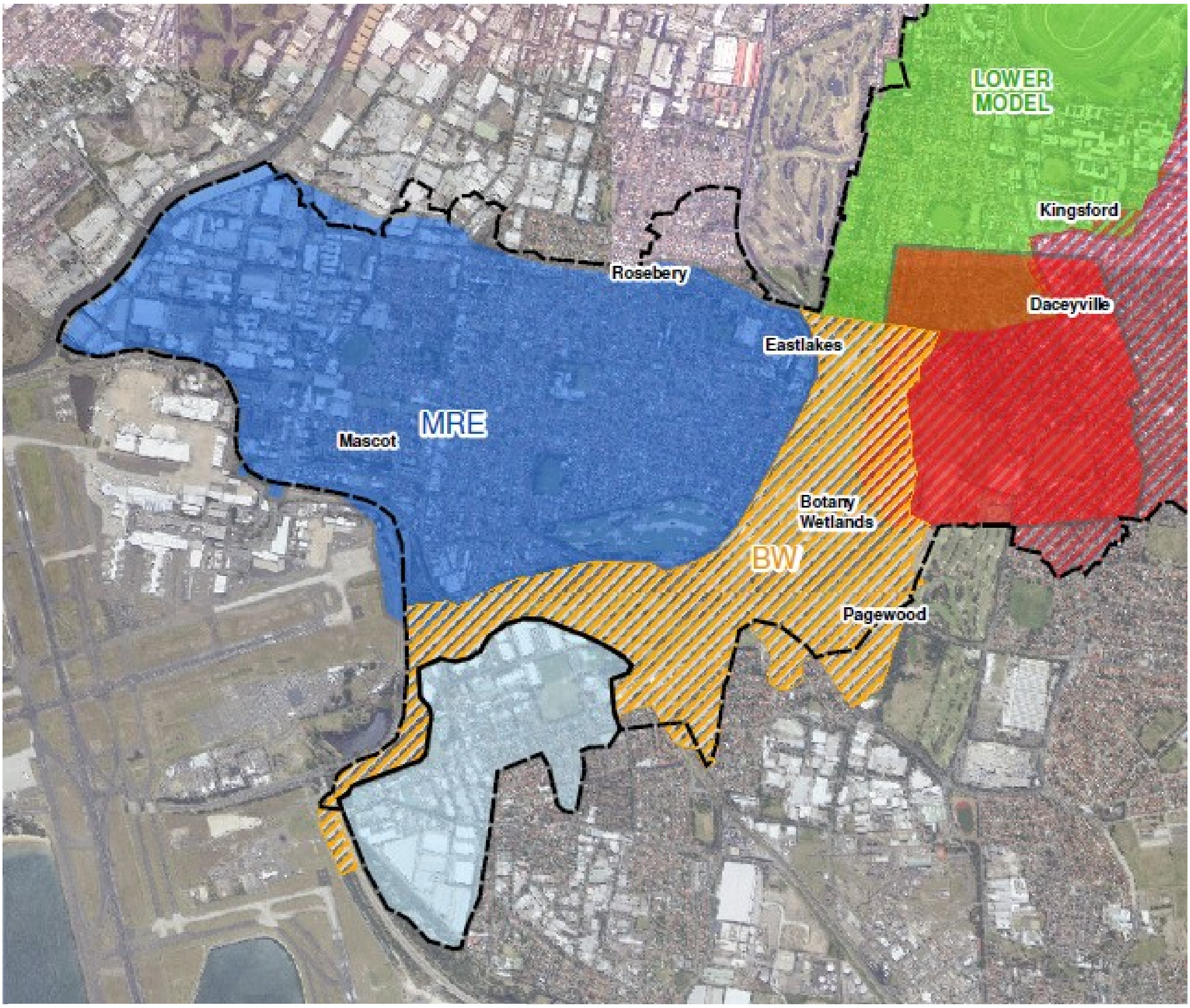
CITY OF BOTANY BAY

MASCOT, ROSEBERY & EASTLAKES FLOOD STUDY

FINAL REPORT



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Project Mascot, Rosebery and Eastlakes Flood Study	**Project Number** 113077
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MASCOT, ROSEBERY AND EASTLAKES FLOOD STUDY

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LIST OF ABBREVIATIONS

1D	One (1) Dimensional
2D	Two (2) Dimensional
ALS	Airborne Laser Scanning same as LiDAR
AR&R	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
BW	Botany Wetlands and Pagewood Catchments
CBB	City of Botany Bay Council
CBH	Chase Burke Harvey - surveyors
DEM	Digital Elevation Model
DRAINS	Hydrologic computer model
GIS	Geographic Information System (a spatial database)
HEC-RAS	1D Hydraulic computer model
IFD	Intensity-Frequency-Duration
LGA	Local Government Area
LiDAR	Light Detection and Ranging same as ALS
MRE	Mascot, Roseberry and Eastlakes Catchment
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SWC	Sydney Water Corporation
SWSOOS	Southern and Western Suburbs Ocean Outfall Sewer
TIN	Triangular Irregular Network
TUFLOW	1D/2D Hydraulic computer model

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FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government provides funding for flood studies, floodplain risk management plans and works to alleviate existing problems, to undertake the necessary technical studies to identify and address the problem and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Federal Government may also provide funding in some circumstances.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. ***Flood Study***
   Determines the nature and extent of the flood problem
2. ***Floodplain Risk Management Study***
   Evaluates management options for the floodplain in respect of both existing and proposed development
3. ***Floodplain Risk Management Plan***
   Involves formal adoption by Council of a plan of management for the floodplain
4. ***Implementation of the Plan***
   Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard

The Mascot, Rosebery and Eastlakes Flood Study constitutes the first stage of the management process for the catchment. This study has been prepared by WMAwater for the City of Botany Bay and was undertaken to provide the basis for future management of flood liable lands within the study area.

EXECUTIVE SUMMARY

BACKGROUND

The Mascot, Rosebery and Eastlakes study area is located approximately 6km south of the Sydney CBD in the City of Botany Bay local government area (LGA). The study area includes the suburbs of Mascot, Rosebery, Eastlakes, Pagewood as well as the coastal freshwater wetland system known as the Botany Wetlands.

The components of the study are to:

- collate available historical flood related data;
- analyse historical rainfall and flooding data;
- undertake a community consultation program;
- develop computational hydrologic and hydraulic models and validate them against historical events;
- determine the flood behaviour including design flood levels, velocities and flood extents within the catchments;
- to assess the sensitivity of flood behaviour to potential climate change effects such as increase in rainfall intensities and sea level rise; and
- to assess the floodplain categories in accordance with Council policy and undertake provisional hazard mapping.

COMMUNITY CONSULTATION

In collaboration with City of Botany Bay Council a questionnaire was distributed to residents in the study area. The purpose of the questionnaire was to identify what residents had experienced problems with flooding and to collate as much historical flood data as possible. From this, 234 responses were received.

Of those that responded 66 had experienced flooding in their properties with 12 of those properties having experienced flooding above floor level. Some residents indicated that they have employed their own flood mitigation measures; including sandbags, gravel pits and raising laundries above floor levels.

MODELLING SUMMARY

The study area was split into two separate catchments for modelling purposes:

- MRE Catchment – Included the suburbs of Mascot, Rosebery and Eastlakes
- BW Catchment – Included the suburb of Pagewood and the Botany Wetlands system

The study used hydrologic and hydraulic modelling techniques in order to define flood behaviour in the study area. The modelling programs used in the study are:

- DRAINS (Hydrologic) – The model was used to calculate the flow hydrographs for input into the TUFLOW model.
- TUFLOW (Hydraulic) – The 2D hydraulic model was used to assess the complex overland flow regimes of the urban catchments to analyse flooding behaviour in the study area.

The hydrological and hydraulic modelling undertaken for this study has defined flood behaviour for the nominated design flood events. Due to the limited data available for model calibration and significant changes to the catchment in recent history, only a limited verification of the models to historic data could be undertaken. Sensitivity analyses were undertaken to assess the influences of modelling assumptions on key outputs, and the potential impacts of future climate change.

KEY STUDY OUTCOMES

The study has quantified flood behaviour in the study area, and the modelling tools that have been developed will assist City of Botany Bay Council to undertake flood-related planning decisions for future and existing developments. With regard to flooding in the catchment:

- There are a number of trapped low points in the study area where significant flood depths may occur, with the potential to inundated properties. The locations include Mascot Drive, Florence Avenue, Francis Street, Hollingshed Street, Gardners Road, Mascot Public School, Baxter Road, Coward Street, Ricketty Street, Kent, Ewan Street and Bay Street.
- This study has identified that flooding in Botany Wetlands will not spill over into the Bay St catchment up to the 1% AEP event, but overflow is likely to occur in more extreme events such as the PMF.
- There appears to be inadequate local stormwater drainage on the eastern side of Botany Road near the intersection with Forster Street. This has resulted in above floor flooding of nearby residential property. However this appears to be an issue relating to local road grading and locations of stormwater inlets and pipe drainage, rather than a "flooding" issue, as the problem has occurred regularly and in relatively low-intensity storm events. It is recommended that these complaints be investigated further by Council / RMS immediately rather than through the Floodplain Risk Management process.

A recommendation from this study is that following the next major event, flood data should be collected immediately in the same or following day. This is essential to improve the accuracy of the design flood estimates

1. INTRODUCTION

1.1. Background

The Mascot, Rosebery and Eastlakes catchment area is within the City of Botany Bay (CBB) local government area (LGA) and includes the suburbs of Mascot, Rosebery, Eastlakes, Pagewood as well as the Botany Wetlands. The catchment extents for Mascot and Rosebery align closely with the boundary of the local government area. The Botany Wetlands are in the lower portion of a larger catchment with its upper reaches to the north at Moore Park, Centennial Park and Queens Park. The catchment continues through Randwick, Kensington, Kingsford and Daceyville until it meets the current study area where is subsequently drains into Botany Bay. Isolated parts of Pagewood also drain into the Botany Wetlands.

There have been a number of previous studies in the catchment located upstream of the current study area. The catchment and the locations of the previous studies are shown in Figure 1.

The present study has been commissioned by CBB, with assistance from the NSW Office of Environment and Heritage (OEH) to define flood behaviour in the catchment. Flooding problems have been experienced at a number of locations within the catchment during periods of heavy rainfall. The study aims to identify these problem areas so that they can be assessed for possible mitigation options in the future Floodplain Risk Management Study and Plan.

1.2. Objectives

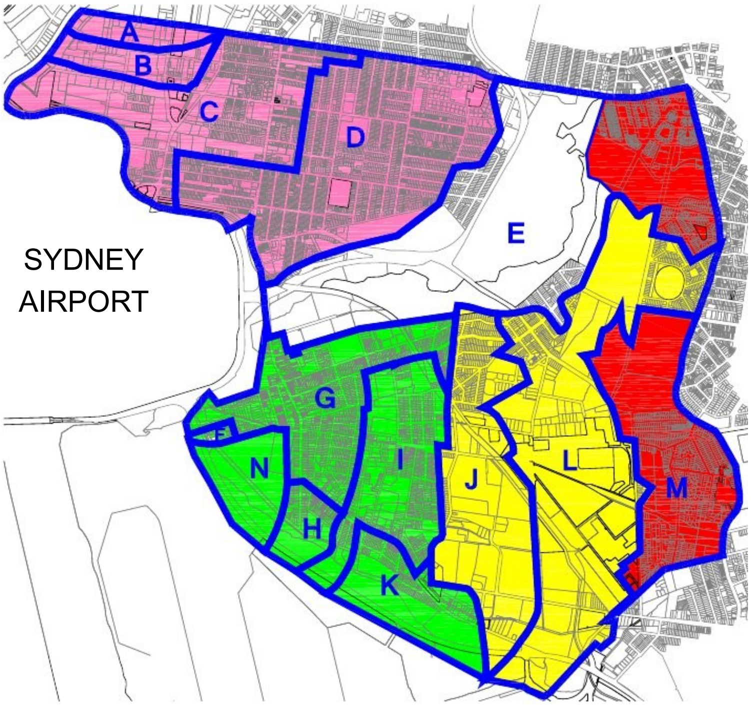
The primary objective of this Flood Study is to develop computational hydrologic and hydraulic models that define design flood behaviour for the 50%, 20%, 10%, 5% and 1% AEP design storms and the Probable Maximum Flood (PMF) and to:

- Prepare suitable models of the catchment and floodplain for use in a subsequent Floodplain Risk Management Study;
- Provide results for flood behaviour in terms of design flood levels, depths, velocities, flows and flood extents within the study area;
- prepare maps of provisional hydraulic categories and provisional hazard categories; and
- Assess the sensitivity of flood behaviour to potential climate change effects such as increases in rainfall intensities and sea level rise.

A glossary of flood related terms is provided in Appendix A.

1.3. Description of the Study Area

Diagram 1: Botany City Council Catchment Areas



The study consists of two catchment areas which are shown in Figure 2. The area highlighted in pink (A, B, C and D) covers Mascot, Roseberry and Eastlakes (referred to in the study using the abbreviation **MRE**) and the area highlighted in white (E) covers Botany Wetlands and Pagewood (referred to as **BW**).

1.3.1. Mascot, Roseberry and Eastlakes - MRE

The land usage of the MRE catchments comprises a mix of residential and commercial developments, including some light industrial, together with areas of open space including Mascot Park and Mascot Public School.

Elevations in the upper part of the catchment reach approximately 27 m AHD on Gardeners Road in Eastlakes. The overall catchment slope averages 3% however areas to the west of Botany Road are much flatter, with an average slope of 0.6%. Areas near the Southern and Western Suburbs Ocean Outfall Sewer (SWSOOS) are in some locations much steeper, with slopes of up to 10%.

The greater catchment is divided roughly by Botany Road with the Mascot catchment to the west and the Rosebery and Eastlakes catchments to the east. The Mascot catchment is divided in the centre by the SWSOOS, which separates overland flows in the catchment. The western side of the catchment drains to the Alexandra Canal and is part of the Cooks River catchment. The eastern side generally falls north to south, eventually draining to Botany Bay by the piped drainage system or via "soakaways" which rely on infiltration of water into the Botany Aquifer. The Metropolitan Goods Railway Line (for freight from Port Botany) forms a major hydraulic feature of the catchment, obstructing overland flow at Baxter Road. Drainage from Baxter Road can only occur via the piped drainage network, or via overland flow towards Botany Road, where there is a major drainage structure under the railway line.

Drainage elements in the catchment include kerbs and gutters, pits and pipes, and a network of trunk drainage elements including culverts and open channels. Ownership of the assets is divided between SWC and Council, with SWC typically owning the trunk elements.

1.3.2. Botany Wetlands and Pagewood - BW

The BW catchment consists primarily of golf courses and playing fields, with some urbanised areas on the fringes of the catchment. These urbanised areas include the suburb of Daceyville in the upper north-eastern part of the study area, small areas of Pagewood (residential), Botany (commercial), and the eastern portion of the Eastlakes residential area bounded by St Helena Parade and Southern Cross Drive. The catchment also receives inflows from Centennial Park and Kensington to the north (Randwick and City of Sydney Local Government Areas).

Elevations in the Botany Wetlands reach approximately 27m on Gardeners Road in Daceyville. The overall catchment slope of the wetland from Gardeners Road to the outflow at the SWOOS is 0.6%. Elevations in the Pagewood catchment reach approximately 31m in Macarthur Avenue Pagewood. The slope of the Pagewood catchment varies between 4-8%. This is measured from the highest elevations to the outflow in the Lakes Golf Course.

Botany Wetlands is the largest coastal freshwater wetland system in the Sydney region. The wetlands and interconnected ponds cover area of approximately 58 hectares, which stretch over four kilometres, extending from Gardeners Road, Daceyville to Foreshore Drive.

The Botany Wetlands interact with and provide a major recharge source for the Botany Sands Aquifer. The area comprises of Aeolian sand deposits that have accumulated at least over the last 100,000 years to depths of over 80 meters (Reference 23).

2. COMMUNITY CONSULTATION

In collaboration with CBB a newsletter and questionnaire were distributed to residents within the catchment describing the role of the Flood Study and requesting information on experiences of flooding in the catchment and to request records of historical flooding. From this 234 response were received from the distributed questionnaires.

Of those that responded 66 had experienced flooding in their properties with 12 of those properties having experienced flooding above floor level.

2.1. Community Responses

Some statistics from the returned questionnaires are shown in Figure 12. The responses identified several key points:

- There are numerous reports of the stormwater drainage system becoming blocked after heavy rain causing localised flooding especially on Botany Road. Residents have expressed the view that the drains are blocked by debris and plant material.
- Many residents have had their daily routines affected and believe that their safety has been put at risk due to localised stormwater flooding.
- There appears to be inadequate local stormwater drainage on the eastern side of Botany Road near the intersection with Forster Street. This has resulted in above floor flooding of nearby residential property. However this appears to be an issue relating to local road grading and locations of stormwater inlets and pipe drainage, rather than a “flooding” issue, as the problem has occurred regularly and in relatively low-intensity storm events. It is recommended that these complaints be investigated further by Council / RMS immediately rather than through the Floodplain Risk Management process.
- Affected residents have employed their own flood mitigation measures; including sandbags, gravel pits and raising laundries above flood levels.

3. AVAILABLE DATA

3.1. Overview

The first stage in the investigation of flooding matters is to establish the nature, size and frequency of the problem. On large river systems such as the Cooks River there are generally stream height and historical records dating back a considerable period, in some cases over one hundred years. However, in urban catchments such as the Mascot, Rosebery, Eastlakes and Pagewood there are generally no stream gauges or official historical records available. In some Lakes and Wetland systems there are permanent water level gauges however there is no such data available for the Botany Wetlands. A picture of flooding must therefore be obtained from an examination of Council or SWC records, previous reports, rainfall records and local knowledge obtained through community consultation.

3.2. Data Sources

Data utilised in the study has been sourced from a variety of organisations. Table 1 lists the type of data sourced and from where it has been extracted.

Table 1: Data Sources

Type of Data	Format Provided (Source)	Format Stored
Location, description and invert depths of pits, pipes and trunk drainage network	GIS (SWC and CBB)	DRAINS and TUFLOW models
Ground levels from ALS data	GIS (SWC and CBB)	GIS and TUFLOW model
Detailed survey data	GIS (SWC, CBB and CBH)	GIS and TUFLOW model
GIS information (cadastre, drainage pipe layout)	GIS (SWC and CBB)	GIS and TUFLOW model
Design rainfall	AR&R (1987)	DRAINS
Recorded flood data	Observation by SWC	Report
Hydrology	ASCII text (BoM, SWC)	DRAINS

3.3. Topographic Data

Airborne Light Detection and Ranging (LiDAR), otherwise known as Airborne Laser Scanning (ALS) survey of the catchment and its immediate surroundings was provided for the study by SWC. It was advised that the data were collected in 2007 and 2008 by the aerial survey company AAMHatch. These data typically have accuracy in the order of:

- +/- 0.15m (for 70% of points) in the vertical direction on clear, hard ground; and
- +/- 0.75m in the horizontal direction.

The accuracy of the ALS data can be influenced by the presence of open water or vegetation (tree or shrub canopy) at the time of the survey which means in some areas data is missing or the points are of poor quality.

From this data, a Triangular Irregular Network (TIN) was generated. This TIN was sampled at a regular spacing of 1 m by 1 m to create a Digital Elevation Model (DEM), which formed the basis of the two-dimensional hydraulic modelling for the study (Figure 3).

3.4. Cross-section Data

Within the Mascot catchment the main drainage network includes regular open channel sections. For these areas, the definition to the top of the concrete-lined channel was based on cross-sections provided by the SWC capacity assessment report (Reference 1), works-as-executed maps and SWC's drainage database.

In locations where bridges traverse the open channel, additional survey was undertaken by Chase Burke & Harvey (CBH) surveyors in May 2013. From this, definition of the cross-sectional area was obtained, particularly where the bridge soffit was not the same height as the top of the concrete-lined channel, like the example shown in Photo 1.

Photo 1: Bridge traversing open channel in Qantas site (provided by CBH)

3.5. Pit and Pipe Data

The SWC capacity assessment report (Reference 1) provided dimensions for SWC owned underground pipes, in addition to the open channel cross-sections discussed above. Appended to this SWC drainage network are underground pipes owned by the CBB within the catchment.

The CBB provided pit location and pipe dimensions for the infrastructure within their Council area (where available) and undertook some additional survey in May and December 2013 and January 2014 to obtain missing data.

3.6. Weir Data

The water levels in the Botany Wetlands are controlled by a series of weirs that allow water to be stored in the different ponds throughout the system. There are also a number of bridges throughout the system to allow golfers to traverse Eastlakes Golf Course and The Lakes Golf Course. In order to model these weirs and bridges accurately a site visit was undertaken to inspect the weirs and bridge structures. The dimension and elevations of these structures were determined by measurements taken during the site inspections in conjunction with the surrounding ground levels estimated using the aerial survey data. An example of these structures is shown in Photo 2.

Photo 2: Bridge and weir structure Botany Wetalands

3.7. Historical Flood Level Data

Historic flood data was provided by SWC and included limited flood level information for the 1975 and 1993 storm events. A summary of available historical flood levels is provided in Table 2 and Figure 4.

Table 2: Summary of Historical Flood Levels

Flood Events	Total Records	Number of Observed Flood Levels
March 1975	5	5
February 1993	1	1

3.8. Historical Rainfall Data

3.8.1. Overview

Rainfall data is recorded either daily (24-hour rainfall totals to 9:00 am) or continuously (pluviometers measuring rainfall in small increments – less than 1 mm). Daily rainfall data has been recorded for over 100 years at many locations within the Sydney basin. In general, pluviometers have only been installed since the 1970s; however Kingsford Smith Airport has a longer record. Together these records provide a picture of when and how often large rainfall events have occurred in the past.

Care must be taken when interpreting historical rainfall measurements. Rainfall records may not provide an accurate representation of past events due to a combination of factors including local site conditions, human error or limitations inherent to the type of recording instrument used. Examples of limitations that may impact the quality of data used for the present study are highlighted in the following:

- Rainfall gauges frequently fail to accurately record the total amount of rainfall. This can occur for a range of reasons including operator error, instrument failure, overtopping and vandalism. In particular, many gauges fail during periods of heavy rainfall and records of large events are often lost or misrepresented.
- Daily read information is usually obtained at 9:00 am in the morning. Thus if a single storm is experienced both before and after 9:00 am, then the rainfall is “split” between two days of record and a large single day total cannot be identified.
- In the past, rainfall over weekends was often erroneously accumulated and recorded as a combined Monday 9:00 am reading.
- The duration of intense rainfall required to produce overland flooding in the study area is typically less than 4 hours (though this rainfall may be contained within a longer period of rainfall). This is termed the “critical storm duration”. For the study area a short intense period of rainfall can produce more severe flooding than sustained rainfall with a higher total depth. If the rain occurs quickly (e.g. a thunder storm), the daily rainfall total may not necessarily reflect the severity of the storm and the subsequent flooding. Alternatively the rainfall may be relatively consistent throughout the day, producing a large total but only minor flooding.
- Rainfall records can frequently have “gaps” ranging from a few days to several weeks or even years.
- Pluviometer (continuous) records provide a much greater insight into the intensity (depth vs. time) of rainfall events. This data has much fewer limitations than daily read data.
- Pluviometers have moving parts and automated recording mechanisms, which can fail during intense storm events due to the extreme weather conditions.

Intense rainfall events which cause overland flooding in highly urbanised catchments are usually localised and as such are only accurately represented by a nearby gauge, preferably within the catchment. Gauges sited even only a kilometre away can show very different intensities and total rainfall depths.

3.8.2. Rainfall Stations

Table 3 presents a summary of the official rainfall gauges sourced from the BoM located close to or within the catchments. This includes daily read stations, continuous pluviometer stations, operational stations and synoptic stations. These gauges are operated either by SWC or the BoM.

Table 3: Rainfall stations within 5km of the centre of the catchment

Station Number	Station Name	Operating Authority	Distance from centre of the catchment (km)	Elevation (m AHD)	Date Opened	Date Closed	Type
566028	Mascot Bowling Club	SWC	1.1	5	1973	current	Continuous
66021	Alexandria (Erskineville)	BoM	1.4	6	1948	1973	Daily
66101	Marrickville (Fernbank)	BoM	2.4	-	1889	1913	Daily
566026	Marrickville	SWC	2.5	5	1979	current	Continuous
66007	Botany No. 1 Dam	BoM	2.6	6	1870	1978	Daily
66037	Sydney Airport AMO	BoM	2.8	6	1951	current	Continuous
66037	Sydney Airport AMO	BoM	2.8	6	1929	current	Daily
66033	Alexandria (Henderson Rd)	BoM	3.0	15	1962	2002	Daily
66097	Randwick Bunnerong Rd	BoM	3.0	-	1904	1924	Daily
66036	Marrickville Golf Club	BoM	4.7	6	1904	current	Daily
66015	Crown St Reservoir	BoM	4.8	-	1882	1960	Daily

3.8.3. Analysis of Daily Read Data

An analysis of the records of daily rainfall stations Botany No. 1 Dam (66007) and Sydney Airport AMO (66037) was undertaken. Both gauges are located to the south of the catchment and are shown on Figure 5.

From this data it can be seen that February 1956 was one of the largest events recorded at both gauges with very similar rainfall depths. The May 1889, March 1975, August 1986 and February 1990 storm events also were significant. Another notable event in the local area not identified in these records was November 1984.

Table 4: Daily Rainfalls greater than 150mm at Botany No. 1 Dam and Sydney Airport AMO

Botany No. 1 Dam (66007)		
Jan 1870 – Dec 1978		
Rank	Date	Rainfall (mm)
1	28/5/1889	252
2	10/2/1956	221
3	10/2/1958	220
4	6/4/1882	173
5	19/11/1900	168
6	13/1/1911	166
7	28/7/1952	163
8	20/3/1989	161
9	16/6/1952	155
10	23/6/1885	153
11	30/10/1959	153
12	28/4/1966	151

Sydney Airport AMO (66037)		
Nov 1929 – Nov 2003		
Rank	Date	Rainfall (mm)
1	3/2/1990	216
2	10/2/1956	208
3	6/8/1986	207
4	11/3/1975	202
5	13/12/1963	182
6	4/2/1990	178
7	30/4/1988	174
8	1/5/1955	166
9	8/1/1973	157
10	11/6/1991	151

3.8.4. Analysis of Pluviometer Data

Continuous pluviometer records provide a more detailed description of temporal variations in rainfall. The Mascot Bowling Club, Marrickville and Sydney Airport AMO pluviometer stations were analysed. These pluviometer stations are operated by SWC and BoM, with Marrickville and Mascot Bowling Club having the longest records.

Rainfall intensities at the gauges were assessed for the 30 minute, 1 hour and 2 hour storm burst durations and compared to frequencies derived from Australian Rainfall and Runoff 1987 (Reference 2) in Table 5. These durations were selected for analysis based upon the size of the Mascot West catchment.

Table 5: Approximate ARI Recorded at Pluviometer Stations

Station Name	Years of Record	Highest Approximate ARI (AR&R 1987)		
		30 min storm burst	1 hour storm burst	2 hour storm burst
Mascot Bowling Club (566028)	40	50yr – 100yr ARI	20yr – 50yr ARI	20yr – 50yr ARI
Marrickville (566026)	34	20yr ARI	10yr – 20yr ARI	10yr – 20yr ARI
Sydney Airport AMO (66037)	51	100yr ARI	20yr – 50yr ARI	20yr – 50yr ARI

The largest storms recorded at these gauges are listed in Table 6 but there is very little agreement between the pluviometer stations. The 12th February 2010 event produced the highest intensity 1 hour storm burst at the Mascot Bowling Club pluviometer, the only pluviometer within the catchment, however it appears to have been a very localised rainfall event and did not record significant rainfall at nearby gauges.

Table 6: Peak Burst Intensities of Signficant Rainfall Events (mm/h)

Rainfall Event	Mascot BC (566028)			Marrickville (566026)			Sydney Airport (66037)		
	30 min	1 hour	2 hour	30 min	1 hour	2 hour	30 min	1 hour	2 hour
13th December 1963	-	-	-	-	-	-	89	64	51
23rd March 1966	-	-	-	-	-	-	137	77	39
10th March 1975	73	71	48	-	-	-	74	69	48
5th November 1984	86	48	33	56	31	27	-	-	-
17th February 1993	39	27	16	94	64	41	59	44	29
10th April 1998	46	40	29	89	64	38	37	35	25
13th May 2003	48	37	25	101	65	33	42	41	26
12th February 2010	126	75	39	20	16	9	-	-	-

Comparison of significant rainfall events and design rainfall intensities from AR&R 1987 are shown on Figure 6. A comparison of rainfall events against preliminary updated design rainfall depth estimates released by the BoM in July 2013 are shown on Figure 7.

3.8.5. October 2014 Event

The rainfall event on Tuesday 14th October 2014 (while this study was being undertaken) resulted in widespread flooding across Sydney, particularly in the Canterbury district. The Sydney Water gauge at Bexley Bowling Club (566062) recorded a 1% AEP event for the 3hr duration on that evening. Although there were significant events recorded in Bexley and the surrounding suburbs the largest event recorded at Sydney Water gauge at Eastlakes SW Depot (566028) was only a 1 EY event. The magnitude of the event recorded for each duration is shown in Table 7.

Table 7: Approximate exceedance probablitiy 14th October 2014 – Eastlakes SW Depot (566028)

Duration	AEP
30 minutes	-
1 hour	-
2 hours	1 EY
3 hours	1EY
6 hours	1EY

3.9. Design Rainfall Data

New design rainfall depths were released by the BoM in July 2013. Whilst it is expected that the new design rainfall depths will undergo minor revisions as they are independently verified, it is unlikely they will change substantially within the Sydney metropolitan area. The 2013 design rainfall estimates require other information from the revision of AR&R including temporal patterns, aerial reduction factors, losses and base flows before they can be used in design flood estimation. Until the completion of the AR&R revision project, design rainfall intensities and techniques from AR&R 1987 will continue to be used.

The design rainfall intensity-frequency-duration (IFD) data were obtained from the BoM online design rainfall tool and provided on Table 8.

Table 8: Rainfall IFD data at the centre of the Mascot West catchment (AR&R 1987)

DURATION	Design Rainfall Intensity (mm/hr)						
	1 yr EY	2 yr EY	5yr EY	10 % AEP	5% AEP	2% AEP	1% AEP
5 minutes	97.8	125	160	180	206	240	266
6 minutes	91.5	117	150	168	193	225	250
10 minutes	74.9	96.4	124	140	161	118	209
20 minutes	54.9	71.1	92.7	105	122	114	160
30 minutes	44.7	58.0	76.2	87.1	101	120	134
1 hour	30.2	39.3	52.1	59.7	69.5	82.6	92.6
2 hours	19.6	25.5	33.8	38.7	45.0	53.5	60.0
3 hours	15.0	19.5	25.8	29.5	34.3	40.6	45.5
6 hours	9.51	12.3	16.1	18.4	21.3	25.1	28.1
12 hours	6.06	7.84	10.2	11.6	13.4	15.8	17.6
24 hours	3.91	5.05	6.56	7.45	8.61	10.1	11.3
48 hours	2.49	3.21	4.18	4.74	5.49	6.46	7.21
72 hours	1.84	2.38	3.09	3.51	4.05	4.76	5.31

The Probable Maximum Precipitation (PMP) estimates were derived according to BoM guidelines, namely the *Generalised Short Duration Method* (Reference 3) and are summarised in Table 9.

Table 9: PMP Design Rainfalls

Duration	Design Rainfall Depth (mm)
15 minutes	160
30 minutes	230
45 minutes	290
1 hour	340
1.5 hours	380
2 hours	430
2.5 hours	460
3 hours	480
4 hours	530

3.10. Previous Studies

3.10.1. Mascot West SWC 63 Capacity Assessment (Reference 1)

This report was prepared by SWC and investigated the performance of the Mascot West SWC63 system and gives an estimate of the impact of simulated urban consolidation on that performance.

The drainage data used for the study included the SWC trunk drainage system and the analysis was undertaken using a spread sheet analysis based on:

- Rational Method calculations from AR&R 1987 for inflows;
- coefficients of runoff based on the percentage impervious;
- approximate capacities of pipes based on grade and area;
- approximation of channel capacities using Manning's "n" formula; and the
- Hydraulic Grade Line method.

The soils in the study area are highly permeable and an allowance for soil type was made by reducing the coefficient of runoff for pervious areas to 0.1.

The hydraulic capacity in the main stormwater channel discharging into Alexandra Canal was found to be 10.8 m^3/s with a 20% AEP peak flow of 17.4 m^3/s. The capacity of the main channel was found to be in the range of 1 – 2 year ARI with 12% of the current trunk drainage system able to contain flows from a 20% AEP storm event.

3.10.2. Alexandra Canal Mascot Station Precinct Stormwater Study (Reference 4)

This study was commissioned to address both stormwater quantity and quality issues for the Mascot Station precinct and the Alexandra Canal industrial corridor.

The data collected included pit levels and pipe dimensions missing from the CBB or SWC databases. Survey of important features in trapped low points was also undertaken.

The hydrologic/hydraulic model established for the study was DRAINS. This model was not calibrated to any data, but model parameters were chosen to match those in the 1991 Sheas Creek Flood Study (a nearby tributary to Alexandra Canal where more historical data are available). The downstream tail water level in Alexandra Canal for design events corresponded with a mean high water level of 0.54 mAHD.

The study determined that the existing stormwater infrastructure in the catchment generally had capacities less than a 20% AEP. A number of hot spots (Table 10) were identified in the study, most of which consisted of low points which resulted in a ponded depth of flooding. Modelled depths at a number of these low points are reproduced in Table 11.

Table 10: Hotspots Identified in Reference 4

MASCOT WEST CATCHMENT	GARDENERS ROAD CATCHMENT
Gardeners Road (between Ellis and Botany Road)	Gardeners Road and Kent Road
Gardeners Road and Botany Road	Gardeners Road (West)
Miles Street	Ricketty Street (West)
Hughes Avenue	
Carinya Avenue	**CHURCH AVENUE CATCHMENT**
Coward Street	John Street (West)
Forster Street	John Street (between Laycock Street and the SWSOOS)
Macintosh Street	Ricketty Street (West)
Tunbridge Street	Ossary Street (West).
Mascot Primary School	
O'Riordan Street (between Coward Street and Bourke Road)	**COWARD STREET CATCHMENT**
Near intersection of SWSOOS and Mascot West drainage culverts	Coward Street (West)
Car park (Qantas) off Kent Road	
King Street (West)	
Ewan Street (West)	

Table 11: Potential Ponding Depths from Reference 4

Sag Location	Ponding Depths* (mm)	Ponding Depth Control
Corner of Gardeners Road and Kent Road	850 – 950 (20% to 1% AEP)	The intersection is super-elevated and the control is the crest level of the road (3.3 mAHD) at the N-W corner of the intersection.
Western end of Gardeners Road	750 – 1150 (20% to 1% AEP)	The capacity of the overland flowpath (private road) draining to Ricketty Street.
Western end of Ricketty Street	1100 (20% to 1% AEP)	The coping level of the Alexandra Canal adjacent to the Ricketty Street bridge which is estimated to be at 2 mAHD
Western end of John Street	400 – 600 (20% to 1% AEP)	The dimensions of the sag point
John Street between Laycock Street and the SWSOOS	500 Larger than 20% AEP	The high-point level at the intersection of John Street and Laycock Street of 8.5 mAHD
Western end of Ossary Street	1500 – 1700 (20% to 1% AEP)	The high-point level at the intersection of Ossary Street and Kent Road of 3.6 mAHD
Western end of Coward Street, approximately 150 metres east of Alexandra Canal	600 – 1000 (20% to 1% AEP)	The sag point level of 1.0 m AHD in Coward Street and the coping level of Alexandra Canal of approximately 2.0 mAHD
Western end of Robey Street under railway goods line	Up to 400 (1% AEP)	The hydraulic performance of the drainage system managed by Sydney Airports Corporation

* The potential depths of ponding were estimated assuming that all sites are fully developed and that ponding only occurs in road reserves and that overland flow only occurs in roadways and drainage easements

3.10.3. Botany – Church, John & Ossary Streets Flood Study Report (Reference 5)

BMD Consulting was commissioned by the CBB to carry out an investigation of the existing drainage system bounded by Gardeners Road to the north, O'Riordan Street to the east, Coward and Ossary Streets to the south, and Alexandra Canal on the west.

The hydrologic model used for the study area was DRAINS. The flow rates produced by DRAINS were applied to a HEC-RAS hydraulic model for the 5% and 1% AEP design events in order to determine water surface profiles.

3.10.4. Kensington – Centennial Park Flood Study (Reference 11)

The study was commissioned by Randwick Council in order to determine the extent and behaviour of flooding in the Kensington and Centennial Park Catchment. The catchment is located in the eastern suburbs of Sydney with urbanisation significantly altering the nature of drainage within the catchment as urban development is located along many of the existing drainage paths from Centennial Park south to Botany Bay. The study area is relatively unique for the Sydney region in that many trapped low points exist and that these depressions historically drained only to via infiltration to the underlying Botany Aquifer.

The overall study area was broken into two model domains:

- Upper Model – Queens Park, Centennial Park, east of Randwick Racecourse,
- Lower Model – Alison Road entrance of Randwick Racecourse south to Gardeners Road including overflow from Centennial Park.

Hydrologic modelling was undertaken using a combination of Mike-Storm and DRAINS. Hydraulic modelling was undertaken using a 2m resolution dynamically integrated 1D/2D TUFLOW model. The high resolution 2D domain is particularly advantageous in this study area to define the floodplain storage in the trapped low points and the high level relief areas.

Extensive peak flood level flood data were collected for the two storms of the 5/6th November and the 8/9th of November 1984. The 8/9th November event was utilised as a calibration event while the prior 5/6th November event was used to verify the calibrated model.

Design flood analysis of the calibrated model has been undertaken for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% Annual Exceedance Probability (AEP) flood events as well as for the Probable Maximum Flood (PMF).

The outflows from the models at Gardeners Road were used as the inflows into the Botany Wetlands hydraulic model at Eastlakes Golf Course for the current study.

3.10.5. Daceyville/Astrolabe Park Flood Study (Reference 21)

The study was commissioned by Botany Bay City Council for the Daceyville / Astrolabe catchment that falls within the Botany Bay Council LGA.

The Daceyville/Astrolabe Park catchment extends from the outlet in Botany Wetlands to Alison Road near Randwick Racecourse. This includes the suburbs of Randwick, a very small part of Kensington (part of UNSW), Kingsford, Pagewood, Maroubra and Daceyville. However the study area for the Daceyville/Astrolabe Park study only included the land within the Botany City Council (LGA) – the areas south of Gardeners Road and west of Bunnerong Road. Approximately 80% of the catchment is within Randwick LGA and 20% within Botany LGA.

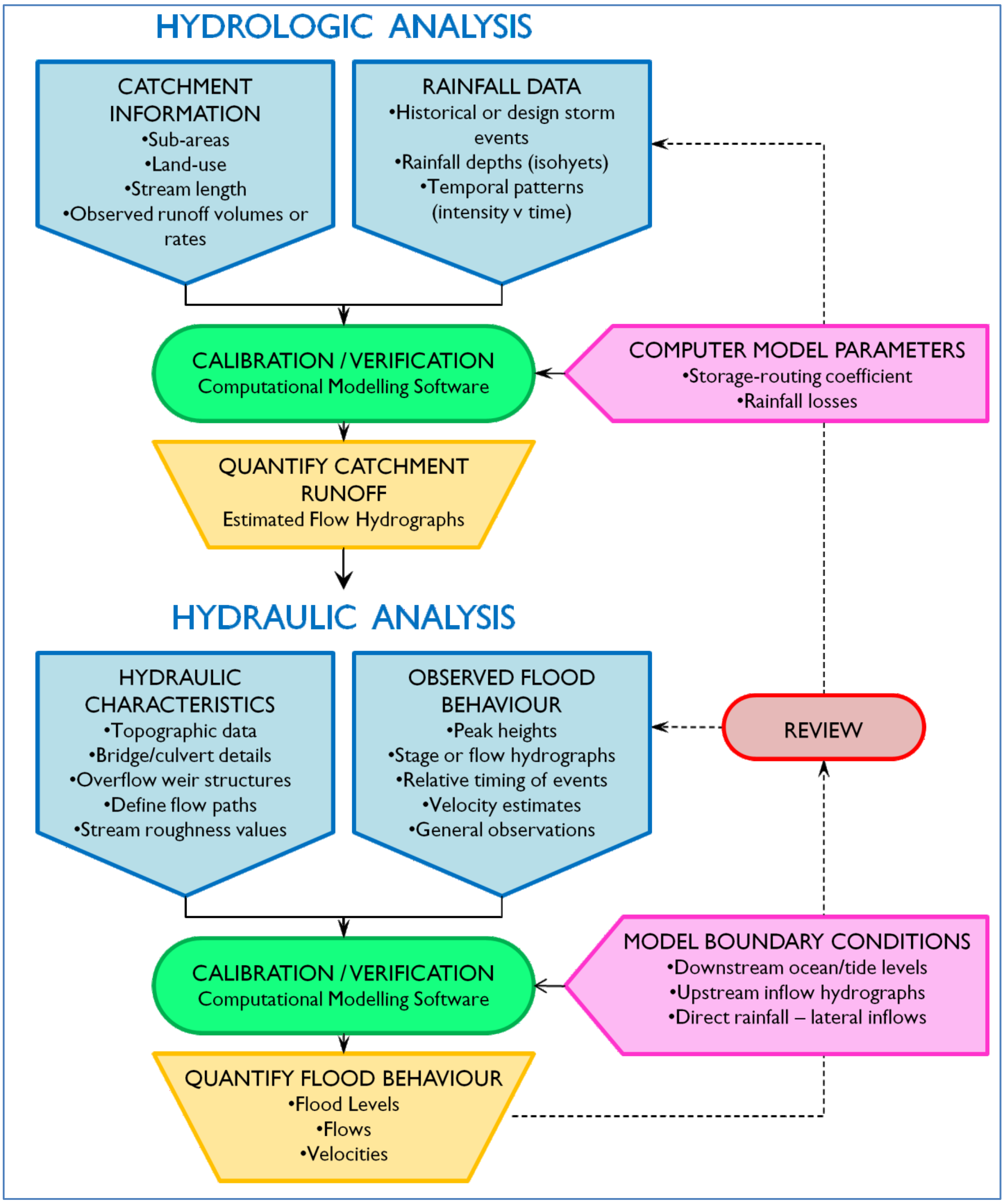
Hydrologic modelling was undertaken using the DRAINS model. Hydraulic modelling was undertaken using a 2m resolution dynamically integrated 1D/2D TUFLOW model.

The study estimated the existing design flood behaviour for a range of flood events from the 2 year EY to the Probable Maximum Flood.

4. STUDY METHODOLOGY

A diagrammatic representation of the Flood Study process is shown in Diagram 2. The urbanised nature of the study area with its mix of pervious and impervious surfaces, and existing piped and overland flow drainage systems, has created a complex hydrologic and hydraulic flow regime.

Diagram 2: Flood Study Process



The estimation of flood behaviour in a catchment is undertaken as a two-stage process, consisting of:

1. hydrologic modelling to convert rainfall estimates to overland flow and stream runoff; and
2. hydraulic modelling to estimate overland flow distributions, flood levels and velocities.

The broad approach adopted for this study was to use a widely utilised and well-regarded hydrologic model to conceptually model the rainfall concentration phase (including runoff from roof drainage systems, gutters, etc.). The hydrologic model used design rainfall patterns specified in AR&R (Reference 2) and the runoff hydrographs were then used in a hydraulic model to estimate flood depths, velocities and hazard in the study area.

The sub-catchments in the hydrologic model were kept small (on average approximately 2.2 ha) such that the overland flow behaviour for the study area was generally defined by the hydraulic model. This joint modelling approach was verified against previous studies and alternative methods.

The DRAINS software (Reference 6) was used to create flow boundary conditions for input into a two-dimensional unsteady flow hydraulic model using the TUFLOW software (Reference 7).

Good historical flood data facilitates calibration of the models and increases confidence in the estimates. The calibration process involves modifying the initial model parameter values to produce modelled results that concur with observed data. Validation is undertaken to ensure that the calibration model parameter values are acceptable in other storm events with no additional alteration of values. Recorded rainfall and stream-flow data are required for calibration of the hydrologic model, while historic records of flood levels, velocities and inundation extents can be used for the calibration of hydraulic model parameters. In the absence of such data, model verification using limited historical data is the only option and a detailed sensitivity analysis of the different model input parameters constitutes current best practice.

There are no stream-flow records in the catchment, so the use of a flood frequency approach for the estimation of design floods or independent calibration of the hydrologic model was not possible.

4.1. Hydrologic Model

DRAINS is a hydrologic/hydraulic model that can simulate the full storm hydrograph and is capable of describing the flow behaviour of a catchment and pipe system for real storm events, as well as statistically based design storms. It is designed for analysing urban or partly urban catchments where artificial drainage elements have been installed.

The DRAINS model is broadly characterised by the following features:

- the hydrological component is based on the theory applied in the ILSAX model which has seen wide usage and acceptance in Australia;

- its application of the hydraulic grade line method for hydraulic analysis throughout the drainage system; and
- the graphical display of network connections and results.

DRAINS generates a full hydrograph of surface flows arriving at each pit and routes these through the pipe network or overland, combining them where appropriate. Consequently, it avoids the "partial area" problems of the Rational Method and additionally it can model detention basins (unsteady flow rather than steady state). Runoff hydrographs for each sub-catchment area are calculated using the time area method.

DRAINS is not a true unsteady flow model and therefore does not account for the attenuation effects of routing through temporary floodplain storage (down streets or in yards). As such the use of DRAINS within this study was limited to some minor upstream catchment routing and development of hydrological inputs into the downstream TUFLOW model.

4.2. Hydraulic Model

The availability of high quality aerial survey data means that the study area is suitable for two-dimensional (2D) hydraulic modelling. Various 2D software packages are available and the TUFLOW package was adopted as it is widely used in Australia and WMAwater has extensive experience with the model.

The TUFLOW modelling package includes a finite difference numerical model for the solution of the depth averaged shallow water flow equations in two dimensions. The TUFLOW software is produced by BMT WBM and has been widely used for a range of similar projects. The model is capable of dynamically simulating complex overland flow regimes. It is especially applicable to the hydraulic analysis of flooding in urban areas which is typically characterised by short duration events and a combination of supercritical and subcritical flow behaviour, and interactions between overland flow and a sub-surface drainage network.

In TUFLOW the ground topography is represented as a uniformly-spaced grid with a ground elevation and a Manning’s “n” roughness value assigned to each grid cell. The grid cell size is determined as a balance between the model result definition required and the computer run time (which is largely determined by the total number of grid cells). A cell size of 2 m by 2 m was found to provide an appropriate balance for this study.

4.3. Design Flood Modelling

Following validation of the hydrologic model against previous studies with similar catchment characteristics and alternative calculation methods, the following steps were undertaken:

- design outflows for localised sub-catchments were obtained from the DRAINS hydrologic model and applied as inflows to the TUFLOW model; and
- sensitivity analysis was undertaken to assess the relative effect of changing various TUFLOW modelling parameters.

5. HYDROLOGIC MODEL SETUP

5.1. Sub-catchment Definition

Three separate hydrological models were built for the study:

1. Mascot / Rosebery / Eastlakes urban catchment
2. Botany Wetlands catchment
3. Pagewood Urban catchment

The separate hydrological models were needed to provide inflows for the three separate hydraulic models that were built for the catchment.

MASCOT / ROSEBERY / EASTLAKES URBAN

The total catchment represented by the DRAINS model is 4.8 km^2. This area has been represented by a total of 227 sub-catchments giving an average sub-catchment size of approximately 0.021 km^2. The sub-catchment delineation ensures that where hydraulic controls exist that these are accounted for and able to be appropriately incorporated into hydraulic routing. The sub-catchment layout is shown in Figure 8.

BOTANY WETLANDS

The total catchment represented by the Botany Wetlands DRAINS model is 1.7 km^2. This area has been represented by a total of 71 sub-catchments giving an average sub-catchment size of approximately 0.023 km^2. The sub-catchment delineation ensures that where hydraulic controls exist that these are accounted for and able to be appropriately incorporated into hydraulic routing. The sub-catchment layout is shown in Figure 9.

PAGEWOOD

The total catchment represented by the Pagewood Urban DRAINS model is 0.282 km^2. This area has been represented by a total of 40 sub-catchments giving an average sub-catchment size of approximately 0.007 km^2. The sub-catchment delineation ensures that where hydraulic controls exist that these are accounted for and able to be appropriately incorporated into hydraulic routing. The sub-catchment layout is shown in Figure 9.

5.2. Impervious Surface Area

Runoff from connected impervious surfaces such as roads, gutters, roofs or concrete surfaces occurs significantly faster than from vegetated surfaces. This results in a faster concentration of flow within the downstream area of the catchment, and increased peak flow in some situations. It is therefore necessary to estimate the proportion of the catchment area that is covered by such surfaces.

DRAINS categorises these surface areas as either:

- paved areas (impervious areas directly connected to the drainage system);
- supplementary areas (impervious areas not directly connected to the drainage system,

instead connected to the drainage system via the pervious areas); and
- grassed areas (pervious areas).

Within the Mascot West catchment, a uniform 5% was adopted as a supplementary area across the catchment. The remaining 95% was attributed to impervious (or paved areas) and pervious surface areas, as estimated for each individual sub-catchment. This was undertaken by determining the proportion of the sub-catchment area allocated to a land-use category and the estimated impervious percentage of each land-use category as summarised in Table 12.

Table 12: Impervious Percentage per Land-use

Land-use Category	Impervious Percentage
Residential property	70% impervious
Commercial property	95% impervious
Vacant land	5% impervious
Vegetation (such as public parks)	5% impervious
Pavement and car parks	100% impervious
Roadway	100% impervious

The proportion of each land-use category within a sub-catchment was determined based upon 2011 aerial photography provided by CBB.

5.3. Rainfall Losses

Methods for modelling the proportion of rainfall that is "lost" to infiltration are outlined in AR&R (Reference 2). The methods are of varying degrees of complexity, with the more complex options only suitable if sufficient data are available. The method most typically used for design flood estimation is to apply an initial and continuing loss to the rainfall. The initial loss represents the wetting of the catchment prior to runoff starting to occur and the continuing loss represents the ongoing infiltration of water into the saturated soils while rainfall continues.

Rainfall losses from a paved or impervious area are considered to consist of only an initial loss (an amount sufficient to wet the pavement and fill minor surface depressions). Losses from grassed areas are comprised of an initial loss and a continuing loss. The continuing loss is calculated from an infiltration equation curve incorporated into the model and is based on the selected representative soil type and antecedent moisture condition. The catchment soil was assumed to have a slow infiltration rate and the antecedent moisture condition was considered to be rather wet.

The adopted parameters are summarised in Table 13. These are generally consistent with the parameters adopted in a previous study within the Mascot West catchment undertaken by AWT Engineering (Reference 4) and the adjacent Sheas Creek catchment Flood Study. The exception was the choice of soil type for the catchment. The soil within the catchment is typically sand and the CBB has several "soakaway" pits which take advantage of the high infiltration rate. The selected soil type represents the highest soil infiltration rate available in the model.

Table 13: Adopted DRAINS hydrologic model parameters

RAINFALL LOSSES	
Paved Area Depression Storage (Initial Loss)	1.0 mm
Grassed Area Depression Storage (Initial Loss)	5.0 mm
SOIL TYPE	**1**
High infiltration rates. This parameter, in conjunction with the AMC, determines the continuing loss	
ANTECEDENT MOISTURE CONDITONS (AMC)	**3**
Description	Rather wet
Total Rainfall in 5 Days Preceding the Storm	12.5 to 25 mm

6. HYDRAULIC MODEL – MASCOT / ROSEBERY / EASTLAKES

6.1. TUFLOW Hydraulic Model

The TUFLOW model uses a regularly spaced computational grid, with a cell size of 2 m by 2 m. This resolution was adopted as it provides an appropriate balance between providing sufficient detail for roads and overland flow paths, while still resulting in workable computational run-times. The model grid was established by sampling from a 1 m by 1 m DEM. This DEM was generated from a triangulation of filtered ground points from the LiDAR dataset, discussed in Section 3.3. This DEM is shown in Figure 3.

The TUFLOW hydraulic model extends from Qantas Drive, Joyce Drive and Southern Cross Drive to the south and east, past Gardeners Road to the north and is bounded by Alexandra Canal to the west. The total area included in the 2D model is 4.7 km^2. The extents of the TUFLOW model are shown in Figure 10.

6.2. Boundary Locations

6.2.1. Inflows

For local sub-catchments within the TUFLOW model domain, local runoff hydrographs were extracted from the DRAINS model (see Section 5). These were applied to the downstream end of the sub-catchments within the 2D domain of the hydraulic model. The inflow locations typically corresponded with inlet pits on the roadway as these have been constructed to service low points within the catchment topography.

There is one area of the MRE model that has an inflow from the Botany Wetlands DRAINS model. This inflow location is King Street which runs beneath Southern Cross Drive from The Lakes Golf Course.

6.2.2. Downstream Boundary

There are several downstream boundaries in the model. On the western side of the model the boundary was located along Alexandra Canal, as shown in Figure 10. The Alexandra Canal boundary conditions were taken from (Reference 13).

To the south a constant tailwater level is applied to the Ascot Drain downstream of Mill Pond Road and prior to it discharging into Mill Pond. Several pipes discharge into The Lakes Golf Course and an assumed constant tailwater was applied at these outlets.

6.3. Roughness Co-efficient

The hydraulic efficiency of the flow paths within the TUFLOW model is represented in part by the hydraulic roughness or friction factor formulated as Manning's "n" values. This factor describes the net influence of bed roughness and incorporates the effects of vegetation and other features which may affect the hydraulic performance of the particular flow path.

The Manning's "n" values adopted for the study area, including flow paths (overland, pipe and in-channel), are shown in Table 14. These values have been adopted based on site inspection and past experience in similar floodplain environments. The values are consistent with typical values given in Chow, 1959 (Reference 8) and Henderson, 1966 (Reference 9).

Table 14: Manning's "n" values adopted in TUFLOW

Surface	Manning's "n" Adopted
Pipes	0.015
Concrete Lined Channel	0.015
Roads and Footpaths	0.022
Light Vegetation	0.035
Medium Vegetation	0.060
Properties	0.040

6.4. Hydraulic Structures

6.4.1. Buildings

Buildings and other significant features likely to act as flow obstructions were incorporated into the model network based on building footprints, defined using aerial photography. These types of features were modelled as impermeable obstructions to the floodwaters.

6.4.2. Fencing and Obstructions

Smaller localised obstructions, such as fences, can be explicitly represented in TUFLOW in a number of ways including as an impermeable obstruction, a percentage blockage or as an energy loss. These obstructions may also be modelled implicitly by increasing Manning's roughness within the vicinity. There were few examples in the catchment where fencing would cause complete blockage of an overland flow path, and therefore fences were explicitly represented within the hydraulic model as a percentage blockage.

Given the large number of fences within the eastern (predominantly residential) part of the catchment, all fences were assumed to be of a constant height and permeability. Examples of typical fencing within the catchment are shown in Photo 3 and Photo 4.

Standard colourbond fencing is 1.5 m to 1.8 m in height and the height of brick fencing within the catchment varies. The permeability would range from 50% to 100% blockage. As such the following have been adopted throughout the catchment:

- fence height = 1.5 m;
- fence blockage = 70%;
- form loss co-efficient = 0.2.

Photo 3: Colourbond fencing next to an open channel

Photo 4: Example of fencing within the catchment

6.4.3. Bridges

Key hydraulic structures were included in the hydraulic model, as shown in Figure 10. Culverts and bridges were modelled as 1D features within the 1D channels, with the purpose of maintaining continuity within the model.

The modelling parameter values for the culverts and bridges were based on the geometrical properties of the structures, which were obtained from detailed survey, photographs taken during site inspections, and previous experience modelling similar structures.

6.4.4. Sub-surface Drainage Network

Figure 10 shows the location and extent of drainage lines within the study catchment that have been included in the TUFLOW model.

6.5. Design Blockage Assumptions

6.5.1. Background

In order to determine design flood behaviour the likelihood and consequences of blockage needs to be considered. Guidance on the application of blockage can be found in AR&R Revision Project 11: Blockage of Hydraulic Structures, 2014 (Reference 10).

Blockage of hydraulic structures can occur with the transportation of a number of materials by flood waters. This includes vegetation, garbage bins, building materials and cars, the latter of which has been seen in the June 2007 Newcastle and August 1998 Wollongong Floods (Photo 5 and Photo 6).

Photo 5: Cars in a culvert inlet – Newcastle (Reference 10)

Photo 6: Urban debris in Wollongong (Reference 10)

The potential quantity and type of debris reaching a structure from a contributing source area depends on several factors. AR&R guidelines suggest adopted design blockage factors are based upon consideration of:

- the availability of debris,
- the ability for it to mobilise, and
- the ability for it to be transported to the structure.

The availability of debris is dependent on factors such as the potential for soil erosion, local geology, the source area, the amount and type of vegetative cover, the degree of urbanisation, land clearing and preceding wind and rainfall. However, the type of materials that can be mobilised can vary greatly between catchments and individual flood events.

Observations of debris conveyed in streams strongly suggest a correlation between event magnitude and debris potential at a site. Rarer events produce deeper and faster floodwater able to transport large quantities and larger sizes of debris, smaller events may not be able to transport larger blockage material at all. Debris potential is adjusted as required for greater or lesser probabilities to establish the *most likely* and *severe* blockage levels for that event.

The likelihood of blockage at a particular structure depends on whether or not debris is able to bridge across the structure inlet or become trapped within the structure. Research into culvert blockage in Wollongong showed a correlation with blockage and opening width. The *most likely* blockage to occur at a structure is determined by considering the potential quantity and type of debris and the structure opening size as in Table 15.

Table 15: Most Likely Blockage Levels – B_{DES} (Table 6 in Reference 10)

Control Dimension	At-Site Debris Potential		
	High	Medium	Low
W < L10	100%	50%	25%
$W \geq L_{10} \leq 3 \times L_{10}$	20%	10%	0%
$W > 3 \times L_{10}$	10%	0%	0%

Notes: W refers to the opening diameter / width
L_{10} refers to the length of the longest 10% of debris that could arrive at the site

A severe blockage level is proposed where the consequences are very high and Reference 10 suggests a *severe* blockage of twice the *most likely* blockage criteria. At structures where the consequence of blockage is very low, a 0% blockage is suggested.

6.5.2. Adopted Blockage

The adopted blockage criteria are listed in Table 16.

Table 16: Adopted Blockage Conditions

Type	Blockage Criteria
Pipes	• < 450 mm assumed 100% blockage • > 450 mm assumed clear
Pits	• Assumed 0% blockage
Bridges	• < 3m wide – 25% blockage • > 3m wide – assumed clear
Fences	• Assumed 70% blockage
Baxter Road, Ewan Street and King Street outflow pipes	• Assumed 50% blockage

7. HYDRAULIC MODEL – BOTANY WETLANDS

7.1. TUFLOW Hydraulic Model

Due to the varying degree of model detail and result resolution required for the Botany Wetlands catchment and the Pagewood urban catchment, two separate models were built.

BOTANY WETLANDS

The Botany Wetlands model uses a regular spaced computational grid with a cell size of 4 m by 4 m. The detail required for roads and overland flow paths was minimal as the catchment consisted of two golf courses, a wetland system and open spaces.

The Botany Wetlands model extends from Gardeners Road in Daceyville, encompassing the entire Botany Wetlands system which includes Eastlakes Golf Course and The Lakes Golf Course. The model is bounded by Southern Cross Drive to the west and the suburbs of Daceyville, Pagewood and Botany to the east. The model extent is shown in Figure 11.

PAGEWOOD

The Pagewood Urban model uses a regular spaced computational grid with a cell size of 2 m by 2 m. This resolution was adopted as it provides sufficient detail for modelling roads and the kerb and gutter system.

The Pagewood model is split into two domains. Each domain consists of a catchment that provides inflows into the Botany Wetlands model. Domain 1 is bounded by the railway line to the west, Page Street to the south, Dudley Street to the east and The Lakes Golf Course to the north. Domain 2 is bounded by Mutch Park to the south, Lang and Wentworth Avenue to the west and is surrounded by the Lakes Golf Course to the north and east. The model extent is shown in Figure 11.

The remaining area of the suburb Pagewood was not modelled for the purpose of this study as it did not provide any inflow into the Botany Wetlands catchment. WMAwater understands these areas will be included in a later Flood Study.

7.2. Boundary Locations

7.2.1. Inflows

For local sub-catchments within the TUFLOW model domains, local runoff hydrographs were extracted from the DRAINS model (see Section 5). These were applied to the downstream end of the sub-catchments within the 2D domain of the Botany Wetland and Pagewood hydraulic model. The inflow locations in Pagewood typically corresponded with inlet pits on the roadway as these have been constructed to service low points within the catchment topography.

The Botany Wetlands model has inflows from three different hydraulic models in the form of overland flow and discharge from culverts:

1. Centennial Park / Kensington (Reference 11);
2. Daceyville / Astrolabe Park (Reference 21); and
3. Pagewood (Current Study).

The location of the inflows is shown in Figure 11.

CENTENNIAL PARK / KENSINGTON

The inflows from the Centennial Park / Kensington model enter the upstream boundary of the Botany Wetlands model at three locations:

1. Through three culverts that run beneath Gardeners Road between Leonard Avenue and Court Avenue. The culverts enter an open channel that runs adjacent to the Eastlakes Golf Course Clubhouse and car park.
2. Through three culverts that run beneath Gardeners Road between Maitland Avenue and Aboud Avenue. The culverts enter the maintenance area of Eastlakes Golf Course.
3. The overland flow path that flows from Tunstal Avenue, Maitland Avenue and Aboud Avenue across Gardeners Road and into Eastlake Golf Course.

DACEYVILLE / ASTROLABE PARK

The inflows from the Daceyville / Astrolabe model enter the eastern boundary of the Botany Wetlands at two locations:

1. Through a culvert that runs beneath Astrolabe Park and the overland flow path directly above that culvert.
2. An overland flow path south of Astrolabe Road.

PAGEWOOD

The inflows from the Pagewood model enter the western boundary of the Botany Wetlands model at three locations:

1. The overland flow path at Martin Avenue and Donaldson Street;
2. The overland flow path at Lang Avenue; and
3. The overland flow path at Myrtle Street.

7.2.2. Downstream Boundary

The downstream boundary of the Botany Wetland model is the open channel that is located adjacent to Foreshore Road. The water level of the channel is tidal and is governed by water level in Botany Bay. Downstream boundary levels are discussed in Section 10.3.

The downstream boundary of the Pagewood model is the Lakes Golf Course. The outflows at the boundary were input into the Botany Wetlands model as discussed in Section 7.2.1.

7.2.3. Roughness Coefficient

Refer to Section 6.3.

7.3. Hydraulic Structures

7.3.1. Buildings

Refer to Section 6.4.1.

7.3.2. Bridges

The bridges that traverse Eastlakes Golf Course and The Lakes Golf Course were included in the hydraulic model, as shown in Figure 11. The bridges were modelled in the 2D domain for the purpose of maintaining continuity in the model.

The modelling parameter values for the bridges were based on the geometrical properties of the structures, which were obtained from detailed survey, photographs taken during site inspections, and previous experience modelling similar structures. An example of a bridge included in the model is shown in Photo 7.

Photo 7: Bridge and weir structure Botany Wetalands

7.3.3. Weirs

The water levels in the Botany Wetlands are controlled by a series of weirs that allow water to be stored in the different ponds throughout the system. The weirs were modelled in the 2D domain for the purpose of maintaining continuity in the model.

The modelling parameter values for the weirs were based on the geometrical properties of the structures, which were obtained from detailed survey, photographs taken during site inspections, and previous experience modelling similar structures.

7.3.4. Sub-surface Drainage Network

Figure 11 shows the location and extent of drainage lines within the study catchment that have been included in the TUFLOW model.

7.4. Design Blockage Assumptions

Refer to Section 6.5

8. MODEL VERIFICATION

8.1. Introduction

Prior to use for defining design flood behaviour it is important that the performance of the overall modelling system be substantiated. Calibration involves modifying the initial model parameter values to produce modelled results that concur with observed data. Validation is undertaken to ensure that the calibration model parameter values are acceptable in other storm events with no additional alteration of values. Ideally the modelling system should be calibrated and validated to multiple events, but this requires adequate historical flood observations and sufficient pluviometer rainfall data.

Typically in urban areas such information is lacking. Issues which may prevent a thorough calibration of hydrologic and hydraulic models are:

- There is only a limited amount of historical flood information available for the study area. For example, in the Sydney metropolitan area (east of Parramatta) there are only two water level recorders in urban catchments similar to that of the study area; and
- Rainfall records for past floods are limited and there is a lack of temporal information describing historical rainfall patterns within the catchment.

In the event that a calibration and validation of the models is not possible or limited in scope, it is best practice to undertake a verification of the models and a detailed sensitivity analysis. This was the approach adopted for this study. A summary of available data is shown in Table 17.

Table 17: Data Available for Various Storm Events

Storm Events	Flood Levels	Approximate ARI	Pluviometer Stations in Operation
March 1975	5	5% to 2% AEP	Sydney Airport AMO (66037) Mascot BC (566028)
February 1993	1	1yr EY to 10% AEP	Sydney Airport AMO (66037) Marrickville (566026) Mascot BC (566028)

8.2. Hydrologic Model Verification

Verification was undertaken by comparing results from the current study with similar studies in adjacent catchments and general expectations of catchment flooding behaviour.

Flow results from the Kensington – Centennial Park Flood Study, June 2013 (Reference 11) and the Rushcutters Bay Flood Study, October 2007 (Reference 12) were compared to those used in the current study for individual sub-catchments. Table 18 provides the model comparisons for three random sub-catchments from each model.

Table 18: Comparable Subcatchment Hydrologic Model Check

Model	Area (ha)	Impervious %	5% AEP Peak Discharge (m³/s)	5% AEP Specific Yield (m³/s/ha)	1% AEP Peak Discharge (m³/s)	1% AEP Specific Yield (m³/s/ha)
Mascot, Rosebery and Eastlakes	4.6	93	1.8	0.4	2.4	0.5
Mascot, Rosebery and Eastlakes	2.5	87	1.0	0.4	1.3	0.5
Mascot, Rosebery and Eastlakes	2.1	57	0.7	0.4	0.7	0.5
Botany Wetlands	3.3	5	0.3	0.09	0.4	0.1
Botany Wetlands	2.1	5	0.2	0.1	0.3	0.1
Botany Wetlands	4.0	5	0.4	0.1	0.5	0.1
Pagewood	0.8	60	0.4	0.5	0.5	0.6
Pagewood	1.3	55	0.7	0.5	0.9	0.7
Pagewood	1.1	5	0.5	0.5	0.6	0.5
Kensington – Centennial Park	3.3	95	1.8	0.5	2.3	0.7
Kensington – Centennial Park	2.3	80	1.0	0.5	1.3	0.6
Kensington – Centennial Park	3.5	83	1.6	0.5	2.1	0.6
Rushcutters Bay	1.4	93	0.7	0.5	0.9	0.7
Rushcutters Bay	4.8	17	1.9	0.4	2.4	0.5
Rushcutters Bay	0.6	87	0.3	0.5	0.4	0.6

The specific yields from four different studies were found to be comparable for the 5% and 1% AEP events. The exception was the Botany Wetlands model where the peak discharge and specific yield for each subcatchment was roughly 20% of the other studies. This is due to the high rainfall losses of the Botany Wetlands catchment. The pervious area of the Botany Wetlands catchment is was modelled at 95% with this pervious area being predominantly sandy soils which have been accounted for in the DRAINS model.

8.3. Hydraulic Model Verification

There was no data available to verify the Botany Wetland and Pagewood models. The parameters used in the model were based on parameters used in previous studies for similar catchments. The major flood causing factor in the Botany Wetlands catchment is the inflow form the Centennial Park/Kensington catchment which enters Botany Wetlands at Gardeners Road. This inflow was obtained from the calibrated hydraulic model from the Kensington – Centennial Park Flood Study, June 2013 (Reference 11)

Verification of the MRE hydraulic model was undertaken by:

- Comparing the flood levels collated from all the observed historic storm events to modelled design flood levels;
- Comparing the modelled design results against previous studies; and
- Comparing the data collected from the community consultation to modelled historical events.

8.3.1. Comparison with Observed Flood Levels

All flooding observations from the SWC database were made in areas where surrounding development has changed. As such they are unable to be compared against existing conditions. A description of each recorded level is given in Table 19.

Table 19: Available Historic Flood Level Data

Storm Event	Location	Description
10/3/1975	Gardeners Road, Mascot	0.06 m above northern footpath
10/3/1975	Gardeners Road, Mascot	0.06 m above southern footpath
10/3/1975	Hughes Avenue, Mascot	0.34 m above pathway
10/3/1975	Hughes Avenue, Mascot	0.3 m depth – at top entrance step
10/3/1975	O'Riordan Street, Mascot	0.61 m above coping
17/2/1993	O'Riordan Street, Mascot	Flood marks on safety fence 0.4 m above coping

GARDENERS ROAD LOW POINT

Flooding was reported along Gardeners Road near Ellis Avenue in 1975. In current conditions the site south of the reported flooding has a number of large industrial buildings which block the overland flow path (Photo 8 and Photo 9).

Photo 8: Aerial photograph of Gardeners Road (2011)

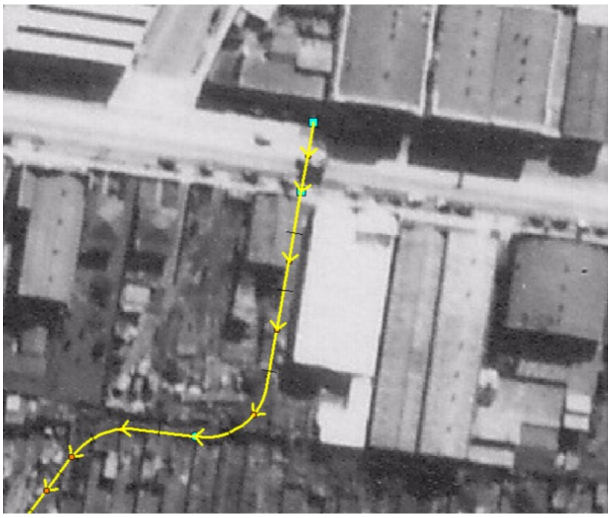


Photo 9: Aerial photograph of Gardeners Road (1953)

The Gardeners Road low point is drained by a 900 mm pipe owned by SWC. Once the pipe or inlet pit capacities are exceeded, water levels within the Gardeners Road low point must reach a flood level of 9.3 mAHD before being able to flow south through properties to Miles Street. This level corresponds to depths of approximately 0.4 to 0.5 m above the Gardeners Road footpath, far in excess of recorded levels.

Aerial photography from 1953 shows that buildings to the south of Gardeners Road do not block the overland flow path as much as existing conditions. Between 1953 and current conditions, the properties south of Gardeners Road have been developed and the situation in 1975 is unknown. As the building layout is a key driver of the flow behaviour, a reliable comparison to the March 1975 historic levels is not possible at this location.

HUGHES AVENUE

Flooding along Hughes Avenue was recorded in March 1975 upstream of SWC's open channel, near the junction of the Hughes Avenue branch and the main Mascot West trunk drainage line. Peak design flood levels from TUFLOW have been compared to the recorded flooding observations in Table 20.

Table 20: Comparison of Observed Flooding in Hughes Avenue to Design Levels

Observation	Ground Level (mAHD)	20% AEP Event		1% AEP Event	
		Level (mAHD)	Depth (m)	Level (mAHD)	Depth (m)
0.34 m above pathway	7.4	7.6	0.4	8.0	0.6
0.3 m depth – at top of entrance step	7.6	7.6	0.0	8.0	0.4

Generally the historic levels are comparable to the design levels.

O'RIORDAN STREET

Flooding within the open channel upstream of O'Riordan Street was observed in March 1975 and February 1993. The area has changed significantly in the past 60 years, with land use changing from open space (Photo 10) to medium density commercial (Photo 11). In current conditions, commercial buildings effectively block the overland flow paths on the eastern, western and northern sides of the channel, reducing its effectiveness in receiving flood waters.

Photo 10: Aerial photograph of open channel upstream O'Riordan Street (1953)

Photo 11: Aerial photograph of open channel upstream O'Riordan Street (2011)

The area adjacent to the open channel is highly vegetated and the level of vegetation is likely to have changed over the years. Survey of the channel was undertaken in May 2013, and examples of existing levels of vegetation are shown on Photo 12 and Photo 13.

Photo 12: Open channel looking downstream towards bridge crossing

Photo 13: Open channel looking upstream from bridge crossing

The exact locations of flood height observations are unknown and it was assumed that they were taken upstream of the pedestrian bridge crossing on the western end of the channel. Comparison of design flood levels against observed flooding observations are made in Table 21.

Table 21: Comparison of Observed Flooding upstream of O'Riordan Street to Design Levels

Date	Observation	Approx Level (mAHD)	20% AEP Flood Level (mAHD)	1% AEP Flood Level (mAHD)
10/3/1975	0.61 m above coping	6.1	5.5	6
17/2/1993	Flood marks on safety fence 0.4 m above coping	5.9	5.5	6

The design flood levels are probably a bit low compared to the observed levels, as they suggest the two observed levels were close to a 1% AEP level which is unlikely. However it is likely that the building changes have reduced levels in this area by obstructing upstream flow, so the results are considered reasonable.

8.3.2. Comparison with Mascot West SWC 63 Capacity Assessment Report (Reference 1)

Comparison was undertaken on the 20% AEP peak flows produced in the TUFLOW hydraulic model and those in the Mascot West SWC 63 Capacity Assessment Report, summarised in Table 22.

The current study has a significant amount of overland flow adjacent to the trunk drainage system. As such, comparisons with Reference 1 in Table 22 are only valid when the majority of flow is contained within the trunk drainage system.

Flows in the current study are consistently lower than those derived in Reference 1. The largest difference between the two studies may be accounted for by the location of the SWSOOS, and changes to buildings in overland flow areas identified above, which act as a physical barrier to overland flow. Additional differences between the studies can be attributed to overland flow paths which occur away from the trunk drainage system, particularly along roads.

Table 22: Reference 1 Peak Flows Compared to the Current Study 20% AEP event

Pipe/Channel ID	Branch	Trunk Drainage Type	SWC Report (1998) (m^3/s)	Current Study (m^3/s)
A-B	Main Branch	Open Channel	17.4	5.7
B-BA	Main Branch	Open Channel	17.0	4.9
BA-C	Main Branch	Open Channel	17.0	4.6
C-D	Main Branch	Closed Section	15.4	4.3
D-E	Main Branch	Closed Section	15.4	4.3
E-F	Main Branch	Open Channel	14.4	4.2
F-G	Main Branch	Open Channel	14.3	4.0
G-H	Main Branch	Closed Section	13.9	3.9
H-J	Main Branch	Closed Section	13.0	4.0
J-K	Main Branch	Open Channel	12.6	4.0
K-L	Main Branch	Open Channel	11.8	3.9
L-M	Main Branch	Closed Section	11.6	3.8
M-N	Main Branch	Closed Section	7.5	2.8
N-O	Main Branch	Closed Section	7.7	2.7
O-P	Main Branch	Closed Section	7.9	2.7
P-PA	Main Branch	Closed Section	7.4	2.7
PA-Q	Main Branch	Open Channel	6.6	2.7
Q-R	Main Branch	Culvert under Carinya Ave	6.6	2.6
R-S	Main Branch	Open Channel	6.2	2.5
S-T	Main Branch	Culvert under Hughes Ave	3.4	1.5
T-U	Main Branch	Open Channel	2.6	1.4
U-V	Main Branch	Closed Section	2.6	1.0
V-W	Main Branch	Closed Section	1.6	1.0
W-X	Main Branch	Closed Section	1.6	1.0
X-Y	Main Branch	Pipe	1.7	0.5
K-KA	Mascot Park Branch	Open Channel	1.0	0.3
KA-KB	Mascot Park Branch	Pipe	1.0	0.3
KB-KC	Mascot Park Branch	Pipe	0.5	0.3
KC-KD	Mascot Park Branch	Pipe	0.5	0.3
M-MA	King St Branch	Closed Section	4.3	1.3
MA-MB	King St Branch	Closed Section	4.3	1.3
S-SA	Hughes St Branch	Closed Section	3.2	0.3
SA-SB	Hughes St Branch	Closed Section	3.2	0.3

Within the King Street branch, a large amount of overland flow is directed south towards Hatfield Street. The catchment area of the Hughes Street branch in the current study is less than previous, with the current study showing some of the total overland flow being directed south down Botany Road and through properties in Hughes Street.

8.3.3. Alexandra Canal Mascot Station Precinct Stormwater Study (Reference 4)

Peak flood depths and flows detailed in Reference 4 were compared to those produced by the current study, as shown in Table 23 and Table 24.

Table 23: Reference 4 Compared to Current Study Results – Peak Flows (m^3/s)

Location	Type	AWT Engineering 20% AEP	AWT Engineering 1% AEP	Current Study 20% AEP	Current Study 1% AEP
Corner of Church Ave and Kent Road	Overland	-	4.7	1.8	4.4
	Piped	-	3.6	1.5	1.8
Western end of Ossary Street	Overland	-	6.1	0.2	0.9
	Piped	-	2.6	1.7	1.6
Outflow pipe near Ossary Street and Ricketty Street	Piped	-	2.7	2.0	1.7
Culvert downstream Mascot Public School	Piped	7.7	7.8	3.8	4
SWC Trunk Drainage downstream of Coward Street	Open Channel	29.9	34.3	6.3	14.9

Peak flows within the Church Avenue, Ossary Street and Ricketty Street catchment were only available from Reference 4 for the 1% AEP event. Church Avenue flows are comparable, however at the western end of Ossary Street the current study produces lower flows due to the majority of overland flow being directed down Ricketty Street instead.

For the Mascot catchment, flows were compared within the trunk drainage system downstream of Mascot Public School and downstream of Coward Street before the SWC open channel discharges into Alexandra Canal.

Significant differences were found between the previous and current study. In the current study it was found that overland flow does not always follow the direction of the trunk drainage system. In a 2D hydraulic model such as TUFLOW, overland flow direction is implicitly accounted for whereas in DRAINS it must be explicitly defined. The DRAINS hydraulic model (i.e. Reference 4) is also likely to have under-estimated catchment attenuation and storage of floodwaters in trapped low points.

Reference 4 has assumed that all properties are fully developed and no overland flow is permitted though them. Where overland flow paths exist, such as at the western end of John Street and Ossary Street, results from Reference 4 are conservative.

In areas near the trunk drainage system or Alexandra Canal the backwater influences are not able to be accounted for within DRAINS, and in these locations depths of ponding are likely to be underestimated.

Table 24: Reference 4 Compared to Current Study Results – Ponding Depths

Location	Reference 4		Current Study	
	Depth[1] (mm)	Level[2] (mAHD)	20% AEP Level (mAHD)	1% AEP Level (mAHD)
Corner of Gardeners Road and Kent Road	850 – 950 (20 – 1% AEP)	3.3 – 4.3	3.3	3.5
Western end of Gardeners Road	750 – 1150 (20 – 1% AEP)	2.7 – 3.1	3.1	3.3
Western end of Ricketty Street	1100 (20 – 1% AEP)	2.0	2.3	2.6
Western end of John Street	400 – 600 (20 – 1% AEP)	6.4 – 6.6	6.1	6.1
John Street between Laycock Street and the SWSOOS	500 (> 20% AEP)	8.5	8.5	8.5
Western end of Ossary Street	1500 – 1700 (20 – 1% AEP)	3.6 – 3.7	2.8	2.9
Western end of Coward Street, approximately 150 metres east of Alexandra Canal	600 – 1000 (20 – 1% AEP)	1.6 – 2.0	2.3	2.5
Western end of Robey Street under railway goods line	Up to 400 (1% AEP)	2.4	2.5	2.5

Note **1)** The potential depths of ponding were estimated assuming that all sites are fully developed and that ponding only occurs in the road reserves and that overland flow only occurs in roadways and drainage easements

2) An approximate ponding level has been estimated for comparative purposes

8.3.4. Botany – Church, John & Ossary Streets Flood Study Report (Reference 5)

Although tabulated results from the DRAINS hydrologic and hydraulic model were included in Reference 5, no figure of the model layout and naming convention was available. As such, it was not possible to compare flow results with those from Reference 5.

Reference 5 estimated design flood levels for the 1% AEP event using a HEC-RAS model and a comparison is summarised in Table 25.

Table 25: Reference 5 Compared to Current Study Results – Peak Level (mAHD)

Location	HEC-RAS Section	Reference 5	Current Study	
		1% AEP Level (mAHD)	20% AEP Level (mAHD)	1% AEP Level (mAHD)
Church St	900	5.1	5.3	5.4
Church St	850	4.7	4.8	4.9
Church St	800	4.4	4.5	4.6
Church St	750	4.0	4.1	4.2
Church St	700	3.9	4.0	4.1
Ossary St	600	3.9	4.0	4.1
Ossary St	550	3.6	3.8	3.9
Ossary St	500	3.2	3.3	3.3

Location	HEC-RAS Section	Reference 5	Current Study	
		1% AEP Level (mAHD)	20% AEP Level (mAHD)	1% AEP Level (mAHD)
Ossary St	450	3.0	3.1	3.1
Ossary St	400	2.7	2.8	2.9
Ossary St	350	2.7	2.8	2.9
Ossary St	300	2.6	2.7	2.8
Industrial area	250	2.6	2.5	2.6
Industrial area	200	2.6	2.3	2.6
Industrial area	150	2.6	2.3	2.6
Industrial area	100	2.6	2.3	2.6
End Ricketty St	50	2.6	2.3	2.6

The previous study assumed that the introduction of OSD within the study area would reduce inflows for the 1% AEP event to a 20% AEP 5 minute duration event. No OSD was included in the hydraulic model of the current flood study.

8.3.5. Verification Events

The choice of calibration or verification events for flood modelling depends on a combination of the severity of the flood event and the quality of the available data. As is the case with most urban studies there was no quantitative data available either in the form of flood marks or surveyed flood levels for the study area. There was qualitative information provided by residents through the community consultation with regard to their properties being flood affected and whether they had been flooded in their yard, garage or above floor level, but this information could not generally be translated to accurate flood levels.

The two events chosen for verification were the November 1984 event and the March 2014 event. The November 1984 event was chosen as it was an event that caused widespread damage in the Sydney region and the March 2014 event was chosen as it was a recent event that was identified through the community consultation as having caused flooding problems in the study area. A comparison of the modelled events is shown in Table 26.

Table 26: Verification events recorded at Mascot Bowling Club (560028)

Storm Events	Duration hr	Rainfall Depth	Estimated ARI
8th November 1984	24	160mm	5yr
8th November 1984	3	66mm	2yr – 5yr
24th March 2014	2	40mm	1 – 2yr

The results shown in Table 27 indicate that model replicates flooding for the historical events in the same locations that resident have reported flooding in the past. The location of the verification points and peak flood depths is shown in Figure 13 to Figure 14.

Table 27: Verification locations and flood depths

ID	Street	Previous Flooding	8th Nov 1984 3hr	8th Nov 1984 24hr	10th Mar 2014 2hr
1	Tranway Street	Garage	0.19	0.19	0.17
2	Macquarie Street	Above Floor	0.18	0.18	0.16
3	Mascot Drive	Garage	0.33	0.43	0.2
4	Cleland Street	Above Floor	0.34	0.38	0.21
5	Picton Street	Above Floor	0.2	0.22	0.14
6	Sutherland Street	Garage	0.24	0.27	0.19
7	Frogmore Street	Garage	0.24	0.31	0.15
8	Frogmore Street	Yard	0.18	0.25	0.1
9	Alfred Street	Above Floor	0.26	0.33	0.15
10	Alfred Street	Above Floor	0.21	0.27	0.11
11	Alfred Street	Yard	0.14	0.22	0.01
12	Johnson Street	Yard	0.12	0.32	0.07
13	Hardie Street	Above Floor	0.39	0.61	0.19
14	Macintosh Street	Garage	0.27	0.43	0.16
15	Turnbridge Street	Above Floor	0.1	0.11	0.06
16	Oliver Street	Garage	0.25	0.3	0.16
17	Oliver Street	Yard	0.16	0.21	0.06
18	O'Riordan Street	Garage	0.26	0.27	0.23
19	Bourke Road	Above Floor	0.19	0.18	0.14

9. DESIGN EVENT MODELLING – MASCOT / ROSEBERY / EASTLAKES

9.1. Overview

Design flood levels in the catchment are a combination of flooding from rainfall over the local catchment, as well as elevated tailwater levels in Alexandra Canal from flooding in the Cooks River, Sheas Creek, and or Botany Wetlands. For simplicity flooding in Alexandra Canal is termed Cooks River flooding whilst flooding from local rainfall and runoff catchment is termed overland flooding.

9.2. Design Flood Levels – Cooks River

Design flood levels for Cooks River flooding are provided in Reference 13 and these are listed in Table 28.

Table 28: Design Flood Levels (Reference 13) in Alexandra Canal (downstream)

Design Event	Alexandra Canal Peak Level (mAHD)
50% AEP	1.6 to 1.7
20% AEP	Data not in Reference
10% AEP	Data not in Reference
5% AEP	2 to 2.3
2% AEP	Data not in Reference
1% AEP	2.4 to 2.7
PMF	3.5 to 4.1

9.3. Critical Duration - Overland Flooding

To determine the critical storm duration for various parts of the catchment (i.e. produce the highest flood level), modelling of the 1% AEP event was undertaken for a range of design storm durations from 15 minutes to 9 hours, using temporal patterns from AR&R (Reference 2). An envelope of the model results was created, and the storm duration producing the maximum flood depth was determined for each grid point within the study area.

It was found that the 1 and 2 hour design storms were critical at different areas of the catchment, but the peak levels produced were very close. It was determined to use the 2-hour design event as the critical duration for the MRE catchment. In the PMF it was found that the 30 minute, 45 minute and 1 hour design storms were critical at different areas of the catchment, but the 1 hour event produced peak levels very close to the other durations.

Based on this outcome, it was considered appropriate to adopt the 2 hour storm for events up to the 1% AEP event, and the 1 hour storm for the PMF event.

9.4. Downstream Boundary Conditions – Overland Flooding

In addition to runoff from the catchment, downstream areas can also be influenced by high water levels within the Alexandra Canal. Consideration must therefore also be given to accounting for the joint probability of coincident flooding from both catchment runoff and the Cooks River / Sheas Creek catchments.

A full joint probability analysis to consider the interaction of these two mechanisms is beyond the scope of the present study. It is accepted practice to estimate design flood levels in these situations using a 'peak envelope' approach that adopts the highest of the predicted levels from the two mechanisms. A table of design tail-water scenarios adopted for this study is given in Table 29 with design levels in Alexandra Canal taken from Reference 13.

For the 2050 and 2100 sea level rise scenarios, water levels within Alexandra Canal were adopted from the Cooks River Floodplain Risk Management Study, 2013 (Reference 14). The study considered sea level rise scenarios, with water levels in Botany Bay of 1.5 mAHD and 2.0 mAHD specified respectively, in accordance with guidelines from the NSW State Government (Reference 15). These guidelines are no longer endorsed by the NSW Government, but in the absence of alternative guidance they provide an appropriate method for assessing potential climate change impacts.

Table 29: Design Rainfall Event and Downstream Boundary Conditions – Overland Flow

Design Event (AEP)	Rainfall Event over the catchment	Design Water Level in Alexandra Canal
50% AEP	50% AEP	50% AEP
20% AEP	20% AEP	20% AEP
10% AEP	10% AEP	10% AEP
5% AEP	5% AEP	5% AEP
2% AEP	2% AEP	5% AEP
1% AEP	1% AEP	5% AEP
PMF	PMP	1% AEP

9.5. Design Results

The results from this study are presented for both Overland Flow and Cooks River flooding as:

- Peak flood depths and level contours in Figure B1 to Figure B7;
- Peak flood velocities in Figure B8 to Figure B14;
- Provisional hydraulic hazard in Figure B15 to Figure B16; and
- Provisional hydraulic categorisation in Figure B17 to Figure B18.

The results have been provided to CBB in digital format compatible Council's Geographic Information Systems. The digital data should be used in preference to the figures in this report as they provide more detail.

9.5.1. Summary of Results

Peak flood levels, depths and flows at key locations within the catchment are summarised below. These key locations coincide with the key locations used for the sensitivity analysis discussed in Section 11. A tabulated summary of peak flood depth and level results at key locations as shown in Figure 10 are detailed in Table 30.

Table 30: Peak Flood Levels (m AHD) and Depths (m) at Key Locations – MRE Catchment

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
H01	Gardeners Road between Ellis and Botany Road	Level	9.3	9.3	9.4	9.4	9.4	9.4	9.8
		Depth	0.4	0.5	0.5	0.5	0.5	0.6	0.9
H02	Macintosh Street	Level	6.8	6.8	6.9	7	7.1	7.2	7.6
		Depth	0.2	0.3	0.3	0.5	0.6	0.7	1.1
H03	Mascot Primary School	Level	6.7	6.8	6.9	7	7.1	7.2	7.6
		Depth	0.4	0.6	0.6	0.7	0.8	0.9	1.3
H04	Robey Street	Level	4.8	4.9	5	5.3	5.7	6	6.1
		Depth	0.1	0.2	0.3	0.6	1	1.3	1.4
H05	Baxter Road	Level	4.8	4.9	5	5.3	5.7	6	6.1
		Depth	0.4	0.5	0.6	0.9	1.3	1.6	1.7
H06	O'Riordan Street (between Coward St and Bourke Rd)	Level	7.2	7.3	7.3	7.4	7.4	7.5	8.0
		Depth	0.3	0.3	0.4	0.4	0.5	0.5	1.1
H07	Gardeners Road and Kent Road	Level	3.3	3.3	3.4	3.4	3.4	3.5	3.8
		Depth	0.5	0.6	0.6	0.7	0.7	0.7	1
H08	Gardeners Road	Level	3	3.1	3.1	3.2	3.2	3.3	3.6
		Depth	1	1.1	1.2	1.2	1.3	1.3	1.7
H09	John Street (between Laycock Street and the SWSOOS)	Level	8.5	8.5	8.5	8.5	8.5	8.5	8.8
		Depth	0.4	0.4	0.5	0.5	0.5	0.5	0.8
H10	Kent Road and Church Avenue	Level	3.9	4	4	4	4.1	4.1	4.3
		Depth	0.2	0.3	0.4	0.4	0.4	0.5	0.7
H11	Ossary Street (West)	Level	2.7	2.8	2.8	2.8	2.8	2.8	3.1
		Depth	0.5	0.6	0.6	0.6	0.6	0.7	0.9
H12	Ricketty Street	Level	2.1	2.3	2.4	2.5	2.5	2.6	3.0
		Depth	0.8	1	1.1	1.2	1.2	1.2	1.6
H13	Coward Street (West)	Level	2	2.3	2.4	2.4	2.5	2.5	2.9
		Depth	0.9	1.2	1.3	1.3	1.4	1.4	1.8
H14	O'Riordan Street (between King and Ewan Street)	Level	6.7	6.8	6.8	6.8	6.8	6.8	6.9
		Depth	0.4	0.4	0.4	0.5	0.5	0.5	0.6
H15	Ewan Street (West)	Level	4.7	4.9	5	5.1	5.2	5.3	5.8
		Depth	0.8	1	1.1	1.2	1.3	1.4	1.8
H16	O'Riordan Street (between Baxter Rd and Joyce Dr)	Level	5	5	5.1	5.1	5.1	5.1	5.3
		Depth	0.9	0.9	0.9	1	1	1	1.1
H17	Botany Lane	Level	5.6	5.9	6.1	6.2	6.3	6.4	6.8
		Depth	0.3	0.6	0.8	0.9	1	1	1.5
H18	Hardie Street	Level	5.7	5.9	6.1	6.2	6.3	6.4	6.9
		Depth	0.2	0.4	0.6	0.7	0.8	0.9	1.3
H19	Hollingshed Street	Level	5.7	5.9	6.1	6.2	6.3	6.4	6.9
		Depth	0.1	0.4	0.5	0.7	0.8	0.8	1.3
H20	Corner Cleland Street and Francis Street	Level	10	10.1	10.2	10.2	10.3	10.3	10.7
		Depth	0.3	0.4	0.4	0.5	0.5	0.5	0.9

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
H21	Florence Street	Level	12	12.2	12.3	12.3	12.4	12.4	12.7
		Depth	0.1	0.3	0.4	0.5	0.5	0.5	0.8
H22	Frogmore Street	Level	6.7	6.8	6.9	6.9	7	7.1	7.7
		Depth	0.2	0.2	0.3	0.4	0.4	0.5	1.1
H23	Mascot Drive	Level	14.8	14.9	15	15	15.1	15.1	15.4
		Depth	0.5	0.6	0.6	0.7	0.8	0.8	1.1
H24	Barber Street	Level	14.8	14.9	15	15	15.1	15.1	15.4
		Depth	0.6	0.7	0.7	0.8	0.8	0.9	1.2
H25	Randolph Street	Level	13.5	13.6	13.6	13.6	13.7	13.7	14.1
		Depth	0.3	0.4	0.4	0.5	0.5	0.5	0.9
H26	Hardie Ln	Level	5.8	5.9	6.1	6.2	6.3	6.4	6.9
		Depth	0	0.2	0.4	0.5	0.6	0.7	1.2
H27	Johnson St	Level	6.2	6.2	6.3	6.3	6.4	6.5	7.0
		Depth	0.1	0.1	0.1	0.2	0.2	0.3	0.9

The tabulated summary of peak flows at the key locations is shown in Table 31.

Table 31: Peak Flows (m^3/s) at Key Locations – MRE Catchment

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Q01	Upstream of Miles Street	Overland	0.2	0.6	0.9	1.4	2	2.6	15.8
		Pipe/Channel	0.8	1	1.1	1.1	1.2	1.4	1.4
Q02	Between Forster and Macintosh Streets	Overland	0.2	0.8	1.3	2.1	3.1	4.2	34.8
		Pipe/Channel	0.6	0.8	0.9	1	1.2	1.2	1.4
Q03	King Street south of Mascot Public School	Overland	0.2	0.4	0.5	0.5	0.6	1.2	33.8
		Pipe/Channel	0.1	0.1	0.3	0.5	0.8	1.1	1.7
Q04	Robey Street	Overland	0.3	0.4	0.5	0.8	1.3	1.9	46.2
		Pipe/Channel	0.9	1	1.1	1.1	1.1	1.1	1.8
Q05	Upstream of O'Riordan Street	Overland	-	-	-	-	-	-	-
		Pipe/Channel	2.7	4	4.1	4.2	4.2	4.3	4.7
Q06	Gardeners Road (West)	Overland	0.5	1.3	1.8	2.4	2.8	3.4	12.8
		Pipe/Channel	0.9	0.8	0.8	0.7	0.7	0.7	0.8
Q07	Church Avenue (West)	Overland	1.2	1.8	2.3	3	3.6	4.4	18.6
		Pipe/Channel	1	1.4	1.7	1.7	1.8	1.8	2.1
Q08	Ricketty Street	Overland	0.4	0.8	1.6	2.6	3.5	4.5	19.3
		Pipe/Channel	-	-	-	-	-	-	0.1
Q09	Ossary Street	Overland	0	0.2	0.4	0.6	0.7	0.9	4.1
		Pipe/Channel	1.7	1.7	1.6	1.6	1.6	1.6	1.5
Q10	Coward Street	Overland	1.2	2.2	2.8	3.5	4.2	4.9	20.2
		Pipe/Channel	0.5	0.4	0.3	0.1	0.1	0.1	0.1
Q11	Coward Street (north of Open Channel)	Overland	0	1.4	2.8	4.5	5.4	6.3	21.5
		Pipe/Channel	-	-	-	-	-	-	-
Q12	O'Riordan Street Underpass	Overland	0.3	0.4	0.5	0.6	0.7	1	3.3
		Pipe/Channel	-	-	-	-	-	-	-
Q13	Robey Street Underpass	Overland	0.7	0.7	0.7	0.6	0.7	0.9	4.0
		Pipe/Channel	0.6	0.6	0.6	0.6	0.6	0.6	1.1
Q14	Trunk Drainage (D/S Mascot Primary School)	Overland	-	-	-	-	-	-	-
		Pipe/Channel	2.5	3.8	4	4.2	3.9	3.9	3.9
Q15	Trunk Drainage (U/S O'Riordan	Overland	-	-	-	-	-	-	-

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
	Street)	Pipe/Channel	2.7	4	4.1	4.2	4.2	4.3	4.7
Q16	Trunk Drainage (D/S Qantas Car Park)	Overland	-	-	-	-	-	-	-
		Pipe/Channel	2.9	4.3	4.8	5.1	5.8	6.3	10.9
Q17	Trunk Drainage (D/S Coward Street)	Overland	-	-	-	-	-	-	-
		Pipe/Channel	3.6	6.3	8.7	11	12.9	14.9	43.8
Q18	Botany Lane	Overland	0.1	0.2	0.4	0.6	0.7	0.8	6.0
		Pipe/Channel	2.4	3.7	4.1	4.3	4.3	4.3	4.5
Q19	Hardie Street	Overland	0.2	0.3	0.3	0.4	0.6	0.8	7.6
		Pipe/Channel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Q20	Hollingshed Street	Overland	0.2	0.7	1.1	2.1	3.3	4.5	25.6
		Pipe/Channel	1.3	1.9	2.2	2.2	2.3	2.3	2.8
Q21	Corner Cleland Street and Francis Street	Overland	0.4	0.8	1	1.4	1.6	1.9	7.0
		Pipe/Channel	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Q22	Florence Street	Overland	0.1	0.5	1.1	1.8	2.6	3.4	14.2
		Pipe/Channel	1	1.4	1.4	1.4	1.4	1.4	1.6
Q23	Frogmore Street	Overland	0.2	0.4	0.6	0.9	1.2	1.4	4.9
		Pipe/Channel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Q24	Mascot Drive	Overland	0.1	0.1	0.1	0.1	0.2	0.3	0.7
		Pipe/Channel	0	0	0	0	0	0	0.1
Q25	Barber Street	Overland	0.2	0.3	0.5	0.6	0.8	1	2.8
		Pipe/Channel	0	0	0	0.1	0.1	0.1	0.1
Q26	Randolph Street	Overland	0.2	0.2	0.3	0.4	0.4	0.5	2.1
		Pipe/Channel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Q27	Hardie Ln	Overland	0	0.1	0.1	0.1	0.1	0.1	0.2
		Pipe/Channel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Q28	Johnson St	Overland	0.1	0.2	0.3	0.3	0.3	0.4	1.8
		Pipe/Channel	-	-	-	-	-	-	-

9.5.2. Provisional Hydraulic Categorisation

The hydraulic categories, namely floodway, flood storage and flood fringe, are described in the Floodplain Development Manual (Reference 16). However, there is no technical definition of hydraulic categorisation that would be suitable for all catchments, and different approaches are used by different consultants and authorities, based on the specific features of the study catchment in question.

For this study, hydraulic categories were defined by the following criteria, which correspond in part with the criteria proposed by Howells et. al, 2003 (Reference 17):

- Floodway is defined as areas where:
  - the peak value of velocity multiplied by depth (V x D) > 0.25 m^2/s **AND** peak velocity > 0.25 m/s, **OR**
  - peak velocity > 1.0 m/s **AND** peak depth > 0.15 m

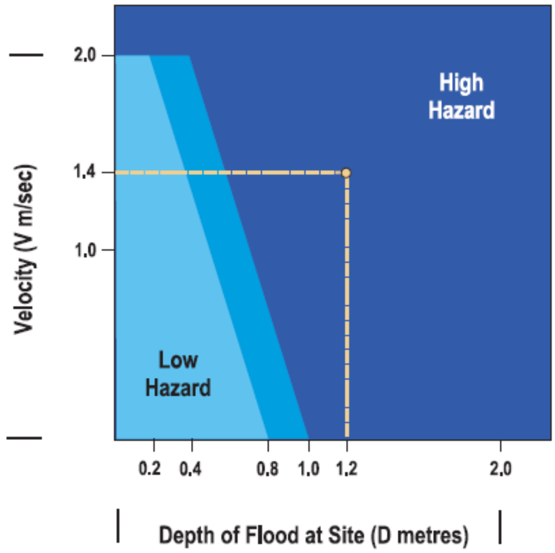
The remainder of the floodplain is either Flood Storage or Flood Fringe,

- Flood Storage comprises areas outside the floodway where peak depth > 0.5 m; and
- Flood Fringe comprises areas outside the Floodway where peak depth < 0.5 m.

9.5.3. Provisional Flood Hazard Categorisation

Provisional hazard categories were determined in accordance with Appendix L of the NSW Floodplain Development Manual (Reference 16), the relevant section of which is shown in Diagram 3. For the purposes of this report, the transition zone presented in Diagram 3 (L2) was considered to be high hazard.

Diagram 3: (L2) Velocity and Depth Relationship; (L2) Provisional Hydraulic Hazard Categories (NSW State Government, 2005)



10. DESIGN EVENT MODELLING – BOTANY WETLANDS

10.1. Overview

Design flood levels in the catchment are a combination of the inflows from the upstream catchments outlined in Section 7.2.1 as well and the contribution of local overland flow. Elevated tailwater levels from Port Botany do not significantly influence flooding within the wetland pond system, although this may change under potential future sea level rise scenarios.

10.2. Critical Duration - Overland Flooding

To determine the critical storm duration for various parts of the catchment (i.e. produce the highest flood level), modelling of the 1% AEP event was undertaken for a range of design storm durations from 15 minutes to 36 hours, using temporal patterns from AR&R (Reference 2). An envelope of the model results was created, and the storm duration producing the maximum flood depth was determined for each grid point within the study area.

PAGEWOOD

It was found that the 25 minute duration storm was critical across the majority of the catchment, the exception being at two locations on Bay Street. The first location situated adjacent to the railway line and the second situated at the intersection with Lang Avenue. The differences in flood levels adjacent to the railway line were negligible. There is a trapped low point on Bay Street near the intersection with Lang Avenue and therefore the longer duration events will tend to produce greater flood levels due to the volume of water being the main contributing factor. Drainage details for this low point were not known with confidence. For a consistent approach across the entire catchment the shorter 25 minute duration was chosen for all events from the 50% AEP through to the PMF.

BOTANY WETLANDS

It was found that the 9 hour duration storm was critical across the majority of the catchment. When the 9 hour event was compared against the envelope of all the durations tested the differences were negligible therefore the 9 hour duration storm was adopted for all events from the 50% AEP through to the 1% AEP event. The critical duration for the PMF was the 6 hour event.

10.3. Downstream Boundary Conditions – Botany Bay

Assumed downstream water levels in Botany Bay for design flooding were adopted from Reference 22, to provide a consistent assumption across the catchment. The assumed levels were reviewed and considered reasonable. The levels are summarised in Table 32.

Table 32: Assumed Botany Bay Tailwater Levels

Design Event (AEP)	Design Tidal Level Botany Bay
50% AEP	1.2
20% AEP	1.2
10% AEP	1.2
5% AEP	1.4
2% AEP	1.42
1% AEP	1.43
PMF	1.45

10.4. Design Results

The results from this study are presented for both Botany Wetlands and Pagewood as:

- Peak flood depths and level contours in Figure C1 to Figure C7
- Peak flood velocities in Figure C8 to Figure C14
- Provisional hydraulic hazard in Figure C15 to Figure C16; and
- Provisional hydraulic categorisation in Figure C17 to Figure C18

The mapping extent for Figure C1 to Figure C18 includes the Pagewood urban catchment and the Botany Wetlands. The Bay Street catchment was not included in the mapping as it is outside the scope of this study. This area is very low lying and has been known to flood from even minor local rainfall in conjunction with a high tide. WMAwater understands that this area will be investigated in more detail in a future study. This study has identified that flooding in Botany Wetlands will not spill over into the Bay St catchment up to the 1% AEP event, but overflow is likely to occur in more extreme events such as the PMF.

10.4.1. Summary of Results

Peak flood levels, depths and flows at key locations within the catchment are summarised below. These key locations coincide with the key locations used for the sensitivity analysis discussed in Section 11. A tabulated summary of peak flood depth and level results at key locations as shown in Figure 11 are detailed in Table 33.

Table 33: Peak Flood Levels (m AHD) and Depths (m) at Key Locations – BW Catchment

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
L01	Eastlakes Golf Club Car Park	Level	17.4	17.6	17.6	17.8	17.9	18	18.3
		Depth	-	-	-	-	-	-	-
L02	Eastlakes Golf Course East	Level	16.7	16.8	16.9	17	17.2	17.3	18
		Depth	-	-	-	-	-	-	-
L03	Eastlakes	Level	14.9	15.1	15.3	15.4	15.6	15.8	16.6
		Depth	-	-	-	-	-	-	-

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
L04	Wentworth Avenue	Level	10.4	10.7	10.9	11.1	11.4	11.6	12.5
		Depth	-	-	-	-	-	-	-
L05	The Lakes Golf Course	Level	6.3	6.6	6.7	7	7.2	7.3	8
		Depth	-	-	-	-	-	-	-
L06	Botany Road	Level	3.8	3.9	4	4.1	4.2	4.3	5.3
		Depth	-	-	-	-	-	-	-
L07	Mill Pond	Level	1.7	1.9	1.9	2	2.1	2.2	4.1
		Depth	-	-	-	-	-	-	-
L08	Bay Street Adjacent to Railway	Level	8.5	8.6	8.7	8.8	8.8	8.9	8.9
		Depth	0.2	0.4	0.4	0.5	0.6	0.6	0.6
L09	Banksia Street adjacent to Railway	Level	9.8	9.8	9.8	9.9	9.9	9.9	9.9
		Depth	0.3	0.4	0.4	0.4	0.4	0.4	0.5
L10	Heffron Street near Wentworth Avenue	Level	13.9	14	14	14	14	14	14.1
		Depth	0.3	0.3	0.3	0.3	0.4	0.4	0.4
L11	Bay Street near Lang Avenue	Level	13.6	13.7	13.7	13.8	13.8	13.8	13.9
		Depth	0.4	0.4	0.5	0.5	0.6	0.6	0.7
L12	Eastlakes Golf Course Near Cowper Ave	Level	13.6	13.6	13.6	13.6	13.6	13.6	13.6
		Depth	0.1	0.1	0.1	0.1	0.1	0.1	0.1
L13	Prothero Place	Level	26.6	26.6	26.6	26.6	26.6	26.6	26.6
		Depth	0.2	0.2	0.2	0.2	0.2	0.3	0.3
L14	Corner Martin Avenue and Donaldson Street	Level	19.9	19.9	19.9	19.9	19.9	19.9	19.9
		Depth	0.03	0.03	0.03	0.03	0.04	0.04	0.05

The tabulated summary of peak flows at the key locations is shown in Table 31.

Table 34: Peak Flows (m^3/s) at Key Locations – BW Catchment

ID	Location	Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
L01	Eastlakes Golf Club Car Park	BW	21.2	27.5	29.1	35.2	46.6	55.3	69.3
		Piped	-	-	-	-	-	-	-
L02	Eastlakes Golf Course East	BW	20.3	28.1	31.2	40.6	55	65.8	96.8
		Piped	-	-	-	-	-	-	-
L03	Eastlakes	BW	15.8	25.5	34.9	45.8	60.3	72.1	226.1
		Piped	-	-	-	-	-	-	-
L04	Wentworth Avenue	BW	14.8	24.5	32.9	43.6	58.7	68.8	140.9
		Piped	-	-	-	-	-	-	-
L05	The Lakes Golf Course	BW	14.5	24.3	32.3	43.1	57.7	66.5	101.4
		Piped	-	-	-	-	-	-	-
L06	Botany Road	BW	14.4	24.2	32.3	42.7	57.1	66.4	175.8
		Piped	-	-	-	-	-	-	-
L07	Overtopping SWOOS	BW	0	0	0	0	0	0	76.7
		Piped	-	-	-	-	-	-	-
L08	Bay Street Adjacent to Railway	Overland	1	1.5	1.7	2	2.1	2.2	3.1
		Piped	0.2	0.2	0.2	0.2	0.2	0.2	0.2
L09	Banksia Street adjacent to Railway	Overland	0.7	1.1	1.3	1.7	1.8	2	2.7
		Piped	0.2	0.2	0.2	0.2	0.3	0.3	0.3
L10	Heffron Street near Wentworth Avenue	Overland	0.7	1.2	1.4	1.7	1.8	2.2	3.6
		Piped	0.2	0.3	0.3	0.3	0.3	0.3	0.3
L11	Bay Street near Lang Avenue	Overland	0	0	0	0	0	0	0
		Piped	0	0	0	0	0.1	0	0.1
L12	Eastlakes Golf Course Near Cowper Ave	Overland	0.5	0.8	0.9	1.1	1.1	1.2	1.3
		Piped	0	0.1	0.1	0.1	0.1	0.1	0.1
L13	Prothero Place	Overland	0.1	0.2	0.2	0.3	0.3	0.3	0.5
		Piped	-	-	-	-	-	-	-
L14	Corner Martin Avenue and Donaldson Street	Overland	0.1	0.2	0.3	0.3	0.3	0.4	0.6
		Piped	0.1	0.1	0.1	0.1	0.1	0.1	0.1

10.4.2. Provisional Flood Hazard Categorisation

Refer to Section 9.5.3

10.4.3. Provisional Hydraulic Categorisation

Refer to Section 9.5.2

11. SENSITIVITY ANALYSIS

11.1. Overview

A number of sensitivity analyses were undertaken for each hydraulic model to establish the variation in design flood levels and flow that may occur if different parameter assumptions were made. These sensitivity scenarios, shown in Table 35.

Table 35: Overview of Sensitivity Analyses

Scenario	Description
Manning's "n"	The hydraulic roughness values were increased and decreased by 20%
Pipe, Culvert and open Channel Blockage	Sensitivity to blockage of all culverts was assessed for 25%, 50% and 75% blockage, open channels were assessed for blockage at bridge crossing and culvert entrances for the same percentages and Sensitivity to blockage of key "soakaway" culverts was assessed (Baxter Rd, Ewan St, King St)
Climate Change	Sensitivity to rainfall and runoff estimates were assessed by increasing the rainfall intensities by 10%, 20% and 30% as recommended under the current guidelines; Sea level rise scenarios of 0.4 m and 0.9 m were assessed.

11.2. Climate Change Background

Intensive scientific investigation is ongoing to estimate the effects that increasing amounts of greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide, ozone) are having on the average earth surface temperature. Changes to surface and atmospheric temperatures may affect climate and sea levels. The extent of any permanent climatic or sea level change can only be established with certainty through scientific observations over several decades. Nevertheless, it is prudent to consider the possible range of impacts with regard to flooding and the level of flood protection provided by any mitigation works.

Based on the latest research by the United Nations Intergovernmental Panel on Climate Change, evidence is emerging on the likelihood of climate change and sea level rise as a result of increasing greenhouse gasses. In this regard, the following points can be made:

- greenhouse gas concentrations continue to increase;
- global sea level has risen about 0.1 m to 0.25 m in the past century;
- many uncertainties limit the accuracy to which future climate change and sea level rises can be projected and predicted.

11.2.1. Rainfall Increase

The Bureau of Meteorology has indicated that there is no intention at present to revise design rainfalls to take account of the potential climate change, as the implications of temperature changes on extreme rainfall intensities are presently unclear, and there is no certainty that the changes would in fact increase design rainfalls for major flood producing storms. There is some recent literature by CSIRO that suggests extreme rainfalls may increase by up to 30% in parts of

NSW (in other places the projected increases are much less or even decrease); however this information is not of sufficient accuracy for use as yet (Reference 18).

Any increase in design flood rainfall intensities will increase the frequency, depth and extent of inundation across the catchment. It has also been suggested that the cyclone belt may move further southwards. The possible impacts of this on design rainfalls cannot be ascertained at this time as little is known about the mechanisms that determine the movement of cyclones under existing conditions.

Projected increases to evaporation are also an important consideration because increased evaporation would lead to generally dryer catchment conditions, resulting in lower runoff from rainfall. Mean annual rainfall is projected to decrease, which will also result in generally dryer catchment conditions.

The combination of uncertainty about projected changes in rainfall and evaporation makes it extremely difficult to predict with confidence the likely changes to peak flows for large flood events within the Mascot, Rosebery and Eastlakes catchment under warmer climate scenarios.

In light of this uncertainty, the NSW State Government's (Reference 18) advice recommends sensitivity analysis on flood modelling should be undertaken to develop an understanding of the effect of various levels of change in the hydrologic regime on the project at hand. Specifically, it is suggested that increases of 10%, 20% and 30% to rainfall intensity be considered.

11.2.2. Sea Level Rise

The *NSW Sea Level Rise Policy Statement* (Reference 19) was released by the NSW Government in October 2009. This Policy Statement was accompanied by the *Derivation of the NSW Government's sea level rise planning benchmarks* (Reference 20) which provided technical details on how the sea level rise assessment was undertaken. Additional guidelines were issued by OEH, including the *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments 2010* (Reference 15).

The Policy Statement says:

> *"Over the period 1870-2001, global sea levels rose by 20 cm, with a current global average rate of increase approximately twice the historical average. Sea levels are expected to continue rising throughout the twenty-first century and there is no scientific evidence to suggest that sea levels will stop rising beyond 2100 or that current trends will be reversed… However, the 4th Intergovernmental Panel on Climate Change in 2007 also acknowledged that higher rates of sea level rise are possible"* (Reference 19).

In light of this uncertainty, the NSW State Government's advice is subject to periodical review. As of 2012 the NSW State Government withdrew endorsement of sea level rise predictions but still requires sea level rise to be considered. In the absence of any other advice the previous NSW State Government benchmarks of sea level rise of 0.4 m by the year 2050 and 0.9 m by the year 2100, relative to 1990 levels have been adopted in this study.

11.3. Sensitivity Analysis Results – MRE

The sensitivity scenario results were compared to the 1% AEP rainfall event with the 5% AEP ocean level. A summary of peak flood level and peak flow differences at various locations are provided in:

- Table 36 for variations in routing and roughness;
- Table 37 and Table 38 for variations in blockage;
- Table 39 for variations in climate conditions.

11.3.1. Roughness Variations – MRE

Overall peak flood level results were shown to be relatively insensitive to variations in the roughness parameter. The largest change in flood levels occurs within the Robey Street and Baxter Road low points, which have a contributing catchment extending from Gardeners Road and Botany Road. The time taken for flow to concentrate in these low points is generally longer than the rest of the catchment. Therefore, assuming no downstream pipe blockage, the routing speed of overland flow will influence the total volume of water stored in these locations.

These results were found to be within ± 0.1 m, which can usually be accommodated within the freeboard (typically 0.5 m), applied to the 1% AEP results to determine the Flood Planning Level.

Table 36: Results of Roughness Variation Sensitivity Analysis – 1% AEP Levels (m)

ID	Location	Peak Flood Level 1% AEP	Difference with 1% AEP (m)	
			Roughness Decreased by 20%	Roughness Increased by 20%
H01	Gardeners Rd between Ellis Ave and Botany Rd	9.4	-0.01	0.01
H02	Macintosh Street	7.2	0.02	-
H03	Mascot Primary School	7.2	0.02	0
H04	Robey Street	6	0.04	-0.03
H05	Baxter Road	6	0.04	-0.03
H06	O'Riordan St (between Coward St and Bourke Rd)	7.5	0.01	-0.01
H07	Gardeners Road and Kent Road	3.5	-0.01	0.01
H08	Gardeners Road	3.3	-0.01	0.01
H09	John Street (between Laycock Street and the SWSOOS)	8.5	-0.01	0.01
H10	Kent Road and Church Avenue	4.1	-0.01	0
H11	Ossary Street (West)	2.8	-0.01	0.01
H12	Ricketty Street	2.6	-0.01	0.01
H13	Coward Street (West)	2.5	-0.01	0.01
H14	O'Riordan Street (between King and Ewan St)	6.8	-	-
H15	Ewan Street (West)	5.3	-	-
H16	O'Riordan Street (between Baxter Rd and Joyce	5.1	-	-

ID	Location	Peak Flood Level 1% AEP	Difference with 1% AEP (m)	
			Roughness Decreased by 20%	Roughness Increased by 20%
	Drive)			
H17	Botany Lane	6.4	0.01	-0.01
H18	Hardie Street	6.4	-	-0.01
H19	Hollingshed Street	6.4	0.01	-0.01
H20	Corner Cleland Street and Francis Street	10.3	-0.01	0.01
H21	Corner Cleland Street and Francis Street	12.4	-0.01	0.01
H22	Florence Street	7.1	0	-
H23	Mascot Drive	15.1	-0.01	0.01
H24	Barber Street	15.1	-0.01	-

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

11.3.2. Blockage Variations - MRE

Peak flood level results were found to be relatively sensitive to blockage of the underground pipes in the drainage system. This is due to the large number of trapped low points in the study area. Some of the worst affected areas include the Robey Street and Baxter Road areas, which CBB has indicated are drained by a "soakaway" system. When these pipes become blocked, flood levels will increase by up to 0.3 m. The Ewan Street trapped low point is another example where blockage of the "soakaway" pipes increase flood levels by up to 0.3 m. Ewan Street is particularly susceptible due to the small pipe sizes (< 450 mm) draining the location.

Table 37: Results of Pipe Blockage Sensitivity Analysis – 1% AEP Depths (m)

ID	Location	Peak Flood Level 1% AEP	Difference with 1% AEP (m)		
			Culverts blocked 25%	Culverts blocked 50%	Culverts blocked 75%
H01	Gardeners Rd between Ellis and Botany Rd	9.4	-	-	-
H02	Macintosh Street	7.2	-	-	-
H03	Mascot Primary School	7.2	-	-	-
H04	Robey Street	6	0.1	0.2	0.3
H05	Baxter Road	6	0.1	0.2	0.3
H06	O'Riordan St (between Coward St and Bourke Rd)	7.5	-	0.1	0.2
H07	Gardeners Road and Kent Road	3.5	-	-	-
H08	Gardeners Road	3.3	-	-	-
H09	John Street (between Laycock Street and the SWSOOS)	8.5	-	0.1	0.1
H10	Kent Road and Church Avenue	4.1	-	-	-
H11	Ossary Street (West)	2.8	-	-	-
H12	Ricketty Street	2.6	-	-	-
H13	Coward Street (West)	2.5	-	-	-
H14	O'Riordan Street (between King and Ewan St)	6.8	-	-	-

ID	Location	Peak Flood Level 1% AEP	Difference with 1% AEP (m)		
			Culverts blocked 25%	Culverts blocked 50%	Culverts blocked 75%
H15	Ewan Street (West)	5.3	-	-	0.1
H16	O'Riordan Street (between Baxter Rd and Joyce Drive)	5.1	-	-	-
H17	Botany Lane	6.4	-	0.1	0.1
H18	Hardie Street	6.4	-	0.1	0.1
H19	Hollingshed Street	6.4	-	0.1	0.1
H20	Corner Cleland Street and Francis Street	10.3	-	-	-
H21	Corner Cleland Street and Francis Street	12.4	-	-	-
H22	Florence Street	7.1	-	-	0.1
H23	Mascot Drive	15.1	-	-	-
H24	Barber Street	15.1	-	-	-

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

Table 38: Results of Flowpath Blockage Sensitivity Analysis – 1% AEP Levels (m)

ID	Location	Peak Flood Depth 1% AEP	Difference with 1% AEP (m)
			Soakaways Blocked
H04	Robey Street	0.2	0.38
H05	Baxter Road	0.5	0.38
H15	Ewan Street (West)	0.6	0.29

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

11.3.3. Climate Variations – MRE

The effect of increasing the design rainfalls by 10%, 20% and 30% was evaluated for the 1% AEP rainfall event with impacts on peak flood levels observed throughout the study area. Generally speaking, each incremental 10% increase in rainfall results in an increase in peak flood levels at most of the locations analysed. The 1% AEP event with a rainfall increase of 30% is approximately equivalent to a 0.2% AEP event in present day conditions. The largest variation in flood level occurred within Robey Street, Baxter Road and Ewan Street.

Sea level rise scenarios have the greatest effect on the western side of the catchment, near Alexandra Canal. Within the Ricketty Street, Ossary Street and Coward Street trapped low points flood levels were found to increase by approximately 0.1 m. Adjacent to the open channel trunk drainage system, the increase in flood level was closer to 0.3 m. Increases due to sea level rise were generally limited to west of Kent Road. Directly adjacent to the open channel, increases in flood level were found to extend to downstream of O'Riordan Street.

Table 39: Results of Climate Change Analysis – 1% AEP Depths (m)

ID	Location	Peak Flood Depth 1% AEP	Difference with 1% AEP (m)				
			Rain +10%	Rain +20%	Rain +30%	2050 Sea Level Rise + 0.4 m	2100 Sea Level Rise + 0.9 m
H01	Gardeners Rd between Ellis and Botany Rd	9.4	0.02	0.04	0.05	-	-
H02	Macintosh Street	7.2	0.05	0.09	0.13	-	-
H03	Mascot Primary School	7.2	0.05	0.09	0.13	-	-
H04	Robey Street	6	0.13	0.23	0.29	-	-
H05	Baxter Road	6	0.13	0.23	0.29	-	-
H06	O'Riordan St (between Coward St and Bourke Rd)	7.5	0.04	0.08	0.13	-	-
H07	Gardeners Road and Kent Road	3.5	0.02	0.03	0.04	0.03	-
H08	Gardeners Road	3.3	0.03	0.05	0.07	0.06	0.02
H09	John Street (between Laycock Street and the SWSOOS)	8.5	0.02	0.03	0.05	-	-
H10	Kent Road and Church Avenue	4.1	0.01	0.03	0.04	-	-
H11	Ossary Street (West)	2.8	0.02	0.03	0.04	0	0.01
H12	Ricketty Street	2.6	0.03	0.05	0.08	0.05	0.12
H13	Coward Street (West)	2.5	0.03	0.05	0.07	0.05	0.14
H14	O'Riordan Street (between King and Ewan St)	6.8	0.01	0.02	0.03	-	-
H15	Ewan Street (West)	5.3	0.06	0.12	0.17	-	-
H16	O'Riordan Street (between Baxter Rd and Joyce Drive)	5.1	0.02	0.03	0.04	-	-
H17	Botany Lane	6.4	0.04	0.08	0.11	-	-
H18	Hardie Street	6.4	0.04	0.08	0.12	-	-
H19	Hollingshed Street	6.4	0.04	0.08	0.12	-	-
H20	Corner Cleland Street and Francis Street	10.3	0.02	0.04	0.06	-	-
H21	Corner Cleland Street and Francis Street	12.4	0.02	0.04	0.06	-	-
H22	Florence Street	7.1	0.04	0.07	0.11	-	-
H23	Mascot Drive	15.1	0.02	0.05	0.07	-	-
H24	Barber Street	15.1	0.02	0.05	0.07	-	-

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

11.4. Sensitivity Analysis Results – BW

The sensitivity scenario results were compared to the 1% AEP rainfall event with the 1% AEP ocean level. A summary of peak flood level and peak flow differences at various locations are provided in:

- Table 40 for variations in routing and roughness;
- Table 41 for variations in blockage; and
- Table 42 for variations in climate conditions.

11.4.1. Routing and Roughness Variations – BW

Overall peak flood level results in the Botany Wetlands catchment were shown to be relatively insensitive to variations in the roughness parameter. The largest change in flood levels occurs within the Eastlakes Golf Course Car Park and The Lakes Golf Course. This increase has little effect on the surrounding areas. . The Pagewood catchment is insensitive to variations in the roughness parameter and this is due to the steep gradient the majority of the catchment.

These results were found to be within ± 0.1 m, which can usually be accommodated within the freeboard (typically 0.5 m), applied to the 1% AEP results to determine the Flood Planning Level.

Table 40: Results of Roughness Variation Sensitivity Analysis – 1% AEP Levels (m)

ID	Location	Peak Flood Level 1% AEP	Difference with 1% AEP (m)	
			Roughness Decreased by 20%	Roughness Increased by 20%
L1	Eastlakes Golf Club Car Park	9.4	-0.07	0.08
L2	Eastlakes Golf Course East	7.2	-0.02	0.03
L3	Eastlakes	7.2	-0.01	0.01
L4	Wentworth Avenue	6	-0.01	0.03
L5	The Lakes Golf Course	6	0	0.04
L6	Botany Road	7.5	-0.04	0.04
L7	Mill Pond	3.5	0.01	-
L8	Bay Street Adjacent to Railway	3.3	-	-
L9	Banksia Street adjacent to Railway	8.5	-0.01	0.01
L10	Heffron Street near Wentworth Avenue	4.1	-	0.01
L11	Bay Street near Lang Avenue	2.8	-0.01	0.01
L12	Eastlakes Golf Course Near Cowper Ave	2.6	-	-
L13	Prothero Place	2.5	-	-
L14	Corner Martin Avenue and Donaldson Street	6.8	-	-

11.4.2. Blockage Variations – BW

Peak flood levels were found to be relatively insensitive to blockage of the trunk drainage system. This is due to the small capacity of the system, with the majority of the flow being conveyed through overland flow.

Table 41: Results of Pipe Blockage Sensitivity Analysis – 1% AEP Depths (m)

ID	Location	Peak Flood Level 1% AEP	Difference with 1% AEP (m)		
			Culverts blocked 25%	Culverts blocked 50%	Culverts blocked 75%
L8	Bay Street Adjacent to Railway	3.3	0.01	0.02	0.03
L9	Banksia Street adjacent to Railway	8.5	-	-	-
L10	Heffron Street near Wentworth Avenue	4.1	-	-	-
L11	Bay Street near Lang Avenue	2.8	-0.01	-0.02	-0.03
L12	Eastlakes Golf Course Near Cowper Ave	2.6	-	-	-
L13	Prothero Place	2.5	-	-	-
L14	Corner Martin Avenue and Donaldson Street	6.8	-	-	-

11.4.3. Climate Variations - BW

The effect of increasing the design rainfalls by 10%, 20% and 30% was evaluated for the 1% AEP rainfall event with impacts on peak flood levels observed throughout the study area. Generally speaking, each incremental 10% increase in rainfall results in an increase in peak flood levels at most of the locations analysed. The 1% AEP event with a rainfall increase of 30% is approximately equivalent to a 0.2% AEP event in present day conditions. The largest variation in flood level occurred within Eastlakes Golf Course and in the trapped low point on Bay Street near Lang Avenue.

Sea level rise only affected the level of Mill Pond as the rest of the catchment is separated by weirs.

Table 42: Results of Climate Change Analysis – 1% AEP Depths (m)

ID	Location	Peak Flood Depth 1% AEP	Difference with 1% AEP (m)				
			Rain +10%	Rain +20%	Rain +30%	2050 Sea Level Rise + 0.4 m	2100 Sea Level Rise + 0.9 m
L1	Eastlakes Golf Club Car Park	9.4	-	-	-	-	-
L2	Eastlakes Golf Course East	7.2	-	-	0.01	-	-
L3	Eastlakes	7.2	0.02	0.04	0.05	-	-
L4	Wentworth Avenue	6	0.03	0.06	0.08	-	-
L5	The Lakes Golf Course	6	0.02	0.03	0.04	-	-
L6	Botany Road	7.5	0.01	0.03	0.04	-	-
L7	Mill Pond	3.5	0.01	0.02	0.03	0.03	0.5
L8	Bay Street Adjacent to Railway	3.3	-	-	-	-	-
L9	Banksia Street adjacent to Railway	8.5	-	0.01	0.03	-	-
L10	Heffron Street near Wentworth Avenue	4.1	-	-	0.01	-	-
L11	Bay Street near Lang Avenue	2.8	0.03	0.04	0.05	-	-
L12	Eastlakes Golf Course Near Cowper Ave	2.6	0.07	0.09	0.11	-	-
L13	Prothero Place	2.5	0.01	0.01	0.02	-	-
L14	Corner Martin Avenue and Donaldson Street	6.8	0.01	0.01	0.01	-	-

12. FLOODING HOT SPOTS

Historically flooding problems occur throughout the MRE catchment. Some of the areas where flooding is problematic are described here in "hotspots" and are discussed in some detail. Figure B19 provides an overview of the locations discussed.

12.1. Mascot Drive Low Point

The Mascot Drive low point occurs in a natural depression which affects Mascot Drive, Barber Avenue and Evans Avenue. The predominant land use is medium and high density residential (Photo 14 and Photo 15) and the upstream catchment includes the Eastlakes shopping centre and Eastlakes Reserve. Flooding with the low point is controlled by high ground levels to the east of Maloney Street and flood waters reach depths of up to 1 m in the 1% AEP event.

Photo 14: Medium density residential on Barber Ave

Photo 15: Corner of Mascot Drive and Barber Ave looking west

Design flood levels within the low point are shown in Table 43 with Figure B20 showing the location of the low point, topography and flood depths and extents.

Table 43: Design Flood Levels within the Mascot Drive low point

Event	Peak Flood Level (mAHD)
50% AEP	14.8
20% AEP	14.9
10% AEP	15
5% AEP	15
2% AEP	15.1
1% AEP	15.1
PMF	15.4

12.2. Florence Avenue

The Florence Avenue catchment drains from the north near Evans Avenue to the south near the East Lakes Golf Course. The majority of overland flow is restricted to the road reserve however some flooding does occur within properties. The southern end of Florence Avenue has been flooded the past with residents reporting flooding up to 0.5 m in depth. To the south of the road reserve mounding within the Golf Course is built up and restricts the egress of flow (Photo 16). One resident noted that prior to the installation of a new stormwater pit within the street (Photo 17), flooding would occur regularly and his garage would be inundated requiring the use of sandbagging. Flood depths and flood extents are shown in Figure B21

Photo 16: Mounding in the golf course elevated above road reserve in Florence Avenue

Photo 17: Recently installed stormwater pit

The additional inlet capacity would have alleviated more frequent flooding however flood affectation in larger events depends on the overland flow capacity through the Golf Course.

12.3. Francis Street

Photo 18: Cleland St looking south towards Francis St

Photo 19: Francis St near Cleland St looking south

Modelled results indicate that there is a significant amount of overland flow directed through Francis Street properties. Council has installed a large number of stormwater pits near the

Corner of Cleland and Francis Streets in order to alleviate regular flooding however in larger flood events the inlet capacity is exceeded (Photo 18 and Photo 19). Design flows through Francis Street properties are shown in Table 44 and the location of the properties is shown in Figure B22.

Table 44: Design Flow Behaviour through Francis Street properties

Event	Peak Flow (m^3/s)
50% AEP	0.7
20% AEP	1.8
10% AEP	2.6
5% AEP	3.7
2% AEP	4.6
1% AEP	5.6
PMF	20.8

12.4. Hollingshed Street Low Point

The Hollingshed Street low point is located to the eastern side of Botany Road and extends approximately from Botany Lane to Sutherland Street (Figure B23). The contributing catchment includes most areas to the east of Botany Road and is approximately 1.8 km^2. Downstream, Botany Road acts as a weir with the lowest road crests located adjacent to Hollingshed Street and near the intersection with Wentworth Avenue.

The road crest is 5.9 mAHD near Wentworth Avenue and 6.0 mAHD near Hollingshed Street. The box culvert draining the low point is 1.8 x 1.2 m in dimension. Excess overland flow initially discharges via the Wentworth Avenue low point however the capacity of Botany Lane and the Wentworth Avenue low point is limited and during larger flood events Botany Road near Hollingshed Street is overtopped, discharging to the west into the Baxter Road low point.

Adjacent properties are commercial and residential in nature and due to the relatively flat gradient there is a large area of affectation. Design flood levels within the low point, flows within the downstream culvert and overland flows over the two Botany Road low points are summarised in Table 45.

Table 45: Design Flow Behaviour near the Hollingshed Street low point

Event	Peak Flood Level (mAHD)	Outflow (m^3/s)		
		Culvert Outflow	Hollingshed St Low point	Wentworth Ave Low point
50% AEP	5.7	3.1	0.2	0
20% AEP	5.9	4.3	0.7	0
10% AEP	6.1	4.6	1.1	0.4
5% AEP	6.2	4.8	2.1	1.2
2% AEP	6.3	4.8	3.3	2.3
1% AEP	6.4	4.8	4.5	3.3
PMF	6.9	6.2	25.6	53.3

A set of twin culverts are located below the railway line near the Botany Road and Wentworth Avenue intersection (Photo 21). The culverts are each approximately 5 m x 3 m and have an invert level of 4.8 mAHD. In current conditions, the culverts are ineffective as there is a raised path downstream which completely blocks overland flow from reaching the Ascot Drain. The culverts appear to have been constructed with the purpose of draining the Hollingshed Street low point; however the Botany Road and Wentworth Avenue intersection is raised to a level of 5.9 mAHD and may have been lower in the past.

Photo 20: Botany Lane looking South

Photo 21: culverts below railway near Wentworth Avenue

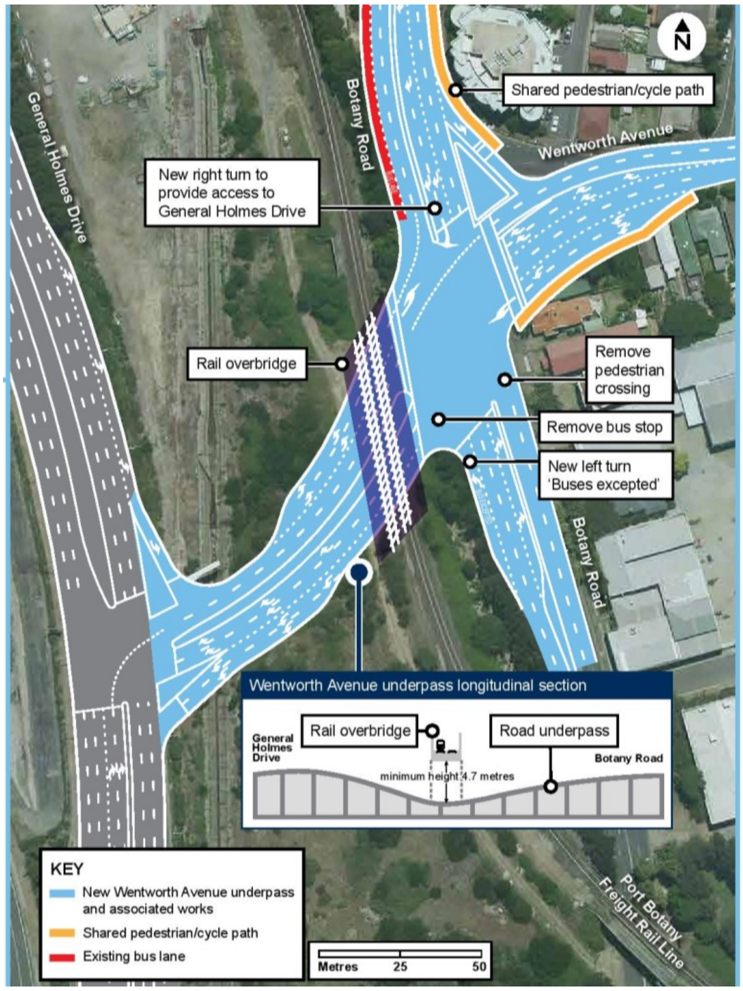
Given the severity of flooding and level of affectation within the Hollingshed Street low point, upgrade of drainage infrastructure or road regrading should be considered. Any drainage works will need to take into consideration services and will require permission from the RMS and Transport for NSW as works below Botany Road and the railway are necessary.

Constructing a large culvert at the southern end of Botany lane through to Wentworth Avenue and eventually to the Ascot Drain would alleviate flooding to some degree.

As part of the proposed WestConnex enabling works in the airport east precinct (Reference 21), there is a planned rail overbridge to the south-west of the Botany Road and Wentworth Avenue intersection (Diagram 4). It is likely that the underpass will be flood affected by excess overland flow from the Wentworth Avenue low point.

In summary there are significant flooding problems within the Hollingshed Street low point and this is likely to impact on the underpass proposed as part of the WestConnex enabling works. Drainage works completed in conjunction with works undertaken by the RMS could alleviate the flooding issue and may present an opportune time to undertake works.

Diagram 4: Proposed WestConnex enabling works near Wenworth Avenue (from Reference 21)



12.5. Gardeners Road Low Point

See Section 8.3.1 for discussion of the flood behaviour and buildings at this location.

Design flood levels are provided in Table 46 along with peak piped and overland flows. An overview of the Gardeners Road hotspot is shown on Figure B24.

Table 46: Design Flow Behaviour near the Gardeners Road low point

Event	Peak Flood Level (mAHD)	Piped Flow (m^3/s)	Overland Flow (m^3/s)
50% AEP	9.3	0.8	0.2
20% AEP	9.3	1	0.6
10% AEP	9.4	1.1	0.9
5% AEP	9.4	1.2	1.4
2% AEP	9.4	1.3	2
1% AEP	9.4	1.5	2.6
PMF	9.8	1.7	15.8

12.6. Carinya Avenue Low Point

The open channel near Carinya Avenue becomes covered (seen in both Photo 22 and Photo 23) as it enters a commercial property and this restricts overland flow from exiting the low point.

Photo 22: Existing aerial photograph near Coward Street showing 1% AEP flood depths

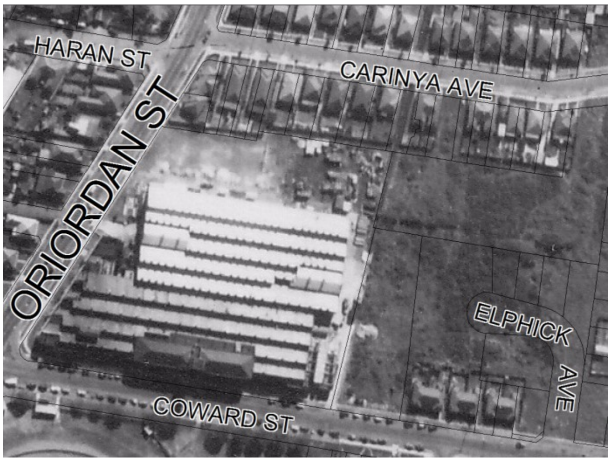


Photo 23: Historic aerial photograph near Coward Street (from 1953)

Peak design flood levels within the Carinya Avenue low point are shown in Table 47. 1% AEP flood depths and levels are mapped on Figure B24.

Table 47: Design Flow Behaviour near the Carinya Avenue low point

Event	Peak Flood Level (mAHD)
50% AEP	7.4
20% AEP	7.4
10% AEP	7.6
5% AEP	7.8
2% AEP	7.9
1% AEP	8
PMF	8.7

12.7. Mascot Public School Oval Low Point

Mascot Public School is one of the worst flood affected areas in the catchment. To the east, commercial premises have been constructed which potentially block overland flow from entering the open channel. Ground levels near the building are approximately 2 metres higher than the Mascot Public School low point. Photo 24 and Photo 25 show existing conditions during the 1% AEP event and historic conditions in 1953.

Photo 24: Existing aerial photograph near King Street showing 1% AEP flood depths

Photo 25: Historic aerial photograph near King Street (from 1953)

Very limited flow reaches SWC's Mascot West trunk drainage system due to limited inlet capacity within the Mascot Public School oval and lack of overland flow path. The main obstruction to drainage of the Mascot Public School oval and surrounds is the raised ground levels to the west. Design flood levels are provided in Table 48 and existing 1% AEP flood depths and levels are shown on Figure B25.

Table 48: Design Flow Behaviour near the Mascot Public School Oval low point

Event	Peak Flood Level (mAHD)
50% AEP	6.7
20% AEP	6.8
10% AEP	6.9
5% AEP	7
2% AEP	7.1
1% AEP	7.2
PMF	7.6

12.8. Baxter Road Low Point

Overland flow from much of the catchment drains to Baxter Road and its egress is restricted by the railway embankment. The upstream Mascot catchment is approximately 1.1 km^2 and a large proportion of the overland flow ends up in the Baxter Road low point. During large flood events water from the Hollingshed Avenue low point may overtop Botany Road and the excess floodwaters drain into Baxter Road.

The Baxter Road "low point" is drained by a box culvert (1.5 m wide by 0.75 m high) which then reduces to a 1.2 m diameter pipe. Further downstream and below the railway embankment the pipe size increases to 1.8 m diameter then connects to the Ascot Drain which ultimately drains to Botany Bay. The combined capacity of the culvert and inlets within Baxter Road are unable to convey floodwaters for events as frequent as the 50% AEP event.

Excess stormwater which is unable to be conveyed by the underground stormwater conduit collects north of the railway embankment, affecting a number of properties within Baxter Road and Robey Street. Design flood levels within Baxter Road for existing conditions are provided in Table 49 and existing 1% AEP flood depths and levels are shown on Figure B26.

Table 49: Design Flow Behaviour near the Baxter Road Low Point

Event	Peak Flood Level (mAHD)	Outflow (m^3/s)	
		Culvert	Overland
50% AEP	4.8	1.3	0
20% AEP	4.9	1.5	0
10% AEP	5	1.5	0.1
5% AEP	5.3	1.6	3.4
2% AEP	5.7	1.8	7.2
1% AEP	6	2	11.1
PMF	6.1	2.1	95.1

Under existing conditions there are a number of properties affected by flooding within the Baxter Road low point and upgrading the culvert system has the potential to reduce the amount of future flood damages within the area.

12.9. Gardeners Road West, Coward Street, Ossary Street, Ricketty Street and Kent Road Low Points

Within the area bounded by Alexandra Canal to the west and the SWSOOS to the east there are a number of locations where significant water depths occur. These are generally due to depressions in the local topography which can only drain with the assistance of an underground drainage system. Where the underground drainage system is insufficient in capacity, these points fill with stormwater and act as detention basins.

Within these areas the majority of properties are either commercial or industrial in nature. Flooding issues in these locations have been investigated previously in References 4 and 5 and they are known problem spots. A summary of flood behaviour in these trapped low points is made in Table 50 with locations shown on Figure B27.

Table 50: Design Flood Levels between Alexandra Canal and the SWSOOS

Event	Peak Flood Level (mAHD)				
	Gardeners Road	Coward Street	Ossary Street	Ricketty Street	Kent Road
50% AEP	3.3	2	2.7	2.1	3.9
20% AEP	3.3	2.3	2.8	2.3	4
10% AEP	3.4	2.4	2.8	2.4	4
5% AEP	3.4	2.4	2.8	2.5	4
2% AEP	3.4	2.5	2.8	2.5	4.1
1% AEP	3.5	2.5	2.8	2.6	4.1
PMF	3.8	2.9	3.1	3.0	4.3

12.10. Ewan Street Low Point

The Ewan Street catchment drains to the west and ultimately reaches a trapped low point adjacent to the railway embankment. The surrounding properties are residential, industrial and commercial in nature (Photo 26).

The low point is serviced by three stormwater inlet pits which have a high potential for blockage due to vegetation and the nature of businesses in the area (Photo 27). Two stormwater pipes drain the low point however their dimensions are unknown (assumed to be 375 mm in diameter). When the capacity of the underground drainage system is exceeded, the trapped low point acts as a detention basin behind the railway embankment and will pond up to three metres before it is overtopped.

Photo 26: Properties within the Ewan Street low point

Photo 27: Inlet pits within the Ewan Street low point

Water levels in the trapped low point are highly dependent on the amount of blockage as well as storm duration and volume. Design flood levels within the low point assume a 50% blockage of the drainage network and are reproduced in

Table 51. An overview of the hotspot is shown in Figure B28.

Table 51: Design Flood Levels within the Ewan Street Low point

Event	Peak Flood Level (mAHD)
50% AEP	4.7
20% AEP	4.9
10% AEP	5
5% AEP	5.1
2% AEP	5.2
1% AEP	5.3
PMF	5.8

12.11. Bay Street and Banksia Low Point

Flooding in the Bay Street and Banksia Street low points are caused by overland flow having to enter the channel in the railway corridor. Once the capacity of the trunk drainage system is met the water level rises until it can flow over the median strip at the end of each street. The design flood levels are shown in Table 52. The peak flood depths and the topography of the area are shown in Figure C19.

Table 52: Design Flood Levels within the Bay Street and Banksia Avenue Low point

Event	Peak Flood Level (mAHD) Bay St	Peak Flood Level (mAHD) Banksia St
50% AEP	8.5	9.8
20% AEP	8.6	9.8
10% AEP	8.7	9.8
5% AEP	8.8	9.9
2% AEP	8.8	9.9
1% AEP	8.9	9.9
PMF	8.9	9.9

12.12. Bay Street near Lang Avenue Low Point

There is a low point in the topography on Bay Street in between Lang Avenue and Wentworth Avenue. This causes water to pond during a storm event once the capacity of the trunk drainage system has been met. The design flood levels are shown in Table 53. The peak flood depths and the topography of the area are shown in Figure C20.

Table 53: Design Flood Levels within the Bay Street Low point

Event	Peak Flood Level (mAHD)
50% AEP	13.6
20% AEP	13.7
10% AEP	13.7
5% AEP	13.8
2% AEP	13.8
1% AEP	13.8
PMF	13.9

13. PRELIMINARY FLOOD PLANNING AREA

13.1. Background

Land use planning is one of the most effective means of minimising flood risk and damages from flooding. The Flood Planning Area (FPA) identifies land that is subject to flood related development controls and the Flood Planning Level (FPL) is the minimum floor level applied to development proposals within the FPA.

The process of defining FPAs and FPLs is somewhat complicated by the variability of flow conditions between mainstream and local overland flow, particularly in urban areas. Traditional approaches that were developed for riverine environments and “mainstream” flow areas generally cannot be applied in steeper urban overland flow areas.

Defining the area of flood affectation due to overland flow (which by its nature includes shallow flow) often involves determining at which point it becomes significant enough to classify as “flooding” rather than just drainage of local runoff. The difference in peak flood level between events of varying magnitude may be minor in areas of overland flow, such that applying the typical freeboard of 0.5 m can result in a FPL much greater than the Probable Maximum Flood (PMF) level.

The FPA should identify properties where future development can potentially result in adverse impacts on flood behaviour in the surrounding area, and areas of high hazard that pose a risk to safety or life. Further to this, the FPL is determined with the purpose to decrease the likelihood of over-floor flooding of buildings and the associated damages.

Further consideration of flood planning areas and levels are typically undertaken as part of the Floodplain Management Study where council decides which approach to adopt for inclusion in their Floodplain Management Plan. For this study, the approach for defining the FPA was based on identifying cadastral lots where flood affectation is significant enough to warrant planning controls on future development.

13.2. Identification of Flood Control Lots

Flood Tagging is the process where cadastral lots are identified as flood liable. The “tagged” lots will be subject to 10.7 Planning Certificate notification (under NSW Local Government Act) indicating that their properties are subject to flood-related development controls. This simply means that should development of the lots occur, flooding will need to be considered and Council’s LEP, DCP and any other relevant flood related policies will apply.

Flood tagging was undertaken using the following process:

- Automated spatial analysis identifying the properties subject to flooding from the modelling results of the flood study;
- Filtering out of properties where the flood affectation is minor, such as very shallow flow;
- “Ground truthing” involving detailed assessment of the flood behaviour at individual lots

to determine the final tagging status.

This process is consistent with that adopted in a number of similar studies throughout the Sydney metropolitan area. Identification of properties subject to flood-related development controls is undertaken by using the 1% AEP model results, with filtering to remove nuisance or non-damaging levels of flow, then applying subsequent ground truthing to determine whether individual properties are tagged or not. For this study, there were no areas where typical mainstream flood techniques (adding freeboard and stretching the results) produced reasonable outcomes. Each of the properties identified were based on overland flow criteria as identified below.

- Automated GIS Tagging: Lots were originally classified as “flood control lots” and therefore within the FPA, if they were affected by the modelled 1% AEP flood extent (after applying filtering). The flood depth map was filtered to remove areas less than 0.15 m deep. Properties were then identified as preliminary “flood control lots” where 10% or more of the property was affected by this filtered flood extent.

Detailed review of individual properties was then undertaken. The considerations applied during this process, and categories assigned to various properties as part of this process, are summarised in Table 54. The final lots identified for flood tagging are shown on Figure B29 (lots within the 1% AEP Preliminary Flood Planning Area) and Figure B30 (PMF affected lots).

Table 54: Ground truthing classifications for flood control lot identifications process

Classification	Description
Initially tagged in automated GIS analysis. Tag retained.	
A1	Property reviewed and flood tagging confirmed, due to inundation from or proximity to significant flow path
Initially NOT tagged in automated GIS analysis. Tag added.	
B1	Ground levels for part or all of the lot are below the adjacent 1% AEP flood level plus 0.5 m freeboard, for a major flow path or localised depression/sag point.
B2	Adjacent properties are inundated, and the DEM within the lot contains incorrect higher levels or obstructions that were not apparent from site review. Inundation of property is likely to be consistent with adjacent properties.
B3	Site analysis identified a local sag point that was not apparent from the DEM, and therefore the modelling did not reflect likely or potential inundation.
B4	Building footprint occupies a large portion of the lot, and excludes inundation in the modelling. Review confirmed that adjacent flooding would be likely to cause inundation if the building were removed.
B5	Nearby properties identified as tagged, and review confirmed the lot would potentially be inundated via similar mechanisms.
B6	Property downstream of or adjacent to a sag point. Ground truthing identified that there would be a potential overland flow path resulting from flow exceeding the stormwater network capacity, or blockage of kerb inlets, pipes or gutters. Flood risk to adjacent properties could also potentially be exacerbated by blocking flow through the lot, requiring development controls to be applied.
B7	Railway corridor.

Classification	Description
Initially NOT tagged in automated GIS analysis, confirmed by ground truthing.	
C1	Flood depth on or surrounding the property is less than 150 mm. Deemed to be a shallow overland or local drainage flow path, without major risk of exacerbation of flood depth, and therefore not requiring tagging under 10.7 certification process.
C2	Review confirmed that ground levels of the property are greater than the adjacent flood level plus freeboard.
C3	Not flood affected in the 1% AEP and no ground truthing undertaken.
Initially tagged in automated GIS analysis. Tag removed.	
D1	Review found that initial tagging was due to DEM features or processing artefacts that did not reflect the true ground surface, and the inundation criteria for tagging were not met.
D2	Minor flow path adjacent to property reviewed, and judged to be likely to be contained within the road network or stormwater drains, or otherwise easily managed by localised works.
D3	Review found that the flood risk was not severe enough to require development controls through the 10.7 planning certificate process.

14. PUBLIC EXHIBITION

A draft version of this study was placed on Public Exhibition from 18 September 2018 to 16 September 2018. Local residents were informed of the public exhibition period and were invited to provide comments on the draft report. Letters were sent to affected residents and landowners, and notifications of the public exhibition period were included in The Leader local newspaper and on the Bayside Council website.

A website was set up on Council's "Have Your Say" platform that included the Draft Flood Study document, an online submission option and a question and answer forum.

A community information session was also held on 4 October 2018 at Mascot Library. Council and WMAwater project staff were available to explain the study, present results and answer questions from the community.

A report summarising the public exhibition program, and a compilation of the submissions and Council responses can be found in Appendix A. Generally, the community had concerns regarding the flooding issues within the catchment and how these are to be managed. These issues are mainly concerned with drainage, including the blockage, maintenance and upgrade of the stormwater system. Consideration of potential mitigation of flood issues is part of the next phase – the Floodplain Risk Management Study and Plan.

15. ACKNOWLEDGEMENTS

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- City of Botany Bay;
- NSW Office of Environment and Heritage;
- Residents of the Mascot, Rosebery and Eastlakes catchment.

16. GLOSSARY

TERMINOLOGY OF FLOOD RISK

Australian Rainfall and Runoff (ARR, editors Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			PMP/ PMPDF	

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% or 1 in 100 AEP event (sometimes referred to as a 100 year ARI), has a 1% chance of being equalled or exceeded in any year. ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events of 50% AEP or rarer and EY for all events more frequent than this.

GLOSSARY OF TERMS

Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill

	development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
DRAINS	Stormwater Drainage System design and analysis program.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed

	evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc.

	Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
LiDAR	Surveying method that measures distances via laser.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: $ the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or $ water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or $ major overland flow paths through developed areas outside of defined drainage reserves; and/or $ the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the

	submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
RAFTS	Runoff routing model for hydrologic and hydraulic analysis of storm water drainage and conveyance systems.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RORB	General runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
SOBEK	Integrated 1D/2D modelling suite for flood modelling, flood forecasting and optimisation of drainage systems.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
TUFLOW	One-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model).
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.

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Figures

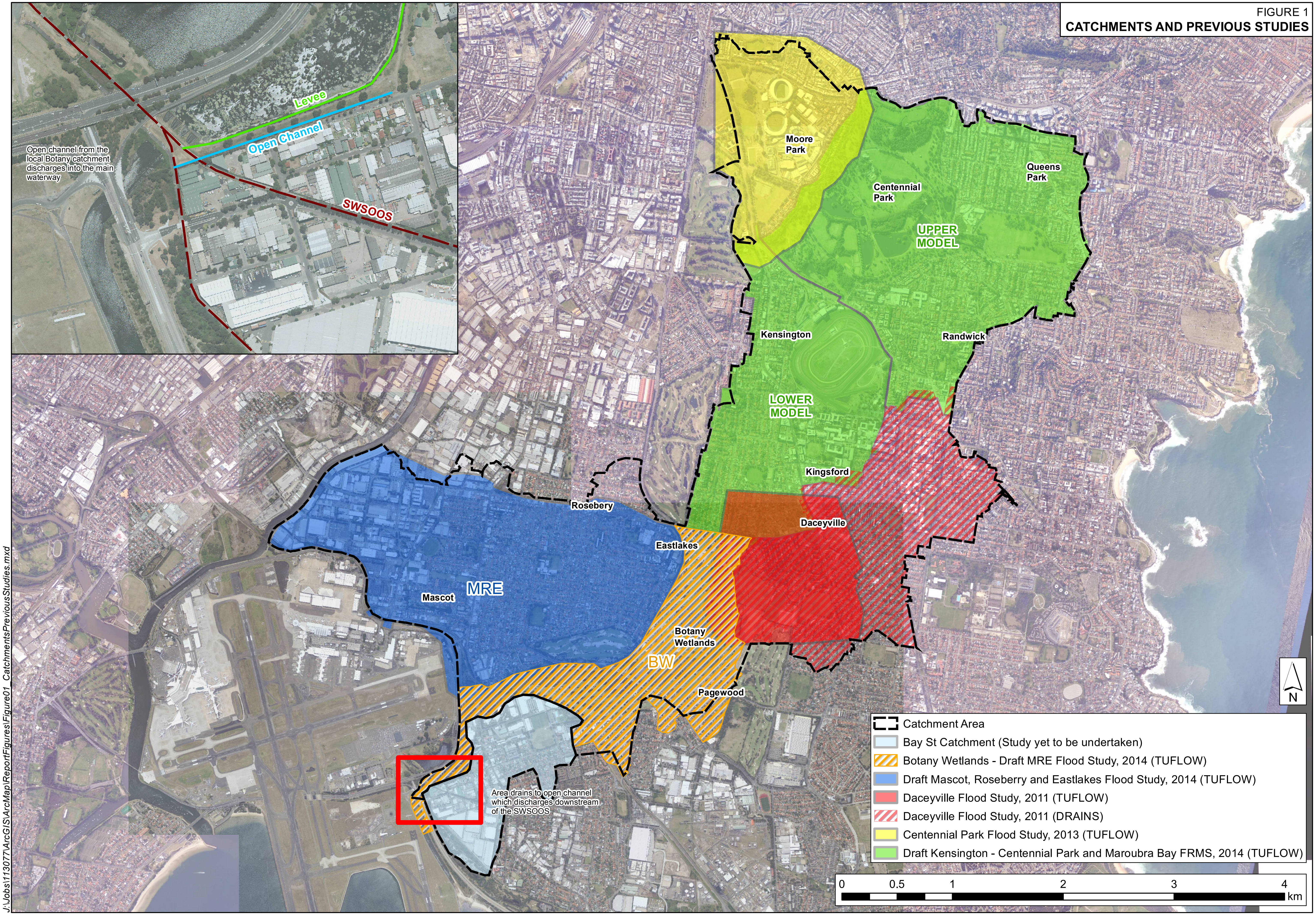
FIGURE 1
CATCHMENTS AND PREVIOUS STUDIES
Levee
Open Channel
SWSOOS
Open channel from the local Botany catchment discharges into the main waterway
Moore Park
Centennial Park
Queens Park
UPPER MODEL
Kensington
Randwick
LOWER MODEL
Kingsford
Rosebery
Daceyville
Eastlakes
Mascot
MRE
Botany Wetlands
BW
Pagewood
Area drains to open channel which discharges downstream of the SWSOOS
N
Catchment Area
Bay St Catchment (Study yet to be undertaken)
Botany Wetlands - Draft MRE Flood Study, 2014 (TUFLOW)
Draft Mascot, Roseberry and Eastlakes Flood Study, 2014 (TUFLOW)
Daceyville Flood Study, 2011 (TUFLOW)
Daceyville Flood Study, 2011 (DRAINS)
Centennial Park Flood Study, 2013 (TUFLOW)
Draft Kensington - Centennial Park and Maroubra Bay FRMS, 2014 (TUFLOW)
0 0.5 1 2 3 4
km
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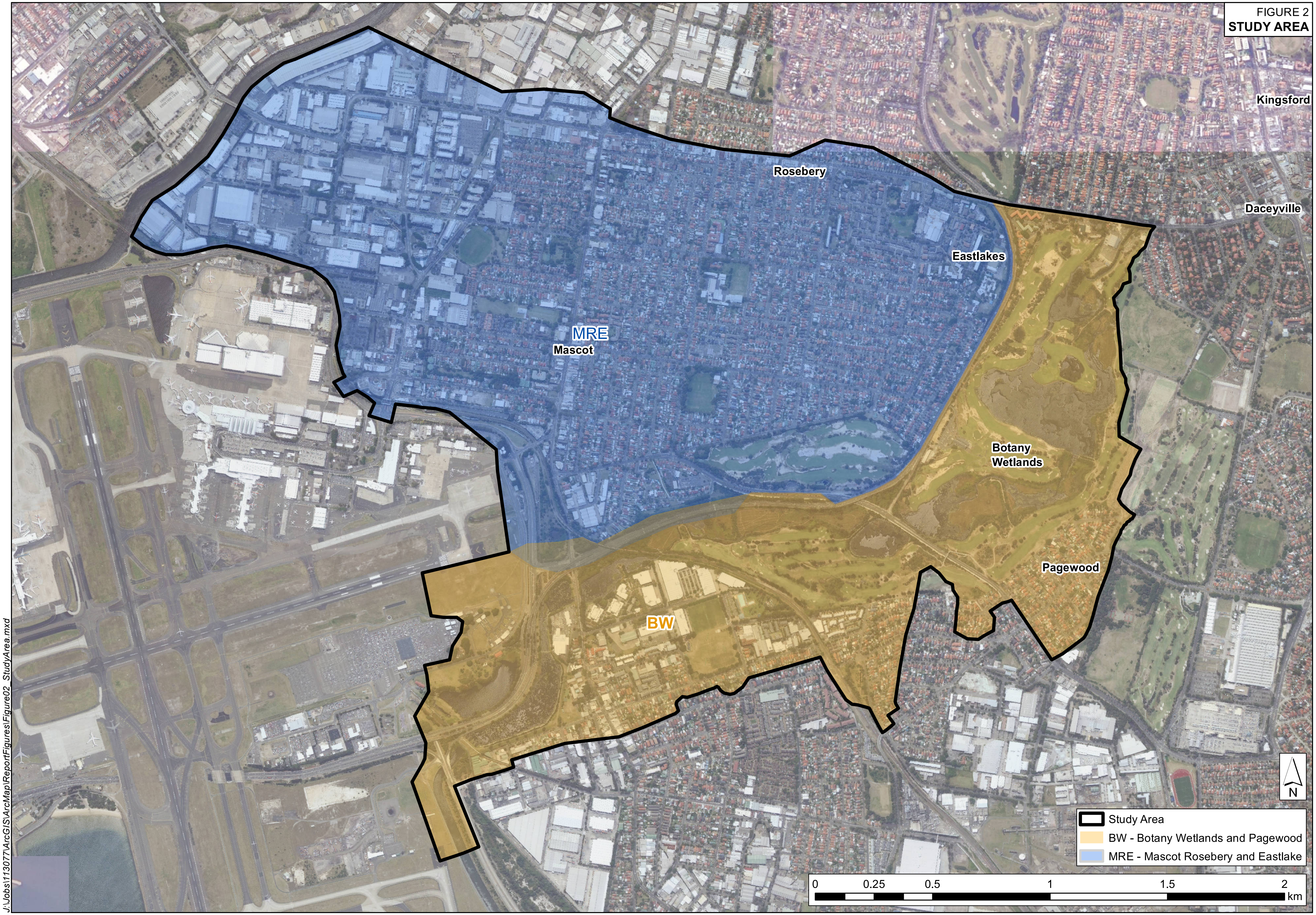


FIGURE 2
STUDY AREA
Kingsford
Rosebery
Daceyville
Eastlakes
MRE
Mascot
Botany
Wetlands
Pagewood
BW
N
Study Area
BW - Botany Wetlands and Pagewood
MRE - Mascot Rosebery and Eastlake
0
0.25
0.5
1
1.5
2
km
J:\Jobs\113077\ArcGIS\ArcMap\ReportFigures\Figure02_StudyArea.mxd

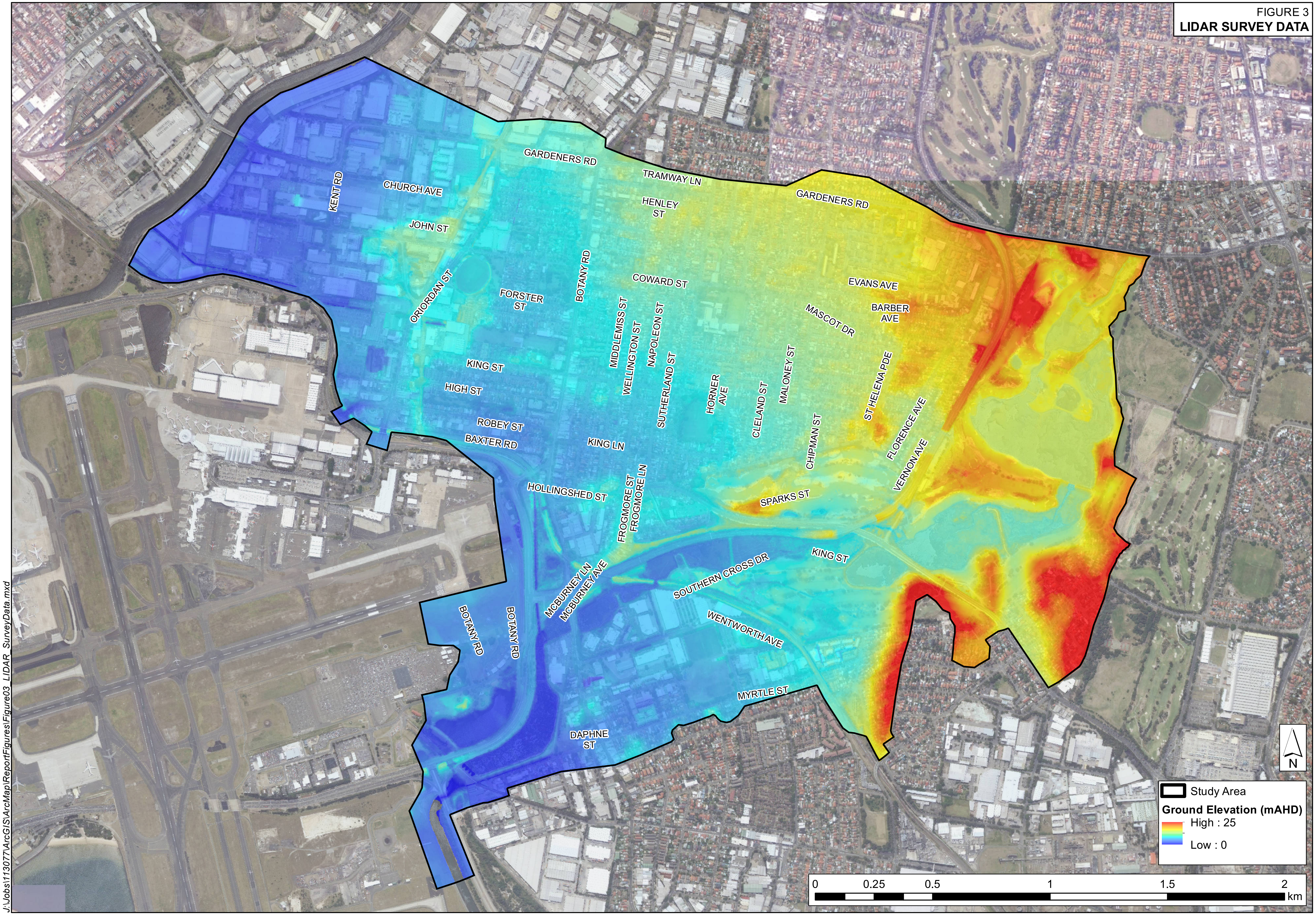


FIGURE 3
LIDAR SURVEY DATA
GARDENERS RD
TRAMWAY LN
GARDENERS RD
KENT RD
CHURCH AVE
HENLEY ST
JOHN ST
O'RIORDAN ST
BOTANY RD
COWARD ST
EVANS AVE
FORSTER ST
BARBER AVE
MASCOT DR
MIDDLEMISS ST
WELLINGTON ST
NAPOLEON ST
KING ST
SUTHERLAND ST
MALONEY ST
HIGH ST
HORNER AVE
CLELAND ST
ST HELENA PDE
ROBEY ST
CHIPMAN ST
FLORENCE AVE
BAXTER RD
KING LN
VERNON AVE
HOLLINGSHED ST
FROGMORE ST
FROGMORE LN
SPARKS ST
KING ST
SOUTHERN CROSS DR
MCBURNEY LN
MCBURNEY AVE
BOTANY RD
BOTANY RD
WENTWORTH AVE
MYRTLE ST
DAPHNE ST
N
Study Area
Ground Elevation (mAHD)
High : 25
Low : 0
0
0.25
0.5
1
1.5
2
km
J:\Jobs\113077\ArcGIS\ArcMap\ReportFigures\Figure03_LIDAR_SurveyData.mxd

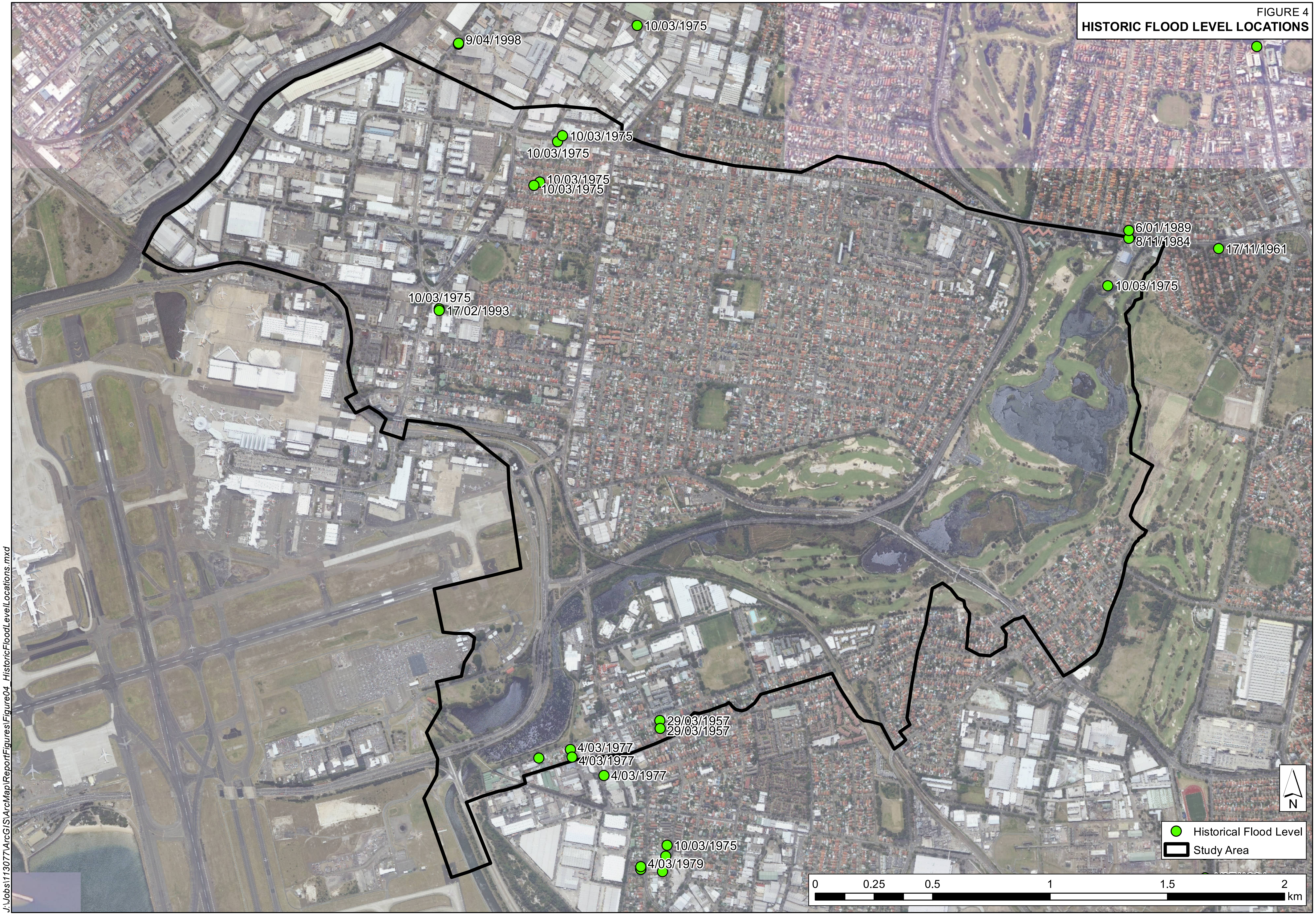
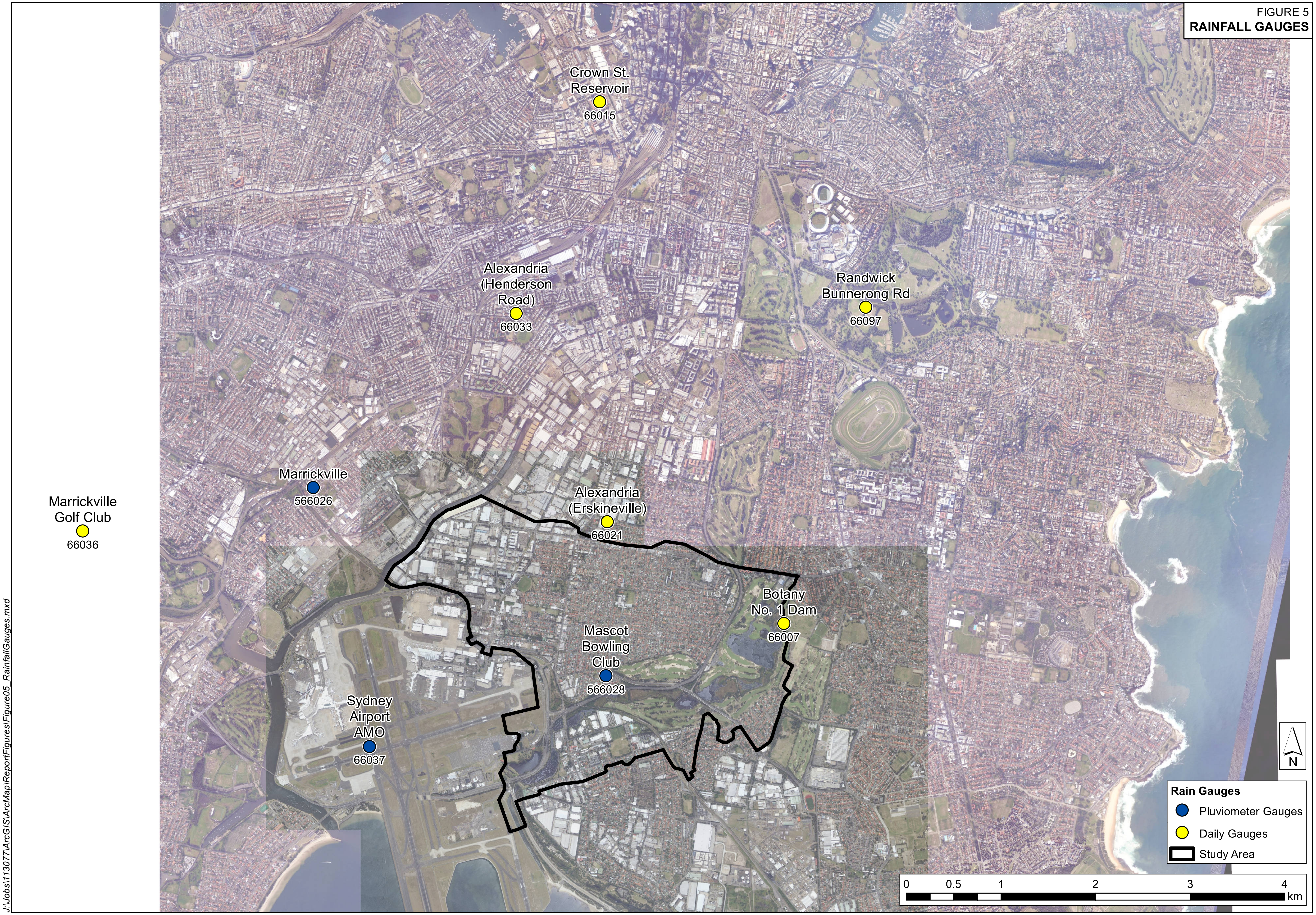


FIGURE 4
HISTORIC FLOOD LEVEL LOCATIONS

J:\Jobs\113077\ArcGIS\ArcMap\ReportFigures\Figure04_HistoricFloodLevelLocations.mxd

FIGURE 5
RAINFALL GAUGES



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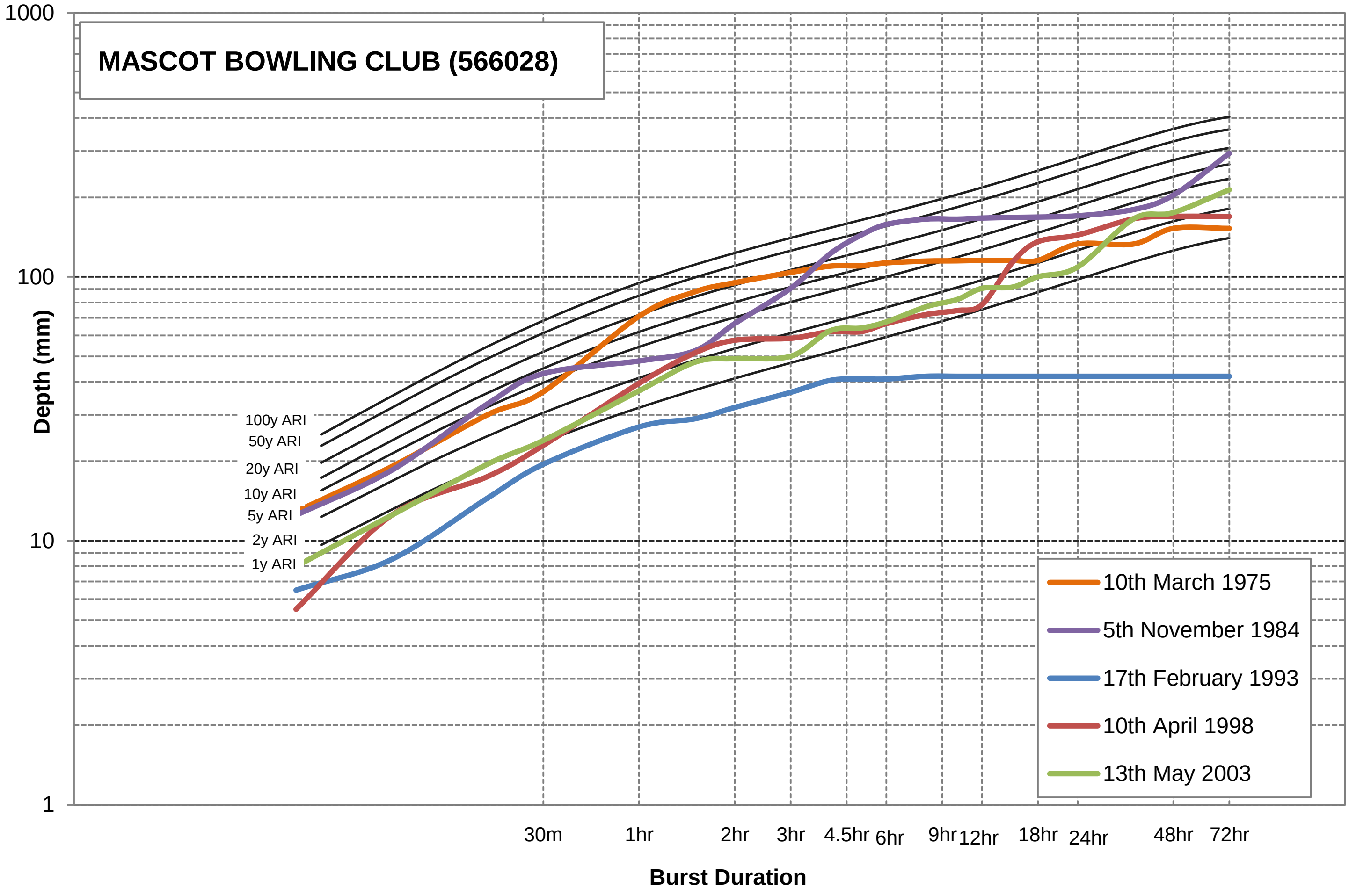
HISTORIC RAINFALL VERSUS AR&R 1987 IFD DATA



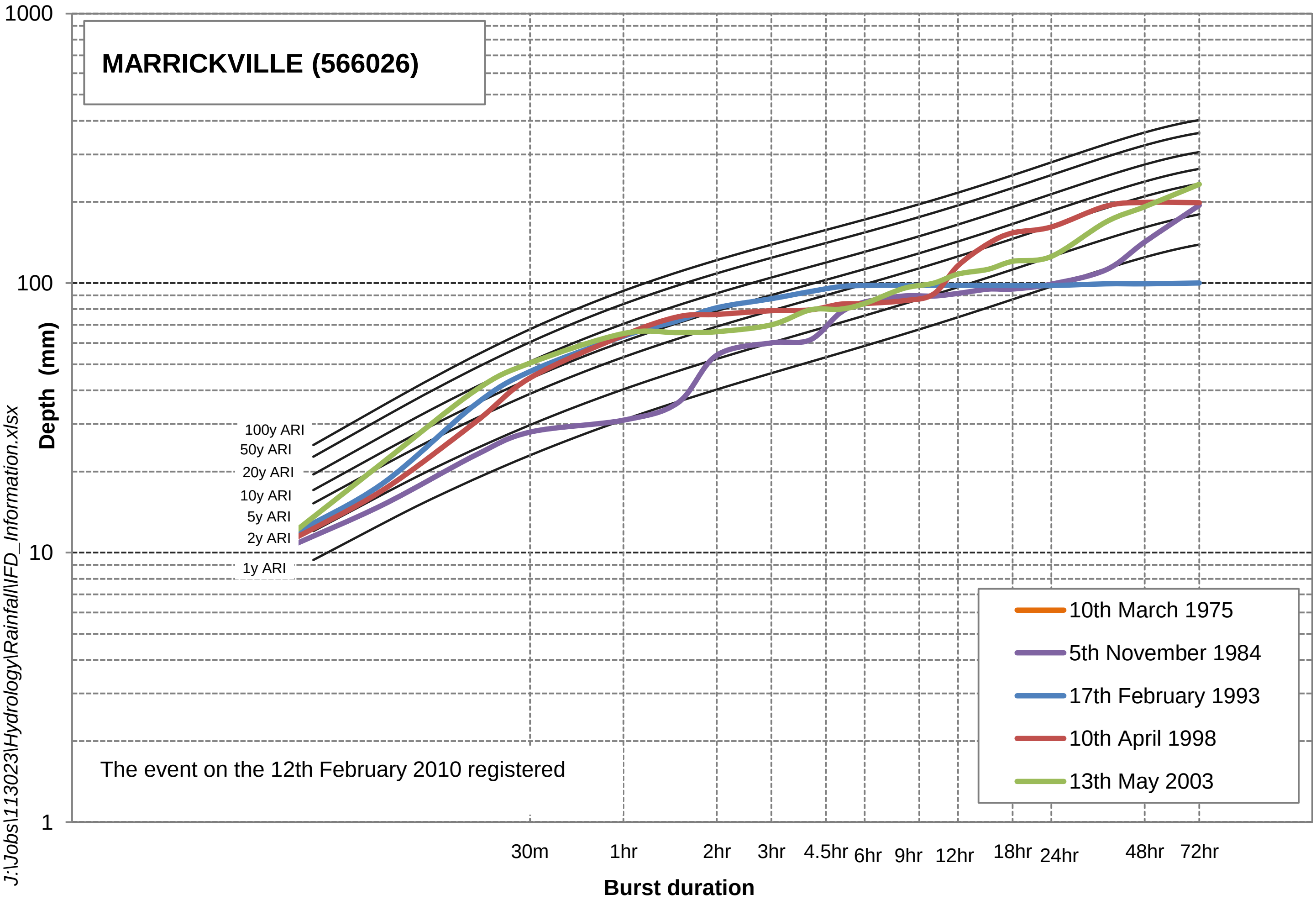
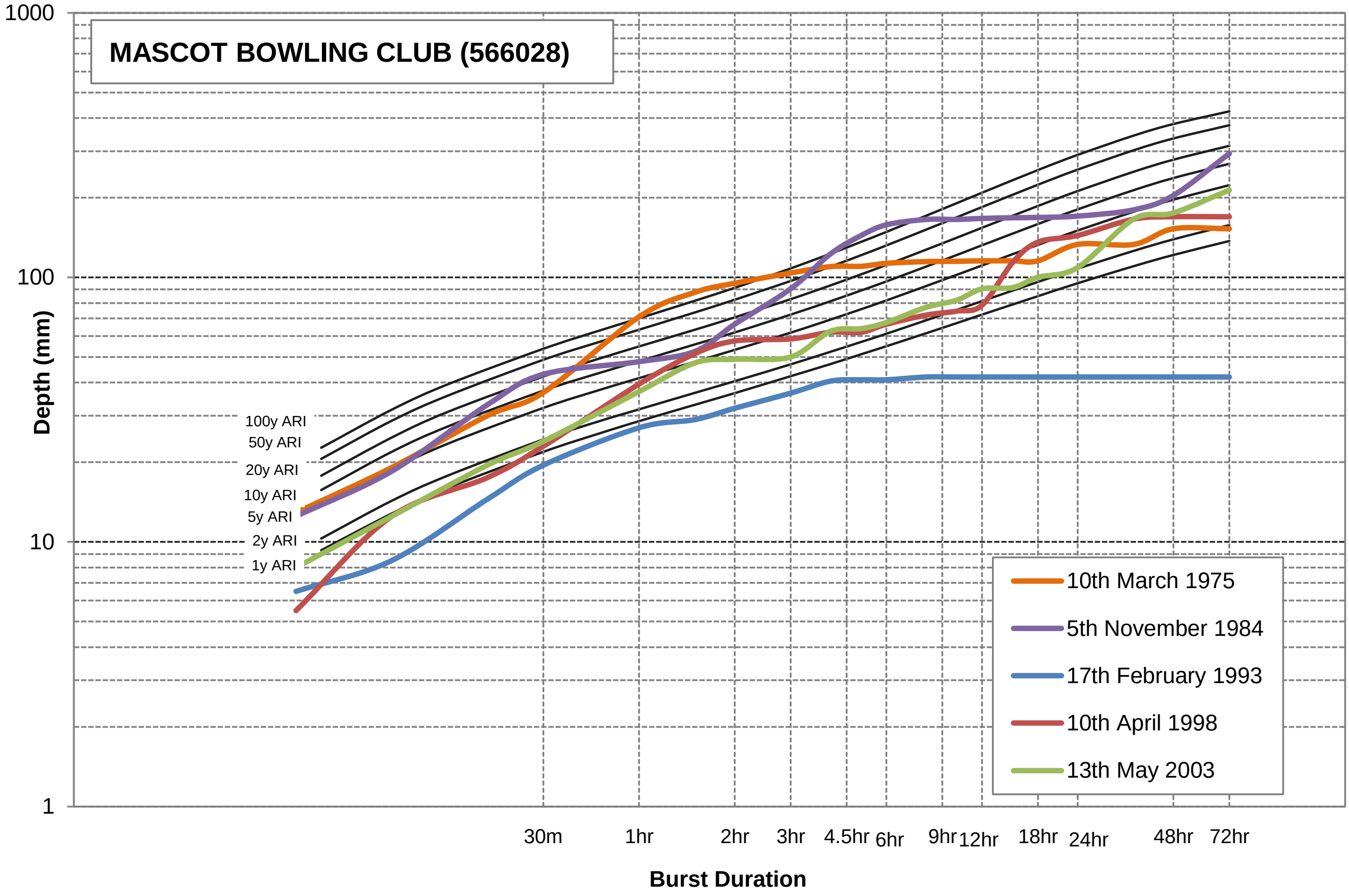


FIGURE 7

HISTORIC RAINFALL VERSUS BOM 2013 IFD DATA



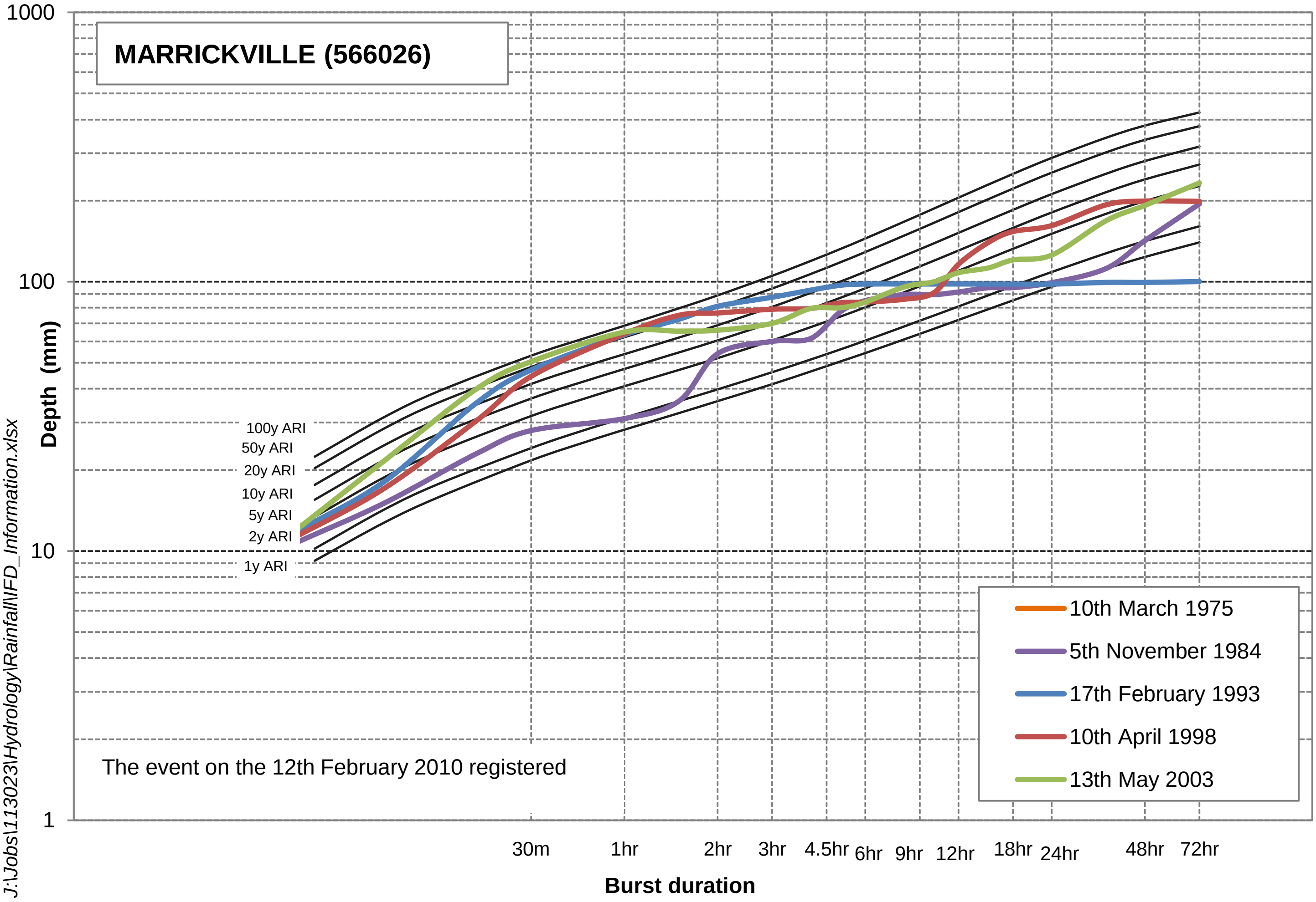


FIGURE 8
HYDROLOGICAL MODEL SCHEMATISATION MRE CATCHMENT

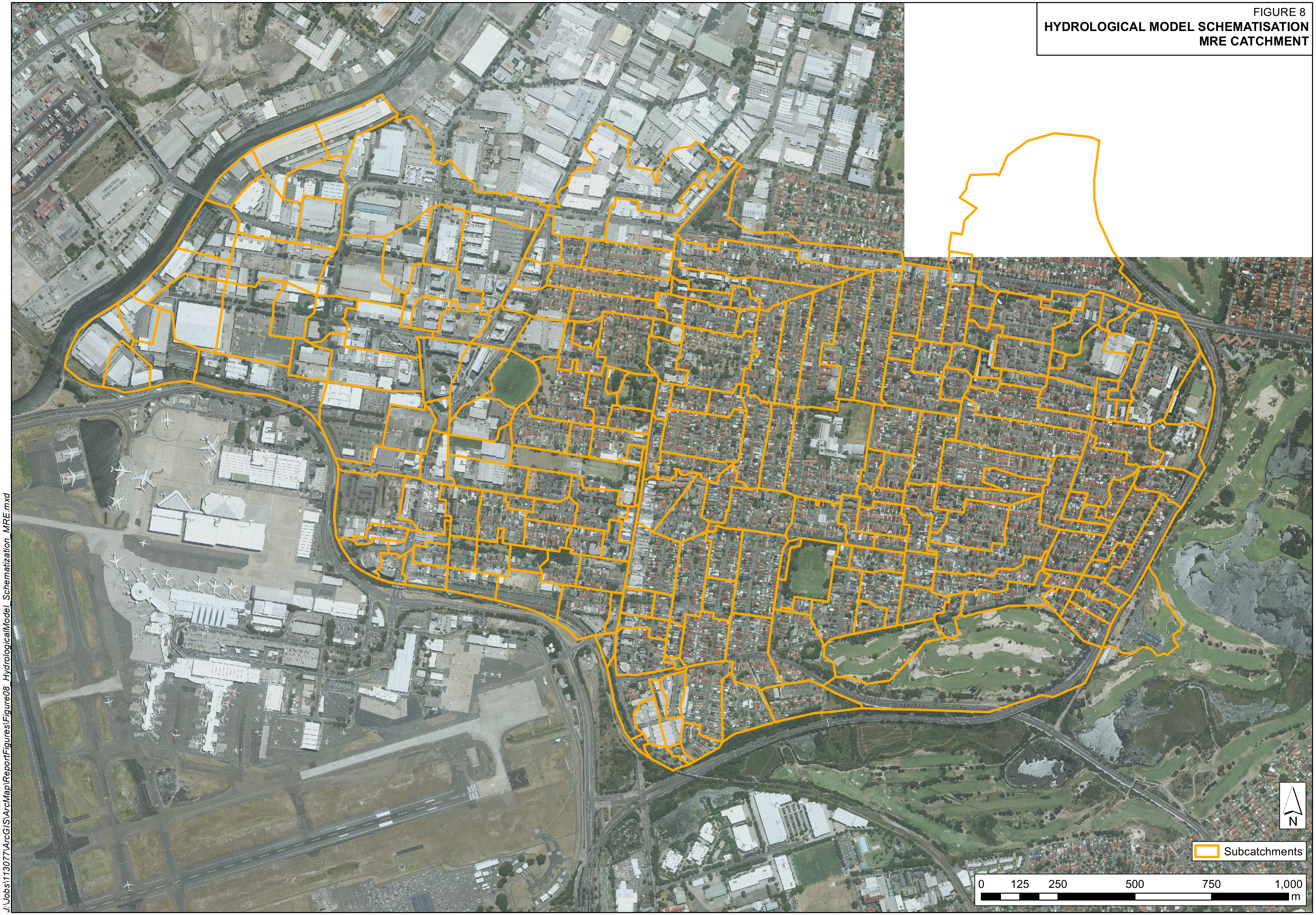
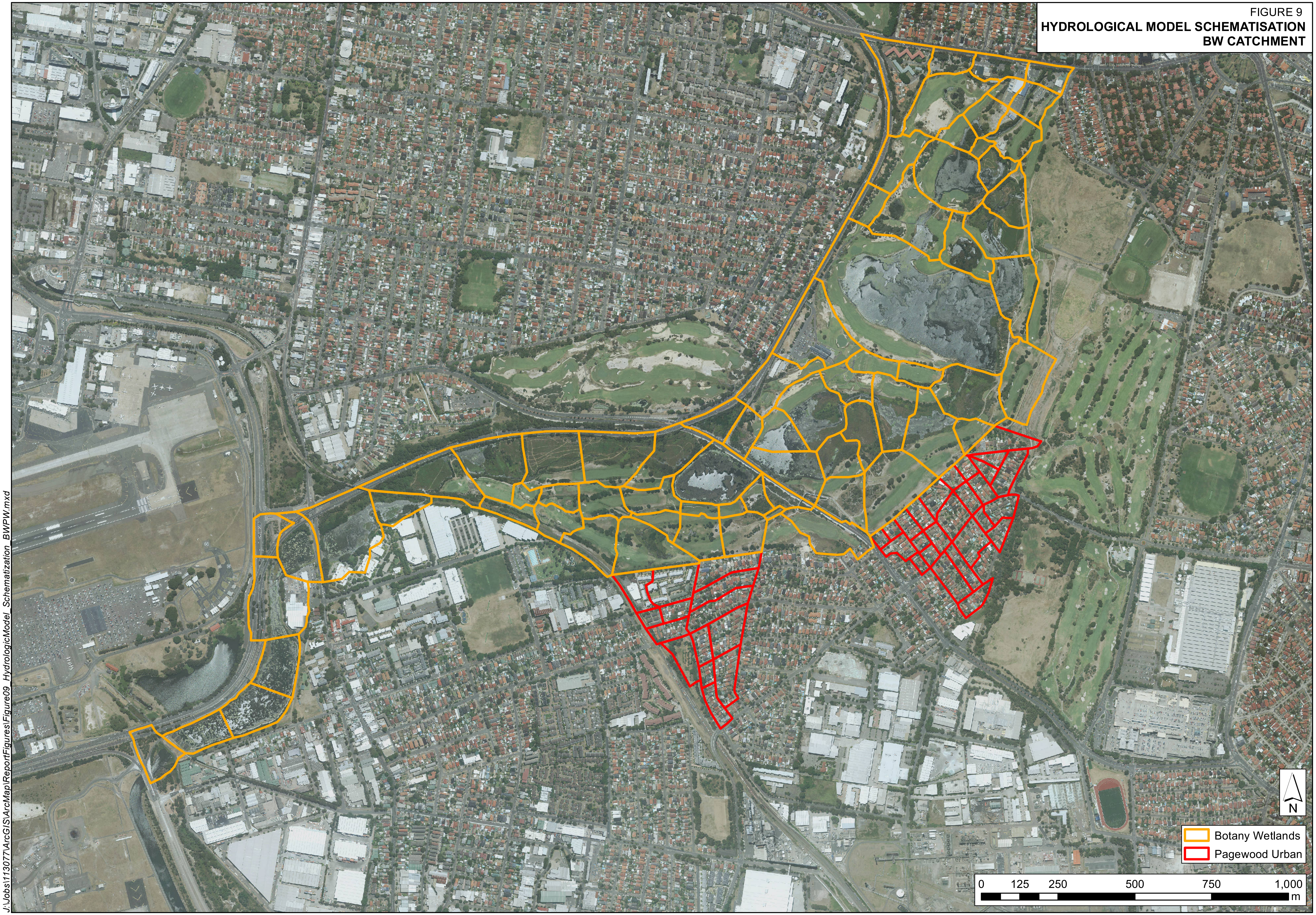


FIGURE 9
HYDROLOGICAL MODEL SCHEMATISATION
BW CATCHMENT



J:\Jobs\113077\ArcGIS\ArcMap\ReportFigures\Figure09_HydrologicModel_Schematization_BWPW.mxd

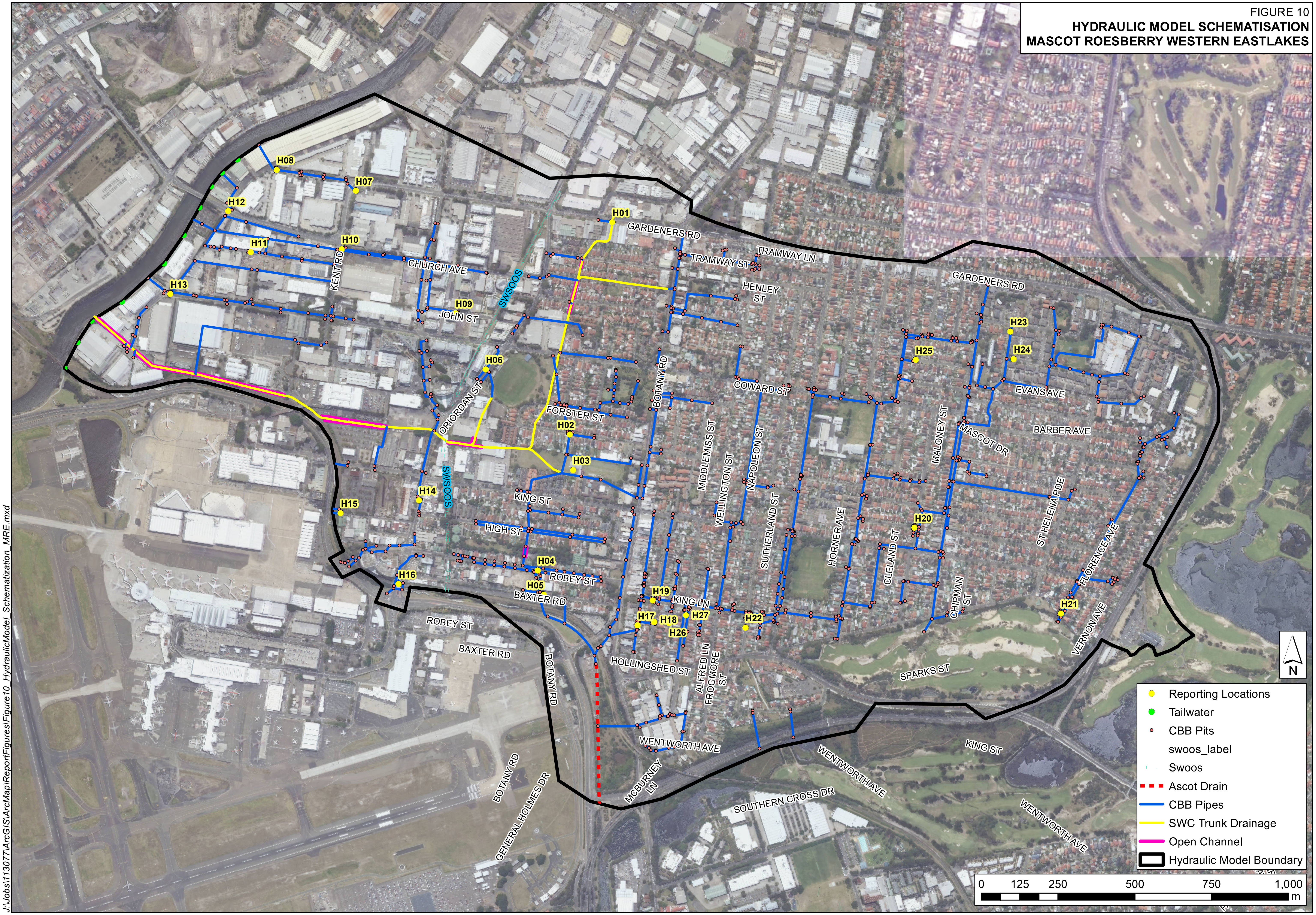


FIGURE 10
HYDRAULIC MODEL SCHEMATISATION
MASCOT ROESBERRY WESTERN EASTLAKES

J:\Jobs\113077\ArcGIS\ArcMap\ReportFigures\Figure10_HydraulicModel_Schematization_MRE.mxd

FIGURE 11
HYDRAULIC MODEL SCHEMATISATION
BW CATCHMENT

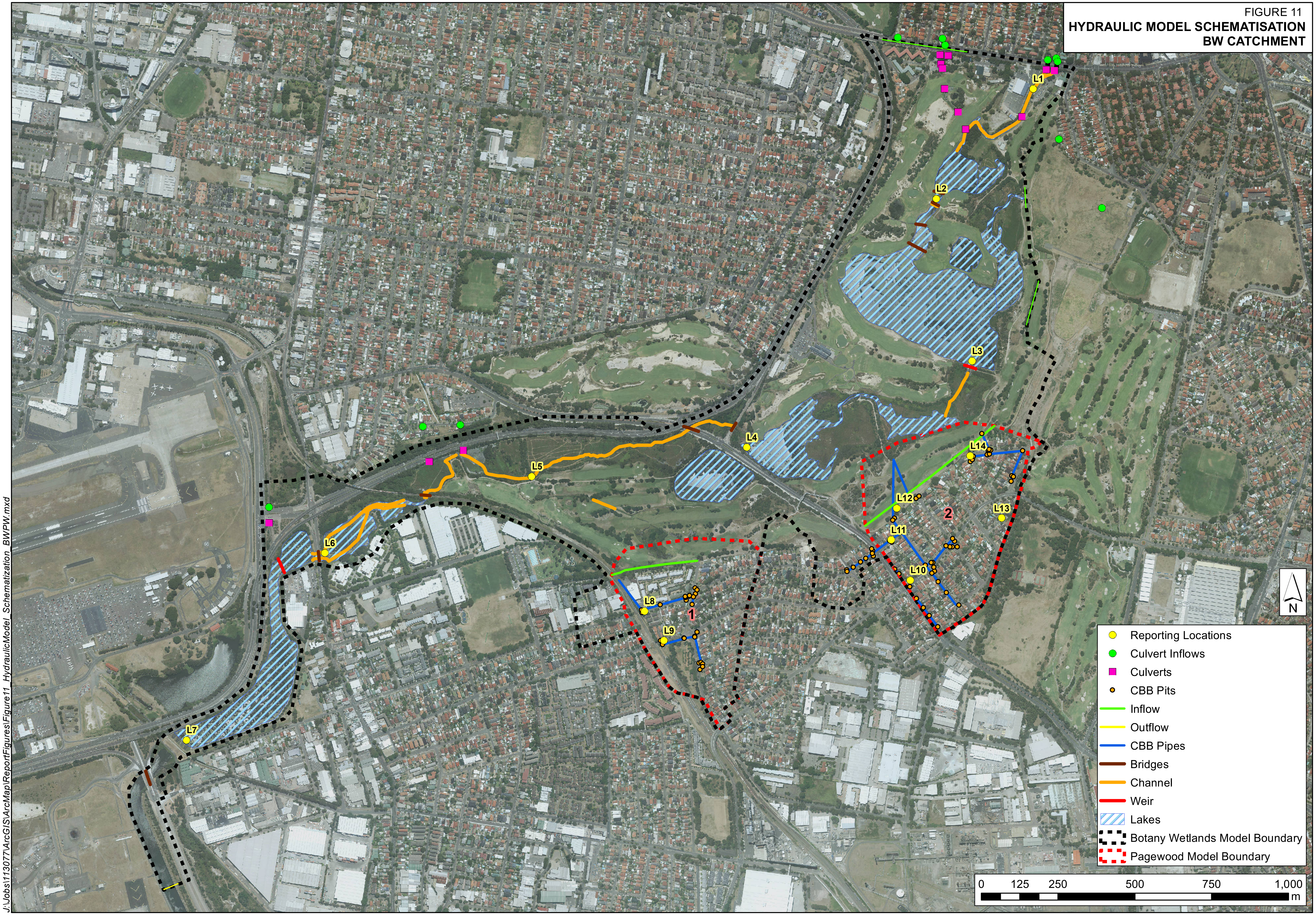


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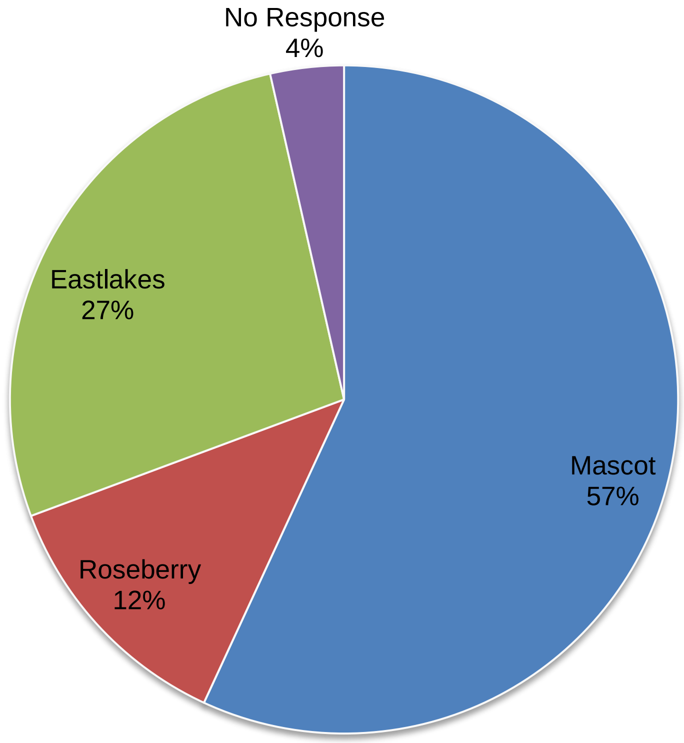
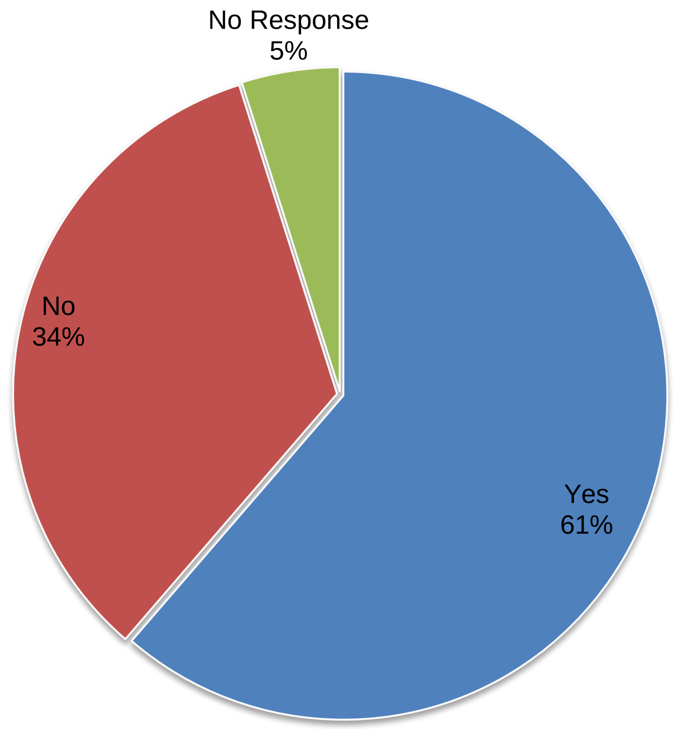
FIGURE 12
COMMUNITY RESPONSES

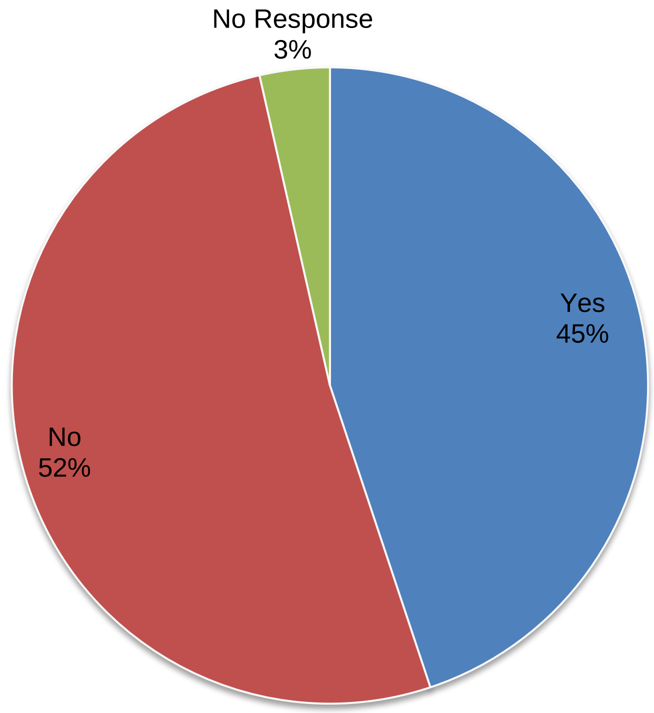
Respondants Per Suburb



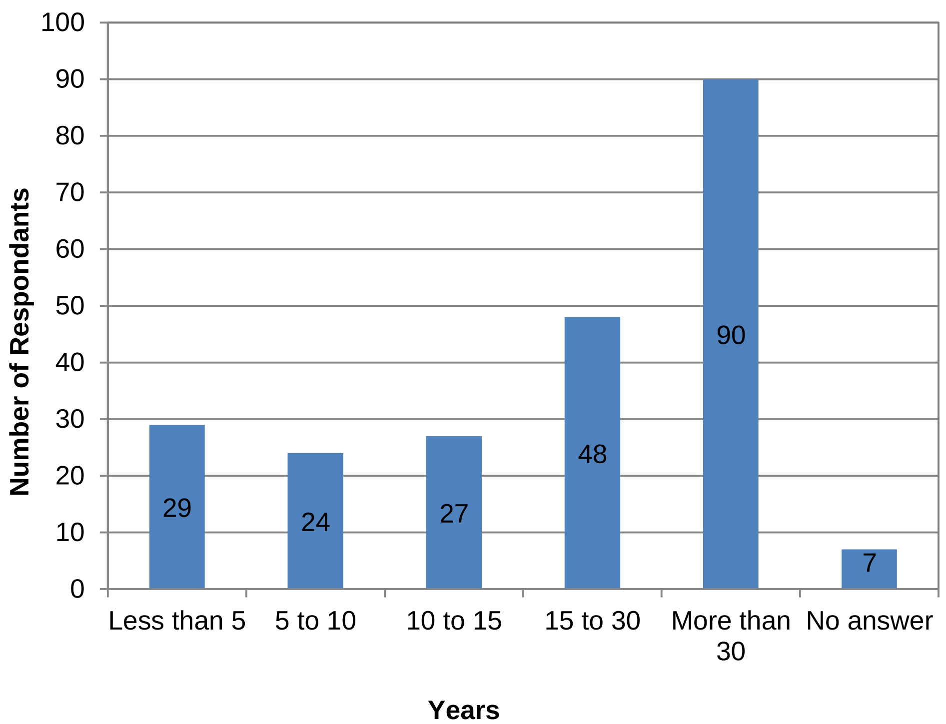
Are you aware of stormwater flooding from streets or channels in your catchment?



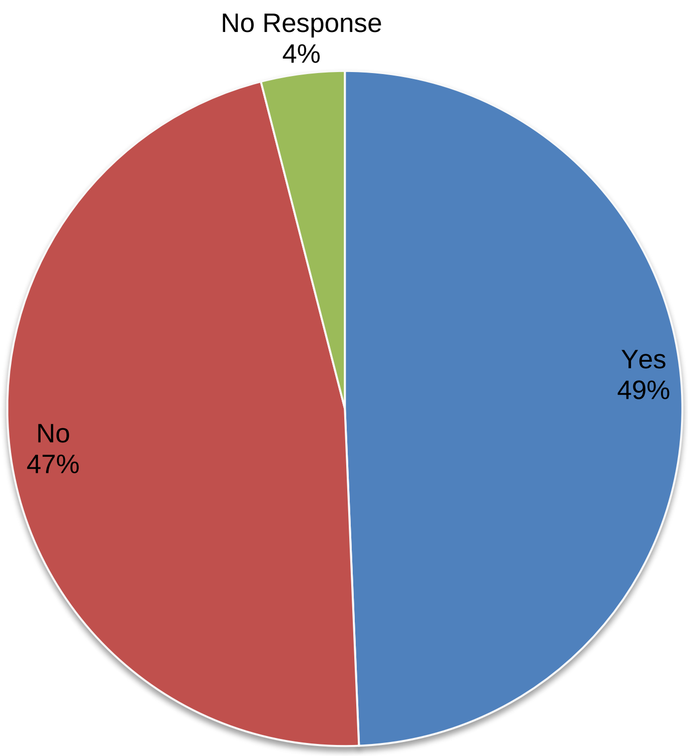
Did you notice any bridges and/or drains to be blocked during the flooding



Period of Residency



Have you ever been inconvenienced by uncontrolled floodwater/stormwater from streets or channels in this area?



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

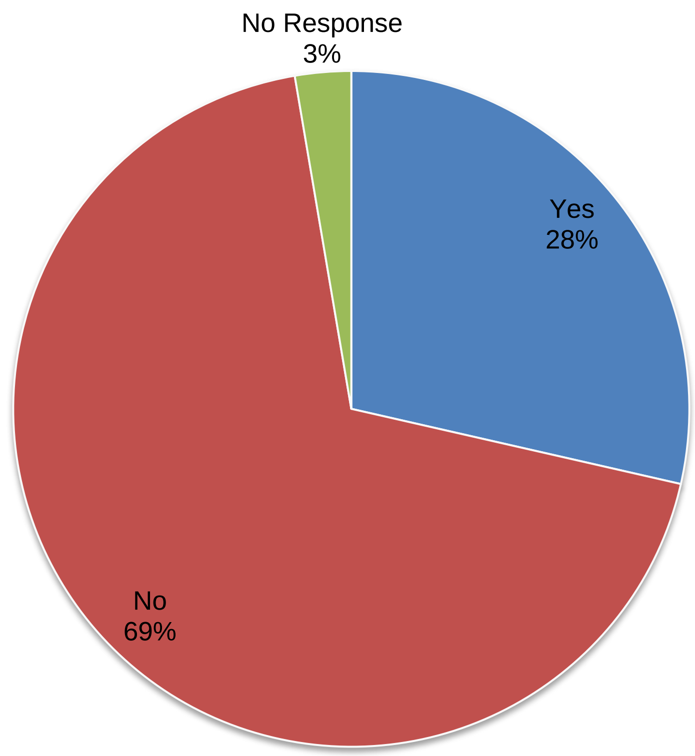


FIGURE 13
PEAK FLOOD LEVELS AND DEPTHS
8TH NOVEMBER 1984 24HR EVENT

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J:\Jobs\113077\ArcGIS\ArcMap\ReportFigures\Figure14_PeakLevelsDepths_March2014.mxd

APPENDIX A: PUBLIC EXHIBITION AND COMMUNITY CONSULTATION

Appendix A

Public Exhibition and Community Consultation Report

Prepared By: Bayside Council
Date: 20 Dec 2019

Contents

1. Overview

Community engagement is an important element of the floodplain risk management process and is important in the development of a flood study as it provides an opportunity for the community to 'have their say' and raise awareness of flood prone land. Engagement can also help with acceptance of the overall project.

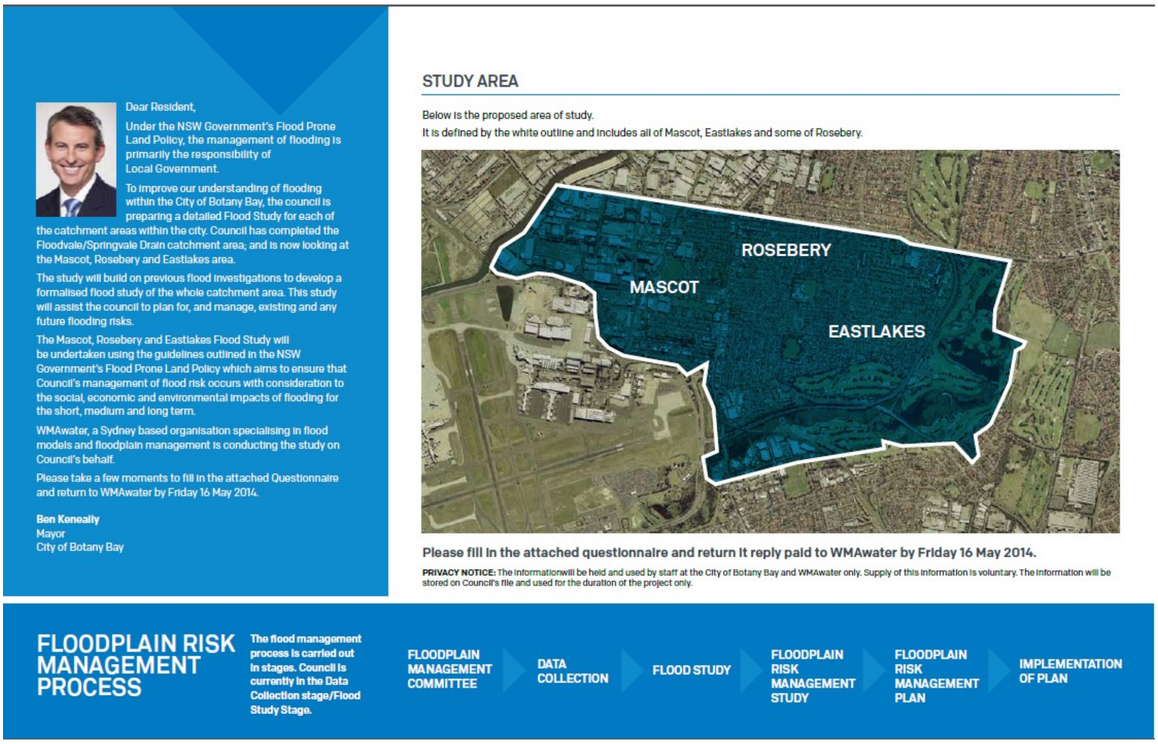
2. Engagement Activities

2.1 Community engagement during preparation of studies

Community Information Session 2014 - Flood Study:

A newsletter and a questionnaire were distributed to residents within the catchment describing the flood study and requesting information on experiences of flooding and to request records of historical flooding. 234 responses were received from the distributed questionnaires. Of those that responded 66 had experienced flooding in their properties with 12 of those experienced flooding above the floor level.

A copy of the newsletter and questionnaire shown below:


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 Mascot, Rosebery and Eastlakes 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 Mascot, Rosebery and Eastlakes 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.

WMAwater, a Sydney based organisation specialising in flood models and floodplain management is conducting the study on Council's behalf.

Please take a few moments to fill in the attached Questionnaire and return to WMAwater by Friday 16 May 2014.

Ben Keneally
Mayor
City of Botany Bay

STUDY AREA

Below is the proposed area of study.
It is defined by the white outline and includes all of Mascot, Eastlakes and some of Rosebery.

Please fill in the attached questionnaire and return it reply paid to WMAwater by Friday 16 May 2014.

PRIVACY NOTICE: The informationwill be held and used by staff at the City of Botany Bay and WMAwater only. 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

Figure 2.1.1: Flood Study Newsletter

MASCOT, ROSEBERY & EASTLAKES **FLOOD STUDY** – Please complete and return by Friday 16 2014.

INTRODUCTION

The City of Botany Bay is carrying out a Flood Study for the Mascot, Rosebery and Eastlakes catchments.

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?

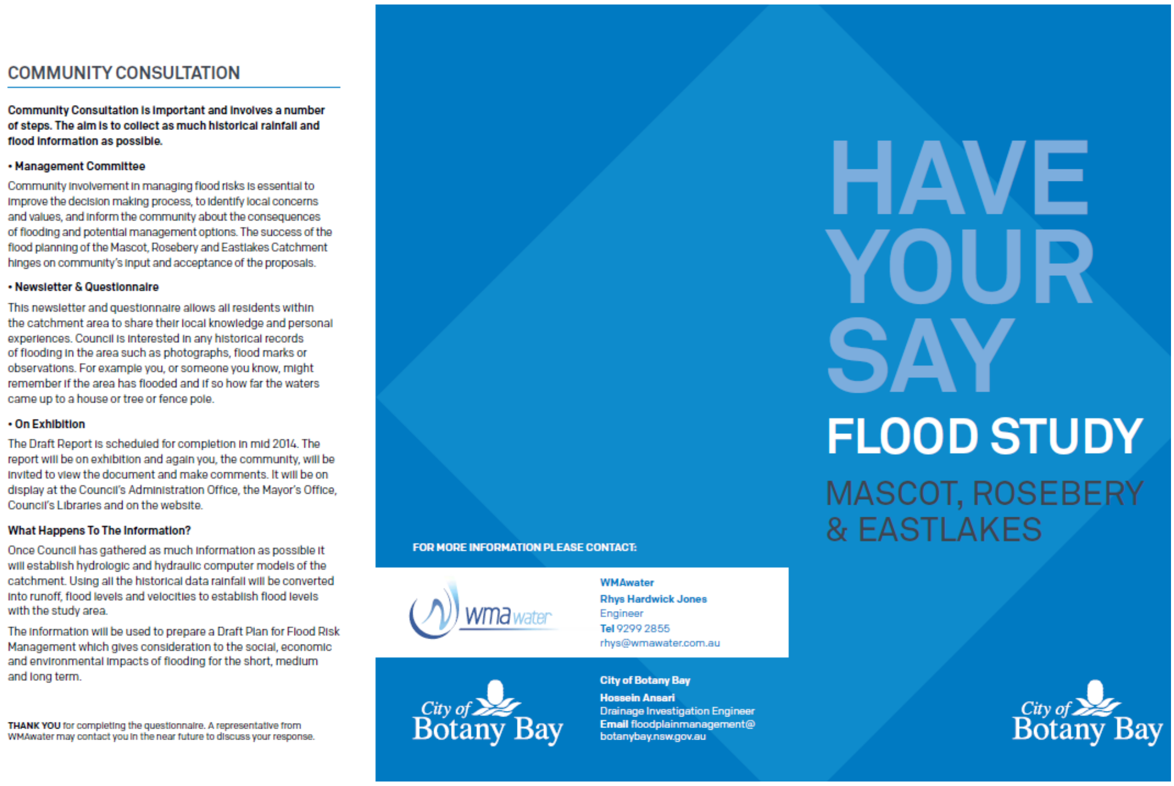
8. Do you have any evidence of past floods (eg. photos, video footage, watermarks on walls or posts)

YES ☐ NO ☐

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

9. Do you have any more information you think might help the Mascot, Rosebery and Eastlakes Flood Study?

Figure 2.1.2: Mascot, Rosebery and Eastlakes Flood Study Questionnaire



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.

• Management Committee

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 Mascot, Rosebery and Eastlakes 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 mid 2014. 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, flood levels and velocities to establish flood levels with 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 WMAwater may contact you in the near future to discuss your response.

HAVE YOUR SAY

FLOOD STUDY

MASCOT, ROSEBERY & EASTLAKES

FOR MORE INFORMATION PLEASE CONTACT:

WMAwater
Rhys Hardwick Jones
Engineer
Tel 9299 2855
rhys@wmawater.com.au

City of Botany Bay
Hossein Ansari
Drainage Investigation Engineer
Email floodplainmanagement@botanybay.nsw.gov.au

Figure 2.1.3: Mascot, Rosebery and Eastlakes Flood Study Newsletter

Community Information Session 2016 – Floodplain Risk Management Study

On 5th April 2016 a community information session was held at Botany Town Hall which was advertised on Council's website and in the local newspaper. The aim of the community engagement session was to obtain community knowledge of flooding hotspots and ideas of potential flood mitigation options to reduce flood affectation in Mascot, Rosebery and Eastlakes catchment.

A consulting engineer from RHDHV undertook door knocking exercise to gather more information from the community in May 2016.

Letters were distributed to all owners and residents affected by 1% AEP flooding on 19th May 2016 to notify residents and owners of the floodplain risk management study and flood level survey inspection.

A copy of the letter is provided below:

City of
Botany Bay

Our Ref: S13/118 Trim Doc 16/17674

19 May 2016

TO THE RESIDENT

Dear Resident

RE: PREPARATION OF FLOOD RISK MANAGEMENT STUDY AND PLAN – MASCOT, ROSEBERY, EASTLAKES AND BOTANY WETLANDS – FLOOR LEVEL SURVEY AND INSPECTION

Botany Bay City Council has undertaken a comprehensive Flood Study in the areas of Mascot, Rosebery, Eastlakes and Botany Wetlands, which was completed in May 2015. The Study identified significant flooding issues in this catchment. As part of the NSW Government's Flood Management Plan, Council is now undertaking a Flood Risk Management Study and Plan (FRMSP).

The FRMSP will determine the flood control and mitigation strategy for these areas. Council consultants are working on preparing the strategy and are following the Study Work Plan approved by the NSW Office of Environment and Heritage. As part of that Work Plan, we are required to collect floor level survey data for some properties, which would enable us to prepare the Flood Risk Management Plan.

In the majority of cases our consultant will not need to access your property as some reading can be taken from the street; however there may be occasions where access is required. In this case you will be contacted by an authorised officer to arrange a time for the survey to be undertaken. Your co-operation is highly appreciated.

Should you have any questions please contact Nick Lewis on 0288545104.

Yours faithfully

Steven Poulton

STEVEN POULTON
Manager City Infrastructure

Administration Centre, 141 Coward Street, Mascot NSW 2020. (PO Box 331 Mascot NSW 1460)
Telephone: (02) 9366 3666 Facsimile: (02) 9366 3777
E-mail: council@botanybay.nsw.gov.au Internet: http://www.botanybay.nsw.gov.au

Figure 2.1.4: Initial letter to residents informing the Flood Risk Management Study

2.2 Consultation on Draft Flood Study and Floodplain Risk Management Plan in 2018

The Mascot, Rosebery and Eastlakes Flood Study and Floodplain Risk Management Study consultation period was four weeks from Tuesday 18 September 2018 to Tuesday 16 October 2018 for community feedback.

This was advertised on Council's website (have your say) and in the local newspaper on Tuesday 18th September 2018.

A letter was sent to flood affected residents and landowners as below:

Our Ref: F18/567

17 September 2018

The Owner/Resident
[redacted]
MASCOT NSW 2020

Dear Sir/Madam

Draft Mascot Rosebery and Eastlakes Flood Study and Floodplain Risk Management Study

Under the NSW Government's Flood Prone Land Policy all NSW councils are responsible for identifying and managing flood prone areas within their local government boundary.

In accordance with this policy Council has undertaken a Flood Study of the Mascot, Rosebery and Eastlakes catchment to determine the probability and impact of flooding. This information has identified your property as being affected by flooding in the 1% Annual Exceedance Probability (AEP) flood event.

Council has also completed a draft Floodplain Risk Management Study (FRMS) of the Mascot, Rosebery and Eastlakes catchment. The purpose of the FRMS is to identify, assess and compare various flood risk management options.

We are writing to all the property owners in areas identified as being flood affected to advise them that the Mascot, Rosebery and Eastlakes Flood Study and Floodplain Risk Management Study will be on public exhibition between 18 September 2018 and 19 October 2018. We invite you to view these documents and provide feedback. These documents can be viewed:

- Online at www.haveyoursay.bayside.nsw.gov.au;
- at Mascot library, 2 Hatfield Street, Mascot
- at Rockdale Library, 444-446 Princes Highway, Rockdale

A community drop in session will be held on **Thursday 4 October between 6pm and 8pm** at Mascot Library, 2 Hatfield Street, Mascot. This will be an opportunity for you to speak directly with Council staff and consultants about the studies.

If you would like to speak with a Council Officer about flooding in this catchment, please contact Pulak Saha, Strategic Floodplain Engineer on 9562 1652 or by email at flooding@bayside.nsw.gov.au.

Yours faithfully

Clare Harley
Manager – Strategic Planning

Figure 2.2.1: Letter sent out to Flood affected residents for feedback on Flood Study and Flood Risk Management Study

A drop in session was held at Mascot Library on 04 October 2018. A total of 14 people attended.

Southern Courier Advertisement on 18th September 2018

HAVE YOUR SAY

Bayside Council has completed a Flood Study and Floodplain Risk Management Study (FRMS) of the Mascot, Rosebery and Eastlakes catchment.

These studies will be on public exhibition between Tuesday 18 September and Tuesday 16 October 2018. We invite you to view these documents and Have Your Say. These documents can be viewed;

- Online at **haveyoursay.bayside.nsw.gov.au**
- At Mascot Library, 2 Hatfield Street
- At Rockdale Library, 444-446 Princes Highway

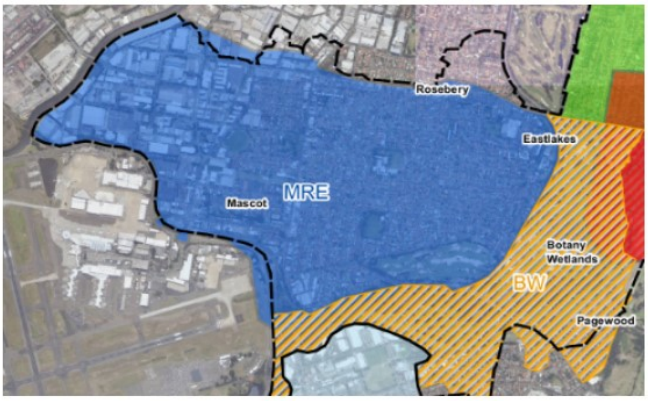
A community drop in session will be held:
Thursday 4 October 2018, 6pm – 8pm
Mascot Library, 2 Hatfield Street

If you would like to speak with a Council Officer about these studies, please contact Council's Strategic Floodplain Engineer on 9562 1652 or via email to flooding@bayside.nsw.gov.au

Figure 2.2.2: The Southern Courier Advertisement 18th September 2018

Public Exhibition: Mascot, Rosebery and Eastlakes Flood Study and Floodplain Risk Management Study

Consultation has concluded



Bayside Council has completed a Flood Study and Floodplain Risk Management Study (FRMS) of the Mascot, Rosebery and Eastlakes catchment.

These studies will be on public exhibition between 18 September 2018 and 19 October 2018. During this period the community is invited to make comments. These documents can be viewed at the following locations:

- Council's website www.haveyoursay.bayside.nsw.gov.au
- Mascot library, 2 Hatfield Street, Mascot
- Rockdale Library, 444-446 Princes Highway, Rockdale

Written comments are due on Friday 19 October 2018 and can be provided in the following ways:

- Online - Click Submission Form below
- Email - flooding@bayside.nsw.gov.au
- In Writing - Attention: Strategic Floodplain Engineer, Bayside Council, PO Box 21, Rockdale NSW 2216.

Please quote reference number F18/567 in your submission.

Bayside Council is holding a **community drop in session** on **Thursday 4 October between 6.00pm and 8.00pm** at Mascot Library, 2 Hatfield Street, Mascot. This is an opportunity for you to speak directly with Council staff and consultants about the studies.

Figure 2.2.3: Advertisement on Council's have your say page on 18th September 2018

3.0 Have your Say website - summary of engagement

Table 3.1.1 - Have your say summary

Number of days open	29 days
Number of visits to Have Your Say website	192
Number of Document downloads	74
Number of survey submissions	13
Number of visitor attended at drop in session	14

Have your say project report / snapshot:

Figure 3.1.2: Bayside have your say- visitors summary

Aware Participants	138
Aware Actions Performed	**Participants**
Visited a Project or Tool Page	138
Informed Participants	**81**
Informed Actions Performed	**Participants**
Viewed a video	0
Viewed a photo	0
Downloaded a document	74
Visited the Key Dates page	4
Visited an FAQ list Page	24
Visited Instagram Page	0
Visited Multiple Project Pages	77
Contributed to a tool (engaged)	3

Widget Type	Engagement Tool Name	Visitors	Views/Downloads
Document	Flood Study Final Draft Volume 1	41	45
Document	MRE 1% AEP Flood extent map	39	48
Document	Overall property tagging map	31	34
Document	Draft Flood Risk Management Study	26	26
Document	MRE property tagging Map 3	20	22
Document	MRE property tagging Map 1	16	17
Document	MRE property tagging Map 4	15	15
Document	Flood Study Final Draft Volume 2 Appendix B	15	16
Document	MRE property tagging Map 2	14	15
Document	Flood Study Final Draft Volume 2 Appendix C	12	13
Faqs	faqs	24	28
Key Dates	Key Date	4	5

Figure 3.1.3: Bayside have your say - document download summary

4.0 Submissions

There were a total of 13 comments received from the community via 4 forums.

Table 4.1.1: Submission summary

Submission source	# Submissions received
Drop in session	4
Email	4
Online submission form (have your say)	3
Phone	2
Total	13

All submissions and responses to the comments are provided below.

Public Exhibition – Community Feedback and Council Staff Responses			
Date	**Communication method**	**Community Feedback**	**Council Staff Response**
4/10/2018	Drop-in	Resident from Forster Street, Mascot: Very thorough study & report but it excludes the airport area! I believe that reclamation of the land & subsequent developments of the airport and surrounding infrastructure has affected runoff & drainage of areas in the study area (Mascot, Rosebery & Eastlakes study area) exacerbating (if not actually causing) some of the flooding around Robey Street, Baxter road & Hardie Street. The airport area needs to be assessed in this regard.	Thank you for your feedback and suggestion. Flood study completed by WMAwater identified the Baxter Road low point as a flooding hotspot. Among the many reasons, it was identified that flooding occurs due to limited capacity of stormwater conduit under the railway embankment. The Flood risk management study then reviewed increasing drainage capacity downstream of Baxter Road and found negligible benefits. Flood planning control, community flood education and emergency management are considered as viable options to reduce flood risk. The Airport area is managed by Commonwealth Government. Council does not have access to the drainage and flooding data to investigate this area, although the topography is reflected in the model.
4/10/2018	Drop-in	Henry Kendall Crescent, Mascot: Thank you Bayside Council for making this study. According to the results Council may be able to prepare (better) for floods in the region. As to the house we have lived in for the last 42 years, we have often experienced heavy rains, but the house has not been affected, as it is raised from the ground sufficiently, i.e. 2 steps. With respect to the yard it is mostly lawn, garden or pavings and the water has always receded promptly. We were told by old neighbours that there used to be a creek running from North to South into Botany Bay and that Botany Road was built parallel to the creek. The waterboard may have used the creek to build the still existing sewerage drain. Therefore we have Burch Lane that runs down from Miles Street to the Knox Church on Botany Road.	The feedback regarding the studies is noted. No response required.
4/10/2018	Drop-in	Resident from Alfred Street Mascot: Insurance duty to report any changes.	In some cases insurance companies use Council's flood model when review the insurance cover and policy while other cases insurance companies conduct their own flood study to identify flood affected properties. It is advised that you review your existing insurance policy to identify your responsibility to provide any known information. There is no change in flood affectation or existing risk of flooding to this site. Through the flood study, Council now have better information regarding flooding in this catchment and you have been informed about the risk of flooding to your property.
4/10/2018	Drop-in	Send link to FRMS and have your say.	Mascot, Rosebery and Eastlakes flood study can be viewed from the link below: https://haveyoursay.bayside.nsw.gov.au/public-exhibition-mascot-rosebery-and-eastlakes-flood-study-and-floodplain-risk-management-study
19/09/2018	Online (have your say)	Resident/owner from Macintosh Street, Mascot: Thank you for your time on the phone just now. As discussed, any adverse effect on land and property values that results from the flood study identifying Macintosh Street as flood prone is without question the responsibility of council because after years of polite and reasonable correspondence on this issue, there is still no firm plan to install stormwater drains in the street. Myself and the other owners pay stormwater fees to Sydney water and rates to the council for services that are simply not delivered. If you see the correspondence below you will not we have been patient and reasonable. Bottom line is that if the stormwater drains are installed, the flood risk goes away.	There are many factors that can affect the value of any property including inflation, a change in interest rates, increased aircraft noise or construction of a new road or shopping centre nearby. The extent to which a property's value is affected once it has been identified as flood affected is impossible to determine. While the notification may affect one potential buyer's decision to purchase a property it may have no impact for another. Ultimately, it is the market that determines the value. Under the NSW Government's Flood Prone Land Policy Council is responsible for identifying and managing flood prone areas within their local government boundary. There is no new change in flood affectation or existing risk of flooding to this site. Through the flood study, Council now have better understanding regarding flooding in this catchment. With regard to stormwater drainage, Council's piped stormwater system is designed to convey frequent minor flood with the aim of reducing day-to-day nuisance flooding. Major storms are conveyed via overland flow paths with the aim of protecting life and property in major events. Hence additional drainage may help in minor rain event flood, however it will not be able to cater for 1% AEP flood event. It is not economically feasible to construct stormwater drainage system that have capacity with 1% AEP flood. The 1% AEP flood means there is a 1% (i.e. a 1 in 100) chance of a flood of this magnitude or greater occurring in any one year. Council is not required to provide this capacity under any legislation or design guidelines. Council's responsibility relates to management of flood risk, which includes planning controls such as restrictions on development in flood prone areas. Unfortunately, the Flood risk management plan has not identified any economically viable option to mitigate

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			flooding in your local area. As next step Council will further investigate options to mitigate minor flooding in this catchment subject to availability of funding.
21/09/2018	Email	Resident from Cleland Street, Mascot: [Name and site address was censored] I have been having problems with flooding under my house in the last 3 years. I had an engineer assess the damage and he advised me to have the house re-pointed - which I did. The damage is still occurring and getting worse every day. So far it has cost me $20000 for re-pointing, $2000 for internal crack repairs and painting (which have already come back - wide cracks in walls skirting boards picture rails. I had to get a carpenter out to adjust my front doors as I couldn't open them from inside and the windows now cannot be locked due to the movement in the foundations. I had a new plumbing system put in with better drainage which cost $4000 and after all this expense (I am on an aged pension) there is no improvement at all. It is actually getting worse day by day. I cannot afford to keep this sort of upkeep and would very much appreciate if you could give me some answers.	I understand your concerns. I have reviewed Mascot, Rosebery and Eastlakes flood report prepared by WMAwater Pty Ltd and identified that in 1% AEP flood event, the risk for your property identified as low hazard. Depth of water and velocity are also considered low. The 1% AEP flood means there is a 1% chance of a flood of this height, or higher occurring in a period of one (1) year. From the information you have provided in the email it is unlikely that this damages occurred due to flood. The damage may be due to original construction issue and site soil condition. I recommend you immediately contact an experienced geotechnical and structural engineer to determine the reason for your house movement and find a solution.
26/09/2018	Email	Resident from Hardie Street: [Name and site address was censored] I was wondering if you could provide us with details of when the Mascot , Roseberry and Eastlakes area has ever flooded? Is there a map of the areas that it has previously affected? What has changed that makes the council believe this area is now flood prone?	We appreciate your feedback in relation to the Mascot, Rosebery and Eastlakes flood study. Floods do not occur in a regular pattern. There may be a period of no floods and a period of several floods. For example, the last time the Brisbane River flooded before the 2011 disaster was in 1974. Residents who moved there in more recent times had not experienced flooding until the floods in January 2011. Following intensive rain larger floods can occur. As part of the flood study Council collected flood information from the properties in this catchment. Please refer to figure 13 and 14 of the flood study report volume 1, for the reported flood affected property locations. The last known large storm events were March 1975 (5% to 2% AEP), February 1993 (10% AEP), 8th November 1984 (20% AEP) and 24th March 2014 (50% AEP). None of these events was as large as the 1% AEP flood that would result from a 1% AEP rainfall event. The 1% AEP flood means there is a 1% (i.e. a 1 in 100) chance of a flood of this height, or higher occurring in any one year. Please find below images from the 2014 rain event (which was estimated to have a 50% chance of occurring in any one year). [images censored] This rainfall event can be expected to occur relatively frequently. A 1% AEP flood event will result in much greater depth of flooding over a much larger area than the very minor 2014 flood event.

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10/10/2018	Email	Resident from Robey Street: [Name and site address was censored] I am writing you in response to your letter vide above reference. My observation is that the road on our house side may be raised by 1 or 2 inches without affecting storm water outlets. This may reduce the sufferings of road users during heavy rains.	Thank you for your valuable feedback and suggestion. Unfortunately, raising the road will potentially increase the flood depth and hazard to the properties on either side of the road. Please refer to the Floodplain Risk Management Study option D4 and figure B19. In this option the consultant reviewed doubling the pipe capacity which may reduce the flooding in this vicinity. However, this option was not considered viable as it would cost approximately $20 million and is likely to cause significant economic, environmental and social issues due to the broad scope of the works. Planning controls are considered the best and most economical approach to reduce flood risk and property damage. The next step is for Council to further investigate the most feasible options to mitigate flooding in this catchment, subject to funding.
16/10/2018	Phone	Resident from Baxter Road, Mascot: I have received three letters for the community consultation. Is my property has higher risk than other neighbouring property?	It was explained that since the owner holds three properties, they have received three letters. Flood risk is similar to the adjacent neighbouring sites.
11/10/2018	Phone	Resident from Coward Street: Why council does the flood study? Are all the other Council is also undertaking similar flood study?	Flooding can cause significant damage to property and risk to life. Council is required by the NSW State Government to undertake studies to determine what land has the potential to be affected by flooding. This is to ensure that new developments are adequately protected from flood hazards and do not make flooding worse.
30/09/2018	Online (have your say)	Resident from Lyon Street, Mascot: I have been living in the Mascot area since 1968. I cannot recall when Mascot was flooded. Would you be able to provide me with any details of when in the past Mascot was flooded, and to what depth. Is this study referring to a 100, 200 etc.year event or what. Certain sections of roads in mascot flood during heavy downpours but this could be due to dirty or even blocked drains. So please advise me of any records that show significant flooding (where waters have actually entered homes) that have occurred in the Mascot area, say in the last 100 years. The report also says that climate change has been taken into consideration, which brings to mind Tim Flannery's predictions that global warming will mean more droughts, therefore less rain and therefore less flooding? I think Council has a responsibility to not cause undue stress by playing up situations that have only a very small chance of occurring in a person's lifetime. The report should state this. Of course natural disasters occur from time to time, but that is the price we pay living on this planet. I think that there is a greater chance of the earth being struck by a meteor large enough to cause global destruction in the next 50 years than substantial flooding occurring in the Mascot area. Looking forward to your reply.	We appreciate your feedback in relation to the Mascot, Rosebery and Eastlakes flood study. Under the NSW Government's Flood Prone Land Policy Council is responsible for identifying and managing flood prone areas within their local government boundary. There is no new change in flood affectation or existing risk of flooding to this site. Through the flood study, Council now have better understanding regarding flooding in this catchment. Floods do not occur in a regular pattern. There may be a period of no floods and a period of several floods. For example, the last time the Brisbane River flooded before the 2011 disaster was in 1974. Residents who moved there in more recent times had not experienced flooding until the floods in January 2011. Following intensive rain larger floods can occur. As part of the flood study Council collected flood information from the properties in this catchment. Please refer to figure 13 and 14 of the flood study report volume 1, for the reported flood affected property locations. The last known large storm events were March 1975 (5% to 2% AEP), February 1993 (10% AEP), 8th November 1984 (20% AEP) and 24th March 2014 (50% AEP). None of these events were as large as the 1% AEP flood that would result from a 1% AEP rainfall event. The 1% AEP flood means there is a 1% (i.e. a 1 in 100) chance of a flood of this height, or higher occurring in any one year. A 1% AEP flood event will result in much greater depth of flooding over a much larger area than the very minor 2014 flood event.

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19/11/2018	Online (have your say)	I have been living at this address since 1985. We NEVER had flooding in our street until a new house was built across the street from me (roughly number XX, I think). When this house was built anew driveway and a new storm water drain was also put in. Clearly it wasn't installed properly because since then we constantly flood. I have had 2 cars rust and destroyed since the installation.	The last known large storm events were March 1975 (5% to 2% AEP), February 1993 (10% AEP), 8th November 1984 (20% AEP) and 24th March 2014 (50% AEP). None of these events was as large as the 1% AEP flood that would result from a 1% AEP rainfall event. The 1% AEP flood means there is a 1% (i.e. a 1 in 100) chance of a flood of this height, or higher occurring in any one year. Regards to the issue of the flooding due to the new development and driveway, you can lodge your concern with customer service on 1300 581 299. Our compliance team will then be able to review approved development plan and determine if new development worsened the existing flood affectation to your property.
24/09/2018	Email	Resident from Aloha Street, Mascot [name and site address censored: I have received your notification of the proposed Community Drop In on 4th October. Unfortunately I cannot attend I was in hospital and missed the Mascot library days when it was going to be on display. I have tried to access the plans online but all I get is a message saying page is not available. Could you please assist me on where I can view the plan? As discussed during the collection phase of this project I am very interested in this study and the plan Bayside has for managing the problem Thank you for your assistance.	Thank you for your email. You can view the report and plans in the link below: https://haveyoursay.bayside.nsw.gov.au/public-exhibition-mascot-rosebery-and-eastlakes-flood-study-and-floodplain-risk-management-study Hard copies of the report are now available in Rockdale and Mascot Library. We will appreciate if you can provide us with your valuable comments regarding the flood study and Floodplain risk management study.