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Springvale Drain and Floodvale Drain Flood Study

Final Report January 2014

City of Botany Bay

Springvale Drain and Floodvale Drain Flood Study

Prepared for:	City of Botany Bay Council
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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BMT WBM Pty Ltd Level 1, 256-258 Norton Street Leichhardt NSW 2040 Australia PO Box 194, Leichhardt NSW 2040 Tel: +61 2 8987 2900 Fax: +61 2 8987 2999 ABN 54 010 830 421 www.bmtwbm.com.au	**Document:**	R.S1282.003.01.docx
	Title:	Springvale Drain and Floodvale Drain Flood Study
	Project Manager:	Simon Kovacevic
	Author:	Simon Kovacevic
	Client:	City of Botany Bay Council
	Client Contact:	Hossein Ansari
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Synopsis:	**Final report for the Springvale Drain and Floodvale Drain Flood Study. The report covers the data collection process, community consultation, development of computer models, establishment of design flood behaviour and flood mapping.**	

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Executive Summary

Introduction

The Springvale Drain and Floodvale Drain Flood Study has been prepared for the City of Botany Bay Council (Council) to define the existing flood behaviour in the Springvale Drain and Floodvale Drain catchment and establish the basis for subsequent floodplain management activities.

The primary objective of the Flood Study is to define the flood behaviour of the Springvale Drain and Floodvale Drain catchment through the establishment of appropriate numerical models. The study has produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study, and acquisition of additional data including survey as required;
- A community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour and engage the community in the on-going floodplain management process;
- Development and calibration of appropriate hydrologic and hydraulic models;
- Determination of design flood conditions for a range of design events - including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and Probable Maximum Flood (PMF);
- Examination of potential impact of climate change using the latest guidelines for the 1% AEP design event; and
- Presentation of study methodology, results and findings in a comprehensive report incorporating detailed flood mapping.

Catchment Description

The Springvale Drain and Floodvale Drain catchment encompasses an area of approximately 3.75km^2 located within the City of Botany Bay LGA in south-eastern Sydney. This includes the suburbs of Pagewood, Eastgardens, Botany and Banksmeadow.

The catchment is heavily urbanised and is predominantly comprised of industrial development with a large proportion of residential development in the upper catchment.

The natural drainage systems have been heavily modified and most of the study area is now drained by a stormwater pipe network; there are some open channel reaches in the southern area of the catchment. When the capacity of this stormwater drainage network is exceeded, overland flow will occur along the alignments of the original drains or gullies. Many of the old drainage gully alignments are now located through developed properties which presents a significant flood risk.

Historical Flooding

Availability of historical flooding and flood data in the Springvale Drain and Floodvale Drain catchment is limited. The largest historical event identified in the catchment occurred in February 1990, with more recent flooding occurring in February 2010.

Coupled with recorded rainfall data from the Sydney Water Corporation, data collected from various sources (previous reports and community consultation) provided a data set for validating the hydraulic model.

Community Consultation

Community consultation undertaken during the study has aimed to collect information on historical flooding and previous flood experience, and inform the community about the development of the flood study and its likely outcome as a precursor to floodplain management activities to follow. The key element of the consultation process involved the distribution of a questionnaire relating to historical flooding. The return numbers for the questionnaire were low, with minimal additional historical flood information obtained. This is perhaps representative of the relatively low number of significant flooding events historically within the Springvale Drain and Floodvale Drain catchment.

Model Development

With consideration given to the available survey information and local topographical and hydraulic controls, a combined hydrologic and hydraulic model was developed covering the entire Springvale Drain and Floodvale Drain catchment.

This model simulates rainfall, flood depths, extents and velocities utilising the TUFLOW two-dimensional (2D) software developed by BMT WBM. This 2D modelling approach is suited to model the complex interaction between channels and floodplains and converging and diverging of flows through structures and urban environments.

The catchment and floodplain topography is defined using a high resolution digital elevation model (DEM) derived from LiDAR survey for greater accuracy in predicting flows and water levels and the interaction of in-channel and floodplain areas compared with previous studies. The underground pipe drainage network has been defined using data from previous studies and additional survey information acquired during the course of the study.

Model Calibration and Validation

The selection of suitable historical events for calibration of the computer models is largely dependent on available historical flood information. The Springvale Drain and Floodvale Drain catchment is ungauged and accordingly there are no available data for streamflow calibration. Calibration and validation of the model has therefore relied on replicating the general pattern and magnitude of flooding throughout the catchment for the February 1990 and February 2010 events.

A reasonable model calibration has been achieved given the available data for the catchment. The developed models are thus considered to provide a sound representation of the flooding behaviour of the catchment, as demonstrated through comparison of observed peak water depths and flooded locations for the historical events simulated.

Design Event Modelling and Output

The developed models have been applied to derive design flood conditions within the Springvale Drain and Floodvale Drain catchment. Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in Pilgrim (2001). A range of storm durations were modelled (using standard Pilgrim (2001) temporal patterns) in order to capture the worst-case flooding in the catchment, and critical storm durations were identified.

The design events considered in this study include the 20% (5-year ARI), 10% AEP (10-year ARI), 5% AEP (20-year ARI), 2% AEP (50-year ARI), 1% AEP (100-year ARI) 0.5% AEP (200-year ARI) and Probable Maximum Flood (PMF) events. The model results for the design events considered have been presented in a detailed flood mapping series for the catchment. The flood data presented includes design flood inundation, peak flood water levels and peak flood depths.

Provisional flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has been mapped for the 1% AEP and the PMF events, in addition to the hydraulic categories (floodway, flood fringe and flood storage) for flood affected areas.

The flood inundation extents derived from the hydraulic modelling are shown in Appendix A.

Sensitivity Testing

A series of sensitivity tests have been undertaken on the modelled flood behaviour of the Springvale Drain and Floodvale Drain catchment. The tests provide a basis for determining the relative sensitivity of modelling results to adopted parameter values. The tests undertaken include:

- Hydraulic roughness – changes in hydraulic roughness were simulated to represent variation in vegetation condition both in-channel and on the floodplain. The catchment is largely developed and occupied by residential and industrial development, and there is likely to be little seasonal variation in vegetation that can provide for local increases in water levels;
- Structure blockages – structure blockage due to flood debris can result in significant increases to flood levels and redistributions of flood flows. Blockage scenarios of 50% and 100% blockage of all stormwater drainage structures (pit inlets, pipes, culverts and bridges) have been simulated; and
- Design rainfall losses – the initial rainfall loss applied to the catchment for the design rainfall condition is considered higher than typical values for NSW catchments but considered appropriate for the soils of the catchment. Decreases in design rainfall losses have been simulated to represent the effects of antecedent rainfall across the catchment. This provides for an increase in surface runoff for the design rainfall condition.

Climate Change

The potential impacts of future climate change have been considered for a range of design event scenarios as defined in Table 9-2. The impact of climate change scenarios on the standard design flood condition is presented in Appendix B as a series of maps showing the increase in peak flood inundation extents from the baseline (existing) conditions. The most significant impacts of climate change within the study area are associated with increased rainfall intensities.

The results of the climate change analysis highlight the sensitivity of the peak flood level conditions in the Springvale Drain and Floodvale Drain catchment to potential impacts of climate change. Future planning and floodplain risk management in the catchment will need to take due consideration of the increasing flood risk under possible future climate conditions.

Flood Risks

There is an existing flood risk to some existing development as a result of catchment rainfall derived flooding for Springvale Drain and Floodvale Drain. The majority of the residential development is located in the upper catchment where flooding is generally confined to the drainage path.

There are a number of trapped low points across the catchment and significant localised flood inundation may be realised in major flood events, as simulated in the model results for event up to and including the Probable Maximum Flood (PMF).

The following locations have been identified as potential problem areas in relation to flood inundation extent and property affected:

- Heffron Road and Banks Avenue intersection, Pagewood;
- Pagewood Primary School, Pagewood;
- Holloway Street and Gibson Street, Pagewood;
- Spring Street and Dudley Street intersection, Pagewood;
- Anderson Street, Banksmeadow;
- Port Feeder Road – Australand and Mobil Sites, Banksmeadow;
- McPherson Street, Banksmeadow; and
- Botany Road, Banksmeadow.

Conclusions

The primary objective of the Flood Study is to define the flood behaviour of the Springvale Drain and Floodvale Drain catchment through the establishment of an appropriate numerical model. The principal outcome of the flood study is the understanding of flood behaviour in the catchment and in particular the design flood level information that will be used to set appropriate flood planning levels. The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain management process. Accordingly, the adoption of the flood study and predicted design flood levels is recommended.

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1 Introduction

The Springvale Drain and Floodvale Drain Flood Study has been prepared for the City of Botany Bay Council (Council) to define the existing flood behaviour in the Springvale Drain and Floodvale Drain catchment and establish the basis for subsequent floodplain management activities.

This study updates the previous studies within the subject catchment, providing a holistic assessment of flooding within the catchment, accounting for land use changes since previous modelling investigations and the potential influence of climate change.

The study is designed to meet the objectives of the NSW State Government's Flood Prone Land Policy. This project has been conducted under the State Assisted Floodplain Management Program and received State financial support.

Various previous studies have been completed within the Springvale Drain and Floodvale Drain catchment to define and manage the flood behaviour of the subject catchment, including a Catchment Management Study for the subject watercourses (SKM, 1992). Since this previous study, changes have occurred within the catchment, and climate change must be added as a consideration. Therefore, updated information is required to accurately predict flood behaviour in the catchment, and this is provided in this report.

This flood study update also incorporates significant advances in the methodologies used to predict flood behaviour, including updates in modelling techniques and the capture of high quality ground level data (LiDAR).

1.1 Study Location

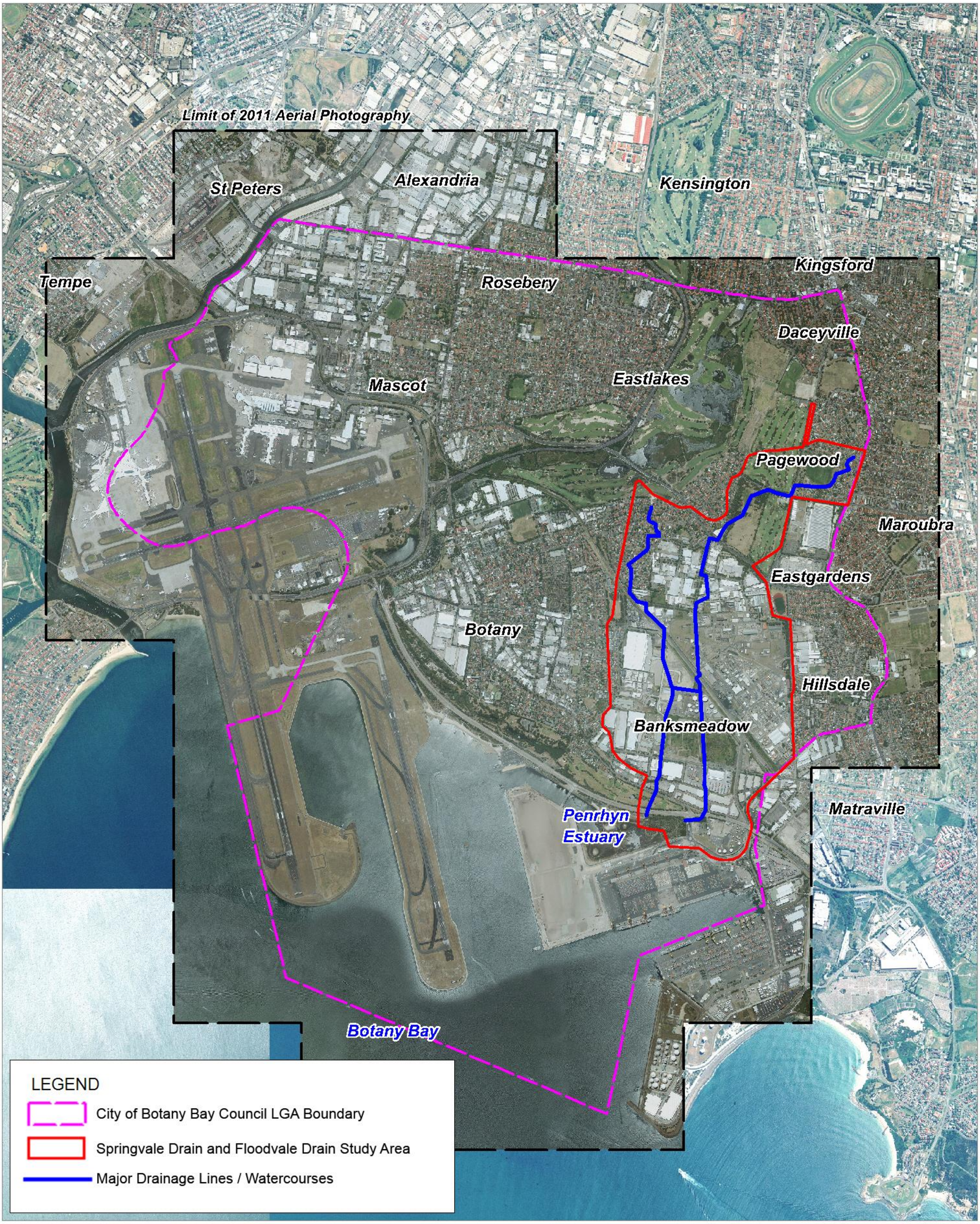
The combined Springvale Drain and Floodvale Drain catchment is situated within the City of Botany Bay LGA, flowing from Pagewood at the northern extent to Botany Bay via Penrhyn Estuary in the south. This includes portions of the suburbs of Pagewood, Eastgardens, Botany and Banksmeadow. The combined catchment drains an area of approximately 375 ha (3.75 km^2). The location of the study area is shown in Figure 1-1.

1.2 The Need for Floodplain Management within the Study Area

There has been some history of flooding within the study area, especially within the following residential areas:

- Intersection of Heffron Road and Banks Avenue, Pagewood;
- Holloway Street, Pagewood; and
- Spring Street, Pagewood.

Flooding has also been reported within the industrial area south of the Port of Botany railway during severe storm events, possibly exacerbated by the interconnectivity of the two drains within this area. Furthermore, Council has indicated that Exell Street and Botany Road (within the industrial area at the southern extent of the study area) are both prone to flooding.



Title:
Study Locality

Figure: **1-1**

Rev: **A**

N

0 0.75 1.5km
Approx. Scale

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Due to the increasing development pressure in the LGA, especially related to the expansion of Port Botany and heavy usage of Sydney Airport, the likelihood of inappropriate development in flood liable areas is increased. The Botany Bay Local Environmental Plan 2013 is a relatively new environmental planning instrument being gazetted on 21 June 2013. The Council's current Development Control Plans are currently under review and a new comprehensive draft DCP was placed on exhibition from Tuesday 2 July 2013 and concluding at 4.30pm on Friday 23 August 2013. Furthermore, the study area is partially covered by the State Environmental Planning Policy (Port Botany and Port Kembla, 2013). It is intended that the results of this Flood Study and subsequent Floodplain Risk Management Plan will feed into the comprehensive DCP to reduce flood risk.

Floodplain risk management considers the consequences of flooding on the community and aims to develop appropriate floodplain management measures to minimise and mitigate the impact of flooding. This incorporates the existing flood risk associated with current development, future flood risk associated with future development and changes in land use (urbanisation).

Current practice in floodplain management also requires consideration of the impact of potential climate change scenarios on design flood conditions. For the Springvale Drain and Floodvale Drain catchment this includes increases in design rainfall intensities and sea level rise scenarios impacting on ocean boundary conditions. Accordingly, these potential changes will translate into increased design flood inundation in the catchment, such that future planning and floodplain management in the catchment will need to take due consideration of this increased flood risk.

This study comprises the initial stages of a considered and systematic approach to managing flood risk, as outlined in the Floodplain Development Manual (NSW Government, 2005). The approach will allow for more informed planning decisions within the floodplain of Springvale Drain and Floodvale Drain.

1.3 The Floodplain Management Process

The NSW State Government's Flood Prone Land 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. Policy and practice are defined in the NSW State Government's Floodplain Development Manual (2005).

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

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

Table 1-1 Stages of Floodplain Management

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

This study represents Stages 2 and 3 of the above process and aims to provide an understanding of local catchment flood behaviour within the Springvale Drain and Floodvale Drain catchment.

1.3.1 Climate Change Policy

The primary impacts of climate change in coastal areas are likely to result from sea level rise, which, coupled with a potential increase in the frequency and severity of storm events, may lead to increased coastal erosion, tidal inundation and flooding.

In 2009 the NSW State Government announced the NSW Sea Level Rise Policy Statement (DECCW, 2009) that adopted sea level rise planning benchmarks to ensure consistent consideration of sea level rise in coastal areas of NSW. These planning benchmarks adopt increases (above 1990 mean sea level) of 40 cm by 2050 and 90 cm by 2100. However, on 8 September 2012 the NSW Government announced its Stage One Coastal Management Reforms which no longer recommends state-wide sea level rise benchmarks for use by local councils. Instead councils have the flexibility to consider local conditions when determining future hazards of potential sea level rise.

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

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

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

As the majority of analysis and modelling tasks associated with this current Flood Study were completed prior to the announcement of the NSW Government's Coastal Management Reforms in September 2012, the potential impacts of sea level rise have been based on sea level rise projections from the 2009 NSW Sea Level Rise Policy Statement. Given that the Chief Scientist and Engineer's Report identifies the science behind these sea level rise projections is adequate, it was agreed between Council and BMT WBM that the potential impacts of sea level rise for the Springvale Drain and Floodvale Drain catchment were based on the best available information at hand during preparation of this report.

For Springvale Drain and Floodvale Drain, rising sea level is expected to increase the frequency, severity and duration of flooding in the lower reaches of the catchments adjacent to Penrhyn Estuary and Botany Bay.

In 2007 the NSW State Government released a guideline for practical consideration of climate change in the floodplain management process that advocates consideration of increased design rainfall intensities of up to 30%. Accordingly, this increase in design rainfall will translate into increased flood inundation in the Springvale Drain and Floodvale Drain catchment. Future planning and floodplain management in the catchment will need to take due consideration of this increased flood risk.

In consultation with Council and the Office of Environment and Heritage (OEH), a range of climate change sensitivity tests incorporating different combinations of sea level rise and increased design rainfall intensity have been formulated, as outlined in Section 9. The results of these sensitivity tests have been compared to the base case (i.e. models with existing sea level and climate) in order to assess the potential increase in flood risk due to climate change.

1.4 Study Objectives

The primary objective of the study is to define the flood behaviour under existing and future conditions in the Study Area. The study is to produce information on flood levels and depths, velocities, flows, hydraulic categories and provisional hazard categories. This will be identified for existing and future conditions for a full range of design flood events. The flood study is to be used to identify the impact on flood behaviour as a result of future climate change and potential changes in the catchment. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study, and acquisition of additional data including survey as required;
- A community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour and engage the community in the on-going floodplain management process;
- Development and calibration of appropriate hydrologic and hydraulic models;
- Determination of design flood conditions for a range of design events - including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and Probable Maximum Flood (PMF – an extreme flood event);

- Examination of potential impact of climate change using the latest guidelines for the 1% AEP design event; and
- Presentation of study methodology, results and findings in a comprehensive report incorporating detailed flood mapping.

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

- Outline the flood behaviour within the catchment to aid Councils strategic land use management planning; and
- Form the basis for a subsequent floodplain risk management study where detailed assessment of flood mitigation options and floodplain risk management measures will be undertaken.

1.5 About this Report

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

Section 1 introduces the study.

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

Section 3 outlines the community consultation program undertaken.

Section 4 details the development of the computer models.

Section 5 details the model calibration and validation process.

Section 6 details the design flood conditions.

Section 7 details the design flood results and associated flood mapping.

Section 8 details the sensitivity testing conducted.

Section 9 details the climate change analysis.

2 Study Approach

2.1 The Study Area

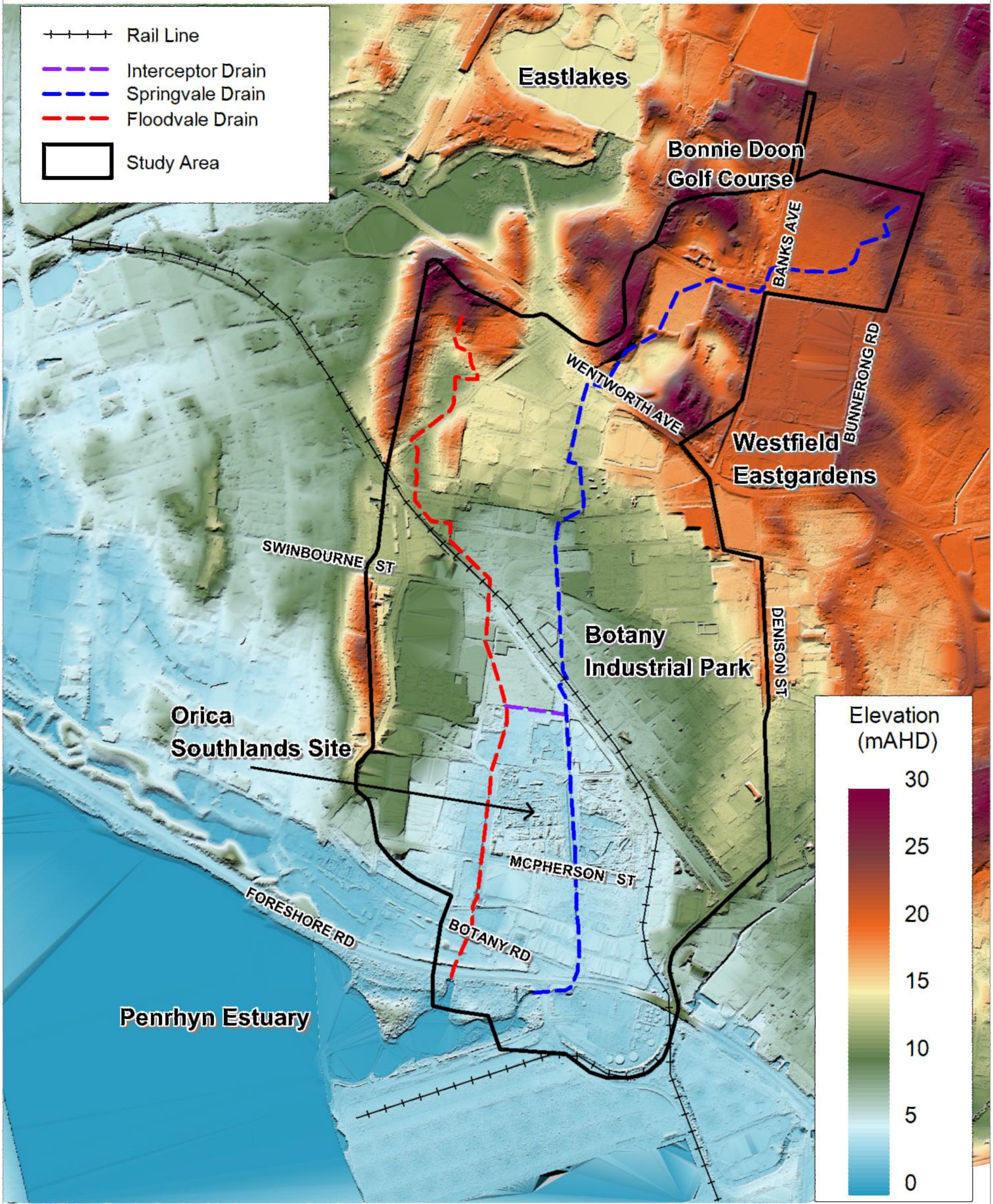
The combined Springvale Drain and Floodvale Drain catchment is situated within the City of Botany Bay LGA, flowing from Pagewood at the northern extent to Botany Bay via Penrhyn Estuary in the south. This includes portions of the suburbs of Pagewood, Eastgardens, Botany and Banksmeadow. The combined catchment drains an area of approximately 375 ha (3.75 km^2).

The catchment is heavily urbanised and is predominantly comprised of industrial development with residential development in the upper catchment. The upper Springvale Drain catchment includes open space comprising Bonnie Doon Golf Course, Jellicoe Park and Mutch Park, whilst the lower Floodvale Drain catchment includes Botany Golf Club.

The trunk drainage system formed by Springvale Drain and Floodvale Drain comprises predominantly pipe reaches in the upper catchment (north) and open channel reaches in the lower catchment (south). The 1992 SKM Catchment Management Study gave the total length of Springvale Drain as approximately 3.9 km comprising 2.5 km of closed conduit and 1.4 km of open channel, and the total length of Floodvale Drain as 2.9 km comprising 2.1 km of closed conduit and 0.8 km of open channel.

The topography of the Springvale Drain and Floodvale Drain catchment is shown in Figure 2-1.

The subject catchments are characterised by highly permeable sandy soils which can provide a high rate of infiltration following rainfall events. However, the catchments are heavily urbanised, resulting in a significant degree of impervious land cover.



Title:
Catchment Topography

Figure: **2-1**

Rev: **A**

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0 375 750m

Approx. Scale

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2.1.1 Springvale Drain

Springvale Drain commences within the residential area at Wark Avenue in Pagewood and flows through a local park to Murray Road, Park Parade and Banks Avenue to the roundabout at the intersection of Banks Avenue and Heffron Road. Other surface drainage from Banks Avenue and Heffron Road east of the intersection combines with the main trunk drainage in this vicinity before the trunk drain continues westwards along Heffron Road.

The trunk drainage system continues in a southerly direction through Mutch Park and crosses Wentworth Avenue to flow southwards along Baker Street. A major side connection enters the drain along Baker Street which conveys water from Wentworth Avenue via Page Street, Dalley Avenue and Holloway Street. At Moore Street, the drain diverts to the east and flows through industrial development via a combination of pipe drainage and open channel to Meadow Way. The drain flows back to Baker Street and heads south before discharging to open channel just south of Anderson Street.

The open channel reach of Springvale Drain continues southwards through Botany Industrial Park and flows under the Port of Botany railway before continuing through the Orica Southlands site. The drain is culverted under McPherson Street with a trash screen present at the upstream side of the crossing, and continues as open channel to the Southern and Western Suburbs Ocean Outfall Sewer (SWSOOS No.2). The drain flows through an inverted syphon under the SWSOOS No.2 before continuing as box culverts through the Discovery Cove Industrial Park, ultimately discharging south of Botany Road. The channel turns west and flows under Penrhyn Road to Penrhyn Estuary and Botany Bay.

2.1.2 Floodvale Drain

Floodvale Drain commences within the residential area at Bay Street in Pagewood and flows generally in a southerly direction through residential properties, crossing Banksia Street, Holloway Street and Gibson Street before entering Page Street. Two separate drainage lines run in a south-westerly direction along Page Street, southwards along Dudley Street crossing Spring Street and through residential property under the disused railway embankment to Ocean Street where the two lines combine.

The drain continues along Ocean Street before turning south and running in a south-easterly direction through industrial development. The trunk drain combines with flow from a separate pipe originating at Anderson Street before flowing under the Port of Botany Railway via box culverts. This culverted reach continues in a southerly direction before discharging to an open channel reach at the northern extent of the Mobil Terminal site.

The open channel reach of Floodvale Drain continues southwards via a culvert under the Mobil site before flowing under a bridge at Port Feeder Road then running parallel to Port Feeder Road. The drain is culverted at McPherson Street with a trash screen present at the upstream side of the crossing. The open channel continues southwards to Penrhyn Estuary via a culvert (inverted syphon) at the SWSOOS No.2 and a culverted reach under the Botany Golf Course.

2.1.3 Inter-Catchment Flow

Due to the flat nature of the catchment and floodplain, cross-flow between the two subject catchments occurs, particularly in the lower half of the catchment. The two main locations where this cross-flow occurs are as follows:

- Anderson Street - During storm events, runoff from both catchments collects on Anderson Street before it eventually drains via inlets to a pipe draining to Floodvale Drain through the industrial development on the southern side of Anderson Street.
- Mobil Site Interceptor Drain - An interceptor drain has previously been constructed to facilitate such cross-flow between the two drains which runs along the northern boundary of the Mobil site.

2.1.4 External Catchment Flows

The topography of the study area and adjacent catchments is such that trapped low points are formed where, following periods of heavy rainfall, runoff ponds and will drain slowly through the pipe drainage system or by infiltration to the underlying sandy soils (WMA, 2011).

At such locations, water can pond to such depths to cause water to spill into neighbouring catchments. Four such locations where this can occur (affecting the subject catchments of this flood study) are as follows:

- Prince Edward Circle / Towner Gardens, Pagewood – The trunk drainage from this residential area flows northwards across Birdwood Avenue as part of the Astrolabe Park trunk drainage system. Once the capacity of the trunk drainage has been exceeded, there is no overland flow path from this area (this would typically follow the pipe drainage alignment) due to the elevation of Birdwood Avenue. Excess water ponds in this trapped low point until it spills in a westerly direction to Banks Avenue where it enters the Springvale Drain system.
- Corish Circle, Eastgardens – Overland flow from the British American Tobacco Site (bounded by Banks Avenue, Heffron Road and Bunnerong Road) flows southwards along Banks Avenue to the intersection with Wentworth Avenue, adjacent to the Westfield development. Flow exceeding the local drainage system capacity heads south across Wentworth Avenue and combines with overland flow from the sub-catchments along Denison Road, ultimately ponding in the trapped low point on Corish Circle at the southern boundary of the athletics field. Water is then able to commence spilling through the driveway to the Botany Industrial Park site, flowing southwards towards Springvale Drain.
- Pagewood Public School – A formalised drainage network is present in the area which discharges to Floodvale Drain. Following significant rainfall events the collected runoff may overflow southeast towards Floodvale Drain or north to the neighbouring catchment.
- Botany Golf Course – Towards the downstream of the catchment, runoff from the Floodvale Drain catchment overflows and drains to Botany Bay Golf Course and Sir Joseph Banks Park following significant rainfall events. This area has previously not been considered as part of the Springvale Drain and Floodvale Drain catchment.

2.2 Compilation and Review of Available Data

2.2.1 Introduction

Compilation and data review has been undertaken as the first stage in this flood study in order to consolidate and summarise all of the currently available data so that any missing data required for the successful completion can be determined. This allowed for the missing data to be collected during the initial phases of the study.

The review included:

- Previous studies undertaken within the Springvale Drain and Floodvale Drain catchment;
- Council flooding complaints;
- Roads and Maritime Services drainage plans;
- Available water level, tide and rainfall data; and
- Data contained in recent Development Applications.

Council has provided any digitally available information such as aerial photography, aerial topographic survey, cadastral boundaries, watercourses, and drainage networks in the form of GIS datasets. Aerial photography captured in 2011 and aerial topographic survey in the form of LiDAR data captured in 2007 and 2008 has been supplied by Council for use in the flood study.

2.2.2 Previous Flood Studies and Investigations

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

(1) Investigation for Storm Drain Outfalls – Botany Bay Northern Foreshore Development (Laurie, Montgomerie & Pettit, 1975)

This report summarises the investigations regarding new outfalls for Springvale Drain and Floodvale Drain associated with the development of port facilities on the northern foreshore of Botany Bay.

Of particular reference for this current study are the design plans for the culverts under the South Western Suburbs Ocean Outfall Sewer (SWSOOS No.2).

(2) Catchment Management Study – Floodvale & Springvale Drains, Botany (SKM, 1992)

Sinclair Knight & Partners (now Sinclair Knight Merz, referred to herein as SKM) completed a catchment management study for Springvale Drain and Floodvale Drain on behalf of Botany Municipal Council.

This study developed a MOUSE model for both hydrological and hydraulic analysis of the upper piped reaches. The lower open channel reaches were modelled using HEC-2 software. The models were based on field survey obtained for the study, including both drainage survey (pit and pipe) and open channel survey.

The hydraulic models were not available for review as part of this current study. A register of data relating to the trunk drainage system has been included as part of the study report and this data has been utilised in this current study where appropriate.

It has not been possible to source a full record of the survey data following enquiries with the consultant and surveyor from the study. It can therefore be concluded that the detail contained in the report and any files held by Council forms the only surviving record of this survey.

(3) Proposed Expansion of Container Port Facilities in Botany Bay, NSW – Hydrologic and Hydraulic Studies (Lawson and Treloar, 2003)

Lawson and Treloar completed a flood impact assessment on behalf of Sydney Ports Corporation associated with the proposed container port expansion at Port Botany. The study included flood modelling for the Springvale Drain and Floodvale Drain catchment.

Details from this report have been used to verify assumptions and data applied in this current flood study. The SOBEK hydraulic model developed for the study has not been sourced for use in this current flood study.

(4) ORICA/ Goodman Southlands Remediation/ Development Project – Flood Investigations (Connell Wagner, 2007)

Orica Australia Limited and Goodman International Limited (previously Macquarie Goodman) jointly proposed developing the site known as 'Southlands' at Banksmeadow as part of an industrial development. Flood modelling has been undertaken as part of this development application and planning process by Connell Wagner Limited. This flood investigation involved topographic survey, hydrologic modelling (using XP-RAFTS) and hydraulic modelling (using MIKE 11) to determine the existing flooding characteristics of the site and surrounding floodplain. The models have subsequently been used to assess development plan options.

(5) ORICA Southlands Remediation and Development Project – Hydraulic Modelling Report (Aurecon, 2010)

Following on from the previous flood investigations (Connell Wagner, 2007) additional flood modelling was undertaken by Aurecon Limited (previously Connell Wagner) to address comments from the NSW Department of Planning. The previous modelling work was updated and a two-dimensional hydraulic model (MIKE 21) was developed. The one and two dimensional hydraulic models (MIKE-11 and MIKE-21) were dynamically coupled using MIKE FLOOD. The models have subsequently been used to assess flood mitigation measures to ensure there are no adverse flooding impacts as a result of the proposed development.

Given the recent nature of the study much of the data is highly relevant for this current flood study. Recognising this importance, Orica has provided the various topographic data and models to Council for use in this flood study. Use of the topographic data and model data is described in Section 2.2.6 and Section 4, respectively.

Whilst the development has not yet been built, the final site design will be incorporated into the hydraulic model developed for this current study for the purpose of simulating the range of design flood events and preparing flood mapping.

(6) Daceyville / Astrolabe Park Flood Study (WMA Water, 2011)

This report was prepared by WMA Water for City of Botany Bay Council and Sydney Water to define the design flood behaviour within the Daceyville / Astrolabe Park catchment which adjoins the northern catchment boundary of Springvale Drain. Details from this report have been used to verify assumptions and data applied in this current flood study.

2.2.2.1 Recent Development Applications

Details of various recent development applications have been made available for use in this study by Council. Of particular interest for this current flood study are details of the existing or proposed drainage system, or work as executed drainage system (as related to drainage). These data have been used to compile a database of the drainage system details for use in the hydraulic modelling exercise.

The development applications details reviewed as part of this current flood study are for the following locations:

- 1 Moore Street, Banksmeadow;
- 10 Anderson Street, Banksmeadow;
- 32 Swinbourne Street, Botany;
- 1753-1765 Botany Road, Banksmeadow;
- 1767 Botany Road Banksmeadow;
- Lot 1 DP776089 (British American Tobacco Australia Site), Eastgardens;
- Corner of Exell and McPherson Streets, Banksmeadow; and
- Intersection of Hill Street and Botany Road, Banksmeadow.

2.2.2.2 Summary of Previous Studies

The 1992 SKM Catchment Management Study is the only study that undertook hydraulic analyses for the entire catchment. However, this was undertaken using different modelling methods for different parts of the catchment. Both the Lawson and Treloar and Aurecon studies modelled the floodplain south of the Port of Botany railway, with both studies using the same hydrological analysis method (XP-RAFTS rainfall-runoff model).

2.2.2.3 Hydrological and Hydraulic Models

Orica Australia Limited has developed an hydrologic XP-RAFTS model and hydraulic MIKE-FLOOD model as outlined in ORICA Southlands Remediation and Development Project – Hydraulic Modelling Report (Aurecon, 2010). Orica has provided the various topographic data and models to Council for use in this flood study.

The XP-RAFTS model covers the entire existing Springvale Drain and Floodvale Drain catchment using 37 sub-catchment areas. The XP-RAFTS model was adapted from an existing XP-RAFTS model prepared by Lawson and Treloar (May, 2003) and detailed in Appendix I of the Port Botany Expansion Environmental Impact Statement (Volume 4).

The Lawson and Treloar model was modified by Aurecon to incorporate more detail in the Orica Southlands site. The Orica XP-RAFTS model utilises the following key model parameters:

- Pervious Surfaces: Initial Loss = 50mm, Continuing Loss = 15mm/hr, Manning's n = 0.025
- Impervious Surface: Initial Loss = 1mm, Continuing Loss = 1mm/hr ,Manning's n = 0.01

The Orica MIKE-FLOOD hydraulic model integrates a two-dimensional MIKE-21 and one-dimensional MIKE-11 hydraulic models into a coupled hydraulic modelling system. The MIKE-FLOOD model extends from the interceptor drain linking Springvale Drain and Floodvale Drain north of the Mobil site (northern extent of model), downstream to Botany Bay (southern extent of model). The MIKE-11 model represents both the Springvale Drain and Floodvale Drain aiming to accurately resolve the conveyance of the drains and hydraulic control structures. The MIKE-21 model aims to better represent the dynamic overland flow of the catchment using a two-dimensional hydraulic model.

2.2.3 Historical Flood Levels

The 1992 Catchment Management Study undertaken by SKM found that there are limited records of flooding within the study area and there was little or no quantitative data available for model calibration purposes.

The report indicates Council received two letters of complaint from residents of Holloway Street and Spring Street following heavy rain on 13 January 1980. A letter was also received by Council from Esso Australia Ltd following flooding of their Botany Terminal (now operated by Mobil Oil Australia Ltd) on 4 February 1990. An operator of a market garden on State Rail Authority (SRA) land adjacent to Springvale Drain also wrote to Council in December 1991 complaining of losses due to flooding.

The report identifies three properties which experienced significant flooding problems as a result of the February 1990 event being Laporte Chemicals, Mobil Oil and the Port Botany Container Depot. It has been reported that McPherson Street at Floodvale Drain was inundated to a depth of about 0.3m. The Laporte property located upstream of McPherson Street adjacent to the right bank of the drain was also flooded. The Port Botany Container Depot experienced some flooding of its warehouse located near the left bank of Floodvale Drain upstream of Botany Road. The Mobil Terminal suffered flooding with overflows depths of about 0.2m at Floodvale Drain and up to 0.5m at Springvale Drain. Other than the events of January 1980 and February 1990, the report did not indicate any other specific flood event within the study area.

Subsequent studies within the study area have not identified any additional known flooding events. Studies of neighbouring catchments have identified additional significant rainfall events in November 1984 and August 1986.

Additional historical flooding information was gathered as part of the community consultation process (refer to Section 3 for further detail). The community identified specific and general dates when they had experienced flooding on their properties which included 1970's, 2010, 8 November 2010, 12 February 2010, twice in 2011, May – June 2011 and May 2012. The community also provided indicative depths of flooding at various locations but these were largely not attributed to specific flood events. Two neighbouring residents at Towner Gardens, Pagewood and one resident on Banksia Street did provide indicative flood depths for the 12 February 2012 flood event. The available historical flood levels are summarised in Table 2-1.

The City of Botany Bay Council maintained a flooding complaints database from 2010 to 2011. The database of resident complaints indicated significant flood events on 12 February 2010, 4 June 2010 and 8 November 2010. No detailed flood levels were recorded.

It is known that flooding occurs within the catchment with identified flooding 'hot-spots' but there are no accurate data (flood levels, depths or photographs) to identify specific events. The flooding hot spots identified by Council are as follows:

- Heffron Road and Banks Avenue intersection, Pagewood
- Holloway Street, Pagewood;
- Spring Street, Pagewood;
- Anderson Street, Banksmeadow; and
- Exell Street, Banksmeadow.

Table 2-1 Historical Flood Levels

Flood Event	Location	Indicative Flood Depth (m)	Source
Feb 1990	McPherson St at Floodvale Drain	0.30 – 0.40	SKM (1992)
Feb 1990	Mobil Terminal at Floodvale Drain	0.20	SKM (1992)
Feb 1990	Mobil Terminal at Springvale Drain	0.50	SKM (1992)
Feb 2010	35 Towner Gardens, Pagewood Property Kerb	 0.30 0.40	Community Questionnaire
Feb 2010	33 Towner Gardens, Pagewood - Gutter	0.40	Community Questionnaire
Feb 2010	153 Banksia St, Pagewood - Backyard	0.45	Community Questionnaire

2.2.4 Water Level and Ocean Tide Data

No water level gauges are present in the Springvale Drain and Floodvale Drain catchment.

Botany Bay tide levels will be used as a dynamic downstream water level boundary in the hydraulic model as discussed in Section 4. The tides in the Botany Bay are typical of the NSW east coast, being semidiurnal, that is generally two high tides and two low tides each day with a diurnal inequality. Tidal predictions for Botany Bay have been used for modelling historical events. Botany Bay tide levels are provided in Table 2-2 with illustrated in Figure 2-2.

Table 2-2 Botany Bay Tide Levels

Tidal Level		Level (m) Tide Gauge	Level (m) AHD
Maximum	Maximum Recorded Tide [1]	2.3	1.4
HAT	Highest Astronomical Tide [2]	2.0	1.1
MHWS	Mean High Water Springs [2]	1.5	0.6
MHWN	Mean High Water Neaps [2]	1.3	0.4
MSL	Mean Sea Level [2]	0.9	0.0
MLWN	Mean Low Water Neaps [2]	0.5	-0.4
MLWS	Mean Low Water Springs [2]	0.3	-0.6
LAT	Lowest Astronomical Tide [2]	0.0	-0.9

Sources:
1 Bureau of Meteorology – monthly sea levels for Botany Bay – 1981 to 2010 (accessed online Aug 2012)
2 Port 60390 – AusTides – Australia Hydrographic Service - 2012

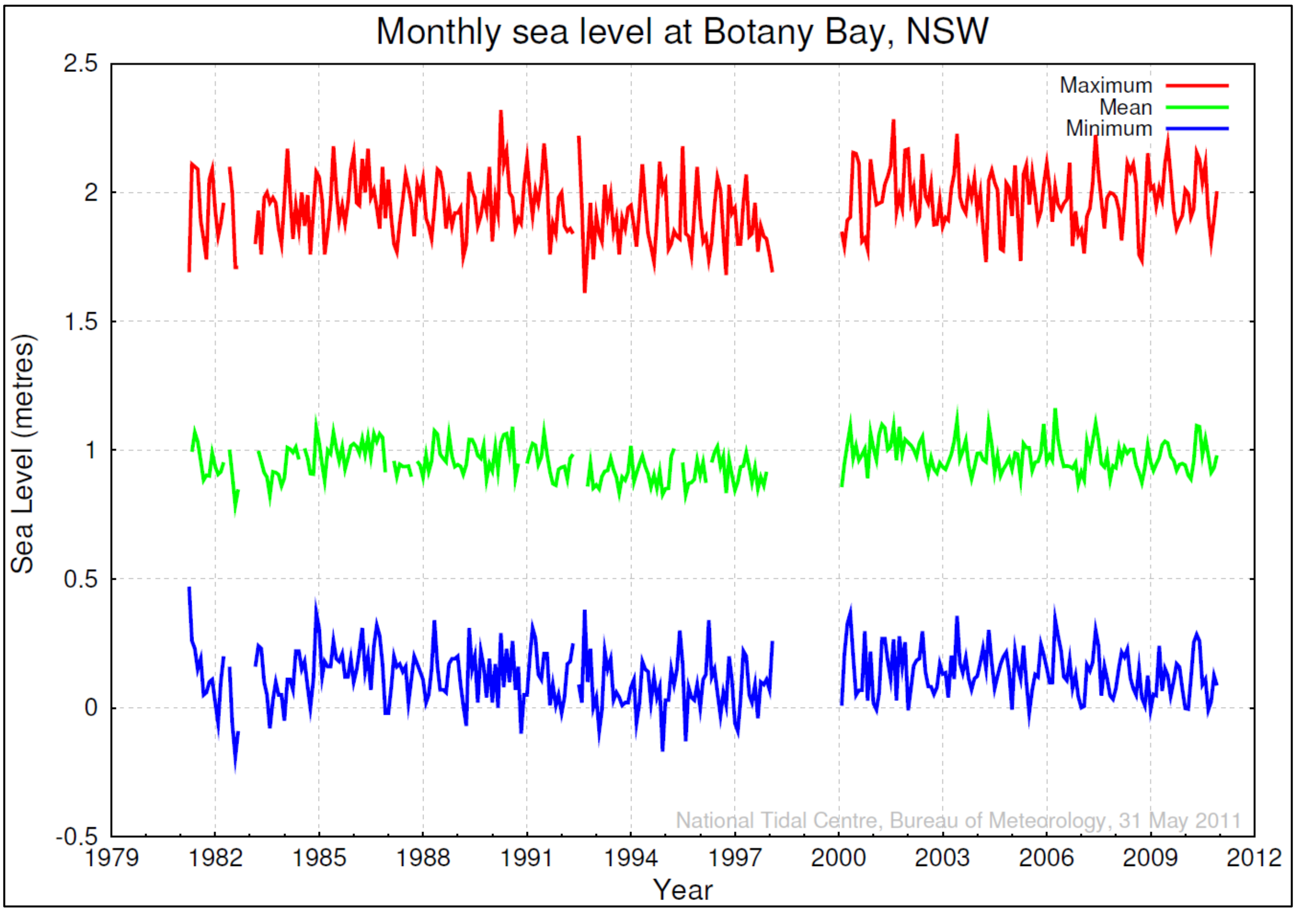

Figure 2-2 Botany Bay Sea Level 1981 - 2010

2.2.5 Rainfall Data

There is an extensive network of rainfall gauges across the Sydney area, many of which are operated by the Bureau of Meteorology (BoM) and Sydney Water Corporation (SWC). There are no gauges located within the study area. The closest operational gauge to the study area is a SWC operated continuous gauge, located at Eastlakes Sports Club. This gauge has a long period of record, commencing in 1973 and has been used to model historical events. There are a further 13 rainfall gauges located within 5km of the study area, six of which are daily read gauges. The closest BoM-operated continuous gauge is located around 3.5km from the study area at Sydney Airport. A list of these rainfall stations with their respective period of record, including closed stations, is shown in Table 2-3. The distribution of the gauges is shown in Figure 2-3.

Table 2-3 Rainfall Gauges in the Springvale Drain and Floodvale Drain Locality

Station No.	Name	Operator	Type	Start Year	End Year
566034	Pagewood	SWC	Continuous	1959	1973
66007	Botany No.1 Dam	BoM	Daily	1870	1978
566028	Eastlakes Sports Club	SWC	Continuous	1973	Current
66122	Maroubra RSL Bowling Club	BoM	Daily	1964	1974
566123	Maroubra Bowling Club	SWC	Continuous	1995	1998
566088	Malabar STP	SWC	Continuous	1991	Current
566043	Randwick (Army)	SWC	Continuous	1956	1970
66021	Erskineville	BoM	Daily	1904	1973
66037	Sydney Airport AMO	BoM	Continuous	1960	current
566099	Randwick Racecourse	SWC	Continuous	1991	current
66073	Randwick Racecourse	BoM	Daily	1937	current
66051	Little Bay (The Coast Golf Club)	BoM	Continuous	1925	2009
66052	Randwick Bowling Club	BoM	Daily	1888	current
66101	Fernbank	BoM	Daily	1889	1913

Title:

Rain Gauges in the Vacinity of Springvale Drain and Floodvale Drain Catchments

Figure: 2-3

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2.2.6 Topographic Data

2.2.6.1 Aerial Topographic Survey

Aerial topographic survey in the form of LiDAR data covering the study area has been provided by Council. Whilst the metadata for the data has not been made available, it has been assumed for this study that this data is the same as collected in two separate dates in 2007 and 2008 by AAM Hatch. This particular LiDAR data set has a stated vertical accuracy of +/- 0.15m with 68% confidence and horizontal accuracy of +/- 0.55m with 68% confidence.

The filtered ground data has been converted into a 1m resolution digital elevation model (DEM) using terrain modelling software (MapInfo Vertical Mapper). The filtered data removes features such as vegetation and buildings to provide a representation of the natural surface.

2.2.6.2 Detailed Topographic Ground Survey

As part of Orica's proposal to developed an industrial estate known as 'Southlands' at Banksmeadow, flooding investigations have been undertaken including extensive topographic survey of the subject site and adjacent properties. Orica have made these data available for use in this current flood study for which the key topographic survey components can be summarised as follows:

- ground levels of the Southlands site and other adjacent industrial sites;
- elevations along McPherson Street (east of Exell Street);
- ground levels within the Mobil Terminal site;
- open channel reaches of Springvale Drain and Floodvale Drain;
- culverts and bridges over Springvale Drain and Floodvale Drain;
- interceptor drain connecting Springvale Drain and Floodvale Drain; and
- open channel and culverts for Springvale Drain on the Orica site north of and passing under the railway.

Furthermore, the bulk earthworks model of the approved Stage 1 and Stage 2 of the site development has been made available by Orica. This data set will be included in the adopted hydraulic model for this current flood study on the basis of the design having been approved for construction by Council.

2.2.7 Stormwater Drainage Network

Information on the pit and pipe drainage network has been compiled from the various sources discussed in Section 2.2.2.

Much of the detail of the existing drainage network has been taken from the 1992 Catchment Management Study of the subject catchments. As discussed in Section 2.2.2, the report from this previous study includes a register of data of the trunk drainage system, providing invert levels and pipe sizes along the route of the main trunk drainage. This information has been supplemented with a GIS layer provided by Council (prepared around the same time as the previous study) which contains additional detail of the drainage network not contained in the 1992 SKM report.

Pit and pipe details have been provided by the NSW Roads and Maritime Services (RMS) along the various state routes within the study area. This information has enabled more accurate schematisation of the road drainage and connection to trunk drainage, particularly on Wentworth Avenue at the intersections with Baker Street and Page Street.

2.3 Site Inspections

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

- Presence of local structural hydraulic controls;
- Location and characteristics of surface drainage pits and pipes;
- General nature of Springvale Drain and Floodvale Drain and associated floodplain noting channel form and vegetation types; and
- Location of existing development and infrastructure on the floodplain.

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

2.4 Additional Drainage Survey

Following the review of available data, a combined database of drainage details was compiled to allow identification of locations where additional pit and pipe survey was required.

A survey brief was prepared whilst considering the following:

- Locations of known flooding problems;
- Accuracy and reliability of any existing data; and
- Verification of the alignment of various drainage pipes.

A limited budget was allocated for acquiring additional data. Therefore, the survey brief was targeted to capture the critical areas identified using the above criteria. A surveyor was engaged to undertake this survey for the identified locations in the survey brief. This survey campaign was completed in late August 2012 after which the data was incorporated into the study.

2.5 Community Consultation

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

2.6 Development of Computer Models

2.6.1 Hydrological Model

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

In recent years the advancement in computer technology has enabled the use of the direct rainfall approach as a viable alternative. With the direct rainfall method the design rainfall is applied directly to the individual cells of the 2D hydraulic model. This is particularly useful for overland flow studies where model results are desired in areas with very small contributing catchments. Furthermore, this method is advantageous in accounting for inter-catchment flow, such as occurs in this study area as discussed in Section 2.1.3. This study has therefore adopted the direct rainfall approach for modelling hydrology, details of which are discussed in Section 4.

2.6.2 Hydraulic Model

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

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

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

2.7 Calibration/Validation and Sensitivity Testing of Models

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

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

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

The available historical information highlighted two flood events with sufficient data to potentially support a calibration process – the February 1990 and February 2010 events. Flood information collected in the community questionnaire not specific to particular flood events has also been used to aid the model calibration and validation process.

The calibration and validation of the hydraulic model is presented in Section 4.2. A series of sensitivity tests were also carried out to evaluate the model. These tests were conducted to examine the performance of the models and determine the relative importance of different hydrological and hydrodynamic factors. The sensitivity testing of the model is detailed in Section 8.

2.8 Establishing Design Flood Conditions

Design floods are statistical-based events which have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event, which is sometimes referred to as the 1 in 100 year Average Recurrence Interval (ARI) flood, is the best estimate of a flood with a peak discharge that has a 1% (i.e. 1 in 100) chance of occurring in any one year. For the Springvale Drain and Floodvale Drain catchment, design floods were based on design rainfall estimates according to Australian Rainfall and Runoff (IEAust, 2001).

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

2.9 Mapping of Flood Behaviour

Design flood mapping is undertaken using output from the hydraulic model. Maps are produced showing water level, water depth and velocity. The maps present the peak value of each parameter. Provisional flood hazard categories and hydraulic categories are derived from the hydrodynamic model results and are also mapped. The mapping outputs are described in Section 7 and presented in Appendix A.

2.10 Conclusion

The Springvale Drain and Floodvale Drain catchment is heavily urbanised and is predominantly comprised of industrial development with a large proportion of residential development in the upper catchment. The natural drainage systems have been heavily modified and most of the study area is now drained by a stormwater pipe network; there are some open channel reaches in the southern area of the catchment. When the capacity of this stormwater drainage network is exceeded, overland flow will occur along the alignments of the original drains or gullies. Many of the old drainage gully alignments are now located through developed properties which presents a significant flood risk.

Availability of historical flooding and flood data in the Springvale Drain and Floodvale Drain catchment is limited. The largest historical event identified in the catchment occurred in February 1990, with more recent flooding occurring in February 2010.

3 Community Consultation

3.1 The Community Consultation Process

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

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

- Media release to inform the wider community of the study;
- Development and maintenance of a project web-page providing general information on the study background and objectives, reporting progress of the flood study against key milestones, and provide preliminary study output subject to Council approval;
- Distribution of a questionnaire to landowners, residents and businesses within the study area;
- An information session for the community to present technical information, inform about the flood study outcome as well as elicit options and ideas from the community about what can be done to help minimise future risks to life and property; and
- Public exhibition of the draft Flood Study.

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

3.2 Media Release

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

3.3 Information Website

A website has been established to keep the community informed on the study progress. The website has further information on flooding in the Springvale Drain and Floodvale Drain catchment. Community members were also able to complete the community questionnaire and send photographs through the website.

3.4 Community Questionnaire

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

A total of 104 completed questionnaires were received out of the 1300 letters delivered, representing a response rate of 8%. On average the respondents have resided at their property for over 25 years. The responses have been compiled into a GIS layer and database by BMT WBM.

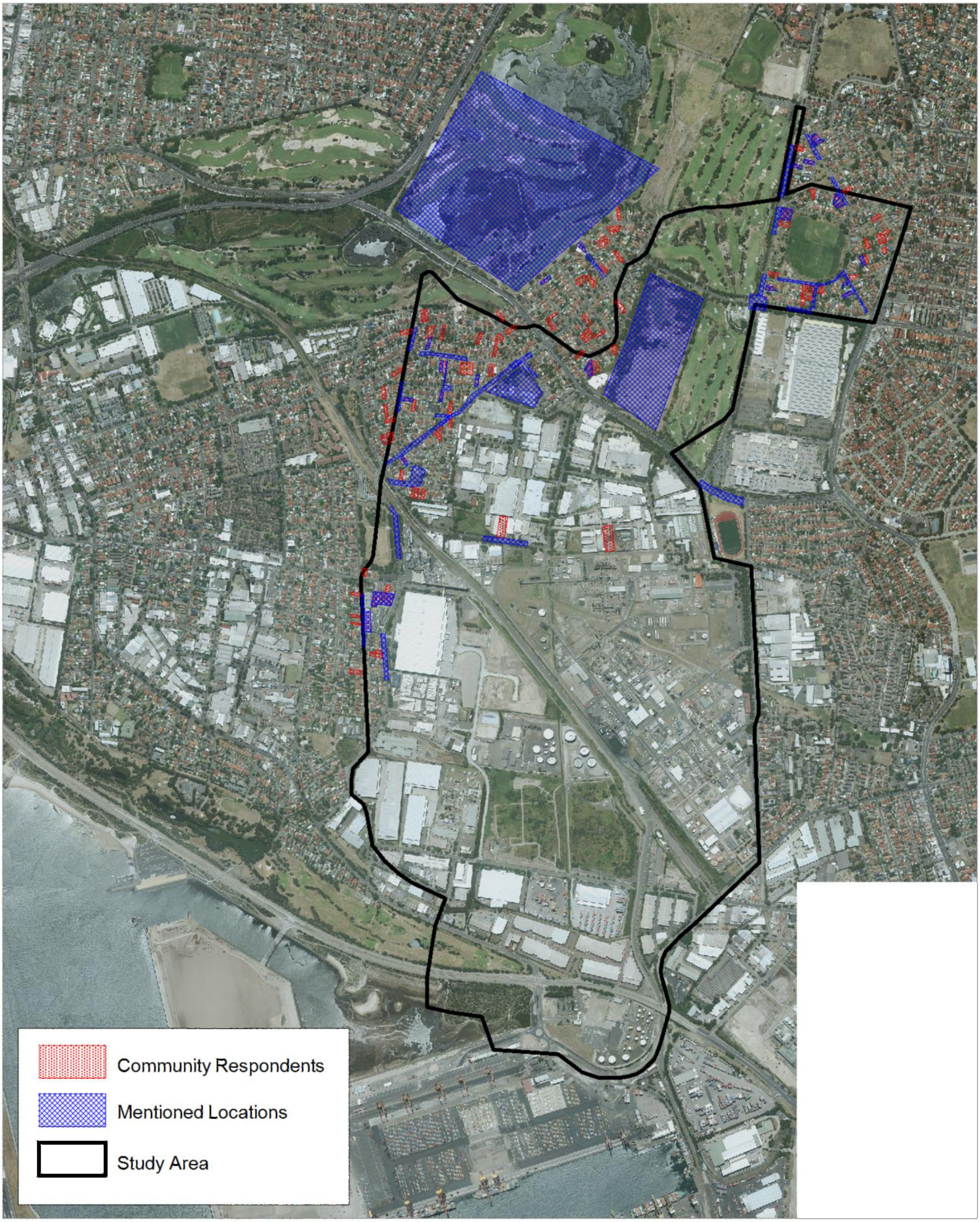
The distribution of responses along with mentioned locations is presented in Figure 3-1. It can be seen that there is a fairly comprehensive coverage across the residential area with only two responses from the industrial areas near Baker Street.

Comments relating to flood behaviour have been extracted where useful for model calibration and validation purposes. The community responses did not indicate any specific rainfall events that resulted in flooding across the catchment, but rather, the information received identified certain areas of the study area where flooding occurs on a regular basis. Numerous comments have included indicative flood depths but these are largely not attributed to specific flood events. Two neighbouring residents at Towner Gardens, Pagewood (external to the defined catchment boundary) and one resident on Banksia Street did provide indicative flood depths for the 12 February 2012 flood event.

The questionnaire asked the community about past flooding on their property as well as their street. Property flooding experiences are summarised in Table 3-1 and illustrated in Figure 3-2. A total of 25 community respondents have experienced some degree of flooding within the grounds of their property, two of which experiencing flooding above floor level.

Streets that the community have identified as having experienced flooding are summarised in Table 3-2. A total of 27 residents indicated that they had experienced flooding in their street, 12 of which reported flooding across one or both traffic lanes.

Key areas the community identified as having flooding issues are summarised in Table 3-3. The community identified 11 key areas that have been subject to past flooding. The primary areas of concern raised were Page Street and the intersection of Park Parade and Kenny Road in Pagewood.



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Community Questionnaire Responses

Figure: 3-1

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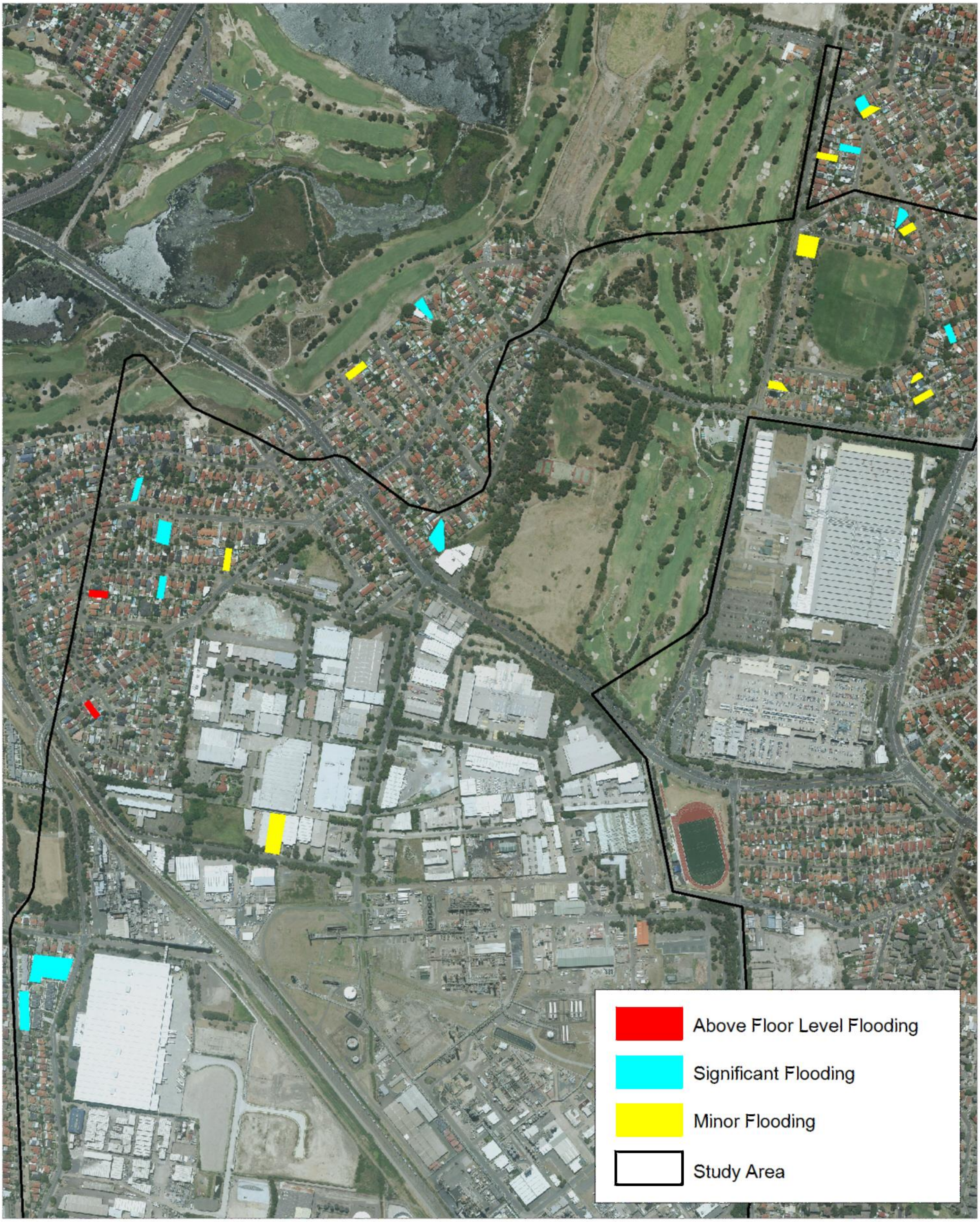

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Property Flooding Experienced

Figure: 3-2

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Table 3-1 Property Flooding Experiences

ID	Degree of Property Flooding			Date of Flood	Regular Event	Approximate Water Depth
	Above Floor	Significant	Minor			
2			Yes	Every heavy storm	Yes	Front yard - 2 inches, back yard - 4 inches
6			Yes			
13			Yes	Unsure	No	
22		Yes		Over many years	Yes	Several inches
32	Yes			2009	No	
41			Yes	May – June 2011	Yes	
43		Yes		Whenever there is heavy rain	Yes	8 to 10 inches in the backyard
45			Yes	From Dec - June (after very heavy and continuous rain)	Yes	
46			Yes		Yes	
52		Yes		Ongoing	Yes	4 or 5 inches
54		Yes		2010, 2011 (x2)		Ankle deep in garage
65		Yes	Yes	12/2/10 (worst episode)	Yes (minor flooding)	30cm on property at front door
69		Yes	Yes	10 years	2–3/ year	
77			Yes	12/2/2010	No	
80		Yes			Yes	10cm
90		Yes		2 – 3 times per year after heavy rain	Yes	Front yard and carport 15cm
91		Yes	Yes	Few Times. Put drain in not happening now	No	
92		Yes			No	Garage 8 inches
93			Yes	1970's	No	15cm on property
95			Yes	When heavy rain occurs	No	
96			Yes	After lots of rain	Yes	
97		Yes		May 2012	Yes	5cm
98	Yes	Yes			Yes (3x since 1988)	1 to 1.5 feet
101			Yes		Yes	½ to ¾ the way up the driveway
102		Yes		At least twice a year 2009,2010,2011,2012. Including 12/02/2010 & 8/11/2011	Yes (at least twice a year)	45cm ponding in backyard

Table 3-2 Street Flooding Experiences

ID	Degree of Street Flooding		Regular Event	Depth Indications
	Across One or Both Traffic Lanes	Minor Along Gutters		
2	Yes		Yes	
5		Yes	No	100mm
6		Yes	Yes	
13		Yes	Yes	Top of kerb
17		Yes	Yes	
23				Water covers the road, maybe 50cm deep
32		Yes	No	
34		Yes	No	About 0.5m
42		Yes	No	
44		Yes		
46				Park Pde and Kenny St south side of Jellicoe Park, 3-4 inches high
52		Yes	Yes	4 or 5 inches
53	Yes			30cm on Page Street
54		Yes		
55	Yes		Yes	
65	Yes	Yes	Yes	40cm at kerb
69	Yes		2 – 3 per year	
70		Yes	No	
71		Yes	Yes	Gutter level after heavy period of rain.
74				Stephen Rd 0.5m, Page St 0.4m, Chegwyn St 0.5m.
77		Yes	No	Depth in the gutter was 40cm
80				10cm
84	Yes		No – only in very heavy rains	Written on back of bus stops usually flood up to just under the seat
90				15cm
92		Yes	Yes	
93	Yes		No	25cm on the road
94		Yes	Only a couple of times	
98	Yes		Yes	
100	Yes			Approximately 1m
101	Yes		Yes	
102	Yes		Yes	

Table 3-3 Recognised Flood Prone Locations

Location	No. Times Mentioned
Page St, Pagewood	6
Intersection of Park Pde and Kenny Rd, Pagewood (south of Jellicoe Park)	4
Maxwell Rd, Pagewood	3
Stephen Rd, Pagewood (adjacent to Garnet Jackson Reserve)	3
Intersection of Heffron Rd and Banks Rd, Pagewood (Roundabout)	3
Towner Gardens, Pagewood	3
Pagewood Primary School	2
Anderson St, Pagewood	2
Mutch Park, Pagewood	2
Wentworth Ave, Pagewood (outside East Gardens)	2
Spring St, Pagewood	2

3.5 Public Exhibition of Draft Flood Study Report

3.5.1 Public Exhibition and Community Information Session Details

The Draft Springvale Drain and Floodvale Drain Flood Study was placed on public exhibition from 11 November to 11 December 2013. Throughout the exhibition period hard copies of the draft flood study report were available for viewing at the Council's Customer Service Centre, Mayor's Office, Central Library and Mascot Library. An electronic version of the draft flood study report was also available for download on the project website.

Four community information sessions were conducted during the public exhibition period on Tuesday 26 November and Tuesday 3 December. The community information sessions were attended by Council, OEH and BMT WBM representatives and registered community members. The sessions presented an overview of the floodplain management process and outcomes of the flood study with presentations made by BMT WBM and OEH. Community members were encouraged to discuss their concerns and suggestions with the representatives present. Feedback forms were also provided to the attendees.

The community was notified of the public exhibition and community information sessions via advertisements in the local newspaper and notifications on Council's website and the project website. Council also directly mailed notifications to 279 individual property owners whose property falls within the 100 year ARI flood extent.

3.5.2 Community Response

A total of 11 individuals registered to attend a community information session, of which 7 attended. A summary of the issues raised in the community information sessions are provided below:

- ***Property Value***: several residents were concerned about the impact of the flood study on their property re-sale value.

- ***Property Flooding Impact***: several residents wanted to know how their property would be impact by the 100 year flood event and how they could obtain that information from Council.
- ***Road Raising***: residents along Spring St, Pagewood and Park Pde, Pagewood were concerned that previous raising of the road profile had adversely impacted property flooding.
- ***Drainage Works***: residents of Banks Ave, Page St and Heffron Rd, Pagewood were concerned the local drainage in the areas is undersized.
- ***Street Cleaning***: several individuals raised the issue of Council's ongoing streets cleaning, recognising its importance in preventing flooding by improving drainage. A resident of Spring St, Pagewood noted a decline street cleaning over the years whilst another in Banks Ave, Pagewood noted an increase. A resident of Heffron Rd, Pagewood also noted previous cleaning of the drainage pipes in the area which may now been in need.
- ***Development Approvals***: The individual was concerned about the impact of new developments (particularly site filling, raised floor levels and closer proximity to open channels) on surrounding areas, and the cumulative flood impact of these developments. The individual also suggested redirecting a portion of large project contributions towards addressing wider flooding issues.
- ***Vegetation***: a resident noted that trees were being planted over drainage lines and was concerned the roots would damage the drainage pipes. Another resident was concerned that the type of vegetation planted along the Floodvale Drain open channel banks was contributing to blockage of the McPherson St trash rack. A resident of Heffron Rd, Pagewood was concerned leaf litter from the large trees in the area are contributing to blockage of inlets and sediment build-up in the drainage pipes.

At the closure of the public exhibition period no formal written submissions on the draft flood study had been received, other than the feedback forms from the community sessions.

3.6 Conclusion

Community consultation undertaken during the study has aimed to collect information on historical flooding and previous flood experience, and inform the community about the development of the flood study and its likely outcome as a precursor to floodplain management activities to follow. The key element of the consultation process involved the distribution of a questionnaire relating to historical flooding. The return numbers for the questionnaire were low, with minimal additional historical flood information obtained. This is perhaps representative of the relatively low number of significant flooding events historically within the Springvale Drain and Floodvale Drain catchment.

4 Model Development

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

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

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

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

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

Development of a hydraulic model follows a relatively standard procedure:

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

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

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

4.1 Hydraulic Model

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

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

4.1.1 Model Configuration

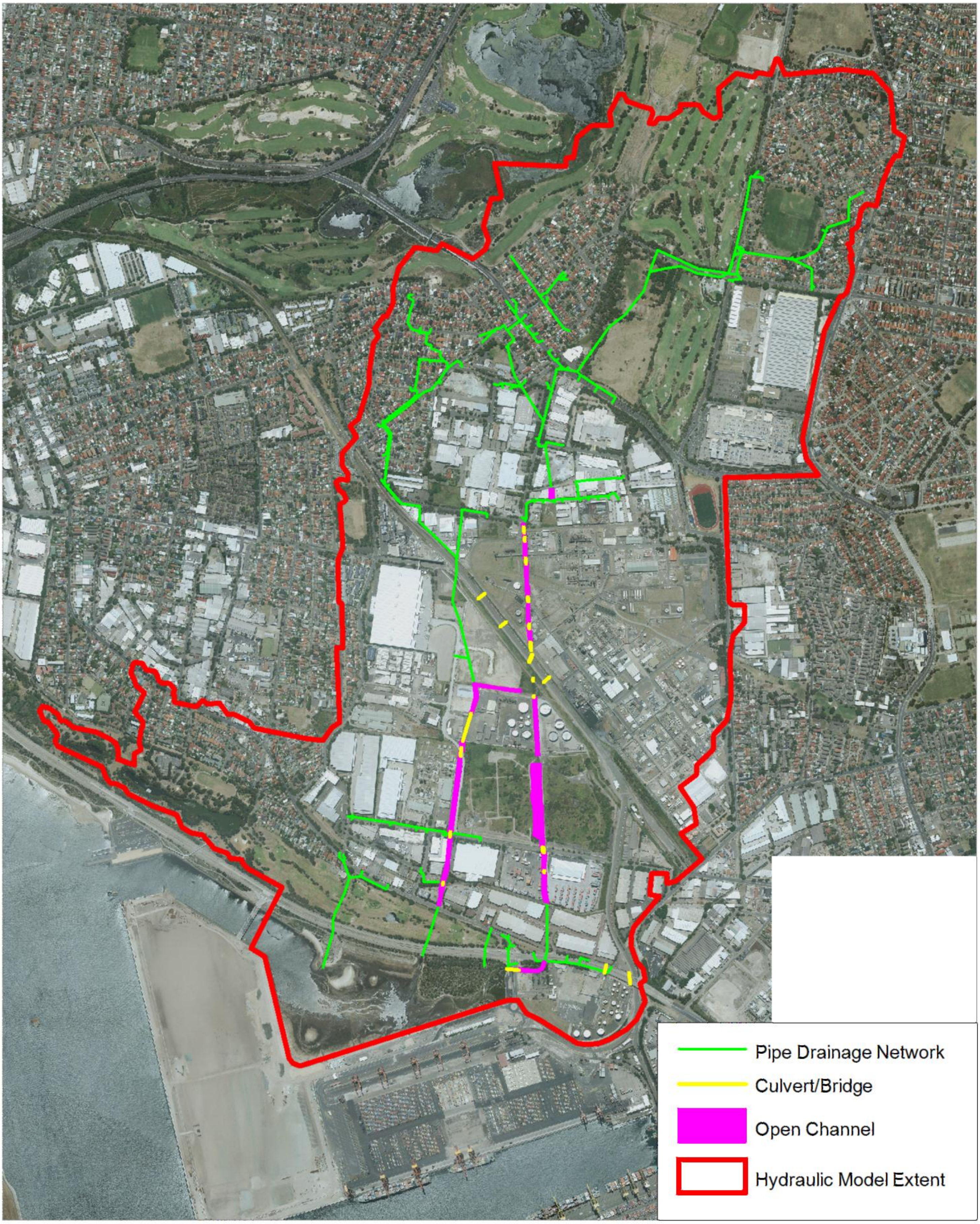
Consideration needs to be given to the following elements in constructing the model:

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

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

The total floodplain area modelled within the 2D domain comprises a total area of some 5.4km^2 (up to an elevation of approximately 35m AHD) which encompasses and extends beyond the study area (defined by Council's catchment boundary). The larger model area adopted for the 2D model was required to account for areas in adjacent catchments where floodplain flows interact between catchments. The adopted TUFLOW model layout is presented in Figure 4-1.

A TUFLOW 2D domain model resolution of 4m was adopted for study area. It should be noted that TUFLOW samples elevation points at the cell centres, mid-sides and corners, so a 4m cell size results in DEM elevations being sampled every 2m. This resolution was selected to give necessary detail required for accurate representation of floodplain topography and its influence on overland flows. With a 4m cell size the model includes approximately 335,000 grid cells.



Title:

TUFLOW Model Layout

Figure: 4-1

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Approx. Scale

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4.1.2 Topography

The ability of the model to provide an accurate representation of the overland flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the Springvale Drain and Floodvale Drain model, a high resolution DEM (1m grid) was derived from LiDAR survey provided by Council. This DEM was further supplemented by incorporating additional topographical ground survey and bulk earthworks design for the Southlands site as outlined in Section 2.2.6.2. This additional ground information was incorporated within the TUFLOW model as either 3D 'breaklines' or TINs (triangulations) of elevation points.

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

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

Linear features that potentially influence the flow behaviour, such as gullies and levees were incorporated into the topography using 3D 'breaklines' in TUFLOW to ensure that these were contained within the model grid and accurately represented in the model.

It is noted that although brick walls and fences could also significantly affect local overland flood flowpaths, these have not been explicitly incorporated into the model in urban areas. As outlined in the following sections additional modifications have been made for building footprints and open channels.

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

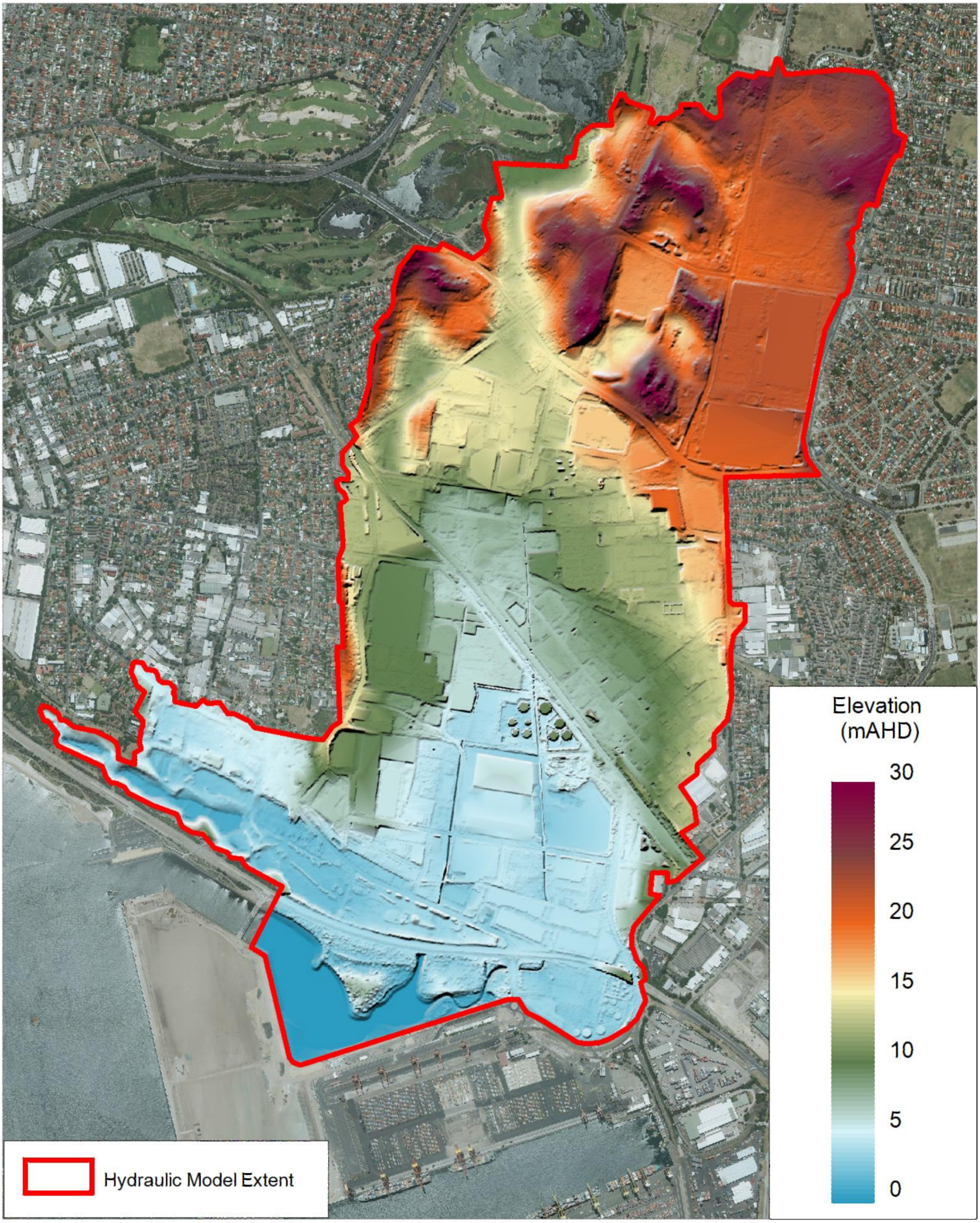
4.1.2.1 Buildings

In general, a DEM developed from LiDAR data does not adequately represent building footprints, particularly for larger buildings.

For this flood study, ground elevations defining selected building footprints were processed on an individual basis using elevations sourced from the LiDAR-based DEM. The footprints of these buildings within the study area have been digitised from the available aerial photography.

4.1.2.2 Open Channels

LiDAR surveys are generally considered insufficient to define open channel geometry with an appropriate level of detail. In addition, LiDAR surveys cannot provide information on hydraulic structures, such as culverts. Additional topographic ground survey was sourced from Orica (as outlined in Section 2.2.6.2) to enable a more accurate representation of the Springvale Drain and Floodvale Drain open channels.



Title:

Hydraulic Model Topography

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To ensure the conveyance of the open channels were adequately represented in the model the open channels were modelled in the 1D domain linked to the 2D domain at the banks as illustrated in Figure 4-3. Modelling the open channels in the 1D domain allows for a great definition of the flow path, independent of the 2D grid size.

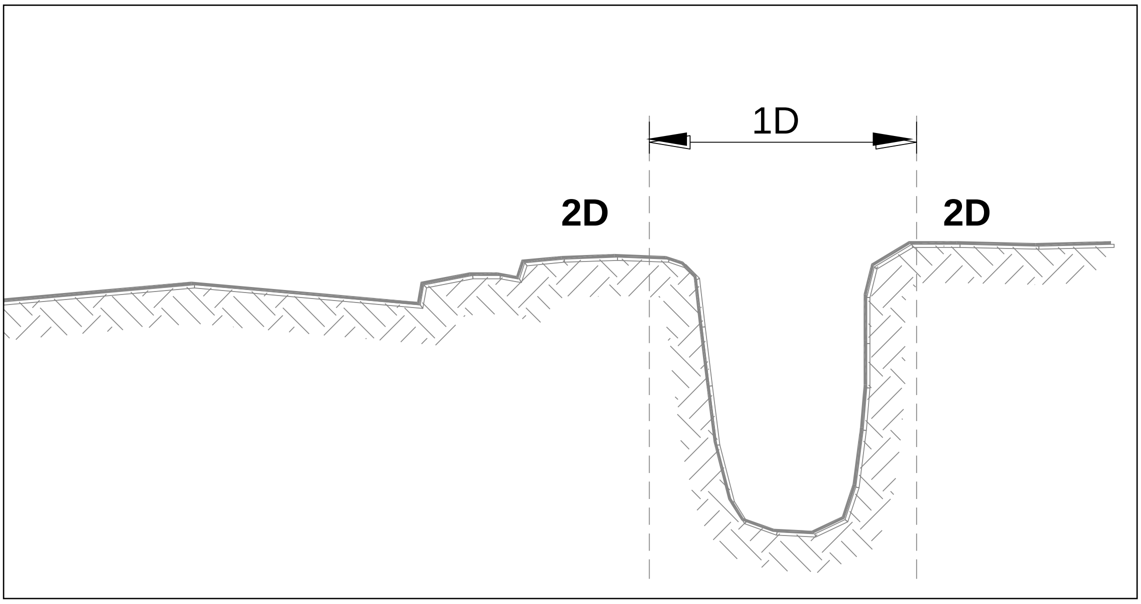


Figure 4-3 Modelling a Channel in 1D and the Floodplain in 2D

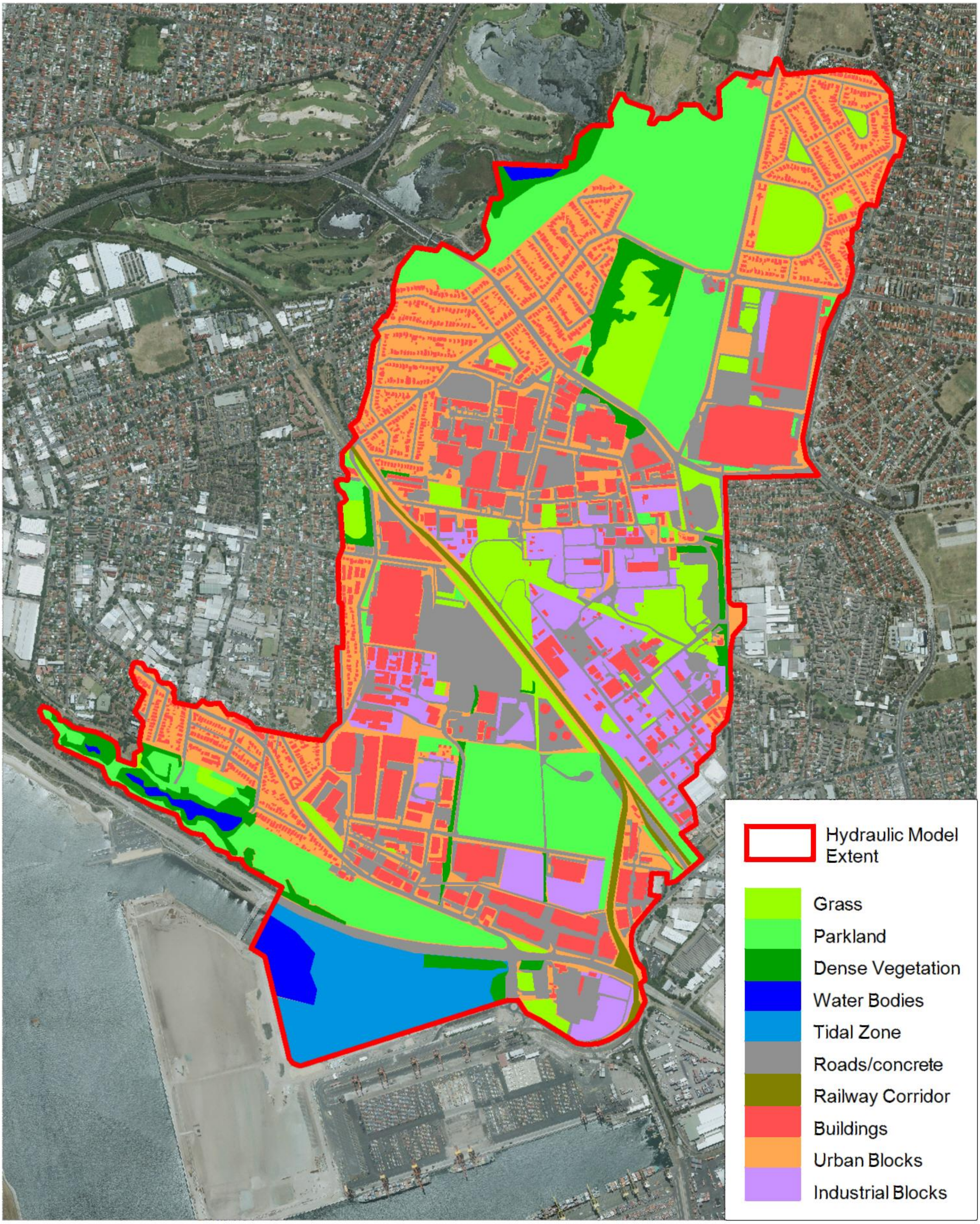
4.1.3 Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness (Manning's 'n') zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (eg. forest, cleared land, roads, urban areas, etc) for modelling the variation in flow resistance. The 2011 aerial photography supplied by Council has been used to generate the land-use surface types and roughness zones for the study area. The base land-use map used to assign the different hydraulic roughness zones across the model is shown in Figure 4-4.

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

4.1.4 Representation of Buildings

The presence of buildings may impede and divert flood flows as well as provide flood storage. In order to incorporate the effect of buildings, the footprint of all buildings has been digitised from aerial photography and included in the flood model to restrict the flow that is able to pass through each building. In general, buildings were modelled at ground level (see Section 4.1.2.1) with a flood depth-dependent Manning's 'n' hydraulic roughness value.



Title:

Land Use Map

Figure: **4-4**

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4.1.5 Stormwater Drainage Network

The study requires the modelling of the drainage system across the catchment. Information on the pit and pipe drainage network has been compiled from various sources, as discussed in Section 2.2.7, and included the additional drainage survey outlined in Section 2.4.

The review of the available stormwater drainage system found the data to be largely complete along the main drainage lines with only local gaps where survey access had not been possible. In areas where no pipe survey was available pipe size details were assumed from upstream and downstream configurations. The invert levels were interpolated between known locations, maintaining the upstream and downstream pipe gradients where appropriate. These were then cross-checked against the DEM elevations to take account of any local topographic features and to maintain minimum cover levels. A sample longitudinal profile of a modelled drainage line is shown in Figure 4-5. The figure shows the invert and obvert levels according to culvert dimensions, the ground surface level as derived from the DEM, and a minimum cover level of 600mm.

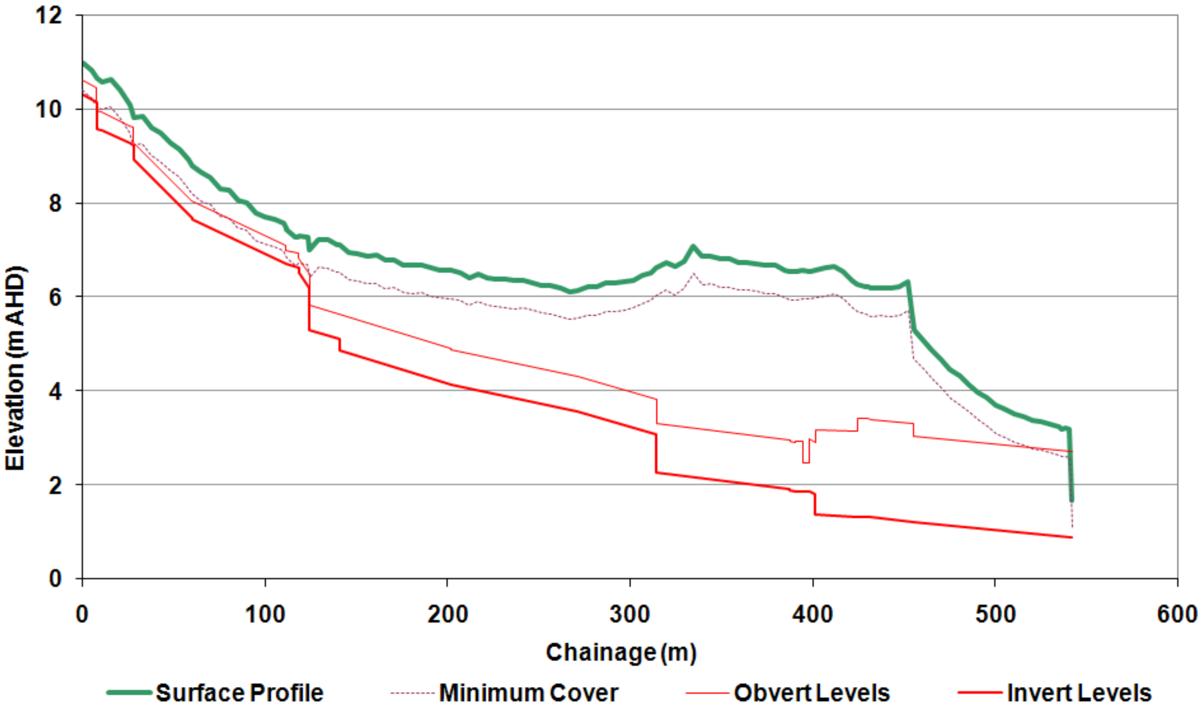

Figure 4-5 Sample Drainage Line Longitudinal Profile

For this study the entire drainage network indicated by the collected data was modelled. The study area contains a number of locations that would drain poorly without the inclusion of the pipe network. Modelling all pipes ensures that the drainage of these areas is well represented.

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

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

The pipe network, represented as a 1D layer in the model, is dynamically linked to the 2D domain at specified pit locations for inflow and surcharging, as illustrated in Figure 4-6. The modelled pipe network, which consists of around 350 pipes with a combined run length of approximately 11.45km, is shown in Figure 4-1.

Pit inlet capacities have been modelled using lintel opening lengths and grate sizes based on the collected data. Pit inlet dimensions were assumed where data was not available based on site inspections and nearby pits. Pit inlet curves have been developed for sag pit configurations based on equations from the Sutherland Shire Council (SSC) Urban Drainage Design Manual. The SSC values are based on laboratory tests by the NSW Department of Main Roads and are considered sufficiently reliable for the purpose of this study. The SSC's Urban Drainage Design Manual equations for pit inlet capacity have been used to derive a database with pit inlet curves. The pit inlet curves for a number of lintel opening and grate sizes, as applied in the TUFLOW model, are presented in Appendix D.

For the magnitude of events under consideration in the study, the pipe drainage system capacity is expected to be well exceeded with the major proportion of flow conveyed in overland flow paths. Therefore any limitations in the available data or model representation of the drainage system may not have a significant effect on flooded area for the major flood events considered.

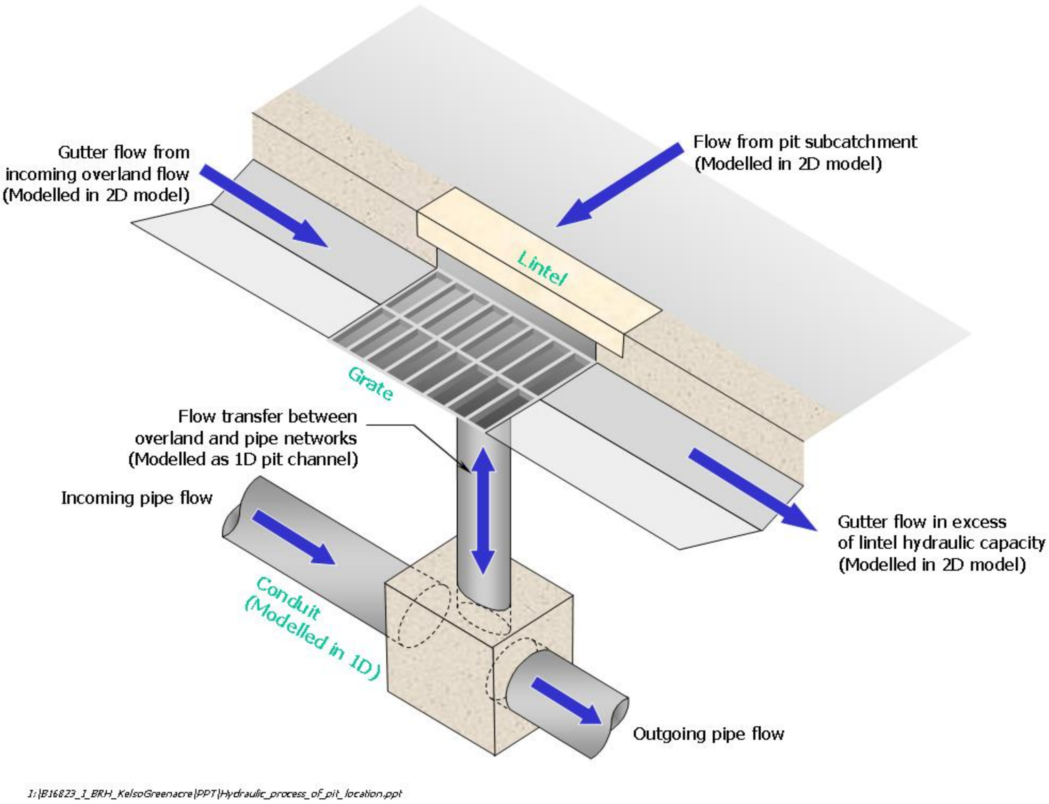

Figure 4-6 Linking Underground 1D Stormwater Drainage Network to the Overland 2D Domain

4.1.6 Structures

There are a number of culvert and bridge crossings over Springvale Drain and Floodvale Drain as illustrated in Figure 4-1. These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporating these major hydraulic structures into the hydraulic model accounts for hydraulic losses associated with these structures and their influence on flood behaviour within the catchment.

4.1.7 Boundary Conditions

The model boundary conditions are derived as follows:

- Inflow – the catchment runoff is determined through the hydrological component of the model. With the direct rainfall approach, rainfall is applied directly every cell in the hydrologic catchment extent, where it is routed as sheet flow until the runoff contribution is substantial enough to generate an overland flow path. Flow is automatically transferred to the 1D domain where sufficient pipe and inlet capacity is available. Surcharging will then occur from the 1D to the 2D domain once the pipe capacity has been exceeded.
- Downstream Water Level – the downstream model limit corresponds to the tidal water level in Botany Bay. A water level time series has been applied at this location for the duration of the modelled events.

The adopted water level boundary for the design events is discussed further in Section 6.2.

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

4.2 Hydrological Model

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

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

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

- The runoff routing and hydrological response of the catchment within the 2D model is driven by the surface type and underlying topography. Where appropriate, runoff is diverted into 1D pipe domains of the 2D/1D model (more detail is provided in Section 4.1).

- The amount and intensity of rainfall can be varied across the catchment based on available data and information. For historical events, this can be very subjective if little or no rainfall recordings exist.
- The antecedent moisture conditions are modelled by varying the amount of rainfall which is "lost" into the ground and "absorbed" by storages. For very dry antecedent moisture conditions, there is typically a higher initial rainfall loss.

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

4.2.1 Catchment Delineation

The study catchment drains an area of approximately 3.7km^2 via Springvale Drain and Floodvale Drain to Penrhyn Estuary into Botany Bay.

Discretisation of the study area into sub-catchments has not been required for this study given that rainfall is being applied directly to the 2D domain and traditional rainfall-runoff modelling is not being used. However, the delineation of the overall catchment boundary is important for defining the limits of the hydraulic model and the associated direct rainfall input. The study area catchment boundary is not clearly defined due to the presence of low points at the catchment boundaries as discussed in Section 2.1.4. During significant rainfall events these low points collect runoff which cannot be adequately drained by the formalised drainage network. The low points act as storages which can overflow to the Springvale Drain and Floodvale Drain catchment, the neighbouring catchments or both during significant rainfall events.

The hydrologic catchment boundary and the hydraulic model extent have been sufficiently extended beyond Council's defined catchment area to account for the potential interactions with the neighbouring catchments.

4.2.2 Rainfall Data

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

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

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

The procedure for defining these properties is different for historical and design events. For historical events, the recorded hyetographs at continuous rainfall gauges provide the observed rainfall depth and temporal pattern (refer to Figure 2-3 for rainfall gauge locations). Where only daily read gauges are available within a catchment, assumptions regarding the temporal pattern may need to be made.

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

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 5 with design events discussed in Section 6.1.

4.2.3 Rainfall Losses

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

The rainfall loss parameters for the historical calibration/validation events and design events are discussed in further detail in Section 5 and Section 6.1.3 respectively.

4.3 Conclusion

With consideration given to the available survey information and local topographical and hydraulic controls, a combined hydrologic and hydraulic model was developed covering the entire Springvale Drain and Floodvale Drain catchment.

This model simulates rainfall, flood depths, extents and velocities utilising the TUFLOW two-dimensional (2D) software developed by BMT WBM. This 2D modelling approach is suited to model the complex interaction between channels and floodplains and converging and diverging of flows through structures and urban environments.

The catchment and floodplain topography is defined using a high resolution digital elevation model (DEM) derived from LiDAR survey for greater accuracy in predicting flows and water levels and the interaction of in-channel and floodplain areas compared with previous studies. The underground pipe drainage network has been defined using data from previous studies and additional survey information acquired during the course of the study.

5 Model Calibration and Validation

5.1 Selection of Calibration Events

The selection of suitable historical events for calibration and validation of flood models is largely dependent on the availability of relevant historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design events to be considered.

Within the Springvale Drain and Floodvale Drain catchment there is insufficient quantity and quality of historical flood data to allow a conventional calibration of the hydrologic and hydraulic model parameters. Instead, model parameters were based on:

- typical values deemed suitable for the catchment conditions;
- validation of model results against collected historical flood data;
- comparison of model parameters and results with previous studies; and
- sensitivity testing of model parameters.

Review of the available data for the Springvale Drain and Floodvale Drain catchment highlighted two flood events with sufficient data to support a validation process – the February 2010 and February 1990 events. The February 1990 is representative of a longer duration significant rainfall event with three distinct rainfall bursts. Conversely the February 2010 is representative of a high intensity, single rainfall burst short duration significant rainfall event. The available data, modelling approach and model results for each of these events are discussed in further detail in the following sections.

Comparisons of the model parameters with previous studies are also provided in the following sections. The sensitivity testing conducted is outlined in Section 8.

5.2 February 2010 Model Validation

5.2.1 Validation Data

5.2.1.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of the Springvale Drain and Floodvale Drain catchment is shown in Figure 2-3 with their respective periods of record shown in Table 2-3. Of these rainfall gauges, 4 continuous read gauges and 2 daily read gauges were active on the 12th February 2010. The recorded daily totals (for the 24 hours to 9am) for 12th February 2010 for five of the active rainfall gauges are summarised in Table 5-1. The spatial rainfall distribution for the February 2010 rainfall event is illustrated in Figure 5-1.

The nearest rainfall gauge to the study area is a pluviograph located at Eastlakes Sports Club. The 6-minute pluviograph data from this gauge, as illustrated in Figure 5-2, was used to model the February 2010 event.

Title:
February 2010 Rainfall Distribution

Figure: 5-1

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

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Approx. Scale

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Table 5-1 Recorded Rainfall February 2010 Event

Station	Name	Operator	Type	24hr Rainfall Total (to 9am 13/02/2010) (mm)
566028	Eastlakes Sports Club	SWC	Continuous	80
566088	Malabar STP	SWC	Continuous	46
66037	Sydney Airport AMO	BoM	Continuous	14
66073	Randwick Racecourse	BoM	Daily	49
66052	Randwick Bowling Club	BoM	Daily	54

The recorded hyetographs at the three closest continuous rainfall gauges to the Springvale Drain and Floodvale Drain catchment are shown in Figure 5-2. The hyetograph period shown is 8:30pm to 10:24pm on 12th February 2010.

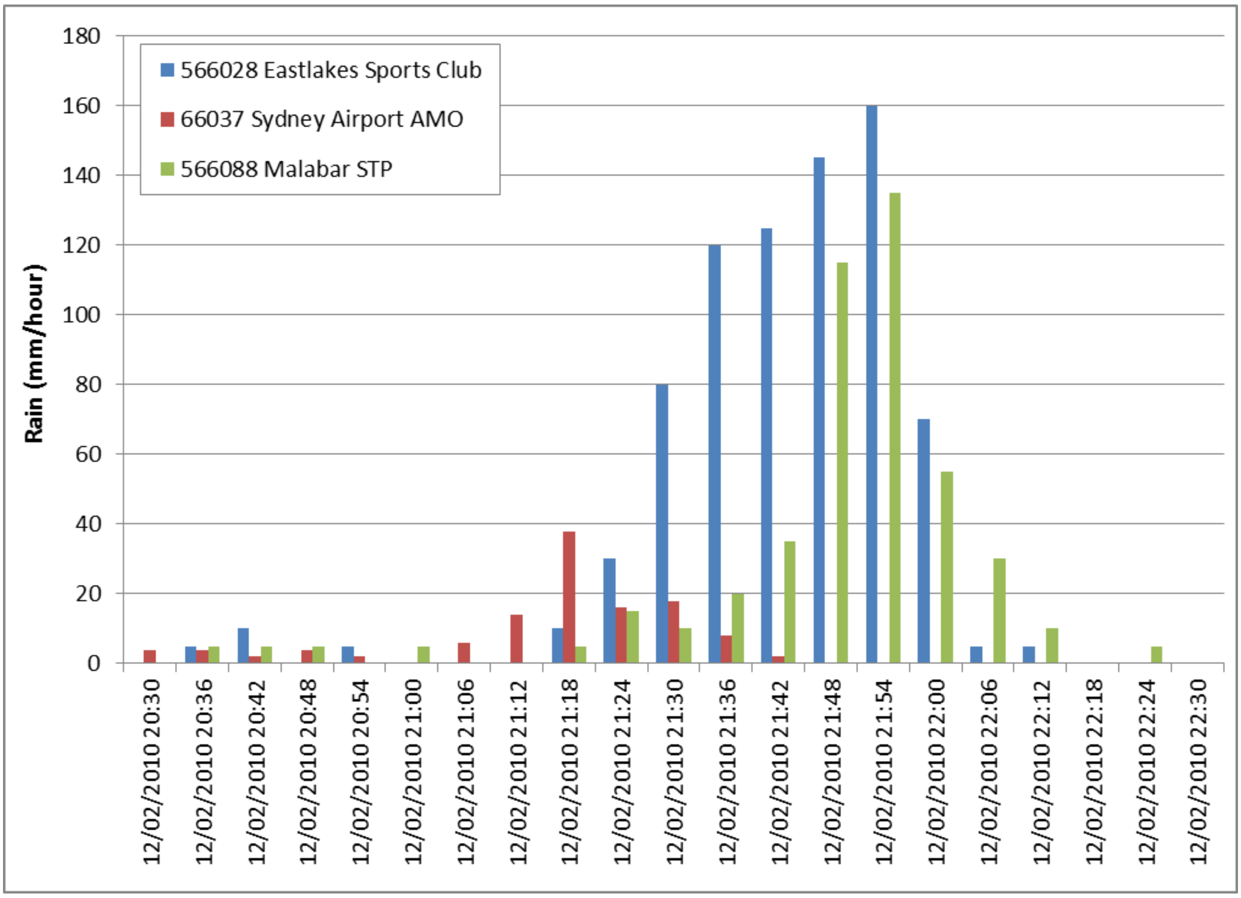


Figure 5-2 February 2010 Recorded Rainfall Hyetographs

As evidenced in the recorded hyetographs, the highest rainfall intensity was recorded at the gauge located nearest to the Springvale Drain and Floodvale Drain catchment (Eastlakes Sports Club) with the rainfall occurring as a single burst.

To gain an appreciation of the relative intensity of the February 2010 event, the recorded rainfall depths at the Eastlakes Sports Club (566028) continuous read rainfall gauge for various storm durations were compared with the design IFD data for the Springvale Drain and Floodvale Drain catchment, as shown in Figure 5-3.

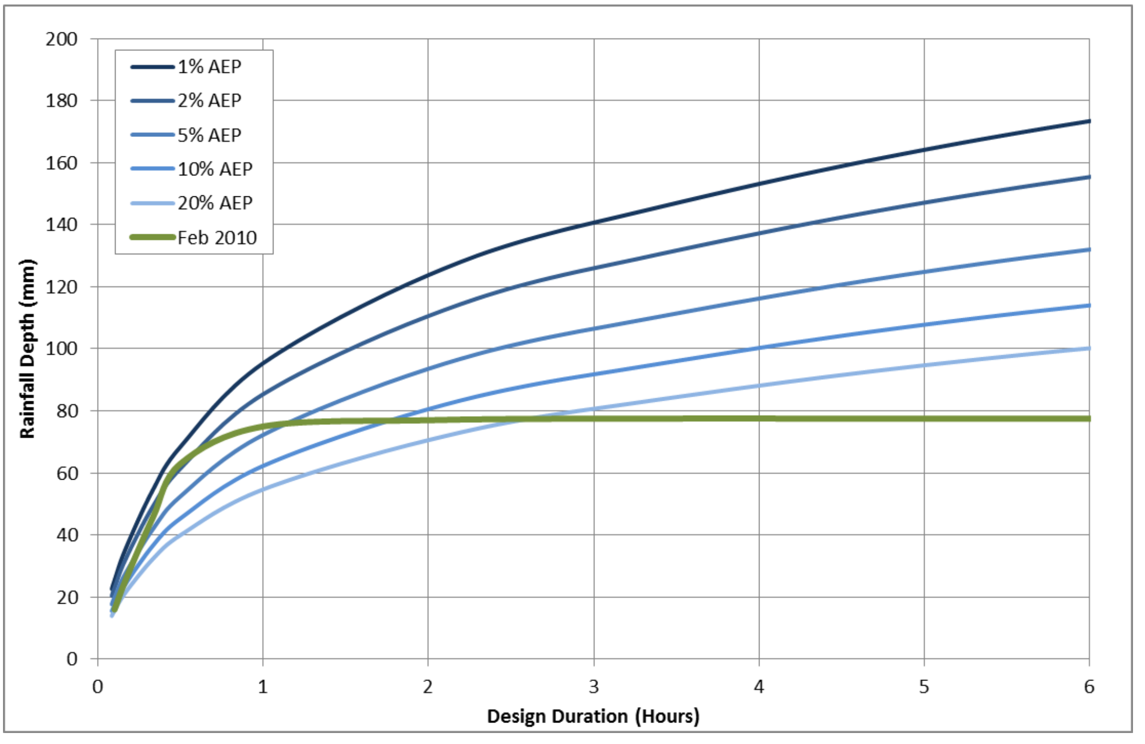


Figure 5-3 Comparison of February 2010 Rainfall with IFD Relationships

The following can be concluded about the rainfall for the February 2010 event at the Eastlakes Sports Club rainfall station:

- For a 20-min duration burst, the event compares well with the design 5% AEP (20 year ARI) event;
- For a 30-min duration burst, the event compares well with the design 2% AEP (50 year ARI) event;
- For a 1-hr duration burst, the event compares well with the design 5% AEP (20 year ARI) event.

The February 2010 rainfall event can therefore be considered to be a 5% AEP (20 year ARI) rainfall event, with bursts up to 2% AEP (50 year ARI) design intensities during the storm.

5.2.2 Downstream Boundary Condition

The downstream model limit corresponds to the water level in Botany Bay. A dynamic downstream water level boundary for the February 2010 event has been developed based on tidal predictions for Botany Bay.

Additional model boundaries have been included at a few locations where runoff will spill across the subject catchment boundary and exit the study area (i.e. to the adjacent catchment). In these instances water level versus discharge relationships have been applied in the 2D domain using assumed water surface slopes. The impact of these boundaries is insignificant in determining flood levels within the study area and so no event specific boundary conditions have been applied.

The relationship between predicted Botany Bay tide levels and recorded rainfall at the Eastlakes Sports Club for the February 2010 event is shown in Figure 5-4.

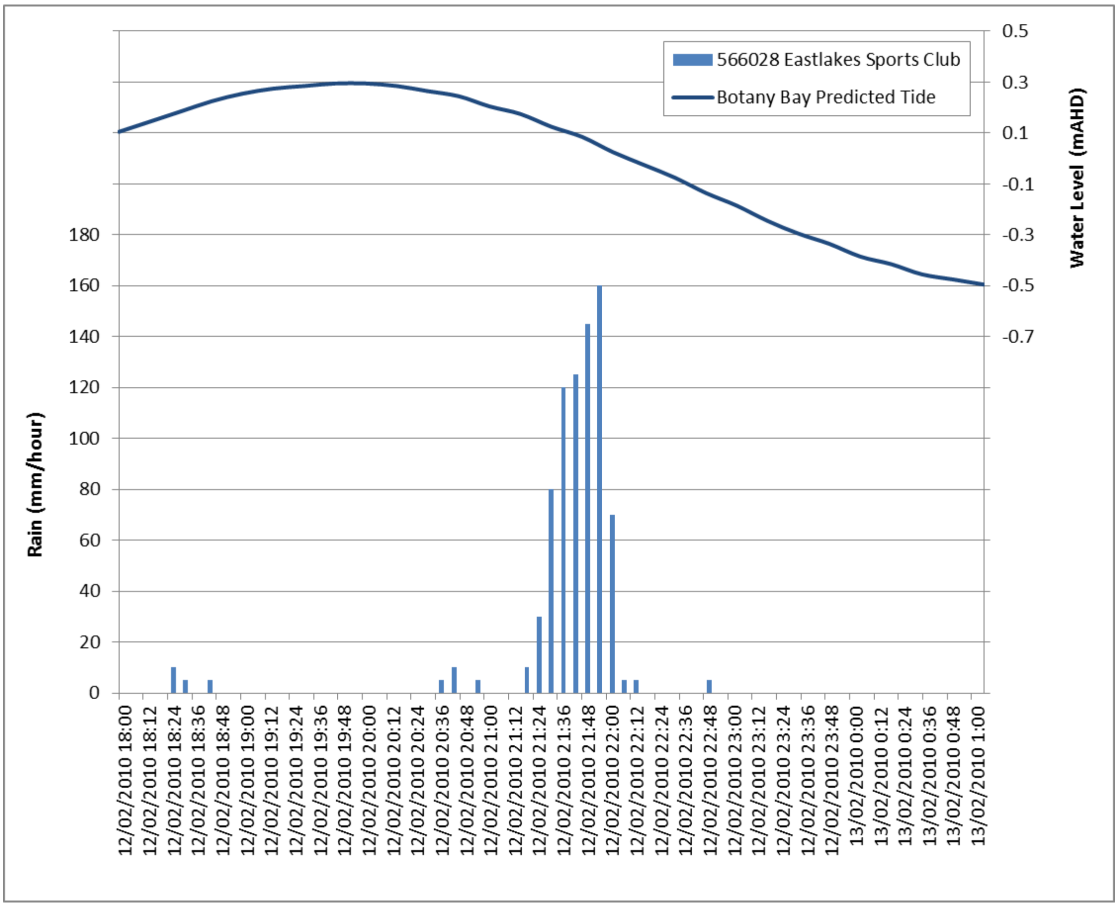


Figure 5-4 February 2010 Predicted Tide Level

5.2.3 Adopted Model Parameters

The model validation focused on the rainfall loss values (hydrological model parameters) and the hydraulic roughness Manning's n values (hydraulic model parameters). The selected parameters as outlined in the following were found to give a good result in representing the hydraulic behaviour in the Springvale Drain and Floodvale Drain catchment for the February 2010 event.

A 0% blockage factor for all stormwater drainage structures (pit inlets, pipes, culverts and bridges) has been assumed for modelling historical events. In addition the bulk earthworks design for the Southlands site discussed in Section 4.1.2 was not included in the TUFLOW model for modelling historical events.

5.2.3.1 Rainfall Losses

The initial loss-continuing loss model has been adopted in the TUFLOW model developed for the Springvale Drain and Floodvale Drain catchment. The initial loss component represents a depth of rainfall effectively lost from the system and not contributing to runoff and simulates the wetting up of the catchment to a saturated condition. The continuing loss represents the rainfall lost through soil infiltration once the catchment is saturated and is applied as a constant rate (mm/hr) for the duration of the runoff event.

Typical design loss rates applicable for NSW catchments east of the western slopes are initial loss of 10 to 35mm and continuing loss of 2.5mm/hr (Pilgrim (2001)). For pervious surfaces, an initial loss of 50mm and continuing loss of 5mm/hour were found to provide a reasonable fit to the observed hydrological behaviour in the Springvale Drain and Floodvale Drain catchment for the February 2010 event. These rates are higher than those generally recommended for design event losses in Pilgrim (2001), but are appropriate for well-draining sandy soils such as those of the Springvale Drain and Floodvale Drain catchment. Lawson and Treloar (2003) stated the infiltration capacity of the Botany Sands to be extremely high and specified pervious initial loss and continuing losses of 50 mm and 15 mm/hr respectively used for RAFTS hydrologic modelling.

Despite this high infiltration the study area is still subject to flooding from high intensity rainfall, as is evident from the February 2010 event.

The applied losses are linearly varied across the hydraulic model extent based on the impervious percentage (i.e. 100% impervious – 0mm initial and continuing loss applied) of the land use surface type as illustrated in Figure 4-4. As outlined in Section 4.1.3, the land use surface types were identified based on aerial photography and cadastral data supplied by Council. The impervious percentages applied to the various land use surface types are provided in Table 5-2.

Table 5-2 Impervious Percentage of Land Use Surface Types

Land Use	Percent Impervious
Grass (maintained)	0%
Parkland	0%
Dense vegetation	0%
Permanently wet area / water bodies	100%
Tidal inundation zone	100%
Roads, car parks, open concrete, interceptor drain	100%
Railway corridor	0%
Buildings	100%
Urban blocks	20%
Industrial blocks	90%

Sensitivity testing has been carried out on the applied rainfall losses as described in Section 8.3.

5.2.3.2 Hydraulic Roughness

Hydraulic roughness values have been applied based on the land use surface types present. Aerial photography and cadastral data was used to identify different land use surface types (eg. grass, dense vegetation, roads, urban areas, etc) across the extent of the hydraulic model. The most recent aerial photography available from 2011 has been used to delineate the land use surface type as show in Figure 4-4.

In order to accurately represent the hydraulic characteristics of the study area, a variable depth dependent hydraulic roughness value was applied in the model. For land uses such as urban blocks, railways and dense land vegetation, a higher roughness value was applied at shallow flood depths to account for increased friction losses when sheet flow occurs. For buildings, a lower roughness (smooth surface) was applied at shallow flood depths (to allow rainfall to runoff relatively unconstrained) and a higher roughness was applied at higher flood depths (to restrict overland flow through the building).

Values of the roughness coefficients have been based on industry standards (e.g. Chow, 1959 and Arcement and Schneider, 1989) and adopted values of previous TUFLOW models developed by BMT WBM. The adopted Manning's 'n' roughness coefficients for the land uses within the study area are listed in Table 5-3. For verification of the roughness coefficients a comparison was undertaken with values used in 2D hydraulic models for previous studies for the catchment and surrounding areas. The hydraulic roughness coefficients applied in previous studies are summarised in Table 5-4. Comparing roughness coefficients for the various land use types in Table 5-3 and Table 5-4 shows a close similarity in adopted roughness coefficients.

The roughness values have been subjected to sensitivity testing as discussed in Section 8.1.

Table 5-3 Adopted Manning's 'n' Roughness Coefficients in TUFLOW Model

Land Use	Manning's 'n' Depth ≤ 30mm	Manning's 'n' Depth > 100mm
Grass (maintained)	0.100	0.030
Parkland	0.100	0.040
Dense vegetation	0.100	0.090
Permanently wet area / water bodies	0.022	0.022
Tidal inundation zone	0.031	0.031
Roads, car parks, open concrete, interceptor drain	0.020	0.020
Railway corridor	0.100	0.080
Buildings	0.015	1.000
Urban blocks	0.100	0.070
Industrial blocks	0.050	0.050

Note: The Manning's 'n' values between flood depths of 30 and 100 mm are interpolated linearly

Table 5-4 Manning's 'n' Roughness Coefficients from Previous Studies

Land Use	Manning's 'n'
Connell Wagner (2007) – MIKE21	
Roads (concrete)	0.015
Roads (asphalt/gravel)	0.020
Floodplain	0.050
Grass	0.030
Thick Vegetation	0.100
Buildings (not blocked out)	0.400
WMA Water (2011) – TUFLOW	
Roads and Footpaths	0.022
Inside Fence Boundaries	0.050
Other	0.025
Parklands	0.040

5.2.4 Observed and Simulated Flood Behaviour

There are no official water level records available for calibration within the study area. Validation data were therefore derived through relevant comments and photographs from the community questionnaire responses and other available resources (see Section 2.2.3 and Section 3.4).

Comments relating to flood behaviour have been compiled and compared with modelled outputs for the February 2010 event. Although most comments received do not relate to a specific flood event, the February 2010 event is specifically mentioned on several occasions. The reliability of individual flood depth observations is highly variable and some observers will be able to better assess flood depths than others.

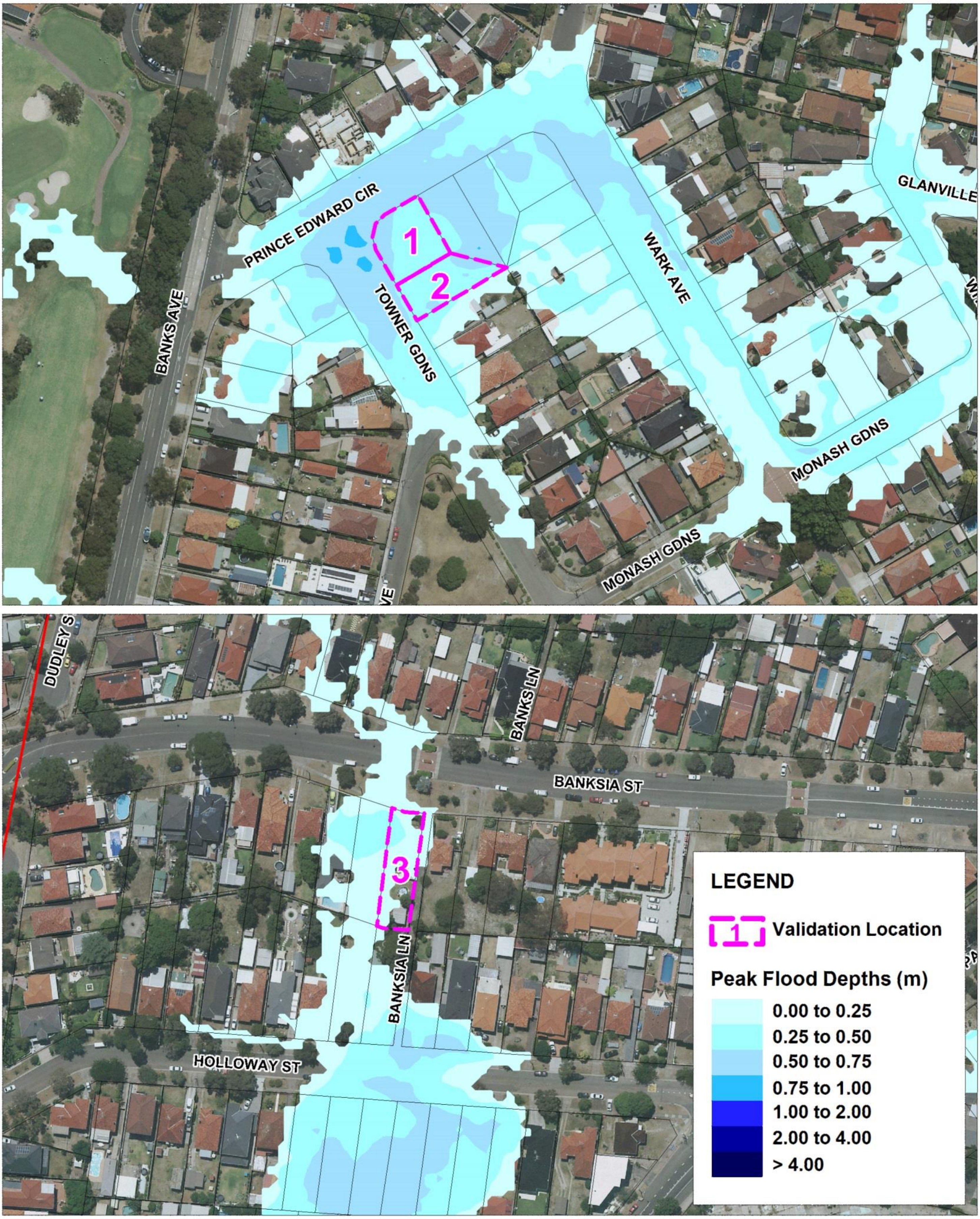
The general pattern and magnitude of flooding indicated by the model results provides a good match with the comments received from the community. A comparison of the model results against historical data and recognised flood prone locations is provided in Table 5-5 and Table 5-6. The locations of the historical data from Table 5-5 are indicated in Figure 5-5.

Table 5-5 February 2010 Validation Data

ID	Source	Approx. Location	Observed Flooding Behaviour	Modelled Flooding Depth (m)	Comment
1	Community Questionnaire	35 Towner Gardens, Pagewood	Depth at property front door = 0.30m Depth at kerb = 0.40m	0.65 0.70	-
2	Community Questionnaire	33 Towner Gardens, Pagewood	Depth at gutter = 0.40m	0.60	-
3	Community Questionnaire	153 Banksia Street, Pagewood	Depth at backyard = 0.45m	0.15	Overland flow path is blocked by property fence. Resident mentioned ponding occurs as debris blocks any gaps in fence.

Table 5-6 February 2010 Modelled Flooding at Recognised Flood Prone Locations

Location	Modelled Flooding Behaviour
Page St, Pagewood	Road inundated from Dalley Ave to Wentworth Ave (~0.5m) and near Collins St. (~0.2m)
Intersection of Park Pde and Kenny Rd, Pagewood (Southside of Jellicoe Park)	Intersection inundated (~0.3m)
Maxwell Rd, Pagewood	Intersection with Park Pde inundated (~0.2m)
Stephen Rd, Pagewood (Alongside Garnet Jackson Reserve)	Road inundated (~0.2m)
Intersection of Heffron Rd and Banks Rd, Pagewood (Roundabout)	Intersection inundated. Heffron Rd. east of intersection inundated (~0.3m). Banks Ave north of intersection inundated (~0.6m)
Towner Gardens, Pagewood	Road inundated along Towner Gdns (~0.7m), Prince Edward Cir (~0.6m) and Wark Ave (~0.5m)
Pagewood Primary School	Dudley St. inundated (~0.9m). School grounds inundated (~0.5m)
Anderson St, Pagewood	Road inundated (~0.9m)
Mutch Park, Pagewood	Tennis Courts inundated (~0.4m)
Wentworth Ave, Pagewood (outside East Gardens)	Road inundated (~0.4m) between Banks Ave and Denison St intersection.
Spring St, Pagewood	Road inundated at Dudley St. intersection (~0.2m) as well as Dudley St. (~0.4m)



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February 2010 - Validation Locations and Modelled Peak Flood Depths

Figure: **5-5**

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0 37.5 75m

Approx. Scale

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5.3 February 1990 Model Validation

5.3.1 Validation Data

5.3.1.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of the Springvale Drain and Floodvale Drain catchment was shown in Figure 2-3 with their respective periods of record shown in Table 2-3. Of these rainfall gauges 4 continuous read gauges and 2 daily read gauges were active during the February 1990 event. The recorded daily totals (for the 24 hours to 9am) for 2nd to 5th February 1990 for the five active rainfall gauges are summarised in Table 5-7. The rainfall distribution for the February 2010 rainfall event is illustrated in Figure 5-6. The closest gauge to the study area is a pluviograph located at Eastlakes Sports Club. The 6-minute pluviograph data from this gauge, as illustrated in Figure 5-7, was used to model the February 1990 event.

Table 5-7 Recorded Rainfall February 1990 Event

Station	Name	Operator	Type	24hr Total (mm) (to 9am 2/2/1990)	24hr Total (mm) (to 9am 3/2/1990)	24hr Total (mm) (to 9am 4/2/1990)	24hr Total (mm) (to 9am 5/2/1990)
566028	Eastlakes Sports Club	SWC	Continuous	48	246	206	6
66037	Sydney Airport AMO	BoM	Continuous	27	224	167	54
66073	Randwick Racecourse	BoM	Daily	15	244	-	248*
66051	Little Bay (The Coast Golf Club)	BoM	Continuous	7	-	-	219*
66052	Randwick Bowling Club	BoM	Daily	19	225	175	17

(*) – Total Rainfall since last daily recording

The record hyetographs at the two closest continuous rainfall gauges to the Springvale Drain and Floodvale Drain catchment are shown in Figure 5-7. The hyetograph period shown is 12:00am 2nd February 1990 to 12:00am 5th February 1990. The highest rainfall intensity was recorded at the gauge located nearest to the Springvale Drain and Floodvale Drain catchment (Eastlakes Sports Club) with the rainfall occurring as three distinct bursts.

To gain an appreciation of the relative intensity of the February 1990 event, the recorded rainfall depths at the Eastlakes Sports Club (566028) continuous read rainfall gauge for various storm durations were compared with the design IFD data for the Springvale Drain and Floodvale Drain catchment as shown in Figure 5-8.

The February 1990 event generally significantly exceeds the design 1% AEP (100-year ARI) rainfall depth for a 48 hour duration rainfall event. For the Eastlakes Sports Club continuous rainfall gauge the following comparisons to design rainfall depths can be made for the February 1990 event:

- 24-hr duration – 269 mm recorded compared with 281 mm design 1% AEP (100-year ARI);
- 48-hr duration – 472 mm recorded compared with 360 mm design 1% AEP (100-year ARI); and
- 72-hr duration – 495 mm recorded compared with 398 mm design 1% AEP (100-year ARI).

Title:

February 1990 Rainfall Distribution

Figure: **5-6**

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

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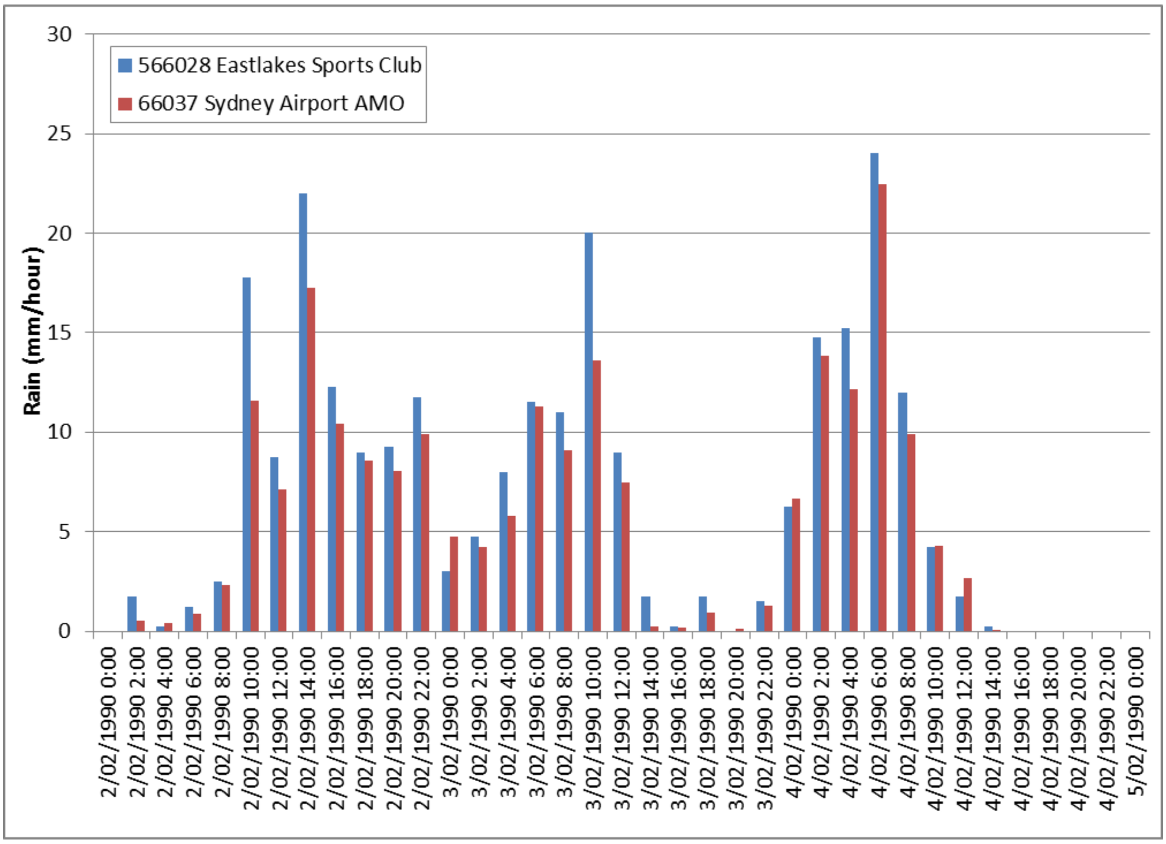


Figure 5-7 February 1990 Recorded Rainfall Hyetographs

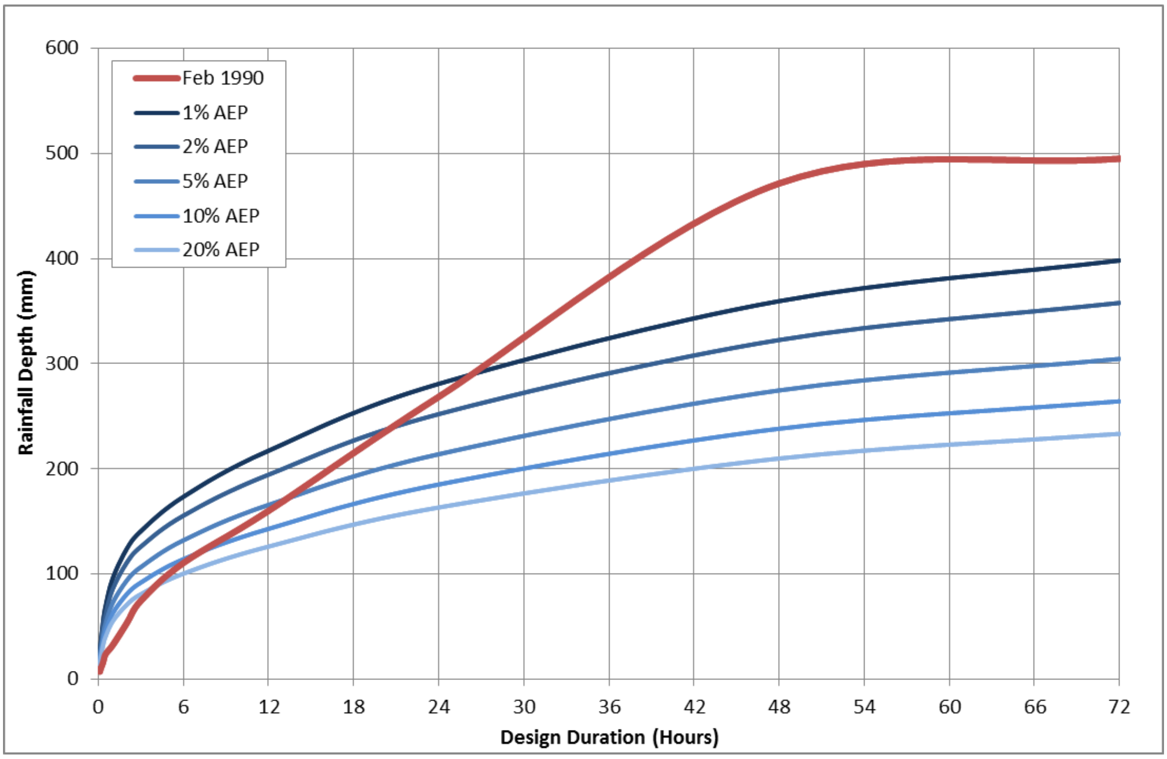


Figure 5-8 Comparison of February 1990 Rainfall with IFD Relationships

5.3.2 Downstream Boundary Condition

The downstream model limit corresponds to the water level in Botany Bay. A dynamic downstream water level boundary for the February 1990 event has been developed based on tidal predictions for Botany Bay.

Additional model boundaries have been included at a few locations where runoff will spill over the catchment boundary and exit the study area (i.e. to the adjacent catchment). In these instances water level versus discharge relationships applied in the 2D domain using assumed water surface slopes. The impact of these boundaries is insignificant in determining flood levels within the study area and so no event specific boundary conditions have been applied. The relationship between the predicted Botany Bay tide levels and recorded rainfall at the Eastlakes Sports Club for the February 1990 event is shown in Figure 5-9.

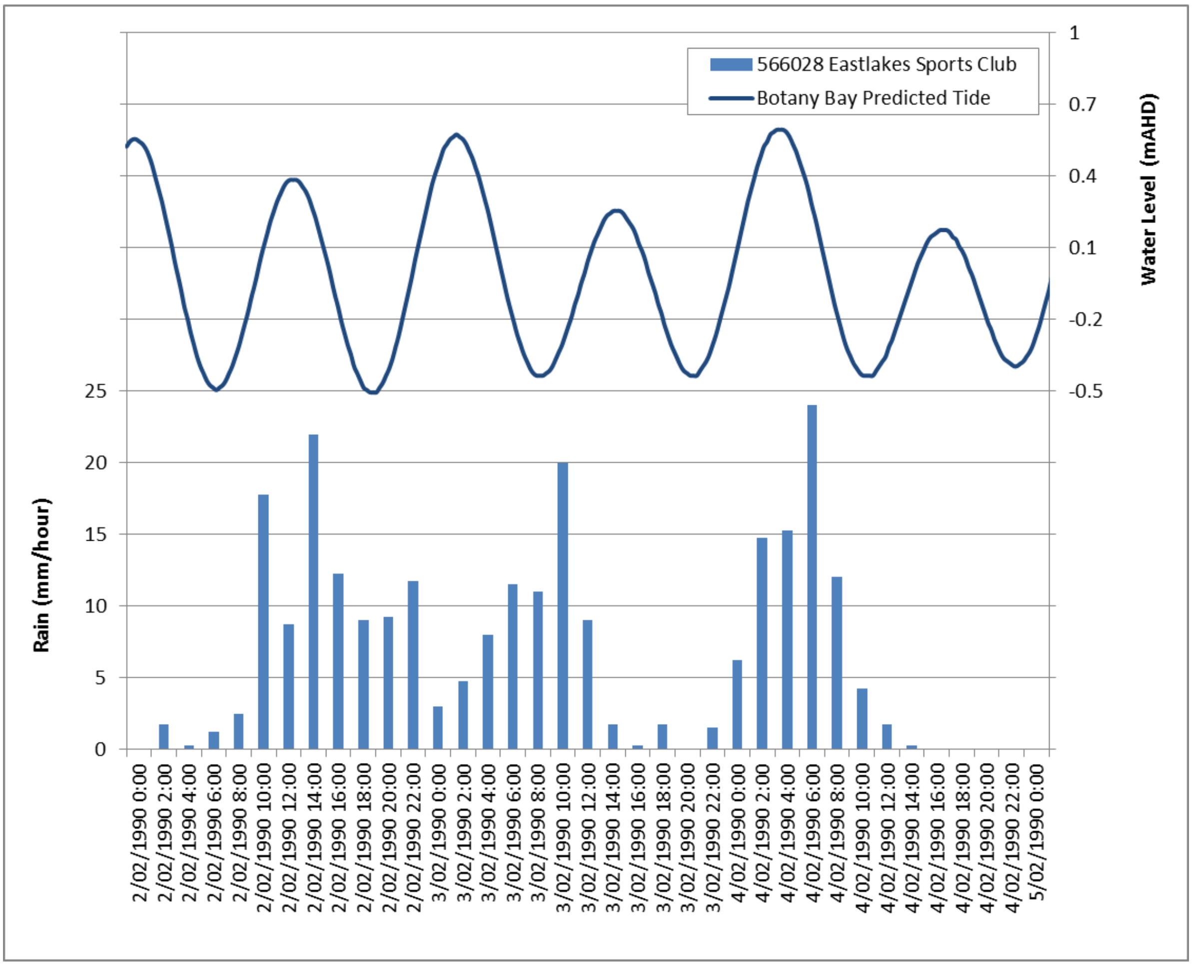


Figure 5-9 February 1990 Predicted Tide Level

5.3.3 Observed and Simulated Flood Behaviour

There are no official water level records available for calibration within the study area. Validation data were therefore derived through relevant comments and photographs from the community questionnaire responses and other available resources (see Section 2.2.3 and Section 3.4).

Comments relating to flood behaviour have been compiled and compared with modelled outputs for the February 1990 event. The community questionnaire feedback did not provide any comments relating to the February 1990 event. The Catchment Management Study (SKM, 1992) did provide comments and indicative floods levels at several locations for the February 1990 event. The reliability of individual flood depth observations is highly variable and some observers will be able to better assess flood depths than others.

The general pattern and magnitude of flooding indicated by the model results provides a good match with the comments received from the community. A comparison of the model results against historical data and recognised flood prone locations is provided as Table 5-8 and Table 5-9. The locations of the historical data given in Table 5-8 are indicated in Figure 5-10.

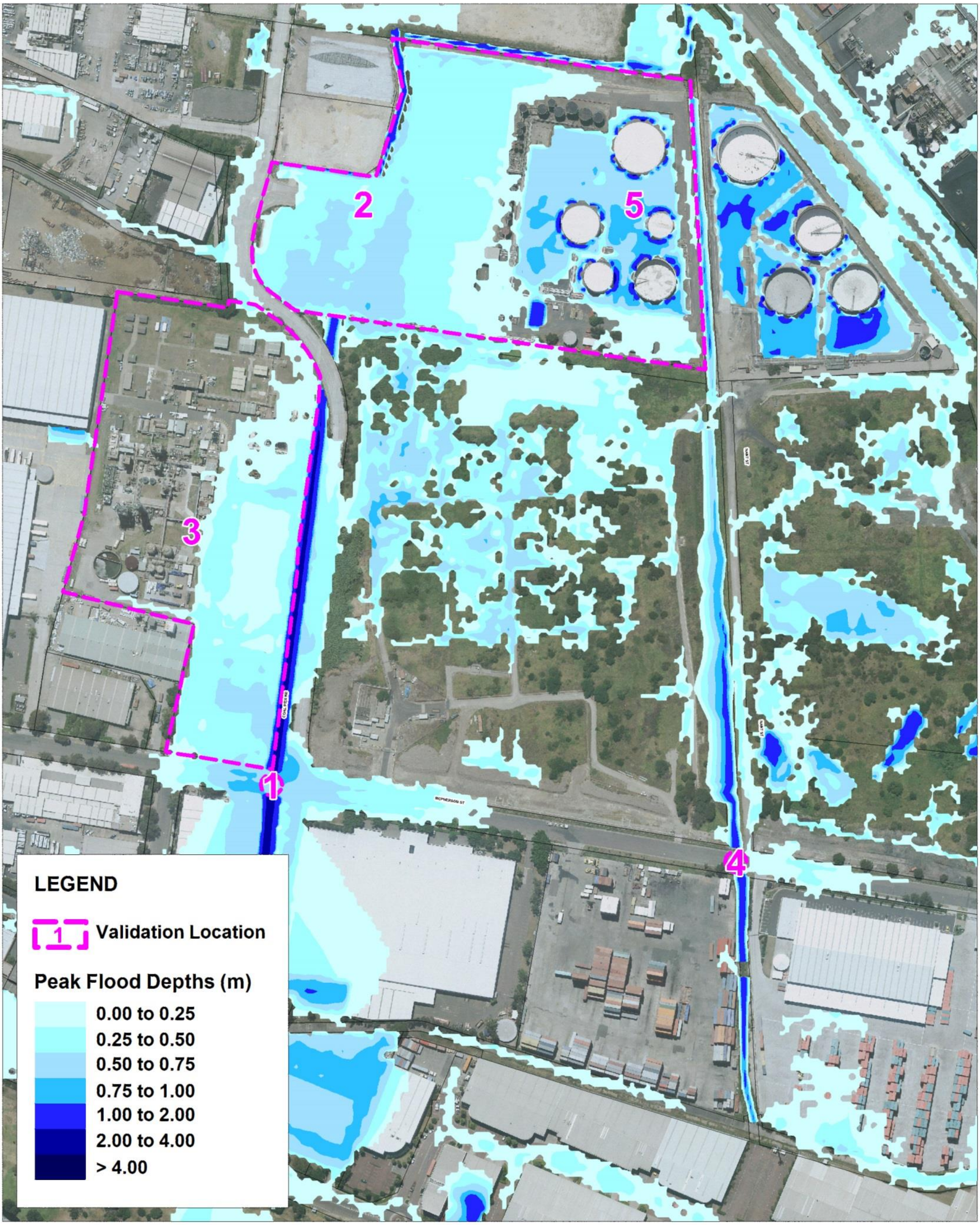
Table 5-8 February 1990 Validation Data

ID	Approx. Location	Observed Flooding Comment	Observed Flooding Behaviour	Modelled Flooding Depth (m)	Modelled Flooding Behaviour
1	McPherson St at Floodvale Drain	Overtopping of McPherson St by about 0.3 to 0.4m	Depth = 0.30-0.40m	0.70	-
2	Mobil Terminal at Floodvale Drain	Flow over the culvert through the Mobil Terminal to a depth of about 0.2m	Depth = 0.20m	0.35	-
3	Laporte Chemicals	Overtopping of the right bank of Floodvale Drain at the Laporte Chemicals property upstream of McPherson St	-	-	Indicates the right bank of Floodvale Drain overtops upstream of the McPherson St culverts inundating the neighbouring property
4	McPherson St at Springvale Drain	No flow over McPherson St or the downstream pipe culverts	-	-	Indicates the open channel does not overflow at McPherson St or downstream to the culverts
5	Mobil Terminal at Springvale Drain	Overtopping of the right bank at the Mobil Terminal	Depth = 0.50m	0.70	-

Note: All data sourced from SKM (1992)

Table 5-9 February 1990 Modelled Flooding at Recognised Flood Prone Locations

Location	Modelled Flooding Behaviour
Page St, Pagewood	Road inundated from Dalley Ave to Wentworth Ave (~1.1m)
Intersection of Park Pde and Kenny Rd, Pagewood (Southside of Jellicoe Park)	Intersection inundated (~0.2m)
Maxwell Rd, Pagewood	Minor ponding at Park Pde intersection (~0.1m)
Stephen Rd, Pagewood (Alongside Garnet Jackson Reserve)	Road inundated (~0.4m)
Intersection of Heffron Rd and Banks Rd, Pagewood (Roundabout)	Intersection inundated. Heffron Rd. east of intersection inundated (~0.6m). Banks Ave north of intersection inundated (~0.9m)
Towner Gardens, Pagewood	Road inundated along Towner Gdns (~0.8m), Prince Edward Cir (~0.7m) and Wark Ave (~0.6m)
Pagewood Primary School	Dudley St. inundated (~1.5m). School grounds inundated (~1.2m)
Anderson St, Pagewood	Road inundated (~0.8m)
Mutch Park, Pagewood	Tennis Courts inundated (~0.9m)
Wentworth Ave, Pagewood (outside East Gardens)	Road inundated (~0.4m) between Banks Ave and Denison St intersection.
Spring St, Pagewood	Dudley St inundated (~0.6m)



Title:

February 1990 - Validation Locations and Modelled Peak Flood Depths

Figure: 5-10

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Approx. Scale

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5.3.4 Comparison with Previous Studies

The February 1990 flood event has previously been modelled for the catchment as part of the SKM (1992) and Lawson and Treloar (2003) studies outlined in Section 2.2.2.

A comparison of the model results from the current and previous studies for the February 1990 flood event has been made as summarised in Table 5-10. The peak flood discharges have been compared at applicable locations generally in the lower catchment.

The comparison indicates that the peak flood discharges for the current study are comparable for Floodvale Drain and slightly lower for Springvale Drain than those of the previous studies. The variation in the peak flood discharges between the current and previous flood studies may be attributed to the following factors:

- Differences in modelling approach and software;
- Differences in topographical data sets;
- Differences in applied rainfall;
- Differences in applied downstream tide levels; and
- Catchment land use changes.

Comparison between the current flood study results and those of previous studies is further discussed in Section 7.3.

Table 5-10 Comparison of Peak Discharges of February 1990 Event to Previous Studies

Location	1% AEP Peak Flood Discharges (m^3/s)	
	Current Study	Previous Flood Study
Floodvale Drain		
McPherson Street	8.2	7.2[b]
Botany Road	8.3	7.0[a] 7.6[b]
Outlet	7.1	7.7[b]
Springvale Drain		
McPherson Street	6.9	12.1[a]
Penrhyn Road	8.5	9.0[a]
Outlet	11.1	13.1[b]

(a) Catchment Management Study Floodvale & Springvale Drains, Botany (SKM,1992)

(b) Proposed Expansion of Container Port Facilities in Botany Bay, NSW – Hydrologic and Hydraulic Studies (Lawson and Treloar, 2003) - RAFTS Results

5.4 Conclusion

The selection of suitable historical events for calibration of the hydrodynamic model is largely dependent on available historical flood information. The Springvale Drain and Floodvale Drain catchment is ungauged and accordingly there are no available data for streamflow calibration. Calibration and validation of the model has therefore relied on replicating the general pattern and magnitude of flooding throughout the catchment for the February 1990 and February 2010 events.

A reasonable model calibration has been achieved given the available data for the catchment. The developed models are thus considered to provide a sound representation of the flooding behaviour of the catchment, as demonstrated through comparison of observed peak water depths and flooded locations for the historical events simulated.

6 Design Flood Conditions

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

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

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

Table 6-1 Design Flood Terminology

ARI[1]	AEP[2]	Comments
200 years	0.5%	A hypothetical flood or combination of floods which represent the worst case scenario likely to occur on average once every 200 years
100 years	1%	As for the 0.5% AEP flood but with a 1% probability or 100 year return period
50 years	2%	As for the 0.5% AEP flood but with a 2% probability or 50 year return period
20 years	5%	As for the 0.5% AEP flood but with a 5% probability or 20 year return period
10 years	10%	As for the 0.5% AEP flood but with a 10% probability or 10 year return period
5 years	20%	As for the 0.5% AEP flood but with a 20% probability or 5 year return period
Extreme Flood/PMF[3]		A hypothetical flood or combination of floods which represent an extreme scenario

1 Average Recurrence Interval (years)
2 Annual Exceedance Probability (%)
3 PMF (Probable Maximum Flood) is not necessarily the same as an Extreme Flood

The design events simulated include the PMF event, 0.5%, 1%, 2%, 5%, 10%, and 20% AEP events for catchment derived flooding and the Mean High Water Springs (MHWS) and Highest Astronomical Tide (HAT) tides for ocean/tidal derived flooding. The 1% AEP flood is generally used as a reference flood for land use planning and control.

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

6.1 Design Rainfall

Design rainfall parameters have been derived using standard procedures defined in Pilgrim (2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for the Springvale Drain and Floodvale Drain catchment is presented herein.

6.1.1 Rainfall Depths

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in Pilgrim (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is “the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year” (Pilgrim (2001)). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years and is beyond the “credible limit of extrapolation”. That is, it is not possible to use rainfall depths determined for the more frequent events (eg 1% AEP) to extrapolate the PMP. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology. The method is appropriate for durations up to 6 hours and considered suitable for small catchments in the Botany region.

A range of storm durations from 15 minutes to 72 hours were modelled in order to identify the critical storm duration for design event flooding in the catchment. Table 6-2 shows the average design rainfall intensities based on Pilgrim (2001) adopted for the modelled events.

Due to the relatively small size of the catchment and adopting a conservative approach, no areal reduction factor was applied in this study. The areal reduction factor takes into account the unlikelihood that larger catchments will experience rainfall of the same design intensity (eg 1% AEP) over the entire area.

Table 6-2 20% to 1% AEP & PMP Design Events Rainfall Intensities (mm/h)

Duration (hours)	Design Event Frequency						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMP
0.25	110	124	142	166	184	208	600
0.50	80	91	105	123	137	156	460
0.75	65	73	85	100	112	128	387
1.00	55	62	72	85	95	109	330
1.50	43	49	56	67	75	85	287
2.0	35	40	47	55	62	71	250
3.0	27	31	36	42	47	54	200
4.5	20	23	27	32	35	n/a	n/a
6.0	17	19	22	26	29	33	135
9.0	13	14	17	20	22	n/a	n/a
12	11	12	14	16	18	n/a	n/a
18	8.1	9.2	11	13	14	n/a	n/a
24	6.8	7.7	8.9	10	12	n/a	n/a
30	5.9	6.7	7.8	9.1	10	n/a	n/a
36	5.3	6.0	6.9	8.1	9.1	n/a	n/a
48	4.4	5.0	5.7	6.7	7.5	n/a	n/a
72	3.2	3.7	4.2	5.0	5.5	n/a	n/a

6.1.2 Temporal Patterns

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

For frequent, large and rare design flood events including the 20% to 0.5% AEP events, design temporal rainfall patterns from Pilgrim (2001) for temporal zone 1 have been adopted. For the PMF event, the temporal pattern as provided in BoM (2003) was used.

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

6.1.3 Rainfall Losses

The following initial and continuing rainfall losses were applied to pervious areas of the catchment:

- 20% to 0.5% AEP events – an initial loss 50mm and a continuing loss of 5mm/hr; and
- PMF event - an initial loss 0mm and a continuing loss of 1mm/hr.

The rainfall losses adopted for the 20% to 0.5% AEP design events PMF were the same as those used for model verification as outlined in Section 5.2.3. The rainfall losses applied to the PMF event were applied as per Pilgrim (2001) recommendations and in line with Lawson and Treloar (2003).

The applied losses are linearly varied across the hydraulic model extent based on the impervious percentage (i.e. 100% impervious – 0mm initial and continuing loss applied) of the land use surface type as illustrated in Figure 4-4. As outlined in Section 4.1.3, the land use surface types were identified based on aerial photography and cadastral data supplied by Council. The impervious percentages applied to the various land use surface types are provided in Table 5-2.

6.1.4 Critical Storm Duration

A series of model runs were carried out in order to identify the critical storm duration for the Springvale Drain and Floodvale Drain catchment. Standard durations from the 15-minute to the 72-hour events were simulated utilising the design temporal patterns from Pilgrim (2001).

No single critical storm duration was found for the study area, but rather, the critical duration varies across the catchment. Some regions of the catchment are affected more by the total volume produced in a given rainfall event, particularly in trapped low points. The variation in critical storm duration is discussed further in Section 7.1.2.

6.2 Design Ocean Boundary

A normal ocean boundary, representative of a mean spring tide condition for Botany Bay has been adopted for the catchment derived deign flood events as shown in Figure 6-1 in accordance with Section 7.5 of the Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments (DECCW, 2010). The timing of the 0.6m AHD peak water level was adjusted to coincide with the peak catchment inflow for the range of rainfall event durations. A fixed tide level was used to apply the mean high water springs and highest astronomical tide levels for the tidal inundation modelling.

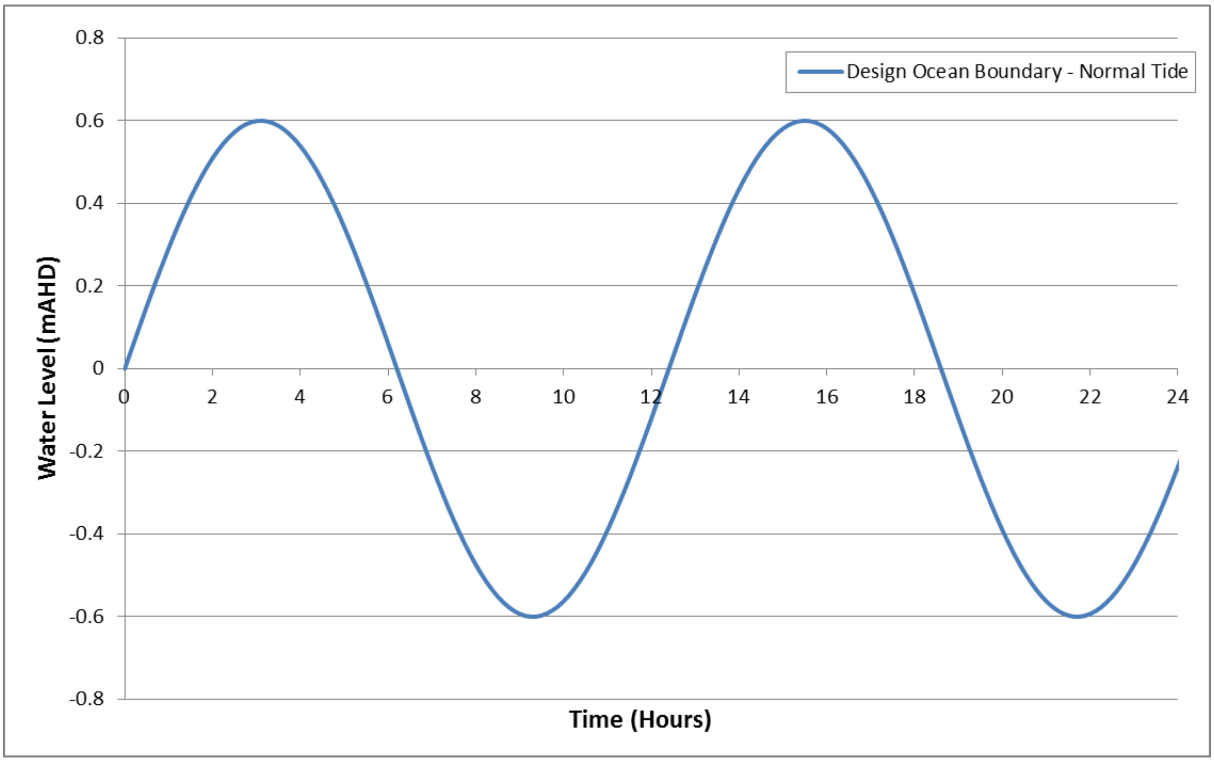


Figure 6-1 Design Ocean Boundary – Normal Tide

6.3 Modelled Design Events

A suite of design event scenarios were defined that are most suitable for future floodplain management planning in Springvale Drain and Floodvale Drain catchment. Consideration has been given to design flood events driven by both catchment and ocean processes. In addition the potential impact of climate change on flood behaviour within the Springvale Drain and Floodvale Drain catchment has been considered as discussed in Section 9.

6.3.1 Catchment Derived Flood Events

A range of design events were defined to model the behaviour of catchment derived flooding within the Springvale Drain and Floodvale Drain catchment including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events. The catchment derived flood events were based on the following:

- Design rainfall parameters derived from standard procedures defined in Pilgrim (2001);
- A normal ocean boundary representative of a mean spring tide condition for Botany Bay for the downstream boundary; and

- Applying a 0% and 50% blockage factor to all drainage structures (pit inlets, pipes, culverts and bridges).

6.3.2 Tidal Inundation

The current tidal inundation was investigated by applying varying downstream boundary levels in Penrhyn Estuary whilst applying no rainfall in the hydraulic model. The tidal inundation events modelled included:

- Mean high water springs level;
- Highest astronomical tide level; and
- Applying a 0% blockage factor to all drainage structures (pit inlets, pipes, culverts and bridges).

6.4 Conclusion

Design flood conditions have been simulated by generating design rainfall and tidal conditions for the Springvale Drain and Floodvale Drain catchment. Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in Pilgrim (2001). A range of storm durations were modelled (using standard Pilgrim (2001) temporal patterns) in order to capture the worst-case flooding in the catchment, and critical storm durations were identified.

7 Design Flood Results

A range of design flood events were modelled, the results of which are presented and discussed below. The simulated design events included the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events for catchment derived flooding and the mean high water springs (MHWS) tide level and highest astronomical tide (HAT) level for the tidal inundation mapping. A series of design flood maps for these events is provided in Appendix A.

A range of design event storm durations have been simulated for each event. The design results presented in the remainder of the report represent the maximum values across all durations for each design event simulated.

7.1 Peak Flood Conditions

7.1.1 Flooding Behaviour

7.1.1.1 Overview

Section 2.1 provides a general overview of the layout of the drainage network infrastructure and major flow paths. The trunk drainage network formed by Springvale Drain and Floodvale Drain comprises predominantly pipe reaches in the upper catchment (north) and open channel reaches in the lower catchment (south). Overland flow is significant to flooding throughout the catchment with overland flow paths generally following a similar route to the formalised drainage network. This includes flow through residential and industrial properties as well along roadways which is more typical to urban environments. With flows through residential properties the impact of residential fences on flood depths and extents may be significant with the potential to impeded and divert flows.

Inter-catchment flow between the two main drains occurs at Anderson Street and the Mobil site interceptor drain. External catchment flows are also present due to ponding of trapped low points at Prince Edward Circle / Towner Gardens, Pagewood, Corish Circle, Eastgardens, Pagewood Public School and Botany Golf Course.

The design event modelling indicates the formalised drainage network is typically at capacity during a 20% AEP (5-year ARI) event without blockage factors being applied.

7.1.1.2 Upper Springvale Drain

The upper catchment of Springvale Drain commences within the residential area near Wark Avenue in Pagewood. During rainfall events the trap low point connecting Prince Edward Circle, Towner Gardens and Wark Avenue, located to the north of the study area, collects runoff which may overflow south to the catchment via Banks Ave and draining to Boonie Doon Golf Course. This overflow route is the initial overflow path for this trap low point with the design event modelling indicating the overflow may occur as early as a 20% AEP event.

The Springvale Drain formalised pipe and pit drainage network commences along Banks Avenue and Park Parade converging at the Banks Avenue/ Heffron Road intersection where ponding across the roadway north of the intersection is expected as the drainage network is near capacity at a 20% AEP event. Properties likely to be impacted by flooding are located east of this area, predominantly on Banks Avenue and Park Parade.

Flows from this area of the catchment drain west via Bonnie Doon Golf Course then south to Wentworth Avenue via Mutch Park. The open spaces in Mutch Park, and to a lesser degree Bonnie Doon Golf Course, provide significant flood storage.

Runoff from the area surrounding the Wentworth Ave/ Page St intersection drains to the trapped low point adjacent to Pagewood Primary School on Dalley Avenue. Properties likely to be impacted by flooding are located along Dalley Ave bordering the school and north along Page Street. During events in excess of the 20% AEP event this significant ponding area may back up to Wentworth Ave with the potential for the ponded water to drain north to Eastlakes Golf Club.

From Wentworth Ave the formal drainage network continues south along Baker Street to Anderson Street. Runoff in excess of the Springvale Drain and Floodvale Drain drainage networks drain to the low point along Anderson Street potentially impacting industrial properties to the immediate south.

Springvale Drain continues as a constructed earth lined open channel with several crossover culverts from Anderson Street south to the rail line. The design event modelling indicates the capacity of the open channel is generally sufficient for events up to the 1% AEP.

Botany Industrial Park in the area appears to have little formalised drainage with minor ponding apparent across the site, particularly on roadways, from the 20% AEP event.

7.1.1.3 Upper Floodvale Drain

Floodvale Drain commences within the residential area at Bay Street in Pagewood with both the underground network and overland path draining generally in a southerly direction through residential properties crossing Banksia Street to Holloway Street and Gibson Street. A topographical low point results in ponding at and between Holloway Street and Gibson Street from the 20% AEP event with the ponded water expanding predominantly northward with larger rainfall events. Properties likely to be impacted by flooding are those at the low point between Holloway Street and Gibson Street.

Floodvale Drain continues south-west along Page Street to Dudley Street where inundation of the road is expected to occur before crossing Spring Street. Properties likely to be impacted by flooding are those along this section of Dudley Street and in particular those directly south across Spring Street.

From the Dudley Street/Spring Street intersection Floodvale Drain continues south to Ocean Street reaching Anderson Street where excess flows may pond in the low point with those from the upper Springvale Drain catchment, potentially impacting industrial properties to the immediate south. Floodvale Drain then continues south crossing the rail line.

7.1.1.4 Rail Line and Interceptor Drain

Both drainage lines flow south crossing the rail line, Floodvale Drain via an underground pipeline discharging to the interceptor drain and Springvale Drain from the constructed open channel to a poorly formed minor drainage line via several culverts.

There is the potential for some flood storage north of the rail line however this is reduced due to the presence of several additional culverts spaced along a 650m length on the rail line. Overland flow is expected to cross the rail line from a 20% AEP event, initially near the Mobil site to the south. Overland flow from the rail culverts, including Springvale Drain, follows the alignment of the rail line draining south from Floodvale Drain and north from the Mobil site to the intersection of Springvale Drain and the interceptor drain. Initially these flows then drain south via Springvale Drain through the Mobil site, along with a portion of the flow from Floodvale Drain which flows east from the interceptor drain. With increased runoff the flows from the rail line also drain to the interceptor drain forcing a change in the flow direction within the drain. With the interceptor drain now flowing to the west the runoff drains south via the Floodvale Drain constructed open channel.

7.1.1.5 Lower Springvale Drain

From the north of the Mobil site a constructed vegetated channel forms Springvale Drain from an initial culvert draining south through the Mobil and Southlands sites to McPherson Street. The Mobil site is expected to experience inundation from the 20% AEP event due to the depressed and/or bunded topography of the site. This may be further exacerbated by overflow from the interceptor drain/Springvale Drain intersection during larger flood events expected to be in the order of the 5% AEP flood event.

With the proposed Southlands development the existing section of the Southlands open channel reach will be widened. The bulk earthworks for the Southlands site also involve creating a wide linked channel along the northern boundary of the site from Springvale Drain to Floodvale Drain as well as an offline detention basin for flood storage located east of Springvale Drain. As mentioned in Section 4.1.2 these bulk earthworks designs have been incorporated into the current flood study TUFLOW model. At the commencement of rainfall events, the Southlands detention basin collects and drains runoff from the surrounding area to Springvale Drain. During the 20% AEP event Springvale Drain is expected to overflow to the detention basin, via a dedicated low point in the left bank, thereby making use of the Southlands site for flood storage.

Springvale Drain continues as an open channel crossing McPherson Street via several culverts to the SWSOOS No.2. Inundation of McPherson Street at Springvale Drain is expected at a 20% AEP event however this is as a result of runoff from the local sub-catchment draining to a low point in the road east of the culverts and not as a result of overflow from Springvale Drain. During larger flood events overflows from Springvale Drain would be expected to contribute to inundation along McPherson Street.

From the SWSOOS No.2 Springvale Drain drains south via an underground pipe network through Discovery Business Park crossing Botany Road and discharging to a concrete open channel. The industrial properties in the area may experience ponding from a 20% AEP flood event due to the impervious nature of the largely concreted surfaces. However this may be reduced if adequate onsite drainage is present. During a PMF event overflow from Springvale Drain is expected to inundate Botany Road.

Downstream of Botany Road Springvale Drain flows via the tidally influenced open channel to the west crossing Penrhyn Road via several culverts before discharging to Penrhyn Estuary.

7.1.1.6 Lower Floodvale Drain

From the interceptor drain Floodvale Drain continues southward initially as a constructed open channel before crossing the remainder of the Mobil site via a culvert approximately 100m in length. A large portion of the Mobil site is expected to be inundated in this area from the 20% AEP flood event as a result of overflow from Floodvale Drain as well as collected runoff from the surrounding area.

The culvert discharges at the boundary of the Mobil site with Floodvale Drain continuing south as a vegetated open channel crossing Port Feeder Road Bridge, McPherson Street and the SWSOOS No.2 to Botany Road. Floodvale Drain is expected to overflow from the open channel in a 20% AEP flood event. Overflow is initially expected to occur over the McPherson Street culvert, followed by the left bank upstream of the SWSOOS No.2 and right bank upstream of McPherson Street. At the 10% AEP flood event Floodvale Drain is expected to overflow to Botany Road. In larger events Floodvale Drain may overflow to Botany Road and drain west to Botany Golf Course. Botany Golf Course provides significant flood storage for the neighbouring catchment as well as any Floodvale Drain overflow. During a PMF event overflow from Floodvale Drain is expected to inundate Foreshore Road.

The industrial properties in the area may experience ponding from a 20% AEP flood event due to the impervious nature of the largely concreted surfaces. However this may be reduced if adequate onsite drainage is present. The low lying property on the left bank at Botany Road (No. 1767-1771) is expected to be particular prone to flooding from Floodvale Drain.

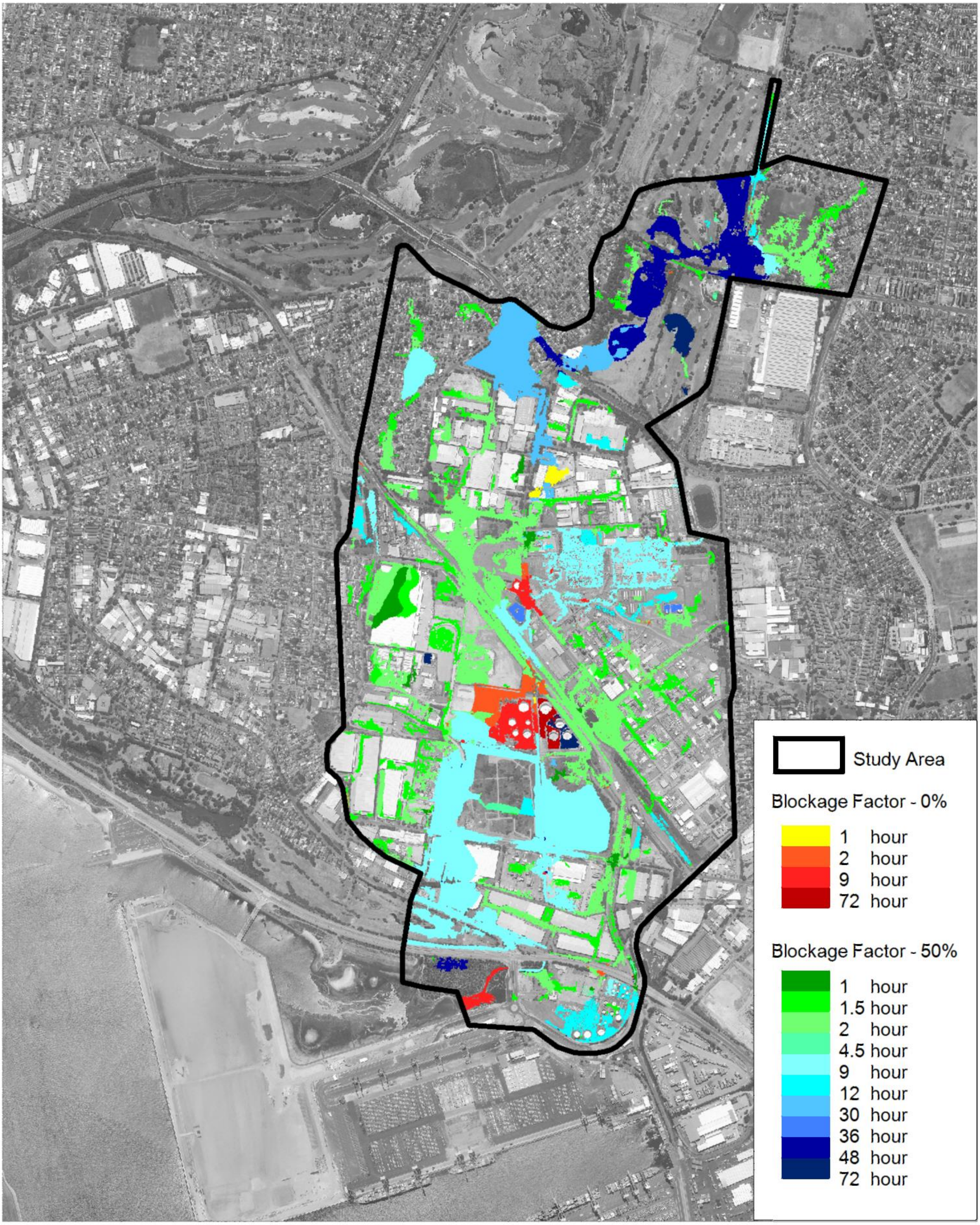
7.1.2 Catchment Derived Flood Events

A range of design event durations have been simulated with a 0% and 50% drainage network blockage factor to determine the critical duration for flooding throughout the study area. Across the majority of the study area the model simulations indicated the 50% blockage factor produced the peak water level. Areas where the unblocked (or 0% blockage factor) produced the peak water level include Mutch Park and Springvale Drain in the vicinity of the rail line.

In general the critical duration varies across the study area from 2-hours to 48-hours for the 1% to 20% AEP, 2-hours to 6-hours (which was the longest duration considered for the AEP) for the 0.5% AEP and 15 minutes to 3-hours for the PMF. The critical duration producing the peak water level for the 1% AEP is illustrated in Figure 7-1, highlighting the spatial variation in critical duration across the study area.

The design flood results are the maximum condition for all of the modelled durations with a 0% and 50% blockage factor. The design flood results are presented in a flood mapping series in Appendix A (Figures A-1 to A-21). For the simulated design events including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events, a map of peak flood level, depth and velocity is presented covering the study area.

Predicted flood levels at selected locations are provided in Table 7-1 and illustrated as longitudinal profiles in Figure 7-2 and Figure 7-3 for the full range of design event magnitudes considered. The locations of reported flood levels and the alignment of the flood longitudinal profiles are indicated in Figure 7-4.



Title:

Critical Duration for the 1% AEP Event

Figure: 7-1

Rev: A

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Approx. Scale

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Table 7-1 Modelled Peak Flood Levels for Catchment Derived Design Events

Location	Modelled Peak Flood Level (m AHD)						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMP
Botany Golf Club	3.5	3.5	3.6	3.6	3.7	3.7	4.5
Botany Rd	3.6	3.6	3.7	3.8	3.9	3.9	4.5
McPherson St - Floodvale Drain	3.7	3.8	3.9	3.9	4.0	4.0	4.9
McPherson St - Springvale Drain	-	3.8	3.9	4.0	4.1	4.1	4.9
Southlands Site - McPherson St	3.7	3.8	3.9	4.0	4.1	4.1	4.9
Anderson St	7.6	7.6	7.7	7.7	7.7	7.8	8.2
Stephen Rd	12.5	12.5	12.5	12.5	12.5	12.5	12.7
Spring St	11.0	11.1	11.2	11.3	11.4	11.5	12.9
Moore St	13.0	13.1	13.1	13.2	13.2	13.2	13.8
Gibson St	11.8	11.9	12.1	12.2	12.4	12.6	13.4
Holloway St	11.8	11.9	12.1	12.2	12.4	12.6	13.4
Banksia St	14.8	14.8	14.8	14.8	14.8	14.9	15.1
Pagewood Public School	13.7	14.0	14.2	14.3	14.3	14.3	14.8
Page St	13.7	14.0	14.2	14.3	14.3	14.3	14.8
Mutch Park	16.2	16.2	16.2	16.3	16.3	16.3	17.1
Heffron Rd	19.0	19.0	19.1	19.1	19.1	19.1	19.7
Banks Ave	20.6	20.7	20.7	20.8	20.8	20.8	21.4
Kenny Rd	21.1	21.1	21.1	21.1	21.1	21.2	21.4

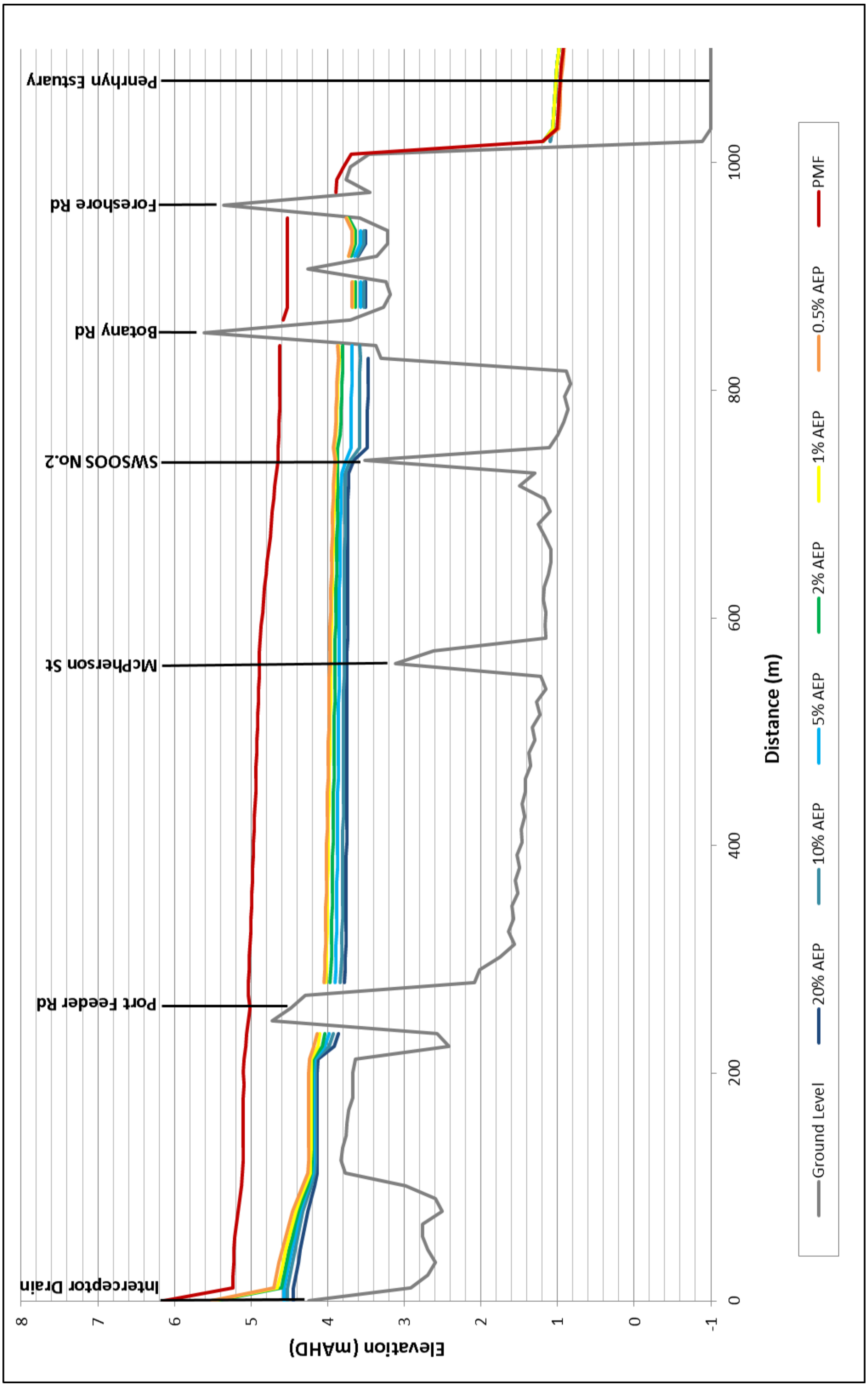


Figure 7-2 Design Peak Flood Level Longitudinal Profile – Floodvale Drain

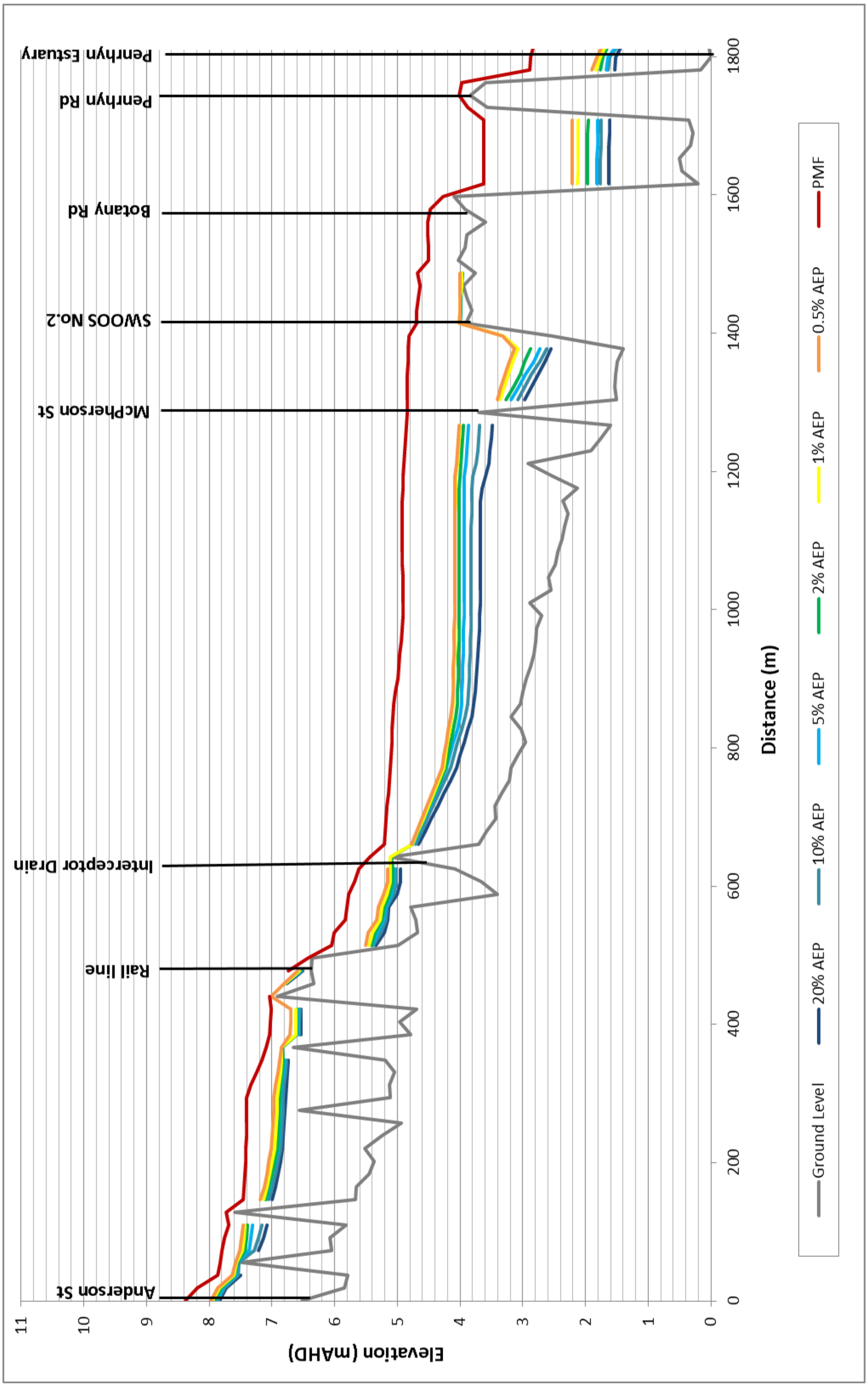
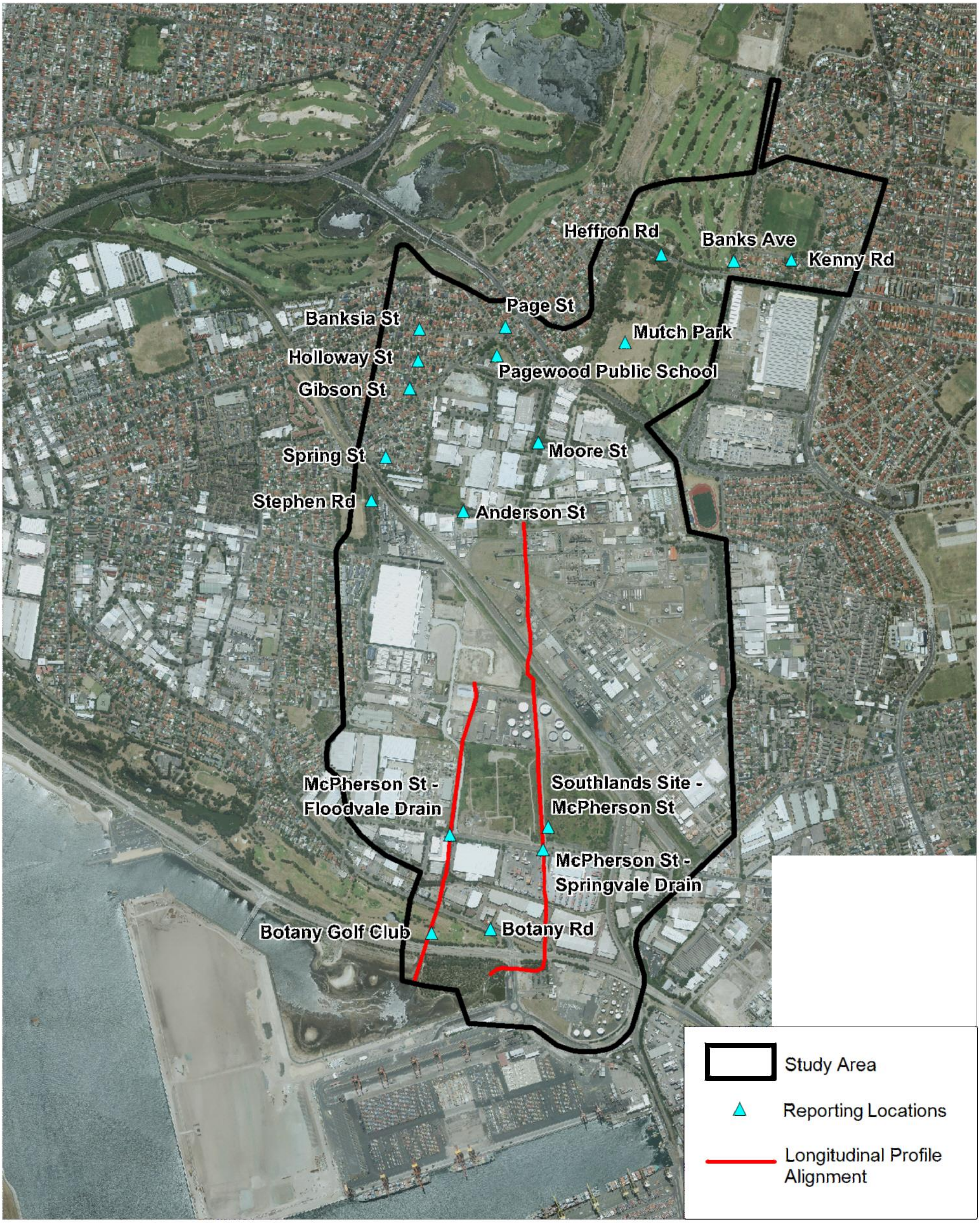


Figure 7-3 Design Peak Flood Level Longitudinal Profile – Springvale Drain



Title:
Design Event Peak Flood Level Reporting Locations

Figure: **7-4**

Rev: **A**

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

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7.1.3 Tidal Inundation

Tidal inundation modelling was undertaken for the mean high water springs level and highest astronomical tidal level for Botany Bay. The tidal levels were applied as a constant water level at the downstream boundary of the model located at Penrhyn estuary. The tidal inundation extents are presented in Appendix A (Figure A-22).

7.1.4 Potential Flooding Problem Areas

In simulating the design flood conditions for the Springvale Drain and Floodvale Drain catchment, the following locations have been identified as potential problem areas in relation to flood inundation extent and property affected:

- Heffron Road and Banks Avenue intersection, Pagewood

  Rainfall runoff drains overland along roadways in the vicinity, specifically, south along Banks Avenue and west along Park Parade and Heffron Road to the intersection. Initial ponding occurs on Banks Avenue north of the intersection before inundating the intersection and spreading north along Banks Avenue and east along Heffron Road and Park Avenue. The low point immediately north of the Heffron Road and Banks Avenue intersection experiences the greatest flood depths.

- Pagewood Primary School, Pagewood

  Rainfall runoff drains overland along roadways and initially ponds at the low points along Page Street (between Wentworth Avenue and Dalley Avenue) and Dalley Avenue (near Page Street). The flood inundation spreads to the adjacent properties along Page Street and Dalley Avenue and inundates the majority of the school grounds during the 20% AEP event. During larger rainfall events the flood inundation extends south to Holloway Street and north to Wentworth Avenue. The Dalley Avenue low point experiences the greatest flood depths.

- Holloway Street and Gibson Street, Pagewood

  Rainfall runoff drains overland along roadways to low points midway along Banksia Street, Holloway Street and Gibson Street. The runoff ponds in these areas with the flood inundation extending from Banksia Street to Gibson Street through a number of residential properties. During larger rainfall events the flood inundation may extend south to Page Street and north to Bay Street. Flood depths are greatest from Holloway Street to Gibson Street.

- Spring Street and Dudley Street intersection, Pagewood

  Rainfall runoff drains overland along roadways to pond at the low point at the intersection of Spring Street and Dudley Street. The flood inundation extends to the residential properties immediately south of the intersection. During larger rainfall events the flood inundation may extend north to Page Street and inundate further residential properties from the Dudley Street intersection with Spring Street to Page Street. Flood depths are greatest at the Spring Street and Dudley Street intersection.

- Anderson Street, Banksmeadow

  Rainfall runoff drains overland along roadways and ponds at the low point midway along Anderson Street. The initial ponding occurs at the road low point and extends to the industrial properties immediately north and south of the low point. The collected runoff may overflow to the industrial properties to the south and continue to drain south to the rail line. During larger rainfall events the inundation may extend west and east along Anderson Street to Baker Street. The Anderson Street low point experiences the greatest flood depths.

- Port Feeder Road – Australand and Mobil Sites, Banksmeadow

  Rainfall runoff drains overland from the surrounding local sub-catchment and ponds in the south west of the Australand site. The flood inundation spreads north and east inundating a significant portion of the site before draining south to the Southlands site. During larger rainfall events overflow from the Floodvale Drain open channel and interceptor drain located to the north of the site may also contributing to the flooding.

  Inundation of the Mobil site initially results from rainfall being detained in the bunded impervious area of the site. During larger rainfall events runoff from the Australand site as well as overflow from the Floodvale Drain, interceptor drain and Springvale Drain may further increase the flood depths at the site. The Mobile site located between the Floodvale Drain and Springvale Drain experiences the greatest flood depths.

- McPherson Street, Banksmeadow

  Both Floodvale Drain and Springvale Drain open channels separately cross McPherson Street via several culverts. McPherson Street is impacted by flooding near both of these locations. The greatest flood depths along McPherson Street occur at the Floodvale Drain culverts.

  Rainfall runoff drains overland along the road and ponds at a low point on McPherson Street located east of the Springvale Drain culvert. Upstream of McPherson Street Springvale Drain overflows east to the Southlands Site inundating a significant portion of the site. During larger rainfall events Springvale Drain may also overflow south to McPherson Street contributing to the flooding extent along the road in both an east and west direction. The industrial property south of McPherson Street may also experience flooding from overflow of the Springvale Drain open channel.

  Overflow from Floodvale Drain occurs initially at the McPherson Street culverts followed by both the left and right banks extending both upstream and downstream of McPherson Street impacting several industrial properties. During larger rainfall events the flood inundation from the overflow may and progressively extend as far north as the Port Feeder Road bridge and as far south as the SWSOOS No.2.

- Botany Road, Banksmeadow

  Rainfall runoff drains overland along roadways to the low point on Botany Road, east of the Discovery Business Park entrance road. Initial ponding occurs along the roadway extending to the Foreshore Road intersection. The Floodvale Drain concrete channel overflows to Botany Road as it enters the culverts discharging to Penrhyn Estuary. The open channel also overflows to the industrial property on the left bank (east) of the drain.

During larger rainfall events the overflow from the Botany Road low point and Floodvale Drain open channel drains west along Botany Road entering the Botany Golf course near Hill Street which provides significantly flood storage. Flood depths are greatest along Botany Road at the low point east of the Discovery Business Park entrance road.

7.2 Design Flood Hydrographs

A range of storm durations were modelled in order to identify the critical storm duration for design event flooding in Springvale Drain and Floodvale Drain catchment. Design durations considered included the 15-minute, 30-minute, 45-minute, 1-hour, 1.5-hour, 2-hour, 3-hour, 4.5-hour, 6-hour, 9-hour, 12-hour, 18-hour, 24-hour, 30-hour, 36-hour, 48-hour and 72-hour durations.

Outputs from the model simulations indicate that the maximum peak inflows to Penrhyn Estuary are generally derived when using a design storm duration of 9 hours for the 20% to 1% AEP design event, 2 hours for the 0.5% AEP design event and 3 hours for the PMF design event. Results presented hereafter represent these critical duration for peak flows discharging to Penrhyn Estuary.

The simulated 1% AEP 9-hour duration hydrographs for each of Springvale Drain and Floodvale Drain discharging to Penrhyn Estuary are shown in Figure 7-5. Also shown for reference is the combined inflows to the Estuary from the Springvale Drain and Floodvale Drain catchment. For the simulated 1% AEP 9-hour design event the combined peak inflow into Penrhyn Estuary is some 20 m^3/s. The combined inflows for other selected critical design event magnitudes are shown in Figure 7-6 for comparison.

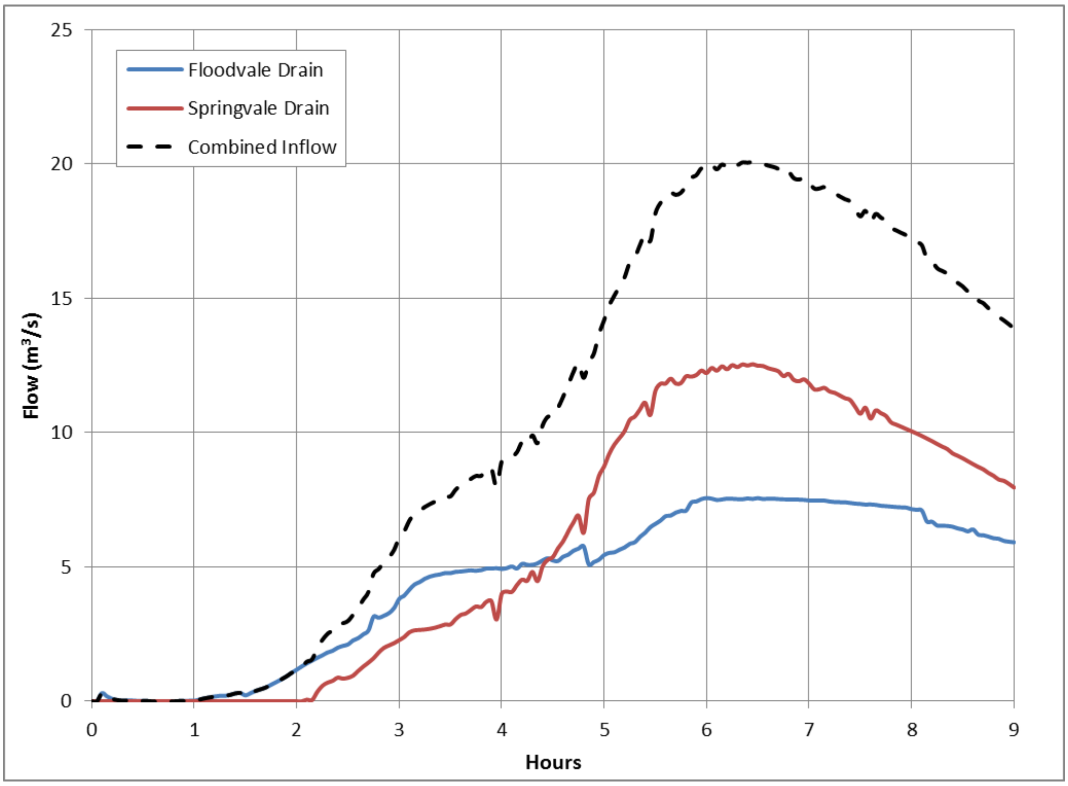

Figure 7-5 Design Event Peak Flow to Penrhyn Estuary (1% AEP Event)

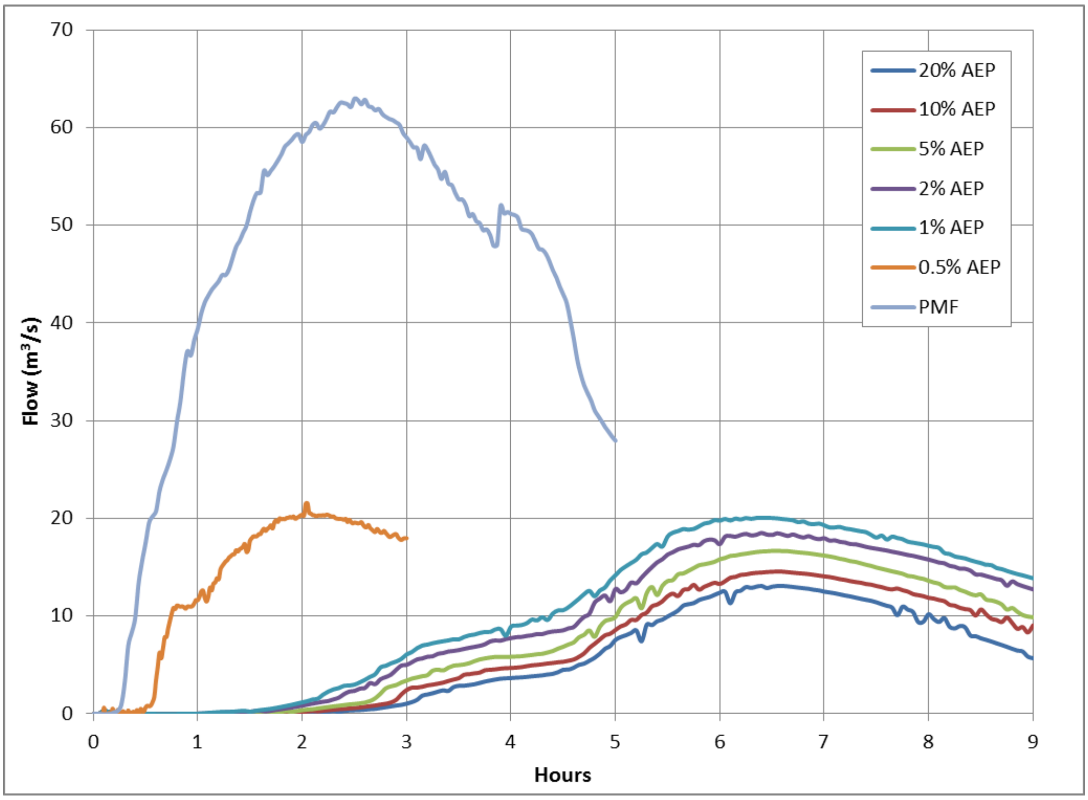

Figure 7-6 Combined Inflow to Penrhyn Estuary for Sample Design Events

7.3 Comparison with Previous Studies

The design event results of the current flood study have been compared to those of hydraulic modelling undertaken in the Springvale Drain and Floodvale Drain catchment for previous flood studies. Hydraulic models for which results are available include:

- Catchment Management Study Floodvale & Springvale Drains, Botany (SKM, 1992) – A one dimensional MOUSE model used for the hydrologic and hydraulic analysis of the upper reaches of the catchment incorporating both pipe and open channel reaches. One dimensional HEC-2 used to model the downstream reaches;
- Proposed Expansion of Container Port Facilities in Botany Bay, NSW - Hydrologic and Hydraulic Studies (Lawson and Treloar, 2003) – A XP-RAFTS hydrological model developed for the entire catchment. A one-dimensional SOBEK hydraulic model routing flows from the Southlands site to Botany; and
- ORICA Southlands Remediation and Development Project – Hydraulic Modelling Report (Aurecon, 2010) – adaptation of the Lawson and Treloar XP-RAFTS hydrological model. A MIKE-FLOOD hydraulic model integrating a two-dimensional MIKE-21 and one-dimensional MIKE-11 hydraulic models into a coupled hydraulic modelling system. The MIKE-FLOOD model extends from the interceptor drain linking Springvale Drain and Floodvale Drain north of the Mobil site (northern extent of model), downstream to Botany Bay (southern extent of model).

A comparison of the peak flood levels for the 1% AEP design event from the current study with those of the previous flood studies undertaken within the Springvale Drain and Floodvale Drain catchment for several key locations is presented in Table 7-2.

Table 7-2 Comparison of Peak Flood Levels to Previous Flood Studies

Location	1% AEP Peak Flood Level (m AHD)	
	Current Study	Previous Study
Floodvale Drain		
Interceptor Drain (North limit of Mobil Terminal)	4.77	4.70[a]
Upstream Port Feeder Rd Bridge (South limit of Mobile Terminal) / Upstream of Southlands Site	4.13	4.39[a] 4.14[c]
Upstream McPherson Street	3.96	4.28[a] 4.13[c]
Upstream SWSOOS No.2	3.91	4.07[a] 3.95[c]
Downstream SWSOOS No.2	3.91	3.72[a]
Upstream of Botany Road Culvert	3.86	3.64[a] 3.73[b]
Springvale Drain		
Downstream Anderson Street	7.95	7.93[a]
Botany Industrial Park (ICI Property)	7.13	7.38[a]
Opposite Substation	6.62	6.72[a]
Upstream Rail Culverts	6.65	6.51[a]
North limit of Mobil Terminal	5.17	5.36[a]
North limit of Mobil Terminal / Upstream of Southlands Site	4.13	4.72[a] 4.20[c]
Upstream McPherson Street	4.07	4.09[a] 4.03[c]
Upstream SWSOOS No.2	3.02	2.77[a] 4.03[c]
Upstream Penrhyn Road	2.11	2.06[a] 1.94-2.03[b]

(a) Catchment Management Study Floodvale & Springvale Drains, Botany (SKM,1992)
(b) Proposed Expansion of Container Port Facilities in Botany Bay, NSW – Hydrologic and Hydraulic Studies (Lawson and Treloar, 2003) - RAFTS Results
(c) ORICA Southlands Remediation and Development Project – Hydraulic Modelling Report (Aurecon, 2010)

The peak flood level comparisons indicate that the peak flood levels in the mid-catchment for the current study are slightly lower than the previously modelled peak flood levels. The peak flood levels in the lower Floodvale Drain downstream of the SWSOOS No.2 are slightly higher than the previously modelled peak flood levels. There is little variation between peak flood levels of the lower Springvale Drain.

Generally the predicted peak water levels between the current study and previous studies are of a similar order with typical variations less than 0.3m (typical of order of accuracies expected through a model calibration process).

A comparison of the peak flood discharge for the 1% AEP design event from the current study with those of the previous flood studies undertaken within the Springvale Drain and Floodvale Drain catchment for several key locations is presented in Table 7-3. For this comparison the 9-hour duration, 50% blockage factor results from the current study were used.

Table 7-3 Comparison of Peak Flood Discharge to Previous Flood Studies

Location	1% AEP Peak Flood Level (m AHD)	
	Current Study	Previous Study
Floodvale Drain		
Interceptor Drain (North limit of Mobil Terminal)	12.6	18.2[a]
Upstream McPherson Street	12.1	20.1[a]
Downstream McPherson Street	11.3	20.0[a]
Upstream of Botany Road Culvert	11.7	24.5[a] 15-16[b]
Springvale Drain		
North limit of Mobil Terminal	5.2	6.7[a]
Upstream McPherson Street	8.0	14.1[a]
Downstream McPherson Street	8.0	7.6[c]
Upstream SWSOOS No.2	9.9	16.3[a]
Upstream Penrhyn Road	10.4	21.2[a] 24.0[b]

(a) Catchment Management Study Floodvale & Springvale Drains, Botany (SKM,1992)
(b) Proposed Expansion of Container Port Facilities in Botany Bay, NSW – Hydrologic and Hydraulic Studies (Lawson and Treloar, 2003) - RAFTS Results
(c) ORICA Southlands Remediation and Development Project – Hydraulic Modelling Report (Aurecon, 2010)

The peak flood discharge comparisons shown in Table 7-3 indicate that the peak flood discharges for the current study are lower in the lower catchment then the previously modelled peak flood discharges.

The variation in the both peak flood levels and discharges between the current study and previous studies may be attributed to the following factors:

- Differences in modelling approach and software;
- Differences in topographical data sets;
- Improved model calibration and use of historical data;
- Changes to flow structures;
- Catchment land use changes.

The TUFLOW model developed for the current study represents the most comprehensive hydraulic model of the Springvale Drain and Floodvale Drain catchment completed to date. Previous studies have replied on numerous hydrological and hydraulic models to calculate runoff and flooding behaviour across the catchment. The hydrological rainfall-runoff models have been used to estimate runoff from sub-catchment areas, with the resulting discharges applied at point locations throughout the catchment in subsequent hydraulic models.

In these previous studies, both 1D and 2D hydraulic models have been used to route runoff through the drainage network and as overland flow to produce information on flood levels and flows. These models do not account for the attenuation that occurs within the catchment at trapped low points and informal storage areas such as Mutch Park and can therefore be considered to over-estimate the flows passing downstream to the lower floodplain.

The TUFLOW model developed for this current study applies direct rainfall uniformly across the catchment. As mentioned in Section 2.1 the study area does not have a defined catchment boundary due to several trap low points along catchment boundaries. By extending the hydraulic model beyond previous estimates of the catchment extent and applying direct rainfall the developed TUFLOW model ensures all flows to the catchment are considered.

A significant portion of runoff from the Springvale Drain and Floodvale Drain is conveyed as overland flow in addition to that which is drained via the pit and pipe drainage network and open channels. The catchment experiences inter-catchment flows between the Springvale Drain and Floodvale Drain. The developed TUFLOW model represents the drainage network as 1D elements dynamically linked to the 2D floodplain ensuring all flow paths and their interconnectivity are adequately represented.

The developed TUFLOW model encompasses the hydrological and hydraulic modelling of the entire Springvale Drain and Floodvale Drain catchment, eliminating the need for numerous hydrological and hydraulic models to simulate flood events as with previous studies. Furthermore, the TUFLOW model represents all relevant catchment features such as trapped low points (determined by topography), informal storages (e.g. Mutch Park), the stormwater drainage network and overland flow paths, resulting in a comprehensive modelling tool to represent the flooding characteristics of the catchment. It is therefore reasonable to expect a decrease in peak discharges in the lower reaches of the catchment, as presented in Table 7-3.

7.4 Hydraulic Classification

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

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

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

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

- Peak flood velocity;
- Peak flood depth;
- Peak velocity * depth (sometimes referred to as unit discharge);
- Cumulative volume conveyed during the flood event; and
- Combinations of the above.

The definition of flood impact categories that was considered to best fit the application within the Springvale Drain and Floodvale Drain catchment was based on a combination of velocity*depth and depth parameters. The adopted hydraulic categorisation is defined in Table 7-4.

Preliminary hydraulic category mapping for the 1% AEP and PMF design events is included in Appendix A (Figures A-23 and A-24). It is also noted that mapping associated with the flood hydraulic categories may be amended in the future, at a local or property scale, subject to appropriate analysis that demonstrates no additional impacts (e.g. if it is to change from floodway to flood storage).

Table 7-4 Hydraulic Categories

Hydraulic Category	Definition	Description
Floodway	Velocity * Depth > 0.5 m^2/s	Areas and flowpaths where a significant proportion of floodwaters are conveyed during a flood (including all bank-to-bank creek sections).
Flood Storage	Velocity * Depth < 0.5 m^2/s and Depth > 0.5m	Floodplain areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Velocity * Depth < 0.5 m^2/s and Depth < 0.5m	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

7.5 Provisional Hazard Categories

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

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

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

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

Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005) are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 7-7. The provisional hydraulic hazard is included in the mapping series provided in Appendix A for the 1% AEP and PMF events (Figures A-25 and A-26).

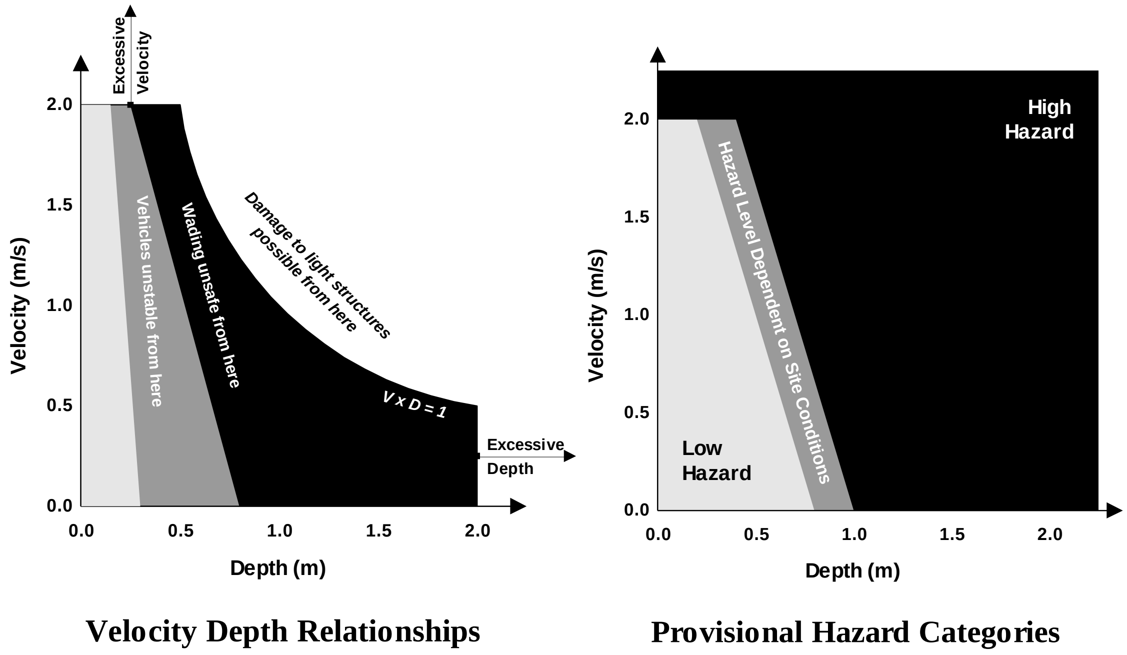

Figure 7-7 Provisional Flood Hazard Categorisation

7.6 Flood Emergency Response Classification

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

- **High Flood Island** – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island includes enough land higher than the limit of flooding to provide refuge.
- **Low Flood Island** – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island is lower than the limit of flooding.
- **High Trapped Perimeter** – fringe of the floodplain. Road access may be cut by floodwater. The area includes enough land higher than the limit of flooding to provide refuge.
- **Low Trapped Perimeter** – fringe of the floodplain. Road access may be cut by floodwater. The flood island is lower than the limit of flooding.
- **Areas with Overland Escape Routes** – areas available for continuous evacuation. Access roads may cross low lying flood prone land but evacuation can take place by walking overland to higher ground.

- **Areas with Rising Road Access** – areas available for continuous evacuation. Access roads may rise steadily uphill away from rising floodwaters. Evacuation can take place vehicle and communities cannot be completely isolated before inundation reaches its maximum ;and
- **Indirectly Affected Areas** – areas outside the limit of flooding and therefore will not be inundated or lose road access. They may be indirectly affected as a result of flood damaged infrastructure or due to loss of services.

The flood emergency response classification is included in the mapping series provided in Appendix A for the full range of design events simulated (Figures A-27 and A-33).

7.7 Preliminary Residential Flood Planning Level

Mapping of the preliminary residential flood planning level has been provided in Appendix A as Figure A-34. The preliminary residential flood planning level has been based on the 1% AEP (100 year ARI) peak flood level with an additional 0.5m freeboard applied. The extent of the preliminary residential flood planning level is limited to the 1% AEP flood extent. Areas beyond the 1% AEP flood extent may be extrapolated from the nearest preliminary residential flood planning level. For reference purposes the PMF flood extent has also be illustrated in Figure A-34. Please note that with the additional 0.5m freeboard on the 1% AEP peak flood level, the preliminary residential flood planning level may exceed the PMF peak flood level in some locations and therefore extend beyond the PMF flood extent.

7.8 Conclusion

The developed models have been applied to derive design flood conditions within the Springvale Drain and Floodvale Drain catchment using the design rainfall and tidal conditions described in Section 6. The design events considered in this study include the 20% (5-year ARI), 10% AEP (10-year ARI), 5% AEP (20-year ARI), 2% AEP (50-year ARI), 1% AEP (100-year ARI) 0.5% AEP (200-year ARI) and Probable Maximum Flood (PMF) events. The model results for the design events considered have been presented in a detailed flood mapping series for the catchment. The flood data presented includes design flood inundation, peak flood water levels and peak flood depths.

Provisional flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has been mapped for the 1% AEP and the PMF events, in addition to the hydraulic categories (floodway, flood fringe and flood storage) for flood affected areas.

The flood inundation extents derived from the hydraulic modelling are shown in Appendix A.

8 Sensitivity Testing

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

- hydraulic roughness;
- blockage of the stormwater drainage system;
- reduced rainfall losses;
- sea level; and
- 2D model resolution.

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

As outlined in Section 7.1.2 the critical duration varies across the catchment. For the purpose of sensitivity testing the 1% AEP, 2-hour duration, unblocked (0% blockage factor) design storm event has been used as the design base case. The impact of the sensitivity tests is presented in Appendix B as a series of peak water level afflux diagrams.

8.1 Hydraulic Roughness

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

The results of the sensitivity tests on hydraulic roughness are summarised in Table 8-1 for the reporting locations indicated in Figure 7-4. The change in peak flood level conditions from the adopted design base case is also shown as afflux diagrams in Figure B-1 and Figure B-2 in Appendix B.

The model simulation results show minor reductions in peak flood level (generally < 0.05m) for reduced hydraulic roughness generally in the lower part of the catchments. The main areas affected are downstream of the interceptor drain including the Mobil and Southlands industrial sites downstream to Port Feeder Road and McPherson Street. The decrease in roughness has minimal influence on the inundation extents.

Similarly, minor increases in peak flood level in the lower part of the catchments (generally <0.05m) are predicted for the increased hydraulic roughness conditions applied in the sensitivity test. Again, the principal areas affected are downstream of the interceptor drain including the Mobil and Southlands industrial sites downstream to Port Feeder Road and McPherson Street with minimal influence on the flood inundation extents.

Table 8-1 Peak 1% AEP Flood Levels for Hydraulic Roughness Sensitivity Tests

Location	1% AEP Peak Flood Level (m AHD)		
	Base Case	20% Decrease in Hydraulic Roughness	20% Increase in Hydraulic Roughness
Botany Golf Club	3.5	3.5 (0.0)	3.5 (0.0)
Botany Rd	3.6	3.6 (0.0)	3.6 (0.0)
McPherson St - Floodvale Drain	3.9	3.9 (0.0)	3.9 (0.0)
McPherson St - Springvale Drain	3.8	3.8 (0.0)	3.9 (+0.1)
Southlands Site - McPherson St	3.9	3.8 (-0.1)	3.9 (0.0)
Anderson St	7.7	7.7 (0.0)	7.7 (0.0)
Stephen Rd	12.5	12.5 (0.0)	12.5 (0.0)
Spring St	11.2	11.2 (0.0)	11.2 (0.0)
Moore St	13.1	13.1 (0.0)	13.1 (0.0)
Gibson St	12.1	12.1 (0.0)	12.1 (0.0)
Holloway St	12.1	12.1 (0.0)	12.1 (0.0)
Banksia St	14.8	14.8 (0.0)	14.8 (0.0)
Pagewood Public School	13.7	13.7 (0.0)	13.7 (0.0)
Page St	13.7	13.7 (0.0)	13.7 (0.0)
Mutch Park	16.2	16.2 (0.0)	16.2 (0.0)
Heffron Rd	19.0	19.0 (0.0)	19.0 (0.0)
Banks Ave	20.7	20.7 (0.0)	20.7 (0.0)
Kenny Rd	21.1	21.1 (0.0)	21.1 (0.0)

Note: Bracketed value is change in peak flood level from base case conditions rounded to nearest 100mm

8.2 Stormwater Drainage Blockage

Structure blockages have the potential to substantially increase the magnitude and extent of property inundation through local increases in water level, redistribution of flows on the floodplain, and activation of additional flow paths. As outlined in Section 6.3 the design event modelling has considered both a 0% and 50% blockage factor of all stormwater drainage structures (pit inlets, pipes, culverts and bridges).

A sensitivity test has been undertaken to account for the potential for structure blockage. In addition to a 0% and 50% blockage factor a 100% blockage of the stormwater drainage structures, thereby eliminating pipe flow, has also been considered.

The results of the sensitivity tests on blockages are summarised in Table 8-2 for the reporting locations indicated in Figure 7-4. The change in peak flood level conditions from the adopted design base case is also shown as afflux diagrams in Figure B-3 and Figure B-4 in Appendix B.

Table 8-2 Peak 1% AEP Flood Levels for Blockage Sensitivity Tests

Location	1% AEP Peak Flood Level (m AHD)		
	Base Case	50% Blockage Factor	100% Blockage Factor
Botany Golf Club	3.5	3.6 (+0.1)	3.7 (+0.2)
Botany Rd	3.6	3.7 (+0.1)	3.8 (+0.2)
McPherson St - Floodvale Drain	3.9	3.9 (0.0)	4.4 (+0.5)
McPherson St - Springvale Drain	3.8	3.9 (+0.1)	4.2 (+0.4)
Southlands Site - McPherson St	3.9	4.0 (+0.1)	4.2 (+0.3)
Anderson St	7.7	7.7 (0.0)	7.8 (+0.1)
Stephen Rd	12.5	12.5 (0.0)	12.5 (0.0)
Spring St	11.2	11.4 (+0.2)	11.8 (+0.6)
Moore St	13.1	13.2 (+0.1)	13.2 (+0.1)
Gibson St	12.1	12.3 (+0.2)	12.5 (+0.4)
Holloway St	12.1	12.3 (+0.2)	12.5 (+0.4)
Banksia St	14.8	14.8 (0.0)	14.8 (0.0)
Pagewood Public School	13.7	13.8 (+0.1)	14.0 (+0.3)
Page St	13.7	13.8 (+0.1)	14.0 (+0.3)
Mutch Park	16.2	16.2 (0.0)	16.2 (0.0)
Heffron Rd	19.0	19.0 (0.0)	19.1 (+0.1)
Banks Ave	20.7	20.7 (0.0)	20.8 (+0.1)
Kenny Rd	21.1	21.1 (0.0)	21.2 (+0.1)

Note: Bracketed value is change in peak flood level from base case conditions rounded to nearest 100mm

The model simulation results show a general increase in peak flood levels along the major flow paths within the study area. A small decrease is evident (generally <0.1m) at the Mobil Site downstream of the interceptor drain for the 50% blockage case. Increased peak flood levels are particularly evident along the major flow paths as outlined in Table 8-3.

Table 8-3 Changes in Flood Levels for Blockage Sensitivity Tests

Major Flow Path Location	Typical Increase in Modelled Peak Flood Level (m AHD)	
	50% Blockage Factor	100% Blockage Factor
Banks Ave to Heffron Rd	<0.05 m	<0.10 m
Pagewood Primary School to Wentworth Ave	<0.20 m	<0.50 m
Gibson St to Holloway St	<0.30 m	<0.50 m
Dudley St to Spring St	<0.20 m	<0.60 m
Port Feeder Rd	<0.02 m	<0.20 m
Southlands Site	<0.10 m	<0.30 m
Botany Rd at Floodvale Drain	<0.20 m	<0.30 m

The 50% blockage factor has minimal influence on inundation extents. A minor increase in the inundation extents is evident with the 100% blockage factor downstream of the interceptor drain, including McPherson Street, the Southlands site and Botany Road.

8.3 Rainfall Losses

For this study an initial loss of 50mm and continuing loss of 5mm/hour were applied to pervious areas. These values were selected based typical values for the well-draining sandy soils presents in the Springvale Drain and Floodvale Drain catchment.

Sensitivity tests on the rainfall losses were undertaken by applying a 35mm and 20mm initial loss value for pervious areas. The results of the sensitivity tests on initial rainfall losses are summarised in Table 8-4 for the reporting locations indicated in Figure 7-4. The change in peak flood level conditions from the adopted design base case is also shown as afflux diagrams in Figure B-5 and Figure B-6 in Appendix B.

Table 8-4 Peak 1% AEP Flood Levels for Rainfall Losses Sensitivity Tests

Location	1% AEP Peak Flood Level (m AHD)		
	Base Case	35mm Initial Loss	20mm Initial Loss
Botany Golf Club	3.5	3.5 (0.0)	3.5 (0.0)
Botany Rd	3.6	3.6 (0.0)	3.6 (0.0)
McPherson St - Floodvale Drain	3.9	3.9 (0.0)	3.9 (0.0)
McPherson St - Springvale Drain	3.8	3.9 (+0.1)	3.9 (+0.1)
Southlands Site - McPherson St	3.9	3.9 (0.0)	4.0 (+0.1)
Anderson St	7.7	7.7 (0.0)	7.7 (0.0)
Stephen Rd	12.5	12.5 (0.0)	12.5 (0.0)
Spring St	11.2	11.2 (0.0)	11.3 (+0.1)
Moore St	13.1	13.1 (0.0)	13.1 (0.0)
Gibson St	12.1	12.1 (0.0)	12.2 (+0.1)
Holloway St	12.1	12.1 (0.0)	12.2 (+0.1)
Banksia St	14.8	14.8 (0.0)	14.9 (+0.1)
Pagewood Public School	13.7	13.7 (0.0)	13.9 (+0.2)
Page St	13.7	13.7 (0.0)	13.9 (+0.2)
Mutch Park	16.2	16.2 (0.0)	16.2 (0.0)
Heffron Rd	19.0	19.1 (+0.1)	19.1 (+0.1)
Banks Ave	20.7	20.7 (0.0)	20.7 (0.0)
Kenny Rd	21.1	21.1 (0.0)	21.2 (+0.1)

Note: Bracketed value is change in peak flood level from base case conditions rounded to nearest 100mm

The model simulation results show increases to the peak flood levels with the decreases in initial loss values at selected locations throughout the catchments. The main areas affected are similar to those affected by the blockage sensitivity testing as outlined in Table 8-5.

Table 8-5 Changes in Flood Levels for Rainfall Losses Sensitivity Tests

Major Flow Path Location	Typical Increase in Modelled Peak Flood Level (m AHD)	
	35mm Initial Loss	20mm Initial Loss
Banks Ave to Heffron Rd	<0.05 m	<0.05 m
Pagewood Primary School to Wentworth Ave	<0.10 m	<0.30 m
Gibson St to Holloway St	<0.10 m	<0.20 m
Dudley St to Spring St	<0.05 m	<0.10 m
Port Feeder Rd	<0.05 m	<0.05 m
Southlands Site	<0.05 m	<0.10 m
Botany Rd at Floodvale Drain	<0.05 m	<0.10 m

The decreases in initial loss values have minimal influence on the inundation extents with minor water level increases at Pagewood Primary School to Wentworth Avenue and the Southlands site.

8.4 Sea Level

The model developed for this study adopted a dynamic downstream water level boundary representative of a mean tide condition for Botany Bay. The timing of the 0.6m AHD peak water level was adjusted to coincide with the peak catchment inflow for the varying rainfall event durations.

To investigate the impact of the adopted downstream boundary level a sensitivity test was conducted using a constant water level equivalent to the lowest astronomical tide (LAT) level of -0.9m AHD for Botany Bay. The impact of an increased tide level has been considered as part of the climate change sensitivity testing as outlined in Section 9.

The results of the sensitivity test applying the LAT are summarised in Table 8-6 for the reporting locations indicated in Figure 7-4. The change in peak flood level conditions from the adopted design base case is also shown as an afflux diagram in Figure B-7 in Appendix B.

Table 8-6 Peak 1% AEP Flood Levels for Sea Level Sensitivity Tests

Location	Modelled Peak Flood Level (m AHD)	
	Base Case	LAT
Botany Golf Club	3.5	3.5 (0.0)
Botany Rd	3.6	3.6 (0.0)
McPherson St - Floodvale Drain	3.9	3.9 (0.0)
McPherson St - Springvale Drain	3.8	3.8 (0.0)
Southlands Site - McPherson St	3.9	3.9 (0.0)
Anderson St	7.7	7.7 (0.0)
Stephen Rd	12.5	12.5 (0.0)
Spring St	11.2	11.2 (0.0)
Moore St	13.1	13.1 (0.0)
Gibson St	12.1	12.1 (0.0)
Holloway St	12.1	12.1 (0.0)
Banksia St	14.8	14.8 (0.0)
Pagewood Public School	13.7	13.7 (0.0)
Page St	13.7	13.7 (0.0)
Mutch Park	16.2	16.2 (0.0)
Heffron Rd	19.0	19.0 (0.0)
Banks Ave	20.7	20.7 (0.0)
Kenny Rd	21.1	21.1 (0.0)

Note: Bracketed value is change in peak flood level from base case conditions rounded to nearest 100mm

As shown in Table 8-6 and the afflux mapping in Appendix B, the downstream boundary condition has negligible impact on flood conditions within the study area.

8.5 2D Model Resolution

A TUFLOW 2D domain model resolution of 4m was adopted for study area. This resolution was selected to give necessary detail required for accurate representation of floodplain topography and its influence on overland flows whilst maintaining reasonable model simulation runtimes. The model simulation runtimes were particularly relevant given the long duration storm events modelled for the full range of AEP design storm events.

A sensitivity test was conducted to provide a comparison between the selected 4m model grid size and a finer 2m model grid size. For the Springvale Drain and Floodvale Drain TUFLOW model the 2m model grid size represented a 9-fold increase in model runtime compared to the 4m model grid size.

The results of the sensitivity test applying the 2m model grid size are summarised in Table 8-7 for the reporting locations indicated in Figure 7-4. The change in peak flood level conditions from the adopted design base case is also shown as an afflux diagram in Figure B-8 in Appendix B.

Table 8-7 Peak 1% AEP Flood Levels for Model Grid Resolution Sensitivity Tests

Location	Modelled Peak Flood Level (m AHD)	
	Base Case	2m Model Grid Size
Botany Golf Club	3.5	3.5 (0.0)
Botany Rd	3.6	3.6 (0.0)
McPherson St - Floodvale Drain	3.9	3.8 (-0.1)
McPherson St - Springvale Drain	3.8	-
Southlands Site - McPherson St	3.9	3.8 (-0.1)
Anderson St	7.7	7.7 (0.0)
Stephen Rd	12.5	12.5 (0.0)
Spring St	11.2	11.2 (0.0)
Moore St	13.1	13.1 (0.0)
Gibson St	12.1	12.0 (-0.1)
Holloway St	12.1	12.0 (-0.1)
Banksia St	14.8	14.8 (0.0)
Pagewood Public School	13.7	13.7 (0.0)
Page St	13.7	13.7 (0.0)
Mutch Park	16.2	16.2 (0.0)
Heffron Rd	19.0	19.0 (0.0)
Banks Ave	20.7	20.7 (0.0)
Kenny Rd	21.1	21.1 (0.0)

Note: Bracketed value is change in peak flood level from base case conditions rounded to nearest 100mm

The model simulation results show a reduction in flood levels (generally<0.1m) at selected locations within the study area and along the main flow paths as outlined in Table 8-8.

Table 8-8 Changes in Flood Levels for Model Grid Resolution Sensitivity Tests

Major Flow Path Location	Typical Change in Modelled Peak Flood Level (m AHD)
	2m Model Grid Size
Gibson St to Holloway St	<0.10 m
Dudley St to Spring St	<0.05 m
Port Feeder Rd	<0.05 m
Southlands Site	<0.10 m
Botany Rd at Floodvale Drain	<0.20 m

This testing has shown that the 2m model grid size has minimal influence on the inundation extents compared with the 4m grid size model.

8.6 Conclusion

A series of sensitivity tests have been undertaken on the modelled flood behaviour of the Springvale Drain and Floodvale Drain catchment. The tests provide a basis for determining the relative sensitivity of modelling results to adopted parameter values. The parameters assessed include:

- Hydraulic roughness;
- Structure blockages;
- Design rainfall losses;
- Sea level; and
- 2D model resolution.

9 Climate Change Analysis

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

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

As discussed in Section 1.3.1, it was agreed between Council and BMT WBM that the sea level rise benchmarks from the 2009 NSW Sea level Rise Policy Statement be adopted based on the conclusion that it was the best available information at the time of preparation of this report.

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

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

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

Key elements of future climate change (e.g. sea level rise, rainfall intensity) have been incorporated into the assessment of future flooding conditions in the Springvale Drain and Floodvale Drain catchment for consideration in the ongoing floodplain risk management.

9.1 Potential Climate Change Impacts

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

The following changes in the physical characteristics of the Springvale Drain and Floodvale Drain system have potential influence on the flood behaviour of the system and implications for medium and long term floodplain management:

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

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

9.1.1 Ocean Water Level

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

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

The ocean water level boundary conditions for present day flood conditions were discussed in Section 6.2. The sea level rise allowances provide for direct increases in these ocean water levels. Table 9-1 presents a summary of adopted peak ocean water levels for existing water level conditions and the 2050 and 2100 sea level rise benchmarks.

Table 9-1 Design Peak Ocean Water Levels Incorporating Sea Level Rise

Water Level (m AHD)		
Existing	**2050 (+0.4m)**	**2100 (+0.9m)**
0.60	1.00	1.50

9.1.2 Design Rainfall Intensity

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

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

9.2 Climate Change Model Conditions

A range of design event simulations have been undertaken incorporating combinations of increases in rainfall intensities and ocean water levels. A summary of the modelled scenarios for the 1% AEP design event is provided in Table 9-2.

Table 9-2 Summary of Design Model Runs for Climate Change Considerations

Design Flood	Rainfall Intensity Increase	Dynamic Ocean Boundary Peak Water Level (m AHD)
1% AEP 2hr duration 0% Blockage	10%	1.00 (Normal tide 0.6m + 0.4m to 2050)
1% AEP 2hr duration 0% Blockage	10%	1.50 (Normal tide 0.6m + 0.9m to 2050)
1% AEP 2hr duration 0% Blockage	20%	1.00 (Normal tide 0.6m + 0.4m to 2050)
1% AEP 2hr duration 0% Blockage	20%	1.50 (Normal tide 0.6m + 0.9m to 2050)
1% AEP 2hr duration 0% Blockage	30%	1.00 (Normal tide 0.6m + 0.4m to 2050)
1% AEP 2hr duration 0% Blockage	30%	1.50 (Normal tide 0.6m + 0.9m to 2050)

9.3 Climate Change Results

The modelled peak flood levels for the climate change scenarios are presented in Table 9-3 for the reporting locations indicated in Figure 7-4. The impact of potential climate change scenarios on the standard design flood condition is presented in Figure B-9 to Figure B-14 in Appendix B as a series of maps showing increase in peak flood inundation extents from the baseline (existing) conditions.

Comparison between the model simulation results indicates the impact of the increased sea level on the study area is expected to be minimal and generally limited to the areas downstream of Botany Road and Foreshore Road.

The model simulation results show a general increase in peak flood levels along the major and some minor flow paths within the study area with increasing rainfall intensity. Increased peak flood levels are particularly evident along the major flow paths as outlined in Table 9-4.

Table 9-3 Peak 1% AEP Flood Levels for Climate Change Considerations

Location	Modelled Peak Flood Level (m AHD)						
	Base Case	+10% Rainfall Intensity +0.4m SLR	+20% Rainfall Intensity +0.4m SLR	+30% Rainfall Intensity +0.4m SLR	+10% Rainfall Intensity +0.9m SLR	+20% Rainfall Intensity +0.9m SLR	+30% Rainfall Intensity +0.9m SLR
Botany Golf Club	3.5	3.6 (+0.1)	3.6 (+0.1)	3.7 (+0.2)	3.6 (+0.1)	3.6 (+0.1)	3.7 (+0.2)
Botany Rd	3.6	3.7 (+0.1)	3.8 (+0.2)	3.9 (+0.3)	3.7 (+0.1)	3.8 (+0.2)	3.9 (+0.3)
McPherson St - Floodvale Drain	3.9	3.9 0.0)	4.0 (+0.1)	4.0 (+0.1)	3.9 (0.0)	4.0 (+0.1)	4.0 (+0.1)
McPherson St - Springvale Drain	3.8	3.9 (+0.1)	4.0 (+0.2)	4.1 (+0.3)	3.9 (+0.1)	4.0 (+0.2)	4.1 (+0.3)
Southlands Site - McPherson St	3.9	4.0 (+0.1)	4.0 (+0.1)	4.1 (+0.2)	4.0 (+0.1)	4.0 (+0.1)	4.1 (+0.2)
Anderson St	7.7	7.8 (+0.1)	7.8 (+0.1)	7.8 (+0.1)	7.8 (+0.1)	7.8 (+0.1)	7.8 (+0.1)
Stephen Rd	12.5	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)
Spring St	11.2	11.3 (+0.1)	11.3 (+0.1)	11.4 (+0.2)	11.3 (+0.1)	11.3 (+0.1)	11.4 (+0.2)
Moore St	13.1	13.2 (+0.1)	13.2 (+0.1)	13.2 (+0.1)	13.2 (+0.1)	13.2 (+0.1)	13.2 (+0.1)
Gibson St	12.1	12.2 (+0.1)	12.3 (+0.2)	12.4 (+0.3)	12.2 (+0.1)	12.3 (+0.2)	12.4 (+0.3)
Holloway St	12.1	12.2 (+0.1)	12.3 (+0.2)	12.4 (+0.3)	12.2 (+0.1)	12.3 (+0.2)	12.4 (+0.3)
Banksia St	14.8	14.8 (0.0)	14.9 (+0.1)	14.9 (+0.1)	14.8 (0.0)	14.9 (+0.1)	14.9 (+0.1)
Pagewood Public School	13.7	13.8 (+0.1)	13.9 (+0.2)	14.1 (+0.4)	13.8 (+0.1)	13.9 (+0.2)	14.1 (+0.4)
Page St	13.7	13.8 (+0.1)	13.9 (+0.2)	14.1 (+0.4)	13.8 (+0.1)	13.9 (+0.2)	14.1 (+0.4)
Mutch Park	16.2	16.2 (0.0)	16.3 (+0.1)	16.3 (+0.1)	16.2 (0.0)	16.3 (+0.1)	16.3 (+0.1)
Heffron Rd	19.0	19.1 (+0.1)	19.1 (+0.1)	19.1 (+0.1)	19.1 (+0.1)	19.1 (+0.1)	19.1 (+0.1)
Banks Ave	20.7	20.7 (0.0)	20.8 (+0.1)	20.8 (+0.1)	20.7 (0.0)	20.8 (+0.1)	20.8 (+0.1)
Kenny Rd	21.1	21.1 (0.0)	21.2 (+0.1)	21.2 (+0.1)	21.1 (0.0)	21.2 (+0.1)	21.2 (+0.1)

Note: Bracketed value is change in peak flood level from base case conditions rounded to nearest 100mm

Table 9-4 Changes in Flood Levels for Climate Change Considerations

Major Flow Path Location	Typical Increase in Modelled Peak Flood Level (m AHD)		
	10% Rainfall Intensity Increase	20% Rainfall Intensity Increase	30% Rainfall Intensity Increase
Banks Ave to Heffron Rd	<0.05m	<0.10m	<0.10m
Pagewood Primary School to Wentworth Ave	<0.20m	<0.30m	<0.50m
Gibson St to Holloway St	<0.20m	<0.30m	<0.50m
Dudley St to Spring St	<0.10m	<0.20m	<0.20m
Port Feeder Rd	<0.10m	<0.20m	<0.20m
Southlands Site	<0.10m	<0.20m	<0.30m
Botany Rd at Floodvale Drain	<0.20m	<0.30m	<0.30m

Inspection of the results indicates that catchment-derived flooding remains the dominant flooding mechanism for the study area. With increasing rainfall intensity the inundation extents have increased in the vicinity of the following areas:

- Pagewood Primary School to Wentworth Avenue;
- Gibson Street to Holloway Street;
- Southlands Site; and
- Botany Road at Floodvale Drain.

9.4 Conclusion

The potential impacts of future climate change have been considered for a range of design event scenarios as defined in Table 9-2. The impact of climate change scenarios on the standard design flood condition is presented in Appendix B as a series of maps showing the increase in peak flood inundation extents from the baseline (existing) conditions. The most significant impacts of climate change within the study area are associated with increased rainfall intensities.

The results of the climate change analysis highlight the sensitivity of the peak flood level conditions in the Springvale Drain and Floodvale Drain catchment to potential impacts of climate change. Future planning and floodplain risk management in the catchment will need to take due consideration of the increasing flood risk under possible future climate conditions.

10 Conclusions

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

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

- Collation of database of historical flood information for the Springvale Drain and Floodvale Drain catchment;
- Acquisition of topographical data for the catchment including cross section, hydraulic structure survey and stormwater drainage network survey;
- Consultation with the community to acquire historical flood information and liaison in regard to flooding concerns/perceptions and future floodplain management activities;
- Development of a hydrological and hydraulic model (using TUFLOW software) to simulate flood behaviour in the catchment;
- Calibration and validation of the developed model using available data for the February 1990 and February 2010 flood events;
- Prediction of design flood conditions in the catchment using the calibrated models; and
- Production of design flood mapping series.

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

- Heffron Road and Banks Avenue intersection, Pagewood;
- Pagewood Primary School, Pagewood;
- Holloway Street and Gibson Street, Pagewood;
- Spring Street and Dudley Street intersection, Pagewood;
- Anderson Street, Banksmeadow;
- Port Feeder Road – Australand and Mobil Sites, Banksmeadow;
- McPherson Street, Banksmeadow; and
- Botany Road, Banksmeadow.

The flooding issues with the Springvale Drain and Floodvale Drain study area are largely restricted to locations that were naturally creek/gully lines but are now occupied by urban development. Along these alignments natural depressions in the topography and those created by manmade obstructions, such as roads and other land-raising activities, fill with runoff to significant depths during major design flood events. Once the available stormwater drainage network capacity has been exceeded (typically designed to around a 20% AEP standard) the depressions will quickly fill with excess runoff, acting as local flood storages. For large flood events such as the 1% AEP these storages are filled to capacity and flooding can progress via the lowest adjoining point in the topography. This type of flooding is widespread throughout the study area.

Most of the study area drains to the floodplain in the south of the catchment in the vicinity of the open channels of both Springvale Drain and Floodvale Drain. The surrounding development and higher ground prevents progression of overland flow and flood water rises as the available storage volume is filled and the stormwater drainage network reaches capacity.

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

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

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

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12 Acknowledgements

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- NSW Roads and Maritime Services (RMS); and
- Orica Australia Pty Ltd, and their consultants Aurecon Australia Limited and Cardno Limited

Appendix A Design Flood Mapping

Appendix B Sensitivity Tests – Flood Impact Mapping

Appendix C Community Newsletter and Questionnaire

Springvale Drain and Floodvale Drain Flood Study

Community Newsletter July 2012

What is the study about?

The Council of the City of Botany Bay is carrying out a flood study to understand flood risks in the Springvale Drain and Floodvale Drain catchments.

The catchment includes parts of the suburbs of Banksmeadow, Pagewood and a small section of Botany. The catchment drains an area of approximately 375 hectares to Penrhyn Estuary via a formalised stormwater drainage network and open channels.

The catchment area is a combination of urban residential land use, parklands including Jellicoe Park, Mutch Park, Bonnie Doon Golf Course, and extensive industrial land use in the lower portion of the catchment including Botany Industrial Park and Southgate Industrial Park.

Who is responsible?

Council will administer the study.

BMT WBM, an independent company specialising in flooding and floodplain risk management, will undertake the study. The NSW Office of Environment and Heritage is providing financial and technical assistance.

Potential Flood Risks

As both Springvale Drain and Floodvale Drain connect with Botany Bay via Penrhyn Estuary, the downstream of the catchment may be influenced by tidal conditions. Critical flood behaviour may be a combination of overland flow and main stream flooding from the local catchment and elevated water levels in Penrhyn Estuary (tidal and storm surge components).

The Flood Study will investigate flooding in the catchment to identify the critical or worst case flood conditions for a range of flood events for both catchment and ocean derived flooding, including local overland flooding. Overland flows are typical in urban environments where it is not feasible to design stormwater drainage to capture very large and infrequent flood events.

The study will also consider the potential flooding impacts of climate change, from both sea level rise and increased rainfall intensity, in line with current government policy and best practice.

Key Study Outputs

At the core of the study will be the development, calibration and verification of detailed computer models of the catchment to simulate flood behaviour. Historical flood information such as rainfall, peak water levels, flooded property details etc, is used to ensure the computer models are representative of the real catchment behaviour.

The flood study results will be used to provide more effective flood planning in the catchment and will assist Council in:

- Setting appropriate levels for development control;
- Identifying potential works to reduce existing flooding; and
- Improving flood emergency response and recovery.

City of Botany Bay   BMT WBM

http://SpringvaleFloodvale.bmtwbm.com.au/

Community input

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

There are a number of ways you can be involved in the study:

- QUESTIONNAIRE

Please take a minute or two of your time to complete and return the study questionnaire. This will greatly assist in collating people's knowledge and experience about previous flooding history and existing flood problem areas. You can also complete the questionnaire online via the flood study website link at the bottom of the page. This information is strictly confidential and only used for the study.

- INFORMATION SESSION

A community information session will be held (location and time to be confirmed). Please come along to hear about the existing and future flood risk posed to the community, and to give your ideas and concerns in regard to ongoing management of flooding in the Springvale Drain and Floodvale Drain catchments.

- WEBSITE

A website has been established to keep the community informed on the study progress. The website has further information on flooding in the Springvale Drain and Floodvale Drain catchment and will be updated throughout the study as new information becomes available. Community members will also be able to send their views and comments to the study team so they can be considered during the course of the study.

On the website you can also upload your own photos and videos of flooding in the catchment.

Study timetable

Set out below is an indicative timetable which the project will follow, with key project stages/milestones and their proposed completion dates.

STAGE 1 – Data Collection and Community Consultation

Completion by July 2012

STAGE 2 – Hydrological & Hydraulic Modelling

Completion by mid-August 2012

STAGE 3 – Draft Flood Study Report & Public Exhibition

Completion by mid-September 2012

STAGE 4 – Final Flood Study Report

Completion by October 2012

The Final Flood Study Report will be considered by Council.

Want more information?

For more information about the Springvale Drain and Floodvale Drain Flood Study , please contact:

City of Botany Bay Council
Mr. Gil Gillani
Team Leader Assets, Assets & Environment
Ph 02 9366 3619
Gillanig@botanybay.nsw.gov.au

BMT WBM (Consultant)
Mr. Simon Kovacevic
Project Manager
Ph 02 8987 2900
Simon.Kovacevic@bmtwbm.com.au

Or visit the study website:

http:// SpringvaleFloodvale.bmtwbm.com.au

Springvale Drain and Floodvale Drain Flood Study
Community Questionnaire July 2012

Your feedback is valued

The Council of the City of Botany Bay is undertaking a detailed flood study of the Springvale Drain and Floodvale Drain catchments to help identify flooding problem areas. We are seeking the community's help by collecting information on any flooding or drainage problems that you may have experienced in the past.

Please take a minute or two to read through these questions and provide responses wherever you can. Please return this form to Council's consultant in the enclosed envelope (no stamp required) by the 27th of July 2012. All information provided is confidential and used only for the purposes of the study. For more information or to complete the questionnaire online please visit:

http://SpringvaleFloodvale.bmtwbm.com.au

Contact and Property Details

Name:...

Address:...

Phone or email:...

Please tick your type of property :

☐ House ☐ Unit/Flat/Apartment

☐ Business ☐ Other (please specify)

....

How long have you been at this property?

.... Years

Previous Flooding Experience

Have you ever experienced flooding on your property?

☐ Yes – inside the dwelling above the floor level

☐ Yes – significant flooding within the grounds or garage but not inside the main dwelling

☐ Yes – minor flooding within a small portion of the grounds only

☐ No

If yes, what dates or years did this happen?

....

If yes, does this occur regularly? **Y / N**
(i.e. several times a year)

Have you ever experienced flooding on your street?

☐ Yes – across one or both lanes of traffic

☐ Yes – minor along gutters

☐ No

If yes, does this occur regularly? **Y / N**
(i.e. several times a year)

Are you able to indicate the depth that flood waters reached on your property or elsewhere such as roads?

....

....

....

A map is provided on the back, please mark your property and any known flooding areas.

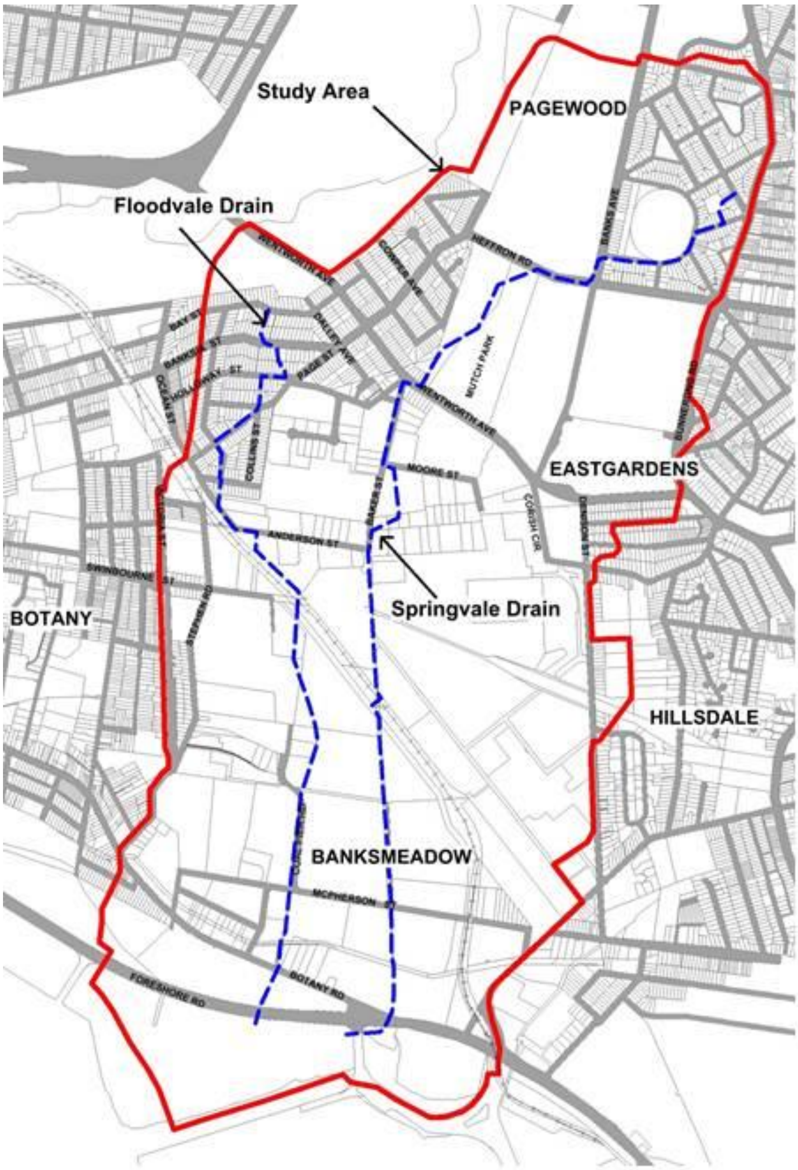
Photographs and Video

Do you have any photographs or video of flooding that you are willing to share?

☐ Yes ☐ No

Photographs and video can be returned with this form or emailed to:

SydFlood@bmtwbm.com.au



Please mark your property and any known flooding areas on the map.

Please describe any flooding experienced below if you can (i.e. approximate water depth, duration of the flooding, where the flood water came from and drained to).

Are there any flooding issues you would like the study to consider?

Please provide any additional comments or information that you think will help the study.

<u>THANK YOU</u> for your participation. Please return this form to Council's consultant in the enclosed envelope (no stamp required) by the <u>27th of July 2012</u>

Appendix D Pit Inlet Curves

Figure D-1 Pit Inlet Capacity Curves for Selected Nominal Lintel Lengths (Lintel only)

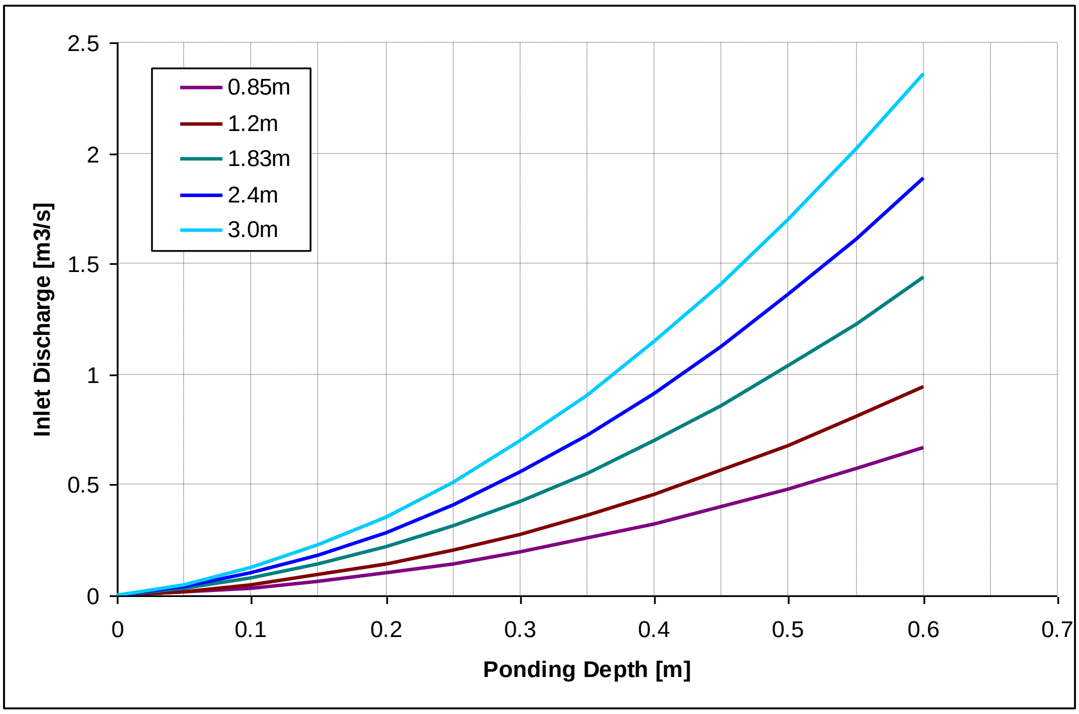
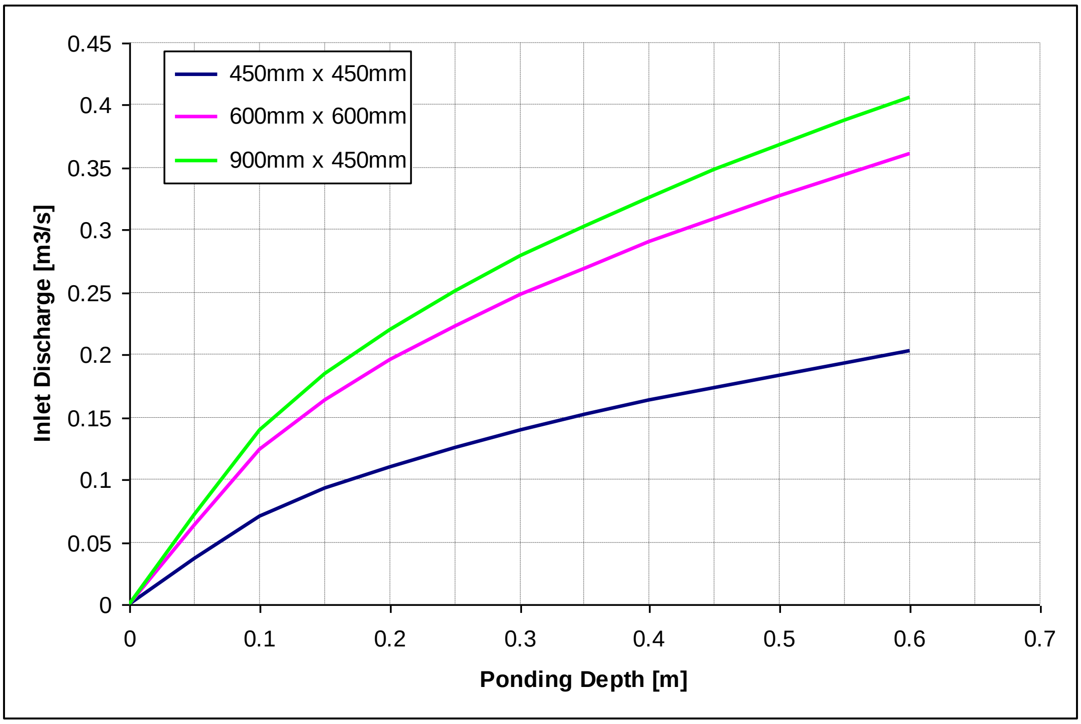


Figure D-2 Pit Inlet Capacity Curves for Selected Grate Dimensions (Grate Only)



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BMT WBM Bangalow
6/20 Byron Street, Bangalow 2479
Tel +61 2 6687 0466 Fax +61 2 66870422
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Brisbane
Level 8, 200 Creek Street, Brisbane 4000
PO Box 203, Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, #B120
Centennial, Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com

BMT WBM London
International House, 1st Floor
St Katharine's Way, London E1W 1AY
Email london@bmtwbm.co.uk
Web www.bmtwbm.com

BMT WBM Mackay
Suite 1, 138 Wood Street, Mackay 4740
PO Box 4447, Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street, Melbourne 3000
PO Box 604, Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street, Broadmeadow 2292
PO Box 266, Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Suite 6, 29 Hood Street, Subiaco 6008
Tel +61 8 9328 2029 Fax +61 8 9486 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Level 1, 256-258 Norton Street, Leichhardt 2040
PO Box 194, Leichhardt NSW 2040
Tel +61 2 8987 2900 Fax +61 2 8987 2999
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
Suite 401, 611 Alexander Street
Vancouver British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com