Sheep Station Gully Flood Study

Volume 1 of 2

Flood Study Report

Prepared by Brisbane City Council's, City Projects Office

June 2015

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Brisbane City Council

City Projects Office

Level 1, 505 St Pauls Terrace

Fortitude Valley QLD 4006

GPO Box 1434

Brisbane QLD 4000

Telephone 07 3403 8888

Facsimile 07 3334 0071

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Note: *The Sheep Station Gully Flood Study is a joint initiative of Brisbane City Council and the Queensland Government.*

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Executive Summary

Introduction

Brisbane City Council (BCC) is in the process of updating all of its flood studies to reflect the current conditions of the city's catchments and best practice flood modelling techniques. The most recent flooding investigation for the catchment was undertaken in 2001 by City Design (now City Projects Office). This report was finalised in June 2001 and was entitled Sheep Station Gully Stormwater Management Plan: Technical Report. The Sheep Station Gully Catchment is located within the greater Oxley Creek Catchment, approximately 17 km south of the Brisbane CBD. The catchment area is approximately 6.6 km^2, and lies within the suburbs of Algester, Calamvale and Parkinson.

Project Objectives

The primary objectives of the project were as follows:

- Reconstruct the Sheep Station Gully flood models (hydrologic and hydraulic) to represent the current catchment conditions and best practice flood modelling techniques.
- Adequately calibrate and verify the flood models to historical storm events to confirm that the models are suitable for the purposes of simulating design flood events.
- Estimation of design and rare / extreme flood magnitudes.
- Determination of flood levels for the design and rare / extreme events.
- Quantify the impacts of Minimum Riparian Corridor (MRC) and filling / development outside the Modelled Flood Corridor (MFC).
- Produce flood inundation mapping for the selected range of design and rare / extreme events.
- Quantify the impacts of climate variability as well as hydraulic structure blockages on flooding within the catchment.

Project Elements

The flood study consists of two main components, as follows:

Model Development and Calibration

Hydrologic and hydraulic models of the Sheep Station Gully Catchment have been developed using the XP-RAFTS and TUFLOW modelling software, respectively.

The hydrologic model simulates the catchment rainfall-runoff and runoff-routing processes. The hydrologic model also utilises high-level routing methodology to simulate the flow of floodwater in the major waterways within the catchment. The hydraulic model uses more sophisticated routing to simulate the movement of this floodwater through these waterways in order to predict flood levels, flood discharges and velocities. The hydraulic model takes into account the effects of the channel / floodplain topography; downstream tailwater conditions and hydraulic structures.

Calibration is the process of refining the model parameters to achieve a good agreement between the modelled results and the historical / observed data. Model calibration is achieved when the model simulates the historical event to within specified tolerances. Verification is then undertaken on additional flooding events to confirm the calibrated model is suitable for use in simulating synthetic design storm events.

Calibration of the XP-RAFTS and TUFLOW models was undertaken utilising two historical storms; namely 27th January 2013 and 23rd January 2015. Verification of the XP-RAFTS and TUFLOW models utilising a third storm could not be undertaken due to a lack of calibration data at the time of the study.

An acceptable correlation was achieved between the simulated and historical records for the two calibration events. At the Maximum Height Gauges (MHGs), the simulated peak levels were well within the specified tolerance of ± 0.3 m.

Utilising the adopted parameters from the calibration process, an independent verification would normally be undertaken against another storm event. However, due the lack of availability of data, verification was achieved via a Catchment Correlation, where results were compared with Design Events from similar recent catchment studies within Brisbane City.

Given the results of the calibration and verification process were quite reasonable, the XP-RAFTS and TUFLOW models were considered acceptable for use in the second part of the flood study, in which design flood levels were estimated. However, it should be noted that due to the relatively small magnitude of the calibration events, the ability of the models to reliably calculate flood levels for larger events, including design flood events, may be limited.

Design and Extreme Event Modelling

The calibrated hydrologic and hydraulic models were then used to simulate a range of synthetic design flood events. Design and extreme flood magnitudes were estimated for the full range of events from 2-yr ARI to PMF. These analyses assumed ultimate catchment hydrological conditions. Three waterway scenarios were considered, as follows:

- Scenario 1 – Existing Waterway Conditions: Based on the current waterway conditions. Some minor modifications were made to the TUFLOW model developed as part of the calibration / verification phase.
- Scenario 2 – Minimum Riparian Corridor (MRC): Includes an allowance for a riparian corridor along the edge of the channel.
- Scenario 3 – Ultimate Conditions: Includes an allowance for the minimum riparian corridor (as per Scenario 2) and also assumes development infill to the boundary of the MFC in order to simulate potential development.

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

- Peak flood discharges
- Critical storm durations at selected locations
- Peak flood levels at 100 m intervals along the AMTD line
- Peak flood extent mapping
- Hydraulic structure flood immunity

Sensitivity analyses were undertaken to understand the impacts of the following:

- Climate variability for two planning horizons; namely 2050 and 2100.
- Hydraulic Structure Blockages

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Glossary of Terms

Term	Definition
Annual Exceedance Probability(AEP)	The probability that a given rainfall total or flood flow will be exceeded in any one year.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20 year ARI design flood will occur on average once every 20 years.
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.
Catchment	The area of land draining through the main stream (as well as tributary streams) to a particular site. It always relates to an area above a specific location.
Digital Elevation Model (DEM)	A three-dimensional model of the ground surface elevation.
Design Event, Design Storm	A hypothetical flood/storm representing a specific likelihood of occurrence (for example the 100 year ARI).
ESTRY	TUFLOW 1D engine.
Floodplain	Area of land subject to inundation by floods up to and including the probable maximum flood (PMF) event
Flood Frequency Analysis (FFA)	Method of predicting flood flows at a particular location by fitting observed values at the location to a standard statistical distribution.
HEC-RAS	Hydraulic modelling software package.
Hydrograph	A graph showing how the discharge or stage/flood level at any particular location varies with time during a flood.
Manning's 'n'	The Manning coefficient, used to represent roughness in 1D/2D flow equations.
Minimum Riparian Corridor (MRC)	A buffer zone of 15m minimum width, either side of the active waterway.
Modelled Flood Corridor (MFC)	The greater extent of Flood Planning Area 3 (FPA3) and the waterway corridor
Probable Maximum Flood (PMF)	An extreme flood deemed to be the largest flood that could conceivably occur at a specific location.
Probably maximum Precipitation (PMP)	Probable Maximum Precipitation. The maximum precipitation (rainfall) that is reasonably estimated to not be exceeded.
XP-RAFTS	Hydrologic modelling software package.

List of Abbreviations

Abbreviation	Definition
1d	One dimensional, in the context of hydraulic modelling
2d	Two dimensional, in the context of hydraulic modelling
AMTD	Adopted Middle Thread Distance
ALS	Airborne Laser Scanning
AR&R	Australian Rainfall and Runoff (1999)
BCC	Brisbane City Council
CBD	Central Business District
CL	Continuing rainfall loss (mm/hr)
IFD	Intensity Frequency Duration
IL	Initial rainfall loss (mm)
m AHD	metres above AHD
MHG	Maximum Height Gauge
MFC	Modelled Flood Corridor
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
WQA	Water Quantity Assessment

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1.0 Introduction

1.1 Catchment Overview

The Sheep Station Gully Catchment is located within the greater Oxley Creek Catchment, approximately 17 km south of the Brisbane CBD. The catchment area is approximately 6.6 km^2, and lies within the suburbs of Algester, Calamvale and Parkinson. Figure 1.1 indicates the locality of the catchment.

1.2 Study Background

BCC is in the process of updating all of its flood studies to reflect the current conditions of the city's catchments and best practice flood modelling techniques. This flood study has been undertaken in accordance with the current BCC flood study procedures.[1]

The most recent flooding investigation for the catchment was undertaken in 2001 by City Design (now City Projects Office). This report was finalised in June 2001 and was entitled Sheep Station Gully Stormwater Management Plan: Technical Report. [2]

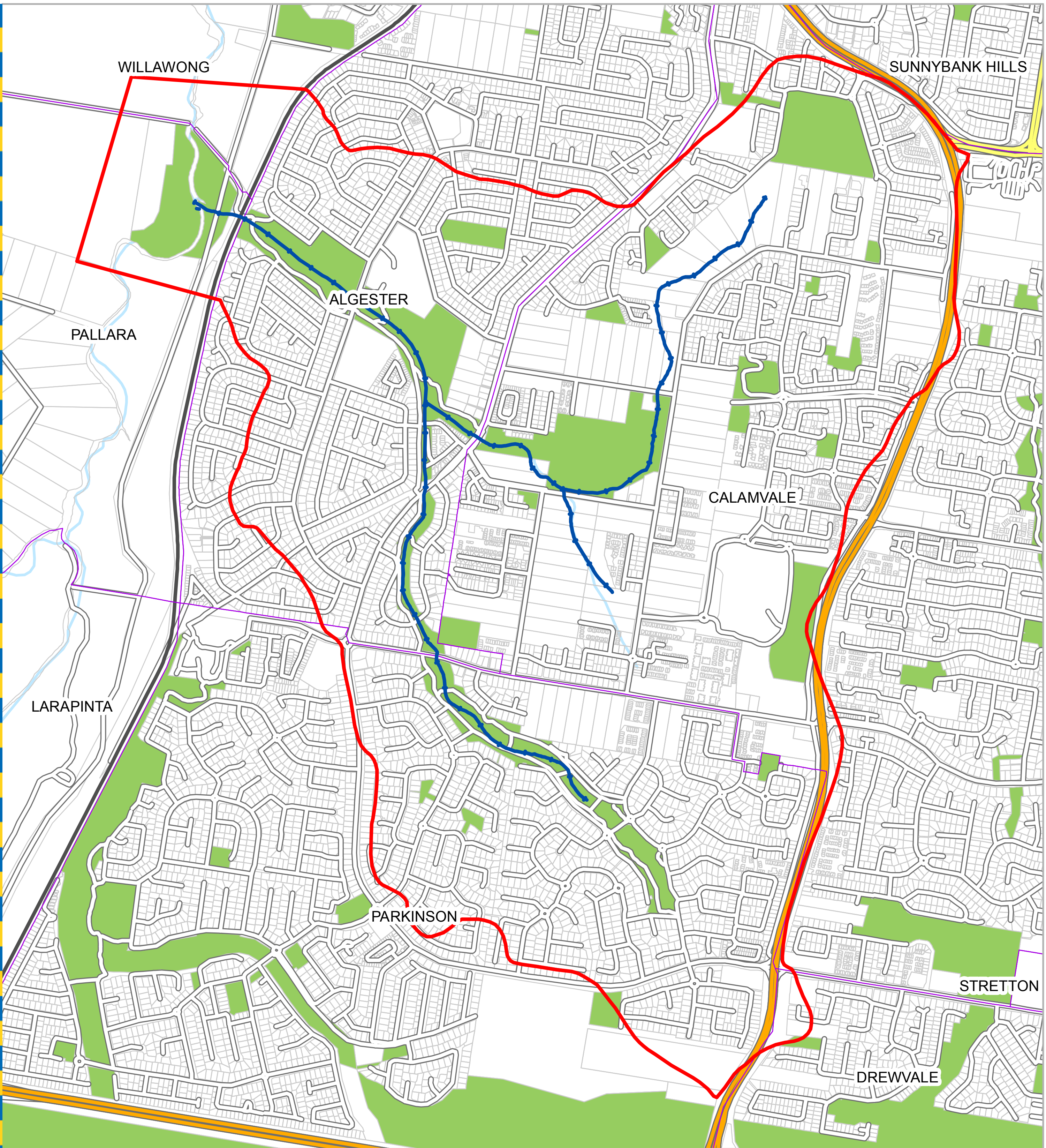
1.3 Study Objectives

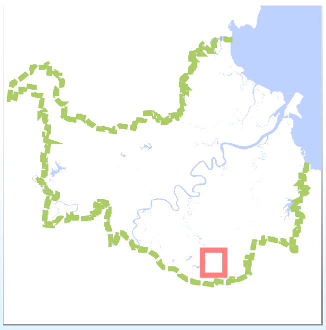
The primary objectives of the project were as follows:

- Reconstruct the Sheep Station Gully flood models (hydrologic and hydraulic) to represent the current catchment conditions and best practice flood modelling techniques.
- Adequately calibrate and verify the flood models to historical storm events to confirm that the models are suitable for the purposes of simulating design flood events.
- Estimation of design and rare / extreme flood magnitudes.
- Determination of flood levels for the design and rare / extreme events.
- Quantify the impacts of Minimum Riparian Corridor (MRC) and filling / development outside the Modelled Flood Corridor (MFC).
- Produce flood inundation mapping for the selected range of design and rare / extreme events.
- Quantify the impacts of climate variability as well as hydraulic structure blockages on flooding within the catchment.

[1] Brisbane City Council 2015, *Creek Flood Study Procedure Document Version 7.0*

[2] Brisbane City Council 2001, *Sheep Station Gully Stormwater Management Plan: Technical Report*, prepared by BCC City Design, Brisbane





Legend

Catchment Area	Park Boundaries
Creek Centreline	Suburb Boundaries
Railway Station	Property Holdings
Railway Line	Water
Freeways/Highways	
Major Roads	
Streets	

0 250 500 750
Metres

N W E S

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DATA INFORMATION

Brisbane City Council
City Projects Office
GPO Box 1434
Brisbane Qld 4001

For more information
visit www.brisbane.qld.gov.au
or call (07) 3403 8888

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Figure 1.1: Locality Plan

GIM - 150336 - 011

1.4 Scope of the Study

The following tasks were undertaken to achieve the project objectives as outlined in Section 1.3:

- Reconstruct an XP-RAFTS hydrologic model of the catchment, superseding the previous XP-RAFTS model.
- Develop a 1-dimensional (1d) / 2-dimensional (2d) TUFLOW hydraulic model of the creek system to replace the existing 1d MIKE11 hydraulic model.
- Calibrate the hydrologic and hydraulic models to the 27th January 2013 and 23rd January 2015 historical flood events.
- Verify the hydrologic and hydraulic models against Design Event estimates from similar catchments in Brisbane City, called a Catchment Correlation.
- Estimate the design and extreme flood magnitudes for the full range of events from 2-yr ARI to PMF.
- Simulate synthetic Australian Rainfall and Runoff (AR&R) design storms for multiple durations to determine the critical duration at various locations within the catchment.
- Utilise the calibrated flood models to determine peak design flood levels for the design and rare / extreme events.
- Make adjustments to the hydraulic model to simulate the effects of MRC and filling outside the MFC.
- Combine the modelling results for the various storm durations to produce peak results throughout the catchment for each Average Recurrence Interval (ARI).
- Produce flood extent mapping for the selected range of design and rare / extreme events.
- Undertake climate variability modelling for the 100-yr, 200-yr and 500-yr ARI events to determine the impacts.

1.5 Study Limitations

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

- The models have only been calibrated / verified at locations where stream gauge and MHG records exist. This should be taken into account when considering the accuracy of results outside the influence of the gauge locations.
- 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.
- BCC 2009 ALS data has been used to represent the hydraulic model floodplain topography. 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."
- 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 calibrate / verify the models.
  - The number of historical stream gauge / MHG locations throughout the catchment.
  - The purpose of the study (i.e. catchment / broad-scale or detailed).

2.0 Catchment Description

2.1 Catchment and Waterway Characteristics

The catchment area of Sheep Station Gully is approximately 6.5 km^2, and is a confluence to Oxley Creek at Paradise Road approximately 19 km upstream of the Brisbane River. The Sheep Station Gully Catchment is bounded by Stable Swamp Creek (north), Bulimba Creek (north-east), Scrubby Creek (east to south), and Oxley Creek (south-west to north-west) catchments.

The highest elevation in the catchment is approximately 95 m AHD and is situated along the north-east catchment boundary along Beaudesert Road. Sheep Station Gully breaks into two branches 1.2km upstream of the Paradise Road outlet (250m downstream from Algester Road). The south-branch is 3km long and terminates close to the Logan Motorway (south headwaters) in Parkinson. The north-branch is also 3km long and terminates at Beaudesert Road (north headwaters) in Calamvale. The south-branch experiences slopes of between 1% (in the lower reaches) and 2% (in the upper reaches). The north-branch experiences slopes of between 2% (in the lower reaches) and 6% (in the upper reaches).

Sheep Station Gully is an open man-made floodway from Paradise Road, up to where the north and south branches join below Algester Road, then along both the north and south branches up to Algester Road. The floodway is wide, in the order of 65m to 80m, and is surfaced with short well-kept grass. The south branch still consists of a floodway some 40m to 55m wide between Algester Road and Nottingham Road, where the active lower channel and invert is remnant of the previous natural waterway. Upstream of Nottingham Road to the Lakewood Estate, the channel is natural and well vegetated. The north branch upstream of Algester Road to Highlands Drive is mostly natural and well vegetated.

As discussed in the land use section below, the catchment is mostly urbanised, with many stormwater inlets discharging to the main waterways along the entire length of the Gully and its branches. The creek is subject to downstream (non-tidal) hydraulic interaction with Oxley Creek.

2.2 Land Use

The total catchment area is effectively fully developed with the primary land-use being low / low to medium density residential development. There are also significant areas of emerging community zoning. There are scattered green space areas (for example, urban parks) throughout the catchment. The largest urban green space is Calamvale Park. Both the north and south branches contain significant amounts of natural remnant forested land adjacent to the active waterways. Significant transportation corridors which cross or outskirt the catchment, include Beaudesert Road, Algester Road, and Paradise Road. Appendix C provides a figure indicating the catchment land-use, which is based upon BCC City Plan 2014.

3.0 Hydrometric Data and Storm Selection

3.1 Selection of Historical Storm Events

Historically there have been many storm events in the Sheep Station Gully catchment, however only relatively recently were two Maximum Height Gauges installed in the catchment, therefore the data necessary to calibrate models against historic flood events is sparse. Table 3.1 indicates the more significant flooding events which have occurred within the catchment for which calibration data is available. Note that there are no continuous stream gauge instruments within the catchment. Selection criteria are normally applied to the various storms to determine which should be adopted for a flood study. However, due to the limited availability of calibration data, the events in Table 3.1 were therefore adopted.

Table 3.1 – Maximum Height Gauge data availability

Creek	Gauge ID	Location	Data Availability (m AHD)		Significant Events on Record (m AHD)	
			MHG Opened	MHG Status	27th Jan 2013	23rd Jan 2015
Sheep Station Gully	SG120	Algester Rd (south branch)	24th Mar 2011	Open	16.72	16.48
	SG210	Formby St (north branch)	24th Mar 2011	Open	23.45	23.45
Oxley Creek	OX510	Col Bennett Park	16th Jun 2004	Open	--- (1)	NR (2,3)
	OX500	Paradise Road	9th Jun 2004	Open	--- (1)	NR (2,3)
	OX260	Oxley Creek (200m d/s)	9th Jun 2004	Open	--- (1)	NR (2,3)

(1) [---] Gauge read but “no flooding”, as per the MHG MS Access Database symbology.
(2) NR denotes “not read”.
(3) As SG120 indicates 27th January 2013 was the larger event, it is likely that the Oxley Creek MHGs could also have registered [---] for 23rd January 2015.

3.2 Availability of Rainfall for Selected Storms

Three rainfall stations were initially identified for the calibration events. Figure 3.1 and Table 3.2 indicates the location and current status of each rainfall station, and the availability of rainfall data for selected storm events. One rainfall station (40784) is located at the Calamvale Hotel along Beaudesert Road and appears to be just within the catchment, while the remaining two gauges (540234 and 540029) are outside the catchment. Gauge 540234 is located adjacent to a large water tower which may interfere with rainfall capture. Gauge 540029 is located 5km to the north-west of the catchment, and is too far away to reliably represent rainfall within Sheep Station Gully. Therefore only gauge 40784 is considered for the purposes of this flood study.

Table 3.2 – Rainfall Station data availability

Gauge ID	Old BCC ID	Catchment	Location	Status	Data Availability	
					27th Jan 2013	23rd Jan 2015
40784	OXR114	Sheep Station Gully	Beaudesert Road	Open	✓	✓
540234	S_R205	Scrubby Creek	Gowan Road	Open	✓(1)	✓(1)
540029	BLR736	Blunder Creek	Bowhill Road	Open	✓(2)	✓(2)

3.2.1 Downstream Boundary Information

There is no stream gauge at the confluence of Sheep Station Gully with Oxley Creek. As the model calibration relies on the SG120 and SG210 MHGs upstream of Algester Road, the TWL used at the Sheep Station Gully outlet for calibration will not influence the simulated MHG readings if set to a reasonable "normal flow" value. Downstream boundary conditions for Design Event modelling, however, were determined by analysis of Coincident Flooding (see Section 5.3.5) with Oxley Creek.

3.3 Characteristics of Historical Events

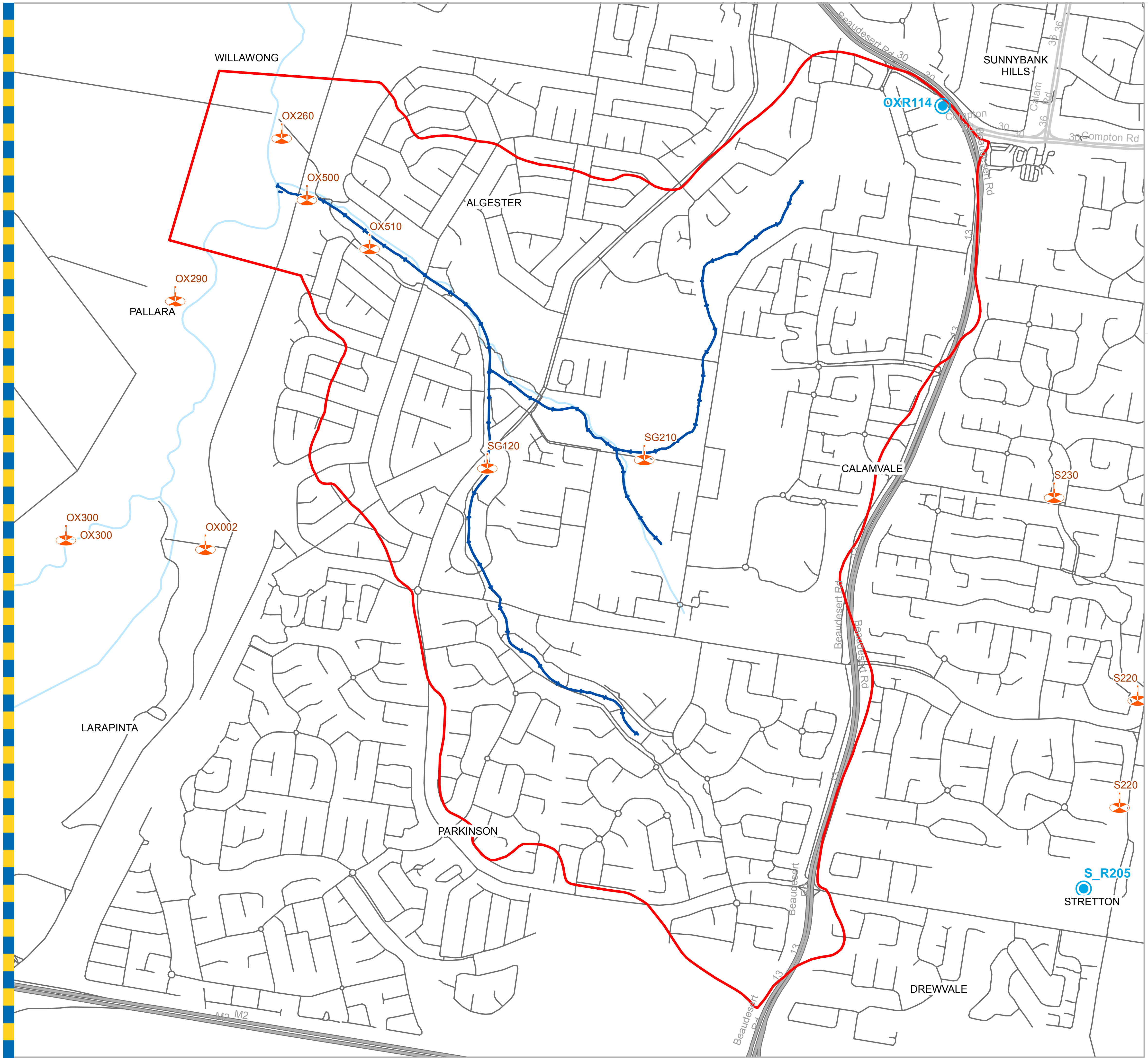
3.3.1 27th January 2013 event

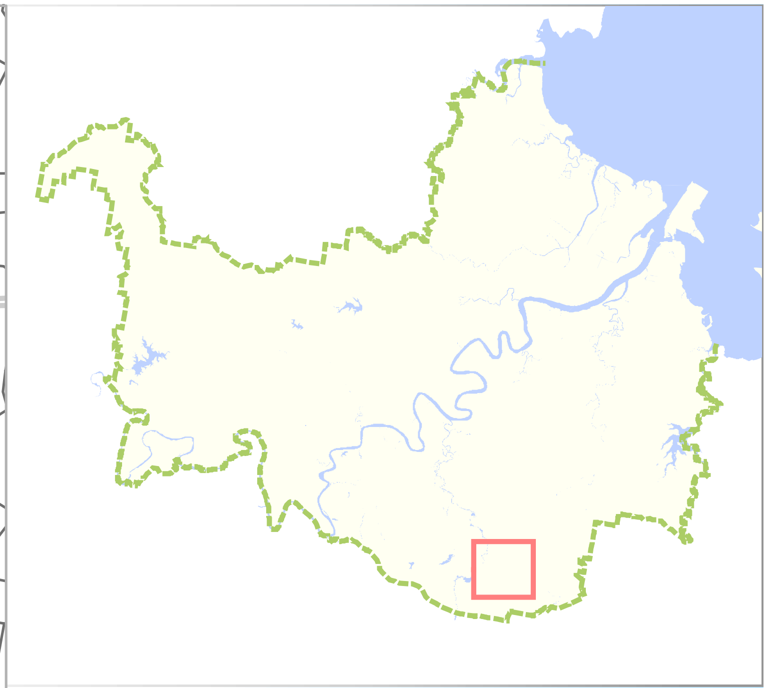
This event was a relatively small flooding event which produced a flood level of RL 16.72 m AHD at the MHG upstream of Algester Road on the south branch. The most intense burst occurred over 4 hours between 2 pm and 6 pm. See Appendix A for the cumulative rainfall and rainfall hyetograph for Gauge ID 40784. Table 3.3 below shows antecedent rainfall estimates and rainfall depths for the storm event. For the storm duration of 60 to 90 minutes which was determined to be critical for the catchment (See Section 6.5.1), the rainfall ARI estimate was less than 1yr ARI (see Table 3.4).

3.3.2 23th January 2015 event

This event was a relatively small flooding event which produced a flood level of RL 16.48 m AHD at the MHG upstream of Algester Road on the south branch. The most intense burst occurred over 3 hours between 8am and 11am. See Appendix A for the cumulative rainfall and rainfall hyetograph for Gauge ID 40784. Table 3.3 below shows antecedent rainfall estimates and rainfall depths for the storm event. For the storm duration of 60 to 90 minutes, the rainfall ARI estimate was approximately 1yr ARI (see Table 3.4).

Although the 2013 event registered the highest flood level at Algester Road, the 2015 event registered the highest rainfall ARI of 1yr. This is believed to be due to the low amount of antecedent rainfall preceding the 2015 event (6mm over 4 days) contributing to a high initial loss for the 2015 storm burst.





Legend

- Maximum Height Gauges
- Pluviograph Stations
- Continuous Recording Stream Gauges
- Creek Centreline
- Freeways/Highways
- Major Roads
- Streets
- Catchment Area

N, W, E, S

0 160 320 480
Metres

Prepared : 089958
Checked : NC
Revision : 0
Publication Date : 17 Jun 2015
Project Number : 150336

DATA INFORMATION

Location: G:\BICD\Proj\15\150336_Sheep_Station_Gully_Fld_Study\ArcGIS\GIM_150336_012_CatchmentMap.mxd

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Figure 3.1: Catchment Map and Gauge Location

GIM - 150336 - 012

Table 3.3 - Rainfall characteristics for Selected Floods: Gauge 40784

Flood Event	Antecedent Rainfall (mm)		Event Rainfall (mm)	
	14-day	4-day	Peak 3hr burst	Full day
27th January 2013	91 mm	83 mm	62 mm	170 mm
23rd January 2015	48 mm	6 mm	79 mm	155 mm

Table 3.4 - Rainfall IFD for Selected Floods: Gauge 40784

ARI (yr)	Duration (hrs)			
	1 hr	2 hr	3 hr	6 hr
27th January 2013	<1yr	1yr	1yr-2yr	2yr-5yr
23rd January 2015	1yr	2yr-5yr	2yr-5yr	2yr-5yr

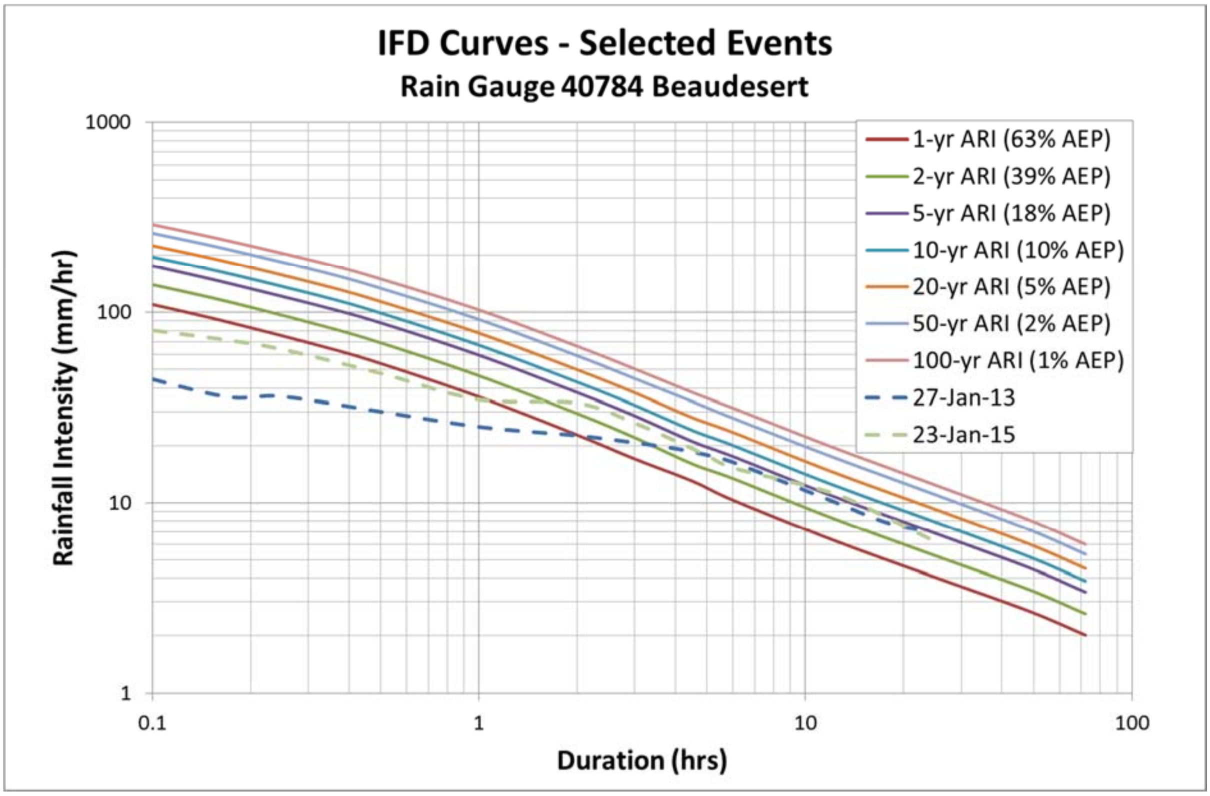


Figure 3.2: IFD Curves for Selected Floods at Gauge 40784 Beaudesert.

4.0 Hydrologic Model Development and Calibration

4.1 Overview

The hydrologic model simulates the rainfall-runoff process within the catchment and calculates the flow hydrograph at the outlet of each sub-catchment. A XP-RAFTS (version 2013) model was developed for the total catchment area (see Appendix J: Model User Guide).

4.2 Sub-catchment Data

4.2.1 General

This section describes the sub-catchment parameters used in the XP-RAFTS model. The "two sub-catchment" approach was used to separately define the impervious and pervious sub-catchments. This approach is recommended for highly urbanised catchment areas such as this study area. The adopted sub-catchment parameters for the calibration events are presented in Appendix B. The same sub-catchment parameters have been used for all events due to the relatively recent age of the calibration events and the minimal changes in catchment / channel topography and development during this period.

4.2.2 Sub-catchment Delineation

The XP-RAFTS model comprises 88 sub-catchments and the layout is shown in Figure 4.1. Based on a total catchment area of 6.6 km^2, this results in an average sub-catchment size of 0.075 km^2 (or 7.5 ha). The sub-catchment delineation was based upon the 2009 city-wide 2m DEM, and considered the major piped tributary locations as well as man-made boundaries such as the roads and creek crossings.

4.2.3 Sub-catchment Slope

Sub-catchment slopes have been calculated from the topography by identifying indicative flow paths and associated equal area slopes. The sub-catchment slopes ranged from 1.1 % for Sub-catchment BJ to 10.1 % for Sub-catchment AI.

4.2.4 Percentage Impervious

The percentage impervious values were generally derived from the catchment land-use types, by assuming a percentage impervious for each land-use type. Where XP-RAFTS sub-catchments contained more than one type of land-use, weighted averages of the percentage imperviousness were applied for each sub-catchment.

Two sets of impervious areas were calculated. The first set of impervious areas was based on Council's 2009 impervious area grid generated originally from near infra-red satellite imagery using Remote Sensing techniques. This set of impervious areas represents the existing case present day catchment, and was used for the hydrological model calibration for the 27th January 2013 and 23rd January 2015 flood events.

The total catchment is considered to be mostly urbanised, with the predominant land-use being low-density residential and to a lesser degree emerging communities. It is unlikely that the undeveloped forested areas adjacent to the open channels and within the catchment headwaters would be developed in the future, as these are conservation areas and parks.

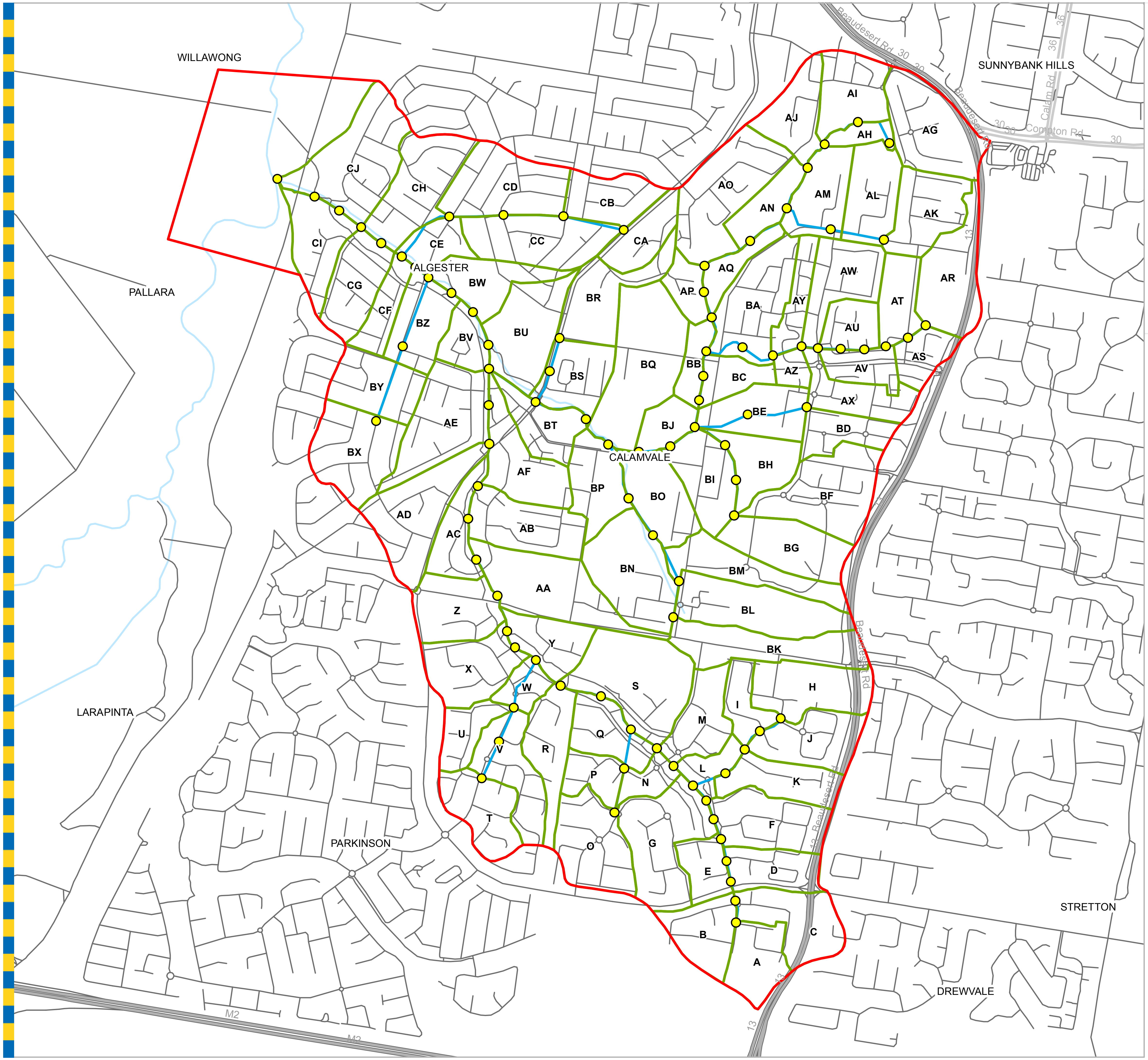
The second set of impervious areas were calculated using the BCC City Plan 2014 as indicated by Figure C.1 Catchment Land Use in Appendix C, and, the adopted % Impervious fraction in the Impervious Area table also in Appendix C. This set of impervious areas was used for the developed case future catchment, for Design and Extreme event flood prediction. For the present day existing catchment, the average overall catchment imperviousness was found to be 42%. For the fully developed ultimate catchment, the average overall catchment imperviousness was found to be 55%.

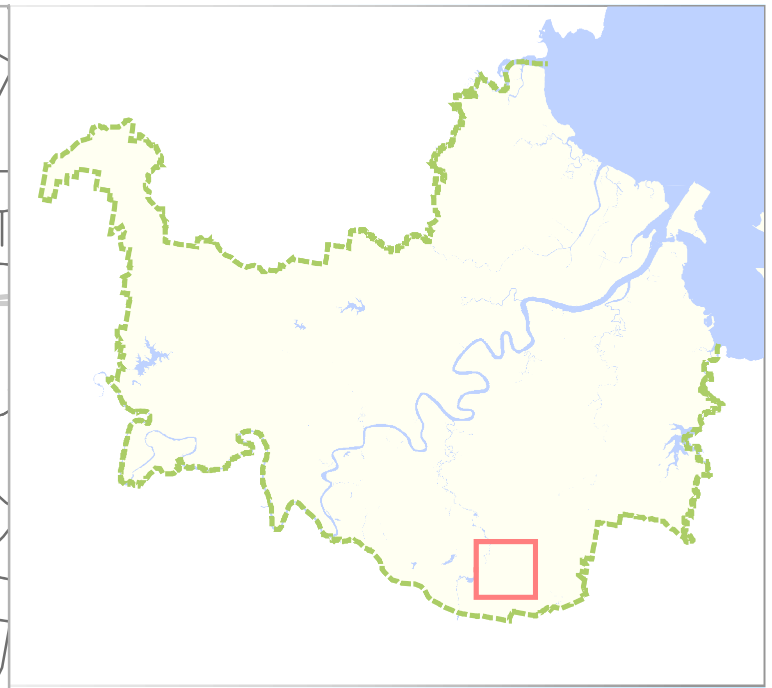
4.2.5 Hydrologic Roughness (PERN)

The hydrologic roughness parameter (PERN) is input as a Manning's 'n' representation of the average sub-catchment roughness. Generally, a value of n = 0.018 was used for the impervious sub-catchment and a value of n = 0.06 for the pervious sub-catchment. However, in the heavily forested areas, a higher value was used for the pervious sub-catchment to reflect the significantly denser vegetation.

4.2.6 Link and Routing Parameters

Routing of the open waterway was undertaken using the Muskingum-Cunge methodology, whereby the program calculates the Muskingum K and X values based on the channel cross-sectional and longitudinal characteristics. The cross-sections were obtained by extracting sections from Council's 2009 2m DEM. Manning's 'n' roughness values were estimated for the left bank, main channel, and right bank, and input into the model for each cross section. Open channel and overland flow routing branches were used for the entire model, without the application with any lag-type channels.





Legend

- RAFTS Nodes
- RAFTS Links/Routes
- Freeways/Highways
- Major Roads
- Streets
- RAFTS Subcatchments
- Catchment Area

N / W / E / S

0 160 320 480
Metres

Prepared : 089958
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DATA INFORMATION

Brisbane City Council
City Projects Office
GPO Box 1434
Brisbane Qld 4001

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Figure 4.1: XP-RAFTS Model Schematisation

GIM - 150336 - 013

Location: G:\BI\CD\Proj15\150336_Sheep_Station_Gully_Fld_Study\ArcGIS\GIM_150336_013_XP-RAFTS.mxd

4.3 Event Rainfall

4.3.1 Observed Rainfall

Recorded data from each calibration event was incorporated into the XP-RAFTS model using a standard HYDSYS database format. The HYDSYS rainfall database which was used in the hydrological modelling incorporates recorded rainfall at five minutes intervals, noting that the rainfall gauge only records information when 1 mm or more of rain has fallen. As discussed in Section 3.2, the Beaudesert Rainfall Gauge 40784 is selected for the study area. Distributions for the two events are presented in Appendix A. The Blunder Creek Rainfall Gauge 540029 is also shown on the cumulative distribution plots purely for comparative purposes.

4.3.2 Rainfall Losses

The Initial Loss (IL) and Continuing Loss (CL) methodology was used to simulate the rainfall losses. The IL (mm) is known to be the amount of rainfall that occurs before the start of surface runoff. The initial loss comprises factors such as interception storage (e.g. tree leaves); depression storage (e.g. ditches, surface puddles, etc.) and the initial infiltration capacity of the soil, whereby a dry soil has a larger capacity than a saturated soil. The CL (mm/hr) is assumed to be the average loss rate throughout the remainder of the rainfall event and is predominantly dependant on the underlying soil type and porosity.

4.4 Calibration and Verification Procedure

4.4.1 General

The calibration and verification process was developed to suit the study objectives and requirements, and also, in the case of this study, available data. Normally, the general requirement is to produce a hydrologic (RAFTS) model sufficiently robust to accurately predict design discharges without the need to run the hydraulic model. However for this study, a continuous recording stream gauge is not available for the catchment, therefore rainfall runoff hydrographs for the calibration events in RAFTS could not be directly compared with flood discharges derived from stream gauge recordings.

The only physical calibration data available in the Gully which record flood parameters are the two MHGs discussed in Section 3.1. In order to calibrate the hydrological model, discharges from the RAFTS model must be imported into the hydraulic flood model (TUFLOW), and the model run to see if the predicted flood levels match the recorded flood levels. The process is one of iteration, where model parameters (predominantly in the hydrological model) are adjusted until agreement is obtained between the hydraulic model and measured flood levels. This process of calibration is commonly referred to as a "Joint Calibration".

The general approach adopted for the Joint Calibration and verification is outlined in Section 4.4.3. The development of the hydraulic model (TUFLOW) is outlined in Section 5.

4.4.2 Tolerances

BCC flood studies aim to achieve the following tolerances with regard to a Joint Calibration / verification:

- MHGs - within ± 0.30 m of the peak flood level.
- Debris marks - within ± 0.40 m of the peak flood level.

4.4.3 Methodology

The methodology applied to the Joint Calibration and verification of the hydrological (RAFTS) model was as follows:

1) Input the observed rainfall data and apportion the rainfall to each sub-catchment.
2) Run the calibration events (i.e. 27th January 2013, 23rd January 2015) in the RAFTS model, and import the resulting hydrographs into the TUFLOW model.
3) Run the calibration event in the TUFLOW model, and compare the simulated flood level results against the observed MHG readings.
4) Iteratively adjust the model parameters (generally the hydrological parameters) and re-run the model to achieve the best possible fit with the observed data. The predominant model parameters to adjust normally include the IL (mm), CL (mm/hr), the Manning's 'n' values of the channel cross sections, and lastly the storage delay time coefficient multiplier (Bx).
5) Adopt model parameters based on the calibration results.
6) Run the verification event through the calibrated RAFTS model and with use of the TUFLOW model compare the simulated flood levels against the observed flood levels at the MHGs. (In this study a verification event was not available, therefore a Catchment Correlation was undertaken as discussed in Section 4.7).
7) Make adjustments to the initial loss (as required) to represent the event specific rainfall lost at the start of the event.
8) Repeat steps 2 to 7 (as necessary) following the results of the hydraulic model simulations. Refer to Section 5 for more detail on the hydraulic modelling.

4.5 Simulation Parameters

Table 4.1 indicates the start and finish times of the hydrologic simulations as well as the time step used.

Table 4.1 – Hydrologic Simulation Parameters

Event	Start Time	Finish Time	Duration (hrs)	Time Step (min)
27th January 2013	24/01/2013 0:00	29/01/2013 00:00	120	5
23th January 2015	23/01/2015 00:00	26/01/2015 00:00	36	5

4.6 Hydrologic Model Calibration Results

4.6.1 27th January 2013

Recall in Table 3.3, this event received a substantial amount of antecedent rainfall, 83mm over a 4 day period prior to the main storm. The results of this calibration event were insensitive to any Initial Loss < 83mm. Initial estimates of water level in the TUFLOW model were too high, and the only way to lower these reasonably was to select a high Continuing Loss (3.5mm/hr) and high Bx storage factor of 3.0. The higher than normal Continuing Loss of 3.5 mm/hr (2.5mm/hr is standard) could be ascribed to the very sandy nature of the catchment. The calibration results and adopted model parameters are given in Table 4.2 and Table 4.3 respectively.

4.6.2 23rd January 2015

In Table 3.3, this event received a small amount of antecedent rainfall, just 6mm over a 4 day period prior to the main storm. The results of this calibration event were sensitive to initial losses. The 3.5mm Continuing Loss established for this catchment in the 27th January 2013 event was maintained, as was the Bx factor of 3.0. However the simulated flood levels were still higher than the MHG readings. In upper limit Initial Loss of 50mm was selected which represents an incredibly dry catchment. The calibration results and adopted model parameters are given in Table 4.2 and Table 4.3 below.

Table 4.2 – Joint Calibration Results (m AHD)

Event	MHG Name	MHG Level	Simulated Level	Difference (Sim-MHG)
27th January 2013	SG210 Formby Street	23.45	23.45	0.00
	SG120 Algester Road	16.72	16.87	0.15
23rd January 2015	SG210 Formby Street	23.45	23.41	-0.04
	SG120 Algester Road	16.48	16.83	0.35

Table 4.3 – Adopted RAFTS Calibration Parameters

Parameter	Description	27rd January 2013	23rd January 2015
n	Storage non-linearity exponent	-0.285	-0.285
Bx	Storage delay time coefficient multiplier	3.0	3.0
IL (Imp.) (mm)	Impervious Area Initial Loss (mm)	1	1
CL (Imp.) (mm/hr)	Impervious Area Continuing Loss (mm/hr)	0.0	0.0
IL (Perv.) (mm)	Pervious Area Initial Loss (mm)	0	50
CL (Perv.) (mm/hr)	Pervious Area Continuing Loss (mm/hr)	3.5	3.5

4.7 Hydrologic Model Verification (Catchment Correlation)

As discussed previously, a storm event was not available for the purposes of model verification. A Catchment Correlation has therefore been undertaken to compare the results of this study with other similar catchments within the Brisbane LGA. Peak 100-yr ARI discharges were extracted at key locations from several recent urban flood studies, and divided by catchment area to form a 100-yr ARI unit discharge. The approach seeks to normalise results so that trends between similar catchments may become evident. The previous studies chosen were the Moolabin Rocky Flood Study (2015), Wynnum Creek Flood Study (2014), and Norman Creek Flood Study (2013). One point was also examined from the previous Stormwater Management Plan (2001) at Paradise Road.

The results of the calculation are shown below in Table 4.4. Initially it may be seen that there is a significant scatter in the Q/A values. It is understood however that the relative flood discharge generated by a catchment either decreases or increases with catchment area. For example in New Zealand it is well documented[3] that flood discharge is a function of catchment area to the power of 0.8. When Q/A is plotted against A as in Figure 4.2, the trend becomes evident. It may be seen in Figure 4.2 that the results of this study are consistent with other similar catchments in the Brisbane LGA, for which significant calibration and verification effort was also conducted. The equation to the trend line shown in Figure 4.2 is:

*Q/A = B/(1+C*exp(-DA))* *Equation 4.8.1*

Where Q=100yr ARI Discharge (m^3/s)
A= catchment area (km^2)
B= 13.16 (calibration coefficient)
C= -0.68 (calibration coefficient)
D= 0.14 (calibration coefficient)

[3] McKerchar, A.I., and Pearson, C.P., 1989. Flood Frequency New Zealand . Publication No. 20 of the Hydrology Centre (DSIR), Christchurch, New Zealand.

Equation 4.8.1 was derived from the mathematical simulation software CurveExpert4. The software applies Monte-Carlo simulation to nine Model Families of curves. The above equation is called the Logistic Model, and was fitted to the catchment discharge data with a Standard Error (S) of 3.3 and Correlation Coefficient (R) of 0.83. The analysis only demonstrates that discharges from Sheep Station Gully are comparable to other similar catchments in the Brisbane LGA, however should not be used for design or flood estimation purposes. The estimates are only intended as an approximate verification.

Table 4.4 – Catchment Correlation

Flood Study	Location	Catchment Area (km^2) [A]	100yr ARI Discharge [Q]	[Q]/[A]
Norman Creek (2013)	WR Gauge	15.6	216	13.9
	Freeway	13.8	221	16.0
Wynnum Creek (2014)	Radford Road	1.0	30	31.1
	Wondall	2.8	90	32.0
	QLD Rail	5.7	113	19.9
Moolabin Rocky (2015)	Railway_Tafe	4.0	67	16.8
	Muriel Ave	5.6	105	18.7
	Gow St	2.8	66	23.4
	Railway Moolabin	4.1	85	20.8
SWMP (2001)	Paradise Rd	6.5	113	17.4
Sheep Station Gully (2015)	Algester Rd (Sth)	2.2	50	22.9
	Algester Rd (Nth)	2.8	57	20.4
	Paradise Rd	6.3	114	18.1

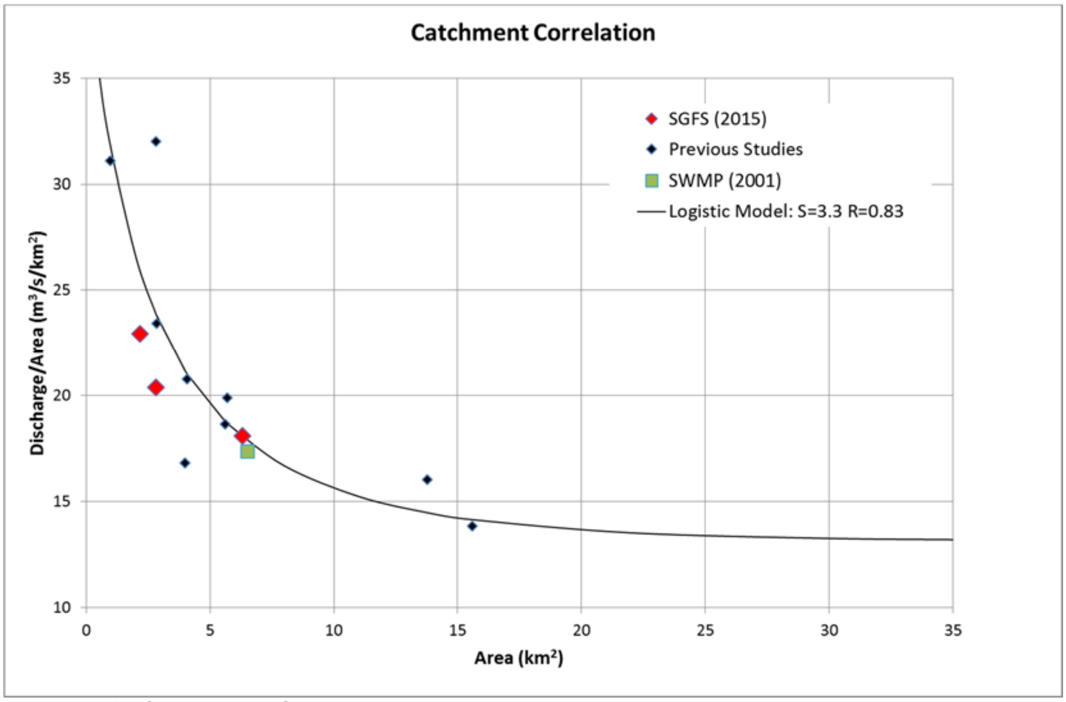


Figure 4.2: Catchment Correlation

[4] http://www.curveexpert.net

5.0 Hydraulic Model Development and Calibration

5.1 Overview

The previous hydraulic model of Sheep Station Gully was a 1d MIKE11 model, developed for the previous Stormwater Management Plan. To achieve best practice, it was considered appropriate to upgrade the 1d model to a 1d / 2d model. This would provide better representation of the floodplain flooding characteristics in the middle to lower sections of the creek, as well as a more efficient tool to produce flood mapping products.

The TUFLOW hydrodynamic model (version 2013-12-AD) was selected for the hydraulic analysis of Sheep Station Gully (see Appendix J: Model User Guide).

5.2 Available Data

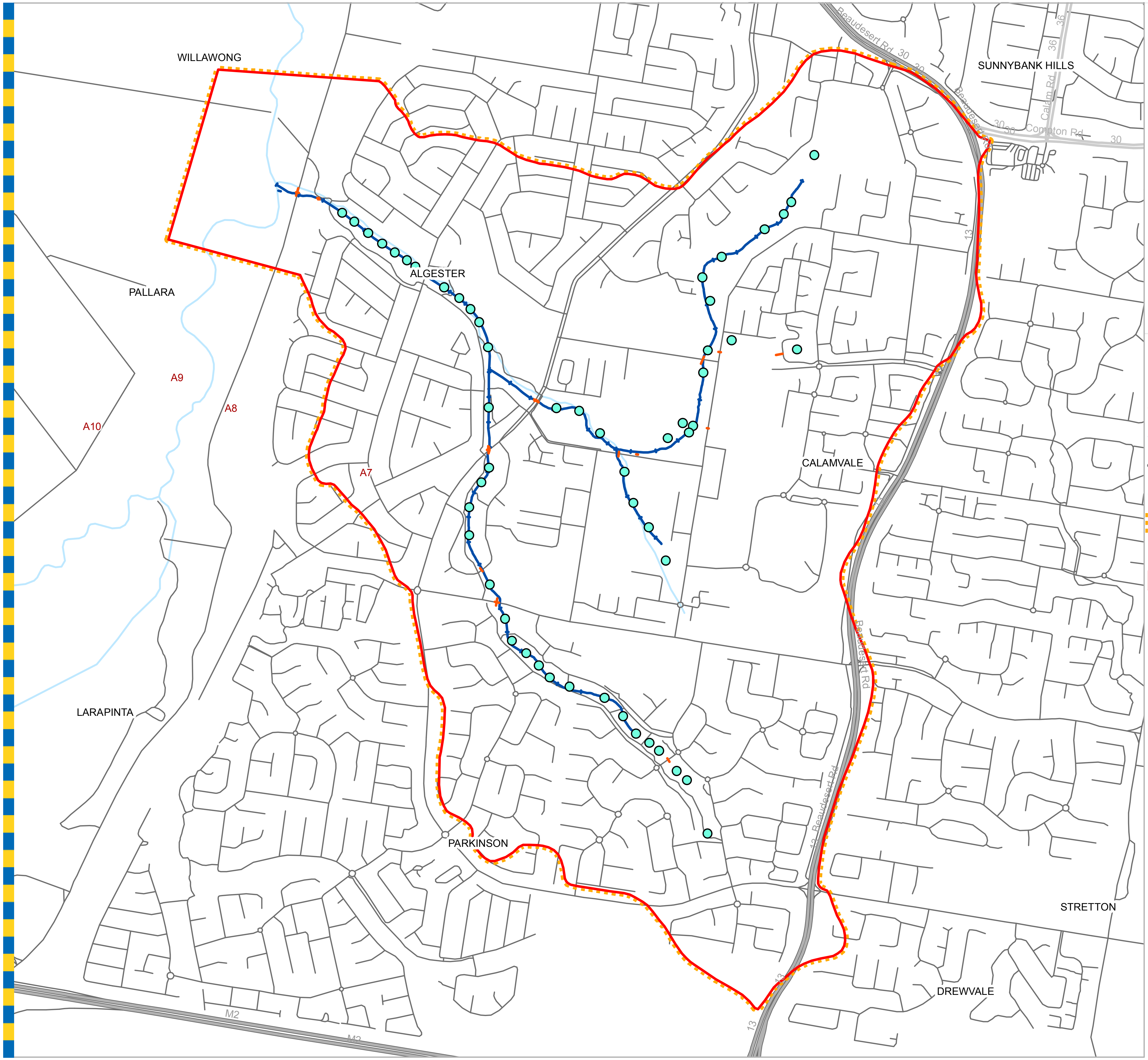
The following data was utilised in the development of the TUFLOW model:

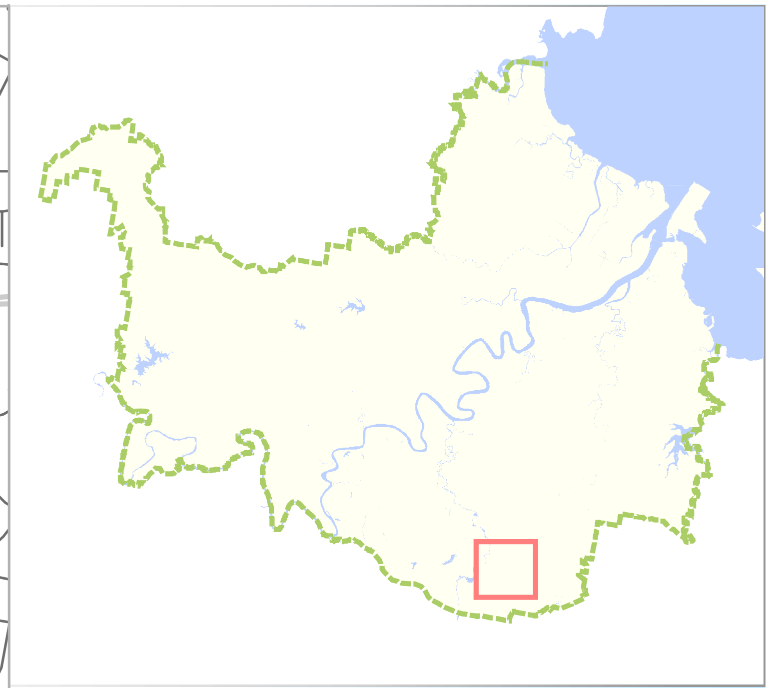
- MIKE11 model – 2001 Sheep Station Gully Stormwater Management Plan
- BCC 1992, 1994 cross-section survey
- BCC 1997 hydraulic structures survey
- BCC November 2014 supplementary cross-section survey (15)
- BCC aerial photography – 2012
- BCC 2009 Airborne Laser Scanning (ALS) data
- BCC 2009 Impervious Area Mapping grid
- 2014 BCC City Plan
- Hydraulic structure drawings / reference sheets. Refer to Appendix H for further details.
- BCC Cadastre and GIS databases

5.3 Model Development

5.3.1 Model Schematisation

Figure 5.1 indicates the extents of the TUFLOW model, as well as the inflow locations and the hydraulic structures included in the model. The model consists of a predominantly 2d schematisation, with the 1d domain (structures only) modelled in ESTRY, which is the TUFLOW 1d engine.





Legend

- Inflow Locations
- Hydraulic Structures
- Creek Centreline
- Freeways/Highways
- Major Roads
- Model Boundary
- Streets
- Catchment Area

N E S W

0 160 320 480
Metres

Prepared : 089958
Checked : NC
Revision : 0
Publication Date : 17 Jun 2015
Project Number : 150336

Brisbane City Council
City Projects Office
GPO Box 1434
Brisbane Qld 4001

For more information
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Figure 5.1: TUFLOW Model Schematisation

Location: G:\BI\CD\Proj15\150336_Sheep_Station_Gully_Fld_Study\ArcGIS\GIM_150336_014_TUFLOW.mxd

GIM - 150336 - 014

5.3.2 Topography

1d Domain

The 1d domain in the new TUFLOW model comprises only hydraulic structures or cross road drainage. These structures were surveyed in 1997. The 1d domain is not used for the representation of open channels or waterways. The 1992 & 1994 survey was supplemented with 15 cross-sections from survey undertaken in November 2014. The location of the November 2014 surveyed cross-sections was selected at sites where the 1997 surveyed cross-sections appeared least representative of the channel shape, or where known changes to the floodplain had taken place, such as the Calamvale Park improvements.

2d Domain

The 2d domain consisted of a 4 m grid which was created from 2009 BCC DEM, based again on the 2009 ALS data. The 2m DEM was trimmed to the catchment boundary, which was then able to be read directly into and resampled to 4m in the TUFLOW model. Detailed checks were made of the DEM by comparing it with the 1992 and 1994 cross section survey in the previous Mike11 model. It was found generally that the DEM provided a very good match, and locations which were different in profile often looked to be clear errors in the cross section data (truncated sections, or overly narrow sections, likely resulting from Mike11 manipulations). At some cross sections, the surveyed thalweg levels were 200mm to 500mm lower than the DEM. At these locations, the "gully-line" function in TUFLOW was used to lower the cells along the low-flow channel centre lines.

5.3.3 Land Use

The Manning's 'n' values shown in Table 5.1 were adopted within the 2d domain of the TUFLOW model. The assignment of the appropriate roughness values to the land-use / topographical feature was based upon experience with similar studies and relevant hydraulic literature. The delineation of the land-use and topographical areas was undertaken utilising a combination of BCC aerial photography, BCC City Plan and a number of site visits.

5.3.4 Hydraulic Structures

Culverts and Bridges

The major bridge and culvert structures within the model domain were represented in the TUFLOW model. These structures generally consisted of road crossings and rail crossings. Table 5.2 indicates the location and details of the structures as well as the modelling approach used. The modelled head-loss across bridge structures was checked utilising the HEC-RAS modelling software, as recommended in the TUFLOW manual. All structures were modelled as a 1d representation of the waterway opening, with a 2d representation of the overtopping (weir). Refer to Section 5.5 for further details.

Table 5.1 – Adopted roughness parameters

Topographical feature / Land-use	Adopted Manning's 'n'
City Plan Land-use	
Low Density Residential	0.12
Low – Medium Density Residential	0.15
High Density Residential	0.15
Tourist Accommodation	0.15
Neighbourhood Centre	0.15
District Centre	0.15
Industrial	1.00
Sport And Recreation	0.04
Open Space	0.04
Conservation	0.08
Emerging Communities	0.06
Rural	0.04
Rural Residential	0.06
Community Facilities (Community Purposes)	0.10
Community Facilities (Education Purposes)	0.10
Community Facilities (Emergency Services)	0.15
Community Facilities (Health Care Purposes)	0.15
Specialised Centres	0.12
Special Purpose (Transport Infrastructure)	0.04
Special Purpose (Utility Services)	0.04
Multi-Purpose Centre Convenience Centre	0.15
Multi-Purpose Centre Suburban Centre	0.15
Additional Roughness	
Road pavement	0.02
Road verge	0.03
Channel – concrete lined	0.015
Vegetation – light to high density	0.035 to 0.15
Buildings	1.00
Minimum Riparian Corridor (MRC)	0.15

Table 5.2 – Hydraulic Structures represented in the TUFLOW model

Creek	TUFLOW ID	Structure location	Structure details (m)	Modelled structure representation	Origin of data used for coding the structure
Sheep Station	Cul_01	Paradise Road	RCBC 6/ (W 3.0 x H 3.0)	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station	Cul_02	Railway Bridge	Bridge 3 Span (W 8.86, 8.87, 8.52) H 4.15m	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station)	Cul_03	Ridgewood Road	RCBC 5/ (W 3.67 x H 1.84)	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station (Tributary A)	Cul_08 & 09	Algester Road North	RCBC 3/ (W 3.65 x H 1.5)	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station	Cul_04 & 05	Algester Road South	RCBC 3/ (W 3.65 x H 1.5)	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station	Cul_06	Laurel Oak Drive	RCBC 3/ (W 2.75 x H 1.25)	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station	Cul_10	Nottingham Road	BEBO Arch W 12m H 3m	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station (Tributary B)	Cul_11	Formby Road	RCP 7/ 0.6 dia	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station (Tributary A)	Cul_07	Ormskirk Street	RCP 3/ 1.2 dia	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station (Tributary A)	Cul_12	Calamvale Pk Entrance	RCBC 2/ (W 1.50 x H 0.75)	1d culvert / 2d weir	1997 survey and 2009 ALS
Sheep Station (Tributary A)	Cul_13	Benhiam St Culvert (North)	RCP 3/ 0.9 dia	1d culvert / 2d weir	BCC Stormwater database
Sheep Station (Tributary A)	Cul_14	Benhiam St Culvert (South)	RCP 3/ 0.9 dia	1d culvert / 2d weir	BCC Stormwater database
Sheep Station (Tributary A)	Cul_15	Hamish Street Detention Basin	Orifice Plate dia 1.1	1d culvert / 2d weir	Orifice plate at outlet measured in field.
Sheep Station	Cul_16	Ontario Cr Bridge.	W 28 H 1.75	1d culvert / 2d weir	Estimated onsite and in GIS. Soffit permanently submerged in lake.

5.3.5 Boundary Conditions

Inflow Boundaries

Inflows to the hydraulic model were taken from the XP-RAFTS hydrologic model. All inflows were represented as a discharge versus time (Q-T) relationship, with the inflow locations as indicated in Figure 5.1. The inflow locations were generally adopted to match the XP-RAFTS model sub-catchment schematisation at the outlet of the sub-catchments.

Downstream Boundary

A static or fixed tailwater level (TWL) was used to represent the downstream boundary conditions at the confluence of Sheep Station Gully with Oxley Creek. An analysis of Coincident Flooding was undertaken in accordance with QUDM's (2013, Provisional Version) Quick IFD Method in Section 8.3.4 of QUDM. This method assumes that for a localised storm event, there is often some amount of regional rainfall or flooding. The receiving water body (Oxley Creek) having the longer catchment response time, experiences minor but sustained flooding over the duration of the localised flood in Sheep Station Gully. The results of the analysis are shown in Table 5.3. To put these TWLs into some context, the Sheep Station Gully outlet culverts at Paradise Road have an invert level of RL 9.2m AHD (which is also about the level of the Oxley Creek active channel), and an obvert level of RL 12.2m AHD.

Table 5.3 – Adopted Tailwater Level Estimates

Local Event ARI (yr)	Local RAFTS Discharge (m^3/s)	Adopted Oxley Creek TWL (m AHD)
2	61	9.5
5	82	9.9
10	96	10.2
20	114	10.5
50	135	10.8
100	156	11.1
200	186	11.3
500	223	11.6
2000	276	12.1
PMF	802	12.5

For the climate variability sensitivity tests, tailwater levels were interpolated from Table 5.3, based on the estimated Q local runoff from RAFTS.

1d-2d Boundaries

1d structures were linked to the upstream and downstream sides of waterway crossings (railway, roads, embankments) using a "SX" type flow boundary condition. The SX line was digitised as a zig-zag line across the waterway, connecting the first 3 rows or cells upstream and downstream of structures to ensure model stability.

5.3.6 Run Parameters

Time Step

The 1d ESTRY component was run using a 0.25 second time step and 2d TUFLOW component using a 1.5 second time step.

Eddy Viscosity

The Smagorinsky method was used for specifying the eddy viscosity in the 2d domain. This method is recommended in the TUFLOW manual and is the default approach, in lieu of the Constant method. This method uses the Smagorinsky formula with a "Constant Coefficient" of 0.1 and "Smagorinsky Coefficient" of 0.2.

5.4 Calibration Procedure

As this investigation employed the method of a "Joint Calibration", discussed previously in Section 4.4, a separate calibration exercise of the Hydraulic Model is not possible due to the unavailability of calibration data. However, a hydraulic structure verification is undertaken as follows, to check that key bridge structures are performing correctly in minor to extreme flood/discharge events.

5.5 Hydraulic Structure Verification

The TUFLOW manual strongly recommends confirming the head-loss across hydraulic structures, by comparison with one of the following methods:

- *Calibration to recorded information (if available).*
- *Cross-checked using desktop calculations based on theory and/or standard publications (e.g. Hydraulics of Bridge Waterways, US FHA 1973).*
- *Cross-checked with results using other hydraulic software.*

It is common practice in BCC flood studies to cross-check structure head-losses against results from the HEC-RAS hydraulic modelling software. Generally, HEC-RAS is regarded as one of the better hydraulic modelling packages when it comes to accurately representing hydraulic structures such as bridges. The majority of the hydraulic structures within the catchment(s) are culverts, of which the TUFLOW and HEC-RAS algorithms are similar. Therefore, it was considered more important to check the head-loss at a number of the bridge structures.

The bridge structures where HEC-RAS checks were undertaken included the Railway Bridge at the bottom of the catchment just above Paradise Road, and the Arch Bridge at Nottingham Road on the South-branch. Checks were made by extracting results from the TUFLOW model using the PMF event, then using these results as boundary conditions in the HEC RAS model. Table 5.4 provides a comparison of the head-loss across the structure between TUFLOW and the HEC-RAS model.

Table 5.4 – HEC-RAS Bridge Modelling Checks for PMF

Time (hr)	PMF Discharge (m^3/s)	HEC-RAS Head-loss (m)	TUFLOW Head-loss (m)	Difference (TF-HR) (m)
	Railway Bridge			
1.0	54	0.03	0.15	0.12
1.5	100	0.07	0.25	0.18
2.0	151	0.46	0.55	0.09
2.5	236	1.24	1.06	-0.18
3.0	402	1.18	1.09	-0.09
3.5	775	1.47	1.28	-0.19
	Nottingham Bridge			
1.0	24	0.05	0.36	0.31
1.5	35	0.12	0.40	0.28
2.0	53	0.24	0.68	0.44
2.5	83	0.95	0.92	-0.03
3.0	131	1.36	1.07	-0.29
3.5	224	1.30	1.12	-0.18

Generally, the TUFLOW head-losses for the bridge structures checked were within ± 0.3 m (see Section 4.4.2) of the HEC-RAS values for the full range of flows at which checks were undertaken. This is considered reasonable and gives validity to the TUFLOW results.

6.0 Design Event Analysis

6.1 Design Event Terminology

The use of the terms "*recurrence interval*" and "*return period*" has been criticised as leading to confusion in the minds of some decision-makers and members of the public. Therefore, the current update of AR&R will utilise different terminology. Generally, for the larger flood magnitude discharges, the term AEP (%) is now preferred by AR&R, in lieu of ARI. Table 6.1 gives the equivalent AEP value (rounded to a whole number) with respect to ARI. The relationship can be expressed by the following equation:

$$AEP = 1 - exp(-1 / ARI) \qquad \text{Equation 6.1.1}$$

Table 6.1 – ARI versus AEP

ARI (year)	AEP (%)
2	39
5	18
10	10
20	5
50	2
100	1
200	0.50
500	0.20
1000	0.10
2000	0.05

It is common to see the 50 % AEP being equated to the 2-yr ARI and also the 20 % AEP being equated to the 5-yr ARI. This is not technically correct; however the use of $AEP = 1 / ARI$ is very prevalent within the industry and often used for simplicity.

For the purpose of this technical report, the correct values indicated in Table 6.1 will be utilised. The flood probability will be firstly expressed firstly in ARI and then secondly in the equivalent AEP, for example 2-yr ARI (39 % AEP).

However, as the mapping products in Volume 2 will likely be viewed by a wider audience, for ease of common understanding the simplified $AEP = 1 / ARI$ will be utilised. The 2-yr ARI and 5-yr ARI will be referred to as 50 % AEP and 20 % AEP respectively.

6.2 Design Event Scenarios

Table 6.2 indicates the three scenarios utilised in the modelling of the design events, noting that all design event scenarios were modelled using ultimate hydrological conditions. For the purpose of this report, the term “design events” refers to those events from 2-yr ARI (39 % AEP) to 100-yr ARI (1 % AEP).

Table 6.2 – Design Event Scenarios

ARI (year)	AEP (%)	Scenario 1	Scenario 2	Scenario 3
2	39	✓	✗	✓
5	18	✓	✗	✓
10	10	✓	✗	✓
20	5	✓	✗	✓
50	2	✓	✗	✓
100	1	✓	✓	✓

The following describes the design event scenarios:

Scenario 1: Existing Waterway Conditions

Scenario 1 is based on the current waterway conditions. Some minor modifications were made to the TUFLOW model developed as part of the calibration / verification; refer to Section 6.4 for further details.

Scenario 2: Minimum Riparian Corridor (MRC)

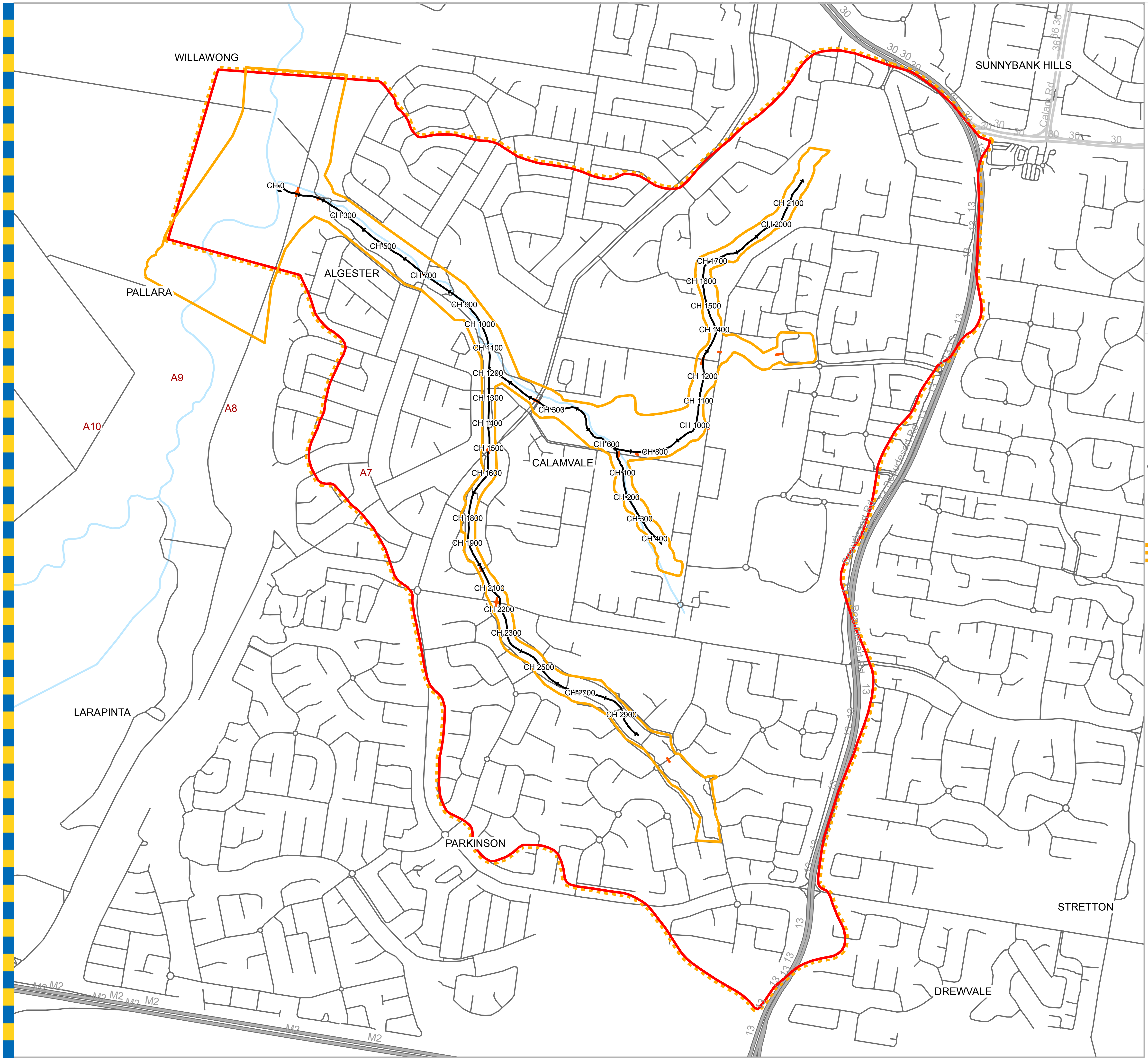
Scenario 2 includes an allowance for a riparian corridor along the edge of the channel. This involved firstly reviewing the existing vegetation and land-use adjacent to the channel to determine an appropriate Manning’s ‘n’ roughness value for the riparian corridor. In most locations the default value of n = 0.15 was used, however where the existing manning’s ‘n’ is higher than n = 0.15, the manning’s ‘n’ was left unchanged.

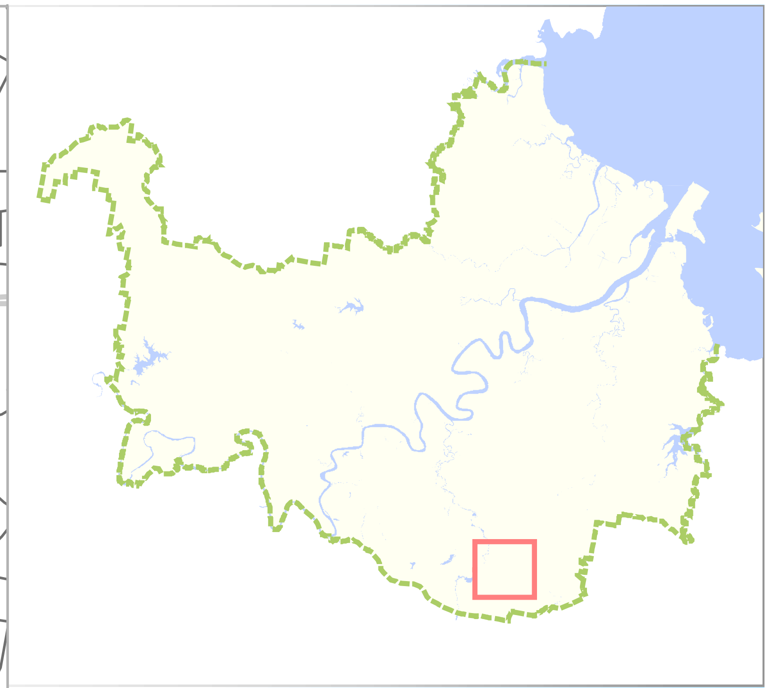
A 30 m wide corridor (15m wide each side from the low flow channel) was defined by changing the Manning’s n of the 1d cross sections (as applicable) and a new 2d materials layer within the TUFLOW model. In areas where the 15 m width was not available, the MRC was set to the maximum possible width (i.e. less than 15 m) up to the boundary of the MFC.

Scenario 3: Filling to the Modelled Flood Corridor (MFC) + Minimum Riparian Corridor (MRC)

Figure 6.1 indicates the MFC. The MFC (modelled flood corridor) is the greater extent of Flood Planning Area 3 (FPA3) and the waterway corridor. FPA3 is the greater extent of not less than, 0.6m depth and 0.6 m^2/s D*V in the 100-yr ARI (1 % AEP) event.

Scenario 3 assumes filling to the MFC boundary to represent potential development. In the design events, 2-yr ARI (39 % AEP) to 100-yr ARI (1 % AEP), the filling acts as a barrier and the MFC can be modelled simplistically as a glass-wall of infinite height. This is a simple and conservative assumption used to develop design planning levels. It does not necessarily reflect allowable development assumptions under City Plan.





Legend

- AMTD Line
- Conveyance Corridor Polyline
- Hydraulic Structures
- Freeways/Highways
- Major Roads
- Streets
- Model Boundary
- Catchment Area

N W E S

0 160 320 480
Metres

Prepared : 089958
Checked : NC
Revision : 0
Publication Date : 17 Jun 2015
Project Number : 150336

DATA INFORMATION

Location: G:\BI\CD\Proj15\150336_Sheep_Station_Gully_Fld_Study\ArcGIS\GIM_150336_016_TUFLOW_Conveyance.mxd

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Figure 6.1: TUFLOW Model Conveyance Corridor

GIM - 150336 - 016

6.3 Design Event Hydrology

6.3.1 Overview

This study utilises the synthetic design storm concept from AR&R (1987) to estimate the design ARI flood. This methodology is as follows:

- Design Intensity Frequency Duration (IFD) estimates are determined from AR&R for the full range of storm ARIs (2-yr to 100-yr) and durations (30 minutes to 4.5 hours).
- Design temporal patterns are determined and design hyetographs produced for the full range of ARIs and durations.
- Appropriate design rainfall loss parameters are adopted by reference to the calibration and industry standard techniques.
- Using the calibrated models, design storms are simulated and the peak discharges and critical durations established within the model domain.

6.3.2 RAFTS Model Set-up

The calibrated XP-RAFTS model was used to simulate the design storm rainfall-runoff and sub-catchment routing process. The following describes the adjustments made to the model in order to simulate the design events.

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.

Appendix B presents the XP-RAFTS catchment parameters that were adopted for the design event modelling scenarios. The current adopted version of BCC City Plan (2014) 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 Appendix C.

Rainfall Losses

The Initial Loss (IL) and Continuing Loss (CL) approach was used to simulate the rainfall losses in order to determine the rainfall excess. An IL of 0 mm was adopted for both the impervious and pervious areas within the catchment. This value is based on the principle that “Design Events” are representative of a storm burst, however do not account for antecedent rainfall which may saturate the catchment prior to the main burst.

A CL of 2.5 mm/hr was adopted for the pervious areas within the catchment, and 0 mm/hr for the impervious areas. This values are lower than those derived from the results of the calibration process. However it was considered reasonable to adopt this conservative approach in recognition of the limited calibration data, and in order to conform to the collective practice in Queensland for design event hydrology.

Design hyetographs
Design hyetographs were derived from the techniques in AR&R (1987). Hyetographs were created for the 2-yr ARI (39 % AEP), 5-yr ARI (18 % AEP), 10-yr ARI (10 % AEP), 20-yr ARI (5 % AEP), 50-yr ARI (2 % AEP) and 100-yr ARI (1 % AEP) events, considering durations of 30 minutes, 1 hour, 1.5 hours, 2 hours, 3 hours and 4.5 hours.

6.4 Design Event Hydraulic Modelling

6.4.1 Overview

The TUFLOW model was used to determine design flows and flood levels for those scenarios as detailed in Table 6.2 for the 2-yr ARI (39 % AEP) to the 100-yr ARI (1 % AEP) events. These events were simulated for durations from 30 minutes to 4.5 hours.

6.4.2 TUFLOW model roughness

The hydraulic roughness in the calibrated TUFLOW model was updated as required to represent the ultimate catchment conditions.

6.4.3 TUFLOW model boundaries

Design Inflows
The design inflow (Q-T) boundaries to the TUFLOW model were taken from the XP-RAFTS model for each ARI and duration, with the inflow locations being the same as the Calibration modelling.

Design Tailwater Boundary
The design event TUFLOW model utilised a fixed or static tailwater level (TWL), using the same Coincident Flooding analysis as presented in Section 5.3.5.

6.5 Results and Mapping

6.5.1 Critical Durations

A full range of durations (30 minutes, 1 hour, 1.5 hours, 2 hours, 3 hours and 4.5 hours) were simulated for the 2-yr ARI (39 % AEP) to 100-yr ARI (1 % AEP) events. From the results, the critical duration at key locations within the catchment was extracted and is provided in Table 6.3. For this purpose, the critical duration is the storm duration which produces the peak flood level.

The results indicate the 60-minute duration storm is critical for larger volume ARI events, and/or locations upstream of Algester Road where floodplain storage is relatively smaller. The 90-minute duration storm is critical for smaller volume ARI events, and/or locations downstream of Algester Road where floodplain storage is relatively larger.

Table 6.3 – Critical Durations at Key Locations

Key Location	Critical Duration (minutes)					
	2-yr ARI (39% AEP)	5-yr ARI (18% AEP)	10-yr ARI (10% AEP)	20-yr ARI (5% AEP)	50-yr ARI (2% AEP)	100-yr ARI (1% AEP)
Sheep Station Gully Creek						
Paradise Road	90	90	90	90	90	60
Ridgewood Road	90	90	90	90	60	60
Algester Road South	90	90	90	90	60	60
Laurel Oak Drive	90	90	90	90	60	60
Nottingham Road	90	90	90	90	60	60
Algester Road North (Tributary A)	90	90	90	90	60	60
Formby Road (Tributary A)	60	60	60	60	60	60
Ormskirk Street (Tributary A)	60	60	60	60	60	60

6.5.2 Peak Discharge Results

The following Table 6.4 provides peak flows at selected major hydraulic structures for the Scenario 1 conditions. The results indicate that the peak flow generally increases in the downstream direction of both creeks, as would typically be expected. An exception to this is at Formby Road where the discharge is slightly lower, primarily a result of storage attenuation within Calamvale Park.

Table 6.4 – Design Event Peak Discharge at Selected Major Structures (Scenario 1)

Key Location	Peak Discharge (m^3/s)					
	2-yr ARI (39% AEP)	5-yr ARI (18% AEP)	10-yr ARI (10% AEP)	20-yr ARI (5% AEP)	50-yr ARI (2% AEP)	100-yr ARI (1% AEP)
Sheep Station Gully Creek						
Paradise Road	39.1	56.3	67.6	81.8	98.6	114.2
Ridgewood Road	35.8	52.6	63.9	78.1	93.9	110.8
Algester Road South	14.7	22.5	28.0	34.7	41.7	49.9
Laurel Oak Drive	13.1	20.4	25.6	32.2	38.6	46.1
Nottingham Road	12.6	19.8	25.2	31.5	37.6	44.9
Algester Road North (Tributary A)	20.1	27.5	32.1	39.6	48.8	57.3
Formby Road (Tributary A)	8.4	11.3	12.1	15.1	18.3	19.3
Ormskirk Street (Tributary A)	6.9	10.3	11.6	15.9	20.0	23.5

6.5.3 Peak Flood Levels

Tabulated peak flood level results for the design events are provided at the following locations for the open waterway sections of both creeks:

- Scenario 1: 2-yr ARI (39 % AEP) to 100-yr ARI (1 % AEP) events – Appendix D
- Scenario 2: 100-yr ARI (1 % AEP) events – Appendix J
- Scenario 3: 2-yr ARI (39 % AEP) to 100-yr ARI (1 % AEP) events – Appendix E

The peak flood levels are the maximum flood level when considering the full range of durations from 30-minute to 4.5 hours. The peak flood levels are extracted along the current AMTD line.

6.5.4 ARI Estimates of Calibration Events

In order to estimate the ARI of the calibration events modelled, comparisons of discharge were made at key locations with discharge from the Design Events modelled above. The corresponding ARI for the calibration events based on discharge are provided in Table 6.5.

Table 6.5 – Estimated ARI of the Calibration Events

Location	27th Jan 2013		23rd Jan 2015	
	Discharge (m^3/s)	ARI (yrs)	Discharge (m^3/s)	ARI (yrs)
Algester Road North	9.1	<1	11.8	~1
Algester Road South	8.2	<1	11.7	~1
Paradise Road (outlet)	20.0	<1	28.0	~1

6.5.5 Flood Immunity of Existing Crossings

The flood immunities of the existing waterway crossings under Scenario 1 conditions are presented in Table 6.6. Only levels of immunity of up to 100-yr ARI (1 % AEP) are considered. Interpolation between ARIs to ascertain an intermediate ARI value has not been undertaken. The flood immunity estimates are determined from the Hydraulic Structure Reference Sheets in Appendix H. It should be noted that these flood immunities represent localised flooding from Sheep Station Gully only, along with minor coincident flooding in Oxley Creek. These immunities do not consider full scale regional flooding dominated by Oxley Creek.

Table 6.6 – Flood Immunity at Major Structures

Location	Flood Immunity (ARI)
Paradise Road	<1yr
Railway Crossing	100yr
Ridgewood Rd	20yr
Algester Rd North	<1yr
Algester Rd South	100yr
Laurel Oak Dr	20yr
Formby St	<1yr
Ormskirk St	<1yr
Nottingham Rd	100yr

6.5.6 Hydraulic Structure Reference Sheets

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

6.5.7 Flood Mapping

The flood mapping products are provided in Volume 2 and include the Scenario 1 Flood Extent Mapping, for the events 2-yr ARI (39 % AEP) to 100-yr ARI (1 % AEP).

7.0 Rare and Extreme Event Analysis

7.1 Rare and Extreme Event Scenarios

Table 7.1 indicates the events and scenarios modelled as part of the rare and extreme event analysis. These scenarios have been previously described in Section 6.2. All rare and extreme event modelling was undertaken using ultimate hydrological conditions, and in accordance with City Project Office's adopted methodology[5].

Table 7.1 – Extreme Event Scenarios

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

For the modelling of the Scenario 3 events, the fill height outside of the MFC is set to the Scenario 3 100-yr ARI (1 % AEP) flood level plus an additional height allowance of 0.3 m. The "100-yr ARI (1 % AEP) plus 0.3 m flood surface" is then required to be stretched, of which the methodology is detailed below.

7.2 Flood Extent Stretching Process

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 Scenario 1 "existing" 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.

In order to create the "stretched" flood surface(s), the Scenario 3 "ultimate" flood level surfaces were firstly required to be generated. As previously discussed in Section 6.2, the ultimate scenario involves modifying the flood model topography to represent a fully developed (filled) floodplain in accordance with City Plan and in most instances making further allowances for a riparian corridor.

WaterRIDE was utilised for the purpose of stretching the Scenario 3 "ultimate" case results and producing the "stretched" flood surface(s). The WaterRIDE 'buffer width' tool was used, whereby the surface is extended by an equal number of grid cells (or TIN triangles) as a buffer around the current wet cells. A minimum depth threshold is used to determine what surrounding cells (within the buffer width) are considered 'available' for stretching. For this purpose, a value of 200 was used for the

[5] Technical Memorandum for Adopted Methodology – Extreme Events Modelling. Planning & Design Branch, City Projects Office. Trim reference: CA13/648738. 15th March 2013.

buffer width and -2 for the minimum depth threshold. Using these high values / tolerances ensured the flood surface was initially stretched far beyond the realistic limit of stretching. The stretched flood surface was then mapped onto the ground surface terrain grid to produce the mapped flood extents of the stretched flood surface.

From experience to date, it is known that there are inherent anomalies with the stretching process and some degree of manual intervention is typically required by an experienced / skilled practitioner to produce a more realistic stretched flood surface. To facilitate this process, a comparison of the mapped extent against the “existing” flooding extents (including larger events) was undertaken. In areas where there were obvious anomalies, some minor adjustments were made to the mapped extents of the stretched flood surface.

7.3 Rare and Extreme Event Hydrology

7.3.1 Overview

Rare and extreme event flood hydrology was determined for the following events, as detailed further in Sections 7.3.2 to 7.3.4.

(i) 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) events

(ii) 2000-yr ARI (0.05 % AEP) event, and

(iii) Probable Maximum Precipitation (PMP)

7.3.2 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) Events

The 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) design IFD rainfall data was obtained using the CRC-Forge method for the events. Table 7.2 indicates the adopted 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) design rainfall intensities with comparison to the adopted 100-yr ARI (1 % AEP). The 2-hour and 4.5-hour values were interpolated as CRC-Forge does not produce results for these intermediate values. The interpolation was based by plotting a graph (i.e. 200-yr and 500-yr ARI) and estimating the values at the time of interest. The 100-yr ARI (1 % AEP) AR&R design temporal pattern was adopted for both these events to create the hyetograph.

Table 7.2 – Adopted IFD (200-yr ARI and 500-yr ARI)

Duration (hr)	Rainfall Intensity (mm/hr)		
	100-yr ARI (1 % AEP)	200-yr ARI (0.5 % AEP)	500-yr ARI (0.2 % AEP)
0.5	150.0	174.2	203.7
1	103.0	121.4	141.9
2	66.3	76.8 (1)	89.8 (1)
3	50.4	57.53	67.3
4.5	38.0	43.2 (1)	50.5 (1)

Note (1) - Interpolated value

7.3.3 2000-yr ARI (0.05 % AEP) and PMP

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	0.0	0.0	3.17	58	37.7	89.1
0.17	1	4.0	11.8	3.33	70	37.7	89.1
0.33	3	4.0	11.8	3.50	75	14.7	45.4
0.50	4	4.0	11.8	3.67	77	7.0	32.8
0.67	5	4.0	11.8	3.83	80	7.0	32.8
0.83	6	4.0	11.8	4.00	82	7.0	32.8
1.00	8	4.0	11.8	4.17	84	7.0	21.9
1.17	9	4.0	16.0	4.33	86	7.0	21.9
1.33	10	4.0	16.0	4.50	89	7.0	21.9
1.50	11	4.0	16.0	4.67	90	4.0	16.0
1.67	14	7.0	21.9	4.83	91	4.0	16.0
1.83	16	7.0	21.9	5.00	92	4.0	16.0
2.00	18	7.0	21.9	5.17	94	4.0	11.8
2.17	20	7.0	32.8	5.33	95	4.0	11.8
2.33	23	7.0	32.8	5.50	96	4.0	11.8
2.50	25	7.0	32.8	5.67	97	4.0	11.8
2.67	30	14.7	45.4	5.83	99	4.0	11.8
2.83	34	14.7	45.4	6.00	100	4.0	11.8
3.00	46	37.7	89.1				

The 2000-yr ARI (0.05 % AEP) IFD rainfall 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 on 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 this more extreme 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 312.5 mm.

For the PMP scenario, the 6-hr super-storm approach was also undertaken 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 is to be used to estimate the PMP over areas up to 520 km^2 and for durations up to 6 hours. A catchment size of 6.9 km^2, terrain type rough or 'R', 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 969 mm.

7.4 Hydraulic Modelling

7.4.1 General

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 / produced.

7.4.2 TUFLOW model extents

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

7.4.3 TUFLOW model roughness

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

7.4.4 TUFLOW model boundaries

Design Inflows

Again, the rare and extreme event inflow (Q-T) boundaries to the TUFLOW model were taken from the RAFTS model. No changes were made to the inflow locations.

Design Tailwater Boundary

Tailwater level boundaries were used as developed in Section 5.3.5.

7.4.5 Hydraulic Structures

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

7.5 Results and Mapping

7.5.1 Peak Flood Levels

Tabulated peak flood level results for the rare and extreme events are provided at the following locations for the open waterway sections of both creeks:

- Scenario 1, 200-yr ARI (0.5 % AEP) to 2000-yr ARI (0.05 % AEP) events – (on file – Additional Model Results.xls)
- Scenario 3, 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) events – Appendix F

7.5.2 Flood Mapping

The flood mapping products are provided in Volume 2 and include Scenario 1 Flood Extent Mapping: 200-yr ARI (0.5 % AEP), 500-yr ARI (0.2 % AEP) and 2000-yr ARI (0.05 % AEP).

7.5.3 Longitudinal Profiles

Longitudinal plots of the Scenario 1 100-yr ARI (1 % AEP) to PMF flood profiles are provided in Figure 7.1 and Figure 7.2 respectively. The average increase in flood level along the length of both creeks when compared to the 100-yr ARI (1 % AEP) flood profile is indicated in Table 7.4. The results indicate the average increase in flood level is consistent, with higher increases in the lower flatter reaches (Paradise Road to Algester Road), and lower increases in the upper steeper reaches above Algester Road.

Table 7.4 – Average Increase in Flood Level of Extreme Events Over 100yr ARI

Event	Average Increase in Flood Level (m) with reference to the 100-yr ARI (1 % AEP) flood level			
	Paradise Rd to Algester West	Algester West to Nottingham Road	Paradise Rd to Algester East	Algester East to Ormskirk Street
200-yr ARI (0.5 % AEP)	0.21	0.20	0.21	0.08
500-yr ARI (0.2 % AEP)	0.45	0.39	0.45	0.17
2000-yr ARI (0.05 % AEP)	0.90	0.61	0.92	0.32
PMF	2.20	1.59	2.22	1.05

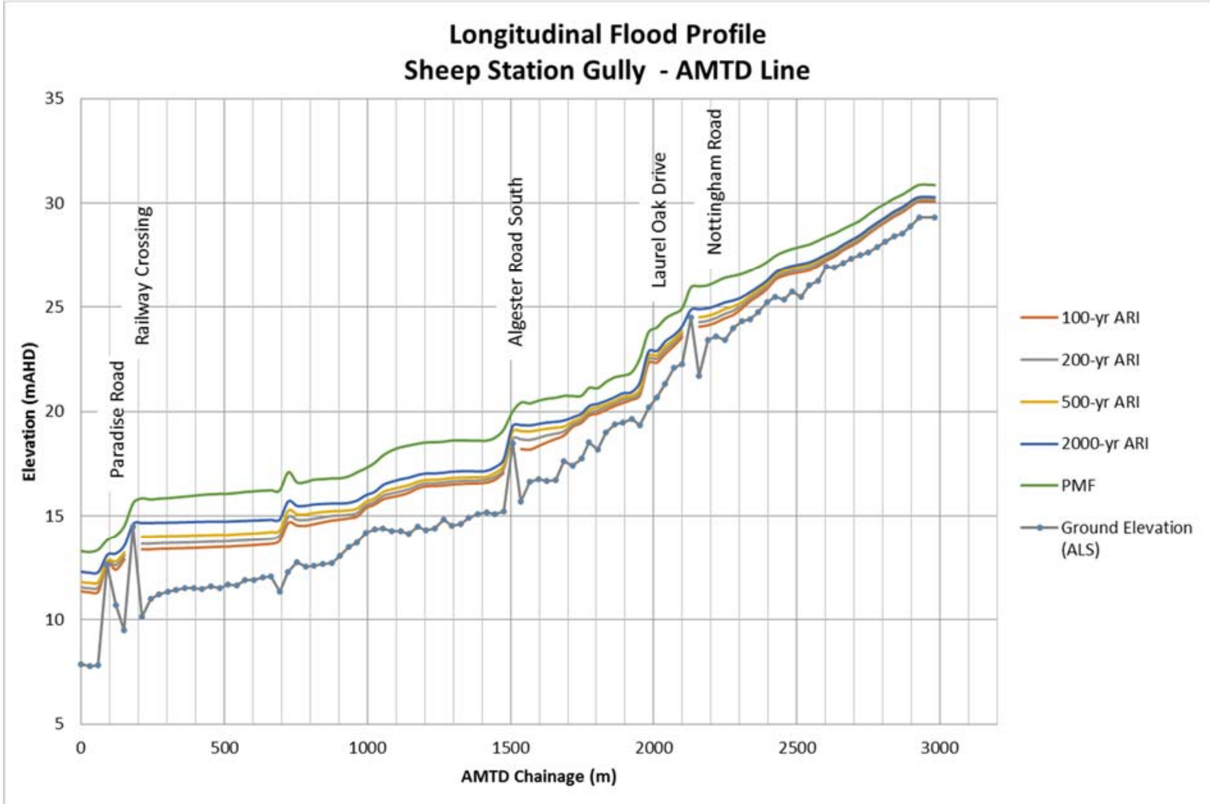

Figure 7.1: Longitudinal Flood Profile – Sheep Station Gully - AMTD Line

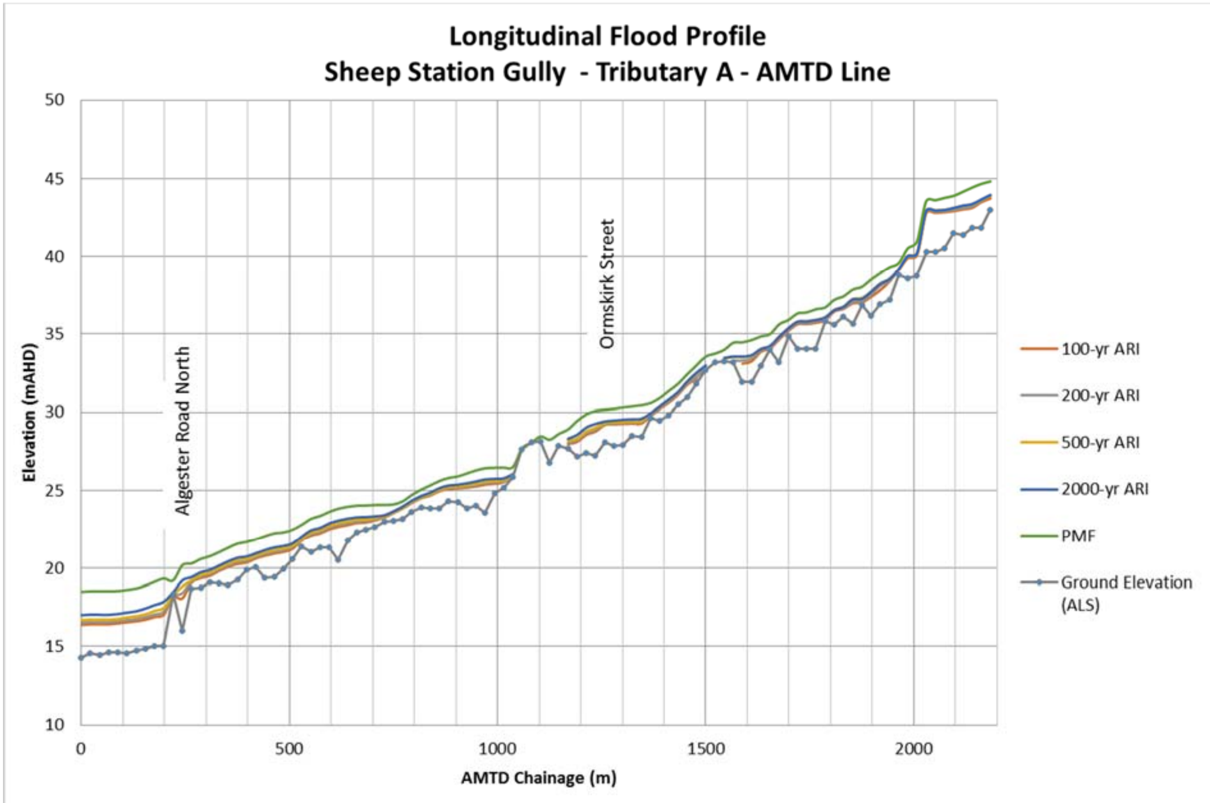

Figure 7.2: Longitudinal Flood Profile – Tributary A - AMTD Line

8.0 Climate Variability and Structure Blockage

8.1 Overview

To enable comprehensive strategic planning to be undertaken, BCC flood studies are required to undertake a sensitivity analysis to address the following:

- Climate variability
- Hydraulic structure blockage

The following sections provide the details of these analyses.

8.2 Climate Variability

8.2.1 Overview

To enable BCC to undertake future land-use planning from an informed perspective, there is a requirement to understand the impacts of climate variability on flooding. BCC flood studies are therefore required to utilise the latest statutory guidelines in order to assess the impacts of climate variability. To enable BCC to understand and plan for the impacts of climate variability on flooding, a number of climate variability e scenarios were undertaken, as outlined below. These scenarios are consistent with the most 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

8.2.2 Modelled Scenarios

Modelling was undertaken to determine the climate variability 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 variability modifications undertaken.

Table 8.1 – Climate Variability Modelling Scenarios

ARI (year)	AEP (%)	Planning horizon	Rainfall Intensity	Tailwater 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	✓	×

8.2.3 Hydraulic Modelling

The climate variability TUFLOW model(s) incorporated the same model set-up as the design event TUFLOW model(s). The inflow boundary locations did not change from the design event modelling. Tailwater level boundaries were used as developed in Section 5.3.5. The XP-RAFTS model was utilised to derive the inflow boundary conditions for the +10 % rainfall intensity and +20 % rainfall intensity scenarios.

8.2.4 Impacts of Climate Variability

Tables 8.2 to 8.4 indicate a comparison of the peak flood levels for the Scenario 1 climate variability conditions. The flood level results are provided at selected locations for the 100-yr ARI (1 % AEP), 200-yr ARI (0.5 % AEP) and 500-yr ARI (0.2 % AEP) events. The results indicate that climate variability impacts within the catchment will increase the magnitude of flooding, for example:

- By the year 2050, the 100-yr ARI (1 % AEP) flood levels will be of similar magnitude to the current day 200-yr ARI (0.5 % AEP) flood levels.
- By the year 2100, the 200-yr ARI (0.5 % AEP) flood levels will be of similar magnitude to the current day 500-yr ARI (0.2 % AEP) flood levels.

Table 8.2 – 100-yr ARI (1 % AEP) Climate Variability Impacts at Selected Locations (Scenario 1)

Structure Location	100-yr ARI (1 % AEP) Flood Level (m AHD)		
	Existing	2050	2100
Paradise Road	12.41	12.55	12.67
Railway Crossing	13.35	13.50	13.85
Ridgewood Rd	14.55	14.72	15.05
Algester Rd North	18.10	18.20	18.68
Algester Rd South	18.17	18.43	18.96
Laurel Oak Dve	22.31	22.41	22.60
Formby Rd	22.99	23.03	23.13
Ormskirk St	29.15	29.28	29.34
Nottingham Rd	24.01	24.12	24.39

Table 8.3 – 200-yr ARI (0.5 % AEP) Climate Variability Impacts at Selected Locations (Scenario 1)

Structure Location	200-yr ARI (0.5 % AEP) Flood Level (m AHD)		
	Existing	2050	2100
Paradise Road	12.59	12.64	12.89
Railway Crossing	13.62	13.82	14.24
Ridgewood Rd	14.85	15.02	15.34
Algester Rd North	18.36	18.64	19.00
Algester Rd South	18.64	18.94	19.21
Laurel Oak Dve	22.49	22.60	22.77
Formby Rd	23.07	23.12	23.23
Ormskirk St	29.09	29.33	29.40
Nottingham Rd	24.22	24.39	24.71

Table 8.4 – 500-yr ARI (0.2 % AEP) Climate Variability Impacts at Selected Locations (Scenario 1)

Structure Location	500-yr ARI (0.2 % AEP) Flood Level (m AHD)	
	Existing	2100
Paradise Road	12.72	13.16
Railway Crossing	13.95	14.59
Ridgewood Rd	15.12	15.55
Algester Rd North	18.78	19.23
Algester Rd South	19.04	19.37
Laurel Oak Dve	22.64	22.92
Formby Rd	23.15	23.33
Ormskirk St	29.05	29.47
Nottingham Rd	24.45	24.97

8.3 Hydraulic Structure Blockage

8.3.1 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 provide an understanding of the potential impacts should the selected hydraulic structure(s) become blocked during an event.

8.3.2 Blockage Scenarios

A total of 9 hydraulic structures were selected for blockage assessment, that is, those contained in the Hydraulic Structure Reference Sheets in Appendix H: Hydraulic Structure Reference Sheets. See

Table 8.5 below. These structures were selected primarily on their function to convey flow under transport routes which cross the main branches of the creek, and therefore pose the highest potential consequences if blockage occurs. Other factors were considered, including the following:

- the predominant upstream catchment use;
- availability of woody debris;
- existing submergence of the inlet;
- flood risk to upstream properties; and
- flooding characteristics of the reach

The blockage analysis has been carried out with the existing case scenario (Scenario 1) for the 100-yr ARI (1 % AEP) design event only. Individual structures were blocked and modelled separately to ensure that the blockage impacts would not be masked by the effect of blocking other upstream structures.

The Queensland Urban Drainage Manual (QUDM) was used as guidance for the degree of blockage for each structure; refer to Table 10.4.1 of this manual. For the purposes of this sensitivity analysis "severe" blockage conditions have been assumed. "Severe" blockage is defined as the level of blockage considered possible during the design life of the structure. Given that the sensitivity analysis is only being undertaken for a low probability large flooding event (i.e. 100-yr ARI), which is only likely to occur one or two times during the design life of the structure, this level of blockage is considered more appropriate than the "design" blockage.

8.3.3 Impacts of Structure Blockage

Table 8.5 gives the 100-yr ARI (1 % AEP) flood level and afflux immediately upstream of the hydraulic structure for each of six blockage simulations. The 2000-yr ARI (0.05 % AEP) flood level is also shown for comparative purposes. The flood level results for the AMTD Lines are provided on file (Additional Model Results.xls). The following observations are made:

- The results indicate that at two locations the full blockage of the structure results in an upstream flood level greater than the 2000-yr ARI (0.05 % AEP) flood level. These locations are at Algester Road North and Laurel Oak Drive.
- At Formby Street, the full blockage of the structure results in negligible afflux. This is a result of the structure being downstream controlled and completely drowned during even minor events.

Table 8.5 – 100-yr ARI Blockages (Scenario 1)

Blockage Scenario	Structure Location	Structure Details (m)	Blockage (%)(2)	Flood Level (m AHD)			Afflux (m)
				100-yr ARI (1% AEP)		2000-yr ARI (0.05% AEP)	
				Exist.	Blocked		
CUL_01	Paradise Rd	RCBC 6 / (W3 x H3)	50	12.41	12.77	13.14	0.36
CUL_02	Railway	Br. 3 Span (W8.9, 8.9, 8.52) H4.2m	30	13.35	13.63	14.62	0.28
CUL_03	Ridgewood Rd	RCBC 5/ (W3.7xH1.8)	60	14.55	15.15	15.55	0.59
CUL_04-05(1)	Algester Rd Sth	RCBC 3/ (W3.7xH1.5)	100	18.17	19.28	19.33	1.12
CUL_06	Laurel Oak	RCBC 3/ (W2.8xH1.3)	100	22.31	22.85	22.85	0.54
CUL_07	Ormskirk Rd	RCP 3/1.2	100	29.15	29.32	29.48	0.17
CUL_08-09(1)	Algester Rd Nth	RCBC 3/ (W3.7xH1.5)	100	18.10	19.29	19.18	1.18
CUL_10	Nottingham Rd	BEBO Arch W12m H3m	50	24.01	24.39	24.84	0.38
CUL_11	Formby St	RCP 7/0.6	100	22.99	23.01	23.29	0.02

(1) Composite structure, made up of an irregular culvert with a low flow middle channel, and two rectangular outside cells.

(2) Based on the relative size of the culvert or bridge and the potential for blockage. Paradise Rd culverts are wide (3m) and require long vegetation to block culverts. This vegetation is likely to collect on culverts upstream. The Railway bridge comprises large spans, therefore allow for moderate blockage on piers only. Ridgewood Road cells are greater than 3m, however the culvert heights are lower. The number of culverts at the Algester Rd crossings (north and south) are small, therefore allow total blockage. Ormskirk Rd and Formby St culverts are small therefore allow total blockage. Nottingham Rd is a large BEBO arch bridge, however has significant sediment aggradation, therefore allow moderate blockage.

9.0 Summary of Study Findings

This flood study report details the calibration and verification, design events, extreme events and sensitivity modelling for Sheep Station Gully. New hydrologic and hydraulic models have been developed for the study using the XP-RAFTS and TUFLOW modelling software respectively.

Hydrometric data was sourced from the available recorded rainfall data. Four MHG's are present within the catchment; however no continuous stream gauges exist. Joint Calibration of the XP-RAFTS and TUFLOW models was undertaken for the 27th January 2013 and 23rd January 2015 events. Verification of the XP-RAFTS and TUFLOW models was undertaken using a Catchment Correlation analysis based on the modelling outputs for other similar urban catchments within the Brisbane LGA.

The results of the hydraulic calibration and verification indicated that the XP-RAFTS and TUFLOW models were able to generally replicate the historical flooding events to within the specified tolerances. However, the one exception was at the MHG SG120 (Algester Road south crossing), where the simulated flood of 23rd January 2015 was 350mm higher than that measured at the MHG.

Cross-checks of the TUFLOW structure head-losses were undertaken at selected structures using the HEC-RAS software, from which it was confirmed that the model was representing the structures adequately.

Design and extreme flood magnitudes were estimated for the full range of events from 2-yr ARI (39% AEP) to PMF. These analyses assumed hydrologic ultimate catchment development conditions in accordance with BCC City Plan (2014).

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 MRC along the edge of the channel.
- Scenario 3 includes an allowance for the MRC (as per Scenario 2) and also assumes filling to the MFC boundary to simulate potential development.

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 100 m intervals along the AMTD line and well as model cross-sections
- Peak flood extent mapping
- Hydraulic structure flood immunity data

As part of the required sensitivity analysis a climate variability 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 ARI (1% AEP), 200-yr ARI (0.5% AEP) and 500-yr ARI (0.2% AEP) events.

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APPENDICES

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Appendix A: Rainfall Distribution Plots

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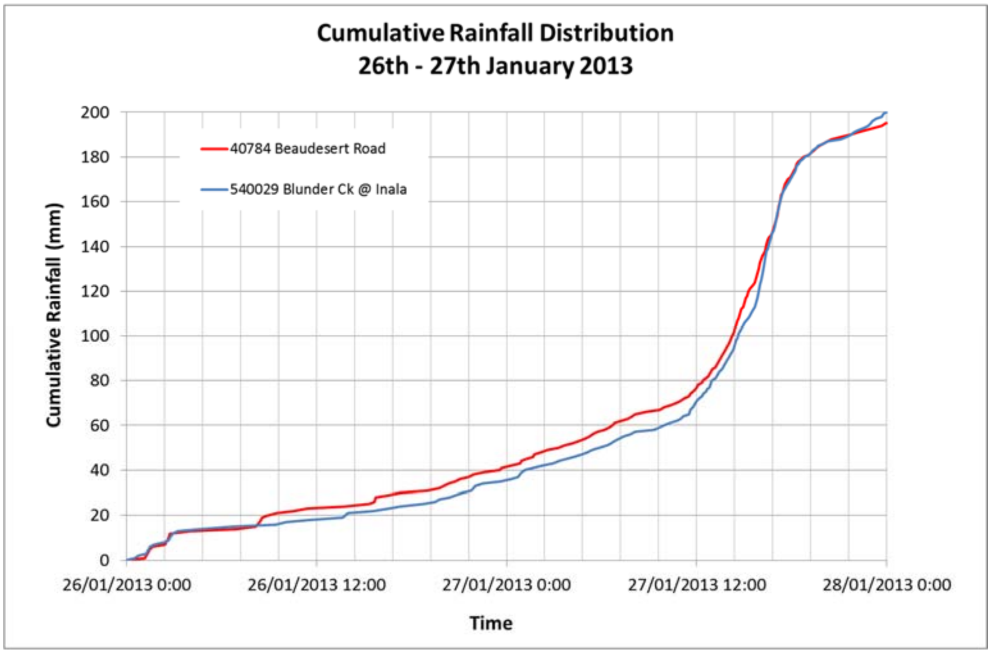
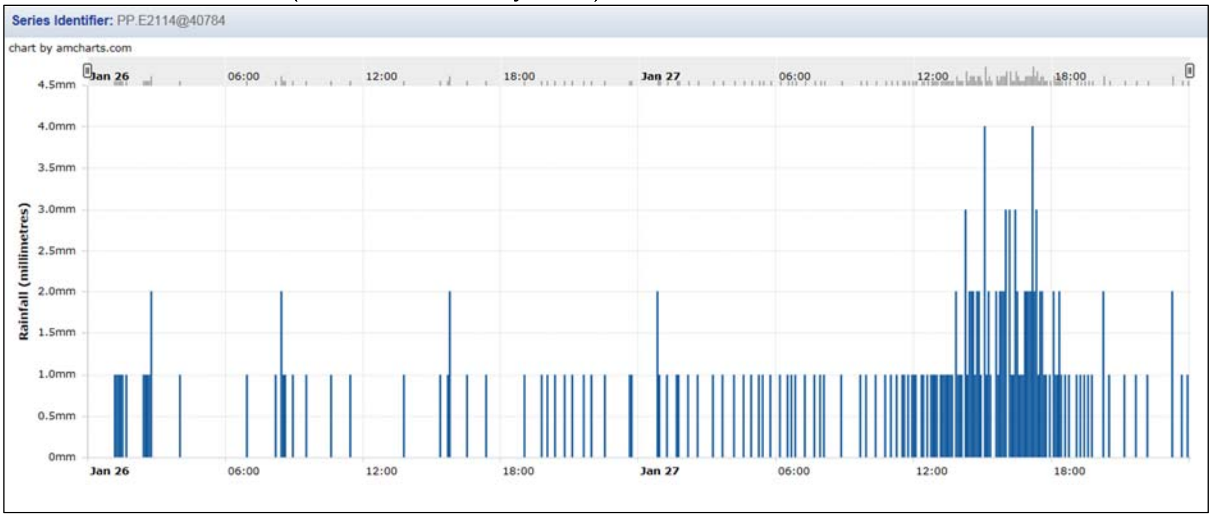
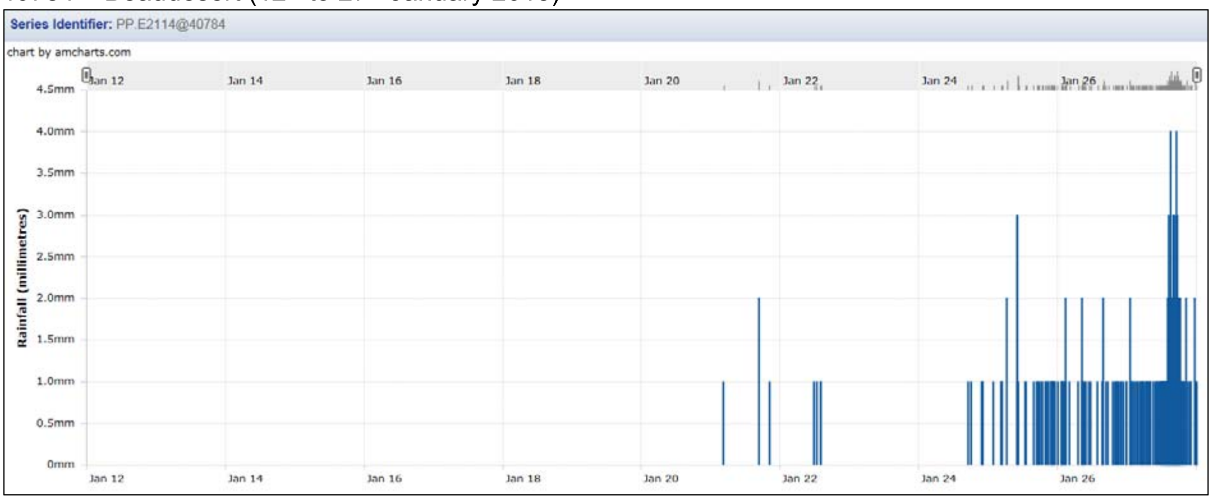
27th January 2013 Event



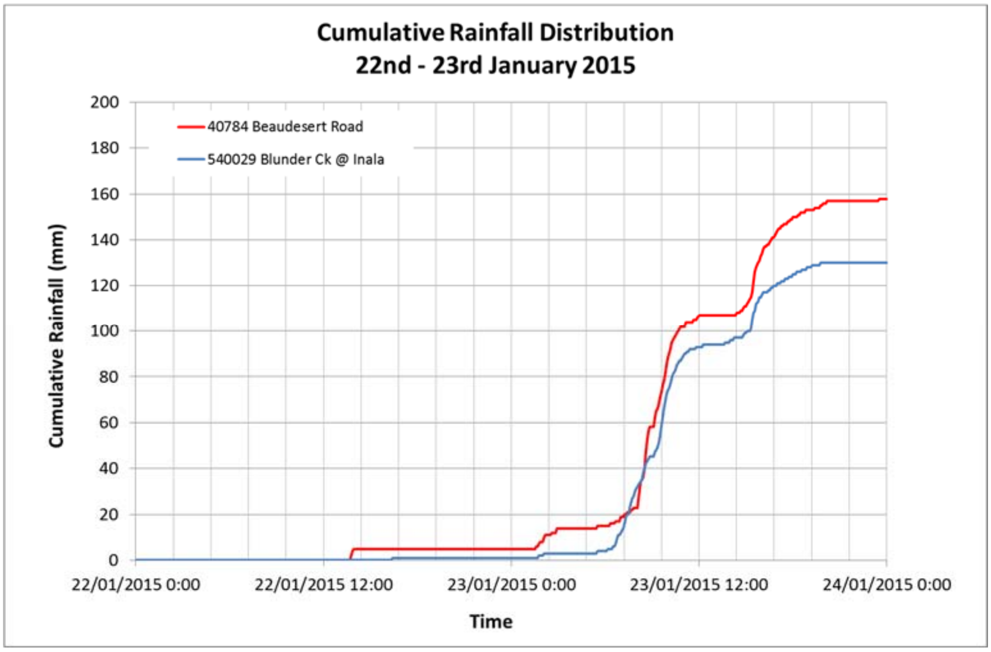
40784 – Beaudesert Rd (26th to 27th January 2013)



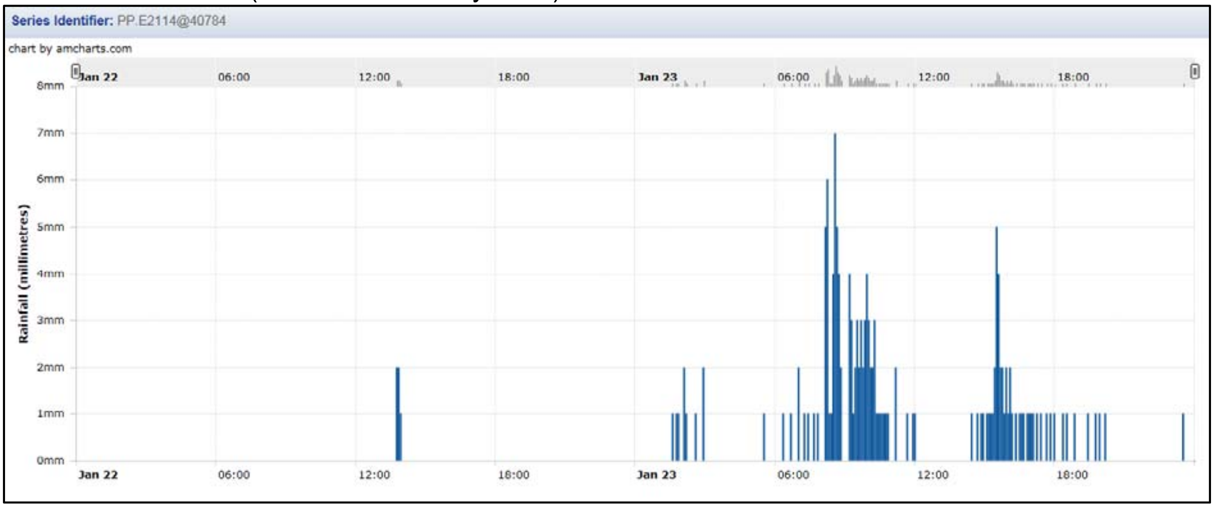
40784 – Beaudesert (12th to 27th January 2013)



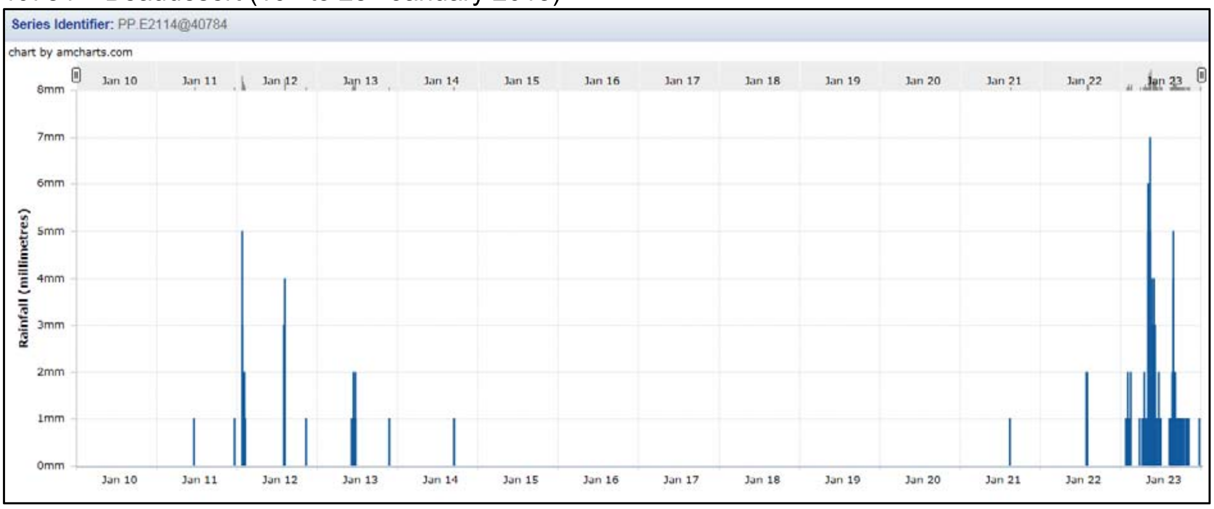
23th January 2015 Event



40784 – Beaudesert (22th to 23th January 2013)



40784 – Beaudesert (10th to 23th January 2013)



Appendix B: XP-RAFTS Sub-catchment Parameters

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Catchment ID	Sub-Catchment Type	Impervious (%)	Area Existing Case (ha)	Area Ultimate Case (ha)	Slope (%)	Roughness (Manning's 'n')
A	PERV	0	4.55	2.3	4.8	0.06
	IMP	100	1.78	4.02	4.8	0.018
AA	PERV	0	7.72	6.05	3.1	0.06
	IMP	100	4.9	6.57	3.1	0.018
AB	PERV	0	4.4	4.03	3.7	0.06
	IMP	100	4.78	5.15	3.7	0.018
AC	PERV	0	2.8	2.86	2.8	0.06
	IMP	100	2.75	2.69	2.8	0.018
AD	PERV	0	4.98	4.89	3.9	0.06
	IMP	100	6.72	6.82	3.9	0.018
AE	PERV	0	5.83	5.32	3.8	0.06
	IMP	100	6.05	6.57	3.8	0.018
AF	PERV	0	4.67	4.0	2.4	0.06
	IMP	100	3.97	4.65	2.3	0.018
AG	PERV	0	5.23	4.87	6.2	0.06
	IMP	100	6.16	6.52	6.2	0.018
AH	PERV	0	1.83	2.02	5.9	0.09
	IMP	100	0.29	0.11	5.9	0.018
AI	PERV	0	5.66	5.56	10.1	0.07
	IMP	100	2.01	2.12	10.1	0.018
AJ	PERV	0	4.32	2.85	5.9	0.06
	IMP	100	2.44	3.91	5.9	0.018
AK	PERV	0	4.37	3.49	5.8	0.06
	IMP	100	3.91	4.78	5.8	0.018
AL	PERV	0	5.93	3.37	4.0	0.07
	IMP	100	1.75	4.31	4.0	0.018
AM	PERV	0	5.84	2.68	7.5	0.07
	IMP	100	1.48	4.64	7.4	0.018
AN	PERV	0	4.09	1.41	7.0	0.09
	IMP	100	0.6	3.29	7.0	0.018
AO	PERV	0	6.75	5.43	4.7	0.06
	IMP	100	6.5	7.82	4.7	0.018
AP	PERV	0	2.5	1.1	4.2	0.07
	IMP	100	0.79	2.2	4.2	0.018
AQ	PERV	0	2.51	1.04	4.4	0.07
	IMP	100	0.91	2.38	4.4	0.018
AR	PERV	0	7.96	3.5	5.6	0.07
	IMP	100	1.93	6.38	5.6	0.018
AS	PERV	0	1.88	1.71	4.2	0.06
	IMP	100	2.19	2.37	4.2	0.018
AT	PERV	0	3.34	2.26	5.5	0.06
	IMP	100	1.9	2.98	5.5	0.018
AU	PERV	0	2.41	1.95	5.0	0.06
	IMP	100	1.77	2.23	5.0	0.018
AV	PERV	0	1.69	1.73	4.9	0.06
	IMP	100	2.44	2.4	4.9	0.018

Catchment ID	Sub-Catchment Type	Impervious (%)	Area Existing Case (ha)	Area Ultimate Case (ha)	Slope (%)	Roughness (Manning's 'n')
AW	PERV	0	4.06	3.57	6.8	0.06
	IMP	100	3.9	4.4	6.8	0.018
AX	PERV	0	3.08	2.99	4.6	0.06
	IMP	100	3.13	3.22	4.6	0.018
AY	PERV	0	2.3	2.24	3.2	0.06
	IMP	100	1.88	1.95	3.2	0.018
AZ	PERV	0	1.46	1.29	1.8	0.06
	IMP	100	0.38	0.55	1.8	0.018
B	PERV	0	3.72	2.75	5.4	0.06
	IMP	100	2.88	3.85	5.4	0.018
BA	PERV	0	5.98	4.29	2.9	0.06
	IMP	100	5.03	6.72	2.9	0.018
BB	PERV	0	2.34	1.87	2.0	0.07
	IMP	100	0.78	1.25	2.0	0.018
BC	PERV	0	3.3	1.82	2.0	0.07
	IMP	100	0.65	2.13	2.0	0.018
BD	PERV	0	2.09	2.13	5.2	0.06
	IMP	100	2.88	2.84	5.2	0.018
BE	PERV	0	5.7	2.92	3.3	0.06
	IMP	100	1.8	4.57	3.3	0.018
BF	PERV	0	5.59	5.12	3.2	0.06
	IMP	100	6.78	7.25	3.2	0.018
BG	PERV	0	3.84	3.64	3.5	0.06
	IMP	100	5.04	5.23	3.5	0.018
BH	PERV	0	5.19	1.94	4.3	0.07
	IMP	100	1.06	4.31	4.3	0.018
BI	PERV	0	4.74	2.83	3.9	0.06
	IMP	100	2.91	4.82	3.9	0.018
BJ	PERV	0	3.42	3.46	1.2	0.06
	IMP	100	0.23	0.18	1.2	0.018
BK	PERV	0	4.54	3.55	4.3	0.06
	IMP	100	5.39	6.38	4.3	0.018
BL	PERV	0	7.19	4.37	4.3	0.06
	IMP	100	4.38	7.21	4.3	0.018
BM	PERV	0	5.54	3.15	4.4	0.06
	IMP	100	2.45	4.84	4.4	0.018
BN	PERV	0	8.65	4.1	3.1	0.07
	IMP	100	3.41	7.96	3.1	0.018
BO	PERV	0	5.4	2.79	2.5	0.06
	IMP	100	2.46	5.07	2.5	0.018
BP	PERV	0	5.44	2.71	3.1	0.06
	IMP	100	1.64	4.37	3.1	0.018
BQ	PERV	0	13.69	8.6	2.3	0.07
	IMP	100	1.97	7.07	2.2	0.018
BR	PERV	0	4.81	3.21	5.3	0.06
	IMP	100	3.8	5.41	5.3	0.018

Catchment ID	Sub-Catchment Type	Impervious (%)	Area Existing Case (ha)	Area Ultimate Case (ha)	Slope (%)	Roughness (Manning's 'n')
BS	PERV	0	3.56	3.47	3.6	0.06
	IMP	100	3.59	3.68	3.6	0.018
BT	PERV	0	3.65	2.84	4.0	0.06
	IMP	100	2.31	3.13	4.0	0.018
BU	PERV	0	6.87	5.97	4.4	0.06
	IMP	100	3.37	4.26	4.4	0.018
BV	PERV	0	2.27	2.19	2.7	0.06
	IMP	100	1.62	1.7	2.7	0.018
BW	PERV	0	4.72	4.15	6.8	0.06
	IMP	100	2.13	2.69	6.8	0.018
BX	PERV	0	4.79	4.42	5.0	0.06
	IMP	100	5.93	6.3	5.0	0.018
BY	PERV	0	3.58	3.27	4.7	0.06
	IMP	100	4.32	4.63	4.7	0.018
BZ	PERV	0	4.16	3.29	3.3	0.06
	IMP	100	3.12	4.0	3.3	0.018
C	PERV	0	5.33	3.49	4.4	0.06
	IMP	100	3.28	5.12	4.4	0.018
CA	PERV	0	2.47	2.19	3.5	0.06
	IMP	100	2.8	3.08	3.5	0.018
CB	PERV	0	3.22	2.62	5.1	0.06
	IMP	100	3.12	3.71	5.1	0.018
CC	PERV	0	5.95	4.64	3.5	0.05
	IMP	100	4.62	5.92	3.5	0.018
CD	PERV	0	6.02	5.14	4.9	0.05
	IMP	100	5.18	6.06	4.9	0.018
CE	PERV	0	2.76	2.19	4.1	0.06
	IMP	100	1.29	1.87	4.1	0.018
CF	PERV	0	2.2	2.15	4.2	0.06
	IMP	100	2.03	2.08	4.2	0.018
CG	PERV	0	4.21	3.83	4.2	0.06
	IMP	100	3.41	3.79	4.2	0.018
CH	PERV	0	6.27	5.24	5.0	0.06
	IMP	100	4.38	5.42	5.0	0.018
CI	PERV	0	4.88	4.04	3.2	0.06
	IMP	100	2.62	3.46	3.2	0.018
CJ	PERV	0	8.7	6.91	3.6	0.06
	IMP	100	5.14	6.93	3.6	0.018
D	PERV	0	2.35	2.52	5.0	0.06
	IMP	100	3.62	3.46	5.0	0.018
E	PERV	0	2.0	1.81	4.9	0.06
	IMP	100	2.22	2.41	4.8	0.018
F	PERV	0	4.05	3.93	5.2	0.06
	IMP	100	5.29	5.41	5.1	0.018
G	PERV	0	6.38	6.21	2.5	0.06
	IMP	100	6.23	6.4	2.5	0.018

Catchment ID	Sub-Catchment Type	Impervious (%)	Area Existing Case (ha)	Area Ultimate Case (ha)	Slope (%)	Roughness (Manning's 'n')
H	PERV	0	4.32	3.37	4.5	0.06
	IMP	100	4.9	5.85	4.5	0.018
I	PERV	0	1.41	1.67	3.1	0.06
	IMP	100	2.65	2.39	3.1	0.018
J	PERV	0	2.97	3.36	4.9	0.06
	IMP	100	5.03	4.64	4.9	0.018
K	PERV	0	3.31	2.61	4.5	0.06
	IMP	100	3.33	4.03	4.5	0.018
L	PERV	0	1.36	1.62	3.9	0.06
	IMP	100	1.68	1.42	3.9	0.018
M	PERV	0	3.31	2.87	4.1	0.06
	IMP	100	3.41	3.85	4.1	0.018
N	PERV	0	1.29	1.51	3.2	0.06
	IMP	100	1.53	1.31	3.2	0.018
O	PERV	0	4.59	4.09	3.3	0.06
	IMP	100	5.3	5.79	3.3	0.018
P	PERV	0	1.84	1.6	3.6	0.06
	IMP	100	2.04	2.29	3.6	0.018
Q	PERV	0	3.28	3.57	2.6	0.06
	IMP	100	2.97	2.69	2.6	0.018
R	PERV	0	3.31	3.37	4.8	0.06
	IMP	100	3.88	3.82	4.8	0.018
S	PERV	0	11.87	6.29	2.7	0.07
	IMP	100	2.62	8.19	2.7	0.018
T	PERV	0	3.54	3.13	3.5	0.06
	IMP	100	4.06	4.47	3.5	0.018
U	PERV	0	1.65	1.84	5.1	0.06
	IMP	100	2.67	2.48	5.1	0.018
V	PERV	0	3.7	3.59	3.9	0.06
	IMP	100	4.61	4.72	3.9	0.018
W	PERV	0	1.69	1.7	3.1	0.06
	IMP	100	1.29	1.29	3.1	0.018
X	PERV	0	3.43	3.99	6.0	0.06
	IMP	100	5.15	4.59	6.0	0.018
Y	PERV	0	3.78	3.5	3.4	0.06
	IMP	100	2.2	2.49	3.4	0.018
Z	PERV	0	3.57	3.84	4.1	0.06
	IMP	100	4.61	4.34	4.1	0.018
ZZ	PERV	0	0.001	0.001	0.0	0.06
	IMP	100	0.001	0.001	0.0	0.018

Appendix C: Adopted Ultimate Land-use

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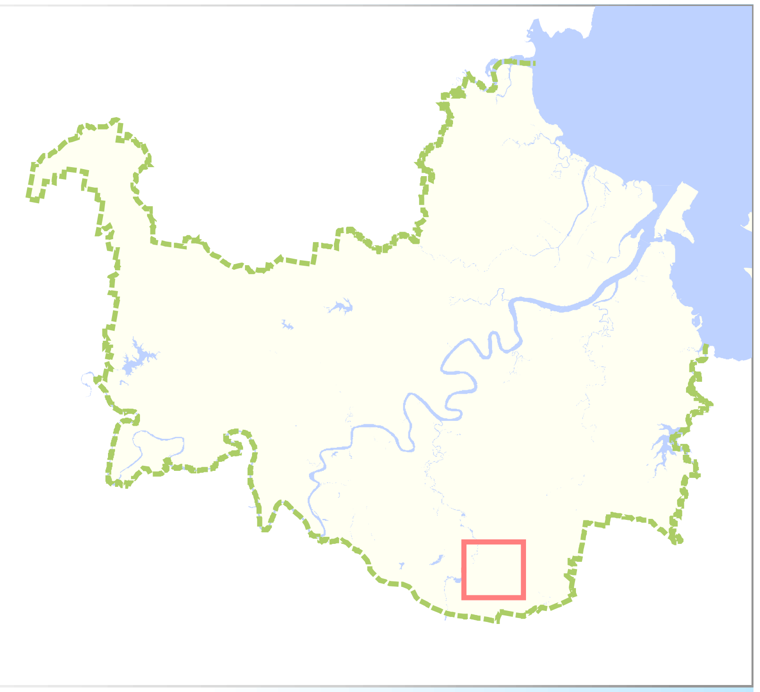
Land-use Type	% Impervious
Low density residential	60
Character residential (Character)	70
Character residential (Infill housing)	70
Low-medium density residential (2 storey mix)	70
Low-medium density residential (2 or 3 storey mix)	70
Low-medium density residential (Up to 3 storeys)	70
Medium density residential	80
High density residential (Up to 8 storeys)	90
High density residential (Up to 15 storeys)	90
Tourist accommodation	80
Neighbourhood centre	90
District centre (District)	90
District centre (Corridor)	90
Major centre	90
Principal centre (City centre)	90
Principal centre (Regional centre)	90
Low impact industry	90
Industry (General industry A)	90
Industry (General industry B)	90
Industry (General industry C)	90
Special industry	90
Industry investigation	90
Sport and recreation	20
Sport and recreation (Local)	20
Sport and recreation (District)	20
Sport and recreation (Metropolitan)	20
Open space	5
Open space (Local)	5
Open space (District)	5
Open space (Metropolitan)	5
Environmental management	5
Conservation	0
Conservation (Local)	0
Conservation (District)	0
Conservation (Metropolitan)	0
Emerging community	70

Land-use Type	% Impervious
Extractive industry	90
Mixed use (Inner city)	90
Mixed use (Centre frame)	90
Mixed use (Corridor)	90
Rural	20
Rural residential	30
Township	80
Community facilities (Major health care)	70
Community facilities (Major sports venue)	60
Community facilities (Cemetery)	40
Community facilities (Community purposes)	70
Community facilities (Education purposes)	70
Community facilities (Emergency services)	70
Community facilities (Health care purposes)	70
Specialised centre (Major education and research facility)	90
Specialised centre (Entertainment and conference centre)	90
Specialised centre (Brisbane Markets)	90
Specialised centre (Large format retail)	90
Specialised centre (Mixed industry and business)	90
Specialised centre (Marina)	80
Special purpose (Defence)	80
Special purpose (Detention facility)	80
Special purpose (Transport infrastructure)	75
Special purpose (Utility services)	75
Special purpose (Airport)	60
Special purpose (Port)	60



Legend

- Creek Centreline
- Freeways/Highways
- Major Roads
- Streets
- Catchment Area

N W E S

0 160 320 480
Metres

Prepared : 089958
Checked : NC
Revision : 0
Publication Date : 17 Jun 2015
Project Number : 150336

Brisbane City Council
City Projects Office
GPO Box 1434
Brisbane Qld 4001

For more information
visit www.brisbane.qld.gov.au
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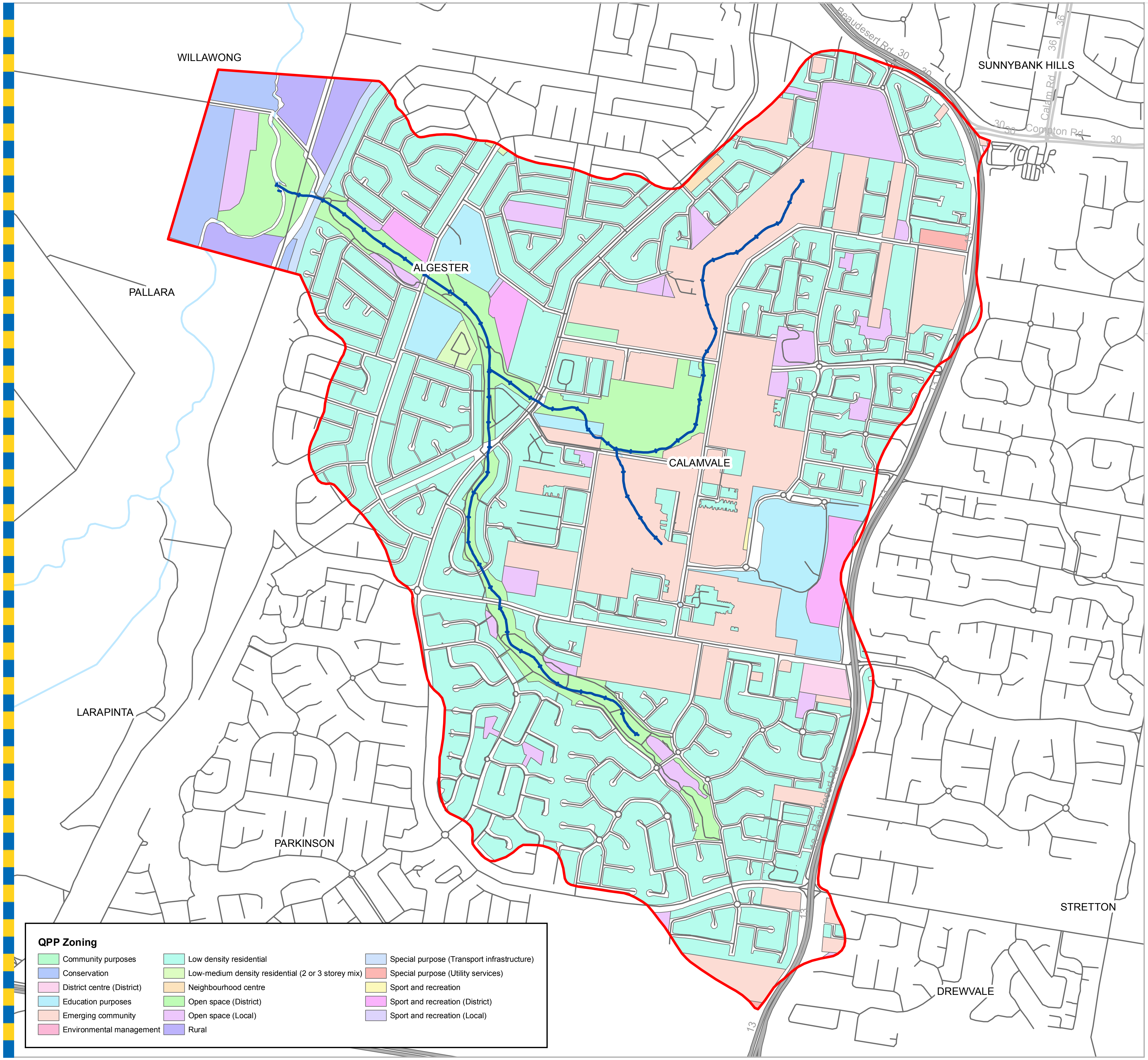
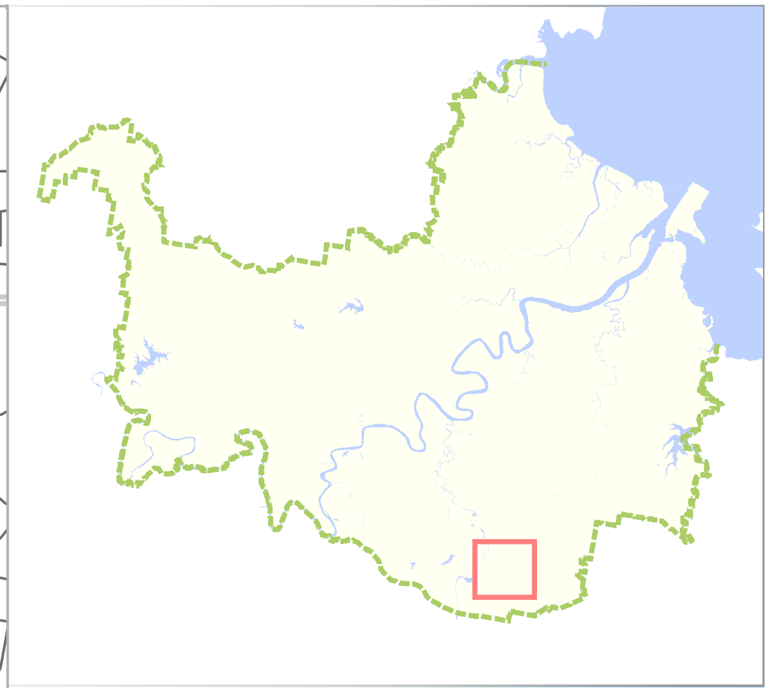
Figure C.2: Catchment Aerial Image

Location: G:\BI\CD\Proj15\150336_Sheep_Station_Gully_Fld_Study\ArcGIS\GIM_150336_018_Aerial.mxd

GIM - 150336 - 018





Legend

- Creek Centreline
- Freeways/Highways
- Major Roads
- Streets
- Catchment Area

N W E S

0 160 320 480
Metres

Prepared : 089958
Checked : NC
Revision : 0
Publication Date : 17 Jun 2015
Project Number : 150336

DATA INFORMATION

Location: G:\BI\CD\Proj15\150336_Sheep_Station_Gully_Fld_Study\ArcGIS\GIM_150336_019_CityPlan.mxd

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City Projects Office
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Brisbane Qld 4001

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Sheep Station Gully Creek Flood Study

Figure C.1: Catchment Land Use

GIM - 150336 - 019

Appendix D: Design Events (Scenario 1) - Peak Flood Levels

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AMTD (m)	Design Events – Scenario 1 (Existing Waterway Conditions) Peak Flood Levels (m AHD)					
	2-yr ARI (39% AEP)	5-yr ARI (18% AEP)	10-yr ARI (10% AEP)	20-yr ARI (5% AEP)	50-yr ARI (2% AEP)	100-yr ARI (1% AEP)
Main Branch						
CH 0	9.87	10.30	10.54	10.81	11.10	11.37
Paradise Road						
CH 100	11.71	12.23	12.28	12.32	12.40	12.50
Railway						
CH 200	12.07	12.48	12.67	12.92	13.17	13.37
CH 300	12.15	12.53	12.73	12.98	13.23	13.42
CH 400	12.32	12.61	12.79	13.03	13.27	13.46
CH 500	12.50	12.73	12.88	13.10	13.33	13.51
CH 600	12.68	12.88	13.02	13.20	13.41	13.59
CH 700	13.04	13.22	13.34	13.48	13.96	14.09
Ridgewood Road						
CH 800	13.82	13.99	14.10	14.23	14.38	14.62
CH 900	14.17	14.34	14.45	14.58	14.67	14.82
CH 1000	14.82	14.98	15.06	15.19	15.29	15.40
CH 1100	15.27	15.45	15.55	15.67	15.81	15.95
CH 1200	15.75	15.94	16.05	16.18	16.31	16.42
CH 1300	15.83	16.03	16.14	16.27	16.40	16.51
CH 1400	15.96	16.12	16.24	16.35	16.47	16.57
CH 1500	16.88	17.19	17.38	17.70	18.06	18.22
Algester Road (South)						
CH 1600	17.27	17.55	17.71	17.95	18.24	18.40
CH 1700	18.71	18.81	18.87	18.92	19.00	19.08
CH 1800	19.23	19.34	19.41	19.49	19.57	19.65
CH 1900	19.65	19.79	19.89	19.97	20.06	20.15
CH 2000	20.23	20.31	20.39	20.49	20.63	20.78
Laurel Oak Drive						
CH 2100	22.19	22.39	22.51	22.64	22.77	22.90
Nottingham Road						
CH 2200	23.05	23.27	23.40	23.54	23.86	24.02
CH 2300	23.55	23.81	23.97	24.13	24.32	24.48
CH 2400	24.79	24.97	25.08	25.19	25.30	25.40
CH 2500	25.81	26.03	26.15	26.26	26.38	26.47
CH 2600	26.11	26.32	26.45	26.57	26.70	26.80
CH 2700	27.07	27.23	27.32	27.42	27.52	27.59
CH 2800	28.08	28.21	28.28	28.36	28.44	28.51

AMTD (m)	Design Events – Scenario 1 (Existing Waterway Conditions) Peak Flood Levels (m AHD)					
	2-yr ARI (39% AEP)	5-yr ARI (18% AEP)	10-yr ARI (10% AEP)	20-yr ARI (5% AEP)	50-yr ARI (2% AEP)	100-yr ARI (1% AEP)
CH 2900	28.92	29.08	29.17	29.27	29.36	29.42
CH 3000	29.98	30.07	30.12	30.19	30.25	30.30
Tributary A						
CH 0	15.73	15.92	16.03	16.15	16.28	16.39
CH 100	15.85	16.04	16.15	16.27	16.40	16.52
CH 200	16.30	16.46	16.57	16.74	16.90	17.06
Algester Road (North)						
CH 300	19.14	19.21	19.26	19.33	19.41	19.48
CH 400	20.23	20.24	20.26	20.28	20.35	20.42
CH 500	20.80	20.88	20.93	21.00	21.09	21.16
CH 600	22.11	22.22	22.28	22.37	22.47	22.55
Formby Street						
CH 700	22.90	22.93	22.97	23.00	23.04	23.08
CH 800	24.13	24.19	24.22	24.25	24.29	24.32
CH 900	24.83	24.93	24.97	25.03	25.09	25.14
CH 1000	25.26	25.29	25.31	25.37	25.42	25.47
CH 1100	26.81	26.89	26.90	26.93	26.99	26.99
CH 1200	27.74	27.94	28.05	28.14	28.23	28.34
Ormskirk Street						
CH 1300	28.97	29.07	29.11	29.17	29.22	29.27
CH 1400	30.12	30.22	30.27	30.33	30.39	30.44
CH 1500	31.97	32.20	32.33	32.42	32.52	32.63
CH 1600	32.56	32.76	32.85	32.97	33.11	33.22
CH 1700	35.15	35.24	35.27	35.31	35.34	35.36
CH 1800	35.68	36.34	36.38	36.42	36.45	36.50
CH 1900	37.16	37.29	37.33	37.40	37.43	37.54
CH 2000	39.84	39.92	39.96	40.04	40.10	40.13
CH 2100	42.86	42.95	43.00	43.07	43.12	43.18
CH 2200	43.60	43.70	43.76	43.84	44.05	44.15
Tributary B						
CH 0	22.35	22.45	22.51	22.59	22.68	22.76
CH 100	22.76	22.85	22.89	22.95	23.00	23.06
CH 200	23.57	23.64	23.68	23.73	23.78	23.82
CH 300	24.71	24.79	24.84	24.90	24.94	25.00
CH 400	26.44	26.50	26.53	26.57	26.59	26.63

Appendix E: Design Events (Scenario 3) - Peak Flood Levels

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AMTD (m)	Design Events – Scenario 3 (Ultimate Waterway Conditions) Peak Flood Levels (m AHD)					
	2-yr ARI (39% AEP)	5-yr ARI (18% AEP)	10-yr ARI (10% AEP)	20-yr ARI (5% AEP)	50-yr ARI (2% AEP)	100-yr ARI (1% AEP)
Main Branch						
CH 0	9.81	10.24	10.49	10.75	11.05	11.31
Paradise Road						
CH 100	11.73	12.27	12.31	12.35	12.43	12.51
Railway						
CH 200	12.09	12.49	12.69	12.91	13.16	13.34
CH 300	12.39	12.72	12.90	13.11	13.36	13.54
CH 400	12.68	12.97	13.13	13.33	13.56	13.74
CH 500	12.91	13.19	13.35	13.53	13.76	13.93
CH 600	13.11	13.39	13.54	13.72	13.95	14.12
CH 700	13.38	13.65	13.81	14.11	14.30	14.47
Ridgewood Road						
CH 800	14.21	14.46	14.60	14.77	15.00	15.16
CH 900	14.56	14.81	14.95	15.10	15.31	15.45
CH 1000	15.12	15.34	15.47	15.60	15.79	15.92
CH 1100	15.68	15.93	16.07	16.21	16.40	16.53
CH 1200	16.06	16.30	16.43	16.56	16.74	16.87
CH 1300	16.19	16.45	16.58	16.71	16.90	17.03
CH 1400	16.39	16.66	16.81	16.93	17.13	17.26
CH 1500	16.95	17.23	17.41	17.89	18.11	18.28
Algester Road (South)						
CH 1600	17.35	17.65	17.83	18.12	18.35	18.51
CH 1700	18.77	18.84	18.94	19.02	19.16	19.27
CH 1800	19.40	19.60	19.73	19.84	19.98	20.10
CH 1900	19.87	20.10	20.24	20.36	20.51	20.65
CH 2000	20.43	20.67	20.80	20.91	21.08	21.23
Laurel Oak Drive						
CH 2100	22.37	22.61	22.75	22.88	23.06	23.21
Nottingham Road						
CH 2200	23.19	23.43	23.56	23.83	24.04	24.18
CH 2300	23.67	23.97	24.14	24.30	24.52	24.68
CH 2400	24.79	24.99	25.12	25.23	25.36	25.48
CH 2500	25.80	26.05	26.18	26.29	26.42	26.52
CH 2600	26.12	26.38	26.52	26.64	26.79	26.91
CH 2700	27.05	27.25	27.36	27.44	27.55	27.64
CH 2800	28.06	28.21	28.30	28.37	28.46	28.54

AMTD (m)	Design Events – Scenario 3 (Ultimate Waterway Conditions) Peak Flood Levels (m AHD)					
	2-yr ARI (39% AEP)	5-yr ARI (18% AEP)	10-yr ARI (10% AEP)	20-yr ARI (5% AEP)	50-yr ARI (2% AEP)	100-yr ARI (1% AEP)
CH 2900	28.90	29.10	29.20	29.29	29.39	29.47
CH 3000	29.97	30.10	30.17	30.23	30.31	30.38
Tributary A						
CH 0	16.04	16.28	16.41	16.54	16.72	16.85
CH 100	16.18	16.42	16.54	16.67	16.85	16.98
CH 200	16.48	16.72	16.84	16.98	17.15	17.30
Algester Road (North)						
CH 300	19.30	19.42	19.47	19.55	19.63	19.71
CH 400	20.26	20.31	20.36	20.43	20.52	20.60
CH 500	20.97	21.09	21.15	21.23	21.32	21.40
CH 600	22.26	22.38	22.44	22.52	22.62	22.70
Formby Street						
CH 700	22.95	22.99	23.02	23.07	23.14	23.21
CH 800	24.27	24.32	24.34	24.37	24.40	24.43
CH 900	25.04	25.12	25.16	25.21	25.27	25.31
CH 1000	25.34	25.42	25.46	25.52	25.60	25.65
CH 1100	26.93	27.05	27.11	27.21	27.33	27.39
CH 1200	27.99	28.14	28.23	28.36	28.46	28.55
Ormskirk Street						
CH 1300	29.04	29.15	29.21	29.29	29.36	29.42
CH 1400	30.36	30.49	30.55	30.62	30.68	30.74
CH 1500	32.12	32.38	32.48	32.67	32.80	32.89
CH 1600	32.83	33.06	33.22	33.36	33.50	33.62
CH 1700	35.18	35.25	35.29	35.34	35.39	35.45
CH 1800	36.34	36.41	36.45	36.51	36.57	36.65
CH 1900	37.52	37.70	37.84	37.97	38.04	38.12
CH 2000	40.10	40.21	40.26	40.34	40.39	40.47
CH 2100	42.99	43.14	43.21	43.31	43.38	43.47
CH 2200	44.10	44.23	44.31	44.40	44.46	44.58
Tributary B						
CH 0	22.45	22.59	22.65	22.74	22.84	22.93
CH 100	23.07	23.19	23.25	23.32	23.39	23.45
CH 200	23.63	23.72	23.76	23.82	23.87	23.93
CH 300	24.76	24.86	24.91	24.97	25.03	25.08
CH 400	26.49	26.55	26.59	26.63	26.65	26.70

Appendix F: Rare Events (Scenario 1) - Peak Flood Levels

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AMTD (m)	Rare Events – Scenario 1 (Existing Waterway Conditions) Peak Flood Levels (m AHD)		
	200-yr ARI (0.5%AEP)	500-yr ARI (0.2% AEP)	2000-yr ARI (0.05% AEP)
Main Branch			
CH 0	11.56	11.82	12.31
Paradise Road			
CH 100	12.71	12.86	13.26
Railway			
CH 200	13.64	13.97	14.64
CH 300	13.70	14.02	14.68
CH 400	13.73	14.05	14.71
CH 500	13.77	14.08	14.73
CH 600	13.84	14.15	14.78
CH 700	14.24	14.50	15.07
Ridgewood Road			
CH 800	14.88	15.15	15.56
CH 900	15.03	15.25	15.61
CH 1000	15.54	15.70	16.03
CH 1100	16.14	16.33	16.70
CH 1200	16.56	16.72	17.03
CH 1300	16.66	16.83	17.12
CH 1400	16.71	16.85	17.15
CH 1500	18.68	19.03	19.27
Algester Road (South)			
CH 1600	18.77	19.14	19.43
CH 1700	19.19	19.32	19.52
CH 1800	19.77	19.89	20.05
CH 1900	20.29	20.41	20.59
CH 2000	20.86	21.00	21.35
Laurel Oak Drive			
CH 2100	23.08	23.26	23.48
Nottingham Road			
CH 2200	24.23	24.45	24.85
CH 2300	24.70	24.91	25.23
CH 2400	25.53	25.67	25.83
CH 2500	26.59	26.72	26.82
CH 2600	26.93	27.08	27.18
CH 2700	27.70	27.82	27.88
CH 2800	28.61	28.72	28.77

AMTD (m)	Rare Events – Scenario 1 (Existing Waterway Conditions) Peak Flood Levels (m AHD)		
	200-yr ARI (0.5%AEP)	500-yr ARI (0.2% AEP)	2000-yr ARI (0.05% AEP)
CH 2900	29.52	29.63	29.67
CH 3000	30.38	30.47	30.50
Tributary A			
CH 0	16.54	16.70	17.01
CH 100	16.66	16.82	17.12
CH 200	17.27	17.49	17.89
Algester Road (North)			
CH 300	19.58	19.68	19.85
CH 400	20.54	20.64	20.80
CH 500	21.27	21.38	21.54
CH 600	22.67	22.78	22.94
Formby Street			
CH 700	23.14	23.21	23.34
CH 800	24.37	24.41	24.48
CH 900	25.21	25.27	25.37
CH 1000	25.54	25.62	25.76
CH 1100	27.06	27.11	27.20
CH 1200	28.44	28.54	28.78
Ormskirk Street			
CH 1300	29.34	29.39	29.53
CH 1400	30.53	30.60	30.63
CH 1500	32.84	32.96	33.00
CH 1600	33.40	33.61	33.64
CH 1700	35.43	35.49	35.49
CH 1800	36.55	36.60	36.58
CH 1900	37.85	38.00	37.98
CH 2000	40.16	40.24	40.23
CH 2100	43.31	43.42	43.42
CH 2200	44.31	44.39	44.43
Tributary B			
CH 0	22.89	23.01	23.18
CH 100	23.16	23.26	23.40
CH 200	23.88	23.95	23.94
CH 300	25.08	25.17	25.15
CH 400	26.69	26.74	26.72

Appendix G: Rare Events (Scenario 3) - Peak Flood Levels

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AMTD (m)	Rare Events – Scenario 3 (Ultimate Conditions) Peak Flood Levels (m AHD)	
	200-yr ARI (0.5% AEP)	500-yr ARI (0.2% AEP)
Main Branch		
CH 0	11.50	11.78
Paradise Road		
CH 100	12.64	12.80
Railway		
CH 200	13.57	13.86
CH 300	13.76	14.04
CH 400	13.94	14.20
CH 500	14.12	14.37
CH 600	14.31	14.56
CH 700	14.63	14.82
Ridgewood Road		
CH 800	15.37	15.59
CH 900	15.63	15.83
CH 1000	16.10	16.31
CH 1100	16.72	16.94
CH 1200	17.06	17.27
CH 1300	17.22	17.43
CH 1400	17.44	17.66
CH 1500	18.64	19.04
Algester Road (South)		
CH 1600	18.82	19.19
CH 1700	19.43	19.64
CH 1800	20.26	20.43
CH 1900	20.83	21.01
CH 2000	21.39	21.56
Laurel Oak Drive		
CH 2100	23.39	23.59
Nottingham Road		
CH 2200	24.37	24.64
CH 2300	24.88	25.12
CH 2400	25.62	25.81
CH 2500	26.65	26.82
CH 2600	27.06	27.25
CH 2700	27.75	27.90
CH 2800	28.63	28.76

AMTD (m)	Rare Events – Scenario 3 (Ultimate Conditions) Peak Flood Levels (m AHD)	
	200-yr ARI (0.5% AEP)	500-yr ARI (0.2% AEP)
CH 2900	29.57	29.70
CH 3000	30.46	30.57
Tributary A		
CH 0	17.04	17.25
CH 100	17.17	17.37
CH 200	17.50	17.72
Algester Road (North)		
CH 300	19.82	19.93
CH 400	20.70	20.83
CH 500	21.51	21.63
CH 600	22.82	22.94
Formby Street		
CH 700	23.31	23.44
CH 800	24.46	24.51
CH 900	25.37	25.44
CH 1000	25.73	25.83
CH 1100	27.50	27.62
CH 1200	28.68	28.83
Ormskirk Street		
CH 1300	29.49	29.58
CH 1400	30.81	30.90
CH 1500	33.01	33.16
CH 1600	33.78	33.94
CH 1700	35.53	35.62
CH 1800	36.75	36.86
CH 1900	38.26	38.40
CH 2000	40.56	40.66
CH 2100	43.59	43.72
CH 2200	44.73	44.86
Tributary B		
CH 0	23.05	23.19
CH 100	23.54	23.63
CH 200	24.00	24.09
CH 300	25.17	25.26
CH 400	26.75	26.82

Appendix H: Hydraulic Structure Reference Sheets

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Creek:	Sheep Station Gully	**Immunity Rating:**	<2yr ARI
Location:	Paradise Road		AEP

DATE OF SURVEY: 1997	UBD REF: 53G1
SURVEYED CROSS SECTION ID:	BCC ASSET ID: W5516
MODEL ID: SG20	AMTD (m): 90

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 6 / 3003 x 3008mm

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

U/S INVERT LEVEL (m)	9.2m	U/S OBVERT LEVEL (m)	12.275m
D/S INVERT LEVEL (m)	9.12m	D/S OBVERT LEVEL (m)	12.202m

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 12.1m

LENGTH OF CULVERT AT OBVERT (m): 12.1m

TYPE OF LINING: Concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 12.1m — PIER WIDTH (m): 0.3typ

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

LOWEST POINT OF WEIR (m AHD): 12.67m

HEIGHT OF GUARDRAIL/HANDRAIL: Handrail 1.1m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: Concrete barrier with handrail on top

PLAN NUMBER: W5516

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

W13079 - Drawing not available from plan custodian

Creek:	Sheep Station Gully
Location:	Paradise Road

ARI (AEP %)	DISCHARGE (m3/s)*	U/S Water Level*	D/S Water Level*	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)*	FLOW DEPTH ABOVE STRUCTURE (m)*	VELOCITY (m/s)*	
		(m AHD)					Weir	Structure
2000-yr (0.05%)	240.2	13.14	12.38	759	610	0.00 - 0.80	1.95	2.20
500-yr (0.2%)	164.7	12.72	11.86	861	602	0.00 - 0.70	1.80	2.20
200-yr (0.2%)	137.9	12.59	11.74	848	596	0.00 - 0.65	1.45	2.13
100-yr (0.1%)	114.2	12.41	11.54	877	582	0.00 - 0.60	1.30	1.98
50-yr (0.2%)	98.6	12.29	11.36	932	490	0.00 - 0.56	1.20	1.86
20-yr (5%)	81.8	12.07	11.01	1056	365	0.00 - 0.40	1.14	1.71
10-yr (10%)	65.5	11.92	10.81	1113	178	0.00 - 0.35	1.09	1.58
5-yr (20%)	56.3	11.79	10.63	1168	146	0.00 - 0.26	0.95	1.46
2-yr (50%)	39.1	11.48	10.29	1186	66	0.00 - 0.15	0.65	1.35

* value can vary


Paradise Rd Crossing, 1997 facing downstream


Paradise Rd Crossing, 2015 facing downstream

Paradise Rd Crossing, 1997 facing upstream

Paradise Rd Crossing, 2015 facing upstream

Creek:	Sheep Station Gully	**Immunity Rating:**	>100yr ARI
Location:	Railway Crossing		<1% AEP

DATE OF SURVEY: 1997	UBD REF: 53 G1
SURVEYED CROSS SECTION ID:	BCC ASSET ID: W6726
MODEL ID: SG61	AMTD (m): 178

STRUCTURE DESCRIPTION: Steel Bridge

STRUCTURE SIZE: 3 Span 8.86,8.87,8.52

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

U/S INVERT LEVEL (m) 9.12m — U/S OBVERT LEVEL (m) 13.275m

D/S INVERT LEVEL (m) — D/S OBVERT LEVEL (m) 13.275m

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): N/A

LENGTH OF CULVERT AT OBVERT (m): N/A

TYPE OF LINING: N/A

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

IS THERE A SURVEYED WEIR PROFILE?

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): 2.29m — PIER WIDTH (m): 1.39m

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

LOWEST POINT OF WEIR (m AHD): 14.60m

HEIGHT OF GUARDRAIL/HANDRAIL: Nil

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: N/A

PLAN NUMBER: W6726

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

None

Creek:	Sheep Station Gully
Location:	Railway Crossing

ARI (AEP %)	DISCHARGE (m3/s)*	U/S Water Level*	D/S Water Level*	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)*	FLOW DEPTH ABOVE STRUCTURE (m)*	VELOCITY (m/s)*	
		(m AHD)					Weir	Structure
2000-yr (0.05%)	240.69	14.62	13.74	887	144	0.00 - 1.25	3.95	3.28
500-yr (0.2%)	164.87	13.95	13.32	630	0	0.00	0.00	2.72
200-yr (0.2%)	138.27	13.62	13.18	440	0	0.00	0.00	2.29
100-yr (0.1%)	114.64	13.35	13.00	345	0	0.00	0.00	2.03
50-yr (0.2%)	99.02	13.16	12.88	279	0	0.00	0.00	1.86
20-yr (5%)	82.52	12.91	12.68	233	0	0.00	0.00	1.70
10-yr (10%)	67.62	12.67	12.47	193	0	0.00	0.00	1.55
5-yr (20%)	56.46	12.47	12.30	167	0	0.00	0.00	1.42
2-yr (50%)	39.16	12.07	11.93	135	0	0.00	0.00	1.24

* value can vary

Railway Crossing, 1997 facing downstream

Railway Crossing, 2015 facing downstream

Railway Crossing, 1997 facing upstream

Railway Crossing, 2015 facing upstream,

Creek:	Sheep Station Gully
Location:	Ridgewood Rd

Immunity Rating:	<50yr ARI
	>2%AEP

DATE OF SURVEY: 1997	UBD REF: 53 H3
SURVEYED CROSS SECTION ID:	BCC ASSET ID: W4527C
MODEL ID: S3	AMTD (m):

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 5 X 3.67w X 1.84h

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

U/S INVERT LEVEL (m) 11.39m
U/S OBVERT LEVEL (m) 13.23m

D/S INVERT LEVEL (m) 11.36m
D/S OBVERT LEVEL (m) 13.20m

For culverts give floor level
For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 11.39m

LENGTH OF CULVERT AT OBVERT (m): 11.36m

TYPE OF LINING: Precast concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 17.3m
PIER WIDTH (m): 0.3typ

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

LOWEST POINT OF WEIR (m AHD): 14.25m

HEIGHT OF GUARDRAIL/HANDRAIL: No handrail or guardrail present

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS:

PLAN NUMBER: CD090048

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

None

Creek:	Sheep Station Gully
Location:	Ridgewood Rd

ARI (AEP %)	DISCHARGE (m3/s)*	U/S Water Level*	D/S Water Level*	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)*	FLOW DEPTH ABOVE STRUCTURE (m)*	VELOCITY (m/s)*	
		(m AHD)					Weir	Structure
2000-yr (0.05%)	230.70	15.55	14.82	732	227	0.00 - 1.15	4.45	3.34
500-yr (0.2%)	163.69	15.12	14.26	853	171	0.00 - 0.75	3.75	3.41
200-yr (0.2%)	135.38	14.85	13.98	869	150	0.00 - 0.58	3.25	3.27
100-yr (0.1%)	110.78	14.55	13.74	814	107	0.00 - 0.33	2.25	3.07
50-yr (0.2%)	93.90	14.22	13.57	654	54	0.00 - 0.02	0.60	2.77
20-yr (5%)	78.06	13.86	13.42	440	0	0.00	0.00	2.30
10-yr (10%)	63.86	13.59	13.29	299	0	0.00	0.00	1.83
5-yr (20%)	52.59	13.33	13.17	153	0	0.00	0.00	1.56
2-yr (50%)	35.80	13.14	13.01	124	0	0.00	0.00	1.16

* value can vary

Ridgewood Rd Crossing, 1997 facing downstream

Ridgewood Rd Crossing, 2015 facing downstream

Ridgewood Rd, 1997 facing upstream,

Ridgewood Rd, 2015 facing upstream

Creek:	Sheep Station Gully	**Immunity Rating:**	<2yr ARI
Location:	Algester Rd North		>39% AEP

DATE OF SURVEY: 1997

UBD REF: 53 J4

SURVEYED CROSS SECTION ID:

BCC ASSET ID: W4527

MODEL ID: SG225

AMTD (m): 705

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 3 cells, 2@ 1.5h x 3.65w & 1 @ 3.65 h x varying height

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

U/S INVERT LEVEL (m) 15.22/15.70   U/S OBVERT LEVEL (m) 17.48m

D/S INVERT LEVEL (m) 15.04/15.62   D/S OBVERT LEVEL (m) 17.43m

For culverts give floor level   For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 23.3m

LENGTH OF CULVERT AT OBVERT (m): 23.3m

TYPE OF LINING: Precast concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 23.3m   PIER WIDTH (m): 0.35m

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

LOWEST POINT OF WEIR (m AHD): 18.42m

HEIGHT OF GUARDRAIL/HANDRAIL: 1.0m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: Steel rails at RL 20.2 & RL 19.34 steel bars 25mm sq.

PLAN NUMBER: W4527

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

None

Creek:	Sheep Station Gully
Location:	Algester Rd North

ARI (AEP %)	DISCHARGE (m3/s)*	U/S Water Level*	D/S Water Level *	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)*	FLOW DEPTH ABOVE STRUCTURE (m)*	VELOCITY (m/s)*	
		(m AHD)					Weir	Structure
2000-yr (0.05%)	116.18	19.18	18.00	1177	124	0.00 - 0.54	3.60	6.85
500-yr (0.2%)	86.46	18.78	17.58	1203	110	0.00 - 0.35	2.90	6.52
200-yr (0.2%)	70.97	18.36	17.37	982	86	0.00 - 0.23	2.50	5.79
100-yr (0.1%)	57.34	18.10	17.16	936	86	0.00 - 0.15	2.25	3.86
50-yr (0.2%)	48.80	17.96	17.01	952	82	0.00 - 0.10	2.23	3.88
20-yr (5%)	39.60	17.87	16.82	1043	82	0.00 - 0.07	2.10	3.83
10-yr (10%)	32.07	17.80	16.65	1151	60	0.00 - 0.065	1.45	3.60
5-yr (20%)	27.50	17.76	16.54	1223	59	0.00- 0.055	1.35	3.47
2-yr (50%)	20.08	17.50	16.37	1124	55	0.00 - 0.05	1.20	3.20

* value can vary

Algester Rd North Crossing, 1997 facing downstream


Algester Rd North Crossing, 2015 facing downstream

Algester Rd North Crossing, 1997 facing upstream

Algester Rd North Crossing, 2015 facing upstream

Creek:	Sheep Station Gully	**Immunity Rating:**	>100yr ARI
Location:	Algester Rd South		<1% AEP

DATE OF SURVEY: 1997	UBD REF: 53 K3
SURVEYED CROSS SECTION ID:	BCC ASSET ID: W4527
MODEL ID: SG1030	AMTD (m): 1510

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 3 cells, 2@ 1.5h x 3.65w & 1 @ 3.65 h x varying height

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

U/S INVERT LEVEL (m)	15.69/15.90	U/S OBVERT LEVEL (m)	17.31m
D/S INVERT LEVEL (m)	15.21/15.77	D/S OBVERT LEVEL (m)	17.24

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 31.2m

LENGTH OF CULVERT AT OBVERT (m): 31.2m

TYPE OF LINING: Precast concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 31.2m — PIER WIDTH (m): 0.35m

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

LOWEST POINT OF WEIR (m AHD): 18.53m

HEIGHT OF GUARDRAIL/HANDRAIL: 0.97m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: Steel rails at RL 9.66 & RL 18.93 steel bars 25mm sq.

PLAN NUMBER: W4527

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

None

Creek:	Sheep Station Gully
Location:	Algester Rd South

ARI (AEP %)	DISCHARGE (m3/s)*	U/S Water Level*	D/S Water Level*	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)*^	FLOW DEPTH ABOVE STRUCTURE (m)*	VELOCITY (m/s)*	
		(m AHD)					Weir	Structure
2000-yr (0.05%)	100.70	19.33	17.87	1453	185	0.00 - 0.90	3.10	6.88
500-yr (0.2%)	74.18	19.04	17.60	1438	152	0.00 - 0.65	2.00	6.63
200-yr (0.2%)	61.14	18.64	17.39	1255	109	0.00 - 0.30	0.95	6.01
100-yr (0.1%)	49.93	18.17	17.21	959	0	0.00	0.00	5.01
50-yr (0.2%)	41.70	18.01	17.08	930	0	0.00	0.00	3.75
20-yr (5%)	34.71	17.65	16.94	711	0	0.00	0.00	3.51
10-yr (10%)	27.98	17.35	16.81	536	0	0.00	0.00	3.28
5-yr (20%)	22.54	17.16	16.71	455	0	0.00	0.00	3.11
2-yr (50%)	14.65	16.86	16.45	407	0	0.00	0.00	2.77

* value can vary

Algester Rd South Crossing, 1997 facing downstream

Algester Rd South Crossing, 2015 facing downstream


Algester Rd South Crossing, 1997 facing upstream


Algester Rd South Crossing, 2015 facing upstream

Creek:	Sheep Station Gully		**Immunity Rating:**	<50yr ARI
Location:	Laurel Oak Dr			>2% AEP

DATE OF SURVEY: 1997	UBD REF: 53 L3
SURVEYED CROSS SECTION ID:	BCC ASSET ID: W4527PIS 2
MODEL ID: SG1100	AMTD (m): 2025

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 3 cells, 2 @1.25h x 2.752 & 1 @ 1.44h x 2.75w

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

U/S INVERT LEVEL (m)	19.74m	U/S OBVERT LEVEL (m)	19.59m
D/S INVERT LEVEL (m)	21.16/20.96	D/S OBVERT LEVEL (m)	21.04/20.84

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 13.5m

LENGTH OF CULVERT AT OBVERT (m): 13.5m

TYPE OF LINING: Concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 13.5m — PIER WIDTH (m): 0.13m

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

LOWEST POINT OF WEIR (m AHD): ~2.6m

HEIGHT OF GUARDRAIL/HANDRAIL: 1.77m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: 50 dia tube steel rails @ RL 23.21 & 22.66

PLAN NUMBER: W4527PIS2

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: unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

None

Creek:	Sheep Station Gully
Location :	Laurel Oak Dr

ARI (AEP %)	**DISCHARGE (m3/s)***	**U/S Water Level ***	**D/S Water Level ***	**AFFLUX (mm)**	**FLOW WIDTH ABOVE STRUCTURE (m)***	**FLOW DEPTH ABOVE STRUCTURE (m)***	**VELOCITY (m/s)***	
		(m AHD)					**Weir**	**Structure**
2000-yr (0.05%)	89.74	22.85	21.48	1366	92	0.00 -0.78	5.08	6.35
500-yr (0.2%)	70.36	22.64	21.18	1466	78	0.00 - 0.65	4.50	6.46
200-yr (0.2%)	57.33	22.49	21.07	1421	70	0.00 - 0.50	4.00	6.20
100-yr (0.1%)	46.10	22.31	20.91	1399	63	0.00 - 0.45	2.55	5.92
50-yr (0.2%)	38.61	22.15	20.75	1403	45	0.00 - 0.25	2.25	5.62
20-yr (5%)	32.21	21.81	20.63	1176	0	0.00	0.00	5.01
10-yr (10%)	25.63	21.41	20.49	925	0	0.00	0.00	3.17
5-yr (20%)	20.44	21.25	20.39	861	0	0.00	0.00	3.00
2-yr (50%)	13.12	21.05	20.25	790	0	0.00	0.00	2.59

* value can vary

Laurel Oak Dve Crossing, 1997 facing downstream

Laurel Oak Dve Crossing, 2015 facing downstream

Laurel Oak Dve Crossing, 1997 facing upstream

Laurel Oak Dve Crossing, 2015 facing upstream

Creek:	Sheep Station Gully		**Immunity Rating:**	<2yr ARI
Location:	Formby St			>39% AEP

DATE OF SURVEY:	1997	UBD REF:	53 K5
SURVEYED CROSS SECTION ID:		BCC ASSET ID:	L-12-93
MODEL ID: SG2010		AMTD (m):	7020

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 7 X 600 dia

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

U/S INVERT LEVEL (m)	20.79m	U/S OBVERT LEVEL (m)	20.54m
D/S INVERT LEVEL (m)	21.39m	D/S OBVERT LEVEL (m)	21.14m

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 19.2m

LENGTH OF CULVERT AT OBVERT (m): 19.2m

TYPE OF LINING: Concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 19.2 — PIER WIDTH (m): 0.2typ

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

LOWEST POINT OF WEIR (m AHD): 22.24

HEIGHT OF GUARDRAIL/HANDRAIL: 0.6m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: Armco Top RL 22.79 Underside RL 22.49

PLAN NUMBER:

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:

HAS THE STRUCTURE BEEN UPGRADED?

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

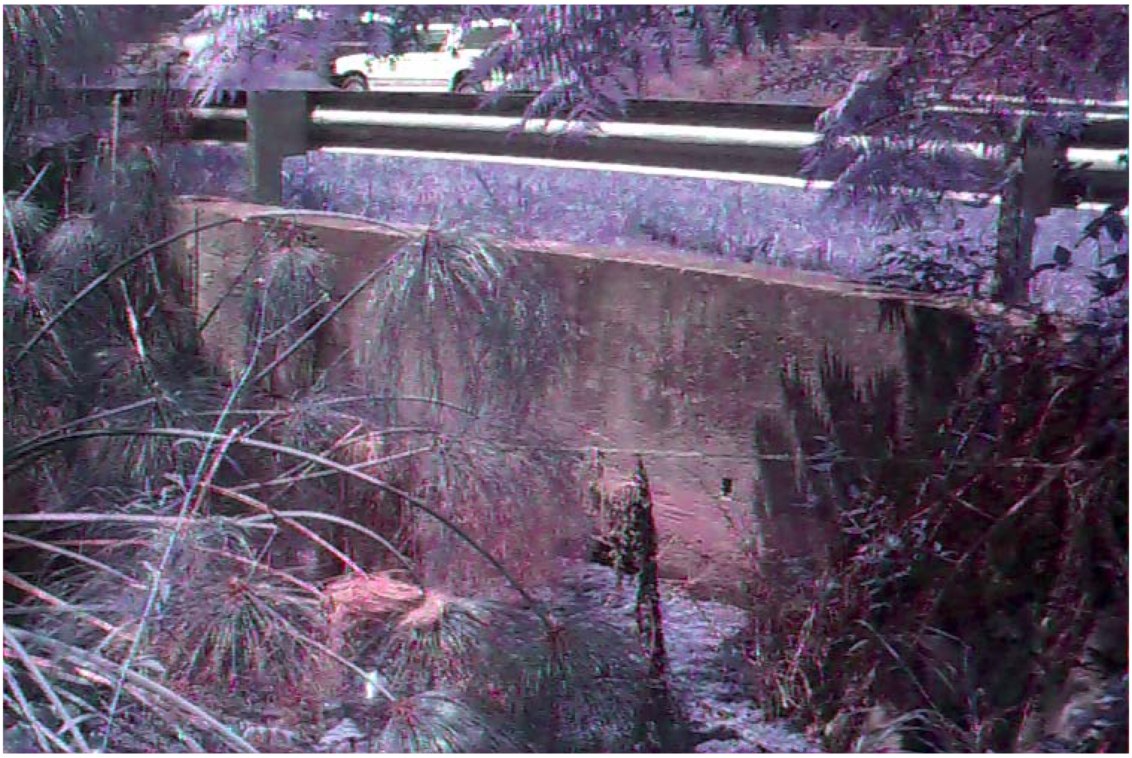
ADDITIONAL COMMENTS:

Creek:	Sheep Station Gully
Location:	Formby St

ARI (AEP %)	DISCHARGE (m3/s)*	U/S Water Level*	D/S Water Level *	AFFLUX (mm)	FLOW WIDTH ABOVE STRUCTURE (m)*	FLOW DEPTH ABOVE STRUCTURE (m)*	VELOCITY (m/s)*	
		(m AHD)					Weir	Structure
2000-yr (0.05%)	27.91	23.29	23.23	65	230	0.00 - 1.35	2.25	1.29
500-yr (0.2%)	27.05	23.15	23.07	87	218	0.00 - 1.20	2.25	2.03
200-yr (0.2%)	23.09	23.07	22.95	123	209	0.00 - 1.05	1.90	2.19
100-yr (0.1%)	19.28	22.99	22.83	158	191	0.00 - 0.94	1.85	1.92
50-yr (0.2%)	17.30	22.93	22.76	176	189	0.00 - 0.85	1.78	1.93
20-yr (5%)	15.11	22.84	22.67	170	180	0.00 - 0.75	1.75	1.97
10-yr (10%)	12.93	22.76	22.59	167	176	0.00 - 0.65	1.67	1.74
5-yr (20%)	11.25	22.72	22.53	183	175	0.00 - 0.53	1.63	1.92
2-yr (50%)	8.36	22.62	22.42	191	161	0.00 - 0.35	1.45	1.76

Formby St Crossing, 1997 facing downstream

Formby St Crossing, 2015 facing downstream



Formby St Crossing, 1997 facing upstream

Formby St Crossing 2015 facing upstream

Creek:	Sheep Station Gully	**Immunity Rating:**	<2yr ARI
Location:	Ormskirk St		>39% AEP

DATE OF SURVEY:	1997	UBD REF:	53 H5
SURVEYED CROSS SECTION ID:		BCC ASSET ID:	L-12-93
MODEL ID:	SG380	AMTD (m):	5265

STRUCTURE DESCRIPTION: Culvert

STRUCTURE SIZE: 3 X 1200 dia

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

U/S INVERT LEVEL (m)	25.59m	U/S OBVERT LEVEL (m)	26.77m
D/S INVERT LEVEL (m)	25.64m	D/S OBVERT LEVEL (m)	26.93m

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 19.7m

LENGTH OF CULVERT AT OBVERT (m): 19.7m

TYPE OF LINING: Concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 19.7 — PIER WIDTH (m): 0.3typ

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

LOWEST POINT OF WEIR (m AHD): 28.23m

HEIGHT OF GUARDRAIL/HANDRAIL: 0.7m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS: Armco Top RL 28.77 Underside RL 28.47

PLAN NUMBER: L-12-93

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown Unknown

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

ADDITIONAL COMMENTS:

None

Creek:	Sheep Station Gully
Location:	Ormskirk St

ARI (AEP %)	**DISCHARGE (m3/s)***	**U/S Water Level***	**D/S Water Level***	**AFFLUX (mm)**	**FLOW WIDTH ABOVE STRUCTURE (m)***	**FLOW DEPTH ABOVE STRUCTURE (m)***	**VELOCITY (m/s)***	
		(m AHD)					**Weir**	**Structure**
2000-yr (0.05%)	53.31	29.48	29.27	208	88	0.00 - 1.64	2.40	2.27
500-yr (0.2%)	36.77	29.05	28.47	577	85	0.00 - 1.52	2.35	2.36
200-yr (0.2%)	30.07	29.09	28.54	556	81	0.00 - 1.48	2.25	2.35
100-yr (0.1%)	23.53	29.15	28.65	508	78	0.00 - 1.42	1.95	2.32
50-yr (0.2%)	20.01	29.20	28.74	456	77	0.00 - 1.38	1.83	2.29
20-yr (5%)	15.89	29.24	28.81	429	74	0.00 - 1.33	1.62	2.30
10-yr (10%)	12.79	29.30	28.92	382	73	0.00 - 1.26	1.40	2.30
5-yr (20%)	10.31	29.35	29.03	322	72	0.00 - 1.20	1.35	2.29
2-yr (50%)	6.91	28.96	28.34	619	70	0.00 - 1.13	1.15	2.25

* value can vary

Ormskirk St Crossing, 1997 facing downstream

Ormskirk St Crossing, 2015 facing downstream

Ormskirk St Crossing, 1997 facing upstream

Creek:	Sheep Station Gully		**Immunity Rating:**	>100yr ARI
Location:	Nottingham Rd			<1% AEP

DATE OF SURVEY: 1997	UBD REF: 240 A1
SURVEYED CROSS SECTION ID: W8826	BCC ASSET ID: SG1140
MODEL ID: S9	AMTD (m): 2175

STRUCTURE DESCRIPTION: BEBO Arch Culvert

STRUCTURE SIZE: Arch culvert, span 12m, rise 3m

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

U/S INVERT LEVEL (m)	20.9	U/S OBVERT LEVEL (m)	20.9
D/S INVERT LEVEL (m)	23.9	D/S OBVERT LEVEL (m)	23.9

For culverts give floor level — For bridges give bed level

For culverts:

LENGTH OF CULVERT AT INVERT (m): 29.8m

LENGTH OF CULVERT AT OBVERT (m): 29.8m

TYPE OF LINING: Concrete

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

IS THERE A SURVEYED WEIR PROFILE?

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): 29.8m — 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): 24.560m

HEIGHT OF GUARDRAIL/HANDRAIL: 1.4m

DESCRIPTION OF HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERISDE OF GUARD RAILS:

PLAN NUMBER: W8826

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: Unknown

HAS THE STRUCTURE BEEN UPGRADED? Unknown

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

ADDITIONAL COMMENTS:

Creek:	Sheep Station Gully
Location:	Nottingham Rd

ARI (AEP %)	**DISCHARGE (m3/s)***	**U/S Water Level***	**D/S Water Level***	**AFFLUX (mm)**	**FLOW WIDTH ABOVE STRUCTURE (m)***	**FLOW DEPTH ABOVE STRUCTURE (m)***	**VELOCITY (m/s)***	
		(m AHD)					**Weir**	**Structure**
2000-yr (0.05%)	86.28	24.84	23.76	1076	95	0.00 - 0.43	1.75	2.91
500-yr (0.2%)	68.29	24.45	23.61	843	0	0.00	0.00	2.47
200-yr (0.2%)	55.73	24.22	23.44	782	0	0.00	0.00	2.04
100-yr (0.1%)	44.88	24.01	23.29	715	0	0.00	0.00	1.69
50-yr (0.2%)	37.55	23.84	23.19	651	0	0.00	0.00	1.45
20-yr (5%)	31.45	23.51	23.10	408	0	0.00	0.00	1.26
10-yr (10%)	25.15	23.38	22.99	390	0	0.00	0.00	1.03
5-yr (20%)	19.80	23.24	22.86	382	0	0.00	0.00	0.87
2-yr (50%)	12.61	23.05	22.59	459	0	0.00	0.00	0.73

* value can vary

Nottingham Rd Crossing, 1997 facing downstream

Nottingham Rd Crossing, 2015 facing downstream


Nottingham Rd Crossing, 2007 facing upstream


Nottingham Rd Crossing, 2015 facing upstream

Appendix I: External Peer Review

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BMT WBM Pty Ltd
Level 8, 200 Creek Street
Brisbane Qld 4000
Australia
PO Box 203, Spring Hill 4004

Tel: +61 7 3831 6744
Fax: + 61 7 3832 3627

ABN 54 010 830 421

www.bmtwbm.com.au

Our Ref: L.B20679.005.SSGFS.docx

18 June 2015

Brisbane City Council
City Projects Office
Green Square, Level 1
505 St Pauls Terrace
Fortitude Valley
Qld 4006

Attention: Paul Ollett

Dear Paul

RE: SHEEP STATION GULLY FLOOD MODELLING PEER REVIEW

Background

BMT WBM was commissioned by Council to undertake a peer review of the Sheep Station Gully flood modelling prepared as part of the Sheep Station Gully Flood Study. This letter documents the outcomes of BMT WBM's review.

At the commencement of the review process, Council submitted the following data to BMT WBM:

- Hydrological models;
- Hydraulic models including all model output files;
- GIS data; and
- Initial reporting.

These data were reviewed and initial feedback on the hydraulic modelling was provided to Council by email 11th May 2015 and on the hydrologic modelling on 21st May 2015. Some minor issues in the hydraulic modelling were identified and rectified following feedback provided to Council – these are not discussed in this letter as they have since been resolved.

Overview of the Modelling Approach

Hydrological models were developed using XP-RAFTS. The structure of the XP-RAFTS models and the sub-catchment parameters has been reviewed. Hydraulic models of the Sheep Station Gully system were developed using TUFLOW. A 4m computational grid cell size was used. The creek system was modelled in the 2D domain. Culverts at crossing structures were modelled using 1D culvert channels embedded into the 2D domain.

The gully drains into the larger Oxley Creek. Coincident flooding was considered in the determination of downstream boundary conditions, with a range of static tail water levels adopted.

Model Performance

The model performance has been checked in relation to: mass balance error, negative depth warnings, and instability. The model performance is considered acceptable to meet the objectives of Council's Flood Study. It is noted that Council has also assessed the model performance in relation to replication of historical events (calibration and verification). Council's acceptable tolerance for calibration is 0.15m variance for peak flood levels at stream gauges and 0.3m variance for peak flood levels at maximum height gauges. This correlates with standard industry practice. Note that the review did not include the calibration – discussed further below.

Limitations of the Review

This review focussed on scrutinising the design and performance of the models developed by Council. The scope of the review does not include the underlying data used to develop the model or the broader flood study methodology and procedure. For example, the accuracy of the topographic data, land use mapping, structure details and historic flood data has not been explicitly checked. If supplied information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions may change. As a consequence, BMT WBM provides no liability to the accuracy or the precision of the supplied data. All liability to do with the assumptions that rely on the accuracy or the precision of the supplied data rest with Brisbane City Council.

While the design and performance of the models used for calibration has been reviewed, the calibration and verification exercise has not been reviewed (for example, BMT WBM has not inspected modelled water levels at Maximum Height Gauge locations or reviewed comparisons of observed data versus modelled results).

Conclusion

The flood modelling undertaken as part of the Sheep Station Gully Flood Study complies with current industry practice, and is considered suitable for the purposes of the study. Limitations to this endorsement are discussed in this letter.

It is also noted that a significant flood event occurred in 1st May 2015, for which Council have collected flood records. It would be prudent to refine the calibration or verify the model's accuracy using the April 2015 flood records.

Yours Faithfully
BMT WBM

Richard Sharpe
Senior Flood Engineer

Ben Caddis RPEQ (9234)
Supervising Engineer

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Appendix J: Model User Guide

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The TUFLOW model was run using the 2012-05-AE-iSP-w64 version of the TUFLOW executable. To run the model from the TUFLOW control file a batch file is required. The lines of code required for the batch file are as follows:

Set TUFLOWEXE=***<insert path to TUFLOW executable here>***\TUFLOW_iSP_w64.exe

Set RUN=start "TUFLOW" /wait/low "%TUFLOWEXE%" –nwk –b

–S ***<insert scenario number>*** -e1***<insert ARI>*** -e2***<insert duration> <insert .TCF file name>***.TCF

All text in red must be replaced with the relevant code. Codes for ARIs are shown in Table1, codes for durations are shown in Table2 and scenario numbers are shown in Table 3.

Table1: Code for Events

ARI	Event Code
2	02yr
5	05yr
10	10yr
20	20yr
50	50yr
100	100yr
200	200yr
500	500yr
2000	2000yr
PMF	PMFyr

Table2: Code for Durations

Duration	Event Code
30 Minutes	030min
45 Minutes	045min
1 Hour	060min
1.5 Hours	090min
2 Hours	120min
3 Hours	180min
4.5 Hours	270min
Extreme Events Super Storm	360min

Table3: Code for Scenarios

Scenario Number	Description
S1	Existing Waterway Condition
S2	Existing Waterway Condition+ MRC
S3	Ultimate Waterway Condition+ MRC

The following revisions have been used for the following modelling scenarios:

Model Scenario	TCF File Name
Scenario 1, all events	S1_~e1~_~e2~_015.tcf
Scenario 2, all events	S2_~e1~_~e2~_015.tcf
Scenario 3, all events	S3_~e1~_~e2~_015.tcf

All model results including flood level, depth, velocity and depth-velocity surfaces/grids are available in electronic format. The DEM is read in ASCII text format and all other files are in MID/MIF MapInfo format. TUFLOW directory structure is shown below:

Main Folder Structure	Results Folder Structure