Cabbage Tree Creek Flood Study
Volume 1 of 2

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Cabbage Tree Creek Flood Study

Volume 1 of 2

Prepared by AECOM Australia Pty Ltd
Prepared for Brisbane City Council

June 2014

Dedicated to a better Brisbane

AECOM

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Cabbage Tree Creek Flood Study

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Executive Summary

Background and Scope

AECOM has been commissioned by Brisbane City Council (BCC) to undertake an updated flood study of the Cabbage Tree Creek catchment. The previous flood study (BCC, 2000) for the catchment was undertaken by the then Waterways Section of BCC.

The scope of this study is summarised as follows:

- Development and calibration of an URBS hydrologic model
- Development and calibration of a 1D/2D TUFLOW hydraulic model
- Modelling of a series of design events considering three separate floodplain conditions (existing, minimum riparian corridor (MRC), and ultimate)
- Production of peak flood level, depth and velocity depth product mapping
- Conducting a flood frequency analysis (FFA) using the calibrated URBS model and rainfall sequences derived from Brisbane CBD rain gauges.

Catchment Overview

The Cabbage Tree Creek catchment is located in the Brisbane City Local Government Area (LGA) north of the Brisbane River and covers a total area of 42.9 km^2 extending from Ferny Hills in the upper reaches of the catchment to its confluence with the mouth of Nundah Creek where both waterways flow into Moreton Bay at Shorncliffe. The catchment lies within two council boundaries: Brisbane City and Moreton Bay Regional Councils. It covers 12 suburbs within Brisbane City's northern outskirts and three suburbs within Moreton Bay Regional Council. There are two main tributaries that form the Cabbage Tree Creek catchment; Cabbage Tree Creek and Little Cabbage Tree Creek and several smaller tributaries including Carseldine Channel and Taigum Channel.

Calibration and Verification

The URBS and TUFLOW models were jointly calibrated to two (2) historic flood events and were subsequently verified to another two (2) historic events. These have been summarised in Table 1.

Table 1 Calibration and verification events

Calibration Events	Verification Events
October 2010 May 2009	March 2004 March 2001

Peak flood levels and flood timings for each of the historic events were compared to modelled results at three (3) telemetry stream gauges located at Deagon (C_A561), Carseldine (C_E702) and Aspley (LCA570). In addition to these locations peak flood levels were compared at Maximum Height Gauge (MHG) locations. Table 2, Table 3, Table 4 and Table 5 summarise peak flood level comparisons at stream gauge locations.

Table 2 October 2010 flood event summary

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	2.58	2.58	0.00
Carseldine (C_E702)	12.58	12.49	-0.09
Aspley (LCA570)	29.05	28.99	-0.06

Table 3 May 2009 flood event summary

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	1.97	1.95	-0.02
Carseldine (C_E702)	11.96	11.92	-0.04
Aspley (LCA570)	28.80	28.74	-0.06

Table 4 March 2004 flood event summary

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	1.81	1.86	0.05
Carseldine (C_E702)	11.72	12.01	0.29
Aspley (LCA570)	28.92	28.87	-0.05

Table 5 March 2001 flood event summary

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	2.53	2.67	0.14
Carseldine (C_E702)	12.59	12.98	0.39
Aspley (LCA570)	29.69	29.35	-0.34

Calibration Results (October 2010 and May 2009)

The hydraulic modelling results indicated a generally good fit in terms of peak flood height and peak flood timing between recorded and modelled results for the calibration events. Key points from the calibration modelling results were:

- All modelled peak flood levels were within ±0.15 m all recorded peak flood levels at the supplied telemetry gauges
- Peak flood timings were generally good with the majority of peak flood levels modelled within 15 minutes of recorded flood peaks
- MHG peak flood level records indicated relatively good matches between modelled and recorded peak flood levels. Some inconsistencies were observed but no trends of consistent over or under-prediction of peak flood levels were observed across the calibration events modelled.

Verification Results (March 2004 and March 2001)

Hydraulic modelling results for the validation events were not as consistent as those observed in the calibration events. Although this is the case modelling results are considered reasonable for these events. Key points from the verification modelling results were:

- The modelled peak flood levels for the March 2004 event were generally consistent with those recorded at the telemetry gauging stations. Peak flood level difference was 0.3 m at the Carseldine gauge. MHG gauges indicate good agreement between modelled and recorded levels for the 2004 event.
- Peak flood timings were also considered good for the March 2004 event.
- Modelled peak flood levels upstream of the confluence of Cabbage Tree Creek and Little Cabbage Tree Creek appear under-predicted compared to recorded levels for the March 2001 flood event. Potentially this could be due to under-prediction of rainfall intensity in the upper catchment due to sparse rainfall gauging information.

Design Event Modelling

Ten (10) different recurrence interval events between the 2 year Average Recurrence Interval (ARI) to the Probable Maximum Flood (PMF) were modelled as part of this study, these have been listed in Table 6. In addition to these ten (10) design event, two (2) climate change scenarios were modelled as follows;

- **Climate Change Scenario 1:** 10% increase in rainfall intensity and 0.3 m increase in downstream boundary level
- **Climate Change Scenario 2:** 20% increase in rainfall intensity and 0.8 m increase in downstream boundary level

For all design events modelled up to three (3) different floodplain conditions have been modelled:

- **Existing Floodplain:** existing floodplain conditions with ultimate catchment development hydrology
- **Existing Floodplain + Minimum Riparian Corridor:** Existing floodplain plus MRC condition applied with ultimate catchment development hydrology; and
- **Ultimate Floodplain:** Existing floodplain plus MRC conditions plus Waterway Corridor (WC) conditions with ultimate catchment development hydrology.

Table 6 summarises all the design events modelled in this study.

Table 6 Design event scenarios

Design Flood Scenario	Existing Floodplain	Existing Floodplain + MRC	Ultimate Case
2 yr	✓	×	✓
5 yr	✓	×	✓
10 yr	✓	×	✓
20 yr	✓	×	✓
50 yr	✓	×	✓
100 yr	✓	✓	✓
100 yr +CC1	✓	×	✓
100 yr + CC2	✓	×	✓
200 yr	✓	×	✓
200 yr + CC1	×	×	✓
200 yr + CC2	×	×	✓
500 yr	✓	×	✓
500 yr + CC2	×	×	✓
2000 yr	✓	×	×
PMF	✓	×	×

Design Event Results

Flood mapping has been provided in a separate volume: *Cabbage Tree Creek Flood Study Design Event Mapping Addendum.*

The most significant flooding issues for events up to the 100 year ARI occurs between Albany Creek Road and the confluence of Cabbage and Little Cabbage Tree Creeks. Significant overbank flooding occurs in this area with hydraulic interaction between the two catchments occurring. Key roads including Gympie Road and Albany Creek Road are predicted to be overtopped in this area in events smaller than the 100 year ARI.

For the extreme flood events modelled (in particular the 2000 year ARI and PMF) the lower lying suburbs, especially Fitzgibbon, Deagon and Sandgate, suffer from significant inundation.

Flood Frequency Analysis (FFA)

Using the calibrated URBS model a FFA was undertaken based on peak rainfall burst data supplied by BCC. Rainfall data was derived from CBD gauges operated by the Bureau of Meteorology (BOM) and BCC. Annual maximum sequences were fitted to two frequency distributions; the Generalised Extreme Value (GEV) and Log Pearson Type III (LP3). Peak flows resulting from the FFA were compared to peak flows derived from the URBS model. Results of this comparison showed that the design hydrology peak flows were generally within ±5% of those predicted by the FFA.

Table 7 FFA Results C_A573 (Everton Hills)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology(URBS)	GEV	LP3
2	35.00	34.78	34.64
5	48.60	49.49	49.12
10	57.20	59.91	59.80
20	68.90	70.39	70.95
50	82.00	84.73	86.83
100	94.30	96.09	99.91

Table 8 FFA Results LCA570 (Aspley)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	26.30	26.67	26.58
5	36.50	37.72	37.46
10	43.00	45.56	45.50
20	51.90	53.48	53.89
50	61.80	64.33	65.85
100	71.60	72.97	75.70

Table 9 FFA Results C_E702 (Carseldine)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	94.60	89.38	89.25
5	129.50	127.01	126.36
10	151.10	153.67	153.63
20	180.00	180.52	182.03
50	218.60	217.26	222.35
100	249.50	246.40	255.42

Table 10 FFA Results C_A561 (Deagon)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	137.20	131.36	131.16
5	186.20	185.55	184.47
10	217.40	223.64	223.20
20	259.10	261.78	263.15
50	314.20	313.65	319.27
100	359.10	354.58	364.85

Summary and Conclusions

BCC engaged AECOM to undertake an updated flood study of Cabbage Tree Creek in the Brisbane City LGA. This work updates previous flood study works undertaken by BCC and other in this catchment. The scope of works involved;

- Development and calibration of an URBS hydrologic model
- Development and calibration of a 1D/2D TUFLOW hydraulic model
- Modelling of a series of design events considering three separate floodplain conditions (existing, MRC, and ultimate)
- Production of peak flood level, depth and velocity depth product mapping
- Conducting a FFA using the calibrated URBS model and rainfall sequences derived from Brisbane CBD rain gauges.

Design flood event modelling results indicate that breakout of both Cabbage Tree Creek and Little Cabbage Tree Creek occurs between Albany Creek Road and the North Coast Railway (Carseldine) in events larger than the 10 year ARI flood event. In addition to the flooding described in Carseldine significant inundation of low lying areas of Fitzgibbon, Deagon and Shorncliffe occurs during large and extreme events. A number of road crossings in the catchment have been identified as possibly having low flood immunity.

Based on the work undertaken, the following recommendations are made to further improve upon the results of this study;

- As part of this study 60 new bathymetric cross sections were surveyed. This represented approximately 25% of the cross sections used in this study. Some of the data used for the other cross sections dates back to the 1970s. It is considered that significant value could be added by updating all waterway bathymetry for the model.
- A single downstream boundary level has been considered for design events in this study (excepting climate change scenarios). A range of different tidal and storm surge levels should be modelled to assess the impacts of coincident ocean and estuarine events.
- Given that the hydrologic and hydraulic modelling is based on methods that contain some uncertainty. It is recommended that additional modelling be undertaken to quantify this uncertainty. It is recommended that sensitivity runs be untaken varying Manning's 'n' values used and assessing the 95% and 5% confidence intervals for the 10 and 100 year ARI events.
- During the course of this study the BOM have updated the published AR&R design rainfall figures. Going forward these new values will form the accepted set of design rainfall depths. It is recommended that a selection of the design events modelled be remodelled using the new design rainfall depths to quantify any differences in flows and flood levels.

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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. (see ARI/AEP conversion table)
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.
Brisbane Bar	Location at the mouth of the Brisbane River
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).
Duration Independent Storm (DIS)	Synthetic design storm pattern developed by BCC intended to simulate all standard design storm peak bursts.
ESTRY	TUFLOW 1D engine.
FLIKE	Software for fitting observed data to standard statistical distributions. Developed at the University of Newcastle.
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.
Flood Regulation Line (FRL)	Planning line used to denote extent of a waterway. The maximum encroachment of floodplain development.
Generalised Extreme Value (GEV)	Statistical distribution used to predict hydrologic phenomena such as rainfall depths or flood flows based on observed data.
HEC-RAS	Hydrodynamic modelling software package.
Hydrograph	A graph showing how the discharge or stage/flood level at any particular location varies with time during a flood.
Isohyet	A line drawn on a map connecting points that receive equal amounts of rainfall.
Log Pearson Type III (LP3)	Statistical distribution used to predict hydrologic phenomena such as rainfall depths or flood flows based on observed data.
Manning's 'n'	The Gauckler–Manning coefficient, used to represent roughness in 1D/2D flow equations.
MIKE11	Hydrodynamic modelling software package.
Minimum Riparian Corridor (MRC)	An area of (maximum) 15m width either side of the main flow channel.
Pluviograph	An instrument for measuring the amount of water that has fallen (ie. rain gauge), with a feature to register the data in real time to demonstrate rainfall over a short period of time, often an automated graphing instrument.
Probable Maximum Flood (PMF)	An extreme flood deemed to be the largest flood that could conceivably occur at a specific location.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year
TUFLOW	Hydrodynamic modelling software package.

Term	Definition
URBS	Hydrologic modelling software package.
Waterway Corridor (WC)	Area inside of the FRL (see FRL)

ARI to AEP Conversion

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

Abbreviations

Abbreviation	Definition
1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
AR&R	Australian Rainfall & Runoff
ARI	Average Recurrence Interval
BCC	Brisbane City Council
CC1	Climate Change Scenario 1
BOM	Bureau of Meteorology
CC2	Climate Change Scenario 2
CFMP	Catchment Floodplain Management Plan
DEM	Digital Elevation Model
DIS	Duration Independent Storm
DNRW	Department of Natural Resources and Water
FFA	Flood Frequency Analysis
FRL	Flood Regulation Line
GEV	Generalised Extreme Value
HSRS	Hydraulic Structure Reference Sheet
IFD	Intensity Frequency Duration
LP3	Log Pearson Type III
M	Metre
MBRC	Moreton Bay Regional Council
MHWS	Mean High Water Spring
Min	Minute
MRC	Minimum Riparian Corridor
MSQ	Maritime Safety Queensland
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QUDM	Queensland Urban Drainage Manual
WC	Waterway Corridor

1.0 Introduction

1.1 Catchment Overview

The Cabbage Tree Creek catchment is located in the Brisbane City Local Government Area (LGA) north of the Brisbane River and covers a total area of 42.9 km^2 extending from Ferny Hills in the upper reaches of the catchment to its confluence with the mouth of Nundah Creek where both waterways flow into Moreton Bay at Shorncliffe. The catchment lies within two council boundaries: Brisbane City and Moreton Bay Regional Councils. It covers 12 suburbs within Brisbane City's northern outskirts and three suburbs within Moreton Bay Regional Council. Figure 2 shows the locality of the Cabbage Tree Creek Catchment.

The catchment is bounded by Bald Hills Creek and Pine River catchments to the north, Nundah Creek and Kedron Brook catchments to the south, and Wongam Creek catchment to the west. There are two main tributaries that form the Cabbage Tree Creek catchment; Cabbage Tree Creek and Little Cabbage Tree Creek and several smaller tributaries including Carseldine Channel and Taigum Channel.

The lower portion of the catchment, from the outfall at Moreton Bay to just beyond the Gateway Arterial, is tidally dominated. Cabbage Tree Creek flows from the upper reaches of Ferny Hills and Arana Hills, through many northern Brisbane suburbs, including; McDowall, Aspley, Fitzgibbon, Deagon and Shorncliffe. The creek then briefly flows into an estuary shared with Nundah Creek before entering Moreton Bay. Little Cabbage Tree Creek flows from the suburb of McDowall, through Chermside West, before joining Cabbage Tree Creek in Aspley.

1.2 Study Background

AECOM has been commissioned by Brisbane City Council (BCC) to undertake an updated flood study of the Cabbage Tree Creek catchment. The previous flood study (BCC, 2000) for the catchment was undertaken by the then Waterways Section of BCC. The BCC study involved development of calibrated hydrologic (URBS) and hydraulic (MIKE11) models.

The purpose of the current study is to;

- update the URBS hydrologic model using the latest data available and recalibrate to contemporary flood events
- create a calibrated 1D/2D hydrodynamically linked hydraulic model of the Cabbage Tree Creek
- provide updated flood study report presenting results of the calibration and design event modelling
- produce flood mapping products based on BCC's latest flood modelling/mappings protocols.

1.3 Study Scope and Objectives

Figure 1 shows the scope of works to be undertaken as part of this flood study. This report documents the background, scope, methodology and results of the updated Cabbage Tree Creek flood study. Design event mapping is supplied in a separate document; *Cabbage Tree Creek Flood Study Design Event Mapping Addendum.*

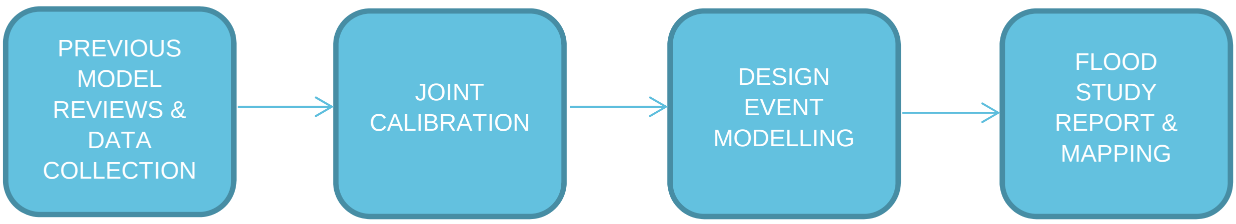


Figure 1 Study Scope

DATUM GDA 1994, PROJECTION MGA ZONE 56

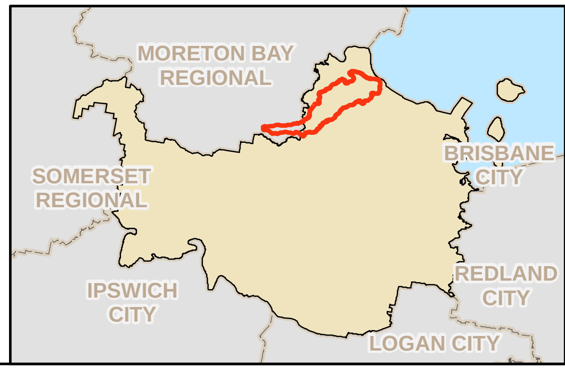
0 2,500 5,000 10,000

Metres

1:100,000 (when printed at A3)

Legend

- Brisbane
- Railway
- Highway
- Main Road
- Stream
- Waterbody
- Catchment Boundary
- LGA Boundary



Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

LOCATION MAP

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BRISBANE CITY

Figure 2

A3 size

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2.0 Catchment Description

2.1 Catchment and Waterway Characteristics

The Cabbage Tree Creek catchment can be generally split into three areas; upper, middle and lower.

The Upper Catchment starts from the convergence of Cabbage Tree Creek and Little Cabbage Tree Creek and extends into the upper reaches of the catchment, including both the Cabbage Tree and Little Cabbage Tree Creek tributaries. This catchment is characterised by moderately steep slopes, with rainfall runoff travelling quickly over impervious ground and into the waterway. Elevations in the Upper Catchment vary from 180 mAHD at the very upstream extent of the catchment to 10 mAHD in the creek bed at the confluence of Cabbage Tree Creek and Little Cabbage Tree Creek. The upper catchment is highly developed with the majority of the area utilised for residential purposes, in particular low-density residential. The major urban centre in Cabbage Tree Creek catchment is located close to the confluence of Cabbage Tree and Little Cabbage Tree Creeks in the Upper Catchment.

The middle catchment extends from the boundary of the tidal limit, between the Gateway Motorway and Lemke Road, upstream to the confluence of Cabbage Tree Creek and Little Cabbage Tree Creek. The eastern and western boundaries follow the ridge lines which naturally subdivide the catchment. This catchment is characterised by less steep slopes than the Upper Catchment, with rainfall runoff travelling quickly over impervious ground and into the waterway. The highest elevation in the middle catchment is approximately 52 mAHD on the ridge that forms the upper limit of the Carseldine Channel catchment. The creek bed at the eastern boundary (close to Lemke Road) sits at an elevation of approximately 0 mAHD. Much of the Middle Catchment is highly developed, with significant areas of low-medium residential areas along the Creek.

The lower catchment extends from the tidal limit of the catchment to the mouth of Cabbage Tree Creek. The boundary to the west follows a ridge line running north-south, which act as a natural catchment divider. The lower catchment is characterised by generally flat slopes, with rainfall runoff travelling slowly over impervious ground and into the waterway. Elevations within this catchment range from approximately 32 mAHD at the ridges to the west of the catchment to approximately 0 mAHD in the floodplain near the mouth of the river. The catchment is moderately developed, mostly with low density residential areas. The Lower Catchment contains significant areas of open space and parkland, including the Boondall and Deagon Wetlands and the parkland around the Brisbane Entertainment Centre.

2.2 Land Use

Overall the Cabbage Tree Creek catchment is dominated by residential zonings (low and low-medium) with approximately 35% of the total catchment area zoned residential. The majority of the remaining catchment area is dominated by green space areas (sports and recreation, parks, conservation areas etc) which make up 20% of the total catchment area. Table 11 summarises land use by Upper, Middle and Lower areas of the catchment.

Table 11 Land Use Summary

Catchment Sub-Area	Key Land Use Types (% of Area)	Overview
Upper Catchment	Residential, low density (41%) Green Space Areas (20%) Emerging Communities (9%)	The upper catchment is dominated by low-density residential areas. Significant 'Emerging Community' areas exist upstream of Hamilton Road. Green space areas make up a significant portion of non-residential areas with most of the creek banks in this area lined with parks. The major urban centre in the catchment is situated around the intersection of Albany Creek and Gympie Roads.
Middle Catchment	Residential, low density (26%) Residential, medium density (11%) Green Space Areas (15%) Emerging Communities (23%)	The middle catch has a significant proportion of both low and low- medium density residential areas. Significant 'Emerging Communities' areas exist in the middle catchment, in particular in the Carseldine Channel subcatchment. As with the rest of the Cabbage Tree Creek catchment a significant proportion of the Middle Catchment is green space.

Catchment Sub-Area	Key Land Use Types (% of Area)	Overview
Lower Catchment	Residential, low density (24%)	As with other parts of the catchment the majority of the Lower Catchment is residential areas. The Lower Catchment has the highest proportion of green space areas, in particular sports and recreation areas. The lower catchment area also contains significant special purposes areas (Brisbane Entertainment Area and Marina).
	Green Space Areas (28%)	
	Emerging Communities (6%)	

2.3 Flood History

Documentation of flooding history in the Cabbage Tree Creek catchment is variable, while rainfall and streamflow gauging data records are good, the actual impact of historic flood events are not well documented. Based on the gauging data and previous flood studies supplied by BCC it is understood that the Cabbage Tree Creek catchment has experienced a number of flood events in the last 40 years. Flood events recorded in this period are shown in Table 12.

Table 12 Historic Flood Events

Historic Flood Events	
- January 1974	- March 2001
- March 1974	- March 2004
- June 1983	- May 2009
- February 1992	- February 2010
- January 1996	- October 2010
- May 1996	- January 2011

Based on gauged records the January 1974, March 2001 and October 2010 have been the most significant events within the catchment. BCC operate a flood warning gauge at Deagon (C_A561). Flood levels at this gauge are categorised as minor (1.9 mAHD), moderate (2.5 mAHD) and major (3.4 mAHD). Based on this rating the January 1974, March 2001 and October 2010 events would all be categorised as moderate floods.

3.0 Available Information

3.1 Previous Studies

3.1.1 1996 Flood Study (updated 2000)

This previous report details the flood study for Cabbage Tree Creek prepared by BCC (BCC, 2000). Calibrated URBS hydrologic and MIKE11 hydraulic models were produced as part of this study. The flood assessment produced inundation maps of Cabbage Tree Creek for 100, 50, 20, 10, 5 and 2 year ARI flood events. The MIKE11 model produced during this study was used as input into this updated flood study.

3.1.2 Cabbage Tree Creek Catchment Floodplain Management Plan

BMT WBM Pty Ltd was engaged by BCC to undertake a draft catchment floodplain management plan (CFMP) for Cabbage Tree Creek catchment (BMT WBM, 2012). As part of this study a TUFLOW model was created to produce flood mapping across the catchment. The TUFLOW model created as part of this CFMP was used as input into this updated flood study.

3.1.3 Taigum Channel Flood Study

This report details the flood study for Taigum Channel, prepared by BCC (BCC, 2012). The purpose of the Taigum Channel Flood Study was to determine flood levels within the main flow path of Taigum Channel for a range of standard storm events. The TUFLOW model created as part of this CFMP was used as input into this updated flood study.

3.1.4 Carseldine Channel

In 2011 BCC undertook a detailed flood assessment of Carseldine Channel within the Cabbage Tree Creek Catchment (BCC, 2011). The purpose of this study was to update the previous MIKE11 model based on flood mitigation works undertaken within the Carseldine Channel catchment. The updated MIKE11 model created as part of this study was used as input into this updated flood study

3.2 Rainfall Data

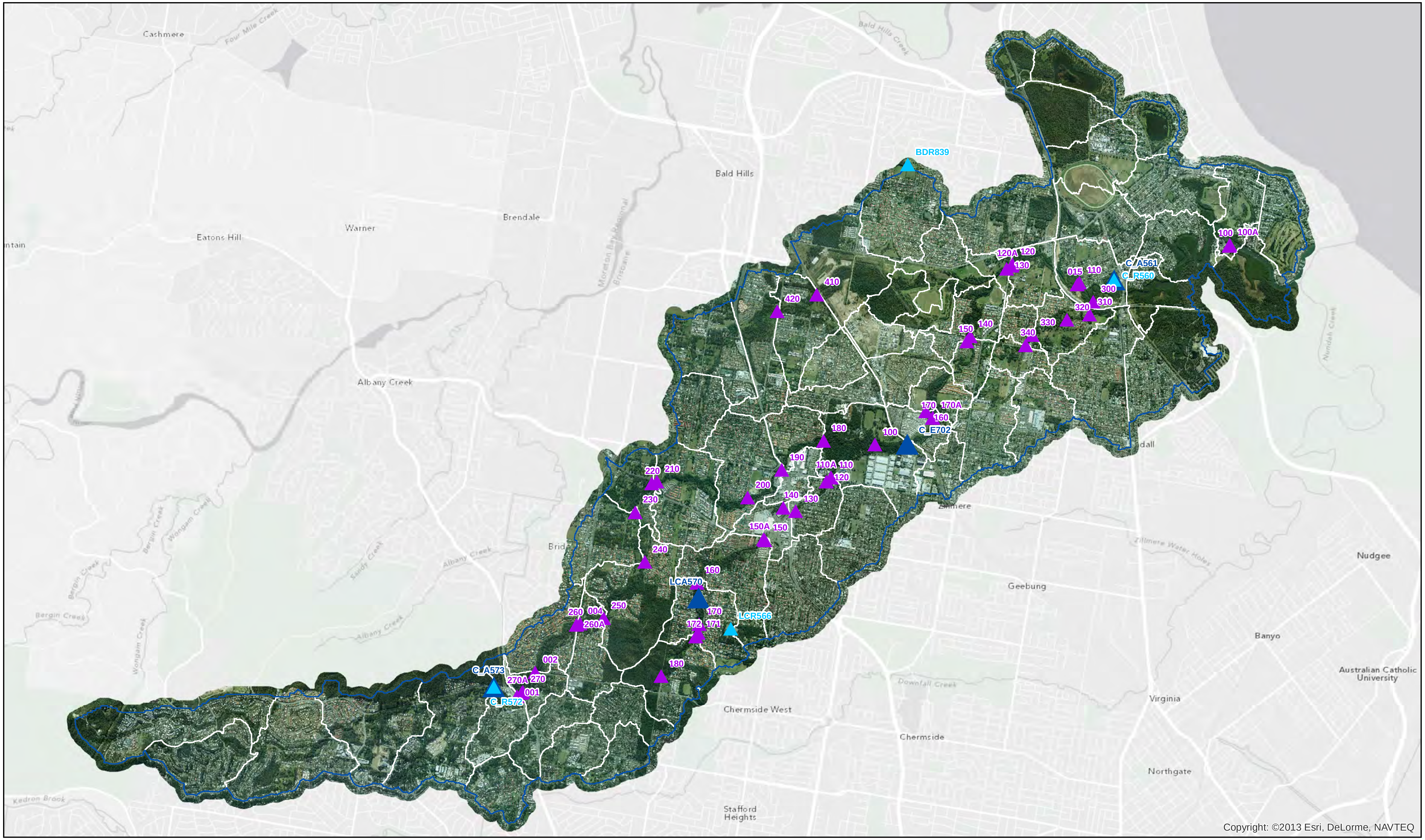
3.2.1 BCC Rain Gauges

BCC operates 10 pluviographic rain gauges within the Cabbage Tree Creek Catchment as shown in Figure 3. These gauges record rainfall depths in 5 minute intervals. BCC have provided pluviographic rainfall data for significant flood events for all gauges. Table 13 summarises the BCC gauge ID and location information for each gauge.

Table 13 BCC Operated Telemetry Rainfall Gauges

Gauge ID	Location
A_R842	Bronson St, Bridgeman Downs
BDR839*	Jude St Reservoir, Bracken Ridge
C_R560	Cabbage Tree Ck at Deagon
C_R572	Cabbage Tree Ck at Everton Hills
K_R539	Osborne Rd, Everton Park
LCR566	Little Cabbage Tree Ck at Aspley Reservoir
MBR752	Queens Parade, Sandgate
Z_R850	Zillman Waterholes, Zillmere
C_R733	Cabbage Tree Ck at Boondall Wetlands
C_R715	Cabbage Tree Ck at Carseldine

** This gauge is located on the boundary of Cabbage Tree creek Catchment*



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 | 1,125 | 2,250 | 4,500

Metres

1:45,000 (when printed at A3)

Legend

- Rainfall Gauge
- Flood Gauge Telemetry
- Flood Gauge Max Height
- Catchment Outline
- URBS Subcatchments

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

GAUGE LOCATIONS

AECOM
www.aecom.com

Figure 3

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\BodyReportMaps\ReportBody_Figure3_GaugeLocations.mxd

Table 14 details the specific events for which rainfall data has been provided for each gauge listed in Table 13.

Table 14 Supplied Rainfall Data

Gauge ID	Jan 2011	Oct 2010	Feb 2010	May 2009	Mar 2004	Mar 2001	May 1996	Jan 1996	Feb 1992
A_R842	✓	✓	✓	✓					
BDR839	✓	✓	✓	✓					
C_R560	✓	✓	✓	✓	✓	✓	✓	✓	✓
C_R572	✓	✓	✓		✓	✓	✓	✓	
K_R539	✓	✓	✓	✓	✓	✓	✓	✓	
LCR566	✓	✓	✓	✓	✓	✓	✓	✓	
MBR752	✓	✓	✓	✓	✓	✓			
Z_R850	✓	✓	✓	✓					
C_R733						✓			
C_R715						✓	✓	✓	

In addition BCC have also supplied graphical representations of the IFD data for the October 2010, May 2009, March 2004 and March 2001 historic rainfall events. These have been included as Appendix M.

3.2.2 Bureau of Meteorology Rain Gauges

In addition to the supplied BCC rain gauges daily rainfall data for specific Bureau of Meteorology (BOM) rainfall stations were compiled. The BOM daily rainfall data was used to supplement the BCC rain gauge data to get a better understanding of the total rainfall over the upper reaches of the catchment. The BOM rain gauges are located west, outside of the top of the catchment. BOM gauge data is summarised in Table 15.

Table 15 BOM Rain Gauges

Station Name	Station Number	Available Data
Clear Mountain, Buranda Rd	040960	May 2009, Oct 2010
Samsonford CSIRO	040241	Mar 2001
Samsonford, Kay Dr	040977	Oct 2010

3.2.3 Rainfall Intensity Data

Annual peak rainfall bursts for duration between 30 min and 72 hours were supplied by BCC. An annual sequence for the years 1911 to 2009 was supplied. These rainfall bursts were derived from the BOM CBD gauge and the BCC operated CBD gauge. Gauge records are summarised in Table 16.

Table 16 Annual Maximum Gauge Sequences

Gauge	Records Used
BOM CBD Gauge	1911 - 1990
BCC CBD Gauge	1991 - 2009

3.3 Water Level Data

3.3.1 Water Level Telemetry Gauges

As part of this study BCC have provided telemetry streamflow gauging data for 4 river height gauges in and around Cabbage Tree Creek catchment. Table 17 summarises the gauge IDs and locations. Table 18 summarises the data available at each gauge listed in Table 17. Figure 3 show the detailed locations of the water level gauges. It is noted Gauge C_A573 is outside of the model extent and was not used as part of this study.

Table 17 BCC Operated Streamflow Telemetry Gauges

Gauge ID	Location
C_A573	Cabbage Tree Creek at Everton Hills
LCA570	Little Cabbage Tree Creek at Aspley Reservoir
C_A561	Cabbage Tree Creek at Deagon
C_E702	Cabbage Tree Creek at Carseldine – QUT Campus

Table 18 Available Flood Height Telemetry Data

Gauge ID	Jan 2011	Oct 2010	Feb 2010	May 2009	Mar 2004	Mar 2001	May 1996	Jan 1996
C_A573	✓	✓	✓	✓	✓	✓	✓	✓
LCA570	✓	✓	✓	✓	✓	✓	✓	✓
C_A561		✓	✓	✓	✓	✓	✓	✓
C_E702	✓	✓	✓	✓	✓	✓	✓	✓

3.3.2 Maximum Height Gauges

In addition to streamflow telemetry gauges, BCC operate a number of Maximum Height Gauges (MHG) in the Cabbage Tree Creek Catchment. These gauges record peak flood height only. The locations of these gauges are shown in Figure 3.

3.4 Topographic Data

3.4.1 LIDAR Survey

BCC have provided LIDAR data for the area of Cabbage Tree Creek Catchment that fall within the BCC local government area (LGA). The data was delivered in the format of LIDAR points and was converted into a 1m DEM. The vertical accuracy of the LIDAR data is estimated to be ±0.15m.

3.4.2 Creek Bathymetry

As part of this flood study update BCC arranged for 60 creek cross sections to be field surveyed. Creek cross sections were provided in raw XYZ data format. This number of cross sections represents approximately 25% of the total cross sections used in this study. Cross sections were generally taken in key locations such as structures and gauge locations.

In addition BCC have also provided pdf format cross sections taken at streamflow telemetry gauge LCA570 (Aspley). The supplied pdfs contained cross section profile data. These were surveyed in 2006.

3.5 Hydraulic Structures

Details of the configuration, size and levels of the majority of hydraulic structures within Cabbage Tree Creek catchment has been supplied by BCC. This includes bridges, culverts, weirs etc. This information was supplied as a number of formats including:

- processed structure data provided in spreadsheet format
- design drawings
- structures previously incorporated into the TUFLOW/MIKE11 models used as input in this study.

Where previous model data has been used cross checking with BCC supplied structure data has been undertaken where possible.

3.6 Aerial Photography

Two different sources of aerial photography were obtained during this study:

- Historic aerial imagery supplied by BCC
- Current aerial imagery sourced from the Queensland Spatial Imagery Acquisition Program.

BCC has supplied aerial imagery for the years 1995, 1997, 1999, 2001, 2005, 2007 and 2009. No metadata was supplied with the imagery, though the imagery was of adequate resolution to determine land use types.

Current high resolution imagery was sourced from the Queensland Government's Queensland Spatial Imagery Acquisition Program. Urban imagery for the Program is captured at a minimum resolution of 25 cm. Imagery was captured in 2012.

4.0 Selection of Calibration and Verification Events

Total rainfall depths for the supplied historic flood events are given in Table 19. Recorded peak flood levels at telemetry gauging stations are given in Table 20.

Table 19 Historic Event Total Rainfall Depths

Event	Total Rainfall Depth											
	A_R842	BDR839	CVR560	CVR572	CVR715	CVR733	KVR539	LCR566	MBR752	ZVR850	040960 (BOM)	040977 (BOM)
Jan 2011*	-	-	-	-	-		-	-	-	-	-	-
Oct 2010	369	368	394	311	-	-	280	337	365	390	301	208
Feb 2010	99	84	107	136	-	-	155	113	97	121	137	-
May 2009	307	339	320	-	-	-	334	299	358	314	362	-
Mar 2004	-	-	123	149	-	-	151	141	141	-	-	-
Mar 2001	-	-	129	187	171	95	124	183	124	-	-	-
May 1996	-	-	471	535	490	-	570	527	-	-	-	-
Jan 1996	-	-	111	138	121	-	138	128	-	-	-	-

** January 2011 flood event gauging records were largely incomplete due to multiple gauge failures during this event*

Table 20 Historic Event Recorded Peak Flood Levels

Gauge ID	Recorded Peak Flood Level (mAHD)							
	Jan 2011	Oct 2010	Feb 2010	May 2009	Mar 2004	Mar 2001	May 1996	Jan 1996
C_A573	-	44.19	44.06	44.25	44.16	44.29	44.25	44.06
LCA570	-	29.05	28.49	28.80	28.92	29.69	29.06	28.88
C_A561	-	2.58	0.35	1.97	1.81	2.53	1.95	1.28
C_E702	-	12.58	11.46	11.96	11.72	12.59*	12.12	11.64

** This level is not the peak flood level as peak flood level was not recorded due to gauge malfunction*

Based on the data summarised in Table 19 and Table 20 calibration and verification events were selected, these have been summarised in Table 21. Events have been selected such that similar gauge levels are represented in both calibration and verification events and maximum rain gauge coverage is used.

Table 21 Calibration and Verification Events

Calibration Events	Verification Events
October 2010 May 2009	March 2004 March 2001

5.0 Hydrologic Model Development

5.1 Overview

Hydrologic modelling for this study was performed using the rainfall runoff routing software URBS. URBS has the advantage of providing the option to model channel and subcatchment routing separately. This allows better compatibility with the hydraulic model, as the channel routing component can be matched to the hydraulic model, while varying the subcatchment routing parameters to achieve calibration to recorded events. URBS also allows the effects of urbanisation to be accounted for on a subcatchment basis, making it well suited to urban catchments.

An URBS model was previously developed for the Cabbage Tree Creek catchment in 1996. Since the development of the model there have been changes in flow paths and subcatchment boundaries due to urban development within the catchment. Considering these changes, and the availability of more recent data it was decided that a better outcome could be achieved by developing a new URBS model.

URBS allows the use of nine catchment variables when modelling the runoff response for a catchment. The variables included in the Cabbage Tree Creek URBS model were selected based on the availability of accurate data and the requirements of the model. Table 22 presents an overview of the catchment variable included in the URBS model.

Table 22 URBS catchment variables

Catchment variable	Description
L	Channel length (Mandatory)
Sc	Channel slope
CS	Subcatchment slope
U	Urbanisation index
I	Impervious fraction
IL	Pervious initial loss

5.2 URBS Model Setup and Schematisation

5.2.1 Catchment Delineation

Subcatchment delineation was performed using the software CatchmentSIM. CatchmentSIM automatically delineates catchment boundaries based on topographic input data. Subcatchment outlet locations were manually defined. The locations of the outlets were selected to:

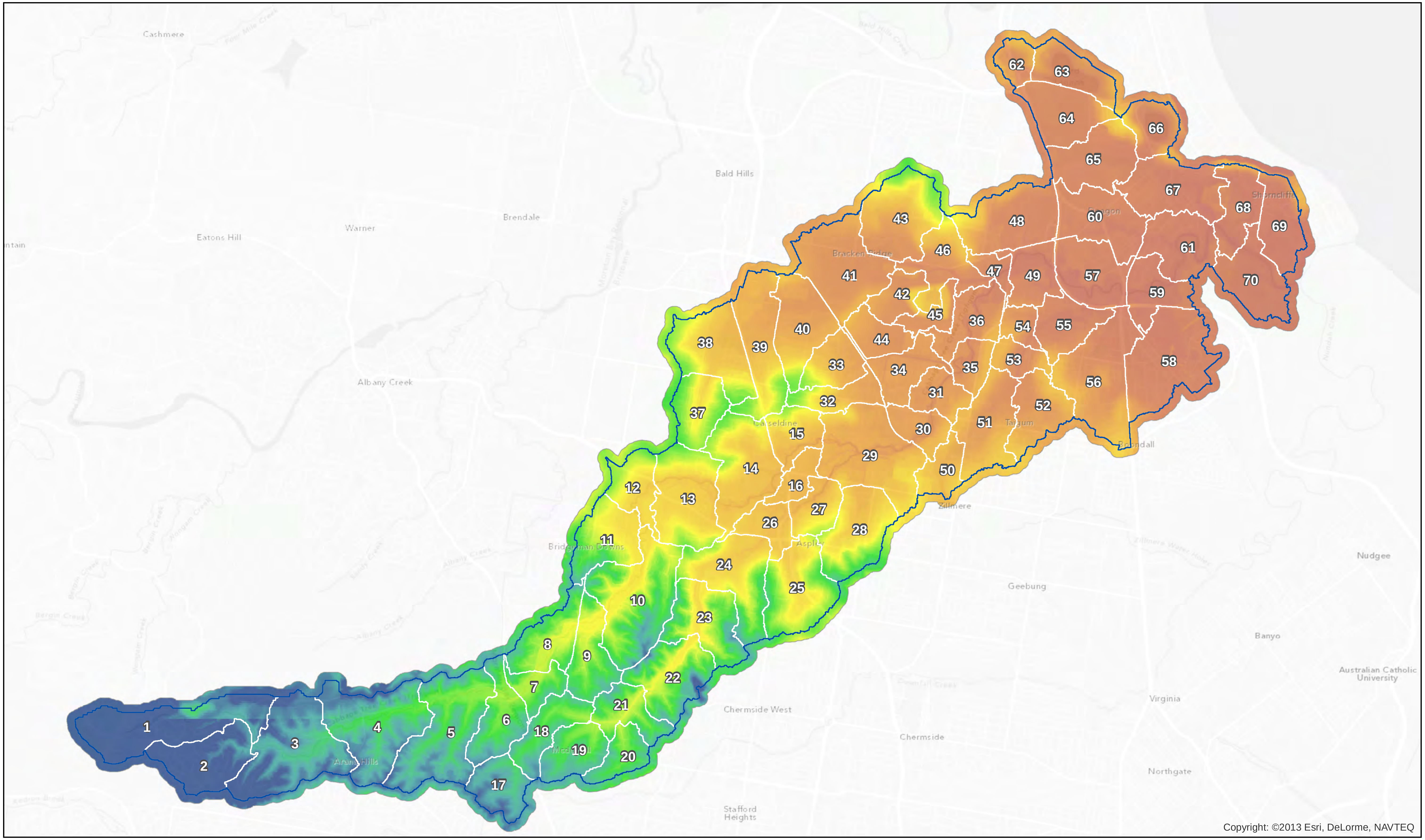
- achieve similar subcatchment sizes
- avoid elongated subcatchments where possible (URBS assumes circular subcatchments)
- ensure there are at least 5 subcatchments upstream of calibration points
- provide flows upstream of major structures.

The Cabbage Tree Creek Catchment delineation is composed of 70 subcatchments. Subcatchment layout is shown in Figure 4. The previous catchment delineation has been included in Appendix A.

5.2.2 Catchment Properties

5.2.2.1 Subcatchment Area and Slope

Subcatchment areas and slopes are presented in Appendix B.



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,125 2,250 4,500

Metres

1:45,000 (when printed at A3)

Legend

- Catchment Outline
- URBS Subcatchments

Digital Elevation Model (m AHD)

High : 181.971

Low : -0.479797

Data sources:
Brisbane City Council
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

DEM & SUBCATCHMENT DELINEATION

AECOM
www.aecom.com

Figure 4

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\BodyReportMaps\ReportBody_Figure4_ModelDEM_Subcatchments.mxd

A3 size

5.2.2.2 Land Use

The effects of urbanisation are modelled in URBS using an urbanisation index, U, to determine the decrease in lag, and fraction imperviousness, I, to determine the increase in runoff volume. The URBS model provides the option to specify urbanisation indices for each subcatchment. The following urbanisation indices were included in the URBS model,

- **UL** - Urban Low density
- **UM** - Urban Medium density
- **UH** - Urban High density
- **UR** – Urban Rural
- **UI** - Threshold Urban Impervious fraction above which land is considered as UH.

The fraction impervious for the UR index is 0%, and that for indices UL, UM, UH and UI can be assigned by the user. Using these indices, URBS calculates the impervious fraction, I, and urbanisation index, U, for each subcatchment.

The fraction impervious for different development categories was estimated using Table 4.05.1 in the Queensland Urban Drainage Manual, (DNRW, 2007) and the aerial imagery. Table 23 presents an overview of the urbanisation indices used in the Cabbage Tree Creek URBS model, the land use they are used to represent, and the fraction impervious assigned to each indices. A value of 0.5 was assigned as the UI index. Appendix B presents the resulting subcatchment properties.

Table 23 Urbanisation indices and fraction impervious assigned to land uses

Land Use	Fraction impervious (%)	Urbanisation Index
Multi Purpose Centre Suburban Centre	0.9	UH
Special Purpose Centre Vehicle Sales And Service		
General Industry		
Character Residential	0.6	UM
Community Use Area Community Facilities		
Low Density Residential		
Low-Medium Density Residential		
Community Use Area Education Purposes	0.1	UL
Community Use Area Utility Services		
Rural		
Emerging Communities		
Sport And Recreation		
Environmental Protection	0	UR
Forested area		
Conservation		
Park Land		

Residential development within the catchment includes both low and low-medium residential development. Comparison of the land use GIS layer with aerial imagery revealed that areas classified as low and low-medium residential in the land use GIS layer appear similar, and in some cases seem inaccurately assigned. It was therefore decided to model both low and low-medium residential areas with the same fraction impervious.

The land use GIS layer contained polygons that covered all of the land parcels but there were gaps for the road corridors. These road corridor areas included both the paved road surfaces as well as a significant amount of grassed area adjacent to the roadway. These roadway areas are therefore modelled using the UH index (50% impervious).

5.2.3 Rainfall Input

5.2.3.1 Rainfall Depth

The gauged mean rainfall depth across subcatchments was estimated for each calibration and verification events using the isohyetal method. The isohyetal contours were interpolated from the gauge data using the Kriging method, from which the mean rainfall for each subcatchment was calculated. The Kriging Method is a geostatistical prediction technique which can be used to interpolate Isohyetal contours based on the spatial correlation among neighbouring rainfall observations. A mathematical function is fitted to rainfall observation points, which is then used to predict the rainfall depth at ungauged locations. The Kriging Method is considered to provide a more accurate representation of areal rainfall distribution than conventional techniques such as the Theissen Polygon technique, (Tabios and Salas, 1985; Philips et al, 1992). Interpolation of isohyetal contours and calculation of the mean rainfall was performed using ArcGIS. The resulting isohyetal maps are displayed in Appendix C.

A comparison was done between the isohyetal and theissen polygon methods of assigning rainfall depth. Both methods were compared for the October 2010 and March 2001 events. In both cases average differences in subcatchment rainfall depths were less than 7%.

5.2.3.2 Rainfall Temporal Distribution

The rainfall temporal pattern assigned to subcatchments was taken from the closest rainfall pluviographic gauge. The gauge closest to each subcatchment was assessed using Theissen polygons. The Theissen polygons were produced using ArcGIS. The resulting theissen polygons are displayed in Appendix D.

5.2.4 Loss Parameters

A uniform continuing loss model was used to model pervious infiltration losses within the catchment. This model assumes an initial loss before rainfall becomes effective (i.e. is converted to runoff), after which a continuing loss rate is applied to the rainfall. Loss parameters were varied within a realistic range to achieve calibration to event records. No impervious losses were included in the model.

5.2.5 Stream Gauge Rating Information

No stream gauge rating data are available for any of the streamflow telemetry gauges supplied as part of this study. To allow the hydrologic model to be calibrated to the recorded water levels, rating curves were extracted from the hydraulic model. Rating curves were continuously updated through iterations of hydrologic and hydraulic model calibration.

6.0 Hydraulic Model Development

6.1 Overview

The hydraulic model developed for this study has been based on the following previous models:

- The 1D/2D TUFLOW model developed as part of the 2012 Cabbage Tree Creek Flood Risk Management Study (FRMS), which was not calibrated (BMT WBM, 2012).
- The 1D/2D TUFLOW model of the Taigum Channel developed by BCC (BCC, 2012)
- The 1D MIKE11 model of Carseldine Channel developed by BCC (BCC, 2011)
- The 1D MIKE11 model of the entire Cabbage Tree Creek catchment undertaken by BCC for the 1996 flood study, updated in 2000 (BCC, 2000).

The TUFLOW modelling package was selected to undertake the updated modelling for Cabbage Tree Creek. Hydrodynamically linked 1D/2D TUFLOW modelling is commonly used for this type of application.

The previous models were reviewed and used as the basis for an overall catchment model. Model inputs were updated where it was deemed appropriate or additional/updated data was supplied. Updates to model input data consisted generally of the following;

- additional structure data
- updated channel bathymetry data
- updated Manning's 'n' roughness values based on supplied aerial photography and BCC land use planning data.

The following sections detail the hydraulic modelling methodology used in this study.

6.1.1 Model Setup and Schematisation Topography and Bathymetry

Model topography has been derived from LIDAR information supplied by BCC. The data was supplied as classified point data with a vertical accuracy assumed to be in the order of ±0.15m. This was processed into a 1m DEM. The DEM as utilised in the modelling process is shown in Figure 4.

Creek bathymetry has been sourced from the following:

- 2013 survey provided by BCC
- 2006 cross section survey for the Aspley gauge provided by BCC
- The MIKE11 model constructed as part of the original 1996 flood study (updated in 2000).

The updated TUFLOW model incorporates approximately 240 1D cross sections throughout the Cabbage Tree Creek Catchment. Approximately 70% of these cross sections have been sourced from the MIKE11 model developed during the 1996 flood study (BCC, 2000). It is understood from communications with BCC that many of these cross sections were likely surveyed during the 1970's. Given the age of many of these cross sections, there is the potential that channel conveyance has not been accurately represented over much of the Cabbage Tree Creek Catchment. The 2013 surveyed cross sections were taken at key locations such as hydraulic structures to more accurately represent the most up to date channel geometry.

6.1.2 Grid Size and Time Step

The BMT WBM 2012 TUFLOW model was based on a 4 m grid size. On review of the model it was deemed that this resolution was appropriate for the purpose of developing the updated model. Although the majority of the major channels in the catchment have been represented in 1D, some smaller flowpaths have been represented in 2D so the grid cell resolution is considered appropriate.

Through the model development phase it was found that a timestep of 2 seconds represented the best compromise between model stability and total model runtimes. Total runtimes for calibration event runs were up to 20hrs.

6.1.3 Manning's 'n' Roughness

Manning's 'n' roughness values used in the BMT WBM 2012 TUFLOW model were reviewed and it was determined that there was adequate resolution in the set of land use values used. The Manning's 'n' values used in the modelling process are shown in Table 24.

Table 24 TUFLOW model land use types

Material Type	Manning's 'n' Roughness
Dense vegetation	0.090
Medium dense vegetation	0.075
Light brush and trees	0.035
Creeks channels	0.065
Roads/Footpaths	0.020
Urban block	0.180
Urban - footpaths	0.050
Maintained grass	0.040
Vegetated creek banks	0.120

The land use layers used in the BMT WBM 2012 TUFLOW model were also reviewed in consideration of the latest available aerial photography and BCC planning data and thus updated where appropriate. The 2D model domain land use is shown in Figure 6. In-bank Manning's 'n' values used in the 1D domain were based on the 1996 flood study (BCC, 2000). Appendix F shows adopted Manning's 'n' values.

6.1.4 Channel Sections

Cabbage Tree Creek, Little Cabbage Tree Creek, Carseldine Channel and Taigum Channel have all been represented using the ESTRY 1D solution scheme. Channel data has been sourced from previous TUFLOW and MIKE11 modelling efforts and updated with 2013 cross section survey information where available. The layout of the 1D network is shown in Figure 7.

6.1.5 Hydraulic Structures

Structures in the model have been represented as either 2D 'flow constrictions' or as 1D elements. The majority of structures were incorporated into the 1D domain. Table 25 summarise the structures not incorporated into the model with justification.

Table 25 Omitted Structures

Structure	Reach	Justification
Bikeway Bridge near Livingstone Crt/Nemira St	Cabbage Tree Creek	Small single span bridge, no structure details available
Footbridge near Bangalow St	Cabbage Tree Creek	Small single span bridge, no structure details available
Footbridge near Costner Pl	Cabbage Tree Creek	Small single span bridge, no structure details available
Footbridge near Althorp Rd	Cabbage Tree Creek	Small single span bridge, no structure details available
Footbridge near Jasmine Crt	Cabbage Tree Creek	Small single span bridge, no structure details available

Structure	Reach	Justification
Footbridge near Cambridge Crs	Cabbage Tree Creek	Small single span bridge, no structure details available
Lemke Rd Pedestrian Footbridge	Cabbage Tree Creek	Incorporated into road crossing structure
Gateway Mwy Pedestrian Footbridge	Cabbage Tree Creek	Incorporated into road crossing structure
Shorncliffe Railway Bridge	Cabbage Tree Creek	Incorporated into Sandgate Rd crossing
Blackwood Rd Bikeway Bridge	Cabbage Tree Creek	Incorporated into Sandgate Rd crossing
Footbridge near Hawera Ct	Little Cabbage Tree Creek	Small single span bridge, no structure details available
Footbridge near Trouts Rd	Little Cabbage Tree Creek	No structure details available, not visible on Google Maps
Burr St culvert	Little Cabbage Tree Creek	Outside of model extent
Beams Rd culverts	Carseldine channel	Outside of model extent
Footbridges near Silky Oak Circuit (2 structures)	Cabbage Tree Creek	No structure data, not on main channel
Footbridge near Desert Willow Way	Cabbage Tree Creek*	No structure data, not on main channel

* Unnamed tributary

A limited number of structures along the drainage channel in Deagon which runs through Albert Edward Paddon Park have been represented in the 2D domain. This channel has been modelled in 2D and as such the structures were modelled in 2D to minimise 1D/2D linkages and thus increase stability.

Figure 5 **Structures Represented in 2D**

6.1.5.1 Culverts

Culverts (circular and box culverts) have been modelled based on design information supplied by BCC and input data associated with previous models. The internal culvert equations within ESTRY (TUFLOW 1D engine) was used for the majority of culvert structures. ESTRY automatically estimates structure head losses based on the inputted structure geometry.

6.1.5.2 Bridges

Bridges have been modelled using the ESTRY bridge representation. This requires bridge opening geometry and user-defined head losses. Bridge openings have been modelled based on bathymetry survey and design information supplied by BCC. Bridge head losses have been estimated based on recorded calibration data and HEC-RAS modelling.

All TUFLOW structure losses have been compared to structure losses calculated in HEC-RAS. Where significant differences (greater than 150 mm) occurred structure losses were reviewed. Both the supplied calibration data and the HEC-RAS modelling was taken into account when adjusting structure losses based on differences between TUFLOW and HEC-RAS, i.e. final structure losses were applied such that the best agreement between calibration data and model predictions was achieved.

6.1.6 Boundary Conditions

6.1.6.1 Hydrologic Inputs

Flows at the upstream boundaries have been applied as flow versus time hydrographs derived using the calibrated URBS hydrology model. Locations of upstream boundaries have been summarised in Table 26. The location of upstream boundaries are shown in Figure 7.

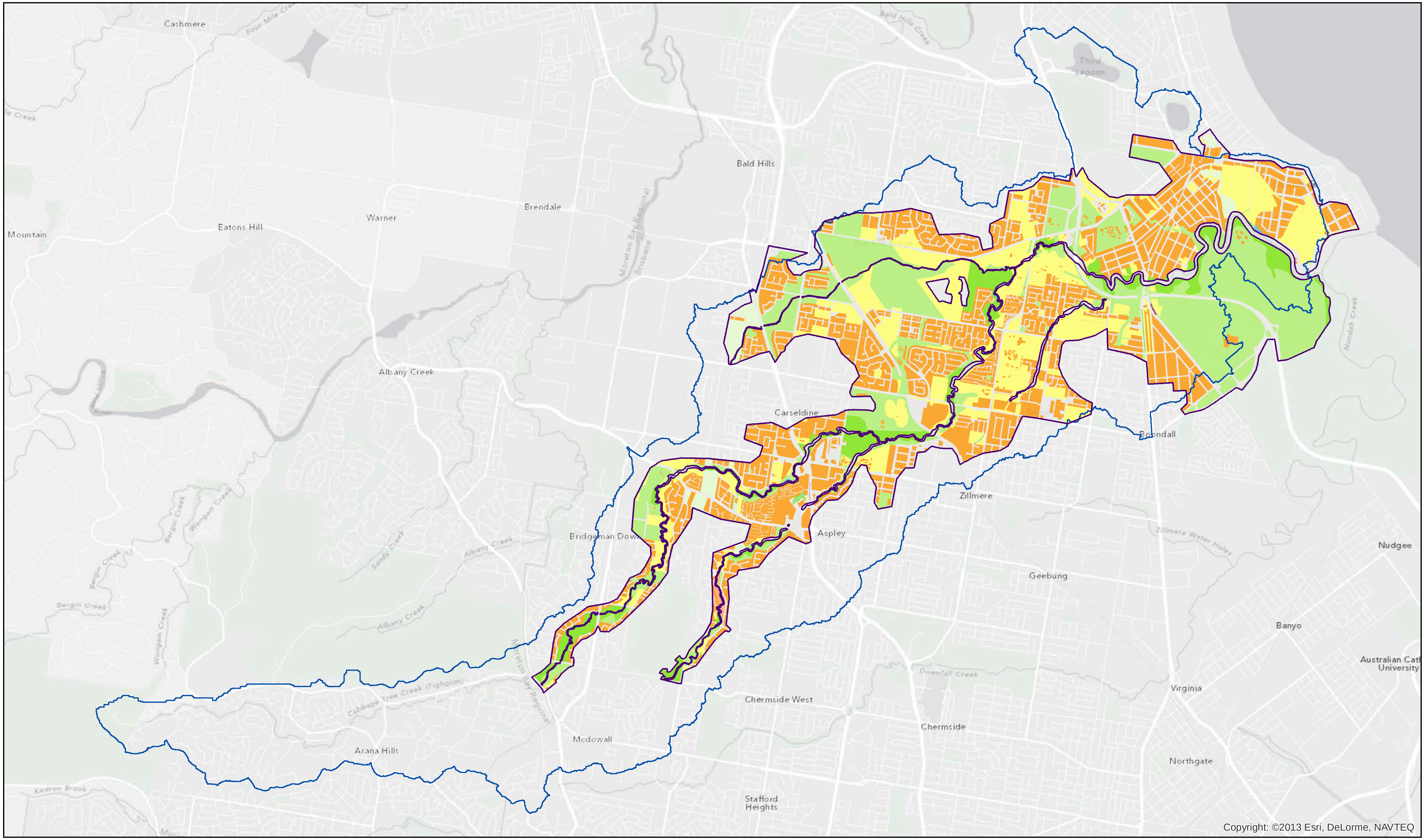
Table 26 Upstream Boundary Locations

Reach	Location
Cabbage Tree Creek	Upstream side of Old Northern Road
Little Cabbage Tree Creek	Upstream side of Hamilton Road
Carseldine Channel	Downstream side of Beams Road
Taigum Channel	Model extends to top of catchment

Subcatchment flows within the model domain have been applied as ‘flow over area’ boundaries. This type of boundary applies inflows initially in the lowest elevation cell within the catchment then to all wet cell after that. The rainfall boundaries are based on the subcatchment delineation and are shown in Figure 7.

6.1.6.2 Tailwater Conditions

Tidal boundaries for each calibration event were created from tidal constituent data for Brisbane Bar sourced from the Australian Hydrographic Service (www.hydro.gov.au). These results were then adjusted to Cabbage Tree Creek mouth using information published in the Queensland Tide Tables (www.msq.qld.gov.au). These tidal boundaries were applied as time-varying signals at the downstream boundary which was placed at the mouth of Cabbage Tree Creek. It has been assumed that no storm surge conditions existed during any of the flood events modelled, i.e. a ‘normal’ tidal signal has been applied at the downstream boundary for each flood event.



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,125 2,250 4,500

Metres

1:45,000 (when printed at A3)

Legend

- Catchment Outline
- 2D Model Extent

2D Domain Land Use

- Dense Vegetation
- Medium Dense Vegetation
- Light Brush and Trees
- Creeks
- Vegetated Banks
- Roads and Footpaths
- Urban Block
- Urban Footpaths
- Maintained Grass - Golf Course, Interspersed With Trees
- Channel Banks - Heavily Vegetated

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

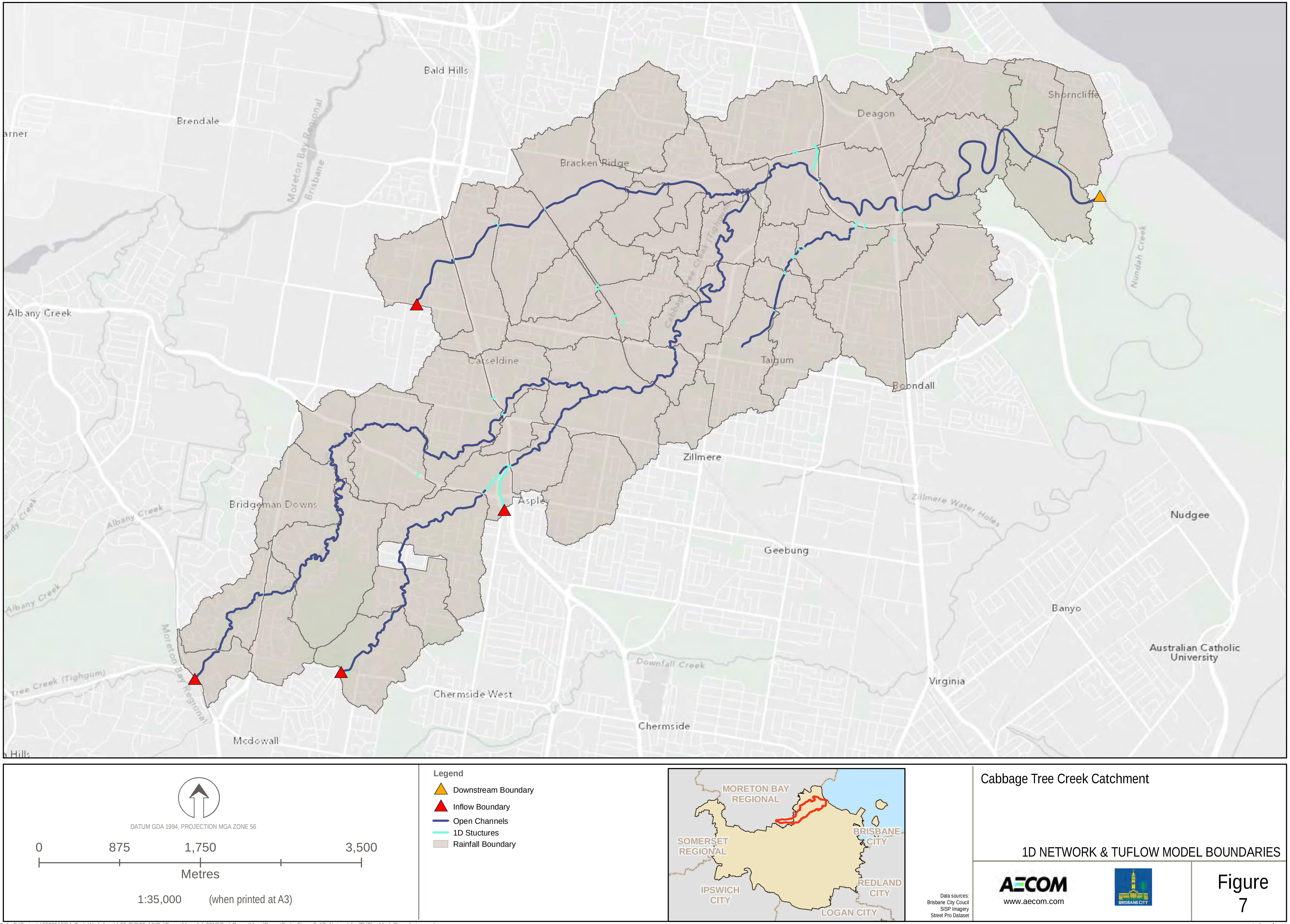
2D DOMAIN LAND USE

AECOM
www.aecom.com

Figure 6

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\BodyReportMaps\ReportBody_Figure6_2D_DomainLands.mxd



Data sources: Brisbane City Coucil, SISP Imagery, Street Pro Dataset

Cabbage Tree Creek Catchment

1D NETWORK & TUFLOW MODEL BOUNDARIES

www.aecom.com

Figure 7

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\BodyReportMaps\ReportBody_Figure7_1D_NetworkAndTUFlowModelBoundaries.mxd

7.0 Calibration and Verification

7.1 Joint Calibration Process

The calibration of the Cabbage Tree Creek TULFOW and URBS models was undertaken in a joint calibration process. This approach was driven largely by the lack of streamflow rating data at any of the stream height gauges in the catchment. During this phase an iterative approach was taken with information passing between the two models at each iteration. The models were calibrated to the following two flood events;

- October 2010
- March 2004.

Model results were assessed against gauging data supplied by BCC. Two forms of gauging data were supplied; stream height telemetry gauging and maximum height gauging (MHG). Three BCC stream height telemetry gauges are located within the model extents, these are;

- Aspley (LCA570)
- Carseldine (C_E702)
- Deagon (C_A561).

Stream gauge data (stream height) was supplied at 5 minute intervals. The telemetry gauges have been used to compare flood heights and the timing of the flood wave.

In addition to the telemetry gauging BCC operate MHGs within the Cabbage Tree Creek catchment. These gauges record peak flood heights only.

Once the best-fit calibration was achieved to the above events the models were verified using the following flood events;

- May 2009
- March 2001.

The purpose of the validation events is to test the chosen calibration parameters against a different set of events to assess the performance of the calibration parameters.

7.2 Event Independent Hydrologic Parameters

7.2.1 Channel Routing Parameters

URBS provides the option to model channel and catchment routing separately, therefore allowing the channel routing component to be matched to the results of the hydraulic model. This matching process involved running sinusoidal hydrographs through the TUFLOW and URBS model and varying the channel routing parameters in URBS to match the output of the TUFLOW model. This analysis was performed for the following three reaches of the model:

- Little Cabbage Tree Creek - from Hamilton Rd to upstream of the confluence with Cabbage Tree Creek (Reach1)
- Cabbage Tree Creek - from Old Northern Rd to the confluence with Little Cabbage Tree Creek (Reach 2)
- Cabbage Tree Creek - from the confluence with Little Cabbage Tree Creek to the catchment outlet (Reach 3).

The three reaches behaved significantly different, with good agreement between the models requiring different URBS channel routing parameters for each reach. Table 27 summarises the individual reach parameters derived for best fit. URBS only allows global routing parameters to be assigned. Parameters were subsequently selected to achieve reasonable consistency with the TUFLOW model output for all the reaches. Table 28 shows the resulting URBS channel routing parameters.

Table 27 Reach Specific URBS Channel Routing Paramters

	Parameter	Description	Value
Reach 1	α	Channel lag parameter	0.032
	X	Muskingum translational parameter	0.300
	n	Muskingum non-linearity parameter	0.720
Reach 2	α	Channel lag parameter	0.031
	X	Muskingum translational parameter	0.200
	n	Muskingum non-linearity parameter	0.770
Reach 3	α	Channel lag parameter	0.005
	X	Muskingum translational parameter	0.000
	n	Muskingum non-linearity parameter	1.070

Table 28 Final URBS channel routing parameters

Parameter	Description	Value
α	Channel lag parameter	0.01
X	Muskingum translational parameter	0.15
n	Muskingum non-linearity parameter	0.95

While reasonable reproduction of the hydraulic (TUFLOW) model routing was produced, the hydraulic complexity of the model means that absolute reproduction cannot be achieved in the scope of this study.

7.2.2 Subcatchment Routing Parameters

Subcatchment routing parameters were derived through iteration of the hydrologic/hydraulic models. Table 29 shows subcatchment routing parameters used across all models.

Table 29 URBS subcatchment routing parameters

Parameter	Description	Value
β	Catchment lag parameter	6.00
m	Catchment non-linearity parameter	0.78

7.3 Calibration Events

7.3.1 October 2010 Flood Event

7.3.1.1 Rainfall Data

Table 30 presents the rainf gauge stations used for the October 2010 flood event. Rainfall depth isohyets were created using both pluviographic and BOM daily rainfall data. Rainfall isohyets maps are given in Appendix C. Rainfall temporal patterns were assigned to subcatchments based on nearby recorded pluviographic data and Theissen polygons for the catchment.. Theissen polygon maps are given in Appendix D.

Table 30 October 2010 Flood Event Rainfall Data

Gauge	Data Type
A_R842	BCC Pluviographic data
BDR839	BCC Pluviographic data
C_R560	BCC Pluviographic data

Gauge	Data Type
C_R572	BCC Pluviographic data
K_R539	BCC Pluviographic data
LCR566	BCC Pluviographic data
MBR752	BCC Pluviographic data
Z_R850	BCC Pluviographic data
040960	BOM daily rainfall data
040977	BOM daily rainfall data

7.3.1.2 Hydrologic Modelling Results

The pervious loss parameters used to model the October 2010 event are presented in Table 31. Figure 8 and Figure 9 show a comparison of recorded and modelled flood levels at the Aspley and Carseldine gauging stations. These flood levels were derived from the URBS model discharge using the rating curves extracted from the hydraulic model. A comparison of the URBS model result and recorded data is not presented for the Deagon gauge, as the water level at this gauge is influenced by tidal variations which are not represented in the URBS model.

Table 31 Pervious infiltration losses for the 2010 flood event

Initial loss (mm)	Continuing loss (mm/hr)
10	0

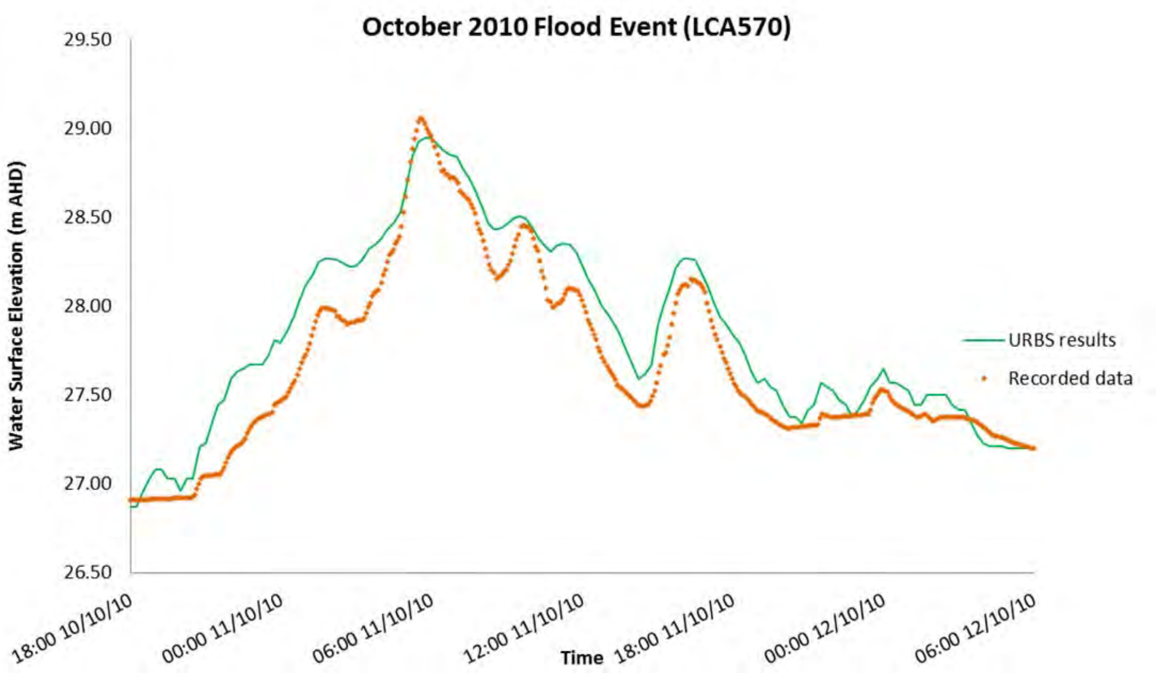


Figure 8 Comparison of flood levels at telemetry gauge LCA570 (Aspley), URBS model, October 2010 flood event

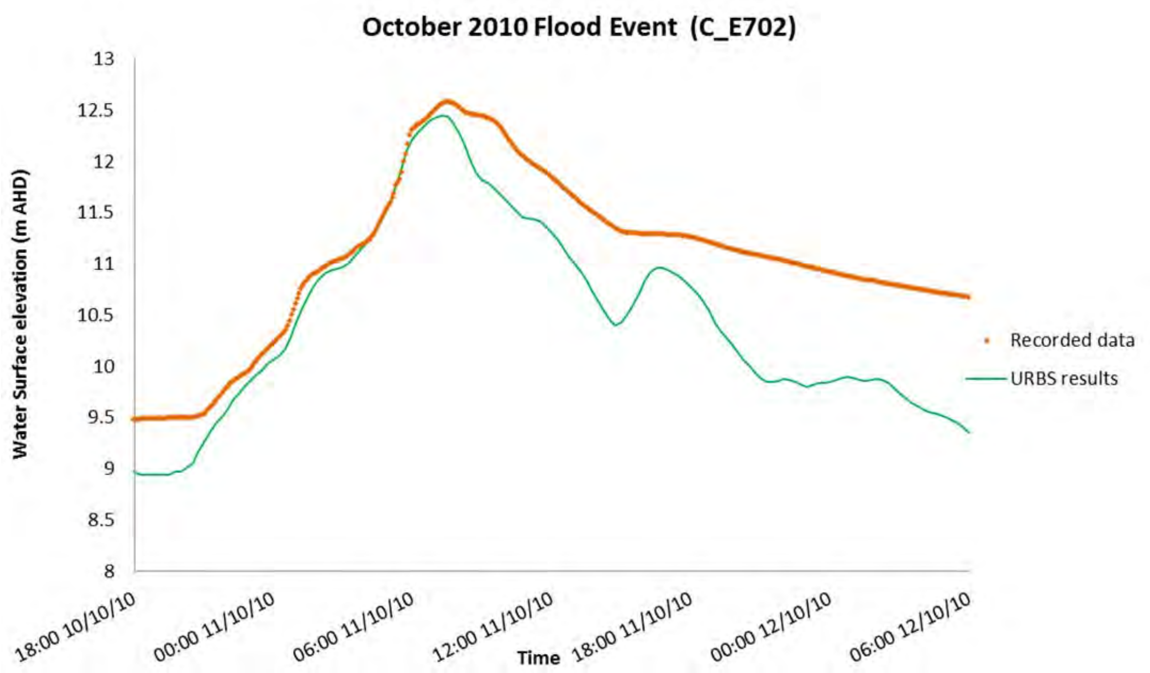


Figure 9 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), URBS model, October 2010 flood event

7.3.1.3 Hydraulic Modelling Results

Peak flood level maps for the October 2010 flood event are shown in Appendix E. The maps also show peak flood level comparison with supplied MHG data. The peak flood level maps also show recorded and modelled flood levels at MHGs. Figure 10, Figure 11 and Figure 12 show modelled flood levels versus recorded streamflow telemetry data for the Aspley, Carseldine and Deagon gauging stations. Table 32 summarises the peak flood levels at the telemetry gauges for the October 2010 flood event.

Table 32 Summary of Peak Flood Levels - October 2010 Flood Event

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	2.58	2.58	0.00
Carseldine (C_E702)	12.58	12.49	-0.09
Aspley (LCA570)	29.05	28.99	-0.06

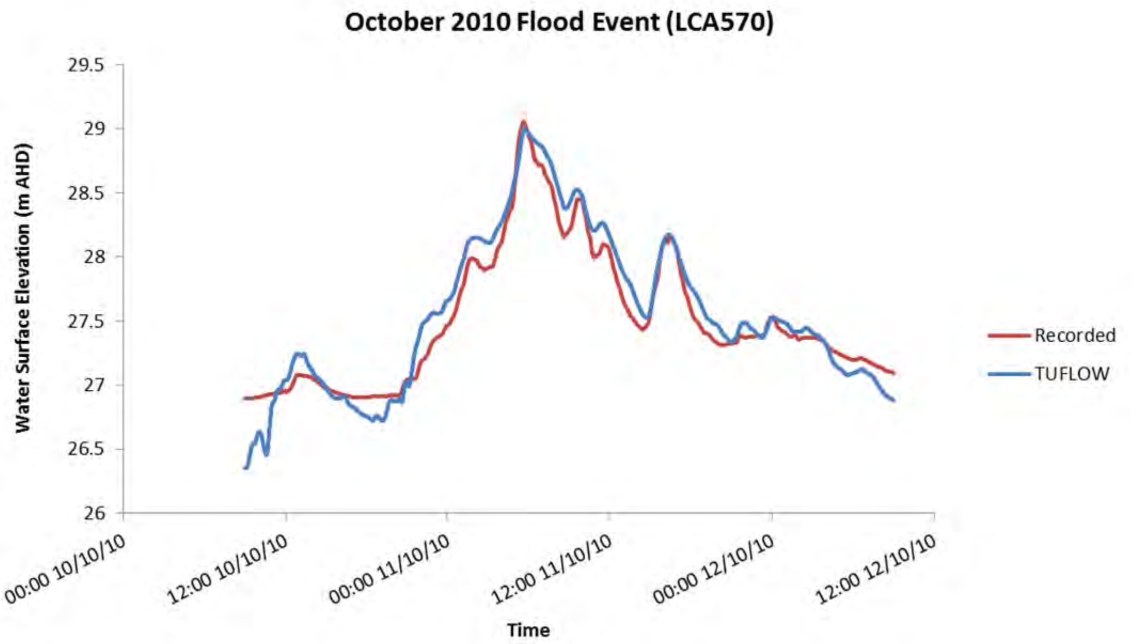


Figure 10 Comparison of flood levels at telemetry gauge LCA570 (Aspley), TUFLOW model, October 2010 flood event

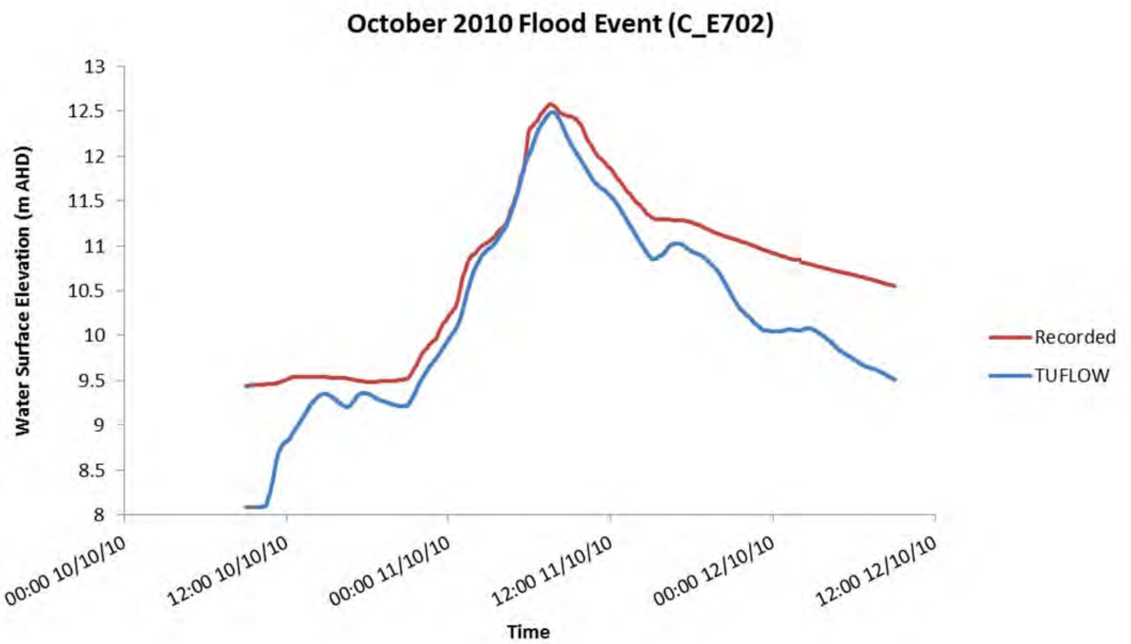


Figure 11 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), TUFLOW model, October 2010 flood event

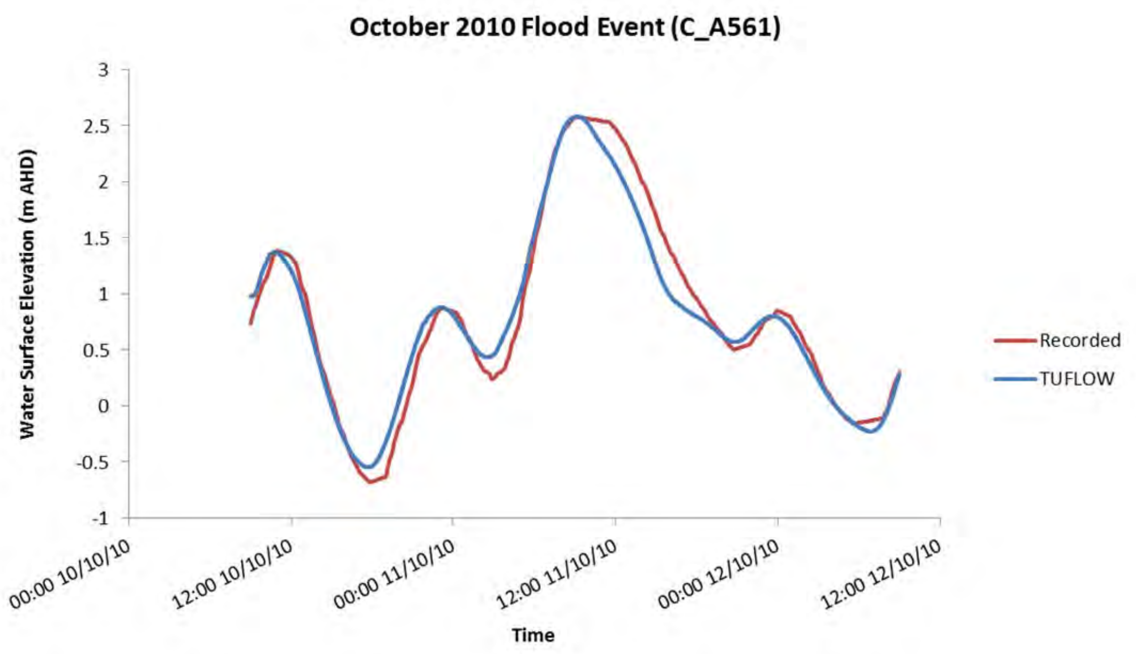


Figure 12 Comparison of flood levels at telemetry gauge C_A561 (Deagon), TUFLOW model, October 2010 flood event

Hydraulic Modelling Results indicate:

- Aspley and Carseldine gauges peak slightly below the recorded results, but both within ±0.15 m of the recorded peaks at those gauges.
- The modelled flood peak level at Deagon is the same to that recorded.
- MHG results indicate a reasonable match between modelled and recorded peak flood levels. The only area where a consistent trend of over or under-prediction was seen is the area between Old Northern Rd and Beckett Rd where flood levels appear under-predicted. This was not consistent across calibration events.
- All flood modelled flood peaks occur within 15 minutes of those recorded
- The 'shape' of the modelled hydrographs are generally consistent.

7.3.2 May 2009 Flood Event

7.3.2.1 Rainfall Data

Table 33 presents the rain gauge stations used for the May 2009 flood event. Rainfall depth isohyets were created using both pluviographic and daily rainfall data. Rainfall isohyets maps are given in Appendix C. Rainfall temporal patterns were assigned to subcatchments based on Theissen polygons generated from the pluviographic data. The Theissen polygon maps are given in Appendix D.

Table 33 May 2009 flood event rainfall data

Gauge	Data Type
A_R842	BCC Pluviographic data
BDR839	BCC Pluviographic data
C_R560	BCC Pluviographic data
K_R539	BCC Pluviographic data
LCR566	BCC Pluviographic data
MBR752	BCC Pluviographic data
Z_R850	BCC Pluviographic data

Gauge	Data Type
040960	BOM daily rainfall data

7.3.2.2 Hydrologic Modelling Results

The pervious loss parameters used to model the May 2009 event are presented in Table 34. Figure 13 and Figure 14 show a comparison of recorded and modelled flood levels at the Aspley and Carseldine gauging stations. These flood levels were derived from the URBS model discharge using the rating curves extracted from the hydraulic model. A comparison of the URBS model result and recorded data is not presented for the Deagon gauge, as the water level at this gauge is influenced by tidal variations which cannot be included in the URBS model.

Table 34 Pervious infiltration losses for the May 2009 event

Initial loss (mm)	Continuing loss (mm/hr)
25	0

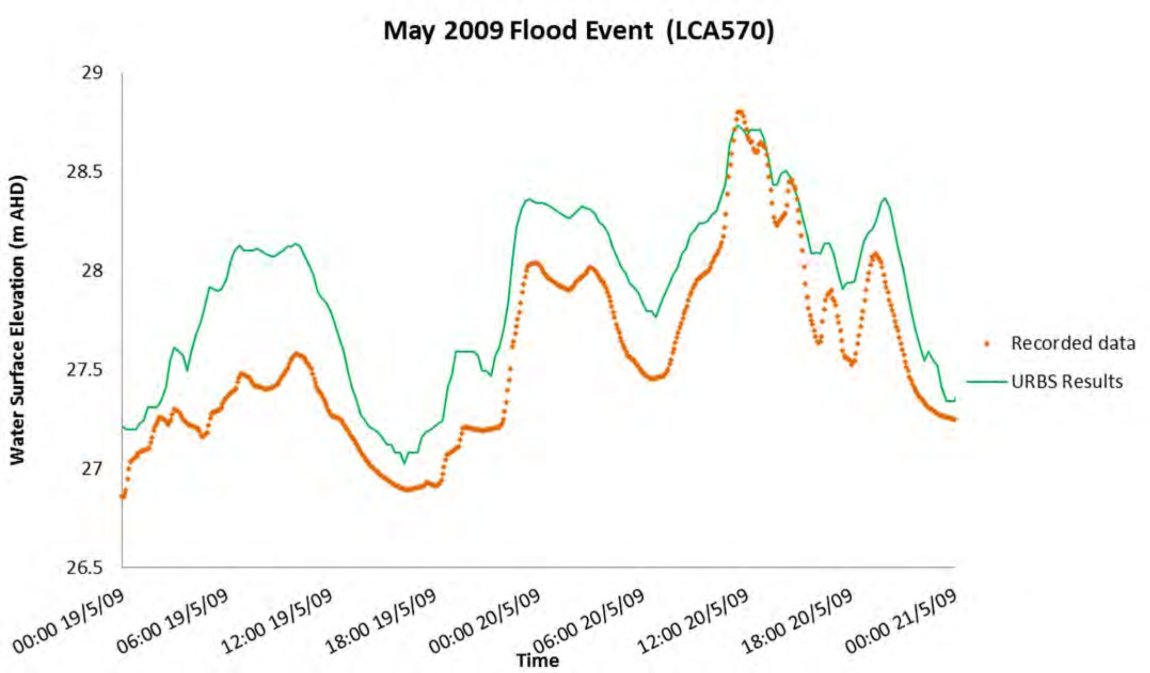


Figure 13 Comparison of flood levels at telemetry gauge LCA570 (Aspley), URBS model, May 2009 flood event

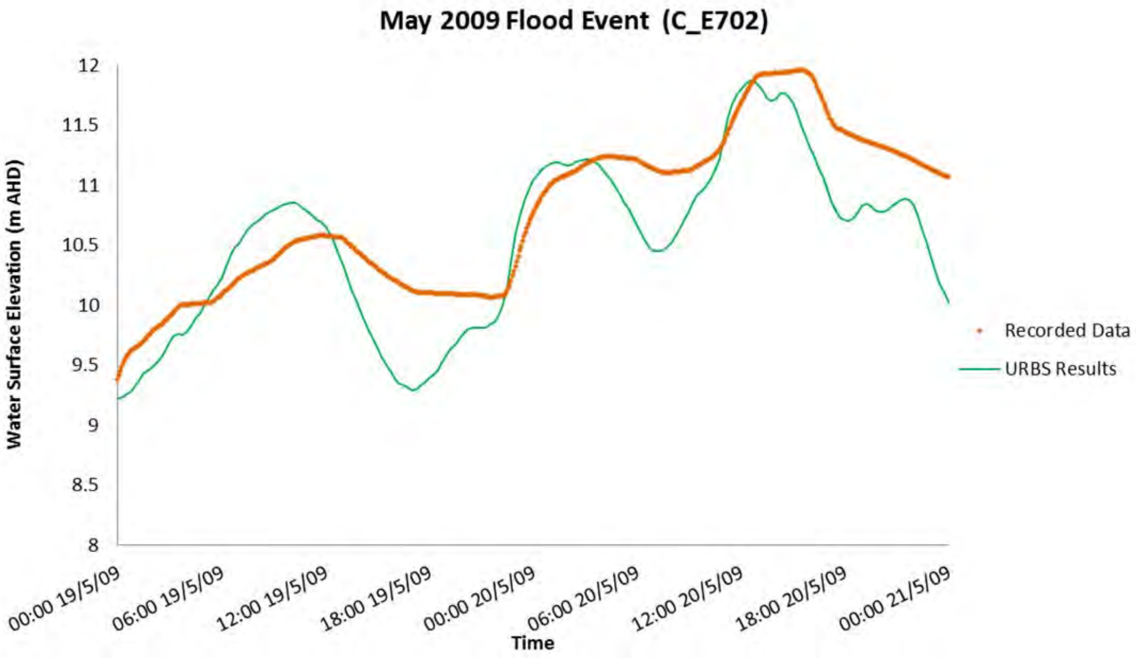


Figure 14 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), URBS model, May 2009 flood event

7.3.2.3 Hydraulic Modelling Results

Peak flood level maps for the May 2009 flood event are shown in Appendix E. The maps also show peak flood level comparison with supplied MHG data. Figure 15, Figure 16 and Figure 17 show modelled flood levels versus recorded streamflow telemetry data for the Aspley, Carseldine and Deagon gauging stations. Table 35 summarises the peak flood levels at the telemetry gauges for the May 2009 flood event.

Table 35 Summary of Peak Flood Levels – May 2009 Flood Event

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	1.97	1.95	-0.02
Carseldine (C_E702)	11.96	11.92	-0.04
Aspley (LCA570)	28.80	28.74	-0.06

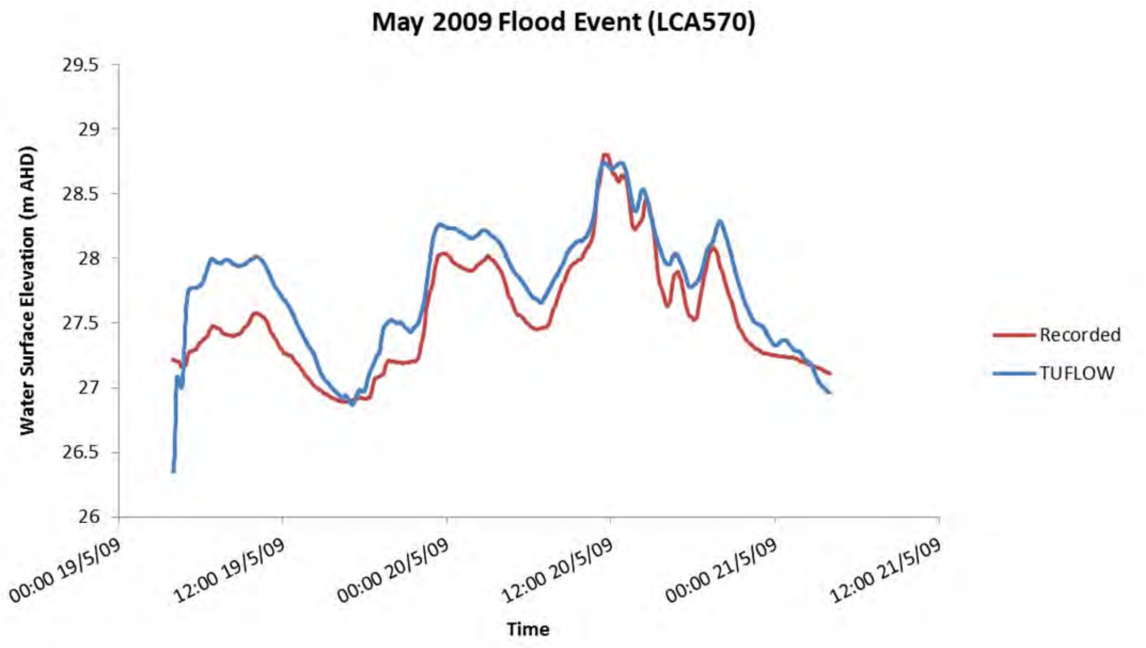


Figure 15 Comparison of flood levels at telemetry gauge LCA570 (Aspley), TUFLOW model, May 2009 flood event

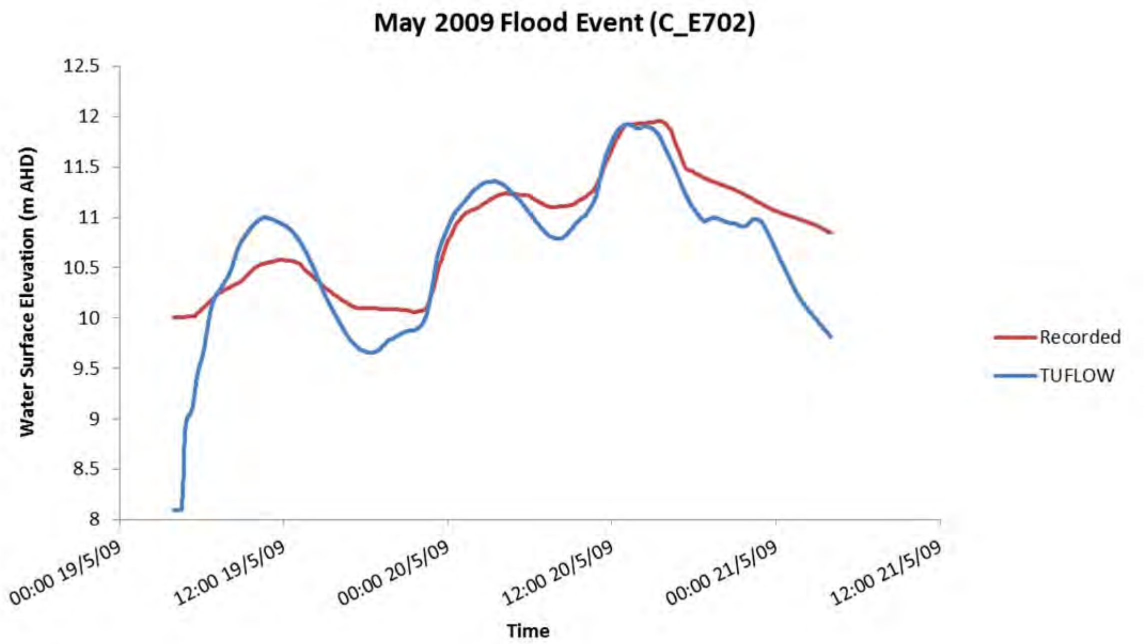


Figure 16 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), TUFLOW model, May 2009 flood event

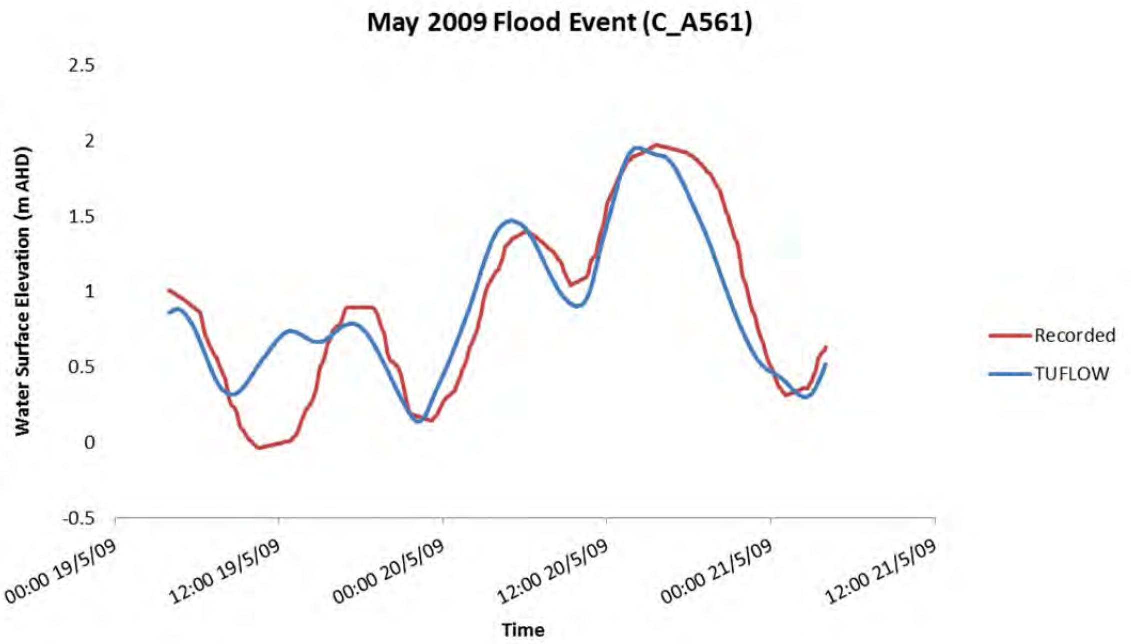


Figure 17 Comparison of flood levels at telemetry gauge C_A561 (Deagon), TUFLOW model, May 2009 flood event

Hydraulic Modelling Results indicate:

- Aspley, Carseldine and Deagon gauge peak flood levels peak slightly below the recorded results, but all are within ±0.15m of the recorded peak levels at those gauges
- MHG results indicate a reasonable match between modelled and recorded peak flood levels. The only area where a consistent trend of over or under-prediction was seen is the structure at Roghan Road where flood levels appear over-predicted. Levels upstream and downstream of this location show good agreement between recorded and modelled levels.
- The modelled flood peak at the Aspley gauge occurs within 10 minutes of the recorded peak.
- Deagon and Carseldine modelled flood peak levels occur approximately 1-2 hours before the recorded peaks. In both cases the recorded peak is very flat so timing is considered acceptable for these events.
- The 'shape' of the modelled hydrographs are generally consistent.

7.4 Verification Events

7.4.1 March 2004 Flood Event

7.4.1.1 Rainfall Data

Table 36 presents the rain gauge stations used for the March 2004 flood event. Rainfall depth isohyets were created using both pluviographic and daily rainfall data. Rainfall isohyets maps are given in Appendix C. Rainfall temporal patterns were assigned to subcatchments based on Theissen polygons generated from the pluviograpic data. Theissen polygon maps are given in Appendix D.

Table 36 March 2004 flood event rainfall data

Gauge	Data Type
C_R560	BCC Pluviographic data
C_R572	BCC Pluviographic data
K_R539	BCC Pluviographic data
LCR566	BCC Pluviographic data
MBR752	BCC Pluviographic data

7.4.1.2 Hydrologic Modelling Results

The pervious loss parameters used to model the March 2004 event are presented in Table 37. Figure 18 and Figure 19 show a comparison of recorded and modelled flood levels at the Aspley and Carseldine gauging stations. These flood levels were derived from the URBS model discharge using the rating curves extracted from the hydraulic model. A comparison of the URBS model result and recorded data is not presented for the Deagon gauge, as the water level at this gauge is influenced by tidal variations which cannot be included in the URBS model.

Table 37 Pervious infiltration losses for the March 2004 event

Initial loss (mm)	Continuing loss (mm/hr)
30	0

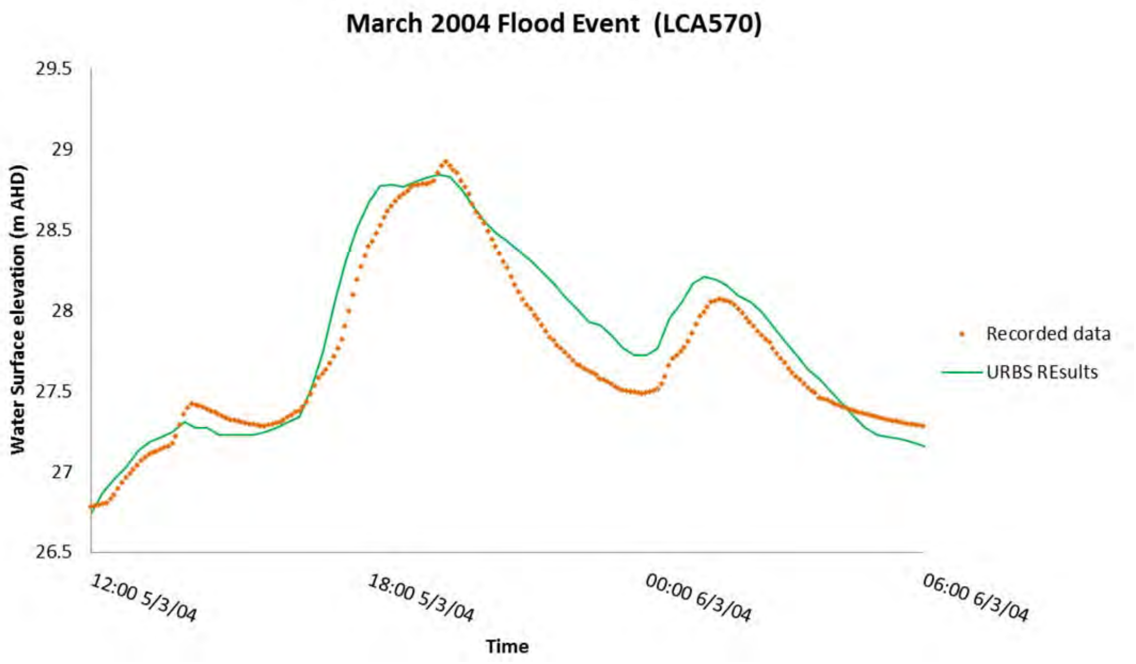


Figure 18 Comparison of flood levels at telemetry gauge LCA570 (Aspley), URBS model, March 2004 flood event

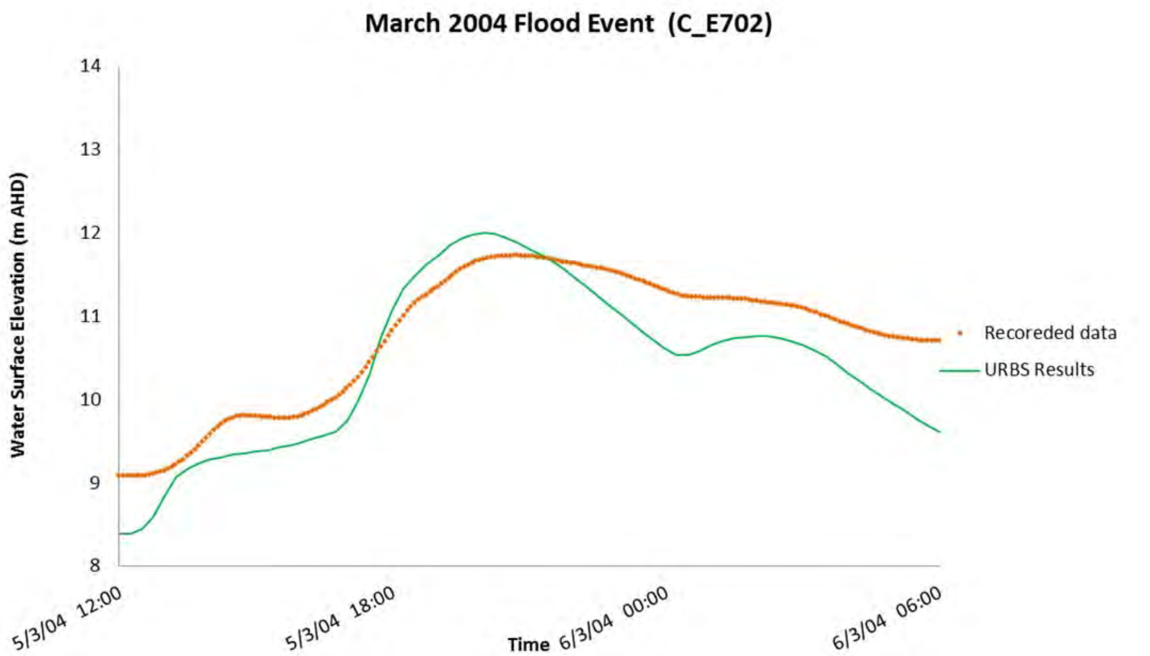


Figure 19 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), URBS model, March 2004 flood event

7.4.1.3 Hydraulic Modelling Results

Peak flood level maps for the March 2004 flood event are shown in Appendix E. The maps also show peak flood level comparison with supplied MHG data. Figure 20, Figure 21 and Figure 22 show modelled flood levels versus recorded streamflow telemetry data for the Aspley, Carseldine and Deagon gauging stations. Table 38 summarises the peak flood levels at the telemetry gauges for the March 2004 flood event.

Table 38 Summary of Peak Flood Levels – March 2004 Flood Event

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	1.81	1.86	0.05
Carseldine (C_E702)	11.72	12.01	0.29
Aspley (LCA570)	28.92	28.87	-0.05

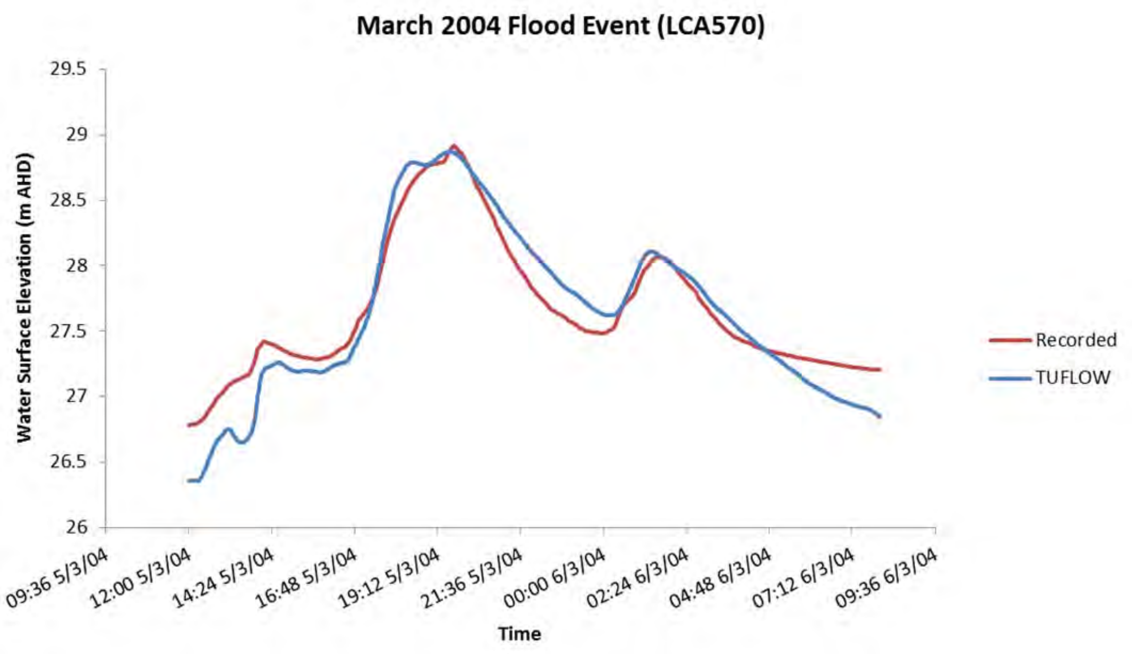


Figure 20 Comparison of flood levels at telemetry gauge LCA570 (Aspley), TUFLOW model, March 2004 flood event

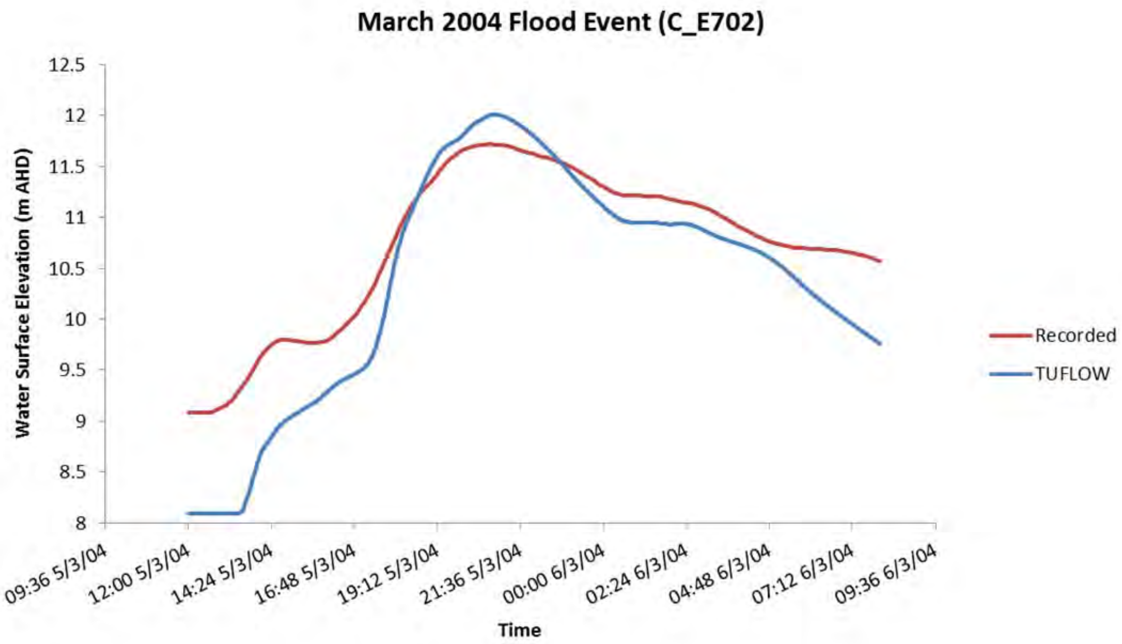


Figure 21 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), TUFLOW model, March 2004 flood event

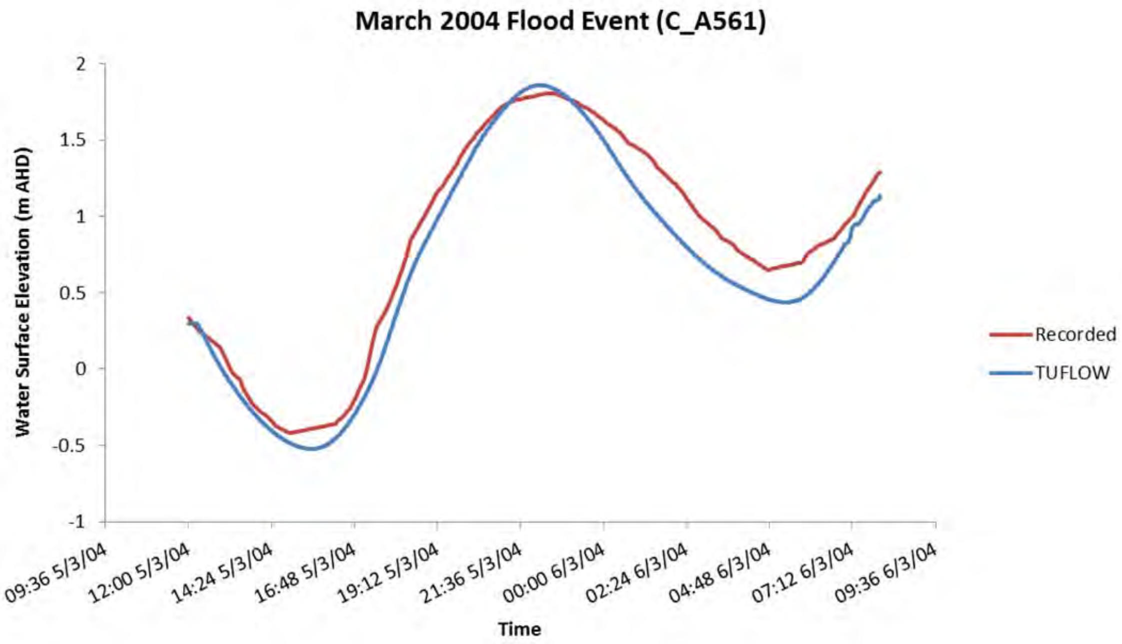


Figure 22 Comparison of flood levels at telemetry gauge C_A561 (Deagon), TUFLOW model, March 2004 flood event

Hydraulic Modelling Results indicate:

- Modelled peak flood levels at the Aspley and Deagon gauges are marginally higher than that recorded
- Modelled peak flood level at the Carseldine gauge is approximately 0.3 m higher than that recorded. The shape of the recorded hydrograph appears more attenuated than that modelled. MHG data in the vicinity indicate good agreement with modelled results.
- MHG results generally indicate a reasonable match between modelled and recorded peak flood levels. Some inconsistency between modelled and recorded levels between the Gateway Motorway and the North Coast Railway is observed, although there is neither consistency in under or over prediction.
- All modelled flood peak at the telemetry gauges occur within 15 minutes of the recorded peaks.

- The 'shape' of the modelled hydrographs are generally consistent.

7.4.2 March 2001 Flood Event

7.4.2.1 Rainfall Data

Table 39 presents the rain gauging stations used for the March 2001 flood event. Rainfall depth isohyets were created using both pluviographic and daily rainfall data. Rainfall isohyets maps are given in Appendix C. Rainfall temporal patterns were assigned to subcatchments based on Theissen polygons generated from the pluviograpic data. Theissen polygon maps are given in Appendix D.

Table 39 March 2001 Rainfall Gauges

Gauge	Data Type
CVR560	BCC Pluviographic data
CVR572	BCC Pluviographic data
CVR715	BCC Pluviographic data
CVR733	BCC Pluviographic data
KVR539	BCC Pluviographic data
LCR566	BCC Pluviographic data
MBR752	BCC Pluviographic data
040241	BOM daily rainfall data

7.4.2.2 Hydrologic Modelling Results

The pervious loss parameters used to model the March 2001 event are presented in Table 40. Figure 23 and Figure 24 show a comparison of recorded and modelled flood levels at the Aspley and Caseldine gauging stations. These flood levels were derived from the URBS model discharge using the rating curves extracted from the hydraulic model. A comparison of the URBS model result and recorded data is not presented for the Deagon gauge as the water level at this gauge is influenced by tidal variations which cannot be included in the URBS model.

Table 40 Pervious infiltration losses for the March 2001 event

Initial loss (mm)	Continuing loss (mm/hr)
60	0

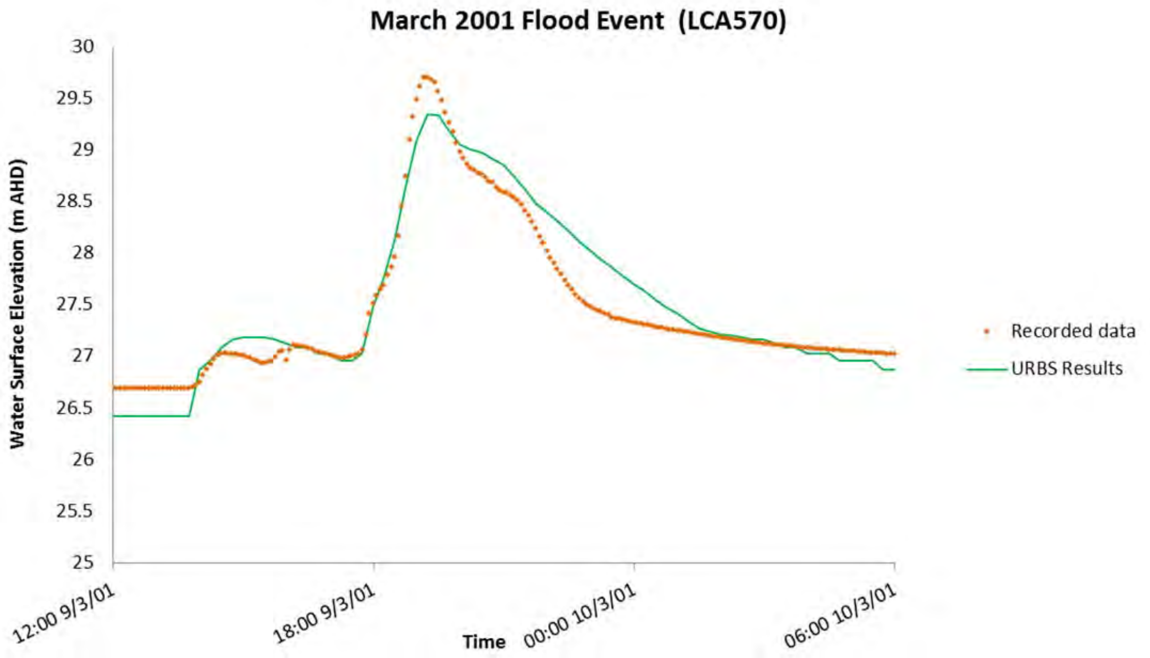


Figure 23 Comparison of flood levels at telemetry gauge LCA570 (Aspley), March 2001 flood event

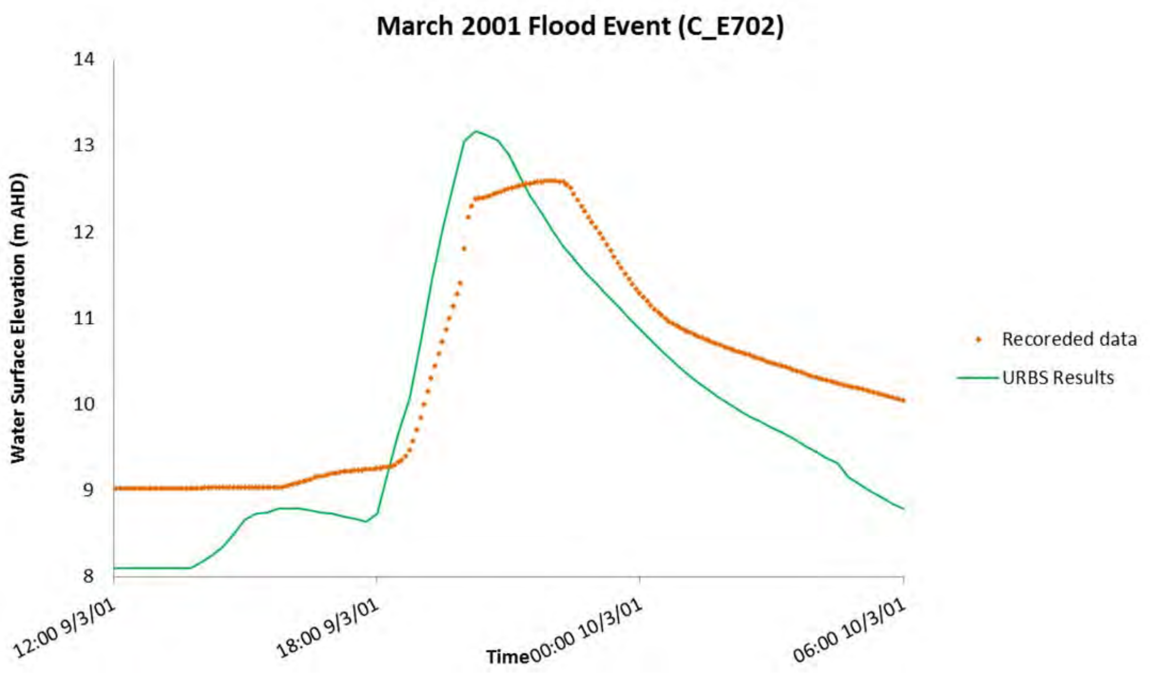


Figure 24 Comparison of flood levels at telemetry gauge C_E702 (Carseldine), March 2001 flood event

7.4.2.3 Hydraulic Modelling Results

Peak flood level maps for the March 2001 flood event are shown in Appendix E. The maps also show peak flood level comparison with supplied MHG data. Figure 25, Figure 26 and Figure 27 show modelled flood levels versus recorded streamflow telemetry data for the Aspley, Carseldine and Deagon gauging stations. Table 41 summarises the peak flood levels at the telemetry gauges for the March 2001 flood event.

Table 41 Summary of Peak Flood Levels – March 2001 Flood Event

Gauge	Observed (mAHD)	Modelled (mAHD)	Difference (m)
Deagon (C_A561)	2.53	2.67	0.14
Carseldine (C_E702)	12.59	12.98	0.39
Aspley (LCA570)	29.69	29.35	-0.34

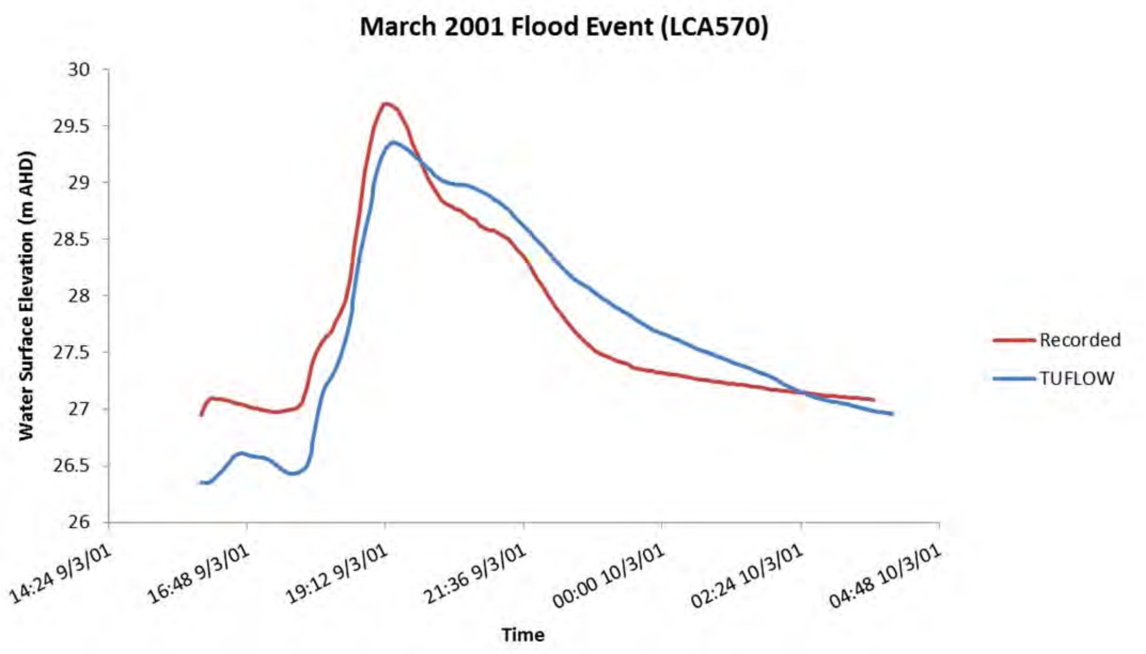


Figure 25 Comparison of flood levels at telemetry gauge LCA570 (Aspley), March 2001 flood event

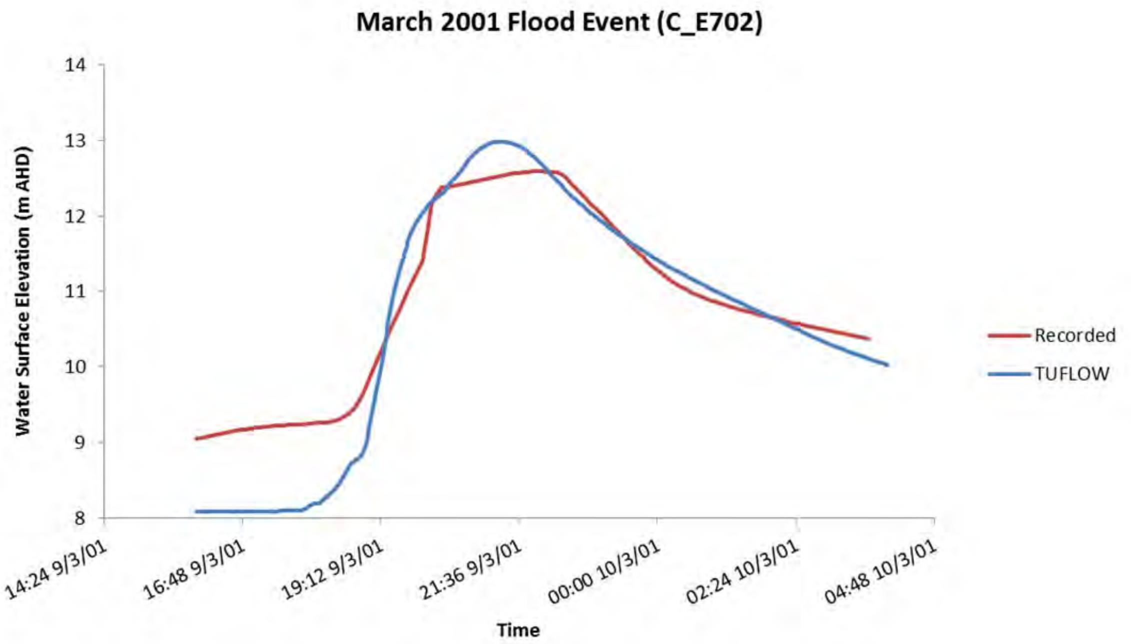


Figure 26 **Comparison of flood levels at telemetry gauge C_E702 (Carseldine), March 2001 flood event**

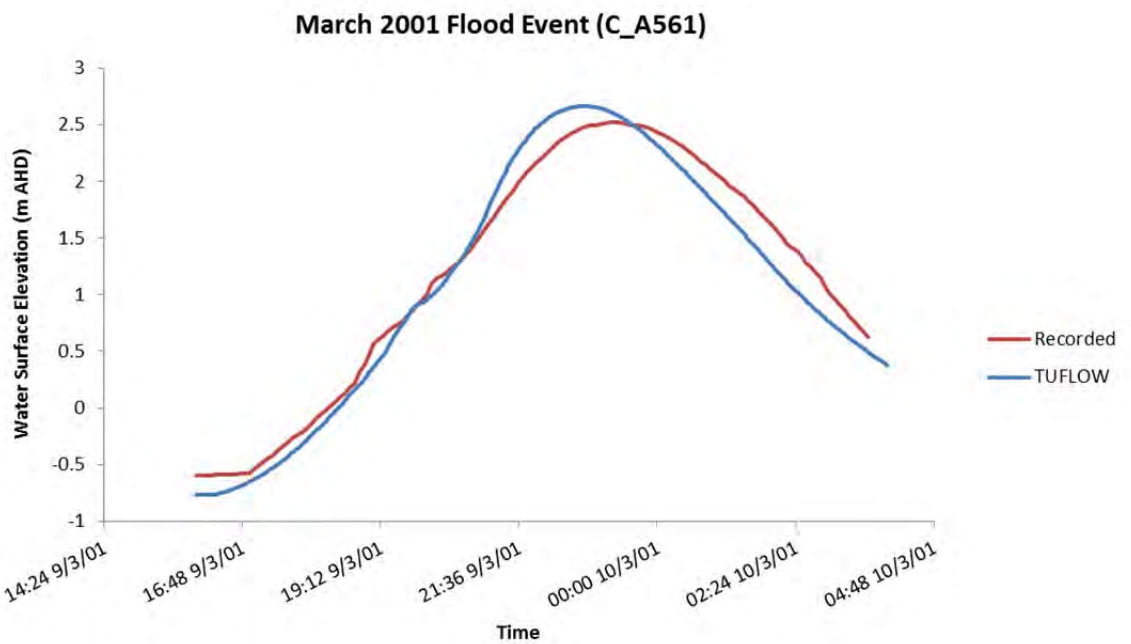


Figure 27 **Comparison of flood levels at telemetry gauge C_A561 (Deagon), March 2001 flood event**

Hydraulic Modelling Results indicate:

- The modelled peak flood level at the Aspley gauge is approximately 0.3 m lower than that recorded. MHG results show modelled flood levels on Little Cabbage Tree to be lower that recorded levels upstream of Gympie Road.
- The modelled peak flood level at the Carseldine gauge is approximately 0.3 m higher than that recorded. It is understood that the gauge did not function properly during the 2001 event and the peak was not captured.
- Modelled peak flood level at the Deagon gauge is within 0.15 m of the recorded value.

- MHG results generally support the telemetry gauge results. Modelled peak flood levels upstream of Gympie Road appear under-predicted, although a number of levels at MHGs are within 0.3 m. The majority of MHG levels downstream of Gympie Road are within 0.3 m.
- The modelled timing of the Aspley flood peak is within 15 minutes of the recorded value. The difference in recorded and modelled peak level at the Deagon gauge is approximately 1 hour.
- The 'shape' of the modelled hydrographs are generally consistent (with the exception of the Carseldine gauge).

7.5 Structure Loss Comparisons

Comparison of final TUFLOW and HEC-RAS structure losses for the October 2010 and May 2009 flood events are presented in Appendix H. It is considered that the flows for these events are representative of the verification events.

Average head loss differences for the majority of structures are below 0.15 m. Where there is deviation from this justification has been provided in Appendix H.

7.6 Calibration Summary

An integrated 1D/2D hydraulic model and associated hydrologic model has been created for the purpose of updating the Cabbage Tree Creek Flood Study. The models have been jointly calibrated to two historical flood events (October 2010 and May 2009) and validated against a further two events (March 2004 and March 2001).

Calibration Results (October 2010 and May 2009)

The hydraulic modelling results indicated a generally good fit in terms of peak flood height and peak flood timing between recorded and modelled results for the calibration events. Key points from the calibration modelling results were:

- All modelled peak flood levels were within ±0.15 m for all recorded peak flood levels at the supplied telemetry gauges
- Peak flood timings were generally good with the majority of peak flood levels modelled within 15 minutes of recorded flood peaks
- MHG peak flood level records indicated relatively good matches between modelled and recorded peak flood levels. Some inconsistencies were observed but no trends of consistent over or under-prediction of peak flood levels were observed across the calibration events modelled.

Verification Results (March 2004 and March 2001)

Hydraulic modelling results for the validation events were not as consistent as those observed in the calibration events. Although this is the case modelling results are considered reasonable for these events. Key points from the verification modelling results were:

- The modelled peak flood levels for the March 2004 event were generally consistent with those recorded at the telemetry gauging stations. Peak flood level difference was 0.3 m at the Carseldine gauge. MHG gauges indicate good agreement between modelled and recorded levels for the 2004 event.
- Peak flood timings were also considered good for the March 2004 event.
- Modelled peak flood levels upstream of the confluence of Cabbage Tree Creek and Little Cabbage Tree Creek appear under-predicted compared to recorded levels for the March 2001 flood event. Potentially this could be due to under-prediction of rainfall intensity in the upper catchment due to sparse rainfall gauging information.

Based on the results of the calibration and verification event modelling it was determined that the hydraulic and hydrologic modelling parameters developed are a reasonable representation of the Cabbage Tree creek catchment conditions.

8.0 Design Hydrology

8.1 IFD Parameters

IFD parameters for the 2 year to 100 year ARI events were derived using the online tool available from the BOM (www.bom.gov.au). Parameters were derived for a single point within the Cabbage Tree Creek catchment. The location used to derive IFD parameters was 27.350°S, 153.025°E. Table 42 summarises design IFD information used for this study.

Table 42 IFD Data

Duration (min)	ARI (Years)					
	2	5	10	20	50	100
30	70.0	90.0	102.0	118.0	140.0	156.0
60	47.8	62.0	71.0	82.0	98.0	110.0
120	30.1	39.2	44.8	52.2	62.2	70.0
180	22.8	29.8	34.1	39.8	47.4	53.4
270	17.0	23.0	26.0	30.0	36.0	40.7
360	14.2	18.6	21.3	24.9	29.7	33.5

Given the size of Cabbage Tree Creek catchment aerial reduction factors were not used in this study. It is considered that the point rainfall depths will give more conservative estimates of the design flood events.

8.2 Design Event Loss Parameters

Table 43 summarises the design event loss parameters adopted. The lowest initial loss value from the calibration and verification events was adopted.

Table 43 Design Event Loss Parameters

Initial Loss (mm)	Continuing Loss (mm/h)
10	0

8.3 Ultimate Land Use

All design event hydrology has been run using ultimate development conditions. The current BCC City Plan was supplied in GIS format as part of this study. To simulate ultimate development conditions, the impervious percentage of all areas of ‘emerging communities’ was increased to low-medium residential. For the areas of the catchment within the MBRC LGA an estimate of areas of future development was made based on aerial photography.

After design hydrology was developed ultimate case catchment fraction impervious was sourced from a hydrology model supplied by MBRC. A comparison was made with the estimates made from the aerial photography. Based on this comparison it was found that the impervious fractions used in the design hydrology were generally more conservative that those supplied in the MBRC model, with differences ranging from -0.03 to 0.29. These comparisons are considered approximate only as catchment delineation in the two models differed.

8.4 Extreme Event Hydrology

Design event rainfall depths for events larger than the 100 year ARI and design temporal patterns for the 2000 year ARI and PMP events have been provided by BCC. Appendix I describes the methodology used to derive rainfall depths and summarises the supplied rainfall depths. Standard AR&R (EA, 1997) temporal patterns have been used for 200 year and 500 year ARI events. Temporal patterns for the 2000 year ARI and PMP events have been supplied by BCC and are described in Appendix I.

8.5 Climate Change Hydrology

Two different climate change scenarios have been considered as part of this study, i.e. 2050 and 2100 scenarios. These scenarios were defined by BCC as part of the scope of this study. Table 44 outlines the hydrological scenarios applied.

Table 44 Climate Change Scenarios

Scenario	ARI Events	Change in Rainfall Depth
Scenario 1, 2050 (CC1)	100 and 200 year ARI Events	+10%
Scenario 2, 2100 (CC2)	100, 200 and 500 year ARI Events	+20%

8.6 Flood Frequency Analysis

8.6.1 Overview

A flood frequency analysis (FFA) was performed at each of the telemetry gauge locations. The FFA was used as a comparison with the modelled design events. BCC and BOM Brisbane CBD gauge data was used to generate annual series of peak rainfall bursts as these gauges have the longest rainfall record; the period 1911 to 2009 was used. Peak rainfall bursts were derived by BCC using HYD-SYS.

8.6.2 Rainfall Inputs

Peak rainfall bursts for the period 1911 – 2009 were supplied by BCC. Peak rainfall bursts of 1hr, 2hr, 3hr and 6hr were considered as these have been shown to be the critical durations based on the design rainfall results (see Section 9.1).

Table 45 Rainfall Records

Gauge	Records Used
BOM CBD Gauge	1911 - 1990
BCC CBD Gauge	1991 - 2009

8.6.3 Statistical Fitting

The rainfall data was fitted to two statistical distributions; the Generalised Extreme Value (GEV) and Log-Pearson III (LP3). Fitting was done using the FLIKE software developed by George Kuczera at the University of Newcastle (Kuczera, 1999).

8.6.4 FFA Results

FFA results for telemetry gauge locations are shown in Table 46, Table 47, Table 48 and Table 49. FFA results have been compared to the peak flows obtained at each gauge using design rainfall depths. In general FFA results (for both distributions considered) are within 5% of those predicted using design hydrology. In addition to the tabulated results, graphical representations of the LP3 and GEV fitting are given in Figure 28 and Figure 29 respectively.

Table 46 FFA Results C_A573 (Everton Hills)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	35.00	34.78	34.64
5	48.60	49.49	49.12
10	57.20	59.91	59.80
20	68.90	70.39	70.95
50	82.00	84.73	86.83
100	94.30	96.09	99.91

Table 47 FFA Results LCA570 (Aspley)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	26.30	26.67	26.58
5	36.50	37.72	37.46
10	43.00	45.56	45.50
20	51.90	53.48	53.89
50	61.80	64.33	65.85
100	71.60	72.97	75.70

Table 48 FFA Results C_E702 (Carseldine)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	94.60	89.38	89.25
5	129.50	127.01	126.36
10	151.10	153.67	153.63
20	180.00	180.52	182.03
50	218.60	217.26	222.35
100	249.50	246.40	255.42

Table 49 FFA Results C_A561 (Deagon)

ARI Event	Peak Flow (m^3/s)		
	Design Hydrology (URBS)	GEV	LP3
2	137.20	131.36	131.16
5	186.20	185.55	184.47
10	217.40	223.64	223.20
20	259.10	261.78	263.15
50	314.20	313.65	319.27
100	359.10	354.58	364.85

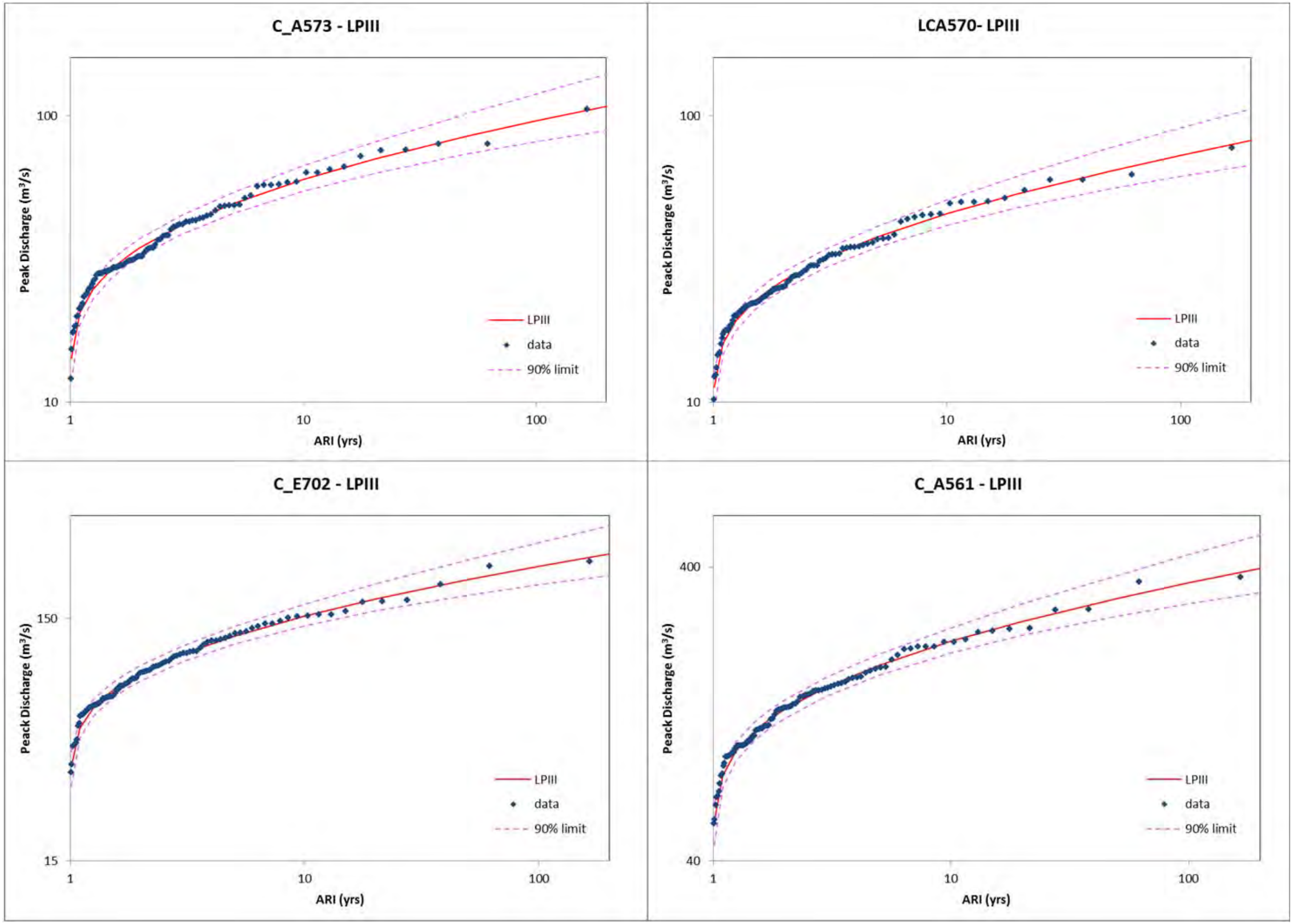


Figure 28 LP3 distribution curves

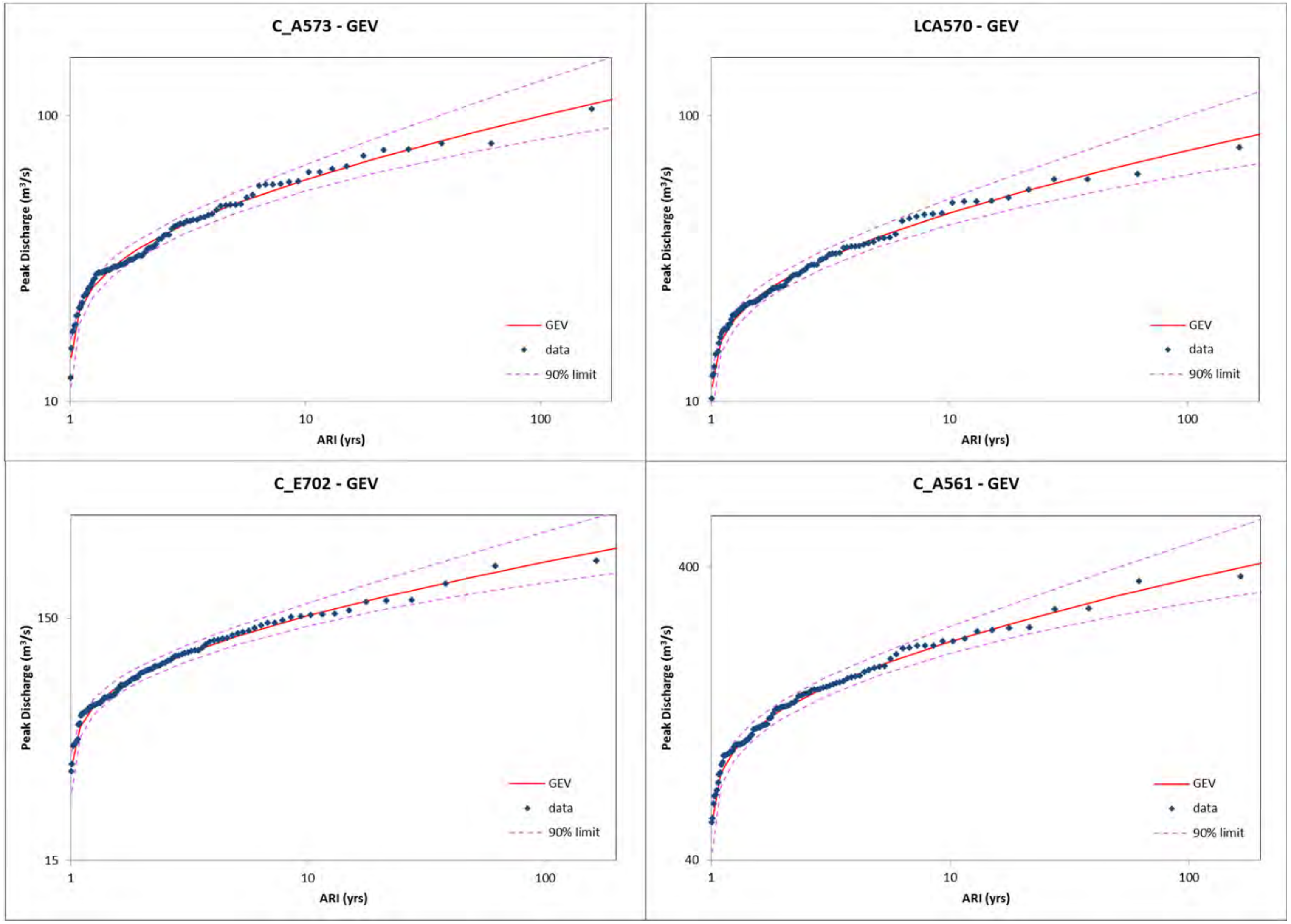


Figure 29 GEV distribution curves

9.0 Design Hydraulics

9.1 Critical Durations

A critical duration analysis was performed using the 100 year ARI event. The following durations were initially considered; 30 min, 60 min, 120 min, 180 min, 270 min and 360 min. The 100 year ARI critical duration map is shown in Appendix J. Based on the critical duration map the following is observed;

- The 60 min event is critical in the upper reaches of Little Cabbage Tree Creek, Carseldine Channel and Taigum Channel
- The 120 min event is critical in the upper reaches of Cabbage Tree Creek, the areas of Little Cabbage Tree Creek that were not 60 min critical, the middle reaches of Carseldine Channel and the lower reaches of Taigum Channel
- The 180 min event is critical for much of Cabbage Tree Creek between Gympie Road and the Gateway Motorway and the lower reaches of Carseldine Channel
- The 360 min event was the dominant critical event for the areas of Cabbage Tree Creek downstream of the Gateway Motorway.

The 60 min, 120 min, 180 min and 360min durations were selected as the critical envelope of events. The difference between the selected durations and the total suite of durations was calculated and is also shown in Appendix J. Differences between the two peak flood level surfaces are negligible.

9.2 Design Events Modelled

Table 50 summarises the design events modelled as part of this study. Three different floodplain scenarios have been considered:

- Existing floodplain
- Existing floodplain + Minimum Riparian Corridor (MRC)
- Ultimate catchment conditions.

Table 50 Design Event Summary

Scenario	Existing Floodplain	Existing Floodplain + MRC	Ultimate Case
2 yr	✓	×	✓
5 yr	✓	×	✓
10 yr	✓	×	✓
20 yr	✓	×	✓
50 yr	✓	×	✓
100 yr	✓	✓	✓
100 yr +CC1	✓	×	✓
100 yr + CC2	✓	×	✓
200 yr	✓	×	✓
200 yr + CC1	×	×	×
200 yr + CC2	×	×	×
500 yr	✓	×	✓

Scenario	Existing Floodplain	Existing Floodplain + MRC	Ultimate Case
500 yr + CC2	×	×	×
2000 yr	✓	×	×
PMF	✓	×	×

9.3 Existing Floodplain

Existing floodplain conditions assumes land use conditions based on the supplied City plan data. Catchment elevations were as per the supplied LIDAR derived DEM. As described in Section 8.0 the existing floodplain modelling was undertaken using ultimate landuse hydrologic inflows.

9.4 Existing Floodplain + Minimum Riparian Corridor (MRC)

The MRC scenario assumes a densely vegetated riparian corridor. For the purposes of this study it was assumed that the riparian corridor consisted of an area extending 15 m outward from either side of the creek bank. Where this width of vegetation was not possible due to current development constraints the maximum allowable vegetation width was assumed. A Manning's 'n' of 0.15 was applied to the MRC areas.

As described in Section 8.0 the MRC floodplain modelling was undertaken using ultimate landuse hydrologic inflows.

9.5 Ultimate Floodplain Condition

Ultimate floodplain conditions have been simulated as a combination of MRC and waterway corridor (WC) conditions. The WC condition assumes that floodplain filling to 0.3 m above the 100 year ARI flood level has occurred up to the boundary of the Flood Regulation Line (FRL). The FRL is indicated on all ultimate floodplain maps.

For events larger than the 100 year ARI event (200 and 500 year) the ultimate development floodplain has been simulated as follows;

- 0.3m was added to the modelled ultimate case 100 year ARI event flood level
- Outside of the FRL, the floodplain was filled to the above level until it intersected the existing terrain levels.

As described in Section 8.0 the ultimate floodplain modelling was undertaken using ultimate landuse hydrologic inflows.

9.5.1 Ultimate Floodplain Results Post-Processing

All ultimate floodplain condition results were remapped against the existing floodplain elevations. As the ultimate floodplain conditions effectively 'glass-walls' some results within the waterway corridor, this involved stretching (horizontally) of the modelled water surfaces until intersection with existing floodplain topography is achieved. This process was undertaken in the WaterRide software package which has some automated tools for this purpose. This process contains some inherent limitations as there are no implicit hydraulic considerations in the stretching algorithm, i.e. it is a raster interpolation tool. In addition the algorithm is susceptible to 'break-outs' of the flood surface which results in higher flood levels being interpolated long distances downstream. The process of stretching the water surface involves several iterations to insert limit lines to control areas of break-out. Placement of limit lines is subject to significant amounts of engineering judgement as to where break-outs are controlled. In general limit lines have been placed along natural boundaries such as catchment boundaries or road crests where is has been considered appropriate.

Given that no hydraulic calculations are used in the stretching process and the placement of limit lines is a manual process, a reasonable level of uncertainty exists in flood levels outside of the waterway corridor area (i.e. in areas that have been stretched). A map showing the 100 year ARI breaklines is presented in Appendix P. This map also highlights areas where significant levels of interpretation/judgement were required.

9.6 Tailwater Conditions

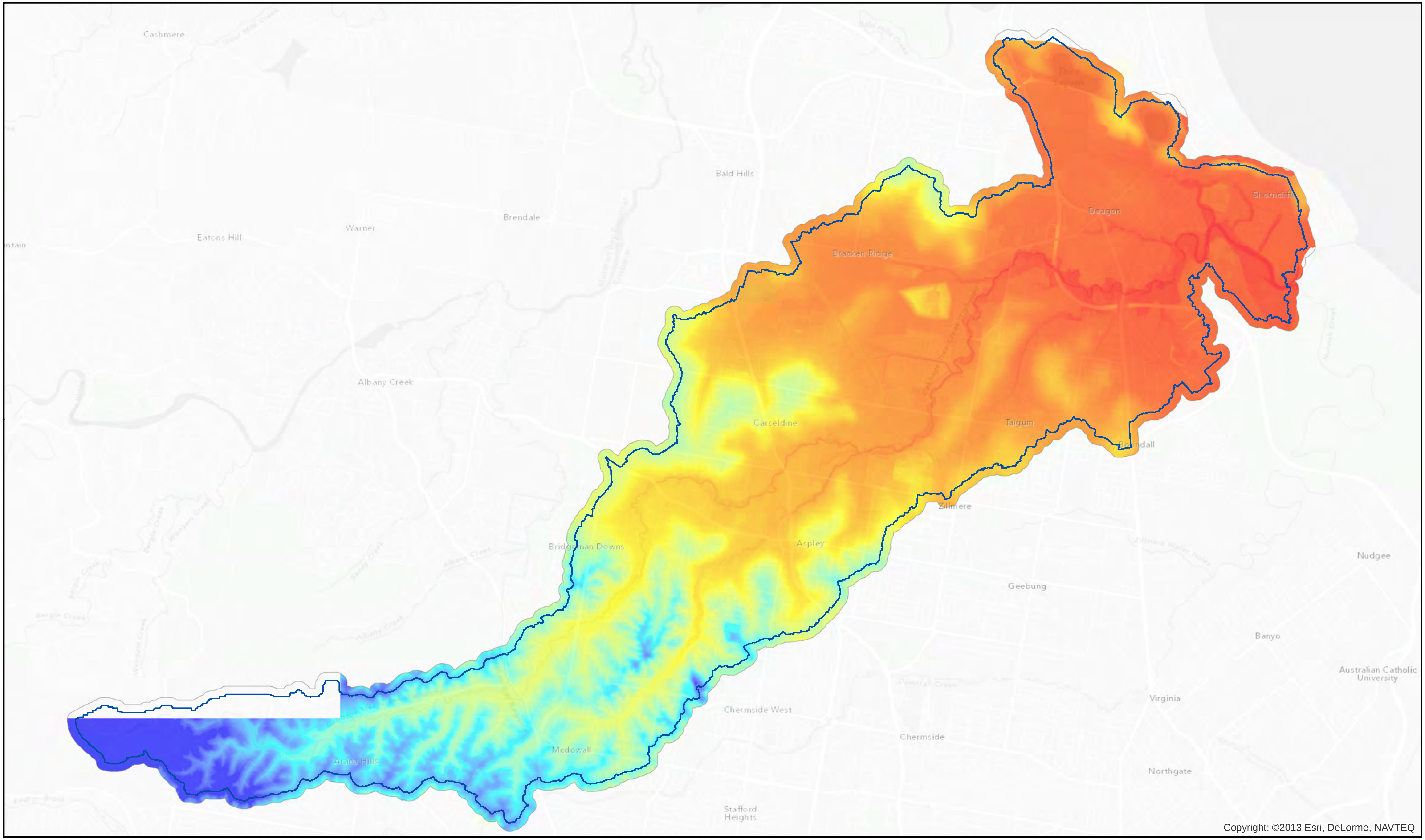
All tailwater levels used for design event modelling were based on the Mean High Water Spring (MHWS) level at the mouth of Cabbage Tree Creek. The MHWS level was sourced from the 2013 QLD Tide Tables book (MSQ 2013).

Table 51 Design Event Tailwater Conditions

Scenario	Tailwater Condition	Tailwater Level (mAHD)
Existing Floodplain	MHWS	0.77
MRC	MHWS	0.77
Ultimate Development	MHWS	0.77
Ultimate Development + Climate Change Scenario 1	MHWS + 0.3m	1.07
Ultimate Development + Climate Change Scenario 2	MHWS + 0.8m	1.57

9.7 Structure Handrail Blockages

Consistent with BCC modelling policy all handrails were modelled assuming 100% blockage of the handrail. Where handrail heights could be derived from design/construction drawings this approach was taken. Where no design/construction data was available handrail heights have been estimated using Google Streetview.



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,125 2,250 4,500

Metres

1:45,000 (when printed at A3)

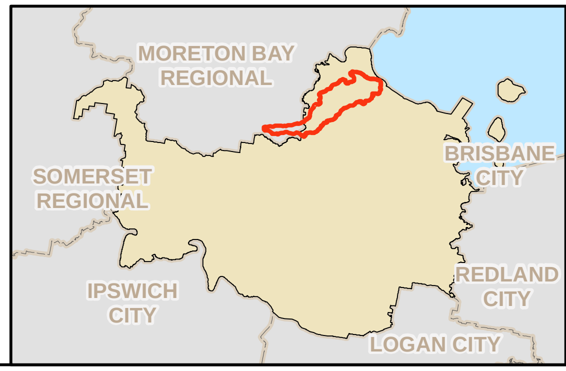
Legend

Catchment Outline

Digital Elevation Model (m AHD)

High : 181.971

Low : -0.44426



Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

ULTIMATE MODEL DEM

AECOM
www.aecom.com

Figure 30

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\BodyReportMaps\ReportBody_Figure28_ModelDEM_Subcatchments.mxd

10.0 Design Event Results

10.1 Design Event Flood Mapping

Table 52 summarises the mapped design events. Mapping products are presented in Appendix N (Volume II). Discussion of peak flood levels and flows are given in the following sections.

Table 52 Mapped Scenarios

Scenario	Peak Flood Levels	Peak Flood Depth
2 Year ARI Existing Floodplain	✓ (extent only)	×
5 Year ARI Existing Floodplain	✓ (extent only)	×
10 Year ARI Existing Floodplain	✓ (extent only)	×
20 Year ARI Existing Floodplain	✓ (extent only)	×
50 Year ARI Existing Floodplain	✓ (extent only)	×
100 Year ARI Existing Floodplain	✓ (extent only)	×
200 Year ARI Existing Floodplain	✓ (extent only)	×
500 Year ARI Existing Floodplain	✓ (extent only)	×
2000 Year ARI Existing Floodplain	✓ (extent only)	×
2 Year ARI Ultimate Floodplain	✓	✓
5 Year ARI Ultimate Floodplain	✓	✓
10 Year ARI Ultimate Floodplain	✓	✓
20 Year ARI Ultimate Floodplain	✓	✓
50 Year ARI Ultimate Floodplain	✓	✓
100 Year ARI Ultimate Floodplain	✓	✓
200 Year ARI Ultimate Floodplain	✓	×
500 Year ARI Ultimate Floodplain	✓	×

10.2 Design Event Peak Flows and Levels

10.2.1 Existing Floodplain Results

Design event creek profiles are given in Appendix K. Peak flood levels and flows for design events up the 100 year ARI event at key locations are given in Table 53 and Table 54 respectively.

Table 53 Existing floodplain peak flood levels

Location	ARI (years)					
	2	5	10	20	50	100
Cabbage Tree Creek (mAHD)						
US of Hamilton Road	39.64	39.91	40.05	40.24	40.45	40.63
US of Albany Creek Road	24.97	25.32	25.50	25.71	25.96	26.16
US of Nth Coast Railway	11.54	11.96	12.21	12.61	13.11	13.49
US of Gateway Motorway	2.38	2.75	2.97	3.23	3.50	3.72
Little Cabbage Tree Creek (mAHD)						
US of Martindale Street	31.40	31.59	31.69	31.82	31.98	32.10
US of Gayford Road	18.59	19.11	19.60	19.62	19.79	19.89
Carseldine Channel (mAHD)						
US of Gympie Road	16.77	16.96	17.15	17.44	17.70	17.76
US of Nth Coast Railway	11.14	11.28	11.36	11.47	11.61	11.71
Taigum Channel (mAHD)						
US of Quarrion Street	5.71	5.90	6.01	6.15	6.29	6.39
US of Roghan Road	5.17	5.44	5.58	5.73	5.90	6.00

Table 54 Existing floodplain peak flood flows through selected crossings

Location	ARI (years)					
	2	5	10	20	50	100
Cabbage Tree Creek (m^3/s)						
Albany Creek Road	49	69	82	99	119	137
Nth Coast Railway	75	107	128	157	192	218
Gateway Motorway	100	140	167	199	236	266
Deagon Gauge (C_A561)	120	168	198	237	283	321
Little Cabbage Tree Creek (m^3/s)						
Martindale Street	22	31	37	45	54	63
Albany Creek Road	31	45	53	64	76	87
Carseldine Channel (m^3/s)						
Gympie Road	10	14	17	21	25	29
Nth Coast Railway	15	22	26	31	38	43
Taigum Channel (m^3/s)						
Quarrion Street	9	12	15	18	21	23
Roghan Road	13	19	23	28	32	35

From the design event creek profiles in Appendix J it can be seen that the gradient of the peak flood water surface profile in both Cabbage Tree and Little Cabbage Tree Creeks is relatively steep from the upper extent of the modelling to the confluence of the two waterways. Once the two creeks converge the surface gradient flattens out with a very flat water surface observed from the Gateway Motorway crossing to the mouth of Cabbage Tree Creek.

The water surface gradient in Carseldine Channel is relatively steep upstream of the Gympie Road crossing and flattens out downstream of this structure. The areas downstream of the North Coast Railway are particularly flat.

Taigum Channel water surface gradient are is flatter than in the upper parts of the Cabbage Tree Creek catchment which mirrors the topographical differences in the waterways.

Only minor break out of the designated channel areas upstream of Albany Creek Road occur in either Cabbage Tree or Little Cabbage Tree Creeks. For flood events greater than the 10 year ARI significant breakout of both Cabbage Tree and Little Cabbage tree Creeks occurs between Albany Creek Road and the North Coast Railway with interaction of flood waters between catchments. A number of properties in the vicinity of the intersection of Albany Creek and Gympie Roads are likely to be affected by flooding in the larger ARI events. Downstream of the North Coast Railway Cabbage Tree Creek is largely confined to the creek area, although some properties in low-lying areas of Deagon east of Braun Street are affected by flooding in most ARI events.

Significant breakout of flood waters in the Carseldine Channel catchment occurs in all ARI events considered. Although this is the case few properties appear at risk of inundation as the majority of the flooding is confined to open spaces. Similarly with Taigum Channel the majority of overbank flooding is confined to open spaces along the waterway. The exception to this is the area immediately upstream of Beams Road which appears to be significantly affected in the 100 year ARI event.

Peak flood levels for events greater than the 100 year ARI event (extreme events) are given in Table 55. Flooding behaviour of the 200 year and 500 year ARI events are similar to that of the 100 year ARI event, although to larger extents.

Both the 2000 year ARI and PMF events cause significant flooding in Cabbage Tree Creek Catchment. Areas particularly affected are the commercial areas near the intersection of Albany Creek and Gympie Roads, Fitzgibbon, Deagon and Shorncliffe. Large numbers of properties are affected in these locations with almost the entire suburbs of Fitzgibbon, Deagon and Shorncliffe being inundated in the PMF event.

Table 55 Extreme event peak flood levels

Location	ARI (years)			
	200	500	2000	PMF
Cabbage Tree Creek (mAHD)				
US of Hamilton Road	40.72	41.08	42.22	43.27
US of Albany Creek Road	26.26	26.52	27.00	27.85
US of Nth Coast Railway	13.72	13.97	14.33	15.06
US of Gateway Motorway	3.89	4.17	5.11	6.60
Little Cabbage Tree Creek (mAHD)				
US of Martindale Street	32.21	32.40	32.94	33.72
US of Gayford Road	19.95	20.05	20.30	21.09
Carseldine Channel (mAHD)				
US of Gympie Road	17.80	17.85	17.92	18.03
US of Nth Coast Railway	11.76	11.93	12.58	13.11
Taigum Channel (mAHD)				
US of Quarrion Street	6.46	6.52	7.35	8.09
US of Roghan Road	6.07	6.14	6.49	7.10

10.2.2 Ultimate Floodplain Results

As described in Section 9.5 design event have also been modelled using ultimate floodplain conditions representing maximum likely floodplain filling conditions within the catchment. Ultimate catchment condition mapping products are presented in the Appendix N (Volume II). Table 56 summarises ultimate catchment peak flood levels for a selection of design events at key locations.

Table 56 Ultimate floodplain peak flood levels

Location	ARI (years)				
	10	20	50	100	500
Cabbage Tree Creek (mAHD)					
US of Hamilton Road	40.11	40.30	40.51	40.69	41.22
US of Albany Creek Road	25.60	25.85	26.13	26.34	26.69
US of Nth Coast Railway	12.29	12.70	13.20	13.53	14.10
US of Gateway Motorway	3.01	3.28	3.60	3.84	4.31
Little Cabbage Tree Creek (mAHD)					
US of Martindale Street	31.72	31.87	32.03	32.14	32.49
US of Gayford Road	19.35	19.63	19.80	19.92	20.13
Carseldine Channel (mAHD)					
US of Gympie Road	17.10	17.31	17.61	17.78	17.89
US of Nth Coast Railway	11.42	11.54	11.68	11.79	12.04
Taigum Channel (mAHD)					
US of Quarrion Street	6.23	6.37	6.47	6.50	6.89
US of Roghan Road	5.64	5.80	5.97	6.01	6.29

10.3 Climate Change Results

Long sections comparing the 100 year ARI climate change results are given in Appendix K. The most significant changes to flood levels are seen in the lower catchment, downstream of the Gateway Motorway. The major contributor to these increases in flood levels in the lower part of the catchment is the increase in tailwater levels in the modelled climate change scenarios (0.3 m and 0.5 m increases). Increases in peak flood levels in the lower catchment area vary by 0.2 m to 0.3 m for climate change scenario 1 (2050 scenario) and 0.3 m to 0.8 m for scenario 2 (2100 scenario). Differences in peak flood levels in the middle catchment area for climate change scenarios 1 and 2 vary on average by approximately 0.15 m and 0.25 m respectively. Differences in peak flood levels in the upper catchment are on average approximately 0.05 m and 0.15 m for scenarios 1 and 2 respectively.

10.4 Flood Immunity of Existing Crossings

Table 57 below highlights crossings that the modelling shows have low immunity. As described in Section 9.7 all structure handrails have been modelled as 100% blocked which will makes predicting the true immunity of these structures difficult. This assessment has been made based on 2 year to 20 year ARI existing floodplain modelling results. It is likely that a number of structures have been designed to higher recurrence interval design events but this information was not available at the time of assessment. It is considered that the 2 year to 20 year ARI events gives a reasonable picture of potential low immunity crossings.

Given the modelling approach used in this study, more detailed drainage investigations of each location would need to be undertaken to confirm immunity, particularly for ARI events below 10 year ARI where smaller stormwater infrastructure may effect results.

Table 57 Crossing Immunity

Structure(s)	Description
Albany Creek Road, Gayford Street, Gympie Road, Little Cabbage Tree Creek	The area around the intersection of Albany Creek Road and Gympie Road become inundated during the 10 year ARI event. This also leads to overtopping of Gympie Road in the 20 year ARI event. This occurs between the Little Cabbage and Cabbage Tree Creek crossings. It is known that there are large underground stormwater assets in this area. Some of these have been incorporated in the TUFLOW model though modelling of stormwater infrastructure was outside the scope of this study. The pit and pipe network in this area may have an effect of the degree of inundation.
Beams Road, Cabbage Tree Creek	Beams Road culvert is overtopped during the 20 year ARI event.
Church Road, Taigum Channel	Church Road culvert is overtopped during the 2 year ARI event.
Dorville Road, Cabbage Tree Creek	Dorville Road is overtopped to the south of the Cabbage Tree Creek crossing during the 2 year ARI event. This occurs at the location of a minor drainage path between Cabbage and Little Cabbage Tree Creeks.
Gympie Road, Carseldine Channel	Gympie Road north of the Carseldine Channel crossing is overtopped in the 5 year ARI event. This flow may potentially be confined to underground stormwater infrastructure.
Lacey Road, Carseldine Channel	Lacey Road north of the Carseldine Channel crossing is overtopped in the 2 year ARI event.
Lemke Road, Cabbage Tree Creek	Lemke Road south of the Cabbage Tree Creek crossing is overtopped in the 2 year ARI event.

Hydraulic Structure Reference Sheets (HSRS) are given in Appendix L. These detail peak flood levels, peak flood flows and key hydraulic properties of the structures modelled.

10.5 Structure Loss Comparisons

Comparison of final TUFLOW and HEC-RAS structure losses for the 100 year and 50 year ARI flood events are presented in Appendix H.

Average head loss differences for the majority of structures are below 0.15m. Where there is deviation from this justification has been provided in Appendix H.

10.6 Comparison with Previous Flood Study

Table 58 summarises the design hydrologic flows calculated in the previous flood study (BCC, 2000) and the current flood study. FFA, URBS and MIKE11 flows from the previous study are shown. Two different sets of URBS results have been presented for the previous study. These represent Duration Independent Storm (DIS) and AR&R Zone 3 rainfall inputs. Flows have been compared at the Carseldine (C_E702) and Deagon (C_A561) gaues. Table 59 summarises predicted peak flood levels for each study at selected location. Figure 31 shows a long section profile of the Cabbage Tree Creek main branch for the 100 year ARI event incorporating selected levels from the previous MIKE11 model.

Based on the results given it is seen that the previous study utilised higher flows than the current study, particularly in the higher ARI events. FFA results are generally consistent between the studies except for the Deagon gauge in the 50 year and 100 year ARI events, where the previous study calculated significantly higher flows. URBS model peak flows calculated using AR&R rainfall depths and temporal patterns are also consistent between the two studies and both are consistent with the updated FFA results.

It is not known what distribution was used to fit the historic flows in the previous flood study; the report refers only to a “curve of best fit” (BCC, 2000). All of FFA curves show significant variation (approximately 50-70 m^3/s) from the historic flow for the 100 year ARI event with the curve showing much higher flows. The updated FFA shows much closer alignment with the historic flows, with most fitted values being with 5% of the observed data. The TUFLOW model flows are generally lower than those predicted by the updated FFA, although are within the 90% confidence bounds (see Section 8.6.4).

Given the differences in flow magnitudes adopted for each study it is difficult to make any direct comparisons between the predicted flood levels. This is compounded by the fact that different downstream boundary conditions have been used in each study with the previous study incorporating storm surge levels into the adopted tailwater levels. The 100 Year ARI peak flood levels for the MIKE11 model are significantly higher than those predicted in TUFLOW model, in particular in the lower reaches of the catchment. This is expected due to the larger flow and higher tailwater levels used. Levels predicted in the 20 year and 5 year ARI events are more consistent between the models, although there are still significant differences in levels at some locations.

Table 58 Comparison of design flows

ARI	Location	Flows (m^3/s)						
		1996 FFA*	Updated FFA	1996 URBS*	1996 URBS (AR&R)*	Current URBS	MIKE 11*	TUFLOW
100	C_E702	270	255	294	250	250	301	218
	C_A561	485	365	519	393	359	507	321
50	C_E702	224	222	227	221	219	216	192
	C_A561	401	319	400	340	314	349	283
20	C_E702	170	182	179	182	180	181	157
	C_A561	310	263	313	277	259	275	237
10	C_E702	144	154	146	153	151	143	130
	C_A561	248	224	260	234	217	234	198
5	C_E702	120	127	120	125	130	116	109
	C_A561	195	186	213	194	186	196	168
2	C_E702	84	89	88	87	95	81	78
	C_A561	140	131	153	136	137	146	120

** For comparison with Deagon gauge results flows from the previous study have been taken at the creek mouth*

Table 59 Comparison of TUFLOW and MIKE11 models at selected locations

Location	100 Year ARI			20 Year ARI			5 Year ARI		
	TUFLOW (mAHD)	MIKE 11 (mAHD)	Diff (m)	TUFLOW (mAHD)	MIKE 11 (mAHD)	Diff (m)	TUFLOW (mAHD)	MIKE 11 (mAHD)	Diff (m)
Beckett Road US	37.17	37	*0.17*	36.67	36.06	*0.61*	36.26	35.64	*0.62*
Albany Creek Road US	26.16	26.92	*-0.76*	25.71	26.14	*-0.43*	25.33	25.62	*-0.29*
Gympie Road US	19.49	19.26	*0.23*	19.12	18.43	*0.69*	18.53	17.81	*0.72*
Dorville Road US	16.89	17.14	*-0.25*	16.58	16.46	*0.12*	16	15.71	*0.29*
North Coast Rwy US	13.49	14.01	*-0.52*	12.61	12.7	*-0.09*	11.98	12.16	*-0.18*
Beams Road US	12.45	12.51	*-0.06*	11.99	11.51	*0.48*	11.44	11.04	*0.4*
Roghan Road US	8.19	9.14	*-0.95*	7.8	8.23	*-0.43*	7.45	7.72	*-0.27*
Lemke Road US	4.27	4.83	*-0.56*	4.05	4.35	*-0.3*	3.83	4.09	*-0.26*
Gateway Mwy US	3.72	4.35	*-0.63*	3.23	3.32	*-0.09*	2.75	2.65	*0.1*
Braun Street US	3.06	3.73	*-0.67*	2.58	2.83	*-0.25*	1.98	2.11	*-0.13*

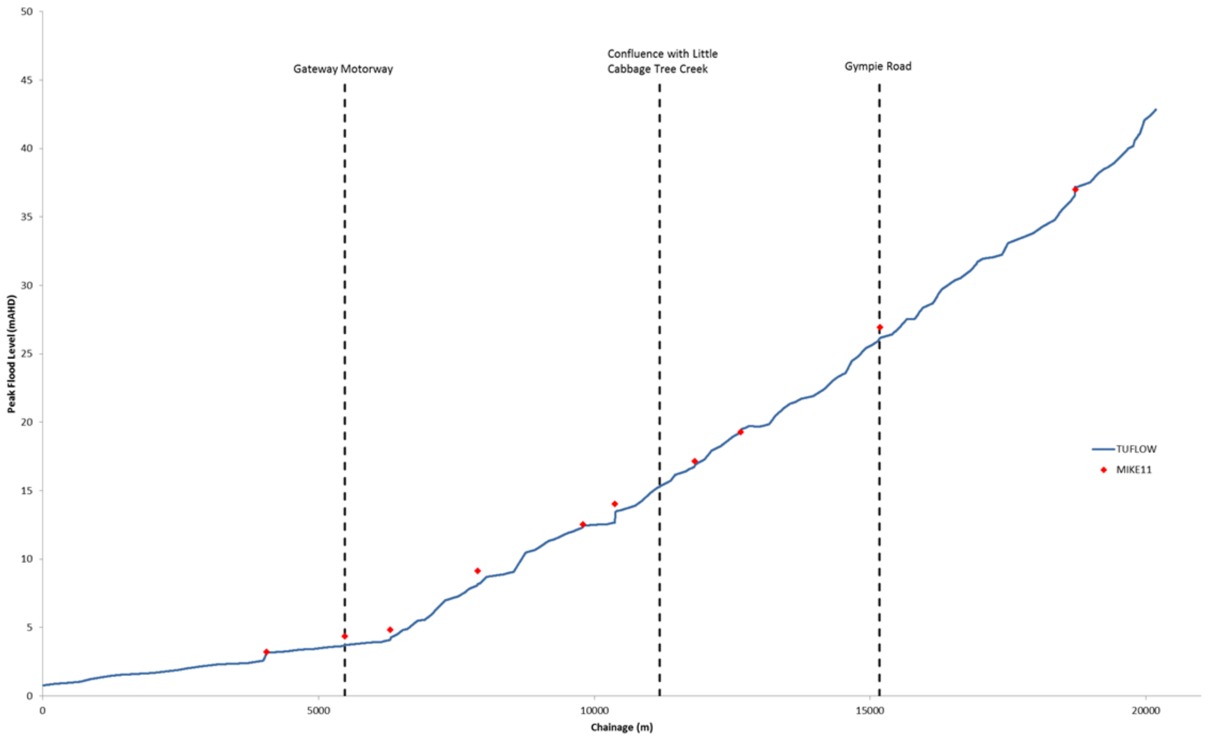


Figure 31 Long section of Cabbage Tree Creek showing selected MIKE11 levels, 100 year ARI event

11.0 Summary and Conclusions

BCC engaged AECOM to undertake an updated flood study of Cabbage Tree Creek in the Brisbane City LGA. This work updates previous flood study works undertaken by BCC and other in this catchment. The scope of works involved;

- Development and calibration of an URBS hydrologic model
- Development and calibration of a 1D/2D TUFLOW hydraulic model
- Modelling of a series of design events considering three separate floodplain conditions (existing, MRC, and ultimate)
- Production of peak flood level, depth and velocity depth product mapping
- Conducting a FFA using the calibrated URBS model and rainfall sequences derived from Brisbane CBD rain gauges.

Design flood event modelling results indicate that breakout of both Cabbage Tree Creek and Little Cabbage Tree Creek occurs between Albany Creek Road and the North Coast Railway (Carseldine) in events larger than the 10 year ARI flood event. In addition to the flooding described in Carseldine significant inundation of low lying areas of Fitzgibbon, Deagon and Shorncliffe occurs during large and extreme events. A number of road crossings in the catchment have been identified as possibly having low flood immunity.

Based on the work undertaken, the following recommendations are made to further improve upon the results of this study:

- As part of this study 60 new bathymetric cross sections were surveyed. This represented approximately 25% of the cross sections used in this study. Some of the data used for the other cross sections dates back to the 1970s. It is considered that significant value could be added by updating all waterway bathymetry for the model.
- A single downstream boundary level has been considered for design events in this study (excepting climate change scenarios). A range of different tidal and storm surge levels should be modelled to assess the impacts of coincident ocean and estuarine events.
- Given that the hydrologic and hydraulic modelling is based on methods that contain some uncertainty. It is recommended that additional modelling be undertaken to quantify this uncertainty. It is recommended that sensitivity runs be untaken varying Manning's 'n' values used and assessing the 95% and 5% confidence intervals for the 10 and 100 year ARI events.
- During the course of this study the BOM have updated the published AR&R design rainfall figures. Going forward these new values will form the accepted set of design rainfall depths. It is recommended that a selection of the design events modelled be remodelled using the new design rainfall depths to quantify any differences in flows and flood levels.

12.0 References

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Appendix A

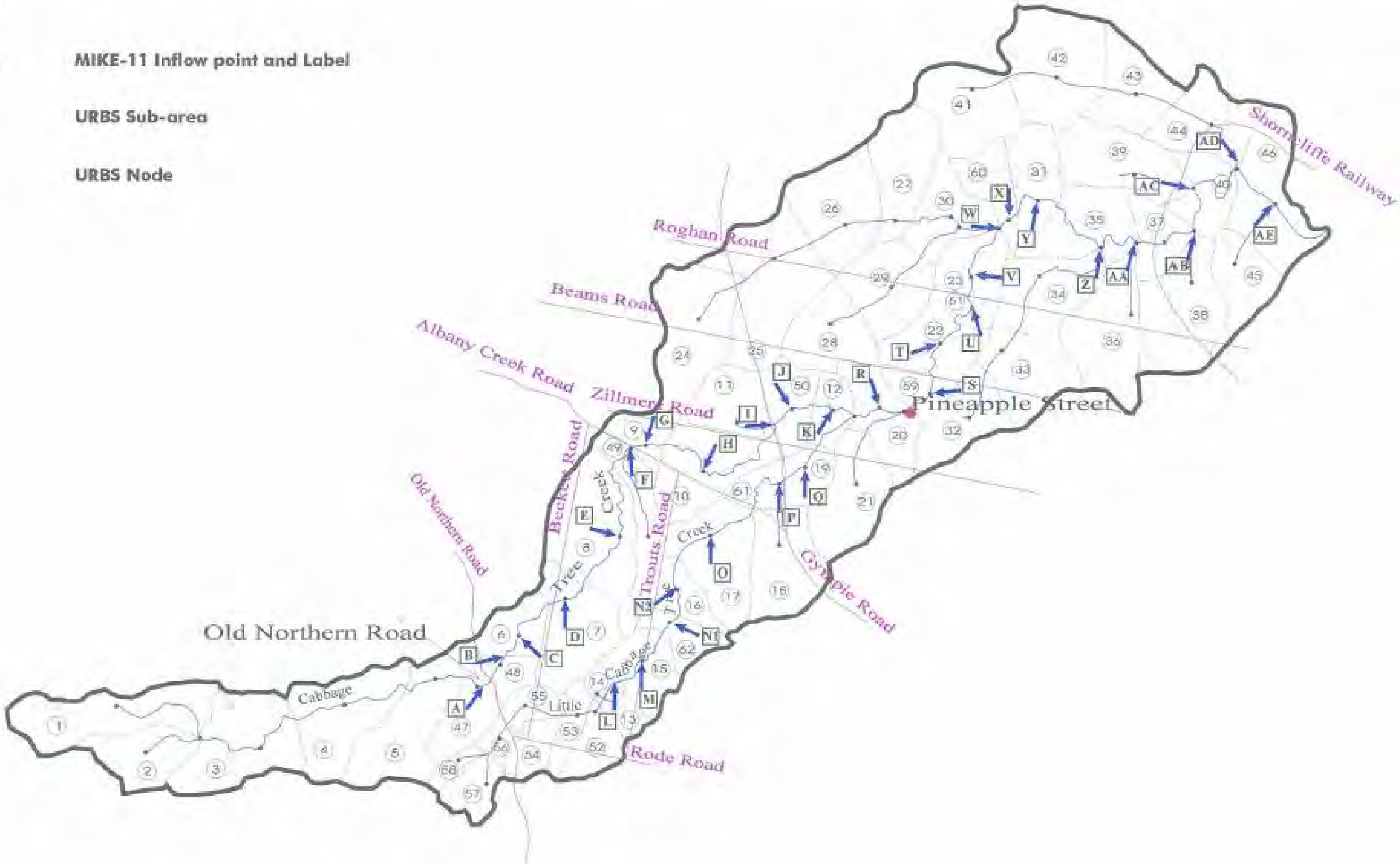
1996 URBS Subcatchments

KEY

[A] MIKE-11 Inflow point and Label

(4) URBS Sub-area

· URBS Node



Scale 0.0 0.5 1.0 1.5 2.0 2.5 km

URBS Model Layout

FIGURE 3

Appendix B

URBS Catchment Properties

Appendix B URBS Catchment Properties

Table 60 Subcatchment areas and slopes

Subcatchment ID	Area (km^2)	Subcatchment slope (m/m)
1	1.156	0.014
2	0.716	0.018
3	1.216	0.016
4	1.13	0.01
5	1.188	0.008
6	0.556	0.013
7	0.294	0.017
8	0.566	0.017
9	0.559	0.01
10	1.255	0.007
11	0.628	0.014
12	0.437	0.013
13	0.954	0.009
14	0.953	0.008
15	0.406	0.011
16	0.247	0.003
17	0.446	0.02
18	0.486	0.012
19	0.471	0.02
20	0.331	0.021
21	0.441	0.015
22	0.766	0.012
23	0.726	0.012
24	0.899	0.01
25	0.851	0.014
26	0.324	0.009
27	0.368	0.011
28	0.78	0.016
29	1.194	0.007
30	0.333	0.012
31	0.346	0.006
32	0.361	0.013
33	0.41	0.011
34	0.471	0.003

Subcatchment ID	Area (km^2)	Subcatchment slope (m/m)
35	0.287	0.011
36	0.517	0.004
37	0.501	0.02
38	0.833	0.015
39	0.852	0.009
40	0.727	0.006
41	1.007	0.002
42	0.321	0.006
43	0.894	0.009
44	0.346	0.004
45	0.233	0.005
46	0.599	0.007
47	0.169	0.014
48	0.859	0.003
49	0.453	0.005
50	0.317	0.009
51	0.746	0.008
52	0.562	0.01
53	0.259	0.019
54	0.21	0.011
55	0.496	0.007
56	1.119	0.005
57	0.68	0.002
58	1.082	0.002
59	0.473	0.003
60	0.743	0.004
61	0.642	0.001
62	0.226	0.005
63	0.478	0.003
64	0.633	0.002
65	0.714	0.004
66	0.385	0.004
67	0.801	0.002
68	0.513	0.002
69	0.5375	0.003
70	0.6395	0.001

Table 61 Subcatchment land use for 2001 event

Subcatchment ID	UL	UM	UH	UR
1	0.390	0.513	0.005	0.092
2	0.090	0.823	0.000	0.087
3	0.316	0.570	0.025	0.089
4	0.654	0.134	0.028	0.184
5	0.658	0.104	0.056	0.183
6	0.116	0.534	0.114	0.235
7	0.584	0.263	0.000	0.153
8	0.014	0.770	0.000	0.217
9	0.100	0.684	0.000	0.216
10	0.127	0.424	0.000	0.448
11	0.533	0.438	0.000	0.028
12	0.719	0.238	0.000	0.044
13	0.601	0.334	0.000	0.065
14	0.118	0.785	0.019	0.078
15	0.132	0.737	0.039	0.092
16	0.212	0.372	0.415	0.001
17	0.409	0.566	0.003	0.022
18	0.248	0.736	0.000	0.017
19	0.509	0.480	0.000	0.011
20	0.561	0.439	0.000	0.000
21	0.175	0.747	0.000	0.078
22	0.243	0.356	0.000	0.401
23	0.081	0.758	0.000	0.161
24	0.061	0.769	0.006	0.164
25	0.039	0.943	0.018	0.000
26	0.216	0.271	0.512	0.000
27	0.004	0.874	0.075	0.047
28	0.100	0.867	0.033	0.000
29	0.708	0.000	0.266	0.026
30	0.128	0.694	0.005	0.174
31	0.190	0.614	0.000	0.196
32	0.281	0.665	0.000	0.053
33	0.240	0.746	0.000	0.014
34	0.230	0.695	0.000	0.075
35	0.337	0.477	0.000	0.186
36	0.241	0.590	0.000	0.169

Subcatchment ID	UL	UM	UH	UR
37	0.090	0.903	0.000	0.006
38	0.770	0.211	0.000	0.019
39	0.643	0.118	0.000	0.239
40	0.686	0.127	0.000	0.187
41	0.855	0.029	0.017	0.099
42	0.994	0.006	0.000	0.000
43	0.198	0.694	0.013	0.095
44	0.747	0.248	0.000	0.005
45	0.889	0.111	0.000	0.000
46	0.519	0.464	0.000	0.018
47	0.497	0.366	0.000	0.138
48	0.341	0.540	0.000	0.120
49	0.369	0.303	0.000	0.328
50	0.165	0.440	0.300	0.095
51	0.467	0.509	0.000	0.024
52	0.371	0.431	0.149	0.050
53	0.604	0.367	0.000	0.029
54	0.212	0.705	0.000	0.083
55	0.648	0.294	0.000	0.058
56	0.203	0.764	0.000	0.033
57	0.154	0.549	0.033	0.264
58	0.379	0.452	0.169	0.000
59	0.024	0.507	0.074	0.395
60	0.366	0.594	0.012	0.028
61	0.071	0.601	0.004	0.324
62	0.000	0.536	0.000	0.464
63	0.000	0.207	0.529	0.264
64	0.000	0.259	0.000	0.741
65	0.455	0.325	0.088	0.132
66	0.000	0.290	0.638	0.073
67	0.278	0.609	0.031	0.083
68	0.442	0.492	0.014	0.053
69	0.503	0.470	0.000	0.026
70	0.283	0.138	0.000	0.578

Table 62 Subcatchment land use for 2004 event

Subcatchment ID	UL	UM	UH	UR
1	0.340	0.563	0.005	0.092
2	0.040	0.873	0.000	0.087
3	0.216	0.670	0.025	0.089
4	0.604	0.184	0.028	0.184
5	0.608	0.154	0.056	0.183
6	0.066	0.584	0.114	0.235
7	0.484	0.363	0.000	0.153
8	0.014	0.770	0.000	0.217
9	0.100	0.684	0.000	0.216
10	0.027	0.524	0.000	0.448
11	0.483	0.488	0.000	0.028
12	0.719	0.238	0.000	0.044
13	0.551	0.384	0.000	0.065
14	0.118	0.785	0.019	0.078
15	0.082	0.787	0.039	0.092
16	0.212	0.372	0.415	0.001
17	0.359	0.616	0.003	0.022
18	0.248	0.736	0.000	0.017
19	0.459	0.530	0.000	0.011
20	0.511	0.489	0.000	0.000
21	0.175	0.747	0.000	0.078
22	0.243	0.356	0.000	0.401
23	0.081	0.758	0.000	0.161
24	0.061	0.769	0.006	0.164
25	0.039	0.943	0.018	0.000
26	0.066	0.421	0.512	0.000
27	0.004	0.874	0.075	0.047
28	0.100	0.867	0.033	0.000
29	0.675	0.033	0.266	0.026
30	0.128	0.694	0.005	0.174
31	0.190	0.614	0.000	0.196
32	0.231	0.715	0.000	0.053
33	0.240	0.746	0.000	0.014
34	0.230	0.695	0.000	0.075
35	0.287	0.527	0.000	0.186

Subcatchment ID	UL	UM	UH	UR
36	0.191	0.640	0.000	0.169
37	0.090	0.903	0.000	0.006
38	0.770	0.211	0.000	0.019
39	0.443	0.318	0.000	0.239
40	0.636	0.177	0.000	0.187
41	0.855	0.029	0.017	0.099
42	0.994	0.006	0.000	0.000
43	0.098	0.794	0.013	0.095
44	0.747	0.248	0.000	0.005
45	0.889	0.111	0.000	0.000
46	0.519	0.464	0.000	0.018
47	0.497	0.366	0.000	0.138
48	0.341	0.540	0.000	0.120
49	0.369	0.303	0.000	0.328
50	0.165	0.440	0.300	0.095
51	0.367	0.609	0.000	0.024
52	0.371	0.431	0.149	0.050
53	0.604	0.367	0.000	0.029
54	0.062	0.855	0.000	0.083
55	0.648	0.294	0.000	0.058
56	0.203	0.764	0.000	0.033
57	0.154	0.549	0.033	0.264
58	0.379	0.452	0.169	0.000
59	0.024	0.507	0.074	0.395
60	0.366	0.594	0.012	0.028
61	0.071	0.601	0.004	0.324
62	0.000	0.536	0.000	0.464
63	0.000	0.207	0.529	0.264
64	0.000	0.259	0.000	0.741
65	0.455	0.325	0.088	0.132
66	0.000	0.290	0.638	0.073
67	0.278	0.609	0.031	0.083
68	0.442	0.492	0.014	0.053
69	0.503	0.470	0.000	0.026
70	0.283	0.138	0.000	0.578

Table 63 Subcatchment land use for 2009 and 2010 events

Subcatchment ID	UL	UM	UH	UR
1	0.290	0.613	0.005	0.092
2	0.040	0.873	0.000	0.087
3	0.216	0.670	0.025	0.089
4	0.554	0.234	0.028	0.184
5	0.558	0.204	0.056	0.183
6	0.066	0.584	0.114	0.235
7	0.484	0.363	0.000	0.153
8	0.014	0.770	0.000	0.217
9	0.100	0.684	0.000	0.216
10	0.027	0.524	0.000	0.448
11	0.433	0.538	0.000	0.028
12	0.719	0.238	0.000	0.044
13	0.401	0.534	0.000	0.065
14	0.118	0.785	0.019	0.078
15	0.082	0.787	0.039	0.092
16	0.212	0.372	0.415	0.001
17	0.359	0.616	0.003	0.022
18	0.248	0.736	0.000	0.017
19	0.459	0.530	0.000	0.011
20	0.411	0.589	0.000	0.000
21	0.175	0.747	0.000	0.078
22	0.193	0.406	0.000	0.401
23	0.081	0.758	0.000	0.161
24	0.061	0.769	0.006	0.164
25	0.039	0.943	0.018	0.000
26	0.066	0.421	0.512	0.000
27	0.004	0.874	0.075	0.047
28	0.100	0.867	0.033	0.000
29	0.575	0.133	0.266	0.026
30	0.128	0.694	0.005	0.174
31	0.190	0.614	0.000	0.196
32	0.231	0.715	0.000	0.053
33	0.190	0.796	0.000	0.014
34	0.130	0.795	0.000	0.075
35	0.287	0.527	0.000	0.186

Subcatchment ID	UL	UM	UH	UR
36	0.191	0.640	0.000	0.169
37	0.090	0.903	0.000	0.006
38	0.720	0.261	0.000	0.019
39	0.143	0.618	0.000	0.239
40	0.436	0.377	0.000	0.187
41	0.805	0.079	0.017	0.099
42	0.994	0.006	0.000	0.000
43	0.098	0.794	0.013	0.095
44	0.697	0.298	0.000	0.005
45	0.839	0.161	0.000	0.000
46	0.519	0.464	0.000	0.018
47	0.497	0.366	0.000	0.138
48	0.291	0.590	0.000	0.120
49	0.319	0.353	0.000	0.328
50	0.115	0.490	0.300	0.095
51	0.217	0.759	0.000	0.024
52	0.221	0.581	0.149	0.050
53	0.554	0.417	0.000	0.029
54	0.062	0.855	0.000	0.083
55	0.598	0.344	0.000	0.058
56	0.203	0.764	0.000	0.033
57	0.154	0.549	0.033	0.264
58	0.379	0.452	0.169	0.000
59	0.024	0.507	0.074	0.395
60	0.366	0.594	0.012	0.028
61	0.071	0.601	0.004	0.324
62	0.000	0.536	0.000	0.464
63	0.000	0.207	0.529	0.264
64	0.000	0.259	0.000	0.741
65	0.455	0.325	0.088	0.132
66	0.000	0.290	0.638	0.073
67	0.278	0.609	0.031	0.083
68	0.442	0.492	0.014	0.053
69	0.503	0.470	0.000	0.026
70	0.283	0.138	0.000	0.578

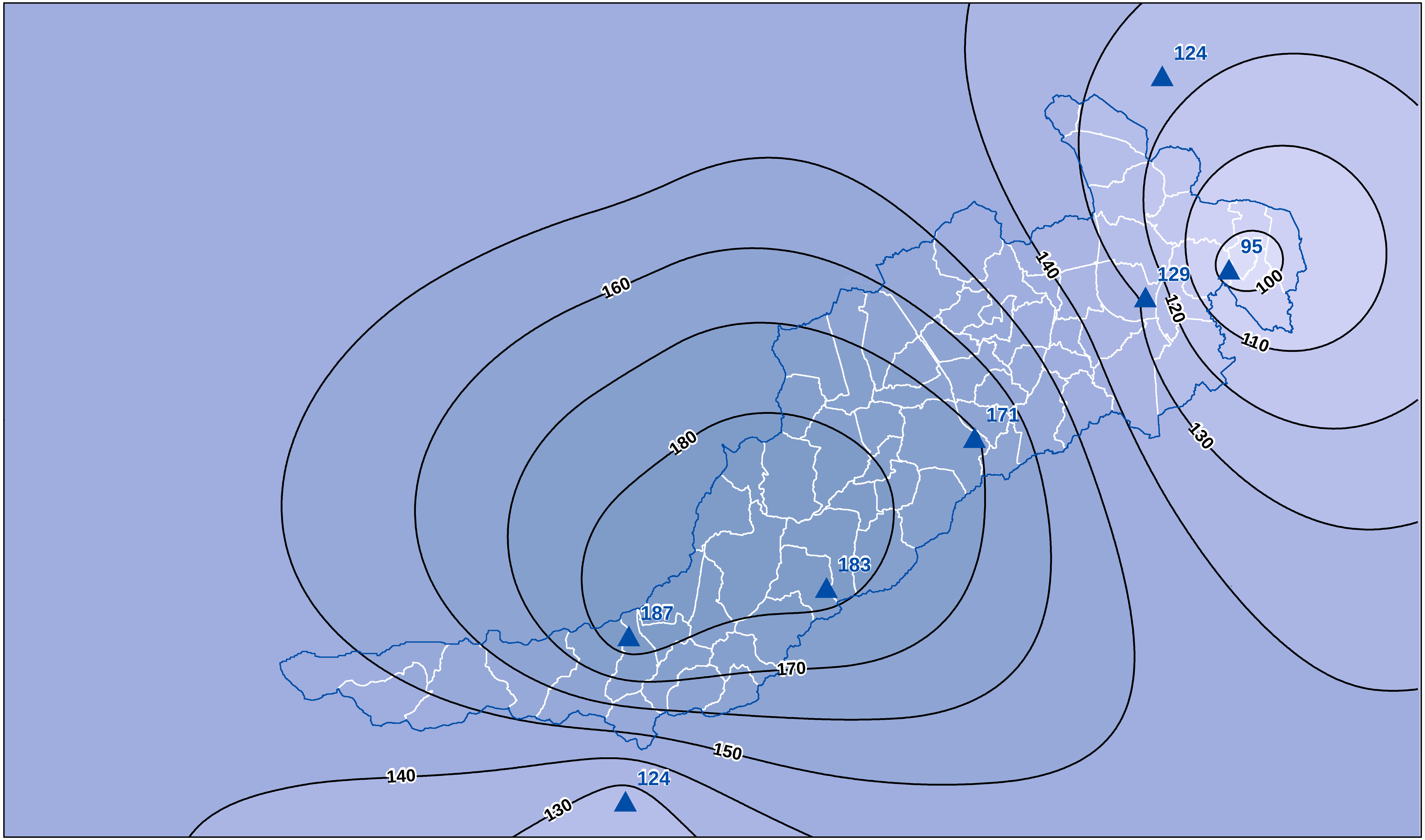
Table 64 Subcatchment land use for design events

Subcatchment ID	UL	UM	UH	UR
1	0	0.903	0.005	0.092
2	0	0.913	0	0.087
3	0	0.886	0.025	0.089
4	0	0.788	0.028	0.184
5	0	0.762	0.056	0.183
6	0	0.65	0.114	0.235
7	0	0.847	0	0.153
8	0	0.783	0	0.217
9	0	0.784	0	0.216
10	0.008	0.544	0	0.448
11	0.427	0.544	0	0.028
12	0.719	0.238	0	0.044
13	0.037	0.898	0	0.065
14	0.085	0.817	0.019	0.078
15	0.002	0.867	0.039	0.092
16	0.039	0.545	0.415	0.001
17	0.019	0.956	0.003	0.022
18	0	0.983	0	0.017
19	0.14	0.849	0	0.011
20	0.128	0.872	0	0
21	0.132	0.79	0	0.078
22	0.102	0.497	0	0.401
23	0.054	0.785	0	0.161
24	0.018	0.812	0.006	0.164
25	0.029	0.954	0.018	0
26	0	0.488	0.512	0
27	0	0.878	0.075	0.047
28	0.1	0.867	0.033	0
29	0.575	0.133	0.266	0.026
30	0.128	0.694	0.005	0.174
31	0.19	0.614	0	0.196
32	0.18	0.766	0	0.053
33	0.015	0.97	0	0.014
34	0.074	0.852	0	0.075
35	0.123	0.691	0	0.186

Subcatchment ID	UL	UM	UH	UR
36	0.15	0.681	0	0.169
37	0.004	0.99	0	0.006
38	0.148	0.833	0	0.019
39	0.022	0.739	0	0.239
40	0.014	0.799	0	0.187
41	0.096	0.789	0.017	0.099
42	0.493	0.507	0	0
43	0.055	0.837	0.013	0.095
44	0.011	0.984	0	0.005
45	0.659	0.341	0	0
46	0.51	0.472	0	0.018
47	0.447	0.415	0	0.138
48	0.006	0.875	0	0.12
49	0.094	0.577	0	0.328
50	0.115	0.49	0.3	0.095
51	0.053	0.923	0	0.024
52	0.018	0.784	0.149	0.05
53	0.48	0.491	0	0.029
54	0	0.917	0	0.083
55	0.054	0.889	0	0.058
56	0.079	0.888	0	0.033
57	0.128	0.576	0.033	0.264
58	0.379	0.452	0.169	0
59	0.024	0.507	0.074	0.395
60	0.366	0.594	0.012	0.028
61	0.071	0.601	0.004	0.324
62	0	0.536	0	0.464
63	0	0.207	0.529	0.264
64	0	0.259	0	0.741
65	0.455	0.325	0.088	0.132
66	0	0.29	0.638	0.073
67	0.278	0.609	0.031	0.083
68	0.442	0.492	0.014	0.053
69	0.474	0.47	0.029	0.026
70	0.198	0.138	0.086	0.578

Appendix C

Rainfall Isohyet Maps



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,350 2,700 5,400

Metres

1:54,000 (when printed at A3)

Legend

- ▲ Calibration Gauges (March 2001)
- Isohyetal 2001
- Catchment Outline
- URBS Subcatchments

Precipitation [mm]

84 - 90	141 - 150
91 - 100	151 - 160
101 - 110	161 - 170
111 - 120	171 - 180
121 - 130	181 - 190
131 - 140	

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

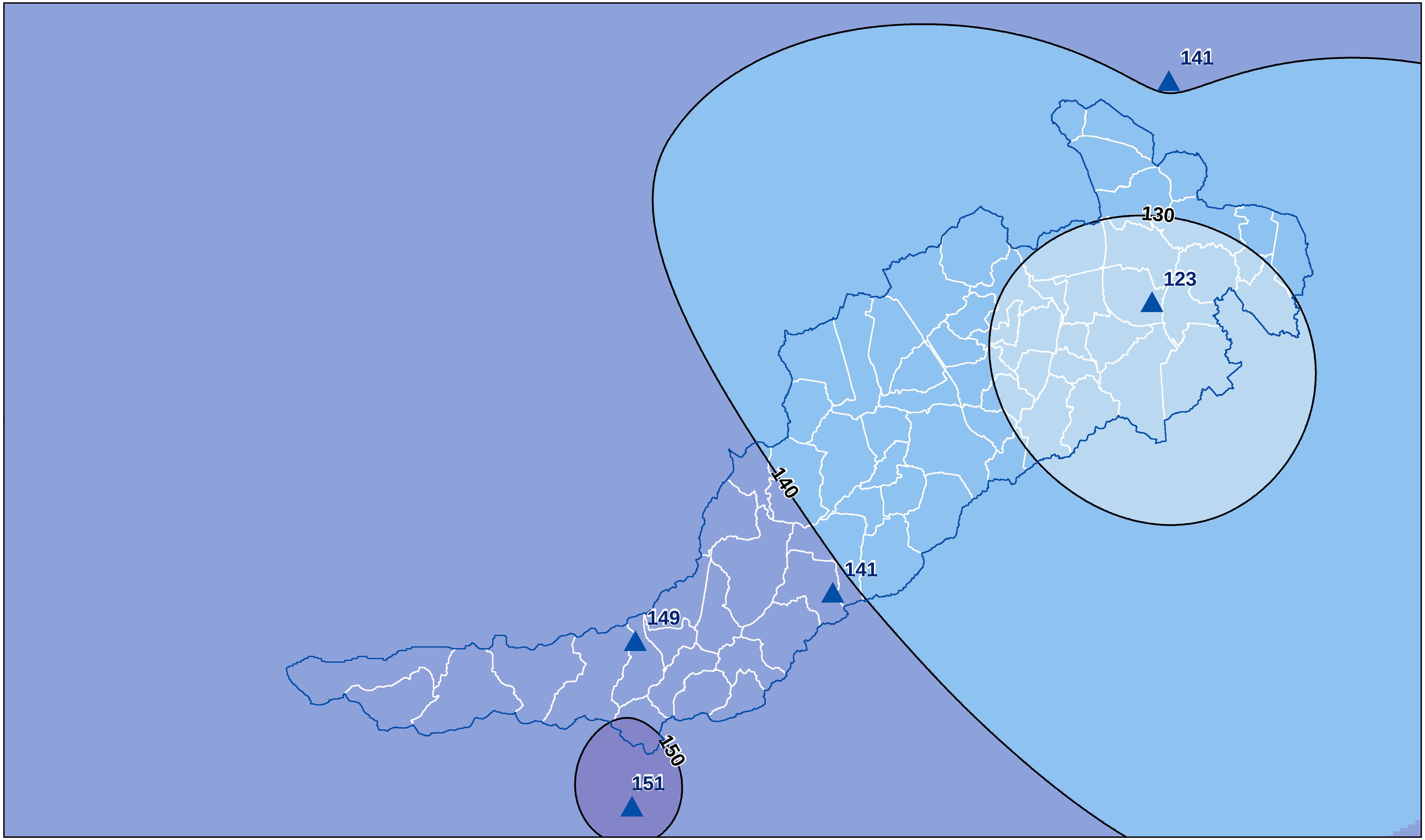
Cabbage Tree Creek Catchment

ISOHYETAL 2001

AECOM
www.aecom.com

Map C1

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,350 2,700 5,400
Metres

1:54,000 (when printed at A3)

Legend

- Calibration Gauge March 2004
- Catchment Outline
- Isohyetal March 2004
- URBS Subcatchments

Precipitation (mm)

- 123
- 124 - 130
- 131 - 140
- 141 - 150
- 151 - 151

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

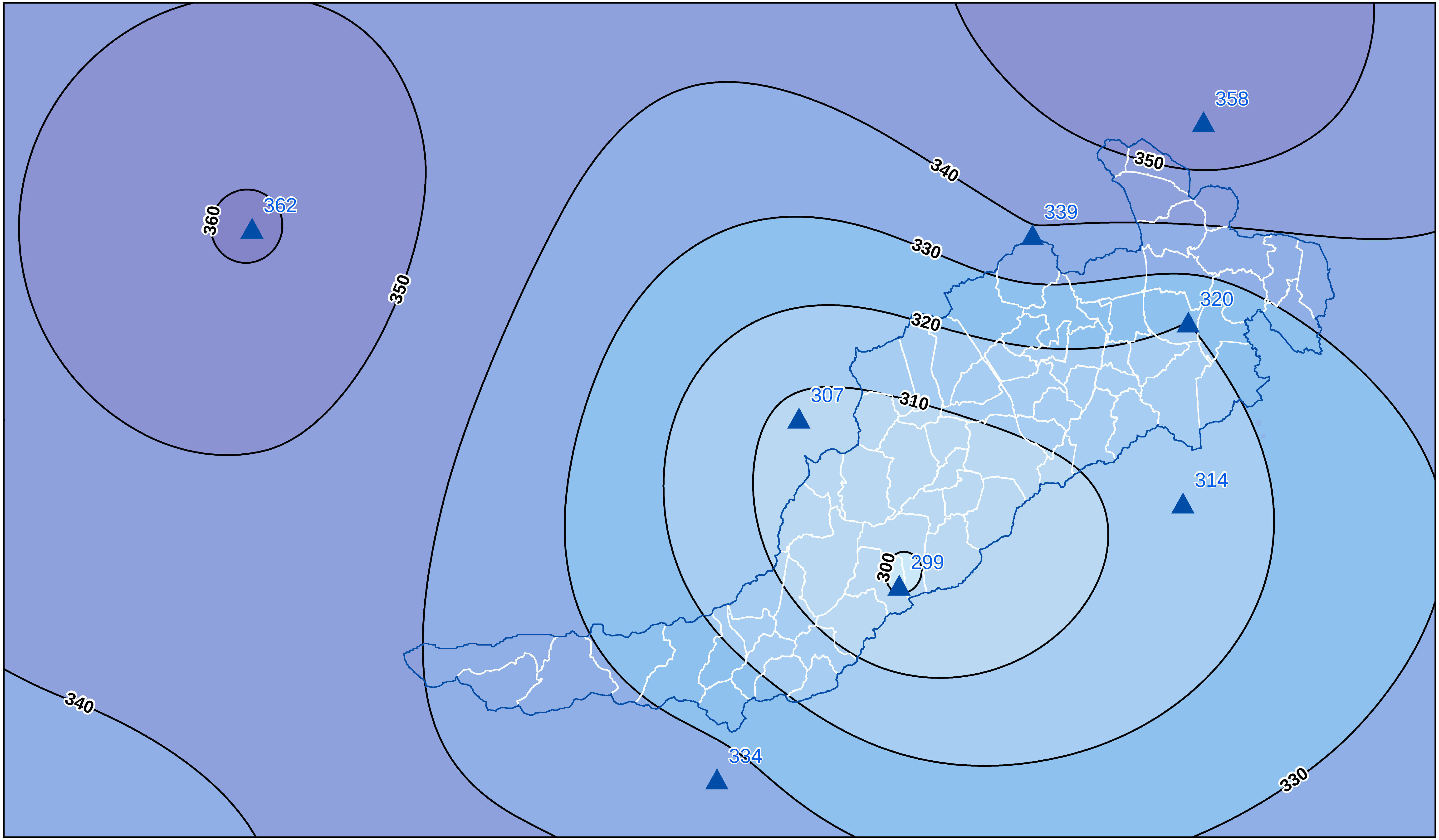
ISOHYETAL MARCH 2004

AECOM
www.aecom.com

Map C2

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixC_RainfallIsohyetMaps\AppendixC_MapC2_RainfallIsohyet_Mar_2004.mxd



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,500 3,000 6,000

Metres

1:60,211 (when printed at A3)

Legend

- ▲ Calibration Gauge May 2009
- Isohyetal May 2009
- Catchment Outline
- URBS Subcatchments

Precipitation (mm)

- 299
- 300 - 300
- 301 - 310
- 311 - 320
- 321 - 330
- 331 - 340
- 341 - 350
- 351 - 360
- 361 - 362

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

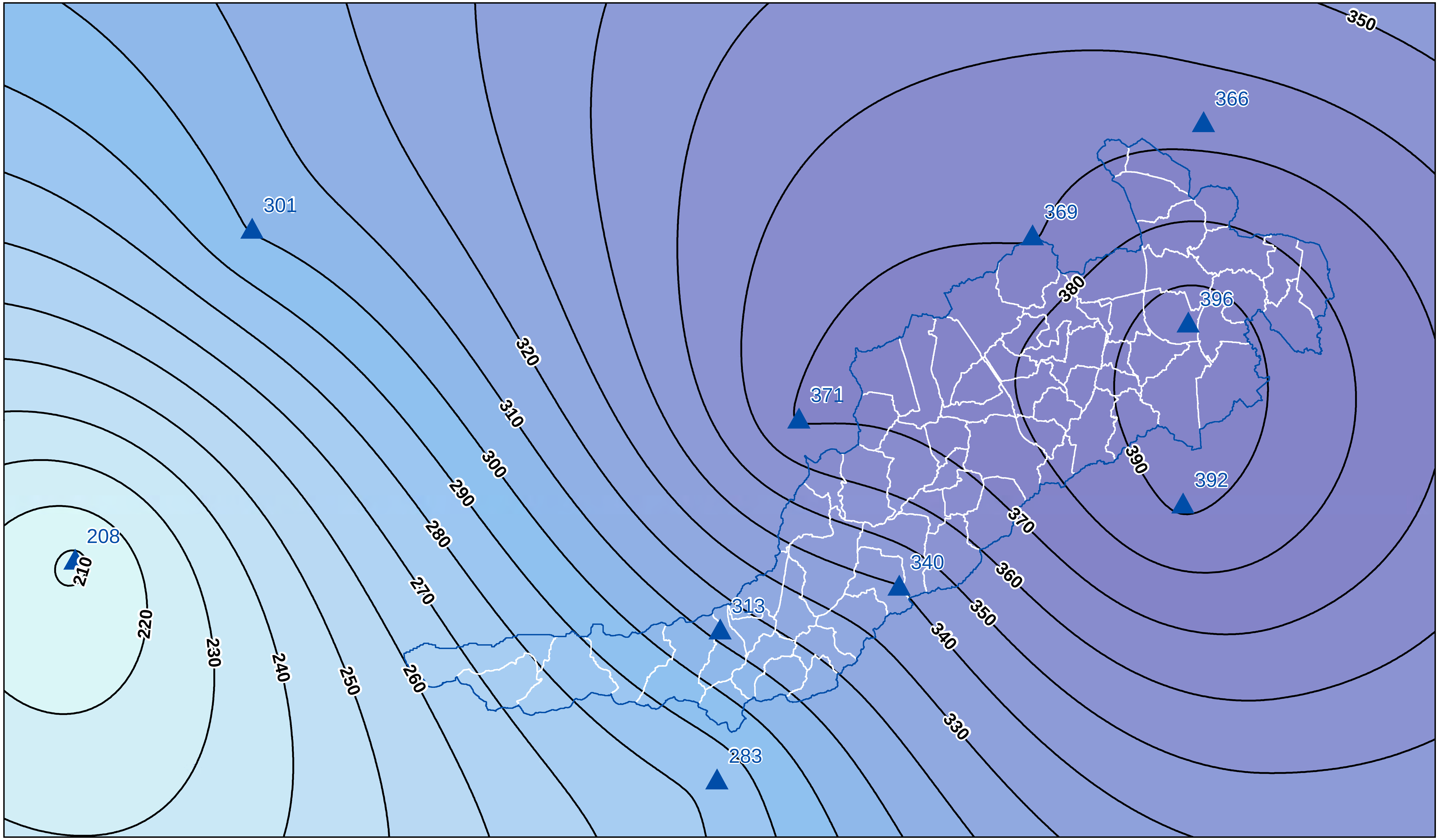
ISOHYETAL MAY 2009

AECOM
www.aecom.com

Map
C3

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixC_RainfallIsohyetMaps\AppendixC_MapC3_RainfallIsohyet_May_2009.mxd

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 | 1,500 | 3,000 | 6,000

Metres

1:60,247 (when printed at A3)

Legend

- Calibraton Gauges Oct 2010
- Isohyetal Oct 2010
- Catchment Outline
- URBS Subcatchments

Precipitation (mm)	
208 - 220	291 - 300
221 - 230	301 - 310
231 - 240	311 - 320
241 - 250	321 - 330
251 - 260	331 - 340
261 - 270	341 - 350
271 - 280	351 - 360
281 - 290	361 - 370
	371 - 380

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

ISOHYETAL OCTOBER 2010

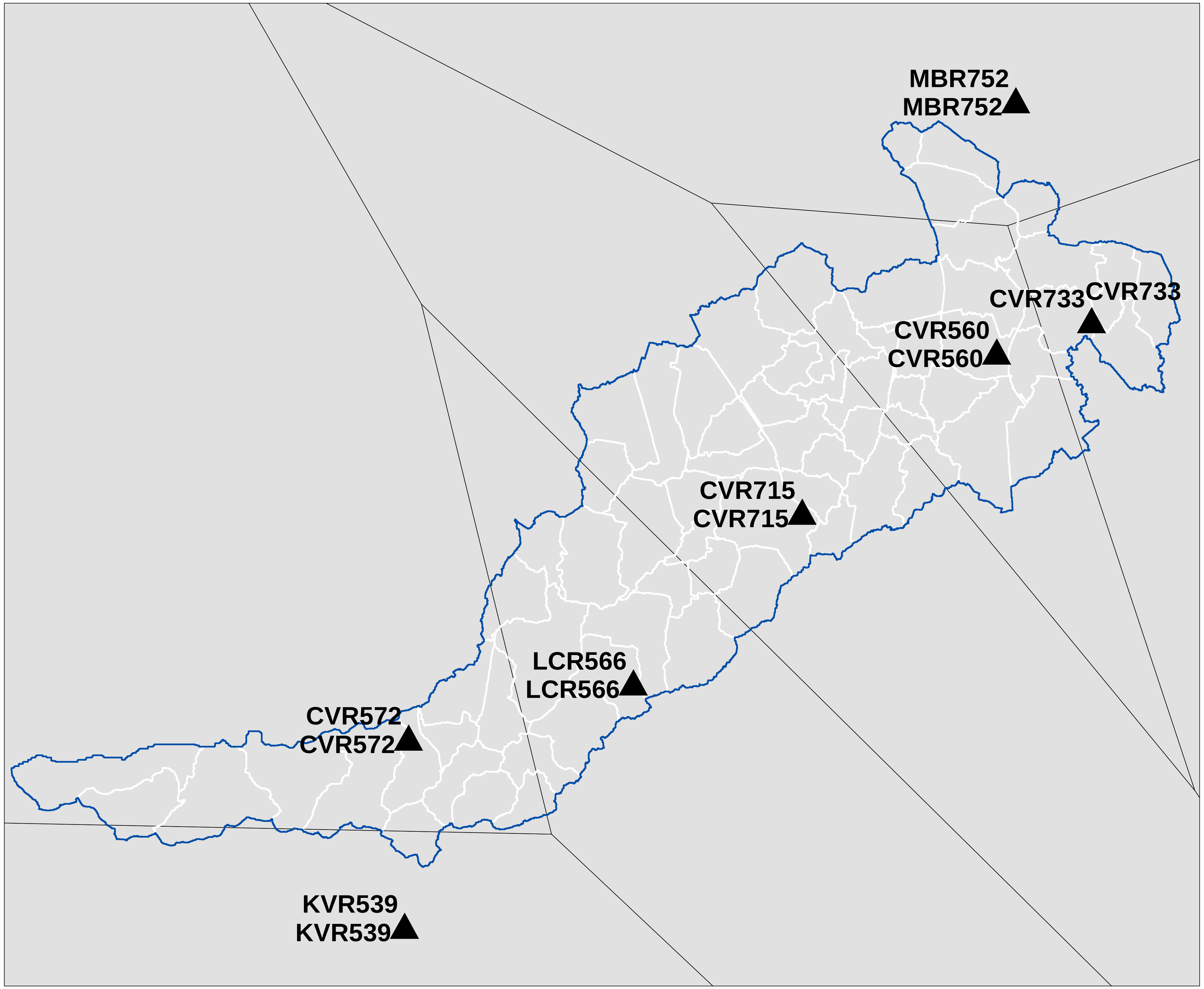
AECOM
www.aecom.com

Map C4

A3 size

Appendix D

Thiessen Polygon Maps



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,500 3,000 6,000

Metres

1:60,000 (when printed at A3)

Legend

- ▲ Calibration Gauge March 2001
- Catchment Outline
- URBS Subcatchments
- Calibration Thiessen March 2001

Data sources:
Brisbane City Council
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

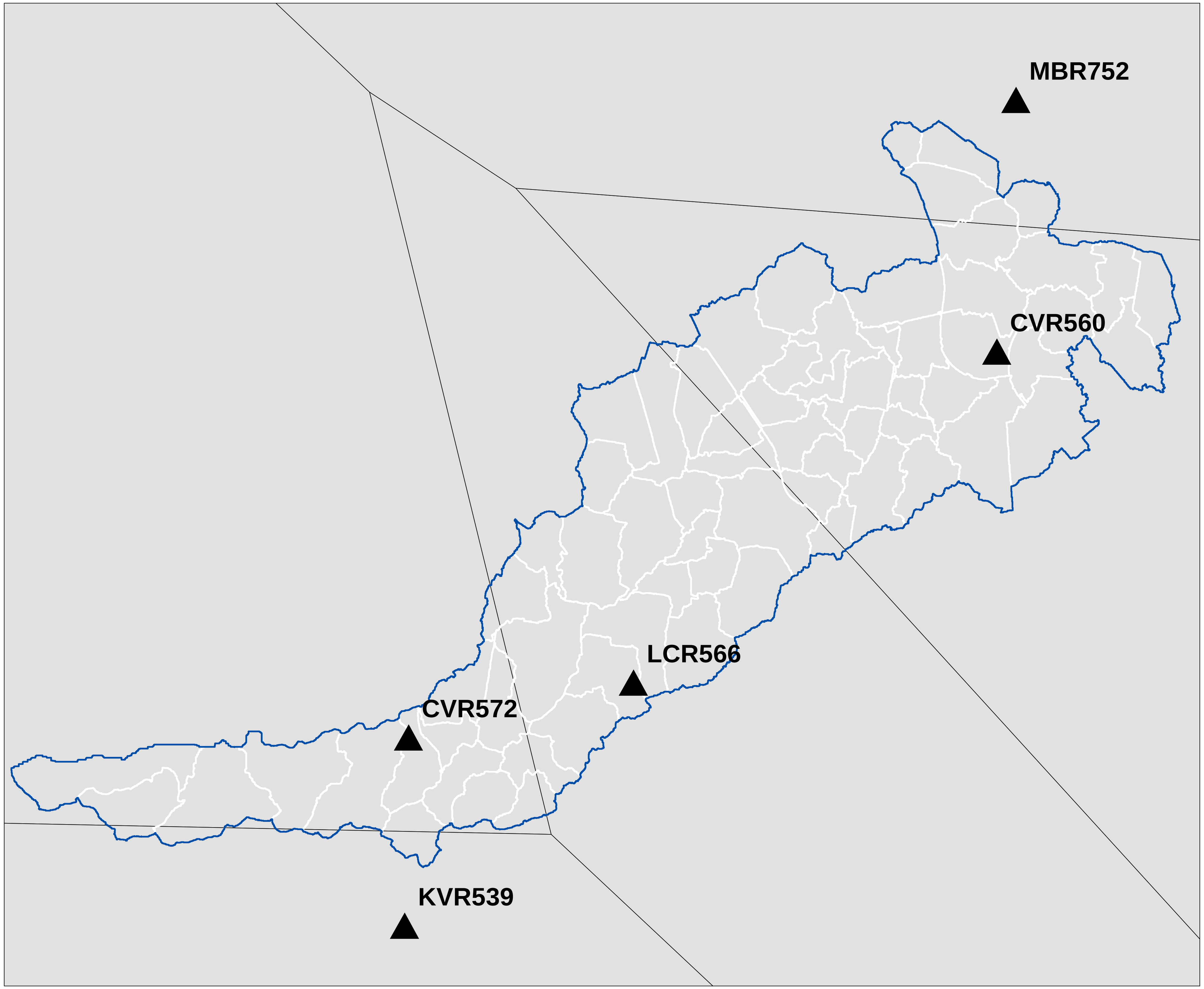
THIESSEN POLYGONS MARCH 2001

AECOM
www.aecom.com

Map D1

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixD_ThiessenPolygonMaps\AppendixD_MapD1_ThiessenPolygon_2001.mxd

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,500 3,000 6,000
Metres

1:60,000 (when printed at A3)

Legend

- ▲ Calibration Gauge March 2004
- Catchment Outline
- URBS Subcatchments
- Calibration Thiessen March 2004

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

THIESSEN POLYGONS MARCH 2004

www.aecom.com

Map D2

A3 size

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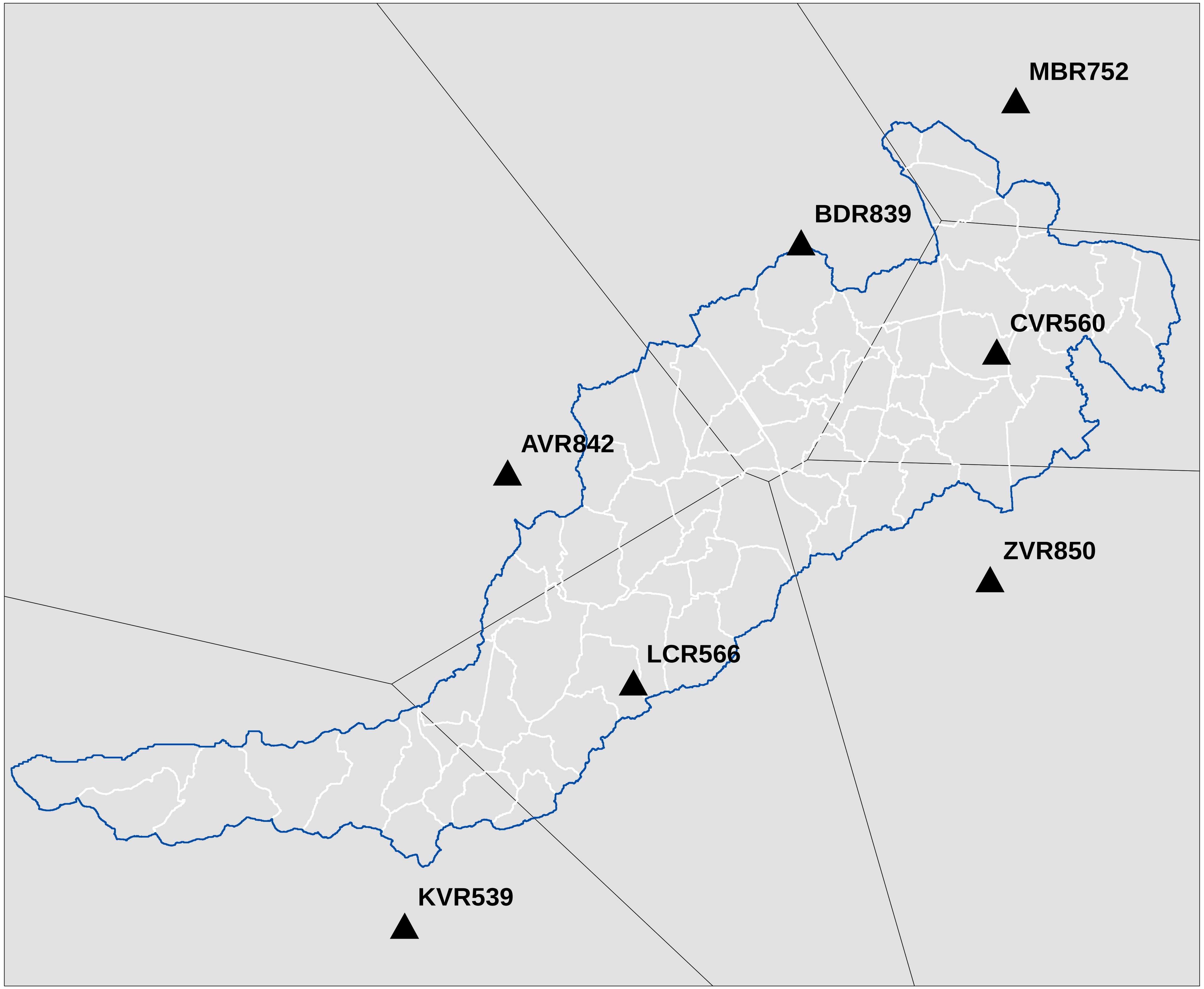

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,500 3,000 6,000

Metres

1:60,000 (when printed at A3)

Legend

- ▲ Calibration Gauge May 2009
- Catchment Outline
- URBS Subcatchments
- Calibration Thiessen May 2009

Data sources:
Brisbane City Council
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

THIESSEN POLYGONS MAY 2009

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Map D3

A3 size

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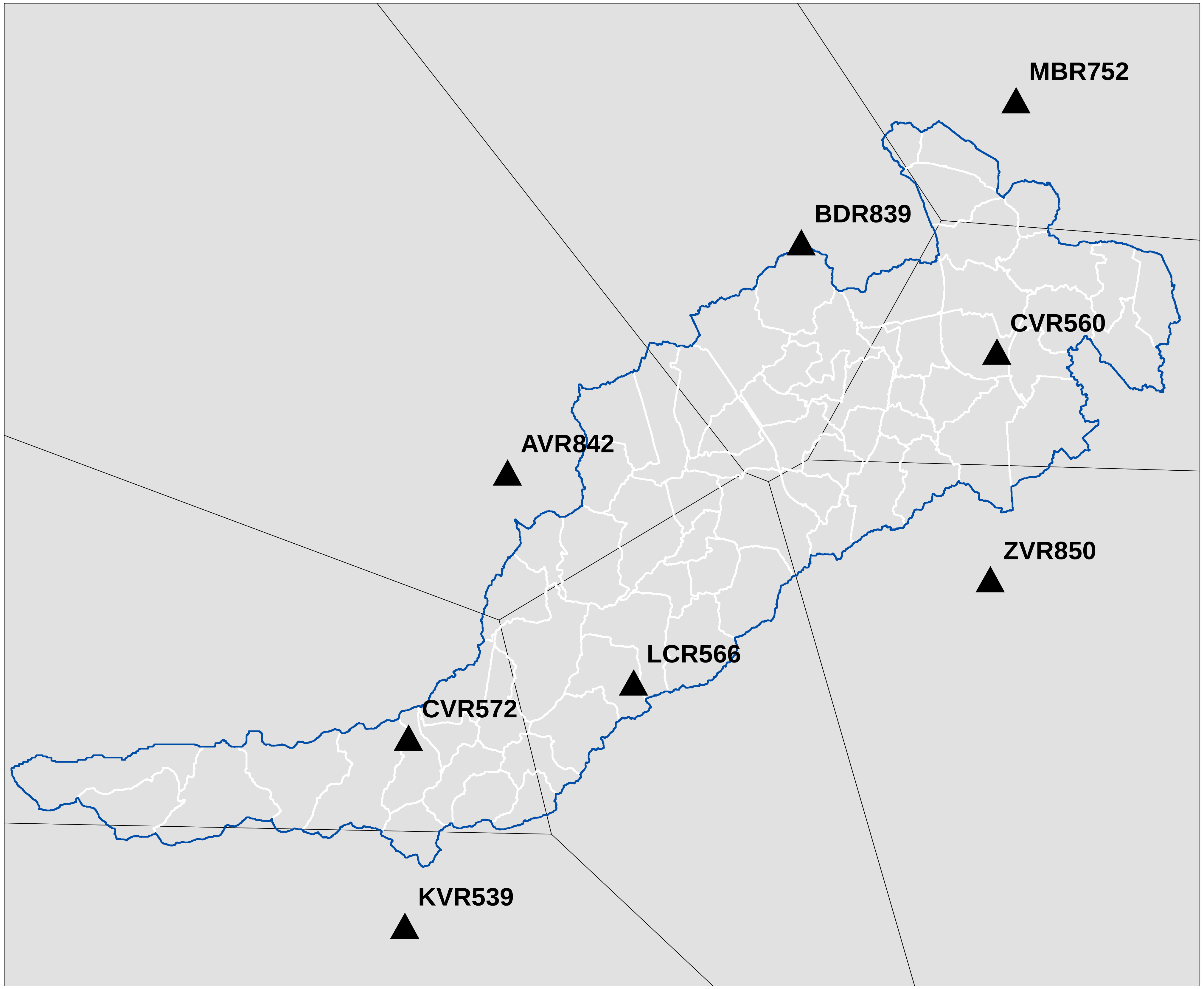

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,500 3,000 6,000

Metres

1:60,000 (when printed at A3)

Legend

- ▲ Calibration Gauge Oct 2010
- Catchment Outline
- URBS Subcatchments
- Calibration Thiessen Oct 2010

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

THIESSEN POLYGONS OCTOBER 2010

AECOM
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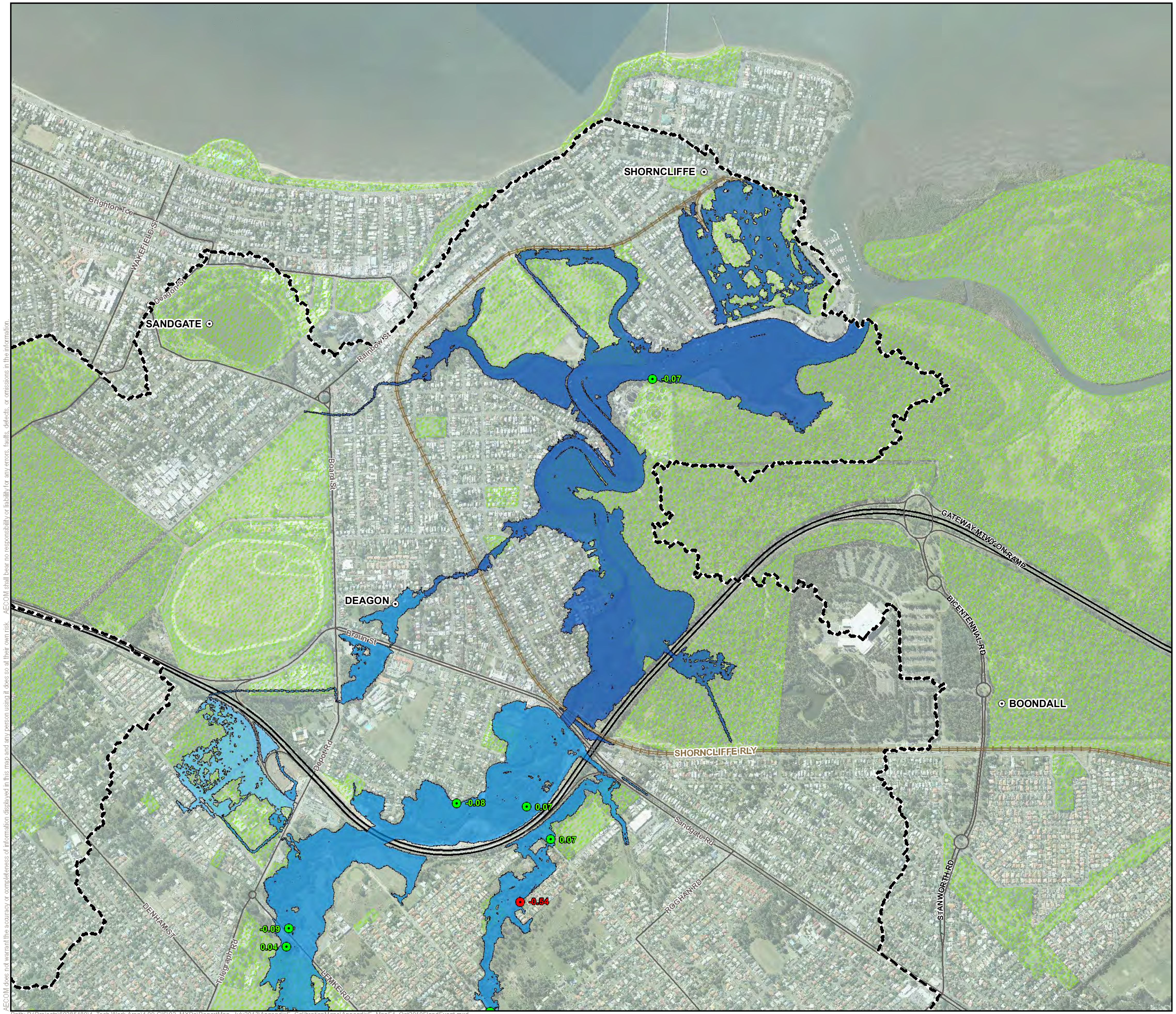
Map D4

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixD_ThiessenPolygonMaps\AppendixD_MapD4_ThiessenPolygon_Oct2010.mxd

A3 size

Appendix E

Calibration Maps



CABBAGE TREE CREEK

AECOM
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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

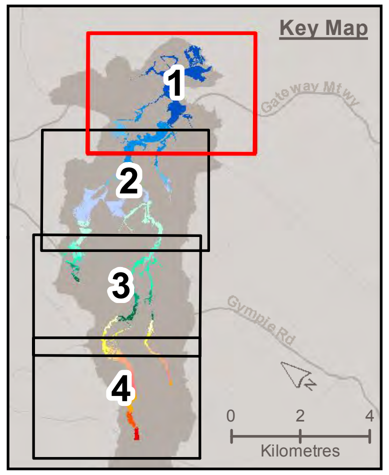
- Suburbs
- Railway
- Park
- Catchment Boundary

October 2010 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

OCTOBER 2010 FLOOD EVENT PEAK FLOOD LEVELS

MAP E1
Sheet 1 of 4

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE1_Oct2010FloodEvent.mxd

A3 size

CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

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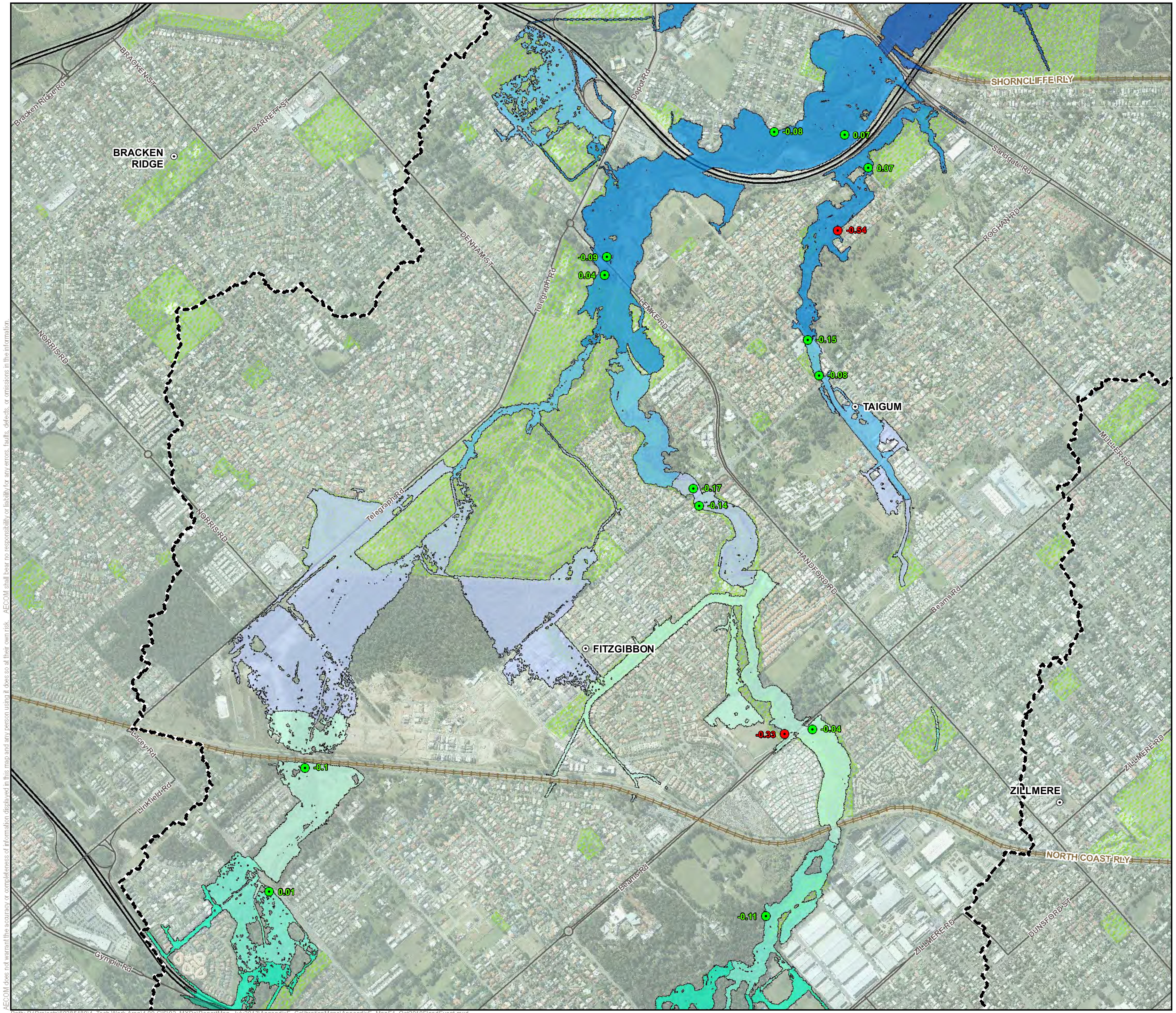


Legend

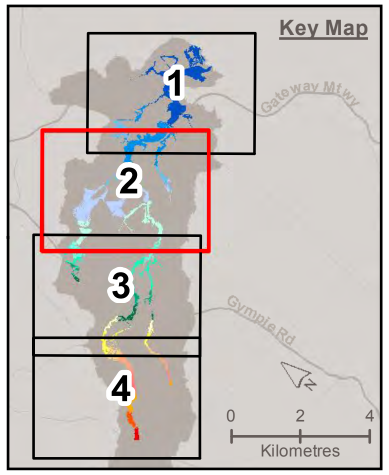
- Suburbs
- Railway
- Park
- Catchment Boundary

October 2010 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



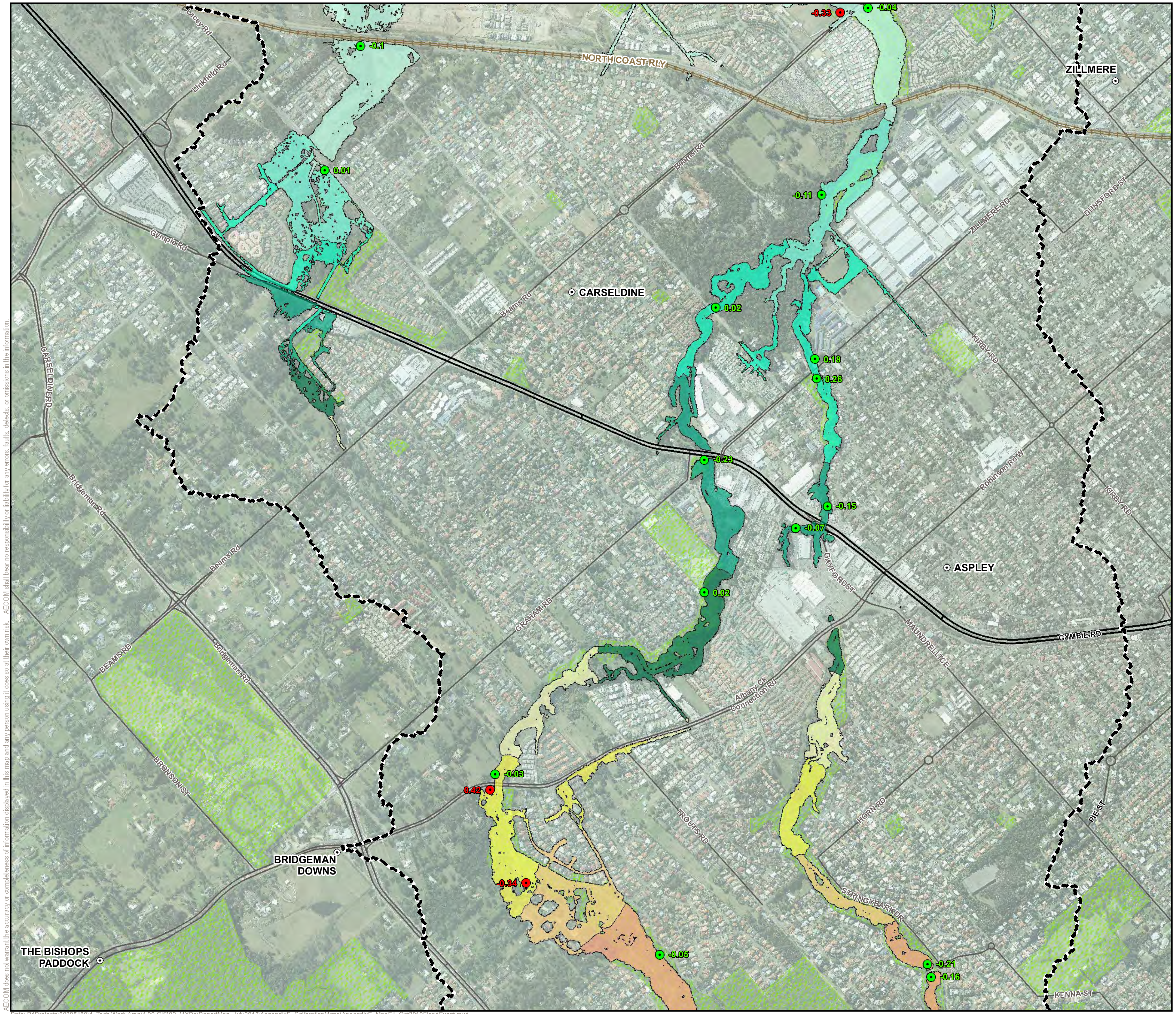
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

OCTOBER 2010 FLOOD EVENT PEAK FLOOD LEVELS

MAP E1
Sheet 2 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE1_Oct2010FloodEvent.mxd



CABBAGE TREE CREEK

AECOM
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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

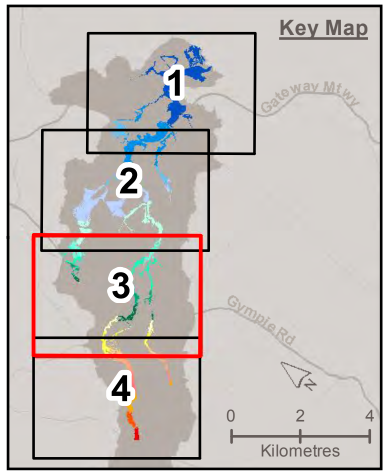
- Suburbs
- Railway
- Park
- Catchment Boundary

October 2010 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



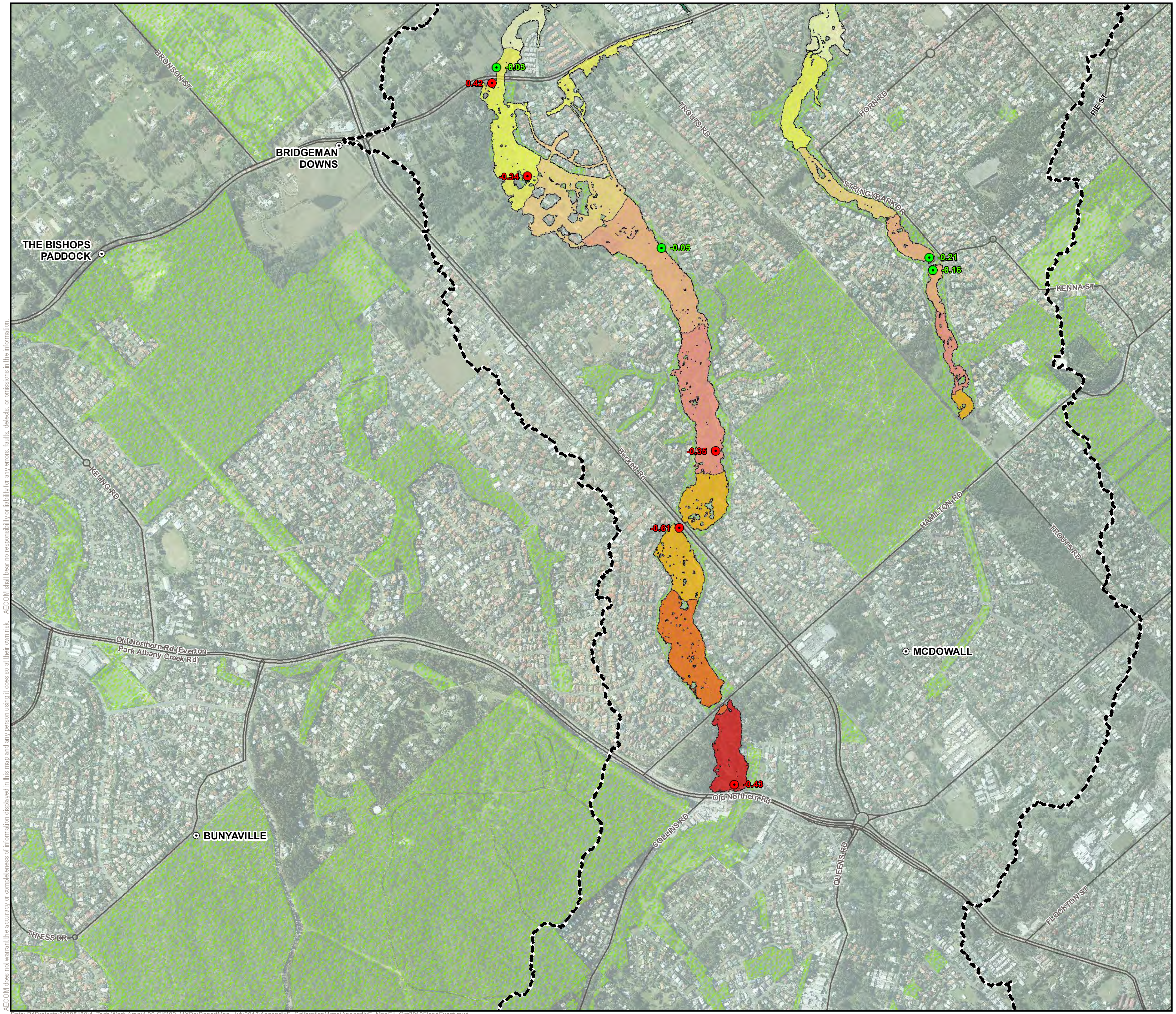
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

OCTOBER 2010 FLOOD EVENT PEAK FLOOD LEVELS

MAP E1 Sheet 3 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE1_Oct2010FloodEvent.mxd



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CABBAGE TREE CREEK

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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

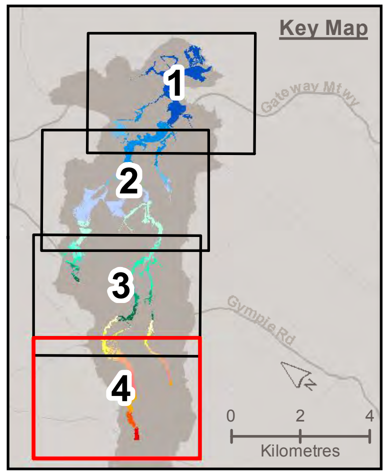
- Suburbs
- Railway
- Park
- Catchment Boundary

October 2010 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

OCTOBER 2010
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E1
Sheet
4 of 4

A3 size

CABBAGE TREE CREEK

AECOM
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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

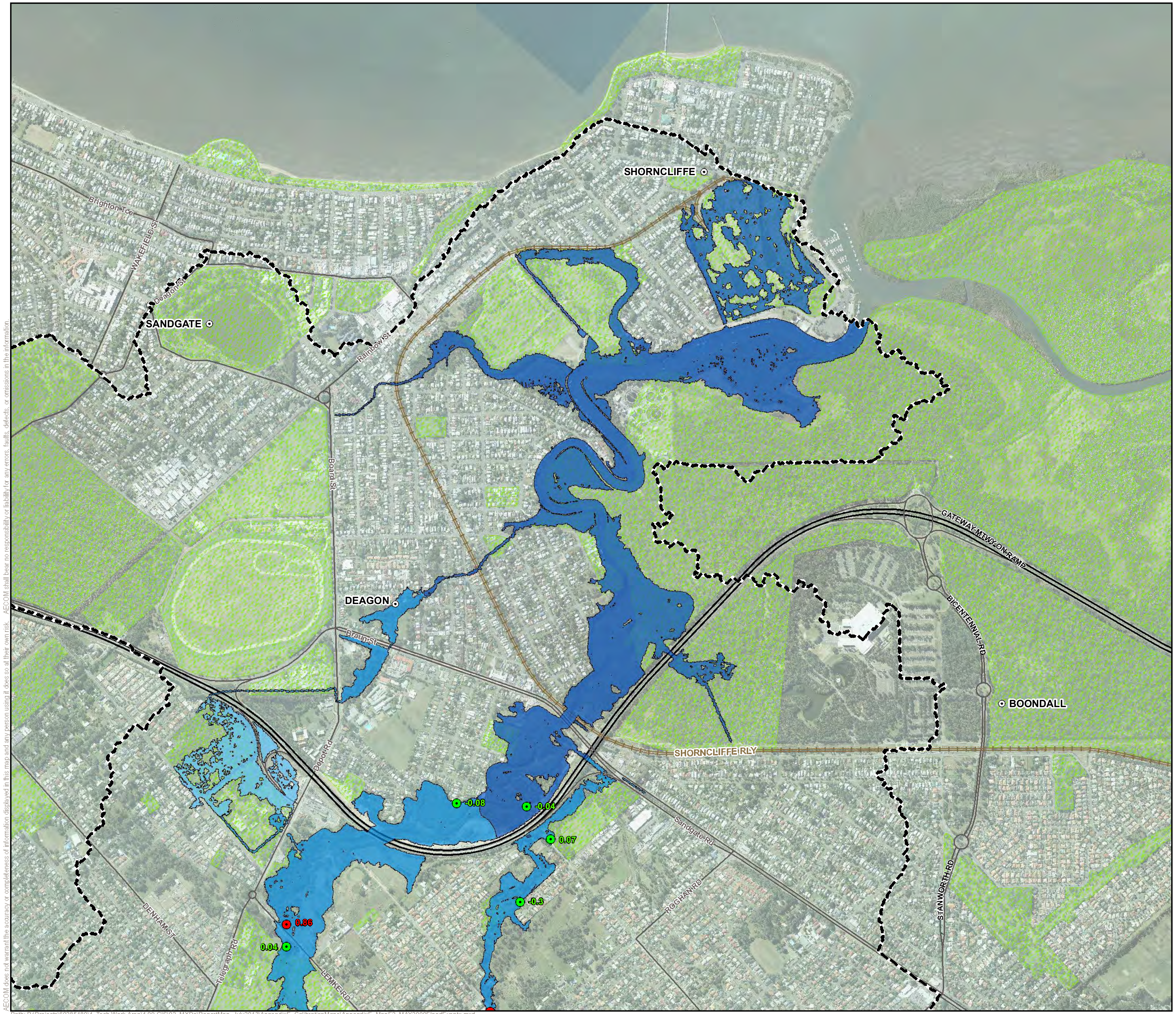
- Suburbs
- Railway
- Park
- Catchment Boundary

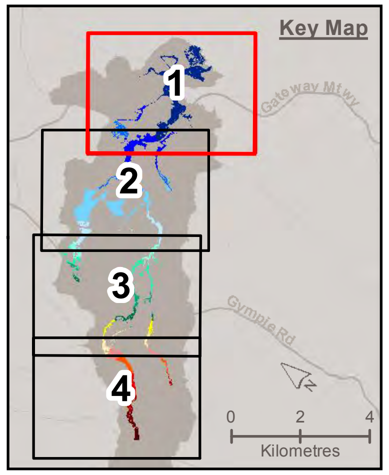
May 2009 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013





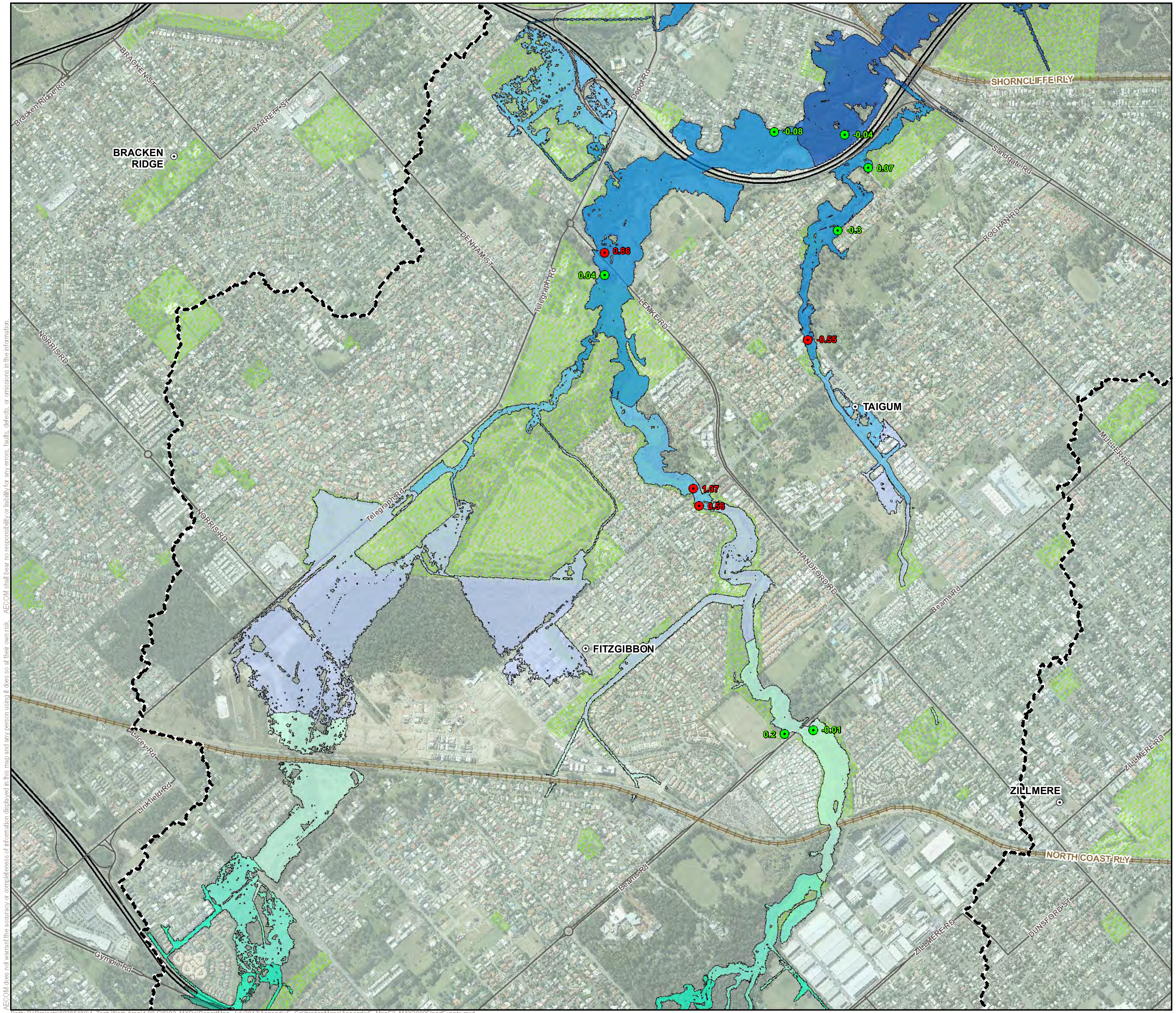
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MAY 2009
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E2
Sheet
1 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE2_MAY2009FloodEventx.mxd



CABBAGE TREE CREEK

BRISBANE CITY

AECOM
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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

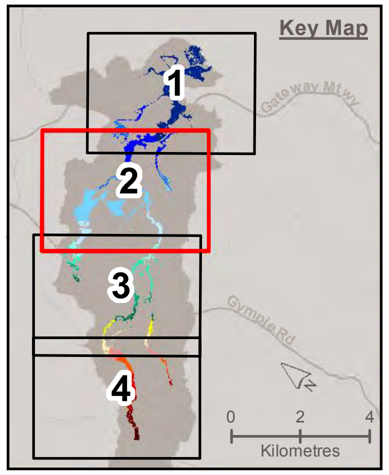
- Suburbs
- Railway
- Park
- Catchment Boundary

May 2009 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



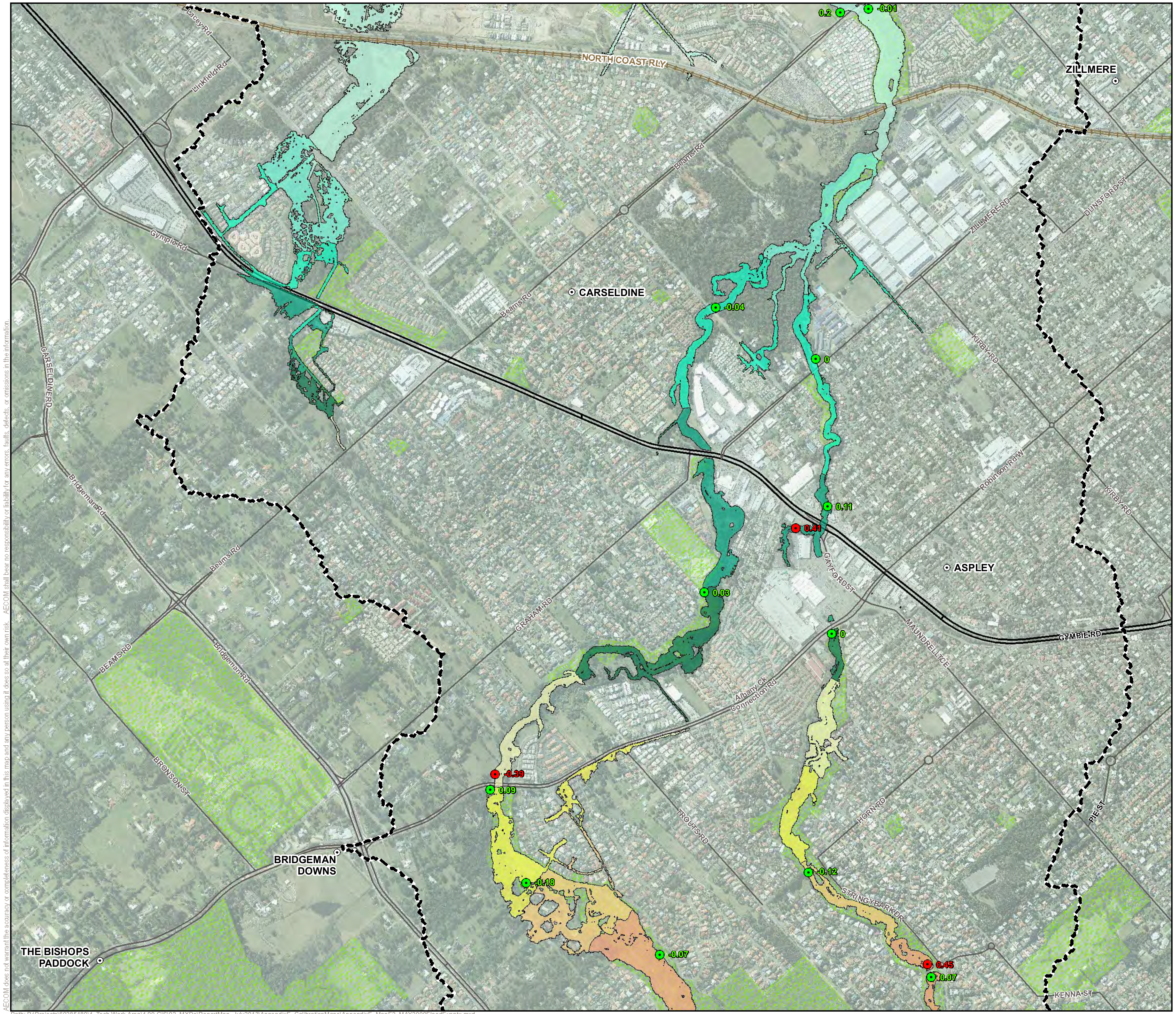
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MAY 2009 FLOOD EVENT PEAK FLOOD LEVELS

MAP E2
Sheet 2 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE2_MAY2009FloodEvent.mxd



CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

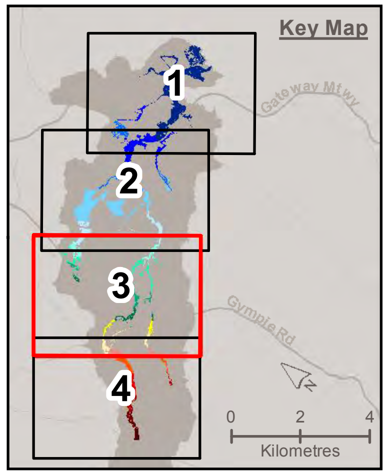
- Suburbs
- Railway
- Park
- Catchment Boundary

May 2009 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MAY 2009
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E2
Sheet
3 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE2_MAY2009FloodEventx.mxd

CABBAGE TREE CREEK

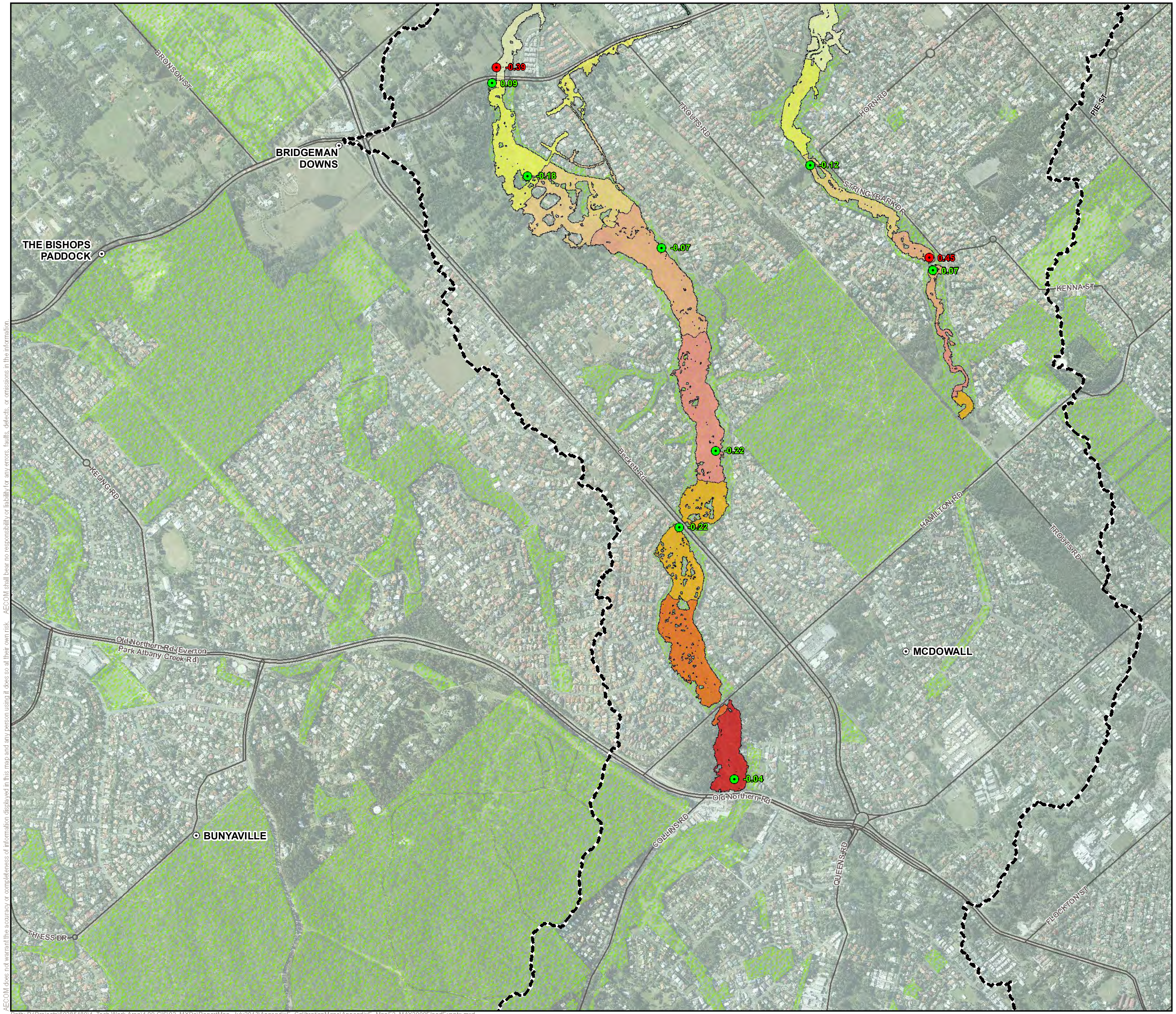
BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)



Legend

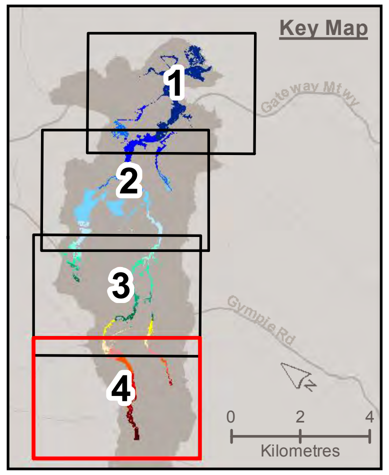
- Suburbs
- Railway
- Park
- Catchment Boundary

May 2009 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MAY 2009
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E2
Sheet
4 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE2_MAY2009FloodEventx.mxd

CABBAGE TREE CREEK

AECOM
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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

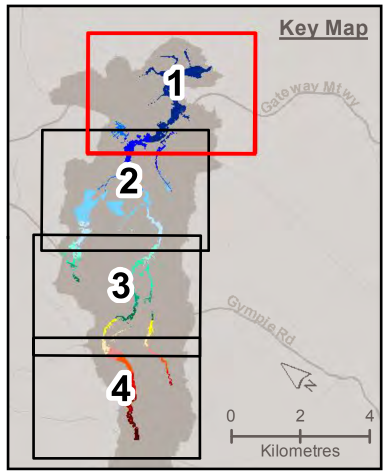
- Suburbs
- Railway
- Park
- Catchment Boundary

March 2004 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



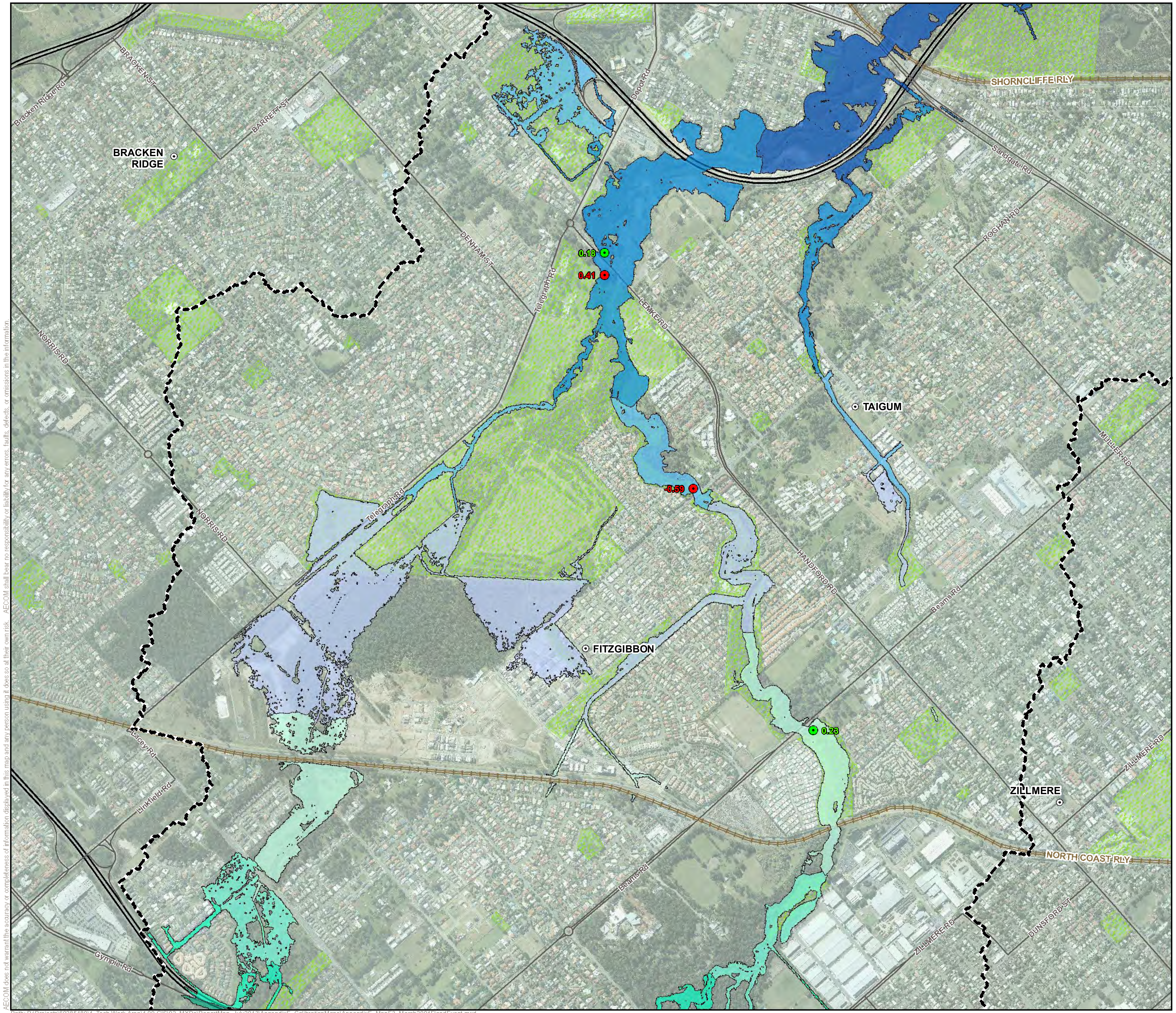
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2004
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E3
Sheet
1 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE3_March2004FloodEvent.mxd



CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

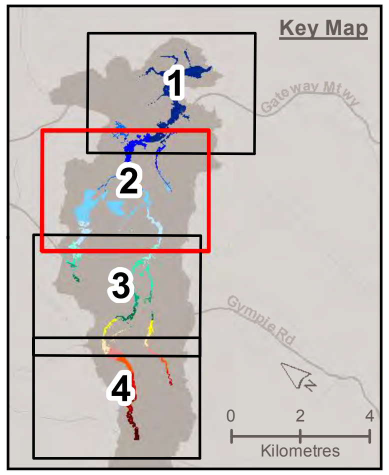
- Suburbs
- Railway
- Park
- Catchment Boundary

March 2004 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013

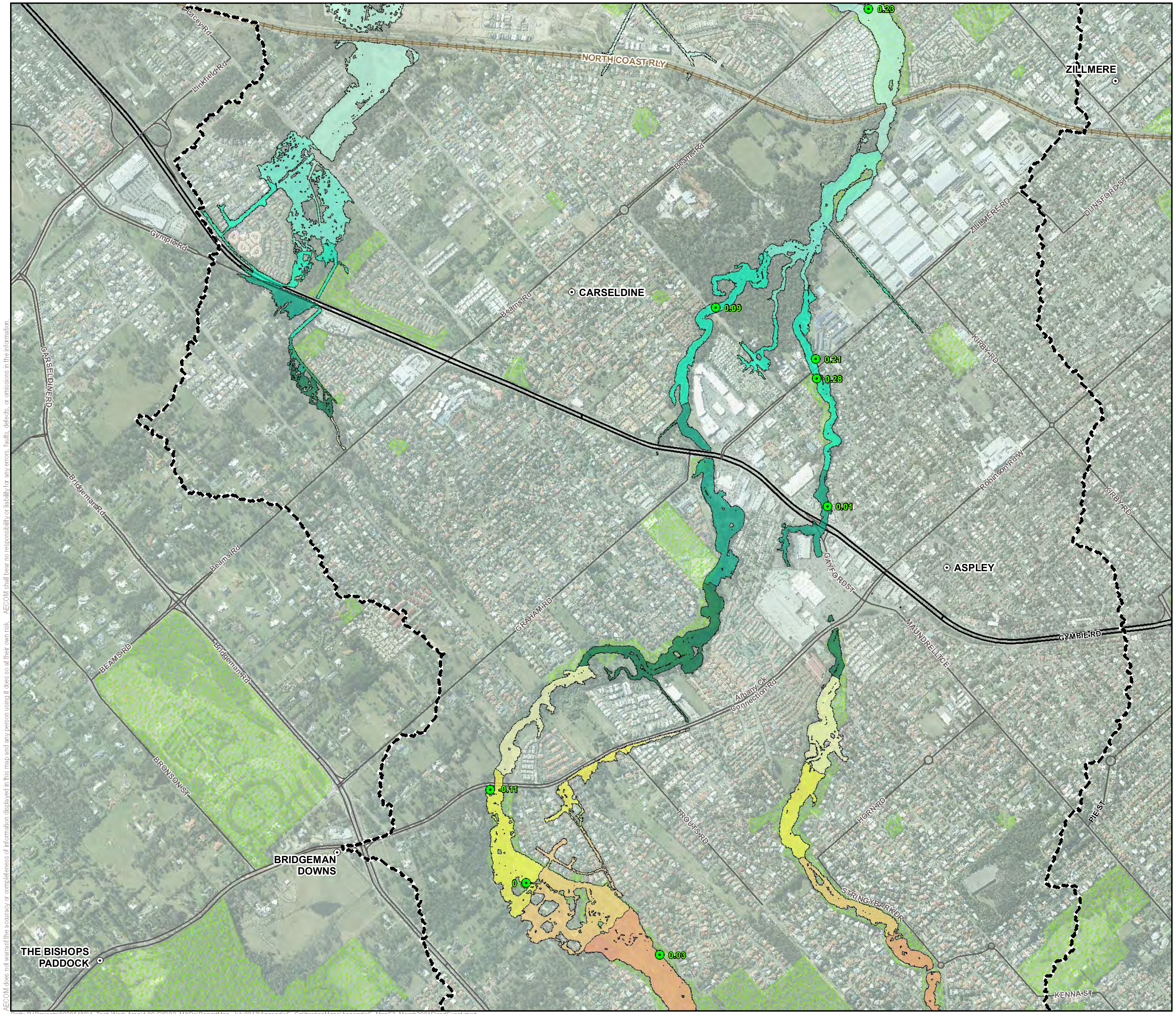


Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2004
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E3
Sheet
2 of 4

A3 size



CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

- Suburbs
- Railway
- Park
- Catchment Boundary

March 2004 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013

Key Map

1
2
3
4
Gateway Mwy
Gympie Rd
0 2 4
Kilometres

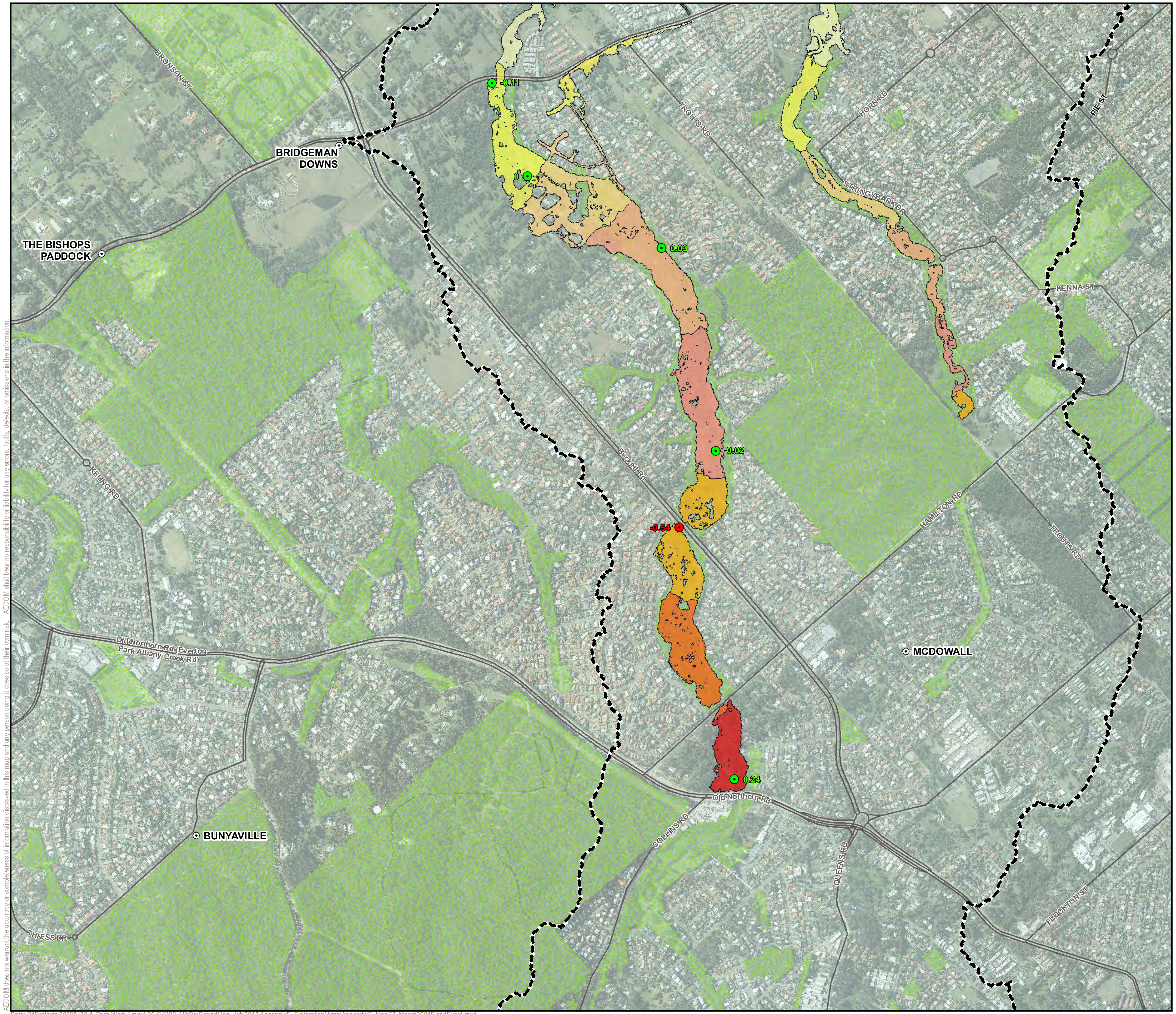
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2004
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E3
Sheet
3 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE3_March2004FloodEvent.mxd



CABBAGE TREE CREEK

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

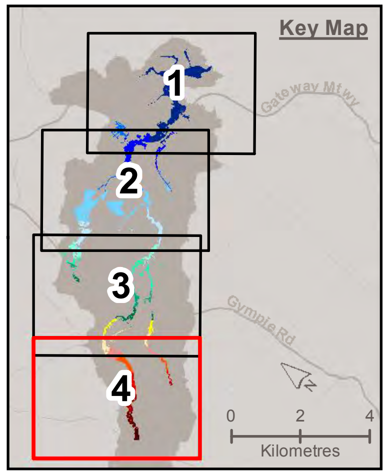
- Suburbs
- Railway
- Park
- Catchment Boundary

March 2004 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



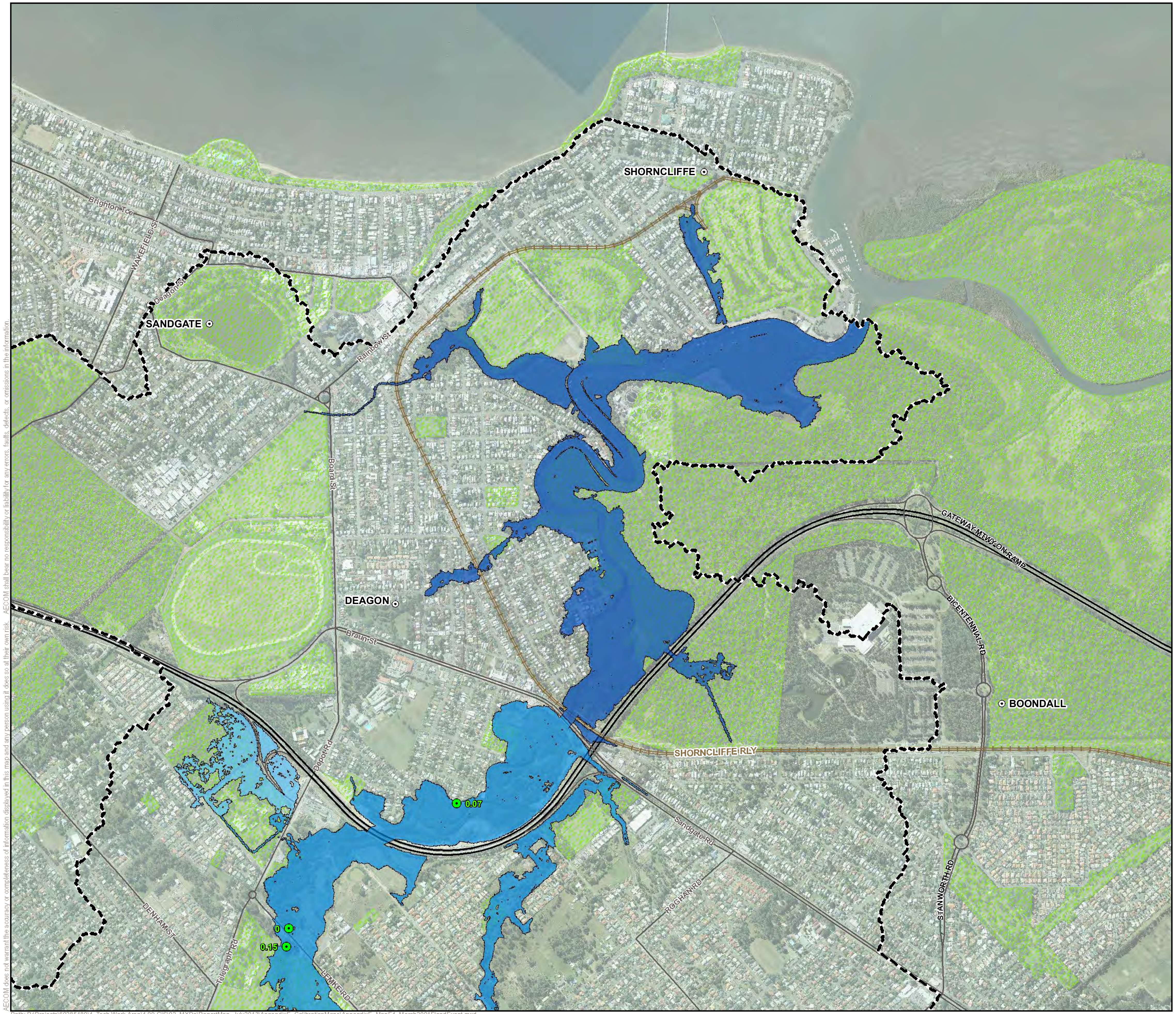
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2004
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E3
Sheet
4 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE3_March2004FloodEvent.mxd



CABBAGE TREE CREEK

AECOM
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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

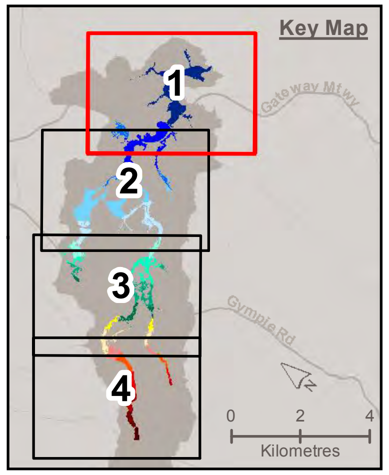
- Suburbs
- Railway
- Park
- Catchment Boundary

March 2001 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2001
FLOOD EVENT
PEAK FLOOD LEVELS

MAP E4
Sheet
1 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE4_March2001FloodEvent.mxd

CABBAGE TREE CREEK

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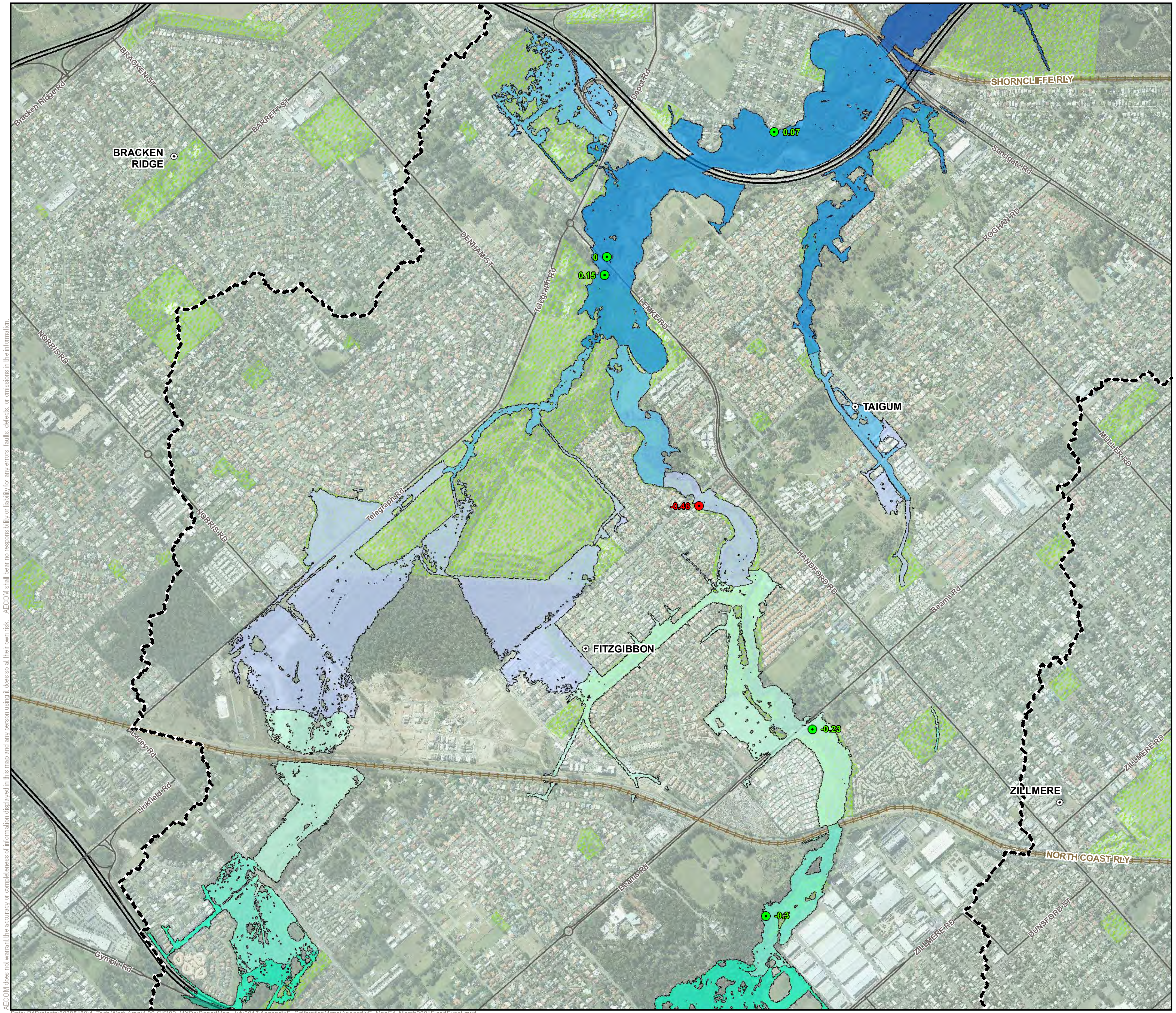


DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

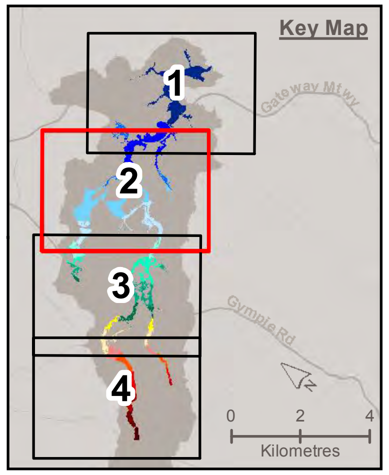
- Suburbs
- Railway
- Park
- Catchment Boundary

March 2001 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2001 FLOOD EVENT PEAK FLOOD LEVELS

MAP E4 Sheet 2 of 4

A3 size

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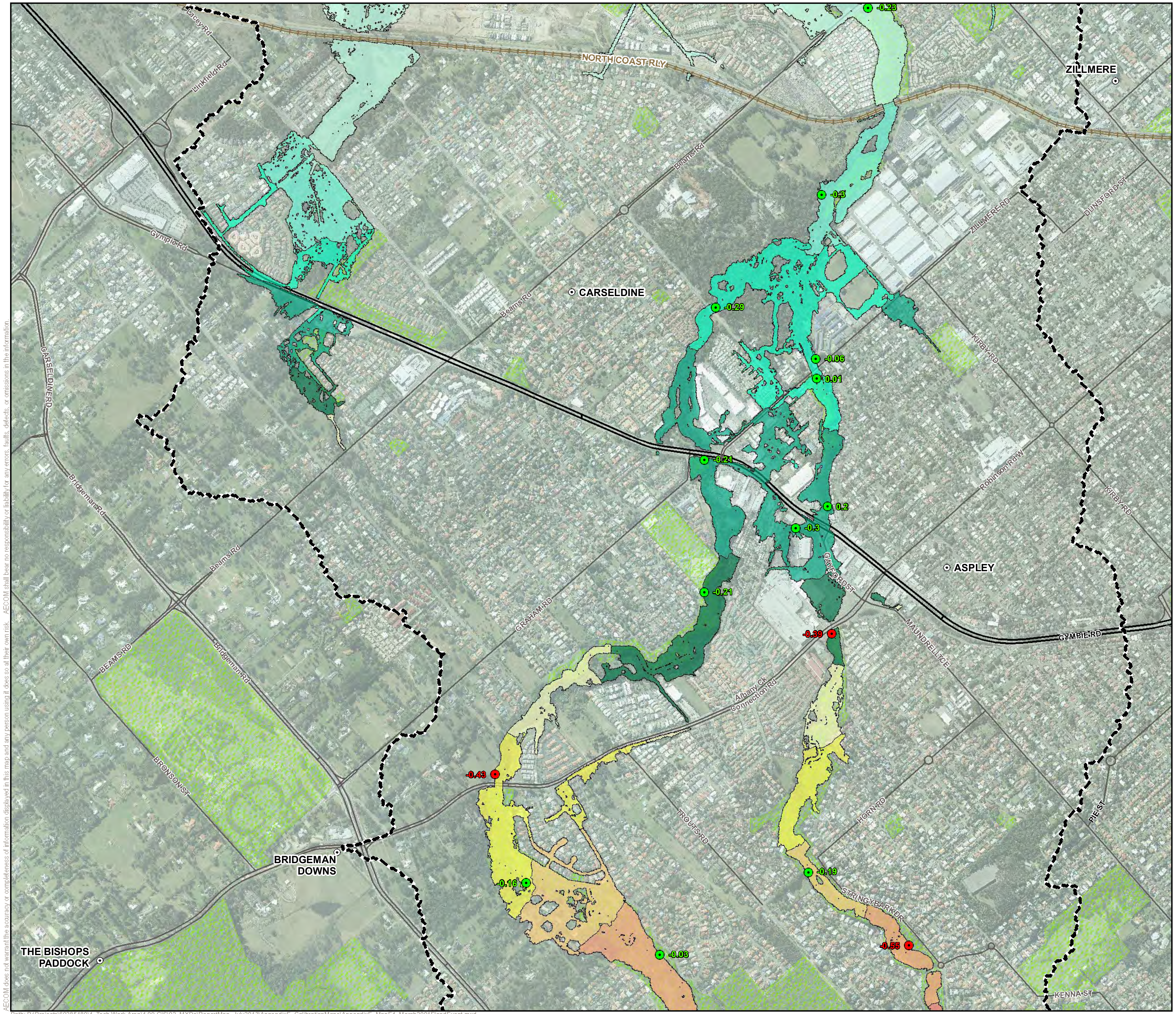

CABBAGE TREE CREEK

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DATUM GDA 1994, PROJECTION MGA ZONE 56

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Metres

1:15,000 (when printed at A3)

Legend

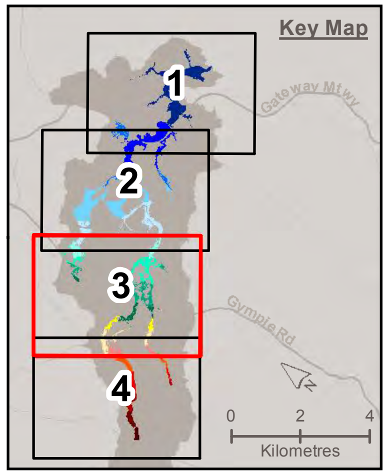
- Suburbs
- Railway
- Park
- Catchment Boundary

March 2001 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
5.0 - 7.5	20.0 - 22.5	35.0 - 37.5
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



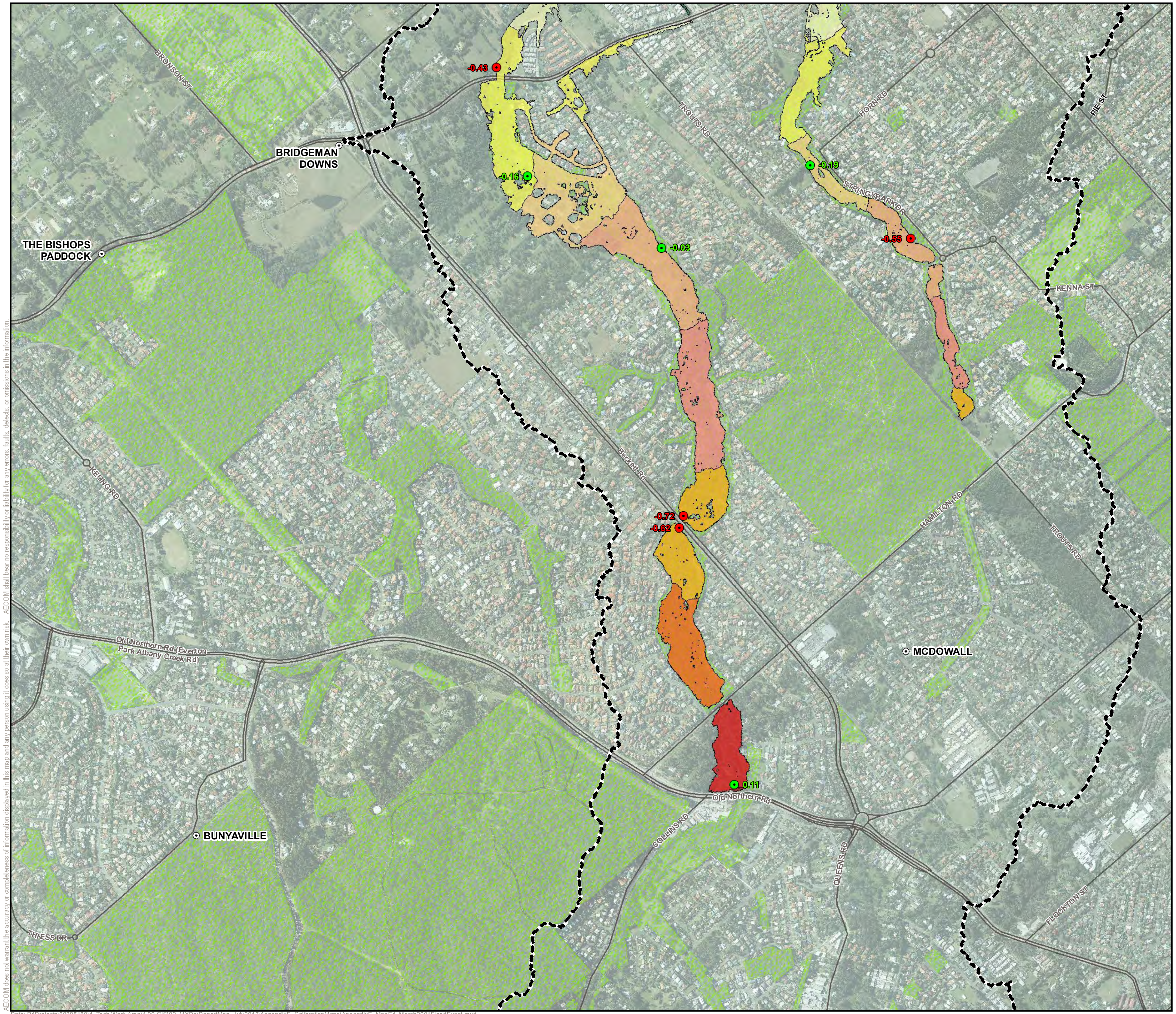
Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2001 FLOOD EVENT PEAK FLOOD LEVELS

MAP E4 Sheet 3 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE4_March2001FloodEvent.mxd



CABBAGE TREE CREEK

BRISBANE CITY

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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

- Suburbs
- Railway
- Park
- Catchment Boundary

March 2001 Flood Event. Peak Flood Level (m AHD)

<2.5	15.0 - 17.5	30.0 - 32.5
2.5 - 5.0	17.5 - 20.0	32.5 - 35.0
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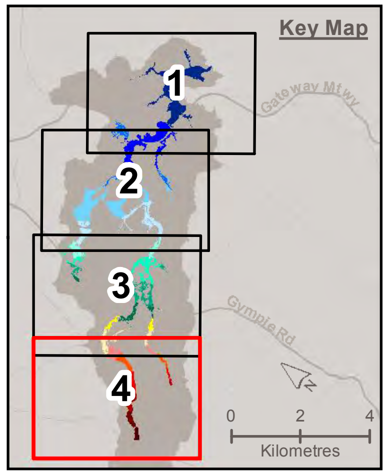
7.5 - 10.0	22.5 - 25.0	37.5 - 40.0
10.0 - 12.5	25.0 - 27.5	40.0 - 42.5
12.5 - 15.0	27.5 - 30.0	>42.5

Difference in Peak Flood Levels (Modelled minus Recorded)

4/10/2013



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

MARCH 2001 FLOOD EVENT PEAK FLOOD LEVELS

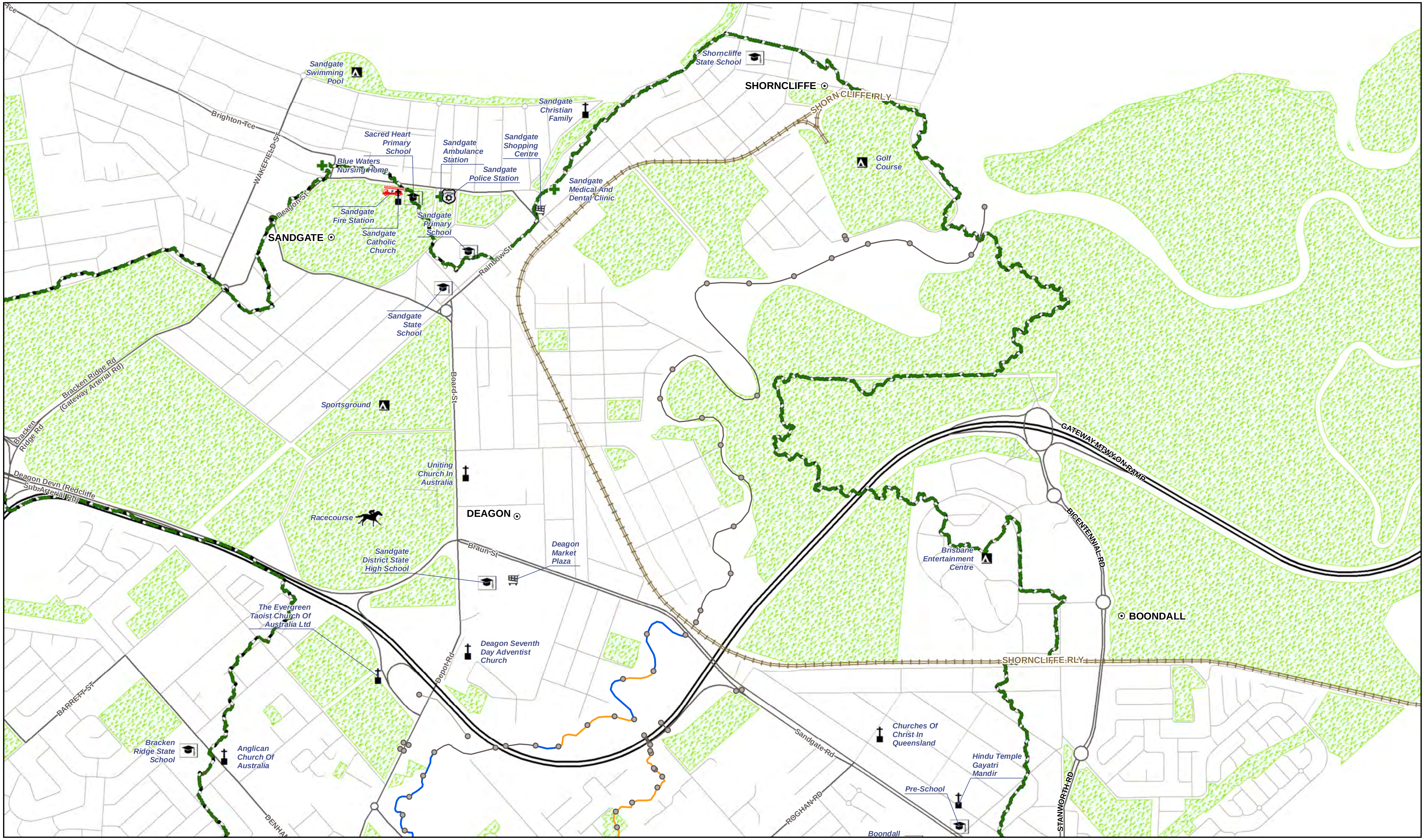
MAP E4 Sheet 4 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixE_CalibrationMaps\AppendixE_MapE4_March2001FloodEvent.mxd

Appendix F

1D Manning's N Values



DATUM GDA 1994, PROJECTION MGA ZONE 56

0 375 750 1,500

Metres

1:15,000 (when printed at A3)

Legend

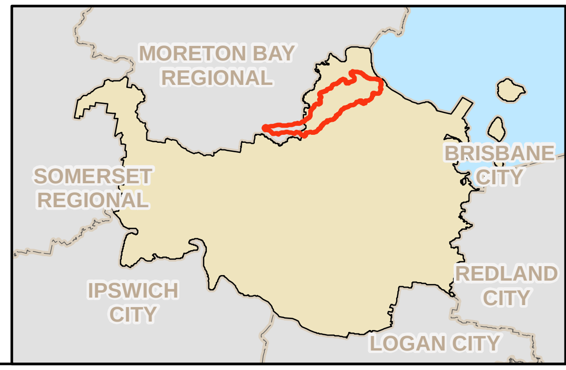
- Suburbs
- Catchment Boundary
- Railway
- Shopping Centre
- Mine or Quarry
- Sports and Recreation
- Racecourse
- Education
- Business
- Library
- Church, Cemetry
- Health Services
- Police Station
- Fire Station
- Post Office

Manning's n Values

- Model network nodes

Model reaches and associated n values

- < 0.02
- 0.02 to 0.05
- 0.05 to 0.07
- 0.07 to 0.1
- > 0.1



Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

MODEL MANNING'S N VALUES

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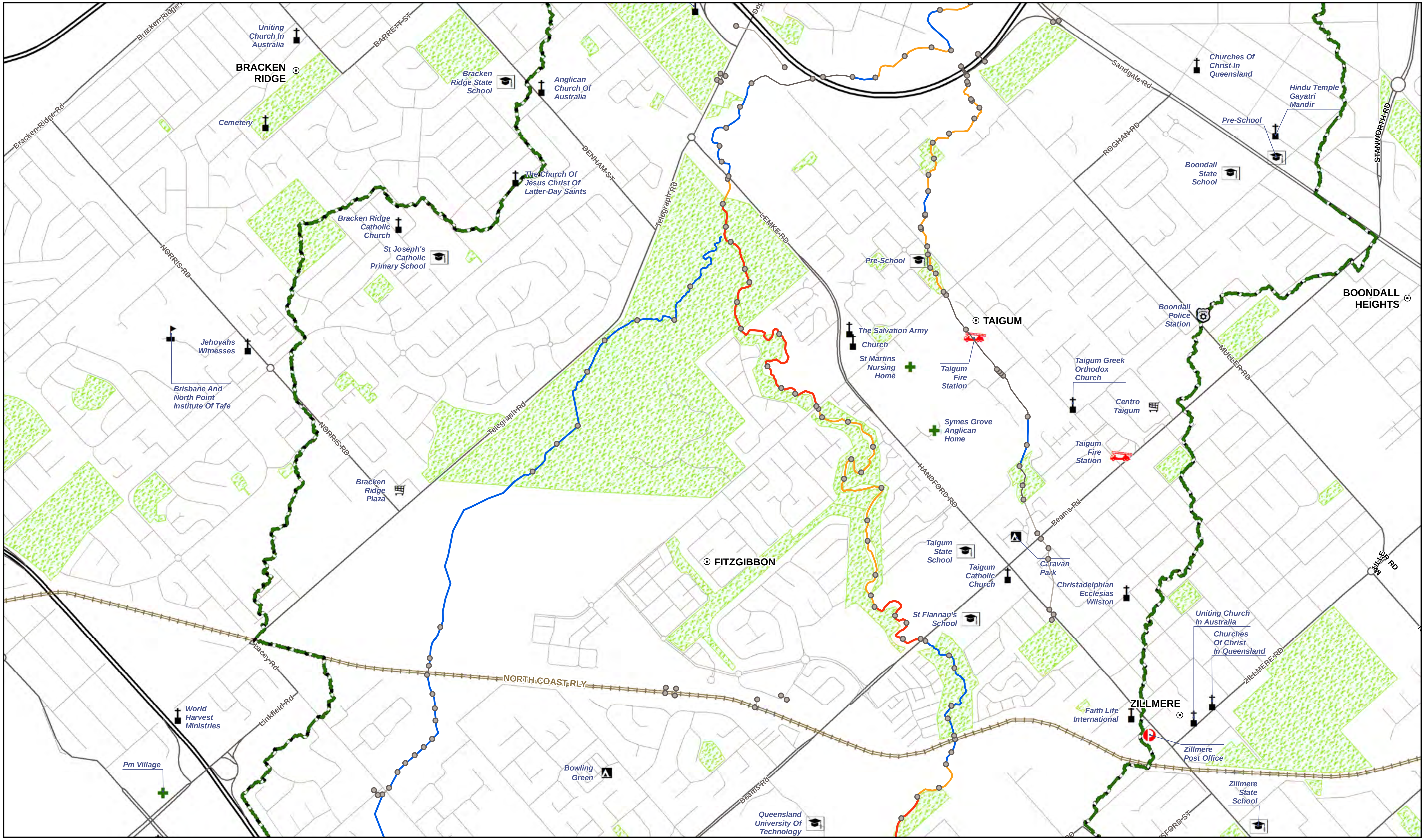
MAP F
Sheet
1 of 4

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixF_1DManning_s_NValues\AppendixF_MapF_Manning_s_Nvalue.mxd

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 56

0 375 750 1,500

Metres

1:15,000 (when printed at A3)

Legend

- Suburbs
- Catchment Boundary
- Railway
- Shopping Centre
- Mine or Quarry
- Sports and Recreation
- Racecourse
- Education
- Business
- Library
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- Health Services
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- Post Office

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- Model network nodes

Model reaches and associated n values

- < 0.02
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- 0.05 to 0.07
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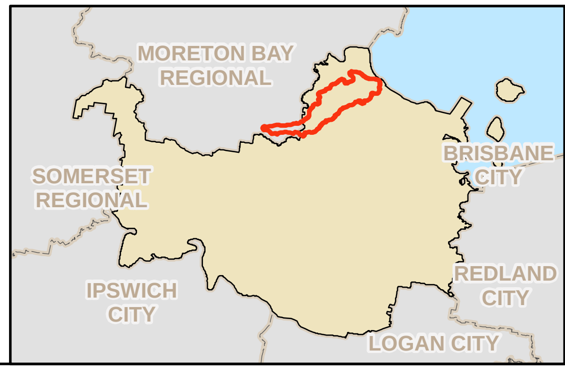
- > 0.1



Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

MODEL MANNING'S N VALUES

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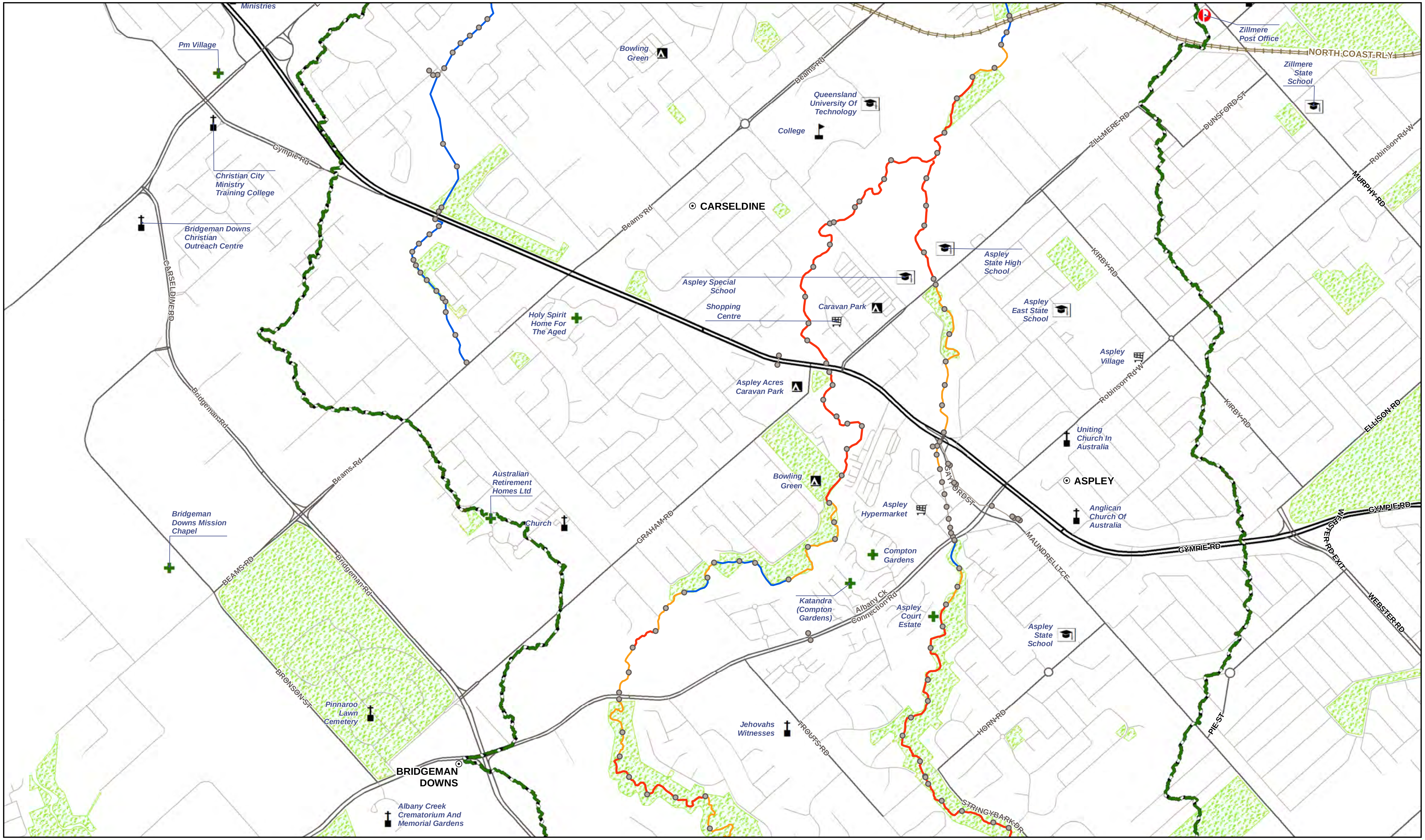
MAP F
Sheet
2 of 4

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 56

0 375 750 1,500

Metres

1:15,000 (when printed at A3)

Legend

- Suburbs
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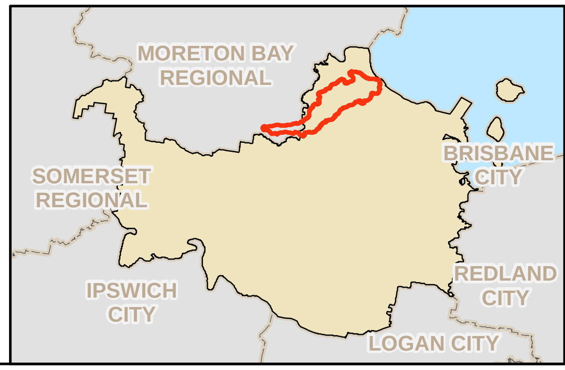

Data sources:
Brisbane City Council
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

MODEL MANNING'S N VALUES

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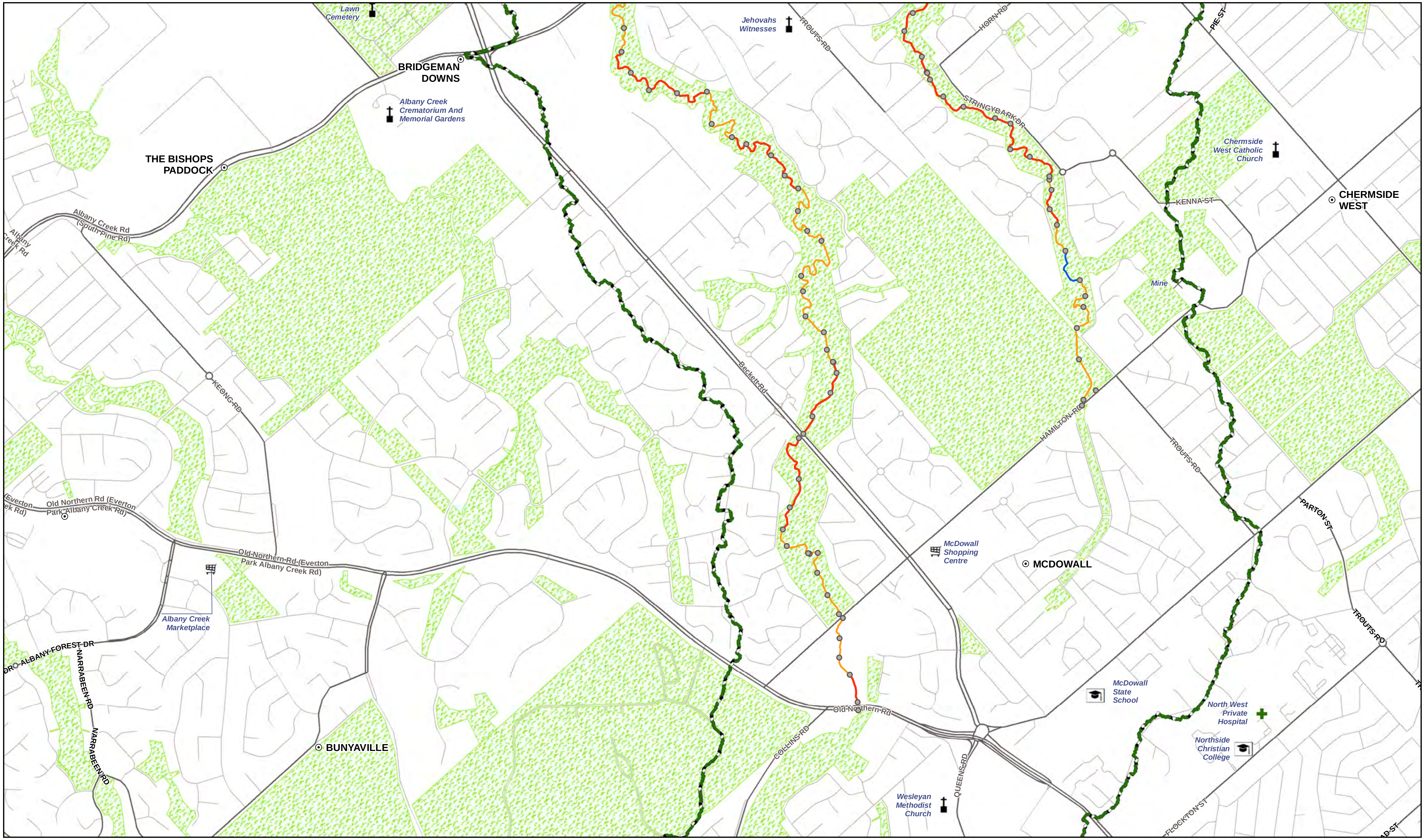
MAP F
Sheet
3 of 4

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 56

0 375 750 1,500

Metres

1:15,000 (when printed at A3)

Legend

- Suburbs
- Catchment Boundary
- Railway
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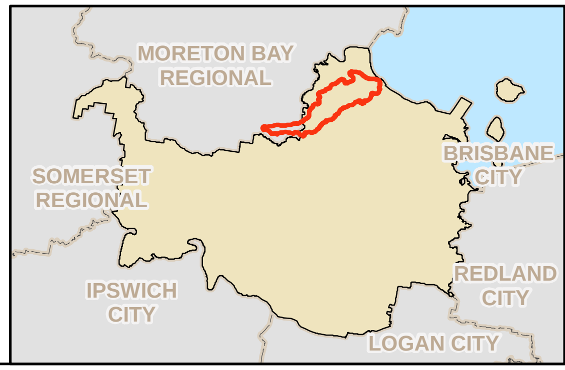

Data sources: Brisbane City Coucil SISP Imagery Street Pro Dataset

Cabbage Tree Creek Catchment

MODEL MANNING'S N VALUES

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MAP F Sheet 4 of 4

A3 size

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixF_1DManning_s_NValues\AppendixF_MapF_Manning_s_Nvalue.mxd

Appendix G

MHG Results

Appendix G MHG Results

Reach	Gauge	Oct-10	May-09	Mar-04	Mar-01
C	100	N/A	N/A	N/A	N/A
C	100A	-0.07	N/A	N/A	N/A
C	110	-0.08	-0.08	N/A	0.07
C	120	N/A	0.86	0.18	N/A
C	120A	-0.09	N/A	N/A	0.00
C	130	0.04	0.04	0.41	0.15
C	140	-0.17	1.07	-0.59	N/A
C	15	N/A	N/A	N/A	N/A
C	150	-0.14	0.58	N/A	-0.46
C	160	-0.33	0.20	N/A	N/A
C	170	N/A	-0.01	0.23	N/A
C	170A	-0.04	N/A	N/A	-0.23
C	180	0.02	-0.04	0.09	-0.29
C	190	-0.23	N/A	N/A	-0.21
C	2	N/A	N/A	N/A	N/A
C	200	0.02	0.03	N/A	-0.21
C	210	-0.03	-0.39	N/A	-0.43
C	220	0.42	0.09	-0.11	N/A
C	230	-0.34	-0.18	0.00	-0.16
C	240	-0.05	-0.07	0.03	-0.03
C	250	-0.35	-0.22	-0.02	N/A
C	260	N/A	-0.22	-0.54	N/A
C	260A	-0.61	N/A	N/A	-0.62
C	270	N/A	-0.04	0.24	N/A
C	270A	-0.43	N/A	N/A	0.11
C	300	0.07	-0.04	N/A	N/A
C	310	0.07	0.07	N/A	N/A
C	320	-0.54	-0.30	N/A	N/A
C	330	-0.15	-0.55	N/A	N/A
C	340	-0.08	N/A	N/A	N/A
C	4	N/A	N/A	N/A	-0.72
C	410	-0.10	N/A	N/A	N/A
C	420	0.01	N/A	N/A	N/A
LC	100	-0.11	N/A	N/A	-0.30
LC	110	N/A	0.00	0.21	-0.06

Reach	Gauge	Oct-10	May-09	Mar-04	Mar-01
LC	110A	0.18	N/A	N/A	N/A
LC	120	0.26	N/A	0.28	0.01
LC	130	-0.15	0.11	0.01	0.20
LC	140	-0.07	0.41	N/A	-0.30
LC	150	N/A	N/A	N/A	N/A
LC	150A	N/A	0.00	N/A	-0.39
LC	160	N/A	-0.12	N/A	-0.19
LC	170	N/A	N/A	N/A	-0.55
LC	171	-0.21	0.45	N/A	N/A
LC	172	-0.16	0.07	N/A	N/A

Appendix H

HEC-RAS Head Loss Comparisons

Appendix H HEC-RAS Head Loss Comparisons

Structure	2010			2009			Q100			Q050			AVG Diff	Comments
	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS		
Old Northern Road	50	0.03	0.13	40	0.02	0.08	100	0.18	0.41	90	0.13	0.34	0.15	Structure is upstream boundary
Hamilton Road	50	0.14	0.08	40	0.11	0.05	110	0.42	0.34	90	0.35	0.24	0.08	
Beckett Road	60	0.15	0.11	40	0.10	0.05	120	0.61	0.53	100	0.50	0.32	0.09	
Costner Place	60	0.05	0.18	40	0.04	0.18	120	0.05	0.16	100	0.05	0.16	0.12	
Albany Creek Road	80	0.03	0.10	50	0.01	0.03	140	0.20	0.36	120	0.15	0.28	0.09	
Gympie Road	90	0.12	0.36	60	0.09	0.40	150	0.28	0.14	130	0.24	0.14	0.20	Significant differences in head loss observed in 2010 and 2009 events. All MHG gauges in vicinity are within 0.3m tolerance. Q100 and Q50 results indicate slightly conservative TUFLOW head losses.
Dorville Road	90	0.07	0.11	60	0.03	0.06	130	0.12	0.22	130	0.12	0.23	0.07	
North Coast Railway	140	0.31	0.60	90	0.25	0.45	220	0.80	0.94	190	0.60	0.80	0.21	Significant differences in head loss observed in 2010 and 2009 events. Telemetry gauging shows less than 0.1m difference in these events.
Beams Road	150	0.06	0.11	100	0.02	0.04	230	0.11	0.29	190	0.09	0.20	0.09	
Roghan Road	150	0.07	0.06	110	0.04	0.09	200	0.11	0.13	190	0.10	0.10	0.02	
Lemke Road	160	0.21	0.27	120	0.18	0.20	250	0.17	0.10	190	0.21	0.26	0.05	
Gateway Motorway	200	0.06	0.07	140	0.05	0.06	270	0.08	0.06	240	0.06	0.07	0.01	
Sandgate Road	200	0.38	0.65	150	0.21	0.65	280	0.43	0.28	240	0.52	0.75	0.27	Significant differences in head loss observed in 2010 and 2009 events. Telemetry gauging nearby shows less than 0.05m difference in these events.
	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS		
Martindale Street	30	0.02	0.06	20	0.02	0.02	60	0.12	0.24	50	0.11	0.07	0.05	
Horn Road	30	0.11	0.22	30	0.07	0.23	70	0.28	0.34	60	0.27	0.36	0.11	
Albany Creek Road	40	0.44	0.50	30	0.60	0.60	90	0.92	0.83	80	0.76	0.61	0.08	
Gayford Road & Gympie Road	50	0.30	0.37	40	0.15	0.22	100	0.39	0.36	90	0.40	0.38	0.05	
Zillmere Road	60	0.02	0.08	40	0.01	0.02	110	0.13	0.25	90	0.12	0.22	0.07	
	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS	Peak Flow	TUFLOW	HEC-RAS		
Gateway Motorway	30	0.05	0.08	40	0.05	0.13	40	0.03	0.15	30	0.00	0.08	0.08	

Structure	2010			2009			Q100			Q050			AVG Diff	Comments
401a Church Road	30	0.17	0.07	20	0.43	0.02	30	0.15	0.12	30	0.12	0.02	0.16	Significant difference in 2009 head loss values. All other events appear satisfactory.
Church Road	30	0.06	0.17	20	0.04	0.08	30	0.09	0.17	30	0.07	0.17	0.08	
Roghan Road	30	0.06	0.10	20	0.02	0.08	30	0.12	0.11	30	0.08	0.12	0.04	
Quarrion Street	20	0.03	0.06	10	0.02	0.02	30	0.04	0.11	20	0.03	0.05	0.03	
	Peak Flow	**TUFLOW**	**HEC-RAS**	**Peak Flow**	**TUFLOW**	**HEC-RAS**	**Peak Flow**	**TUFLOW**	**HEC-RAS**	**Peak Flow**	**TUFLOW**	**HEC-RAS**		
Gympie Road	10	0.63	0.81	10	0.53	0.44	20	1.27	1.09	20	1.20	0.95	0.18	TUFLOW head losses generally more conservative than HEC-RAS. TUFLOW losses not changed
Lacey Road	20	0.14	0.10	20	0.09	0.14	40	0.33	0.43	40	0.28	0.35	0.06	
North Coast Railway	20	0.13	0.16	20	0.08	0.17	50	0.35	0.44	40	0.35	0.55	0.10	

Appendix I

Extreme Event Hydrology

Cabbage Tree (extracted from CRC FORGE)

Rainfall Rate (mm/hr)

	5	10	20	50	100	200	500	1000	2000
15min	121	137	158	186	211	239	278	310	344
30min	87	98	114	135	154	174	202	225	250
1hour	60	68	79	95	108	122	142	158	175
3hour	29	33	38	46	52	59	69	76	85
6hour	18	21	24	29	33	37	43	48	53
12hour	11	13	15	18	21	23	27	30	33
18hour	9	10	12	14	16	18	21	24	27
24hour	7	9	10	12	14	16	18	20	22
48hour	5	6	7	8	9	11	13	15	17
72hour	4	4	5	6	7	8	10	11	13
96hour	3	4	4	5	6	7	8	9	11
120hour	3	3	4	4	5	6	7	8	9

Total Rainfall Over Event Duration (mm)

	5	10	20	50	100	200	500	1000	2000
15min	30	34	39	46	53	60	70	77	86
30min	43	49	57	67	77	87	101	113	125
1hour	60	68	79	95	108	122	142	158	175
3hour	87	99	115	137	157	177	206	229	255
6hour	108	124	145	172	196	222	258	288	319
12hour	135	155	182	217	247	279	325	362	402
18hour	159	183	215	258	294	332	387	431	478
24hour	179	206	242	291	332	375	437	486	540
48hour	238	274	322	388	448	515	615	699	793
72hour	273	316	371	446	518	598	717	820	934
96hour	300	346	406	489	568	657	789	903	1030
120hour	311	358	421	507	589	681	818	936	1067

2000 Year ARI

Time(hr)	Rainfall(mm)	Duration (%)	Rainfall (%)
0.00	0.000	0	0
0.17	4.333	3	1
0.33	4.333	6	3
0.50	4.333	8	4
0.67	4.333	11	5
0.83	4.333	14	6
1.00	4.333	17	8
1.17	4.333	19	9
1.33	4.333	22	10
1.50	4.333	25	11
1.67	7.583	28	14
1.83	7.583	31	16
2.00	7.583	33	18
2.17	7.583	36	20
2.33	7.583	39	23
2.50	7.583	42	25
2.67	16.000	44	30
2.83	16.000	47	34
3.00	41.000	50	46
3.17	41.000	53	58
3.33	41.000	56	70
3.50	16.000	58	75
3.67	7.583	61	77
3.83	7.583	64	80
4.00	7.583	67	82
4.17	7.583	69	84
4.33	7.583	72	86
4.50	7.583	75	89
4.67	4.333	78	90
4.83	4.333	81	91
5.00	4.333	83	92
5.17	4.333	86	94
5.33	4.333	89	95
5.50	4.333	92	96
5.67	4.333	94	97
5.83	4.333	97	99
6.00	4.333	100	100

PMP

Time(hr)	Rainfall(mm)	Duration (%)	Rainfall (%)
0.00	0	0	0
0.17	9.917	3	1
0.33	9.917	6	2
0.50	9.917	8	4
0.67	9.917	11	5
0.83	9.917	14	6
1.00	9.917	17	7
1.17	13.458	19	9
1.33	13.458	22	11
1.50	13.458	25	12
1.67	18.417	28	14
1.83	18.417	31	17
2.00	18.417	33	19
2.17	27.625	36	22
2.33	27.625	39	26
2.50	27.625	42	29
2.67	38.250	44	34
2.83	38.250	47	39
3.00	75.083	50	48
3.17	75.083	53	57
3.33	75.083	56	66
3.50	38.250	58	71
3.67	27.625	61	74
3.83	27.625	64	78
4.00	27.625	67	81
4.17	18.417	69	83
4.33	18.417	72	86
4.50	18.417	75	88
4.67	13.458	78	89
4.83	13.458	81	91
5.00	13.458	83	93
5.17	9.917	86	94
5.33	9.917	89	95
5.50	9.917	92	96
5.67	9.917	94	98
5.83	9.917	97	99
6.00	9.917	100	100

Dedicated to a better Brisbane

MEMORANDUM

Brisbane City Council

To:	**Natural Environment Water and Sustainability Branch (NEWS)**	Date:	**15/03/2013**
Attn:	**Suba Subasing Gamachchige -** Project Owner, NEWS		
CC:	**Ellen Davidge -** Principal Engineering Officer, NEWS **Evan Caswell** - Principal Engineer, Flood Management		
From:	**Allan Herring -** Design Manager, Flood Management **Hanieh Zolfaghari –** Engineer, Flood Management		
Re:	**Technical Memorandum for Adopted Methodology - Extreme Events Modelling**		

Planning & Design Branch
Flood Management

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1.0 Introduction

The Flood Management team, within the Planning and Design Branch of the City Projects Office, has been asked to provide a technical memorandum for the adopted methodology for the extreme events hydrologic modelling which has been undertaken with the intention to update Council's creek flood studies.

2.0 Background

The additional scenarios to be modelled as part of the flood studies include the 200, 500 and 2000 year average recurrence interval (ARI) events and the Probable Maximum Precipitation (PMP) event. This memorandum documents the methodology adopted as well as the limitations of the methodology.

3.0 Methodology

Events Up to 100 year ARI

The events up to the 100 year ARI are developed using the AR&R temporal pattern which involves running multiple model runs to simulate the various standard storm durations.

200 and 500 year ARI Events

For the 200 and 500 Year ARI events, the CRC-Forge rainfall data were derived and used for each catchment. The CRC-Forge method adopts the AR&R temporal pattern to simulate rainfall within the catchment, and also requires multiple model runs to simulate the various standard storm durations.

The durations modelled were 30min. 1hr, 3 hrs and 6 hrs.

A 9hr rainfall depth was interpolated for Kedron Brook and Bulimba Creek.

2000 year ARI Event

To analyse the 2000 Year ARI flood event, the CRC-Forge rainfall depths were adopted. However, to simplify the analysis over a large number of similarly sized catchments, (based on the average size of catchments in the Brisbane area) the adopted rainfall data was extracted for a catchment size of 60 km^2 located at the north-west part of Brisbane. Note that rainfall depth varies by less than 10% across the entire area.

To avoid running multiple storm patterns for different storm durations, a super-storm approach was adopted. This is a common practice adopted overseas for broad scale planning scenario flood mapping with the temporal pattern built up to reflect the extreme rainfall depths published by the BoM. The rationale for adopting this approach is that world-wide research shows that as storm rainfall depths increase for short duration storms, the rainfall intensity becomes more uniform. For this reason, the multi peaked temporal patterns for the 100 year from AR&R were not considered suitable for the analysis of the more extreme events.

For this analysis, a 6 hour super storm was developed in 30 min blocks to represent a number of shorter extreme events. Shorter durations than 30 minutes were not considered. The pattern developed is representative of the 30, 60, 90, 120, and 180 minute storm burst. The total rainfall depth and duration of the storm was set equal to 6 hours for all catchments except Kedron Brook and Bulimba Creek.

For these two catchments only, a nine hour pattern was developed and applied, with the central part of the storm replicating the six hour pattern. This was considered necessary to ensure that all catchment routing was complete by the end of the model run.

Reference: *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM), BoM, June 2003.*

PMP

For the PMP scenario, the rainfall depth was derived from the 6 hour temporal pattern using the Generalised Short Duration Method (GSDM). For the tropical and subtropical coastal areas it is recommended that this method is to be used to estimate the PMP over areas up to 520km^2 and for durations up to 6 hours.

For the purpose of PMP estimation for the creeks and to be consistent across the Brisbane area, an average catchment size of 60 km^2 and moisture adjustment factor of 0.85 were adopted. This method is adopted for most of the creeks within the Brisbane area; however, exception is made to Oxley Creek due to the longer response time of the catchment. The adopted PMP temporal Pattern is shown in ***Appendix A***.

Other Durations and ARI's

No methodology or guidance is provided by the BoM or by AR&R for the estimation of PMP rainfall depths for durations longer than 6 hours or ARI's between 2000 years and PMP. One common method used by practitioners makes use of Log-Log interpolation. The challenge with this methodology is to provide an ARI for the PMP event and then to interpolate between the 2000 year ARI rainfall depths and the PMP rainfall depths. The method is approximate only but is considered reasonable considering the paucity of observed extreme rainfall observations in Australia and overseas. It is generally accepted that the probability of the PMP is in the order of 1 in 10^6 to 1 in 10^7.

All rainfall depths derived by the methods described were rounded to the nearest 10mm and they are shown in ***Appendix B***.

3.1 Verification

The storm pattern derived using methodology mentioned above was compared against 2 extreme storm events, which were the Carrara event and the Maroochydore event. The Maroochydore was in the order of 2000 year ARI and the Carrara event between 500 and 2000 year ARI respectively.

The comparison shows a good correlation and certified the adopted methodology.

3.2 Limitations

The assumptions and limitations of the adopted methodology to model extreme events include:

- The GSDM method is only valid for catchments with areas up to 520km^2; however, the majority of the catchments in Brisbane are smaller than 100 km^2 in size, with an average size of 60 km^2.

- Derived rainfall depths vary by less than 10% within the different catchments in the Brisbane area; however, the adoption of an average catchment size of 60km^2 is considered a reasonable approach considering the significant amount of rainfall during an extreme event.

- The adopted PMP pattern is well suited for catchments with a response time of half an hour up to 6 hours. This is the response time for the majority of the creeks in Brisbane with the exception of Oxley Creek.

For a better understanding of the limitations of this method, *The Estimation of Probable Maximum Precipitation in Australia: GSDM, June 2003* paper is attached to this memorandum (***Appendix C***).

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Appendix A

Adopted Temporal Pattern

Duration (%)	0	3	6	8	11	14	17	19	22	25
Rainfall (%)	0	1	2	4	5	6	7	9	11	12
Duration (%)	28	31	33	36	39	42	44	47	50	53
Rainfall (%)	14	17	19	22	26	29	34	39	48	57
Duration (%)	56	58	61	64	67	69	72	75	78	81
Rainfall (%)	66	71	74	78	81	83	86	88	89	91
Duration (%)	83	86	89	92	94	97	100			
Rainfall (%)	93	94	95	96	98	99	100			

Appendix B

200 and 500 Year ARI Event Rainfall Depth (mm)

Creek Name	Storm Events									
	200 Year ARI					500 Year ARI				
	30 min	1 Hour	3 Hour	6 Hour	9 Hour	30 min	1 Hour	3 Hour	6 Hour	9 Hour
Bulimba Creek	80	110	160	200	252	90	120	180	230	294
Kedron Creek	90	120	170	220	271	100	140	200	250	315
Lota Creek	80	110	160	210		90	130	190	240	
Norman Creek	80	120	170	210		100	130	190	240	
Breakfast Creek	90	130	180	230		100	150	210	260	
Perrin Creek	80	110	170	210		100	130	200	250	
Pine River Creek	90	120	180	220		100	140	200	260	
Albany Creek	90	130	180	230		110	150	210	270	
Cabbage Tree Creek	90	120	180	220		100	140	210	260	
Nundah Creek	90	120	180	220		100	140	200	260	

2000 Year ARI, PMP, Carrara and Maroochydore Events Rainfall Depth (mm)

Event	Storm Duration									
	0.5 hour	1 hour	1.5 hour	2 hour	2.5 hour	3 hour	4 hour	4.5 hour	5 hour	6 hour
2000 year ARI	120	170	190	220	240	260	290	300	310	340
PMP	230	340	440	510	570	620	700	730	770	820
Carrara	80	150	190	230	260	280	340	360	380	440
Maroochydore	60	120	160	200	220	260	310	330	350	350

Appendix C

COMMONWEALTH
BUREAU OF METEOROLOGY

The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method

HYDROMETEOROLOGICAL ADVISORY SERVICE
http://www.bom.gov.au/hydro/has/gsdm_document.shtml
JUNE 2003

The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method

DISCLAIMER

The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM) offers guidance to those engaged in estimating the probable maximum precipitation for durations up to three or six hours in Australia. Despite careful preparation, it may contain typographical or other errors that affect use of the procedures and/or the numerical values obtained. Readers are encouraged to report suspected errors to the Hydrology Unit of the Bureau of Meteorology. Once confirmed, errors will be noted and, where circumstances allow, corrected. The Bureau will maintain a list of GSDM errata/corrigenda accessible via the World Wide Web. The location of the list will be advised through the Hydrometeorological Advisory Service section of the Bureau's web site: http://www.bom.gov.au/hydro/has. The Bureau of Meteorology does not give any commitment to communicate errors, whether suspected or confirmed. Nor is liability accepted from losses arising from use of the GSDM, its procedures, howsoever caused. The Bureau of Meteorology has not approved any instruction that use of the GSDM procedures be made mandatory for particular applications.

This publication is a guide only and is made available on the understanding that the Bureau is not thereby engaged in rendering professional services or advice. It is designed be used only by professional meteorologists, or those otherwise qualified to estimate extreme rainfalls.

HYDROMETEOROLOGICAL ADVISORY SERVICE
http://www.bom.gov.au/hydro/has/gsdm_document.shtml
JUNE 2003

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1. INTRODUCTION

Probable Maximum Precipitation (PMP) is defined by the World Meteorological Organization (1986) as '*the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year*'.

Hydrologists use a PMP magnitude, together with its spatial and temporal distributions, for the catchment of a dam to calculate the probable maximum flood (PMF). The PMF is one of a range of conceptual flood events used in the design of hydrological structures. In the main, it is used to design a spillway that will minimise the risk of overtopping of the dam. Overtopping of a dam structure can result in damage to the dam wall or abutments through breaching. The risk of loss of life, cost of rebuilding the dam, cost of the additional flood damage downstream and cost to the community due to the loss of a water supply can thus be minimised.

The purpose of this publication is to provide a method that can be used to make consistent and timely estimates of probable maximum precipitation for catchment areas up to 1000 km^2. Estimates are limited to a duration of six hours along the tropical and subtropical coastal areas and three hours in inland and southern Australia. The method allows for two classes of terrain and takes into account the local moisture availability and the mean elevation of the catchment.

The low density of the raingauge networks, particularly the pluviograph network, has resulted in few severe short-duration rainstorms having been recorded or documented in Australia. This is particularly the case in the sparsely populated part of the continent away from the coastal fringe and is a severe limitation on the estimation of short duration probable maximum precipitation in Australia. For this reason, United States data and Australian data have been used in the development of the Generalised Short Duration Method for use in Australia. Areal rainfall data are provided for some major Australian rainstorms in Appendix 3 to support the PMP magnitudes derived.

Design temporal and spatial distributions of PMP based on average storm characteristics are also given. These facilitate the distribution of the PMP depth when used in hydrological models.

This document replaces 'Bulletin 53: The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method' (Bureau of Meteorology, December 1994), and should be used instead. It was considered that a new version was required as, since 1994, a revised method of spatial distribution has been introduced and the moisture factors updated.

2. HISTORY OF THE DEVELOPMENT OF PMP METHODOLOGY IN AUSTRALIA

The early methods used to estimate extreme floods, other than reliance on local knowledge, were statistical. Frequency analysis has been used in most parts of Europe where it is relatively effective due to the homogeneity of the storm population, the long length of records and the availability of historical flood marks. The original spillway designs of some Australian dams, such as the Warragamba Dam, were based on this method. In the tropics and subtropics (e.g. Australia), the lack of homogeneity in the storm population and relatively short length of records cause significant deficiencies in the severe storm rainfall sample available for frequency analysis. This led to the need to develop deterministic methods, which used the sample outliers to estimate the rainfall from the optimum storm mechanism and a maximisation factor to adjust the storm rainfall to that possible with the potential extreme moisture inflow.

The deterministic methods of estimating PMP have developed from '*in situ* maximisation' through 'storm transposition' to the current 'generalised' methods.

2.1 *In Situ* Storm Maximisation Method

Early estimates of PMP in Australia (1950s to 1970s) were based on *in situ* maximisation. Only storms that had occurred over the catchment were considered for maximisation. The rainfall depths from storms covering a range of durations were maximised for moisture and the maximum depth at a specified duration was taken as the PMP for that duration. The maximisation procedure consisted of the adjustment of the rainfall depth measured in a storm by the ratio of the highest observed atmospheric moisture content in the area of the catchment to that observed in the storm. In some cases, the rainfall was also maximised for potential wind speed and direction accompanying the rainfall, but in general there was insufficient information available to make this practical. Wind speed and direction are now considered to be part of the overall storm mechanism. Recorded temporal and spatial distributions of the individual storms were used as design patterns.

The occurrence or lack of occurrence of an outlier in the storm sample, within the length of rainfall records available for different catchments, led to inconsistencies between PMP estimates for catchments in the same general area.

2.2 Storm Transposition Method

During the late 1960s and early 1970s storm transposition was gradually introduced. This procedure increased the size of the sample of significant storms that could be maximised for a catchment. The larger sample improved the consistency of PMP estimates within regions of similar topography, and generally led to higher PMP estimates than those produced using *in situ* maximisation.

The method was limited to the transposition of storms that had occurred near the catchment in regions with similar topographic features to those of the catchment. No guidance was available on how to adjust storm depths for the response of rainfall to differing topography. Consequently, storms that occurred near the subject catchment could not be transposed if they had occurred over a region with different topography. In addition, the individual storm spatial patterns of the transposed storms reflected the topography of the storm area and were not always appropriate for use in the target catchment. The choice of storms for transposition introduced a significant level of subjectivity to the methodology.

A storm transposition method is used for catchments in southwestern Tasmania, as described in ‘Development of the Method of Storm Transposition and Maximisation for the West Coast of Tasmania - HRS 7’ (Xuereb et al., 2001); the extreme lack of data making it impractical to develop a generalised method for this region.

2.3 Generalised Methods

Generalised methods of estimating PMP have gradually been developed for various parts of Australia and were introduced from the mid-1970s onward. This follows the trend in the United States where they were gradually introduced from the early 1960s. Generalised methods differ from the *in situ* and transposition methods in that they use all available data over a large region and include adjustments for moisture availability and differing topographic effects on rainfall depth. These storm data are enveloped by smoothing over a range of areas and durations. Generalised methods also provide design spatial and temporal patterns of PMP for the catchment. These methods require a considerable investment of time to develop, but when completed, estimates for individual catchments can be made more easily and objectively.

The United States generalised methods for areas with minimal topographic enhancement were developed first as an extension of the limited transposition methods. This type of method was suitable for most of the United States east of the Rocky Mountains (United States National Weather Service, 1978). Variations on the basic method were then gradually developed for areas with significant topographic enhancement of the rainfall. The method of dealing with topographic effects varies considerably, reflecting the specific problems posed by the prevailing meteorological regime and the availability of meteorological information (World Meteorological Organization, 1986; United States Weather Bureau, 1961, 1965, 1969; United States National Weather Service 1977, 1984, 1988; Wang, 1986).

The use of generalised methods has tended to increase the PMP estimates for a given catchment, compared with those obtained using the ‘*in situ* maximisation’ and ‘storm transposition’ methods due to the increased chance of the larger sample containing an outlier. This is discussed with respect to the Warragamba Dam Catchment in Pearce (1993). Generalised method estimates have a lower notional Annual Exceedance Probability (AEP). They also have the advantage of providing regionally consistent estimates, although the notional AEP may vary slowly across a large zone or differ between zones. In assessment of both comparative risk and cost-benefit analyses between dams within a region, generalised methods set a more uniform standard than *in situ* or limited transposition methods (where topographic effects made transposition subjective).

The generalised methods currently available in Australia are:

i) The Generalised Short Duration Method (GSDM) described in chapters 3 and 4.

(ii) The Generalised Southeast Australia Method (GSAM), which was finalised in 1992. This method is for use in catchments in southeast Australia and is described by Kennedy et al. (1988), Pearce and Kennedy (1993, 1994) and Minty et al. (1996). Figure 1 shows the two zones for application of the GSAM: inland and coastal. The maximum duration covered by this method ranges from 3 to 5 days

(iii) The revised version of the Generalised Tropical Storm Method (GTSMR), which was finalised in 2003. This method is applicable to those parts of Australia affected by tropical storms and divides the region into 3 parts: the coastal application zone (CAZ), the inland application zone (IAZ) and the southwest Western Australia application zone (SWAZ). Figure 1 shows these zones. The maximum duration covered by this method is 5 days in the coastal zone in summer and 4 days for all other zones and seasons. The method is described in Walland et al. (2003).

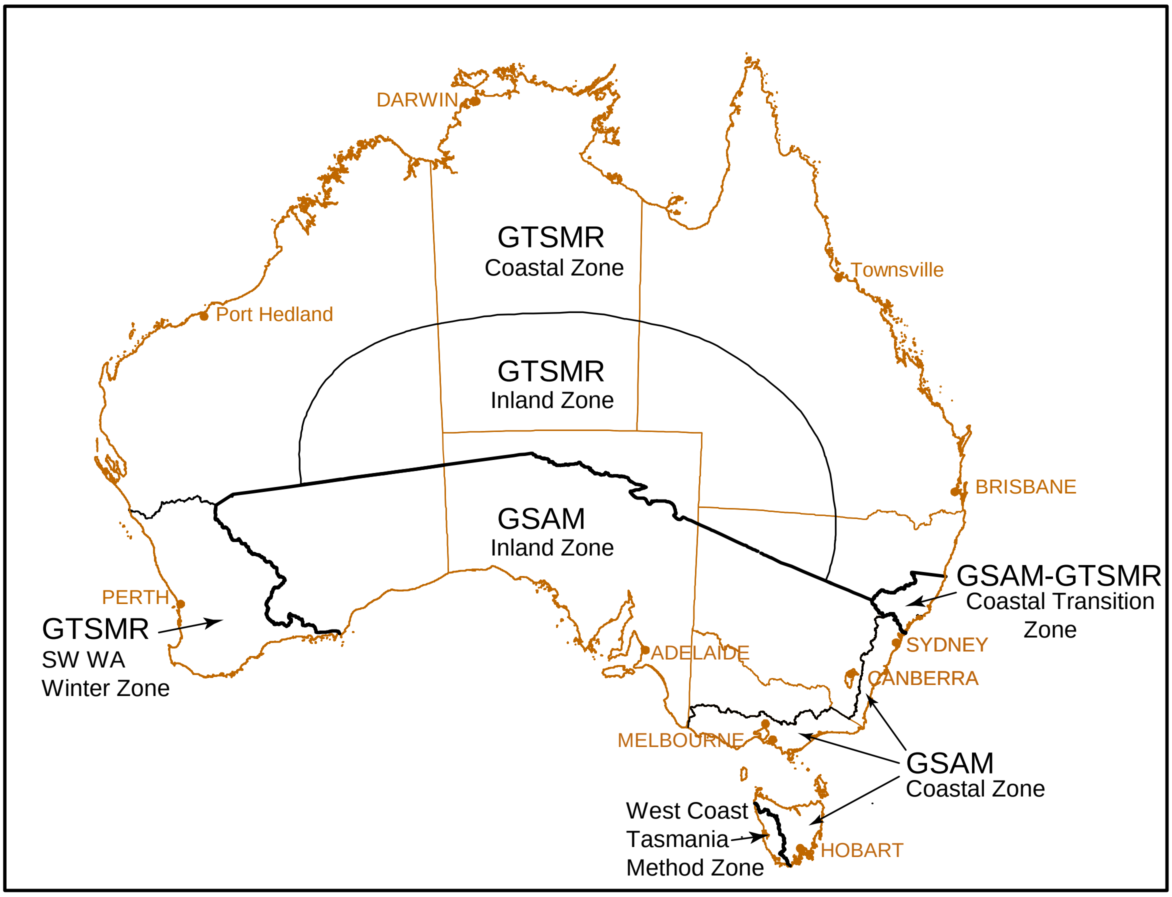

Figure 1: Generalised Tropical Storm Method and Generalised Southeast Australia Method Zones

2.4 Limitations and Restrictions on Generalised PMP Estimation Methods used in Australia

The accuracy and reliability of an estimate depends on the amount and quality of the data available for use in the estimating procedure and the maintenance of a balance in the degree of maximisation used in order to obtain realistic estimates. The transposition method was limited to the use of storms that occurred near the catchment in areas with similar topographic features. The generalised methods use a deterministic approach to adjust for topographic and moisture effects and thus increase the usable transposition area. However, even with these adjustments there are meteorological limitations on the transposability of some types of storms. The selection of meteorologically compatible zones in generalised PMP methodology requires that an equivalent optimum storm mechanism could occur anywhere in the transposition area; the frequency of occurrence is not important. The GTSMR, for example, is only applicable to those parts of Australia affected by tropical storms. The frequency of occurrence of the storm mechanisms varies considerably across the zones, but this does not necessarily affect the magnitude of the estimated PMP.

The restrictions on the GSAM and GTSMR PMP estimation methods for short durations are due to the limitations on availability and quality of short duration storm data. The development of these methods relied significantly on daily data in order to make the most effective use of record length and network density for the storm search procedures. These methods therefore need to be used in conjunction with the GSDM where appropriate (i.e. over small catchments where the critical duration is between that covered by the GSDM and the GSAM or GTSMR).

All three of the generalised methods are based on single storm events only, including single storms with multiple peaked temporal distributions. This means that the methods have an upper limit to the effective duration for which they can be applied to the catchment. The joint probability of a design sequence of two or more extreme rainfall events would be much lower than the probability of the generalised PMP event by itself.

None of the methods incorporates long-term climate change, other than climatic variability implicitly contained within the available years of records. However, climatic trends progress slowly so their influence on PMP is small compared to other uncertainties in estimating extreme values. This is consistent with the current practice described in World Meteorological Organization (1986).

3. BACKGROUND TO PMP ESTIMATION FOR SHORT DURATIONS

Methods for estimating PMP for small areas and short durations have been used by the Bureau of Meteorology since 1960. The first depth-duration-area (DDA) values used in Australia were those published by the United States Weather Bureau in 1945 (United States Weather Bureau, 1945).

The original method was known as the 'Thunderstorm Model' method because extreme rainfall totals for short durations and small areas are most likely to be produced by large, efficient convective cells. These cells may be either isolated thunderstorms or form part of a mesoscale or synoptic scale storm system. Later, the method became known as the 'method of adjusted United States data' (Kennedy, 1982). PMP estimation for short durations and small areas in Australia was based on the maximisation of United States thunderstorm depth-duration-area (DDA) data because of an inadequate supply of Australian short duration rainfall data. The Australian network of daily rainfall gauges has a far greater density and more effective years of record than the pluviograph network.

Initially it was recommended that the method be used to estimate PMP over areas up to 200 mi^2 (520 km^2) and for durations up to 6 hours for catchments in the tropical and subtropical coastal strips of the continent. The method was later extended to cover inland and southern Australia where the limit to the duration was 3 hours. The maximum area for application was also increased to 1000 km^2 for all areas.

In 1978 the DDA curves used by the Bureau of Meteorology were updated using information given in later hydrometeorological reports (United States Weather Bureau, 1960, 1969; United States National Weather Service, 1977, 1978) and by Wiesner (1970). At this time, terrain classifications of 'rough' and 'smooth' were introduced, with separate sets of DDA curves being provided for each category.

In 1984 a phenomenal storm occurred near Dapto in New South Wales (Shepherd and Colquhoun, 1985). For some areas and durations, the maximised rainfall from this storm exceeded the adjusted United States values. Areal rainfall depths recorded in this storm were added to the United States data when the method was published in 1985 as 'Bulletin 51: The Estimation of Probable Maximum Precipitation in Australia for Short Durations and Small Areas' (Bureau of Meteorology, 1985).

With the publication of *Bulletin 51*, the six-hour zone was broadened, especially in northern Australia, and an intermediate zone was introduced between the three and six hour zones. Subsequently, the definitions of 'rough' and 'smooth' terrain were altered, as described in 'Australian Rainfall and Runoff' (The Institution of Engineers, Australia, 1987). This and other adjustments were included in the next edition, published as *Bulletin 53* in 1994. Since then, the method has been referred to as the 'Generalised Short Duration Method' (GSDM), in line with the terms used to describe other generalised methods.

The GSDM is suitable for application to small catchments such as those of tailings dams and small reservoirs anywhere in Australia. Chapter 4 explains the GSDM procedure in detail and a worked example is found in Appendix 2. Additionally areal rainfall depths recorded in a number of severe Australian storms are given in Appendix 3.

4. GSDM PROCEDURE

This section describes in detail the steps to be followed in determining GSDM PMP estimates for a catchment. A sample calculation sheet to use with this procedure is given in Appendix 1 and an example covering all the steps is provided in Appendix 2.

4.1 Selection of Duration Limits

The first step is to establish the maximum duration for which the method is applicable to the catchment. Figure 2 shows the areas of Australia subject to the duration limits of three and six hours. There is also an intermediate zone where the maximum duration can be determined by using linear interpolation, setting the boundary values to three and six hours.

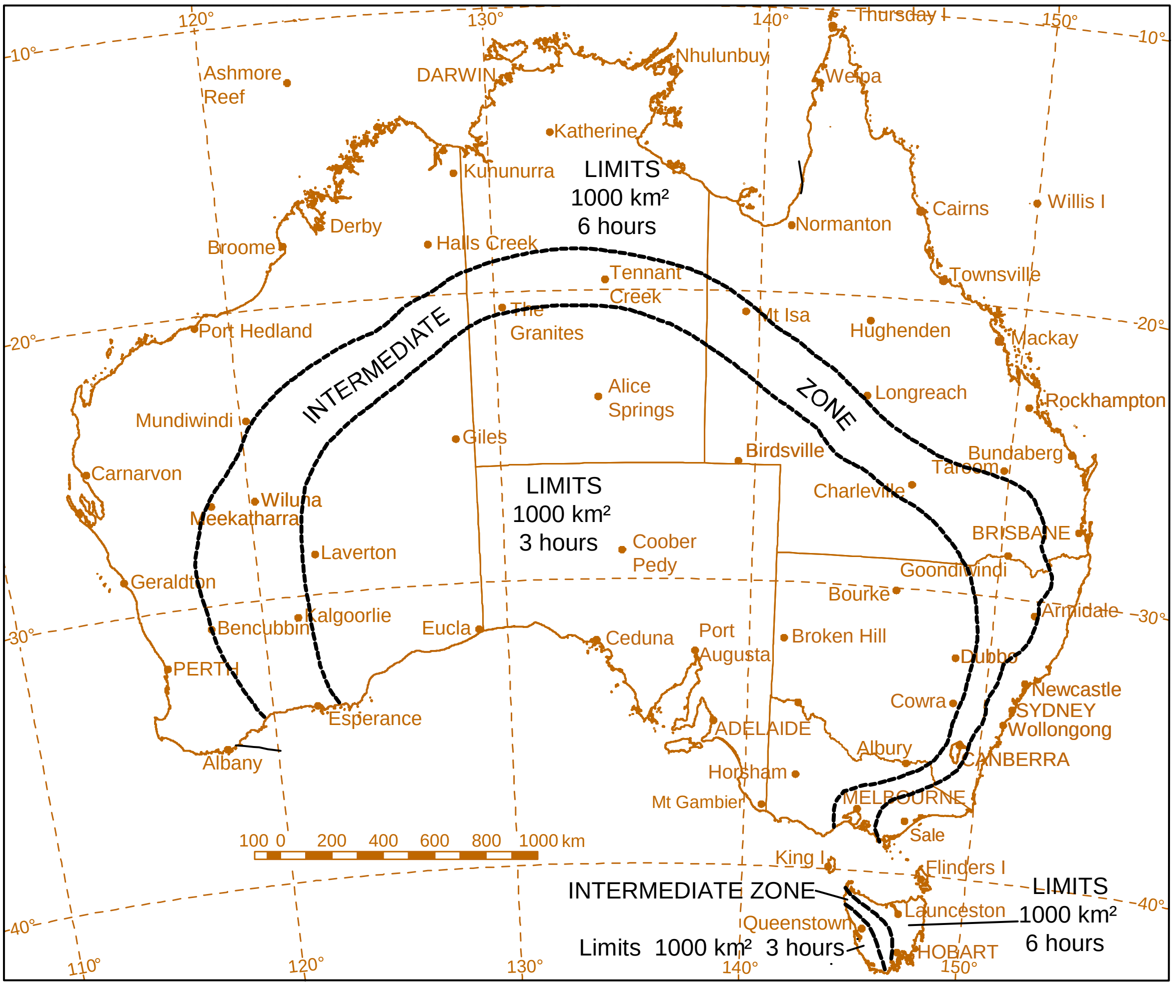

Figure 2: Generalised Short-Duration Method zones.

4.2 Selection of Terrain Category

Rainfall from single, short duration thunderstorm events is not significantly affected by the terrain. Therefore, it is not necessary to classify the terrain of the catchment for durations of an hour or less.

If durations longer than one hour are required, the next step is to establish the terrain category of the catchment and to calculate the percentages of the catchment that are ‘rough’ and ‘smooth’. ‘Rough’ terrain is classified as that in which elevation changes of 50 m or more within horizontal distances of 400 m are common. ‘Rough’ terrain induces areas of low level convergence which can contribute to the development and redevelopment of storms, thereby increasing rainfall in the area over longer durations.

Terrain that is within 20 km of generally ‘rough’ terrain should also be classified as ‘rough’. If there is ‘smooth’ terrain within the catchment that is further than 20 km from generally ‘rough’ terrain, an areally weighted factor of ‘rough’ (**R**) and ‘smooth’ (**S**) terrain should be calculated such that **R** plus **S** equals one. If a catchment proves difficult to classify under these guidelines then the whole catchment should be classified as ‘rough’.

4.3 Adjustment for Catchment Elevation

The next step is calculation of the Elevation Adjustment Factor (**EAF**). The mean elevation of the catchment should be estimated from a topographic map. If this value is less than or equal to 1500 m the EAF is equal to one. For elevations exceeding 1500 m the EAF should be reduced by 0.05 for every 300 m by which the mean catchment elevation exceeds 1500 m. For most catchments in Australia the EAF will be equal to one.

4.4 Adjustment for Moisture

The moisture index used in PMP work is the precipitable water value corresponding to the 24-hour persisting dewpoint. By assuming a saturated atmosphere with a pseudo-adiabatic lapse rate during storm conditions, the precipitable water value can be estimated from the surface dew point temperature, a commonly measured quantity. The ratio of the extreme moisture index for a storm location to the moisture index at the time of the storm was used in the maximisation process.

The rainfall Depth-Duration-Area (DDA) curves in Figure 4 have been standardised to a moisture index equivalent to a surface dew point temperature of 28EC. An adjustment is required to allow for the potential moisture availability at the catchment. A map has been constructed based on the percentage adjustment for any locality and is given in Figure 3. The Moisture Adjustment Factor (**MAF**) for a catchment can be read from this map.

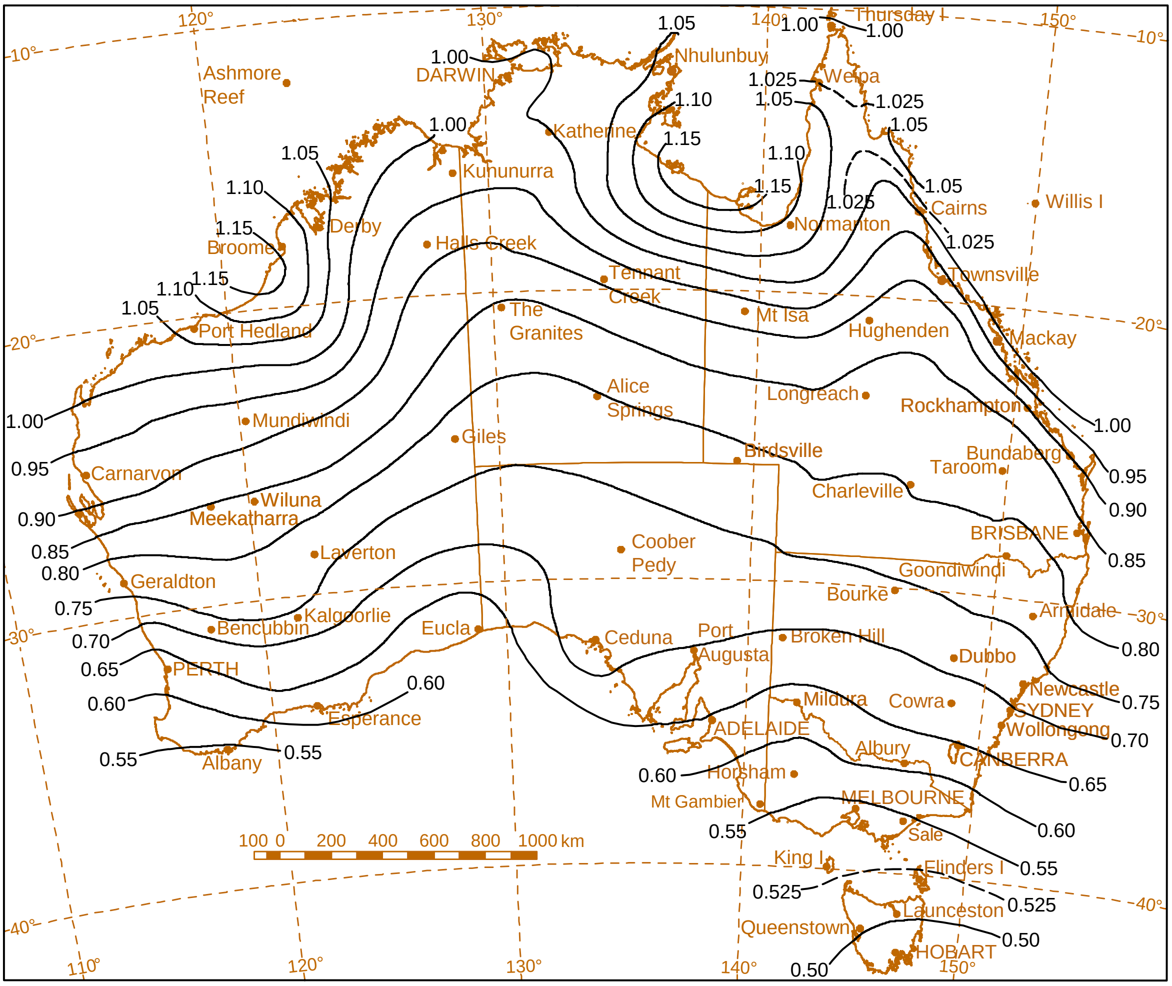

Figure 3: Moisture Adjustment Factor

4.5 Calculation of PMP Estimates

The DDA curves, given in Figure 4, were produced by drawing enveloping curves to the highest recorded United States and Australian rainfall depths, which had been adjusted to correspond to a common moisture index.

Also given in Figure 4 are PMP values applicable to a point, based on those given by Wiesner (1970). If a PMP value is required for an area smaller than 1 km^2 the value can be estimated by using linear interpolation between the 1 km^2 and the point values.

The initial rainfall depth for the 'smooth' (**D_S**) and/or 'rough' (**D_R**) terrain categories are read from the DDA curves for the required catchment area and storm duration. To obtain rainfall values for intermediate durations a plot of rainfall (log) versus duration (linear) can be used. The value for the specified duration can then be interpolated.

The PMP estimates for the catchment are calculated from:

PMP Value = (S H D_S + R H D_R) H MAF H EAF

This value should then be rounded to the nearest 10 mm.

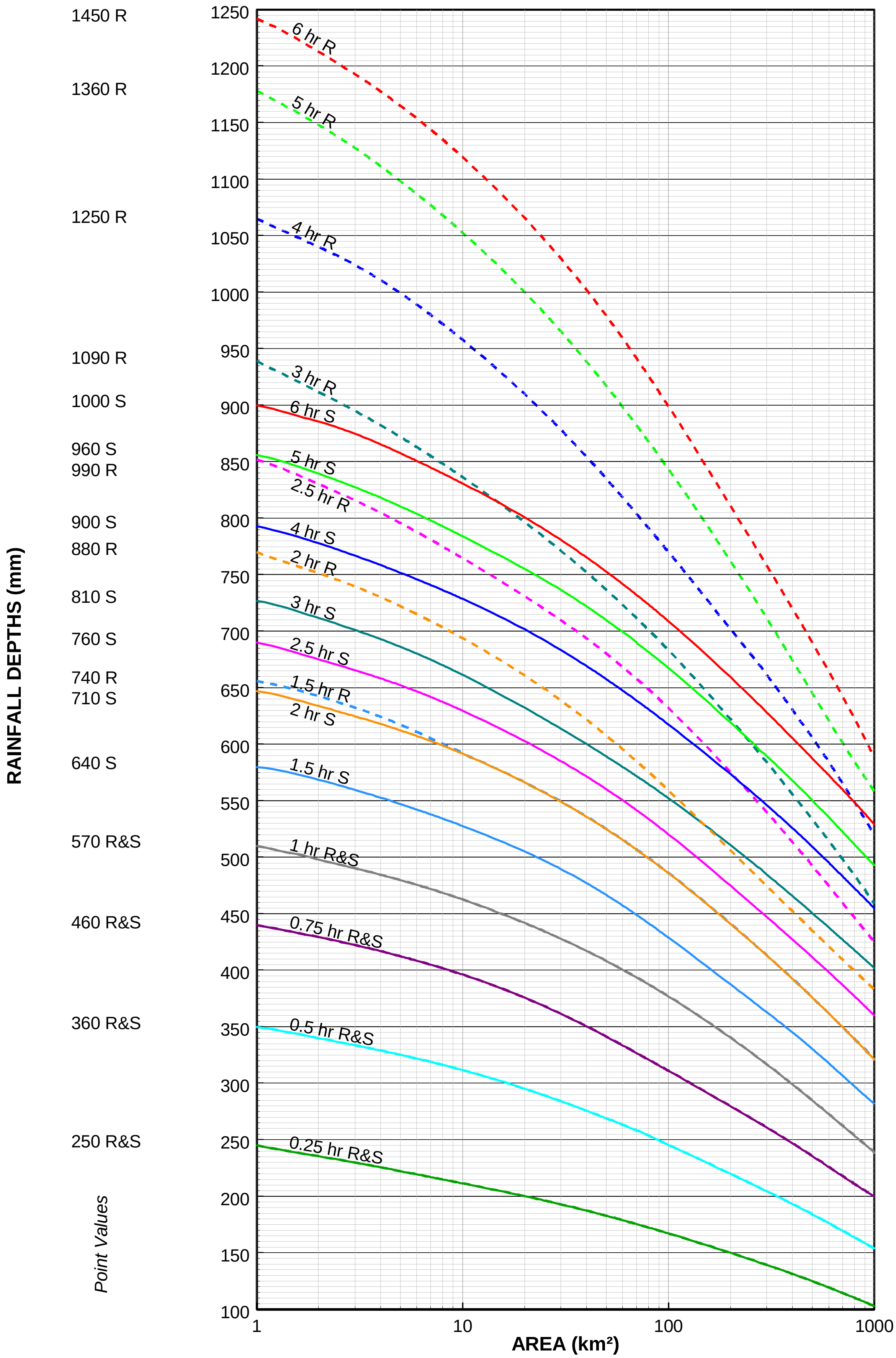

Figure 4: Depth-Duration-Area Curves of Short Duration Rainfall

5. DESIGN TEMPORAL DISTRIBUTION OF PMP

A design temporal distribution was derived using pluviograph traces recorded in major Australian storms. This pattern is shown in Table 1 with figures rounded to 1% and presented as a mass curve in Figure 9.

Table 1: Design Temporal Distribution of Short Duration PMP

% of time	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
% of PMP	0	4	10	18	25	32	39	46	52	59	64	70	75	80	85	89	92	95	97	99	100

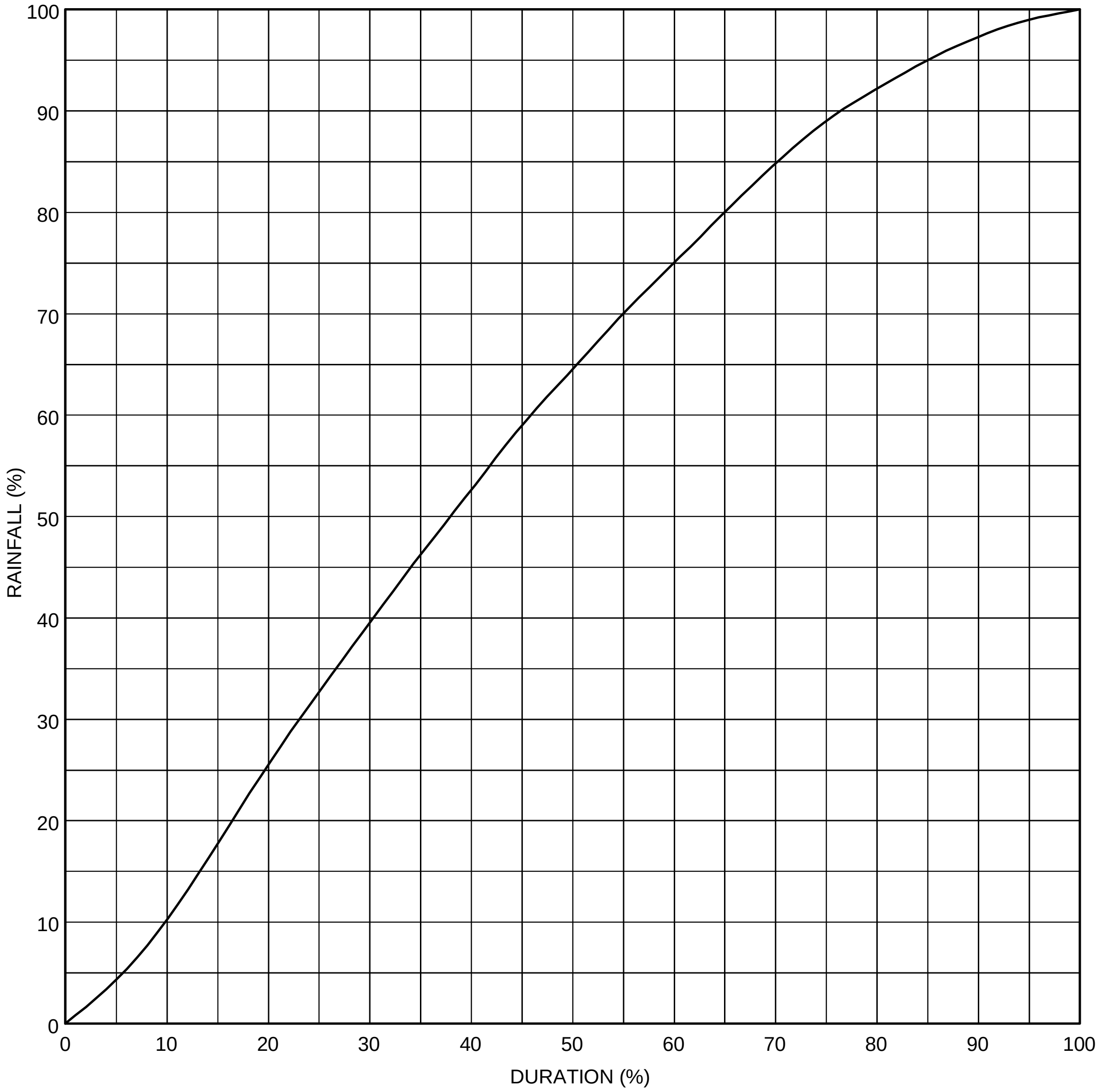

Figure 5: Generalised Short Duration Method Temporal Distribution

6. DESIGN SPATIAL DISTRIBUTION OF PMP

The design spatial distribution for convective storm PMP is given in Figure 6. It is based on the distribution provided by the United States Weather Bureau (1966) and the World Meteorological Organization (1986) but has been modified in light of Australian experience. It assumes a virtually stationary storm and can be oriented in any direction with respect to the catchment. Instructions for the application of the spatial distribution are given below and an example is given in Appendix 2.2.

For simplicity and consistency of application, it is recommended that PMP depth be distributed using a step-function approach. This means having a constant value at all points in the interval between consecutive ellipses (or within the central ellipse), and stepping to a new constant value at each new ellipse. This constant value between ellipses is the mean rainfall depth for that interval and is derived by the procedure described below. Further information on the rationale behind this method may be found in Taylor et al. (1998).

Instructions for the use of the spatial distribution diagram

Step 1 Positioning the spatial distribution diagram

Enlarge or reduce the size of the spatial distribution diagram (Figure 6) to match the scale of the catchment outline map. Overlay the spatial distribution diagram on the catchment outline and move it to obtain the best fit by the smallest possible ellipse. This ellipse is now the outermost ellipse of the distribution.

Step 2 Areas of catchment between successive ellipses

Determine the area of the catchment lying *between* successive ellipses ($CBtn_i$, where the i^{th} ellipse is one of the ellipses A to J).

Where the catchment completely fills both ellipses, this is just the difference between the areas enclosed by each ellipse as given in Table 2.3:

$$CBtn_i = Area_i - Area_{i-1}$$

Where the catchment only partially fills the interval between ellipses, use planimetering or a similar method to determine this area.

Step 3 Area of catchment enclosed by each ellipse

Determine the area of the catchment *enclosed by* each ellipse ($CEnc_i$):

$$CEnc_i = \sum_{k=A}^{i} CBtn_k$$

The area of the catchment enclosed by the outermost ellipse will be equal to the total area of the catchment.

Step 4 Initial mean rainfall depth enclosed by each ellipse

Obtain the x-hour initial mean rainfall depths ($IMRD_i$) for each of the areas enclosed by successive ellipses ($CEnc_i$) (Step 3).

Where the catchment completely fills an ellipse ($CEnc_i$=$Area_i$), determine the x-hour initial mean rainfall depth for this area from Table 2.3. Where the catchment only partially fills an ellipse ($CEnc_i$ < $Area_i$), determine the x-hour initial mean rainfall depth for that area from the appropriate Depth-Duration-Area (DDA) curves (Figure 4).

Table 2: Initial Mean Rainfall Depths Enclosed by Ellipses A-H in Figure 6

Ellipse label	*Area Enclosed ((km²)*	*Area between (km²)*	*Initial Mean Rainfall Depth (mm)*										
			Duration (hours)										
			0.25	*0.5*	*0.75*	*1*	*1.5*	*2*	*2.5*	*3*	*4*	*5*	*6*
SMOOTH													
A	2.6	2.6	232	336	425	493	563	628	669	705	771	832	879
B	16	13.4	204	301	383	449	513	575	612	642	711	765	811
C	65	49	177	260	330	397	453	511	546	576	643	695	737
D	153	88	157	230	292	355	404	459	493	527	591	639	679
E	280	127	141	207	264	321	367	418	452	490	551	594	634
F	433	153	129	190	243	294	340	387	422	460	520	562	599
G	635	202	118	174	223	269	314	357	394	434	491	531	568
H	847	212	108	161	208	250	293	335	373	414	468	506	544
ROUGH													
A	2.6	2.6	232	336	425	493	636	744	821	901	1030	1135	1200
B	16	13.4	204	301	383	449	575	672	742	810	926	1018	1084
C	65	49	177	260	330	397	511	590	663	717	811	890	950
D	153	88	157	230	292	355	459	527	598	647	728	794	845
E	280	127	141	207	264	321	418	480	546	590	669	720	767
F	433	153	129	190	243	294	387	446	506	548	621	664	709
G	635	202	118	174	223	269	357	417	469	509	578	613	656
H	847	212	108	161	208	250	335	395	441	477	541	578	614

Note that no initial mean rainfall depths are required for ellipses I and J because the areas of these ellipses are greater than 1,000 km² which is the areal limit of the DDA curves.

Step 5 Adjusted mean rainfall depth enclosed by each ellipse

Adjust the initial mean rainfall depths for moisture and elevation using the adjustment factors and procedure described in Section 4:

$$AMRD_i = IMRD_i \times MAF \times EAF$$

The adjusted mean rainfall depth (AMRD) for the area enclosed by the outermost ellipse will be equal to the (unrounded) PMP for the whole catchment (Section 4.5).

Step 6 Volume of rain enclosed by each oval

Multiply the area of the catchment enclosed by each ellipse ($CEnc_i$) (Step 3) by the corresponding adjusted mean rainfall depth for that area ($AMRD_i$) (Step 5) to obtain the volume of rainfall over the catchment and within each ellipse ($VEnc_i$):

$$VEnc_i = AMRD_i \times CEnc_i$$

Step 7 Volume of rainfall between successive ellipses

Obtain the volume of rainfall over the catchment and between successive ellipses ($VBtn_i$) by subtracting the consecutive enclosed volumes ($VEnc_i$) (Step 6):

$$VBtn_i = VEnc_i - VEnc_{i-1}$$

The volume of rainfall within the central ellipse has already been obtained in Step 6.

Step 8 Mean rainfall depth between successive ellipses

Obtain the mean rainfall depth over the catchment and between successive ellipses (MRD_i) by dividing the volume of rainfall between the ellipses ($VBtn_i$) (Step 7) by the catchment area between them ($CBtn_i$) (Step 2):

$$MRD_i = \frac{VBtn_i\,(Step 7)}{CBtn_i\,(Step 2)}$$

Step 9 Other PMP Durations

Repeat steps 1 to 8 for other durations.

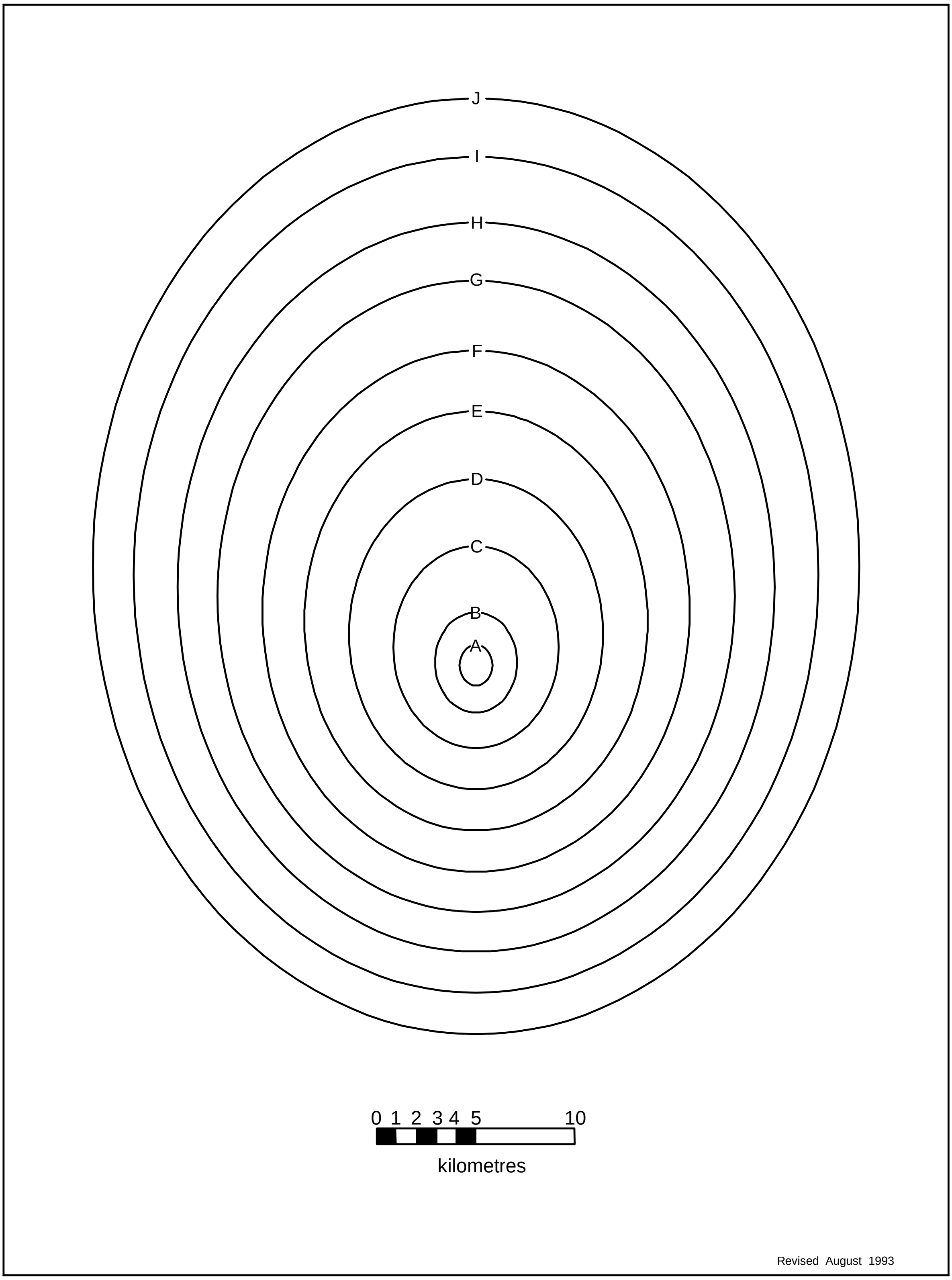

Figure 6: Generalised Short Duration Method Spatial Distribution

7. SEASONAL VARIATION OF PMP

The meteorological events associated with short duration, limited area PMP are most likely to be summer or early autumn convective storms. They may be isolated ‘supercells’, or they may consist of numerous convective cells embedded in a larger storm system. However, other seasonal factors, such as high antecedent rainfall, may cause greater floods to occur at other times of the year.

In some regions summers are mostly dry so very large catchment loss rates may be assumed in the calculation of the probable maximum summer flood. If the winters are wet, winter PMP values with low losses may produce a higher flood. This is sometimes the case in southwestern Australia.

The areal limit for short duration winter PMP estimates is taken as 500 km^2. It is reasonable to transpose smaller scale convective storms between seasons, as their basic structure is not considered to vary significantly with season. However, seasonal transposition of synoptic-scale storms to estimate PMP over large areas is not considered realistic.

For Australian catchments south of 30ES, Figure 7 can be used to convert the annual PMP to the PMP for a specific month. The monthly percentage moisture adjustment has been derived for a number of locations in southern Australia by calculating the extreme moisture index for each month as a percentage of the extreme annual moisture index. The highest monthly values are given in Figure 7. It is a straightforward procedure to calculate the annual PMP and convert it to a monthly PMP by multiplying by the appropriate percentage given in Figure 7.

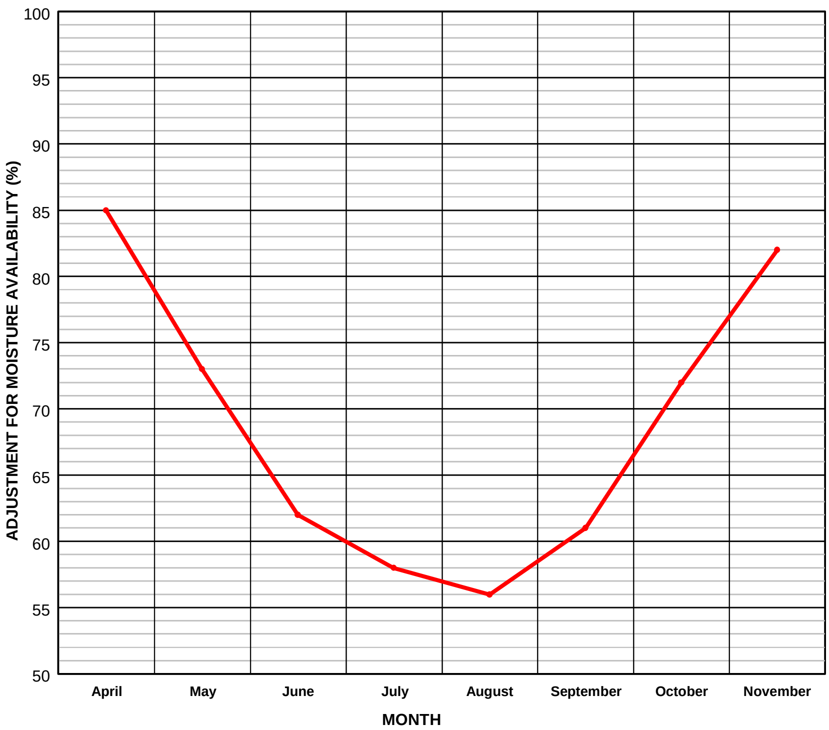

Figure 7: Monthly Percentage Moisture Adjustment for Southern Australia (south of 30ES) Note: The areal limit for winter is 500km^2

8. NOTIONAL AEP OF PMP DEPTHS DERIVED USING THE GSDM

In theory, the PMP concept, as defined in section 2, implies zero probability of exceedance. However, the estimates made by the various PMP methods have a non-zero probability of exceedance. For example, the '*in situ* maximisation' method PMP estimates for the Fortescue River catchment in Western Australia were exceeded by rainfall from Tropical Cyclone Joan in 1975 (Kennedy, 1982). The maximised storm depths from the Dapto 1984 storm (Shepherd and Colquhoun, 1985) near Wollongong in NSW exceeded the 'method of adjusted United States data' PMP estimates used at the time. Notional probabilities of exceedance can therefore be associated with the application of the method (i.e. the methodology plus the limitations of available data) used to estimate the PMP, but not with the concept of PMP itself.

Using deterministic methods of estimating PMP rather than statistical methods, means that the assignment of Annual Exceedance Probabilities (AEPs) to the PMP estimates is not straightforward. The uncertainties associated with any estimate of the exceedance probability of a PMP depth are very large. However, by using the same assumptions to estimate AEPs for each of the PMP methods, the results can provide useful guidance in a comparative sense (Pearce, 1994).

Estimates of PMP depth have been made using a variety of methods for some catchments (e.g. *in situ*, limited transposition, generalised), but the associated notional probabilities vary considerably. Generalised methods of PMP estimation, applicable to different meteorological regions, can also have different exceedance probabilities. Probabilities of variables such as temporal patterns, spatial patterns, antecedent rainfall, losses, reservoir levels, flood model assumptions etc. assumed in converting rainfall to floods will also affect the notional exceedance probability of the PMF with respect to that of the PMP estimates. However, as discussed above for the PMP, if similar assumptions and flood models are used in transforming the PMP to PMF, the resultant design flood can provide useful guidance in comparing safety between various dams.

Kennedy and Hart (1984) used notional AEPs for various PMP methods as a means of indicating the different security levels provided by the different methods. Laurenson and Kuczera (1999) issued interim estimates of the AEP which included a modification of Kennedy and Hart's (1984) figures. They recommended an AEP of 10^{-7} for areas of 100 km^2 and below, rising to 10^{-6} for an area of 1000 km^2. On the subject of confidence limits, they added:

- Recommended AEP values plus or minus two orders of magnitude of AEP be regarded as notional upper and lower limits for true AEPs;
- Recommended AEP values plus or minus one order of magnitude of AEP be regarded as confidence limits with about 75% subjective probability that the true AEP lies within the limits; and
- The recommended AEP values be regarded as the current best estimates of the AEPs.

9. CONCLUSION

The Generalised Short Duration Method of estimating Probable Maximum Precipitation described here enables design engineers to make estimates of PMP for small areas and short durations for any site in Australia. The method is based partly on United States data as only a few severe short duration rainstorms have been adequately documented in Australia. It should be noted, however, that the highest rainfall depths at some durations for the ‘rough’ terrain category were derived from depths recorded in a storm that occurred near Dapto, New South Wales in 1984.

This document included both the revised method of spatial distribution of GSDM depth estimates introduced in 1996 and the updated moisture data used by the Hydrometeorology Section of the Bureau of Meteorology since 2001. It supersedes ‘Bulletin 53: The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method’ (Bureau of Meteorology, 1994), and should be used instead.

The notional AEP of the GSDM estimates is approximately 10^{-7} for an area of 100 km^2 rising to 10^{-6} for an area of 1000 km^2 for all durations covered by the method (Laurenson and Kuczera, 1999). The uncertainty attached to these estimates is discussed in Section 8.

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Appendix 1

GSDM CALCULATION SHEET

LOCATION INFORMATION

Catchment .... Area .... km²

State .... Duration Limit .... hrs

Latitude ....°..............’ S Longitude.....................°...............’ E

Portion of Area Considered:

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

ELEVATION ADJUSTMENT FACTOR (EAF)

Mean Elevation ....m

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

EAF = ... (0.85 - 1.00)

MOISTURE ADJUSTMENT FACTOR (MAF)

MAF = ... (0.40 - 1.00)

PMP VALUES (mm)

Duration (hours)	**Initial Depth - Smooth (D_S)**	**Initial Depth - Rough (D_R)**	**PMP Estimate = $(D_S \times S + D_R \times R) \times MAF \times EAF$**	**Rounded PMP Estimate (nearest 10 mm)**
0.25				
0.50				
0.75				
1.0				
1.5				
2.0				
2.5				
3.0				
4.0				
5.0				
6.0				

Prepared by .... Date ..../.........../..........

Checked by .... Date ..../.........../..........

Appendix 2

EXAMPLE OF THE APPLICATION OF THE GSDM

A2.1 PMP Estimates for the Example Catchment

All calculations and relevant information are recorded on the GSDM Calculation Sheet, Table A2.1.

(i) Estimates of short duration PMP are required for a hypothetical catchment in New South Wales, centred around the coordinates 36E25’ S 148E15’ E. The catchment area is 110 km².

(ii) From Figure 2 it is determined that the catchment lies within the intermediate zone. Linear interpolation across the zone indicated a maximum duration of 5 hours.

(iii) From a suitably contoured map of the area, it was found that 10% of the catchment was considered ‘smooth’ and the remaining 90% ‘rough’. ‘Rough’ terrain is that in which elevation changes of 50 m or more within horizontal distances of 400 m are common. Terrain that was within 20 km of ‘rough’ terrain was classified as ‘rough’. ‘Smooth’ terrain within the catchment but further than 20 km from ‘rough’ terrain was classified as ‘smooth’.

S = 0.1 and R = 0.9

(iv) From Figure 4, the initial depths for both the ‘smooth’, D_S, and ‘rough’, D_R, categories were read, for a catchment area of 110 km^2 for each duration up to 5 hours.

(v) The average elevation of the catchment was found to be 1750 m.

Adjustment for Elevation	=	- 0.05 per 300 m above 1500m
	=	- ((1750-1500)/300) H (0.05)
	=	- 0.04

EAF = 1.0 - 0.04 = 0.96

(vi) From Figure 3, the moisture adjustment factor was found to be 0.60.

MAF = 0.60

(vii)

PMP depth	=	(S H D_S + R H D_R) H EAF H MAF
	=	(0.1 H D_S + 0.9 H D_R)H 0.96 H 0.60

The estimates were then rounded to the nearest 10 mm.

Table A2.1: Example GSDM Calculation Sheet

LOCATION INFORMATION

Catchment ..... EXAMPLE .....

Area ..... 110 ..... km²

State ..... N.S.W. ......

Duration Limit ..... 5 ..... hrs

Latitude ..... 36..E ..... 25..’ S

Longitude ..... 148..E..... 15..’ E

Portion of Area Considered:

Smooth , **S** = ... 0.1 ..... (0.0 - 1.0)

Rough , **R** = ... 0.9 ..... (0.0 - 1.0)

ELEVATION ADJUSTMENT FACTOR (EAF)

Mean Elevation ..... 1750 ..... m

Adjustment for Elevation (-0.05 per 300m above 1500m) ....-0.04 .....

EAF = ... 0.96 ..... (0.85 - 1.00)

MOISTURE ADJUSTMENT FACTOR (MAF)

MAF = ... 0.60 ..... (0.40 - 1.00)

PMP VALUES (mm)

Duration (hours)	Initial Depth - Smooth (D_S)	Initial Depth - Rough (D_R)	PMP Estimate = (D_SHS + D_RHR) H MAF H EAF	Rounded PMP Estimate (nearest 10 mm)
0.25	164	164	94	90
0.50	242	242	139	140
0.75	306	306	176	180
1.0	372	372	214	210
1.5	423	480	273	270
2.0	480	552	314	310
2.5	514	624	353	350
3.0	546	675	381	380
4.0	611	760	429	430
5.0	661	832	469	470
6.0	-	-	-	-

Prepared by ....N. Smith....................................... Date ..../1...../...06....../...03.......

Checked by ....P. Citizen..................................... Date ....3..../.....06....../.....03.......

A2.2 Spatial distribution over the example catchment

In this example, the distribution of only the three-hour PMP will be derived. Results are given in columns a-h of Table A2.2.

Step 1 Positioning the spatial distribution diagram

The scale of the spatial distribution diagram was altered to match that of the catchment outline map. The spatial distribution diagram was placed over the catchment outline to obtain the best fit by the smallest possible ellipse. Ellipse E encloses the catchment as shown in Figure A2.1.

Step 2 Areas of catchment between successive ellipses

The catchment areas *between* successive ellipses ($CBtn_i$) were determined. The results are listed in column b.

e.g. between ellipses A and B,	$CBtn_B = 13.4\ km^2$	(from Table 2)
between ellipses B and C,	$CBtn_C = 37.7\ km^2$	(by planimetering)

Step 3 Area of catchment enclosed by each ellipse

The catchment area *enclosed by* each ellipse ($CEnc_i$) (column c) was calculated by progressively accumulating the catchment areas between ellipses (column b).

e.g. for ellipse C, $CEnc_C = 2.6 + 13.4 + 37.7 = 53.7\ km^2$

As a check, the area enclosed by the outermost ellipse, ellipse E, which is 110 km^2, should equal the area of the catchment.

Step 4 Initial mean rainfall depth enclosed by each ellipse

Since the catchment completely fills ellipses A and B, the 3-hour initial mean rainfall depths ($IMRD_i$) at these areas may be determined from Table 2, weighting and summing the 'smooth' and 'rough' depths according to the proportions of 'smooth' and 'rough' terrain (Section A2.1).

i.e.,	3 hr, ellipse A, 'smooth'	= 705 mm
	3 hr, ellipse A, 'rough'	= 901 mm
	$IMRD_A$	$= (0.1 \times 705 + 0.9 \times 901) = 881$ mm

For ellipses C, D and E, the initial mean rainfall depths were determined from the 3-hour DDA curves in Figure 4.

e.g. for ellipse C,	3 hr, 53.7 km^2, 'smooth'	= 585 mm
	3 hr, 53.7 km^2, 'rough'	= 731 mm
	$IMRD_C$	$= (0.1 \times 585 + 0.9 \times 731) = 716$ mm

The initial mean rainfall depths are listed in column d.

Step 5 Adjusted mean rainfall depth enclosed by each ellipse

The initial mean rainfall depths (column d) were adjusted for moisture and elevation (column e) by multiplying by the moisture and elevation adjustment factors (Section A2.1).

e.g. for ellipse C, $AMRD_C = 716 \times 0.60 \times 0.96 = 412$ mm

As a check, the adjusted mean rainfall depth for the area enclosed by the outermost ellipse, ellipse E, which is 382 mm, should approximately equal the 3-hour (unrounded) PMP for the catchment (Section A2.1).

Step 6 Volume of rainfall enclosed by each ellipse

The adjusted mean rainfall depths (column e) were multiplied by the areas of the catchment enclosed by each ellipse (column c) to give values for the volume of rainfall enclosed by each ellipse ($VEnc_i$) (column f).

e.g. for ellipse C, $VEnc_C = 412 \text{ x } 53.7 = 22{,}124 \text{ mm.km}^2$

Step 7 Volume of rainfall between successive ellipses

Consecutive enclosed rainfall volumes (column f) were subtracted to obtain the rainfall volume between ellipses ($VBtn_i$) (column g).

e.g. between ellipses B and C, $VBtn_C = 22{,}124 - 7{,}312 = 14{,}812 \text{ mm.km}^2$

Step 8 Mean rainfall depth between successive ellipses

The mean rainfall depths between successive ellipses (MRD_i) (column h) were obtained by dividing the rainfall volume between ellipses (column g) by the area between ellipses (column b).

e.g. between ellipses B and C, $MRD_C = 14{,}812 / 37.7 = 393$ mm

Step 9 Other PMP Durations

Repeat the above steps for other durations for which the spatial distribution of PMP is required.

Table A2.2: Calculation of the Spatial Distribution of 3-hour PMP over the Example Catchment

a Ellipse	b Step 2 Catchment area between ellipses (km^2)	c Step 3 Catchment area enclosed by ellipse (km^2)	d Step 4 Initial mean rainfall depth (mm)	e Step 5 Adjusted mean rainfall depth (mm)	f Step 6 Rainfall volume enclosed by ellipse (mm.km^2)	g Step 7 Rainfall volume between ellipses (mm.km^2)	h Step 8 Mean rainfall depth between ellipses (mm)
A	2.6	2.6	881	507	1,318	1,318	507
B	13.4	16	793	457	7,312	5,994	447
C	37.7	53.7	716	412	22,124	14,812	393
D	42.6	96.3	673	388	37,364	15,240	358
E	13.7	**110**	663	**382**	42,020	4,656	340

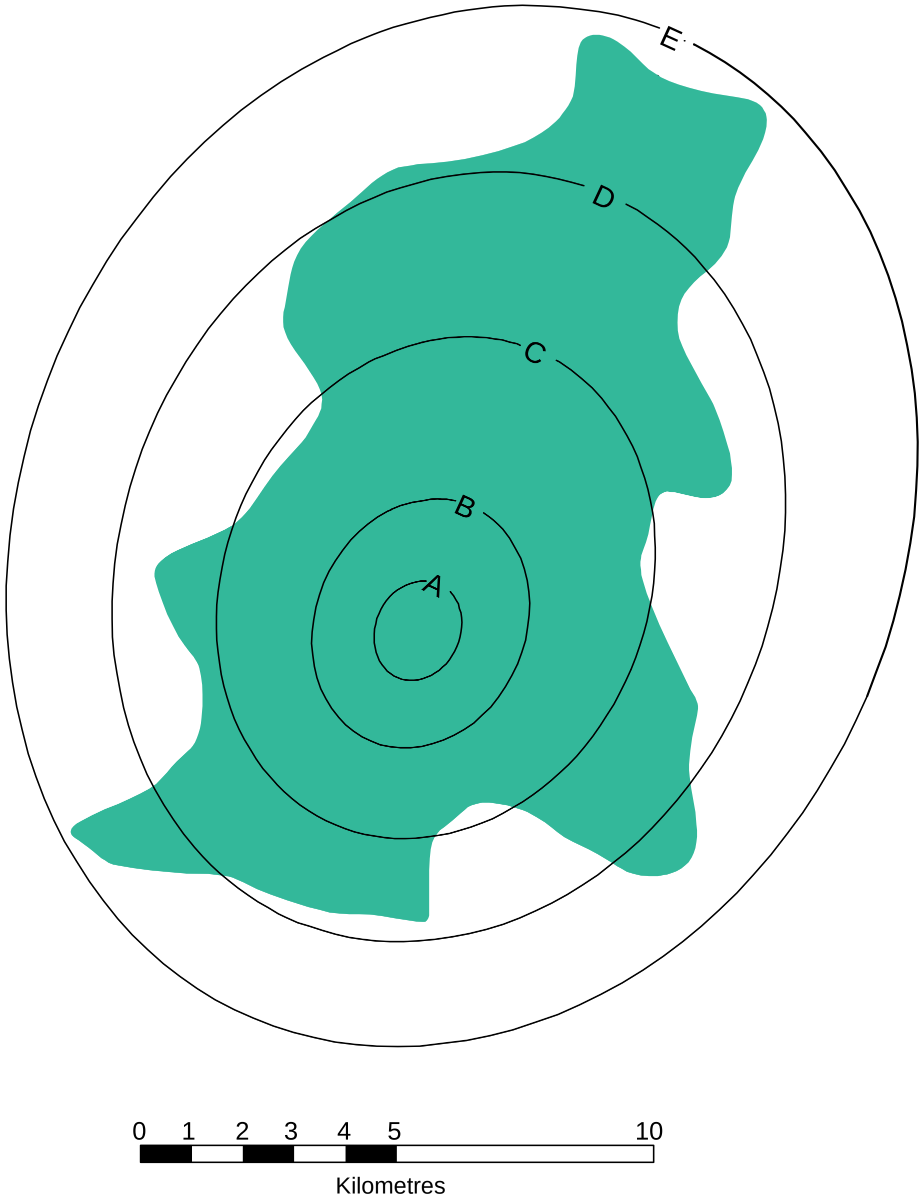

Figure A2.1: Spatial Distribution over Example Catchment

Appendix 3

NOTABLE SHORT DURATION AREAL RAINFALL EVENTS RECORDED IN INLAND AND SOUTHERN AUSTRALIA

A3.1 The Molong Storm of 20 March 1900

On 20 March 1900 a series of thunderstorms formed over a strip of country about 75 km wide extending from near Hungerford to the southeast near Moss Vale in New South Wales. The heaviest rainfall occurred in the Orange-Molong area. The information given by Russell (1901) indicates that the storm lasted for about three hours. The storm dew point temperature was estimated as 19EC. The recorded storm rainfall and the rainfall normalised for the moisture content corresponding to an extreme dew point temperature of 23.5EC are compared with the PMP estimates in Table A4.1.

Table A3.1: Depth-Area Data for the Molong Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 23.5EC (mm)	3-hour PMP Estimate (mm)
10	205	300	450
50	195	290	400
100	190	280	380
500	180	260	310
1000	170	250	270

A3.2 The St Albans Storm of 8 January 1970

On 8 January 1970 between 1400 and 1730 EST an intense thunderstorm was located in the St Albans area about 15 km west-northwest of Melbourne. Near the centre of the storm rainfall totals exceeding 120 mm were recorded. The storm was studied by Finocchiaro (1970). Radar observations and information obtained from private raingauge readers indicate that about 90 per cent of the total rainfall fell within a period of 1.5 hours. The storm dew point was assessed to have been 13EC and the extreme dew point for the storm area for January is 20.4EC. The storm data are compared with the PMP estimates in Table A3.2.

Table A3.2: Depth-Area Data for the St Albans Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 20.4EC (mm)	1.5-hour PMP Estimate (mm)
1	111	210	300
10	88	170	280
20	80	150	260
30	72	140	260
50	63	120	240

A3.3 The Woden Valley Storm of 26 January 1971

During the evening of 26 January 1971 extremely heavy rainfall associated with an almost stationary thunderstorm complex fell over the Canberra suburbs of Farrer and Torrens for about 90 minutes (Bureau of Meteorology, 1972). The resulting flood in the Woden Valley claimed several lives. The storm dew point temperature was assessed as 14EC and the extreme dew point is 22.8EC. The storm data are compared with the PMP estimates in Table A3.3.

Table A3.3: Depth-Area Data for the Woden Valley Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 22.8EC (mm)	1.5-hour PMP Estimate (mm)
1	102	220	370
10	99	210	340
50	87	190	300
100	78	170	270
250	62	130	240

A3.4 The Melbourne Storm of 17 February 1972

On the afternoon of 17 February 1972 an intense thunderstorm developed over the city of Melbourne and the suburbs immediately north of the city. The storm was observed by radar and three pluviograph traces were obtained from sites near the centre of the storm. This storm lasted for about 60 minutes and produced severe local flooding. Rainfall depths for this storm are given by Pierrehumbert and Kennedy (1982). The storm dew point was estimated as 12EC and the extreme dew point is 20.9EC. The storm depth-area values are compared with the PMP estimates in Table A3.4.

Table A3.4: Depth-Area Data for the Melbourne Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 20.9EC (mm)	1-hour PMP Estimate (mm)
2	83	180	270
20	73	160	240
50	68	150	220
100	60	130	200
250	49	110	180

A3.5 The Laverton Storm of 7 April 1977

A storm lasting for about 12 hours brought exceptionally heavy rain to areas to the west and north of Melbourne on 7 April 1977. The heaviest burst in the storm lasted for about 3 hours and affected areas from Laverton to Sunbury. The Melbourne and Metropolitan Board of Works (1979) gives details of the rainfall recorded over the entire storm area. The representative storm dew point temperature was 10EC and the extreme dew point is 20.1EC. The recorded and maximised storm depth-area data are compared with the PMP estimates in Table A3.5.

Table A3.5: Depth-Area Data for the Laverton Storm

Area (km^2)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 20.1EC (mm)	3-hour PMP Estimate (mm)
10	121	310	340
100	96	240	280
400	73	180	240
600	60	150	220
800	53	130	210
1000	51	130	200

A3.6 The Buckleboo Storm of 26 January 1981

On the afternoon of 26 January 1981 an intense and almost stationary thunderstorm produced some of the highest short-duration rainfalls ever recorded in South Australia. While the only quantitative data are daily totals, it is reliably reported that virtually all the rain fell in a period of about three hours. The representative storm dew point was estimated to have been 19EC. The recorded values were adjusted for a moisture content corresponding to a surface dew point temperature of 23.5EC for comparison with the PMP estimates in Table A3.6.

Table A3.6: Depth-Area Data for the Buckleboo Storm

Area (km^2)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 23.5EC (mm)	3-hour PMP Estimate (mm)
10	187	270	450
50	169	250	400
100	154	230	380
500	106	160	310
1000	77	110	270

A3.7 The Barossa Valley Storm of 2 March 1983

During the evening of 2 March 1983 numerous thunderstorm cells produced very heavy rainfall over the Adelaide Plains and the eastern part of the Mt Lofty Ranges. Nearly all the rain fell in a period of about three hours. The thunderstorms occurred in a moist airmass of tropical origin which was fed into the area from the northeast. The storm is described by Burrows (1983).

The rainfall produced severe flash flooding and extensive property damage, particularly in the Barossa Valley and around Dutton. An unofficial gauge on a farm 1 km north of Dutton recorded 330 mm during the storm. Several unofficial gauges recorded totals in excess of 200 mm, whereas the highest value recorded by an official gauge was 103 mm at Angaston. This illustrates the problem of detecting severe local storms with the sparse network of official gauges.

The representative storm dew point temperature was estimated as 20EC and the extreme dew point is 22.2EC. The storm rainfalls are compared with the PMP estimates for a duration of three hours in Table A3.7.

Table A3.7: Depth-Area Data for the Barossa Valley Storm

Area (km^2)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 22.2EC (mm)	3-hour PMP Estimate (mm)
1	300	360	440
10	222	270	400
50	190	230	350
100	173	210	340
500	129	150	270
1000	110	130	240

A3.8 The Dapto Storm of 18 February 1984

An extraordinary heavy rainfall event occurred near Dapto in New South Wales on 18 February 1984, as described by Shepherd and Colquhoun (1985). The rainfall was particularly heavy on and near the Illawarra escarpment. While rain fell for more than 24 hours most of the rain fell in a period of about 6 hours. For durations of around 6 hours and areas up to about 200 km^2 the normalised rainfall values exceed the adjusted United States data. The maximised rainfall values from the Dapto storm were used in deriving the `rough' terrain category DDA curves in Figure 2 in the first edition of *Bulletin 51* by the Bureau of Meteorology (1985). The storm dew point temperature was estimated to be 19EC. The extreme dew point temperature for February is 23.3EC. The 6-hour rainfall values for this storm are given in Table A3.8 where they are compared with the PMP estimates.

Table A3.8: Depth-Area Data for the Dapto Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 23.3EC (mm)	6-hour PMP Estimate (mm)
10	520	750	750
50	450	650	650
100	410	590	600
500	250	360	460
1000	160	230	390

A3.9 The Sydney Storm of 4-7 August 1986

A low pressure centre which moved southwards close to the coast brought very heavy rainfall to the Sydney metropolitan area, the Blue Mountains and the Illawarra region, causing extensive local flooding. Six fatalities resulted from the storm. The Sydney rainfall for the 24 hours to 9 am on 6 August 1986 was a record 328 mm. There was a particularly heavy period of rain on the afternoon of 5 August 1986. Pluviograph data have been used to extract maximum 6 hour depths for that part of the storm which occurred over the metropolitan area. The storm dew point was 10EC and the extreme dew point is 16.7EC. The storm is described by the Bureau of Meteorology (1987). The depth-area rainfall values for the storm are compared with the PMP estimates in Table A3.9.

Table A3.9: Depth-Area Data for the Sydney Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 16.6EC (mm)	6-hour PMP Estimate (mm)
50	133	250	320
200	124	230	270
500	112	210	240
1000	103	190	200

A3.10 The St Kilda Storm of 7 February 1989

On the afternoon of 7 February 1989, a severe thunderstorm brought torrential rainfall to the inner southern and southeastern suburbs of Melbourne (Board of Works, 1989). The storm was centred over the St Kilda area and caused flash flooding. The heavy rainfall part of the storm lasted for about one hour. The representative storm dew point temperature was estimated to have been 14EC and the extreme dew point for February is 20.9EC. The depth-area rainfall values for the storm are compared with PMP estimates in Table A3.10.

Table A3.10: Depth-Area Data for the St. Kilda Storm

Area (km²)	Recorded Storm Rainfall (mm)	Storm Rainfall Adjusted to 20.9EC (mm)	1-hour PMP Estimate (mm)
5	91	160	260
10	85	150	250
20	75	140	240
40	62	110	230
60	53	100	220
80	49	90	210

A3.11 References for Appendix 3

Board of Works (1989). ‘Storm Report, 7 February 1989’. Internal Report.

Bureau of Meteorology (1972). ‘Final Report, Woden Valley Storm, 26 January 1971’. Internal Report.

Bureau of Meteorology (1985). ‘The Estimation of Probable Maximum Precipitation in Australia for Short Durations and Small Areas’. Bulletin 51, August 1984. AGPS, Canberra.

Bureau of Meteorology (1987). ‘A Report on the Heavy Rainfall and Flood Event in the Sydney Metropolitan and Nearby Areas Over the Period 4-7 August 1986’. Internal Report.

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Finocchiaro, N.J. (1970). ‘Heavy Rainfall on 8 January 1970 at St Albans, Victoria’. Met. Note 47, Bureau of Meteorology.

Melbourne and Metropolitan Board of Works (1979). ‘Report on the Easter Storm 1977’. Vol. 1 Rainfall. MMBW-D-0018.

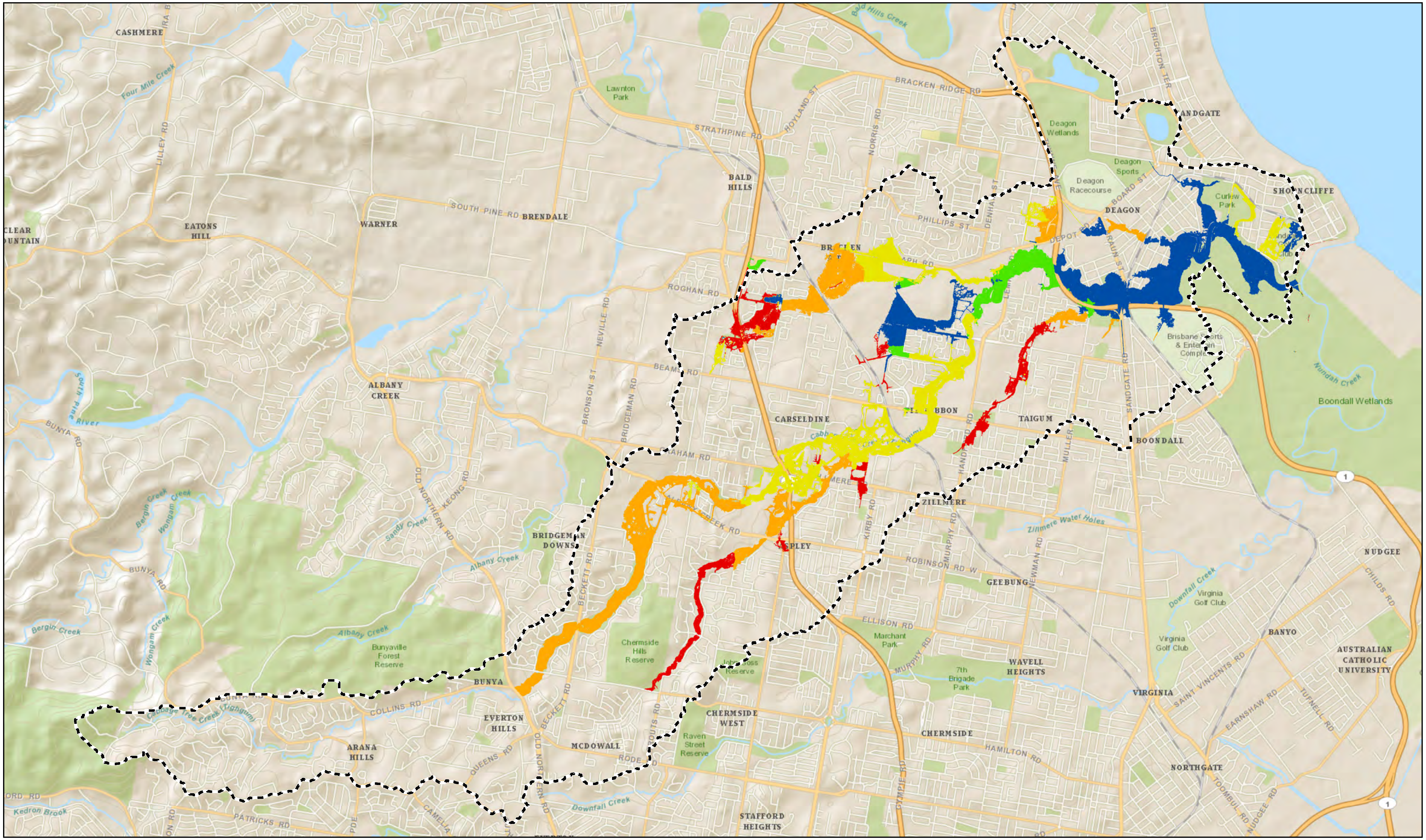
Pierrehumbert, C.L. and Kennedy, M.R. (1982). ‘The Use of Adjusted United States Data to Estimate Probable Maximum Precipitation’. Proceeding of the Workshop on Spillway Design, Melbourne, 1981. AWRC Conf. Ser. No.6, AGPS, Canberra.

Russell, H.C. (1901). ‘Results of Rain, River, and Evaporation Observations made in New South Wales during 1900’. Govt. Printer, Sydney.

Shepherd, D.J. and Colquhoun, J.R. (1985). ‘Meteorological Aspects of an Extraordinary Flash Flood Event Near Dapto, NSW’. *Australian Meteorological Magazine*, Vol. 33, No. 2, pp 87-102.

Appendix J

Critical Duration Maps



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 | 1,125 | 2,250 | 4,500

Metres

1:45,000 (when printed at A3)

Legend

Catchment Boundary

Critical Duration

- 1 Hour Event
- 2 Hour Event
- 3 Hour Event
- 4.5 Hour Event
- 6 Hour Event

Service Layer Credits:
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

CRITICAL DURATION

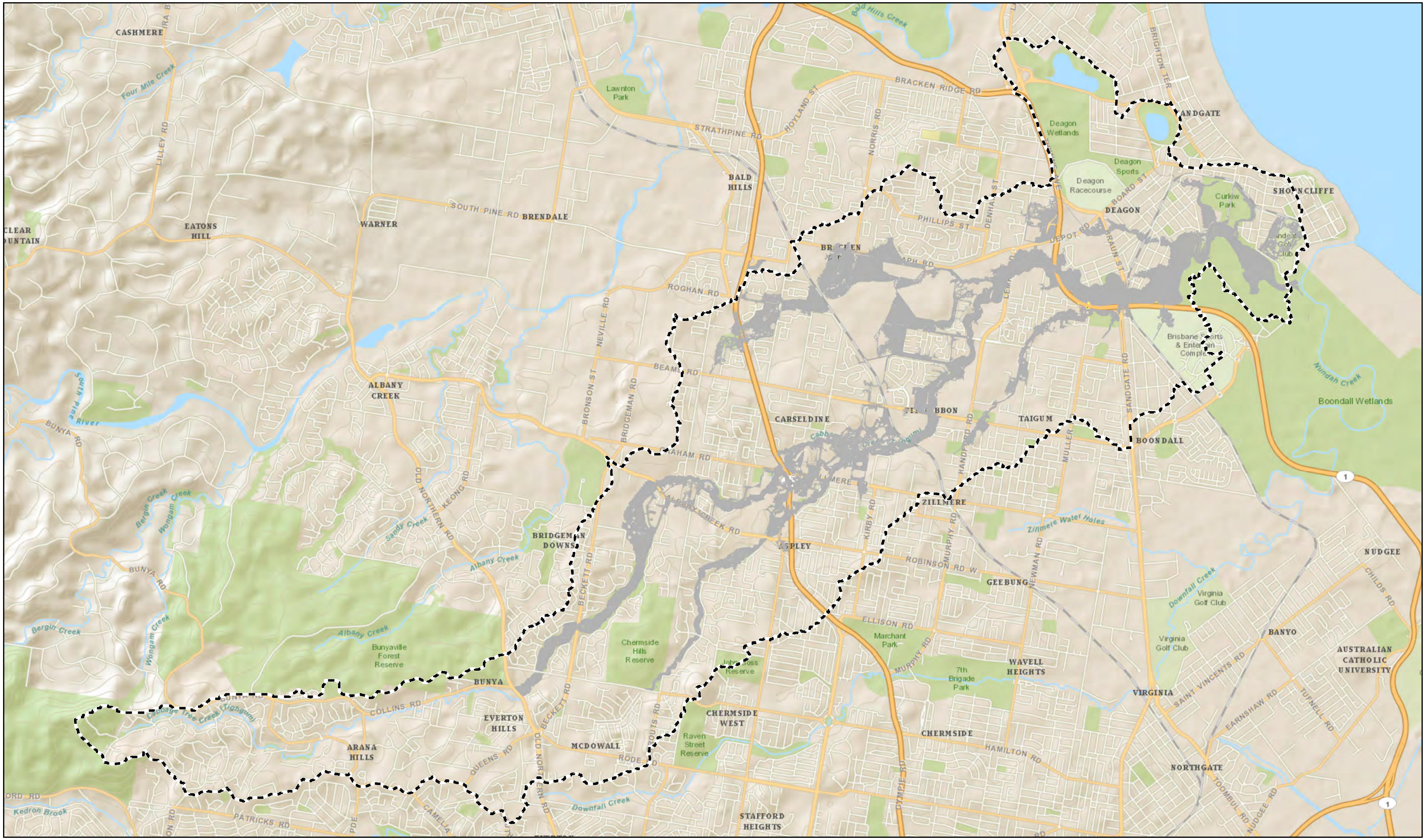
AECOM
www.aecom.com

BRISBANE CITY

Map
J1

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixJ_CriticalDurationMaps\AppendixJ1_MapJ1_CriticalDuration_Landscape.mxd

A3 size



DATUM GDA 1994, PROJECTION MGA ZONE 55

0 1,125 2,250 4,500
Metres

1:45,000 (when printed at A3)

Legend

Catchment Boundary

Critical Difference [m]

- -0.02 - 0.02
- -0.1 - 0.1
- <-0.1 - >0.1

Service Layer Credits:
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Data sources:
Brisbane City Coucil
SISP Imagery
Street Pro Dataset

Cabbage Tree Creek Catchment

CRITICAL ENVELOPE DIFFERENCE

AECOM
www.aecom.com

Map J2

Path: P:\Projects\60285180\4. Tech Work Area\4.99 GIS\02_MXDs\ReportMap_July2013\AppendixJ_CriticalDurationMaps\AppendixJ2_MapJ2_CriticalDifference_Landscape.mxd

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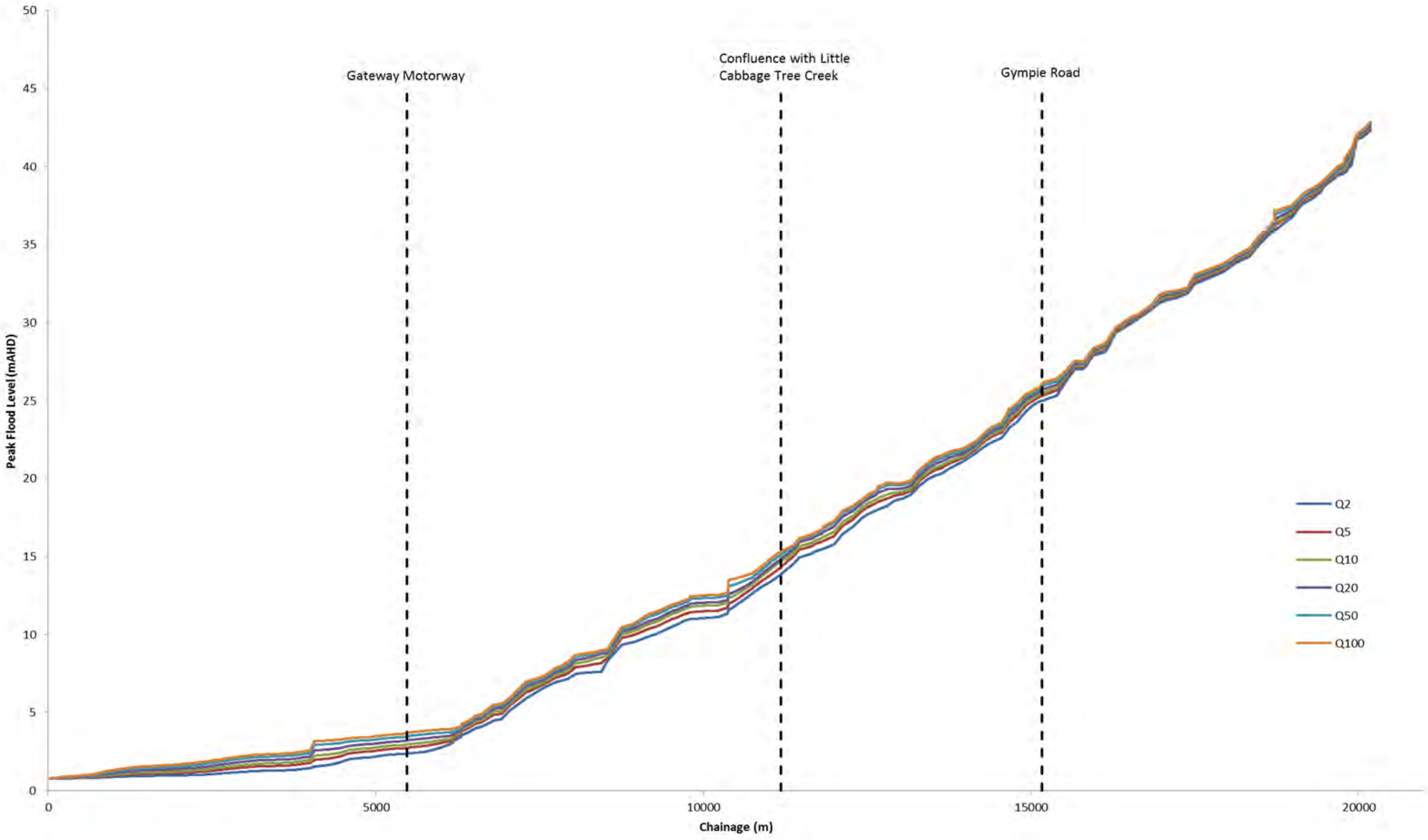
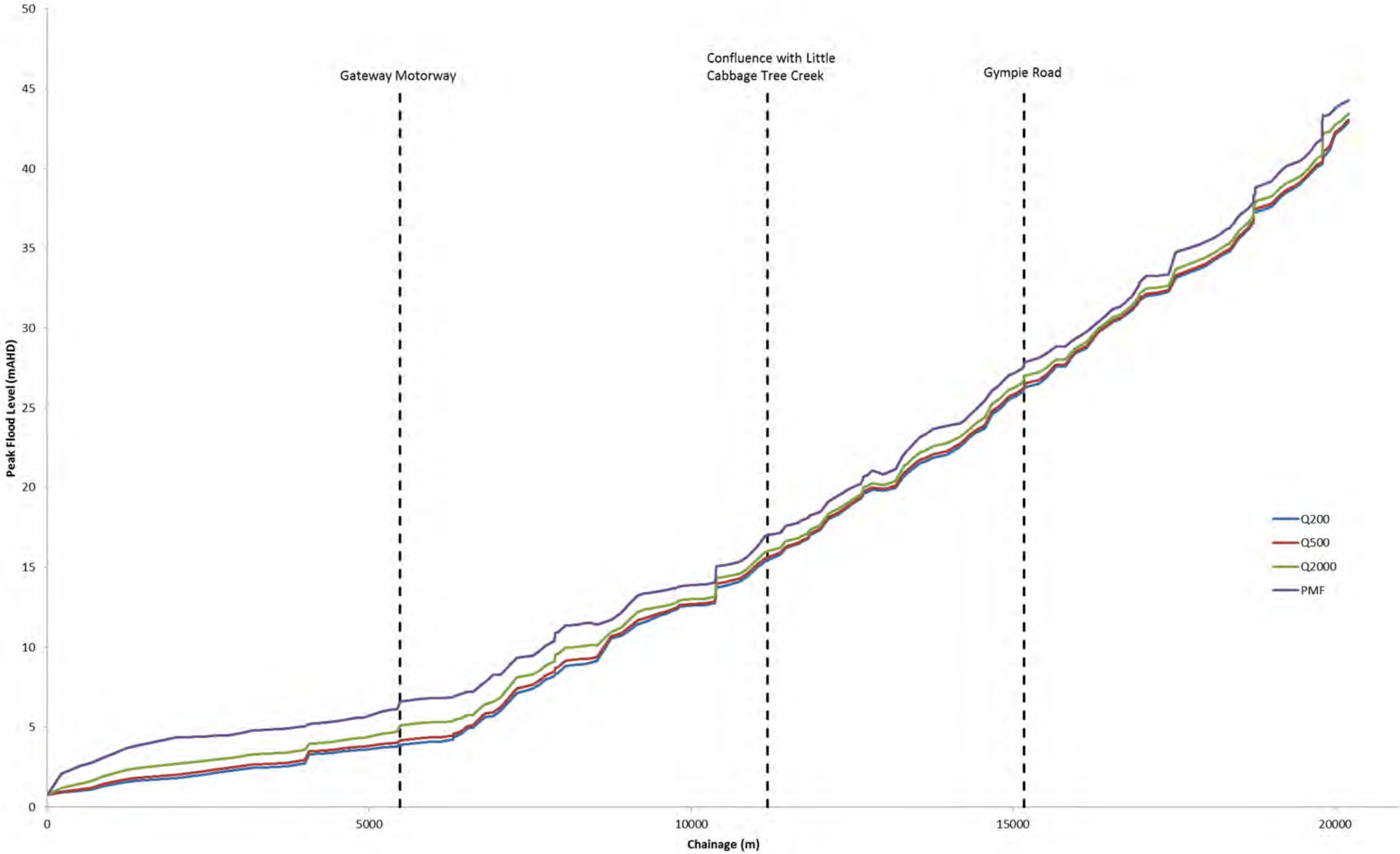
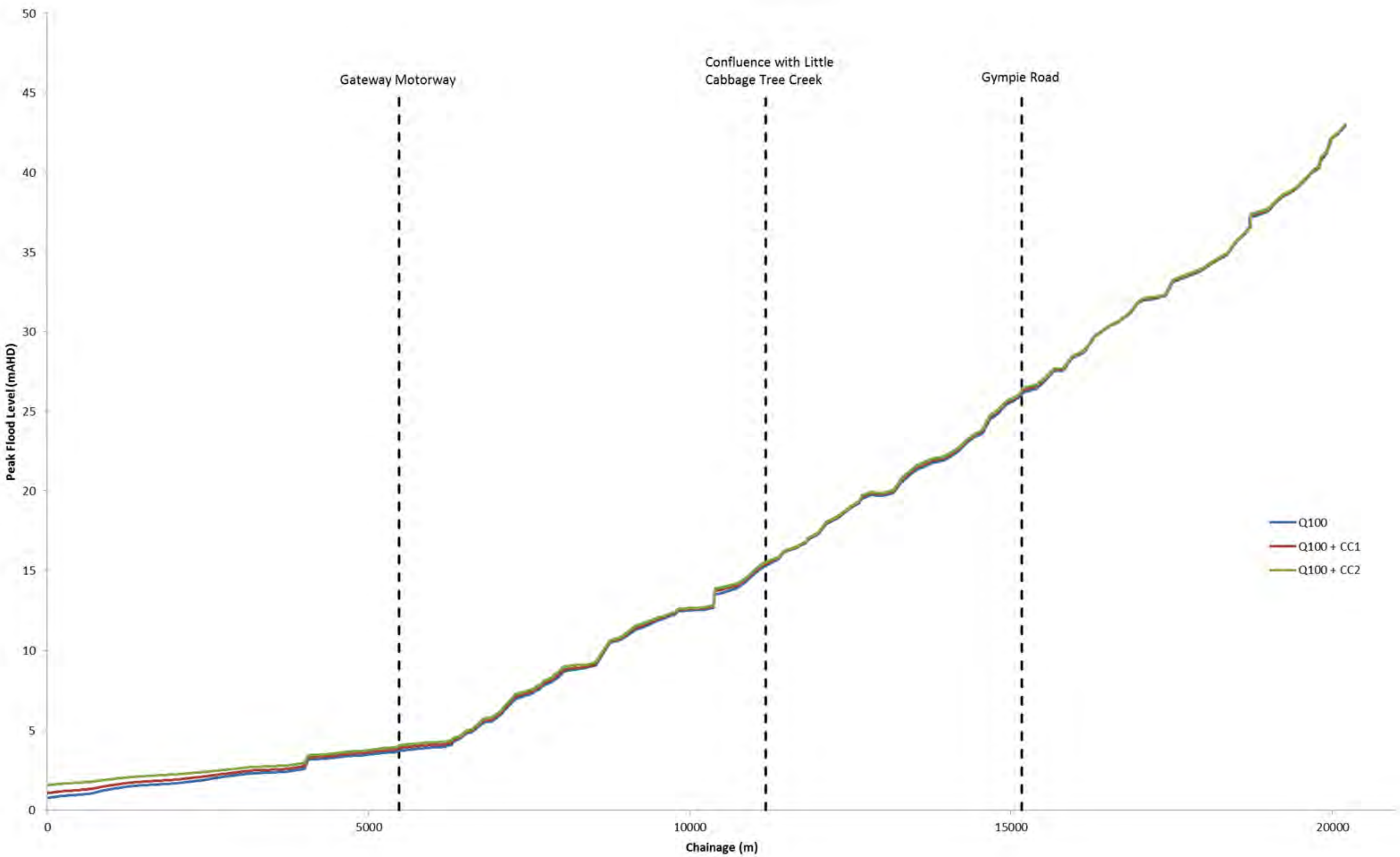
Appendix K

Design Event Creek Profiles

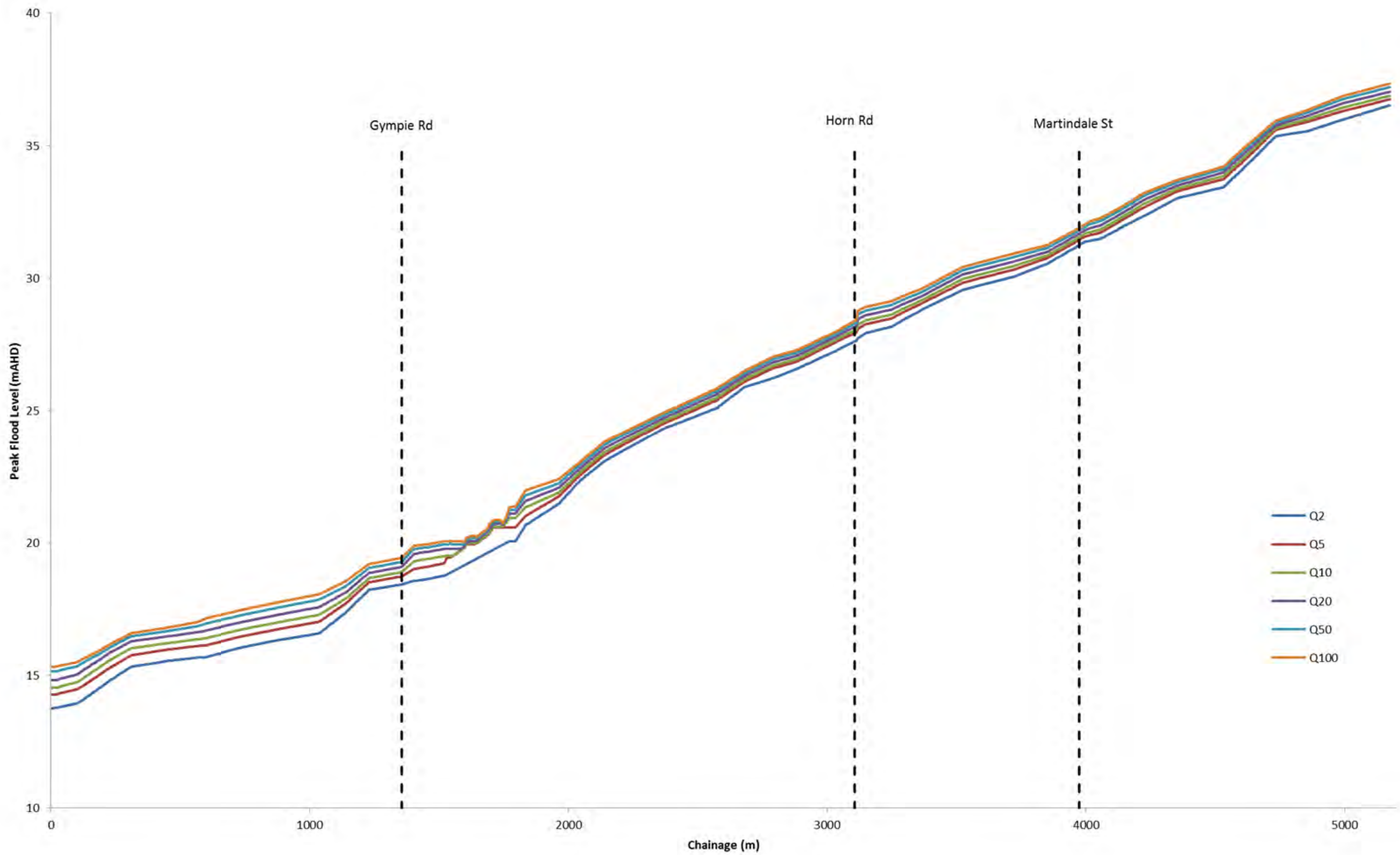
Appendix K Design Event Long Sections

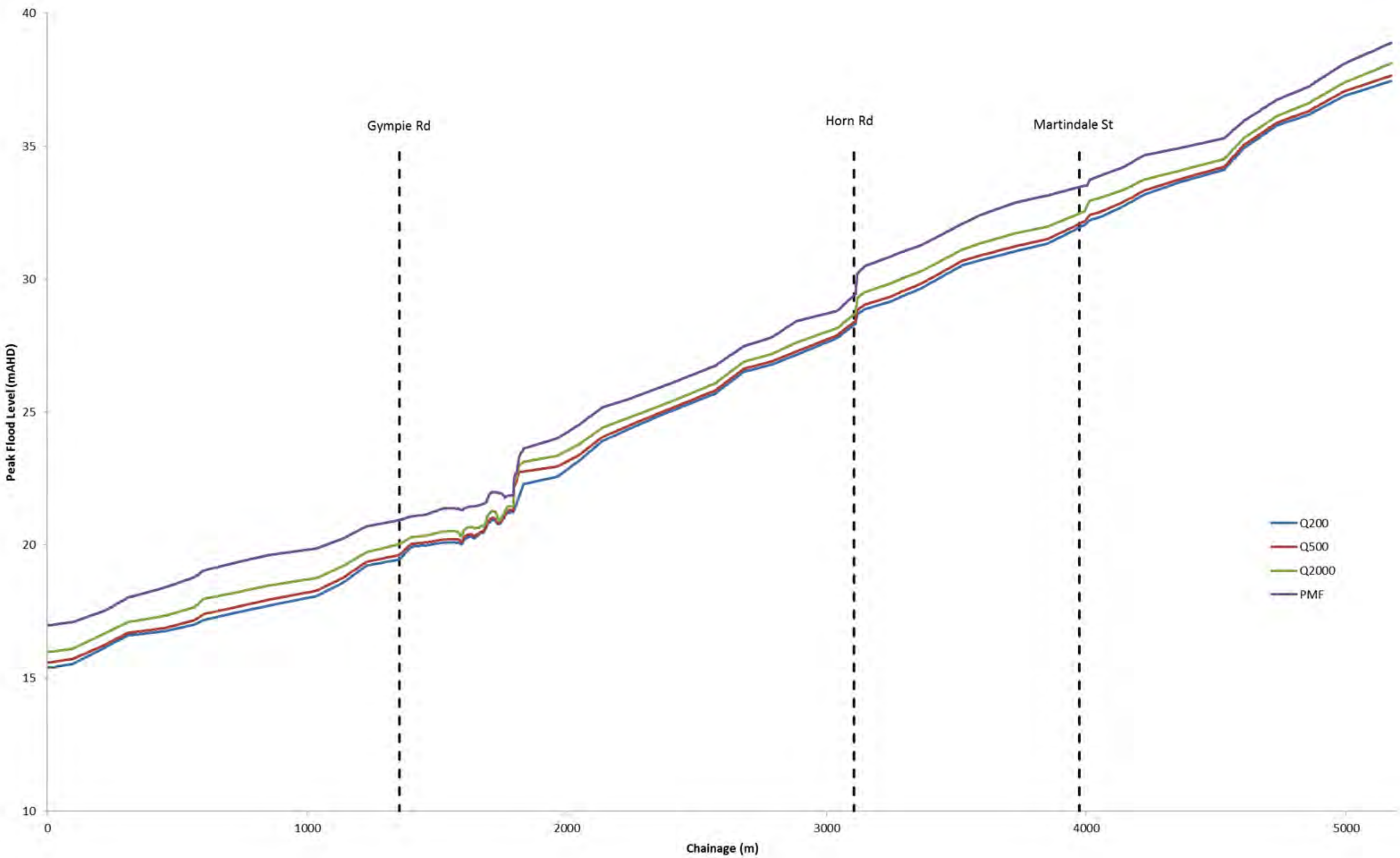


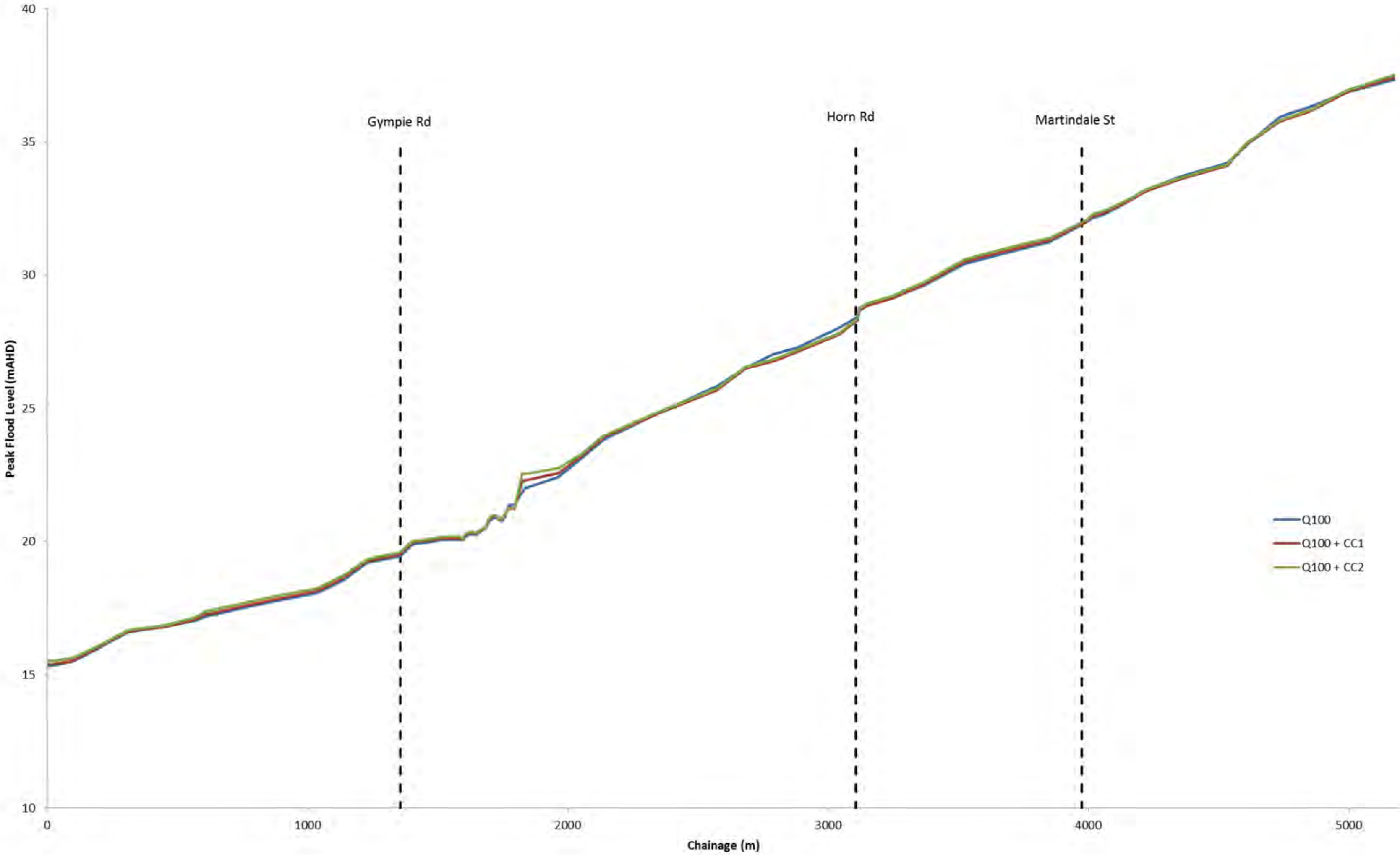

50
45
40
35
30
25
20
15
10
5
0
Peak Flood Level (mAHD)
0
5000
10000
15000
20000
Chainage (m)
Gateway Motorway
Confluence with Little
Cabbage Tree Creek
Gympie Road
Q200
Q500
Q2000
PMF

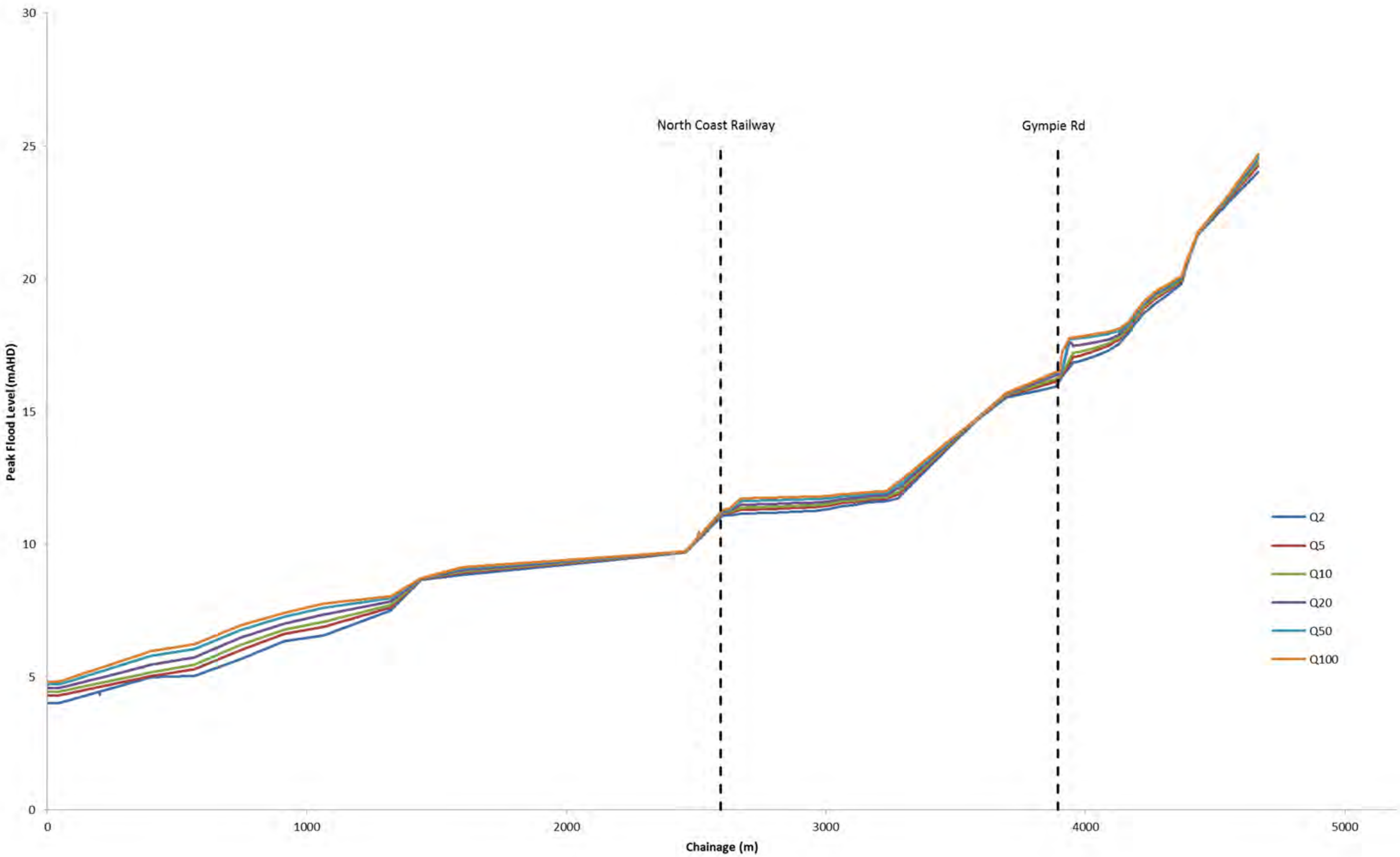


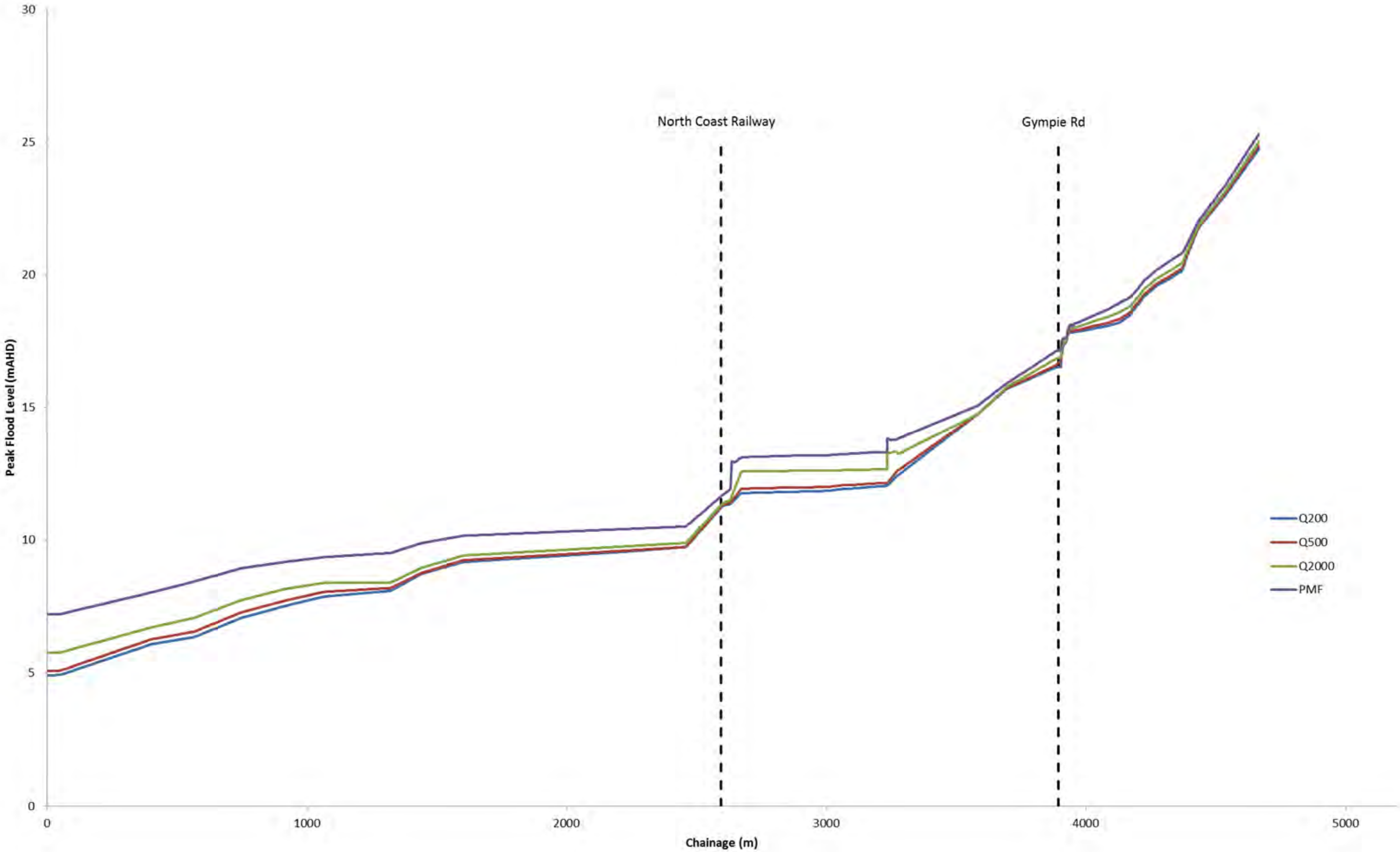
Peak Flood Level (mAHD)
Chainage (m)
Gateway Motorway
Confluence with Little Cabbage Tree Creek
Gympie Road
Q100
Q100 + CC1
Q100 + CC2
0
5
10
15
20
25
30
35
40
45
50
0
5000
10000
15000
20000


Gympie Rd
Horn Rd
Martindale St
Peak Flood Level (mAHD)
Chainage (m)
40
35
30
25
20
15
10
0
1000
2000
3000
4000
5000
Q2
Q5
Q10
Q20
Q50
Q100

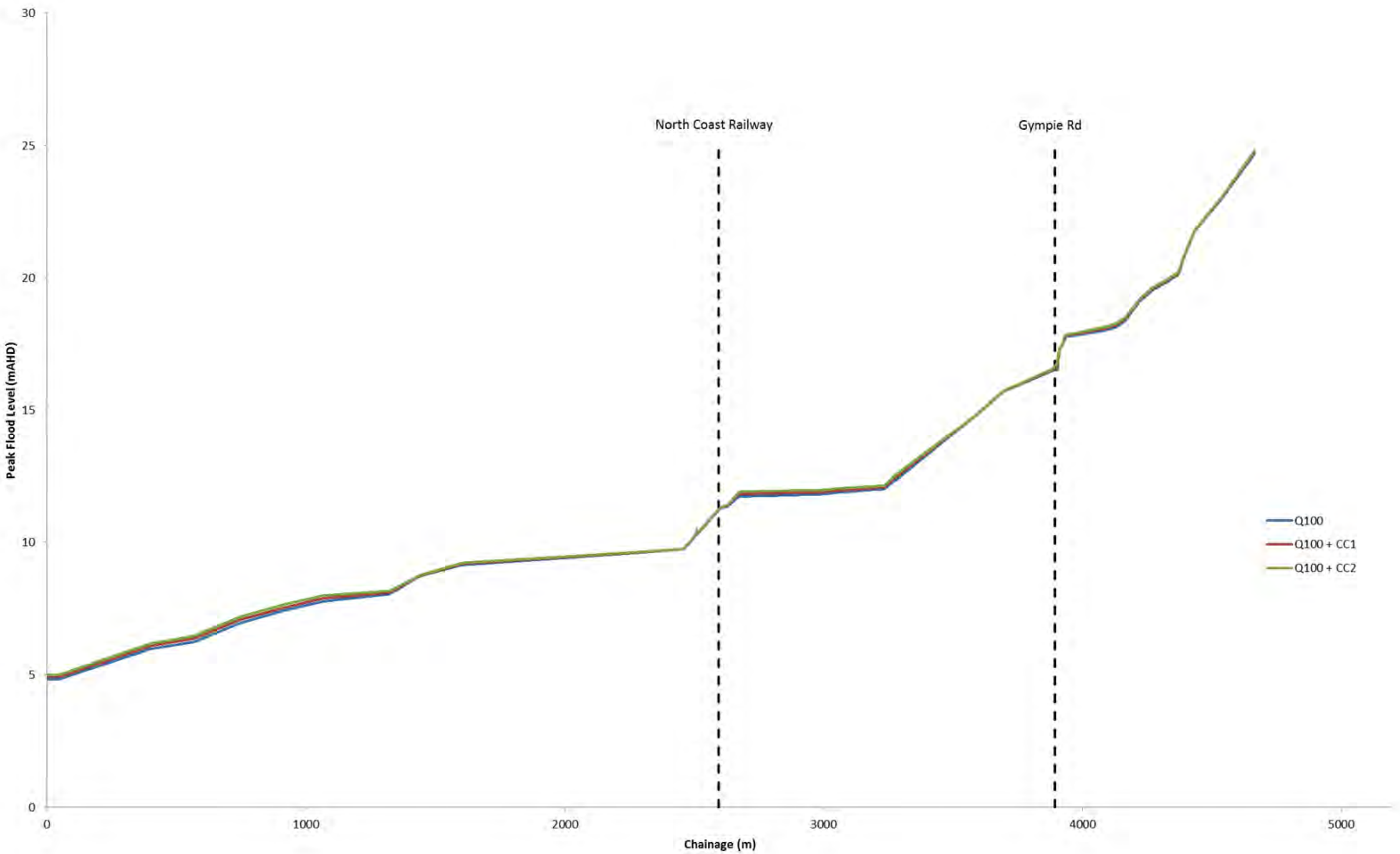

Gympie Rd
Horn Rd
Martindale St
Peak Flood Level (mAHD)
40
35
30
25
20
15
10
0
1000
2000
3000
4000
5000
Chainage (m)
Q200
Q500
Q2000
PMF


40
35
30
25
20
15
10
Peak Flood Level (mAHD)
Gympie Rd
Horn Rd
Martindale St
Q100
Q100 + CC1
Q100 + CC2
0
1000
2000
3000
4000
5000
Chainage (m)

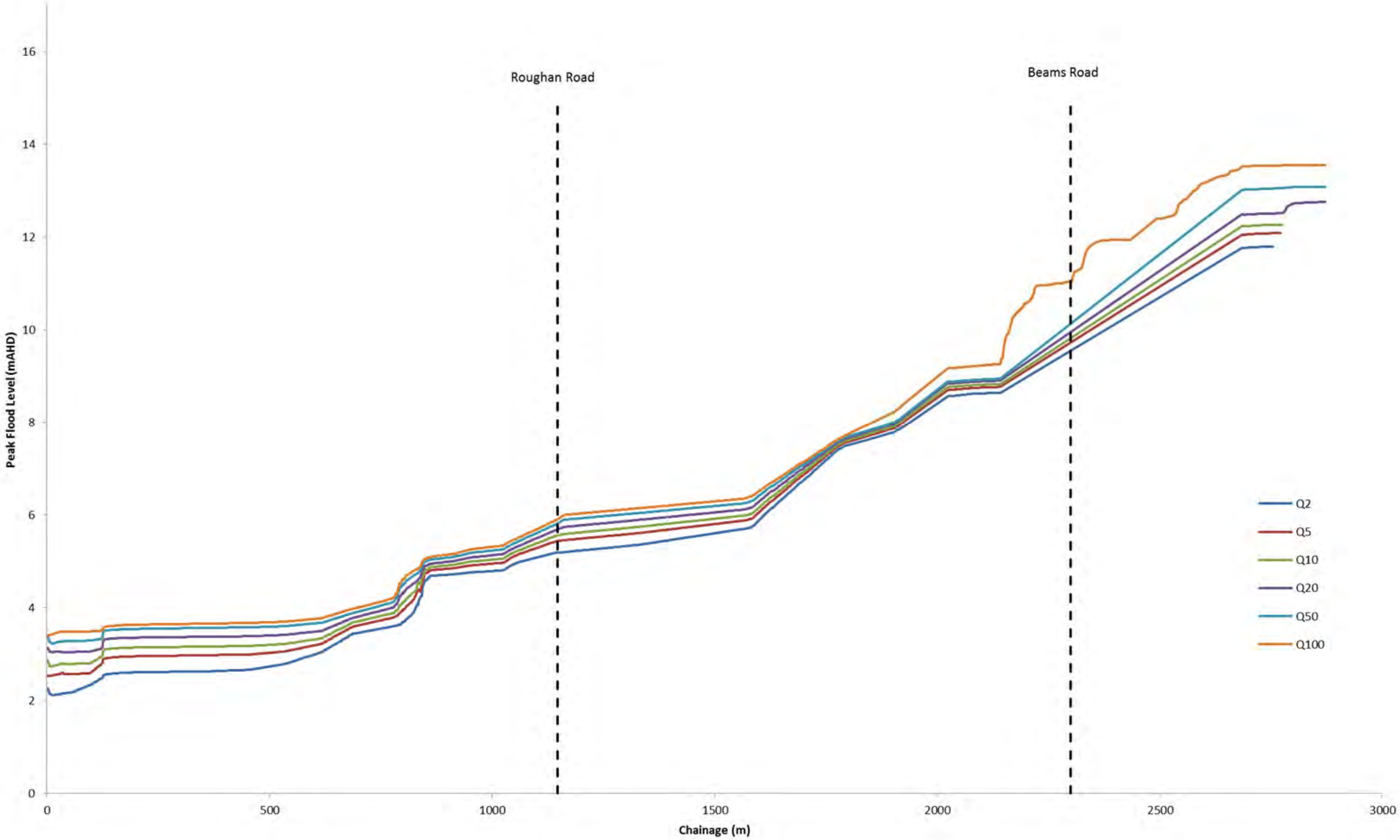

North Coast Railway
Gympie Rd
Peak Flood Level (mAHD)
Chainage (m)
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
Q2
Q5
Q10
Q20
Q50
Q100



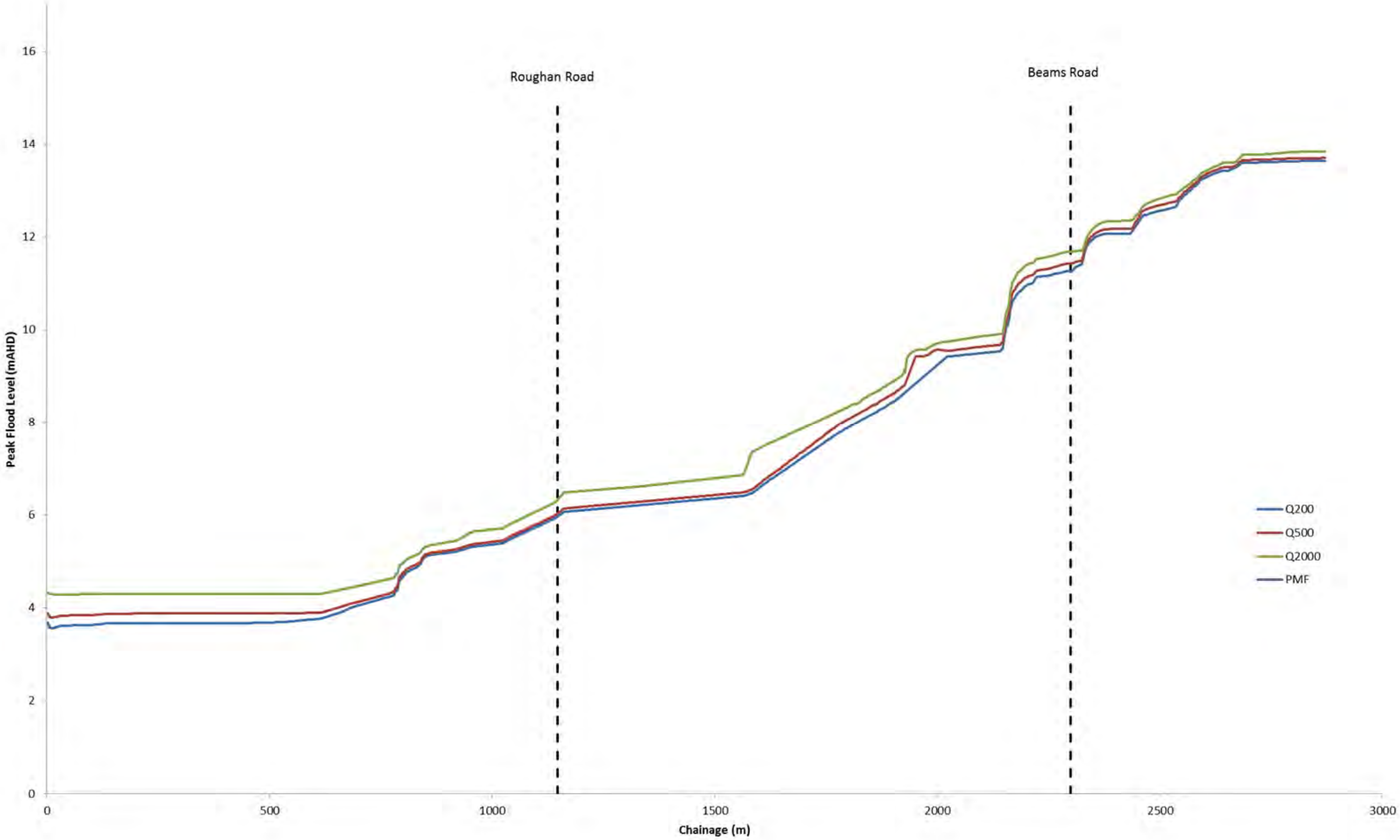
30
25
20
15
10
5
0
Peak Flood Level (mAHD)
North Coast Railway
Gympie Rd
Q200
Q500
Q2000
PMF
0
1000
2000
3000
4000
5000
Chainage (m)



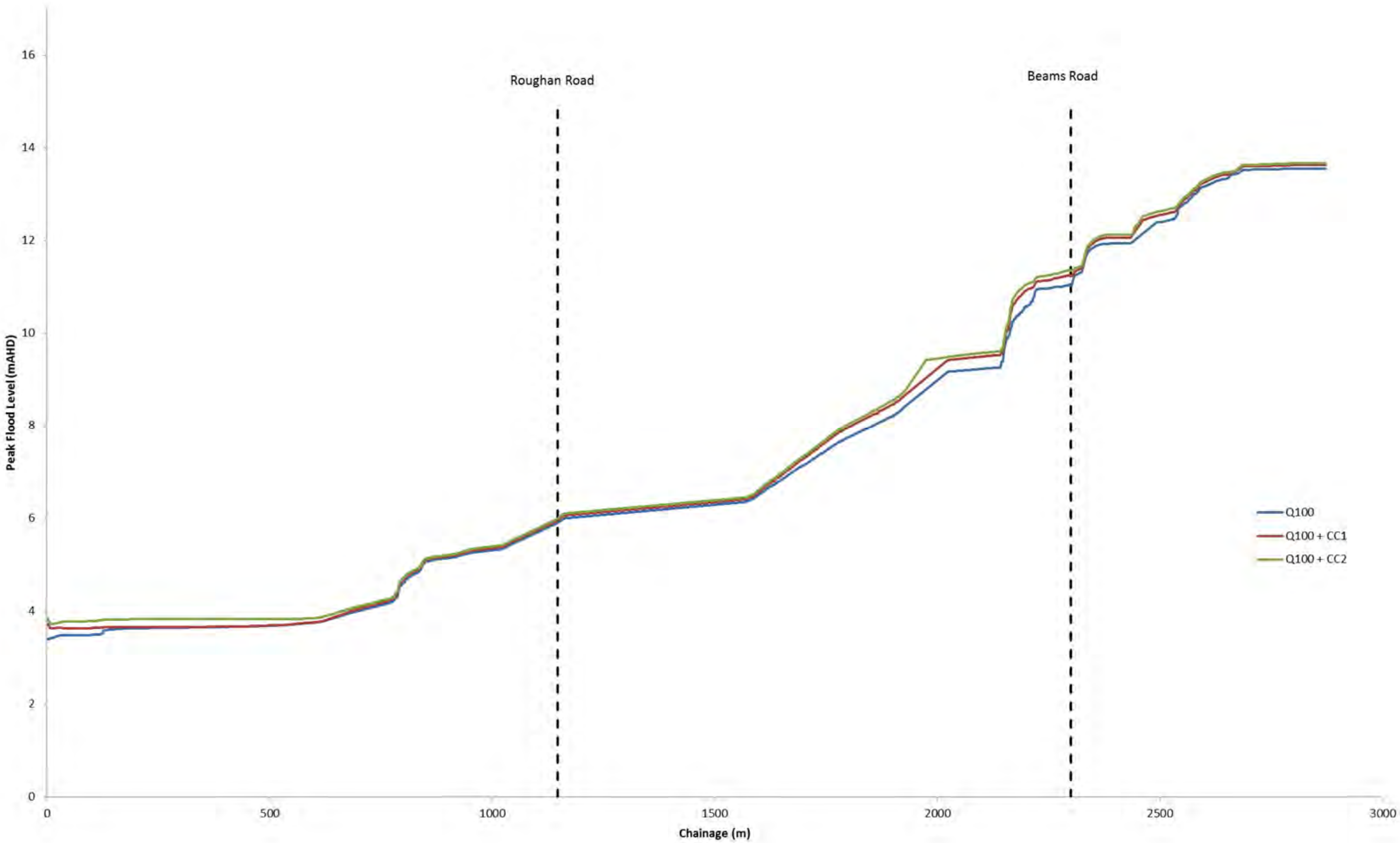
30
25
20
15
10
5
0
Peak Flood Level (mAHD)
0
1000
2000
3000
4000
5000
Chainage (m)
North Coast Railway
Gympie Rd
Q100
Q100 + CC1
Q100 + CC2



Peak Flood Level (mAHD)
0
2
4
6
8
10
12
14
16
Chainage (m)
0
500
1000
1500
2000
2500
3000
Roughan Road
Beams Road
Q2
Q5
Q10
Q20
Q50
Q100



Peak Flood Level (mAHD)
0
2
4
6
8
10
12
14
16
Roughan Road
Beams Road
Q200
Q500
Q2000
PMF
0
500
1000
1500
2000
2500
3000
Chainage (m)


Roughan Road
Beams Road
Peak Flood Level (mAHD)
Chainage (m)
Q100
Q100 + CC1
Q100 + CC2
0
2
4
6
8
10
12
14
16
0
500
1000
1500
2000
2500
3000

Appendix L

Hydraulic Structure Reference Sheets (HSRS)

APPENDIX L: Hydraulic Structure Reference Sheet (HSRS)

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	Quarrion Street

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 4/[3.6Wx1.5H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 5.00mAHD UPSTREAM OBVERT LEVEL: 6.46 mAHD

DOWNSTREAM INVERT LEVEL: 4.95mAHD DOWNSTREAM OBVERT LEVEL: 6.41 mAHD
For culverts give floor level. For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 12.03m

LENGTH OF CULVERT BARREL AT OBVERT (m):12.03m

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):20m LOWEST POINT OF WEIR (m AHD):8.32

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: 01/22/2001 PLAN NUMBER: WP3457

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Taigum Channel**
LOCATION	**Quarrion Street**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	23.34	23.34	6.3933	0.04	13.951	0	1.673	0
50	0	20.717	20.717	6.2884	0.035	12.900	0	1.606	0
20	0	17.635	17.635	6.1513	0.032	11.481	0	1.536	0
10	0	14.648	14.648	6.0129	0.028	10.215	0	1.434	0
5	0	12.358	12.358	5.8975	0.026	9.250	0	1.336	0
2	0	9.012	9.012	5.7143	0.024	7.676	0	1.174	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	Roghan Road

DATE OF SURVEY: **16/05/2011**	UBD REF: Map110, G14
AERIAL PHOTO No:	STRUCTURE ID: C0183B
BCC XS No:	CHAINAGE (m): Ch 982
STRUCTURE DESCRIPTION: ROAD CULVERT	
STRUCTURE SIZE 3/[3.6Wx1.5H] For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths	
UPSTREAM INVERT LEVEL: 3.7 mAHD DOWNSTREAM INVERT LEVEL: 3.61mAHD For culverts give floor level.	UPSTREAM OBVERT LEVEL: 5.2 mAHD DOWNSTREAM OBVERT LEVEL: 5.11 mAHD For bridges give bed level
For Culverts LENGTH OF CULVERT BARREL AT INVERT (m): 17.73m LENGTH OF CULVERT BARREL AT OBVERT (m):17.73m TYPE OF LINING: Concrete (e.g. concrete, stones, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? If yes give details ie. Plan number and/or survey book number. Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.	Refer to Sec2 of the attached surveyed sections
WEIR WIDTH (m):18m (In direction of flow, ie. distance from u/s face to d/s face)	LOWEST POINT OF WEIR (m AHD):7.03
HEIGHT OF GUARDRAILS: Handrail: 1.07m DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	
The following should also be provided. Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.	
CONSTRUCTION DATE OF CURRENT STRUCTURE:01/03/1975	PLAN NUMBER: W5280
HAS THE STRUCTURE BEEN UPGRADED? If yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	

CREEK	**Taigum Channel**
LOCATION	**Roghan Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0.61	34.082	34.692	5.999	0.116	16.199	0.645	2.104	0.946
50	0.263	31.758	32.021	5.895	0.097	16.203	0.339	1.96	0.776
20	0.011	27.497	27.508	5.7345	0.063	16.203	0.029	1.697	0.385
10	0	22.971	22.971	5.5806	0.037	16.200	0	1.418	0
5	0	19.284	19.284	5.4405	0.021	14.543	0	1.326	0
2	0	13.374	13.374	5.1681	0.007	10.109	0	1.323	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	Church Road

DATE OF SURVEY: **18/05/2011**	UBD REF: Map110, G13
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m): Ch1192

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 4/[3.3Wx1.35H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 2.66 mAHD UPSTREAM OBVERT LEVEL: 4.01 mAHD

DOWNSTREAM INVERT LEVEL: 2.46mAHD DOWNSTREAM OBVERT LEVEL: 3.81 mAHD
For culverts give floor level. For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 21.9m

LENGTH OF CULVERT BARREL AT OBVERT (m):21.9m

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Refer to Sec3 of the attached surveyed sections
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):30m LOWEST POINT OF WEIR (m AHD):5.96

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.18m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: 01/03/1998 PLAN NUMBER: WP865

HAS THE STRUCTURE BEEN UPGRADED?
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

Dimensions taken are as best a representation of the culverts as conditions on site allowed with regard to sediment, water and vegetation.

CREEK	**Taigum Channel**
LOCATION	**Church Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	4.65	18.94	23.59	5.2738	0.089	19.791	5.549	0.957	0.838
50	3.801	17.716	21.517	5.1948	0.077	19.794	4.775	0.895	0.796
20	3.032	16.711	19.743	5.0922	0.069	19.800	3.979	0.844	0.762
10	2.34	15.658	17.998	4.9978	0.061	19.795	3.214	0.791	0.728
5	1.728	14.489	16.217	4.914	0.052	19.794	2.534	0.732	0.682
2	0.7	12.185	12.885	4.7508	0.037	19.813	1.167	0.615	0.6

Photo Looking upstream

NA

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	401A Church Rd

DATE OF SURVEY: **18/05/2011**	UBD REF: Map110, G13
AERIAL PHOTO No:	STRUCTURE ID:
BCC XS No:	CHAINAGE (m): Ch1281

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 2/[1.8Wx0.6H]m RCP
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 2.19 mAHD UPSTREAM OBVERT LEVEL: 2.79mAHD

DOWNSTREAM INVERT LEVEL: 2.16mAHD DOWNSTREAM OBVERT LEVEL: 2.76mAHD
For culverts give floor level. For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 3.87

LENGTH OF CULVERT BARREL AT OBVERT (m):3.87

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Refer to Sec4 of the attached surveyed sections
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):10m LOWEST POINT OF WEIR (m AHD):5.46

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.25m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: Not Available

HAS THE STRUCTURE BEEN UPGRADED?
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

LOCATION	**401A Church Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	6.439	6.632	13.071	5.0864	0.149	2.160	4.351	3.07	1.48
50	6.332	6.616	12.948	5.0245	0.164	2.160	4.302	3.063	1.472
20	6.036	6.598	12.634	4.9356	0.218	2.160	4.140	3.055	1.458
10	5.114	6.57	11.684	4.8604	0.308	2.160	3.695	3.042	1.384
5	4.369	6.55	10.919	4.7967	0.397	2.160	3.315	3.032	1.318
2	3	6.517	9.517	4.6689	0.577	2.160	2.558	3.017	1.173

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	401 Church Rd

DATE OF SURVEY: **18/05/2011**	UBD REF: Map110, G13
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m): Ch1342

STRUCTURE DESCRIPTION: Timber Bridge

STRUCTURE SIZE 5.0m Span (3.9m width)
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 1.6mAHD UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL: 1.6mAHD DOWNSTREAM OBVERT LEVEL:
For culverts give floor level. For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 5.15m

LENGTH OF CULVERT BARREL AT OBVERT (m): 5.15m

TYPE OF LINING: No Lining
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Refer to Sec5 of the attached surveyed sections
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):7.156 LOWEST POINT OF WEIR (m AHD):4.2

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.0m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: Not Available

HAS THE STRUCTURE BEEN UPGRADED?
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Taigum Channel**
LOCATION	**401 Church Rd**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	7.033	35.43	42.463	4.628	0.394	11.156	6.394	3.176	1.1
50	3.736	34.052	37.788	4.5073	0.36	11.154	4.009	3.053	0.932
20	0.528	30.815	31.343	4.3028	0.276	11.153	0.980	2.763	0.539
10	0	25.944	25.944	4.0706	0.166	11.154	0	2.326	0
5	0	21.732	21.732	3.8945	0.095	11.116	0	1.955	0
2	0	15.124	15.124	3.6145	0.014	8.314	0	1.819	0

Photo Looking upstream

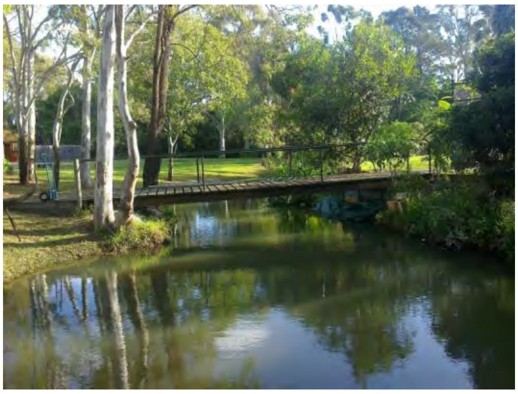


Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	334 Muller Road

DATE OF SURVEY: **24/05/2011**	UBD REF: Map110, K13
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m): Ch1985

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE *2/1.825m RCP & **1/1.825m RCP & ***1/1.425m RCP
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: (mAHD)
*0.9 & **-0.32&***1.72

UPSTREAM OBVERT LEVEL: (mAHD)
***3.24

DOWNSTREAM INVERT LEVEL: (mAHD)
*1&**-0.41&***1.64
For culverts give floor level.
* Pipe1 ** Pipe2 *** Pipe3

DOWNSTREAM OBVERT LEVEL: (mAHD)
***3.15
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 4.7m

LENGTH OF CULVERT BARREL AT OBVERT (m):4.7m

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Refer to Sec7 of the attached surveyed sections
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):5.5m

LOWEST POINT OF WEIR (m AHD):3.4

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: Not Available

HAS THE STRUCTURE BEEN UPGRADED?
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Taigum Channel**
LOCATION	**334 Muller Road**

ARI (years)	DISCHARGE (m^3/s)					U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)				VELOCITY (m/s)			
	Weir	Structure	Structure	Structure	Total			Structure	Structure	Structure	Weir	Structure	Structure	Structure	Weir
100	0.798	16.317	8.159	3.862	29.136	3.5257	0.075	5.230	2.615	1.287	1.269	3.12	3.12	3.001	0.629
50	0	14.883	7.442	3.381	25.706	3.3704	0.073	5.229	2.615	1.199	0	2.846	2.846	2.819	0
20	0	13.767	6.901	2.876	23.544	3.1263	0.064	5.181	2.614	1.094	0	2.657	2.64	2.63	0
10	0	10.922	5.997	2.386	19.305	2.8851	0.076	4.688	2.614	1.088	0	2.33	2.294	2.193	0
5	0	9.168	5.393	1.74	16.301	2.7035	0.112	4.372	2.614	0.879	0	2.097	2.063	1.98	0
2	0	6.245	5.339	0.753	12.337	2.3528	0.114	3.104	2.615	0.537	0	2.012	2.042	1.403	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	350 Muller Road

DATE OF SURVEY: **20/05/2011**	UBD REF: Map110, K13
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE *1/1.725m RCP & **1/1.625m RCP
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: (mAHD)
*-0.45& **-0.51

UPSTREAM OBVERT LEVEL: (mAHD)
*1.32&**1.25

DOWNSTREAM INVERT LEVEL: (mAHD)
*-0.26& **-0.67
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: (mAHD)
*1.49&**1.09
For bridges give bed level

* Pipe1 ** Pipe2

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): *9.9m&**9.56m

LENGTH OF CULVERT BARREL AT OBVERT (m): *9.9m&**9.56m

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? Refer to Sec8 of the attached surveyed sections
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 0.7m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: Not Available

HAS THE STRUCTURE BEEN UPGRADED?
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Taigum Channel**
LOCATION	**350 Muller Road**

ARI (years)	DISCHARGE (m^3/s)				U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)			VELOCITY (m/s)		
	Weir	Structure	Structure	Total			Structure	Structure	Weir	Structure	Structure	Weir
100	N/A	7.181	6.87		3.4802	0.006	2.321	2.138	N/A	3.094	3.214	N/A
50	N/A	7.165	6.909		3.2764	0.023	2.302	2.137	N/A	3.113	3.233	N/A
20	N/A	7.162	6.802		3.0423	0.004	2.327	2.137	N/A	3.078	3.183	N/A
10	N/A	7.134	6.765		2.7844	0.021	2.322	2.137	N/A	3.072	3.166	N/A
5	N/A	7.038	6.812		2.5665	0.005	2.303	2.137	N/A	3.056	3.188	N/A
2	N/A	5.878	5.867		2.1583	0.032	2.256	2.137	N/A	2.606	2.745	N/A

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	Gateway Motorway (Downstream of Taigum Channel)

DATE OF SURVEY: **20/05/2011**	UBD REF: Map110, K13
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE *2/[2.4Wx2.1H] & *2/[2.4Wx1.9H] &**1/[2.4Wx2.5H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: (mAHD)
*-0.5 & **-0.8

UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL: (mAHD)
*&** -1.12
For culverts give floor level.
* Pipe1 ** Pipe2

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 47m

LENGTH OF CULVERT BARREL AT OBVERT (m):47m

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE? No
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: MRD244255

HAS THE STRUCTURE BEEN UPGRADED?
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Taigum Channel**
LOCATION	**Gateway Motorway (Downstream of Taigum Channel)**

ARI (years)	DISCHARGE (m^3/s)					U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)				VELOCITY (m/s)			
	Weir	Structure	Structure	Structure	Total			Structure	Structure	Structure	Weir	Structure	Structure	Structure	Weir
100	N/A	14.543	13.625	8.781		3.3753	0.024	6.231	5.848	5.893	N/A	2.334	2.33	1.49	N/A
50	N/A	15.541	13.968	8.301		3.2053	0.003	6.997	5.798	5.362	N/A	2.221	2.409	1.548	N/A
20	N/A	17.478	15.35	10.177		2.9789	0.044	7.782	6.834	5.822	N/A	2.246	2.246	1.748	N/A
10	N/A	13.755	13.352	6.914		2.6391	0.006	5.244	5.224	4.742	N/A	2.623	2.556	1.458	N/A
5	N/A	15.728	14.136	8.481		2.445	0.014	6.096	6.693	5.412	N/A	2.58	2.112	1.567	N/A
2	N/A	16.235	14.591	8.543		2.0743	0.012	5.953	6.909	5.290	N/A	2.727	2.112	1.615	N/A

Photo Looking upstream
NA

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Taigum Channel**
LOCATION	Gateway Motorway (Downstream of Muller Road)

DATE OF SURVEY: **N/A**	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: D17000016
BCC XS No:	CHAINAGE (m):
STRUCTURE DESCRIPTION: ROAD CULVERT	
STRUCTURE SIZE 3/[1.5Wx1.5H] For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths	
UPSTREAM INVERT LEVEL: -0.215 mAHD DOWNSTREAM INVERT LEVEL: -1.115mAHD For culverts give floor level.	UPSTREAM OBVERT LEVEL: DOWNSTREAM OBVERT LEVEL: For bridges give bed level
For Culverts LENGTH OF CULVERT BARREL AT INVERT (m): 46.8m LENGTH OF CULVERT BARREL AT OBVERT (m): 46.8m TYPE OF LINING: Concrete (e.g. concrete, stones, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? No If yes give details ie. Plan number and/or survey book number. Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.	
WEIR WIDTH (m): (In direction of flow, ie. distance from u/s face to d/s face)	LOWEST POINT OF WEIR (m AHD):
HEIGHT OF GUARDRAILS: Handrail: DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	
The following should also be provided. Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.	
CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: MRD244255 HAS THE STRUCTURE BEEN UPGRADED? If yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	

CREEK	**Taigum Channel**
LOCATION	**Gateway Motorway (Downstream of Muller Road)**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	N/A	6.405	6.405	3.4627	0.052	6.749	N/A	0.949	N/A
50	N/A	6.483	6.483	3.306	0.092	6.753	N/A	0.96	N/A
20	N/A	6.202	6.202	3.0469	0.096	6.749	N/A	0.919	N/A
10	N/A	5.906	5.906	2.8049	0.103	6.750	N/A	0.875	N/A
5	N/A	5.425	5.425	2.5226	0.029	6.748	N/A	0.804	N/A
2	N/A	5.553	5.553	2.1386	0.009	6.747	N/A	0.823	N/A

Photo Looking upstream

N/A

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	CTC Old Northern Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):
STRUCTURE DESCRIPTION: ROAD CULVERT	
STRUCTURE SIZE 5/[3.6Wx2.7H] For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths	
UPSTREAM INVERT LEVEL: 40.159 mAHD DOWNSTREAM INVERT LEVEL: 38.52 mAHD For culverts give floor level.	UPSTREAM OBVERT LEVEL: 42.859 mAHD DOWNSTREAM OBVERT LEVEL: 38.22 mAHD For bridges give bed level
For Culverts LENGTH OF CULVERT BARREL AT INVERT (m): 34.8 LENGTH OF CULVERT BARREL AT OBVERT (m): 34.8 TYPE OF LINING: Concrete (e.g. concrete, stones, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? If yes give details ie. Plan number and/or survey book number. Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.	
WEIR WIDTH (m): (In direction of flow, ie. distance from u/s face to d/s face)	LOWEST POINT OF WEIR (m AHD):
HEIGHT OF GUARDRAILS: Handrail: 1.2m DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	
The following should also be provided. Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.	
CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available	PLAN NUMBER: 270737
HAS THE STRUCTURE BEEN UPGRADED? No If yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	

CREEK	**CTC**
LOCATION	**Old Northern Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	103.0	103.0	43.0642	0.184	48.585	0	2.12	0
50	0	89.7	89.7	42.921	0.131	47.840	0	1.875	0
20	0	75.1	75.1	42.765	0.084	39.402	0	1.906	0
10	0	62.4	62.4	42.6314	0.054	32.981	0	1.892	0
5	0	53.2	53.2	42.531	0.037	32.459	0	1.639	0
2	0	38.737	38.7	42.354	0.019	19.614	0	1.975	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	CTC Hamilton Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION:

STRUCTURE SIZE 5/[3.6Wx2.7H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 37.7 mAHD

UPSTREAM OBVERT LEVEL: 40.4 mAHD

DOWNSTREAM INVERT LEVEL: 37.6 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 40.3 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 21.6

LENGTH OF CULVERT BARREL AT OBVERT (m): 21.6

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 47.965

LOWEST POINT OF WEIR (m AHD): 20.7

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: WP438

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Hamilton Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	107.5	107.5	40.628	0.418	46.984	0	2.288	0
50	0	93.58	93.58	40.448	0.344	43.934	0	2.13	0
20	0	78.27	78.27	40.241	0.268	37.183	0	2.105	0
10	0	64.88	64.88	40.0521	0.206	30.881	0	2.101	0
5	0	55.51	55.51	39.91	0.166	26.960	0	2.059	0
2	0	39.32	39.32	39.637	0.103	20.164	0	1.95	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Streisand

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 2/ 1.35m
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 36.15 mAHD

UPSTREAM OBVERT LEVEL: 37.5 mAHD

DOWNSTREAM INVERT LEVEL: 36.1 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 37.45 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 6.6

LENGTH OF CULVERT BARREL AT OBVERT (m): 6.6

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 6.6

LOWEST POINT OF WEIR (m AHD): 38.045

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: WP3457

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	CTC
LOCATION	**Streisand**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	15.101	10.571	25.67	39.0547	0.07	2.861	11.835	3.695	1.276
50	14.934	10.531	25.47	38.9771	0.075	2.861	11.722	3.681	1.274
20	14.795	10.507	25.30	38.8863	0.083	2.861	11.631	3.672	1.272
10	14.566	10.453	25.02	38.7993	0.091	2.861	11.515	3.653	1.265
5	14.38	10.404	24.784	38.7315	0.102	2.861	11.422	3.636	1.259
2	13.751	10.279	24.03	38.6028	0.146	2.862	11.063	3.592	1.243

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Beckett Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 4/[3.3Wx3.3H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 33.02 mAHD

UPSTREAM OBVERT LEVEL: 36.32 mAHD

DOWNSTREAM INVERT LEVEL: 32.91 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 36.21 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 25.6

LENGTH OF CULVERT BARREL AT OBVERT (m): 25.6

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: W8058, WP622, W8058

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	CTC
LOCATION	**Beckett Rd**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	3.7753	110.575	114.3503	37.175	0.61	43.568	17.717	2.538	0.2094
50	0	99.522	99.534	36.9534	0.495	43.554	0	2.285	0
20	0	83.294	83.294	36.6697	0.346	43.564	0	1.912	0
10	0	69.183	69.183	36.4212	0.231	43.293	0	1.598	0
5	0	58.968	58.968	36.264	0.18	41.910	0	1.407	0
2	0	41.73	41.73	35.9657	0.104	38.964	0	1.071	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Costner Place

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):
STRUCTURE DESCRIPTION: FOOTPATH CULVERT	
STRUCTURE SIZE 3/[2.1Wx2.1H] For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths	
UPSTREAM INVERT LEVEL: 31.424 mAHD DOWNSTREAM INVERT LEVEL: 31.409 mAHD For culverts give floor level.	UPSTREAM OBVERT LEVEL: 33.524 mAHD DOWNSTREAM OBVERT LEVEL: 33.509 mAHD For bridges give bed level
For Culverts LENGTH OF CULVERT BARREL AT INVERT (m): 2.6 LENGTH OF CULVERT BARREL AT OBVERT (m): 2.6 TYPE OF LINING: Concrete (e.g. concrete, stones, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? If yes give details ie. Plan number and/or survey book number. Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.	
WEIR WIDTH (m): 2.6 (In direction of flow, ie. distance from u/s face to d/s face)	LOWEST POINT OF WEIR (m AHD): 33.816
HEIGHT OF GUARDRAILS: Handrail: DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	
The following should also be provided. Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.	
CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available	PLAN NUMBER:
HAS THE STRUCTURE BEEN UPGRADED? No If yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	

CREEK	CTC
LOCATION	**Costner P**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	6.248	17.341	23.589	34.8018	0.048	13.227	9.510	1.311	0.657
50	6.01	17.161	23.171	34.7178	0.048	13.231	9.106	1.297	0.66
20	5.69	16.982	22.672	34.6173	0.049	13.226	8.531	1.284	0.667
10	5.289	16.736	22.025	34.5249	0.048	13.230	7.882	1.265	0.671
5	4.913	16.567	21.48	34.4525	0.048	13.232	7.300	1.252	0.673
2	4.131	16.2	20.331	34.3126	0.046	13.235	6.004	1.224	0.688

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	CTC Albany Ck Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 6/[3.0Wx3.0H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 20.95 mAHD

UPSTREAM OBVERT LEVEL: 23.95 mAHD

DOWNSTREAM INVERT LEVEL: 20.84 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 23.84 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 28.1

LENGTH OF CULVERT BARREL AT OBVERT (m): 28.1

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD): 26.995

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W5266, 255868

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	CTC
LOCATION	**Albany Ck Rd**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	136.823	136.8952	26.1607	0.216	53.995	0	2.534	0
50	0	119.344	119.344	25.959	0.147	54.002	0	2.21	0
20	0	98.622	98.622	25.7142	0.083	54.010	0	1.826	0
10	0	82.089	82.089	25.4996	0.047	54.006	0	1.52	0
5	0	69.427	69.427	25.316	0.028	53.987	0	1.286	0
2	0	48.657	48.657	24.9728	0.009	54.003	0	0.901	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	CTC Gympie Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD BRIDGE

STRUCTURE SIZE 2/ 14.35m Span (11.58m width)
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 14.92 mAHD

UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL:
14.92 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 39.628

LENGTH OF CULVERT BARREL AT OBVERT (m): 39.628

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 47.965

LOWEST POINT OF WEIR (m AHD): 20.7

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.2m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: 168248

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Gympie Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	133.115	133.115	19.5113	0.284	108.312	0	1.229	0
50	0	122.793	122.793	19.3707	0.241	108.379	0	1.133	0
20	0	105.565	105.565	19.1153	0.177	108.383	0	0.974	0
10	0	85.995	85.995	18.773	0.129	103.112	0	0.834	0
5	0	73.759	73.759	18.5248	0.113	94.201	0	0.783	0
2	0	52.337	52.337	18.0264	0.085	76.516	0	0.684	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Dorville Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 5/[3.6Wx3.6H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 12.37 mAHD
UPSTREAM OBVERT LEVEL: 15.97 mAHD

DOWNSTREAM INVERT LEVEL: 12.35 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 15.95 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 15

LENGTH OF CULVERT BARREL AT OBVERT (m): 15

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 15
LOWEST POINT OF WEIR (m AHD): 17.09

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 0.6m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available
PLAN NUMBER: W6794, W9758

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Dorville Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	127.757	127.757	16.9233	0.175	54.690	0	2.336	0
50	0	120.417	120.417	16.8158	0.151	64.810	0	1.858	0
20	0	104.884	104.884	16.5781	0.106	52.998	0	1.979	0
10	0	86.118	86.118	16.2577	0.064	38.411	0	2.242	0
5	0	73.451	73.451	16.0033	0.04	45.821	0	1.603	0
2	0	51.902	51.902	15.4909	0.026	34.304	0	1.513	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	Zillmere Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: E15017176
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE * 5/[3.6Wx2.4H] & **1/1.8m
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL:
*&** 12.86 mAHD

UPSTREAM OBVERT LEVEL:
*15.26 **14.66 mAHD

DOWNSTREAM INVERT LEVEL:
*&**12.68 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
*15.08 **14.48 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 27.6

LENGTH OF CULVERT BARREL AT OBVERT (m): 27.6

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):27.6

LOWEST POINT OF WEIR (m AHD): 18.035

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.125m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: W10748

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Zillmere Road**

ARI (years)	DISCHARGE (m^3/s)				U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)			VELOCITY (m/s)		
	Weir	Structure	Structure	Total			Structure	Structure	Weir	Structure	Structure	Weir
100	0	94.0	5.145	99.145	17.071	0.126	43.199	2.543	0	2.176	2.023	0
50	0	82.163	4.486	86.649	16.887	0.089	43.198	2.543	0	1.902	1.764	0
20	0	68.999	3.751	72.75	16.649	0.055	43.205	2.273	0	1.597	1.65	0
10	0	67.524	3.669	71.193	16.62	0.052	43.202	2.198	0	1.563	1.669	0
5	0	49.627	2.594	52.221	16.1582	0.019	32.844	1.565	0	1.511	1.658	0
2	0	34.911	1.753	36.664	15.6785	0.009	23.879	1.060	0	1.462	1.654	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	LCTC Gympie Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: F14000002
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE *6/[2.0W] & ** 1/[3.35W x 2.45H] & *** 2/[2.3Wx2.45H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL:
*16, **&***16.125 mAHD

UPSTREAM OBVERT LEVEL:
*18, **&***18.575 mAHD

DOWNSTREAM INVERT LEVEL:
*15.5, **&***15.979 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
*17.5, **&*** 18.429 mAHD

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): *44 , **&*** 40

LENGTH OF CULVERT BARREL AT OBVERT (m): *44 , **&*** 40

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):44

LOWEST POINT OF WEIR (m AHD):19.75

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 0.9m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: W5868

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

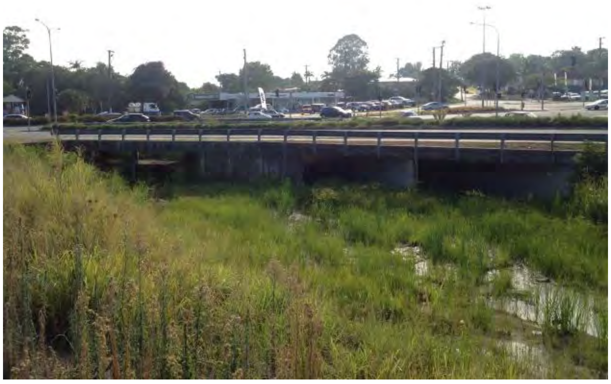
ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**LC Gympie Road**

ARI (years)	DISCHARGE (m^3/s)					U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	VELOCITY (m/s)			
	Weir	Structure	Structure	Structure	Total			Structure	Structure	Structure	Weir
100	2.22	24.408	18.766	24.976	70.37	19.87	0.492	2.591	2.286	2.216	0.581
50	0.093	24.271	18.576	24.724	67.664	19.7649	0.514	2.577	2.263	2.194	0.202
20	0	23.938	18.124	24.121	66.183	19.5811	0.505	2.541	2.208	2.14	0
10	0	23.797	18.235	24.27	66.302	19.5683	0.51	2.526	2.222	2.154	0
5	0	19.211	13.891	18.488	51.59	19.0403	0.274	2.083	1.692	1.64	0
2	0	13.535	9.691	12.902	36.128	18.5653	0.133	2.346	1.568	1.571	0

Photo Looking upstream

Photo Looking downstream



HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	LCTC Gayford Street

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: F140000007
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 2/[4.0Wx2.0H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 16.4 mAHD

UPSTREAM OBVERT LEVEL: 18.4 mAHD

DOWNSTREAM INVERT LEVEL: 16.33 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 18.33 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 18

LENGTH OF CULVERT BARREL AT OBVERT (m): 18

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 18

LOWEST POINT OF WEIR (m AHD): 19.581

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W5868

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Gayford**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	3.765	49.691	53.456	19.8936	0.313	31.450	6.571	1.58	0.573
50	3.063	49.581	52.644	19.7888	0.213	31.460	5.364	1.576	0.571
20	0.451	49.325	49.776	19.6223	0.18	31.538	1.323	1.564	0.341
10	0.139	42.359	42.498	19.5998	0.634	31.993	0.602	1.324	0.231
5	0	45.462	45.462	19.1147	0.136	29.049	0	1.565	0
2	0	32.027	32.027	18.5856	0.041	20.399	0	1.57	0

Photo Looking upstream

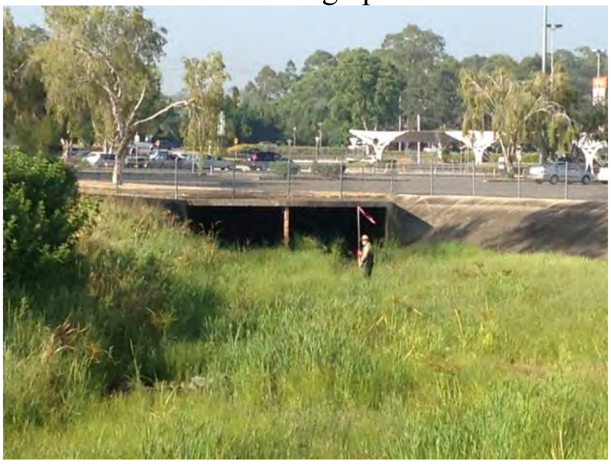
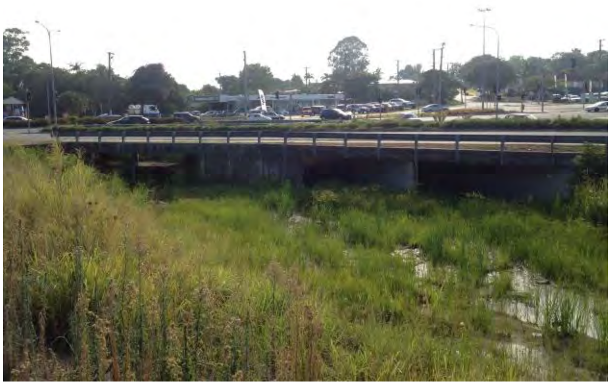


Photo Looking downstream



HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	LCTC Albany Creek Rd US

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: F140000003
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 3/[4.6Wx2.33H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 19.279 mAHD

UPSTREAM OBVERT LEVEL: 21.609 mAHD

DOWNSTREAM INVERT LEVEL: 19.259 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 21.589 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 3

LENGTH OF CULVERT BARREL AT OBVERT (m):

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W5868

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Albany Creek US**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	87.485	87.485	22.0754	0.12	26.170	0	3.343	0
50	0	75.777	75.777	21.8388	0.124	23.695	0	3.198	0
20	0	64.098	64.098	21.5615	0.109	20.940	0	3.061	0
10	0	52.636	52.636	21.2838	0.084	18.163	0	2.898	0
5	0	44.523	44.523	21.0646	0.087	16.167	0	2.754	0
2	0	31.023	31.023	20.642	0.025	16.141	0	1.922	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	LCTC Albany Creek RD DS 1

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: F14000004
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 6/[2.13Wx2.33H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 19.259 mAHD

UPSTREAM OBVERT LEVEL: 21.589 mAHD

DOWNSTREAM INVERT LEVEL: 19.159 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 21.48 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 15

LENGTH OF CULVERT BARREL AT OBVERT (m): 15

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 0.5m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W5868

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Albany Creek Rd DS 1**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	86.851	86.851	21.9557	0.178	20.679	0	4.2	0
50	0	75.437	75.437	21.7143	0.222	18.826	0	4.007	0
20	0	63.699	63.699	21.4527	0.213	16.816	0	3.788	0
10	0	51.986	51.986	21.1994	0.217	14.702	0	3.536	0
5	0	44.189	44.189	20.978	0.188	13.179	0	3.353	0
2	0	31.022	31.022	20.6168	0.025	10.410	0	2.98	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	LCTC Albany Creek RD DS 2

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: F14000004
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 3/[4.6Wx2.33H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 19.159 mAHD

UPSTREAM OBVERT LEVEL: 21.489 mAHD

DOWNSTREAM INVERT LEVEL: 18.1 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 20.43 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 17

LENGTH OF CULVERT BARREL AT OBVERT (m): 17

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W5868

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Albany Creek Rd DS 2**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	87.052	87.052	21.7781	0.608	21.017	0	4.142	0
50	0	75.446	75.446	21.4925	0.392	19.315	0	3.906	0
20	0	63.524	63.524	21.2392	0.225	17.225	0	3.688	0
10	0	52.083	52.083	20.9821	0.092	15.110	0	3.447	0
5	0	44.1	44.1	20.7899	0.169	13.503	0	3.266	0
2	0	31.022	31.022	20.449	0.387	10.679	0	2.905	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	Horn Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: B1000
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: FOOTPATH BRIDGE

STRUCTURE SIZE 1/[16.8m span (4.292m W)]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 25.46 mAHD

UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL:
25.46 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 4.292

LENGTH OF CULVERT BARREL AT OBVERT (m): 4.292

TYPE OF LINING: Steel
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W8377

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Horn Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	52.578	52.578	28.5522	0.307	16.344	0	3.217	0
50	0	49.838	49.838	28.4275	0.276	15.565	0	3.202	0
20	0	44.828	44.828	28.242	0.217	14.057	0	3.189	0
10	0	39.587	39.587	28.0701	0.168	12.516	0	3.163	0
5	0	34.787	34.787	27.9229	0.119	11.072	0	3.142	0
2	0	25.061	25.061	26.6782	0.071	8.084	0	3.1	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	Martindale Street

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: G14100100
BCC XS No:	CHAINAGE (m):
STRUCTURE DESCRIPTION: ROAD CULVERT	
STRUCTURE SIZE 5/[3.6Wx3.0H] For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths	
UPSTREAM INVERT LEVEL: 28.65 mAHD DOWNSTREAM INVERT LEVEL: 28.56 mAHD For culverts give floor level.	UPSTREAM OBVERT LEVEL: 31.65 mAHD DOWNSTREAM OBVERT LEVEL:31.56 mAHD For bridges give bed level
For Culverts LENGTH OF CULVERT BARREL AT INVERT (m): 17.08 LENGTH OF CULVERT BARREL AT OBVERT (m): 17.08 TYPE OF LINING: Concrete (e.g. concrete, stones, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? If yes give details ie. Plan number and/or survey book number. Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.	
WEIR WIDTH (m): (In direction of flow, ie. distance from u/s face to d/s face)	LOWEST POINT OF WEIR (m AHD):
HEIGHT OF GUARDRAILS: Handrail: 1.5m DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	
The following should also be provided. Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.	
CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available HAS THE STRUCTURE BEEN UPGRADED? No If yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	PLAN NUMBER: W7398

CREEK	**LCTC**
LOCATION	**Martindale Street**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	62.814	62.814	32.101	0.121	54.0103	0	1.163	0
50	0	54.301	54.301	31.9799	0.09	53.9771	0	1.006	0
20	0	44.698	44.698	31.8239	0.061	53.9831	0	0.828	0
10	0	37.105	37.105	31.6937	0.042	52.1138	0	0.712	0
5	0	31.384	31.384	31.5858	0.029	44.5795	0	0.704	0
2	0	22.463	22.463	31.3993	0.017	33.0825	0	0.679	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Little Cabbage Tree Creek**
LOCATION	LC Hamilton Rd

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: BEC606-S-LC/001
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD BRIDGE

STRUCTURE SIZE 1/[32.5m span (14.34 Width)]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 34.101 mAHD

UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL: 34.101 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 14.34

LENGTH OF CULVERT BARREL AT OBVERT (m): 14.34

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.9m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER:

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**LCTC**
LOCATION	**Hamilton Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	32.141	32.141	37.3429	0.005	15.640	0	2.055	0
50	0	31.466	31.466	37.2099	0.008	15.900	0	1.979	0
20	0	30.049	30.049	37.0458	0.009	15.386	0	1.953	0
10	0	28.536	28.536	36.9051	0.01	15.774	0	1.809	0
5	0	25.773	25.773	36.7841	0.01	10.611	0	2.429	0
2	0	18.482	18.482	36.5646	0.008	9.136	0	2.023	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Carseldine**
LOCATION	North Coast Line (telegraph rd) (NCoastRail)

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: W0072
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: RAIL BRIDGE

STRUCTURE SIZE 2 parallel bridges, US 10.3m + 9.3m, DS 2x13.5m span
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 8.285 mAHD

UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL:
8.285 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 14 across both

LENGTH OF CULVERT BARREL AT OBVERT (m): 14 across both

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 16.25

LOWEST POINT OF WEIR (m AHD): 14.351

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 0.9m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: QR plan S 10878 & S25165

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Cabbage Tree Creek**
LOCATION	North Coast Line (telegraph rd)

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	217.94	217.94	13.4894	0.815	57.978	0	3.759	0
50	0	191.719	191.719	13.1062	0.607	57.991	0	3.306	0
20	0	156.981	156.981	12.6062	0.394	50.869	0	3.086	0
10	0	128.107	128.107	12.2094	0.292	43.397	0	2.952	0
5	0	107.337	107.337	11.9582	0.272	38.117	0	2.816	0
2	0	74.612	74.612	11.5395	0.236	28.554	0	2.613	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Beams Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE *5/[3.6Wx1.8H] + **4/[3.6Wx3.6H] + ***1/[3.6Wx2.7H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL:
*9.2 mAHD, **7.4 mAHD, ***8.7 mAHD

UPSTREAM OBVERT LEVEL:
*11 mAHD,**11 mAHD, ***11.4 mAHD

DOWNSTREAM INVERT LEVEL:
*9.1 mAHD & **7.26 mAHD & ***8.58 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
*10.9 mAHD, **10.86 mAHD, ***11.28 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): * & *** 24.4, **25

LENGTH OF CULVERT BARREL AT OBVERT (m): * & *** 24.4, **25

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 25

LOWEST POINT OF WEIR (m AHD): 12.98

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: W10112

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Beams Road**

ARI (years)	DISCHARGE (m^3/s)					U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	VELOCITY (m/s)			
	Weir	Structure	Structure	Structure	Total			Structure	Structure	Structure	Weir
100	0	65.584	109.429	20.261	195.274	12.4499	0.141	2.024	2.111	2.085	0
50	0	60.971	101.777	18.842	181.59	12.2801	0.12	1.882	1.963	1.938	0
20	0	51.808	86.713	16.04	154.561	11.9868	0.078	1.599	1.673	1.65	0
10	0	42.205	71	13.114	126.319	11.6626	0.043	1.303	1.37	1.349	0
5	0	35.002	59.32	11.353	105.675	11.3896	0.024	1.08	1.144	1.168	0
2	0	24.912	42	6.581	73.493	10.9219	0.008	0.777	0.81	0.795	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Roghan Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: B9976
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD BRIDGE

STRUCTURE SIZE 2/ 17m span
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 2.958 mAHD

UPSTREAM OBVERT LEVEL:

DOWNSTREAM INVERT LEVEL: 2.958 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 15.355

LENGTH OF CULVERT BARREL AT OBVERT (m): 15.355

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 15.355

LOWEST POINT OF WEIR (m AHD): 9.48

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: W10119

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Roghan Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	194.746	194.746	8.1877	0.118	103.920	0	1.874	0
50	0	176.889	176.889	8.0354	0.095	95.719	0	1.848	0
20	0	150.375	150.375	7.7998	0.065	82.488	0	1.823	0
10	0	125.202	125.202	7.5753	0.49	69.518	0	1.801	0
5	0	107.365	107.365	7.3799	0.044	57.630	0	1.863	0
2	0	74.029	74.029	7.0379	0.032	40.787	0	1.815	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Lemke Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: B1240
BCC XS No:	CHAINAGE (m):
STRUCTURE DESCRIPTION: ROAD BRIDGE	
STRUCTURE SIZE 2/ 13.981m span For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths	
UPSTREAM INVERT LEVEL: -0.546 mAHD DOWNSTREAM INVERT LEVEL: -0.546 mAHD For culverts give floor level.	UPSTREAM OBVERT LEVEL: DOWNSTREAM OBVERT LEVEL: For bridges give bed level
For Culverts LENGTH OF CULVERT BARREL AT INVERT (m): 10.452 LENGTH OF CULVERT BARREL AT OBVERT (m): 10.452 TYPE OF LINING: Concrete (e.g. concrete, stones, brick, corrugated iron)	
IS THERE A SURVEYED WEIR PROFILE? If yes give details ie. Plan number and/or survey book number. Note: This section should be at the highest part of the road eg crown, kerb, hand rails guard rails whichever is higher.	
WEIR WIDTH (m): 11.919 (In direction of flow, ie. distance from u/s face to d/s face)	LOWEST POINT OF WEIR (m AHD): 5.35
HEIGHT OF GUARDRAILS: Handrail: 1.5m DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	
The following should also be provided. Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels. For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.	
CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available	PLAN NUMBER: W6661
HAS THE STRUCTURE BEEN UPGRADED? No If yes, explain type and date of upgrade. Include plan number and location if applicable. ADDITIONAL COMMENTS:	

CREEK	**CTC**
LOCATION	**Lemke Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	140.307	140.307	4.2705	0.205	69.597	0	2.016	0
50	0	137.902	137.902	4.1609	0.221	69.577	0	1.982	0
20	0	133.374	133.374	4.025	0.217	69.574	0	1.917	0
10	0	126.048	126.048	3.8912	0.194	69.601	0	1.811	0
5	0	117.105	117.105	3.7676	0.167	69.581	0	1.683	0
2	0	88.315	88.315	3.4492	0.093	69.594	0	1.269	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Gateway Mwy NB

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID:
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD BRIDGE

STRUCTURE SIZE 11 x 10m span
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: -1.31 mAHD

DOWNSTREAM INVERT LEVEL: -1.31 mAHD
For culverts give floor level.

UPSTREAM OBVERT LEVEL:

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 43.902

LENGTH OF CULVERT BARREL AT OBVERT (m): 43.902

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 43.902

(In direction of flow, ie. distance from u/s face to d/s face)

LOWEST POINT OF WEIR (m AHD): 6

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: C090-8000

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Gateway Mwy NB**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	266.259	266.259	3.7195	0.076	366.748	0	0.726	0
50	0	235.773	235.773	3.5003	0.061	355.615	0	0.663	0
20	0	198.909	198.909	3.2256	0.052	328.775	0	0.605	0
10	0	166.667	166.667	2.9666	0.043	304.693	0	0.547	0
5	0	140.025	140.025	2.7529	0.038	284.026	0	0.493	0
2	0	100.022	100.022	2.3781	0.032	247.579	0	0.404	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Cabbage Tree Creek**
LOCATION	Sandgate Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID:
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD BRIDGE

STRUCTURE SIZE 2 x 10.516m + 10.668m
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: -2.06 mAHD

DOWNSTREAM INVERT LEVEL: -2.06 mAHD
For culverts give floor level.

UPSTREAM OBVERT LEVEL:

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 70.441

LENGTH OF CULVERT BARREL AT OBVERT (m): 70.441

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 70.441

(In direction of flow, ie. distance from u/s face to d/s face)

LOWEST POINT OF WEIR (m AHD): 4.2

HEIGHT OF GUARDRAILS: Handrail: 1m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: 112833

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**CTC**
LOCATION	**Sandgate Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	252.459	252.459	3.1667	0.59	115.807	0	2.18	0
50	0	236.119	236.119	2.9278	0.524	115.801	0	2.039	0
20	0	203.764	203.764	2.5752	0.39	115.841	0	1.759	0
10	0	172.977	172.977	2.2456	0.281	115.781	0	1.494	0
5	0	146.954	146.954	1.9784	0.203	115.803	0	1.269	0
2	0	105.428	105.428	1.5529	0.105	115.855	0	0.91	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Carseldine**
LOCATION	CD_NCRail

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: N/A
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD BRIDGE

STRUCTURE SIZE 3/ 3.45m span
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 9.3 mAHD

DOWNSTREAM INVERT LEVEL: 9.3 mAHD
For culverts give floor level.

UPSTREAM OBVERT LEVEL:

DOWNSTREAM OBVERT LEVEL:
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 27

LENGTH OF CULVERT BARREL AT OBVERT (m): 27

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

(In direction of flow, ie. distance from u/s face to d/s face)

LOWEST POINT OF WEIR (m AHD):

HEIGHT OF GUARDRAILS: Handrail:

DESCRIPTION OF ALL HAND AND GUARD RAILS AND
HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available PLAN NUMBER: S24473#0026

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Carseldine**
LOCATION	**CD_NCRail**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	0	43.487	43.4892	11.7106	0.358	21.475	0	2.025	0
50	0	38.281	38.2896	11.6076	0.289	21.068	0	1.817	0
20	0	31.315	31.315	11.4704	0.206	20.467	0	1.53	0
10	0	25.858	25.858	11.3638	0.15	19.921	0	1.298	0
5	0	21.716	21.716	11.28	0.111	19.424	0	1.118	0
2	0	14.947	14.947	11.141	0.058	18.499	0	0.808	0

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Carseldine**
LOCATION	CD Lacey Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID: D14018831
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE *4/[3.3Wx1.5H] & ** 1/[3.3Wx1.8H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: -10.975 mAHD

UPSTREAM OBVERT LEVEL: 12.475

DOWNSTREAM INVERT LEVEL: 10.825 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 12.325
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 34.8

LENGTH OF CULVERT BARREL AT OBVERT (m): 34.8

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m): 34.8

LOWEST POINT OF WEIR (m AHD): 10.525

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 1.2m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: WP53853

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Carseldine**
LOCATION	**Lacey Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	9.083	28.55	37.633	12.2987	0.306	15.018	4.748	1.901	1.913
50	8.009	24.861	32.87	12.1895	0.265	13.352	4.553	1.862	1.759
20	6.896	21.044	27.94	12.0666	0.225	11.493	3.918	1.831	1.76
10	5.717	17.119	22.836	11.9428	0.175	9.596	3.278	1.784	1.744
5	4.885	14.222	19.107	11.8428	0.136	8.264	2.842	1.721	1.719
2	3.752	10.551	14.303	11.7055	0.094	6.570	2.173	1.606	1.727

Photo Looking upstream

Photo Looking downstream

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Carseldine**
LOCATION	CD Gympie Road

DATE OF SURVEY:	UBD REF:
AERIAL PHOTO No:	STRUCTURE ID:
BCC XS No:	CHAINAGE (m):

STRUCTURE DESCRIPTION: ROAD CULVERT

STRUCTURE SIZE 5/[1.5Wx0.9H]
For Culverts: Number of cells/pipes & sizes For Bridges: Number of Spans and their lengths

UPSTREAM INVERT LEVEL: 15.969 mAHD

UPSTREAM OBVERT LEVEL: 16.869 mAHD

DOWNSTREAM INVERT LEVEL: 15.783 mAHD
For culverts give floor level.

DOWNSTREAM OBVERT LEVEL: 16.683 mAHD
For bridges give bed level

For Culverts
LENGTH OF CULVERT BARREL AT INVERT (m): 30.88

LENGTH OF CULVERT BARREL AT OBVERT (m): 30.88

TYPE OF LINING: Concrete
(e.g. concrete, stones, brick, corrugated iron)

IS THERE A SURVEYED WEIR PROFILE?
If yes give details ie. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
eg crown, kerb, hand rails guard rails whichever is higher.

WEIR WIDTH (m):

LOWEST POINT OF WEIR (m AHD):

(In direction of flow, ie. distance from u/s face to d/s face)

HEIGHT OF GUARDRAILS: Handrail: 0.5m

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:

The following should also be provided.
Wingwall/Headwall details, entrance details eg. pipe flush with embankment or projecting, socket or square end, entrance rounding, levels.
For bridges, details of piers and section under bridge including abutment details. Specify Survey Book No.

CONSTRUCTION DATE OF CURRENT STRUCTURE: Not Available

PLAN NUMBER: 214775 & 214772

HAS THE STRUCTURE BEEN UPGRADED? No
If yes, explain type and date of upgrade. Include plan number and location if applicable.

ADDITIONAL COMMENTS:

CREEK	**Carseldine**
LOCATION	**Gympie Road**

ARI (years)	DISCHARGE (m^3/s)			U/S WATER LEVEL (m AHD)	AFFLUX AT MAX FLOW (mm)	AREA (m^2)		VELOCITY (m/s)	
	Weir	Structure	Total			Structure	Weir	Structure	Weir
100	*N/A	18.981	29.042	17.76	1.237	6.750	*N/A	2.812	*N/A
50	*N/A	18.439	24.5884	17.7026	1.189	6.749	*N/A	2.732	*N/A
20	*N/A	15.91	20.988	17.4376	0.972	6.750	*N/A	2.357	*N/A
10	*N/A	12.668	17.1012	17.1539	0.755	5.655	*N/A	2.24	*N/A
5	*N/A	10.099	14.0335	16.9559	0.617	4.717	*N/A	2.141	*N/A
2	*N/A	7.235	10.2168	16.7697	0.509	3.772	*N/A	1.918	*N/A

Note: *For the weir the flow over the road doesn't always occur over the structure and therefore is difficult to distinguish what values to use

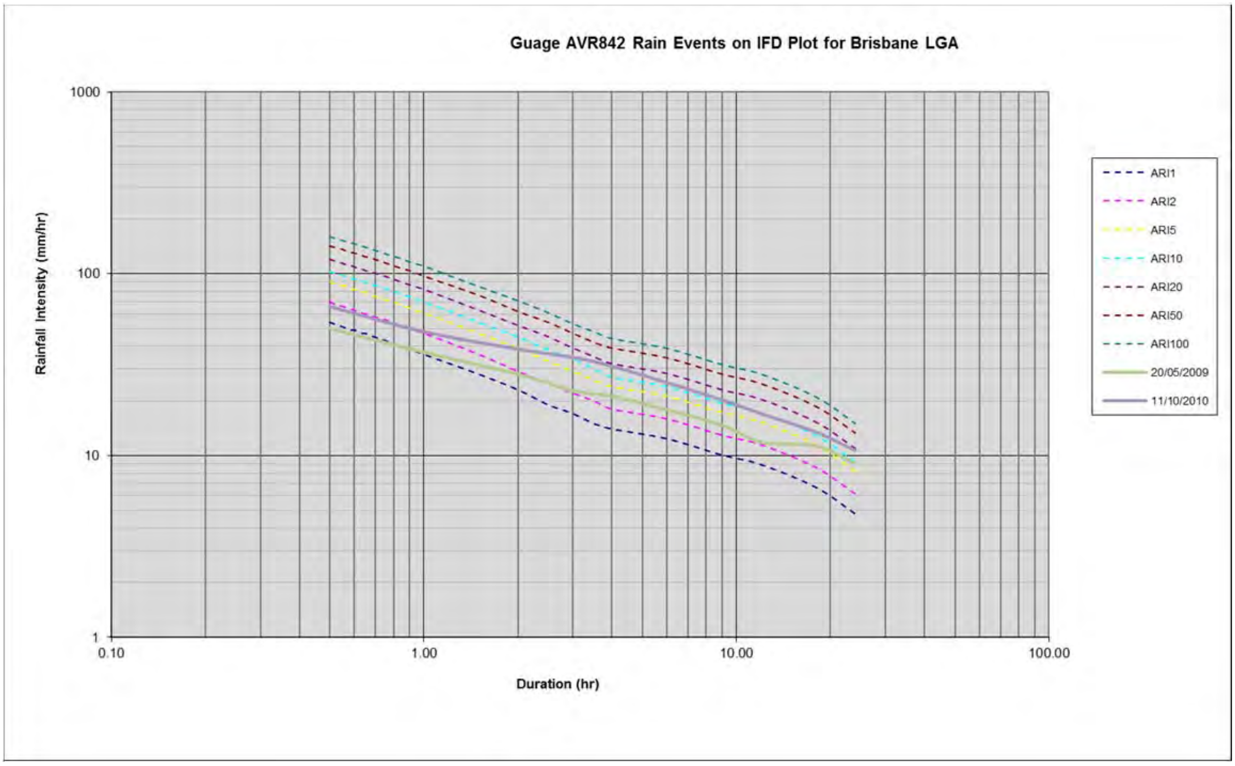
Photo Looking upstream

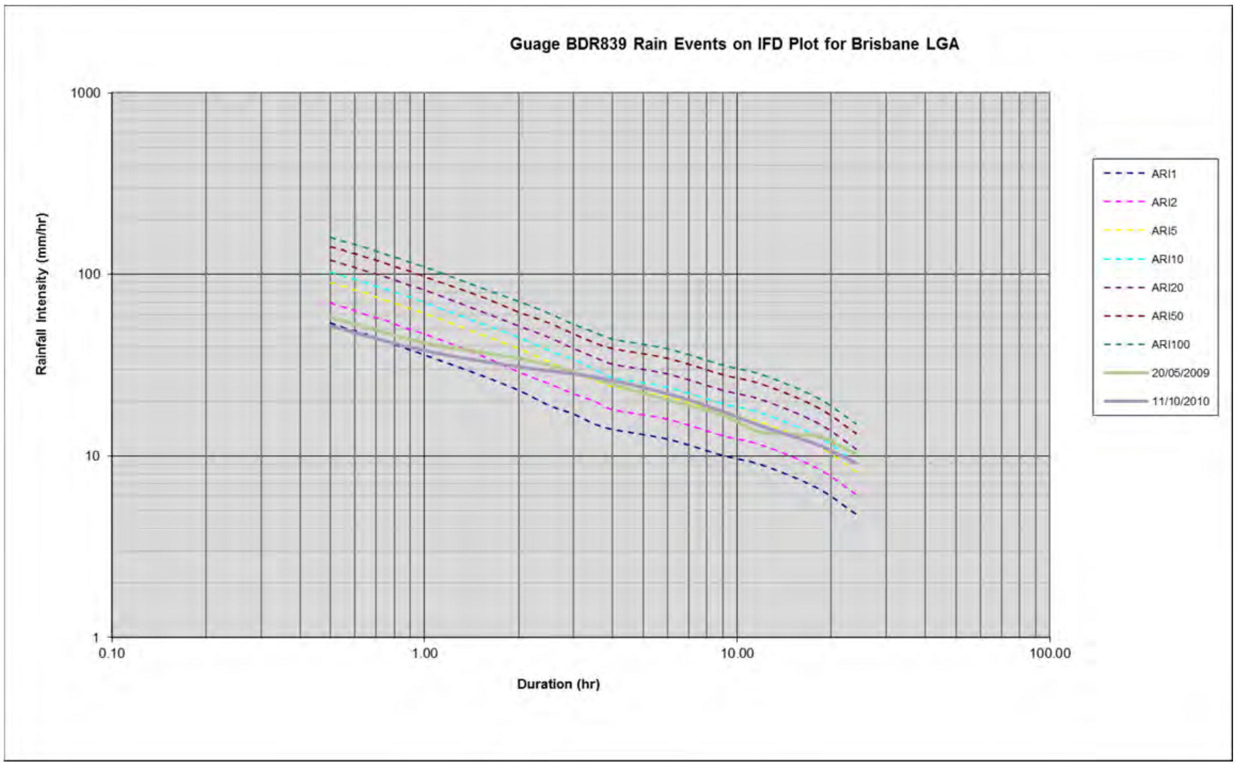
Photo Looking downstream

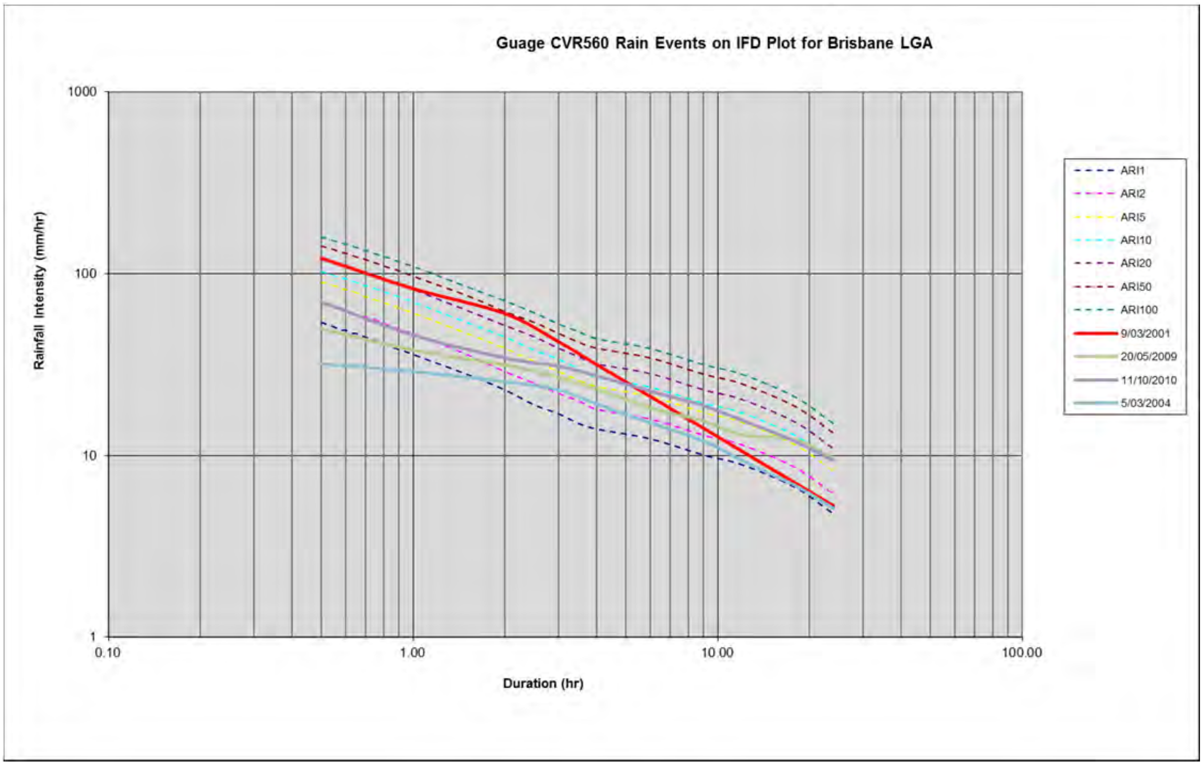
Appendix M

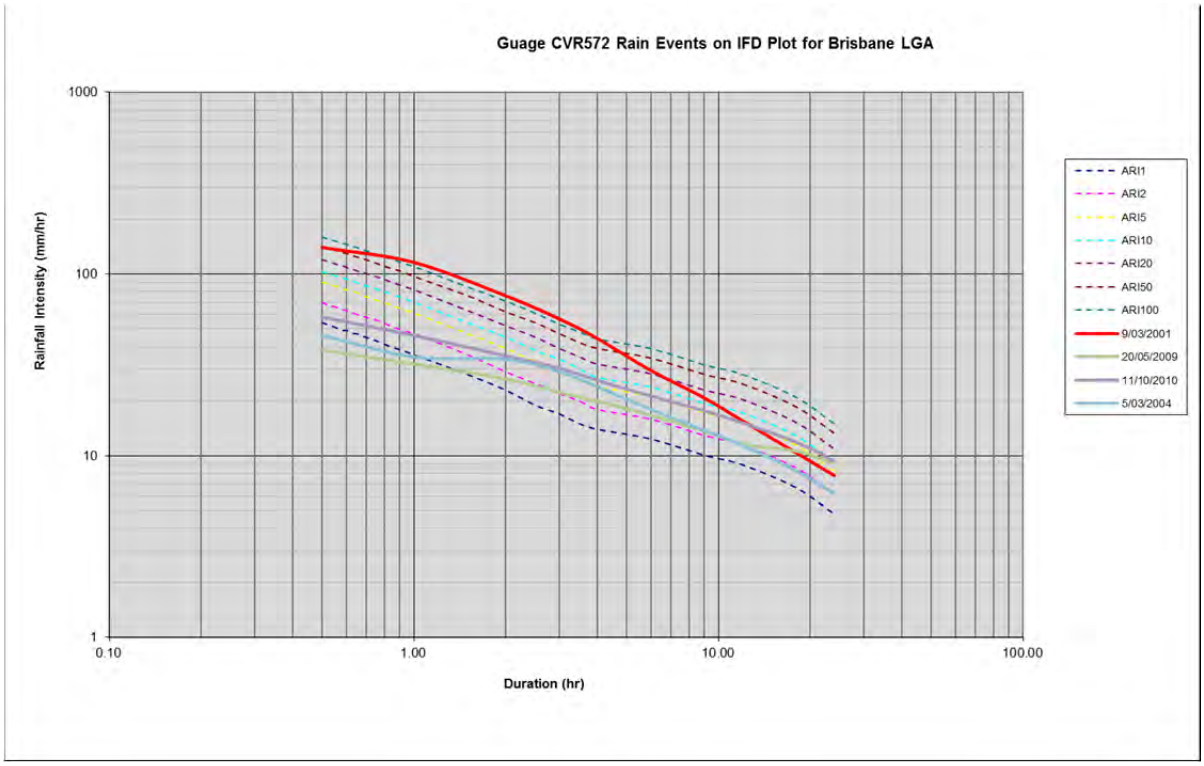
Historic Event IFD Graphs

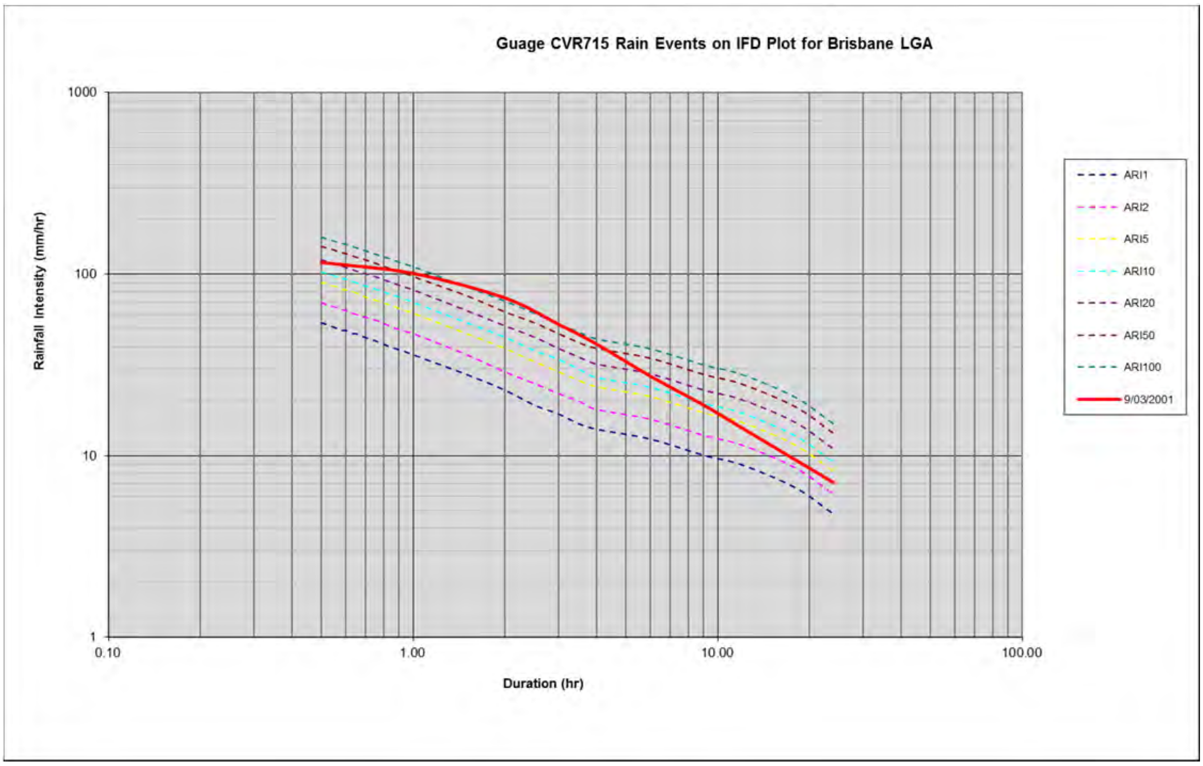
Appendix M Historic Event IFD Graphs

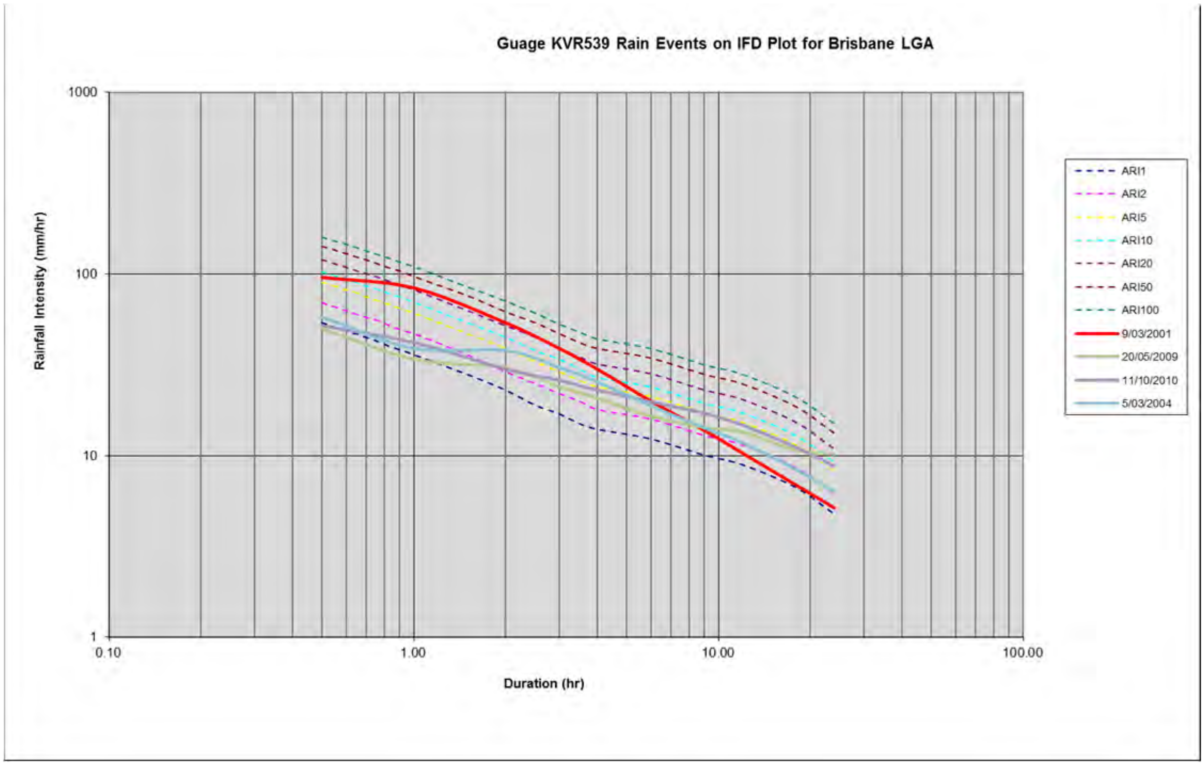


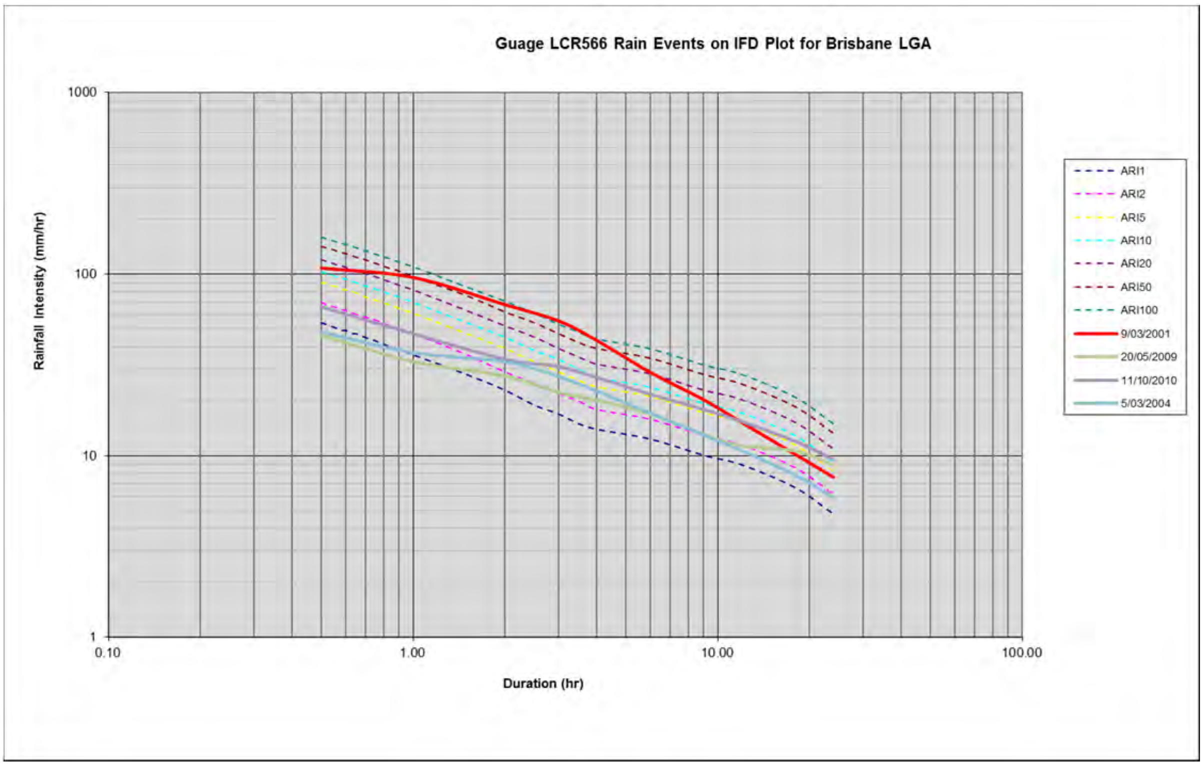


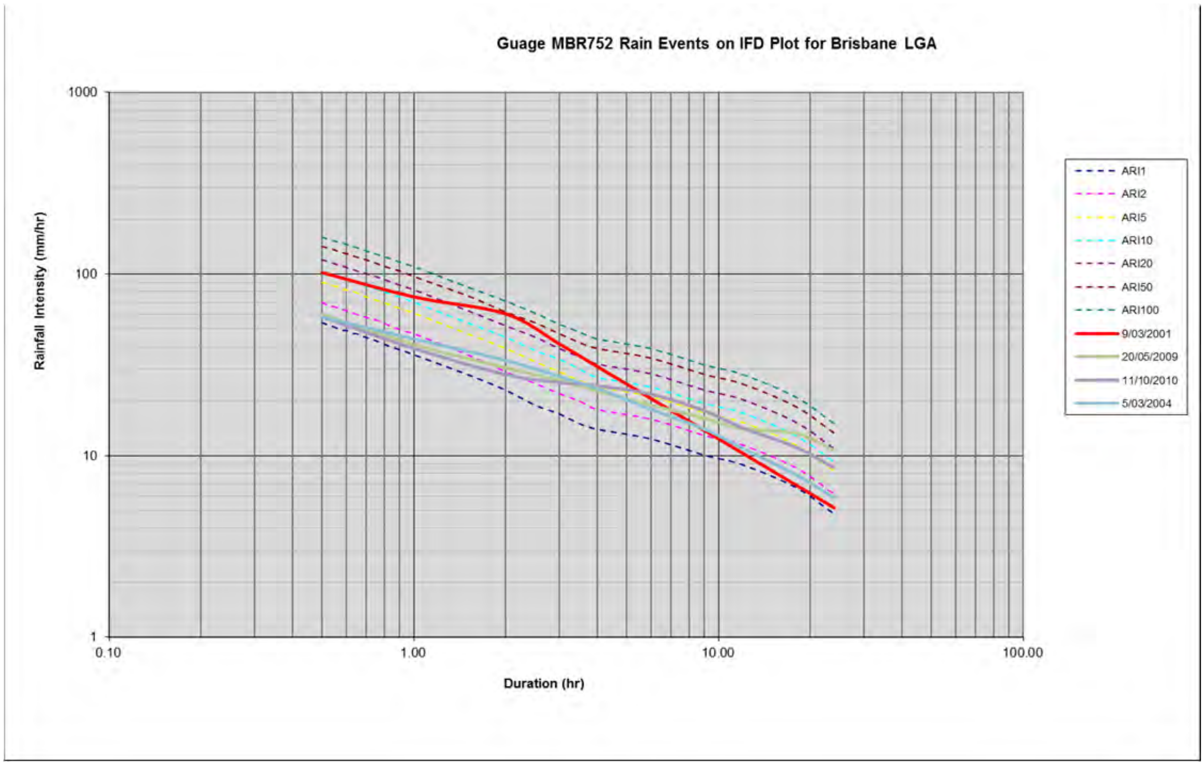

Guage CVR560 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
9/03/2001
20/05/2009
11/10/2010
5/03/2004

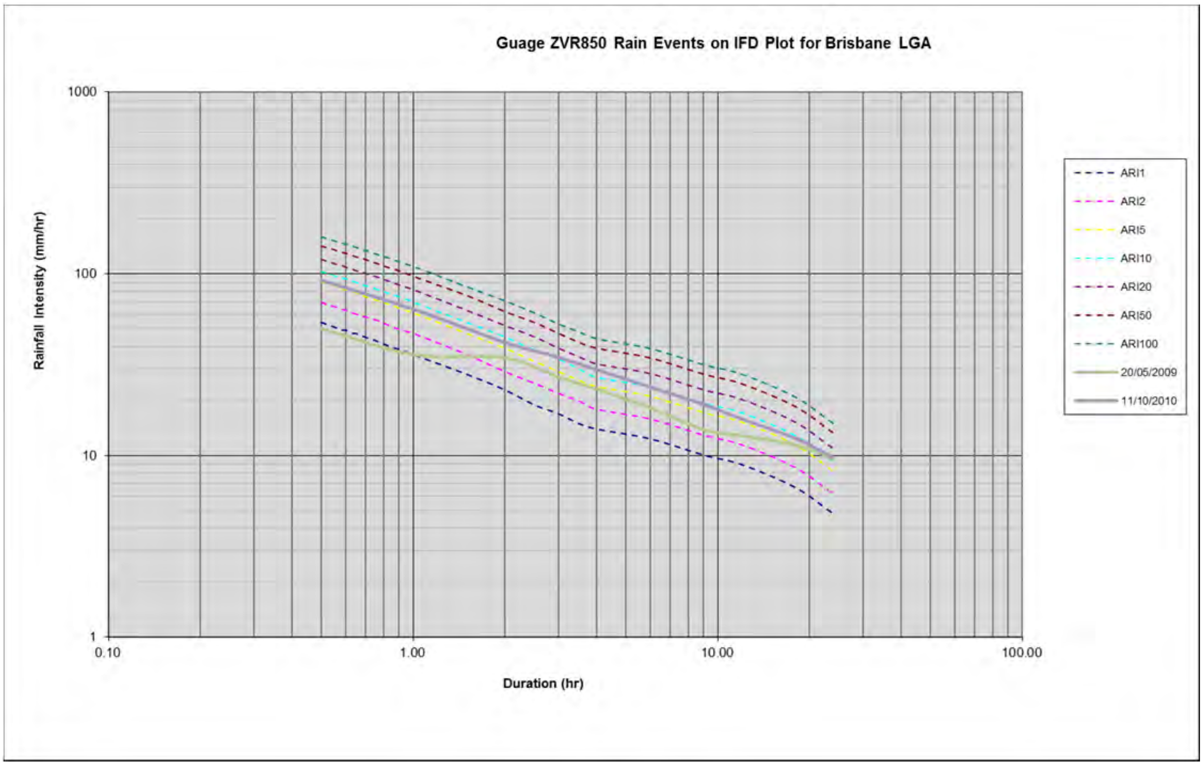

Guage CVR572 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
9/03/2001
20/05/2009
11/10/2010
5/03/2004


Guage CVR715 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
9/03/2001


Guage KVR539 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
9/03/2001
20/05/2009
11/10/2010
5/03/2004


Guage LCR566 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
9/03/2001
20/05/2009
11/10/2010
5/03/2004


Guage MBR752 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
9/03/2001
20/05/2009
11/10/2010
5/03/2004


Guage ZVR850 Rain Events on IFD Plot for Brisbane LGA
Rainfall Intensity (mm/hr)
1000
100
10
1
0.10
1.00
10.00
100.00
Duration (hr)
ARI1
ARI2
ARI5
ARI10
ARI20
ARI50
ARI100
20/05/2009
11/10/2010

Appendix N

Design Event Flood Maps – Volume 2

Appendix O

Cabbage Tree Creek Peer Review

Dedicated to a better Brisbane

MEMORANDUM

To: Richard Yearsley	Date: 22/10/2013
From: Megan Gould	
Re: Peer Review of Cabbage Tree Creek Flood Models	

Brisbane City Council

Flood Management

City Projects Office

Brisbane Infrastructure

GPO Box 1434
Brisbane Qld 4001
Phone: 07 3178 8685
Facsimile: 07 3334 0212
Email: megan.gould@brisbane.qld.gov.au
Internet: www.brisbane.qld.gov.au

1 Introduction

This review has been undertaken to ensure:

- Council has received all required data associated with the Cabbage Tree Creek Flood Study (AECOM 2013) to enable future adoption into Council systems
- The flood study has been delivered in accordance with Council procedures and methods
- The output is fit for purpose

The review is not a detailed technical review of the models. It is assumed that AECOM have applied best-practise Quality Assurance in producing the flood study and that the work has been prepared under suitably qualified RPEQ supervision as is required by State law.

Reference is made to the 'FLM - Cabbage Tree Creek Flood Study - Calibration & Verification Draft 1 - CPO Peer Review Comments 1' document which was used to track and close out issues during the study. Previous versions of the document are also saved at: G:\BI\CD\Proj12\121408_Update_of_Cabbage_Tree_Creek_Flood_Study\Flood Managment\Documents\Project_Management.

1.1 Files reviewed

G:\BI\CD\Proj12\121408_Update_of_Cabbage_Tree_Creek_Flood_Study\Flood Managment\Models\Final Models Provided 20131009

2 Hydrology Model

2.1 Sub-catchment representation

- 70 sub-catchments for 43km^2 is sufficient
- Delineation looks reasonable – similarly sized sub-catchments, no elongated/odd shapes, appropriate resolution for this type of study
- Catchment file looks correct (area matches; predominantly medium density land use); land use assignment for calibration events vs design events not checked
- Routing lengths and slopes not checked; consistency checks with hydraulic model undertaken and hydraulic model is being used to route flow
- Vector file not checked – set up and logic looks correct

2.2 Model parameters

- Beta of 6 is quite high, indicating significant sub-catchment storage; Alpha of 0.01 is low (indicating average velocities of 28 m/s) but model has achieved reasonable calibration

2.3 Calibration

- Event independent calibration of channel routing parameters was undertaken by Consultant, using a sinusoidal curve (in hydrology and hydraulic models) to set channel routing parameters (Alpha, X, n) and then sub-catchment routing parameters (loss values, Beta and m) adjusted for each event by iteration of the hydrology/hydraulic models; once the routing parameters were set, the calibration events were then matched by adjusting losses
- Event rainfall data not checked (depths and spatial variability) but report indicates that a thorough process has been applied
- Despite some uncertainty over the method applied, the overall calibration looks reasonable – peaks (at stream gauges and MHGs), timing and shape match pretty well

2.4 Design rainfall data

- AR&R design storms simulated
- IFD data (up to 100yr) spot checked (2yr and 100yr) against online IFD tool and correct
- 2000yr rainfall depth and pattern matches CPO used storm (FLM - DESIGN - BCC Catchments 2000yr PMP Superstorm.xlsx)
- PMF rainfall depth and pattern matches CPO used storm (FLM - DESIGN - BCC Catchments 2000yr PMP Superstorm.xlsx)
- 100yr6hr storm file set-up checked and looks correct
- CRC-Forge 200 and 500 yr rainfall depths checked against CPO data (Extreme Events_Rev03.xlsx) and match
- AR&R temporal patterns not checked (zone3.pat)
- IL = 10, CL = 0 adopted - unknown why industry standard values of IL = 0 and CL = 2.5 not used
- Model was run for 100yr event – ran successfully and outputs matched digital data

2.5 Consistency check

- Check was made by Consultant: FFA undertaken at stream gauge locations using City Gauge data (long term record) with good results

3 Hydraulic Model

3.1 Schematic

- Model includes Cabbage Tree Creek, Little Cabbage Tree Creek, Carseldine Channel and Taigum Channel utilising previously developed models/data
- Some minor tributaries and open channels excluded (but have had channel invert defined within 2D domain)
- 1D/2D TUFLOW model developed in ArcGIS, 4m grid
- Main creeks have been modelled in 1D (Estry) (cross section spreadsheets not checked)

3.2 Topography

- Model has used ALS (2009) and some 2013 survey as well as older data
- Major floodplain controls (motorway/railway embankments) should be reasonably represented by a 4m grid; modifications have been made to correct issues and define inverts/crests
- Ultimate topography has referenced Waterway Corridor (not FRL included in originally provided data)
- Spot check made of ultimate case topography modifications - set up seems to generally align with requirement to fill outside WC to 100yr-ult+300mm level. Breaklines have been used within the process to prevent ‘bleeding’ but these lines have not been provided. These breaklines impact the ultimate case mapping (examples shown in Attachment 1). The

process is very subjective and can be difficult to apply where there are parallel channels as is the case for Cabbage Tree Creek.

- A grid was created (Grid_Math) by subtracting the unmodified ALS from the 'ultimate_dem'. It is recognised that this comparison does not take account of topographic modifications (zsh, zln, etc) made to the existing case dtm. It demonstrates that the floodplain filling has occurred generally as expected.

3.3 Roughness

- Manning's 'n' values not checked in detail; values tabulated in report are within the range of industry accepted values

3.4 Boundary conditions

- Spot check made and URBS model outflows match TUFLOW model inflows
- Spot check confirmed correct tide boundary has been adopted for design studies: MHWS = 0.77m AHD; 2050 runs = 1.07 (+0.3m) and 2100 runs = 1.57 (+0.8m)

3.5 Structures

- The set-up of structures has not been checked. HEC-RAS models were developed to check the performance of major structures and a comparison of the results is included in the report.
- Hydraulic Structure Reference Sheets summarise immunity of structures

3.6 Model performance

3.6.1 Calibration

- Calibration achievement discussed with Council throughout study; calibration maps/graphs indicate a reasonable level of calibration has been achieved
- Oct 2010 and May 2009 events generally achieved calibration target of within 150mm at three stream flow gauges (Deagon, Carseldine, Aspley); Oct 2010 and May 2009 events achieved calibration target of within 300mm at MHGs except in upper reach for 2010 event

3.6.2 Stability and mass errors

- _H.csv hydrographs spot checked and look stable up to PMF
- _MB.csv graphs spot checked and no issues found
- Digital data did not include check files; model not simulated for this review

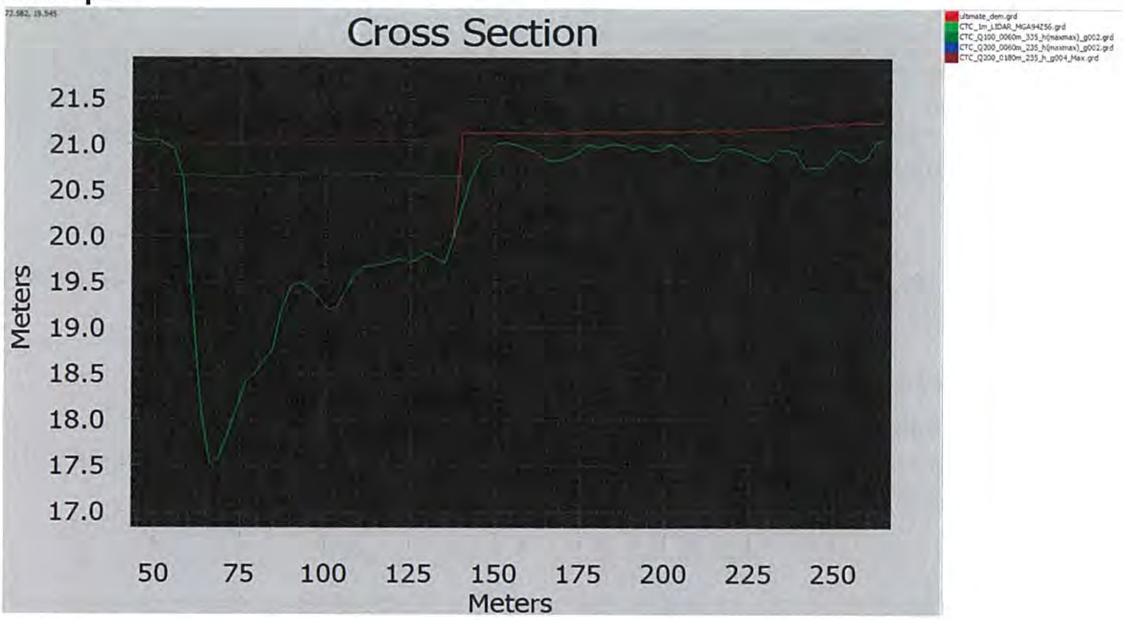
3.7 Quality Assurance

- Model log not included in digital data – this should be requested in future studies
- Model has utilised logical naming conventions and standard folder structure
- Model Handover Guides included

4 Outputs and Mapping

- Report format is of a very high standard (aside from minor spelling/grammar errors)
- Clarity required for scenario labelling of results
- FRL not included on maps

Example



5 Conclusion

In general it appears the models have been prepared diligently and are fit for purpose. Required input and output data has been handed over in a logical format.

It is important however to understand the limitations involved in developing the 'ultimate case' DTM and the limitations with the associated mapping. **<u>THESE DO NOT REPRESENT ACTUAL FLOOD EXTENTS.</u> The ultimate case flood levels have been stretched to create an ultimate 'extent' (ie the ultimate levels overlaid onto the existing DTM). In addition, modifications made to create the filled floodplain topography have change the floodplain characteristics significantly in places.**

The flood study adoption and implementation process will need to consider the ultimate case representation with caution.

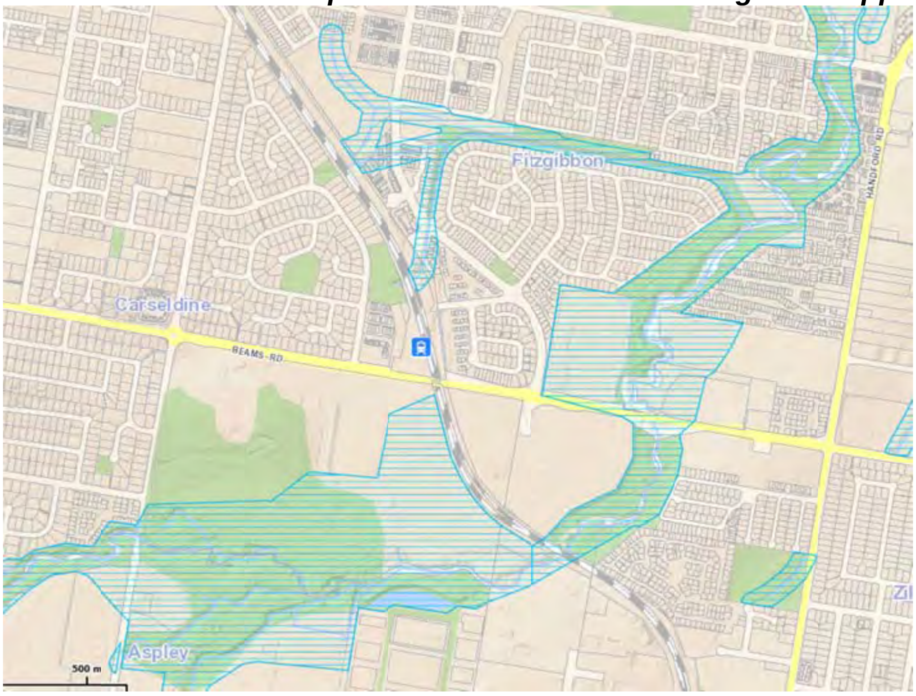
Approved by:

....	....
Megan Gould (RPEQ No. 09266)	**Evan Caswell**
BCC Peer Reviewer	**Principal Engineer, Flood Management**

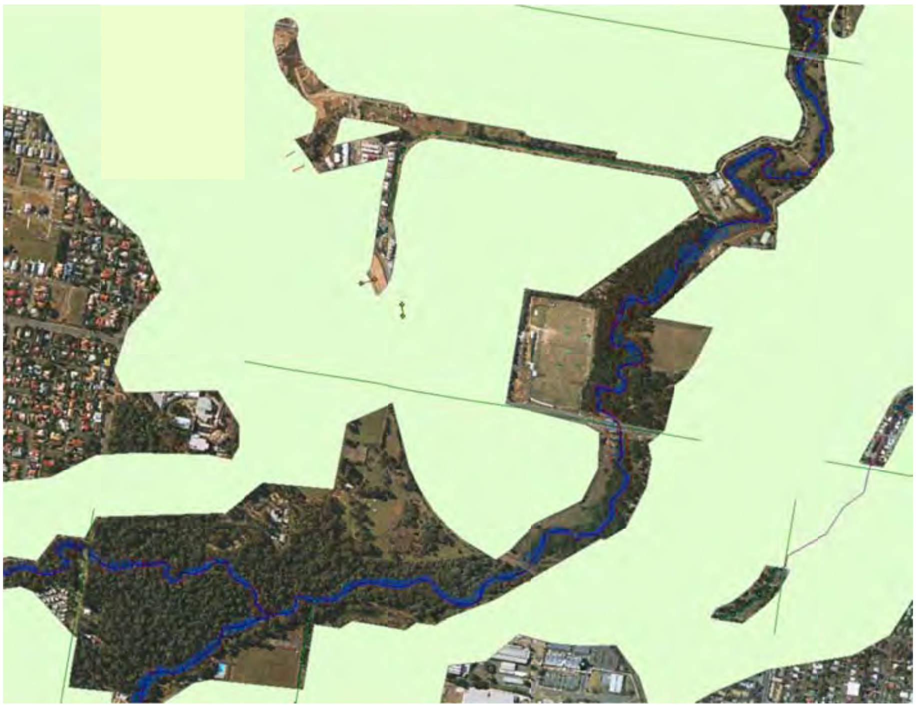
Attachment 1: Example of Ultimate Case Modelling and Mapping

***Attachment 2:* Peer Review Checklist**

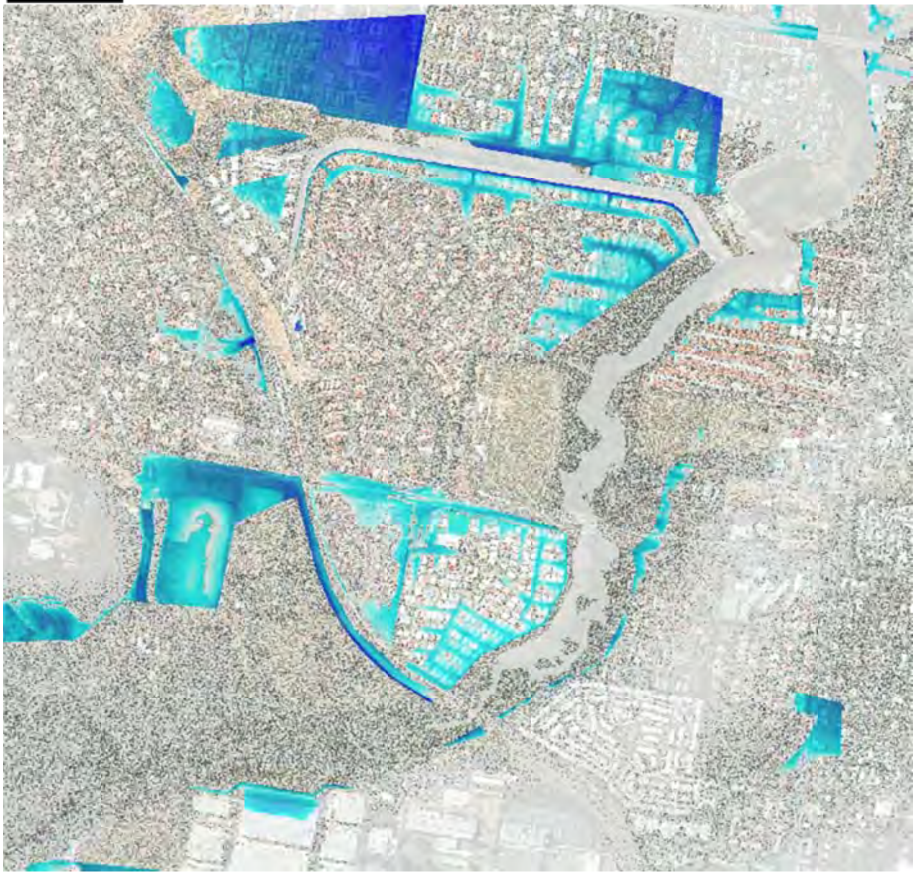
ATTACHMENT 1: *Example of Ultimate Case Modelling and Mapping*



Waterway Corridor



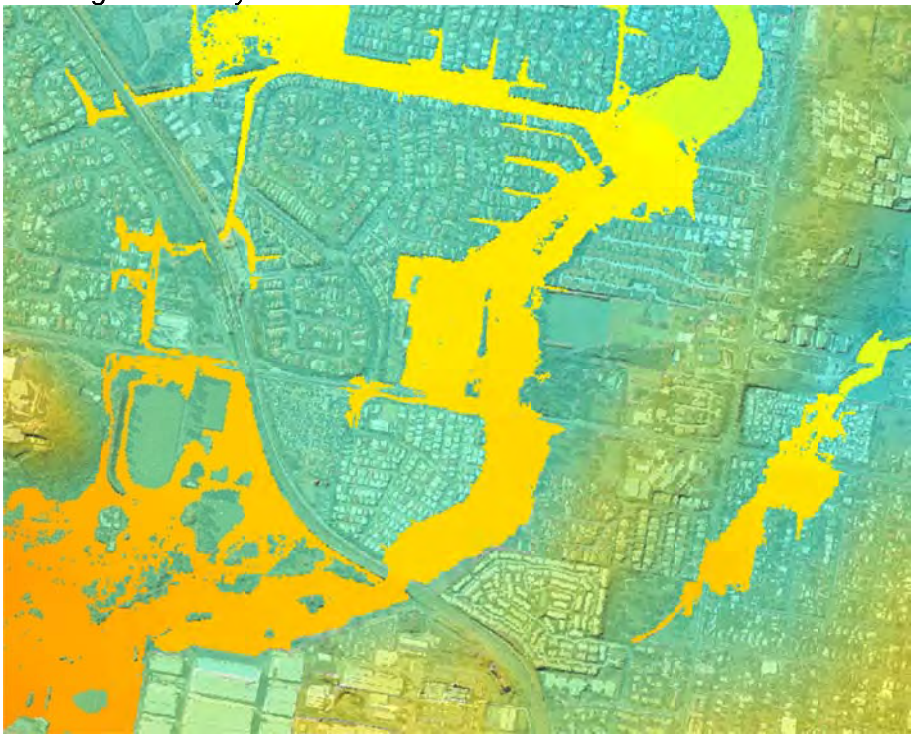
Area where topography is modified to create ultimate topography – outside WC



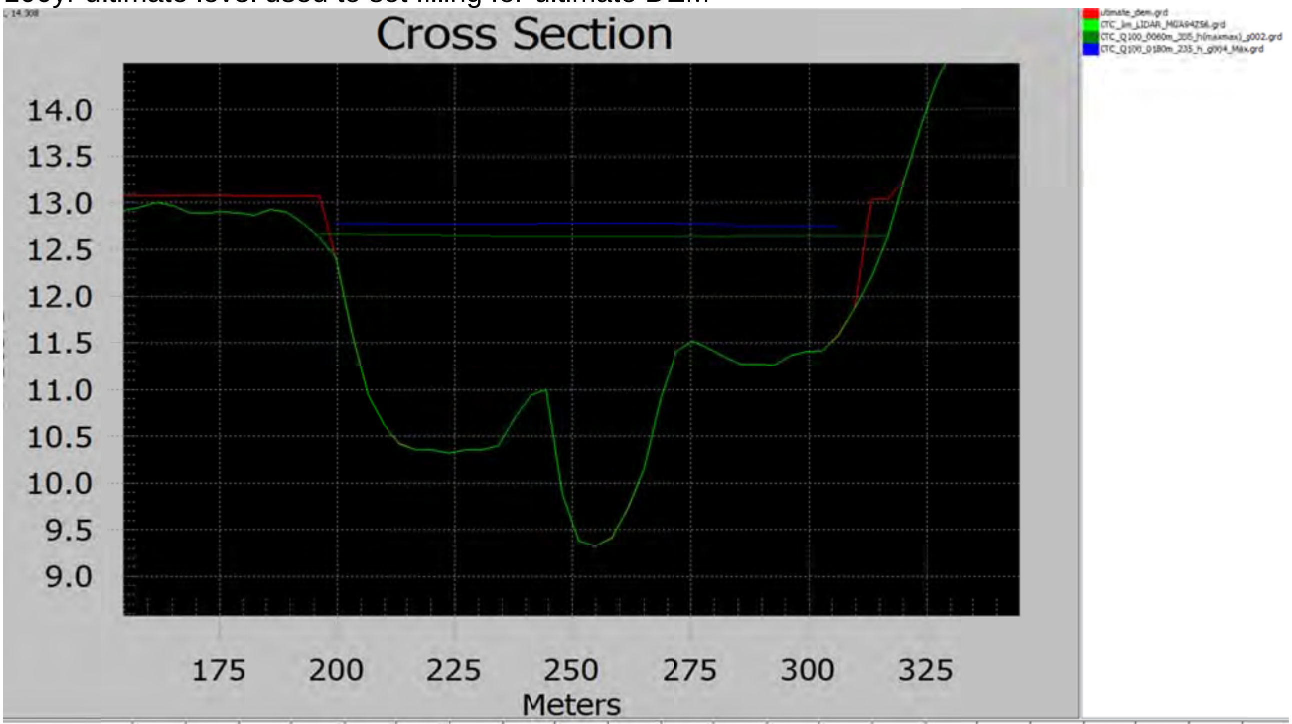
Difference between Ultimate DEM and ALS (ie filled areas). It appears a breakline has been included along the railway and used to increase the level by 1.5-2.0m.

	Value	Percentile
	-0.00	0.00
	0.25	94.07
	1.00	97.40
	2.00	99.16
	3.84	100.00

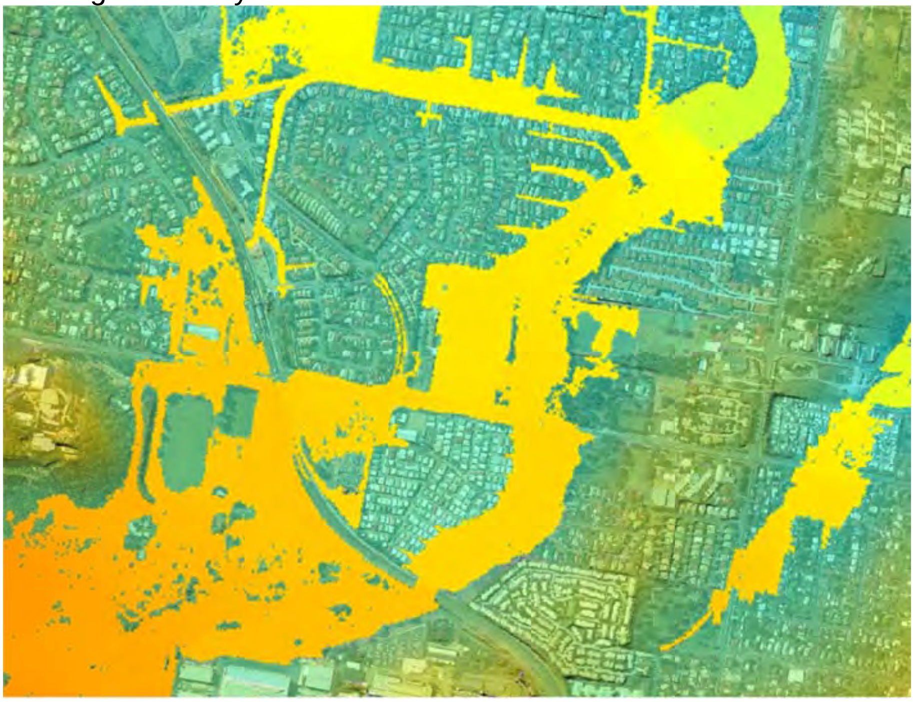
Existing case 100yr



100yr ultimate level used to set filling for ultimate DEM



Existing case 200yr

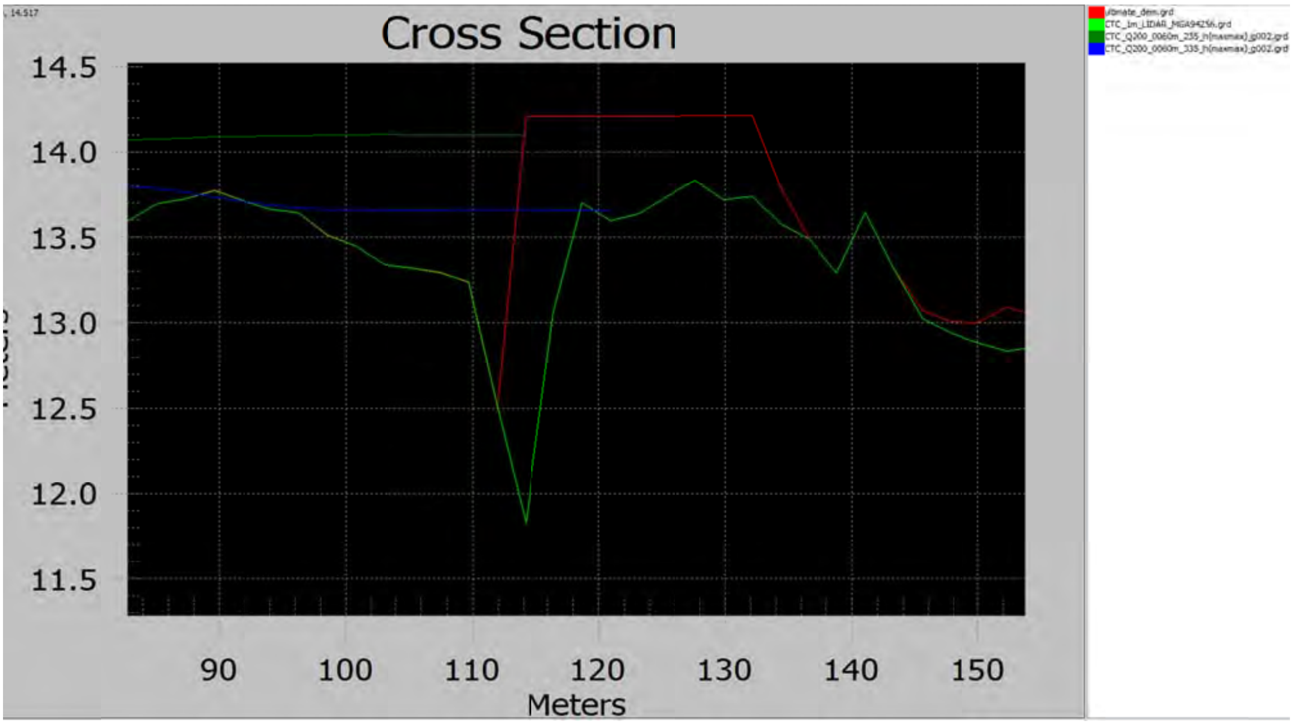


Ultimate case 100yr

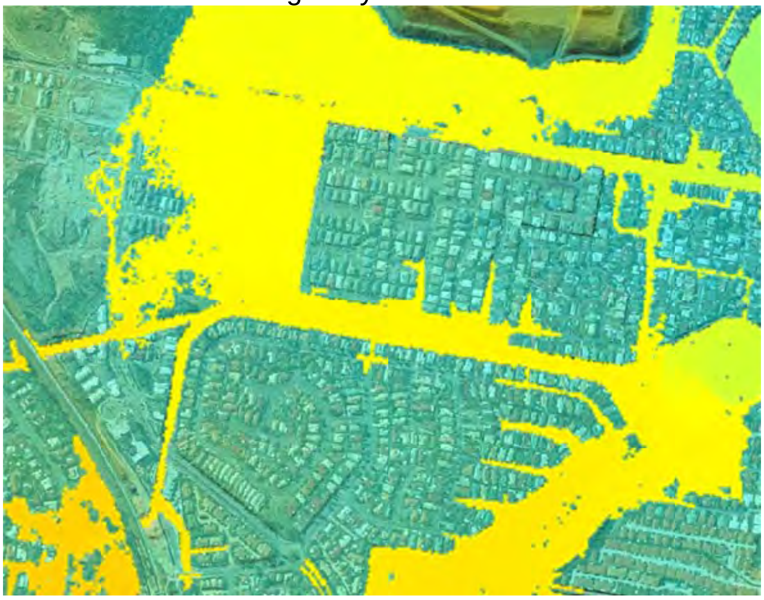
Section from upstream of rail to downstream; breakline (set to upstream 100yr-ult level+300mm) has lifted railway and prevented 100yr ultimate flow from weir-ing over railway. Upstream is WC and is not be filled; downstream is outside of WC and should be filled. Green line = existing 100yr; blue line = ultimate 100yr. Breakline was probably applied during creation of ultimate DEM as no filling occurs upstream but filling occurs downstream; however it has affected the flood maps.

Ultimate case 200yr

Blue line = existing 200yr; green line = ultimate 200yr. Based on the actual height of the railway, flow should weir over to the 'filled' area downstream under ultimate conditions. If the surface had been stretched as is the standard process, it would have been difficult to integrate the upstream surface with the downstream surface and artificially take account of losses over the structure. This highlights the subjectivity of the process.

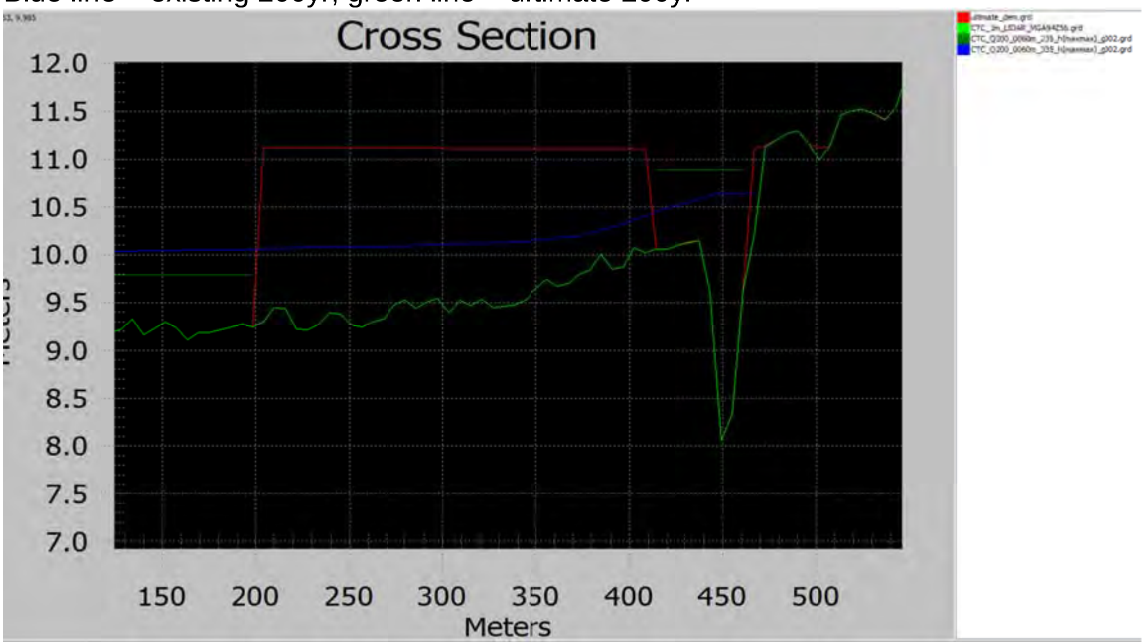


Further north - Existing 200yr



Ultimate 200yr

Section showing that flood surface would join if not for filling constraining it.
Blue line = existing 200yr; green line = ultimate 200yr



1.0 Project Details

Project Name:	Cabbage Tree Creek Flood Study
Client:	NEWS - BCC
Project Job Number:	121408, 130875, 131367
Date:	25/10/2013
Modellers Name:	Ari Craven
Modellers Organisation:	AECOM
Reviewers Name:	Megan Gould
Reviewers Organisation:	BCC - Flood Management, CPO
Major Catchment Name:	Pine
Creek Name:	Cabbage Tree Creek

Review Status

- [ ] Model Build
- [ ] Calibration / Verification
- [ ] Design Modelling
- [x] Final Handover
- [ ] Other (specify)

Purpose of Study

- [x] Flood Planning Levels (e.g. flood study)
- [ ] Flood Mitigation Design (e.g detention basin)
- [ ] Hydraulic Impact Assessment (e.g. bridge upgrade)
- [ ] Flood Hazard Mapping
- [ ] Flood Warning
- [ ] Other (specify)

Modelling software

[ ] RAFTS	[ ] MIKE 11
[x] URBS	[x] HEC RAS
[ ] WBNM	[x] TUFLOW
[ ] RORB	[ ] MIKE 21/FLOOD
[ ] Other (specify)	[ ] Other (specify)

Further description of the modelling

2.0 Models

Hydrology model

Can model be opened and run?	[x] Yes [ ] No	[ ] N/A
Do results match accompanying report?	[x] Yes [ ] No	[ ] N/A

Hydraulics model

Can model be opened and run?	[x] Yes [ ] No	[ ] N/A
Do results match accompanying report?	[x] Yes [ ] No	[ ] N/A
Have all technical issues identified at hold points been addressed and resolved? (reference progress meeting minutes and any responses from draft interim reviews)	[x] Yes [ ] No	[ ] N/A

3.0 Documentation

Does handover documentation include?		
Detailed report in required format	[x] Yes [ ] No	[ ] N/A
Model handover guide, detailing:		
- Model software and version/patch details	[x] Yes [ ] No	[ ] N/A
- Key data sources with date stamp	[ ] Yes [x] No	[ ] N/A
- Data file structure and naming format	[x] Yes [ ] No	[ ] N/A
- Instructions for model use	[x] Yes [ ] No	[ ] N/A
- Limitations and future use of model (incl. data requirements)	[x] Yes [ ] No	[ ] N/A
- Other instruction notes/'read me' files	[ ] Yes [x] No	[ ] N/A
Quality assurance documentation:		
- Models logs	[ ] Yes [x] No	[ ] N/A
- Interval verification checklists	[ ] Yes [x] No	[ ] N/A
- Sign off by RPEQ	[ ] Yes [x] No	[ ] N/A
Is output considered to be ‘fit for purpose’?	[x] Yes [ ] No	[ ] N/A

Other Comments / Issues

Refer memorandum

3.0 Archiving

Models copied to central location?	☐ Yes ☑ No	☐ N/A
Master model catalogue completed with:		
- Brief history of model	☐ Yes ☑ No	☐ N/A
- Who worked on model and why	☐ Yes ☑ No	☐ N/A
- Model software and version/patch details	☐ Yes ☑ No	☐ N/A
- Key data sources (and date stamp)	☐ Yes ☑ No	☐ N/A
- Hydrology summary (e.g. URBS model developed/modified)	☐ Yes ☑ No	☐ N/A
- Hydraulics summary (e.g. TUFLOW model developed/modifiied)	☐ Yes ☑ No	☐ N/A
- Calibration and validation summary	☐ Yes ☑ No	☐ N/A
- Limitations and future use of model	☐ Yes ☑ No	☐ N/A

Other Comments / Issues

A model storage system is not currently in use. Final models have been saved to:
G:\BI\CD\Proj12\121408_Update_of_Cabbage_Tree_Creek_Flood_Study\Flood Managment\Models\Final Models Provided 20131009

This includes the model handover guide.

The final report is saved in TRIM 197/630/543/922; hard copies are with FM, NEWS and in the CPO Library.

Appendix P

Flood Surface Stretching Breaklines

CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

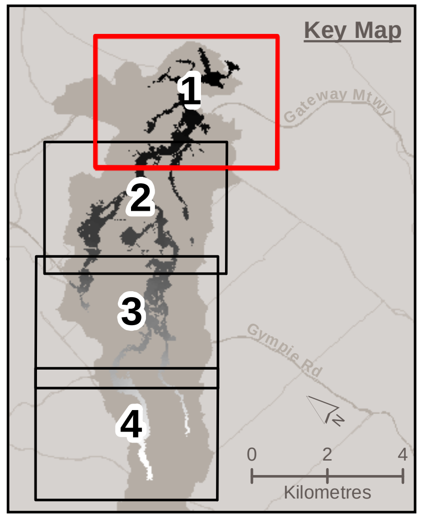
Legend

- Suburbs
- Railway
- Park
- Catchment Boundary
- Breakline
- Area of Uncertainty

Ultimate 100 Year ARI

- Stretched Flood Extent

26/06/2014



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

ULTIMATE CONDITIONS
100 YEAR ARI
PEAK WATER SURFACE
STRETCHING BREAKLINES

MAP P1
Sheet 1 of 4

A3 size

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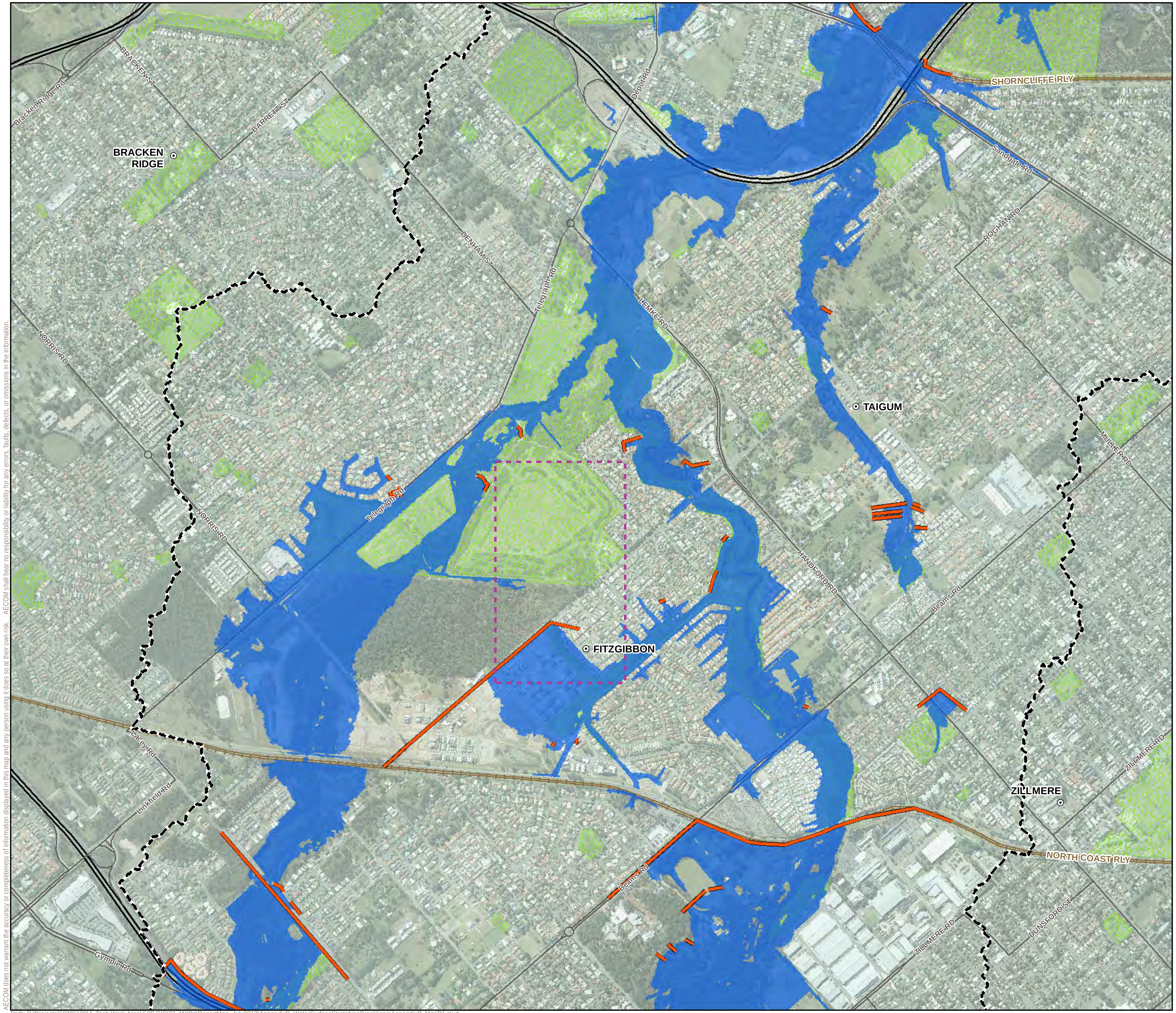

CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

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- Park
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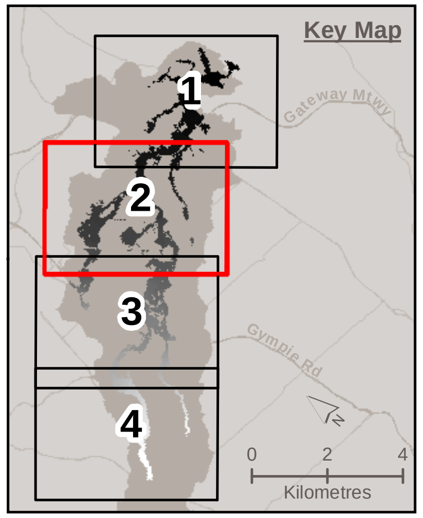
Ultimate 100 Year ARI

- Stretched Flood Extent

26/06/2014



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

ULTIMATE CONDITIONS
100 YEAR ARI
PEAK WATER SURFACE
STRETCHING BREAKLINES

MAP P1
Sheet
2 of 4

A3 size

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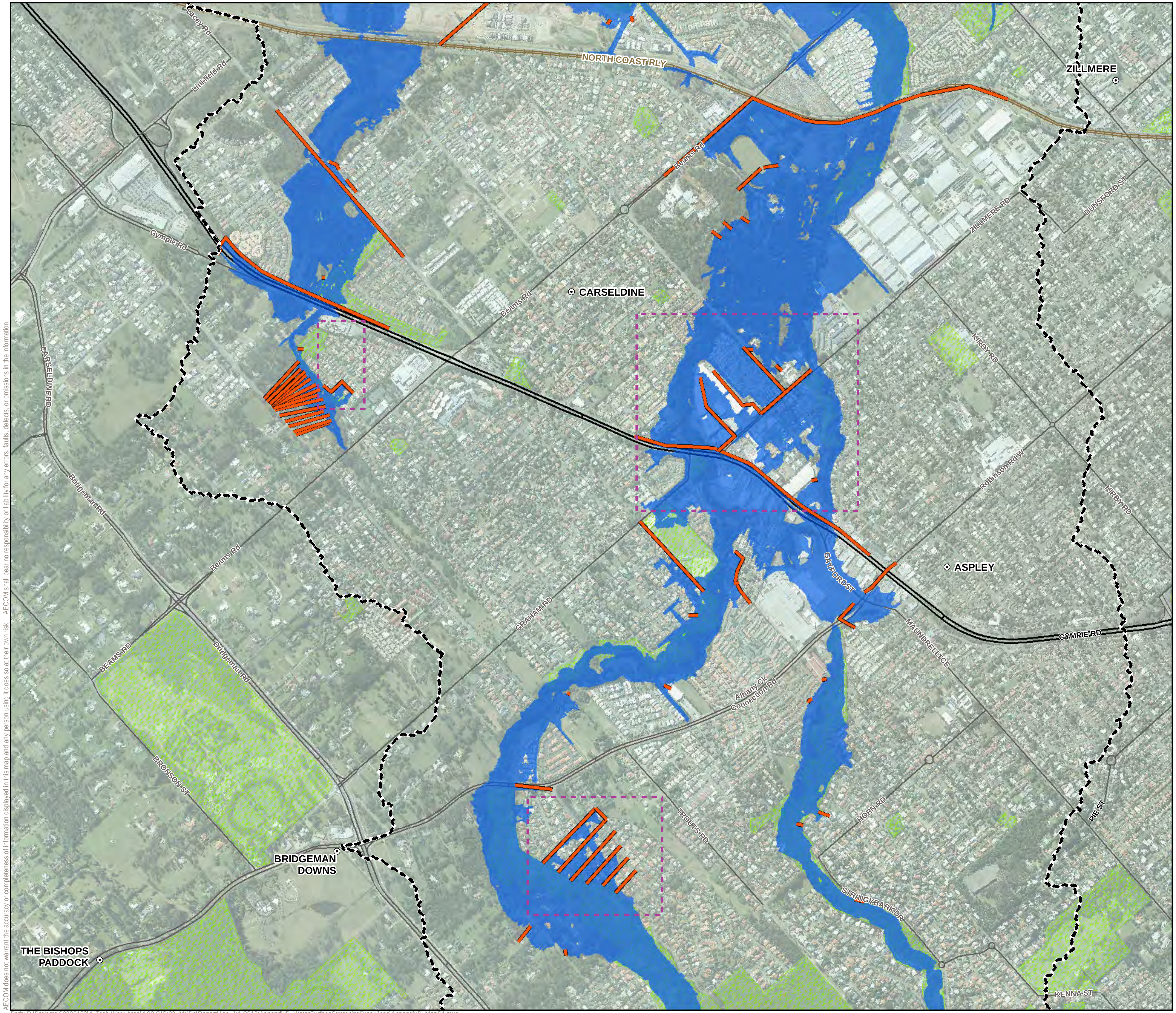

CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600
Metres

1:15,000 (when printed at A3)

Legend

- Suburbs
- Railway
- Park
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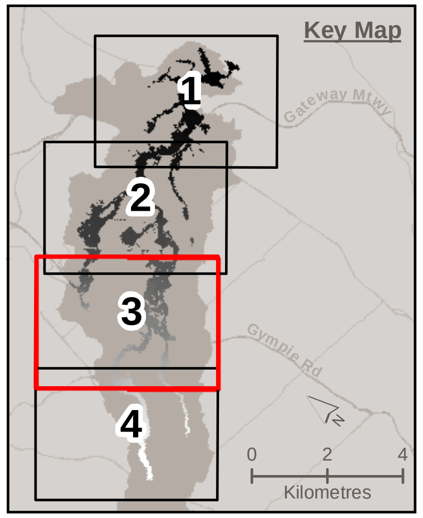
- Breakline
- Area of Uncertainty

Ultimate 100 Year ARI

- Stretched Flood Extent

26/06/2014



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

ULTIMATE CONDITIONS
100 YEAR ARI
PEAK WATER SURFACE
STRETCHING BREAKLINES

MAP P1
Sheet
3 of 4

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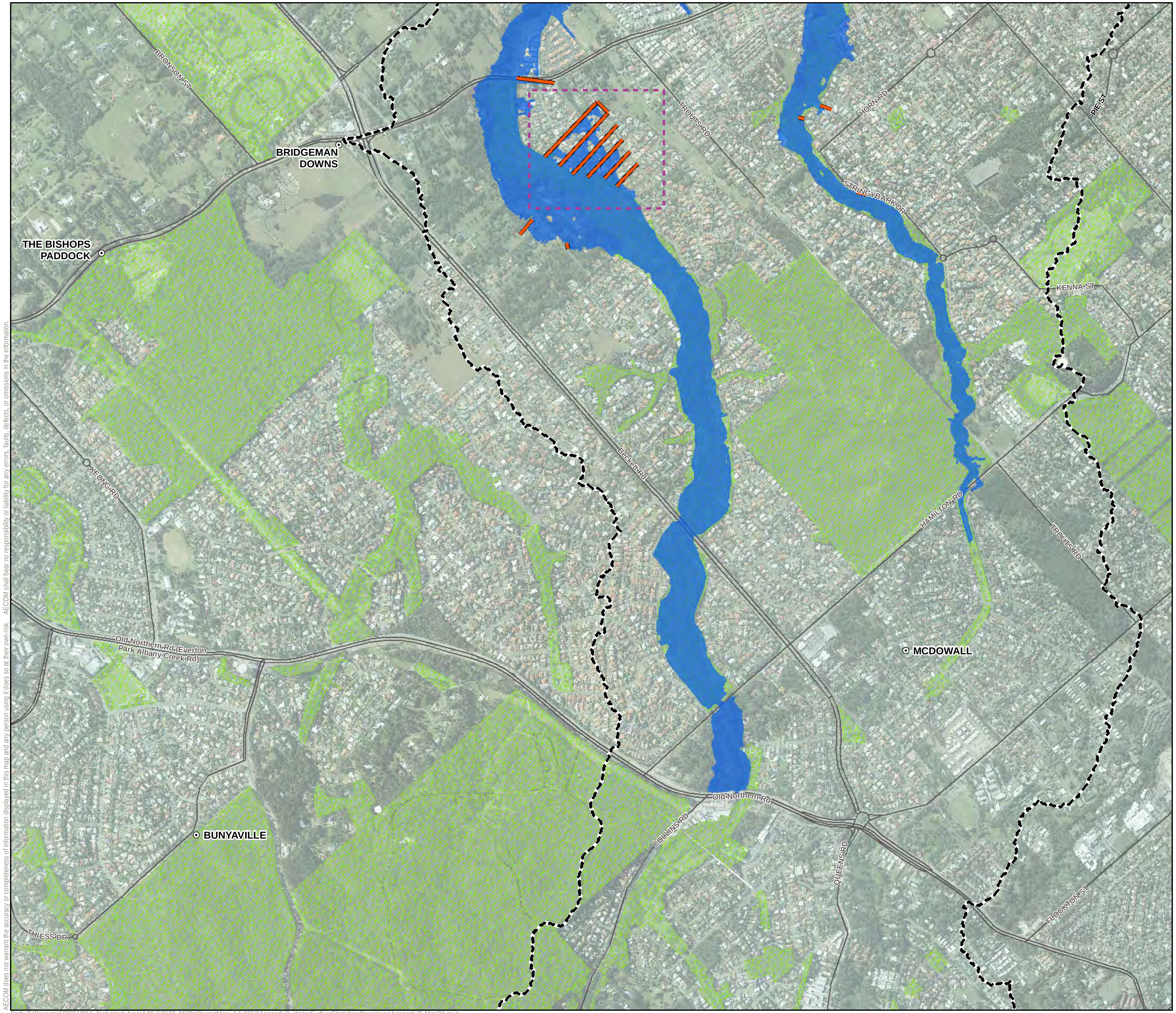

CABBAGE TREE CREEK

BRISBANE CITY

AECOM
www.aecom.com

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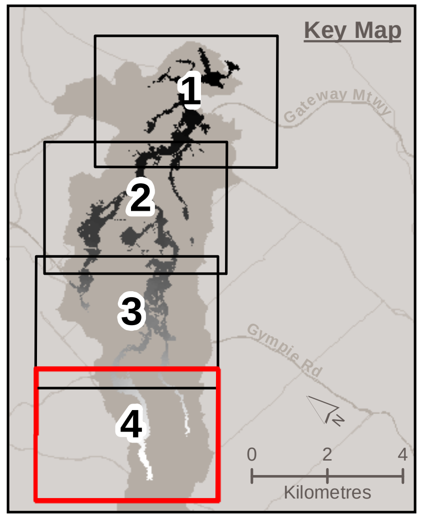
26/06/2014



Data sources:
Imagery: SISP
Features, Streets, Suburbs, Railway, Parks: Street Pro

ULTIMATE CONDITIONS
100 YEAR ARI
PEAK WATER SURFACE
STRETCHING BREAKLINES

MAP P1
Sheet
4 of 4

A3 size

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