Paddington Flood Study

Draft Report

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Catchment Simulation Solutions

Paddington Flood Study

Draft Report

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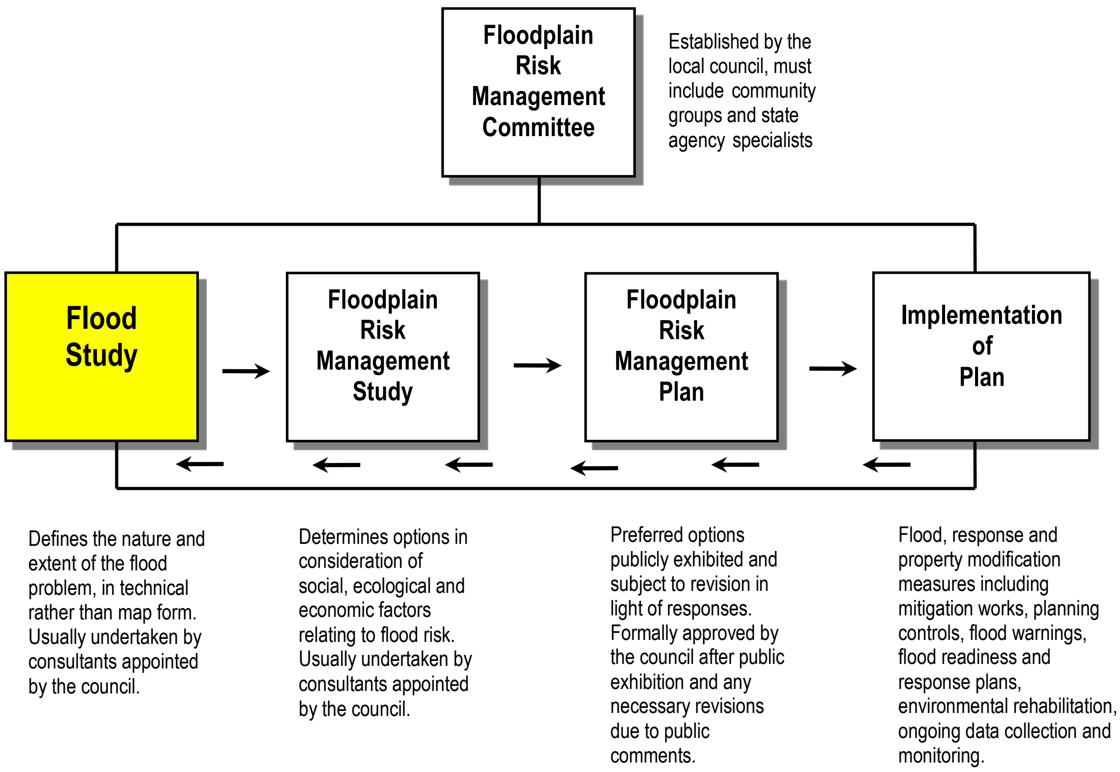
FOREWORD

The State Government's Flood Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Policy is defined in the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005)*.

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

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



The Paddington Flood Study represents the first of the four stages in the process outlined above. The aim of the Flood Study is to produce information on flood discharges, levels, depths and velocities, for a range of flood events under existing topographic and development conditions. This information can then be used as a basis for identifying those areas where the greatest flood damage is likely to occur, thereby allowing a targeted assessment of where flood mitigation measures would be best implemented as part of the subsequent Floodplain Risk Management Study and Plan.

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1 INTRODUCTION

1.1 Catchment Description

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

1.2 Purpose of Study

The urbanised sections of the Paddington catchment are typically drained by a sub-surface stormwater pipe system. During most frequent rainfall events, the stormwater system has sufficient capacity to carry the stormwater runoff below ground towards a network of open channels in the vicinity of the White City tennis centre. The open channels convey that runoff beneath New South Head Road and into Rushcutters Bay.

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

In an effort to better understand the flooding and drainage issues confronting the area, Council commissioned the *'Rushcutters Bay Flood Study'* (2007). This investigation was subsequently followed by the *'Rushcutters Bay Floodplain Risk Management Study & Plan'* (2012) which investigated a range of options for managing the existing, future and continuing flood risk across the catchment.

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

In recognition of the limitations of the previous studies, Council resolved to prepare a dedicated flood study for Paddintgon. This report forms the flood study for Paddington and documents flood behaviour across the catchment for a range of design floods for existing topographic and development conditions. This includes information on flood discharges, levels, depths and flow velocities for a range of design floods. It also provides estimates of the variation in flood hazard and hydraulic categories across the catchment and provides an assessment of the potential impacts of climate change on existing flood behaviour.

2 METHODOLOGY

2.1 Objectives

The primary objective of the flood study was to provide a reliable description of contemporary flood behaviour across Paddington. This includes producing detailed flood maps suitable for determining local flood levels throughout the study area. The flood study was also to serve as the basis for preparing a floodplain risk management study and plan for Paddington.

2.2 Adopted Approach

The general approach and methodology employed to achieve the study objectives involved:

- compilation and review of available flood-related information (Chapter 3);
- the development of a computer-based hydraulic model to simulate the movement of floodwaters across Paddington (Chapter 4);
- calibration of the computer model to reproduce historic floods (Chapter 5);
- use of the computer model to determine peak discharges, water levels, depths, flow velocities and flood extents for the full range of design events up to and including the PMF for existing topographic and development conditions (Chapter 6);
- use of the computer model results to generate provisional flood hazard and hydraulic category mapping (Chapter 7),

3 DATA COLLECTION AND REVIEW

3.1 Overview

A range of data were made available to assist with the preparation of Paddington Flood Study. This included previous reports, hydrologic data and GIS data.

A description of each dataset along with a synopsis of its relevance to the flood study is summarised below.

3.2 Previous Reports

A summary of flood reports that have previously been prepared for the Paddington area are provided in the following section. They are listed in chronologic order.

3.2.1 Rushcutters Bay Catchment Flood Study (2007)

The *"Rushcutters Bay Catchment Flood Study"* report was prepared by Web, McKeown & Associates (now WMAwater) for Woollahra Municipal Council. The primary objective of the study was to define flood behaviour across the Rushcutters Bay catchment for existing (i.e., 2007) conditions. As shown in **Figure 1**, the Paddington study area falls within the Rushcutters Bay catchment.

Through an analysis of recorded rainfall data as well as information provided by the community, the report notes that notable flooding across the Rushcutters Bay catchment occurred on the following dates:

- 9 November 1984;
- 6 January 1989;
- 9 March 1989; and,
- 26 January 1991.

The report compiled historic flood information from a range of sources including previous reports and community questionnaires. This information indicates that several properties have been subject to flooding in the past with the 1984, 1989 and 1991 events being the most significant. Several historic flood marks were also extracted as part of the study and are reproduced on **Figure 2**.

Detailed survey of the open channel adjoining White City was also collected as part of the study. It was considered that this information could be used to assist in the development of the hydraulic model for the current study. The location of the surveyed cross-sections is shown on **Figure 2**.

Hydrology across the Rushcutters Bay catchment was defined using a DRAINS model. The DRAINS model was also used to define the capacity of the stormwater system. The DRAINS modelling indicated that the vast majority of the stormwater pipes within the catchment have less than a 20% AEP (i.e., 1 in 5 year) capacity. The DRAINS modelling also indicates that the upper catchment (including Paddington) would experience significant overland flow during large floods that may result in cars and/or pedestrians being washed away.

A fully 2-dimensional hydraulic model was developed to define the movement of floodwaters. The hydraulic model was developed using the SOBEK software. However, the hydraulic model only covered the portion of the catchment located downstream of Hampden Road. A 2 metre grid size was adopted to define the variation in terrain and hydraulic roughness.

Calibration of the SOBEK model was attempted using historic flood mark information concentrated around White City for the 1984, 1989 and 1991 floods. As there are no stream gauges located within the catchment, no calibration of the DRAINS model was attempted. However, the design flows generated by the DRAINS model were verified against previous studies.

The DRAINS and SOBEK models were subsequently used to simulate design floods ranging from the 20% AEP flood up to the PMF. The 1% AEP flood extent generated by the SOBEK model is shown on **Figure 2**.

A range of sensitivity simulations were also completed to quantify the impact that uncertainty in rainfall, blockage, Rushcutters Bay water level and Manning's "n" roughness may have on model results. It was noted that no climate change assessment was completed as part of the flood study.

The study determined that a number of properties within the catchment may be subject to over floor flooding during relatively frequent floods (i.e., 47 properties would be inundated above floor level during the 20% AEP flood). This flood liability was further confirmed based on the results of a community questionnaire, where 81 respondents had indicated they had experienced over floor flooding.

The over floor flooding information was also used to estimate flood damages costs. This determined that the average annual damages for the Rushcutters Bay catchment would be $1.3 million. However, the report notes that the damage estimate only considered the damage potential across the lower sections of the catchment and that there are a number of properties in the upper catchment areas (including much of Paddington) that are likely to be subject to over floor flooding.

Overall, it is considered that the DRAINS model provides a suitable description of catchment hydrology and can be used as part of the current study. However, the hydraulic model does not extend sufficiently upstream to provide a reliable description of overland flood behaviour across Paddington. Nevertheless, much of the information that was collected across the downstream sections of the catchment could be used to assist in the development of the computer model for the current (e.g., survey).

3.2.2 Rushcutters Bay Flood Study (2013)

The *"Rushcutters Bay Flood Study"* report was prepared by WMAwater for The City of Sydney. The flood study was prepared to define existing flood behaviour across that section of the Rushcutters Bay catchment falling within the City of Sydney LGA. As shown in **Figure 1**, the

City of Sydney LGA is located immediately west and south of the Woollahra Municipal Council LGA.

This study also notes that significant flooding was experienced across the catchment in 1984, 1989 and 1991. A photograph is also provided in the report showing flooding in Victoria Street, Paddington on 9th January, 1989 (refer **Plate 1**). A number of historic flood marks are also documented in the study for the 1989 and 1991 floods. The location of the flood marks is shown in **Figure 2**.

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

Hydrologic processes across the catchment were defined using a DRAINS computer model. No calibration of the DRAINS hydrology was completed. However, peak flows generated by the DRAINS model were verified against other studies including the "*Rushcutters Bay Catchment Flood Study*" (Web, McKeown & Associates, 2007). In general, the peak flows were determined to be comparable.

The movement of floodwaters across the catchment was simulated using a hydraulic model that was developed using the TUFLOW software. The full stormwater system was included within the TUFLOW model as a dynamically linked 1-Dimensional (1D) network. This allowed representation of the conveyance of flows by the stormwater system below ground as well as the 2-dimensional simulation of overland flows once the capacity of the stormwater system is exceeded.

The TUFLOW model was validated using historic flood mark information for the 1984, 1989 and 1991 floods. The report noted that many of the flood marks were based on anecdotal reports of inundation depths and are approximate only. In most cases the TUFLOW model was able to provide a reasonable reproduction of the reported flooding depths. However, some more significant differences were noted, particularly in Taylor Street. The report argued that these differences may be associated with changes to fences and other flow impediments in the area, which would alter the historic impediment to flow relative to contemporary conditions.

The DRAINS and TUFLOW models were used to simulate a range of design floods from a 50% AEP flood up to the PMF. A range of maps were produced to display the results of the modelling including peak floodwater depths, levels, hazard categories and hydraulic categories.

A flood damages assessment was also completed using the design flood levels generated by the TUFLOW model in conjunction with surveyed floor level information for 138 properties. This determined that the average annual flood damages for those properties contained within the City of Sydney LGA was $2.15 million.

3.2.3 Rushcutters Bay Floodplain Risk Management Study and Plan (2012)

The *"Rushcutters Bay Floodplain Risk Management Study and Plan"* report was prepared by WMAwater for Woollahra Municipal. It follows on from the "*Rushcutters Bay Catchment Flood Study"* (Web, McKeown & Associates, 2007) and was prepared to provide a plan for the management of flood liable land within the Rushcutters Bay catchment. This included a review of planning controls, flood planning levels and flood risk mitigation measures that could be potentially implemented to reduce the impact of flooding on current and future development within the catchment.

A range of measures were considered in an effort to mitigate existing flooding problems across the upper and lower catchment. The report noted that flooding problems across the upper catchment (including Paddington) included:

- Garages and building floor levels below street level;
- Ponding of overland flows at "sag" points;
- Over floor flooding of dwellings;
- Blockage of overland flow paths; and,
- Diversion of overland flow paths.

Measures identified for consideration to mitigate the identified flooding problems across the upper catchment included:

- Stormwater pit and pipe upgrades;
- Redistribution of overland flows;
- Management of blockage;
- Flood proofing of properties;
- Voluntary house raising;
- Voluntary house purchase;
- Onsite detention systems
- Planning controls;

The study noted that the identification of overland flooding problems and the assessment of mitigation options across the upper catchment was hampered by the lack of a suitable 2-dimensional hydraulic model of the area. Accordingly, the evaluation of the potential mitigation options was largely based on a qualitative assessment. In recognition of this limitation, the study recommended the development of a new 2-dimensional flood model of the upper catchment.

3.3 Hydrologic Data

3.3.1 Historic Rainfall Data

A number of daily read and continuous (i.e., pluviometer) rainfall gauges are located near Paddington. The location of each gauge is shown in **Figure 3**. Key information for each gauge is summarised in **Table 1**.

The information provided in **Table 1** indicates that daily rainfall records in the vicinity of the study area are available dating back to 1858 (Sydney Observatory Hill gauge). However, continuous rainfall records are only available from 1913 onwards.

3.3.2 Historic Stream Gauge Data

There are no stream gauges located within Paddington or Rushcutters Bay catchment. Accordingly, no stream flow information is available for the study area.

3.4 Topographic and Survey Information

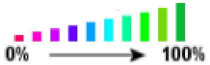
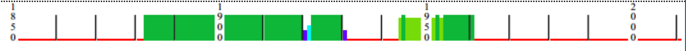
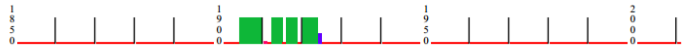
3.4.1 2013 LiDAR

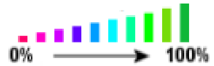
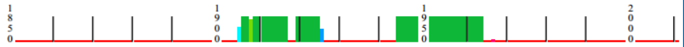
Light Detection and Ranging (LiDAR) data was collected across Sydney in April 2013 by the NSW Government's Land and Property Information department. The LiDAR has a stated absolute horizontal accuracy of better than 0.8 metres and an absolute vertical accuracy of better than 0.3 metres. It is considered that the vertical and horizontal accuracy provided by the LiDAR data is suitable for defining major overland flow paths and is, therefore, suitable for the study.

The raw LiDAR point data provides an average point spacing of at least one point per square metre. Therefore, it was considered to be sufficiently detailed to enable development of a 1 metre grid based Digital Elevation Model (DEM). The DEM that was developed using the LiDAR is provided in **Figure 2**.

As the LiDAR was collected relatively recently, it is considered to provide a reliable representation of contemporary topographic conditions across the majority of the catchment. However, LiDAR can provide a less reliable representation of the terrain in areas of high vegetation density. This is associated with the laser ground strikes often being restricted by the vegetation canopy. Errors can also arise if non-ground elevation points (e.g., vegetation canopy) are not correctly removed from the raw LiDAR dataset. Therefore, additional checks were completed across areas of dense vegetation to confirm if the terrain representation was reliable.

Table 1 Available rain gauges in the vicinity of Paddington

Gauge Number	Gauge Name	Gauge Type	Source*	Period of Record		Distance from Paddington	Temporal Availability and Percentage of Annual Record Complete
				From	To		
66139	Paddington	Daily	BOM	Jan 1970	Dec 1976	1.6	
66160	Centennial Park	Daily	BOM	Jun 1900	Mar 2015	1.8	
66006	Sydney Botanic Gardens	Daily	BOM	Jan 1885		2.2	
66066	Waverley Shire Council	Daily	BOM	Jan 1936	1964 Oct	2.7	
66098	Royal Sydney Golf Club	Daily	BOM	Mar 1928		3.0	
66015	Crown St. Reservoir	Daily	BOM	Feb 1882	Dec 1960	3.1	
66005	Bondi Bowling Club	Daily	BOM	Jul 1939	Oct 1982	3.1	
66062	Sydney (Observatory Hill)	Daily Continuous	BOM	Jul 1858 Jan 1913		3.4	
66052	Randwick (Randwick St)	Daily	BOM	Jan 1888		3.4	
66073	Randwick Racecourse	Daily	BOM	Jan 1937		3.4	
66097	Randwick Bunnerong Road	Daily	BOM	Jan 1904	Apr 1924	3.8	
66187	Tamarama (Carlisle St)	Daily	BOM	Jul 1991	Mar 1999	3.9	
66179	Bronte Surf Club	Daily	BOM	Jan 1918	Feb 2009	4.1	
66033	Alexandria (Henderson Road)	Daily	BOM	May 1962	June 1999	4.3	
66112	Bondi	Daily	BOM	Jan 1887	Dec 1924	4.7	
66149	Glebe Point Syd. Water Supply	Daily	BOM	Jun 1907	Apr 1914	4.8	
66068	Vaucluse	Daily	BOM	Mar 1934	Jul 1975	4.9	
66021	Alexandria (Erskineville)	Daily	BOM	Aug 1948	Nov 1973	5.1	

Gauge Number	Gauge Name	Gauge Type	Source*	Period of Record		Distance from Paddington	Temporal Availability and Percentage of Annual Record Complete 
				From	To		
66184	Mosman Council	Daily Continuous	BOM	Sep 1984 Sep 1984	July 2013 Aug 2007	5.3	
66041	Mosman Water Supply	Daily	BOM	Jun 1904	Dec 1966	5.4	

NOTE: * BOM = Bureau of Meteorology
Data sourced from: http://www.bom.gov.au/climate/data/

Plate 2 provides an example of the LiDAR ground point density near the corner of Neild Avenue and Lawson Street. **Plate 2** shows the point density is high across non-vegetated areas (e.g., sports fields, car park, roads). The point density is also generally high in the vicinity of sparse vegetation. However, the point density drops considerably in the vicinity of buildings and dense vegetation. Although this indicates that non-ground points have been removed, it is noted that the lower point density may result in a weaker definition of the variation in ground surface elevation across heavily vegetated sections of the study area. Accordingly, care needs to be taken when extracting terrain information directly from the LiDAR in the vicinity of dense vegetation.

Plate 2 ALS ground data points (yellow) near the corner of Neild Ave and Lawson Street

3.5 GIS Data

A number of Geographic Information System (GIS) layers were also provided by Council to assist with the study. This included:

- Aerial Photography – provides 2014 ortho-rectified aerial imagery at a 0.1 metre pixel size;
- Cadastre – provides property boundary polygons;
- Local Environmental Plan (LEP) – provides zoning / land use information;
- Pipes – provides the alignment and size of stormwater pipes;
- Pits – provides locations of stormwater pits/inlets;

A review of the stormwater pits and pipes layer showed that the GIS information did not always provide a reliable description of the pit locations. Therefore, it was necessary to complete some manual relocation of pits and pipes to ensure they were appropriately located (e.g., stormwater pits were located within gutters).

Moreover, the pit and pipe layers that were provided only described the stormwater system contained within the Woollahra LGA. That is, no pit and pipe information was available for the upstream sections of the catchments contained within the City of Sydney LGA. In this regard, the City of Sydney made stormwater pit and pipe information available that was prepared as part of the "*Rushcutters Bay Flood Study*" (WMAwater, 2013).

A comparison of the pit and pipe information along the common LGA boundary (i.e., Boundary Street) showed some discrepancies between the two stormwater datasets. The City of Sydney dataset appeared to provide a more detailed description of the drainage system so was adopted in preference to the Woollahra Council data along the LGA boundary.

3.6 Community Consultation

3.6.1 General

A key component of the flood study involved development and calibration of a computer flood model. The computer model is typically calibrated to ensure it is providing a reliable representation of flood behaviour. This is completed by using the model to replicate floods that have occurred in the past (i.e., historic floods).

Although some historic flood information could be sourced from the previous investigations and flood photos, additional information on past flooding was sought from the community to assist with the model calibration. Therefore, several community consultation devices were developed to inform the community about the study and to obtain information from the community about their past flooding experiences. Further information on each of these consultation devices is provided below.

3.6.2 Flood Study Website

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

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

During the course of the study, the website was visited over 200 times by 98 unique users.

3.6.3 Community Information Brochure and Questionnaire

A community information brochure and questionnaire was prepared and distributed to potentially flood liable households and businesses within the Paddington study area. The properties that were targeted as part of the mail out were identified by completing a preliminary Probable Maximum Flood (PMF) simulation using the computer flood model (refer Section 4). The brochure and questionnaire were subsequently mailed out to all properties and owners of properties falling within the preliminary PMF extent. This resulted in the brochure and questionnaire being sent to 740 households and businesses. A copy of the brochure and questionnaire is included in **Appendix A**.

The questionnaire sought information from the community regarding whether they had experienced flooding, the nature of flood behaviour, if roads and houses were inundated and whether residents could identify any historic flood marks. A total of 114 questionnaire responses were received. A summary of all questionnaire responses is provided in **Appendix A**. The spatial distribution of questionnaire respondents is shown in **Figure A1**, which is also enclosed in **Appendix A**.

The responses to the questionnaire indicate that:

- The majority of respondents have lived in or around the catchment for at least 15 years. Accordingly, most respondents would have been living in the area when the 2015 floods occurred. However, only a limited number of respondents are likely to have experience the 1989 and 1991 events
- 45% of respondents have experienced some form of disruption as a result of flooding in the study area. This ranges from traffic disruptions through to garages and homes/businesses being inundated. The spatial distribution of respondents that have reported past flooding problems is shown in **Figure A1** in **Appendix A** (refer red dots).
- The following streets/areas were identified by several respondents as being particularly susceptible to flooding problems:
  -> Cecil Street, Cecil Lane, Royalston St and Hampden
  -> Jersey Road, Forbes St, Sutherland Ave and Harris St
  -> Cascade Street and Glenmore Road
  -> Boundary Street and Neild Avenue

A number of respondents also provided photos of past floods. A selection of these photographs are presented in the following section.

3.7 Flood Photographs and Videos

A selection of photographs and videos of historic floods across Paddington were provided by Council staff and the community as part of the community consultation. The majority of the videos/photos were for floods that occurred in April 2012, April 2015 and August 2015. The photographs as well as a selection of "still" from the videos are reproduced in **Plate 3** to **Plate 12**.

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

- Flooding from a surcharging stormwater pit in the lower catchment (**Plate 3**);
- Shallow but fast moving water that is largely contained within the roadway but extending onto the adjoining footpath across the steeper sections of the catchment (**Plate 4, Plate 8**, **Plate 9** and **Plate 11**); and,
- Deeper "ponded" water contained within localised depressions (**Plate 5**).
- Water cascading down stairs (**Plate 12**)

Plate 3 Surcharging stormwater pit in Hampden Street during April 2012 flood

Plate 4 Flooding along Paddington Street during April 2015 flood

Plate 5 Flooding near Trumper Park during April 2015 flood

Plate 6 Intersection of New South Head Road and Neild Ave during August 2015 event

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

Plate 8 Cooper Street during August 2015 event

Plate 9 Boundary St (near Glenview St) during August 2015 event

Plate 10 Jersey Road during August 2015 event

Plate 11 Comber St looking towards Boundary St during August 2015 event

Plate 12 Water cascading down stairs between Forbes St and Sutherland Ave during August 2015 event

4 Computer Flood Model

4.1 General

Computer models are the most common method of simulating flood behaviour through a particular area of interest. They can be used to predict flood characteristics such as peak flood level and flow velocity and the results of the modelling can also be used to define the variation in flood hazard.

As discussed, a DRAINS computer model of the Rushcutters Bay was previously developed as part of the "*Rushcutters Bay Catchment Flood Study*" (Web, McKeown & Associates, 2007). This model was considered to be sufficiently detailed to also define hydrologic (i.e., rainfall-runoff) processes as part of the current study.

A SOBEK computer model was also developed as part of the "*Rushcutters Bay Catchment Flood Study*" (Web, McKeown & Associates, 2007) to define flood hydraulics across the Rushcutters Bay catchment. However, as noted in Section 3.2.1, the SOBEK model only covered the downstream sections of the catchment. As a result, it did not describe overland flood behaviour across the Paddington area. Therefore, a new hydraulic computer model was developed as part of the current flood study that focused on providing a reliable description of overland flood behaviour across Paddington.

In this regard, the TUFLOW software was used to develop a computer model of the Paddington study area. TUFLOW is a fully dynamic, 1D/2D finite difference model developed by BMT WBM (2012). It is used extensively across Australia to assist in defining flood behaviour.

The following sections describe the model development process, as well as the outcomes of the model calibration.

4.2 Model Development

4.2.1 2D Model Extent and Grid Size

A 2-dimensional computer model of the Paddington study area was developed using the TUFLOW software (version 2013-12-AE). The extent of the TUFLOW model area is shown in **Figure 4**. As discussed, the focus of the current study involves providing a detailed description of overland flood behaviour across the upper sections of the catchment that are centred around Paddington. However, it was also considered important to ensure the interaction between overland flooding and mainstream flooding across the downstream reaches of the catchment was also provided. Therefore, as shown in **Figure 4**, the TUFLOW model was extended downstream to also include the downstream sections of the Rushcutters Bay catchment.

The TUFLOW software uses a grid to define the spatial variation in topography and hydrologic/hydraulic properties (e.g., Manning's 'n' roughness, rainfall losses) across the study area. Accordingly, the choice of grid size can have a significant impact on the performance of the model. As the catchment is highly urbanised with a number of relatively narrow flow paths, a 1 metre grid size was adopted.

Elevations were assigned to grid cells within the TUFLOW model based on the Digital Elevation Model derived from LiDAR data. As the LiDAR data was collected in 2013, it was considered to provide a reliable representation of contemporary topographic conditions across the study area. However, some manual updates where completed to the topographic definition in the vicinity of dense vegetation to compensate for the poor definition provided by the LiDAR in the vicinity of dense vegetation.

4.2.2 1D Domain

A dynamically linked 1-dimensional (1D) network was embedded within the 2D domain to represent the open channel between Glenmore Road (located downstream of Trumper Oval) and Rushcutters Bay. The flow carrying capacity of the open channel was defined using the surveyed cross-sections gathered for the *"Rushcutters Bay Catchment Flood Study"* (Web, McKeown & Associates, 2007) (refer Section 3.2.1).

The extent of the 1D domain is shown in **Figure 4**.

4.2.3 Material Types

The TUFLOW software employs material polygons to define the variation in hydraulic (i.e., Manning's 'n') properties across the study area. The material polygons for this study were developed using an automated remote sensing approach that takes advantage of the full range of information collected by LiDAR, particularly multiple returns, LiDAR intensity as well as aerial imagery (Ryan, 2013).

The automated approach provides a detailed spatial description (i.e., 1m grid size) of the variation in materials/land use across the catchment. However, there were several misclassifications that were identified. These are primarily associated with shadowing effects and occasional misclassification of buildings. Therefore, some manual updates to the remote sensing outputs were completed to ensure a reliable description of material types was provided across the full study area.

The spatial distribution of the different material types is shown in **Figure 4**. As shown in **Figure 4**, the study area was subdivided into six different material types:

- Buildings;
- Trees;
- Concrete;
- Roads;
- Grass; and,
- Water;

4.2.4 Manning's 'n' Roughness

Manning's 'n' is an empirically derived coefficient that is used to define the resistance to flow (i.e., roughness) afforded by different material types / land uses. It is one of the key input parameters used in the development of the TUFLOW model.

The material types shown in **Figure 4** were used as the basis for assigning Manning’s ‘n’ to each grid cell in the TUFLOW model. The Manning's 'n' values that were adopted for each material type are summarised in **Table 2**.

Table 2 Manning's 'n' Roughness Values

Material Description	Manning's 'n'
Building	1.000
Water	0.025
Trees with minimal undergrowth	0.040
Trees with undergrowth (e.g., Trumper Park)	0.080
Grass	0.030
Concrete	0.012
Roads	0.015

4.2.5 Stormwater System

The stormwater system has the potential to convey a significant proportion of runoff across the study area during relatively frequent rainfall events. Therefore, it was considered important to incorporate the conveyance provided by the stormwater system in the TUFLOW model to ensure the interaction between piped stormwater and overland flows was represented.

The full stormwater system was included within the TUFLOW models as a dynamically linked 1-Dimensional (1D) network. This allowed representation of the conveyance of flows by the stormwater system below ground as well as simulation of overland flows in 2D once the capacity of the stormwater system is exceeded.

As discussed in Section 3.2.1, the stormwater pits and pipes across the Woollahra LGA section of the catchment were previously included in a DRAINS computer model. Accordingly, this information was exported from DRAINS in GIS format and converted into a format suitable for inclusion in the TUFLOW software. This provided a description of all key attributes necessary to define the conveyance of the stormwater system within the Woollahra LGA (e.g., pipe diameters, pit types, invert elevations etc).

As discussed in Section 3.5, the stormwater pit and pipe system contained within the City of Sydney LGA section of the catchment were also previously analysed as part of a TUFLOW model. This information was provided by the City of Sydney and was included within the TUFLOW model developed for the current study.

The extent of the stormwater system included within the TUFLOW models is shown in **Figure 4**.

Inlet capacity curves were then prepared to define the pit inflow capacity at each pit location. The 'Drains Generic Pit Spreadsheet' (Watercom Pty Ltd, July 2005), was used to develop the inlet capacity curves. The inlet capacity curves were developed to take account of:

- The different pit inlet types (e.g., sag inlets, grated inlets, kerb inlets, combination inlets); and,
- The different pit dimensions and lintel sizes.

A copy of the inlet capacity curves are provided in **Appendix C**.

4.2.6 Building Representation

The Paddington catchment is highly urbanised. This high level of urbanisation provides many flow obstructions. One of the most significant impediments to overland flow in urban environments is buildings. Available research indicates that buildings have a considerable influence on flow behaviour in urban environments by significantly impeding and deflecting flows (Smith et al, 2012). Accordingly, it was considered necessary to include a representation of the buildings in the computer model.

The lower part (i.e., the area between the ground surface and the floor level) of each building located within major overland flow paths was represented as a complete flow obstruction. This is shown conceptually in **Plate 13**. Surveyed floor levels were used to define the floor level information, where available. In areas where no surveyed floor level information was available, all elevations contained within the building footprint were raised by 0.3 metres.

Plate 13 Conceptual representation of buildings in TUFLOW model

Once the water level exceeded the floor level of each building, it was allowed to "enter" the building. However, a high Manning's "n" value of 1.0 was adopted to reflect the significant impediment to flow afforded by the many flow obstructions contained with a typical house (e.g., walls, furniture etc). This is also shown conceptually in **Plate 13**.

4.2.7 Fences

Fences can also provide a significant impediment to flow in urbanised catchments (refer **Plate 14**). Therefore, it was also considered important to include a representation of fences within the TUFLOW model. An automated approach was employed to extract approximate fence alignments across urbanised floodplain areas based on information contained in cadastre and LEP GIS layers. This involved using lot boundaries across residential areas as a proxy for fence alignments. The extent of fence lines that were generated based on this approach is shown in **Plate 15**.

Plate 14 Example of paling fence causing a notable impediment and redistributable of overland flows

It was recognised that even relatively permeable fence types can become partially blocked during the course of a flood. During the early stages of a flood, debris (e.g., litter, leaves, branches) will be mobilised and conveyed down major flow paths until it reaches an obstruction whose aperture is too small to transmit the debris. Therefore, by the peak of the flood there is a significant probability that most fences will be at least partially blocked with debris.

It was recognised that there is likely to be considerable variability in the degree of blockage provided by different fence types. However, a comprehensive review of the blockage provided by all fence types across the catchments was considered to be primitively time consuming and expensive. Therefore, all fences were implemented with a global blockage factor of 75%. That is, a 75 % reduction in conveyance capacity is provided through the fences. It was felt that a 75% blockage factor provided a conservatively realistic estimate of the average degree of blockage provided by all fence types across the study area (even relatively permeable fence types when debris blockage is considered).

Plate 15 Extent of fences (yellow lines) extracted using cadastre, zoning and roadway GIS layers

It was also assumed that all fences were 1.0 metre high. Although many fences will be higher than 1 metre, it was considered that most fences would collapse once the water exceeds this level. Therefore, all flow that approaches a fence will be subject to 75% blockage up to a depth of 1.0 metres. All flow in excess of 1.0 metres will not be subject to any blockage and will travel across the top of the fence "unabated". A form loss coefficient of 0.9 was also incorporated to reflect the additional entrance and exit losses through the fence openings.

5 Computer Model Calibration

5.1 Overview

Computer flood models are approximations of a very complex process and are generally developed using parameters that are not always known with a high degree of certainty and/or are subject to natural variability. This includes catchment roughness/vegetation density as well as blockage of hydraulic structures. Accordingly, the model should be calibrated using flow and flood mark information from historic floods to ensure the adopted model parameters are producing reliable estimates of flood behaviour.

Calibration is typically completed by routing recorded rainfall from historic floods through a computer model. Simulated flows and flood levels are extracted from the model results at locations where recorded data are available. Calibration is completed by iteratively adjusting the model parameters within reasonable bounds to achieve the best possible match between simulated and recorded flood flows and flood marks.

Unfortunately, there are no stream gauges located within the study area. Therefore, it is not possible to complete a full calibration of the computer model developed for this study.

However, historic flood marks are available for the 1989, 1991 and 2015 events. Therefore, it is possible to complete a 'pseudo-calibration' by routing historic rainfall through the computer models and comparing simulated water levels against recorded flood mark elevations/depth for these floods.

Further details of the TUFLOW model calibration process are provided below.

5.2 January 1989 Flood

5.2.1 Hydrology

The January 1989 flood occurred over a 30 minute period on 6 January 1989 commencing around 2:20pm. It flooded a number of residential and commercial properties above floor level.

Accumulated daily rainfall totals for each rainfall gauge that was operational during the 1989 event were used to develop a rainfall isohyet map for the 1989 event, which is shown in **Figure 5**. The isohyet map shows that around 65 mm of rain fall across the catchment within a 24 hour period (although, as discussed above, the majority of the rain fell within a 3 hour period). As there was minimal spatial variation in rainfall during the 1989 event, a uniform rainfall depth of 65 mm was applied to the DRAINS model.

The temporal (i.e, time-varying) distribution of rainfall was applied based on the closest continuous rainfall gauge. The closest continuous gauge was determined to be the Sydney (Observatory Hill) gauge (Gauge #66062), which is located approximately 3.5 kilometres north-west of Paddington. The pluviograph for this gauge for the 1989 event is provided in **Figure E1** in **Appendix E**.

The continuous rainfall information was also analysed relative to design rainfall-intensity-duration information. This information is presented in **Appendix D** and indicates that the 1989 rainfall was only slightly less severe that a 1% AEP rainfall event.

The DRAINS model was used to simulate the transformation of rainfall into runoff for the 1989 event and generate discharge hydrographs for each subcatchment contained within the Rushcutters Bay catchment. A total of 671 local hydrographs were produced by the DRAINS model. Peak discharges for each subcatchment are summarised in **Appendix E**.

The discharge hydrographs were subsequently applied to the TUFLOW model. Further information on the results generated by the TUFLOW model is provided below.

5.2.2 Hydraulics

Calibration of the TUFLOW hydraulic model was attempted based upon 34 flood marks for the 1989 flood. Modifications were completed to the TUFLOW model across Cecil Lane and Trumper Oval to reflect topographic conditions across this area at the time of the 1989 event.

As discussed, calibration was undertaken by routing the recorded rainfall through the DRAINS model to generate discharge hydrographs for each subcatchment. The discharge hydrographs were applied to the TUFLOW model and the TUFLOW model was used to route the flows across the study area. Peak flood depths generated by the TUFLOW model were compared with historic flood depths. TUFLOW model parameters were iteratively adjusted until a reasonable agreement between simulated flood levels and recorded flood marks was achieved.

The stormwater system plays an important role in conveying flows during most rainfall events. However, the degree of blockage of stormwater pits can have a significant impact on the performance of the stormwater system. For the 1989 simulation, it was assumed that 'on grade' pits were subject to 20% blockage and 'sag' pits were subject to 50% blockage. These blockage factors were applied based upon information contained in the Australian Rainfall & Runoff "Project 11: Blockage of Hydraulic Structures" (Engineers Australia, 2013). Additional simulations were completed assuming no blockage, however, the results generated by the TUFLOW model were largely unchanged. This is likely associated with the stormwater pipe system being "fully charged" during the 1989 flood by the time it reaches the most seriously impacted areas of the catchment. As a result, no additional flow can "fit" into the stormwater system across these areas regardless of the blockage.

Peak floodwater depths were extracted from the results of the 1989 flood simulation and are included on **Figure 6**. It should be noted that only water depths greater than 0.1 metres are shown in **Figure 6** to help distinguish between areas of shallow versus more significant inundation depths.

A comparison between recorded floodwater depths and simulated flood depths is presented in **Table 3**. The recorded and simulated floods depths are also presented in **Figure 6**.

Table 3 Comparison between simulated flood depths and recorded flood depths for 1989 flood

Location	Recorded Floodwater Depth (m)	Simulated Floodwater Depth (m)	Difference (m)
1 Tivoli Street, Paddington	0.08	0.08	0.00
18 George Street, Paddington	0.60	0.72	0.12
11 Elizabeth Place, Paddington	0.08	0.16	0.08
380 Oxford St, Paddington	1.00	1.06	0.06
126 Queen Street, Woollahra	0.50	0.53	0.03
25 Elizabeth Street, Paddington	0.08	0.02	-0.06
48 Victoria St, Paddington	0.40	0.53	0.13
130 Underwood Street, Paddington	0.05	0.14	0.09
9 Tara Street, Woollahra	0.15	0.30	0.15
Spicer Lane, Woollahra	0.50	0.64	0.14
21 Paddington Street, Paddington	0.15	0.20	0.05
18 Norfolk Street, Paddington	0.08	0.12	0.04
204 Jersey Road, Paddington	1.00	1.00	0.00
88 Hargrave Street, Paddington	1.50	1.43	-0.07
14 Hargrave Street, Paddington	0.70	0.63	-0.07
12 Hargrave Street, Paddington	1.50	1.61	0.11
1 Harris Street, Paddington	0.85	0.75	-0.10
Low point in Hargrave Lane	0.60	0.71	0.11
66 Elizabeth Street, Paddington	0.15	0.17	0.02
55 Boundary St, Darlinghurst	0.15	0.18	0.03
51 Boundary St, Darlinghurst	0.15	0.24	0.09
39 Sutherland St, Paddington	0.10	0.11	0.01
9 Sutherland St, Paddington	0.10	0.22	0.07
Corner Boundary & Liverpool St, Darlinghurst	0.50	0.58	0.08
6 Hampden St, Paddington	0.30	0.43	0.13
8 Hampden St, Paddington	0.30	0.39	0.09
Nield Avenue properties	0.50	0.52	0.02
1-13 Royalston Street, Paddington	1.00	0.95	-0.05
48 Cecil Street, Paddington	0.95	0.90	-0.05
357 Glenmore Road, Paddington	0.30	0.22	-0.08
10 Neild Avenue, Darlinghurst	0.20	0.26	0.06
Neild Ave & New South Head Road intersection	0.40	0.41	0.01
422 Glenmore Road, Edgecliff	0.20	0.36	0.16
White City	0.60	0.54	-0.06
		Average:	0.04

The flood depth comparison provided in **Table 3** and **Figure 6** shows that the TUFLOW model provides a reasonable reproduction of recorded flood depths. More specifically, all historic water depths are reproduced by the TUFLOW model to better than 0.16 metres with the average difference being 0.04 metres.

5.3 January 1991 Flood

5.3.1 Hydrology

The January 1991 flood occurred on the 26th January 1991. The main rainfall event occurred over 45 minutes starting around 2:30pm. Accumulated daily rainfall totals for each rainfall gauge that was operational during the 1991 event were used to develop a rainfall isohyet map, which is shown in **Figure 7**. The isohyet map indicates that there was only a slight spatial variation in rainfall across the catchment during the 1991 event. It indicates that around 54 mm of rain fell across the catchment during the event. Accordingly, a uniform rainfall depth of 54 mm was applied to the DRAINS model.

The temporal (i.e, time-varying) distribution of rainfall was applied to the DRAINS model based on rainfall records for the Sydney (Observatory Hill) gauge (Gauge #66062). The pluviograph for this gauge for the 1991 event is provided in **Figure E2** in **Appendix E**.

The rainfall information for this gauge was also analysed relative to design rainfall-intensity-duration information. This information is presented in **Appendix D** and indicates that the 1991 rainfall was slightly less severe than a 5% AEP event.

The DRAINS model was used to simulate the transformation of rainfall into runoff for the 1991 event and generate discharge hydrographs for each subcatchment contained within the Rushcutters Bay catchment. Peak discharges for each subcatchment are summarised in **Appendix E**.

5.3.2 Hydraulics

Calibration of the TUFLOW hydraulic model was attempted based upon 14 flood marks for the 1991 flood. As with the 1989 simulation, the topography across the Cecil Lane and Trumper Park area was modified to provide a better description of topographic conditions in 1991.

The calibration was undertaken by routing the discharge hydrographs produced by the DRAINS model through the TUFLOW model and adjusting model parameter values until a reasonable agreement between simulated flood levels and recorded flood marks was achieved.

Peak floodwater depths were extracted from the results of 1991 simulation and are included on **Figure 8**. It should be noted that only water depths greater than 0.10 metres are shown in **Figure 8**.

A comparison between recorded flood depths and simulated flood depths for each blockage scenario is also presented in
Table 4. A comparison between the peak flood depths generated by the TUFLOW model and the recorded flood depths is also provided in **Figure 8**.

Table 4 Comparison between simulated flood depths and recorded flood depths for 1991 flood simulation

Location	Recorded Floodwater Depth (m)	Simulated Floodwater Depth (m)	Difference (m)
1 Tivoli Street, Paddington	0.02	0.02	0.00
18 George Street, Paddington	0.60	0.57	-0.03
11 Elizabeth Place, Paddington	0.04	0.09	0.05
25 Elizabeth Street, Paddington	0.40	0.50	0.10
130 Underwood Street, Paddington	0.30	0.37	0.07
9 Tara Street, Woollahra	0.05	0.06	0.01
Holdsworth Community Centre	0.50	0.55	0.05
Spicer Lane, Woollahra	0.50	0.54	0.04
8 Norfolk Street, Paddington	0.08	0.01	-0.07
8 Hampden St, Paddington	0.15	0.30	0.15
48 Cecil Street, Paddington	0.60	0.65	0.05
Low point of McLachlan Ave	0.15	0.10	-0.05
Trumper Oval	0.15	0.21	0.06
White City	0.30	0.31	0.01
		Average:	0.03

The flood depths comparisons provided in
Table 4 indicate that the TUFLOW model provides a reasonable reproduction of recorded flood mark elevations with all historic flood depths being reproduced to within 0.15 metres. **Table** 4 also shows that the average difference between simulated and recorded flood depths is 0.03 metres.

5.4 August 2015 Flood

5.4.1 Hydrology

The August 2015 flood occurred on the 24th August 2015. The most intense downpour occurred over a 20 minute period commencing around 8:50pm. The flood inundated a number of garages and residential properties above floor level.

Accumulated daily rainfall totals for each rainfall gauge that was operational during the 2015 event were used to develop a rainfall isohyet map, which is shown in **Figure 9**. The isohyet map indicates that there was only a slight spatial variation in rainfall across the catchment during the 2015 event. It indicates that around 70 mm of rain fell across the catchment during the event. Therefore, a rainfall depth of 70 mm was applied to the DRAINS model.

The temporal (i.e, time-varying) distribution of rainfall was applied to the DRAINS model based on rainfall records for the Sydney (Observatory Hill) gauge (Gauge #66062). The pluviograph for this gauge for the 2015 event is provided in **Figure E3** in **Appendix E**.

The rainfall information for this gauge was also analysed relative to design rainfall-intensity-duration information. This information is presented in **Appendix D** and indicates that the 2015 rainfall had an annual exceedance probability of between 2% and 5%.

The DRAINS model was used to simulate the transformation of rainfall into runoff for the 2015 event and generate discharge hydrographs for each subcatchment contained within the Rushcutters Bay catchment. Peak discharges for each subcatchment are summarised in **Appendix E**.

5.4.2 Hydraulics

Calibration of the TUFLOW hydraulic model was attempted based upon 17 flood marks for the August 2015 flood. The calibration was undertaken by routing the discharge hydrographs produced by the DRAINS model through the TUFLOW model and adjusting model parameter values until a reasonable agreement between simulated flood levels and recorded flood marks was achieved.

Peak floodwater depths were extracted from the results of 1991 simulation and are included on **Figure 10**. It should be noted that only water depths greater than 0.10 metres are shown in **Figure 10**.

A comparison between recorded flood depths and simulated flood depths for each blockage scenario is also presented in **Table 5**. A comparison between the peak flood depths generated by the TUFLOW model and the recorded flood depths is also provided in **Figure 10**.

The flood depths comparisons provided in **Table 5** indicate that the TUFLOW model provides a reasonable reproduction of recorded flood mark elevations with all historic flood depths being reproduced to within 0.15 metres. **Table 5** also shows that the average difference between simulated and recorded flood depths is 0.04 metres.

5.5 Summary

The outcomes of the calibration shows that the TUFLOW model provides a reasonable reproduction of flood depths for each of the three historic floods considered as part of the study. All historic flood depths were reproduced to better than 0.16 metres by the TUFLOW model and the average difference between recorded and simulated flood depths is 0.04 metres.

Overall, it is considered the TUFLOW model provides a reliable description of flood behaviour across Paddington and provides a suitable tool to assist in defining design flood behaviour for contemporary topographic and development conditions.

Table 5 Comparison between simulated flood levels and recorded flood marks for 2012 flood simulation

Location	Recorded Floodwater Depth (m)	Simulated Floodwater Depth (m)	Difference (m)
Corner Forbes and Sutherland Street	0.30	0.36	0.06
Corner Glenmore and Brown St Street	0.18	0.12	-0.06
Corner of Boundary and Glenview Street	0.30	0.29	-0.01
Corner of Glenview St and Boundary Street	0.20	0.30	0.10
4 Harris Street	0.43	0.41	-0.02
Neild Ave across from Lawson Street	0.20	0.17	-0.03
13 Royalston Street	0.49	0.62	0.13
Corner of Neild and Boundary Street	0.35	0.30	-0.05
Corner of New South Head Rd and Neild Ave	0.15	0.24	0.09
21 Elizabeth Street	0.10	0.22	0.12
66 Glenview Street	0.15	0.21	0.06
420 Glenmore Road	1.00	0.92	-0.08
23 Lawson Street	0.20	0.23	0.03
30 Winsor Street	0.10	0.15	0.05
11 Sutherland Ave	0.15	0.15	0.00
2A Hampden Street	0.45	0.52	0.07
400 Glenmore Road	0.30	0.44	0.14
		Average:	0.04

6 Design Flood Estimation

6.1 General

Design floods are hypothetical floods that are commonly used for planning and floodplain management investigations. Design floods are based on statistical analysis of rainfall and flood records and are typically defined by their probability of exceedance. This is typically expressed as an Annual Exceedance Probability (AEP).

The AEP of a flood level / depth at a particular location is the probability that the flood level / depth will be equalled or exceeded in any one year. For example, a 1% AEP flood is the best estimate of a flood that has a 1% chance of being equalled or exceeded in any year.

Design floods can also be expressed by their Average Recurrence Interval (ARI). For example, the 1% AEP flood can also be expressed as a 1 in 100 year ARI flood. That is, the 1% AEP flood will occur, on average, once every 100 years.

It should be noted that there is no guarantee that a 1% AEP flood will occur once in a 100 year period. It may occur more than once, or at no time at all in the 100 year period. This is because design floods are based upon a long-term statistical average. Therefore, it is prudent to understand that the occurrence of recent large floods does not preclude the potential for another large flood to occur in the immediate future.

Design floods are typically estimated by applying design rainfall to the computer model and using the model to route the rainfall excess across the catchment to determine design flood level, depth and velocity estimates. The procedures employed in deriving design flood estimates across Paddington are outlined in the following sections.

6.2 Computer Model Setup

6.2.1 Boundary Conditions

Design Rainfall

Design rainfall for the 100%, 20%, 10%, 5% and 1% AEP events were derived using standard procedures outlined in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia, 1987). The resulting intensity-frequency-duration curves for Paddington are provided in **Appendix D**.

For all design storms up to and including the 1% AEP event, the design rainfall was uniformly distributed across the entire study area. That is, there was no spatial variation in design rainfall across the study area. In addition, due to the small size of the catchment, no areal reduction factors were applied to the rainfall.

The design rainfall estimates were used in conjunction with standard design temporal patterns to describe how the design rainfall varies with respect to time throughout each design storm.

As part of the flood study it was also necessary to define flood characteristics for the Probable Maximum Flood (PMF). The PMF is estimated by routing the Probable Maximum Precipitation (PMP) through the computer model. The PMP is defined as the greatest depth of precipitation that is meteorologically possible at a specific location. Accordingly, it is considered the largest quantity of rainfall that could conceivably fall within a particular catchment.

PMP depths were derived for Paddington for a range of storm durations up to and including the 6-hour event based on procedures set out in the Bureau of Meteorology's *'Generalised Short Duration Method'* (GSDM) (Bureau of Meteorology, 2003). The PMP estimates were varied spatially and temporally based on the GSDM approach before application to the DRAINS model.

The GSDM PMP calculations are included in **Appendix F**. The PMP estimates are also included in the intensity-frequency-duration curves provided in **Appendix D**.

Downstream Boundary Conditions

The Paddington study area falls within the Rushcutters Bay catchment which drains into Port Jackson. Accordingly, the prevailing water level in Port Jackson has the potential to impact on flood behaviour across the downstream sections of the Rushcutters Bay catchment.

The *"Rushcutters Bay Catchment Flood Study"* (Web, McKeown & Associates, 2007) adopted a very high solstice tide level of 1.0 mAHD for all design flood simulations. This water level was retained for all design flood simulations completed as part of the current study.

As the current study is concerned with defining flood behaviour across the upper sections of the Rushcutters Bay catchment, it is considered that any uncertainty associated with the downstream boundary condition should not impact on the model results across the area of interest.

6.2.2 Hydraulic Structure Blockage

During most floods, sediment, vegetation and urban debris (e.g., litter) from the catchment can become mobilised leading to blockage of stormwater inlets (refer **Plate 16**). Consequently, these drainage structures will typically not operate at full efficiency during most floods. This can increase the severity of flooding across areas located adjacent to these structures.

In recognition of this, blockage factors were applied to stormwater pits. The blockage factors were based on the latest available structure blockage information contained in 'Blockage of Hydraulic Structures: Blockage Guidelines' (Engineers Australia, 2015). This resulted in the following blockage factors being adopted for each design flood simulation:

- Sag inlets: 50% blockage
- On-grade inlets: 20% Blockage

Plate 16 View showing blockage of a stormwater pit located on Glenmore Road following a storm event in 2015

No blockage of culverts was adopted for any of the design flood simulations as all culverts are located across the downstream reaches of the catchment (i.e., outside of the study area). However, the impact of no blockage as well as complete blockage of pits and culverts on 1% AEP results was assessed as part of the sensitivity analysis.

6.3 Results

6.3.1 Critical Duration

It was recognised that a single storm duration will not necessarily produce the "worst case" flooding across all sections of the study area. Therefore, the TUFLOW model was used to simulate flood behaviour across Paddington for a range of different durations for each design storm. The results from the 1% AEP design flood simulations were subsequently interrogated to determine the "critical" storm durations across the study area. The outcomes from this assessment are shown graphically in **Plate 17** and are also tabulated in **Table 6**.

The information contained in **Plate 17** shows that storm durations of between 15 minutes and 2 hours produce the highest 1% AEP flood levels across the majority of the study area. The 15-minute storm generally dominates in areas of shallow flow while the 1.5-hour storm duration typically dominates along the major overland flow paths.

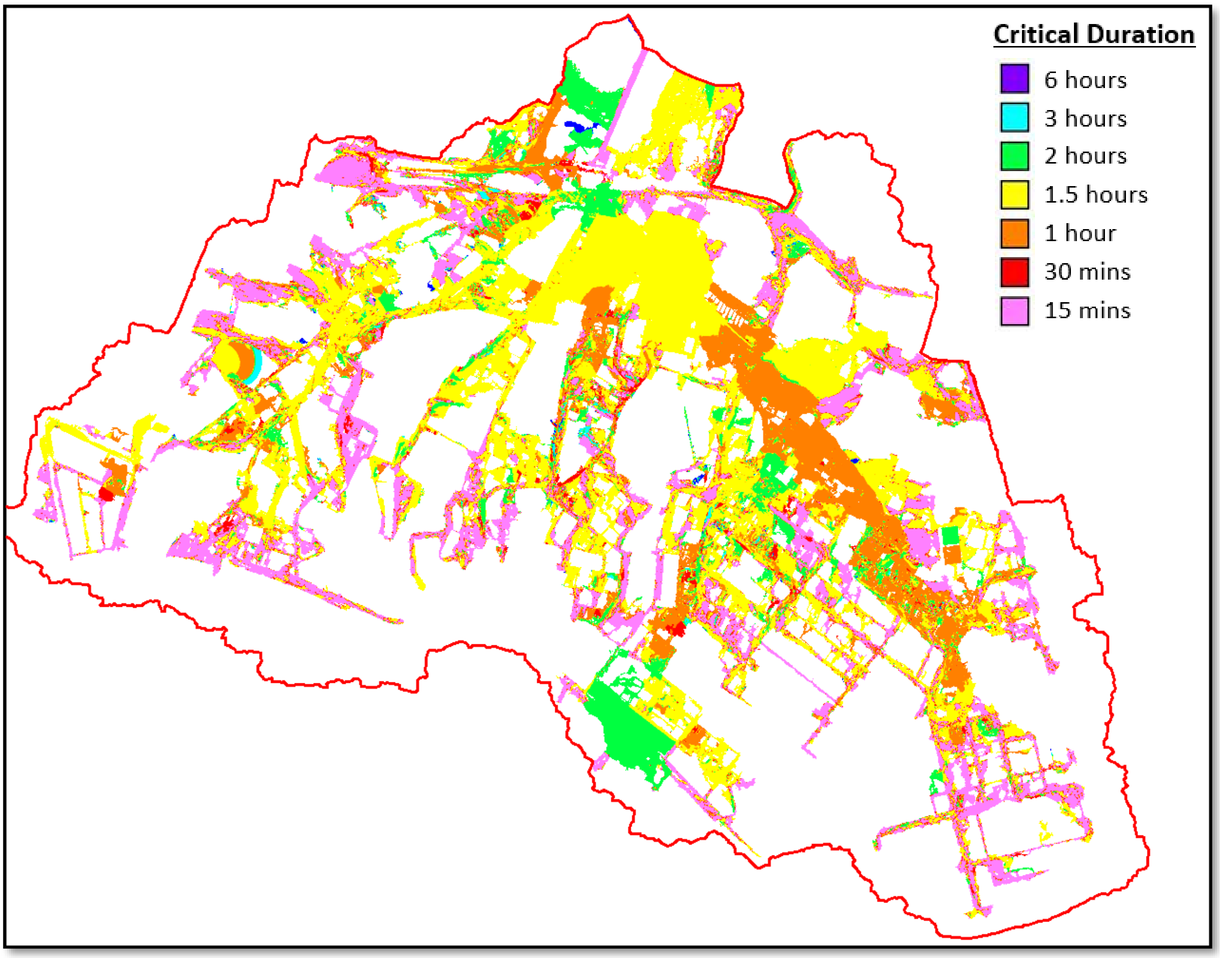


Plate 17 Spatial Variation in Critical Duration for the 1% AEP Storm

Table 6 Summary of Critical Storm Durations across Paddington

Storm Duration (hours)	Proportion of Catchment Where Storm Duration is Critical	Rank
6	0.3%	7
3	0.8%	6
2	11.8%	4
1.5	44.1%	1
1	17.3%	3
0.5	5.3%	5
0.25	20.4%	2

The 0.5, 1 and 2-hour storms are also critical across small sections of the study area. The 3 and 6 hour durations were critical across only a very small section of the study area (i.e., <1%). Therefore, they were not included as part of the design flood simulations.

6.3.2 Design Flood Envelope

As discussed, a range of storm durations were simulated for each design flood to ensure the highest peak flood level was defined across all sections of the study area. The results from each simulation for each design flood were interrogated and combined to form a "design flood envelope" for each design flood. It is this "design flood envelope", comprising the worst case depths, velocities and levels at each TUFLOW cell that forms the basis for the results documented in the following sections.

6.3.3 Presentation of Model Results

During a typically storm, the majority of the catchment will be "wet". However, most of the runoff will comprise relatively shallow depths of flow that will not present a significant flood hazard. To assist in identifying areas with more significant overland inundation, only areas subject to inundation depths of more than 0.1 metres were included in the mapping.

6.3.4 Design Floodwater Depths & Velocities

Peak floodwater depths for the 100%, 20%, 10%, 5% and 1% AEP events as well as the Probable Maximum Flood (PMF) were extracted from the results of the TUFLOW model and are presented in **Figures 11** to **16**. Peak flow velocities for each design event were also extracted from the results of the modelling and are presented in **Figures 17** to **22**.

6.3.5 Discussion

The results show that flood behaviour across the upstream sections of the catchment are characterised by relatively shallow, but fast moving water. The majority of the flow across the upstream sections of the catchment is contained within roadways. However, there are some locations where water is predicted to overtop gutters and flow through adjoining properties. This includes areas adjoining "sag" points in Jersey Road, Victoria Street, Underwood Street, Dudley Street, Hargrave Street, Hargrave Lane and Sutherland Street.

Figure 11 also shows that overland flow is predicted during the 100% AEP event. This indicates that the stormwater system has less than a 100% AEP (i.e., 1 in 1 year ARI) capacity across some sections of the catchment. Therefore, during particularly severe rainfall events across the catchment, the majority of runoff would be conveyed overland.

Flood behaviour across the downstream sections of the catchment (downstream of Harris Street & Hampden Street) is characterised by deeper and slower moving water. This is associated with the comparatively flat topography and some significant overland flow impediments (e.g., northern end of Cecil Street). Floodwater depths of over 1 metre are predicted during the 1% AEP flood across some sections of the lower catchment.

6.4 Sensitivity Analysis

Computer flood models require the adoption of several parameters that are not necessarily known with a high degree of certainty or are subject to natural variation (e.g., vegetation density during the summer versus winter months). Each of these parameters can impact on the results generated by the model.

As discussed in Sections 5, the TUFLOW models were calibrated and verified using historic flood information. In general, the models were found to provide a reasonable reproduction of historic floods.

Nevertheless, it is important to understand how any uncertainties in model input parameters may impact on the results produced by the model. One of the main areas of uncertainty involves blockage of hydraulic structures (i.e., stormwater pits, culverts). Accordingly, additional simulations were completed to assess the sensitivity of the results generated by the model to variations in structure blockage. The outcomes of this assessment are presented below.

6.4.1 Hydraulic Structure Blockage

The TUFLOW model was updated to include complete blockage as well as no blockage of stormwater pits and culverts. The updated model was used to re-simulate the 1% AEP flood. Water levels were extracted from the results of the revised modelling and were compared against peak flood levels for "base" design conditions. This allowed water level difference mapping to be prepared showing the magnitude of any change in water levels/depths associated with the change in initial loss values.

The difference mapping is presented in **Plate 30** and **31** for the "no blockage" and "complete blockage" scenarios respectively. Decreases in 1% AEP "design" flood levels are shown in shades of blue and increases in 1% AEP flood levels are shown in shades of yellow/red.

Plate 19 shows that complete blockage will cause some significant changes to 1% AEP flood levels, particularly across the lower sections of the catchment (e.g., upstream of New South Head Road), where 1% AEP flood levels are predicted to increase by over 1 metre.

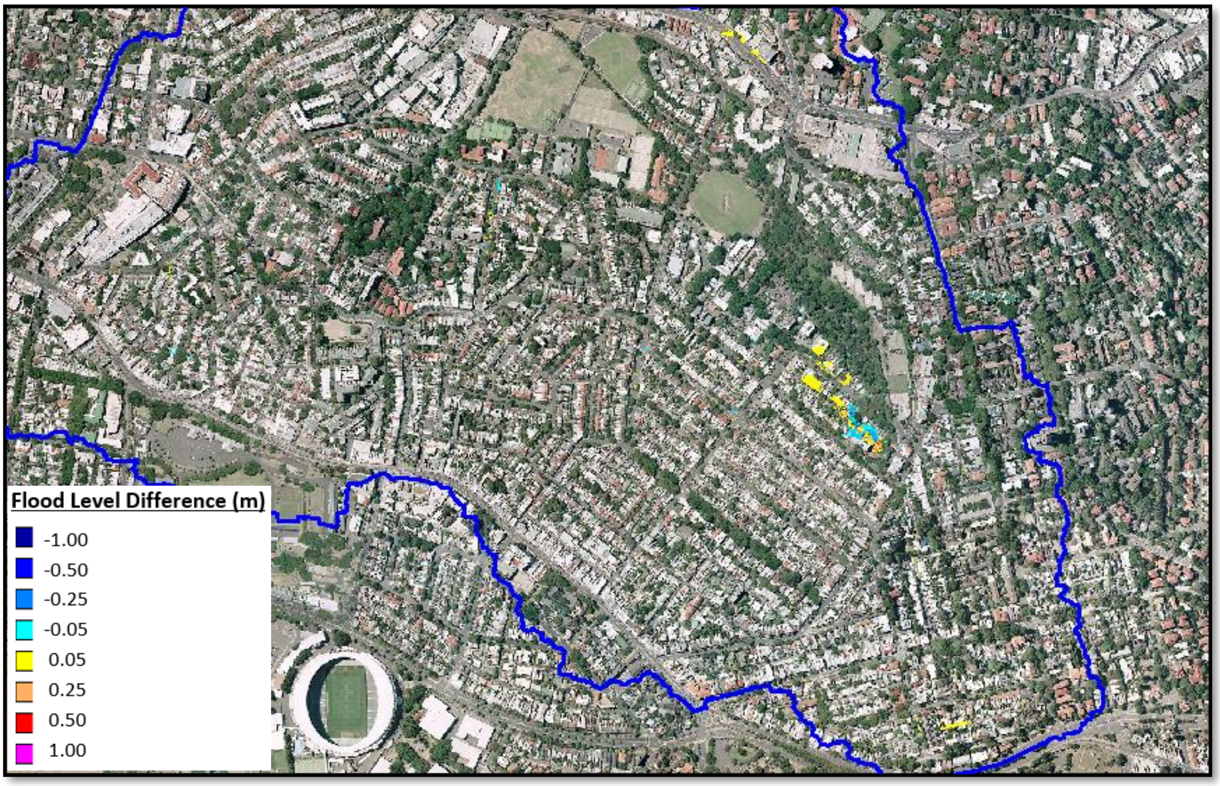


Plate 18 Flood level difference map for the "no blockage" scenario

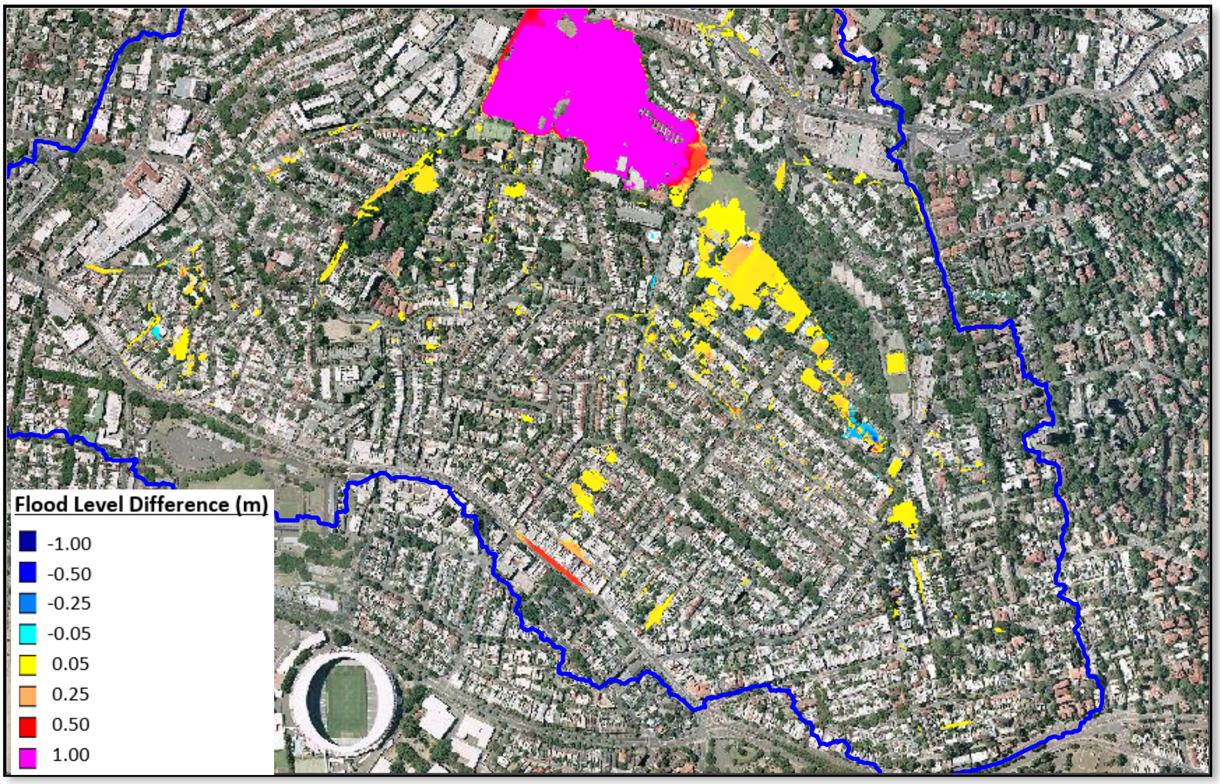


Plate 19 Flood level difference map for the "complete blockage" scenario

Plate 18 shows that reductions in stormwater blockage are not predicted to have a significant impact on 1% AEP water levels across the majority of the urban area. This comparative lack of sensitivity with no blockage is likely associated with the limited pipe capacity across the catchment. The quantity of overland flow shown in **Figure 15** indicates that most pipes within the catchment have a limited capacity (i.e., much less than a 1% AEP capacity). As a result, the pipe system is generally *"fully charged"* during the 1% AEP flood regardless of the blockage that is applied to the stormwater pits (i.e., the limited stormwater capacity is governed by the pipe capacity rather than the stormwater inlet/pit capacity and any associated pit blockage).

However, **Plate 18** shows that complete blockage of stormwater pits will produce increases in 1% AEP flood levels of at least 0.05 metres across relatively large sections of the catchment. Accordingly, although the relative proportion of flow carried by the stormwater system during large floods is relatively small, removing this sub-surface conveyance capacity does have a tangible impact on flood levels. This emphasises the need for regular maintenance of stormwater pits to ensure they are free from blockage and operating at optimum efficiency.

6.5 Climate Change Assessment

Climate change refers to a significant and lasting change in weather patterns arising from both natural and human induced processes. The Office of Environment and Heritage's (formerly Department of Environment, Climate Change and Water) *'Practical Consideration of Climate Change'* states that climate change is expected to have adverse impacts on sea levels and rainfall intensities in the future.

Increases in rainfall intensities would produce increases in runoff volumes across the catchment. This, in turn, would likely produce an increase in the depth, extent and velocity of floodwaters.

To assess the potential impacts of rainfall intensity increases across Paddington, additional 1% AEP simulations were completed with 10% and 20% increases in rainfall intensity. The revised 1% AEP water levels were extracted from the results of the modelling and were compared against peak water flood levels for "base" design conditions to develop flood level difference mapping. The flood level difference mapping is provided in **Plates 20** and **21**.

Plates 20 and **21** shows that increases in rainfall intensities have the potential to increase current 1% AEP flood levels by at least 0.1 metres along major watercourses and overland flow paths. This is particularly evident in the vicinity of Trumper Park, Hampden Street and White City/Weigall Sportsground. Across other areas subject to relatively shallow inundation depths, the increases in current 1% AEP flood levels are typically less than 0.05 metres.

Accordingly, it can be concluded that climate change has the potential to cause some significant increases in current 1% AEP flood levels across major conveyance areas. The increases are more modest across areas of shallow inundation depths. However, if combined with stormwater blockage, there is potential for more significant adverse impacts to be experienced across large sections of the catchment.

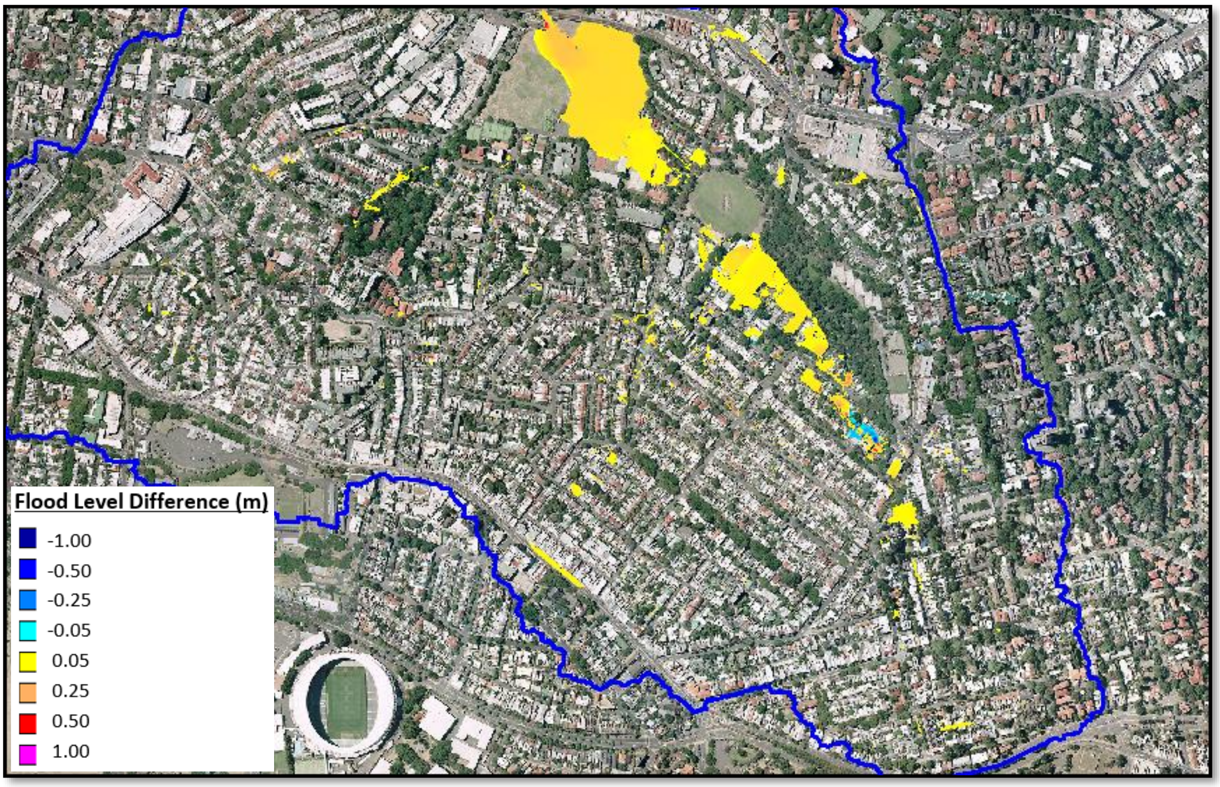


Plate 20 Flood level difference map with 10% increase in rainfall

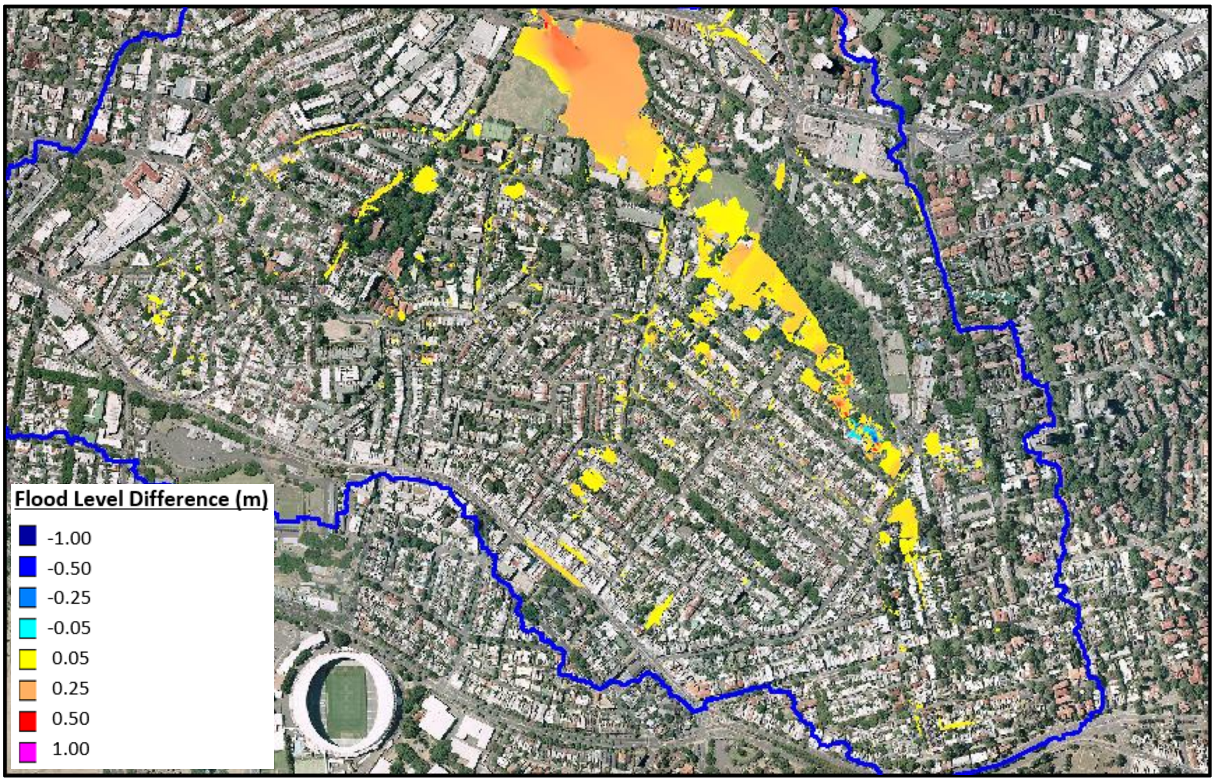


Plate 21 Flood level difference map with 20% increase in rainfall

7 Flood Hazard and Hydraulic Categories

7.1 Flood Hazard

7.1.1 Overview

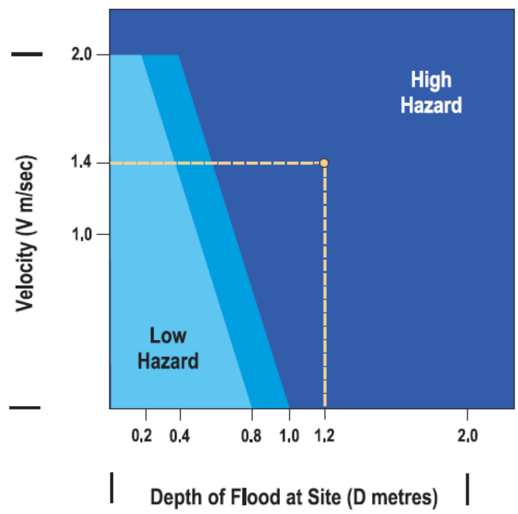
Flood hazard defines the potential impact that flooding will have on development and people across different sections of the floodplain.

The determination of flood hazard at a particular location requires consideration of a number of factors, including (NSW Government, 2005):

- depth and velocity of floodwaters;
- size of the flood;
- effective warning time;
- flood awareness;
- rate of rise of floodwaters;
- duration of flooding; and
- potential for evacuation.

Consideration of the depth and velocity of floodwater in isolation is referred to as the *hydraulic* or *provisional* flood hazard. The provisional flood hazard at a particular area of a floodplain can be established from Figure L2 of the *"Floodplain Development Manual"* (NSW Government, 2005). This figure is reproduced on the right.

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



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

7.1.2 Provisional Flood Hazard

The TUFLOW hydraulic software was used to automatically calculate the variation in provisional flood hazard across Paddington based on the criteria shown in Figure L2 for the 1% AEP flood as well as the PMF. These hazard category maps are shown in **Figures 23** and **24**.

It should be noted that the hazard represented in this mapping is provisional only. This is because it is based only on an interpretation of the flood hydraulics and does not reflect the effects of other factors that influence flood hazard. Refinement of the provisional hazard categories to include consideration of these other factors will be completed as part of the future floodplain risk management study.

7.2 Hydraulic Categories

7.2.1 Overview

The NSW Government's *'Floodplain Development Manual'* (NSW Government, 2005) also characterises flood prone areas according to the hydraulic categories presented in **Table 7**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour and highlights areas that should be retained for the conveyance of floodwaters.

Table 7 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Floodplain Development Manual Definition	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	Areas subject to a velocity depth product >0.4 m^2/s or Areas exposed to a velocity of greater than 2 m/s
Flood Storage	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • if the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	Areas that are not floodway and where the depth of inundation is greater than 0.15 metres
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	Areas that are not floodway where the depth of inundation is less than 0.15 meters

7.2.2 Adopted Hydraulic Categories

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

The results of the design flood simulations were interrogated to assess the potential extent of floodway areas based on the qualitative guidelines listed in **Table 30**. In general, floodways were defined as an area where there was a significant velocity depth product (VxD >0.4 m^2/s), and/or velocities (i.e., >2 m/s). This aimed to identify areas where the majority of flood flows were being conveyed.

Flood storage areas were then defined as those areas located outside of floodways but where the depth of inundation was greater than 0.15 metres. This aimed to identify areas where a significant amount of flow was not necessarily conveyed, however, the depths of water indicate a significant amount of storage capacity was being provided. The remaining areas not classified as floodway or flood storage where defined as flood fringe areas.

The resulting hydraulic category maps for the 1% AEP flood and PMF are shown in **Figures 25** and **26**.

8 CONCLUSION

This report documents the outcomes of investigations completed to quantify flood behaviour across Paddington, which falls within the Rushcutters Bay catchment. It provides information on design flood levels, depths and velocities as well as hydraulic and flood hazard categories for a range of design floods.

Flood behaviour across the catchment was defined using a previously developed DRAINS model to define rainfall-runoff processes and a two-dimensional hydraulic computer model that was developed using the TUFLOW software. The TUFLOW model was used to simulate the conveyance of runoff via the stormwater drainage system as well as the movement of overland flows once the capacity of the stormwater system was exceeded.

The computer model was calibrated/verified using historic rainfall and flood marks for floods that occurred in 1989, 1991 and 2015. The model was subsequently used to simulate the 100%, 20%, 10%, 5% and 1% AEP events as well as the Probable Maximum Flood (PMF). The following conclusions can be drawn from the results of the investigation:

- Flooding across Paddington generally occurs as a result of the capacity of the stormwater system being exceeded following heavy rainfall in the catchment leading to 'overland' flooding.
- Flooding has been experienced on a number of occasions. This includes 1989, 1991 as well as 2015.
- The trunk drainage system was determined to have limited capacity (less than 100% AEP capacity in some instances). Accordingly, overland flooding is predicted to occur relatively frequently.
- Overland flooding typically occurs as result of relatively short duration, high intensity rainfall bursts. This type of storm system is most typically associated with thunder storms. The critical storm duration for those areas subject to overland flooding was determined to be 1.5 hours.
- Although a number of properties are predicted to be inundated during each of the simulated design floods, the depths of inundation are typically shallow. As a result, most areas are subject to a low provisional flood hazard during the 1% AEP flood (the high hazard areas are primarily restricted to roadways).
- At the peak of the 1% AEP flood, approximately 1,300 properties (out of 5,366 contained within the catchment) are predicted to experience depths of inundation that exceed 0.1 metres. The areas that are most significantly impacted by floodwaters include:
  - Spicer Lane
  - Jersey Road
  - Forbes Street
  - Sutherland Ave
  - Harris Street
  - Hampden Street
  - Cecil Street and Cecil Lane

- low points in Victoria Street, Underwood Street, Dudley Street, Hargrave Street, Hargrave Lane and Sutherland Street
- Cascade Street / Glenmore Road
- Boundary Street
- Goodhope Lane
- Brown Street / Neild Avenue

9 REFERENCES

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Appendix A

Community Consultation

Why Do We Need to Prepare a Flood Study?

Flooding is the most costly natural disaster in Australia. During the recent April 2015 floods, 8 people also lost their lives in the Sydney and Hunter regions. Accordingly, flooding imposes significant financial burden on families and communities and can place lives at risk.

The preparation of a flood study will help Woollahra Municipal Council to understand the existing flooding problem within the Paddington catchment. It will also help to identify where flood damage reduction measures may be best implemented to reduce the cost of flooding on individuals within the catchment as well as the broader community. It will also assist with emergency management and evacuation processes and guide future development / re-development in a way that is compatible with the flood risk.

How *you* can help...

The flood study will include the development of computer models to simulate flood behaviour across the catchment. To ensure the computer models are providing reliable descriptions of flood behaviour they will be calibrated so they reproduce floods that have occurred in the past.

Enclosed with this brochure is a questionnaire that aims to collect as much historic flood information as possible to assist with the computer model calibration. If you have information on past floods you are encouraged to complete the questionnaire and return it by **Friday 28th August 2015**. Alternatively, the questionnaire can be completed online via the flood study website:

www.Paddington.floodstudy.com.au

Further Information

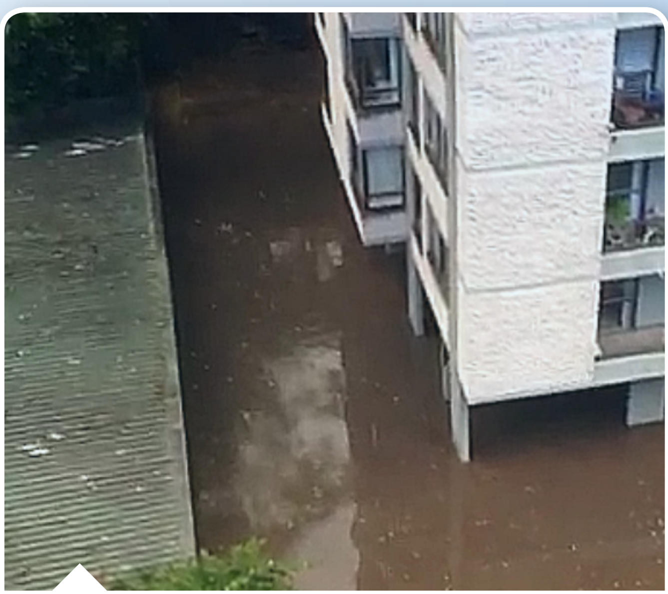
To obtain further information on the Paddington Flood Study or to submit any information that you think may be valuable to the study, please contact:

Catchment Simulation Solutions

David Tetley
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney NSW 2000
(02) 9247 4882
dtetley@csse.com.au

Michael Casteleyn
Woollahra Municipal Council
536 New South Head Road
Double Bay NSW 2028
(02) 9391 7131
michael.casteleyn@woollahra.nsw.gov.au

Alternatively, you can visit the flood study website:
www.Paddington.floodstudy.com.au



Floodwaters near Trumper Park during April 2015 flood

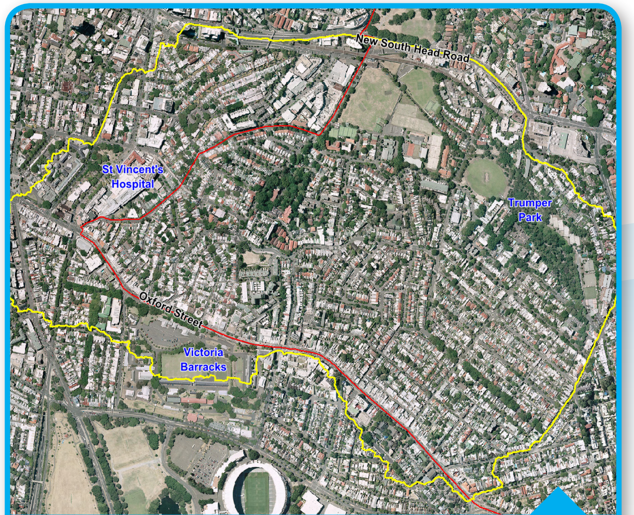
Paddington Flood Study

Community Information Brochure

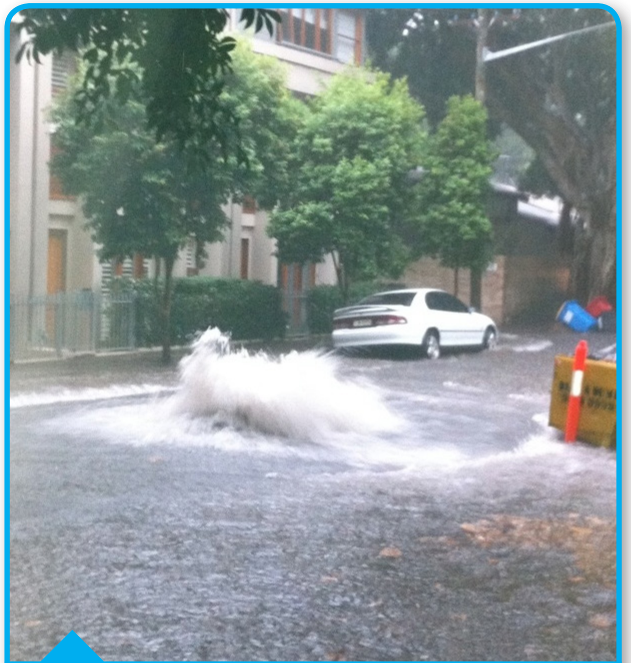
Introduction

Woollahra Municipal Council is preparing a flood study of the Paddington catchment area. The extent of the study area is shown below.

During most rainfall events across Paddington, runoff is carried by the stormwater system into Rushcutters Bay. But during periods of heavy rainfall the capacity of the stormwater system is sometimes exceeded leading to overland flooding. Significant overland flooding has occurred on a number of occasions in the past, most recently in April 2015.



Extent of the Paddington Catchment



Surcharging stormwater pit in Hampden Street during 2012 flood

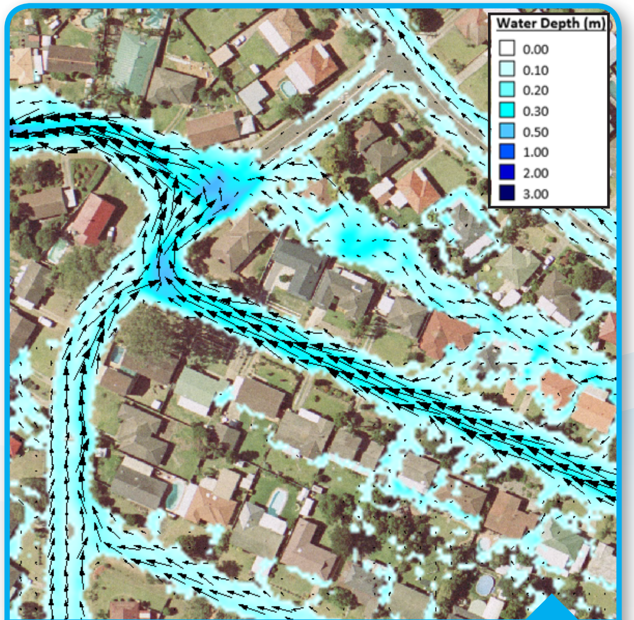
Council has previously completed a Flood Study for the broader Rushcutters Bay catchment that concentrated on the lower sections of the catchment. The current Flood Study will provide a more detailed look at the upper catchment centered around the Paddington area.

The information generated as part of the flood study will allow Council to identify where flood mitigation measures (e.g., stormwater pipe upgrades) may be best implemented to reduce the impact of flooding on property owners across Paddington.

What is a Flood Study?

A flood study identifies the nature and extent of the existing flooding problem. The preparation of a flood study includes development of a computer flood model, which will be used to quantify the capacity of the stormwater system and simulate how overland flow would move through the catchment.

Council has commisioned specialist flood consultants, Catchment Simulation Solutions, to prepare the flood study.



Sample floodwater depth and velocity output from flood model

7. DO YOU HAVE ANY OTHER COMMENTS OR INFORMATION THAT MAY ASSIST THE STUDY?

PROTECTING YOUR PRIVACY – The personal information requested on this form will only be used for the Paddington Flood Study. The supply of this information by you is voluntary. Council is regarded as the agency that holds the information and will endeavour to ensure that this information remains secure, accurate and up-to-date. Access to information is restricted to Council Officers and other authorised people. You may make applications for access to information held by Council. You may also request an amendment to information held by Council. Should you require further information please contact Woollahra Municipal Council.

Paddington Flood Study

Questionnaire

This questionnaire has been prepared on behalf of Woollahra Municipal Council to better understand flooding across Paddington. Information gathered from the questionnaire responses will be used to assist in the calibration and testing of a computer flood model that will be developed as part of the Paddington Flood Study.

The following questionnaire should only take around 10 minutes to complete. Please note that all questions are optional but try to answer as many questions as possible and give as much detail as possible (attach additional pages if necessary).

Once complete, please return the questionnaires via email or mail by **Friday 28th August 2015**. Alternatively, if you have internet access, an online version of the questionnaire can be completed at: www.paddington.floodstudy.com.au

If you have any questions, require any further information or would like to contribute additional information to the study, please contact:

Catchment Simulation Solutions

David Tetley
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney NSW 2000

Michael Castelyn
Woollahra Municipal Council
536 New South Head Road
Double Bay NSW 2028

CONTACT DETAILS

Can you please provide the following contact details in case we need to contact you for additional information? If you do provide contact details, this information will remain confidential at all times and will not be published (refer to privacy statement on the last page).

Name: __________

Address: __________

Phone No. __________

Email: __________

Catchment Simulation Solutions

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

☐ Residential
☐ Commercial
☐ Industrial
☐ Vacant land
☐ Other (Please specify:____)

2. WHAT IS THE OCCUPIER STATUS OF THIS PROPERTY?

☐ Owner occupied
☐ Rental property
☐ Business
☐ Other (Please specify:____)

3. HOW LONG HAVE YOU LIVED / WORKED IN THE AREA?

(a) At this address? ____

(b) In the Paddington area? ____

4. HAS YOUR PROPERTY EVER BEEN AFFECTED BY FLOODING?

☐ Yes
☐ No

5. DO YOU HAVE ANY PHOTOGRAPHS OR VIDEOS OF PAST FLOODS?

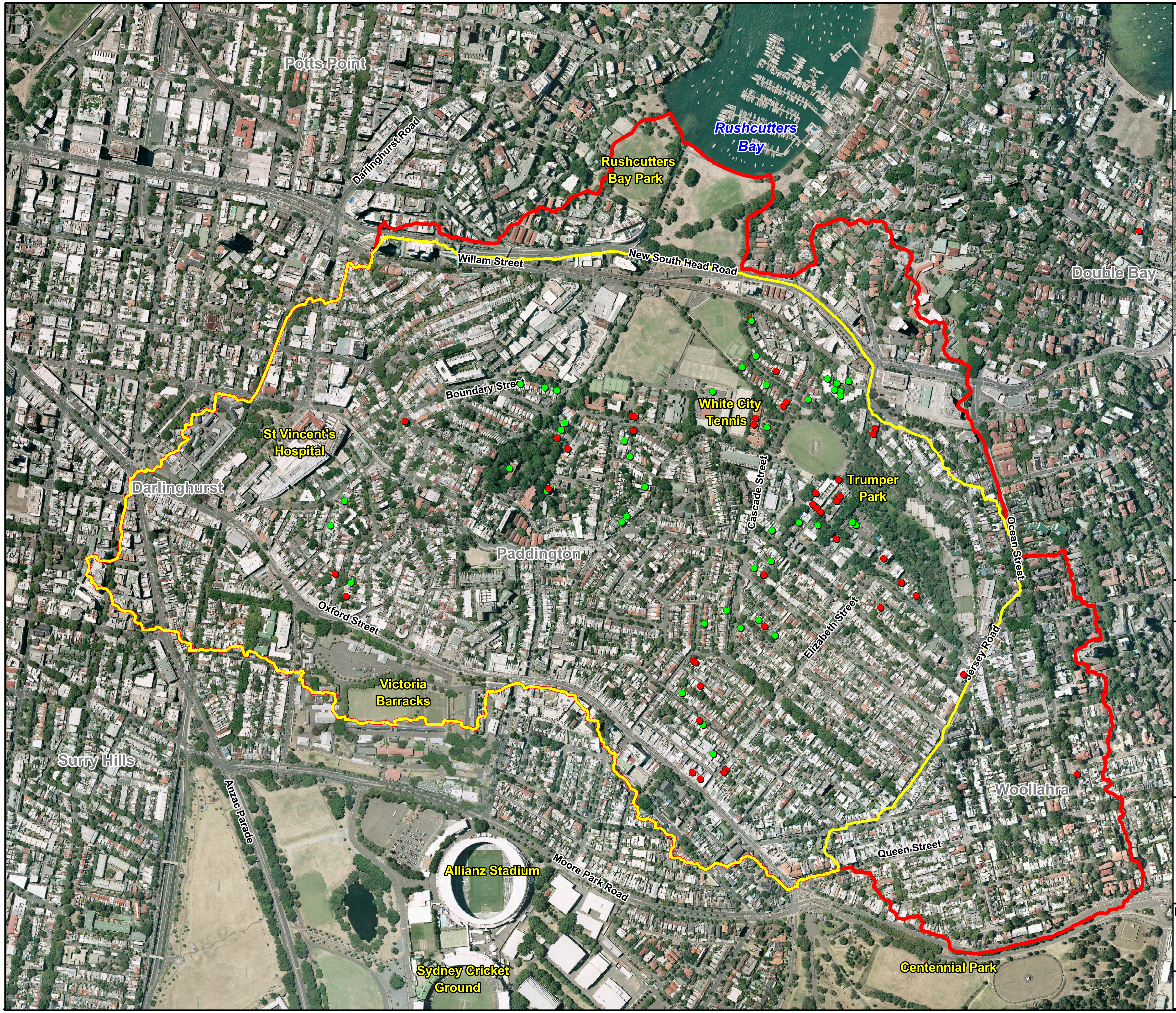
☐ Yes ☐ No

If you answered 'Yes', can you provide a copy of these photos/videos to assist with the computer flood model calibration?

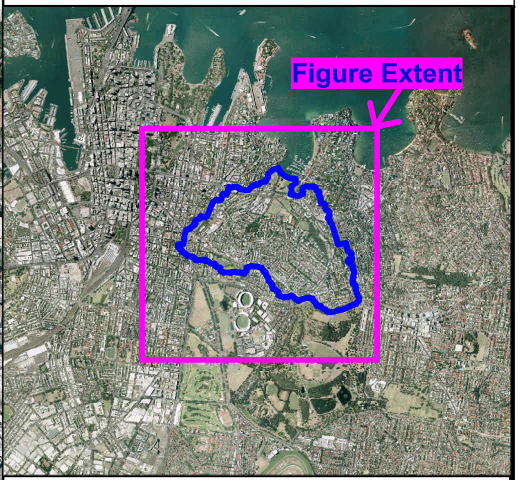
☐ Yes ☐ No

6. PLEASE PROVIDE ADDITIONAL INFORMATION ON YOUR PAST FLOODING EXPERIENCES

Date of flood(s)		
Flood depth / height & location		
How confident are you with the height / depth of the flood?	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)	☐ High (exact) ☐ Medium (within 10cm) ☐ Low (within 50cm)
How long or over what period did you observe the flood height / depth?		
How was your property affected by the flood waters?		



WOOLLAHRA MUNICIPAL COUNCIL



LEGEND

- Paddington Study Area
- Rushcutters Bay Catchment

Questionnaire Response Locations
Has flooding been experienced?
- No
- Yes

Notes:
Aerial photograph date: January 2014

N
W E
S

Scale 1:8,000 (at A3)
0 0.25 0.5
Km

Figure A1: Spatial Distribution of Questionnaire Responses

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

File Name: Fig A1 - Spatial Distribution of Questionnaire Responses.wor

Community Questionnaire Responses - Paddington Flood Study

#	Property Type	Occupier Status	How long have your lived in area? Current Address		In the general area?		Has your property ever been affected by flooding?	Do you have any photographs or videos of past floods?	Please provide additional information on your past flood experiences: Date of Floods	Flood Depth / Height & Location	How confidence are you with the height/depth of the flood?	How long or over what period did you observe the flood height/depth?	How was your property affected by the flood waters?	Do you have any other comments or information that may assist the study?
1	Other, Rented Apartment	Business	20	Years	25-30	Years	Yes	No						Soon after purchasing 144A boundary St. Heavy rain caused water to flow down campbell st under the front door. A gutter wall was built to deflect the flow
2	Residential	Owner Occupied	2	Years	4	Years	No	No						
3	Residential	Owner Occupied	18	Years			No	No						
4	Residential	Owner Occupied	20	Years	30	Years	Yes	No	2013 Approximately	The owners tenants had to be evacuated .			3/46 -54 is a street level apartment in a cuthole has water flooded to the lower level of the building.	When we were flooded the water rushed past my place and poured down to the unit below. On one occasion a small amount of water came up above the pathway into my apartment
5	Residential	Owner Occupied	14	Years			Yes	No	4/07/1905	30 cm	Medium	24 hours	Over $15k - $20k in property damage	Yes, the stormwater pit in Hampden St pictured in the brochure still overflows. I am concerned about 2012 flooding being repeated
6	Residential	Rental Property					No	No						Seems a ridiculour waste of money to us
7	Residential	Owner Occupied	11	Years			Yes	No	Wasn't a flood didn't appear to come from arround up may have been in roof			Water, week	marginally I cleaned it up	
8	Residential	Owner Occupied	15	Years	15	Years	Yes	No	2005	20cm	Medium		garage flooded	Much of the flood water that hit onMonday 24/8/2015 came from the front. This was the first time since living here that this occurred. Water came down trumper park. On previous occassions we have only ever been affected by flooding in cecil lane.
									2012	50cm	Medium		garage flooded	
									24/08/2015	22cm	High		Garage flooded	
9	Residential	Rental Property	1.25	Years	3	Years	No	No						
10	Residential	Owner Occupied	13	Years			Yes	No	Aug-15	15 Cecil St 3 rooms flooded depths 10mls	Medium	3 hours	rugs and furniture soaked	Cecil St badly affected last night, bad flooding
11	Residential	Owner Occupied	15	Years			Yes	No	8/06/2012	20 Hopewell St Paddington 500cm	low	2 hours	Entered under frton door and down carpeted stairs, through light fixtures and downstairs through well. There is a drain that discharges straight into my house in flood	After 2 such incidents, I am no longer covered by the insurance company. The street converges in heavy rain to the lowest point and enters my house. The kerb and guttering are council property and it has created a public nuisance
									20/08/2015	not home	low			
12	Residential	Owner Occupied	15	Years			Yes	No	24/08/2015	5 feet	High	24 hours	Suit and property damage	I did not work, flood poured down, south end of cecil lane, water discharged onto road
13	Residential	Rental Property	16	Years	16	Years	No	No						
14	Residential	Owner Occupied	43	Years	48	Years	Yes	No	approx 1974	several inches through the house	Medium	not sure	water covered through the house from the back to the front	The flooding referred to overlay was the result of an unserviced stormwater ingress at he the end of elizabeth place. It has since been fixed by council
15	Residential	Rental Property					No	No						
16	Residential	Owner Occupied	40	Years			Yes		24/8/2015 9pm to 9:25 pm	1m at stormwater drain next to 420 Glenmore road	Medium	30 mins	mud and debris from porch and hallway entire side and back garden.	We have had many floodings over the last 3 decades. I think this one has been the worst. The drains are not cleaned. One of the big problems arises from the stormwater collecting debris from trumper park opposite rubish.
17	Residential	Owner Occupied	5	Years			No		Lawson Lane 24/8/2015	Lawson Land floods like a river not sure how deep enough to wash garabage bins away		Approx half an hour	not affected	
18	Residential	Owner Occupied	4	Years			No	No						
19	Residential	Owner Occupied	47	Years	48	Years	No	No						
20	Residential	Rental Property	16	Years			No							
21	Residential	Owner Occupied	35	Years			Yes	No	When rose bay cars were swept down street	1 foot enough to enter house	Low	Overnight and next day	had to dry out the house	
22	Residential	Rental Property	13	Years	16	Years	Yes	No	Various dates	Blocked drainage on the street outside our building i.e. 10	Medium	Several Days	Stret Parking much worse	
23	Residential	Owner Occupied	14	Years	15	Years	Yes	No	Every Major rain event	Stormwater drain collection in Lawson stret between 44 Laswon street and 77 Goodhope St at bottom of 6 foot drainage reserve, > 40cms	Medium	It drains away once we clear the leaves/rubbish off the drain grating	dampness to side wall if pool gets too deep it floods over roads	When there is heavy rain the water from five ways runs down goodhope st and some runoff the channels eastward into hopple street. Leaves rubbish covering grates filling up to 15 -30 cms.
24	Other, Fabric Showroom	Business			20	Years	No	No						
25	Residential	Rental Property	14	Years	14	Years	No	No						In heavy rain the gutters in jersey road (in the vicinity of 204 kersey road) overflow because of trapped leaves. Same applies to the gutters between queen street and the jersey road intersection with holdsworth street
26	Residential	Owner Occupied	9	Years	56	Years	No	No						
27	Residential	Owner Occupied	1	Year	2	Years	No	No						
28	Residential	Owner Occupied	20	Years	20	Years	No	No						
29	Residential	Owner Occupied	2	Years	2	Years	No	No						While not considered flooded. There is contunious water flowing in windsor home behind the houses at 22 to 30 windsor street. A number of houses on the northern side of the street have had water issues including 16,20 and 30 Windsor
30	Residential	Owner Occupied	3	Years	15	Years	No	No	2015 April	minor flooding in the garage basement. At 400 glennmore road				
31	Residential	Owner Occupied	33	Years	33	Years	No	No						
32	Residential	Owner Occupied	18	Years	18	Years	No	No						
33	Residential	Owner Occupied	24	Years	26	Years	Yes	No	10/04/1998	500mm in garage	High	Varies	Garage flooded 2 cars damaged, one written off	The overland flowpath has definitely helped but not the total answer for a major event I believe
									7/03/2001	200 mm in garage	High	Varies		
									12/02/2010	500 mm in garage	High	Varies		
									17/04/2012	200 mm in garage	High	Varies		
34	Residential	Owner Occupied	18	Years	18	Years	No	No						Council could make sure that gutter grates are cleared after rainfall. Water from guner st southside near bus stop flows easterly towards cascade St. The drainage acess to gutter crates is extremely poor
35	Residential	Owner Occupied	6	Years	6	Years	Yes	No	Approx 2008	Flooded my front room and entrance foyer up to skating board height	Medium	after one night of rain	see above	
36	Residential	Rental Property					No	No						
37	Residential	Owner Occupied	44	Years			No	No						
38	Residential	Owner Occupied	7	Years	7	Years	No							

#	Property Type	Occupier Status	How long have your lived in area?				Has your property ever been affected by flooding?	Do you have any photographs or videos of past floods?	Please provide additional information on your past flood experiences					Do you have any other comments or information that may assist the study?
			Current Address		In the general area?				Date of Floods	Flood Depth / Height & Location	How confidence are you with the height/depth of the flood?	How long or over what period did you observe the flood height/depth?	How was your property affected by the flood waters?	
39	Residential	Rental Property	1.4	Years	1.4	Years	Yes	Yes	24/08/2015	water came in from Cecil St, almost a foot high outside, a couple of inches deep inside the house	High	about an hour, also saw the watermark on the front fence afterwards	Cost of cleaner would have been several hundred dollars. no carpet, furniture was wet but appears to be salvaged. My housemate's car got flooded and it appears to be ok but could have been written off if the water got much higher.	There appeared to be some issue with the drains in Cecil st which may have contributed to the flooding
40	Residential	Rental Property	0.5	Years	3	Years	No							Bottom of Glenmore Road outside Trumper Park has flooded several times in the last 6 months, most recently on the 24th/25th August. Water level covering car tyres at the bottom of this road.
41	Residential	Owner Occupied	2	Years	2	Years	No							
42	Residential	Owner Occupied	22	Years			Yes							
43	Residential	Owner Occupied	14	Years	24	Years	Yes		08/24/2015	20cm possibly higher, 23 Lawson st, paddington	Medium	minimum 1 hour	Insurance claim currently pending. Damage to floor coverings, damage to wooden floor and skirting boards, damage to paint work in house.	The storm drains in Lawson Street and Hoddle Street are completely inadequate during heavy downpours. It is only through intervention by residents in the middle of storms clearing drains and blockages that there has not been more house flooding. The situation requires urgent review given the increasing frequency of heavy downpours and consequent blockages and overwhelming of drains.
									several occassions prior, drains blocking outside our house and over the road	23 Lawson St paddington	Low	minimum 1 hour		
									same as above	as above	Low	minimum 1 hour		
44	Residential	Owner Occupied	0.75	Years	0.75	Years	Yes	Yes	towards end of April 2015 over several days	Cnr Neild, Brown and Boundary Streets - 20-22cm	High	Observed on a number of occasions over four or five days.	Unclear, although there is significant damp to the rear of the property, facing up Brown Street (the direction from which the majority of the water flows).	During the rain on 24 August, water could be seen rising from around the inspection cover in the pavement at the corner of Brown and Boundary Streets (south side of Boundary).
									24/08/2015	Cnr Neild, Brown and Boundary Streets - 20-22cm	High	Observed for around 45 mins (it had not dissipated when I ceased observing)..		
45	Residential	Owner Occupied	7	Years			Yes	Yes	2012	4 inches in house		30 minutes	Carpet and wooden flooring on ground level. Various electrical items, computer, washing machine, gulf bag, hundreds of old family photo's which were in a box on the floor.	If you look at your pamphlet titled Paddington Flood Study you will see our front door to the left of the gushing water. The street floods and then pours through our front door and windows. While the storm water man hole blows off every few months, it is only the occasional storm that will generate enough water to completely flood the street. Recent work undertaken to allow storm water to flood onto Trumper oval did help a little. At the rear of the house, the storm water comes UP the storm water outlet in the common garage flooding the garage and everything in it. So we get it from front and back. Basically, the ancient storm water pipe under Hampton street needs to be enlarged from about our house to the open storm water drain at the other side of the oval leading to Rushcutters bay. No amount of patch up work will fix it and we will continue to get flooded on a regular basis. It takes a long time to get the moisture out of our home which is a absolute health issue not to mention the loss of property.
									1/08/2015	2 inches in house		30 minutes		
46	Residential	Owner Occupied	26	Years	36	Years	Yes	No	1989	1989 Cellar Flooding 60 cm	High	1 week (problem reduced by installing bilgepump)	Flood 1 - pump installation and creation of drainage channels & pipes (cost ???) Flood 3 - installation of 2nd pump and concrete barriers, new drainage pipes, cost approx $4,500	There is a constant flow of water exiting into the road guttering on the Southern side of Windsor Street (near Lucio's Restaurant). This is regardless of weather conditions although there is a marked increase during wet periods. Given the slope of Windsor Street to the north this means that the majority of drainage runs via the northern side of Windsor Street. At times this causes the nature strip to flood (outside No. 30) which, in turn, triggers water flooding in our cellar. This has been a problem since we purchased 30 Windsor St some 26 years ago.It is also a problem affecting neighbouring properties (i.e. No's 26 & 28) which can be seen by water exiting in the back lane. The matter has been reported on numerous occasions to Woollahra Council but no action has been taken to date to address the root of the problem.
									almost every year since then	Cellar flooding during havy rain periods 10 cm	High	Pump running almost continuously during heavy rain		
									2015	Sever cellar flooding back and front 2015 10 cm	High	Additional pump needed to be installed to cope with volume		
47	Residential	Owner Occupied	10	Years			Yes	Yes	Every year when heavy rain, at least 10 times severley	All gutters in Glenview st get blocked with leaves o no where for water to get drained 50cm to 1m	High	every year at least once a week during wet season	Mostly its my time because i get out on the street and get drenched unblocking drain pipes of leaves from glenviews St and boundary to prevent the water coming into my house as the water gets so high that i put sandbags on my front doorstep. I have seen cars go sliding down the street. The floods have swept away about $500 hundred dollars worth of plant of plants over the years and damaged my floorboards. There will be a record with council of my calling to have drained pumped and unblocked. Maybe about 20 request or reminders to clean the gutters properly. I have seen many council workers just sweep the leaves back down the drain. I	This issue seriously needs to be addressed. Its not about heavy rain, it floods because all drains are blocked from streets away and the ripple effect is it floods into Glenview St like a river gushing into Boundary St. All gutters at the very least need to be cleaned and pumped out regularly.
48	Residential	Owner Occupied	17	Years	21	Years	No							

#	Property Type	Occupier Status	How long have your lived in area?				Has your property ever been affected by flooding?	Do you have any photographs or videos of past floods?	Please provide additional information on your past flood experiences					Do you have any other comments or information that may assist the study?
			Current Address		In the general area?				Date of Floods	Flood Depth / Height & Location	How confidence are you with the height/depth of the flood?	How long or over what period did you observe the flood height/depth?	How was your property affected by the flood waters?	
49	Residential	Rental Property	6	Years			Yes	No						I have had the property since around 2006. It has been affectedly terribly by the storm. Causing rising damp internally. It's rotten the deck. It's causing severe cracking in the retaining garden wall. It's got under the back door. My house seriously needs some sort of barrier to be built above the street line at the back to protect all houses. Anymore you need and let me know.
50	Residential	Owner Occupied	16	Years	16	Years	Yes	Yes	24-Aug-16	Cnr Glenview, Boundary and Liverpool Streets			Flood water poured in the back double doors flooding the kitchen 4 cm depth.	This corner is reknowned for flooding being at the meeting point of 3 hills (Glenview, Boundary and Liverpool). The drains seem to be blocked most of the time with leafs and there are rare visits from council to clean away.
51	Residential	Owner Occupied	15	Years	20	Years	No							
52	Residential	Rental Property	1	Years	10	Years	Yes	Yes	24/08/2015	15cm on entire ground floor	High	3 hours	$10,000 - ruined sofa, damaged coffee table & side cabinet	The Woollahra Council needs to fix this problem. It's happened on a few occasions and frankly it's unacceptable. An Engineer needs to be assigned to find a solution. Our house is at a low point in Sutherland Ave and the street slopes into the terrace.
									26/04/2015	5cm on front of house	High	1 hour		
									A few days ago	Water flow at level of 10cms	Medium	As above		
53	Residential	Owner Occupied	19	Years			No							When heavy rain, water run down to Boundary street like a torrent. 24/8/15, it happened again: At the corner of Boundary street and Gosbell street the drain was blocked by rubbish and leaves. Solution: Council workers & unemployment people needs to physically sweep the pavements/gutters on regular basis (use unemployment people who are getting the doles payment). To send the sweeper van is useless. Please note lower streets got more rubbish, leaves and rubbish as wind seems to bring the lot in lower street. As Council is not doing it, over the months, leaves and rubbish go into the water drain and block them. -Fine the people on the spot when dropping cigarettes butts, dog poos, rubbish and dog poos bags. -Do not allow people to cement/tiles their front garden as water run into the street instead been absorbed by the garden. -Tree management needs to improve, should not be hanging over the roof of people as it blocks the gutters therefore again water run into the street. Thank you.
54	Residential	Rental Property	7	Years			Yes	No	1/08/2015	In the garage/storage area 1/3 meter high with high velocity			Cascading water at high velocity poured down Cascade Street and Glenmore Road, blocking all drains and washing out the council beds, with very low retaining walls at the roundabout, over flowing into the property of 400 Glenmore Road. At the same time water gushed up through the drains in the floor of the garage area. All goods and papers in the storage sheds where wet up to half a meter. Luckily at this time my drain in front courtyard was kept clear enabling water to drain.	
55	Residential	Owner Occupied	0.33	Years	12	Years	No							
56	Residential	Owner Occupied	29	Years	29	Years	No							Boundary Street floods at the intersection of at Neild Avenue during torrential rains and the stormwater drains also overflow on Gosbell St near Boundary St and Boundary St near Gosbell St during torrential rains.
57	Residential	Owner Occupied	31	Years	31	Years	No							While my property has not been directly affected I have witnessed very often torrents of water surging down into Cecil Street from Trumper Park Reserve and blocking/overflowing the drains.
58	Residential	Owner Occupied	2	Years	2	Years	Yes	No	February 1938 massive flood in Stephen Street (probable not relevant but often discussed locally)	about 20 feet google trove.nla.gov.au/ndp/del/article/11144903				New South Head road and Nield Avenue intersection always floods when it rains
59	Residential	Rental Property	37	Years			Yes	No	2012	25cms	Medium	several hours	first flood: $1500. second flood: awaiting assessment by agent	floods becoming more frequent of recent times. ?poor strom water drainage.
									26/08/2015	45 cms	Medium	several hours		
60	Residential	Owner Occupied	5	Years	5	Years	No							
61	Residential	Owner Occupied	16	Years	16	Years	Yes	Yes	date not known. Several times over the last 16 years	about 150mm 8 Hampden Street Paddington	Medium	about 1 hour	We are a block of apartments. The floods have caused damage to our lift several times, carpet several times. The latest flood- the carpet in the stairs to our basement car park had not yet been replaced from the last flood. There was no damage to my apartment.	Since the drainage works were done earlier this year, the flooding has been worse. It seems to me that we are now receiving much more of upper Paddington's storm water than we used to- that it has all been diverted our way.
									1/04/2015	about 150mm 8 Hampden Street Paddington	Medium	about 1 hour		
									24/08/2015	in excess of 150mm 8 Hampden street Paddington	Medium	several hours		
62	Residential	Owner Occupied	2	Years	2	Years	No							
63	Residential	Owner Occupied	0.4	Years	8	Years	Yes	No	1/04/2015	water gushing down the lane and the front of the property at torrential levels	Low	30cm	no	
									1/08/2015	backyard flooded, blocked drain, water nearly got into the house	Low	30cm		
64	Residential	Owner Occupied	1	Years	15	Years	Yes	No	Yesterday 24/8/2015	Basement garage of this unit complex. In places about 30cms	Medium	30 minutes	No	We are believed to be on a flood plain. Water rises coming from the general ditrection of Rushcutters Bay
65	Residential	Owner Occupied	1	Years	1	Years	No							We have a drain out that back that seems to have stagnant water in it that I would like the council to look at

#	Property Type	Occupier Status	How long have your lived in area? Current Address		In the general area?		Has your property ever been affected by flooding?	Do you have any photographs or videos of past floods?	Please provide additional information on your past flood experiences: Date of Floods	Flood Depth / Height & Location	How confidence are you with the height/depth of the flood?	How long or over what period did you observe the flood height/depth?	How was your property affected by the flood waters?	Do you have any other comments or information that may assist the study?
66	Private recreational	Owner Occupied	5	Years			No							
67	Residential	Owner Occupied	8	Years	8	Years	Yes	No					Yes	
68	Residential	Owner Occupied	4	Years	4	Years	No							The drain keeps popping up on Hampden Street and it's extremely dangerous. Also after large down pours the roads constantly have large potholes, in same places (Where Glenmore meets New South Head Road)
69	Residential	Owner Occupied	6	Years	6	Years	Yes	Yes	2/12/2010	1 metre? At the end of Harris St, right up to our front door. Our car was floated up the street.	Low	The leftover tide mark was what we saw next morning. Plus our car wasn't where it should be…	Including the car, $20,000.	
70	Residential	Owner Occupied	6	Years	7	Years	No							
71	Residential	Rental Property	0.5	Years	1	Year	Yes	No	really big rains a couple of months ago	Backyard and street	Medium	1 Day	No	The pipes under my property leading to the street are old and likely not set up for massive rains like we recently had. The street was flooded to about 10-20 cm on the south side which leached into the telstra phone cabling, disrupting phone / internet for users on our street.
72	Mixed use - Office/Residence	Owner occupied	16	Years	16	Years	Yes	No	12/02/2010	1m high in garage (Cecil Lane) AHD 7.3	High	1-2 hours	My car was written off due to floodwater inundation. Cost $20,000-	In my opinion the reinstatement of overland flow is much more important and effective than any piped solution. The piped solution will always be subject to failure and ineffectiveness. When the flow of storm water through to the harbour is achieved without resistance, that is the point where the flooding problem is resolved.
73	Residential	Owner Occupied	7.5	Years	9.5	Years	No							
74	Residential	Owner Occupied	16	Years	20	Years	Yes	No	during any heavy rain	cnr Underwood streets and Victoria Place			No	footpaths, gutters and drains need to be cleaned - especially during the Autumn months when there is more leaves falling and therefore clogging up the drains
75	Residential	Owner Occupied	25	Years	33	Years	No							
76	Residential	Rental Property	3	Years	50	Years	Yes	No	usually winter also sewerage problems from surrounding houses	ground run off behind the house	Low	every year - randomly	Yes	plumbing needs to be fixed in area as a number of houses are on the same pipe system and the pipes can not hold the amount of water, especially if there is a blockage
77	Residential	Owner Occupied	10	Years	12	Years								During heavy rain, water runs down the alley parallel to Goodhope Street. Often the drain on Lawson Street at the base of the alley becomes blocked, and water floods across Lawson Street and overflows the gutter and on to the pavement outside our house (and the set of terraces adjoining) Residents are required to try and clear the drain (from leaves etc) during heavy rain, to prevent flooding into the houses. This is of serious concern to us and should be addressed.
78	Residential	Rental Property					No							
79	Residential	Rental Property					No							Drainage at the property is a always a worry. But we have not been affected by floods as Harkness Street is on a slope.
80	Residential	Owner Occupied	1.16	Years	1.5	Years	Yes							
81	Residential	Owner Occupied	18	Years	18	Years	No							Nobody on Walker Avenue has ever experienced any flooding. I am surprised that the area is still classified a flood zone, especially given the recent drainage works on Glenmore Road and Cascade Road which effectively take away any stormwater. I highly recommend that the flood zoning classification be removed.
82	Residential	Owner Occupied	56	Years	56	Years	No							
83	Residential	Rental Property	0.33	Years	20	Years	No							
84	Residential	Owner Occupied	14	Years			Yes	No	Between 2008 - 2010	It was happened in the end of South Street when the heavy rain occurred at that time, then all the water came down to unit 5-8, cause we are located at the bottom of the building. II can't recall the height and depth now, I remember it was very serious, especially it happend in the middle of the night.	Low	For sometime until council put the pressure machine in front of the street.	Yes	
85	Residential	Owner Occupied	4	Years	15	Years	No							The flooding seems to mainly occur at the insection of new south head road and neild avenue; this can become very problematic during heavy rains. Even though we have a large storm water drain directly behind our house, it is never more than 1/3 full even in the heaviest of rain.
86	Residential	Owner Occupied	13	Years	13	Years	No							No
87	Residential	Owner Occupied	10	Years	35	Years	Yes	No	12/13 February 2010	600cm	Medium	curred over night, water had drained by day light	mud in car port and courtyard water in car, back and front. car was parked in courtyard house was saved by very efficient drains in courtyard and surrounding the house. at 19 Elizabeth st. mud entered the house as that proerty does not have good drains.	

#	Property Type	Occupier Status	How long have your lived in area?				Has your property ever been affected by flooding?	Do you have any photographs or videos of past floods?	Please provide additional information on your past flood experiences					Do you have any other comments or information that may assist the study?
			Current Address		In the general area?				Date of Floods	Flood Depth / Height & Location	How confidence are you with the height/depth of the flood?	How long or over what period did you observe the flood height/depth?	How was your property affected by the flood waters?	
88	Residential	Owner Occupied	42	Years	42	Years	Yes	No	1/01/1989	Probably about 200 mm	Low	Less than a day with major damage.	It was a long time ago but Woollahra Council, Sydney Water and NRMA Insurance will have records. In March 2004 the area under our front steps was damp proofed and a hydrolic engineer advised under-house pipes. In March 2006 three six-inch pipes were installed under the house from the front to discharge into Hargrave Lane. Sydney Water rebuilt the drainage to Rushcutters Bay and there enormous sumps were placed under Hargrave Street with large grates at road level. We have had no property flood and no damage for 10 years. In heavy rain a huge volume of water runs down Cascade Street from and is fed into Hargrave Street reaching a frightening level on the road sometimes but without damage. The cleanness and leaf-free-ness of the road grates is a major issue.	Only anecdotal. Researchers should talk to the Council and Sydney Water. We were told in 1989 that the relevant authorities had no idea were the water and drainage pipes were in Oxford Street: there were no records or maps! We were also told by the workers replacing the drainage under Cascade Street going down to the Harbour that in their first 25 metres of excavation they found no workable stormwater pipes and at one point blockage by a dead cow!!
									1/03/1989	About a metre above our ground floor	Medium	Less than a day with severe damage. Our large refrigerator was on its back in the bathroom. Heirloom furniture and china smashed.		
									April 19989	Probably about 100 mm	Low	Brief and no damage. There was a fourth major flood in March 2003.		
89	Residential	Owner Occupied	7	Years	7	Years	No							
90	Residential	Owner Occupied	1	Years			No							
91	Residential	Rental Property					No							
92	Residential	Owner Occupied	30	Years	30	Years	No							the only comment relates to the possible maintenance of drains. One cannot, obviously cut down the trees to avoid the large number of leaves that can accumulate (in nature these would form mulch) so better maintenance is the only alternative.
93	Residential	Owner Occupied	3	Years			Yes	Yes	23/05/2015	up to 2 cm deep over three quarters of my apartment raw sewage	High	from 8am until about 5 pm	bedroom, bathroom loungeroom flooded with raw sewage damage to wooden floor and lost approx $2000 worth of personal effects	
									ongoing	1/2 cm dump of water onto kitch floor	High	since I moved in on and off (Dec 2012)	it's damage the flooring (wooden) near the flooding point	
94														The issue in harris st lower is that water comes from the upper part of harris st (Near Quarry St) and runs into water from elizabeth/ Harris St the confluence is directly outside our front gate
95	Aged care facility	Business	3	Years	3	Years	No	No						
96	Residential	Owner Occupied	28	Years	43	Years	No	No						Flooding of basement areas is not uncommon but usually due to poor buildng design. Minor flooding regularly occurs from the southern street gutter across the road oppsite number approx 48 windsor st due to insufficient gutter depth
97	Commercial	Rental Property	35	Years	35	Years	No	No						
98	Residential	Rental Property	47	Years	47	Years	Yes	No	Several times	cark park basement heavy rain and the cark park 15 - 25 cms	Medium	Few days	Several times building is reinforced concrete frame only cark park below road level affected	block off flats on free standing columns car park area below road flooded but in recent times. Good drainage
									24/08/2015	40cm in carport 21 Elizabeth St, flooding in courtyard, flooding in shed 10 cm	High	Flash Flood over night	Debris from Elizabeth Place in carport and courtyard damage to items in shed including power tools	
99	Residential	Owner Occupied	29	Years			No	No						The fig tree roots in the paddington area are and have been a huge problem and should be considered in the paddington flood study
100	Commercial	Rental Property	60	Years	60	Years	Yes	No	1/09/2014	394- 396 Oxford St Paddington, 404 oxford St Paddington		Always had problems but since September 2014 more and more issues		
101	Residential	Owner Occupied	12	Years	40	Years	Yes	No	24/08/2015	426 Glenmore Road approx 61cm				
102	Residential	Owner Occupied	3	Years	12	Years	Yes		13/02/2010	200mm in sunroom kitchen and formal dining	Medium	Overnight and next day	Swallon timber floors and debris	European plain tree in my back yard (19 Elizabeth St) and Macodameia tree in 23 Elizaebth St Paddington. Blocking storm water. Lack of maintenance to elizabeth place
103	Other, Strata SP 7220 95 Lots	Owner Occupied	42	Years			Yes	Yes	1/04/2015	Council installed drainage to no effect			Refer pictures lifty shaft drainage 17000.00	
									29-30 August	Same as prev flooding incident				
104	Residential	Owner Occupied	14	Years	14	Years	No		two weeks ago, has also happened twice	2 Feet	Low	Hour	It was not affected as floodwater went into my neighbours home which is lower than mine.	Number 20 Hopewell Street has experienced severe flooding three times in the last 10 years. This occurred
105	Residential	Owner Occupied	13.4	Years	13.4	Years	Yes	No	7/07/2005	About level of the gutter and pavement in Cecil Lane. Many previous innudations before work done in Cecil lane by WMC. Much higher levels (1 metre + in Cecil Lane)	Medium	Minutes	Never affected internally since new house built in 2002 but Cecil St area has been flooded covering pavement and lower driveway in front of the house in previous decade	We believe there has been a dramatic change for the better in the flooding of Cecil Lane since the remedial works carried out by council. We have never had flooding in our property from Cecil St which is built at a reasonable level above the Cecil Street surface. The affected properties in Cecil St appear to be those three story properties built at a lower level.
106	Residential	Owner Occupied	3	Years	3	Years	Yes	No	Approx 2010					

#	Property Type	Occupier Status	How long have your lived in area?				Has your property ever been affected by flooding?	Do you have any photographs or videos of past floods?	Please provide additional information on your past flood experiences					Do you have any other comments or information that may assist the study?
			Current Address		In the general area?				Date of Floods	Flood Depth / Height & Location	How confidence are you with the height/depth of the flood?	How long or over what period did you observe the flood height/depth?	How was your property affected by the flood waters?	
									24/08/2015	1 foot stormwater manholes blew out on Hampden St again. Causing massive damage to my home	High	About 20 minutes	Absolutely	Woollahra Council should be ashamed of themselves too prided and congratulated yourselves on working out problems with the stormwater drains arround our area last year. It has clearly not worked!
107	Residential	Owner Occupied	36	Years			Yes	No	3 once in a life time floods in Jan 1986/ (approx Feb)	1.5 and 2 Feet came in front door, night, t hen soaked thrash to basement level underneath floor		Over 12 hours	Two rooms flooded carpet ruined total new kitchen was rebuilt	AS a result of the 3 floods Woollahra Council put in extra drains and large pit front front of number 12 - 10 Hargrave St. This was effective. Since then the pit was removed for other drains. We were concerned of the new drain when the flood water come down the pavement it is extremely dangerous.
108	Residential	Rental Property	65	Years			No	No						
109	Residential	Owner Occupied	1	Year			Yes	Yes, photos sent with letter to Woollahra Council	22/02/2010	about a metre, 10 - 15 cm outside	High	8:10 pm to 8 :30pm	See Letter	I am of the opinion the drains in glenmore road opposite trumper park are inadequate and the debris clog the drain openings.
									28/04/2015		High			
									24/08/2015		High			
110	Residential	Owner Occupied	35	Years			No	No						
111	Residential	Owner Occupied	31	Years	37	Years	Yes	No	24/09/2015	unknown, 40 cm above base of gutter		0.5 to 1 hour	Damage to flooring on back of house	The Guuters in hopewell st cannot cope with the amount of water which was droppped during these storms. Our backyard fills with water from the back of the shops behind us in glenmore road. The water level in the gutter outside our house rise to a height of 40 cm above the base.
									approx. 2000	unknown, 40 cm			Damage to flooring on back of house	
112	Residential	Owner Occupied	6	Years			No	No						I live at Double bay but have 2 properties in paddington which are rented by tenants. 116 Boundary St, 92 Cascade St
113	Residential	Rental Property	30	Years	30	Years	No	No						
114	Residential	Owner Occupied	28	Years	28	Years	No							Stormwater drain between 8A and 10 A cooper Street Paddington used ti be attended.

Appendix B

Manning's 'n' Calculations

Manning's 'n' Calculations

Prepared by: D. Tetley | **Date:** 22/08/2014
Checked by: C. Ryan | **Date:** 12/05/2015

The following provide Manning's' n roughness coefficient calculations based on the modified Cowan method documented in the USGS Paper 2339: "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains' (Arcement & Schneider). The approach is appropriate for direct rainfall modelling as it can account for the variation in 'n' with respect to flow depth.

Overview

Manning's 'n' is calculated using the modified Cowan method based on the following formula:

$n = m (n_b + n_1 + n_2 + n_3 + n_4)$

Where: n_b = a base value of n for the floodplain's natural bare soil surface
n_1 = a correction factor for the effect of surface irregularities
n_2 = a value for variations in shape and size of the floodplain cross-section (assumed to be 0.0)
n_3 = a value for obstructions
n_4 = a value for vegetation on the floodplain
m = a correction factor for sinuosity (assumed to be 1.0)

Description of Surface / Material Type

Material Type 5 - Grass
Relatively short grass. Occasional tree or fence post

n_b Calculation

n_b is extracted from the following table:

Table 1. Base Values of Manning's *n*

		Base *n* Value	
Bed Material	**Median Size of bed material (in millimeters)**	**Straight Uniform Channel[1]**	**Smooth Channel[2]**
Sand Channels			
Sand[3]	0.2	0.012	--
	.3	.017	--
	.4	.020	--
	.5	.022	--
	.6	.023	--
	.8	.025	--
	1.0	.026	--
Stable Channels and Flood Plains			
Concrete	--	0.012-0.018	0.011
Rock Cut	--	--	.025
Firm Soil	--	0.025-0.032	.020

Coarse Sand	**1-2**	**0.026-0.035**	**--**
Fine Gravel	**--**	**--**	**.024**
Gravel	**2-64**	**0.028-0.035**	**--**
Coarse Gravel	**--**	**--**	**.026**
Cobble	**64-256**	**0.030-0.050**	**--**
Boulder	**>256**	**0.040-0.070**	**--**

[Modified from Aldridge & Garret, 1973, Table 1 --No data
1Benson & Dalrymple --No data
[2] For indicated material; Chow(1959)
[3] Only For Upper regime flow where grain roughness is predominant

Assume "Firm Soil" for manicured grass areas

n_b = 0.025

n_1 Calculation (Degree of Irregularity)

n_1 is extracted from the following table:

Smooth	0.000	Compares to the smoothest, flattest flood-plain attainable in a given bed material.
Minor	0.001-0.005	Is a Flood Plain Slightly irregular in shape. A few rises and dips or sloughs may be more visible on the flood plain.
Moderate	0.006-0.010	Has more rises and dips. Sloughs and hummocks may occur.
Severe	0.011-0.020	Flood Plain very irregular in shape. Many rises and dips or sloughs are visible. Irregular ground surfaces in pasture land and furrows perpendicular to the flow are also included.

Assume "moderate" to cater for undulating terrain across most of the study area

n_1 = 0.006

n_3 Calculation (Effect of Obstructions)

n_3 is extracted from the following table:

Negligible	0.000-0.004	Few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
Minor	0.040-0.050	Obstructions occupy less than 15 percent of the cross-sectional area.
Appreciable	0.020-0.030	Obstructions occupy from 15 percent to 50 percent of the cross-sectional area.

Occasional tree stump or obstruction may be present:

n_3 = 0.004

n_4 Calculation (Effect of Vegetation)

n_4 is largely driven by the height of flow relative to the height of vegetation as defined in the following table:

Small	0.001-0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrow-weed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1-to-2-year-old willow trees in the dormant season..
Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of the vegetation; 8-to-10-years-old willow or cottonwood trees intergrow with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 0.607 m.;or mature row crops such as small vegetables, or mature field crops where depth flow is at least twice the height of the vegetation.
Very Large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; or moderate to dense brush, or heavy stand of timber with few down trees and little undergrowth where depth of flow is

		timber with few down trees and little undergrowth where depth of flow is below branches, or mature field crops where depth of flow is less than the height of the vegetation.
Extreme	0.100-0.200	Dense bushy willow, mesquite, and saltcedar(all vegetation in full foliage), or heavy stand of timber, few down trees, depth of reaching branches.

Assume grass is equal to or less than 0.05 metres in height

n_4 = 0.065	When water depth is < 0.03m	(water depth less than height of grass)
n_4 = 0.03	When water depth is ~ 0.05m	(water depth equal in height to grass)
n_4 = 0.015	When water depth is ~ 0.07m	(water depth less than twice height of grass)
n_4 = 0.001	When water depth is > 0.1m	(water depth more than twice height of grass)

Final 'n' Value

$n = m (n_b + n_1 + n_2 + n_3 + n_4)$

n = 0.11	When water depth is < 0.03m
n = 0.075	When water depth is ~ 0.05m
n = 0.055	When water depth is ~ 0.07m
n = 0.03	When water depth is > 0.1m

Manning's 'n' Calculations

Prepared by: D. Tetley **Date:** 22/08/2014
Checked by: C. Ryan **Date:** 12/05/2015

The following provide Manning's' n roughness coefficient calculations based on the modified Cowan method documented in the USGS Paper 2339: "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains' (Arcement & Schneider). The approach is appropriate for direct rainfall modelling as it can account for the variation in 'n' with respect to flow depth.

Overview

Manning's 'n' is calculated using the modified Cowan method based on the following formula:

$$n = m (n_b + n_1 + n_2 + n_3 + n_4)$$

Where: n_b = a base value of n for the floodplain's natural bare soil surface
n_1 = a correction factor for the effect of surface irregularities
n_2 = a value for variations in shape and size of the floodplain cross-section (assumed to be 0.0)
n_3 = a value for obstructions
n_4 = a value for vegetation on the floodplain
m = a correction factor for sinuosity (assumed to be 1.0)

Description of Surface / Material Type

Material Type 3 - Trees
Trees (> 2metres in height) with medium to dense undergrowth

n_b Calculation

n_b is extracted from the following table:

Table 1. Base Values of Manning's *n*

Bed Material	Median Size of bed material (in millimeters)	Base *n* Value: Straight Uniform Channel[1]	Base *n* Value: Smooth Channel[2]
Sand Channels			
Sand[3]	0.2	0.012	--
	.3	.017	--
	.4	.020	--
	.5	.022	--
	.6	.023	--
	.8	.025	--
	1.0	.026	--
Stable Channels and Flood Plains			
Concrete	--	0.012-0.018	0.011
Rock Cut	--	--	.025
Firm Soil	--	0.025-0.032	.020

Coarse Sand	**1-2**	**0.026-0.035**	**--**
Fine Gravel	**--**	**--**	**.024**
Gravel	**2-64**	**0.028-0.035**	**--**
Coarse Gravel	**--**	**--**	**.026**
Cobble	**64-256**	**0.030-0.050**	**--**
Boulder	**>256**	**0.040-0.070**	**--**

[Modified from Aldridge & Garret, 1973, Table 1 --No data
1Benson & Dalrymple --No data
[2] For indicated material; Chow(1959)
[3] Only For Upper regime flow where grain roughness is predominant

Assume "Firm Soil"

n_b = 0.025

n_1 Calculation (Degree of Irregularity)

n_1 is extracted from the following table:

Smooth	0.000	Compares to the smoothest, flattest flood-plain attainable in a given bed material.
Minor	0.001-0.005	Is a Flood Plain Slightly irregular in shape. A few rises and dips or sloughs may be more visible on the flood plain.
Moderate	0.006-0.010	Has more rises and dips. Sloughs and hummocks may occur.
Severe	0.011-0.020	Flood Plain very irregular in shape. Many rises and dips or sloughs are visible. Irregular ground surfaces in pasture land and furrows perpendicular to the flow are also included.

Assume "moderate" to cater for undulating terrain across most of the study area

n_1 = 0.01

n_3 Calculation (Effect of Obstructions)

n_3 is extracted from the following table:

Negligible	0.000-0.004	Few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
Minor	0.040-0.050	Obstructions occupy less than 15 percent of the cross-sectional area.
Appreciable	0.020-0.030	Obstructions occupy from 15 percent to 50 percent of the cross-sectional area.

Many obstructions likely

n_3 = 0.025

n_4 Calculation (Effect of Vegetation)

n_4 is largely driven by the height of flow relative to the height of vegetation as defined in the following table:

Small	0.001-0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrow-weed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1-to-2-year-old willow trees in the dormant season..
Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of the vegetation; 8-to-10-years-old willow or cottonwood trees intergrow with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 0.607 m.;or mature row crops such as small vegetables, or mature field crops where depth flow is at least twice the height of the vegetation.
Very Large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; or moderate to dense brush, or heavy stand of timber with few down trees and little undergrowth where depth of flow is

		timber with few down trees and little undergrowth where depth of flow is below branches, or mature field crops where depth of flow is less than the height of the vegetation.
Extreme	0.100-0.200	Dense bushy willow, mesquite, and saltcedar(all vegetation in full foliage), or heavy stand of timber, few down trees, depth of reaching branches.

Assume significant undergrowth up to 0.3 m in height, less dense shrubs up to 1.5m & tree branch above 2m

n_4 = 0.1	When water depth is < 0.3m	(Shrubs, trees & undergrowth in contact with flow)
n_4 = 0.05	When water depth is ~ 1.5m	(Shrubs & tree trunks in contact with flow)
n_4 = 0.02	When water depth is >2m	(Tree trunks in contact with flow)

Final 'n' Value

$n = m (n_b + n_1 + n_2 + n_3 + n_4)$

n = 0.16	When water depth is < 0.3m
n = 0.11	When water depth is ~ 1.5m
n = 0.08	When water depth is >2.0m

Manning's 'n' Calculations

Prepared by: D. Tetley **Date:** 22/08/2014
Checked by: C. Ryan **Date:** 12/05/2015

The following provide Manning's' n roughness coefficient calculations based on the modified Cowan method documented in the USGS Paper 2339: "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains' (Arcement & Schneider). The approach is appropriate for direct rainfall modelling as it can account for the variation in 'n' with respect to flow depth.

Overview

Manning's 'n' is calculated using the modified Cowan method based on the following formula:

$n = m (n_b + n_1 + n_2 + n_3 + n_4)$

Where: n_b = a base value of n for the floodplain's natural bare soil surface
n_1 = a correction factor for the effect of surface irregularities
n_2 = a value for variations in shape and size of the floodplain cross-section (assumed to be 0.0)
n_3 = a value for obstructions
n_4 = a value for vegetation on the floodplain
m = a correction factor for sinuosity (assumed to be 1.0)

Description of Surface / Material Type

Material Type 2 - Roads
Concrete kerb & gutter for containing low flows with road pavement at higher stages

n_b Calculation

n_b is extracted from the following table:

Table 1. Base Values of Manning's *n*

Bed Material	Median Size of bed material (in millimeters)	Base *n* Value: Straight Uniform Channel[1]	Base *n* Value: Smooth Channel[2]
Sand Channels			
Sand[3]	0.2	0.012	--
	.3	.017	--
	.4	.020	--
	.5	.022	--
	.6	.023	--
	.8	.025	--
	1.0	.026	--
Stable Channels and Flood Plains			
Concrete	--	0.012-0.018	0.011
Rock Cut	--	--	.025
Firm Soil	--	0.025-0.032	.020

Coarse Sand	**1-2**	**0.026-0.035**	**--**
Fine Gravel	**--**	**--**	**.024**
Gravel	**2-64**	**0.028-0.035**	**--**
Coarse Gravel	**--**	**--**	**.026**
Cobble	**64-256**	**0.030-0.050**	**--**
Boulder	**>256**	**0.040-0.070**	**--**
[Modified from Aldridge & Garret, 1973, Table 1 --No data 1Benson & Dalrymple --No data 2 For indicated material; Chow(1959) 3 Only For Upper regime flow where grain roughness is predominant			

Assume "Concrete"

n_b = 0.012

n_1 Calculation (Degree of Irregularity)

n_1 is extracted from the following table:

Smooth	0.000	Compares to the smoothest, flattest flood-plain attainable in a given bed material.
Minor	0.001-0.005	Is a Flood Plain Slightly irregular in shape. A few rises and dips or sloughs may be more visible on the flood plain.
Moderate	0.006-0.010	Has more rises and dips. Sloughs and hummocks may occur.
Severe	0.011-0.020	Flood Plain very irregular in shape. Many rises and dips or sloughs are visible. Irregular ground surfaces in pasture land and furrows perpendicular to the flow are also included.

Relatively minor grades along most roadways

n_1 = 0.002

n_3 Calculation (Effect of Obstructions)

n_3 is extracted from the following table:

Negligible	0.000-0.004	Few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
Minor	0.040-0.050	Obstructions occupy less than 15 percent of the cross-sectional area.
Appreciable	0.020-0.030	Obstructions occupy from 15 percent to 50 percent of the cross-sectional area.

May be garbage bins etc, but assume negligible

n_3 = 0.002

n_4 Calculation (Effect of Vegetation)

n_4 is largely driven by the height of flow relative to the height of vegetation as defined in the following table:

Small	0.001-0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrow-weed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1-to-2-year-old willow trees in the dormant season..
Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of the vegetation; 8-to-10-years-old willow or cottonwood trees intergrow with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 0.607 m.;or mature row crops such as small vegetables, or mature field crops where depth flow is at least twice the height of the vegetation.
Very Large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; or moderate to dense brush, or heavy stand of timber with few down trees and little undergrowth where depth of flow is

		below branches, or mature field crops where depth of flow is less than the height of the vegetation.
Extreme	0.100-0.200	Dense bushy willow, mesquite, and saltcedar(all vegetation in full foliage), or heavy stand of timber, few down trees, depth of reaching branches.

Assume water contained in gutter initially and then spreads onto road pavement

n_4 = 0.001	When water depth is < 0.04m	(Water contained within gutter)
n_4 = 0.005	When water depth is ~ 0.1m	(Water comes into contact with pavement aggregate)
n_4 = 0.002	When water depth is > 0.15m	(Water well above aggregate/gutter height)

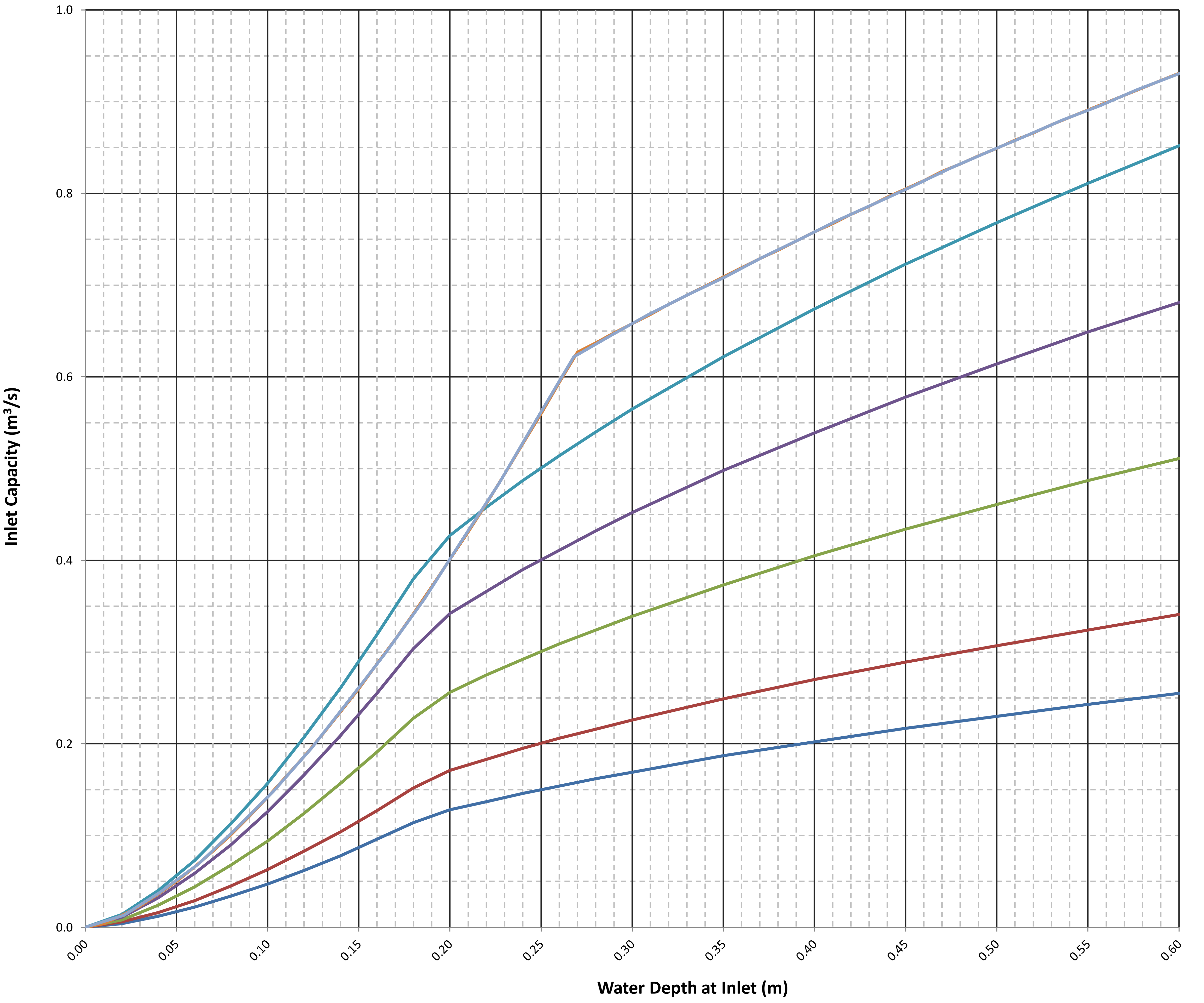
Final 'n' Value

$n = m (n_b + n_1 + n_2 + n_3 + n_4)$

n = 0.017	When water depth is < 0.04m
n = 0.021	When water depth is ~ 0.1m
n = 0.02	When water depth is >0.15m

Appendix C

Stormwater Pit Inlet Capacity Curves



LEGEND

- Combination Inlet with 0.9m Lintel
- Combination Inlet with 1.2m Lintel
- Combination Inlet with 1.8m Lintel
- Combination Inlet with 2.4m Lintel
- Combination Inlet with 3m Lintel
- Grate Only Inlet
- Kerb Only Inlet

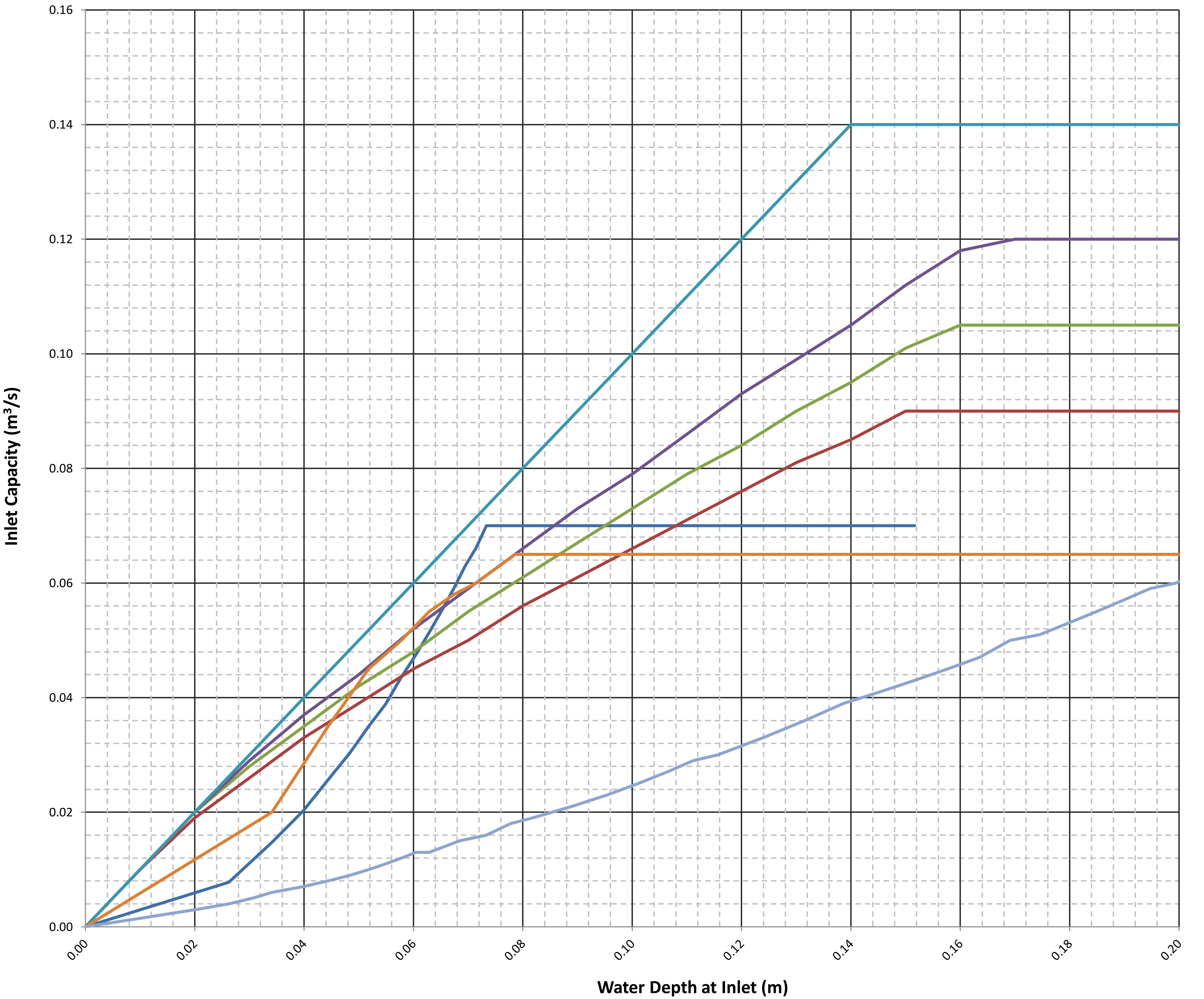
Notes:

Inlet capacity curves do not consider blockage.

Figure C1:
Inlet Capacity Curves for Sag Pits

Prepared By:
Catchment Simulation Solutions
Suite 1, Level 2, 210 George Street
Sydney, NSW, 2000

File Name: Inlet Capcacity Curves.xls



LEGEND

- Combination Inlet with 0.9m Lintel
- Combination Inlet with 1.2m Lintel
- Combination Inlet with 1.8m Lintel
- Combination Inlet with 2.4m Lintel
- Combination Inlet with 3m Lintel
- Grate Only Inlet
- Kerb Only Inlet

Notes:

Inlet capacity curves do not consider blockage. A 4% on-grade slope has been used for the generation of these curves.

Figure C2: Inlet Capacity Curves for On Grade Pits

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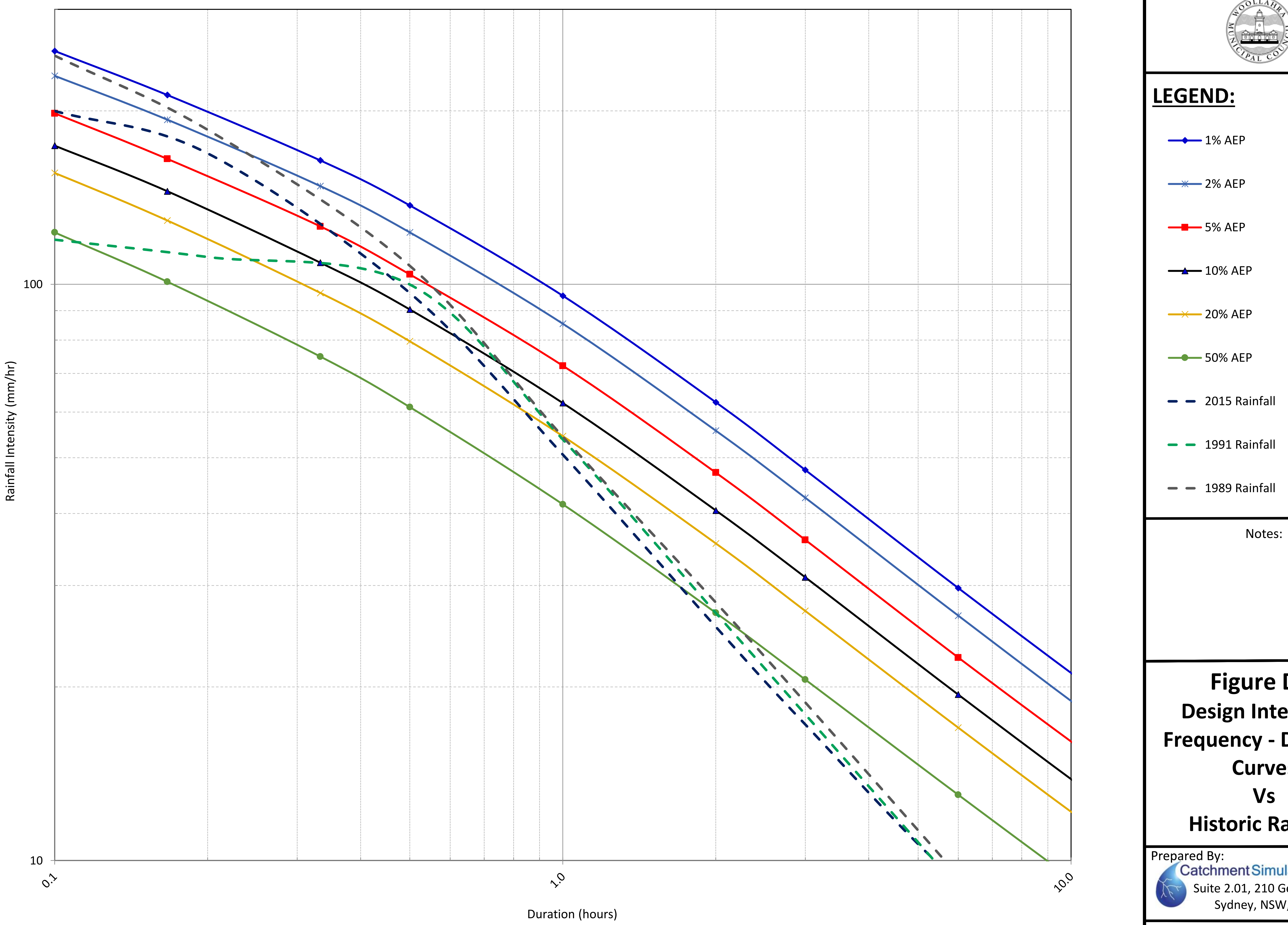
Catchment Simulation Solutions
Suite 1, Level 2, 210 George Street
Sydney, NSW, 2000

File Name: Inlet Capcacity Curves.xls

Appendix D

Intensity-Frequency-Duration Data



Notes:

Figure D1:
Design Intensity - Frequency - Duration Curves Vs Historic Rainfall

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

File Name: Paddington IFD Curves.xlsx

APPENDIX E

DRAINS MODEL INPUT / OUTPUT FOR CALIBRATION SIMULATIONS

DRAINS - PEAK SUBCATCHMENT DISCHARGES

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aDP18A10	0.23	0.11	0.23
aDP18A11	0.18	0.09	0.18
aDP18A12	0.28	0.14	0.28
aDP18A13	0.16	0.08	0.15
aDP18A2	0.06	0.03	0.06
aDP18A3	0.11	0.05	0.10
aDP18A3_1	0.38	0.18	0.37
aDP18A4	0.18	0.09	0.17
aDP18A5	0.03	0.02	0.03
aDP18A6	0.10	0.05	0.10
aDP18A7	0.04	0.02	0.04
aDP18B1	0.02	0.01	0.02
aDP18B2	0.02	0.01	0.02
aDP18B3	0.01	0.00	0.01
aDP18B4	0.01	0.00	0.01
aDP18B5	0.09	0.04	0.08
aDP18B6	0.19	0.09	0.19
aDP18B7	0.19	0.09	0.19
aDP18B8	0.04	0.02	0.04
aDP18B9	0.03	0.01	0.02
aDP18C1	0.03	0.02	0.03
aDP18D1	0.42	0.20	0.40
aDP18E1	0.79	0.38	0.77
aDP18E2	0.08	0.04	0.07
aDP18E3	0.08	0.04	0.07
aDP18F1	0.10	0.05	0.10
aDP18G1	0.00	0.00	0.00
aDP18G2	0.49	0.23	0.47
aDP18H1	0.02	0.01	0.02
aDP18I1	0.10	0.05	0.10
aDP18I2	0.02	0.01	0.02
aDP18I3	0.28	0.14	0.28
aDP18I4	1.40	0.69	1.38
aP11A3	0.06	0.03	0.06
aP11JZ0A	0.05	0.02	0.05
aP11JZ4	0.20	0.10	0.20
aP11ZB1	0.92	0.41	0.83
aP11ZB2	0.00	0.00	0.00
aP11ZB3	0.74	0.34	0.68
aP11ZB4	0.48	0.22	0.43
aP11ZC1	0.03	0.01	0.03
aP11ZD1	0.03	0.02	0.03
aP11ZE1	0.00	0.00	0.00
aP12A2	0.00	0.00	0.00
aP12A3	0.00	0.00	0.00
aP12A4	0.02	0.01	0.02
aP13A16	0.01	0.00	0.01
aP13A17	0.05	0.03	0.05
aP13A19	0.26	0.13	0.26
aP13BA10	0.25	0.12	0.24
aP13BA11	0.31	0.15	0.31
aP13BA12	0.19	0.09	0.18
aP13BA13	0.14	0.07	0.14
aP13BA14	0.24	0.11	0.23
aP13BA15	0.55	0.27	0.54
aP13BB1	0.12	0.06	0.12
aP13BB2	0.12	0.06	0.12
aP13BC2	0.09	0.05	0.09
aP13D1	0.03	0.01	0.03
aP13E1	0.00	0.00	0.00
aP13F1	0.00	0.00	0.00
aP13F2	0.03	0.01	0.03
aP13G1	0.00	0.00	0.00
aP13G2	0.02	0.01	0.02
aP14A2	0.01	0.01	0.01
aP14A3	0.05	0.03	0.05
aP14A4	0.00	0.00	0.00
aP15A1	0.04	0.02	0.04

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP15A4	0.16	0.08	0.16
aP16A1	0.13	0.06	0.12
aP17A10	0.00	0.00	0.00
aP17A11	0.01	0.00	0.01
aP17A12	0.11	0.06	0.11
aP17A15	0.04	0.02	0.04
aP17A16	0.00	0.00	0.00
aP17A17	0.03	0.02	0.03
aP17A18	0.27	0.13	0.26
aP17A3A	0.29	0.14	0.29
aP17A4	0.08	0.04	0.08
aP17A5	0.05	0.02	0.05
aP17A6	0.15	0.07	0.14
aP17A9	0.01	0.00	0.01
aP17B1	0.09	0.04	0.09
aP17B2	0.03	0.01	0.03
aP17C1	0.00	0.00	0.00
aP17C2	0.38	0.18	0.37
aP17E1	0.03	0.02	0.03
aP18A12	0.01	0.01	0.01
aP18A13	0.02	0.01	0.02
aP18A14	0.23	0.11	0.22
aP18A4	0.01	0.00	0.01
aP18A6	0.00	0.00	0.00
aP18B1	0.14	0.07	0.13
aP18C1	0.02	0.01	0.02
aP18D1	0.02	0.01	0.02
aP18E2	0.04	0.02	0.04
aP18F2	0.24	0.12	0.24
aP18G1	0.01	0.00	0.01
aP18H1	0.05	0.03	0.05
aP18I1	0.23	0.11	0.23
aP18K1	0.01	0.00	0.01
aP18L1	0.01	0.00	0.01
aP18M1	0.07	0.03	0.07
aP18N1	0.67	0.33	0.66
aP18O1	0.04	0.02	0.04
aP18P1	0.00	0.00	0.00
aP18P2	0.00	0.00	0.00
aP18P3	0.01	0.00	0.01
aP18Q1	0.00	0.00	0.00
aP18Q2	0.22	0.11	0.22
aP18Q3	0.03	0.01	0.03
aP18R1	0.07	0.03	0.07
aP18S1	0.04	0.02	0.04
aP18S2	0.23	0.11	0.23
aP18U1	0.47	0.23	0.46
aP18UA1	0.46	0.22	0.45
aP18V1	0.02	0.01	0.02
aP19A2	0.14	0.07	0.13
aP19B1	0.21	0.10	0.20
aP19C1	0.07	0.03	0.06
aP19D1	0.03	0.01	0.02
aP19D2	0.22	0.11	0.22
aP1A1	0.13	0.06	0.13
aP1A2	0.46	0.22	0.45
aP1A3	0.04	0.02	0.04
aP1A4	0.01	0.01	0.01
aP1A5	0.05	0.03	0.05
aP1A6	0.00	0.00	0.00
aP1A7	0.12	0.06	0.12
aP1A8	0.15	0.07	0.14
aP1AA1	0.26	0.13	0.25
aP1B1	0.05	0.02	0.05
aP1C1	0.02	0.01	0.02
aP1C2	0.01	0.01	0.01
aP1C3	0.10	0.05	0.10
aP1C4	0.19	0.09	0.18
aP1C5	0.01	0.00	0.01
aP1C6	0.08	0.04	0.08

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP1D1	0.06	0.03	0.06
aP1F2	0.10	0.05	0.09
aP1G1	0.31	0.15	0.30
aP21A3	0.09	0.04	0.08
aP21B2	0.23	0.11	0.22
aP21B3	0.05	0.03	0.05
aP21B3A	0.15	0.07	0.15
aP21B3B	0.10	0.05	0.10
aP21B4	0.26	0.12	0.25
aP21B6	0.44	0.21	0.43
aP21B6A	0.20	0.10	0.20
aP21B6B	0.01	0.00	0.01
aP21C1	0.22	0.11	0.22
aP21D1	0.21	0.10	0.21
aP21E1	0.08	0.04	0.08
aP21F2	0.03	0.01	0.02
aP21F3	0.03	0.02	0.03
aP21F4	0.02	0.01	0.02
aP21F6	0.02	0.01	0.02
aP21G1	0.11	0.05	0.11
aP21H1	0.10	0.05	0.10
aP21K1	0.16	0.08	0.15
aP22A11	0.00	0.00	0.00
aP22A12	0.12	0.06	0.12
aP22A13	0.34	0.16	0.33
aP22A2	0.08	0.04	0.07
aP22A3	0.29	0.14	0.28
aP22A6	0.01	0.00	0.01
aP22A7	0.00	0.00	0.00
aP22A8	0.02	0.01	0.02
aP22A9	0.28	0.14	0.28
aP22AA1	0.42	0.20	0.41
aP22AB1	0.04	0.02	0.04
aP22AB2	0.04	0.02	0.04
aP22AB3	0.10	0.05	0.09
aP22AC1	0.02	0.01	0.02
aP22AC2	0.01	0.00	0.01
aP22AC3	0.01	0.01	0.01
aP22B1	1.92	0.92	1.76
aP22C1	0.01	0.01	0.01
aP22C2	0.28	0.13	0.27
aP22D2	0.13	0.06	0.12
aP22E1	0.65	0.31	0.63
aP22F1	0.36	0.17	0.35
aP22G1	0.11	0.05	0.11
aP22H1	0.04	0.02	0.04
aP22H2	0.15	0.07	0.14
aP22K10	0.02	0.01	0.02
aP22K11	0.19	0.09	0.19
aP22K12	0.03	0.01	0.03
aP22K13	0.02	0.01	0.02
aP22K14	0.03	0.02	0.03
aP22K15	0.03	0.02	0.03
aP22K16	0.02	0.01	0.02
aP22K17	0.02	0.01	0.02
aP22K18	0.06	0.03	0.05
aP22K19	0.03	0.01	0.03
aP22K2	0.26	0.13	0.26
aP22K3	0.31	0.15	0.31
aP22K3B	0.57	0.28	0.56
aP22K4	0.52	0.25	0.51
aP22K5_1	0.01	0.00	0.01
aP22K6	0.02	0.01	0.02
aP22K7	0.02	0.01	0.02
aP22K8	0.02	0.01	0.02
aP22K9	0.01	0.01	0.01
aP22L1	0.01	0.00	0.01
aP22L2	0.36	0.18	0.35
aP22L3	0.03	0.02	0.03
aP22M2	0.45	0.22	0.45

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP22N2	0.01	0.00	0.01
aP22N3	0.10	0.05	0.10
aP22P1	0.00	0.00	0.00
aP22P2	0.02	0.01	0.02
aP22Q1	0.00	0.00	0.00
aP22Q2	0.02	0.01	0.02
aP22R1	0.27	0.13	0.27
aP22R2	0.02	0.01	0.02
aP22T3	0.01	0.01	0.01
aP22T4	0.20	0.10	0.20
aP22T5	0.01	0.01	0.01
aP22T6	0.06	0.03	0.06
aP22T9	0.56	0.27	0.55
aP22V1	0.11	0.05	0.11
aP22V2	0.09	0.04	0.09
aP22W1	0.33	0.16	0.33
aP22W3	0.82	0.40	0.81
aP22Z2	0.10	0.05	0.10
aP23A6_1	0.02	0.01	0.02
aP23A8	0.05	0.03	0.05
aP23A9	0.14	0.07	0.14
aP23B1	0.01	0.01	0.01
aP23B2	0.13	0.07	0.13
aP23B3	0.21	0.10	0.20
aP23C1	0.13	0.06	0.13
aP23D1	0.09	0.04	0.09
aP23E1	0.02	0.01	0.02
aP23E2	0.07	0.04	0.07
aP23F1	0.11	0.05	0.11
aP23F2	0.11	0.05	0.11
aP23F3	0.02	0.01	0.02
aP23G1	0.01	0.00	0.01
aP23G2	0.09	0.04	0.09
aP23H1	0.10	0.05	0.10
aP23K2	0.01	0.00	0.01
aP23K3	0.06	0.03	0.06
aP23K5	0.01	0.00	0.01
aP23K6	0.03	0.02	0.03
aP23L1	0.00	0.00	0.00
aP23L2	0.09	0.04	0.09
aP23M1	0.39	0.19	0.37
aP23O1	0.60	0.29	0.58
aP23P1	0.07	0.03	0.07
aP23Q1	0.17	0.08	0.17
aP23R1	0.01	0.00	0.01
aP23R2	0.06	0.03	0.06
aP23T2	0.03	0.02	0.03
aP23U3	0.60	0.29	0.59
aP23V3	0.40	0.20	0.40
aP23W2	0.10	0.05	0.09
aP23X1	0.08	0.04	0.07
aP23Y1	0.01	0.00	0.01
aP23Y2	0.03	0.01	0.03
aP24A1C	0.62	0.31	0.61
aP24AA	0.09	0.04	0.09
aP24AA1	3.71	1.83	3.62
aP24AA2	9.52	4.73	9.23
aP24AC	0.00	0.00	0.00
aP24AC2	0.01	0.01	0.01
aP24AC3	0.15	0.08	0.15
aP24AF	2.15	1.06	2.12
aP24AH	1.01	0.49	0.99
aP24AI	0.01	0.00	0.01
aP24AJ	0.01	0.00	0.01
aP24AK	0.01	0.00	0.01
aP24AL	0.20	0.10	0.19
aP24AM	0.14	0.07	0.14
aP24AN	0.03	0.02	0.03
aP24AO	0.01	0.00	0.01
aP24AP	0.08	0.04	0.08

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP24AQ10	0.20	0.10	0.19
aP24AQ2	0.36	0.18	0.36
aP24AQ3	0.01	0.00	0.01
aP24AQ4	0.12	0.06	0.12
aP24AQ5	0.07	0.03	0.07
aP24AQ6	0.17	0.08	0.17
aP24AQ7	0.04	0.02	0.04
aP24AQ8	0.05	0.02	0.05
aP24AQ9	0.14	0.07	0.14
aP24AR	0.01	0.00	0.01
aP24AS	0.03	0.02	0.03
aP24AT	0.06	0.03	0.06
aP24AT1	0.53	0.26	0.52
aP24AT3	0.31	0.15	0.30
aP24AV1	0.20	0.10	0.20
aP24AW1	0.02	0.01	0.02
aP24AX1	0.18	0.09	0.17
aP24B1	0.08	0.04	0.08
aP24C1	0.59	0.29	0.59
aP24D2	0.00	0.00	0.00
aP24D3	0.53	0.26	0.52
aP24D4	0.18	0.09	0.18
aP24E1	0.54	0.26	0.53
aP24F1	0.22	0.11	0.22
aP24G1	0.06	0.03	0.06
aP24G10	0.07	0.03	0.07
aP24G11	0.01	0.01	0.01
aP24G12	0.31	0.15	0.30
aP24G16	0.08	0.04	0.07
aP24G17	0.17	0.09	0.17
aP24G4	0.01	0.01	0.01
aP24G5	0.12	0.06	0.12
aP24G6	0.02	0.01	0.02
aP24G7	0.02	0.01	0.02
aP24G8	0.01	0.00	0.01
aP24G9	0.28	0.14	0.27
aP24H0A	0.01	0.01	0.01
aP24H1	0.10	0.05	0.10
aP24I1	0.39	0.19	0.38
aP24I2	0.02	0.01	0.02
aP24I3	0.01	0.00	0.01
aP24I4	0.12	0.06	0.12
aP24L1	0.34	0.17	0.34
aP24M1	0.10	0.05	0.09
aP24N2	0.41	0.20	0.40
aP24O1	0.00	0.00	0.00
aP24O2	0.73	0.36	0.72
aP24O4	0.09	0.04	0.09
aP24O6	0.07	0.03	0.06
aP24P1	0.24	0.12	0.23
aP24Q1	0.41	0.20	0.41
aP24R1	0.16	0.08	0.15
aP24S1	0.08	0.04	0.08
aP24T1	0.04	0.02	0.04
aP24T3	0.33	0.16	0.33
aP24U1	0.15	0.07	0.15
aP24V1	0.20	0.10	0.20
aP24V2	0.05	0.02	0.05
aP24W1	0.01	0.00	0.01
aP24X1	0.00	0.00	0.00
aP24X2	0.08	0.04	0.07
aP24Y1	0.58	0.28	0.57
aP24Z1A	5.03	2.48	4.92
aP25A2	0.17	0.08	0.16
aP25A3	0.11	0.05	0.10
aP25A4	0.21	0.10	0.21
aP25A5	0.15	0.07	0.15
aP25A6	0.02	0.01	0.02
aP25C1	0.59	0.37	0.61
aP25D1	0.06	0.03	0.06

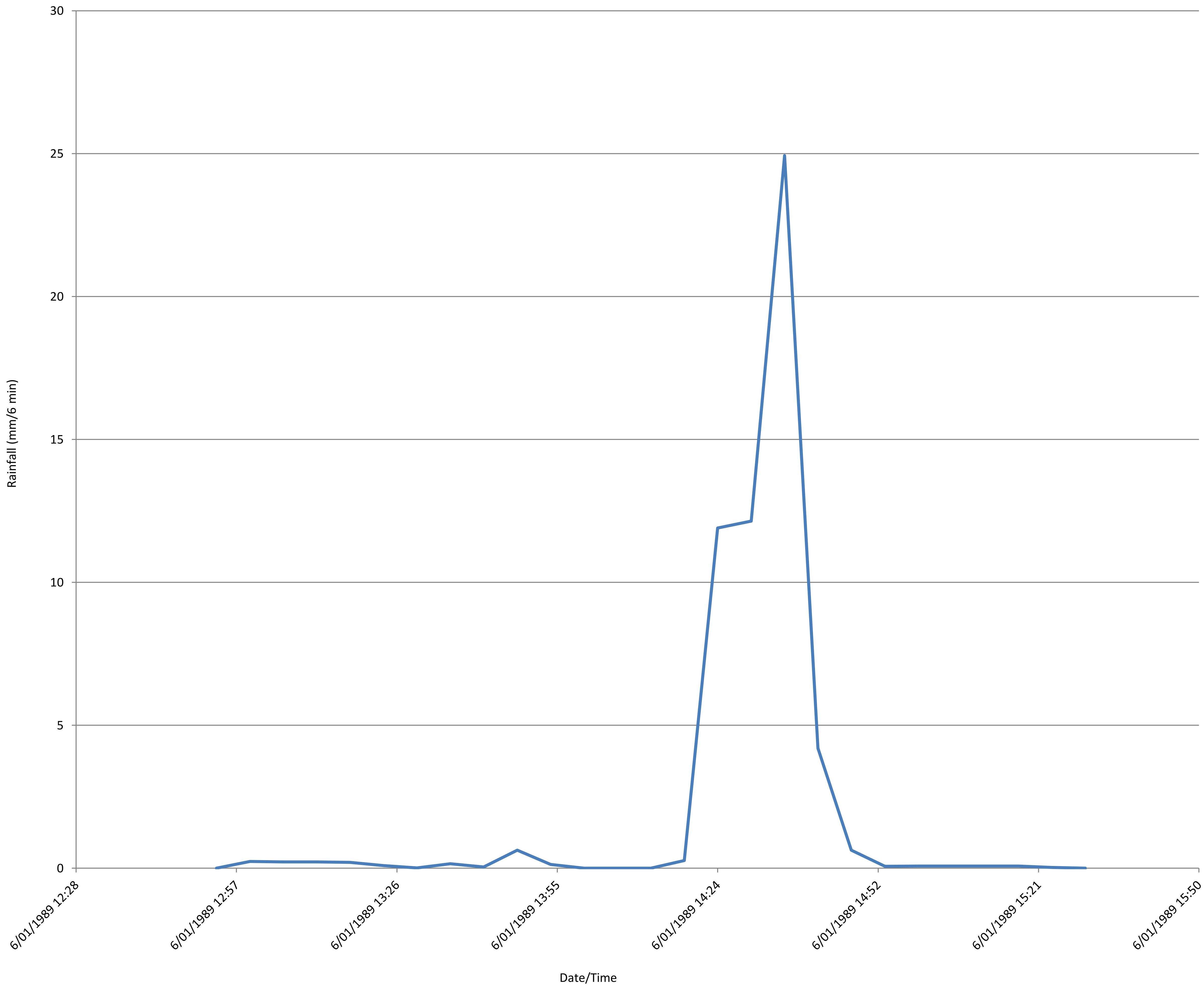
Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP25E1	0.06	0.03	0.06
aP25F1	0.11	0.05	0.10
aP25G1	0.01	0.01	0.01
aP25G2	0.01	0.00	0.01
aP25G4	0.04	0.02	0.04
aP25G5	0.30	0.15	0.30
aP25H2	0.18	0.09	0.18
aP26A1	11.59	5.93	11.06
aP26A2	0.09	0.04	0.09
aP27A1	0.38	0.18	0.37
aP2A1	1.24	0.59	1.13
aP3A1	1.71	0.77	1.57
aP5017	0.72	0.35	0.71
aP502	0.03	0.01	0.03
aP5A3	0.05	0.03	0.05
aP5A4	0.01	0.00	0.01
aP5A5	0.01	0.00	0.01
aP5A6	0.15	0.07	0.14
aP5A8	0.03	0.02	0.03
aP5AA	0.22	0.11	0.21
aP5AB	0.03	0.01	0.03
aP5AC	0.22	0.11	0.22
aP5B1	0.05	0.02	0.05
aP5C1	0.24	0.11	0.23
aP5C2	0.06	0.03	0.06
aP5E1	0.08	0.04	0.07
aP5E2	0.06	0.03	0.06
aP5F1	0.00	0.00	0.00
aP5F2	0.62	0.30	0.60
aP5G1	0.22	0.11	0.22
aP5G3	0.08	0.04	0.08
aP5G5	0.06	0.03	0.06
aP5G6	0.27	0.13	0.27
aP5H2	0.04	0.02	0.03
aP5H3	0.05	0.02	0.05
aP5I1	0.03	0.02	0.03
aP5K1	0.10	0.05	0.09
aP5L1	0.12	0.06	0.12
aP5M1	0.05	0.02	0.05
aP5M2	0.03	0.02	0.03
aP5M4	0.13	0.06	0.12
aP5N1	0.31	0.15	0.31
aP5N2	0.10	0.05	0.09
aP5N3	0.26	0.13	0.25
aP5N4	0.17	0.08	0.17
aP5O1	0.01	0.00	0.01
aP5O11A	0.21	0.10	0.20
aP5O13	0.08	0.04	0.08
aP5O14	0.07	0.04	0.07
aP5O14D	0.15	0.07	0.15
aP5O15	0.01	0.00	0.01
aP5O16	0.03	0.01	0.03
aP5O2A	0.04	0.02	0.04
aP5O2B	0.17	0.08	0.16
aP5O5	0.03	0.02	0.03
aP5O7	0.05	0.02	0.05
aP5O9	0.04	0.02	0.04
aP5O9A	0.00	0.00	0.00
aP5P1	0.01	0.01	0.01
aP5P2	0.08	0.04	0.08
aP5Q1	0.32	0.16	0.31
aP5R1	0.09	0.04	0.08
aP5R1A	0.00	0.00	0.00
aP5S1	0.30	0.14	0.29
aP5T1	0.39	0.19	0.38
aP5U1	0.26	0.13	0.26
aP5V1	0.01	0.00	0.01
aP5W1	0.03	0.02	0.03
aP5X1	0.01	0.00	0.01
aP5X2	0.07	0.03	0.07

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP5X3	0.07	0.03	0.07
aP5X4	0.28	0.14	0.28
aP5Y1	0.03	0.01	0.03
aP5Z1	0.01	0.01	0.01
aP6A10	0.14	0.07	0.14
aP6A11	0.13	0.07	0.13
aP6A14	0.07	0.04	0.07
aP6A15	1.17	0.57	1.15
aP6A6	0.08	0.04	0.08
aP6A7	0.12	0.06	0.12
aP6A9	0.03	0.01	0.03
aP6B2	0.18	0.09	0.18
aP6B3	1.00	0.49	0.99
aP6C0	0.07	0.03	0.07
aP6C1	0.22	0.11	0.21
aP6C2	0.04	0.02	0.04
aP6C3	0.35	0.17	0.34
aP6D1	0.07	0.03	0.07
aP6E1	0.08	0.04	0.08
aP6G2	0.63	0.31	0.62
aP6G3	0.01	0.01	0.01
aP6G4	1.88	0.92	1.86
aP6H1	0.01	0.01	0.01
aP6H3	0.28	0.14	0.28
aP6I1	0.03	0.02	0.03
aP6K1	0.02	0.01	0.02
aP6K2	0.17	0.08	0.17
aP6K3	0.01	0.00	0.00
aP6K5	0.01	0.00	0.01
aP6K6	0.12	0.06	0.11
aP7A1	0.08	0.05	0.09
aP7A11	0.04	0.02	0.04
aP7A13	1.83	0.90	1.80
aP7A14	1.49	0.73	1.46
aP7A3	0.10	0.05	0.10
aP7A9A	0.10	0.05	0.10
aP7AA2	0.03	0.02	0.03
aP7AA3	0.03	0.01	0.03
aP7AA4	0.02	0.01	0.02
aP7AB1	0.36	0.18	0.36
aP7AC3	0.31	0.15	0.30
aP7AC6	0.77	0.38	0.76
aP7AD1	0.42	0.21	0.42
aP7AD1_1	0.37	0.18	0.37
aP7AD2	0.36	0.18	0.35
aP7AE1	0.05	0.03	0.05
aP7AE1B	0.30	0.15	0.29
aP7AF2	0.15	0.07	0.13
aP7AF2A	0.00	0.00	0.00
aP7AF2B	0.00	0.00	0.00
aP7AF2C	0.00	0.00	0.00
aP7AF3	0.00	0.00	0.00
aP7AF4	0.01	0.01	0.01
aP7AF5	0.03	0.02	0.03
aP7AF6	0.14	0.07	0.13
aP7AFA2	0.72	0.35	0.71
aP7AG1	0.00	0.00	0.00
aP7AG10	0.00	0.00	0.00
aP7AG11	0.01	0.01	0.01
aP7AG2	0.00	0.00	0.00
aP7AG3	0.00	0.00	0.00
aP7AG4	0.02	0.01	0.02
aP7AG5	0.00	0.00	0.00
aP7AG6	0.01	0.01	0.01
aP7AG7	0.00	0.00	0.00
aP7AG8	0.00	0.00	0.00
aP7AG9	0.00	0.00	0.00
aP7AH1	0.09	0.04	0.08
aP7AH2	0.01	0.01	0.01
aP7AH3	0.00	0.00	0.00

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP7AH3A	0.01	0.00	0.01
aP7AH4	0.09	0.05	0.09
aP7AH5	0.01	0.01	0.01
aP7AH6	0.07	0.03	0.07
aP7AH7	0.03	0.01	0.03
aP7AH8	0.81	0.39	0.80
aP7AH9	0.09	0.05	0.09
aP7AI1	0.01	0.01	0.01
aP7AI2	0.06	0.03	0.06
aP7AJ2	0.01	0.00	0.01
aP7AJ3	0.02	0.01	0.02
aP7AK1	0.24	0.12	0.24
aP7AK2	0.31	0.15	0.30
aP7AK3	0.02	0.01	0.02
aP7AK4	0.11	0.05	0.11
aP7AL1	0.09	0.04	0.09
aP7AL2	0.09	0.04	0.09
aP7AM1	0.07	0.03	0.07
aP7AN1	0.04	0.02	0.04
aP7AN3	0.07	0.03	0.07
aP7AN4	0.02	0.01	0.02
aP7AN5	0.36	0.18	0.36
aP7AP1	0.77	0.38	0.76
aP7AQ1	0.21	0.10	0.20
aP7AQ2	0.06	0.03	0.06
aP7AQ3	0.53	0.26	0.52
aP7B1	0.30	0.15	0.29
aP7C1	0.08	0.04	0.08
aP7D4	0.19	0.09	0.18
aP7D5	0.44	0.21	0.42
aP7E2	0.03	0.02	0.03
aP7E3	0.02	0.01	0.02
aP7E4	0.14	0.07	0.14
aP7E5	0.08	0.04	0.08
aP7F7	0.01	0.00	0.01
aP7F8	0.04	0.02	0.04
aP7F9	0.06	0.03	0.06
aP7H1	0.01	0.00	0.01
aP7H2	0.05	0.03	0.05
aP7I1	0.01	0.00	0.01
aP7I1A	0.01	0.01	0.01
aP7I2	0.11	0.05	0.11
aP7K2	0.44	0.21	0.42
aP7K3	0.88	0.42	0.86
aP7N10	0.00	0.00	0.00
aP7N11	0.05	0.02	0.05
aP7N14	0.04	0.02	0.04
aP7N15	0.07	0.04	0.07
aP7N16	0.31	0.15	0.31
aP7N3	0.01	0.01	0.01
aP7N5	0.02	0.01	0.02
aP7N6	0.00	0.00	0.00
aP7N8	0.02	0.01	0.02
aP7N8A	0.16	0.08	0.16
aP7P1	0.20	0.10	0.20
aP7Q2	0.20	0.10	0.19
aP7R2	0.01	0.00	0.01
aP7R3	0.04	0.02	0.04
aP7R4	0.03	0.01	0.03
aP7R5	0.70	0.34	0.69
aP7S1	0.03	0.01	0.03
aP7S2	0.27	0.13	0.26
aP7T1	0.00	0.00	0.00
aP7T2	0.00	0.00	0.00
aP7T3	0.13	0.06	0.13
aP7T4	0.30	0.15	0.29
aP7U1	0.00	0.00	0.00
aP7U2	0.04	0.02	0.04
aP7V1	0.01	0.00	0.01
aP7V2	0.02	0.01	0.02

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aP7V4	0.01	0.00	0.01
aP7V5	0.09	0.04	0.09
aP7W2	0.12	0.06	0.12
aP7X10	0.01	0.01	0.01
aP7X11	0.68	0.33	0.67
aP7X12	0.53	0.26	0.52
aP7X2	0.47	0.23	0.47
aP7X3	0.41	0.20	0.40
aP7X8	0.01	0.00	0.01
aP7X9	0.06	0.03	0.06
aP7Y1	0.24	0.12	0.23
aP7Y2	0.01	0.01	0.01
aP7Y3	0.02	0.01	0.02
aP7Y4	0.07	0.04	0.07
aP7Y5	0.19	0.09	0.19
aP7Y6	0.07	0.04	0.07
aP7Y7	0.02	0.01	0.02
aP7Y8	0.25	0.12	0.25
aP7Z10	0.22	0.11	0.21
aP7Z11	0.12	0.06	0.12
aP7Z2	0.16	0.08	0.16
aP7Z3	0.20	0.10	0.20
aP7Z5	0.02	0.01	0.02
aP7Z6	0.80	0.39	0.79
aP7Z7	0.24	0.12	0.24
aP7Z8	0.06	0.03	0.06
aP7Z9	0.46	0.23	0.46
aP7ZC2	0.01	0.00	0.01
aP7ZC3	0.57	0.28	0.56
aP7ZD1	0.05	0.02	0.05
aP7ZJ1	0.68	0.33	0.66
aP7ZJ2	0.01	0.00	0.01
aP7ZJ3	0.20	0.10	0.19
aP8A3	0.30	0.15	0.30
aP8B1	0.12	0.06	0.11
aP9A1	1.28	0.62	1.24
aW5A10	1.59	0.78	1.56
aW5A2	0.09	0.05	0.09
aW5A3	0.24	0.12	0.24
aW5A5	0.13	0.06	0.13
aW5A6	0.16	0.08	0.16
aW5A7	0.34	0.17	0.34
aW5AA1	0.10	0.05	0.10
aW5AA2	0.03	0.02	0.03
aW5AA8	0.18	0.09	0.18
aW5AB1	1.06	0.52	1.05
aW5AC3	0.16	0.08	0.16
aW5AD1	0.12	0.06	0.11
aW5AD2	0.18	0.09	0.18
aW5AD4	0.86	0.42	0.84
aW5AE1	0.01	0.01	0.01
aW5AF4	0.01	0.00	0.01
aW5AF5	0.11	0.05	0.11
aW5AF6	1.22	0.60	1.20
aW5AG1	0.02	0.01	0.02
aW5AG2	0.02	0.01	0.02
aW5AG3	0.01	0.00	0.01
aW5AG4	0.19	0.09	0.19
aW5AI1	0.07	0.03	0.07
aW5B1	0.05	0.02	0.05
aW5C1	0.05	0.02	0.05
aW5D1	0.71	0.35	0.70
aW5E10	0.09	0.04	0.09
aW5E11	0.78	0.38	0.77
aW5E2	0.14	0.07	0.14
aW5E4	0.17	0.08	0.17
aW5E5	0.01	0.01	0.01
aW5E7	0.01	0.00	0.01
aW5E8	0.06	0.03	0.06
aW5E9	0.25	0.12	0.25

Subcatchment ID	Peak Subcatchment Discharge (m^3/s)		
	1989	1991	2015
aW5F1	0.09	0.04	0.09
aW5G1	0.54	0.27	0.53
aW5H1	0.29	0.14	0.29
aW5H4	0.40	0.20	0.39
aW5I1	0.03	0.01	0.03
aW5I10	0.02	0.01	0.02
aW5I11	0.28	0.14	0.27
aW5I2	0.18	0.09	0.18
aW5I3	0.04	0.02	0.04
aW5I4	0.04	0.02	0.04
aW5I5	1.19	0.58	1.17
aW5I6	0.13	0.07	0.13
aW5I8	0.95	0.46	0.93
aW5I9	0.49	0.24	0.49
aW5K1	0.06	0.03	0.06
aW5K3	0.09	0.05	0.09
aW5M1	0.14	0.07	0.14
aW5M2	0.04	0.02	0.04
aW5M3	0.41	0.20	0.40
aW5M4	1.14	0.56	1.12
aW5M5	0.11	0.05	0.11
aW5N1	0.13	0.07	0.13
aW5N2	0.17	0.08	0.17
aW5O2	0.00	0.00	0.00
aW5O3	0.00	0.00	0.00
aW5O4	0.02	0.01	0.02
aW5P2	0.50	0.25	0.50
aW5Q1	0.26	0.13	0.26
aW5Q3	0.02	0.01	0.02
aW5Q4	0.45	0.22	0.44
aW5R1	0.88	0.43	0.87
aW5S1	0.01	0.01	0.01
aW5S2	0.07	0.04	0.07
aW5S3	2.75	1.36	2.69
aW5S4	0.13	0.06	0.13
aW5T2	0.04	0.02	0.04
aW5U1	0.03	0.01	0.03
aW5U2	0.84	0.41	0.83
aW5U4	0.00	0.00	0.00
aW5U5	0.01	0.01	0.01
aW5U6	0.27	0.13	0.27
aW5W1	0.56	0.27	0.55
aW5W2	0.26	0.13	0.26
aW5W3	0.29	0.14	0.29
aW5X1	0.02	0.01	0.02
aW5X2	0.52	0.25	0.51
aW5Z1	0.02	0.01	0.01
aW5Z2	0.05	0.03	0.05
aW5Z3	0.67	0.33	0.66
InletDS	0.14	0.07	0.14
InletUS	1.02	0.49	0.94



LEGEND:

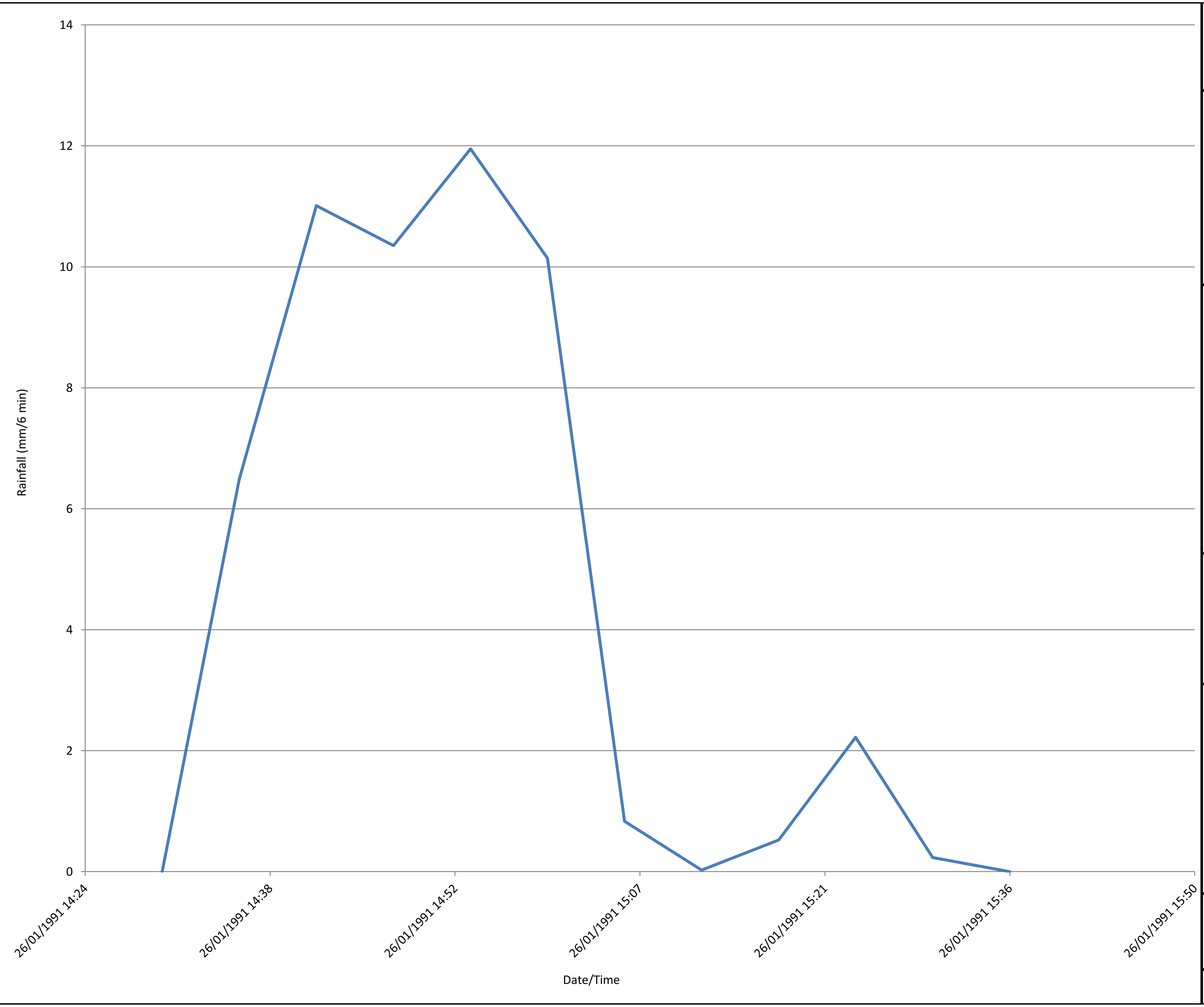
Factored Rainfall Pluviograph

Notes:

Figure E1: Continuous Rainfall Data for the 1989 Event

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

File Name:
Paddington_Pluviographs.xlsx



WOOLLAHRA MUNICIPAL COUNCIL

LEGEND:

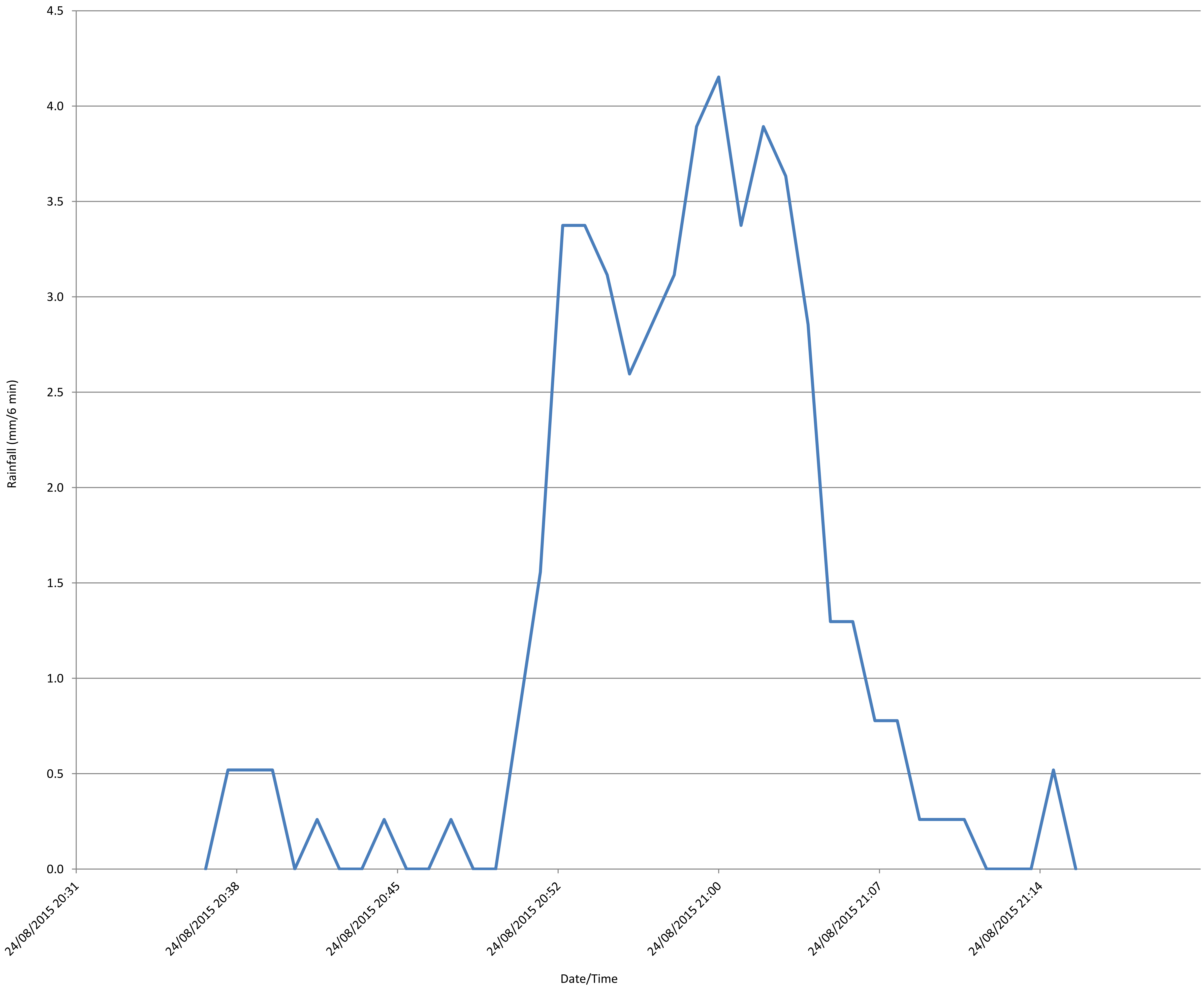
Factored Rainfall Pluviograph

Notes:

Figure E2:
Continuous Rainfall Data for the 1991 Event

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

File Name:
Paddington_Pluviographs.xlsx



LEGEND:

Factored Rainfall Pluviograph

Notes:

Figure E3: Continuous Rainfall Data for the 2015 Event

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

File Name:
Paddington_Pluviographs.xlsx

Appendix F

PMP Calculations

GSDM CALCULATION SHEET

LOCATION INFORMATION

Catchment Paddington Area 2.46 km^2

State New South Wales Duration Limit 6.0 hrs

Latitude 33.8823^{0}S Longitude 151.2299^{0}E

Portion of Area Considered:

Smooth, **S** = 0.00 (0.0 - 1.0) Rough, **R** = 1.00 (0.0 - 1.0)

ELEVATION ADJUSTMENT FACTOR (EAF)

Mean Elevation 40 m

Adjustment for Elevation (-0.05 per 300m above 1500m) 0.00

EAF = **1.00** (0.85 – 1.00)

MOISTURE ADJUSTMENT FACTOR (MAF)

MAF = **0.70** (0.40-1.00)

PMP VALUES (mm)

Duration (hours)	Initial Depth -Smooth (D_S)	Initial Depth -Rough (D_R)	PMP Estimate = (D_SxS + D_RxR) x MAF x EAF	Rounded PMP Estimate (nearest 10 mm)
0.25	233	233	163	160
0.50	337	337	236	240
0.75	426	426	298	300
1.00	494	494	346	350
1.50	564	638	446	450
2.00	629	746	522	520
2.50	670	823	576	580
3.00	707	903	632	630
4.00	773	1032	723	720
5.00	834	1138	797	800
6.00	881	1203	842	840

Prepared By D. Tetley Date 14/01/2016

Checked By C. Ryan Date 15/01/2016

GSDM SPATIAL DISTRIBUTION

GSDM SPATIAL DISTRIBUTION

DURATION = 0.25 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	234	164	347	347	164
B	0.34	2.46	233	163	400	53	156
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 0.50 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	339	237	502	502	237
B	0.34	2.46	337	236	579	77	226
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 0.75 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse (mm.km^2)	Rainfall Volume between Ellipses (mm.km^2)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	428	300	633	633	300
B	0.34	2.46	426	298	732	99	288
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 1.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse (mm.km^2)	Rainfall Volume between Ellipses (mm.km^2)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	497	348	735	735	348
B	0.34	2.46	494	346	850	114	334
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 1.5 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	642	449	949	949	449
B	0.34	2.46	638	446	1096	147	429
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 2.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	750	525	1110	1110	525
B	0.34	2.46	746	522	1282	172	502
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 2.5 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	829	580	1226	1226	580
B	0.34	2.46	823	576	1415	189	552
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 3.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	909	636	1345	1345	636
B	0.34	2.46	903	632	1553	208	608
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 4.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse (mm.km^2)	Rainfall Volume between Ellipses (mm.km^2)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	1038	727	1536	1536	727
B	0.34	2.46	1032	723	1775	239	698
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DURATION = 5.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse (mm.km^2)	Rainfall Volume between Ellipses (mm.km^2)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	1146	802	1694	1694	802
B	0.34	2.46	1138	797	1956	262	765
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

GSDM SPATIAL DISTRIBUTION (continued)

DURATION = 6.0 Hours							
Ellipse	Catchment Area Between Ellipse (km^2)	Catchment Area Enclosed by Ellipse (km^2)	Initial Mean Rainfall Depth (mm)	Adjusted Mean Rainfall Depth (mm)	Rainfall Volume enclosed by Ellipse ($mm.km^2$)	Rainfall Volume between Ellipses ($mm.km^2$)	Mean Rainfall Depth between ellipses (mm)
A	2.11	2.11	1211	847	1791	1791	847
B	0.34	2.46	1203	842	2068	277	810
C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX G

DRAINS MODEL OUTPUT FOR DESIGN SIMULATIONS

PEAK DESIGN FLOOD DISCHARGES - PMF

Subcatchment ID						
	15 min	30 min	60 min	90 min	120 min	180 min
aDP18B7	0.65	0.52	0.42	0.38	0.32	0.27
aDP18B6	0.66	0.52	0.43	0.38	0.32	0.27
aDP18B5	0.29	0.23	0.19	0.17	0.14	0.12
aDP18B4	0.03	0.02	0.02	0.02	0.01	0.01
aDP18G2	1.66	1.31	1.08	0.96	0.82	0.69
aDP18G1	0.00	0.00	0.00	0.00	0.00	0.00
aDP18I4	4.80	3.88	3.16	2.82	2.42	2.03
aDP18I3	0.98	0.78	0.64	0.57	0.49	0.41
aDP18I2	0.09	0.07	0.06	0.05	0.04	0.04
aDP18I1	0.35	0.28	0.23	0.20	0.17	0.15
aDP18A13	0.54	0.43	0.35	0.31	0.27	0.22
aDP18A12	0.98	0.78	0.64	0.57	0.49	0.41
aDP18A11	0.64	0.50	0.41	0.37	0.31	0.26
aDP18A10	0.81	0.64	0.53	0.47	0.40	0.34
aDP18A7	0.12	0.10	0.08	0.07	0.06	0.05
aDP18A6	0.35	0.28	0.23	0.20	0.17	0.15
aDP18A5	0.11	0.08	0.07	0.06	0.05	0.04
aW5E10	0.30	0.24	0.19	0.17	0.15	0.12
aW5E11	2.69	2.14	1.75	1.57	1.34	1.12
aW5K1	0.22	0.17	0.14	0.13	0.11	0.09
aW5K3	0.32	0.25	0.21	0.19	0.16	0.13
aW5H1	1.02	0.81	0.66	0.59	0.50	0.42
aW5H4	1.39	1.10	0.90	0.80	0.69	0.57
aW5E7	0.02	0.01	0.01	0.01	0.01	0.01
aW5E8	0.22	0.17	0.14	0.13	0.11	0.09
aW5E9	0.87	0.69	0.56	0.50	0.43	0.36
aW5E5	0.04	0.03	0.03	0.03	0.02	0.02
aW5F1	0.30	0.24	0.19	0.17	0.15	0.12
aW5G1	1.88	1.49	1.22	1.09	0.93	0.78
aW5E4	0.59	0.47	0.38	0.34	0.29	0.24
aW5I11	0.95	0.76	0.62	0.55	0.47	0.40
aW5I10	0.08	0.06	0.05	0.04	0.04	0.03
aW5I9	1.71	1.36	1.11	0.99	0.85	0.71
aW5I8	3.12	2.49	2.04	1.82	1.56	1.30
aW5I6	0.46	0.37	0.30	0.27	0.23	0.19
aW5I5	4.11	3.28	2.68	2.39	2.05	1.71
aW5I4	0.14	0.11	0.09	0.08	0.07	0.06
aW5I3	0.14	0.11	0.09	0.08	0.07	0.06
aW5I2	0.62	0.49	0.40	0.36	0.30	0.25
aW5I1	0.09	0.07	0.06	0.05	0.05	0.04
aW5E2	0.49	0.39	0.32	0.28	0.24	0.20
aW5D1	2.44	1.94	1.59	1.42	1.21	1.01
aW5C1	0.17	0.13	0.11	0.10	0.08	0.07
aW5B1	0.17	0.13	0.11	0.10	0.08	0.07
aW5W3	1.01	0.80	0.66	0.59	0.50	0.42

Subcatchment ID	15 min	30 min	60 min	90 min	120 min	180 min
aW5W2	0.91	0.72	0.59	0.53	0.45	0.38
aW5W1	1.93	1.53	1.25	1.12	0.96	0.80
aW5X2	1.79	1.42	1.16	1.04	0.89	0.74
aW5X1	0.08	0.06	0.05	0.05	0.04	0.03
aW5AA1	0.34	0.27	0.22	0.20	0.17	0.14
aW5AA2	0.11	0.09	0.07	0.07	0.06	0.05
aW5AD4	2.83	2.25	1.84	1.65	1.41	1.18
aW5AD2	0.60	0.47	0.39	0.35	0.30	0.25
aW5AD1	0.40	0.31	0.26	0.23	0.20	0.16
aW5AE1	0.04	0.03	0.03	0.02	0.02	0.02
aW5AC3	0.54	0.42	0.35	0.31	0.26	0.22
aW5AF6	4.03	3.21	2.63	2.35	2.01	1.68
aW5AF5	0.37	0.29	0.24	0.21	0.18	0.15
aW5AF4	0.02	0.01	0.01	0.01	0.01	0.01
aW5AG4	0.62	0.49	0.40	0.36	0.31	0.26
aW5AG3	0.02	0.02	0.01	0.01	0.01	0.01
aW5AG2	0.07	0.06	0.05	0.04	0.04	0.03
aW5AG1	0.07	0.05	0.04	0.04	0.03	0.03
aW5AI1	0.23	0.18	0.15	0.13	0.11	0.09
aW5AA8	0.60	0.48	0.39	0.35	0.30	0.25
aW5AB1	3.68	2.93	2.40	2.14	1.83	1.53
aW5Z3	2.32	1.85	1.51	1.35	1.15	0.96
aW5Z2	0.19	0.15	0.12	0.11	0.09	0.08
aW5Z1	0.05	0.04	0.03	0.03	0.03	0.02
aW5N2	0.58	0.47	0.38	0.34	0.29	0.24
aW5N1	0.46	0.37	0.30	0.27	0.23	0.19
aW5M5	0.38	0.30	0.25	0.22	0.19	0.16
aW5M4	3.89	3.14	2.56	2.29	1.96	1.64
aW5M3	1.40	1.11	0.91	0.81	0.70	0.58
aW5M2	0.15	0.12	0.10	0.09	0.07	0.06
aW5M1	0.48	0.38	0.31	0.28	0.24	0.20
aW5R1	3.06	2.44	1.99	1.78	1.52	1.27
aW5P2	1.73	1.39	1.13	1.01	0.87	0.73
aW5O4	0.06	0.05	0.04	0.04	0.03	0.03
aW5O3	0.01	0.01	0.01	0.01	0.00	0.00
aW5O2	0.01	0.01	0.01	0.01	0.00	0.00
aW5A5	0.45	0.36	0.29	0.26	0.22	0.19
aW5A3	0.83	0.66	0.54	0.48	0.41	0.34
aW5A2	0.32	0.25	0.21	0.19	0.16	0.13
aW5Q4	1.56	1.24	1.01	0.90	0.77	0.65
aW5Q3	0.06	0.05	0.04	0.04	0.03	0.03
aW5Q1	0.90	0.72	0.59	0.52	0.45	0.37
aW5S4	0.43	0.34	0.28	0.25	0.21	0.18
aW5S3	8.97	7.37	5.98	5.36	4.61	3.85
aW5S2	0.25	0.20	0.16	0.15	0.12	0.10
aW5S1	0.04	0.03	0.02	0.02	0.02	0.02
aW5A7	1.12	0.90	0.73	0.65	0.56	0.47

Subcatchment ID						
	15 min	30 min	60 min	90 min	120 min	180 min
aW5A6	0.54	0.43	0.35	0.31	0.27	0.22
aW5U6	0.89	0.71	0.58	0.52	0.44	0.37
aW5U5	0.05	0.04	0.03	0.03	0.02	0.02
aW5U4	0.01	0.01	0.01	0.01	0.01	0.01
aW5U2	2.78	2.22	1.81	1.62	1.38	1.16
aW5U1	0.10	0.08	0.06	0.06	0.05	0.04
aW5T2	0.15	0.12	0.09	0.08	0.07	0.06
aW5A10	5.13	4.20	3.41	3.06	2.63	2.20
aP24C1	2.06	1.63	1.34	1.19	1.02	0.85
aP24D4	0.61	0.49	0.40	0.36	0.30	0.25
aP24D3	1.82	1.45	1.19	1.06	0.91	0.76
aP24D2	0.01	0.01	0.01	0.01	0.01	0.00
aP24G17	0.60	0.48	0.39	0.35	0.30	0.25
aP24G16	0.26	0.21	0.17	0.15	0.13	0.11
aP24G12	1.06	0.84	0.69	0.62	0.53	0.44
aP24G11	0.05	0.04	0.03	0.03	0.02	0.02
aP24G10	0.23	0.18	0.15	0.13	0.11	0.09
aP24G9	0.96	0.76	0.63	0.56	0.48	0.40
aP24G8	0.03	0.03	0.02	0.02	0.02	0.01
aP24G7	0.07	0.05	0.04	0.04	0.03	0.03
aP24G6	0.06	0.05	0.04	0.04	0.03	0.03
aP24G5	0.43	0.34	0.28	0.25	0.21	0.18
aP24G4	0.03	0.03	0.02	0.02	0.02	0.01
aP24G1	0.20	0.16	0.13	0.12	0.10	0.08
aP24AA	0.31	0.24	0.20	0.18	0.15	0.13
aP24H1	0.35	0.28	0.23	0.20	0.17	0.15
aP24L1	1.18	0.94	0.77	0.69	0.59	0.49
aP24I4	0.42	0.33	0.27	0.24	0.21	0.17
aP24I3	0.02	0.02	0.01	0.01	0.01	0.01
aP24I2	0.07	0.06	0.05	0.04	0.04	0.03
aP24I1	1.35	1.07	0.88	0.78	0.67	0.56
aP24E1	1.86	1.48	1.21	1.08	0.92	0.77
aP24F1	0.77	0.61	0.50	0.45	0.38	0.32
aP24O2	2.54	2.02	1.65	1.48	1.26	1.05
aP24O1	0.01	0.01	0.01	0.01	0.01	0.01