Brighton Creek Flood Study
Volume 1 of 2

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Brighton Creek Flood Study

Volume 1 of 2

Prepared by Brisbane City Council's, City Projects Office

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Executive Summary

Introduction

Brighton Creek is a tidally impacted catchment located within the north-eastern corner of Brisbane. It covers a catchment area of approximately 244 hectares (ha) within the suburb of Brighton, which was built on reclaimed land. The catchment is relatively flat with a maximum ground elevation of 20m AHD at its northern and western boundaries. The level drops to about 3m AHD within approximately 600m of the catchment boundary. The catchment is mostly developed leaving limited areas for future development.

The western boundary to Brighton Creek catchment is Bald Hills Creek catchment and Deagon Deviation while the eastern boundary is Bramble Bay. Its northern boundary is a mangrove wetland partly reclaimed in 1930's. The southern boundary consists of two lagoons and some residentially developed land. Runoff from the catchment is conveyed through two small open channels located within vegetated wetlands and those channels merge before draining in to the Bramble Bay between 16^{th} and 17^{th} Avenues. The wetlands significantly contribute to flood storage and attenuate flood peaks.

Brisbane City Council is currently updating flood studies undertaken for Brisbane creeks to keep up with best practice modelling techniques and to reflect current and future catchment development. The existing flood study for Brighton Creek catchment was undertaken by Brisbane City Council Department of Works in 1997 and was used to define flood regulation lines and design flood levels. The hydrology and hydraulic models developed in that study required updating.

Study Objectives

The objectives of the Brighton Creek Flood Study are as follows:

- Review, update and validate the hydrological modelling of the Brighton Creek catchment using the latest modelling software, topographic and flood information data to represent city plan development
- Develop a two dimensional (2D or 1D/2D) hydraulic model using the best practice flood modelling techniques to derive reliable flood information
- Estimate design flood information for the design flood events including large and extreme events considering planning requirements and quantifying the impacts of Minimum Riparian Corridor (MRC) and Waterway Corridor (WC)

- Produce flood inundation, flood depth and flood hazard mapping for the selected range of design and extreme events up to the PMF as required for flood emergency planning
- Quantify the impacts of climate change on flooding within the catchment
- Quantify the impacts of blockage on selected structures within the catchment.

Study Elements

The Brighton Creek Flood Study consists of the following elements:

Calibration and Verification Modelling

The hydrologic model developed in the Flood Study, 1997 for the Brighton Creek Catchment was reviewed and upgraded to current version of the XP-RAFTS software using the most recent topographic information and City Plan development. A new two dimensional hydraulic model was developed for the catchment using the TUFLOW-2D modelling software.

Calibration of TUFLOW and XP-RAFTS models was undertaken utilizing the 25th January 1974 Australia Day storm. Verification of the XP-RAFTS and TUFLOW models with consistency checking were undertaken using the 20th May 2009 and 10th October 2010 rainfall events. The TUFLOW model was also verified for bank full discharge events using the results of the Brighton Creek Flood Study, 1997. Structure head losses derived from TUFLOW model were verified by developing HEC-RAS models for each structure.

The Selection of model parameters for the catchment was undertaken such that the models could re-produce the recorded flood level information for the historical events to an acceptable accuracy.

Design and Extreme Events modelling including Sensitivity Testing

The calibrated hydrologic and hydraulic models were then used to simulate the full range of design flood events from 2 to 100 years Average Recurrence Interval (ARI). Large to extreme flood magnitudes were estimated for 200, 500 and 2000 year ARI events including the Probable Maximum Flood (PMF). These analyses assumed ultimate catchment development conditions in accordance with the current version of BCC City Plan.

Three waterway scenarios were considered in the analysis as follows:

Scenario-1: based on the current waterway conditions. No further modifications were made to the TUFLOW model developed as part of the calibration / verification phase.

Scenario-2: includes an allowance for a re-vegetated riparian corridor along the edge of the channel.

Scenario-3: includes an allowance for the riparian corridor (as per Scenario 2) and also assumes filling to the Waterway Corridor (WC) boundary to simulate potential development outside the WC.

The results from the TUFLOW modelling were used to produce the following:

- Peak flood discharges
- Critical storm durations at selected locations
- Peak flood levels
- Peak flood extent mapping
- Peak flood depth mapping
- Hydraulic structure Reference Sheets

A climate change analysis was undertaken to determine the impacts for two planning horizons; namely 2050 and 2100. This included making allowances for increased rainfall intensity and increased mean sea level rise. This analysis was undertaken for the 100 year, 200 year and 500 year ARI events. The results from the TUFLOW modelling were used to produce the impacts to peak flood levels

Blockage analysis was also conducted using the 100 year ARI event to determine the impacts for 5 significant structures in the Brighton Creek Catchment. Inlet and sediment blockage were represented for independent model simulations. The results from the TUFLOW modelling were used to quantify potential impacts to peak flood levels upstream of each structure.

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Glossary of Terms

Term	Definition
AHD	Australian Height Datum (AHD) is the reference level for defining reduced levels adopted by the National Mapping Council of Australia. The level of 0.0 m AHD is approximately mean sea level.
AMTD	Adopted Middle Thread Distance
ARI	The Average Recurrence Interval (ARI) is a statistical estimate of the average period in years between the occurrences of a flood of a given size at a specific location. For example, a 100-year ARI could also be expressed as having a 1 in 100 chance or a 1 per cent chance of occurring in any given year.
AEP	The Annual Exceedance Probability that a given rainfall total or flood flow will be exceeded in any one year. For example, a 100-year ARI could also be expressed as having a 1 in 100 chance or a 1 per cent chance of occurring in any given year.
DEM	Digital Elevation Model (DEM) A three-dimensional model of the ground surface elevation
Design Event, Design Storm	A mathematical/storm representing a precipitation event
DIS storm	Duration Independent Storm, a Synthetic design storm pattern developed by BCC intended to simulate design events
ESTRY	1-dimensional flood modeling component of TUFLOW software
PMF	Probable Maximum Flood. The maximum flood that is reasonably estimated to not be exceeded. Derived from a PMP.
PMP	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year.

List of Abbreviations

Abbreviation	Definition
AMTD	Adopted Middle Thread Distance
ALS	Airborne Laser Scanning
AR&R	Australian Rainfall and Runoff (1999)
BCC	Brisbane City Council
CBD	Central Business District
IFD	Intensity Frequency Duration
MHG	Maximum Height Gauge
MRC	Minimum Riparian Corridor
MSQ	Maritime Safety Queensland
POT	Peak Over Threshold
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
QUDM	Queensland Urban Drainage Manual (2013)
WC	Waterway Corridor

1.0 Introduction

1.1 Catchment Overview

Brighton Creek catchment is located 19km to the north of Brisbane CBD within the suburb of Brighton, which was built on reclaimed land. The area was home to the World War II Barracks from 1940 to 1946. It was re-developed as a residential suburb by mid-1995. The western boundary to Brighton is Bald Hills Creek catchment and Deagon Deviation while the eastern boundary is Bramble Bay. Its northern boundary is a mangrove wetland partly reclaimed in 1930's while the southern boundary consists of two lagoons and some residentially developed land. It is a tidally impacted catchment enclosing an area of 244 hectares (ha) approximately.

The catchment consists of three wetlands, which are being maintained by the Brisbane City Council. These are considered as wooded wetlands and named as Goodenia Woods (South wetland), Pimelea Woods (Main wetland) and Dinella Woods (North wetland). Runoff resulting from rainfall on the catchment drains into the tidal canal through these wetlands. After crossing the culvert in Beaconsfield Terrace the tidal canal flows through a concrete lined canal into Bramble Bay between 15th and 16th Avenues.

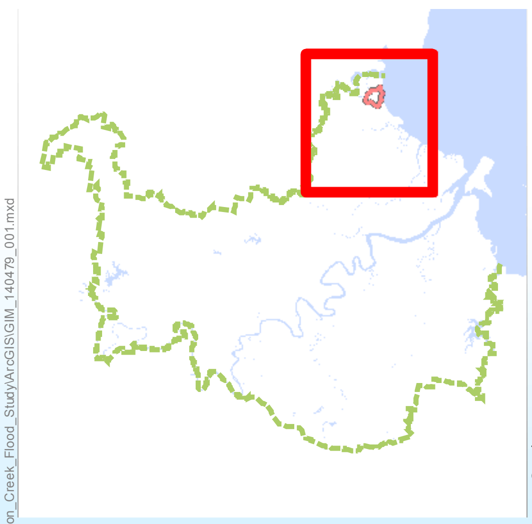
Brighton Creek consists of two main branches named South and North, which is re-named as the Main branch after they merge. A location map of the catchment is included in **Figure 1.1**.

1.2 Study Background

A Flood Study was carried out for the Brighton Creek catchment by the Works Department of Brisbane City Council (BCC) in 1997. The aim of that study was to delineate Flood Regulation Lines (FRL's) for the catchment and determine flood levels. In the study a hydrological model with XP-RAFTS Version 5.1 software and a hydraulic model with MIKE11-Version 3.2 software were developed to assess the hydrology and hydraulic characteristics. Presently these models are not in working condition and require updating. FRL's had been introduced as a means of demarcating the desired extents of fill areas for land development.

The catchment was analysed for design floods ranging from 2 to 100 year ARI events. Two methods had been used for the determination of design flows: namely the Duration Independent Storms (DIS) and standard Australian Rainfall & Runoff storms (AR&R), 1987.

Earlier, in 1974, Blain Bremer and Williams carried out a flood study to estimate design flood levels for the full Brighton Creek catchment. These results were used to identify the rehabilitation areas, flood mitigation measures and properties required for acquisition by the Council.



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Legend

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- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Channels
- Railway Station
- Railway Line
- Freeways/Highways
- Major Roads
- Streets
- Park Boundaries
- Suburb Boundaries

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Brighton Creek Locality Map

Figure 1.1

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1.3 Study Objectives

BCC is in the process of updating most BCC creek flood studies to reflect the future catchment conditions as per the current City Plan, and to apply best practice flood modelling techniques.

Objectives of the Brighton Creek Flood Study are:

- Review, update and validate the hydrology modelling of the Brighton Creek catchment using the latest modelling software and available data to represent city plan development.
- Develop a two dimensional (2D or 1D/2D) hydraulic model using the best practice flood modelling techniques to derive reliable flood information.
- Estimate design flood information for the design flood events including large and extreme events considering planning requirements.
- Produce flood inundation, flood depth and flood hazard mapping for the selected range of design and extreme events up to the PMF as required for flood emergency planning.

1.4 Report Scope and Limitations

The following tasks were undertaken to achieve the project objectives outlined above:

- Collating and reviewing previous flood studies and models, topographic information and recorded flood information if available
- Upgrading the existing XP-RAFTS hydrologic model developed for the Brighton Creek catchment in the Flood study, 1997 (BCFS, 1997).
- Developing a 2-dimensional hydraulic model using TUFLOW software for the Brighton Creek catchment to replace the existing 1-dimensional MIKE11 hydraulic model
- Calibration and verification of the XP-RAFTS and TUFLOW models based on the availability of recorded flood information. Verification of model results was also undertaken with reference to the BCFS, 1997
- Modelling of design flood events for 2, 5, 10, 20, 50 and 100 year ARI events using Australian Rainfall and Runoff 1987 (AR&R, 1987) storms for the ultimate catchment development conditions. Impacts of storm tide also considered to identify the maximum flood levels as the creek is tidally impacted
- Rare to extreme events modelling, which included 200, 500, 2000 year ARI and PMF events
- Modelling of climate variability scenarios for the 100-yr, 200-yr and 500-yr ARI events to quantify the impacts.
- Flood inundation and depth-velocity mapping.

2.0 Catchment Description

2.1 Catchment and Waterway Features and Characteristics

Brighton Creek catchment is a tidally impacted area located within the northern suburbs of Brisbane. The catchment is small and relatively flat with a maximum ground elevation of 20m AHD at its northern and eastern boundaries. The level drops to about 3m AHD within approximately 600m of the catchment boundary. The catchment is mostly developed leaving limited areas for future residential development.

There are three wetland areas, managed by the BCC located within the flatter part of the catchment generally below the 3m AHD level. Runoff from the most upstream area is connected through the stormwater runoff system. The majority of runoff is carried by a small open channel system located through the wetlands and drains into Bramble Bay through the tidally impacted canal. These wetlands contribute to flood storage and thereby help to control and attenuate peak flood levels.

Catchment runoffs flowing into the North and South wetlands are retained by Queens Parade and culverts located at these wetland crossings. The Main wetland is located between Queens Parade and Beaconsfield Terrace as in **Figure 2.1**. There are five significant channel crossings and these are located at Wickham Street, Queens Parade, Seaview Street, Townsend Street and Beaconsfield Terrace. In addition a few minor foot bridges/culvert crossings also exist.

2.2 Brighton Creek Tributaries

Brighton Creek channel consists of two main branches named South and North as shown in **Figure 2.1**. After the confluence of these two branches the channel is referred to as the Main Branch. This naming convention is as per the previous BCFS, 1997.

2.2.1 Northern branch

The Northern channel originates at Craig Street (outlet of stormwater pipe) and continues about 170m before entering into a 60m long pipe culvert which crosses Wickham Street and merges into the channel located within the northern wetland. It then discharges via the wetland and merges with the southern branch after crossing Queens Parade. The total length of the Northern branch is approximately 1400m.

2.2.2 Southern branch

The Southern branch appears to start as an open stormwater drain at the intersection of Dunne Street and Easter Street. Heading in easterly direction, it crosses Saul Street as an open drain and channel through the southern wetland. It crosses Queens Parade and Seaview Street through two reinforced concrete pipe culverts approximately 112m long, emerging as a concrete lined channel which continues until the Townsend Street culvert crossing. The Southern branch merges with the Northern branch after the Townsend Street crossing within the Main wetland. The channel is renamed as the Main branch after the merge.

2.2.3 Main Branch

Main Branch originates about 300m upstream (to the west) of Beaconsfield Terrace and drains into Bramble Bay after crossing Flinders Parade between Fifteenth and Sixteenth Avenues. The main branch is approximately 600m in length and part of the channel is concrete lined from Beaconsfield Terrace to Flinders Parade. The crossing at Beaconsfield Terrace consists of 5 pipe culverts, while a single span bridge crossing exists at Flinders Parade. There is also a small tributary immediately upstream of the Beaconsfield Terrace crossing. It merges with the Main branch after crossing the Shepherd Street to the north.

2.3 Land Use

The Brighton Creek catchment mainly consists of low density residential zoning with approximately 18% of the area occupied by vegetated wetlands, which are designated as conservation areas. There are a few pockets of land zoned as Emerging Communities (EC) and Sport and Recreation (SR) that are mainly adjacent to the wetlands. **Figure C.1** in Appendix C shows the land use adopted as per the City Plan.

2.4 Flood History

Flooding of the Brighton Creek catchment occurred during the Australia day floods of 1974. Observed flood level markers were surveyed after the January 1974 event with flood levels varying from 2 to 2.57 m AHD in the wetland areas of the catchment. These are the only historic flood levels available for the catchment.

After the 2011 January floods it was reported that wetlands became sodden but no houses were flooded. There has been some storm tide impact on properties in the catchment along the eastern boundary at Flinders Parade coinciding with severe weather conditions.

Legend

- Telemetry Gauge
- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Channels
- Freeways/Highways
- Major Roads
- Streets
- Property Holdings
- Suburb Boundaries
- Park Boundaries

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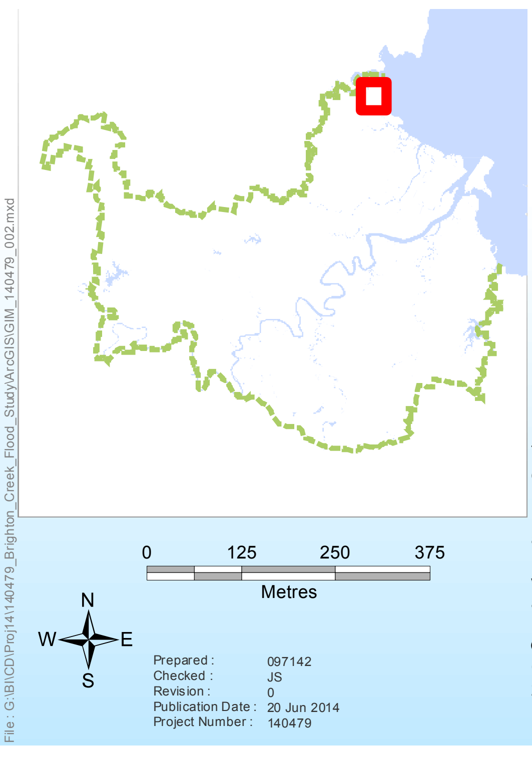

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Brighton Creek Catchment Area

Figure 2.1

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3.0 Available Information

3.1 Previous Studies

As described in Section 1.2, a flood study had been undertaken for the Brighton Creek catchment in 1997 which provides the current design flood level information. The flood study had estimated flood levels for the 2, 5, 10, 20, 50 and 100 year ARI events and demarcated a Flood Regulation Line.

3.2 Topographic Survey Data

3.2.1 Field Survey

Cross section survey was conducted by Brisbane City Council in 1997 prior to the BCFS, 1997 and these details are available for use. A Location map of these surveyed cross sections is given in **Figure A.1** in Appendix-A. New survey was not undertaken as there were no considerable changes in the catchment since 1997.

3.2.2 Aerial Survey and Photography

Aerial images are available for the Brighton area from 1995 up to 2012 within Council's GIS system. LIDAR data of 2002 and 2009 are available and these were used to obtain topographic information. Contour maps developed in 2002 and 2009 are also available and were used for demarcating catchment boundaries and sub catchment layout for the hydrology model.

3.2.3 Bathymetric Survey

The creek runs through the wetlands with its channel section varying from 4 to 6m in width. The existing survey indicates that the bed level of the channel in tidally impacted areas varies between -0.3 to 0.7 mAHD. However there was no separate bathymetry survey undertaken for the Brighton creek catchment. It is believed that the existing survey provides sufficient information on bathymetry which is fit for the purpose of this study.

3.2.4 Site Visits

Site visits were undertaken to identify the existing conditions of the waterway, characteristics of storage areas provided by the wetlands and the hydraulic structures. These visits were made in high and low tide conditions to inspect the hydraulic behaviour under tidal influences.

3.3 Hydrometric Data and Analysis

3.3.1 Recorded Rainfall

There is a rainfall gauge: MBR752 (as shown in **Figure 2.1**) located near the Brighton Bowls Club in the Brighton Creek catchment which has been in operation since December 1999. Rainfall gauges in nearby catchments are located at Jude Street reservoir in Bracken Ridge Road in Bracken Ridge in the Bald Hills Creek catchment: BDR839 (from February 2009 to date) and at Braun Street Deagon in Cabbage Tree Creek catchment: C_R560 (from June 1994). Prior to that there was a rainfall gauge located in Bracken Ridge Road, Bracken Ridge in Bald Hills Creek catchment: BDR712, which was operated from June 1994 to November 2003. The rainfall station that was available during the 1974 storms was the Sandgate Work's depot rainfall gauge operated by BCC.

The BCFS, 1997 has used the January 1974 and May 1996 rainfall events to calibrate/validate the hydrology and hydraulic models. From the recent events the storms that occurred in October 2010 and May 2009 resulted in considerable rainfall in the catchment. Total rainfalls observed in these events are listed in Table 3.1 below.

Table 3.1: Available Rainfall Data

Event Date	Period	Rainfall	Approximate ARI of the event
25 January 1974	24/01/1974 9:00am 28/04/1974 8:45am	658mm	50-100 year (6-24 hr)
01 May 1996	24/01/1974 0:00 am to 07/05/19996 22:45 pm	443mm	2-5 year (9-12 hr)
10 October 2010	08/10/2010 1:00am 11/10/2010 23:15 pm	367mm	5-10 year (6 – 12 hr)
20 May 2009	18/05/2009 17:00 to 22/05/2009 00:00	353mm	5-10 year (6-12 hr)
11 January 2011	09/11/2011 00:00 am to 12/01/2011	154mm	2 year (12-24 hr)

3.3.2 Recorded Flood Levels

Stream Gauge and Maximum height Gauge Data

There are no stream height gauges or maximum height gauges available in the catchment and therefore no recorded flood level information exists along Brighton Creek or in the catchment. However there is some surveyed flood level information for the 1974 Australia Day event and this had been used for the model verification in the BCFS, 1997.

Debris Marks

Surveyed flood levels of debris marks for the Australia day flood in 1974 were obtained from Table-12 of the Flood Study, (1997). It was identified that the peak tide level was 1.53 m AHD for the event, obtained from the Department of Transport. The surveyed flood level at the foreshore area was 2.26m AHD, which may potentially be due to wave run up and local runoff.

3.4 Tidal Information

Historic tidal information was obtained from the Brisbane Bar tide gauge operated by Maritime Safety Queensland (MSQ) as there is no tide gauge located at the mouth of Brighton Creek. The tidal gauge data was available for rainfall events listed in Table 3.1.

3.5 Hydraulic Structure Data

There are five culvert crossings and a single span bridge included in the study. These crossings were located in Wickham Street, Queens Parade, Beaconsfield Terrace, Townsend Street, Sheffield Street and Flinders Parade crossings. Data for these structures was sourced mainly from as constructed drawings.

4.0 Hydrologic Model Development and Calibration

4.1 Overview

The RAFTS-XP model for Brighton Creek Catchment was developed as part of the BCFS, 1997. This model had been verified against the results of the MIKE11 hydraulic model developed with that study which in turn had been calibrated against surveyed debris levels from the 1974 Australia day flood.

The existing RAFTS-XP model was reviewed and updated for the new flood study with reference to City Plan 2010. The same procedure as adopted in the previous flood study was undertaken in calibrating and verifying the model. The extent of the catchment and the sub-catchment layout is given in **Figure 4.1**: Sub-catchment layout map and the rainfall gauge location.

4.2 Model Set Up and Schematisation

A number of modifications were made to the existing RAFTS-XP model as part of this study as follows:

- The RAFTS model was updated to the XP-RAFTS 2009 version.
- Sub catchment layout was digitised using the contour maps and also with reference to the BCFS, 1997 layout. Larger sub-catchment areas were sub-divided into finer areas for better representation of the catchment and stormwater inflow
- Catchment slopes were reviewed and updated as a result of better topographical data
- Impervious fractions were updated with reference to the recent City Plan and QUDM revision recommendations
- Model link data adopted was the same as the existing RAFTS-XP model.

Brighton Creek catchment was divided into 15 sub-catchments in the BCFS, 1997. In the digitised layout, sub-catchment 6, 7 and 12 were further sub-divided. A new map for the sub-catchment layout for the Brighton Creek catchment is given in **Figure 4.1**. Percentage impervious fractions adopted for each land development categories within the Brighton Creek catchment are listed in Table4.1. The catchment parameters adopted in the updated XP-RAFTS model are listed in Table 4.2.

Existing wetland areas provide considerable storage within the catchment. As the hydrology model results were to be verified against the hydraulic model results, wetland areas were modelled as detention basins in the XP-RAFTS model. Stage-discharge and stage-storage values derived for the Southern, Northern and Main wetlands were given in the BCFS, 1997 in tables 7, 8, 9. These data were reviewed and amended for use in the model as given in Appendix-B, Table B.1 to B.3.

Table 4.1: Percentage impervious fractions adopted for catchment development categories

Item	Land use type	% Impervious (QUDM 2007 and estimated)
1	Emerging Communities	30
2	Low Density Residential	55
3	Community Use Area Health Care Purposes	80
4	Community Use Area Utility Services	45
5	Multi-Purpose Centre Convenience Centre	60
6	Sport And Recreation	15
7	Park Land	0
8	Remainder (Road Reserve)	65
9	Conservation	0
10	Environmental Protection	0

Table 4.2: Catchment parameters adopted in the XP-RAFTS model

Sub-catchment ID	Area (ha)	% Impervious	Impervious Area (ha)	Pervious Area	Catchment Slope (%)
1	10.5	57.5	6.1	4.5	2.1
1B	5.1	48.1	2.5	2.7	1.8
2	14.8	54.7	8.1	6.7	2.4
3	10.2	41.9	4.3	5.9	2.9
4	16.0	46.1	7.4	8.6	2.1
5	11.0	38.1	4.2	6.8	1.5
6A	18.8	51.0	9.6	9.2	1.7
6B	9.8	20.5	2.0	7.8	0.5
7A	13.0	35.4	4.6	8.4	1.3
7B	10.2	42.3	4.3	5.9	1.2
8	17.7	56.8	10.7	7.6	1.5
9	4.3	24.1	1.0	1.7	1.7
10	13.1	57.3	7.5	5.6	2.6
11	9.8	49.8	4.9	4.9	1.3
12A	17.6	31.7	5.6	12.0	0.9
12B	16.3	46.8	7.6	8.7	0.4
13	9.9	49.7	4.9	5.0	0.8
14	15.1	48.1	7.3	7.8	0.4
15	20.7	57.6	11.9	8.8	0.4
16	7.15	57.0	4.09	3.06	0.4

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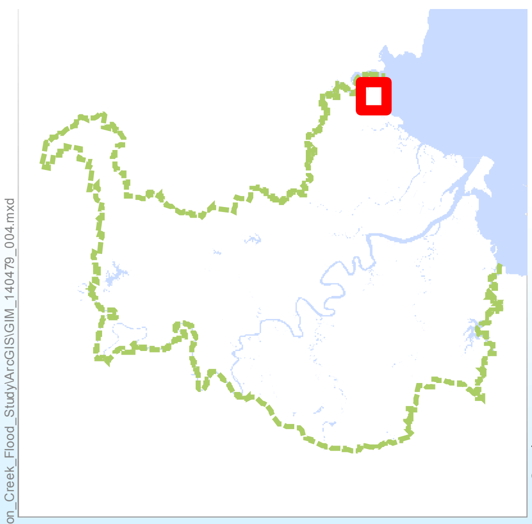

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Brighton Creek Subcatchment Layout Map

Figure 4.1

GIM - 140479 - 004

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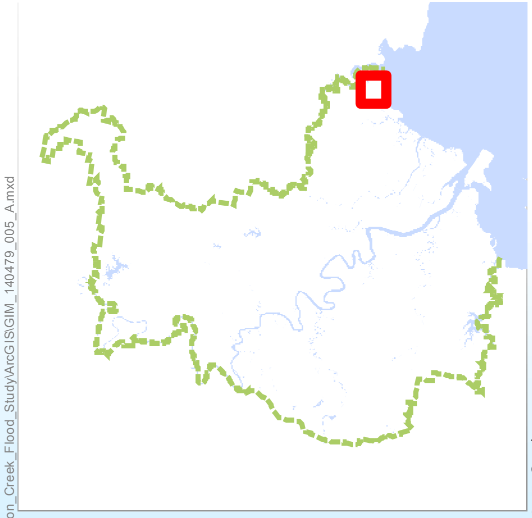

Legend

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- Telemetry Gauge
- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Subcatchments
- Brighton Creek Channels
- Freeways/Highways
- Major Roads
- Streets
- Suburb Boundaries

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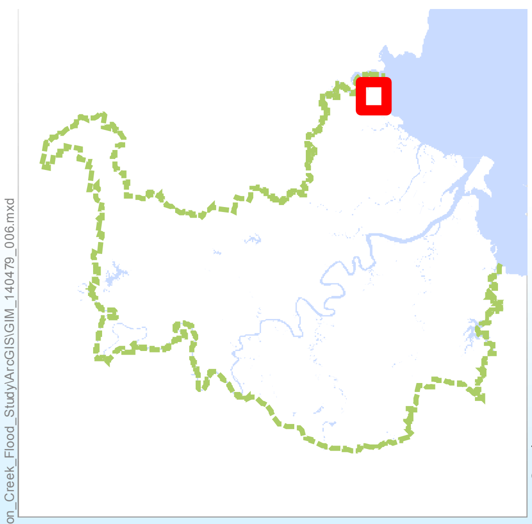
Brighton Creek Subcatchment Layout Map
2012 Aerial Image
Figure 4.2

GIM - 140479 - 005



Legend

- Brighton Creek XP-RAFTS Nodes
- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Subcatchments
- Brighton Creek Channels
- Freeways/Highways
- Major Roads
- Streets
- Property Holdings
- Suburb Boundaries
- Park Boundaries

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Brighton Creek XP-RAFTS Model Layout

Figure 4.3

GIM - 140479 - 006

4.3 Selection of Calibration and Verification Events

The selection of rainfall events for calibration and verification was based upon the event size, as well as the data availability for the period of the rain event. As listed in Table 3.1 rainfall events were recorded in the catchment in 2009, 2010 and 2011 events while for 1974 and 1996 events rainfall data was available in nearby gauges. However, there are no stream gauges existing in the catchment and therefore no flood level records available for calibration other than those surveyed debris levels available for the 25th January 1974 flood.

The 10th October 2010 and 20th May 2009 events were identified as having ARI of 5 to 10 years for 6-12 hour durations when compared IFD:1987 curves and peak discharges. These two events were selected for model verification together with hydraulic model TUFLOW results. The verification procedure is discussed in section 4.4. Details of the selected events are as follows:

4.3.1 25th January 1974 Event

Rainfall data was available from 9:00 am on 24/01/1974 to 28/01/1974 for this event. Recorded daily rainfall totals are listed below in Table 4.3. Cumulative rainfall plots are given in **Figure A.2** in Appendix-A. In comparison to IFD: 1987 data this event rated at between 50 and 100 year ARI (1% and 2% AEP) for 6 to 24 hour duration events. Highest daily rainfall total was reported on 25/01/1974. Table 4.4 lists the levels of debris marks surveyed after the event.

Table 4.3: Rainfall totals

Date	Daily Rainfall Total(mm)
24/01/1974	32
25/01/1974	333.7
26/01/1974	172.1
27/01/1974	104.5
Total	642.3

Table 4.4: Details of debris marks of 25th January1974 flood

Location (Figure D.1-Appendix D)	Debris level (mAHD)
Upstream of Beaconsfield Terrace	2.46
North Branch-Queens Parade upstream (MIKE11 chainage-710m)	2.50
Wickham Street upstream	3.38
South Branch- Queens Parade upstream (Mike11 ch-705m)	2.57
Saul Street upstream	3.10

4.3.2 20 May 2009 Event

Rainfall occurred from 18th May 2009 and continued until 21st May 2009 with heaviest rain falling on 20th May 2009 (Table 4.5). The majority of the rainfall for the event fell between 4:00 pm on the 19th May to the afternoon on 20th May 2009 and cumulative rainfall plots are in **Figure A.3** of Appendix-A . Cumulative rainfall of the event was 357mm, while 215 mm (60%) fell on 20th May as measured by Brighton Creek rain gauge records. The flood peak occurred at mid night on the 20th May 2009 with reference to the hydrologic analysis.

Table 4.5: Rainfall totals for May 2009 event

Date	Daily Rainfall Total (mm)
18/05/2009 (from 5pm)	10
19/05/2009	130
20/05/2009	215
21/05/2009	2
Total	357 mm

4.3.3 10 October 2010 event

Rain fell continuously from 10th October 2010 afternoon to the following evening with a total of 202 mm (55%) recorded within that period. Cumulative rainfall of 367 mm (Table 4.6) was recorded for the whole event from 08th October 2010 to 11th October 2010 in the Brighton Creek gauge and cumulative plot is given in **Figure A.4** Appendix-A. Hydrologic analysis indicated that flood peak occurred in early morning on 11th October 2010.

Table 4.6: Rainfall totals for October 2010 event

Date	Rainfall Total(mm)
08/10/2010	115
09/10/2010	29
10/10/2010	21
11/10/2010	202
Total	367 mm

4.4 Calibration Process

The hydrology model XP-RAFTS was used to simulate the above rainfall events and outflow hydrographs were obtained at selected locations. After developing the TUFLOW hydraulic model, runoff for these events obtained from XP-RAFTS model were simulated through the TUFLOW model. The discharge profiles obtained from the two models at selected locations were then compared. Results of the modelling is summarised after hydraulic model development. Default parameters adopted in the XP-RAFTS model are given in Table 4.7.

Table 4.7: Model Parameter in XPRAFTS Model

Description	Notation	Value adopted
Storage-non-linearity exponent	n	-0.285
Storage delay time coefficient multiplier	BX	1.0
Continuing loss (mm/hour)	CL	0

5.0 Hydraulic Model Development and Calibration

5.1 Overview

The previous hydraulic model for the Brighton Creek catchment was a one dimensional MIKE11 model developed in conjunction with the BCFS,1997. Topographic characteristics of the catchment together with a tidally impacted channel best suites the adoption of a 2D flood model to assess the impacts of flooding. This is justified as follows:

- Flatter and wider flood plain with low flow channels
- Existence of wetlands that provide significant flood storage
- Excess floodwaters in two of the wetlands spill over Queens Parade at a few locations
- Runoff from the most upstream portions of the catchment is transported via a piped stormwater drainage system and discharging into the Brighton creek channels
- Tidal intrusion in the lower part of the catchment
- Culvert crossings with wide overflow lengths.

A 2D-flood model was best suited for the Brighton Creek catchment to assess the hydraulic behaviour and flooding impacts with flood storage provided by the conservation areas and overflow through the bounded roads. As the catchment is very small it was decided to build a TUFLOW-2D (Version 2012-05-AE) with a smaller grid size for the catchment to achieve the desired outcomes. Adoption of a 2m grid size would help to represent the creek channel configuration with low flow channels through the wetlands fairly accurate.

5.2 Available Data

The following data was available for the development of the hydraulic model:

- MIKE11 model developed with BCFS, 1997
- BCC, 1997 cross section survey
- Airborne Laser Scanning (ALS) data of 2009
- Contour Maps and GIS data of BCC
- City plan (current version)
- As constructed drawings of BCC for hydraulic structures.

5.3 Model Development

5.3.1 Model Schematisation

The extents of the TUFLOW hydraulic model adopted for Brighton Creek are shown in **Figure 5.1**.

As described in Section 2.2, Brighton Creek consists of two main branches running through wetlands. The Northern Branch originates from Craig Street at the intersection of Lebanon Street. The Southern Branch originates from Dunne Street at the intersection of Easter Street. The Northern Branch is renamed as the Main Branch after it merges with the Southern Branch. Full lengths of tributaries are included in the TUFLOW-2D model from Craig and Dunne Streets in the west, to Flinders Parade in the east, covering the whole catchment area to Bramble Bay.

5.3.2 Topography-2D domain

TUFLOW model bathymetry for the Creek catchment was derived using the ALS data of 2009. A Digital Elevation Model (DEM) was created with 1m and 2m grid (projection MGA zone 56). Existing survey cross section information of 1997 was used to update the creek bed levels in the DEM and it was assumed this would provide the accuracy required in meeting the modelling objectives. Levels at the structure crossings were verified with as constructed drawings and bathymetry was updated to represent the invert levels and 2D road surfaces. TUFLOW model base runs were undertaken and grid check files were generated. These grid files were then used to check the adopted cross section geometry of the waterway channel in the TUFLOW model bathymetry. This procedure verified the representation of the channel topography in the TUFLOW model with reference to the existing surveyed cross section information.

Legend

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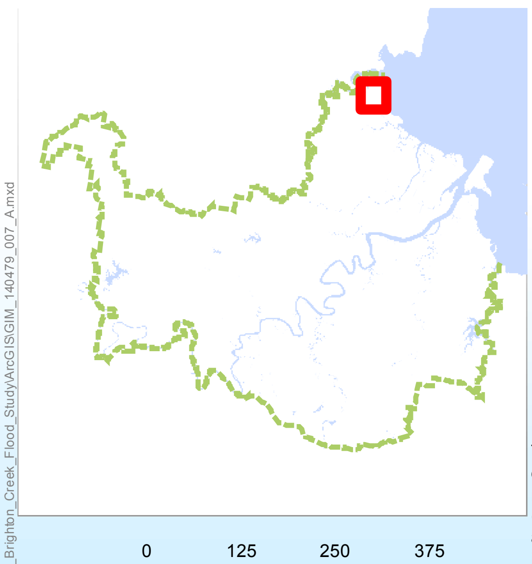

TUFLOW Model Area		Freeways/Highways	
AMTD Line		Major Roads	
Brighton Creek Subcatchments		Streets	
Brighton Creek Channels		Property Holdings	
		Suburb Boundaries	
		Park Boundaries	

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Brighton Creek TUFLOW Model Layout

Figure 5.1

GIM - 140479 - 007

5.3.3 Land Use

The Manning's 'n' values adopted in the TUFLOW model are shown in Table 5.1. BCC City Plan, aerial photography, and site visits were used to identify the land-use and topographical features within the TUFLOW model domain. The selection of appropriate roughness values were based on the existing flood studies and experience from similar projects. **Figure C.2** in Appendix-C shows the adopted material data (roughness values) for land use zones with reference to the City Plan.

5.3.4 Hydraulic Structures

Six culvert structures and a small bridge structure were included in the TUFLOW model. Culverts were modelled as one dimensional structures, with the overflow areas represented in the 2D grid. The bridge at Flinders Parade was modelled as a 2D bridge structure. Head loss across the structures was checked by developing HEC-RAS models for each crossing. Table 5.2 lists the details and locations of structures that were modelled in the TUFLOW model.

5.3.5 Boundary Conditions

Inflow data for the TUFLOW hydraulic model was obtained from the XP-RAFTS hydrology model and used in the TULOW model by introducing locations with spatial polygon. These inflow locations were introduced with reference to the sub catchment schematisation and stormwater discharge points. A time dependant water level was adopted as the downstream tidal boundary level. Brisbane Bar tide gauge data (obtained from tide data book) was updated to represent the modelling location. Tide levels for the January 1974 flood were taken from the BCFS, 1997 originally obtained data was from the Department of Transport. **Figure 5.2** shows the inflow point location map with position of tidal boundary.

5.3.6 Run Parameters

The time step in the TUFLOW-1D (Estry Control File:ecf) and TUFLOW-2D (TUFLOW Control File:tcf) both were run initially using one second. In order to reduce the instabilities noticed at some structures the 1D time step was reduced to 0.5 seconds.

Legend

- TUFLOW Model Inflow Points
- Culverts
- AMTD Line
- Brighton Creek Channels
- TUFLOW Model Area
- Freeways/Highways
- Major Roads
- Streets
- Brighton Creek Subcatchments
- Property Holdings
- Suburb Boundaries
- Park Boundaries

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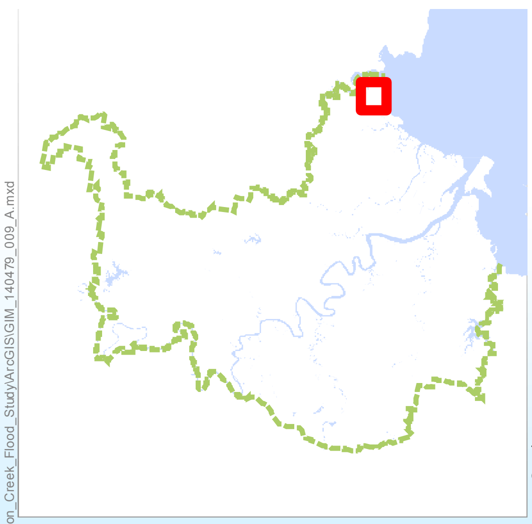

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DATA INFORMATION

Brighton Creek TUFLOW Model Layout
Inflow Locations
Figure 5.2

GIM - 140479 - 009

Table 5.1: Adopted roughness parameters in the TUFLOW material data

	Topographical Feature / Land use	Adopted Manning's n
	Community Use Area Community Facilities	0.1
	Community Use Area Education Purposes	0.1
	Community Use Area Emergency Services	0.15
	Community Use Area Health Care Purposes	0.15
	Community Use Area Railway	0.13
	Community Use Area Utility Services	0.04
	Emerging Communities	0.06
	Sport And Recreation	0.04
	High Density Residential	0.15
	Low – Medium Density Residential	0.15
	Low Density Residential	0.12
	Light Industry	0.15
	Multi-Purpose Centre Convenience Centre	0.15
	Multi-Purpose Centre Suburban Centre	0.15
	Park Land	0.04
	Sports and Recreation	0.04
	Conservation, Environment protection	0.08
	Additional Roughness	
	Roads	0.02
	Channel – smooth (e.g. concrete)	0.015
	Channel – smooth to medium	0.025
	Channel – medium (little or no vegetation)	0.035
	Channel – medium to rough	0.05
	Vegetation – little or none (e.g. grass)	0.035
	Vegetation – light density	0.05
	Vegetation – medium density	0.08
	Vegetation – medium to high density	0.12
	Vegetation – high density	0.15
	Buildings	1.00
	Minimum Riparian Corridor (MRC)	0.15

Table 5.2: Details of Hydraulic Structures modeled in the TUFLOW Model

ID	Brighton Creek Branch	Location	Data Source	Type	Size (m)	No.of Cells	Length (m)
1	North branch	Wickham St	As constructed drawings	RCP	1.35 (diameter)	2	62
				RCP	1.2 (diameter)	1	62
2	North Branch	Queens Parade	As constructed drawings	RCBC	2.1(w) x 1.15(h)	2	12
3	South Branch	Queens Parade	As constructed drawings	RCP	1.22m (diameter)	2	115
4	South Branch	Townsend Street	As constructed drawings	RCP	1.22m (diameter)	2	12
5	Main branch	Beaconsfield Terrace	As constructed drawings	RCP	1.8m (diameter)	5	22
6	Main branch	Flinders Parade	As constructed drawings	Bridge	9.9 span	Single span	16
7	Tributary of Main branch	Shepard Street	As constructed drawings	RCBC	3(w) x 1.2(h)	1	12

5.4 Calibration Procedure

As described in section 3.3.2 stream gauges or maximum height gauges are not located in the Brighton Creek catchment. There was no recorded flood level information available except for a few surveyed debris mark levels collected after the 1974 Australia Day flood event. Rainfall records are available with the Brighton Creek rainfall gauge for the May 2009 and October 2010 rainfall events. The other available information is the flood level results derived from the MIKE11 model developed in BCFS, 1997.

The following procedure was adopted in calibrating and verifying the TUFLOW and XP-RAFTS models.

1. Calibration of the TUFLOW model with debris marker levels from 25th January 1974 flood event to see if ± 400mm tolerance limits could be achieved. Comparison of discharge profiles at selected locations obtained from XP-RAFTS hydrology model and TUFLOW hydraulic model were also undertaken to see the peaks and timing.
2. Flood levels for low flow events (i.e. 2 and 5 year ARI events) derived from the MIKE11, 1997 model were used to verify the TUFLOW model results. The MIKE11 model flood discharges for Duration Independent storm (DIS) events were ran with the TUFLOW model with similar boundary conditions. The peak flood level results were compared from both models which helped to identify the TUFLOW model behaviour during lower discharges.

3. Comparison of flood discharge profiles obtained from XP-RAFTS and TUFLOW models for 20th May 2009 and 10th October 2010 events at selected locations: The XP-RAFTS runoff from these historical storm event simulations was used in the TUFLOW model simulation. Discharge hydrographs obtained from XP-RAFTS and TUFLOW model were then compared at selected locations. This helped to verify the consistency between XP-RAFTS and TUFLOW models.

4. Structure head loss results comparison between TUFLOW and HECRAS models: HEC-RAS models were developed for modelled structure crossings in TUFLOW. structure head loss for selected discharges from HEC-RAS model was compared with the TUFLOW results (This was undertaken as a part of the structure verification and results are included in section 5.7).

5.5 Hydraulic Model Calibration and Verification Results

5.5.1 Comparison of Flood levels for 25th January 1974 event with debris marker levels

Flood levels obtained from TUFLOW model for 25th January 1974 event at debris mark locations were compared with surveyed levels and tabulated in Table 5.3. Comparison of discharge hydrographs for 25th January 1974 event obtained from XP-RAFTS and TUFLOW models are included in section 5.5.3 with plots of 2009 and 2010 events.

Table 5.3 Recorded and derived debris mark levels from 25th January 1974 event

Location	Measured level (m AHD)	Modelled level (TUFLOW) m AHD)	Difference (m)
Beaconsfield Terrace US	2.46	2.25	**0.210**
North Branch-US of Queens Parade	2.38	2.34	0.04
Wickham St -US	3.38	3.20	**0.18**
South branch-BR330	2.57	2.4	**0.17**
Saul Street-US	3.10	3.12	**-0.02**

5.5.2 Verification of the TUFLOW model and MIKE11, (1997) results for low flow events

Existing MIKE11 model results files were available for the Duration Independent Storm runs (DIS) for 2, 5, 10, 20, 50 and 100 year ARI events. The TUFLOW model was run with the flood discharges for 2 and 5 year ARI DIS storms as adopted in the MIKE11 model and the flood levels results between the two models were then compared at selected locations. Plots of the comparison of 2 year ARI storm at the locations listed below are given in **Figures: 5.3** to **5.6**.

- Main Branch: Beaconsfield Terrace (at cross section BR105)
- North Branch: Speight Street (at cross section BR170)
- South Branch: Upstream of Townsend Street (at cross section BR300).

Comparison of flood level results with MIKE11 results at the model chainage points are tabulated in Appendix-D Table D.1.

Figure 5.3: Comparison of MIKE11 model and TUFLOW model flood level results (2yr-DIS storm) at Beaconsfield Terrace

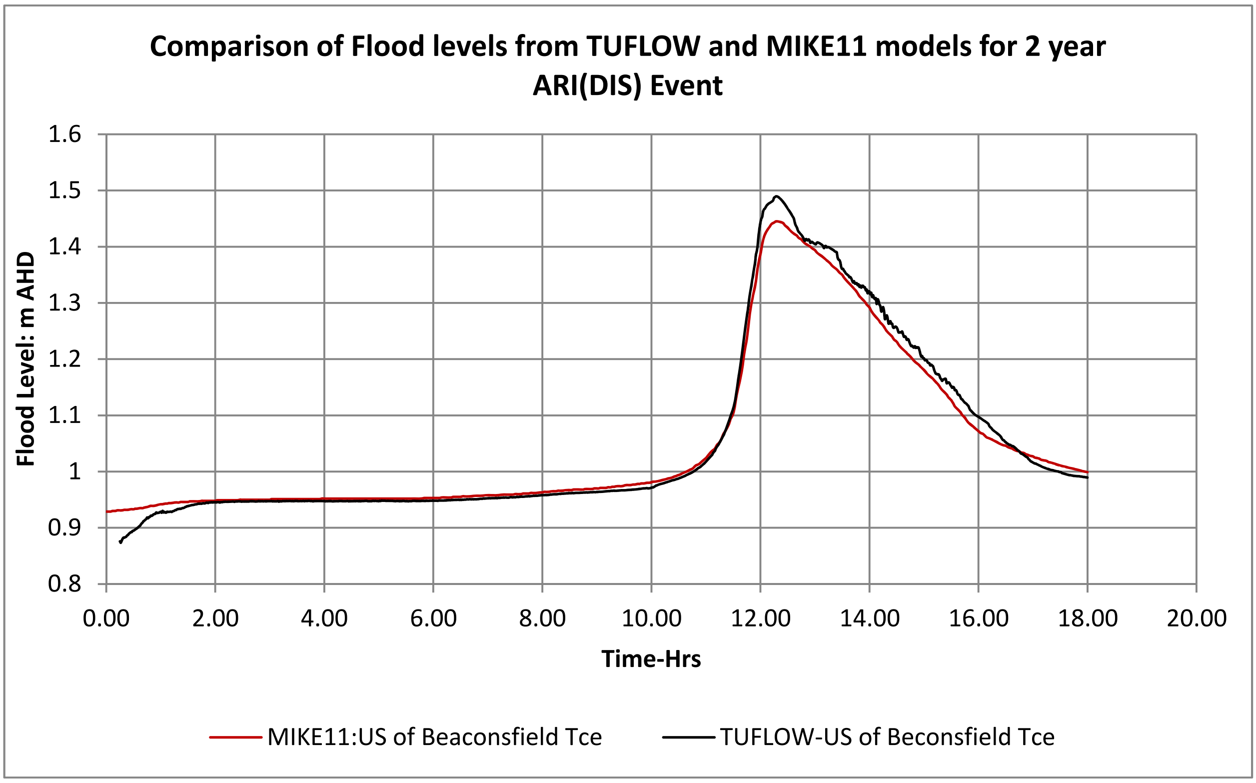


Figure 5.4: Comparison of MIKE11 model and TUFLOW model flood level results (2yr-DIS storm) at Speight Street

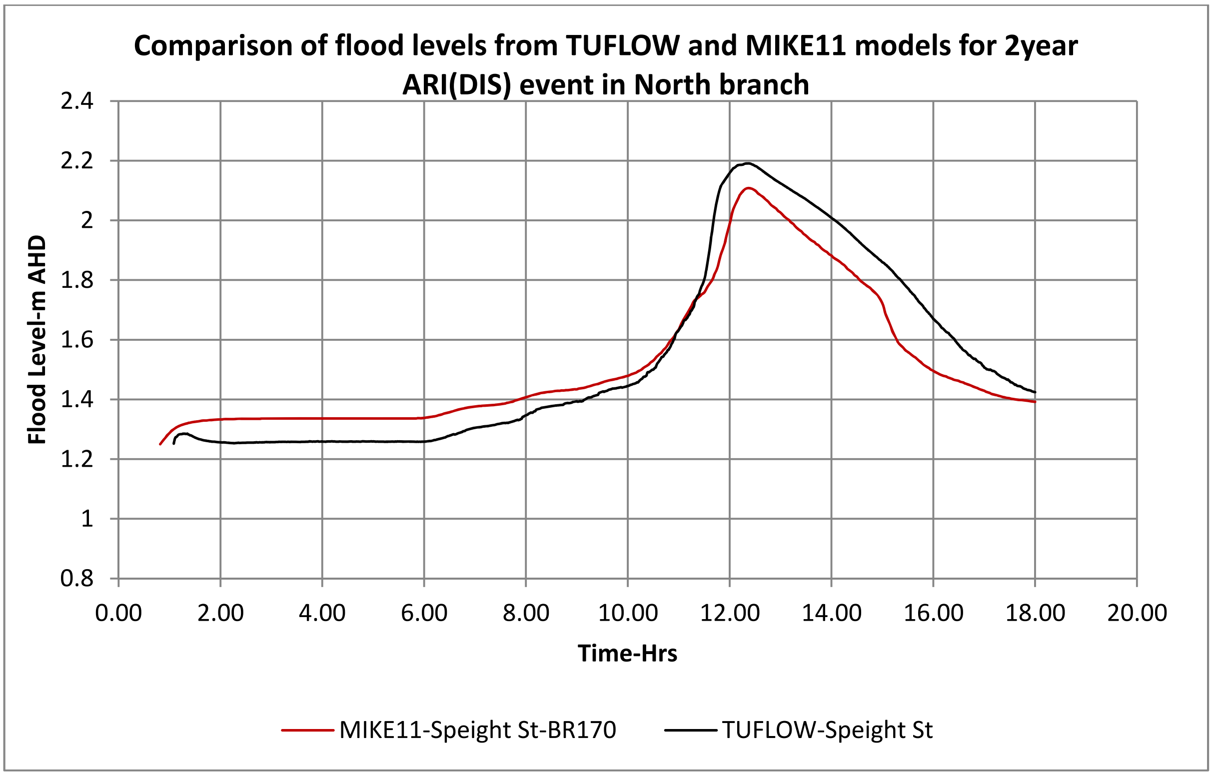
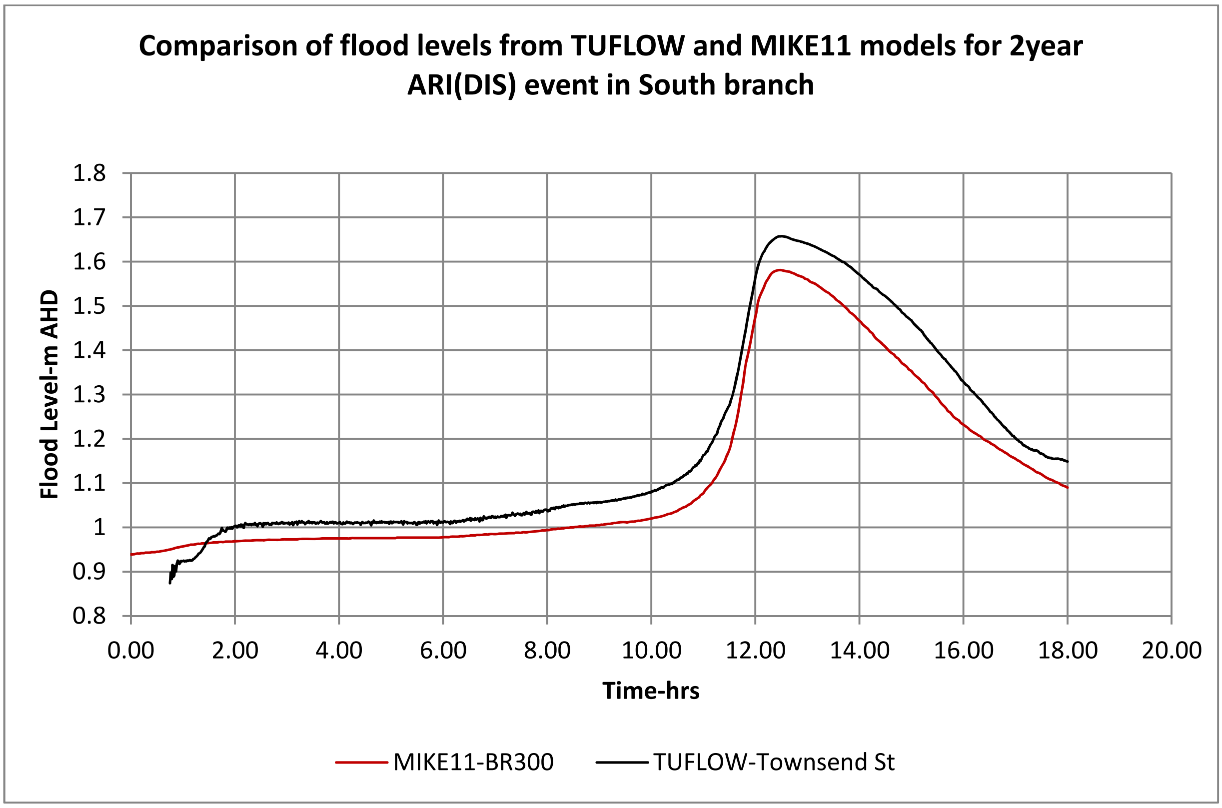


Figure 5.5: Comparison of MIKE11 model and TUFLOW model flood level results (2yr-DIS storm) at Townsend Street



5.5.3 Comparison of Discharge hydrographs from XP-RAFTS and TUFLOW models for recorded events

Discharge hydrographs obtained from XP-RAFTS and TUFLOW models for recorded flood events were compared at the selected locations as listed below. (These points were selected with reference to the locations of XP-RAFTS model nodes and the derived TUFLOW model flow profiles).

- North Branch: at cross section BR180
- Main Branch; at Beaconsfield Terrace upstream
- South Branch : at cross section BR355

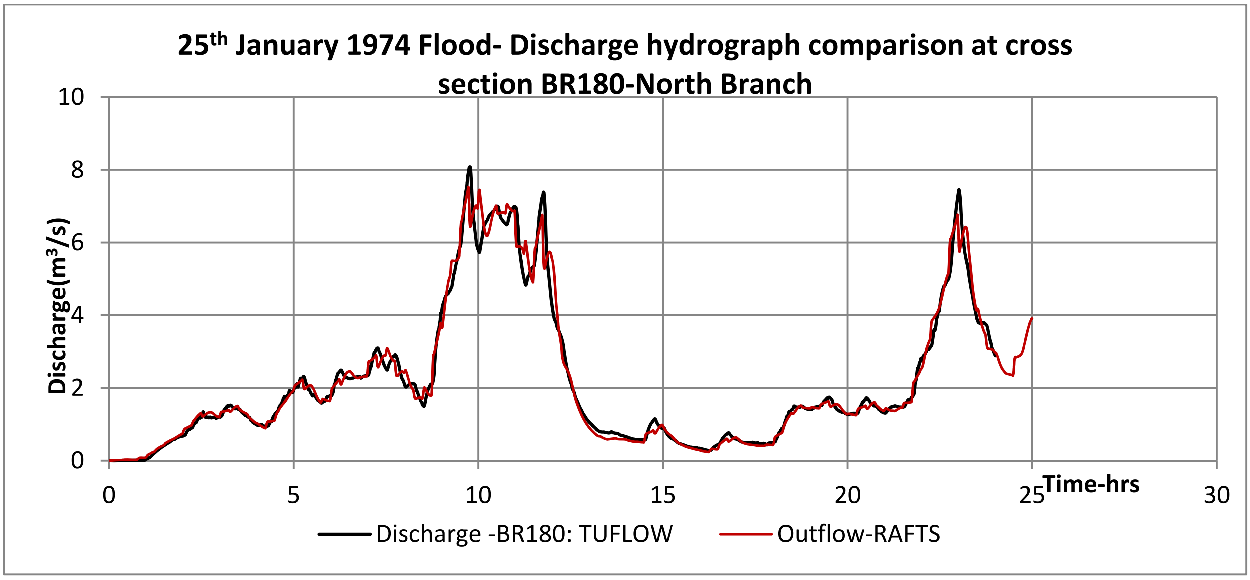


Figure 5.6a: Discharge hydrograph for 25th January 1974 event at cross section BR180

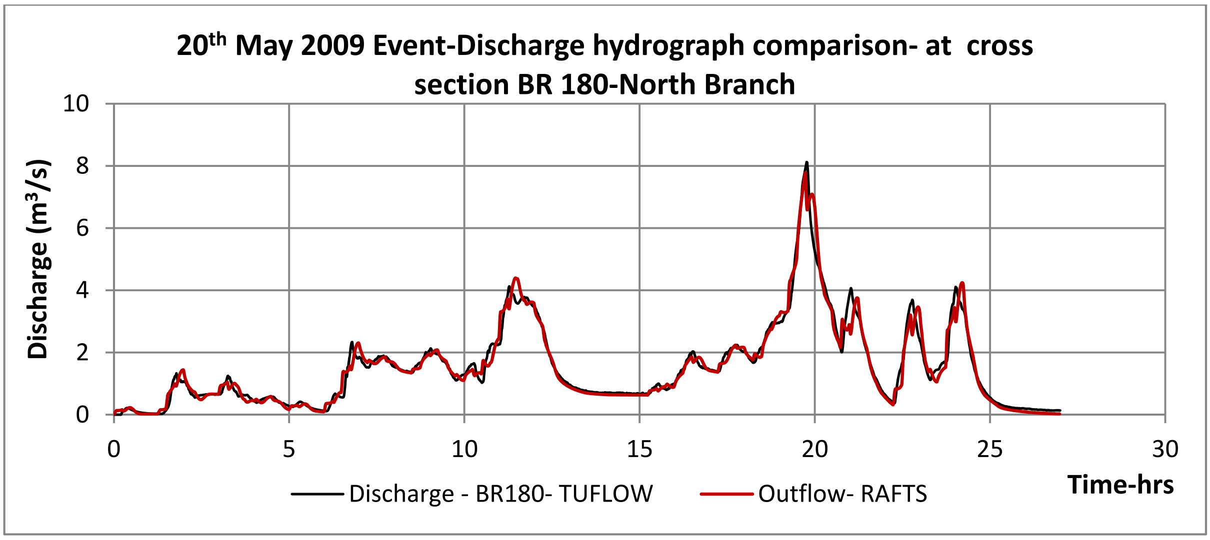


Figure 5.6b: Discharge hydrograph for 20th May 2009 event at cross section BR180

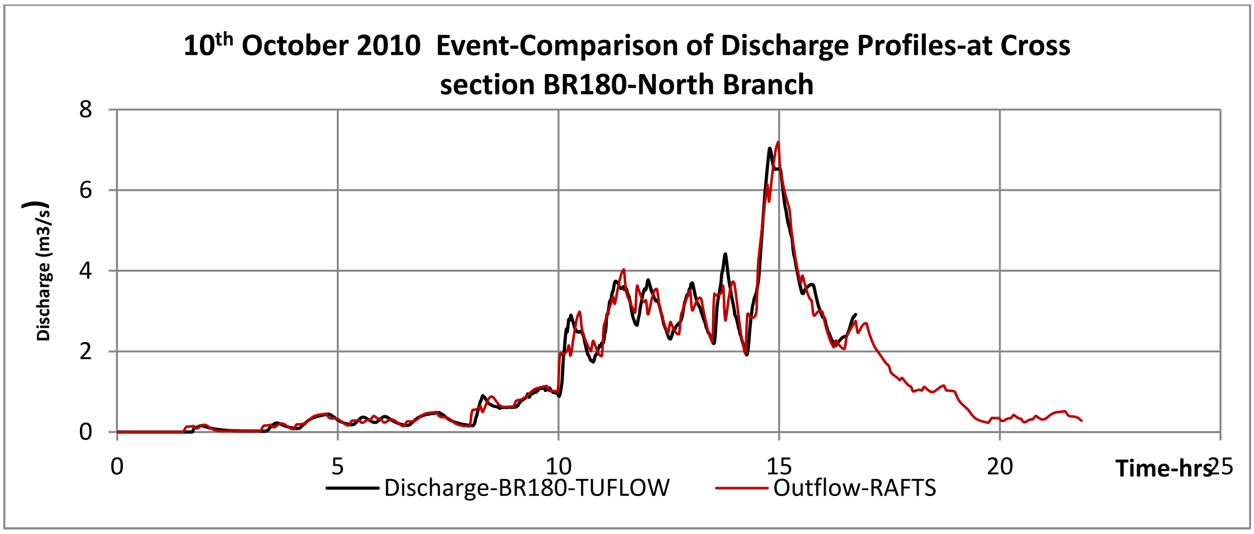


Figure 5.6c: Discharge hydrograph for 10th October 2010 event at cross section BR180

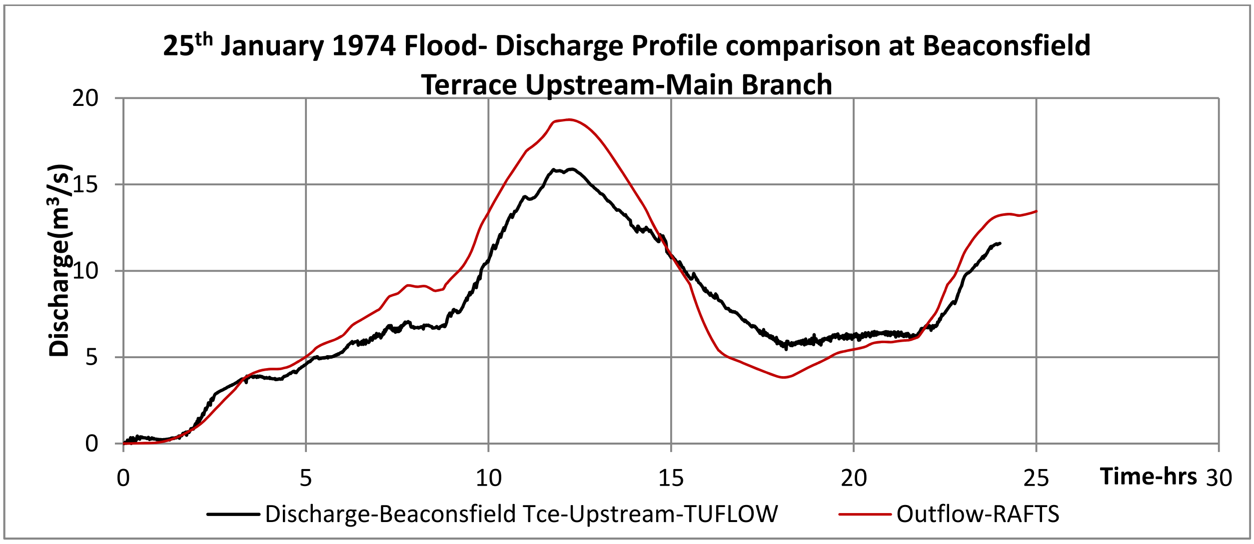


Figure 5.7a: Discharge hydrograph for 25th January 1974 event at Beaconsfield Terrace

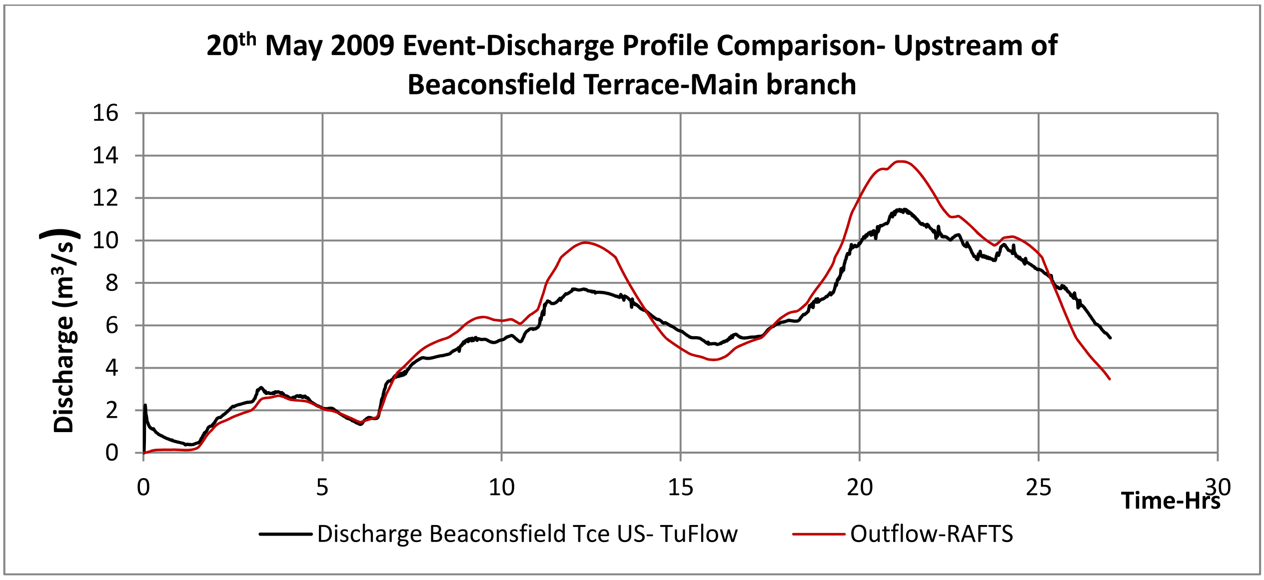


Figure 5.7b: Discharge hydrograph for 20th Mary 2009 event at Beaconsfield Terrace

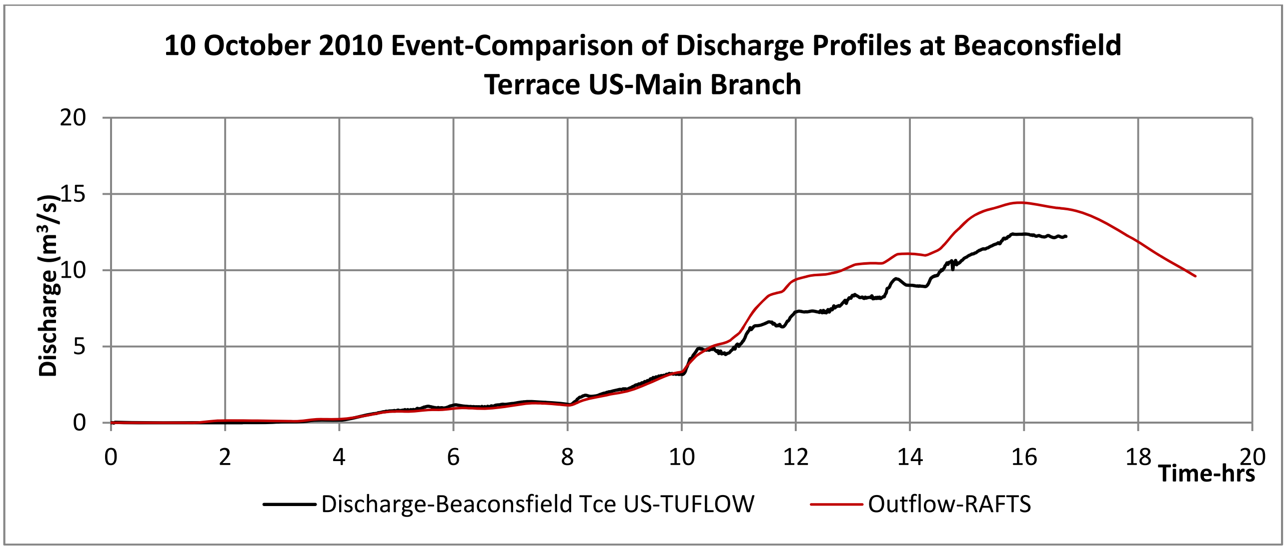


Figure 5.7c: Discharge hydrograph for 10th October 2010 event at Beaconsfield Terrace

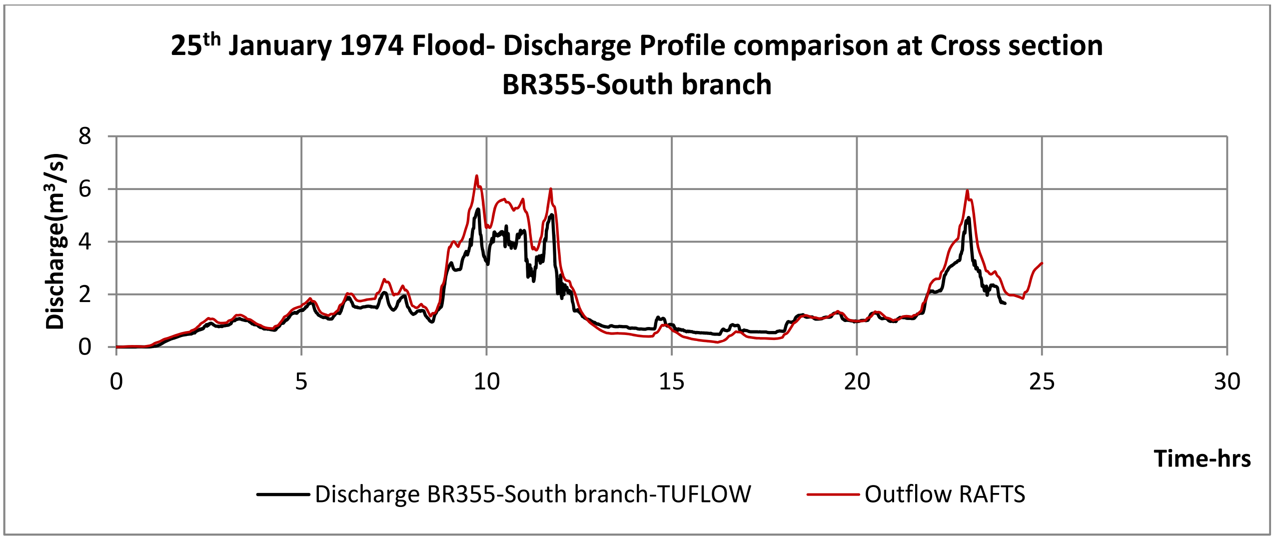


Figure 5.8a: Discharge hydrograph for 25th January 1974 event at cross section BR355

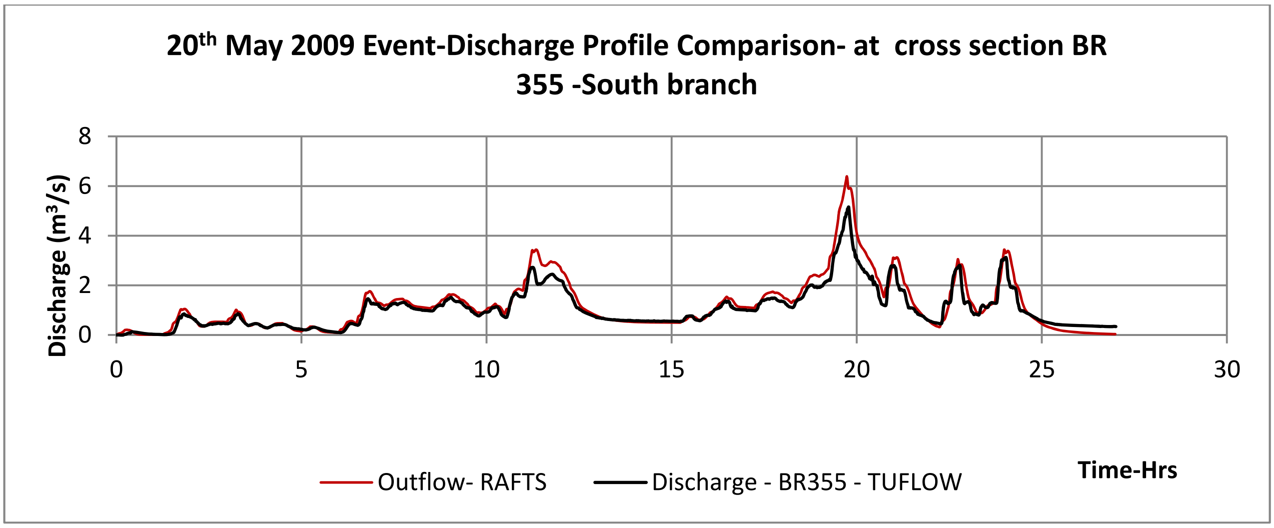


Figure 5.8b: Discharge hydrograph for 20th May 2009 event at cross section BR355

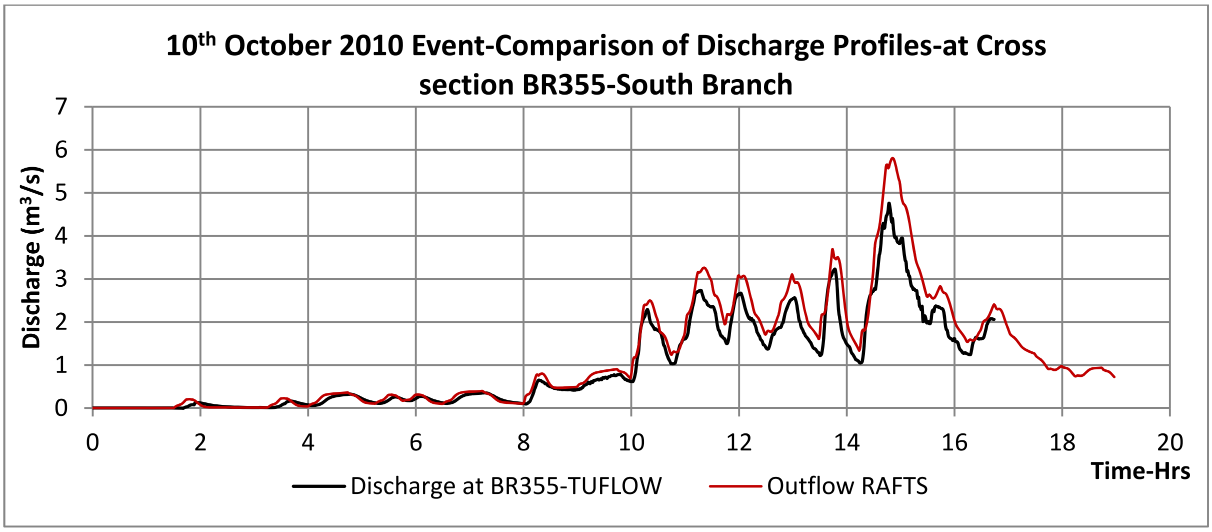


Figure 5.8c: Discharge hydrograph for 10th October 2010 event at cross section BR355

5.6 Hydrologic-Hydraulic Model Consistency Check

Comparison of hydraulic model discharge hydrographs and XP-RAFTS outflow hydrographs were undertaken as documented in section 5.5.3 above at three selected locations for recorded rainfall events on 25th January 1974, 20th May 2009 and 10th October 2010. The discharge hydrograph plots show a good correlation in the timing of the peaks. The discharge magnitudes also appear to correspond quite well. It appears that storage areas in the catchment change the shape of the hydrograph slightly between the two models. These results indicate a good consistency between the hydrologic and hydraulic models.

5.7 Hydraulic Structure Verification

The TUFLOW model manual recommends checking and confirming the hydraulic structure head-loss across hydraulic structures as follows:

1. Calibration to recorded information (if available)
2. Cross-checks to be undertaken using desktop calculations based on theory and/or standard publications (e.g. Waterway Design Guide, Aust Roads).
3. Cross-checks with the results of other hydraulic software.

It is common practice in BCC flood studies to check the structure head-losses against results from the HEC-RAS hydraulic modelling software. Therefore HEC-RAS models were used to assess the head losses of following hydraulic structures that were modelled in the TUFLOW model:

- Beaconsfield Terrace- Pipe Culvert crossing
- Wickham Street – Pipe culvert crossing

- Townsend Street-pipe culvert crossing
- Queens Parade North-Box culvert crossing
- Queens parade South – pipe culvert crossing

All these structures in the hydraulic model are culverts and TUFLOW and HEC-RAS adopt similar techniques in the hydraulic analysis. However head losses were investigated for the selected flood discharges that correspond to the design event flows of the structures. Results of the analysis are tabulated in Table E-1 in Appendix E.

Generally, the TUFLOW head-losses for the hydraulic structures (which were checked) were within ± 0.08 m of the HEC-RAS values for the full range of design flows at which checks were undertaken. These are considered reasonable and confirm the validity of TUFLOW model results.

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6.0 Design Event Analysis

6.1 Design Event Scenarios

The term likely to be adopted to define design event terminology will be described soon with the release of AR&R update and the following recommendation is expected:

- Annual Exceedance Probability (AEP) is to be used (in lieu of ARI) when an annual maximum frequency series has been utilised to derive the data being used.
- Average Recurrence Interval (ARI) is to be used (in lieu of AEP) when a peak over threshold (POT) frequency series has been utilised to derive the data being used.

The design rainfall data provided in AR&R effectively represents the results of a frequency analysis of the POT series rainfall data. As the design flood estimation used in this study is to be based entirely on the design rainfall data provided in AR&R, the correct terminology is to use ARI rather than AEP.

However, in this study the term ARI is used and the equivalent AEP definition for each design events are given in Table 6.1. The relationship between ARI and AEP can be expressed by the following equation:

$$AEP = 1 - \exp(-1 / ARI)$$

Table 6.1: ARI and AEP

ARI (Year)	AEP (%)
2	50
5	20
10	10
20	5
50	2
100	1
200	0.5
500	0.2
2000	0.05

In the study, design event analysis is referred to the analysis of those flood events having ARI of 2, 5, 10, 20, 50 and 100 years. AR&R defines flooding events having ARIs 200, 500 and 2000 years as rare events and analysis of those events are included in the next chapter.

6.2 Design Event Modelling Scenarios

Flood study procedure of BCC recommends modelling the following scenarios with reference to the waterway corridor.

- **Scenario-1: Existing Waterway Conditions**

Scenario-1 is based on the existing flood plain conditions. Topography is as defined from the latest ALS or available survey data.

- **Scenario-2: Minimum Riparian Corridor (MRC)**

As for the Existing conditions but with a 15m wide vegetated riparian corridor in both banks of the waterway. Modelling is undertaken by assigning a Manning's "n" value of 0.15 for the vegetated area.

- **Scenario-3: Ultimate Waterway conditions**

Includes the assumptions in Scenario 2: MRC, and also assumes that filling has occurred up to the waterway corridor.

Table 6.2 lists the design event modelling requirements for the three scenarios. **Figure 6.1** shows the extent of waterway corridor of Brighton Creek and **Figure 6.2** shows the definition of Scenario 2 and 3 conditions.

Figure 6.1: Definition Waterway Corridor Filling

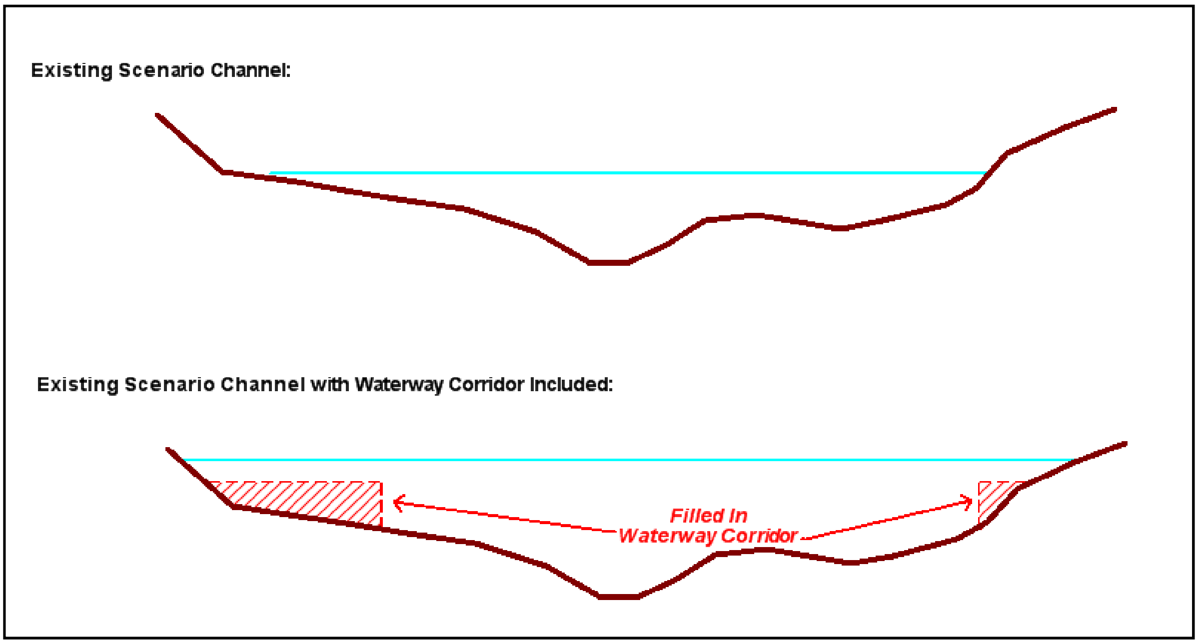


Table 6.2: Design Event Modelling Scenarios

ARI (year)	AEP (%)	Scenario 1	Scenario 2	Scenario 3
2	50	✓	×	✓
5	20	✓	×	✓
10	10	✓	×	✓
20	5	✓	×	✓
50	2	✓	×	✓
100	1	✓	✓	✓

6.3 Design Hydrology

Design flood estimation could be undertaken with flood frequency analysis (FFA) of annual maximum flows or peak over threshold series if observed stream flow records were available for the site. FFA enables the magnitude of floods of selected probability of exceedance to be estimated by undertaking statistical analysis of annual flow peaks of recorded floods over a number of years. However, there are no stream gauges located in the Brighton Creek catchment and therefore FFA is not possible for this catchment.

The design flood analysis undertaken for the catchment in this study is based on the Australia Rainfall & Runoff (ARR), 1987 data, which was developed using industry accepted methodology.

6.4 Investigation Methodology

The hydraulic model was used to estimate design discharges for the 2, 5, 10, 20, 50 and 100 year ARI events for durations from 30 minutes to 6 hours. The following procedure was adopted:

- IFD curves provided by the BoM in AR&R, 1987 is used to estimate the rainfall intensity for design events of ARI 2, 5, 10, 20, 50 and 100 years with 30, 60, 90, 120, 180, 270 and 360 minute durations
- Design temporal patterns provided by the AR&R, 1987 are used to distribute design rainfall over the duration of the storm
- Design events are simulated through the calibrated and verified hydrology model after adopting rainfall loss parameters as recommended and depending on the catchment condition
- Hydraulic model simulations are undertaken for the proposed scenarios using the design event discharges in estimating flood levels, depths and velocities.

6.5 XP-RAFTS Model Setup

The calibrated XP-RAFTS model was used to simulate the rainfall for design flood events (2 to 100 year ARI) with 30-360 minute duration storms. The following describes the adjustments made to the model in order to simulate the design events.

6.5.1 Catchment Development

The design events were modelled using ultimate catchment hydrological conditions. These conditions assume that the state of development within the catchment is at its ultimate condition, with reference to the current adopted planning scheme. Depending on the developed state of the catchment, an increase in development will generally affect the percentage impervious and the PERN hydrologic roughness values.

The current adopted version of BCC City Plan was used to establish the ultimate catchment hydrological conditions. The adopted land-use for the ultimate catchment development is shown on a catchment map in **Figure C.1** in Appendix C.

6.5.2 Rainfall Losses

Rainfall losses were introduced as Initial Loss (IL) and Continuing Loss (CL parameters) in order to determine the rainfall excess. An IL of zero mm was adopted for the design events modelling. This value is typically used in BCC flood studies. A continuous loss rate of 2.5 mm/hour was recommended in the Flood study procedure. However zero mm/hour was adopted as identified in the hydrology and hydraulic model consistency checking process.

Design flood discharge estimation was carried out by simulating the RAFTS model with 2 to 100 year ARI events for 30 minute to 6 hour storm durations. It was identified that the critical duration at the catchment outlet was 120m for all standard ARI events except for 2 year for which 90minute was the critical duration.

6.6 Design Hydraulics

The TUFLOW model was used to determine design flood levels for the three scenarios as detailed in Table 6.2 for the 2-yr ARI to the 100-yr ARI events. These events were simulated for durations from 30 minutes to 3 hours after determining the critical duration of storms.

6.6.1 Modelled scenarios

Scenario-1: Existing Waterway conditions

TUFLOW model developed in the calibration/verification phase was used without further modification.

Scenario-2: Minimum Riparian Corridor (MRC)

This considers the existence of vegetated waterway corridor. This involved reviewing existing vegetation and land-use adjacent to the waterway to determine appropriate roughness value for the MRC. A Manninng's Roughness value of 0.15 was used for the corridor except in areas where the calibrated value was higher than 0.15, then it was left unchanged.

A 15m wide corridor was defined in each side of the waterway banks by introducing a new materials layer within the TUFLOW model files. In areas where 15m width was not available, the MRC was set to the maximum available distance.

Scenario-3: Filling the waterway corridor + MRC

Scenario-3 assumes filling the waterway corridor in conjunction with use of the MRC to assess the impact of potential development. The filling acts as a barrier and the WC can be modelled as a glass wall of infinite height for the design events from 2 to 100 year ARI. For modelling events greater than 100 year ARI, the fill height outside the WC is set to the ARI 100 year flood level of Scenario-3 plus 300mm allowance. This is to allow the rare and extreme events to spill out over the floodplain.

This is a simple and conservative assumption used to develop design planning levels. It does not necessarily reflect allowable development assumptions under City Plan.

It should be noted that the waterway corridor lines for the purposes of modelling were modified slightly to encompass all the inflow points to allow water flows into the waterway corridors from the upstream catchment where there is no waterway defined. Modifications were also made to join any breaks in the waterway corridor which would have created a blockage upstream of waterway crossings.

6.6.2 Model roughness

The hydraulic roughness in the calibrated TUFLOW model was updated to represent the ultimate catchment conditions as per the current version of City Plan. This required some changes to areas where proposed development is planned, such as the "Emerging Community" land-use.

6.6.3 TUFLOW model boundaries

The design inflow boundaries to the TUFLOW model were taken from the results of the XP-RAFTS model for each ARI and duration. The inflow locations did not change from that of the calibrated TUFLOW model.

The downstream boundary for the TUFLOW model was adopted as a fixed water level at its downstream extent (i.e. Bramble Bay). A Mean High Water Springs (MHWS) value of 0.92 m AHD was adopted for all design events. It should be noted that the joint probability of fluvial and tidal events has not been considered in the modelling.

6.7 Design Event Results

6.7.1 Critical Durations

Table 6.3 indicates the critical durations at structure crossing locations for the 2, 5, 10, 20, 50 and 100 year ARI events within the catchment.

Table 6.3: Critical Storm Durations at Structures

Location	2 year	5 year	10 year	20 year	50 year	100 year
	Critical duration (minutes)					
Wickham Street culvert	60	60	60	60	60	60
Queens Parade North	90	90	90	90	90	120
Beaconsfield Terrace	90	120	120	120	120	120
Townsend Street	90	120	120	120	120	120
Queens Parade South	90	120	120	120	120	120

6.7.2 Peak Discharge

Peak flood discharges estimated from the TUFLOW model simulations were extracted at structure crossing locations. These discharges are presented in Table 6.4 and correspond to total flow at that location, including discharge through all culverts and associated overflow. Corresponding peak flood levels at these locations are also included in the table.

6.7.3 Peak flood Levels along the Creek

Peak flood level results are provided in Appendix H for Brighton Creek North, South and Main Branches with reference to the existing cross section locations. These results include 2, 5, 10, 20, 50 and 100 year ARI events for Scenario-3. The corresponding AMTD (Adopted Middle Thread Distance) value is indicated at the location of cross sections.

Table 6.4: Design flood discharges and levels at structure locations

Location	Design Flood event ARI					
	2 year	5 year	10 year	20 year	50 year	100 year
	Peak flood discharge (m3/s)					
Wickham Street culvert	5.0	6.4	7.3	8.3	9.1	9.7
Queens Parade North	4.5	5.9	6.9	8.3	9.7	11.2
Beaconsfield Terrace	7.8	10.8	12.1	13.1	15.2	16.4
Townsend Street	2	2.4	2.8	3.2	3.9	4.4
Queens Parade South	1.9	2.3	2.6	3.0	3.4	4.0
	Peak flood level (mAHD)					
Wickham Street culvert	3.20	3.40	3.52	3.75	3.89	4.09
Queens Parade North	2.05	2.16	2.20	2.25	2.33	2.36
Beaconsfield Terrace	1.38	1.65	1.75	1.93	2.05	2.15
Townsend Street	1.75	1.91	1.96	2.08	2.18	2.26
Queens Parade South	1.91	2.08	2.14	2.22	2.30	2.36

6.7.4 Flood Immunity of Existing Crossings

The flood immunity of the structures under Scenario 3 was determined for each crossing by comparing peak flood levels upstream of the crossing with the minimum overtopping levels. The estimated structure immunities are presented in Table 6.5, where the minimum event considered was the 2-yr ARI and the maximum was the 100-yr ARI. Hydraulic Structure Reference Sheets (HSRS) were also produced which outline the hydraulic characteristics of each structure in Appendix F.

Table 6.5: Flood Immunity of Crossings

	Structure name	Flood immunity(ARI)
1	**Wickham Street culvert**	100 year
2	**Queens Parade North**	2 year
3	**Beaconsfield Terrace**	100 year
4	**Townsend Street**	10 year
5	**Queens Parade South**	5 year
6	**Shepherd Street culvert**	2year

6.7.5 Hydraulic Structure Reference Sheets

Details of flood level and flow data derived for hydraulic structure crossings modelled in the TUFLOW model are summarised in Hydraulic Structure Reference Sheets and included in Appendix F.

6.7.6 Flood Mapping

The flood mapping products are provided in Appendix-J (A3 Booklet) and include the following mapping products:

- Flood Level / Extent Mapping
  - Scenario-3: 2, 5, 10, 20, 50 and 100 year ARI
- Flood Depth Mapping
  - Scenario-3: 2, 5, 10, 20, 50 and 100 year ARI

Scenario-3 "ultimate" flood level planning surfaces were required to be generated and mapped. Within the flood modelling context, the ultimate scenario involves modifying the flood model topography to represent a fully developed floodplain in accordance with City Plan and in most instances applying an allowance for a riparian corridor as outlined in Section 6.6.1 Modelled Scenarios. This process generally results in design flood levels being increased. Council requires these increased levels to then be mapped against the current floodplain topography thus providing a flood extent that is conservative, extends beyond the "existing" flood extent and 'flags' the additional properties that could potentially be at flood risk in the future and should have development controls (planning levels) applied.

With the move to 'two-dimensional' flood models, the production of flood levels, extents and depth-velocity products is inherent in simulating a model, i.e. a flood map is a direct output from a model simulation removing the requirement to apply a separate process. For the "existing" case simulations, the model is run and the direct output is able to be mapped or referenced in a GIS environment. In order to simulate the "ultimate" scenario, the model topography must be modified to represent filling associated with development. This in turn affects the resulting flood mapping with the flood extent limited to the edge of the filled floodplain. Post processing of the model output is required to represent the modelled flood levels against the current floodplain conditions.

The Water Ride stretching tool was selected for the purpose of processing the "ultimate" case results and producing the planning flood levels and surfaces. The stretching calculation starts at the north-easterly corner where it identifies each "dry cell" which is located immediately adjacent to the "wet cells". It then calculates a water level for the dry cell by interpolating the neighbouring flood levels. If the assigned flood level is higher than the ground level for that cell, then the cell will be identified as wet. If this condition is not met (ie water level is less than ground level) then this cell will be identified as dry. This is an iterative process and continues counter clockwise until there is no wet cell left in a single revolution. To better control the process a tolerance is adopted in the determination of a wet cell, being a water depth of 300mm.

From experience to date, it is known that the Water Ride stretching tool alone cannot provide robust surface and level information in all conditions. Therefore, a thorough review of each surface produced by the tool was undertaken and manual intervention applied to the process to ensure suitable outcomes. To help with the initial review process, a comparison of the stretched extent with calculated flood extents including existing scenarios and larger events was undertaken. To modify the stretched surface, break lines were used to limit the expansion of the surface and to stop the “leakage” (upstream higher water level projecting to the downstream lower area) of the surface in problematic areas. Applying break lines at the right place enhances the produced flood levels and surfaces and minimises the anomalies across the flood extent.

In general, the modified areas are mostly observed around tight bends, at structures with high head losses, steep areas where the water can leak, stream junctions where cross-flow is likely, parallel channels, secondary paths and breakout areas. Specific application of the break lines for this flood study is detailed in Appendix K.

Despite the review of the stretched surfaces and the inclusion of break lines to manipulate the stretching process, the process and outputs are still subject to limitations as follows:

- The application of break lines will result in significant steps in the generated surface in some locations
- The application of break lines is highly subjective in some locations
- The application of break lines will not necessarily be consistent across all design events (i.e. they will change in number and location depending on the magnitude of the design event considered)
- The stretching process may not be readily repeatable (i.e. the output has not come directly from a model simulation and if model outputs change, it cannot be guaranteed that the process will not need further refinement to produce acceptable results)

Particularly difficult areas to apply the stretching process to and which may benefit from further refinement are highlighted in Appendix K.

7.0 Rare and Extreme Event Analysis

7.1 Overview

As a part of the flood study rare and extreme event modelling was undertaken for the following events:

- 200 and 500 year ARI event
- 2000 year ARI event
- PMF event

Details of the scenarios modelled with these events are listed in Table 7.1.

Table 7.1: Rare and Extreme events modelling scenarios

ARI	AEP (%)	Scenario-1	Scenario-2	Scenario-3
200	0.5	✓	×	✓
500	0.2	✓	×	✓
2000	0.05	✓	×	×
PMF		✓	×	×

7.2 Hydrologic Modelling

Design rainfall intensities for the 200 and 500 year ARI events were derived using the CRC-Forge method for the Brighton Creek catchment. AR&R temporal pattern was used to distribute the rainfall burst within the storm period. Table 7.2 lists the rainfall intensities derived for the 200 and 500 year ARI events. The intensities for 1.5hr and 4.5hr are obtained by interpolation as CRC forge data does not include those durations.

Table 7.2: Rainfall intensities for 200 and 500 year ARI events (CRC Forge method)

Storm Duration (hr)	100 year (mm/hr)	200 year (mm/hr)	500 year (mm/hr)
0.5	160	180.1	210.7
1	110	125.8	147.2
1.5	85.3	98	114
2	70.7	81.5	94.8
3	53.5	61.8	72.3
4.5	40.5	47.6	56
6	32.2	39.1	45.8

7.2.1 2000-yr ARI (0.05 % AEP)

The 2000-yr ARI (0.05 % AEP) event rainfall intensity was determined using the CRC-Forge method. To avoid the need to simulate all of the different storm durations, a simplified super-storm method was used. This same methodology has also been used in other BCC flood studies currently being undertaken.

The rationale for adopting this approach is that world-wide research indicates that as storm rainfall depths increase during short duration storms, the rainfall intensity becomes more uniform. For this reason, the multi-peaked AR&R temporal pattern (as used for the 200-yr ARI and 500-yr ARI) was not considered suitable for the analysis of the largest event.

A 6-hr super-storm was developed to represent all storm durations up to 6 hours. The super-storm was developed in 30-minute blocks and incorporates the 0.5-hr, 1-hr, 1.5-hr, 2-hr and 3-hr storm bursts. Durations less than 30 minutes were not considered. The total rainfall depth of the super-storm was set equal to the 6-hr 2000-yr ARI (0.05 % AEP) CRC-Forge rainfall depth (representative across the Brisbane Region), which was determined as 340 mm.

7.2.2 Probable Maximum Precipitation (PMP)

The 6-hr super-storm approach was also undertaken for the PMP scenario, using the same temporal pattern as the 2000-yr ARI (0.05 % AEP) event.

The total PMP depth was derived from the 6-hr storm duration using the Generalised Short Duration Method (GSDM). For the tropical and sub-tropical coastal areas it is recommended that this method be used to estimate the PMP over areas up to 520 km2 and for durations up to 6 hours. To apply a consistent methodology across the majority of BCC an average catchment size of 60 km2 and moisture adjustment factor of 0.85 were adopted. The total rainfall depth of the super-storm was set equal to the 6-hr GSDM PMP rainfall depth, which was determined as 816 mm.

Table 7.3 indicates the adopted super-storm temporal pattern and hyetographs for the 2000-yr ARI (0.05 % AEP) and the PMP.

Table 7.3: Adopted Super-storm Hyetographs

Time (hr)	Rainfall (%)	Rainfall (mm)		Time (hr)	Rainfall (%)	Rainfall (mm)	
		2000-yr ARI (0.05 % AEP)	PMP			2000-yr ARI (0.05 % AEP)	PMP
0.00	0	0.00	0.00	3.17	58	41.00	75.08
0.17	1	4.33	9.92	3.33	70	41.00	75.08
0.33	3	4.33	9.92	3.50	75	16.00	38.25
0.50	4	4.33	9.92	3.67	77	7.58	27.63
0.67	5	4.33	9.92	3.83	80	7.58	27.63
0.83	6	4.33	9.92	4.00	82	7.58	27.63
1.00	8	4.33	9.92	4.17	84	7.58	18.42
1.17	9	4.33	13.46	4.33	86	7.58	18.42
1.33	10	4.33	13.46	4.50	89	7.58	18.42
1.50	11	4.33	13.46	4.67	90	4.33	13.46
1.67	14	7.58	18.42	4.83	91	4.33	13.46
1.83	16	7.58	18.42	5.00	92	4.33	13.46
2.00	18	7.58	18.42	5.17	94	4.33	9.92
2.17	20	7.58	27.63	5.33	95	4.33	9.92
2.33	23	7.58	27.63	5.50	96	4.33	9.92
2.50	25	7.58	27.63	5.67	97	4.33	9.92
2.67	30	16.00	38.25	5.83	99	4.33	9.92
2.83	34	16.00	38.25	6.00	100	4.33	9.92
3.00	46	41.00	75.08				

7.3 Hydraulic Modelling

7.3.1 Overview

The TUFLOW model was used to simulate the scenarios as detailed in Section 7.1 to enable design flood levels and flood mapping products to be determined.

7.3.2 TUFLOW model roughness

No changes were made to the design event TUFLOW model(s).

7.3.3 TUFLOW model boundaries

The extreme event inflow boundaries to the TUFLOW model were taken from the results of the XP-RAFTS model for each ARI and duration. The same inflow locations were adopted as of the design event modelling with TUFLOW model.

The TUFLOW model utilised a fixed water level (H-T) boundary at its downstream extent (i.e. Moreton Bay). The following values were adopted for each respective event:

- 200-yr ARI (0.5 % AEP) – HAT (1.5 m AHD)
- 500-yr ARI (0.2 % AEP) – HAT (1.5 m AHD)
- 2000-yr ARI (0.05 % AEP) – HAT (1.5 m AHD)
- PMF – HAT (1.5 m AHD)

7.3.4 Hydraulic Structures

All extreme event TUFLOW models incorporated the same hydraulic structures as the design event TUFLOW models.

7.4 Results and Mapping

7.4.1 Peak Flood Levels

Tabulated peak flood level results are provided in Appendix G for Brighton Creek. These tabulated flood levels are provided for the following events and scenarios:

- 200-yr ARI (0.5 % AEP) – Scenario 3
- 500-yr ARI (0.2 % AEP) – Scenario 3

Tabulated peak flood levels for the 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) for Scenario 1 are provided in the separate Model Handover Guide.

7.4.2 Flood Mapping Products

The flood mapping products are provided in Appendix J (A3 Booklet) and include the following mapping products:

- Flood Level / Extent Mapping
    - Scenario-1: 2000-yr ARI (0.05 % AEP) and PMF
    - Scenario-3: 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP)

See Section 6.7.6 Flood Mapping for discussion of the mapping process.

7.4.3 Discussion of Results

A plot of the flood profiles are presented in **Figure 7.1** and **7.2** to aid in the discussion of the results.

The Wickham Street culverts represent a major hydraulic control with pronounced differences in flood levels upstream. The level differences immediately downstream of Wickham Street are minor but gradually increase further downstream. Downstream of Beaconsfield Terrace the flood profiles drop rapidly and the change in tail water level is apparent. The South Branch is characterised by a very flat water profile and consistent differences between events. Brighton Creek catchment is mostly low lying with significant flood storage in the wetland areas. This is reflected in the extreme event water profiles.

Table 7.2 shows the average level differences for each rare and extreme event compared against the corresponding 100 year design level. As expected, the level difference increases consistently with larger storm events. The scenario 3 events show a markedly higher difference in flood levels but they remain under 0.3 meters. This indicates limited overtopping of the filled floodplain. Scenario 3 flood level differences are also higher in the South Branch compared to the rest of the waterway this is due to the narrow waterway corridors in the vicinity of Queens Parade. The corresponding head loss can be observed in **Figure 7.1**.

Table 7.4: Average Flood Level Increases

	Average Flood Level increase from the Q100 Existing and Ultimate		
Event	North and Main Branch (m)	South Branch (m)	Total (m)
Q200 Scenario-1	0.16	0.14	0.15
Q500 Scenario-1	0.23	0.21	0.22
Q2000 Scenario-1	0.42	0.39	0.41
PMF Scenario-1	0.90	0.89	0.90
Q200 Scenario-3	0.18	0.20	0.19
Q500 Scenario-3	0.28	0.32	0.29

Figure 7.1: Peak Flood Level Profile for Rare and Extreme events and 100 Year ARI event – North and Main Branch

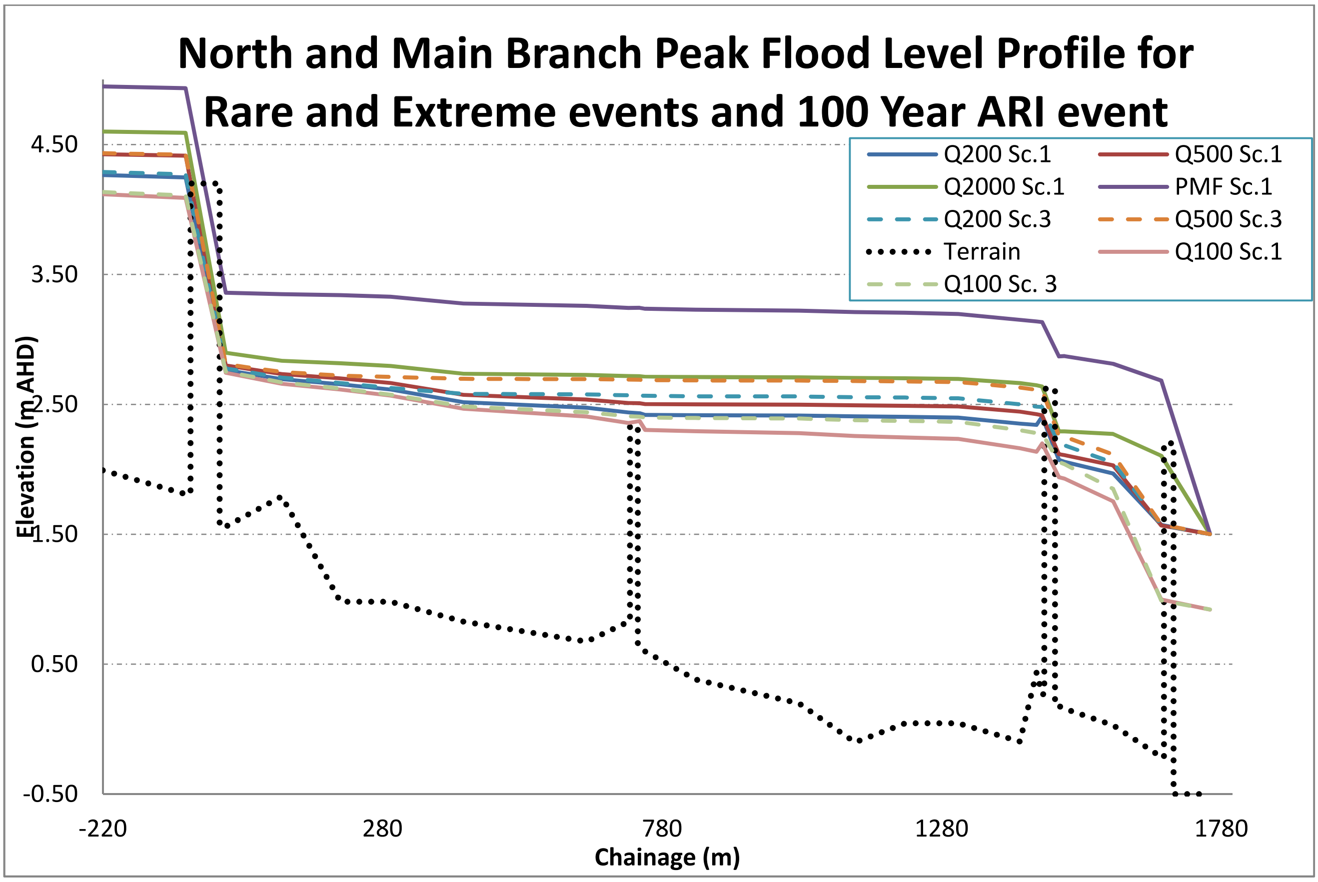
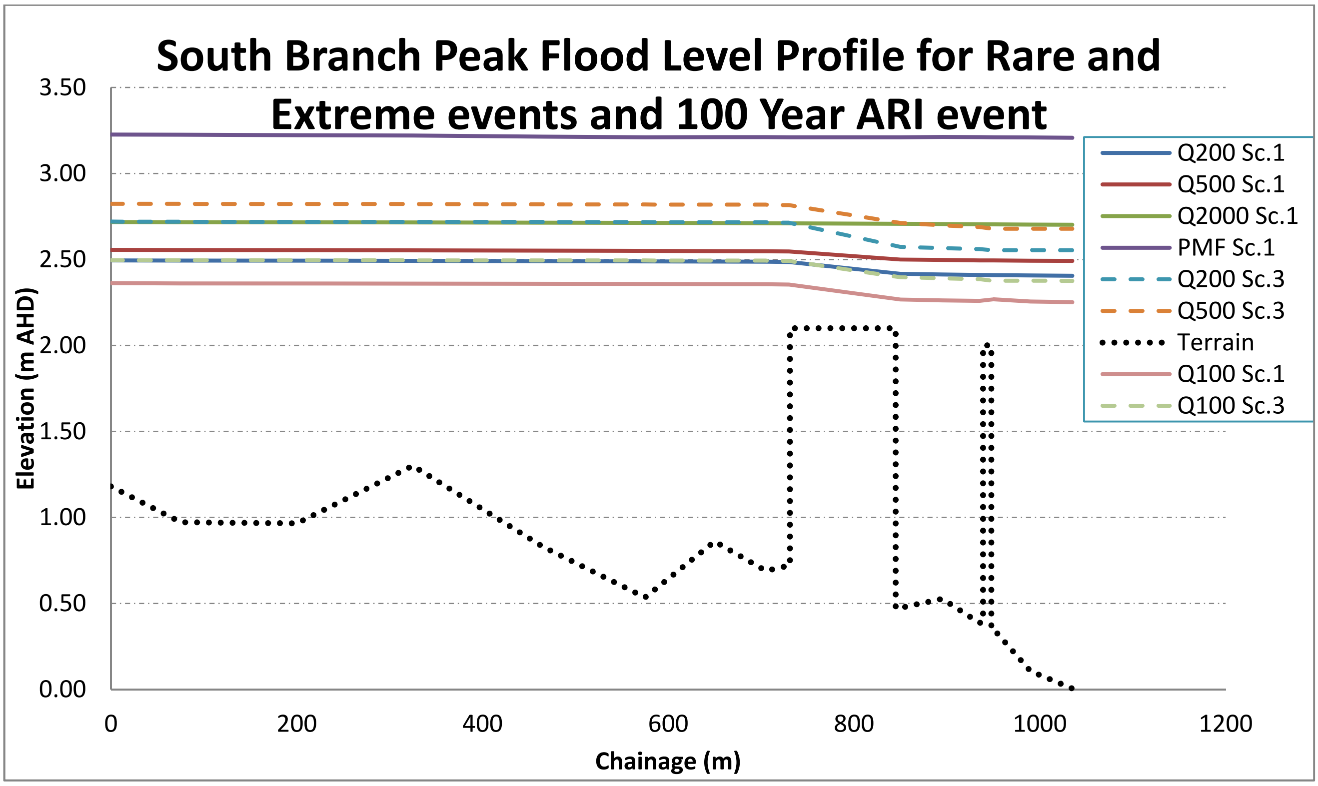


Figure 7.2: Peak Flood Level Profile for Rare and Extreme events and 100 Year ARI event – South Branch



8.0 Sensitivity Analysis

8.1 Climate Change

8.1.1 Overview

To allow BCC to intelligently undertake future land-use planning, there is a requirement to understand the impacts of climate change on flooding. BCC flood studies are therefore required to utilise the latest statutory guidelines in order to assess the impacts of climate change.

To enable BCC to understand and plan for the impacts of climate change on flooding in the Wynnum Creek Catchment, a number of climate change scenarios were undertaken, as outlined below. These scenarios are consistent with those undertaken in recently completed BCC flood studies and the latest statutory guidelines.

- 2050 Planning Horizon
  - 10 % increase in rainfall intensity
  - 0.3 m increase in mean sea level

- 2100 Planning Horizon
  - 20 % increase in rainfall intensity
  - 0.8 m increase in mean sea level

8.1.2 Modelled Scenarios

Modelling was used to determine climate change impacts for the 100-yr ARI (1 % AEP), 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) events. Table 8.1 indicates the events modelled and the respective climate change modifications undertaken.

The rainfall intensity in the XP-RAFTS model was increased by 10 % (or 20 %) and simulations undertaken to determine the climate change hydrographs. These hydrographs were then input into the TUFLOW model and simulations undertaken for all climate change scenarios.

Table 8.1 Climate Change Modelling Scenarios

ARI (year)	AEP (%)	Planning horizon	Rainfall Condition	Tail water Condition	Scenario-1	Scenario-3
100	1	2050	+ 10 %	MHWS + 0.3 m	✓	✓
		2100	+ 20 %	MHWS + 0.8 m	✓	✓
200	0.5	2050	+ 10 %	HAT + 0.3 m	✓	×
		2100	+ 20 %	HAT + 0.8 m	✓	×
500	0.2	2100	+ 20 %	HAT + 0.8 m	✓	×

8.1.3 Impact on Flood Level

Tables 8.2 to 8.5 indicate the increase in peak flood level as a result of climate change at selected locations along the creek for the scenario 3 and 1 100-yr ARI (1 % AEP), scenario 1 200-yr ARI (0.5 % AEP) and scenario 1 500-yr ARI (0.2 % AEP) events respectively. See Appendix I for the full results of the 100-yr Scenario 3, 2050 and 2100 planning horizons.

Table 8.2: 100-yr ARI Climate Change Impacts at Selected Locations (Scenario 3)

Structure Location	Flood Level (m AHD)		
	Existing	2050	2100
Wickham Street	4.11	4.23	4.32
Queens Parade North	2.41	2.51	2.65
Queens Parade South	2.49	2.62	2.76
Townsend Street	2.38	2.50	2.64
Beaconsfield Terrace	2.28	4.23	4.32

Table 8.3: 100-yr ARI Climate Change Impacts at Selected Locations (Scenario 1)

Structure Location	Flood Level (m AHD)		
	Existing	2050	2100
Wickham Street	4.09	4.20	4.30
Queens Parade North	2.36	2.41	2.49
Queens Parade South	2.35	2.44	2.52
Townsend Street	2.26	2.35	2.47
Beaconsfield Terrace	2.20	2.36	2.45

Table 8.4: 200-yr ARI Climate Change Impacts at Selected Locations (Scenario 1)

Structure Location	Flood Level (m AHD)		
	Existing	2050	2100
Wickham Street	4.25	4.35	4.44
Queens Parade North	2.44	2.53	2.75
Queens Parade South	2.49	2.56	2.75
Townsend Street	2.41	2.52	2.74
Beaconsfield Terrace	2.41	2.50	2.70

Table 8.5: 500-yr ARI Climate Change Impacts at Selected Locations (Scenario 1)

Structure Location	Flood Level (m AHD)	
	Existing	2100
Wickham Street	4.41	4.58
Queens Parade North	2.51	2.81
Queens Parade South	2.55	2.80
Townsend Street	2.49	2.80
Beaconsfield Terrace	2.42	2.76

Table 8.6 shows the expected average increase in flood level due to Climate Change compared with the corresponding current average flood level.

Table 8.6: Average Flood Level Increase due to Climate Change

	Flood Level (m AHD)			
Planning Horizon	**Scenario 3 100-yr ARI**	**Scenario 1 100-yr ARI**	**Scenario 1 200-yr ARI**	**Scenario 1 500-yr ARI**
2050	0.12	0.09	0.10	-
2100	0.26	0.21	0.32	0.31

8.2 Structure Blockage

8.2.1 Overview

Blockage of hydraulic structures is a common cause of increasing flood risk over and above the risk due to the intensity and duration of the rainfall. Current guidance recommends that designers of hydraulic structures should make allowances for the risk of blockage in the design. However, current guidance does not stipulate that blockage is required to be included as part of the determination of the overall design flood level.

BCC has taken the approach to include the blockage of selected hydraulic structures as part of a sensitivity analysis. This approach will allow BCC to understand the potential impacts should the selected hydraulic structures become blocked during an event.

8.2.2 Selection of Hydraulic Structures

The following five hydraulic structures were selected for the blockage analysis:

- Wickham Street – 1/ 1.2 m diameter, 2/ 1.35 m diameter RCP
- Queens Parade North – 2/ 2.1 x 1.13 RCBC
- Queens Parade South – 2/ 1.22 m diameter RCP
- Townsend Street – 2/ 1.22 m diameter RCP
- Beaconsfield Terrace – 5/ 1.8m diameter RCP

Due to the limited number of crossings in Brighton Creek all significant structures have been modelled with blockage.

8.2.3 Blockage Scenarios

The blockage analysis has been carried out with the scenario 1, 100 year design event. Table 6.3 in the 'Design Hydraulics' section of this report shows the critical storm durations for each of the structures. These storm durations were used for the model runs. Individual structures were modelled separately to ensure that the blockage impacts would not be masked by other crossings.

The Queensland Urban Drainage Manual (QUDM) was used to determine the degree of blockage for each structure. QUDM recommends that box culverts of the size found in Brighton Creek adopt 25% sediment blockage in the chamber and 20% inlet blockage at the sidewalls (equal to 40% blockage of total flow area). Queens Parade North is the only structure with box culverts so this was achieved by raising the invert and adjusting the geometry accordingly. The concrete pipe culverts were modelled by adjusting the pipe diameter to reduce the total flow area by 40%, the invert was then raised by 25% of the original pipe diameter. The remaining structures were modelled in this fashion.

8.2.4 Impacts of Structure Blockage

Table 6.8 displays the scenario 1 and corresponding blockage scenario flood levels at the upstream reporting locations for each significant structure. Townsend Street, Queens Parade North and South are not particularly sensitive to the blockage conditions. This is unsurprising as these structures are low lying and easily overtopped in the 100 year event.

Flood levels upstream of Wickham Street experience the most dramatic rise. A 400mm increase in flood level is likely to inundate homes northwest of the upstream creek corridor. The rise in flood level upstream of Beaconsfield Terrace is not as significant as Wickham Street however the afflux propagates further upstream with the blockage impacts also being felt in the North and South Branches. The blockage would worsen flooding for properties already impacted in these areas. Conversely, such blockage has shown to reduce flood levels on the other side of Beaconsfield Terrace by the equivalent amount, offering some mitigation potential to properties immediately downstream.

Table 8.7: Blockage Impacts at Structure Locations

Structure	Q100 Scenario 1 Water Level Upstream of Structure (m AHD)	Q100 Blocked Scenarios Water Level Upstream of Structure (m AHD)	Afflux (mm)
Wickham Street	4.09	4.49	400
Queens Parade North	2.34	2.35	10
Queens Parade South	2.35	2.37	20
Townsend Street	2.26	2.27	10
Beaconsfield Terrace	2.13	2.24	110

9.0 Summary of Study Findings

9.1 Summary and Conclusions

This report details the calibration and verification events, design events, extreme events and sensitivity modelling for the Brighton Creek Catchment in the north-eastern area of the BCC region. Hydrologic and hydraulic models of the Brighton Creek Catchment have been developed using the XP-RAFTS and TUFLOW modelling software respectively.

Calibration of XP-RAFTS and TUFLOW was undertaken utilising the 1974 Australia Day storm. Verification of the XP-RAFTS and TUFLOW also utilised storm events from May 2009 and October 2010. Hydrometric data was sourced from recorded rainfall data and surveyed debris markings available for 25th January 1974 event. There are no Stream Gauges or Maximum Height Gauges in the Brighton Creek catchment.

During the calibration process little adjustment of the parameters was necessary due to the limited calibration data that lead to a reasonable fit. There was some minor adjustment to the channel manning's n roughness values and the bridge loss coefficient at Flinders Parade. Cross-checks of the TUFLOW structure head-losses were undertaken at the major structures using the HEC-RAS software, from which is was confirmed that the model was representing the structures adequately.

Utilising the adopted parameters from the calibration process, the verification was undertaken. Similar to the calibration results, the verification achieved a good agreement between the simulated and historical records for both of the verification events. Given the results of the calibration and verification process were quite reasonable, the XP-RAFTS and TUFLOW models were considered acceptable for use in estimation of the design flood levels.

Design and extreme flood magnitudes were estimated for the full range of events from 2-yr ARI to PMF. These analyses assumed hydrologic ultimate catchment development conditions in accordance with the current version of BCC City Plan.

Three waterway scenarios were considered as follows: Scenario-1 is based on the current waterway conditions. No further modifications were made to the TUFLOW model developed as part of the calibration / verification phase. Scenario-2 includes an allowance for a riparian corridor along the edge of the channel. Scenario-3 includes an allowance for the riparian corridor (as per Scenario-2) and also assumes filling to the WC boundary to simulate potential development outside the WC.

The results from the TUFLOW modelling were used to produce the following:

- Peak flood discharges at selected locations
- Critical storm durations at selected locations
- Peak flood levels at cross section reporting points
- Peak flood extent mapping
- Peak flood depth mapping
- Hydraulic structure flood immunity

The TUFLOW results demonstrate that Brighton Creek is a waterway of minimal hydraulic grade. Downstream of Wickham Street all water surfaces drop no more than two metres before reaching the bay and the vast majority of this head loss occurs downstream of Beaconsfield Terrace. The flood information generated indicates that numerous properties have low flood immunity. During the lower order design events flood waters are for the most part contained within the wetland areas. As flood levels increase toward the 1% Flood Level significant areas of backwater inundation form. Notable areas of backwater exist in the vicinity of Prince Street, toward the southern end of Victoria Street and immediately downstream of Beaconsfield Terrace.

As part of the required sensitivity analysis a climate change analysis was then undertaken to determine the impacts for two planning horizons; namely 2050 and 2100. This included making allowances for increased rainfall intensity and increased mean sea level rise. This analysis was undertaken for the 100-yr, 200-yr and 500-yr ARI events. The average flood level increase due to climate change for the scenario 3, 100 year event, was 0.12m by 2050 and 0.26m by 2100.

The sensitivity analysis also requires blockage scenario model runs be carried out on significant structures. The five major structures in Brighton Creek catchment were blocked as per the QUDM guidelines. Each structure was run independently with its own model simulation to ensure no interference from the effects of blockage to other structures. Wickham Street and Beaconsfield Terrace were identified as the most sensitive structures to blockage conditions.

Hydraulic Structure Reference Sheets (HSRS) for all major crossings within the TUFLOW model area were also prepared. The HSRS provide data for each hydraulic structure and include data relating to the structure description, location, hydraulic performance and history.

9.2 Model limitations

In utilising the models it is important to be aware of their limitations which can be summarised as follows:

- The models have been only calibrated / verified at locations where survey debris records exist. This should be taken into account when considering the accuracy of results outside the influence of these locations.
- No calibration / verification were undertaken to MHG or Stream Gauges, as there were no data available for those particular events.
- These models are catchment scale and have been developed to simulate the flooding characteristics at a broad scale. As a result, smaller more localised flooding characteristics may not be apparent in the results.
- The XP-RAFTS and TUFLOW models must be used together to produce flooding results, as the XP-RAFTS model has not been developed as a "standalone" model.
- BCC 2009 ALS data has been used as the basis for the TUFLOW model topography, with some minor modifications undertaken in places. Detailed checks have not been undertaken on the accuracy of the ALS data, it is assumed that the data is representative of the topography and "fit for purpose."
- Future changes to the catchment conditions that are not reflected in the modelling will impact the validity of the study.
    - The accuracy of the model results is directly linked to the following:
    - The accuracy limits of the data used to develop the model (e.g. ALS, survey information, bridge data, etc.).
    - The accuracy and quality of the hydrometric data used to verify the models.
    - The number of historical stream gauge / MHG / Debris Survey Marking locations throughout the catchment.
    - The purpose of the study (i.e. catchment / broad-scale or detailed)

APPENDICES

APPENDIX A – Cumulative Rainfall Plots

APPENDIX B - Hydrologic Model: XP-RAFTS Model Data

APPENDIX C – Land Use Details

APPENDIX D - Calibration and Verification Details

APPENDIX E –Structure Head Loss Comparison

APPENDIX F – Hydraulic Structure Reference Sheets

APPENDIX G – Hydraulic Model Peer Review and Response

APPENDIX H - Design Event Peak Flood Levels

APPENDIX I - Extreme Event and Climate Change Peak Flood Levels

APPENDIX J - Flood Mapping

APPENDIX K – Stretching Limitations

Appendix A: Cumulative Rainfall Plots

Table A.1: Peak flood discharges for calibration event (XP-RAFTS)

Historic Flood Event	Flood event discharges		
	Peak inflow at Beaconsfield Tce (m^3/s)	Discharge at Mouth (m^3/s)	Peak tide level (mAHD)
25 January 1974	24.4	19.5	1.53
20 May 2009	19.1	14.2	0.98
10 October 2010	18.6	14.8	1.1

Table A.2: Cumulative Rainfall data for 25 January 1974 Event

Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)
27/05/1974 0:00	0	24/01/1974 21:00	26.5	24/01/1974 21:15	26.9	25/01/1974 9:30	148.8
24/01/1974 9:00	0.3	24/01/1974 21:15	26.9	24/01/1974 21:30	27.5	25/01/1974 9:45	164.6
24/01/1974 9:15	0.3	24/01/1974 21:30	27.5	24/01/1974 21:45	28.4	25/01/1974 10:00	170.6
24/01/1974 9:30	0.3	24/01/1974 21:45	28.4	24/01/1974 22:00	28.7	25/01/1974 10:15	182.3
24/01/1974 9:45	0.3	24/01/1974 22:00	28.7	24/01/1974 22:15	29	25/01/1974 10:30	194.1
24/01/1974 10:00	0.3	24/01/1974 22:15	29	24/01/1974 22:30	29.4	25/01/1974 10:45	203.9
24/01/1974 10:15	0.3	24/01/1974 22:30	29.4	24/01/1974 22:45	29.9	25/01/1974 11:00	215.8
24/01/1974 10:30	0.3	24/01/1974 22:45	29.9	24/01/1974 23:00	30.6	25/01/1974 11:15	220.4
24/01/1974 10:45	0.4	24/01/1974 23:00	30.6	24/01/1974 23:15	31.2	25/01/1974 11:30	229.5
24/01/1974 11:00	0.7	24/01/1974 23:15	31.2	24/01/1974 23:30	31.8	25/01/1974 11:45	244.5
24/01/1974 11:15	1.6	24/01/1974 23:30	31.8	24/01/1974 23:45	32	25/01/1974 12:00	246.6
24/01/1974 11:30	4.2	24/01/1974 23:45	32	25/01/1974 0:00	32.2	25/01/1974 12:15	250.2
24/01/1974 11:45	7.9	25/01/1974 0:00	32.2	25/01/1974 0:15	32.3	25/01/1974 12:30	251.5
24/01/1974 12:00	8.5	25/01/1974 0:15	32.3	25/01/1974 0:30	32.4	25/01/1974 12:45	252.3
24/01/1974 12:15	8.7	25/01/1974 0:30	32.4	25/01/1974 0:45	32.4	25/01/1974 13:00	253
24/01/1974 12:30	15	25/01/1974 0:45	32.4	25/01/1974 1:00	32.9	25/01/1974 13:15	253.6
24/01/1974 12:45	16.4	25/01/1974 1:00	32.9	25/01/1974 1:15	33.9	25/01/1974 13:30	254.5
24/01/1974 13:00	16.4	25/01/1974 1:15	33.9	25/01/1974 1:30	35.2	25/01/1974 13:45	255.5
24/01/1974 13:15	16.6	25/01/1974 1:30	35.2	25/01/1974 1:45	36.8	25/01/1974 14:00	256.3
24/01/1974 13:30	17	25/01/1974 1:45	36.8	25/01/1974 2:00	38.4	25/01/1974 14:15	257
24/01/1974 13:45	17.6	25/01/1974 2:00	38.4	25/01/1974 2:15	40.7	25/01/1974 14:30	257.8
24/01/1974 14:00	18.2	25/01/1974 2:15	40.7	25/01/1974 2:30	43.5	25/01/1974 14:45	260.3
24/01/1974 14:15	18.6	25/01/1974 2:30	43.5	25/01/1974 2:45	45.2	25/01/1974 15:00	261.6
24/01/1974 14:30	18.9	25/01/1974 2:45	45.2	25/01/1974 3:00	47	25/01/1974 15:15	262.1
24/01/1974 14:45	19.5	25/01/1974 3:00	47	25/01/1974 3:15	49.9	25/01/1974 15:30	262.4
24/01/1974 15:00	19.8	25/01/1974 3:15	49.9	25/01/1974 3:30	52.1	25/01/1974 15:45	262.6
24/01/1974 15:15	20	25/01/1974 3:30	52.1	25/01/1974 3:45	53.6	25/01/1974 16:00	262.8
24/01/1974 15:30	20.1	25/01/1974 3:45	53.6	25/01/1974 4:00	54.7	25/01/1974 16:15	262.9
24/01/1974 15:45	20.1	25/01/1974 4:00	54.7	25/01/1974 4:15	55.9	25/01/1974 16:30	263.8
24/01/1974 16:00	20.1	25/01/1974 4:15	55.9	25/01/1974 4:30	58.5	25/01/1974 16:45	265.6
24/01/1974 16:15	20.2	25/01/1974 4:30	58.5	25/01/1974 4:45	62.1	25/01/1974 17:00	266.4
24/01/1974 16:30	20.4	25/01/1974 4:45	62.1	25/01/1974 5:00	65.7	25/01/1974 17:15	267
24/01/1974 16:45	20.6	25/01/1974 5:00	65.7	25/01/1974 5:15	70.1	25/01/1974 17:30	267.6
24/01/1974 17:00	20.6	25/01/1974 5:15	70.1	25/01/1974 5:30	72.1	25/01/1974 17:45	268.1
24/01/1974 17:15	20.6	25/01/1974 5:30	72.1	25/01/1974 5:45	74	25/01/1974 18:00	268.9
24/01/1974 17:30	20.8	25/01/1974 5:45	74	25/01/1974 6:00	77	25/01/1974 18:15	271.3
24/01/1974 17:45	21.9	25/01/1974 6:00	77	25/01/1974 6:15	82.3	25/01/1974 18:30	274.6
24/01/1974 18:00	22.1	25/01/1974 6:15	82.3	25/01/1974 6:30	85.7	25/01/1974 18:45	277.2
24/01/1974 18:15	22.2	25/01/1974 6:30	85.7	25/01/1974 6:45	89.3	25/01/1974 19:00	279.3
24/01/1974 18:30	22.3	25/01/1974 6:45	89.3	25/01/1974 7:00	93	25/01/1974 19:15	281.7
24/01/1974 18:45	22.4	25/01/1974 7:00	93	25/01/1974 7:15	99.5	25/01/1974 19:30	284.8
24/01/1974 19:00	22.4	25/01/1974 7:15	99.5	25/01/1974 7:30	102.6	25/01/1974 19:45	286.5
24/01/1974 19:15	22.4	25/01/1974 7:30	102.6	25/01/1974 7:45	107.8	25/01/1974 20:00	288.2
24/01/1974 19:30	22.6	25/01/1974 7:45	107.8	25/01/1974 8:00	109.6	25/01/1974 20:15	290.2
24/01/1974 19:45	22.9	25/01/1974 8:00	109.6	25/01/1974 8:15	112.8	25/01/1974 20:30	293.5
24/01/1974 20:00	23.8	25/01/1974 8:15	112.8	25/01/1974 8:30	114.2	25/01/1974 20:45	295.7
24/01/1974 20:15	25.3	25/01/1974 8:30	114.2	25/01/1974 8:45	118.5	25/01/1974 21:00	297.4
24/01/1974 20:30	25.7	25/01/1974 8:45	118.5	25/01/1974 9:00	129.9	25/01/1974 21:15	299.9
24/01/1974 20:45	26.1	25/01/1974 9:00	129.9	25/01/1974 9:15	138.1	25/01/1974 21:30	302.2

Table A.2: Cumulative Rainfall data for 25 January 1974 Event-continued

Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)
25/01/1974 21:45	305.4	26/01/1974 10:30	450.4	26/01/1974 23:15	528.7	27/01/1974 12:00	608.3
25/01/1974 22:00	312.1	26/01/1974 10:45	454.8	26/01/1974 23:30	533.3	27/01/1974 12:15	609.4
25/01/1974 22:15	318.1	26/01/1974 11:00	459.9	26/01/1974 23:45	537.8	27/01/1974 12:30	610
25/01/1974 22:30	327.2	26/01/1974 11:15	461.3	27/01/1974 0:00	540.1	27/01/1974 12:45	611.1
25/01/1974 22:45	336.3	26/01/1974 11:30	461.5	27/01/1974 0:15	542	27/01/1974 13:00	612.6
25/01/1974 23:00	351.1	26/01/1974 11:45	461.6	27/01/1974 0:30	543.9	27/01/1974 13:15	613.2
25/01/1974 23:15	356.6	26/01/1974 12:00	461.7	27/01/1974 0:45	545.8	27/01/1974 13:30	613.7
25/01/1974 23:30	360.2	26/01/1974 12:15	461.8	27/01/1974 1:00	547.8	27/01/1974 13:45	614.2
25/01/1974 23:45	365.7	26/01/1974 12:30	461.9	27/01/1974 1:15	549.4	27/01/1974 14:00	614.7
26/01/1974 0:00	368.8	26/01/1974 12:45	462	27/01/1974 1:30	550.6	27/01/1974 14:15	616
26/01/1974 0:15	372.4	26/01/1974 13:00	462.1	27/01/1974 1:45	551.7	27/01/1974 14:30	616.9
26/01/1974 0:30	375.8	26/01/1974 13:15	462.2	27/01/1974 2:00	553.4	27/01/1974 14:45	617.6
26/01/1974 0:45	382.9	26/01/1974 13:30	462.3	27/01/1974 2:15	553.9	27/01/1974 15:00	618
26/01/1974 1:00	390.3	26/01/1974 13:45	462.3	27/01/1974 2:30	554.7	27/01/1974 15:15	618.4
26/01/1974 1:15	397	26/01/1974 14:00	462.3	27/01/1974 2:45	557.3	27/01/1974 15:30	618.6
26/01/1974 1:30	399.4	26/01/1974 14:15	462.3	27/01/1974 3:00	559.1	27/01/1974 15:45	619.6
26/01/1974 1:45	401.4	26/01/1974 14:30	462.3	27/01/1974 3:15	561.3	27/01/1974 16:00	622.8
26/01/1974 2:00	402.6	26/01/1974 14:45	462.3	27/01/1974 3:30	563.1	27/01/1974 16:15	625.4
26/01/1974 2:15	404.2	26/01/1974 15:00	462.3	27/01/1974 3:45	564.8	27/01/1974 16:30	630.7
26/01/1974 2:30	406.7	26/01/1974 15:15	462.5	27/01/1974 4:00	567.6	27/01/1974 16:45	633.6
26/01/1974 2:45	407.4	26/01/1974 15:30	462.7	27/01/1974 4:15	568.9	27/01/1974 17:00	634.4
26/01/1974 3:00	408.3	26/01/1974 15:45	462.9	27/01/1974 4:30	569.5	27/01/1974 17:15	635
26/01/1974 3:15	409.7	26/01/1974 16:00	463	27/01/1974 4:45	569.7	27/01/1974 17:30	635.4
26/01/1974 3:30	410.5	26/01/1974 16:15	463.1	27/01/1974 5:00	571.2	27/01/1974 17:45	635.9
26/01/1974 3:45	411	26/01/1974 16:30	463.2	27/01/1974 5:15	573.1	27/01/1974 18:00	636.5
26/01/1974 4:00	411.6	26/01/1974 16:45	463.2	27/01/1974 5:30	574.3	27/01/1974 18:15	637.1
26/01/1974 4:15	413.1	26/01/1974 17:00	463.2	27/01/1974 5:45	575.6	27/01/1974 18:30	638.5
26/01/1974 4:30	414.8	26/01/1974 17:15	463.3	27/01/1974 6:00	576.8	27/01/1974 18:45	638.7
26/01/1974 4:45	417.1	26/01/1974 17:30	463.5	27/01/1974 6:15	578.2	27/01/1974 19:00	638.8
26/01/1974 5:00	419.9	26/01/1974 17:45	464.3	27/01/1974 6:30	579.6	27/01/1974 19:15	639.3
26/01/1974 5:15	422.9	26/01/1974 18:00	467.8	27/01/1974 6:45	581.6	27/01/1974 19:30	639.4
26/01/1974 5:30	426.1	26/01/1974 18:15	474	27/01/1974 7:00	582.1	27/01/1974 19:45	639.5
26/01/1974 5:45	428.6	26/01/1974 18:30	478.9	27/01/1974 7:15	583.1	27/01/1974 20:00	639.6
26/01/1974 6:00	431.9	26/01/1974 18:45	481.3	27/01/1974 7:30	584.3	27/01/1974 20:15	639.7
26/01/1974 6:15	434.2	26/01/1974 19:00	484.2	27/01/1974 7:45	586.3	27/01/1974 20:30	639.8
26/01/1974 6:30	436.1	26/01/1974 19:15	486.5	27/01/1974 8:00	587.7	27/01/1974 20:45	639.9
26/01/1974 6:45	438	26/01/1974 19:30	488	27/01/1974 8:15	590	27/01/1974 21:00	640
26/01/1974 7:00	438.9	26/01/1974 19:45	489.2	27/01/1974 8:30	592.4	27/01/1974 21:15	640.1
26/01/1974 7:15	439.5	26/01/1974 20:00	490.4	27/01/1974 8:45	598.4	27/01/1974 21:30	640.3
26/01/1974 7:30	440.2	26/01/1974 20:15	491.8	27/01/1974 9:00	598.8	27/01/1974 21:45	640.5
26/01/1974 7:45	441	26/01/1974 20:30	493.6	27/01/1974 9:15	599.1	27/01/1974 22:00	640.7
26/01/1974 8:00	441.6	26/01/1974 20:45	496.2	27/01/1974 9:30	599.4	27/01/1974 22:15	640.8
26/01/1974 8:15	442.3	26/01/1974 21:00	498.9	27/01/1974 9:45	599.7	27/01/1974 22:30	640.9
26/01/1974 8:30	443.2	26/01/1974 21:15	501.7	27/01/1974 10:00	600.1	27/01/1974 22:45	641.1
26/01/1974 8:45	443.7	26/01/1974 21:30	505	27/01/1974 10:15	600.5	27/01/1974 23:00	641.3
26/01/1974 9:00	445.9	26/01/1974 21:45	509.6	27/01/1974 10:30	601	27/01/1974 23:15	641.5
26/01/1974 9:15	447	26/01/1974 22:00	512.5	27/01/1974 10:45	601.6	27/01/1974 23:30	641.8
26/01/1974 9:30	447.3	26/01/1974 22:15	514.4	27/01/1974 11:00	602.5	27/01/1974 23:45	642.3
26/01/1974 9:45	448	26/01/1974 22:30	517.3	27/01/1974 11:15	603.9	28/01/1974 0:00	642.6
26/01/1974 10:00	448.7	26/01/1974 22:45	521.3	27/01/1974 11:30	604.5		
26/01/1974 10:15	449.4	26/01/1974 23:00	526.3	27/01/1974 11:45	606.8		

Table A.3: Cumulative Rainfall data for 20 May 2009 Event

Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)
18/05/2009 17:00	0	19/05/2009 5:15	28	19/05/2009 17:30	101	20/05/2009 5:45	203
18/05/2009 17:15	0	19/05/2009 5:30	28	19/05/2009 17:45	102	20/05/2009 6:00	204
18/05/2009 17:30	4	19/05/2009 5:45	28	19/05/2009 18:00	103	20/05/2009 6:15	205
18/05/2009 17:45	5	19/05/2009 6:00	29	19/05/2009 18:15	106	20/05/2009 6:30	207
18/05/2009 18:00	5	19/05/2009 6:15	31	19/05/2009 18:30	106	20/05/2009 6:45	208
18/05/2009 18:15	5	19/05/2009 6:30	32	19/05/2009 18:45	107	20/05/2009 7:00	210
18/05/2009 18:30	5	19/05/2009 6:45	33	19/05/2009 19:00	107	20/05/2009 7:15	213
18/05/2009 18:45	5	19/05/2009 7:00	34	19/05/2009 19:15	108	20/05/2009 7:30	217
18/05/2009 19:00	5	19/05/2009 7:15	34	19/05/2009 19:30	109	20/05/2009 7:45	219
18/05/2009 19:15	5	19/05/2009 7:30	35	19/05/2009 19:45	109	20/05/2009 8:00	221
18/05/2009 19:30	5	19/05/2009 7:45	38	19/05/2009 20:00	109	20/05/2009 8:15	223
18/05/2009 19:45	5	19/05/2009 8:00	41	19/05/2009 20:15	110	20/05/2009 8:30	227
18/05/2009 20:00	5	19/05/2009 8:15	45	19/05/2009 20:30	110	20/05/2009 8:45	231
18/05/2009 20:15	7	19/05/2009 8:30	48	19/05/2009 20:45	110	20/05/2009 9:00	234
18/05/2009 20:30	7	19/05/2009 8:45	51	19/05/2009 21:00	110	20/05/2009 9:15	236
18/05/2009 20:45	7	19/05/2009 9:00	55	19/05/2009 21:15	112	20/05/2009 9:30	240
18/05/2009 21:00	7	19/05/2009 9:15	59	19/05/2009 21:30	113	20/05/2009 9:45	246
18/05/2009 21:15	7	19/05/2009 9:30	62	19/05/2009 21:45	119	20/05/2009 10:00	251
18/05/2009 21:30	7	19/05/2009 9:45	64	19/05/2009 22:00	122	20/05/2009 10:15	257
18/05/2009 21:45	7	19/05/2009 10:00	65	19/05/2009 22:15	124	20/05/2009 10:30	269
18/05/2009 22:00	7	19/05/2009 10:15	67	19/05/2009 22:30	127	20/05/2009 10:45	285
18/05/2009 22:15	7	19/05/2009 10:30	68	19/05/2009 22:45	130	20/05/2009 11:00	290
18/05/2009 22:30	7	19/05/2009 10:45	70	19/05/2009 23:00	132	20/05/2009 11:15	295
18/05/2009 22:45	7	19/05/2009 11:00	74	19/05/2009 23:15	134	20/05/2009 11:30	299
18/05/2009 23:00	7	19/05/2009 11:15	78	19/05/2009 23:30	136	20/05/2009 11:45	300
18/05/2009 23:15	7	19/05/2009 11:30	84	19/05/2009 23:45	139	20/05/2009 12:00	309
18/05/2009 23:30	7	19/05/2009 11:45	86	20/05/2009 0:00	143	20/05/2009 12:15	313
18/05/2009 23:45	7	19/05/2009 12:00	91	20/05/2009 0:15	146	20/05/2009 12:30	314
19/05/2009 0:00	8	19/05/2009 12:15	92	20/05/2009 0:30	148	20/05/2009 12:45	314
19/05/2009 0:15	10	19/05/2009 12:30	92	20/05/2009 0:45	149	20/05/2009 13:00	314
19/05/2009 0:30	10	19/05/2009 12:45	92	20/05/2009 1:00	151	20/05/2009 13:15	314
19/05/2009 0:45	11	19/05/2009 13:00	92	20/05/2009 1:15	154	20/05/2009 13:30	318
19/05/2009 1:00	13	19/05/2009 13:15	92	20/05/2009 1:30	155	20/05/2009 13:45	328
19/05/2009 1:15	13	19/05/2009 13:30	92	20/05/2009 1:45	160	20/05/2009 14:00	330
19/05/2009 1:30	15	19/05/2009 13:45	92	20/05/2009 2:00	164	20/05/2009 14:15	330
19/05/2009 1:45	16	19/05/2009 14:00	92	20/05/2009 2:15	174	20/05/2009 14:30	332
19/05/2009 2:00	17	19/05/2009 14:15	92	20/05/2009 2:30	179	20/05/2009 14:45	335
19/05/2009 2:15	19	19/05/2009 14:30	92	20/05/2009 2:45	185	20/05/2009 15:00	346
19/05/2009 2:30	20	19/05/2009 14:45	92	20/05/2009 3:00	190	20/05/2009 15:15	350
19/05/2009 2:45	21	19/05/2009 15:00	92	20/05/2009 3:15	193	20/05/2009 15:30	350
19/05/2009 3:00	22	19/05/2009 15:15	93	20/05/2009 3:30	194	20/05/2009 15:45	350
19/05/2009 3:15	22	19/05/2009 15:30	93	20/05/2009 3:45	195	20/05/2009 16:00	350
19/05/2009 3:30	22	19/05/2009 15:45	93	20/05/2009 4:00	196	20/05/2009 16:15	350
19/05/2009 3:45	23	19/05/2009 16:00	93	20/05/2009 4:15	197	20/05/2009 16:30	350
19/05/2009 4:00	23	19/05/2009 16:15	93	20/05/2009 4:30	198	20/05/2009 16:45	350
19/05/2009 4:15	23	19/05/2009 16:30	94	20/05/2009 4:45	199	20/05/2009 17:00	350
19/05/2009 4:30	24	19/05/2009 16:45	98	20/05/2009 5:00	200	20/05/2009 17:15	350
19/05/2009 4:45	27	19/05/2009 17:00	100	20/05/2009 5:15	201	20/05/2009 17:30	350
19/05/2009 5:00	27	19/05/2009 17:15	100	20/05/2009 5:30	202	20/05/2009 17:45	350

Table A.3: Cumulative Rainfall data for 20 May 2009 Event-continued

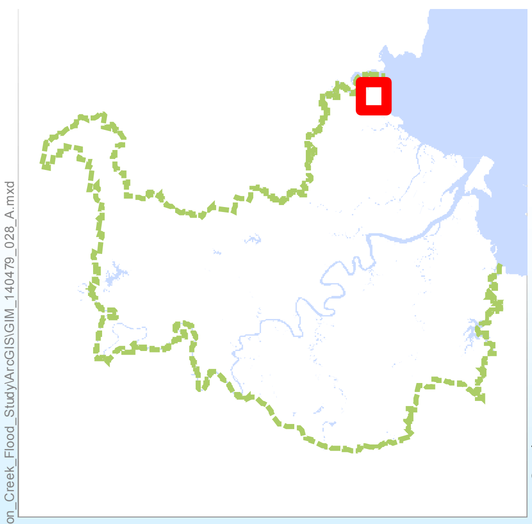
Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)
20/05/2009 18:00	350	21/05/2009 6:15	355	21/05/2009 18:30	355
20/05/2009 18:15	350	21/05/2009 6:30	355	21/05/2009 18:45	355
20/05/2009 18:30	351	21/05/2009 6:45	355	21/05/2009 19:00	355
20/05/2009 18:45	351	21/05/2009 7:00	355	21/05/2009 19:15	355
20/05/2009 19:00	351	21/05/2009 7:15	355	21/05/2009 19:30	355
20/05/2009 19:15	351	21/05/2009 7:30	355	21/05/2009 19:45	355
20/05/2009 19:30	351	21/05/2009 7:45	355	21/05/2009 20:00	355
20/05/2009 19:45	351	21/05/2009 8:00	355	21/05/2009 20:15	355
20/05/2009 20:00	351	21/05/2009 8:15	355	21/05/2009 20:30	355
20/05/2009 20:15	351	21/05/2009 8:30	355	21/05/2009 20:45	355
20/05/2009 20:30	351	21/05/2009 8:45	355	21/05/2009 21:00	355
20/05/2009 20:45	351	21/05/2009 9:00	355	21/05/2009 21:15	355
20/05/2009 21:00	351	21/05/2009 9:15	355	21/05/2009 21:30	355
20/05/2009 21:15	351	21/05/2009 9:30	355	21/05/2009 21:45	355
20/05/2009 21:30	351	21/05/2009 9:45	355	21/05/2009 22:00	355
20/05/2009 21:45	351	21/05/2009 10:00	355	21/05/2009 22:15	355
20/05/2009 22:00	352	21/05/2009 10:15	355	21/05/2009 22:30	355
20/05/2009 22:15	352	21/05/2009 10:30	355	21/05/2009 22:45	355
20/05/2009 22:30	352	21/05/2009 10:45	355	21/05/2009 23:00	355
20/05/2009 22:45	352	21/05/2009 11:00	355	21/05/2009 23:15	355
20/05/2009 23:00	352	21/05/2009 11:15	355	21/05/2009 23:30	355
20/05/2009 23:15	352	21/05/2009 11:30	355	21/05/2009 23:45	355
20/05/2009 23:30	352	21/05/2009 11:45	355	22/05/2009 0:00	355
20/05/2009 23:45	353	21/05/2009 12:00	355		
21/05/2009 0:00	353	21/05/2009 12:15	355		
21/05/2009 0:15	353	21/05/2009 12:30	355		
21/05/2009 0:30	353	21/05/2009 12:45	355		
21/05/2009 0:45	353	21/05/2009 13:00	355		
21/05/2009 1:00	353	21/05/2009 13:15	355		
21/05/2009 1:15	353	21/05/2009 13:30	355		
21/05/2009 1:30	354	21/05/2009 13:45	355		
21/05/2009 1:45	354	21/05/2009 14:00	355		
21/05/2009 2:00	354	21/05/2009 14:15	355		
21/05/2009 2:15	354	21/05/2009 14:30	355		
21/05/2009 2:30	354	21/05/2009 14:45	355		
21/05/2009 2:45	354	21/05/2009 15:00	355		
21/05/2009 3:00	354	21/05/2009 15:15	355		
21/05/2009 3:15	355	21/05/2009 15:30	355		
21/05/2009 3:30	355	21/05/2009 15:45	355		
21/05/2009 3:45	355	21/05/2009 16:00	355		
21/05/2009 4:00	355	21/05/2009 16:15	355		
21/05/2009 4:15	355	21/05/2009 16:30	355		
21/05/2009 4:30	355	21/05/2009 16:45	355		
21/05/2009 4:45	355	21/05/2009 17:00	355		
21/05/2009 5:00	355	21/05/2009 17:15	355		
21/05/2009 5:15	355	21/05/2009 17:30	355		
21/05/2009 5:30	355	21/05/2009 17:45	355		
21/05/2009 5:45	355	21/05/2009 18:00	355		
21/05/2009 6:00	355	21/05/2009 18:15	355		

Table A.4: Cumulative Rainfall for 10 October 2010 event

Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)
8/10/2010 1:00	0	8/10/2010 13:15	60	9/10/2010 1:30	125	9/10/2010 13:45	139
8/10/2010 1:15	0	8/10/2010 13:30	60	9/10/2010 1:45	126	9/10/2010 14:00	140
8/10/2010 1:30	4	8/10/2010 13:45	60	9/10/2010 2:00	129	9/10/2010 14:15	140
8/10/2010 1:45	20	8/10/2010 14:00	60	9/10/2010 2:15	130	9/10/2010 14:30	140
8/10/2010 2:00	40	8/10/2010 14:15	61	9/10/2010 2:30	130	9/10/2010 14:45	140
8/10/2010 2:15	51	8/10/2010 14:30	61	9/10/2010 2:45	131	9/10/2010 15:00	140
8/10/2010 2:30	55	8/10/2010 14:45	61	9/10/2010 3:00	132	9/10/2010 15:15	140
8/10/2010 2:45	56	8/10/2010 15:00	62	9/10/2010 3:15	132	9/10/2010 15:30	141
8/10/2010 3:00	56	8/10/2010 15:15	63	9/10/2010 3:30	133	9/10/2010 15:45	141
8/10/2010 3:15	57	8/10/2010 15:30	66	9/10/2010 3:45	133	9/10/2010 16:00	141
8/10/2010 3:30	58	8/10/2010 15:45	67	9/10/2010 4:00	133	9/10/2010 16:15	141
8/10/2010 3:45	58	8/10/2010 16:00	69	9/10/2010 4:15	133	9/10/2010 16:30	141
8/10/2010 4:00	58	8/10/2010 16:15	71	9/10/2010 4:30	133	9/10/2010 16:45	142
8/10/2010 4:15	58	8/10/2010 16:30	72	9/10/2010 4:45	133	9/10/2010 17:00	142
8/10/2010 4:30	58	8/10/2010 16:45	72	9/10/2010 5:00	133	9/10/2010 17:15	142
8/10/2010 4:45	59	8/10/2010 17:00	73	9/10/2010 5:15	133	9/10/2010 17:30	142
8/10/2010 5:00	59	8/10/2010 17:15	74	9/10/2010 5:30	133	9/10/2010 17:45	142
8/10/2010 5:15	59	8/10/2010 17:30	75	9/10/2010 5:45	133	9/10/2010 18:00	142
8/10/2010 5:30	59	8/10/2010 17:45	78	9/10/2010 6:00	134	9/10/2010 18:15	142
8/10/2010 5:45	60	8/10/2010 18:00	80	9/10/2010 6:15	134	9/10/2010 18:30	143
8/10/2010 6:00	60	8/10/2010 18:15	81	9/10/2010 6:30	134	9/10/2010 18:45	143
8/10/2010 6:15	60	8/10/2010 18:30	84	9/10/2010 6:45	134	9/10/2010 19:00	143
8/10/2010 6:30	60	8/10/2010 18:45	88	9/10/2010 7:00	134	9/10/2010 19:15	143
8/10/2010 6:45	60	8/10/2010 19:00	91	9/10/2010 7:15	134	9/10/2010 19:30	143
8/10/2010 7:00	60	8/10/2010 19:15	92	9/10/2010 7:30	134	9/10/2010 19:45	143
8/10/2010 7:15	60	8/10/2010 19:30	93	9/10/2010 7:45	134	9/10/2010 20:00	143
8/10/2010 7:30	60	8/10/2010 19:45	93	9/10/2010 8:00	134	9/10/2010 20:15	143
8/10/2010 7:45	60	8/10/2010 20:00	94	9/10/2010 8:15	134	9/10/2010 20:30	143
8/10/2010 8:00	60	8/10/2010 20:15	95	9/10/2010 8:30	134	9/10/2010 20:45	143
8/10/2010 8:15	60	8/10/2010 20:30	96	9/10/2010 8:45	134	9/10/2010 21:00	143
8/10/2010 8:30	60	8/10/2010 20:45	96	9/10/2010 9:00	134	9/10/2010 21:15	143
8/10/2010 8:45	60	8/10/2010 21:00	96	9/10/2010 9:15	134	9/10/2010 21:30	143
8/10/2010 9:00	60	8/10/2010 21:15	97	9/10/2010 9:30	134	9/10/2010 21:45	143
8/10/2010 9:15	60	8/10/2010 21:30	98	9/10/2010 9:45	134	9/10/2010 22:00	143
8/10/2010 9:30	60	8/10/2010 21:45	100	9/10/2010 10:00	134	9/10/2010 22:15	143
8/10/2010 9:45	60	8/10/2010 22:00	100	9/10/2010 10:15	134	9/10/2010 22:30	144
8/10/2010 10:00	60	8/10/2010 22:15	103	9/10/2010 10:30	134	9/10/2010 22:45	144
8/10/2010 10:15	60	8/10/2010 22:30	107	9/10/2010 10:45	134	9/10/2010 23:00	144
8/10/2010 10:30	60	8/10/2010 22:45	109	9/10/2010 11:00	134	9/10/2010 23:15	144
8/10/2010 10:45	60	8/10/2010 23:00	110	9/10/2010 11:15	135	9/10/2010 23:30	144
8/10/2010 11:00	60	8/10/2010 23:15	112	9/10/2010 11:30	135	9/10/2010 23:45	144
8/10/2010 11:15	60	8/10/2010 23:30	114	9/10/2010 11:45	137	10/10/2010 0:00	144
8/10/2010 11:30	60	8/10/2010 23:45	115	9/10/2010 12:00	138	10/10/2010 0:15	144
8/10/2010 11:45	60	9/10/2010 0:00	116	9/10/2010 12:15	138	10/10/2010 0:30	144
8/10/2010 12:00	60	9/10/2010 0:15	117	9/10/2010 12:30	138	10/10/2010 0:45	144
8/10/2010 12:15	60	9/10/2010 0:30	119	9/10/2010 12:45	138	10/10/2010 1:00	144
8/10/2010 12:30	60	9/10/2010 0:45	122	9/10/2010 13:00	138	10/10/2010 1:15	144
8/10/2010 12:45	60	9/10/2010 1:00	123	9/10/2010 13:15	139	10/10/2010 1:30	144
8/10/2010 13:00	60	9/10/2010 1:15	124	9/10/2010 13:30	139	10/10/2010 1:45	144

Table A.4: Cumulative Rainfall for 10 October 2010 event-continued

Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)	Date & Time	Cumulative Rainfall (mm)
10/10/2010 2:00	144	10/10/2010 14:15	155	11/10/2010 2:30	190	11/10/2010 14:45	351
10/10/2010 2:15	144	10/10/2010 14:30	155	11/10/2010 2:45	191	11/10/2010 15:00	351
10/10/2010 2:30	144	10/10/2010 14:45	155	11/10/2010 3:00	195	11/10/2010 15:15	352
10/10/2010 2:45	144	10/10/2010 15:00	155	11/10/2010 3:15	204	11/10/2010 15:30	357
10/10/2010 3:00	144	10/10/2010 15:15	155	11/10/2010 3:30	210	11/10/2010 15:45	358
10/10/2010 3:15	144	10/10/2010 15:30	155	11/10/2010 3:45	212	11/10/2010 16:00	361
10/10/2010 3:30	144	10/10/2010 15:45	155	11/10/2010 4:00	220	11/10/2010 16:15	363
10/10/2010 3:45	144	10/10/2010 16:00	155	11/10/2010 4:15	224	11/10/2010 16:30	363
10/10/2010 4:00	145	10/10/2010 16:15	155	11/10/2010 4:30	226	11/10/2010 16:45	364
10/10/2010 4:15	145	10/10/2010 16:30	155	11/10/2010 4:45	231	11/10/2010 17:00	364
10/10/2010 4:30	145	10/10/2010 16:45	155	11/10/2010 5:00	239	11/10/2010 17:15	364
10/10/2010 4:45	145	10/10/2010 17:00	155	11/10/2010 5:15	242	11/10/2010 17:30	365
10/10/2010 5:00	145	10/10/2010 17:15	155	11/10/2010 5:30	244	11/10/2010 17:45	365
10/10/2010 5:15	145	10/10/2010 17:30	155	11/10/2010 5:45	255	11/10/2010 18:00	365
10/10/2010 5:30	145	10/10/2010 17:45	156	11/10/2010 6:00	257	11/10/2010 18:15	365
10/10/2010 5:45	145	10/10/2010 18:00	156	11/10/2010 6:15	258	11/10/2010 18:30	365
10/10/2010 6:00	145	10/10/2010 18:15	156	11/10/2010 6:30	267	11/10/2010 18:45	365
10/10/2010 6:15	145	10/10/2010 18:30	156	11/10/2010 6:45	283	11/10/2010 19:00	365
10/10/2010 6:30	145	10/10/2010 18:45	156	11/10/2010 7:00	293	11/10/2010 19:15	365
10/10/2010 6:45	145	10/10/2010 19:00	156	11/10/2010 7:15	298	11/10/2010 19:30	365
10/10/2010 7:00	145	10/10/2010 19:15	156	11/10/2010 7:30	301	11/10/2010 19:45	365
10/10/2010 7:15	146	10/10/2010 19:30	157	11/10/2010 7:45	307	11/10/2010 20:00	366
10/10/2010 7:30	146	10/10/2010 19:45	157	11/10/2010 8:00	310	11/10/2010 20:15	366
10/10/2010 7:45	147	10/10/2010 20:00	157	11/10/2010 8:15	312	11/10/2010 20:30	366
10/10/2010 8:00	147	10/10/2010 20:15	158	11/10/2010 8:30	316	11/10/2010 20:45	366
10/10/2010 8:15	147	10/10/2010 20:30	159	11/10/2010 8:45	322	11/10/2010 21:00	367
10/10/2010 8:30	148	10/10/2010 20:45	160	11/10/2010 9:00	325	11/10/2010 21:15	367
10/10/2010 8:45	148	10/10/2010 21:00	160	11/10/2010 9:15	327	11/10/2010 21:30	367
10/10/2010 9:00	148	10/10/2010 21:15	160	11/10/2010 9:30	329	11/10/2010 21:45	367
10/10/2010 9:15	148	10/10/2010 21:30	161	11/10/2010 9:45	330	11/10/2010 22:00	367
10/10/2010 9:30	148	10/10/2010 21:45	161	11/10/2010 10:00	332	11/10/2010 22:15	367
10/10/2010 9:45	149	10/10/2010 22:00	162	11/10/2010 10:15	333	11/10/2010 22:30	367
10/10/2010 10:00	150	10/10/2010 22:15	162	11/10/2010 10:30	335	11/10/2010 22:45	367
10/10/2010 10:15	150	10/10/2010 22:30	162	11/10/2010 10:45	337	11/10/2010 23:00	367
10/10/2010 10:30	152	10/10/2010 22:45	163	11/10/2010 11:00	338	11/10/2010 23:15	367
10/10/2010 10:45	152	10/10/2010 23:00	164	11/10/2010 11:15	338	11/10/2010 23:30	367
10/10/2010 11:00	152	10/10/2010 23:15	165	11/10/2010 11:30	338	11/10/2010 23:45	367
10/10/2010 11:15	152	10/10/2010 23:30	165	11/10/2010 11:45	338	12/10/2010 0:00	367
10/10/2010 11:30	153	10/10/2010 23:45	165	11/10/2010 12:00	339		
10/10/2010 11:45	154	11/10/2010 0:00	165	11/10/2010 12:15	339		
10/10/2010 12:00	154	11/10/2010 0:15	168	11/10/2010 12:30	340		
10/10/2010 12:15	154	11/10/2010 0:30	169	11/10/2010 12:45	340		
10/10/2010 12:30	154	11/10/2010 0:45	170	11/10/2010 13:00	341		
10/10/2010 12:45	155	11/10/2010 1:00	171	11/10/2010 13:15	342		
10/10/2010 13:00	155	11/10/2010 1:15	173	11/10/2010 13:30	343		
10/10/2010 13:15	155	11/10/2010 1:30	175	11/10/2010 13:45	343		
10/10/2010 13:30	155	11/10/2010 1:45	177	11/10/2010 14:00	343		
10/10/2010 13:45	155	11/10/2010 2:00	178	11/10/2010 14:15	348		
10/10/2010 14:00	155	11/10/2010 2:15	186	11/10/2010 14:30	349		



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Legend

- Surveyed Cross Sections (1997)
- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Channels
- Freeways/Highways
- Major Roads
- Streets
- Brighton Creek Subcatchments
- Property Holdings
- Suburb Boundaries
- Park Boundaries

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Brighton Creek Surveyed Cross Sections 1997 Location Map

Figure A.1

GIM - 140479 - 028

Figure A.2: Cumulative Rainfall 25 January 1974 events

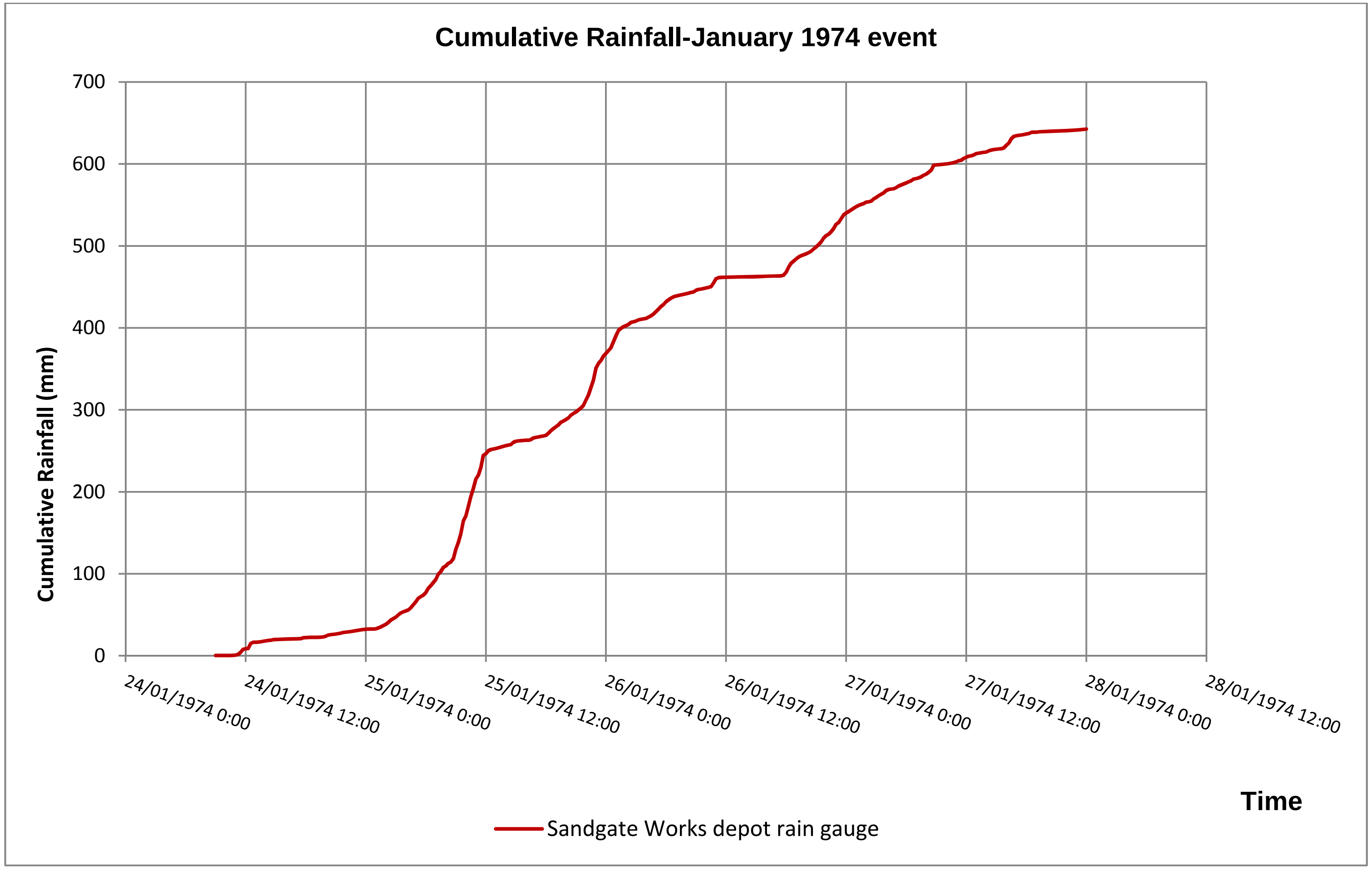


Figure A.3: Cumulative rainfall 20th May 2009 event

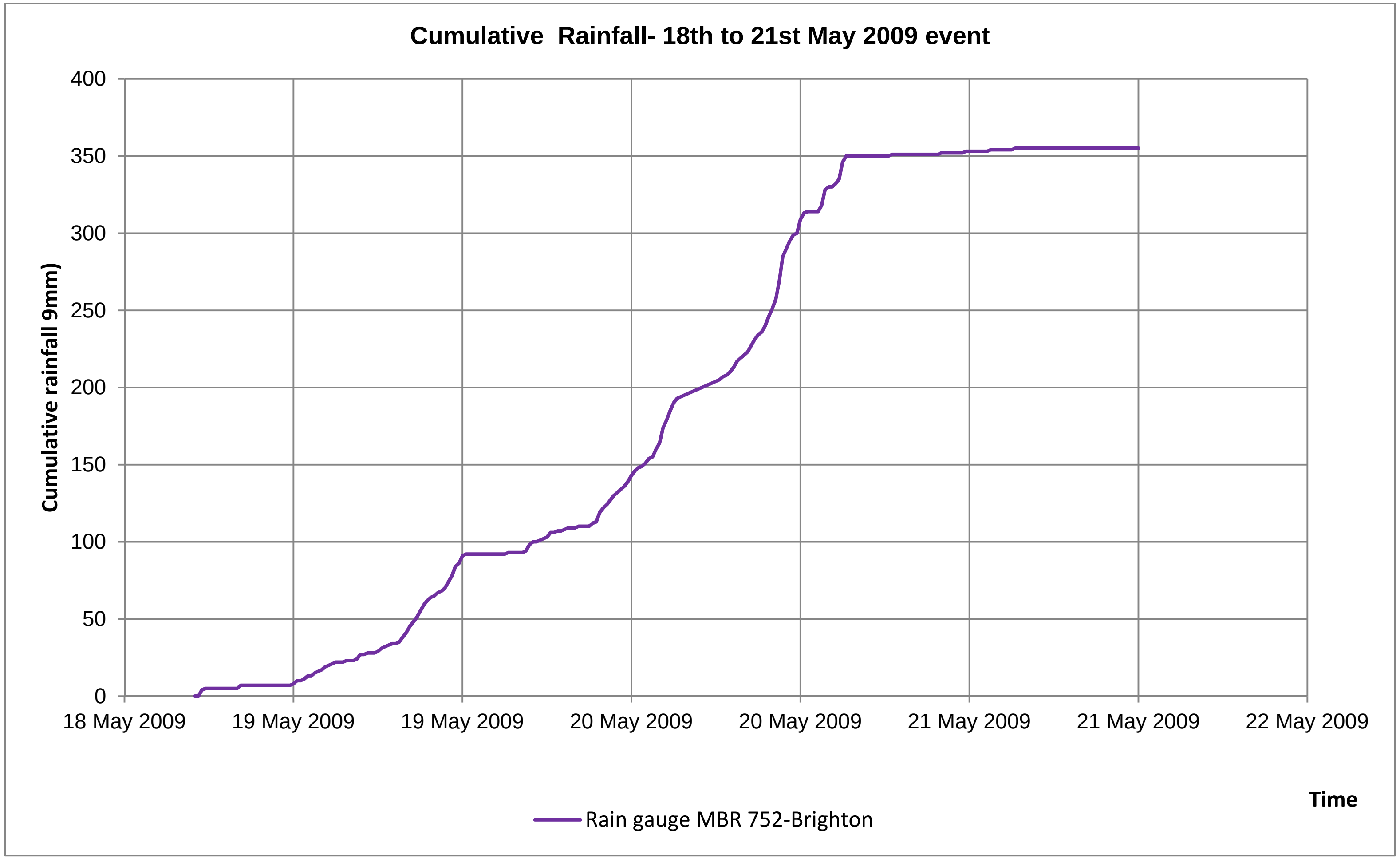
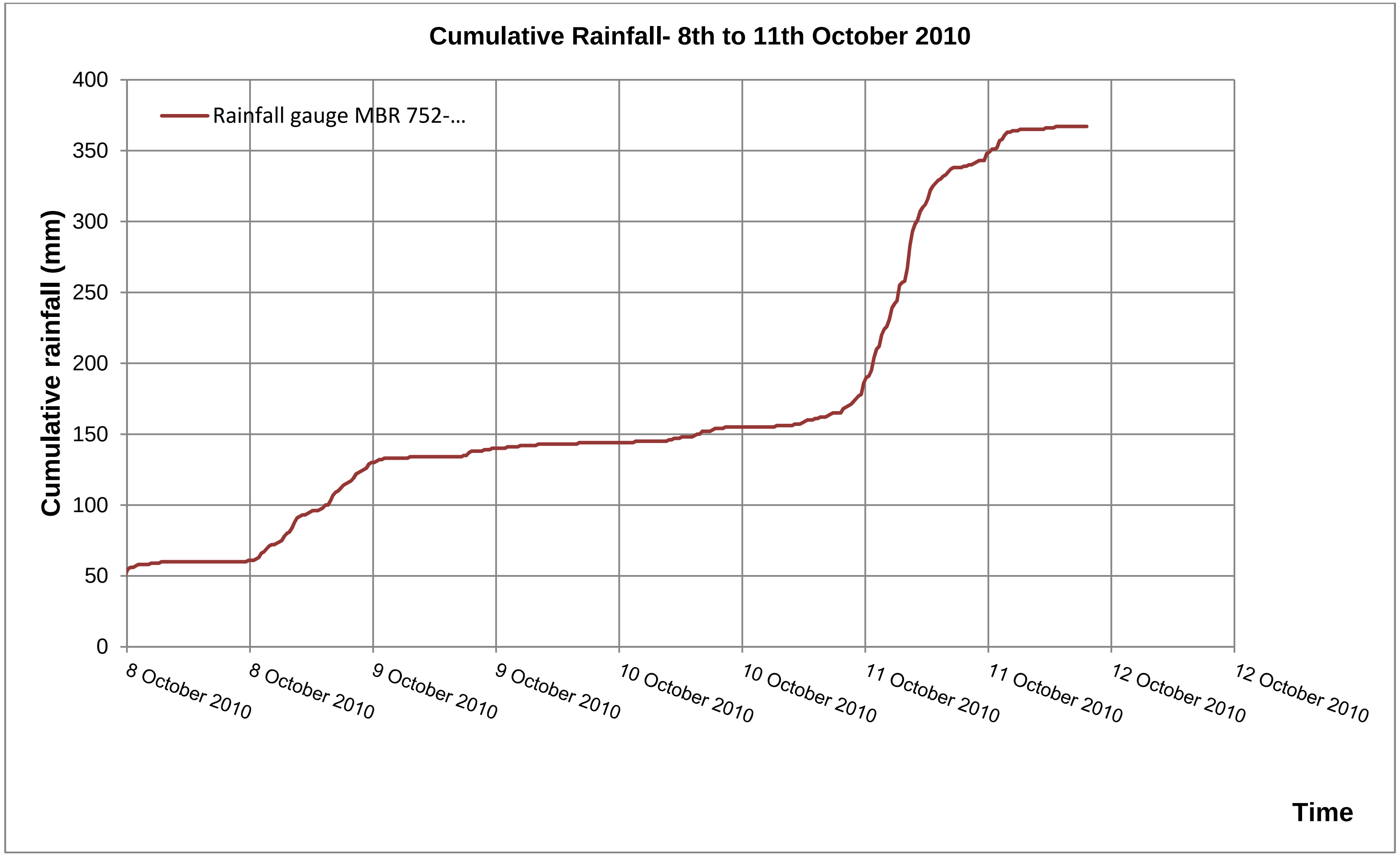


Figure A.4: Cumulative Rainfall-10th October 2010 event



Appendix B- Hydrologic Model: XP-RAFTS Model data

Table B.1: Stage, storage and discharge details for wetland detention basins (for XP-RAFTS) Northern wetland detention basin: Stage-storage and discharge details

Stage (mAHD)	Storage (m3)	Discharge (m3/s)
0.5	975	0
0.9	2875	0.28
1.2	4850	1.2
1.4	6350	2.2
1.6	11495	3.9
1.8	20285	6.4
2	29075	8.8
2.2	50385	11.13
2.3	61040	11.9
2.6	97820	15

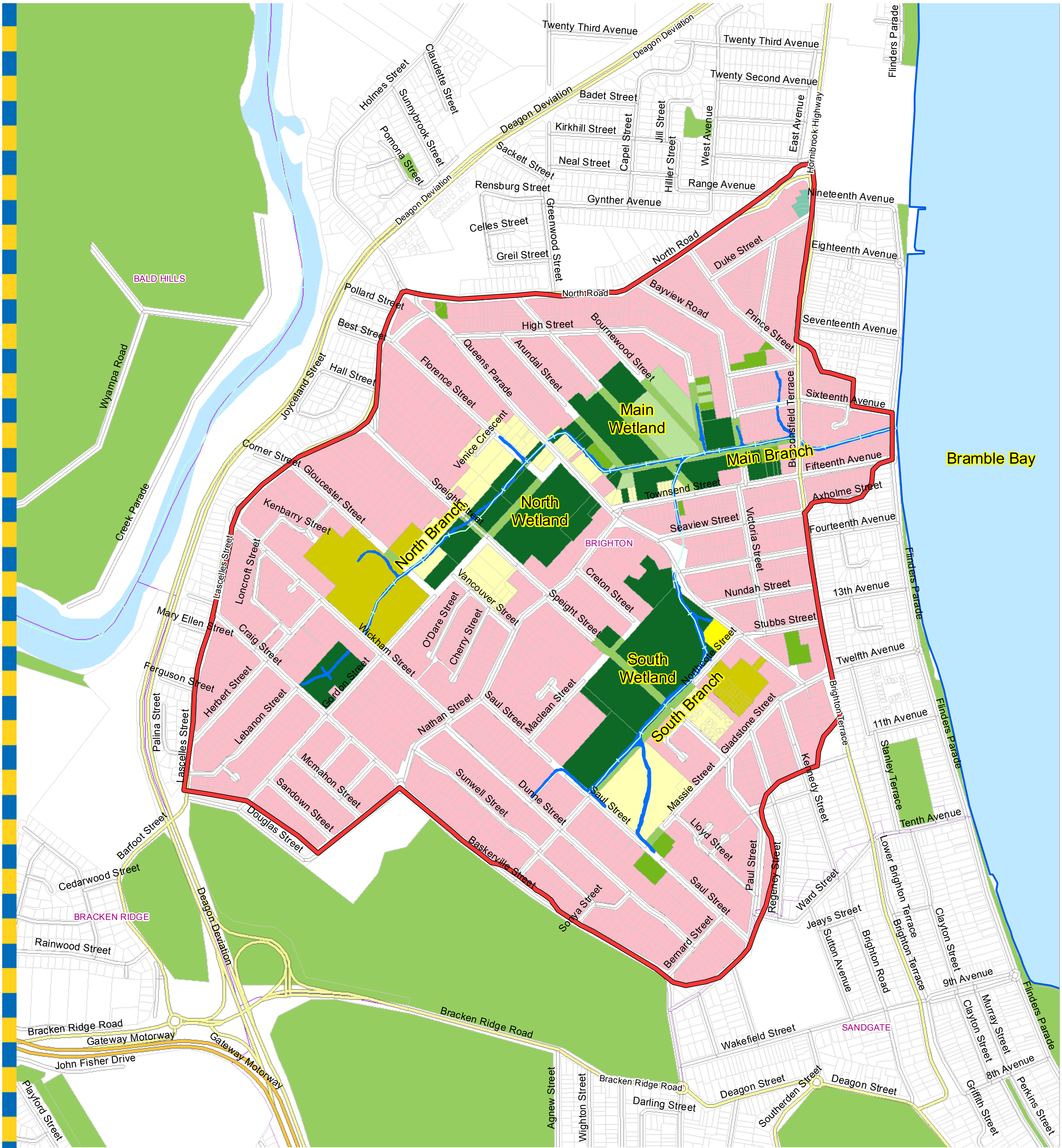
Table B.2: Main branch wetland detention basin

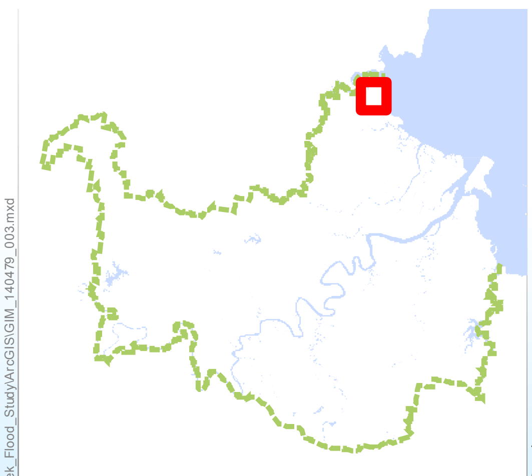
Stage (mAHD)	Storage (m^3)	Discharge (m^3/s)
0.4	120	0.0
1	5100	4.6
1.1	8120	6.0
1.2	12900	7.6
1.3	16450	9.4
1.4	20600	11.2
1.6	41650	15.4
1.8	72500	19.9
1.9	89000	22.1
1.95	96400	23.1
2.2	170160	28.1

Table B.3: Southern branch wetland detention basin

Stage (mAHD)	Storage (m^3)	Discharge (m^3/s)
0.76	575	0.0
1.4	6559	1.2
1.6	13830	2.0
1.8	25530	2.9
2	37230	3.8
2.2	51628	4.6
2.3	58827	5.0
3	92100	6.0

Appendix C: Land Use Details





Legend

- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Channels
- Property Holdings
- Suburb Boundaries
- Park Boundaries

City Plan - Area Classifications **For Information Only - Not Council Policy**

- Conservation (CN)
- Environmental Protection (EP)
- Park Land (PK)
- Sport and Recreation (SR)
- Low Density Residential (LR)
- Convenience Centre (MP4)
- Utility Installation (CU8)
- Emerging Communities (EC)

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Metres

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Project Number : 140479

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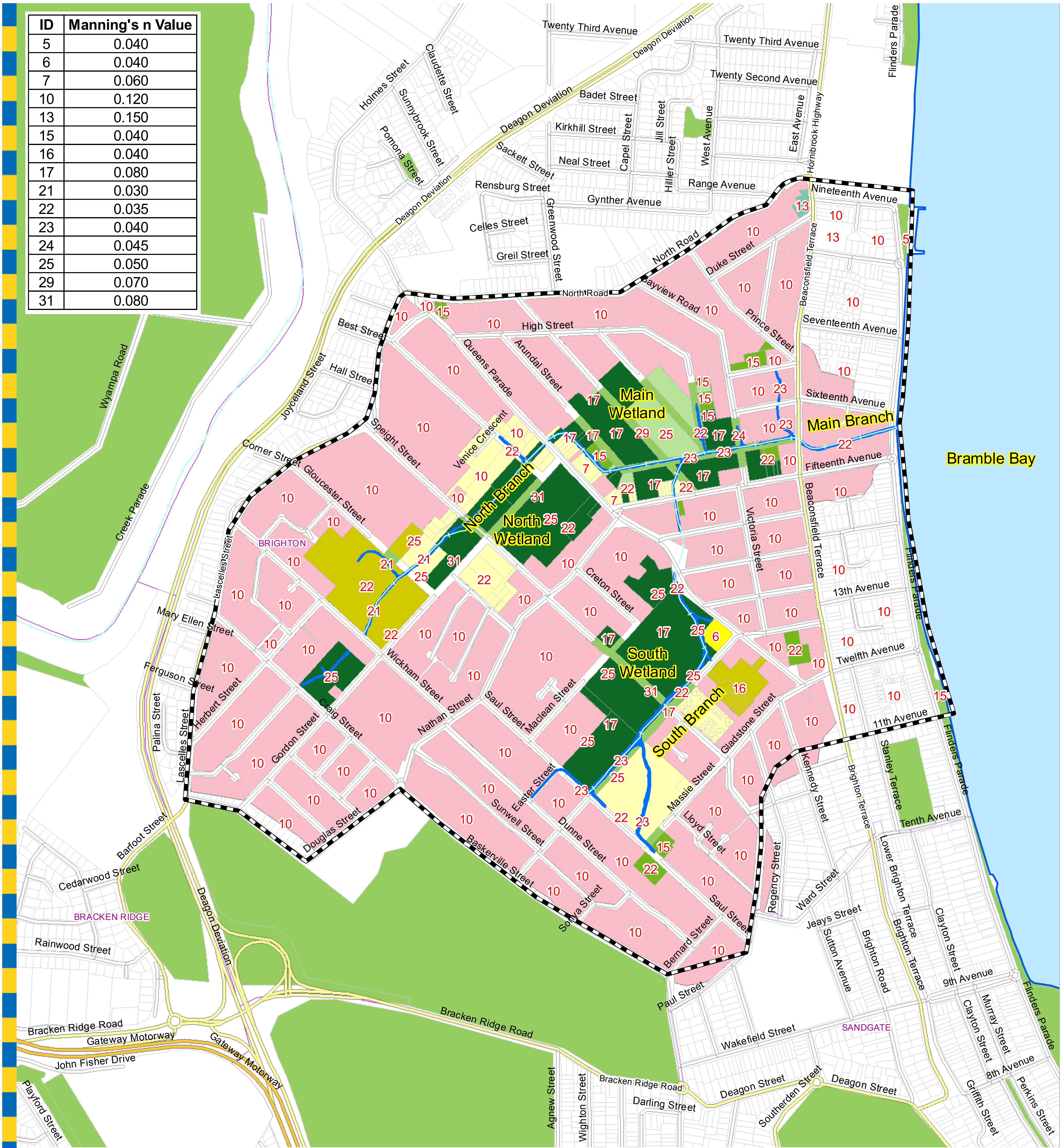
Brighton Creek Catchment City Plan - Land Uses

Figure C.1

GIM - 140479 - 003

ID	Manning's n Value
5	0.040
6	0.040
7	0.060
10	0.120
13	0.150
15	0.040
16	0.040
17	0.080
21	0.030
22	0.035
23	0.040
24	0.045
25	0.050
29	0.070
31	0.080



Legend

- 10 Roughness Parameter ID
- TUFLOW Model Area
- AMTD Line
- Brighton Creek Channels
- Property Holdings
- Suburb Boundaries
- Park Boundaries

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- Conservation (CN)
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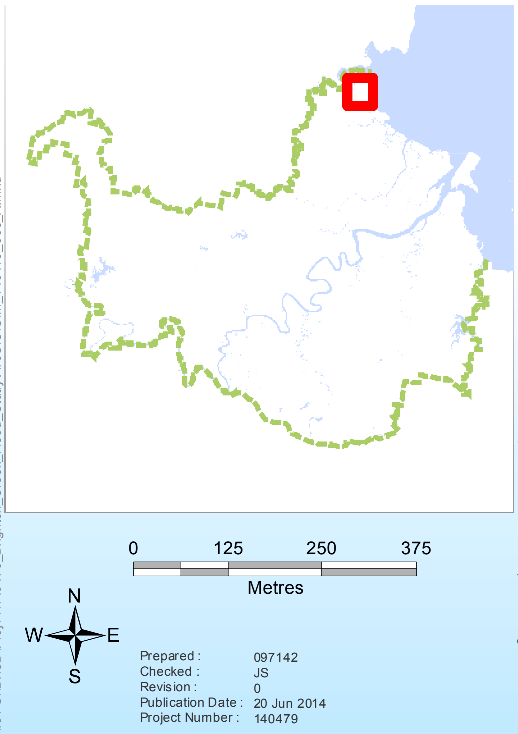

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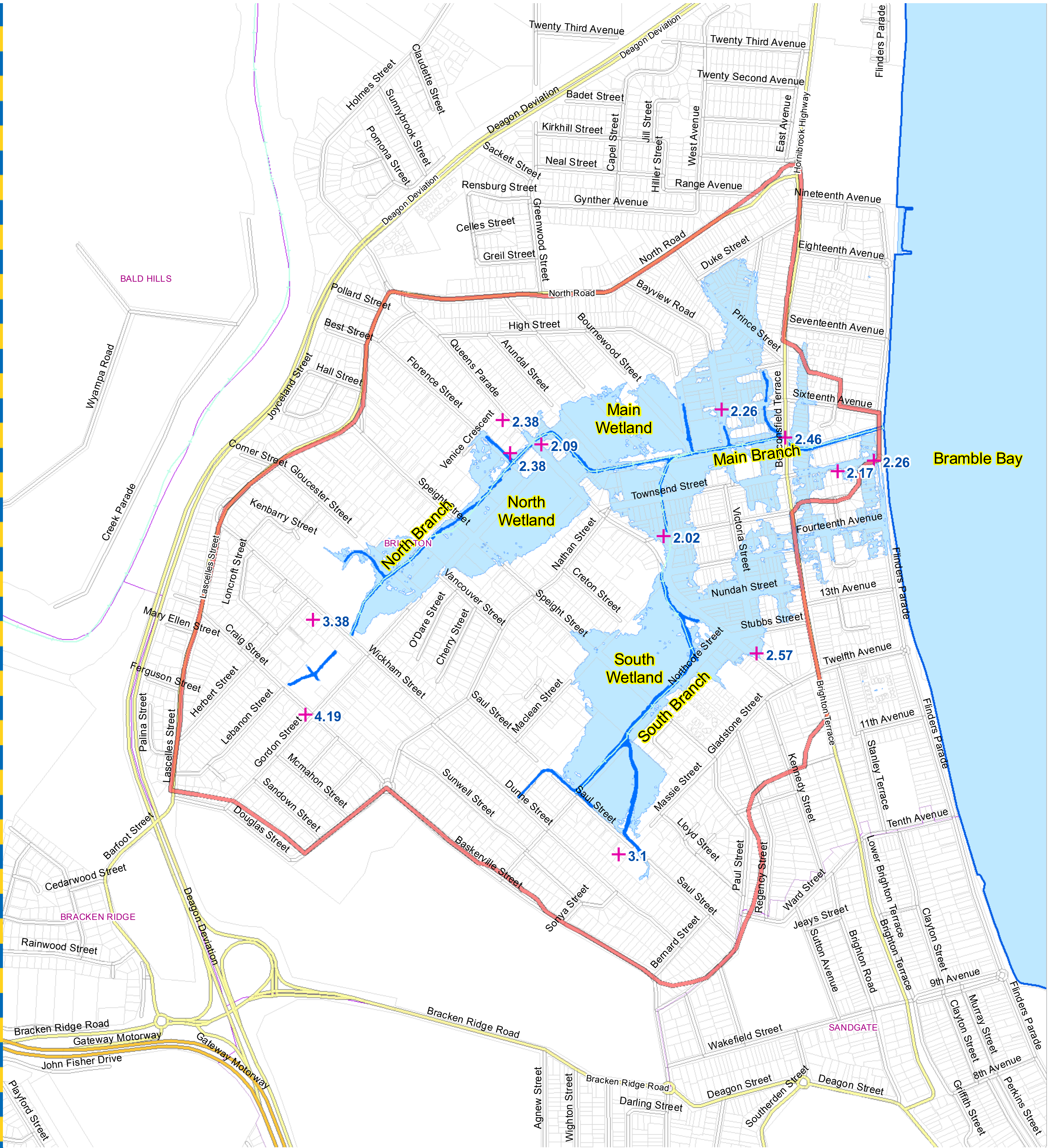
Brighton Creek TUFLOW Model Layout
Roughness Parameters
Figure C.2

GIM - 140479 - 008

Appendix D: Calibration & Verification Details

Table D.1: Comparison of the TUFLOW and MIKE11 (1997) model results for low flow events: ARI of 2 and 5 year DIS storms

Cross section ID	Chainage (m)	AMTD (m)	Flood Level (mAHD)		Difference (m)	Flood Level (mAHD)		Difference (m)
			2 year DIS			5 year DIS		
North & Main Branches			MIKE11	TUFLOW		MIKE11	TUFLOW	
BR190	100	1660	2.47	2.48	0.01	2.54	2.55	0.01
BR180	205	1555	2.22	2.34	0.12	2.34	2.42	0.08
Vancouver st	285	1475	2.18	2.27	0.09	2.29	2.36	0.07
BR170	425	1335	2.05	2.18	0.13	2.16	2.28	0.12
BR160	645	1115	1.83	2.06	0.23	2.04	2.18	0.14
Queens Pde US	720	1040	1.82	2.01	0.19	2.04	2.05	0.01
Queens Pde DS	740	1020	1.75	1.86	0.11	1.91	2.01	0.1
BR145 copy	750	1010	1.74	1.84	0.1	1.91	1.98	0.07
BR145	840	920	1.64	1.75	0.11	1.8	1.93	0.13
BR140	1025	735	1.55	1.62	0.07	1.69	1.76	0.07
BR120	1215	545	1.52	1.58	0.06	1.65	1.71	0.06
BR110	1310	450	1.5	1.56	0.06	1.63	1.69	0.06
BR105	1420	340	1.47	1.47	0	1.6	1.61	0.01
BR105	1450	310	1.44	1.48	0.04	1.57	1.57	0
Beaconsfield TceUS	1460	300	1.44	1.44	0	1.56	1.58	0.02
Beaconsfield TceUS	1490	270	1.35	1.33	-0.02	1.45	1.45	0
Canal DS	1500	260	1.33	1.36	0.03	1.44	1.42	0.02
Canal DS	1587	173	1.24	1.22	-0.02	1.33	1.33	0
Flinders Pde	1673	87	1.11	1.05	-0.06	1.18	1.12	-0.06
Mouth	1760	0	0.92	0.92	0	0.92	0.92	0
South Branch								
BR360	0	1035	1.82	1.98	0.16	1.94	2.04	0.1
BR355	75	960	1.79	1.9	0.11	1.94	1.94	0
BR350	200	835	1.79	1.86	0.07	1.94	1.91	-0.03
BR340	325	710	1.79	1.73	-0.06	1.94	1.87	-0.07
BR335	465	570	1.79	1.72	-0.07	1.94	1.86	-0.08
BR333	575	460	1.78	1.71	-0.07	1.93	1.85	-0.08
BR331	650	385	1.78	1.71	-0.07	1.93	1.85	-0.08
BR330	705	330	1.77	1.71	-0.06	1.93	1.84	-0.09
Queens Pde US	730	305	1.57	1.7	0.13	1.93	1.84	-0.09
Seaview St DS	850	185	1.57	1.65	0.08	1.71	1.8	0.09
BR305	895	140	1.53	1.64	0.11	1.71	1.8	0.09
Townsend St US	935	100	1.53	1.62	0.09	1.71	1.78	0.07
Townsend St DS	950	85	1.53	1.63	0.1	1.66	1.8	0.14
BR299	990	45	1.53	1.64	0.11	1.66	1.8	0.14
Merge	1035	0	1.53	1.63	0.1	1.66	1.8	0.14
BR360	0	1035	1.82	1.98	0.16	1.94	2.04	0.1



Legend

For Information Only - Not Council Policy

- 1974 Flood Levels (mAHD)
- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Channels
- 25 Jan 1974 Flood Extent
- Freeways/Highways
- Major Roads
- Streets
- Property Holdings
- Suburb Boundaries

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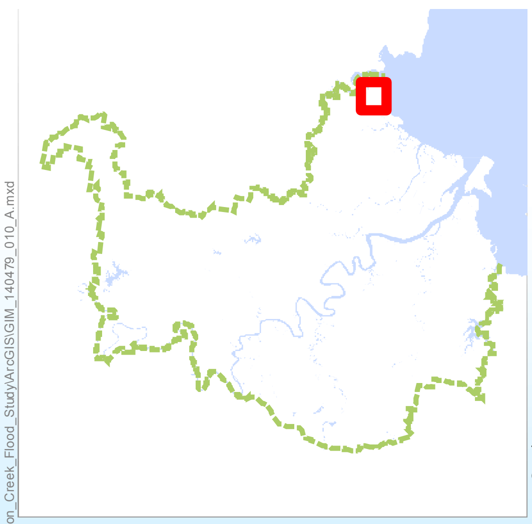

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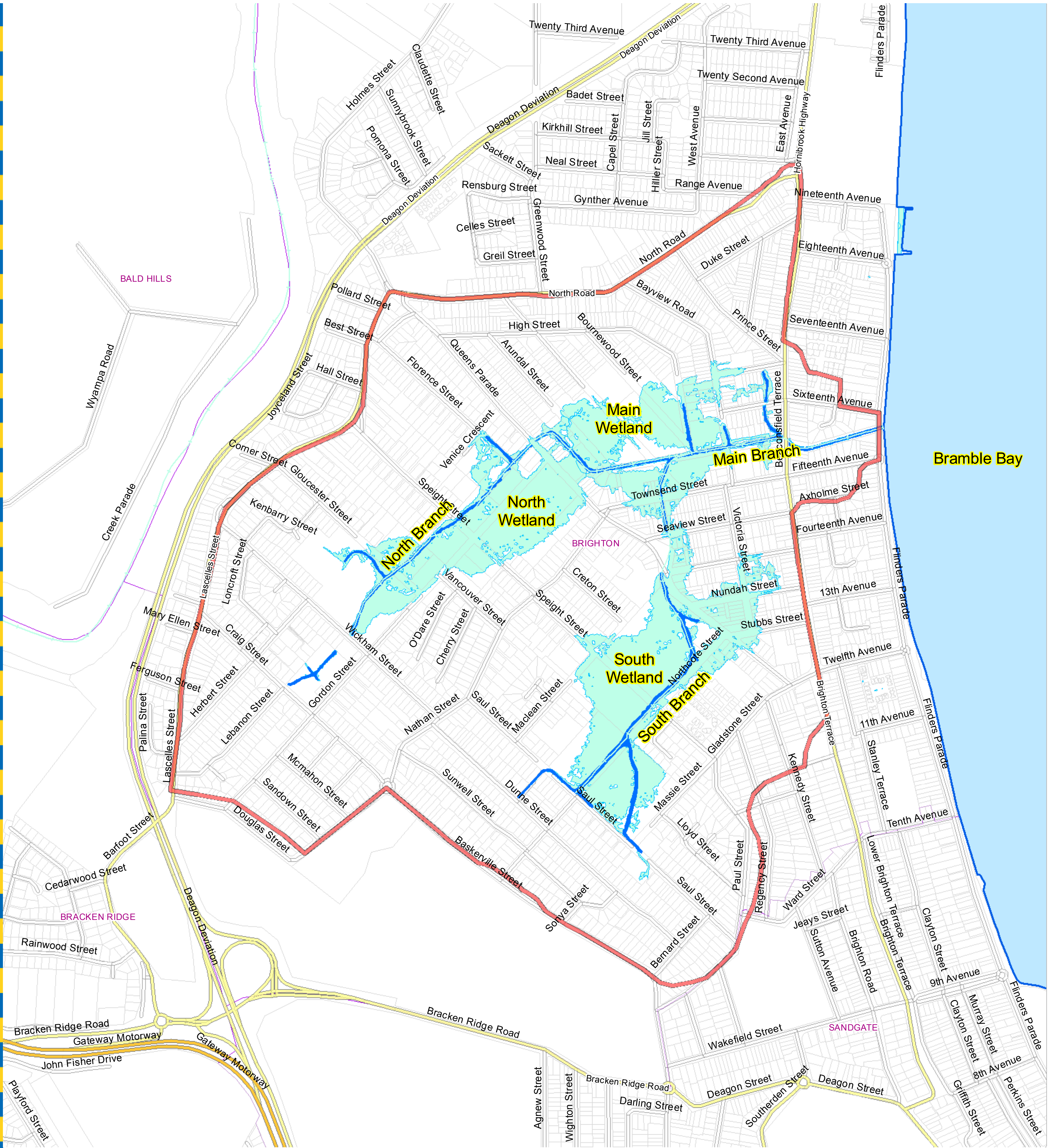
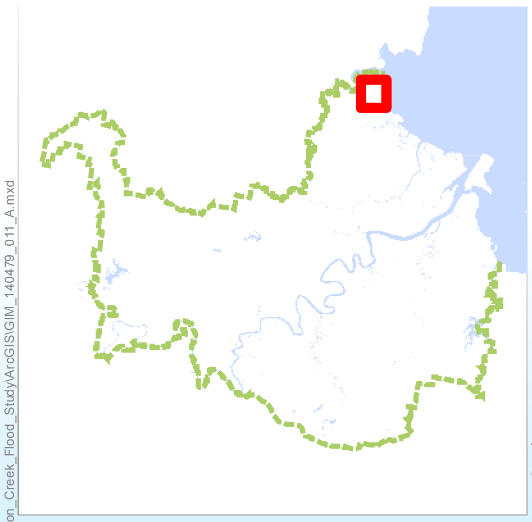
DATA INFORMATION

Brighton Creek 1974 Flood Extent

Figure D.1

GIM - 140479 - 010





Legend

- Brighton Creek Catchment Area
- AMTD Line
- Brighton Creek Channels
- 19 May 2009 Flood Extent
- Freeways/Highways
- Major Roads
- Streets
- Property Holdings
- Suburb Boundaries

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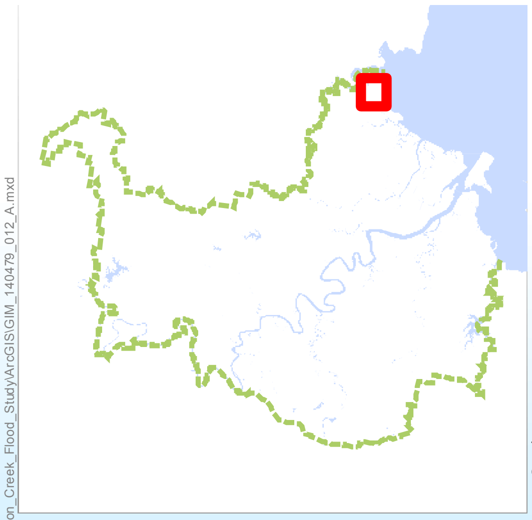
Brighton Creek 2009 Flood Extent

Figure D.2

GIM - 140479 - 011



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Legend

- Brighton Creek Catchment
- AMTD Line
- Brighton Creek Channels
- 10 Oct 2010 Flood Extent
- Freeways/Highways
- Major Roads
- Streets
- Property Holdings
- Suburb Boundaries

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Brighton Creek 2010 Flood Extent

Figure D.3

GIM - 140479 - 012

Appendix E: Structure Head Loss Comparison

Table E.1: Verification of structure head losses using HEC-RAS models

	HEC-RAS model results			TUFLOW model results			Difference in afflux
Flow	PWL-US	PWL-DS	Afflux	PWL-US	PWL-DS	Afflux	
(m3/s)	(mAHD)	(mAHD)	m	(mAHD)	(mAHD)	m	m
Beaconsfield Terrace culverts							
10.0	1.31	1.2	0.11	1.38	1.26	0.11	0.00
12.6	1.44	1.32	0.12	1.65	1.52	0.13	-0.01
14.5	1.54	1.42	0.12	1.75	1.61	0.15	-0.03
16.2	1.63	1.50	0.13	1.93	1.79	0.14	-0.01
19.7	1.82	1.68	0.14	2.05	1.88	0.16	-0.02
24.0	2.05	1.89	0.16	2.14	1.94	0.20	-0.04
Wickham Street culverts							
4.5	3.23	2.61	0.62	3.16	2.57	0.59	0.03
6.1	3.38	2.66	0.72	3.33	2.61	0.72	0.00
7.0	3.49	2.69	0.8	3.45	2.66	0.79	0.01
8.3	3.69	2.72	0.97	3.62	2.69	0.92	0.05
9.3	3.77	2.75	1.02	3.79	2.72	1.07	-0.05
10.6	3.95	2.78	1.17	3.92	2.75	1.17	0.00
Townsend Street culverts							
2	1.77	1.7	0.07	1.75	1.69	0.07	0.00
2.5	1.98	1.88	0.1	1.91	1.88	0.04	0.06
2.8	2	1.96	0.04	1.98	1.96	0.02	0.02
3.2	2.08	2.08	0	2.08	2.07	0.01	-0.01
3.9	2.18	2.18	0	2.18	2.18	0.01	-0.01
4.5	2.25	2.25	0	2.26	2.25	0.00	0.00
Queens Parade(North) culverts							
4.5	1.98	1.91	0.07	2.05	1.93	0.12	-0.05
5.9	2.04	1.92	0.12	2.16	2.05	0.11	0.01
6.9	2.22	2.07	0.15	2.20	2.10	0.10	0.05
Queens Parade(South) culverts							
2	1.9	1.75	0.15	1.91	1.78	0.13	0.02
2.35	2.12	1.91	0.21	2.08	1.93	0.16	0.05
2.6	2.15	1.98	0.17	2.14	1.99	0.15	0.02
3	2.19	2.08	0.11	2.22	2.09	0.13	-0.02
3.4	2.21	2.18	0.03	2.30	2.19	0.11	-0.08
3.9	2.27	2.26	0.01	2.32	2.27	0.05	-0.04

Appendix F – Hydraulic Structure Reference Sheets

HYDRAULIC STRUCTURE REFERENCE SHEET

Creek:	Brighton Creek
Location:	Wickham Street

Immunity Rating:	100 Year

DATE OF SURVEY:	N/A	UBD REF:	100/H-17
SURVEYED CROSS SECTION ID:	N/A	BCC ASSET ID:	B17000056
MODEL ID:	N/A	AMTD (m):	1800

STRUCTURE DESCRIPTION: Reinforce Concrete Pipe Culvert

STRUCTURE SIZE: 1 / 1.35 m diameter, 2 / 1.20 m diameter RCP

For Culverts: Number of cells/pipes & sizes — For Bridges: Number of Spans and their lengths

U/S INVERT LEVEL (m AHD)	1.88 & 2.38	U/S OBVERT LEVEL (m AHD)	3.08 & 3.65
D/S INVERT LEVEL (m AHD)	1.60 & 2.10	D/S OBVERT LEVEL (m AHD)	2.80 & 3.45

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 60

LENGTH OF CULVERT AT OBVERT (m): 60

TYPE OF LINING: Concrete

(e.g. concrete, stone, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? No N/A

If yes give details i.e plan number and/or survey book number. Note: this section should be at the highest part of the road eg. Crown, kerb, hand rails whichever is higher

WEIR WIDTH (m): 60 PIER WIDTH (m): N/A

In direction of flow, i.e distance from u/s face to d/s face

LOWEST POINT OF WEIR (m AHD): 4

HEIGHT OF GUARDRAIL/HANDRAIL (m): 1

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 50mm tubular galvanised monowills handrail

PLAN NUMBER: W6411

BRIDGE OR CULVERT DETAILS:

Wingwall/Headwall details e.g Pipe flusk with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge inclucing abutment details. Specific survey book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: October 1981

HAS THE STRUCTURE BEEN UPGRADED? Yes Added 1200mm dia.pipe in 2003 January ,

If, yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

Creek:	Brighton Creek
Location:	Wickham Street

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	13.6	4.59	2.93	1660	0	0	0	3.29
0.2	11.2	4.41	2.83	1580	0	0	0	3.19
1	9.5	4.09	2.77	1320	0	0	0	2.92
2	9.1	3.9	2.74	1160	0	0	0	2.71
5	8.1	3.75	2.71	1040	0	0	0	2.52
10	7.2	3.52	2.67	850	0	0	0	2.25
20	6.4	3.4	2.64	760	0	0	0	2.25
50	4.9	3.21	2.58	630	0	0	0	2.18

NB: Results are based on existing stream conditions.

Creek:	Brighton Creek
Location:	Wickham Street

Wickham Street culvert looking downstream

Wickham Street culvert looking upstream

HYDRAULIC STRUCTURE REFERENCE SHEET

Creek:	Brighton Creek
Location:	Queens Parade (Northern Branch)

Immunity Rating:	2 Year

DATE OF SURVEY:	January 1997	UBD REF:	100/K-15
SURVEYED CROSS SECTION ID:	BR150	BCC ASSET ID:	C0120P
MODEL ID:	N 0.730	AMTD (m):	1030

STRUCTURE DESCRIPTION: Reinforced Concrete Box Culvert

STRUCTURE SIZE: 2 / 2.1m x 1.13m RCBC

For Culverts: Number of cells/pipes & sizes — For Bridges: Number of Spans and their lengths

U/S INVERT LEVEL (m AHD)	0.67	U/S OBVERT LEVEL (m AHD)	1.8
D/S INVERT LEVEL (m AHD)	0.66	D/S OBVERT LEVEL (m AHD)	1.79

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 12.2

LENGTH OF CULVERT AT OBVERT (m): 12.2

TYPE OF LINING: Concrete

(e.g. concrete, stone, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Yes BR150

If yes give details i.e plan number and/or survey book number. Note: this section should be at the highest part of the road eg. Crown, kerb, hand rails whichever is higher

WEIR WIDTH (m): 12.2 PIER WIDTH (m): N/A

In direction of flow, i.e distance from u/s face to d/s face

LOWEST POINT OF WEIR (m AHD): 2.33

HEIGHT OF GUARDRAIL/HANDRAIL(m): 0.9

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 0.75 x 0.75 timber rails DS & tubular galvanised monowills hand

PLAN NUMBER: W4328

BRIDGE OR CULVERT DETAILS:

Wingwall/Headwall details e.g Pipe flusk with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge inclucing abutment details. Specific survey book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: February 1970

HAS THE STRUCTURE BEEN UPGRADED? No

If, yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

Creek:	Brighton Creek
Location:	Queens Parade (Northern Branch)

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	26.1	2.51	2.5	0	-	0.18	1.1	1.02
0.2	22.4	2.44	2.42	20	-	0.11	1.1	1.06
1	20.1	2.34	2.35	-10	-	0.01	1.7	0.96
2	17.3	2.3	2.25	50	-	0	1.6	1
5	14.4	2.25	2.17	80	-	0	3.9	1.03
10	11.5	2.2	2.1	100	-	0	1.9	0.98
20	9.4	2.16	2.05	110	-	0	1.2	0.96
50	6.1	2.05	1.93	120	-	0	2	0.87

NB: Results are based on existing stream conditions.

Creek:	Brighton Creek
Location:	Queens Parade (Northern Branch)

Queens Parade culvert North looking downstream

Queens Parade culvert North looking upstream

HYDRAULIC STRUCTURE REFERENCE SHEET

Creek:	Brighton Creek
Location:	Queens Parade (Southern Branch)

Immunity Rating:	5 Year

DATE OF SURVEY:	January 1997	UBD REF:	100/L-16
SURVEYED CROSS SECTION ID:	BR330/BR310	BCC ASSET ID:	C4031P
MODEL ID: S 0.840		AMTD (m):	830

STRUCTURE DESCRIPTION: Reinforced Concrete Pipe Culvert

STRUCTURE SIZE: 2/ 1.22 m diameter RCP

For Culverts: Number of cells/pipes & sizes — For Bridges: Number of Spans and their lengths

U/S INVERT LEVEL (m AHD)	0.76	U/S OBVERT LEVEL (m AHD)	1.96
D/S INVERT LEVEL (m AHD)	0.48	D/S OBVERT LEVEL (m AHD)	1.7

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 115

LENGTH OF CULVERT AT OBVERT (m): 115

TYPE OF LINING: Concrete

(e.g. concrete, stone, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Yes BR310/BR330

If yes give details i.e plan number and/or survey book number. Note: this section should be at the highest part of the road eg. Crown, kerb, hand rails whichever is higher

WEIR WIDTH (m): 115 PIER WIDTH (m): N/A

In direction of flow, i.e distance from u/s face to d/s face

LOWEST POINT OF WEIR (m AHD): 2.1

HEIGHT OF GUARDRAIL/HANDRAIL: 1

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 50mm tubular galvanised monowills handrail

PLAN NUMBER: W639

BRIDGE OR CULVERT DETAILS:

Wingwall/Headwall details e.g Pipe flusk with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge inclucing abutment details. Specific survey book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: January 1964

HAS THE STRUCTURE BEEN UPGRADED? No

If, yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

Creek:	Brighton Creek
Location:	Queens Parade (Southern Branch)

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	5.2	2.53	2.5	30	-	0.43	0.9	1.01
0.2	4.2	2.45	2.41	40	-	0.35	0.5	1.02
1	3.4	2.35	2.27	80	-	0.25	0.8	1.17
2	3	2.3	2.19	110	-	0.2	1	1.27
5	2.9	2.22	2.09	130	-	0.12	1	1.22
10	2.6	2.14	1.99	150	-	0.04	0.7	1.13
20	2.3	2.08	1.93	150	-	0	0.6	1.04
50	1.9	1.91	1.78	130	-	0	-	1.06

NB: Results are based on existing stream conditions.

Creek:	Brighton Creek
Location:	Queens Parade (Southern Branch)

Queens Parade culvert South looking downtream

Queens ParadeSouth culvert -Downstream view at Seaview Street crossing

HYDRAULIC STRUCTURE REFERENCE SHEET

Creek:	Brighton Creek
Location:	Townsend Street

Immunity Rating:	10 Year

DATE OF SURVEY: January 1997	UBD REF: 100/L-16
SURVEYED CROSS SECTION ID: BR300	BCC ASSET ID: C0188P
MODEL ID: S 0.945	AMTD (m): 725

STRUCTURE DESCRIPTION: Reinforced Concrete Pipe Culvert

STRUCTURE SIZE: 2/ 1.22 m diameter RCP

For Culverts: Number of cells/pipes & sizes — For Bridges: Number of Spans and their lengths

U/S INVERT LEVEL (m AH 0.48 — U/S OBVERT LEVEL (m AHI 1.66

D/S INVERT LEVEL (m AH 0.38 — D/S OBVERT LEVEL (m AHI 1.56

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 12.3

LENGTH OF CULVERT AT OBVERT (m): 12.3

TYPE OF LINING: Concrete

(e.g. concrete, stone, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Yes BR300

If yes give details i.e plan number and/or survey book number. Note: this section should be at the highest part of the road eg. Crown, kerb, hand rails whichever is higher

WEIR WIDTH (m): 12.3 — PIER WIDTH (m): N/A

In direction of flow, i.e distance from u/s face to d/s face

LOWEST POINT OF WEIR (m AHD): 2

HEIGHT OF GUARDRAIL/HANDRAIL: 1

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 50mm tubular galvanised monowills handrail

PLAN NUMBER: W639

BRIDGE OR CULVERT DETAILS:

Wingwall/Headwall details e.g Pipe flusk with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge inclucing abutment details. Specific survey book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: January 1964

HAS THE STRUCTURE BEEN UPGRADED? No

If, yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

Creek:	Brighton Creek
Location:	Townsend Street

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	6	2.49	2.49	0	-	0.49	1.1	1.02
0.2	5.4	2.4	2.4	0	-	0.4	1	1.03
1	3.9	2.26	2.26	0	-	0.26	1	1.02
2	3.3	2.18	2.18	0	-	0.18	1	1.38
5	2.9	2.08	2.07	10	-	0.08	1	1.3
10	2.8	1.98	1.96	20	-	0	1	1.19
20	2.3	1.91	1.88	30	-	0	0.8	1.07
50	1.9	1.75	1.69	60	-	0	0.3	0.91

NB: Results are based on existing stream conditions.

Creek:	Brighton Creek
Location:	Townsend Street

Townsend Street culvert looking downstream

Townsend Street culvert looking upstream

HYDRAULIC STRUCTURE REFERENCE SHEET

Creek:	Brighton Creek
Location:	Beaconsfield Terrace

Immunity Rating:	100 Year

DATE OF SURVEY: January 1997	UBD REF: 100/N-15
SURVEYED CROSS SECTION ID: BR100	BCC ASSET ID: C0120P
MODEL ID: M 1.475	AMTD (m): 285

STRUCTURE DESCRIPTION: Reinforced Concrete Pipe Culvert

STRUCTURE SIZE: 5 / 1.8 m diameter RCP

For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

U/S INVERT LEVEL (m AH 0.34 U/S OBVERT LEVEL (m AHI 2.14

D/S INVERT LEVEL (m AH 0.19 D/S OBVERT LEVEL (m AHI 1.99

For culverts give floor level For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 22

LENGTH OF CULVERT AT OBVERT (m): 22

TYPE OF LINING: Concrete

(e.g. concrete, stone, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Yes BR100

If yes give details i.e plan number and/or survey book number. Note: this section should be at the highest part of the road eg. Crown, kerb, hand rails whichever is higher

WEIR WIDTH (m): 22 PIER WIDTH (m): N/A

In direction of flow, i.e distance from u/s face to d/s face

LOWEST POINT OF WEIR (m AHD): 2.62

HEIGHT OF GUARDRAIL/HANDRAIL: 0.9

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 50mm tubular galvanised monowills handrail

PLAN NUMBER: W4238

BRIDGE OR CULVERT DETAILS:

Wingwall/Headwall details e.g Pipe flusk with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge inclucing abutment details. Specific survey book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: February 1970

HAS THE STRUCTURE BEEN UPGRADED? No

If, yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

Creek:	Brighton Creek
Location:	Beaconsfield Terrace

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	-	2.42	2.1	320	-	0	0	1.96
0.2	-	2.36	2.06	300	-	0	0	1.99
1	16.5	2.14	1.94	200	-	0	0	1.29
2	15.2	2.05	1.88	170	0	0	0	1.22
5	13.1	1.93	1.79	140	0	0	0	1.11
10	12.1	1.75	1.61	140	0	0	0	1.12
20	10.8	1.65	1.52	130	0	0	0	1.05
50	7.8	1.38	1.26	120	0	0	0	0.97

NB: Results are based on existing stream conditions.

Creek:	Brighton Creek
Location:	Beaconsfield Terrace

Beaconsfield Terrace culvert looking downstream

Beaconsfield Terrace culver looking upstream

HYDRAULIC STRUCTURE REFERENCE SHEET

Creek:	Brighton Creek
Location:	Shepherd Street

Immunity Rating:	2 Year

DATE OF SURVEY: January 1997	UBD REF: 100/M-15
SURVEYED CROSS SECTION ID: BR20	BCC ASSET ID: C0684B
MODEL ID:	AMTD (m): 100
STRUCTURE DESCRIPTION: Reinforced Concrete Box Culvert	
STRUCTURE SIZE: 1.2 x 3m RCBC For Culverts: Number of cells/pipes & sizes	For Bridges: Number of Spans and their lengths
U/S INVERT LEVEL (m AH 0.15 D/S INVERT LEVEL (m AH 1.35 For culverts give floor level	U/S OBVERT LEVEL (m AHI 0.1 D/S OBVERT LEVEL (m AHI 1.3 For bridges give bed level
For culverts: LENGTH OF CULVERT AT INVERT (m): 12.2 LENGTH OF CULVERT AT OBVERT (m): 12.2 TYPE OF LINING: Concrete (e.g. concrete, stone, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? Yes BR20 If yes give details i.e plan number and/or survey book number. Note: this section should be at the highest part of the road eg. Crown, kerb, hand rails whichever is higher	
WEIR WIDTH (m): 12.2 In direction of flow, i.e distance from u/s face to d/s face LOWEST POINT OF WEIR (m AHD): 1.65	PIER WIDTH (m): N/A
HEIGHT OF GUARDRAIL/HANDRAIL: 1 DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 50mm tubular galvanised monowills handrail	
PLAN NUMBER: W4776 BRIDGE OR CULVERT DETAILS: Wingwall/Headwall details e.g Pipe flusk with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge inclucing abutment details. Specific survey book No. CONSTRUCTION DATE OF CURRENT STRUCTURE: 29342 HAS THE STRUCTURE BEEN UPGRADED? Yes Timber bridge prior to 1980 If, yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	

Creek:	Brighton Creek
Location:	Shepherd Street

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	4.8	2.48	2.47	-	170	0.33	-	1.4
0.2	4.7	2.37	2.36	-	160	0.22	-	1.4
1	4.6	2.19	2.17	-	40	0.14	-	1.3
2	4.4	2.09	2.07	-	35	0.04	-	1.2
5	4	1.95	1.94	-	0	-	-	1.1
10	3.5	1.79	1.78	-	0	-	-	0.96
20	3	1.69	1.67	-	0	-	-	0.85
50	2.2	1.53	1.5	-	0	-	-	0.62

NB: Results are based on existing stream conditions.

Creek:	Brighton Creek
Location:	Shepherd Street

Shepherd Street culvert looking downstream

Shepherd Street culvert looking upstream

Appendix G – Hydraulic Model Peer Review & Response

M E M O R A N D U M

Brisbane Infrastructure

To:	Richard Yearsley	Date: 03/04/14
Via:		
CC:	Suba Subasing Gamachchige	
From:	Chandra Gunaratne: Senior flood modelling engineer	
Re:	**Brighton Creek Flood Study- Peer review comments**	

City Projects Office

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1. Introduction

As a part of the Flood Study Procedure it is required to undertake peer review of the hydrology and hydraulic models before finalising the model development stage. This is a progressive process, as outlined in the study brief. Where a study is delivered by City Projects Office (CPO), the peer review will be undertaken by an appropriately skilled third party.

The peer review consultant, BMT-WBM was selected by CPO in January 2014 for the Brighton Creek Flood Study project. The hydrology model (XP-Rafts) and Hydraulic model (TUFLOW) developed for the Brighton Creek catchment in 2013/ 2014 was handed over to the peer review consultant in February 2014 together with geographical information for the catchment and previous flood study reports and other relevant modelling data.

2. Peer review comments received from the Consultant on 19/03/2014

Having undertaken the peer review the consultant commented on the hydraulic and hydrology modelling undertaken by the CPO on Brighton Creek catchment. The contents of the-mail are copied in to the memorandum. Following is a summarised version of comments sent by e-mail:

1. The application of form loss coefficient (FLC) in the" lfcsh" layer did not account for the fact that FLCs are inserted per metre width of bridge for region objects. Since there are no piers, the FLC for layer 1 should be zero.
2. The concrete channel at the end of the catchment (downstream of Beaconsfield Terrace) conveys much of the flow, even in the 100 year event. This 7m wide channel is modelled in 2D with a 2m grid cells size. It would be a better approach to model the concrete channel in 1D linked to the 2D floodplain since the flow out of the catchment is controlled by the road crossing structures and this channel.
3. It was suggested to wrap "sx" line across a few more grid cells and lowering the 1D time step to 0.5 second to fully eliminate the instability at Queens Parade culvert crossing.
4. The Mangrove pencil roots in the creeks are likely to increase the hydraulic roughness. However, their influence will diminish as flow depths increase. Hence a depth varying Manning's n was recommended. With a high Manning's n for the length of the pencil root height, then varied linearly to the typical Manning's n already adopted as below:
    a. Manning's n of 0.08 for 0m to 0.2m (assuming the pencil roots are typically 0.2m high – please adjust this assumption if you have better information)
    b. Manning's n varying linearly from 0.08 to the existing Manning's n for 0.2m to 0.4m flow depth (i.e. double the height of the pencil root)
    c. The existing Manning's n for depths above 0.4m.

    It was noted that the reviewer was not aware of any good written guidance on Manning's n through Mangrove roots, so this guidance is to be based on judgement.

5. Check that the “zsh” layer to carve the creeks into the 2D topography has worked as intended. Note that there is also the zsh polyline approach which may save time.
6. Check the Manning’s n used in the RAFTS model – has higher roughness values been used for catchments with forested areas.

3. Action taken by the CPO:

Comment 1: Form loss coefficient for the bridge was corrected and used as zero.

Comment 2:

In developing the Brighton Creek hydraulic model it was decided to adopt TUFLOW /2D model (with a 2m grid) in order to achieve the objectives of the flood study depending on the catchment size and its topography. Results of the model were verified with the existing MIKE11 model results undertaken in 1997 as there were no calibration data available for the catchment.

Having discussed the peer reviewer comments with Evan, Meagan and Scott it was agreed that adoption of 2D modelling would provide the required accuracy for the flood study. It should also be noted that the lower part of the catchment is subject to tidal intrusion and design flood levels are dominated by storm surge.

It was decided by CPO to adopt the TUFLOW/2D only model and to verify the flood levels in the canal between Beaconsfield Terrace and Flinders Parade with a HECRAS model.

Comment 3: Attended as recommended.

Comment 4: Manning’s “n” adopted for the channel (in the area specified) is varying between 0.05 and 0.07 and it is believed that the accuracy provided in the modelling is sufficient as there are no calibration data available to verify the results.

Comment 5: Attended and checked.

Comment 6: Attended and corrected in the areas as recommended.

4. Finalisation of hydraulic and hydrology models

The hydrology model (Rafts) and hydraulic model (TUFLOW/2D) developed for the Brighton Creek catchment were finalised after attending the above comments. Consistency between the hydrology and hydraulic models were undertaken by running the existing MIKE11 model flow data for the Duration Independent Storms (DIS) as modelled in the MIKE11 model.

Peer review comments received from the Consultant on 19/03/2014

Just to summarise the comments we discussed yesterday:

1. The application of form loss coefficient (FLC) in the lfcsh layer did not account for the fact that FLCs are inserted per metre width of bridge for region objects. Since there are no piers, the FLC for layer 1 should be zero.
2. The concrete channel at the end of the catchment (downstream of Beaconsfield Terrace) conveys much of the flow, even in the 100 year event. This 7m wide channel is modelled in 2D with a 2m grid cells size. Since the flow out of the catchment is controlled by the road crossing structures and this channel, I think it would be a better approach to model the concrete channel in 1D linked to the 2D floodplain. Since the channel length is relatively short and the upstream end is connected to a 1D structure, this should be a relatively easy approach to adopt.
3. I note that there is a bit of instability at Queens Parade culvert crossing. Try wrapping the sx line across a few more grid cells and lowering the 1D time step to 0.5 second. It may not be possible to fully eliminate the instability, due to the flood behaviour at this culvert. But its worth giving the two recommendations a try.
4. The Mangrove pencil roots in the creeks are likely to increase the hydraulic roughness. However, their influence will diminish as flow depths increase. I recommend using a depth varying Manning's n. With a high Manning's n for the length of the pencil root height, then varied linearly to the typical Manning's n already adopted as below:
    a. Manning's n of 0.08 for 0m to 0.2m (I've assumed the pencil roots are typically 0.2m high – please adjust this assumption if you have better information)
    b. Manning's n varying linearly from 0.08 to the existing Manning's n for 0.2m to 0.4m flow depth (i.e. double the height of the pencil root)
    c. The existing Manning's n for depths above 0.4m.

    Note that I am not aware of any good written guidance on Manning's n through Mangrove roots, so this guidance is based on my judgement. I'm happy to discuss further.
5. Check that the zsh to carve the creeks into the 2D topography has worked as intended. Note that there is also the zsh polyline approach which may save time.
6. Check the Manning's n used in the RAFTS model – has higher roughness values been used for catchments with forested areas.

Thanks

Richard Sharpe
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Appendix H - Design Event Peak Flood Levels

Table H.1: Peak design flood levels Scenario 3 - Ultimate Case

Cross section ID	Mike Chainage (m)	AMTD (m)	Peak flood level (mAHD)					
			2 Yr	5 Yr	10 Yr	20 Yr	50 Yr	100 Yr
Craig St DS		1980	3.40	3.63	3.73	3.85	3.96	4.13
Wickham St US		1832	3.20	3.40	3.52	3.75	3.90	4.11
Wickham St DS	0	1760	2.57	2.62	2.65	2.70	2.72	2.75
BR190	100	1660	2.48	2.53	2.57	2.60	2.64	2.67
BR180	205	1555	2.38	2.45	2.49	2.54	2.59	2.62
Vancouver St	295	1465	2.32	2.40	2.44	2.49	2.54	2.57
BR170	425	1335	2.22	2.30	2.34	2.39	2.45	2.48
BR160	645	1115	2.15	2.23	2.27	2.33	2.39	2.44
Queens Pde US	720	1040	2.06	2.17	2.21	2.26	2.33	2.41
Queens Pde DS	740	1020	1.98	2.12	2.17	2.24	2.32	2.41
BR145 Copy	750	1010	1.94	2.08	2.14	2.21	2.31	2.40
BR145	840	920	1.89	2.05	2.12	2.20	2.31	2.40
BR140	1025	735	1.84	2.02	2.09	2.18	2.30	2.39
BR130	1125	635	1.73	1.90	1.99	2.13	2.28	2.38
BR120	1215	545	1.64	1.84	1.96	2.11	2.27	2.37
BR110	1310	450	1.60	1.82	1.94	2.10	2.26	2.36
BR105 Copy	1420	340	1.47	1.70	1.83	2.02	2.19	2.30
BR105	1450	310	1.43	1.66	1.80	1.99	2.16	2.28
Beaconsfield Rd US	1460	300	1.43	1.66	1.80	1.99	2.16	2.28
Beaconsfield Rd DS	1490	270	1.33	1.52	1.67	1.85	1.97	2.06
Canal DS	1500	260	1.30	1.49	1.64	1.83	1.96	2.04
Canal DS 2	1587	173	1.21	1.35	1.52	1.65	1.76	1.85
Flinders Pde US	1673	87	0.94	0.94	0.96	0.97	0.97	0.99
Mouth	1760	0	0.92	0.92	0.92	0.92	0.92	0.92
South Branch								
BR360	0	1035	2.02	2.12	2.19	2.29	2.41	2.50
BR355	75	960	1.99	2.12	2.19	2.29	2.41	2.50
BR350	200	835	1.98	2.12	2.19	2.29	2.41	2.50
BR340	325	710	1.98	2.12	2.19	2.29	2.41	2.50
BR335	465	570	1.98	2.12	2.19	2.29	2.41	2.49
BR333	575	460	1.95	2.11	2.19	2.29	2.41	2.49
BR331	650	385	1.93	2.11	2.19	2.29	2.40	2.49
BR330	705	330	1.93	2.11	2.19	2.28	2.40	2.49
Queens Pde US	730	305	1.92	2.10	2.18	2.28	2.40	2.49
Seaview St DS	850	185	1.80	1.98	2.05	2.16	2.30	2.40
BR305	895	140	1.79	1.97	2.05	2.15	2.29	2.39
Townsend St US	935	100	1.78	1.96	2.04	2.15	2.28	2.38
Townsend St DS	950	85	1.72	1.89	1.99	2.13	2.27	2.38
BR299	990	45	1.71	1.89	1.98	2.13	2.27	2.38
Merge	1035	0	1.71	1.88	1.98	2.12	2.27	2.38

Appendix I – Extreme Event and Climate Change Peak Flood Levels

Table I.1: Extreme Peak Flood Levels Scenario 3 – Ultimate Case

Cross section ID	Mike Chainage (m)	AMTD (m)	Ultimate Peak flood level (mAHD)	
			200 Year	500 Year
Craig St DS		1980	4.29	4.43
Wickham St US		1832	4.27	4.42
Wickham St DS	0	1760	2.78	2.81
BR190	100	1660	2.71	2.75
BR180	205	1555	2.66	2.72
Vancouver St	295	1465	2.63	2.71
BR170	425	1335	2.58	2.70
BR160	645	1115	2.58	2.69
Queens Pde US	720	1040	2.57	2.69
Queens Pde DS	740	1020	2.57	2.69
BR145 Copy	750	1010	2.57	2.69
BR145	840	920	2.56	2.68
BR140	1025	735	2.56	2.68
BR130	1125	635	2.55	2.68
BR120	1215	545	2.55	2.68
BR110	1310	450	2.55	2.67
BR105 Copy	1420	340	2.50	2.63
BR105	1450	310	2.48	2.61
Beaconsfield Rd US	1460	300	2.48	2.61
Beaconsfield Rd DS	1490	270	2.19	2.26
Canal DS	1500	260	2.18	2.25
Canal DS 2	1587	173	2.05	2.11
Flinders Pde US	1673	87	1.57	1.58
Mouth	1760	0	1.50	1.50
South Branch				
BR360	0	1035	2.72	2.82
BR355	75	960	2.72	2.82
BR350	200	835	2.72	2.82
BR340	325	710	2.72	2.82
BR335	465	570	2.72	2.82
BR333	575	460	2.72	2.82
BR331	650	385	2.72	2.82
BR330	705	330	2.72	2.82
Queens Pde US	730	305	2.71	2.82
Seaview St DS	850	185	2.57	2.71
BR305	895	140	2.57	2.70
Townsend St US	935	100	2.56	2.69
Townsend St DS	950	85	2.55	2.68
BR299	990	45	2.55	2.68
Merge	1035	0	2.55	2.68

Table I.2: Climate Change Peak Flood Levels Scenario 3 – Ultimate Case

Cross section ID	Mike Chainage (m)	AMTD (m)	Current Peak flood level (mAHD)	2050 Peak flood level (mAHD)		2100 Peak flood level (mAHD)	
			100 Year	100 Year	Change (m)	100 Year	Change (m)
Craig St DS		1980	4.13	4.25	0.12	4.33	0.2
Wickham St US		1832	4.11	4.23	0.12	4.32	0.21
Wickham St DS	0	1760	2.75	2.76	0.01	2.79	0.04
BR190	100	1660	2.67	2.70	0.03	2.72	0.05
BR180	205	1555	2.62	2.65	0.03	2.69	0.07
Vancouver St	295	1465	2.57	2.61	0.04	2.67	0.1
BR170	425	1335	2.48	2.53	0.05	2.66	0.18
BR160	645	1115	2.44	2.52	0.08	2.65	0.21
Queens Pde US	720	1040	2.41	2.51	0.1	2.65	0.24
Queens Pde DS	740	1020	2.41	2.51	0.1	2.65	0.24
BR145 Copy	750	1010	2.40	2.51	0.11	2.64	0.24
BR145	840	920	2.40	2.50	0.1	2.64	0.24
BR140	1025	735	2.39	2.50	0.11	2.64	0.25
BR130	1125	635	2.38	2.49	0.11	2.64	0.26
BR120	1215	545	2.37	2.49	0.12	2.63	0.26
BR110	1310	450	2.36	2.48	0.12	2.63	0.27
BR105 Copy	1420	340	2.30	2.43	0.13	2.59	0.29
BR105	1450	310	2.28	2.41	0.13	2.57	0.29
Beaconsfield Rd US	1460	300	2.28	2.42	0.14	2.57	0.29
Beaconsfield Rd DS	1490	270	2.06	2.13	0.07	2.25	0.19
Canal DS	1500	260	2.04	2.12	0.08	2.24	0.2
Canal DS 2	1587	173	1.85	1.96	0.11	2.12	0.27
Flinders Pde US	1673	87	0.99	1.30	0.31	1.80	0.81
Mouth	1760	0	0.92	1.22	0.3	1.72	0.8
South Branch							
BR360	0	1035	2.50	2.63	0.13	2.77	0.27
BR355	75	960	2.50	2.63	0.13	2.77	0.27
BR350	200	835	2.50	2.63	0.13	2.77	0.27
BR340	325	710	2.50	2.63	0.13	2.77	0.27
BR335	465	570	2.49	2.63	0.14	2.77	0.28
BR333	575	460	2.49	2.63	0.14	2.76	0.27
BR331	650	385	2.49	2.63	0.14	2.76	0.27
BR330	705	330	2.49	2.63	0.14	2.76	0.27
Queens Pde US	730	305	2.49	2.62	0.13	2.76	0.27
Seaview St DS	850	185	2.40	2.51	0.11	2.66	0.26
BR305	895	140	2.39	2.50	0.11	2.65	0.26
Townsend St US	935	100	2.38	2.50	0.12	2.64	0.26
Townsend St DS	950	85	2.38	2.49	0.11	2.64	0.26
BR299	990	45	2.38	2.49	0.11	2.64	0.26
Merge	1035	0	2.38	2.49	0.11	2.63	0.25

Appendix J –Flood Mapping

(Refer to Brighton Creek Flood Study Volume 2 of 2 – Flood Mapping)

Appendix K – Stretching Limitations

Stretching Limitations in Mapping

Types of limitations that may arise from the stretching and break-line process are as follows:

Stretched structure head loss – When a waterway crossing produces significant head loss the upstream surface may be incorrectly stretched to downstream areas. This can be managed by placing a break-line along the road or rail line that crosses the creek however the level difference produced by the structure will be stretched out to areas of ineffective flow where no such level difference would exist in reality.
Over stretching on flat terrain – Water Ride will stretch a surface until the terrain comes to within the threshold depth. On flat terrain stretching will continue indefinitely and break-lines need to be applied to restrict it. There is little way of knowing where the surface would realistically reach and the placement of break-lines in this situation is subjective.
Misrepresented flow paths – When flood waters break out of a main channel it is not uncommon for a separate flow path to form with an independent level profile. When stretching beyond the waterway corridor these potential flow paths can behave as break out areas that stretch an upstream surface too far downstream. Break-lines are applied to prevent this from happening but the potential flow paths can then be filled with inappropriate surfaces from the main channel, lower surfaces from downstream, or none at all.
Tributaries merging – At the confluence of two tributaries, one tributary can stretch over the stretched surface of another. Between tributaries break-lines can be placed along ridgelines or other features if they exist but a drop in level may be apparent where the surface of one tributary meets that of another either side of the break-lines.
Artificial waterfalls – When stretching a surface to produce the scenario 3 filled floodplain the same issues arise as when stretching a surface for mapping purposes. The use of break-lines will produce elevation drops in the filled floodplain terrain. This can result in waterfalls and artificial flow paths in the rare and extreme model simulations that would not occur in reality. These raw model results are then stretched to the existing terrain.

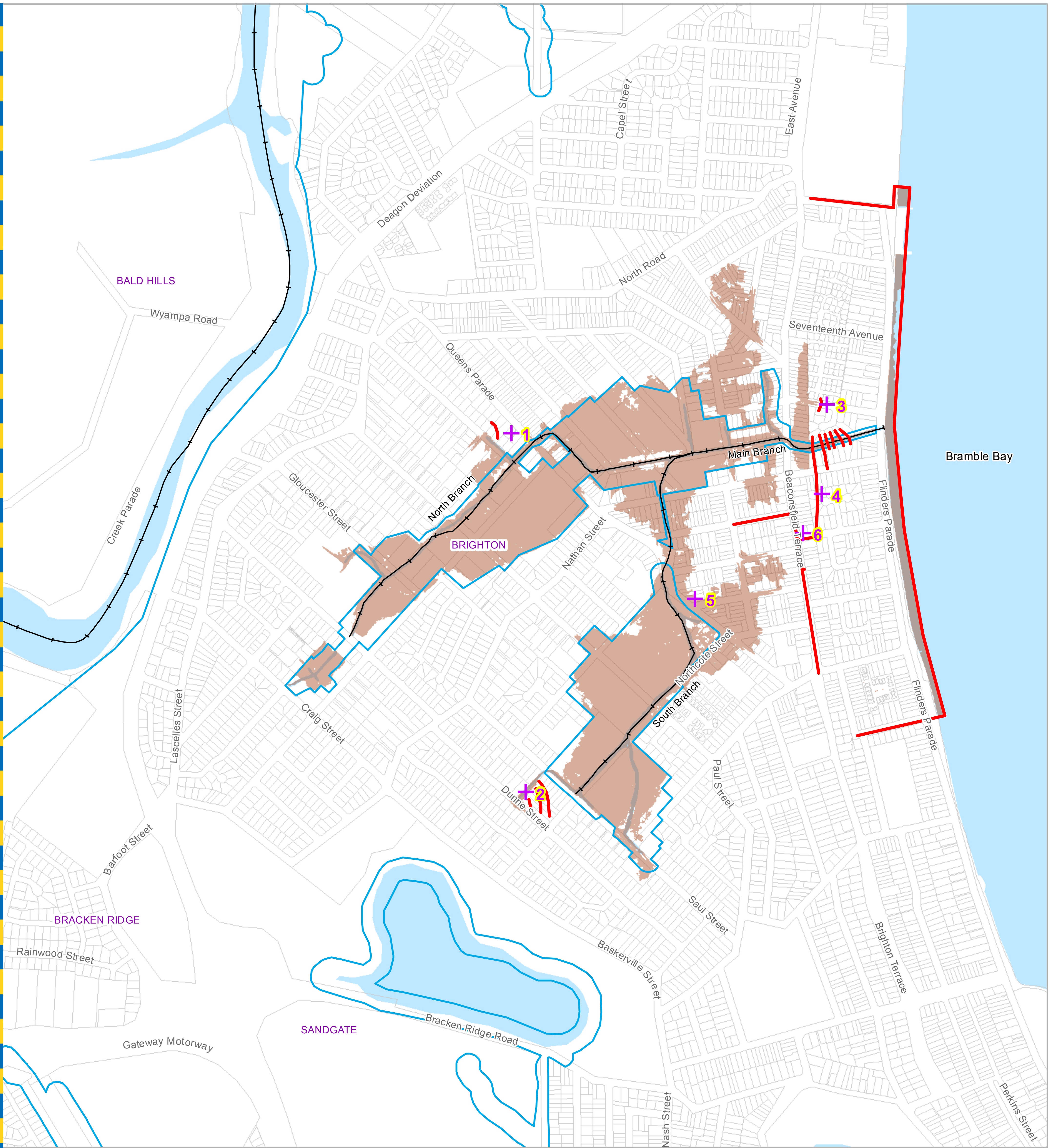
Please also note that the stretching process has used a depth threshold of 0.3 m AHD which was identified as the standard at the time of stretching. Brighton Creek catchment is characteristically flat and there is low variability between scenario 1 and 3 flood levels. This has resulted in under stretching of scenario 3 flood extents in which they are exceed by the equivalent scenario 1 extents in some locations.

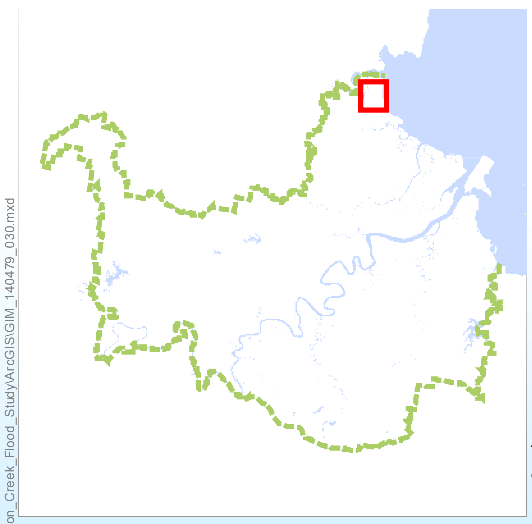
The details at which the above limitations occur in the Brighton Creek catchment are shown below in Table K1.

Table K.1: Stretching Limitations

Limitation Number	Limitation Type	Location Description	Additional Comments
1	Misrepresented flow path	Venice Cres to Queens Pde	Occurred in +300 filled floodplain development
2	Misrepresented flow path	Dunne St to Cnr of Saul and Northcote	Levels carried over from main channel using break-lines
3	Misrepresented flow path	Sixteenth Ave	Surface removed from area to avoid overstretching
4	Over stretching on flat terrain	From Fourteenth Ave to main channel between Bugden Avenue and Beaconsfield Terrace.	US levels had to be halted to prevent filling of entire foreshore
5	Misrepresented flow path	From Cnr Nundah St and Queens Pde via Cnr Seaview St and Beaconsfield and out to the bay.	Large flow path that bypasses the main branch is impeded by filled floodplain. US surfaces stretch to the bay without long break-line
6	Artificial Waterfalls	East end of Seaview St to Budgen St.	Flow path breaks over filled floodplain in Q500 only

The 100 Year ARI break-lines and limitation locations are shown below in **Figure K.1**.





Legend

- Limitation Numbers
- WaterRide Break Lines
- AMTD Line
- City Plan Waterway Corridors
- 1% AEP Ultimate Case Scenario Flood Inundation Extent
- Waterway/Waterbody

0 125 250 375
Metres

N W E S

Prepared : 097142
Checked : JS
Revision : 0
Publication Date : 25 Jun 2014
Project Number : 140479

File : G:\BI\CD\Proj14\140479_Brighton_Creek_Flood_Study\ArcGIS\GIM_140479_030.mxd

DATA INFORMATION

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Brighton Creek Break Lines and Limitation Numbers

Figure K.1

GIM - 140479 - 030