Bald Hills Creek Flood Study
Volume 1 of 2

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Bald Hills Creek Flood Study

Prepared by Cardno Pty Ltd
Prepared for Brisbane City Council

June 2014

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Document Control:

Issue No.	Date of Issue	Amdt	Prepared By (Author/s)		Reviewed By		Approved for Issue (Project Director)
			Initials	RPEQ Number and Signature	Initials	RPEQ Number and Signature	Initials
1	August 2014		[signature]		[signature]	9408 [signature]	[signature]

Executive Summary

The Bald Hills Creek catchment is located at the northern boundary of the Brisbane City Council (BCC) local government area.

The total area of the catchment is approximately 1,150 hectares. The creek outlets into the Pine River near its mouth into Moreton Bay.

Brisbane City Council (BCC) commissioned Cardno to carry out a flood study of Bald Hills Creek, comprising:

- an XP-RAFTS hydrologic model; and
- a TUFLOW 1D/2D hydraulic model.

BCC defined the study area for the hydraulic model, as shown in Figure 4-1.

Based on the available rainfall and Maximum Height Gauge (MHG) data, the following four events were selected for the calibration and verification of the hydrologic and hydraulic models:

- March 2001 (calibration);
- May 2009 (verification);
- October 2010 (verification); and
- January 2012 (calibration).

Good agreement was generally achieved at all MHGs for all calibration events, with differences between the recorded and calculated flood levels within ±70 mm. Ten of the 15 differences were within 70 mm, and a further two were within 140 mm.

The results of the hydrologic model and hydraulic model were compared at two locations within the catchment. These results demonstrated that the hydrologic and hydraulic models were providing consistent results.

The calibrated hydrologic and hydraulic models were used to analyse flood events with an Average Recurrence Interval (ARI) from 2 years to 2,000 years, and the Probable Maximum Flood. Design event modelling was carried out using the Australian Rainfall and Runoff temporal patterns.

In addition, flood discharges for design events were estimated by undertaking a flood frequency analysis. A comparison to the peak discharges calculated using the AR&R storm events demonstrated a high level of consistency with the flood frequency analysis results.

The calibrated hydraulic model was used to determine the peak flood levels along the creek for three scenarios:

- Scenario 1: Existing waterway conditions with ultimate catchment hydrology.
- Scenario 2: Existing waterway conditions plus application of Minimum Riparian Corridor (MRC), with ultimate catchment hydrology.
- Scenario 3: Existing waterway conditions plus application of Minimum Riparian Corridor (MRC) plus filling to the Waterway Corridor (WC), with ultimate catchment hydrology.

Flood maps are contained in Volume 2, showing:

- peak flood levels and extent of inundation for the 2 to 2000 year ARI flood events; and
- peak flood depths for the 2 to 100 year ARI flood events.

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List of Abbreviations

AEP	Annual Exceedance Probability
ALS	Airborne Laser Scanning
ARI	Average Recurrence Interval
BCC	Brisbane City Council
BoM	Bureau of Meteorology
IFD	Intensity-Frequency-Duration
MHG	Maximum Height Gauge
QUDM	Queensland Urban Drainage Manual
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe

1.0 Introduction

1.1 Catchment Overview

The Bald Hills Creek catchment is located at the northern boundary of the Brisbane City Council (BCC) local government area.

The total area of the catchment is approximately 1,150 hectares. The creek outlets into the Pine River near its mouth into Moreton Bay.

The catchment takes in the suburbs of Bald Hills, Bracken Ridge and Brighton.

The majority of the catchment comprises residential development. However, a number of other land uses exist in the catchment, as described in Section 2.2.

1.2 Study Background

The most recent flood study carried out in the Bald Hills Creek catchment was completed by Brisbane City Council in 1999. The results are documented in the report titled *Stormwater Management Plan – Bald Hills Creek, Technical Report* (Water and Environment, City Design, June 1999). This flood study only examined the main branch of Bald Hills Creek, upstream of the Gateway Arterial Motorway.

A separate study of the eastern tributary of Bald Hills Creek upstream of the Gateway Motorway was carried out in 2004. The results of this study are contained in the report titled *Flooding Investigation, Sungate Estate at Bracken Ridge* (Water and Environment, City Design, November 2004).

Both of these studies are relatively old, and more advanced modelling techniques are now available. In addition, a number of changes have occurred in the catchment over the last 15 years, including catchment development, changes to the watercourses, and construction of new road crossings. Thus, the current flood study was commissioned to model the entire Bald Hills Creek catchment, to ensure that Council has the most up-to-date information available for floodplain management purposes.

1.3 Study Objectives

The objectives of the Flood Study are as follows:

- Setup and jointly calibrate hydrologic and hydraulic models of the Bald Hills Creek catchment.
- Calculate flood level and discharge information throughout the catchment, for a range of design flood events.
- Produce flood maps within the catchment.

1.4 Study Scope and Limitations

The scope of this report includes the calculation of flood level and discharge information in the main waterways and floodplains in the Bald Hills Creek catchment. This includes the flooding of roads and properties due to the creek breaking out of its normal high-flow banks. However, the report does not include localised flooding due to undersized stormwater drainage infrastructure, i.e. pipes and overland flow paths.

The accuracy of the calculated results is limited by the accuracy of the survey information used in the hydrologic and hydraulic models.

The main source of data used in the models was obtained from Airborne Laser Scanning (ALS) survey. The stated accuracy of this data is as follows: the standard error (68% confidence level, or 1 sigma) is ±150 mm on “clear ground”. The definition of the ground level in vegetated areas or under trees may be less accurate.

ALS data does not provide ground levels in areas inundated by standing water, such as lakes and tidal areas.

No bathymetric survey data was provided for the flood study. Thus, details of the creek topography below standing water level in the following areas are not known:

- the lagoon in Bald Hills Creek upstream of the Gateway Motorway and Bracken Ridge Road, i.e. in Gus Davies Park and Harold Kielly Park;
- tidal reaches of Bald Hills Creek downstream, i.e. downstream of the Gateway Motorway;
- the Pine River; and
- the lake located adjacent to St John Fisher College, on the eastern tributary of Bald Hills Creek.

As-constructed survey data was provided for most of the significant culverts and bridges within the catchment. However, data was unavailable for some minor culverts under the Gateway Motorway (located to the west of the eastern tributary of Bald Hills Creek). Consequently, invert levels were determined based on ALS data and/or nearby culvert invert levels.

The hydraulic model of Bald Hills Creek commenced on the downstream side of the Gympie Arterial Road at Bald Hills. Multiple stormwater pipes discharge under the Gympie Arterial Road in this area, however the inclusion of these pipes was beyond the scope of this study. Thus, the flood immunity of the Gympie Arterial Road has not been assessed.

2.0 Catchment Description

2.1 Catchment and Waterway Features and Characteristics

The Bald Hills Creek catchment is generally bounded by the following catchments and waterways:

- Cabbage Tree Creek catchment to the south;
- South Pine River catchment to the west;
- Pine River to the north; and
- coastal area of Brighton to the east.

The upper reaches of Bald Hills Creek (i.e. upstream of Hoyland Street) generally comprise constructed drains and channels, to direct stormwater runoff around residential developments. The middle reach of the creek (between Hoyland Street and the Gateway Motorway) primarily contains a large waterbody, located in Harold Kielly Park (upstream of Bracken Ridge Road) and Gus Davies Park (downstream of Bracken Ridge Road). The lower reach of the creek is generally tidal, and flows through the Tinchi Tamba Wetlands Reserve to the Pine River.

The upstream end of the eastern tributary comprises a grass channel between Quinlan Street and Denham Street. The channel flows into a large lake located adjacent to St John Fisher College. This lake outlets through three large culverts under the Gateway Motorway, and discharges into an open channel to the north of the Gateway Motorway. This channel flows in an easterly direction and connects to the tidal reach of Bald Hills Creek.

2.2 Land Use

The upper and middle reaches of the catchment (i.e. upstream of the Gateway Motorway) generally contain residential development, in the suburbs of Bald Hills and Bracken Ridge. The catchment downstream of the Gateway Motorway is dominated by the Tinchi Tamba Wetlands Reserve, with some small areas of residential development situated to the east of the Deagon Deviation.

Some other key land uses in the catchment include:

- Brisbane North Institute of TAFE
- Norris Road State School
- Bracken Ridge State School
- Bracken Ridge High School
- St John Fisher College
- Broadcast Australia site (formerly National Transmission Authority)
- Bracken Ridge Reservoir
- Harold Kielly Park
- Gus Davies Park
- Stanley Day Park
- McPherson Park
- Ferguson Park

- Bald Hills Cemetery
- Barrett Street shopping centre

2.3 Flood History

There is no continuous stream gauge operating in the catchment. However, Maximum Height Gauges have recorded peak flood levels at a number of locations throughout the catchment since 1988. The largest recorded flood event in recent times was the event which occurred in March 2001, which was equivalent to a 20 to 50 year ARI flood event in parts of the catchment.

3.0 Available Information

3.1 Previous Studies

Previous flood studies carried out in the catchment include the following:

- Bald Hills Creek Flood Study, Bracken Ridge (Water Studies Pty Ltd, January 1994).
- Stormwater Management Plan, Bald Hills Creek, Technical Report (Water & Environment, City Design, June 1999).
- Flooding Investigation, Sungate Estate at Bracken Ridge (Water & Environment, City Design, November 2004).

3.2 Topographic Survey Data

3.2.1 Field Survey

The following field survey was provided for use in the current flood study where applicable:

- 1993 – Survey of the ground levels around the lake upstream and downstream of Bracken Ridge Road, i.e. in Gus Davies Park and Harold Kielly Park.
- 1997 – Cross sections of the main branch of Bald Hills Creek upstream of the Gateway Motorway.
- 2002 – Survey of the Council-owned land, generally bounded by Gympie Arterial Road to the west, Telegraph Road to the south, and the Caboolture railway line to the north-east.
- 2002 – Survey of the area upstream and downstream of the new Hoyland Street connection.
- 2011 – Survey of a small open space area between Parer Street and Elstree Street.

3.2.2 Aerial Survey and Photography

Two sets of Airborne Laser Scanning (ALS) survey data of the catchment were provided. This data was collected in 2002 and 2009.

Aerial photography of the catchment was provided for the following years: 1997, 2001, 2009 and 2012.

3.2.3 Bathymetric Survey

No bathymetric survey data was provided for the flood study.

Gully lines along the waterways were included in the model, derived from the following sources: structure invert levels; as-constructed or design drawings of culverts and channels; site observations; ALS data; and 1997 cross sections of Bald Hills Creek.

A standing water level in the lagoon at Bracken Ridge Road of 1.7 mAHD was adopted in the model for all events. This level was derived from the information contained in the ALS data over the lagoon area.

3.2.4 Site Visits

Inspections of the catchment were carried out during January and February 2014. The inspections provided information on structure details, hydraulic roughness, overland flow paths, etc.

3.3 Hydrometric Data and Analysis

3.3.1 Recorded Rainfall

Rainfall data recorded in the Bald Hills Creek catchment was provided for the following flood events:

- March 2001;
- May 2009;
- October 2010; and
- January 2012.

For the March 2001 event, the rainfall was recorded at the Bracken Ridge Road Pump Station (BDR712). However, this station was later closed. Thus, for all subsequent historic events, the rainfall was recorded at the Jude Street Reservoir (BDR839). The locations of these two rainfall gauges are shown in Figure 4.-1.

The cumulative rainfall recorded during each event is shown in Figures A1 to A4 in Appendix A. Intensity-Frequency-Duration (IFD) curves for each event are shown in Figure A5 in Appendix A.

Given the size of the Bald Hills Creek catchment, peak flood levels are expected to be produced along the majority of the waterway due to short duration rainfall events, i.e. duration between 30 minutes and 3 hours. The IFD curves show that the March 2001 event was approximately equal to a 20 to 100 year Average Recurrence Interval (ARI) event for these durations. In comparison, the other three events were in the order of 1 to 5 year ARI events for these durations.

3.3.2 Recorded Flood Levels

Recorded flood levels are available from Maximum Height Gauges (MHGs) in the catchment, as shown in Table 3-1. The locations of the Maximum Height Gauges are shown in Figure 5-1.

Table 3-1 Maximum Height Gauge Data

MHG Identification	Recorded Flood Level (mAHD)			
	March 2001	May 2009	October 2010	January 2012
110	No reading	2.47	No reading	No reading
120	2.23	Gauge closed		
130	3.55	2.72	No reading	3.21
140	3.55	3.17	No reading	No reading
150	Gauges not installed until September 2010		4.27	3.98
160			7.14	6.87
210			4.14	4.11
220			3.24	3.14

3.3.3 Tidal Information

Tidal information recorded at the Brisbane Bar gauge was provided for the flood events listed in Section 3.3.1. This gauge is approximately 10 kilometres south of the mouth of Bald Hills Creek. The difference in high and low tide times between the mouth of Bald Hills Creek and the Brisbane Bar is approximately 1 minute. In addition, the difference in Mean Sea Level between the two locations is approximately 150 mm. It was therefore considered acceptable to apply the Brisbane Bar tidal information to the mouth of Bald Hills Creek for the analysis of the historical flood events.

The tide level recorded at the Brisbane Bar gauge for each event is shown in Figures A1 to A4 in Appendix A.

3.4 Hydraulic Structure Data

Design drawings and as-constructed plans were provided for the significant hydraulic structures and open channels within the catchment. Thus, this information was applied to the hydraulic model where appropriate.

Invert levels were not available for some minor culverts under the Gateway Motorway, although the number and size of these culverts were provided. The invert levels were therefore inferred based on other information provided in the vicinity of these structures.

No blockage of handrails at the structures was assumed for the calibration events, as there was no evidence that partial or complete blockage occurred at the various road crossings. However, 100% blockage of handrails is assumed for design events, in accordance with Council's Brief.

3.5 Other Model Data

No other model data was used for the flood study.

3.6 Selection of Calibration and Verification Events

The calibration and verification events were specified by Brisbane City Council, as follows:

- Calibration Events
  - March 2001
  - January 2012
- Verification Events
  - May 2009
  - October 2010

4.0 Hydrologic Model Development and Calibration

4.1 Overview

The hydrologic modelling of the runoff in the Bald Hills Creek catchment was carried out using XP-RAFTS (Version 2009). XP-RAFTS is an urban and rural runoff routing model used to calculate flood hydrographs from rainfall, catchment and channel inputs.

4.2 Model Set Up and Schematisation

For the hydrologic model, the Bald Hills Creek catchment was subdivided into 26 subareas. The subcatchment delineation is shown in Figure 4-1. The XP-RAFTS subcatchment parameters are shown in Table E1 in Appendix E. The layout of the hydrology model is shown in Figure 4-1.

The fraction impervious of each subarea was determined for three scenarios:

- 2001 conditions (for the March 2001 calibration event), based on historical aerial photography;
- existing conditions (for the May 2009, October 2010 and January 2012 calibration events), based on aerial photography from 2009 and 2012; and
- ultimate catchment development (for the design flood events), based on planning information from Brisbane City Council's City Plan (2000).

The fraction impervious value adopted for each land use is shown in Table 4-1. These values were determined in accordance with the Queensland Urban Drainage Manual (Queensland Government, 2008) Table 4.05.1. The areas for each CityPlan Land Use are shown in Figure 4-2.

Table 4-1 Land Use Types

Land Use	Fraction Impervious
Conservation	0%
Community Use Areas	5% – 30%
Emerging Communities	60%
Environmental Protection	0%
Low-Medium Density Residential	50%
Low Density Residential	50%
Multi-Purpose Centres	90%
Park Land	5%
Rural	10%
Road Reserves	90%
Sport And Recreation	5%

Each subarea was divided into two parts to reflect the impervious and pervious sections of the subarea. An initial loss of 0 mm was applied to all subareas. A continuing loss rate of 0 mm/h and 2.5 mm/h was applied to the impervious and pervious sections of the subarea respectively.

The average catchment slope (based on the equal area method) for each subcatchment was derived from the available topographic data, based on an analysis of typical flowpaths in the catchment.

4.3 Calibration Procedure

No stream gauges are located within the Bald Hills Creek catchment. Consequently, no direct calibration of the hydrologic model to recorded stream flows was possible. However, the flows calculated by the hydrologic model were input into the hydraulic model, for calibration to the recorded flood peaks.

For all calibration events, an initial loss of 0 mm was adopted, and a continuing loss rate of 0 mm/h and 2.5 mm/h was adopted in the impervious and pervious areas respectively. An initial loss of 0 mm was considered acceptable, as some lead-up rainfall was recorded for each storm event prior to the heaviest burst of rain which caused the flooding in the catchment.

4.4 Hydrologic Model Calibration and Verification Results

As discussed in Section 4.3, there are no stream gauges located within the Bald Hills Creek catchment and hence, direct calibration of the hydrologic model was not possible.

However, the results of the hydrologic model were reviewed to check for consistency with the hydraulic model results at the following key locations within the catchment:

- Bald Hills Creek at Bracken Ridge Road; and
- Eastern Tributary at John Fisher Drive culverts (Bracken Ridge Road).

These results are discussed in Section 5.6.

File Path: O:\J13078\MapInfo

Scale: 1:18,000

180 0 180 360 540

Metres

N
W E
S

LEGEND

- Stream Line
- Rain Gauge
- BCC Boundary
- XP-RAFTS Subcatchment Boundary

Figure 4-1

Catchment Plan

Bald Hills Creek Flood Study

SHEET	A3
Project No:	J13078
Date:	7/2/14
Revision Number:	0
Designed by:	MD
Client Name:	BCC

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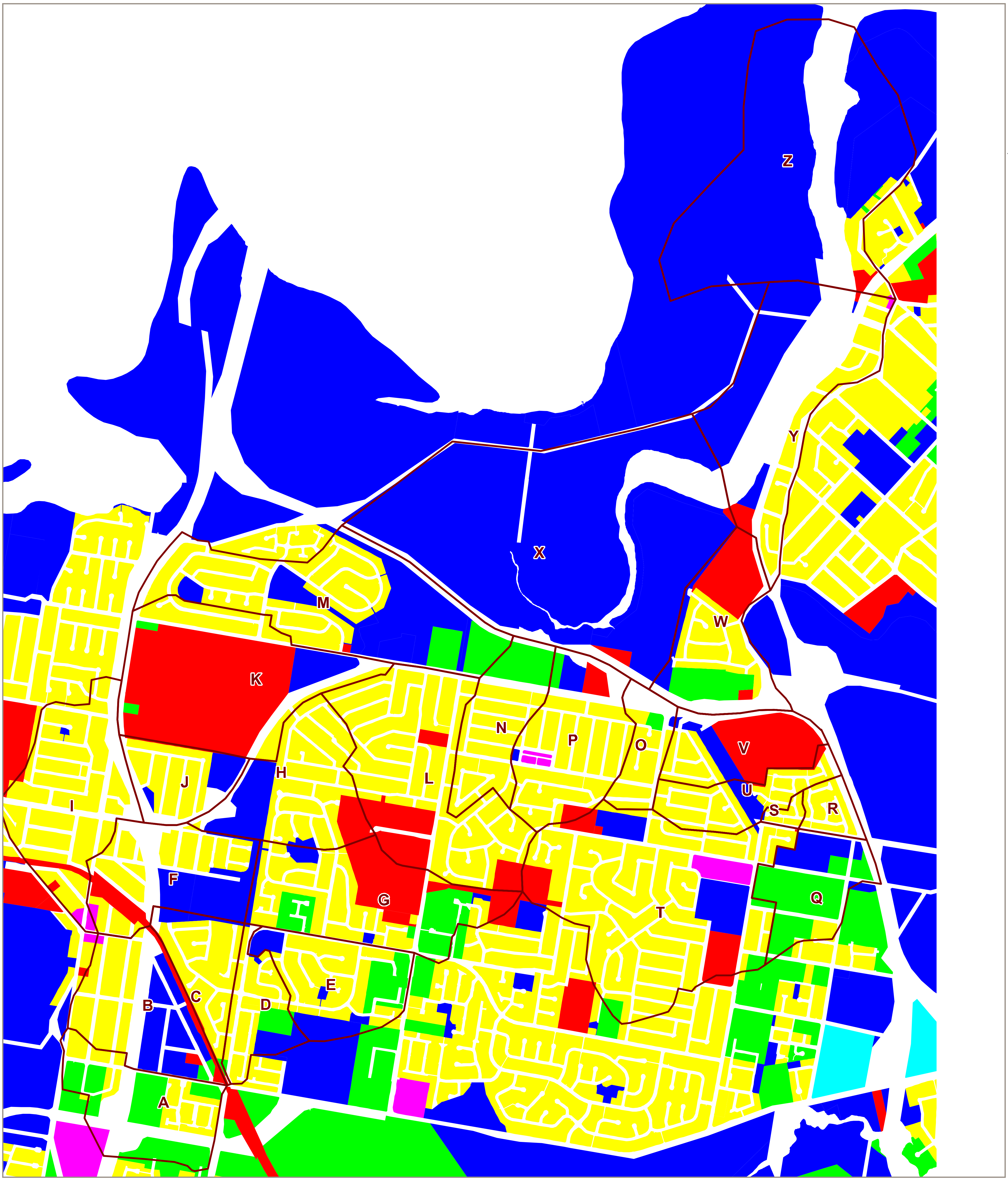

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Scale: 1:18,000

180 0 180 360 540

Metres

N W E S

SHEET	A3
Project No:	J13078
Date:	7/2/14
Revision Number:	0
Designed by:	MD
Client Name:	BCC

LEGEND

- Community Use Areas
- Emerging Communities
- Green Space Areas
- Multi Purpose Centres
- Residential Areas
- Special Purpose Centres

Figure 4-2

CityPlan Land Use

Bald Hills Creek Flood Study

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5.0 Hydraulic Model Development and Calibration

5.1 Overview

The hydraulic modelling of Bald Hills Creek was carried out using TUFLOW (Build 2013-12-AA-iSP). TUFLOW is a combined 1-dimensional/2-dimensional unsteady flow hydraulic model, which can model free-surface flows in one-dimensional links (such as open channels, pipes and culverts, bridges, etc) and two-dimensional domains.

5.2 Model Development

5.2.1 Model Schematisation

For the flood study, a fine four (4) metre grid was used to define flow in the 2-dimensional domain. 1-dimensional links were used to model the hydraulic structures included within the study area as follows:

- Caboolture Railway Line
- Aldea Circuit
- Barbour Road Bikeway
- Barbour Road Detention Basin outlet
- Hoyland Street
- Bracken Ridge Road
- Gateway Motorway Bridge
- Gateway Motorway small culverts (5 locations)
- Denham Street Bikeway
- John Fisher Drive

A time step of 2 seconds was used in the model.

The layout of the hydraulic model is shown in Figure 5-1.

5.2.2 Topography

Topographic information for the TUFLOW model was obtained from ALS data provided by BCC. This data was collected in 2002 and 2009.

The only significant changes in the model topography between the earliest calibration event (March 2001) and the later events (2009 to 2012) are as follows.

- The residential development around Aldea Circuit (bounded by the Caboolture Railway Line to the south and west, Barbour Road bikeway to the north, and Denning Road to the east) was not constructed in 2001.
- Hoyland Street, between the Gympie Arterial Road and Bracken Ridge Road, was under construction in 2001. Thus, the road embankment was partially formed at the time of the March 2001 event, however the creek crossing (culverts) had not been constructed.

Consequently, the Aldea Circuit residential development and Hoyland Street crossing were not included in the model for the March 2001 event. Topographic data collected in 2002 was used in place of the 2009 data for the Aldea Circuit residential development.

Council also provided detailed ground survey for two areas, collected in 2002:

- open space area upstream of the Caboolture Railway Line (bounded by the railway line to the north and east, Telegraph Road to the south, and the Gympie Arterial Road to the west); and
- creek corridor immediately upstream and downstream of Hoyland Street.

The topographic data used in the model, including the changes adopted for the March 2001 event, is shown in Figure 5-2.

5.2.3 Land Use

The land uses in the catchment were determined from site inspections and review of aerial photography. The Manning's n roughness values used in the TUFLOW model are listed in Table 5-1 and shown in Figure 5-3.

Table 5-1 Manning's n Values

Land Use	Manning's n Value
Residential Areas	0.15
Dense Vegetation & Mangroves	0.15
Medium Vegetation	0.10
Light Vegetation	0.05
Open Space & Parks	0.04
Road Reserves	0.03
Grassed Channels	0.035
Open Waterways	0.025

5.2.4 Hydraulic Structures

The flood model included a number of hydraulic structures. The details of these structures are shown in Table 5-2. The locations of the structures are shown in Figure 5-1.

Table 5-2 Hydraulic Structure Details

Location	Details
Caboolture Railway Line	8 / 1.2 x 0.9 metre RCBCs
Aldea Circuit	5 / 2.4 x 1.2 metre RCBCs
Barbour Road Bikeway	5 / 2.4 x 1.2 metre RCBCs
Barbour Road Detention Basin Outlet	2 / 1.2 metre RCPs
Hoyland Street	5 / 3.6 x 1.5 metre RCBCs
Bracken Ridge Road	6 / 3.0 x 1.8 metre RCBCs
Gateway Motorway Bridge	2 x 14.85 metre Bridge Spans
Gateway Motorway Culvert 1	2 / 1.05 metre RCPs
Gateway Motorway Culvert 2	2 / 0.9 metre RCPs
Gateway Motorway Culvert 3	5 / 1.5 metre RCPs
Gateway Motorway Off Ramp	2 / 1.05 metre RCPs
Gateway Motorway On Ramp	6 / 1.05 metre RCPs
Denham Street Bikeway	7 / 1.05 metre RCPs
John Fisher Drive	1.65, 1.80 & 1.95 metre RCPs

Details of the culverts and bridge structure were provided by BCC, including the Queensland Government Department of Main Roads' drawings of the drainage structures under the Gateway Motorway. The invert levels of some of the small culverts under the Gateway Motorway were not included on the Main Roads plans (at Culvert 3, Off Ramp, and On Ramp). Thus, the inverts at these culverts were inferred from topographic data and nearby structures.

Hydraulic Structure Reference Sheets for each structure (except for the five sets of small culverts under the Gateway Motorway) are contained in Appendix C.

5.2.5 Boundary Conditions

Inflows to the TUFLOW model were provided by the XP-RAFTS model. Local inflow hydrographs were obtained from each of the 26 subareas within the XP-RAFTS model. No total flow hydrographs from the XP-RAFTS model were used as boundary conditions.

A tailwater level boundary along the Pine River was used. The location of this boundary is shown in Figure 5-1. The adopted tailwater levels are discussed in Section 3.3.3 and shown in the Figures in Appendix A.

5.3 Calibration Procedure

The peak flood levels calculated by the hydraulic model were compared to the recorded Maximum Height Gauge (MHG) readings, for each flood event. The results are discussed in the following sections.

The locations of the Maximum Height Gauges are shown in Figure 5-1.

The recorded Maximum Height Gauge levels are generally considered to have an accuracy of ±300 mm, due to gauge reading errors, problems with the operation of the gauge, flow patterns around the gauge, etc. Thus, calibration to the recorded levels is considered acceptable if the model results are within approximately 300 mm of the Maximum Height Gauge levels.

As results show, a good calibration was generally achieved across all events.

5.4 Hydraulic Model Calibration and Verification Results

5.4.1 March 2001 (Calibration)

The March 2001 event is the largest of the calibration and verification events. Based on the IFD curves of the recorded rainfall, the average recurrence interval of the event was in the order of 20 to 100 years for storm durations of between approximately 1 and 10 hours (also refer Section 6.4.2).

The peak runoff from the catchment occurred at a similar time to the high tide, however the level of the high tide was relatively small (approximately 1.1 mAHD).

A comparison of the recorded peak flood levels to the modelled peaks is shown in Table 5-3.

Table 5-3 Peak Flood Levels – March 2001 Event

Maximum Height Gauge	Recorded Peak Flood Level (mAHD)	Calculated Peak Flood Level (mAHD)	Difference (m)
BD120	2.23	2.17	-0.06
BD130	3.55	3.48	-0.07
BD140	3.55	3.52	-0.03

Excellent agreement was achieved at all MHGs, with the differences less than or equal to 70 mm.

5.4.2 January 2012 (Calibration)

The January 2012 event was a relatively minor flood event. Based on the IFD curves of the recorded rainfall, the average recurrence interval of the event was less than 5 years for durations of up to 4.5 hours.

The peak burst of rainfall occurred at a similar time to the high tide, and the level of the high tide was relatively large (approximately 1.5 mAHD).

A comparison of the recorded peak flood levels to the modelled peaks is shown in Table 5-4.

Table 5-4 Peak Flood Levels – January 2012 Event

Maximum Height Gauge	Recorded Peak Flood Level (mAHD)	Calculated Peak Flood Level (mAHD)	Difference (m)
BD130	3.21	3.17	-0.04
BD150	3.98	4.12	+0.14
BD160	6.87	7.17	+0.30
BD210	4.11	4.14	+0.03
BD220	4.14	4.20	+0.06

Good agreement was achieved at all MHGs, with the differences less than or equal to 300 mm.

5.4.3 May 2009 (Verification)

Based on the IFD curves of the recorded rainfall, the May 2009 event was similar in magnitude to the January 2012 event. The peak burst of rainfall during the storm event occurred at a similar time to the low tide.

A comparison of the recorded peak flood levels to the modelled peaks is shown in Table 5-5.

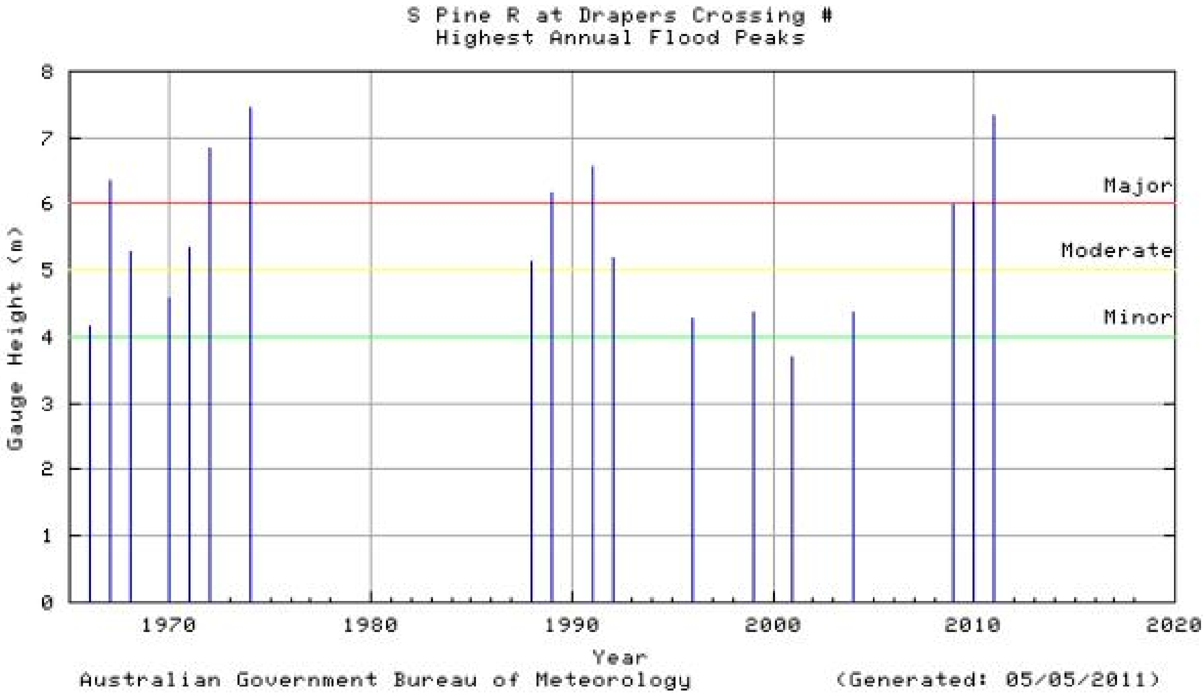
Table 5-5 Peak Flood Levels – May 2009 Event

Maximum Height Gauge	Recorded Peak Flood Level (mAHD)	Calculated Peak Flood Level (mAHD)	Difference (m)
BD110	2.47	1.27	-1.20
BD130	2.72	3.16	+0.44
BD140	3.17	3.20	+0.03

Good agreement was achieved at MHG BD140, with a difference of only 30 mm. A poor match was achieved at the other two MHGs, as discussed below.

The recorded level at MHG BD130 is significantly lower than that recorded at MHG BD140. These two gauges are located downstream and upstream of Bracken Ridge Road respectively, and are less than 100 metres apart. In the March 2001 event, these two gauges recorded an identical peak flood level. For all calibration and verification events, the flood model results indicate a difference in flood level between the upstream and downstream sides of Bracken Ridge Road of less than 50 mm, with Bracken Ridge Road overtopped by floodwaters across a wide area. Thus, it appears incongruous that these two gauges would record a difference in peak flood level of 450 mm in the May 2009 event. For these reasons, it is considered that the peak flood level recorded at MHG BD130 in May 2009 is incorrect.

May 2009 produced a significant flood event in the Pine River catchment. The image below (from the Bureau of Meteorology) shows that the May 2009 event was a major flood event in the South Pine River at Draper's Crossing.



MHG BD110 is situated at the downstream end of Bald Hills Creek, near the confluence with the Pine River. Thus, the peak flood level recorded at this gauge was affected by the flood levels in the Pine River. Consequently, the TUFLOW model could not match the recorded peak at MHG BD110.

5.4.4 October 2010 (Verification)

Based on the IFD curves of the recorded rainfall, the October 2010 event was similar in magnitude to the January 2012 and May 2009 events. The peak burst of rainfall during the storm event occurred at a similar time to the low tide.

A comparison of the recorded peak flood levels to the modelled peaks is shown in Table 5-6.

Table 5-6 Peak Flood Levels – October 2010 Event

Maximum Height Gauge	Recorded Peak Flood Level (mAHD)	Calculated Peak Flood Level (mAHD)	Difference (m)
BD150	4.27	4.14	-0.13
BD160	7.14	7.17	+0.03
BD210	4.14	4.10	-0.04
BD220	4.24	4.19	-0.05

Good agreement was achieved at all MHGs, with differences of less than 130 mm.

5.5 Hydraulic Structure Verification

The structure losses at the major bridge and culvert crossings, as calculated by the TUFLOW model, were verified by checking the results with an independent hydraulic package. The losses through the culverts were checked using the software CULVERTW, and the losses through the Gateway Motorway bridge were checked using HEC-RAS (version 4.1.0).

The biggest calibration event was March 2001. Thus, this event produced the largest flows through each of the structures. The other three events (January 2012, May 2009 and October 2010) all produced reasonably similar, smaller flows through the various structures.

Thus, to verify the losses through the hydraulic structures, the results from the March 2001 and January 2012 events were used. These two events provide a broad range of flows to check the model performance.

The calculated head loss for each structure, for each calibration event, is shown in Table 5-7. The results from the TUFLOW model were taken at the time of the peak flood level.

Table 5-7 Comparison of Hydraulic Model Structure Losses

Structure	Flood Event	Discharge (m^3/s)	Head Loss TUFLOW (m)	Head Loss Check (m)	Head Loss Difference (m)
Railway Line	Jan 2012	6.1	0.63	0.64	0.01
	March 2001	11.1	0.15	0.15	0.00
Aldea Circuit	Jan 2012	6.1	0.02	0.02	0.00
	March 2001	n/a	n/a	n/a	n/a
Barbour Road Bikeway	Jan 2012	6.9	0.02	0.02	0.00
	March 2001	8.6	0.03	0.03	0.00
Hoyland Street	Jan 2012	23.8	0.07	0.06	-0.01
	March 2001	n/a	n/a	n/a	n/a
Bracken Ridge Road	Jan 2012	18.6	0.03	0.02	0.00
	March 2001	16.4	0.02	0.02	0.00
Gateway Motorway Bridge	Jan 2012	38.9	0.01	0.02	0.01
	March 2001	67.8	0.02	0.04	0.03
Denham Street Bikeway	Jan 2012	2.8	0.05	0.03	-0.01
	March 2001	1.9	0.01	0.00	-0.01
John Fisher Drive	Jan 2012	12.7	0.96	0.95	-0.01
	March 2001	17.9	1.75	1.74	-0.01

These results demonstrate that the structure losses calculated by the TUFLOW model are reliable. The upstream water level at each culvert is generally within 10 mm of the level calculated by CULVERTW. For the Gateway Motorway Bridge crossing, the results are within 30 mm of those from the HEC-RAS model.

5.6 Hydrologic-Hydraulic Model Consistency Check

As discussed in Section 5.2.5, the flows extracted from the XP-RAFTS model for use in the TUFLOW model were local inflow hydrographs only, i.e. no total flow hydrographs were used. Consequently, the TUFLOW model carried out the necessary channel routing in the catchment. It is preferable to do the channel routing in the TUFLOW model, as the hydraulic model can account for factors which cannot be represented in the hydrologic model, e.g. backwater due to the downstream conditions, impact of hydraulic structures on flood storage and flows, large areas of floodplain storage, break out of high level flows to another part of the catchment, etc. Thus, the total flow calculated by the XP-RAFTS model should only be used as a guide to the flow in the catchment at that point.

The results of the hydrologic model and hydraulic model were compared at two locations:

- Bald Hills Creek at Bracken Ridge Road; and
- Eastern Tributary at John Fisher Drive culverts (Bracken Ridge Road).

The comparison for each calibration and verification event is shown in Appendix B. These results demonstrate that the hydrologic and hydraulic models are providing consistent results.

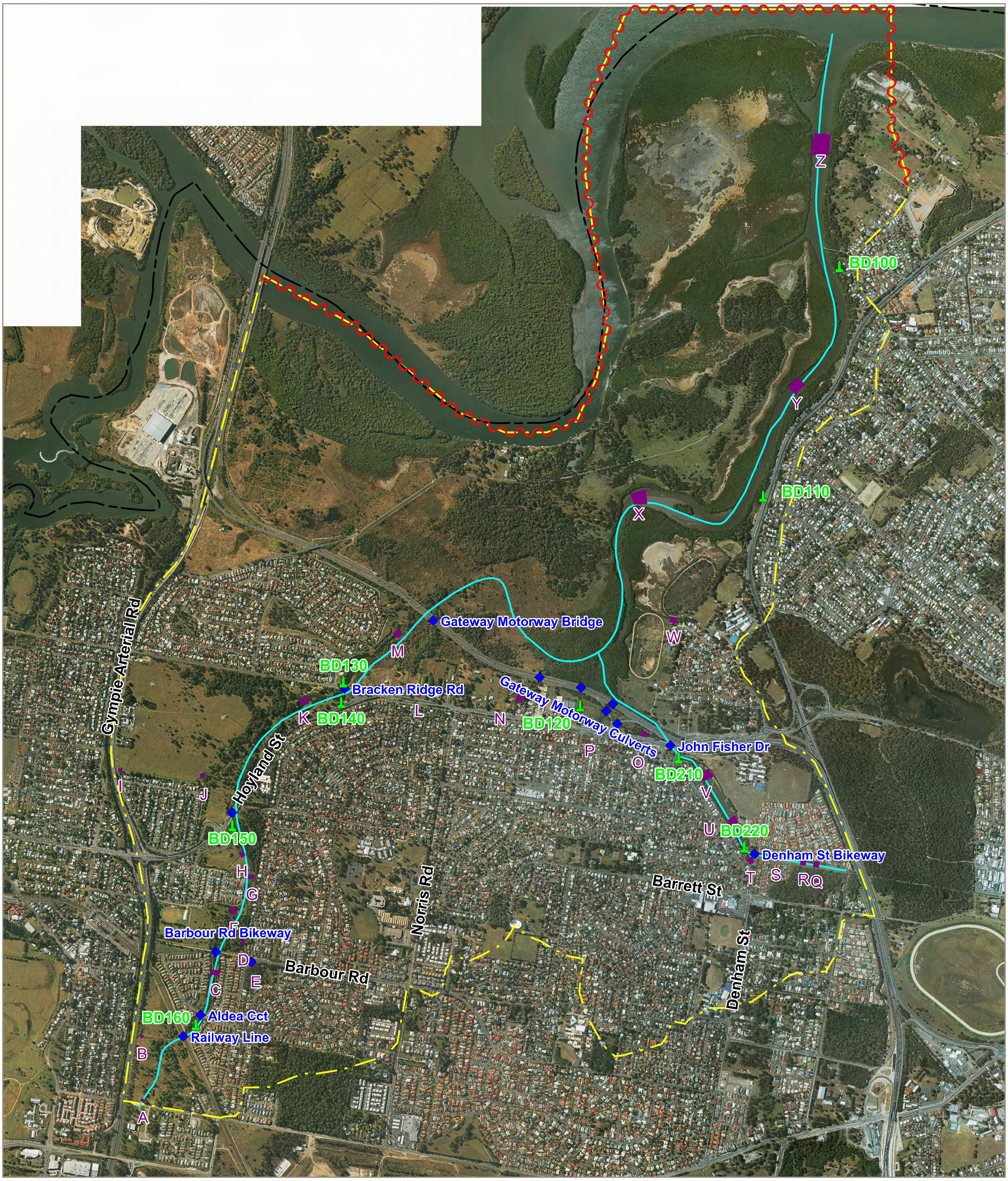
The consistency between the two models at Bracken Ridge Road is not as good as that demonstrated at John Fisher Drive. This is because it is not possible to replicate the interaction between the lagoon flood storage area and the Gateway Motorway in the XP-RAFTS model. However, given this limitation of the XP-RAFTS model, the consistency at Bracken Ridge Road is considered acceptable.

5.7 Calibration Results

The results of the calibration and verification events demonstrate that:

- the XP-RAFTS and TUFLOW models are providing consistent results;
- the structure losses calculated by the TUFLOW model are reliable; and
- the models have been calibrated for all flood events, with the majority of calculated peak flood levels within ±70 mm of the recorded MHG levels.

The models are therefore considered suitable to calculate the design flood levels in the Bald Hills Creek catchment.



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180 0 180 360 540

Metres

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SHEET	A3
Project No:	J13078
Date:	7/2/14
Revision Number:	0
Designed by:	MD
Client Name:	BCC

LEGEND

- 1D Structures
- Maximum Height Gauge
- Tailwater Level Boundary
- Stream Line
- TUFLOW Model Extent
- BCC Boundary
- Model Inflow

Figure 5-1

Hydraulic Model Layout

Bald Hills Creek Flood Study

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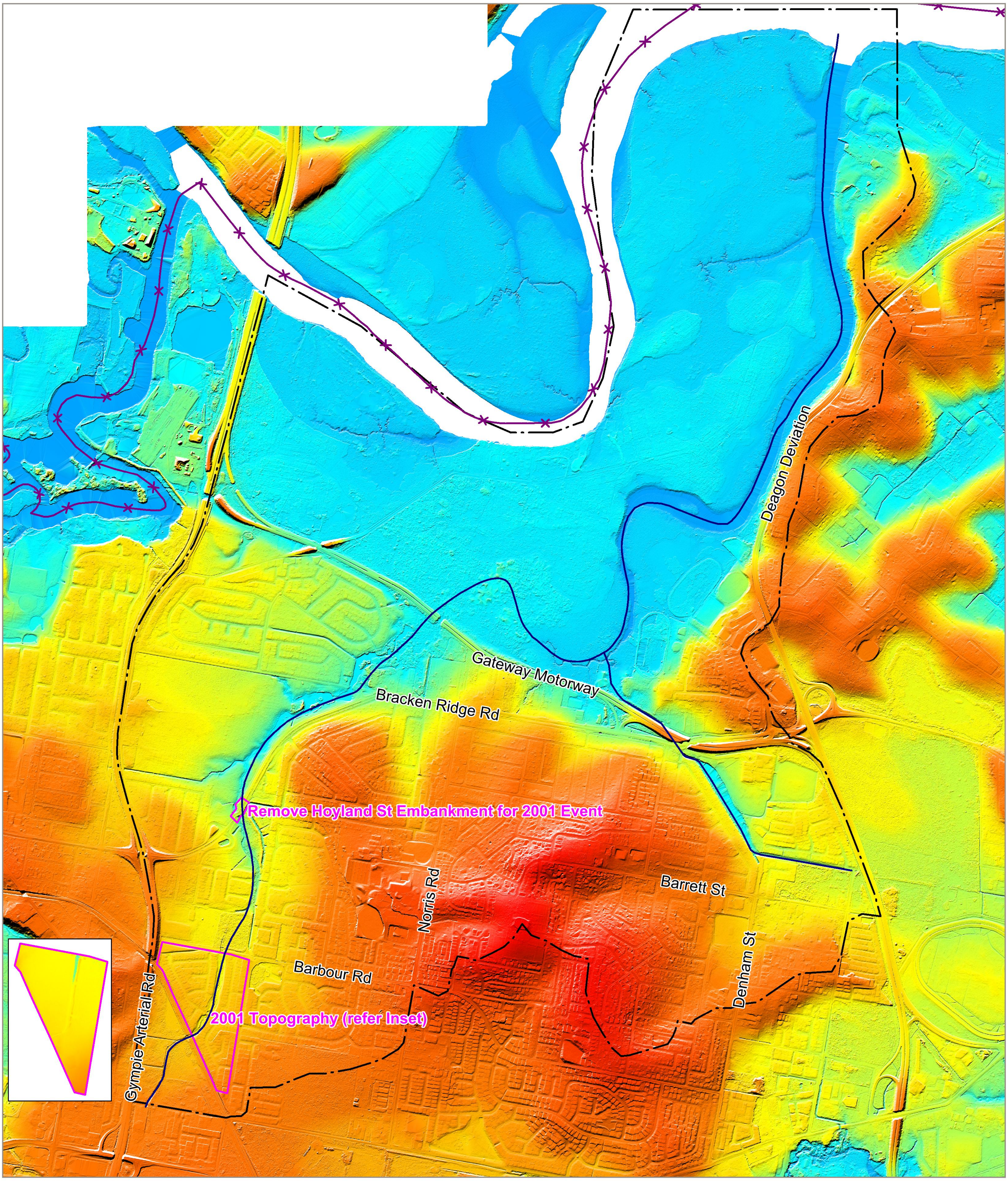

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TUFLOW Model Extent

Changes in Topography for 2001 Event

Stream Line

BCC Boundary

Figure 5-2

Topographic Data

Bald Hills Creek Flood Study

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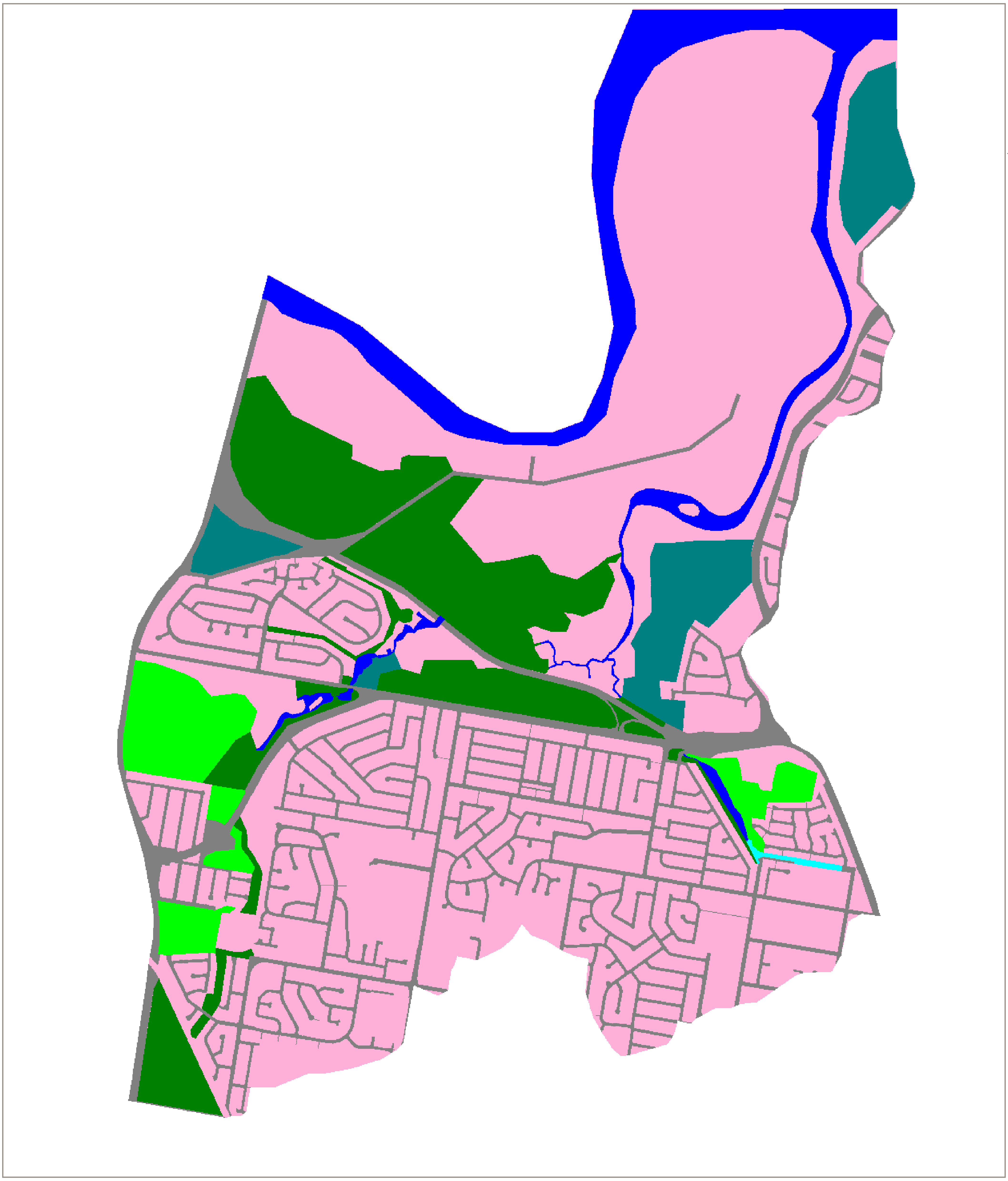

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Metres

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LEGEND

- (n = 0.15) Residential Areas, Dense Vegetation & Man
- (n = 0.025) Open Waterways
- (n = 0.03) Road Reserves
- (n = 0.035) Grassed Open Channels
- (n = 0.10) Medium Vegetation
- (n = 0.05) Light Vegetation
- (n = 0.04) Open Space & Parks

Figure 5-3

Adopted Hydraulic Roughness

Bald Hills Creek Flood Study

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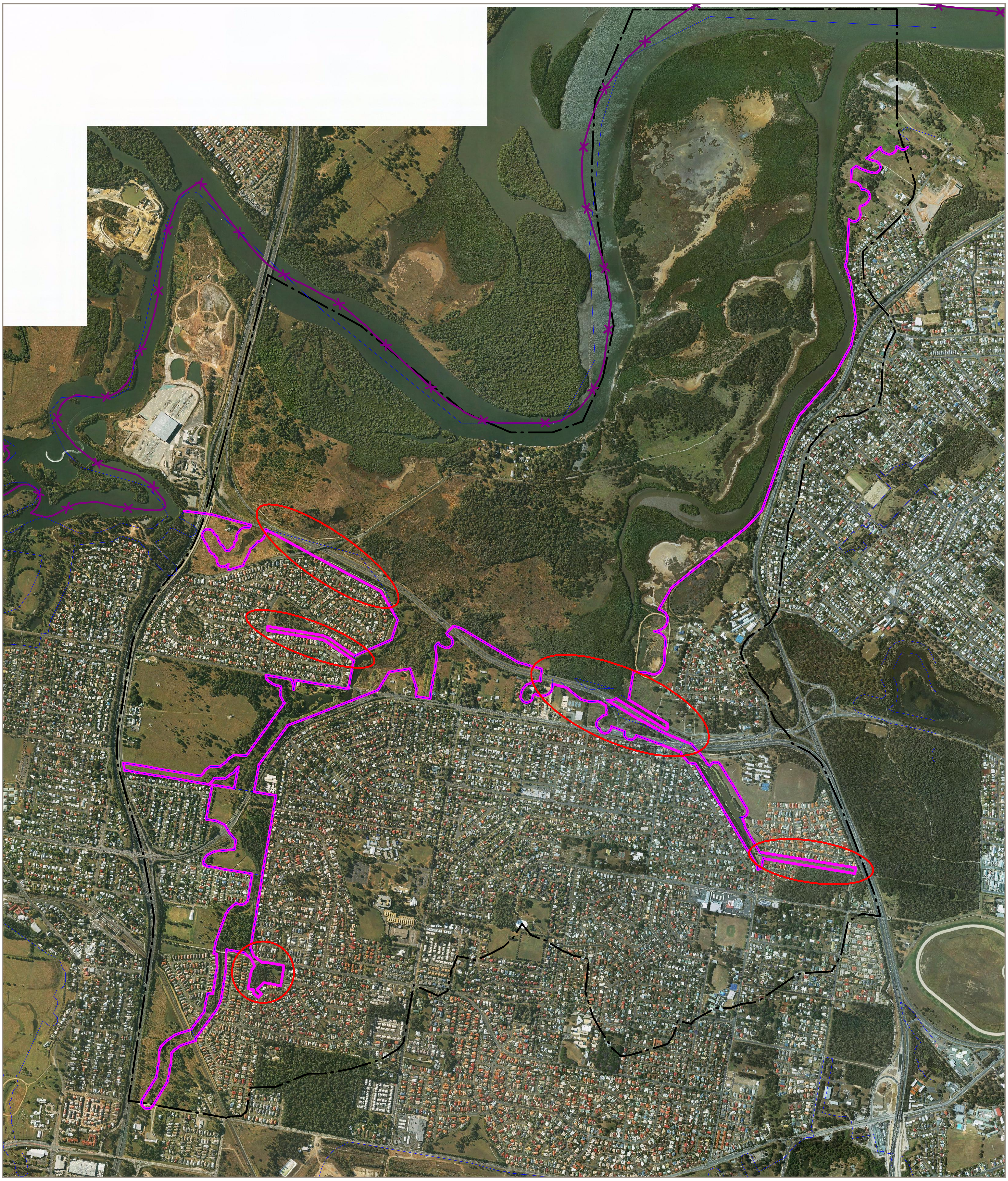

File Path: O:\J13078\Mapinfo

Scale: 1:18,000

180 0 180 360 540

Metres

N W E S

LEGEND

- TUFLOW Model Extent
- BCC Boundary
- BCC Waterway Corridor
- Modelled Waterway Corridor
- Flow Conveyance Zone Amendments

Figure 5-4

Waterway Corridors

Bald Hills Creek Flood Study

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6.0 Design Event Analysis

6.1 Design Event Scenarios

The calibrated hydrologic and hydraulic models were used to analyse design flood events with an Average Recurrence Interval from 2 years to 100 years.

Rare and extreme events, with an Average Recurrence Interval of 200, 500 and 2,000 years, and the Probable Maximum Flood, were also analysed. The results for these events are shown in Section 7.

The relationship between Average Recurrence Interval (ARI) and Annual Exceedance Probability (AEP) is shown in Table 6-1.

Table 6-1 Design Event Frequency

Average Recurrence Interval	Annual Exceedance Probability
2 years	50%
5 years	20%
10 years	10%
20 years	5%
50 years	2%
100 years	1%
200 years	0.5%
500 years	0.2%
2,000 years	0.05%

The following scenarios were simulated in the hydrologic and hydraulic models:

- Scenario 1: Existing waterway conditions with ultimate catchment hydrology.
- Scenario 2: Existing waterway conditions plus application of Minimum Riparian Corridor (MRC), with ultimate catchment hydrology.
- Scenario 3: Existing waterway conditions plus application of Minimum Riparian Corridor (MRC) plus filling to the Waterway Corridor (WC), with ultimate catchment hydrology.

6.2 Minimum Riparian Corridor

Vegetation beside a waterway is called riparian vegetation. It is a key contributor to waterway health, acting as a buffer between the waterway and adjacent lands. A well vegetated riparian zone can improve water quality by filtering overland flow and reducing erosion along creek banks. Shady trees protect vulnerable organisms from extremes of temperature; root systems and woody debris become habitat for fauna; and organic matter sustains aquatic food webs. Vegetation also provides habitat and forage for fauna and adds to a waterway's recreational value.

This study calculates anticipated flood levels assuming a minimum vegetated riparian corridor width along the entire creek system. It does not in any way imply that Council is planning to establish a minimum riparian vegetated corridor width in the creek catchment. The minimum vegetated riparian corridor is modelled solely in recognition that at some unspecified time in the future, revegetation may occur, either through natural regeneration or as a result of planting programs. The results of this modelling are intended to ensure that the habitable floor levels of new developments within the floodplain take account of future revegetation.

Minimum riparian corridors were applied to the main branch and eastern tributary of Bald Hills Creek in the hydraulic model. The minimum riparian corridor was simulated as dense vegetation by applying a 'Manning's n' value of 0.15, extending from the top of the low flow banks for a maximum width of 15 metres on both sides of the creek, or until the Waterway Corridor boundary was reached. Where there was no obvious low flow channel, the vegetation was applied at the anticipated 2 year ARI flood level on the basis that this size event is generally contained within the bed and banks of the creek.

The exceptions to the above application of the minimum riparian corridor were as follows.

- The grass lined channel between the Gateway Motorway and the Denham Street footbridge is not defined as a waterway, thus a minimum riparian corridor was not applied along this channel.

- A maintenance plan is in place around the edge of the lake upstream of Bracken Ridge Rd, thus there is no intention to have dense planting in this area.

- The open channel between the railway and Barbour Road Bikeway was designed in accordance with natural channel design guidelines, with a channel-averaged Manning's n roughness value of 0.08. This value was therefore maintained.

- The channel adjacent to Sophy Crescent (approximately between Grand St and Cavalier Close) was designed in accordance with natural channel design guidelines, with Manning's n values of 0.10 and 0.04 in the main channel and overbank areas respectively. These values were therefore maintained.

The minimum riparian corridors were included in the Scenario 2 and Scenario 3 models. The application of the Minimum Riparian Corridor is shown in Figure 6-1.

6.3 Waterway Corridors

Waterway corridors are an integral part of the Council's Planning Scheme for Brisbane. City Plan describes waterway corridors as:

> *"The corridors along a waterway indicated on the Planning Scheme maps. These corridors are defined by:*
>
> - *A flood regulation line (FRL);*
> - *A local plan environmental corridor or a waterway corridor (WC);*
> - *A waterway corridor defined in a stormwater management plan;*
> - *A waterway corridor defined in a waterway management plan.*
>
> *If more than one of these is available for a particular waterway, the largest applies.*
>
> *If there is no FRL described in local plan, SMP or WMP, a 30 metre distance measured on each side from the centre line of the waterway would apply. (BCC 2000, vol. 1, ch. 3, p. 75).*

These corridors identify zones where water flow, water quality, ecology and open space, and recreational and amenity values are to be preserved and/or managed in an ecologically sustainable manner.

Waterway corridors are represented in the hydraulic model by the exclusion of the conveyance and/or water storage characteristics of the watercourse beyond the limits of the waterway corridor location. Essentially, this practice assumes that filling and development will ultimately occur beyond the boundary of the waterway corridors.

The waterway corridors have been included in the hydraulic model for Scenario 3 flood events. Traditionally, the inclusion of waterway corridors within the hydraulic model was simulated by 'walling off' the zone outside of the waterway corridor, as shown in Plate 1.

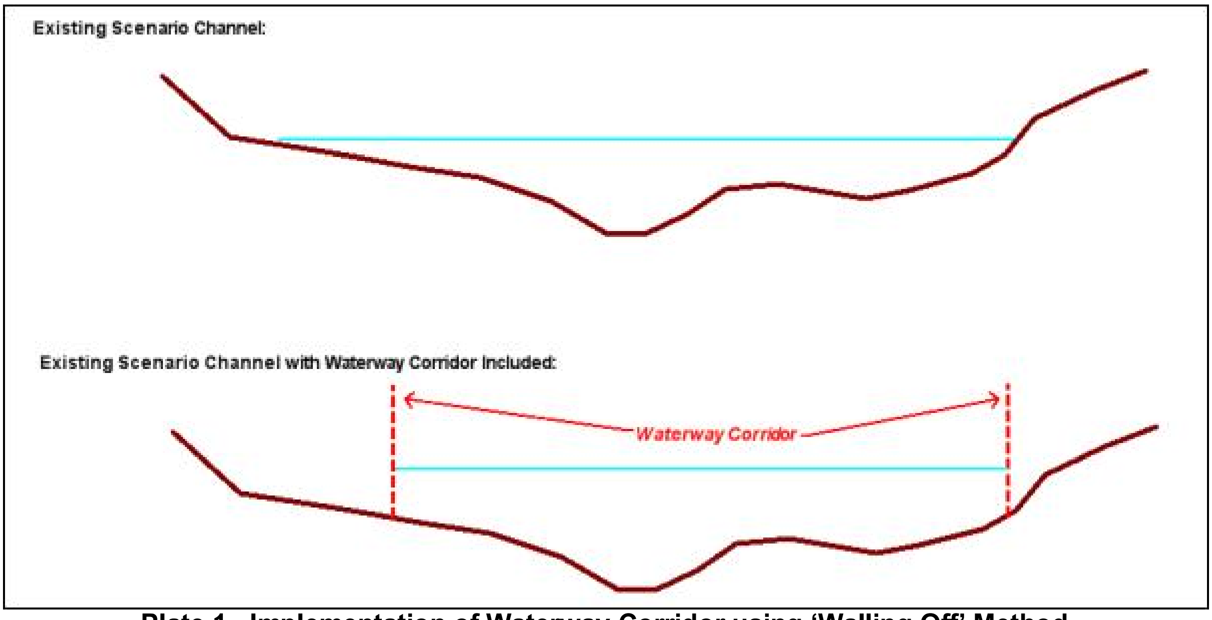

Plate 1. Implementation of Waterway Corridor using 'Walling Off' Method

Note that best practise suggests that an appropriate Manning's roughness value be applied to these 'walls' (i.e. not assumed to be frictionless) to ensure correct calculation of wetted perimeter at each cross-section.

This methodology has proved satisfactory when simulating 50% AEP to 1% AEP design flood events. However, when simulating larger flows such as 0.5% AEP and 0.2% AEP design events, prior experience has shown that the Waterway Corridor 'walls' resulted in conservatively high water levels and stability issues in some hydraulic modelling software packages.

For this flood study, the following alternative method for simulating the presence of a Waterway Corridor was adopted:

- implement Waterway Corridor within the hydraulic model using the 'walling off' methodology and include Minimum Riparian Corridor assumptions.
- simulate the Ultimate Case 1% AEP flood event.
- take the resulting Ultimate Case 1% AEP flood levels and add 300 mm development freeboard; and
- in areas outside the Waterway Corridor, raise the terrain model to this height until natural surface level is intersected, as shown in Plate 2.

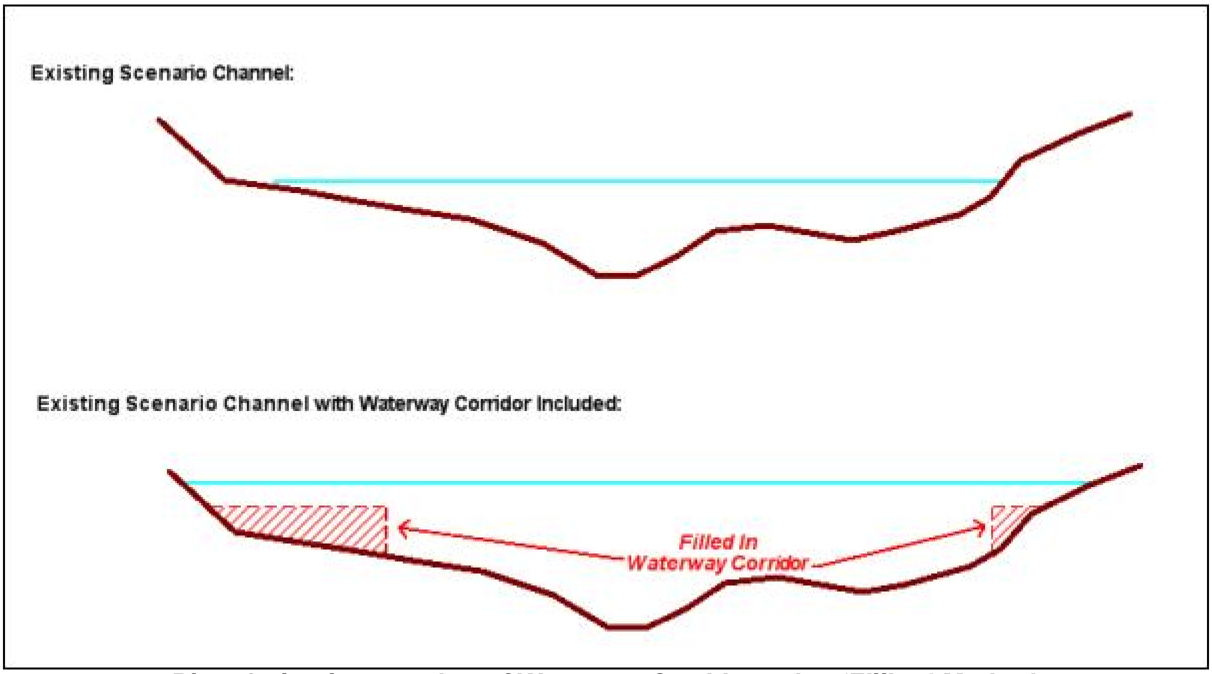

Plate 2. Implementation of Waterway Corridor using 'Filling' Method

This alternative method of simulating Waterway Corridors allows for more accurate and stable modelling of larger flow events (i.e. 0.5% and 0.2% AEP events), in particular when utilising two-dimensional hydraulic modelling packages. Extreme event modelling is discussed further in Section 7.

The Waterway Corridors are shown in Figure 5-4. Some minor amendments to BCC's Waterway Corridors were required in the hydraulic model to allow floodwaters to flow in certain areas of the creek. The locations of these flow conveyance zone amendments are also shown in Figure 5-4.

6.4 Design Hydrology

The hydrologic modelling of the catchment for the design flood events adopted land uses assuming ultimate catchment development (based on current planning). Ultimate land use maps were obtained from the BCC City Plan (2000).

For all design events, an initial loss of 0 mm was adopted, and a continuing loss rate of 0 mm/h and 2.5 mm/h was adopted in the impervious and pervious areas respectively. This is consistent with the losses used for the calibration events.

The 2, 5, 10, 20, 50 and 100 year Average Recurrence Interval (ARI) flood events were modelled, using the Australian Rainfall and Runoff (AR&R, 1987) temporal patterns. These events were simulated for durations from 30 minutes to 6 hours.

The local runoff hydrographs calculated by XP-RAFTS were used in the TUFLOW model.

6.5 Flood Frequency Analysis

Flood discharges for design events were also estimated by undertaking a flood frequency analysis to determine flows in Bald Hills Creek. Peak discharges from the Flood Frequency Analysis procedure were then compared against peak discharges from XP-RAFTS using AR&R storm patterns.

The flood frequency analysis of the XP-RAFTS model flows were based on Brisbane Central Business District (CBD) rainfall from 1911 to 2011. The analysis assumed historically recorded Brisbane CBD rainfall was representative of rainfall in the Bald Hills Creek catchment as a whole.

The most severe recorded rainfall events from each year between 1911 and 2011 (inclusive), for a range of standard durations were selected. The rainfall recorded at gauges located within the Brisbane CBD was used for the analysis rather than data collected within the Bald Hills Creek catchment due to the long and continuous record available via the CBD gauges. Further, given the relatively close proximity of the Bald Hills Creek catchment to the Brisbane CBD, it was considered that the use of the CBD data was acceptable.

A range of standard duration storms, from 30 minutes to 24 hours, was applied to the catchment to ensure that the peak discharge was calculated at all points along the creek. The standard duration storms used in the analysis are:

- 30 minutes
- 1 hour
- 2 hours
- 3 hours
- 4 hours
- 6 hours
- 12 hours
- 24 hours

Discharges in Bald Hills Creek were calculated for the standard duration rainfall events for each of the 101 years of rainfall data. Two key representative locations in the catchment were then selected to perform the flood frequency analysis:

- Bracken Ridge Road; and
- John Fisher Drive (Eastern Tributary).

The 101 annual peak discharges at each location were ranked from highest to lowest. The plotting position (P_i) (which provides an estimate of the Average Recurrence Interval) of each calculated discharge was determined using Cunnane's formula (Institution of Engineers Australia, 1987):

$$P_i = \frac{r - 0.4}{N + 0.2}$$

where: *r* = rank of discharge (the largest flood having r = 1)

N = number of annual peak discharges

The peak annual discharge series at each location (on a logarithmic scale) was plotted against the plotting position (average recurrence interval) of the storms (on a normal distribution scale). A line of best fit was drawn through these annual peak discharge series to determine the anticipated design discharge, for return periods ranging from 2 years to 100 years, as shown in Figures D1 and D2 (in Appendix D). A comparison to the peak discharges calculated using the AR&R storm events is also shown in these Figures, and demonstrates a high level of consistency with the flood frequency analysis results.

6.6 Design Hydraulics

Bald Hills Creek outlets into the Pine River near Deep Water Bend. Consequently, the tidal water levels at this location were adopted for all design event scenarios. In accordance with Council's brief, the following tailwater level was used (source: *Queensland Tide Tables*, Queensland Government, 2014):

- 2 year to 100 year ARI events – Mean High Water Springs (MHWS) = 0.93 mAHD.

For all design events, it was assumed that the handrails at hydraulic structures were completely blocked by debris.

6.7 Design Event Results

6.7.1 Design Flows and Levels

The peak flood levels and discharges along Bald Hills Creek for Scenario 3 (i.e. Existing waterway conditions plus application of Minimum Riparian Corridor (MRC) plus filling to the Waterway Corridor (WC), with ultimate catchment hydrology) are detailed for the 2 year to 100 year Average Recurrence Interval events in Table 6-2 and Table 6-3 respectively.

Table 6-2 Peak Flood Levels – Design Events

Location	AMTD (m)	Peak Flood Level (mAHD)					
		2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
Bald Hills Creek							
Mouth	0	0.93	0.93	0.93	0.93	0.93	0.93
MHG BD100	1180	0.95	0.96	0.97	0.97	0.98	1.00
MHG BD110	2410	1.00	1.05	1.08	1.13	1.20	1.27
D/S Gateway Motorway	5010	2.61	2.72	2.78	2.85	2.94	3.01
U/S Gateway Motorway	5060	2.62	2.73	2.79	2.87	2.95	3.03
MHG BD130	5540	3.05	3.25	3.35	3.46	3.59	3.69
D/S Bracken Ridge Rd	5550	3.06	3.27	3.37	3.49	3.62	3.72
U/S Bracken Ridge Rd	5570	3.09	3.33	3.44	3.57	3.72	3.84
MHG BD140	5640	3.10	3.34	3.45	3.58	3.73	3.85
D/S Hoyland St	6450	4.18	4.37	4.48	4.63	4.79	4.90
U/S Hoyland St	6500	4.22	4.45	4.58	4.76	4.98	5.15
MHG BD150	6550	4.22	4.45	4.58	4.76	4.98	5.15
D/S Barbour Bikeway	7210	7.12	7.23	7.30	7.38	7.45	7.49
U/S Barbour Bikeway	7230	7.14	7.28	7.36	7.45	7.55	7.61
D/S Aldea Circuit	7550	7.24	7.41	7.50	7.60	7.72	7.79
U/S Aldea Circuit	7570	7.26	7.45	7.55	7.69	7.83	7.91
MHG BD160	7610	7.29	7.47	7.58	7.72	7.86	7.95
D/S Railway Line	7680	7.49	7.62	7.70	7.84	7.97	8.06
U/S Railway Line	7720	8.09	8.26	8.35	8.47	8.61	8.74
Eastern Tributary							
MHG BD120	n/a	3.34	3.34	3.35	3.36	3.40	3.45
D/S Gateway Motorway	490	3.08	3.29	3.40	3.48	3.57	3.61
U/S Gateway Motorway	680	3.74	4.28	4.58	4.91	5.27	5.45
MHG BD210	690	3.76	4.29	4.59	4.92	5.29	5.46
MHG BD220	1260	4.08	4.48	4.72	5.01	5.35	5.52
D/S Denham Bikeway	1330	4.11	4.50	4.73	5.02	5.35	5.53
U/S Denham Bikeway	1350	4.32	4.50	4.75	5.05	5.40	5.59

Table 6-3 Peak Discharges – Design Events

Location	AMTD (m)	Peak Discharge (m^3/s)					
		2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
Bald Hills Creek							
Gateway Motorway	5035	27.8	40.3	47.2	56.6	68.9	78.8
Bracken Ridge Rd	5560	23.4	32.9	38.2	45.9	55.6	64.0
Hoyland St	6475	20.9	27.0	30.6	35.1	42.2	48.3
Barbour Bikeway	7220	7.6	11.0	13.0	16.3	20.2	23.0
Aldea Circuit	7560	8.9	12.1	13.9	16.3	18.4	20.2
Railway Line	7700	9.3	12.7	14.7	17.4	19.5	21.2
Eastern Tributary							
Gateway Motorway	585	10.8	13.5	14.3	16.3	19.2	24.6
Denham Bikeway	1340	5.3	7.1	8.1	9.6	10.7	11.1

6.7.2 Return Periods of Historic Events

The March 2001 event was the largest calibration event. As discussed in Section 4.2.1, the average recurrence interval of the event (based on the IFD curves of the recorded rainfall) was in the order of 20 to 100 years for durations of between approximately 1 and 10 hours. This is consistent with the results of the hydraulic modelling, which indicates that the peak flood levels recorded at MHG BD130 and MHG BD140 are approximately 20 to 50 year ARI levels.

The other three calibration events were all of similar magnitude (refer Sections 5.4.2, 5.4.3 and 5.4.4), with an Average Recurrence Interval of less than 5 years. This is consistent with the results of the hydraulic modelling, which indicates that the peak flood levels recorded at the Maximum Height Gauges are approximately 2 to 5 year ARI levels.

6.7.3 Flood Immunity of Existing Crossings

The flood immunity of the existing hydraulic structures is shown in Table 6-4.

Further information is contained in the Hydraulic Structure Reference Sheets in Appendix C.

Table 6-4 Hydraulic Structure Flood Immunity

Location	Flood Immunity
Caboolture Railway Line	> 2000 years
Aldea Circuit	200 years
Barbour Road Bikeway	5 years
Hoyland Street	200 years
Bracken Ridge Road	< 2 years
Gateway Motorway Bridge	500 years
Denham Street Bikeway (Eastern Tributary)	50 years
John Fisher Drive (Eastern Tributary)	20 years

6.7.4 Flood Mapping

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

With the move to 2-dimensional flood models, the production of flood levels, extents and depth-velocity products is inherent in simulating a model, i.e. a flood map is a direct output from a model simulation removing the requirement to apply a separate process. For the “existing” case simulations, the model is run and the direct output is able to be mapped or referenced in a GIS environment. In order to simulate the “ultimate” scenario, the model topography must be modified to represent filling associated with development. This in turn affects the resulting flood mapping with the flood extent limited to the edge of the filled floodplain. Post processing of the model output is required to represent the modelled flood levels against the current floodplain conditions.

The MapInfo software was selected for the purpose of processing the “ultimate” case results and producing the planning flood levels and surfaces. The flood extents calculated for the “ultimate” cases were projected out to the adjacent floodplain with the filling described in Section 6.3 removed. The flood extent was stopped where the projected flood level intersected the ground level. The resultant flood extent was then reviewed.

Despite the review of the stretched surfaces and the slight modification of the waterway corridor to manipulate the stretching process, the process and outputs are still subject to limitations as follows.

- The stretched surfaces are not the result of the detailed 2-dimensional flood modelling. Rather, they are inferred results based on the results of the flood model assuming Scenario 3 conditions.
- The adoption of the Waterway Corridor has the potential to block flow along overland flow paths adjacent to the creek, e.g. along roads or other drainage easements. Thus, the stretched surfaces would not represent the flow along these paths.

Flood mapping is contained in Volume 2 for the following events:

- 2 year to 100 year Average Recurrence Interval events for Scenario 3 (flood levels and depths); and
- 2 year to 100 year Average Recurrence Interval events for Scenario 1 (flood extent).

Scale: 1:18,000

180 0 180 360 540

Metres

N W E S

LEGEND

Manning's n Values

- 0.15
- 0.10
- 0.04
- 0.08
- TUFLOW Model Extent
- BCC Boundary

Figure 6-1

Minimum Riparian Corridor

Bald Hills Creek Flood Study

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Date:	10/6/14
Revision Number:	J13078
Designed by:	HD
Client Name:	BCC

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7.0 Rare and Extreme Event Analysis

7.1 Overview

The verified hydrologic and hydraulic models were used to analyse rare and extreme events, with an average recurrence interval of 200, 500 and 2,000 years, and the Probable Maximum Flood.

As discussed in Section 6.1, a range of scenarios were simulated in the hydrologic and hydraulic models. The following Scenarios were modelled for the rare and extreme events:

- Scenario 1 – 200, 500 and 2,000 year ARI events, and the Probable Maximum Flood.
- Scenario 3 – 200 and 500 year ARI events

7.2 Hydrologic Modelling

The hydrologic modelling of the catchment for the rare and extreme flood events adopted land uses assuming ultimate catchment development. Ultimate land use maps were sourced from the BCC City Plan 2000.

For all rare and extreme events, an initial loss of 0 mm was adopted, and a continuing loss rate of 0 mm/h and 2.5 mm/h was adopted in the impervious and pervious areas respectively. This is consistent with the losses used for the calibration and design events.

The 200 and 500 year Average Recurrence Interval (ARI) flood events were modelled, using the Australian Rainfall and Runoff (AR&R) temporal patterns. These events were simulated for durations from 30 minutes to 6 hours. The rainfall depth for the 200 and 500 year ARI events were extracted using the CRC-FORGE application.

The 2000 year ARI event and the Probable Maximum Precipitation event were also modelled. The 6 hour duration “superstorm” temporal pattern developed by Brisbane City Council was used for these events.

The local runoff hydrographs calculated by XP-RAFTS were used in the TUFLOW model.

7.3 Hydraulic Modelling

Bald Hills Creek outlets into the Pine River near Deep Water Bend. Consequently, the tidal water levels at this location were adopted for the rare and extreme events. The following tailwater level was used (source: *Queensland Tide Tables*, Queensland Government, 2014):

- 200 year to 2000 year ARI events and the Probable Maximum Flood – Highest Astronomical Tide (HAT) = 1.48 mAHD.

For the rare and extreme events, it was assumed that the handrails at hydraulic structures were completely blocked by debris.

7.4 Results and Mapping

The peak flood levels and discharges along Bald Hills Creek for Scenario 3 (i.e. Existing waterway conditions plus application of Minimum Riparian Corridor (MRC) plus filling to the Waterway Corridor (WC), with ultimate catchment hydrology) are detailed for the 200 year to 500 year average recurrence interval events in Table 7-1 and Table 7-2 respectively.

Table 7-1 Peak Flood Levels – Extreme Events

Location	AMTD (m)	Peak Flood Level (mAHD)	
		200 Year	500 Year
Bald Hills Creek			
Mouth	0	1.48	1.48
MHG100	1180	1.52	1.53
MHG110	2410	1.72	1.79
D/S Gateway Motorway	5010	3.09	3.18
U/S Gateway Motorway	5060	3.20	3.40
MHG130	5540	3.84	4.00
D/S Bracken Ridge Rd	5550	3.86	4.02
U/S Bracken Ridge Rd	5570	3.97	4.10
MHG140	5640	3.98	4.11
D/S Hoyland St	6450	5.02	5.15
U/S Hoyland St	6500	5.33	5.48
MHG150	6550	5.33	5.48
D/S Barbour Bikeway	7210	7.53	7.56
U/S Barbour Bikeway	7230	7.66	7.70
D/S Aldea Circuit	7550	7.86	7.91
U/S Aldea Circuit	7570	7.99	8.04
MHG160	7610	8.02	8.07
D/S Railway Line	7680	8.13	8.19
U/S Railway Line	7720	8.87	9.00
Eastern Tributary			
MHG120	n/a	3.62	3.83
D/S Gateway Motorway	490	3.67	3.76
U/S Gateway Motorway	680	5.60	5.71
MHG210	690	5.61	5.72
MHG220	1260	5.67	5.78
D/S Denham Bikeway	1330	5.67	5.77
U/S Denham Bikeway	1350	5.71	5.79

Table 7-2 Peak Discharges – Extreme Events

Location	AMTD (m)	Peak Discharge (m^3/s)	
		200 Year	500 Year
Bald Hills Creek			
Gateway Motorway	5035	89.6	105.8
Bracken Ridge Rd	5560	75.6	90.7
Hoyland St	6475	56.5	69.0
Barbour Bikeway	7220	25.5	27.8
Aldea Circuit	7560	22.1	23.9
Railway Line	7700	22.8	24.2
Eastern Tributary			
Gateway Motorway	585	29.0	34.0
Denham Bikeway	1340	11.5	11.9

Flood mapping is contained in Volume 2 for the following events:

- 200 year and 500 year Average Recurrence Interval events for Scenario 3 (flood levels); and
- 200, 500 and 2,000 year Average Recurrence Interval events for Scenario 1 (flood extent only).

8.0 Sensitivity Analysis

8.1 Overview

Sensitivity analyses were carried out for the following conditions:

- Climate Change (to year 2050 and 2100)
- Structure Blockage

The results are discussed in the following sections.

8.2 Climate Change

8.2.1 Model Boundary Conditions

8.2.1.1 Tidal and Tailwater Conditions

Revised tailwater level boundary conditions were adopted for the Climate Change Scenarios:

- To 2050 – 300 mm rise in tide level; and
- To 2100 – 800 mm rise in tide level.

Thus, the following tailwater levels were adopted for the modelling:

- 2 year to 100 year ARI events – MHWS (2050) = 1.23 mAHD
- 2 year to 100 year ARI events – MHWS (2100) = 1.73 mAHD
- 200 year to 500 year ARI events – MHWS (2050) = 1.78 mAHD
- 200 year to 500 year ARI events – MHWS (2100) = 2.28 mAHD

8.2.1.2 Inflow Boundary Conditions

Revised rainfall intensities were adopted for the Climate Change Scenarios:

- To 2050 – 10% increase in rainfall intensity; and
- To 2100 – 20% increase in rainfall intensity.

8.2.2 Results

The peak flood levels along Bald Hills Creek for Scenario 3 (i.e. Existing waterway conditions plus application of Minimum Riparian Corridor (MRC) plus filling to the Waterway Corridor (WC), with ultimate catchment hydrology) for the two Climate Change scenarios for the 100 year average recurrence interval event is shown in Table 8-1.

Table 8-1 Peak Flood Levels – Climate Change Events

Location	AMTD (m)	100 Year ARI Peak Flood Level (mAHD)	
		Climate Change to 2050	Climate Change to 2100
Bald Hills Creek			
Mouth	0	1.23	1.73
MHG100	1180	1.28	1.76
MHG110	2410	1.52	1.92
D/S Gateway Motorway	5010	3.07	3.12
U/S Gateway Motorway	5060	3.15	3.26
MHG130	5540	3.80	3.89
D/S Bracken Ridge Rd	5550	3.82	3.92
U/S Bracken Ridge Rd	5570	3.93	4.01
MHG140	5640	3.94	4.02
D/S Hoyland St	6450	4.98	5.07
U/S Hoyland St	6500	5.28	5.38
MHG150	6550	5.28	5.38
D/S Barbour Bikeway	7210	7.52	7.54
U/S Barbour Bikeway	7230	7.65	7.68
D/S Aldea Circuit	7550	7.84	7.88
U/S Aldea Circuit	7570	7.97	8.01
MHG160	7610	8.00	8.04
D/S Railway Line	7680	8.11	8.15
U/S Railway Line	7720	8.84	8.91
Eastern Tributary			
MHG120	n/a	3.57	3.69
D/S Gateway Motorway	490	3.66	3.70
U/S Gateway Motorway	680	5.57	5.63
MHG210	690	5.58	5.64
MHG220	1260	5.64	5.70
D/S Denham Bikeway	1330	5.64	5.70
U/S Denham Bikeway	1350	5.70	5.74

Table 8-2 Peak Discharges – Climate Change Events

Location	AMTD (m)	100 Year ARI Peak Discharge (m^3/s)	
		Climate Change to 2050	Climate Change to 2100
Bald Hills Creek			
Gateway Motorway	5035	86.2	94.3
Bracken Ridge Rd	5560	72.2	80.0
Hoyland St	6475	54.1	60.1
Barbour Bikeway	7220	24.8	26.3
Aldea Circuit	7560	21.6	22.7
Railway Line	7700	22.3	23.2
Eastern Tributary			
Gateway Motorway	585	28.1	30.5
Denham Bikeway	1340	11.8	12.0

The calculated changes in the peak 100 year ARI flood levels due to Climate Change to the year 2050 are up to 300 mm near the mouth (due to the change in the adopted tail water level) and 50 mm to 130 mm in all other areas of the creek.

Similarly, the calculated changes in the peak 100 year ARI flood levels due to Climate Change to the year 2100 are up to 800 mm near the mouth (due to the change in the adopted tail water level) and 50 mm to 240 mm in all other areas of the creek.

8.3 Structure Blockage

A sensitivity analysis was carried out assuming partial blockage of the hydraulic structures along Bald Hills Creek.

Blockage Factors were obtained from Table 4.10.1 of the Queensland Urban Drainage Manual (2013). All culverts structures are relatively small (i.e. height less than three metres, or width less than five metres), thus a blockage factor of 20% was adopted for all culverts. Thus, all culverts were assumed to be blocked by 20% for the analysis.

The sensitivity analysis considered the 100 year Average Recurrence Interval event for the Scenario 1 model (i.e. Existing waterway conditions with ultimate catchment hydrology).

The results showed that the partial blockage of the structures generally caused an increase in flood level of approximately 30 to 80 mm. No additional break out flow paths were identified.

9.0 Summary of Study Findings

The Flood Study included the setup and verification of hydrologic and hydraulic models of the Bald Hills Creek catchment. The results demonstrated that the models were calibrated for all calibration and verification events, with the majority of calculated peak flood levels within ±70 mm of the recorded MHG levels. Ten of the 15 differences were within 70 mm, and a further two were within 140 mm.

The results also demonstrated that the XP-RAFTS and TUFLOW models are providing consistent results, and that the structure losses calculated by the TUFLOW model are reliable.

The models were therefore suitable to calculate the design flood levels and discharges in the Bald Hills Creek catchment.

The Flood Frequency Analysis also showed consistency with the AR&R XP-RAFTS results.

The models simulated a range of average recurrence interval flood events, from the 2 year to the 2,000 year ARI event, and the Probable Maximum Flood. The models also considered a range of hydraulic conditions along the creek, including:

- existing waterway conditions;
- application of Minimum Riparian Corridor (MRC); and
- filling to the Waterway Corridor (WC).

A range of sensitivity analyses were also carried out, including:

- impact of Climate Change (to 2050 and 2100); and
- impact of partial blockage of structures.

APPENDICES

APPENDIX A – Hydrometric Data

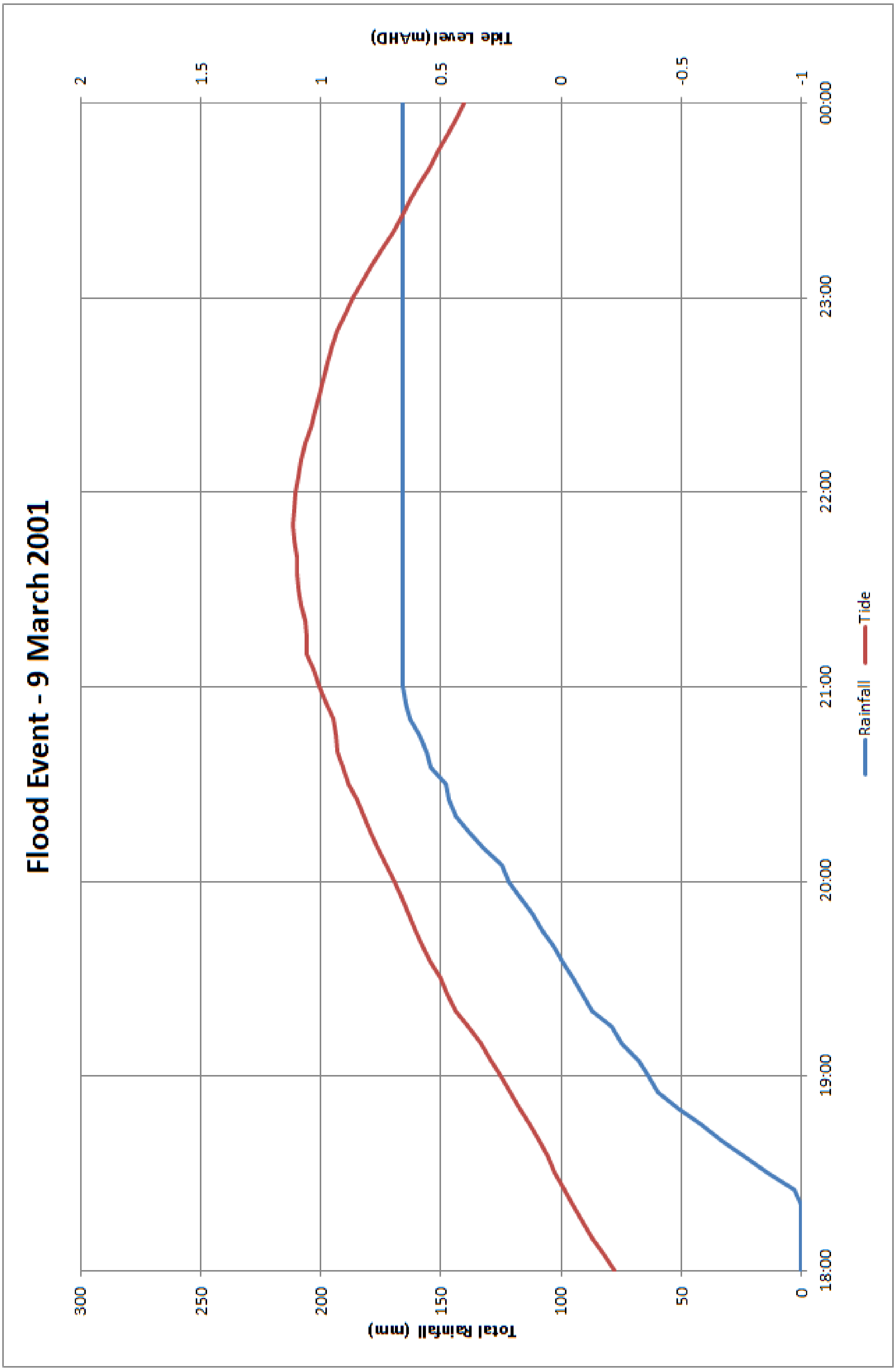

Figure A1. Rainfall and Tide Information – March 2001 Event

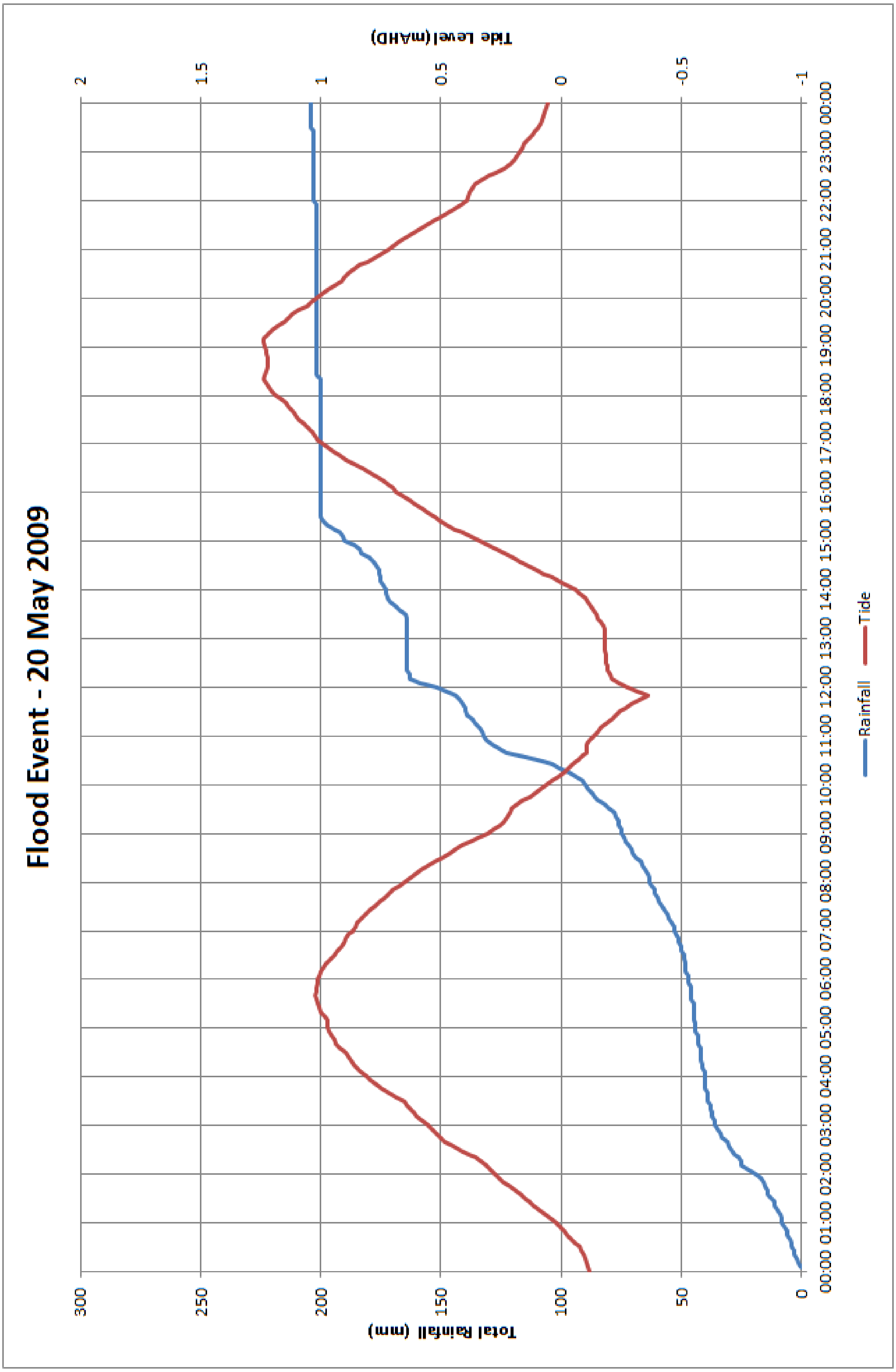

Figure A2. Rainfall and Tide Information – May 2009 Event

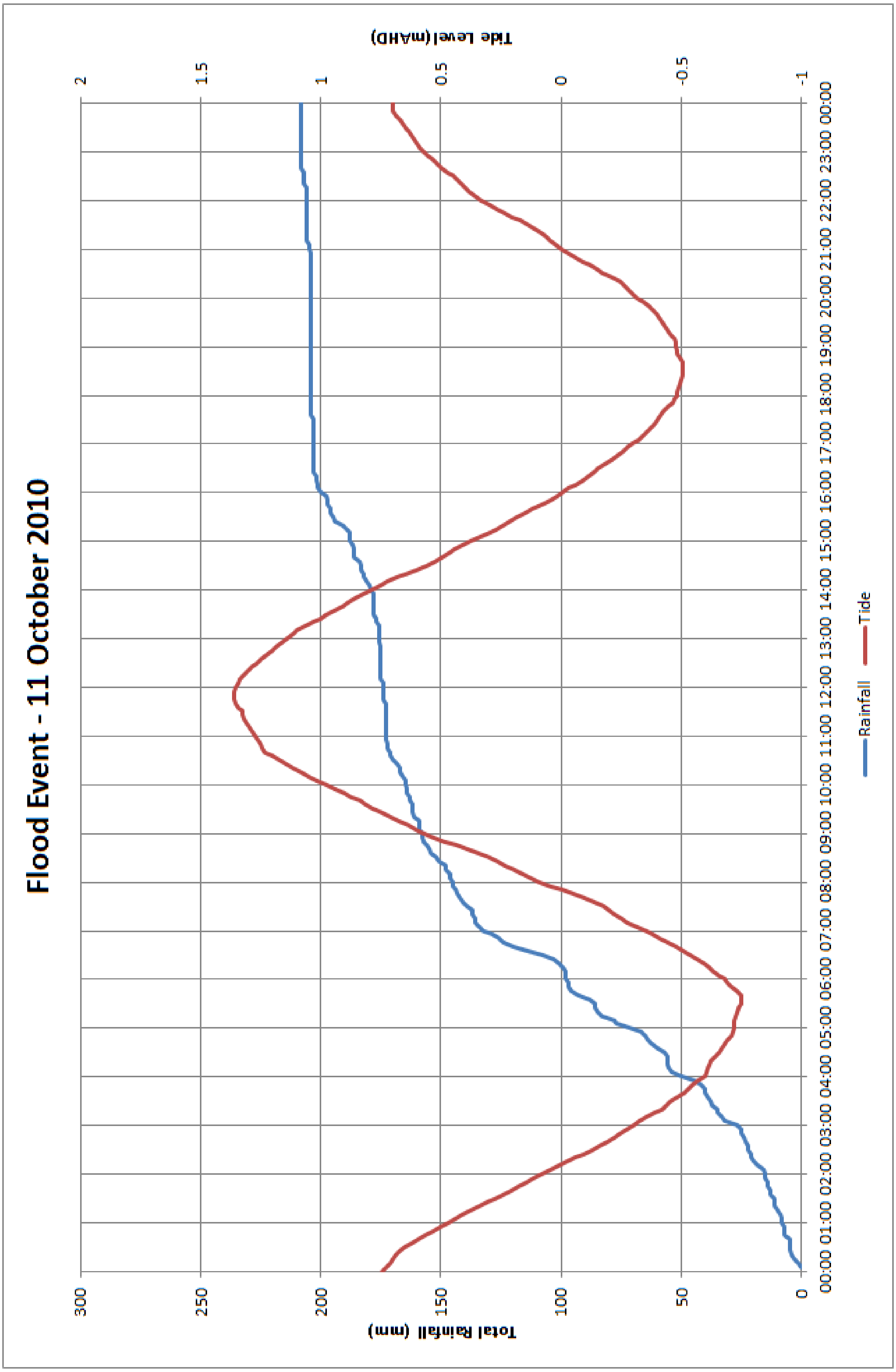

Figure A3. Rainfall and Tide Information – October 2010 Event

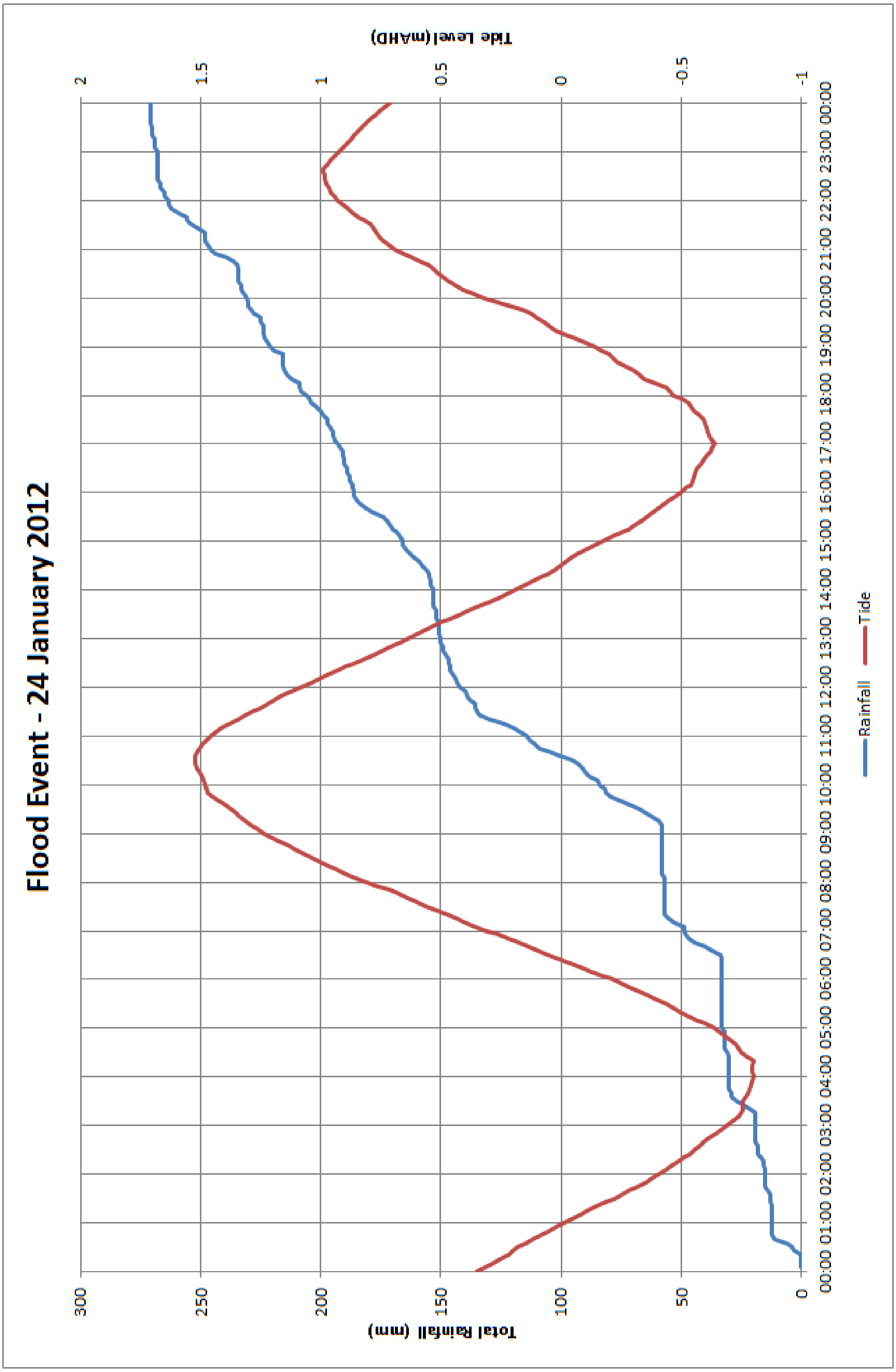

Figure A4. Rainfall and Tide Information – January 2012 Event

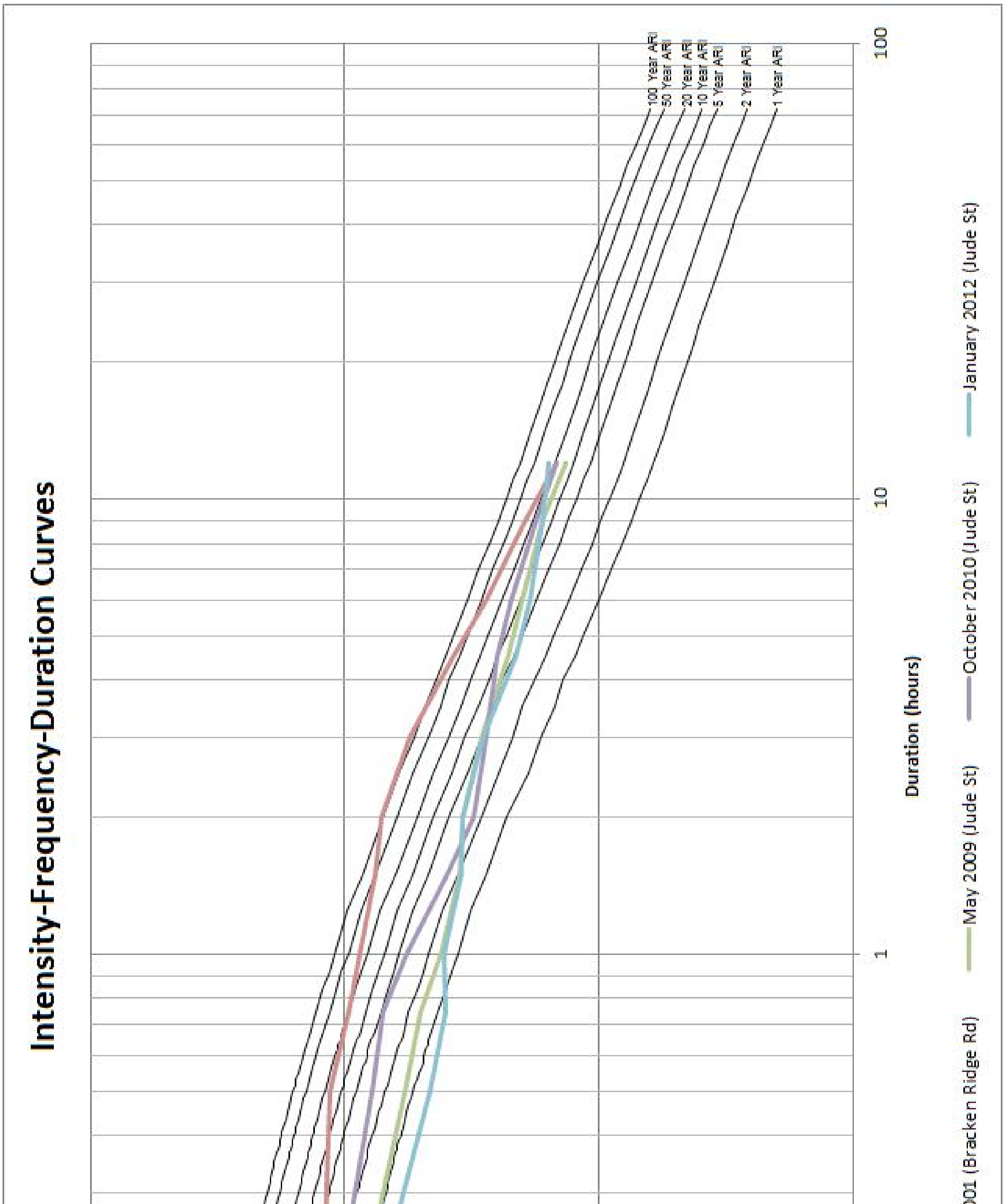

Figure A5. Intensity-Frequency-Duration Analysis

APPENDIX B – Hydrologic & Hydraulic Model Consistency Check

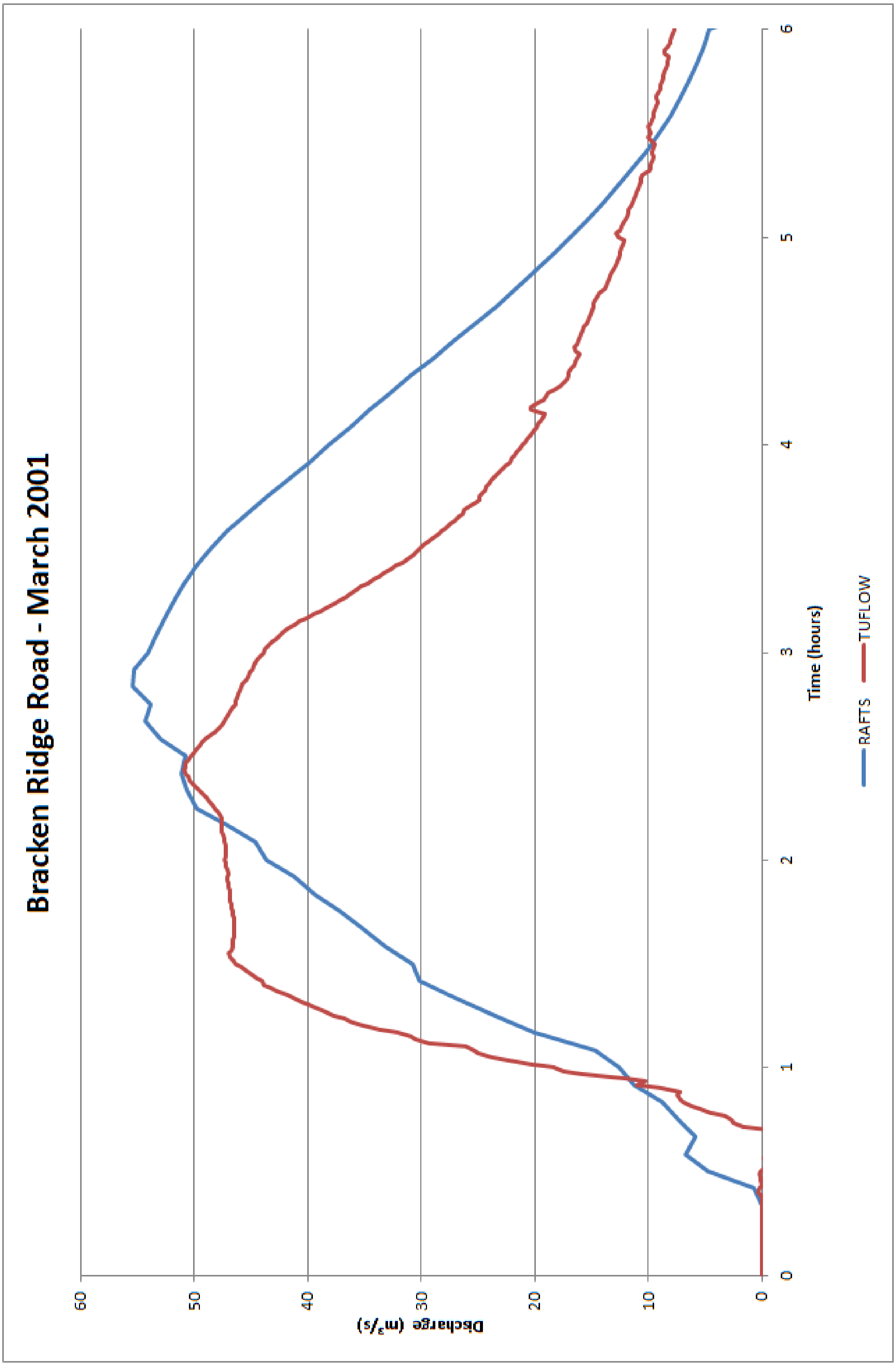

Figure B1. Model Consistency Check – Bracken Ridge Road, March 2001

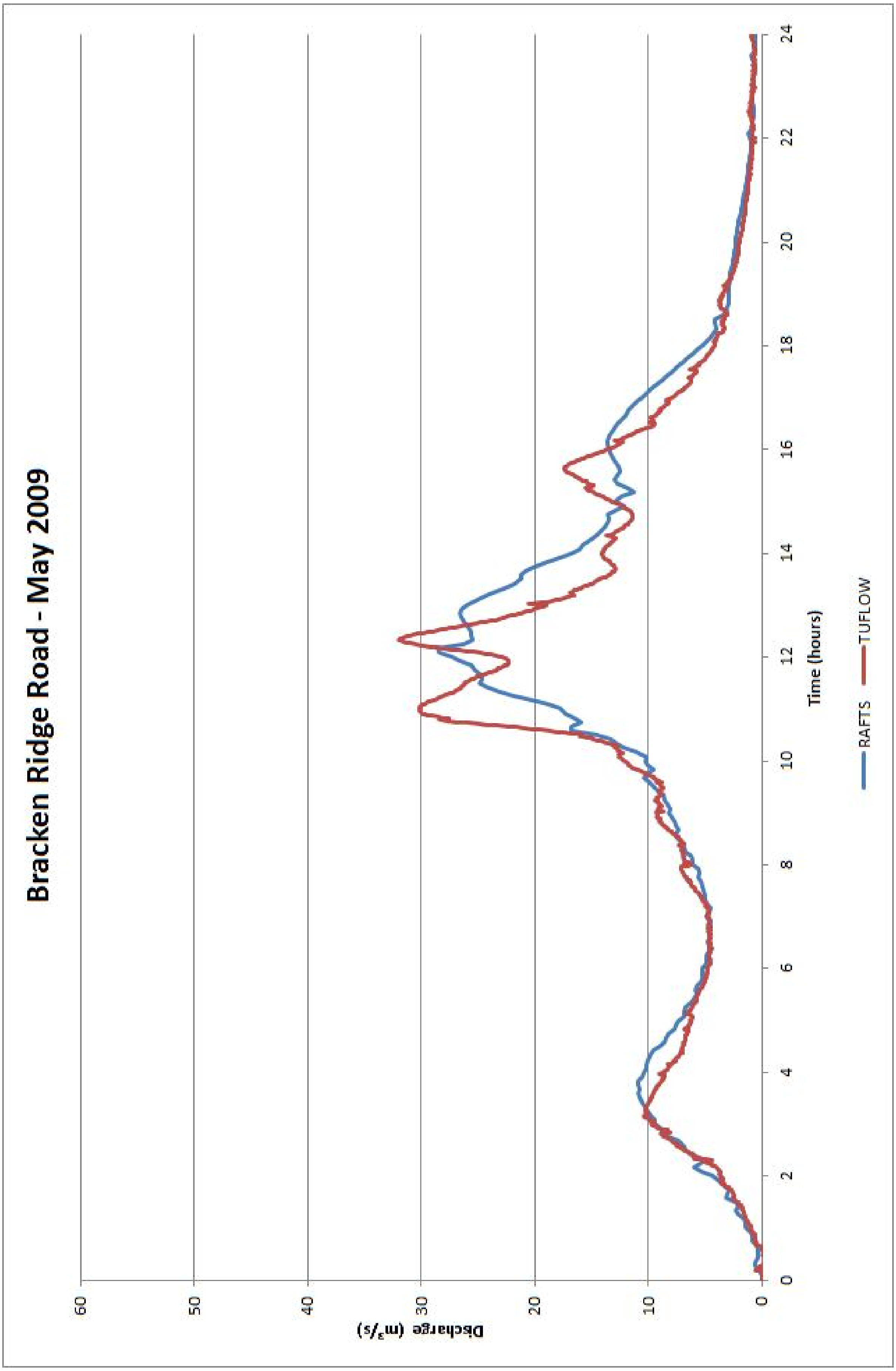

Figure B2. Model Consistency Check – Bracken Ridge Road, May 2009

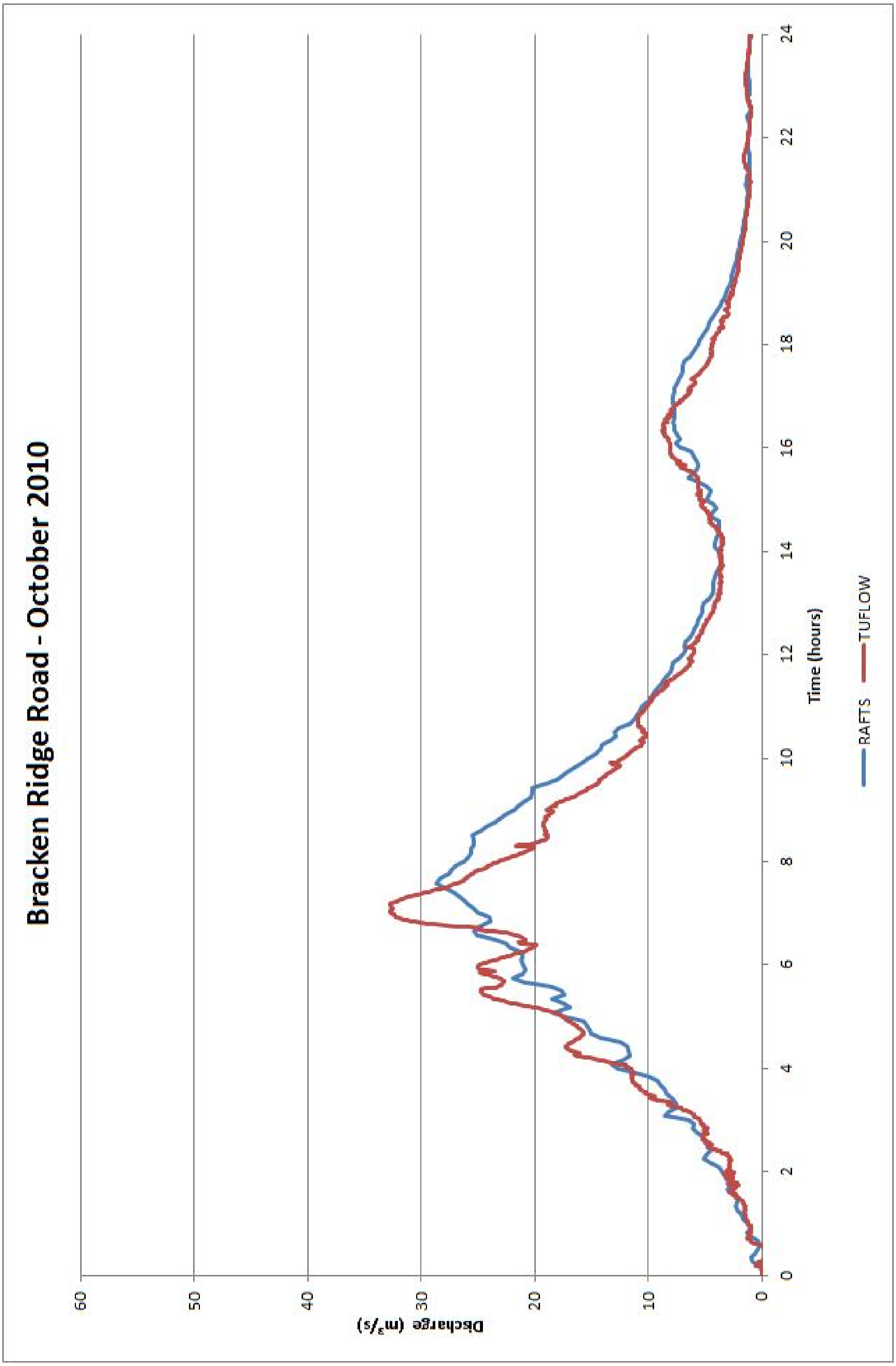

Figure B3. Model Consistency Check – Bracken Ridge Road, October 2010

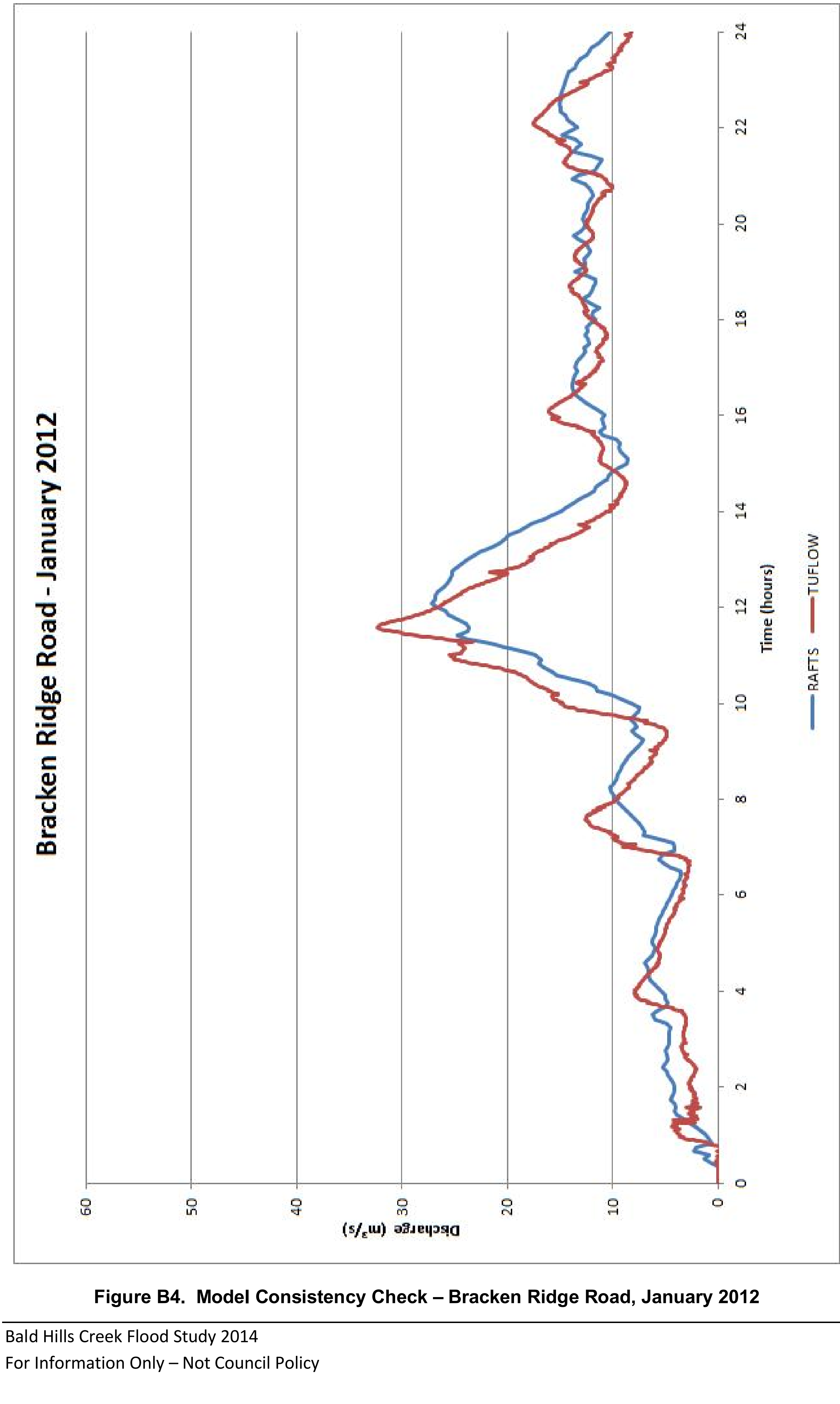

Figure B4. Model Consistency Check – Bracken Ridge Road, January 2012

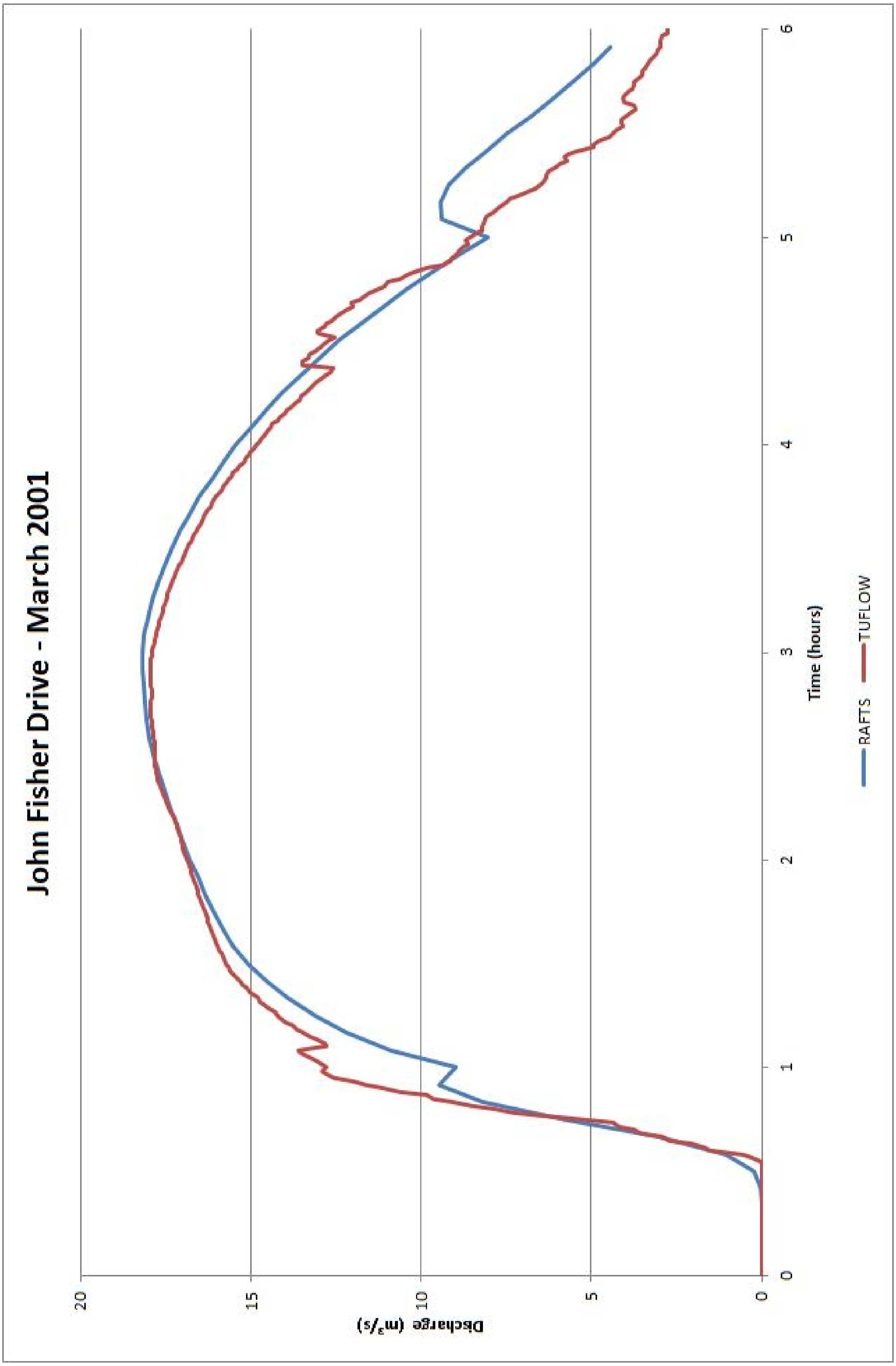

Figure B5. Model Consistency Check – John Fisher Drive, March 2001

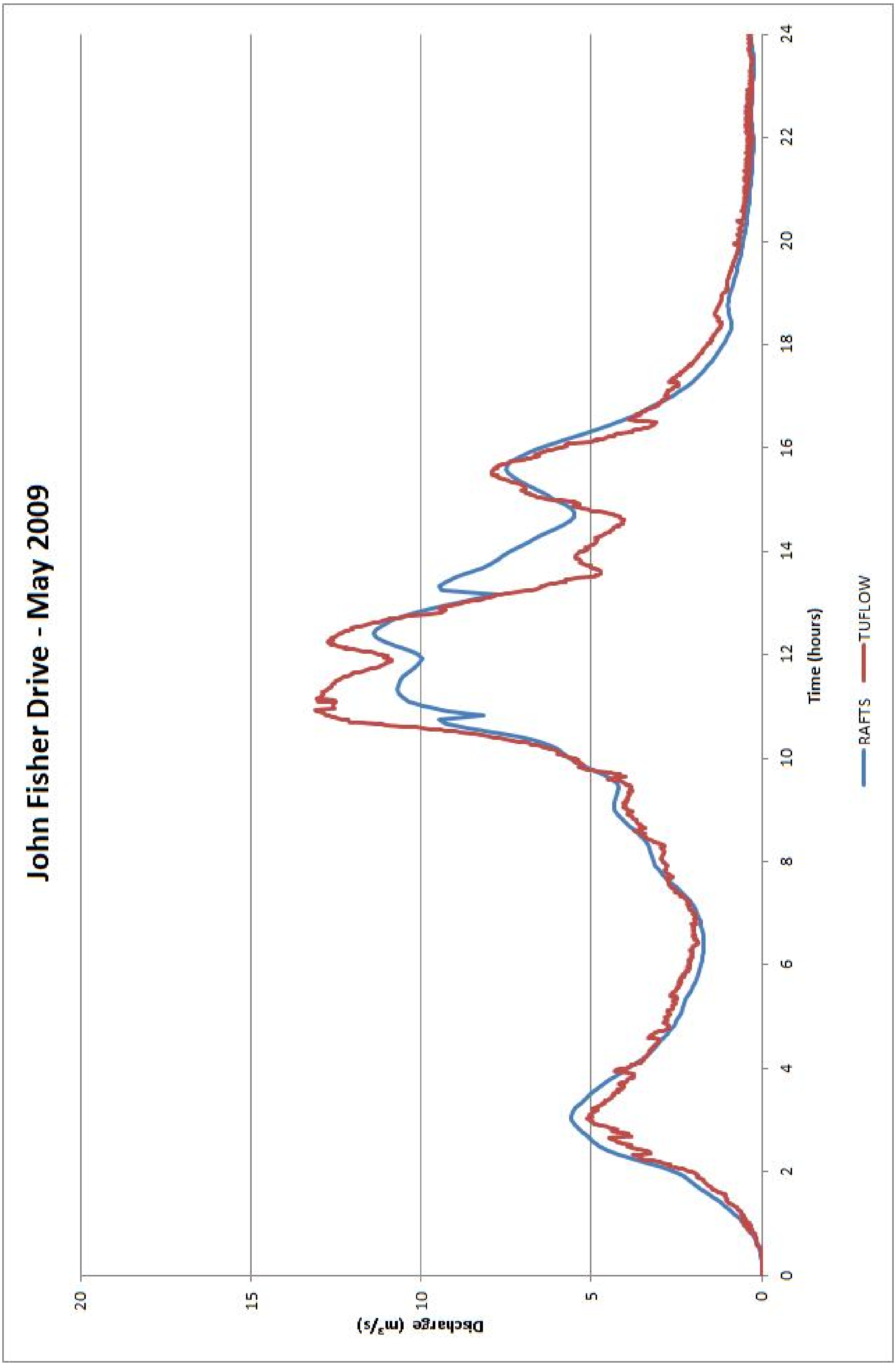

Figure B6. Model Consistency Check – John Fisher Drive, May 2009

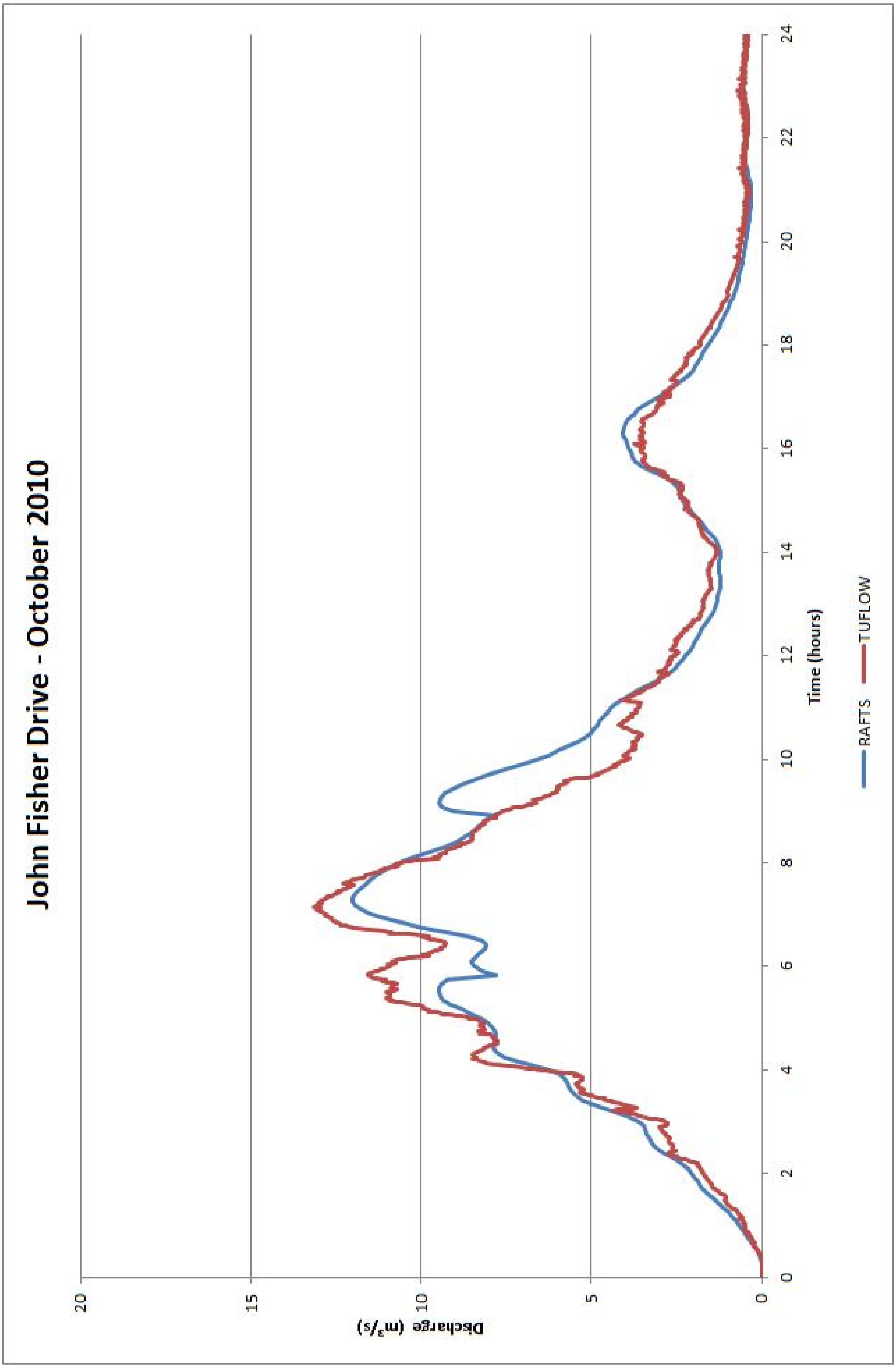

Figure B7. Model Consistency Check – John Fisher Drive, October 2010

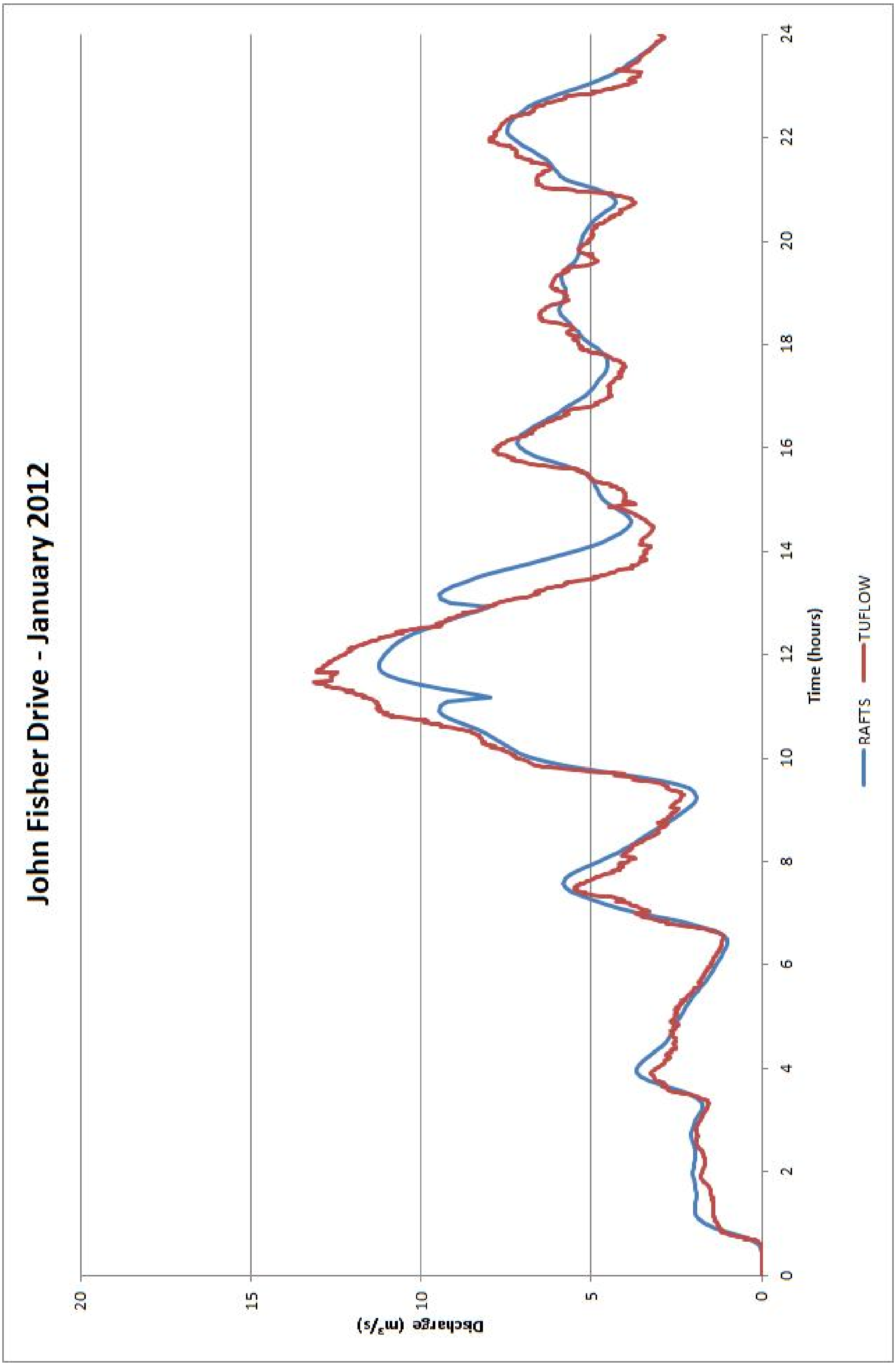

Figure B8. Model Consistency Check – John Fisher Drive, January 2012

APPENDIX C – Hydraulic Structure Reference Sheets

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**
LOCATION:	**North Coast Railway**

IMMUNITY RATING:	**>2000yr ARI**

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**109 K7**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	**C3548B**
MODEL ID:	**Railway**	AMTD (m):	**7770**

STRUCTURE DESCRIPTION: **Box Culverts**

STRUCTURE SIZE : **8 / 1.2 x 0.9 metre**

For Culverts: Number of cells/pipes and sizes

For Bridges: Number of spans and their lengths

Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**7.35**	UPSTREAM OBVERT LEVEL:	**8.25**
DOWNSTREAM INVERT LEVEL:	**7.10**	DOWNSTREAM OBVERT LEVEL:	**8.00**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **20**

LENGTH OF CULVERT BARREL AT OBVERT (m): **20**

TYPE OF LINING: **Concrete**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**21.9**	LOWEST POINT OF WEIR (m AHD):	**9.30**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**N/A**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD): **N/A**

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS: **N/A**

ADDITIONAL STRUCTURE DETAILS:

Timber acoustic barriers (2400 mm high) on downstream side.

For culverts, wingwall/headwall details, entrance details e.g. 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:

PLAN NUMBER: **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:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**North Coast Railway**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	23.8	8.96	7.98	0.98	0	0	0.0	4.6
0.2	18.7	8.55	7.83	0.73	0	0	0.0	3.6
0.5	16.0	8.41	7.70	0.70	0	0	0.0	2.6
1	13.8	8.31	7.61	0.69	0	0	0.0	2.5
2	12.0	8.22	7.55	0.68	0	0	0.0	2.4
5	10.0	8.12	7.46	0.66	0	0	0.0	2.2
10	8.4	8.04	7.38	0.66	0	0	0.0	2.1
20	7.2	7.97	7.32	0.65	0	0	0.0	2.0
50	5.1	7.85	7.22	0.63	0	0	0.0	1.8

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**North Coast Railway**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	Bald Hills Creek
LOCATION:	Aldea Circuit

IMMUNITY RATING:	200 yr ARI

DATE OF SURVEY:	ALS 2009	UBD REF:	109 K7
SURVEYED CROSS SECTION ID:	N/A	BCC ASSET ID:	C2190B
MODEL ID:	Aldea	AMTD (m):	7560

STRUCTURE DESCRIPTION: **Box Culverts**

STRUCTURE SIZE : **5 / 2.4 x 1.2 metre**

For Culverts: Number of cells/pipes and sizes
For Bridges: Number of spans and their lengths
Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	5.69	UPSTREAM OBVERT LEVEL:	6.89
DOWNSTREAM INVERT LEVEL:	5.67	DOWNSTREAM OBVERT LEVEL:	6.87
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **20**

LENGTH OF CULVERT BARREL AT OBVERT (m): **20**

TYPE OF LINING: **Concrete**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	20	LOWEST POINT OF WEIR (m AHD):	7.50
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	N/A		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD):	**N/A**
DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	**Timber post and rail (refer photo)**

ADDITIONAL STRUCTURE DETAILS:

No wingwalls. Culverts flush wth embankment. Refer photo.

For culverts, wingwall/headwall details, entrance details e.g. 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:	**2004**
PLAN NUMBER:	**WP3929-AC**
HAS THE STRUCTURE BEEN UPGRADED?	**No**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Aldea Circuit**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	23.8	7.86	7.66	0.20	140	0.20	0.1	1.5
0.2	18.6	7.70	7.55	0.15	35	0.04	0.0	1.3
0.5	15.9	7.60	7.49	0.11	0	0.00	0.0	1.1
1	13.6	7.51	7.43	0.08	0	0.00	0.0	0.9
2	11.9	7.43	7.37	0.06	0	0.00	0.0	0.8
5	9.9	7.34	7.30	0.04	0	0.00	0.0	0.7
10	8.3	7.26	7.24	0.03	0	0.00	0.0	0.6
20	7.1	7.19	7.17	0.02	0	0.00	0.0	0.5
50	5.0	7.07	7.06	0.01	0	0.00	0.0	0.3

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Aldea Circuit**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**	**IMMUNITY RATING:**	**5 yr ARI**
LOCATION:	**Barbour Road Bikeway**		

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**109 L6**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	**C1381B**
MODEL ID:	**Barbour_Bike**	AMTD (m):	**7220**
STRUCTURE DESCRIPTION:			**Box Culverts**

STRUCTURE SIZE : **5 / 2.4 x 1.2 metre**

For Culverts: Number of cells/pipes and sizes

For Bridges: Number of spans and their lengths

Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**5.41**	UPSTREAM OBVERT LEVEL:	**7.81**
DOWNSTREAM INVERT LEVEL:	**5.36**	DOWNSTREAM OBVERT LEVEL:	**7.76**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **8**

LENGTH OF CULVERT BARREL AT OBVERT (m): **8**

TYPE OF LINING: **Concrete**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**8.6**	LOWEST POINT OF WEIR (m AHD):	**7.2**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**N/A**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD):	**N/A**
DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	**Steel post and rail (refer photo)**

ADDITIONAL STRUCTURE DETAILS:

No wingwall. Culvert fluxh with embankment. Refer photo.

For culverts, wingwall/headwall details, entrance details e.g. 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:	**2003**
PLAN NUMBER:	**WP3929-AC**
HAS THE STRUCTURE BEEN UPGRADED?	**Yes, 2003**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Barbour Road Bikeway**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	30.4	7.48	7.38	0.10	325	0.33	0.6	1.1
0.2	23.0	7.40	7.32	0.08	295	0.25	0.5	1.0
0.5	19.3	7.36	7.29	0.07	290	0.21	0.5	1.5
1	16.1	7.32	7.26	0.06	275	0.17	0.4	0.9
2	13.9	7.28	7.22	0.06	170	0.13	0.3	1.3
5	11.1	7.23	7.18	0.05	95	0.08	0.2	1.1
10	9.0	7.17	7.13	0.03	20	0.02	0.1	1.2
20	7.6	7.11	7.09	0.02	0	0.00	0.0	1.0
50	5.6	7.01	7.00	0.01	0	0.00	0.0	1.0

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres
Flow width is width of bikeway affected. Inundation extends beyond bikeway.

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Barbour Road Bikeway**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**
LOCATION:	**Hoyland Street**

IMMUNITY RATING:	**200 yr ARI**

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**109 L3**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	**C1359B**
MODEL ID:	**Hoyland**	AMTD (m):	**6475**

STRUCTURE DESCRIPTION: **Box Culverts**

STRUCTURE SIZE : **3 / 3.6 x 1.5 metre**

For Culverts: Number of cells/pipes and sizes
For Bridges: Number of spans and their lengths
Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**2.20**	UPSTREAM OBVERT LEVEL:	**5.80**
DOWNSTREAM INVERT LEVEL:	**2.15**	DOWNSTREAM OBVERT LEVEL:	**5.75**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **40**

LENGTH OF CULVERT BARREL AT OBVERT (m): **40**

TYPE OF LINING: **Concrete**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**40**	LOWEST POINT OF WEIR (m AHD):	**5.2**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**N/A**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD):	**N/A**
DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	**Flexbeam guardrails with bullnose terminal plus steel post/rail and**

ADDITIONAL STRUCTURE DETAILS:

Wingwalls – angle varies. Culvert design includes low flow channel and fauna track.

For culverts, wingwall/headwall details, entrance details e.g. 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:	**2002**
PLAN NUMBER:	**W11733**
HAS THE STRUCTURE BEEN UPGRADED?	**No**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	Bald Hills Creek
LOCATION	Hoyland Street

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	102.3	5.64	5.14	0.50	175	0.59	1.1	2.4
0.2	63.5	5.24	4.82	0.42	60	0.19	0.5	2.1
0.5	55.0	5.02	4.70	0.33	0	0.00	0.0	1.9
1	48.1	4.86	4.61	0.25	0	0.00	0.0	1.7
2	43.3	4.73	4.53	0.20	0	0.00	0.0	1.5
5	37.7	4.57	4.41	0.16	0	0.00	0.0	1.3
10	32.8	4.43	4.32	0.11	0	0.00	0.0	1.1
20	29.7	4.28	4.19	0.09	0	0.00	0.0	1.0
50	23.3	4.08	4.02	0.07	0	0.00	0.0	1.0

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Hoyland Street**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**
LOCATION:	**Bracken Ridge Road**

IMMUNITY RATING:	**< 2 yr ARI**

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**109 N1**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	**C0122B**
MODEL ID:	**BrackenRidge**	AMTD (m):	**5560**

STRUCTURE DESCRIPTION: **Box Culverts**

STRUCTURE SIZE : **3 / 1.8 x 0.6 metre**

For Culverts: Number of cells/pipes and sizes

For Bridges: Number of spans and their lengths

Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**0.65**	UPSTREAM OBVERT LEVEL:	**2.45**
DOWNSTREAM INVERT LEVEL:	**0.64**	DOWNSTREAM OBVERT LEVEL:	**2.44**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **12**

LENGTH OF CULVERT BARREL AT OBVERT (m): **12**

TYPE OF LINING: **Concrete**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**12.6**	LOWEST POINT OF WEIR (m AHD):	**2.8**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**N/A**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD): **N/A**

DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS: **Post and rail**

ADDITIONAL STRUCTURE DETAILS:

45^{o} wingwalls. Services pipes along obvert of culverts.

For culverts, wingwall/headwall details, entrance details e.g. 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: **1973**

PLAN NUMBER: **W5227**

HAS THE STRUCTURE BEEN UPGRADED? **No**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Bracken Ridge Road**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	138.2	4.24	4.20	0.04	365	1.50	0.4	1.0
0.2	86.3	3.91	3.85	0.06	295	1.17	0.3	1.2
0.5	71.8	3.78	3.71	0.06	280	1.04	0.3	1.2
1	61.0	3.66	3.60	0.06	215	0.92	0.3	1.1
2	53.2	3.57	3.51	0.06	190	0.83	0.3	1.1
5	44.6	3.44	3.39	0.05	145	0.70	0.3	1.0
10	37.2	3.33	3.28	0.05	115	0.59	0.3	1.0
20	31.5	3.23	3.18	0.04	100	0.49	0.2	0.9
50	23.6	3.00	2.97	0.04	60	0.26	0.1	0.7

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres
Bracken Ridge Road is affected by backwater.

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Bracken Ridge Road**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**
LOCATION:	**Gateway Motorway**

IMMUNITY RATING:	**500 yr ARI**

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**99 Q19**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	
MODEL ID:	**Gateway**	AMTD (m):	**5035**

STRUCTURE DESCRIPTION: **Bridge**

STRUCTURE SIZE : **2 x 14.85 metre spans**

For Culverts: Number of cells/pipes and sizes

For Bridges: Number of spans and their lengths

Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**1.2**	UPSTREAM OBVERT LEVEL:	**3.2**
DOWNSTREAM INVERT LEVEL:	**1.2**	DOWNSTREAM OBVERT LEVEL:	**3.2**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **n/a**

LENGTH OF CULVERT BARREL AT OBVERT (m): **n/a**

TYPE OF LINING: **n/a**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**30**	LOWEST POINT OF WEIR (m AHD):	**3.6**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**1.2**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD):	**N/A**
DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	**Solid concrete (refer photo)**

ADDITIONAL STRUCTURE DETAILS:

Refer As Constructed drawings.

For culverts, wingwall/headwall details, entrance details e.g. 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:	**1995**
PLAN NUMBER:	**W9670**
HAS THE STRUCTURE BEEN UPGRADED?	**No**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Gateway Motorway**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	162.1	2.98	2.93	0.05	110	0.10	0.7	2.9
0.2	109.8	2.85	2.82	0.03	0	0.00	0.0	2.2
0.5	91.5	2.80	2.78	0.02	0	0.00	0.0	2.0
1	77.9	2.76	2.74	0.02	0	0.00	0.0	1.8
2	67.8	2.72	2.70	0.02	0	0.00	0.0	1.7
5	56.6	2.68	2.67	0.01	0	0.00	0.0	1.7
10	47.1	2.64	2.63	0.01	0	0.00	0.0	1.6
20	40.4	2.61	2.60	0.01	0	0.00	0.0	1.5
50	29.1	2.55	2.54	0.01	0	0.00	0.0	1.4

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Gateway Motorway**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**
LOCATION:	**Denham Street Bikeway**

IMMUNITY RATING:	**50 yr ARI**

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**110 F4**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	**C2502P**
MODEL ID:	**Denham_Bike**	AMTD (m):	**1340**

STRUCTURE DESCRIPTION: **Pipes**

STRUCTURE SIZE : **7 / 1.05 diameter**

For Culverts: Number of cells/pipes and sizes

For Bridges: Number of spans and their lengths

Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**3.565**	UPSTREAM OBVERT LEVEL:	**4.615**
DOWNSTREAM INVERT LEVEL:	**3.512**	DOWNSTREAM OBVERT LEVEL:	**4.562**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **5**

LENGTH OF CULVERT BARREL AT OBVERT (m): **5**

TYPE OF LINING: **Concrete**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**5**	LOWEST POINT OF WEIR (m AHD):	**6.0**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**N/A**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD):	**N/A**
DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	**Timber post and single rail (refer photo)**

ADDITIONAL STRUCTURE DETAILS:

No wingwalls. Culvert flush with embankment.

For culverts, wingwall/headwall details, entrance details e.g. 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:	**2007**
PLAN NUMBER:	**CD051493**
HAS THE STRUCTURE BEEN UPGRADED?	**No**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Denham Street Bikeway**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	10.1	5.80	5.79	0.01	75	0.55	0.2	1.5
0.2	13.0	5.55	5.53	0.02	50	0.30	0.2	2.1
0.5	12.2	5.43	5.41	0.02	45	0.18	0.1	2.0
1	11.5	5.31	5.28	0.02	40	0.06	0.1	2.1
2	10.5	5.15	5.11	0.04	0	0.00	0.0	2.0
5	9.6	4.89	4.86	0.03	0	0.00	0.0	2.1
10	8.1	4.65	4.63	0.01	0	0.00	0.0	1.9
20	7.1	4.46	4.36	0.10	0	0.00	0.0	1.8
50	5.3	4.32	4.12	0.20	0	0.00	0.0	1.6

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**Denham Street Bikeway**

Photograph looking upstream at structure

Photograph looking downstream at structure

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK:	**Bald Hills Creek**
LOCATION:	**John Fisher Drive**

IMMUNITY RATING:	**20 yr ARI**

DATE OF SURVEY:	**ALS 2009**	UBD REF:	**110 D2**
SURVEYED CROSS SECTION ID:	**N/A**	BCC ASSET ID:	
MODEL ID:	**JohnFisher**	AMTD (m):	**585**

STRUCTURE DESCRIPTION: **Pipes**

STRUCTURE SIZE : **1.65, 1.8 & 1.95 metre diameters**

For Culverts: Number of cells/pipes and sizes
For Bridges: Number of spans and their lengths
Where dimensions have been estimated, this should be clearly stated.

UPSTREAM INVERT LEVEL:	**1.95**	UPSTREAM OBVERT LEVEL:	**varies**
DOWNSTREAM INVERT LEVEL:	**1.63**	DOWNSTREAM OBVERT LEVEL:	**varies**
For culverts give floor level.		For bridges give bed level.	

For Culverts

LENGTH OF CULVERT BARREL AT INVERT (m): **187**

LENGTH OF CULVERT BARREL AT OBVERT (m): **187**

TYPE OF LINING: **Corrugated Metal**

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

IS THERE A SURVEYED WEIR PROFILE? **No (2009 ALS Data used)**

If yes give details i.e. Plan number and/or survey book number.
Note: This section should be at the highest part of the road
e.g. crown, kerb, hand rails, guard rails or whichever is higher.

WEIR WIDTH (m)	**N/A**	LOWEST POINT OF WEIR (m AHD):	**5.2**
(In direction of flow, i.e. distance from u/s face to d/s face)		(Level at which water overtops road)	
PIER WIDTH (m):	**N/A**		

HYDRAULIC STRUCTURE REFERENCE SHEET

HEIGHT OF GUARDRAILS (m AHD):	**N/A**
DESCRIPTION OF ALL HAND AND GUARD RAILS AND HEIGHTS TO TOP AND UNDERSIDE OF GUARD RAILS:	**Steel post and mesh fence**

ADDITIONAL STRUCTURE DETAILS:

Services pipe across upstream obvert.

For culverts, wingwall/headwall details, entrance details e.g. 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:	**2004**
PLAN NUMBER:	**W12719/MRD222001**
HAS THE STRUCTURE BEEN UPGRADED?	**No**

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

ADDITIONAL COMMENTS:

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**John Fisher Drive**

AEP (%)	DISCHARGE (m^3/s)	U/S WATER LEVEL (m AHD)	D/S WATER LEVEL (m AHD)	AFFLUX (m)	FLOW WIDTH ABOVE STRUCTURE (m)	FLOW DEPTH ABOVE STRUCTURE (m)	VELOCITY (m/s)	
							Weir	Structure
0.05	48.2	5.81	3.78	2.03	365	0.61	0.7	2.7
0.2	28.4	5.51	3.60	1.91	290	0.31	0.5	2.6
0.5	23.3	5.39	3.52	1.87	260	0.19	0.3	2.5
1	18.8	5.26	3.50	1.76	230	0.05	0.1	2.4
2	17.5	5.08	3.47	1.61	155	0.00	0.0	2.3
5	15.8	4.82	3.42	1.40	0	0.00	0.0	2.1
10	14.6	4.56	3.30	1.25	0	0.00	0.0	2.1
20	14.1	4.29	3.24	1.06	0	0.00	0.0	2.0
50	11.3	3.79	3.09	0.71	0	0.00	0.0	1.7

NB: Results are based on existing stream conditions.
Velocities are average values
Flow width is to nearest 5 metres

HYDRAULIC STRUCTURE REFERENCE SHEET

CREEK	**Bald Hills Creek**
LOCATION	**John Fisher Drive**

Photograph looking downstream at structure

APPENDIX D – Flood Frequency Analysis

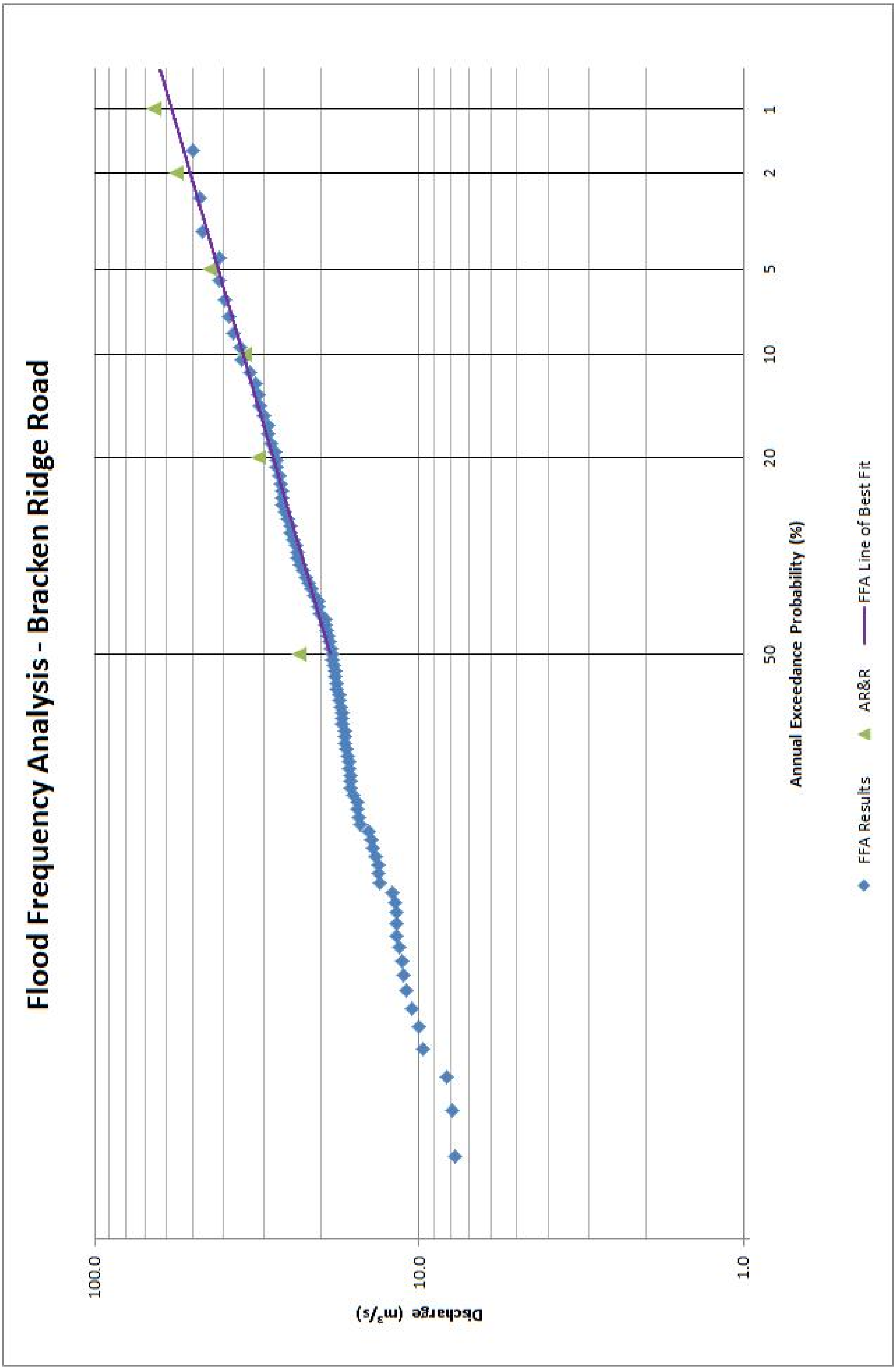

Figure D1. Hydrologic Model Peak Discharges – Bracken Ridge Road

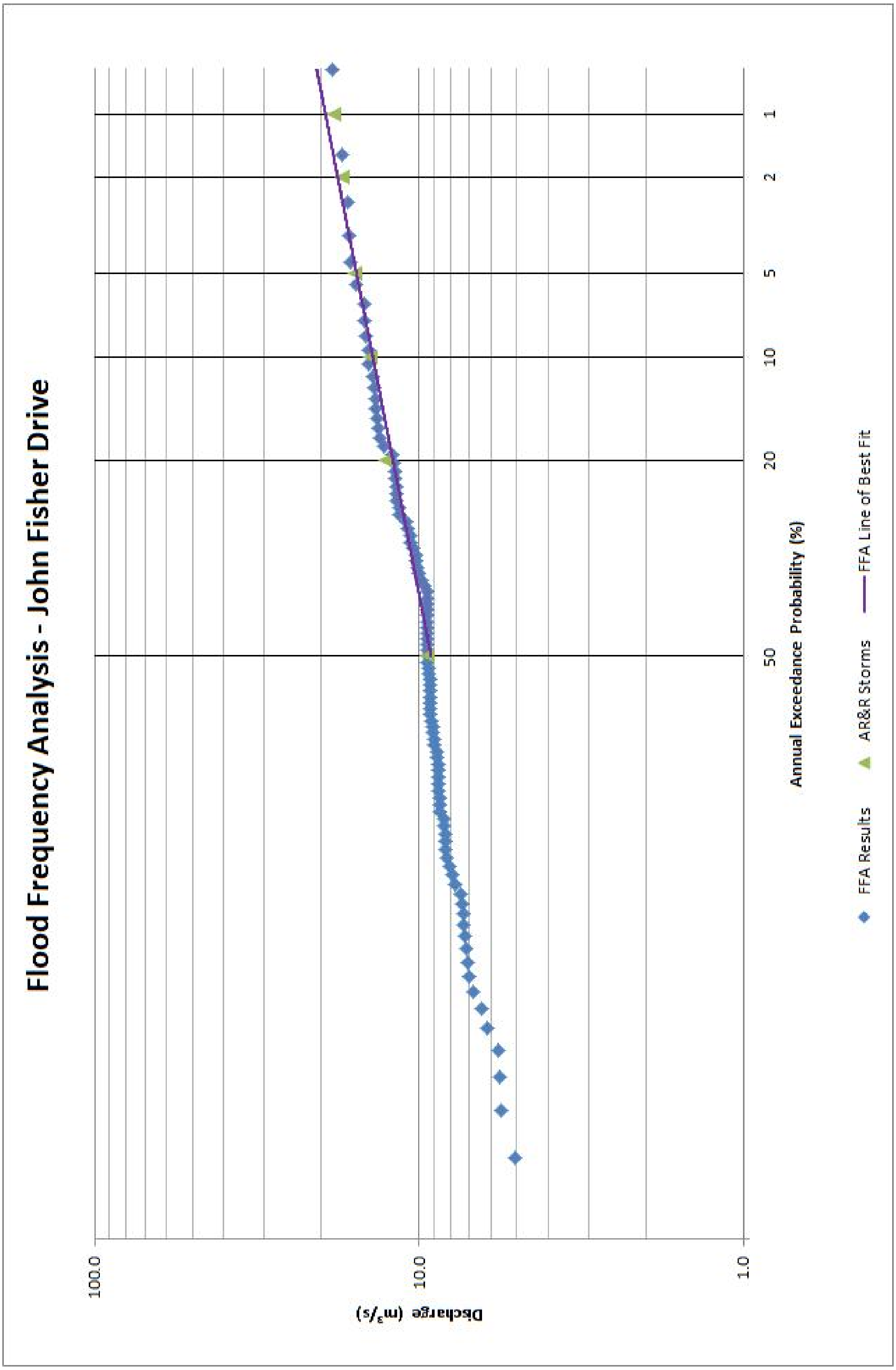

Figure D2. Hydrologic Model Peak Discharges – John Fisher Drive

APPENDIX E – XP-RAFTS Data

Table E1. XP-RAFTS Model Data

Subarea Name	Area (ha)	Fraction Impervious (%)	Pervious Area PERN	Impervious Area PERN	Vectored Slope (%)
A	33.3	44.4	0.050	0.015	1.0
B	36.1	39.4	0.050	0.015	1.3
C	18.8	21.8	0.025	0.015	0.5
D	17.0	45.4	0.025	0.015	0.6
E	30.2	40.7	0.025	0.015	0.9
F	37.0	39.1	0.025	0.015	0.7
G	50.1	33.9	0.025	0.015	2.5
H	37.7	47.4	0.025	0.015	1.2
I	48.0	62.2	0.025	0.015	0.8
J	18.9	54.8	0.025	0.015	1.4
K	66.7	23.0	0.050	0.015	1.0
L	65.9	54.1	0.025	0.015	1.1
M	70.3	38.7	0.025	0.015	0.5
N	25.4	51.6	0.025	0.015	1.5
O	13.0	63.8	0.025	0.015	3.1
P	38.3	56.5	0.025	0.015	2.6
Q	24.0	23.0	0.050	0.015	2.7
R	6.8	61.9	0.025	0.015	0.7
S	2.2	53.2	0.025	0.015	0.6
T	93.5	52.0	0.025	0.015	1.8
U	17.9	28.4	0.025	0.015	0.7
V	24.6	41.0	0.025	0.015	0.9
W	35.7	46.2	0.025	0.015	1.6
X	154.5	4.3	0.050	0.015	1.0
Y	65.7	25.0	0.050	0.015	1.0
Z	112.6	3.9	0.050	0.015	1.0
TOTAL	**1144.5**				

APPENDIX F – BCC Peer Review

Dedicated to a better Brisbane

Brisbane City Council

M E M O R A N D U M

To:	**Richard Yearsley – Program Officer Engineer – Natural Environment, Water and Sustainability**	Date:	**05.08.2014**
Via:	**Evan Caswell – Principal Engineer, Flood Management**		
CC:			
From:	**Matt Krestan - Engineer, Flood Management**		
Re:	**Peer Review of Bald Hills Creek Flood Study Models**		

City Projects Office

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Internet: www.brisbane.qld.gov.au

1. Introduction

The purpose of this memorandum is to summarise the peer review undertaken by City Project's Office on the Bald Hills Creek Flood Study project. The study was undertaken by Cardno.

The peer review has been undertaken to ensure:

- Council has reviewed all required data associated with the Bald Hills Creek Flood Study (Cardno 2014) to enable future adoption into Council systems
- The flood study has been delivered in accordance with Council procedures and methods current at the time the study was undertaken
- The output is fit for purpose

The peer review includes a high level technical review of the models and results. It has been undertaken in three parts, namely;

- Base hydrology model review
- Calibrated hydrology and hydraulic model review, and,
- Design hydraulic model plus flood mapping review

It is assumed that Cardno have applied best-practice 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.

A peer review check list of the calibrated hydraulic model is included in **Appendix A**.

2. Hydrology Model

The base XP-RAFTS hydrological model was reviewed. The following comments (in black) in relation to the review were provided by BCC to Cardno, with their response shown (in red) where applicable.

Base Hydrology Model Review

- The hydrologic model was developed using the XP-RAFTS. The modelled catchment covers the whole catchment extents as specified in the project brief.

Land use types:

- Procedure adopted in selecting the percentage impervious fraction for each land use type is not specified. *Information will be added to the report, stating that these impervious fractions were determined in accordance with values listed in QUDM.*

Catchment slopes:

- Details of estimation of catchment slopes are not provided for review. *Information will be added to the report, stating that slopes were derived from the DEM based on an analysis of typical flowpaths in the catchment.*

Sub-catchment layout:

- Areas to the east of Gympie Arterial Road in sub-catchments A, B, and F should be represented as separate sub-catchments. *Not appropriate to subdivide these subcatchments for a catchment-wide flood study. In addition, there are generally multiple stormwater catchments discharging to separate pipes under the Gympie Arterial Road from these catchments. The model has been successfully calibrated without the need to subdivide these catchments.*

Comments on RAFTS Hydrology model:

- Basin -1 at the end of nodes A and B is specified as a retarding basin. Spillway level has been specified as 99. This figure should correspond to a realistic ground level so that extreme events may spill over. *The spillway level was changed during the calibration of the model.*
- Basin-2 retarding basin connecting to node E: Spillway level has been specified as 99. This should represent the correct level as extreme events could spill over. Spillway details based on road geometry should be considered. *The spillway level was changed during the calibration of the model.*
- Routing channel roughness's adopted for link-C, link-F, link-H, link-I, link-J, link H-J, link-K, link-L are 0.15. I believe that this figure may be reduced. *Routing channel roughness values were derived as part of ensuring consistency between the hydrologic and hydraulic models. The roughness values used in the hydrologic model are attempting to account for a number of hydraulic factors, e.g. culverts, storage areas, backwater, etc. Thus, while the value may seem high, it assists the hydrologic model to be consistent with the hydraulic model. It is also noted that TUFLOW does all of the actual channel routing; RAFTS only provides local inflows.*

Based on the comments submitted by Cardno in response to Council's review (above), the model was accepted in its current form. However, two additional comments were provided to Cardno to keep in mind when undertaking future work on the project. These comments were;

- That not splitting the subcatchments to the west of the Bruce Highway was accepted. However, please note the limitation in the final report that the immunity of the Bruce Highway has not been assessed.
- Keeping the in-channel roughnesses in the hydrologic model to n=0.15 is accepted. However, please note in the final report the limitations regarding the hydrology.

3. Hydraulic Model

Calibrated Hydrologic-Hydraulic Model and Report Review

The calibrated hydrologic and hydraulic models and report were reviewed. The following comments (in black) in relation to the review were provided by BCC to Cardno, with their response shown (in red) where applicable.

A peer review check list of the calibrated hydraulic model is included in **Appendix A**.

Generally, the model is considered to be fit for purpose with no observed errors.

Model Review Comments:

- Has blockage of handrails been considered for any calibration events? For design runs, please confirm that the assumption of blocked handrails is being applied as per the Flood Study Procedure (I think it has been via the zpts used for the overtopping levels in some cases but Bracken Ridge/Gateway Motorway bridge does not appear to have it applied). *No blockage has been assumed for the calibration events, as there was no evidence that partial or complete blockage occurred at the various road crossings. However, blockage will be assumed for design events as per the Brief.*
- Do any culverts have trash screens and have they been considered? *No trash screens were observed on culverts during site visits, so they have not been included.*
- Gully line inverts and 1997 survey points appear inconsistent in places; gully line inverts do appear reasonable when compared to ALS though. Please provide an explanation (verbally/email) on how these were defined (is it a mixture of 1997 points and information from structure drawings?) and also discuss the creek invert definition in S5.2.2 of the report. *Gully lines were derived from the following sources: structure invert levels; as constructed or design drawings of culverts and channels; site observations; ALS data; and 1997 survey. This will be included in the report.*
- Could you please explain how the IWL was set for the lagoons? For the Lagoon on the main branch, the level is approx. 0.5m below the standing water level picked up by the ALS. *The Initial Water Level (IWL) of 1.2 mAHD was based on the invert level of the bridge opening under the Gateway Motorway at the downstream end of the Lagoon. A higher IWL can be adopted to be consistent with the ALS, if we assume there is some sort of weir/blockage upstream of the bridge.* A standing water level of 1.7mAHD was adopted by Cardno in the model in consultation with BCC to match existing ALS2009 levels.
- Although the MHG correlation for the 2001 event is good, the consistency between the hydrology and hydraulics models is only fair at Bracken Ridge Road. It is recognised that the consistency between the two models was going to be difficult to achieve due to the structure/basin interaction not being represented in the hydrology model. But the hydraulic model is actually demonstrating less attenuation than the hydrology model. What investigation has been undertaken to try and improve this? I think some comment on this should be included in the report. *The RAFTS model parameters will be adjusted to improve the consistency with the TUFLOW model results.*
- The 1D network .csv files indicate some instabilities but generally only at the start and end of the event; please check that these are not affecting the peak results. *Agreed.*
- There is a high velocity zone/instability on the Pine R boundary – it is probably having no impact on results and not near any houses but I just wanted to mention it as it will show up in the results. *Apologies for this instability at the TWL boundary. It only seems to occur in the 2010 and 2012*

events. It will be investigated and resolved, prior to proceeding with the Design Events.

- During the 2001 event, high velocities are observed at the Gateway Motorway bridge and the John Fisher lagoon; please check these are reasonable. *Results appear reasonable.*
- During the review we have identified the following storage added to the Gateway Motorway (main channel);

1. Stage-Storage relationship at two nodes at the upstream and downstream ends of the structure
2. Storage within the structure as part of the 'Len_or_ANA' attribute
3. Storage within the structure as part of the 'UCS' attribute

Can you please provide an explanation as to why this method was adopted within the hydraulic model at this structure, and what (if any) impacts it has had on the model results?

The use of the NA Table (stage-storage relationship) for the Gateway Motorway Bridge means that TUFLOW uses this information instead of the storage which would be calculated using the Bridge length and width. In other words, Item 1 in your list is used by the model, not Items 2 or 3.

Sensitivity analyses were carried out to examine the impact of using a larger or smaller storage area. A value of 2,500 m² was adopted, but values of 5,000 m² and 1,000 m² were also trialled. There was no significant difference in the results from all three models, although the flow through the bridge was moderately unstable with a nodal area of only 1,000 m². Thus, the value of 2,500 m² was adopted. The independent check using HEC-RAS confirmed that the structure was being correctly modelled by TUFLOW.

Report Review Comments:

- 'hazard' should be 'depth velocity product' *Okay*
- Cover page/footer – report title is all in the black text (minor thing) *Okay*
- S5.4.3 – gauge 130 reference should be 110 *Okay*
- Table 5-7 Structure losses – I think the values are mismatched with the discharges; please amend the table to relate flows to event and also to demonstrate the calculated loss through the structure by both methods. The procedure asks for the checks to be made for the 1% and 10% AEP design runs however the use of the two calibration events satisfies the objective. *1% and 10% AEP Design Events are not yet modelled, so can't use these events for structure checks at this stage. The structure losses were assessed at the time of the peak flood level. At some structures (Bracken Ridge Road culvert and Denham Street bikeway culvert), the peak flood level occurred at a time of a relatively low discharge through the culverts due to backwater effects. Consequently, the flow used in the 2001 event was lower than that for the 2012 event at these structures.*
- App B figure captions have some numbering errors *Okay*
- It could be beneficial to have some discussion on the calibration event characteristics – timing of rainfall/runoff vs high tide, the fact that the tide approaches/is above HAT on some of the events, etc. *This will be added to the report.*

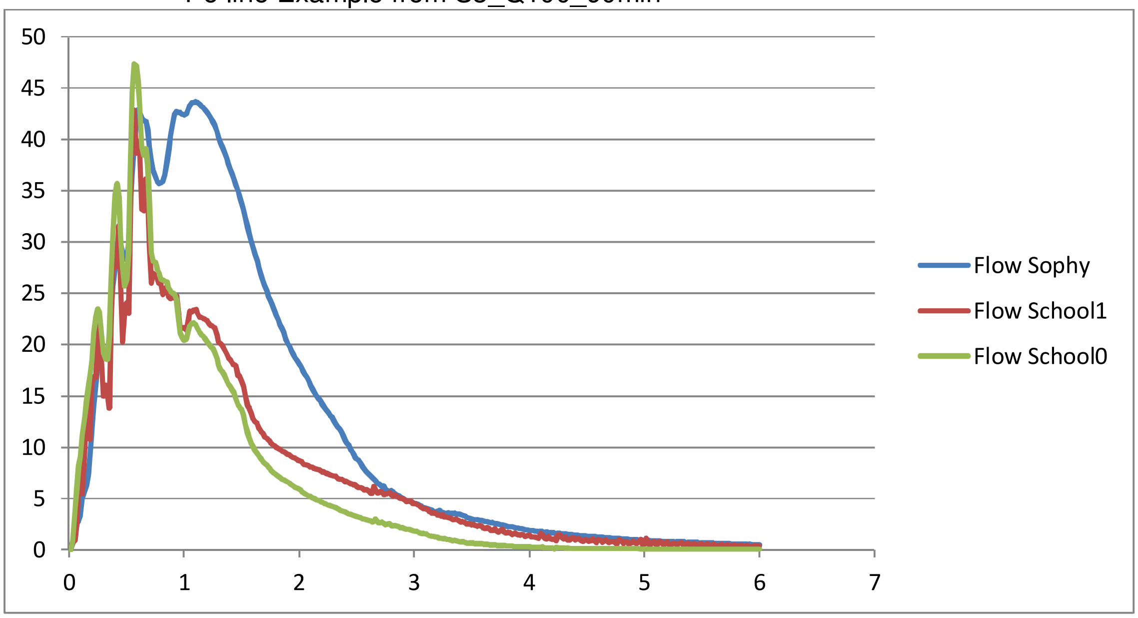
Design Hydraulic Model and Mapping Review

The design hydraulic model and draft Ultimate Case stretched mapping was reviewed. The following review comments were provided to Cardno.

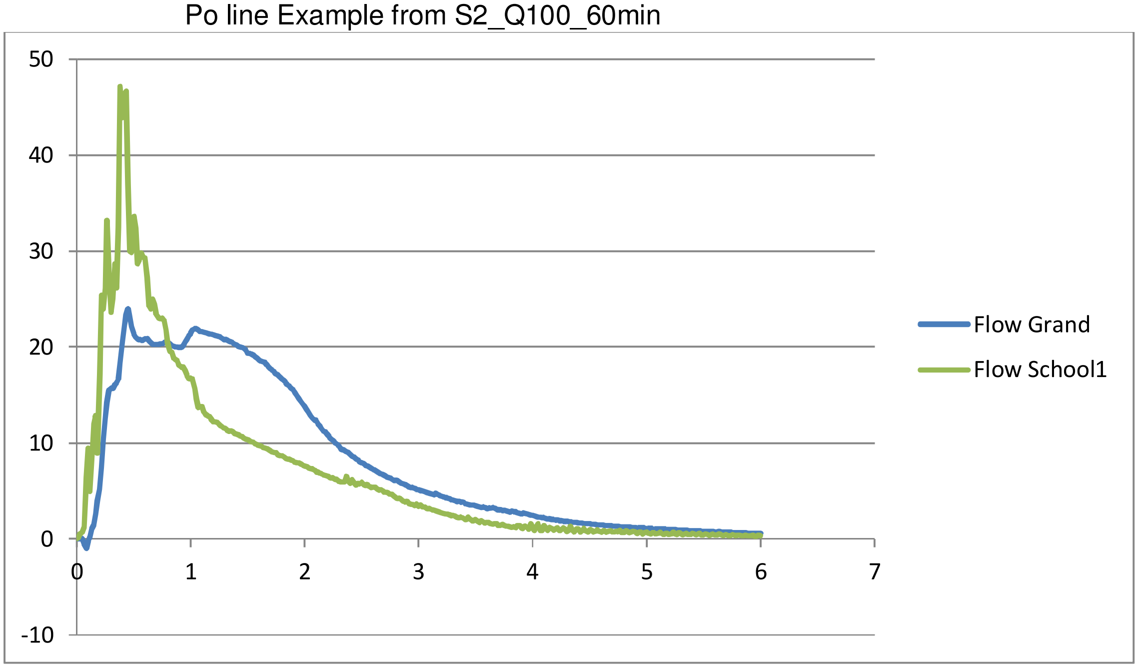
Model Review Comments:

- Spot Check was undertaken on model output (PO.csv , 1d_Q.csv and 1d_H.csv)
- Instability on discharge hydrographs was observed at the following location. Please note that the instabilities may not be limited to these locations as I only did the spot check.

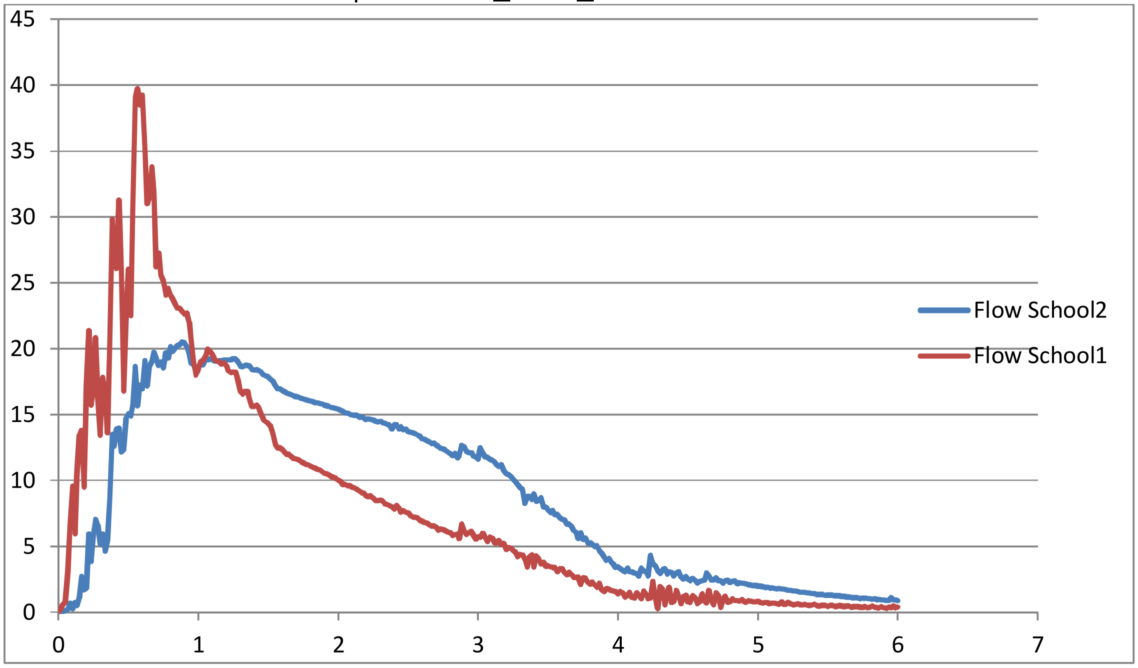
Po line Example from S3_Q100_90min



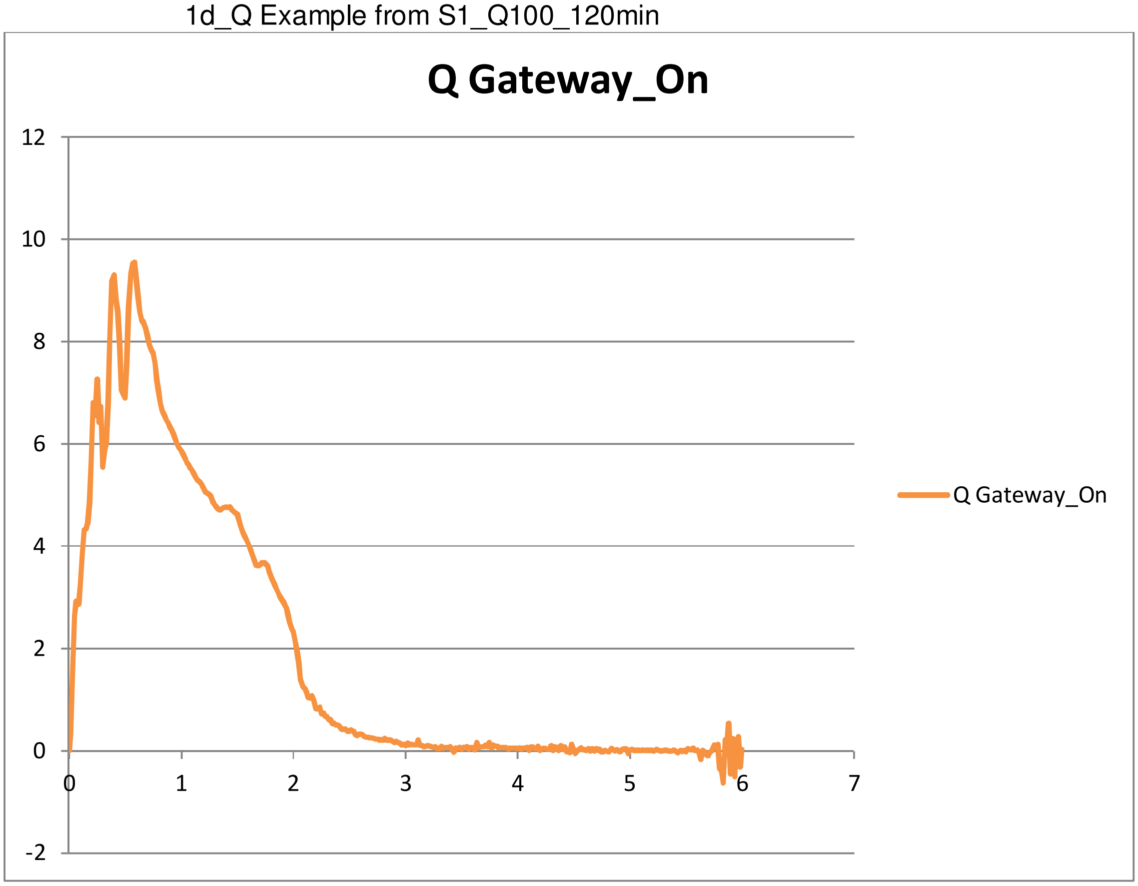
Po line Example from S2_Q100_60min



PO line Example from S1_Q100_90min

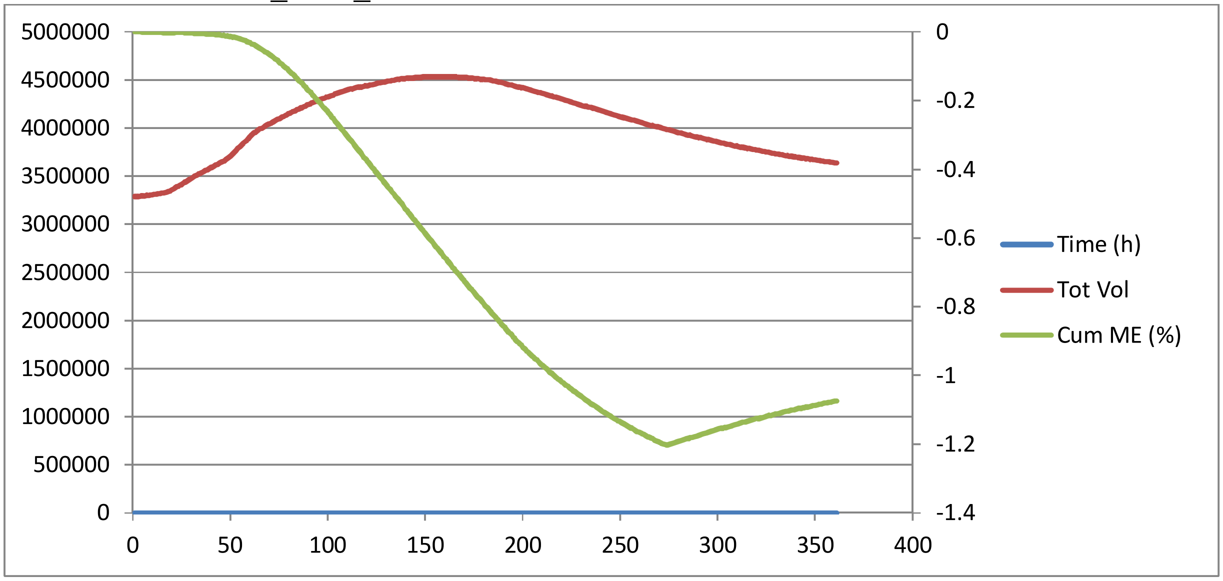


1d_Q Example from S1_Q100_120min



- However the flood level vs time seems reasonably stable

- Mass Error was checked and was within acceptable range for majority of the runs However, for some extreme events the mass error exceeds the acceptable range marginally. However it happens after the peak and therefore it is considered acceptable. Graph below shows the mass error for the S3_Q500_180m run



- Roughness values for design events should be based on City Plan landuse. Currently the landuse for ultimate scenario is based on aerial photography and underestimates the roughness in some areas.
- There is only one blockage scenario modelled including 20% blockage of all structures, while the blockage should be assessed separately for each major structures. Cardno undertook a sensitivity check (at the request of CPO) of downstream discharges in the model to check the difference in peak discharges between the blocked and unblocked scenarios for the 100yr ARI event. It was determined that there were only minor differences in peak discharges and hence structure blockage was not having a significant impact on creek flows. The method of blockage modelling adopted by Cardno was thus accepted.
- As the new AR&R has not been released yet, the AR&R sensitivity run should be removed from FS report.

Cardno Response

Cardno comments in response to the design hydraulic model review is below.

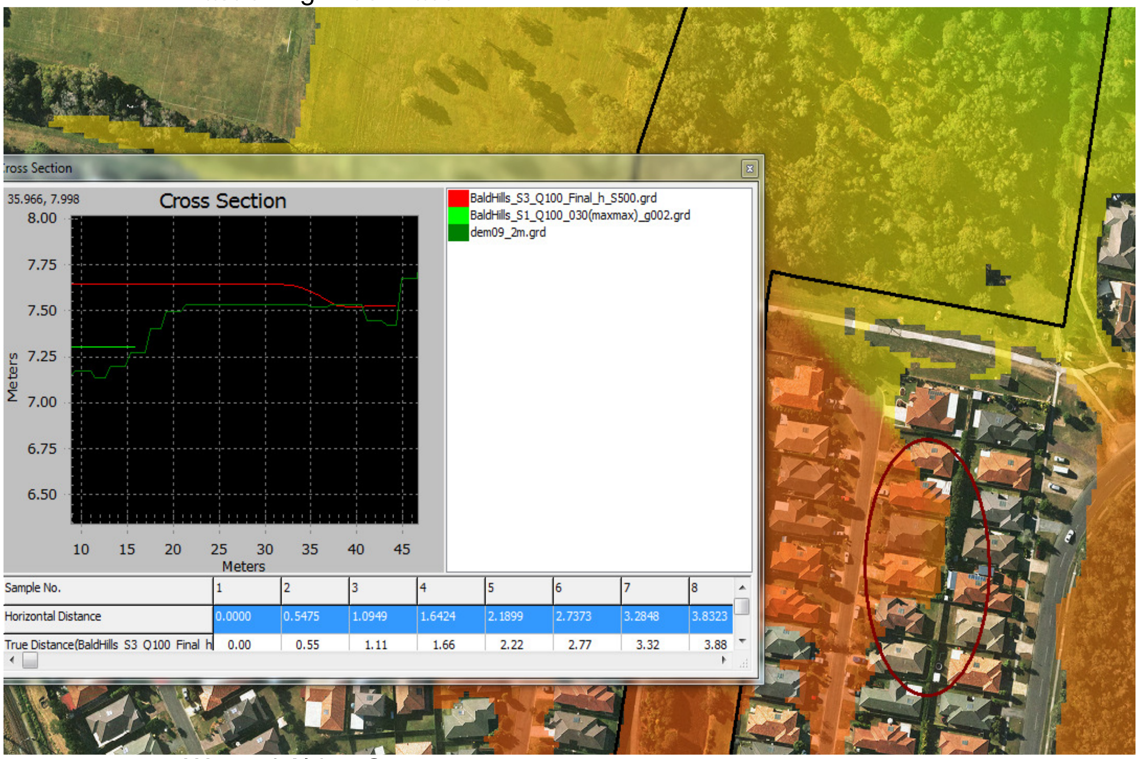
The flow hydrographs at School0, School1 and School2 give the appearance of being relatively unstable because inflows are being applied directly into the deep lake adjacent to John Fisher College in this area. The combination of the inflows and the deep, smooth hydraulic area produce these flow hydrographs. However, the water level hydrographs in this area are very stable. Thus, there are no issues with the model here. A similar situation exists at Sophy and Grand.

The Gateway_On culvert is one of the small culverts under the Gateway Motorway. The water level hydrographs at the culvert nodes are stable.

Mapping Review Comments:

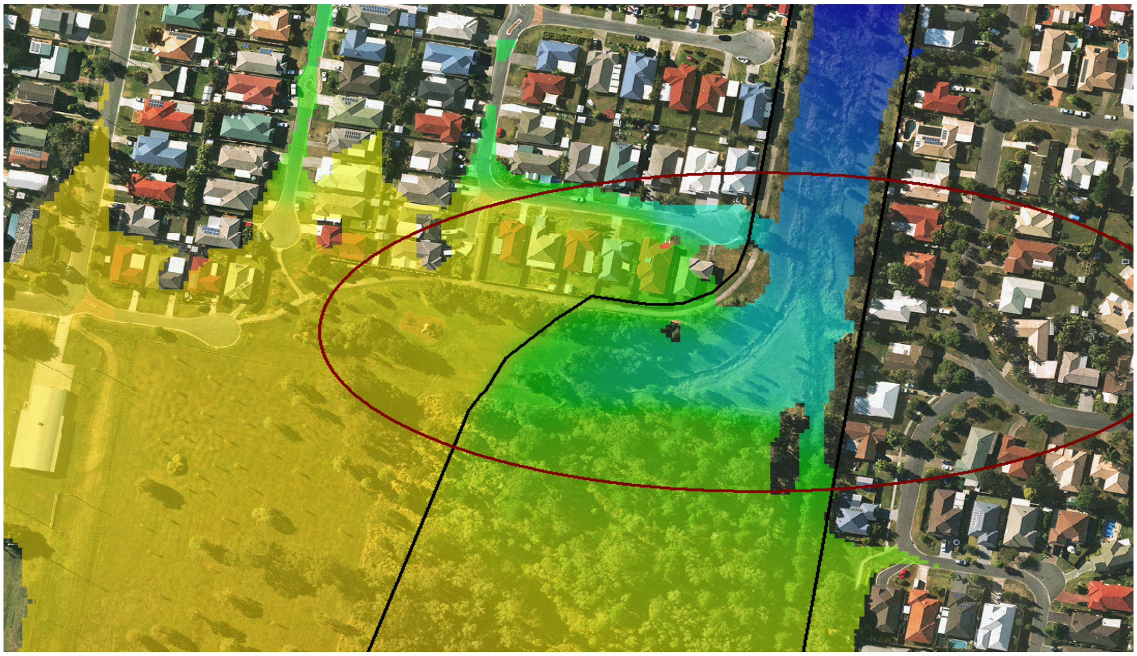
- In general, this stretching method does not properly represent the backwater in most areas.
- The filled DEM is believed to have similar issues.

East of Fig Tree Place

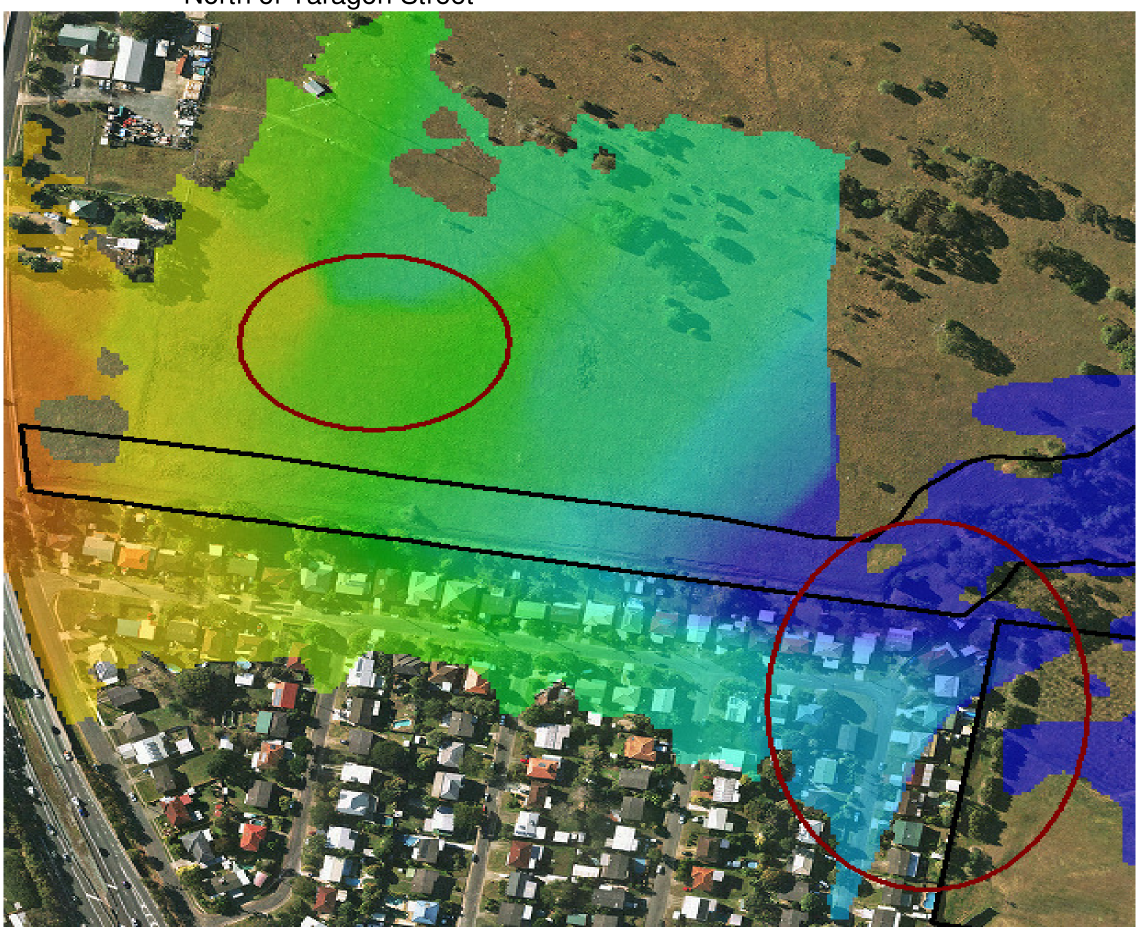


West of Aldea Crct

North of Grand Street



North of Taragon Street



Upstream of Bracken Ridge Road

Cardno Response

Cardno comments in response to the mapping review are below.

We have revised the procedure for the flood mapping. This has fixed the issues you identified, and improved the overall flood mapping in other areas.

4. 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.

Council has made sure that the work has been undertaken in accordance with the required standards and procedures through the reviews documented above, and through regular communication and meetings with Cardno. We acknowledge that Cardno has appropriately addressed the issues/concerns as noted by Council throughout the review process.

....
Matt Krestan
Flood Engineer

....
Evan Caswell (RPEQ No.10498)
Principal Engineer, Flood Management

Appendix A – Calibrated Hydraulic Model Peer Review Checklist

1.0 Project Details

Project Name:	Bald Hills Creek Flood Study
Client:	NEWS - BCC
Project Job Number:	BUD No AA20 / Job No 140450
Date:	27/03/2014 (model files dated 13/03/2014)
Modellers Name:	Michael Della
Modellers Organisation:	Cardno
Reviewers Name:	Megan Gould (RPEQ 09266)
Reviewers Organisation:	Flood Management - BCC
Major Catchment Name:	Pine Rivers Basin, Bald Hills Creek
Creek Name:	Bald Hills Creek

Review Status	☐	Model Build				
	✓	Calibration / Verification				
	☐	Design Modelling				
	☐	Other (specify)				
Purpose of Model	✓	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	✓	TUFLOW	✓	1D / 2D	☐	2D
	☐	MIKE 11				
	☐	MIKEFLOOD	☐	1D / 2D	☐	2D
	☐	HEC-RAS	☐	Steady	☐	Unsteady
	☐	XP-SWMM / XP-STORM				
	☐	Other (specify)				

Further description of the modelling

Reviewed workspace at G:\BI\CD\Proj14\140450_Bald_Hills_Creek_Flood_Study\Data13032014_Workspace.WOR

Bald Hills Creek flows into the Pine River close to the mouth. Storm tide is not being assessed and the scoping study concluded that there was not a need to assess coincident flooding with Pine R; instead a MHWS level is being applied along the Pine R boundary. Coarse representation d/s of the Gateway only is required.

Major hydraulic controls are road crossings (Gympie Road, Gateway Motorway, Bracken Ridge Road, Hoyland St).


Moreton
Bay
Regional
South Pine River
PINE
RIVER
BRUCE HIGHWAY
GYMPIE ARTERIAL ROAD
GATEWAY MOTORWAY
MOTORWAY
Bald
Hills
BALD
HILLS
CREEK
BRACKEN RIDGE RD
BRACKEN ST
GYMPIE RD
STRATHPINE RD
NORRIS RD
Bracken
Ridge
BARFOUR RD
PHILLIPS ST
TELEGRAPH RD
LINKFIELD RD
1 km
1 mi

2.1 Hydraulic Model Build - Model Extents

Model extents as per the study brief?	☑ Yes ☐ No	☐ N/A
Are the extents of the model sufficient to prevent glass walling?	☑ Yes ☐ No	
Model extends sufficiently upstream / downstream of the study area to negate boundary effects?	☑ Yes ☐ No	☐ N/A
Model extents sufficient to capture potential afflux limits?	☑ Yes ☐ No	☐ N/A

2.2 Hydraulic Model Build - Channel Representation

Origin of bathymetry data: Source of topographic data described in consultancy brief and flood study report - ALS and ground survey; no new survey undertaken

Origin of each cross-section defined in the report?	☐ Yes ☐ No	☑ N/A

Precision of bathymetry data: The only bathymetry data available is from 1997 ground survey of main channel. Age of data reduces reliability.

Channel representation in the model: ☐ 1D Channel ☑ 2D grid ☐ Flexible mesh — Grid size =

Cross-sections geo-referenced?	☐ Yes ☐ No	☑ N/A
Cross-section spacing sufficient?	☐ Yes ☐ No	☑ N/A
Cross-sections perpendiclur to flow?	☐ Yes ☐ No	☑ N/A
Spacing of sections agree with chainage?	☐ Yes ☐ No	☑ N/A
Channel reach lengths represented adequately	☐ Yes ☐ No	☑ N/A
Cross-sections left to right when viewed in the downstream direction (BCC preferred)?	☐ Yes ☐ No	☑ N/A
Are interpolated cross-sections used?	☐ Yes ☐ No	☑ N/A

(If yes, state why)

Top of bank / section markers represented adequately?	☐ Yes ☐ No	☑ N/A
Manning's n for the channel represented adequately?	☑ Yes ☐ No	Single value for channel
Manning's n categories defined in the report?	☑ Yes ☐ No	
Most applicable radius type selected (MIKE11 only)?	☐ Yes ☐ No	☑ N/A
Conveyance checks undertaken?	☐ Yes ☐ No	☑ N/A
Is the channel generally represented adequately in the model?	☑ Yes ☐ No	Refer comments below

Other Comments / Issues

Discussion was held with Cardno regarding whether BCC wanted flooding upstream of the Gympie Arterial to be considered. It was agreed that only the open channel downstream needs to be considered. The hydology model has not included the culvert structures or any storage associated with the highway. This limitation will be discussed in the report including the inability to assess flood immunity if the Gympie Arterial.

Model is predominantly 2D using a 4m grid. 1D elements used for structures. Creek is approx. 15 m wide in upstream reaches therefore channel represented by approx. 4 cells which is reasonable. No new channel survey was undertaken. Generally 2009 ALS used with available channel survey (1997 cross sections of main channel) stamped into the model DEM using gully lines and detailed ground survey (2002 data) stamped in around Hoyland St and upstream of the railway. Low flow channel therefore represented by a single line of 4m cells lowered to the invert level defined. Above water definition is provided by ALS. Gully line inverts and 1997 survey points appear inconsistent in places however values assigned to gully lines are generally reasonable compared to ALS. In places the invert is dropped by over a metre but generally it is much less.

Overall, the low flow channel geometry is represented coarsley but within the limitations of available data and sufficiently for use in a catchment scale model assessing large and extreme events.

2.3 Hydraulic Model Build - Floodplain Representation

Origin of topographic data: ALS 2009
2002 ground survey (provided as DEM) also stamped into specific areas.

Precision of topographic data: Standard ALS accuracy
Model includes wetland areas and large bodies of water - below water areas not represented in ALS

Floodplain representation in the model
- [ ] Extended 1D sections
- [ ] Quasi 2D
- [x] 2D Grid — Grid size =
- [ ] Multiple sized 2D Grids — Grid sizes =
- [ ] Flexible mesh

	Yes	No	N/A
Is the floodplain representation consistent with the study objectives and data limitations?	☑	☐	☐
Channel / floodplain interface represented adequately?	☐	☐	☑
Channel breakout flows represented adequately?	☑	☐	☐
Major obstructions (e.g buildings) represented adequately?	☑	☐	☐
Floodplain storage adequately represented?	☑	☐	☐
Cross-sections perpendiclur to flow on floodplain (1D / Quasi 2D)?	☐	☐	☑
Floodplain reach lengths represented adequately	☐	☐	☑
Ineffective flow areas considered and represented adequately (if applicable)?	☐	☐	☑
Manning's n for the floodplain represented adequately?	☑	☐	
Manning's n categories defined in the report?	☑	☐	
Is the floodplain generally represented adequately in the model?	☑	☐	

Other Comments / Issues

Major road embankments represented in ALS
Other major hydraulic controls are structures (represented as 1D structures and deck levels stamped into DEM) and storage in wetlands/ponded areas
Buildings represented by Manning's 'n' value as is standard for catchment scale models

2.4 Hydraulic Model Build - Bridges

Number of bridges in the model: 1 - Gateway Motorway

Repeat the following for each bridge structure

Bridge name / bridge reference: Gateway

River / creek name: Bald Hills Creek

Origin of bridge data: Provided structure data

- Bridge structure:

- Upsteam / downstream cross-sections:

- Road / weir profile:

Bridge modelling approach
(e.g. Energy, WSPRO, USBPR, etc): TUFLOW bridge structure routine

Is the bridge modelling approach the most applicable for the structure?
- [x] Yes
- [ ] No
- [ ] N/A

(If no, state why)

Are there dual bridges (e.g. dual carriage motorway)
- [x] Yes
- [ ] No

If yes, are the bridges represented individually or combined?
- [ ] Individual structures
- [x] Combined structure

If yes, is this representation considered the most appropriate?
- [x] Yes
- [ ] No
- [ ] N/A

(If no, state why)

Is the bridge skewed to the normal flow direction?
- [ ] Yes
- [x] No

If yes, have the skew effects been represented adequately?
- [ ] Yes
- [ ] No
- [x] N/A

(If no, state why)

2.5 Hydraulic Model Build - Culverts

Number of culverts in the model: 17

Repeat the following for each culvert

Culvert name / culvert reference: Culverts not checked in detail

River / creek name

Origin of culvert data

- Culvert details

- Upsteam / downstream cross-sections

- Road / weir profile

Are there dual structures (e.g. dual carriage motorway)
☐ Yes
☐ No

If yes, are the culvert structures represented individually or combined?
☐ Individual structures
☐ Combined structure

If yes, is this representation considered the most appropriate?
☐ Yes ☐ N/A
☐ No

(If no, state why)

Is the road/weir skewed to the normal flow direction?
☐ Yes
☐ No

If yes, have the skew effects been represented adequately?
☐ Yes ☐ N/A
☐ No

(If no, state why)

Is there a trash rack at the culvert inlet?
☐ Yes
☐ No

If yes, have the headlosses been represented adequately?
☐ Yes ☐ N/A
☐ No

Is this structure being modelled as part of a group of structures?
(e.g. culvert plus floodplain relief culverts)
☐ Yes ☐ N/A
☐ No

If yes, is this representation considered the most appropriate?	☐ Yes ☐ No	☐ N/A
Cross-sections located at the most appropriate location for the modelling software and bridge routine?	☐ Yes ☐ No	
Culvert dimensions correctly represented?	☐ Yes ☐ No	
Does the weir profile represent the highest elevation along the road?	☐ Yes ☐ No	☐ N/A
Are the culvert coefficients reasonable? (e.g. weir, friction, inlet / outlet, contraction / expansion, etc)	☐ Yes ☐ No	
Handrail / guardrail blockage considered?	☐ Yes ☐ No	☐ N/A
Handrail / guardrail represented adequately?	☐ Yes ☐ No	☐ N/A
Headlosses at hydraulic structures appear logical / sensible?	☐ Yes ☐ No	☐ N/A
Headlosses at hydraulic structures checked by an alternate method?	☐ Yes ☐ No	☐ N/A
Hydraulic Structure Reference Sheets provided in report	☐ Yes ☐ No	☐ N/A

Other Comments / Issues

Culvert structures not individually checked

Culverts modelled using TUFLOW 1d culvert structure routine

Reasonable loss factors applied

Check of headloss has been made by Cardno using CulvertW with reasonable results

Report table should be amended to show calculated headloss

Consultant to confirm if handrails/trashscreens have been considered

2.6 Hydraulic Model Build - Outflow Boundary Conditions (generic not run specific)

Downstream boundary

- [ ] Normal depth
- [ ] Rating Curve
- [ ] Specified WL
- [x] Head v Time
- [ ] Other

Origin / Derivation of downstream boundary

Calibration events have time series (water level) applied from event
using Brisbane Bar tide data
Design events have fixed level - MHWS or HAT

Will selection of the downstream boundary significantly influence results?

- [x] Yes
- [ ] N/A
- [ ] No

Is the downstream boundary appropriate?

- [x] Yes
- [ ] N/A
- [ ] No

2.7 Hydraulic Model Build - Inflow Boundary Conditions (generic not run specific)

Inflow boundary(s)

- [x] Flow v Time
- [ ] Steady flow(s)
- [ ] Head v Time
- [ ] Direct rainfall
- [ ] Combination of the above
- [ ] Other

Origin / Derivation of inflow boundaries

RAFTS model - local inflows

Is there a need to check the inflows?

- [ ] Yes
- [ ] N/A
- [x] No

Is the type of inflow the most appropriate for the analysis?

- [x] Yes
- [ ] N/A
- [ ] No

Inflow locations in the hydraulic model at the most appropriate locations and consistent with the hydrologic analysis?

- [x] Yes
- [ ] N/A
- [ ] No

Are there sufficient inflow locations to achieve the modelling objectives?

- [x] Yes
- [ ] N/A
- [ ] No

Is the inflow distributed over a suitably wide section to capture the flow width?

- [x] Yes
- [ ] N/A
- [ ] No

Other Comments / Issues

Bald Hills Creek flows into the Pine River close to the mouth. Storm tide is not being assessed and the scoping study concluded that there was not a need to assess coincident flooding with Pine R; instead a MHWS level is being applied along the Pine R boundary.

Local inflows are appropriate to allow hydraulic model to assess storage behind structures

Inflows applied as SA tables

3.0 Model Simulation (generic not run specific)

Run type	☐ Steady	
	☐ Unsteady (fixed time step)	
	☑ Unsteady (variable time step)	
	☐ Other	
Does the software use an implicit or explicit finite difference scheme?	☑ Implicit	☐ N/A
	☐ Explicit	
Initial conditions	☑ User input Q and WL / Depth	
	☐ Hotstart file	
	☐ Other	
Are there special items (e.g. reservoirs) which need unique initial conditions?	☑ Yes	☐ N/A
	☐ No	Reservoirs
Will selection of the initial conditions influence the modelling results?	☐ Yes	☐ N/A
	☑ No	
Are the initial conditions generally acceptable?	☑ Yes	☐ N/A
	☐ No	
What is the time step?	2 sec	
Courant conditions satisfied?	☐ Yes	☐ N/A
	☐ No	
Is the timestep appropriate? (note, if impact assessment a fixed timestep may be more appropriate)	☑ Yes	☐ N/A
	☐ No	
Have all warning and error messages been checked and resolved?	☐ Yes	☐ N/A
	☐ No	
Has the model results / log file been provided and checked?	☐ Yes	☐ N/A
	☐ No	
Results / log file checked for mass balance?	☐ Yes	☐ N/A
	☐ No	
Hydrographs at selected locations in the model checked for visual instabilities?	☑ Yes	☐ N/A
	☐ No	
Results / log file checked for non-convergence / max number of iterations exceeded?	☐ Yes	☐ N/A
	☐ No	
Model run time suitable for the intended use of the model?	☐ Yes	☐ N/A
	☐ No	
Model reporting intervals suitable to detect instabilities and satisfy modelling objectives?	☐ Yes	☐ N/A
	☐ No	

Other Comments / Issues

Model not rerun and limited output received - unable to check mass balance, errors and warnings

Hydrographs provided for PO lines and 1D network - spot checked; some instabilities observed in 1D network at start and end of simulations but generally not affecting peak of event (Consultant should check and confirm)

There is a high velocity zone on the Pine R boundary that is not affecting flood impacts but will appear in the maps and should be corrected if possible

During the 2001 event, high velocities are observed at the Gateway Motorway bridge and the John Fisher lagoon

and should be checked by the Consultant

4.1 Calibration (generic not run specific)

Number of calibration events	2	
Dates of calibration events	Mar-01	
	Jan-12	
Approximate ARI of smallest calibration event	1-5 yrs	
Approximate ARI of largest calibration event	20-100 yrs	
Are the events selected suitable for calibration?	☑ Yes ☐ No	☐ N/A
(If no, why)		
Specific details of each calibration event described in the report?	☑ Yes ☐ No	☐ N/A Limited information
Details of the historical catchment changes detailed in the report?	☑ Yes ☐ No	☐ N/A
Specifics and the limitations of the recorded / gauged data detailed in the report?	☑ Yes ☐ No	☐ N/A
Basis of the calibration? (e.g. joint hydrologic / hydraulic)	☑ Joint ☐ Hydraulic only	☐ Other ☐ N/A
Calibration tolerances specified?	☑ Yes ☐ No	☐ N/A
What parameters were calibrated?	Not specified - assumed to be roughness within hydraulic model	
Headlosses at hydraulic structures appear logical / sensible?	☑ Yes ☐ No	☐ N/A
Headlosses at hydraulic structures checked by an alternate method?	☑ Yes ☐ No	☐ N/A
Fit to hydrograph timing adequately achieved?	☐ Yes ☐ No	☑ N/A
Fit to peak flood level adequately achieved acceptable ranges?	☑ Yes ☐ No	☐ N/A
Fit to volume achieved in hydrological calibration?	☐ Yes ☐ No	☑ N/A
Are the calibrated parameters within acceptable ranges?	☑ Yes ☐ No	☐ N/A
Calibration produced a consistent set of parameters to use in verification?	☑ Yes ☐ No	☐ N/A

Locations at which a good fit has not been achieved (and reasons why)	The report explains where calibration has not been achieved within targets.

Other Comments / Issues

There is no stream gauge to calibrate to. Calibration is jointly only with modelled levels being compared to MHG peak readings. RAFTS and TUFLOW consistency has been checked at two locations - Bracken Ridge Rd and John Fisher Drive but it was recognised that the RAFTS model will not accurately represent the structure interaction and storage. Local flows only have been applied to the hydraulic model.

May 2009 event - d/s of Bracken Ridge Road gauge reading considered to be suspect due to high recorded head loss of ~450mm. The u/s recorded level is at approximately handrail level. Thus, blockage of the handrails may have contributed to a large headloss.The flow during the 2009 event is not known but unlikely to be high due to the storage effects in this area. In the 2001 event this structure has the same recorded level upstream and downstream (drowned or low flow). There are no other available u/s and d/s recorded levels for this structure. Thus, the headloss for smaller events can only be assessed by the hydraulic model and via alternate checks of the modelled structure headlosses. Once these checks have been made, the inaccuracy of the reading should be confirmed. It is considered by the reviewer that the assumption of an erroneous reading is reasonable.

The RAFTS and TUFLOW models indicate about a 10% difference in discharge at Bracken Ridge Road for the 2001 event and a timing difference of approx. 0.5 hour. The shape is fair and volume ok. The other events have a better match. Generally the consistency is fair-good as was expected due to the RAFTS model not including the structures and not generally being able to represent the storage affects that the TUFLOW model is. At John Fisher Drive the consistency is reasonably good.

The scope of the study does not require flooding in the Pine River to be considered. The inability to match the 2009 event at guage 110 is due to this limitation of the study and accepted.

4.2 Verification (generic not run specific)

Number of verification events	2
Dates of verification events	May-09
	Oct-10
Approximate ARI of smallest verification event	1-5 yrs
Approximate ARI of largest verification event	1-5 yrs

Are the events selected suitable for verification? ☑ Yes ☐ No ☐ N/A

(If no, why)

Specific details of each verification event described in the report? ☐ Yes ☐ No ☐ N/A

Details of the historical catchment changes detailed in the report? ☐ Yes ☐ No ☐ N/A

Specifics and the limitations of the recorded / gauged data detailed in the report? ☐ Yes ☐ No ☐ N/A

Verification tolerances specified? ☐ Yes ☐ No ☐ N/A

Headlosses at hydraulic structures appear logical / sensible? ☐ Yes ☐ No ☐ N/A

Headlosses at hydraulic structures checked by an alternate method? ☐ Yes ☐ No ☐ N/A

Fit to hydrograph timing adequately achieved? ☐ Yes ☐ No ☐ N/A

Fit to peak flood level adequately achieved acceptable ranges? ☐ Yes ☐ No ☐ N/A

Fit to volume achieved in hydrological verification? ☐ Yes ☐ No ☐ N/A

Does the verification give confidence the model is producing accurate results and is suitable for design runs ☐ Yes ☐ No ☐ N/A

Locations at which a good fit has not been achieved (and reasons why)

Other Comments / Issues

Refer calibration comments

5.1 Design - Flood Planning Levels (generic not run specific)

Range of design ARI events: 50%,20%,10%,5%,2%,1%,0.5%,0.2%,0.05% AEP and PMF

Does the design ARI consider joint probability of creek / river; creek / tide; etc; interaction?
- [x] Yes
- [ ] No
- [ ] Other
- [ ] N/A

If no, should it have been considered?
- [ ] Yes
- [ ] No
- [ ] N/A

(If yes, why)

Interaction of tide and creek flooding has been considered for the purpose of modelling the flood levels for Bald Hills Creek

MHWS for standard design events and HAT for all extreme events

For climate change scenarios, similar but +300mm for year 2050 and +800mm for year 2100

Has the joint probability analysis been applied correctly?
- [x] Yes
- [ ] No
- [ ] N/A

(what methodology was used?)

It is consistent with the standard aproach for all other flood studies in BCC

Type of hydraulic scenario(s)?
- [x] Existing (Ex)
- [x] Ex + MRC
- [x] Ex + MRC + WWC
- [ ] Other

Origin or the design hydrology?
- [x] Hydrology model (AR&R)
- [ ] Hydrology model (DIS)
- [ ] Rational Method
- [ ] Other

Is the design hydrology existing or ultimate catchment conditions?
- [ ] Existing
- [x] Ultimate
- [ ] Other

Is the design hydrology calibrated or un-calibrated?
- [ ] Calibrated
- [x] Un-calibrated
- [ ] Other
- [ ] N/A

Are the design model parameters consistent with the calibrated model?
- [x] Yes
- [ ] No
- [ ] N/A

Has the Minimum Riparian Corridor been modelled aqequately?
- [x] Yes
- [ ] No
- [ ] N/A

Has the Waterway Corridor been modelled aqequately?
- [x] Yes
- [ ] No
- [ ] N/A

Have the design ARI flood level results been compared against previous results?
- [ ] Yes
- [x] No
- [ ] N/A

If yes, are the results comparable to these results?
- [ ] Yes
- [ ] No
- [ ] N/A

(If no, why)

It wasn't part of scope of work

Have the design ARI flood level results been compared against each other for consistency?	[x] Yes [ ] No	[ ] N/A
Headlosses at hydraulic structures appear logical / sensible?	[x] Yes [ ] No	[ ] N/A
Headlosses at hydraulic structures checked by an alternate method?	[x] Yes [ ] No	[ ] N/A
Has a sensitivity analysis been undertaken?	[x] Yes [ ] No	[ ] N/A
If yes, what parameters?	[ ] Manning's n [x] Blockages	[ ] Boundary conditions [x] Other
Has a climate change assessment been undertaken?	[x] Yes [ ] No	[ ] N/A
Has the climate change change assessment been modelled appropriately?	[x] Yes [ ] No	[ ] N/A
Modelling results appear to be accurate and suitable for the study objectives?	[x] Yes [ ] No	

Other Comments / Issues

The hydrology model is uncalibrated due to the absence of stream gauge data . However, the model results have been verified at couple of locations with the results from the hydraulic model.