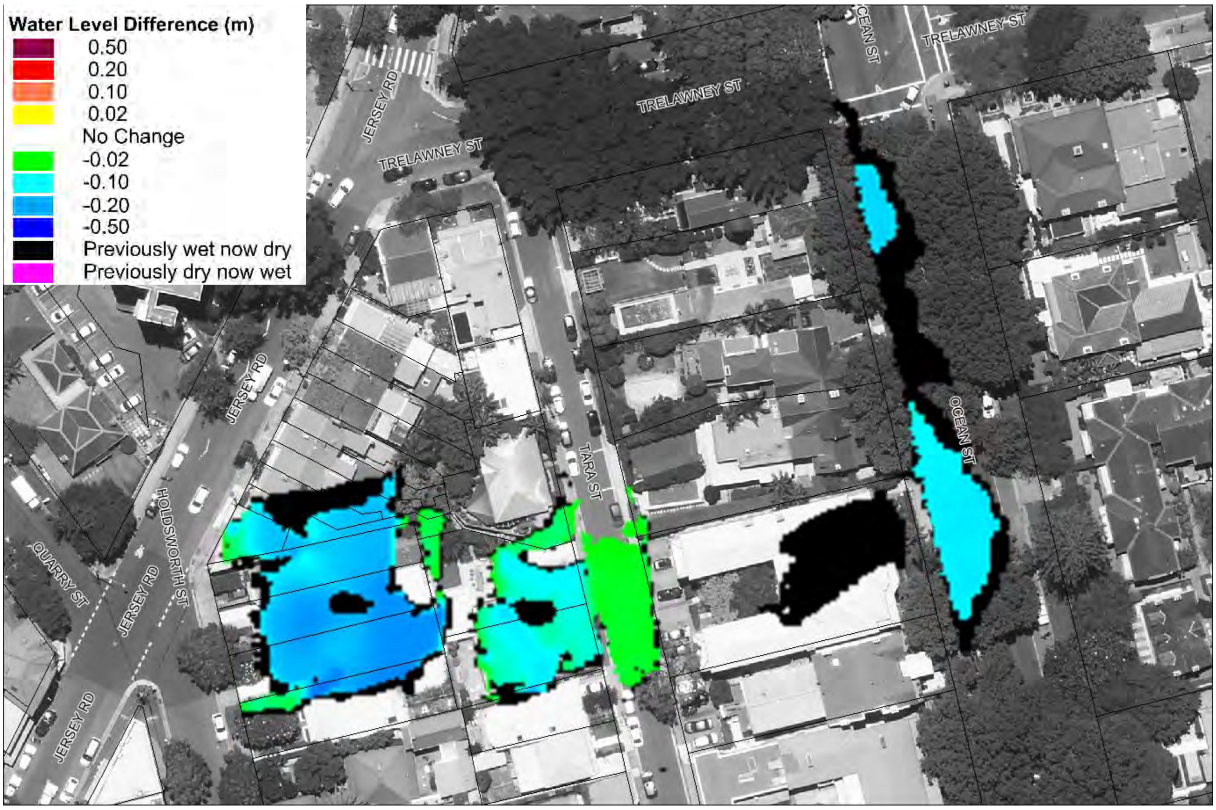


Plate 60 Peak 20% AEP Flood Level Difference Mapping for Tara Street Stormwater Upgrades

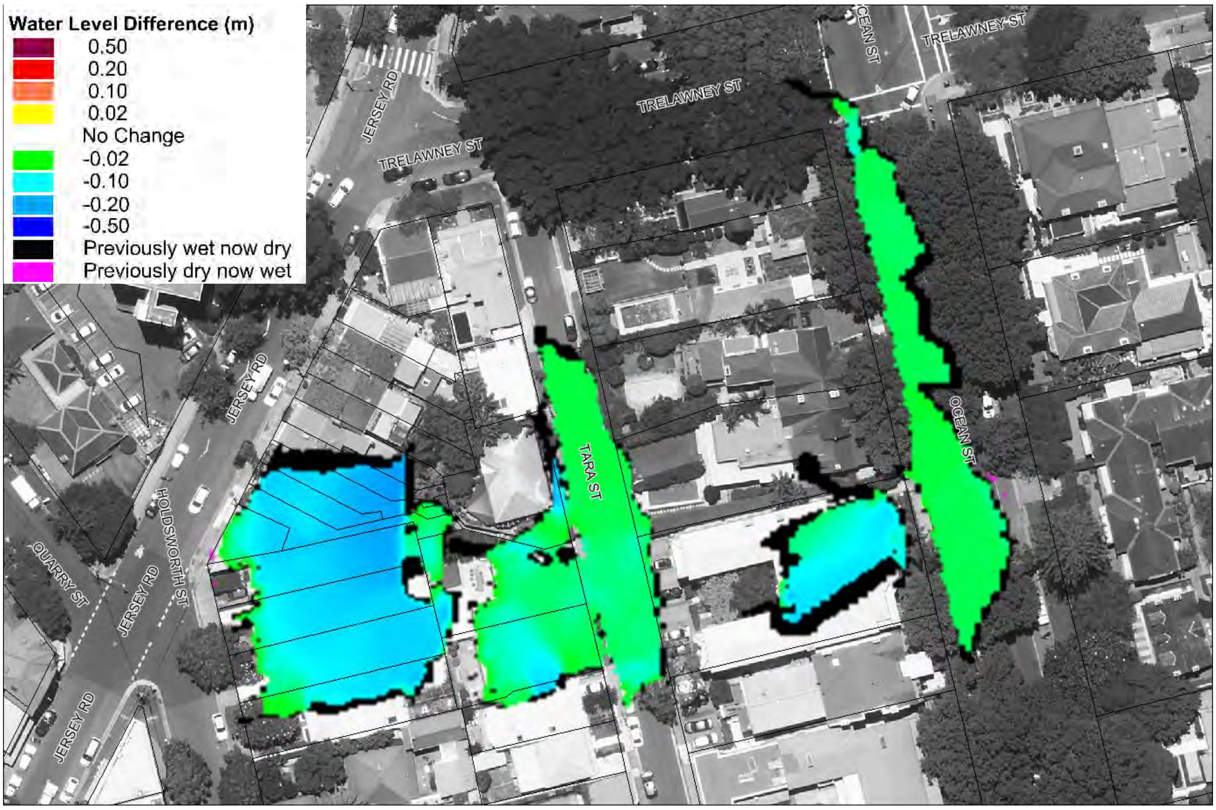


Plate 61 Peak 1% AEP Flood Level Difference Mapping for Tara Street Stormwater Upgrades

The cost to implement the drainage upgrades is estimated to be about $1.7 million. A detailed breakdown of costs is provided in **Appendix C**. The majority of the expense for this option is associated with tunnel boring beneath the existing properties.

The potential financial benefit associated with implementation of the detention basin was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the basin in place. The outcomes of the revised damages assessment determined that the drainage upgrades would reduce total flood damage costs by $285,000 over the 50-year design life. This yielded a preliminary benefit-cost ratio of 0.2. Accordingly, the financial costs of implementing this option are predicted to outweigh the benefits.

The area is significantly developed with numerous fences, garages and buildings located in the vicinity of the potential works. The potential to complete the suggested upgrade works would also be dependent on detailed subsurface investigations which were not completed as part of the current assessment. If significant obstructions are uncovered there may be opportunities to run new pipelines north from the sag points in Tara and Ocean Streets towards Trelawney Street and then west to Jersey Road. This alternative alignment was investigated by Council and a cost estimate of $600,000 was provided. This yielded a preliminary benefit-cost ratio of 0.5. Although, the financial benefits of implementing this option are still predicted to outweigh the costs, this provides a more favourable outcome than the other alignment. However, there would still be a need to confirm the potential for utility conflicts as this could increase the potential costs.

Overall, this option does afford some benefits to properties in Ocean Street and Tara Street. The benefit cost ratio is less than 1, which makes the option difficult to support from a purely financial standpoint. However, given the relatively frequent inundation that is experienced in this area, it is recommended that further detailed investigations be completed to refine the cost estimate and determine if more cost-effective options may be available.

Recommendation: Recommended for further detailed investigations

5.5.3 Forbes Street to Harris Street

This option would look to upgrade the existing drainage network from near Forbes Street and Sutherland Street to north of Harris Street.

The extent of the work associated with this option are provided in **Plate 62**.

The stormwater upgrades were included within an updated TUFLOW model and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20%, 10% and 1% AEP events was prepared based upon the results of the revised modelling and are presented in **Plate 63**, **Plate 64** and **Plate 65**.

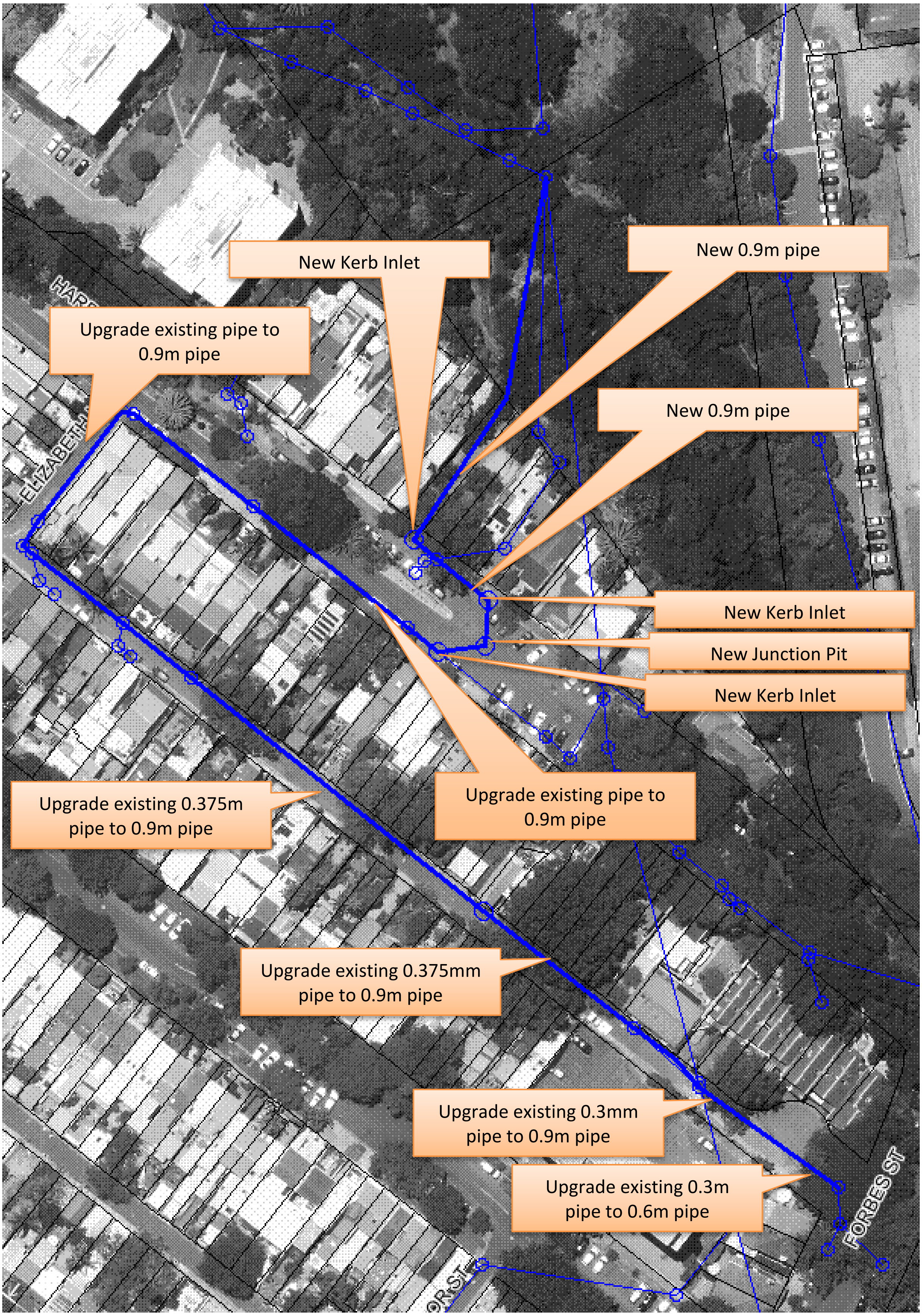


Plate 62 Design Concept for Forbes Street to Harris Street Drainage Upgrades

Plate 63 Peak 20% AEP Flood Level Difference Mapping for Forbes Street to Harris Street Drainage Upgrades

Plate 64 Peak 10% AEP Flood Level Difference Mapping for Forbes Street to Harris Street Drainage Upgrades

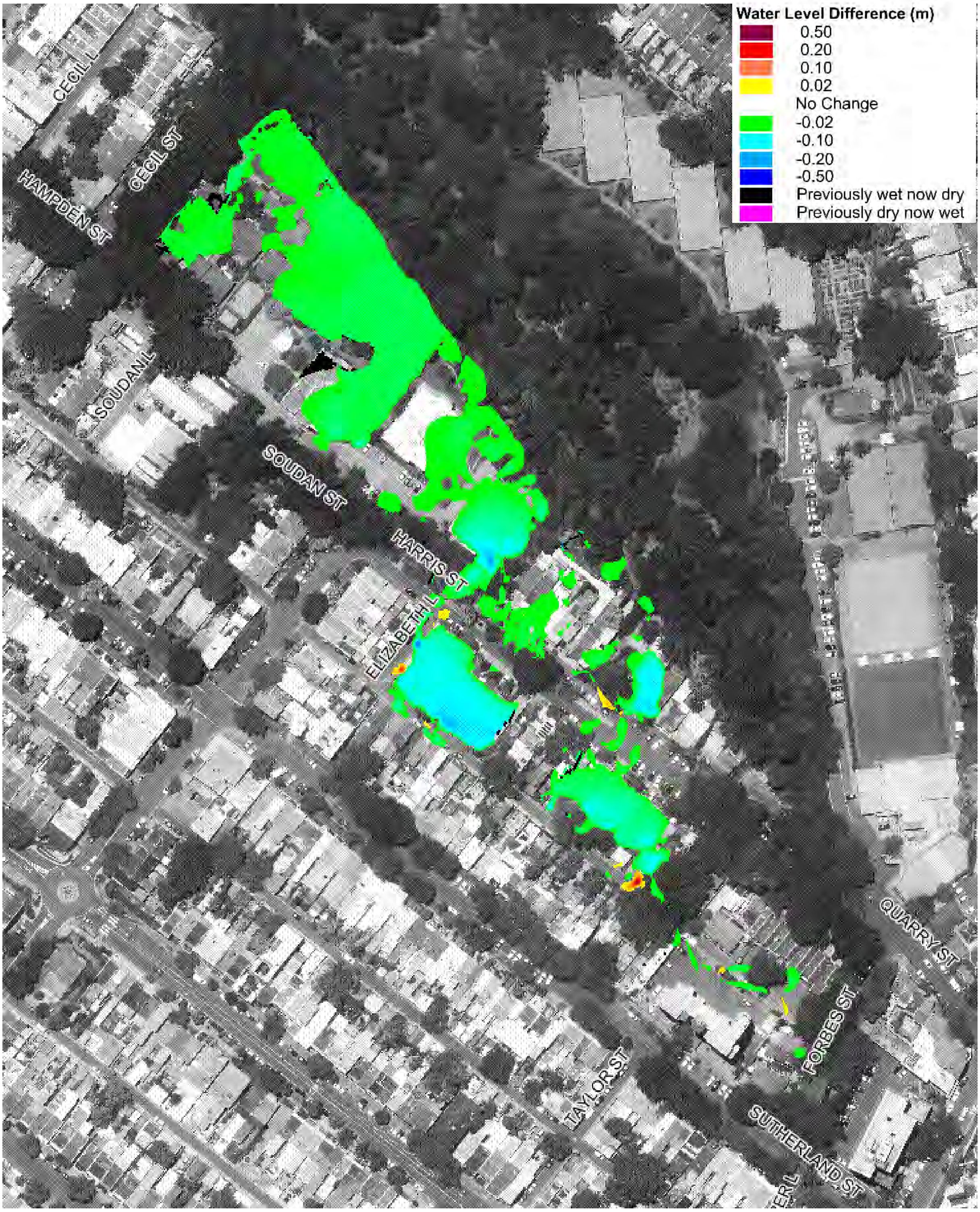


Plate 65 Peak 1% AEP Flood Level Difference Mapping for Forbes Street to Harris Street Drainage Upgrades

Plate 63, Plate 64 and **Plate 65** show that this option is predicted to reduce existing flood levels during both frequent and more severe floods across a significant area. The flood level reductions are predicted to be less than 0.1 metres across most areas and events. However, more significant reductions of up to 0.14 metres are predicted across some properties on the northern side of Sutherland Avenue.

The drainage upgrades are predicted to result in four fewer properties being exposed to above floor inundation during the 20% and 10% AEP floods. No reduction in above floor inundation is predicted during the 1% AEP flood.

A cost estimate for the drainage upgrades is included in **Appendix C**. This shows that the drainage upgrades are expected to cost approximately $2 million to implement.

Revised flood damage costs were prepared with the drainage upgrades in place and this determined that implementation of the option would reduce flood damage costs by about $3.3 million over 50 years. This yields a benefit-cost ratio of 1.6 indicating the reduction in flood damage costs exceeds the cost to implement the option.

This drainage upgrade option would involve work to both Council and Sydney Water drainage assets. Therefore, coordination and potential funding for the upgrade would need to be arranged between both parties.

The benefit cost ratio indicates that this option is likely to be feasible from a cost perspective and afford notable hydraulic benefits. Therefore, this option is recommended for implementation.

Recommendation: Recommended for implementation

5.5.4 Harris Street

There is currently a small detention basin at the end of the lower section of Harris Street. Water is predicted to overtop the detention basin and flow through 4 Harris Street. Above floor inundation has been experienced on a number of occasions and there is evidence of significant scour associated with overland flows. The scouring of top soil associated with overtopping of the basin carries significant debris loads into the lower catchment, increasing the potential for blockage of the existing stormwater system. Furthermore, the existing house at 4 Harris Street is exhibiting cracking in the external walls associated with subsidence of the underlying ground. It is considered that the scouring associated with overtopping of the basin is contributing to this problem.

Therefore, opportunities to modify the existing basin outlet pipe were investigated to reduce the frequency of overtopping of the basin. This would be achieved by providing a larger pipe outlet (the existing 300mm pipe would be upgraded to a 900mm pipe) to direct a greater proportion of flow below ground and into the downstream channel.

This option also looked to enclose the existing open channel downstream of Harris Street to prevent water spilling into 8 Hampden Street. Additional stormwater inlets were also included in the receiving channel at the rear of 8 Hampden Street to help direct a greater proportion of flows during frequent rainfall events into the stormwater system. The design concept for this option is presented in **Plate 66**.

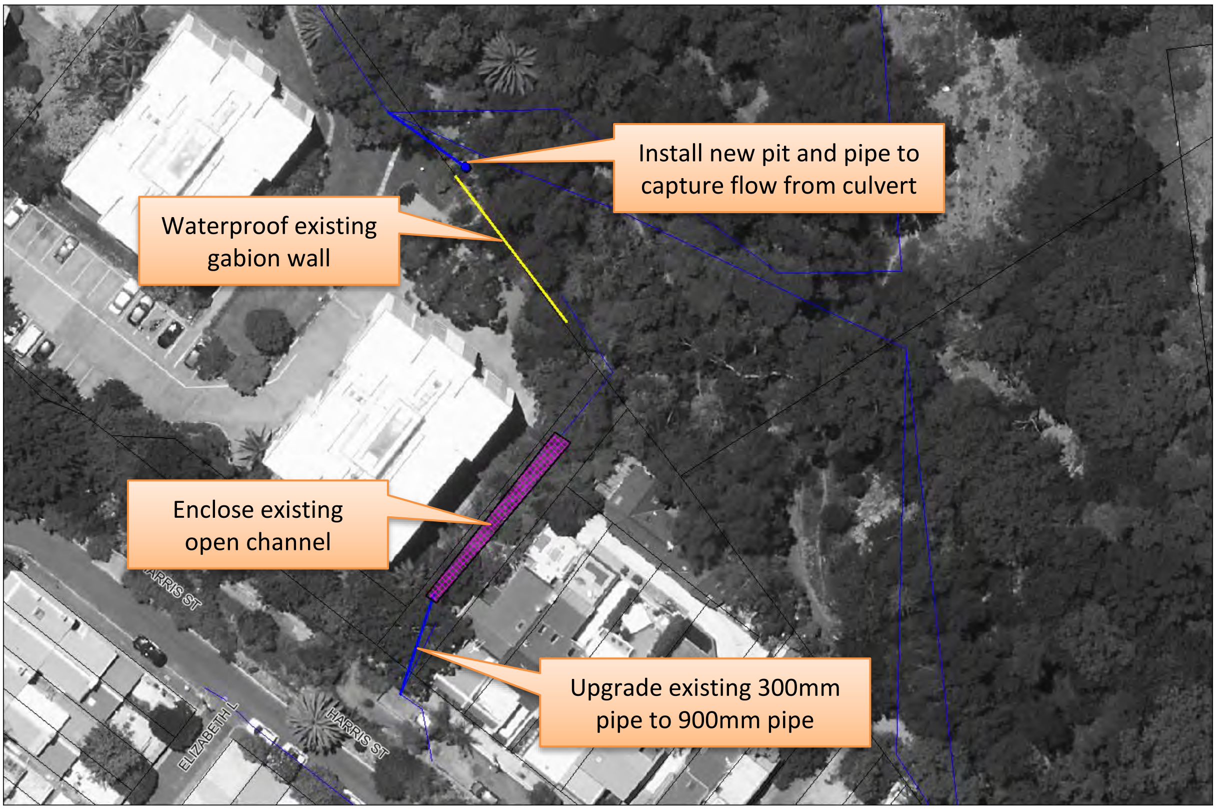


Plate 66 Design Concept for Harris Street Drainage Upgrades

Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 67** and **Plate 68**.

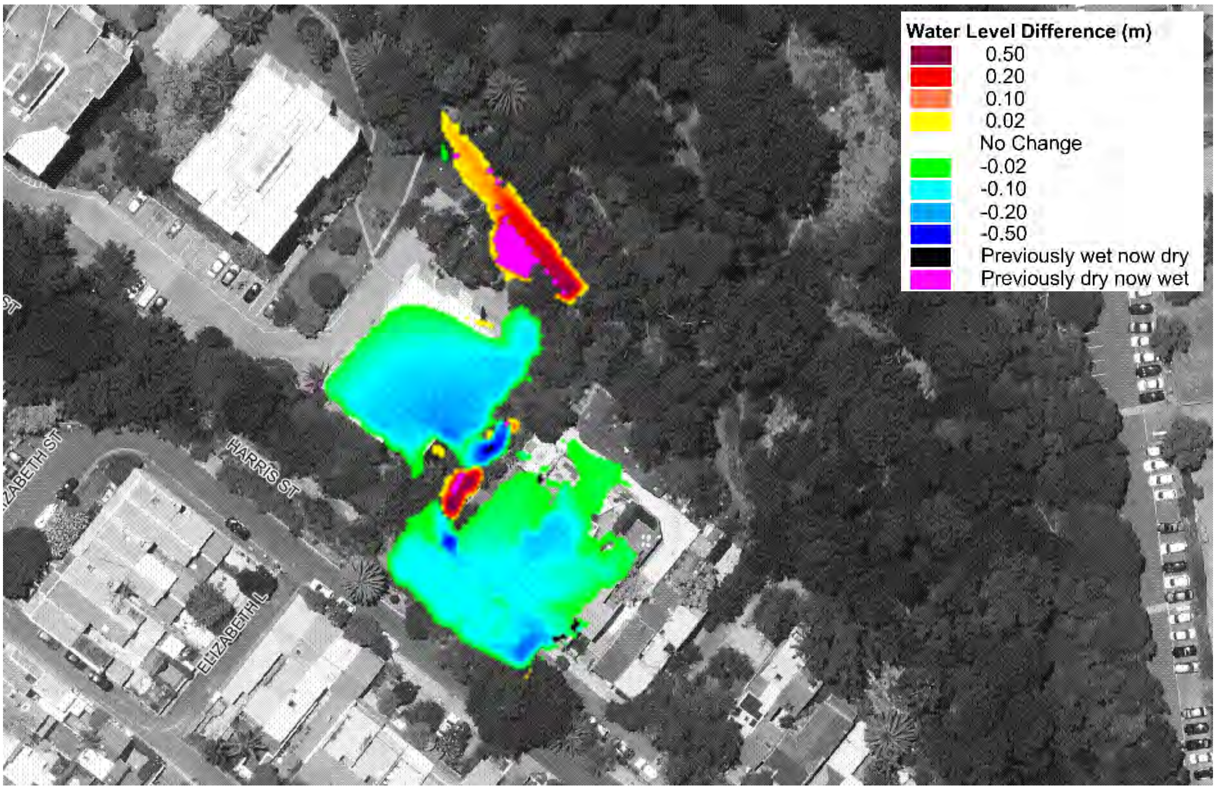


Plate 67 Peak 20% AEP Flood Level Difference Mapping for Harris Street Drainage Upgrades

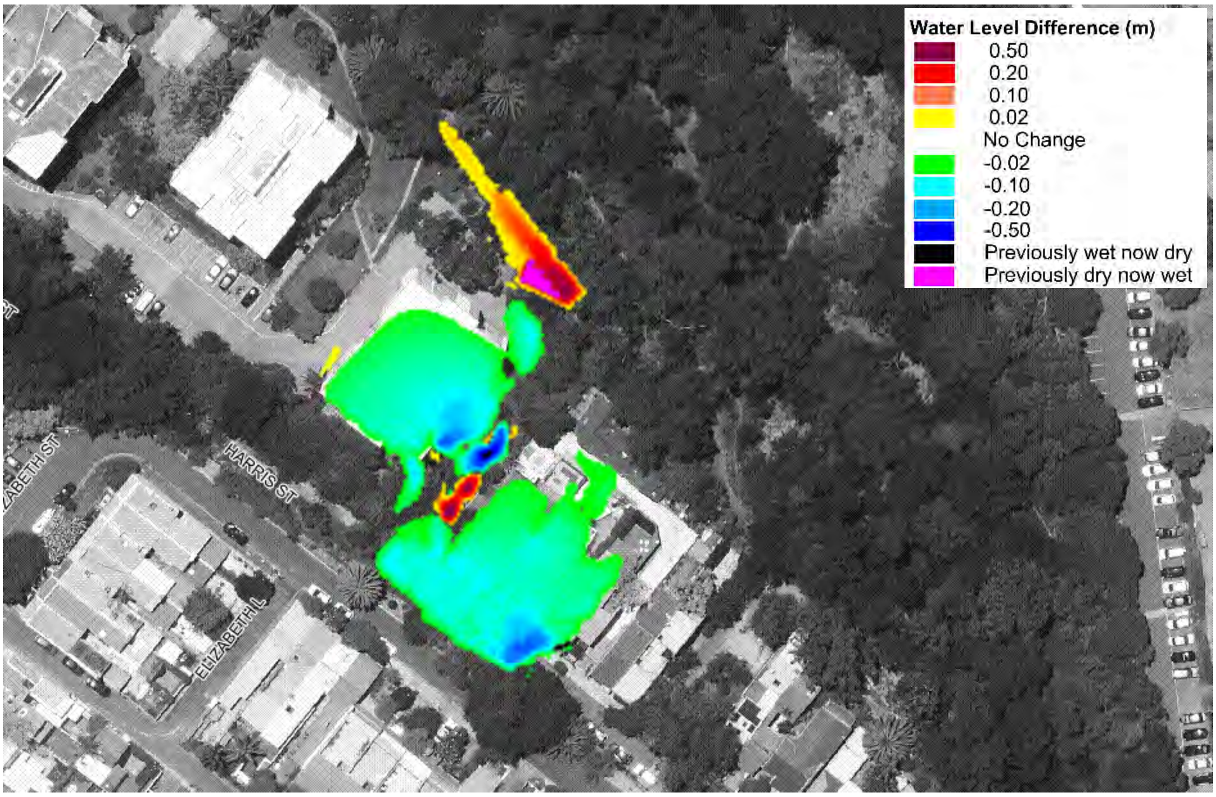


Plate 68 Peak 1% AEP Flood Level Difference Mapping for Harris Street Drainage Upgrades

Plate 67 and **Plate 68** show that the drainage modifications are predicted to generate reductions in peak 20% and 1% AEP flood levels within properties at the western end of Harris Street of up to 0.3 metres and 0.2 metres, respectively. Reductions in peak 20% and 1% AEP flood levels of up to about 0.2 metres are also predicted within 8 Hampden Road.

However, as shown in **Plate 67** and **Plate 68**, the difference mapping does indicate localised increases in peak 1% AEP flood levels of up to 0.15 metres within the northern area of 6-8 Hampden Road. However, increases within this property are typically less than 0.1 metres and within the driveway and carparking areas of this site.

In general, the suggested drainage upgrades were supported by the community, particularly those properties in Harris Street and the eastern part of Hampden Street. However, some concerns were raised by residents in Cecil Street who were of the opinion that the drainage upgrades may increase the existing flooding problem in their area.

The cost to implement the drainage upgrades is estimated to be about $210,000. A detailed breakdown of costs is provided in **Appendix C**.

The potential financial benefit associated with implementation of the detention basin was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the basin in place. The outcomes of the revised damages assessment determined that the drainage upgrades would reduce total flood damage costs by $49,000 over the 50-year design life. This yielded a preliminary benefit-cost ratio of 0.2. Accordingly, the financial benefits of implementing this option are not predicted to outweigh the costs.

Opportunities to improve the visual amenity of the existing outlet structure could be investigated as part of this option. This would arguably add visual value to Trumper Park and adjoining properties and improve the overall benefit-cost-ratio.

Despite the benefit-cost ratio being less than 1, this option is still considered worth pursuing. This is primarily driven by the damage that has been incurred across existing properties in Harris Street and the need to implement measures to ensure this damage is not increased in the future.

Recommendation: Recommended for implementation

5.5.5 Prospect Street to Mary Place

The resident of 34 Prospect Street, Paddington, advised Council that the drain in front of 29 Prospect Street overflowed during the June 2016 flood event and resulted in minor flooding at the end of Prospect Street. The drain was subsequently inspected and tested by Council and it was determined that the drainage network between Prospect Street and Mary Place required upgrading.

A review of the stormwater network indicates that there is a 300mm diameter pipe from Prospect Street to Rowe Lane, which flows into a 225mm pipe from Rowe Lane to Mary Place and along Mary Place to Liverpool Street. It is recommended that further investigation (e.g., CCTV) of this section of stormwater network be undertaken and the potential for upgrades to remove bottlenecks in the system be considered.

Recommendation: Undertake CCTV inspection of this section of the network

5.5.6 Hargrave Lane and Elizabeth Street

There is no piped system along the section of Elizabeth Street between Hargrave Street and Hargrave Lane, or along Hargrave Lane. There are only two pits at the low point in Hargrave Lane to capture any flow within the roadway. Therefore, any overland flow draining to the area from Elizabeth Street or any localised floodwaters draining along Hargrave Lane are not captured within any piped system until it is ponding at the low point. Accordingly, there is potential to add a pit and pipe system along this section of Elizabeth Street and down Hargrave Lane to reduce the amount of overland flow within the roadway and draining through the properties on the northern side of Hargrave Lane.

This option was included in the TUFLOW model and was used to re-simulate each design flood. The results from the revised simulations were reviewed and it was determined that the option would produce only very small (i.e., less than <0.04 metre) reduction in existing flood levels during each design flood. Therefore, this option was not pursued further and is not recommended for implementation.

Recommendation: Not recommended

5.5.7 George Street to Cascade Street (Option A)

A number of roadway "sag" points in the upper catchment areas are drained by relatively small pipes (i.e. 300mm diameter pipes and below). This includes George Street, Elizabeth Street, Elizabeth Place, Victoria Street, Underwood Street and Ashton Lane. Therefore, the potential benefits associated with upgrading the pipe and pit system through this area was investigated.

The location and extent of the stormwater upgrades associated with this option are highlighted in **Plate 69**. As shown in **Plate 69**, this option would include significant drainage upgrades extending from Elizabeth Street and George Street downstream to Cascade Street. This would include installation of over 500m of new stormwater pipes/pipe tunnel coring plus 10 new/upgraded pits.

The TUFLOW model was updated to include the drainage upgrades and was used to re-simulate each of the design floods with the option in place. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place was prepared and is presented in **Plate 70** and **Plate 71**.

Plate 70 and **Plate 71** show that the drainage upgrades are predicted to reduce peak 20% and 1% AEP flood levels across an extensive area of Paddington. This includes reductions in flood levels as far upstream as George Street and Oxford Street and as far downstream as Hopetoun Lane. Peak flood levels are predicted to reduce by well over 0.2 metres in some locations.

It is noted that some small increases in flood level are predicted at the southern end of Cascade Street. However, these increases are predicted to be fully contained to the roadway quickly dissipate.

The flood level reductions are predicted to significantly reduce the number of properties predicted to be subject to above floor inundation. 15 fewer properties are predicted to be inundated above floor level during the 20% AEP flood and 17 fewer properties are predicted to be inundated above floor level during the 1% AEP flood. Accordingly, the drainage upgrades are predicted to significantly reduce the frequency of above floor inundation.

A cost estimate for the drainage upgrades are included in **Appendix C**. As outlined in **Appendix C**, the drainage upgrades are anticipated to cost over $7 million dollars to implement. Accordingly, the capital outlay for this option is significant.

The potential financial benefit associated with implementation of the drainage upgrades was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the drainage upgrades in place. The outcomes of the revised damages assessment determined that the drainage upgrades would reduce total flood damage costs by over $9 million over the 50-year design life. This yielded a preliminary benefit-cost ratio of 1.3. Accordingly, the financial benefits of implementing this option are predicted to outweigh the costs.

Plate 69 Design Concept for Victoria Street/Elizabeth Street to Cascade Street Drainage Upgrades (Option A)

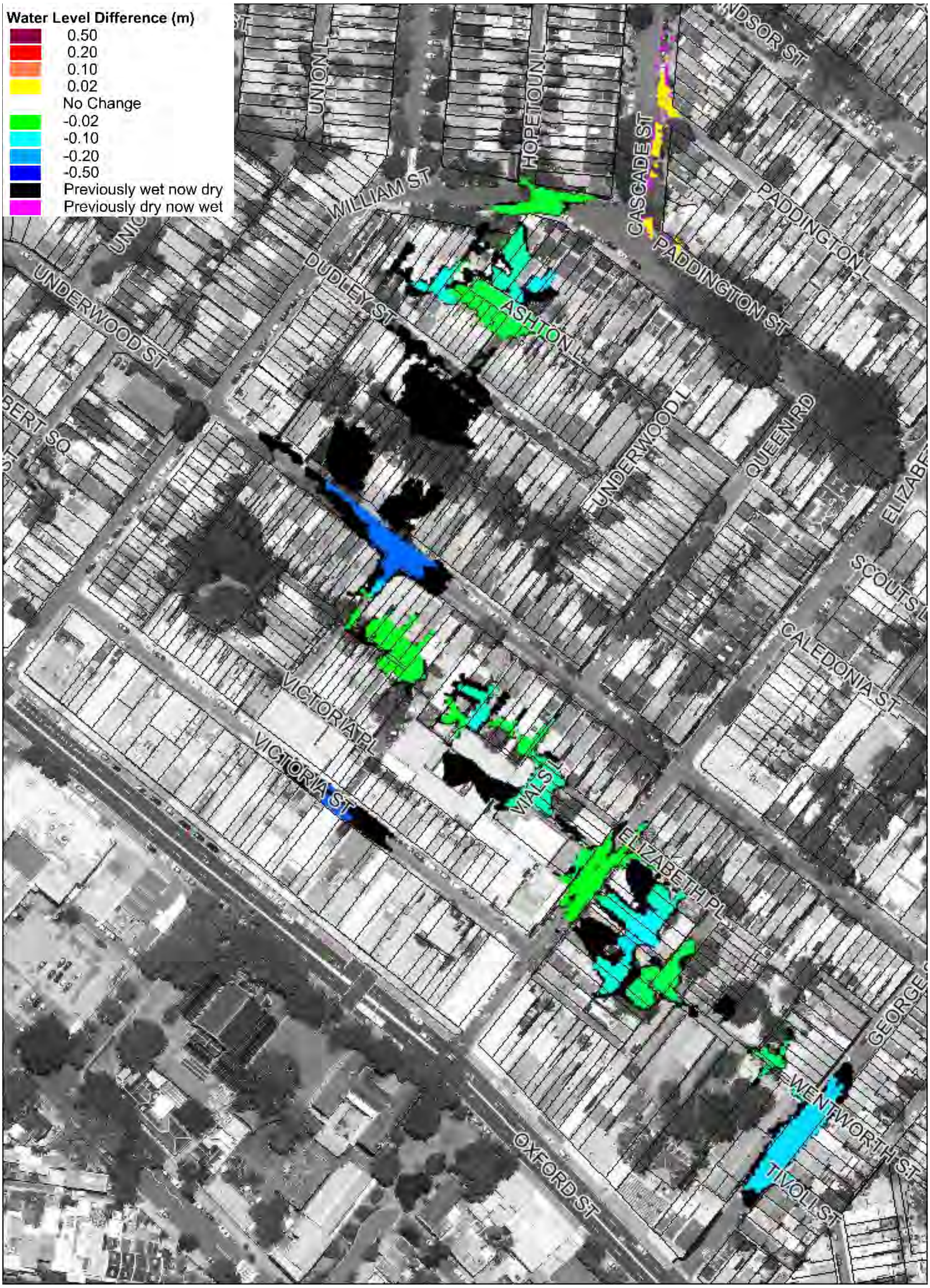


Plate 70 Peak 20% AEP Flood Level Difference Mapping Victoria Street/Elizabeth Street to Cascade Street Drainage Upgrades (Option A)

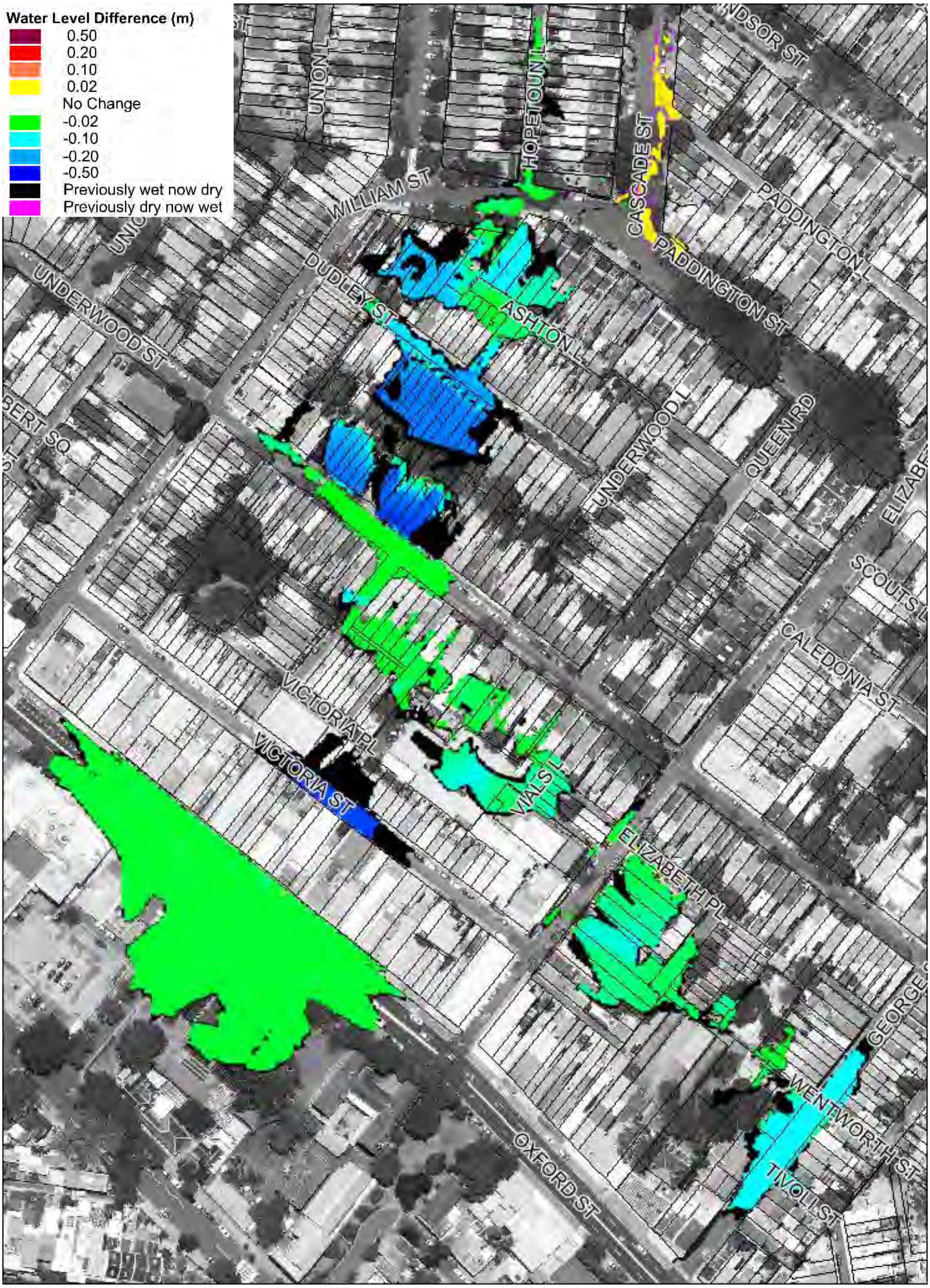


Plate 71 Peak 1% AEP Flood Level Difference Mapping for Victoria Street/Elizabeth Street to Cascade Street Drainage Upgrades (Option A)

It is noted that many of the existing stormwater pipes follow alignments directly below existing buildings. Therefore, if the upgraded pipes were to follow similar alignments it would be necessary to install the new pipes by tunnel coring. To confirm the feasibility of this option, it will be necessary to undertake detailed subsurface investigations to ensure no major constraints exist. Alternatively, pipes could be aligned with roadways to avoid the need for coring (although the lengths of pipes required would increase).

There is also potential for utility conflicts, which would likely increase the construction costs. However, the benefit cost ratio is still expected to remain above 1.

Overall this option is considered to afford significant benefits. However, during the public exhibition of the draft report, a number of local residents objected to the prospect of providing new or upgraded pipes through private property. As a result, a revised drainage upgrade option (Option B) was investigated, which is discussed below. It is recommended that the revised drainage upgrade option be implemented in preference to this option. However, drainage upgrade Option A, or a variation of this option, could be reconsidered if Option B is not found to be feasible and subject to further consultation with the local community.

Recommendation: Not recommended for implementation at this stage. Could be considered if Option B is not the preferred solution after further detailed investigations and subject to community support from the affected residents and property owners.

5.5.8 George Street to Cascade Street (Option B)

As discussed above, the area located between George Street and Cascade Street is predicted to be exposed to significant overland flow depths even during relatively frequent floods. The "Option A" drainage upgrade discussed above is predicted to afford some notable hydraulic benefits across this upper catchment area.

However, feedback from the local community indicated that property owners did not approve of the upgraded stormwater pipes running through private property. Therefore, an alternate drainage upgrade option was investigated (referred to as "Option B"). The Option B drainage upgrades involve placing new and upgrades pits and pipes within the road reserves only (i.e., no upgrades would extend through private property).

The location and extent of the upgrades associated with Option B are highlighted in **Plate 72**. As shown in **Plate 72**, this option would include significant drainage upgrades extending from Elizabeth Street and George Street downstream to Cascade Streets. It would include installation of over 1000m of new stormwater pipes to supplement the existing stormwater pipes plus installation of 24 new/upgraded pits. Accordingly, "Option B" incorporates additional lengths of larger pipes as well as additional pits relative to "Option A".

The TUFLOW model was updated to include the drainage upgrades associated with Option B and was used to re-simulate each of the design floods with the option in place. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place was prepared and is presented in **Plate 73** and **Plate 74**.

Plate 72 Design Concept for Victoria Street/Elizabeth Street to Cascade Street Drainage Upgrades (Option B)

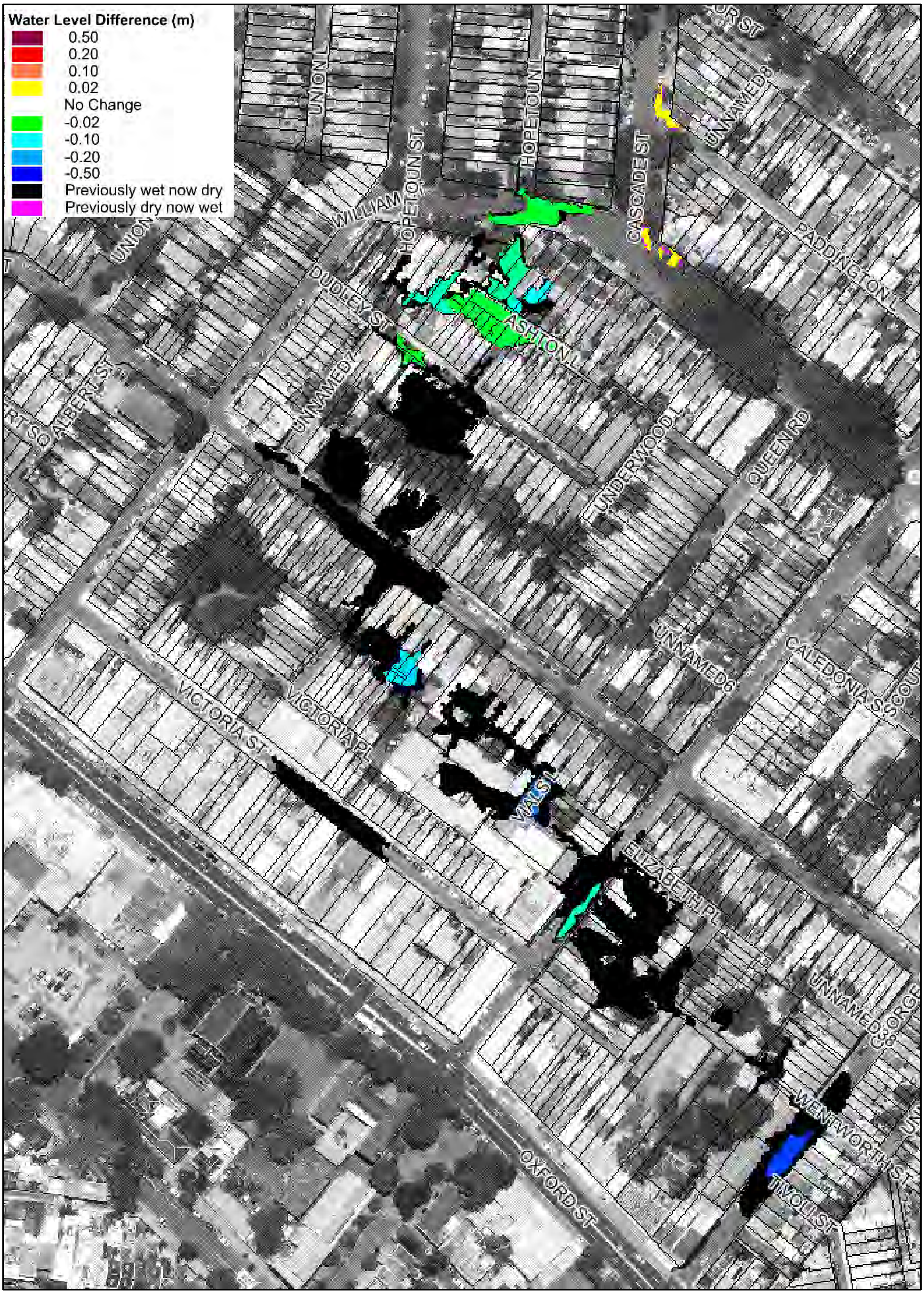


Plate 73 Peak 20% AEP Flood Level Difference Mapping for Victoria Street/Elizabeth Street to Cascade Street Drainage Upgrades (Option B)

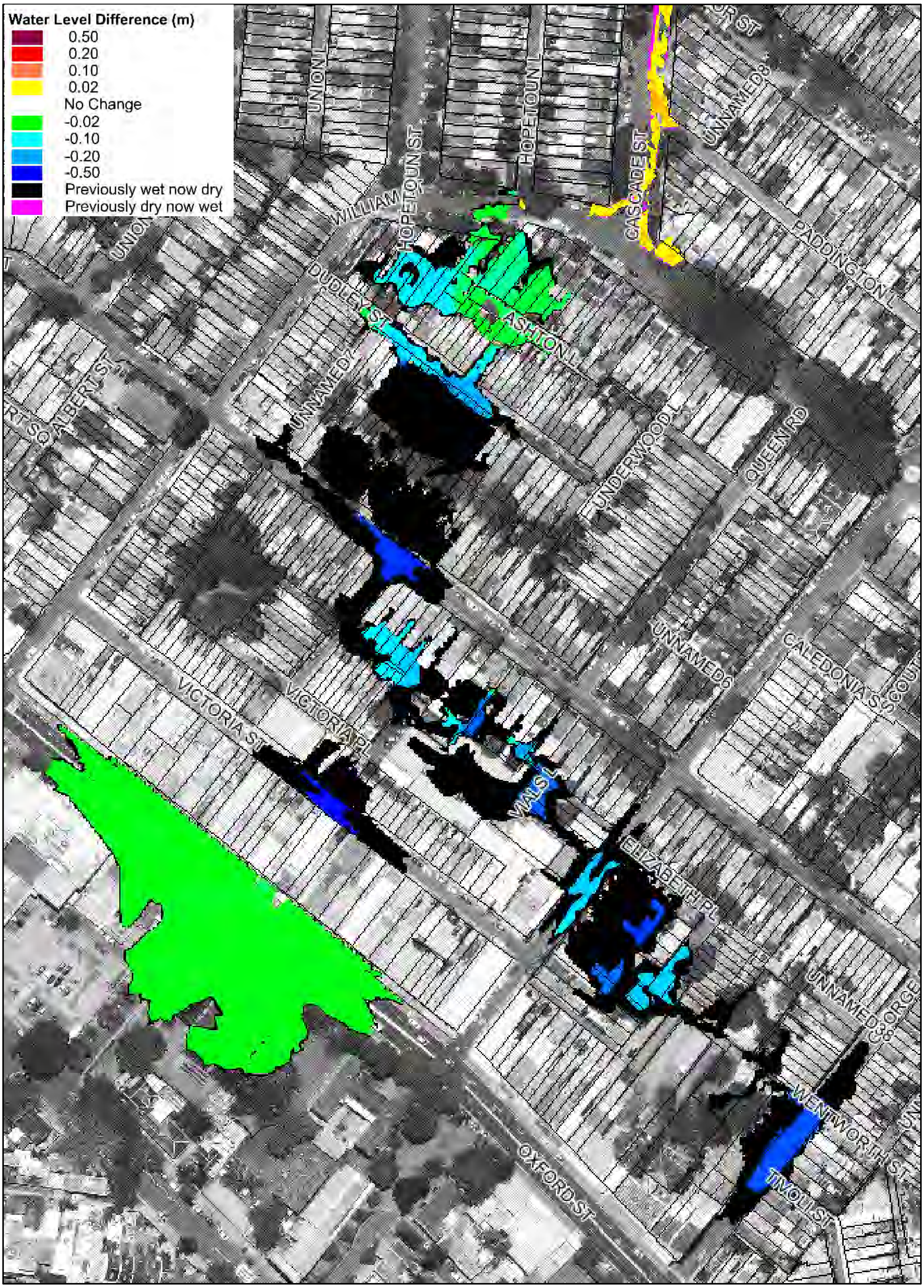


Plate 74 Peak 1% AEP Flood Level Difference Mapping for Victoria Street/Elizabeth Street to Cascade Street Drainage Upgrades (Option B)

Plate 73 shows that the drainage upgrades are predicted to largely eliminate inundation across the upper catchment area during the 20% AEP flood. Small areas of inundation are predicted to remain, such as in George Street. However, existing flood levels are predicted to be reduced by around 0.5 metres at this location (i.e., the remaining water would be very shallow and would be contained to the roadway).

Plate 74 also shows that the drainage upgrades are predicted to significantly reduce the extent and depth of inundation during the 1% AEP flood. This includes typical flood level reductions of around 0.5 metres along most roadways. Flood level reductions are also predicted to extend upstream to Oxford Street. Accordingly, this option would provide flood level reductions across multiple residential and commercial properties during significant rainfall events.

It is noted that some small increases in flood level are predicted at the southern end of Cascade Street, especially during the 1% AEP flood. However, these increases are predicted to be fully contained to the roadway and quickly dissipate.

The flood level reductions are predicted to significantly reduce the number of properties predicted to be subject to above floor inundation. More specifically, 22 fewer properties are predicted to be inundated above floor level during the 20% AEP flood and 38 fewer properties are predicted to be inundated above floor level during the 1% AEP flood. Accordingly, the drainage upgrades are predicted to afford benefits to a large number of upper catchment properties.

A cost estimate for the Option B drainage upgrades is included in **Appendix C**. As outlined in **Appendix C**, the drainage upgrades are anticipated to cost about $12 million dollars to implement. Accordingly, Option B is predicted to be more expensive than Option A. Opportunities to implement this option in stages could be investigated in an effort to spread the cost over several years and improve the financial feasibility.

The potential financial benefit associated with implementation of the drainage upgrades was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the drainage upgrades in place. The outcomes of the revised damages assessment determined that the drainage upgrades would reduce total flood damage costs by around $12 million over the 50-year design life. Accordingly, Option B is predicted to afford greater reductions in flood damage relative to Option A. However, the preliminary benefit-cost ratio of 1.0 is lower for Option B relative to Option A. Nevertheless, there is still enough economic incentive to pursue the Option B drainage upgrades.

Overall this option is considered to afford significant benefits. Despite the higher capital cost of Option B, it affords greater hydraulic and above floor flooding benefits and greater public support relative to Option A. Therefore, Option B is recommended for implementation subject to further detailed investigations. It is recommended that detailed survey (e.g., services) is completed and detailed design plans are prepared to allow for more detailed cost estimates to be prepared.

Recommendation: Recommended for implementation subject to further detailed investigations

5.5.9 Hopetoun Lane

The piped system draining from Hopetoun Street to Cascade Street is predicted to be at 50-100% capacity during a 1 exceedance per year flood. Therefore, there is potential to upgrade part of the existing pit and pipe network in this area, thereby reduce the amount of overland flow down the roadways (most notably Hopetoun Lane) and through private properties.

The design concept for the drainage upgrades are illustrated in **Plate 75** and will include the upgrading of existing pipes as well as the installation of a new 600mm diameter pipeline down the eastern side of Hopetoun Lane.

Plate 75 Design Concept for Hopetoun Lane Drainage Upgrades

The TUFLOW model was updated to include the drainage upgrades and was used to re-simulate each of the design floods with the option in place. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place was prepared and is presented in **Plate 76** and **Plate 77.**

Plate 76 and **Plate 77** show that the drainage upgrades are predicted to reduce peak 20% and 1% AEP flood levels in the immediate vicinity of Hopetoun Lane. This includes reductions in flood levels of up to 0.2 metres during the 1% AEP flood and up to 0.1 metres during the 20% AEP flood. This is predicted to result in three fewer properties being inundated above floor level during the 20% AEP flood. However, there is predicted to be no reduction in the number of properties subject to above floor inundation during the 1% AEP event.

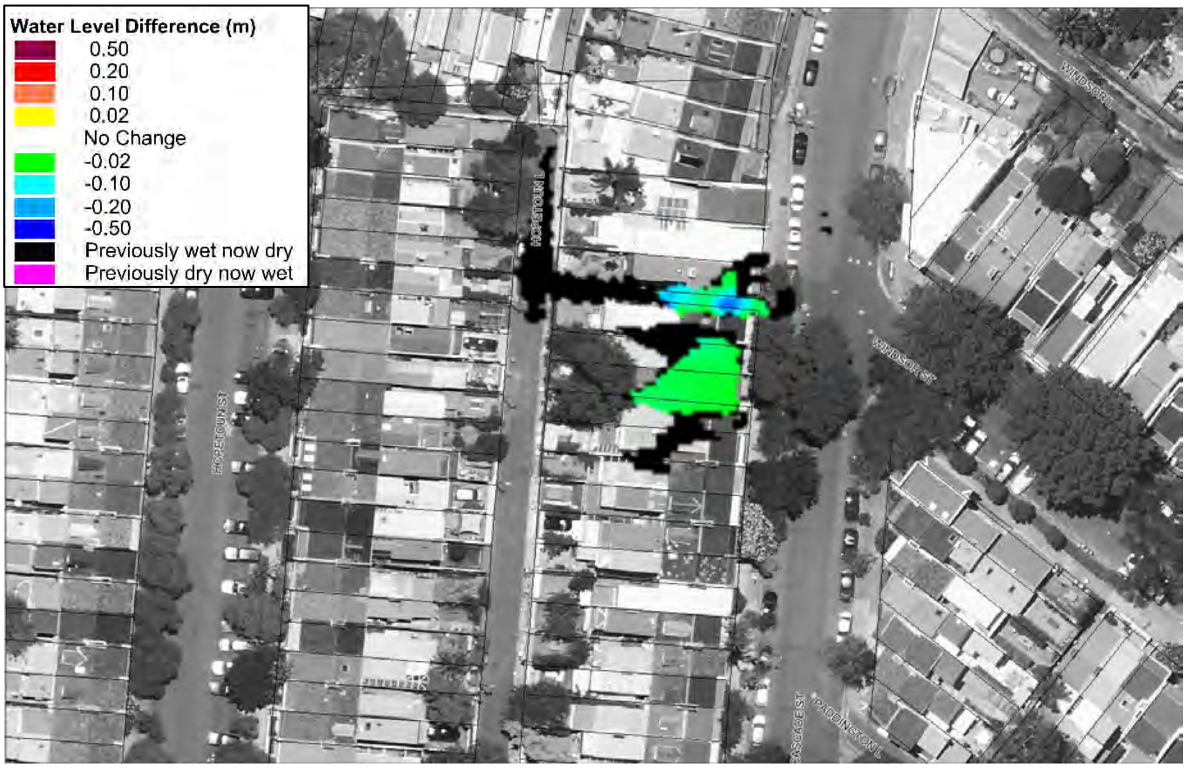


Plate 76 Peak 20% AEP Flood Level Difference Mapping for Hopetoun Lane Drainage Upgrades

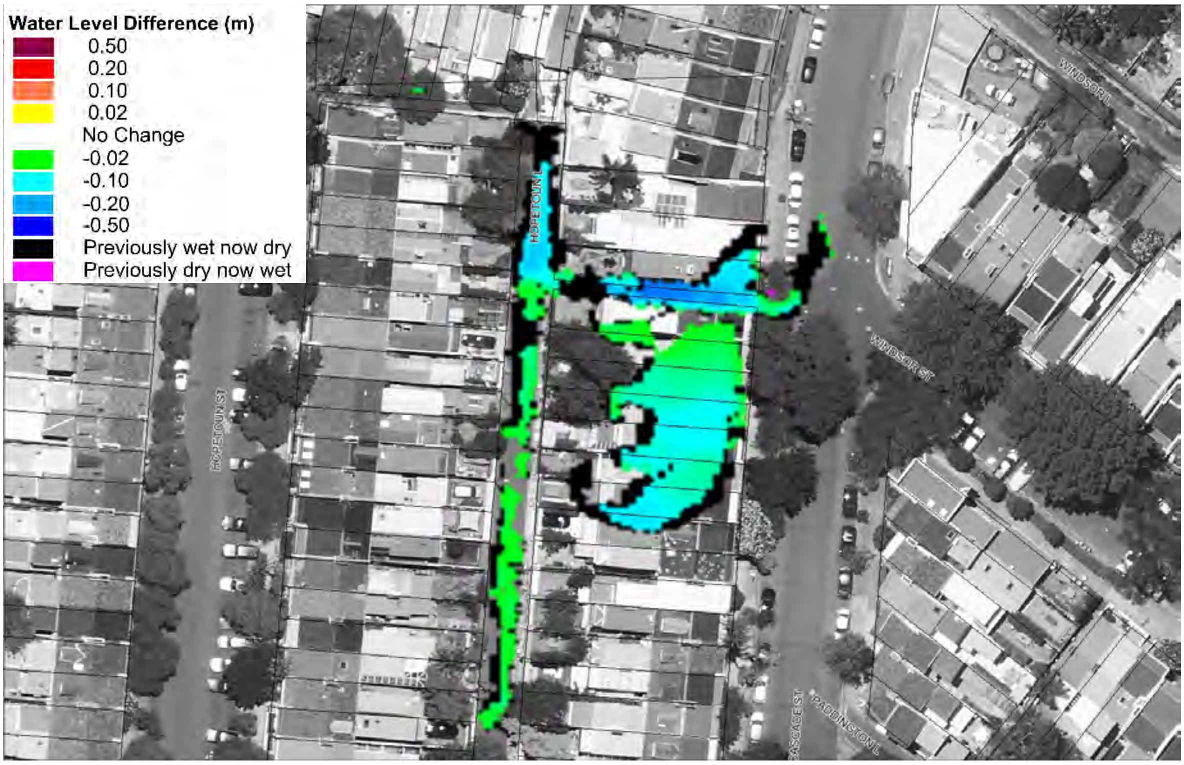


Plate 77 Peak 1% AEP Flood Level Difference Mapping for Hopetoun Lane Drainage Upgrades

A cost estimate for the Hopetoun Lane drainage upgrades is included in **Appendix C** and shows that the drainage upgrades are expected to cost just about $1 million to implement.

Revised flood damage cost was prepared with the drainage upgrades in place and this determine that implementation of the option would reduce flood damage costs by just over $1 million over 50 years. This yields a benefit-cost ratio of 1 indicating the benefits are approximately equal to the costs of the option.

Overall this option requires greater capital expenditure and provides a lower benefit-cost ratio relative to the regrading discussed in Section 5.4.5. Therefore, this option is not considered worth pursuing if the regrading option is implemented.

Recommendation: Not recommended for implementation

5.5.10 Sutherland Street to Trumper Oval

A major trunk drainage pipeline extends from the low point in Sutherland Street north and joins the Sydney Water drainage asset at Trumper Oval. This pipe system is predicted to generally have less than a 1 year capacity. Consequently, significant overland flows are predicted between Sutherland Street and Trumper Oval during severe rainfall events. There is also evidence of this pipeline flowing under significant pressure resulting in manhole covers being “blown off”. Therefore, opportunities to upgrade this drainage system were investigated.

The extent of the drainage upgrades that were investigated as part of the option are summarised in **Plate 78**. As shown in **Plate 78**, the option involves installation of a new 1.2 m diameter pipes along Cecil Lane, Hampden Street and Royalston St. New inlet pits would also be installed along these streets to assist in capturing local runoff and new junction pits would be provided where the new pipe joins or passes through the existing trunk drainage asset.

The TUFLOW model was updated to include the drainage upgrades and was used to re-simulate each of the design floods with the option in place. Peak floodwater level difference mapping for the 20%, 10% and 1% AEP events with this option in place was prepared and is presented in **Plate 79**, **Plate 80** and **Plate 81.**

Plate 79, **Plate 80** and **Plate 81.** show that the drainage upgrades are predicted to reduce peak 20%, 10% and 1% AEP flood levels across an extensive area extending between Cecil Street and Trumper Oval. The flood level reductions extend across a more significant area during the 20% and 10% AEP events where a greater proportion of the overall flow is predicted to be conveyed by the upgraded pipe system than in the 1% AEP event. Flood level reductions of more than 0.05 metres are anticipated across most areas during both the 20% and 10% AEP floods and slightly less than 0.05 metres during the 1% AEP event.

The drainage upgrades are predicted to result in 2 fewer properties being exposed to above floor inundation during the 20% and 10% AEP floods.

The estimated cost to implement this option is expected to be $8 million. Accordingly, the capital cost to implement this option is significant.

Plate 78 Design Concept for Sutherland Street to Trumper Oval Drainage Upgrades

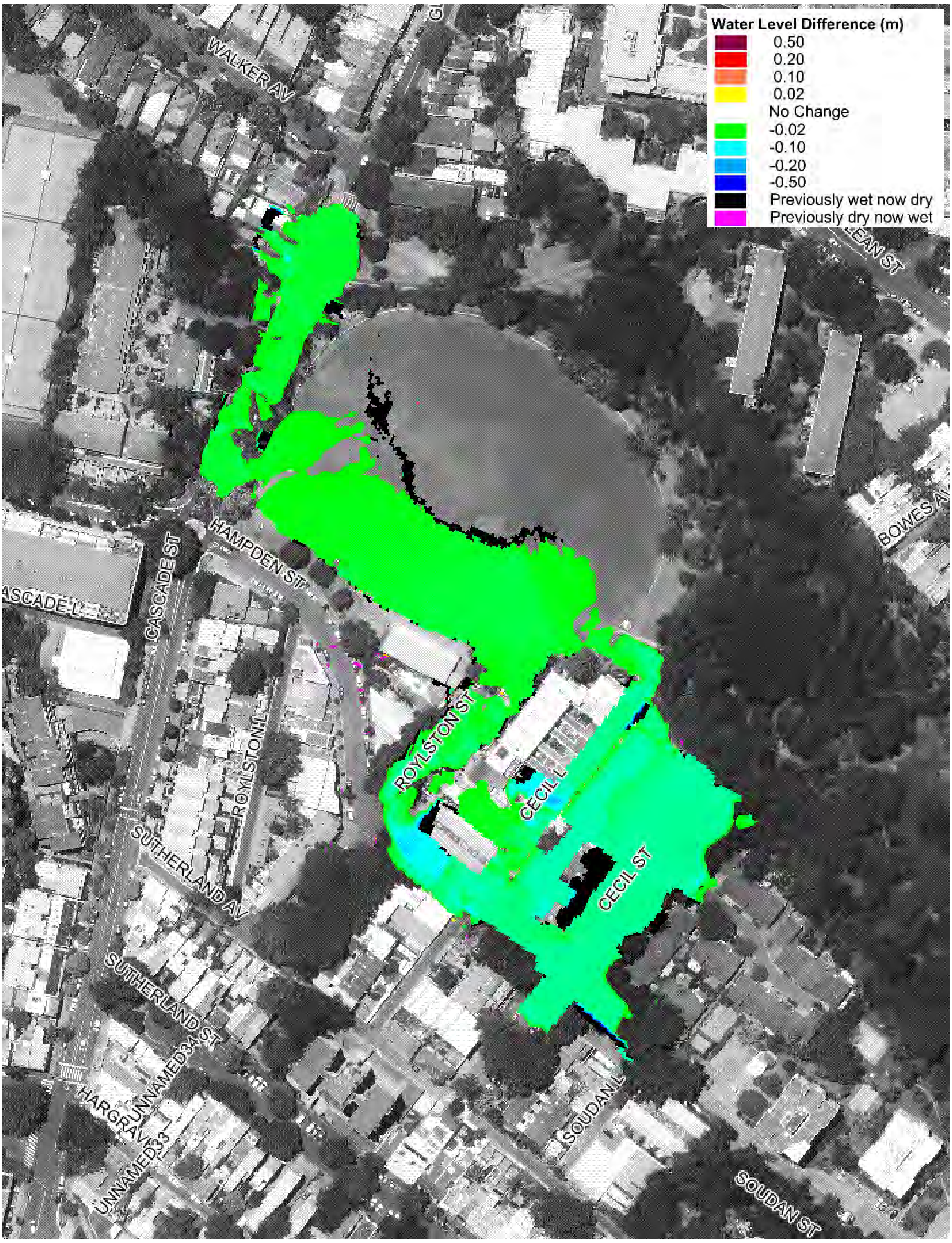


Plate 79 Peak 20% AEP Flood Level Difference Mapping for Sutherland Street to Trumper Oval Drainage Upgrades

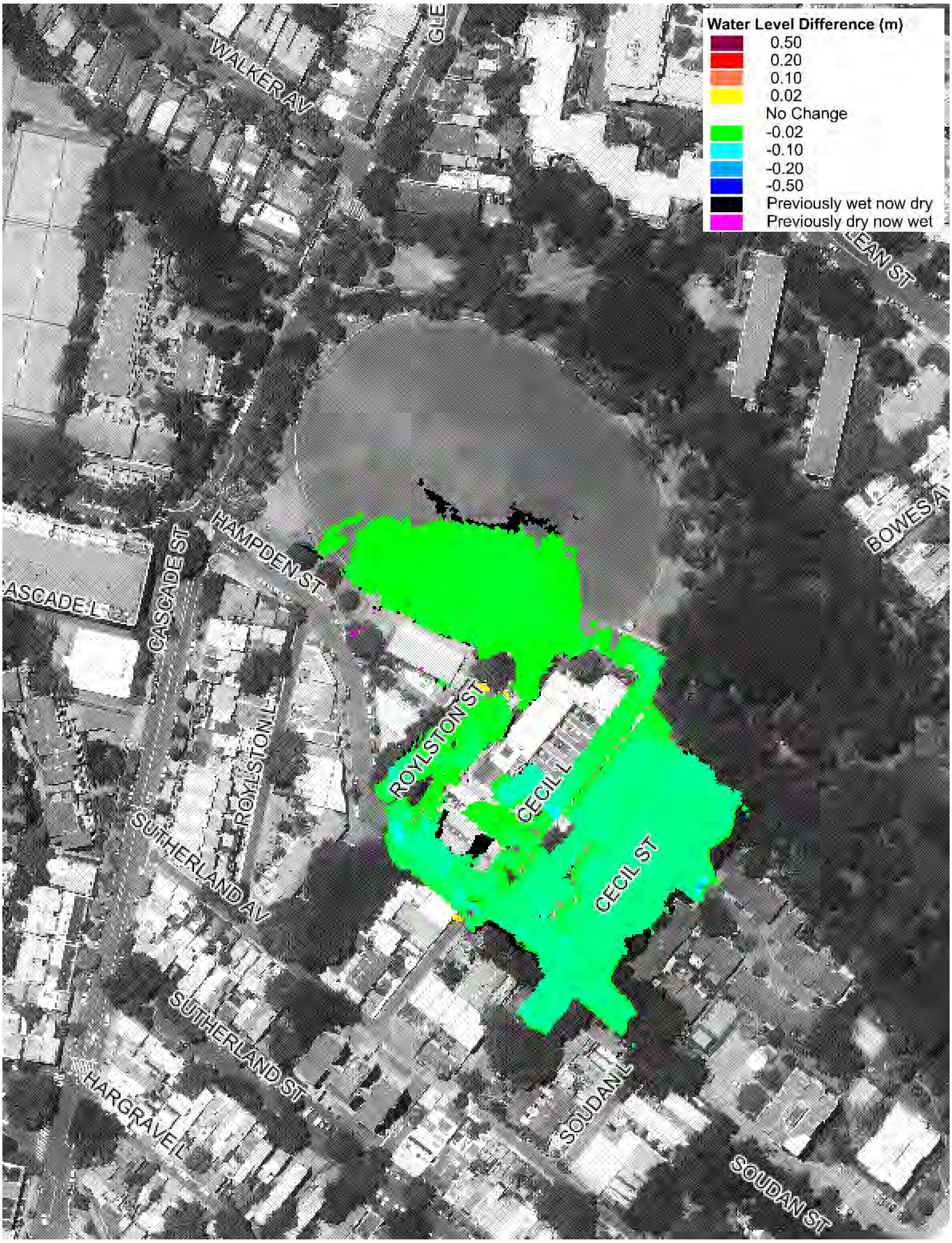


Plate 80 Peak 10% AEP Flood Level Difference Mapping for Sutherland Street to Trumper Oval Drainage Upgrades

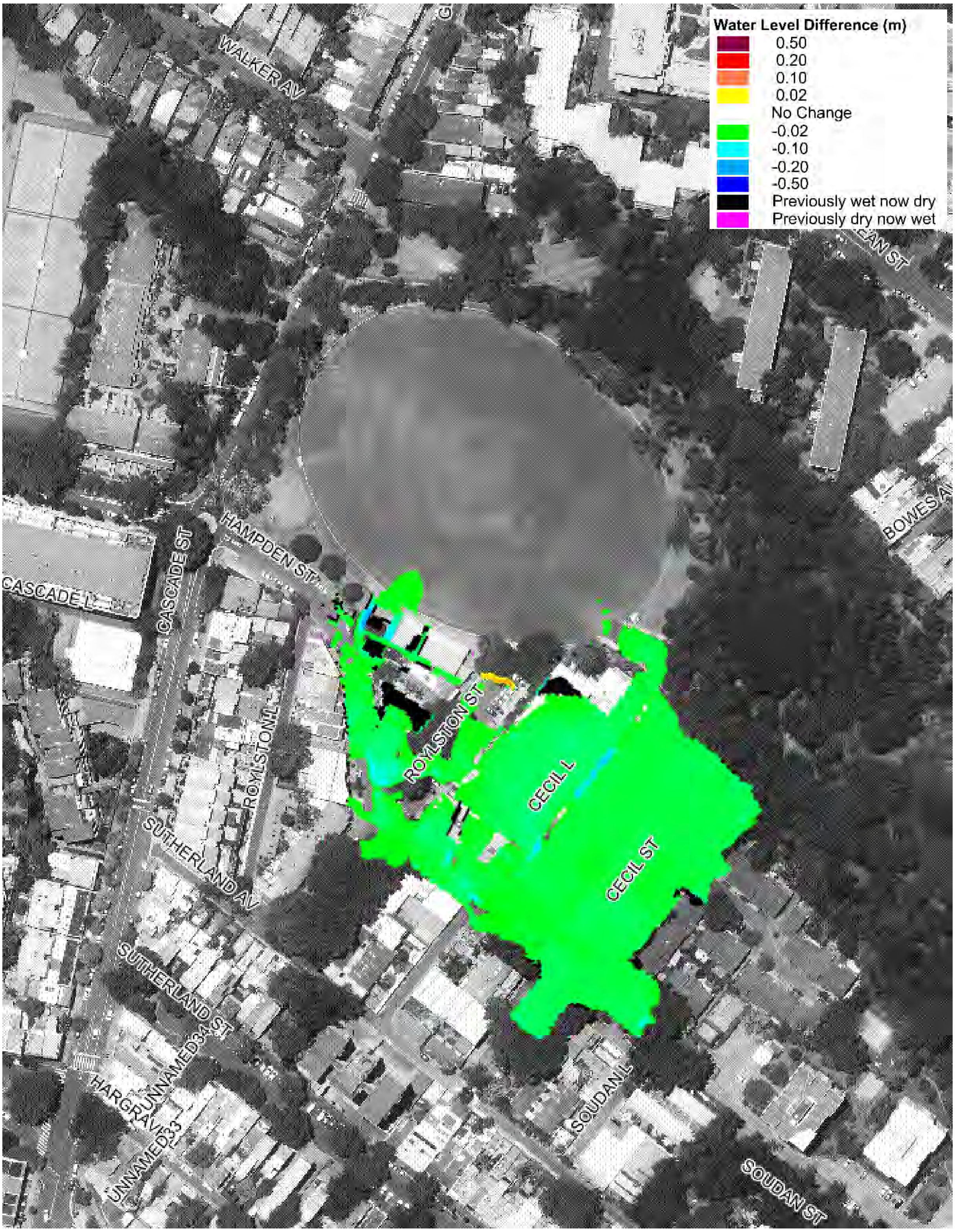


Plate 81 Peak 1% AEP Flood Level Difference Mapping for Sutherland Street to Trumper Oval Drainage Upgrades

Revised flood damage costs were prepared with the drainage upgrades in place and this determined that implementation of the option would reduce flood damage costs by about $1.8 million over 50 years. This yields a benefit-cost ratio of 0.2 indicating the costs outweigh the benefits of the option.

As with the other drainage upgrade options considered as part of this study, undertaking sub-surface drainage upgrades works will implement a number of construction challenges such as utility conflicts. Specially designed junction pits will also need to be designed and constructed recognising that the current drainage asset flows under pressure during significant rainfall events.

Overall, this option affords notable benefits across some of the most significant impacted sections of the study area. However, the significant cost is a major impediment to implementation. It is considered that implementation of other options (e.g., Cecil Street flood mitigation measures) may be a more cost-effective option for treating the flood risk in this area.

It is understood that Sydney Water are exploring opportunities for modifying the existing manhole cover in Hampden Street to prevent the manhole lid from being dislodged during heavy rainfall event. This should continue to be explored. Opportunities to install a "surcharge" pit could also be investigated in a location where the surcharging water would not damage properties (e.g., Trumper Oval).

Recommendation: Not recommended for implementation. However, modification to manhole arrangement in Hampden Street should continue to be explored.

5.5.11 Boundary Street

The *'Rushcutters Bay Catchment Floodplain Risk Management Plan' (WMA, 2015)*, prepared for the City of Sydney, recommended an upgrade of the trunk drainage system along Boundary Street and Neild Avenue to reduce the high hazard overland flow within the City of Sydney LGA. This option (referred to in the report as Option FM – RB04) involves upgrading the capacity of the pit and pipe system and regrading some sections of the pipe network.

The capital cost of the trunk drainage upgrades along Boundary Street from Oxford Street to Weigall Sportsground (as well as upgrades on Sims, Taylor and Sturt Streets within the City of Sydney LGA) was estimated to be approximately $15,987,900 with $17,100 ongoing annual costs.

Boundary Street forms the boundary between the City of Sydney and Woollahra Municipal Council LGAs. Accordingly, any drainage upgrades along this roadway will likely afford benefits across both LGAs. Across the Woollahra LGA properties fronting Boundary Street and Neild Avenue, as well as those properties in upstream areas where the existing stormwater network discharges into the Boundary Street/Neild Avenue trunk drainage system (e.g., Hopewell Street, Kidman Lane, Comber Street, Glenview Street, Glenview Lane, Liverpool Street, Cooper Street) would likely benefit.

Although the capital cost associated with this option is significant, there is potential to share the cost between both Councils. It is suggested that discussions between both Councils be completed to determine the financial feasibility of pursing this option.

Recommendation: Undertake discussions with The City of Sydney Council to determine financial feasibility of the option

5.5.12 Further Investigation of Potential Bottlenecks in the System

Pipe pW5W0 from the low point in Morrell Street is a 450mm diameter pipe and flows into a 1.2m diameter pipe at Jersey Road, however pipes into the system at Morrell Street junction are 400mm and 750mm diameter pipes. Accordingly, the 450 mm diameter pipe appears to be a significant "bottle neck". It is recommended that further investigation of this section of stormwater network be undertaken (e.g., CCTV) to confirm the pipe sizes and the potential for upgrades to remove bottlenecks in the system be considered.

Recommendation: Undertake CCTV inspections to confirm pipe sizes

5.6 Maintenance Program

Paddington includes extensive tree-lined streets as well as areas of significant vegetation (e.g., Trumper Park). Although this vegetation provides a significant visual amenity for the area, it increases the potential for leaf litter and other debris to be mobilised during significant rainfall events leading to blockage of stormwater pipes and pits. This will reduce the effectiveness of the existing drainage infrastructure which, in turn, will increase overland flows across Paddington.

Council has a formal weekly and monthly maintenance program which focuses on known flooding "trouble spots". Drainage maintenance staff visually inspect and, if necessary, clean the drains weekly as well as after significant rainfall events. Contractors are also engaged to empty litter and leaves and, if necessary, repair the stormwater pits.

Council also undertakes regular CCTV investigations to assist with planning and implementing Council's maintenance program.

It is recommended that Council's Maintenance Program be updated to reflect the information in this Floodplain Risk Management Study and Plan. Most notable, it is recommended that each of the flooding "trouble spots" identified in this report be targeted as part of the maintenance program.

Recommendation: Council's Maintenance Program for stormwater drainage be updated to reflect the information in the Paddington Floodplain Risk Management Study and Plan.

5.7 Recommendations

A summary of the evaluation of each flood modification option recommended for implementation is provided in **Table 8**. As shown in **Table 8**, the following options are recommended for further consideration to assist in managing the existing flood risk across Paddington:

- Cecil Street/Trumper Park flood mitigation measure
- Roadworks on Hopetoun Lane/Paddington Street and Glenmore Road
- Drainage Upgrades:
  - George Street to Cascade Street
  - Harris Street
  - Forbes Street & Harris Street
- Updating Council's drainage maintenance program to address flooding problem areas identified in the Floodplain Risk Management Study and Plan.

Table 8 Evaluation Matrix for Recommended Flood Modification Options

Option	Evaluation Criteria / Score#						
	Hydraulic Impacts	Inundated Buildings	Financial Feasibility	Community Acceptance	Environmental Impacts	Emergency Response	Technical Feasibility
Cecil Street Flood Mitigation Measures	++	++	++	+	-	+	-
Trumper Park Floodway	++	++	++	+	-	+	-
Hopetoun Lane/Paddington St Roadworks	+	+	+	+	-N-	+	+
Glenmore Road Regrading	+	-	+	++	-N-	+	+
Forbes Street to Harris Street Drainage Upgrades	+	++	-	+	-N-	+	--
Harris Street Drainage Upgrades	+	+	-	+	-N-	-N-	-
George Street to Cascade Street Drainage Upgrades	++	++	+	+	-N-	+	--
Drainage Maintenance Program	Not evaluated						

Refer to **Table 7** for evaluation criteria and scoring system

6 PROPERTY MODIFICATION OPTIONS

6.1 Introduction

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

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

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

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

6.2 Property Modification Options

6.2.1 Voluntary House Purchase

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

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

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

- High flood hazard areas; and
- Floodway areas.

It was determined that no existing residential properties within the study area meet the above requirements. Therefore, no properties were considered eligible for voluntary purchase.

Recommendation: Not recommended

6.2.2 Voluntary House Raising

Voluntary house raising (VHR) is a well-established method of reducing the frequency, depth and duration of above floor inundation . VHR can be a suitable measure for reducing the flood damage for individual dwellings or can be used as a compensatory measure where other flood mitigation works are predicted to adversely impact on flood behaviour across individual dwellings. An example of house raising is provided in **Plate 82**.

Plate 82 Examples of houses before (top image), during (middle image) and after (bottom image) house raising (photos courtesy of Fairfield City Council)

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

Unfortunately, the existing housing stock in Paddington primarily comprises multi-storey terrace style housing, which is not suited to house raising. Therefore, house raising is not considered practical for Paddington.

Recommendation: Not recommended for implementation

6.3 Planning Options

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 relevant planning legislation and policies that affect the development of land within the Woollahra LGA. 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.

6.3.1 SEPP (Exempt and Complying Development Codes) 2008

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

Clause 1.5 of the Codes SEPP defines a "flood control lot" as a lot to which flood related development controls apply in respect of residential development (other than development for the purposes of group homes or seniors housing). These development controls are typically exercised through Council's *Local Environmental Plan* or *Development Control Plan*, which are discussed in more detail below. Exempt development is not permitted on flood control lots but some complying development is permitted 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.

6.3.2 Woollahra Local Environmental Plan 2014

The *Woollahra Local Environmental Plan 2014* (Woollahra LEP 2014) outlines the zoning of land, what development is allowed in each land use zone and any special provisions applying to land. The land zoning map for the Paddington area is reproduced in **Plate 83** and shows that majority of the Paddington study area comprises "R2" (low density residential) with smaller areas of R3 (medium density residential) adjoining Trumper Park and B4 (mixed use) primarily adjoining Oxford Street. Some significant areas of "RE1" (public recreation) are also contained in the study area, the most notable of which is Trumper Park.

Suitability of Current LEP 2014 Zoning

The LEP is developed based upon consideration of a range of "opportunities" and "constraints". This includes the potential flood risk. However, detailed overland flood risk information was not previously available to help inform the current land use zones across Paddington. Therefore, an assessment was undertaken to establish the compatibility of the Woollahra LEP 2014 land use zones with the three flood risk precincts defined in the *Woollahra Development Control Plan 2015* (refer to Section 6.3.3 and **Figure A16**).

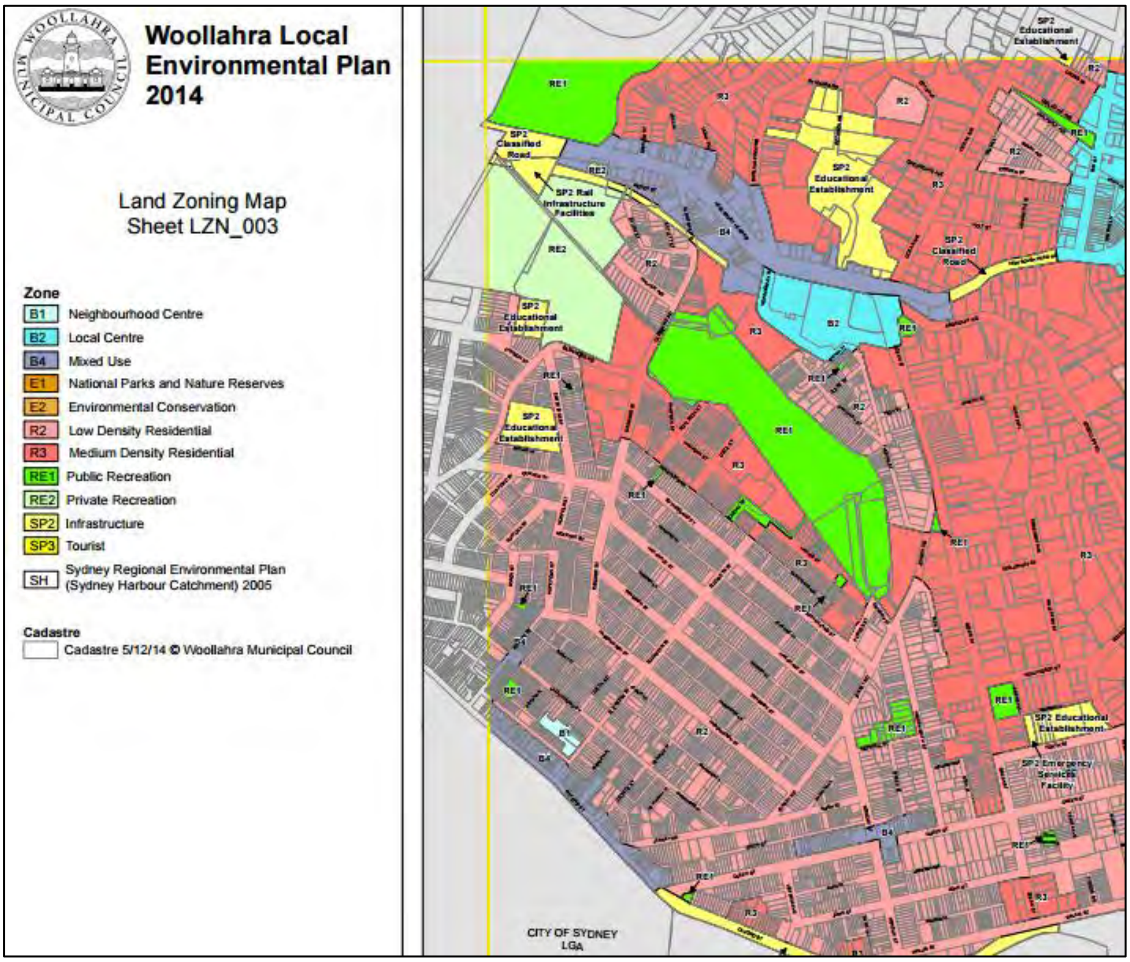


Plate 83 Current Land Zoning Map for Paddington

The assessment quantified the percentage of each LEP zone falling within each flood risk precinct. This information is presented in **Table 9** and shows that less than 1% of business zones B1 and B2 as well as residential zone R2 fall within the high flood risk precinct areas. This outcome indicates that, in general, the LEP 2014 land use zones appear to be compatible with the flood risk.

Table 9 Percentage of LEP Zones falling within each Flood Risk Precinct

LEP Zone	Located Outside of Flood Risk Precincts	Low Flood Risk Precinct	Medium Flood Risk Precinct	High Flood Risk Precinct
B1	52.6	27.1	19.9	0.5
B4	78.9	18.3	2.5	0.3
R2	80.7	12.5	6.0	0.8
R3	60.7	18.7	15.7	4.9
RE1	30.1	49.3	16.4	4.1
RE2	5.9	26.7	63.6	3.8
SP2	78.2	18.5	2.6	0.7

It is noted that approximately 5% of residential zone R3 falls within the high flood risk precinct. Therefore, additional investigations were completed to determine where these properties are located, which is shown in **Plate 84**.

Plate 84 Residential and business allotments where over 50% of the lot area is exposed to high flood risk precinct

The areas highlighted in **Plate 84** include:

- R2 lot adjoining Sydney Water channel on western side of Glenmore Road (currently not developed).
- Small strip of land between Hoddle St and Lawson St that currently serves as a pedestrian pathway (and overland flowpath), which is currently zoned R2 residential (currently not developed).
- Allotment adjoining 24 Sutherland Street that is currently zoned R2 residential. The allotment is currently undeveloped and provides vehicular access around the adjoining apartment building.
- Two lots located near the corner of Forbes Street and Sutherland Street. This includes an apartment building where the high flood risk is driven by the significant water depths in the ground floor car park (i.e., the habitable areas are elevated indicating the flood risk may be overestimated at this location).
- Thirteen lots located between Sutherland Avenue and Harris Street.
- One lot located in Harris Street.

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

Suitability of Flood Planning Provisions

Flood planning is addressed in clause 6.3 of the LEP and relates to all land identified as "flood planning area" on the flood planning maps. The flood planning map contained in the LEP for the Paddington area is reproduced in **Plate 85**.

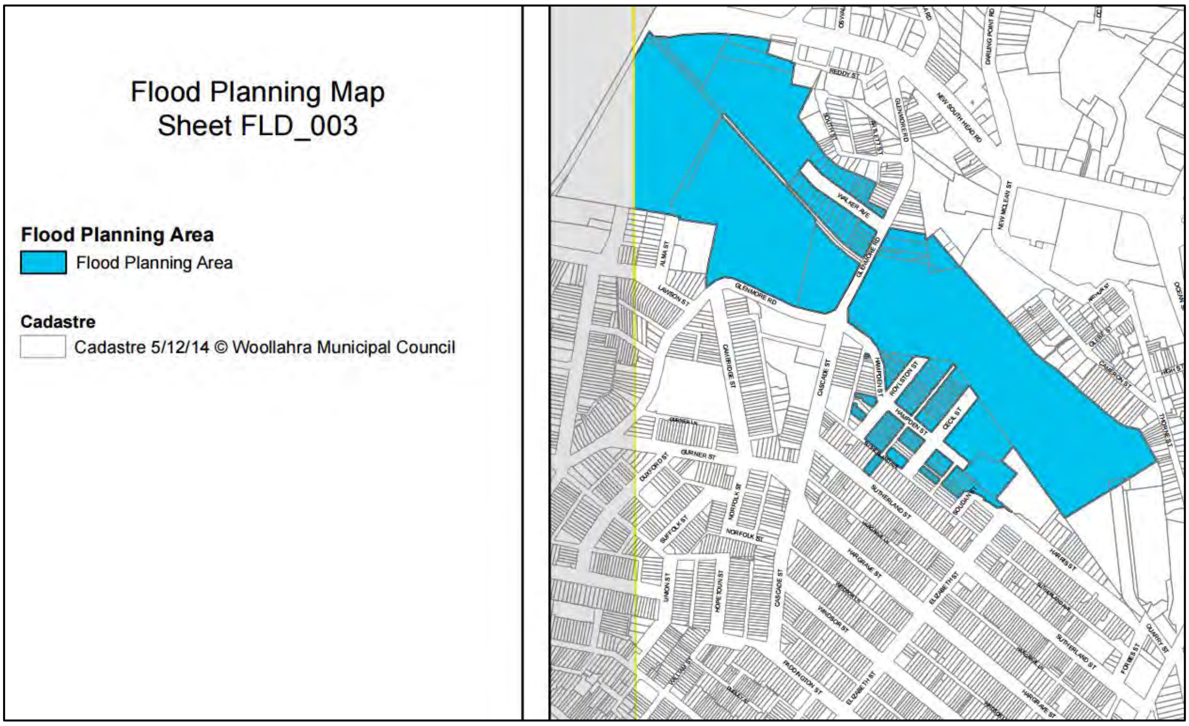


Plate 85 Current Flood Planning Area Map for Paddington

The flood planning map shows extensive areas of the lower Rushcutters Bay catchment that fall within Council's flood planning area (i.e., flood control lots). However, no parcels of land south of Lawson Street, Harris Street, Sutherland Street and Glenmore Road are identified in the map. Therefore, it is recommended that the flood planning map be updated to incorporate the detailed overland flood mapping generated as part of the current study.

Recommendations: Update flood planning map to take advantage of updated flood information generated as part of the current study

6.3.3 Woollahra Development Control Plan 2013

Woollahra Development Control Plan 2015 (Woollahra DCP 2015) sets the design and construction standards that apply when carrying out development within the LGA. It supports Woollahra LEP 2014, which regulates the uses that are permissible on the land.

Chapter E2: Stormwater and Flood Risk Management of the Woollahra DCP 2015 outlines the general development controls relating to management of stormwater and flood risk. Chapter E2 is reviewed below.

Flood Planning Levels

Flood planning levels (FPLs) set the floor level height for development in areas which are contained within the flood planning area. The FPLs defined by the Woollahra DCP 2015 vary depending on the relative flood risk and the proposed development type, as listed in **Table 10** below. Flood planning levels (FPLs) has been stipulated also in *Woollahra Local Environment Plan (LEP) Clause 6.3.5*

Table 10 Flood Planning Levels in Woollahra DCP 2015

Development Type	Flood Planning Level (FPL)
Habitable floor areas	1% AEP flood level plus 0.5m freeboard
Non-habitable floor areas	1% AEP flood level plus 0.3m freeboard
Ground level, open car parking spaces	5% AEP flood level plus 0.3m freeboard
Non-habitable floor areas	1% AEP flood level plus 0.3m freeboard
Ground level, open car parking spaces	5% AEP flood level plus 0.3m freeboard

As part of this study, Council requested an investigation into the potential to modify the FPL for habitable floor areas within Paddington. This involved an assessment of the viability of adopting a freeboard lower than 0.5 metres. The outcome of this assessment is presented in **Appendix D** and determined that the following freeboards could be adopted across the Paddington area:

- Downstream Catchment Areas: Areas west and north of Glenmore Road, north of Alma Street/Vialoux Ave, south of New South Head Road and east of Nield Ave: **0.5 metre freeboard**

- Upstream Catchment Areas Remainder of study area: **0.3 metre freeboard**

To affect this freeboard change, it would be necessary to alter Table 9 of the DCP to stipulate a minimum habitable floor level requirement in line with the 1% AEP flood level and variable freeboard outlined above.

Flood precinct definitions

The flood risk management controls defined within the Woollahra DCP 2015 apply to all land within the LGA that lie within a flood risk precinct. “Flood risk precincts” are defined as a categorisation of a site’s flood risk for land-use planning purposes and have been devised based on flood hazard categorisation in the 1% AEP event (based upon Figure L2 of the Floodplain Development Manual) and the hydraulic categorisation. There are three (3) precinct classifications as follows:

- **High Flood Risk Precinct:** All land where high hazard conditions occur during a 1% AEP flood; where safe evacuation routes cannot be provided and flood refuge areas are required; and all floodways;
- **Medium Flood Risk Precinct:** All land that is inundated by the 1% AEP flood that is not classified as high risk; areas on the edge of the identified 1% AEP floodplain where the topography provides low hazard rated excavation routes.
- **Low Flood Risk Precinct:** Land within the floodplain that is above the 1% AEP flood but below the extent of the PMF.

The Woollahra DCP 2015 also includes consideration of **Other Flood Prone Properties**, which may be outside the identified floodplain but subject to overland flow because it is either:

- On the low side of the road or boundary levels are below the line of Council’s kerb;
- Lower than surrounding properties;
- Property is in a natural low point, gully or depression;
- Adjacent to or contains a flow path, open channel, watercourse or drainage line.

A property may also be flood prone if it includes underground habitable areas or a low-level driveway or an underground car park.

The Woollahra DCP 2015 suitably defines the categorisation of each flood risk precinct within the text. However, flood hazard and hydraulic categories need to be defined in *Appendix 1 – Definitions* for reference by the user.

The adopted 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 and Sensitive Development’; ‘Residential Development’; ‘Commercial and Mixed Use Development’; and ‘Alterations and Additions (only) Developments’. These development types are suitably defined in Appendix 1 of the DCP, however they do not relate specifically to the land use zoning specified in the Woollahra LEP 2014.

Risk Compatibility Categories

The Woollahra DCP 2015 provides a list of compatible development and flood related development controls for properties in each flood risk precinct, as follows:

- **High Flood Risk Precinct**:

  Unsuitable for all development (except additions and alterations to existing development) unless a Flood Risk Management Report has been prepared outlining appropriate risk management measures. Buildings to be constructed to withstand the PMF event. No new fencing permitted unless it can be demonstrated that there will be no adverse impact on flooding to the property or surrounding land.

- **Medium Flood Risk Precinct**:

  Generally unsuitable for critical and sensitive development. Impervious and continuous fencing is not permitted unless it can be demonstrated that there will be no adverse impact on flooding to the property or surrounding land.

- **Low Flood Risk Precinct**:

  Critical and sensitive developments permitted where all habitable and non-habitable floor levels are no lower than the PMF level; all structures have flood compatible building components below the PMF level; and it can be demonstrated that any structure can withstand the forces of floodwater, debris and buoyancy up to and including the PMF flood level.

For "Other Flood Prone Land", a site-specific assessment is required to determine the level of flood risk and to allow the setting of FPLs. A Flood Risk Management Report prepared, by a suitably qualified practitioner, outlining appropriate risk management measures may be required.

Although the DCP describes the permitted development types in each flood risk precinct following the definition of each precinct, it would be useful to include a matrix of permitted development types/flood risk combinations for easy reference by the user.

Existing prescriptive criteria: nature of controls

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

- **Minimum floor levels** for habitable and non-habitable areas (E2.3.3 C1 and E2.3.4 C27). These are set to the 1% AEP flood level plus 0.5m freeboard (habitable), the 1% AEP level plus 0.3m freeboard (non-habitable) or the PMF (for critical or sensitive facilities), which is consistent with common practice. The DCP also allows for special consideration of lower minimum floor levels, specifically for alterations and/or additions only development (E2.3.3 C2), ground floor levels of commercial and mixed use developments to match existing street levels and for accessibility (E2.3.3 C6), as well as for heritage conservation properties (E2.3.3 C7). To avoid confusion, it is recommended that the flood planning level requirements for critical and sensitive development specified in Section E2.3.4 C27 also be listed in the tabulated flood planning levels requirements in Section E2.3.3 C1.
- **Minimum levels for electrical equipment** (E2.3.4 C2). All electrical equipment (e.g., air conditioners and pool pumps) to be located or protected to above the 1% AEP flood level plus 0.5m freeboard.

- **Minimum levels of open car parking spaces** (C1), carports and driveways. These are set to the 5% AEP flood level plus 0.3m freeboard, which accords with common practice. The DCP also allows for special consideration of lower minimum levels for alterations and/or additions only development (E2.3.3 C2)
- **Minimum levels of enclosed car parking spaces** (C1 and C3). These are set to the 5% AEP flood level plus 0.3m freeboard for parking areas of three or fewer vehicles; and the 1% AEP flood level plus 0.3m freeboard for parking areas for more than three vehicles. To achieve the required minimum car parking level, Council may allow the use of mechanical barriers where 0.5m freeboard is provided and the barrier default is the "closed" position. The DCP also allows for special consideration of lower minimum levels for alterations and/or additions only development (E2.3.3 C2). These requirements are consistent with common practice.
- **Access and egress** for pedestrian and emergency services' vehicles during flooding, to an area of refuge (E2.3.4 C5). These criteria draw upon the concept of hydraulic hazard (combinations of depths and velocities). But more precise definitions of the hazard specifically relating to pedestrian and vehicular stability and using the current understanding of best practice are required to support these clauses, lest the coarser understanding of hazard described in Figure L2 of the FDM (and which is used for defining the flood precincts) be used instead. The current criterion requiring pedestrian egress from the lowest habitable floor level to an appropriate point of refuge located above the PMF is appropriate given that it is desirable that people be able to evacuate out of the floodplain *entirely* to effectively manage the residual risk to life.
- **Structural integrity** of the building (E2.3.4 C4, C23 and C29). This control is fairly standard and requires structures to be built to withstand forces of floodwater, debris and buoyancy up to and including the 1% AEP flood plus 0.5m freeboard, as defined in the general controls in Section E2.3.4 C4. However, Section E2.3.4 C23 specifies that buildings or structures be designed to withstand the PMF event within high flood risk precincts and Section E2.3.4 C28 requires that for critical and sensitive development within low flood risk precincts all structures can withstand up to and including the PMF flood. The floor level for sensitive uses is set at the PMF level, presumably to provide a refuge of last resort above the reach of floodwaters and to reduce the urgency of evacuation, so it makes sense that the building is also structurally capable of withstanding a PMF. To avoid confusion, it is recommended that the structural integrity requirements for critical and sensitive development could be referenced in Section E2.3.4 C4. The DCP also makes reference to the Building Code of Australia 2013 relating to requirements for construction standards in flood hazard areas. This should be updated to reference the 2016 version of the Building Code of Australia.
- **Flood compatible materials** (E2.3.4 C1). In the general development controls, the DCP requires all structures have flood compatible building components below the 1% AEP flood level plus 0.5m freeboard. However, the specific controls stated for development in low flood risk precincts require that this control should be satisfied for the PMF for critical or sensitive facilities permitted to be built in the floodplain. To avoid confusion, it is recommended that these requirements for critical and sensitive development could be referenced in Section E2.3.4 C1. It is also recommended that a definition of flood compatible materials and a list of types of suitable materials for each building component (e.g., flooring, wall structure, doors, windows, wiring, etc) be included in the DCP to better

convey the full scope of building components that should be flood compatible. It is suggested that this could be included as an appendix.

- **Fencing** (E2.3.4 C7, C8, C9, C24 and C26) No new fencing is permitted in High Flood Risk Precincts unless it can be demonstrated that there will be no adverse impact on flooding to the property or surrounding areas. This requirement is consistent with the definition of high flood risk areas as all floodway and the need to ensure unimpeded movement of floodwaters in floodway areas. In medium flood risk precincts, impervious and continuous fencing is not permitted unless it can be demonstrated that there will be no adverse impact on flooding to the property or surrounding areas. Diagrams presenting suitable fencing solutions may assist developers to apply this provision.
- **Filling of floodplains** (E2.3.3 C4). This control specifies that the filling of the site, where acceptable to Council, may change the flood risk for the subject land and that the flood planning level is determined by the new site levels. However, it does not specify where filling can or cannot take place (e.g. undesirable in high flood risk precincts).
- **Overland Flow Paths** (E2.3.4 C10 to C20). These criteria relate to the provision of the free passage of overland flow. The DCP generally requires that all overland flow paths are free of structures and fences and that existing overland flow paths are maintained. Overland flow paths form a critical part of the drainage system, conveying stormwater when the stormwater volume is greater than the pipe system capacity. As there are known capacity issues within the Paddington area, maintaining the integrity of overland flow paths is critical for managing the flood risk.
- **Evacuation and evacuation plans** (E2.3.4 C5). As discussed, the DCP requires that reliable evacuation access for pedestrians is provided from the lowest habitable floor area to a refuge area above the PMF level and designed to withstand PMF water forces. However, the DCP does not specify the need for proposed developments within the flood risk precincts to provide evidence that safe egress/access is available. Therefore, it is recommended that Council include a control requiring the preparation of a Site Emergency Response Flood Plan by suitably qualified practitioners for all new development within the defined flood risk precincts and the inclusion of this plan with the associated Development Applications (DAs). Appendix 1 of the DCP includes a definition for a Site Emergency Response Flood Plan.
- **The impacts of climate change**. Section E2.3.3 outlines climate change considerations for foreshore developments subject to coastal inundation. However, there are no requirements for consideration of climate change with relation to the impact of rainfall intensity increases on overland flow flooding or mainstream flooding. For those developments which have a lifespan of more than fifty years (e.g., for medium- and high-density development) Council could consider adding a requirement that the impact due to increased rainfall intensities should be considered.
- **Flood effects** elsewhere in the floodplain. This control is fairly standard to DCP's and typically outlines 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, for floods up to and including at least the 1% AEP flood. However, such a control has not been explicitly included in the Woollahra DCP 2015. However, Section E2.3.4 C9, which is under the heading of 'Fencing' does outline that *"The flood impact of the development is considered to ensure that the development will not increase flood effects elsewhere. Where a*

significant change in use of the site is proposed, a flood impact assessment is required". This control should be relocated within the DCP into the previous section under the heading 'General' and it is recommended that it include criterion that flood effects be considered for events up to at least the 1% AEP flood.

Alterations and/or Additions Development Only

Section E2.3.3 C2 allows for merit-based consideration of alterations and/or additions (only) development, where it is not practical to meet the required habitable, non-habitable and car parking floor levels due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings. It outlines that a lower floor level would only be permitted where the habitable floor area increases by 40m² or less. In these circumstances, the floor level is to be as high as practical, and no lower than the existing floor level and this concession will be made no more than once for any given property. Subsequent development applications will be required to meet the FPLs and EPLs as outlined in C1.

It is recommended that for alterations and/or additions (only) development requesting floor levels below the FPL, that a control requiring the preparation of an evacuation plan be specified in the DCP.

Special Consideration

The DCP provides for special merit-based consideration if an application seeks to lower the minimum FPL. Such requests are required to be accompanied by a Flood Risk Management Report prepared by a suitably qualified practitioner that at a minimum should include:

- Acknowledgement that the proposed development seeks to lower the minimum standard FPL required by Council's Stormwater Drainage and Flood Risk Management Development Control Plan;
- Proposed risk management measures to minimise the impact of flood inundation;
- Demonstration that the risk management measures will not adversely affect other properties;
- An Emergency Management Plan that includes an evacuation strategy.

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

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

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

- Permit development in floodway areas;
- Permit development that will result in significant flood impacts to other properties;
- Permit a significant increase in the development of that land;
- Are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services; or

- Permit development to be carried out without development consent except for the purposes of agriculture, roads or exempt development.

Recommendations: When next amending the Woollahra DCP, it is recommended that the following changes be considered by Council:

- Amend Table 9 of the DCP to stipulate a minimum habitable floor level requirement in line with the 1% AEP flood level and variable freeboard approach.
- Define Flood Hazard in *Appendix 1 – Definitions* (as they relate to the specified Flood Risk Precincts) for reference by the user.
- Include a matrix of permitted development types/flood risk combinations for easy reference by the user.
- List the flood planning level requirements for critical and sensitive development (which are specified in Section E2.3.4 C27) in the tabulated flood planning levels requirements in Section E2.3.3 C1.
- Reference the structural integrity requirements for critical and sensitive development in Section E2.3.4 C4.
- Define flood compatible materials and include a tabulated list of types of suitable materials for each building component (e.g., flooring, wall structure, doors, windows, wiring, etc) to better convey the full scope of building components that should be flood compatible.
- Include diagrams presenting suitable fencing solutions to assist developers to apply the provisions relating to fencing.
- Include a requirement for proposed development to provide evidence of safe access/egress, or the preparation of a Site Emergency Response Flood Plan by suitably qualified practitioners for all new development within the defined flood risk precincts and the inclusion this plan with the associated Development Applications (DAs).
- Require that the impact due to increased rainfall intensities should be considered for those developments which have a lifespan of more than fifty years (e.g., for medium- and high-density development).
- Relocate Control C9 in Section 2.3.4 from under “Fencing” to under “General” heading, and include criterion that flood effects be considered for events up to at least the 1% AEP flood.
- Include a control requiring the preparation of an evacuation plan for alterations and/or additions (only) development requesting floor levels below the flood planning level.

The Direction also requires that councils must not impose flood related development controls above the residential flood planning level (typically the 1% 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.

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) states 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*”.

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.

Need for 'appropriate justification'/'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 beyond the FPA. This was assessed by considering the difference in water levels/depths between the 1% AEP and PMF events and whether people could be expected to survive in existing buildings should a PMF occur. The resulting flood level/depth difference map (prepared by subtracting the peak 1% AEP flood level from the PMF level) is provided in **Plate 86**.

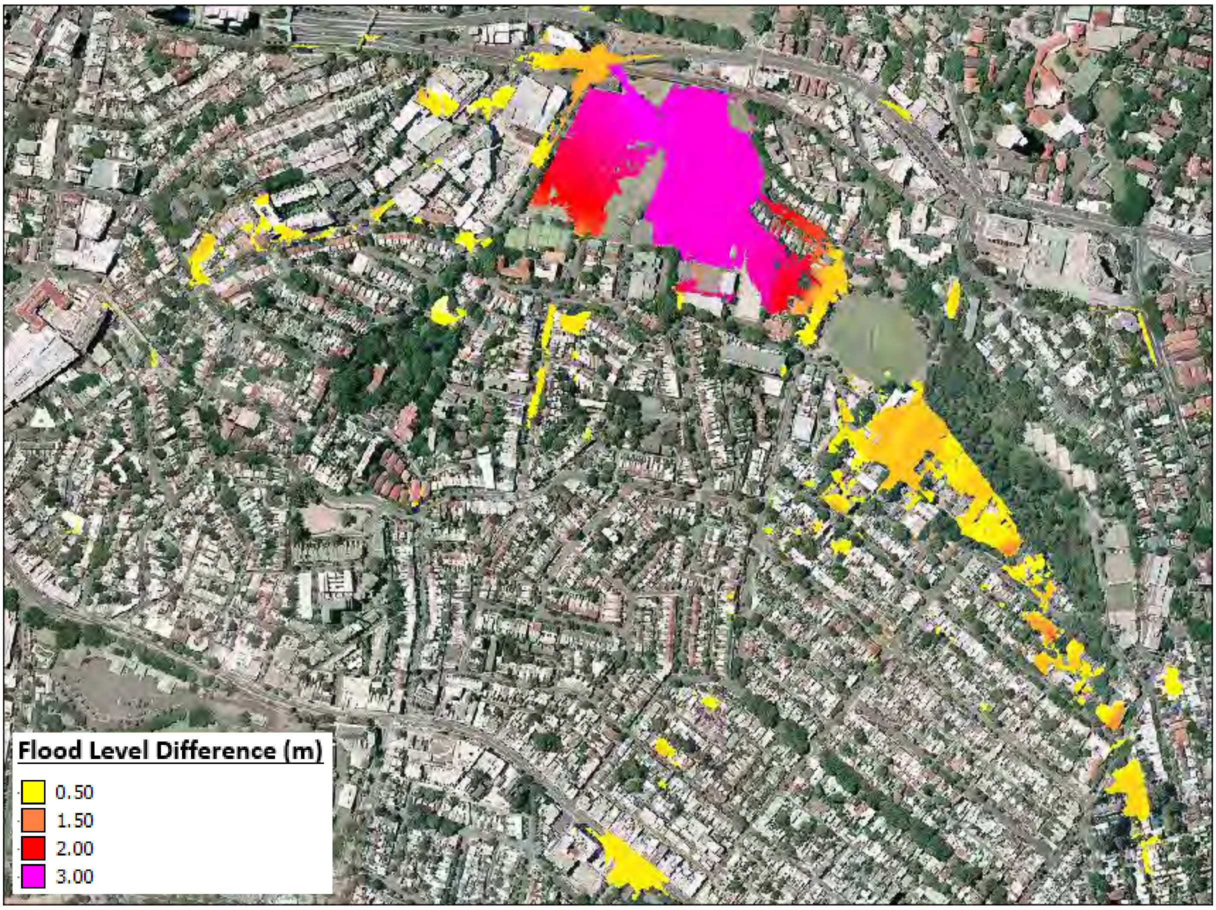


Plate 86 Difference between PMF and 1% AEP water levels

Once flood height differences exceed 1.5m (i.e., > 1 metre above the FPL) serious consideration must be given to the need for 'exceptional circumstances' due to the high potential risk to life. As shown in Plate 86, the flood height difference between the PMF and 1% AEP water levels is typically less than 1.5 metres, particularly across the upper catchment areas. However, there are some areas within the lower catchment area (downstream of Glenmore Road) where flood level differences are predicted to exceed 1.5 metres.

Those areas of the floodplain that are beyond the 1% AEP flood extent but are exposed to Flood Hazard Category H6 during the PMF event were also identified and are shown in **Plate 87**. The H6 classification highlights property where early evacuation would be required to manage the risk to life in an extreme flood due to the potential for structural failure of buildings. It was determined that there are six (6) properties with existing residential dwellings on the northern side of Walker Avenue to which this criterion applies. In general, the H6 classification is restricted to the front third of each lot. Therefore, it is not considered necessary to apply for 'exceptional circumstances' given that the majority of each lot is located outside of the H6 classification and there are areas of each lot located beyond the PMF extent.

Plate 87 Areas where exceptional circumstances could be considered

Recommendation: Applying for 'exceptional circumstances' is not considered necessary.

6.4 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 Paddington:

- DCP Amendments.

7 Response Modification Options

7.1 Introduction

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

Response modifications options considered as part of the study include:

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

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

7.2 Emergency Response Planning Options

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

7.2.1 Local Flood Plan

A Local Flood Plan sets out procedures to follow before, during and after a flood including who is responsible for each of these activities. Accordingly, it is an important tool for managing the local flood risk.

Currently there is no Local Flood Plan for the Woollahra LGA. Therefore, it is recommended that this Floodplain Risk Management Study and Plan be referred to the SES to inform the preparation of a Local Flood Plan.

Recommendations: SES to develop a Local Flood Plan with assistance from Council

7.2.2 Emergency Response Plans

Home Flood Plan Preparation

It is unlikely that many private dwellings at risk of overland flooding will have formal flood emergency response plans. This requires innovative approaches to persuade residents to plan ahead for floods. It is considered that the most effective method, albeit a labour-intensive method, will be via direct outreach from the NSW SES to specific properties. The SES could, with Council's assistance, host a community drop in "stall" (potentially at a local market). Council could attend the drop-in stall with laptops enabling the inspection of flood risks at property scales and SES personnel could then help property owners translate that information into effective home emergency plans.

Recommendations: Host "drop in" stall to promote the preparation of Home Emergency Plans (Council/SES)

Business Flood Plan Preparation

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. The preparation and implementation of such plans is an important risk management option across particularly flood liable sections of the catchment.

Although flood plans may have already been prepared for some businesses, they need to be reviewed and updated regularly to ensure all staff remain fully aware of the requirements of the plan and to ensure the plan takes advantage of the latest available information. As for 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.

A SES Business Breakfast could be hosted to promote the development or updating of Business FloodSafe Plans, with sufficient Council and SES staff present to help guide business owners through the process. 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.

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

7.2.3 Community Education

Actual flood damages can be reduced, and safety increased, where communities are flood-ready. It is difficult to accurately assess the benefits of a community flood education program but anecdotal evidence suggests that benefits far outweigh the costs. Nevertheless, there is a need to acknowledge that ongoing funding is required to sustain gains that have been made.

It is suggested that the following education avenues could be explored to promote community educations:

- Flood Information/FloodSafe Brochures that aim to reinforce key education message (e.g., Never drive, ride, walk or play in floodwaters). This information could be distributed with rate notices (it is noted that this approach will not distribute to occupiers of rental properties, so may need to be supplemented with a letter box drop);

- Updates to Council website to include catchment specific flood information. This could also include links to the SES webpage;
- Communication with the Paddington Society, who could subsequently disseminate information to the local community;
- Encouraging to community to utilise social media, in particular, Twitter and Facebook, where various agencies post information on impending storms/floods (e.g., @BoM_NSW on Twitter and BoM and NSW SES on Facebook)

Recommendations: Develop educational messages targeting dangerous behaviours and improving the community's understanding of flooding and readiness for future floods (Council and NSW SES)

7.2.4 Assessment of Potential of Safe Refuge in Place (SRIP)

It is widely acknowledged that if evacuation can be safely implemented, this is the most effective strategy for managing the residual flood risk for individual property owners and occupiers. Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome.

However, the '*Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events'* (AFAC, 2013) recognises that evacuating too late may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters, particularly fast-moving flood waters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater. This is considered to be particularly relevant for Paddington where flooding is typically associated with relatively short, high intensity rainfall bursts.

Therefore, an assessment was completed to determine if residents and/or business owners could safely refuge in place should they not be able to evacuate before the onset of flooding.

The potential risks of sheltering in place 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.

The appropriateness of a safe refuge in place strategy was assessed based upon the following logical expressions, based on the PMF:

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

The outcome of this assessment is presented in Plate 88.

Plate 88 Areas where evacuation is considered essential.

The information presented in **Plate 88** shows that safe refuge in place is likely to be feasible across the majority of Paddington. This includes most of the steeper sections of the catchment where floodwater depths are shallow, even during the PMF. Nevertheless, the analysis did show that there are some properties where the depth and velocity of water during the PMF presents a risk of structural failure of buildings and/or a risk to life (refer to yellow polygons in Plate 88). Across these areas, early evacuation is considered necessary.

<u>Recommendation</u>: Safe refuge in place is considered possible across a large section of Paddington. However, there are several properties in the lower catchment where early evacuation in considered necessary

7.3 Options to Improve Emergency Response During a Flood

7.3.1 Flash Flood Warning System

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts and reduce the potential for property damage and risk to life.

The Bureau of Meteorology issues a number of products that provide warnings of potentially impending floods. This includes:

- Flood Watches, which typically provide 24 to 48 hours' notice that flooding is possible; and,
- Severe Thunderstorm Warnings, which typically provide between 0.5 and 2 hours' notice of an impending thunderstorm.

Flooding across Paddington can often be localised and very "flashy". The Bureau of Meteorology acknowledges that providing effective warning for flash floods can be very difficult because of their rapid onset. As a result, the Bureau does not traditionally issue flood predictions for flash flood catchments regardless of the extent of flood warning infrastructure such as rainfall and stream gauges.

The Bureau of Meteorology's Flash Flood Advisory Resource (FLARE) was used to assess the potential requirements of a flood warning system for Paddington that could operate independently of the Bureau. FLARE includes a method of assessing risk. A 1% AEP flood ("unlikely" likelihood) would cause damage to multiple residential and commercial properties ("high" consequence), which translates to a "medium" risk. FLARE suggests that a medium risk requires an "advanced" flash flood warning system. Elements of such a system are depicted in **Table 11**.

Council currently has negligible components of a flood warning system outlined in **Table 11**. Therefore, the development of a flash flood warning system for Paddington would require a significant capital and time investment by Council, emergency services and Bureau staff. Furthermore, the warning system would need to be complemented with appropriate educational material to ensure the community interprets the information disseminated via the warning system correctly and is able to react in the most appropriate manner. Furthermore, with the "flashy" nature of flooding across Paddington, it is likely that a real-time flood warning system would only afford a relatively small amount of additional warning time.

Table 11 Components of an advanced flash flood warning system for an urban area

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

Source: Adapted from FLARE (Bureau of Meteorology)

Overall, it is unlikely that the significant investment in a flood warning system would provide Council and the broader community with a good value for money outcome. However, if a flash flood warning system was developed it could service Paddington as well as other catchments. This may assist in disbursing the potential costs and benefits across multiple catchments and increase the overall return on such an investment.

Recommendation: Not recommended for implementation in isolation. Could be considered as part of an LGA-wide flood warning system

7.3.2 Roadway/Evacuation Route Improvements

Between 2000 and 2015, 178 people have lost their lives as a result of flooding. The majority of these deaths are associated with motorists attempting to drive across flooded bridges, culverts, causeways or roads in their local area. Although flood deaths have been steadily declining since the 1960s, motor vehicle related deaths in floodwaters are rising (Haynes et al, 2016).

In general, floodwaters across most of the Paddington area are shallow but fast moving. The hazard categories provided in Figure A12 and A13 indicates that a number of roadways would be considered high hazard areas. This indicates that they would not be trafficable at the peak of a significant rainfall events.

The drainage upgrades recommended in Section 5 will likely serve to reduce the frequency and depth of roadway inundation if they are implemented. This will likely improve the potential for evacuation by vehicle during future floods. However, this will not reduce the flood risk across all roadways during all design events. That is, a risk will remain if drivers attempt to drive through floodwaters.

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

Given the flood behaviour and types of flooding that occur in the LGA, flood depth indicators are not considered appropriate in urban areas such as Paddington.

Recommendation: Not recommended for implementation.

7.4 Options to Aid in Post-Flood Recovery

7.4.1 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 89**)
- The size and the floor level of the house
- The material used to build the house

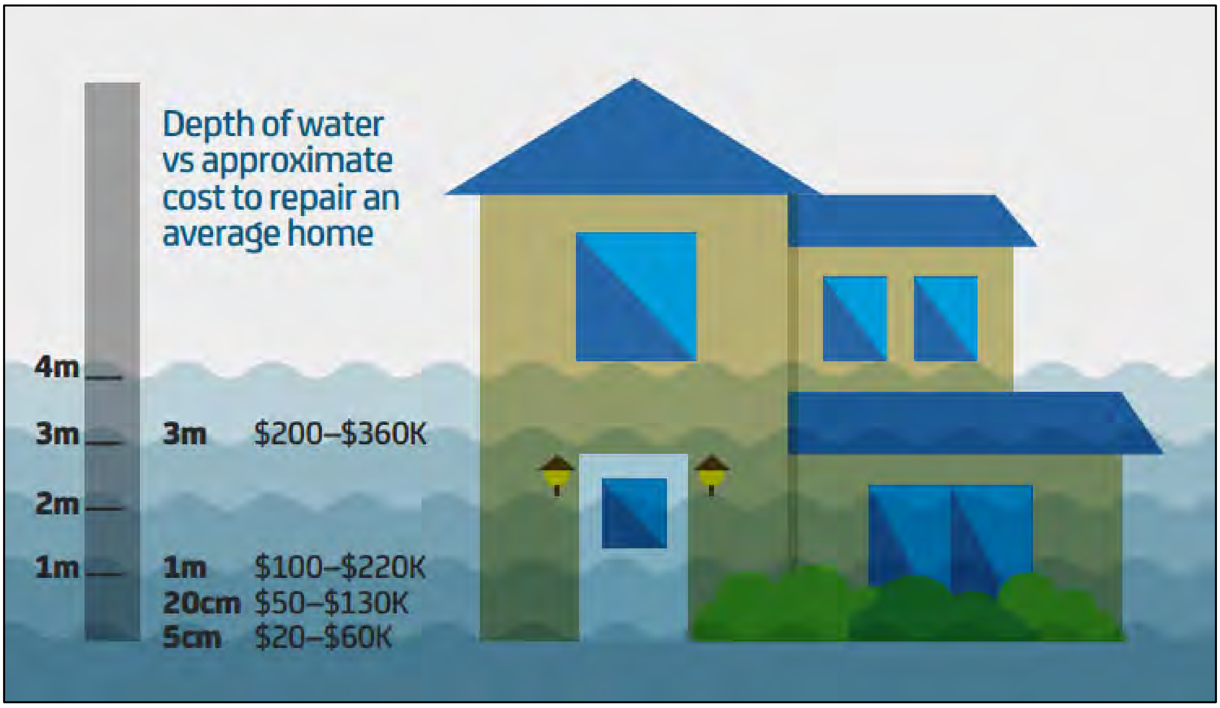


Plate 89 Examples of repair costs versus depth of above floor inundation used by insurance companies to estimate premiums (NRMA, 2015)

Therefore, buildings with a high likelihood of flooding and/or high flood damage potential will face higher insurance premiums. The cost of insurance must be borne by the building owners. Therefore, those properties that are at higher risk of flooding and would arguably benefit the most from flood insurance will face the highest premiums. In such instances, property owners may not be able to afford such premiums.

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 89**). Council could assist property owners as part of this process by providing property level flood information, so property owners can understand their flood risk and the potential financial implications of a significant flood. Based on this, the property owners can make an informed decision on the need to acquire flood insurance. Assuming flood insurance is desired by the property owners, the property level flood information can also be used to assist in negotiating premiums with insurance companies.

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

7.4.2 Disaster Relief

Disaster relief provides financial assistance following the declaration of a natural disaster. A disaster declaration is initiated by the State Government and, depending on the nature and extent of the disaster, may be supplemented by the Federal Government (subject to a natural disaster declaration by the attorney-General's Department).

Local government areas that are declared natural disaster zones are eligible for the Natural Disaster Assistance Scheme, including:

- Disaster assistance for Individuals
- Primary producers (loans & transport subsidies)
- Small businesses
- Assistance for Councils
- Trustees of parks and reserves
- Sporting clubs
- Churches and voluntary non-profit organisations

However, such disaster assistance may not be available to all individuals or organisations. For example, relief grants for individuals will typically only be available for those with limited financial resources and no insurance. Furthermore, funding may only partly offset the total damage costs.

Therefore, disaster relief may only provide financial support for some individuals and groups during large floods that are declared a natural disaster. Like flood insurance, disaster relief funding does not reduce the potential for flood damage or the residual flood risk.

8 DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

8.1 Introduction

The draft Floodplain Risk Management Plan sets out options that can be implemented in the short, medium and long term to manage the flood risk across Paddington. It also outlines responsibilities for the implementation of each option along with cost estimates and funding opportunities.

8.2 Recommended Options

The options that are recommended for implementation as part of the draft Paddington Floodplain Risk Management Plan are summarised in **Table 12** and are also shown in the figure on the following page. The options have been selected from a range of potential flood modification, property modification and response modifications measures based upon their impact on flood hydraulics and existing properties, capital and ongoing costs as well as any potential social and environmental impacts. The outcomes of the detailed assessment are discussed in more detail in Sections 5, 6 and 7 of this report.

8.3 Plan Implementation

8.3.1 Prioritisation/Timing

The recommended options have been prioritised according to how easily each option could be implemented and the anticipated benefits afforded by each option (i.e., options that are relatively straight forward to implement and have a significant benefit would be assigned a high priority). A timeframe has also been estimated that reflects the likely time to implement each option based upon available resources (i.e., financial and human resources) as well as the need to undertake additional investigations and/or community consultation.

In general, it is anticipated that the majority of the options would be implemented progressively over a 10-year time frame. However, this will be dependent on the budgetary commitments of Council and availability of funding from other sources.

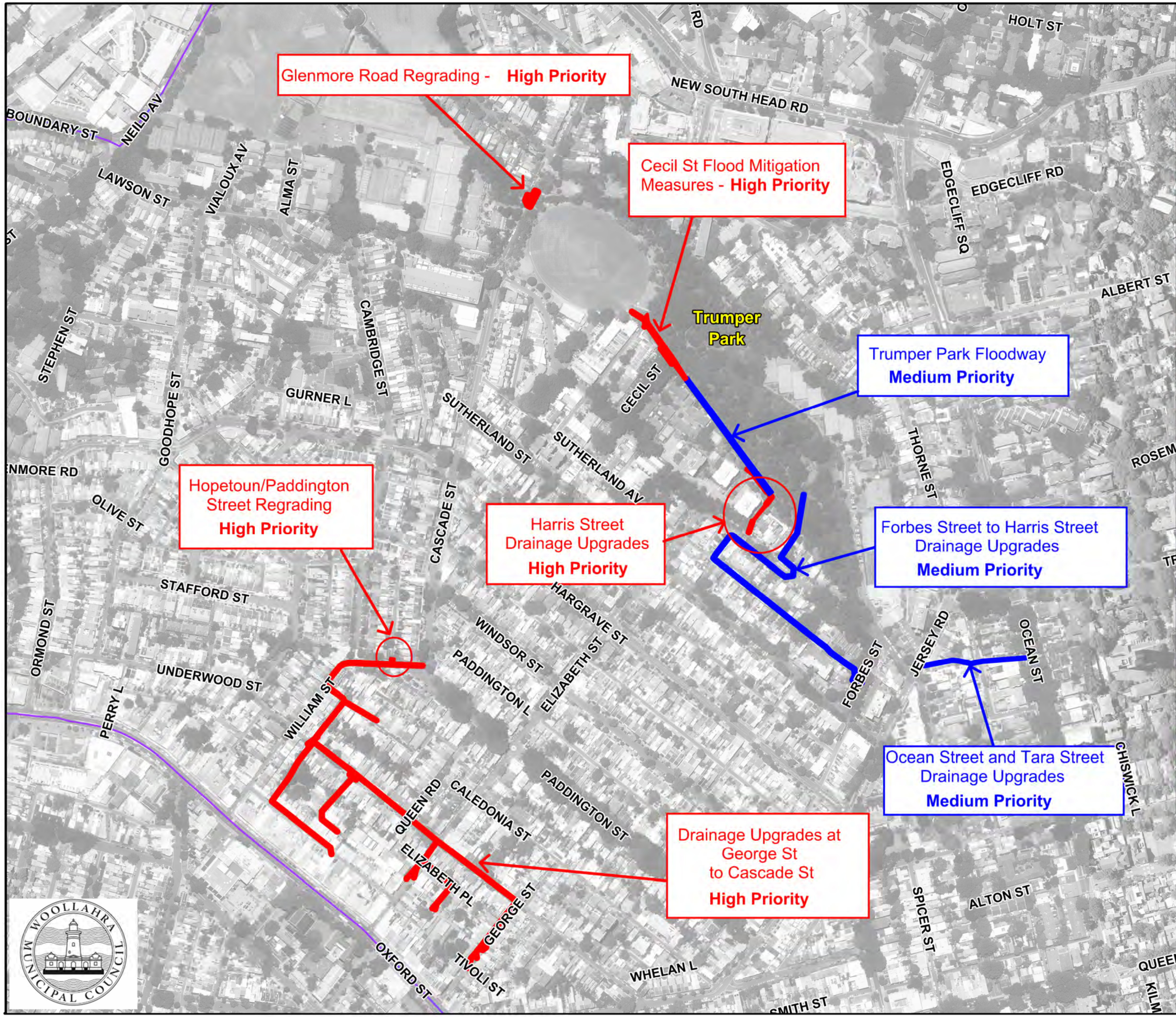
8.3.2 Costs and Funding

The total capital cost to implement the Plan is expected to be about $16 million. The most significant costs are associated with the George Street to Cascade Street drainage upgrades ($12 million) and the Forbes Street to Harris Street Drainage Upgrades ($2 million).

As noted in **Table 12**, many of the options will require an investment in time from various agencies including Woollahra Municipal Council and the State Emergency Service in addition to monetary contributions.

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

- Woollahra Municipal Council's capital and operating budgets
- NSW State Government's Floodplain Management Grants (through OEH)



Option

High Priority Options:

- Cecil Street Flood Mitigation Measures
- George Street to Cascade Street drainage upgrades
- Regrading/roadworks in Hopetoun Lane/Paddington Street
- Harris Street drainage upgrade
- Glenmore Road Regrading
- Various community education activities including holding community meetings to promote preparation of flood plans and develop strategies to discourage dangerous behaviour
- Update Council website to include catchment specific flood information
- Reviewing and updating Council's drainage maintenance program

Medium Priority Options:

- Trumper Park floodway
- Forbes Street to Harris Street Drainage Upgrades
- Ocean Street and Tara Street Drainage Upgrades
- Development Control Plan (DCP) modifications
- CCTV inspections of potential drainage “bottlenecks”

Low Priority Options:

- Flood insurance (Council could also assist property owners by providing property specific flood information to assist in negotiating insurance premiums)

Draft Paddington Floodplain Risk Management Plan

- Section 94 contributions
- Commonwealth Government's Natural Disaster Resilience Program
- Volunteer labour from community groups

It is expected that most options will be eligible for funding through the NSW State Government's Floodplain Management Grants on a 2:1 basis (State Government : Council). This can include additional investigations, design activities as well as construction. However, funding under this program cannot be guaranteed as funding must be distributed to competing projects across the state. Furthermore, the NSW Government's Floodplain Management Grants are primarily available to manage risk to residential properties and are generally not awarded to manage the flood risk to commercial and industrial properties. It should also be noted that ongoing costs will generally be the responsibility of Council.

8.3.3 Review of Plan

It is important that the Floodplain Risk Management Plan is continually reviewed and updated over time to ensure that it evolves with the catchment and takes advantage of any improvements in flood knowledge, such as new flood studies, historic floods or information on climate change.

As noted in **Table 12**, all options are scheduled for implementation within a 10-year time frame. Therefore, as a minimum, it is recommended that the Plan be revisited after 10 years.

Table 12 Draft Paddington Floodplain Risk Management Plan

Flood modification option | Property modification option | Response modification option

Option	Report Section	Implementation Responsibility	Capital Cost	Priority	Timing	Comments
Cecil Street Flood Mitigation Measures	5.3.3	Council	$2-3+ million	High	1 year	Detailed assessment underway
Trumper Park Floodway	5.3.4	Council	$240,000	Medium	2 years	Cost assumes Cecil Street flood mitigation measures are constructed immediately before Trumper Park floodway
Hopetoun/Paddington Street Regrading	5.4.5	Council	$40,000	High	2 years	
Glenmore Road Regrading	5.4.8	Council	$50,000	High	2 years	
Harris Street Drainage Upgrades	5.5.4	Council	$210,000	High	1 year	
George Street to Cascade Street Drainage Upgrades (Option B)	5.5.8	Council	$12 million	High	7 years	Potential to stage implementation to distribute costs
Forbes Street to Harris Street Drainage Upgrades	5.5.3	Council/Sydney Water	$2 million	Medium	5 years	
Ocean Street and Tara Street	5.5.2	Council	$600,000	Medium	5 years	Further detailed investigations recommended to determine if more cost-effective design options are available

<table>
<tr><th colspan="2">Option</th><th>Report Section</th><th>Implementation Responsibility</th><th>Capital Cost</th><th>Priority</th><th>Timing</th><th>Comments</th></tr>
<tr><td colspan="2">Reviewing and updating Council's drainage maintenance program</td><td>5.6</td><td>Council</td><td>Council time</td><td>High</td><td>1 year</td><td>Council's existing stormwater drainage Maintenance Program be updated to reflect the information in the Paddington Floodplain Risk Management Study and Plan.
May require additional funding to secure additional maintenance staff to apply updated program</td></tr>
<tr><td colspan="2">CCTV inspections of potential drainage bottlenecks</td><td>5.5.5
5.5.11</td><td>Council</td><td>$20,000</td><td>Medium</td><td>1 year</td><td></td></tr>
<tr><td colspan="2">DCP Amendments</td><td>6.3.3</td><td>Council</td><td>Council time</td><td>Medium</td><td>3 years</td><td>When next amending the Woollahra DCP, it is recommended that Council consider the changes listed in Section 6.3.3 of this report</td></tr>
<tr><td colspan="2">Preparation of Local Flood Plan</td><td>7.2.1</td><td>SES with input from Council</td><td>SES time</td><td>High</td><td>1 year</td><td></td></tr>
<tr><td rowspan="2">Preparation of Emergency Response Plan</td><td>Home Flood Plans</td><td>7.2.2</td><td>Council & SES</td><td>Council time + venue hire ($3k assuming 3 meetings completed)</td><td>Medium</td><td><2 years</td><td rowspan="2">Should be repeated periodically (e.g., every 5 years) to cater for potential turnover.</td></tr>
<tr><td>Business Flood Plan</td><td>7.2.2</td><td>Council & SES</td><td>Council and SES time + venue hire ($1k)</td><td>Medium</td><td><2 years</td></tr>
</table>

Option		Report Section	Implementation Responsibility	Capital Cost	Priority	Timing	Comments
Community Education	Develop educational messages targeting dangerous behaviours	7.2.3	Council & SES	Council& SES time	Medium	1 year	
	Update Council website to include catchment specific flood information	7.2.3	Council	Council time	High	1 year	
	Undertake discussions with the Paddington Society to disseminate flood information	7.2.3	Council	Council time	High	1 year	
	Continue to develop social media platforms for flood safe messaging	7.2.3	SES	SES time	High	2 years	
Flood Insurance	Individual property owners should consider flood insurance	7.4.1	Property owners	Varies depending on property in question	Low	1 year	Cost will need to be borne by property owners
	Council to assist property owners by providing property specific flood information	7.4.1	Council	Council time	Low	As required	

9 REFERENCES

- Australian Emergency Management Institute *(Editor)* (2013) *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*. Edited and published by the Australian Emergency Management Institute, part of the Australian Government Attorney-General's Department
- Australian Government (2009), Flood Warning, Australian Emergency Manuals Series, Manual 21.
- Australian Government (2014), Technical Flood Risk Management Guideline: Flood Hazard, Australian Emergency Management Handbook Series.
- Australian Institute for Disaster Resilience, (2017), *Guideline 7-2: Flood Emergency Response Classification of the Floodplain*, Commonwealth of Australia
- BMT WBM (2015). TUFLOW User Manual. Version 2013-12-AE.
- Department of Environment and Climate Change (2007). *Floodplain Risk Management Guideline: Floodway Defintion*. Version 1.01.
- Department of Environment and Climate Change (2007). Floodplain Risk Management Guideline: Practical Consideration of Climate Change. Version No. 1.0.
- Engineers Australia (2015). Australian Rainfall & Runoff – Blockage of Hydraulic Structures: Blockage Guidelines, Authors: W. Weeks & E. Rigby.
- Engineers Australia (2013). *Australian Rainfall & Runoff – Book 9, Chapter 6: Safety Design Criteria*. Prepared by Smith, G & Cox, R. Chapter Status: External Review
- Engineers Australia (2013). *Project 11 Blockage of Hydraulic Structures - Stage 2 Report.* Prepared by W. Weeks, G. Witheridge, A Barthelmess, G. O'Loughlin & E. Rigby.
- Engineers Australia (2015), Blockage of Hydraulic Structures – Blockage Guidelines. Prepared by W. Weeks & E. Rigby.
- Haynes, K., Coates, L., Dimer de Oliveira, F., Gissing, A., Bird, D., van den Honert, R., Radford, D., D'Arcy, R, Smith, C. (2016). *An analysis of human fatalities from floods in Australia 1900-2015*. Report for the Bushfire and Natural Hazards CRC.
- Keys, C. (2002). 'A combat agency and its hazard: a New South Wales State Emergency Service perspective on the management of flooding', Australian Journal of Emergency Management, 17(2), 14-18, 50-55.
- McLuckie, Duncan (2014). *Updating National Guidance on Best Practice Flood Risk Management*. Paper presented at the Floodplain Management Association National Conference, Tweed Heads, 2014.
- MECA (2017). *Two Harbors Cemetery Detention Basin*. Prepared by Minnesota Erosion Control Association. Website visited on 03/07/2017. http://mnerosion.org/two-harbors_cemetery-detention-basin/
- Office of Environment & Heritage (2013a), Floodplain Management Program: Guidelines for voluntary house raising schemes, OEH 2013/0055
- Office of Environment & Heritage (2013b), Floodplain Management Program: Guidelines for voluntary purchase schemes, OEH 2013/0056

- Paddington Society. *http://www.paddingtonsociety.org.au/*. Website accessed 24/01/2017.
- Ryan, C (2013). *Using LiDAR Survey for Land Use Classification*. Paper presented at the 2013 Floodplain Management Authorities Conference, Tweed Heads.
- Web, McKeown & Associates (2007). *Rushcutters Bay Catchment Flood Study*. Prepared for Woollahra Municipal Council.
- WMAwater (2012). *Rushcutters Bay Floodplain Risk Management Study and Plan*. Prepared for Woollahra Municipal Council.
- WMAwater (2016). *Rushcutters Bay Flood Study*. Prepared for The City of Sydney Council.
- WMAwater (2016). *Rushcutters Bay Catchment Floodplain Risk Management Study and Plan*. Prepared for The City of Sydney Council.

10 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

Figures

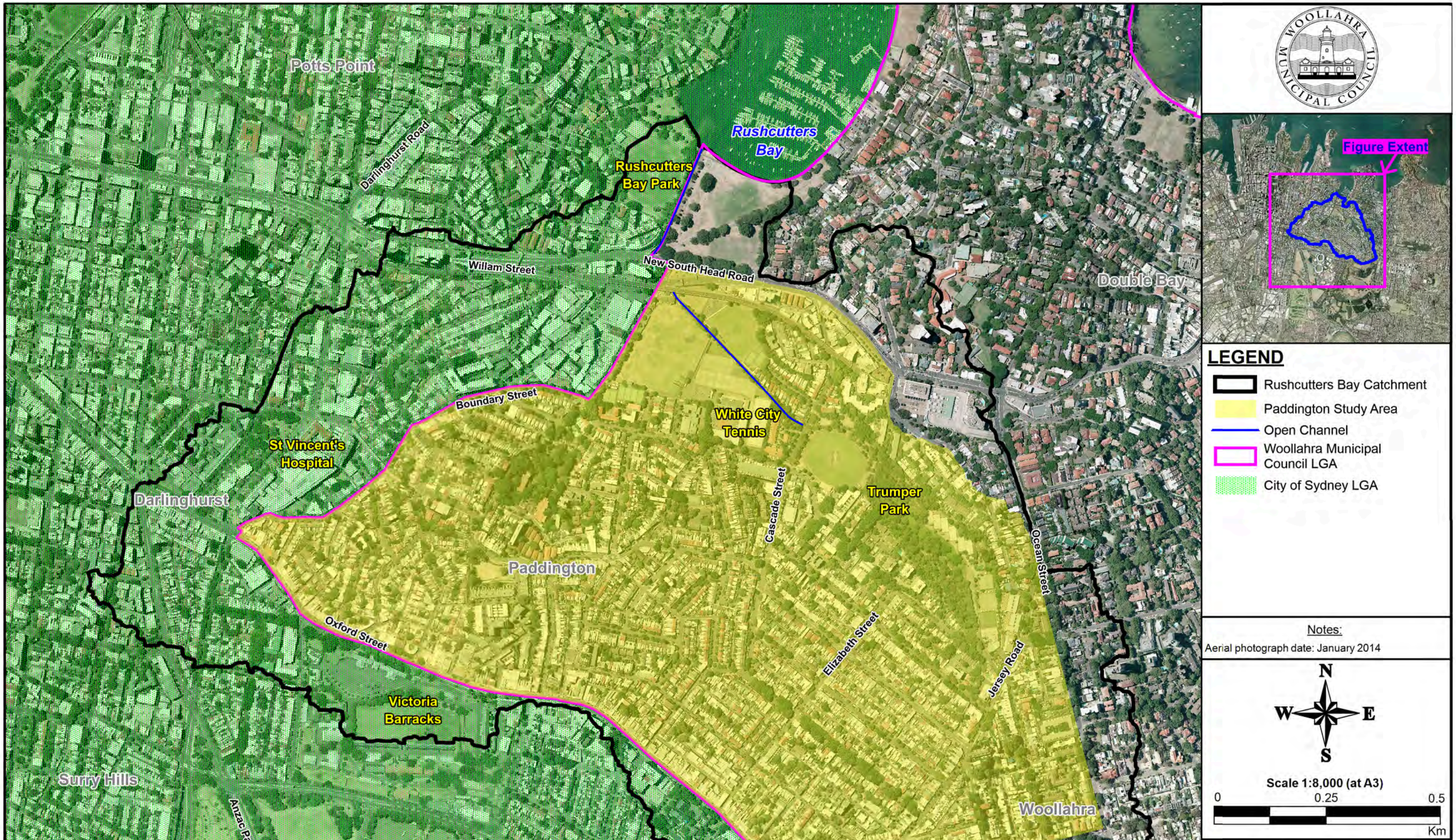


Figure 1: Paddington Study Area

Prepared By:
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File Name: Fig1.1- Paddington Study Area.wor

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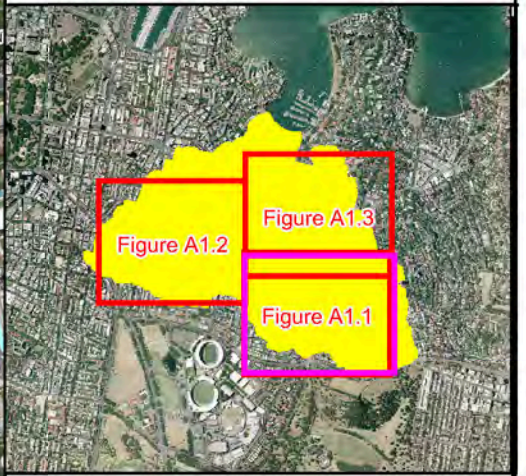

LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

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Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A1.1: Peak Floodwater Depths for the 20% AEP Flood

Prepared By:

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File Name: FigA1.1 - Peak Floodwater Depths for the 20% AEP Flood.wor

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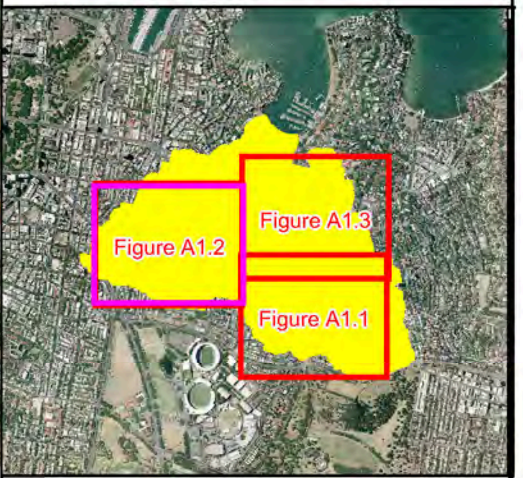

LEGEND

Depths (m)

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- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

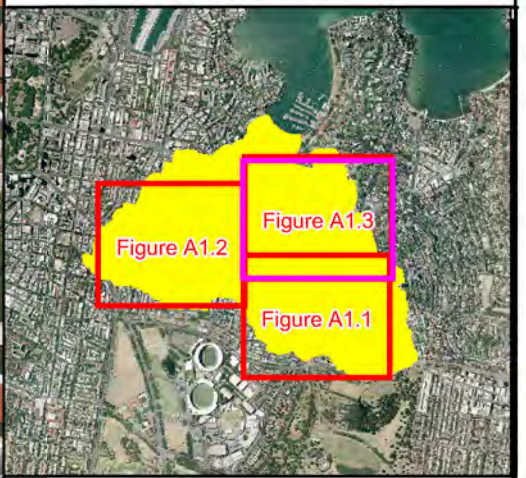
0 0.1 0.2 Km

Figure A1.2: Peak Floodwater Depths for the 20% AEP Flood

Prepared By:

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

File Name: FigA1.2 - Peak Floodwater Depths for the 20% AEP Flood.wor



LEGEND

Depths (m)

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Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

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Scale 1:3,000 (at A3)

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Km

Figure A1.3: Peak Floodwater Depths for the 20% AEP Flood

Prepared By:
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Sydney, NSW 2000

File Name: FigA1.3 - Peak Floodwater Depths for the 20% AEP Flood.wor

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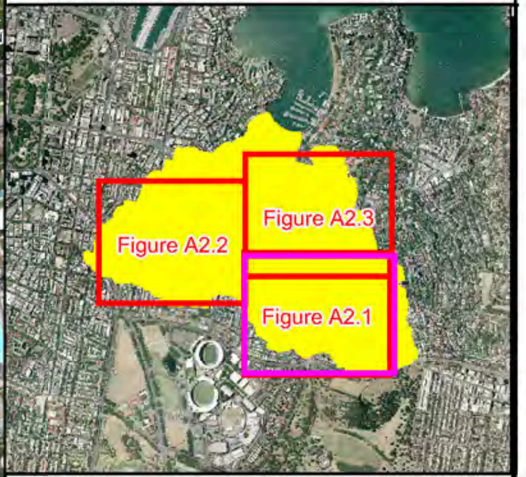

LEGEND

Depths (m)

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- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

0 0.1 0.2 Km

**Figure A2.1:
Peak Floodwater Depths
for the 5% AEP Flood**

Prepared By:

Catchment Simulation Solutions
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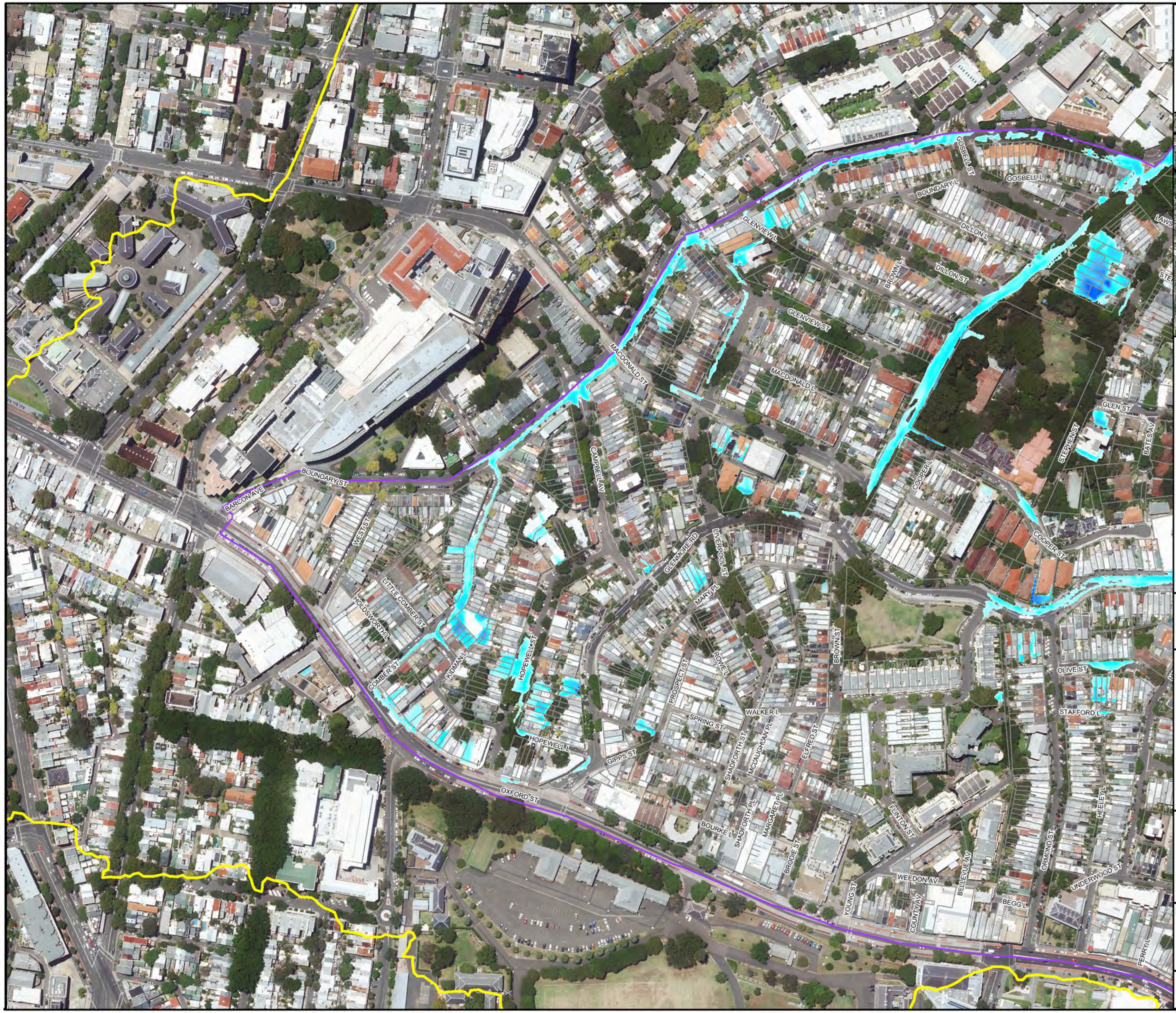
Sydney, NSW 2000

File Name: FigA2.1 - Peak Floodwater Depths for the 5% AEP Flood.wor



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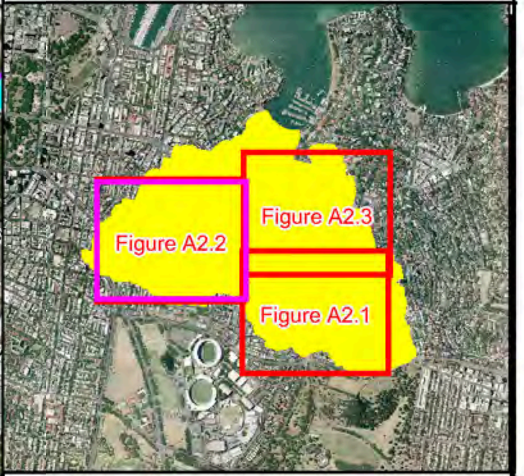

LEGEND

Depths (m)

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- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

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Scale 1:3,000 (at A3)

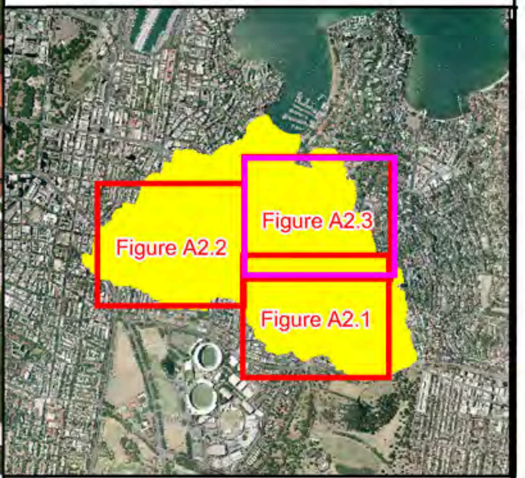
0 0.1 0.2
Km

Figure A2.2: Peak Floodwater Depths for the 5% AEP Flood

Prepared By:

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

File Name: FigA2.2 - Peak Floodwater Depths for the 5% AEP Flood.wor



LEGEND

Depths (m)

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- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

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Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A2.3: Peak Floodwater Depths for the 5% AEP Flood

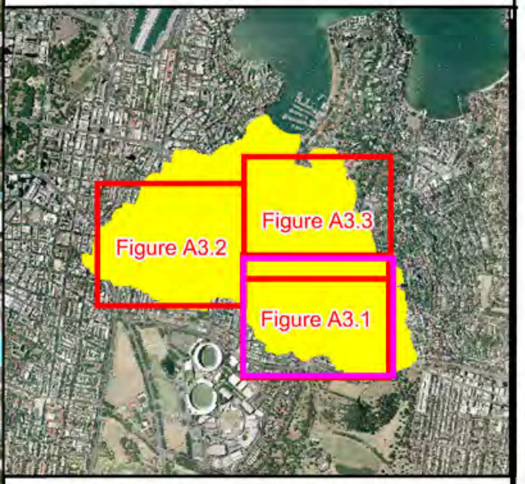
Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigA2.3 - Peak Floodwater Depths for the 5% AEP Flood.wor

LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0



Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

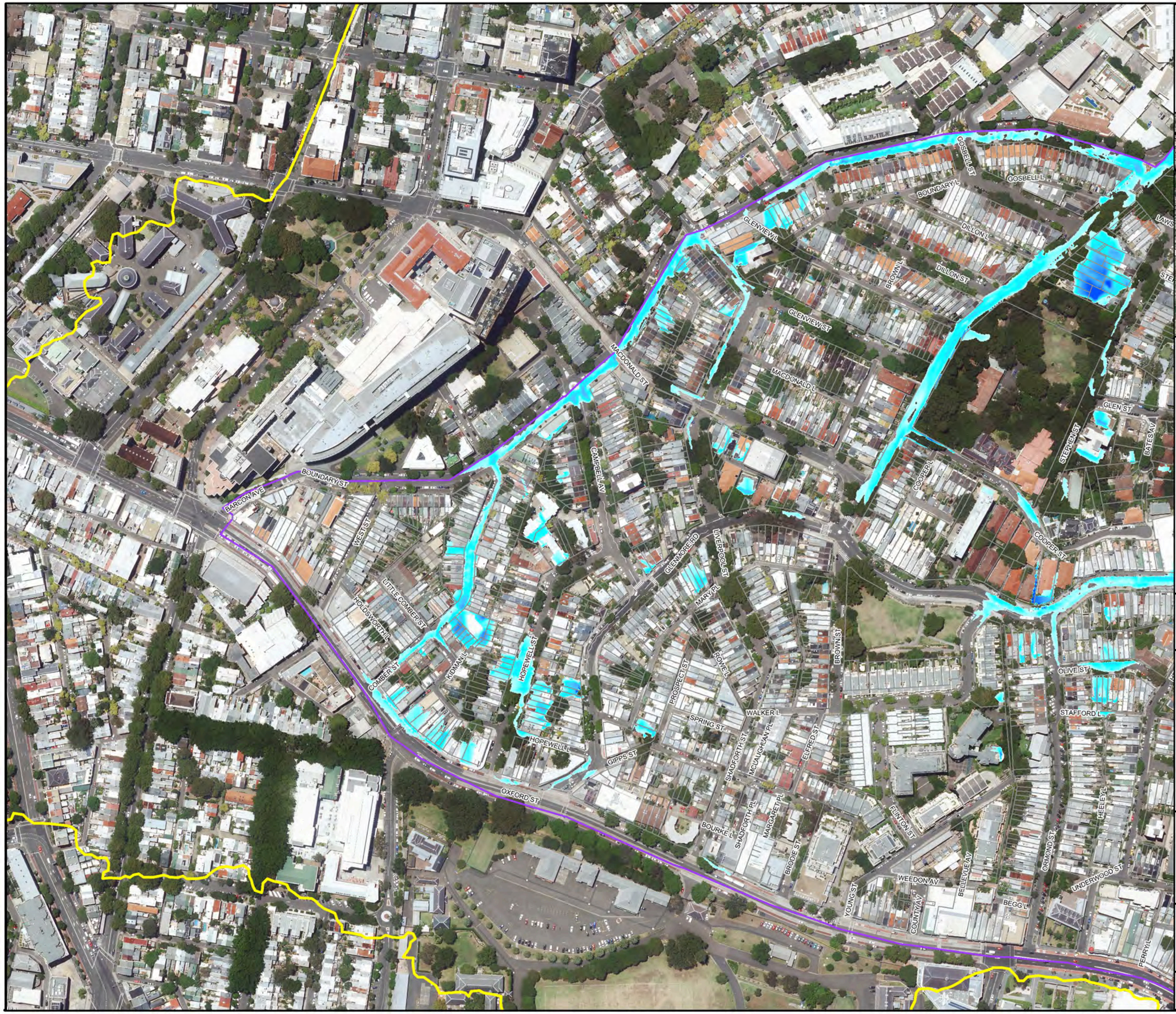
Scale 1:3,000 (at A3)

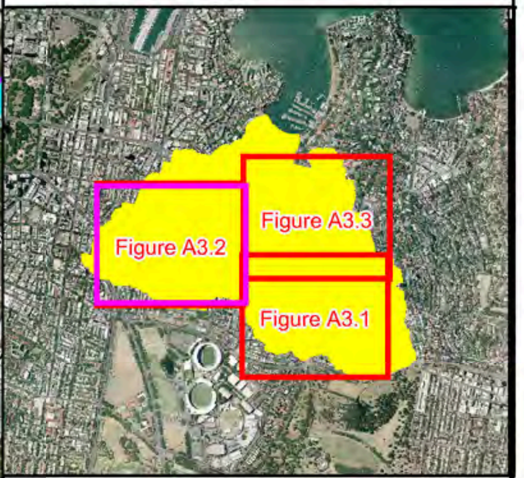
0 0.1 0.2 Km

Figure A3.1: Peak Floodwater Depths for the 1% AEP Flood

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

File Name: FigA3.1 - Peak Floodwater Depths for the 1% AEP Flood.wor





LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

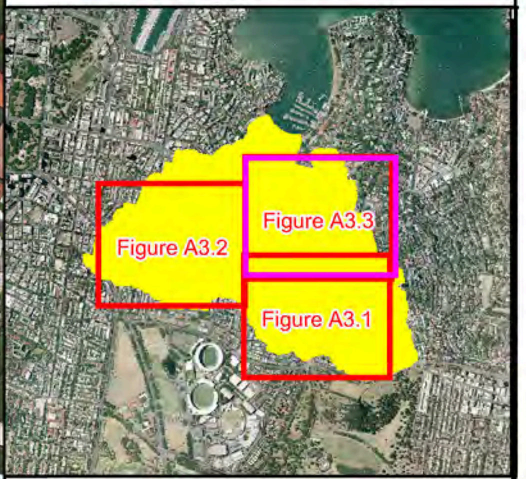
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A3.2: Peak Floodwater Depths for the 1% AEP Flood

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

File Name: FigA3.2 - Peak Floodwater Depths for the 1% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

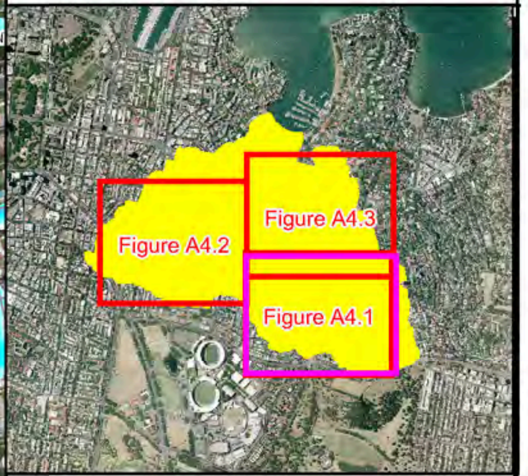
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A3.3: Peak Floodwater Depths for the 1% AEP Flood

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

File Name: FigA3.3 - Peak Floodwater Depths for the 1% AEP Flood.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

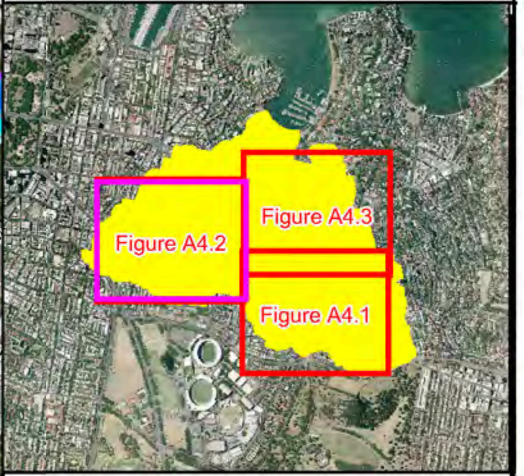
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A4.1: Peak Floodwater Depths for the PMF

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

File Name: FigA4.1 - Peak Floodwater Depths for the PMF.wor



LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

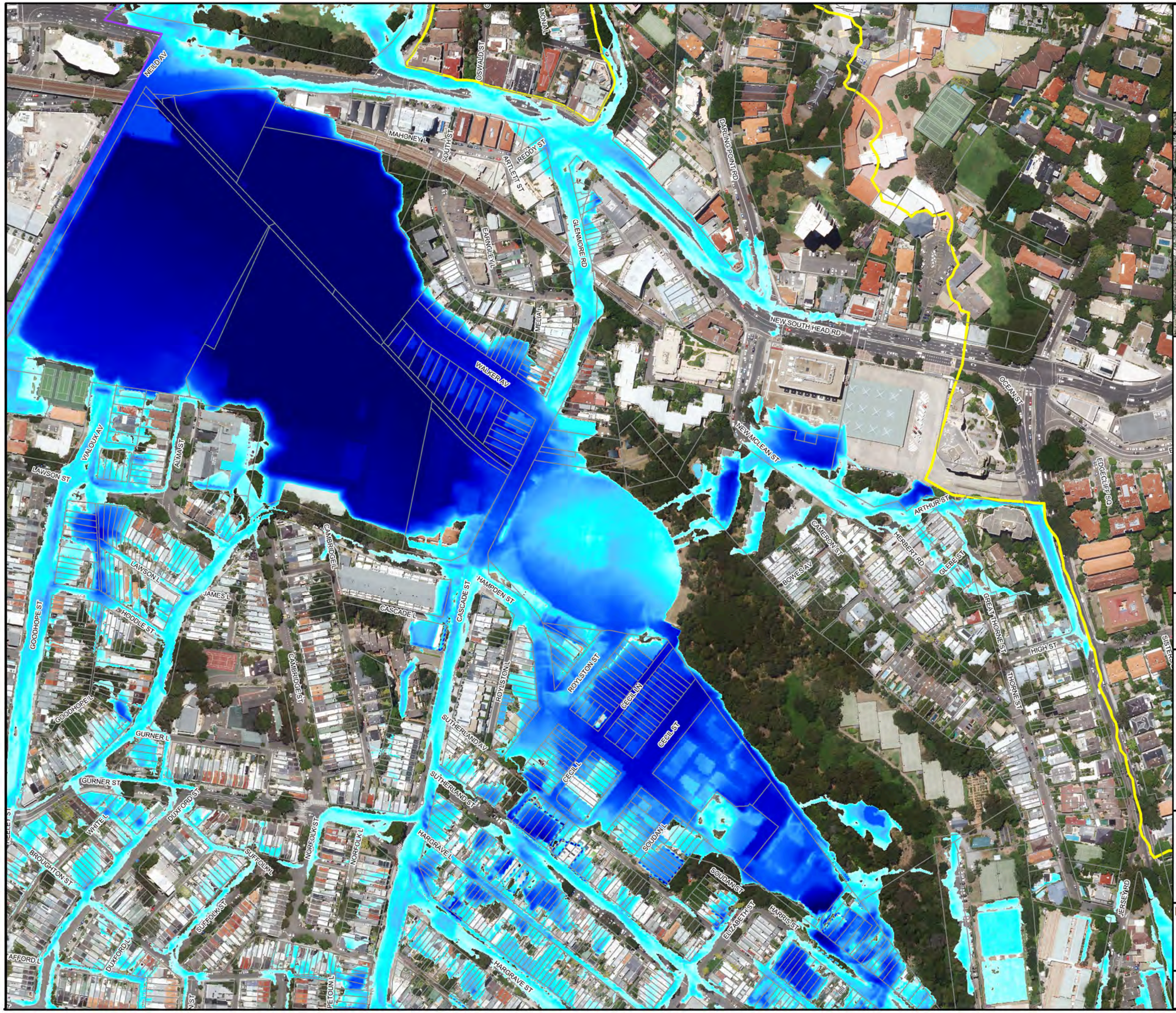
0 0.1 0.2 Km

Figure A4.2: Peak Floodwater Depths for the PMF

Prepared By:

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

File Name: FigA4.2 - Peak Floodwater Depths for the PMF.wor



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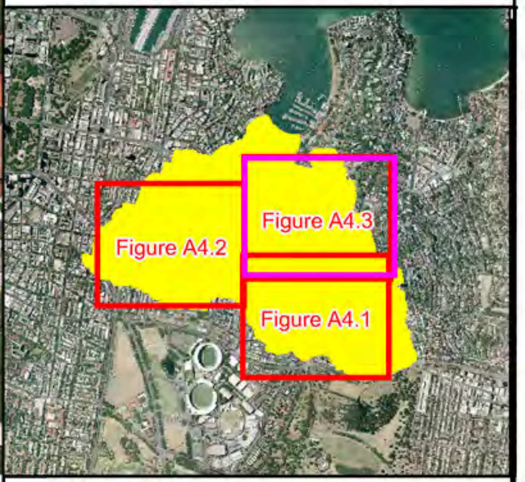


LEGEND

Depths (m)

- 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

0 0.1 0.2 Km

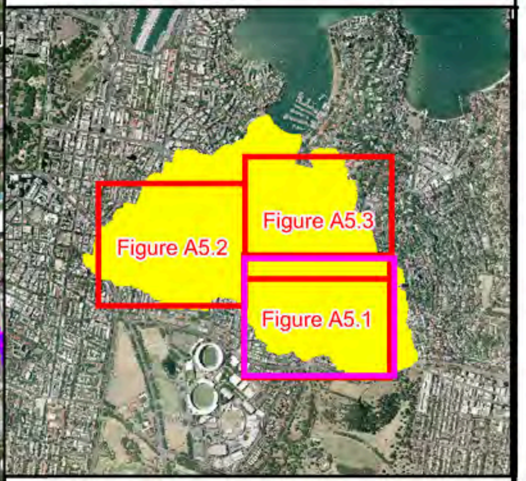
Figure A4.3: Peak Floodwater Depths for the PMF

Prepared By:

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

File Name: FigA4.3 - Peak Floodwater Depths for the PMF.wor

WOOLLAHRA MUNICIPAL COUNCIL



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

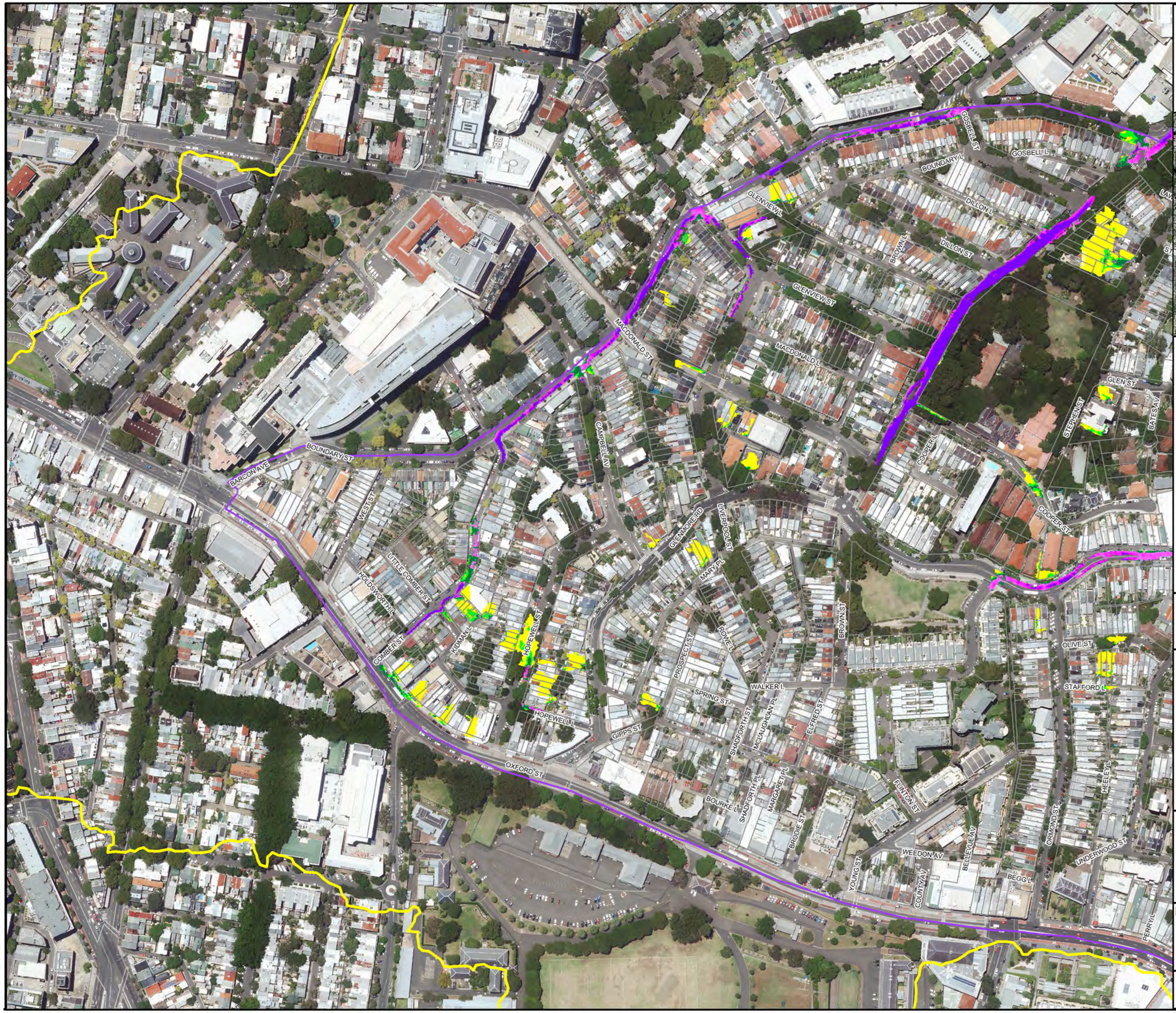
0 0.1 0.2 Km

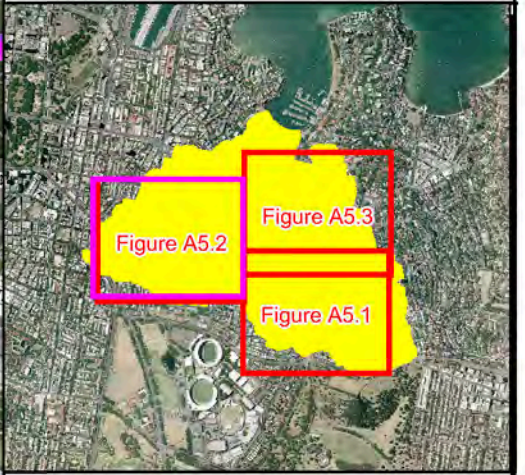
Figure A5.1: Peak Floodwater Velocities for the 20% AEP Flood

Prepared By:

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

File Name: FigA5.1 - Peak Flow Velocity for the 20% AEP Flood.wor





LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

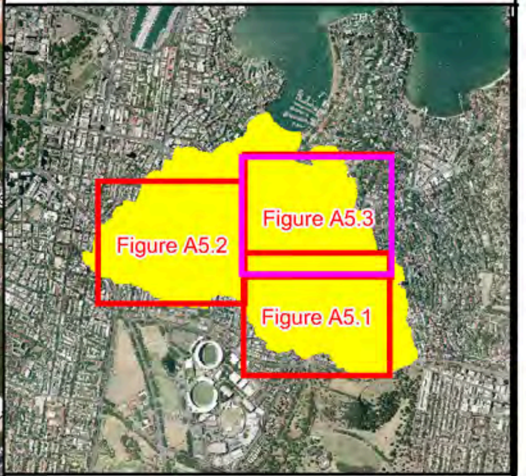
0 0.1 0.2 Km

Figure A5.2: Peak Floodwater Velocities for the 20% AEP Flood

Prepared By:

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

File Name: FigA5.2 - Peak Flow Velocity for the 20% AEP Flood.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

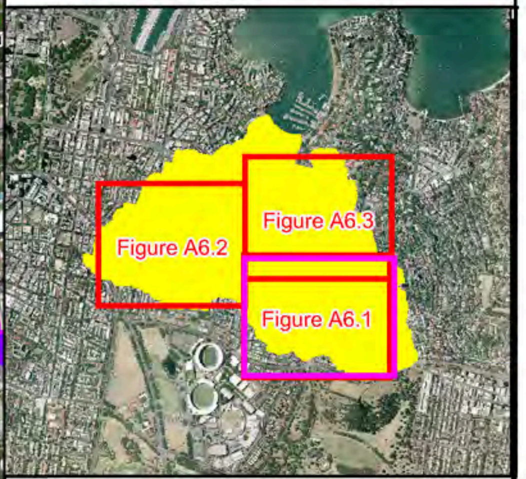
Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A5.3: Peak Floodwater Velocities for the 20% AEP Flood

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

File Name: FigA5.3 - Peak Flow Velocity for the 20% AEP Flood.wor



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LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

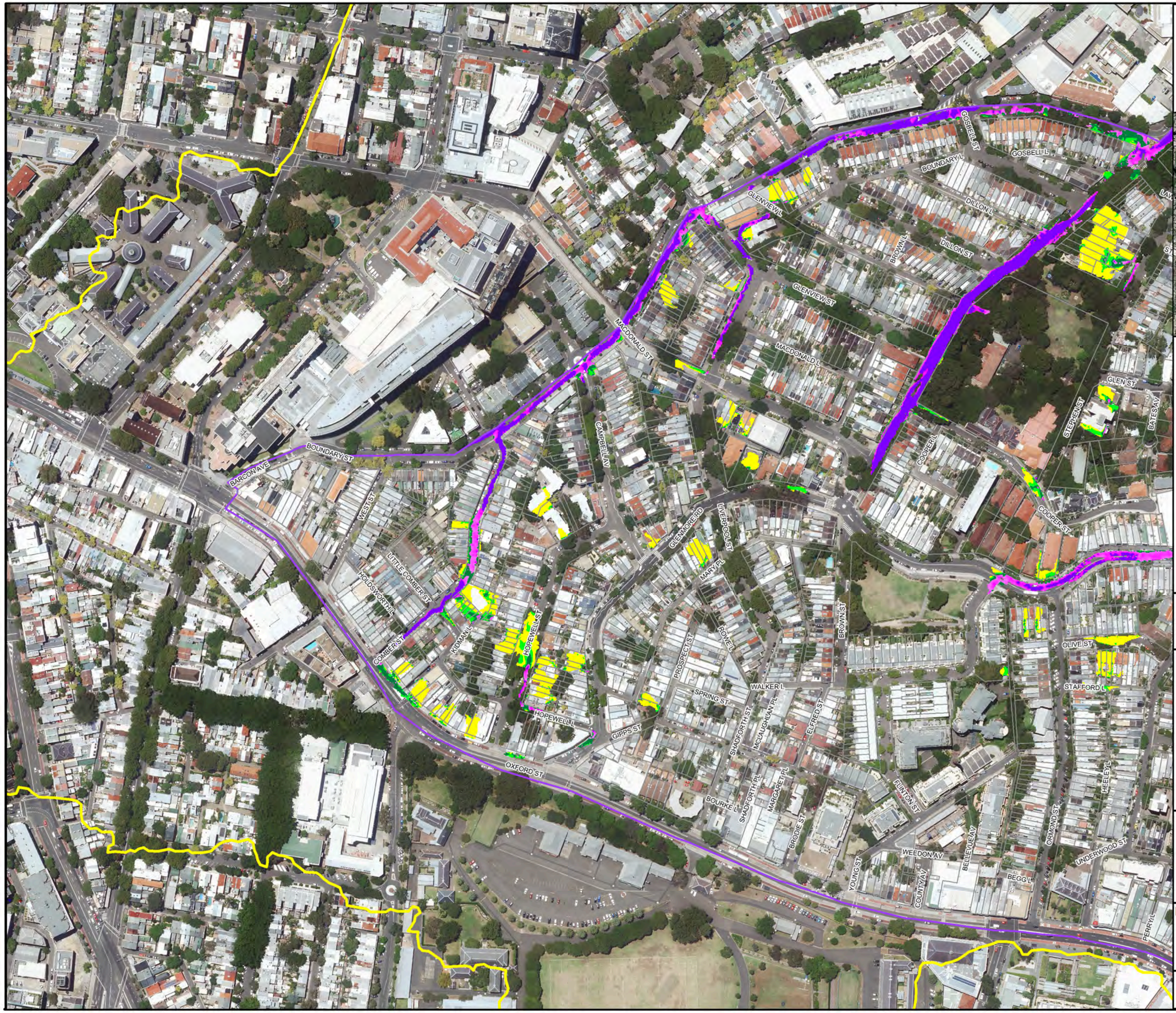
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A6.1: Peak Floodwater Velocities for the 5% AEP Flood

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

File Name: FigA6.1 - Peak Flow Velocity for the 5% AEP Flood.wor



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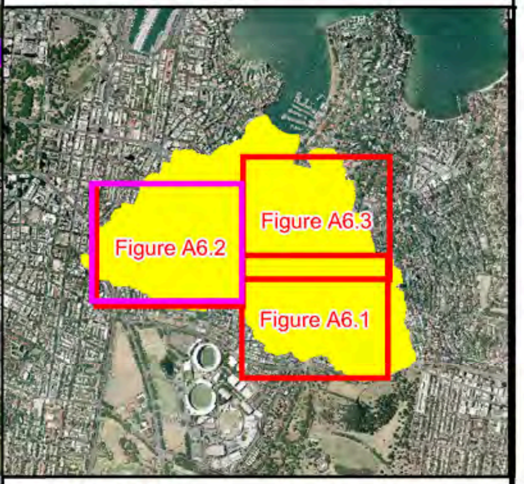


LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

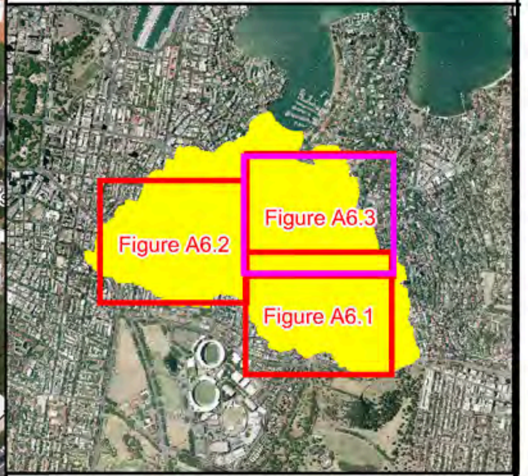
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A6.2: Peak Floodwater Velocities for the 5% AEP Flood

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

File Name: FigA6.2 - Peak Flow Velocity for the 5% AEP Flood.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

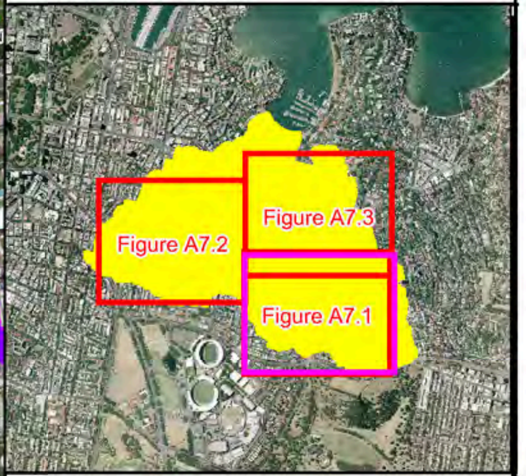
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A6.3: Peak Floodwater Velocities for the 5% AEP Flood

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

File Name: FigA6.3 - Peak Flow Velocity for the 5% AEP Flood.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

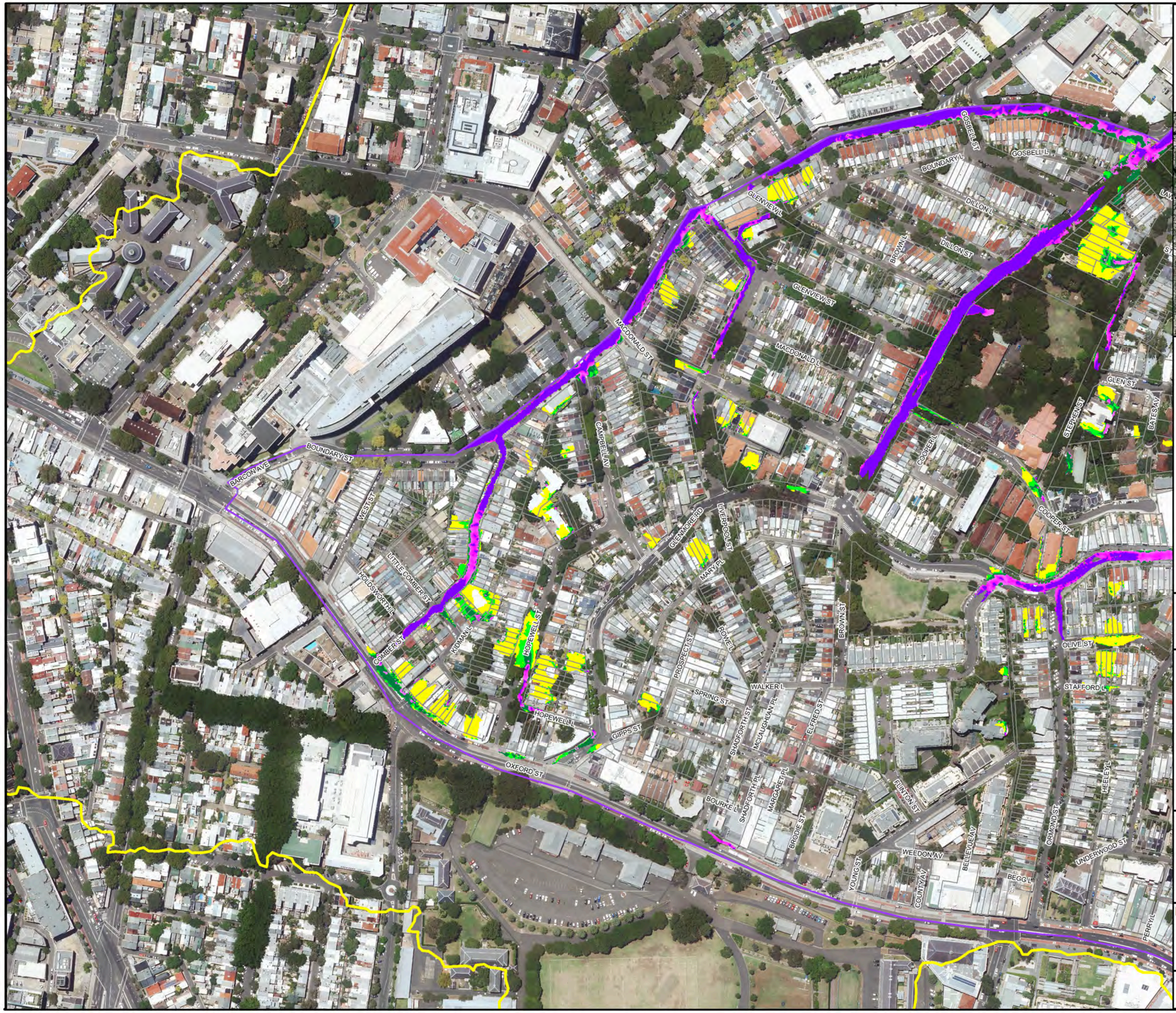
0 0.1 0.2 Km

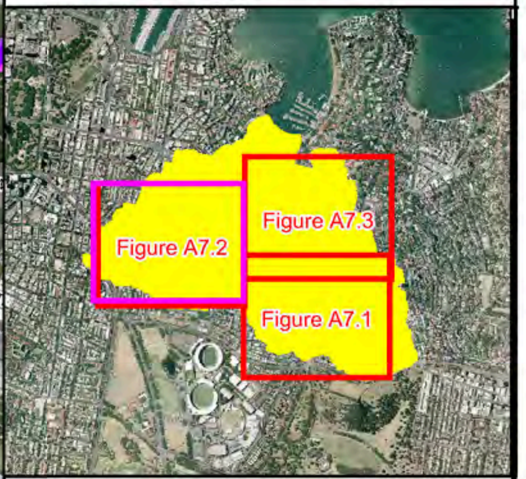
Figure A7.1: Peak Floodwater Velocities for the 1% AEP Flood

Prepared By:

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

File Name: FigA7.1 - Peak Flow Velocity for the 1% AEP Flood.wor





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LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

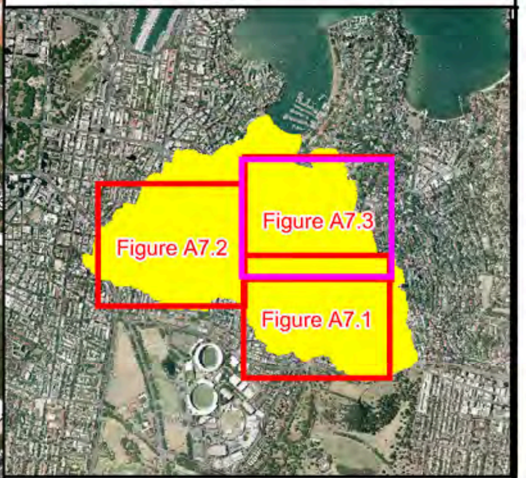
0 0.1 0.2 Km

Figure A7.2: Peak Floodwater Velocities for the 1% AEP Flood

Prepared By:

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

File Name: FigA7.2 - Peak Flow Velocity for the 1% AEP Flood.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

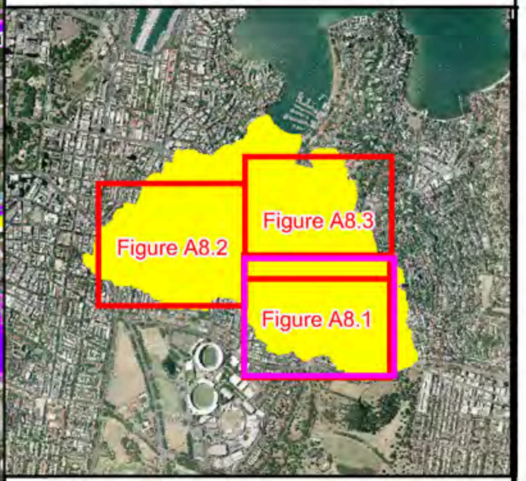
0 0.1 0.2 Km

Figure A7.3: Peak Floodwater Velocities for the 1% AEP Flood

Prepared By:

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

File Name: FigA7.3 - Peak Flow Velocity for the 1% AEP Flood.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

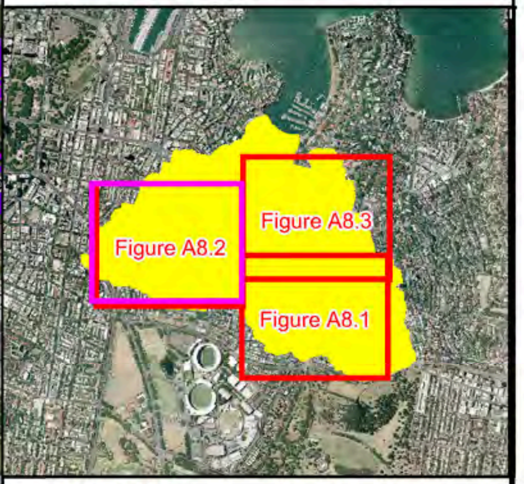
0 0.1 0.2 Km

Figure A8.1: Peak Floodwater Velocities for the PMF

Prepared By:

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

File Name: FigA8.1 - Peak Flow Velocity for the PMF.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

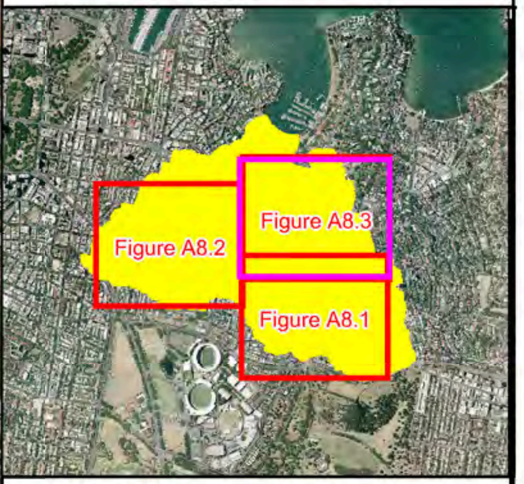
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A8.2: Peak Floodwater Velocities for the PMF

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

File Name: FigA8.2 - Peak Flow Velocity for the PMF.wor



LEGEND

Velocities (m/s)

- 0.01 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 10.0

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

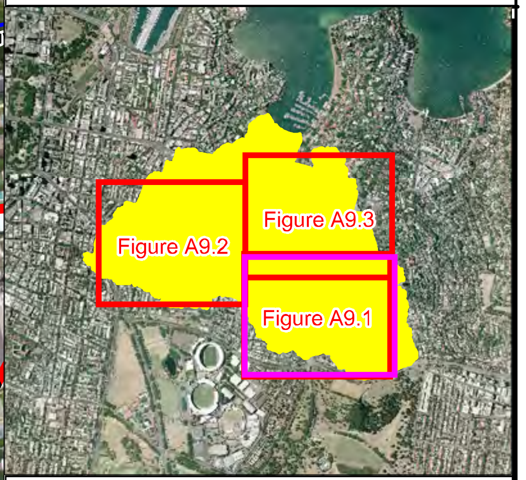
N W E S

Scale 1:3,000 (at A3)
0 0.1 0.2
Km

Figure A8.3: Peak Floodwater Velocities for the PMF

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

File Name: FigA8.3 - Peak Flow Velocity for the PMF.wor



LEGEND

Failure AEP
- <= 100% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- >= 1% AEP

Pit Failure Type
- No Failure
- Surcharge
- Ponding

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)
0 0.1 0.2
Km

Figure A9.1: Stormwater Capacity

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

File Name: FigA9.1 - Stormwater Capacity .wor

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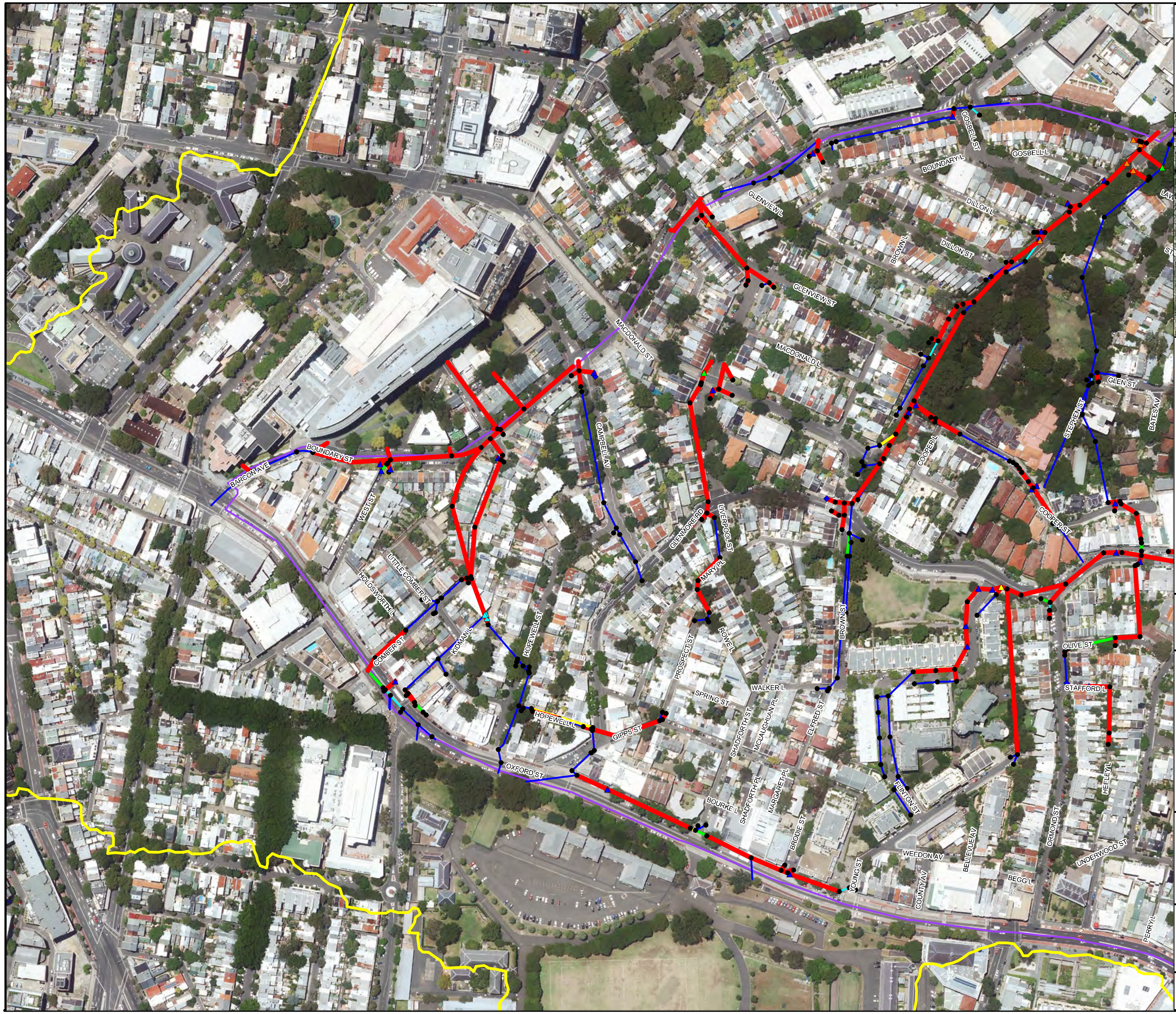
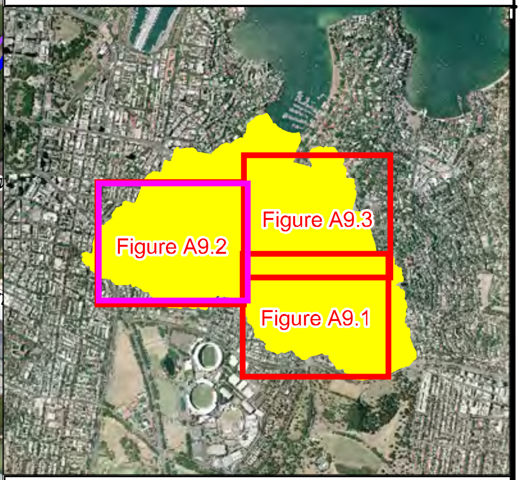




LEGEND

Failure AEP	Pit Failure Type
<= 100% AEP (red)	● No Failure
20% AEP (yellow)	▲ Surcharge
10% AEP (green)	◆ Ponding
5% AEP (cyan)	
>= 1% AEP (blue)	

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

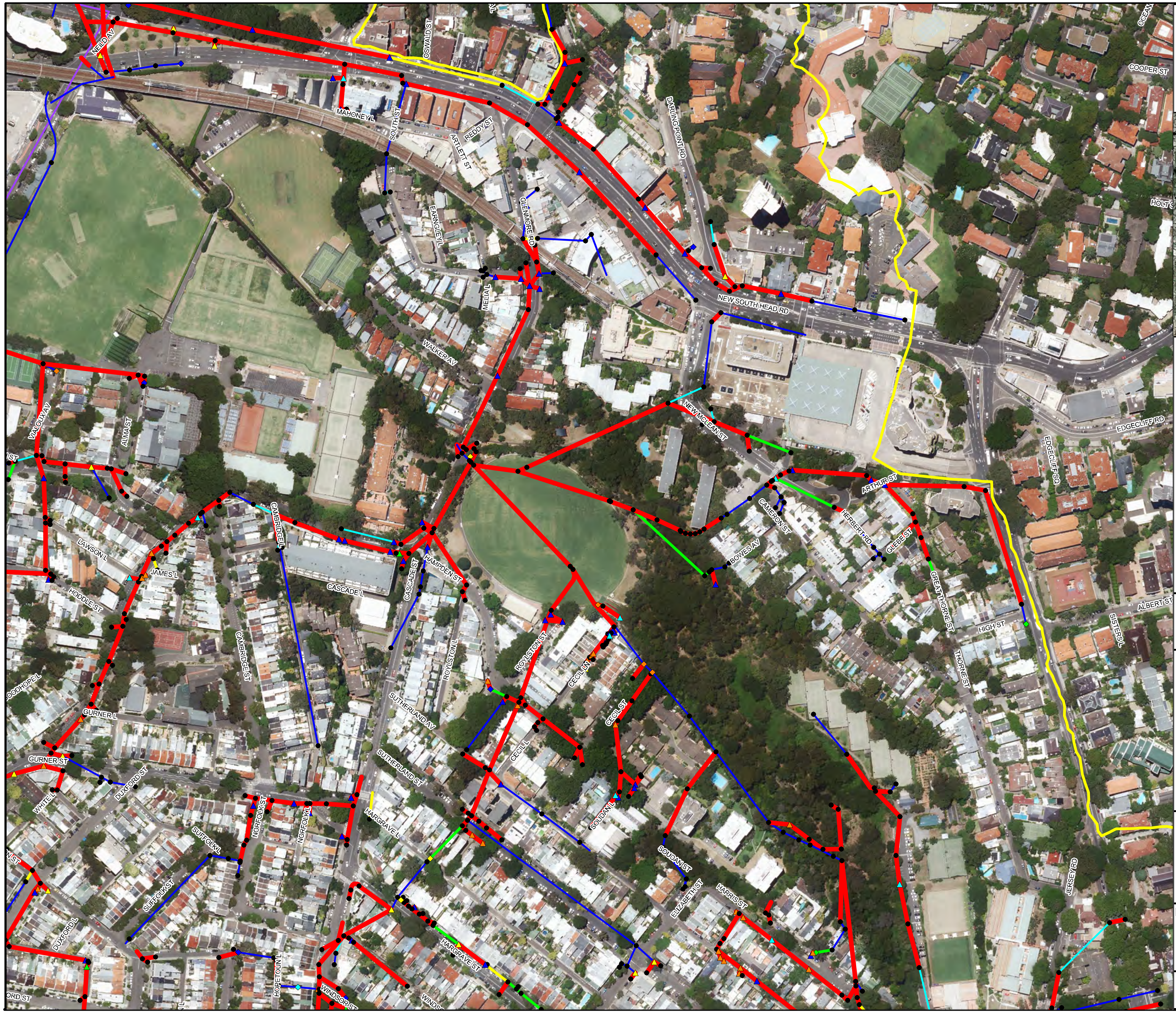
Scale 1:3,000 (at A3)

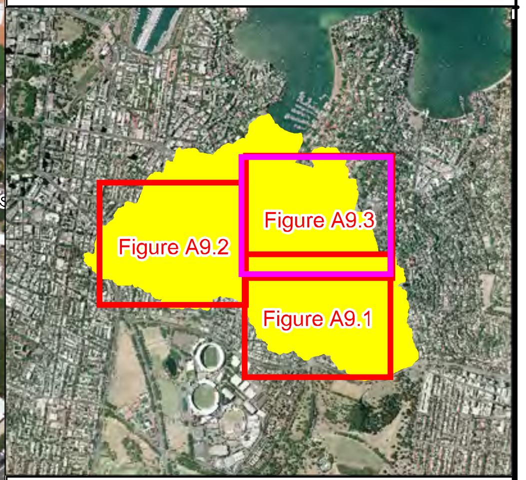
0 0.1 0.2
Km

Figure A9.2: Stormwater Capacity

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

File Name: FigA9.2 - Stormwater Capacity .wor





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LEGEND

Failure AEP
- <= 100% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- >= 1% AEP

Pit Failure Type
- ● No Failure
- ▲ Surcharge
- ◆ Ponding

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N S E W

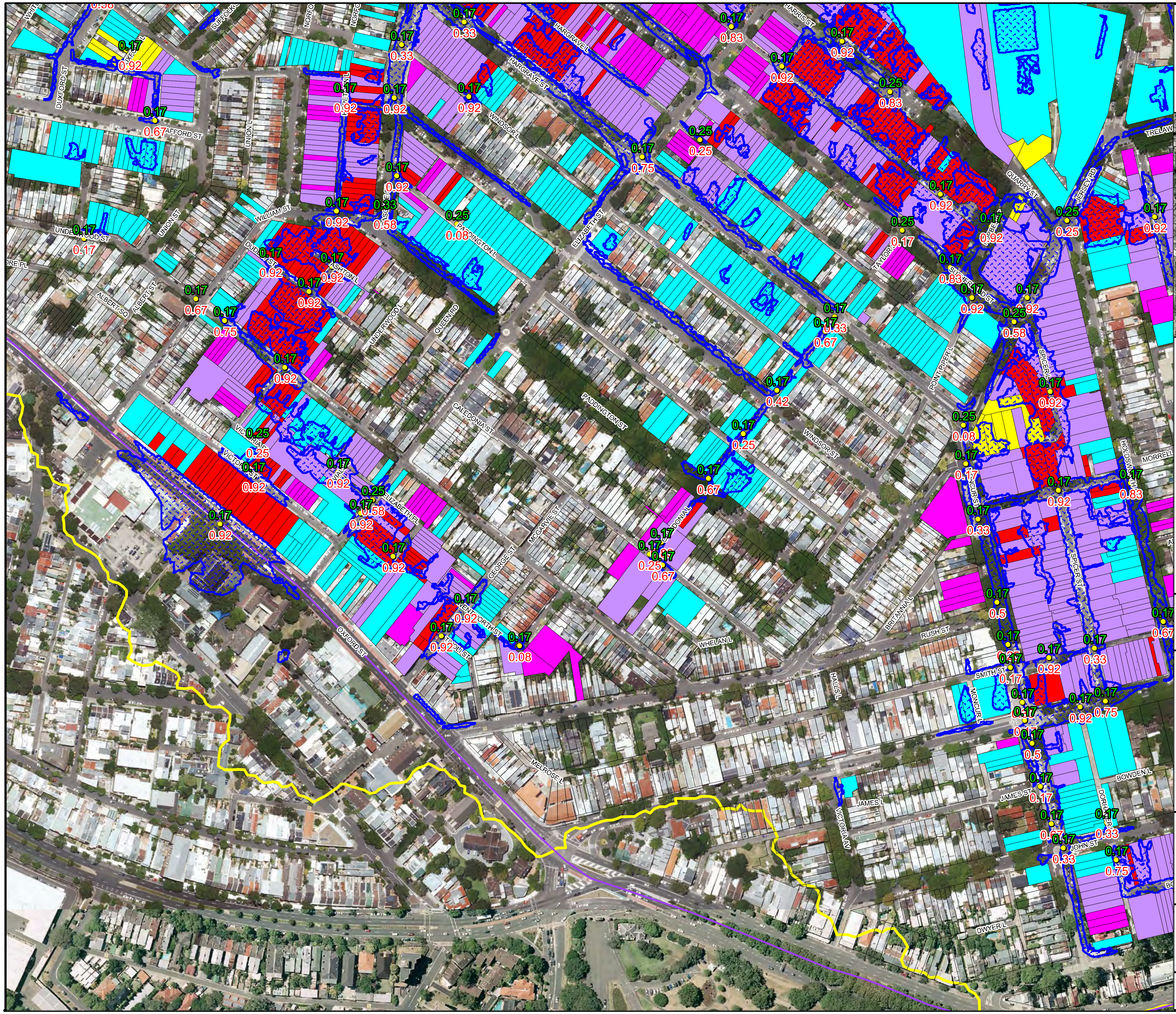
Scale 1:3,000 (at A3)

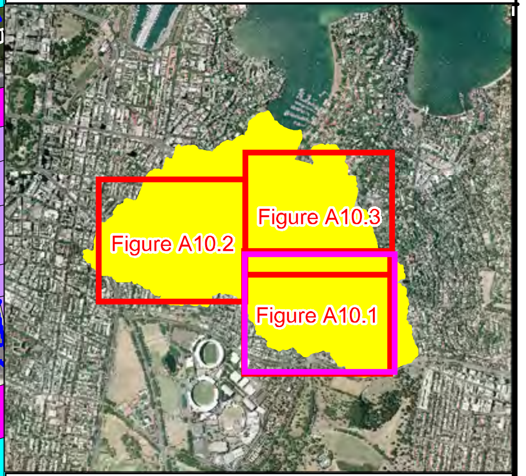
0 0.1 0.2 Km

Figure A9.3: Stormwater Capacity

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

File Name: FigA9.3 - Stormwater Capacity .wor





LEGEND

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts
- Inundation Extent

Road Overtopping Location

- 1.5 Time of Road First Overtopping (hours)
- 0.5 Duration of Overtopping (hours)

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

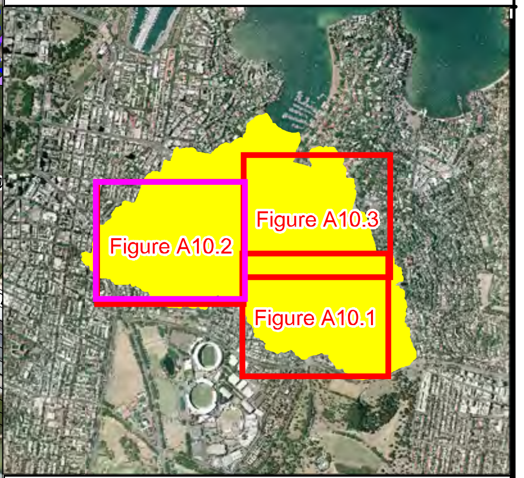
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A10.1: Emergency Response Classifications for the 1% AEP Flood

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

File Name: FigA10.1 - ERC for the 1% AEP Flood.wor



LEGEND

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts
- Inundation Extent

Road Overtopping Location

- 1.5 — Time of Road First Overtopping (hours)
- 0.5 — Duration of Overtopping (hours)

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

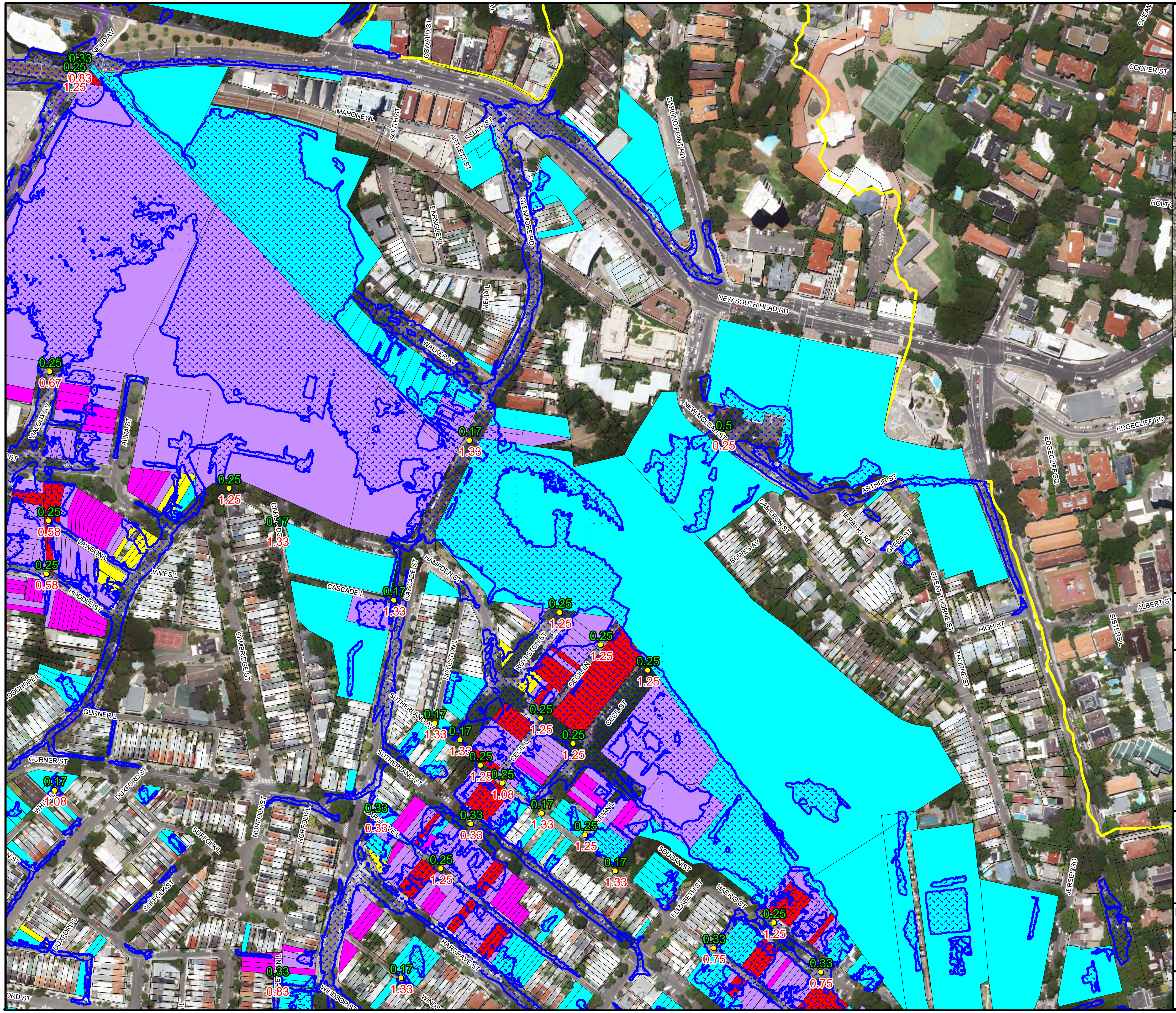
Scale 1:3,000 (at A3)

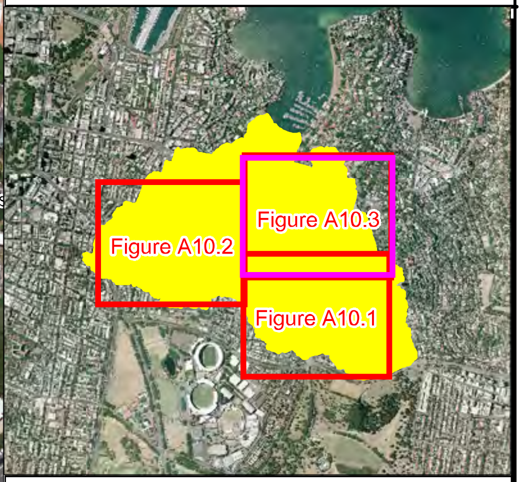
0 0.1 0.2 Km

Figure A10.2: Emergency Response Classifications for the 1% AEP Flood

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

File Name: FigA10.2 - ERC for the 1% AEP Flood.wor





LEGEND

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts
- Inundation Extent

Road Overtopping Location

- 1.5 Time of Road First Overtopping (hours)
- 0.5 Duration of Overtopping (hours)

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)

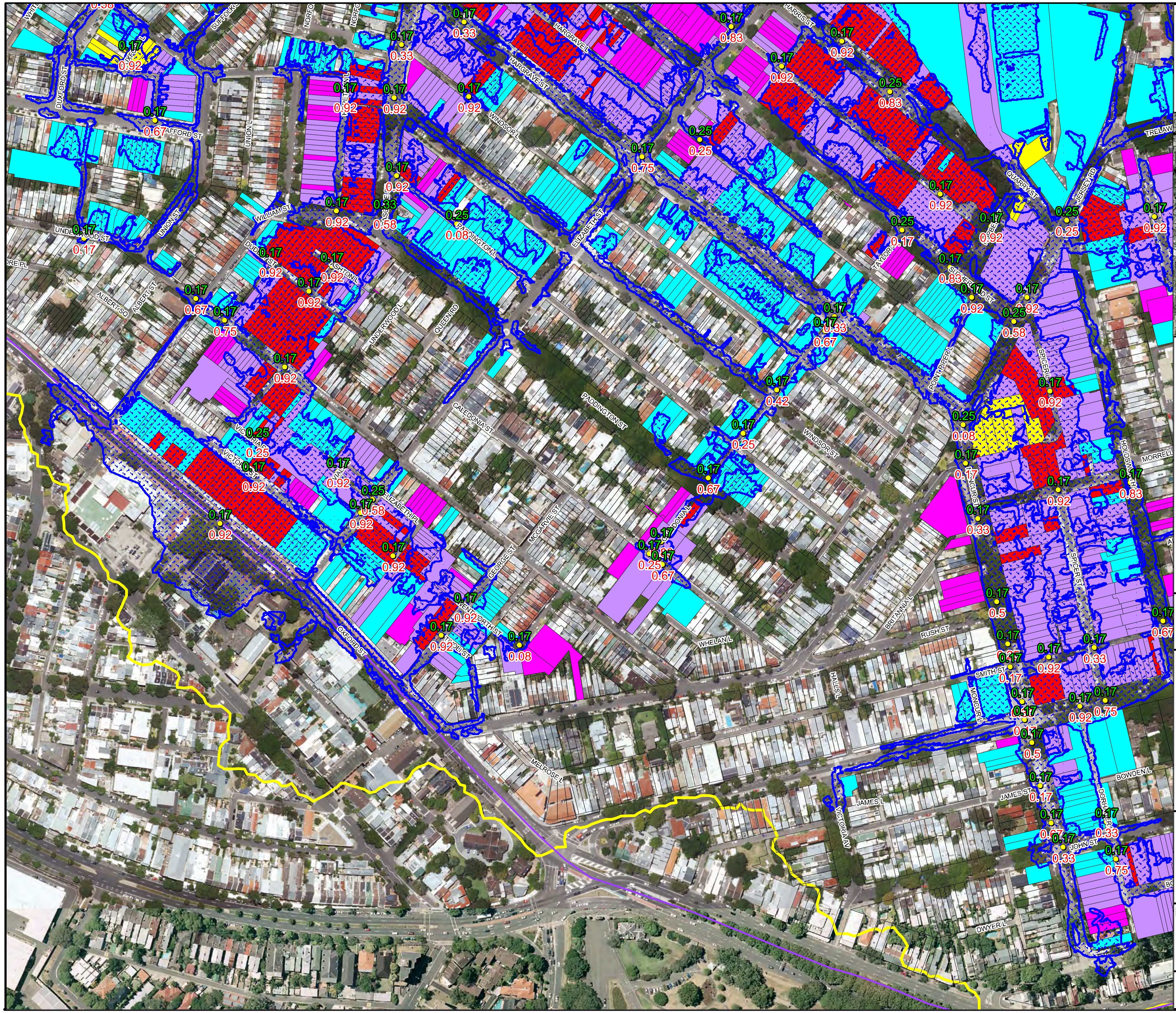
0 0.1 0.2 Km

Figure A10.3: Emergency Response Classifications for the 1% AEP Flood

Prepared By:

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

File Name: FigA10.3 - ERC for the 1% AEP Flood.wor



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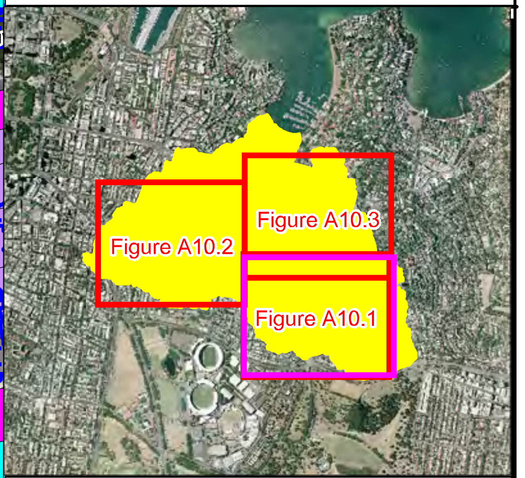


LEGEND

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts
- Inundation Extent

Road Overtopping Location

1.5 Time of Road First Overtopping (hours)

0.5 Duration of Overtopping (hours)

Notes:

Aerial photograph date: January 2014

Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A11.1: Emergency Response Classifications for the PMF

Prepared By:

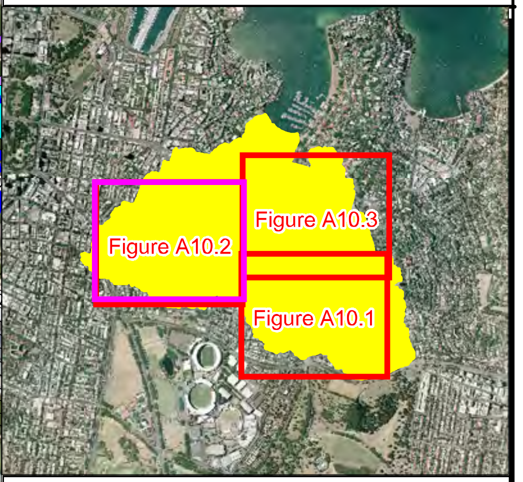
Catchment Simulation Solutions

Suite 2.01, 210 George St

Sydney, NSW 2000

File Name: FigA11.1 - ERC for the PMF.wor

WOOLLAHRA MUNICIPAL COUNCIL



LEGEND

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts
- Inundation Extent

Road Overtopping Location

- 1.5 Time of Road First Overtopping (hours)
- 0.5 Duration of Overtopping (hours)

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

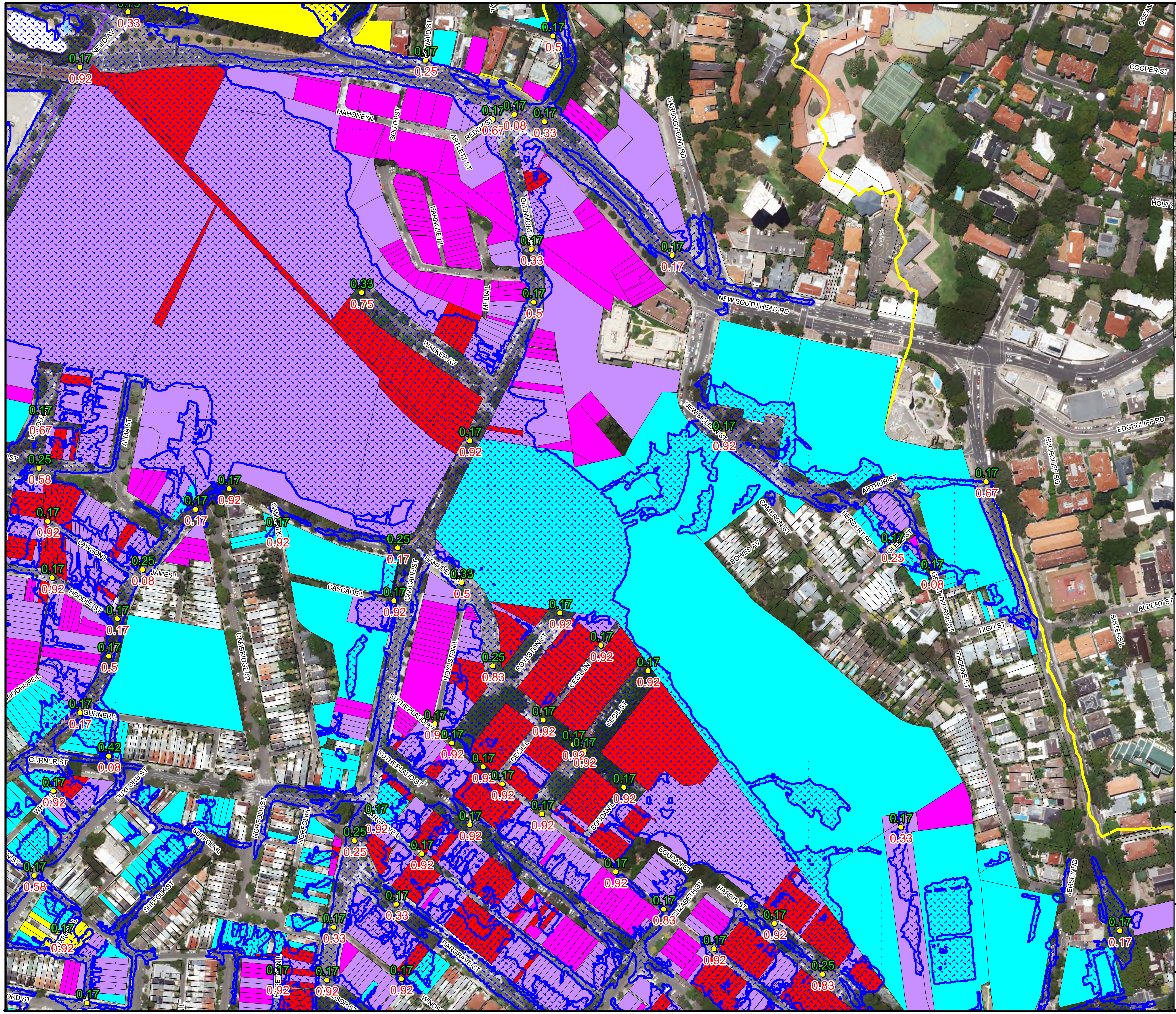
N
W E
S

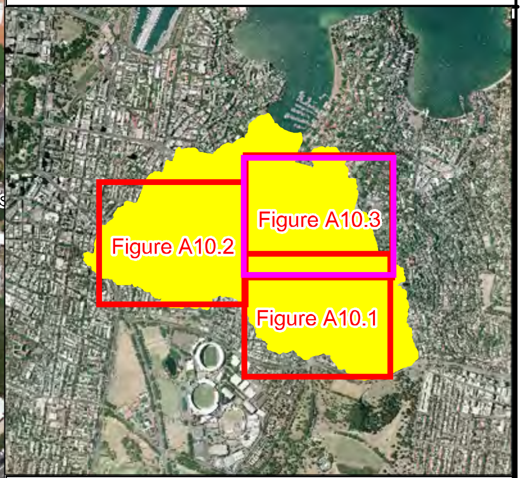
Scale 1:3,000 (at A3)
0 0.1 0.2
Km

Figure A11.2: Emergency Response Classifications for the PMF

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

File Name: FigA11.2 - ERC for the PMF Flood.wor





LEGEND

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts
- Inundation Extent

Road Overtopping Location

- 1.5 Time of Road First Overtopping (hours)
- 0.5 Duration of Overtopping (hours)

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

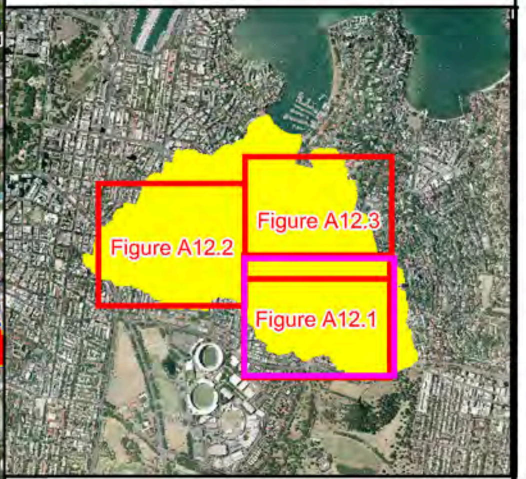
Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A11.3: Emergency Response Classifications for the PMF

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

File Name: FigA11.3 - ERC for the PMF.wor



LEGEND

Hazard

- Low
- Transition
- High

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N E S W

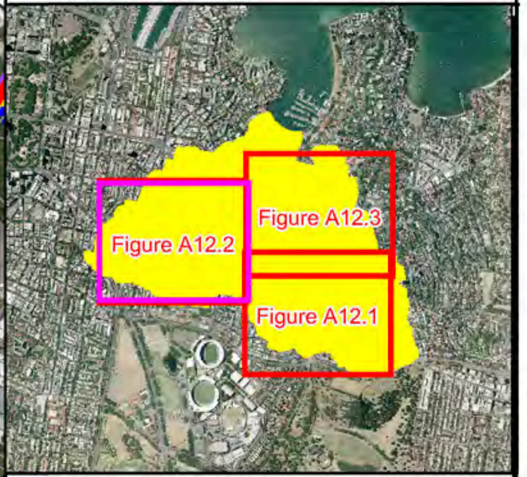
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A12.1: Provisional Flood Hazard for the 1% AEP Flood

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

File Name: FigA12.1 - Provisional Flood Hazard for the 1% AEP Flood.wor



LEGEND

Hazard

- Low
- Transition
- High

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

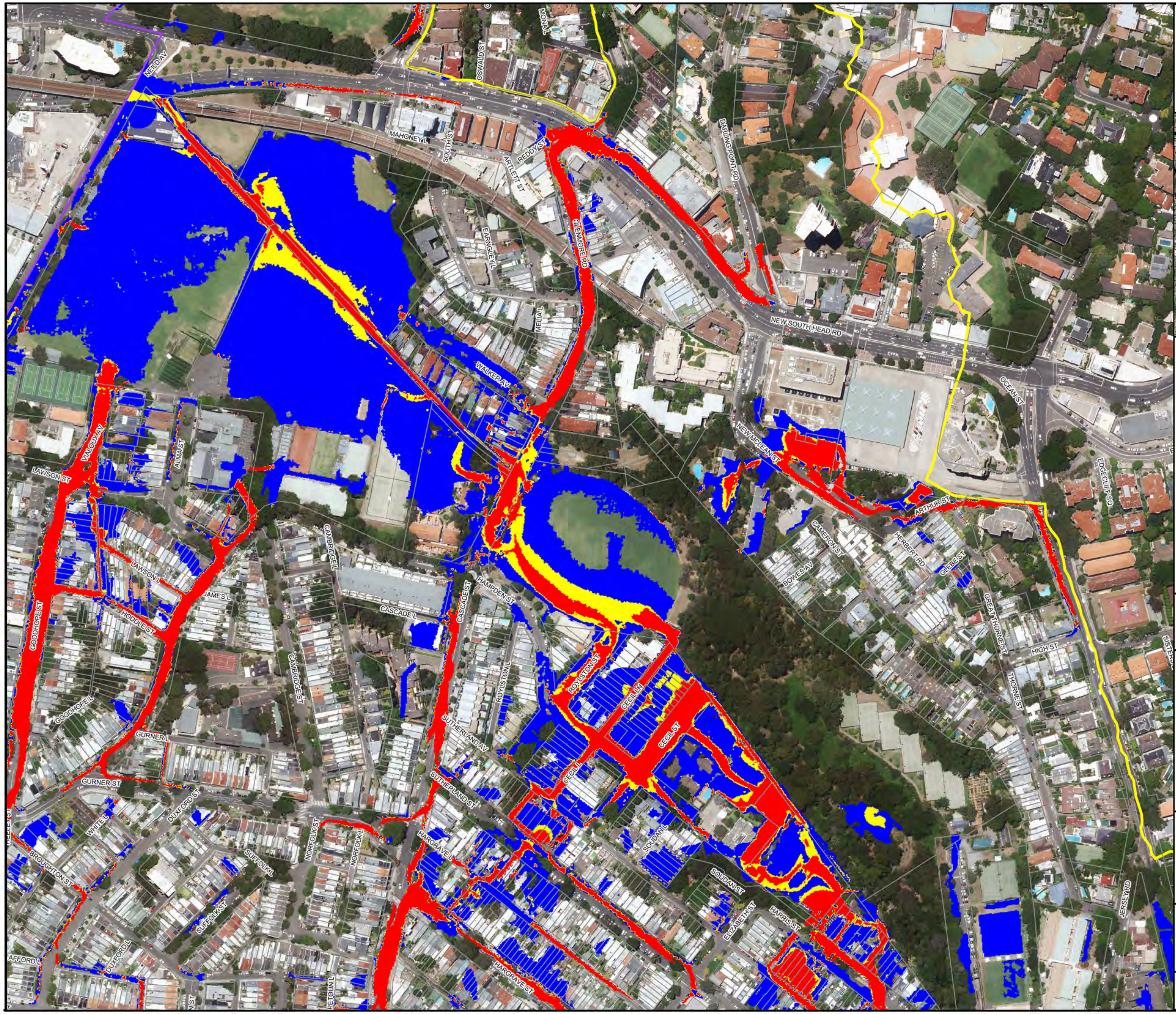
Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A12.2: Provisional Flood Hazard for the 1% AEP Flood

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

File Name: FigA12.2 - Provisional Flood Hazard for the 1% AEP Flood.wor



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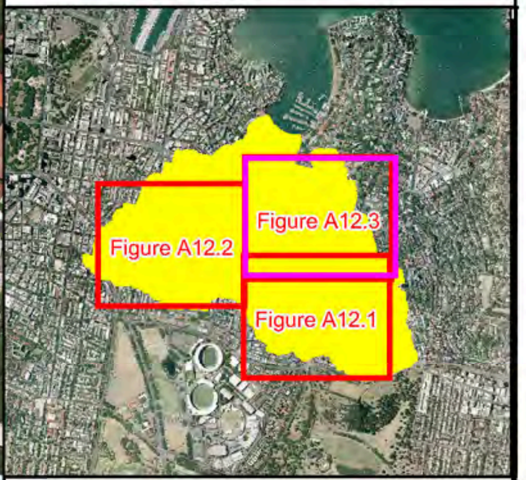


LEGEND

Hazard

- Low
- Transition
- High

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

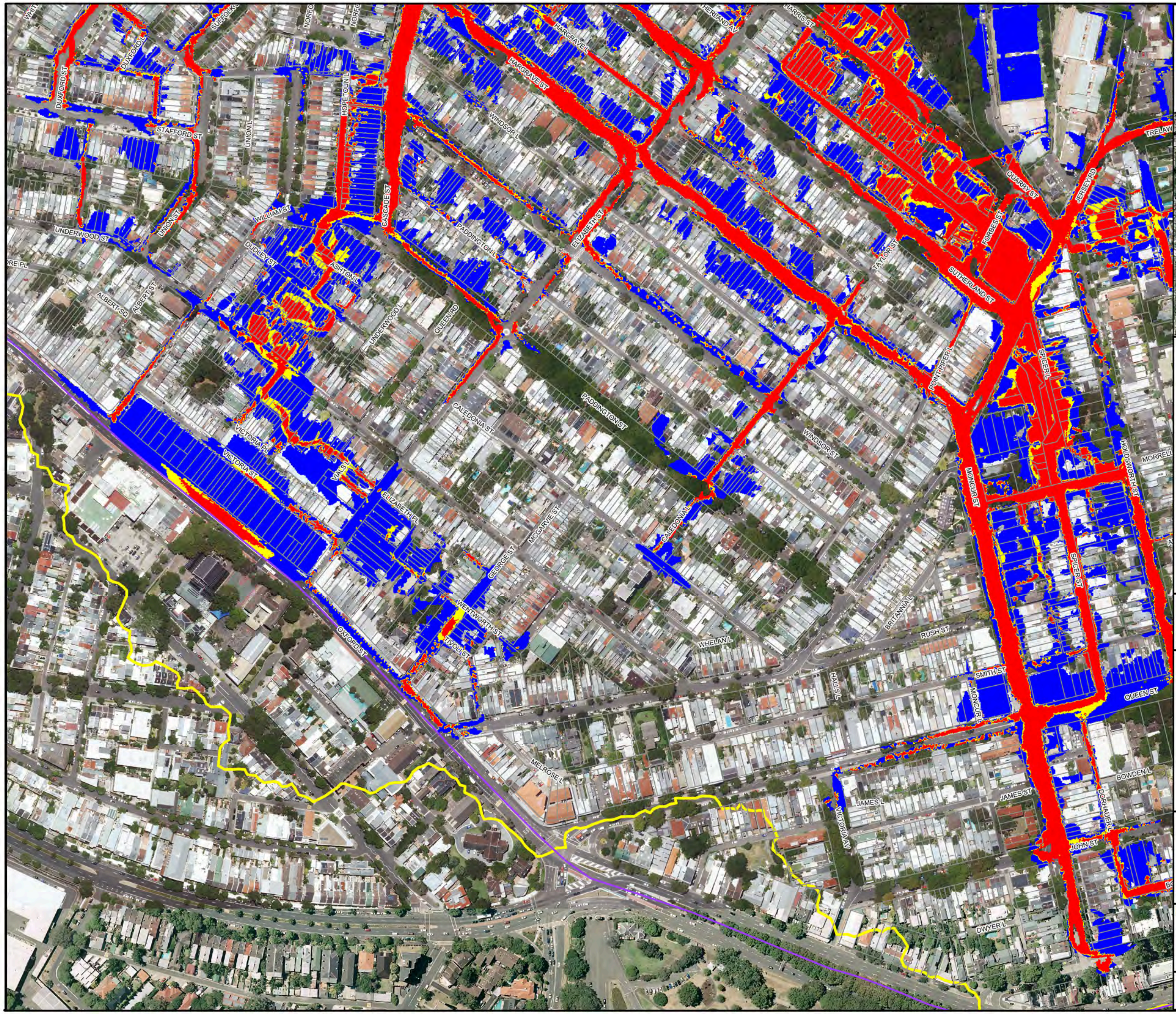
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A12.3: Provisional Flood Hazard for the 1% AEP Flood

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

File Name: FigA12.3 - Provisional Flood Hazard for the 1% AEP Flood.wor



LEGEND

Hazard

- Low
- Transition
- High

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

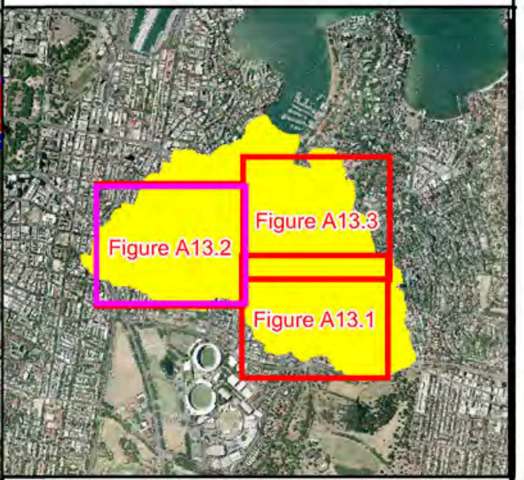
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A13.1: Provisional Flood Hazard for the PMF

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

File Name: FigA13.1 - Provisional Flood Hazard for the PMF.wor



LEGEND

Hazard

- Low
- Transition
- High

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

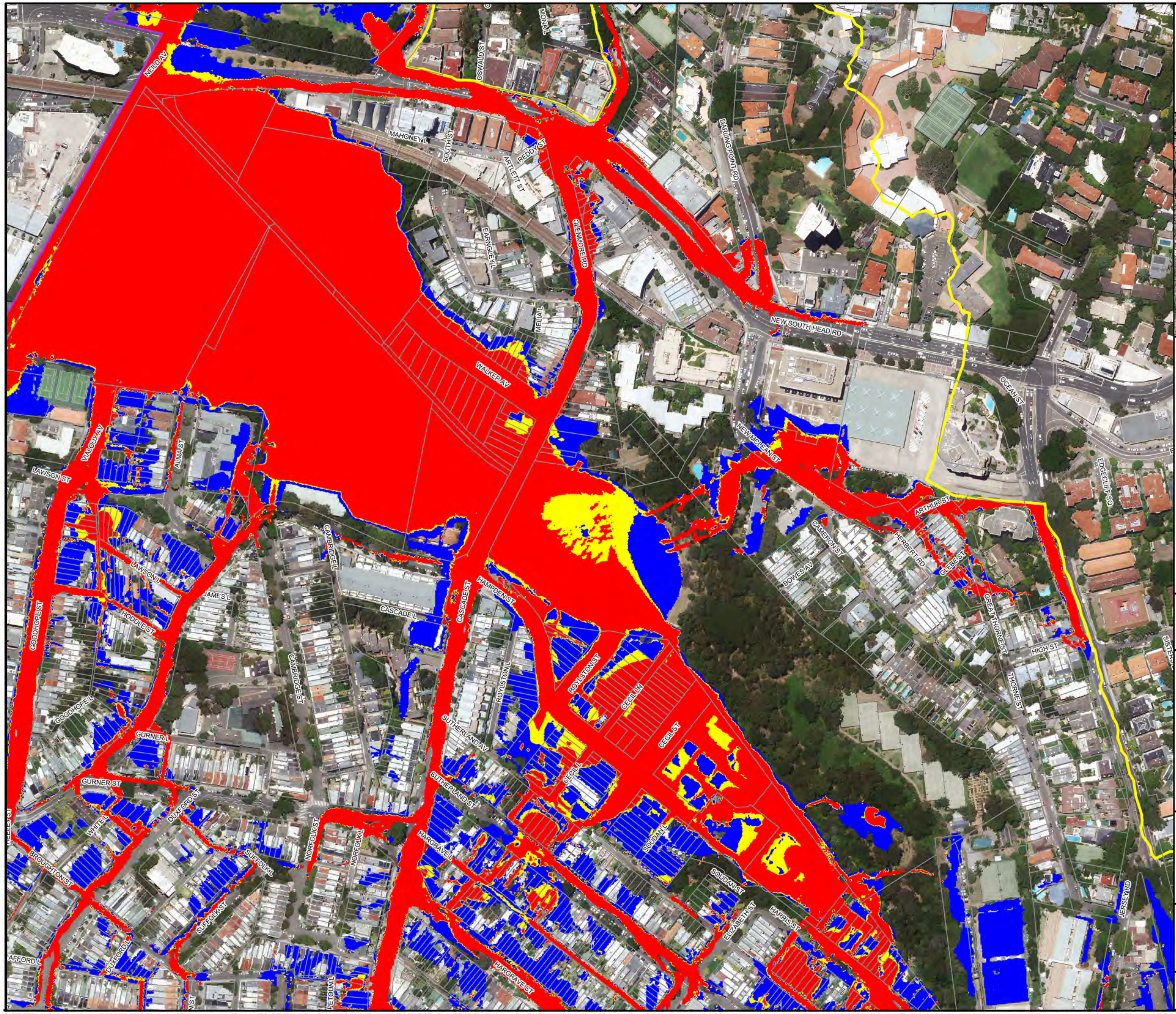
Scale 1:3,000 (at A3)

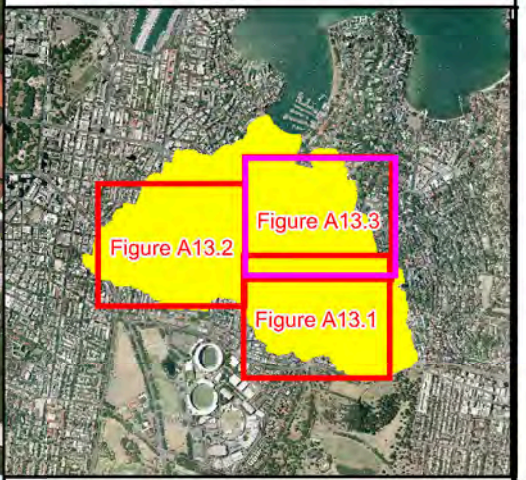
0 0.1 0.2
Km

Figure A13.2: Provisional Flood Hazard for the PMF

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

File Name: FigA13.2 - Provisional Flood Hazard for the PMF.wor





LEGEND

Hazard

- Low
- Transition
- High

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure A13.3: Provisional Flood Hazard for the PMF

Prepared By:

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

File Name: FigA13.3 - Provisional Flood Hazard for the PMF.wor

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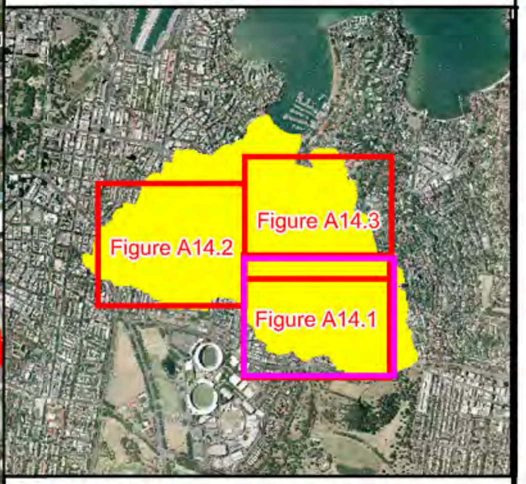


LEGEND

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

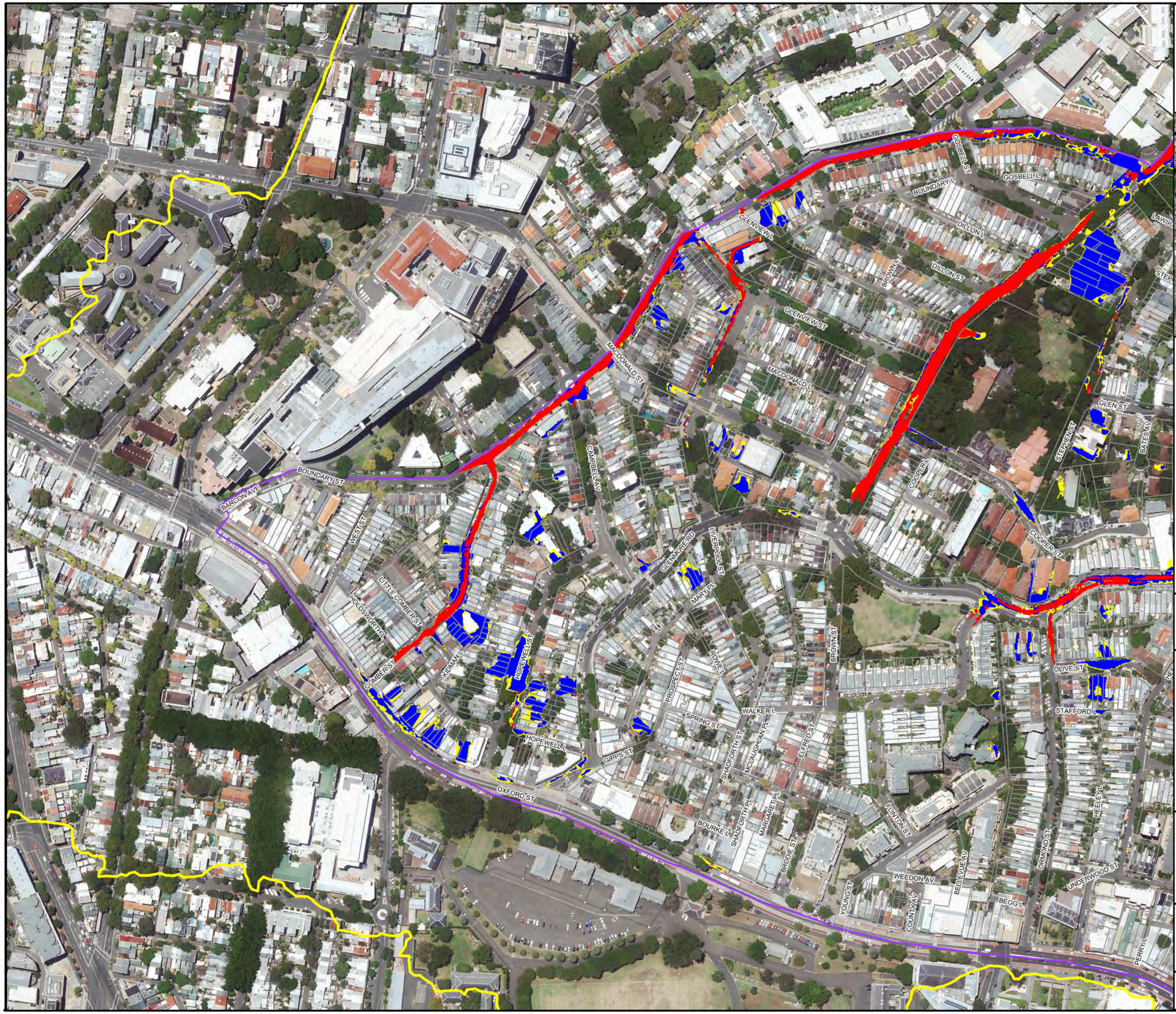
0 0.1 0.2 Km

Figure A14.1: Hydraulic Categories for the 1% AEP Flood

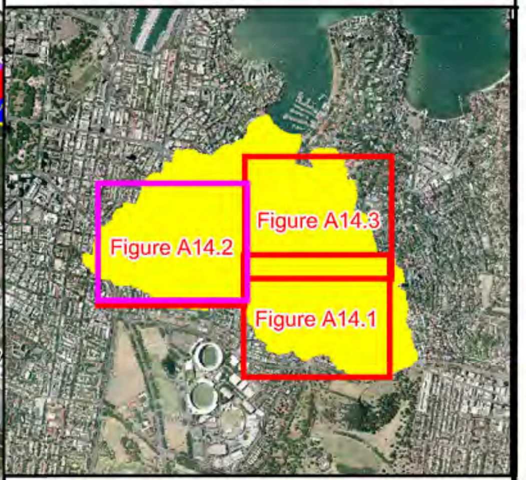
Prepared By:

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

File Name: FigA14.1 - Hydraulic Categories for the 1% AEP Flood.wor



WOOLLAHRA MUNICIPAL COUNCIL



LEGEND

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

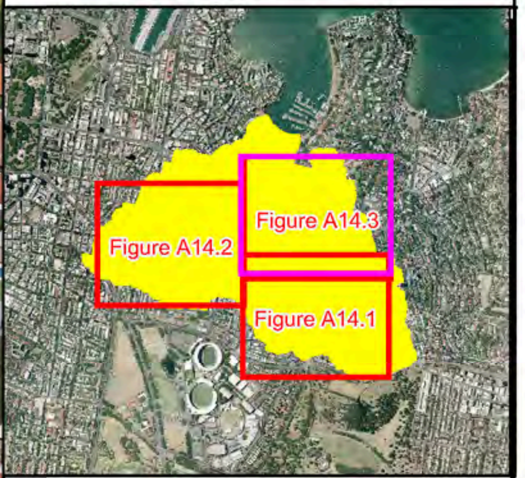
0 0.1 0.2 Km

Figure A14.2: Hydraulic Categories for the 1% AEP Flood

Prepared By:

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

File Name: FigA14.2 - Hydraulic Categories for the 1% AEP Flood.wor



LEGEND

Hydraulic Categories

- Flood Fringe (yellow)
- Flood Storage (blue)
- Floodway (red)

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

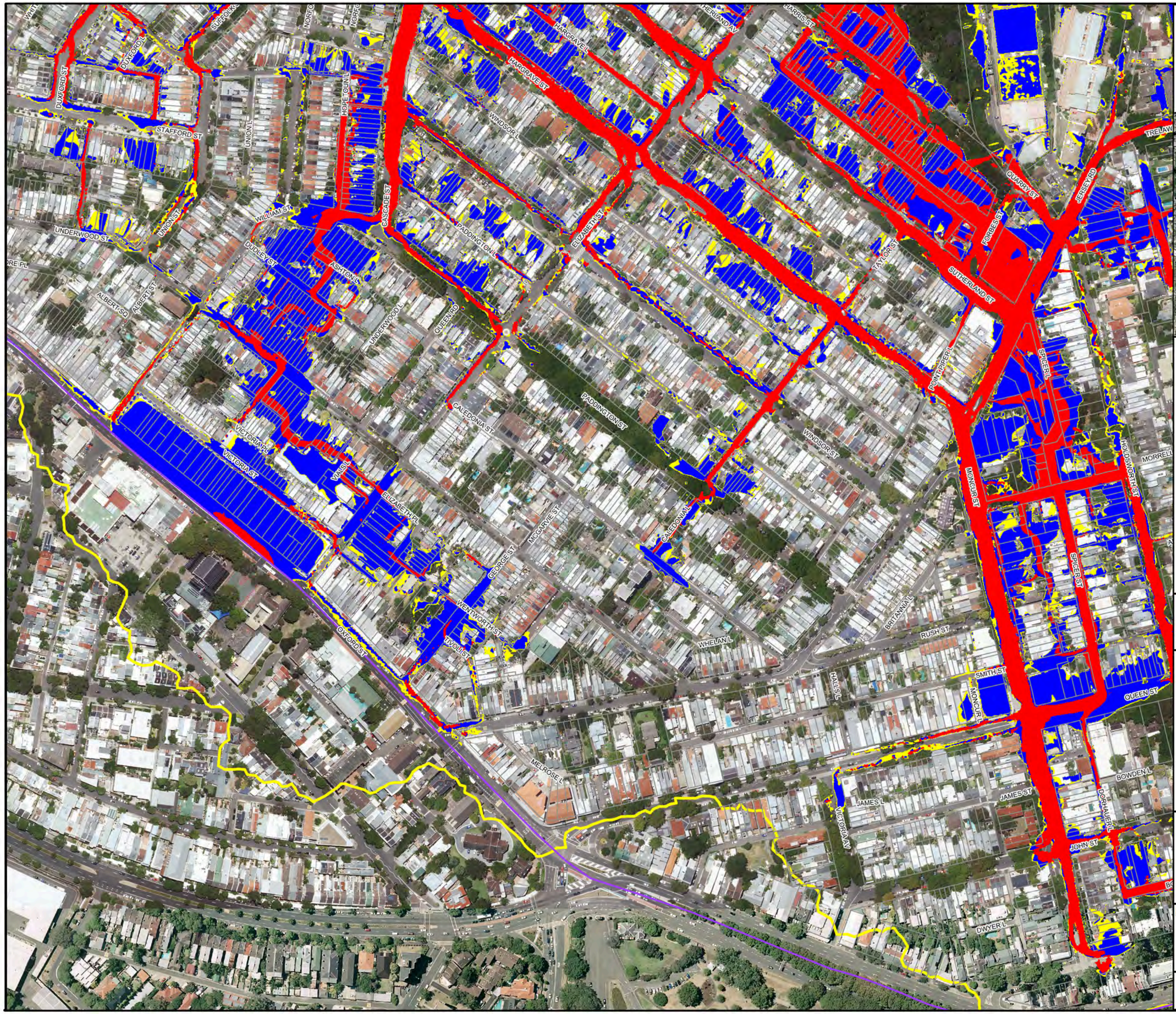
Scale 1:3,000 (at A3)

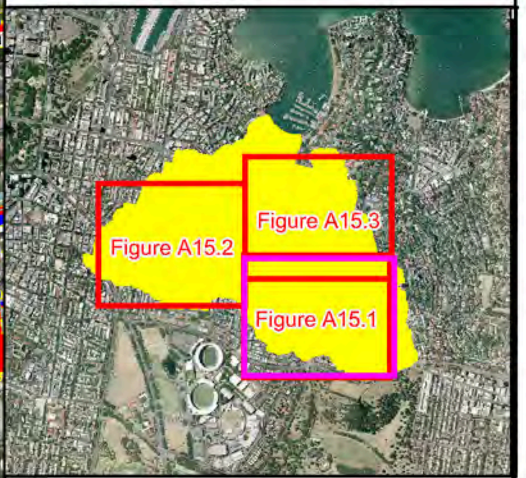
0 0.1 0.2
Km

Figure A14.3: Hydraulic Categories for the 1% AEP Flood

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

File Name: FigA14.3 - Hydraulic Categories for the 1% AEP Flood.wor





LEGEND

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A15.1: Hydraulic Categories for the PMF

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

File Name: FigA15.1 - Hydraulic Categories for the PMF.wor

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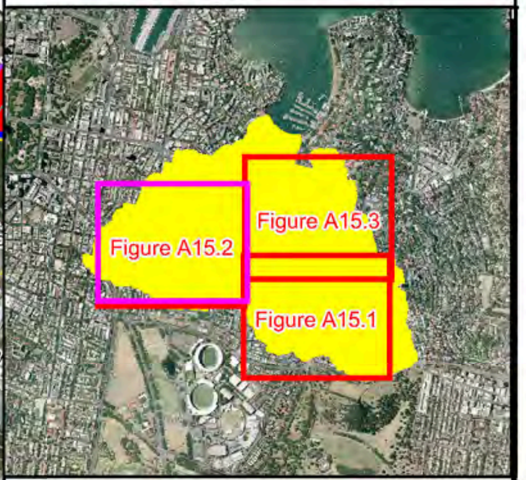


LEGEND

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

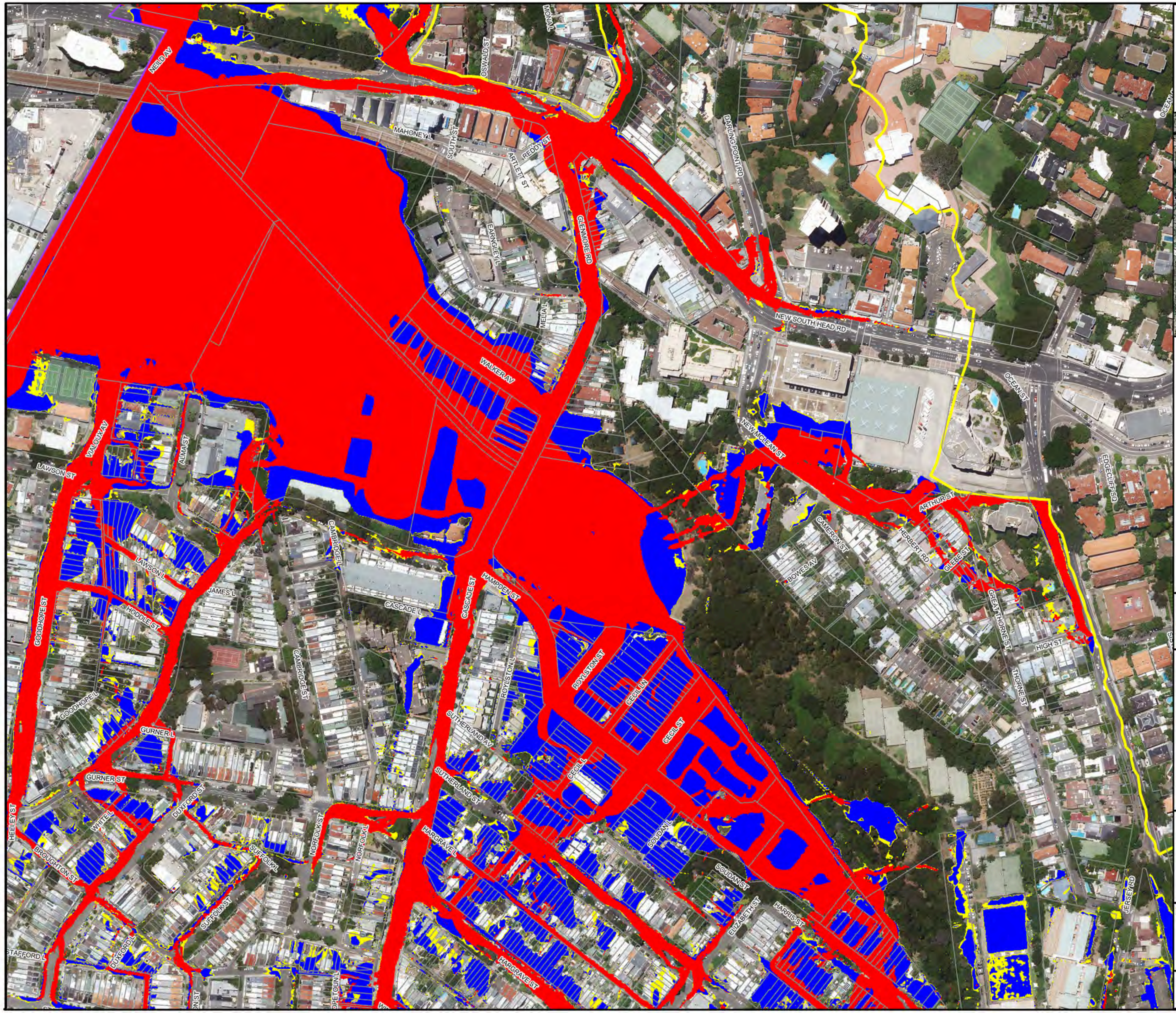
0 0.1 0.2 Km

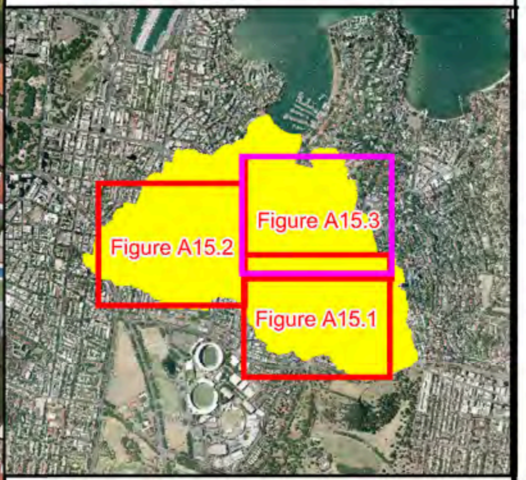
Figure A15.2: Hydraulic Categories for the PMF

Prepared By:

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

File Name: FigA15.2 - Hydraulic Categories for the PMF.wor





LEGEND

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

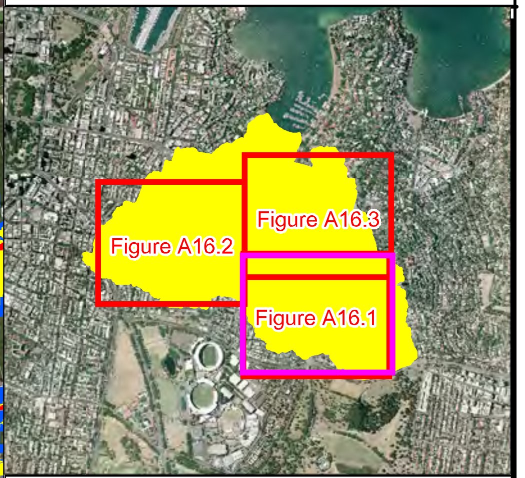
Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A15.3: Hydraulic Categories for the PMF

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

File Name: FigA15.3 - Hydraulic Categories for the PMF.wor



Flood Risk

- Low
- Medium
- High

Notes:

Aerial photograph date: January 2014
Flood Risk only shown within Woollahra Municipal Council LGA

N
W E
S

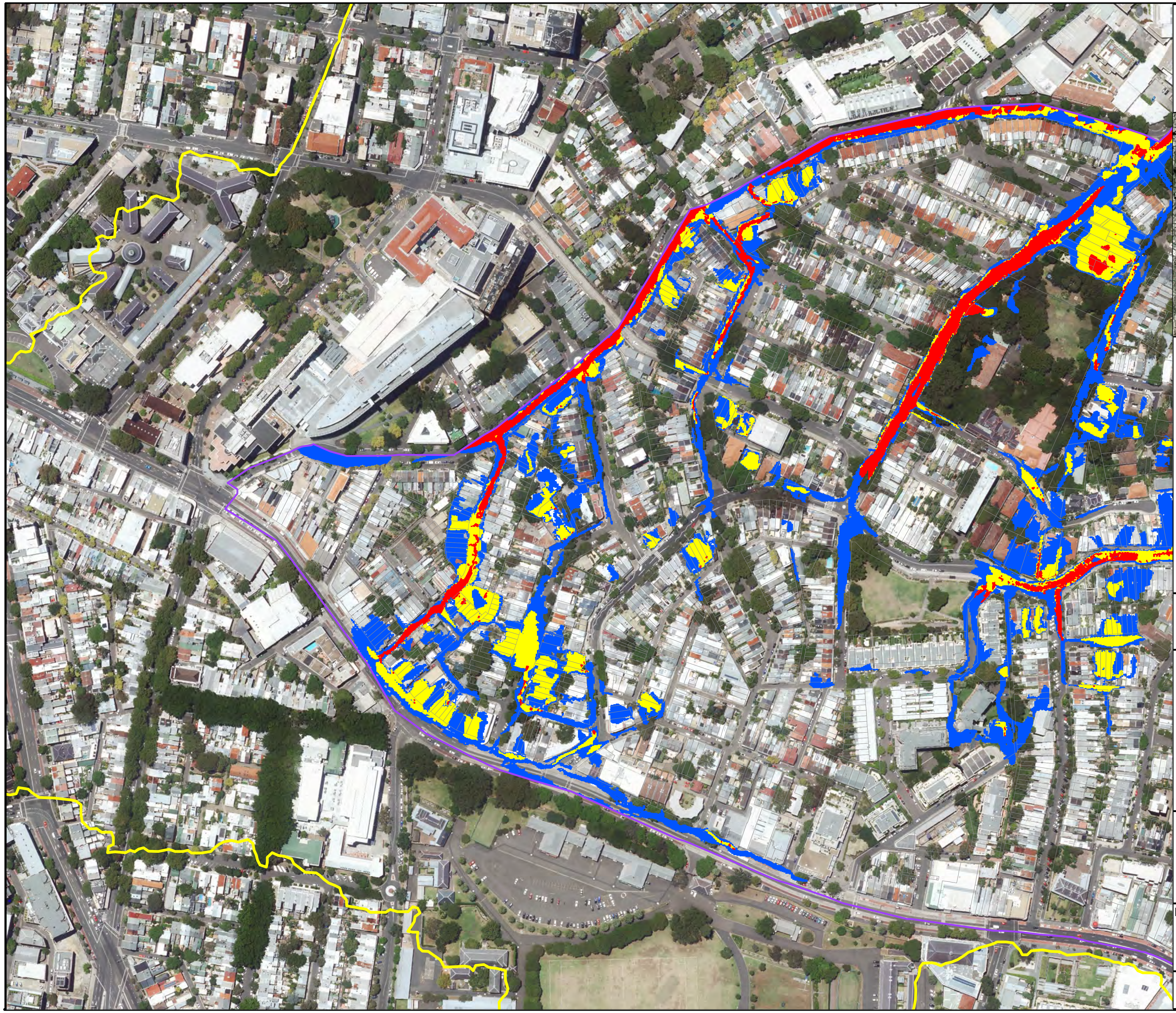
Scale 1:3,000 (at A3)

0 0.1 0.2
Km

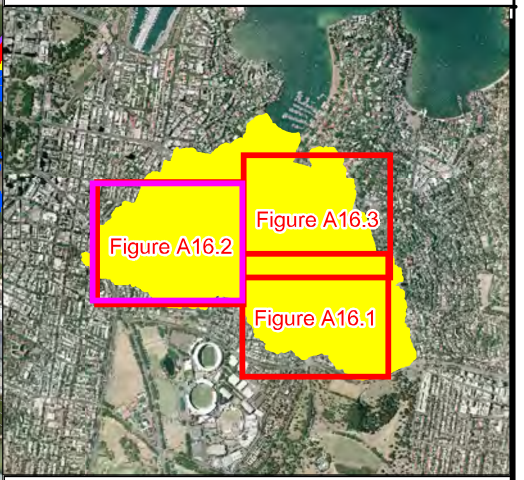
Figure A16.1:
Flood Risk Precincts

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

File Name: FigA16.1 - Existing Flood Risk Precinct.wor



WOOLLAHRA MUNICIPAL COUNCIL



Flood Risk

- Low
- Medium
- High

Notes:

Aerial photograph date: January 2014
Flood Risk only shown within Woollahra Municipal Council LGA

N
W E
S

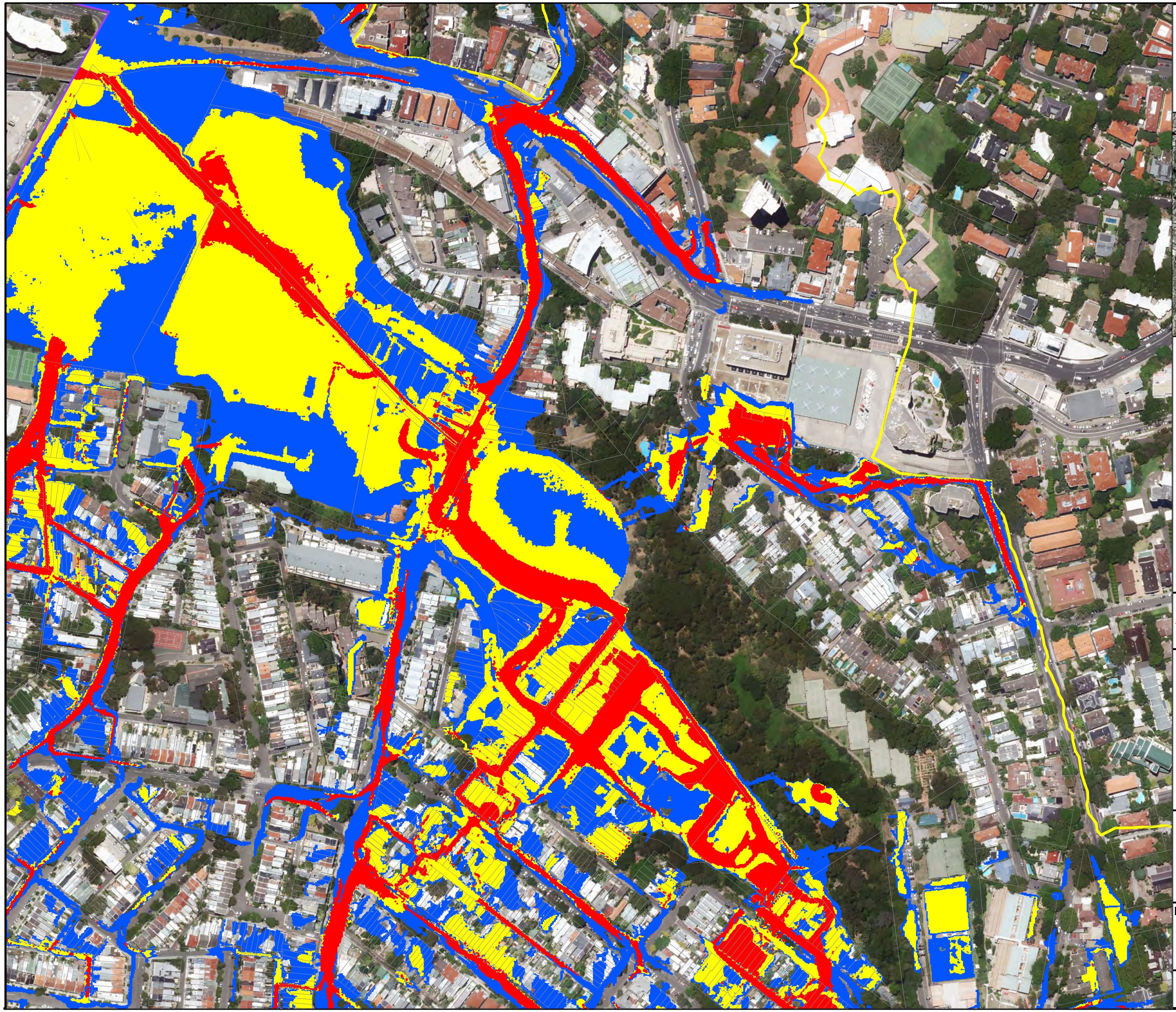
Scale 1:3,000 (at A3)

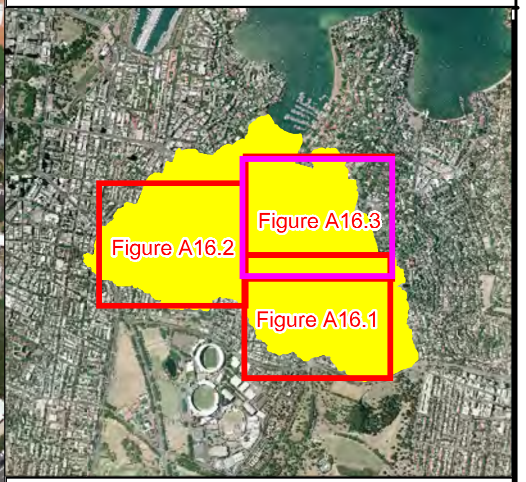
0 0.1 0.2
Km

Figure A16.2: Flood Risk Precincts

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

File Name: FigA16.2 - Existing Flood Risk Precinct.wor



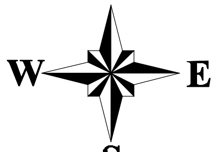


Flood Risk

- Low
- Medium
- High

Notes:

Aerial photograph date: January 2014
Flood Risk only shown within Woollahra Municipal Council LGA



Scale 1:3,000 (at A3)

0 0.1 0.2
Km

Figure A16.3: Flood Risk Precincts

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

File Name: FigA16.3 - Existing Flood Risk Precinct.wor

APPENDIX B

FLOOD DAMAGE CALCULATIONS

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

Sydney Office
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SYDNEY NSW 2000
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(02) 8355 5505
dtetley@csse.com.au

B1 FLOOD DAMAGE COST CALCULATIONS

1.1 Introduction

The Paddington catchment has been impacted by flooding on numerous occasions in the past. The level of impact has ranged from roadways being cut by floodwaters through to yards, garages and dwellings being inundated. This is likely to cause significant inconvenience to those living and working in the study area, but also has the potential to impose significant costs if buildings and contents are inundated.

In an effort to quantify the impact that flooding has on the Paddington catchment, the number of properties subject to over floor flooding and the likely flood damage that would be incurred during the full range of modelled design floods was calculated.

1.2 Building Floor Levels

It is necessary to have information describing the floor height / level of every building within the PMF extent to enable the number of properties subject to above floor flooding to be estimated. The floor levels were defined using either surveyed floor level information or were estimated using a "drive by" survey. The surveyed floor levels were generally extracted from detailed floor level survey collected as part of the *"Rushcutters Bay Floodplain Risk Management Study and Plan"* (WMA Water, 2012). This surveyed data generally only covered properties in the lower catchment (i.e., downstream of Hampden Street). These surveyed floor levels are concentrated in the lower portion of the catchment and represent 158 of the 1824 buildings located within the PMF extent.

Where surveyed floor levels were not available, the floor levels were estimated using the following "drive by" survey process:

1. Google Street View was used to estimate how high the floor level of each building was elevated above the adjoining ground;
2. The ground level at the point where the floor height was estimated was extracted from the available LiDAR data;
3. The floor level was subsequently estimated by adding the floor height (calculated in step 1) to the ground elevation (calculated in step 2).

1.3 Property Database

Subsequent to the definition of building floor levels, a property database was developed as part of the study to enable damage calculations to be prepared across residential, commercial and industrial properties. The database was developed in GIS and included the details of all habitable buildings located within the PMF extent. During the detailed and "drive by" survey described in **Section 1.2**, the following additional information was also included as fields within the database for each building:

- Property type (i.e., residential, commercial or industrial);
- Building floor level;
- Building floor area (gained through automated GIS interrogation);
- Residential building type (i.e., two story, single level high set, single level low set or apartments);
- Number of apartments on each level of residential apartments blocks
- Commercial property contents value (low, medium or high value);

1.4 Flood Level Estimates

The peak design flood levels at the centroid of each building were then determined by comparing the defined floor level against the peak flood level. This allowed the number of buildings subject to above floor flooding during each design flood to be estimated. Additionally, the depth of inundation across each of these buildings could be computed and used to determine the potential over floor flood damage costs for each design flood.

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.

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by waters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with water coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific inundation event. This can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

Due to the difficulty associated with assigning monetary values to intangible damages, only tangible damages were considered as part of this study. Further information on how damages costs were estimated is presented in the following sections.

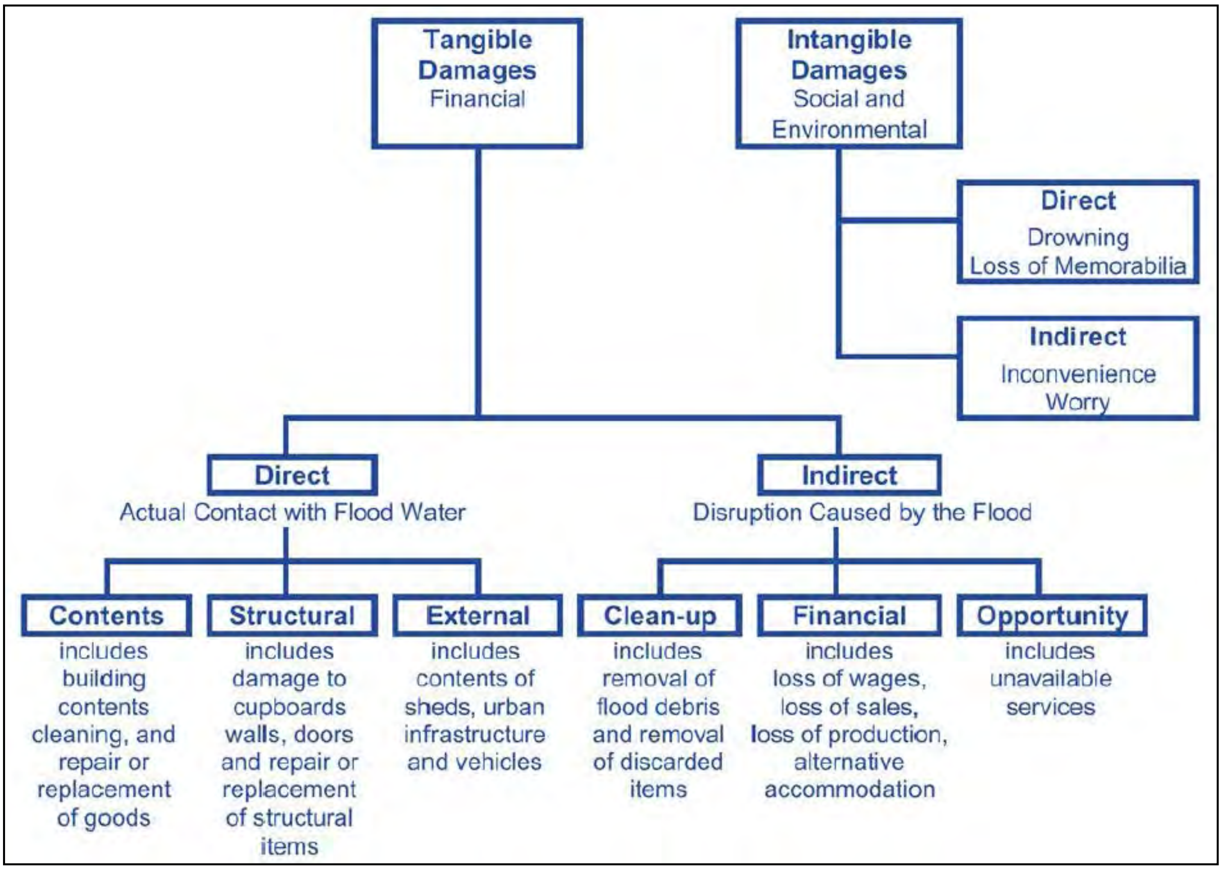


Plate 1 Flood Damage Categories (NSW Government, 2005)

1.5 Flood Damage Calculations

1.5.1 Residential Properties

The NSW Office of Environment and Heritage (OEH) has prepared a spreadsheet that provides a standardised approach for deriving damage curves for residential properties (version 3.00, October 2007). The damage curves describe flood damage costs relative to the depth of flooding above floor level.

The spreadsheet requires a range of parameters to be defined to enable a meaningful damage estimate to be derived. The default parameters that were adopted for the current study are provided on the following page.

It was noted that the resulting depth-damage curves incorporate a damage allowance for 'negative' depths. This is intended to reflect that property damage can be incurred when the water level is below floor level (e.g., damage to fences, garages). The damage curves for 'single storey low set' and 'two storey' properties commence at -0.2 metres, which was considered to be appropriate for the catchment. However, the default 'single storey high set' damage curves commence at -5 metres, which was considered to be too low for the study area.

In order to verify this, single storey high set building floor levels within the PMF extent were compared against the minimum ground elevation within each lot (i.e., the minimum elevation within each lot at which inundation will first occur and, therefore, where damage is likely to commence). This determined that the median difference between the building

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007

PROJECT	DETAILS	DATE	JOB No.
Paddington	Flood Damages Assessment	3/03/2016	

BUILDINGS

Regional Cost Variation Factor	1.00	From Rawlinsons					
Post late 2001 adjustments	2.23	Changes in AWE see AWE Stats Worksheet					
Post Flood Inflation Factor	1.00	1.0	to	1.5			
Multiply overall structural costs by this factor		Judgement to be used. Some suggestions below					
	Regional City			Regional Town			
	Houses Affected		Factor	Houses Affected			Factor
Small scale impact	<	50	1.00	<	10		1.00
Medium scale impacts in Regional City		100	1.20		30		1.30
Large scale impacts in Regional City	>	150	1.40	>	50		1.50
Typical Duration of Immersion	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	100	m^2	240 m^2 is Base				
Building Size Adjustment	0.4						
Total Building Adjustment Factor	**0.79**						

CONTENTS

Average Contents Relevant to Site	$ 47,336	Base for 240 m^2 house	$ 60,000		
Post late 2001 adjustments	2.23	From above			
Contents Damage Repair Limitation Factor	0.75	due to no insurance	short duration		long duration
Sub-Total Adjustment Factor	1.67	Suggested range	0.75	to	0.90
Level of Flood Awareness	low	low or high only. Low default unless otherwise justifiable.			
Effective Warning Time	0	hour			
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor			
Typical Table/Bench Height (TTBH)	0.90	0.9m is typical height. If typical is 2 storey house use 2.6m.			
Total Contents Adjustment Factor AFD <= TTBH	**1.67**	AFD = Above Floor Depth			
Total Contents Adjustment Factor AFD > TTBH	**1.67**				

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	0.9				
Effective Warning time (hours)	**0**	**3**	**6**	**12**	**24**
RAM Average IDRF Inexperienced (Low awareness)	0.90	0.80	0.80	0.80	0.70
DRF (ARF/0.9)	1.00	0.89	0.89	0.89	0.78
RAM AIDF Experienced (High awareness)	0.80	0.80	0.60	0.40	0.40
DRF (ARF/0.9)	0.89	0.89	0.67	0.44	0.44
Site Specific DRF (DRF/0.9) for Awareness level for iteration	1.00	0.89	0.89	0.89	0.78
Effective Warning time (hours)	0	3	0		
Site Specific iterations	1.00	0.89	1.00		

ADDITIONAL FACTORS

Post late 2001 adjustments	2.23	From above
External Damage	$ 6,700	$6,700 recommended without justification
Clean Up Costs	$ 4,000	$4,000 recommended without justification
Likely Time in Alternate Accommodation	0.5	weeks
Additional accommodation costs /Loss of Rent	$ 450	$220 per week recommended without justification

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871		x	AFD in metres
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to			6	m
Single Storey High Set	16586	+	7454		x	AFD
Structure with GST	AFD	greater than	-1.20	m		
Validity Limits	AFD	less than or equal to			6	m
Contents	20000	+	20000		x	AFD
Contents with GST	AFD	greater than			0	
Validity Limits	AFD	less than or equal to			2	

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007

PROJECT	DETAILS	DATE	JOB No.
Paddington	Flood Damages Assessment	3/03/2016	

BUILDINGS

Regional Cost Variation Factor	1.00	From Rawlinsons				
Post late 2001 adjustments	2.23	Changes in AWE see AWE Stats Worksheet				
Post Flood Inflation Factor	1.00	1.0	to	1.5		
Multiply overall structural costs by this factor		Judgement to be used. Some suggestions below				

	Regional City			Regional Town		
	Houses Affected		Factor	Houses Affected		Factor
Small scale impact	<	50	1.00	<	10	1.00
Medium scale impacts in Regional City		100	1.20		30	1.30
Large scale impacts in Regional City	>	150	1.40	>	50	1.50

Typical Duration of Immersion	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	50	m^2	240 m^2 is Base		
Building Size Adjustment	0.2				
Total Building Adjustment Factor	**0.39**				

CONTENTS

Average Contents Relevant to Site	$ 23,668		Base for 240 m^2 house	$ 60,000	
Post late 2001 adjustments	2.23	From above			
Contents Damage Repair Limitation Factor	0.75	due to no insurance	short duration		long duration
Sub-Total Adjustment Factor	1.67	Suggested range	0.75	to	0.90
Level of Flood Awareness	low	low or high only. Low default unless otherwise justifiable.			
Effective Warning Time	0	hour			
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor			
Typical Table/Bench Height (TTBH)	0.90	0.9m is typical height. If typical is 2 storey house use 2.6m.			
Total Contents Adjustment Factor AFD <= TTBH	**1.67**	AFD = Above Floor Depth			
Total Contents Adjustment Factor AFD > TTBH	**1.67**				

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	0.9				
Effective Warning time (hours)	**0**	**3**	**6**	**12**	**24**
RAM Average IDRF Inexperienced (Low awareness)	0.90	0.80	0.80	0.80	0.70
DRF (ARF/0.9)	1.00	0.89	0.89	0.89	0.78
RAM AIDF Experienced (High awareness)	0.80	0.80	0.60	0.40	0.40
DRF (ARF/0.9)	0.89	0.89	0.67	0.44	0.44
Site Specific DRF (DRF/0.9) for Awareness level for iteration	1.00	0.89	0.89	0.89	0.78
Effective Warning time (hours)	0	3	0		
Site Specific iterations	1.00	0.89	1.00		

ADDITIONAL FACTORS

Post late 2001 adjustments	2.23	From above
External Damage	$ 6,700	$6,700 recommended without justification
Clean Up Costs	$ 4,000	$4,000 recommended without justification
Likely Time in Alternate Accommodation	0.5	weeks
Additional accommodation costs /Loss of Rent	$ 450	$220 per week recommended without justification

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves

AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871		x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m			
Validity Limits	AFD	less than or equal to			6	m	
Single Storey High Set	16586	+	7454		x	AFD	
Structure with GST	AFD	greater than	-1.20	m			
Validity Limits	AFD	less than or equal to			6	m	
Contents	20000	+	20000		x	AFD	
Contents with GST	AFD	greater than			0		
Validity Limits	AFD	less than or equal to			2		

floor level and minimum ground level within the corresponding lot was 1.2 metres. Accordingly, the 'single-storey high set' damage curves were adjusted so that damage commenced only when the flood level was less than 1.2 metres below the floor level.

As noted in **Section 1.2**, building floor areas were calculated using an automated GIS interrogation method. The building floor area serves as one of the residential damage curve inputs. The typical floor area for residential buildings within the catchment was reviewed and it was determined that the median floor area was 100 m^2.

The resulting residential depth-damage curves are included on the following page. The residential depth-damage curves include allowances for both direct and indirect cost components.

It is noted that there are a number of apartment buildings located within the catchment. Apartments have the potential to contribute significantly to the flood damage costs. Therefore, the number of apartments located on the lowest habitable level of each apartment building was determined and the total building floor area divided by this number to establish a representative average floor area for apartments within the study area. This was found to be 60 m^2, and this was used to develop separate depth-damage curves for apartment blocks using the same procedure as for traditional residential buildings.

1.5.2 Commercial and Industrial Properties

Unlike residential flood damage calculations, there are no standard curves available for estimating commercial or industrial flood damages in NSW. Commercial buildings located within the study area include, but are not limited to; art galleries, retail, restaurants, cafes, pubs/hotels, offices/public halls, convenience stores/supermarkets and schools. Industrial properties within the study area include warehouses and vehicle repairs premises.

The depth-damage curves used as part of *"Wallsend Floodplain Risk Management Plan – Implementation Works"* (SMEC, 2015) were extracted and used to define commercial and industrial flood damages for the study area. However, the depth-damage curves were updated to 2016 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS) before application to the catchment.

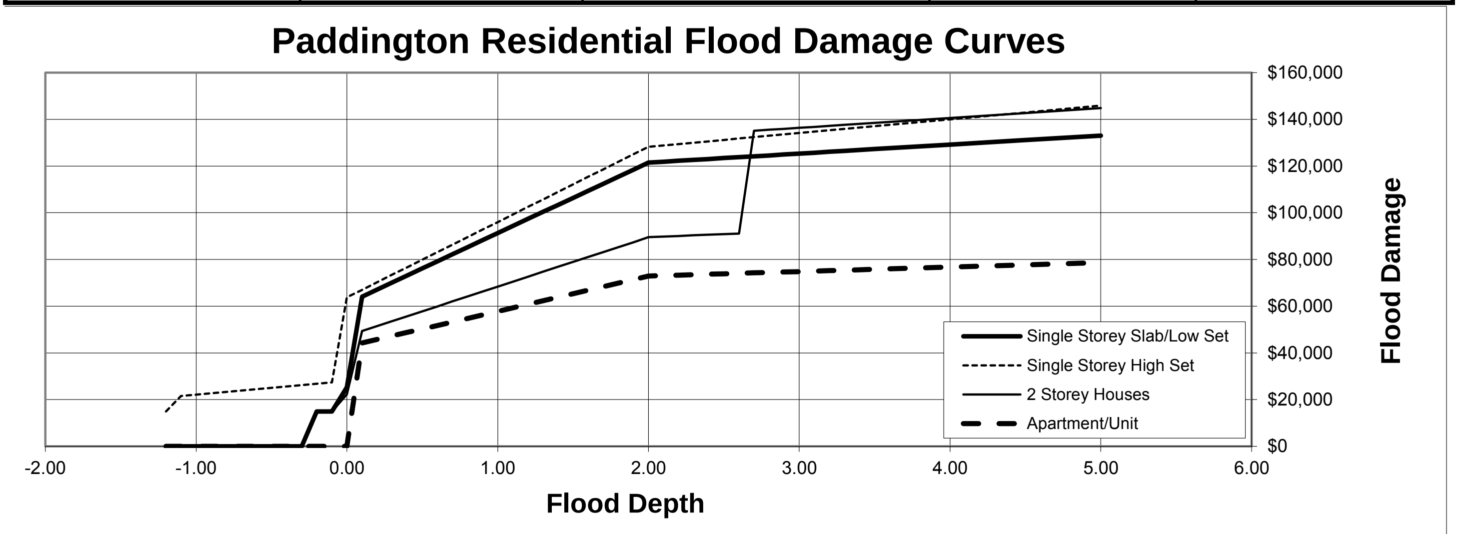
As noted in **Section 1.3**, each commercial and industrial property was classified according to the value of the contents (i.e., low, medium and high damage potential). This is intended to reflect the fact that the damage incurred across commercial and industrial properties is likely to be directly related to the value of its contents. **Table 1** and **Table 2** provide a summary of common commercial and industrial property types and the associated contents.

The resulting damage curves are presented as a per unit area rate for various above floor inundation depths. Accordingly, the damage per square metre is multiplied by the floor area of the premises to estimate the expected damage during a particular flood event. The adopted commercial/Industrial depth-damage curves are presented on the following page.

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve 0.1 m

	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses	Apartment/Unit
Type	1	2	3	4
AFD from Modelling	Damage	Damage	Damage	Damage
-5.00	$0	$0	$0	$0
-1.20	$14,925	$0	$0	$0
-1.10	$21,541	$0	$0	$0
-1.00	$22,130	$0	$0	$0
-0.90	$22,718	$0	$0	$0
-0.80	$23,306	$0	$0	$0
-0.70	$23,894	$0	$0	$0
-0.60	$24,482	$0	$0	$0
-0.50	$25,070	$0	$0	$0
-0.40	$25,658	$0	$0	$0
-0.30	$26,246	$0	$0	$0
-0.20	$26,834	$14,925	$14,925	$0
-0.10	$27,422	$14,925	$14,925	$0
0.00	$63,783	$25,310	$22,195	$0
0.10	$67,007	$64,103	$49,350	$44,220
0.20	$70,231	$67,124	$51,464	$45,730
0.30	$73,455	$70,144	$53,578	$47,240
0.40	$76,679	$73,165	$55,693	$48,750
0.50	$79,904	$76,185	$57,807	$50,261
0.60	$83,128	$79,205	$59,921	$51,771
0.70	$86,352	$82,226	$62,035	$53,281
0.80	$89,576	$85,246	$64,150	$54,791
0.90	$92,800	$88,267	$66,264	$56,301
1.00	$96,024	$91,287	$68,378	$57,812
1.10	$99,249	$94,307	$70,493	$59,322
1.20	$102,473	$97,328	$72,607	$60,832
1.30	$105,697	$100,348	$74,721	$62,342
1.40	$108,921	$103,369	$76,835	$63,852
1.50	$112,145	$106,389	$78,950	$65,363
1.60	$115,370	$109,409	$81,064	$66,873
1.70	$118,594	$112,430	$83,178	$68,383
1.80	$121,818	$115,450	$85,293	$69,893
1.90	$125,042	$118,471	$87,407	$71,403
2.00	$128,266	$121,491	$89,521	$72,914
2.10	$128,854	$121,875	$89,790	$73,106
2.20	$129,442	$122,260	$90,059	$73,298
2.30	$130,030	$122,644	$90,328	$73,490
2.40	$130,618	$123,028	$90,597	$73,682
2.50	$131,206	$123,412	$90,866	$73,874
2.60	$131,794	$123,797	$91,135	$74,067
2.70	$132,382	$124,181	$135,107	$74,259
2.80	$132,971	$124,565	$135,529	$74,451
2.90	$133,559	$124,950	$135,952	$74,643
3.00	$134,147	$125,334	$136,375	$74,835
3.10	$134,735	$125,718	$136,797	$75,027
3.20	$135,323	$126,102	$137,220	$75,219
3.30	$135,911	$126,487	$137,643	$75,411
3.50	$137,087	$127,255	$138,488	$75,796
4.00	$140,027	$129,177	$140,602	$76,756
4.50	$142,967	$131,098	$142,715	$77,717
5.00	$145,907	$133,019	$144,829	$78,678



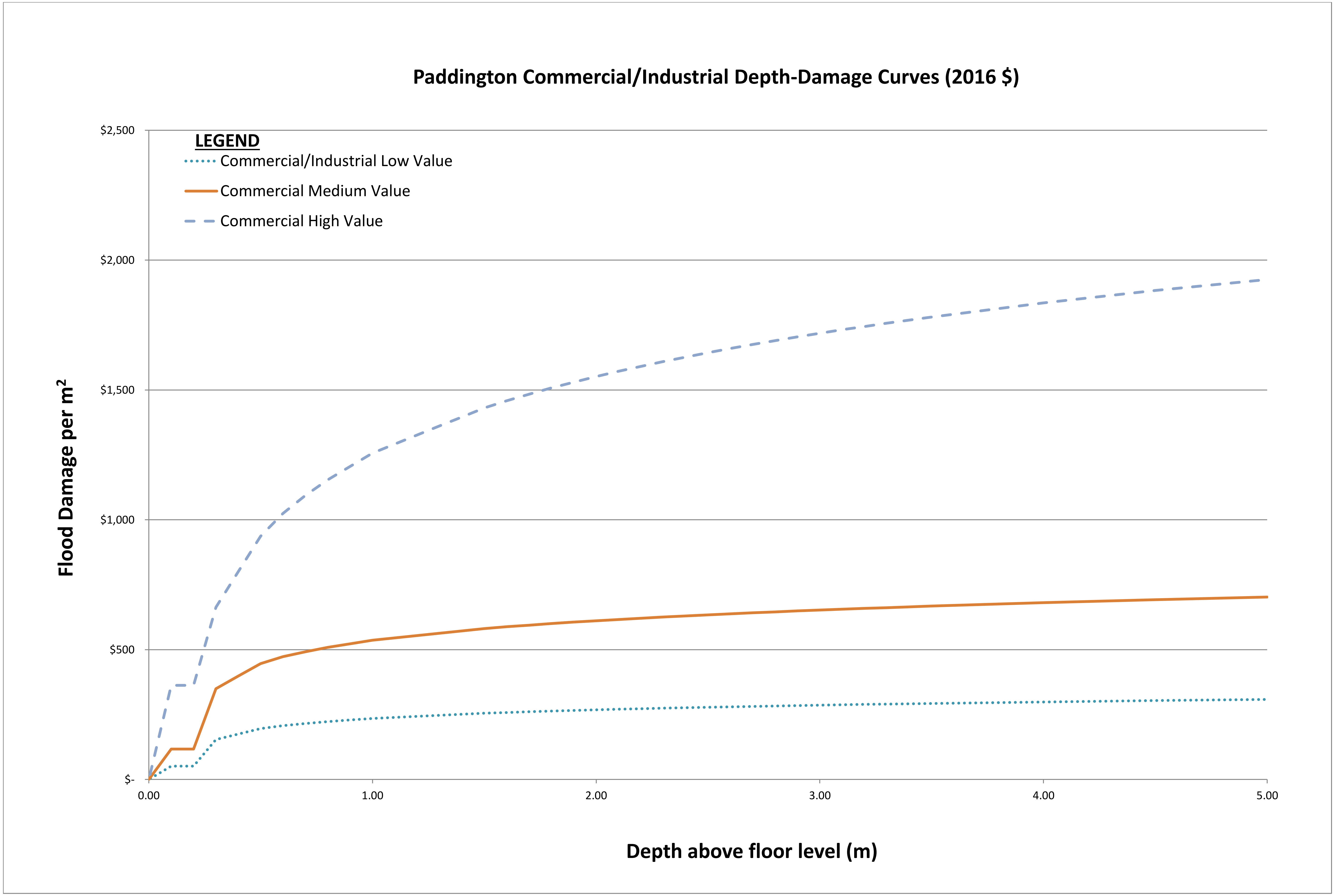

Paddington Commercial/Industrial Depth-Damage Curves (2016 $)
LEGEND
Commercial/Industrial Low Value
Commercial Medium Value
Commercial High Value
Flood Damage per m2
$2,500
$2,000
$1,500
$1,000
$500
$-
0.00
1.00
2.00
3.00
4.00
5.00
Depth above floor level (m)

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
Laundrettes	Dry cleaners	Sporting goods
Public halls	Professions (e.g., solicitors)	Furniture
	Small hardware	DVD rental
	Small retail	Kitchenware
		Restaurants
		Schools

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		

No specific allowance is included in the commercial/industrial damage curves for indirect losses, such as clean-up costs and loss of income while clean-up occurs. Therefore, indirect damage costs were estimated as 25% of the direct flood damages, and this was added to the base damage curves.

1.5.3 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, electricity and telephone. Infrastructure damage has not been calculated as part of the damagers assessment.

1.5.4 Potential versus Actual Damages

The residential, commercial and industrial damage calculations outlined above assume that no actions are taken by residents and business owners to reduce the potential damage. However, if some warning is provided of the impending flood, there may be sufficient time for residents and business owners to undertake actions to reduce the potential damage costs incurred during a flood. For example, residents and business owners could potentially 'sandbag' properties to prevent the ingress of floodwaters, relocate vehicles to high ground and/or elevate electrical devices above the anticipated peak flood level.

However, as the critical duration for the catchment is short (typically less than 2 hours), it was considered that negligible time would be available for residents to reduce the damage potential (particularly if the flood occurs at night or when residents are at work). As a result, no damage reduction factors were applied to covert "potential" damages to "actual" damages.

1.6 Summary of Inundation Costs

1.6.1 Damage Costs

Flood damages were calculated using the flood level surfaces for each design flood in conjunction with the appropriate depth-damage curves and floor levels for each building. The individual property damage estimates were subsequently summed with calculated infrastructure damage to calculate the total flood damages for each design event. The total damage costs for the modelled flood events is summarised in **Table 3**. The number of buildings from the various categories in which are incurring flood damages for each modelled design event are presented in **Table 4**. In general, damage to residential property is the primary contributor to the total damage bill for each event.

1.6.2 Average Annual Damages

The total flood damages for each flood event were plotted on a chart against the probability of each flood occurring (i.e., AEP). The chart was then used as the basis for calculating the average annual damages (AAD) for the study area for existing conditions. The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe.

The AAD for the study area, for existing conditions is calculated as being $5.9 million.

Table 3 Flood Damages

Flood Event	**Flood Damages** ($ millions)		
	Residential	**Commercial/ Industrial**	**Total Damages**
1EY	1.96	0.15	2.11
20% AEP	6.18	0.79	6.97
10% AEP	7.71	0.83	8.54
5% AEP	9.48	0.90	10.38
1% AEP	12.60	1.18	13.77
PMF	37.70	7.82	45.52

Table 4 Number of Properties with Above Floor Inundation

Flood Event	Number of buildings with Above Flood Inundation		
	Residential	Commercial/ Industrial	Total Number
1EY	26	0	26
20% AEP	94	1	95
10% AEP	121	2	123
5% AEP	145	2	147
1% AEP	185	5	190
PMF	502	9	511

1.7 Limitations of Inundation 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.

C1 References

1. WMA Water (2012). *Rushcutters Bay Floodplain Risk Management Study and Plan*. Prepared for Woollahra Municipal Council.
2. SMEC (2015). *Wallsend Floodplain Risk Management Plan – Implementation Works*. Hydrologic and Hydraulic Investigations, Structural and Building Analysis, Property Acquisition and Implementation Strategy. Prepared for The City of Newcastle.

APPENDIX C

COST ESTIMATES

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
Trumper Park Floodway

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different flood management options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

NOTE: This cost estimate assumes that the Cecil St Floodway is constructed prior

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$40,000**
	1.01	Site Establishment (allowance only)	Lump sum		10,000	$10,000
	1.02	Erosion and Sediment Control (allowance only)	Lump sum		10,000	$10,000
	1.03	Relocate Services (allowance only)	Lump sum		20,000	$20,000
2		**Floodway & associated Earthworks**				**$94,420**
	2.01	Remove Trees (<500mm girth)	Item	40	154	$6,160
	2.02	Clearing site of medium vegetation	m^2	500	1.00	$500
	2.03	Excavation of floodway (clay, 1.5m deep)	m^3	70	130	$9,100
	2.04	Retaining walls for sides of floodway (Brickwork. 230mm thick)	m^2	80	244	$19,520
	2.05	Reinforced concrete for base of floodway	m^2	120	312	$37,440
	2.06	Disposal of fill (low level contaminated) to approved land fill	m^3	70	310	$21,700
3		**Landscaping**				**$7,245**
	3.01	Turf, laid, rolled & watered for 2 weeks	m^2	828	8.75	$7,245
					SUBTOTAL	**$141,665**
4		**ENGINEERING DESIGN**				
	4.01	Preparation of engineering design plans				**$25,000**
5		**PROJECT MANAGEMENT**				
	5.01	Supervision, Project Management etc (25%)				**$35,416**
6		**OTHER CONTINGENCIES**				
	6.01	General (25%)				**$35,416**
					TOTAL (Rounded to nearest $10,000)	**$240,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Harris Street Stormwater Improvements

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different flood management options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$10,000**
	1.01	Site Establishment (allowance only)	Lump sum		5,000	$5,000
	1.02	Erosion and Sediment Control (allowance only)	Lump sum		5,000	$5,000
2		**Pipe Tunnel Coring**				**$170,000**
	2.01	Tunnel Coring and lining (0.9m diameter) including site establishment costs, microtunnelling, insertion of jacking pipe and connections	m	20	8,000	$160,000
	2.02	Reconfiguration of pits on Harris Street (excavation of existing, installation of new pit and connection to pipe tunnel -excavation of pits in confined spaces - soft rock)	Lump sum	1	10,000	$10,000
3		**Culvert Enclosure**				**$8,909**
	3.01	Enclosing existing channel at rear of 8 Hampden St (concrete 'roof' installed on existing box channel) - suspended slab < 150mm thick	m3	4	308	$1,109
	3.02	Reconfiguration of downstream end of enclosed channel (Tie into existing terrain) excavation in soft rock	m3	20	70	$1,400
	3.03	Retaining walls at downstream of enclosed channel along northern boundary of 8 Hampden St (0.5m High by 40 metres) (Keystone wall, core filling, up to 1m high)	m^2	20	320	$6,400
					SUBTOTAL	**$188,909**
6		**OTHER CONTINGENCIES**				
	6.01	General (10%)				**$18,891**
					TOTAL (Rounded to nearest $10,000)	**$210,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
Hopetoun Street Roadworks

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different flood management options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.02	Traffic/Pedestrian Management Plan	Lump sum	1	10,000	$10,000
2		**REGRADING**				**$12,238**
	2.01	Road regrading/reprofiling on intersection of Hopetoun Lane and Paddington Street	m2	175	59	$10,238
	2.02	Kerb and Gutter modification (inlet on Paddington St/outlet on Cascade St) - cast in-situ concrete 250x150mm kerb and gutter	m	10	118	$1,180
	2.03	Installation of dish drain	m	4	205	$820
					SUBTOTAL	**$23,238**
3		**ENGINEERING DESIGN**				
	3.01	Preparation of engineering design plans				**$5,000**
4		**PROJECT MANAGEMENT**				
	4.01	Supervision, Project Management etc (20%)				**$4,648**
5		**OTHER CONTINGENCIES**				
	5.01	General (25%)				**$5,809**
			TOTAL (Rounded to nearest $10,000)			**$40,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Glenmore Road Roadworks

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different flood management options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,000**
	1.01	Site Establishment (allowance only)	Lump sum		1,000	$1,000
	1.02	Traffic/Pedestrian Management Plan	Lump sum	1	4,000	$10,000
2		**EARTHWORKS**				**$6,698**
	2.01	Disasemble/reassemble fencing and signage around site (assume 2 person, Group 3 Labourer)	hours	10	150	$1,500
	2.02	Excavate roadway, kerb, footpath and ground to transition from roadway into drainage channel (Excavate <1m deep in hard rock)	m3	17	315	$5,198
3		**ROAD WORKS**				**$10,394**
	3.01	Reprofiling and resurface Western side of Glenmore Road to match new transition into drainage channel (night work)	m2	87	58.50	$5,090
	3.02	Lay reinforced concrete slab adjacent Glenmore Road to drainage channel (150mm thick slab on fill, including placement)	m2	17	312.00	$5,304
					SUBTOTAL	**$28,091**
4		**ENGINEERING DESIGN**				
	4.01	Preparation of engineering design plans				**$6,000**
5		**PROJECT MANAGEMENT**				
	5.01	Supervision, Project Management etc (20%)				**$5,618**
6		**OTHER CONTINGENCIES**				
	6.01	General (25%)				**$7,023**
					TOTAL (Rounded to nearest $10,000)	**$50,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
Stormwater Upgrades

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Tara Street Stormwater Upgrades

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$44,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
	1.02	Traffic/Pedestrian Management Plan	Lump sum	1	10,000	$10,000
	1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
	1.04	Services Investigation	Lump sum	1	20,000	$20,000
2		**EARTHWORKS**				**$12,720**
	2.01	Excavate roadway, base and ground for coring machine access point (3 access points) including backfilling (excavate pits 1-2m deep in soft rock)	m3	36.00	210	$7,560
	2.02	Extract existing pipe and dispose (recyclable material)	m	8.00	15	$120
	2.03	Reconfiguration of 2 pits on Ocean St and 1 on Tara Street (excavation in soft rock of existing pit, installation of new pit and connection to pipe tunnel)	m3	24	210	$5,040
3		**PIPE TUNNEL CORING**				**$1,033,200**
	3.01	Tunnel Coring under properties and lining (0.75m diameter) including site establishment costs, microtunnelling, insertion of jacking pipe and connections	m	129	8,000	$1,033,200
4		**DRAINAGE INFRASTRUCTURE**				**$8,370**
		Stormwater Inlets/pits				
	4.01	Kerb inlet with grate & 3m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	3	2,790	$8,370
5		**ROAD WORKS**				**$245**
	5.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering coring machine access point and/or excavated trench	m2	8	30.60	$245
					SUBTOTAL	**$1,098,535**
6		**ENGINEERING DESIGN**				**$40,000**
	6.01	Preparation of engineering design plans				$40,000
7		**PROJECT MANAGEMENT**				**$70,000**
	7.01	Supervision, Project Management etc				$70,000
8		**OTHER CONTINGENCIES**				**$439,414**
	8.01	General (40%)				$439,414
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$1,650,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Stormwater Upgrades

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Forbes Street to Harris Street Stormwater Upgrades

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$384,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
	1.02	Traffic/Pedestrian Management Plan and Control	Lump sum	1	70,000	$70,000
	1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
	1.04	Services Relocation	Lump sum	1	300,000	$300,000
2		**EARTHWORKS**				**$574,185**
	2.02	Excavate roadway, base and ground above pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench 1-2m deep in soft rock)	m3	2700	210	$566,940
	2.03	Extract existing pipe and dispose (recyclable material)	m	303	15	$4,545
	2.04	Labour to install 3 new pits on Harris St and 3 new pits on Sutherland Ave (installation and connection to pipe / cored tunnel - 3 hour allowance / 2 person, Group 3 Labourer)	each	6	450	$2,700
4		**DRAINAGE INFRASTRUCTURE**				**$213,516**
		Circular Pipes				
	4.03	0.6m RCP (Class 2)	m	10	205	$2,050
	4.03	0.9m RCP (Class 2)	m	426	466	$198,516
		Stormwater Inlets/pits				
	4.05	Kerb inlet with grate & 1.8m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	3	2,190	$6,570
	4.06	Kerb inlet with grate & 2.4m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	2	2,390	$4,780
	4.07	1.2m square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	1	1,600	$1,600
5		**ROAD WORKS**				**$5,764**
	5.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering excavated trench	m2	188	30.60	$5,764
					SUBTOTAL	**$1,177,464**
6		**ENGINEERING DESIGN**				**$50,000**
	6.01	Preparation of engineering design plans				$50,000
7		**PROJECT MANAGEMENT**				**$110,000**
	7.01	Supervision, Project Management etc				$110,000
8		**OTHER CONTINGENCIES**				**$470,986**
	8.01	General (40%)				$470,986
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$1,810,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
Stormwater Upgrades

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

George St to Cascade Street Stormwater Upgrades - Option A

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$74,000**
1.01	Site Establishment (allowance only)	Lump sum	1	10000	$10,000
1.02	Traffic/Pedestrian Management Plan	Lump sum	1	10000	$10,000
1.03	OHS&R Plan	Lump sum	1	4000	$4,000
1.04	Services Investigation	Lump sum	1	50000	$50,000
2	**EARTHWORKS**				**$148,020**
2.01	Excavate roadway, base and ground for coring machine access point (9 access points) including backfilling	m3	108	210	$22,680
2.02	Excavate roadway, base and ground above pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench 1-2m deep in sift rock)	m3	570	210	$119,700
2.03	Services Investigation	m	92	15	$1,380
2.04	Reconfiguration of 2 pits on Victoria St (excavation in soft rock of existing pit, installation of new pit and connection to pipe tunnel)	m3	16	210	$3,360
2.05	Labour to install 2 new pits on Underwood St (installation and connection to pipe / cored tunnel - 3 hour allowance / 2 person, Group 3 Labourer)	each	2	450	$900
3	**PIPE TUNNEL CORING**				**$4,017,000**
3.01	Tunnel Coring under properties and lining (0.45m diameter) including site establishment costs, microtunnelling, insertion of jacking pipe and connections	m	74	7000	$518,000
3.02	Tunnel Coring under properties and lining (0.6m diameter) including site establishment costs, microtunnelling, insertion of jacking pipe and connections	m	74	7500	$555,000
3.03	Tunnel Coring under properties and lining (0.75m diameter) including site establishment costs, microtunnelling, insertion of jacking pipe and connections	m	53	8000	$424,000
3.04	Tunnel Coring under properties and lining (1.65m diameter) including site establishment costs, microtunnelling, insertion of jacking pipe and connections	m	252	10000	$2,520,000
4	**DRAINAGE INFRASTRUCTURE**				**$47,467**
	Circular Pipes				
4.01	0.3m RCP (Class 2)	m	12	128	$1,536
4.02	0.375m RCP (Class 2)	m	45	145	$6,525
4.03	0.45m RCP (Class 2)	m	16	166	$2,656
4.04	0.9m RCP (Class 2)	m	19	550	$10,450
	Stormwater Inlets/pits		0	0	
4.05	Kerb inlet with grate & 2.4m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	4	2390	$9,560
4.06	Kerb inlet with grate & 3m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	6	2790	$16,740
5	**ROAD WORKS**				**$2,448**
5.01	Stormwater Inlets/pits	m2	80	30.6	$2,448
				SUBTOTAL	**$4,288,935**
6	**ENGINEERING DESIGN**				**$428,894**
6.01	Preparation of engineering design plans (10%)				$428,894
7	**PROJECT MANAGEMENT**				**$857,787**
7.01	Supervision, Project Management etc (20%)				$857,787
8	**OTHER CONTINGENCIES**				**$1,715,574**
8.01	General (40%)				$1,715,574
				TOTAL at 7% NPV (Rounded to nearest $10,000)	**$7,290,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Stormwater Upgrades	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

George St to Cascade Street Stormwater Upgrades - Option B

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$74,000**
1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
1.02	Traffic/Pedestrian Management Plan	Lump sum	1	10,000	$10,000
1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
1.04	Services Investigation	Lump sum	1	50,000	$50,000
2	**EARTHWORKS**				**$9,575,277**
2.02	Excavate roadway, base and ground above pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench 1-2m deep in soft rock)	m3	45545	210	$9,564,477
2.05	Labour to install 24 new/upgraded pit housings (installation and connection to pipe - 3 hour allowance / 2 person, Group 3 Labourer)	each	24	450	$10,800
4	**DRAINAGE INFRASTRUCTURE**				**$801,349**
	Circular Pipes				
4.01	0.375m RCP (Class 2) (Underwood St)	m	16	145	$2,320
4.02	0.45m RCP (Class 2) (George St, Elizabeth Pl, Elizabeth St, Victoria St)	m	45	166	$7,503
4.03	0.525m RCP (Class 2) (Elizabeth Pl)	m	206	185	$38,110
4.04	0.6m RCP (Class 2) (Victoria Pl)	m	90	205	$18,471
4.05	0.75m RCP (Class 2) (George St, Elizabeth St, Dudley St, Victoria St)	m	484	344	$166,565
4.06	0.9m RCP (Class 2) (Elizabeth St)	m	29	588	$17,228
4.07	1.2m RCP (Class 2) (Underwood St)	m	122	711	$86,742
4.08	1.5m RCP (Class 2) (UnderwoodSt)	m	87	1,050	$91,350
4.09	2.1m RCP (Class 2) (William Ln)	m	66	1,450	$95,700
4.1	2.4m RCP (Class 2) (William St)	m	118	1,800	$212,400
	Stormwater Inlets/pits				
4.05	Kerb inlet with grate & 2.4m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square) (1 x George St, 1 x Elizabeth Pl, 1 x Underwood St, 1 x Ashton Ln)	No.	5	2,390	$11,950
4.06	Kerb inlet with grate & 3m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square) (1 x Underwood St, 2 x Victoria St, 1 x Dudley St, 1 x Elizabeth St, 1 x Ashton ln)	No.	19	2,790	$53,010
5	**ROAD WORKS**				**$696,840**
5.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering or excavated trenches	m2	22773	30.60	$696,840
				SUBTOTAL	**$11,147,467**
6	**ENGINEERING DESIGN**				**$70,000**
6.01	Preparation of engineering design plans				$70,000
7	**PROJECT MANAGEMENT**				**$200,000**
7.01	Supervision, Project Management etc				$200,000
8	**OTHER CONTINGENCIES**				**$557,373**
8.01	General (5%)				$557,373
				TOTAL at 7% NPV (Rounded to nearest $10,000)	**$11,970,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
Stormwater Upgrades

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Hopetoun Lane Stormwater Upgrades

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$74,000**
1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
1.02	Traffic/Pedestrian Management Plan	Lump sum	1	10,000	$10,000
1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
1.04	Services Investigation	Lump sum	1	50,000	$50,000
2	**EARTHWORKS**				**$510,545**
2.01	Excavate roadway, base and ground above pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench 1-2m deep in soft rock)	m3	2410	210	$506,150
2.02	Extract existing pipe and dispose (recyclable material)	m	173	15	$2,595
2.03	Labour to install 4 new pits on Hopetoun Lane (installation and connection to pipe / cored tunnel - 3 hour allowance / 2 person, Group 3 Labourer)	Lump sum	4	450	$1,800
3	**DRAINAGE INFRASTRUCTURE**				**$107,247**
	Circular Pipes				
3.01	0.375m RCP (Class 2)	m	22	145	$3,190
3.02	0.525m RCP (Class 2)	m	57	205	$11,685
3.03	0.6m RCP (Class 2)	m	18	674	$12,132
3.04	0.9m RCP (Class 2)	m	40	588	$23,520
3.05	1.05m RCP (Class 2)	m	2	680	$1,360
3.06	1.95m RCP (Class 2)	m	34	1,300	$44,200
	Stormwater Inlets/pits				
3.07	Kerb inlet with grate & 3m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	4	2,790	$11,160
4	**ROAD WORKS**				**$198**
4.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering coring machine access point and/or excavated trench	m2	6	30.60	$198
				SUBTOTAL	**$691,990**
5	**ENGINEERING DESIGN**				**$50,000**
5.01	Preparation of engineering design plans				$50,000
6	**PROJECT MANAGEMENT**				**$60,000**
6.01	Supervision, Project Management etc				$60,000
7	**OTHER CONTINGENCIES**				**$276,796**
7.01	General (40%)				$276,796
				TOTAL at 7% NPV (Rounded to nearest $10,000)	**$1,080,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Stormwater Upgrades	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared. Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Elizabeth Place Underground Storage

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$9,474,000**
1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
1.02	Traffic/Pedestrian Management Plan	Lump sum	1	5,000	$5,000
1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
1.04	Services Relocation	Lump sum	1	80,000	$80,000
1.05	Property/Easement Purchase Cost (Broad estimate based on previous Council experience)	m2	500	18,600	$9,300,000
1.06	Legal fees for land acquisition and subdivision	Lump sum	5	15,000	$75,000
2	**EARTHWORKS**				**$296,818**
2.02	Excavate roadway, base and ground above pipe (including backfilling/compaction) (trench of 1.2 x pipe width) (Excavate trench 1-2m deep in soft rock)	m3	223	210	$46,812
2.02	Excavate underground storage area (4.5m deep x 20m x 25m) for basement or similar in hard rock	m3	2263	110.5	$250,006
4	**DRAINAGE INFRASTRUCTURE**				**$1,560,804**
	"Rainvault" Stormwater harvesting and reuse system (includes filter and pump kit)	m3	2250	660	$1,485,000
	Labour to install Rainvault and connections to stormwater system - 80 hour allowance / 4 person, Group 3 Labourer	Lump sum	320	86	$27,520
	Circular Pipes				
4.02	0.45m RCP (Class 2)	m	10	166	$1,726
4.05	0.75m RCP (Class 2)	m	67	344	$23,048
	Stormwater Inlets/pits				
4.05	Kerb inlet with grate & 2.4m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	4	2,390	$9,560
4.06	Kerb inlet with grate & 3m lintel - includes 900mm square precast concrete pit and Class D cast iron gully grating (600mm square)	No.	5	2,790	$13,950
5	**ROAD WORKS**				**$3,411**
5.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering excavated trench	m2	111	30.60	$3,411
6	**Landscaping**				**$10,375**
6.01	Turf, laid, rolled & watered for 2 weeks	m^2	500	8.75	$4,375
6.02	Planting of appropriate vegetation (allowance)	Lump sum	1	6,000	$6,000
				SUBTOTAL	**$11,335,033**
6	**ENGINEERING DESIGN**				**$50,000**
6.01	Preparation of engineering design plans				$50,000
7	**PROJECT MANAGEMENT**				**$200,000**
7.01	Supervision, Project Management etc				$200,000
8	**OTHER CONTINGENCIES**				**$1,133,503**
8.01	General (10%)				$1,133,503
		TOTAL at 7% NPV (Rounded to nearest $10,000)			**$12,720,000**

APPENDIX D

FLOOD PLANNING LEVEL

Catchment Simulation Solutions

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D1 FLOOD PLANNING LEVEL

Flood Planning Levels (FPLs) are an important tool in the management of flood risk. FPLs are typically derived by adding a freeboard to the "planning" flood. The FPL 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.

A major consideration of this study involved the determination of an appropriate flood planning level for Paddington. Therefore, a review of the suitability of the current standard outlined in the Woollahra LEP 2014 LEP was completed as part of the current study.

The NSW Floodplain Development Manual (2015) states that "…FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific ARIs) and freeboards selected for floodplain risk management purposes, as determined in risk management studies and incorporated in risk management plans." The Manual also notes that it is generally not feasible or justifiable to adopt the PMF as the planning flood.

As noted above, the Woollahra LEP 2014 LEP defines the flood planning level (FPL) across the Woollahra LGA as "the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard". This wording is taken from the standard LEP template for NSW and effectively applies a "one size fits all" approach for defining the flood planning level across the LGA. This approach fails to consider the variable flood characteristics that are evident across the LGA (including Paddington) and does not follow the merits based approach that is encouraged in the 'Floodplain Development Manual' (NSW Government, 2015). More specifically, the Manual advocates consideration of the risk to life across the full range of floods, social issues, land availability/needs, duration of flooding, the value of land, existing level of development and the current FPL for planning purposes.

Using the 1% AEP flood for deriving flood planning levels is common across Australia. It is considered to provide a reasonable compromise between the risk associated with occupation of flood liable areas and the value that this occupation provides. There is no obvious reason for deviating from adoption of the 1% AEP flood for defining flood planning levels for Paddington.

However, there is a case to support adopting a freeboard that is lower than 0.5 metres. The freeboard is, in essence, a "factor of safety" that is used to cater for uncertainties in the estimation of the planning flood (1% AEP event). The uncertainties that are accounted for in in the freeboard include:

- Modelling uncertainty (i.e., uncertainty associated with modelling inputs such as Manning's "n" roughness and blockage of stormwater pits):
- Factors that can't be explicitly represented in the modelling (e.g., parked cars, flow obstructions from debris mobilised during a flood: refer **Plate D1**).
- Changes in future flood behaviour associated with climate change (e.g., increases in rainfall intensity and sea level rise).

Plate D1 Examples of urban flow obstructions that cannot be explicitly represented in computer model

Modelling and climate change uncertainty can be quantified by undertaking various sensitivity and climate change simulations and using the outputs from these simulations to prepare a "confidence limit" layer. This "confidence limit" layer effectively quantifies how much confidence we can place in the "base" 1% AEP flood levels at various locations and therefore, how much of an allowance needs to be incorporated within the freeboard to ensure we can cater for this uncertainty. In order to reliably define confidence limits to the

1% AEP results, it would be necessary to undertake thousands (potentially tens of thousands) of simulations to reflect the numerous combinations/permutations of potential parameter estimates and provide a sufficiently large population to enable meaningful statistical analysis. Unfortunately, the long simulation times only permit a limited number of parameter scenarios to be investigated. For this study, additional simulations were completed with complete & no blockage, climate change with 10%, 20% and 30% increases in rainfall and changes to Manning's "n" roughness.

In instances where a sufficiently large "population" of results is not available, it is still possible to derive confidence limits using the Student's t-test (Zhang, 2013). This approach involves interrogating peak flood level estimates from all 1% AEP simulations at each TUFLOW grid cell. This information is used to calculate a mean water level and standard deviation at each grid cell. This information can then be combined with the population size (i.e., number of different 1% AEP simulations) to develop 99% confidence limit estimates at each TUFLOW grid cell.

The resulting "99% Confidence Limit" grid is shown in **Plate D2**. Green colours indicate small confidence limits (i.e., high confidence in results) and red colours indicate higher confidence limits (i.e., less confidence in results). **Plate D2** shows that across the upper catchment, the model confidence is generally high (i.e., less than 0.10 metres). The uncertainty increases to over 0.5 metres in areas downstream of Glenmore Road. The higher levels of uncertainty across the downstream sections of the catchment are primarily driven by the significant impacts that blockage of the New South Head Road culverts has on flood behaviour across this area.

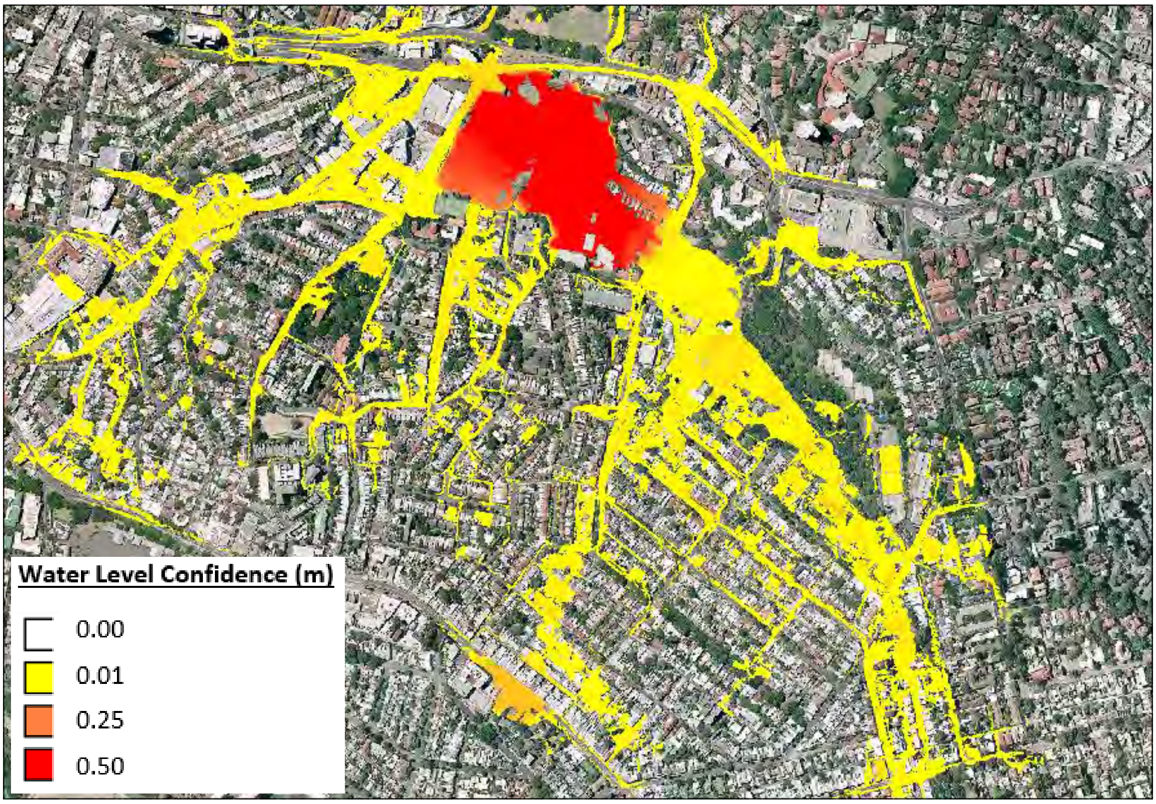


Plate D2 99% confidence interval grid for 1% AEP water levels (defines model and climate change uncertainty)

Unfortunately, it is more difficult to quantify an allowance for factors that cannot be explicitly represented by the model (refer **Plate D1**). However, it is argued that the potential impact of these "other" factors is proportional to the flow velocity. That is, there is a greater potential for a flow obstruction to alter flood behaviour in areas of faster moving water relative to areas of ponded water. Therefore, a greater allowance should be made for "other" factors in areas of fast moving water.

The impacts of flow obstructions that are commonly encountered in flood modelling (e.g., bridge deck/piers) is quantified by multiplying an empirical loss coefficient (K) by the velocity head ($v^2/2g$) at a particular location. The velocity head can be calculated at any location using the computer model outputs for the 1% AEP flood. The appropriate loss coefficient will vary depending on the location and the type of obstruction. Unfortunately, loss coefficients are not readily documented for the types of flow obstructions typically encountered in an urban environment. Furthermore, Franz and Melching (1997) note that flow through an abrupt transition is a complex phenomenon and evaluation of hydraulic losses is difficult. It also notes that the adoption of a loss coefficient / velocity head to calculate hydraulic losses is an approximation but no suitable replacement/alternative is readily available. Therefore, this approach was pursued.

The *'HEC-RAS River Analysis System - Hydraulic Reference Manual'* (US Army Corp of Engineers, 2016) notes that loss coefficients will not exceed 1.0 and will generally be higher for subcritical flows than supercritical flows. It goes on to note that:

- A contraction/expansion coefficient of 0.8 is generally appropriate for "abrupt" transitions in cross-sectional area where subcritical flow is evident.
- A contraction/expansion coefficient of 0.2 is generally appropriate for "abrupt" transitions in cross-sectional area where supercritical flow is evident.

It was considered that the types of flow obstructions shown in **Plate D1** would represent an "abrupt" change in flow conveyance so were considered appropriate to use to assist in quantifying the potential uncertainty in flood level estimates associated with these "other" factors. The following steps were subsequently employed for developing a layer describing the potential variation in 1% AEP water levels associated with other factors.

- Calculate the 1% AEP Froude number and velocity head at each model grid cell;
- If the Froude number is greater than 1 (i.e., supercritical flow), multiply the velocity head by a loss coefficient of 0.2
- If the Froude number is less than 1 (i.e., subcritical flow), multiply the velocity head by a loss coefficient of 0.8

However, the above approach did introduce some notable discontinuities in areas that transitioned between supercritical and subcritical flow. Therefore, the approach was refined so that the loss coefficient was gradually transitioned between 0.8 and 0.2 when the Froude number was between 0.9 and 1.1. The resulting water level uncertainty grid associated with 'other' factors is shown in Plate D3.

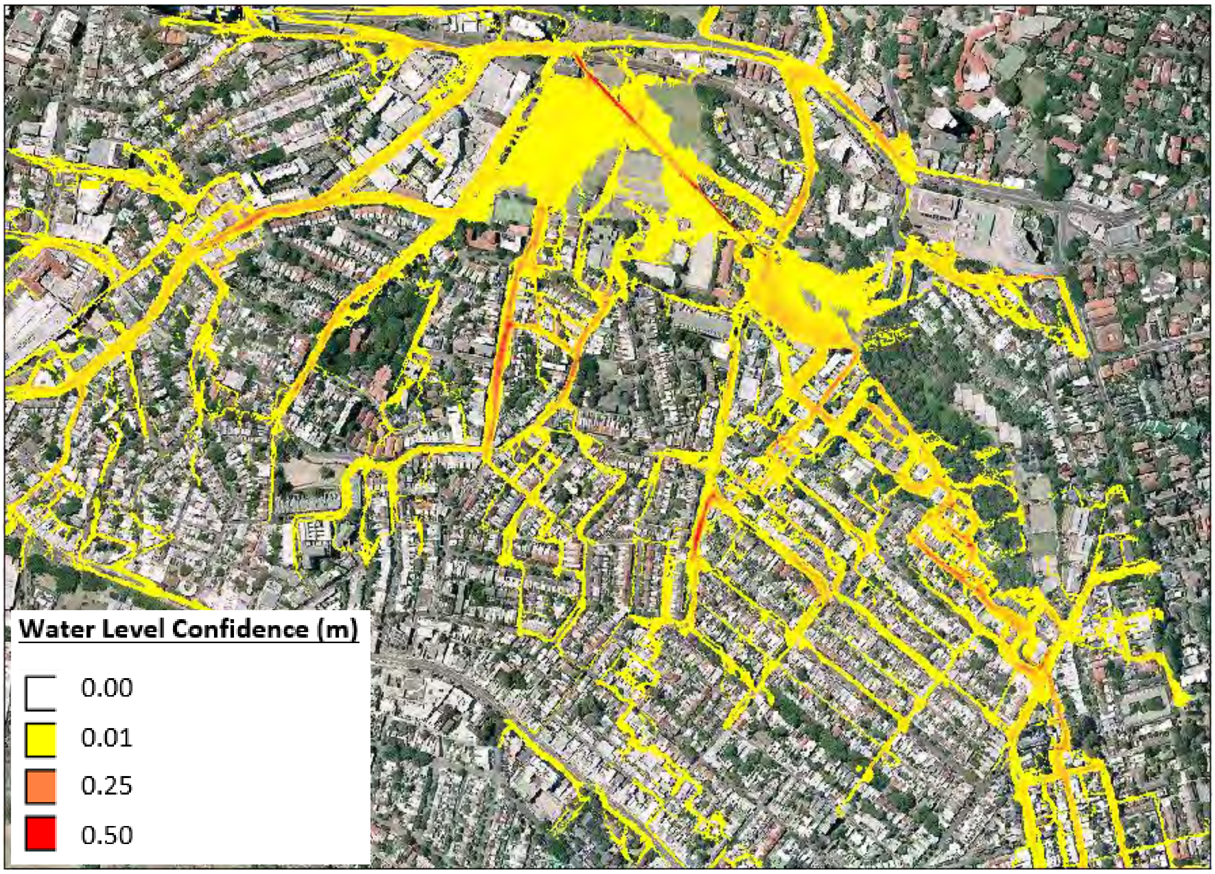


Plate D3 Water level uncertainty grid for other factors that cannot be represented in flood model

The impact of wave action cannot be calculated using model results. However, across the study area, the wind fetch length is small, water depths are generally shallow and any boats or cars would typically be operating at low speeds. As shown in **Plate D4**, under these circumstances, the waves generated by cars are unlikely to exceed 0.15 metres and dissipate significantly in height by the time the wave reaches the edges of the road. Therefore, a wave action allowance of 0.15 metres is considerd to be sufficient.

The following approach was then used to calculate an appropriate freeboard for each location in the study area:

- The modelling/climate change confidence limit grid was added to the uncertainty grid for 'other' factors to represent the total water level uncertainty at a particular location. This formed the "base line" freeboard for Paddington.
- A minimum freeboard of 0.15 metres was adopted to account for wave action for all locations (refer **Plate D4**)
- A maximum freeboard of 0.5 metres was adopted in line with Council's LEP.

The resulting freeboard grid is shown in Plate D5. It shows that the freeboard is typically less than 0.3 metres across most upstream areas. However, localised increases approaching 0.5 metres are predicted in areas subject to higher velocity flows (typically roadways). Plate D5 also shows that areas downstream of Glenmore Road would retain the 0.5 metre freeboard under this scheme.

Plate D4 Example of cars driving through flood waters and generating waves (typical wave heght <0.1 metres)

Plate D5 Variable freeboard grid that considers model uncertainty, climate change uncertainty as well as other uncertainty that cannot be explicitly represented in the modelling.

In practice, a variable freeboard may be difficult to implement if Council officers do not have ready access to a GIS platform and difficult to describe and interpret for property owners and developers. However, as discussed and as shown in Plate D5, there is a notable difference in freeboard across the upper catchment areas versus the lower catchment areas. Therefore, it is considered that the following more general rules can apply for the definition of freeboards across the Paddington study area:

- Downstream Catchment Areas: Areas west and north of Glenmore Road, north of Alma Street/Vialoux Ave, south of New South Head Road and east of Nield Ave: 0.5 metre freeboard
- Upstream Catchment Areas Remainder of study area: 0.3 metre freeboard (in general, a 0.15 metre freeboard is likely to be appropriate across the majority of the upper catchment. However, some localised areas of higher velocity dictate a more conservative 0.3 metre freeboard if a general freeboard is to be applied).

A comparison between PMF and 1% AEP flood levels was also completed to ensure that the adoption of a lower freeboard would not expose the upper catchment areas to an unreasonable increase in flood risk during extreme floods. Based on the flood hazard vulnerability curves presented in **Plate 12**, once floodwater depths exceed 1.2 metres, children and the elderly would be exposed to a high flood risk. Therefore, areas where the PMF flood level is more than 1.5 metres (1.2m critical depth plus 0.3metre freeboard) above 1% AEP flood level were identified (refer **Plate D6**).

Plate D6 Areas that would be exposed to a high flood risk if a 0.3m freeboard was adopted (yellow).

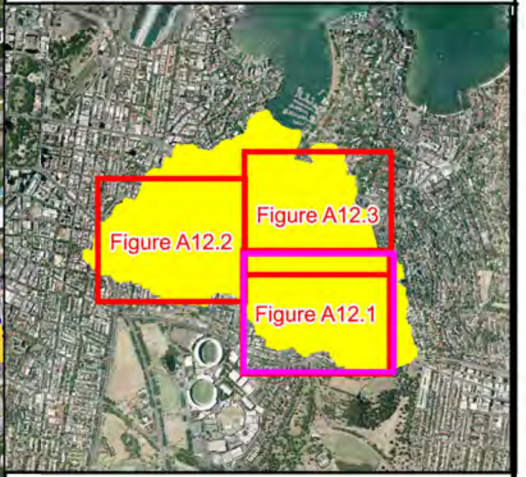
As shown in **Plate D6**, only the lower catchment (where a 0.5 metre freeboard is recommended) is predicted to be exposed to a high flood risk during the PMF. Therefore, the adoption of a 0.3 metre freeboard is not predicted to expose the upper catchment to a high flood risk during all floods up to and including the PMF.

To further assess the potential impacts associated with adopting a variable freeboard versus a global 0.5 metre freeboard, a flood planning area map with a global 0.5 metres freeboard as well as a variable freeboard (i.e., reduced 0.3 metres freeboard across upper catchment areas).

To affect this freeboard change, it would be necessary to alter the standard LEP clause, which would require the LEP to go through a public exhibition process and also gain approval from Department of Planning and Environment. Alternatively, the LEP clause can stay 'as is' and the DCP could be updated to define what controls to apply below the standard FPL (i.e., 1% AEP + 0.5m freeboard). For example, the DCP could stipulate a minimum floor level requirement in line with the 1% AEP flood level and variable freeboard approach outlined above.

APPENDIX E

NATIONAL FLOOD HAZARD CATEGORIES



LEGEND

Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

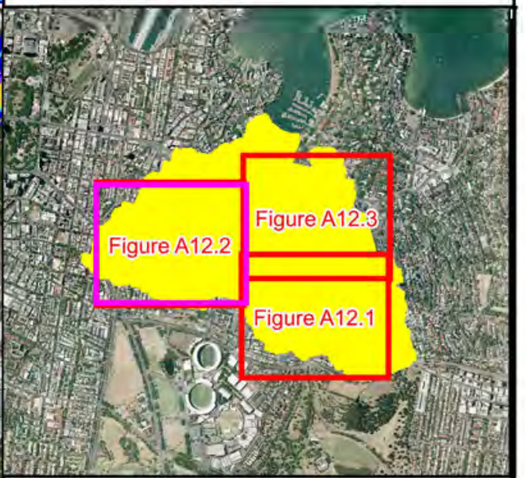
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure E1.1: National Flood Hazard for the 1% AEP Flood

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

File Name: FigE1.1 - National Flood Hazard for the 1% AEP Flood.wor



LEGEND

Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

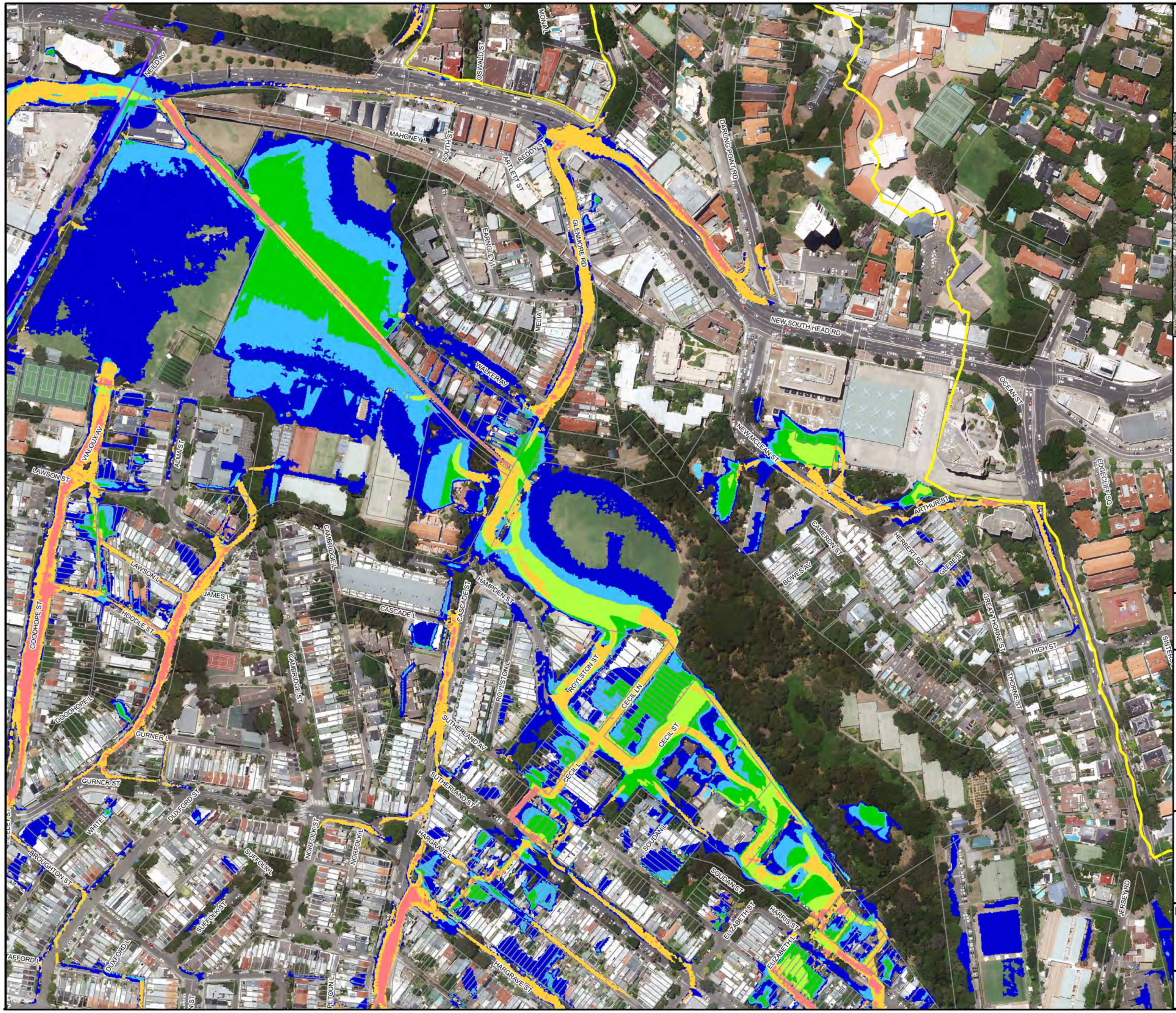
Scale 1:3,000 (at A3)

0 0.1 0.2
Km

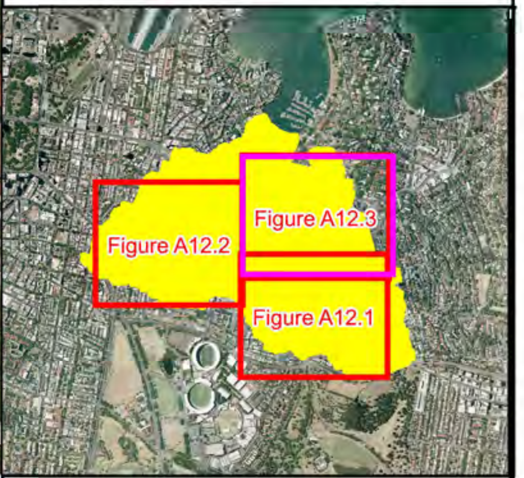
**Figure E1.2:
National Flood Hazard
for the 1% AEP Flood**

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

File Name: FigA12.2 - Provisional Flood Hazard for the 1% AEP Flood.wor



WOOLLAHRA MUNICIPAL COUNCIL



LEGEND

Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:
Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

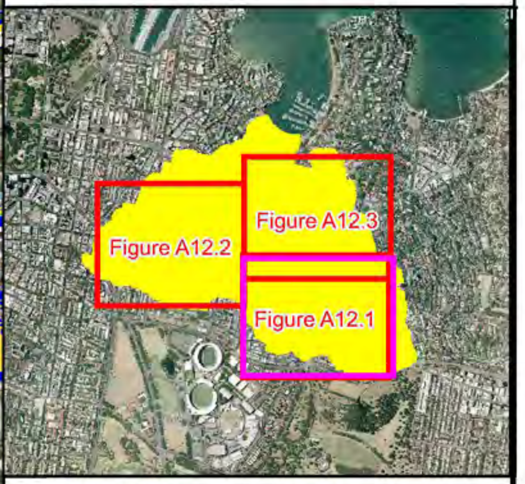
0 0.1 0.2 Km

Figure E1.3:
National Flood Hazard for the 1% AEP Flood

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

File Name: FigA12.3 - Provisional Flood Hazard for the 1% AEP Flood.wor

WOOLLAHRA MUNICIPAL COUNCIL



LEGEND

Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

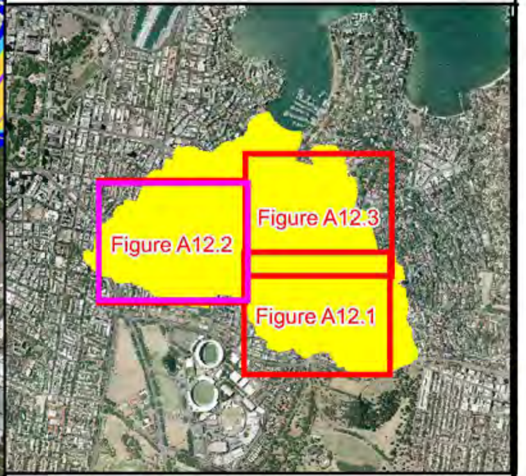
Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure E2.1: National Flood Hazard for the PMF

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

File Name: FigE2.1 - National Flood Hazard for the PMF.wor



LEGEND

Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N
W E
S

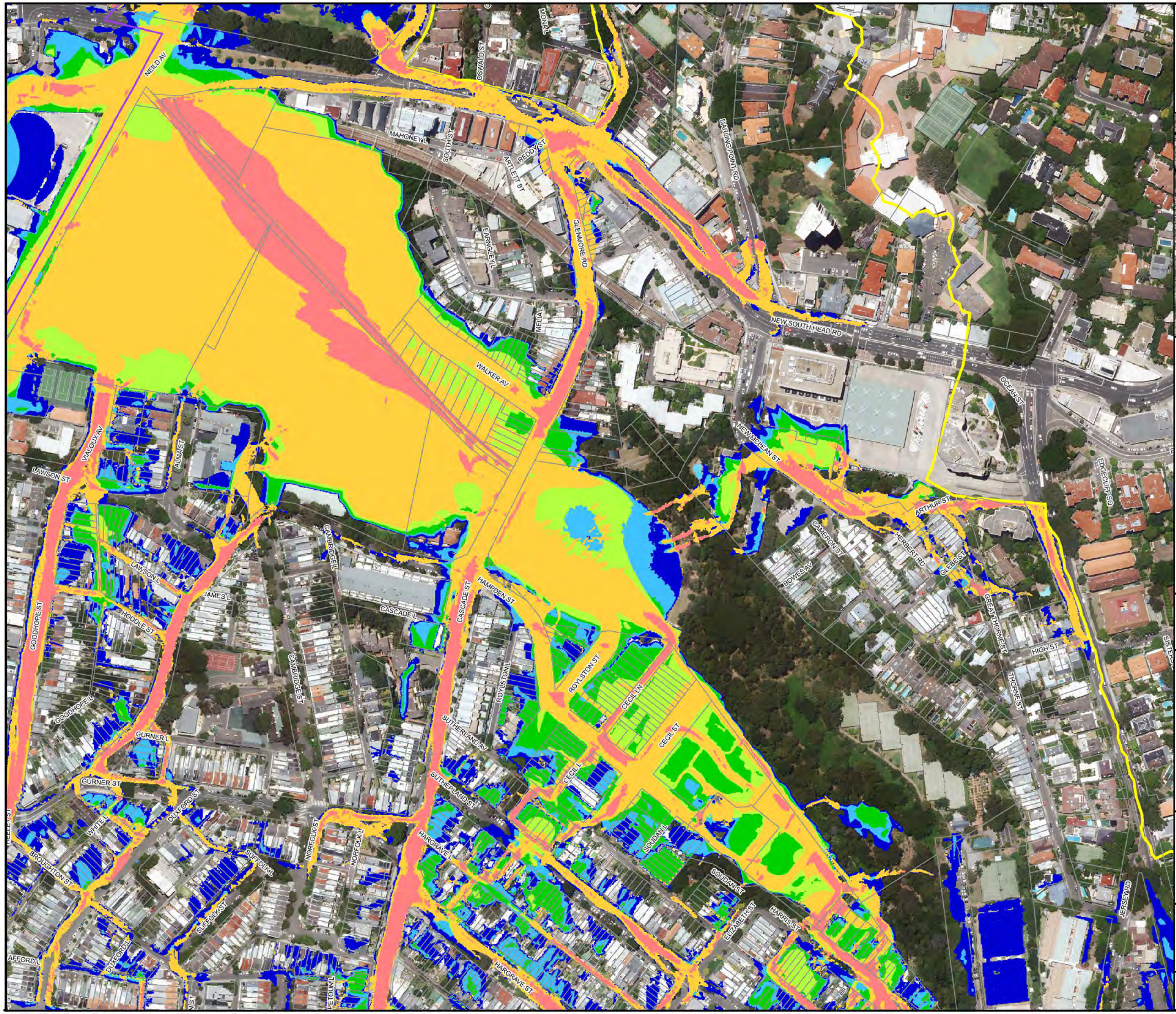
Scale 1:3,000 (at A3)

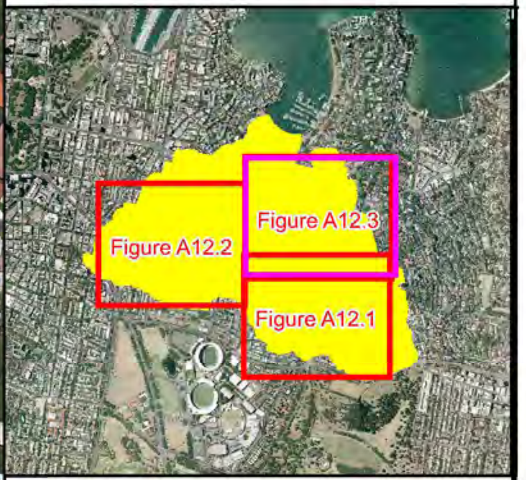
0 0.1 0.2
Km

Figure E2.2:
National Flood Hazard for the PMF

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

File Name: FigE2.2 - National Flood Hazard for the PMF.wor





LEGEND

Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:3,000 (at A3)

0 0.1 0.2 Km

Figure E2.3: National Flood Hazard for the PMF

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

File Name: FigE2.3 - National Flood Hazard for the PMF.wor

APPENDIX F

PUBLIC EXHIBITION COMMENTS AND RESPONSES

#	Comment	Response
1	Notes flooding of house has occurred on a number of occasions as a result of a surcharging manhole (although a specific address is not provided). Questions if the recommendations in the plan will be followed through.	The completion and adoption of the Plan itself does not manage flood risk - this relies on implementation, which is a critical step in the management process. Implementation of the Plan is the responsibility of Council and will be overseen by the floodplain risk management committee, which includes community representatives. The implementation schedule will need to be developed by Council following adoption of the plan and will be dependent on a number of factors such as the effectiveness of the measure, costs and resourcing. Recommendations in the Plan will be eligible for state government funding, which will assist Council in funding the recommended works. No modifications to report considered necessary.
2	Notes that disruptive local flooding issues occur on the upper section of Begg Lane, which is not identified in the report. Notes this problem is associated with properties on Oxford St and Ormand St channel stormwater onto Begg Lane and argues the contribution of flow from this area is not recognised in the report. Recommends property owners adjacent to Begg Lane be required to direct water into drainage system rather than onto Begg lane	The flood modelling completed for the study recognises the contribution of flow from all sections of the local catchment. However, the study focussed on areas subject to more significant inundation depths (a minimum depth threshold of 0.1m was adopted). Notwithstanding, it is acknowledged that even relatively shallow depths of water can present a significant hazard when travelling at speed (such as what may happen in the steeper areas of the catchment). It is unlikely that individual property owners will be willing to pay for the drainage upgrades on their own and measures targeted at individual properties (such as drainage upgrades) will generally not be eligible for state government funding, which will limit their financial feasibility. In addition, information on inter-allotment drainage systems are not commonly available making their inclusion in the flood model (and, therefore, their effectiveness) very difficult to quantify. However, the suggestion is considered to have merit. Council could potentially look at including the suggested drainage works as part of their *Stormwater Asset Management Plan*, should adequate funding be available.
3	Opposes the Moncur Reserve detention basin on the grounds of reduced public amenity and, in particular, the potential for failure of the basin to increase the flood risk downstream of the basin	Any potential flood detention basin would be designed to safely cater for all potential floods up to and including the PMF. Therefore, the potential risk of basin failure is considered to be very low. As outlined in the report, the Moncur Reserve detention basin is not currently recommended for implementation unless supported by the community. Based on the lack of support received so far it is considered unlikely that this option will be put forward for implementation. No action necessary

#	Comment	Response
4	Notes flooding of property has occurred on multiple occasions, primarily due to blockage of the local drainage system resulting in significant property damage. They are supportive of the recommendations in the report as a means of improving the current drainage situation	Noted. No further action necessary
5	Notes reference on Plate 42 in report should refer to Cascade Street and not Paddington Street	This is correct. Report will be updated
6	Notes that development (particularly around Sutherland Ave) has proceeded without due regard to the topography. Makes reference to the history of the area with particular reference to Cascade St. Recommends that website is updated to include sensible and realistic information. Notes that Mona Rd not appearing in draft floodplain risk management study. Also questions where drained water will go and how contamination will be controlled	Labels for all roads (including Mona Rd) were not included as it would make the Plan too "busy". Instead, only a selection of road names were included on the Plan to allow the community to orient themselves while still providing a legible figure. It is also noted that these particular roadways in Darling Point did not form part of the official study area. Website updates are included as one of the recommended "community education" activities. All runoff from the local catchment ultimately drains via the stormwater system and overland flow paths into an open channel (Rushcutters Creek) that commences immediately downstream of Glenmore Road. This channel drains under New South Head Road and into Rushcutters Bay.
7	Notes that regular flooding (originating in George St) has been experienced at their property over the past 30 years. Although the flooding has not been particularly problematic at their property, they state that property owners in George St, Elizabeth St and Elizabeth Place have suffered significant damage/hardship. They note that the drainage upgrades that are recommended in the report are designated as "medium" priority and argue that it should be assigned a higher priority given the significant flooding issues in the area. The submission also makes reference to a current Development Application in this area. A number of points are raised as to why the development is not suitable from a flood perspective including the potential adverse impacts it may	The significant flooding issues in this area are noted. The main reason this was not suggested as a high property option is the high capital cost, which will make it difficult to implement over a short time frame. It was felt that there would be a greater potential for implementation if the costs were spread over a number of years. However, given the large number of responses from this area, it is suggested that the priority could be changed to "high", but the implementation time frame could still extend across a number of years to maintain the financial feasibility (this may allow a staged implementation approach). Any stormwater upgrades that are completed will need to ensure they do not make the flooding situation worse further downstream. Upgrading only the George St to Elizabeth St without further downstream upgrades, may just direct the problem further downstream. If the option is implemented in a staged manner, it is suggested that the upgrades start at the downstream end and progress upstream. It should be noted that the design concepts included in the report are only concepts at this point in time, including the potential alignment of new stormwater pipes as well as construction

#	Comment	Response
	have on flood behaviour and the potential for it to hamper the suggested stormwater upgrades (i.e., proximity of basement car park to proposed pipe upgrade). Suggests, that as a matter of priority, the upgrades between George St and Elizabeth St are implemented.	techniques. For example, if tunnel coring is not found to be feasible beneath Elizabeth St properties, there is an option to run a new pipe along Elizabeth Place. All suggested options in the report would be subject to more detailed investigations prior to implementation. As the consultant responsible for preparation of the Floodplain Risk Management Study, we cannot provide comment on the DA assessment process. However, any development will need to comply with the requirements of the Woollahra DCP which, as a minimum, will require no adverse flood impacts across adjoining properties. Although the Floodplain Risk Management Study makes suggestions on potential updates to Council's planning documents and development requirements (such as consideration of climate change), the report is only a draft document at this stage and the suggestions will only be formally considered once the report is finalised and adopted by Council.
8	Notes that flooding occurs on George Street every year with water at knee level on most occasions with significant damage bills associated with damage to carpets, constant damp problems as well as damage to cars (a separate email submission was received showing car damage and an insurance claim against Council following the 2012 flood). Flooding is often exacerbated by cars driving through the water and pushing waves into adjoining properties No specific comment is provided on the content of the draft report.	The draft report does identify George St as a "problem" location and a recommendation for drainage upgrades is recommended as a medium priority option. However, as noted in the response to comment #7, it is suggested that the priority could be upgraded to "high". Also suggest adding an additional item in the community education section of the report to discourage driving through floodwaters (not only for the drivers' safety but also for the potential damage this causes to adjoining properties).
9	Reports that flooding at this property (as well as adjoining properties) has been experienced on multiple occasions. Suggests the stormwater upgrades for the area should be changed from medium to high priority. Also makes reference to a DA for an adjoining property located within the flood-affected area. Suggests that this development as well as potential developments across other nearby properties will increase the flooding problems. Also questions whether the equipment necessary to install the new pipes beneath existing building are feasible or may cause damage to existing properties and suggests pipes may be	As outlined in response to comments #7 and #8, we proposed to change the priority for the stormwater upgrades from medium to high. As outlined in the response to comment #7, the concept designs are subject to further detailed investigation prior to implementation. This will include a review of the "constructability", potential property impacts and the potential to realign pipes along road reserves (the main downside to laying pipes in the road reserve is the large amount of utilities, which may significantly increase the cost of implementation). It is not common practice to consider climate change in the design of pipes, particularly given the uncertainty around climate change estimates. It is suggested that once the final design for the stormwater upgrades is prepared, a climate change sensitivity assessment could be

#	Comment	Response
	better if aligned with the roadway. Also recommends that the drainage upgrades would consider climate change.	undertaken to assess if climate change has the potential to cause significant impacts on the performance of the drainage system. As outlined in the response to comment #7, we cannot comment on the DA assessment process. However, any development will need to comply with the requirements of the Woollahra DCP which, as a minimum, will require no adverse flood impacts across adjoining properties.
10	Notes that flooding of their property as well as adjoining properties has occurred numerous times resulting in ongoing damage and damp issues. Due to the significant costs of flooding on properties in this area, suggests that it would be more economical for property owners and Council for stormwater upgrades to be implemented as a high property rather than a medium priority. Also makes note of the DA for an adjoining property and the adverse impact that increases in runoff from this property may have on the existing flooding problem.	As outlined in responses to comments #7, #8 and #9 we propose to change the priority of this options from "medium" to "high". Also refer to responses to comments #7 and #9 regarding the DA.
11	Notes significant flooding was experienced through property in August 2015 causing over $15,000 in damage. Suggests that flooding is exacerbated by no stormwater drainage from rear of George St properties as well as illegally constructed hard walls and paving. Like other submission, requests that the drainage upgrades in this area be changed from a medium priority to high priority. Also makes note of the potential adverse impacts of DA on nearby property. Suggests stormwater upgrades are implemented before any additional development to ensure flood problem is not increased.	As outlined in responses to comments #7, #8, #9 and #10 we propose to change the priority of this options from "medium" to "high". Also refer to these responses for comments on the DA.
12	Please refer to separate Table 1 at end of this document for comments and responses	Please refer to separate Table 1 at end of this document for comments and responses
13	Property has been subject to periodic flooding which have damaged the property itself as well as contents. Evidence of flood damage costs are provided for multiple properties.	As noted in other responses, the high capital cost of this option will make it difficult to implement over a short time frame. We suggest that the priority of this option be upgraded from medium to high, but the implementation time frame be retained to allow staged

#	Comment	Response
	Supportive of the Victoria St / Elizabeth St to Cascade St drainage upgrades. However, suggests the 10 year implementation time frame is too long and requests the updates be completed more promptly. Also supportive of the response modification options in Section 6 and 8 of the Plan.	implementation. It is noted that the implementation time frame is a suggestion and Council do have the option of bringing the implementation forward if finances allow.
14	Flooding was quite common in the late 1980s. Since that time, stormwater upgrades have been implemented by Council which has reduced the frequency and severity of flooding. Notes that natural grade diverts water from Cascade St towards Hargrave St and has concerns that upstream pipe upgrades could increase flooding problems.	Any potential mitigation works needs to be supported by appropriate reporting to demonstrate that properties will not be adversely impacted by any works. The drainage upgrades were modelled and this determined that no significant impacts were predicted downstream of the pipe upgrades. This is likely associated with the works not significantly changing the total flow reaching this point but simply directing more of the flow underground rather than overland.
15	Reinforces the flooding problems that have been experienced in George St and notes the problems caused by cars driving through floodwaters making the problem worse. Requests that the area should be prioritised for remediation before further damage or accidents occur	This area is identified in the draft plan as a medium priority area. However, this will be modified to a high priority in the final plan.
16	Provides excellent diagrams of overland flow patterns, properties subject to past flooding (including year of floods, depths and damage caused by water) as well as photographs of past floods. This information tends to confirm the findings of the study which identified this as a flooding problem area. No specific comments are included on the draft report or the suggested options. Phone call subsequently made which echoed other submissions in the area - that is, the area should be included as a high priority option	A review of the flow path maps and flood photos provided generally shows a good agreement with the flood modelling results. No further action necessary in this regard. As outlined in previous responses, it is intended to modify the priority of the drainage upgrades in this area to “high”.
17	Notes that his property would be adversely impacted by the proposed channel works (the exact works are not stated, but we assume it relates to the Cecil St mitigation works). States property has not experienced significant flooding issues since occupation.	The concerns are acknowledged, and the suggestions will be taken on board as the design concept for the area is refined. However, it should be noted that a channel is not the only option under consideration at this location. Other options including a sub-surface culvert and flood proofing are also being considered and are documented in the report. The final option for this area will aim to strike a

#	Comment	Response
	Submission states that land was acquired because of its bushland setting and the house was designed to take advantage of views across Trumper Park which would be significantly reduced by the proposed works. Concerns that privacy would also be compromised. Several suggestions are made on ways in which the potential issues could be overcome.	balance between reducing the flood risk to people and property while minimising the potential adverse impacts (e.g., loss of vegetation in Trumper Park). The culvert option, for example, would look to reinstate the existing topography and much of the vegetation after construction is complete. Therefore, under this proposal, the privacy and amenity value will be largely unchanged while still reducing the existing flooding problem. However, opportunities for improving the level of "screening" should be explored as part of the detailed design to improve the level of privacy afforded. It also needs to be recognised that the floor level of the subject property is located at a higher level than most other properties in Cecil St. Therefore, although this specific property may not have been impacted by flooding, many other properties in Cecil St have been impacted on multiple occasions. As noted in Section 5.3.3, this area is one of the most significantly impacted by flooding in Paddington. Implementation of any mitigation works would not be completed without further consultation with the local community. Accordingly, once the design concept is refined, further opportunity for the community to comment will be provided.
18	Appears to be largely a reproduction of the information submitted as part of Comment #16	Refer response to comment #16
19	Submission claims that Glenmore Road is the most flood affected area and is ignored by the Floodplain Risk Management Study & Plan. Notes that water from Trumper Park and oval carries debris, which prevents water from draining into the downstream channel. Also states the downstream channel is over 100 years old and needs to be enlarged to handle the additional flows from the upper catchment.	Glenmore Road was identified as a flooding problem area in the draft Floodplain Risk Management Study. Therefore, two options were investigated at this location to reduce the flooding issues. This included channel widening (Section 5.3.5) as well as regrading of Glenmore Road to allow water to more readily escape into the downstream channel (Section 5.4.8). It was determined that the channel widening only had limited beneficial impacts due to the limited capacity of the New South Head Road culverts further downstream (i.e., the additional water travelling down the channel would just "build up" behind the New South Head Road embankment). Therefore, the channel option was not recommended in the draft plan. The regrading showed more promise, producing flood level reductions around Glenmore Road without increasing the flooding problem elsewhere. Unfortunately, the benefit cost ratio was less than 1, so the option was not recommended in the draft plan. However, the ratio was only just below 1 (0.8), so there may be opportunities to improve the cost effectiveness of this option. Therefore, we will update the draft report to suggest that this option be investigated in more detail.
20	Notes that a formal submission will be made at a later date	No action necessary

#	Comment	Response
21	Makes note of a "huge flood" some time after December 2014 (most likely the August 2015 event) and that the water reached the front wall of the property and caused significant damage. Also notes a couple of smaller floods that almost came up to the front steps of the property and car has also been damaged in past events	Reinforces significant flooding issues in this area. No specific comments are made regarding the draft study and plan. No further action necessary.
22	Updated version of Comment #16	Refer to response for comment #16
23	Notes major building defects at this property as a result of floodwater impacting the footings of the buildings, which has caused cracking / damage to internal fixtures. States that if flooding issues are not resolved, major structural works on the building would be required and the family would be forced to move out.	Submission provides further support for flooding problems in this area. No specific comments are made regarding the draft study and plan. No further action necessary.
24	Lived on Cecil St since 1991 and reports flooding of properties on multiple occasions including contaminated floodwaters. Happy that actions are being taken to address the issues. Suggests opportunities to maximise infiltration, permeability and detention of stormwater be explored to assist in ensuring the flooding problem is not increased.	Suggestions are noted. Council's DCP already requires on-site detention for all new developments greater than 500m^2 and alterations/additions where the additional impervious area is greater than 40m^2 and the total site area is greater than 500m^2 The DCP also includes discussion on rainwater tanks and green roof areas as an alternative to detention. It is suggested that the report could be updated to recommend the DCP be modified to also encourage permeable paving/additional infiltration.
25	Lived in George St since 2003 and has witnessed many floods. Properties at 2-20 George St have been inundated. Water comes from multiple directions (most notably Tivoli St and from between 17 and 19 George St). Cars driving through floodwaters makes the situation worse. Requests the area be prioritised for remediation before further damage or accidents occurs	As noted in previous responses, the suggested stormwater upgrades for this area will be changed to a "high" priority and community education will be modified to note the issues associated with driving through floodwaters
26	Please refer to separate Table 2 at end of this document for comments and responses.	Please refer to separate Table 2 at end of this document for comments and responses. The comments regarding 'best practice' landscape & urban design are noted. The report will be updated to reference this. However, consideration of these aspects is beyond the scope of the current study and will be considered during more detailed subsequent investigations.

#	Comment	Response
	It is noted that many observations are made regarding the report. However, responses are only provided in Table 2 where specific comments or questions are raised. Many of the comments relate to ensuring the structural mitigation options should be designed with concern for heritage values and 'best practice' urban design and landscape principles.	
27	Comprehensive submission that mirrors several other submissions for this area. Suggests that there is irrefutable evidence of major flooding and drainage problems in the vicinity of George St, Elizabeth St and Elizabeth Place. States that drainage upgrades in the area should be included as a high priority rather than medium priority. Also makes note of his opposition to a DA on adjoining land (i.e., DA should be refused).	Please refer to Response #7.
28	Residence has flooded multiple times in the past. Inundation was due to tree roots growing into the gutter from the footpath. Suggests that removal of roots be considered as part of the flood mitigation plan for Cecil Street and Cecil Lane	Typically, flood mitigation measures focus on measures that benefit multiple properties as there is greater return for the money invested. Nevertheless, this is considered to be a fairly low-cost option, so we will include consideration of this in the final report.

Table 1 Summary of Sydney Water Comments and Responses

Section	Page	Comment	Response
3.2.1	15	Dates and status are incorrect for the previous studies conducted for City of Sydney Council. These are: • Rushcutters Bay Catchment Floodplain Risk Management Study and Plan (WMAwater, 2016) for City of Sydney Council • Rushcutters Bay Flood Study (WMAwater, 2016) for City of Sydney Council	Noted. Dates will be modified.
3.2.1 onwards	Various	Report and maps use the term '20% AEP' repeatedly, though this is equivalent to the 4.48-year ARI event. '18% AEP' is probably intended, as this is equivalent to the 5-year ARI. Australian Rainfall & Runoff 2016 identifies that '18% AEP' is the preferred terminology.	The study was prepared based upon the 1987 version of Australian Rainfall and Runoff, where AEP was calculated as the reciprocal of AEP (i.e., 20% = 5 year ARI). ARR2016 has revised the way in which frequencies are expressed (most notably for more frequent floods), as highlighted by this comment. Given that this study was completed in accordance with ARR1987, it is considered that the adopted terminology is reasonable.
3.2.2 and 3.2.3	17-18	Report states: 'The results of the 1 exceedance per year event also predict overland flow across some sections of the catchment. This indicates that the stormwater system has less than a 1 year capacity across some sections of the catchment.' This is not necessarily true, as it depends on: • the location of sag points • the location / number / capacity of inlet pits • the characteristics of the area experiencing overland flow. If the water cannot get into the trunk system, it doesn't matter how large the system is – there will be overland flooding. The issue is more complex than simply concluding overland flow is due to trunk system deficiency, and some discussion of this is warranted. Many of the results presented in Figure 9 compare favorably with	This comment is noted. We will update the text to include additional commentary on the factors impacting overland flow and stormwater capacity. The differences in pipe capacity between the draft FRPS and Sydney Water capacity assessment may be associated with different assumptions in the assessments. For example, partial blockage of all stormwater pits was assumed, which will impact on the amount of water entering the drainage system. With reference to the New South Head Rd culverts, this is a complex structure with changing geometries along its length. We have taken the capacity of the limiting section as the overall structure capacity. Differences in adopted Rushcutters Bay water levels may also be impacting on the capacity of the culvert system at this location. We can provide additional comment if a copy of the Sydney water report is forwarded.

<table>
<tr><th>Section</th><th>Page</th><th>Comment</th><th>Response</th></tr>
<tr><td></td><td></td><td>Sydney Water's 'Capacity Assessment' for Rushcutters Bay, though some locations are vastly different. For example:
<table><tr><td>Location</td><td>Draft FRM S&P</td><td>Capacity Assessment</td></tr><tr><td>Culverts at New South Head Rd</td><td>1 E/Y</td><td>>20 year ARI</td></tr><tr><td>Tonkin at northern end of Cecil St</td><td>>1% AEP</td><td>2-5 year ARI</td></tr></table></td><td>We will add a note to the capacity map to state that the drainage capacity is dependent on a number of variables, including blockage of drainage structures.</td></tr>
<tr><td>3.2.3 and Fig 9.3</td><td>17-18</td><td>The Sydney Water maintenance holes in both Hampden St and Sutherland Ave are known locations for surcharging, yet the model results presented in Fig 9.3 do not show this.

There should be some discussion in section 3.2.3 of the report about the confidence of modelling pit capacity issues at these locations.</td><td>Fig 9.3 indicates a surcharging pit in the 1 EY event in Hampden St. But as the comment points out, none are shown in Sutherland Ave.
Report text will be updated to make note of the complexities of the drainage system in this area and the potential limitation of the computer modelling.</td></tr>
<tr><td>3.2.5</td><td>19</td><td>The Australian Disaster Resilience Guideline 7-3: Technical flood risk management guideline: Flood hazard, 2014, Australian Institute for Disaster Resilience provides more contemporary guidance on consideration of flood hazard, with six hazard vulnerability classifications that provide clearer guidance on vehicle and human evacuation, and building stability.

It would be beneficial to present hazard data using this resource rather than the older guidance from the Floodplain Development Manual, 2005, NSW Government.

It is notable that sections 6.3.3, 6.3.4 and 7.2.4 indirectly reference this best practice flood hazard guidance, but without providing explanatory detail or references in the body of the report.</td><td>The primary reason for retaining the Floodplain Development Manual categories is that Council currently uses this information when defining their flood risk precincts. However, there is definite merit in having access to the newer hazard categories. Suggest retaining the FDM categories in Appendix A and including the newer hazard categories in a separate appendix.</td></tr>
<tr><td>3.2.8 and 7.2.4</td><td>22 and 103-105</td><td>The NSW State Emergency Service is 'the combat agency for dealing with floods and to coordinate the evacuation and welfare of affected communities' (State Emergency Service Act 1989) and the NSW State Flood Plan is clear that 'evacuations will take place when there is a risk to public safety'.</td><td>Agree.
Based on past discussions with SES, suggest changing reference of "shelter-in-place" to "on-site refuge".
Fortunately, most of the identified vulnerable facilities appear to remain above the peak level of the PMF and floodwater recede relatively quickly meaning that the properties would not be isolated</td></tr>
</table>

Section	Page	Comment	Response
		'Shelter in place' is a challenging issue (and in the case of section 3.2.8 would have additional challenges for vulnerable facilities). Such a course of action should be discussed carefully with the NSW State Emergency Service before being recommended as a course of action to be adopted in a floodplain risk management plan.	for long. Nevertheless, the need for emergency medical access is a key consideration for several of these properties. It may be that owners of these individual properties may need to assess their flood exposure and, through consultation with the SES, determine the best plan of action during future floods. A comment to this effect can be included in the report.
4.3.2	27	Change in number of buildings inundated above flood level is arguably more useful at more frequent events. The 1% AEP is used for determining FPLs and other planning / response controls – but this is at least partly on the basis that such an event is likely to be experienced at least once in a lifetime (Table K1, *Floodplain Development Manual*). From a customer experience perspective, above-floor flooding during events that recur frequently is more traumatic and disruptive. Information about the change in number of buildings inundated above floor level in the 10% or 18% AEPs can add greater weight to the business case for undertaking action.	Noted. The 20% AEP event will be included in the assessment.
Plates 27 and 28 in 5.3.4	43	**Trumper Park Floodway** The difference mapping for this option shows a completed flow path from Cecil St to Trumper Oval. As it is currently presented, there is no information to demonstrate the value of the Trumper Park works as a standalone project following completion of the Cecil St works. If the scenario of inundation after completion of the Cecil Street works is adopted as the base-case, flood difference mapping showing the benefit of the additional Trumper Park works would be possible and would help to alleviate any potential community concerns of more floodwaters from higher up the catchment being transferred to Cecil St.	We don't consider pursuing the Trumper Park floodway in isolation is a worthwhile pursuit (i.e., it's a "package deal"). But by comparing the difference mapping from the combined floodway option against the Cecil St option only, you can gain an understanding of the additional benefits afforded by this option.

Section	Page	Comment	Response
5.3.5	44	**Channel Widening Downstream of Glenmore Road** From a customer perspective the channel widening appears to the most obvious option to alleviate flooding, but most customers can be brought to understand that the issue is the constriction of flow under New South Head Rd. However, this is now the second floodplain risk management study for this catchment to: • conclude that widening the open channel down to New South Head Rd would be ineffectual for reducing flooding • not do any work to assess the merit (or lack thereof) of increasing capacity under New South Head Rd. (The former 2012 study makes some brief comments that removing the constriction under New South Head Rd would provide a significant hydraulic benefit but that the main issue is the high cost of works.) For there to be any chance of future works by either Roads & Maritime Services or Sydney Water to increase the flow capacity under New South Head Rd, the need for such works has to be identified and assessed in a Floodplain Risk Management Study & Plan (being the mechanism via which future measures are identified for such 'state agencies' – see section 3.4 of the Floodplain Development Manual).	It should be noted that the area downstream of Glenmore Road was not specifically assessed as part of the current study as it was previously included in the Rushcutters Bay FPRMS. Therefore, the merits of modifying the New South Head Road culvert were not assessed as it did not form part of the official study area. Discussions will be held with Council to determine if the study could be expanded to include further assessment of this option (i.e., widening of channel and upgrade of culvert).
5.4.4	51	**Harris Street roadworks** The recommendation text concluding this section states: 'Not recommended for implementation' This recommendation text needs to be changed to reflect the benefit of undertaking these works after completion of the potential drainage upgrades in Harris Street (5.5.4). Something like: 'Not recommended for implementation in isolation. Could be implemented following Harris Street drainage upgrades.'	Noted. Text will be updated.

Section	Page	Comment	Response
5.4.6	54-56	**Hargrave Street / Cascade Street roadworks** This option shows that attempts to keep water in Cascade St by installing a local raised area of road at the western end of Hargrave St results in water entering Hargrave La and causing elevation of flood levels. Has there been any analysis of also installing a similar raised area at the western end of Hargrave La? The topography of the area is such that if water can be kept in Cascade St until it reaches Sutherland St, it will then likely flow down to the open channel at Glenmore Rd (and bypass going into the Roylston St subcatchment)	We did investigate this but the one-way cross fall of Cascade St at this location makes it difficult to implement. More specifically, the Cascade St cross fall would likely direct the flow not travelling down Hargrave St and Hargrave Lane into properties on the eastern side of Cascade St. To prevent this, it is likely that the geometry of Cascade St would also need to be significantly modified such that the additional flow is contained in the road rather than directed into adjoining properties. Further modifications would likely also be necessary near Sutherland St as well as further down Cascade St (most notable an apartment complex with a basement car park may be subject to additional inundation). The overall goal of these regrading options was to try and identify relatively cheap/easy fixes. Based on these additional complexities, the merits of pursuing this expanded option are questionable.
5.4.8	57-59	**Glenmore Road roadworks** The properties affected in this location are among those who experience flooding in frequent events. While the option may reduce (but not eliminate) over-floor flooding in the 1% AEP, some discussion about any reduction in the more frequent events would (from a customer perspective) be helpful to understand any benefit (or lack thereof). The BCR is 0.8, which (in actuality) isn't poor for a flood modification option. Given the frequent flooding experience of these residents, it is arguable that these works could be recommended – particularly given the social and other non-cost impacts of flooding.	Further discussion on potential impacts during more frequent events will be provided and consideration of changing the recommendation of this option will be provided.
5.5.2	62	**Ocean Street and Tara Street drainage upgrade** Report says: 'This yielded a preliminary benefit-cost ratio of 0.2. Accordingly, the financial benefits of implementing this option are predicted to outweigh the costs.'	Agree. Report will be updated

Section	Page	Comment	Response
		BCR of 0.2 means the costs outweigh the financial benefits, which is not what the report states.	
Plate 51 in 5.5.3	64	**Forbes Street to Harris Street drainage upgrade** The Sydney Water assets in this location are not pipes and cannot be replaced except through major excavation works, which are not technically feasible due to the presence of private dwellings over the asset. Based on the shallow depth of existing assets, Sydney Water would not support microtunnelling beneath these private dwellings, hence construction of a new line along road alignments to augment the existing assets would be the only technically feasible option – however this is likely to have higher costs than the $5.1 million suggested in the preliminary cost estimate. Please amend Plate 51 to use the term 'asset' (rather than 'pipe') for the existing Sydney Water assets.	This comment is noted. Report text will be updated to reflect suggestions.
5.5.9	77	**Sutherland Street to Trumper Oval drainage upgrade** The Sydney Water assets in this location are not pipes. Please amend the report to use the term 'asset' (rather than 'pipe') for the existing Sydney Water assets. ***MHs in Hampden Street and Sutherland Avenue*** The capacity of the current system and the sudden change in topography between Sutherland St and Sutherland Ave mean that the Royston St branch becomes pressurised between Sutherland Ave and Trumper Oval. This pressurising results in maintenance hole (MH) lids lifting at Sutherland Ave and Hampden St, with two consequences: • additional overland flow due to stormwater surcharging out of the trunk system • safety hazards for pedestrians and vehicles with potential fall into a vertical opening. The Sutherland Street to Trumper Oval option has recommended	Reference to 'pipes' will be updated to 'assets' Comments on technical feasibility of this option are duly noted and we are happy to consider alternative options that may be considered more feasible. If Sydney Water can provide details of their alternate drainage upgrade concept, we can include this option (or a variation of this option) in preference to the current option in the final report. We do note the limitations of sealing of the manhole in Hampden St and have been investigating some alternative options to reduce the potential for surcharging in the interim. The outcomes of this assessment will be documented in the final report.

Section	Page	Comment	Response
		sealing of the MHs regardless of whether the trunk system upgrades are implemented, but without any assessment of the potential consequences: ‘it is recommended that the existing manhole cover in Hampden Street is “bolted down” as a minimum to remove the potential for personnel injury in this area.’ Such a recommendation should not appear in a floodplain risk management study without analysis and discussion of the potential impact. Sealing MHs on the trunk system will only result in pressure build- up and possible failure elsewhere in the system – potentially within private properties, and possibly even within private dwellings. If the study were to analyse sealing the MHs and the consequential impact, the study should also analyse the option of changing the current solid MH lids to grated openings (which would similarly ‘remove the potential for personnel injury in this area’). Note: Sealing MHs would not typically be acceptable to Sydney Water, as MHs exist to be able to gain access and conduct inspection and maintenance. Sealing MHs makes it impossible to conduct such necessary tasks. ***Augmented trunk drainage line*** The current experience of surcharging at the Sutherland Ave MH makes it clear that any measures to address capacity would need to amplify the trunk system from the intersection of Cecil La and Sutherland Ave down to Trumper Oval. The option recommends: • amplification of a Sydney Water asset from 0.9m to 1.5m – but in that location the actual size of the asset is 1.95m x 1.27m • amplification of a Sydney Water asset from 1.2m to 1.8m – but in that location the current asset is a 1.0m diameter asset at a	

Section	Page	Comment	Response
		grade of over 20% and under a multistorey apartment building • augmentation of the existing 1.1m diameter asset with a parallel 1.2m pipe, microtunnelled beneath existing private dwellings. As it stands in the report, the proposed option fails the 'technical feasibility' test set out in section 4.3 of the report. The existing assets invert levels at Sutherland Ave, Hampden St and Trumper Oval are only 3.0 metres below ground surface level. Based on the shallow depth of existing assets, Sydney Water would not support microtunnelling beneath these private dwellings, hence construction of a new line along road alignments to augment the existing assets would be the only technically feasible option. Sydney Water has conducted preliminary investigations of an alternate route along Cecil La, Hampden St, Roylston St and Trumper Oval to develop a preliminary cost estimate. Without accounting for service conflicts and relocations (which are likely to be substantial), our estimated cost for this option is $8.0 million. As a result, the BCR for this option would fall to 0.4 (and likely further with service relocation and asset conflict issues). The report needs to be amended to present a technically feasible option, and impact assessment of this altered asset arrangement would be required to determine the scale of benefit (and hence check the reduction in flood damage costs). Costs should be updated in the report. Sydney Water is open to working with Woollahra Council to determine whether there are any feasible and prudent measures to address the capacity issues of the Roylston St branch.	
5.7	82-83	This section should be updated to include: • Harris Street roadworks (on the proviso that Harris Street drainage upgrades are implemented)	Noted. These changes will be made.

Section	Page	Comment	Response
		• Comber Street roadworks (in conjunction with stormwater upgrades) • CCTV of bottlenecks, particularly the section from Prospect Street to Mary Place • discussions with City of Sydney Council regarding drainage upgrades at Boundary Street. These changes should also be reflected in the Draft Floodplain Risk Management Plan and in Table 8 (pages 112-114).	
7.3.2	107	Report states: 'Since the year 2000, 178 people have lost their lives as a result of flooding.' This statement should be improved to be clear that it relates to fatalities in Australia during the period 2000 to 2015.	Report text will be updated
Table 8	112	Cost and timing of implementation for the Sutherland Street to Trumper Oval option need to be altered: • cost to reflect a technically feasible option • timing for this option is unlikely to proceed within 6 years. Sydney Water wrote to Woollahra Council in September 2017 seeking input to our 2020-2024 capital works program but received no response. It may be possible to include the project in our 2024-2028 capital program, subject to prioritisation alongside other projects.	As noted previously, we are happy to work with Sydney Water to develop a revised concept of this option and document the outcomes in the final report. We will also update the implementation time to reflect potential implementation in the 2024-2028 period
Figures 9.1 to 9.3 and in Appendix B1		'100% AEP' is used when it should instead be '1 E/Y' or '1 exceedance per year'	Noted. References will be updated.

Table 2 Summary of the Paddington Society Comments and Responses

Section	Page	Comment	Response
2	4	Include Elizabeth Pl, Elizabeth St, George St and parts of Underwood St in list of “flooding problem areas”	Noted. This will be included.
5.2	30	Asks whether slow release detention option such as strata cells, storm brix or biofiltration systems have been examined.	Typically, these systems are designed to treat relatively frequent events (less than a 1 in 1 year event). Therefore, they are unlikely to afford significant benefits during major floods. Nevertheless, they do have the potential to reduce runoff during more frequent events and also serve to improve water quality. Therefore, they are worth consideration as part of future development of the area (e.g., works in roadways/footpaths). Will add a suggestion to this effect in the report
5.2.2	31	Suggests landscaping input and alternative “soft” options for detention would afford improved amenity, utility and beauty for the area and gain more support	The primary goal of the FPRMS is to assess the potential merits of each option. In this regard, only concept designs were developed to undertake the assessment. Those options that show merit will move forward and will be subject to more detailed design and investigations. This will include aspects such as vegetation. We will update report to note the importance of maintaining the amenity of the area and landscaping/soft options are a key consideration in this regard
5.2.3	34	Notes that area suggested for the Moncur basin is to be remediated, landscaped and added to the existing park after completion of adjacent building works. Suggest option be re-examined with landscaping input and suggests that terraced retaining walls could be explored	Please refer to above response
5.2.4	35	Landscaped trafficable slow release detention in pocket parks and cul-de-sacs have not been included and should be considered in the final study at the following locations: o Grassed community garden area at the Windsor St / Elizabeth St intersection o Cooks Paddock o Reserve at the eastern end of Sutherland St	As noted above, these sorts of detention systems are typically only designed to cater for relatively frequent events. Therefore, they are unlikely to afford significant benefits during larger floods and the overall benefit cost ratio is likely to be low. Nevertheless, we will explore the potential cumulative benefits of detention at all of these locations and document this in the draft report.

Section	Page	Comment	Response
		o Cul-de sacs adjacent to quarried cliff faces (e.g., ends of Roylston and Cecil St o Vacant grassed areas along the foot of the cliff at 4-8 Hampden St (adjacent to garbage bin storage):	
5.3.3	40	A high priority should be given to addressing flooding in this area (Cecil St). However, the mitigation measure must include urban design and landscape amelioration works integrated and designed from the earliest stages. Requests that more detailed engineering and landscape information is forwarded when available.	Noted. This area is currently the subject of more detailed design work. We will request Council include The Paddington Society in future consultation activities.
5.3.4	41	As capital cost of this option (Trumper Park Floodway) is small and the plant & equipment for 5.3.3 and 5.3.4 will be similar, suggests it would be more economical to undertake both at the same time or sequentially. Regardless of whether they are implemented as the same time, both options should be designed together and should incorporate urban and landscaping design. Requests that Council should allocate funding to undertake both mitigation projects. Also recommends that additional funding be allocated to Harris St drainage upgrade to improve the visual amenity of the existing culvert discharge point adjacent to 8 Hampden St.	This is acknowledged. Report will be updated to recommend design be completed together. It is understood that Council have set aside funding to undertake Cecil St work. This is currently in the detailed concept design phase. We will also include text to suggest modification to the culvert outlet as part of these works and/or 5.5.4.
5.4.3	47	Suggests this option (Trumper Park flow diversion) should be recommended and included in the design of 5.3.3 and 5.3.4	We understand that the detailed concept design for the Cecil St works includes these flow diversion works.
5.4.5	51	Adjacent former bakery building is one of the older significant buildings in Paddington and it is important that the historic fabric and interface are not negatively impacted.	Noted. This will be looked at during subsequent design stages
5.5.4	67	Recommends including additional landscaping at culvert outlet point	Refer response to 5.3.4
5.5.7	70	Echoes the sentiments of a number of residents in the George St/Elizabeth St area regarding significant flooding issues and requests stormwater upgrades deserves to be high priority. Indicates that the area was not included or assessed as part of the study. Requests that extension of investigation of this area be completed and implementation timeframe be significantly reduced.	As noted in other responses, the stormwater upgrades for this area will be modified to a high priority. The implementation timeframe if highly dependent on available funding. Given the high capital cost, funding for implementation of the full extent of works may be difficult in the short term (thus the extended timeframe). We will update the report to suggest that

Section	Page	Comment	Response
			implementation could be “staged” to allow the cost to be distributed over several years rather than a single lump sum. All sections of Paddington were included in the study area (including this particular area). The results of the flood modelling highlighted this area as a “problem location”, which is why mitigation options were investigated. A review of the additional flooding information received during the exhibition agrees with the results of the flood modelling completed and documented in the draft report. Therefore, it is considered that an extension is not necessary.

Appendix G

Upper Catchment Community Consultation

Paddington Upper Catchment Flood Survey

This survey has been prepared on behalf of Woollahra Council to better understand behaviour in the upper catchment of Paddington. Council will use the information you provide to validate the

The survey should take approximately 10 minutes to complete. Please give as much detail as possible (attach additional pages if necessary).

Please return the completed survey via email or mail by **Friday 22nd March 2019**.

If you have any questions, please contact:

David Tetley
Catchment Simulation Solutions
Suite 10.01, 70 Phillip Street
Sydney NSW 2000
(02) 8355 5501
david.tetley@csse.com.au

Michael Castelyn
Woollahra Municipal Council
536 New South Head Road
Double Bay NSW 2028
(02) 9391 7131
michael.casteleyn@woollahra.nsw.gov.au

Contact Details

Can you please provide the following contact details in case we need to contact you for additional information? If you do provide contact details, this information will remain confidential at all times and will not be published (refer to privacy statement at bottom of second page).

Name: ______________________________

Address: ______________________________

____

Phone No. ______________________________

Email: ______________________________

1. What type of property do you live in / own?

- ☐ Residential
- ☐ Commercial
- ☐ Industrial
- ☐ Vacant land
- ☐ Other (Please specify:______________________________)

2. Are you?

- ☐ An owner
- ☐ A renter
- ☐ A business owner
- ☐ Other (Please specify:______________________________)

3. Has your property ever been affected by flooding?

☐ Yes (if yes, please provide further details in the table below)

☐ No

Date of flood(s)		
Location of flooding (e.g., road in front of my house)		
Depth / height of flood water (e.g., 10 cm deep)		
How accurate are the flood depths / heights?	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)
How long did the flooding last (e.g., 10 minutes, 2 hours)?		
How was your property affected (e.g., carpet was damaged, structural damage, rising damp)?		

4. Do you have any photographs or videos of past floods?

☐ Yes ☐ No

If you answered 'Yes', a copy of these photos/videos can be sent to the following email address to assist with validation of the flood model (please try to keep the file size under 10 MB): david.tetley@csse.com.au

5. Do you have any other comments or information that may assist the flood model?

____

____

____

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Community Questionnaire Responses - Paddington Upper Catchment

#	Occupier Status	Has your property ever been affected by flooding?	Please provide additional information on your past flood experiences						Do you have any photographs or videos of past floods?	Do you have any other comments or information that may assist the flood model?
			Date of Floods	Location of Flooding	Depth/height of floodwater	How accurate are the flood depths/heights	How long did the flooding last	How was your property affected?		
1		N								On many occasions my car has been flooded. The gutters in Paddington Street frequently flood and the water rises above wheel level making access difficult also to rim of door
2	An Owner	N							N	
3	An Owner	N							N	No
4		N							N	Nearby George St has flooded in the past close to the Junction with Tivoli St. It was iunclear if the storm drains became partially blocked or were overwhelmed
5	An Owner	N								
6		N							N	
7	An Owner	N								
8		N							N	
9	An Owner	Y	7/02/2017	Road outside my house and the ground floor, lower ground floor and basement were all flooded as result of the drain outside our house overflowing	Over 1m	Medium	A couple of houses until the drain was cleared by Council	Almost $100,000 of damage was caused as a result of the flood. The property was uninhabitable for nearly 6 months	Y	We would ask that any future floodplain risk management alleviates tge risk of the drain at the bottom of Harris St (outside no 6 + 4 Harris St) from overflowing in the future and casuing significant damage to the surrounding houses
10	An Owner	N							N	Keep the leaves out of the gutter in Paddington St
11	An Owner	N							N	
12	An Owner	N								My only observation is the inability of the stormwater drains to remove rainwater in very heavy & extended rain periods - this can make it difficult over time to get from the road onto pavement
13	An Owner	N								I have lived in Sutherland St Paddington since 1984. Both my previous house, 167 and the house I live in now, 157, are on the high side of the street between Taylor and Elizabeth Streets, and neither have been affected by flooding What I have seen, however, is the immese amount of debris this water pushes down the gutters. The trees in Sutherland Street and now very large and the leaf drop, as well as bark and berries is substantial. The gutters are mostly full of leaves and bark and this buildings up around cars and around drains. There are various contributing factors to flooding, but unless the streets are properly cleaned on a regular basis, it will continue.
14	An Owner	N							N	The soil under our house is always damp and the house suffers bad, severe rising damp. Possible passage of water under house?
15	An Owner	Y		Road in front of my house	varies		Depends on the amount of rain. 10mins to 2 hours	No damage to property but impossible to leave and walk down the road. Can be like a river	N	
16	An Owner	N							N	This street is steep. The flooding occurs as the street flattens out a couple of houses below mine. The drain itselfs seems adequate.
18	An Owner	N								
19	An Owner	N								
20	An Owner	N								
21		N							N	Sirs: Thankyou for your thorough response to this issue. I own properties, 95 & 97 Hargrave Street, Paddinton and while flooding has never affected us - the houses are built on sloping rock and when there is excessive rain the water uns over that rock from the back to the front of the houses and seeps onto pavement in front of the houses. Also the dampness creeps up into the interiors of the houses. Ruth Barratt / rnbarratt@aol.com / 62 Hill Street / Uralla, 2358, NSW / Sent from my iPad
22		N							N	
25	An Owner	N								
26		Y	28/11/2018 -> 18/12/2018	1 Harris St	5cm within house	Medium	Minutes to up to 1 hour	Structural damage, rising damp, carpet, mould, floors, walls, kitchen - all damaged	Y	The flooding coninutued until Elizabeth Lane stormwater drain rectification works were performed on 18/12/2018. Videos & photographs are available (extensive) - provided to GIO/Suncorp. Please send USB and I will copy
27	An Owner	N								This [page 1 of questionairre] was the only page we received with the letter to the resident on 21st February
28	An Owner	N							N	From time to time, when these is heavy rain, the area around the interection of Windor and Elizabeth Streets is awash with water, in part because the drain outside Christopher Day Gallery (South East corner of intersection) is perpetually blocked with leaves because our streets are very rarely (if ever) cleared of leaves. This water washes across the road causing danger to traffic and sometimes builds up under parked cars and is high enough to enter the cars, causing damage to carpets and electricals
29	An Owner	N							N	
30	An Owner	N							N	
31	An Owner	N								
32		N							N	
33	A Renter	N							N	
35	An Owner	N							N	I have lived here for over 16 years and to date I have never been affected by floods.
36		N							N	
37	A Renter	Y	20/2/2019 + whenever it rains	Road in front of house. Telstra underground cable unit. Basement in house	0.5-8cm	High	Depends on the duration of rain	Shoes get ruined walking to car parked on the street. Basement mould, damage to stored items. Carpets/rugs damage. Rising damp. Bad smells from wet timber & concrete floor in basement	N	There are reeds/bamboo planted on sidewalk. This blocks the flow of water to the stormwater drain inlet on the street andcauses the water to flood across the street. Basement flooding is from underground water
38		N							N	It is amazing we have not been flooded because often there are so many leaves in the gutters it is hard for the water to drain away
39	An Owner	N							N	
40	An Owner	Y	Whenever a massive downpour. 2-3 times a year over the last 35 years	Water floding into the house from back garden outside in front streets as well as road floods. At worst, water flows all the way to the front door (likely 0.3-0.4m deep in road)	5cm flowing right through the house	Medium	0.5 hour plus - depending on the length of the downpour	No real damage as I have time/am at home to lift carpets/shoes etc from the floor - wooden floors easy to mop up	N	Water in back garden flows from neighbours property under fence and probably from the back lane into my courtyard. I have a sump pump outside the back door but it cannot cope with certain volumes of rain fall
41	An Owner	Y	1/12/2018	Back yard	8cm	High	20 minutes	No damage to property but impossible to leave and walk down the road. Can be like a river		I was concerned the water was not draining away. I went out to see if the drain was blocked by leaves to find that water was coming into my yard through the outlet drain rather than draining away. When the rain lessened the water began to drain away
42	An Owner	N							N	Regular cleaning of storm water drains
43	An Owner	N							N	Sometimes Sutherland Street in front of my house floods in extreme storms, but as yuet it has not inundated the sidewalk, which would lead to flooding of my house
44	An Owner	N								We have only been in this property since 2015 and have never encountered any flooding
45	An Owner	N							N	As a resident of 55 years I have occasionally seen heavy flow in the gutters due to rain, but nothing resembling a flood in the upper part of Paddington Street
46	An Owner	N								
47	An Owner	N							N	
48	An Owner	Y	24/08/2015	Back area - sitting room	15cm			Damage to carpet, underfloor heating, furniture (2 bookcases)	N	My house appears to cope with floods generally. On 24/8/2015 I was ankle deep at bus stop so that deluge was unusual. Next door - No 1 Harris St has always been more affected than No. 3
49	An Owner	N							N	I know it is hard keeping the inlet sumps to street drainage system clear. Is there a programme for the above??
50		N							N	
51	A Renter	Y		Moncur Street between Queen St and Hargraves Street	Gutter overflowing on pavement. 10cm plus	High	2+ hours	This flooding affects the passage along Moncur Street	N	I live at 204 Jersey Rd (apartment block). My apartment is on a high level so not affected by flooding. Flooding in car park after a heavy downpour (far from satisfactory for those using the car park)
52	An Owner	*								
53		N							N	
54	An Owner	N								We bought this house 2 years ago and have had no flooding

#	Occupier Status	Has your property ever been affected by flooding?	Please provide additional information on your past flood experiences						Do you have any photographs or videos of past floods?	Do you have any other comments or information that may assist the flood model?
			Date of Floods	Location of Flooding	Depth/height of floodwater	How accurate are the flood depths/heights	How long did the flooding last	How was your property affected?		
55	An Owner	Y	11/2015 & 1/02/2017	Stormwater drain in Hopetoun Street overfilled and adverse road camber trapper water and directed through rear of property	30cm	High	2 hours	The whole ground floor affected and overflow into cellar floor, carpets, cabinets, walls	Y	3 times in 4 months we reported Hopetoun St stormwater drain need cleaning. Still has to be done. Awaiting corrections to road camber in Hopetoun St
56	An Owner	N							N	Gutters in street overflow in heavy rain but flooding stops when rain eases and drains are able to cope
57		N								Keeping the kerbs swept regularly to remove debritus and leaves in Autumn would help enourmously. Regular sweeping
58	An Owner	Y	1/08/2015	House	5cm					Harris St floods (runs like a river) about 2-3 times a year in heavy rain. The road is usually about ankle-knee deep + flows fast, firstle eastwards towards the cul-de-sac (some down Elizabeth St + Lane) then around and into the lower side of Harris St, back westwards. My house flooded only one sice I've lived here (2005->). That was August 2015 when water came through from the back fence (i.e., Sutherland Ave) at about 5cm depth. We dried it all out afterward so no serious damage. I think a drain got blocked in the garden so probably partly our fault. We sent some photos when Council last asked us to, which are already included in your drafts docs. If we have more we'll send them too!!! Apart from the bottom of Harris St, dam near numbers 2-4, it alls stops pretty quickly once the rain ceases. The issue is the sudden fast-flowing water rather than standing water. No 1 Harris St got seriously flooded in the last big rain but I suspect that was the poor design/buildd as the previous building on the site never flooded
59	An Owner	N							N	
60	Rental Property	N							N	
61	An Owner	N								While I have not been personally affected by the floods in Cecil St, I have witnessed the frequent and severe flooding experienced by neighbours directly opposite me ie north side of Cecil St. Lots of damage to property and possessions (+cars)
62	An Owner	N							N	No flooding in 8 years
63	An Owner	N							N	
64		N								No actual flooding but the excess of water not capture overflows down william street
65	An Owner	N								There are underground stream, nearby that leak out onto street. I worry that basement digging could alter their paths to our house
66	An Owner	N							N	Street continually has water overflow from drains even in light rain. There is obviously a problem under Windsor Street
67	An Owner	Y	1/01/2019	Footpath on northern side of the road	10mm	Medium	2 hours	Not	N	Depth of gutter on the south side of Windsor St cul-de-sac is not sufficient, so that combined with intermittent concrete weheel stops causes major flooding of road surface.
68	An Owner	N							N	
69	An Owner	Y	1/11/2018	Cascade Street and rear dunny lane	4cm	High	1 hour	Basement flooding	N	
70	An Owner	*								
71		N							N	No
72	An Owner	N							N	Not a flood prone area
73	An Owner	N							N	
74	An Owner	Y	1/11/2018	Backyard into ground level of house	2cm	High	1 hour	Not affected as material finish is marble		
75	An Owner	N							N	
76	An Owner	Y	1984, 1989, 1991, 2012, 2015 (twice), 2017	In 1984 flooding from Oxford St down tunnel to 444-our house-where it flooded portion of ground floor. All other floods were down the laneway from Geirge St to old warehouse building and through it to Elizabeth Place	From Oxford St 1984: 10cm. From George St, up to 1 metre against warehouse wall and approx 10cm on warehouse flood	Medium	Approx 30 mins to an hour	Carpet damaged 1984. Warehouse contents damages - not badly - in later floods. Warehouse itself shows signs of moderate subsidence	N	Our house on XXXX has no street frontage and lies at the bottom of a carriageway from Oxford Street. The old warehouse on our adjoining block at 22 George Street, and part of the garden of our home at 444 Oxford Street, have been subject to flooding on various occasions since 1984, as indicated in the attached Survey. The flooding from Oxford Street only occurred once, we think in 1984, but the warehouse, which has a doorway onto a laneway to George Street, has been flooded on numerous occasions over the years, as have the adjoining property at 11 Elizabeth Place and the rear yards of various George Street terraces. As far as any other comments or information which may assist the flood model are concerned, we have noted, although only comparatively recently (ie in late 2018/early 2019) that a good deal of water seems to flow from Oxford Street into both George and Elizabeth Streets during rainfall events. This was so even during the relatively brief and not particularly heavy downpours which occurred on two occasions during this period. (And which did not flood the old warehouse.) The depth of water flowing from Oxford Street into George and Elizabeth on these occasions was probably no more than a few ems but, even so, it was apparent that a fair volume of water was entering the two streets from Oxford Street. Apart from this, I don't think we have any other information which might assist the flood model. However, as you may recall, I addressed a meeting of the Flood Advisory Committee last year, concerned that the flood mitigation proposals suggested in a Draft Plan then being considered, might not be practicable. I raised for consideration the possibility of regrading the Oxford Street ends of George and Elizabeth Streets and also the possible use of detention storage on the undeveloped land at the rear of the Oxford Street shops from nos 432 to 442. As you would be aware, nos 432 and 434 are presently the subject of DA 436/2016, and I note a proposal to install a pit of approx 40 cubic metres in capacity to cope with the additional run off likely to be caused by that development. If such a relatively small detention storage tank is sufficient to overcome the problem then it occurs to me that a larger one on the other properties might be a much cheaper solution to the flooding problems in the area than the drainage upgrade which had proposed. I would be grateful if these thoughts, inexpert as they doubtless are, might be kept in mind when the Plan for the upper catchment area is being reconsidered. I assume that before any such revised Plan is put up for adoption, residents will have a further opportunity to comment and I look forward to hearing about the meeting with residents mentioned at the last meeting of the E&P Committee.
77	An Owner	*								
78	An Owner	Y	1/11/2018	Sutherland Ave	4cm	High	1 hour	Rising damp	N	
80	An Owner	*								
81	An Owner	N							N	
82	An Owner	N							N	Nil
83		Y	13/12/2018	George St and the side of our terrace	50-60cm	Medium	30-45 mins	We have structural subsidence caused by stormwater effecting foundations. Stormwater entering house through side doors pours up-rooted and soil washed away as stormwater travelled down driveway next door	Y	We are at the lowest point of George St where the water is deepest. All this water travels down the side of our house and the driveway next door and runs out towards Elizabeth Pl. Although this passes quickly, the volume of the water is significant as is the damage it causes
84	An Owner	N								George St sometimes floods. We have a laneway at rear at house and this accumalates water at the bottom
85	An Owner	N							N	
86	An Owner	Y	Early 1970s 13/2/2010	Throughout the house, from Elizabeth Place, down the hall, out the front door to Elizabeth St. At rear of property from Elizabeth Place. Compelte inundation prevented by roller door, with towels padding bottom	Several inches through the ground floor Approx 0.5m on roll-a-door	Medium High	Up to about half an hour	Carpets saturated and itemised on flood damage claim assessed by GIO insurance Damage mitigated following previous floods by reconstruction of rear entrance	N	There have been several flooding incidents since those above e.g., August 2015 which also threatened to intrude but on all these occasions vigilence and a supply of towels have prevented the wholesale disaster of the 1970's incident. This does not prevent under floor mould and dampness after wet weather
87	An Owner	N							N	
89	An Owner	N	?	Infront of 136 Paddington St	Gutter overflowing 20-30cm	Medium	Days	Rising damp etc from our courtyard being flooded	N	It is not a flooding issue. It is simply a matter of better management of leaves and debris in the gutter that is constantly blocking the stormwater drains that leads to the gutters blocking and overflowing
90	A Renter	Y	28/11/2018	Jersey Road in front of my building	8-10cm	Medium	Not sure	No damage to building. Just difficulties of residents and car on street parking	Y	No comment. It's not happended frequently
91	An Owner	Y	20/12/2018	At the rear and underneath my house	~2cm deep	Medium	1-2 hours	Rising damp. Severe street flooding predomaintely front of house	N	
93	An Owner	Y	Various times. No idea of dates. No claims	Road & gutters in fron of house	25cm	High	Various. Depndign on downpour & speed of flow	Slight water on inside carpet. Door mat washed away	N	Virtually continuous flow of water everyday from topside of lane to our front door on the northern side. Leaf drop & parked cars & drain outlets in the lane add to the problem. Regularly a foul smell

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			Date of Floods	Location of Flooding	Depth/height of floodwater	How accurate are the flood depths/heights	How long did the flooding last	How was your property affected?		
95		N								
96	An Owner	N							N	Thus far, I have not been affected by flooding at all
97	An Owner									
98	An Owner	Y		Road in front of my house	under 10cm deep	Low		Rising damp	N	Our flooding is caused by blockages in the gutters. Occurs in heavy rail at both fron and back of our house (Victoria Place at back). These floods occur any time there is heavy rain.
99	An Owner	N							N	Please keep me informed as I am aware in heave rain the gutters overflow in out area (top of Cambridge St)
100	An Owner	N							N	
101		N							N	There are large flows along Paddington St flowing across the street from south to north outside nos 43 - 47
102	An Owner	N							N	
103	An Owner	N							N	
104	An Owner	N							N	
105	An Owner	*								
106	An Owner	Y	24/08/2015 08/02/2017 13/12/2018 20/12/2018	Road at rear of house & road at front of house	20cm (measured at rear door of house) 5cm 5cm 5cm	High High High Low	2 hours 0.5 hours 0.5 hours unknown	`- Flood waters entered house. Damage to door & floor boards causing rising damp. `- Flood waters in garage. Damage to storage, cupboards & personlised belongings . Minimal water entered house `- Water entered through garage & just into house `- Water entered through garage & just through rear door	N	We have had sub-floor fan forced ventilation installed to dry the area out and rid rising damp. During heavy rain Elizabeth St, Elizabeth Lane & Vials Lane flood. Prior to us owning house we are of flood waters entinering the home of 10/4/1998, 1989, 1991, 2010
107	An Owner	Don't know								We are recent owner, having bought in Jan 2018 and are not aware of any previous floods
108	An Owner	N							N	Our street does have rising water after heavy rain, but this is due to blocked stormwater drains
109	An Owner	N							N	No - I have lived in Paddington since 1971 - have never witnessed a flood in that time
110	An Owner	N							N	No
112	An Owner	Y	13/02/2010 24/08/2015	`- Back. Photos taken by Gary Dale - Couyncil worker who inspected 14/02/2010 `- Back Photos provided to Mr Tetley 28 Aug 2015 of 21 Elizabeth St & Elizabeth REPLACE	`- Carport: 60cm. Shed: 10cm `- Carport: 40cm. Shed: 4-5cm	Medium	Overnight on both occasions	`- Car damaged water in back & front (5cm front). Tools destroyed `- Power tools destroyed	Y	House is always damp down stairs, mould can be problem. Under floor fans installed. Large Tree in 23 Elizabeth could be blocking drains. DA436 could exacerbate problems of flooding. Water pools in Elizabeth St (21-27) after heavy rain
113	An Owner	N							N	We have owned 129 Queen St for 27 years and it has never flooded. This property is towards the crest of the rise (crest being Oxford St) and is on sandy soil. It has never flooded and all water runs off it down towards Quarry st and into Trumper Park - a distance I estimate to be about 1km
114	An Owner	Y	28/11/2018 20/12/2018	`- Front of house (Paddington St), Taylor Street (Adjacent to house) `- Paddington Lane, Taylor St, Paddington St	10 - 15cm	High	Hours. Residual water sits in Paddington St for weeks and smells foul	`- Some water in garage `- Water in garage . Excess water above the curbs in Taylor St		Very much appreciate the Council engagement,& pursuit of strategic solution. As an interim option, the various drains in Taylor St, Paddington St need far more frequent attention for they are full of leaf matter. In even a moderate rainf the flow is so blocked it raises above the curbing
115	An Owner	Y	Various, when there is heavy rain	Road in front of house + front courtyard	up to 5cm	Medium	Over a period of a couple of hours until the rain stopped	Flooding in the courtyard. Floorboards in the house that adjoin courtyard have been water damaged. Musty smell under the house	N	Heavy rain causes the water level to riuse on the side of the street. The drain in courtyard cannot cope with the heavy + constant frequency of water flow, hence it backs up in the house
116	An Owner	Y	15/4/2015 10/6/2004	`- Down Sutherland Street, through 2 Forbes St & footpath over my strata wall `- Down Sutherland Street from Jersey Road, through 2 Forbes St, to footpath of Sutherland St over boundary wall onto my balcony	10cm	High	3 hours	All carpets, curtains. We repalced walll 3 feet higher	N	I have enclosed my letter to Woollahra Council dated 21/1/2019 and response from Woollahra Council dated 22/1/2019. Since then I have heard nothing referring to levels in courtyard of 2 Forbes St
117	An Owner	N							N	
118	An Owner	N								No paddington lane is built on a slope and water runs down the slope (Taylor St), through Sutherland St/Quarry St and into Trumper Park. No6 Paddington lane has not flooded in the 30 years I have owned it
119	Business	N							N	No sorry
120	An Owner	N							N	
122		Y	Constantly	in front of my property footpath	15-20cm	medium	Stays for over a day	no effect to property	Y	Photo attached of approx puddling size. I cannot step outside my property without jumping over the puddle. It can be dangerous/slip hazard (with my heels when leaving my properties). Could someone please attend to this issue before I or someone else slips onto the floor
123		N								
124			Heavy rain	Road in front of my house.	5-10cm	Medium	Until rain stops & washes away	Pedestrian access from the street impacted. Street only, not our property	N	More like very deep puddles then flooding
125	An Owner	N							N	No
126	An Owner	*								
127	An Owner	Y	?	Whenever there is heavy rain, leaves in the gutter and leaves in drain at Paddington St, Paddington Ln intersection flooding onto footpath & road	20cm	High	While it rains sustained but drains away quickly once rain stops	Rising damp & wall instability along Paddington Lane	N	Uneven footpath & gutter cause water to collect (unable to drain away) down at Paddington Lane i.e., footpath side inadequte to cope with water running down Paddington Lane system
128	An Owner	Y	12/04/2016 Late 1980s	`- Courtyard lower level `- Basement	`- 60cm `- 10cm	Medium	`- Until pumped out ~ 2 hours. `- Water removed manually	`- Furniture soaked. Reaction on slate flood. Threw soaked stuff in storage out	N	Property has to have pump to avoid repeated flooding when major downpour
129	An Owner	Y		Corner of Cascade & Paddington St	1-2 feet		as long as it rains		N	
130	An Owner	N							N	
131	An Owner	Y	Each time there is a lot of rain	Backyard. Coming close to enter the kitchen	8cm	Medium	a few hours	Rising damp	N	
132	An Owner	Y		Lane at back of house, back yard and cement slab	6cm deep	High	2 days	Water damage	N	Neighbour installed gravel/pipe drainage which greatly improved the problem
133	An Owner	N							N	Windsor St (cul-de-sac) historically has poor drainage. Accumlation of leaf matter in gutters heightens the issue during periods of heavy rain. Improved/wider drains and more regular street sweeping would mitigate the issue
134	An Owner		After rain & constant run off down wall from 73 Hargrave	Underneath no 73 Hargrave St is a 'stream' which constantly runs. The floor & joist had to bereplaced in about 2010 & a 'blower' is used to aerate under floor. The water constantly seeps through the wall on Hragrave St and causes the path to be wet & slippery most days	Considerable water is discharged to the drain (storm water pit) outside no 69 during dry weather. Overflow occurs in wet weather					The hard surfaces e.g., driveways replacing earth, garden & trees is causing more run-off & flooding esp down Elizabeth St, cnr Hargrave & Cascade. The 'stream' under no 73 is damaging the wall on Hargrave St and the constant damp slippery from constant seepage
135	Other	N								
136	An Owner	N								The property is tenanted. I have not had any reports of flooding during the years of ownership
137	An Owner	N							N	
138	An Owner	N							N	No
139	An Owner	Y	2015 & before	Rear of property in cul-de-sac area eastern end of Sutherland Ave	Varies		Minutes	no internal damage	Y	There has been no serious flooding since 2015-2016 but we still get an overflow down wall & the stairs (see video) and into the cul de sac area because the street here and above is never cleared of leaf matter & debris (there is a huge ficus) and it blocks the drains.

#	Occupier Status	Has your property ever been affected by flooding?	Please provide additional information on your past flood experiences						Do you have any photographs or videos of past floods?	Do you have any other comments or information that may assist the flood model?
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140	An Owner	N							N	The condition of road side rains is critical when rain is heavy. In 30 years I don't ever recall seeing a drain cleaning in action. Many drains are in a sorry condition and overflow in heavy rain.
141										To whom it may concern I recently received a notice regarding comments to be made re councils storm-water drainage. I am the owner of 17- 19 Paddington st Paddington and would like to advise that your current 100 year RL is incorrect as it assumes that there will be an accumulation of water above Paddinton Street which could cause a flood into the surrounding property's. my question to you all is 1) how does stormwater rise on Paddington street without running down Cascade street plus adjoining lanes and streets that are lower. If this is possible please advise how 2) this council has been around for a very long time, You would think a regular maintenance service or cleaning the stormwater drains plus possibly clearing the leaves before they enter the stormwater system...... or even better updating the drainage system to accommodate your envisaged 100 year report would be a good idea.
142	An Owner	Y	Every single time it rains the gutters outside our property flood is no drain and we are the lowest part of Paddington in this area	In the gutters outside the front of 124 Paddington St the water can't escape so it pools there. Parking your car means you step out into water as it backs up at least a metre…i.e., past drivers door	About 17cm	High	Will last for weeks unless I go out with a broom and sweep it further down the road where there is a slope. 124 Paddington St is near the lowest part of the street with no drain and no run off!	Terrible dampness, mildew on clothing, rising damp…nothing dries out on the south side of the house…green steps/moss	Y	I am so pleased the council is finally addressing this problem. I contacted Michael Castelyn (via email 13 Feb 18) with photos and concerns! The gutter outside our house is at the lowest point in the street and much of the water pools here and it becomes stagnant and absolutely stinks over the summer. If drainage was provided or a levee put in to push the flow of water further down the street our problem would be solved! Thank you
143	An Owner	Y	20/10/18 28/11/18 13/12/18 14/12/18	In house	5cm	Medium	Minutes up to 1 hour	Structural damage, mould, floors/walls/kichen/carpets/contents damaged. Catastrophic damage. Large insurance claim	Y	Subject of large insurance claim with GIO/Suncorp.Extensive videos & images available. Since Council rectification works on 18/12/18 at Elizabeth Lane stormwater drains, no further water entry has occurred. GIO repairs authorised
144	An Owner	Y	Every time there is heavy rain	Road in front of house	10cm?	Low	While the rain is heavy	Not at all	N	Every time there is heavy rain the road in front of our house (Paddington St) floods
145	An Owner	N								
146	An Owner	N							N	
147	An Owner	N							N	
148	An Owner	Y	7/02/2017 + many other occasions	Road in front of my house & stairs down the side of my house	app. 50cm	Medium	Maybe 2 hours. Mostly 1 hour	The water pours down the side of our house floods the side garden bringing tons of mud	Y	The front of our house is the lowest point on the Woollahra side of Paddington & all roads lead to our house. The stormwater drain next to us becomes full very quickly and the water pours over the wall down into Sutherland Lane which becomes a river. These floods happen about once a year. No-one is on most occasions but I have sent some photos of one when we were home on the 7th Febuary 2017. My daughter was home during another flood maybe in 2016 when the water came halfway up the side of her car which was parked in Forbes St outside our front door. She was advised to leave the car to dry out for some days and luckily it started after that. After these floods our lower courtyard is inches deep in mud and rubbish which takes a big job to remove.
149		Y	Late 2014	road in front - comes up tp front wall a caused damp/damage	TBA			Wall plaster on 2 walls needed to be replaced. Constant damp	Already provided	
150	An Owner	Y	Many years ago - 1984-1986	Back Lane. Off Queen Rd (Underwood Lane)	10cm	Medium	10 minutes plus	Flooring, parquetry replaced	N	
151	An Owner	N								
153										
154	An Owner	N							N	
155	An Owner	N							N	No
157	An Owner	Y	Recurring	Storm drain on corner of Underwood Lane (rear 53 Paddington St) & adjacent 38 Dudley St				Water flowing into garden	N	Storm drains reaches overfloowing during torrential rain & takes some time to drain - maybe partially blocked as has not been cleared for many years. Thank you
158	An Owner	N							N	
159	An Owner	Y		Under house			?	Sometimes rugs feel damp & form mould (so no rugs now). There may be structural damage because I experience slight reverberations from trains in transit	N	At Sutherland Ave Paddington, along with 35, 33 and possible 29 have experienced water under the homes. Twenty years ago a friends capenter husband was going to fix the joist under the house & stepped into water that reaches to the base of his calf. I think this row of houses are built above a watercourse running to Rushcutters Bay. Rain no doubt contributes . 35 Sutherland Ave put in a couiple of pumps in a total renovation which may have stopped that amount of water pooling again
160	An Owner	N							N	No
161	An Owner	N								
162	An Owner	Y	?	Road, footpath & pathway at entrance to my property	2-4 cm	Low	1 hour	Rising damp	N	
163	An Owner	N							N	Corner of Windsor Street and Cascade Street can flood in heavy/persistant rain. Seems to overflow from drain and leaves in gutter
164	An Owner	N							N	
165	An Owner	N							N	Not specific
166	An Owner	N							N	
168	An Owner	N								
169	An Owner	y	January 1989 (x2) Feb 2003 August 2015	Lower ground floor + stairs. Water came down Hargrave & from Surner St	`- 1.5m (1989) `- 0.5m (2015)	Medium	1-2 hours	Considerable damage to floord cupboards, carpet on stairs		Surveyors report when we bought house in 1971 said flooding occurred in 1960s, unlikely to re-occur. All houses from 8-16 Hargraves St were flooded in January 1989 - this was the worst flood. We carried out drainage protection in 2005 to keep insurance policy. Drainage in Hargrave St improved in 1990s(?)
171	An Owner	N								Hi! Michael, I just had you on the phone 10:45 AM Friday 8th March. Good luck with the drainage, regards!
172	An Owner	N							N	No
173										
174	An Owner	Y	25 April 2015 15 December 2018 20 December 2018	Road + footpath on the southern side of Sutherland St. Flooding has become worse at Sutherland/Elizabeth St junction	5-10cm	High	Time of rain event + ~10mins	Rising damp + local flooding of lower courtyard	Y	Flooding occuyrs more frequently during smaller rain events since drainage works were completed at the junction of Elizabeth and Sutherland Streets. The new storm drain redirects significant volumes of water from Elizabeth + down Sutherland
175	An Owner	N							N	
176										[Rude and nonsense reply]
177	An Owner	N							N	No
178	An Owner	N								The garage that backs on to Sutherland Lane gets wet during heavy rainfall but not flooding
179	An Owner	N							N	
180	An Owner	N							N	No
181	An Owner	N							N	No
182	An Owner	N							N	Your RL's levels outside my home on paddington street are not accurate. You assume that water will accumulate above paddington st - which is on a hill. How?
183	An Owner	N		Everytime we have heavy rain, water pours out of the stormwater drain in front of 35/37 Windsor St and flows across the road filling the gutters and occasionally seeping onto the lawn					N	Re position concerte blocks on 'odd' side of Windsor St so a)they can be swept properly or provide council workmen with smaller brooms allowing rain water to get away more quickly. In general sweep the street more eficiently
185	An Owner	N							N	
186	Business	N							N	
187	An Owner	N							N	
188	An Owner	N								Flooding has occurred in the area of the stormwater drain in Forbes Street near the steps leading to Sutherland Avenue. Our street gets a lot of leaf debris from the trees. Council sweeps the street but gutters are seldom cleared which means all this debris goes to the stormwater drain - blocking it when a deluge of rain occurs.
190	An Owner	N							N	Paddington Street is on the hill and so not subject to flooding
191	An Owner	N							N	
193	An Owner	Y	Severe weather event 2018 (?)	into side of house from foot path + gutters (poorly graded)	1-2cm (we were home so kept mopping up wat to avoid depths)	Low	6-8 hours	Walls, flooring (hard), mould following, damp	N	Please improve the grading + flows of the water on footpaths + gutters so the water flows away from the houses + does not accumulate so can seep into houses

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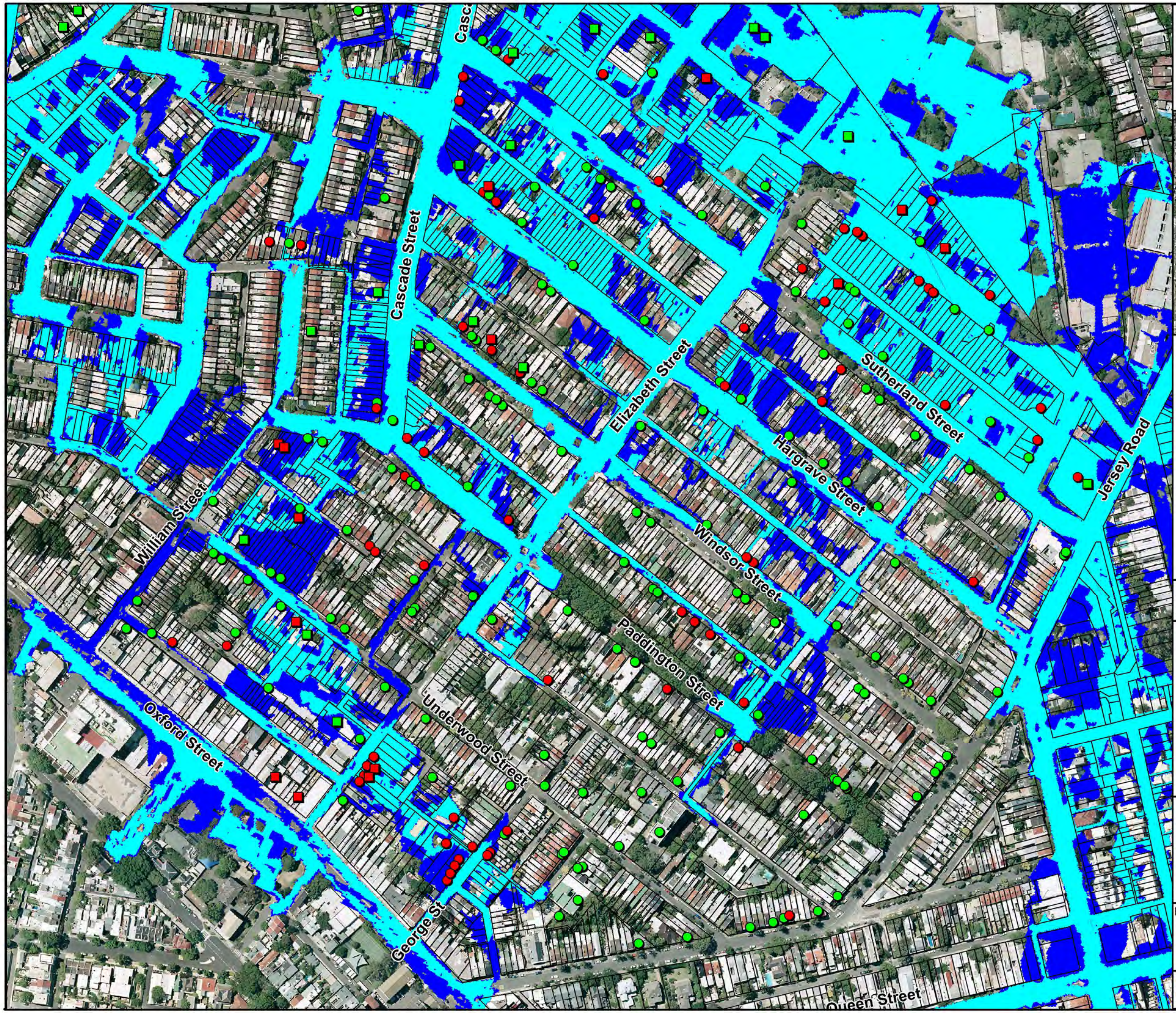
194	An Owner	N							N	Drainage at top of Harris St which is quite steep is not kept clear of leaves - more regular drain clearing would prevent overflow when hit by downpour
195	An Owner	N							N	
196	Other	N							N	
197	An Owner	N								No
198	Rental Property								N	
199	An Owner	N							N	Flooding occures near/outside propertiesno 8, 10, 12 George St as the road dips - the is only one drain on that side of the road. There needs to be another drain at least as there are two on the opposite side (no flooding there)
200	An Owner	N								
201	An Owner	N							N	No
202	An Owner	N							N	
203	An Owner	N							N	No
204	Rental Property	N							N	No thank you
205	An Owner	N								No
206	An Owner	N								
207	An Owner	Y	Every heavy rainfall	footpath in front of my house	5cm deep	Medium	Few hours	Cannot access property without paddling through water pooling	N	If the foootpath drains were regularly cleared rather than being filled with Council tree litter then the flooding on footpaths would be alleviated
208	An Owner	N								
209	An Owner	N							N	
211	An Owner	N							N	There is often a terrible stench coming from drains into gutters in Victoria Street and on Oxford Street between the traffic lights at Mitre 1- and those near Paddington PS
212										4th Letter!
214	An Owner	N							N	Flooding does not happenat the top of cascade street!
215	Other (director of owner)		Concurrently with rain	Front of house	Low			Carpet. Risng damp	N	It seems the while of Paddington is affected. You can hear water flow / underground streams / as you walk along Sutherland St. Any minimisation will be welcome. Diversion of underground streams?
216	An Owner	N							N	
217	An Owner	N							N	
218	An Owner	N							N	
219	An Owner	N								
220		N								
221	An Owner	N							N	
224	An Owner	N							N	No
225	An Owner	N								
226	An Owner	Y		George St quickly becomes awash whenever we have a heavy downpour. If rain lasts longer than 30mins or so water inundates the footpath in parts, another grate near Tivoli St did keep but has not rectified the situation				My house has not been affected as there is a step up from the footpath	N	Regular cleaning of footpaths and debris would keep stop flooding happen so often. Even so, the volume of water is just too great for drain capacity at times.
227	An Owner								N	Our street floods in excess large storms, but generally it drains quickly
228	An Owner								N	Our street floods in excess large storms, but generally it drains quickly
229	An Owner	N							N	There has been a lot of work done in Hargrave St to upgrade stormwater pipes and increasing the width of the footpath to move the water away from the fronts of houses. This seems to have been very effective. Prior to this water used to flow down the lower footpath in very large quantities
230	An Owner	N								
231	An Owner	N								No report of flooding by tenant living in the premises (only broken skylight)
232	An Owner	Y	?	Road/footpath at home	?	N/A	2 hours	none	N	If you cleared the street/gutters of leaves some time - or more - the gutters coiuld do their job and the pipes from our property and others could flow to gutter. Similarly, you could deal with the half dead tree outside our property , I have repeatedly complained about as this also feeds the gutter as well as damaging power lines
233	An Owner	N							N	No
234	An Owner	N							N	There is a continuous stream of water running down Hargrave Lane. It is always flowing and makes the pavement slippery
235	An Owner			In front of my house	5cm	Medium	4 hrs	No	N	Flooding occurs only a few times per year due to poorly maintained drains. Harris St drains are often covered with leaves
237	An Owner	N							N	
238	An Owner	N	Have no accurate details	The drain across the road would be overwhelmed in heavy downpours. Elizabeth Place has no gutters	8-10cm then run along the Place	Low	It could last from 10 minutes to about 12 hours	No damage to my property - though it has been subject to rising damp	N	The Council should be fully aware that Elizabeth Placeis just an alleyway - it is not a street or a lane. It was no footpaths or curb & guttering
239	An Owner	Y	1985-89 (5 times) 2016	water entered from road	10cm	Medium	10-20 mins	Carpets replaced 3 times. Carpets soaked, lengthly drying out		After the flooding in 2016 owners of 9-16 Sutherland Ave lobbied Council for improvement to drains and angle of road surface. This was carries out and drainage has been substantially improved.
240	An Owner	N							N	The property has been affected by water but from roof-blocked gutters occassionally because of the large eucalypt at the rear of my property located on council land
241	An Owner	Y	27 November 2018 5 October 2018	Back sitting room/kitchen & dining	<1cm deep	High	Approx 1 hour	Caught early so less damage (had towels on the floor floor rug got wet). Damage skirting(had to be replaced) + floorboards + damage to floor rug + furniture	N	Extra drainage on Wentworth Lane would be helpful in mitigating further flooding. There was one other instance of flooding sometine in 2016 which resulted in damage to our roof in our back sitting area. We since had the roof replaced and have not had any issues since then.
242	An Owner	N		In front of 43/41 going to other side of road (south->north)	1-2cm constant flow in rain		as long as rain continues	The problem has been alleviated with the instalaltion of a large drain corner of Cascade and Paddington	N	No
243	An Owner	Y						Rising damp - continuous use of extractor fans required	N	As we are on the top of the Paddington hill the issue is more street flooding. Poor drainage along with tree debris make a stinking mess throughout the rain season. The street + footpaths become dangerous to walk on.
244	An Owner	Y	Feb 2010 August 2015		10cm	Medium	A few hours	It flooded from the back and came through the house	N	A council worker took some photos of the 2010 flood
245	An Owner	N							N	I do have an issue infront of my property footpath with a puddle approx size one inch deep and across my property, when ever it rains. The concrete is not graded properly and has made me almost slip/lose balance. Please attend this, photo attached
246	An Owner	N							N	
248	Rental Property	N							N	
249	An Owner	Y	2018 2017	Each time when it rains heavily, basement of our property is flooded	3-10cm	Medium	constant. We have a bilge pump to get rid of water in basement	Basement is very damp	N	
252	An Owner	N							N	
253	An Owner	N							N	
255	An Owner	N							N	Elizabeth Place is at the rear of our house and we are worried that any excavation nearby could jeapardise the flow of the natural watercourse flowing across that area
256	An Owner	N								
257	An Owner	N								
258		Y	On all occasions	Yes. Floods overflow property at 96 Jersey Rd. Damage on walls in front room of property - climbing dampness	at least 10cm depth	Medium		rising damp on walls. Blocked drainage from street overflows stormwater drains		On all occasions when we have a heavy load of rain the off street drains overflowback into the property- the walls are paint peeling from the rising dampness
259a	An Owner	N							N	
259b	Business	N							N	
260	An Owner	N							N	
261	An Owner	N							N	
262	An Owner	N							N	My property is in the elevated area near Oxford St and run off via street is satisfactory. Having lived here since 1961 I know only lower Paddington and Oxford Street near Greens Road are affected - perhaps [illegible]/Cascade St corner

#	Occupier Status	Has your property ever been affected by flooding?	Please provide additional information on your past flood experiences						Do you have any photographs or videos of past floods?	Do you have any other comments or information that may assist the flood model?
			Date of Floods	Location of Flooding	Depth/height of floodwater	How accurate are the flood depths/heights	How long did the flooding last	How was your property affected?		
263	An Owner	N							N	No
264	An Owner	Y	Don't know	Don't know	Don't know	Don't know	Don't know	There's stuctural damage	N	Sorry No
265	An Owner	N							N	There have never been floods in Sutherland St. I have been here 17 years
266	An Owner	N								
267	An Owner	N							N	In 1980 or 1981 I lived at 53 Windsor St when it was severely flooded (in summer). The flood lasted for hours or timber flood had to be completely replaced
268	An Owner	N							N	16 Cook Rd is in an elevated position near the corner of Moore Park Rd. Flooding may be more likely in the gully at Cook Rd/Darvall St or at the bottom of Cook Rd/Lang Rd at Moore Park
269	An Owner	Y	March 2014 April 2015 August 2015	Royalston & Hampden. Manhole cover in Hampden	10cm depth in laundry					
270	An Owner	Y		Manhole at the foot of the flats at 28 Sutherland St at junction with Cecil Lane	Front porch is flooded					Manhole cover is not barricaded like Hampden St
271	An Owner	Y	2017 2018	Garage	10cm	medium	0.5-1 day	Rising damp, paint peeling	No	Not specifically but there's constant water flow in Hargrave Lane not weather triggered. It seems to start at 140/142 Hargrave St and goes down to Elizabeth St. It's a significant amount of flow constantly
273	An Owner	Y	Regularly during past 43 years at time of intense rain	Road in front of house	300-400mm	High	During periods of heavy rain & ~10minutes after	Carpet & furinture damage during worst occurences. . Residual damp following flooding	No	Water enters Harris St from Elizabeth St, Elizabeth Lane & over cliff from upper Harris St. Exits via divided section of Lower Harris St
274	An Owner	Y	1986 1987 (twice) 2015	The first 3 floods, water came through front door on middle level and then tralled through floor and stairs to lower level. 2015 through front door hall + front room	Water leve at front door approx 63 cm	Medium	46 mins to 1 hour	First 3 - carpet, repair to flooring. A new kitchen as it was so damp the cupboard fell off the wall	N	these floods were devestating. Tow level of my house (3 levels) were unlivable while I waited for repairs. The reason the fourth flood was not so bad is because I had a security door installed with a soild base so water now only trickes through
275	An Owner	N							N	N/A
276	A Renter	Y	Any time it rains	The road in front of my house in Paddington St	10cm		Water stays for days sometimes	Makes it very difficult to get to & from the car on the street - especially carrying our baby	N	Constant swelling of water on the road is a continual annoyance. Our street is very leafy with many trees deciduous. The water sits in the gutters and stinks. The drainage is not sufficient to clear the gutters after even a light rainfall. We need this fixed please.
277	An Owner	Y	2012 & 2013		2cm		I had to remove the water with towells	Floor baords are warped	N	The trees should be removed and replaced with trees with less invasive roots
278	An Owner	N							N	We moved into the property June 2018 so not sure if any flooding occurred previously
279	An Owner	Y	Dec 2018 March 2019	Front of house, under door, road in front + on porch	few cm		5-10 minutes	wet floor boards, stove of front porch marked	N	N/A
280	An Owner	N							N	I am aware that alterations to nearby common land eg Rushcutters Bay, may affect tidal inflows and water dispersal in the future. In times of bad storms, volumes of water flowing down Hasgrove St may affect the basement area if they are excessive
281	An Owner	Y	Any day with heavy rain	Rear of home (side facing towards Hargrave Lane)	5cm	High	While it rains	Water comes into kitchen	N	
282	An Owner	Y	August 2015 On going for at least 10 years	`- Water reached doorstep upper edge as drainage was blocked due to rennovations '- Windsor St gutters on north side of street overflow in heavy rain, making it impossible to walk across road to car without getting wet to ankles and above	10cm 10cm	Medium Medium	As long as rain persists then 10 minutes more	none	Y	Pics + videos sent by email 24/3/19 to CSS + WMC
283	An Owner	N							N	No, however I am aware that the southern end of Elizabeth Place is worse off. Neighbours whose garages are situated at the southern end flood in heavy rain
284	An Owner	N							N	Ensure storm water grills are kept clean and free from debris. PS I received this mailing 3 times
285	An Owner	N							N	
286	An Owner	Y	Approx late 80s-90s	From upper road down cliff and steps and into my house. Insurance claim	Destroyed carpet in from section of house		Approx 15-30 mins	Carpet	N	No
288	An Owner	Y	March 2019 + other heavy rain events	Front wall of our house - flood water cause sand in the sandstone wall to seep out	N/A				N	All the flooding occuring in Paddington - especially around Sutherland, Elizabeth and Cascade Streets - is largely due to the failure of the Council to properly clean gutters, rendering the drains totally ineffective when it pours. Services have coutneracted so far that residents try, but fail, to fill the breach. Clean the gutters, drains will works, no flooding
289	An Owner	N								
290	A Renter	Y	Many dates	Few times a year for over a decade in front and in the garden	500mm+	High		Damp, wood rot, mound, rising damp	Y	Have sent them and have saved many
291	A Renter	Y	August 2015 Sept 2015 December 2015 March 2015 December 2017 December 2018	George St in front of house	500mm	High	Depends on the duration of rain + 30mins	Damp, water damage, replace carpet, dryer machine Dec 2015: Damp course, dryer machine	Y	Already sent them. There is flooding every year wioth damage to cars & homes
292	A Renter	Y	Many dates	George St, in front, in garden	500mm+	High	Depends	Damp, wood rot, mould, rising damp	Y	Have sent them and have them saved
293	An Owner		Many - every year	Cellar and in front	100-300	Medium-high	Don't recall	Damp problems		
294	An Owner	N							N	I have resided at this address since 1989 and am unaware of any flood damage from natural causes during that time. The street did sustain hail damage from the 1999 storm causing mainly roof damage
295	An Owner	N								



LEGEND

- 1 in 100 Year Flood Extent
- 1 in 1 Year Flood Extent

Has flooding been experienced?

2015 Questionnaire
- No
- Yes

2019 Questionnaire
- No
- Yes

Notes:

Aerial photograph date: January 2014

N W E S

Scale 1:2,700 (at A3)

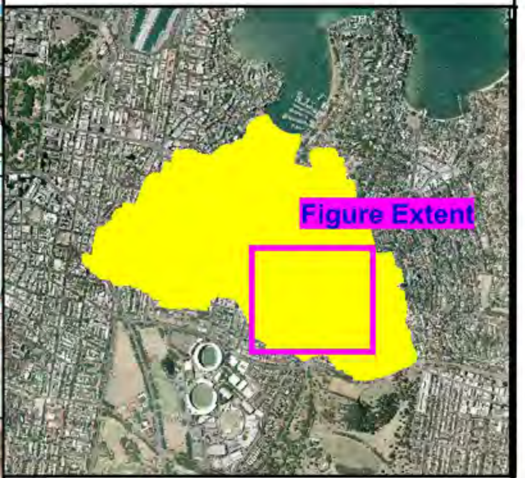
0 0.08 0.16 Km

Figure G1: Spatial Distribution of Upper Paddington Catchment Questionnaire Responses

Prepared By:

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

File Name: Fig G1 - Spatial Distribution of Upper Paddington Questionnaire Resp.wor



LEGEND

Reported Flood Depth (metres) ● Simulated Flood Depth (metres)

August 2015 Flood Simulated Depths (metres)

- < 0.1
- 0.2
- 0.3
- 0.5
- 1.0
- 2.0
- 3.0

Notes:

Aerial photograph date: January 2014
Flood water depths only shown within Woollahra Municipal Council LGA

N W E S

Scale 1:2,700 (at A3)

0 0.08 0.16 Km

Figure G2: Reported Upper Paddington Catchment Questionnaire Depths for August 2015 Flood

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

File Name: FigG2 - Reported Upper Paddington Catch Depths vs Aug 2015.wor

Paddington Floodplain Risk Management Study & Plan

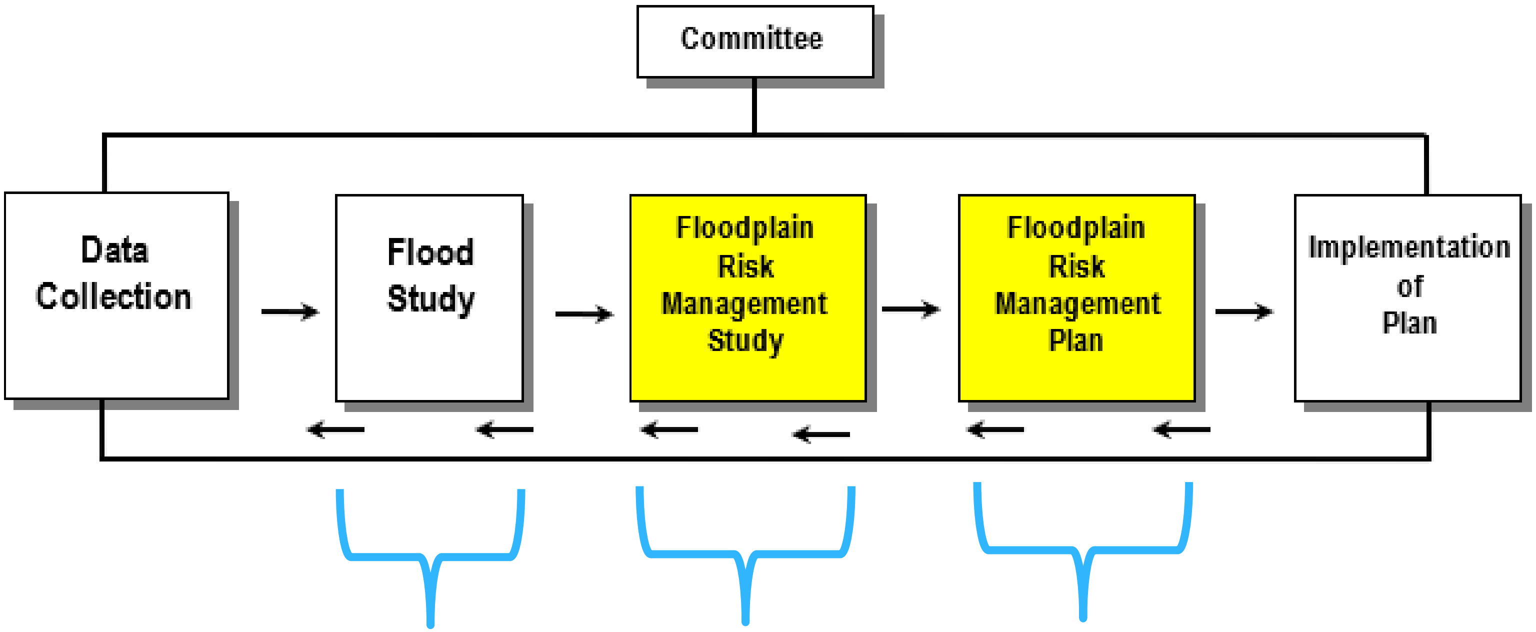
Community Briefing

Why Prepare a Flood Study and Risk Management Plan?

- A flood study and risk management plan helps us to:
  - Identify areas prone to flooding in various types of storms
  - Understand flood behaviour in flood-prone areas
  - Identify and consider measures to address and minimise flood risk and damage from flooding

The Floodplain Risk Management Process

Floodplain Risk Management Process



Identifies the flooding "trouble spots"

Evaluates different options for better managing the flooding problems

Prioritise options for better managing the flooding problems

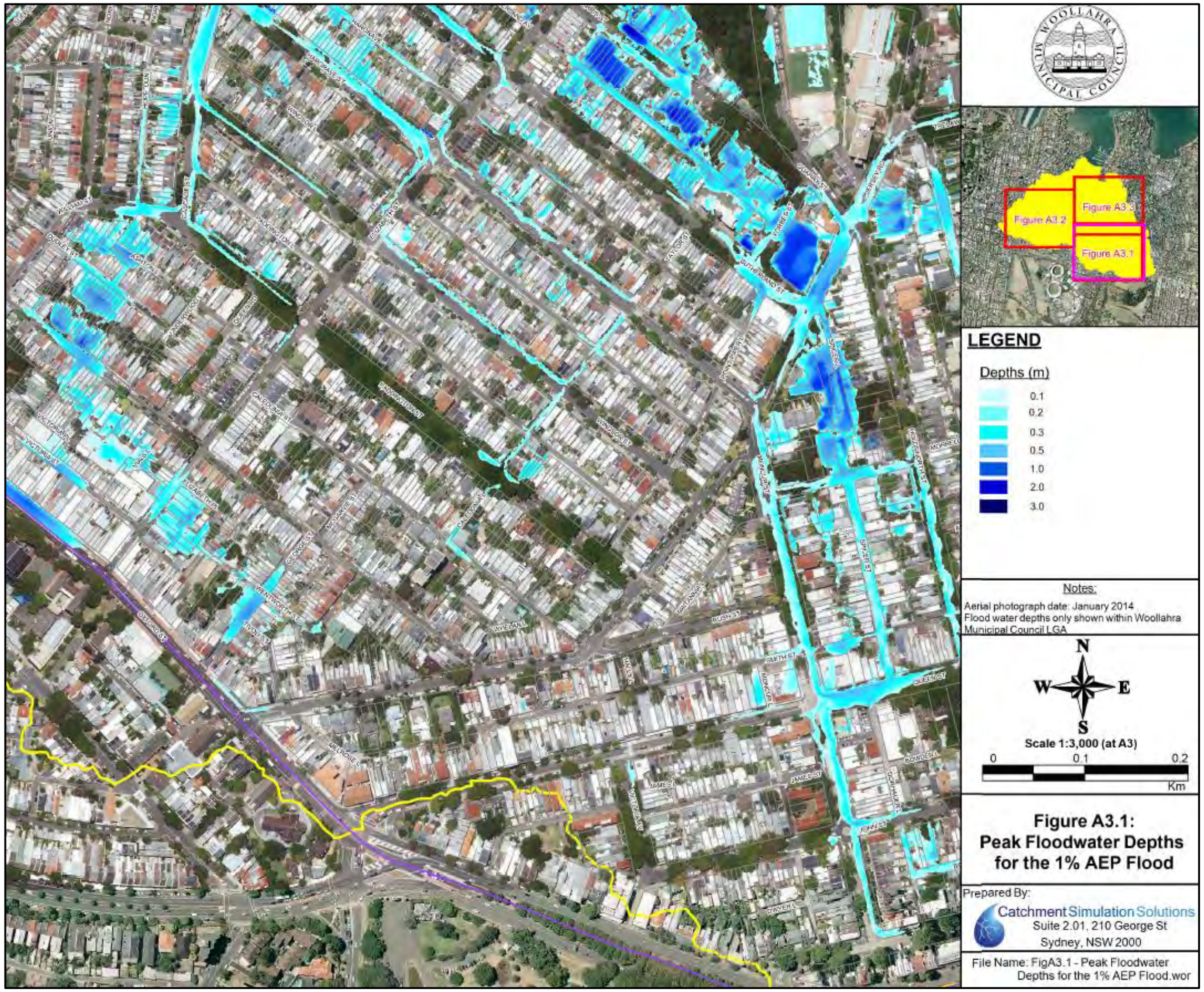
Computer Flood Models

- Computer flood models are:
  - commonly used to help identify flood risk areas.
  - developed based upon the physical characteristics of the catchment (e.g., variation in terrain, stormwater system, impervious/pervious surfaces).
  - tools for simulating floods of various magnitudes
  - used to quantify the impacts of different flood mitigation options (e.g., stormwater upgrades)

NOTE: Models, by definition, provide likely flood scenarios and not exact predictions. The acceptable statistical deviation across the upper Paddington catchment is considered to be <0.1m.

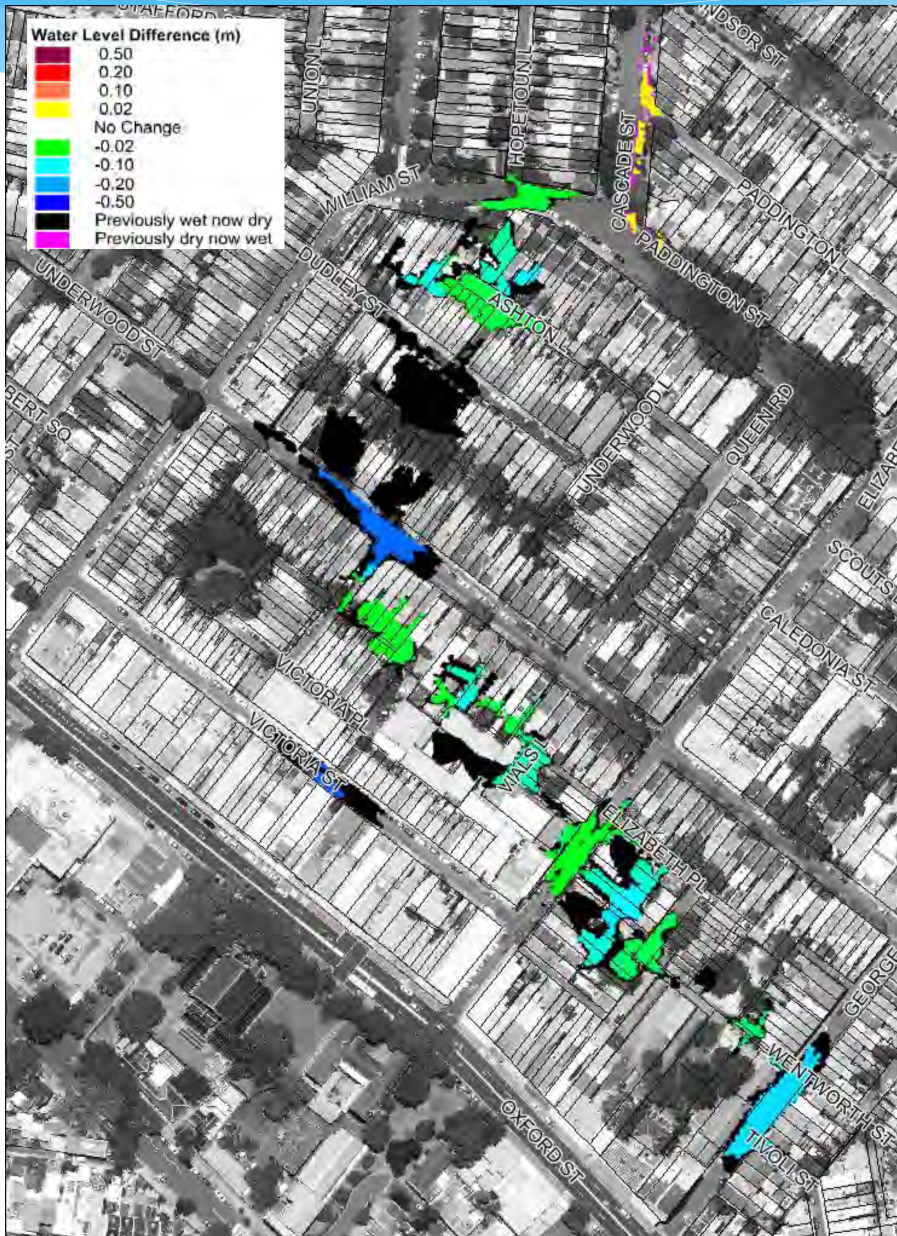
Flood Mapping

Example of 1% AEP Floodwater Depth Map



- Shows predicted <u>water depths for existing conditions</u> during floods of various magnitudes
- Previous reports only showed areas where depth >0.1m
- Updated report will include information on areas where depths are less than 0.1m

Example of 1% AEP Flood Level Difference Map



- Difference maps show the predicted <u>change in flood level</u> associated with implementation of a particular flood mitigation option.

Outcomes of Additional Community Consultation

Community Consultation – How We Consulted

- Letter and questionnaire distributed to 2,779 property owners and residents in the upper catchment.
- 295 questionnaire responses received – an excellent response rate.

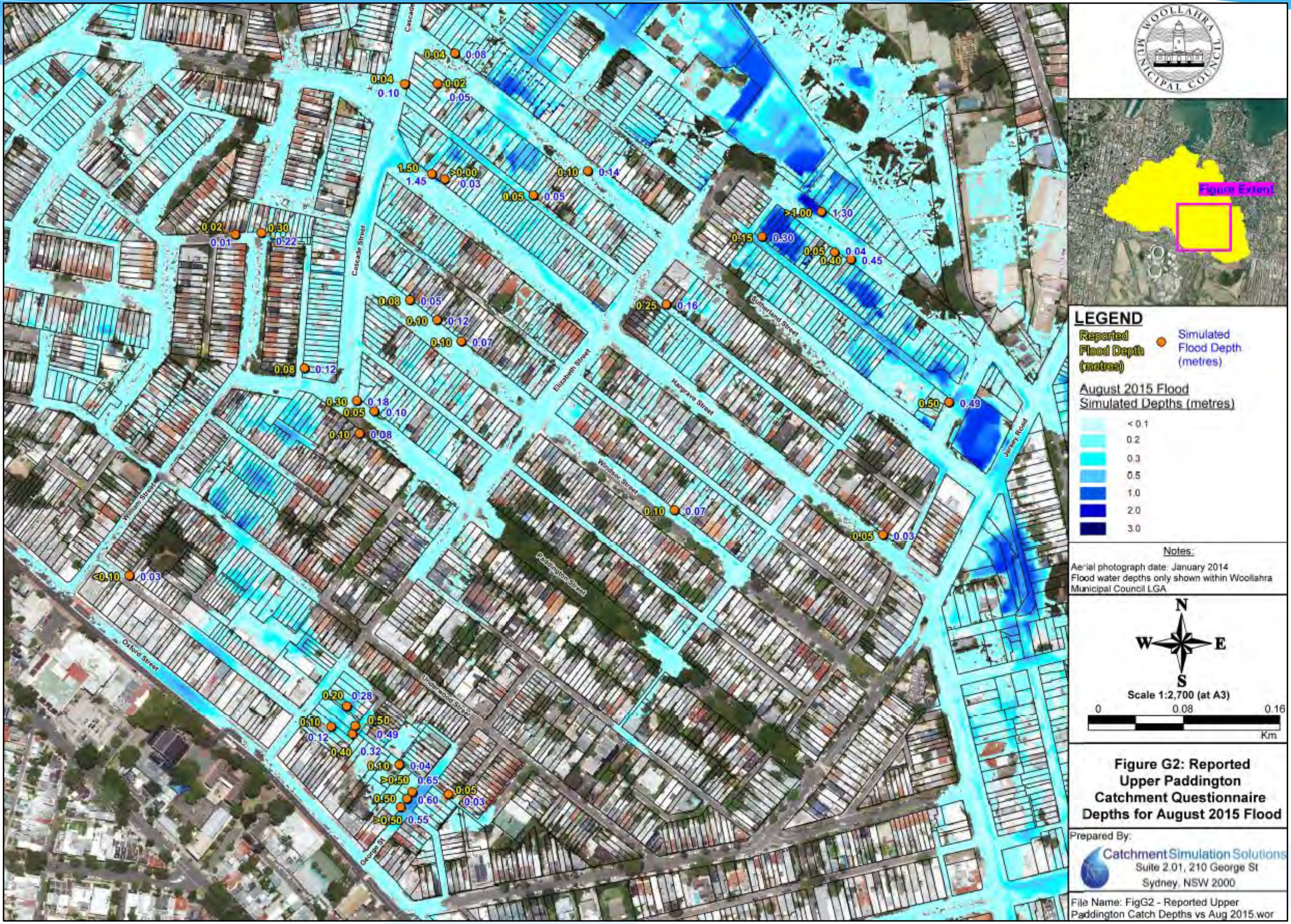
Community Consultation – Community Experience

- 70 respondents indicated that they have been impacted by flooding (i.e., 24%).
- The most commonly reported flooding impacts were:
  - water covering roadways.
  - floodwaters entering buildings resulting in damage to the building itself as well as contents.
  - rising damp.

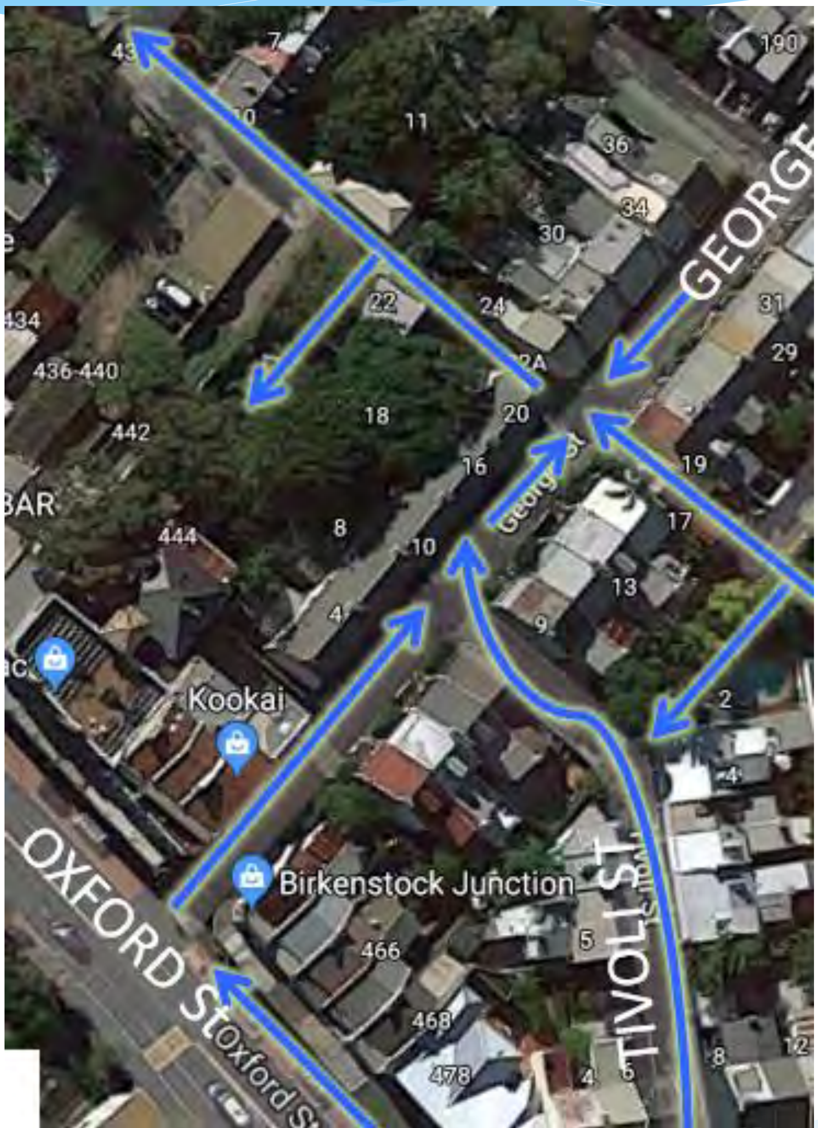
Community Consultation – The Outcome

- We compared historic flood depth information against historic flood simulation results documented in Paddington Flood Study for the August 2015 flood.
- Community feedback corroborated and validated existing data – increasing confidence in the flood model results
- We amended the flood model reporting to reflect the community's lived experience of flood behaviour (e.g., to report both shallow flooding in additional to more significant inundation depths)

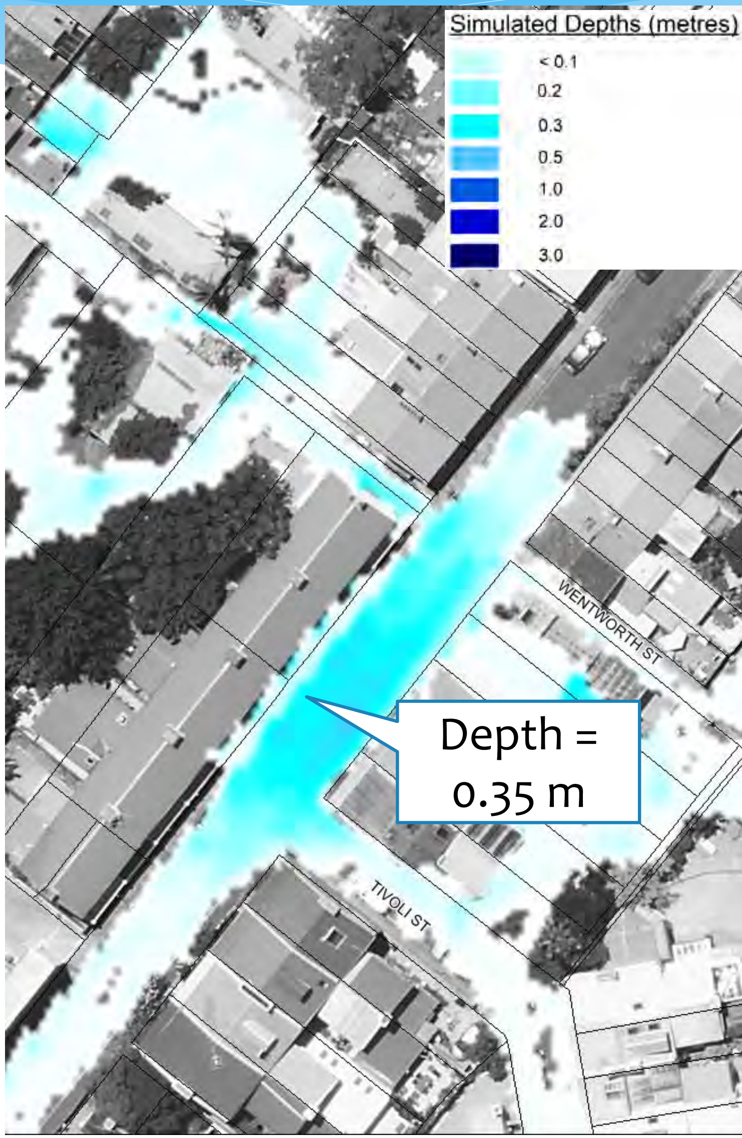
2019 Model Validation – August 2015 Flood



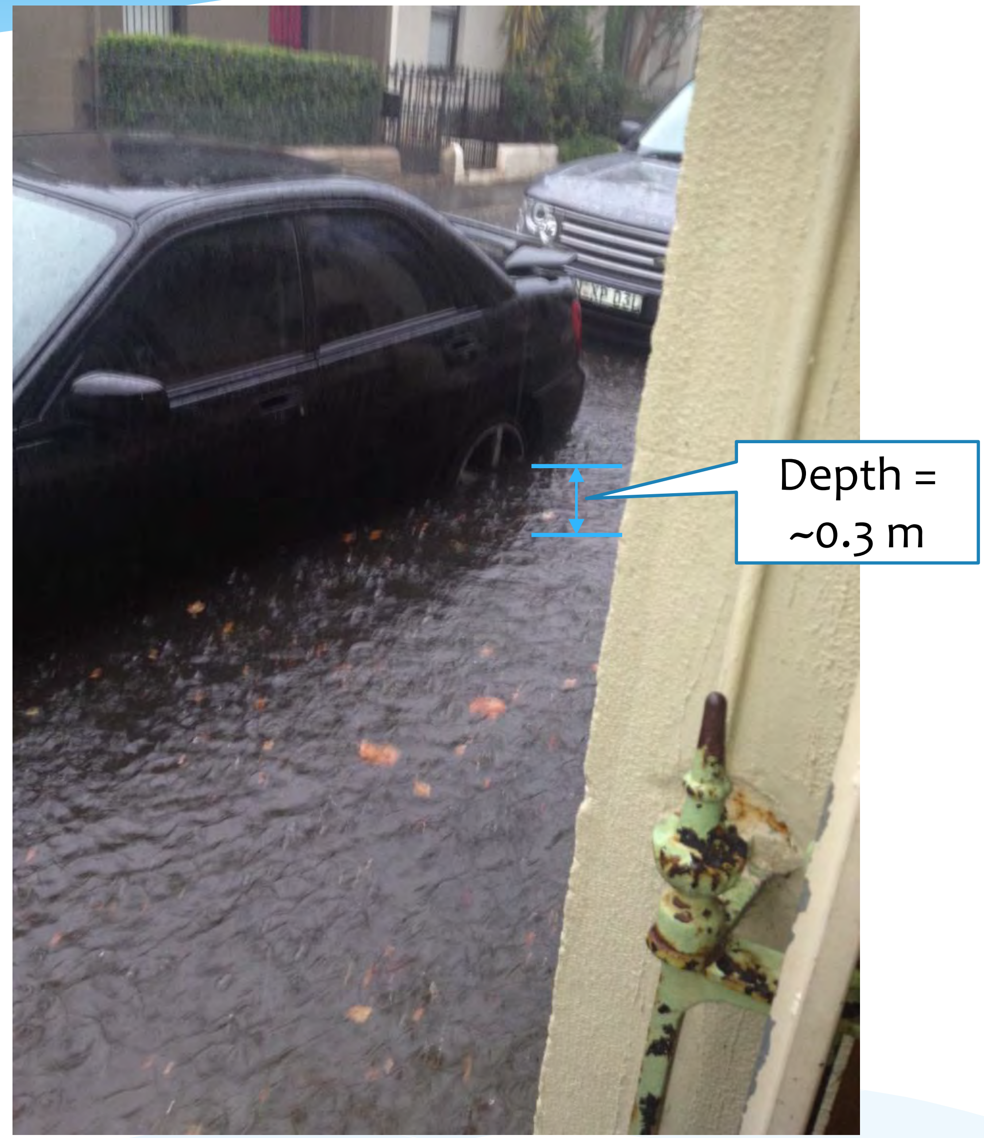
2019 Model Validation – Direction of Water



2019 Model Validation – Community Experience



1 in 1 year Floodwater Depths



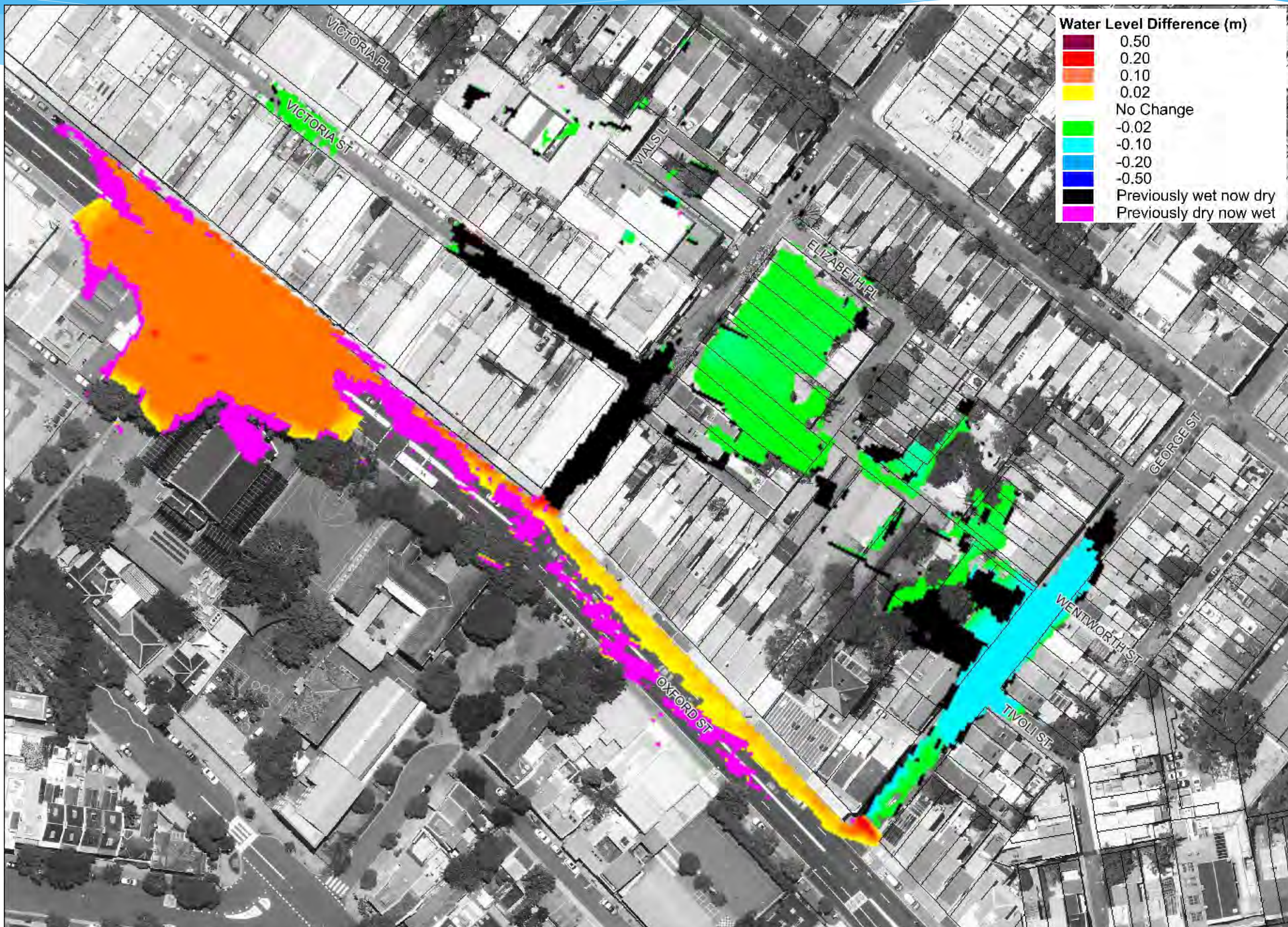
Example of regular inundation in George St

Additional Options

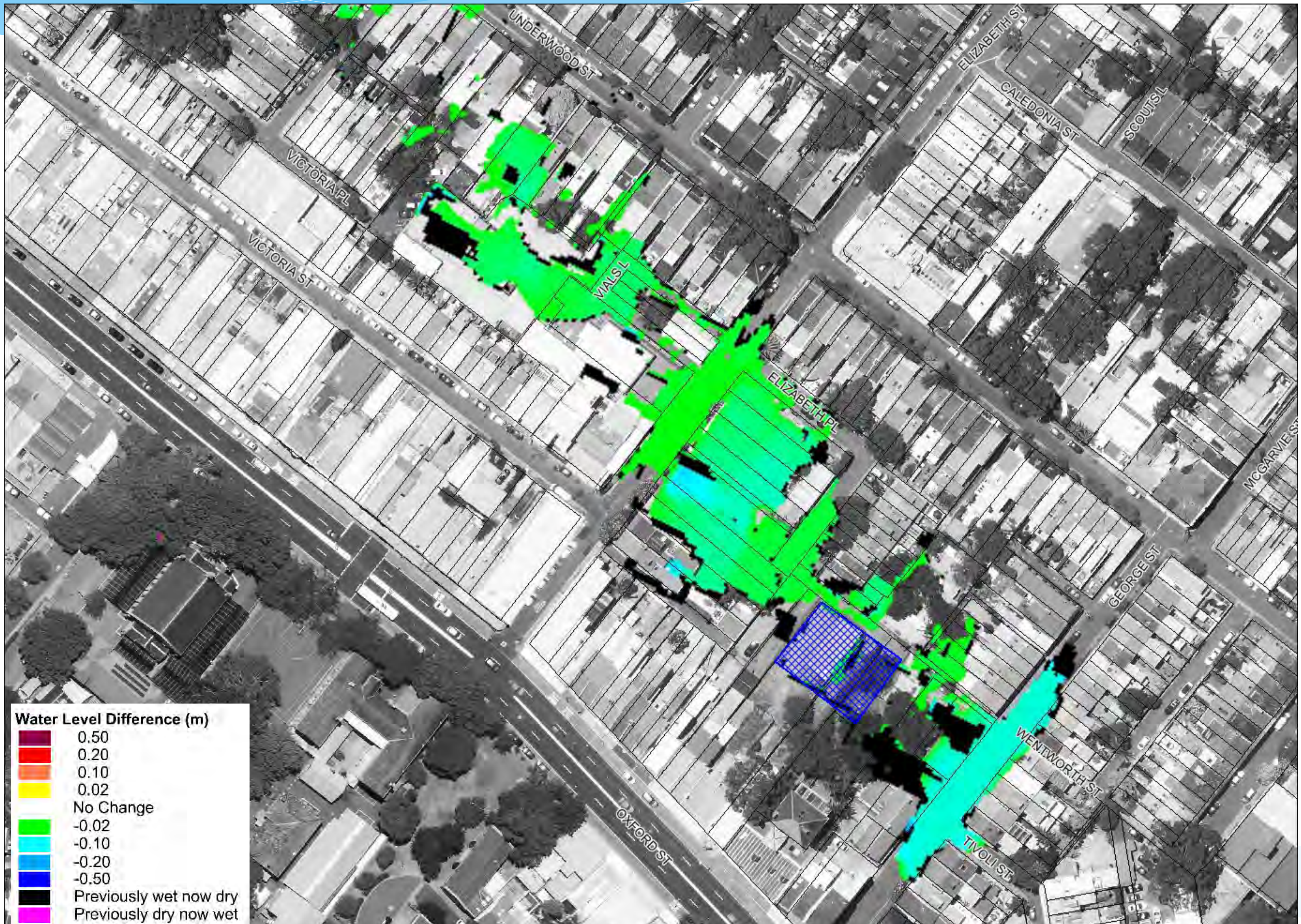
Flood Risk Management: Additional Options Investigations

- Based on community feedback, we investigated two additional flood risk management measures for the upper Paddington catchment:
  - Regrading near intersections of George and Elizabeth Streets with Oxford St
  - Installation of underground storage tanks at rear of Oxford Street properties

Regrading – 20% AEP Flood Level Difference Map



Underground Storage – 20% AEP Flood Level Difference



FRMS Report Updates

Proposed Amendments to Report and Model

- Summarise outcomes of additional community consultation in main body of report and include more detailed information on questionnaire responses in dedicated appendix.
- Including a map outlining the results of the flood model to include areas with water depths less than 0.1m
- Include outcomes of additional risk management options investigations.
- Revise report to reflect potential for installation of stormwater pits and pipes across upper Paddington catchment within road reserve.