"Where will our knowledge take you?"

Botany Bay Foreshore Beach Catchment Flood Study

Final Report

December 2015

Document Control Sheet

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Forward

The NSW State Government's Flood Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and to potential future increases in flood risk, and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Consideration is also given to the change in flood risk to existing and future development through potential climate change. Policy and practice are defined in the NSW State Government's Floodplain Development Manual (2005).

Under the Policy the management of flood liable land remains the responsibility of Local Government. The NSW State Government subsidises floodplain management studies and flood mitigation works to manage existing problems and provides specialist technical advice to assist Council in the discharge of Council's floodplain management responsibilities.

The Policy provides for technical and financial support by the NSW State Government through the six sequential stages:

1. Formation of a Committee

- Established by Council and includes community group representatives and State agency specialists.

2. Data Collection

- Past data such as flood levels, rainfall records, land use, soil types etc.

3. Flood Study

- Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study

- Evaluates management options for the floodplain in respect of both existing and proposed developments.

5. Floodplain Risk Management Plan

- Involves formal adoption by Council of a plan of management for the floodplain.

6. Implementation of the Floodplain Risk Management Plan

- Construction of flood mitigation works to protect existing development. Use of local environmental plans to ensure new development is compatible with the flood hazard.

This study represents Stages 2 and 3 of this process and aims to provide an understanding of existing and future flood behaviour within the Botany Bay Foreshore Beach Catchment.

Executive Summary

Introduction

The primary objective of this Flood Study is to define the flood behaviour under historical, existing and future conditions (incorporating potential impacts of climate change) in the Botany Bay Foreshore Beach Catchment for a full range of design flood events. The study provides information on flood levels and depths, velocities, flows, hydraulic categories and provisional hazard categories. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour, advise on the outcomes of the flood study and flood behaviour predictions, and engage the community in the on-going floodplain management process;
- Development and calibration of appropriate hydrological and hydraulic models;
- Determination of design flood conditions for a range of design events - including the 20% AEP (~5 year ARI), 10% AEP (10 year ARI), 5% AEP (20 year ARI), 2% AEP (50 year ARI), 1% AEP (100 year ARI), 0.5% AEP (200 year ARI) and the Probable Maximum Flood (PMF), noting that AEP refers to an Annual Exceedance Probability event and ARI refers to an Average Recurrence Interval flood; and
- Examination of potential impact of climate change using the latest guidelines.

The models and results produced in this study are intended to:

- Outline the flood behaviour within the catchment to aid in Council's management of flood risk; and
- Form the basis for a subsequent floodplain risk management study where detailed assessment of flood mitigation options and floodplain risk management measures will be undertaken.

Catchment Description

The study area is bounded generally by Sydney Airport to the west, Southern Cross Drive and Eastlakes Golf Course to the north, Stephen Road to the east and Botany Bay to the South. The catchment occupies an area of approximately 3.5 km^2 that is drained via the existing stormwater drainage system, with the eastern catchment draining to Sir Joseph Banks Park and the western catchments draining west to Mill Stream that adjoins to Port Botany.

The topography of the catchment is quite flat, with the exception of a lowlying ridge line located on the eastern boundary of the catchment. This leads to generally poor surface drainage conditions. The catchment generally slopes in a south-westerly direction toward the Botany Bay foreshore. A northwest-southeast chain of ponds/wetlands are located along much of Sir Joseph Banks Park, towards the bottom end of the catchment.

The catchment is a highly modified landscape, comprising high-density residential, commercial and industrial development. It also includes major roads (Botany Road and Foreshore Road) as well as a section of freight railway line.

Community Consultation

Community consultation has been an important component of the current study. The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain management activities. It has provided an opportunity to collect information on community members flood experiences in the catchment and to collect feedback on concerns regarding flooding.

The key elements of the consultation process have been as follows:

- Media release to inform the wider community of the study;
- Development and maintenance of a project web-page providing general information on the study background and objectives, reporting progress of the flood study against key milestones, and provide preliminary study output subject to Council approval; and
- Distribution of a questionnaire to landowners, residents and businesses within the study area.

Model Development and Calibration

Development of hydrologic and hydraulic models has been undertaken to simulate flood conditions in the catchment. The overland flow regime in urban environments is characterised by large and shallow inundation of urban development with interconnecting and varying flow paths. Road networks often convey a considerable proportion of floodwaters due to the hydraulic efficiency of the road surface compared to developed areas (e.g. blocked by fences and buildings), in addition to the underground pipe network draining mainly to open channels. Given this complex flooding environment, a 2D modelling approach is warranted for the overland flooding areas.

BMT WBM has applied the fully 2D software modelling package TUFLOW, developed in-house at BMT WBM. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels, major underground drainage systems, and overland flows through complex overland flow paths using a linked 1D/2D flood modelling approach.

The ability of the model to provide an accurate representation of the overland flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the Botany Bay Foreshore Beach Catchment model, a high resolution DEM (1m grid) was derived from ALS survey provided by Council.

Review of community consultation, Sydney Water Corporation and Council flooding registers and previous studies identified a number of historic events. Based on the availability of data (e.g. flooding reports, rainfall and water level records), the 24th March 2014, 2rd January 2014 and 4th March 1977 events were selected for model calibration/validation.

Design Event Modelling and Mapping

The developed models have been applied to derive design flood conditions within the catchment. Design rainfall depth is based on the generation of intensity-frequency duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). A range of storm durations using standard AR&R (2001) temporal patterns, were modelled in order to identify the critical storm duration for design event flooding in the catchment.

A suite of design event scenarios was defined that is most suitable for future floodplain management planning in the catchment. The potential impact of climate change on flood behaviour within the catchment has also been considered. The design events considered in this study include the 20% AEP, 5% AEP, 2% AEP, 1% AEP, 0.2% AEP and PMF events. The model results for the design events considered have been presented in a detailed flood mapping series for the catchment (see Appendix C). The flood data presented includes design flood inundation, peak flood water levels and depths and peak flood velocities.

Provisional flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has been mapped in addition to the hydraulic categories (floodway, flood fringe and flood storage) for flood affected areas.

Sensitivity Testing

A number of sensitivity tests have been undertaken to identify the impacts of the adopted model conditions on the design flood levels. Sensitivity tests included:

- Reduction in adopted rainfall losses ;
- Changes in the adopted roughness parameters;
- Blockage of the stormwater drainage network; and
- Higher design tailwater conditions in Botany Bay;

The design flood results were found to be most sensitive to blockage of the stormwater drainage network.

Conclusions

In completing the flood study, the following activities were undertaken:

- Collation of database of historical flood information for the catchment;
- Acquisition of topographical data for the catchment including cross section, hydraulic structure survey and stormwater drainage network survey;
- Consultation with the community to acquire historical flood information and liaison in regard to flooding concerns/perceptions and future floodplain management activities;
- Development of a hydrological and hydraulic model (using TUFLOW software) to simulate flood behaviour in the catchment;
- Calibration and validation of the developed model using available data for the March 2014, January 2014 and March 1977 flood events;
- Prediction of design flood conditions in the catchment using the calibrated models; and
- Production of design flood mapping series.

From community consultation and in simulating the design flood conditions for the study area, the following locations have been identified as potential problem areas in relation to flood inundation extent and property affected:

- Corner of Tupia Street and Anniversary Street
- Roundabout at Hale Street and Luland Street
- Hale Street roundabout
- Edgehill Avenue (near street bend)
- Corner of Chelmsford Street and The Esplanade
- Tupia Street
- Botany Street (between Hale Street and Kingston Street)
- Daphne Street
- Botany Road (near Hill St)
- Dent Street
- Bay Street

The principal outcome of the flood study is the understanding of flood behaviour in the catchment and in particular design flood level information that will be used to set appropriate flood planning levels for the study area. The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain management process. The hydraulic model developed for this study provides a tool for assessment of potential flood impact of future development in the catchment.

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1 Introduction

The Botany Bay Foreshore Beach Catchment Flood Study (BBFBC FS) has been prepared for the City of Botany Bay (Council) to define the existing flood behaviour in the catchment and establish the basis for subsequent floodplain management activities.

This project has received technical and financial support from the NSW Government's Floodplain Management Program.

1.1 The Study Location

This study comprises six designated stormwater catchments (F, G, H, I, K and N) located within the City of Botany Bay LGA (see Figure 1-1. The study area is bounded generally by Sydney Airport to the west, Southern Cross Drive and Eastlakes Golf Course to the north, Stephen Road to the east and Botany Bay to the South.

The majority of the subject catchments lie within the Sydney Water stormwater catchment SW_016 Botany – Bay St.

Figure 1-1 shows the approximate catchment boundaries which drains an area of approximately 3.5 km^2 (350 ha), and is fully developed consisting primarily of high-density housing, commercial and industrial development. There are some large open spaces within the study area including Booralee Park, Garnet Jackson Reserve, Sir Joseph Banks Park and Botany Golf Course.

The catchment drains to Botany Bay with the eastern sub-catchments generally draining south to Sir Joseph Banks Park and the western sub-catchments draining west to Mill Stream. The surface slopes within the catchment are generally quite flat which implicitly leads to poor surface drainage following intense rainfall.

The study area is drained via the existing stormwater drainage system which consists mainly of sub-surface pipes, culverts and covered channels. There are some reaches of open channel which generally have a constructed geometry and therefore have a regular profile.

1.2 The Floodplain Management Process

The NSW Government's Flood Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and potential future increases in flood risk and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Consideration is also given to the change in flood risk to existing and future development through potential climate change. Policy and practice are defined in the NSW Government's Floodplain Development Manual (2005).

Under the Policy the management of flood liable land remains the responsibility of Local Government. The NSW Government subsidises floodplain management studies and flood mitigation works to manage existing problems and provides specialist technical advice to assist The Councils in the discharge of their floodplain management responsibilities.

Title:

Botany Bay Foreshore Beach Catchment Flood Study
Subject Stormwater Catchments

Figure: 1-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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The Policy provides for technical and financial support by the NSW Government through the four sequential stages shown in Table 1-1.

Table 1-1 Stages of Floodplain Management

	Stage	Description
1	Formation of a Committee	Established by Council and includes community group representatives and State agency specialists.
2	Data Collection	Past data such as flood levels, rainfall records, land use, soil types etc.
3	**Flood Study**	**Determines the nature and extent of the flood problem.**
4	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
5	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
6	Implementation of the Floodplain Risk Management Plan	Construction of flood mitigation works to protect existing development. Use of local environmental plans to ensure new development is compatible with the flood hazard.

This study represents Stage 2 and Stage 3 of the above process and aims to provide an understanding of existing and future flood behaviour within the Botany Bay Foreshore Beach Catchment.

1.3 Study Objectives

The primary objective of this Flood Study is to define the flood behaviour under historical, existing and future conditions (incorporating potential impacts of climate change) in the Botany Bay Foreshore Beach Catchment for a full range of design flood events. The study will provide information on flood levels and depths, velocities, flows, hydraulic categories and provisional hazard categories. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour, advise on the outcomes of the flood study and flood behaviour predictions, and engage the community in the on-going floodplain management process;
- Development and calibration of appropriate hydrological and hydraulic models;
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AEP refers to an Annual Exceedance Probability event and ARI refers to an Average Recurrence Interval flood; and

- Examination of potential impact of climate change using the latest guidelines.

The models and results produced in this study are intended to:

- Outline the flood behaviour within the catchment to aid in Council's management of flood risk; and
- Form the basis for a subsequent floodplain risk management study where detailed assessment of flood mitigation options and floodplain risk management measures will be undertaken.

1.4 About This Report

This report documents the Study's objectives, results and recommendations.

Volume 01 – Main Report

Section 1 introduces the study.

Section 2 provides an overview of the study and summary of background information.

Section 3 outlines the community consultation program undertaken.

Section 4 details the development of the computer models.

Section 5 details the hydraulic model calibration and validation process.

Section 6 details the design flood conditions.

Section 7 details the sensitivity tests.

Section 8 details the climate change analysis.

Appendix A details calibration approach and results.

Appendix B presents community consultation material.

Volume 02 – Design Mapping

Appendix C presents design result mapping.

Appendix D presents climate change result mapping.

2 Study Approach

2.1 The Study Area

2.1.1 Catchment Description

The Botany Bay Foreshore Beach Catchment is located within the City of Botany Bay LGA, as shown in Figure 1-1. The catchment occupies an area of approximately 3.5 km^2 that is drained via the existing stormwater drainage system, with the eastern catchment draining to Sir Joseph Banks Park and the western catchments draining west to Mill Stream that adjoins to Port Botany.

The topography of the catchment is quite flat, with the exception of a lowlying ridge line located on the eastern boundary of the catchment. This leads to generally poor surface drainage conditions. The catchment generally slopes in a south-westerly direction toward the Botany Bay foreshore. A northwest-southeast chain of ponds/wetlands are located along much of Sir Joseph Banks Park, towards the bottom end of the catchment.

The catchment is a highly modified landscape, comprising high-density residential, commercial and industrial development. It also includes major roads (Botany Road and Foreshore Road) as well as a section of freight railway line.

2.2 Compilation and Review of Available Data

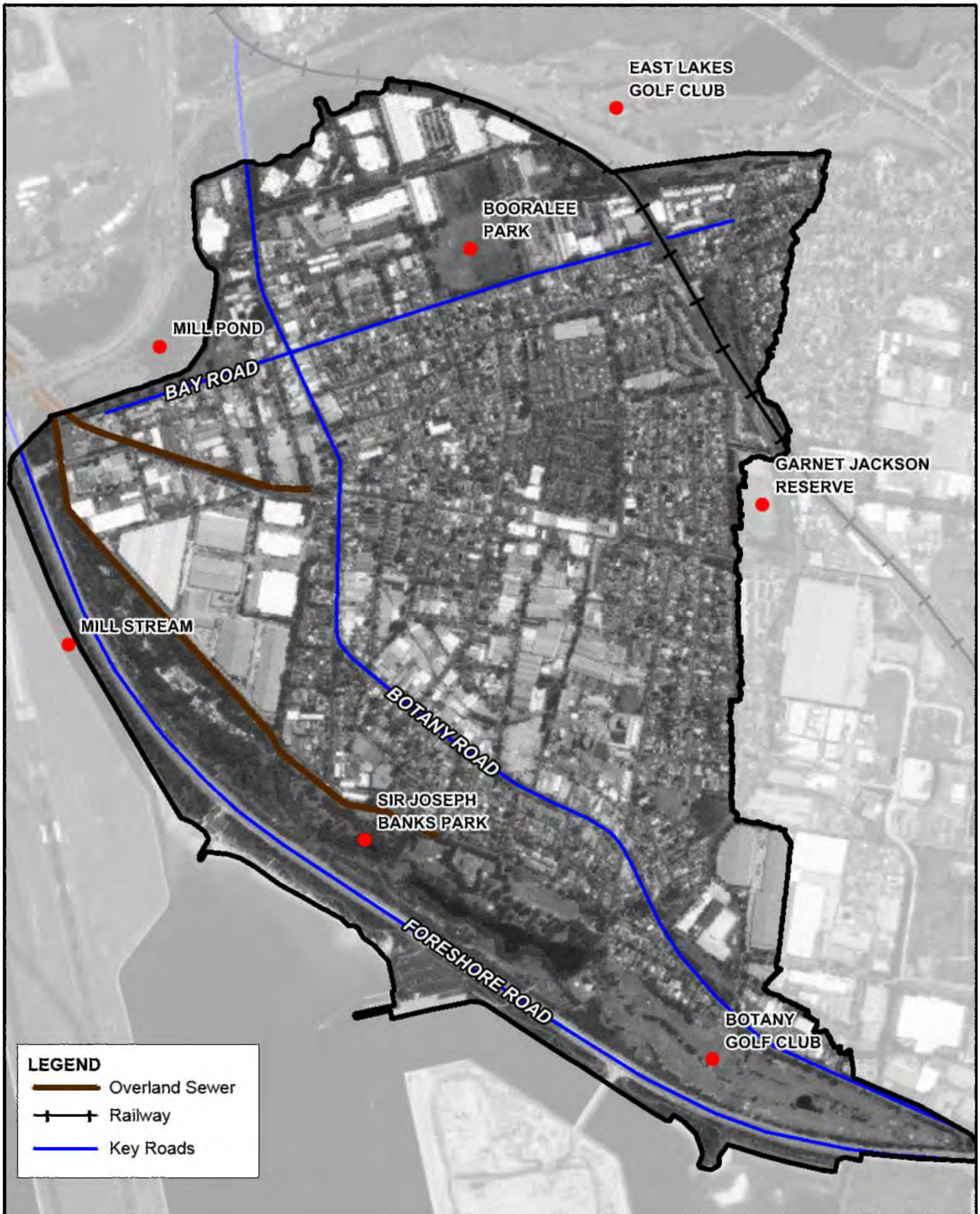
2.2.1 Introduction

The data compilation and review has been undertaken as the first stage in this flood study in order to consolidate and summarise all of the currently available data, and identify any significant data gaps that may affect the successful completion of the study. This allowed for the missing data to be collected during the initial phases of the study.

The review included:

- Previous studies undertaken within the catchment;
- Available water level, tide and rainfall data; and
- Flooding complaints register.

Council has provided digitally available information such as aerial photography, cadastral boundaries, watercourses, and drainage networks in the form of GIS datasets.



Title: **Study Area**

Figure: **2-1**

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2.2.2 Previous Studies and Investigations

Details of previous flood studies undertaken within or adjacent to the study catchment and their relevance in the context of the current flood study are presented in the following sections.

2.2.2.1 Hydrologic and Hydraulic Study – Botany Wetlands – Volume 1 report (SMEC, 1992)

SMEC was commissioned by the Water Board to undertake the hydrologic and hydraulic study of Botany Wetlands from downstream of Gardeners Road to its outlet in Botany Bay. This drainage path is on the edge of the current Botany Bay Foreshore Beach Flood Study.

The 10%, 2% and 1% AEP flood levels and flood behaviour were defined for the existing catchment. Important for the current study is that it was found for all events up to the 1% AEP, existing catchment flooding is within the formed watercourses and do not affect the existing development. That is, water does not break from the levee banks training the major flow path. Cross catchment flows from the Botany Wetlands do not need to be considered for the local catchment study.

2.2.2.2 Botany – Bay Street (SWC 16) Capacity Assessment Report (2002)

This report prepared by Sydney Water assessed the quantitative performance of stormwater drainage elements within Sydney Water's catchment SWC16. The performance or capability is referred to as the Storm Event Capacity (SEC); that is the storm event which causes a peak flow equal to the hydraulic capacity of each drainage element. It is noted that the modelling undertaken for the assessment only considered major drainage paths.

Along with the drainage capacity reports, the SWC capacity assessment report contained detailed data on the trunk drainage systems including open channel cross-sections, pipe dimensions and photographs of key structures. The dimension data was used as a cross check for survey received from Council for the study area.

2.2.2.3 Port Botany Expansion – Environmental Impact Statement (URS, 2003)

URS completed an EIS for the Port of Botany Expansion. Hydrological and hydraulic modelling undertaken of conditions before and after the development shows that the proposed expansion would not have an adverse impact on the flood behaviour in the catchments surrounding Port Botany.

2.2.2.4 Flood and Stormwater Management Report – Parkgrove Botany (Hughes Trueman, 2010)

Hughes Trueman prepared a Flood and Stormwater Management Report to assist with site master planning for The Parkgrove Trust. The site was bound by Pemberton, Wilson and Rancom Streets at Botany. A DRAINS modelling was developed for the assessment.

The study identifies that the Pemberton Street low point defines flood levels for the study area since the overland flow path from Pemberton Street to the stormwater channel is limited by buildings. Survey was undertaken to identify critical control levels and flow path from Pemberton Street.

At 4.05mAHD, a 7m gap through the driveway corridor of 21 Pemberton Street controls flood levels at the low point. For the 1% AEP design event, the Pemberton Street flood level was determined to be 4.46mAHD. The overland flow is not reported.

2.2.2.5 Flood Investigation Assessment and Report – Development at 27 Myrtle St, Pagewood (GEC, July 2013)

GEC consulting prepared a flood investigation assessment for a proposed development at 27 Myrtle Street which lies north of the railway line in the northern limits of the BBFBC FS model domain. The flood investigation utilised a DRAINS model with pit and pipe data implemented. Discharge hydrographs from DRAINS were simulated in a HEC-RAS model to develop flood levels.

The developed model was un-calibrated and therefore provided little value to the current study, given the development of a more comprehensive catchment wide model approach..

2.2.2.6 Moveable Bed Model Testing – Foreshore Beach, Botany (Worley Parsons, September 2013)

The Port Botany Expansion project has resulted in shore erosion and a changed beach alignment (Worley Parsons, 2013). Figure 2-2 depicts the pre-existing beach alignment. This beach is the downstream boundary of the current Flood Study. The Worley Parsons study states that the beach erosion is occurring near the Livingstone Avenue Drain and accretion occurs near the Chelmsford Avenue Drain.

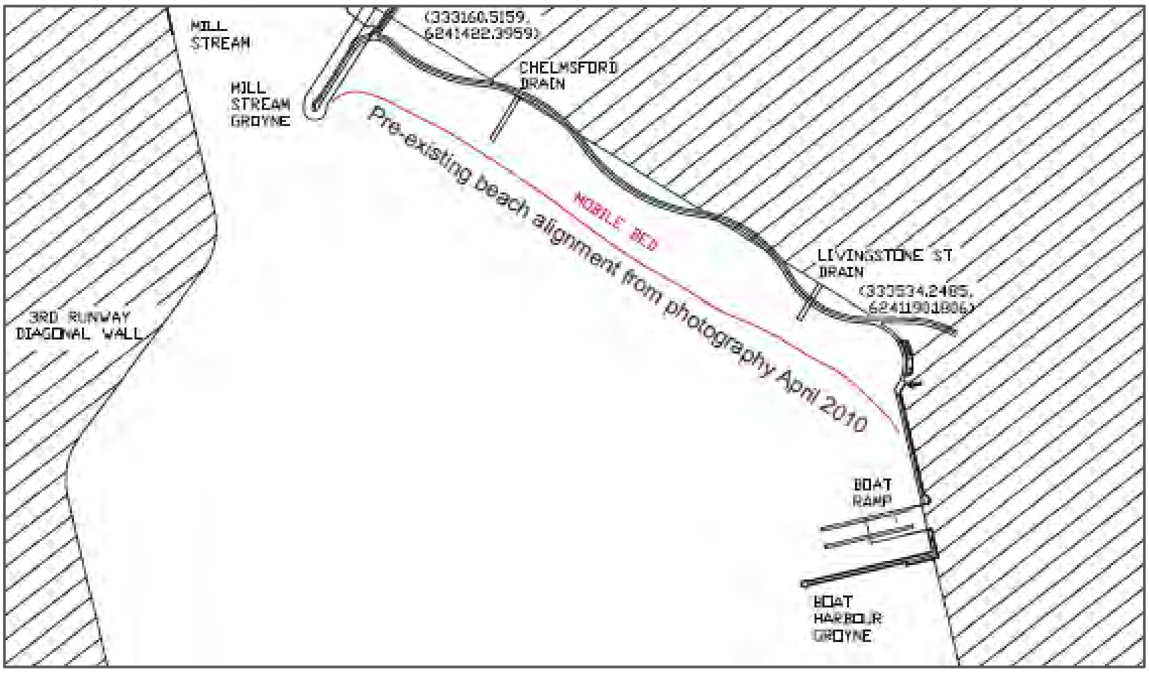

Figure 2-2 Existing beach alignment (2010) noting Chelmsford Ave Drain and Livingstone Ave Drain

As a result of the changed shoreline morphology, renourishment programs have been required. The rate of erosion, and hence cost of renourishment, is greater than expected and this is the key driver for the study. Worley Parsons designed a “Groyne” solution to stabilise the future beach alignment and reduce the cost of nourishing the beach.

In the context of the current flood study, the shoreline study explains the potential for sand blocking the drainage outlets (from accretion or renourishment material) impacting flooding behaviour in the catchment.

2.2.2.7 Botany – Bay Street Catchment Drainage Study (Worley Parsons, September 2013)

Worley Parsons on behalf of Sydney Ports and Sydney Water undertook a flood study for the same catchment as assessed in this current flood study. The Worley Parsons study was undertaken principally to review the consequences of blockage of stormwater outfall pipes with marine sands. It is assumed that the study was undertaken concurrently with Moveable Bed Model Testing Study (September 2013).

The flood study model developed was a lumped hydrologic inflow TUFLOW model. Since the study was focused on trunk drainage principally at the downstream beach outlets, this approach is valid. The June 2010 event (<1 year ARI) was chosen for model calibration and the 20%, 5% and 1% AEP design events were considered for a range of sensitivity assessments. In all cases, irrespective of the storm event or the offshore tailwater level, blockage of the Chelmsford Avenue and Livingstone Avenue lines resulted in increased flood levels. The increases in flood level were to some degree mitigated by stormwater re-routing through the catchment.

2.2.2.8 Springvale Drain and Floodvale Drain Flood Study (BMT WBM, 2014)

BMT WBM previously undertook the flood study for the neighbouring Springvale Drain and Floodvale Drain catchment. In regards to the current study, the Springvale Drain and Floodvale Drain Flood Study provide a framework and precedent for model schematisation and parameterisation. The following is a list of schematisation/parameterisations typically adopted for the current study:

- MHWS design tailwater;
- Land-use categorisation for friction and infiltration potential (for comparable land-uses); and
- Design flood envelope approach adopting multiple durations and blockage scenarios.

Sydney Water WAE drawings (various dates)

An extensive set of work-as-executed (WAE) drawings and GIS pipe layer was received from Sydney Water for the Study area. This data set provided valuable description of drainage elements not described in the Survey undertaken by Council. The key use for these drawings was:

- Defining downstream inverts of stormwater outlets to Foreshore Beach
- Describing Livingstone Avenue drainage prior to the amplification project (circa 1980);

- Describing the Livingstone Avenue amplification project including the bulkhead under Sir Joseph Banks Street;
- Describing the bulkhead at Rochester Street and flow diversion to Folkestone Avenue; and
- Chronology of trunk construction (important for defining 1977 drainage network).

2.2.3 Rainfall Data

There is an extensive network of rainfall gauges across the Sydney area, many of which are operated by the Bureau of Meteorology (BoM) and Sydney Water Corporation (SWC). However, there are no rainfall stations located within the study catchment area. The closest station to the study area is a BoM station located at Sydney Airport. This rainfall station has a long period of record commencing in 1929.

A list of these relevant rainfall stations with their respective period of record is shown in Table 2-1, with the spatial distribution of the rainfall stations shown in Figure 2-3. This combination of daily rainfall stations and pluviometers to define the temporal pattern of rainfall presents a high quality rainfall data set for use in this Flood Study.

Table 2-1 Rainfall stations in the catchment locality area

Station #	Name	Record Period	Type	Authority
066037	Sydney Airport AMO	1929 - current	Daily/Pluvio	BOM
066073	Randwick Racecourse	1937 – current	Daily	BOM
066051	Little Bay	1926 – 2009	Daily	BOM
066052	Randwick (Randwick St)	1888 – current	Daily	BOM
066036	Marrickville Golf Club	1904 – current	Daily	BOM

2.2.4 Flood Level Data

Limited peak flood level survey of historic flooding is available for this study. Model calibration primarily relied upon anecdotal reports of flooding from community consultation, Council records and photographs of flood behaviour. Photographs cannot be assumed to record the peak flood behaviour though importantly identify the flooding hotspots.

2.2.5 Council GIS Data

Digitally available GIS data such as aerial photography, cadastral boundaries, roads, and park streetscapes have been provided by Council. This data provide a means to distinguish between land-use types across the study area to allow spatial variation of distinct hydrologic (e.g. rainfall losses) and hydraulic (e.g. Manning's roughness parameter '*n*') properties.

2.2.6 Botany Bay Water Level Data

The study catchment flows into Botany Bay. Consequently, the water level within Botany Bay can act as a significant downstream control for both overland and piped flows under flooding conditions resulting from rainfall events. The tides in the Botany Bay are typical of the NSW east coast, being semidiurnal, that is generally two high tides and two low tides each day with a diurnal inequality

For all calibration events, a dynamic tailwater boundary for Botany Bay has been adopted based on water level records from obtained from the Bureau of Meteorology's National Tidal Centre. Table 2-2 shows the tidal statistics similarly obtained from the National Tidal Centre. Figure 2-3 shows the location of the tidal gauge in Botany Bay.

Table 2-2 Botany Bay Tide Levels

Tidal Level	Level (m)	
	Tide Gauge	AHD
Maximum Recorded Tide	2.320	1.395
Highest Astronomical Tide (HAT)	2.107	1.182
Mean High Water Springs (MHWS)	1.612	0.687
Mean High Water Neaps (MHWN)	1.369	0.444
Mean Sea Level (MSL)	0.992	0.067
Mean Low Water Neaps	0.615	-0.310
Mean Low Water Springs	0.372	-0.553
Lowest Astronomical Tide	0.073	-0.852
Minimum Recorded Tide	-0.190	-1.115

2.2.7 Stream Gauge Data

There are no stream gauging data within the study area. This is a common data deficiency in urban catchments.

2.2.8 Topographic Data

Aerial topographic survey, also known as ALS (Airborne Laser Scanning) covering the study area has been provided by Council. The survey was captured between the 10th April 2013 and 24th April 2013. Horizontal and vertical accuracy is 0.8m and 0.3m respectively (95% confidence intervals).

The ALS data and has been enhanced for use in this study by applying post-processing methods since numerous large buildings and bridges within the study area influence the ground point data provided.

Figure 2-4 shows the digital elevation model (DEM) developed for the study area, providing a visualisation of potential flow paths.

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Rainfall and Tide Gauges

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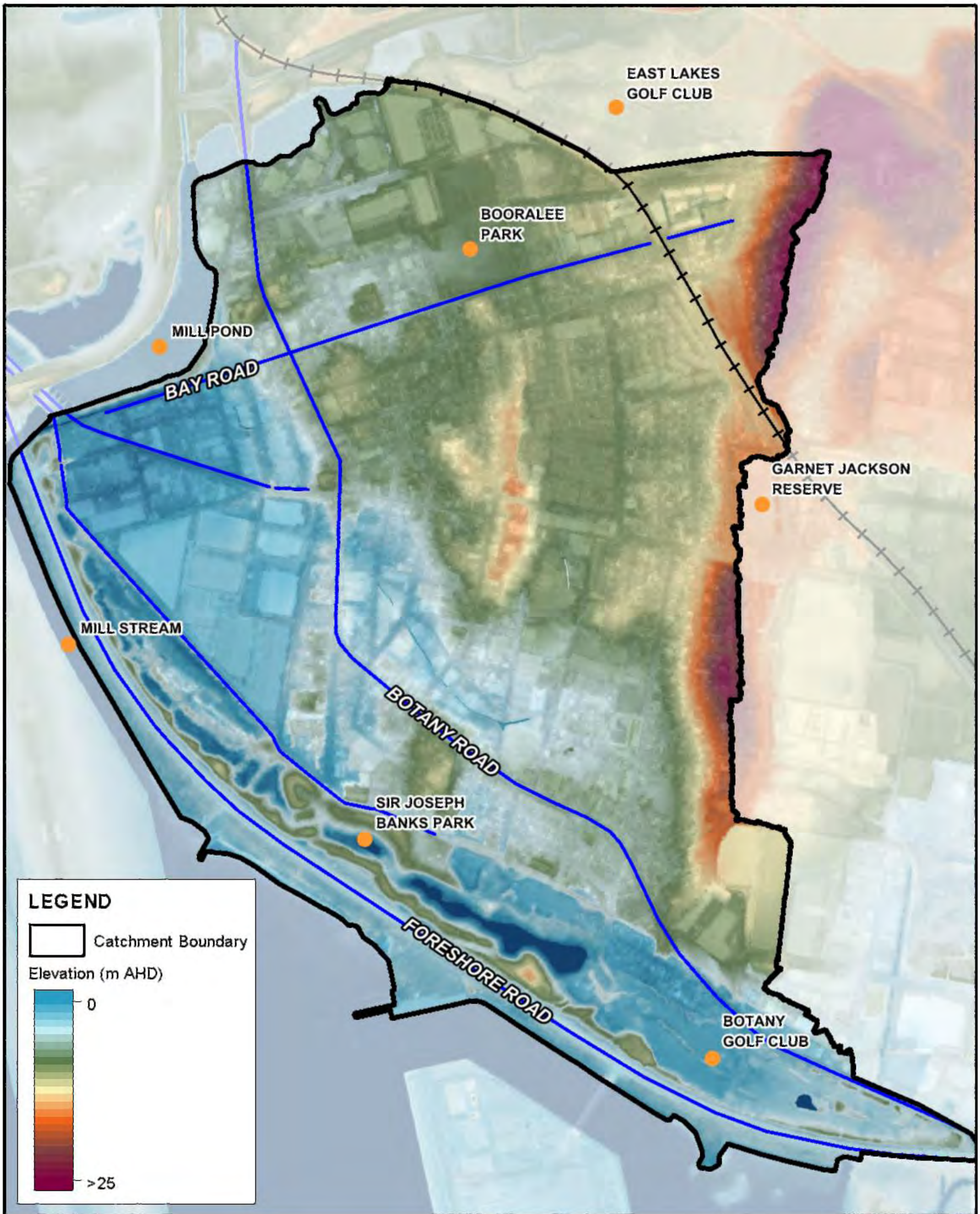

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2.2.9 Stormwater Drainage Network

An extensive network of stormwater infrastructure exists in the study area to provide drainage to Botany Bay. The infrastructure consists of pit and pipe stormwater network and concrete open channel. Sydney Water typically owns the trunk network with Council owning minor systems.

Figure 2-5 shows the stormwater network modelled for the catchment.

2.2.10 Site Inspections

A number of site inspections have been undertaken during the course of the study to gain an appreciation of local features including flood behaviour. Some of the key observations accounted for during the site inspections include:

- Presence of local structural hydraulic controls;
- Location and characteristics of surface drainage pits and pipes;
- General nature of overland flow paths including open channels noting channel form and vegetation types; and
- Location of existing development and infrastructure on the floodplain.

This visual assessment was useful for defining hydraulic properties within the hydraulic model and ground-truthing of topographic features identified from survey.

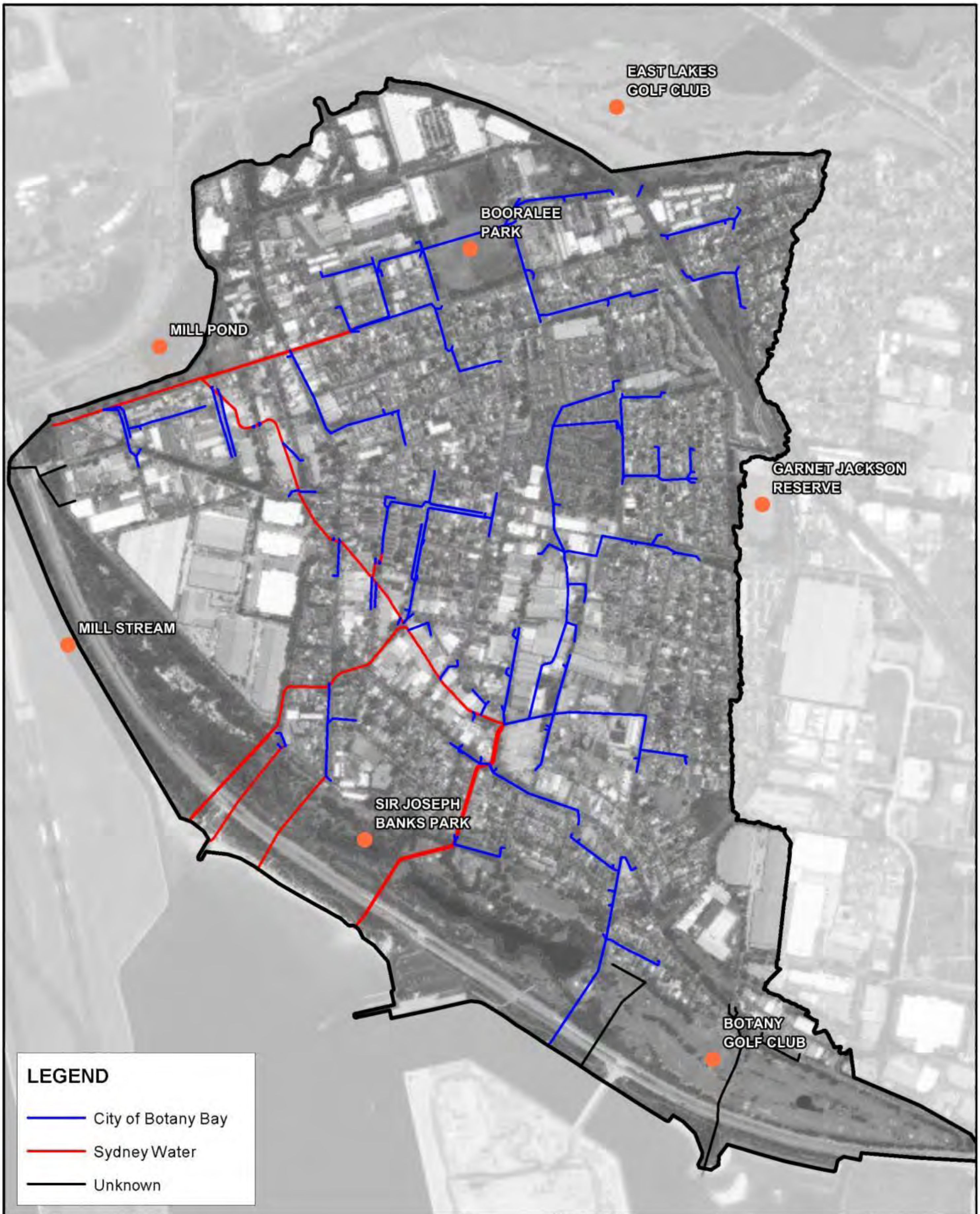
2.3 Community Consultation

The success of a floodplain management plan hinges on its acceptance by the community, residents within the study area, and other stakeholders. This can be achieved by involving the local community at all stages of the decision-making process. This includes the collection of their ideas and knowledge on flood behaviour in the study area, together with discussing the issues and outcomes of the study with them. The key elements of the consultation program undertaken for the study are discussed in Section 3.

2.4 Development of Computer Models

2.4.1 Hydrological Model

Traditionally, for the purpose of the Flood Study, a hydrologic model is developed to simulate the rate of storm runoff from the catchment. The output from the hydrologic model is a series of flow hydrographs at selected locations such as at stormwater drainage pit inlets, which form the inflow boundaries to the hydraulic model.



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Stormwater Network

Figure: 2-5

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In recent years the advancement in computer technology has enabled the use of the direct-rainfall approach as a viable alternative. With the direct-rainfall method the design rainfall is applied directly to the individual cells of the 2D hydraulic model. This is particularly useful for overland flow studies where model results are desired in areas with very small contributing catchments. Furthermore, this method is advantageous in accounting for inter-catchment flow, such as occurs in this study area. This study has therefore adopted the direct-rainfall approach for modelling hydrology, details of which are discussed in Section 4.

An overview of the catchment hydrological system is provided below.

2.4.2 External Catchment Flows

The study area catchment is typically well defined by the local topography. However, in major flood events, there is the potential for additional cross-catchment flows from neighbouring Floodvale Drain sub-catchments.

The Floodvale Drain catchment is located immediately to the east of the current study area. BMT WBM previously investigated flooding in this catchment as part of the Springvale Drain and Floodvale Drain Flood Study (2014). Flows which exceed the capacity of Floodvale Drain flow overland to overtop Botany Road just west of Botany Golf Club. This overtopping flow has potential to impact on flood levels in the catchment on Botany Road and in the immediate locality.

2.4.3 Hydraulic Model

The TUFLOW hydraulic model (discussed in Section 4) developed for this study includes:

- two-dimensional (2D) representation of the entire catchment (i.e. complete coverage of the total study area);
- one-dimensional (1D) representation of the stormwater pipe network; and
- one-dimensional (1D) representation of the open channel drainage network.

The hydraulic model is applied to determine flood levels, velocities and depths across the study area for historical and design events

2.5 Model Calibration/Validation and Sensitivity Analysis

The hydrodynamic model was calibrated and validated against available historical flood event data to establish the values of key model parameters and confirm that the model was capable of adequately simulating real flood events.

The following criteria are generally used to determine the suitability of historical events to use for calibration or validation:

- The availability, completeness and quality of rainfall and flood level event data;
- The amount of reliable data collected during the historical flood information survey; and
- The variability of events – preferably events would cover a range of flood sizes.

The available historical information highlighted two flood events with sufficient data to potentially support a calibration process – the March 2014 and January 2014 events. Flood information collected in the community questionnaire not specific to particular flood events has also been used to aid the model calibration and validation process.

The calibration and validation of the hydraulic model is presented in Section 5 and Appendix A. A series of sensitivity tests were also carried out to evaluate the model. These tests were conducted to examine the performance of the models and determine the relative importance of different hydrological and hydrodynamic factors. The sensitivity testing of the model is detailed in Section 7.

2.6 Establishing Design Flood Conditions

Design floods are statistical-based events which have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event, which is sometimes referred to as the 1 in 100 year Average Recurrence Interval (ARI) flood, is the best estimate of a flood with a peak discharge that has a 1% (i.e. 1 in 100) chance of occurring in any one year. For the study catchment, design floods were based on design rainfall estimates according to Australian Rainfall and Runoff (IEAust, 1987).

The design flood conditions form the basis for floodplain management in the catchment and in particular design planning levels for future development controls. The predicted design flood conditions are presented in Section 6.

2.7 Mapping of Flood Behaviour

Design flood mapping is undertaken using output from the hydraulic model. Maps are produced showing water level, water depth and velocity. The maps present the peak value of each parameter. Provisional flood hazard categories and hydraulic categories are derived from the hydrodynamic model results and are also mapped. The mapping outputs are described in Section 6 and presented in Appendix C – Volume 2.

3 Community Consultation

3.1 The Community Consultation Process

Community consultation has been an important component of the current study. The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain management activities. It has provided an opportunity to collect information on community members flood experiences in the catchment and to collect feedback on concerns regarding flooding.

The key elements of the consultation process have been as follows:

- Media release to inform the wider community of the study;
- Development and maintenance of a project web-page providing general information on the study background and objectives, reporting progress of the flood study against key milestones, and provide preliminary study output subject to Council approval; and
- Distribution of a questionnaire to landowners, residents and businesses within the study area.

These elements are discussed in detail below. Copies of relevant consultation material are included in Appendix B.

3.2 Media Release

A media release was issued by Council to inform the wider community of the study, canvass any existing flooding issues and inform the community of the community consultation process to be carried out as part of the study.

3.3 Information Website

A website has been established to keep the community informed on the study progress and provide further information on flooding in the catchment Figure 3-1). Community members were also able to complete the community questionnaire and send photographs through the website,

The Botany Bay Foreshore Beach Flood Study website can be accessed at http://botany.bmtwbm.com.au/about-the-study.aspx.

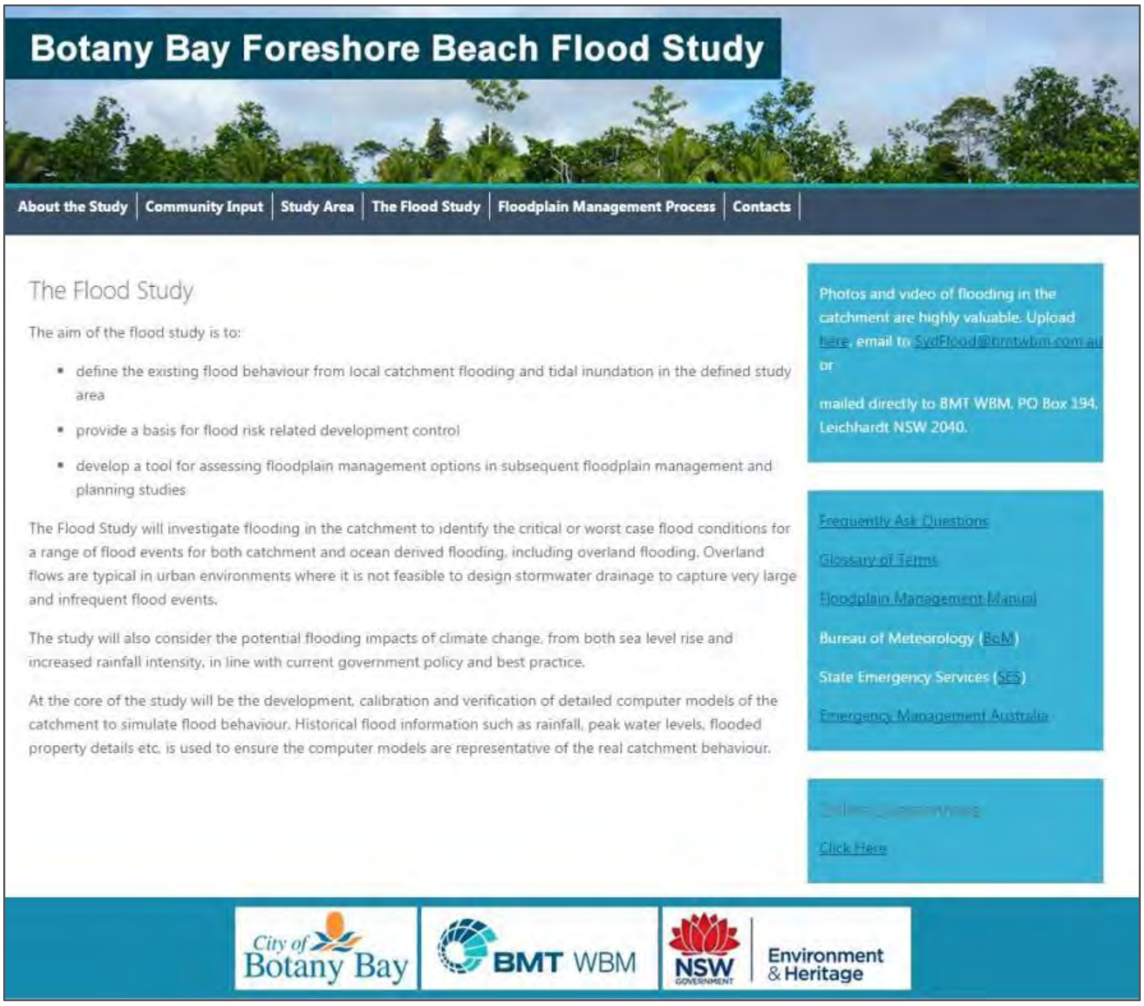


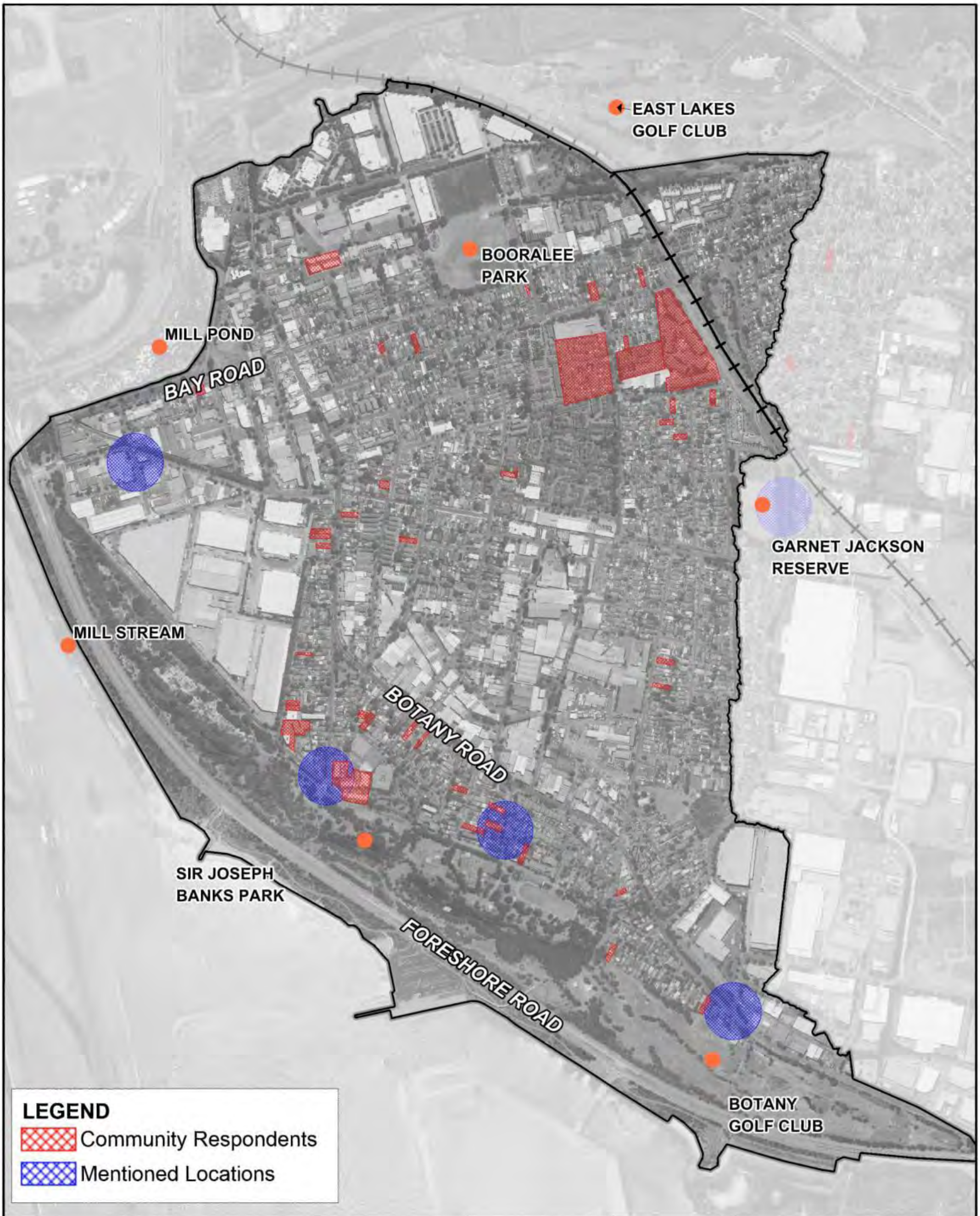
Figure 3-1 Botany Bay Foreshore Beach Flood Study Website

3.4 Community Questionnaire

A questionnaire was distributed to all residential properties and businesses within the study area to collect information on their previous flood experience and flooding issues. The focus of the questionnaire was historical flooding information that may be useful for correlating with predicted flooding behaviour from the modelling. Copies of the newsletter and questionnaire are provided in Appendix B.

A total of 50 completed questionnaires (including electronic responses) were received out of the 4300 letters delivered, representing a response rate of just 1%. On average the respondents have lived in the area for 32 years. The responses have been compiled into a GIS layer and database by BMT WBM.

The distribution of responses along with mentioned locations is presented in Figure 3-2. It can be seen that there is a fairly comprehensive coverage across the residential area.



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Community Consultation Questionnaire Responses

Figure: 3-2

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Comments relating to flood behaviour have been extracted where useful for model calibration and validation purposes. The community responses rarely indicated any specific rainfall events that resulted in flooding across the catchment, but rather, the information received identified certain areas of the study area where flooding occurs on a regular basis. A key event which was identified through the consultation was the March 2014 rainfall event.

A total of 24 community respondents have experienced some degree of flooding within the grounds of their property, two of which experiencing flooding above floor level (Figure 3-3).

Full details of community flooding reports utilised for calibration are presented in Section 5 and Appendix A. The key catchment areas which have community reports of flooding are presented below.

Hale Street Roundabout

Hale Street near Luland Street received a number of reports of flooding. The Community identified that this area is subject to flooding from rainfall events and also from high tides.

The Esplanade

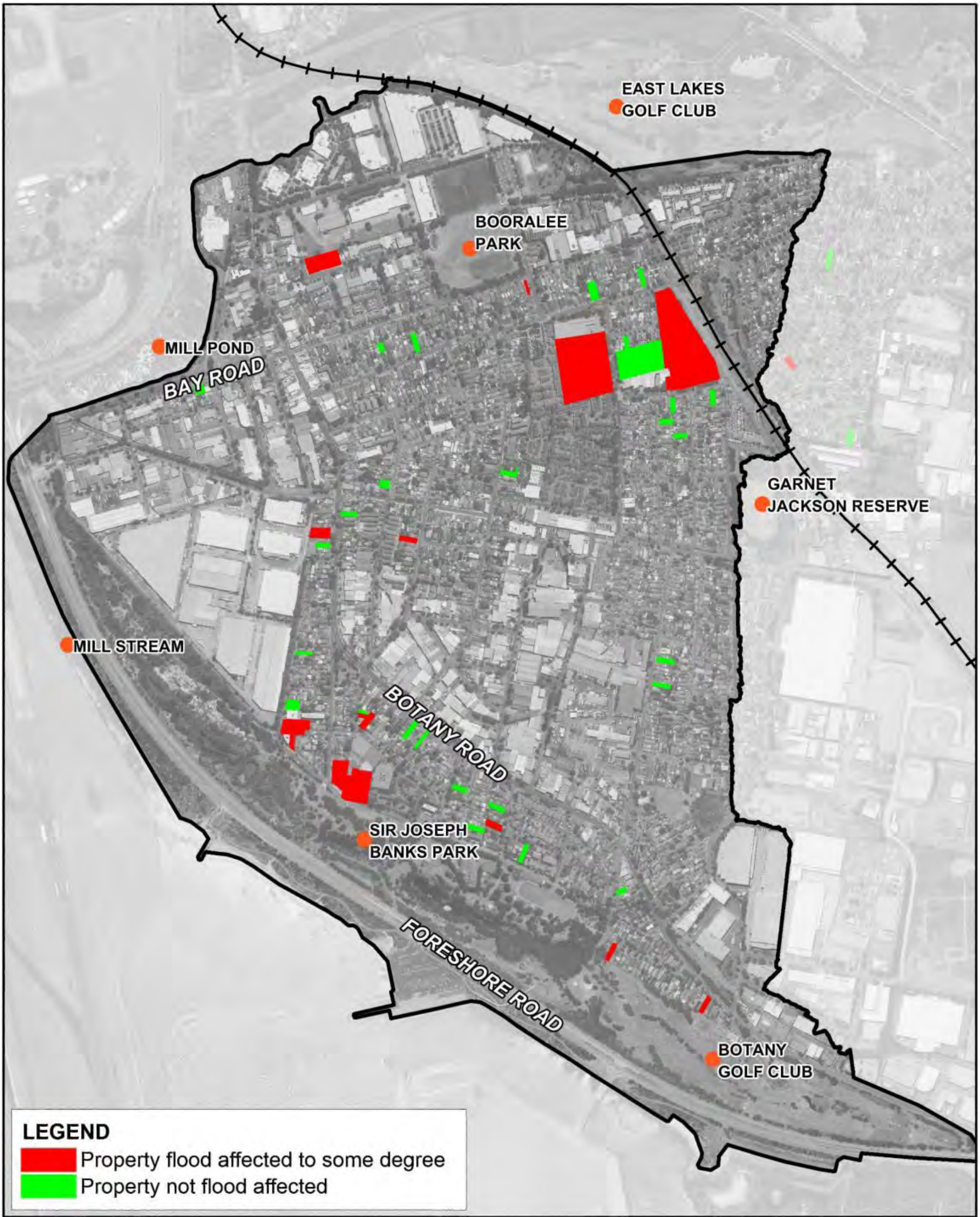
The Esplanade near Chelmsford Avenue received a number of reports of flooding. One report stated that flooding caused a car to float.

Tupia Street

The intersection of Tupia Street and Anniversary Street received a number of reports of extensive though shallow flooding. Some reports indicated blockages may contribute to the flooding.

Botany Road near the Golf Course

Flooding is reported to occur on Botany Road near the Botany Golf Course. This has been reported by residents and also community members who notice the road disruption.



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Community Consultation Property Flooding Experienced

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4 Model Development

Computer models are the most accurate, cost-effective and efficient tools to assess a catchment's flood behaviour. Traditionally, for the purpose of the Flood Study, a hydrologic model and a hydraulic model are developed.

The **hydrologic model** simulates the catchment rainfall-runoff processes, producing the stormwater flows which are used in the hydraulic model.

The **hydraulic model** simulates the flow behaviour of the drainage network and overland flow paths, producing flood levels, flow discharges and flow velocities.

In recent years the advancement in computer technology has enabled the use of the direct-rainfall approach as a viable alternative over the use of "traditional" hydrological models (e.g. XP-RAFTS, WBNM). With the direct-rainfall method the rainfall depths are applied directly to the individual cells of the 2D hydraulic model. This is particularly useful for overland flow studies where model results are desired in areas with very small contributing catchments. This study has adopted the direct-rainfall approach for modelling the catchment hydrology and therefore only a single TUFLOW model has been developed which implicitly performs both hydrologic and hydraulic computation.

Information on the topography and characteristics of the catchment, drainage network and floodplain are built into the model. Recorded historical flood data, including rainfall and flood levels, are used to simulate and validate (calibrate and verify) the model. The model produces as output, flood levels, flows (discharges) and flow velocities.

Development of a hydraulic model follows a relatively standard procedure:

- Discretisation of the catchment, drainage network, floodplain, etc.
- Incorporation of physical characteristics (stormwater pipe details, floodplain levels, structures etc).
- Establishment of hydrographic databases (rainfall, flood flows, flood levels) for historic events.
- Calibration to one or more historic floods (calibration is the adjustment of parameters within acceptable limits to reach agreement between modelled and measured values).
- Verification to one or more other historic floods (verification is a check on the model's performance without further adjustment of parameters).
- Sensitivity analysis of parameters to measure dependence of the results upon model assumptions.

Once model development is complete it may then be used for:

- establishing design flood conditions;
- determining levels for planning control; and
- modelling development or management options to assess the hydraulic impacts (as part of the floodplain risk management study).

4.1 Hydraulic Model

The overland flow regime in urban environments is characterised by large and shallow inundation of urban development with interconnecting and varying flow paths. Road networks often convey a considerable proportion of floodwaters due to the hydraulic efficiency of the road surface compared to developed areas (e.g. blocked by fences and buildings), in addition to the underground pipe network draining mainly to open channels. Given this complex flooding environment, a 2D modelling approach is warranted for the overland flooding areas.

BMT WBM has applied the fully 2D software modelling package TUFLOW. TUFLOW was developed in-house at BMT WBM and has been used extensively for over fifteen years on a commercial basis by BMT WBM. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels, major underground drainage systems, and overland flows through complex overland flow paths using a linked 1D/2D flood modelling approach.

4.1.1 Model Configuration

Consideration needs to be given to the following elements in constructing the model:

- topographical data coverage and resolution (e.g. ALS data);
- location of recorded data (e.g. levels/flows for calibration);
- location of controlling features (e.g. dams, levees, bridges);
- desired accuracy to meet the study's objectives; and
- computational limitations.

With consideration to the available survey information and local topographical and hydraulic controls, a linked 1D/2D model was developed extending from the downstream limit at Botany Bay to the head of the catchment. The stormwater drainage network has been modelled as 1D branches underlying the 2D (floodplain) domain. This approach enables the hydraulic capacity of the pipe drainage to be accurately defined by true pipe dimensions, whilst enabling the overland flow to be represented in 2D.

The total floodplain area modelled within the 2D domain comprises a total area of some 3.5km^2 (up to an elevation of approximately 25m AHD)

A TUFLOW 2D domain model resolution of 2m was adopted for study area. It should be noted that TUFLOW samples elevation points at the cell centres, mid-sides and corners, so a 2m cell size results in DEM elevations being sampled every 1m. This resolution was selected to give necessary detail required for accurate representation of floodplain topography and its influence on overland flows.

4.1.2 Topography

The ability of the model to provide an accurate representation of the overland flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the Botany Bay Foreshore Beach Catchment model, a high resolution DEM (1m grid) was derived from

ALS survey provided by Council. The ground surface elevation for the TUFLOW model grid points are sampled directly from the DEM. It is a representation of the ground surface and does not include features such as buildings or vegetation.

In the context of the overland flow path study, a high resolution DEM is important to suitably represent available flow paths, such as roadway flows that are expected to provide significant flood conveyance within the study area. Experience has proved this to be a successful approach and enables detailed simulation of flooding from overland flow paths.

Linear features that potentially influence the flow behaviour, such as gullies and levees were incorporated into the topography using 3D 'breaklines' in TUFLOW to ensure that these were contained within the model grid and accurately represented in the model. The above ground sewer lines shown in Figure 2-1 are unique catchment features that require breakline definition.

The resulting topography of the hydraulic model is illustrated in Figure 2-4.

4.1.3 Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness (Manning's '*n*') zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (roads and urban areas, etc.) for modelling the variation in flow resistance.

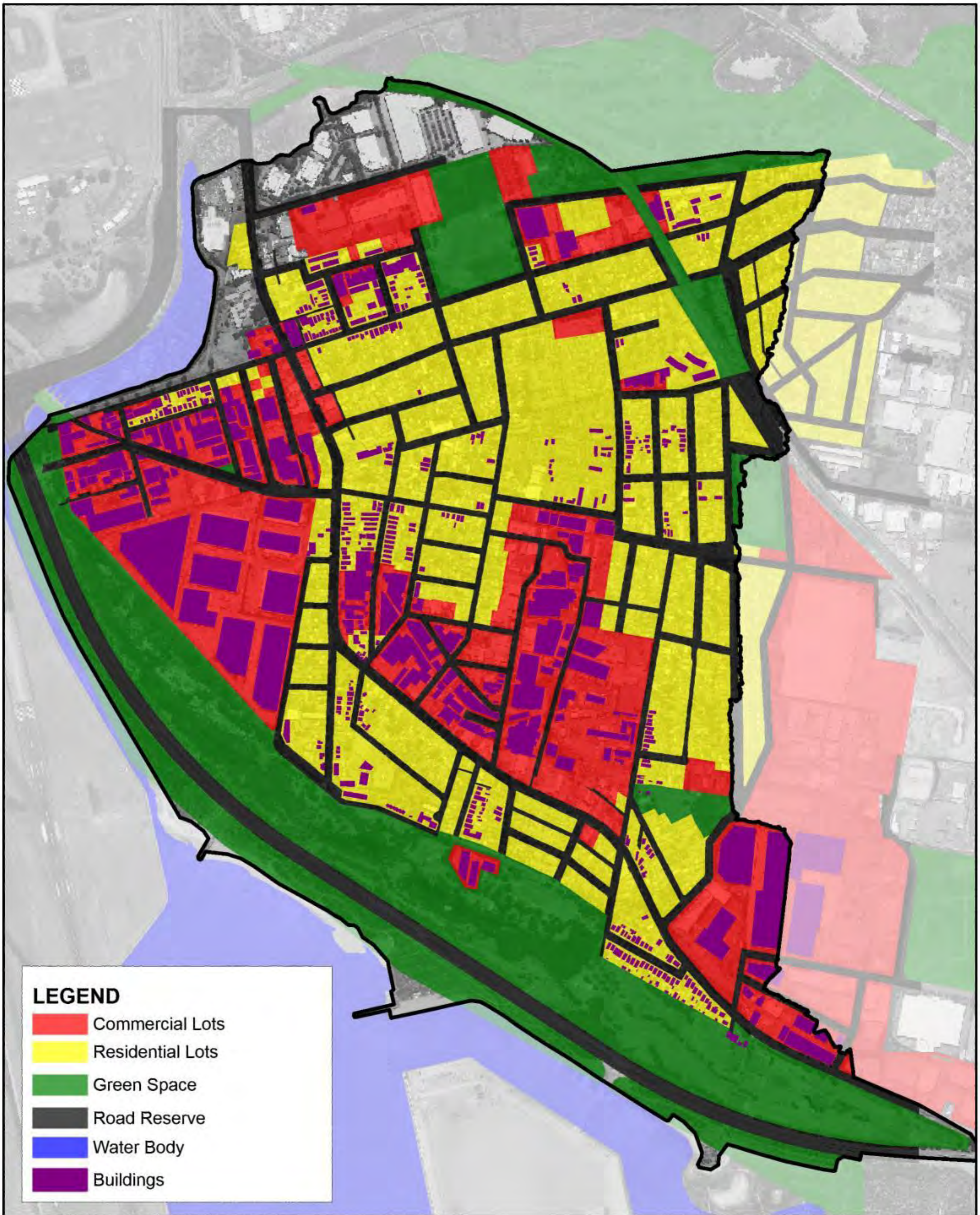
The 2011 aerial photography and cadastre supplied by Council has been used to generate the land-use surface types and roughness zones for the study area. The base land-use map used to assign the different hydraulic roughness zones across the model is shown in Figure 4-1.

The hydraulic roughness is one of the principal calibration parameters within the hydraulic model and has a major influence on flow routing and flood levels. During the model calibration process the Manning's 'n' surface roughness values are adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles.

4.1.4 Representation of Buildings

The presence of buildings and garages/sheds may impede and divert flood flows in the catchment. Buildings further reduce the available overland flood storage available due to building materials such internal and external walls and the concrete slab the building may be constructed upon. The representation of buildings is therefore particularly important in areas conveying significant volumes of flow or experiencing significant ponding depth.

As presented in 5.3, buildings have been represented at ground level with a depth-varying Manning's "*n*" and storage-reduction-factor.



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Land Use Categories

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Depth-varying Manning's "n"

In regards to modelling buildings when a rainfall event first initiates, the most important response is the rapid run-off of water from the building's roof. If a building is in a floodway and the water surrounding the building rises, the most importance response changes to the physical obstruction of the overland flow by the building footprint. A depth-varying manning's allows both responses to be accounted for.

Storage-reduction-factor (SRF)

A key consideration of modelling buildings in a floodplain is adequately representing the flood storage available. If a property is inundated above floor level, water may enter the building as it provides temporary flood storage. Since the building has internal and external walls and is built on an elevated concrete slab the flood storage for the building footprint is reduced compared to the lot before the building was constructed. Certain modelling technique may under or overestimate this storage.

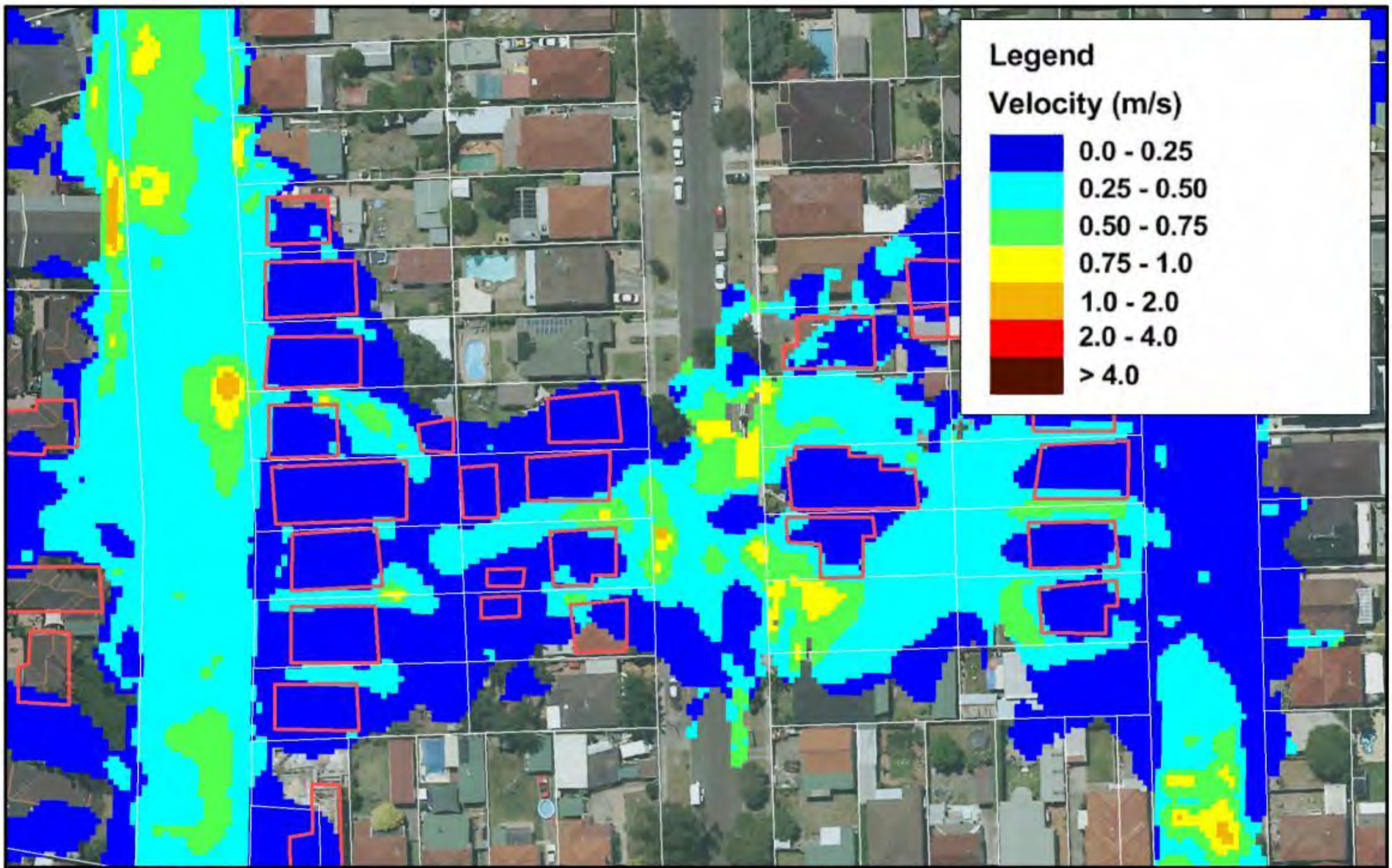
The footprint of the building has been modelled at ground level and the storage available for the building footprint has been reduced by a factor to account for construction materials.

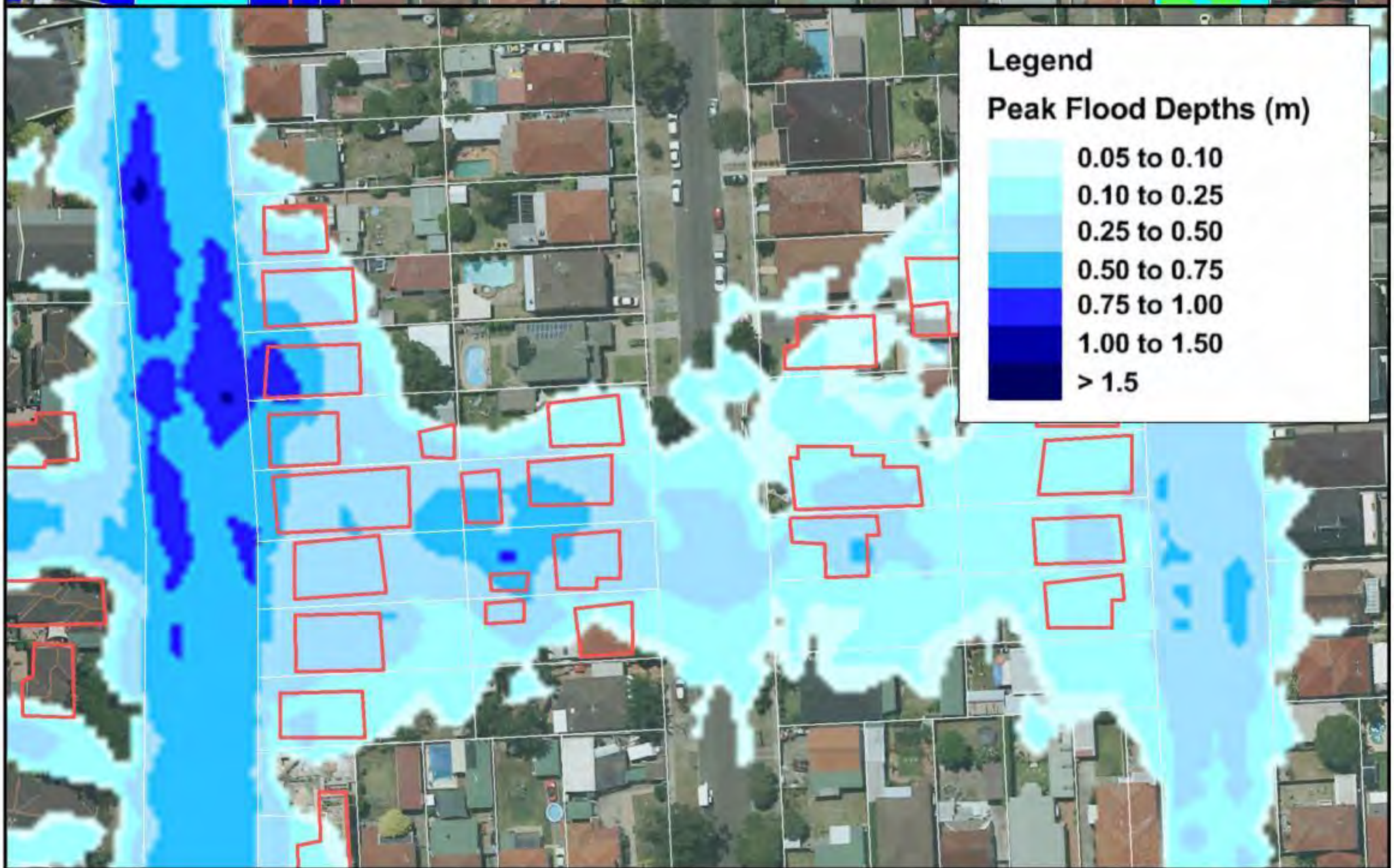
Figure 4-2 shows the flood velocity and depth for a rare flood event as two separate maps. These maps show how the schematisation approach allows physical obstruction of the building (higher velocity flow path around building) to be modelled while still providing temporary flood storage (depth in building footprint). Buildings land-use polygons were manually digitised. Only buildings which interacted with "significant" flows were digitised. In this context, significant was categorised as 0.5% AEP (200 year ARI) flows with either:

- Depth ≥ 0.2 m; or
- Velocity ≥ 0.2m/s; or
- Velocity-depth product ≥ 0.1m^2/s

Stormwater Drainage Network

The review of the available stormwater drainage system found the data to be largely complete along the main drainage lines with only local gaps where survey access had not been possible. In areas where no pipe survey was available pipe size details were assumed from upstream and downstream configurations. The invert levels were interpolated between known locations, maintaining the upstream and downstream pipe gradients where appropriate. These were then cross-checked against the DEM elevations to take account of any local topographic features and to maintain minimum cover levels. A sample longitudinal profile of a modelled drainage line is shown in Figure 4-3. The figure shows the invert and obvert levels according to culvert dimensions, the ground surface level as derived from the DEM, and a minimum cover level of 600mm.





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Velocty, Showing Flow Around Buildings (top), & Depth, Showing Storage in Buildings (bottom)

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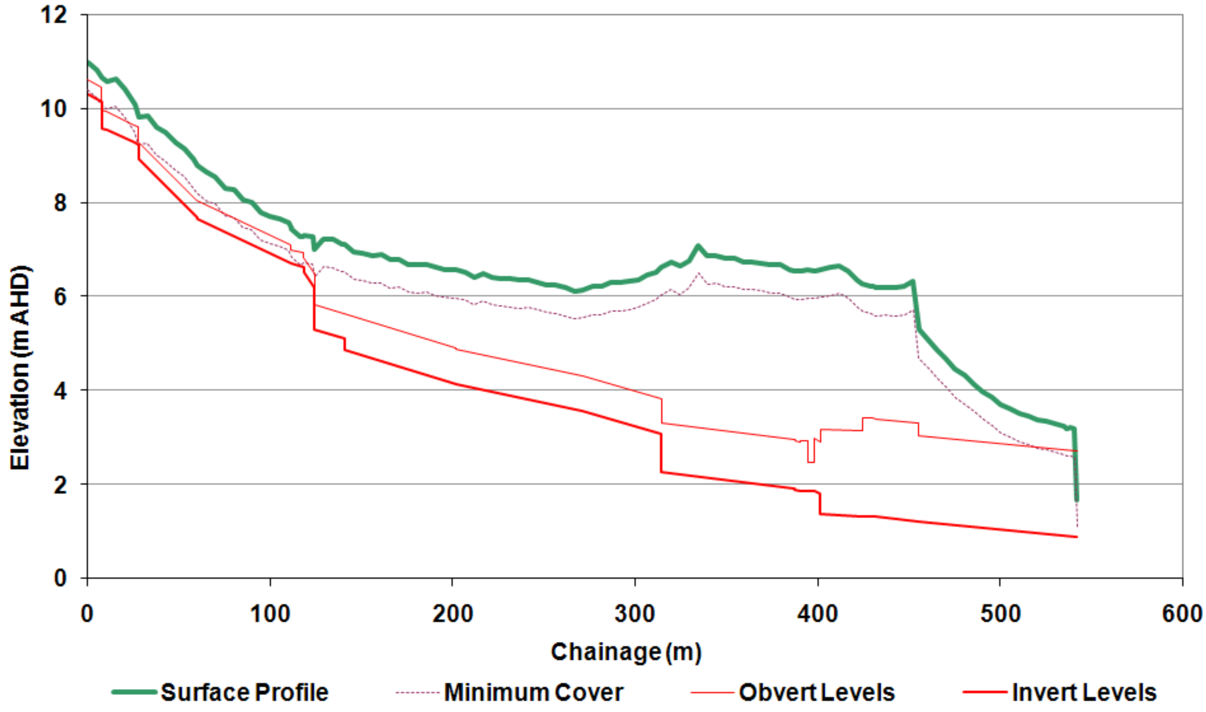


Figure 4-3 Sample Drainage Line Longitudinal Profile

Modelling undertaken for this study incorporated the updated information obtained for the entire stormwater drainage network, noting that the study area contains a number of locations that would drain poorly without the inclusion of the pipe network. Modelling all pipes ensures that the drainage of these areas is well represented.

No private drainage systems or detention basins on private properties have been incorporated in the model. Stormwater on private land is therefore modelled as overland flow to Council's stormwater drainage system. This may have some implications for the definition of flooding. Model results that show ponded stormwater may not flood in reality because private drainage systems may have the capacity to drain some or all of the runoff.

Furthermore, private drainage systems may alter the apparent flooding. Model results in these areas should be interpreted with caution.

4.1.5 Boundary Conditions

The model boundary conditions are derived as follows:

- Rainfall Inflow – the catchment runoff is determined through the hydrological component of the model. With the direct-rainfall approach, rainfall is applied directly every cell in the hydrologic catchment extent, where it is routed as sheet flow until the runoff contribution is substantial enough to generate an overland flow path. Flow is automatically transferred to the 1D domain where sufficient pipe and inlet capacity is available. Surcharging will then occur from the 1D to the 2D domain once the pipe capacity has been exceeded.

- External Flows - flow boundaries have been included on the south-eastern limit where flows from the Floodvale Drain interact with the Botany Bay Foreshore Beach Catchment. These flows have been obtained from the Springvale Drain and Floodvale Drain Flood Study Flood Study model.
- Downstream Water Level – the downstream model limit corresponds to the tidal water level in Botany Bay. A water level time series has been applied at this location for the duration of the modelled events.

The adopted water level boundary for the design events is discussed further in Section 6.

Additional model boundaries have been included at a few locations where runoff will spill across the catchment boundary and exit the hydraulic model extent to the neighbouring catchments. In these instances water level versus discharge relationships were applied in the 2D domain to control the exit of water from the model. The impact of these boundaries is insignificant in determining flood levels within the study area

4.2 Hydrological Model

The hydrological model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff from the catchment is dependent on:

- the catchment slope, area, vegetation, urbanisation and other characteristics;
- variations in the distribution, intensity and amount of rainfall; and
- the antecedent moisture conditions (dryness/wetness) of the catchment.

A direct-rainfall (also referred to as rain-on-grid) approach has been adopted in the TUFLOW hydraulic model (refer to Section 4.1 for details of the model setup). The factors given above have been represented in the model by:

- The runoff routing and hydrological response of the catchment within the 2D model is driven by the surface type and underlying topography. Where appropriate, runoff is diverted into 1D pipe domains of the 2D/1D model (more detail is provided in Section 4.1).
- The amount and intensity of rainfall can be varied across the catchment based on available data and information. For historical events, this can be very subjective if little or no rainfall recordings exist.
- The antecedent moisture conditions are modelled by varying the amount of rainfall which is “lost” into the ground and “absorbed” by storages. For very dry antecedent moisture conditions, there is typically a higher initial rainfall loss.

The general modelling approach and adopted parameters are discussed in the following sections.

4.2.1 Rainfall Data

Rainfall information is the primary input and driver of the hydrological model which simulates the catchment's response in generating surface run-off. Rainfall characteristics for both historical and design events are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36 hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment during any given event and between different events.

The procedure for defining these properties is different for historical and design events. For historical events, the recorded hyetographs at continuous rainfall gauges provide the observed rainfall depth and temporal pattern. Where only daily read gauges are available within a catchment, assumptions regarding the temporal pattern may need to be made.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in Pilgrim (2001). Similarly Pilgrim (2001) defines standard temporal patterns for use in design flood estimation.

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 5.

4.2.2 Rainfall Losses

The antecedent catchment condition reflecting the degree of wetness of the catchment prior to a major rainfall event directly influences the magnitude and rate of runoff. The initial loss – continuing loss model has been adopted during the hydraulic modelling process. The initial loss component represents a depth of rainfall effectively lost from the system and not contributing to runoff and simulates the wetting up of the catchment to a saturated condition. The continuing loss represents the rainfall lost through soil infiltration once the catchment is saturated and is applied as a constant rate (mm/hr) for the duration of the runoff event.

The rainfall loss parameters for the historical calibration/validation events and design events are discussed in further detail in Section 5.

5 Model Calibration and Verification

5.1 Historic Events

Review of community consultation, SWC and Council flooding registers and previous studies yield the following list of historic events (Table 5-1):

Table 5-1 Reported historic flooding events

Flooding Event	Source	Reports	ARI
29 March 1957	Sydney Water Database	2	unknown
10 March 1975	Sydney Water Database	4	100 year
20 May 1975	Sydney Water Database	1	unknown
21 February 1976	Sydney Water Database	1	< 1 year
4 March 1977	Sydney Water Database	6	5 year
1 April 1977	Sydney Water Database	1	unknown
4 March 1979	Sydney Water Database	1	2 year
24 March 2014	Community Consultation, Council Fact Sheet.	11	< 2 year
3 January 2014	Council Fact Sheet (tidal event)	3	No rain
2 January 2014	Council Fact Sheet (tidal event)	3	No rain
3 April 2013	Council Fact Sheet	1	< 1 year
13 June 2012	Council Fact Sheet	1	< 1 year
4 June 2010	Worley Parson FS	2	< 1 year

SWC reports of flooding are very old with no records since 1979. Information about earlier events was derived primarily from Community Consultation and Council records.

The recorded rainfall records for each of the reported historic events at the Sydney Airport gauge were compared with design IFD data. Figure 5-1 shows the earlier SWC events and Figure 5-2 shows the recent events from other sources. For the 4th March 1977, pluviograph rainfall records were also available for the SWC gauge "566028" at 1 hour intervals.

Recent historic events are typically less than a 1 year ARI event with the exception being the 24th March 2014 event which was between a 1 year ARI and 2 year ARI event. The 2nd and 3rd January 2014 flooding event resulted from tidal inundation. No rainfall was recorded during the peak tide. The stormwater network is anticipated to have a design capacity greater than the 1 year ARI event. The reported flooding is therefore anticipated to be a result of other influences such as:

- Stormwater pit inlet blockages at road sags;
- Blockage of trunk pipes at the Botany Bay discharge point due to sand; or
- Combined high tide events in conjunction with rainfall.

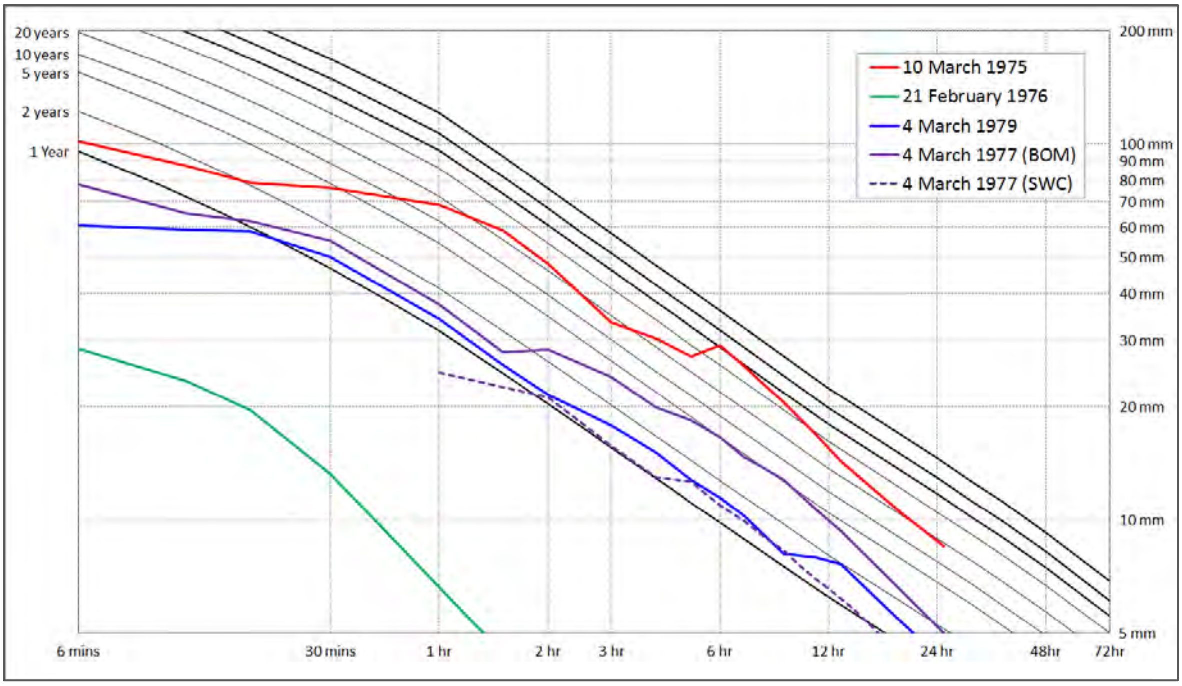


Figure 5-1 Comparison of historic storm with design IFD – earlier events

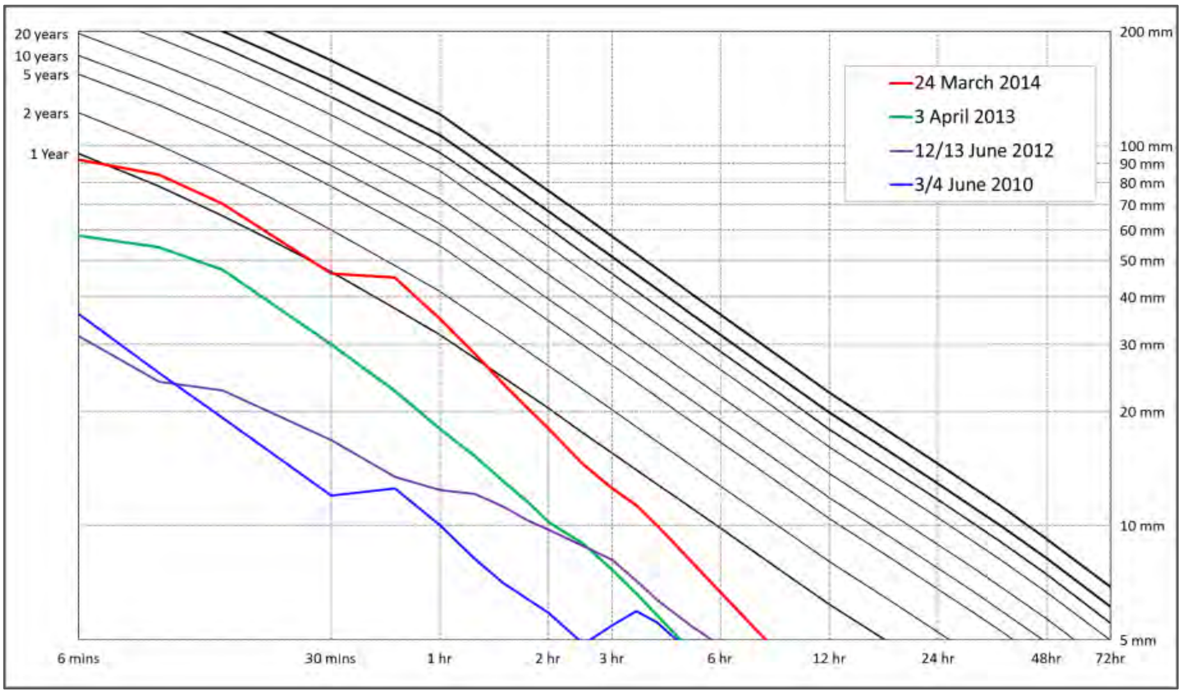


Figure 5-2 Comparison of historic storm with design IFD – recent events

The SWC historic events are greater magnitude with the 10th March 1975 event was equivalent to a 1% AEP (100 year ARI) flood and the 4th March 1977 event was a 20% AEP (~5 year ARI) flood. The issue with the historic events is that significant (and unknown) land use changes and drainage infrastructure changes has occurred in the catchment. Further, details about blockage are not known.

Based on review of available historic flooding records, the 24th March 2014 and 2rd January 2014 events were selected for model calibration. The 24th March 2014 event has a greater number of flooding reports available for calibration since it occurred most recently. The 2nd January event is well documented and demonstrates the inundation potential from tide only.

The 4th March 1977 event was chosen as a verification event noting that there are unresolved differences between the model set up (land use and drainage) and what would have existed for the historic event. The 4th March 1977 was chosen over the 10th March 1975 event since it had greater coverage of flooding reports across the catchment.

Appendix A provides a detailed explanation of the calibration process while a summary is provided in the following sections.

5.1.1 March 2014 rainfall event

Anecdotal reports of flood behaviour for the 24th March 2014 came from multiple sources. Appendix A compiles the flood information obtained and presents results of model calibration. Table 5-2 presents a summary of the reported flood locations and observations.

Table 5-2 Comparison of reported flood behaviour and modelled behaviour (24th March 2014)

Location	Observed Behaviour	Simulated Behaviour
Roundabout at Hale Street and Luland Street	Peak depth ~0.4m	Appendix A Figure 1 10
Corner of Tupia Street and Anniversary Street	Peak depth ~0.3m	Appendix A Figure 1 11
Hale Street roundabout.	Road flooding	Appendix A Figure 1 10
Edgehill Avenue (near street bend)	Flooding prevents property access	Appendix A Figure 1 12
Corner of Chelmsford Avenue and The Esplanade	Peak depth ~0.5m	Appendix A Figure 1 12
Banksia Street (west of Daniel Street)	Minor road flooding	not shown
Tupia Street	Road flooding	Appendix A Figure 1 11
Botany Street (between Hale Street and Kingston Street)	Back yard flooded	Appendix A Figure 1 13
Daphne Street	Road flooding (inundated carpark)	Appendix A Figure 1 14
Botany Road (near Hill St)	Road flooding	Appendix A Figure 1 15
Dent St	Flow through property	Appendix A Figure 1 16

5.1.2 January 2014 tidal event

Anecdotal reports of flood behaviour for the 2nd January 2014 typically came from Council records. Appendix A compiles the flood information obtained and presents results of model calibration. Table 5-3 presents a summary of the observed flood behaviour and provides a comparison with modelled results.

Table 5-3 Comparison of reported flood behaviour and modelled behaviour (2nd January 2014)

Location	Observed Behaviour	Simulated Behaviour
Corner of Luland Street and Hale Street	Peak depths ~ 0.5m	Appendix A Figure 2 6
Booralee Street (near Luland Street)	Peak depths ~ 0.25m	Appendix A Figure 2 6
Bay Street between McFall Street and Byrnes Street	Peak depths ~ 0.1m	Appendix A Figure 2 6

5.1.3 March 1977 rainfall event

Anecdotal reports of flood behaviour for the 4th March 1977 came from Sydney Water records. Appendix A compiles the flood information obtained and presents results of model calibration. Table 5-4 presents a summary of the observed flood behaviour and provides a comparison with modelled results.

Table 5-4 Comparison of reported flood behaviour and modelled behaviour (4th March 1977)

Location	Observed Behaviour	Simulated Behaviour
Corner of Byrnes Street and Erith Street	Lawns flood. Capacity of open channel exceeded.	Figure 3 3
Underwood Avenue	Capacity of open channel exceeded	Figure 3 3
Rochester Street	Property inundation	Figure 3 4
Corner of Cranbrook Street and Salisbury Street.	Property inundation. Capacity of open channel exceed and flow path formed on Margate St	Figure 3 4

5.2 WBNM Catchment Flow Verification

Verification of the adopted direct-rainfall approach for modelling the catchment hydrology has been achieved by undertaking additional hydrological modelling of selected sub-catchments within the overall study area using alternative modelling methods.

The verification approach involved setting up a single WBNM model for an upper study area sub-catchment as shown in Figure 5-3.

5.2.1 Watershed Bound Network Model (WBNM)

WBNM is a runoff-routing hydrological model used to represent catchment rainfall-runoff relationships. WBNM has been developed and tested using Australian catchments in the states of NSW, Queensland, Victoria and South Australia. WBNM models are developed on the basis of a catchment divided into a number of sub-areas based on the stream network. This allows hydrographs to be calculated at various points within the catchment, and the spatial variability of rainfall and rainfall losses to be modelled. WBNM separates overland flow routing from channel routing, allowing changes to either or both of these processes, for example in urbanising catchments.

WBNM uses a Lag Parameter (also referred to as the C value) to calculate the catchment response time for runoff. The Lag Parameter is important in determining the timing of runoff from a catchment, and therefore the shape of the hydrograph. The general relationship is that a decrease in lag time results in an increase in flood peak discharges (Boyd et al., 2007).

5.2.2 Flow Verification Results

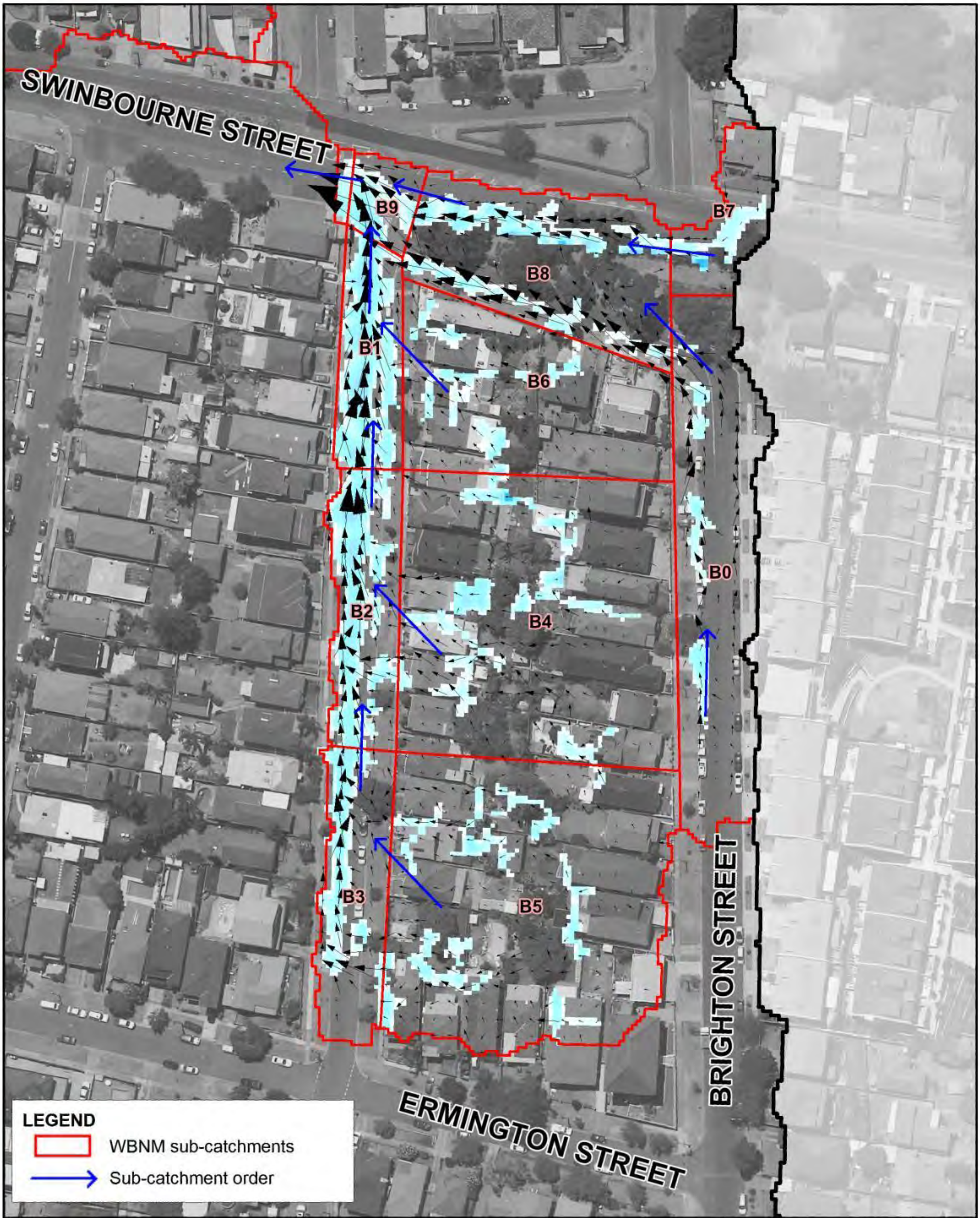
The WBNM model has been schematised using recommended parameters to represent the sub-catchments (Table 5-5). Infiltration losses and fraction impervious were directly translated from TUFLOW direct-rainfall values.

Table 5-5 WBNM Parameter Choices

WBNM Parameter	Value
Pervious Lag Parameter	1.6
Impervious Lag Parameter	0.1
Stream Lag Parameter (Road)	0.33

Modelling using both WBNM and the TUFLOW model developed for this study has been undertaken for the following design rainfall events:

- 10% AEP, 120 minute duration storm; and
- 1% AEP, 120 minute duration storm.



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WBNM Verification

Figure: 5-2

Rev: 1

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0 25 50m
Approx. Scale

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Comparisons between the calculated catchment discharge and the cumulative volume are given in Figure 5-4 for sub-catchment B8 and Figure 5-5 for sub-catchment B9.

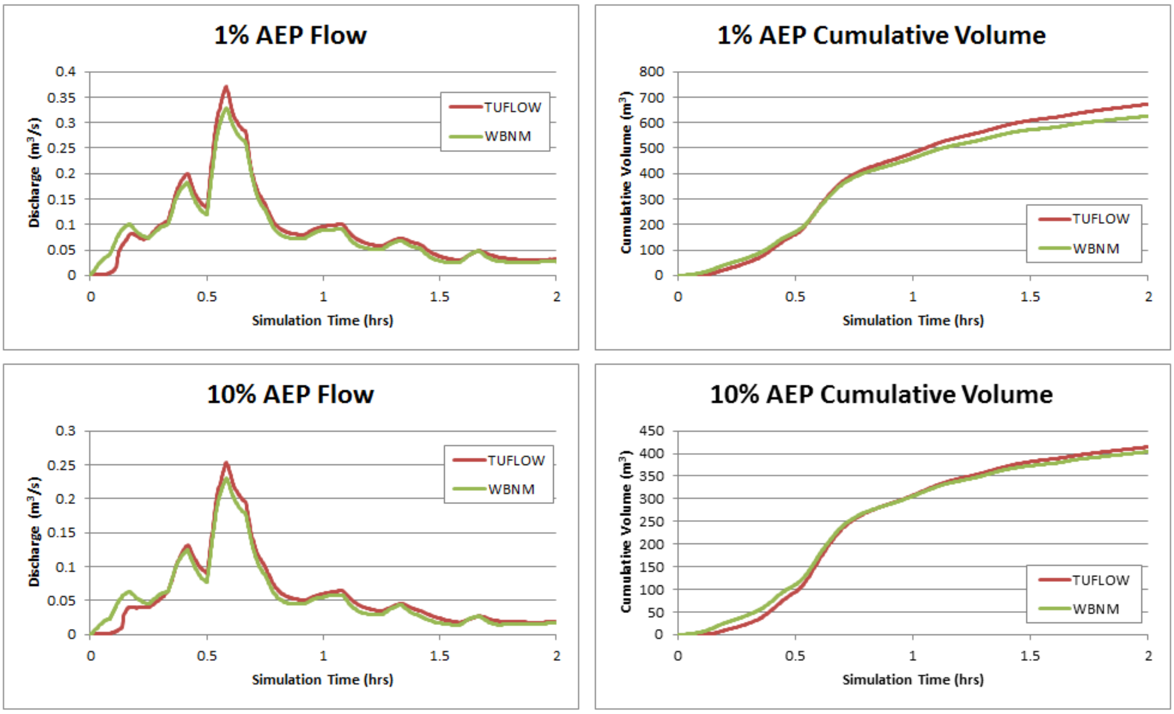


Figure 5-4 Catchment Flow Verification for sub-catchment B8

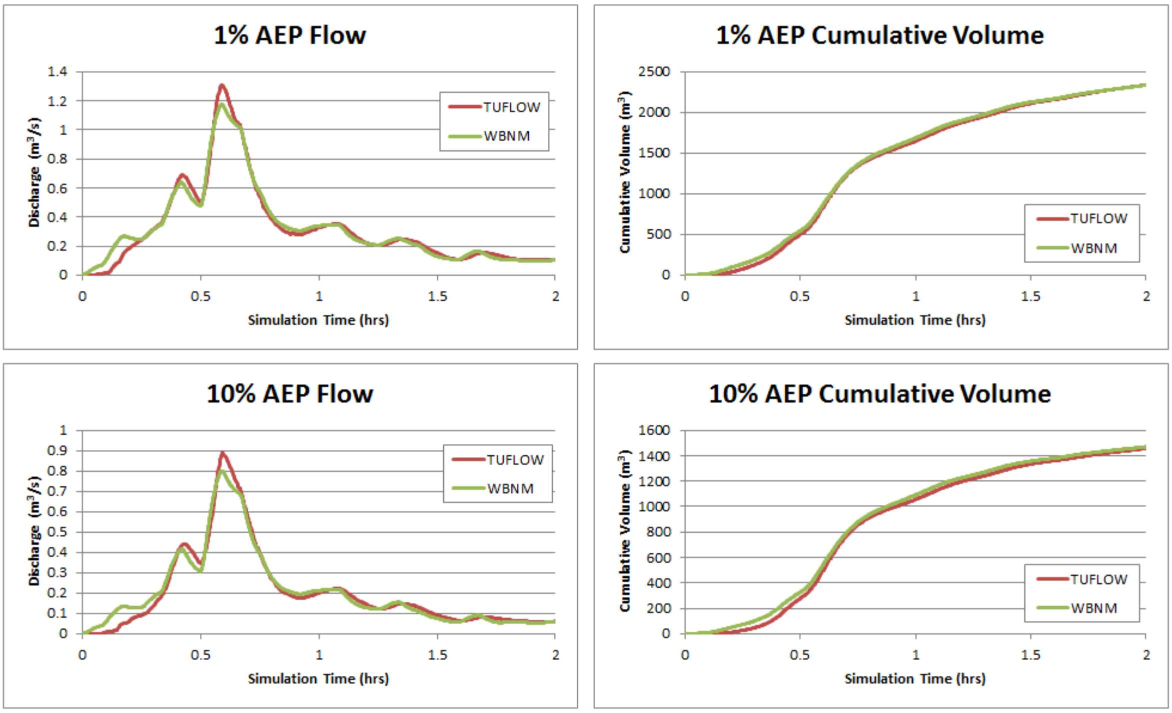


Figure 5-5 Catchment Flow Verification for sub-catchment B9

The figures show that for both catchment locations and for both design storms modelled, the flow generated by TUFLOW correlates well with the WBNM estimates. The following observations can be made:

- The timing of the rising limbs of the hydrographs compare favourably;
- The timing of the peaks and troughs in the hydrographs shape compare favourably;
- TUFLOW produces a slightly more ‘peaky’ catchment response with marginally higher peak flows; and
- The cumulative runoff volumes compare favourably.

WBNM has been verified against empirical data and can therefore be considered to provide a reasonable estimate of the expected runoff for these sub-catchments. However, WBNM is a lumped catchment model and does not represent all the physical features within the catchment which are being modelled in the TUFLOW model (e.g. steep, paved overland flow paths), which may explain some of the differences in the calculated hydrograph shapes.

The good correlation demonstrated between the two modelling methods indicates that the direct-rainfall modelling methodology adopted for the study provides a reasonable basis to assess overall flood behaviour.

5.3 Model Parameters Adopted for Design Event Modelling

The values for the Manning’s ‘*n*’ roughness and rainfall infiltration losses developed for the defined land use categories (refer to Figure 4-1) determined through the model calibration and validation process and adopted for design event modelling are shown in Table 5-6.

Table 5-6 Adopted TUFLOW model parameters

Land Use Category	Manning’s ‘*n*’	Fraction Impervious	Pervious Area Initial Loss (mm)	Pervious Area Infiltration Loss (mm/h)
Residential Lots	0.045	20%	5.0	2.5
Commercial Lots	0.04	90%	5.0	2.5
Default	0.035	10%	10	2.5
Green Space	0.035	5%	10	2.5
Road Reserve	0.02	100%	0.0	0.0
Water Bodies	0.02	100%	0.0	0.0
Buildings	Table 5-7	100%	0.0	0.0

As discussed in Section 4.1.4, building representation is more sophisticated and makes use of depth-varying Manning's "*n*" values to account for shallow roof flow and obstruction to overland flows. Storage reduction factor (SRF) has been used to reduce the storage available on the building parcel to account for building slab and internal/external walls. A storage reduction factor of 0.2 reduced the available flood storage on a parcel by 20%. Table 5-7 presents the building depth varying Manning's "*n*" values and storage reduction factor.

Table 5-7 Building SRF and depth-varying Manning's "*n*"

Land Use Category	Manning's '*n*' Depth ≤ 30mm	Manning's '*n*' Depth ≥ 100mm	Storage Reduction Factor
Buildings	0.02	1.0	0.2

It is noted that the buildings are only digitised when they are in a flow path. Depth varying Manning's "*n*" is used so that early response roof runoff can be conveyed quickly though overland flows are resisted.

Rainfall losses are only applied for "fraction impervious". Zero initial losses and infiltration losses are applied for impervious land area.

A global Manning's "*n*" value of 0.015 was adopted for 1D pipes and 1D concrete open channels.

6 Design Flood Conditions

Design floods are estimated floods used for planning and floodplain management investigations. They are based on having a probability of occurrence specified as either:

- Annual Exceedance Probability (AEP) expressed as a percentage; or
- Average Recurrence Interval (ARI) expressed in years.

Refer to Table 6-1 for a definition of AEP and the ARI equivalent.

Table 6-1 Design flood terminology

ARI[1]	AEP[2]	Comments
200 years	0.5%	An estimated flood or combination of floods which represent the worst case scenario with a 0.5% probability of occurring in any given year.
100 years	1%	As for the 0.5% AEP flood but with a 1% probability.
50 years	2%	As for the 0.5% AEP flood but with a 2% probability.
20 years	5%	As for the 0.5% AEP flood but with a 5% probability.
10 years	10%	As for the 0.5% AEP flood but with a 10% probability.
5 years	20%	As for the 0.5% AEP flood but with a 20% probability.
PMF[3]		An estimated flood or combination of floods which represents the Probable Maximum Flood event possible.

1 Average Recurrence Interval (years)
2 Annual Exceedance Probability (%)
3 Probable Maximum Flood

The design events simulated include the 20% AEP (~5 year ARI), 10% AEP (10 year ARI), 5% AEP (20 year ARI), 2% AEP (50 year ARI), 1% AEP (100 year ARI), 0.5% AEP (200 year ARI) and the Probable Maximum Flood (PMF) for catchment derived flooding. The 1% AEP flood is generally used as a reference flood for land use planning and control.

In determining the design floods it is necessary to take into account the critical storm duration of the catchment. Small catchments are more prone to flooding during short duration storms while for large catchments longer durations will be critical. For example, considering the relatively small size of the study area catchments, they are potentially prone to higher flooding from intense storms extending over a few hours rather than a couple of days.

6.1 Design Rainfall

Design rainfall parameters have been derived using standard procedures defined in *Australian Rainfall and Runoff – A Guide to Flood Estimation* (AR&R) (Pilgrim, DH, 2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for the study catchment is presented herein.

6.1.1 Rainfall Depths

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (Pilgrim, DH, 2001). These curves provide rainfall depths for various design magnitudes for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is "the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year" (Pilgrim, DH, 2001). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology. The method is appropriate for durations up to 6 hours and considered suitable for small catchments in the Sydney region.

A range of storm durations from 15 minutes to 9 hours were modelled in order to identify the critical storm duration for design event flooding in the catchment. Table 6-2 shows the average design rainfall intensities based on AR&R adopted for the modelled events.

Table 6-2 Rainfall intensities for design events (mm/h)

Duration	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMP
15 min	108	122	140	164	182	200	640
25 min	85.4	96.8	112	131	146	161	N/A
30 min	78.1	88.7	102	121	134	149	460
45 min	63.5	72.4	83.9	99.2	111	123	387
1.0 h	54.4	62.3	72.4	85.8	96.1	107	340
1.5 h	41.9	47.8	55.6	65.8	73.6	81.6	273
2.0 h	34.6	39.5	45.9	54.3	60.7	67.3	235
3.0 h	26.4	30.1	34.9	41.2	46.1	51.0	183
9.0 h	12.6	14.4	16.6	19.6	21.8	24.1	N/A

The areal reduction factor takes into account the unlikelihood that larger catchments will experience rainfall of the same design intensity over the entire area. Due to the relatively small size of the catchment and adopting a conservative approach, an aerial reduction factor was not applied in this study.

6.1.2 Temporal Patterns

The IFD data presented in Table 6-2 provides for the average intensity that occurs over a given storm duration. Temporal patterns are required to define what percentage of the total rainfall depth occurs over a given time interval throughout the storm duration.

For frequent, large and rare design flood events including the 18% to 0.5% AEP events, design temporal rainfall patterns from AR&R (Pilgrim, DH, 2001) for temporal zone 1 have been adopted. For the PMF event, the temporal pattern as provided in BOM (2003) was used.

The same temporal pattern has been applied across the whole catchment. This assumes that the design rainfall occurs simultaneously across each of the modelled sub-catchments. The direction of a storm and relative timing of rainfall across the catchment may be determined for historical events if sufficient data exists, however, from a design perspective the same pattern across the catchment is generally adopted.

6.2 Design Ocean Boundary

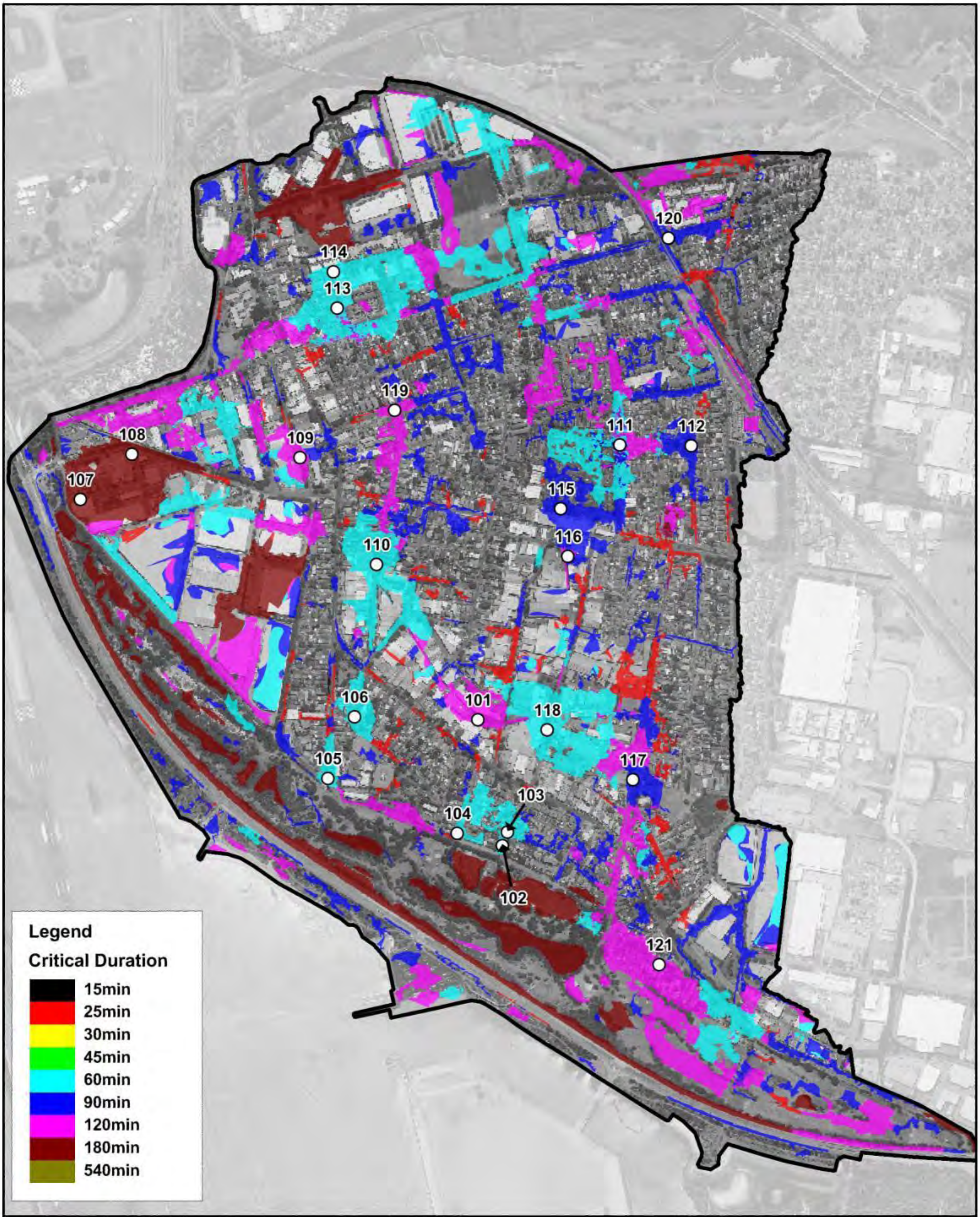
An ocean boundary, representative of a mean high water spring tide condition for Botany Bay has been adopted for the catchment derived design flood events. This is consistent with the neighbouring Spring Vale Drain and Floodvale Flood Study (BMT WBM, 2014) and in accordance the Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments (DECCW, 2010). The tidal boundary for design event modelling and tidal inundation assessment adopted a constant peak water level, while the tidal boundary for historic events was dynamic using recorded tide data at hourly intervals.

6.3 Critical Storm Duration Assessment

As discussed in Section6.1, a range of durations has been modelled. For complete catchment modelling, it is common for different durations to produce critical flood levels at different locations. Upper catchment reaches or isolated areas with small catchments will likely respond to a shorter duration event. Lower catchment reaches, catchment areas with large upstream detention volumes or large upstream areas will likely respond to longer storms with greater volume. An assessment of the critical durations was undertaken for the 1% AEP design event and the PMF design event.

- For the 1% AEP, an envelope of the 25minute and 120minute durations was determined to approximately represent critical duration for the catchment in both upper and lower catchment regions.
- For the PMF, an envelope of the 15minute and 60minute was determined to approximately represent the critical duration for the catchment in both upper and lower catchment regions.

Figure 6-1 graphically shows the 1% AEP critical duration assessment. As presented, upper parts of the catchment are critical for shorter durations such as the 25 minute and 60 minute duration. Lower in the catchment the 120 minute and even 540minute duration storms define the critical flood level. Figure 6-1 clearly shows regions of differing critical duration though it does not inform to what degree (meters depth) the duration is critical by.



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Critical Duration Assessment 1% AEP (100YR ARI)

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Table 6-3 presents the difference in flood depth for individual storm durations compared to the 1% AEP critical duration envelope derived from the 1% AEP 25minute and 1% AEP 120minute storm. As shown, while there a many regions of different critical durations, the difference in flood depths between the regions typically aren't significant. As presented in Table 6-3 an envelope generated from the 25minute and 120minute duration storm never underestimates peak flood level by more than 0.05m.

Critical duration assessment was similarly undertaken for the PMF. Table 6-4 presents the difference in flood depth for individual storm durations compared to the PMF critical duration envelope derived from the 15minute and 60minute storm. As presented in Table 6-4 an envelope generated from the 15minute and 60minute duration storm never underestimates peak flood level by more than 0.01m.

Table 6-3 1% AEP Critical duration assessment (peak flood level difference (m) from maximum envelope)

Location #	015min	025min	030min	045min	060min	090min	120min	180min	540min
101	-0.35	-0.34	-0.34	-0.29	-0.03	-0.01	+0.00	-0.33	-0.50
102	-0.15	-0.05	-0.03	-0.01	+0.00	+0.00	+0.00	-0.03	-0.51
103	-0.15	-0.05	-0.03	-0.01	+0.00	+0.00	+0.00	-0.03	-0.45
104	-0.24	-0.14	-0.13	-0.05	+0.02	+0.00	+0.00	-0.16	-0.48
105	-0.23	-0.15	-0.15	-0.05	+0.04	+0.01	+0.00	-0.22	-0.72
106	-0.17	-0.09	-0.06	-0.02	+0.01	+0.00	+0.00	-0.01	-0.41
107	-0.38	-0.26	-0.23	-0.16	-0.08	-0.04	+0.00	+0.04	-0.58
108	-0.39	-0.26	-0.23	-0.17	-0.08	-0.04	+0.00	+0.04	-0.64
109	-0.08	-0.04	-0.04	-0.02	-0.01	+0.00	+0.00	-0.03	-0.18
110	-0.24	-0.14	-0.11	-0.03	+0.01	+0.00	+0.00	-0.05	-0.50
111	-0.14	-0.06	-0.04	-0.01	+0.01	+0.01	+0.00	-0.03	-0.26
112	-0.05	-0.02	-0.03	-0.03	+0.00	+0.00	+0.00	-0.05	-0.32
113	-0.40	-0.19	-0.14	-0.07	+0.01	-0.01	+0.00	-0.07	-0.83
114	-0.30	-0.19	-0.14	-0.07	+0.00	-0.01	+0.00	-0.07	-0.37
115	-0.35	-0.17	-0.12	-0.04	+0.00	+0.00	+0.00	-0.04	-0.91
116	-0.16	-0.14	-0.14	-0.07	-0.02	-0.01	+0.00	-0.04	-0.53
117	-0.08	-0.04	-0.04	-0.03	-0.01	+0.00	+0.00	-0.05	-0.26
118	-0.17	-0.09	-0.07	-0.02	+0.02	+0.00	+0.00	-0.06	-0.49
119	-0.06	-0.03	-0.03	-0.03	-0.01	+0.00	+0.00	-0.04	-0.25
120	-0.11	-0.06	-0.05	-0.03	-0.01	+0.00	+0.00	-0.05	-0.51
121	-0.46	-0.29	-0.23	-0.12	-0.04	-0.01	+0.00	+0.00	-0.68

Refer to Figure 6-1 for the reporting locations

Table 6-4 PMF critical duration assessment (peak flood level difference (m) from maximum envelope)

Location #	015 min	030 min	045 min	060 min	090 min	120 min	180 min	240 min	300 min	360 min
101	-0.50	-0.24	-0.09	+0.00	+0.03	+0.03	-0.04	-0.10	-0.14	-0.20
102	-0.15	-0.07	-0.02	+0.00	-0.01	-0.02	-0.05	-0.06	-0.08	-0.09
103	-0.15	-0.06	-0.02	+0.00	-0.01	-0.01	-0.05	-0.06	-0.07	-0.09
104	-0.19	-0.06	-0.01	+0.00	+0.01	+0.01	-0.03	-0.06	-0.06	-0.07
105	-0.76	-0.59	-0.35	-0.18	-0.05	-0.02	-0.03	+0.00	-0.01	-0.08
106	-0.28	-0.14	-0.05	+0.00	+0.04	+0.04	+0.02	-0.01	-0.02	-0.05
107	-1.84	-1.33	-1.12	-0.71	-0.56	-0.19	-0.06	+0.00	-0.01	-0.07
108	-1.84	-1.33	-1.12	-0.71	-0.56	-0.19	-0.06	+0.00	-0.01	-0.07
109	-0.11	-0.12	-0.13	-0.14	-0.16	-0.17	-0.05	+0.00	+0.00	-0.06
110	-0.46	-0.18	-0.06	+0.00	+0.04	+0.04	+0.01	-0.02	-0.04	-0.07
111	-0.14	-0.04	-0.01	+0.00	-0.03	-0.05	-0.09	-0.13	-0.15	-0.18
112	+0.00	-0.02	-0.03	-0.05	-0.07	-0.09	-0.13	-0.15	-0.16	-0.18
113	-0.28	-0.09	-0.02	+0.00	-0.02	-0.05	-0.10	-0.15	-0.19	-0.23
114	-0.28	-0.09	-0.02	+0.00	-0.02	-0.05	-0.11	-0.15	-0.19	-0.23
115	-0.17	-0.05	-0.01	+0.00	-0.02	-0.04	-0.09	-0.12	-0.15	-0.18
116	-0.34	-0.11	-0.01	+0.00	-0.02	-0.06	-0.12	-0.18	-0.21	-0.28
117	+0.00	-0.01	-0.02	-0.03	-0.06	-0.08	-0.11	-0.13	-0.14	-0.16
118	-0.33	-0.16	-0.05	+0.00	+0.01	-0.01	-0.08	-0.14	-0.19	-0.25
119	+0.00	-0.01	-0.02	-0.04	-0.06	-0.08	-0.11	-0.12	-0.14	-0.15
120	+0.00	+0.00	+0.01	+0.00	-0.01	-0.03	-0.06	-0.09	-0.10	-0.12
121	-0.77	-0.60	-0.46	-0.38	-0.33	-0.20	-0.08	+0.00	+0.06	+0.06

Refer to Figure 6-1 for the reporting locations

6.4 Design Blockage Factor

Consistent with the methodology applied for the neighbouring Springvale Drain and Floodvale Drain Flood Study (BMT WBM, 2014) a level of blockage was considered for design flood results. Community consultation, literature review and site inspection confirms that there is potential for blockage due to debris at gutter inlets and also sand at beach outlets.

For each storm event and storm duration a blockage and a non-blockage scenario were simulated. Results of the two blockage scenarios were combined with the peak envelope being adopted for design results. Descriptions of the blockage scenarios are provided:

Non-blockage Scenario

Pipes and covered channels were assumed 0% blocked and pits were considered effectively unlimited so pipe capacity rather than pit inlet capacity was the limiting factor. Open channel and bridges were additionally assumed 0% blocked.

Blockage Scenario

Pipes and covered channels were assumed 50% blocked and pits were considered effectively unlimited so blocked pipe capacity rather than pit inlet was the limiting factor. Open channel was assumed 0% blocked, though bridges were assumed 50% blocked.

Flood levels were typically governed by the blocked scenario though isolated locations have higher flood levels for the non-blocked scenario.

6.5 Critical Duration Storm Results

A range of design flood events were modelled, the results of which are presented and discussed below. The simulated design events included the 20% AEP (~5 year ARI), 10% AEP (10 year ARI), 5% AEP (20 year ARI), 2% AEP (50 year ARI), 1% AEP (100 year ARI), 0.5% AEP (200 year ARI) and the Probable Maximum Flood (PMF) for catchment derived flooding.

For each non-PMF event, the 25 minute and 120 minute duration storms were simulations for the blocked and non-blocked scenarios. The design results presented in the remainder of the report represent the maximum values across the two durations and two blockage scenarios (peak envelope) for each design event simulated. For the PMF event, the envelope was created from an envelope of the 15minute and 60minute duration and the blocked and non-blocked scenarios.

A series of design flood maps are provided in Appendix C – Volume 2. Results are presented where the depth is greater than 0.05m OR the velocity-depth product is greater than 0.05m^2/s. Isolated water bodies with areas less than 250m^2 were additionally filtered. Supplementary to mapped result output, tabular results of peak flood behaviour have been provided for all design events in Table 6-5 and Table 6-6. The locations of flooding behaviour reported in the tables are shown in Figure 6-2 and Figure 6-3 respectively. Figure 6-4 shows the flood level profile for the location shown in Figure 6-2

It is noted that the peak overland flow values are typically derived from the blocked scenario while the peak pipe flows are derived from the non-blocked scenarios.

Table 6-5 Peak design flood levels (mAHD)

Location#	20% AEP	10 % AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
101	3.42	3.58	3.69	3.78	3.85	3.89	4.61
102	3.92	3.95	3.97	3.99	4.01	4.02	4.34
103	3.92	3.95	3.97	3.99	4.01	4.02	4.34
104	3.47	3.52	3.63	3.73	3.81	3.89	4.36
105	2.26	2.40	2.58	2.67	2.71	2.74	3.75

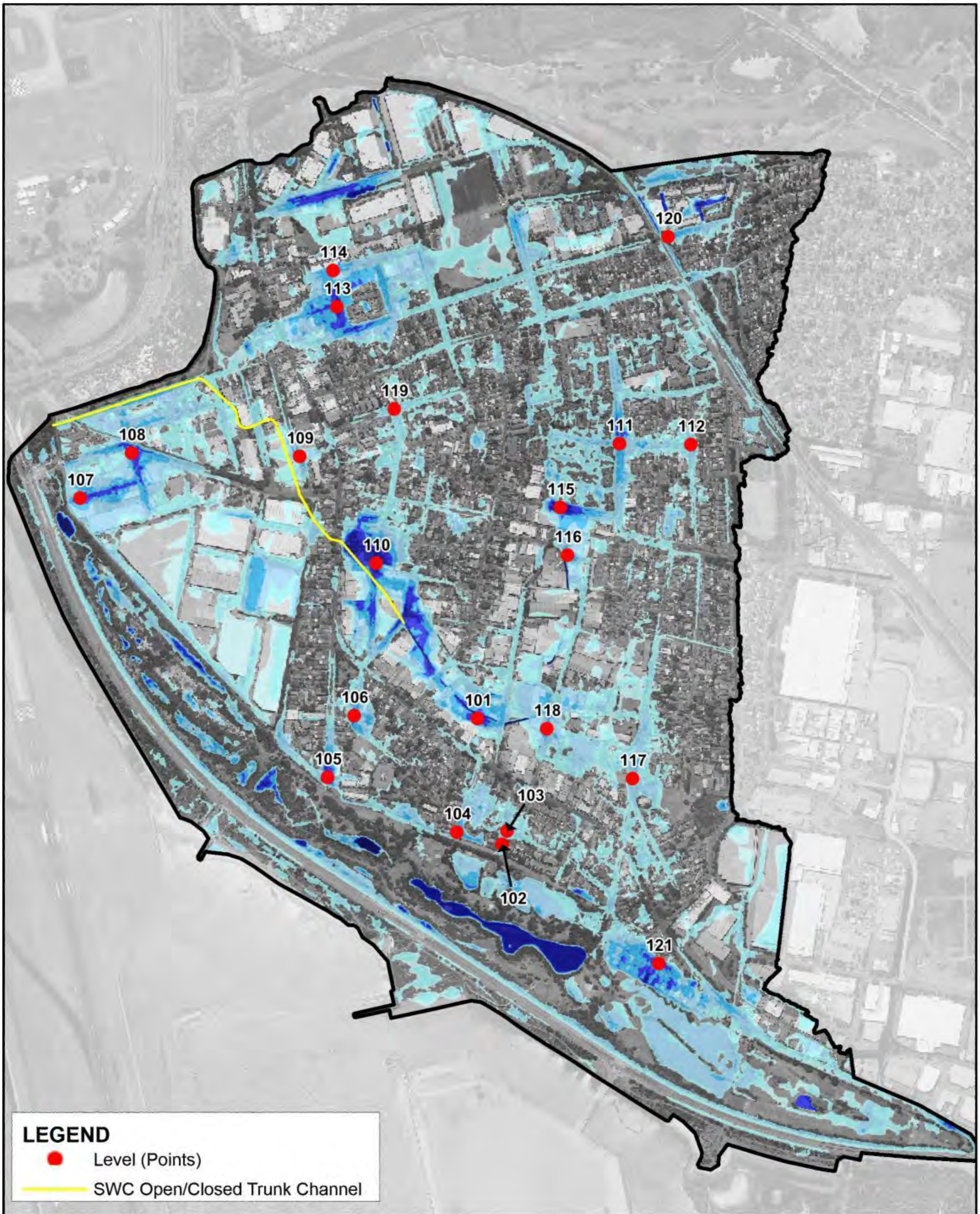
Location#	20% AEP	10 % AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
106	3.33	3.36	3.39	3.42	3.45	3.54	4.00
107	1.58	1.64	1.71	1.79	1.85	1.92	3.24
108	1.58	1.64	1.71	1.79	1.85	1.92	3.24
109	3.27	3.29	3.32	3.34	3.35	3.37	3.53
110	3.10	3.17	3.31	3.51	3.61	3.69	4.21
111	6.95	6.97	7.02	7.05	7.08	7.09	7.46
112	7.85	7.87	7.89	7.90	7.92	7.94	8.10
113	4.86	4.93	5.00	5.08	5.13	5.18	5.74
114	4.86	4.93	5.00	5.08	5.13	5.18	5.75
115	6.76	6.82	6.87	6.93	6.97	7.00	7.42
116	5.95	5.99	6.08	6.20	6.25	6.29	6.82
117	5.03	5.05	5.08	5.10	5.12	5.14	5.32
118	4.16	4.20	4.25	4.29	4.33	4.37	5.06
119	5.81	5.83	5.85	5.87	5.88	5.90	6.05
120	8.79	8.82	8.86	8.89	8.91	8.93	9.10
121	2.31	2.37	2.42	2.47	2.49	2.58	3.69

Refer to Figure 6-2 for the reporting locations

Table 6-6 Peak design flood flows – pipe (P) and overland (Q) (m^3/s)

Location#	Q005	Q010	Q020	Q050	Q100	Q200	QPMF
201	6.5	7.0	7.5	8.0	8.6	9.2	17.3
202	0.9	1.1	1.4	1.7	2.0	2.4	3.5
203	0.0	0.0	0.1	0.3	0.3	0.3	2.1
204	3.9	4.5	5.4	6.2	6.6	7.4	10.8
205	1.3	1.4	1.4	1.4	1.5	1.6	1.9
206	5.9	6.9	7.8	9.5	9.8	10.1	12.7
301	0.0	0.0	0.1	0.1	0.2	0.2	1.1
302	1.9	2.4	2.9	3.5	4.0	4.6	16.9
303	1.6	1.8	1.8	1.8	1.8	1.8	1.8
304	6.5	7.0	7.5	8.0	8.6	9.2	17.3
305	0.9	1.1	1.4	1.7	2.0	2.4	3.5

Refer to Figure 6-3 for the reporting locations



Title:

Level Recording - Points and Profiles

Figure: 6-2

Rev: 1

0 250 500m

Approx. Scale

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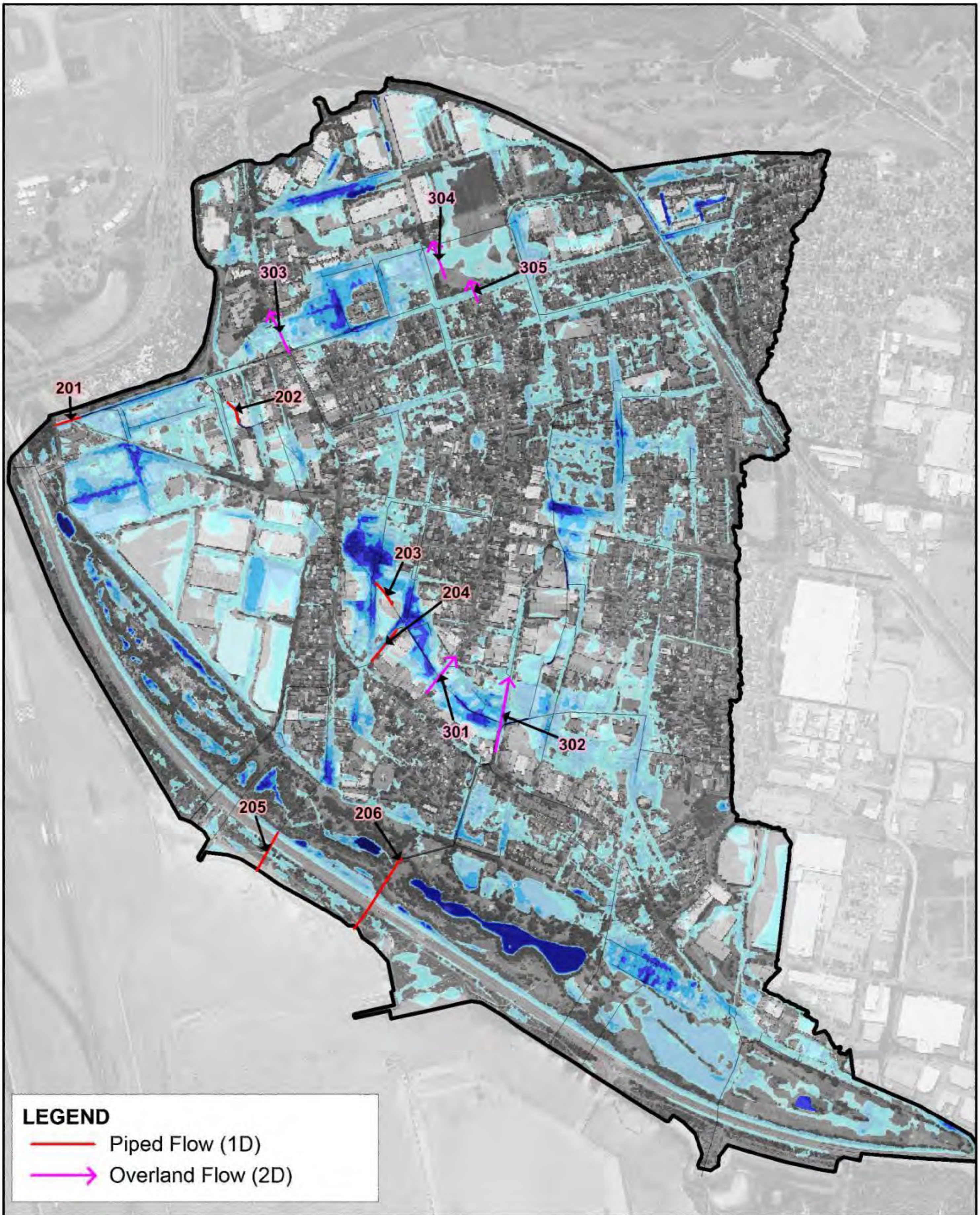

Title:
Flow Recording - Overland and Pipe Flow

Figure: 6-3

Rev: 1

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

0 250 500m
Approx. Scale

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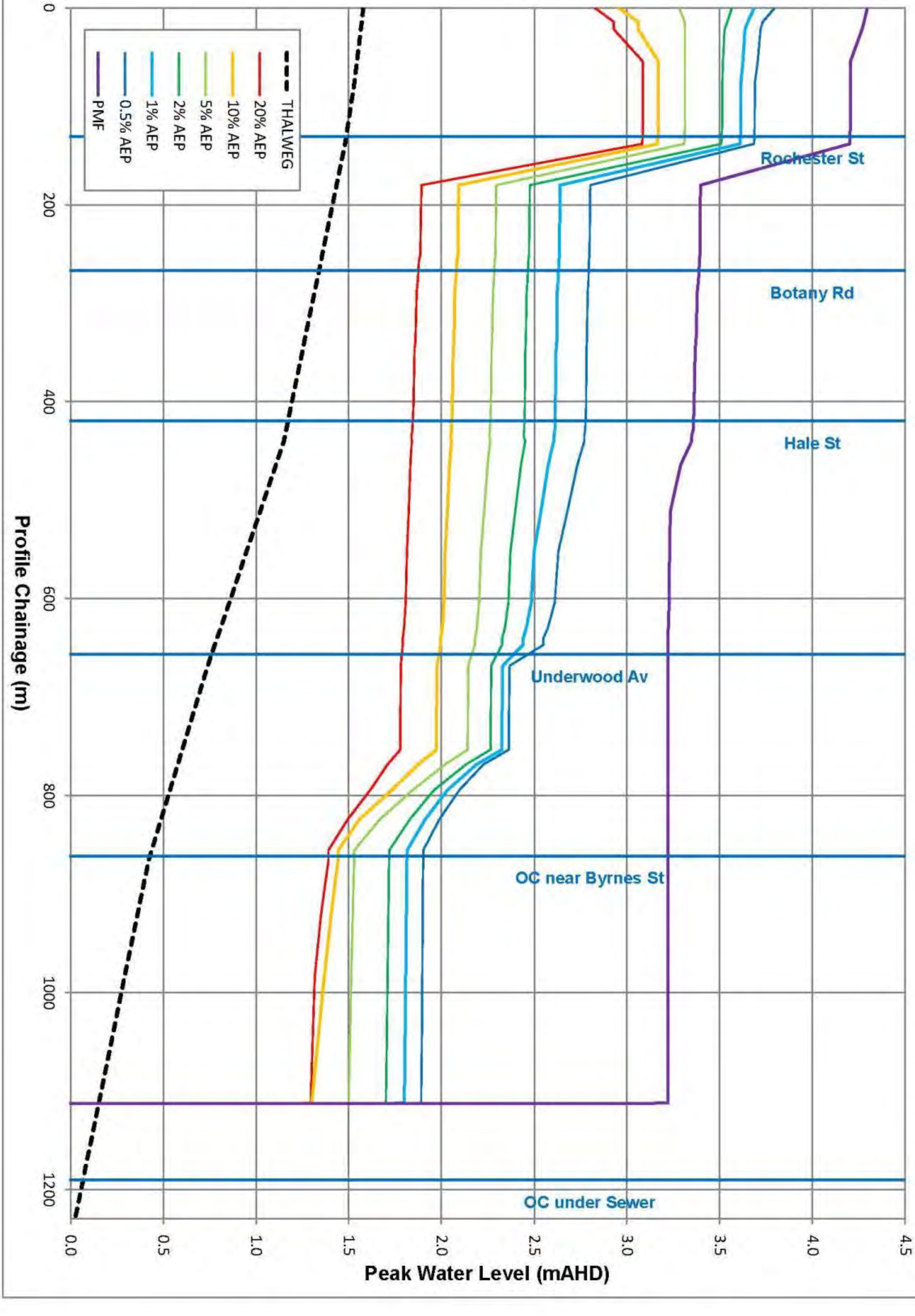
FIGURE 6-4

SWC TRUNK PROFILE - DESIGN EVENT RESULTS



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6.6 Tidal Inundation

Tidal inundation modelling was undertaken for the mean high water springs level (MHWS), highest astronomical tidal (HAT) and maximum recorded tide (MRT) for Botany Bay. The tidal levels were applied as a constant water level at the downstream boundaries of the model. The tidal inundation extents are presented in Appendix C – Volume 2 (Figure C- 22).

Note that Table 2-2 in Section 2.2.6 presents tidal statistics obtained from the Bureau of Meteorology's National Tidal Centre.

As presented in Figure C- 22 the industrial area near Luland Street and Hale Street is most at risk from tidal inundation. Dent Street is another low lying area directly connected to Botany Harbour by piped drainage. Overland inundation does not result at Dent Street for the tidal scenarios trialled though the connected pipes are full from the tailwater and the hydraulic grade line is very close to surcharging.

6.7 Hydraulic Classification

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (NSW Government, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define flood impact categories across the catchment. Approaches to define hydraulic categories that were considered for this assessment included partitioning the floodplain based on:

- Peak flood velocity;
- Peak flood depth;
- Peak velocity * depth (sometimes referred to as unit discharge);

- Cumulative volume conveyed during the flood event; and
- Combinations of the above.

The definition of flood impact categories that was considered to best fit the application within the catchment was based on a combination of velocity*depth and depth parameters. The adopted hydraulic categorisation is defined in Table 6-7.

Preliminary hydraulic category mapping for all design events is included in Appendix C – Volume 2 (Figure C- 23 to Figure C- 29). It is also noted that mapping associated with the flood hydraulic categories may be amended in the future, at a local or property scale, subject to appropriate analysis.

Table 6-7 Hydraulic Categories

Hydraulic Category	Definition	Description
Floodway	Velocity * Depth > 0.25 m2/s AND Velocity > 0.25 m/s OR Velocity > 1.0 m/s.	Areas and flowpaths where a significant portion of floodwaters are conveyed during a flood.
Flood Storage	NOT Floodway AND Depth > 0.2 m	Floodplain areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	NOT Floodway AND Depth < 0.2 m	Areas that are low velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

6.8 Provisional Hazard Categories

The NSW Government's Floodplain Development Manual (2005) defines flood hazard categories as follows:

- **High hazard** – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- **Low hazard** – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity

- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities have no major threat.

Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005) are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 6-5. The provisional hydraulic hazard mapping for the design events is included in Appendix C – Volume 2 (Figure C- 30 to Figure C- 36).

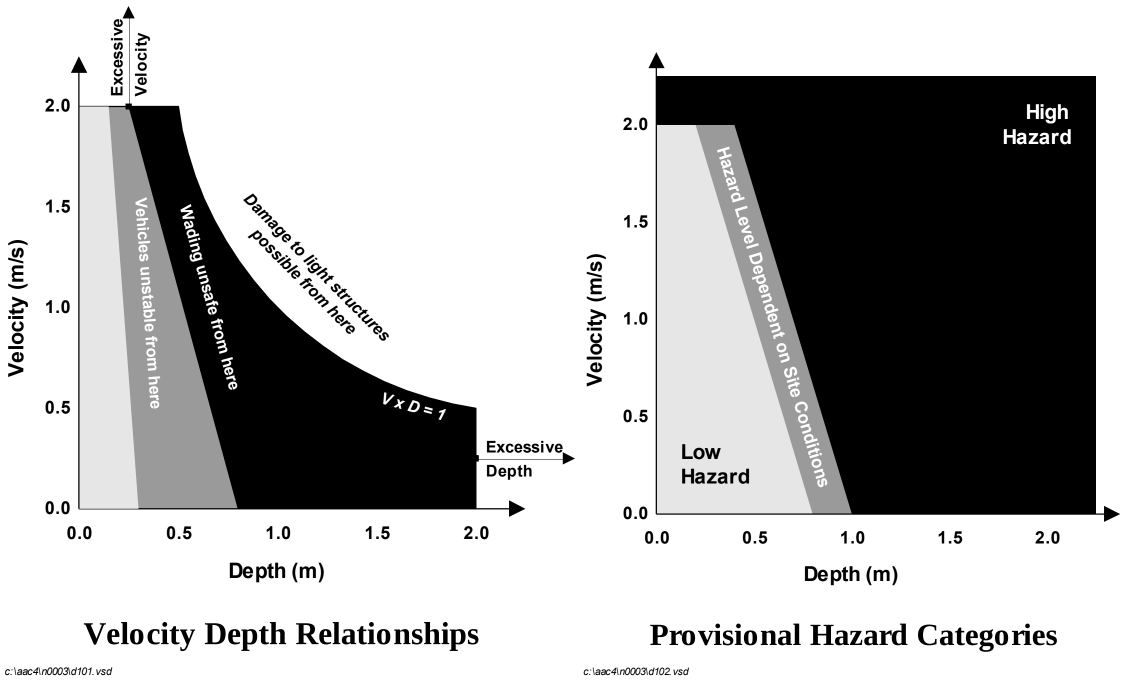


Figure 6-5 Provisional Flood Hazard Categorisation

6.9 Flood Emergency Response Classification

The NSW Government's Floodplain Development Manual (2005) requires flood studies and subsequent floodplain risk management studies to address the management of continuing flood risk to both existing and future development areas. Continuing flood risk may vary across a floodplain and as such the type and scale of emergency response does also. To assist the state emergency services with emergency response planning floodplain communities may be classified into the following categories:

- **High Flood Island** – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island includes enough land higher than the limit of flooding to provide refuge.
- **Low Flood Island** – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island is lower than the limit of flooding.
- **High Trapped Perimeter** – fringe of the floodplain. Road access may be cut by floodwater. The area includes enough land higher than the limit of flooding to provide refuge.
- **Low Trapped Perimeter** – fringe of the floodplain. Road access may be cut by floodwater. The flood island is lower than the limit of flooding.
- **Areas with Overland Escape Routes** – areas available for continuous evacuation. Access roads may cross low lying flood prone land but evacuation can take place by walking overland to higher ground.
- **Areas with Rising Road Access** – areas available for continuous evacuation. Access roads may rise steadily uphill away from rising floodwaters. Evacuation can take place vehicle and communities cannot be completely isolated before inundation reaches its maximum ;and
- **Indirectly Affected Areas** – areas outside the limit of flooding and therefore will not be inundated or lose road access. They may be indirectly affected as a result of flood damaged infrastructure or due to loss of services.

As per recommendations in floodplain risk management guideline (2007), the flood emergency response classification has been undertaken for the 5% AEP (20 year ARI), 1% AEP (100 year ARI) and PMF design events. The mapping series is provided in Appendix C – Volume 2 (Figure C- 37 to Figure C- 39).

6.10 Preliminary Residential Flood Planning Level

Mapping of the preliminary residential flood planning level has been provided in Appendix C – Volume 2 (Figure C- 40). The preliminary residential flood planning level has been based on the 1% AEP (100 year ARI) peak flood level with an additional 0.5m freeboard applied. The extent of the preliminary residential flood planning level is limited to the 1% AEP flood extent. Areas beyond the 1% AEP flood extent may be extrapolated from the nearest preliminary residential flood planning level. For reference purposes the PMF flood extent has also be illustrated in Figure C- 40. Please note that with the additional 0.5m freeboard on the 1% AEP peak flood level, the preliminary residential flood planning level may exceed the PMF peak flood level in some locations and therefore extend beyond the PMF flood extent.

6.11 Provisional Flood Risk Precinct Map

The floodplain has been divided into three provisional flood risk precincts: high, medium and low. The three (provisional) flood risk precincts have been presented in Table 6-8.

Figure C- 41 in Appendix C Volume 2 presents the Provisional Flood Risk Precinct Map for the Botany Bay Foreshore Beach Catchment study area. It has been derived by compilation of the design flood conditions for catchment runoff events only.

Table 6-8 Provisional Flood Risk Categorisation

Flood Risk Category	Description
High Flood Risk	Land below the 100 year flood that is either subject to high hydraulic hazard or where there are significant evacuation difficulties
Medium Flood Risk	Land below the 100 year flood level that is not subject to high hydraulic hazard and where there are no significant evacuation difficulties
Low Flood Risk	All other land within the floodplain (i.e. within the PMF extent) but not identified as either in a high flood risk precinct or medium flood risk precinct

7 Sensitivity Testing

A number of sensitivity tests have been undertaken on the modelled flood behaviour in the catchment. In developing sensitivity tests, consideration has been given to the most appropriate tests taking into account catchment properties and simulated design flood behaviour. The tests undertaken have included:

- hydraulic roughness;
- blockage of the stormwater drainage system;
- rainfall losses; and
- sea level.

The rationalisation for each of these sensitivity tests along with adopted model configuration/parameters and results are summarised in the following sections.

As outlined in Section 6.4 the critical duration varies across the catchment. For the purpose of sensitivity testing the 1% AEP, 2hour duration, un-blocked design storm event has been used as the design base case.

7.1 Hydraulic Roughness

Sensitivity tests on the hydraulic roughness (Manning's '*n*') were undertaken by applying a 20% decrease and a 20% increase in the adopted values for the baseline design conditions. Whilst adopted design parameters are within typical ranges, the inherent variability/uncertainty in hydraulic roughness warrants consideration of the relative impact on adopted design flood conditions.

The results of the sensitivity tests on hydraulic roughness are summarised in Table 7-1 for the reporting locations indicated in Figure 6-2. The change in flood level for different Manning's "*n*" roughness values are minor and typically less than 0.03m with localised impacts of 0.1m.

Table 7-1 Peak 1% AEP Flood Levels for Hydraulic Roughness Sensitivity Tests

Location#	Description	+ 20% (*n*)	- 20% (*n*)
101	Rancom St	-0.10	+0.07
102	Tupia St	+0.00	-0.01
103	Cnr Anniversary St & Tupia St	+0.00	-0.01
104	Livingstone Av	-0.01	+0.01
105	Cnr The Esplanade & Chelmsford Av	-0.02	+0.03
106	Edgehill Av	+0.01	+0.00
107	Booralee St	-0.02	+0.01
108	Cnr Luland St & Hale St	-0.01	+0.02
109	Chegwyn St	+0.01	-0.01

Location#	Description	+ 20% (*n*)	- 20% (*n*)
110	Rochester St	-0.01	+0.00
111	William St	+0.00	-0.01
112	Queen St	+0.00	-0.01
113	Rose St	+0.00	+0.00
114	Daphne St	+0.00	+0.00
115	Aylesbury St	+0.02	-0.01
116	Clevedon St	+0.00	+0.00
117	Wilson St	+0.00	-0.01
118	Pemberton St	+0.01	+0.00
119	Cnr Edward St & Dover Rd	+0.00	-0.01
120	Banksia St (NE end)	+0.00	-0.01
121	Dent St	-0.01	+0.00
	Average	**-0.01**	**+0.00**
	Standard Deviation	**+0.02**	**+0.02**

Refer to Figure 6-2 for the reporting locations

7.2 Stormwater Drainage Blockage

Structure blockages have the potential to substantially increase the magnitude and extent of property inundation through local increases in water level, redistribution of flows on the floodplain, and activation of additional flow paths. As outlined in Section 6.5 the design event modelling has considered both a 0% and 50% blockage factor of all stormwater drainage structures.

A sensitivity test has been undertaken to account for the potential for structure blockage. In addition to a 0% and 50% blockage factor a 100% blockage of the stormwater drainage structures, thereby eliminating pipe flow, has also been considered. For the 100% blockage scenarios, blockages have been applied at pipes only (consistent with location of design blockage scenario)

The results of the sensitivity tests on blockages are summarised in Table 7-2 for the reporting locations indicated in Figure 6-2. Note the base case is the 0% blocked scenario.

Table 7-2 Peak 1% AEP Flood Levels for Blockage Sensitivity Tests

Location#	Description	50% blocked	100% blocked
101	Rancom St	+0.36	+0.55
102	Tupia St	+0.03	+0.09
103	Cnr Anniversary St & Tupia St	+0.03	+0.09
104	Livingstone Av	+0.19	+0.45
105	Cnr The Esplanade & Chelmsford Av	+0.30	+0.69

Location#	Description	50% blocked	100% blocked
106	Edgehill Av	+0.02	+0.34
107	Booralee St	+0.09	+0.28
108	Cnr Luland St & Hale St	+0.10	+0.29
109	Chegwyn St	+0.00	+0.01
110	Rochester St	+0.39	+0.65
111	William St	-0.02	-0.01
112	Queen St	+0.02	+0.04
113	Rose St	+0.18	+0.26
114	Daphne St	+0.18	+0.26
115	Aylesbury St	+0.03	+0.06
116	Clevedon St	+0.16	+0.27
117	Wilson St	+0.01	+0.02
118	Pemberton St	+0.05	+0.16
119	Cnr Edward St & Dover Rd	+0.00	+0.01
120	Banksia St (NE end)	+0.00	+0.01
121	Dent St	+0.04	+0.11
	Average	**+0.10**	**+0.22**
	Standard Deviation	**+0.12**	**+0.22**

Refer to Figure 6-2 for the reporting locations

7.3 Rainfall Losses

Sensitivity tests on the rainfall losses were undertaken by applying a 50% decrease and a 50% increase in the adopted values for the baseline design conditions.

The results of the sensitivity tests on initial rainfall losses are summarised in Table 7-3 for the reporting locations indicated in Figure 6-2. The change in flood level for the changed rainfall loss assumptions are minor and typically less than 0.03m.

Table 7-3 Peak 1% AEP Flood Levels for Rainfall Losses Sensitivity Tests

Location#	Description	+50% Losses	-50% Losses
101	Rancom St	-0.04	+0.04
102	Tupia St	-0.01	+0.00
103	Cnr Anniversary St & Tupia St	-0.01	+0.00
104	Livingstone Av	-0.01	+0.01
105	Cnr The Esplanade & Chelmsford Av	-0.03	+0.03
106	Edgehill Av	+0.00	+0.01
107	Booralee St	-0.01	+0.00

Location#	Description	+50% Losses	-50% Losses
108	Cnr Luland St & Hale St	+0.00	+0.01
109	Chegwyn St	+0.00	+0.00
110	Rochester St	-0.01	+0.01
111	William St	-0.02	-0.01
112	Queen St	-0.01	+0.00
113	Rose St	-0.01	+0.01
114	Daphne St	-0.01	+0.01
115	Aylesbury St	-0.01	+0.01
116	Clevedon St	+0.00	+0.00
117	Wilson St	-0.01	+0.00
118	Pemberton St	-0.01	+0.01
119	Cnr Edward St & Dover Rd	-0.01	+0.00
120	Banksia St (NE end)	-0.01	+0.00
121	Dent St	-0.01	+0.00
	Average	**-0.01**	**+0.01**
	Standard Deviation	**+0.01**	**+0.01**

Refer to Figure 6-2 for the reporting locations

7.4 Tailwater Level

To investigate the impact of the adopted downstream boundary level a sensitivity test was conducted using a water level equivalent to the lowest astronomical tide (LAT) level of -0.85mAHD for Botany Bay. The impact of an increased tide level has been considered as part of the climate change sensitivity testing as outlined in Section 8.

The results of the sensitivity tests on tailwater level are summarised in Table 7-4 for the reporting locations indicated in Figure 6-2. The change in flood level for the lowered tailwater scenario is minimal with the greatest difference of 0.04m observed at Chelmsford Avenue.

Table 7-4 Peak 1% AEP Flood Levels for Tailwater Level Sensitivity Tests

Location[#]	Description	LAT
101	Rancom St	-0.01
102	Tupia St	+0.00
103	Cnr Anniversary St & Tupia St	+0.00
104	Livingstone Av	+0.00
105	Cnr The Esplanade & Chelmsford Av	-0.07
106	Edgehill Av	+0.00
107	Booralee St	-0.01
108	Cnr Luland St & Hale St	+0.00
109	Chegwyn St	+0.00
110	Rochester St	+0.00
111	William St	+0.00
112	Queen St	+0.00
113	Rose St	+0.00
114	Daphne St	+0.00
115	Aylesbury St	+0.00
116	Clevedon St	+0.01
117	Wilson St	+0.00
118	Pemberton St	+0.00
119	Cnr Edward St & Dover Rd	+0.00
120	Banksia St (NE end)	+0.00
121	Dent St	-0.01
	Average	**-0.00**
	Standard Deviation	**+0.02**

[#] Refer to Figure 6-2 for the reporting locations

8 Climate Change

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations. The primary impacts of climate change in coastal areas are likely to result from sea level rise, which, coupled with a potential increase in the frequency and severity of storm events, may lead to increased coastal erosion, tidal inundation and flooding.

In 2009, the NSW Government incorporated consideration of potential climate change impacts into relevant planning instruments. The NSW Sea Level Rise Policy Statement (DECCW, 2009) was prepared to support consistent adaptation to projected sea level rise impacts. The policy statement incorporates sea level rise (SLR) planning benchmarks for use in assessing potential impacts of sea level rise in coastal areas, as well as in flood risk and coastal hazard assessments. The benchmarks are a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100.

The NSW Government announced its Stage One Coastal Management Reforms in September 2012. As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks for use by local councils, but instead provides councils with the flexibility to consider local conditions when determining future hazards within their LGA.

Accordingly, it is recommended by the NSW Government that councils should consider information on historical and projected future sea level rise that is widely accepted by scientific opinion. This may include information in the NSW Chief Scientist and Engineer's Report entitled 'Assessment of the Science behind the NSW Government's Sea Level Rise Planning Benchmarks' (2012).

The NSW Chief Scientist and Engineer's Report (2012) acknowledges the evolving nature of climate science, which is expected to provide a clearer picture of the changing sea levels into the future. The report identified that:

- The science behind sea level rise benchmarks from the 2009 NSW Sea level Rise Policy Statement was adequate;
- Historically, sea levels have been rising since the early 1880's;
- There is considerable variability in the projections for future sea level rise; and
- The science behind the future sea level rise projections is continually evolving and improving.

It was agreed between Council and BMT WBM that the sea level rise benchmarks from the 2009 NSW Sea level Rise Policy Statement be adopted based on the conclusion that it was the best available information at the time of preparation of this report.

Worsening coastal flooding impacts as a consequence of sea level rise in lowland areas such as the southern extent of the catchment are of particular concern for the future. Regional climate change studies (e.g. CSIRO, 2004) indicate that aside from sea level rise, there may also be an increase in the maximum intensity of extreme rainfall events. This may include increased frequency, duration and height of flooding and consequently increased number of emergency evacuations and associated property and infrastructure damage.

The NSW Floodplain Development Manual (2005) requires consideration of climate change in the preparation of Floodplain Risk Management Studies and Plans, with further guidance provided in:

- Floodplain Risk Management Guideline – Practical Consideration of Climate Change (DECC, 2007); and
- Flood Risk Management Guide - Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (DECCW, 2010).

Key elements of future climate change (e.g. sea level rise, rainfall intensity) have been incorporated into the assessment of future flooding conditions in the Botany Bay Foreshore Beach Catchment for consideration in the ongoing floodplain risk management.

8.1 Potential Climate Change Impacts

The impacts of future climate change are likely to lead to a wide range of environmental responses in receiving waters such as Botany Bay. These are likely to manifest throughout the physical, chemical and ecological processes that drive local estuarine ecosystems.

The following changes in the physical characteristics of the Botany Bay Foreshore Beach Catchment have potential influence on the flood behaviour of the system and implications for medium and long term floodplain management:

- Increase in ocean boundary water level – sea level projections provide for a direct increase in tidal and storm surge water level conditions; and
- Increase in rainfall intensity – the frequency and severity of extreme rainfall events is expected to increase.

The model configuration and assumptions adopted for these potential climate change impacts are discussed in the following sections.

8.1.1 Ocean Water Level

As discussed in Section 1.3.1, the sea level rise planning benchmarks provided in the NSW Sea Level Rise Policy Statement (DECCW, 2009) have been adopted for this Flood Study.

The benchmarks are a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100 (DECCW, 2009). Based on these guidelines, design ocean boundary conditions were raised by 0.4 m and 0.9 m to assess the potential impact of sea level rise on flood behaviour in the catchment for the year 2050 and 2100 respectively.

The ocean water level boundary conditions for present day flood conditions were discussed in Section 2.2.4. The sea level rise allowances provide for direct increases in these ocean water levels. Table 8-1 presents a summary of adopted peak ocean water levels for existing water level conditions and the 2050 and 2100 sea level rise benchmarks.

Table 8-1 Design Peak Ocean Water Levels Incorporating Sea Level Rise

Water Level (m AHD)		
Existing	2050 (+0.4m)	2100 (+0.9m)
0.69	1.09	1.59

8.1.2 Design Rainfall Intensity

Current research predicts that a likely outcome of future climatic change will be an increase in flood producing rainfall intensities. Climate Change in New South Wales (CSIRO, 2007) provides projected increases in 2.5% AEP 24hr duration rainfall depths for Sydney Metropolitan catchments of up to 12% and 10%, for the years 2030 and 2070 respectively.

The NSW Government has also released a guideline (DECC, 2007) for Practical Consideration of Climate Change in the floodplain management process that advocates consideration of increased design rainfall intensities of up to 30%. In line with this guidance note, additional tests incorporating 10%, 20% and 30% increases in design rainfall have been undertaken.

8.2 Climate Change Model Conditions

A range of design event simulations have been undertaken incorporating combinations of increases in rainfall intensities and ocean water levels in conjunction with critical durations and design blockages. A summary of the modelled scenarios for the 1% AEP design event is provided in Table 8-2.

Table 8-2 Summary of Design Model Runs for Climate Change Considerations

Design Flood	Rainfall Intensity Increase	Ocean Boundary Water Level (m AHD)	Envelope
1% AEP 120min duration 0% Blockage	10%	0.69 (Existing Tide)	CC10
1% AEP 120min duration 50% Blockage	10%	0.69 (Existing Tide)	CC10
1% AEP 25min duration 0% Blockage	10%	0.69 (Existing Tide)	CC10
1% AEP 25min duration 50% Blockage	10%	0.69 (Existing Tide)	CC10
1% AEP 120min duration 0% Blockage	20%	0.69 (Existing Tide)	CC20

Design Flood	Rainfall Intensity Increase	Ocean Boundary Water Level (m AHD)	Envelope
1% AEP 120min duration 50% Blockage	20%	0.69 (Existing Tide)	CC20
1% AEP 25min duration 0% Blockage	20%	0.69 (Existing Tide)	CC20
1% AEP 25min duration 50% Blockage	20%	0.69 (Existing Tide)	CC20
1% AEP 120min duration 0% Blockage	30%	0.69 (Existing Tide)	CC30
1% AEP 120min duration 50% Blockage	30%	0.66 (Existing Tide)	CC30
1% AEP 25min duration 0% Blockage	30%	0.66 (Existing Tide)	CC30
1% AEP 25min duration 50% Blockage	30%	0.66 (Existing Tide)	CC30
1% AEP 120min duration 0% Blockage	0%	1.09 (0.69m + 0.4m to 2050)	2050
1% AEP 120min duration 50% Blockage	0%	1.09 (0.69m + 0.4m to 2050)	2050
1% AEP 25min duration 0% Blockage	0%	1.09 (0.69m + 0.4m to 2050)	2050
1% AEP 25min duration 50% Blockage	0%	1.09 (0.69m + 0.4m to 2050)	2050
1% AEP 120min duration 0% Blockage	0%	1.59 (0.69m + 0.9m to 2100)	2100
1% AEP 120min duration 50% Blockage	0%	1.59 (0.69m + 0.9m to 2100)	2100
1% AEP 25min duration 0% Blockage	0%	1.59 (0.69m + 0.9m to 2100)	2100
1% AEP 25min duration 50% Blockage	0%	1.59 (0.69m + 0.9m to 2100)	2100

8.3 Climate Change Results

A comparison of the modelled peak flood levels for the climate change scenarios are presented in Table 8-3 for the reporting locations indicated in Figure 6-2. The impact of potential climate change scenarios on the standard design flood condition is presented in Figure D- 1 to Figure D- 5 in Appendix D – Volume 2 as a series of maps showing increase in peak flood inundation extents from the baseline (existing) conditions. Figure 8-1 shows the flood level profile for the location shown in Figure 6-2.

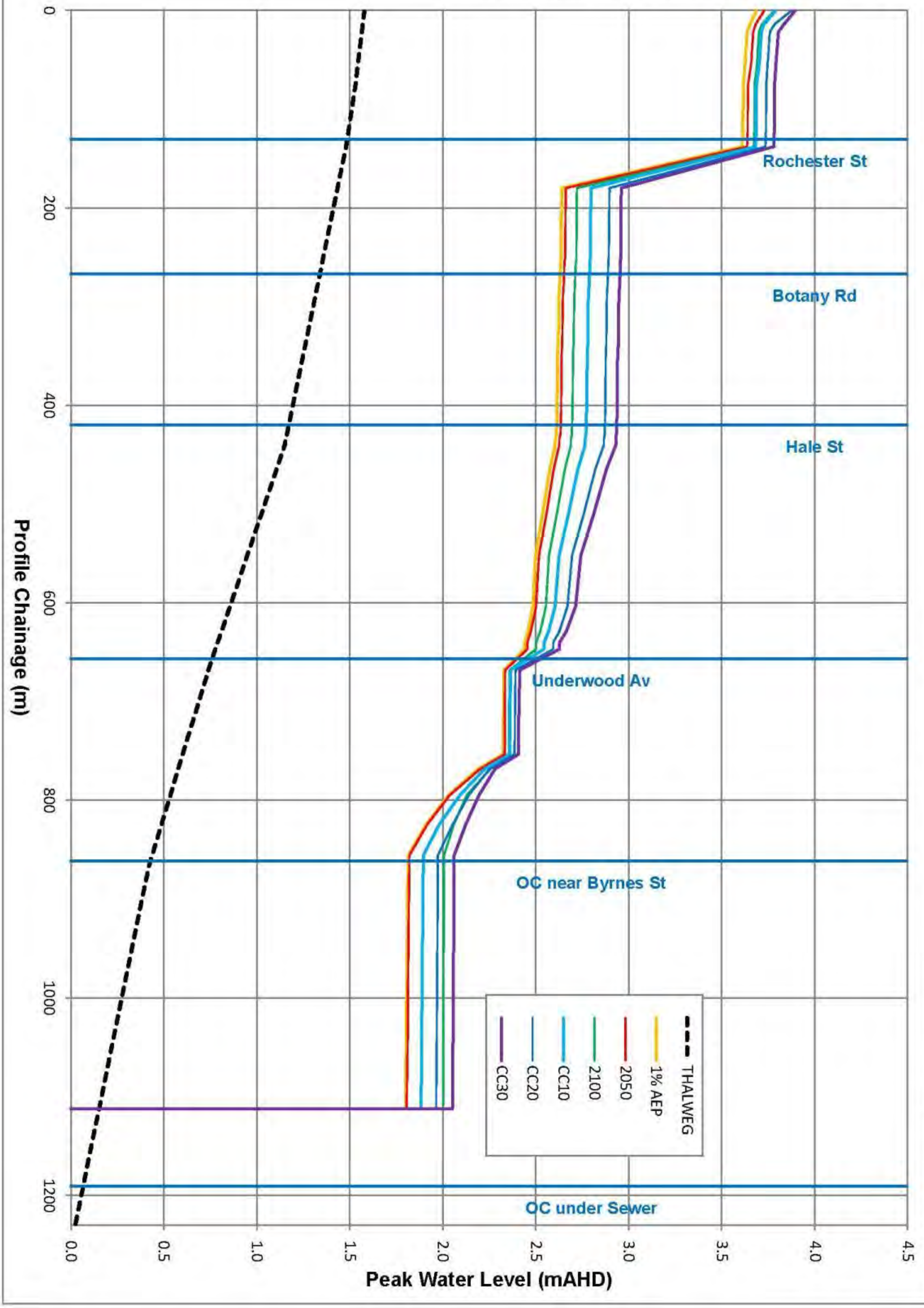
Table 8-3 Peak 1% AEP Flood Levels for Rainfall Losses Sensitivity Tests

Location[#]	CC10	CC20	CC30	2050	2100
101	+0.04	+0.08	+0.12	+0.00	+0.02
102	+0.01	+0.03	+0.04	+0.00	+0.00
103	+0.01	+0.03	+0.04	+0.00	+0.00
104	+0.07	+0.13	+0.18	+0.02	+0.03
105	+0.03	+0.06	+0.14	+0.01	+0.02
106	+0.08	+0.17	+0.23	+0.01	+0.06
107	+0.06	+0.13	+0.20	+0.02	+0.09
108	+0.06	+0.13	+0.20	+0.02	+0.09
109	+0.02	+0.03	+0.04	+0.00	+0.00
110	+0.08	+0.13	+0.17	+0.03	+0.07
111	+0.01	+0.02	+0.05	-0.02	-0.01
112	+0.02	+0.03	+0.04	+0.00	+0.00
113	+0.05	+0.09	+0.12	+0.00	+0.01
114	+0.05	+0.09	+0.12	+0.00	+0.00
115	+0.03	+0.06	+0.09	+0.00	+0.00
116	+0.03	+0.07	+0.10	+0.00	+0.00
117	+0.02	+0.03	+0.05	+0.00	+0.00
118	+0.03	+0.08	+0.12	+0.00	+0.00
119	+0.02	+0.03	+0.04	+0.00	+0.00
120	+0.02	+0.03	+0.05	+0.00	+0.00
121	+0.03	+0.07	+0.11	+0.01	+0.02
Average	**+0.04**	**+0.07**	**+0.11**	**+0.00**	**+0.02**
St. Dev.	**+0.02**	**+0.04**	**+0.06**	**+0.01**	**+0.03**

[#] Refer to Figure 6-2 for the reporting locations

FIGURE 8-1

SWC TRUNK PROFILE - CLIMATE CHANGE RESULTS



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9 Conclusions

The objective of the study was to undertake a detailed flood study of the Botany Bay Foreshore Beach catchment and establish models as necessary for accurate flood level prediction. Central to this was the development of a two-dimensional hydraulic model of the catchment.

In completing the flood study, the following activities were undertaken:

- Collation of database of historical flood information for the catchment;
- Acquisition of topographical data for the catchment including cross section, hydraulic structure survey and stormwater drainage network survey;
- Consultation with the community to acquire historical flood information and liaison in regard to flooding concerns/perceptions and future floodplain management activities;
- Development of a hydrological and hydraulic model (using TUFLOW software) to simulate flood behaviour in the catchment;
- Calibration and validation of the developed model using available data for the March 2014, January 2014 and March 1977 flood events;
- Prediction of design flood conditions in the catchment using the calibrated models; and
- Production of design flood mapping series.

From community consultation and in simulating the design flood conditions for the study area, the following locations have been identified as potential problem areas in relation to flood inundation extent and property affected:

- Corner of Tupia Street and Anniversary Street
- Roundabout at Hale Street and Luland Street
- Hale Street roundabout
- Edgehill Avenue (near street bend)
- Corner of Chelmsford Street and The Esplanade
- Tupia Street
- Botany Street (between Hale Street and Kingston Street)
- Daphne Street
- Botany Road (near Hill St)
- Dent Street
- Bay Street

The flooding issues with the study area are largely restricted to locations that were naturally creek/gully lines but are now occupied by urban development. Along these alignments natural depressions in the topography and those created by manmade obstructions, such as roads and other land-raising activities, fill with runoff to significant depths during major design flood events.

Once the available stormwater drainage network capacity has been exceeded the depressions will quickly fill with excess runoff, acting as local flood storages. For large flood events such as the 1% AEP these storages are filled to capacity and flooding can progress via the lowest adjoining point in the topography. This type of flooding is widespread throughout the study area.

The principal outcome of the flood study is the understanding of flood behaviour in the catchment and in particular design flood level information that will be used to set appropriate flood planning levels for the study area. The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain management process. Accordingly, the adoption of the flood study and predicted design flood levels is recommended.

The hydraulic model developed for this study provides a tool for assessment of potential flood impact of future development in the catchment.

Modelling of climate change scenarios has shown that there is a general increase in flood levels and therefore flood risk along both major and minor flow paths due to increased rainfall intensities. However, the extent of sea level rise impacts in the Botany Bay Foreshore Beach catchment is limited. Future planning and floodplain risk management in the catchment will need to take due consideration of the increasing flood risk under possible future climate conditions.

10 References

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11 Acknowledgements

This study undertaken by BMT WBM was funded by Council and the NSW Office of Environment and Heritage. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- City of Botany Bay Council;
- Sydney Water Corporation; and
- Office of Environment and Heritage.

Appendix A Calibration Information

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List of Tables

1 Calibration Event - 24 March 2014

1.1 Rainfall and Tide

Figure 1-1 shows the recorded tide level of Botany Bay and the rainfall depth recorded at Sydney Airport AMO for the 24th March 2014 rainfall event. The total storm event produced 40mm of rainfall over a 4 hour period, although the majority of the rainfall occurred in a burst less than 1 hour long. The peak of the tide approximately matched the peak of rainfall; however, the tide peak was only 0.4mAHD.

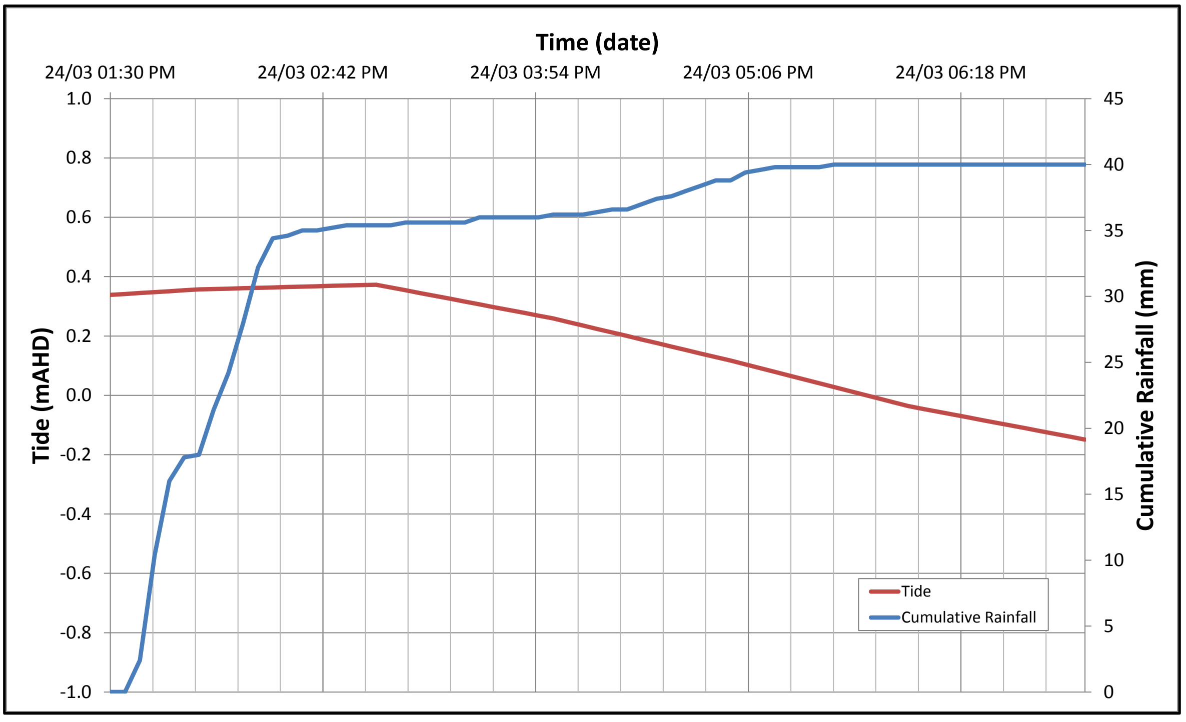


Figure 1-1 Rainfall and Tide record for 24 March 2014 event

To confirm rainfall depth across the broader LGA, recorded daily rainfall depths were reviewed for the period to 9AM on the 25th March. Rainfall depths 2 days prior were additionally reviewed to inform antecedent catchment conditions. Table 1-1 presents the daily read rainfall totals. As shown the peak of the rainfall occurred at the airport gauge which is closest to the catchment and very little rainfall occurred in the two days prior indicating a dry catchment.

Table 1-1 Daily rainfall depths (mm) for March 2014 event

Station #	Name	23 March	24 March	25 March
066037	Sydney Airport AMO	1.4	0.0	40.0
066073	Randwick Racecourse	0.0	2.4	25.4
066051	Little Bay	NA	NA	NA
066052	Randwick (Randwick St)	0.0	3.2	27.2
066036	Marrickville Golf Club	0.0	0.0	25.0

1.2 Flooding Reports

1.2.1 Council Flooding Inspection

An inspection report for the LGA flooding was provided by Council for the rainfall event of the 24th March 2014. Time of the photographs was not provided so it is not known if they represented the peak flooding conditions. Nonetheless, the images provide a valuable indication of flooding behaviour. Relevant images have been extracted from the report and are presented hereunder.

1.2.1.1 Corner of Tupia Street and Anniversary Street

Figure 1-2 and Figure 1-3 shows ponded water near the corner of Tupia Street and Anniversary Street. As presented in the figures, the road crown and gutter is overtopped and flood water overtops the footpath. The flood water does not inundate the property floor levels.

It is assumed that peak flooding depths at this location would be approximately 0.3m in the low point along the gutter alignments.

Figure 1-2 Tupia Street looking south (note Anniversary Street sign)

Figure 1-3 Tupia Street near corner of Anniversary Street

1.2.1.2 Roundabout at Hale Street and Luland Street

Figure 1-4 and Figure 1-5 shows ponded water near the corner of Luland Street and Hale Street. As presented in the figures, the road crown and gutter is overtopped and flood water overtops the footpath. The flood water does not inundate the property floor levels

It is assumed that peak flooding depths at this location would be approximately 0.4m.

Figure 1-4 Hale Street near corner of Luland Street

Figure 1-5 Western side of Luland Street near intersection with Hale Street

1.2.2 Community Reports

Community consultation undertaken provides valuable insights into problem flooding locations and behaviour of flooding. Unfortunately, when asked when the flooding occurred, respondents typically provided general reference to month or even only a year without stating the day or time. Attributing the comments to a specific event is not always possible. An attempt was made however to fully utilise all reports of flooding. The following present descriptions of flooding behaviour for what is assumed to be the 24th March 2014 event or a flood event of similar magnitude.

- Hale Street roundabout

Community residents reported flooding at the roundabout near Hale Street and Luland Street. This flooding has been reported for the 24th March 2014 event were the fire department managed local traffic.

- Edgehill Avenue (near street bend)

Community residents reported that property access is regularly (2-3 times/year) affected on Edgehill Avenue near the street bend.

- Corner of Chelmsford Street and The Esplanade

Community residents reported that the street flooding occurs at the corner of Chelmsford Street and The Esplanade after heavy rain. A resident reported that cars were floated.

- Banksia Street (west of Daniel Street)

Community resident reported that minor street flooding occurred sometime this year. The same report states that in 74 years of occupancy the property has never been flooded. Flooding at this location is minor and limited to the roadway.

- Tupia Street

Community residents reported that flooding occurs on this street. Resident speculates that leaves blocking the drains contribute to the problem.

- Botany Street (between Hale Street and Kingston Street)

Community residents reported that after heavy rain the backyards of properties on Botany Street between Kingston Street and Hale Street flood.

- Daphne Street

Community residents reported that in March 2014 Daphne Street flooded due to blocked drains. It is noted that the carpark was inundated.

- Botany Road (near Hill St)

Botany Road near the golf course was reported to regularly flood causing inconvenience to residents and motorists. Vehicles have been reported to create waves which exacerbate the flood nuisance to residents. In March 2014, flooding was reported to be of similar extent to an “Olympic swimming pool”. Local drains are reported to be constantly blocked by leaves.

- Dent Street

Community resident reported flooding for the 24th March 2014 event. Local drainage was reported inadequate and water flowed into property and flooded the backroom of the respondents residence.

1.3 Key Model Parameterisations

Unless otherwise stated, the TUFLOW calibration model and design models are identical in regards to model schematisation and parameterisation (refer to Section 4 and 5 of report).

The community consultation indicated that certain locations in the study area experienced blockages to the stormwater drainage network. Blockages have been applied to the calibration model to best match flooding performance, however, the blockage assumptions are not always appropriate for design modelling purposes since the blockages do occur for every rainfall event. The blockage assumptions for the calibration model are discussed hereunder.

1.3.1 Chelmsford Avenue and Livingstone Avenue Drains

Blockage of Chelmsford Avenue and Livingstone Avenue drains is known to occur from sand. Figure 1-6 and Figure 1-7 shows images captured by Worley Parsons on March 2013 for the Botany Drainage Study (2013).

Images of the drainage discharge points are not available for the 24th March 2014 calibration event, however, from literature review and community consultation this blockage is identified as an ongoing issue. The two drainage lines are assumed to be blocked by 85% for the 24th March 2014 calibration model.

Figure 1-6 Blocked Livingstone Avenue Drain

Figure 1-7 Assumed location of blocked Chelmsford Avenue Drain

1.3.2 Daphne Street Blockage

Daphne Street is reported to be susceptible to flooding by pit inlet blockage. Without blockage assumptions, modelled flood behaviours do not match that reported by the community. The red drainage lines in Figure 1-8 are assumed 100% blocked for the 24 March 2014 calibration event.

Figure 1-8 Assumed Daphne Street blockage (shown by red line)

Drains near Hill Street and Botany Road are reported to be constantly blocked by leaves. The red drainage lines in Figure 1-9 are assumed 100% blocked for the 24 March 2014 calibration event.

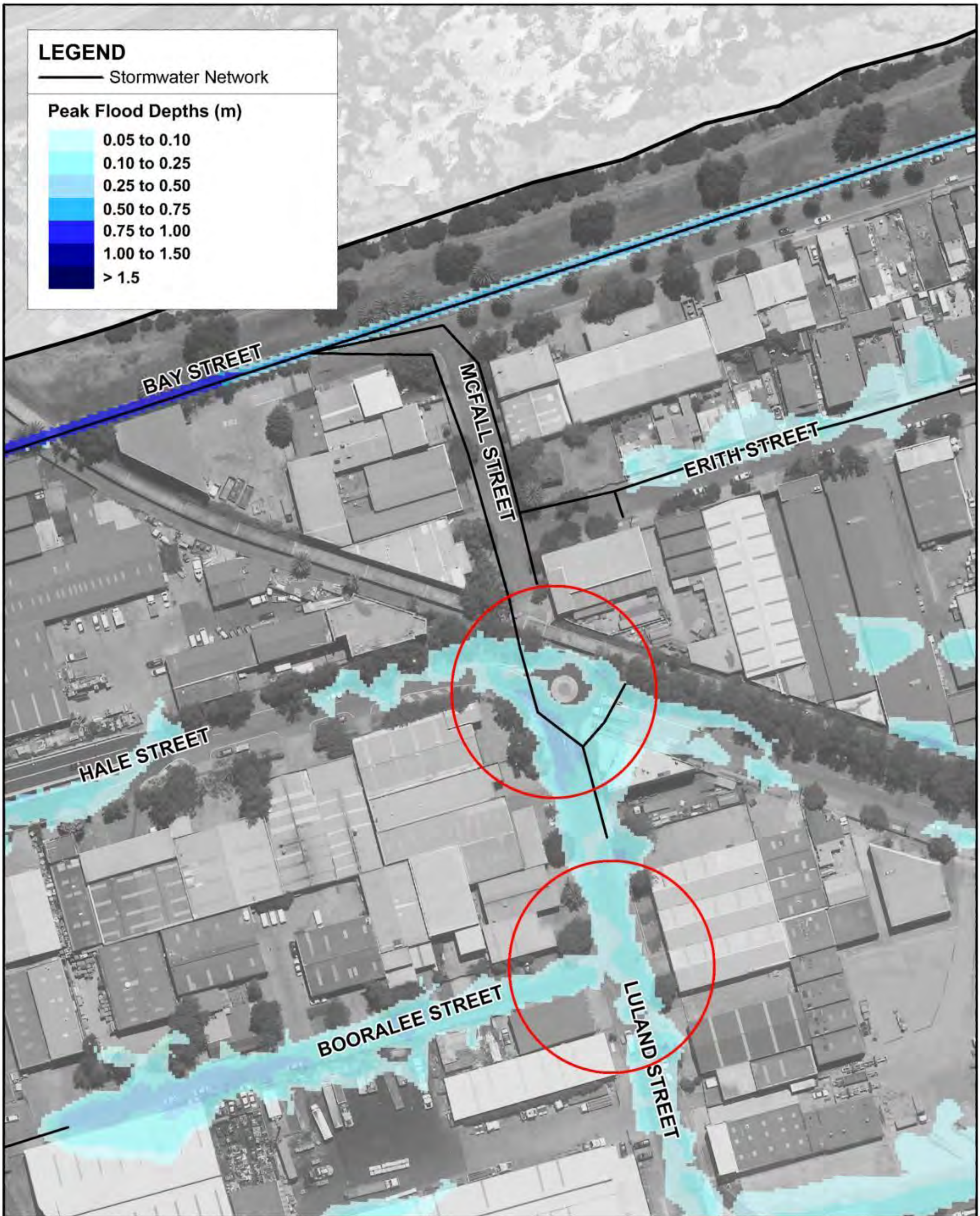
Figure 1-9 Assumed blockage near Botany Golf Club (shown by red line)

1.4 Modelled Flood Behaviour

To demonstrate the TUFLOW models calibration performance, the modelled flood behaviour is compared with observed behaviour from community reports. Table 1-2 presents a summary or reported flood behaviour across the catchment and notes the models performance in each area.

Table 1-2 Comparison of reported flood behaviour and modelled behaviour (24 March 2014)

Location	Observed Behaviour	Simulated
Roundabout at Hale Street and Luland Street	Peak depth ~0.4m	Figure 1-10
Corner of Tupia Street and Anniversary Street	Peak depth ~0.3m	Figure 1-11
Hale Street Roundabout	Road flooding	Figure 1-10
Edgehill Avenue (near street bend)	Flooding prevents property access	Figure 1-12
Corner of Chelmsford Street and The Esplanade	Road flooding with potential to float car	Figure 1-12
Banksia Street (west of Daniel Street)	Minor road flooding	Not shown
Tupia Street	Road flooding	Figure 1-11
Botany Street (between Hale Street and Kingston Street)	Back yard flooded	Figure 1-13
Daphne Street	Road flooding (inundated carpark)	Figure 1-14
Botany Road (near Golf Course)	Road flooding	Figure 1-15
Dent Street	Flow through property	Figure 1-16



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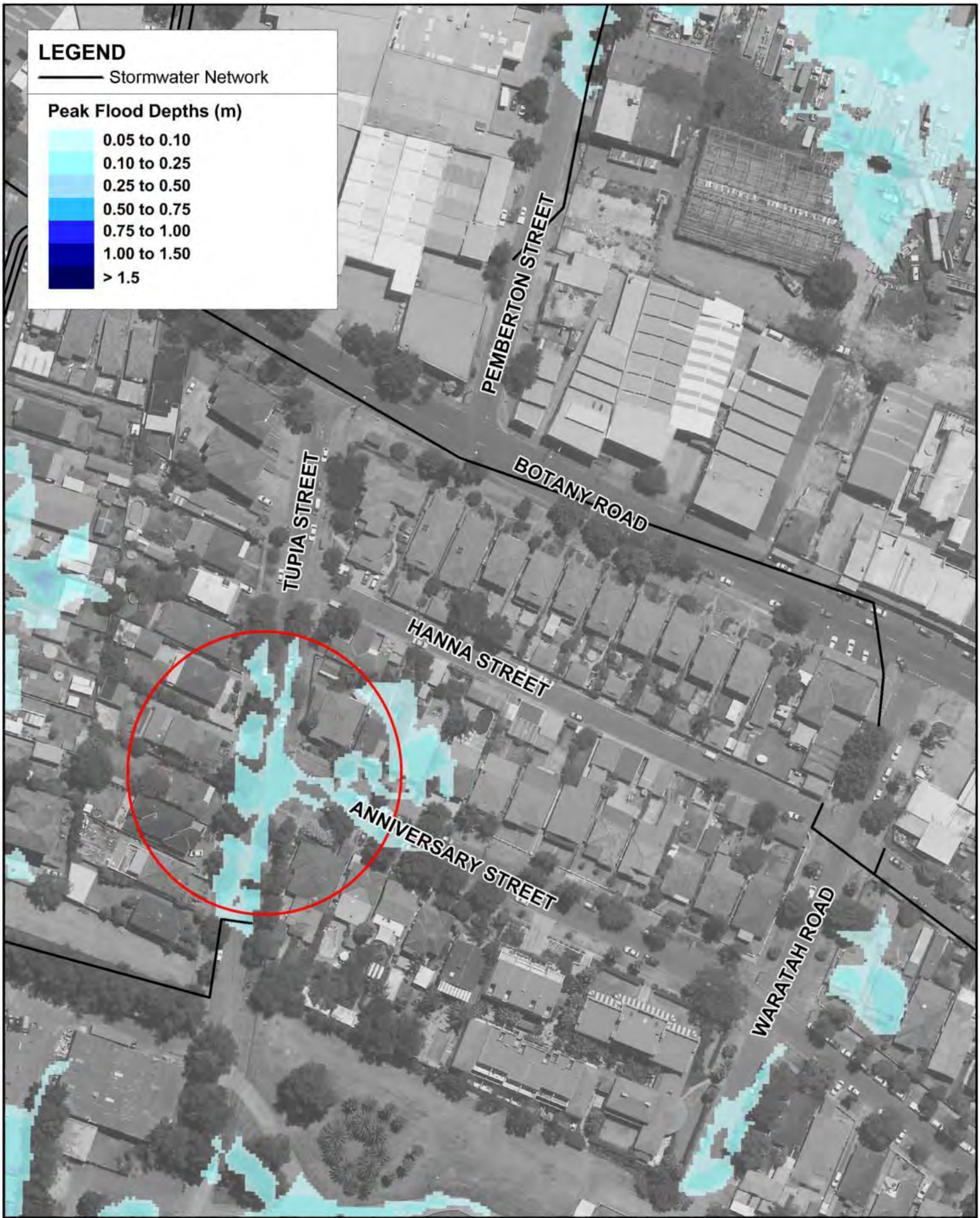

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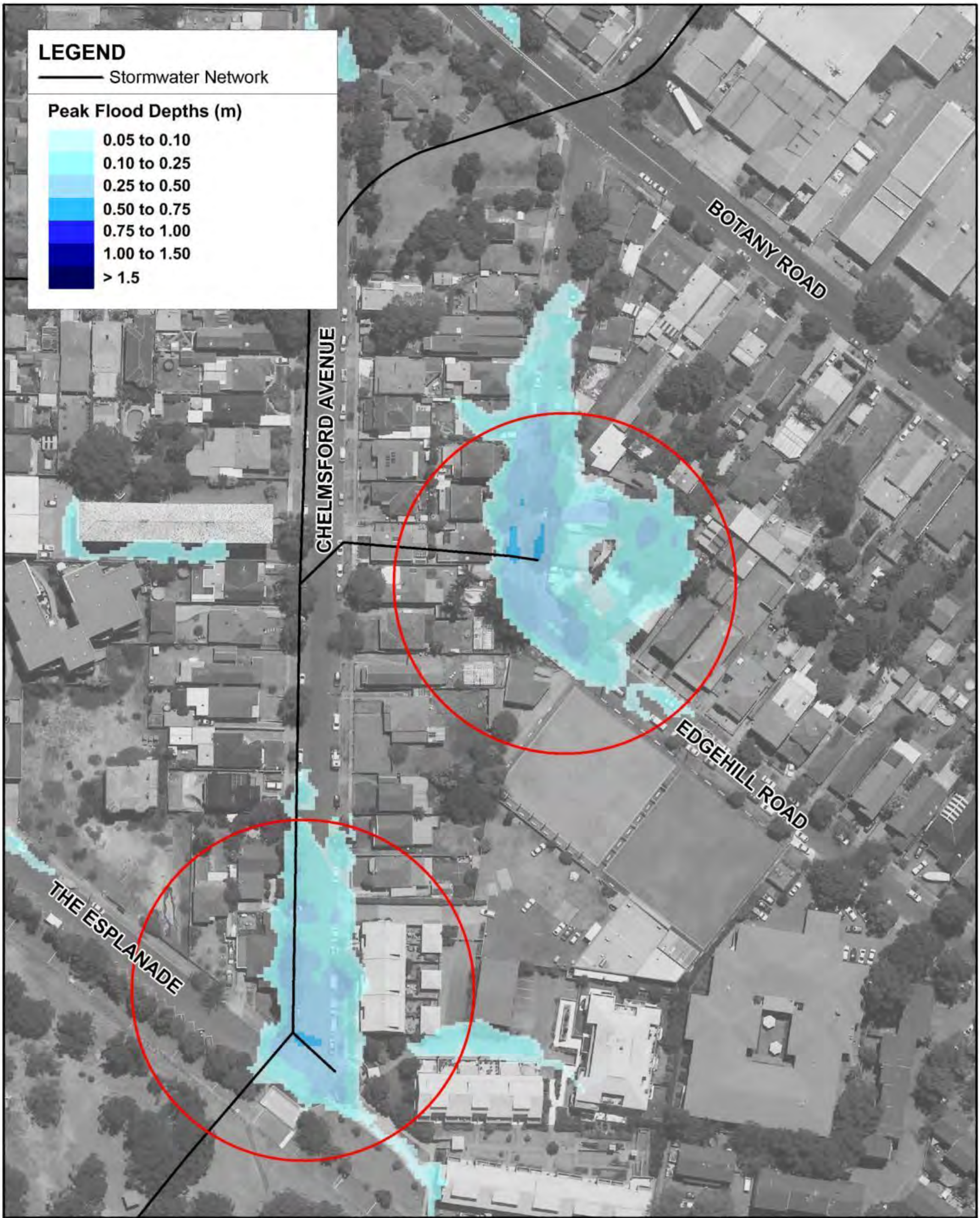

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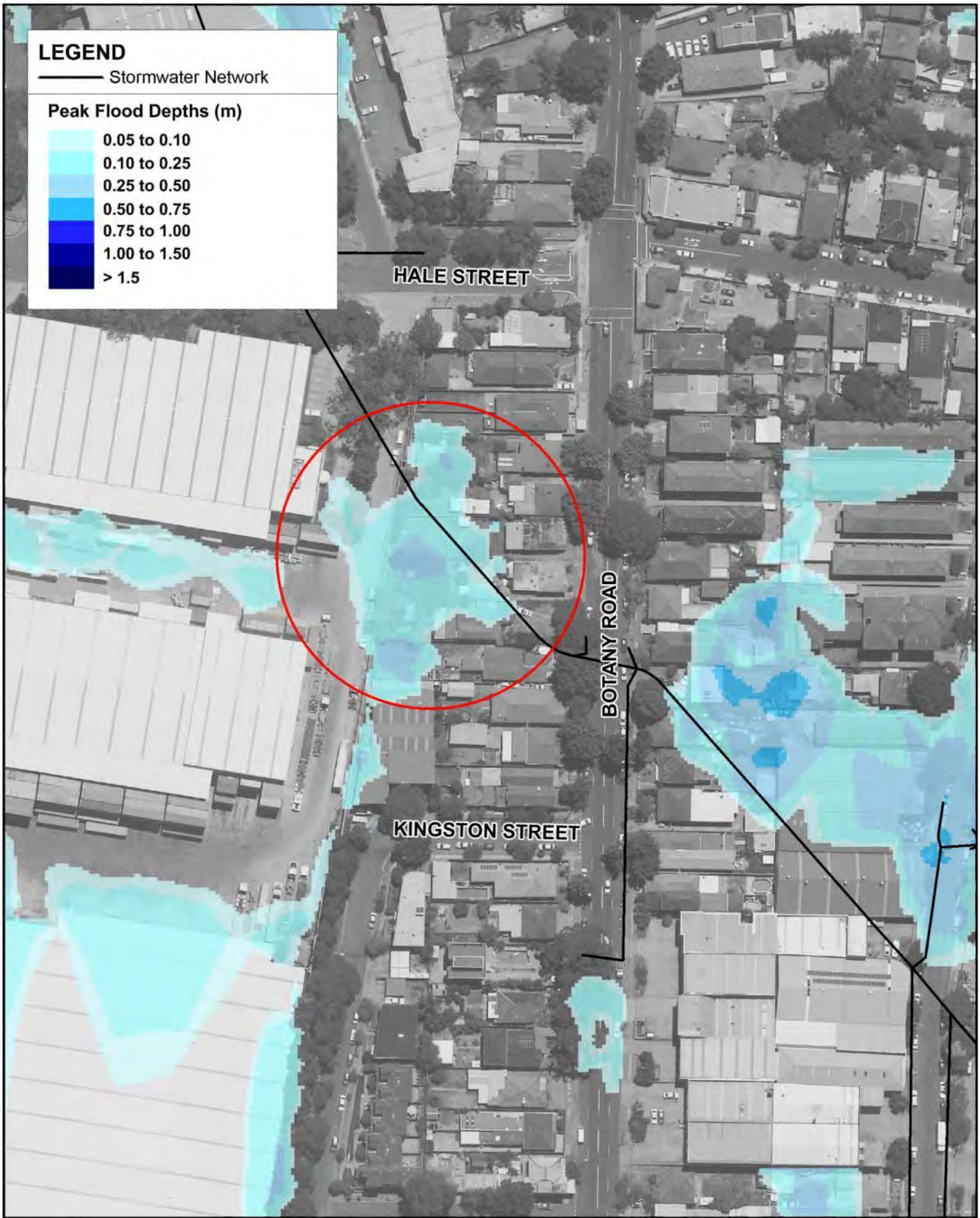

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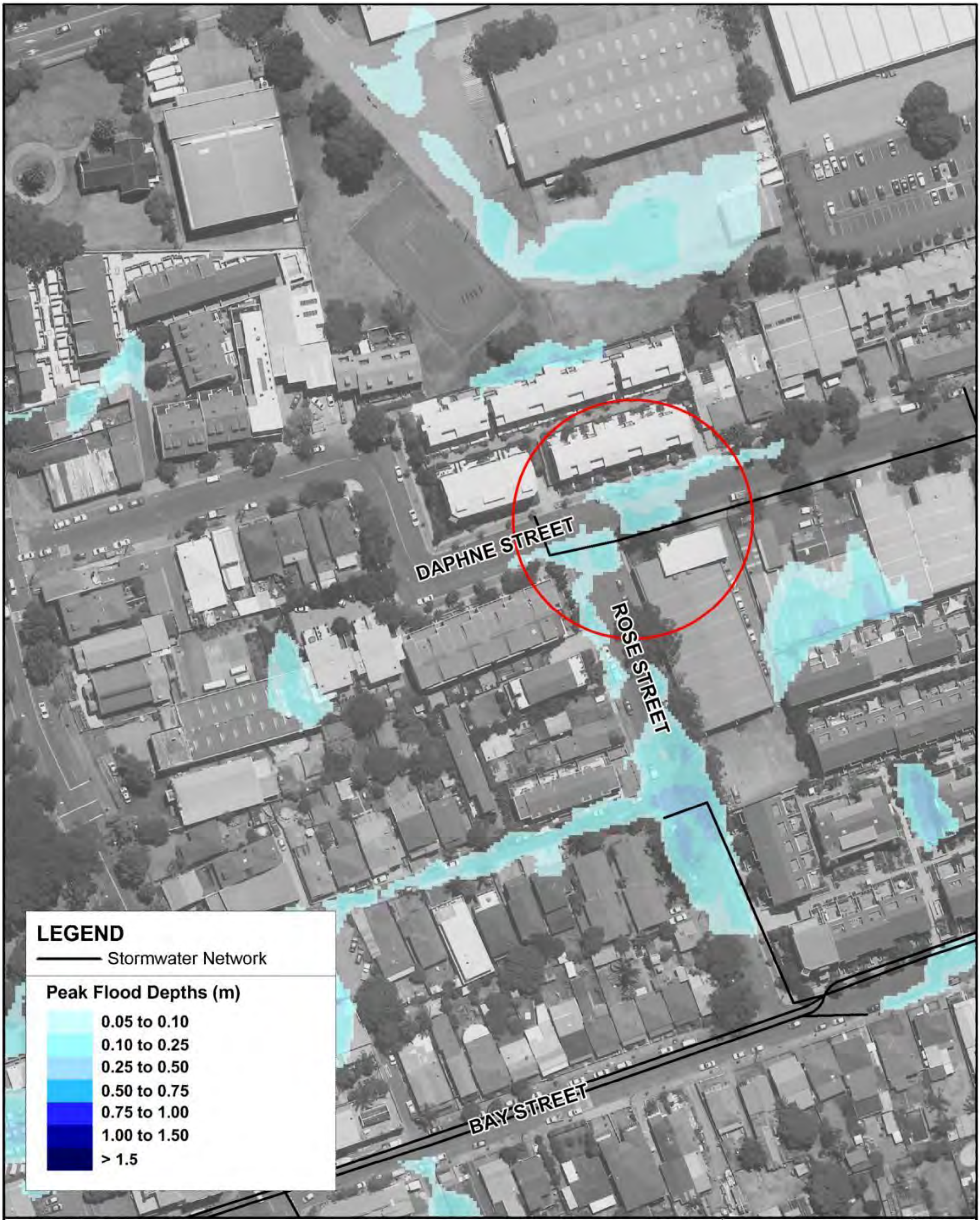

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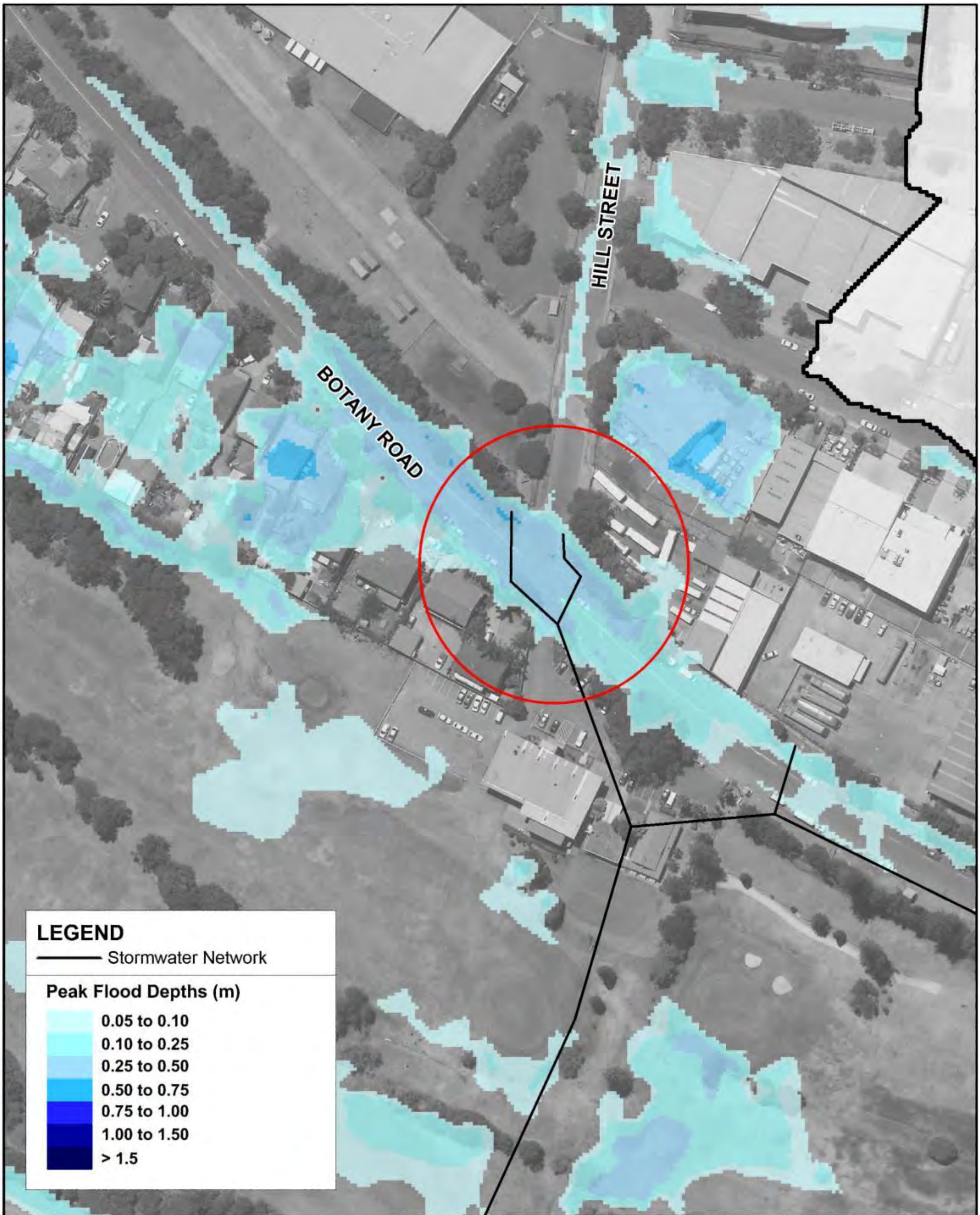

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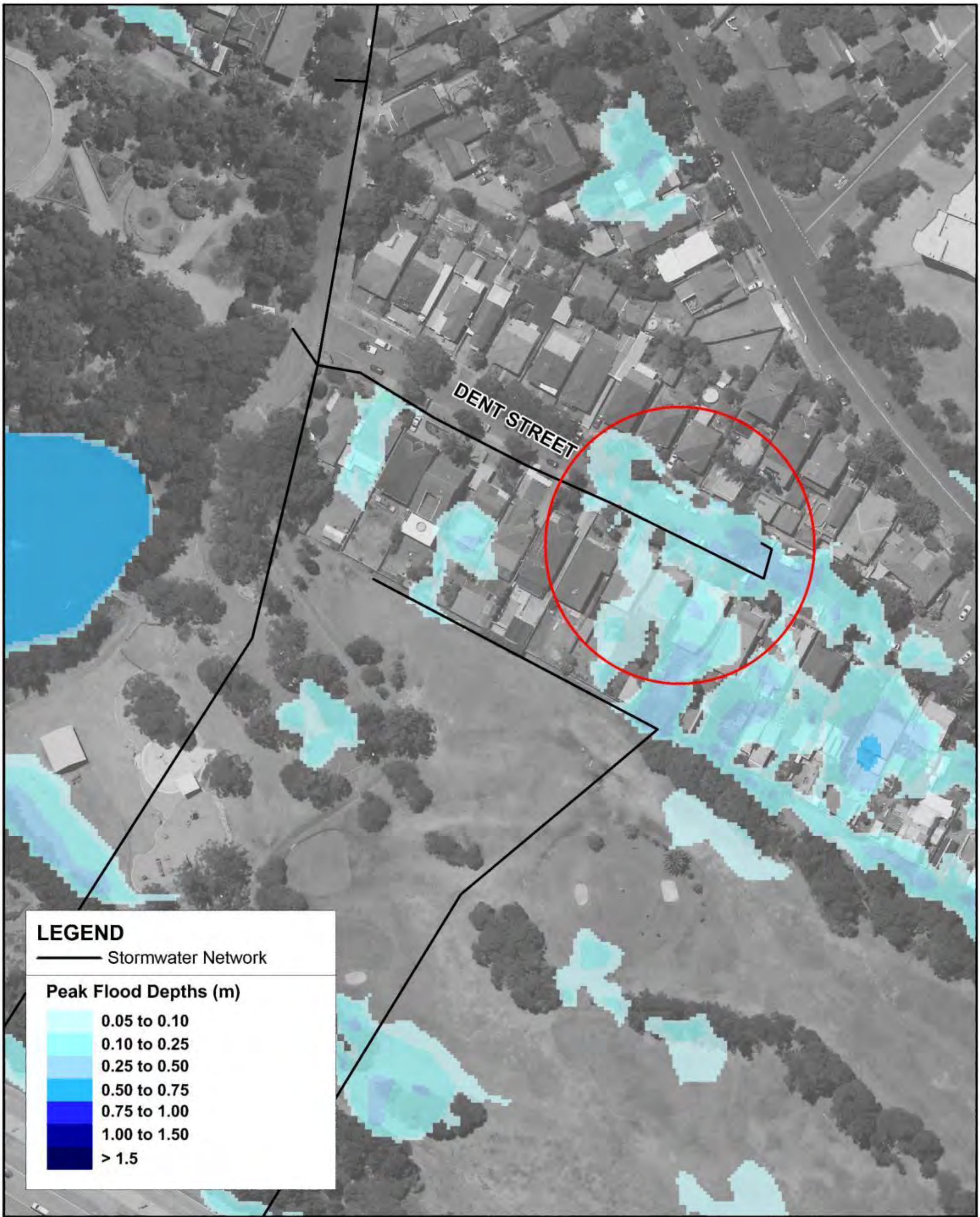

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2 Calibration Event 2 January 2014

2.1 Rainfall and Tide

Figure 2-1 shows the recorded tide level of Botany Bay and the rainfall depth recorded at Sydney Airport AMO for the 2nd January 2014 rainfall event. The event is unique in that there was no rainfall and flooding was entirely generated from a high tide. From a modelling calibration point of view this is valuable since the tailwater driven flooding mechanisms and model schematisation can be reviewed in isolation.

The peak of the tide was 1.3mAHD and occurred at 9:00 AM.

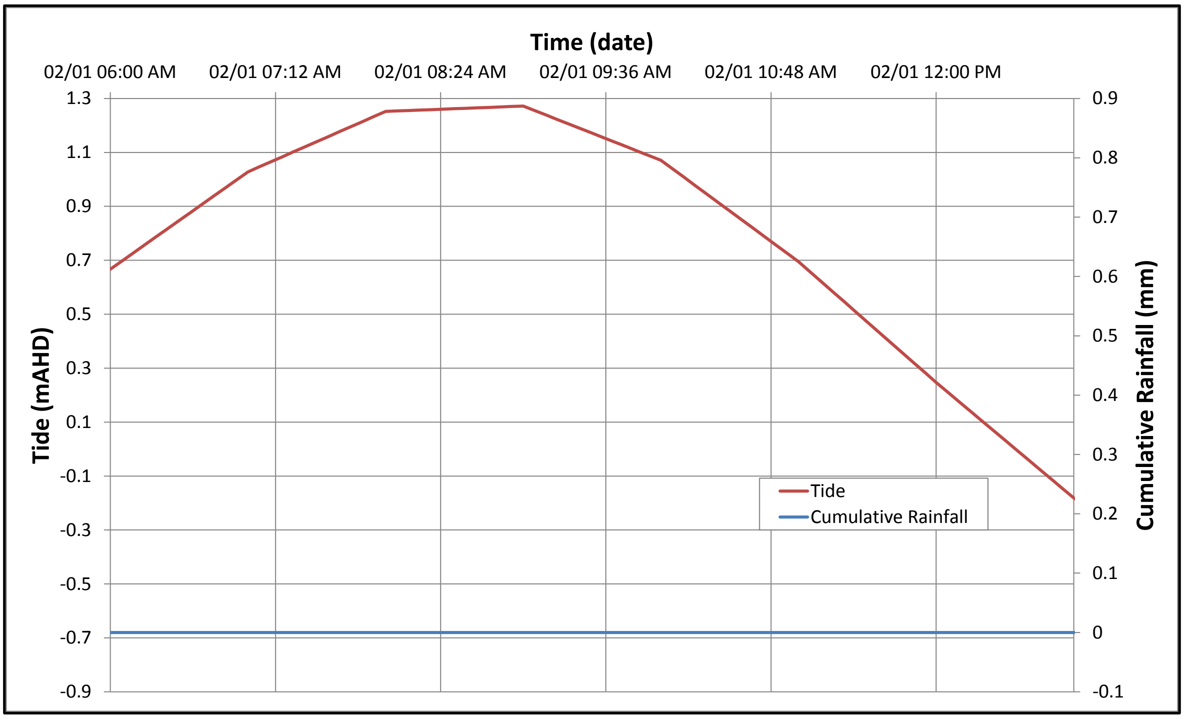


Figure 2-1 Rainfall and Tide record for 3rd January 2014 event

To confirm rainfall depth across the broader LGA, daily rainfall depths were reviewed for the 9AM reading on the 3rd January. Rainfall depths 2 days prior were additionally reviewed to inform antecedent catchment conditions. Table 2-1 presents the daily read rainfall totals. As shown, no runoff producing rainfall occurred over the three days reviewed confirming that the flooding observed is from a tide event only.

Table 2-1 Daily rainfall depths (mm) for 3rd January 2014 event

Station #	Name	01 Jan	02 Jan	03 Jan
066037	Sydney Airport AMO	0.0	0.0	0.4
066073	Randwick Racecourse	0.0	0.0	0.0
066051	Little Bay	NA	NA	NA
066052	Randwick (Randwick St)	0.0	0.2	0.6
066036	Marrickville Golf Club	0.0	0.0	0.0

2.2 Flooding Reports

2.2.1 Council Flooding Inspection

An inspection report for the flooding was provided by Council for the high tide event over the 2nd and 3rd January 2014. Photographs were taken within 30minutes of the tide peak so they can be assumed to approximately represent peak flood behaviour. The peak tide which occurred on the 2nd January was higher than the 3rd January and therefore used for model calibration. Relevant images have been extracted from the report and are presented hereunder.

2.2.1.1 Hale Street and Luland Street roundabout

Figure 2-2 shows ponded water near the corner of Luland Street and Hale Street. As shown, ponded water is approximately at the top roundabout level. Waves created by passing vehicles may misrepresent the actual water level.

It is assumed that peak flooding depths at this location would be approximately 0.5m.

Figure 2-2 Hale Street and Luland Street roundabout

2.2.1.2 Booralee Street

Figure 2-3 shows the ponded water on Booralee Street. As shown the road is entirely inundated and the flood level exceeds the height of the gutter.

It is assumed that peak flooding depths at this location would be approximately 0.25m.

Figure 2-3 Booralee Street (image taken from Luland Street)

2.2.1.3 Bay Street

Figure 2-4 shows tidal inundation on the Bay Street trash rack and Figure 2-5 shows road inundation further west between McFall Street and Byrnes Street.

At the trash rack location the open channel is effectively at bank full capacity though isn't overtopping. At the location shown in Figure 2-5 approximately 0.1m of ponding occurs on the northern side of the road.

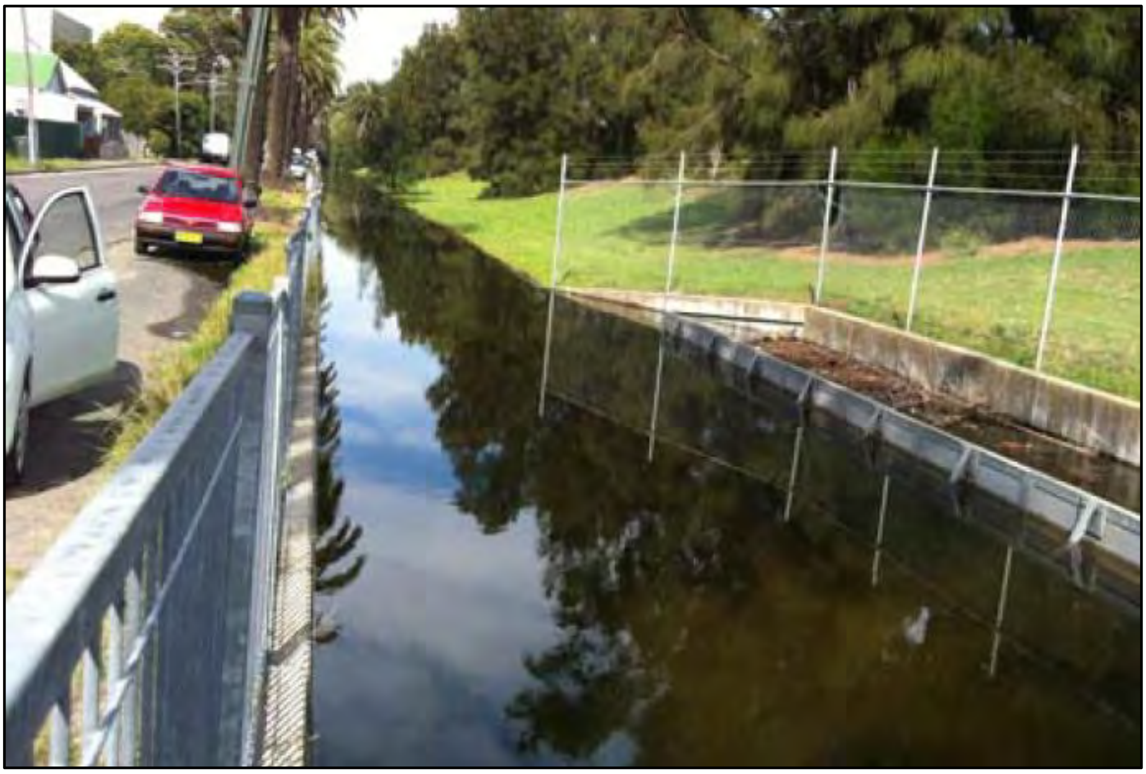


Figure 2-4 Trash rack on Bay Street (near Byrnes Street)

Figure 2-5 Bay Street (between McFall Street and Byrnes Street)

2.3 Modelled Flood Behaviour

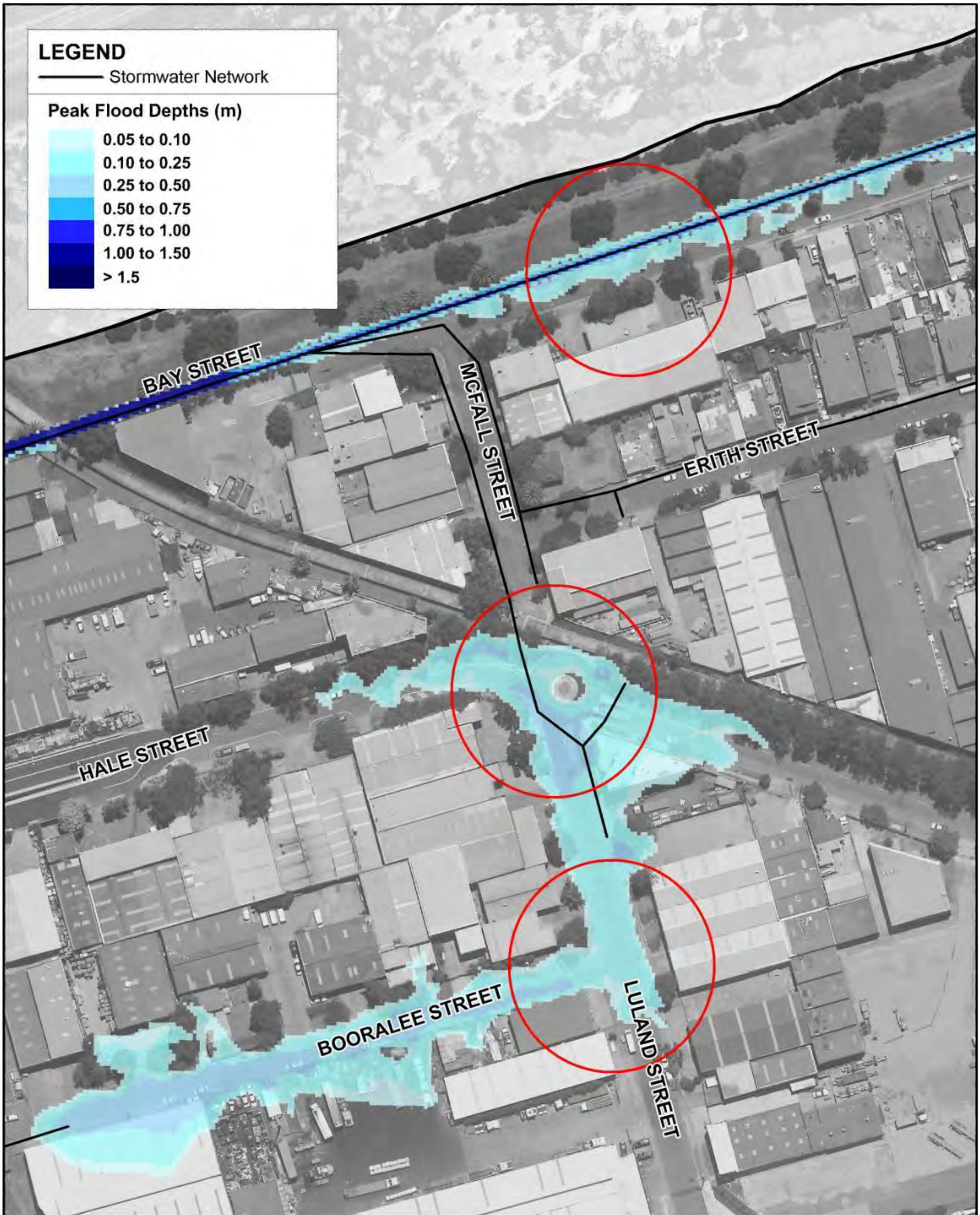
To demonstrate the TUFLOW models calibration performance, the modelled flood behaviour is compared with observed behaviour from community reports. Table 2-2 presents a summary or reported flood behaviour across the catchment and notes the models performance in each area.

Figure 2-6 shows the peak modelled depths at Bay Street and Luland Street.

As presented in the table and the figure, the TUFLOW model produces comparable results as reported. It is noted that the reported depths are approximated from the photograph, although the flood extents are well matched in the calibration modelling.

Table 2-2 Comparison of reported flood behaviour and modelled behaviour (24th March 2014)

Location	Observed Behaviour	Simulated
Corner of Luland Street and Hale Street	Peak depths ~ 0.5m	Figure 2-6
Booralee Street (near Luland Street)	Peak depths ~ 0.25m	Figure 2-6
Bay Street between McFall Street and Byrnes Street	Peak depths ~ 0.1m	Figure 2-6



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3 Calibration Event 4 March 1977

3.1 Rainfall and Tide

Figure 3-1 shows the recorded tide level of Botany Bay and the rainfall depth recorded at Sydney Airport AMO for the 4th March 1977 rainfall event. The total storm event produced 120mm of rainfall over a 16 hour period with the majority of the rainfall occurring in a burst of less than 2 hours duration. The peak tide which occurred just after the storm was only 0.22mAHD (note: only a simplified tidal profile showing peak low and high tide levels shown).

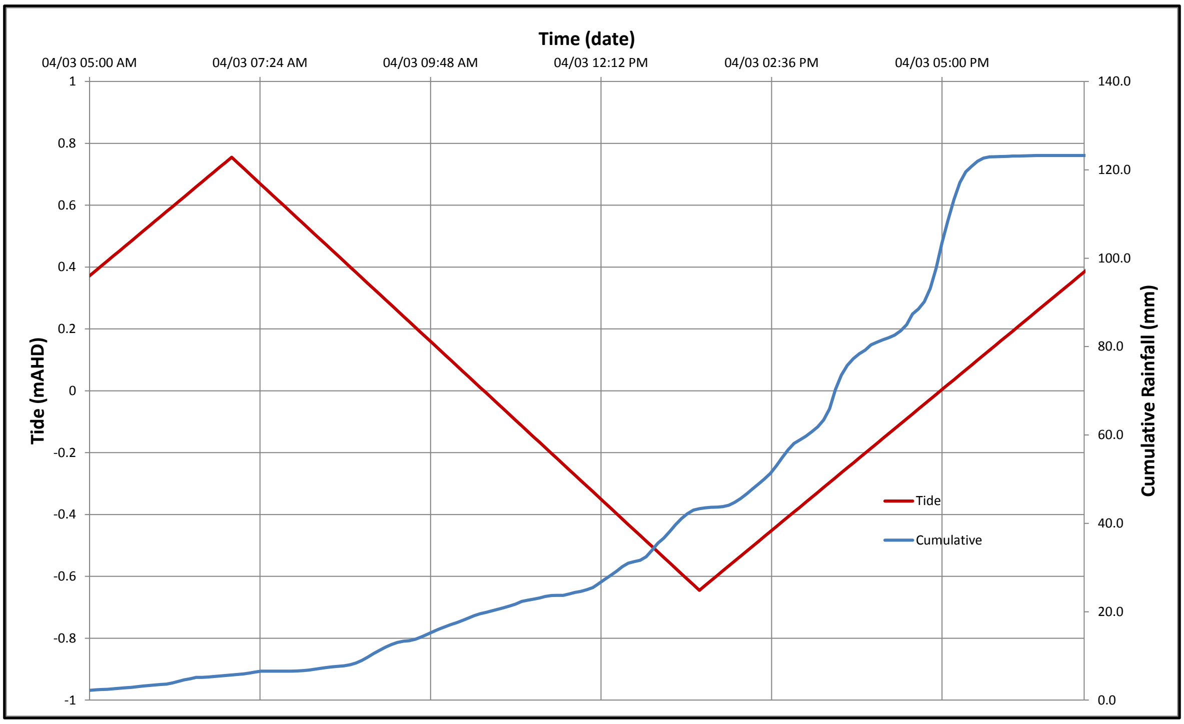


Figure 3-1 Rainfall and Tide record for 4 March 2014 event

To confirm rainfall depth across the broader LGA, daily rainfall depths were reviewed for the 24-hour period to 9AM on the 6th March. Totals for 4 days prior were additionally reviewed to inform antecedent catchment conditions (Table 3-1).

Table 3-1 Daily rainfall depths (mm) for 6 March 2014 and prior days

Station #	Name	2/03	3/03	4/03	5/03	6/03
066037	Sydney Airport AMO (pluvio)	62.4	1.0	13.2	112.7	15.2
566028	Eastlakes Sydney Water Depot (pluvio)	76.5	1.4	84.1	1.6	12.47
066037	Sydney Airport AMO (daily)	63.4	1.2	90.2	34.4	15.2
066073	Randwick Racecourse	85.0	6.8	155.4	NA	NA
066051	Little Bay	26.2	1.2	42.8	42.2	13.8
066052	Randwick (Randwick St)	50.0	6.0	115.2	22.6	NA
066036	Marrickville Golf Club	NA	NA	NA	NA	NA

Review of Table 3-1 indicates that the Airport AMO continuous rainfall records are inconsistent with Airport AMO daily records and the Eastlakes Sydney Water pluviograph gauge. For the Sydney Airport gauge, the daily totals for the 2nd, 3rd and 6th match between the data sets. The totals for the 4th and 5th sum to the same value though are different for each day. Figure 3-2 shows a comparison of the airport and Sydney water pluviograph gauges. Whilst some spatial variability between gauges may be expected, it would appear there is timing shift or offset between the pluviograph records. The nature of this has not been identified, however, the timing of the main rainfall bursts and cumulative rainfall totals are simular relative to the event commencement. A potential timing shift across the 9am recording periods may also explain the discrepancy in the daily totals.

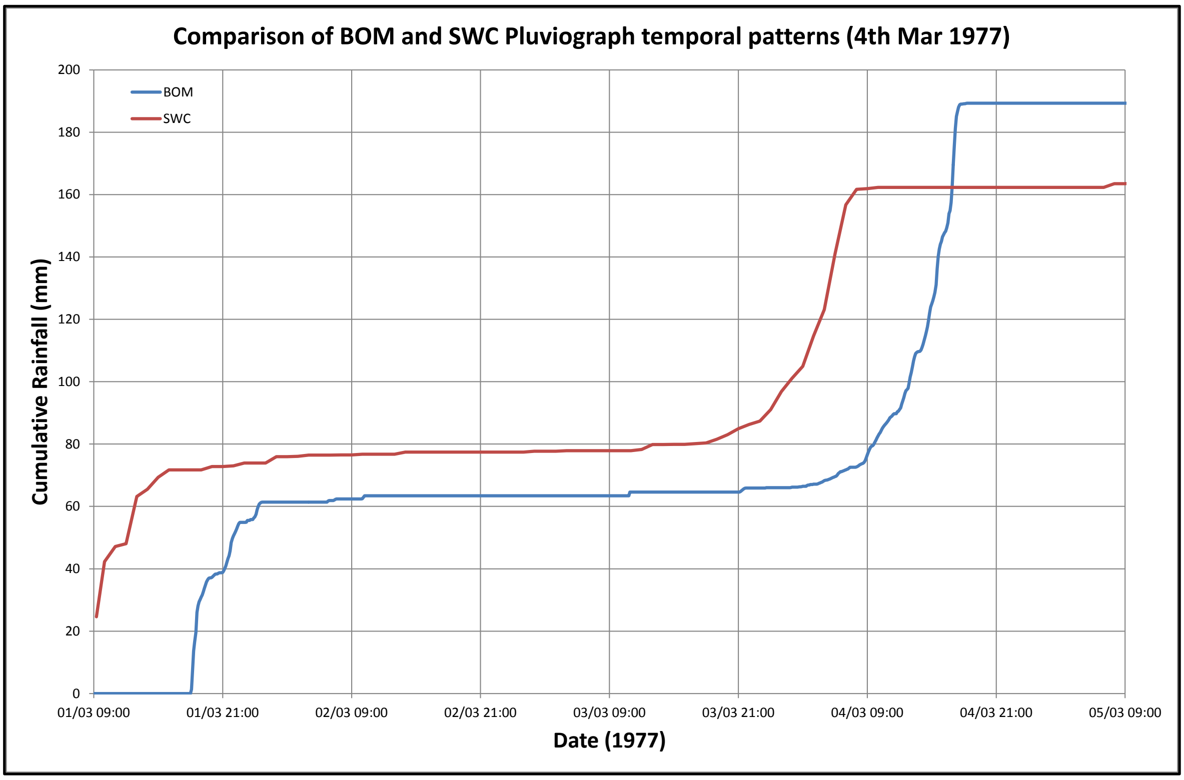


Figure 3-2 Cumulative rainfall comparison between pluviograph gauges

3.2 Flooding Reports

3.2.1 Sydney Water Corporation Records

Sydney Water Corporation records community reports of flooding to the Stormwater Unit. Within SWC catchment 16 there are 16 flooding reports ranging from 1957 to 1973. Flooding reports for the 4th March 1977 event are presented hereunder.

- Corner of Byrnes Street and Erith Street

Two reports in this area indicate that property gardens and lawns were inundated and water exceeded the height of the headwall. It is presumed the reference to the headwall refers to the original drainage lines which were open. Majority of drainage lines are now covered though this indicates that flooding may have exceeded the capacity of the trunk drain.

- Underwood Avenue

Flooding exceeded the height of the headwall for culvert flow under Underwood Avenue, with overland flows accordingly crossing Underwood Avenue.

- Rochester Street

A major Sydney Water drainage line crosses midway along Rochester Street. Near this location a warehouse experienced flooding.

- Corner of Cranbrook Street and Salisbury Street

Flooding reports at this location indicated that flood water exceeded the height of the headwall. A warehouse was further reported as flooded from the open channel and an overland flow path which formed on Margate Street.

3.3 Modelled Flood Behaviour

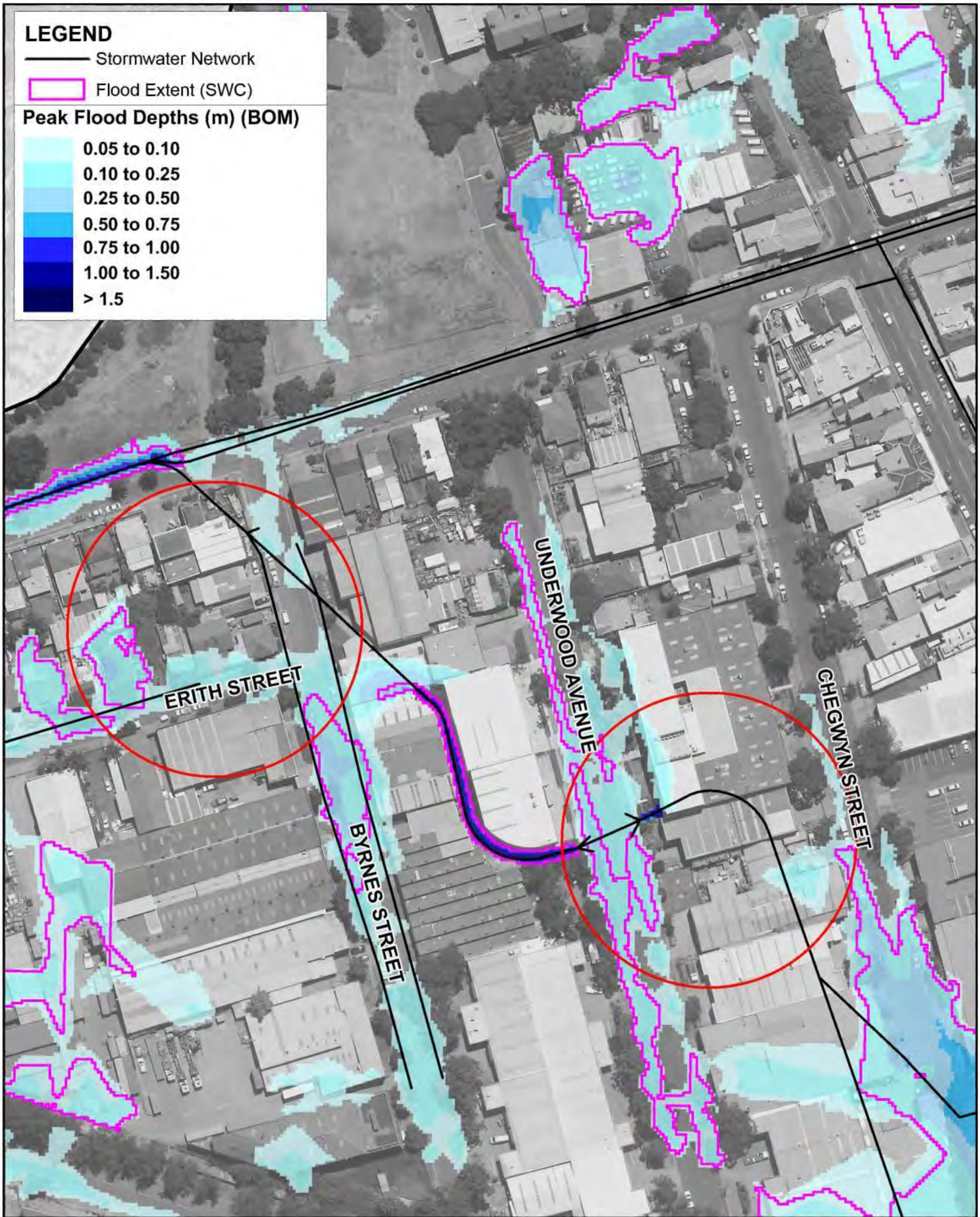
To demonstrate the TUFLOW models calibration performance, the modelled flood behaviour is compared with observed behaviour from Sydney Water's records. Table 3-2 presents a summary or reported flood behaviour across the catchment and notes the models performance in each area.

Figure 3-3and Figure 3-4 shows the peak modelled depths at the locations where flooding was reported. In the figures, the simulated flooding extent for the BOM and SWC pluviograph records is shown. Figure 3-2 shows that more rainfall was recorded at the BOM gauge (airport) as opposed to the SWC gauge (Eastlakes SW Depot), approximately 115mm and 80mm respectively. This explains why a greater flood extent is modelled for the BOM inputs.

As presented in the figures, the TUFLOW model produces comparable results as reported. It is noted that the reported depths are approximated from the photographs though the flood extents are well matched in the calibration modelling.

Table 3-2 Comparison of reported flood behaviour and modelled behaviour (24th March 2014)

Location	Observed Behaviour	Figure
Corner of Byrnes Street and Erith Street	Lawns flood. Capacity of open channel exceeded.	Figure 3-3
Underwood Avenue	Capacity of open channel exceeded	Figure 3-3
Rochester Street	Property inundation	Figure 3-4
Corner of Cranbrook Street and Salisbury Street.	Property inundation. Capacity of open channel exceeded and flow path formed on Margate St	Figure 3-4



Title:

Calibration Performance
4 March 1977 (BOM and SWC pluviograph rainfall records)

Figure: 3-3

Rev: -

0 37.5 75m
Approx. Scale

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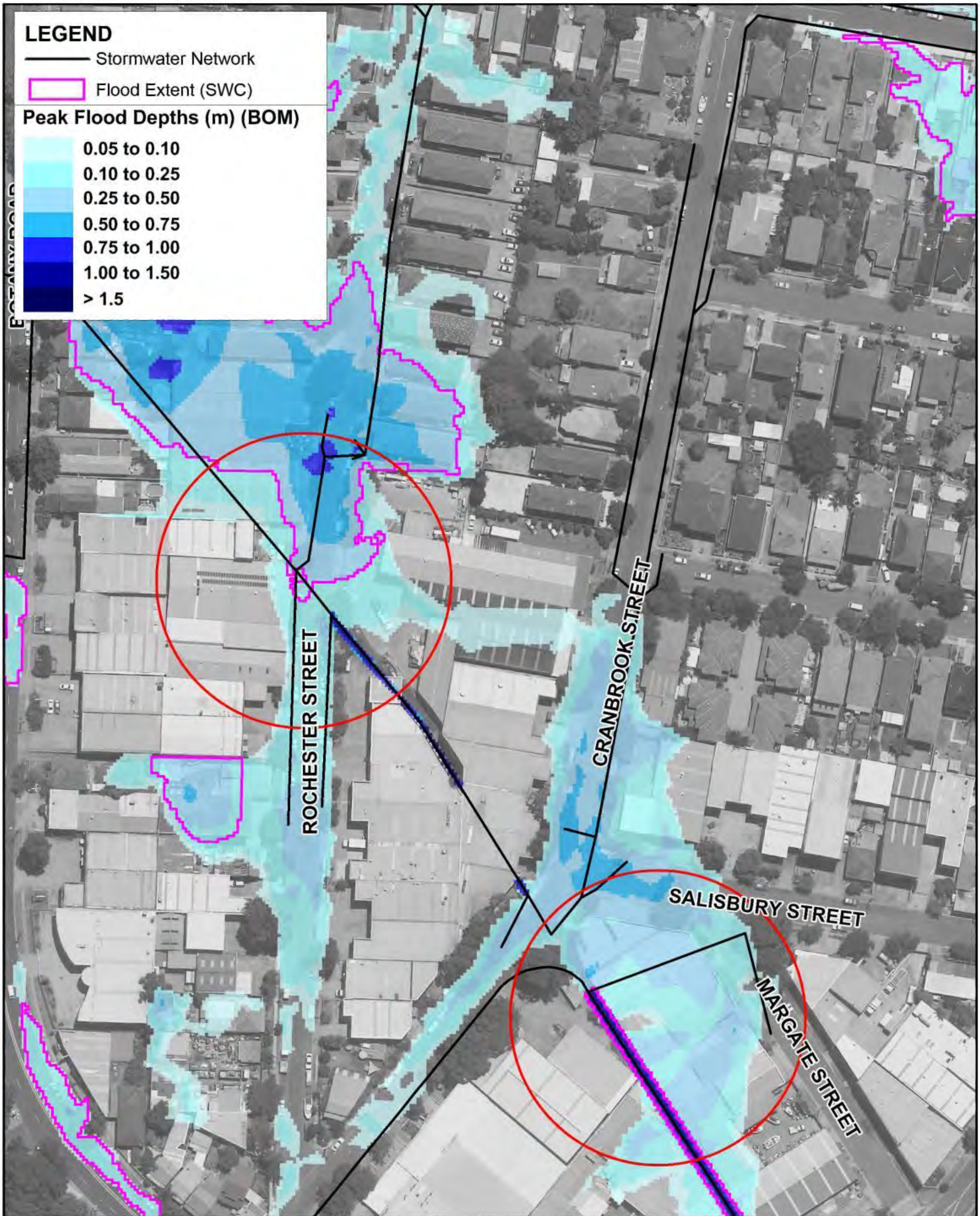

Title:

Calibration Performance
4 March 1977 (BOM and SWC pluviograph rainfall records)

Figure: **3-4**

Rev: **-**

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Appendix B Community Consultation Material

City of Botany Bay

Delivery Address:
PO Box 194
LEICHHARDT NSW 2040

The City of Botany Bay
Flood Study
BMT WBM
Reply Paid 87568
LEICHHARDT NSW 2040

No stamp required
if posted in Australia

COMMUNITY CONSULTATION

Community Consultation is important and involves a number of steps. The aim is to collect as much historical rainfall and flood information as possible.

• Community Involvement

Community involvement in managing flood risks is essential to improve the decision making process, to identify local concerns and values, and inform the community about the consequences of flooding and potential management options. The success of the flood planning of the Botany Bay Foreshore Beach Catchment hinges on community's input and acceptance of the proposals.

• Newsletter & Questionnaire

This newsletter and questionnaire allows all residents within the catchment area to share their local knowledge and personal experiences. Council is interested in any historical records of flooding in the area such as photographs, flood marks or observations. For example you, or someone you know, might remember if the area has flooded and if so how far the waters came up to a house or tree or fence pole.

• On Exhibition

The Draft Report is scheduled for completion in early 2015. The report will be on exhibition and again you, the community, will be invited to view the document and make comments. It will be on display at the Council's Administration Office, the Mayor's Office, Council's Libraries and on the website.

What Happens To The Information?

Once Council has gathered as much information as possible it will establish hydrologic and hydraulic computer models of the catchment. Using all the historical data rainfall will be converted into runoff to establish flood levels within the study area.

The information will be used to prepare a Draft Plan for Flood Risk Management which gives consideration to the social, economic and environmental impacts of flooding for the short, medium and long term.

THANK YOU for completing the questionnaire. A representative from BMT WBM may contact you in the near future to discuss your response.

HAVE YOUR SAY

FLOOD STUDY

BOTANY BAY FORESHORE BEACH CATCHMENT

FOR MORE INFORMATION PLEASE CONTACT:

BMT WBM

BMT WBM
Melanie Gostelow
Water Engineer
Tel 8987 2900
Melanie.Gostelow@BMTWBM.com.au

City of Botany Bay

City of Botany Bay
Hossein Ansari
Drainage
Tel 9366 3666
Email: floodplainmanagement@botanybay.nsw.gov.au

City of Botany Bay

Cyan Magenta Yellow Black
Job: 18889 City of Botany Bay.__1_Top

Dear Resident,

Under the NSW Government's Flood Prone Land Policy, the management of flooding is primarily the responsibility of Local Government.

To improve our understanding of flooding within the City of Botany Bay, the council is preparing a detailed Flood Study for each of the catchment areas within the city. Council has completed the Floodvale/Springvale Drain catchment area; and is now looking at the Botany area.

The study will build on previous flood investigations to develop a formalised flood study of the whole catchment area. This study will assist the council to plan for, and manage, existing and any future flooding risks.

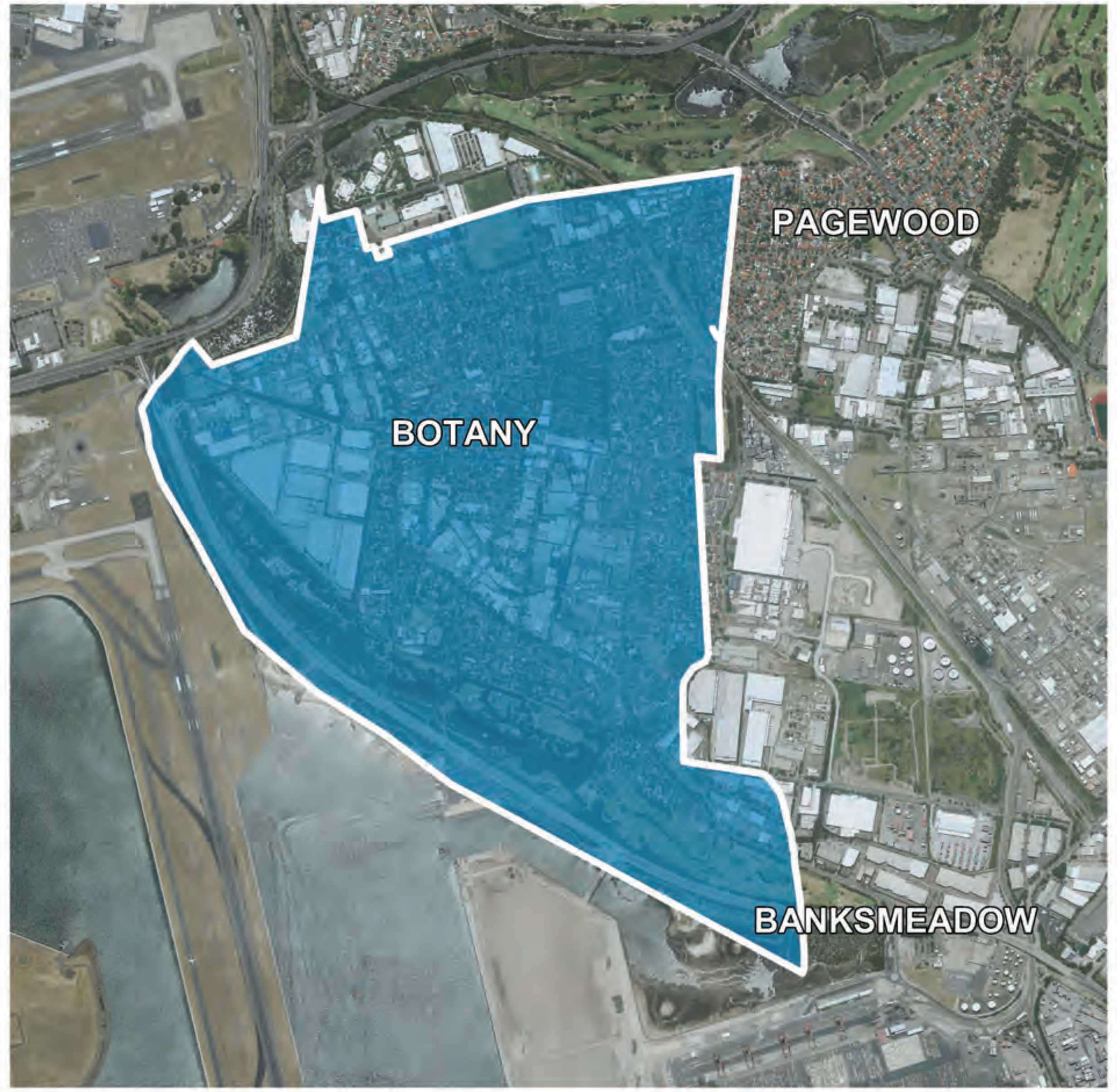
The Botany Bay Foreshore Beach Catchment Flood Study will be undertaken using the guidelines outlined in the NSW Government's Flood Prone Land Policy which aims to ensure that Council's management of flood risk occurs with consideration to the social, economic and environmental impacts of flooding for the short, medium and long term.

BMT WBM, an independent company specialising in flooding and floodplain risk management is conducting the study on Council's behalf.

Please take a few moments to fill in the attached Questionnaire and return to BMT WBM by Friday 8 August 2014.

Ben Keneally
Mayor
City of Botany Bay

STUDY AREA



Left is the proposed area of study.

It is defined by the white outline and includes most of Botany and small sections of Pagewood and Banksmeadow suburbs.

Please fill in the attached questionnaire and return it reply paid to BMT WBM by Friday 8 August 2014 or visit the project website http://botany.bmtwbm.com.au/ and complete the online survey.

PRIVACY NOTICE: The informationwill be held and used by staff at the City of Botany Bay and BMT WBM. Supply of this information is voluntary. The information will be stored on Council's file and used for the duration of the project only.

FLOODPLAIN RISK MANAGEMENT PROCESS

The flood management process is carried out in stages. Council is currently in the Data Collection stage/Flood Study Stage.

FLOODPLAIN MANAGEMENT COMMITTEE → DATA COLLECTION → FLOOD STUDY → FLOODPLAIN RISK MANAGEMENT STUDY → FLOODPLAIN RISK MANAGEMENT PLAN → IMPLEMENTATION OF PLAN

BOTANY BAY FORESHORE BEACH CATCHMENT **FLOOD STUDY** – Please complete and return by Friday 8 August 2014.

INTRODUCTION

The City of Botany Bay is carrying out a Flood Study for the Botany Bay Foreshore Beach Catchment.

Your local knowledge of the catchment and personal experiences of flooding will help us to undertake this flood study.

The extent of the catchment is shown on the enclosed map.

1. The purpose of the Flood Study is to identify the nature of flooding in the catchment area to enable Council to better understand, plan and manage the potential flood risk. We may contact you to discuss some of the information that you provide.

NAME ______

ADDRESS ______

EMAIL ______

PHONE (H/M) ______

2. How long have you lived or worked in the area?

______

3. Are you aware of stormwater flooding from streets or channels in your catchment?

______

4. Have you ever been inconvenienced by uncontrolled floodwater/stormwater from streets or channels in this area? If **No**, please proceed to question 6.

YES ☐ NO ☐

If you answered **Yes**, please tick the appropriate box below and give details of how uncontrolled floodwater/stormwater has inconvenienced you.

- ☐ Daily routine affected
- ☐ Safety threatened
- ☐ Access to property affected
- ☐ Property and/or contents damaged
- ☐ Business unable to operate during the flooded period
- ☐ Other

Details & Dates ______

5. Can you remember when you were inconvenienced by uncontrolled floodwater/stormwater from streets or channels in this area?

______

6. Has your home or other property been flooded because of uncontrolled floodwater/stormwater from streets or channels in this area?

YES ☐ NO ☐

If **Yes**, where was your property flooded and when did it happen? (You may tick more than one box)

- ☐ Front or backyard
- ☐ Garage or shed
- ☐ Residential below floor level
- ☐ Residential above floor level
- ☐ Commercial below floor level
- ☐ Commercial above floor level
- ☐ Industrial eg. factories
- ☐ Other

Details & Dates ______

7. Did you notice any bridges and/or drains to be blocked during the flooding?

YES ☐ NO ☐

If **Yes**, please provide details, (i.e how blocked would you say they were – 50%, 80%) What was causing the blockage?

______

8. Do you have any evidence of past floods (eg. photos, video footage, watermarks on walls or posts)

YES ☐ NO ☐

If **Yes**, please provide as many details as possible:

______

9. Do you have any more information you think might help the Botany Bay Foreshore Beach Catchment Flood Study?

______

Cyan Magenta Yellow Black
Job: 18889 City of Botany Bay.__2_Top

Appendix C Design Flood Mapping

Figure C- 30 Provisional Hydraulic Hazard – 20% AEP (~5 year ARI)

Figure C- 31 Provisional Hydraulic Hazard – 10% AEP (10 year ARI)

Figure C- 32 Provisional Hydraulic Hazard – 5% AEP (20 year ARI)

Figure C- 33 Provisional Hydraulic Hazard – 2% AEP (50 year ARI)

Figure C- 34 Provisional Hydraulic Hazard – 1% AEP (100 year ARI)

Figure C- 35 Provisional Hydraulic Hazard – 0.5% AEP (200 year ARI)

Figure C- 36 Provisional Hydraulic Hazard – Probable Maximum Flood

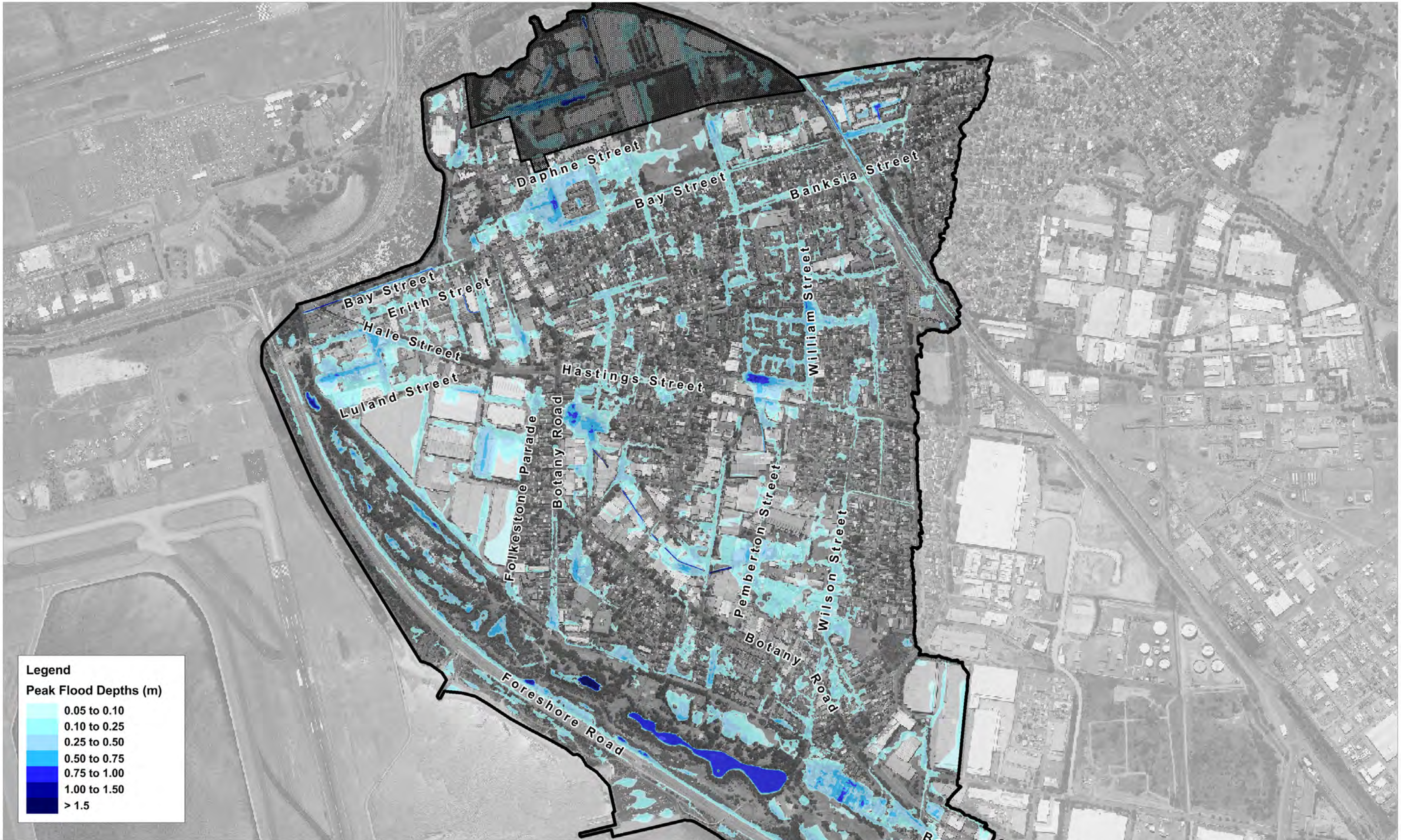
Figure C- 37 Emergency Response Planning Classifications – 5% AEP (20 year ARI)

Figure C- 38 Emergency Response Planning Classifications – 1% AEP (100 year ARI)

Figure C- 39 Emergency Response Planning Classifications – Probable Maximum Flood

Figure C- 40 Flood Planning Area – 1% AEP (100 year ARI) + 0.5m freeboard

Figure C- 41 Flood Risk Precincts



Title:
Peak Flood Depth
18% AEP (5 yr ARI)

Figure: **C-1**

Rev: **-**

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Approx. Scale

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Title:

Peak Flood Depth
10% AEP (10 yr ARI)

Figure: C-2

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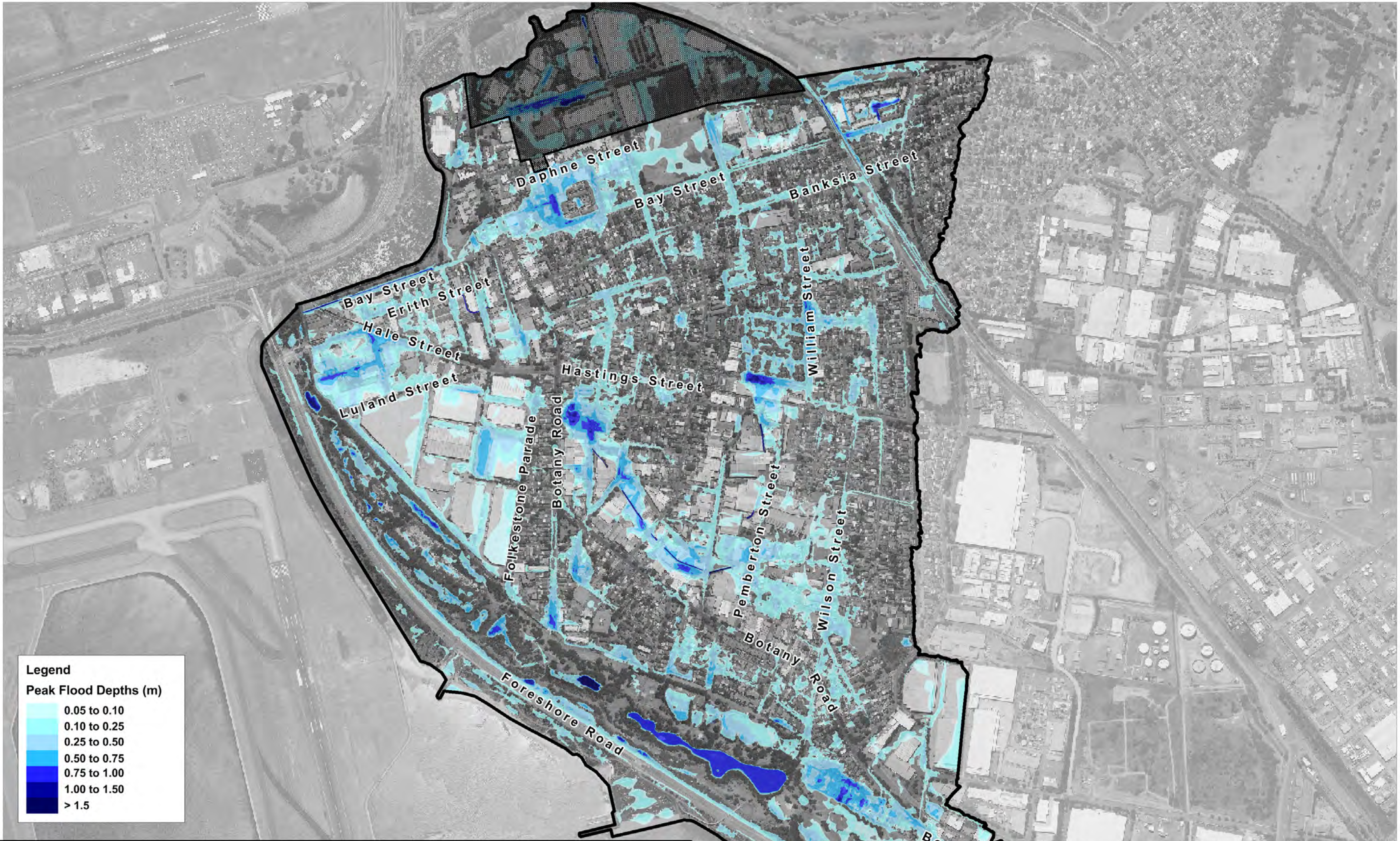

Title:
Peak Flood Depth
5% AEP (20 yr ARI)

Figure: C-3

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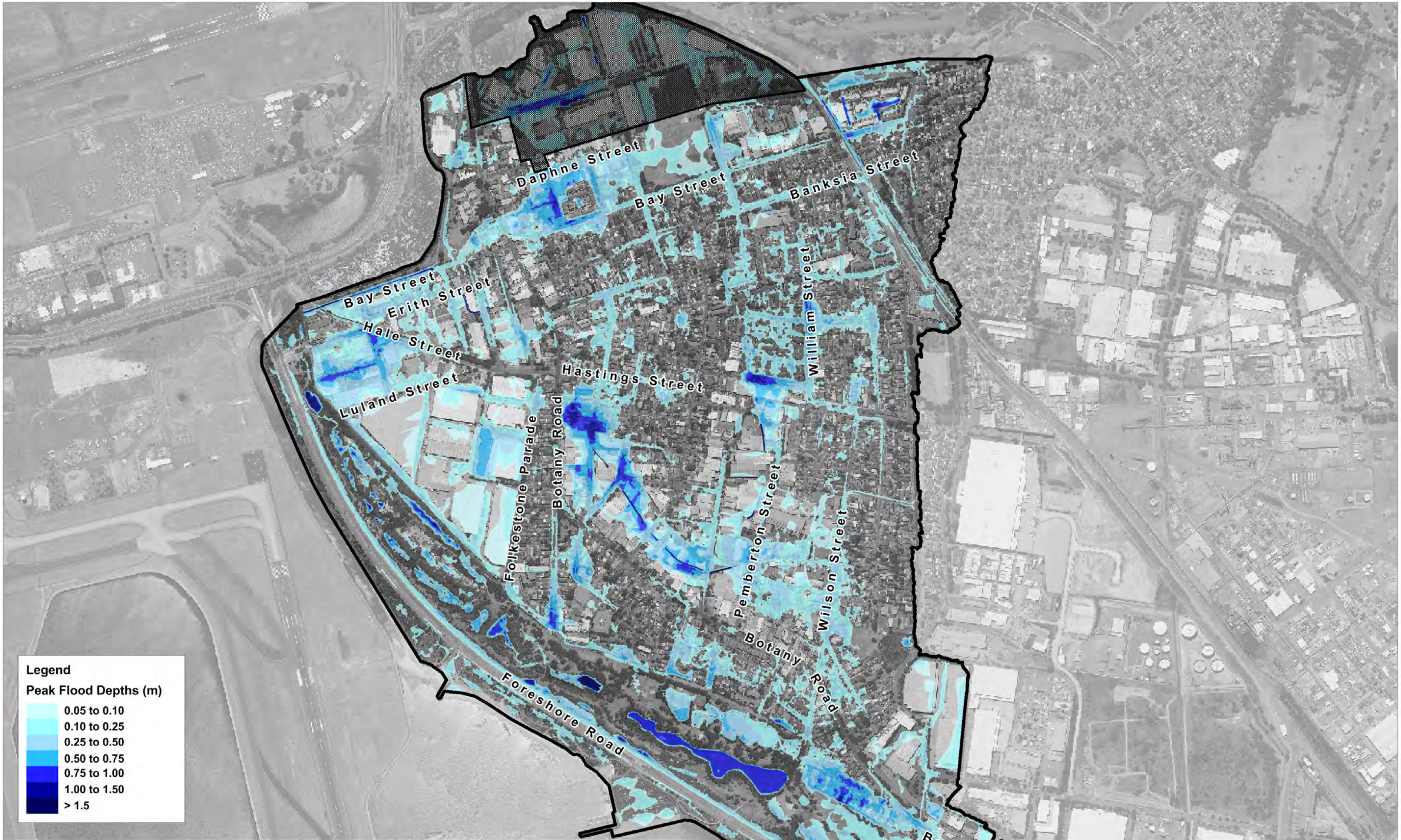

Title:

Peak Flood Depth
2% AEP (50 yr ARI)

Figure: **C-4**

Rev: **-**

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Approx. Scale

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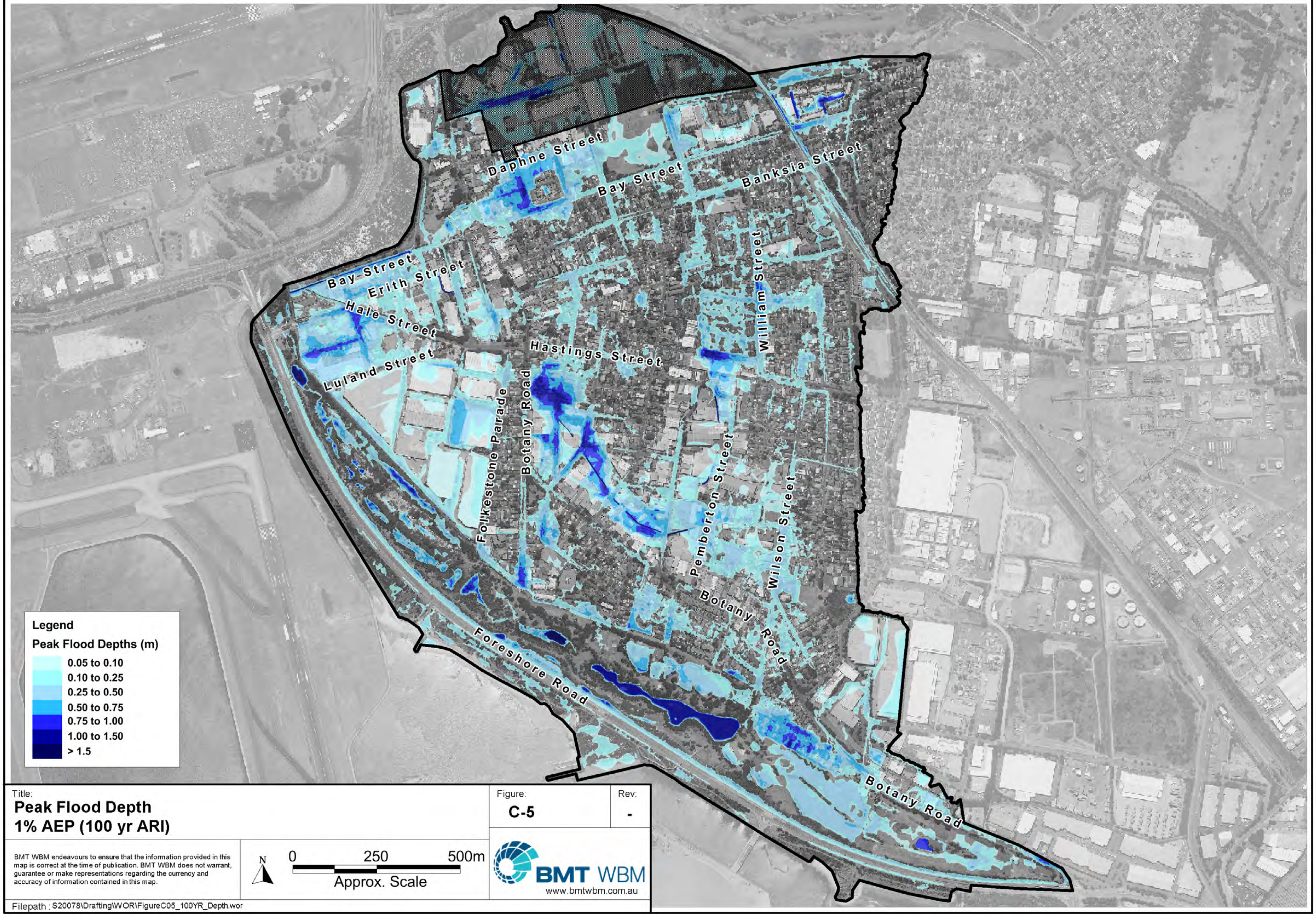

Title:
Peak Flood Depth
1% AEP (100 yr ARI)

Figure: **C-5**

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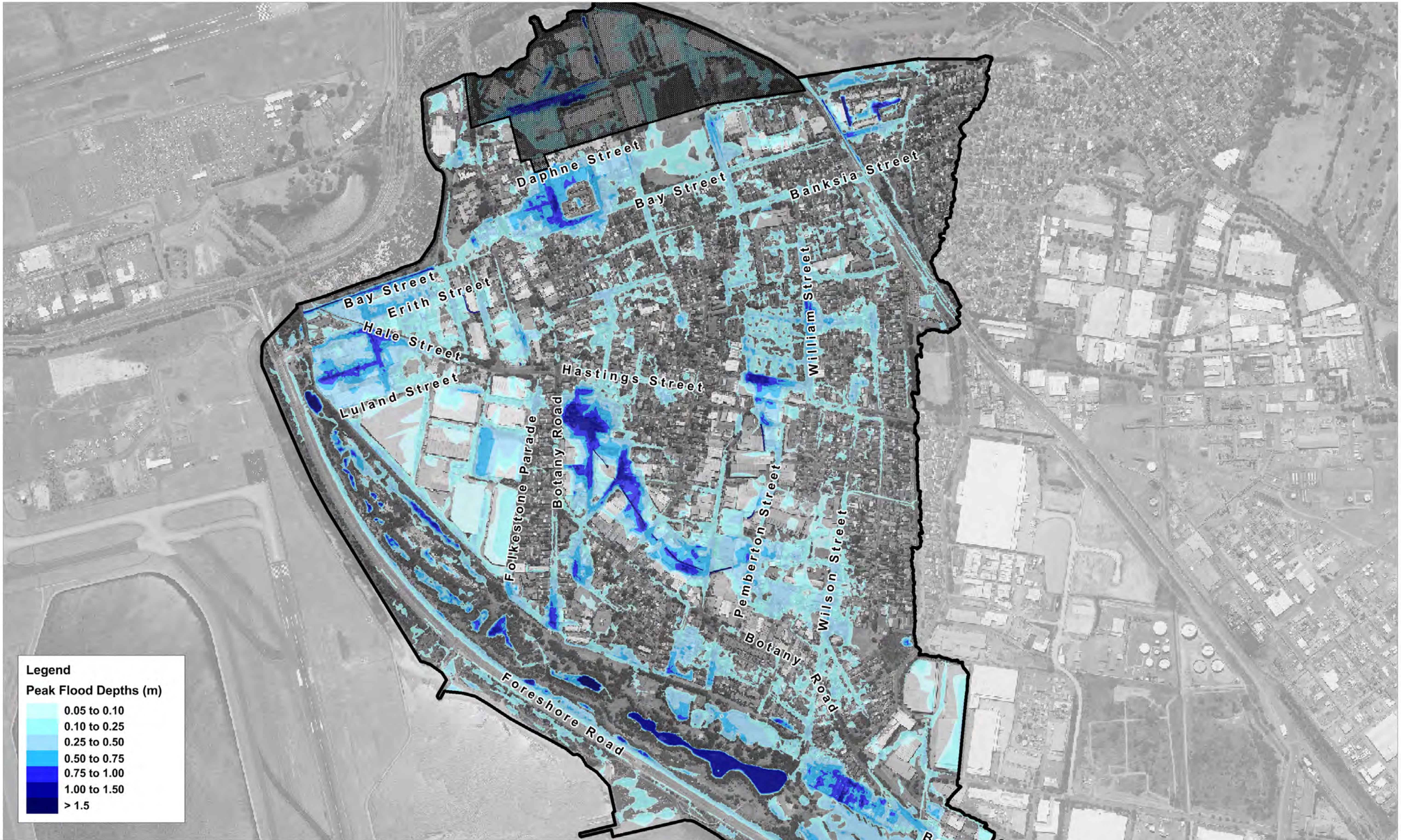

Title:
Peak Flood Depth
0.5% AEP (200 yr ARI)

Figure: C-6

Rev: -

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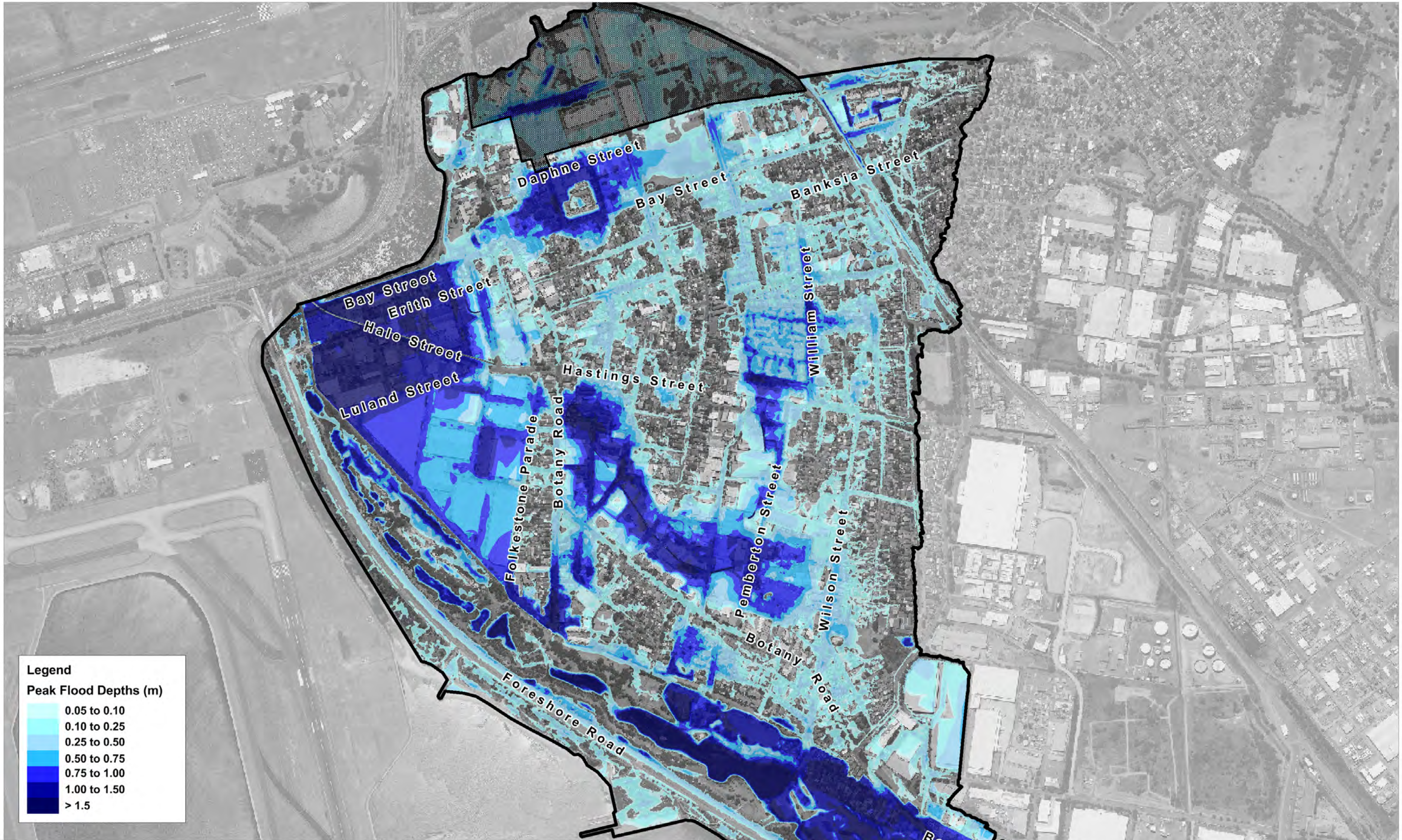

Title: **Peak Flood Depth** **Probable Maximum Flood**	Figure: **C-7**	Rev: **-**

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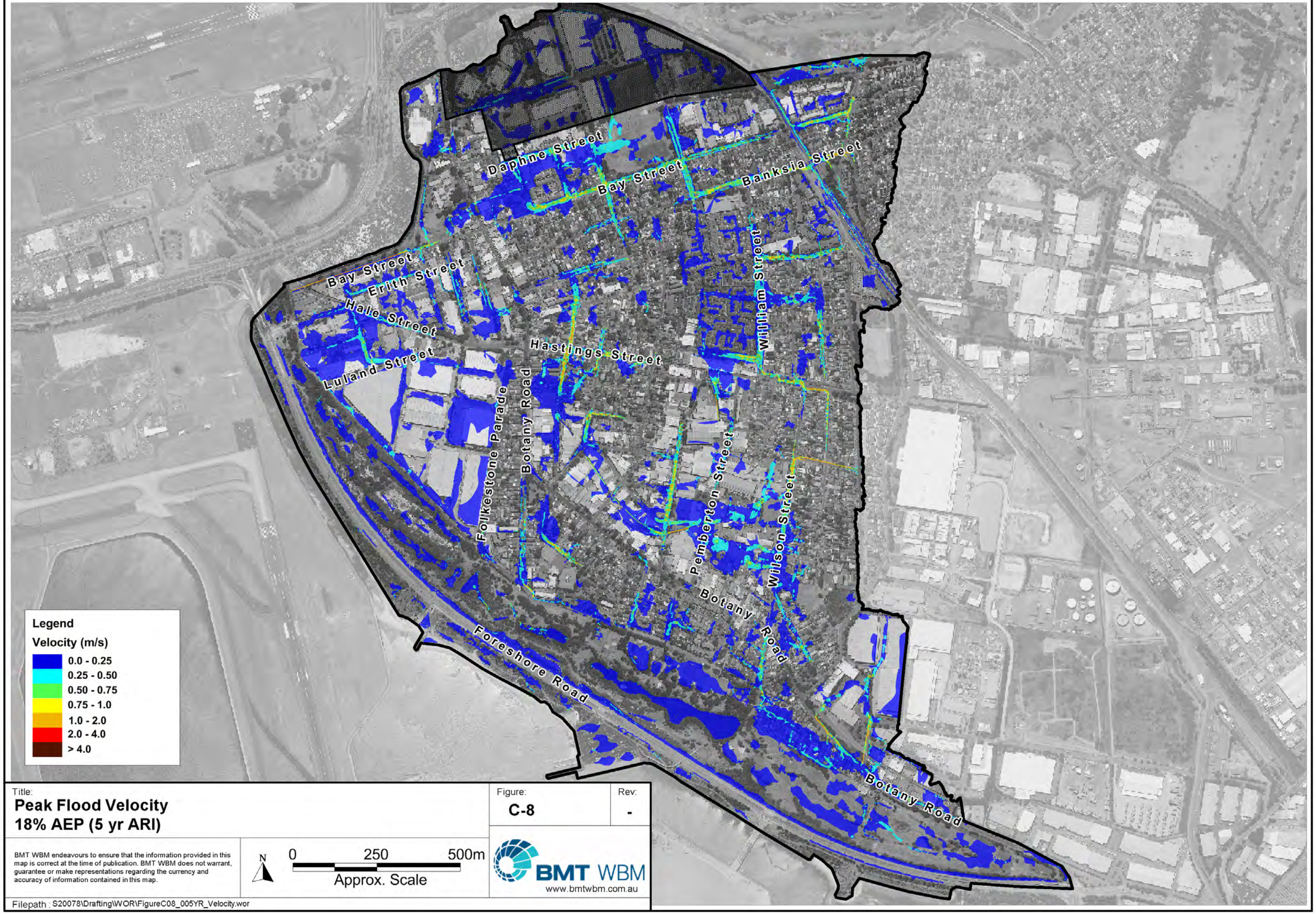

Title:
Peak Flood Velocity
18% AEP (5 yr ARI)

Figure: C-8

Rev: -

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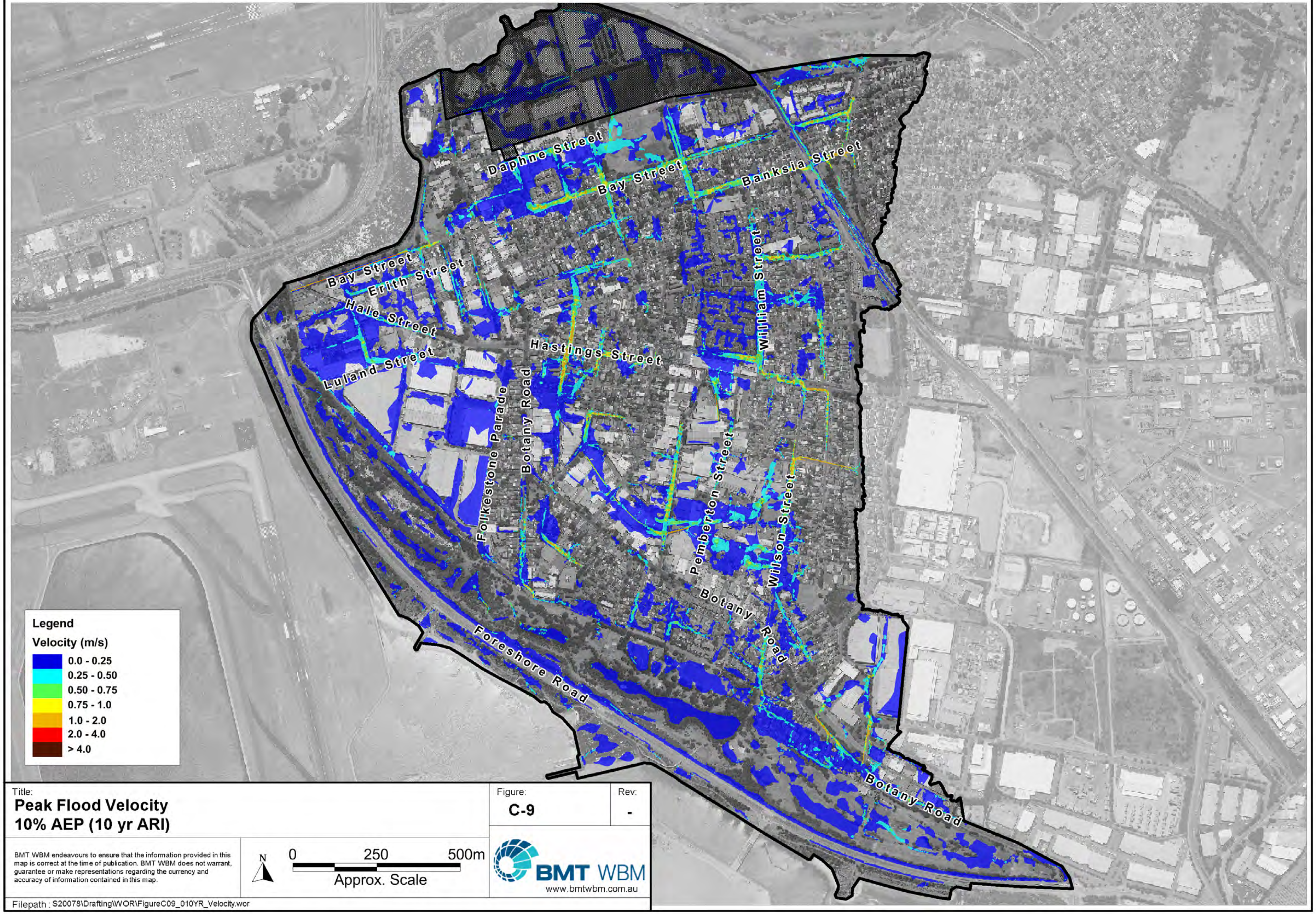

Title:
Peak Flood Velocity
10% AEP (10 yr ARI)

Figure: **C-9**

Rev: **-**

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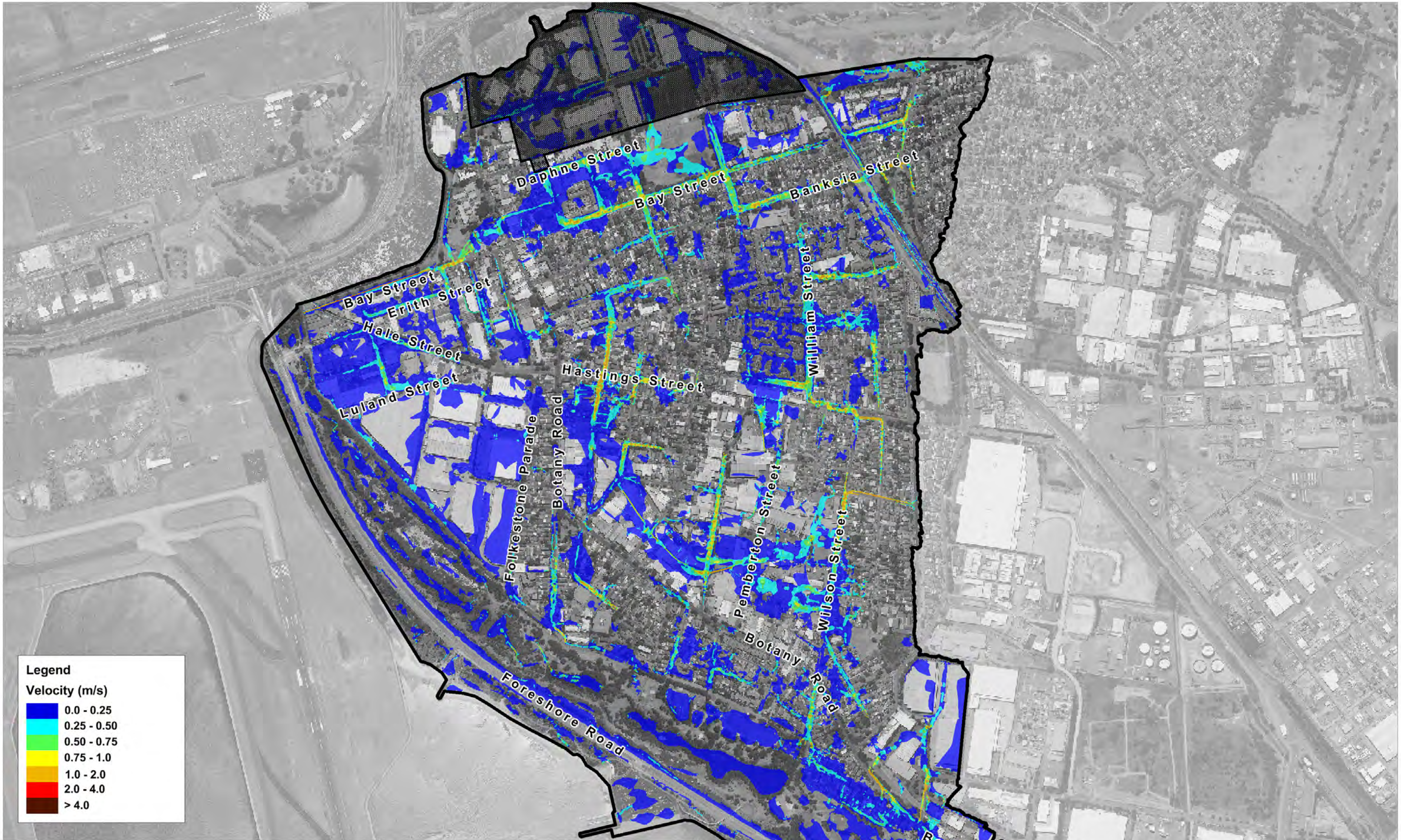

Title:

Peak Flood Velocity
5% AEP (20 yr ARI)

Figure: **C-10**

Rev: **-**

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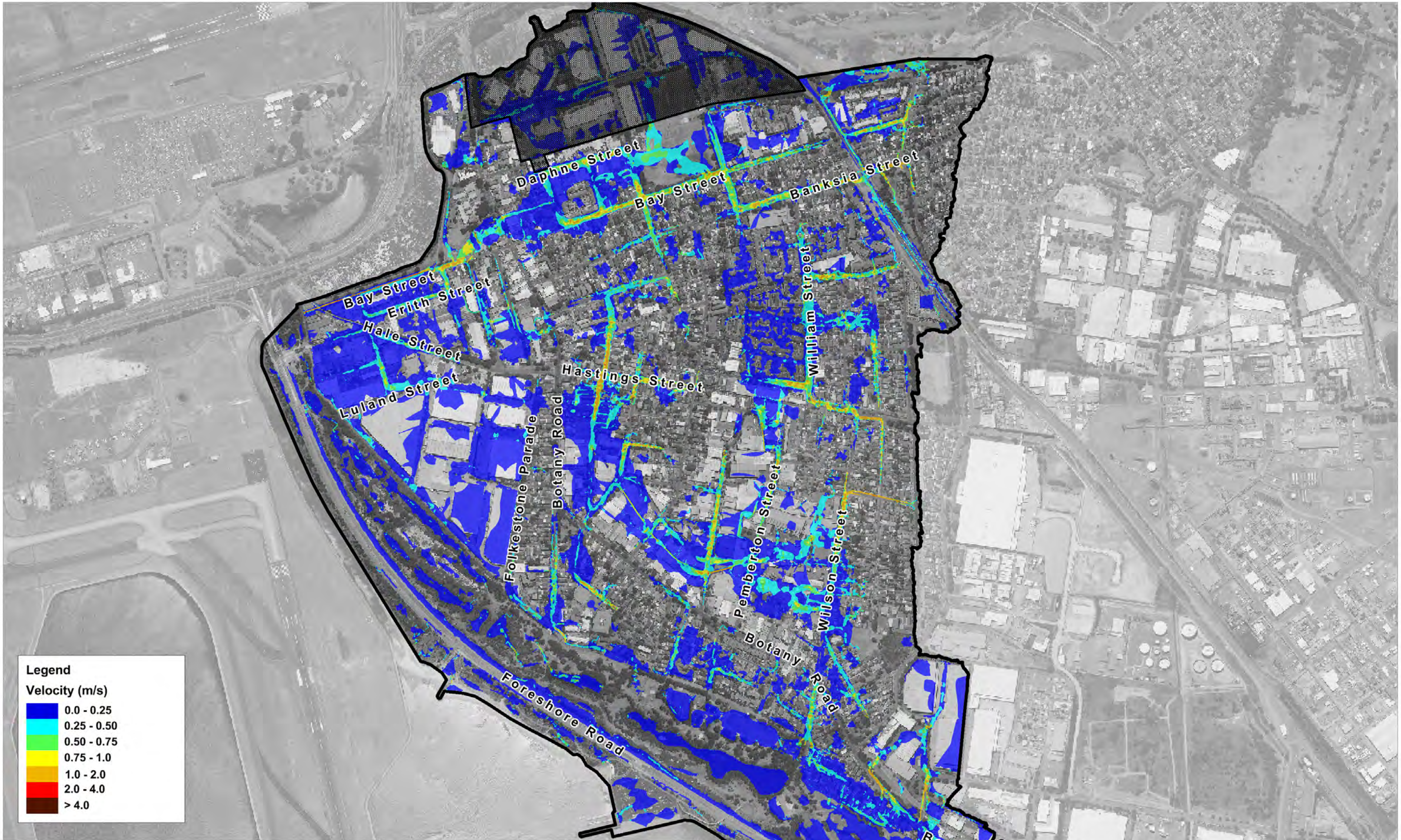

Title:
Peak Flood Velocity
2% AEP (50 yr ARI)

Figure: **C-11**

Rev: **-**

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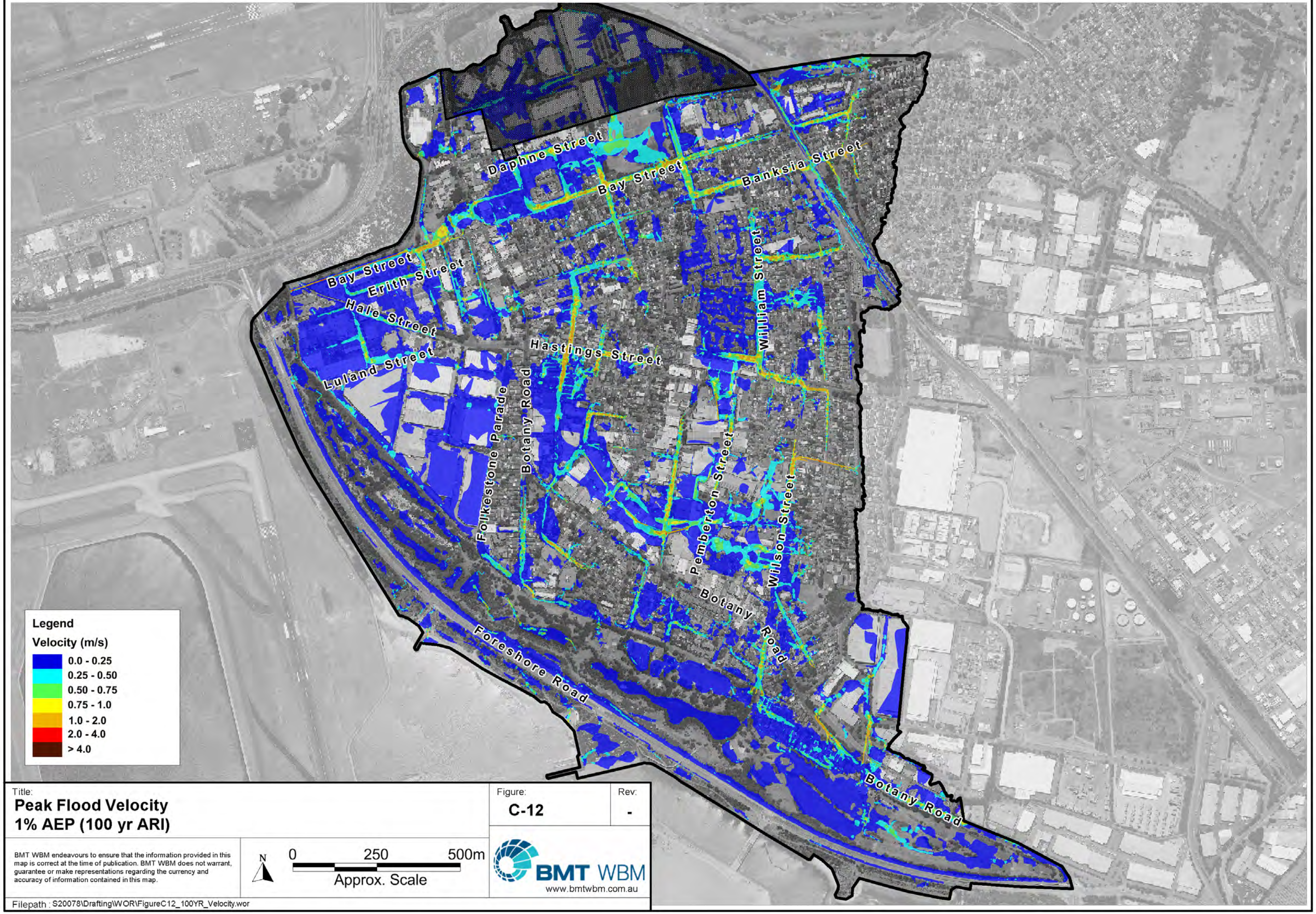

Title:

Peak Flood Velocity
1% AEP (100 yr ARI)

Figure: C-12

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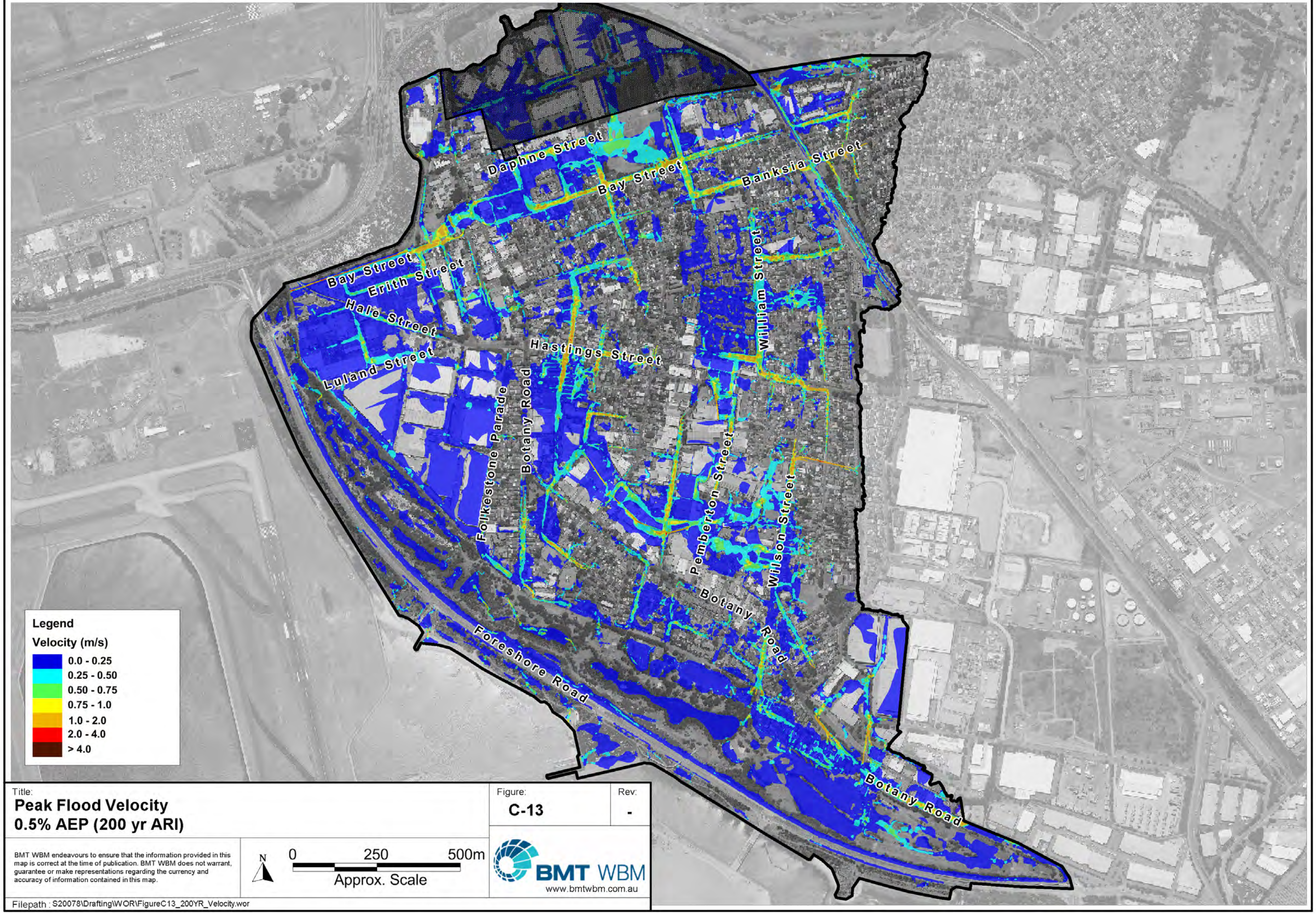

Title:
Peak Flood Velocity
0.5% AEP (200 yr ARI)

Figure: **C-13**

Rev: **-**

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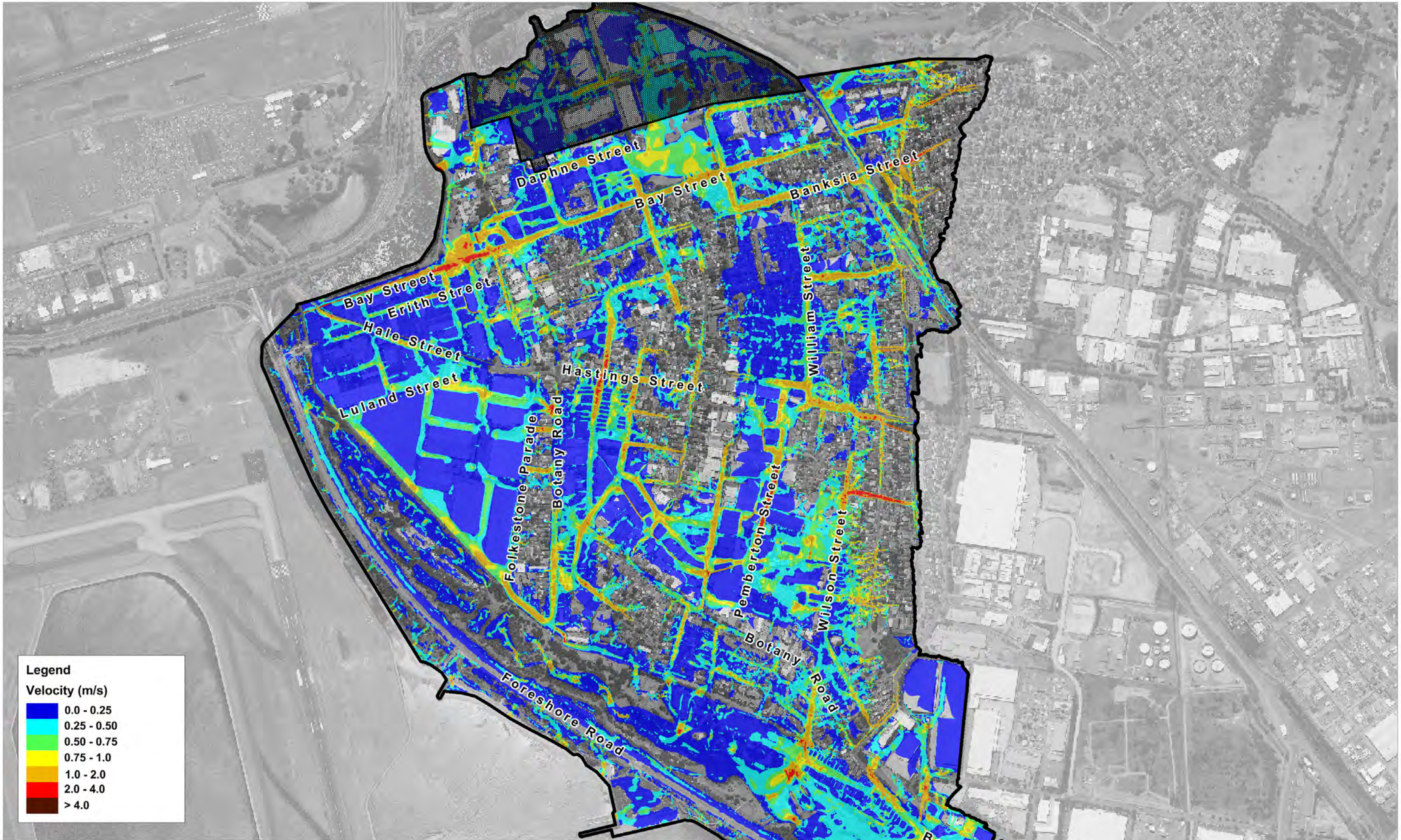

Title: Peak Flood Velocity Probable Maximum Flood	Figure: C-14	Rev: -

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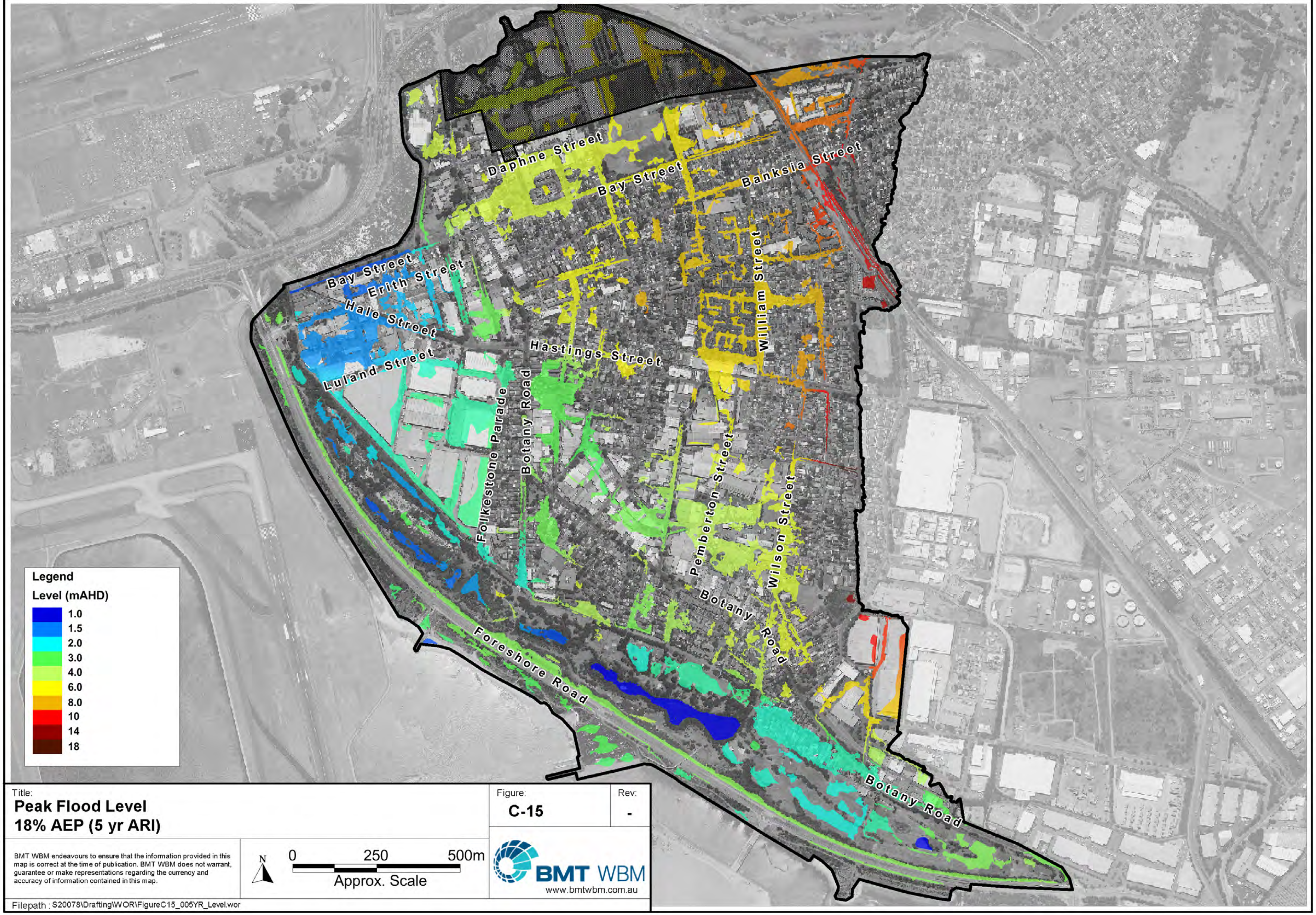

Title:
Peak Flood Level
18% AEP (5 yr ARI)

Figure: **C-15**

Rev: **-**

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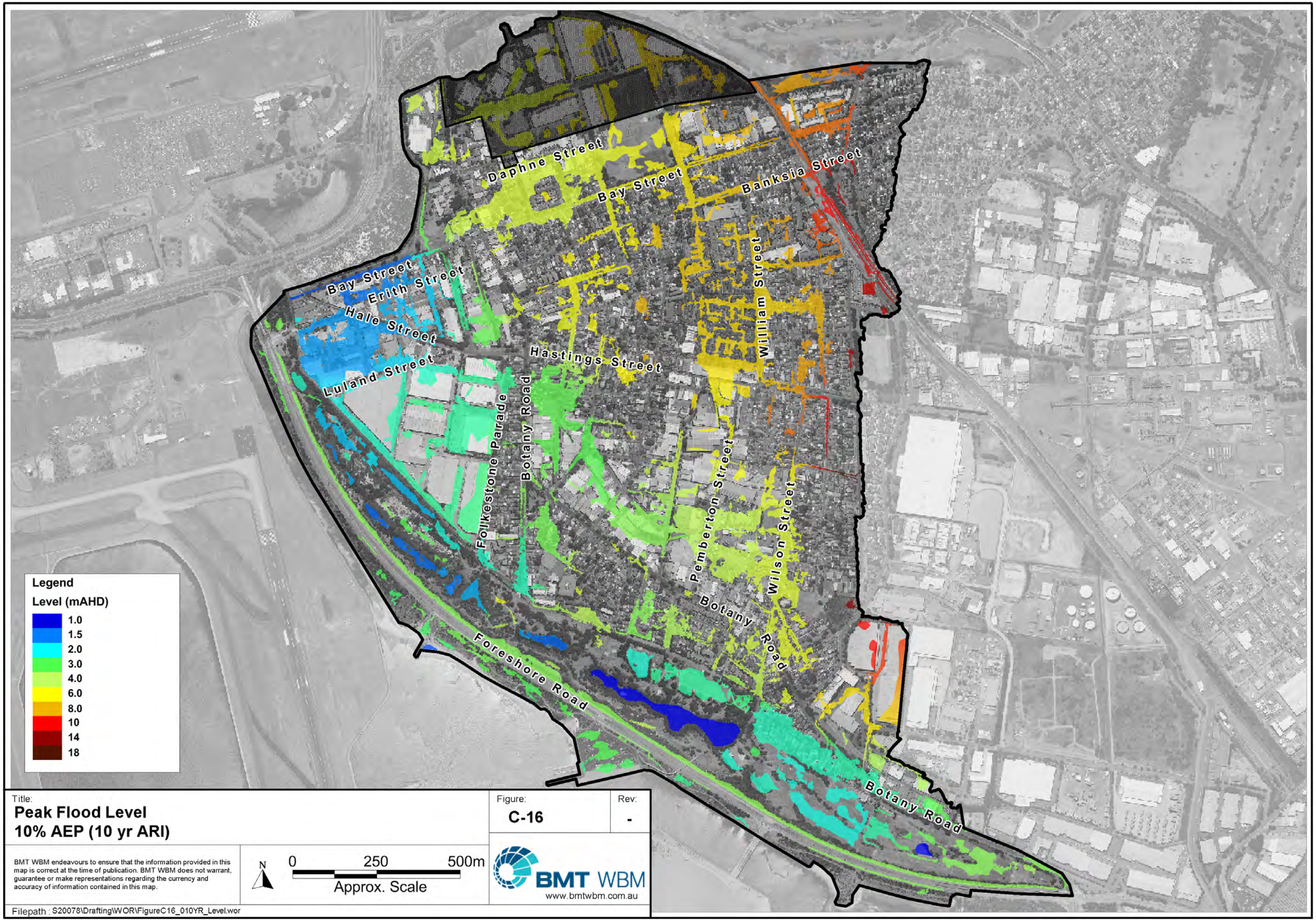

Title:
Peak Flood Level
10% AEP (10 yr ARI)

Figure: C-16

Rev: -

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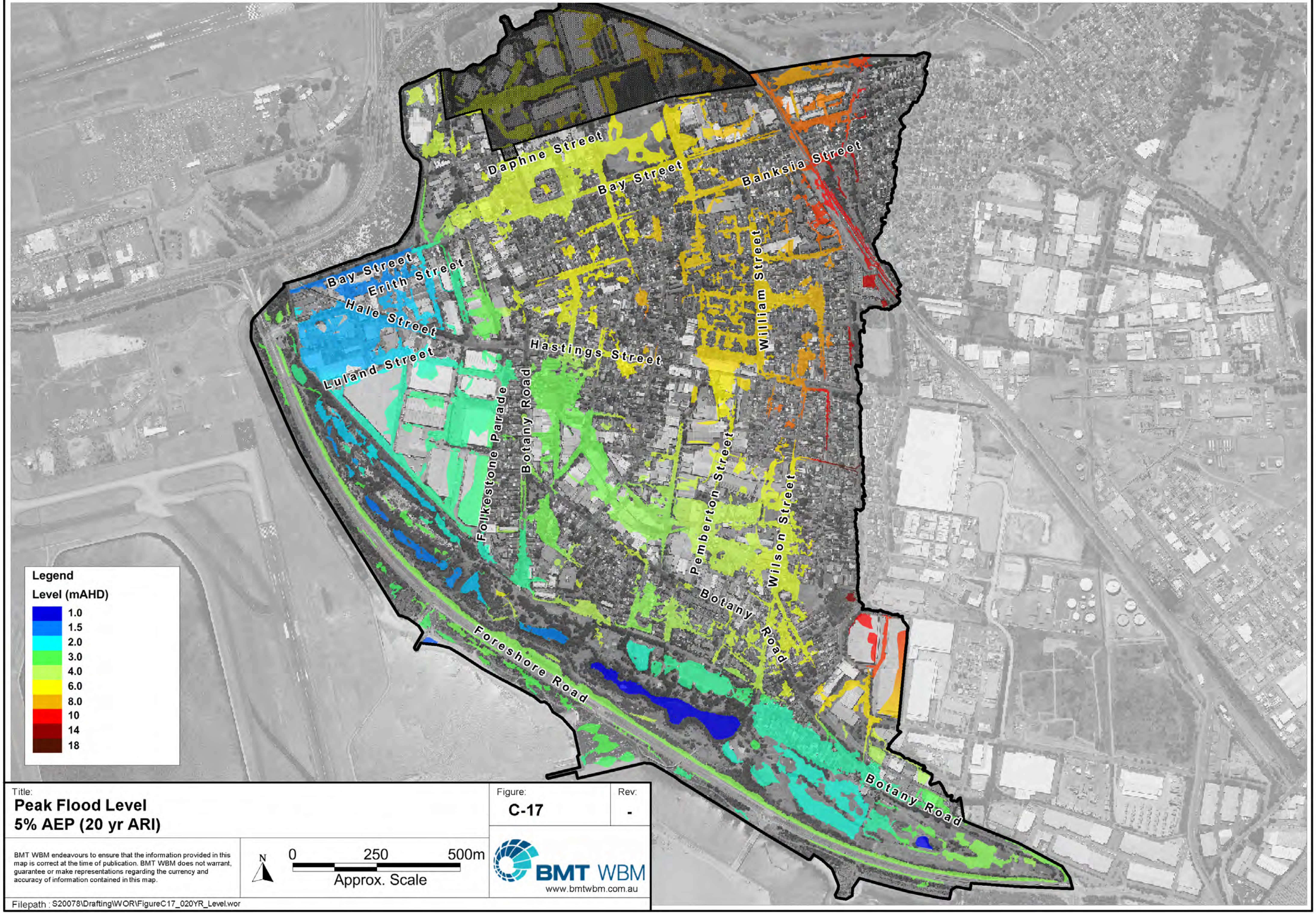

Title:

Peak Flood Level
5% AEP (20 yr ARI)

Figure: **C-17**

Rev: **-**

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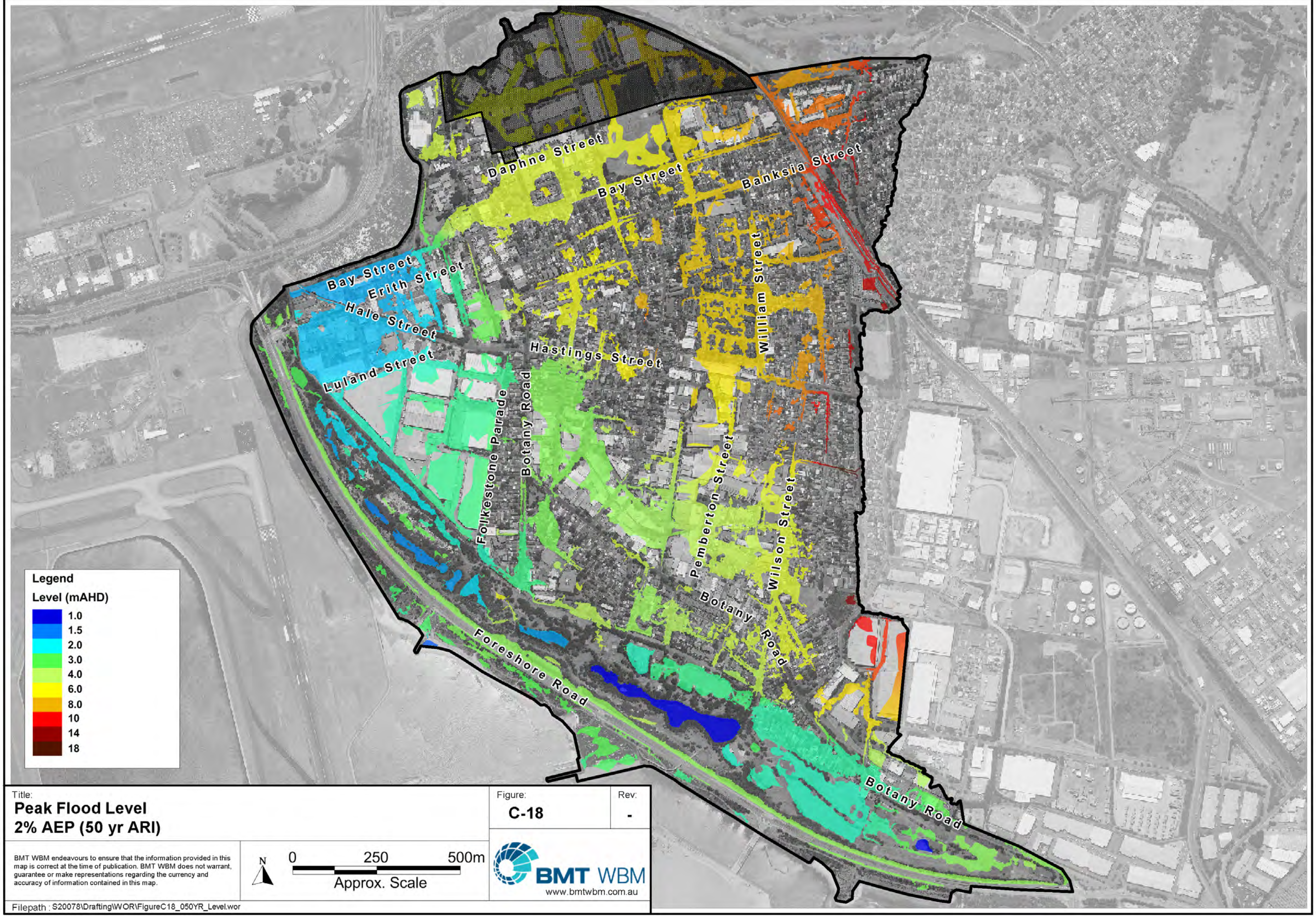

Title:
Peak Flood Level
2% AEP (50 yr ARI)

Figure: **C-18**

Rev: **-**

BMT WBM
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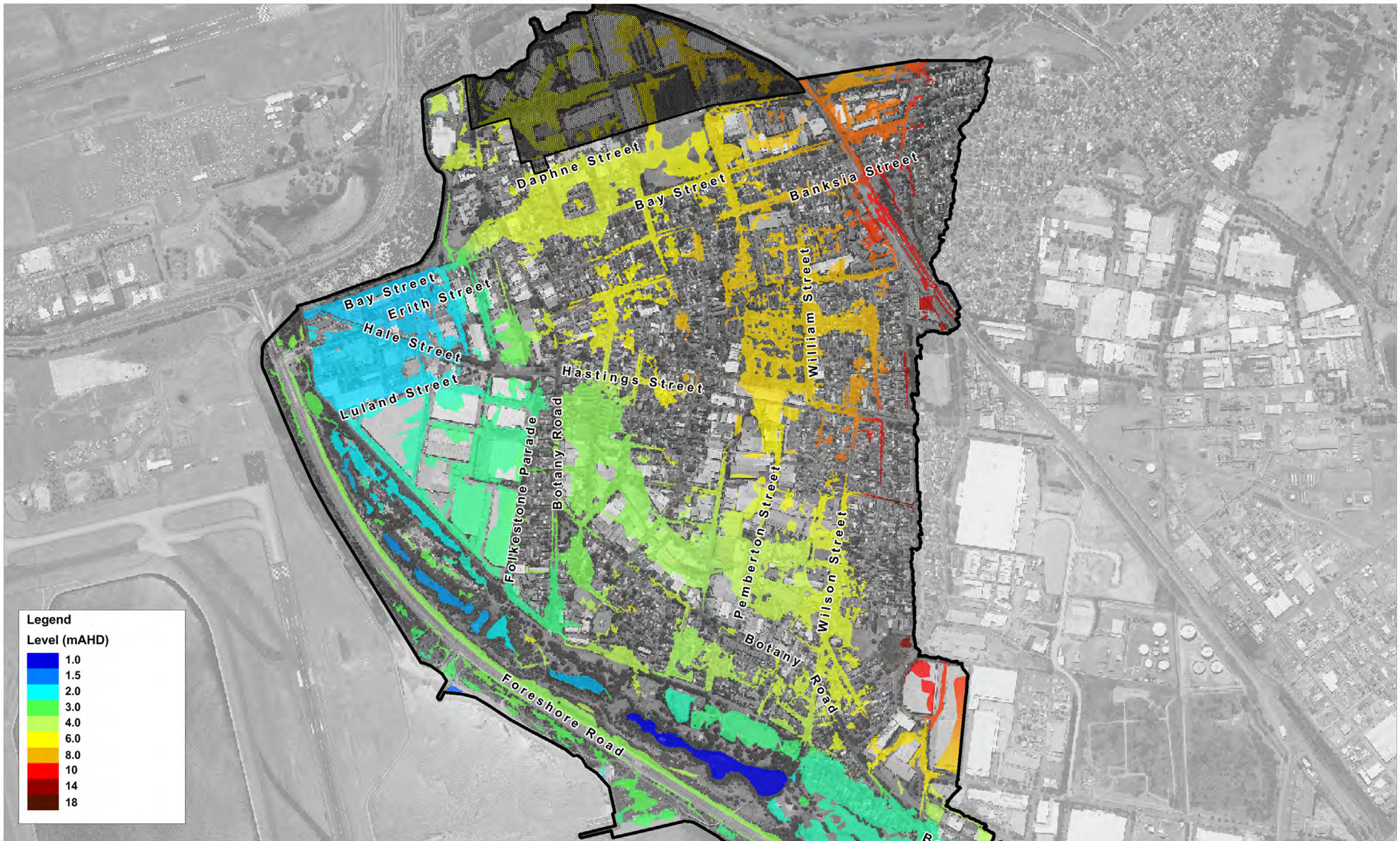

Title:

Peak Flood Level
1% AEP (100 yr ARI)

Figure: **C-19**

Rev: **-**

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Approx. Scale

BMT WBM
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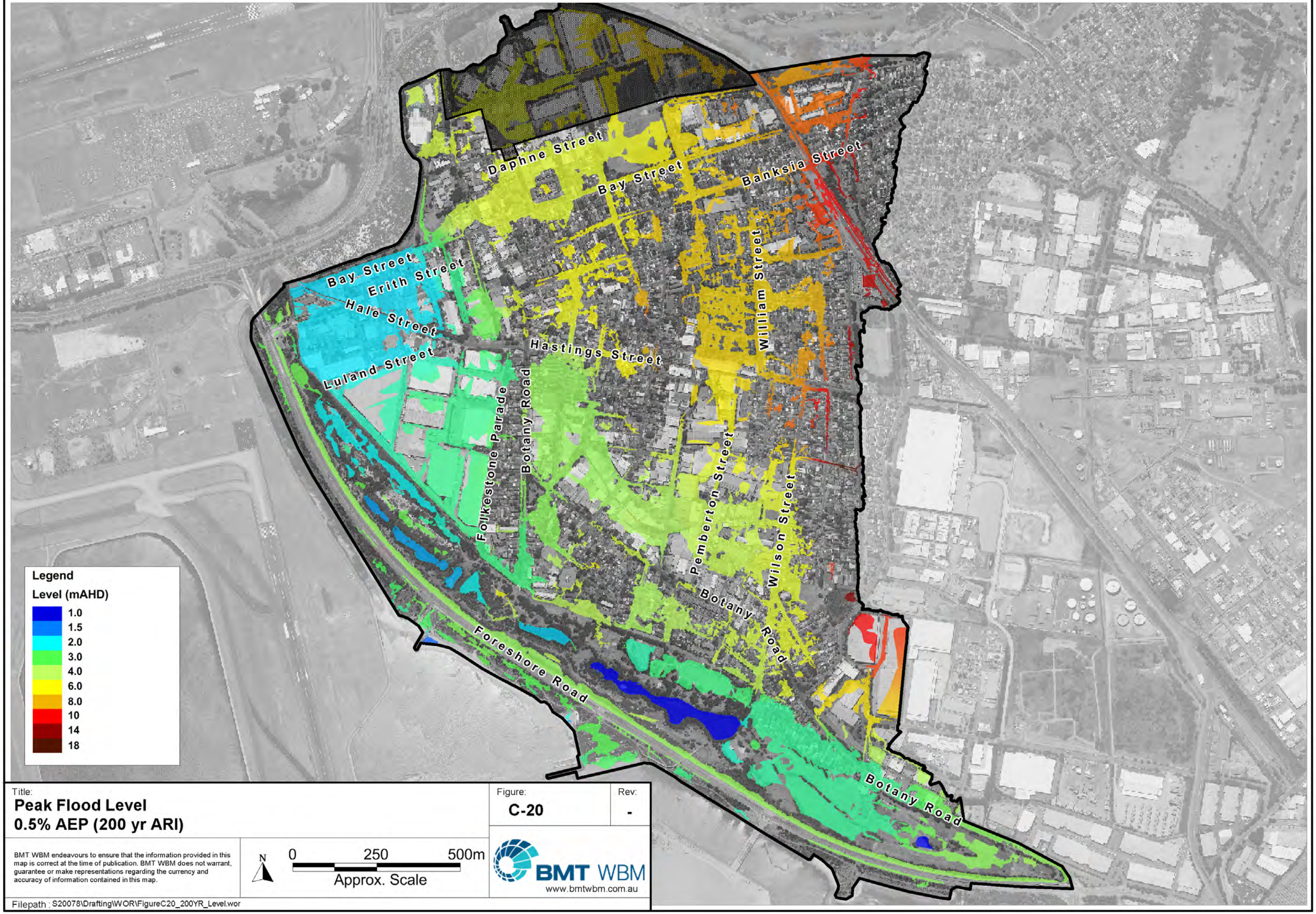

Title:

Peak Flood Level

0.5% AEP (200 yr ARI)

Figure: C-20

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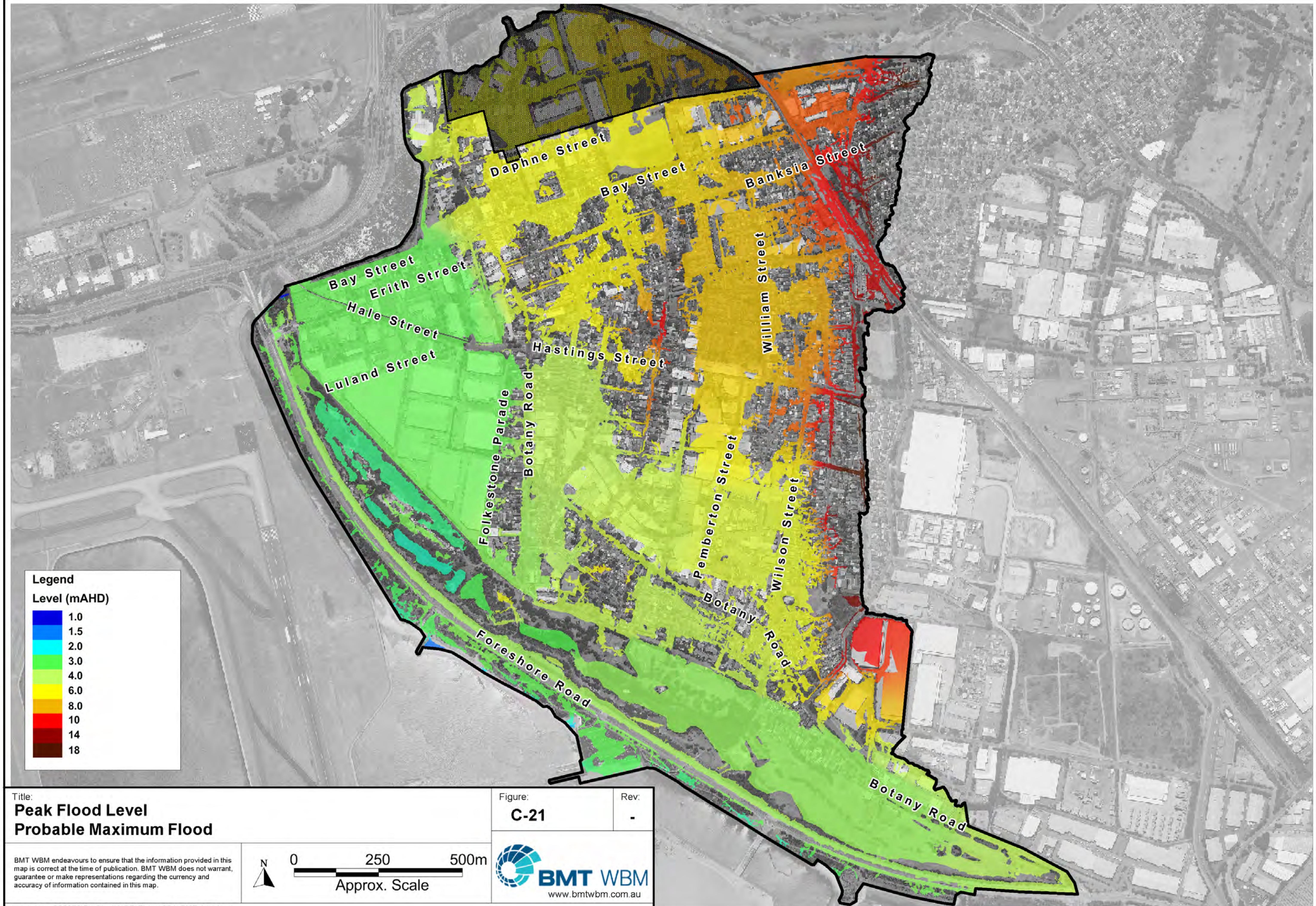

Title:
Peak Flood Level
Probable Maximum Flood

Figure: C-21

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Approx. Scale

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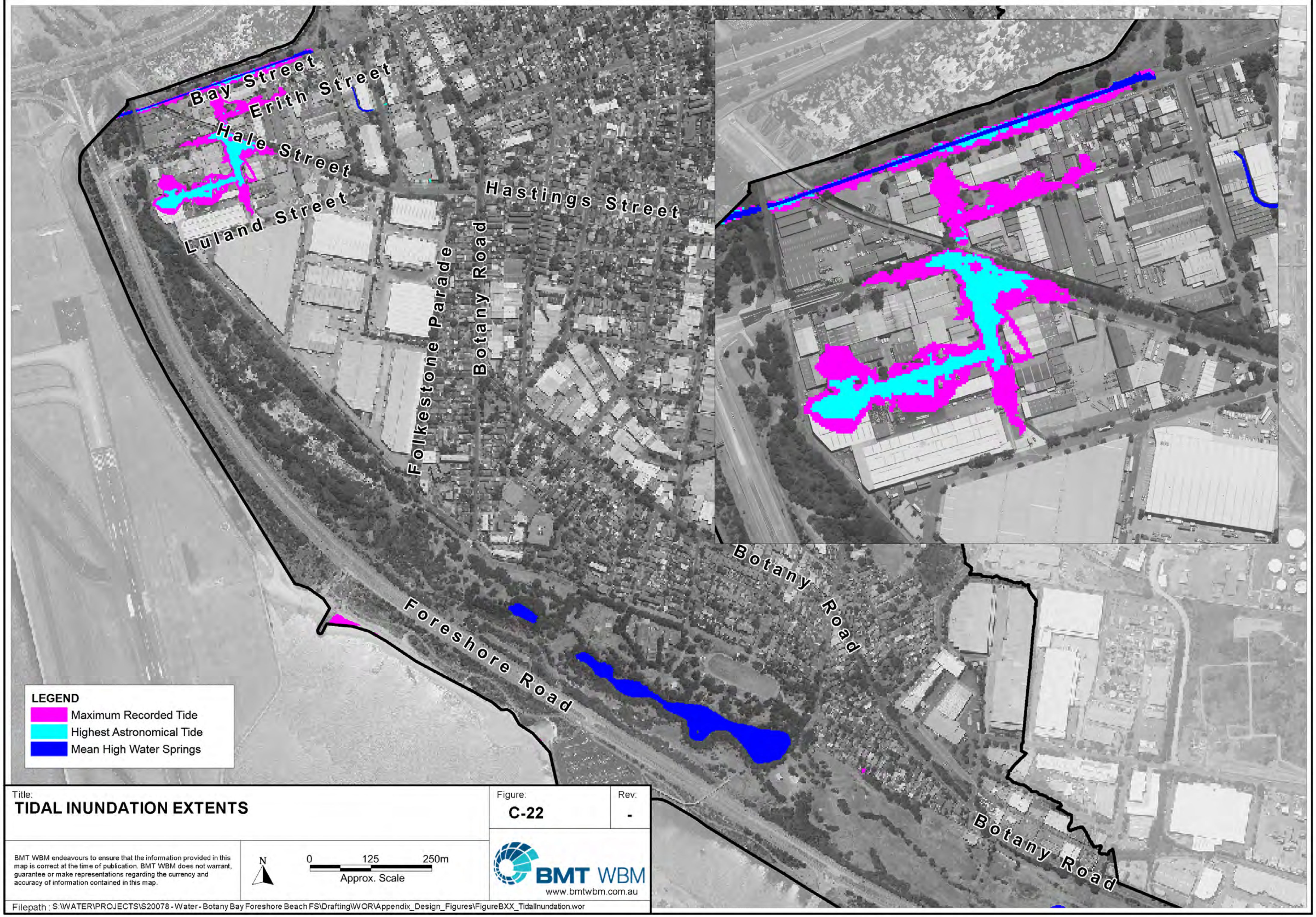

Title:
TIDAL INUNDATION EXTENTS

Figure: **C-22**

Rev: **-**

N

0 125 250m
Approx. Scale

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Title:

Preliminary Hydraulic Categorisation
18% AEP (5 yr ARI)

Figure: **C-23**

Rev: **-**

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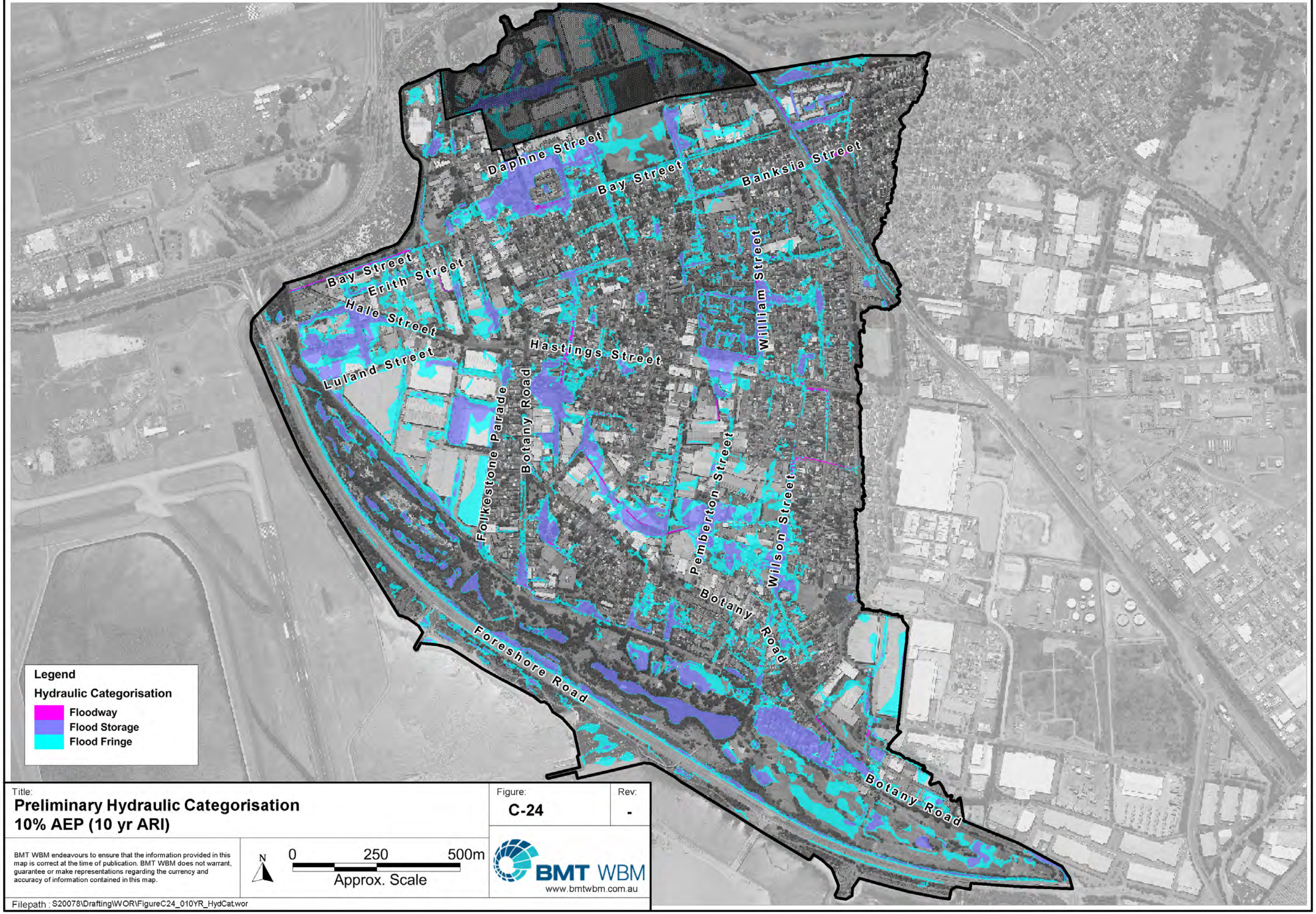

Title:

Preliminary Hydraulic Categorisation
10% AEP (10 yr ARI)

Figure: **C-24**

Rev: **-**

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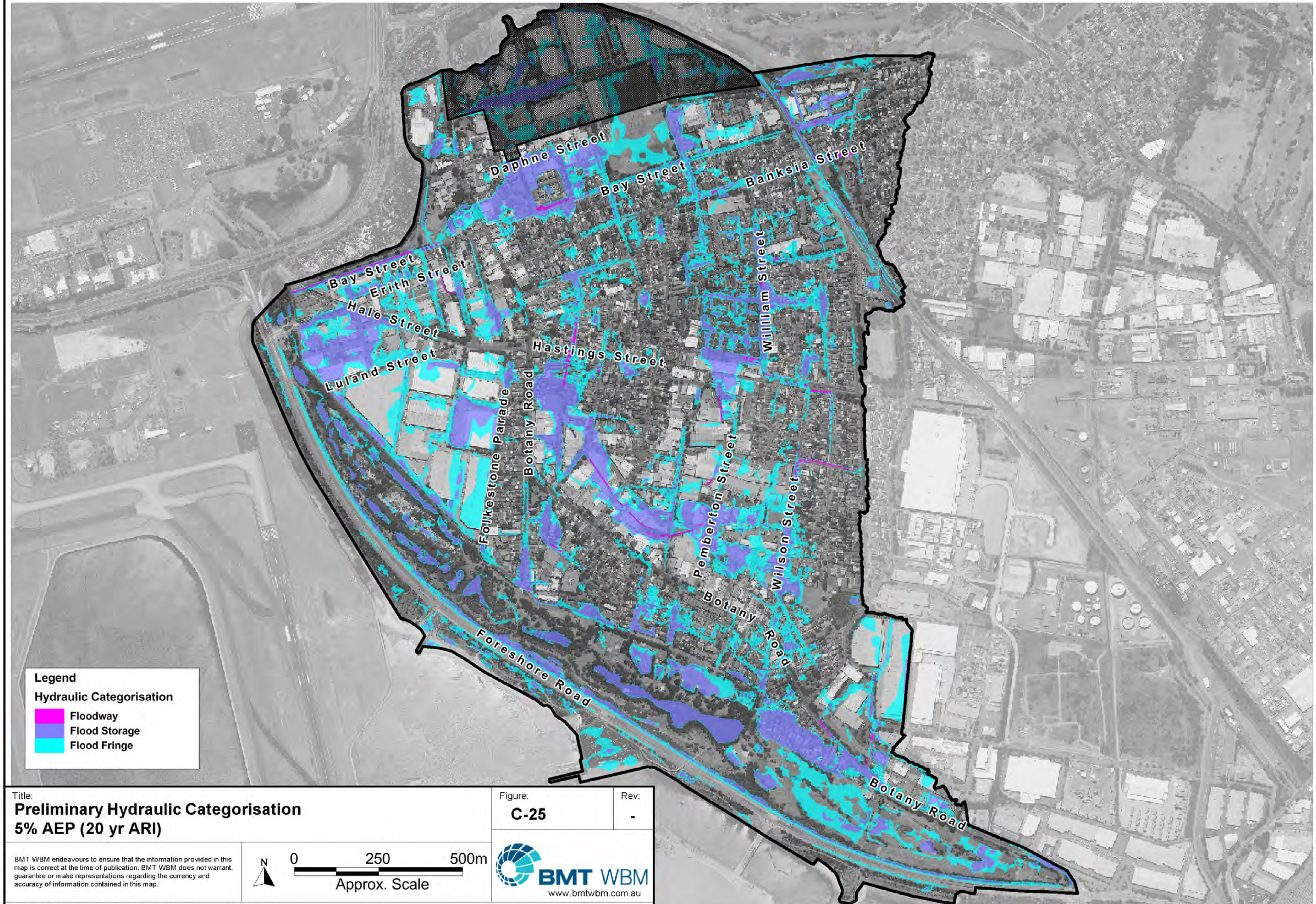
Filepath : S20078\Drafting\WOR\FigureC24_010YR_HydCat.wor



Title:

Preliminary Hydraulic Categorisation
5% AEP (20 yr ARI)

Figure: C-25

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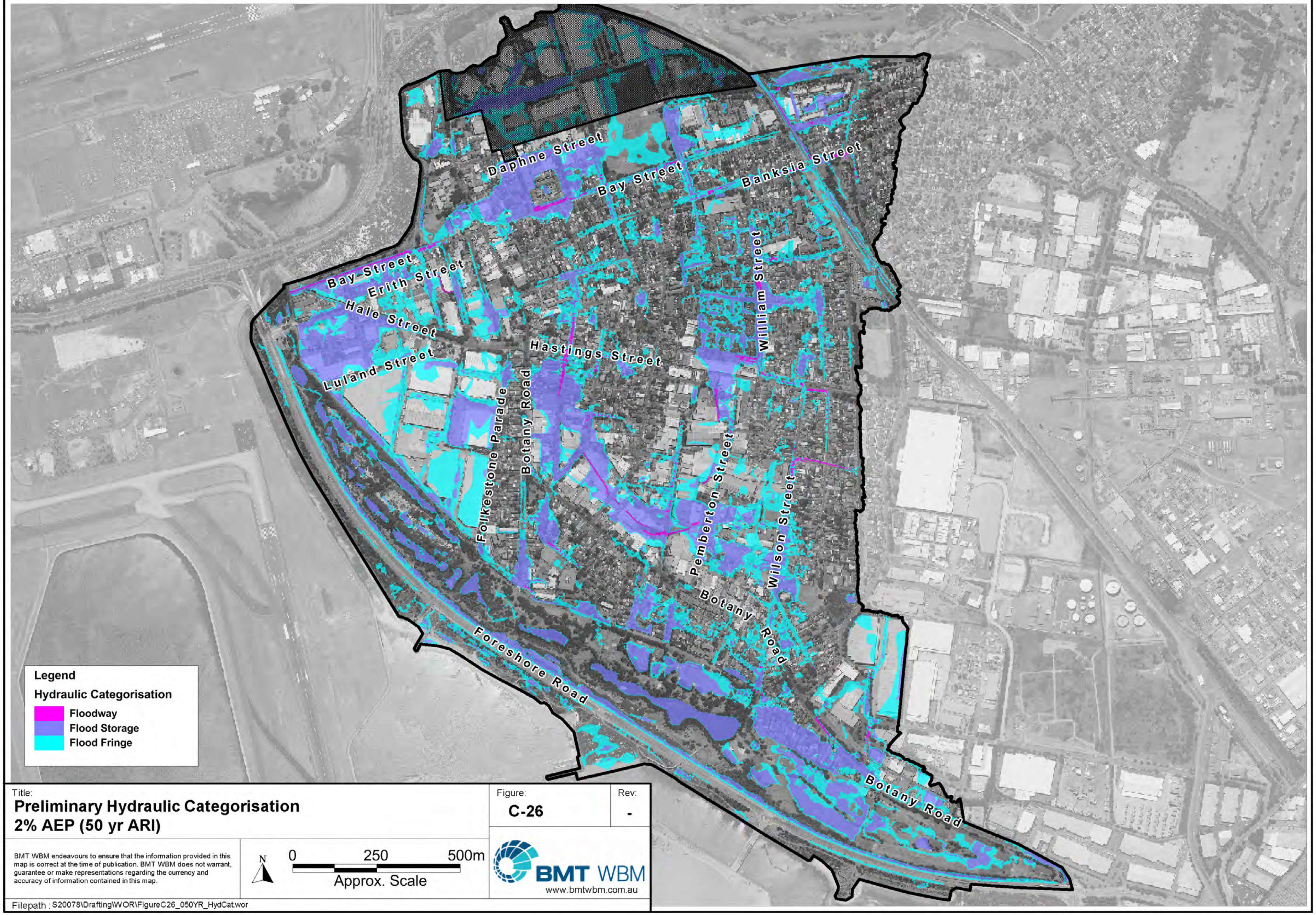
Filepath : S20078\Drafting\WOR\FigureC25_020YR_HydCat.wor



Title:
Preliminary Hydraulic Categorisation
2% AEP (50 yr ARI)

Figure: **C-26**

Rev: **-**

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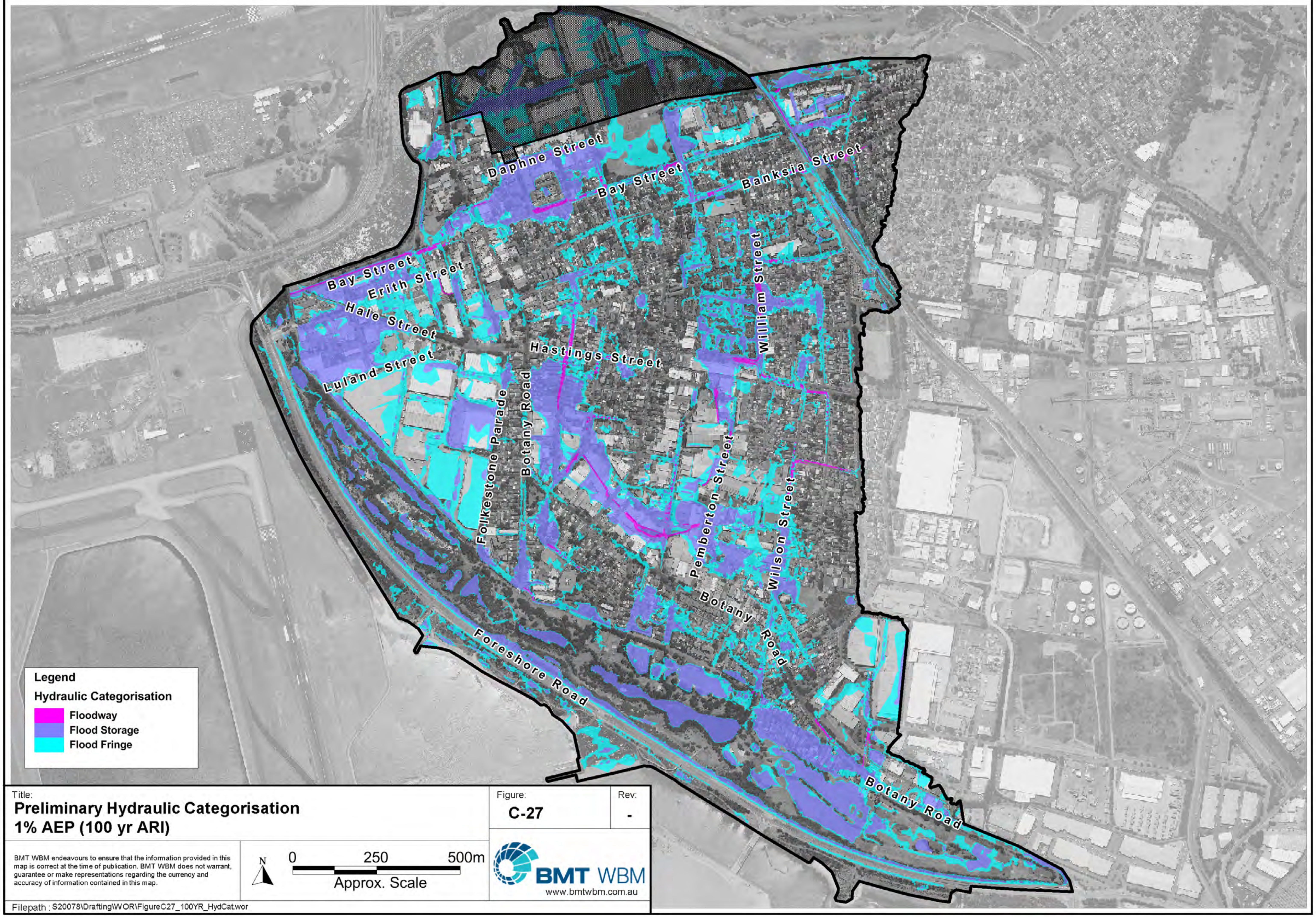
Filepath : S20078\Drafting\WOR\FigureC26_050YR_HydCat.wor



Title:
Preliminary Hydraulic Categorisation
1% AEP (100 yr ARI)

Figure: **C-27**

Rev: **-**

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Filepath : S20078\Drafting\WOR\FigureC27_100YR_HydCat.wor

Title:
Preliminary Hydraulic Categorisation
0.5% AEP (200 yr ARI)

Figure: **C-28**

Rev: **-**

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0 250 500m

Approx. Scale

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Filepath : S20078\Drafting\WOR\FigureC28_200YR_HydCat.wor

Title:

Preliminary Hydraulic Categorisation
Probable Maximum Flood

Figure: C-29

Rev: -

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Approx. Scale

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Filepath : S20078\Drafting\WOR\FigureC29_PMF_HydCat.wor

Title:

Provisional Hydraulic Hazard
18% AEP (5 yr ARI)

Figure: **C-30**

Rev: **-**

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Filepath : S20078\Drafting\WOR\FigureC30_005YR_Hazard.wor

Title:

Provisional Hydraulic Hazard
10% AEP (10 yr ARI)

Figure: **C-31**

Rev: **-**

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Filepath : S20078\Drafting\WOR\FigureC31_010YR_Hazard.wor

Title:
Provisional Hydraulic Hazard
5% AEP (20 yr ARI)

Figure: C-32

Rev: -

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Approx. Scale

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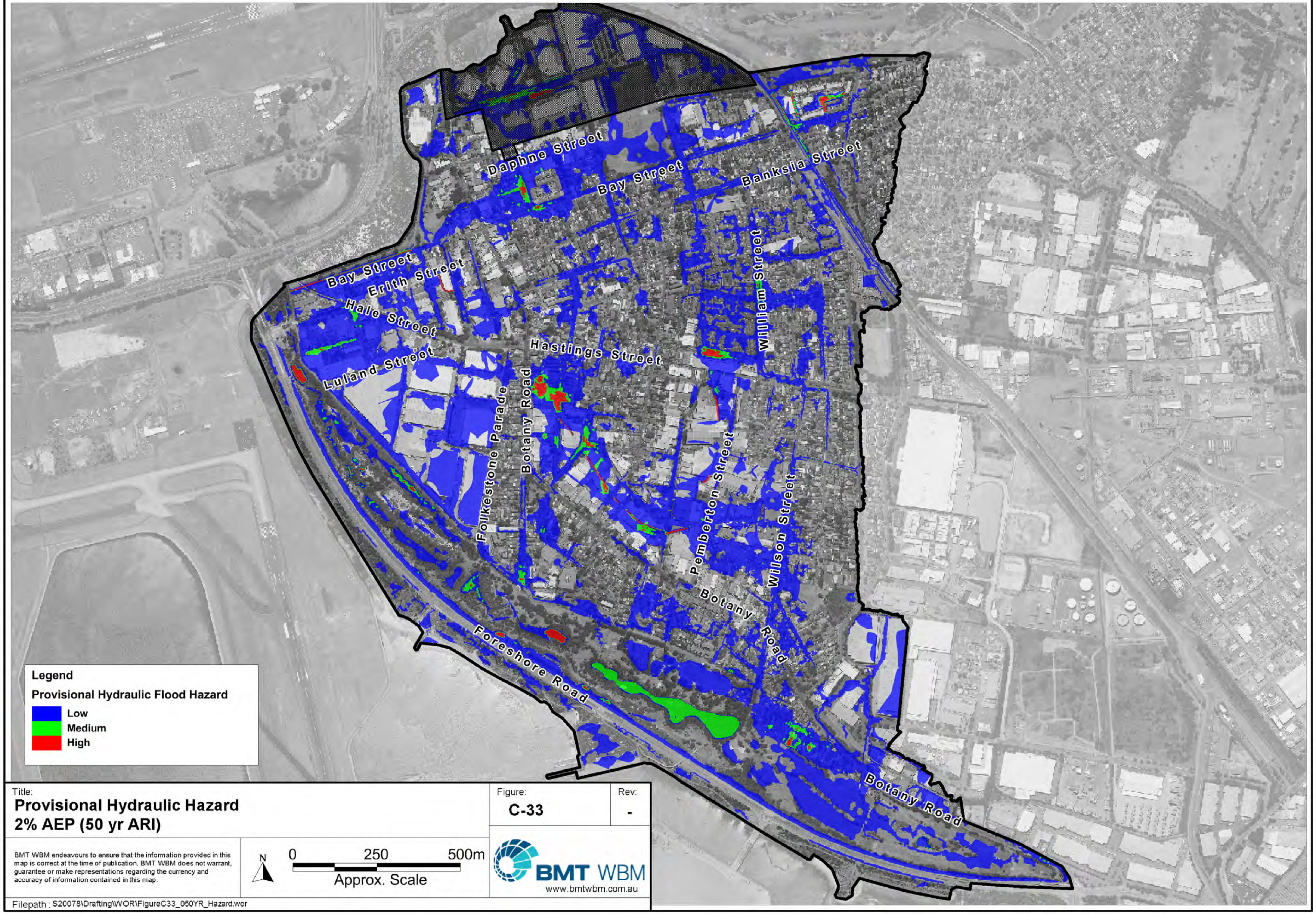

Title:

Provisional Hydraulic Hazard
2% AEP (50 yr ARI)

Figure: **C-33**

Rev: **-**

N

0 250 500m

Approx. Scale

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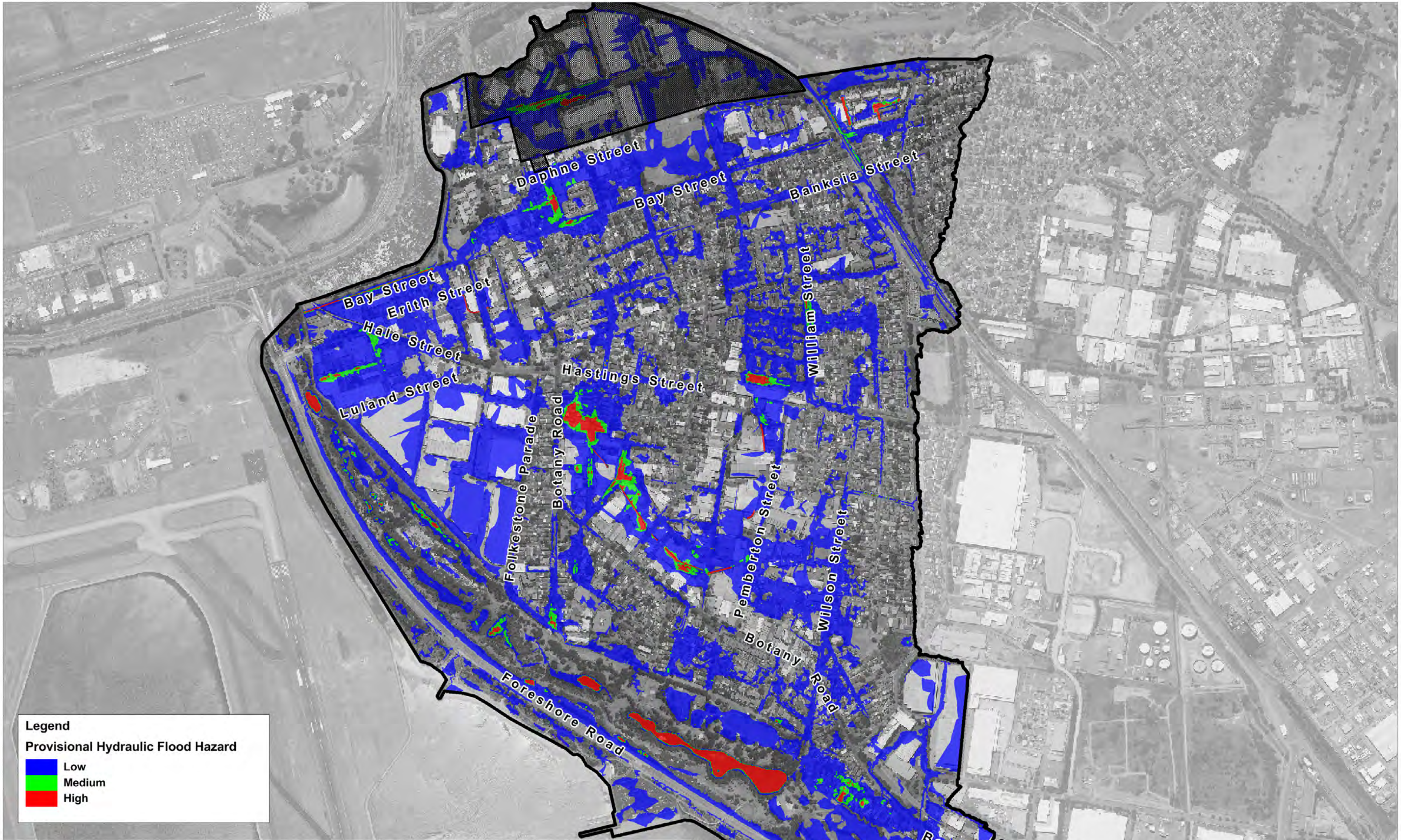
Filepath : S20078\Drafting\WOR\FigureC33_050YR_Hazard.wor



Title:
Provisional Hydraulic Hazard
1% AEP (100 yr ARI)

Figure: C-34

Rev: -

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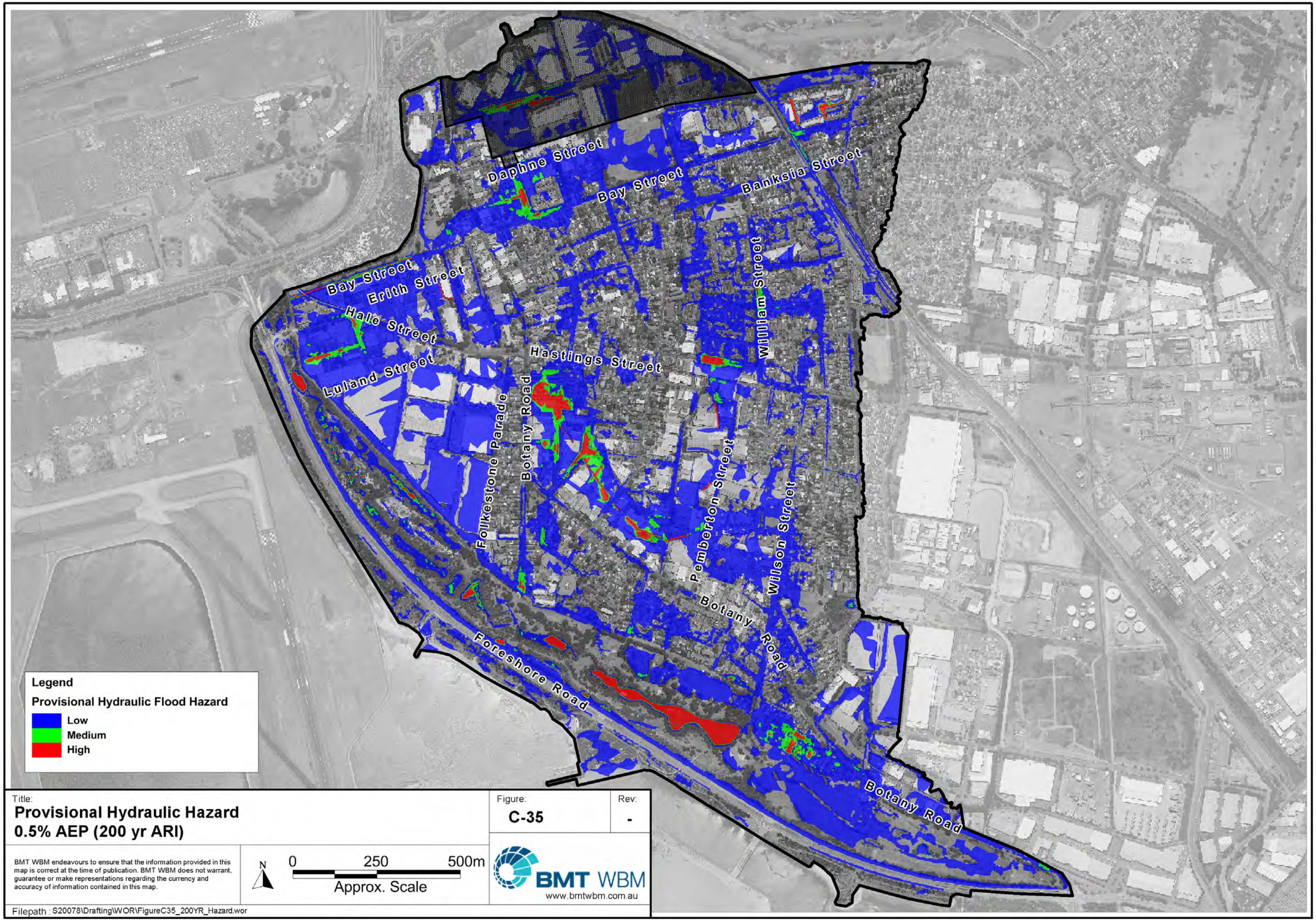
Filepath : S20078\Drafting\WOR\FigureC34_100YR_Hazard.wor



Title:
Provisional Hydraulic Hazard
0.5% AEP (200 yr ARI)

Figure: **C-35**

Rev: **-**

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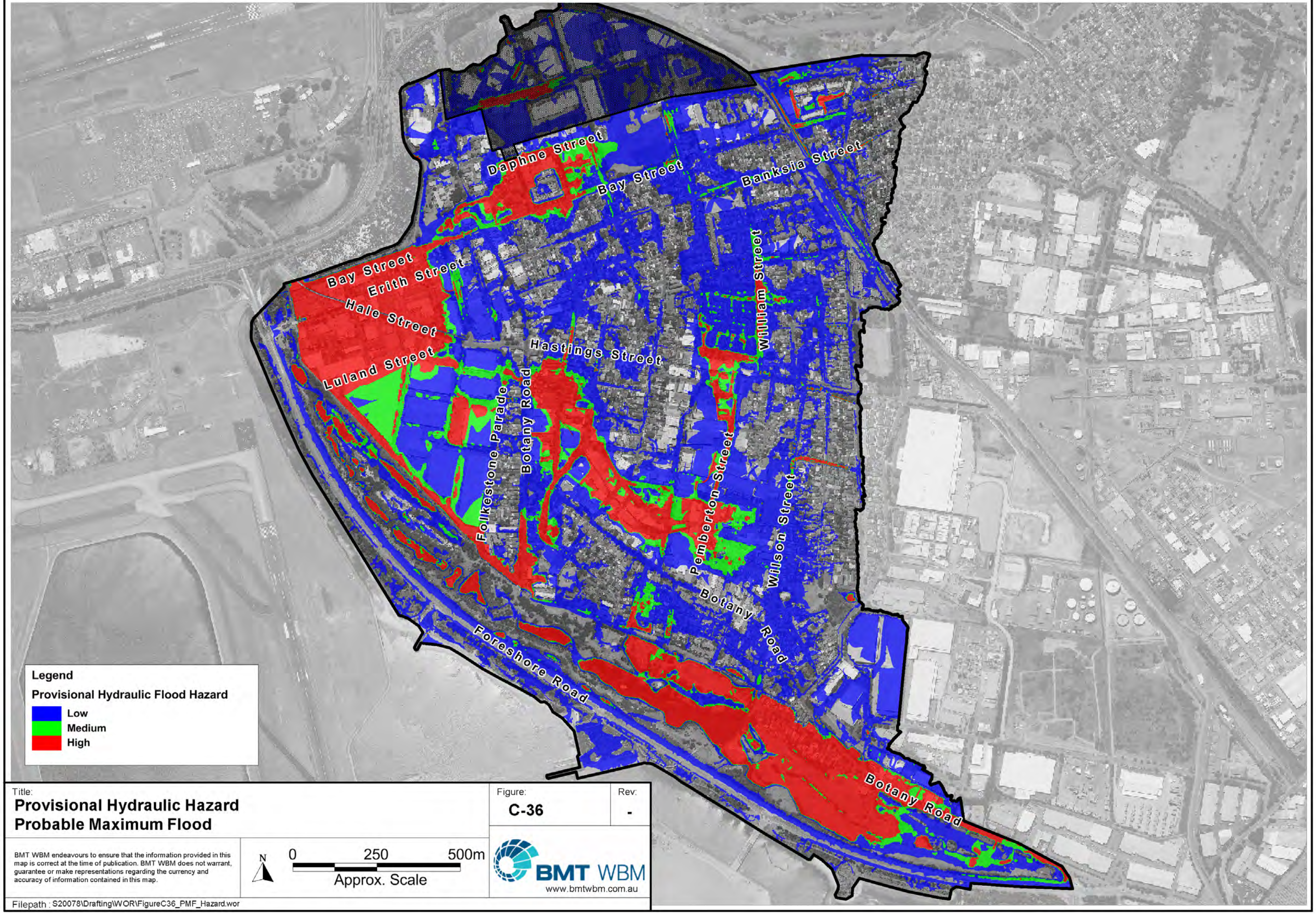
Filepath : S20078\Drafting\WOR\FigureC35_200YR_Hazard.wor



Title:

Provisional Hydraulic Hazard
Probable Maximum Flood

Figure: **C-36**

Rev: **-**

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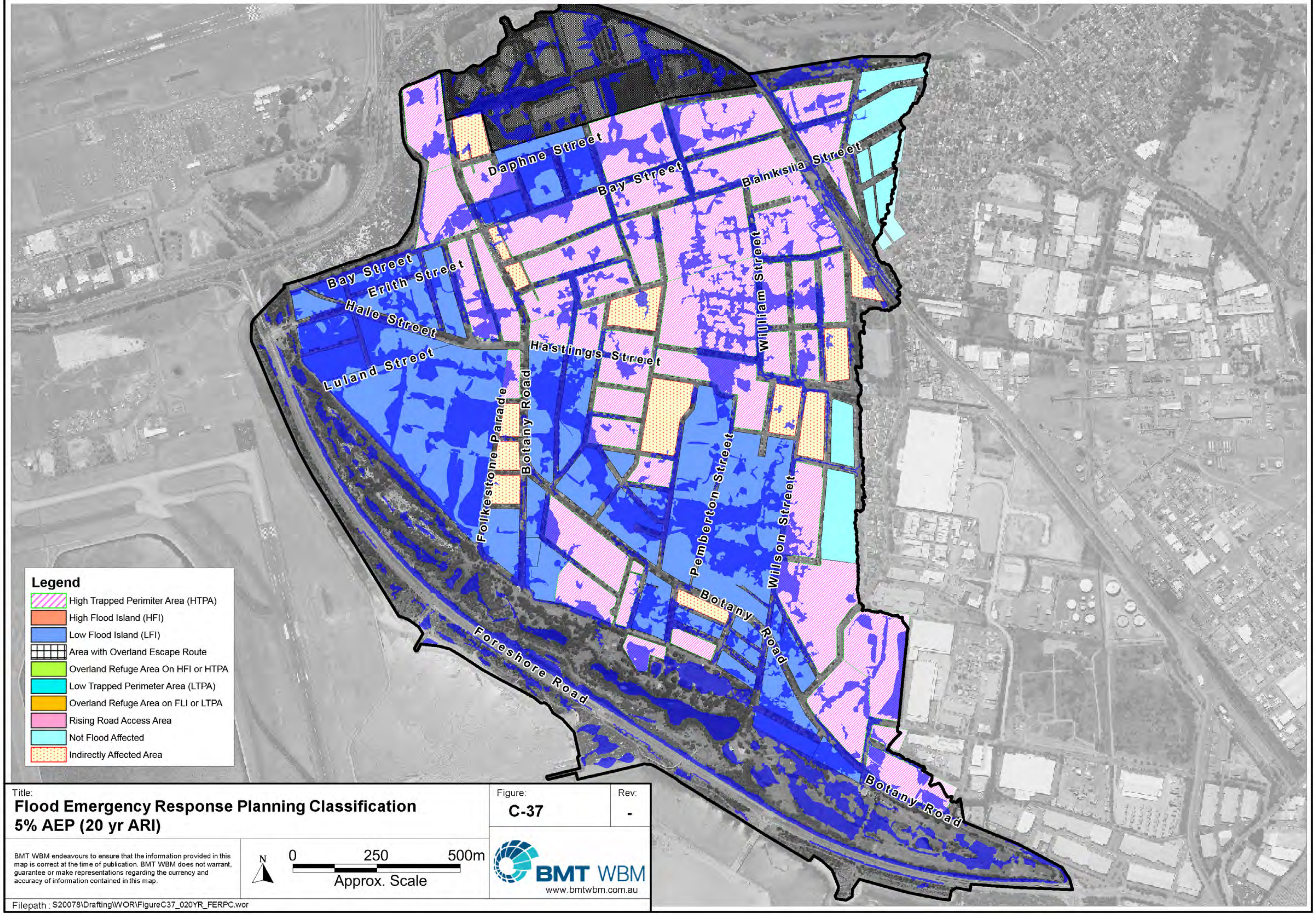
Filepath : S20078\Drafting\WOR\FigureC36_PMF_Hazard.wor



Title:
Flood Emergency Response Planning Classification 5% AEP (20 yr ARI)

Figure: C-37

Rev: -

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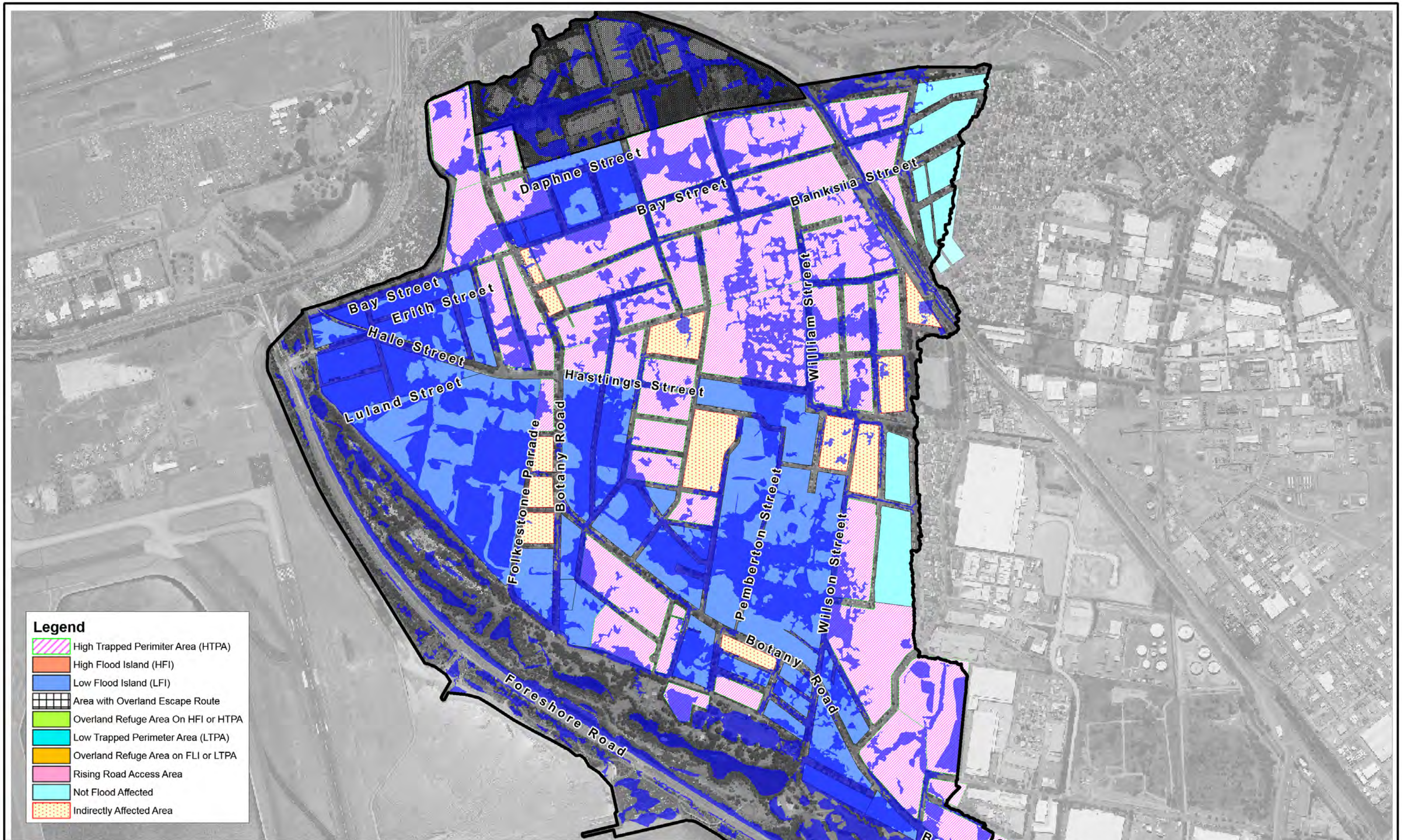
Filepath : S20078\Drafting\WOR\FigureC37_020YR_FERPC.wor



Title:

Flood Emergency Response Planning Classification 1% AEP (100 yr ARI)

Figure: C-38

Rev: -

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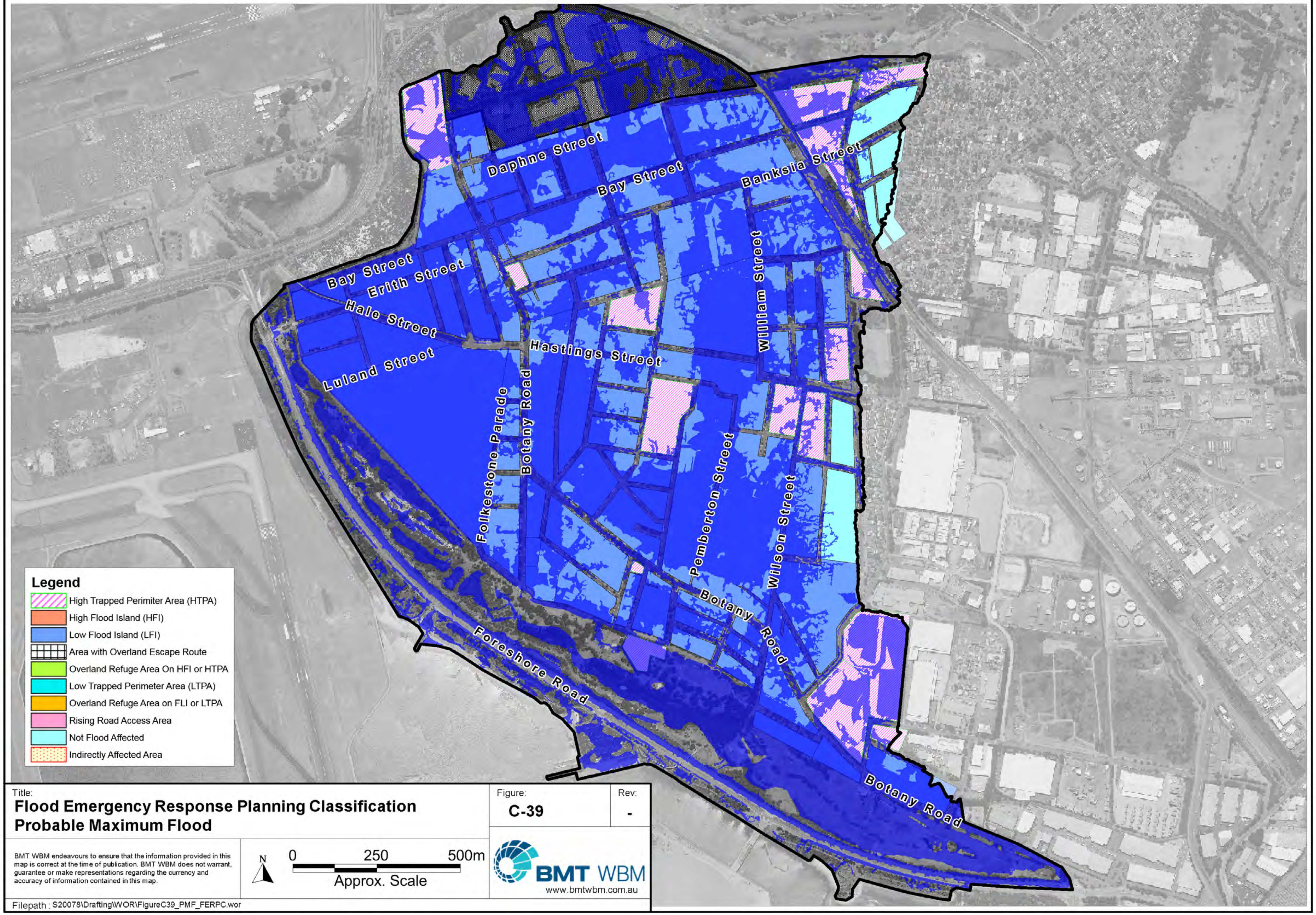
Filepath : S20078\Drafting\WOR\FigureC38_100YR_FERPC.wor



Title:

Flood Emergency Response Planning Classification
Probable Maximum Flood

Figure: **C-39**

Rev: **-**

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Filepath : S20078\Drafting\WOR\FigureC39_PMF_FERPC.wor

Title:

Preliminary Residential Flood Planning Area (FPA)

Figure: C-40

Rev: -

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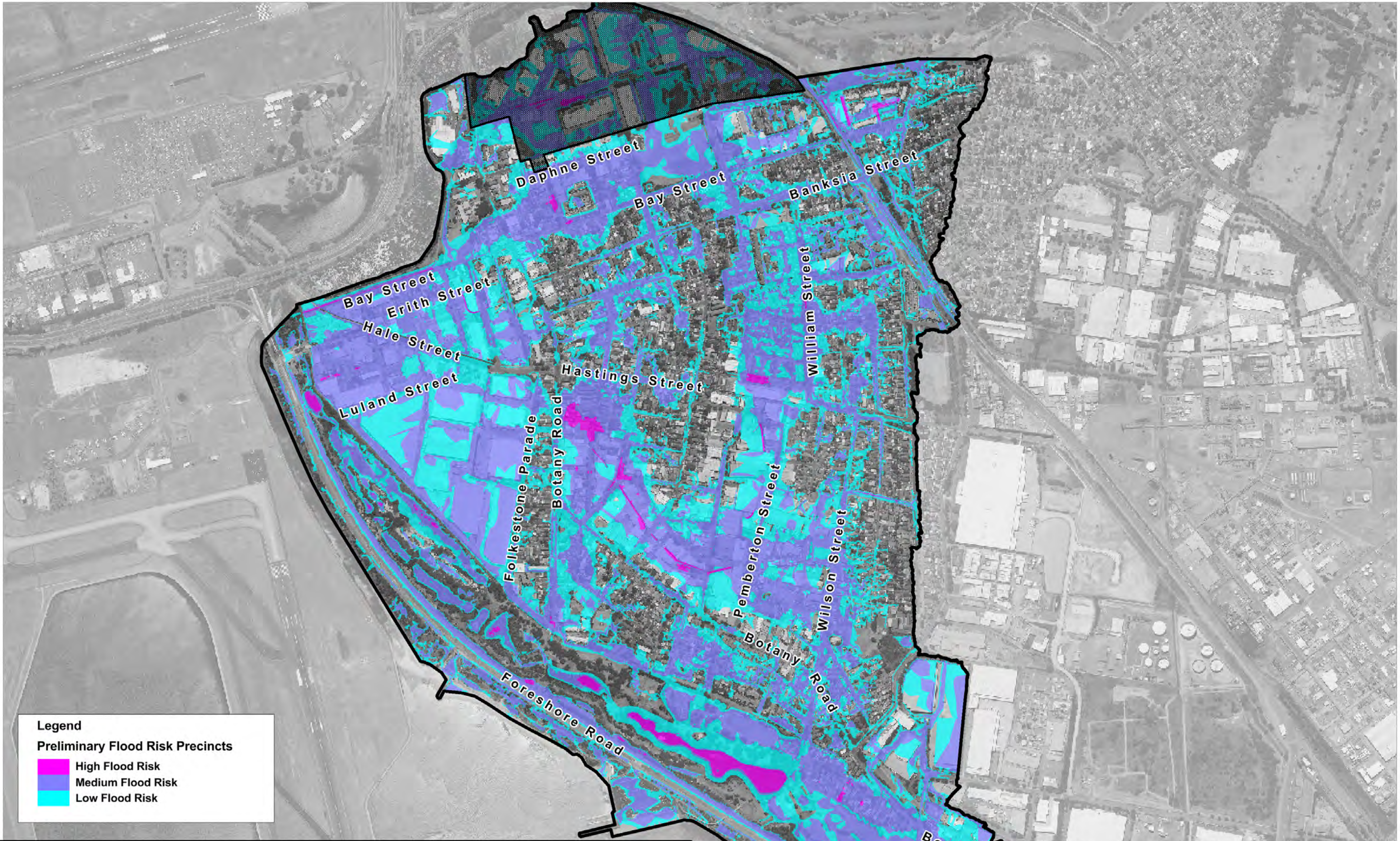

Title:

Preliminary Flood Risk Precincts

Figure: C-41

Rev: -

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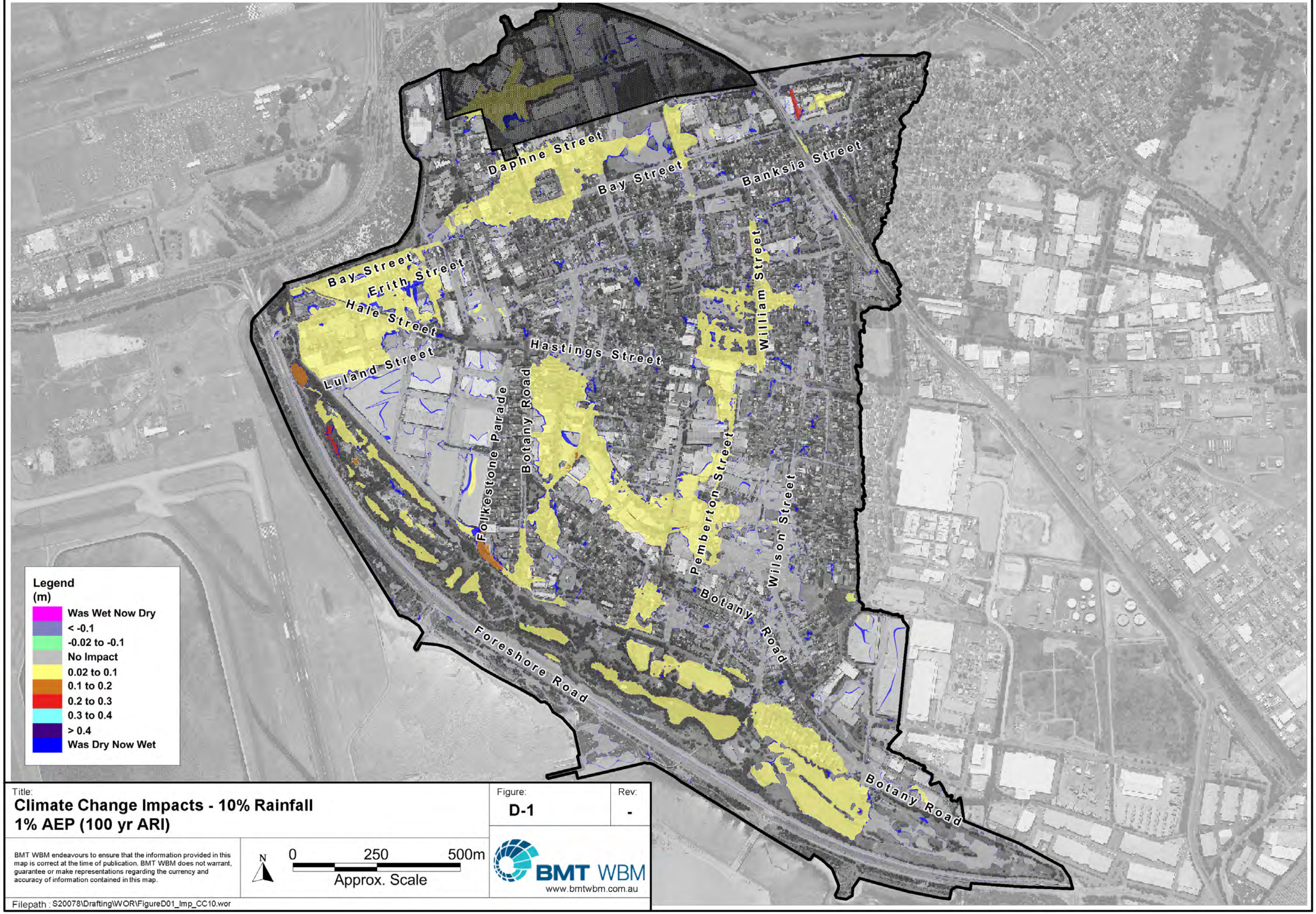
Appendix D Climate Change Impacts



Title:

Climate Change Impacts - 10% Rainfall
1% AEP (100 yr ARI)

Figure: **D-1**

Rev: **-**

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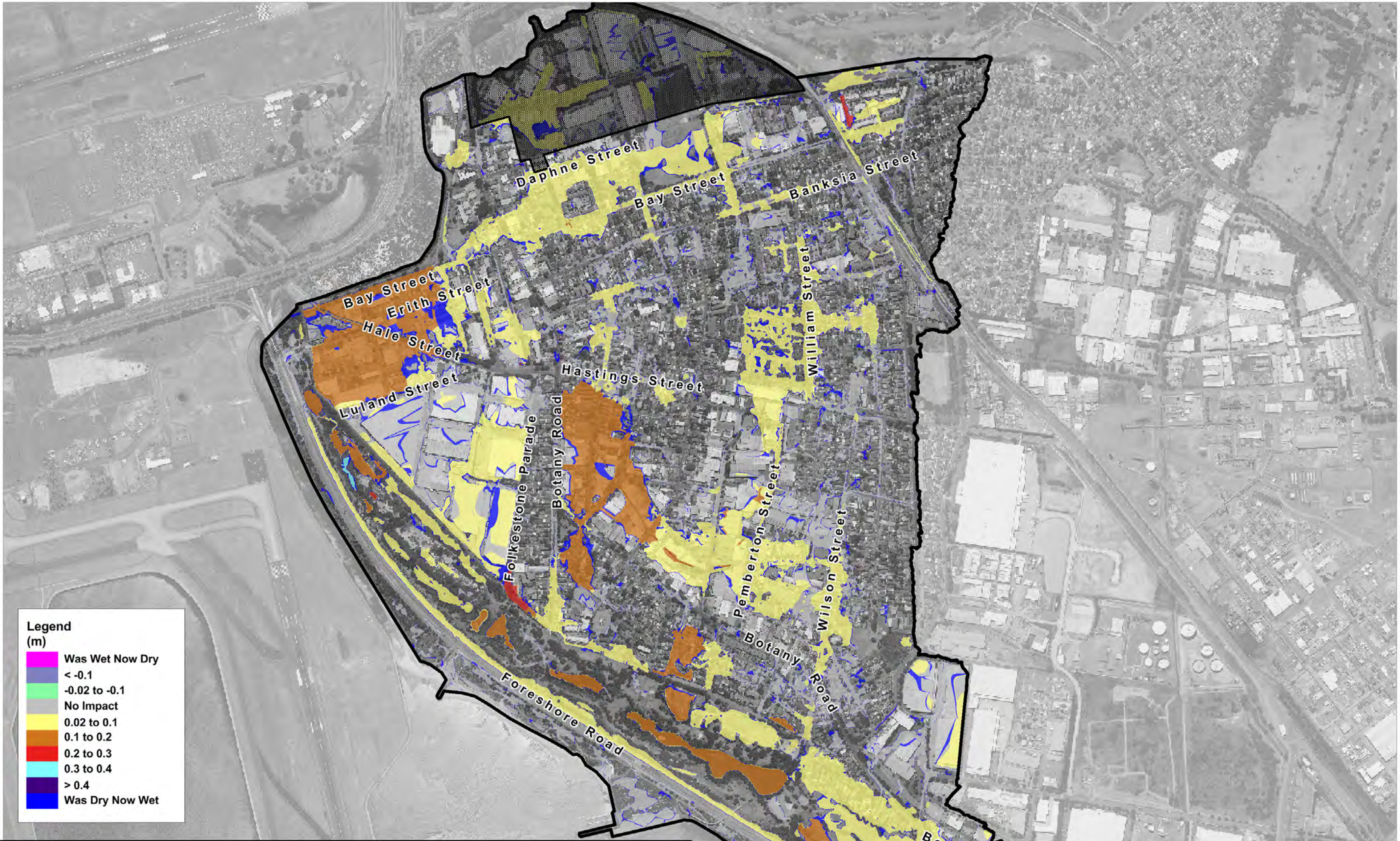
Filepath : S20078\Drafting\WOR\FigureD01_Imp_CC10.wor



Title:
Climate Change Impacts - 20% Rainfall
1% AEP (100 yr ARI)

Figure: **D-2**

Rev: **-**

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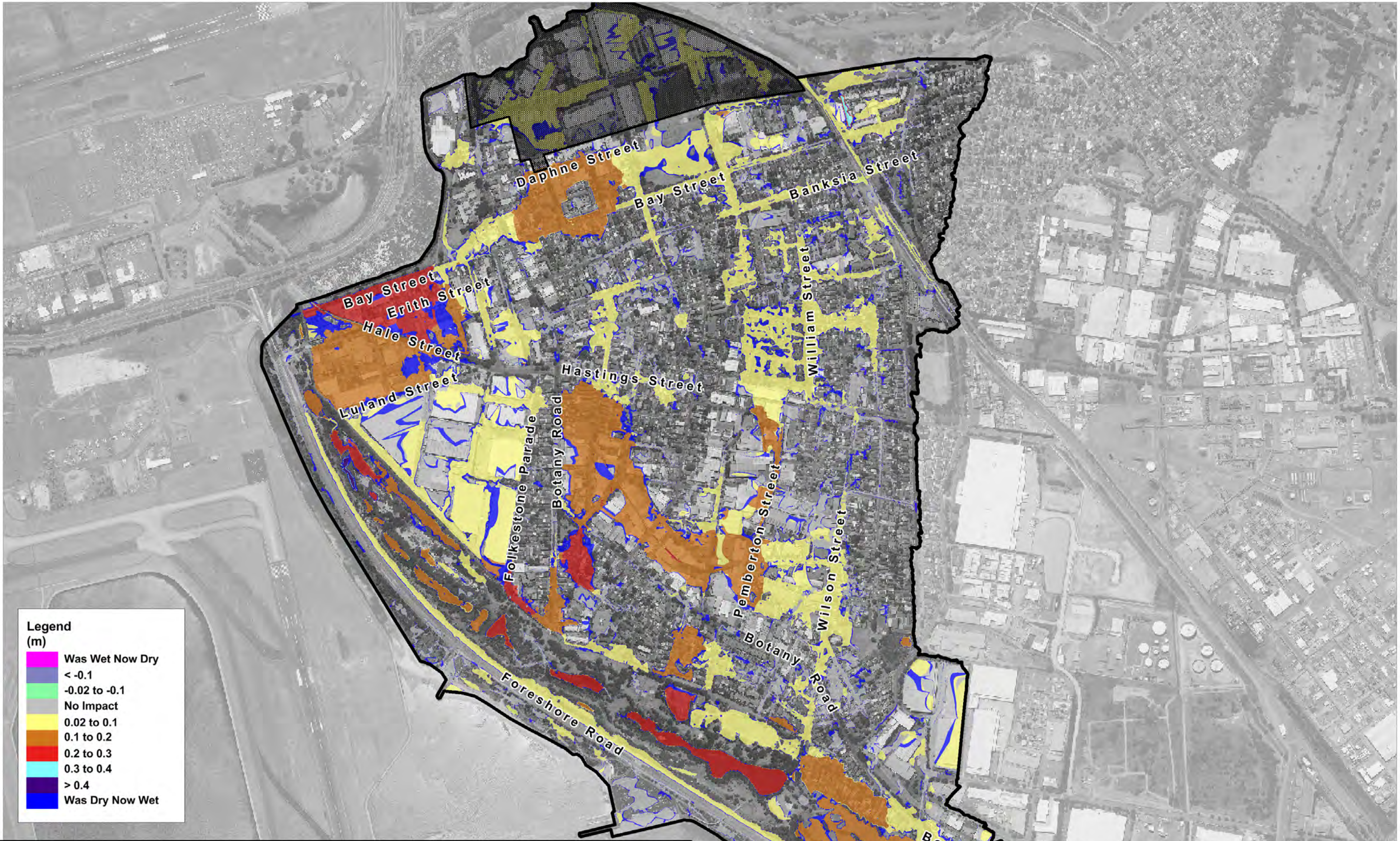

Title:
Climate Change Impacts - 30% Rainfall
1% AEP (100 yr ARI)

Figure: **D-3**

Rev: **-**

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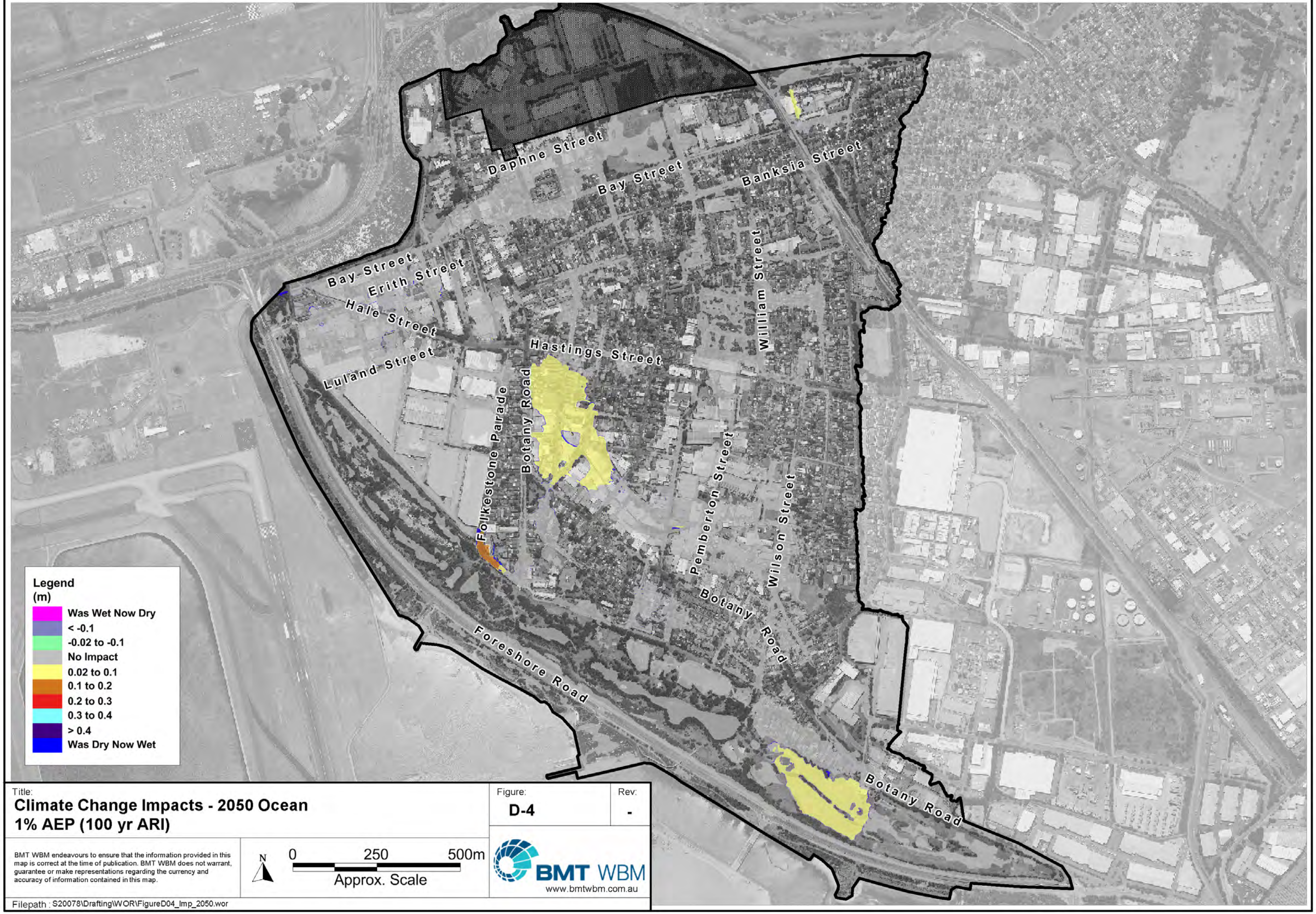

Title:
Climate Change Impacts - 2050 Ocean 1% AEP (100 yr ARI)

Figure: **D-4**

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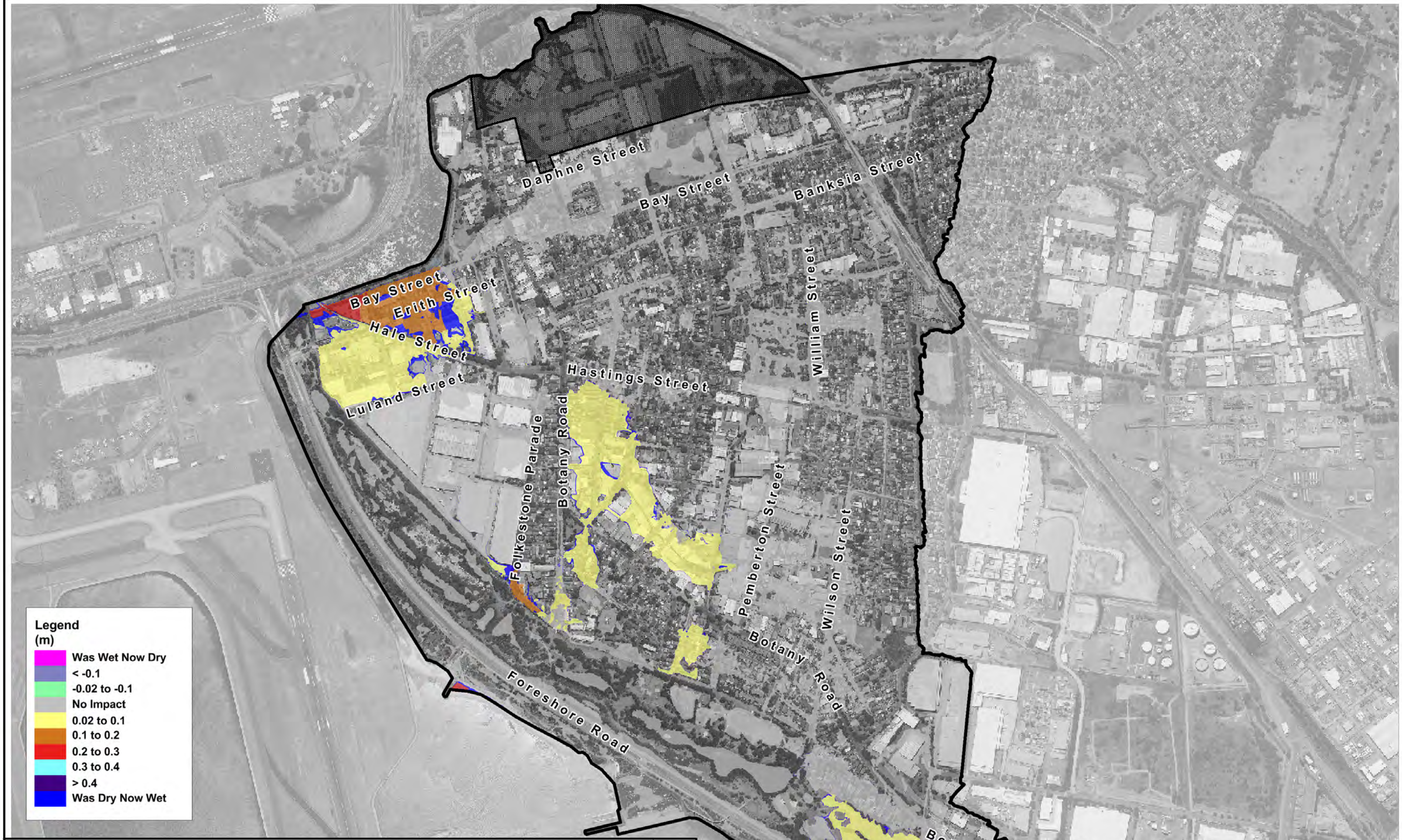
Filepath : S20078\Drafting\WOR\FigureD04_Imp_2050.wor



Title:
Climate Change Impacts - 2100 Ocean 1% AEP (100 yr ARI)

Figure: **D-5**

Rev: **-**

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