“Where will our knowledge take you?”

Milestone Report 3: Detailed Model Development and Calibration

Comprehensive Hydraulic Assessment

Brisbane River Catchment Flood Study

DRAFT FINAL

Prepared for the State of Queensland (acting through):
Department of Infrastructure, Local Government and Planning
Department of Natural Resources and Mines

September 2015

Comprehensive Hydraulic Assessment
as part of the
Brisbane River Catchment Flood Study

Milestone Report 3:
Detailed Model Development and Calibration

Prepared for:	State of Queensland (acting through) Department to Department of Infrastructure, Local Government and Planning Department of Natural Resources and Mines
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

Offices

Brisbane
Denver
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Melbourne
Newcastle
Perth
Sydney
Vancouver

Document Control Sheet

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

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

ABN 54 010 830 421

www.bmtwbm.com.au

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Title:	Milestone Report 3: Detailed Model Development and Calibration
Project Manager:	Bill Syme
Author:	Cathie Barton, Bill Syme, Phillip Ryan, Barry Rodgers, Rachel Jensen
Client:	State Of Queensland
Client Contact:	Dr Wai-Tong Wong (DNRM)
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Executive Summary

The State of Queensland, acting through the Department of Infrastructure, Local Government and Planning (DILGP) (formerly the Department of State Development, Infrastructure and Planning (DSDIP)), and project managed through the Department of Natural Resources and Mines, is undertaking a Comprehensive Hydraulic Assessment (this assessment) to deliver a fully calibrated hydraulic model that accurately defines the flood behaviour of the lower Brisbane River including major tributaries downstream of Wivenhoe Dam. This assessment is a component of a broader framework of the Brisbane River Catchment Floodplain Studies (BRCFS) currently being undertaken by the Queensland Government in response to the Queensland Floods Commission of Inquiry to provide a comprehensive plan to manage Brisbane River flood risk.

This Milestone Report 3: *Detailed Model Development and Calibration* is the third[1] in a series of milestone reports to be delivered as part of the BRCFS Hydraulic Assessment. The purpose of this report is to provide an overview of the development and calibration of the Detailed Hydraulic Model, including data used, methodology adopted for model schematisation, calibration/verification to historical events and proofing for extreme events.

Detailed Hydraulic Model

The Detailed Hydraulic Model is a 1D/2D hydraulic model that is designed to reproduce the hydraulic behaviour of the rivers, creeks and floodplains at a much higher resolution than the Fast Hydraulic Model. The Detailed Model, whilst substantially slower to simulate a flood event than the Fast Model, is far superior for producing flood maps and 3D surfaces of flood depths, water levels, hazard, risk categories and other useful data for floodplain management planning measures. The model will also more accurately predict changes in flood levels and flow patterns due to past and proposed works, including flood mitigation measures and future developments.

The functions of the Detailed Model are to:

- Accurately reproduce the flood behaviour of the Brisbane River, Lockyer Creek and Bremer River at a sufficiently high resolution to produce mapping of flood levels, depths and hazard for broad-scale planning purposes.
- In the future, quantify the impacts or changes in flood levels, depths and hazard due to:
  - Flood mitigation measures, urban developments, road and rail infrastructure, dredging and quarry operations, and other works that change or alter the flood behaviour; and
  - Changes in climate, land-use, sedimentation and erosion, or other factors that may or may not influence the flood behaviour into the future so that planning instruments can accommodate these effects.
- Improve the understanding of the stage-discharge relationships (rating curves) at key stream gauging stations, particularly at those locations affected by backwater.

[1] The first report being BMT WBM (2014) - Milestone Report 1: Data Review and Modelling Methodology, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final - 29 October 2014. The second report being BMT WBM (2015) - Milestone Report 2: Fast Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – April 2015

The 1D sections of the Detailed Model extend along the in-bank sections of Lockyer Creek and the in-bank sections of the Bremer River, and Warrill and Purga Creeks upstream of One Mile Bridge. The remainder of the model is represented as a 30m 2D regular grid. The 1D sections are based on those in the Fast Model.

The Detailed Model was calibrated and verified to the floods of 1974, 1996, 1999, 2011 and 2013. A 1.5x1974 event was simulated to approximate the estimates of peak flows in Brisbane for one of the 1893 events and comparisons made to peak 1893 recorded flood levels. The model was proofed for two extreme events: 5x1974 and 8x1974.

Key observations during the model calibration/verification phase are:

- The model matches the five events in terms of hydrograph timing with water level gauges, flow gaugings and flood marks.
- The Manning's n values are typical of those used in the industry.
- As for the Fast Model, a satisfactory calibration cannot be achieved solely using a Manning's n approach. Additional form (energy) losses at sharp river bends, rock ledges and confluences were needed to reproduce the timing of the flood wave and the steep gradients along sections of the Brisbane River, but of a lesser magnitude than the Fast Model, which only applies the 1D equations. The 2D hydraulic equations are able to simulate most of these losses, but not all the losses.
- The effects of superelevation at river bends is reproduced in the 2D sections, and where recorded flood marks were available these supported the model results.
- Reducing the 2D resolution from a 30m to a 20m cell size does not provide any major improvement in the model calibration or the model's ability to meet the Detailed Model's objectives, and the longer run times of the 20m resolution (3 to 6 days for each of the estimated 50 design events) will be impractical based on current day PC chip technology.

In regard to the suitability of the Detailed Model for simulating the estimated 50 design events:

(1) The Detailed Model at a 30m resolution has a run time of around 16 to 32 hours depending on the flood event duration using a single core on a present day high end PC. At this run time the model, with sufficient computing resources and time, can feasibly be used to turn over the design simulations within a reasonable period. For example, if the 1% AEP event consists of running say 6 to 8 of the 50 selected Monte Carlo events, the 1% event could be completed in around 24 hours using a standard 8 core i7 CPU chip.

(2) The Detailed Model has been calibrated to tidal conditions, a minor flood (2013) and a major flood (2011), and verified to two minor floods (1996 and 1999) and a major flood (1974). These floods vary significantly in behaviour and size, and the ability of the Detailed Model to reproduce such a wide range of events without varying parameters provides a high level of confidence for simulating the design floods up to around the 1% AEP event, which is assumed to be in the order of one of the 1893/1974/2011 floods.

(3) For extreme events greater in size than the calibration events, the Detailed Model gives similar but higher profiles to the Fast Model, and similar profiles to the Updated DMT Model, so is considered suitable for these events.

(4) The Fast and Detailed Models provide consistent results at the ~30 reporting locations being used for the Monte Carlo analysis using the Fast Model results.

The Detailed Model is suited for future floodplain management functions including, but not limited to:

- Planning levels and flood hazard/risk categorisation.
- Quantifying the changes to flood levels, flows and risk associated with assessing past and future works on the floodplain.
- Providing boundaries or other hydraulic data for high resolution localised modelling of past and future flood mitigation measures and other civil works.

The model is not suited for:

- Local creek flood assessments other than for backwater levels caused by a Bremer or Brisbane River catchment flood. For local creeks it is recommended that the maximum of peak flood levels/hazard/risk from both a local hydraulic assessment and the Detailed Model, be used for flood planning measures.
- High resolution hydraulic assessments where it is essential that results on a grid of finer scale than 30m is required. Either an embedded finer grid or a local fine grid model driven by flow and water level boundaries extracted from the Detailed Model should be used for assessments of this kind.

Rating Curve Review

The review of the existing rating curves including those derived during the BRCFS hydrologic assessment, within the domain of the hydraulic modelling, found the rating curves to be commensurate with the hydraulic modelling stage-discharge relationships within the bounds of data inaccuracies, modelling uncertainties, hysteresis effects, and variations in hydraulic behaviour of the different calibration events. On this basis it is considered that there is no justifiable benefit in revising the hydrologic and hydraulic modelling calibrations, and that the rating curves used in the hydrologic and hydraulic assessments are consistent. However, given the importance of signing off on the hydrologic and hydraulic modelling calibrations before proceeding with the design flood modelling, it is recommended that an independent expert opinion from the IPE on whether there should be any further consideration or refinement of the hydrologic and hydraulic modelling calibrations is sought before proceeding to the design flood modelling. Subject to the IPE's views and any necessary refinements, it is intended that the final set of consistent, robust and preferred rating curves will be developed in consultation with the key stakeholders involved and included as part of Milestone Report 5.

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The various plots produced to present the Detailed Model's calibration and verification also contain the Fast Model results to allow comparison between the models. Calibration and verification plots are followed by results of sensitivity tests and are listed below in the order in which they are compiled in the addendum.

Detailed Model – Tidal and Minor Flood Calibration and Verification

2013 DM Flood and Tide Calibration

1996 DM Flood Verification

1999 DM Flood Verification

Detailed Model – Major Flood Calibration and Verification

2011 DM Flood Calibration

1974 DM Flood Verification

List of Abbreviations

1D	One dimensional
2D	Two dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Aerial Laser Survey
ARI	Australian Rivers Institute
AWRC	Australian Water Resources Council
BCC	Brisbane City Council
BCC (CPO)	Brisbane City Council (City Projects Office)
BoM	Bureau of Meteorology
BRCFMP	Brisbane River Catchment Floodplain Management Plan
BRCFMS	Brisbane River Catchment Floodplain Management Study
BRCFS	Brisbane River Catchment Flood Study
CBD	Central Business District
CPU	Central Processing Unit
DCS	Data Collection Study
DEM	Digital Elevation Model - a fixed grid of elevations sampled from a DTM
DILGP	Department of Infrastructure, Local Government and Planning (formerly DSDIP)
DM	Detailed Model
DMT	Disaster Management Tool
DNRM	Department of Natural Resources and Mines
DPI	Department of Primary Industries (former)
DS	Downstream
DSDIP	Department of State Development, Infrastructure and Planning (former Department)
DTM	Digital Terrain Model – a triangulation of raw elevation data points
DTMR	Department of Transport and Main Roads
FCoI	Floods Commission of Inquiry (Qld)
FEWS	Flood Early Warning System
FM	Fast Model
FOSM	Flood Operations Simulation Model
GIS	Geographic Information System
GPU	Graphics Processing Unit
H&H	Hydrologic and Hydraulic
HDD	Hard Disk Drive
ICC	Ipswich City Council

IPE	Independent Panel of Experts (for the current Study)
IRP	Independent Review Panel (commissioned by BCC in 2003)
LGA	Local Government Area
LiDAR	Light Detection and Ranging
LVRC	Lockyer Valley Regional Council
PMF	Probable Maximum Flood
PoB	Port of Brisbane
QGIS	Queensland Government Information Service
QR	Queensland Rail
RAM	Random Access Memory
SEQ	South East Queensland
SRC	Somerset Regional Council
SRTM	Shuttle Radar Topography Mission
TIN	Triangulated Irregular Network
TLPI	Temporary Local Planning Instrument
TWG	Technical Working Group
UDMT	Updated Disaster Management Tool
US	Upstream
WSDOS	Wivenhoe and Somerset Dams Optimisation Study

1 Introduction

1.1 Context

1.1.1 Brisbane River Catchment Floodplain Studies

The State of Queensland, acting through the Department of Infrastructure, Local Government and Planning (DILGP) (formerly the Department of State Development, Infrastructure and Planning, DSDIP) and the Department of Natural Resources and Mines (DNRM) as project manager, is undertaking a Comprehensive Hydraulic Assessment (this assessment) to deliver a fully calibrated hydraulic model that accurately defines the flood behaviour of the lower Brisbane River including major tributaries downstream of Wivenhoe Dam.

This assessment is a component of a broader framework of the Brisbane River Catchment Floodplain Studies (shown in Figure 1-1) currently being undertaken by the Queensland Government in response to Recommendation 2.2 of the Queensland Floods Commission of Inquiry[2] to provide a comprehensive plan to manage Brisbane River flood risk.

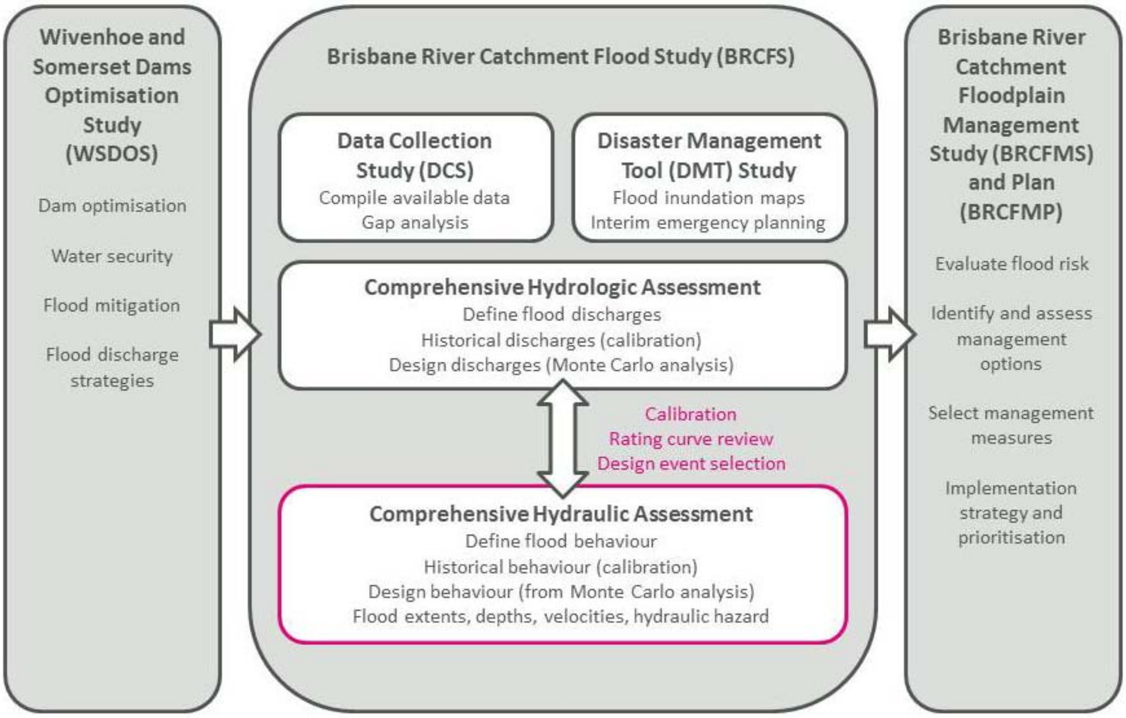

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Figure 1-1 Brisbane River Catchment Floodplain Studies

[2] Final Report, Queensland Floods Commission of Inquiry, March 2012.

Based on Recommendation 2.2[2], this suite of studies follows the traditional and effective flood risk management framework endorsed as current best practice in Australia[3], which incorporates the following steps:

- A Flood Study: The **Brisbane River Catchment Flood Study (BRCFS)** is presently underway to define flood behaviour. The BRCFS comprises a Data Collection Study (DCS), Comprehensive Hydrologic Assessment and Comprehensive Hydraulic Assessment (see Section 1.1.2).
- A Floodplain Management Study: The **Brisbane River Catchment Floodplain Management Study (BRCFMS)** will subsequently evaluate flood risk based on the flood behaviour defined in the BRCFS and identify and assess a range of flood risk management options. Options that involve changes in hydrologic and/or hydraulic conditions will be assessed using the models developed for the BRCFS.
- A Floodplain Management Plan: The **Brisbane River Catchment Floodplain Management Plan (BRCFMP)** will select a range of flood risk management measures based on the options assessed in the BRCFMS to guide the current and future management of flood risk. This will include a prioritised strategy outlining how the measures are to be implemented (including funding, responsibilities, actions, timeframes etc.).

The **Wivenhoe and Somerset Dams Optimisation Study** (WSDOS) is also being carried out in response to the Queensland Floods Commission of Inquiry to investigate potential options to improve dam operations and flood mitigation, taking into consideration water supply security, dam safety and erosion.

1.1.2 Brisbane River Catchment Flood Study (BRCFS)

The Brisbane River Catchment Flood Study (BRCFS) comprises the following stages:

- **Data Collection Study (Aurecon *et al*, 2013):** The Data Collection Study (DCS) was completed by Aurecon in 2013 and identified, compiled and reviewed readily available data and metadata, including a gap analysis.
- **Comprehensive Hydrologic Assessment (Aurecon *et al*, 2015c):** The Hydrologic Assessment commenced in 2013 and is currently being reviewed by the Client. It defines flood flows for the Brisbane River catchment based on flood frequency analysis, design event analysis and hydrologic modelling using a Monte Carlo approach to cater for temporal and spatial variations in rainfall patterns, operation of Wivenhoe Dam and other factors that affect catchment runoff. The Hydrologic Assessment also includes the configuration of a FEWS framework for data and simulation management.
- **Comprehensive Hydraulic Assessment:** The Hydraulic Assessment (this assessment) will define flood behaviour of the lower Brisbane River on the basis of, and in conjunction with, the Hydrologic Assessment. Specifically, this assessment will identify flood extents, depths, velocities and hydraulic hazard, across the full extent of the floodplain, for a range of events

[3] Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Australian Emergency Management Handbook 7, Australian Government Attorney-General's Department, 2013.

up to and including the PMF. The components of the Hydraulic Assessment are outlined in Section 1.1.2.

In addition to the above stages, the **Disaster Management Tool (DMT) Study** (BCC, 2014a) has been undertaken by Brisbane City Council (City Projects Office) (BCC (CPO)) for the BRCFS Steering Committee for the purposes of providing flood inundation maps for interim emergency planning. The DMT also provides significant and useful background for the development of the hydraulic models for this assessment.

1.1.3 BRCFS Hydraulic Assessment

Key elements of the Hydraulic Assessment include the development of an integrated suite of hydraulic models, rigorous and defendable calibration to historical events, and modelling of a comprehensive range of design events to define flood behaviour.

The Hydraulic Assessment incorporates the following phases: data collation, site inspections, modelling, reporting and workshops (shown in Figure 1-2). Two models are developed and calibrated as part of the Hydraulic Assessment: the Fast Model and the Detailed Model. The development and calibration of the Fast Model is detailed in Milestone Report 2 (BMT WBM, 2015) and summarised in Section 1.1.4. This current report details the development and calibration of the Detailed Model.

1.1.4 Fast Model Overview

The Fast Model is based on the established hydraulic modelling approach of using a network of 1D channels and storage nodes that was commonplace prior to 2D flood modelling. The network of channels gives a quasi 2D effect by conveying water through flowpaths representing both the rivers/creeks and floodplains. Spill channels connect the river/creek and floodplain flowpaths. The Fast Model has some 2,350 channels. The development and calibration of the Fast Model is described in Milestone Report 2 (BMT WBM, 2015). The Fast Model is so-named because of its fast run times. A simulation of the Fast Model for one 10 day duration flood event takes approximately 5 minutes on a 2.7GHz i7 chip[4], compared to simulation times in the order of days for the 2D “Detailed Model”. The significantly faster simulation time of the Fast Model is essential in order for the Fast Model to meet its objectives, described as follows.

The primary purpose of the Fast Model is to simulate thousands of Monte Carlo events derived by the Hydrologic Assessment. The peak flows and peak water levels from these thousands of runs will be used to carry out flood frequency analyses (FFA) at 29 reporting locations along the main creeks and rivers. From these FFAs, preliminary flood level AEPs at the reporting locations will be derived, followed by selection of approximately 50 of the Monte Carlo events that give a reasonable representation of the flood level AEPs derived from the FFA.

The Fast Model is best viewed as a stepping stone to the selection of the 50 design flood events for the Detailed Model. The 50 events are to be selected from the thousands of Monte Carlo Events produced by the Hydrologic Assessment. The long run-times of the Detailed Model prohibit using the Detailed Model for the Monte Carlo analysis to derive peak water level AEPs.

[4] The Brief (DSDIP, 2014) specifies that a simulation time of less than 15minutes is required for the Fast Model.

The Fast Model must also be able to reliably reproduce the hydraulics of the Brisbane River Catchment downstream of Wivenhoe Dam, particularly along the main creeks and rivers where the reporting locations are located. Therefore, the Fast Model has been calibrated and verified to a range of historical events. It has also been shown to produce consistent results for extreme events through comparison with other models/analyses.

Importantly, the Fast Model is not intended to calculate the final peak water levels for different AEPs – this will be an output of the Detailed Model. The Fast Model is solely to be used to help select a small sub-set (~50) of the Monte Carlo events that give consistent results with the Monte Carlo FFA.

1.1.5 Detailed Model Function

The Detailed Model is a 1D/2D hydraulic model that is designed to reproduce the hydraulic behaviour of the rivers, creeks and floodplains at a much higher resolution than the Fast Model. The Detailed Model, whilst substantially slower to simulate a flood event than the Fast Model, is far superior for producing flood maps and 3D surfaces of flood depths, water levels, hazard, risk categories and other useful data for floodplain management planning measures. The model will also more accurately predict changes in flood levels and flow patterns due to past and proposed works, including flood mitigation measures and future developments.

The functions of the Detailed Model are to:

- Accurately reproduce the flood behaviour of the Brisbane River, Lockyer Creek and Bremer River at a sufficiently high resolution to produce mapping of flood levels, depths and hazard for broad-scale planning purposes.
- Use the model into the future to quantify the impacts or changes in flood levels, depths and hazard due to:
  - Flood mitigation measures, urban developments, road and rail infrastructure, dredging and quarry operations, and other works that change or alter the flood behaviour; and
  - Changes in climate, land-use, sedimentation and erosion, or other factors that may or may not influence the flood behaviour into the future so that planning instruments can accommodate these effects.
- Improve the understanding of the rating curve relationships at key stream gauging stations, particularly at those locations affected by backwater. Detailed Model results will be used in the rating curve reconciliation process.

1.2 This Report

1.2.1 Purpose and Scope

This Milestone Report 3: Detailed Model Development and Calibration is the third[5] in a series of milestone reports to be delivered as part of the BRCFS Hydraulic Assessment. The purpose of this

[5] The first report being BMT WBM (2014) - Milestone Report 1: Data Review and Modelling Methodology, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final - 29 October 2014. The second report being BMT WBM (2015) - Milestone Report 2: Fast Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – April 2015

report is to provide an overview of the development and calibration of the Detailed Hydraulic Model, including data used, methodology adopted for model schematisation and calibration to historical events. This report was initially released as a Draft prior to the Workshop held on May 14, 2015, at which the findings outlined in this report were presented and discussed with the IPE and TWG members Outcomes, key points and response to comments from the review and workshop are incorporated into this Draft Final report as Appendix A (Outcomes and Actions from Workshop 3) and Appendix B (comments received from IPE). Comments were also received from Seqwater, BCC, ICC and LVRC.

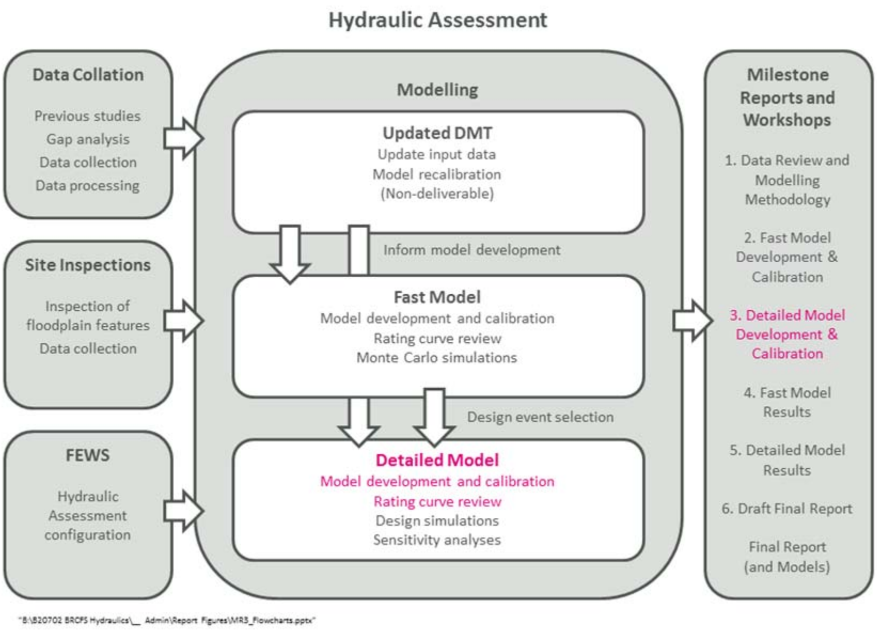


Figure 1-2   BRCFS Hydraulic Assessment

1.2.2 Brief

This Milestone Report 3: Detailed Model Development and Calibration, addresses the relevant components of the following tasks as outlined in the Brief (DSDIP, 2014):

3.10.5.1 Detailed Model Development, Calibration and Validation

A detailed hydraulic model will be developed.

The topography for the model will be derived from a comprehensive DTM of the area, representing the current floodplain and river geometry, with accuracy suitable for hydraulic modelling of small to extreme flood events.

Any hydraulic structures which have a measurable impact on flooding behaviour for small to extreme flood events should be represented in the model.

The model will be calibrated (or validated) against a wide range of representative flood events (small to large) in each of the model catchments including a sufficient number of significant events (including but not limited to the following flood events: 1893 (2 events), 1974, 1999, 2011, and 2013). Calibration will include matching modelled to observed peak levels, goodness of fit of height hydrographs, discharges, velocities, afflux at

Report 2: Fast Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – April 2015 *structures, maximum depths, timing of peaks, and extents of inundation. The recommended calibration strategy is summarised in the following Section.*

For calibration of the model against the 1974 flood event, the modelled river geometry and hydraulic structures will correspond to that existing at the time of the event.

For calibration (or validation) of the model against the 1893 flood events, the modelled river geometry and hydraulic structures will correspond to that existing at the time of the event. This will require the use of historical surveys and other information to modify the topography of the model.

The quality of the calibrations should be quantified by rating the goodness of fit of modelled and observed peak flood levels, and timing of peak at river level gauges, or where reliable surveyed peak level information is available. There should also be comparisons and ratings of goodness of fit of modelled and observed velocity and discharge measurements, where these have been measured during calibration flood events.

Particular attention will be required at this stage to develop a comprehensive understanding of the rating curves (and improve rating quality as required) at key gauges in conjunction with all the associated information and the issues at each priority location, as defined in the rating curve study (also see Section 3.10.1.2). The limitations and assumptions associated with various rating curves should be considered in the assessment.

The rating curves adopted for the comprehensive hydrologic modelling phase will be compared with the rating curves generated from the detailed hydraulic model. Where significant differences exist, reconciliation will be required. Any significant departures from the previously adopted rating curves (and estimated flows) are to be documented appropriately and submitted to the client for consideration. It is expected that a consistent, robust and agreed set of rating curves at key gauges would be achieved as part of the study and there would need to be consensus between various parties (including Seqwater, Bureau of Meteorology, DNRM and Councils). This reconciliation may lead to some changes in the hydrologic modelling phase, or further adjustments to the hydraulic model.

3.10.5.2 Calibration Approach

The consultant will need to demonstrate that the hydraulic model has satisfactory calibration across the model domain for storage-elevation relationships, storage-conveyance relationships, performance to simulate tides and storm surge, performance to simulate passage of riverine floods from the upstream catchments, and performance to simulate tides in combination with riverine floods. A methodical progressive approach to calibration is desirable. It is suggested that the approach should consider the following order of progressive calibration:

- *Storage-Level test. Initial model test to fill the model with water (upstream inflows) with a constant ocean level downstream boundary. Divide the model domain into spatial compartments and then check that each compartment provides satisfactory storage-level relationship as compared to the original DTM Lidar survey for the same area;*
- *Tide simulation test. Run model with no, or minimal upstream inflow, and confirm tide magnitude and timing is correct at multiple representative locations along the estuary up to the upstream tidal limits. A number of tide scenarios should be considered. It should be noted that tide current velocity data may assist to quantify estimates of tidal prism flows.*
- *Small flood tests. Run model small flood event (e.g. 2013, 1999, December 2010) to calibrate hydraulic roughness and other energy loss parameters at lower range of potential flood levels. Iterations to achieve match of peak level (conveyance performance) and timing/shape of hydrograph (storage-conveyance relationship and influence of tides).*

- *Increasing large flood test up to highest practical limit dictated by quality and quantity of available data. The larger flood tests should inform parameterisation of hydraulic roughness and other energy loss parameters at higher ranges of potential flood levels.*
- *Examine the influence of momentum exchange across the waterway (typically where transverse velocity gradients are greatest) as well as for flow around waterway bends.*
- *Calibration parameters (roughness, turbulence, etc.) should be spatially matched to physical characteristics (e.g. vegetation, waterway geometry etc.) and this information should be collated for digital recording and presentation on mapping.*
- *Correspondence between calibration parameters and physical characters as per the above.*
- *Iteration of the above until reasonable calibration is achieved for all requirements of the model calibration.*

The consultant may propose alternative approaches and should outline in the proposal why such approaches may provide more efficient effort and better calibration outcomes. Calibration that only achieves a good match for large floods and poor match for small floods, tides, and simple model storage checks due to lack of effort or poor approach will not be accepted without prior submission of strong supporting evidence which is acceptable to both the IPE and Steering Committee.

Other sections relevant to the work undertaken as part of the Brief are as follows:

3.8 Accuracy Requirements[6]

In terms of water level estimates for specified annual exceedance probabilities, it would be desirable to achieve the following target tolerances:

- *Brisbane River downstream of Oxley Creek ± 0.15 m*
- *Brisbane River between Goodna and Oxley Creek ± 0.30 m*
- *Ipswich urban area ± 0.30 m*
- *Brisbane River and tributaries upstream of Goodna (for non-urban areas), including Bremer River and Lockyer Creek ± 0.50 m*

While there is no independent way of confirming that these accuracies will have been achieved in the results, some indication of the likely accuracy might be obtained through consideration of:

- *the quality of the input (including tolerances of topographic data, currency of topographic and bathymetry data, and the quality of the flood height data and corresponding estimates of flow);*
- *river geomorphology;*
- *the quality of the calibration;*
- *the magnitude of the events used for model calibration, in comparison with the design events;*
- *the discretisation of the hydrodynamic model;*
- *specifications of hydraulic roughness and energy losses (note that consideration may need to be given to variable roughness relationship with depth, and possible careful separation of friction losses versus drag and turbulence losses);*

[6] These tolerances for accuracy contained in the brief relate to the **design** water level estimates rather than the **calibration** water levels. However, at the request of the client, these tolerances are used and discussed in this report in relation to recorded and modelled levels and their differences.

- *the height vs. flow (rating curve) characteristics;*
- *quality of the design flood hydrology;*
- *experience in recent hydraulic modelling work in the catchment;*
- *benchmarking tests for hydraulic models; and*
- *results of sensitivity analyses for the key model parameters.*

The Consultant is required to consider and address the above aspects which affect accuracy, and draw conclusions regarding the likely accuracy of the results. Based on the above considerations, the Consultant is required to nominate "tolerances" which should be applied to the estimated design flood levels. The theory of errors may be used to establish an 'error range' for final levels.

3.9.3. Hydraulic Models (part)

A detailed hydraulic model of the lower Brisbane River is to be developed. This model is to have the following properties.

- *The software platform will satisfy the requirements of the detailed model as described in the Section 3.7 "Hydraulic Modelling Software Platform(s)" and be approved by the BRCFS Steering Committee.*
- *The extent of the model will be in accord with description in the Section 3.6 "Model Extent", and as approved by the BRCFS Steering Committee.*
- *The hydraulic model will be sufficiently detailed and robust to meet the objectives described in Section 3.2.*
- *The hydraulic model will be calibrated against the best available data at the time of the study. Sections 3.10.5.1 and 3.10.5.2 provide more information on the calibration process. All model information (including observed data and concepts used in the calibration, boundary conditions, model parameters and output, sensitivity analysis if any) for each calibration event will be saved, and indexed, so that it will be possible to review or revise the calibration at some future time.*
- *The model will be able to simulate correctly a tide-only boundary condition.*
- *The volume of flood storage in the model for specified water levels should match the flood storage independently calculated from the topographic information used to build the model.*
- *The model will be numerically stable for design and calibration flood events and hydraulic structure calculations should be numerically stable at transition between flow regimes (e.g. constriction to orifice to weir overflow etc.).*
- *The model should conserve mass within acceptable tolerances.*
- *The model should account for the effects of the river-floodplain interface with the transfer of river flow momentum to floodplain flows.*
- *Boundary conditions for the model will be supplied from the URBS runoff-routing model of the Brisbane River catchment developed as part of the Hydrology Study. An efficient interface between the two models is required. This is to be achieved through the Delft-FEWS framework.*

3.10.5.7 Detailed Model Quality Assurance and reporting

A comprehensive report on the development and calibration of the detailed hydraulic model is to be prepared. The report should provide information on topographic data input, structures, schematisation, boundary conditions, modelling of interface between and river and floodplain, tests of robustness and stability, quality of *calibration, interfacing and consistency with the hydrology modelling component (including rating curve comparisons), ability of model to meet the objectives of the study, limitations of model, likely accuracy, and tolerances which should apply to model results.*

The report will also contain a summary of the comparison of ratings at flood warning gauges and stream gauges predicted by the model, with those currently adopted for the hydrology study phase, together with recommendations for further action where significant differences exist.

Presentations to the BRCFS Steering Committee and IPE will be required to describe the model development and calibration.

2 Data Inputs

Input data required to inform the development and simulation of a hydraulic model includes topographic data, hydrographic data, hydraulic structure information, land use data, and inflows. This input data is common to both the Fast Model and the Detailed Model and has been described fully in Milestone Report 2 - Fast Model Development and Calibration (BMT WBM, 2015). As this description of input data is similar for both models, it has been documented in this report (Milestone Report 3) in Appendix A.

Only additional or changed datasets used in the Detailed Model development and calibration are discussed in the following sections.

2.1 Hydrographic Data

2.1.1 Inflows

A detailed background on historical inflows used in the calibration of the Fast and Detailed Models is provided in Appendix A. The following discussion relates only to the inflows used in the Detailed Model for the 1974 event.

As described in Appendix A, the 1974 inflow volumes from the Aurecon URBS model (Aurecon *et al,* 2015a,c) exceed the original Seqwater inflow volumes (Seqwater, 2013b) in the Bremer River and tributaries by up to 40% due to significant variations in IL/CL in these catchments. During the 1974 verification of the Fast Model (BMT WBM, 2015), it was found that the Fast Model generally over-predicted peak flood levels in the Bremer River. While this over-prediction could be minimised using standard hydraulic model parameters (such as Manning's n and form loss), any such variation in these parameters produced poorer (lower water levels) calibration results in the 2011 and 2013 flood events. This led to the belief that the over-prediction of flood levels in the 1974 event using the Aurecon URBS flow inputs is potentially due to the higher inflow volumes. For the Fast Model verification to the 1974 event (BMT WBM, 2015), two scenarios were simulated: 1) using Aurecon URBS inflows, and 2) using Seqwater URBS inflows. The conclusion reached in the Fast Model 1974 verification was that the best result would be achieved with IL/CL values in the Bremer River catchment being somewhere between the Aurecon and Seqwater values. Rather than simulating these two Fast Model scenarios separately for the Detailed Model 1974 verification, IL/CL values in the Bremer, Purga and Warrill catchments for the 1974 event were changed in the URBS model to reflect the *average* of Aurecon and Seqwater values. The IL/CL values used to obtain the inflows for the 1974 event for the verification of the Detailed Model are provided in Table 2-1.

Table 2-1 URBS IL/CL Values for the 1974 Event

Catchment	Losses (IL/CL)		
	Seqwater	Aurecon	Detailed Model (current study)
Lockyer	50 / 2.5	40 / 1.8	40 / 1.8
Bremer	65 / 2.0	30 / 0.3	50 / 1.2

Catchment	Losses (IL/CL)		
Purga	80 / 2.5	40 / 0.8	60 / 1.7
Warrill	80 / 2.0	40 / 0.5	60 / 1.3
Upper Brisbane	45 / 1.2	50 / 1.5	50 / 1.5
Lower (Brisbane Bar)	50 / 2.0	24 / 0.24	24 / 0.24

2.1.2 Historical Flood Extents

Historically, flood extents for flood events were typically determined following the event based on survey of flood marks. These were then used in conjunction with the mapped topography of the land to derive a flood extent, which is a continuous line that identifies the limit to which the flood extended across an area. Inaccuracies in flood extents are directly related to potential inaccuracies in the measurement of flood marks and inaccuracy in the topography used to extend and interpolate the continuous line. In more recent times, flood extents may also be determined from an aerial photograph taken at or near the flood peak, or after the peak using indicators that showed where the water extended. The accuracy of these methods are limited by several factors including whether:

- The aerial photograph was taken at the exact time of the peak of the flood,
- The extent can be seen clearly under vegetation,
- Ponding of perched waters on flat terrain due to rainfall, not due to flooding (Ipswich City Council staff advised this is an issue in some areas), and
- The resolution (clarity) of the aerial photograph.

Availability of recorded flood extents for the historical flood events considered in this assessment is provided in Table 2-2. Flood extents are mapped in Drawing 4 to Drawing 6 and are also contained within the Calibration Drawings from Drawing 10 to Drawing 26.

Table 2-2 Availability of Recorded Flood Extents

Historical Flood Event	Council Area			
	BCC	ICC	SRC	LVRC
1893	Yes	No	No	No
1974	Yes	Yes	Yes	No
1996	No	No	No	No
1999	No	No	No	No
2011	Yes	Yes	Yes	Yes
2013	No	No	Yes	No

2.2 Pipe Data

Within the Brisbane City area, there is a number of large drainage pipes designed to convey local runoff (due to rainfall on local catchments) to the river. However, in larger historical Brisbane River flood events, these pipes have allowed river water to back up into the lower-lying local areas causing inundation. In order to realistically simulate the inundation extent due to backwater in the Detailed Model, the larger pipes were required to be approximately represented in the model. BCC were able to supply rough guidance on the size and location of these larger pipes in digital format (pers. comm. James Charalambous, March 2015). While BCC advised that the information supplied should be verified for accuracy with the BCC Plan Custodian, the unverified data was considered of sufficient accuracy for the purpose of modelling. If accurate conveyance of these pipes was critical (e.g. in a local drainage scenario), the pipe data would require verification. However, within the Detailed Model, the presence of the pipes simply allows the river water to backup and enables the model to portray historical inundation extent in the backwater-affected areas. Pipe conveyance is not critical in this regard, provided the pipe sizes are reasonably indicative of the actual sizes. It is important to note that while it is not expected that the Detailed Model will be used for any assessments in which the accuracy or completeness of this pipe data is critical (e.g. local drainage assessments), future users of the model should be aware of the need to verify the pipe data (pipe size, invert levels and completeness) should these details be critical to a proposed assessment.

Following the 2011 event, a program began to fit these pipes with backwater prevention valves, which are designed to prevent river water backing up into low-lying areas. As such, following calibration, the Detailed Model used in design simulations may model the pipes with backwater prevention valves as “one-way” pipes where installed or planned to be installed.

2.3 Topographic Data

Topographic datasets used in the model build are described in Appendix A. For the most part, the topography used to construct the Detailed Model is the same as that used for building the Fast Model. Notable exceptions are given below.

2.3.1 Gully Lines

Gully lines were used for the following purposes:

- To ensure that the lowest bed elevation within a 2D channel cross section was being applied to at least one of the model grid cells; and
- To make some allowance for minor creeks and gullies within the wider floodplain.

In most locations, gully lines were sampled from the base topography using a semi-automated process in which the lowest elevations along each respective channel were selected from within a narrow search radius of a series of points digitised along the channel/gully. The points were then joined to form a gully breakline. This process of using the base topography to inform the gully lines was not appropriate in the section of the Brisbane River from Wivenhoe Dam to the upstream limit of the Mt Crosby weir pool as the bed elevations within the channel base topography were overstated, due to the lack of bathymetry data. The approach taken to amend bed elevations along this reach consisted of sampling channel inverts from the Fernvale/Lowood cross-section survey and from the Australian Rivers Institute (ARI) cross-section survey (these cross-sections are described further in Appendix A). The inverts of these cross-sections were joined with a breakline to ensure that the bed was lowered accordingly in the model topography. Whilst this approach is still considered approximate, it is an improvement over reliance on the base topography.

Breaklines were also included in the Detailed Model to represent ridges, road and rail embankments and other raised features. Further detail is provided in Appendix A.

2.3.2 Date Specific Topographic Amendments

A raised section of the Cunningham Highway between Warrill and Purga Creeks was removed from the base topography for the 1974 runs (see Figure 2-1).

Before	After Removal

Figure 2-1 Removal of Cunningham Highway Raised Section for 1974 Topography

The sand and gravel quarry near Fernvale was modified in the base topography for the 1974 event by removing noise bunds and spoil heaps.

2.4 Topographic Datasets – Priority Ranking

Each topographic dataset considered for informing both the Fast and Detailed Model topography is discussed in Appendix A. Reproduced in this current section is the priority given to each of these datasets for the purpose of developing the Detailed (and Fast) Models. The priority ranking is only applicable in areas where the datasets overlap and is used to ensure that the most suitable data is utilised within the relevant model area. That is, in an area where only one dataset is available, then that dataset is the one used, regardless of its priority ranking. If datasets do not overlap, they may be assigned the same priority ranking as they are never in competition with each other. For example, there is no overlap between each Priority 1 dataset shown below for in-bank data.

It is important to note that whilst the DMT DEM (BCC (2014a)) receives a priority ranking of 5 below, the DMT DEM is the predominate source of data used across the study area, particularly the floodplains. A ranking of 5 should not imply that the DMT DEM is of insufficient quality, but rather that other data has more recently become available in discrete areas allowing the DMT DEM to be superseded in these areas. Thus, the DMT DEM receives a lower priority in these areas where overlap occurs with the more recently available data. Further background on the DMT DEM is provided in Section C.1.1.

Priority 1 Data (Highest Priority):

- Mt Crosby Weir Pool (2007)
- PoB Lower Brisbane and Lower Bremer (2014).

Priority 2 Data:

- Lower Brisbane River and Tributaries DEM (GHD).

Priority 3 Data:

- Lowood-Fernvale Cross-Sections (2008)[7]

Priority 4 Data:

- ARI Cross-Sections (2012)[6]

Priority 5 Data:

- DMT DEM.

Checking as Required

- Seqwater Gauge Cross-Sections

Not Used

- RUBICON & MIKE11 Model Cross-Sections

[7] The invert levels of these cross-sections were used to ensure the Detailed Model represented the channel invert appropriately at these locations. Further discussion is provided in Section 2.3.

3 Detailed Model Development and Calibration

3.1 Detailed Model Development

3.1.1 Hydraulic Characteristics of the Brisbane River Catchment

Hydraulically, the Brisbane River Valley is a mixture of conveyance and storage dominated reaches. Lockyer Creek, due to its flat wide topography is, in a large event, highly storage dominated, with substantial volumes of floodwaters being stored and conveyed on the floodplain with flood waters originating from its catchment or by backwater from the Brisbane River. Between Lockyer Creek and the Bremer River the Brisbane River is largely conveyance dominated, with relatively minor floodplains, and floodwaters largely confined to the river channel. The river experiences high velocities and steep gradients through these reaches.

The Bremer River and the Brisbane River downstream of Colleges Crossing are a mixture of storage and conveyance with both having significant floodplains that store and/or help convey the flood wave. The lower Brisbane River, unlike most large east coast Australian rivers, has few natural meanders, with many of the river's reaches controlled by the hilly terrain. The hydraulic consequence is that substantially higher velocities, driven by a steep gradient, develop along the lower Brisbane River during a flood. Consequently, the Brisbane River banks are sometimes rock, bends can literally be a sharp 180º (e.g. Kangaroo Point) and the entire flood flow is often solely confined between the river banks with relatively little or no overbank flowpaths.

Backwater, where water ponds and backs up tributaries from raised water elevations on the downstream river, can have significant influence on flood levels for the lower Bremer River and lower Lockyer Creek. In the case of the Bremer, the levels at Ipswich can be dominated by levels on the Brisbane River during significant floods. Such backwater effects are fully accounted for in the Detailed Model.

3.1.2 Detailed Model Objectives

The objectives of the Detailed Model are to:

- Accurately reproduce the flood behaviour of the Brisbane River, Lockyer Creek and Bremer River at a sufficiently high resolution to produce mapping of flood levels, depths and hazard for broad-scale planning purposes.
- Use the model into the future to quantify the impacts or changes in flood levels, depths and hazard due to:
  - Flood mitigation measures, urban developments, road and rail infrastructure, dredging and quarry operations, and other works that change or alter the flood behaviour; and
  - Changes in climate, land-use, sedimentation and erosion, or other factors that may or may not influence the flood behaviour into the future so that planning instruments can accommodate these effects.
- Maximise the 2D areas due to the superior performance of 2D equations in areas of complex flows, which prevails in much of the Hydraulic Assessment area.

- Have a run time (computer simulation time) for a flood event that is practical and manageable. Given that around 50 individual flood events are predicted to define the design flood events, with possibly half a dozen or more just to characterise the 1% AEP event, a run time for a 10 day flood event of longer than a day or two will prove to be awkward and impractical.
- Given the extensive use of the Detailed Model by various stakeholders into the future, the run times above should ideally be achievable on standard high-end PCs.

3.1.3 Detailed Model Construct

The final configuration of the Detailed Model is a 1D/2D hydraulic model, with 1D sections being utilised where the 2D resolution is too coarse to adequately define an important flowpath.

For 2D domains, the full 2D hydrodynamic free-surface flow equations are solved using TUFLOW's CPU based implicit, unconditional, 2nd order spatial solver. The full 2D equations are significantly more accurate than the 1D equations in areas of complex flows characterised by high water speeds and sudden changes in flow direction such as around a river bend. More complex flow phenomena such as superelevation, the surcharging of waters on the outside of a sharp bend, and the interaction of creek/river and floodplain where major overland flowpaths develop and influence flood behaviour, are significantly better represented than with a solely 1D approach. These conditions are particularly prevalent on the Brisbane River due to its large number of sharp bends and high velocities.

After examination of the Updated DMT and Fast Model results, the areas in most need of a 2D solution were considered to be:

- The entire length of the Brisbane River downstream of the Wivenhoe Dam due to the high velocities, sharp river bends and rock outcrops. Superelevation at river bends, complex flow interactions with the floodplains and rock outcrops are prevalent and ideally best modelled using a full 2D approach.
- The floodplains along the Brisbane River that operate as flowpaths, which is most of the floodplain areas in close proximity to the river.
- The Lockyer Creek floodplains due to their complex and variable flow patterns at different flood heights.
- The Bremer River from Three Mile Bridge to upstream of Ipswich.

Areas where a 2D hydraulic solution was not considered to be essential were:

- In-bank Lockyer Creek can be modelled as a 1D solution provided the numerous breakouts onto the floodplain are represented at the resolution of the 2D domain.
- A number of local creeks operate solely as a backwater during a major Brisbane River flood and can be adequately modelled as connected 1D storages. However, for extreme Brisbane River events the lower sections of some creeks become critical flowpaths.
- For major floods, Ipswich and the Bremer River floodplains from around Ipswich downstream primarily operate as a backwater and do not need to be modelled using the 2D equations.

However, it should be noted that in terms of flood level, depth and hazard mapping, liaison with stakeholders and presentation of flood impact assessments, a 2D solution is always preferable, particularly over the floodplain due to its much finer resolution and superior mapping outputs.

3.1.4 Detailed Model Grid Resolution

Model Arrangement Testing

The model was initially divided into several 2D domains of differing resolution with the expectation that an in-bank 1D solution would need to be used for all waterways along the Bremer, and the Brisbane River upstream of either Moggill or Jindalee. Testing of the model's performance and run-times concluded:

- Representing the Brisbane River in-bank as 2D was highly preferable along its entire length, especially in areas such as Lowood/Fernvale and most sections downstream of Mt Crosby, due to the complexity and severity of the flow patterns.
- The linking of 2D domains of differing resolution, whilst providing reduced run times by allowing a coarser 2D resolution in some areas, were sometimes problematic and time-consuming to setup in areas of high velocities and variable water surface. Finding locations where the flow is relatively uniform and away from complex flows for all flood events, including extreme events, is challenging along the Brisbane River.
- A 30m 2D resolution over the entire Hydraulic Assessment area produced satisfactory results and practical run-times of one to two days per event, depending on the event duration, using the latest high-end PC chip technology.

The final model configuration adopted is a 30m 2D resolution over the entire area, with a 1D in-bank representation where the 30m resolution was considered too coarse.

The 1D sections are confined to the in-bank reaches of Lockyer Creek and the Bremer River, Warrill Creek and Purga Creek upstream of One Mile Bridge. These sections are based on the Fast Model, and remained in the 1D form as the recommended 2D resolution of 30m was considered too coarse to adequately represent these waterways.

The remaining areas, ie. all floodplains within the entire Hydraulic Assessment area, and for in-bank sections: the entire length of the Brisbane River from the model start at Wivenhoe Dam; and the Bremer River downstream of One Mile Bridge, are represented as a 2D grid based resolution using a 30m cell size.

The 30m grid resolution of the Detailed Model meets the requirements of the Invitation to Offer (DSDIP, 2014) as confirmed by the IPE (Appendix B). This model is capable of providing flood levels suitable for setting habitable floor levels at property level/scale.

Drawing 7 illustrates the extent of the 1D and 2D domains.

Data Sampling, Computational and Output Resolution and Formats

- It is important to note that ground elevations are sampled on a 15m resolution at the 2D cell centres, mid-sides and corners. Unlike other 2D schemes, which only sample ground elevations at the cell centre, TUFLOW "Classic" samples at twice the resolution. For example, for the 30m grid resolution, elevations are sampled every 15m giving an enhanced representation of the underlying topography where there are significant sub-grid cell variations.

- More importantly, the crest levels of all 3D breakline features (road/rail embankments, levees, etc) are transposed on to the nearest cell centres and/or cell sides to ensure the water does not overtop the embankment until the water level exceeds the crest height. This ensures that irrespective of the 2D cell size, the correct embankment height is modelled, and that there is no need to reduce the cell size to get a better sampling of breakline features. Breaklines can optionally just modify the cell sides for "thin" features that have a width smaller than the grid cell size (eg. a railway embankment in a 30m grid).
- Computation of the water levels are carried out at the centre of the 2D cells, ie. on a 30m interval.
- When outputting results (water levels) to GIS grid formats, the output resolution can be at any resolution, and is, by default, half of the 2D cell size (ie. 15m) and always on a north-south orientation[8].
- A range of non-GIS formats that are mesh (TIN) based can also be output from TUFLOW including WaterRIDE .wrb, 12D .tmo and SMS .dat and .xmdf formats.

<u>Identification of Potential Flood Risk Properties for Development Controls</u>

- The use of a model's output to identify properties that may have a potential flood risk and that may need to be assigned development controls for buildings, etc, is a key flood management/planning task. The Detailed Model's 30m cell size is not relevant as to the approach adopted, however, some preliminary guidance is provided in the following points.
- The Detailed Model's design flood results will need to be post-processed so that all properties that may be subject to flood management development controls are identified, and this process needs to take into account factors such as those below. Note that whilst the water level and depth grids can be output at any resolution, or can be output using a 3D meshed surface, the output resolution and format is not central to the issue or the approach taken.
    - As a freeboard is applied to design flood levels, the water level and depth surfaces need to be raised by the amount of the freeboard, then extended and buffered (see next point) to correctly trap potential properties that fall within a Council's development controls for flooding.
    - The elevations of the ground DEM, usually LiDAR, are not 100% accurate. Therefore, the water level and depth surface needs to be extended horizontally (buffered) using either GIS surface algorithms or by software like WaterRIDE using TUFLOW mesh output to ensure inaccuracies in the ground elevations are taken into account.

[8] On a more technical level, for TUFLOW GIS grid outputs (.asc and .flt formats), the value at the centre of each GIS grid or raster cell is interpolated from a triangular mesh (TIN) of the TUFLOW 2D cells and 1D Water Level Line triangles. To triangulate the 2D cells, the square cell is split into 4 triangles with vertices at the cell corners and a common vertex at the cell centre. Values (eg. water levels) are assigned to the vertices of the triangles from the hydraulic computations. Note that the GIS grid output can be of a different resolution to the 2D hydraulic computation cells, and the orientation of the GIS grid output is always north-south (whereas the 2D hydraulic cells can be any orientation). For mesh output formats produced by TUFLOW (eg. 12D .tmo, SMS .dat and .xmdf, or WaterRIDE .wrb), the original mesh described above based on the 2D cells and 1D WLL triangles is used.

- The Detailed Model output will have a 30m "blocky" edge. The edge will extend beyond the real flood extent at some locations and not extend far enough at other locations – that is the nature of modelling. Therefore, as described above, this requires that the water level and depth surfaces be extended horizontally (buffered).

Testing With 20m Grid Resolution

In parallel to the 30m 2D resolution model, a 20m resolution was setup as a comparison. The run times for the 20m model varied from several days to a week, depending on the event's duration.

The pros and cons of using a different grid resolution and/or a varying grid resolution are discussed below in light of the development and future application of the Detailed Model.

- Reducing the 2D grid resolution from the adopted 30m showed no demonstrable benefit in the tidal response and flood wave propagation speed or shape as demonstrated by sensitivity test ST10 in Section 3.15.2. If a model's primary waterways are being modelled too coarsely (i.e. too large a cell size), the flood wave will typically become delayed as the coarse resolution tends to constrict the flow. There is no apparent existence of this effect in ST10. In addition, if a model of this size (i.e. large spatial extent) has a cell size that is too coarse, evidence of this will be found in a poor reproduction of the flood wave propagation to recorded gauge hydrographs for the calibration events. As the calibration results show, this affect is also not evident. The absence of these identifiers of a "too coarse" grid size indicates that the 30m grid size is of sufficient resolution.
- For the TUFLOW "Classic" software being used for the Detailed Model, a minimum number of 2D cells across the waterway needed to produce reasonable results is typically 3 to 4, although satisfactory results can be achieved with 2 cells. TUFLOW "Classic", which uses a 2nd order spatial implicit matrix based solution of the 2D equations, typically requires less cells across a waterway than other schemes, especially compared with 1st order spatial explicit schemes such as TUFLOW GPU, which preferably represents primary flowpaths using 5 or more cells, although useful results maybe be achieved with less than 5. 2nd order spatial schemes are also a more mathematically exact solution to the equations and tend to require less cells or elements (i.e. a coarser resolution) than 1st order spatial schemes, especially where the flows are highly complex and exhibit strong 2D behaviour. However, 2nd order schemes are computationally more intense and take longer to solve with everything else being the same.
- For the primary flowpaths in the Detailed Model where it was considered that the 30m grid resolution was too coarse (eg. Lockyer Creek), the in-bank waterway has been represented using 1D cross-sections and 1D structures extracted from the Fast Model as discussed in Section 3.13.1.
- Model simulation times need to be realistic and practical to meet the Hydraulic Assessment timeframe and for the use of the model for the BRCFMS. Preferably, a single flood event takes less than one to two days to simulate. Of note is that halving the 2D cell size increases the simulation time by a factor of 8 (4 times as many cells and half the computational timestep), therefore, reducing the 2D cell size is not a trivial matter in terms of run times. The 30m resolution, using the latest CPU water-cooled chip technology, at a run time of 1 to 2 days per event is considered to be workable for the large number of simulations required for the following

design flood events where around a total of 50 separate Monte Carlo events are expected to make up the AEP design flood ensembles. Longer run times than 1 to 2 days would have a substantial impact on the delivery timeframe of the following design phase, and also on the timeframe for the BRCFMS.

- To calibrate the Detailed Model using a finer resolution than 30m within the timeframe of the Hydraulic Assessment would most likely result in a poorer calibration due to the lower turnover of model simulations. To use a finer resolution and achieve an equivalent calibration would require a substantial extension to the Hydraulic Assessment timeframe.
- The initial approach adopted was to represent the 2D areas having different 2D cell sizes. The different 2D cell size regions were to be linked using TUFLOW's 2D-2D linking interface feature that inserts hidden 1D nodes along the 2D-2D interface to transfer the water from one 2D region to another. The primary driver for this approach was to reduce simulation run times by using a coarser cell size in non-urban areas (eg. 60 to 100m cells was intended for the Lockyer Creek floodplain), so that run times for a single event were less than 24 hours. This approach was trialled at the start of the Detailed Model development, but was abandoned after some weeks of testing for the following reasons:
  - The 2D-2D link in areas of high velocities and varying flow behaviour did not perform well in terms of consistently producing representative flow patterns and water surface levels. Whilst the 2D-2D link has been successfully applied on many studies, the much higher velocities and deep water in the Brisbane River caused the 2D-2D link to be computationally “unstable” at times, and also unrepresentative of the complex flow patterns in the vicinity of the link in many instances. 2D-2D links tend to work well where the flow is relatively uniform or benign.
  - Improvements could be made to the 2D-2D link performance through decreasing the computational timesteps, however, this meant substantially longer run times, defeating the purpose of using the varying 2D cell sizes.
  - As a consequence, 20 and 30m grid resolutions were tested as a single 2D region for the entire model domain using specially purchased high end PCs with the fastest CPU clock speeds available. It became apparent that a 30m grid over the entire model area would produce better results, with faster run times, than a 2D-2D linked model using a range of 2D cell sizes varying from 100m in rural areas to 25m in urban areas.
- Also of consideration is that any benefits of a finer grid of, say 20m, versus a 30m grid would be insignificant compared with the uncertainties associated with other aspects of the modelling process. The uncertainties associated with the hydrologic modelling inflows in the Lockyer and Bremer catchments, and the inaccuracies of the in-bank ground elevations from the LiDAR data are of much greater significance than any differences between a 20 and 30m 2D grid resolution.
- The 30m grid model is capable of testing options for the floodplain management phase, and producing the mapping required for floodplain risk management. Note that the Detailed Model is designed for investigating floodplain management measures that have a measureable or quantifiable impact on flood levels that potentially cause adverse effects on surrounding areas due to flooding from the Lockyer, Bremer and/or Brisbane systems. The 30m resolution is sufficiently fine to achieve this.

Finer Scale Flood Mapping

- Irrespective of whether a 20 or 30m grid resolution is used, either resolution could be used for flood mapping based on a finer resolution ground DEM to enhance the mapping resolution around the flood inundation extent and improve the depiction of fine scale topographic features. It is common practice to use the 3D peak flood level surface from a 2D hydraulic model projected on to a finer resolution surface of the ground terrain and bathymetry to produce higher resolution flood extent and depth mapping. Therefore, the 30m resolution of the Detailed Model could be projected on to finer resolution ground DEMs of 5m or less to produce higher resolution depth and extent mapping outputs should this be required.

Finer Scale Modelling

- Whilst the Detailed Model is of sufficient resolution to model the impacts of existing or future works that have a measureable effect on Brisbane River flood levels, there may be a need for works that are highly contentious or have substantial sub 30m topographic complexities to model these works using a finer 2D resolution. In these situations it is standard industry practice to extract the boundary conditions for flow and water level information from a model of the greater river system, such as the Detailed Model, to drive the finer resolution local model.

Relation with Local Creek Models

- The Detailed Model does not replace the flood assessments of local side creeks carried out by councils that enter the main tributaries of the Detailed Model. Flooding of local creeks is caused by localised intense, short duration events, and from backwater flooding from the Brisbane River. To model the localised flooding, finer resolution 1D/2D models would typically be required. Also of note, is that the hydrologic and hydraulic analyses for these studies would not require a Monte Carlo type approach; an industry standard critical duration methodology would be recommended.
- Importantly, the Detailed Model will be able to provide downstream boundary conditions for these local creek models, and where the Detailed Model produces higher flood levels (ie. where backwater flooding is higher than the local flooding), the peak envelope of the Detailed Model and the local model output should be used to set design flood levels and hazards.

3.1.4 Detailed Model Topography

The bathymetric and topographic data used to develop the Detailed Model are described in detail in Appendix A, with priorities assigned to particular datasets described in Section 2.3. These are essentially the same datasets (with the same priorities) used to develop the Fast Model. Due to the lack of historical topography, the same topography (and bathymetry) was used in the Detailed and Fast Models for all calibration and extreme events modelled, with the exception of those specific areas described in Section 2.3.

3.1.5 Hydraulic Structures

Hydraulic structures such as bridges, weirs and culverts are either represented in the Detailed Model as nested, special 1D channels or as appropriate form losses and blockages in the 2D domain. Where the watercourse itself is modelled as a 1D nested channel, any structures within that channel are also represented as 1D special channels. Details of structures were obtained from supplied and/or sourced drawings and existing models. The representation of each structure within the model was then checked back against the source data as part of an internal review process.

Structures were included if they had the potential to impact on flood behaviour along the main watercourses. This included all known structures crossing the main waterways and significant structures in backwater areas. Minor floodplain structures were included, such as culverts through railway embankments, where their omission would result in a constrained flood extent. Structures were removed from the model for calibration events that pre-dated the structure.

Structures are represented within the Detailed Model using one of, or a combination of, the following methods:

- **1D special channels used to model major structures, typically bridges, in the 1D channel network.** These bridges are represented by a height versus width table of the under-bridge waterway, automatically adjusted entrance and exit loss coefficients, bridge deck surcharge discharge coefficient, and a table of energy loss coefficients with height derived using AustRoads (1994)[9].
- **2D Layered flow constrictions used to model bridges within the fully 2D model domain.** 100% blockages are applied within the model to represent the bridge deck, with additional full/partial blockages to represent guard rails, etc. Energy losses are applied at different heights on a cell-by-cell basis to represent the effect of bridge piers, bridge deck, rails and other obstructions. The loss value used is based on that applied in the Fast Model, which was derived from AustRoads (1994)[9].
- **Nested 1D culvert elements connected to the 2D domain at either end.** This method is used for minor hydraulic features on the floodplain, such as culverts or embankment underpasses.

For all structures within the 1D domain, the losses associated with the contraction and expansion of flow (entrance and exit losses) are automatically adjusted according to the approach and departure velocities using industry standard equations (BMT WBM, 2010). This approach ensures that if a bridge causes little or no constriction that the contraction/expansion losses (excluding the losses associated with piers and the deck) are reduced to zero or close to zero, while for bridges with more substantial constrictions, usually associated with significant approach embankments) the losses will be larger.

Where a structure is located within the 2D domain, such as layered flow constrictions or nested culverts, any overtopping of that structure occurs within the 2D domain subject to any blockage factors applied. For structures located within the 1D domain, overtopping occurs over a specified weir channel representing the cross-section of the bridge deck. These weirs are often flowing in a submerged (downstream controlled) state, for which the submergence curve developed by Bradley (FHWA, 1978) was used.

[9] Austroads have updated their publication series such that Austroads (2009) Guide to Bridge Technology Part 4 is seen as a replacement for the previous Austroads (1994) Waterway Design. However, Austroads (1994) still remains the most recent source of detailed technical guidance on application of losses to bridge structures, which is required to model hydraulic structures in a 1D model.

Special mention is made of the Mt Crosby weir. The topography was adjusted in the model to raise the DEM to the deck level of the overbridge. A series of zero-length rectangular culverts were used to represent the openings under the roadway. When modelled flood levels exceed the deck level, water can weir across the structure in the 2D domain. The small low flow culverts under the weir are understood to be blocked and even if fully operational would have negligible influence on flows/levels during flood events. They have not been included in the model.

Hydraulic Structure Reference Sheets have been developed for each mainstream hydraulic structure. These are contained in Appendix E. The sheets provide details of each structure's geometry, document how they are represented in both the Fast and Detailed Models and report on flow, velocity and afflux for all calibration and extreme events. These have been checked against the longitudinal profiles for each calibration event to verify model outputs. Minor floodplain structures have not been included in the reference sheets.

Many hydraulic structures trap debris during a flood event. Debris can reduce hydraulic conveyance through and over the structure altering flow behaviour. Unless event specific evidence of significant debris build up was available, structures were assumed to be unblocked for the calibration events. It is important to note that the approach to blockage of hydraulic structures adopted for the calibration events may differ from that to be adopted during the design events. The methodology for assigning blockage factors to hydraulic structures for design events will be decided in advance of the design flood simulations in the Detailed Model.

3.1.6 Model Boundaries

The Detailed Model boundaries consist of major river and creek inflows around the model's upstream periphery, localised internal inflows for URBS sub-catchments that fall within the model's extent and a tidal water level boundary at the mouth of the Brisbane River. A very minor baseflow input is applied to the Brisbane River to aid with the initialisation of model runs. This baseflow is applied to a steep part of the river, upstream of the confluence with Black Snake Creek. It peaks at $20m^3/s$ and has negligible effect on the flood hydrograph.

On the Brisbane River the model starts immediately downstream of Wivenhoe Dam. For Lockyer Creek, the upstream limit of the 2D modelled floodplain is immediately upstream of Glenore Grove although the dynamically linked 1D section of the model extends for a further 14km upstream to Gatton. This is to ensure that any breakouts from the main creek between Gatton and Glenore Grove are accounted for in the model at the application of the 2D floodplain model boundary. For the Bremer the upstream limit of the model is immediately downstream of Five Mile Bridge near Walloon. Warrill Creek has its modelled upstream limit approximately 4km upstream of Amberley (Greens Road) gauge and the upstream limit for Purga Creek is 1km upstream of the Loamside Alert gauge. For the Bremer River and its tributaries it was noted that the extreme event of 8x1974 showed backwater events extending close to the upstream limit of the model boundary. To prevent any containing effects from the model boundary during extreme events, additional nodal storage is provided to represent the upstream storage available in the floodplain.

Model extents as specified in the project brief and those in the model are summarised in Table 3-1.

Table 3-1 Detailed Model Extents

Watercourse	Minimum Upstream Limit (Specified in ITO)	Upstream Limit in Detailed Model (Distance Upstream from Minimum Extent)
Brisbane River	Wivenhoe Dam	Wivenhoe Dam (0km)
Bremer River	Five Mile Bridge	Five Mile Bridge (0km)
Purga Creek	Loamside Gauge	Loamside Gauge (1km)
Warrill Creek	Amberley (Greens Road) Gauge	Amberley (Greens Road) Gauge (4km)
Lockyer Creek	Lyons Bridge Gauge	Glenore Grove (26km)
Oxley Creek	Beatty Road Gauge	Beatty Road Gauge (3km)
Blunder Creek	King Avenue Gauge	King Avenue Gauge (0.5km)

Table C-5 lists the main periphery inflows and the peak flow values for each historical event based on the URBS models provided by the Hydrology Assessment (Aurecon *et al*, 2015a). As discussed in Section 2.1.1, changes to the Aurecon URBS model IL/CL values were made to improve the Detailed Model verification to the 1974 event. Drawing 7 shows the Detailed Model layout including locations of inflow boundaries.

For all calibration/verification events post Wivenhoe Dam (i.e. 1996, 1999, 2011 and 2013) the flow estimates over the Wivenhoe Dam spillway are used as the inflow to the Detailed Model (i.e. URBS modelling upstream of Wivenhoe Dam is not used). For the 1974 event Wivenhoe Dam was not in existence and the model inflows are based on the URBS generated hydrograph at the Wivenhoe Dam site.

The hydrographs for all the inflows were generated by re-configuring URBS model hydrograph output locations and re-running the URBS models for each event. This was required as the output locations in the provided URBS models did not include any local hydrograph outputs, or outputs at the Detailed and Fast Model's periphery inflow locations. Cross-checks were carried out on the re-configured URBS model by comparing total volume and outflow hydrographs at the Brisbane River mouth with the supplied model, as detailed in BMT WBM (2015a). This ensured that the reconfiguration of the URBS model did not change the URBS model's hydrologic calculations. Additional volume checks were undertaken comparing the Fast Model with the Detailed Model and these results are detailed in Section 3.1.8.

For each calibration event, the recorded water level hydrograph at the Brisbane Bar was applied in the Detailed and Fast Model as the downstream boundary.

The Bremer, Warrill and Purga URBS models included a base flow component. These base flows were applied to the hydraulic models as additional flows. The Lockyer and Lower URBS models have no base flow hydrographs. Seqwater advised (verbal comm, Nov 2014) that Lockyer Creek exhibits a strong, but highly indeterminate and therefore difficult to estimate, base flow component. Consequently a satisfactory match in Lockyer Creek before the flood and on the flood recession would be difficult to achieve.

3.1.7 Solution Scheme

TUFLOW's CPU solver, often now referred to as TUFLOW "Classic", is an implicit 2nd order spatial finite difference solution of the full 2D hydrodynamic equations and an explicit 2nd order solution of the full 1D equations. The solvers include the handling of upstream controlled flow regimes such as weir and supercritical flows. The TUFLOW CPU solver has been used extensively across the world for a wide range of applications for over 25 years. During the last 15 years, numerous enhancements have been made to fine-tune the performance of both 1D and 2D solutions, especially for modelling the more complex flows associated with flooding.

The TUFLOW 1D solver was utilised to solve the 1D equations of free-surface fluid flow often referred to as the St Venant equations. The full momentum equation (ie. includes inertia) is applied at the channels and the mass balance equation at the nodes. Open channels can also automatically switch in and out of upstream controlled super-critical flow should this flow regime occur. For special channels such as bridges, weirs and culverts, the momentum equation is replaced by appropriate equations representing the flow through the structure. These equations cater for a range of upstream and downstream controlled flow regimes that can occur in the structure.

For 2D domains, the full 2D hydrodynamic free-surface flow equations are solved using TUFLOW's CPU based implicit, unconditional, 2nd order spatial solver. The full 2D equations are significantly more accurate than the 1D equations in areas of complex flows characterised by high water speeds and sudden changes in flow direction such as around a river bend. More complex flow phenomena such as: superelevation (the surcharging of waters on the outside of a sharp bend); energy dissipation at major confluences; and the complex interactions of in-bank and overbank flowpaths, are significantly better represented than with a solely 1D approach. These conditions are particularly prevalent on the Brisbane River due to its large number of sharp bends, high velocities and major overland flowpaths.

Most 2D hydraulic models incorporate an eddy visocity term to characterise energy losses caused by turbulence effects at a sub-grid scale (Barton, 2001). The eddy viscosity term can be expressed as a constant parameter or as a function of local flow properties (and will therefore vary at different locations within the model domain). By default, TUFLOW uses the Smagorinsky turbulence formulation which, is currently the most complex eddy viscosity formulation used in flood modelling applications (Babister and Barton, 2011). It dynamically determines the eddy viscosity value for each grid element based on the element size and velocity gradient. The default Smagorinsky formulation has been used in this study along with the default Smagorinksy Coefficient factor of 0.5 and the default Constant Coefficient of 0.05 (BMT WBM, 2015a). While it is possible to change the coefficients, it is not considered appropriate to alter these values to achieve calibration or model stability.

For more details on the solution scheme refer to the TUFLOW software documentation (BMT WBM, 2015).

3.1.8 Quality Control Checks

During the course of the modelling, a number of quality control checks were undertaken:

- **Mass conservation within the hydraulic solution**. A table of the peak and final cumulative mass error for key TUFLOW model simulations is presented below in Table 3-2. For the calibration events and the extreme flood event (8 times the 1974 flows) the peak mass balance in the model did not exceed +/-0.5%. While there are no industry standards, mass error should ideally be less than 1% and is a measure of whether the computational solution is converging.

Table 3-2 Summary of Detailed Model Mass Conservation

Simulation	Peak Cumulative Mass Error (%)	Final Cumulative Mass Error (%)
1974 Verification	-0.41	-0.37
1996 Verification	-0.30	-0.30
1999 Verification	-0.17	-0.14
2011 Calibration	-0.40	-0.33
2013 Calibration	-0.37	-0.33
1974 x 8 Extreme	-0.29	-0.26

Volume checks were previously undertaken on the Fast Model (see report MR2 for details) and confirmed that all flow within the URBS model was being accounted for in the Fast Model. A further comparison has been made between the Fast Model and the Detailed Model. The comparison shows that the inflow volumes entering the Fast Model and Detailed Model are essentially identical allowing for numerical precision as shown in Table 3-3. Note that results cannot be compared directly back to values reported in MR2 due to shorter Detail Model simulation times.

Table 3-3 Summary of Detailed Model Volumes

Run ID	Event	Fast Model Inflows (GL)	Detailed Model Inflows (GL)	Percentage Difference (from FM)
37	1974	3861	3860	-0.03%
37	1996	1707	1712	0.27%
37	1999	1081	1089	0.72%
37	2011[a]	3774	3772	-0.06%
37	2013[b]	1451	1451	0.04%

a) Detailed Model simulation of the 2011 event begins at 17:00 on 5/1/2011 and ends at 0:00 on 17/1/2011.

b) Detailed Model simulation of the 2013 event begins at 21:00 on 25/1/2013 and ends at 0:00 on 2/2/2013

- **Structure head losses** were consistent with hand calculations and desktop checks using industry standard publications. Head loss across structures was also visually assessed on the longitudinal profiles and compared to the head loss values contained in the Hydraulic Structure Reference Sheets (Appendix E).

- **Changes to the model were consistent with expectations**. For example, as part of the sensitivity test ST02, in which the Manning's values are increased throughout the model, we would expect that this change in the model would increase predicted flood levels. For this example, the change to the model creates results that are consistent with expectations. Should the change (whatever the change may be) not be inconsistent with expectations, further investigation is required to identify potential problems or errors.
- **Model file naming, version control and data management protocols** are critical to quality control. These protocols were adhered to as part of the modelling process.

3.2 Detailed Model Construction and Calibration / Verification Approach

The primary purpose of the Detailed Model is to simulate the selected Monte Carlo design events and predict flood behaviour for these events. Flood behaviour includes peak flood levels, depths, velocities and flood hazards. As the Detailed Model is a 2D model, calibration is undertaken not only to river gauge levels, flow recordings and flood marks in the main watercourses, but also to flood marks on the floodplains.

The Detailed Model was calibrated and verified in a similar manner to the Fast Model, using a staged approach as follows:

- Undertake a tidal calibration using the tidal signals in the lead up to the 2013 flood event.
- Consider the learnings from the Fast Model calibration (BMT WBM, 2015), particularly in relation to: a) targeted and general form losses, b) Bremer River 1974 verification, c) Bremer River behaviour and losses at the confluence. Add targeted form losses to the model as a factor of those form losses used in the Fast Model calibration.
- Calibrate to the minor flood of 2013.
- Verify the model against the minor floods of 1996 and 1999.
- Calibrate to the major flood of 2011.
- Verify against the major flood of 1974.
- Proof the model against a range of extreme synthetic flood events to ensure the model schematisation is capable of effectively and realistically modelling such events. The extreme events used to undertake this proofing are: 5x1974, 8x1974 and 1.5x1974 (the latter provides a peak flow of around 16,200m^3/s at Brisbane City, which is believed to be a similar peak flow to that estimated for one of the flood events of 1893).
- Compare the Detailed Model results with the Hydrologic Assessment's (Aurecon *et al*, 2015c) derived rating curves as a cross-check.

3.3 Detailed Model Calibration Parameters

The primary hydraulic parameters available to calibrate the Detailed Model are Manning's n flow resistance values, and form losses (loss of kinetic energy which can also be referred to as an energy or bend or form loss). Where the flow is redirected by rock bends or ledges, or where major river/creek junctions occur, a more appropriate form of representing the losses can be to apply a form or energy loss, which is a proportion of the kinetic energy ($v^2/2g$) available.

It is good practice to apply form losses in 1D domains as the 1D St Venant equations are unable to account for energy losses associated with flow contracting and expanding (eg. at a structure), or being forced to rapidly change direction (eg. at a sharp bend).

The full 2D equations, however, inherently model energy losses associated with flow being forced to change direction and magnitude. The amount of energy loss modelled is dependent upon several factors, including: model resolution; spatial order of the solution scheme; and presence of any three-dimensional flow behaviour (eg. surcharging against a bridge deck or helicoidal flows around a sharp river bend). As such, some additional form losses may be required, particularly at locations where strong three-dimensional effects are likely or the obstructions are of similar or smaller size than the 2D elements (eg. a bridge pier). In all cases, the additional form loss required should be less than that required for a 1D representation.

As explained in Section 3.1.7, the TUFLOW default eddy viscosity formulation and related coefficients are not considered appropriate parameters to change for the purpose of achieving calibration or improving model stability,

Hydrologic parameters that can be varied during a traditional joint hydrologic and hydraulic model calibration exercise include the initial and continuing loss rates and the alpha and beta values of the URBS models. While a true joint calibration of the hydrologic and hydraulic models was not part of the scope for the Detailed Model development and calibration, based on sensitivity assessments undertaken during verification of the Fast Model to the 1974 event (BMT WBM, 2015), IL/CL values in the URBS model for the 1974 event in the Bremer catchment were adjusted as discussed in Section 2.1.1. No other URBS parameters were adjusted for the 1974 event or any of the remaining calibration and verification events.

3.4 Presentation of Calibration and Verification Plots and Table

The Detailed Model’s performance against the five calibration and verification floods is presented in a number of ways:

- **A series of plots** in the accompanying Plot Addendum. The plots consist of comparisons with the water level gauges, flow recordings off Centenary Bridge for the 1974, 2011 and 2013 events, and longitudinal profiles compared with flood marks within 100m and 500m of the river/creek centreline for the 1974, 2011 and 2013 floods.
- **A series of drawings** in the accompanying Drawing Addendum. The drawings show comparisons between the observed and modelled peak flood levels at both gauges and flood marks for the larger events of 1974, 2011 and 2013.
- **Tabulated** comparison of observed and modelled peak flood levels at the gauges for each event (Table 3-4).

3.4.1 Plots

The plots are designed so that when viewing them in digital format they can be readily zoomed into so that a much closer inspection of the plots can be observed without losing image clarity.

The water level gauge plots are grouped by the three main waterways of Lockyer Creek, Bremer River and the Brisbane River downstream of Wivenhoe Dam. Where possible/practical the plots' water level axis scale and range have been kept similar to other nearby gauges to allow ease of comparison between the gauges. All plots contain results from both the Fast and Detailed Models.

Water level gauges that experienced a known or reported problem, or can be demonstrated to have a datum, scaling or quality control issue are shown in a light (cyan) blue instead of dark blue (see Appendix D and Appendix A). If no water level gauge existed or the gauge failed completely, the model results are still shown so as to provide a comparison with the other floods and maintain consistency.

Modelled longitudinal profiles of all calibration events are shown together in Plot 26 (Brisbane River) and Plot 27 (Lockyer Creek and Bremer River). These plots provide an indication as to the relative magnitude of each calibration event in throughout modelled sections of Lockyer Creek, Bremer River and the Brisbane River.

Some of the gauges in the upper sections of the model also include a plot of the largest URBS, Wivenhoe Dam or upstream modelled flow hydrograph so that the timing and magnitude of the flood wave entering that section of the model can be appreciated. This is of particular relevance in understanding the influence of Wivenhoe Dam discharges.

3.4.2 Drawings

Detailed Model calibration performance across the assessment area is provided in Drawing 10 to Drawing 26. These drawings are divided into events and then further divided into regions, where appropriate, with one A3 page per region. A key sheet identifying the regions is provided Drawing 9.

Only events for which there are flood marks (1974, 2011 and 2013) have been divided into regions. As the remaining events contain few comparisons between observed and modelled peak levels, the assessment area can be viewed as a whole on one A3 sheet.

At every flood mark and gauge level, comparisons are undertaken between the observed and modelled peak flood level. The comparisons are colour coded for ease of interpretation with the ranges selected relating directly to the recommended tolerances from the Brief: ±0.15m, ±0.3m and ±0.5m. Colours for each of these difference ranges are provided in the drawing legends.

Historical flood extents were provided by Councils and/or sourced from QGIS for the 1974 and 2011 flood events. This flood extent data is described and displayed in BMT WBM (2014) and in Drawing 4 to Drawing 6, with spatial mapping indicating the source of each flood extent (e.g. Ipswich City Council etc). Where available, these flood extents are also mapped in the 2011 and 1974 calibration drawings of the current report; Drawing 17 to Drawing 21 and Drawing 22 to Drawing 26 respectively. These drawings are focussed on calibration performance and as such do not provide an indication as to the source of the flood extent data, noted simply in the legend as "various sources". Should the source of the flood extents be of interest, the reader is referred to Drawing 4 to Drawing 6 (and BMT WBM, 2014).

The historical flood extents provided for the 1974 and 2011 events (and presented in this report) include flooding from major rivers/tributaries (Brisbane River, Bremer River, Lockyer Creek) and flooding from smaller, local catchments/tributaries. The portion of the flood extent that is due to local flooding is distinguished from major river flooding and is labelled as "Extent Due to Local Flooding" in Drawing 17 to Drawing 21 and Drawing 22 to Drawing 26.

3.4.3 Table

A comparison of observed and modelled peak gauge levels is also provided in Table 3-4. This is placed in Section 3.11 to follow the calibration discussion. The table also contains reference to the recommended tolerances contained in the brief, which vary from region to region.

3.5 Tidal Calibration

The tidal period prior to the 2013 flood arriving was used to carry out an initial calibration of the in-bank tidal waters Manning's n value. An n value of around 0.020 to 0.025 was found to produce the best reproduction of tidal wave propagation in the Brisbane River, with a final value of 0.022 being adopted. This value is highly consistent with the many other tidal calibrations carried out using 1D and 2D schemes and is within the acceptable range for tidal reaches (0.02 to 0.04) provided in Australian Rainfall and Runoff (Babister & Barton, 2012).

3.6 2013 Tide / Minor Flood Calibration

The minor flood of 2013 largely remained in-bank, except for areas of the Lockyer Valley and the upper Bremer River catchment, which both experienced overbank flooding. The flow from Wivenhoe Dam was reduced to zero to coincide with peak flows out of Lockyer Creek and Bremer River, thereby having a major effect on reducing the flows reaching Brisbane.

Plot 1, Plot 2 and Plot 3 show the Detailed and Fast Models' calibration for the Lockyer Creek, Bremer River and Brisbane River gauges respectively. In Lockyer Creek it can be seen that the Detailed Model produces similar results to the Fast Model but replicates the peak level to a greater degree. In the lower reaches of Lockyer Creek, after the peak of the flood, the response is dominated by releases from Wivenhoe Dam. Here, the Detailed Model appears to overstate flood levels, whereas the Fast Model understated them. This is evident at the Wivenhoe Dam Tailwater and Lowood Alert gauges.

The time series plots for the Bremer (Plot 2) again show agreement between the Detailed and Fast Models. The peak flood levels at the gauges are generally captured in both magnitude and timing by the Detailed Model, particularly at Ipswich where the Fast Model slightly underpredicted the peak level. The recession limb of the hydrograph overpredicts flood levels at Moggill which, in turn, has a knock on effect on the Bremer River. This period coincides with releases from Wivenhoe Dam.

Time series plots for the Brisbane River are shown in Plot 3. The 2013 event was relatively small on the lower Brisbane River with a defined flood peak barely noticeable at the City Gauge. Nonetheless the Detailed Model provides a satisfactory match to recorded flood levels at the City

Gauge. The model tracks slightly higher than recorded levels during the post peak Wivenhoe Dam release but overall the estimated peak level is satisfactory.

Plot 4 presents the water level and flow data recordings taken off Centenary Bridge. It can be seen that there is a difference between the Fast and Detailed Models with the latter predicting lower flows at levels on the rise to the peak flood level. This discrepancy is attributed to a greater proportion of flood water being captured on the floodplain in the Detailed Model compared to the Fast Model. This is discussed further in Section 4.9. Plot 5 and Plot 6 show the longitudinal comparison of the calculated peak water levels with recorded flood marks within 100 and 500m of the creek/river centreline. For the 2013 event, aside from the gauges, recorded flood marks were only available on the lower sections of the Brisbane River. For the Lockyer Creek, Bremer River and Mid Brisbane River the long sections show agreement with gauge levels. On the Lower Brisbane River the model predicts peak levels marginally lower than recorded flood levels between Moggill and the confluence with Oxley Creek. Downstream of Oxley a satisfactory match is achieved.

Drawing 10 to Drawing 14 show the spatial performance of the Detailed Model in relation to the observed flood marks in the BCC and LVRC areas, peak gauge levels through the model area and observed flood extent in the Lockyer Valley. A key sheet for these drawings is available as Drawing 9.

The drawings corroborate with previous observations on peak levels from the plots, principally:

- An satisfactory match to peak flood levels on the lower Brisbane River (downstream of Oxley Creek) with many levels within 0.1m and within 0.05m near the CBD.
- Minor under predictions of peak flood levels between Moggill and Oxley Creek with the model typically 0.15m to 0.4m too low.
- A satisfactory match for the flood extent within the SRC region, given the general limitations of such mapping.
- A satisfactory match for in-bank areas of Lockyer Creek with the LVRC region. Floodplain observed peak flood levels also correspond with those modelled. However, steep out of bank gradients mean that the observed (and modelled) flood levels are highly sensitive to small changes in positioning. This is discussed further in Section 4.2.

Table 3-4 provides observed peak levels at gauges within the model area and compares these to peak flood levels predicted by the Detailed Model. Differences between the observed and modelled peak flood levels are coloured green if the variation is within the desired tolerance.

Figure 3-1 contains a statistical assessment of the range of differences between observed and modelled peak flood levels, including all flood marks and peak gauge levels. The colours were chosen to be consistent with those adopted for the difference between modelled and recorded flood marks in the drawings. It can be seen that on average the 2013 peak modelled levels are within -0.01m of the average of the recorded levels.

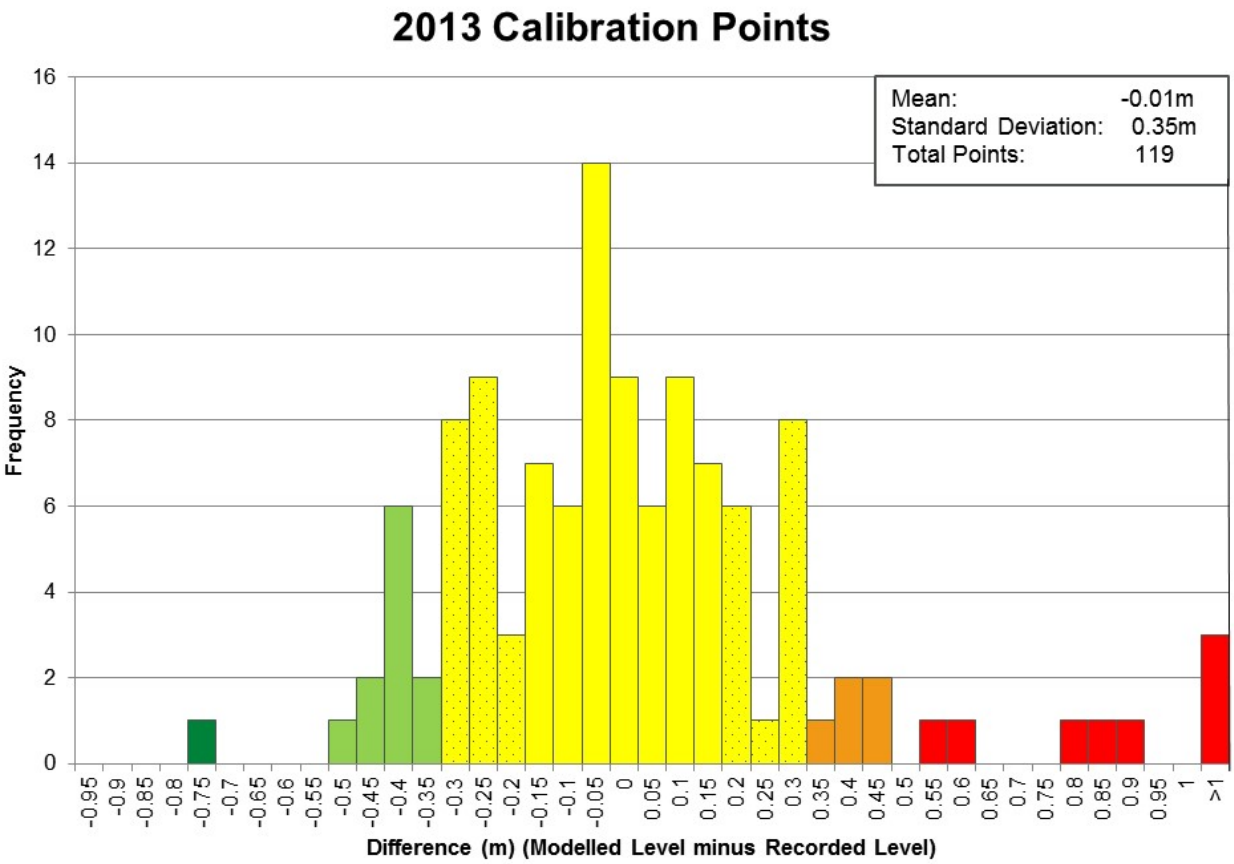


Figure 3-1 2013 Detailed Model Calibration - Statistical Assessment of Differences between Observed & Modelled Peak Flood Levels

3.7 1996 Minor Flood Verification

The minor flood of 1996 was used as a verification of the 2013 minor flood calibration. The 1996 flood largely remained in-bank, with some overtopping onto the Lockyer Creek floodplains. Some localised flooding was observed in some of the minor creeks such as Oxley and Bulimba Creek but there was no notable inundation from the Brisbane River itself. This was due in large part to Wivenhoe Dam retaining all inflows from the Brisbane and Stanley River catchments upstream, so the only catchments that contributed to inflows downstream of Wivenhoe Dam were those of Lockyer Creek and the Bremer River. Of interest are the two peaks that entered the Lockyer system merge to become one peak prior to entering the Brisbane River.

Plot 7, Plot 8 and Plot 9 show the Detailed and Fast Models' 1996 results for the Lockyer Creek, Bremer River and Brisbane River gauges respectively. The plots show the two Lockyer flood peaks, most notably at Glenore Grove, merging into one peak prior to reaching the Brisbane River. The high URBS Initial Loss value of 180 mm for Lockyer Creek is delaying water entering the Detailed Model. This is most apparent on the Lockyer and Warrill Creeks. To better time the rising limb, a lower IL would be required.

In general there is agreement on the timing and magnitude of the modelled peaks with observed data where it exists. Peak levels are slightly over predicted at Moggill. This in turn is impacting on backwater flood elevations along the Bremer River.

The most notable difference between modelled and observed peak levels is at Ipswich where the modelled peak level of around 14mAHD is significantly above the observed level (around 11mAHD). Interestingly, the peak modelled 2013 flood level at Ipswich was also around 14mAHD but for that event the model matches with the observed levels. This comparison suggests that other factors may be contributing to the difference observed for the 1996 event. We believe that the differences between modelled and recorded levels at Ipswich are primarily due to the following factors:

- **Flows:** Seqwater has advised[10] that the 1996 URBS model peak flows at Ipswich varied considerably between the Aurecon (Aurecon et al, 2015a) value of 1850m^3/s (used in the model) and the Seqwater (Seqwater, 2013b) value of 1460m^3/s; a difference of 27%. Should the flows used in the Detailed Model have been of a lesser value (perhaps closer to the Seqwater value), peak modelled flood levels are likely to have been lower and thus closer to the observed peak flood levels at Ipswich.
- **Bathymetry:** Quentin Underwood from LVRC has advised[11] that dredging of the Bremer was occurring around the town bridge before 1996. Quentin has indicated that since 1996, dredging has ceased and bank collapses have occurred and, as such, he believes that the Bremer River in this region has become significantly shallower in that time. If this is the case then the current bathymetry included in the Detailed Model (surveyed in 2014) will result in the Model underestimating conveyance in this region for the 1996 (and 1999) events. As these events are minor flood events, in-bank conveyance is particularly influential on flood behaviour and the underestimation of conveyance will lead to an overestimation of flood levels, which is indeed occurring at the Ipswich gauge for both 1996 and 1999. However, the current bathymetry better represents the 2013 conveyance and hence modelled flood levels are better matched to observed levels for 2013.

In summary, we believe that the overestimation of levels at Ipswich for the 1996 event is primarily due to a combination of the hydrology flow estimates, and historical changes to Bremer River bathymetry.

Drawing 15 presents modelled flood depth mapping for the 1996 verification. Whilst flood marks were not available for this relatively small event, the drawing is useful in showing the extent of predicted by the Detailed Model, in particular within the Lockyer Creek catchment.

Again, Table 3-4 provides observed peak levels at gauges within the model area and compares these to peak flood levels predicted by the Detailed Model. Differences between the observed and modelled peak flood levels are coloured green if the variation is within tolerance.

3.8 1999 Minor Flood Verification

The minor flood of 1999 was used as a second verification of the 2013 minor flood calibration.

[10] Comments received on Milestone Report 3 (this report) on 19 June 2015.
[11] At Workshop 3 (as part of this study) held on 14 May 2015, Quentin is a member of the Technical Working Group.

Plot 10, Plot 11 and Plot 12 show the Detailed and Fast Models' 1999 verification for the Lockyer Creek, Bremer River and Brisbane River gauges respectively.

It can be seen that there is an under prediction of flood levels in Lockyer Creek upstream of O'Reilly's Weir. In the lower reaches the peak levels match with observed levels due to the peak from Wivenhoe Dam showing a satisfactory agreement on levels.

The trend is one of over prediction of peak flood levels in the Bremer including at Ipswich. As described in Section 3.7, the overestimation of peak flood levels in the Bremer is believed to be most likely related to historical changes in bathymetry. This belief is based on advice from Quentin Underwood[11] that the Bremer River around Ipswich has become significantly shallower since dredging ceased around 1996 and bank collapses occurred. As the bathymetry used in the model is based on 2014 survey data, it is likely that the model is underestimating in-bank conveyance for the 1999 and 1996 events, resulting in modelled peak flood levels being higher than observed. This is occurring for both 1996 and 1999 calibrations and it is our belief that bathymetry is a factor in this discrepancy. Without historical bathymetric survey information it is not possible to confirm this advice or subsequent assumptions.

There is agreement on both peak flood level magnitude and timing on the lower Brisbane River although the modelled peak level is noticeably higher at Moggill.

The plots show that the model marginally under-predicts the water level at Savages Crossing during the Wivenhoe Dam drain down phase peak steady-state release of around 1,750 m^3/s whereas the 2013 event, for the same post peak release flows of 1,750 m^3/s slightly over predicts the level at Savages Crossing. This would indicate that there are some differences in the river topography and/or bed resistance/bank vegetation between 1999 and 2013. This is discussed further in Section 4.6.

Drawing 16 presents modelled flood depth mapping for the 1999 verification. Whilst flood marks were not available for this event, the drawing is useful in showing the extent of predicted by the Detailed Model.

Again, Table 3-4 provides observed peak levels at gauges within the model area and compares these to peak flood levels predicted by the Detailed Model. Differences between the observed and modelled peak flood levels are coloured green if the variation is within tolerance.

3.9 2011 Major Flood Calibration

The major flood of 2011 caused extensive flooding throughout the floodplains of Lockyer Creek, Bremer River and Brisbane River. The releases from Wivenhoe Dam played an important role in the hydraulic behaviour of the flood. The flood storage compartment of Wivenhoe was used to help contain and delay the first flood wave upstream of Wivenhoe Dam. However, during the second flood wave into the dam, major releases from the dam were required, sending a short, sharp hydrograph downstream that combined with flood waves from the Lockyer and Bremer catchments.

Plot 13, Plot 14 and Plot 15 show the Detailed and Fast Models' 2011 calibration for the Lockyer Creek, Bremer River and Brisbane River gauges respectively.

It can be seen that both the timing and magnitude of the peak are reproduced by the model along Lockyer Creek. The rising limb of the hydrograph at O'Reilly's weir is also matched by the model before the gauge failure near the peak.

Peak observed flood levels on the Warrill, Purga and Bremer Rivers match with those from the model. There is a slight over prediction at the Amberley Gauge although a match is achieved a short distance upstream at the Greens Road Gauge and downstream at One Mile Bridge. Furthermore it appears as though there was some degree of gauge failure at Amberley. An satisfactory match to peak flood levels is achieved at the Ipswich Gauge.

On the Brisbane River satisfactory matches between observed and modelled levels can be seen. The following points are of note and are discussed further in Section 4.6:

- At the Savages Crossing Gauge the post peak, Wivenhoe release is shown to result in higher modelled flood levels at the gauge than for observed. However, at the Mt Crosby Gauge the post peak release modelled levels compare satisfactorily with observed levels.
- At the Moggill gauge, there is a notable 'attenuated' recession limb on the hydrograph. This in turn impacts on the Bremer River. Downstream at the Jindalee gauge, this extended tail is only marginally apparent and is not noticeable at the Brisbane City Gauge where a satisfactory match to the overall hydrograph shape is achieved.

Plot 16 presents the water level and flow data recordings taken off Centenary Bridge during the 2011 event. As can be seen, the levels and flows calculated by the Detailed and Fast Models agree with the range of levels and flows recorded during the peak of the flood and afterwards during the drain down phase (post flood) dam releases.

Plot 17 and Plot 18 show a comparison of the peak longitudinal flood profile for the Detailed and Fast Models with the water level gauge peaks and flood marks within 100m and 500 m of the river/creek centreline for the Brisbane and Bremer/Lockyer respectively. It can be seen that both the Fast and Detailed models agree with each other and observed flood marks on the Lockyer Creek and Bremer River. The Detailed Model shows higher peak flood levels in the lower Lockyer Creek (Wivenhoe backwater influence area). These higher levels are in agreement with surveyed flood levels. On the Brisbane River there are some notable differences in peak flood levels between the Fast and Detailed models between Wivenhoe and Savages Crossing with the Detailed Model showing higher levels. These higher levels correspond with nearby flood marks. Elsewhere on the Brisbane River both the Fast and Detailed models show a satisfactory match to flood marks with the Detailed Model slightly outperforming the Fast Model in this regard.

Drawing 17 to Drawing 21 show the spatial performance of the Detailed Model in relation to the observed flood marks across the model domain, peak gauge levels through the model area and observed flood extents. A key sheet for these drawings is available as Drawing 9.

Overall, there is satisfactory agreement with flood mark levels, most notably along the Bremer and Brisbane Rivers. Whilst there is scope for some variation in recorded levels due to survey accuracy and the nature of the observation, the large amount of levels available allow the following general trends to be drawn from the dataset:

- In the lower Lockyer, predicted flood levels within the floodplain tend to be lower than those recorded, typically by up to 0.4m lower although in many places levels are within 0.15m. This is discussed in Section 4.2.
- Within Fernvale, predicted flood levels, whilst within the tolerances set out for the study, are lower than recorded. Modelled flood levels match the recorded levels both upstream and downstream of Fernvale. Advice from SRC indicates that up to 15 flood marks in Fernvale are transposed from a single survey point. This is evident as the levels are not entirely consistent with the topography and each other. The properties affected are along Schmidt Road where the model is shown to under predict the flood levels to these properties by around 0.7m. SRC states that these surveyed levels could be out by 300mm. This is discussed further in Section 4.4.
- A satisfactory level of agreement between surveyed and modelled flood levels is achieved throughout much of the Bremer including through Ipswich CBD. Modelled levels are lower than observed in the Ipswich Golf Course area. This is discussed in Section 4.7.
- Within the inner Brisbane area there is again agreement between surveyed and modelled flood levels with the city gauge being within 0.01m.
- Overall the modelled flood extents correspond with the historical extent. In particular, much of the backwater flooding via stormwater pipes in Brisbane CBD has been captured by the model.

Figure 3-2 contains a statistical assessment of the range of differences between surveyed and modelled peak flood levels for over 500 flood marks and the peak gauge levels. The colours were chosen to be consistent with those adopted for flood marks. It can be seen that on average the 2011 peak modelled levels are within -0.07m of the average of the recorded levels. Around 27% of marks were matched by the model to within +/- 0.05m and 66% were within 0.15m. This is considered to be a high level of accuracy, particularly given the potential for error with survey marks and uncertainties in the modelling.

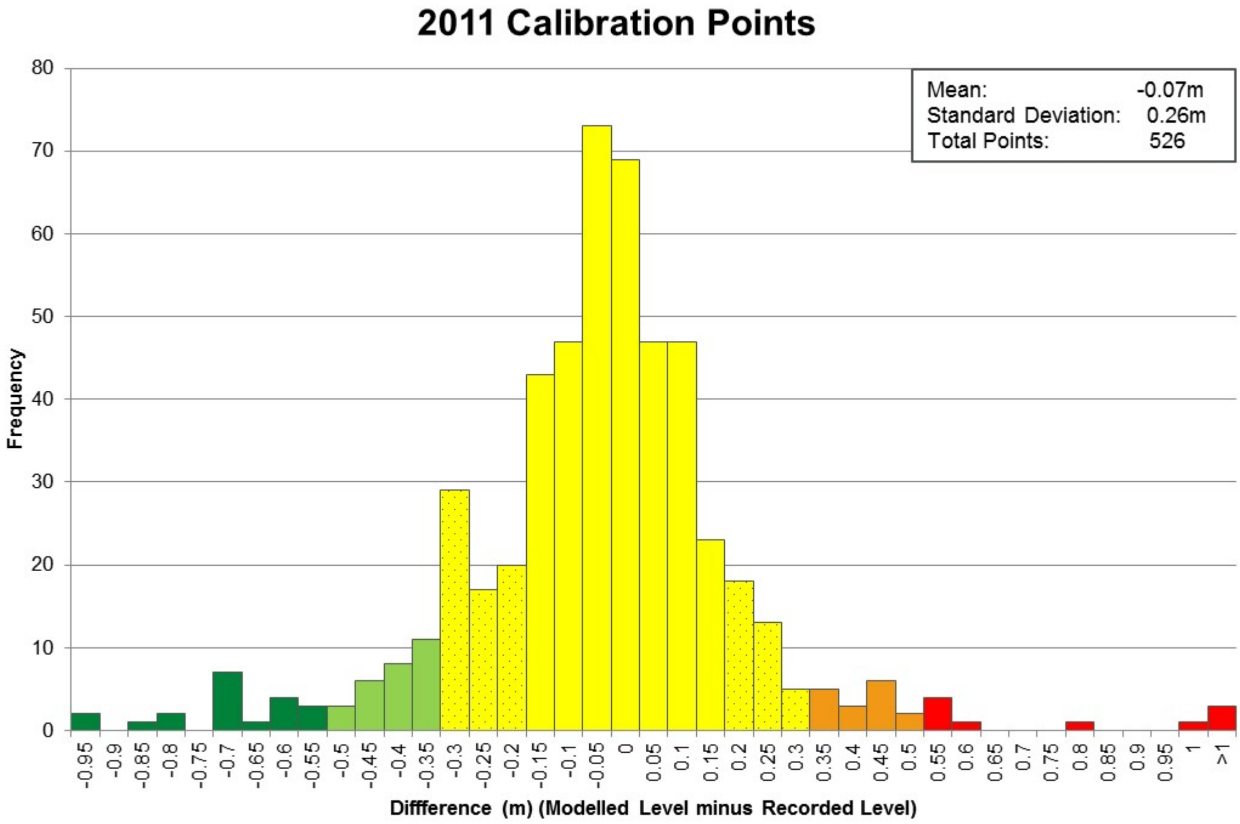


Figure 3-2 2011 Detailed Model Calibration - Statistical Assessment of Differences between Observed & Modelled Peak Flood Levels

Table 3-4 provides observed peak levels at gauges within the model area and compares these to peak flood levels predicted by the Detailed Model. Differences between the observed and modelled peak flood levels are coloured green if the variation is within tolerance.

Modelled peak flood levels in the Bremer are shown to be in agreement with both the 2011 recorded flood marks and the peak of the operational water level gauges. Modelled peak flood levels in the Lockyer are shown to provide a reasonable match to the peak level at the water level gauges. The Mid and Lower Brisbane profiles show satisfactory agreement between the modelled peak levels and the recorded peak levels at all operating water level gauges, with a maximum difference across all gauges (modelled minus recorded) of -0.09m. Satisfactory agreement is also noted between modelled and recorded flood marks for those marks within 100m of the Brisbane River centreline. Flood marks that are further out from the centreline show more scatter and are not always consistent with each other. However, in general, a reasonable agreement between these marks and the modelled peak levels is shown.

3.10 1974 Flood Verification

The major flood of 1974 is the largest flood recorded during the 1900s, but is smaller than the two floods of 1893. The 1974 flood caused extensive flooding throughout the floodplains of Lockyer Creek, Bremer River and Brisbane River producing flood levels typically 1 to 2 metres higher than the 2011 flood in Brisbane, although in the Wivenhoe Dam to Mt Crosby reaches the 2011 flood was higher than 1974.

Wivenhoe Dam was not in existence in 1974, therefore the inflows to the model at the Wivenhoe Dam site were based on the URBS generated hydrographs from the Upper Brisbane and Stanley River catchments. These flow estimates have higher uncertainty than the recorded discharges from Wivenhoe Dam for the other calibration/verification events.

Whilst it was not possible to capture all changes in the terrain between 1974 and present, the topography for the 1974 model was adjusted at the following locations:

- Removal of the raised Cunningham Highway embankment between Warrill and Purga Creeks.
- Removal of noise bunds, fill platforms and extraction holes for the sand and gravel quarry near Fernvale.
- Removal of structures as appropriate in Table C-2 in Appendix A.

These features were typically located in areas of high conveyance and so would have an influence on the model results if left in the model. It is recognised that there are other terrain features which may be present in the DEM but which were not present in 1974. The Ipswich Motorway (M7) is one such feature. As it is located in a predominantly backwater area and has breaks (gaps) in the topography where creeks pass underneath, its presence is not deemed to influence the 1974 verification.

Materials and their associated roughness values were left consistent with those used for more recent events.

As discussed in Section 2.1.1 and Appendix A, the previous 1974 verification of the Fast Model (BMT WBM, 2015) concluded that the best verification result would be achieved with IL/CL values in the Bremer River catchment being somewhere between those used by Aurecon *et al.* (2015a,c) and (Seqwater, 2013b). In the absence of the ability to undertake a joint hydrologic and hydraulic calibration, the IL/CL values in the Bremer catchment for the 1974 event for the current assessment were modelled as the *average* of Aurecon and Seqwater values, ie. halfway between the IL/CL Scenario 1 (Aurecon) and IL/CL Scenario 2 (Seqwater) as presented in Milestone Report 2 on the Fast Model Calibration.

Plot 19, Plot 20 and Plot 21 show the Detailed and Fast Models' 1974 verification for the Lockyer Creek, Bremer River and Brisbane River gauges respectively. Additional recordings at a number of other gauges are shown in Plot 22 (note that a few additional gauge recordings are not shown as these data could not be sourced digitally). Evidence of the uncertainty in the URBS generated hydrographs from the Upper Brisbane and Stanley River catchments is seen in Plot 21, with the URBS flow hydrograph peak shown to occur after the recorded peaks at Lowood[12] and Savages Crossing. In addition, stakeholders have previously expressed concerns that these URBS generated hydrographs produce flows that are too low during the receding (falling) limb of the flood wave. This was investigated in the 1974 verification of the Fast Model (BMT WBM, 2015), which

[12] The recorded peak flood level for 1974 at the Lowood gauge appears low relative to nearby debris marks. As discussed further in Appendix D, stakeholder feedback indicates that this gauge was subject to irregularities in 1974 and the gauge location was most likely different to its present day location.

concluded that flows produced by the URBS modelling upstream of Wivenhoe Dam may under-predict the flows during the receding flood limb. Evidence of this is also seen in the receding limb of hydrographs in Plot 21.

Plot 23 presents the water level and three flow data recordings taken off Centenary Bridge during the 1974 event. The technology used for the 1974 flow recordings is considered to be less accurate than that used for 2011 and 2013 (due to the more advanced ADCP technology used in 2011 and 2013). At present, only the day of the 1974 recordings has been able to be sourced, and on the assumption that the recordings were made during daylight hours, each flow and water level recording is shown as a line extending from 6am to 6pm.

Plot 24 and Plot 25 show a comparison of the Detailed and Fast Models' peak flood level profile with the water level gauge peaks and flood marks within 100m and 500 m of the river/creek centreline. Of note is the significantly larger number of flood marks collected after the 1974 flood compared with that collected from the 2011 flood, thereby giving a recorded profile that helps clearly identify changes in flood profile gradients due to sharp bends, meanders that are shortcut and rock ledges such as at Dutton Park.

Drawing 22 to Drawing 26 show the spatial performance of the Detailed Model in relation to the observed flood marks across the model domain, peak gauge levels through the model area and observed flood extents. A key sheet for these drawings is available as Drawing 9.

Figure 3-3 contains a statistical assessment of the range of differences between observed and modelled peak flood levels, including all flood marks and peak gauge levels and shows a satisfactory verification to nearly 2,000 flood marks and the peak gauge levels with a mean difference of 0.05m.

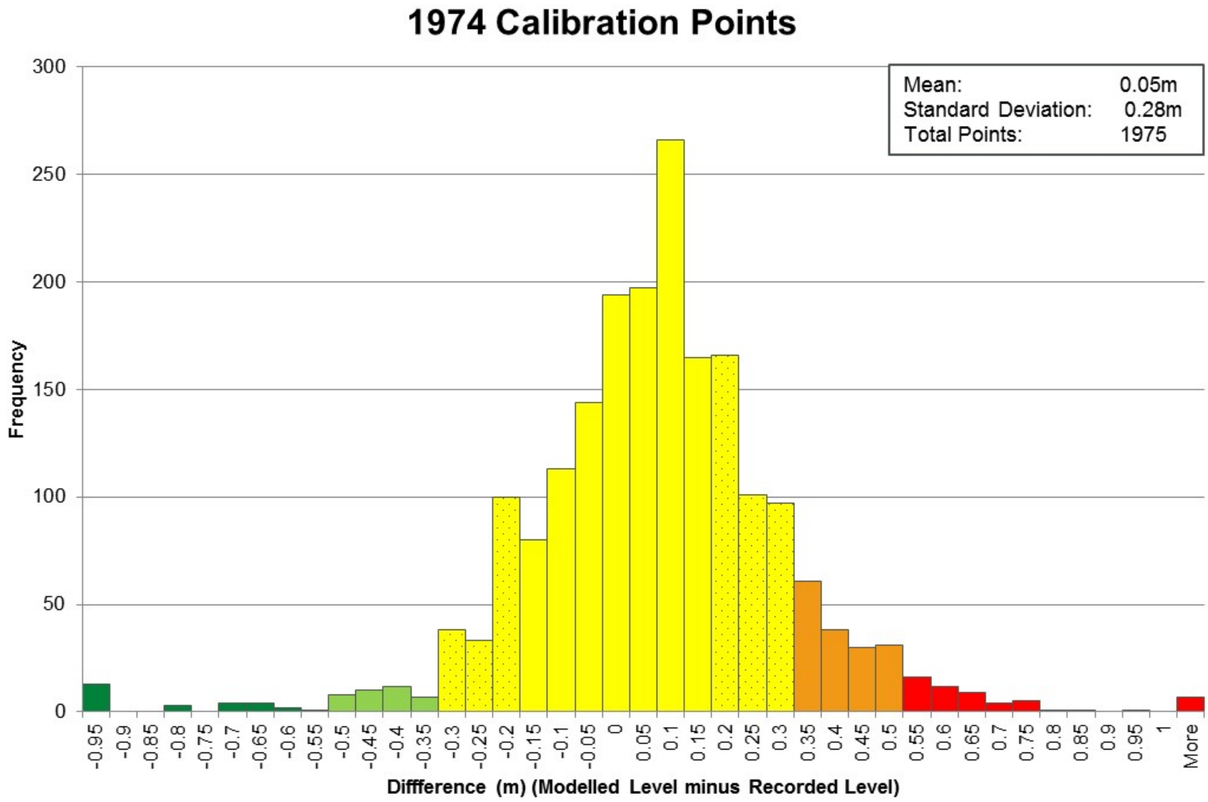


Figure 3-3 1974 Detailed Model Verification - Statistical Assessment of Differences between Observed & Modelled Peak Flood Levels

Table 3-4 provides observed peak levels at gauges within the model area and compares these to peak flood levels predicted by the Detailed Model. Differences between the observed and modelled peak flood levels are coloured green if the variation is within tolerance.

3.11 Calibration & Verification Peak Level Comparison

Table 3-4 summarises the peak recorded and modelled flood level for all calibration events at each gauge location. A legend for this table is shown below the table in the bottom left corner. Accuracy tolerances for each area are provided in the second column. These accuracy tolerances are extracted directly from the Brief (DSDIP, 2014) where they are provided as a guide for the desired accuracy of peak *design* flood levels. They are used here to provide an indication as to how the differences between peak recorded and modelled flood levels sit in relation to the accuracy tolerances.

A difference between peak and modelled flood level that is within tolerance is shaded in green, a difference that is outside tolerance is shaded in red. This summary of peak flood levels should be considered in conjunction with the presentation of recorded and modelled level hydrographs in the calibration plots (Plot 1 through Plot 25). Commentary on model performance relating to Table 3-4 is provided in the preceding sections of the report (Section 3.2 to Section 3.10) and in Section 4.

Note that the 1974 model results provided in this table are based on average IL/CL values in the Bremer River catchment as described in Section 2.1.1.

Plot 26 and Plot 27 provide longitudinal profiles for the Fast and Detailed Models for all calibration and verification events assessed. These plots provide an indication of the relative magnitude of these events in terms of peak levels through the model domain.

Table 3-4 Detailed Model Calibration and Verification Peak Level Comparison at Gauges

Location	Accuracy Tolerance	BoM Gauge No.	AWRC Gauge No.	Gauge Name	System	PO ID / Node ID	Domain	Recorded and Modelled Peak Water Surface Levels														
								1974*			1996			1999			2011			2013		
								Recorded	Modelled	Difference	Recorded	Modelled	Difference	Recorded	Modelled	Difference	Recorded	Modelled	Difference	Recorded	Modelled	Difference
Brisbane River D/S of Oxley Creek	±0.15m	540495	143891	Whyte Island Tide AL	Moreton Bay	1	2D	x	1.50	x	x	1.32	x	x	1.32	x	1.63	1.66	0.03	1.79	1.87	0.08
		540286	143877	Breakfast Creek Mouth Al	Lower Brisbane	5	2D	x	3.10	x	x	1.63	x	x	1.40	x	2.50	2.62	0.12	2.12	2.06	-0.06
		540198	143838	Port Office / City Gauge	Lower Brisbane	7	2D	5.45	5.60	0.15	2.10	1.93	-0.17	1.44	1.46	0.02	4.46	4.44	-0.02	2.32	2.23	-0.09
		-	-	Highgate Hill - Paradise St	Lower Brisbane	43	2D	8.36	8.79	0.43	x	2.60	x	x	1.62	x	x	7.31	x	x	2.62	x
		-	-	St Lucia Ferry	Lower Brisbane	46	2D	?	9.02	?	x	2.62	x	x	1.63	x	x	7.46	x	x	2.63	x
				Dutton Park Cemetery	Lower Brisbane	42	2D	9.57	9.32	-0.25	x	2.74	x	x	1.66	x	x	7.76	x	x	2.69	x
		-	-	Sandy Creek	Lower Brisbane	45	2D	?	9.96	?	x	2.88	x	x	1.69	x	x	8.32	x	x	2.77	x
				Yeronga St	Lower Brisbane	48	2D	10.83	10.79	-0.04	x	7.45	x	x	1.74	x	x	9.07	x	x	2.93	x
		-	-	Tennyson Powerhouse	Lower Brisbane	44	2D	10.81	10.85	0.04	x	3.12	x	x	2.00	x	x	9.15	x	x	2.98	x
				Tennyson	Lower Brisbane	49	2D	11.04	10.93	-0.11	x	35.41	x	x	7.45	x	x	9.18	x	x	7.45	x
Brisbane River D/S of Goodna, U/S of Oxley Creek	±0.30m	540274	143872	Oxley Ck Mouth AL	Lower Brisbane	9	2D	x	11.06	x	x	3.24	x	x	1.78	x	9.20	9.37	0.17	3.36	3.08	-0.28
				OxleyCkCorinda	Lower Brisbane	47	2D	11.00	11.06	0.06	x	4.64	x	x	2.45	x	x	9.40	x	x	4.38	x
		-	-	Clarence Rd	Lower Brisbane	41	2D	11.20	11.34	0.14	x	3.44	x	x	3.15	x	x	9.65	x	x	3.27	x
		41472	-	Centenary Bridge	Lower Brisbane	12	2D	14.10	14.03	-0.07	x	4.54	x	x	2.28	x	12.07	12.25	0.18	x	4.33	x
		540192	143832	Jindalee Alert	Lower Brisbane	11	2D	?	14.77	?	x	4.94	x	?	2.46	?	12.90	12.97	0.07	4.98	4.70	-0.28
Brisbane River U/S of Goodna	±0.50m	540200	143840	Moggill Alert	Lower Brisbane	14	2D	19.91	20.11	0.20	7.10	8.51	1.41	?	4.87	?	18.17	18.36	0.19	7.97	8.09	0.12
		540063	143868	Colleges Crossing Alert	Mid Brisbane	28	2D	x	24.74	x	x	12.35	x	x	10.02	x	?	23.58	?	?	11.35	?
		540199	143839	Mt Crosby AL	Mid Brisbane	29	2D	26.70	26.74	0.04	14.10	14.74	0.64	11.97	12.99	1.02	26.18	25.89	-0.29	13.41	13.78	0.37
		540256	143864	Kholo Bridge AL	Mid Brisbane	30	2D	x	46.80	x	x	46.80	x	x	15.67	x	?	28.83	?	16.62	16.24	-0.38
		540257	143856	Burtons Bridge	Mid Brisbane	32	2D	x	36.32	x	x	25.35	x	x	23.89	x	?	36.18	?	24.69	24.52	-0.17
		540066	143001C	Savages Crossing TM	Mid Brisbane	33	2D	42.13	42.58	0.45	31.03	30.97	-0.06	29.83	29.45	-0.38	42.58	42.70	0.12	30.53	30.08	-0.45
		540182	143001A	Lowood Alert-B	Mid Brisbane	34	2D	?	46.02	?	34.99	35.41	0.42	33.61	33.70	0.09	46.29	46.19	-0.10	35.28	34.74	-0.54
		540178	143823	Wivenhoe Dam TW Alert-P	Mid Brisbane	40	2D	x	66.02	x	x	65.89	x	?	36.44	?	?	48.90	?	37.26	36.96	-0.30
Ipswich Urban Area	±0.30m	40831	143954	Ipswich Alert	Bremer River	17	2D	20.72	20.91	0.19	11.31	13.82	2.51	6.58	7.89	1.31	19.30	19.15	-0.15	13.90	14.08	0.18
		540250	143852	Brassall (Hancocks Bridge)	Bremer River	18	2D	x	22.76	x	x	15.67	x	x	10.10	x	?	19.77	?	?	15.90	?
		40836	14953	One Mile Bridge Alert	Bremer River	19	2D	x	25.16	x	x	18.49	x	12.93	13.97	1.04	21.98	21.59	-0.39	19.05	18.68	-0.37
Bremer River, Non-Urban Area	±0.50m	540550	143114	Berry's Lagoon Alert	Bremer River	WA15_09155.2	1D	x	26.18	x	x	20.16	x	x	15.66	x	?	23.03	?	20.07	20.39	0.32
		40838	143956	Three Mile Bridge AL	Bremer River	BM20_00000.1	1D	x	26.66	x	x	21.46	x	17.26	17.54	0.28	?	23.96	?	?	21.62	?
		540504	143896	Walloon AL	Bremer River	BM10_05036.2	1D	27.96	27.94	-0.02	26.65	26.31	-0.34	?	24.16	?	27.68	27.76	0.08	26.25	26.53	0.28
		540062	143983	Loamside Alert	Purga Creek	PU10_00000.2	1D	x	28.12	x	x	27.00	x	24.71	25.32	0.61	26.14	26.46	0.32	25.33	26.03	0.70
		540210	143113	Loamside TM	Purga Creek	PU10_00000.2	1D	27.68	28.12	0.44	26.47	27.00	0.53	x	25.32	x	x	26.46	x	x	26.03	x
		40816	143108	Amberley (DNRM) TM	Warrill Creek	WA10_04293.2	1D	28.69	28.35	-0.34	25.18	25.24	0.06	23.83	23.63	-0.20	?	26.80	?	27.79	27.47	-0.32
		540180	143825	Amberley-P (Greens Road)	Warrill Creek	WA10_03014.2	1D	x	29.82	x	26.62	27.18	0.56	25.21	25.65	0.44	27.99	28.55	0.56	?	29.20	?
Lockyer Creek	±0.50m	540051	143207	O'Reilly's Weir AL	Lockyer Creek	LO60_03917.2	1D	?	48.37	?	39.47	40.28	0.81	36.29	36.13	-0.16	?	48.64	?	?	39.79	?
		540544	143700	Rifle Range Rd Alert -P	Lockyer Creek	LO30_02619.2	1D	x	60.43	x	61.09	60.30	-0.79	56.69	54.68	-2.01	60.92	60.47	-0.45	61.14	60.36	-0.78
		540174	143819	Lyons Bridge Alert-P	Lockyer Creek	LO20_02940.2	1D	64.95	64.30	-0.65	x	63.98	x	60.08	58.58	-1.50	?	64.42	?	63.93	64.10	0.17
		540149	143808	Glenore Grove Alert	Lockyer Creek	LO10_17895.2	1D	82.05	82.03	-0.02	81.41	81.50	0.09	77.79	76.51	-1.28	82.45	82.06	-0.39	82.21	81.80	-0.41

B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\000_General\090_Gauges\[WSLGauge_CalibrationComparison_DM_007.xlsx]Calibration Comparison

* Note 1: 1974 modelled peak flood levels are based on the flows produced averaging IL/CL values in the Bremer catchment URBS model. Further detail is provided in Section 2.1.1 and Appendix A.

Note 2: Differences between modelled and recorded peak levels that are outside tolerance are due to a number of factors and combinations thereof, including uncertainties in topography, hydrology, recorded levels and so on. These uncertainties are discussed in Section 4 and 4.10.

x	Gauge data not available
?	Gauge data questionable (e.g. gauge failure before peak)
0.12	Difference between recorded and measured within tolerance
0.34	Difference between recorded and measured outside tolerance
18.17	Moggill Gauge Peak Level in 2011 manually adjusted to 18.17m AHD (Seqwater, 2013c)

3.12 Extreme Event Proofing

In 1893, Brisbane experienced two major flood events, both of which were greater in flow magnitude in Brisbane than any other recorded event, including 1974 and 2011. As the Hydraulic Assessment is reliant on events produced by the Hydrologic Assessment (Aurecon *et al*. 2015c), and the recalibration of the URBS model by the Hydrologic Assessment did not include the 1893 event, the Hydraulic Assessment is not able to specifically model this event. However, it is important that the Detailed and Fast Models be capable of running events larger than the calibration events, as the subsequent Monte-Carlo analysis and design events will require this to be so.

The focus of the extreme event proofing in the Detailed Model was to ensure that the model domain caters for the full flood extent, so that the model domain boundaries do not artificially truncate the flood extent. In order to undertake this assessment, only the 8 x 1974 magnitude flow event was required, however the 5x1974 and 1.5x1974 (providing a similar peak flow in Brisbane to that estimated for one of the flood events of 1893) were also run. As well as proofing the detailed model, it allowed for a comparison of peak water levels with the Fast Model.

Longitudinal peak level profiles for the 8x1974, 5x1974 and 1.5x1974 are provided in Plot 26 and Plot 27 for Lockyer Creek, Bremer River and the Brisbane River respectively. For comparison the calibration events are also included. Both Detailed and Fast Model results are included on the plots and it can be seen that consistent profiles are achieved between the two models. Differences in Fast Model and Detailed Model peak flood level profiles evident in these plots for the 5x1974 and 8x1974 events are believed to be primarily due to the magnitude of the head drops (energy losses) at the major constrictions/bends along the Brisbane River. One of the most pronounced locations is the bend immediately downstream of the Breakfast Creek confluence (at a longitudinal profile chainage of approximately 57,000m). For extreme events, this bend becomes a major bottleneck with extremely high velocities and energy losses. It would be expected that the 2D approach would be more accurate than the 1D. The 2D approach is also considered to be more accurate in handling the energy losses associated with water leaving and entering the main river from major ancillary flowpaths that develop at extreme flood heights. Also of note is a previous comparison with the Updated DMT model, which uses a 2D solution. As presented in BMT WBM (2015b), the Updated DMT model shows a similar difference with the Fast Model (ie. the Detailed Model and Updated DMT model have similar profiles).

Whilst the accuracy of the Fast Model at these extreme events might be less than the Detailed Model, this is not considered to be an issue in terms of the purpose and use of the Fast Model for the BRCFS Hydraulic Assessment, namely: to be used for running large numbers of Monte Carlo events, from which preliminary AEP levels can be derived and ensembles of events selected for each AEP. The selected AEP event ensembles will be used in the Detailed Model to establish final model outputs for each event, including peak flood levels throughout the Hydraulic Assessment study area.

The extreme events of 5x1974 and 8x1974 result in significant backwater inundation up the Lockyer Creek and Bremer River. The latter event in the Bremer indicates Brisbane River backwater influences extending to upstream to Amberley and beyond. As this backwater influence extends close to the upstream limit of the model, additional nodal storage is provided, corresponding to the storage within the floodplain upstream of the model extent. This is sufficient in scale to prevent any model boundary containing effects for events up to and including the 8x1974 event.

Drawing 33 contains the peak flood depth and extent for the 8x1974 event, and for interest, Drawing 49 presents the flood hazard for this event. The flood extent for this event is within the model domain boundaries, although the backwater within the Bremer extends to the upstream limit of the model, particularly along Warrill and Purga Creeks. Overall the model is considered fit for purpose in assessing events up to the magnitude of the 8x1974 event, which is expected to be well above the PMF.

Two major flood events occurred in 1893, the first in January and the second in February with the January event resulting in higher observed levels in Brisbane City. As mentioned, the recalibration of the URBS model by the Hydrologic Assessment did not include the 1893 event, and therefore, flow boundary conditions were not available to model these events directly. However, given these are the two largest observed floods on record, it was necessary to give some consideration to these events. There are three estimates of flow for the 1893 events:

- 16,000m^3/s at Indooroopilly Bridge (Seqwater, 2013b)
- 15,830m^3/s at Brisbane CBD (Aurecon, 2015c)
- 17,940m^3/s at Moggill (Aurecon, 2015c).

The 1974 event flows were factored up by 1.5 to achieve a peak flow in the Brisbane CBD of approximately 16,200m^3/s. This flow is similar to those estimated for the 1893 events and the factoring of flow in this way has been used to roughly approximate these events. It is important to highlight that the 1.5x1974 event produces a **similar** peak flow to the **estimated** peak 1893 flows **at Brisbane,** and thus must be regarded as providing only a very rough approximation of the 1893 events. The tidal water level for the 1974 calibration event was used as a downstream boundary condition.

A summary of the observed peak water levels for the January and February events as well as the modelled flood levels (Detailed and Fast Models) for the 1.5x1974 event is presented in Table 3-5. Given the substantial assumptions associated with this comparison the resulting match in levels is considered satisfactory.

Table 3-5 1893 Peak Water Level Summary

Location	Observed Jan 1893 (m AHD)	Observed Feb 1893 (m AHD)	Fast Model 1.5x1974 (m AHD)	Detailed Model 1.5x1974 (m AHD)
Lowood	50.07	-	48.3	48.8
Mt Crosby	32.00	31.28	32.2	31.8
Ipswich	24.50	23.60	24.9	25.3
Moggill	24.50	23.60	24.8	24.8
Centenary	17.90	16.60	16.4	18.4

Location	Observed Jan 1893 (m AHD)	Observed Feb 1893 (m AHD)	Fast Model 1.5x1974 (m AHD)	Detailed Model 1.5x1974 (m AHD)
Brisbane	8.35	8.09	8.5	9.3
Bar	1.33	1.26	1.5	1.5

3.13 Detailed Model Rating Curve Review - Overview

A comprehensive review of rating curves is provided in Section 5. An overview is provided in this section.

The stage-discharge outputs calculated by the Detailed Model for each calibration/verification event are presented in Plot 28. Where backwater or tidal effects occur, the Detailed Model results show a more pronounced hysteresis or looping, with the lower side of the loop (higher flows) occurring during the flood rise, and the higher side (lower flows) on the flood recession. The Brisbane City Gauge results show the strong effect of the ocean tide at the lower levels.

Overall there is consistency between the Detailed Model results and the rating curves derived by Seqwater and Aurecon (Aurecon *et al*, 2015c) (also shown on Plot 28), and on gaugings at Savages Crossing and Amberley. Plot 31 shows the rating curve plots for both the Detailed and Fast Models for the 8x1974 extreme event, described in Section 3.12.

General observations are:

- The most noticeable differences occur during the in-bank stages of Glenore Grove and Rifle Range, and the higher stages of Loamside. For Glenore Grove and Rifle Range the in-bank differences could be due to the uncertainties associated with using LiDAR for in-bank areas and the inaccuracies associated with deriving the rating curves.
- There is some looping (hysteresis) effects at some gauges. Where this occurs the rating curves tend to match with the rising limb of the flood (ie. with the lower side of the hysteresis curve).
- At gauges such as Mt Crosby and Moggill there is a noticeable difference between the major floods of 1974 and 2011, despite having similar peak flows at Mt Crosby. This is most likely due to the different flood shapes; the 2011 flood, due to the influence of Wivenhoe Dam, was a shorter, sharper shape with less volume than the 1974 event. The Bremer River flow entering at Moggill in 1974 was also greater than 2011 making 1974 larger than 2011 downstream of the rivers' confluence. This is aptly illustrated at the lower Brisbane gauges where the flood level was above 10 mAHD for around 3 days in 1974, but less than 2 days in 2011.

3.14 Calibration Parameters

3.14.1 Manning's n Roughness Values

Roughness of the land surface over which the water flows is represented in the hydraulic model by Manning's n values.

Manning's n roughness values were initially set to typical values for each land use type. These values were then adjusted within acceptable bounds as part of the calibration exercise. The values derived from the calibration and verification simulations are presented in Table 3-6. Discussion on the methodology by which the values were derived is provided in Sections 3.5 to 3.10. For the 1D sections the Manning's n values remained unchanged from those used for the Fast Model.

Drawing 8 shows the spatial variation of Manning's n values across the 2D model domain and the targeted form loss values applied to the calibrated model. Note that some of these form losses are applied to channels modelled in 1D and so will be higher than typical values used for channels represented in 2D. See Section 3.14.2 for further detail.

Table 3-6 Manning's n Values (Used in Conjunction with Form Losses)

Landuse Category	Manning's n Fast Model	Manning's n Detailed Model
Brisbane River		
Tidal Waterway	0.022	0.022
Non-Tidal Waterway	0.032	0.030
Riverbank Light Vegetation	0.05	0.045
Riverbank Medium Vegetation	0.07	0.065
Riverbank Dense Vegetation	0.09	0.09
Bremer River		
Tidal Waterway	0.03	0.022
Non-Tidal Waterway	0.08	0.06
Riverbank Light Vegetation	0.08	0.08
Riverbank Medium Vegetation	0.12	0.12
Riverbank Dense Vegetation	0.16	0.16
Lockyer Creek		
Non-Tidal Waterway	0.06	0.06
Riverbank Light Vegetation	0.08	0.08
Riverbank Medium Vegetation	0.12	0.12
Riverbank Dense Vegetation	0.16	0.16
Floodplains		
Roads / Carparks	0.025	0.025
Water bodies	0.03	0.025
Agricultural Fields	0.03	0.035
Vegetation Light	0.06	0.04
Vegetation Medium	0.09	0.06
Vegetation Dense	0.12	0.10
Grass (maintained)	0.03	0.04
Urban Low Density	0.05	0.06

Landuse Category	Manning's n Fast Model	Manning's n Detailed Model
Urban Medium Density	0.1	0.1
Urban High Density	0.2	0.2
Commercial / Industrial	0.2	0.1

3.14.2 Form Loss Coefficients

As discussed in Section 3.3, whilst 2D solutions model the energy losses associated with bends, constrictions and other features that force the water to suddenly change direction and magnitude, they do not model all the losses due to 3D flow patterns (in the vertical), and fine-scale losses such as a bridge pier. As such, additional form losses associated with such hydraulic behaviour may be needed to fully account for the losses within a 2D domain.

A form loss coefficient is applied to the model to simulate the energy losses associated with hydraulic behaviour not able to be represented explicitly in the hydraulic model. The form loss is applied as an energy loss based on the dynamic head equation below where ζ_a is the form loss value.

$$\Delta h = \zeta_a \frac{V^2}{2g}$$

Targeted form loss coefficients at sharp bends or rock outcrops are presented in Table 3-7 (Mid Brisbane), Table 3-8 (Lower Brisbane) and Table 3-9 (Lockyer Creek and Bremer River). Spatial presentation of the form loss coefficients and the area over which they are applied are contained within Drawing **8**, with distinction made between those applied in the 1D domain and those applied in the 2D domain. Note that 1D form losses are applied only to the 1D in-bank channels (e.g. Lockyer Creek) and the 2D form losses to the 2D cells. For the 1D sections of the Detailed Model, the form losses used for the calibrated Fast Model were retained unchanged, as were the Manning's n values.

Where the channel is modelled in 2D, the targeted form loss values were initially set to 20% of the values required for the calibrated Fast Model. As the calibration of the Detailed Model progressed, some localised adjustments of the form loss values were made to fine-tune the calibration, such as upstream of Savages Crossing and downstream of Mt Crosby where it was necessary to adopt higher losses to match calibration point values.

Table 3-7 Targeted Form Losses Mid Brisbane River

River	Location	Domain in DM[13]	FLC[13] (FM)	FLC (DM)	Physical Feature
Mid Brisbane	Confluence Lockyer/Brisbane Rive	2D	1	0.2	Confluence
Mid Brisbane	Wivenhoe Pocket	2D	n/a	1	Bend
Mid Brisbane	Wivenhoe Pocket	2D	n/a	0.7	Bend
Mid Brisbane	Lowood	2D	1.5	0.24	Bend
Mid Brisbane	Savages	2D	n/a	1.6	Quarry Bend
Mid-Brisbane	Savages	2D	1.5	1.5	Quarry Bend D/S
Mid-Brisbane	Savages	2D	n/a	1	Bend
Mid Brisbane	DS Savages Crossing	2D	0.5	0.14	Bend
Mid Brisbane	Fernvale Bend 3	2D	0.5	0.16	Bend
Mid Brisbane	Fernvale Bend 2	2D	0.5	0.18	Bend
Mid Brisbane	Fernvale Bend 1	2D	0.75	0.3	Bend
Mid Brisbane	Black Snake Creek	2D	0.75	0.11	Bend
Mid Brisbane	Hills Crossing	2D	0.5	0.08	Bend
Mid Brisbane	Near Sandy Creek	2D	0.75	0.16	Bend
Mid Brisbane	Lake Manchester	2D	1	0.14	Bend
Mid Brisbane	Near Kholo Road 2	2D	1.5	0.28	Bend
Mid Brisbane	Near Skyline Drive	2D	0.75	0.22	Bend
Mid Brisbane	Kholo Road Bridge	2D	1.5	0.22	Bend
Mid Brisbane	Near Kholo Road 1	2D	0.75	0.14	Bend
Mid Brisbane	Mt Crosby Nth	2D	0.375	0.075	Bend
Mid Brisbane	Mt Crosby Sth	2D	0.375	1.2	Bend
Mid Brisbane	Allawah Road	2D	1.5	1	Bend
Mid Brisbane	Colleges Crossing	2D	1	1	Bend
Mid Brisbane	Johnsons Rocks	2D	1.5	1	Underwater Feature
Mid Brisbane	Kookaburra Park	2D	1.5	0.4	Bend
Mid Brisbane	Taylors Nook	2D	1.5	0.4	Bend

[13] **FLC** = Form Loss Coefficient; **FM** = Fast Model; **DM** = Detailed Model;
Domain in DM = The 1D or 2D nature of the domain used at this location in the Detailed Model;
FLC (FM) = FLC applied in the calibrated FM. If the "Domain in DM" indicates a 1D domain at this location, then the form loss applied in the DM will be the same as that applied in the FM.
FLC (DM) = FLC applied in the calibrated DM.

Table 3-8 Targeted Form Losses Lower Brisbane River

River	Location	Domain in DM[13]	FLC[13] (FM)	FLC (DM)	Physical Feature
Lower Brisbane	The Junction	2D	1	0.21	Bend
Lower Brisbane	Six Mile Creek	2D	1.5	0.32	Bend
Lower Brisbane	Chemical Crossing	2D	0.75	0.16	Bend
Lower Brisbane	Hospital Corner	2D	1.5	0.3	Bend
Lower Brisbane	Wolston Creek Confluence	2D	0.75	0.18	Bend
Lower Brisbane	Popes Reach	2D	0.75	0.2	Bend
Lower Brisbane	Hells Gate	2D	0.75	0.14	Bend
Lower Brisbane	Pullen Pullen Reach	2D	0.75	0.16	Bend
Lower Brisbane	Mt Ommaney Reach	2D	0.75	0.16	Bend
Lower Brisbane	Moggill Creek Confluence	2D	0.75	0.16	Bend
Lower Brisbane	Seventeen Mile Rocks 2	2D	0.25	0.06	Underwater Feature
Lower Brisbane	Seventeen Mile Rocks 1	2D	0.25	0.045	Underwater Feature
Lower Brisbane	Rocks Riverside Park	2D	0.5	0.18	Bend
Lower Brisbane	Carrington Rocks	2D	0.75	0.14	Underwater Feature
Lower Brisbane	Walter Taylor Bridge	2D	1	0.165	Bend
Lower Brisbane	Long Pocket 2	2D	0.5	0.115	Bend
Lower Brisbane	Long Pocket 1	2D	0.75	0.14	Bend
Lower Brisbane	Six Mile Rocks	2D	0.5	0.11	Underwater Feature
Lower Brisbane	Dutton Park Rocks	2D	1	0.204	Underwater Feature
Lower Brisbane	Kayes Rocks	2D	0.75	0.17	Bend
Lower Brisbane	William Jolly Bridge	2D	0.375	0.1	Bend
Lower Brisbane	Captain Cook Bridge	2D	1	0.225	Bend
Lower Brisbane	Story Bridge	2D	1	0.45	Bend
Lower Brisbane	Kinellan Point	2D	0.75	0.21	Bend
Lower Brisbane	Morris Point	2D	0.75	0.24	Bend
Lower Brisbane	Bulimba Point	2D	1.5	0.3	Bend

Table 3-9 Targeted Form Losses Bremer and Lockyer River

River	Location	Domain in DM[13]	FLC[13] (FM)	FLC (DM)	Physical Feature
Bremer	Bremer / Warrill Confluence	1D	1	1	Confluence
Bremer	Berrys Lagoon	1D	1.5	1	Bend
Bremer	Berrys Lagoon 2	1D	n/a	1	Bend
Bremer	Berrys Lagoon 3	1D	n/a	1	Bend
Bremer	One Mile	2D	1	0.22	Bend
Bremer	Hooper St	2D	1.5	0.24	Bend
Bremer	Tiger St	2D	1.5	0.3	Bend
Bremer	Shapcott	2D	1	0.2	Bend
Bremer	Woodend Nature Reserve	2D	1	0.245	Bend
Bremer	Woodend Pocket	2D	1.5	0.25	Bend
Bremer	Parnell Street	2D	1	0.18	Bend
Bremer	Bob Gamble Park	2D	1.5	0.32	Bend
Bremer	Tivoli Rocks	2D	1.5	0.3	Underwater Feature
Bremer	Moores Pocket 2	2D	0.75	0.17	Bend
Bremer	Moores Pocket 1	2D	1.5	0.28	Bend
Bremer	Waterstown Rocks	2D	1	0.24	Underwater Feature
Bremer	Brem_005	2D	0.75	0.16	Bend
Bremer	Brem_004	2D	0.5	0.1	Bend
Bremer	Brem_003	2D	0.75	0.15	Bend
Bremer	Motor Boat Bend	2D	1.5	0.3	Bend
Bremer	Warrego Highway	2D	1	0.26	Bend
Bremer	Brem_002	2D	0.75	0.16	Bend
Bremer	Devils Elbow	2D	1.5	0.32	Bend
Bremer	Brem_001	2D	0.75	0.18	Bend
Lockyer	Glenore Grove	1D	0.75	0.75	Bend
Lockyer	Pomerenke Road	1D	0.5	0.5	Bend
Lockyer	Forest Hill Fernvale Road 2	1D	0.75	0.75	Bend
Lockyer	Lynford	1D	0.5	0.5	Bend
Lockyer	Brightview Pocket	1D	1.5	1.5	Bend
Lockyer	Marschke Road	1D	0.5	0.5	Bend
Lockyer	Radkes Lane	1D	0.5	0.5	Bend
Lockyer	Rifle Range Road	1D	1.5	1.5	Bend
Lockyer	Forest Hill Fernvale Road 1	1D	0.5	0.5	Bend
Lockyer	Mt Tarampa Pocket	1D	1.5	1.5	Bend
Lockyer	Watsons Bridge	1D	0.5	0.5	Bend
Lockyer	Clarendon Station	1D	0.5	0.5	Bend

River	Location	Domain in DM[13]	FLC[13] (FM)	FLC (DM)	Physical Feature
Lockyer	Clarendon Pocket	1D	1.5	1.5	Bend
Lockyer	Mahon Road 2	1D	1	1	Bend
Lockyer	Mahon Road 1	1D	1.5	1.5	Bend
Lockyer	Lowood Patrick Estate Road 2	1D	1.5	1.5	Bend
Lockyer	Lowood Patrick Estate Road 1	1D	1.5	1.5	Bend

3.15 Sensitivity Assessments

3.15.1 ST02 ±10% Change in Manning's n and Form Loss Values

Sensitivity Test 02 established the sensitivity of the Detailed Model to changes in Manning's n values and form loss values applied in the model. The test consisted of two model runs as follows:

- Increase Manning's n values and form loss values by 10%.
- Decrease Manning's n values and form loss values by 10%.

Plot 34 to Plot 39 repeat the plots for the 2011 event with the results from the two sensitivity runs added. The results are as expected with the 10% increased and decreased runs showing higher and lower water levels than the baseline respectively.

Plot 40 to Plot 42 repeat the rating curve plots to show the effect of these sensitivity runs on the rating curves. As would be expected, the 10% decrease shifts the curves to the right (higher flow for lower water level), and the 10% increase shifts to the left.

3.15.2 ST10 Comparison with 20m 2D Resolution

The Detailed Model has been developed using a 30m model grid and was calibrated on that basis. During the course of model calibration, a model using a 20m resolution grid was also developed and run in parallel with the 30m resolution model. This was carried out in part to ascertain whether using a finer resolution caused any major change or notable improvement in results, and to establish the practicality of using the finer grid model in terms of run times.

The 2011 event was used as the primary event to carry out the comparison between the 30m and 20m models, supported by also running the 2013 and 1974 events. All three floods tended to produce consistent results, so only those for the 2011 event are presented in the plots.

The 20m version of the Detailed Model takes around 4 times longer to run than the 30m, bringing run times for the calibration events to 3 to 6 days depending on the event duration. Given that there is planned to be around 50 individual events making up all of the design events, run times of this order are considered somewhat impractical, especially if investigating numerous flood mitigation and future development scenarios.

Plot 43 to Plot 48 are a repeat of the 2011 plots with the results from the 20m resolution run included. For flood flows, the 20m resolution tends to produce lower peak flood levels varying from no change to 0.8m depending on the location. For tidal flows, there is negligible difference in the results throughout the tidal reaches of the river, with both models giving satisfactory results in terms of timing and amplitude.

Two additional 20m model runs were undertaken by increasing the in-bank Manning's n values by 10% and 20% respectively. This was undertaken to achieve an improved calibration of the 20m model to the 2011 flood recordings and to produce results more in-line with the 30m resolution. Model results for these additional runs are also included on Plot 43 to Plot 48.

The reasons for the lower flood levels in the 20m model and hence the need to increase the Manning's n values above those used in the 30m model could be due to one or more of the following effects: although other unknown effects may also be contributing.

- The finer resolution would provide a slightly better reproduction of the river shape, and therefore conveyance, especially at lower flows, and where the river is narrowest.
- The 20m resolution may be less prone to the "saw-tooth" effect that regular grids can experience if there are not sufficient cells across the waterway. The implicit 2nd order spatial solution scheme used by the TUFLOW software generally requires at least 3 or 4 cells across a major waterway to produce satisfactory results. If there are less cells, some constriction of flow can occur. This effect would be most pronounced in the narrower sections of the Brisbane and Bremer Rivers.
- Other somewhat unknown factors including slightly different velocity patterns at sharp river bends causing different energy losses and/or eddy viscosity effects may also contribute.

Given that the maximum difference of 0.8m is less than 5% of the river conveyance and that different approaches to calculating a river's conveyance can vary the conveyance by 10%, it is considered that this difference is not outside expectations.

Also of interest is that the finer 20m resolution did not provide a significant improvement at lower flows during the drain down phase of the Wivenhoe Dam releases that held the flow in the river steady at around 3,500 m^3/s.

In conclusion, whether using a 30m or a 20m resolution, both models need to be calibrated. Calibration results in slightly different Manning's n values, targeted form losses and/or eddy viscosity coefficients. Following satisfactory calibration of the 30m and 20m resolution models, comparison of the models' results indicates that there is little difference between them, as shown in the ST10 plots. As such, there is no major benefit in using the finer resolution 20m resolution model given the longer and impractical run times.

4 Discussion on Detailed Model Performance

4.1 Overview

The Hydraulic Assessment Brief targets the tolerances below as being desirable for the accuracy of water level estimates for the AEP design floods.

- Brisbane River downstream of Oxley Creek ± 0.15 m
- Brisbane River between Goodna and Oxley Creek ± 0.30 m
- Ipswich urban area ± 0.30 m
- Brisbane River and tributaries upstream of Goodna (for non-urban areas), including Bremer River and Lockyer Creek ± 0.50 m.

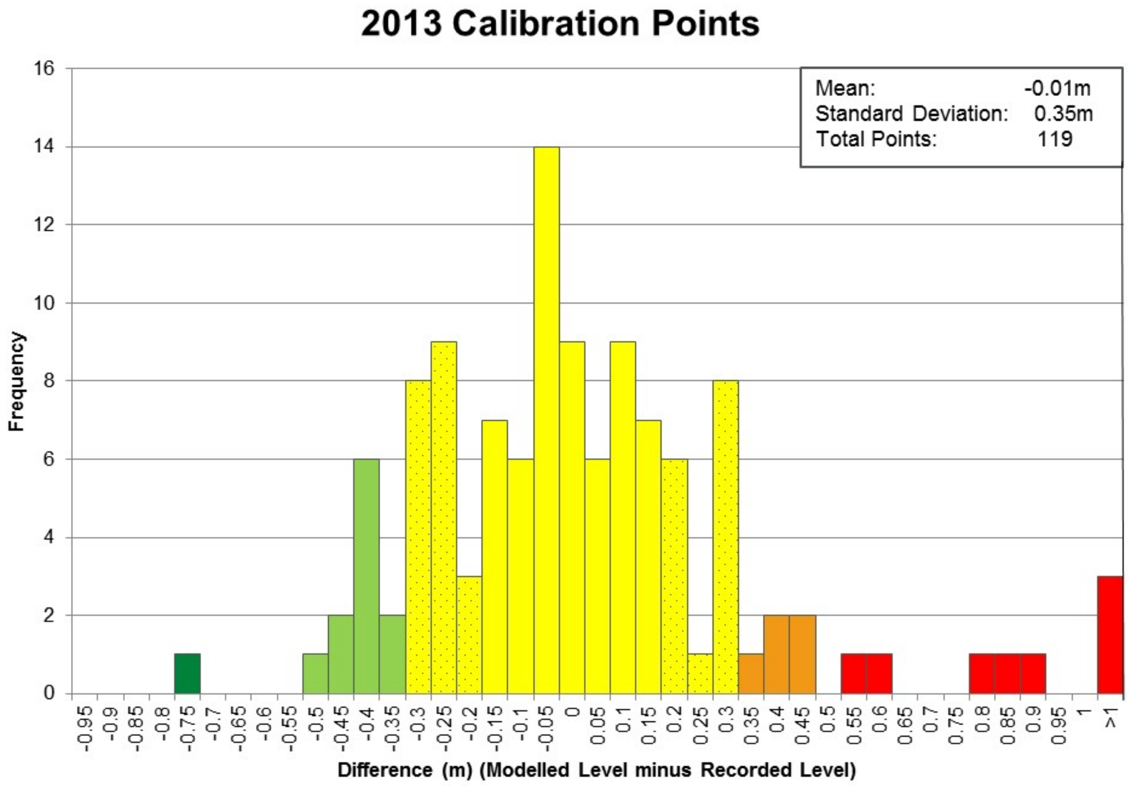
The ability of the Detailed Model's calibration to meet these tolerances is an important performance indicator of the model's accuracy. Other important indicators are the ability reproduce the shape of the historical gauge hydrographs to ensure the flood wave propagation time and speed predicted by the model is replicated.

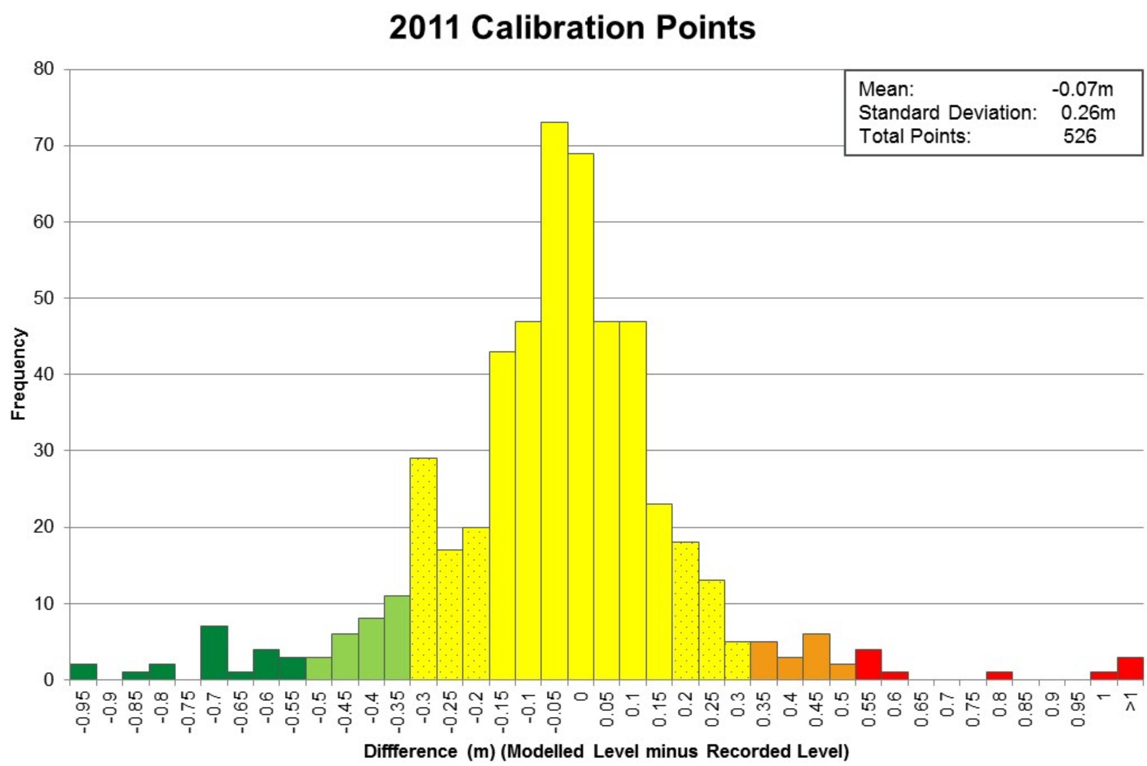
The Detailed Model reproduces the timing and shape of the historical flood waves as evident from the calibration to the gauge recordings presented in the Plot Addendum and discussed for each event in Section 3. The model is therefore considered to provide reliable predictions of the flood propagation speeds.

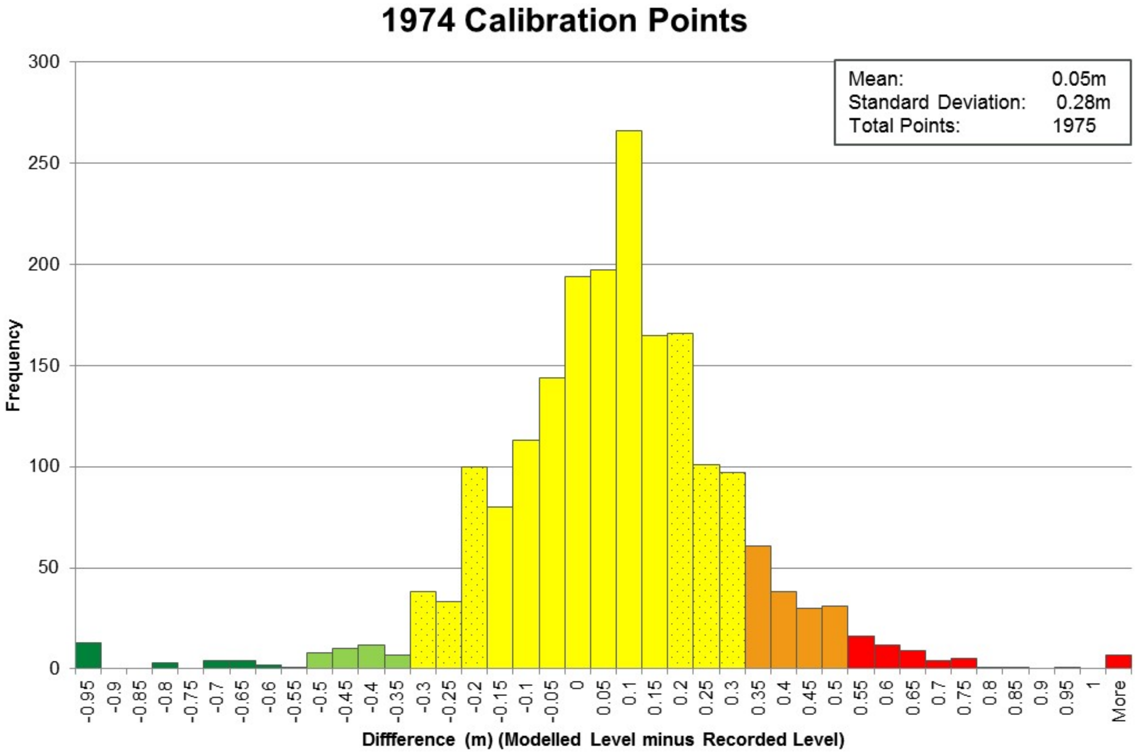
The comparisons with peak water levels at flood marks and gauges as presented in Drawing 10 to Drawing 26 and the profile plots (Plot 6, Plot 5, Plot 17, Plot 18, Plot 24 and Plot 25) show that the large majority of peak water levels predicted by the Detailed Model meets the tolerances above, providing a high quality reproduction of flood behaviour.

The statistical match for the three floods with flood mark data sets shown in Figure 3-1 to Figure 3-3 are reproduced below to illustrate the agreement both in terms of the mean and the distribution of the flood mark levels compared with the Detailed Model's levels.

Gauge levels that are in error or uncertain, and flood level marks that are either inconsistent with other nearby marks or not at the flood peak have been excluded from the statistical analysis. Flood marks in local creeks that are not due to Brisbane River backwater flooding have also been excluded, particularly for 1974 during which many of the local creeks experienced major flooding in their own right. It is important to note that the Detailed Model is not designed or intended to replace the higher resolution modelling that would be required to represent the local creeks.


2013 Calibration Points
Mean: -0.01m
Standard Deviation: 0.35m
Total Points: 119
Frequency
Difference (m) (Modelled Level minus Recorded Level)


2011 Calibration Points
Mean: -0.07m
Standard Deviation: 0.26m
Total Points: 526
Frequency
Diffference (m) (Modelled Level minus Recorded Level)



The model also reproduces the superelevation at river bends. Figure 4-1 illustrates the 2011 flood at Brisbane CBD where the river abruptly bends three times. At each bend there are recorded flood marks on each side of the river varying in height by up to 0.6m across the river. The Detailed Model is showing the same superelevation effects to those recorded highlighting the importance of using a full 2D equation solution where substantial superelevation effects occur. Figure 4-1 also shows the water surface contours highlighted in light grey in 0.1m increments illustrating how the water level can vary significantly from one side of the river to the other.

The model is also nicely reproducing other interesting hydraulic effects. One of these is the almost dead flat water surface profile that occurred on the Tennyson Reach between Clarence Rd and Tennyson in 1974 where the peak flood level along the Oxley Creek side of the river (the right bank looking downstream) varied by less than a few centimetres for 2.5km of river length (see levels in Figure 4-2). The numerous flood marks collected record this effect as shown in the profile plot (see Plot 24) of which the relevant portion is reproduced in Figure 4-3. This somewhat unusual effect is probably caused by a combination of reduced velocity head as the water approaches the abrupt Tennyson river bends, overflow that develops across Long Pocket on the opposite bank short-circuiting the Tennyson meander, and possibly the outflow from Oxley Creek.

Another location is the Bremer / Brisbane River confluence as presented in Figure 4-4. A satisfactory reproduction of the recorded flood mark levels is shown. Of interest is the ~0.4m water surface drop in the Brisbane River between the confluence and the Moggill Alert Gauge that occurs over a relatively short distance due to the two rivers converging (the water surface contours are shown in light grey at 0.1m intervals). A similar affect occurs in the 1974 flood with both recorded and modelled levels matching. The substantial water surface drop and superelevation that occurs at the bend downstream of Moggill can also be observed.

In summary, the performance of the model to be able to reproduce historical events is considered to be of a high standard, with the vast majority of the model not requiring any special attention or investigation during the calibration process. Where further investigations or interesting observations and clarifications were sought, the more important of these have been noted and discussed in the following sections.

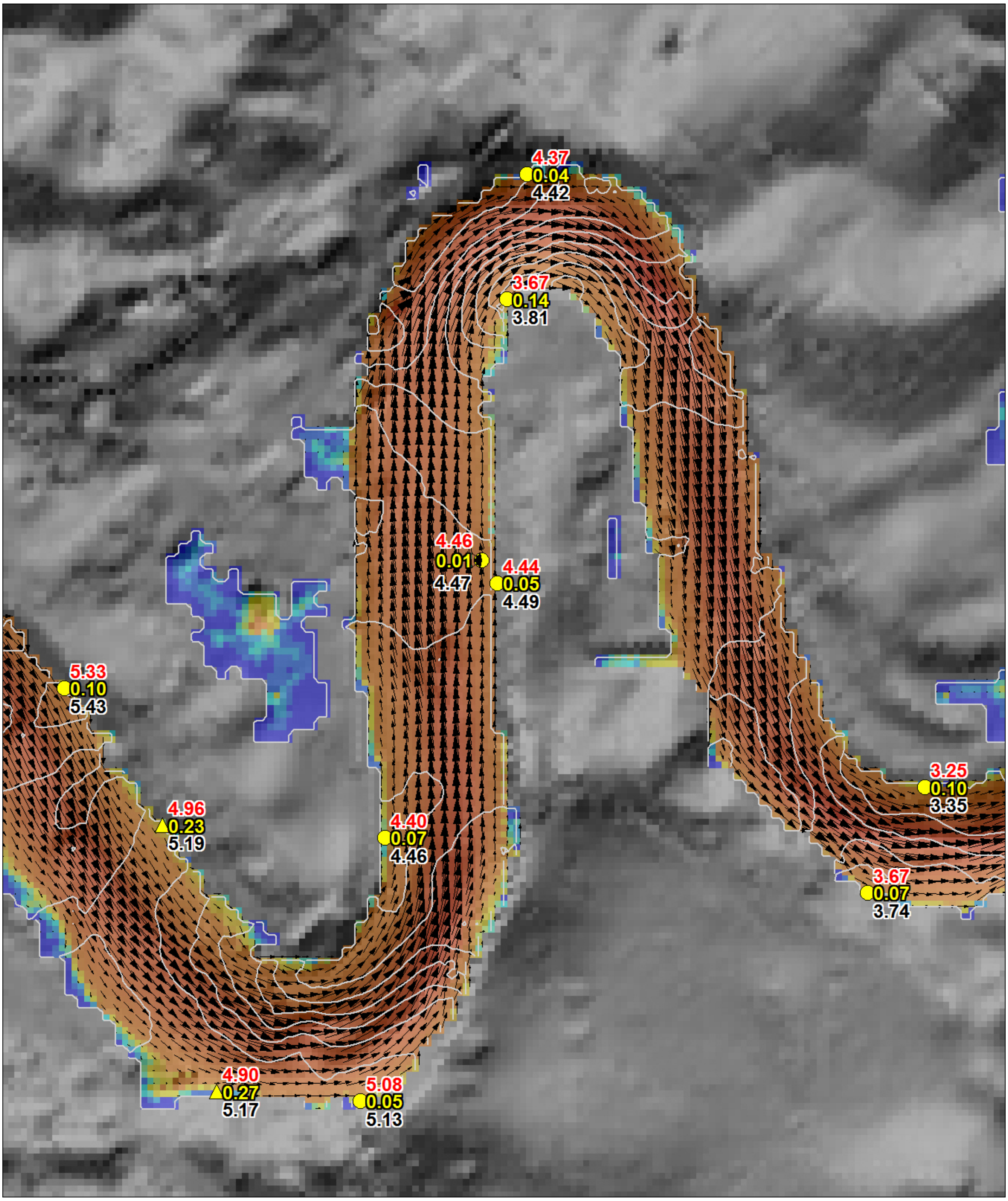


Figure 4-1 Example of Reproduction of Superelevation at River Bends for the 2011 flood – Story Bridge Bend

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)

(Water level contours at 0.1m intervals)

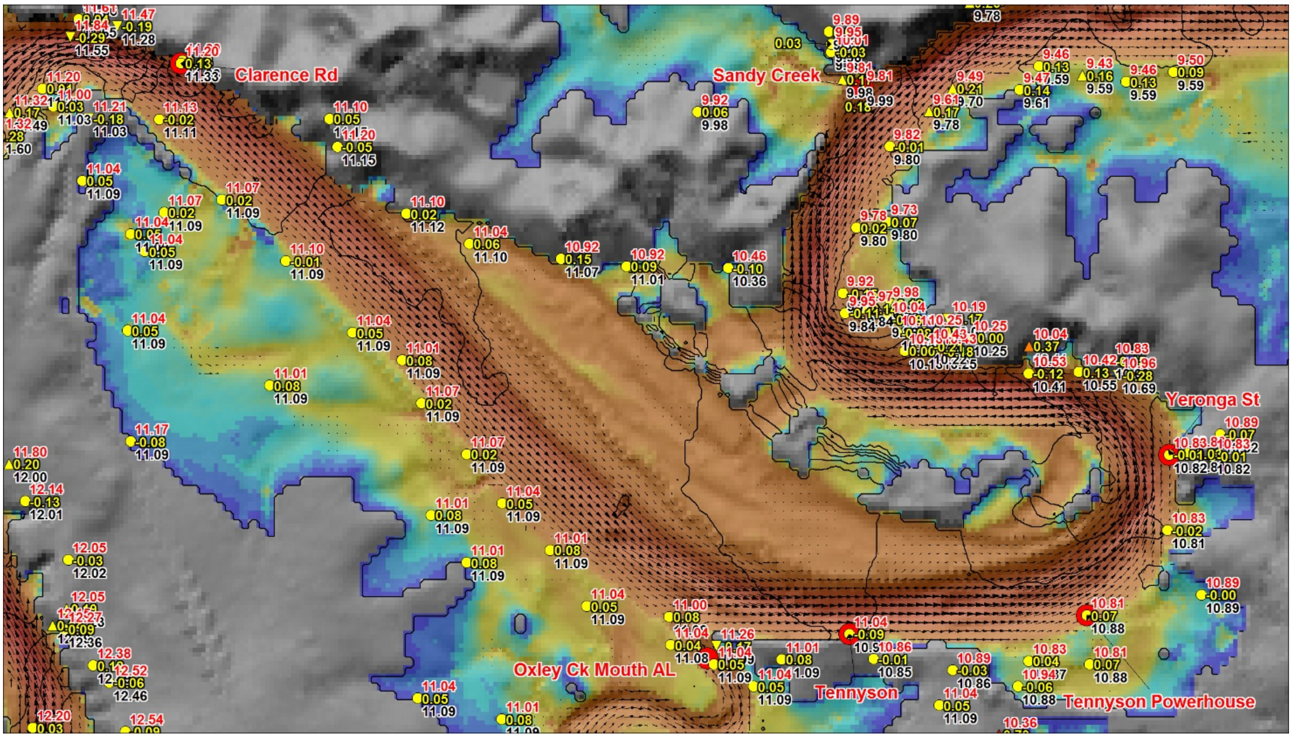


Figure 4-2 Tennyson Reach Flood Mark Comparison for the 1974 Flood

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

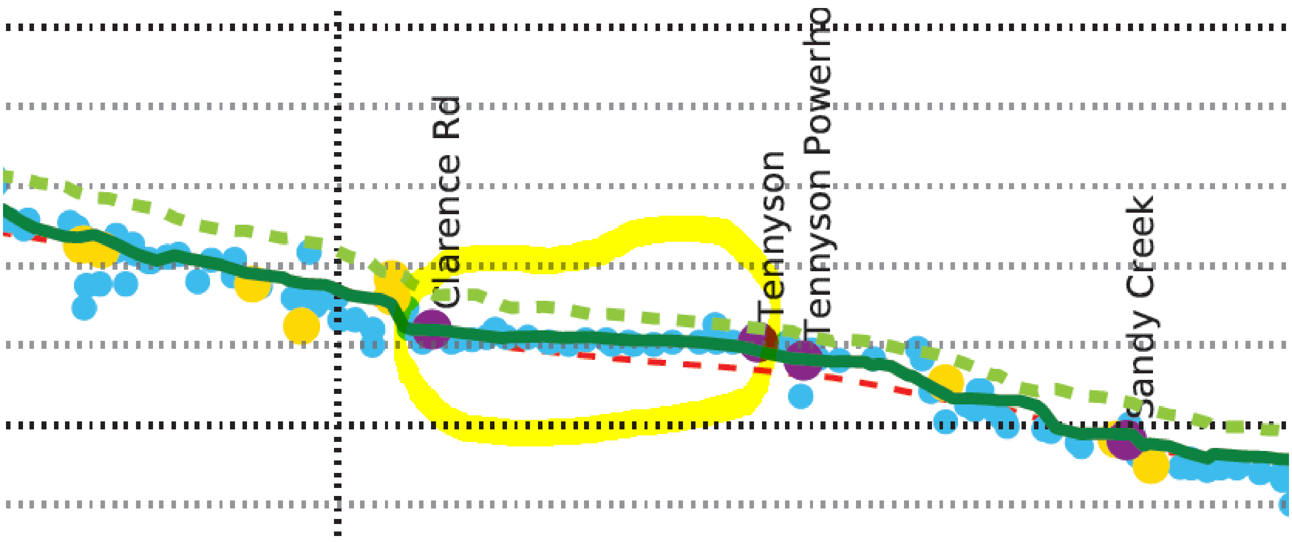


Figure 4-3 Tennyson Reach Profile – Extract from 1974 Flood Profile Plot

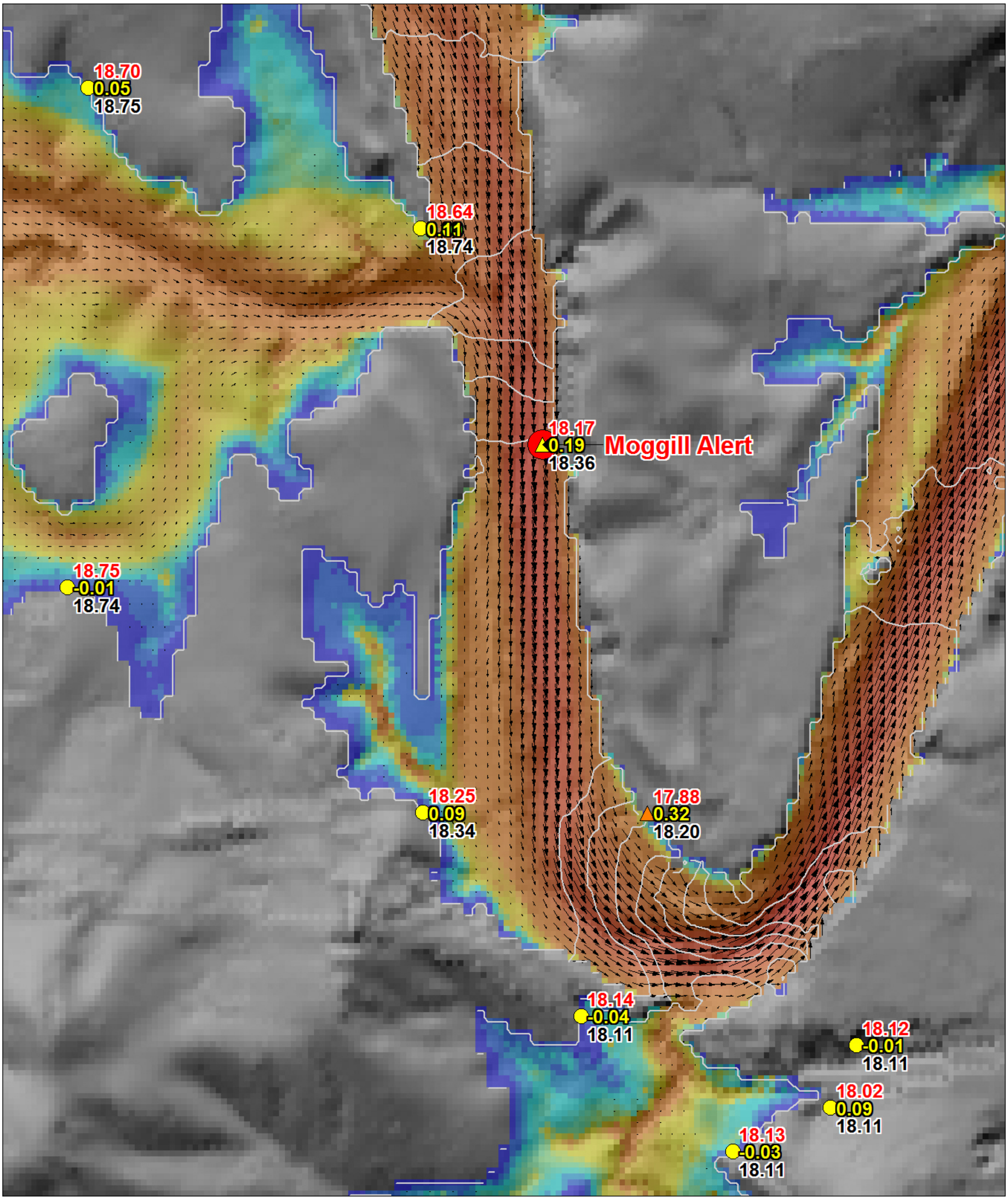


Figure 4-4 Bremer / Brisbane River Confluence for the 2011 flood

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

4.2 Lockyer Creek and Floodplains

The flood mark comparisons for the 2011 event for Lockyer Creek and its floodplains show the majority of levels are within the desired tolerance of ±0.5m. The levels over the Lockyer floodplain that includes the Buaraba Creek floodplain downstream of Atkinson Dam through to O'Reilly's Weir are on the whole lower and were the focus of numerous model tests.

This floodplain is interesting in that it has a surprisingly strong influence on the shape and peak of levels down the Brisbane River, and also the lower Bremer River for larger events. The floodplain carries a substantial percentage of the Lockyer flows in larger events, with around 70% of the total Lockyer flow during the peak of the 2011 flood. Increasing the Manning's n values over this area will raise flood levels, but for n values greater than 0.04 this unacceptably delays and attenuates the flood peak in the Brisbane River. Adjusting the Manning's n values in Lockyer Creek was also tested, although there was less opportunity to change these values as the calibration to smaller flood events would be compromised. The final Manning's n values adopted for the floodplain produces a satisfactory response in terms of timing of the flood wave entering the Brisbane River, but the peak levels for 2011, although within tolerance, are on the whole lower by around -0.35m (see Figure 4-5).

Comparisons of gauges located in areas of high water surface gradients, usually in the vicinity of the natural levee bank should also be treated with caution as modelled flood levels are often on a steep gradient and recorded levels may include the effect of water surcharging against an obstruction. Figure 4-6 below illustrates some examples of flood marks located in high gradient areas.

Primary reasons for the underestimation of levels for the 2011 event in the northern floodplain are:

- Insufficient volume of water, ie. IL/CL values are too high and/or rainfall quantity is under-recorded, particularly in Buaraba Creek.
- Effect of farm levees not accurately picked up by the LiDAR data / DEM, particularly those that influence the overtopping of the creek's banks.
- No base flow applied to the Lockyer.

In addition, the following uncertainties must be acknowledged as additional potential explanations for underestimation of 2011 flood levels:

- Cropping patterns change season to season, resulting in differences in roughness and thus flood behaviour.
- Potential error in survey datum for the recorded peak flood levels.

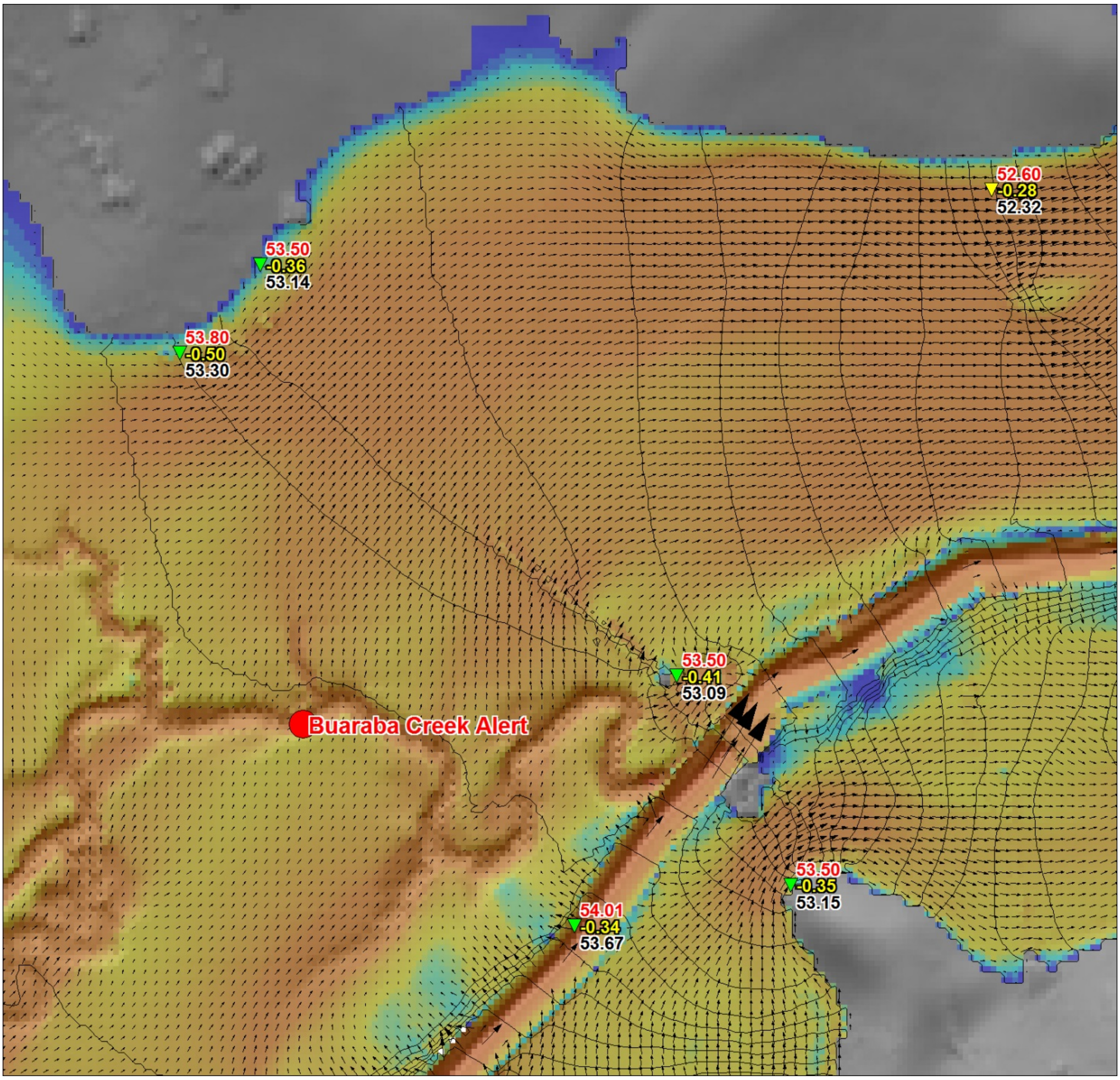


Figure 4-5 Examples of flood marks under-predicting 2011 levels in the northern Lockyer Creek floodplain

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)

(Water level contours at 0.1m intervals)

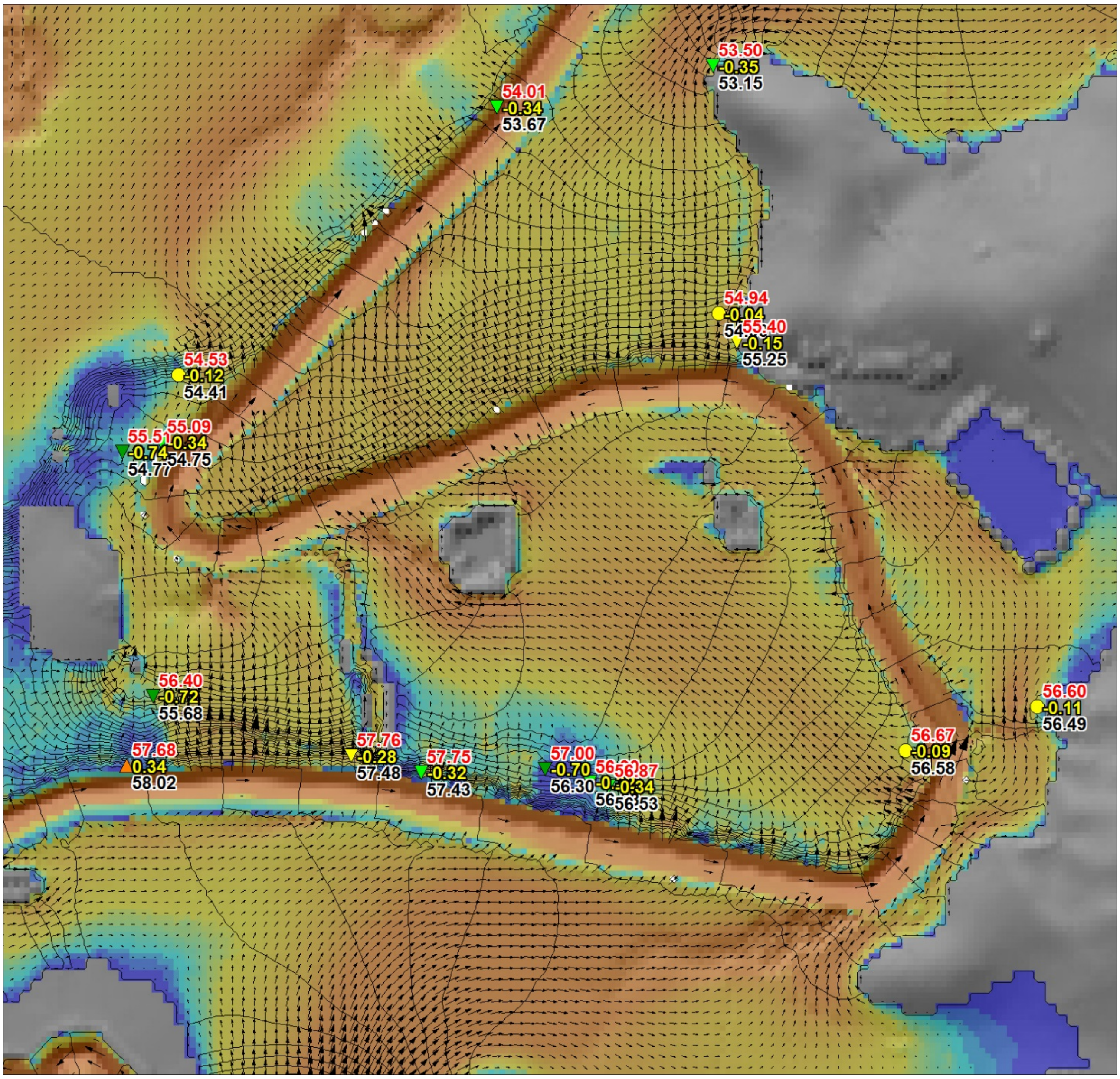


Figure 4-6 Examples of flood marks located in steep gradient areas for the 2011 flood

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

4.3 Upstream of Lowood in 2011

Reproduction of the Lowood flood gauge and flood marks are generally within the ±0.5m tolerance, and the shape of the hydrograph is reproduced in the calibration events.

For 2011, a group of flood marks upstream of Lowood were consistently being underestimated as shown along the left bank in the top right corner of Figure 4-7. These levels were discussed on-site with Somerset Council staff, concluding that there is no reason to believe these levels are inaccurate as they support each other and are considered to be good marks at residential and other buildings. Further testing and examination of the DEM shows the levels are located on the banks of a section of river that has a distinct kink and through the application of higher form losses in this vicinity a better match, within tolerance, was achieved.

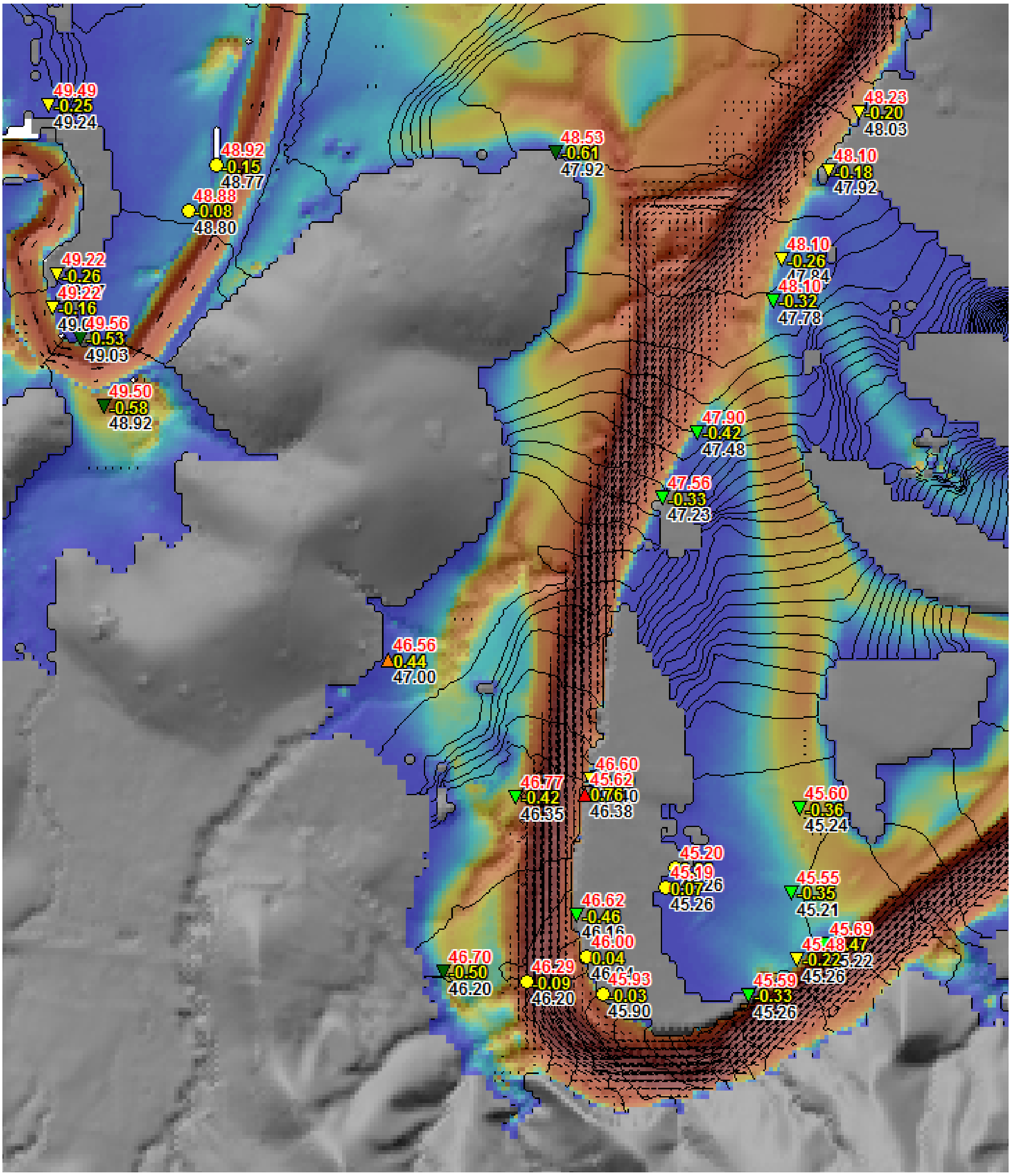


Figure 4-7 Flood marks located around and upstream of Lowood for the 2011 flood

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)

(Water level contours at 0.1m intervals)

4.4 Fernvale

Fernvale was particularly hit hard during the 2011 flood as it became a floodway short circuiting the main river flows. There is also the view that this floodway did not flow during the 1974 event although the few recorded levels from 1974 would indicate that some water would have flowed through Fernvale, albeit lower based on the LiDAR levels. To complicate matters, there are substantial quarry related earthworks on the floodplain immediately to the north of Fernvale that are likely to have changed the floodplain topography between 1974 and 2011.

In 2011 there are a collection of flood level marks in and around Fernvale and on the other side of the river. The Savages Crossing gauge is also located in the river where the Fernvale floodway enters downstream. Initial calibration results for 2011 consistently produced too low levels in Fernvale and upstream of the quarry site. Closer inspection of the site with Somerset Council staff and discussions with the quarry owner provided helpful guidance as to the height of the flood and the severity of flow. On the basis that there would be substantial turbulence and energy losses associated with this river bend and the presence of the quarry works, through increasing the additional form losses through this stretch a match with recorded flood marks was achieved. The high 2D form loss values from the quarry to upstream of Savages Crossing required to achieve a match with recorded levels would indicate other factors were at play.

Subsequent to Workshop 3, Seqwater[14] was able to advise that a 2011 LiDAR dataset exists for a section of the Brisbane River, including portions of the quarry site. This dataset is more recent than the 2009 LiDAR dataset used in the DMT DEM, upon which the modelling is based. Seqwater provided[11] a DEM of difference between the 2011 and the 2009 ground elevations (from the DMT DEM). This revealed that, in 2011, a substantial proportion the quarry site had ground elevations that were higher than those ground elevations measured in 2009. In particular, the northern portion of the quarry site (closest to the sharp bend in the Brisbane River), displayed 2011 elevations that were up to 4m higher than those in 2009. Changes in landform at this location of high conveyance would potentially have an impact on flood behaviour in the vicinity of the quarry. Hence, it is believed that one factor leading to the high form losses required to achieve calibration to the 2011 event, is the unknowns associated with the quarry topography at the time of the 2011 flood. Another factor is the high probability that the 2011 floodwater may have moved large amounts of sediment from the vicinity of the quarry into the channel downstream causing a partial choke downstream. Stakeholder feedback noted the presence of large deposits of sediment at Savages Crossing following the 2011 flood event which would support this possibility.

In addition, and after finalising the model calibration, Somerset Council staff provided new flood mark levels provided by the quarry owner. These levels were added to the flood marks and demonstrated a satisfactory match with the modelled results.

In interpreting the 2011 flood level marks, it should be noted that some care needs to be taken. SRC has stated that many of the survey marks within Fernvale are approximated by transposing a single surveyed flood level across up to 15 properties. They have indicated that levels could be up to 0.3m out. There is therefore some doubt over the authenticity of some of the Fernvale flood marks, which is evident when viewing the flood level marks in detail as the same flood level is often

[14] Personal communication with Michel Raymond and Lindsay Millard from Seqwater between 19 May and 10 June 2015

repeated and a sudden drop occurs between some closely spaced levels. A site inspection with council staff showed there is no logical reason for these discrepancies, and it is accepted by both Council and BMT WBM that the 2011 flood marks in the Fernvale area have some inaccuracies..

Figure 4-8 illustrates the flood marks and flow patterns close to the peak of the 2011 event and Figure 4-9 shows a close up zoom of the levels within Fernvale. Of note is the recorded levels (shown in red) are often the same value, which is being investigated by Somerset Council staff.

For the 1974 flood event the bunds/levees/noise barriers on the quarry site were removed and the levels over the quarry site adjusted based on DNRM topographic contours. The modelled results still show some water flowing down the Fernvale floodway, but at a lower level than in 2011. Unfortunately there are not enough reliable flood marks to compare with in the Fernvale area, however, examination of the DEM (LiDAR) levels with the levels indicate flow would have occurred through Fernvale based on the LiDAR ground levels. There is also a match within tolerance to the few recorded 1974 flood marks in this area.

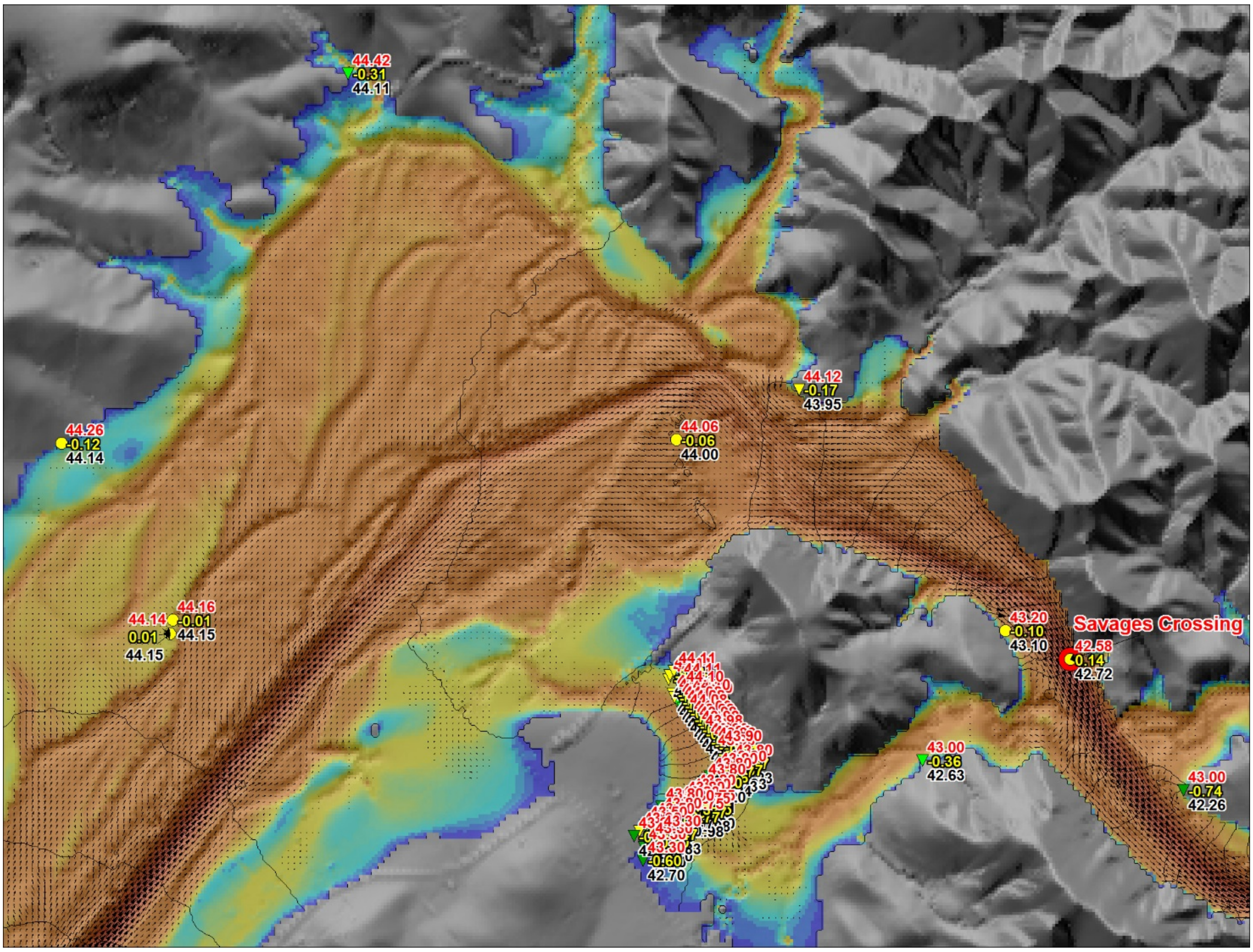


Figure 4-8 Flood marks located around Fernvale for the 2011 flood

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

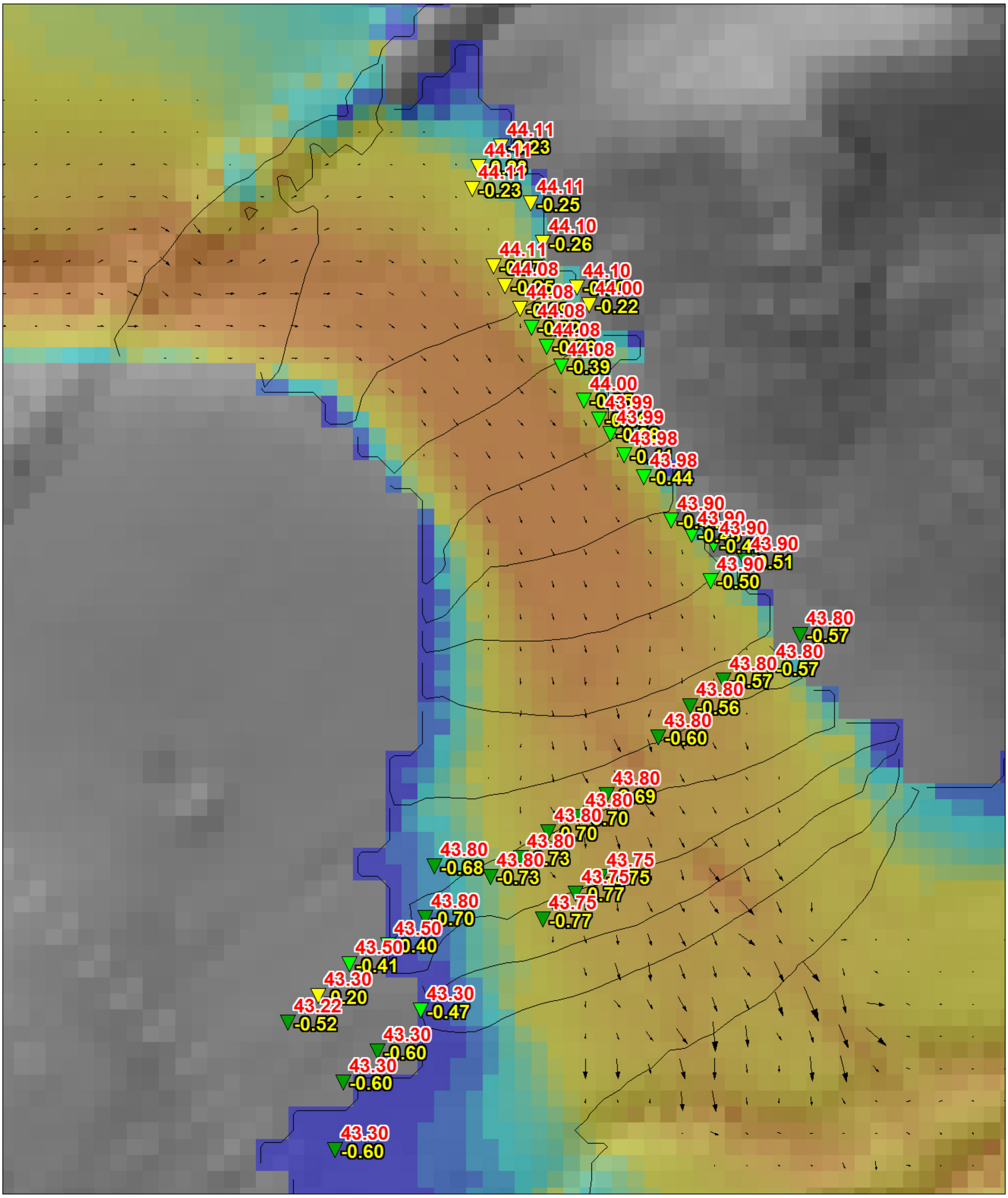


Figure 4-9 Flood marks located in Fernvale for the 2011 flood

(Red font for surveyed level and yellow font for modelled minus surveyed)

(Water level contours at 0.1m intervals)

4.5 Between Savages Crossing and Mt Crosby

This section of the Brisbane River is steep, incised and only has flood marks for the 1974 event. There are gauge recordings at the river crossings at Burtons and Kholo Bridges in 2011 and 2013, however, both of these failed in 2011.

Based on the flood marks available for 1974, there is a possibility the flood levels are being underestimated through this reach (see flood level comparisons in Figure 4-10), although satisfactory matches occur at the gauges for the much smaller 2013 flood. When examining the profile plot for 1974 (Plot 24), the elevated flood marks corresponding to those in Figure 4-10 appear too high and are possibly due to local flooding.

Due to the lack of peak flood mark data for 2011, it is not possible to cross-check whether the 2011 flood is also under predicted. Reasons for the 1974 under prediction would include:

- The flood marks are due to local flooding.
- Errors in the flood mark levels.
- Erosion and scour of the river banks through this stretch during and post 1974.
- Higher Manning's n and/or greater form losses need to be applied, however, testing showed that increasing Manning's n and/or the energy losses adversely affects (delays/attenuates) the shape of the hydrograph arriving at Mt Crosby. It is also noted satisfactory matches occur in 1974 at Savages Crossing and Mt Crosby area (see yellow circles in Figure 4-10).
- Inaccuracies in the LiDAR data, however, as discussed in Milestone Report 1, the LiDAR tends to be higher than ground surveyed levels which would only imply more accurate ground survey would further lower flood levels.
- The 2D model cell resolution of 30m is too coarse, but using a finer resolution would tend to further lower modelled levels.

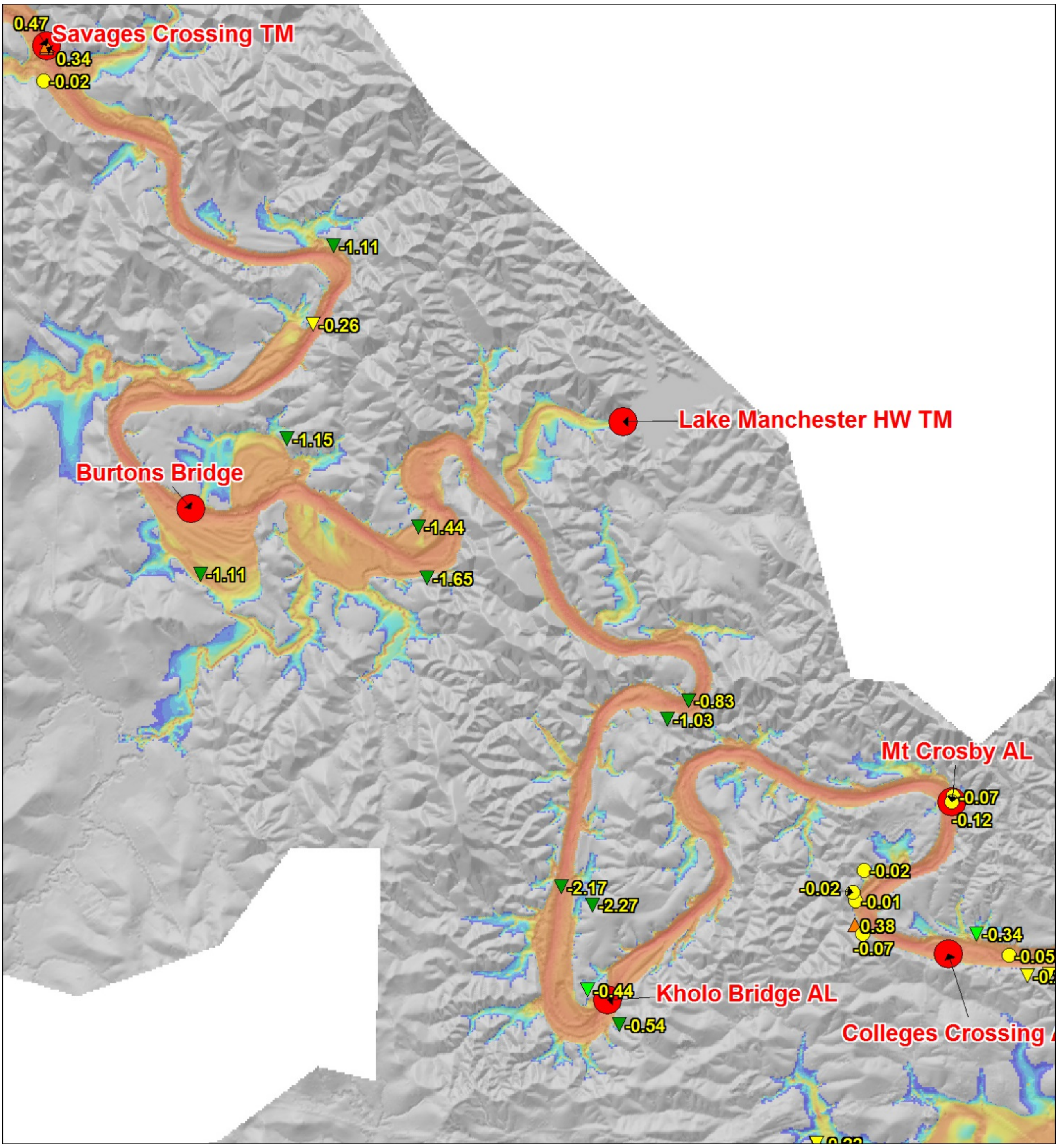


Figure 4-10 Under-predicted flood marks between Savages Crossing and Mt Crosby for the 1974 flood

(Yellow font for modelled minus surveyed)

4.6 Savages Crossing and Moggill Gauges - Near Steady State Flow Conditions

Near steady state conditions occur downstream of Wivenhoe Dam during the drain down phase of dam operations following an event. A satisfactory match with peak levels at the Savages Crossing and Moggill Gauges and surrounding flood marks occurs, however, the model tends to produce too high levels during the drain down phase for 2011 and 2013. The Fast Model also shows too high levels, but is closer. Initially it was thought that this was a consequence of the 30m 2D cell size being too coarse at the lower flows, and that a finer cell size would resolve the issue, however, tests carried out with 20m resolution indicated that the same affect occurs.

Of particular interest is the results from ST02 (see Section 3.15.1) which increases and decreases Manning's n and form loss values by 10%. The plots for this sensitivity test at Savages Crossing and Moggill Gauges extracted from Plot 36 are reproduced below in Figure 4-11 and Figure 4-12. Of particular interest is how the reduced/increased Manning's n and form loss values have little effect on the rising limb, but a significant effect on the recession and during the Wivenhoe drain down phase. Therefore, one possibility for the poor match to the draw down phase observed levels is due to the Manning's n roughness reducing as a consequence of the flood peak "flattening" out the vegetation on the river banks. Another reason could be there may have been erosion or mobilisation of the river bed along this stretch leaving a greater conveyance post flood peak.

In conclusion at Moggill and also at Savages Crossing (but interestingly not at Mt Crosby, Jindalee, Oxley Creek, Brisbane and Breakfast Creek where a match post flood peak occurs), the model may overestimate the water levels during the Wivenhoe Dam drain down phase. Possible reasons for the overestimation are:

- A reduction in Manning's n values for the river bank during the flood around the peak.
- The 2D cell size being too coarse for lower flows, although testing using a 20m resolution shows a similar result during the drain down phase.
- The gauge recordings are in error.

Also of interest is the comparison for the drain down phase at Savages Crossing for the 1999 and 2013 floods, which both had the same post flood discharge or around 1,750 m^3/s (see Figure 4-13 and Figure 4-14). For the same discharge, the 2013 flood level is a metre lower, indicating there has most likely been a change in the topography and/or Manning's n value. The 2013 flood is reasonably soon after the 2011 flood, so there would be an argument that the 2011 flood caused these changes.

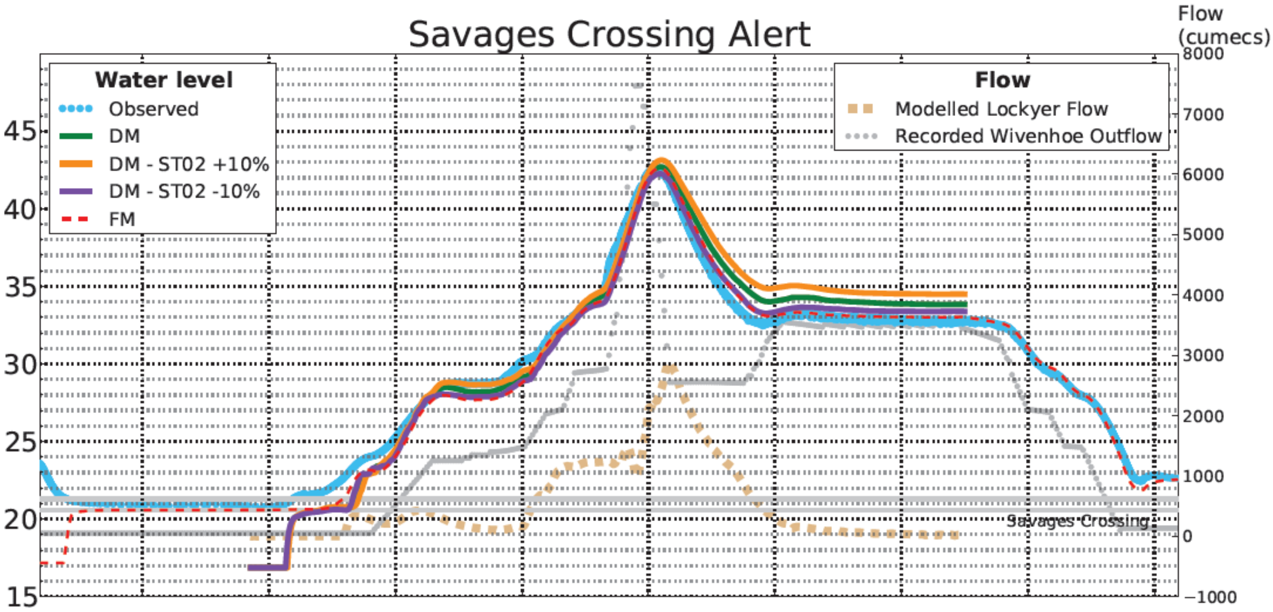


Figure 4-11 Comparison of Levels at Savages Crossing Gauge for 2011 – ST02

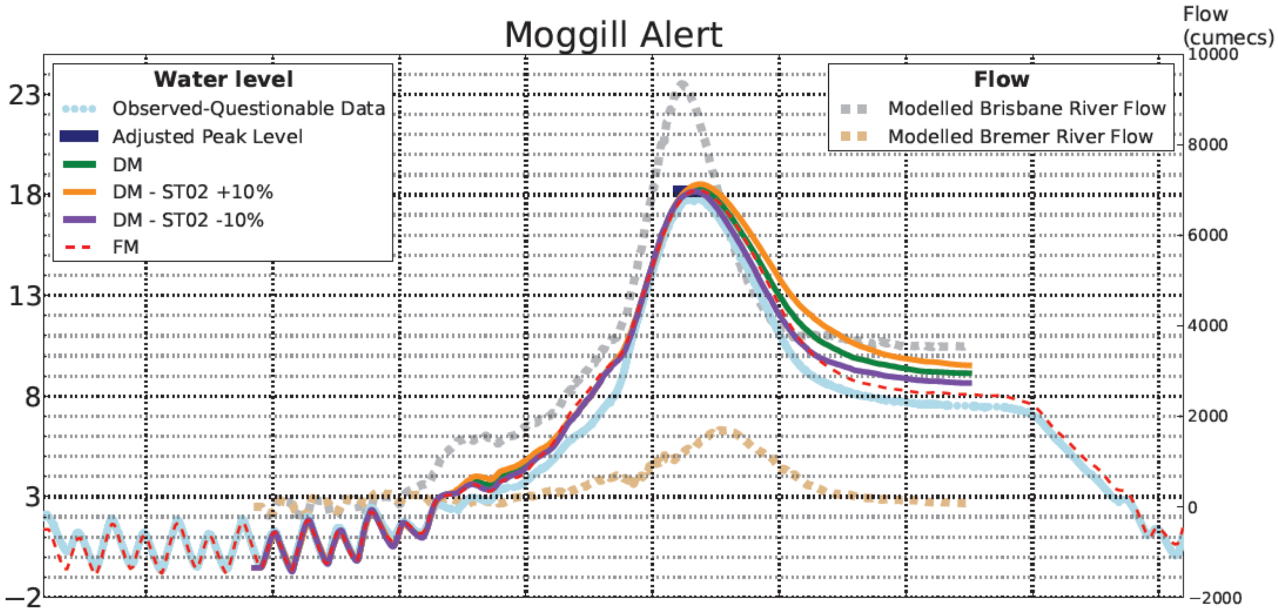


Figure 4-12 Comparison of Levels at Moggill Gauge for 2011 – ST02

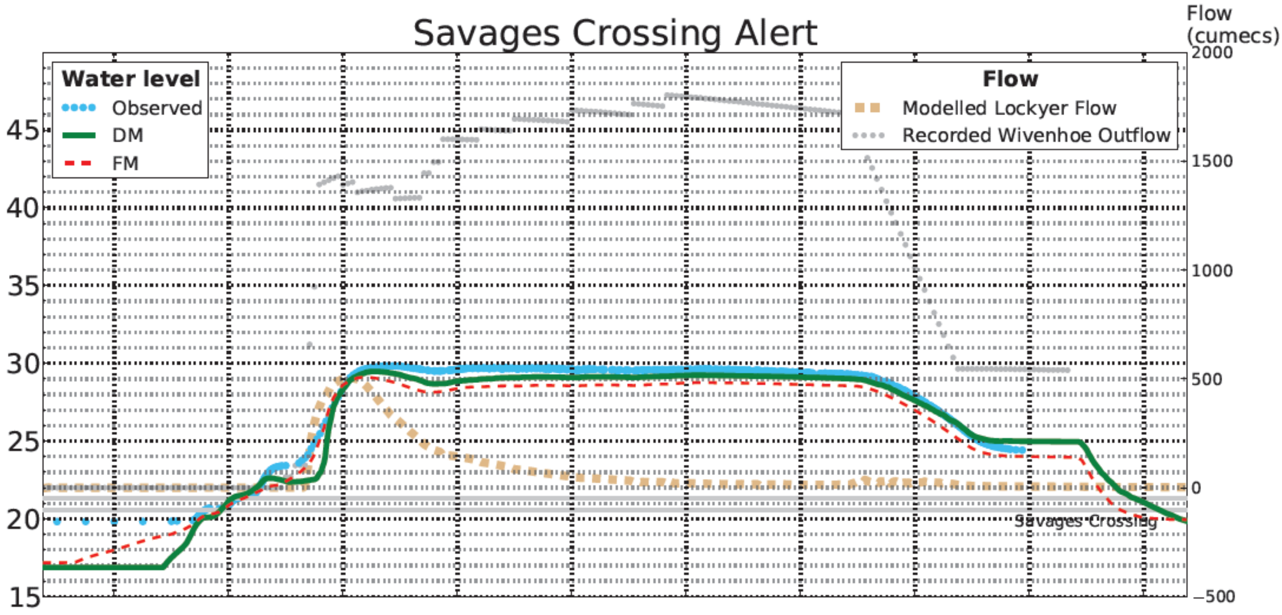


Figure 4-13 Comparison of Levels at Savages Crossing Gauge for 1999

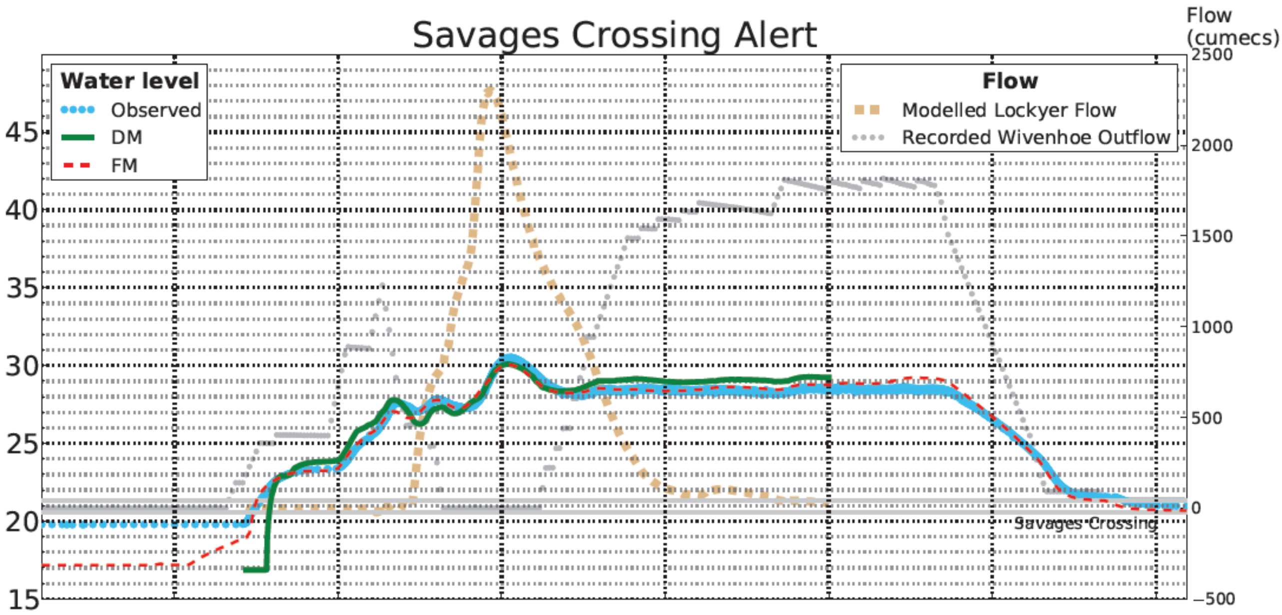


Figure 4-14 Comparison of Levels at Savages Crossing Gauge for 2013

4.7 Ipswich Golf Course to One Mile Bridge

The section of the model along the Bremer River from the Ipswich Golf Course, located just upstream of the Warrill Creek and Bremer River confluence, to One Mile Bridge consistently produce too low levels compared with the 2011 flood marks. Ipswich City Council have been unable to cross-check these levels, but given that the levels appear consistent and the bulk of the 2011 flood marks in the Ipswich area are within tolerance, there is little doubt over the authenticity of these flood marks. Unfortunately, Berry's Lagoon Gauge, located midway, failed to produce reliable levels during the event. The Fast Model calibration shows a similar outcome.

After on-site inspections and discussions with Ipswich City Council staff, there was nothing overly evident as to why the model would under predict levels. Further testing using higher energy losses at the Warrill/Bremer confluence and at the Berry's Lagoon bend improved the calibration to within tolerances as shown in Figure 4-15, which shows the flood level mark comparisons for the final calibration.

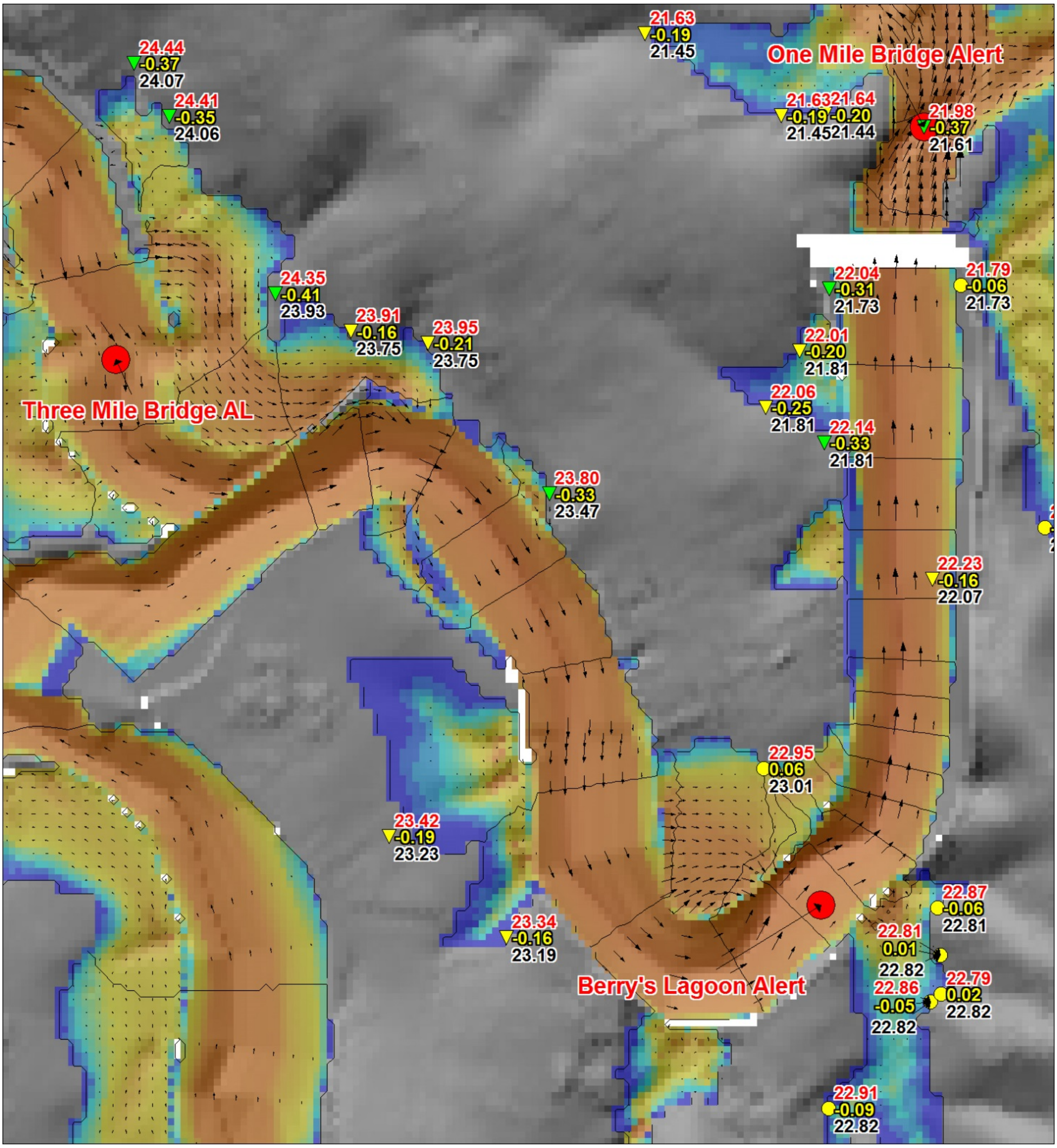


Figure 4-15 Ipswich Golf Course Flood Marks for 2011

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

4.8 St Lucia Reach, 1974

The comparison with the set of 1974 flood marks overall is generally within tolerances and considered a robust verification of the model given the greater uncertainties associated with modelling the 1974 event. The St Lucia reach of the Brisbane River, however, shows the modelled levels are consistently too high by around 0.5m as shown in Figure 4-16. The 2011 calibration, however, shows a satisfactory match albeit to far fewer surveyed flood marks as shown in Figure 4-17.

Possible reasons for the discrepancies in 1974 are:

- River dredging activities or other morphologic changes.
- Local benchmark datum error (it is not unusual for surveys prior to modern surveying technology to use local benchmarks, and if a local benchmark is itself erroneous, the levels surveyed off that benchmark would also be in error). One datum error investigated further was that relating to the conversion of these older surveyed levels (based on State Datum) to that of AHD. However, based on information provided by BCC, the difference between State Datum and AHD is in the order of 0.1m (this varies slightly depending on location). As such, a datum conversion error does not appear to be the explanation for this difference.

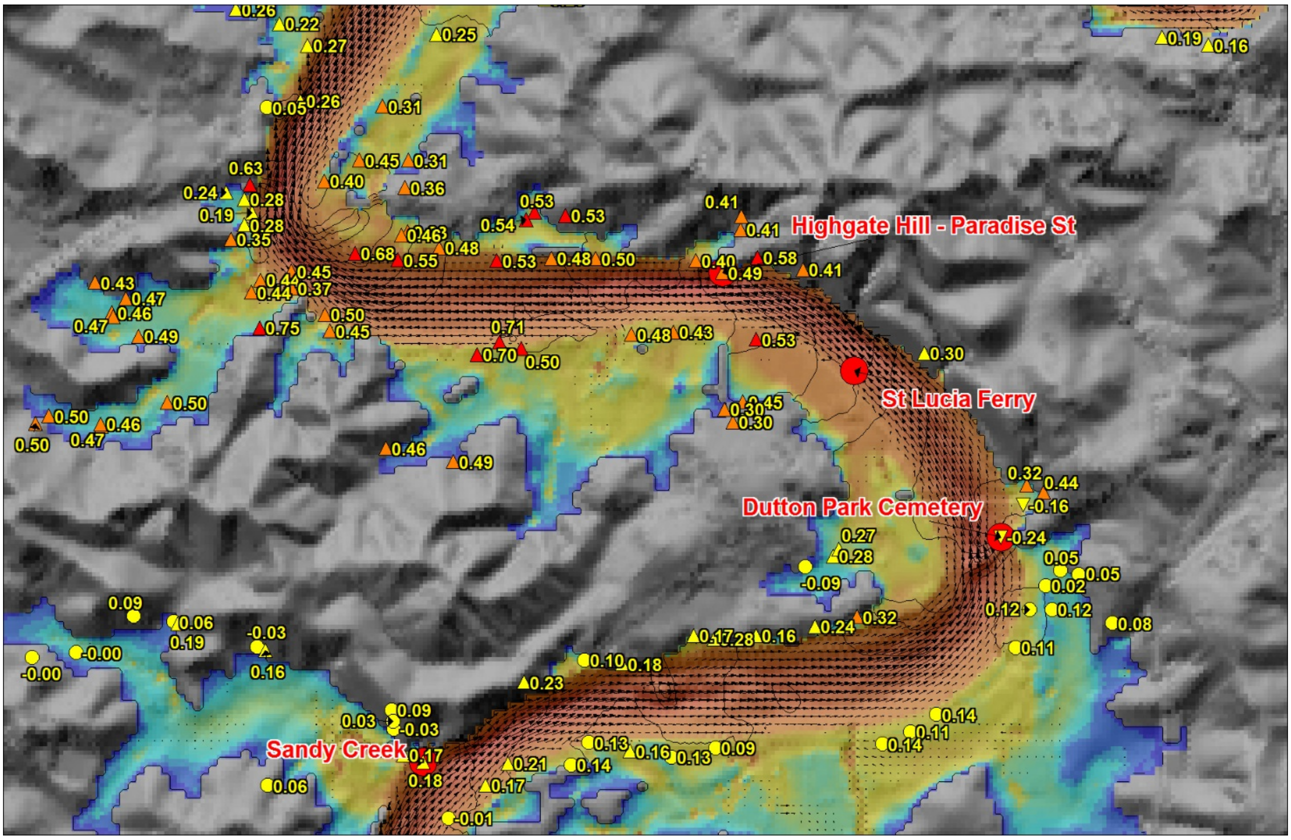


Figure 4-16 St Lucia Reach Flood Marks for 1974

(Yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

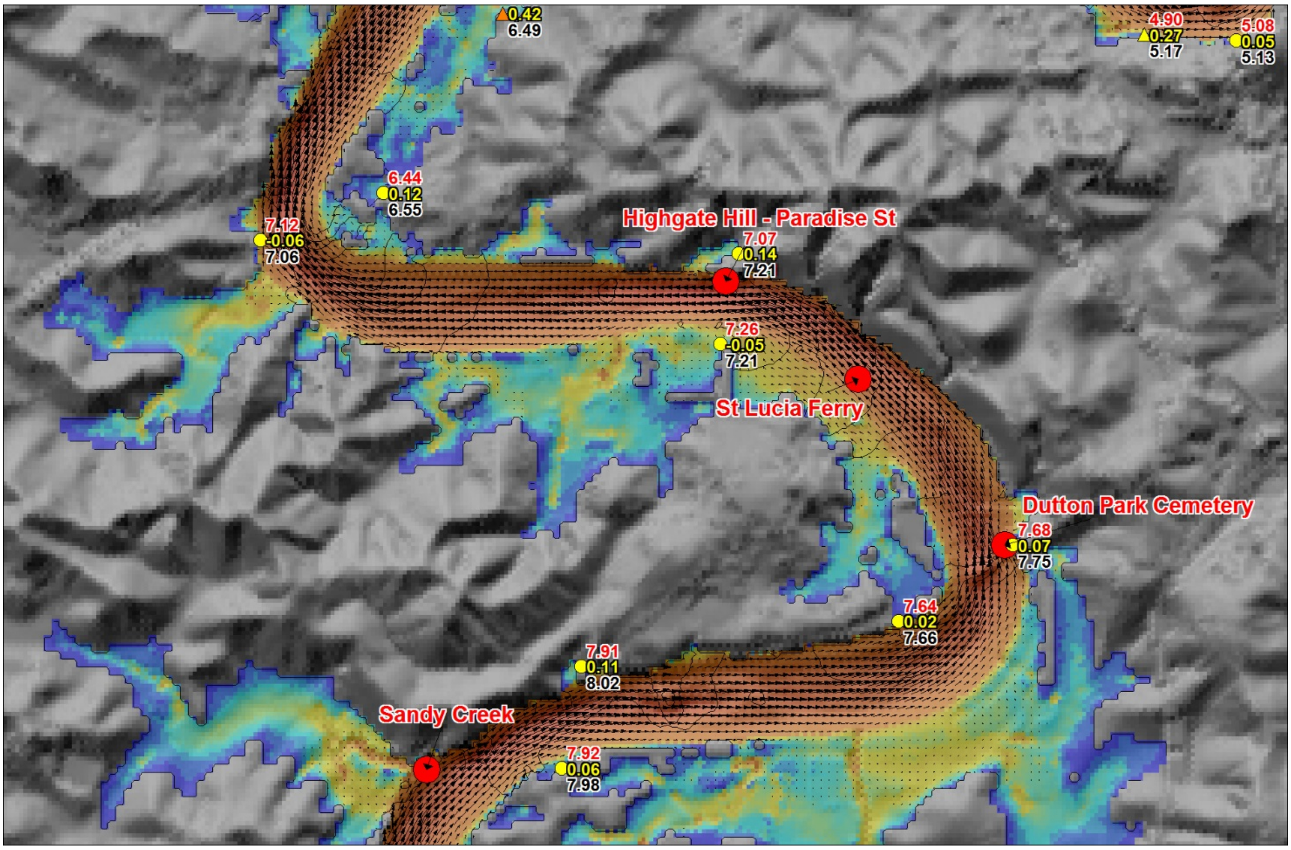


Figure 4-17 St Lucia Reach Flood Marks for 2011

(Red font for surveyed level, black font for modelled level and yellow font for modelled minus surveyed)
(Water level contours at 0.1m intervals)

4.9 2013 Flood Flows

As for 2011, the 2013 flood flows were measured off Centenary Bridge several times near the flood peak and during the drain down phase of the Wivenhoe Dam releases. The model produces a satisfactory match during the 2013 drain down phase dam releases, but underestimates the flood peak measurements (see Plot 4). Of note is that the 2013 drain down phase releases of around 1,750 m^3/s from Wivenhoe Dam would have a good accuracy, whilst at the flood peak the flows are subject entirely to uncertainties in the URBS modelling as there were no Wivenhoe Dam discharges during the peak. Also of note, is that for the 2011 event when similar flow measurements were made off Centenary Bridge, the model reproduces both the flows at the flood peak and during the drain down phase dam releases.

For 2013, there is also a tendency to under predict the Brisbane River flood gauges (see Plot 3) at the flood peak, but provide a satisfactory match or slightly high for the drain down phase releases.

Further investigations through model testing and checking of inflows were made as to why the under prediction occurs at the peak. Also of note is that the Fast Model shows a similar issue, but produces greater flows than the Detailed Model prior to and at the peak. Quality control checks on the volume of inflows to the Detailed Model were repeated and confirmed that both models applied all the inflow hydrographs generated by the URBS model.

Further examination of results between Fast and Detailed Models showed that the Detailed Model in Lockyer Creek and the Bremer River attracted greater quantities of flow onto the floodplains causing the flood peaks in the Lockyer Creek and Bremer River to be lowered by around 150 to 200 m^3/s each, causing the 300 to 400 m^3/s difference in flows between Fast and Detailed Models leading up to the flood peak. A cross-check on the total volumes in the Fast and Detailed Models showed the volume difference between models was equivalent to the difference in area under the flow curve at Centenary for the two models. The Detailed Model is therefore extracting and retaining a greater quantity of flood waters on to the floodplain than the Fast Model for the 2013 event, with the amount being approximately 7% of the combined total inflow into Lockyer Creek and the Bremer River, or 3% of the total inflow to the model if Wivenhoe Dam outflows are included.

The more significant discrepancy with the measured flows was further investigated and it was concluded that:

- Adjusting Manning's n and/or form loss values to improve the calibration to the peak water levels only reduces the peak flows and provides a greater discrepancy with the measured flows at the peak. This also worsens the calibration quality for all the other events.
- The cause for the discrepancy is most likely due to uncertainties in the hydrology inflows. It was initially thought that the unusually high continuing loss rates for the Lockyer and Bremer catchments when compared to the other calibration events may have been the cause. The 2013 event has the highest initial loss and continuing loss rates of all the calibration events, with continuing loss rates more than twice any other event. Reducing the continuing loss rates for the Lockyer and Bremer River would produce more flow at the flood peak, without changing the flow rate during the drain down phase of dam releases. However, Seqwater advised[15] that although the high loss rates were unusual, they were based on successful calibration to good data for more than one event. Instead, Seqwater suggested that the timing of the flood peaks at Ipswich, produced by the Hydrology Assessment during recalibration of the URBS model, occur before the observed flood peak at the gauge. This timing may result in the timing of peak flow in the Bremer not aligning realistically with the peak flow coming down the Brisbane River and as a consequence, the peak flow at Centenary is not achieved.

4.10 Detailed Model Accuracy and Tolerances

The accuracy of flood levels and flows calculated by the Detailed Model is a function of the greatest uncertainties. These uncertainties are considered to be:

- The hydrologic modelling, rainfall distribution and rainfall loss representation.
- The in-bank topographic data where the 2D bathymetry or 1D cross-sections are reliant on LiDAR. These areas are notably:
    - Lockyer Creek
    - Between Wivenhoe Dam and Kholo Bridge
    - Downstream of Mt Crosby Weir to the start of the bathymetric survey

[15] Comments received on Milestone Report 3 (this report) on 19 June 2015.

  - Non-tidal reaches of Bremer, Warrill and Purga Creeks.

- The influence of farm levees and other works either not well defined by the LiDAR surveys, or built subsequent to the LiDAR surveys, particularly on the flood levels in the Lockyer Creek floodplains.
- For the 1D sections of the Detailed Model, where there are high in-bank velocities causing a significant variation in water level across the river/creek at a sharp bend (ie. superelevation). The only location this is possibly an issue is at Berry's Lagoon on the Bremer River.

When comparing 1D and 2D schemes the following points are noted:

- In areas of complex flow where water flows in varying directions, 2D schemes are superior to 1D schemes (for example, being able to model the superelevation effects around Kangaroo Point (see Figure 4-1). In areas of uniform flow, there is significantly less difference between 1D and 2D solutions that solve the complete equations.
- For both 1D and 2D schemes the tolerance or accuracy of predicted flood levels will vary substantially depending on a wide range of factors (as discussed above). The improvement in accuracy between using a 1D and 2D solution will also vary substantially depending on the complexity of flow, however, this will generally be relatively minor compared to the uncertainties associated with the rainfall and hydrologic modelling and in some areas the in-bank topographic data.

Given that the significant majority of levels, including flood marks, fall within the desired tolerances for the model calibration and verification events, and that these events represent a wide range in terms of flood magnitudes and behaviour, these tolerances are considered to indicative of the accuracy of the Detailed Model for events up to around the 1% AEP event on the assumption that the 1% event will be of similar magnitude to one of the 1893/1974/2011 events. The tolerances are:

- Brisbane River downstream of Oxley Creek ± 0.15 m
- Brisbane River between Goodna and Oxley Creek ± 0.30 m
- Ipswich urban area ± 0.30 m
- Brisbane River and tributaries upstream of Goodna (for non-urban areas), including Bremer River and Lockyer Creek ± 0.50 m.

For events larger than the calibration events, these tolerances, from a hydraulic modelling viewpoint, would increase due to lack of calibration data, but by how much is difficult to quantify, but the more extreme the event, the greater the tolerances. Also, for these extreme events, the much greater uncertainties in the hydrologic derivation of the flows for these events would imply even greater tolerances.

It is important to note that due to the uncertainties discussed above, and the need to take into account the sensitivity of peak water levels to the local topography, parameter uncertainties, and other effects, it is not appropriate to simply apply these tolerances when setting planning levels or quantifying a freeboard. The sensitivity of peak flood levels to variations of hydrologic and hydraulic modelling parameters, future catchment conditions and development, climate change, and local topographic effects, need to be taken into account. For example, peak water levels along Lockyer Creek change little once the creek is overtopped due to the large floodplain, where as many sections of the Brisbane River the levels change significantly due to the shortage of a large floodplain.

The Detailed Model demonstrates a consistent and matched reproduction of the travel time and shape of the flood wave for all floods after accounting for any bias carried through from the hydrologic modelling.

There is some evidence that the Manning's n roughness values should be reduced post flood peak, as flood levels along the Brisbane River during the drain down phase of the Wivenhoe Dam releases may be over estimated by the model in some locations, notably Savages Crossing and Moggill. There is also historical evidence of this occurring as discussed in Section 4.6. This effect does not appear to have a bearing on peak flood level and flood hazard mapping, or on the rate of rise of the flood wave.

5 Rating Curve Review

The primary purpose of the review of the rating curves at gauges focuses on the requirements for consistency between the Hydrologic and Hydraulic Assessments, as well as improving our understanding of the stage-discharge relationships at key stream gauging stations, particularly at those locations affected by backwater, with the aim of further refining the existing rating curves as appropriate. The background to the development of the rating curves is summarised as follows:

- Seqwater undertook initial development of the Hydrologic Assessment URBS models and completed a review of the rating curves as part of this work in 2013. The Seqwater investigations undertook extensive calibration to over 35 flood events and this was undertaken conjunctively with a review of the rating curves. This meant that the rating curves informed the calibration of the URBS models and the calibration results were also used to improve the curves. The Seqwater review investigated a broad range of data, however, the Seqwater review only had access to limited hydraulic modelling analyses.
- The Hydrologic Assessment (Aurecon) undertook a further extensive review of the rating curves in 2014 and 2015. The Aurecon review completed a range of further independent and localised hydraulic modelling to inform the review of the rating curves, however only limited calibration was carried out for some of this hydraulic modelling. The DMT modelling results was also used in the latter stages of the review. Some rating curves were revised as part of the Aurecon Review. Aurecon then recalibrated the URBS models, however, this recalibration was limited to the five historical flood events of 1974, 1996, 1999, 2011 and 2013. The key aspects of the rating curves for the Hydrologic Assessment, in order of importance are:
    - The rating curves were used to convert recorded peak gauge height to estimates of rated flow for use in the flood frequency analysis. The flood frequency analysis was then used to reconcile the design AEP peak flow and volume estimates from the Monte Carlo Simulation and Design Event Approach estimates. In this context the rating curves have significant importance for the flood frequency estimates arising from the BRCFS. If significant revision of the rating curves is identified as necessary, the flood frequency analysis may need to be revised and the design AEP peak flow and volume estimates may need to be updated.
    - The revised rating curves were used to recalibrate the URBS models. The purpose here was to confirm the range and 'best fit' of URBS routing parameters that should be used in design flood and Monte Carlo hydrologic modelling. The recalibration performed by Aurecon produced different estimates of historical flood flow hydrographs compared to the estimates derived in the Seqwater model calibration. Considering the different focus of the Seqwater and Aurecon work, these differences are generally of little consequence to the Hydrologic Assessment, but may be important for the Hydraulic Assessment Fast and Detailed Models calibration. The 'best fit' routing URBS parameters were not significantly different to the Seqwater estimates for the URBS models where the catchment vector configuration was not changed.
    - Whilst the URBS model hydrologic calibration and flood frequency analysis are critically dependent upon the rating curves, the rating curves were also reviewed and adjusted by

Aurecon as part of an iterative process in order to achieve consistency of the Hydrologic Assessment results between gauges in each model (representing each sub-catchment) as well as the whole system (catchment-wide).

- The Hydraulic Assessment modelling has relied upon estimates of the historical flood flow hydrographs produced by the Hydrologic Assessment URBS model recalibration for calibration of the Fast and Detailed Models. This means that to some extent the Fast and Detailed Models' calibration is dependent on the rating curves adopted by Aurecon to calibrate the Hydrologic Assessment URBS models. On this basis, it is important for the Fast and Detailed Models information be used to review the rating curves at key gauges to understand the consistency of the rating curve used in the Hydrologic Assessment to deem that the "combined" hydrology and hydraulics model calibrations are acceptably consistent. If significant differences, within the bounds of data inaccuracies and modelling assumptions and uncertainties, are evident it may indicate a need to:
  - revise the entire calibration processes to achieve acceptable closure of the differences, and
  - revise the flood frequency analyses applied in the Hydrologic Assessment as this is important information to reconcile and "adjust" parameters used the design flood estimates arising from the Monte Carlo and design flood event simulations.

The review presented in this section provides a comparison between the rating curves developed by Seqwater and the Hydrologic Assessment to inform the calibration of the URBS models, with the stage-discharge relationships produced by the calibrated Fast and Detailed Models. Based on this comparison a resolution is required as to whether the calibration of the URBS models, and the calibration of the Fast and Detailed Models are compatible or not. If the comparison is considered to be incompatible such that the quality of the hydrologic and hydraulic model calibrations is compromised, within the bounds of data inaccuracies and modelling uncertainties, the calibration of the URBS, Fast and Detailed Models would need to be revised.

The extensive review of the existing rating curves generated by Seqwater, DNRM, BoM and other sources carried out as part of the Hydrologic Assessment are presented in the Data, Rating Curve and Historical Flood Review Report (Aurecon, 2015d) and summarised in the Draft Final Hydrology Report (Aurecon, 2015c). The Seqwater and Hydrologic Assessment (Aurecon) curves are shown on the rating curve plots discussed in this section.

The Fast and Detailed Models, as hydraulic models, produce plots of flow versus water level (the stage-discharge relationship), from which the existing rating curves including those adopted for the Hydrologic Assessment can be compared and refined as appropriate.

Importantly, the stage-discharge relationship at a site can vary, resulting in different flows at the same water level. This hysteresis or looping in the curve occurs where the flood surface gradient and/or backwater effects vary during the flood. For example, flows are usually higher on the rising limb than the falling limb due to the steeper flood surface gradient on the flood rise. Where variable backwater effects occur, for example the tide or the Brisbane River backing up the Bremer River, there can be considerable differences in flows resulting in substantial looping in the stage-discharge relationship, with the greater the backwater effect the lower the flow. Of importance is that where there is little or no hysteresis in the relationship, a reliable rating curve can be derived.

Where hysteresis does occur there is no single rating curve that can represent the stage-discharge relationship.

It is to be noted that different models (eg. URBS hydrologic model and the Fast and Detailed hydraulic models) have varying abilities to represent the complex and variable looping characteristics of rating curves. The hydraulic models with their ability to reproduce variations in hydraulic gradients as the flood rises and falls, and to take into account more accurately the effects of backwater, are considered significantly more accurate in this regard, however, there is always some degree of uncertainty associated with the input data and modelling approximations.

Importantly, comparison of the rating curves needs to take into account these influencing factors including, but not limited to: input data inaccuracies; modelling assumptions and uncertainties; the different hydraulic behaviour of different events; and variations in hydraulic behaviour causing hysteresis.

Plot 28 to Plot 33 present the results from the Fast and Detailed Models plotted against the existing rating curves developed by Seqwater and Aurecon (Hydrologic Assessment). Each site is discussed in detail in the following sections, with observations and preliminary recommendations provided.

In interpreting Plot 28 to Plot 33 (also reproduced in Figure 5-1 to Figure 5-10), note that:

- Detailed Model stage-discharge loops are shown using dark green symbols with different symbol shapes for different events as per the legend.
- Fast Model results are shown in red with the same symbol shapes as the Detailed Model for different events.
- Seqwater rating curves are shown using dark blue circles.
- Aurecon (Hydrologic Assessment) rating curves use cyan (light blue) circles.
- Available gauging information from any past floods, including ones other than the calibration events are shown as a yellow circle. Only a few of the sites have available gauging information.
- Where backwater or tidal effects occur, the Fast and Detailed Model results show a more pronounced hysteresis or looping, with the lower side of the loop (higher flows) occurring during the flood rise, and the higher side (lower flows) on the flood recession.
- The Brisbane City Gauge results show the strong effect of the ocean tide at the lower levels.

General observations are summarised as follows:

- The most noticeable differences occur during the in-bank stages of Glenore Grove and Rifle Range, and the higher stages of Loamside. For Glenore Grove and Rifle Range the in-bank differences could be due to the uncertainties associated with using LiDAR for in-bank areas and the inaccuracies associated with deriving the rating curves.
- There is some looping (hysteresis) effects at some gauges. Where this occurs the rating curves tend to match with the rising limb of the flood (ie. with the lower side of the hysteresis curve).

- At gauges such as Mt Crosby and Moggill there is a noticeable difference between the major floods of 1974 and 2011, despite having similar peak flows at Mt Crosby. This is most likely due to the different flood shapes; the 2011 flood, due to the influence of Wivenhoe Dam, was a shorter, sharper shape with less volume than the 1974 event. The Bremer River flow entering at Moggill in 1974 was also greater than 2011 making 1974 larger than 2011 downstream of the rivers' confluence. This is aptly illustrated at the lower Brisbane gauges where the flood level was above 10 mAHD for around 3 days in 1974, but less than 2 days in 2011.
- The review of the Hydrologic Assessment (Aurecon) rating curves presented in this section considers the curves to be commensurate with the hydraulic modelling stage-discharge relationships within the bounds of data inaccuracies, modelling uncertainties, hysteresis effects, and variations in hydraulic behaviour of the different calibration events. On this basis it is considered that there is no justifiable benefit in revising the hydrologic and hydraulic modelling calibrations. However, given the importance of signing off on the hydrologic and hydraulic modelling calibrations before proceeding with the design flood modelling, it is recommended that an independent expert opinion from the IPE on whether there should be any further consideration or refinement of the hydrologic and hydraulic modelling calibrations is sought before proceeding to the design flood modelling.
- Subject to the IPE's views and any necessary refinements, it is intended that the final set of consistent, robust and preferred rating curves will be developed in consultation with the key stakeholders involved and included as part of Milestone Report 5.

Whilst the Hydraulic Assessment aims to achieve a consistent and robust set of rating curves at key gauge sites, it is noted that different organisations will utilise the rating curves for different purposes, and may choose or not choose to adopt or refine rating curves based on the findings of the Hydraulic Assessment in the future. As can be seen in the following sections, there are uncertainties in the stage-discharge relationship due to hysteresis, along with uncertainties associated with the derivation of the existing (including Seqwater and Aurecon) rating curves, in the topographic data and in the hydrologic and hydraulic modelling. There is also the question over whether to follow the rising limb or the level at the peak flow, as these two approaches can yield different rating curves unless there is no hysteresis. For example, Wivenhoe Dam operators may prefer to use rating curves aligned with the rising limb of a flood when decisions on dam releases are critical, whilst BoM and Councils may prefer to use curves based on the water level at the peak flow if forecasted gauge levels are to be derived from real-time peak flow forecasts.

The rating curves at key gauge sites within the Hydraulic Assessment study area are also important to organisations such as Seqwater, DNRM, BoM, and Councils, for operation of Wivenhoe Dam, for water resources planning and management and for flood forecasting and warnings. The rating curves provide estimates of (a) flow based on measured or predicted flood levels to assist, for example, in operating Wivenhoe Dam releases and in complying with *Water Resource (Moreton) Plan 2007*, and (b) to provide estimates of flood levels based on forecasted flows for flood warning and evacuation operations. Ultimately, it is the responsibility of each organisation to derive and utilise rating curve(s) that meet their particular objectives and ongoing operational needs.

The information and plots in this section may also provide some guidance to organisations in terms of interpreting the uncertainties and level of hysteresis at each gauge site to further refine the existing rating curves as appropriate for their needs. This information, together with the hydraulic modelling information obtained during design event simulations using the Detailed Model, may assist to inform extrapolation of the rating curves to levels beyond historical records or gaugings.

5.1 Loamside (Purga Creek)

The Seqwater and Aurecon rating curves for Loamside on Purga Creek are presented in Plot 28 and Plot 31, and repeated in Figure 5-1. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 28) and hypothetical extreme floods (Plot 31).

Aurecon *et al* (2015c) Commentary

Catchment:	Purga Creek to Loamside	DNRM rating up to 6m then hydraulic model results
Stream:	Purga Creek	Generally good fit of flow gaugings and hydrologic model data. Rating is considered to be reasonable, but becomes very sensitive to changes in level above 7.5m (170m³/s)
Site:	Loamside	
Gauge No:	143113A	
Owner:	DNRM	

Observations

- For flows below 800 m^3/s, which covers all the calibration events, there is little or no hystereris in the model results indicating the site is a suitable rating location for flows up to this magnitude.
- For flows above 800 m^3/s, a significant hystereris can develop as seen for the 1.5x1974, 5x1974 and 8x1974 events. This would be due to backwater effects from the Brisbane River. Loamside is, therefore, not well-suited as a rating site once backwater effects of the Brisbane River take place. For the floods simulated, a consistent rating is seen on the rising limb (lower side of the curve) up to around 1,400 m^3/s.
- The Seqwater and Aurecon rating curves have a similar shape to the stage-discharge relationship from the Fast and Detailed Models, but sit lower by 0.5 to 0.8m. This offset is most likely due to inaccuracies in vertical elevations of the LiDAR that was used for the modelling in this area, especially for heavily vegetated in-bank sections.

Conclusions and Preliminary Recommendations

- The stage-discharge relationship is reliable up to around 800 m^3/s, and on the rising limb up to higher flows depending on the presence of backwater effects from the Brisbane River. The site is unsuitable for rating flows once Brisbane River backwater effects occur.
- In the absence of more accurate ground survey topography, the Loamside rating curves should be preferred over those from the Detailed Model due to uncertainties over the vertical accuracies in the LiDAR used by the model, particularly for in-bank flows. However, the rating curves would benefit from a cross-check of the topography used to generate the curves and a comparison with the Detailed Model topography, which is based on the LiDAR.
- The Aurecon and Seqwater curves are similar, with the Aurecon curve most likely preferred due to its more recent derivation.

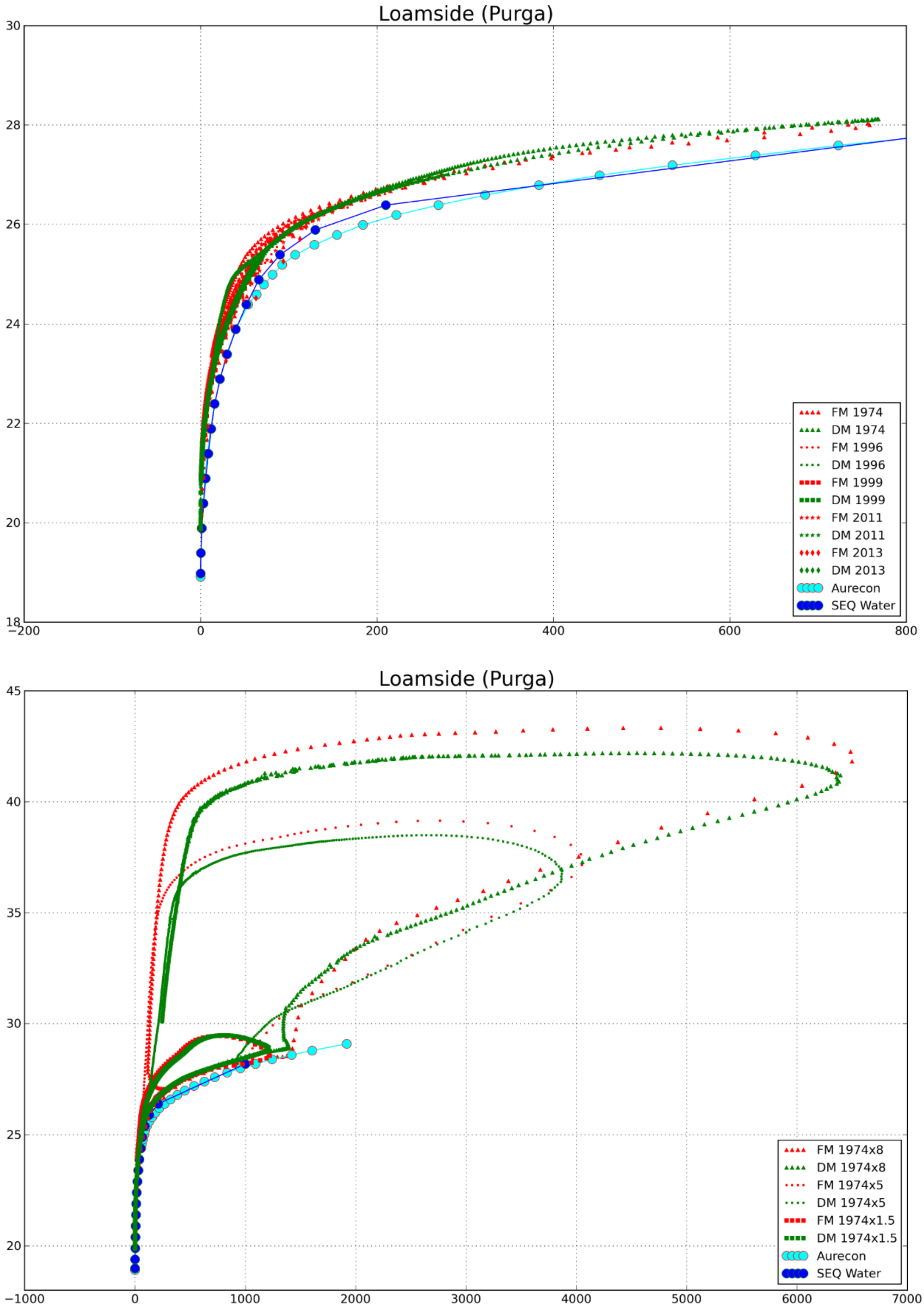


Figure 5-1 Loamside Rating Curve Comparison with Calibration and Extreme Events

5.2 Amberley (Warrill Creek)

The Seqwater and Aurecon rating curves for Amberley on Warrill Creek are presented in Plot 28 and Plot 31, and repeated in Figure 5-2. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 28) and hypothetical extreme floods (Plot 31).

Aurecon *et al* (2015c) Commentary

Catchment:	Warrill Creek to Amberley	Power-law fit of data up to 5m then hydraulic model results
Stream:	Warrill Creek	Good fit of flow gaugings. Deviates significantly from Seqwater rating above 8m due to breakout of flows upstream of gauge location. Rating is considered to be good, but becomes very sensitive to changes in level above 10m (1200m³/s)
Site:	Amberley	
Gauge No:	143108A	
Owner:	DNRM	

Observations

- For flows below 2,000 m^3/s, which covers all the calibration events, there is little or no hystereris in the model results indicating the site is a suitable rating location for flows up to this magnitude.
- A significant hystereris can develop, as seen for the 5x1974 and 8x1974 events, due to backwater effects from the Brisbane River. Amberley is, therefore, not well-suited as a rating site once backwater effects of the Brisbane River take place.
- The Seqwater and Aurecon rating curves have a similar shape to the stage-discharge relationship from the Fast and Detailed Models, with the Aurecon curve providing the best match.
- A number of streamflow gaugings are available for Amberley as shown by the yellow circles. The Fast and Detailed Model results, and the rating curves, align with the gaugings providing confidence in the rating curves and the models at Amberley.
- There is no evidence of the vertical shift between the rating curves and the models as occurred at Loamside (see Section 5.1). This is of interest in that the Fast and Detailed Models use the same LiDAR data for in-bank and overbank ground elevations at Loamside and Amberley.

Conclusions and Preliminary Recommendations

- The stage-discharge relationship is reliable up to around 2,000 m^3/s depending on the presence of backwater effects from the Brisbane River. The site is unsuitable for rating flows once Brisbane River backwater effects occur. However, reliable flows can be estimated on the rising limb prior to any backwater effects.
- The Aurecon curve matches with the model results and is recommended as the preferred rating curve for Amberley. The curve could be further extended using the rising limb for floods exceeding 3,000 m^3/s, provided there are no backwater effects occurring.

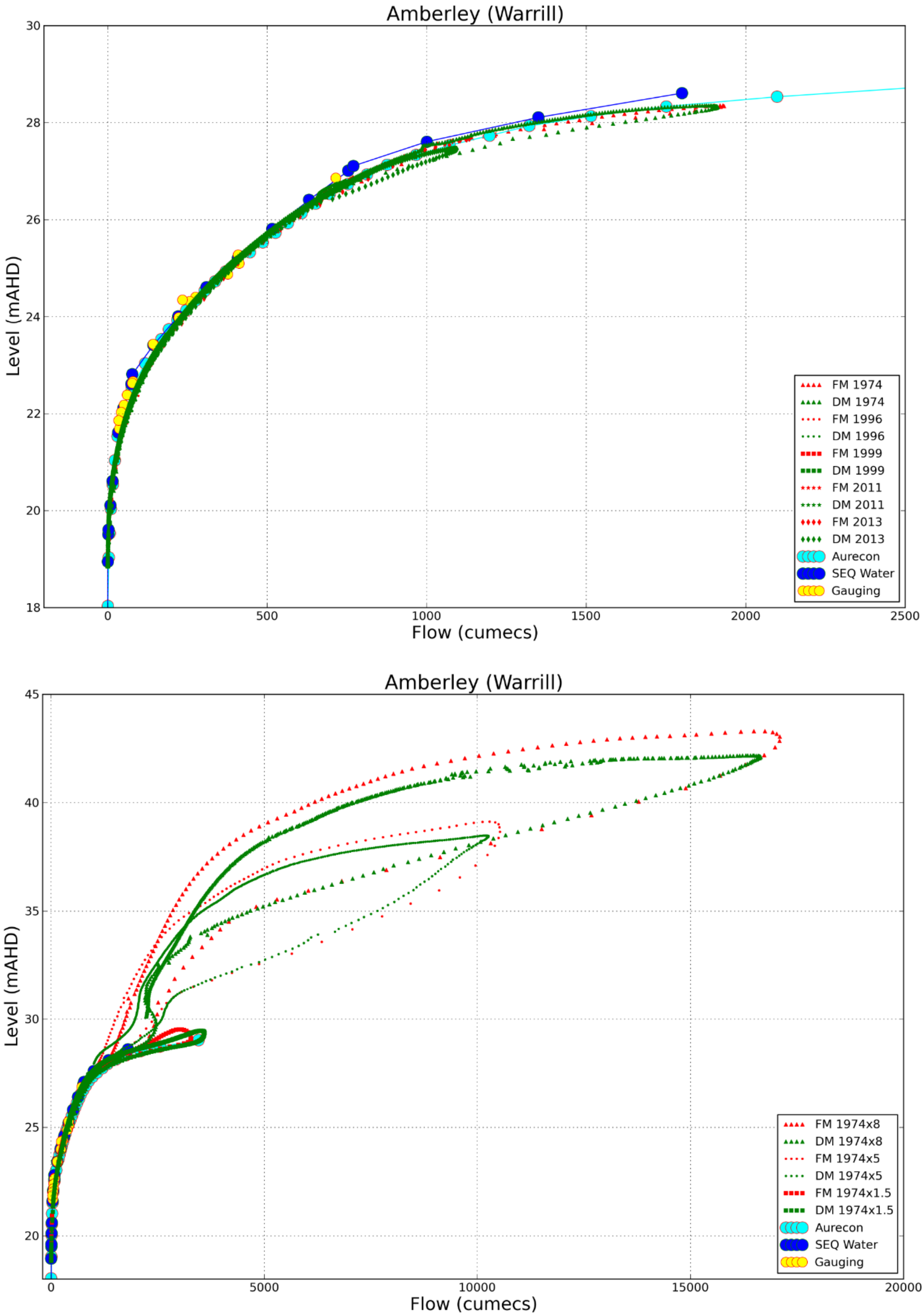


Figure 5-2 Amberley Rating Curve Comparison with Calibration and Extreme Events

5.3 Walloon (Bremer River)

The Seqwater and Aurecon rating curves for Walloon on the Bremer River are presented in Plot 28 and Plot 31, and repeated in Figure 5-3. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 28) and hypothetical extreme floods (Plot 31).

Aurecon *et al* (2015c) Commentary

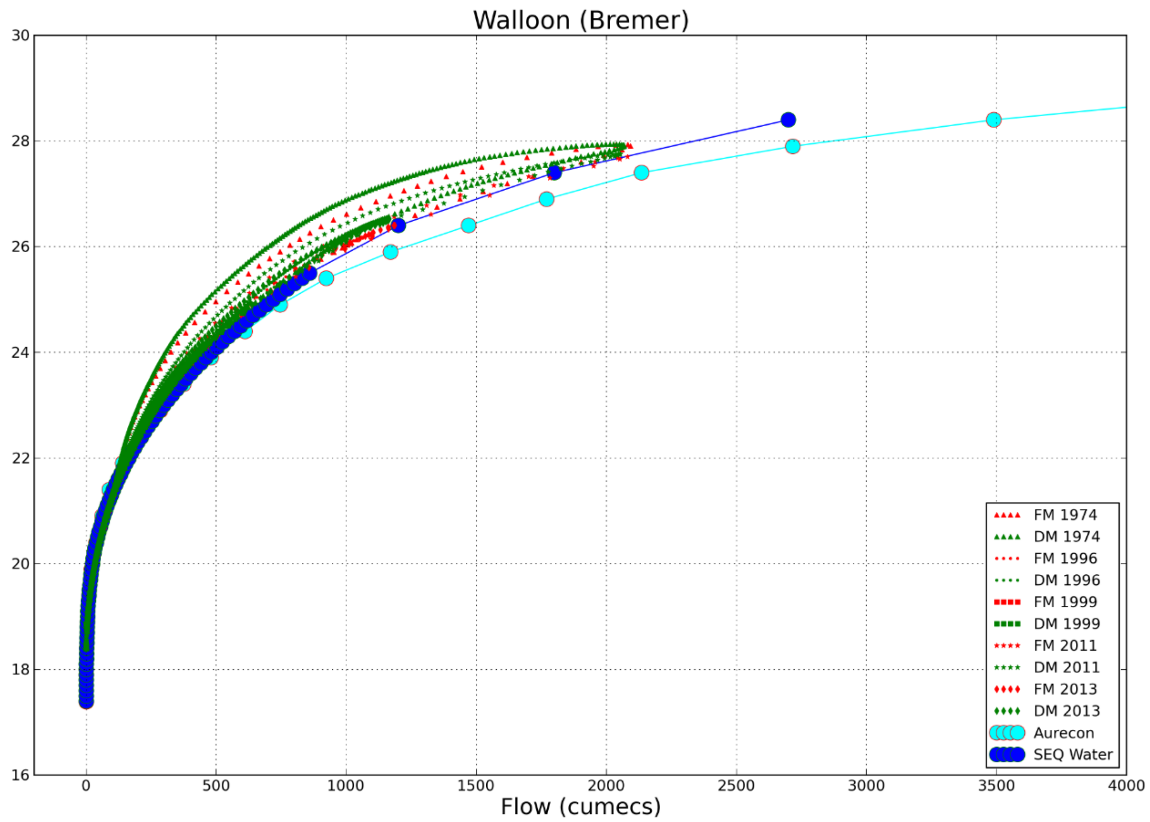
Catchment:	Bremer River to Walloon	DNRM rating up to 5m then hydraulic model results
Stream:	Bremer River	Generally good fit of flow gaugings and hydrologic model data up to about 9m. Rating becomes fairly sensitive at high flows and potentially affected by backwater from major Brisbane River/Warrill Creek floods due to 'choke point' that forms in the reach downstream of the Warrill Creek confluence.
Site:	Walloon	
Gauge No:	143107A	
Owner:	DNRM	

Observations

- For flows up to around 2,000 m^3/s, which covers all the calibration events, there are minor hystereris effects in the model results indicating the site is a reasonable rating location for flows up to this magnitude.
- A significant hystereris can develop due to backwater effects from the Brisbane River as seen for the 1.5x1974, 5x1974 and 8x1974 events. Walloon is, therefore, not well-suited as a rating site once backwater effects of the Brisbane River take place. The exception would be that flows on the rising limb prior to any backwater effects taking place would be considered reliable.
- The Seqwater and Aurecon rating curves have a similar shape to the stage-discharge relationship from the Fast and Detailed Models, with the Seqwater curve providing the best match.
- There is is no evidence of the vertical shift between the rating curves and the models as occurred at Loamside (see Section 5.1). This is of interest in that the Fast and Detailed Models use the same LiDAR data for in-bank and overbank ground elevations at Loamside and Walloon.

Conclusions and Preliminary Recommendations

- The stage-discharge relationship is reliable up to around 2,000 m^3/s depending on the presence of backwater effects from the Brisbane River. The site is unsuitable for rating flows once Brisbane River backwater effects occur. However, reliable flows can be estimated on the rising limb prior to any backwater effects.
- The Seqwater curve matches with the model results and is recommended as the preferred rating curve for Walloon. The curve could be further extended along the rising limb of floods exceeding 2,500 m^3/s, provided there are no backwater effects occurring.
- As the Aurecon curve is not significantly different compared to the preferred rating curve, further consideration for any likely revision or refinement of associated Hydrology Assessment work is not warranted.



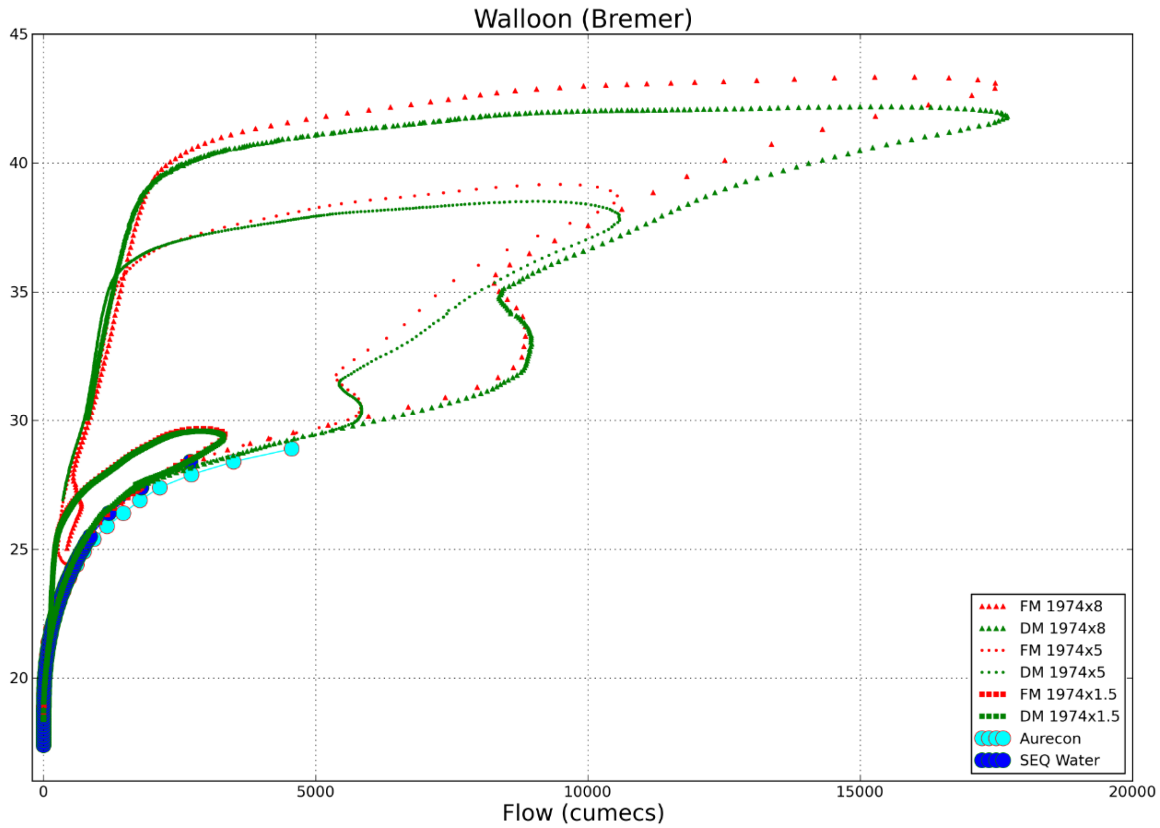


Figure 5-3 Walloon Rating Curve Comparison with Calibration and Extreme Events

5.4 Glenore Grove (Lockyer Creek)

The Seqwater and Aurecon rating curves for Glenore Grove on Lockyer Creek are presented in Plot 29 and Plot 32, and repeated in Figure 5-4. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 29) and hypothetical extreme floods (Plot 32).

Aurecon *et al* (2015c) Commentary

Catchment:	Lockyer Creek to O'Reilly's Weir	Power-law fit of data up to 2.5m then hydraulic model results
Stream:	Lockyer Creek	Rating is considered to be good up to around 13m (900m³/s) with generally good fit of flows (translated from Lyons Bridge) and hydrologic model data. Generally good agreement above this level and rating is considered reasonable, but becomes very sensitive to changes in level
Site:	Glenore Grove	
Gauge No:	143807	
Owner:	BoM	

Observations

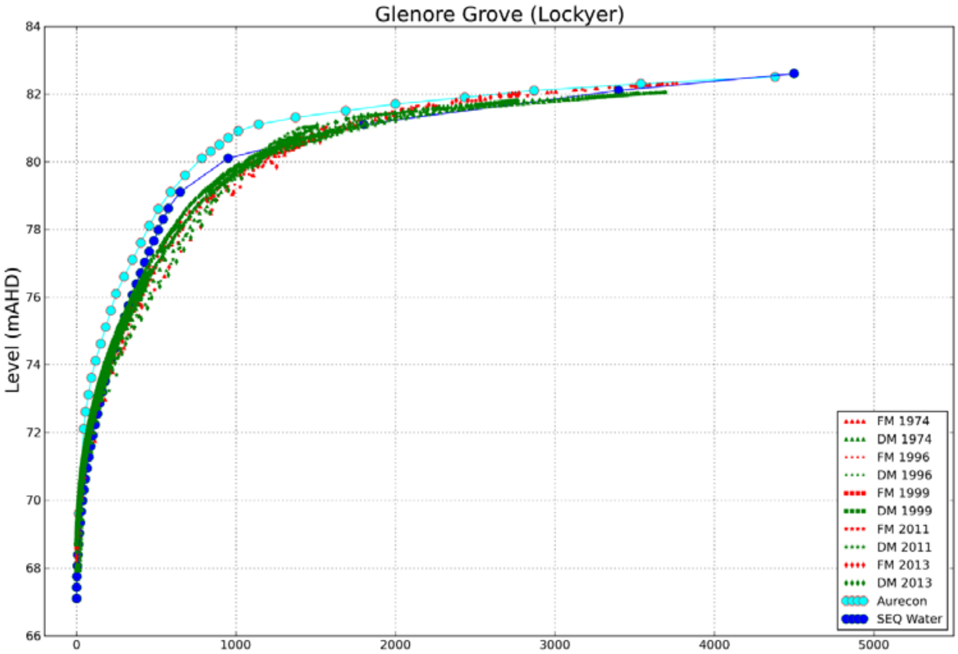
- For flows up to around 4,000 m^3/s, which covers all the calibration events, there are minor hysteresis effects in the model results indicating the site is a reasonable rating location for flows up to this magnitude.
- For larger events, little or no hysteresis effects occur as seen for the 1.5x1974, 5x1974 and 8x1974 events. Glenore Grove is, therefore, well-suited as a rating site at all levels, and the presence of the large Lockyer Creek floodplains downstream seems to have little influence on the stage-discharge relationship.
- The Seqwater and Aurecon rating curves have a similar shape to the stage-discharge relationship from the Fast and Detailed Models, although there is a vertical shift of around 1.0m with the Aurecon curve. The Seqwater curve is a closer match to the model results.
- The large Lockyer Creek floodplains have a pronounced influence on the shape of the stage-discharge relationship, with a major flattening of the curve at around 82 mAHD. The accuracy of the rating curve above this elevation is highly uncertain due to the flat-lining of the curve.
- Whilst the Seqwater and Aurecon curves are in closer agreement with the Fast Model at their limit of around 4,000 m^3/s, the results from the Detailed Model are considered more accurate.
- The stage-discharge accuracy of the Fast and Detailed Models for predominantly in-bank flows only, ie. less than around 1,000 m^3/s, would be subject to the vertical inaccuracies associated with using LiDAR for the in-bank topography.

Conclusions and Preliminary Recommendations

- Glenore Grove is a reliable rating curve location for all flows in that there is little or no hysteresis, however, it should be treated with considerable uncertainty once predominately overbank flows develop due to the flat-lining of the curve.
- The Seqwater curve matches best with the model results and is recommended as the preferred rating curve for Glenore Grove. Consideration should be given to fine-tuning the rating curve for flows in excess of 1,500 m^3/s based on the Detailed Model results. If the rating curve is

extended beyond 4,000 m^3/s, it is recommended that the Detailed Model stage-discharge relationship is used in preference to the Fast Model, however, as mentioned above, the extreme flat-lining of the relationship should be treated with meaning considerable uncertainty.

- As the Aurecon curve is not significantly different compared to the preferred rating curve, further consideration for any likely revision or refinement of associated Hydrology Assessment work is not warranted.



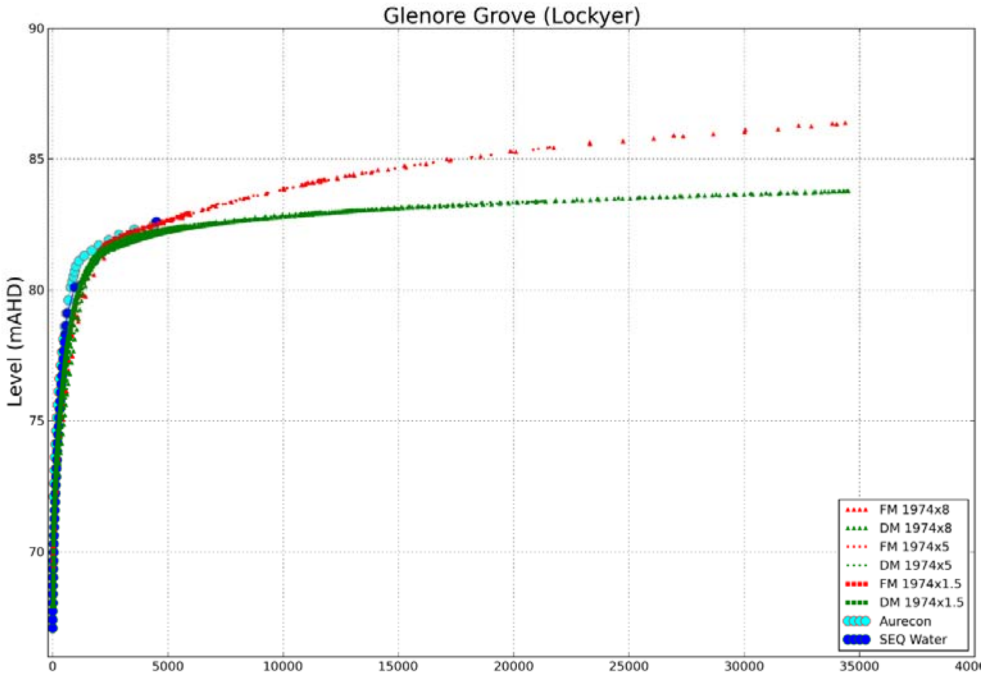


Figure 5-4 Glenore Grove Rating Curve Comparison with Calibration and Extreme Events

5.5 Rifle Range Road (Lockyer Creek)

The Seqwater and Aurecon rating curves for Rifle Range Road on Lockyer Creek are presented in Plot 29 and Plot 32, and repeated in Figure 5-5. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 29) and hypothetical extreme floods (Plot 32).

Aurecon *et al* (2015c) Commentary

Catchment:	Lockyer Creek to O'Reilly's Weir	Power law best-fit of flow gauging and hydrologic model data Reasonable fit of flow gauging data up to 15.85m (830m³/s). Perched channel in wide floodplain with unreliable and potentially inconsistent response above bank-full capacity. Rating should not be used above bank-full (15.5m approx)
Stream:	Lockyer Creek	
Site:	Rifle Range Rd	
Gauge No:	143229A	
Owner:	DNRM	

Observations

- For flows up to around 5,000 m^3/s, which covers all the calibration events, there are minor hysteresis effects in the Detailed Model results indicating the site is a reasonable rating location for flows up to this magnitude. The Fast Model shows a greater spread in the relationship, but is considered less accurate than the Detailed Model.
- For larger events, significant hysteresis effects can occur as seen for the 5x1974 and 8x1974 events once backwater effects from the Brisbane River take place. Rifle Range Road is, therefore, not well-suited as a rating site once backwater effects of the Brisbane River take place. The exception would be that flows on the rising limb prior to any backwater effects occurring could be considered useable, but subject to high uncertainty due to the flat-lining of the curve caused by the large Lockyer Creek floodplains.
- The Seqwater and Aurecon rating curves have a similar shape to the stage-discharge relationship from the Fast and Detailed Models, although there is a significant vertical shift of up to 2m or more for predominately in-bank flows (up to 1,000 m^3/s) and 0.5 to 1.0 m for flows exceeding 1,000 m^3/s. As for Glenore Grove, the flat-lining of the relationship once overbank flows develop make flow estimates considerably uncertain.
- The stage-discharge accuracy of the Fast and Detailed Models for predominantly in-bank flows only, ie. less than around 1,000 m^3/s, would be subject to the vertical inaccuracies associated with using LiDAR for the in-bank topography.

Conclusions and Preliminary Recommendations

- Rifle Range Road is potentially a reasonable rating curve location for in-bank flows with greater uncertainty once predominately overbank flows develop due to the flat-lining of the curve.
- If Rifle Range Road is to be used as a rating location, it would be beneficial to conduct a closer review of the differences between the rating curves and the stage-discharge relationship from the Detailed Model. However, there will always be considerable uncertainty in flow estimates once overbank flows develop, and for this reason, it is not recommended to use Rifle Range Road as a rating location.

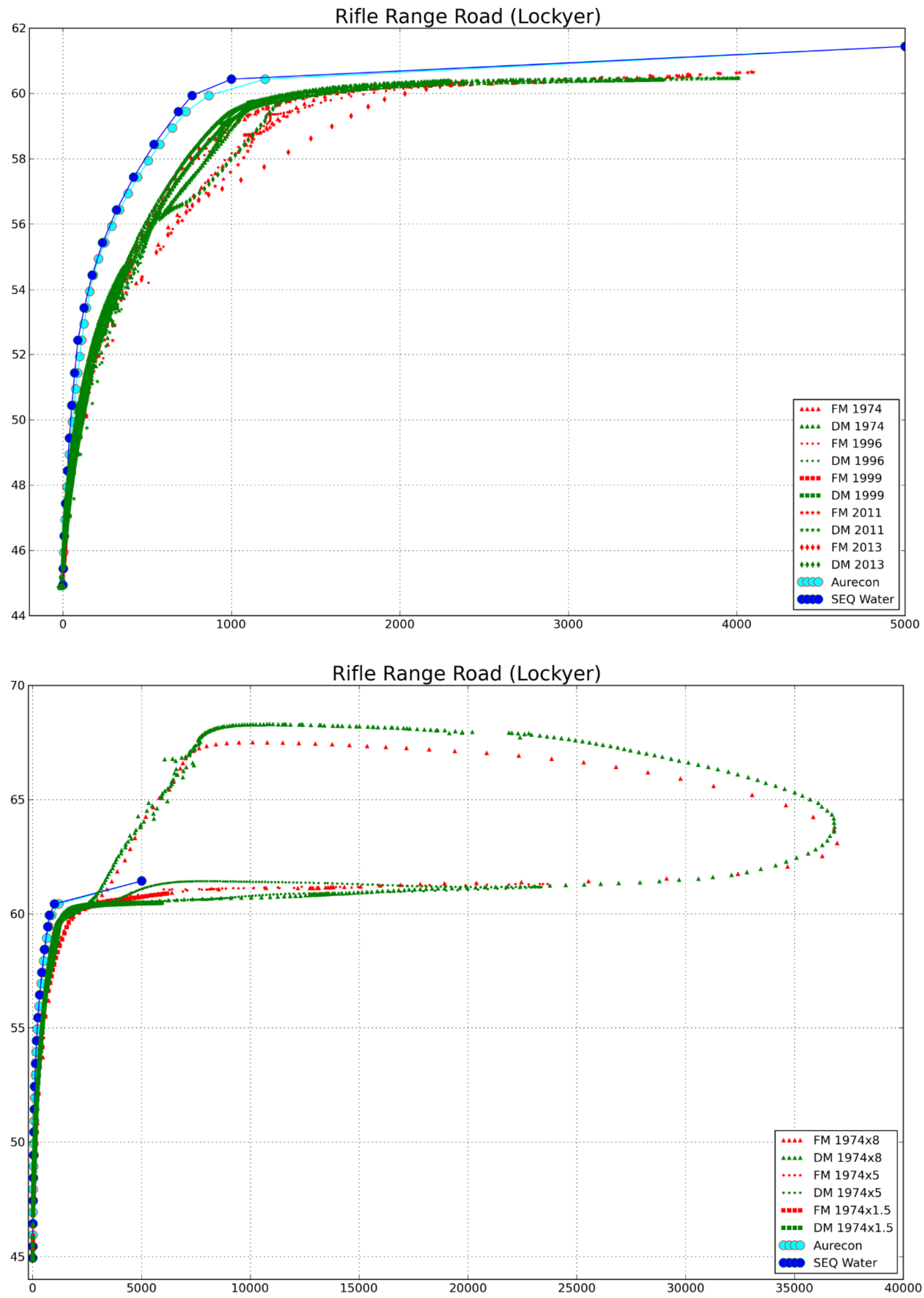


Figure 5-5 Rifle Range Road Rating Curve Comparison with Calibration and Extreme Events

5.6 Savages Crossing (Brisbane River)

The Seqwater and Aurecon rating curves for Savages Crossing on the Brisbane River are presented in Plot 29 and Plot 32, and repeated in Figure 5-6. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 29) and hypothetical extreme floods (Plot 32).

Aurecon *et al* (2015c) Commentary

Catchment:	Lower Brisbane River	Rating updated based on review of gaugings, steady-state release flows and DMT TUFLOW model results Rating provides reasonable fit of flow gauging, steady flow release and hydrologic model data. Well contained site but believed to be subject to changes in rating. Available data displays some historical variation, most notably an abrupt change during/after the 2011 flood event. Gauge is considered to be reasonably rated but not particularly consistent
Stream:	Brisbane River	
Site:	Savages Crossing	
Gauge No:	143001C	
Owner:	DNRM	

Observations

- For flows up to around 10,000 m^3/s, which covers all the calibration events, there are minor hysteresis effects in the model results indicating the site is a reasonable rating location for flows up to this magnitude.
- For larger events, minor hysteresis effects continue to occur as seen for the 1.5x1974, 5x1974 and 8x1974 events. Savages Crossing is, therefore, suited as a rating site at all levels noting that there is an uncertainty associated with hysteresis.
- A number of streamflow gaugings are available for Savages Crossing as shown by the yellow circles. The Detailed Model matches the gaugings closer than the Fast Model, and is also in better agreement than the rating curves. It should be noted that many of the gaugings are probably taken on the receding limb or during post-flood, steady-state, discharges from Wivenhoe Dam, and are therefore not reflective of the rising limb of the stage-discharge relationship results (note that the rising limb is on the lower side of the hysteresis loop).
- The Seqwater and Aurecon rating curves are comparable and have a similar shape to the stage-discharge relationships from the Fast and Detailed Models. There is a particularly close match between the rating curves and the rising limb of the Detailed Model results.

Conclusions and Preliminary Recommendations

- Savages Crossing is a reasonable rating curve location for all flows with minor hysteresis evident.
- The Aurecon and Seqwater curves match with the model results up to 10,000 m^3/s. For flows above 10,000 m^3/s, adjusting and extending the curve to be in line with the rising limb of the Detailed Model stage-discharge relationship is recommended.
- As the Aurecon curve is not significantly different compared to the preferred rating curve, further consideration for any likely revision or refinement of associated Hydrology Assessment work is not warranted.

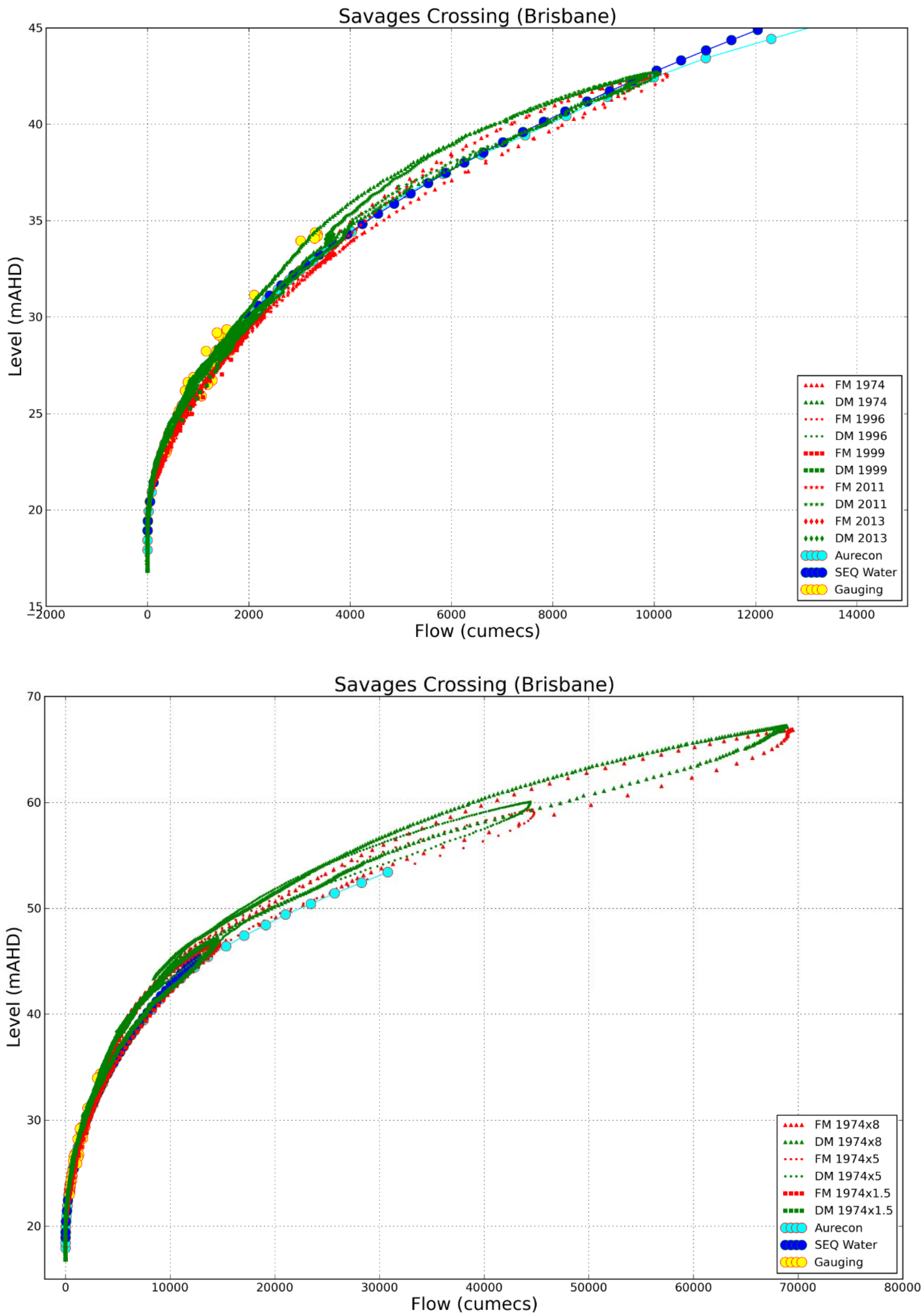


Figure 5-6 Savages Crossing Rating Curve Comparison with Calibration and Extreme Events

5.7 Mt Crosby Weir (Brisbane River)

The Seqwater and Aurecon rating curves for Mt Crosby Weir on the Brisbane River are presented in Plot 29 and Plot 32, and repeated in Figure 5-7. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 29) and hypothetical extreme floods (Plot 32).

Aurecon *et al* (2015c) Commentary

Catchment:	Lower Brisbane River	Rating updated based on review of gaugings, steady-state release flows and DMT TUFLOW model results Gauge location is considered to be reasonable with well-defined weir crest and relatively confined channel. Rating provides generally good fit of flow gauging, steady flow release and most hydrologic data, although it is noted that a number of the hydrologic model results deviate significantly from the rating Importantly, the rating is considered relatively unreliable between around 1,200 and 2,000m³/s. Interference of the bridge is considered a likely cause
Stream:	Brisbane River	
Site:	Mt Crosby Weir	
Gauge No:	430003A	
Owner:	Seqwater	

Observations

- For flows up to around 10,000 m^3/s, which covers all the calibration events, hysteresis effects in the model results are evident indicating the site, while a reasonable rating location for flows up to this magnitude, is subject to greater uncertainty in flow estimates. There is also greater separation between different flood events (compare 1974 with 2011) than for Savages Crossing further upstream that further reduces the certainty of using Mt Crosby as a rating site.

- For larger events, the hysteresis effects evident in the calibration events diminishes as seen for the 5x1974 and 8x1974 events. Mt Crosby Weir is, therefore, suited as a rating site at all levels noting that there is uncertainty associated with hysteresis, especially for flows under 20,000 m^3/s.

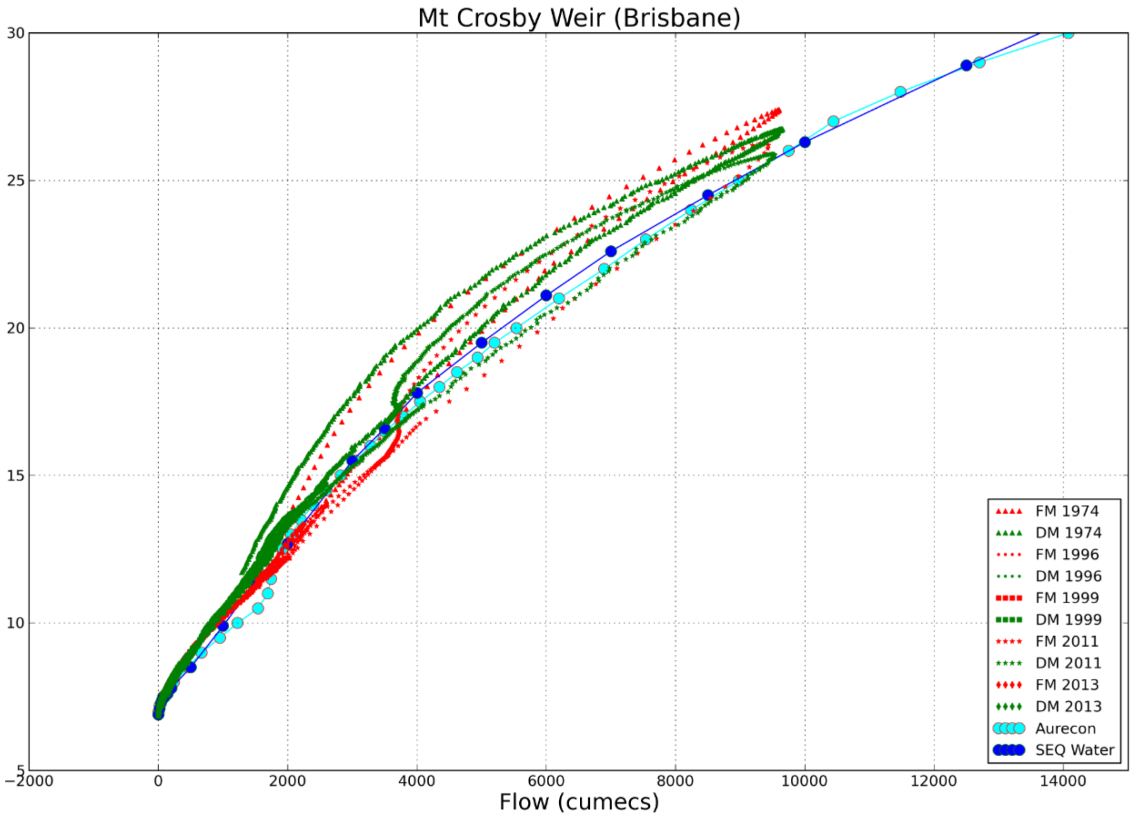
- The Seqwater and Aurecon rating curves are comparable and match the rising limb of the stage-discharge relationship from the Detailed Model. Of interest is that the Aurecon curve matches with the rising limb of the 2011 flood, while the Seqwater curve lies between the rising limbs of the 1974 and 2011 events.

Conclusions and Preliminary Recommendations

- Mt Crosby Weir is a reasonable rating curve location for all flows with uncertainties associated with hysteresis effects, especially for flows below 20,000 m^3/s.

- The Seqwater curve lies between the 1974 and 2011 rising limbs from the Detailed Model and perhaps should be preferred over the Aurecon curve which, whilst matching the 2011 rising limb, is not as good a match with 1974. For flows above 10,000 m^3/s, adjusting and extending the curve to be in line with the rising limb of the Detailed Model stage-discharge relationship is recommended.

- As the Aurecon curve is not significantly different compared to the preferred rating curve, further consideration for any likely revision or refinement of associated Hydrology Assessment work is not warranted.



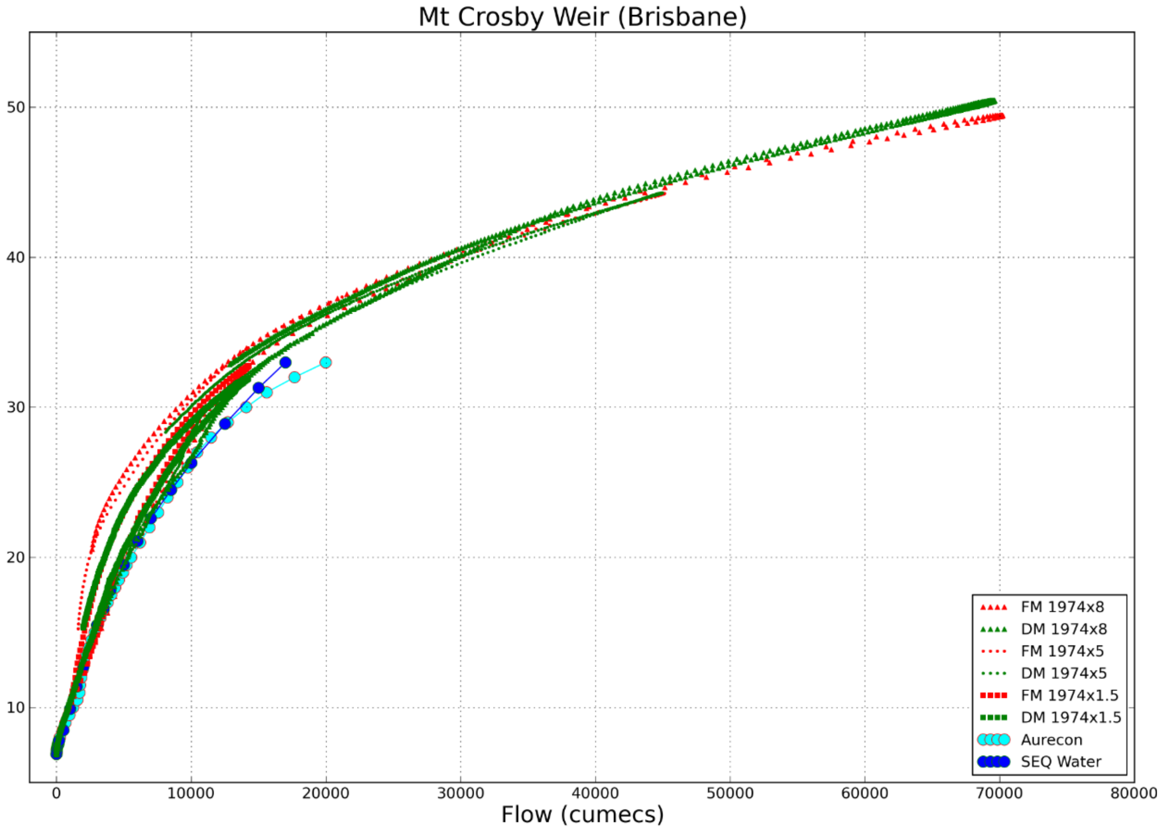


Figure 5-7 Mt Crosby Weir Rating Curve Comparison with Calibration and Extreme Events

5.8 Moggill (Brisbane River)

The Seqwater and Aurecon rating curves for Moggill on the Brisbane River are presented in Plot 28 and Plot 31, and repeated in Figure 5-8. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 28) and hypothetical extreme floods (Plot 31).

Aurecon *et al* (2015c) Commentary

Catchment:	Lower Brisbane River	Rating updated based on review of gaugings, steady-state release flows and DMT TUFLOW model results Rating provides generally good fit of steady flow release and hydrologic data, but no flow gauging available for comparison. Rating is considered to be reasonable, with a fairly well contained site. Revised rating tends to predict higher flows than previously estimated due to dynamic effects and attenuation evident in the TUFLOW model but not properly represented in the hydrologic model
Stream:	Brisbane River	
Site:	Moggill	
Gauge No:	143951	
Owner:	BoM/Seqwater	

Observations

- Similar to Mt Crosby Weir, for flows up to around 12,000 m^3/s, which covers all the calibration events, hysteresis effects in the model results are evident indicating the site, while a reasonable rating location for flows up to this magnitude, is subject to greater uncertainty in flow estimates. There is also greater separation between different flood events (compare 1974 with 2011) than for Savages Crossing further upstream that further increases the uncertainty in flow estimates.
- For larger events, the hysteresis effects evident in the calibration events remains as seen for the 5x1974 and 8x1974 events. Moggill is, therefore, suited as a rating site at all levels noting that there is uncertainty associated with hysteresis.
- The Seqwater and Aurecon rating curves tend to match the rising limbs of the stage-discharge relationships from the Fast and Detailed Models. Of interest is that for flows above 5,000 m^3/s, the Aurecon curve lies between the rising limbs of the 1974 and 2011 floods, while the Seqwater curve matches the 1974 flood, but not the 2011 event.
- The evidence of the tide for flows below 2,000 m^3/s is apparent in the Fast and Detailed Models' results.

Conclusions and Preliminary Recommendations

- Moggill is a reasonable rating curve location for all flows, noting that there are uncertainties associated with hysteresis effects.
- The Aurecon curve lies between the 1974 and 2011 rising limbs from the Fast and Detailed Models and perhaps should be preferred over the Seqwater curve which, whilst matching the 1974 rising limb, is not as good a match with 2011. For flows above 12,000 m^3/s, the Aurecon curve matches the rising limb relationship from the models and should the curve be further extended the rising limb from the Detailed Model results should be utilised. Final resolution of the rating curve for this site will benefit from the design flood simulations.

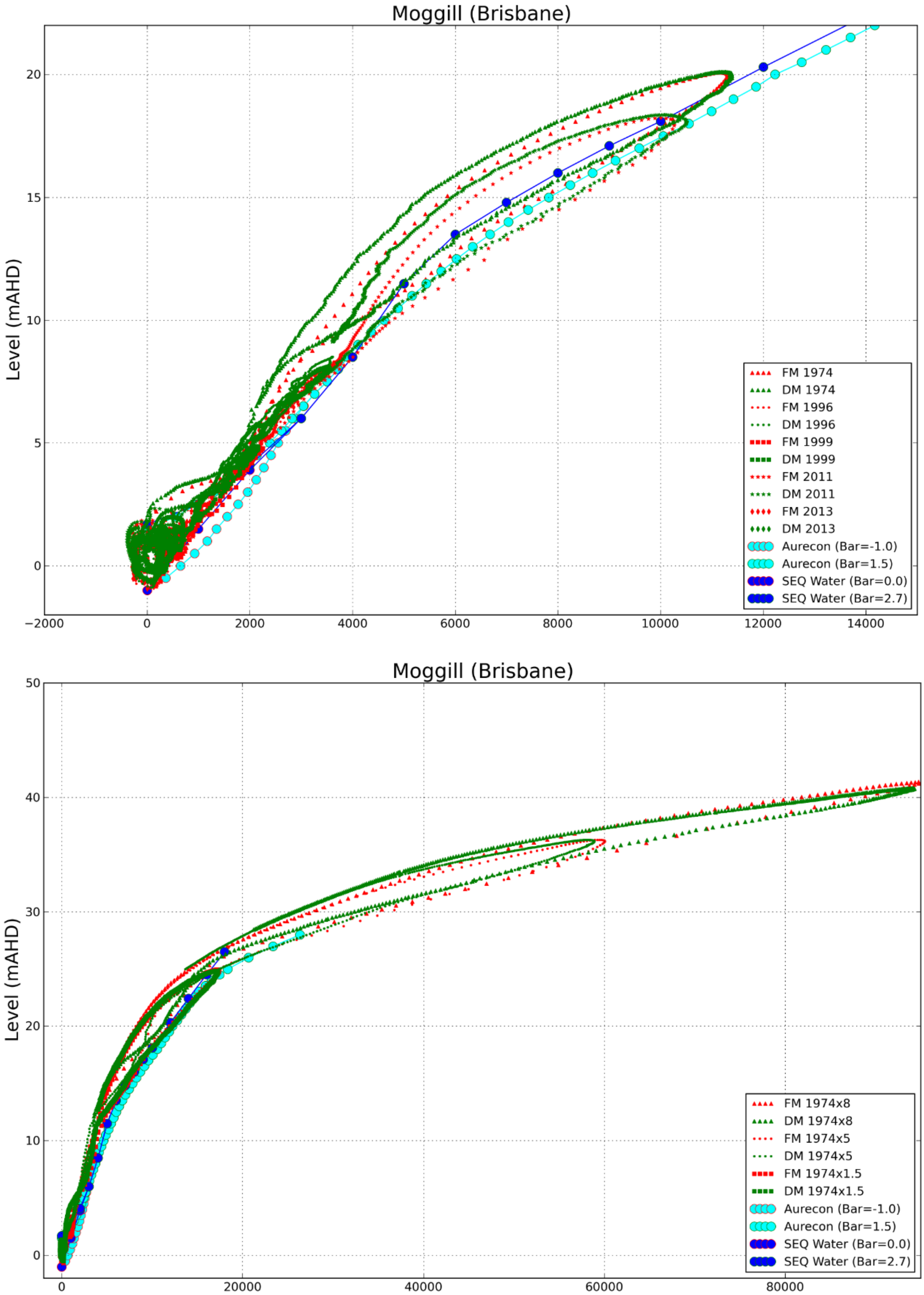


Figure 5-8 Moggill Rating Curve Comparison with Calibration and Extreme Events

5.9 Centenary Bridge (Brisbane River)

The Seqwater and Aurecon rating curves for Moggill on the Brisbane River are presented in Plot 30 and Plot 33, and repeated in Figure 5-9. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 30) and hypothetical extreme floods (Plot 33).

Aurecon *et al* (2015c) Commentary

Catchment:	Lower Brisbane River	Rating updated based on review of gaugings, steady-state release flows and DMT TUFLOW model results Rating provides generally good fit of flow gauging, steady flow release and hydrologic data. Rating is considered to be reasonable, with a fairly well contained site and flow gauging up to high flows (10,000m³/s). However, site is subject to significant dynamic effects, meaning that there is not a direct relationship between flow and level
Stream:	Brisbane River	
Site:	Centenary Bridge	
Gauge No:	43982	
Owner:	BoM	

Observations

- Similar to Moggill, for flows up to around 12,000 m^3/s, which covers all the calibration events, hysteresis effects in the model results are evident indicating the site, while a reasonable rating location for flows up to this magnitude, is subject to greater uncertainty in flow estimates. There is also separation between different flood events (compare 1974 with 2011) that further increases the uncertainty in flow estimates.
- For larger events, the hysteresis effects evident in the calibration events increases as seen for the 5x1974 and 8x1974 events. Centenary Bridge is, therefore, suited as a rating site at all levels noting that there is uncertainty associated with hysteresis, and that this uncertainty increases with extreme events.
- A number of streamflow gaugings are available for Centenary Bridge as shown by the yellow circles. The gaugings, taken at different stages of different floods, demonstrate the variability due to rising and falling limbs. The three recordings from 1974 are all on the falling limb of the event and these align with the falling limb of the Detailed Model results for 1974, but these falling limb flows are significantly different to the higher rising limb flows as predicted by the modelling.
- The Seqwater and Aurecon rating curves tend to match the rising limbs of the stage-discharge relationships from the Fast and Detailed Models. Of interest is that for flows above 5,000 m^3/s, the Aurecon curve lies between the rising limbs of the 1974 and 2011 floods, while the Seqwater curve matches the 1974 flood, but not the 2011 event.
- The evidence of the tide for flows below 4,000 m^3/s is apparent in the Fast and Detailed Models' results.

Conclusions and Preliminary Recommendations

- Centenary Bridge is a reasonable rating curve location for all flows, noting that there are uncertainties associated with hysteresis effects that increases with extreme events.

- The Aurecon curve lies between the 1974 and 2011 rising limbs from the Fast and Detailed Models and perhaps should be preferred over the Seqwater curve which, whilst matching the 1974 rising limb, is not as good a match with 2011. For flows above 12,000 m^3/s, the Aurecon curve matches the rising limb relationship from the Detailed Model in particular, and should the curve be further extended the rising limb from the Detailed Model results should be utilised. Final resolution of the rating curve for this site will benefit from the design flood simulations.

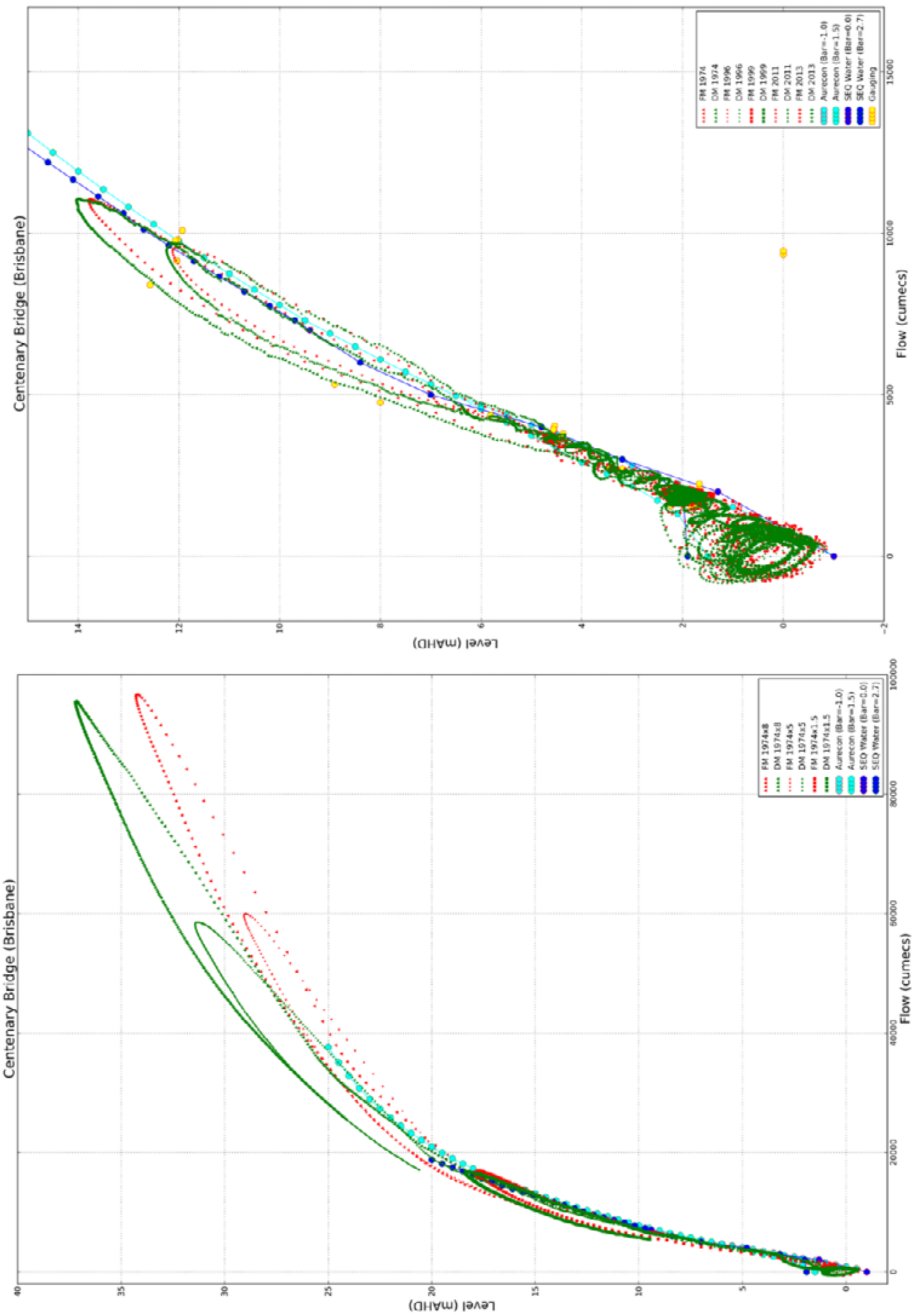


Figure 5-9 Centenary Bridge Rating Curve Comparison with Calibration and Extreme Events

5.10 City Gauge (Brisbane River)

The Seqwater and Aurecon rating curves for City Gauge on the Brisbane River are presented in Plot 30 and Plot 33, and repeated in Figure 5-10. The curves are plotted against the stage-discharge results from the Fast and Detailed Models for the calibration floods (Plot 30) and hypothetical extreme floods (Plot 33).

Aurecon *et al* (2015c) Commentary

Catchment:	Lower Brisbane River	Rating updated based on review of gaugings, steady-state release flows and DMT TUFLOW model results Rating is highly tide dependent even up to high flow rates (>10,000m³/s). Site has also been subjected to dredging and other changes, the effects of which are unquantified Overall, the current rating appears to give a reasonable estimate of the flow order-of-magnitude and match of historical flood events for flows in the range 6,000 to 16,000 m³/s. The site/rating is complex and improving the rating would require significant work (hydraulic modelling) that is outside the scope the current study
Stream:	Brisbane River	
Site:	Brisbane City	
Gauge No:	143838	
Owner:	Seqwater	

Observations

- For flows up to around 12,000 m^3/s, which covers all the calibration events, hysteresis effects in the model results are evident, as are tidal effects, indicating the site, while a reasonable rating location for flows up to this magnitude, is subject to greater uncertainty in flow estimates.
- For larger events, the hysteresis effects and tidal effects evident in the calibration events significantly diminishes as seen for the 5x1974 and 8x1974 events. City Gauge is, therefore, suited as a rating site at all levels noting that there is significant uncertainty associated with hysteresis and tidal effects for flows below 15,000 m^3/s.
- The Seqwater and Aurecon rating curves have two bounds to accommodate the tidal effects. The curves match reasonably well with the range of flows with the Aurecon curves providing the best fit for flows below 7,000 m^3/s. For flows above 7,000 m^3/s there are mixed correlations between the Seqwater and Aurecon curves. For flows above 12,000 m^3/s, the Aurecon curve matches more closely than the Seqwater curve, with the Detailed Model results indicating that the Aurecon flows, although lower than the Seqwater flows, may still be too high for a given water level.

Conclusions and Preliminary Recommendations

- City Gauge is a reasonable rating curve location for extreme flood flows, and can be used for rating flows for floods below 20,000 m^3/s noting that there are significant uncertainties associated with hysteresis and tidal effects.
- If the City Gauge rating curve is to be further improved, the results from the Detailed Model could be used, however, the uncertainties associated with particularly the tidal influences limits the value of the City Gauge rating curve for the majority of flood events.

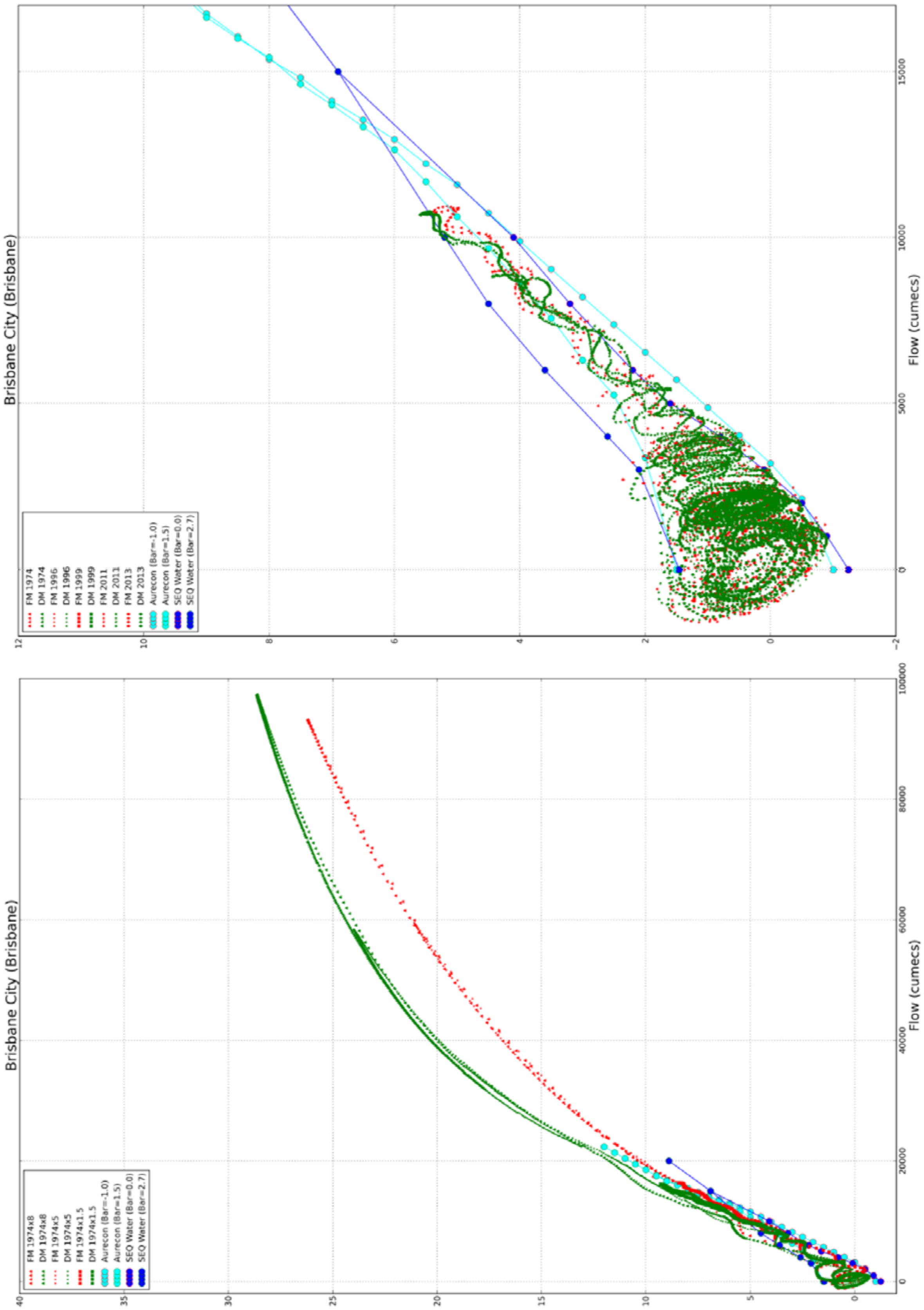


Figure 5-10 Brisbane City Rating Curve Comparison with Calibration and Extreme Events

6 Conclusion

The Detailed Model has been developed as a 1D/2D hydraulic model. The 1D sections extend along the in-bank sections of Lockyer Creek and the in-bank sections of the Bremer River, and Warrill and Purga Creeks upstream of One Mile Bridge. The remainder of the model is represented as a 30m 2D regular grid. The 1D sections are based on those in the Fast Model.

The Detailed Model was calibrated and verified to the floods of 1974, 1996, 1999, 2011 and 2013. A 1.5x1974 event was simulated to roughly approximate the estimates of peak flows in Brisbane for the 1893 events and comparisons made to peak 1893 flood levels. The model was proofed for two extreme events: 5x1974 and 8x1974.

Key observations during the model calibration/verification phase are:

- The model produces a match with the five events in terms of hydrograph timing and in comparison with water level gauges, flow gaugings and flood marks.
- The Manning's n values are typical of those used in the industry.
- As for the Fast Model, a satisfactory calibration cannot be achieved solely using a Manning's n approach. Additional form (energy) losses at sharp river bends, rock ledges and confluences were needed to reproduce the timing of the flood wave and the steep gradients along sections of the Brisbane River, but of a lesser magnitude than the Fast Model, which only applies the 1D equations. The 2D hydraulic equations are able to simulate most of these losses, but not all the losses.
- The effects of superelevation at river bends is reproduced in the 2D sections, and where recorded flood marks were available these supported the model results.
- Reducing the 2D resolution from a 30m to a 20m cell size does not provide any major improvement in the model calibration or the model's ability to meet the Detailed Model's objectives, and the longer run times of the 20m resolution (3 to 6 days for each of the ~50 design events) will be impractical based on current day PC chip technology.

In regard to the suitability of the Detailed Model for simulating the ~50 design events:

(1) The Detailed Model at a 30m resolution has a run time of around 16 to 32 hours depending on the flood event duration using a single core on a present day high end PC. At this run time the model, with sufficient computing resources and time, can feasibly be used to turn over the design simulations within a reasonable period. For example, if the 1% AEP event consists of running say 6 to 8 of the 50 selected Monte Carlo events, the 1% event could be completed in around 24 hours using a standard 8 core i7 CPU chip.

(1) The Detailed Model has been calibrated to tidal conditions, a minor flood (2013) and a major flood (2011), and verified to two minor floods (1996 and 1999) and a major flood (1974). These floods vary significantly in behaviour and size, and the ability of the Detailed Model to reproduce such a wide range of events without varying parameters provides a high level of confidence for simulating the design floods up to around the 1% AEP event, which is assumed to be in the order of one of the 1893/1974/2011 floods.

(2) For extreme events greater in size than the calibration events, the Detailed Model gives similar but higher profiles to the Fast Model, and similar profiles to the Updated DMT Model, so is considered suitable for these events.

(3) The Fast and Detailed Models provide consistent results at the ~30 reporting locations being used for the Monte Carlo analysis using the Fast Model results.

The Detailed Model is suited for future floodplain management tasks including, but not limited to:

- Planning levels and flood hazard/risk categorisation.
- Quantifying the changes to flood levels, flows and risk associated with assessing past and future works on the floodplain.
- Providing boundaries or other hydraulic data for high resolution localised modelling of past and future flood mitigation measures and other civil works.

The model is not suited for:

- Local creek flood assessments other than for backwater levels caused by a Bremer or Brisbane River catchment flood. For local creeks it is recommended that the maximum of peak flood levels/hazard/risk from both a local hydraulic assessment and the Detailed Model, be used for flood planning measures.
- High resolution hydraulic assessments where it is essential that results on a grid of finer scale than 30m is required. Either an embedded finer grid or a local fine grid model driven by flow and water level boundaries extracted from the Detailed Model should be used for assessments of this kind.

The rating curve review presented in Section 5 provides a comparison between the rating curves used by the Hydrologic Assessment. Of particular importance is the need to ensure consistency of the rating curves used by the hydrologic modelling with the stage-discharge relationships produced by the hydraulic modelling. The rating curves were used by the Hydrologic Assessment to inform the calibration of the hydrologic modelling and hydrologic flood frequency analysis. The flow hydrographs from the hydrologic modelling are then used by the hydraulic modelling, therefore, the hydrologic and hydraulic modelling calibrations are dependent on each other and acceptance of the calibrations is conditional on consistency and acceptance of the rating curves.

The review of the existing rating curves including those derived during the BRCFS hydrologic assessment, within the domain of the hydraulic modelling, found the rating curves to be commensurate with the hydraulic modelling stage-discharge relationships within the bounds of data inaccuracies, modelling uncertainties, hysteresis effects, and variations in hydraulic behaviour of the different calibration events. On this basis it is considered that there is no justifiable benefit in revising the hydrologic and hydraulic modelling calibrations, and that the rating curves used in the hydrologic and hydraulic assessments are consistent. However, given the importance of signing off on the hydrologic and hydraulic modelling calibrations before proceeding with the design flood modelling, it is recommended that an independent expert opinion from the IPE on whether there should be any further consideration or refinement of the hydrologic and hydraulic modelling calibrations is sought before proceeding to the design flood modelling.

Subject to the IPE's views and any necessary refinements, it is intended that the final set of consistent, robust and preferred rating curves will be developed in consultation with the key stakeholders involved and included as part of Milestone Report 5.

7 References

Aurecon *et al* (2013), Collection, Collation, Review and Storage of Existing Data – FINAL, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study, April 2013.

Aurecon *et al* (2015a), Hydrologic Model Recalibration Report – Final, Revision 2, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment, 15 May 2015.

Aurecon *et al* (2015b), Monte Carlo Simulation Framework and Methodology – Final, Revision 4, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment, 15 May 2015.

Aurecon *et al* (2015c), Draft Final Hydrology Report, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment, 15 May 2015.

Aurecon *et al* (2015d), Data, Rating Curve and Historical Flood Review Report, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment, Revision 2, 15 May 2015.

Austroads (1994), Waterway Design - A Guide to the Hydraulic Design of Bridges, Culverts and Floodways, Austroads, Sydney 1994.

Austroads (2009), Guide to Bridge Technology, Part 4: Design Procurement and Concept Design, Austroads Publication No: AGBT04/09, Sydney 2009.

Barton, C.L. (2001), Flow Through an Abrupt Constriction – 2D Hydrodynamic Model Performance and Influence on Spatial Resolution, Masters Dissertation, School of Environmental Engineering, Faculty of Environmental Sciences, Griffith University, May 2001.

Babister, M. & Barton, C. (2012), Australian Rainfall and Runoff Revision Project 15, Two Dimensional Modelling in Rural and Urban Floodplains, AR&R Report Number P15/S1/009, ISBN 978-085825-9850, 18 November 2012.

BCC (2014a), Brisbane River Catchment Disaster Management Tool Model Development and Calibration Outcomes Final Report, Prepared for Department of State Development Infrastructure and Planning by Flood Management Unit, City Projects Office, Brisbane Infrastructure Division, Brisbane City Council, 19 June 2014.

BCC (2014b), Brisbane River Catchment Flood Study Digital Terrain Model Development and Bed Level Sensitivity Analysis Final Report, Brisbane City Council, 268 pages.

BCC (2009a), Flood Study of Fernvale and Lowood, Prepared for Somerset Regional Council by Brisbane City Council, June 2009.

BCC (2009b), Brisbane River Hydraulic Model to Probable Maximum Flood, Final Report. Brisbane City Council, June 2009.

BMT WBM (2014), Milestone Report 1: Data Review and Modelling Methodology Draft Final, as part of the Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Prepared for State of Queensland by BMT WBM, 29 October 2014.

BMT WBM (2015a), TUFLOW 2015 User Manual, BMT WBM, Brisbane 2015.

BMT WBM (2015b), Milestone Report 2: Fast Model Development and Calibration Draft Final, as part of the Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Prepared for State of Queensland by BMT WBM, April 2015.

DPI (1994), Brisbane River and Pine River Flood Study, Prepared for South East Queensland Water Board by Qld Department of Primary Industries (DPI), 1994.

DSDIP (2014), Invitation to Offer No. DSDIP-2327-14 - For the provision of a Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Version 005, State of Queensland, 14 February 2014.

FHWA (1978), "Hydraulics of Bridge Waterways," Hydraulic Design Series Number 1, Second Edition, U.S. Department of Transportation, Washington, D.C. (Bradley, J.N.).

FHWA (2012), Hydraulic Design of Safe Bridges (HDS 7), U.S. Department of Transportation Federal Highway Administration, Hydraulic Design Series Number 7, Publication No. FHWA-HIF-12-018, April 2012.

GHD (2014), Coastal Plan Implementation Study Draft Report, Prepared for Brisbane City Council by GHD, September 2014.

Sargent, Gerald E.G. (1978), Side Scan Sonar Records of the Brisbane River and the Interpretation of Ancient Sea Levels, Department of Geology, University of Queensland, October 1978.

Seqwater (2011), January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Seqwater, 2 March 2011.

Seqwater (2013a), January 2013 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Seqwater, 2 April 2013.

Seqwater (2013b), Brisbane River Flood Hydrology Models, Main Report, Seqwater, December 2013.

SKM (2011), Joint Calibration of a Hydrologic and Hydrodynamic Model of the Lower Brisbane River Technical Report, Prepared for Seqwater by SKM, 24 June 2011.

Weeks, W. & Rigby, E. (2014), Australian Rainfall & Runoff (ARR) Project 11: Blockage of Hydraulic Structures. Blockage Guidelines for Culverts and Small Bridges – Draft for Discussion. September 2014.

7.1 Digital Photograph Image References for Hydraulic Structure References Sheets

Allen, R. (2012). *William Jolly Bridge* (looking upstream) [digital photograph]. Retreived from https://www.flickr.com/photos/raeallen/7173158786/in/photostream/.

Bilious. (2007). *The completed Eleanor Schonell Bridge taken on, from the City Cat.* [digital photography]. Retrieved from http://en.wikipedia.org/wiki/File:Eleanor_Schonell_Bridge,_Brisbane,_2007-01-31.jpg.

Bilious. (2008). *Merivale Bridge, Brisbane taken from an oblique elevated vantage* [digital photograph]. Retrieved from http://commons.wikimedia.org/wiki/File:Merivale_Bridge.jpg.

BMT WBM (2014). *Brisbane Valley Highway* (looking downstream) [digital photography].

BMT WBM (2014). *Brisbane Valley Rail Trail Bridge* [digital photography].

BMT WBM (2014). *Burtons Bridge* (looking downstream) [digital photography].

BMT WBM (2014). *Colleges Crossing* (looking upstream) [digital photography].

BMT WBM (2014). *Lyons Bridge* (looking upstream) [digital photography].

BMT WBM (2014). *Mt Crosby Weir* (looking upstream from west bank) [digital photography].

BMT WBM (2014). *One Mile Bridge* (looking downstream) [digital photography].

BMT WBM (2014). *O'Reilly's Weir* (looking upstream) [digital photography].

BMT WBM (2014). *Pointings Bridge* (looking downstream) [digital photography].

BMT WBM (2014). *Savages Crossin* (looking downstream) [digital photography].

BMT WBM (2014). *Twin Bridges* (looking downstream) [digital photography].

BMT WBM (2014). *Watsons Bridge* (looking upstream) [digital photography].

BMT WBM (2015). *Cunningham Highway over Warrill Creek* [digital photography].

BMT WBM (2015). *Kholo Road Bridge* (looking downstream) [digital photography].

BMT WBM (2015). *Pamphlet Bridge* (looking from downstream) [digital photography].

BMT WBM (2015). *Three Mile Bridge* (looking from upstream) [digital photography].

BrisbanePom (2011). *The Captain Cook Bridge over the Brisbane River at Brisbane.* [digital photography]. Retrieved from https://en.wikipedia.org/wiki/Captain_Cook_Bridge,_Brisbane#/media/File:Captain_Cook_Bridge_at_dusk,_Brisbane.jpg.

Department of Public Works (2012), *Goodwill Bridge Aerial* [digital photography], provided by DNRM (Dr Wai-Tong Wong) in Aug 2015.

Figaro, I. (2009). *Fountain at Newstead House in Brisbane, Queensland, Australia* [digital photograph]. Retrieved from http://www.marysrosaries.com/collaboration/index.php?title=File:Victoria-Bridge_Brisbane.jpg.

Goodwin, C. (2009). *Rail bridge across the Bremer River, Ipswich, Queensland*. [digital imagery]. Retrieved from http://en.wikipedia.org/wiki/File:Bremer_R.JPG.

Guard, P. BMT WBM (2008). *Indooroopilly Rail Bridge*. [digital photograph]. Retrieved from https://commons.wikimedia.org/wiki/File:Indooroopilly_Bridge.jpg.

Guard, P. BMT WBM (2008). *Walter Taylor Bridge.* [digital photograph. Retrieved from https://commons.wikimedia.org/wiki/File:Walter_Taylor_Bridge.jpg.

Guard, P. BMT WBM (2009). *Kurilpa Bridge.* [digital photograph]. Retrieved from https://commons.wikimedia.org/wiki/File:KurilpaBridge1.JPG.

Guard, P. BMT WBM (2010). *Go Between Bridge.* [digital photograph]. Retrieved from https://commons.wikimedia.org/wiki/File:Go_between_bridge.jpg.

Guard, P. BMT WBM (2011). *The Sir Leo Hielscher Bridges*. [digital photography]. Retrieved from https://commons.wikimedia.org/wiki/File:Gateway_Bridge_aerial4.JPG.

Ipswich City Council (2015). *David Trumpy Bridge*. [digital photograph].

Ipswich City Council (date unknown). *Bremer River, Warrego Highway* [digital photograph].

Ipswich City Council (date unknown). *Cunningham Highway over Purga Creek* [digital photography].

Ipswich City Council (date unknown). *Hancock Bridge* [digital photograph].

Ipswich City Council (date unknown). *Wulkuraka Rail Bridge, Aerial Imagery* [digital photograph].

Kgbo. (2014) *Centenary Bridge, seen from Jindalee, Queensland, 03.2014.* [digital photograph]. Retrieved from https://commons.wikimedia.org/wiki/File:Centenary_Bridge_03.2014_03.JPG.

Kgbo. (2014). *Jack Pesch Bridge and next to it Albert Bridge, Brisbane.* [digital photography]. Retrieved from https://commons.wikimedia.org/wiki/File:Jack_Pesch_Bridge_05.JPG.

Macey, C.R. (2007). *Story Bridge* [digital photography]. Retreived from http://de.wikipedia.org/wiki/Story_Bridge#mediaviewer/File:Story_Bridge_Panorama.jpg.

Appendix A Outcomes and Actions from Workshop 3

Memorandum

Workshop 3 **Summary of Outcomes/Actions**: Detailed Model Development and Calibration

To:	DNRM (Wai Tong Wong)	From:	BMT WBM (Bill Syme & Cathie Barton)
Date of Workshop:	14 May 2015		
Subject:	B20702-80 Brisbane River Catchment Flood Study Hydraulic Assessment - IPE/TWG Workshop 3 Detailed Model Development and Calibration		

ATTENDEES

Hydraulics IPE (Independent Panel of Experts)

- Mark Babister (Chair) (WMA) [MB]
- Em Prof Colin Apelt [CA]
- Dr John Macintosh [JM]

TWG (Technical Working Group)

- BCC: James Charalambous [JC], Evan Caswell [EC]
- ICC: Hoy Sung Yau [HSY]
- LVRC: Quentin Underwood [QU]
- Seqwater: Michael Raymond [MR] & Lindsay Millard [LM]
- DSITIA: John Ruffini [JR]
- DNRM: Wai-Tong Wong (Client PM for the Hydraulic Assessment) [WTW]
- DNRM: Pushpa Onta (Client PM for the Hydrologic Assessment) [PO]
- DSDIP: Roger Brewster [RB]
- DEWS: Russell Cuerel [RC]
- BoM: Andy Barnes [AB]

Apologies

- DSDIP: Con de Groot (Project Manager) [CdG]
- SRC: Tony Jacobs [TJ]
- BCC: Ouswatta Perera [OP]

BMT WBM Facilitator

- Jo Tinnion (BMT WBM Project Communications Officer) [JET]

BMT WBM BRCFS Hydraulic Assessment Team

- Bill Syme (Project Manager) [WJS]
- Cathie Barton (Project Coordinator) [CLB]
- Barry Rodgers [BR]
- Rachel Jensen [REJ]

This summary was prepared during and following the BRCFS Hydraulic Assessment Workshop 3: Detailed Model Development and Calibration, held at the office of BMT WBM 14 May 2015. A set of presentations and two Agenda Papers are available separately.

WTW reported that all actions from the previous Workshop No. 2 were completed.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
Detailed Model Development			
1. Consideration of Storage within 1D domain	MR concerned about whether storage is appropriately represented within the 1D domain. Storage beyond the 2D domain is accounted for in the linked 1D nodes.	Acceptance of this approach and explanation provided.	**None**
2. Inclusion of Goodna Hwy for 1974 Event	MR advises that the Goodna Hwy was not present in 1974. As the Goodna Hwy is in a backwater area, inclusion or not of this Hwy will not impact on the 1974 verification. Only areas that have a significant effect on the 1974 flood conveyance and/or storage were modified for the 1974 verification.	Acceptance of this explanation. Request for inclusion of discussion on this in report.	**2.1 BMT WBM** to include discussion on the approach and model modifications for the 1974 verification in report.
3. Inclusion of major trunk drainage pipes in model around Brisbane	These pipes are needed to allow floodwater to backup through pipe system to enter areas that were inundated in the historical events. These pipes are not included to convey local rainfall to river. The accuracy of available pipe data is unknown or data was unavailable. The importance of having a "representative" pipe system to replicate the flood extent mapping was noted. Also noted was that the presence or not of the pipes does not have any measureable influence on the model calibration in the river and elsewhere.	3.1 Acceptance of inclusion of pipes and acceptance that they are fit for purpose to reproduce backwater flooding. 3.2 Request for discussion in report so that future users are aware of limitations in pipe data.	**None** **3.2 – BMT WBM** to ensure discussion occurs in report regarding limitations of pipe data and associated limitations for modelling.
4. Application of Form Loss	Targeted form loss applied as needed at sharp bends and rock ledges. They are applied similarly to structure losses (i.e. a	Acceptance of application.	**None**

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
	factor of $v^2/2g$). Confirmation that no general form loss has been applied in the Detailed Model. JR queried the method for application of the targeted form loss. WJS advises that it is applied via a polygon extending across the creek/river in-bank width and typically from the start of the bend/obstruction to downstream as this is where most energy losses occur as the water flow re-establishes a more uniform pattern.		
5. Eddy viscosity	MR queried eddy viscosity formulation. The eddy viscosity formulation used in the TUFLOW model is the default Smagorinsky with a default factor of 0.5 and a constant component of 0.05. WJS advised that Smagorinsky coefficient in the literature varies from 0.1 to 1.0 and for TUFLOW models this formulation or coefficient is not used as a calibration parameter or for stabilising models.	Acceptance of this application. Request to document the formulation and factor within the report.	**5.1 BMT WBM** to add discussion on the eddy viscosity formulation within MR3.
6. 1974 Bremer River Hydrology	Bremer River hydrology adopted for the 1974 event is based on the average of loss values produced by Aurecon and Seqwater based on the outcomes of the Fast Model calibration.	Acceptance of this methodology in the absence of the ability to undertake a joint hydrologic/hydraulic calibration.	**None**
Detailed Model Calibration			
7. Walloon plots and Table 3-4	WJS advises that errors are noted in the hydrograph plots for the Walloon Alert Gauge and associated errors in Table 3-4 for the Walloon row.	No further queries	**6.1 BMT WBM** to correct Walloon hydrograph plots and Table 3-4 values
8. Longitudinal Profile in Plot 26	Energy is shown to increase in a downstream direction. This is not possible and error occurs due to the fact that the digitised line	No further queries	**8.1 BMT WBM** to correct in MR3.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
	used to extract the energy profile from the 2D results is not consistently aligned with the maximum energy profile with the profile line extending from in-bank to overbank and back again. An example of a section demonstrating this effect was shown in the slide show.		
9. Slight bias noted in 1974 calibration histograms.	MB notes a slight bias is evident in the 1974 verification histograms. WJS advised that this bias can be readily shifted/removed through varying the IL/CL values for the Bremer catchment between the Seqwater and Aurecon values. In the absence of a traditional hydrologic/hydraulic joint calibration, a simple average of Aurecon & Seqwater losses has been applied in the Bremer catchment URBS model to obtain Bremer inflows. Removal of the bias is possible by factoring these losses (and thus flows) differently. Further discussion by others that the 1974 event is purely a verification event, not a calibration event.	No further queries	None
10. 1893 Flood Extent	MR proposes that the 1893 flood extent is of limited accuracy and comparison of the pseudo-1893 modelled event is better undertaken with the recorded flood marks. WJS notes that this has been undertaken within MR3 already.	No further queries	None
11. Latest Rating Curves	Realisation that BMT WBM is not in receipt of the latest rating curves from Aurecon. CA indicated that he believes some of these have changed in the lower Brisbane.	No further queries	**11.1 DNRM** to provide latest rating curves from Aurecon **11.2 BMT WBM** to include the updated rating curves within all plots and discussion.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
12. Rating Curve Plots	Suggestion by MR to include “highest gauge level” and “highest recorded level” on plots. Also to include only one plot per page to allow maximum resolution.	No further queries	**12.1 BMT WBM** to discuss with client
13. Gauge Cross-sections	Suggestion by JR to use surveyed cross-sections at gauge locations. Could use these sections to compare to Lidar to give an idea of the accuracy of the Lidar data and the potential influence of use of this data within the model. MR suggests plotting u/s and d/s cross-sections (Lidar and survey). MB and others questioned the benefit of this exercise, highlighting that it was more important to have a more detailed discussion on the accuracy and usefulness of the rating curve comparisons using the Detailed Model for each location.	Not all in agreement with the benefit of this as hydraulic behaviour at the gauge location is not only a function of cross-sections immediately at the gauge location but the cross-sections / bathymetry further along the reach as well. Some suggest showing DEM topography around gauge site instead. In continued discussions no firm agreement reached, although it was generally agreed a discussion on the rating curve comparison and recommendations on whether the existing rating curves can be improved should be provided.	**13.1 BMT WBM** to extend the observations provided in the slide show on each rating curve location into a more detailed discussion in the report and provide recommendations on any improvements that can be made to the existing rating curves.
14. Rifle Range Road Gauge	MR advises that Rifle Range Road gauge is not useful due to strong influence of the large floodplain and very wide floodplain flowpaths.	No further queries	**None**
15. Seqwater Rating Curves	MR advises that all Seqwater rating curves are designed to include ALL flow (that is, channel, floodplain and bypass flow all included). WJS advised this was also that adopted for the rating curve comparison plots from the Fast and Detailed Models.	No further queries	**None**
16. Plots 31,32,33 – Extreme Event Rating Curves	These curves will be provided as soon as possible. They are missing from MR3 as plot output lines in some locations did not extend across the entire floodplain to capture all flow. Detailed model currently being re-run with	No further queries	**16.1 BMT WBM** to provide these plots to stakeholders post workshop.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
	extended Plot Output lines for all extreme events.		
17. Rating curve plot data and calibration water level surface	JC would like to receive the data used to develop the rating curve plots and calibration water level surface.	No further queries.	**17.1 JC** to provide written request on the specifics.
18. Rating curves	PO requests more discussion on rating curve comparisons, particularly in relation to significance of differences. This will lead into the upcoming reconciliation process.	Requests for more information on significance of differences.	**18.1 BMT WBM** to add further discussion on rating curves as per Item 13.1 above.
19. Difference in Grid Sizes	Calibration / verification has been undertaken using a 30m grid resolution throughout the 2D domain. 1D channels are used to represent the in-bank channels in the Lockyer, Warrill, Purga and upper Bremer. Sensitivity tests have been undertaken using a 20m grid resolution (discussions on this contributed to by BCC). New in-bank n values (about 10 to 20% higher) and/or form losses are required to calibrate the 20m grid model as demonstrated by Sensitivity Test ST10. It was noted that there was no notable improvement in model calibration or flood extent switching from 30m to 20m. CA adds that it is futile to argue about why different n values are required for different grid sizes as the model should be considered as a package. MB is of the opinion that there is no practical benefit in chasing a 20m grid size, given the results presented. Considerable time investigating use varied grid resolutions concluded that, in this case, there was no significant benefits, and there	19.1 Agreement by the IPE and TWG members present that use of the 20m grid resolution model is not practical given the excessive run times and has no demonstrable benefit.	**None**

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
	were limitations in producing stable/consistent flow patterns at the transitions especially for large events. It was noted that the ground elevations are sampled at half the cell size (ie. 15m resolution for a 30m grid), and all embankments, etc were applied as breaklines ensuring the nearest 2D elevation point was set to the height of the embankment. Accuracy of the 30m grid considered to be sufficient given the high quality of the calibration and reproductions of localised effects at, for example, river bends. The 30m grid model takes between 16 and 32 hours to run while the 20m grid model takes between 4 to 8 days depending on the event duration on a single CPU core. Choice of the 30m grid resolution was adopted as there was not any demonstrable benefit using a 20m resolution. Furthermore the 30m offered significantly more practical run times, especially given that there is expected to be about 50 events needed to be run all design AEPs.		
20. Timing & Shape of hydrographs	MR queries whether all weirs are within the model. WJS indicates that all weirs provided have been included and that most weirs are completely drowned out anyway. MR comments that the inclusion (or not) of weirs may impact upon the rising & falling limbs of the hydrographs.	No further queries.	**None**
21. Lockyer – Buaraba Ck	Model is within the tolerances of the 2011 peak flood levels in this area, but is	Acknowledgement that the model is not predicting 2011 recorded flood levels within	**21.1 BMT WBM** to check section in report

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
floodplain	consistently ~0.3m to 0.5m too low. Discussion over possible reasons including datum error in survey levels, hydrologic uncertainties, and cropping patterns change season to season resulting in differences in roughness.	the 0.5m target tolerance but is consistently low in this region and reason could be due to a number of uncertainties, especially uncertainty over the volume of rainfall and runoff from Buaraba Creek catchment.	documents all of these uncertainties.
22. Lowood Bend for 1974	1974 gauged level at the peak appears inconsistent with surrounding peak debris levels. Has the gauge moved? JR recalls irregularities with the Lowood gauge measurements for 1974 and believes that gauge has moved around over time.	Acceptance that the Lowood gauge is not consistent with surrounding flood debris mark levels for 1974 and advice that the gauge has most likely moved around.	**22.1 BMT WBM** to include additional discussion in report on this issue based on anecdotal advice provided.
23. Fernvale Area around Quarry	This area has been difficult to calibrate, with ultimately a very high form loss required to achieve calibration. The reason is believed to be related to the unknown state of the quarry topography at the time of the event. A large number of sensitivity assessments were undertaken in this area to achieve calibration. Other suggestions for possible reasons from TWG/IPE include: confirming where local flows are being applied in case this has an influence; sediment movement from the quarry and/or other areas was substantial causing a partial choke (MR noted that large deposits of sediment were noted downstream at Savages Crossing after the 2011 flood); too much conveyance on left bank looking d/s (WJS indicates this has been sensitivity tested). MR suggests referring to Above Photography aerial images in this area (taken about 12hrs after peak). Concern over how to treat this area in the design model. MR/JR suggest that the quarry approval will have a final landform and this should be used in the	23.1 Acknowledgement of the difficulty in calibrating this section of the model and suggestions made as to potential reasons. 23.2 As the topography of the quarry is in a constant state of change, suggestion to include the final approved landform of the quarry in the design runs.	**23.1 DNRM** to source topographic data of approved landform of quarry, if available. **23.2** BMT **WBM** to discuss landform for adoption in the design runs with Client and SRC.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
	design model.		
24. Post-Flood Wivenhoe Releases	Steady flows due to controlled releases from Wivenhoe Dam show that the model over-predicts the 2011 post-peak hydrograph at Savages and Moggill, but not at some other gauges. Possible reasons include reduced n values after flood peak, inaccurate gauge records (the Moggill peak was concluded to be around 0.3m too low based on photos taken of the manual gauge), 2D cell size too coarse (WJS noted little benefit on this issue was gained using a 20m grid). WJS also showed how 1999 and 2013 events both had the same post flood discharge but produced different levels at Savages and elsewhere (the Detailed Model results lie between the 1999 and 2013 recordings). MR indicates that there was a significant change in channel roughness during the 2011 event and subsequent events were also impacted. MR advises that DNRM gaugings that took place at Savages Crossing before & after the 2011 event for the same flow have noted a 1m difference in level due to decreased roughness.	Acceptance that reproduction of the steady-state post-peak hydrograph on some events could be difficult to reproduce more accurately due to potential changes in roughness that occurred due to the high velocities “flattening” the vegetation and/or morphological changes during the 2011 flood.	**27.1 BMT WBM** to review section in report and add discussion points not already presented in report.
25. Ipswich to One Mile Bridge	WTW queries whether Berry’s Lagoon weir is in the model. MR advises that it would be completely drowned out and not influencing flood behaviour at the peak.	none	**None**
26. St Lucia Reach in 1974	A benchmark error is suspected in these recorded flood levels as the difference between recorded and modelled is so	Acceptance that datum error is the most probable cause of the consistent differences in the St Lucia reach for the 1974 event.	**26.1 BMT WBM** to investigate the exact datum shift between AHD and SD and include additional discussion in report on this issue

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
	consistent and not apparent in the 2011 comparisons. CA suggests that it could be an AHD-related datum error as state datum rather than AHD was used in 1974. JR advised that the differences appear consistent with the state datum conversion.		based on advice provided.
27. Bremer Comparison 1996 & 2013	Similar flows in the Bremer for both events however record levels are 3m lower in 1996. MR suggests that hydrologic model may not be producing enough flows due to the limited consideration of impervious areas (Seqwater none & Aurecon only rudimentary representation of impervious areas). JC indicated that the DMT also struggled with this calibration issue. QU advises that dredging of the river was occurring in 1996 but then stopped. He believes that the Bremer has become significantly shallower since 1996 due to no dredging and bank slips into the channel.	Acknowledgement that the comparison between the events indicates that something has changed between 1996 and 2013. General acceptance that the change in river bathymetry over time is the probable cause in conjunction with the possibility that the hydrologic model having limited consideration of impervious areas and/or the significant differences in the IL/CL values adopted for 2013.	**27.1 BMT WBM** to include additional discussion in report on this issue based on advice provided.
28. Inundation extents around the Gateway Motorway	MR queries the extent of inundation shown in this area. WJS advises that the model schematisation is not correct in that the Gateway Motorway is blocking local catchment flows and that the inundation shown is not representative of the Brisbane River backwater. This will be corrected.	Improved schematisation of model required to correctly model backwater effects.	**28.1 BMT WBM** to correct model in this location to improve replication of inundation extent.
29. Hydraulic behaviour	MR suggests a report section on what the model tells us about behaviour of the river. WJS agrees but recommends waiting until Design Events Report in order to discuss a broader range of event magnitudes with associated incremental AEPs.	Agreement that description of hydraulic behaviour should be provided in the Design Events Report.	**29.1 BMT WBM** to include discussion on flood behaviour in the Design Events Report.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
30. Estimation of head loss across a structure	BMT WBM currently building in new feature to TUFLOW code to extract below and above deck flows for 2D structures to populate the Hydraulic Structure Reference Sheets. WJS poses question as to where to position the u/s & d/s cross-sections in a 2D model to estimate head loss? Also, how do we deal with variation in head across the cross-section? CA suggests to use the u/s peak flood level and the d/s average flood level. MR & JC suggest averaging both u/s & d/s. WJS prefers taking the maximum across the waterway as this will capture something close to the energy level on both sides of the structure.	General discussion.	**30.1 BMT WBM** to provide Hydraulic Structure Reference Sheet (App C) as soon as ready.
31. Model Suitability for a Range of Flows	MR requests that documentation contains the range of flows for which the model is suitable for use.	Suggestion	**31.1 BMT WBM** to add this discussion to the report.
32. Small flood of May 2015	MR indicates that data exists for the small flood (about 1,000m^3/s) that occurred in May 2015.	Inflow hydrology is not readily available for May 2015 flood. Small flows can be assessed via the tidal calibration and checked against the fit on the rising limb of calibration events.	**None.**
33. Calibration Data	JM suggests that as part of the documentation package, the complete set of calibration data is needed.	Data could be provided in the handover at project completion as per Terms of Reference.	**33.1 BMT WBM** to note. Format and content will need to be discussed.

ISSUE	WORKSHOP DISCUSSION	OUTCOMES	ACTIONS
Monte Carlo Simulations Update			
No issues raised			
Selection of About 50 Events Proposed Methodology Discussion			
34. Diagrams	Request for diagrams to assist in explaining methodology text.	Suggestion	**34.1 BMT WBM** to provide.
35. Methodology	Presentation of methodology from Agenda Paper 1. JM/MB concern that filtering removes diversification of events and that this may bias results. Suggestion by MB that methodology may need to be adaptable – changing as needed as work progresses. Could possibly use a factored event.	General discussion to understand the proposed methodology.	**35.1 Client** to arrange suitable time next week to discuss further. **BMT WBM** to provide venue.
Structure Blockage Methodology Discussion			
36. At what stage of project should blockage be considered?	Presentation of 3 options from Agenda Paper 2. MR concerned that blockage will create new flowpaths thus creating new hazards. Blockage of Cunningham Hwy over Warrill will push more water into Purga Ck. CA recommends Option 1, believes Option 2 not appropriate. RB requests that local council should be able to provide historical knowledge on which structures are prone to blockage.	Decision that local councils to provide historical background on structure blockage for each structure within their area. This can be used in conjunction with the preliminary guidance from ARR and professional judgement to shortlist which structures may be subject to blockage for future assessment.	**36.1 BCC, ICC, SRC, & LVRC** to provide historical information on structure blockage within their areas. For a list of structures represented see Table A-2 in Appendix A and for their locations see Drawing 7. **36.2 BMT WBM** to use this information and professional judgement to shortlist structures for which blockage could be considered in future (other) assessments.

Appendix B Comments from IPE

IPE Comments on Hydraulics Workshop 3- Milestone report 3

30m Grid suitability

IPE is asked to sign-off that 30m grid resolution satisfactorily meets the requirements of the brief as demonstrated by the results of the modelling to date. This issue is discussed in the following sections 1, 2 and 3. As stated in the Summary at the end of this report, the IPE has concluded that the 30m grid resolution does satisfactorily meet the requirements of the brief.

1. Model Resolution

Model grid size resolution is always a trade off of competing needs when setting up a model. The key constraints are:

- run times,
- ability to calibrate and conduct useful sensitivity assessments,
- future uses of the model,
- stability of the calibration,
- ability of the grid to capture the bathymetry,
- the depth to grid size ratio in the model, and
- computational power available.

Practical run times allow the current and future users to become properly familiar with all aspects of the model. Practical run times are in the order of 8-15hrs. If this cannot be achieved then a 24hr run time is preferred. A reasonable run time will also ensure the model is used in the future.

While a smaller grid is desirable to represent the terrain in finer detail and to stabilise the calibration as grid size gets smaller, this is not possible on the Brisbane River. There are some complications with the use of a smaller grid size. Two dimensional models assume vertically averaged flow and that the bed roughness acts on the square grid element. When the depth to grid size ratio approaches 1 some of the intrinsic 2D modelling assumptions start to become compromised (Barton, 2001), (Toombes & Chanson 2011).

It is probably not an issue if velocities are low or the flow depth is relatively uniform. With a 2D modelling scheme there is an inherit assumption that vertical acceleration is small or negligible. On a river with steep banks, very high river velocities and deep flow depth and relatively shallow overbank depths like the Brisbane River a small grid size and its resultant depth to grid size ratio is pushing the boundaries of the assumptions underlying 2D shallow wave equations.

Most of the overbank area of the lower Brisbane River has relatively low velocity and it is practical to remap and stretch the flood extent at a finer resolution. This is a common practice and is available in common software packages such as Water Ride. While it is easy to remap the flood surface, velocity and hydraulic hazard are more complex. Hydraulic hazard takes account of the combined effects of depth of water and of its velocity and remapping both hazard and velocity at a finer scale requires more work than does remapping the flood surface and careful checking of the results.

It is important that the stage 3 report clearly states that the model has been calibrated based on a 30m grid size and that each different grid size will require some recalibration.

It is important also to note that the use of grid sizes that are smaller than necessary cannot achieve greater overall accuracy since the accuracy of the calibrated model is limited by the accuracy of the input data, especially the topography and hydraulic roughness, and over-all by the uncertain but limited accuracy of the calibration data.

Further, the use of smaller grid sizes would incur penalties of increased run times and associated increased costs and the time required to complete the project without improving the accuracy of the modelling results. BMT WBM reported in the draft Milestone 3 report that the run time for the 30m grid size model is around 16 to 32 hours depending on the flood event duration using a single core on a present day high end PC while the run times of the 20m grid size model is 3 to 6 days for each of the 50 design events.

The IPE has considered two separate issues:
(a) what is needed to achieve the required outcomes concerning flood levels etc for the specified AEPs
(b) what is required by Councils for future use of the model.

With regard to the first issue (a), the IPE has concluded that the calibrated 30m grid size model is fit for purpose to meet the requirements of the brief and that no benefit would be gained by use of a 20m grid size in the model while incurring a severe penalty of increased run times and possible delay of completion of the project. It is acknowledged that the continued development of computers may reduce run times very much but it is highly unlikely that this will happen during this project.

Concerning the second issue (b), the IPE notes that the BMT WBM proposal concerning the detailed model stated that *'The detailed model will utilise TUFLOWs multiple 2D domain feature that allows any number of different 2D model domains (with varying 2D grid sizes) to be linked together within a single model.'* A possible modular design with domains of varying model resolution is outlined in the proposal. This indicates 2D grid resolution test ranges for different regions, including a 10m to 30m range for the floodplains in the Brisbane CBD and for Ipswich. The final 2D cell size configuration for design runs '*will be finalised with the client based on run times, spatial convergence and desired resolutions.*'

The draft Milestone 3 report does not provide any information concerning whether modular design with varying resolution was examined during the development of the detailed model. Such information would be useful for Councils and other authorities that may seek finer spatial resolution than that provided by the 30m grid size in future use of the model. Where results on a grid of finer scale than 30m are required *either an embedded finer grid or a local fine grid model driven by flow and water level boundaries extracted from the Detailed Model should be used for assessments of this kind',* as stated in the report.

It appears that a grid size of 10m may be of interest to some Councils. The IPE is concerned that use of a 10m grid could lead to violation of intrinsic 2D modelling assumptions for some of the Brisbane River channel and for very deep overbank flows. The effect of this on model performance would require further investigation to satisfy the IPE that model validity would not be compromised. If, despite this, a resolution of 10m was applied to the same domain as presently covered by the 30m grid, the run time would be increased by a factor of 27, to approximately 18 - 36 days per design event. Even if the new parallelised version of TUFLOW were used in the model, allowing one simulation to use multiple CPU cores to reduce runtimes, such a model would be still be not practical. However, smaller domains with 10m or even finer resolution could be used where the finer resolution is consistent with intrinsic modelling assumptions; the boundary conditions would be extracted from the calibrated detailed model.

Taking account of all of the issues discussed, the IPE considers that 30m grid size represents the most practical compromise between the competing needs to produce a general purpose model that meets the requirements of the brief.

Local governments and other authorities may wish to carry out additional local modelling using finer grids to evaluate the impact of very local infrastructure proposed (e.g. Kingsford Smith Drive and Ferry terminals) which is a normal industry practice. The necessary boundary conditions for the finer scale modelling could be provided the calibrated BRCFS 30m grid model, as discussed above with regard to issue (b).

2. Meeting the requirements of Sections 3.2.5

From section 3.2.5 the hydraulic model is to be sufficiently detailed and robust to be potentially used for:

Item	20m Grid	30m Grid
Zoning the study into broad categories for land planning, floodplain management and emergency response	Yes	Yes
Assessing the impact of all development within the floodplain including filling and construction of infrastructure	Yes, except for small scale works less than about 40m in horizontal dimension	Yes, except for small scale works less than about 60m in horizontal dimension
Providing flood levels suitable for habitable flood levels at property level/scale	Yes	Yes
Providing information to map flood hazard	At a coarse scale	At a coarse scale
Providing water level hydrograph results to evaluate flood travel times and corresponding lead time for flood warning	Yes (i)	Yes (i)
Assessment of floodplain risk management mitigation measures (as part of the floodplain management study and plan)	Yes	Yes
Analysis or hydraulic design of drainage systems including major cross drainage structures in the floodplain and understanding hydraulic behaviour of structures at different levels of flooding to inform risks to structural integrity of	Yes	Yes

structures such as bridges		
Assessment of environmental impacts resulting from various development activities, proposals or policies	Yes, except for the flow behaviour of very frequent events in the riparian zone	Yes, except for the flow behaviour of very frequent events in the riparian zone

(i) Fast 1D model is more suitable for use during an event

Comment on 10m grid

For the reasons given in Section 1 Model Resolution, a 10m Grid model is not a valid option for the whole system. As a local model in a domain where it is valid, it could be used (with boundary conditions provided by the 30m grid model) to assess the impact of developments with horizontal dimension about 20m and provide flood hazard to a resolution of about 20m.

3. Assessment of accuracy of results from detailed hydraulic model

The IPE has formed the overall assessment that the results produced by the calibrated detailed hydraulic model at a grid resolution of 30m have an accuracy that is close to what is possible. This is based on assessments (a) of the accuracy of peak flood levels, (b) of timings of hydrographs and (c) of rating curves, as summarised in following sections. The IPE has noted that the accuracy of the observed flood data is uncertain and varied and that the topographic data has limited and varied accuracy. Further, only three calibration/verification events are available for appraisal.

3.1 Accuracy of modelling of peak flood levels

Invitation to Offer Section 3.8

In terms of water levels, four target tolerances are set for the study:

- Brisbane River downstream of Oxley Creek ± 0.15 m
- Brisbane River between Goodna and Oxley Creek ± 0.30 m
- Ipswich urban area ± 0.30 m
- Brisbane River and tributaries upstream of Goodna (for non-urban areas), including Bremer River and Lockyer Creek ± 0.50 m

The Invitation to Offer (ITO) specification in Section 3.8 is not a rigorous requirement but a statement of desirable targets. It includes the acknowledgement that *'there is no independent way of confirming that these accuracies will have been achieved in the results, some indication of the likely accuracy might be obtained through consideration of etc '*.Thus, the ITO accepts that only a 'judgement call' can be made concerning accuracy.

The accuracy of modelling can be assessed only for the calibration of the 2011 (large flood) event, of the 2013 (small flood) event and for the verification of the 1974 (large flood) event. These are unavoidably 'contaminated' by the inherent errors in the observed levels and in the flows estimated by the hydrology. The accuracy assessed from the calibration/verification of peak flood levels does not translate directly to estimates of the accuracy of design flood levels; however, this is the only available indication of what is likely to be the case.

The statistical analysis of differences between modelled and observed peak flood levels shown graphically in the *Draft Milestone 3 Report* in Figs 3-1 (2013), 3-2 (2011) and 3-3 (1974) is considered the best indication of the accuracy of the modelling. The results of an approximate analysis of the data in those Figs are summarised in the Table below.

Flood Event	Total data points	Difference -0.15m to +0.15m %	Difference -0.30m to +0.30m %	Difference outside -0.30m to +0.30m %
2013	119	50	79	21
2011	526	67	86	14
1974	1975	57	85	15

The entries in Table 3-4 of the *Draft Milestone 3 Report* show the distribution of differences in the reaches for which the tolerances are specified in Section 3.8 of the ITO.

For the 2011 event the differences between the modelled and the available observed data are within the specified tolerances everywhere except at one point where the difference is only 0.01m greater than specified.

For the 1974 event there are only three points where the differences exceed the specified tolerance; at the City Gauge/Port Office the difference is only greater than specified by 0.01m; at Highgate Hill the large discrepancy could be due to a datum error for the St Lucia reach; at Lyons Bridge Alert the discrepancy -0.65m seems to be of little consequence.

For the 2013 event there are five points where the differences exceed the specified tolerance; Oxley Ck Mouth Alert (-0.28m), Lowood Alert (-0.54m), Walloon Alert (0.69m), Loamside Alert (0.70m), Rifle Range Alert (-0.78m). The 2013 event was essentially in-bank except for Lockyer Creek upstream from O'Reilly's Weir Alert and for the Bremer River upstream from Berry's Lagoon Alert. The accuracy of the modelled flood levels could be affected by inaccuracies in lower levels of stream cross-section data.

Recognising the uncertain accuracy of the observed data and the limited accuracy of topographic data, including that for the lower levels of some streams, the IPE considers that the accuracy of calibration/verification of peak flood levels achieved is close to what is possible. Catchment wide collection of peak flood level data immediately after an event will allow a more reliable calibration.

3.2 Accuracy of modelling of timing of hydrographs

Observed data of flood level hydrographs is less extensive than that for peak levels and some are of doubtful accuracy. Overall, agreement between the timing and shapes of the modelled hydrographs and the observations varies from very well to satisfactory.

This correlation is important in calibration/verification. As noted for peak flood levels, the assessment of accuracy does not translate directly to the accuracy of forecasts of flood timing and lead times in emergency flood management. But this is the only available indication of what is likely to be the case. The degree of correlation between modelled and observed hydrographs at three key locations for flood emergency management is summarised for the 2011 and 1974 flood events in the Table below.

Location	2011 Flood event hydrograph		1974 Flood event hydrograph	
	Timing of rising limb	Timing of peak	Timing of rising limb	Timing of peak
Ipswich-Bremer	Upper half Good First half early by up to about 6hrs	Good	Good	Good
Moggill Alert	Upper half Good First half early by up to about 6hrs	Good	Good	Good
Jindalee Alert	Good	Good	Good	Good

3.3 Accuracy of rating curves produced from modelling

The rating curves for locations along the Brisbane River derived from the detailed hydraulic model display a good self consistency between different floods and generally good correlation with those derived from the hydrology phase and with gauging (at Savages Crossing); this assessment also applies at Amberley on Warrill Creek.

At other locations - Walloon (Bremer River), Loamside (Purga Creek), Glenore Grove (Lockyer) and Rifle Range Road (Lockyer) - there are substantial differences between the rating curves from the several sources. However, there are known problems with each of these gauge sites.

4. Draft Milestone Report 3 - Overall Comments

Apart from the matters discussed above, the draft Report is considered to generally good, requiring only minor additions to explain some details better.

The Summary of Outcomes/Actions from Workshop # 3 provided by BMT WBM (W J Syme & C Barton) identifies all of the matters of concern to the IPE other than those discussed above and the proposed changes in the report are considered satisfactory.

4.1 Draft Milestone 3 Report Section 3.12 Extreme Event Proofing

The longitudinal profiles in Plot 26 for Lower Brisbane between chainages 15000m and 60000m (approx) for 5x1974 and 8x1974 have large differences between the DM and FM (the latter are lower). The profiles are much closer together upstream from this region. The rating curves show these large differences at Brisbane City and Centenary Bridge (Plot 33) while those at Mt Crosby Weir and Savages Crossing are close together (Plot 32). Some comment on this would be useful.

4.2 Minor editorial matters

The index of the *Draft Milestone 3 Report* states incorrectly that Plots 31, 32 and 33 for the extreme event are for 8x1974.

The caption below each Plot 31, 32, 33 is not correct.

Draft Milestone 3 Report page 32 Includes the statement; *'Evidence of the uncertainty in the URBS generated hydrographs from the Upper Brisbane and Stanley River catchments is seen in Plot 21, with the URBS flow hydrograph peak shown to occur after the recorded peaks at Lowood and Savages Crossing.'*
Comment The URBS hydrograph is not shown on the Savages Crossing plot.

5. Summary

- Model grid size resolution is always a trade off of competing needs when setting up a model.

- While a smaller grid may be desirable to represent the terrain in finer detail in some regions and to stabilise the calibration as grid size gets smaller, this is not possible for the whole of the Brisbane River Catchment. It is important also to note that the use of grid sizes that are smaller than necessary cannot achieve greater overall accuracy since the accuracy of the calibrated model is limited by the limited accuracy of the input data and over-all by the uncertain but limited accuracy of the calibration data.

- The calibrated 30m grid size model satisfies the detailed requirements specified in Section 2.3.5 of the ITO, providing flood levels suitable for habitable flood levels at property level/scale and all of the other required results and capabilities, as detailed in the table in Section 2 of this report.

- IPE is asked to sign-off that 30m grid resolution satisfactorily meets the requirements of the brief as demonstrated by the results of the modelling to date. Taking account of all of the issues discussed, the IPE considers that 30m grid size represents the most practical compromise between the competing needs to produce a general purpose model that meets the requirements of the brief.

- The IPE has concluded that the 30m grid resolution does satisfactorily meet the requirements of the brief.

- Local governments and other authorities may wish to carry out additional local modelling using finer grids to evaluate the impact of very local infrastructure proposed (e.g. Kingsford Smith Drive and Ferry terminals) which is a normal industry practice. The necessary boundary conditions for the finer scale modelling will be provided from the calibrated BRCFS 30m grid model.

17 July 2015

Colin Apelt	Mark Babister	John Macintosh
UniQuest Pty Ltd	WMAWater	Water Solutions

References

Barton, C.L. (2001) *Flow Through an Abrupt Constriction – 2D Hydrodynamic Model Performance and Influence of Spatial Resolution*, Thesis submitted as partial fulfilment for Master of Engineering Science, Environmental Engineering, Griffith University.

Toombes and Chanson (2011) *Numerical Limitations of Hydraulic Models,* 34th IAHR World Congress Brisbane.

Appendix C Input Data – Fast and Detailed Models

Model input data required for model development and simulation is primarily the same for both the Fast and Detailed Models. A description of the model input data has been provided previously in Milestone Report 3 – Fast Model Development and Calibration (BMT WBM, 2015). Rather than substantially repeating the model discussion in the main body of this report, in consultation with the Client it was decided the discussion on model input data be placed in an Appendix to allow the main body of this report to focus on calibration results. This ensures that this report (Milestone Report 3) remains a stand-alone report but without a repetition of Input Data chapters in the core of the report, that most readers reviewed in Milestone Report 2.

C.1 Topographic Data

The relevance and priority of the available topographic datasets that were considered for use in the development of the Fast and Detailed Models are discussed in this section.

C.1.1 Disaster Management Tool DEM (DMT DEM)

As part of the Brisbane River Catchment Disaster Management Tool study ("DMT Study") completed by BCC in 2014 (BCC, 2014a), a DEM was developed across the full hydraulic model study area. This DEM is referred to as the DMT DEM. It was based on the latest floodplain LiDAR and bathymetry (post-2011 flood) information and represented the best information available at the time of the DMT study. Further details on the background and development of the DMT DEM are provided in BCC (2014a) and BCC (2014b). Additional discussion on the DMT DEM relating to technical matters and identified data gaps directly relevant to this study is provided in BMT WBM (2014). A Drawing showing the areas of LiDAR data utilised to form the DMT DEM is provided in BMT WBM (2014).

Since development of the DMT DEM, additional topographic and bathymetric data have become available and/or were deliberately sourced in order to fill the data gaps identified by BCC (2014b). It was not possible to incorporate the new data into that DEM[16], instead, the new data has been utilised on a priority basis by the hydraulic models in order to inform hydraulic model topography. Both the new data and other relevant data are described in the following sections. The priority order of all data sets used in the Fast and Detailed Models is described in Section C.1.5.

C.1.2 Lower Brisbane River and Tributaries DEM (GHD)

For the purpose of the Coastal Plan Implementation Plan Study undertaken for BCC by GHD (GHD, 2014), a DEM of the Lower Brisbane River and tributaries was developed. This DEM was developed from BCC LiDAR data and various sources of bathymetric data. Of particular interest to this study are the bathymetric components of the DEM. The bathymetric data used to create the DEM includes:

- Cross-sectional data (BCC) extending up into some tributary creeks (for example, Norman and Oxley Creeks);
- Hydrographic survey data extending up into some tributary creeks (for example, Breakfast Creek and Bulimba Creek); and

[16] Attempts were made to combine these new datasets with the DMT DEM into a single DEM and assistance was sought from the 12D developers and Peter Murray from BCC in this regard. However, due to the computing constraints imposed by the very large size of the DMT DEM it was not possible to incorporate the new data into the DEM.

- Other sources including Dredge Area MSL, Moreton Bay Channel data, MSQ and R plus L Bathymetry (naming of these sources was extracted directly from the explanatory text file that was received with the DEM).

The GHD data typically captures the lower reaches of some of the tidal tributaries that the DMT DEM did not. The original DMT Model modified the bathymetry at these locations using z shapes to lower the creek beds. Comparison of the GHD DTM and the DMT DEM shows little difference in the overbank areas. In general, for the in-bank areas of the lower reaches of the Brisbane River (below Hamilton), the GHD DTM gives higher bed levels than both the DMT DEM and the 2014 Port of Brisbane bathymetry (refer to Section C.1.4.1). We have not used the GHD DEM in these regions, instead giving priority to the 2014 PoB bathymetric survey.

Details on the prioritisation of this DEM for use in the hydraulic models are provided in Section C.1.5.

C.1.3 Future LiDAR Data

Through discussions with stakeholders and DNRM, it is understood that a new LiDAR survey being flown in South East Queensland will cover the area of the Hydraulic Assessment except for the Lockyer Valley. It has been confirmed by DNRM that there is a delay in the delivery of this LiDAR and it has not been possible to include this data within the development and calibration of the Fast and Detailed Models. Further commentary on this future dataset is provided in BMT WBM (2014) with commentary updates anticipated in future BMT WBM Milestone Reports.

C.1.4 Bathymetric Data

Bathymetric data defines the shape of the ground surface below water level. This data can be collected as cross-sections or hydrographic survey. Cross-sections are typically perpendicular to the flow direction and may include components of above-water topography. Hydrographic survey is traditionally limited to the underwater ground surface and is typically provided as a closely spaced set of regularly spread points.

The location of the following bathymetric data sets are shown in Drawing 3.

C.1.4.1 PoB Lower Brisbane and Lower Bremer (2014)

In August 2014, the Port of Brisbane (PoB) (on behalf of the Qld DNRM) provided a 5m gridded DEM bathymetric data point set based on their hydrographic survey of the following areas:

- **Bremer River** - from West Ipswich downstream to the confluence with the Brisbane River;
- **Brisbane River** - from Parker Island (near the Gateway Bridge) downstream to Inner Bar; and
- **Brisbane River** - from Shafston Reach downstream to the Quarries Reach (near the Gateway Bridge) (completed as a part of the BCC Kingsford Smith Drive Stage 3 project).

BMT WBM used these points to create three DEMs: Lower Bremer, Lower Brisbane 1 and Lower Brisbane 2. The use of these DEMs is discussed in Section C.1.5.

C.1.4.2 Mt Crosby Weir Pool (2007)

Seqwater commissioned a detailed hydrographic survey of the Mt Crosby weir pool in 2007, extending about 15km upstream from the Mt Crosby Weir to Pine Mountain. This survey was undertaken as a set of bathymetric cross-sections spaced at 25m. BMT WBM used these sections to create a bathymetric DEM of the Mt Crosby weir pool. The use of this DEM is discussed in Section C.1.5.

C.1.4.3 Lowood-Fernvale Cross-Sections (2008)

As part of the Fernvale and Lowood Flood Study (BCC, 2009), cross-sections were surveyed on both the Brisbane River and Lockyer Creek in 2008. A total of 46 cross-sections were surveyed with 14 of these on Lockyer Creek and 32 on the Brisbane River, as shown in Drawing **2**. The spacing between sections is approximately 500m. A comparison of these surveyed cross-section points with the DMT DEM data in this region revealed that the surveyed points are on average 0.42m lower than the DMT DEM, with a standard deviation of 2.0 m. THE DMT DEM is primarily based on LiDAR in this region and it is typical for LiDAR to be higher than surveyed data due to the effects of vegetation and water.

Suitability for Use in the Fast Model

When initially considering these cross-sections for use in the Fast Model, it was found that the cross-sections did not extend across the entire waterway and in some reaches they were at a spacing that was greater than desired. If these cross-sections were to be used for 1D modelling, they would need to be extended across the full waterway by merging the surveyed component with extracted DMT DEM sections. Given the limited timeframe available this was not a realistic option. Instead, two tests were undertaken to assess the suitability of using the DMT DEM to provide topographic/bathymetric data for the Fast Model in the Lowood Fernvale area:

(1) Sensitivity tests using the unextended Fernvale Lowood cross-sections for in-bank topography in the Fast Model compared with using the DMT DEM. This test concluded that use of the Lowood-Fernvale cross-sections without extending the sections to the full extent of the waterway has a significant and unrealistic impact upon results. As the cross-sections do not extend to the top of bank, the model conveyance in this area is greatly reduced if the cross-sections are used and, as a consequence, modelled flood levels are significantly higher. It was concluded that it was not possible to use these cross-sections in the Fast Model without a substantial amount of effort to extend the sections by merging with the DMT DEM. This sensitivity test is documented in Milestone Report 2 (BMT WBM, 2015).

(2) Comparison of a Seqwater surveyed gauge cross-section with the DMT DEM in this region. The Seqwater surveyed cross-section compares satisfactorily with the DMT DEM section as shown in Figure C-1. The reasonable result of this comparison was unexpected as it was believed that the DTM DEM was based solely on LiDAR data in this region. As LiDAR is unable to provide data below the water surface, it was expected that the bathymetry would not be defined. However, further investigation revealed that the DMT DEM was manually altered to better reflect the gradient of the river bed through this region. According to BCC (2014b), "*a very basic river bed centreline level was graded using riffles (identified by aerial imagery) and low points of sections taken in the 2008 study in the Lowood Fernvale area*". This graded centreline was used to alter the DMT DEM, thus providing some representation of the bathymetry in the Lowood Fernvale area. This explains the better than expected comparison with the surveyed cross-section. The minimum invert level of the survey cross-section is 0.3m lower than the LiDAR DEM data and the cross-sectional area of the survey cross-section is marginally smaller. These differences are not expected to significantly impact upon results.

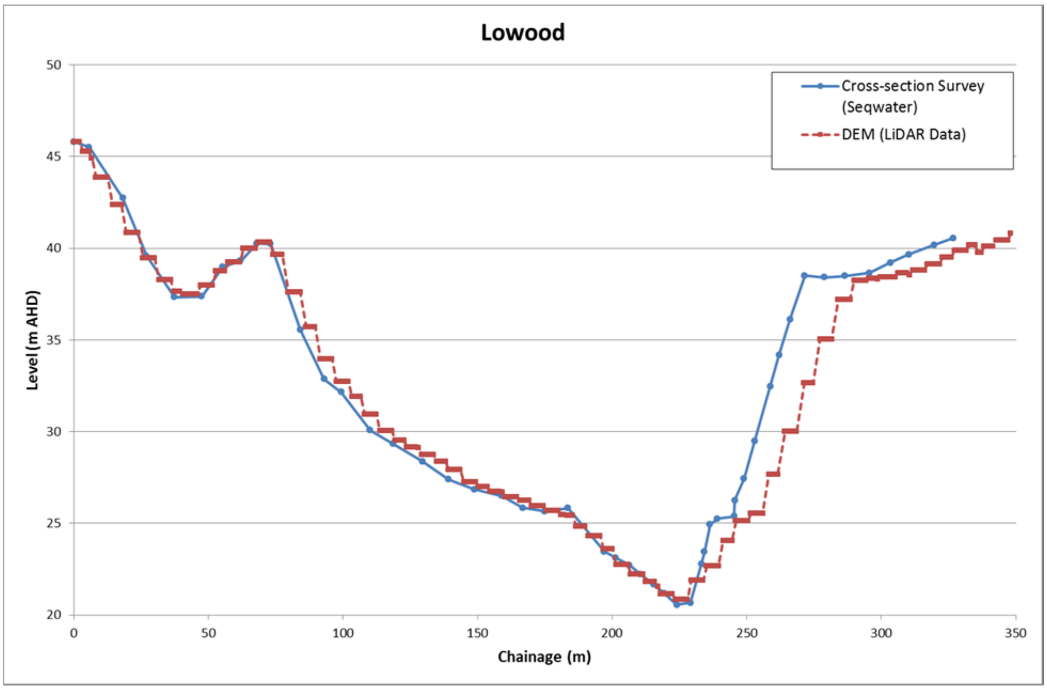


Figure C-1 Comparison of Survey Cross-Section with LiDAR DEM Data at Lowood

The results of these tests gave confidence that the DMT DEM was suitable for use to define the topography in the Lowood-Fernvale region of the Fast Model, rather than the Lowood-Fernvale cross-sections

Suitability for Use in the Detailed Model

The Detailed Model in the Lowood-Fernvale region is fully-2D and a fully-2D model requires a DEM to inform topography. That is, the cross-sections are not able to be used directly in the Detailed Model at this location. In order to be suitable for use in the Detailed Model, these cross-sections would require integration with the surrounding LiDAR data to create a new DEM. This would involve creation of longitudinal breaklines along the full longitudinal extent of the cross-sections and manual manipulation of the existing DEM to smooth the transition from cross-section to LiDAR data (as the overlapping elevation values are not likely to be the same). However, given the results of the comparison of the DMT DEM with the Seqwater surveyed cross-section (refer to item 2 above) in conjunction with the fact that creation of a new DEM was not considered feasible within the timeframe available, it was decided to use the DMT DEM to inform Detailed Model topography in this region.

Summary of Suitability

In summary, the DMT DEM was used to inform topography in this region for both the Fast and Detailed Models for the following reasons:

- The Lowood-Fernvale cross-sections are not suitable for use in the 1D Fast Model due to their limited coverage of the waterway area and the resulting loss of model conveyance, leading to unrealistic modelled flood levels. The cross-sections are not suitable for use directly in the Detailed Model as it is fully 2D in this region and requires a DEM to inform topography.

- The Lowood-Fernvale cross-sections may be of use if they were able to be successfully merged with the LiDAR (DMT DEM) data in the region. For the Fast Model, this would require extending the sections using the LiDAR data such that they cover the full waterway area. For the Detailed Model, which is fully 2D in this area, this would require creation of a new DEM in which the cross-sections were integrated. Both these options were not considered possible within the timing of this assessment.
- The DMT DEM in this area is based on more than just LiDAR data due to the fact that BCC (2014b) undertook manual adjustment river sections below normal water level. Independent checks on the DMT DEM in this area using a Seqwater surveyed gauge-cross-section indicate the DMT DEM represents the cross-sectional area and river conveyance satisfactorily.

As such, the DMT DEM was used in preference to the Lowood-Fernvale cross-sections to inform both the Fast and Detailed Model topography.

C.1.4.4 RUBICON Model Cross-Sections

In 1994, Qld DPI completed the Brisbane River and Pine River Flood Study (DPI, 1994) on behalf of the South East Queensland Water Board. RUBICON hydraulic modelling was undertaken using the following sources of in-bank topographic data:

- 40 cross sections of the Brisbane River surveyed by DPI (formerly the Queensland Water Resources Commission) in 1992 between Wivenhoe Dam and Colleges Crossing. A further 8 cross sections were available from a 1989 survey near Burtons Bridge;
- Cross sections of the Lockyer Creek surveyed by DPI in 1966;
- A hydrographic survey of the Brisbane River extending from the river mouth to just below Colleges Crossing from 1974; and
- A hydrographic survey of the Bremer River from its junction with the Brisbane River to the Basin Reserve in Ipswich by the Bremer River Trust Fund in 1988.

As shown in Drawing 3 these cross-sections are widely spaced. In addition, some of the sections were surveyed many years ago, making their currency less certain. These two facts in combination make the cross-sections of limited value in the modelling undertaken for the current study. However, they have been used to provide further insights into in-bank topography on an as-required basis.

C.1.4.5 Ipswich City Council Cross-Sections

As shown in Drawing 3, the Ipswich City Council cross-sections cover some of the minor tributaries of the Bremer River. The locations of these sections are outside the extent the hydraulic models developed for the current study.

C.1.4.6 ARI Depth Soundings (2012)

Depth soundings of the Brisbane River were collected by the Australian Rivers Institute (ARI) in September/November 2012. The soundings extend from Wivenhoe downstream to the top end of the Mt Crosby weir pool (upstream of Mt Crosby), as shown in Drawing 3 and result in small overlaps with the Lowood-Fernvale Cross-Sections and the Mt Crosby pool data at the upstream and downstream ends respectively Joe McMahon from ARI advised that the underwater ground surface elevation in AHD was estimated by linking the water level measured by ARI with the water level measured by LiDAR, flown in 2011. This allowed water depths measured by ARI to be converted to AHD. BMT WBM compared the ARI bathymetry with that found within the LiDAR dataset and found that ARI bathymetry values were 1.3m lower on average than LIDAR, with a standard deviation of 1.4. This seems reasonable given that the LIDAR does not extend below water level and that ARI data was collected from a canoe.

The ARI data was not suited for incorporation into the Fast Model due to its large spatial variance in the horizontal and it often not being perpendicular to the flow direction. It was therefore not used in the Fast Model. It was further considered for use in the Detailed Model, but again due to the large spatial variance the ARI dataset was not considered suitable for creating a DEM.

C.1.4.7 MIKE 11 Model Cross-Sections

The MIKE11 model of the Brisbane River has been reviewed and updated numerous times. It was initially developed by SKM (1998) using 197 surveyed cross-sections up to the extent of the BCC Council area (about 79km upstream and about 10km downstream of Colleges Crossing). The MIKE11 model was extended up into the Bremer River by SKM (2000) using surveyed cross-sections and photogrammetry of "questionable accuracy" to represent the modelled floodplain topography. In 2005, the SKM (2000) MIKE11 model was extended up to Wivenhoe Dam and into Lockyer Creek to assess the impacts of the Wivenhoe Dam upgrade (Wivenhoe Alliance, 2005). Cross-sections used to extend the model in 2005 were derived from:

- 5 m digital contours of Esk Shire Council area; and
- Cross sections surveyed for DNR for the 1994 study (DNR, 1994) – the "Rubicon Model Cross-Sections".

The most recent review and update of the MIKE11 model was undertaken by SKM (2011) for Seqwater. One significant key finding of this review was that the representation of cross-sections was not found to be appropriate for the magnitude of events relevant to that study.

More recent bathymetric survey now covers the majority of the rivers over which the surveyed MIKE11 cross-sections lie. For areas in which bathymetric survey is not available (e.g. upstream of the Mt Crosby weir pool surveyed section to the Lowood-Fernvale cross-sections), the MIKE11 cross-sections are based on the Rubicon model cross-sections. As previously mentioned in Section C.1.4.4, these sections are too greatly spaced to be of use in the model topography. As such, the MIKE11 sections have not been used in either the Fast or Detailed Models.

C.1.4.8 Seqwater Surveyed Cross-Sections at Gauge Sites

Cross-section information upstream and downstream of gauge sites is held by Seqwater and was supplied to BMT WBM in September 2014. The cross-sections are not suitable for use in the model as they are solely at gauge sites, but they have been used to provide an indication of potential accuracy or otherwise of the LiDAR data used in the in-bank sections of the Fast and Detailed Models. This comparison is discussed in detail in Milestone Report 2 (BMT WBM, 2015) and summarised as follows:

- Glenore Grove - The surveyed cross-section at Glenore Grove (on Lockyer Creek) compares satisfactorily with the LiDAR data in that area. The minimum creek invert level of the survey cross-section is 0.8m higher than the LiDAR DEM data and the cross-sectional area of the survey cross-section is marginally smaller. However, neither of these differences will have a great influence on hydraulic model results.

- Lowood - At Lowood, the Seqwater surveyed cross-section compares satisfactorily with the DMT DEM section. This is documented further in this report in Section C.1.4.3. The reasonable comparison result is due to the fact that the DMT DEM was manually altered to better reflect the gradient of the river bed through this region (BCC, 2014b).
- Jindalee - The bathymetric sections of the surveyed cross-section compare satisfactorily with the DMT DEM. It is important to note the in-bank sections of the DMT DEM at this location are based on bathymetric survey collected post-2011 flood by MSQ (refer to BCC (2014a,b) so it would be expected that the comparison would yield reasonable results, which it does.

These comparisons provide confidence that the bathymetric portions of the datasets used to inform topography in both the Fast and Detailed Models are of sufficient accuracy for hydraulic modelling purposes.

C.1.5 Priority Ranking of Topographic Datasets

For the purpose of the update to the DMT model (BMT WBM, 2015) and development of both the Fast and Detailed Models, each topographic dataset has been given a priority ranking to ensure that the most suitable data is utilised within the relevant model area. The priority ranking is only applicable in areas where the datasets overlap and is used to ensure that the most suitable data is utilised within the relevant model area. That is, in an area where only one dataset is available, then that dataset is the one used, regardless of its priority ranking. If datasets do not overlap, they may be assigned the same priority ranking as they are never in competition with each other. For example, there is no overlap between each Priority 1 dataset shown below for in-bank data.

Priority 1 Data (Highest Priority):

- Mt Crosby Weir Pool (2007)
- PoB Lower Brisbane and Lower Bremer (2014).

Priority 2 Data:

- Lower Brisbane River and Tributaries DEM (GHD).

Priority 3 Data:

- Lowood-Fernvale Cross-Sections (2008)[17]

Priority 4 Data:

- ARI Cross-Sections (2012)[6]

Priority 5 Data:

- DMT DEM.

Checking as Required

- Seqwater Gauge Cross-Sections

[17] The invert levels of these cross-sections were used to ensure the Detailed Model represented the channel invert appropriately at these locations. Further discussion is provided in Section 2.3.

Not Used

- RUBICON & MIKE11 Model Cross-Sections

C.1.6 Breaklines

Breaklines are survey strings used to define continuous linear features. In relation to 2D modelling, they are used to define both the location and elevation of floodplain features such as levees and embankments that need to be specifically included in the DEM and/or the hydraulic model due to their ability to affect hydraulic behaviour.

Digital geo-referenced locations of railway lines and State carriageways were provided by Queensland Rail and DTMR respectively. However, neither of these digital datasets (breaklines) contained elevation data. In order to assign elevation data to these breaklines, automated procedures were developed that used the location of the breakline to search the 5m DEM for the series of high point elevations that best represented the longitudinal elevation of the linear feature for the purposes of hydraulic modelling.

Digital locations of other breakline features such as farm levees, dam walls and minor roads were not available. Instead, these features, where likely to be hydraulically influential, were manually digitised using the DEM and aerial imagery. The Updated DMT Model results (BMT WBM, 2015) were used to limit the extent of manual digitisation required by only considering locations in high velocity x depth areas, as it is these areas that will potentially have the greatest impact on model results. Once the location of these breaklines had been digitised, the same automated procedure as used for railway lines and state carriageways was used to assign high point elevations along each linear feature.

Slim flow obstructions include noise barriers, fences and hand railings. These features may have an impact upon hydraulic behaviour depending upon their location and elevation. Breakline data on slim flow obstructions was not provided for this assessment. Unlike “wider” features like roads and levees that are possible to see on an aerial photograph and whose elevations are reflected in the LiDAR data, slim flow obstructions cannot be seen on an aerial photograph and elevations are not detected by LiDAR due to their “slim” nature. Thus, it was not possible to incorporate these features into the Fast or Detailed Models, simply because the data is not available and not able to be extracted from any existing dataset.

C.1.7 Historical Topographic Data

Topography of floodplains and channels can change over time. In particular, large events can have a major impact on in-bank channel form and vegetative condition. These parameters can then impact upon channel conveyance. For example, significant changes to river conveyance (in-bank bathymetry and roughness) occurred within the Brisbane River catchment due to damage to channels and stripping of vegetation caused by the 2011 event floodwaters. The area downstream of Savages crossing was particularly affected. Michael Raymond from Seqwater (pers.comm., Nov 2014) noted that the impacts of this damage resulted in a general drop in water levels at Mt Crosby and Savages Crossing.

Ideally, channels and floodplains would be surveyed periodically to ensure that changes to topography were recorded and that the relevant topographic dataset could be used in a hydraulic model during calibration to a particular historic event. However, this would be a costly exercise and has not been carried out for the Brisbane River catchment. Accounting for historical changes in channel and floodplain roughness within the hydraulic model is possible by sensitivity testing Manning’s n values in areas where anecdotal or other evidence indicates that these changes have occurred. However, accounting for changes in topography is more difficult unless reasonable topographic surveys are available.

C.2 Hydrographic Data

C.2.1 Historical River Gauge Data

River gauges record water levels with flows derived from the recorded water levels using a rating curve. As part of the calibration process for a hydraulic model, the recorded water levels are compared to modelled water levels for each calibration event. A summary of the river gauges available for each calibration event is provided in Table C-1. Gauges that are indicated as having data of questionable quality are discussed further in Appendix D.

The location of the river gauges is provided in Drawing 1. As the GIS coordinates supplied with the gauge data generally indicate the position of the gauge hut/electronics rather than the pressure sensor (where the water level is actually measured), Seqwater (personal communication, Oct 2014) provided advice on the exact positioning of the pressure sensor for a number of critical gauge sites. This allowed the GIS point of measurement for each gauge to be moved from an out-of-bank location to the more correct in-bank main channel location. While some uncertainty remains on the precise location of some of these pressure sensors; the updated dataset is considered an improvement over that was used previously.

Table C-1 Historical Availability of River Gauge Data for Calibration Events

BoM Gauge No.	AWRC Gauge No.	Gauge Name	System	Historical Calibration Data				
				1974	1996	1999	2011	2013
540495	143891	Whyte Island Tide AL	Moreton Bay	x	x	x	Yes	Yes
40647	143935	Brisbane bar Tide TM	Moreton Bay	Yes	Yes	Yes	Yes	Yes
540129	143847	Hemmant AL	Lower Brisbane	x	x	x	Yes	?
MSQ: R046047A.86		Gateway Bridge	Lower Brisbane	x	Yes	Yes	Yes	x
540286	143877	Breakfast Creek Mouth Al	Lower Brisbane	x	x	x	Yes	Yes
540130	143851	Bowen Hills Alert	Lower Brisbane	x	x	x	Yes	Yes
540198	143838	City Gauge	Lower Brisbane	Yes	Yes	Yes	Yes	Yes
540274	143872	Oxley Ck Mouth AL	Lower Brisbane	x	x	x	Yes	Yes
540132	143848	East Brisbane Alert	Lower Brisbane	x	x	x	Yes	Yes
540192	143832	Jindalee Alert	Lower Brisbane	Yes	x	?	Yes	Yes
41472	-	Centenary Bridge	Lower Brisbane	Yes	x	x	Yes	x
540200	143924	Moggill Alert	Lower Brisbane	Yes	Yes	?	?	Yes
-		Clarence Rd	Lower Brisbane	Yes	x	x	x	x
-		Dutton Park Cemetery	Lower Brisbane	Yes	x	x	x	x
-		Highgate Hill - Paradise St	Lower Brisbane	Yes	x	x	x	x
-		Tennyson Powerhouse	Lower Brisbane	Yes	x	x	x	x
-		Sandy Creek	Lower Brisbane	Yes	x	x	x	x
-		St Lucia Ferry	Lower Brisbane	?	x	x	x	x
-		OxleyCkCorinda	Lower Brisbane	Yes	x	x	x	x
-		Yeronga St	Lower Brisbane	Yes	x	x	x	x
-		Tennyson	Lower Brisbane	Yes	x	x	x	x
540063	143868	Colleges Crossing Alert	Mid Brisbane	x	x	x	?	?
540199	143839	Mt Crosby AL	Mid Brisbane	Yes	Yes	Yes	Yes	Yes
540256	143864	Kholo Bridge AL	Mid Brisbane	x	x	x [11]	?	Yes
540606	143049	Lake Manchester HW TM	Mid Brisbane	x	x	x	Yes	Yes
540257	143856	Burtons Bridge	Mid Brisbane	x	x	x [11]	?	Yes
540066	143001C	Savages Crossing TM	Mid Brisbane	Yes	Yes	Yes	Yes	Yes
540182	143001A	Lowood Alert-B	Mid Brisbane	?	x	Yes	Yes	Yes
540178	143823	Wivenhoe Dam TW Alert-P	Mid Brisbane	x	x	?	?	Yes
40831	143954	Ipswich Alert	Bremer River	Yes	Yes	x	Yes	Yes
540250	143852	Brassall (Hancocks Bridge)	Bremer River	x	x	x	?	?
40836	14953	One Mile Bridge Alert	Bremer River	x	x	Yes	Yes	Yes
540550	143114	Berry's Lagoon Alert	Bremer River	x	x	x	?	Yes
40838	143956	Three Mile Bridge AL	Bremer River	x	x	Yes	?	?
540504	143896	Walloon AL	Bremer River	x	Yes	?	Yes	Yes
540249	143854	Bundamba (Hanlon St) Al	Bundamba Ck	x	x	x	Yes	?

BoM Gauge No.	AWRC Gauge No.	Gauge Name	System	Historical Calibration Data				
				1974	1996	1999	2011	2013
-	143114	Mary St	Bundamba Ck	Yes	x	x	x	x
540248	143857	Churchill Alert	Deebing Ck	x	x	x	Yes	Yes
540062	143983	Loamside Alert	Purga Creek	x	x	Yes	Yes	Yes
540210	143113	Loamside TM	Purga Creek	Yes	Yes	x	x	x
40816	143108	Amberley (DNRM) TM	Warrill Creek	Yes	Yes	Yes	Yes	Yes
540180	143825	Amberley-P (Greens Road)	Warrill Creek	x	Yes	Yes	Yes	x [13a]
40874	143962	Brisbane Road Alert	Woogaroo Creek	x	x	x	Yes	?
540051	143207	O'Reilly's Weir AL	Lockyer Creek	x	?	Yes	Yes	x [13a]
540544	143700	Rifle Range Rd Alert -P	Lockyer Creek	x	Yes	Yes	Yes	Yes
540174	143819	Lyons Bridge Alert-P	Lockyer Creek	Yes	x	Yes	?	x [13a]
540149	143808	Glenore Grove Alert	Lockyer Creek	Yes	x	Yes	Yes	Yes

Yes	Data available and of sufficient quality for use in calibration
x	Data not available or gauge identified as erroneous by Seqwater
?	Data available but of questionable quality. Discussed in Appendix D.

13a – Assessment validated by Seqwater (2013a)
13b – Assessment validated by Seqwater (2013b)
11 – Assessment validated by Seqwater (2011)

C.2.2 Historical Flood Mark Levels

Historical flood mark records exist for the 1974, 2011 and 2013 flood events. These marks are considered to be peak flood levels at spot locations. Locations of these spot levels across the hydraulic model area are contained within Drawing 4 to Drawing 6 for the 1974, 2011 and 2013 flood events respectively. These flood marks were surveyed after the event and are typically based on debris marks or watermarks. It is important to note that debris and watermarks can be inaccurate for a number of reasons including:

- Dynamic hydraulic effects such as waves, eddies, pressure surges, bores or transient effects, which may not be accounted for in the model. For example, if the debris mark is located within a region of fast flowing floodwater it is possible that the floodwater has pushed the debris up against an obstacle, lodging it at a higher level than the surrounding flood level.
- Lodgement of debris at a level lower than the peak flood level. The reason for this is that for debris to be deposited, it needs to have somewhere to lodge and this elevation is not always at the peak flood level. For example, debris lodged in the fork of a tree or on the strands of a barb-wire fence may have been carried there by floodwater that went *higher* than the tree fork or fence wire, but this was not apparent after the event due to the lack of higher lodging places.

Somerset Regional Council (pers. comm. April 2015) has indicated that some of the flood marks recorded recently could be ± 200mm, while others are more accurate. This is due to some being estimated (not based on an actual line), while others are surveyed from distinct and enduring water marks. Unfortunately, none of the flood marks used this assessment have meta-data on accuracy and it is not possible to distinguish between those of high accuracy and those of poor. Flood marks that have been identified as being of questionable quality during the course of this Assessment are discussed further in Appendix D.

C.2.3 Flow Gauging at Centenary Bridge

Flow gauging carried out on the downstream side of Centenary Bridge during the 1974, 2011 and 2013 floods provides valuable data on the flows close to the peaks of these floods. For the 2011 and 2013 floods, flows were also measured during the near "steady-state" drain down phase Wivenhoe Dam releases, once again providing a check on discharges during controlled releases from Wivenhoe Dam. Of note is that the 1974 flow measurements are considered to be of lesser accuracy due to the use of older technology. Water levels off the downstream side were also recorded whilst the flow measurements were taken. In addition, the time of day at which the 1974 flow and level measurements were taken is unknown. As such, when these records are presented on time-series plots, they are represented as a horizontal line from 6am to 6pm on the day of recording.

C.2.4 Flood Extents

Flood extents are described in Section 2.1.1. Any issues identified in the flood extents provided for any of the calibration events is discussed in Appendix D.

C.3 Hydraulic Structure Information

Hydraulic structure information was sourced from a variety of agencies and was received in a number of formats, including plans and existing hydraulic model representations. Further details on the collection of this data and other associated information is provided in BMT WBM (2014). Table C-2 contains a summary of the historical presence of hydraulic structures that has guided their inclusion in the Fast and Detailed Models. The location of each of these structures is shown in Drawing 7, labelled with the ID shown in Table C-2.

Some hydraulic structures have little impact on hydraulic behaviour (e.g. the Sir Leo Hielscher Bridges), nonetheless they are incorporated into the model.

Table C-2 Historical Presence of Hydraulic Structures

ID	Description	River Crossing	1974	1996	1999	2011	2013
TMR_037	Warrego Hwy	Bremer River	Yes	Yes	Yes	Yes	Yes
ICC_058	Hancock Bridge	Bremer River	Yes	Yes	Yes	Yes	Yes
QR_025	Trainline near Riverlink Shopping	Bremer River	Yes	Yes	Yes	Yes	Yes
QR_103	Dixon St	Bremer River	Yes	Yes	Yes	Yes	Yes
TMR_043	David Trumpy Bridge	Bremer River	Yes	Yes	Yes	Yes	Yes
ICC_057	One Mile Bridge	Bremer River	Yes	Yes	Yes	Yes	Yes
ICC_056	Three Mile Bridge	Bremer River	Yes	Yes	Yes	Yes	Yes
BCC_019	Green Bridge	Brisbane River	x	x	x	Yes	Yes
BCC_021	Jack Pesch Bridge	Brisbane River	x	x	Yes	Yes	Yes
BCC_076	Kholo Rd Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
QR_083	Albert Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
BCC_077	Mt Crosby Weir	Brisbane River	Yes	Yes	Yes	Yes	Yes

ID	Description	River Crossing	1974	1996	1999	2011	2013
SRC_073	Twin Bridges	Brisbane River	Yes	Yes	Yes	Yes	Yes
SRC_074	Savages Crossing	Brisbane River	Yes	Yes	Yes	Yes	Yes
SRC_075	Burtons Bridge	Brisbane River	Yes[18]	Yes[18]	Yes[18]	Yes	Yes
BCC_006	Story Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
BCC_008	Goodwill Bridge	Brisbane River	x	x	x	Yes	Yes
BCC_009	Victoria Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
BCC_011	William Jolly Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
TMR_001	Sir Leo Hielscher Bridges[19]	Brisbane River	x	Yes	Yes	Yes	Yes
TMR_038	Captain Cook Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
TMR_050	Brisbane Valley Highway	Brisbane River	x	Yes	Yes	Yes	Yes
TMR_078	Colleges Crossing - Mt Crosby Rd	Brisbane River	Yes	Yes	Yes	Yes	Yes
BCC_020	Walter Taylor Bridge	Brisbane River	Yes	Yes	Yes	Yes	Yes
QR_087	Merivale St Bridge	Brisbane River	x	Yes	Yes	Yes	Yes
SEQw_072	Wivenhoe Dam	Brisbane River	x	Yes	Yes	Yes	Yes
BCC_010	Kurilpa Bridge	Brisbane River	x	x	x	Yes	Yes
BCC_012	Go Between Bridge	Brisbane River	x	x	x	Yes	Yes
TMR_039	Centenary Hwy	Brisbane River	Yes	Yes	Yes	Yes	Yes
SRC_066	Niethe Bridge	Buaraba Ck	Yes	Yes	Yes	Yes	Yes
SRC_067	Boyces Rd	Buaraba Ck	Yes	Yes	Yes	Yes	Yes
SRC_068	Banffs Ln	Buaraba Ck	Yes	Yes	Yes	Yes	Yes
SRC_069	Rock Gully Rd	Buaraba Ck	Yes	Yes	Yes	Yes	Yes
QR_065	Brisbane Valley Rail Trail near Mahons Rd	Lockyer Ck	Yes	Yes	Yes	Yes	Yes
SRC_071	Oreilly's Weir	Lockyer Ck	Yes	Yes	Yes	Yes	Yes
SRC_063	Lyons Bridge	Lockyer Ck	Yes	Yes	Yes	Yes	Yes
SRC_064	Watsons Bridge	Lockyer Ck	x	Yes	Yes	Yes	Yes
SRC_070	Pointings Bridge	Lockyer Ck	x	x	x	Yes	Yes
BCC_023	Pamphlet Bridge - Graceville Ave	Oxley Ck	Yes	Yes	Yes	Yes	Yes
BCC_024	Sherwood Rd	Oxley Ck	Yes	Yes	Yes	Yes	Yes
BCC_084	Beatty Rd	Oxley Ck	Yes	Yes	Yes	Yes	Yes
BCC_085	King Ave	Oxley Ck	x	Yes	Yes	Yes	Yes
QR_031	Tennis Centre Rail	Oxley Ck	x	Yes	Yes	Yes	Yes
TMR_048	Cunningham Highway	Warrill Ck	x	Yes	Yes	Yes	Yes
TMR_049	Cunningham Highway	Purga Ck	x	Yes	Yes	Yes	Yes

x = not yet constructed

Note: A unique structure ID has been developed by BMT WBM for each structure. The ID reflects the owner of the structure, followed by a number unique to that owner. Owner abbreviations are: **BCC** – Brisbane City Council; **DPW** – Department of Housing and Public Works; **ICC** – Ipswich City Council; **QR** –

[18] The survey drawing for Burtons Bridge (prepared in 2000) indicates that a new bridge was constructed around this time with the old bridge being removed. The design drawings for the old bridge were not provided and were not able to be sourced. As such, the model contains the new bridge data for all events, in lieu of the old data.

[19] The original Gateway Bridge was opened in 1986 as single bridge. The bridge was duplicated and the second bridge was opened in 2010. The pair were renamed the Sir Leo Hielscher Bridges at that time.

Queensland Rail; **SEQw** – Seqwater; **SRC** – Somerset Regional Council; **TMR** – Department of Transport and Main Roads.

C.4 Pipes

Pipes are described in Section 2.2.

C.5 Land Use Data

Spatial land use data is used to assist in determining the spatial extent of model roughness values. The digital land use layers received for this study (collected by Aurecon *et al*. (2013)) were not of sufficient spatial accuracy to allow direct application of model roughness parameters based on land use extents. Land use extents were updated by manual digitisation using aerial photographs to locate the land-use layer polygon more accurately. An example of the improvement in land use delineation following the manual digitisation process is provided in Figure C-2; note in particular the inclusion of waterways and refinement of commercial/industrial areas.

Roughness parameters for each land use area are discussed and provided in Section 3.14 for the Detailed Model. Roughness parameters for the Fast Model are documented in BMT WBM (2015).

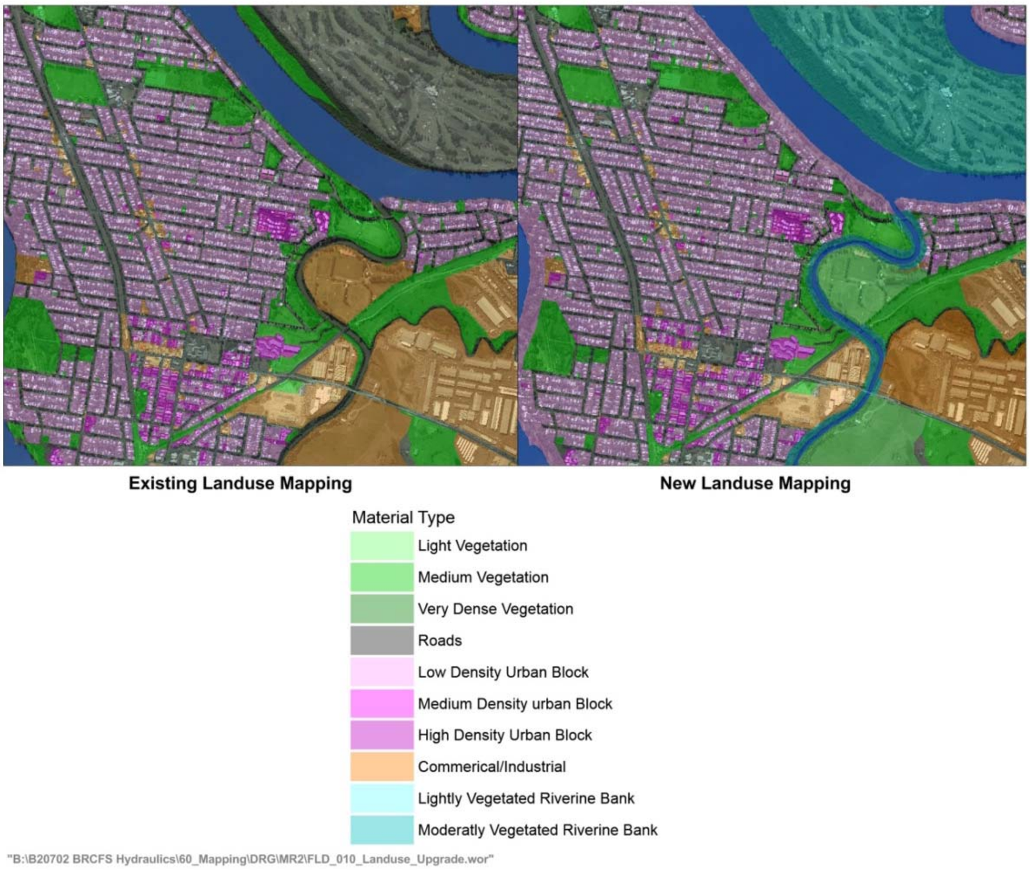


Figure C-2 Example of the Improved Spatial Differentiation of Land Uses

C.6 Inflows

Model inflows are extracted from the calibrated URBS models provided by Aurecon from the Aurecon *et al* (2015a,c) Hydrologic Assessment. Aurecon *et al* (2015a,c) for the purpose of the BRCFS refined the URBS models developed and calibrated by Seqwater. A comparison of the Aurecon and Seqwater URBS parameters is given in Table C-3 with comparisons of the volume outputs and loss parameters given in Table C-4. These values were taken directly from the .q URBS model output files. Note that Aurecon *et al* (2014) adopted a different (non-linear) URBS model channel routing exponent 'n' for the Lockyer, Bremer, and Purga models, compared to the (linear) exponent 'n' adopted by Seqwater in the original URBS model calibration. This means that the α value adopted by Seqwater cannot be directly compared to the α value adopted by Aurecon.

Volume outputs provided in Table C-4 generally demonstrate that the Aurecon URBS model outputs flows of greater volume than the Seqwater URBS model, with the exception of the smaller events of 1996 and 1999. This is of interest to the current study as the previous DMT Model study undertaken by BCC (BCC, 2014a) found the need to use multipliers on the Seqwater URBS model flows to achieve an acceptable calibration. BCC (2014a) contains further details on the rationale and application of the multipliers. However, the current study has generally found that the flows output from the Aurecon URBS model produce an acceptable calibration without the need for multipliers. This is related to the generally greater flow volumes output from the Aurecon URBS model for the larger historical events (refer to Table C-4). However, during Fast Model verification to the 1974 event, it was concluded that the significantly larger flow volumes produced by the Aurecon URBS model flows in the Bremer catchment led to an over-prediction of flood levels. Further discussion on this is provided in BMT WBM (2015) and in Section 2.1.1 of this report. For the purpose of verifying the Detailed Model to the 1974 flood event, IL/CL values in the URBS model were changed to reflect the average of the Aurecon and Seqwater values. Again, further information and tabulated values are provided in Section 2.1.1.

URBS parameters presented in Table C-3 and Table C-4 are provided to give background as to the source of the difference in volume outputs between the Aurecon URBS and Seqwater URBS models. Further detail and discussion on URBS parameters is provided in Aurecon *et al.* (2015a).

In order to produce the total and local flow hydrographs needed to provide inflows to the Fast and Detailed Models, BMT WBM ran the URBS calibration models for each event. Other than the changes to the 1974 IL/CL values as described above and in Section 2.1.1, no changes were made to the URBS models for other historical events other than to ensure output of the needed hydrographs. Locations at which primary periphery inflows were applied to the Fast and Detailed Models using URBS model flows are shown in Table C-5. Drawing 7 shows the location at which these inflows were applied in the Detailed Model. Table C-5 also lists the peak inflows for each calibration event to provide a relative indication of event magnitude at the primary inflow locations. Figure C-6 to Figure C-10 compare the inflow hydrographs at the primary periphery inflow locations for each calibration event to allow the relative importance and timing of each inflow to be understood.

During the use of the Aurecon URBS model (Aurecon *et al*, 2015a) to produce the total and local flows, it was noted that the 5 sub-catchments representing Kedron Brook had been removed from the URBS model. Aurecon confirmed that Kedron Brook was removed from their URBS model as Kedron Brook is not a tributary of the Brisbane River. Future users of the URBS model may note 5 redundant URBS .r files (lower 110 to lower 114) that have been confirmed by Aurecon as being a legacy of the removal of Kedron Brook (pers. comm. Rob Ayre, Aurecon, 21 Jan 2015). It was agreed with the Client that the removal of Kedron Brook from the URBS model will have negligible to no impact on the outcomes of this hydraulic assessment, other than that there will be no inflows from Kedron Brook. In extreme events, there is a potential for flood flows from Kedron Brook to breakout across the Kedron Brook floodplain toward the Brisbane River. However, as the potential breakout floodwater from Kedron Brook will precede the time of the peak flows in the Brisbane River, it is unlikely that Kedron Brook flows will impact upon peak flood levels in the Brisbane River. In small to large events, Kedron Brook flows do not enter the Brisbane River and thus will have no impact on Brisbane River flood behaviour.

Outflows from Wivenhoe Dam were included in the Fast and Detailed Models as an upstream boundary condition. Wivenhoe dam outflow hydrographs were provided by Aurecon for each calibration event, or in the case of the 1974 flood were calculated by the URBS model.

Table C-3 URBS Catchment and Routing Parameters

	Alpha[1]		Beta	
Catchment	Seqwater[2]	Aurecon	Seqwater[2]	Aurecon
Stanley	0.1 to 0.15	0.11	4.1 to 8.0	5.7
Upper Brisbane	0.1 to 0.14	0.12	2.0 to 3.25	2.8
Lockyer	0.15 to 0.3	0.49	3.0	3.1
Bremer	0.25 to 0.4	0.79	2.5 to 3.5	2.8
Warrill	0.7 to 0.9	0.79	1.5 to 4	2.5
Purga	0.15 to 0.8	0.93	3.0 to 4.0	3.8
Lower Brisbane	0.13 to 0.2	0.30	2.5 to 3.0	4.0

[1] Note that Aurecon et al (2015a) adopted a different (non-linear) URBS model channel routing exponent ‘n’ for the Lockyer, Bremer, and Purga models, compared to the (linear) exponent ‘n’ adopted by Seqwater in the original URBS model calibration. This means that the α value adopted by Seqwater cannot be directly compared to the α value adopted by Aurecon.

[2] For the Seqwater WSDOS URBS modelling the Alpha and Beta parameters varied between events

Table C-4 URBS Volume and Loss Comparisons for Each Calibration Event

1974						
	Volume (GL)				Losses (IL/CL)	
Catchment	Seqwater	Aurecon	Change	% increase	Seqwater	Aurecon
Lockyer	567	690	123	22%	50 / 2.5	40 / 1.8
Bremer	250	348	98	39%	65 / 2.0	30 / 0.3
Purga	70	98	28	40%	80 / 2.5	40 / 0.8
Warrill	294	411	117	40%	79 / 2.0	8 / 0.5
Upper Brisbane	1541	1441	-100	-6%	45 / 1.2	50 / 1.5
Lower (Brisbane Bar)	3525	3995	470	13%	50 / 2.0	24 / 0.24
1996						
	Volume (GL)				Losses (IL/CL)	
Catchment	Seqwater	Aurecon	Change	% increase	Seqwater	Aurecon
Lockyer (O'Reillys)	565	595	30	5%	130 / 1.5	180 / 0.7
Bremer (Walloon)	175	200	25	14%	100 / 1.5	100 / 1
Purga	56	54	-2	-4%	55 / 0.5	90 / 0.3
Warrill	117	99	-18	-15%	79 / 1.5	129 / 1.3
Wivenhoe (outflow)	0	0	0	0%	N/A	N/A
Lower (Brisbane Bar)	1538	1693	155	10%	60 / 2.0	138 / 0.2
1999						
	Volume (GL)				Losses (IL/CL)	
Catchment	Seqwater	Aurecon	Change	% increase	Seqwater	Aurecon
Lockyer (O'Reillys)	139	62	-77	-55%	95 / 3.0	135 / 1.5
Bremer (Walloon)	56	55	-1	-2%	50 / 1.0	50 / 0.8
Purga	10	9	-1	-10%	25 / 1.5	45 / 0.7
Warrill	34	33	-1	-3%	50 / 0.7	45 / 0.7
Wivenhoe (outflow)	809	809	0	0%	N/A	N/A
Lower (Brisbane Bar)	1225	1075	-150	-12%	20 /1.5	97 / 0.4

2011						
	Volume (GL)				Losses (IL/CL)	
Catchment	Seqwater	Aurecon	Change	% increase	Seqwater	Aurecon
Lockyer (O'Reillys)	574	761	187	33%	50 / 3.0	60 / 1.1
Bremer (Walloon)	212	201	-11	-5%	30 / 2.0	35 / 2.0
Purga	36	35	-1	-3%	40 / 0.5	40 / 0.5
Warrill	224	219	-5	-2%	35 / 1.1	40 / 1.0
Wivenhoe (outflow)	2692	2692	0	0%	N/A	N/A
Lower (Brisbane Bar)	4085	4405	320	8%	15 / 2.5	33 / 2.0
2013						
	Volume (GL)				Losses (IL/CL)	
Catchment	Seqwater	Aurecon	Change	% increase	Seqwater	Aurecon
Lockyer (O'Reillys)	326	373	47	14%	175 / 4.0	190 / 3.0
Bremer (Walloon)	120	119	-1	-1%	175 / 3.0	160 / 3.5
Purga	11	9	-2	-18%	180 / 7.5	180 / 9.0
Warrill	183	209	26	14%	179 / 5.0	149 / 4.5
Wivenhoe (outflow)	866	862	-4	0%	N/A	N/A
Lower (Brisbane Bar)	1740	1843	103	6%	150 / 2.5	122 / 2.4

Note: Losses are catchment average losses and therefore Warrill and Lower catchments are adjusted by URBS for impervious areas

Table C-5 Fast and Detailed Model - Primary Periphery Inflows from URBS Model

	Peak Flow (m^3/s)				
Periphery Inflows	**1974**	**1996**	**1999**	**2011**	**2013**
Wivenhoe Dam Outfall	7115	0	1804	7471	1817
Lockyer Creek near Tenthill Creek	2866	1659	401	2490	1798
Laidley Creek near Forest Hill	257	96	2	346	109
Spring Creek 1 near Moreton Vale	122	121	26	206	98
Buramba Creek U/S of Atkinson Dam	560	379	261	356	644
Spring Creek 2 near Beutel Road	110	53	30	129	24
England Creek Wivenhoe Somerset Rd	110	68	70	294	31
Banks Creek near Savages Crossing	37	28	11	122	2
Black Snake Creek near Burtons Bridge	276	133	43	510	22
Sandy Creek near Russels Road	154	86	39	223	31
Lake Manchester Outfall	335	172	83	201	242
Bremer River near Amberley	2145	1026	430	2013	1195
Warrill Creek near Amberley Gauge	1971	377	169	683	1084
Purga Creek near Loamside	795	269	68	166	120
Bundamba Creek near Brisbane Road	496	153	17	72	170
Six Mile Creek near Ipswich Motorway	186	67	10	37	62
Goodna Creek at Ipswich Motorway	343	96	11	33	134
Watson Creek at Wacol Station Road	111	49	20	32	62
Pullen Pullen Creek at Moggill Road	124	53	14	24	66
Moggill Creek at Rafting Ground Road	346	141	44	102	162
Oxley Creek near Ipswich Motorway	974	450	94	132	374
Norman Creek near Stanley Street	198	141	61	65	167
Enoggera Creek at Enoggera Road	402	156	96	84	140
Bulimba Creek near Enoggera Reserve	507	219	57	72	375

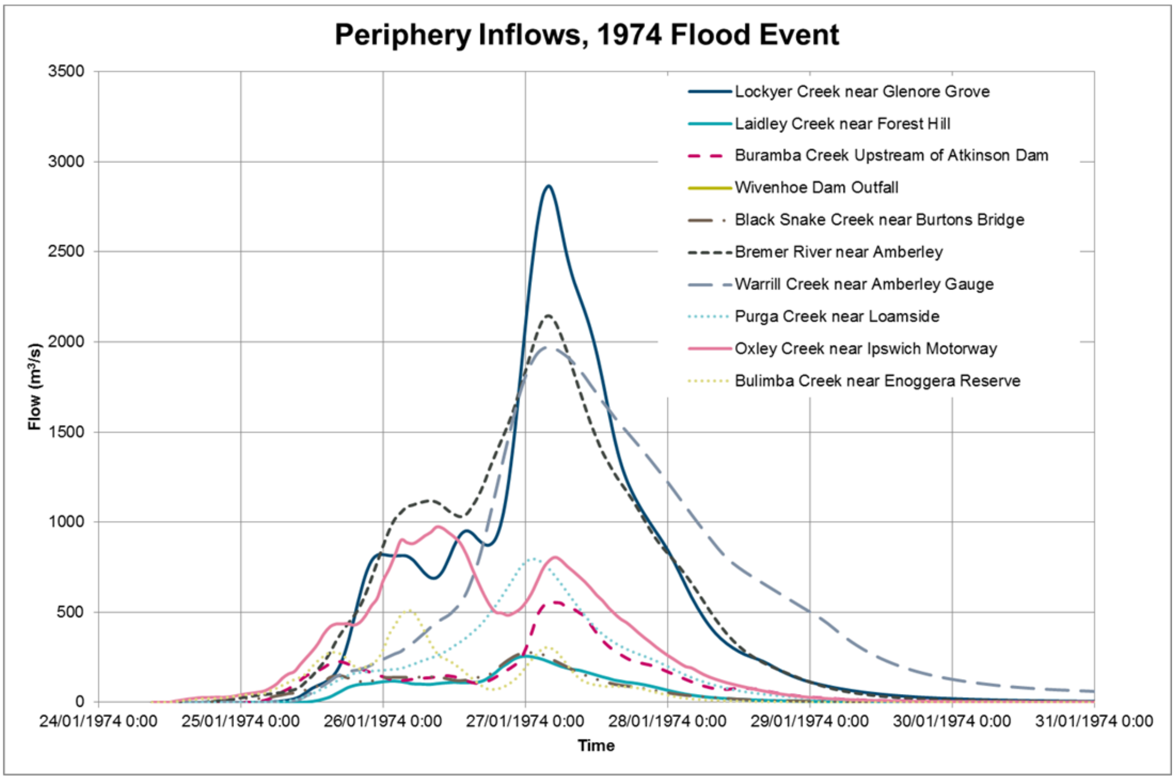


Figure C-3 Periphery URBS Inflows, 1974 Flood Event

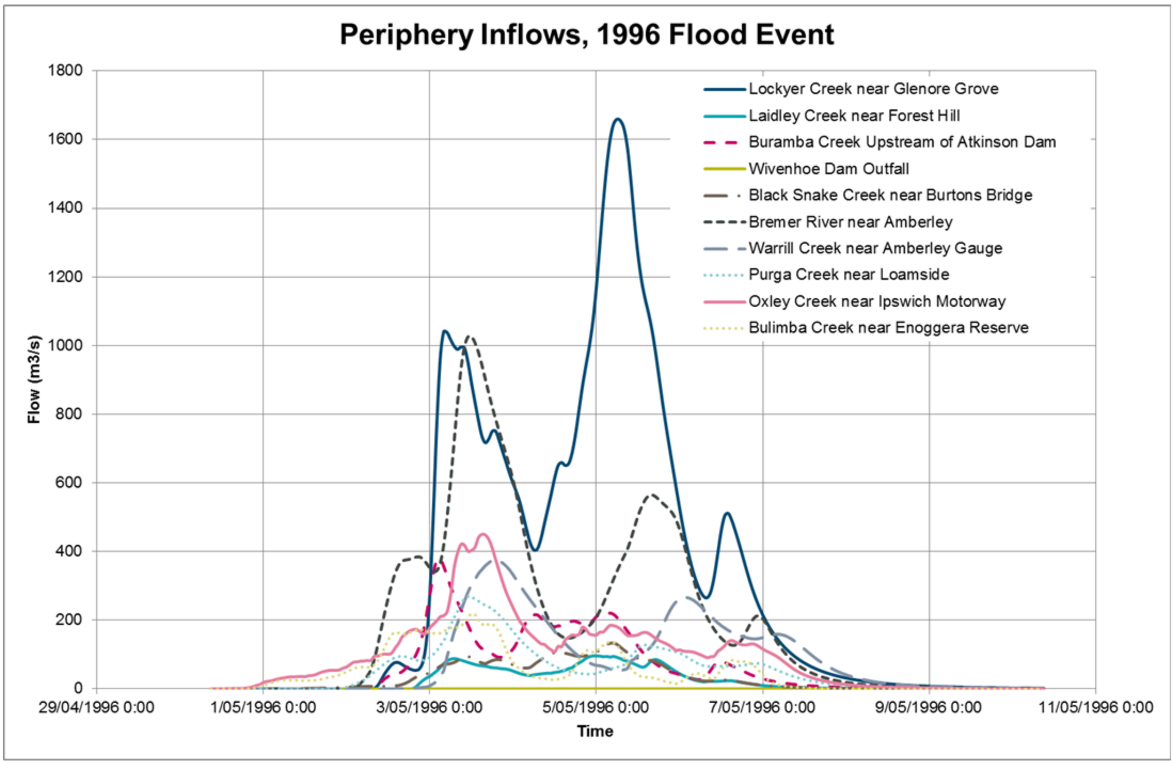


Figure C-4 Periphery URBS Inflows, 1996 Flood Event

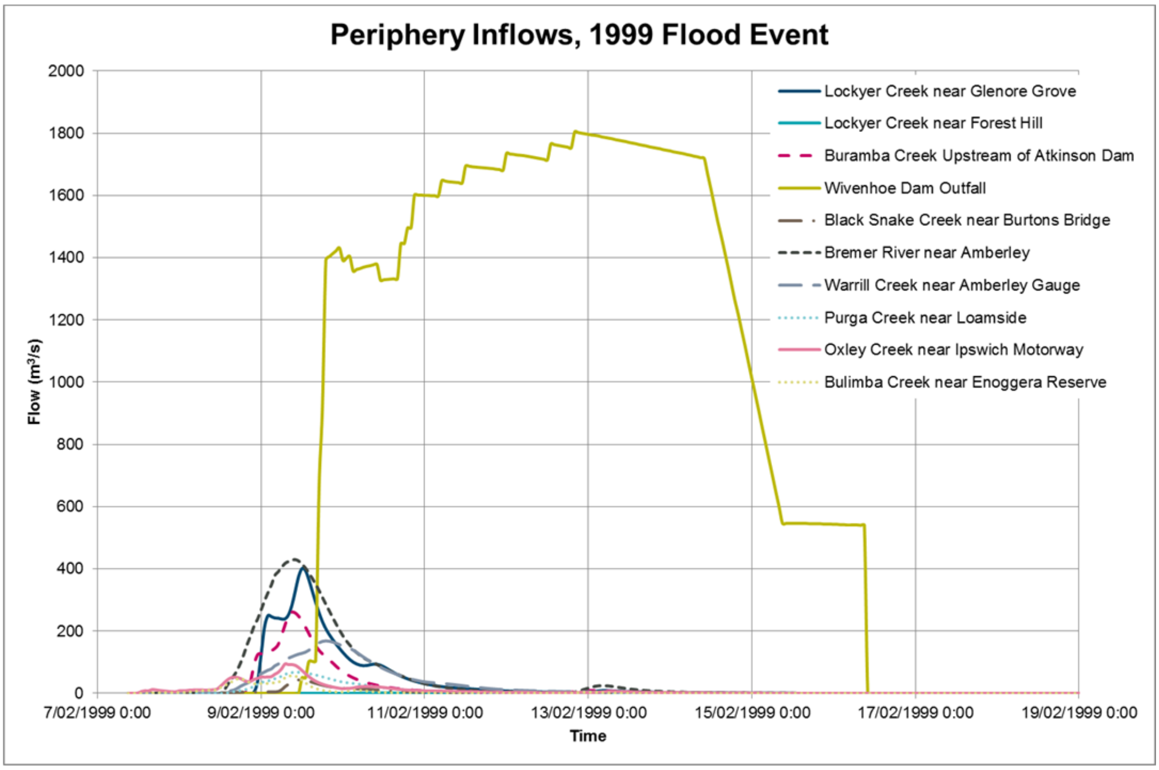


Figure C-5 Periphery URBS Inflows, 1999 Flood Event

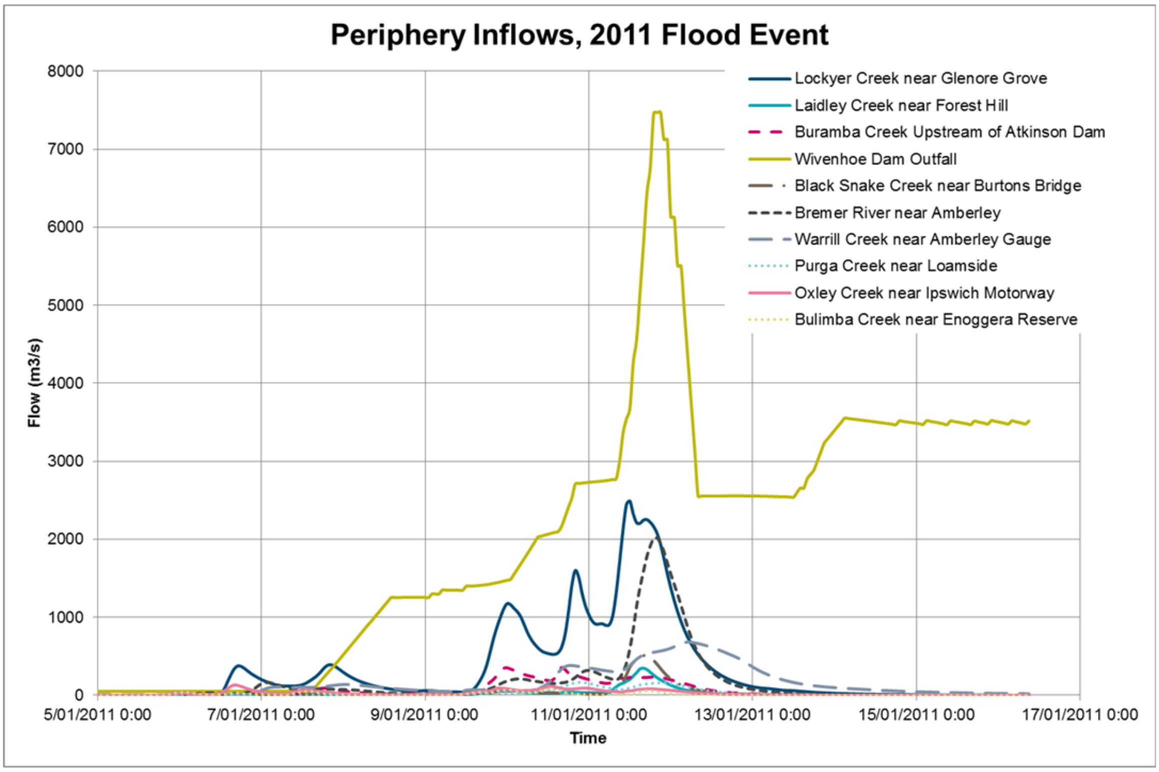


Figure C-6 Periphery URBS Inflows, 2011 Flood Event

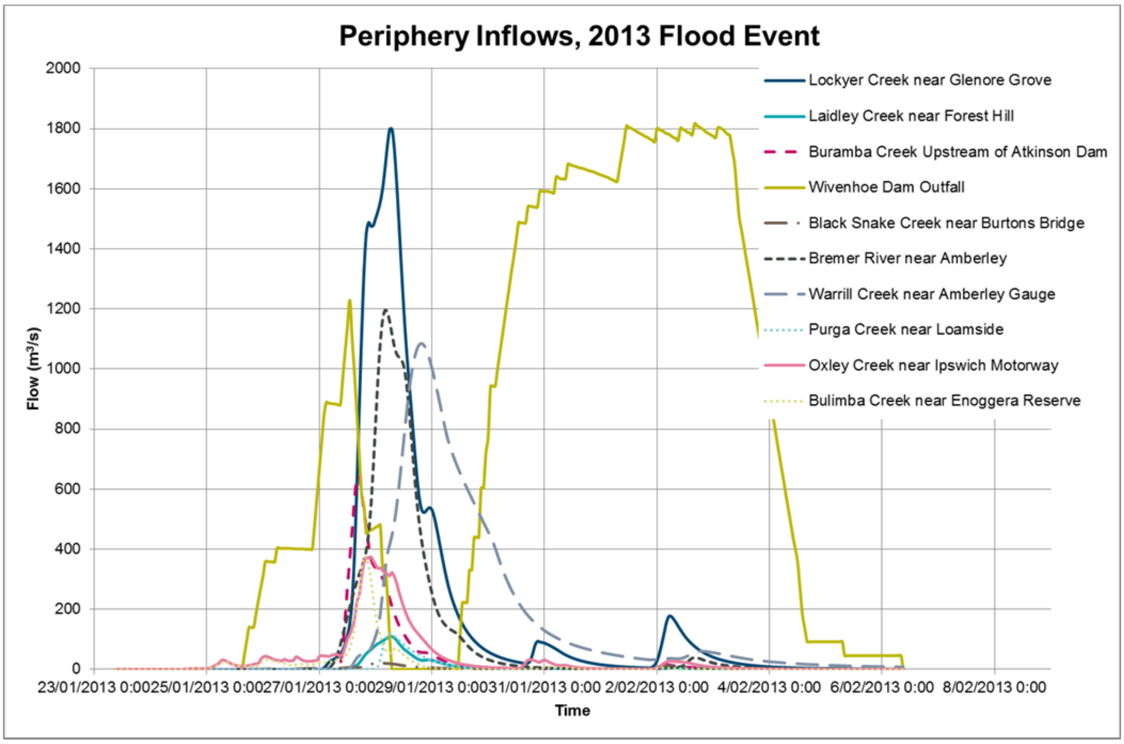


Figure C-7 Periphery URBS Inflows, 2013 Flood Event

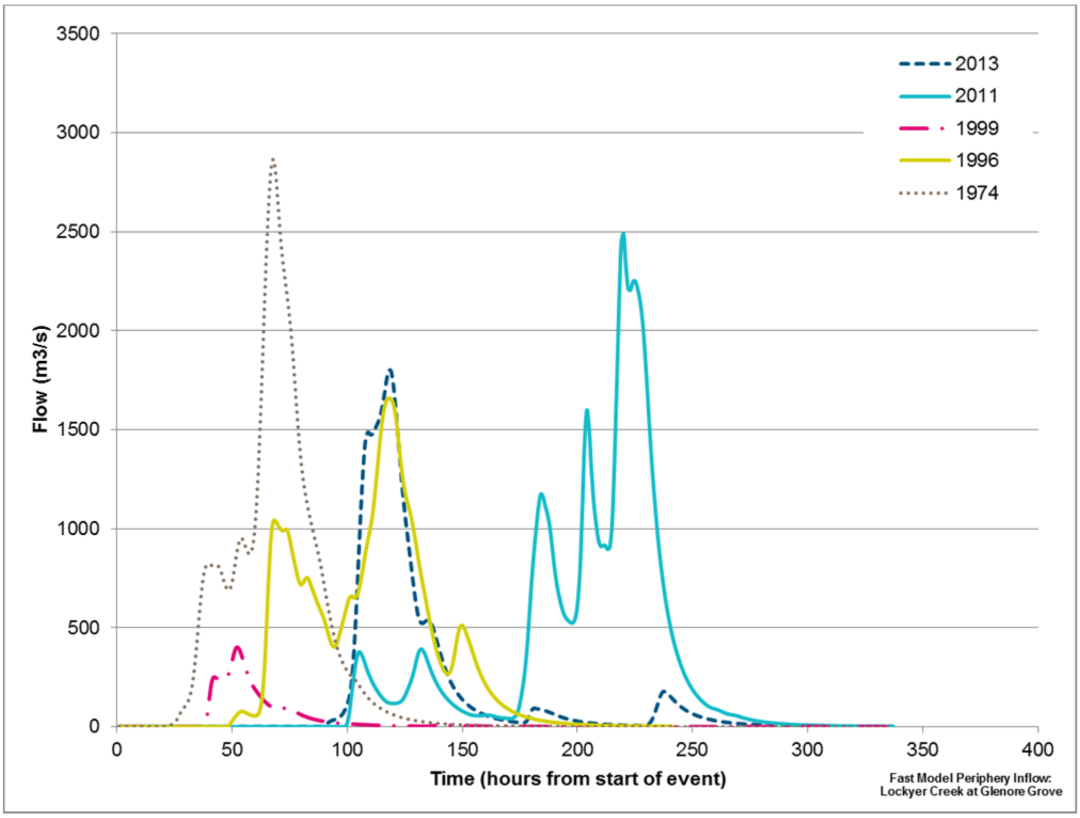


Figure C-8 Periphery URBS Inflows at Glenore Grove All Flood Events

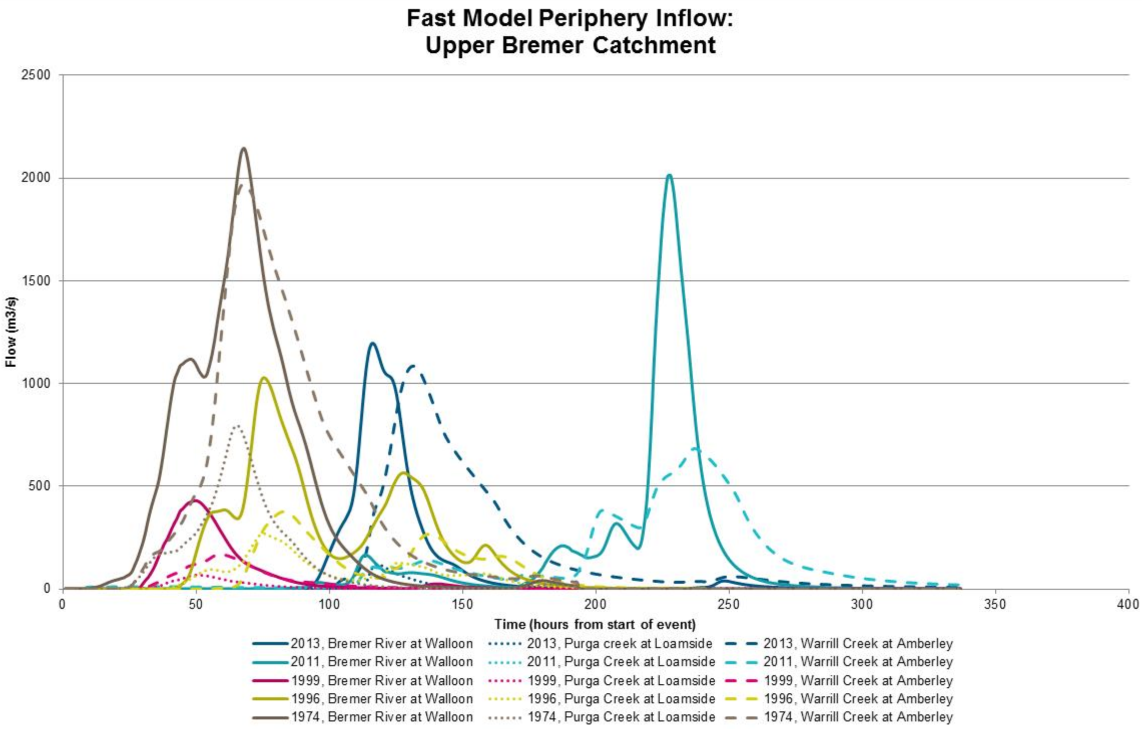


Figure C-9 Periphery URBS Inflows at Walloon, Loamside and Amberley All Flood Events

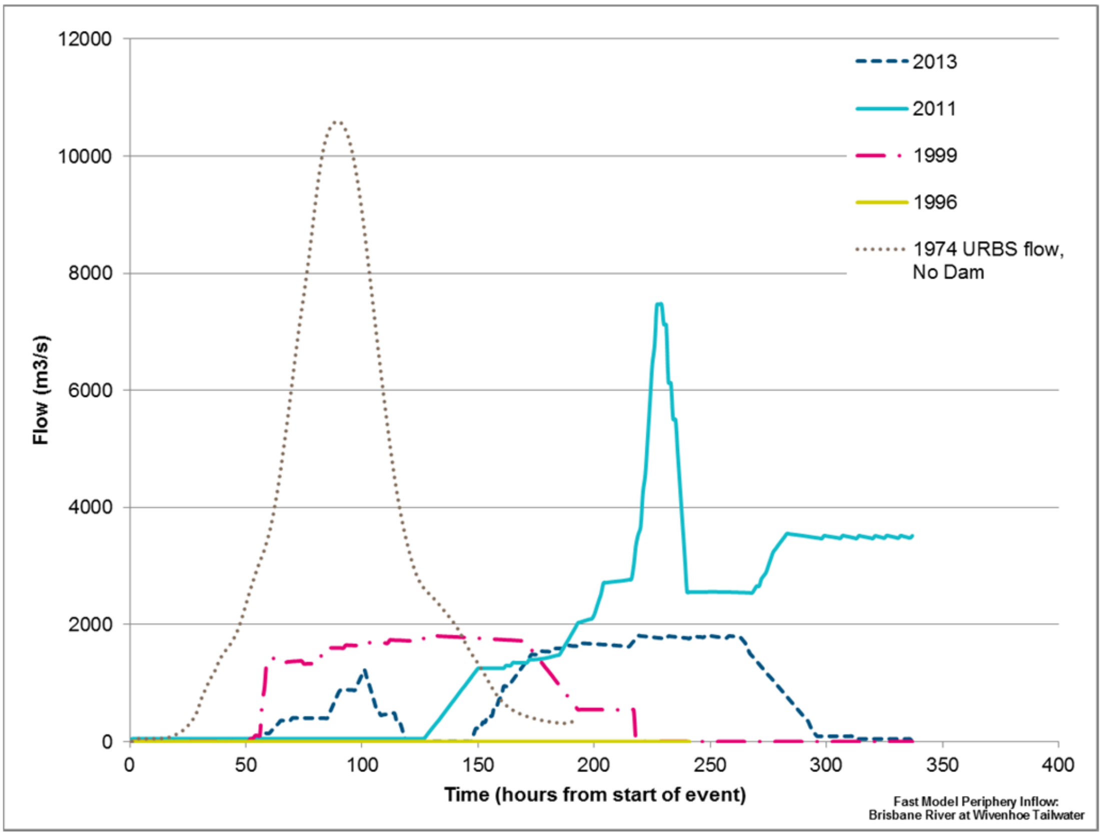


Figure C-10 Periphery URBS Inflows at Wivenhoe Tailwater All Flood Events

Appendix D Recorded Flood Data of Questionable Quality

Recorded flood data includes gauge data, peak flood levels and flood inundation extents. The latter two are typically measured or derived from flood marks. All three data sets can suffer from inaccuracies. In the course of this Hydraulic Assessment, recorded flood data of questionable quality has been identified and is presented in this Appendix.

D.1 Gauge Data

Seqwater (2011, 2013a, 2013b) identified gauge data that was erroneous and/or of insufficient quality for use. In the course of the current study, additional gauge data have been identified as having questionable quality. This Appendix provides discussion on these additional datasets. A summary of gauges and the availability of gauge data is provided in Table C-1.

D.1.1 1974 Event

The Lowood gauge recorded peak level in 1974 appears to be too low. The peak flood level at the gauge is recorded at 44.76m AHD. However, as presented in Figure D-1, three flood marks immediately downstream of the gauge show higher flood levels than the peak recorded gauge level. Either the gauging in 1974 was carried out at a different location to the current alert gauge, or the gauge levels underestimate the peak. John Ruffini recalls[20] irregularities with the Lowood gauge measurements for 1974 and believes that the gauge has moved around over time. This is consistent with the comparisons of the gauge level and surrounding flood marks presented here and adds weight to the likelihood that the Lowood gauge records for 1974 are inaccurate.

[20] At Workshop 3 (as part of this study) held on 14 May 2015, John is a member of the Technical Working Group representing DSITIA.

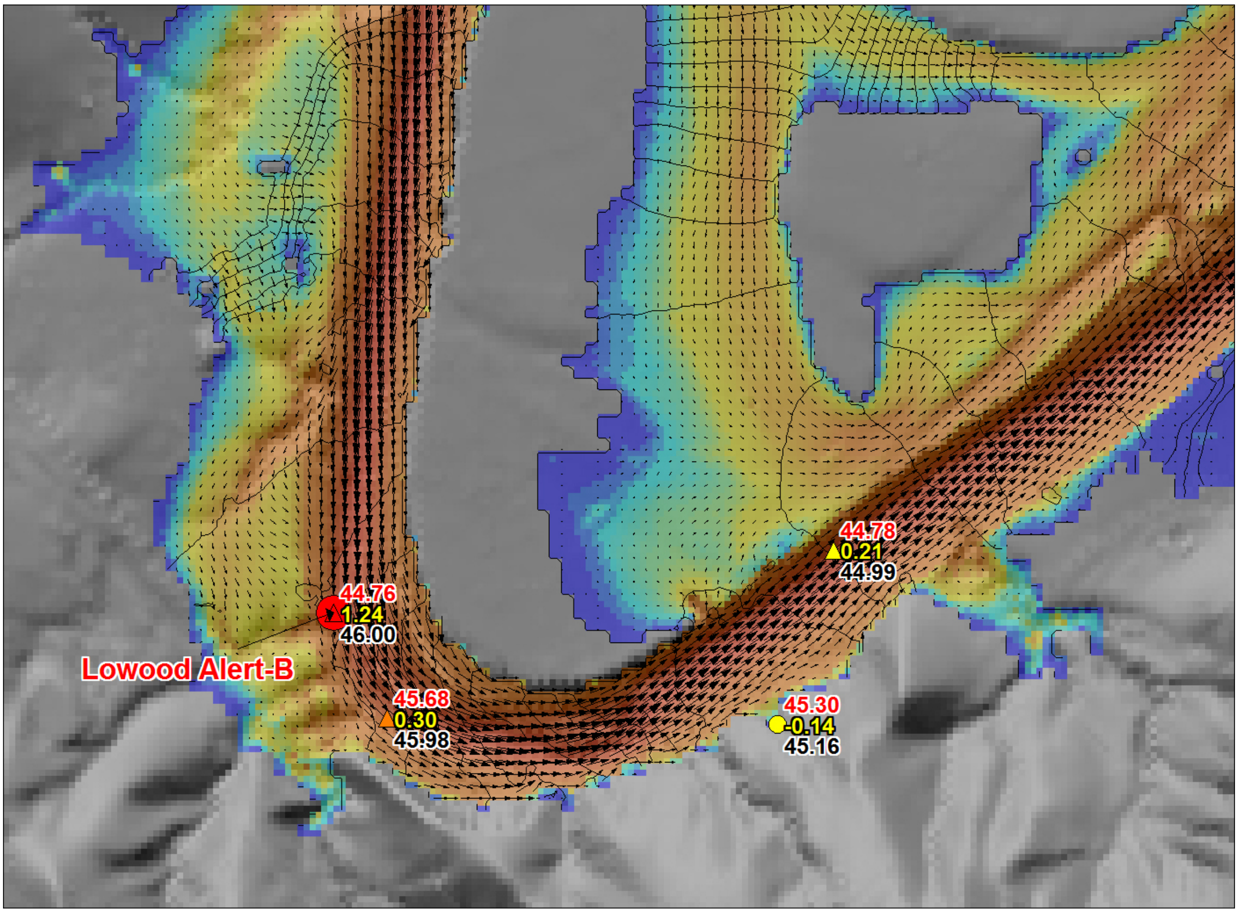


Figure D-1 Lowood Gauge and Surrounding Area - 1974 Event

As shown in Figure D-2, the St Lucia Ferry gauge recordings for 1974 do not record the peak flood level.

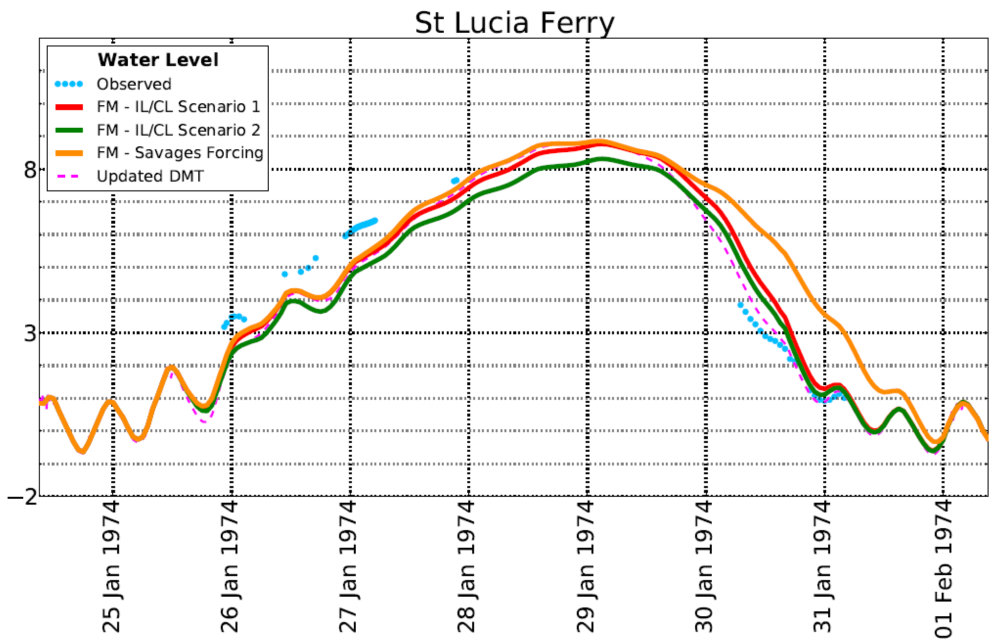


Figure D-2 St Lucia Ferry Gauge – 1974 Records

D.1.2 1996 Event

Aside from that gauge data already identified as erroneous or missing by Seqwater (2011, 2013a, 2013b), no additional gauges were found to have questionable data in the 1996 event.

D.1.3 1999 Event

In 1999, the Moggill gauge failed around the time of the peak as shown in Figure D-3. The Jindalee gauge does not appear to fail but it is likely that the raw gauge data does not include the peak of the flood event, as shown in Figure D-3. These recordings are presented in the time series plots but are not included in Table 3-4, which compares peak recorded with peak modelled flows.

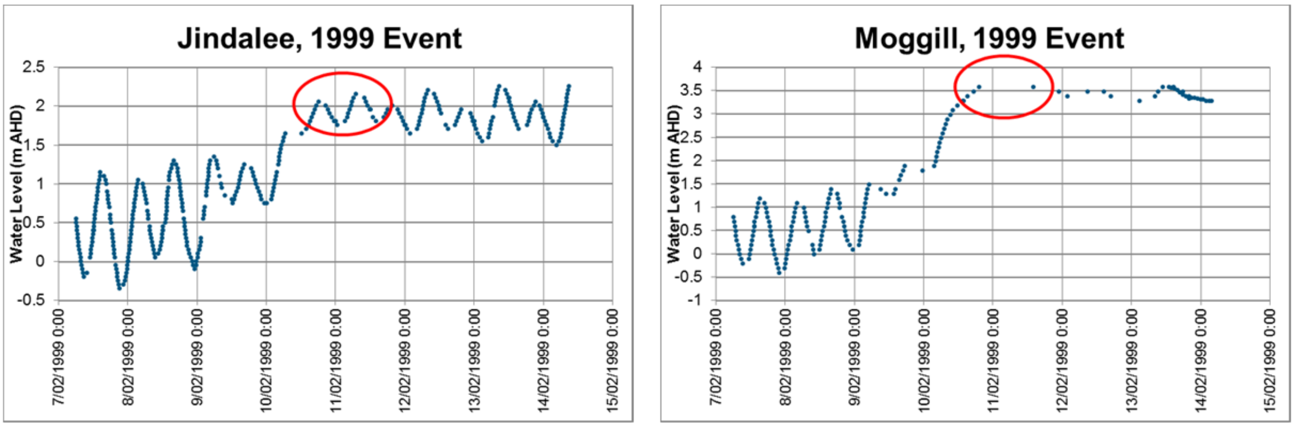


Figure D-3 Questionable 1999 Event Hydrographs

The Walloon gauge on the Bremer River appears to have a datum error in recorded levels for the 1999 event. As shown in Figure D-4, the recorded level hydrograph consistently lies about 2m below the modelled level hydrograph. The recorded flood level prior to the arrival of the flood event at the gauge is about 15.8m AHD, however gauge zero for this gauge is 16.4m AHD. Thus, the gauge record is providing a level below gauge zero, demonstrating that levels for this gauge are questionable for the 1999 event.

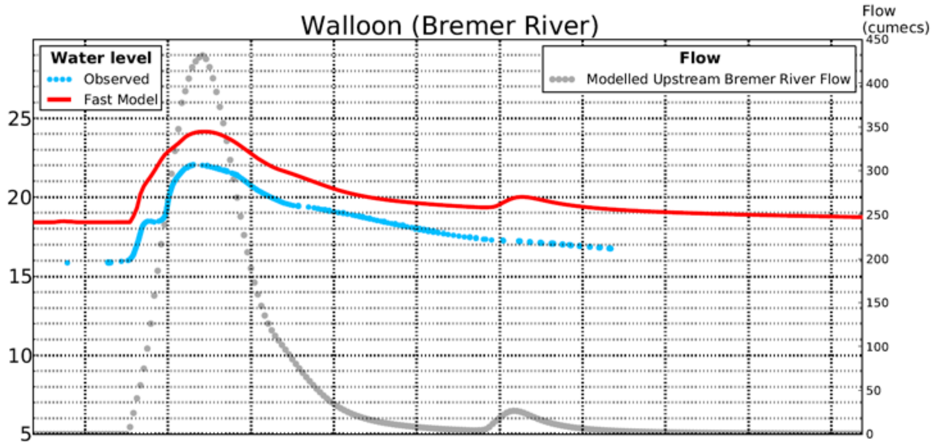


Figure D-4 Questionable 1999 Event Hydrograph, Walloon

There appears to be a datum error in the Wivenhoe tailwater gauge in the 1999 event recordings. As shown in Figure D-5, the Wivenhoe recorded flood levels are lower than the downstream Lowood recorded flood levels.

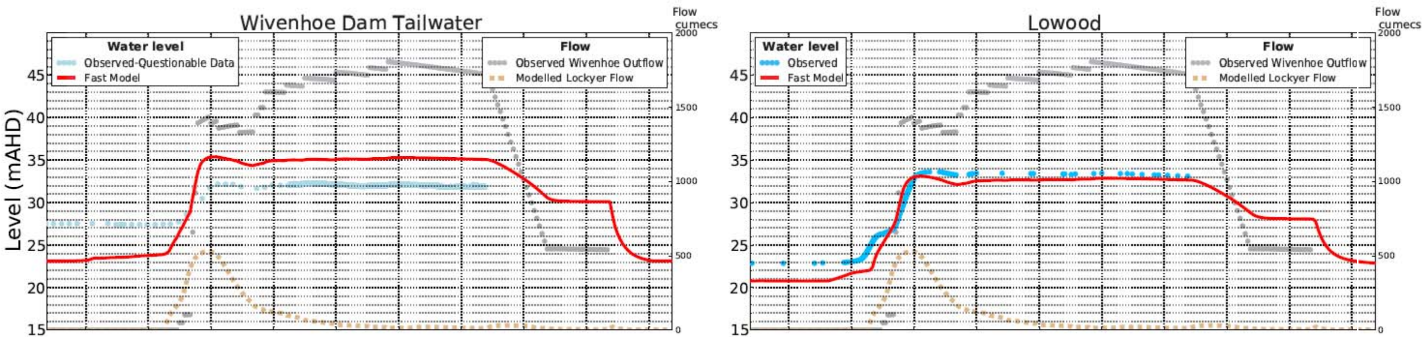


Figure D-5 Comparison of Wivenhoe Tailwater and Lowood Gauge Records – 1999 Event

D.1.4 2011 Event

The Brisbane River Moggill gauge records for the 2011 event have been investigated by BoM and found to be approximately 0.3m too low (Seqwater, 2013c)[21]. This conclusion was reached based on photographic evidence (reproduced in Figure D-6) taken of the manual gauge board just a few hours before the peak. The automatic gauge records for the Moggill gauge in 2011 are also provided in Figure D-6 with the corrected peak level of 18.17m AHD shown. This correction is reflected in all discussion and plots relating to the Moggill Gauge in the 2011 event within this current report.

[21] This was reported in Seqwater (2013c) Supplementary Digital Data within an email from Peter Baddiley (BoM) to the authors of that report and others.

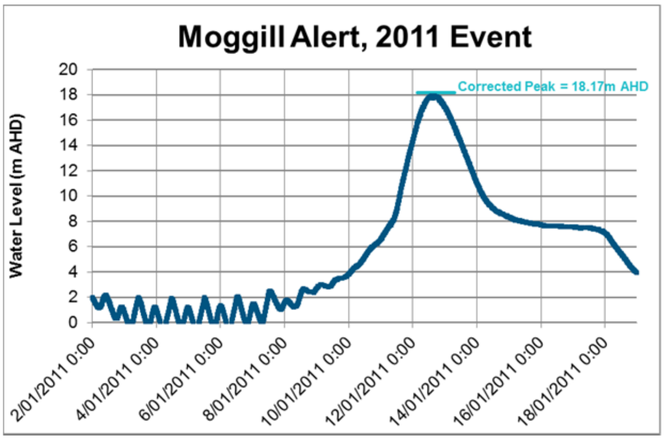


Photo of Moggill Gauge Board (courtesy of Shapland Family via Seqwater (2103c))

Figure D-6 Moggill Gauge in 2011 Flood Event

Several other gauges also experienced issues during this event. Wivenhoe Dam Tailwater, Colleges Crossing and Kholo Bridge all missed the peak of the event. The gauge hydrographs are shown Figure D-7.

The Hancock Bridge gauge on the Bremer River appears to have a datum error for the 2011 event. The hydrograph for this gauge (see below) has a tidal signal that is too high and the flood hydrograph peaks at a similar level to the upstream One Mile Bridge gauge peak (see Plot 14). It is suggested that a datum shift of between 1.5m and 2m needs to be applied (i.e. reduce the recorded levels by this amount).

Three Mile Bridge Gauge is located on the Bremer River, as shown in Figure D-7. In the 2011 event, the recorded level hydrograph at the gauge appears to be complete as shown below. However, the peak level recorded at the gauge for the 2011 event (27.05m AHD) is significantly higher than surrounding flood mark level records. This is demonstrated in Figure D-7, comparing flood mark levels with the peak gauge level. As the surrounding flood mark levels are sufficient in number and consistency to create confidence in their accuracy, the Three Mile Bridge gauge data for the 2011 event must be regarded as erroneous. This was confirmed in discussions with James Charalambous from BCC (personal communication, Dec 2014). As such, the 2011 gauge data has not been used in the calibration of the models.

The Ipswich Gauge appears to have a high tidal signal before and after the flood event compared to surrounding gauges and previous record. However, the peak matches with surrounding flood marks. It is suggested that the gauge datum and scaling factor is in error. This hydrograph has been used in the calibration of the models but with less confidence.

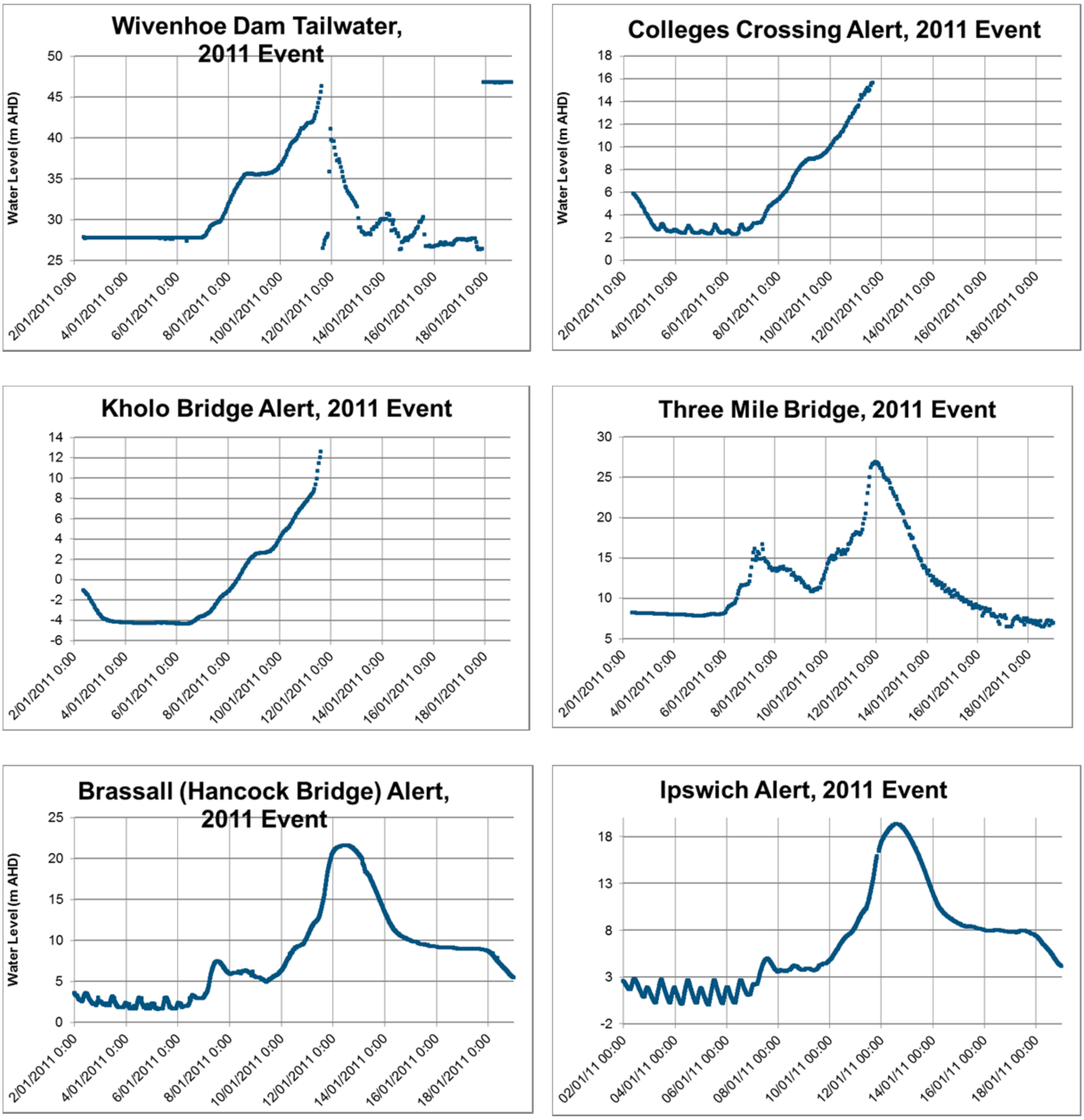


Figure D-7 Questionable 2011 Event Hydrographs

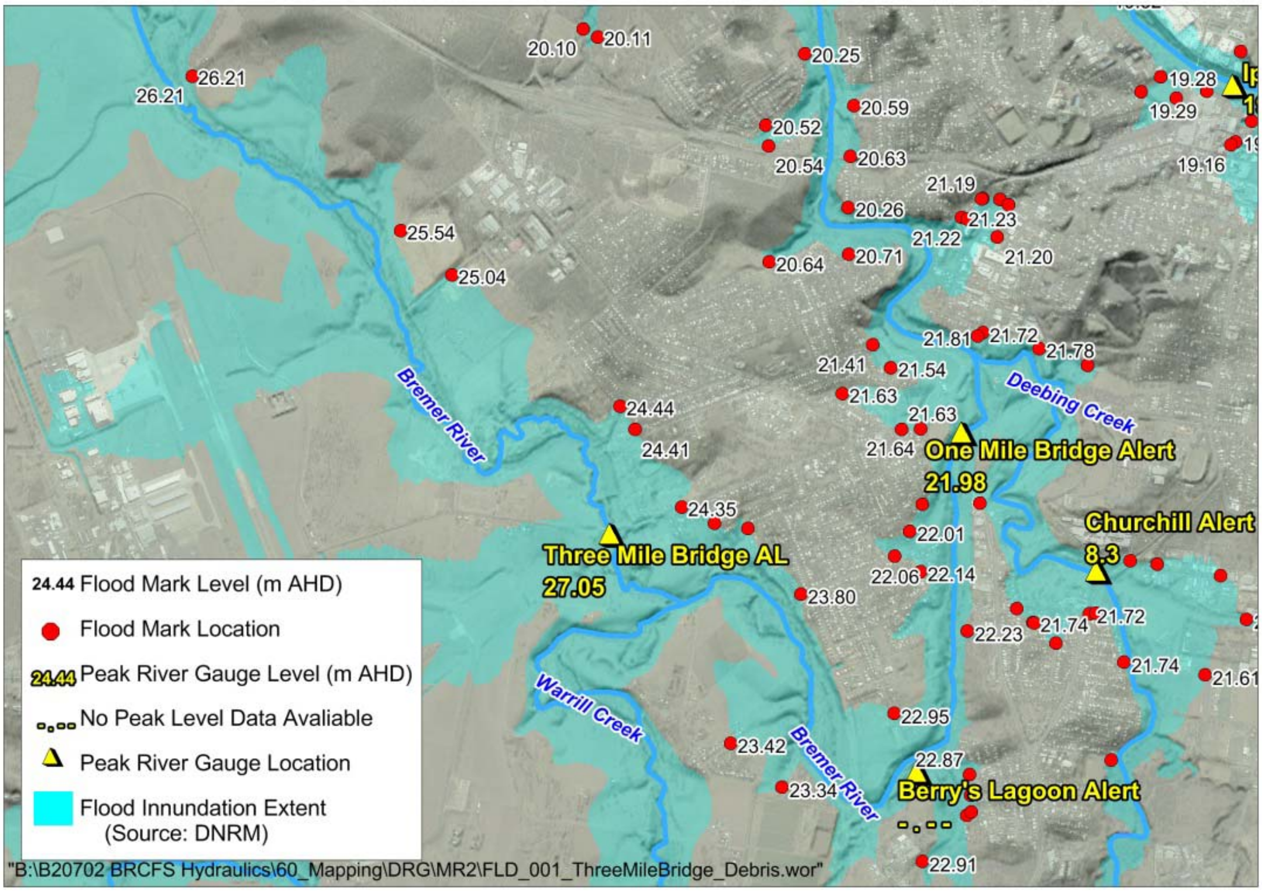


Figure D-8 Comparison of Three Mile Bridge Peak Level to Flood Marks – 2011 Event

D.1.5 2013 Event

Several gauges were identified as providing questionable data for the 2013 event in addition to those already identified by Seqwater (2013a). Amberley (Greens Road) and Brisbane Rd miss the rising limb and peak of the flood hydrograph. Amberley is shown below, while Brisbane Rd recorded one level of 2.72m AHD on 28 January 2013 at 8:24am. This assessment of Amberley is in agreement with Seqwater (2013a), who reported that this gauge “reported suspect readings”.

Colleges Crossing, Bundamba and Brassal (Hancock Bridge) all have scaling issues. Colleges and Bundamba show little range of levels across the event as shown below. Hancock Bridge is not in agreement with the surrounding flood marks.

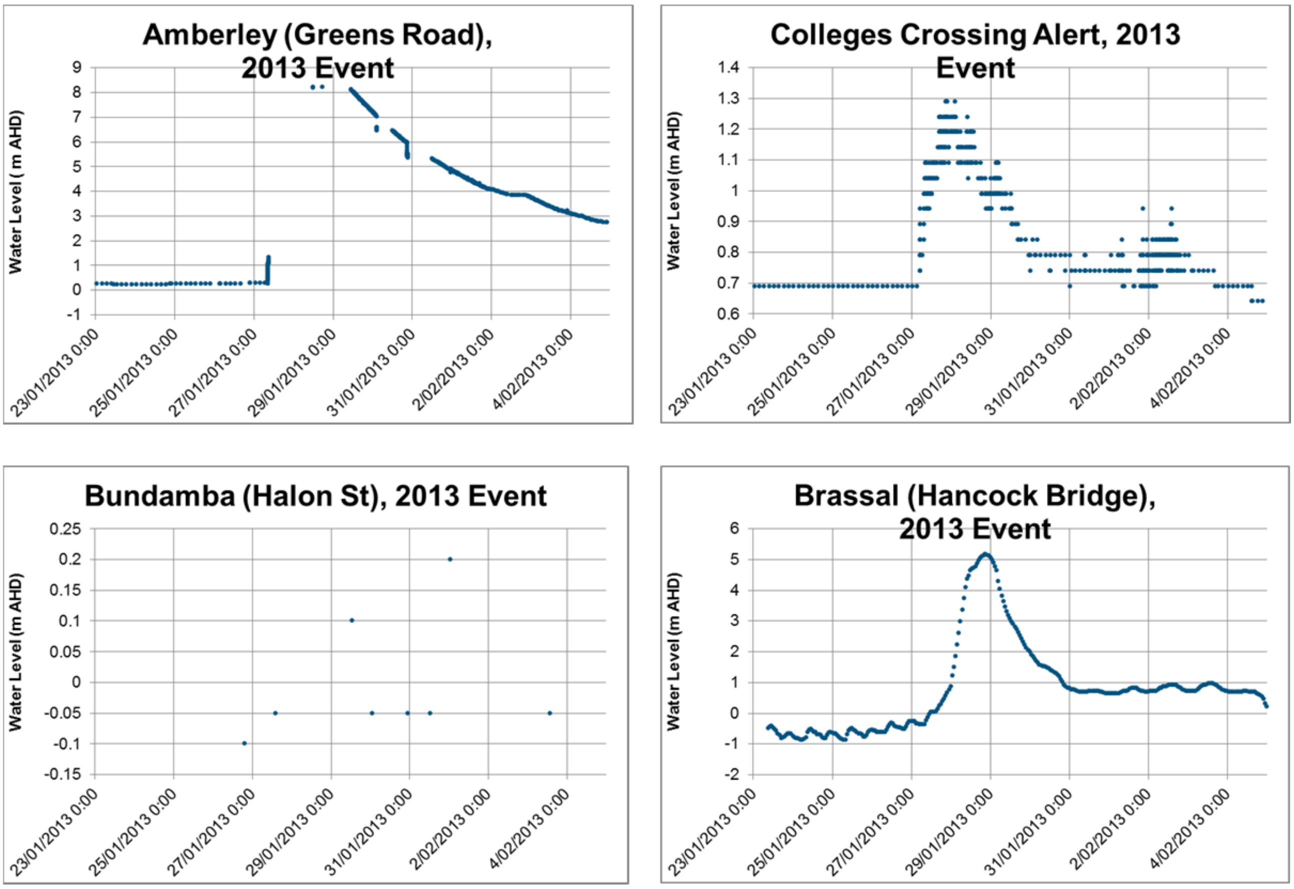


Figure D-9 Questionable 2013 Event Hydrographs

Appendix E Hydraulic Structure Reference Sheets

Hydraulic structure reference sheets have been prepared for all major waterway structures included in the hydraulic model. The sheets provide a summary of key structure details along with a summary of the Fast and Detailed Model results.

In interpreting the results shown in the reference sheets, it is important to appreciate how the hydraulic outputs were derived and what they represent. The following discussion addresses the main issues needed to correctly interpret and analyse the information provided.

There is a degree of subjectivity in the definition of the structures bounds. For example, a structure over the waterway may be elevated above a modelled flood level but an adjacent approach road to the structure may be inundated due to it being at a lower elevation. An example of this is on the southern approach to Centenary Bridge. For the purposes of the hydraulic reference sheets, the structure is typically taken to include the superstructure over the waterway and nearby approaches until high ground is reached. A structure may therefore be reported as overtopping even if the main part of the structure over the waterway has a flood free deck.

The results summary is provided for both Fast and Detailed models and includes the following general outputs:

- Discharges at the time of the peak upstream flood level. These discharges include the flow under and over the structure, the latter including any flow over included approach embankments as discussed above. The discharges are not necessarily reflective of the peak discharge as the peak flood level can occur at a significantly different time to that of the peak discharge, particularly in backwater affected locations and where the ocean tide or storm tide has a strong influence. **Importantly, the reported flows are not necessarily representative of the flows used by agencies to issue warnings such as road closures, and should not be used for any warning advices or interpretation of such advices.**
- Flow areas at the time of peak flood level. The areas include those under and over the structure including the flow area over incorporated approach embankments.
- Depth and width averaged velocities through and over the structure, including any approach embankments, at the time of peak flood level. The velocity shown is the Discharge / Flow Area.
- Peak water surface levels at the structure on the upstream and downstream sides. For the Fast Model and the 1D in-bank sections of the Detailed Model, these elevations represent the flood level in the upstream and downstream 1D nodes, where the assumption in the 1D solution is that the water level is constant (averaged) across the waterway. For the Detailed Model where the structure is modelled in the 2D domain as either a 1D/2D arrangement (eg. Mt Crosby Weir) or solely in 2D, the water levels shown are the average water level across lines digitised upstream and downstream across the main waterway. These lines are typically around 50 metres upstream and downstream of the structure centreline. Importantly, the variation in water level along these lines can vary substantially due to variations in the velocity head (kinetic energy), superelevation and/or the bridge being skewed. Several of the main bridges in the Brisbane CBD are good examples where a significant variation in flood level can occur across these lines. Captain Cook Bridge is an example where the bridge is both strongly skewed to the

flow and is also on a sharp bend with significant superelevation occurring, resulting in variations in flood level across these lines often in excess of 0.5m for the larger floods.

- Maximum head drop across the structure at the time of peak water level. This should not be confused with afflux, which represents the change in water level upstream of the structure as a result of the obstruction to the waterway from the structure. The head drop therefore includes afflux but, in the case of the Detailed Model, also the effects of bed friction and other hydraulic features that may be influencing the flow in the vicinity of the structure.

Caution is advised when comparing outputs from the Fast and Detailed Models as differences can, and should, readily occur. Reasons for the differences include the following:

- The Fast Model's orders of magnitude coarser resolution using a 1D network approach does not have the detailed resolution spatially compared to the Detailed Model's 2D approach, with overbank flows either side of the structure being very simplistically represented in the Fast Model compared with the Detailed Model.
- The over structure flow between the Fast and Detailed Model will not always capture the same total width of flow due to differences in the approach to modelling the floodplain (ie. 1D versus 2D), and also in extracting information for the overbank flow component linked to the structure.
- Differences in the way losses are applied to the structure. For bridges the Fast Model varies the losses estimated for the entire waterway with height, whereas the Detailed Model varies the losses with height for each 2D cell covered by the bridge. However, the variation of losses for each 2D cell in the Detailed Model is limited to four layers, nominally below deck, the bridge deck, bridge rails and above the rails. These different approaches will affect the reported head drop.
- For structures within the 2D domain of the Detailed Model, the head drop also includes the energy loss due to bed friction (Manning's equation), plus any water level changes due to changes in kinetic energy and from losses associated with changes in velocity magnitude and direction (eg. at a bend). A 1D solution, such as used in the Fast Model, cannot represent these effects and is a more simplistic representation.
- Results are extracted at the time of maximum water level, which is tracked every computational timestep. However, occasionally in locations strongly affected by tidal influences the time of peak water level may differ between the Fast and Detailed Models that in turn can have a significant bearing on the flows reported. This is of particular relevance for the 2013 event in the lower reaches for the reasons discussed in Section 4.9.
- Further to the point above, the simulations for the Fast Model were longer with the Fast Model typically starting and finishing several days earlier/later than the Detailed Model. The Detailed Model start/finish times were optimised to minimise the length of the run times, and has no bearing on the flood rise/fall or peak. For structures in the very lower tidal reaches, especially for the minor flood events, the peak level for the Fast Model may result from a high tide level that occurred outside the run time of the Detailed Model (eg. at the Gateway Bridge).
- Flood levels may differ between the Fast and Detailed Models. If differences occur at or near the bridge deck, ie. if one model has floodwater just surcharging against the deck but the other

is just below the deck, more notable differences in head drop may be evident between the models.

Sir Leo Hielscher Bridges (TMR_001) Structure

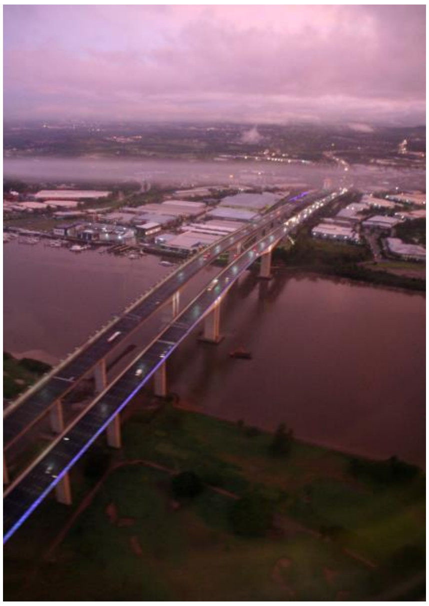
Structure Name	Sir Leo Hielscher Bridges		
Structure ID	TMR_001		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1986	**AMTD**	9940
Date of significant modification	2010	**Co-ordinates (GDA 56)**	509982.86E 6964316.4N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) As-Constructed Drawings (2010)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\TMR_001 New Gateway Bridge\		

Description	Concrete Arch Bridge. Piers and Abutments modelled only, deck sufficiently above Q2000 year ARI water surface level		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	-mAHD	**Number of Barrels**	-
Number of Piers in Waterway	-	**Dimensions**	-
Pier Width	19m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	-mAHD		
Rail height	-m		
Span Length	584m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Gateway Motorway and Sir Leo Hielscher Bridges, looking upstream
Image Reference	Guard, P. BMT WBM (2011*). The Sir Leo Hielscher Bridges.* [digital photography]. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:Gateway_Bridge_aerial4.JPG



Sir Leo Hielscher Bridges (TMR_001) Characteristics

Structure Name	Sir Leo Hielscher Bridges
Structure ID	TMR_001
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	3444	0	3444	3087	0	3087	1.1	0.0	1.1	1.46	1.44	0.02
1999	544	0	544	3054	0	3054	0.2	0.0	0.2	1.37	1.37	0.00
2011	9046	0	9046	3139	0	3139	2.9	0.0	2.9	1.65	1.55	0.10
2013	2416	0	2416	3317	0	3317	0.7	0.0	0.7	1.98	1.97	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	3266	0	3266	2885	0	2885	1.1	0.0	1.1	1.44	1.42	0.02
1999	786	0	786	2863	0	2863	0.3	0.0	0.3	1.37	1.37	0.00
2011	8707	0	8707	2385	0	2385	3.7	0.0	3.7	1.65	1.47	0.18
2013	1863	0	1863	3125	0	3125	0.6	0.0	0.6	1.96	1.96	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

Story Bridge (BCC_006) Structure

Structure Name	Story Bridge		
Structure ID	BCC_006		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1940	**AMTD**	21740
Date of significant modification	-	**Co-ordinates (GDA 56)**	503498.12E 6962171.33N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings (1938)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_006 Storey Bridge\		

Description	Suspension Bridge, Steel truss superstructure		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	29.8mAHD	**Number of Barrels**	-
Number of Piers in Waterway	29.8	**Dimensions**	-
Pier Width	9.6m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	33.5mAHD		
Rail height	1.1*m		
Span Length	82-281m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Story Bridge, looking upstream
Image Reference	Macey, C.R. (2007). *Story Bridge* [digital photography]. Retrieved from below source
Image Source	http://de.wikipedia.org/wiki/Story_Bridge#mediaviewer/File:Story_Bridge_Panorama.jpg

Story Bridge (BCC_006) Characteristics

Structure Name	Story Bridge
Structure ID	BCC_006
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10775	0	10775	3089	0	3089	3.5	0.0	3.5	4.96	4.87	0.08
1996	3556	0	3556	2349	0	2349	1.5	0.0	1.5	1.96	1.94	0.02
1999	746	0	746	2233	0	2233	0.3	0.0	0.3	1.44	1.44	0.01
2011	8960	0	8960	2862	0	2862	3.1	0.0	3.1	4.10	4.03	0.07
2013	2726	0	2726	2432	0	2432	1.1	0.0	1.1	2.30	2.29	0.01
1.5 x 1974	15621	0	15621	4092	0	4092	3.8	0.0	3.8	7.89	7.77	0.12
2 x 1974	19549	0	19549	5200	0	5200	3.8	0.0	3.8	10.65	10.56	0.09
5 x 1974	32342	0	32342	9773	0	9773	3.3	0.0	3.3	20.17	20.06	0.11
8 x 1974	39205	0	39205	11829	0	11829	3.3	0.0	3.3	25.00	24.83	0.18

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10687	0	10687	3711	0	3711	2.9	0.0	2.9	4.92	4.91	0.01
1996	3439	0	3439	2867	0	2867	1.2	0.0	1.2	1.87	1.87	0.00
1999	875	0	875	2744	0	2744	0.3	0.0	0.3	1.45	1.45	0.00
2011	8805	0	8805	3456	0	3456	2.5	0.0	2.5	4.09	4.06	0.02
2013	2278	0	2278	2956	0	2956	0.8	0.0	0.8	2.20	2.20	0.00
1.5 x 1974	15715	0	15715	5021	0	5021	3.1	0.0	3.1	8.51	8.46	0.05
5 x 1974	25161	0	25161	11251	0	11251	2.2	0.0	2.2	23.46	23.43	0.04
8 x 1974	24164	0	24164	13411	0	13411	1.8	0.0	1.8	28.32	28.29	0.03

* At time of peak water level on upstream side

Model Version Number: 43

Captain Cook Bridge (TMR_038) Structure

Structure Name	Captain Cook Bridge		
Structure ID	TMR_038		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1972	**AMTD**	24090
Date of significant modification		**Co-ordinates (GDA 56)**	502861.51E 6960260.23N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings (1970)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\TMR_038 Capitain Cook Bridge\		

Description	Concrete Arch Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	10.4mAHD	**Number of Barrels**	-
Number of Piers in Waterway	10.4	**Dimensions**	-
Pier Width	6m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	9.8mAHD		
Rail height	1.5*m		
Span Length	73-183m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Captain Cook Bridge, looking downstream
Image Reference	BrisbanePom (2011*). The Captain Cook Bridge over the Brisbane River at Brisbane.* [digital photography]. Retrieved from below source
Image Source	https://en.wikipedia.org/wiki/Captain_Cook_Bridge,_Brisbane#/media/File:Captain_Cook_Bridge_at_dusk,_Brisbane.jpg

Captain Cook Bridge (TMR_038) Characteristics

Structure Name	Captain Cook Bridge
Structure ID	TMR_038
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10790	0	10790	3432	0	3432	3.1	0.0	3.1	6.02	5.90	0.13
1996	3571	0	3571	2327	0	2327	1.5	0.0	1.5	2.18	2.15	0.03
1999	1295	0	1295	2152	0	2152	0.6	0.0	0.6	1.49	1.48	0.01
2011	8961	0	8961	3104	0	3104	2.9	0.0	2.9	4.97	4.86	0.11
2013	2759	0	2759	2398	0	2398	1.2	0.0	1.2	2.44	2.42	0.02
1.5 x 1974	16337	0	16337	4459	0	4459	3.7	0.0	3.7	9.38	9.20	0.18
2 x 1974	22191	484	22675	5191	188	5379	4.3	2.6	4.2	12.52	12.24	0.28
5 x 1974	15782	11385	27167	5612	3468	9080	2.8	3.3	3.0	21.94	21.69	0.25
8 x 1974	11545	16205	27749	5612	6642	12254	2.1	2.4	2.3	26.88	26.77	0.11

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10342	0	10342	5850	0	5850	1.8	0.0	1.8	6.22	6.14	0.08
1996	3442	0	3442	3758	0	3758	0.9	0.0	0.9	2.08	2.07	0.01
1999	1431	0	1431	3540	0	3540	0.4	0.0	0.4	1.48	1.48	0.00
2011	8664	0	8664	5234	0	5234	1.7	0.0	1.7	4.97	4.89	0.08
2013	2292	0	2292	3840	0	3840	0.6	0.0	0.6	2.30	2.30	0.01
1.5 x 1974	14597	0	14597	7256	0	7256	2.0	1.0	2.0	10.26	10.11	0.15
5 x 1974	8863	5820	14682	7446	4578	12023	1.2	1.3	1.2	24.87	24.83	0.04
8 x 1974	10678	10336	21014	7442	6894	14335	1.4	1.5	1.5	29.46	29.42	0.04

* At time of peak water level on upstream side

Model Version Number: 43

Goodwill Bridge (BCC_008) Structure

Structure Name	Goodwill Bridge		
Structure ID	BCC_008		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	2001	**AMTD**	24260
Date of significant modification		**Co-ordinates (GDA 56)**	502674.14E 6960341.25N
Source of Structure Information	Structural Design Drawings (1999)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_008 Goodwill Bridge\		

Description	Concrete and Steel Arch Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	6.1mAHD	**Number of Barrels**	-
Number of Piers in Waterway	6.1	**Dimensions**	-
Pier Width	23m, 0.8m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	7.3mAHD		
Rail height	1.6*m		
Span Length	19.7 - 112m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Goodwill Bridge, looking from South Bank
Image Reference	Department of Public Works (2012). *Goodwill bridge from South Bank* [Digital Photograph]. Retrieved from below source
Image Source	Department of Public Works, 2012

BMT WBM

Goodwill Bridge (BCC_008) Characteristics

Structure Name	Goodwill Bridge
Structure ID	BCC_008
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8960	0	8960	3773	0	3774	2.4	0.7	2.4	5.13	5.10	0.04
2013	2760	0	2760	2889	0	2889	1.0	0.0	1.0	2.47	2.46	0.02
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8810	7	8816	3647	5	3652	2.4	1.3	2.4	5.03	5.00	0.03
2013	2291	0	2291	2521	0	2521	0.9	0.0	0.9	2.31	2.25	0.06
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

Victoria Bridge (BCC_009) Structure

Structure Name	Victoria Bridge		
Structure ID	BCC_009		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1865	**AMTD**	25305
Date of significant modification	1897, 1969	**Co-ordinates (GDA 56)**	502072.36E 6961236.33N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings (1966)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_009 Victoria Bridge\		

Description	Concrete Arch Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	8.2mAHD	**Number of Barrels**	-
Number of Piers in Waterway	8.2	**Dimensions**	-
Pier Width	4m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	9.2mAHD		
Rail height	1.5*m		
Span Length	136, 85.3m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Victoria bridge, looking downstream
Image Reference	Figaro, I. (2009*). Fountain at Newstead House in Brisbane, Queensland, Australia* [digital photograph]. Retrieved from below source
Image Source	http://www.marysrosaries.com/collaboration/index.php?title=File:Victoria-Bridge_Brisbane.jpg

Victoria Bridge (BCC_009) Characteristics

Structure Name	Victoria Bridge
Structure ID	BCC_009
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10797	0	10797	3226	0	3226	3.3	0.0	3.3	6.50	6.41	0.08
1996	3584	0	3584	2184	0	2184	1.6	0.0	1.6	2.32	2.29	0.03
1999	1317	0	1317	1996	0	1996	0.7	0.0	0.7	1.52	1.51	0.01
2011	8962	0	8962	2946	0	2946	3.0	0.0	3.0	5.41	5.33	0.08
2013	2822	0	2822	2239	0	2239	1.3	0.0	1.3	2.53	2.51	0.02
1.5 x 1974	15708	0	15708	3855	0	3855	4.1	0.0	4.1	10.21	9.86	0.35
2 x 1974	17992	426	18417	4074	136	4210	4.4	3.1	4.4	13.77	13.06	0.72
5 x 1974	16543	11266	27808	4083	2520	6602	4.1	4.5	4.2	22.74	22.23	0.51
8 x 1974	17226	19162	36388	4083	4101	8183	4.2	4.7	4.4	27.63	27.15	0.49

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10721	0	10721	3762	0	3762	2.9	0.0	2.9	6.61	6.58	0.03
1996	3449	0	3449	2595	0	2595	1.3	0.0	1.3	2.16	2.16	0.00
1999	1467	0	1467	2442	0	2442	0.6	0.0	0.6	1.50	1.50	0.00
2011	8850	0	8850	3342	0	3342	2.6	0.0	2.6	5.36	5.33	0.03
2013	2371	0	2371	2638	0	2638	0.9	0.0	0.9	2.35	2.34	0.00
1.5 x 1974	15312	0	15312	4687	0	4687	3.3	2.6	3.3	10.62	10.56	0.06
5 x 1974	10743	6021	16764	4615	2831	7445	2.3	2.1	2.3	25.02	24.94	0.08
8 x 1974	11245	9223	20468	4571	4005	8576	2.5	2.3	2.4	29.65	29.52	0.13

* At time of peak water level on upstream side

Model Version Number: 43

Kurilpa Bridge (BCC_010) Structure

Structure Name	Kurilpa Bridge		
Structure ID	BCC_010		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	2009	**AMTD**	25705
Date of significant modification		**Co-ordinates (GDA 56)**	501765.75E 6961559.1N
Source of Structure Information	Structural Design Drawings (2007)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_010 Kurilpa Bridge\		

Description	Tensegrity Cable Stay Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	9.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	9.5	**Dimensions**	-
Pier Width	10*m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	10.4mAHD		
Rail height	1.6*m		
Span Length	115m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Kurilpa Bridge, looking upstream
Image Reference	Guard, P. BMT WBM (2009*). Kurilpa Bridge.* [digital photograph]. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:KurilpaBridge1.JPG

BMT WBM

Kurilpa Bridge (BCC_010) Characteristics

Structure Name	Kurilpa Bridge
Structure ID	BCC_010
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8951	0	8951	3514	0	3514	2.5	0.0	2.5	5.55	5.53	0.02
2013	2778	0	2778	2852	0	2852	1.0	0.0	1.0	2.56	2.55	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8825	0	8825	2854	0	2854	3.1	0.0	3.1	5.32	5.29	0.03
2013	2361	0	2361	2286	0	2286	1.0	0.0	1.0	2.35	2.35	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

William Jolly Bridge (BCC_011) Structure

Structure Name	William Jolly Bridge		
Structure ID	BCC_011		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1932	**AMTD**	26035
Date of significant modification		**Co-ordinates (GDA 56)**	501537.64E 6961628.46N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings (1927)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_011 William Jolly\		

Description	Concrete Arch Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	13.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	13.5	**Dimensions**	-
Pier Width	6.6m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	14.3mAHD		
Rail height	1.5*m		
Span Length	72.5m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	William Jolly Bridge, looking downstream
Image Reference	Allen, R. (2012*). William Jolly Bridge (looking upstream)* [digital photograph]. Retrieved from below source
Image Source	https://www.flickr.com/photos/raeallen/7173158786/in/photostream/

William Jolly Bridge (BCC_011) Characteristics

Structure Name	William Jolly Bridge
Structure ID	BCC_011
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10719	0	10719	3882	0	3882	2.8	0.0	2.8	6.85	6.81	0.04
1996	3582	0	3582	2864	0	2864	1.3	0.0	1.3	2.39	2.38	0.01
1999	1324	0	1324	2679	0	2679	0.5	0.0	0.5	1.54	1.53	0.01
2011	8952	0	8952	3621	0	3621	2.5	0.0	2.5	5.70	5.67	0.03
2013	2816	0	2816	2908	0	2908	1.0	0.0	1.0	2.59	2.58	0.01
1.5 x 1974	13248	0	13248	4742	0	4742	2.8	0.0	2.8	10.64	10.58	0.06
2 x 1974	10334	0	10334	5400	0	5400	1.9	0.0	1.9	14.14	14.05	0.09
5 x 1974	6933	2983	9916	5400	1987	7387	1.3	1.5	1.3	23.04	22.99	0.04
8 x 1974	6530	5089	11619	5400	3557	8957	1.2	1.4	1.3	27.97	27.94	0.04

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10524	0	10524	3765	0	3765	2.8	0.0	2.8	6.93	6.89	0.04
1996	3451	0	3451	2639	0	2639	1.3	0.0	1.3	2.20	2.20	-0.01
1999	1514	0	1514	2516	0	2516	0.6	0.0	0.6	1.51	1.51	0.00
2011	8794	0	8794	3413	0	3413	2.6	0.0	2.6	5.64	5.61	0.03
2013	2355	0	2355	2690	0	2690	0.9	0.0	0.9	2.38	2.38	0.00
1.5 x 1974	13917	0	13917	5044	0	5044	2.8	0.0	2.8	11.24	11.18	0.06
5 x 1974	16235	7880	24115	5894	2786	8680	2.8	2.8	2.8	25.39	25.35	0.04
8 x 1974	17631	13063	30694	5894	4218	10112	3.0	3.1	3.0	30.09	30.05	0.04

* At time of peak water level on upstream side

Model Version Number: 43

Merivale St Bridge (QR_087) Structure

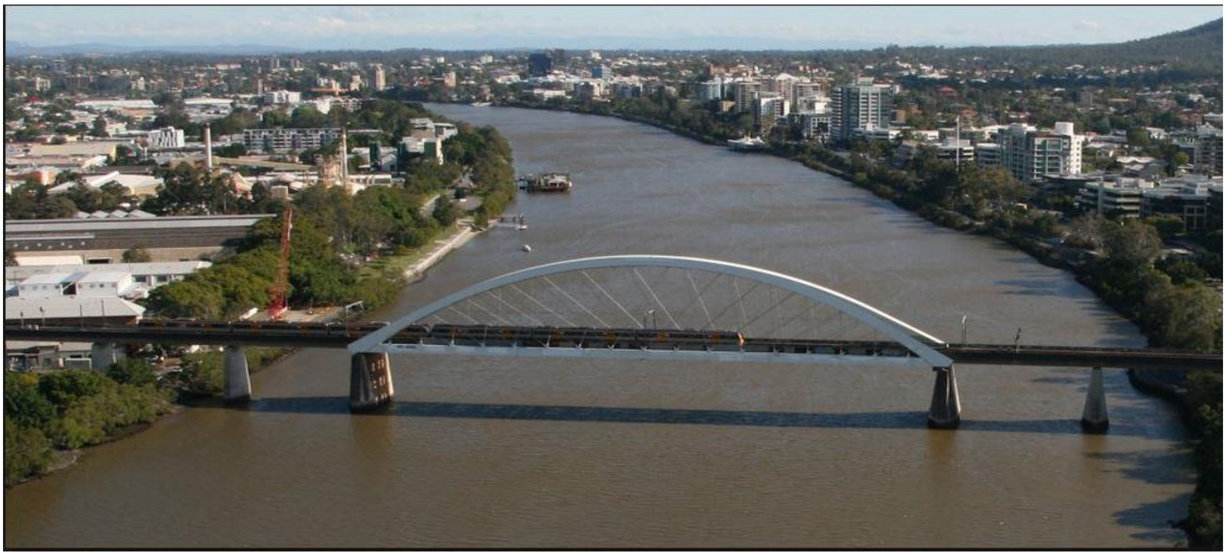
Structure Name	Merivale St Bridge		
Structure ID	QR_087		
Owner	QR	**Waterway**	Brisbane River
Date of Construction	1979	**AMTD**	26290
Date of significant modification		**Co-ordinates (GDA 56)**	501306.22E 6961566.52N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) As-Construcuted Drawings (1974)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\QR_087 Merivale Street Rail\		

Description	Through Arch Bridge with Concrete Deck and Cable Stay Arch		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	14.1mAHD	**Number of Barrels**	-
Number of Piers in Waterway	14.1	**Dimensions**	-
Pier Width	max 13.4m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	15.1mAHD		
Rail height	-m		
Span Length	33.4-132.9m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Merivale St Bridge, looking upstream
Image Reference	Bilious. (2008). *Merivale Bridge, Brisbane taken from an oblique elevated vantage* [digital photograph]. Retrieved from below source
Image Source	http://commons.wikimedia.org/wiki/File:Merivale_Bridge.jpg



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Merivale St Bridge (QR_087) Characteristics

Structure Name	Merivale St Bridge
Structure ID	QR_087
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	3598	0	3598	1691	0	1691	2.1	0.0	2.1	2.51	2.41	0.11
1999	1331	0	1331	1522	0	1522	0.9	0.0	0.9	1.56	1.54	0.02
2011	8956	0	8956	2434	0	2434	3.7	0.0	3.7	6.01	5.75	0.27
2013	2862	0	2862	1728	0	1728	1.7	0.0	1.7	2.66	2.60	0.07
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	3483	0	3483	2394	0	2394	1.5	0.0	1.5	2.25	2.24	0.01
1999	1512	0	1512	2230	0	2230	0.7	0.0	0.7	1.53	1.52	0.00
2011	8809	0	8809	3343	0	3343	2.6	0.0	2.6	5.87	5.81	0.06
2013	2353	0	2353	2430	0	2430	1.0	0.0	1.0	2.41	2.40	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Go Between Bridge (BCC_012) Structure

Structure Name	Go Between Bridge		
Structure ID	BCC_012		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	2010	**AMTD**	29380
Date of significant modification		**Co-ordinates (GDA 56)**	501204.81E 6961523.39N
Source of Structure Information	As-Construcuted Drawings (2010)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_012 Go Between Bridge\		

Description	Concrete Arch Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	6.7mAHD	**Number of Barrels**	-
Number of Piers in Waterway	6.7	**Dimensions**	-
Pier Width	8.9m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	7.5mAHD		
Rail height	1.3m		
Span Length	78.5-117 m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Go Between Bridge, looking upstream
Image Reference	Guard, P. BMT WBM (2010*). Go Between Bridge.* [digital photograph]. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:Go_between_bridge.jpg

BMT WBM

Go Between Bridge (BCC_012) Characteristics

Structure Name	Go Between Bridge
Structure ID	BCC_012
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8956	0	8956	3397	0	3397	2.6	0.0	2.6	6.05	6.03	0.02
2013	2873	0	2873	2470	0	2470	1.2	0.0	1.2	2.68	2.66	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8774	0	8774	3350	0	3350	2.6	0.0	2.6	5.97	5.92	0.05
2013	2369	0	2369	2335	0	2335	1.0	0.0	1.0	2.42	2.41	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Eleanor Schonell (Green) Bridge (BCC_019) Structure

Structure Name	Eleanor Schonell (Green) Bridge		
Structure ID	BCC_019		
Owner	BCC	**Waterway**	Brisbane River
Date of Construction	2006	**AMTD**	35100
Date of significant modification		**Co-ordinates (GDA 56)**	502036.19E 6958442.67N
Source of Structure Information	As-Construcuted Drawings (2005)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_019 Green Bridge\		

Description	Harp Cable Stay Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	11.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	11.5	**Dimensions**	-
Pier Width	6.2-9.5m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	12.4mAHD		
Rail height	1.17m		
Span Length	73-184.4m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Eleanor Schonell (Green) Bridge, looking upstream
Image Reference	Bilious. (2007*). The completed Eleanor Schonell Bridge taken on, from the City Cat.* [digital photography]. Retrieved from below source
Image Source	http://en.wikipedia.org/wiki/File:Eleanor_Schonell_Bridge,_Brisbane,_2007-01-31.jpg

Eleanor Schonell (Green) Bridge (BCC_019) Characteristics

Structure Name	Eleanor Schonell (Green) Bridge
Structure ID	BCC_019
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8972	0	8972	4894	0	4894	1.8	0.0	1.8	7.48	7.47	0.01
2013	2988	0	2988	3507	0	3507	0.9	0.0	0.9	3.00	3.00	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	8904	0	8904	5688	0	5688	1.6	0.0	1.6	7.77	7.75	0.02
2013	2552	0	2552	3896	0	3896	0.7	0.0	0.7	2.68	2.68	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

Jack Pesch Bridge (BCC_021) Structure

Structure Name	Jack Pesch Bridge		
Structure ID	BCC_021		
Owner	BCC	**Waterway**	Brisbane River
Date of Construction	1998	**AMTD**	41550
Date of significant modification		**Co-ordinates (GDA 56)**	497452.41E 6957523.98N
Source of Structure Information	As-Construcuted Drawings (1997)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_021 Walter Taylor Pedestrian Bridge\		

Description	Steel Cable Stay Bridge. NB: Jack Pesch, Indooroopilly Rail (2) and Walter Taylor Bridges modelled as one.		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	15.5*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	15.5*	**Dimensions**	-
Pier Width	-m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	18.4mAHD		
Rail height	1.8*m		
Span Length	167.5m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	See BCC_020
Included in Detailed Model (DM)	Yes	**DM Representation**	See BCC_020

Image Description	Aerial image, looking upstream. Jack Pesch Bridge on right
Image Reference	Kgbo. (2014*). Jack Pesch Bridge and next to it Albert Bridge, Brisbane.* [digital photography]. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:Jack_Pesch_Bridge_05.JPG

BMT WBM

Jack Pesch Bridge (BCC_021) Characteristics

Structure Name	Jack Pesch Bridge
Structure ID	BCC_021
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	1588	0	1588	1651	0	1651	1.0	0.0	1.0	1.94	1.93	0.01
2011	9173	0	9173	3029	0	3029	3.0	0.0	3.0	9.84	9.79	0.06
2013	3557	0	3557	1934	0	1934	1.8	0.0	1.8	3.79	3.76	0.03
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	1629	0	1629	2006	0	2006	0.8	0.0	0.8	1.86	1.86	0.00
2011	8897	0	8897	3231	0	3231	2.8	0.0	2.8	9.49	9.47	0.01
2013	3388	0	3388	2216	0	2216	1.5	0.0	1.5	3.24	3.24	0.00
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

Indooroopilly Railway Bridges (QR_083) Structure

Structure Name	Indooroopilly Railway Bridges		
Structure ID	QR_083		
Owner	QR	**Waterway**	Brisbane River
Date of Construction	1957	**AMTD**	41550
Date of significant modification		**Co-ordinates (GDA 56)**	497432.65E 6957535.32N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings (1951)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\QR_083 Indooroopilly Rail\		

Description	Two steel suspension bridges. Albert Bridge with arched superstructure. NB: Jack Pesch, Indooroopilly Rail (2) and Walter Taylor Bridges modelled as one.		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	15.5*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	15.5*	**Dimensions**	-
Pier Width	7.3m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	16.5mAHD		
Rail height	-m		
Span Length	104.2m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	See BCC_020
Included in Detailed Model (DM)	Yes	**DM Representation**	See BCC_020

Image Description	Aerial image, looking upstream. Indooroopilly Rail Bridges in center
Image Reference	Guard, P. BMT WBM (2008*). Indooroopilly Rail Bridge.* [digital photograph]. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:Indooroopilly_Bridge.jpg

Indooroopilly Railway Bridges (QR_083) Characteristics

Structure Name	Indooroopilly Railway Bridges
Structure ID	QR_083
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10860	0	10860	3331	0	3331	3.3	0.0	3.3	11.38	11.32	0.06
1996	3663	0	3663	1960	0	1960	1.9	0.0	1.9	3.95	3.92	0.03
1999	1588	0	1588	1651	0	1651	1.0	0.0	1.0	1.94	1.93	0.01
2011	9173	0	9173	3029	0	3029	3.0	0.0	3.0	9.84	9.79	0.06
2013	3557	0	3557	1934	0	1934	1.8	0.0	1.8	3.79	3.76	0.03
1.5 x 1974	14844	0	14844	4087	0	4087	3.6	0.0	3.6	15.59	15.24	0.35
2 x 1974	13607	641	14248	4087	267	4354	3.3	2.4	3.3	18.70	18.39	0.32
5 x 1974	4552	3999	8551	4087	2837	6924	1.1	1.4	1.2	27.73	27.70	0.04
8 x 1974	3119	4567	7685	4087	4390	8477	0.8	1.0	0.9	33.18	33.16	0.02

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10790	0	10790	3542	0	3542	3.0	0.0	3.0	11.14	11.11	0.03
1996	3507	0	3507	2239	0	2239	1.6	0.0	1.6	3.39	3.40	0.00
1999	1629	0	1629	2006	0	2006	0.8	0.0	0.8	1.86	1.86	0.00
2011	8897	0	8897	3231	0	3231	2.8	0.0	2.8	9.49	9.47	0.01
2013	3388	0	3388	2216	0	2216	1.5	0.0	1.5	3.24	3.24	0.00
1.5 x 1974	16101	0	16102	4298	0	4298	3.7	4.0	3.7	15.18	15.10	0.08
5 x 1974	5618	2888	8506	4310	2317	6627	1.3	1.2	1.3	29.61	29.60	0.01
8 x 1974	147	107	254	4310	3324	7634	0.0	0.0	0.0	34.92	34.92	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Walter Taylor Bridge (BCC_020) Structure

Structure Name	Walter Taylor Bridge		
Structure ID	BCC_020		
Owner	BCC	**Waterway**	Brisbane River
Date of Construction	1936	**AMTD**	41550
Date of significant modification		**Co-ordinates (GDA 56)**	497399.96E 6957559.5N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings (1934)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_020 Walter Taylor Bridge\		

Description	Concrete Bridge with Steel Suspension. NB: Jack Pesch, Indooroopilly Rail (2) and Walter Taylor Bridges modelled as one.		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	15.5*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	15.5*	**Dimensions**	-
Pier Width	10.1*m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	16.5mAHD		
Rail height	1.8*m		
Span Length	152.4m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Aerial image, looking upstream. Walter Taylor on left
Image Reference	Guard, P. BMT WBM (2008*). Walter Taylor Bridge.* [digital photograph. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:Walter_Taylor_Bridge.jpg

Walter Taylor Bridge (BCC_020) Characteristics

Structure Name	Walter Taylor Bridge
Structure ID	BCC_020
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10860	0	10860	3331	0	3331	3.3	0.0	3.3	11.38	11.32	0.06
1996	3663	0	3663	1960	0	1960	1.9	0.0	1.9	3.95	3.92	0.03
1999	1588	0	1588	1651	0	1651	1.0	0.0	1.0	1.94	1.93	0.01
2011	9173	0	9173	3029	0	3029	3.0	0.0	3.0	9.84	9.79	0.06
2013	3557	0	3557	1934	0	1934	1.8	0.0	1.8	3.79	3.76	0.03
1.5 x 1974	14844	0	14844	4087	0	4087	3.6	0.0	3.6	15.59	15.24	0.35
2 x 1974	13607	641	14248	4087	267	4354	3.3	2.4	3.3	18.70	18.39	0.32
5 x 1974	4552	3999	8551	4087	2837	6924	1.1	1.4	1.2	27.73	27.70	0.04
8 x 1974	3119	4567	7685	4087	4390	8477	0.8	1.0	0.9	33.18	33.16	0.02

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10790	0	10790	3542	0	3542	3.0	0.0	3.0	11.14	11.11	0.03
1996	3507	0	3507	2239	0	2239	1.6	0.0	1.6	3.39	3.40	0.00
1999	1629	0	1629	2006	0	2006	0.8	0.0	0.8	1.86	1.86	0.00
2011	8897	0	8897	3231	0	3231	2.8	0.0	2.8	9.49	9.47	0.01
2013	3388	0	3388	2216	0	2216	1.5	0.0	1.5	3.24	3.24	0.00
1.5 x 1974	16101	0	16102	4298	0	4298	3.7	4.0	3.7	15.18	15.10	0.08
5 x 1974	5618	2888	8506	4310	2317	6627	1.3	1.2	1.3	29.61	29.60	0.01
8 x 1974	147	107	254	4310	3324	7634	0.0	0.0	0.0	34.92	34.92	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Centenary Bridge (TMR_039) Structure

Structure Name	Centenary Bridge		
Structure ID	TMR_039		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1964	**AMTD**	49990
Date of significant modification	1985	**Co-ordinates (GDA 56)**	494771.63E 6955108.12N
Source of Structure Information	Hydraulic Structure Reference Sheet (SKM 1999) Structural Design Drawings, Duplication of Bridge (1985)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\TMR_039 Centenary Bridge\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	13.2mAHD	**Number of Barrels**	-
Number of Piers in Waterway	13.2	**Dimensions**	-
Pier Width	0.7m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	11.1mAHD		
Rail height	1.3m		
Span Length	42.3-48.3 m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Centenary Bridge, seen from Jindalee looking downstream
Image Reference	Kgbo. (2014*) Centenary Bridge, seen from Jindalee, Queensland, 03.2014.* [digital photograph]. Retrieved from below source
Image Source	https://commons.wikimedia.org/wiki/File:Centenary_Bridge_03.2014_03.JPG

Centenary Bridge (TMR_039) Characteristics

Structure Name	Centenary Bridge
Structure ID	TMR_039
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	9825	755	10580	3311	349	3660	3.0	2.2	2.9	13.92	13.80	0.12
1996	3714	0	3714	1722	0	1722	2.2	0.0	2.2	5.05	4.98	0.07
1999	2117	0	2117	1256	0	1256	1.7	0.0	1.7	2.33	2.28	0.05
2011	9241	136	9377	3143	79	3222	2.9	1.7	2.9	12.25	12.13	0.12
2013	3559	0	3559	1685	0	1685	2.1	0.0	2.1	4.84	4.77	0.07
1.5 x 1974	8020	4795	12815	3318	1788	5106	2.4	2.7	2.5	18.12	17.96	0.16
2 x 1974	7238	8091	15329	3318	3232	6549	2.2	2.5	2.3	21.06	20.93	0.13
5 x 1974	7334	19659	26993	3318	7587	10904	2.2	2.6	2.5	29.20	29.07	0.13
8 x 1974	7387	27512	34899	3318	10414	13732	2.2	2.6	2.5	34.43	34.30	0.13

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	10592	429	11021	4154	796	4950	2.6	0.5	2.2	14.12	14.05	0.07
1996	3615	0	3615	2062	0	2062	1.8	0.0	1.8	4.59	4.55	0.05
1999	1688	0	1688	1653	0	1653	1.0	0.0	1.0	2.30	2.28	0.02
2011	9386	85	9471	3774	345	4119	2.5	0.2	2.3	12.31	12.24	0.07
2013	3392	0	3392	2021	0	2021	1.7	0.0	1.7	4.36	4.32	0.04
1.5 x 1974	12063	3960	16023	4173	2737	6910	2.9	1.4	2.3	18.46	18.42	0.04
5 x 1974	14408	25552	39960	4173	10410	14583	3.5	2.5	2.7	31.49	31.47	0.02
8 x 1974	13954	35773	49727	4173	13891	18064	3.3	2.6	2.8	37.26	37.25	0.01

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Colleges Crossing (TMR_078) Structure

Structure Name	Colleges Crossing		
Structure ID	TMR_078		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1894	**AMTD**	85890
Date of significant modification		**Co-ordinates (GDA 56)**	480670.33E 6951875.09N
Source of Structure Information	Structural Design Drawings (1981)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\TMR_078 Colleges\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	2.2mAHD	**Number of Barrels**	-
Number of Piers in Waterway	2.2	**Dimensions**	-
Pier Width	0.6m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	2.6mAHD		
Rail height	0.3m		
Span Length	14m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Colleges Crossing, looking upstream
Image Reference	BMT WBM (2014). *Colleges Crossing (looking upstream)* [digital photography].
Image Source	BMT WBM, 2014

Colleges Crossing (TMR_078) Characteristics

Structure Name	Colleges Crossing
Structure ID	TMR_078
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	58	9531	9590	59	8063	8122	1.0	1.2	1.2	24.93	24.90	0.03
1996	53	2546	2599	59	2408	2467	0.9	1.1	1.1	11.81	11.79	0.02
1999	59	1874	1933	59	1587	1646	1.0	1.2	1.2	9.52	9.49	0.03
2011	61	9204	9266	59	7422	7481	1.0	1.2	1.2	23.54	23.51	0.03
2013	50	2191	2240	59	2192	2251	0.8	1.0	1.0	11.23	11.22	0.02
1.5 x 1974	65	13638	13702	59	10439	10498	1.1	1.3	1.3	30.02	29.99	0.03
2 x 1974	70	16983	17054	59	11913	11972	1.2	1.4	1.4	33.11	33.07	0.04
5 x 1974	90	29596	29686	59	16280	16339	1.5	1.8	1.8	42.04	41.98	0.06
8 x 1974	102	38895	38997	59	18907	18966	1.7	2.1	2.1	47.18	47.10	0.08

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	84	9549	9633	97	8159	8256	0.9	1.2	1.2	24.62	24.59	0.03
1996	83	2509	2592	97	2659	2756	0.9	0.9	0.9	12.18	12.15	0.03
1999	91	1800	1891	97	1699	1796	0.9	1.1	1.1	9.80	9.76	0.04
2011	90	9369	9459	97	7589	7686	0.9	1.2	1.2	23.44	23.39	0.05
2013	84	2026	2109	97	2293	2390	0.9	0.9	0.9	11.19	11.16	0.03
1.5 x 1974	86	13351	13437	97	10496	10593	0.9	1.3	1.3	29.54	29.51	0.02
5 x 1974	128	32902	33030	97	15868	15965	1.3	2.1	2.1	40.85	40.83	0.03
8 x 1974	152	47478	47629	97	17898	17995	1.6	2.7	2.6	45.13	45.10	0.03

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Mt Crosby Weir (BCC_077) Structure

Structure Name	Mt Crosby Weir		
Structure ID	BCC_077		
Owner	Seqwater	**Waterway**	Brisbane River
Date of Construction	1894	**AMTD**	90320
Date of significant modification	1897, 1927	**Co-ordinates (GDA 56)**	480042.24E 6954038.38N
Source of Structure Information	Brief Archival Record (Converge 2013 for SEQwater)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_077 Mt Crosby Weir\		

Description	Multi-cell weir with concrete overbridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	11.2mAHD	**Number of Barrels**	-
Number of Piers in Waterway	11.2	**Dimensions**	-
Pier Width	0.91m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	12.5mAHD		
Rail height	1.5*m		
Span Length	7.6m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	18xRectangular culverts with weir (
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Culvert Channels, 2D Weir

Image Description	Mt Crosby Weir, looking upstream from west bank
Image Reference	BMT WBM (2014). *Mt Crosby Weir (looking upstream from west bank)* [digital photography]
Image Source	BMT WBM, 2014

BMT WBM

Mt Crosby Weir (BCC_077) Characteristics

Structure Name	Mt Crosby Weir
Structure ID	BCC_077
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1741	7856	9598	509	3248	3756	3.4	2.4	2.6	27.40	27.28	0.11
1996	2008	605	2613	509	290	799	3.9	2.1	3.3	14.04	13.62	0.42
1999	1899	0	1899	473	0	473	4.0	0.0	4.0	12.18	11.33	0.85
2011	1812	7557	9369	509	2990	3498	3.6	2.5	2.7	26.25	26.13	0.12
2013	2011	231	2243	509	151	660	4.0	1.5	3.4	13.33	12.87	0.46
1.5 x 1974	1875	11593	13469	509	4463	4971	3.7	2.6	2.7	32.78	32.66	0.13
2 x 1974	1890	13999	15888	509	5130	5638	3.7	2.7	2.8	35.74	35.60	0.14
5 x 1974	1773	19685	21459	509	7048	7557	3.5	2.8	2.8	44.25	44.11	0.14
8 x 1974	1725	23554	25279	509	8223	8732	3.4	2.9	2.9	49.46	49.31	0.15

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	658	8990	9647	509	3285	3794	1.3	2.7	2.5	26.66	26.50	0.15
1996	1776	884	2660	509	399	908	3.5	2.2	2.9	14.65	13.70	0.95
1999	1841	119	1960	509	175	684	3.6	0.7	2.9	12.93	12.28	0.65
2011	701	8822	9523	509	3025	3533	1.4	2.9	2.7	25.80	25.63	0.17
2013	1787	391	2178	509	278	786	3.5	1.4	2.8	13.73	12.95	0.78
1.5 x 1974	478	13527	14005	509	5162	5670	0.9	2.6	2.5	31.80	31.72	0.08
5 x 1974	-184	27672	27488	509	10215	10723	-0.4	2.7	2.6	44.45	44.25	0.20
8 x 1974	-200	31785	31585	509	12526	13035	-0.4	2.5	2.4	50.29	50.10	0.19

* At time of peak water level on upstream side

Model Version Number: 43

Kholo Rd Bridge (BCC_076) Structure

Structure Name	Kholo Rd Bridge		
Structure ID	BCC_076		
Owner	BCC	**Waterway**	Brisbane River
Date of Construction	1970	**AMTD**	99090
Date of significant modification		**Co-ordinates (GDA 56)**	475036.12E 6950949.91N
Source of Structure Information	Structural Design Drawings (1969)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\BCC_076 Kholo Rd Bridge\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	11.2mAHD	**Number of Barrels**	-
Number of Piers in Waterway	11.2	**Dimensions**	-
Pier Width	0.8m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	11.7mAHD		
Rail height	0.6m		
Span Length	12.7m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Kholo Rd Bridge, looking downstream
Image Reference	BMT WBM (2015). *Kholo Road Bridge (looking downstream)* [digital photography].
Image Source	BMT WBM, 2015

BMT WBM

Kholo Rd Bridge (BCC_076) Characteristics

Structure Name	Kholo Rd Bridge
Structure ID	BCC_076
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	736	8100	8836	414	3872	4286	1.8	2.1	2.1	30.06	29.98	0.08
1996	716	1891	2607	414	977	1391	1.7	1.9	1.9	16.78	16.70	0.08
1999	768	1177	1945	414	580	993	1.9	2.0	2.0	14.95	14.84	0.11
2011	771	8042	8812	414	3685	4098	1.9	2.2	2.2	29.20	29.11	0.09
2013	719	1530	2249	414	791	1204	1.7	1.9	1.9	15.92	15.84	0.08
1.5 x 1974	658	9509	10167	414	5047	5461	1.6	1.9	1.9	35.45	35.39	0.07
2 x 1974	590	9812	10402	414	5738	6151	1.4	1.7	1.7	38.62	38.57	0.05
5 x 1974	369	8672	9042	414	7803	8216	0.9	1.1	1.1	48.09	48.07	0.02
8 x 1974	323	8936	9259	414	9071	9485	0.8	1.0	1.0	53.91	53.89	0.02

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	622	6084	6706	402	4010	4412	1.5	1.5	1.5	29.87	29.82	0.06
1996	798	1812	2610	402	1111	1513	2.0	1.6	1.7	17.62	17.53	0.08
1999	758	1145	1903	402	698	1100	1.9	1.6	1.7	15.90	15.78	0.12
2011	669	6215	6884	402	3847	4249	1.7	1.6	1.6	29.18	29.11	0.06
2013	778	1349	2127	402	879	1281	1.9	1.5	1.7	16.54	16.44	0.09
1.5 x 1974	493	6652	7145	402	5210	5612	1.2	1.3	1.3	34.99	34.95	0.05
5 x 1974	28	945	974	402	8217	8619	0.1	0.1	0.1	47.80	47.81	0.00
8 x 1974	2	182	184	402	9479	9882	0.0	0.0	0.0	53.19	53.19	0.00

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Burtons Bridge (SRC_075) Structure

Structure Name	Burtons Bridge		
Structure ID	SRC_075		
Owner	SRC	**Waterway**	Brisbane River
Date of Construction	?	**AMTD**	119090
Date of significant modification	2000	**Co-ordinates (GDA 56)**	469361.11E 6958199.51N
Source of Structure Information	Structural Design Drawings (2000)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\SRC_075 Burtons Bridge\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	18.1*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	18.1*	**Dimensions**	-
Pier Width	1-1.2*m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	19.8mAHD		
Rail height	1.1*m		
Span Length	14.3m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Burtons Bridge, looking downstream
Image Reference	BMT WBM (2014). *Burtons Bridge (looking downstream)* [digital photography].
Image Source	BMT WBM, 2014

BMT WBM

Burtons Bridge (SRC_075) Characteristics

Structure Name	Burtons Bridge
Structure ID	SRC_075
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	272	8000	8272	232	5628	5860	1.2	1.4	1.4	36.42	36.38	0.04
1996	369	2121	2490	232	1124	1356	1.6	1.9	1.8	25.37	25.30	0.07
1999	383	1556	1939	232	803	1036	1.6	1.9	1.9	24.08	23.99	0.09
2011	285	8192	8477	232	5501	5733	1.2	1.5	1.5	36.16	36.12	0.04
2013	379	1890	2268	232	987	1219	1.6	1.9	1.9	24.85	24.76	0.09
1.5 x 1974	235	9629	9864	232	7793	8025	1.0	1.2	1.2	40.79	40.76	0.03
2 x 1974	148	7254	7402	232	9381	9613	0.6	0.8	0.8	43.97	43.96	0.01
5 x 1974	77	9070	9147	232	14911	15144	0.3	0.6	0.6	55.06	55.05	0.01
8 x 1974	76	11347	11424	232	18743	18976	0.3	0.6	0.6	62.74	62.73	0.01

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	661	8501	9163	369	5549	5918	1.8	1.5	1.5	36.33	36.33	0.01
1996	725	1796	2521	369	1034	1403	2.0	1.7	1.8	25.34	25.30	0.04
1999	737	1178	1914	369	688	1057	2.0	1.7	1.8	23.85	23.80	0.05
2011	685	8556	9241	369	5480	5849	1.9	1.6	1.6	36.19	36.19	0.01
2013	732	1430	2161	369	836	1205	2.0	1.7	1.8	24.49	24.44	0.05
1.5 x 1974	763	13085	13848	369	7624	7993	2.1	1.7	1.7	40.58	40.58	0.00
5 x 1974	469	19495	19964	369	14662	15031	1.3	1.3	1.3	55.00	54.99	0.01
8 x 1974	719	32715	33434	369	17996	18365	2.0	1.8	1.8	61.83	61.81	0.02

* At time of peak water level on upstream side

Model Version Number: 43

Savages Crossing (SRC_074) Structure

Structure Name	Savages Crossing		
Structure ID	SRC_074		
Owner	SRC	**Waterway**	Brisbane River
Date of Construction	?	**AMTD**	85990
Date of significant modification		**Co-ordinates (GDA 56)**	467394.57E 6964416.65N
Source of Structure Information	Cottrell Cameron and Steen Survey (2008) for Esk-Lowood Flood Study		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\SRC_074 Savages Crossing\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	20.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	20.5	**Dimensions**	-
Pier Width	0.5-0.6m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	21.31mAHD		
Rail height	0.97m		
Span Length	12.3-12.6m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Savages Crossing, looking downstream
Image Reference	BMT WBM (2014). *Savages Crossing (looking downstream)* [digital photography].
Image Source	BMT WBM, 2014

BMT WBM

Savages Crossing (SRC_074) Characteristics

Structure Name	Savages Crossing
Structure ID	SRC_074
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	88	9428	9515	64	5816	5880	1.4	1.6	1.6	42.35	42.30	0.05
1996	75	2333	2408	64	1692	1756	1.2	1.4	1.4	30.37	30.34	0.04
1999	74	1849	1923	64	1363	1427	1.2	1.4	1.3	28.97	28.93	0.03
2011	89	9704	9793	64	5868	5932	1.4	1.7	1.7	42.47	42.42	0.05
2013	76	2207	2283	64	1584	1648	1.2	1.4	1.4	29.92	29.88	0.04
1.5 x 1974	75	10642	10717	64	7654	7718	1.2	1.4	1.4	46.67	46.64	0.04
2 x 1974	76	12360	12436	64	8712	8776	1.2	1.4	1.4	49.11	49.08	0.04
5 x 1974	81	19901	19982	64	13200	13264	1.3	1.5	1.5	59.25	59.21	0.04
8 x 1974	82	25275	25357	64	16674	16738	1.3	1.5	1.5	66.83	66.79	0.04

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	226	8921	9146	91	4899	4991	2.5	1.8	1.8	42.46	42.43	0.03
1996	164	2301	2465	91	1565	1656	1.8	1.5	1.5	30.79	30.71	0.08
1999	165	1728	1893	91	1238	1329	1.8	1.4	1.4	29.18	29.11	0.07
2011	228	9106	9334	91	4938	5029	2.5	1.8	1.9	42.58	42.55	0.03
2013	167	2011	2178	91	1377	1469	1.8	1.5	1.5	29.86	29.80	0.07
1.5 x 1974	197	10984	11181	91	6326	6418	2.2	1.7	1.7	46.91	46.88	0.04
5 x 1974	189	20528	20717	91	10479	10571	2.1	2.0	2.0	59.86	59.81	0.05
8 x 1974	189	24324	24513	91	12771	12862	2.1	1.9	1.9	67.01	66.94	0.06

* At time of peak water level on upstream side

Model Version Number: 43

Brisbane Valley Highway (TMR_050) Structure

Structure Name	Brisbane Valley Highway		
Structure ID	TMR_050		
Owner	TMR	**Waterway**	Brisbane River
Date of Construction	1993	**AMTD**	123290
Date of significant modification		**Co-ordinates (GDA 56)**	464368.59E 6965778.14N
Source of Structure Information	Structural Design Drawings (1993)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\TMR_050 Brisbane Valley Hway\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	31.1mAHD	**Number of Barrels**	-
Number of Piers in Waterway	31.1	**Dimensions**	-
Pier Width	2m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	33.6mAHD		
Rail height	0.8m		
Span Length	31m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Brisbane Valley Highway, looking downstream
Image Reference	BMT WBM (2014). *Brisbane Valley Highway (looking downstream)* [digital photography].
Image Source	BMT WBM, 2014

BMT WBM

Brisbane Valley Highway (TMR_050) Characteristics

Structure Name	Brisbane Valley Highway
Structure ID	TMR_050
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	2349	0	2349	1438	0	1438	1.6	0.0	1.6	32.15	32.09	0.07
1999	1872	0	1872	1349	0	1349	1.4	0.0	1.4	30.78	30.77	0.01
2011	816	1703	2519	1438	2353	3791	0.6	0.7	0.7	43.48	43.47	0.01
2013	2286	0	2286	1438	0	1438	1.6	0.0	1.6	31.79	31.73	0.06
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	2368	0	2368	1433	0	1433	1.7	0.0	1.7	33.25	33.13	0.11
1999	1847	0	1847	1371	0	1371	1.3	0.0	1.3	31.82	31.75	0.07
2011	919	1551	2471	1433	2422	3855	0.6	0.6	0.6	44.10	44.09	0.01
2013	2187	0	2187	1433	0	1433	1.5	0.0	1.5	32.63	32.54	0.09
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

Twin Bridges (SRC_073) Structure

Structure Name	Twin Bridges		
Structure ID	SRC_073		
Owner	SRC	**Waterway**	Brisbane River
Date of Construction	1900	**AMTD**	124390
Date of significant modification	?	**Co-ordinates (GDA 56)**	463779.36E 6965122.41N
Source of Structure Information	Cottrell Cameron and Steen Survey (2008) for Esk-Lowood Flood Study		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\SRC_073 Twin Bridges\		

Description	2 Concrete Causeways		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	23.3mAHD	**Number of Barrels**	-
Number of Piers in Waterway	23.3	**Dimensions**	-
Pier Width	0.4m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	23.7mAHD		
Rail height	-m		
Span Length	3m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	2 banks of culverts
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Culvert Channels, 2D Weir

Image Description	Twin Bridges, looking downstream
Image Reference	BMT WBM (2014). *Twin Bridges (looking downstream)* [digital photography].
Image Source	BMT WBM, 2014

Twin Bridges (SRC_073) Characteristics

Structure Name	Twin Bridges
Structure ID	SRC_073
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	69	5098	5167	58	7059	7117	1.2	0.7	0.7	43.35	43.34	0.01
1996	124	2226	2350	58	1965	2023	2.1	1.1	1.2	32.51	32.48	0.02
1999	122	1755	1877	58	1560	1618	2.1	1.1	1.2	31.19	31.16	0.02
2011	69	5149	5217	58	7137	7194	1.2	0.7	0.7	43.51	43.50	0.01
2013	127	2165	2292	58	1862	1919	2.2	1.2	1.2	32.18	32.15	0.03
1.5 x 1974	39	4992	5031	58	9037	9094	0.7	0.6	0.6	47.35	47.34	0.01
2 x 1974	33	5370	5403	58	10241	10299	0.6	0.5	0.5	49.78	49.78	0.01
5 x 1974	23	7195	7218	58	15245	15303	0.4	0.5	0.5	59.90	59.90	0.00
8 x 1974	17	8154	8171	58	18973	19031	0.3	0.4	0.4	67.44	67.44	0.00

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-9	5695	5686	58	6438	6496	-0.1	0.9	0.9	43.97	43.98	0.00
1996	-12	2393	2381	58	1865	1923	-0.2	1.3	1.2	33.52	33.53	-0.01
1999	-9	1846	1837	58	1537	1595	-0.2	1.2	1.2	32.11	32.11	0.00
2011	-8	5768	5759	58	6499	6557	-0.1	0.9	0.9	44.11	44.11	0.00
2013	-16	2196	2181	58	1711	1769	-0.3	1.3	1.2	32.92	32.93	-0.01
1.5 x 1974	-2	5648	5646	32	8210	8242	-0.1	0.7	0.7	47.95	47.95	0.00
5 x 1974	-1	7761	7761	32	14032	14064	0.0	0.6	0.6	61.02	61.02	0.00
8 x 1974	0	9870	9870	32	17257	17290	0.0	0.6	0.6	68.26	68.26	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Warrego Hwy (TMR_037) Structure

Structure Name	Warrego Hwy		
Structure ID	TMR_037		
Owner	TMR	**Waterway**	Bremer River
Date of Construction	1953	**AMTD**	5310
Date of significant modification	1990	**Co-ordinates (GDA 56)**	481697.09E 6948960.68N
Source of Structure Information	Structural Design Drawings (1990)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRM\TMR_037 Bremer river Warrego Hwy 18A\		

Description	Dual Concrete Bridges with debris fender system, modelled as single structure		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	14.5*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	14.5*	**Dimensions**	-
Pier Width	1.5*m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	15.8mAHD		
Rail height	1.3*m		
Span Length	30-37m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Aerial Imagery of dual bridges, flow direction bottom to top
Image Reference	*Ipswich City Council. Bremer River, Warrego Highway [* digital photograph].
Image Source	Imagery provided by ICC

BMT WBM

Warrego Hwy (TMR_037) Characteristics

Structure Name	Warrego Hwy
Structure ID	TMR_037
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	69	374	443	1868	1275	3143	0.0	0.3	0.1	20.74	20.74	0.00
1996	1031	0	1031	937	0	937	1.1	0.0	1.1	9.03	9.02	0.01
1999	324	0	324	551	0	551	0.6	0.0	0.6	5.08	5.07	0.01
2011	233	345	578	1868	791	2659	0.1	0.4	0.2	18.89	18.89	0.00
2013	1626	0	1626	1001	0	1001	1.6	0.0	1.6	9.54	9.52	0.02
1.5 x 1974	13	423	436	1868	2518	4385	0.0	0.2	0.1	25.48	25.48	0.00
2 x 1974	13	536	549	1868	3184	5051	0.0	0.2	0.1	28.01	28.01	0.00
5 x 1974	17	986	1002	1868	5436	7304	0.0	0.2	0.1	36.52	36.52	0.00
8 x 1974	20	1323	1343	1868	6789	8656	0.0	0.2	0.2	41.59	41.59	0.00

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	321	178	499	1748	989	2737	0.2	0.2	0.2	20.58	20.58	0.00
1996	1011	0	1011	953	0	953	1.1	0.0	1.1	9.56	9.54	0.02
1999	273	0	273	568	0	568	0.5	0.0	0.5	5.11	5.10	0.01
2011	452	147	599	1748	608	2356	0.3	0.2	0.3	18.84	18.83	0.00
2013	1551	0	1551	1019	0	1019	1.5	0.0	1.5	10.14	10.09	0.04
1.5 x 1974	212	256	467	1748	1986	3734	0.1	0.1	0.1	25.15	25.14	0.00
5 x 1974	256	774	1031	1748	4460	6207	0.1	0.2	0.2	36.47	36.47	0.00
8 x 1974	393	1444	1837	1748	5454	7201	0.2	0.3	0.3	41.02	41.02	0.00

* At time of peak water level on upstream side

Model Version Number: 43

David Trumpy Bridge (TMR_043) Structure

Structure Name	David Trumpy Bridge		
Structure ID	TMR_043		
Owner	TMR	**Waterway**	Bremer River
Date of Construction	1965	**AMTD**	16720
Date of significant modification		**Co-ordinates (GDA 56)**	476469.74E 6945831.92N
Source of Structure Information	Structural Design Drawings (1961)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRM\TMR_043 Bremer river Warrego connection\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	20.9mAHD	**Number of Barrels**	-
Number of Piers in Waterway	20.9	**Dimensions**	-
Pier Width	0.5m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	24.5*mAHD		
Rail height	1.6m		
Span Length	40.8-50.3m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	David Trumpy Bridge 1974, looking upstream
Image Reference	Ipswich City Council (2015*). David Trumpy Bridge.* [digital photograph].
Image Source	Imagery provided by ICC

Image Not Avaliable

David Trumpy Bridge (TMR_043) Characteristics

Structure Name	David Trumpy Bridge
Structure ID	TMR_043
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	2022	0	2022	2990	0	2990	0.7	0.0	0.7	21.01	21.01	0.01
1996	1662	0	1662	1132	0	1132	1.5	0.0	1.5	12.28	12.27	0.01
1999	687	0	687	465	0	465	1.5	0.0	1.5	6.57	6.56	0.01
2011	1361	0	1361	2520	0	2520	0.5	0.0	0.5	19.16	19.15	0.00
2013	1789	0	1789	1254	0	1254	1.4	0.0	1.4	13.06	13.06	0.01
1.5 x 1974	1839	252	2091	3536	370	3905	0.5	0.7	0.5	25.59	25.57	0.01
2 x 1974	1928	778	2706	3536	1097	4633	0.5	0.7	0.6	28.11	28.10	0.01
5 x 1974	1579	2369	3948	3536	3544	7080	0.4	0.7	0.6	36.61	36.60	0.01
8 x 1974	639	2481	3120	3536	5001	8537	0.2	0.5	0.4	41.67	41.66	0.01

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	2187	0	2187	2823	0	2823	0.8	0.0	0.8	20.91	20.91	0.00
1996	1611	0	1611	1357	0	1357	1.2	0.0	1.2	13.81	13.79	0.02
1999	696	0	696	670	0	670	1.0	0.0	1.0	7.91	7.84	0.07
2011	1456	0	1456	2397	0	2397	0.6	0.0	0.6	19.15	19.14	0.00
2013	1665	0	1665	1404	0	1404	1.2	0.0	1.2	14.08	14.06	0.02
1.5 x 1974	2900	136	3036	3355	188	3543	0.9	0.7	0.9	25.28	25.27	0.01
5 x 1974	2497	1874	4372	3355	2920	6275	0.7	0.6	0.7	36.56	36.56	0.00
8 x 1974	1454	1543	2997	3355	4024	7378	0.4	0.4	0.4	41.12	41.12	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Railway Workshop Bridge (QR_025) Structure

Structure Name	Railway Workshop Bridge		
Structure ID	QR_025		
Owner	QR	**Waterway**	Bremer River
Date of Construction	1895	**AMTD**	17000
Date of significant modification	?	**Co-ordinates (GDA 56)**	476213.02E 6945933.83N
Source of Structure Information	Structural Design Drawings (1895)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRM\QR_025 Riverlink Shopping Centre Rail\		

Description	Steel Truss Supported Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	20.6*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	20.6*	**Dimensions**	-
Pier Width	2.2*m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	21.1mAHD		
Rail height	1.7*m		
Span Length	45.57m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Railway Bridge, Ipswich, looking usptream
Image Reference	Goodwin, C. (2009*). Rail bridge across the Bremer River, Ipswich, Queensland.* [digital imagery]. Retrieved from below source
Image Source	http://en.wikipedia.org/wiki/File:Bremer_R.JPG

Railway Workshop Bridge (QR_025) Characteristics

Structure Name	Railway Workshop Bridge
Structure ID	QR_025
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	2099	0	2099	2331	0	2331	0.9	0.0	0.9	21.04	21.02	0.02
1996	1662	0	1662	1105	0	1105	1.5	0.0	1.5	12.33	12.32	0.01
1999	687	0	687	507	0	507	1.4	0.0	1.4	6.62	6.61	0.01
2011	1359	0	1359	2116	0	2116	0.6	0.0	0.6	19.17	19.16	0.01
2013	1789	0	1789	1203	0	1203	1.5	0.0	1.5	13.11	13.10	0.01
1.5 x 1974	2148	638	2786	2331	597	2927	0.9	1.1	1.0	25.61	25.59	0.02
2 x 1974	2442	1306	3748	2331	1060	3391	1.0	1.2	1.1	28.14	28.11	0.03
5 x 1974	2539	3462	6001	2331	2615	4946	1.1	1.3	1.2	36.64	36.61	0.03
8 x 1974	1722	3222	4943	2331	3538	5868	0.7	0.9	0.8	41.68	41.67	0.02

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	3644	0	3644	2288	0	2288	1.6	0.0	1.6	20.98	20.92	0.07
1996	1619	0	1619	1206	0	1206	1.3	0.0	1.3	13.96	13.90	0.06
1999	677	0	677	379	0	379	1.8	0.0	1.8	8.11	7.92	0.18
2011	1474	0	1474	2014	0	2014	0.7	0.0	0.7	19.18	19.17	0.01
2013	1679	0	1679	1231	0	1231	1.4	0.0	1.4	14.20	14.17	0.03
1.5 x 1974	2305	690	2995	2289	833	3121	1.0	0.8	1.0	25.33	25.31	0.03
5 x 1974	1728	2306	4034	2289	3559	5848	0.8	0.6	0.7	36.58	36.57	0.01
8 x 1974	859	1609	2469	2289	4663	6951	0.4	0.3	0.4	41.13	41.12	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Hancock Bridge (ICC_058) Structure

Structure Name	Hancock Bridge		
Structure ID	ICC_058		
Owner	ICC	**Waterway**	Bremer River
Date of Construction	1895	**AMTD**	20420
Date of significant modification	?	**Co-ordinates (GDA 56)**	474756.37E 6946775.98N
Source of Structure Information	Survey taken as part of Bremer River Flood Study, Reports 1 and 2		
Link to data source	K:\B20702.k.saw_Brisbane_River\10 Data Management\10-05_Structures\Structure_Details\BRI\BRM\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	11*mAHD	**Number of Barrels**	-
Number of Piers in Waterway	11*	**Dimensions**	-
Pier Width	0.8*m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	14.8*mAHD		
Rail height	1.2*m		
Span Length	18.3m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	HW and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Hancock Bridge, Bremer River flow left to right
Image Reference	*Ipswich City Council. Hancock Bridge [* digital photograph].
Image Source	Imagery provided by ICC

Hancock Bridge (ICC_058) Characteristics

Structure Name	Hancock Bridge
Structure ID	ICC_058
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1301	2767	4068	750	1392	2142	1.7	2.0	1.9	22.65	22.57	0.08
1996	1669	0	1669	750	0	750	2.2	0.0	2.2	14.14	14.01	0.13
1999	690	0	690	362	0	362	1.9	0.0	1.9	8.05	8.04	0.01
2011	799	876	1674	750	705	1456	1.1	1.2	1.2	19.59	19.56	0.03
2013	1794	3	1797	750	6	757	2.4	0.4	2.4	14.92	14.77	0.15
1.5 x 1974	905	3358	4263	750	2357	3108	1.2	1.4	1.4	26.04	26.01	0.04
2 x 1974	838	4108	4946	750	3099	3849	1.1	1.3	1.3	28.52	28.48	0.03
5 x 1974	1058	9461	10519	750	5650	6400	1.4	1.7	1.6	37.02	36.97	0.05
8 x 1974	1168	13231	14399	750	7157	7907	1.6	1.8	1.8	42.04	41.98	0.06

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1591	2184	3775	775	1719	2494	2.1	1.3	1.5	22.76	22.74	0.02
1996	1462	158	1620	775	111	885	1.9	1.4	1.8	15.69	15.60	0.09
1999	680	0	680	511	0	511	1.3	0.0	1.3	10.10	10.06	0.03
2011	1085	818	1903	775	1001	1775	1.4	0.8	1.1	19.78	19.76	0.02
2013	1472	201	1672	775	139	913	1.9	1.4	1.8	15.92	15.83	0.09
1.5 x 1974	1579	3613	5192	775	2586	3361	2.0	1.4	1.5	26.00	25.99	0.01
5 x 1974	1263	7119	8382	775	5543	6317	1.6	1.3	1.3	36.80	36.81	0.00
8 x 1974	1508	10565	12074	775	6777	7551	1.9	1.6	1.6	41.32	41.31	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Wulkuraka Rail Bridge (QR_103) Structure

Structure Name	Wulkuraka Rail Bridge		
Structure ID	QR_103		
Owner	QR	**Waterway**	Bremer River
Date of Construction	1895	**AMTD**	22300
Date of significant modification	?	**Co-ordinates (GDA 56)**	474327.63E 6945513.17N
Source of Structure Information	Structural Design Drawings (1895)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRM\QR_103 DIxon St\		

Description	Steel Truss Supported Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	25.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	25.5	**Dimensions**	-
Pier Width	1.2m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	28.1*mAHD		
Rail height	2.2*m		
Span Length	46.5m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Wulkuraka Rail Bridge, Aerial Imagery
Image Reference	*Ipswich City Council. Wulkuraka Rail Bridge, Aerial Imagery [* digital photograph].
Image Source	Imagery provided by ICC

BMT WBM

Wulkuraka Rail Bridge (QR_103) Characteristics

Structure Name	Wulkuraka Rail Bridge
Structure ID	QR_103
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	4143	0	4143	2147	0	2147	1.9	0.0	1.9	24.09	24.08	0.01
1996	1665	0	1665	901	0	901	1.8	0.0	1.8	16.02	16.01	0.01
1999	686	0	686	366	0	366	1.9	0.0	1.9	10.70	10.70	0.01
2011	2325	0	2325	1444	0	1444	1.6	0.0	1.6	20.46	20.46	0.01
2013	1801	0	1801	978	0	978	1.8	0.0	1.8	16.70	16.69	0.01
1.5 x 1974	6573	0	6573	2625	0	2625	2.5	0.0	2.5	27.73	27.55	0.18
2 x 1974	7810	814	8624	2625	388	3013	3.0	2.1	2.9	29.70	29.43	0.27
5 x 1974	7252	7300	14551	2625	2334	4959	2.8	3.1	2.9	37.75	37.54	0.21
8 x 1974	5924	9297	15221	2625	3482	6107	2.3	2.7	2.5	42.50	42.36	0.14

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	4024	0	4024	2125	0	2125	1.9	0.0	1.9	23.98	23.88	0.11
1996	1616	0	1616	1054	0	1054	1.5	0.0	1.5	17.00	16.94	0.07
1999	680	0	680	584	0	584	1.2	0.0	1.2	11.76	11.65	0.11
2011	2282	0	2282	1520	0	1520	1.5	0.0	1.5	20.58	20.50	0.08
2013	1682	0	1682	1073	0	1073	1.6	0.0	1.6	17.22	17.15	0.07
1.5 x 1974	6290	0	6290	2693	0	2693	2.3	1.1	2.3	27.23	27.09	0.14
5 x 1974	4783	3654	8437	2739	2093	4832	1.7	1.7	1.7	37.33	37.28	0.05
8 x 1974	3293	3820	7113	2739	3133	5872	1.2	1.2	1.2	41.67	41.65	0.02

* At time of peak water level on upstream side

Model Version Number: 43

One Mile Bridge (ICC_057) Structure

Structure Name	One Mile Bridge		
Structure ID	ICC_057		
Owner	ICC	**Waterway**	Bremer River
Date of Construction	1936	**AMTD**	24230
Date of significant modification	2004	**Co-ordinates (GDA 56)**	475079.71E 6944381.61N
Source of Structure Information	Structural Design Drawings, Upgrade (2004)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRM\ICC_057\		

Description	Concrete bridge on Bremer River downstream of Deebing Creek confluence		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	15.43mAHD	**Number of Barrels**	-
Number of Piers in Waterway	15.43	**Dimensions**	-
Pier Width	1.2m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	17.43mAHD		
Rail height	1.4m		
Span Length	29.7-30.0m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	One Mile Bridge, looking from downstream
Image Reference	BMT WBM (2014). *One Mile Bridge (looking downstream)* [digital photography]
Image Source	BMT WBM, 2015

One Mile Bridge (ICC_057) Characteristics

Structure Name	One Mile Bridge
Structure ID	ICC_057
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1044	3105	4148	1095	2750	3846	1.0	1.1	1.1	25.28	25.25	0.02
1996	1597	74	1671	1095	52	1147	1.5	1.4	1.5	18.08	18.03	0.05
1999	685	0	685	709	0	709	1.0	0.0	1.0	13.45	13.44	0.01
2011	1089	1364	2453	1095	1179	2274	1.0	1.2	1.1	21.73	21.70	0.03
2013	1616	189	1805	1095	123	1218	1.5	1.5	1.5	18.67	18.61	0.06
1.5 x 1974	1069	4988	6057	1095	4299	5394	1.0	1.2	1.1	28.74	28.71	0.02
2 x 1974	1134	6431	7566	1095	5222	6317	1.0	1.2	1.2	30.80	30.78	0.03
5 x 1974	950	9535	10486	1095	8871	9966	0.9	1.1	1.1	38.96	38.94	0.02
8 x 1974	454	7039	7493	1095	10772	11867	0.4	0.7	0.6	43.21	43.20	0.01

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	911	2763	3674	472	2311	2783	1.9	1.2	1.3	25.12	25.08	0.04
1996	1552	45	1597	472	67	538	3.3	0.7	3.0	18.27	18.06	0.22
1999	671	0	671	272	0	272	2.5	0.0	2.5	13.39	13.29	0.10
2011	1056	1240	2296	472	953	1425	2.2	1.3	1.6	21.52	21.45	0.07
2013	1583	80	1663	472	90	562	3.4	0.9	3.0	18.48	18.26	0.22
1.5 x 1974	955	4101	5056	472	3581	4052	2.0	1.1	1.2	28.46	28.43	0.03
5 x 1974	1001	8882	9883	472	7251	7723	2.1	1.2	1.3	38.14	38.12	0.02
8 x 1974	760	7847	8606	472	8707	9179	1.6	0.9	0.9	41.98	41.97	0.01

* At time of peak water level on upstream side

Model Version Number: 43

Three Mile Bridge (ICC_056) Structure

Structure Name	Three Mile Bridge		
Structure ID	ICC_056		
Owner	ICC	**Waterway**	Bremer River
Date of Construction	1970	**AMTD**	29310
Date of significant modification	2004	**Co-ordinates (GDA 56)**	473160.25E 6943533.27N
Source of Structure Information	Structural Design Drawings (2006)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRM\ICC_056\		

Description	Concrete bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	16.7mAHD	**Number of Barrels**	-
Number of Piers in Waterway	16.7	**Dimensions**	-
Pier Width	0.55m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	19.2mAHD		
Rail height	1.3*m		
Span Length	25m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Three Mile Bridge, looking form upstream
Image Reference	BMT WBM (2015*). Three Mile Bridge (looking from upstream)* [digital photography]
Image Source	BMT WBM, 2015

Three Mile Bridge (ICC_056) Characteristics

Structure Name	Three Mile Bridge
Structure ID	ICC_056
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	57	1026	1082	257	1941	2198	0.2	0.5	0.5	26.38	26.37	0.01
1996	349	685	1033	257	408	665	1.4	1.7	1.6	21.19	21.13	0.06
1999	465	0	465	257	0	257	1.8	0.0	1.8	17.45	17.33	0.12
2011	244	1346	1591	257	1123	1380	1.0	1.2	1.2	23.70	23.68	0.03
2013	249	596	845	257	485	742	1.0	1.2	1.1	21.50	21.46	0.04
1.5 x 1974	18	1032	1050	257	2836	3093	0.1	0.4	0.3	29.31	29.31	0.00
2 x 1974	11	1054	1065	257	3424	3681	0.0	0.3	0.3	31.23	31.23	0.00
5 x 1974	1	973	974	257	5833	6090	0.0	0.2	0.2	39.11	39.11	0.00
8 x 1974	0	375	375	257	7108	7365	0.0	0.1	0.1	43.28	43.28	0.00

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	12	635	647	257	2007	2264	0.0	0.3	0.3	26.59	26.59	0.00
1996	287	682	969	257	485	742	1.1	1.4	1.3	21.50	21.46	0.04
1999	460	0	460	257	0	257	1.8	0.0	1.8	17.67	17.54	0.12
2011	215	1189	1404	257	1205	1463	0.8	1.0	1.0	23.97	23.96	0.02
2013	244	627	871	257	524	781	0.9	1.2	1.1	21.65	21.62	0.03
1.5 x 1974	3	469	472	257	2813	3070	0.0	0.2	0.2	29.23	29.23	0.00
5 x 1974	0	-111	-111	90	5631	5721	0.0	0.0	0.0	38.45	38.45	0.00
8 x 1974	-5	-1906	-1911	257	6759	7016	0.0	-0.3	-0.3	42.14	42.14	0.00

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Cunningham Hwy (TMR_048) Structure

Structure Name	Cunningham Hwy		
Structure ID	TMR_048		
Owner	TMR	**Waterway**	Warrill Ck
Date of Construction	1991	**AMTD**	7630
Date of significant modification		**Co-ordinates (GDA 56)**	470262.48E 6940695.99N
Source of Structure Information	Structural Design Drawings (1991)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\WAR\TMR_048 Cunningham Hwy\		

Description	Flat Deck Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	25.6mAHD	**Number of Barrels**	-
Number of Piers in Waterway	25.6	**Dimensions**	-
Pier Width	0.7m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	27mAHD		
Rail height	0.75m		
Span Length	14m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Cunningham hwy over Warrill Creek
Image Reference	BMT WBM (2015). *Cunningham Highway over Warrill Creek* [digital photography].
Image Source	BMT WBM, 2015

Cunningham Hwy (TMR_048) Characteristics

Structure Name	Cunningham Hwy
Structure ID	TMR_048
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	266	0	266	268	0	268	1.0	0.0	1.0	23.45	23.44	0.02
1999	68	0	68	110	0	110	0.6	0.0	0.6	20.88	20.87	0.01
2011	106	0	106	302	0	302	0.4	0.0	0.4	23.94	23.94	0.01
2013	95	0	95	238	0	238	0.4	0.0	0.4	22.98	22.98	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	296	0	296	281	0	281	1.1	0.0	1.1	23.65	23.63	0.02
1999	67	0	67	109	0	109	0.6	0.0	0.6	20.85	20.85	0.01
2011	159	0	159	327	0	327	0.5	0.0	0.5	24.31	24.30	0.01
2013	155	0	155	256	0	256	0.6	0.0	0.6	23.26	23.25	0.01
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

Cunningham Hwy (TMR_049) Structure

Structure Name	Cunningham Hwy		
Structure ID	TMR_049		
Owner	TMR	**Waterway**	Purga Ck
Date of Construction	1991	**AMTD**	2290
Date of significant modification		**Co-ordinates (GDA 56)**	472413.14E 6940314.45N
Source of Structure Information	Structural Design Drawings (1991)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\PRG\TMR_049 Cunningham Hwy\		

Description	Flat Deck Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	25.3mAHD	**Number of Barrels**	-
Number of Piers in Waterway	25.3	**Dimensions**	-
Pier Width	0.7m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	26.8mAHD		
Rail height	0.75m		
Span Length	16m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Cunningham hwy over Purga Creek
Image Reference	*Ipswich City Council. Cunningham Highway over Purga Creek [* digital photography].
Image Source	Imagery provided by ICC

BMT WBM

Cunningham Hwy (TMR_049) Characteristics

Structure Name	Cunningham Hwy
Structure ID	TMR_049
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	408	0	408	297	0	297	1.4	0.0	1.4	24.56	24.55	0.01
1999	187	0	187	150	0	150	1.3	0.0	1.3	22.86	22.85	0.01
2011	771	0	771	471	0	471	1.6	0.0	1.6	26.31	26.25	0.06
2013	1063	19	1082	544	32	576	2.0	0.6	1.9	27.13	26.99	0.14
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	405	0	405	299	0	299	1.4	0.0	1.4	24.58	24.57	0.01
1999	188	0	188	150	0	150	1.3	0.0	1.3	22.87	22.86	0.01
2011	738	0	738	463	0	463	1.6	0.0	1.6	26.22	26.18	0.04
2013	989	0	989	531	0	531	1.9	0.0	1.9	26.89	26.77	0.12
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

O'Reilly's Weir (SRC_071) Structure

Structure Name	O'Reilly's Weir		
Structure ID	SRC_071		
Owner	SEQw	**Waterway**	Lockyer Ck
Date of Construction	1951	**AMTD**	1480
Date of significant modification		**Co-ordinates (GDA 56)**	459557.06E 6967166.25N
Source of Structure Information	Various As-Constructed and Maintenance Plans (1951)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\LKY\SRC_071\		

Description	Concrete single-cell weir		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	-mAHD	**Number of Barrels**	-
Number of Piers in Waterway	-	**Dimensions**	-
Pier Width	-m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	31.1mAHD		
Rail height	-m		
Span Length	27.6m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	Weir Channel
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Weir Channel

Image Description	O'Reilly's Weir, looking upstream
Image Reference	BMT WBM (2014*). O'Reilly's Weir (looking upstream)* [digital photography].
Image Source	BMT WBM, 2014

O'Reilly's Weir (SRC_071) Characteristics

Structure Name	O'Reilly's Weir
Structure ID	SRC_071
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	0	-1123	-1123	0	2071	2071	0.0	0.0	-0.5	47.38	47.39	-0.01
1996	0	2334	2334	0	746	746	0.0	3.1	3.1	39.73	39.51	0.22
1999	0	519	519	0	267	267	0.0	1.9	1.9	35.52	35.44	0.08
2011	0	-595	-595	0	2150	2150	0.0	0.0	-0.3	47.73	47.74	0.00
2013	0	2377	2377	0	746	746	0.0	3.2	3.2	39.73	39.50	0.23
1.5 x 1974	0	-1257	-1257	0	2492	2492	0.0	0.0	-0.5	49.24	49.24	0.00
2 x 1974	0	-1766	-1766	0	2759	2759	0.0	0.0	-0.6	50.42	50.43	-0.01
5 x 1974	0	-1789	-1789	0	4925	4925	0.0	0.0	-0.4	59.99	59.99	0.00
8 x 1974	0	-2023	-2023	0	6624	6624	0.0	0.0	-0.3	67.50	67.50	0.00

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	0	-1022	-1022	0	2295	2295	0.0	0.0	-0.4	48.37	48.38	0.00
1996	0	2392	2392	0	819	819	0.0	2.9	2.9	40.28	40.10	0.18
1999	0	501	501	0	329	329	0.0	1.5	1.5	36.13	36.09	0.05
2011	0	-986	-986	0	2357	2357	0.0	0.0	-0.4	48.64	48.65	0.00
2013	0	2288	2288	0	754	754	0.0	3.0	3.0	39.79	39.59	0.20
1.5 x 1974	0	-1425	-1425	0	2691	2691	0.0	-0.5	-0.5	50.12	50.13	-0.01
5 x 1974	0	-1952	-1952	0	5234	5234	0.0	-0.4	-0.4	61.36	61.36	0.00
8 x 1974	0	-2136	-2136	0	6841	6841	0.0	-0.3	-0.3	68.46	68.45	0.01

* At time of peak water level on upstream side

Model Version Number: 43

Pointings Bridge (SRC_070) Structure

Structure Name	Pointings Bridge		
Structure ID	SRC_070		
Owner	SRC	**Waterway**	Lockyer Ck
Date of Construction	?	**AMTD**	3930
Date of significant modification	2010	**Co-ordinates (GDA 56)**	457621.09E 6964188.17N
Source of Structure Information	As-Constructuted Drawings (2009)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\LKY\SRC_070\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	38.7mAHD	**Number of Barrels**	-
Number of Piers in Waterway	38.7	**Dimensions**	-
Pier Width	1.05m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	40.2mAHD		
Rail height	1.2*m		
Span Length	29.9, 30m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Pointings Bridge, looking downstream
Image Reference	BMT WBM (2014). *Pointings Bridge (looking downstream)* [digital photography].
Image Source	BMT WBM, 2014

Pointings Bridge (SRC_070) Characteristics

Structure Name	Pointings Bridge
Structure ID	SRC_070
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	666	931	1597	407	418	825	1.6	2.2	1.9	48.55	48.46	0.10
2013	946	563	1509	407	217	623	2.3	2.6	2.4	44.53	44.36	0.17
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-
2011	531	789	1320	407	442	849	1.3	1.8	1.6	49.04	48.97	0.06
2013	890	475	1364	407	195	602	2.2	2.4	2.3	44.10	43.95	0.15
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Brisbane Valley Rail Trail, Mahons Rd (QR_065) Structure

Structure Name	Brisbane Valley Rail Trail, Mahons Rd		
Structure ID	QR_065		
Owner	QR	**Waterway**	Lockyer Ck
Date of Construction	1926	**AMTD**	13510
Date of significant modification		**Co-ordinates (GDA 56)**	453580.13E 6966961.39N
Source of Structure Information	Structural Design Drawings (1926)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\BRI\QR_065\		

Description	Wooden Railway Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	51.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	51.5	**Dimensions**	-
Pier Width	0.85m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	52.5mAHD		
Rail height	-m		
Span Length	6.7m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Brisbane Valley Rail Trail bridge
Image Reference	BMT WBM (2014*). Brisbane Valley Rail Trail Bridge* [digital photography].
Image Source	BMT WBM, 2014

BMT WBM

Brisbane Valley Rail Trail, Mahons Rd (QR_065) Characteristics

Structure Name	Brisbane Valley Rail Trail, Mahons Rd
Structure ID	QR_065
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1716	230	1946	825	125	951	2.1	1.8	2.0	53.75	53.58	0.18
1996	1304	106	1410	825	75	900	1.6	1.4	1.6	53.25	53.13	0.11
1999	547	0	547	522	0	522	1.0	0.0	1.0	47.75	47.74	0.01
2011	1729	234	1962	825	127	952	2.1	1.8	2.1	53.77	53.59	0.18
2013	1317	112	1429	825	77	903	1.6	1.5	1.6	53.27	53.16	0.12
1.5 x 1974	2253	413	2666	825	184	1009	2.7	2.2	2.6	54.34	54.03	0.31
2 x 1974	2601	633	3234	825	244	1069	3.2	2.6	3.0	54.94	54.52	0.42
5 x 1974	455	689	1144	825	755	1580	0.6	0.9	0.7	60.05	60.03	0.02
8 x 1974	40	539	579	825	1501	2326	0.0	0.4	0.2	67.51	67.50	0.00

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1254	85	1339	825	67	893	1.5	1.3	1.5	53.17	53.12	0.06
1996	1149	16	1165	825	21	846	1.4	0.8	1.4	52.71	52.66	0.05
1999	519	0	519	501	0	501	1.0	0.0	1.0	47.47	47.46	0.01
2011	1266	93	1359	825	72	897	1.5	1.3	1.5	53.22	53.16	0.06
2013	1164	17	1182	825	22	848	1.4	0.8	1.4	52.72	52.67	0.05
1.5 x 1974	1464	202	1666	825	125	951	1.8	1.6	1.8	53.75	53.67	0.08
5 x 1974	220	501	721	825	888	1713	0.3	0.6	0.4	61.38	61.38	0.01
8 x 1974	7	172	178	825	1596	2422	0.0	0.1	0.1	68.46	68.46	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Watsons Bridge (SRC_064) Structure

Structure Name	Watsons Bridge		
Structure ID	SRC_064		
Owner	SRC	**Waterway**	Lockyer Ck
Date of Construction	?	**AMTD**	18460
Date of significant modification	1982	**Co-ordinates (GDA 56)**	454415.25E 6964784.8N
Source of Structure Information	Structural Design Drawings (1982)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\LKY\SRC_064\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	52.3mAHD	**Number of Barrels**	-
Number of Piers in Waterway	52.3	**Dimensions**	-
Pier Width	0.5m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	53mAHD		
Rail height	0.3m		
Span Length	18m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Watsons Bridge, looking upstream
Image Reference	BMT WBM (2014). *Watsons Bridge (looking upstream)* [digital photography]
Image Source	BMT WBM, 2014

BMT WBM

Watsons Bridge (SRC_064) Characteristics

Structure Name	Watsons Bridge
Structure ID	SRC_064
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	713	388	1101	575	275	850	1.2	1.4	1.3	56.56	56.52	0.04
1999	367	0	367	493	0	493	0.7	0.0	0.7	51.08	51.07	0.01
2011	826	483	1309	575	299	874	1.4	1.6	1.5	56.86	56.81	0.05
2013	727	401	1128	575	279	854	1.3	1.4	1.3	56.61	56.57	0.04
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
2 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	-	-	-	-	-	-	-	-	-	-	-	-
1996	828	459	1287	575	284	859	1.4	1.6	1.5	56.68	56.62	0.05
1999	367	0	367	488	0	488	0.8	0.0	0.8	51.02	51.01	0.01
2011	958	548	1506	575	299	874	1.7	1.8	1.7	56.86	56.79	0.07
2013	867	486	1353	575	289	864	1.5	1.7	1.6	56.73	56.68	0.06
1.5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
5 x 1974	-	-	-	-	-	-	-	-	-	-	-	-
8 x 1974	-	-	-	-	-	-	-	-	-	-	-	-

* At time of peak water level on upstream side

Model Version Number: 43

BMT WBM

Lyons Bridge (SRC_063) Structure

Structure Name	Lyons Bridge		
Structure ID	SRC_063		
Owner	SRC	**Waterway**	Lockyer Ck
Date of Construction	1955	**AMTD**	27480
Date of significant modification	?	**Co-ordinates (GDA 56)**	453585.31E 6961344.89N
Source of Structure Information	Site photographs		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\LKY\SRC_063\		

Description	Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	60.5mAHD	**Number of Barrels**	-
Number of Piers in Waterway	60.5	**Dimensions**	-
Pier Width	0.8m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	61mAHD		
Rail height	0.5m		
Span Length	30m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	1D Bridge and Weir Channels

Image Description	Lyons Bridge, looking upstream
Image Reference	BMT WBM (2014). *Lyons Bridge (looking upstream)* [digital photography].
Image Source	BMT WBM, 2014

Lyons Bridge (SRC_063) Characteristics

Structure Name	Lyons Bridge
Structure ID	SRC_063
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	1218	797	2016	734	364	1098	1.7	2.2	1.8	65.14	65.03	0.11
1996	974	474	1448	734	283	1017	1.3	1.7	1.4	64.33	64.27	0.06
1999	372	0	372	501	0	501	0.7	0.0	0.7	58.32	58.32	0.01
2011	1272	877	2149	734	382	1115	1.7	2.3	1.9	65.32	65.19	0.13
2013	1017	541	1558	734	303	1037	1.4	1.8	1.5	64.53	64.46	0.07
1.5 x 1974	1360	1052	2412	734	421	1155	1.9	2.5	2.1	65.71	65.56	0.15
2 x 1974	1380	1186	2565	734	451	1184	1.9	2.6	2.2	66.01	65.83	0.17
5 x 1974	1570	1643	3212	734	548	1281	2.1	3.0	2.5	66.98	66.74	0.23
8 x 1974	503	704	1207	734	616	1349	0.7	1.1	0.9	67.66	67.64	0.02

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	483	225	708	734	278	1011	0.7	0.8	0.7	64.28	64.26	0.02
1996	540	209	749	734	243	976	0.7	0.9	0.8	63.93	63.91	0.02
1999	372	0	372	502	0	502	0.7	0.0	0.7	58.33	58.33	0.01
2011	431	224	655	734	291	1025	0.6	0.8	0.6	64.41	64.40	0.01
2013	533	219	752	734	256	990	0.7	0.9	0.8	64.06	64.05	0.02
1.5 x 1974	397	218	615	734	296	1030	0.5	0.7	0.6	64.46	64.45	0.01
5 x 1974	-1	-41	-41	734	427	1160	0.0	-0.1	0.0	65.77	65.77	0.00
8 x 1974	-14	-181	-196	734	688	1421	0.0	-0.3	-0.1	68.38	68.38	0.00

* At time of peak water level on upstream side

Model Version Number: 43

Pamphlet Bridge (BCC_023) Structure

Structure Name	Pamphlet Bridge		
Structure ID	BCC_023		
Owner	BCC	**Waterway**	Oxley Ck
Date of Construction	1964	**AMTD**	150
Date of significant modification		**Co-ordinates (GDA 56)**	499513.94E 6955446.4N
Source of Structure Information	Hydraulic Structure Reference Sheet (Aurecon 2013)		
Link to data source	B:\B20702 BRCFS Hydraulics\10_Data Management\10_03_Structures\Structure_Details\OXL\BCC_023 Pamphlet Bridge\		

Description	Flat Deck Concrete Bridge		
BRIDGES		**CULVERTS**	
Lowest Point of Deck Soffit	7.1mAHD	**Number of Barrels**	-
Number of Piers in Waterway	7.1	**Dimensions**	-
Pier Width	0.7m	**Length**	-
		Upstream invert	-
		Downstream Invert	-
Lowest point of Deck/Embankment	8.1mAHD		
Rail height	0.8*m		
Span Length	16.7m - 21.3m		

*estimated

Included in Fast Model (FM)	Yes	**FM Representation**	XZ and LC table
Included in Detailed Model (DM)	Yes	**DM Representation**	2D Layered Flow Constriction

Image Description	Pamphlet Bridge, looking from downstream
Image Reference	BMT WBM (2015*). Pamphlet Bridge (looking from downstream)* [digital photography].
Image Source	BMT WBM, 2015

Pamphlet Bridge (BCC_023) Characteristics

Structure Name	Pamphlet Bridge
Structure ID	BCC_023
Link to model data	B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\200_Calibration_S2\TUFLOW\F\model\bg\CSV

FAST MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	401	213	615	506	206	712	0.8	1.0	0.9	10.77	10.75	0.02
1996	34	0	34	279	0	279	0.1	0.0	0.1	3.68	3.68	0.00
1999	-29	0	-29	170	0	170	-0.2	0.0	-0.2	1.85	1.85	0.00
2011	262	64	326	506	91	597	0.5	0.7	0.5	9.28	9.27	0.01
2013	218	0	218	269	0	269	0.8	0.0	0.8	3.52	3.51	0.01
1.5 x 1974	283	510	793	506	529	1035	0.6	1.0	0.8	14.92	14.84	0.08
2 x 1974	363	821	1184	506	763	1269	0.7	1.1	0.9	18.01	17.99	0.02
5 x 1974	287	1328	1615	506	1502	2008	0.6	0.9	0.8	27.60	27.59	0.01
8 x 1974	333	1987	2319	506	1926	2432	0.7	1.0	1.0	33.11	33.09	0.02

* At time of peak water level on upstream side

DETAILED MODEL

Event	Discharge (m^3/s)*			Area (m^2)*			Velocity (m/s)*			Peak Water Surface Level (mAHD)		Max Head Drop* (m)
	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	Under Structure	Over Structure	Total	US	DS*	
1974	13	8	20	505	323	828	0.0	0.0	0.0	11.06	11.06	0.00
1996	112	0	112	199	0	199	0.6	0.0	0.6	3.27	3.27	0.00
1999	-2	0	-2	155	0	155	0.0	0.0	0.0	1.79	1.79	0.00
2011	-23	-4	-28	505	97	602	0.0	0.0	0.0	9.37	9.37	0.00
2013	289	0	289	195	0	195	1.5	0.0	1.5	3.14	3.12	0.02
1.5 x 1974	-372	-510	-882	505	805	1310	-0.7	-0.6	-0.7	15.08	15.08	0.00
5 x 1974	-40	-112	-152	505	2502	3007	-0.1	0.0	-0.1	29.22	29.22	0.00
8 x 1974	3	298	300	505	3153	3658	0.0	0.1	0.1	34.64	34.64	0.00

* At time of peak water level on upstream side

Model Version Number: 43

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BMT WBM Bangalow	6/20 Byron Street, Bangalow 2479 Tel +61 2 6687 0466 Fax +61 2 66870422 Email bmtwbm@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Brisbane	Level 8, 200 Creek Street, Brisbane 4000 PO Box 203, Spring Hill QLD 4004 Tel +61 7 3831 6744 Fax +61 7 3832 3627 Email bmtwbm@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Denver	8200 S. Akron Street, #B120 Centennial, Denver Colorado 80112 USA Tel +1 303 792 9814 Fax +1 303 792 9742 Email denver@bmtwbm.com Web www.bmtwbm.com
BMT WBM London	International House, 1st Floor St Katharine's Way, London E1W 1AY Email london@bmtwbm.co.uk Web www.bmtwbm.com
BMT WBM Mackay	PO Box 4447, Mackay QLD 4740 Tel +61 7 4953 5144 Fax +61 7 4953 5132 Email mackay@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Melbourne	Level 5, 99 King Street, Melbourne 3000 PO Box 604, Collins Street West VIC 8007 Tel +61 3 8620 6100 Fax +61 3 8620 6105 Email melbourne@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Newcastle	126 Belford Street, Broadmeadow 2292 PO Box 266, Broadmeadow NSW 2292 Tel +61 2 4940 8882 Fax +61 2 4940 8887 Email newcastle@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Perth	Level 3, 20 Parkland Road, Osborne, WA 6017 PO Box 1027, Innaloo WA 6918 Tel +61 8 9328 2029 Fax +61 8 9486 7588 Email perth@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Sydney	Level 1, 256-258 Norton Street, Leichhardt 2040 PO Box 194, Leichhardt NSW 2040 Tel +61 2 8987 2900 Fax +61 2 8987 2999 Email sydney@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Vancouver	Suite 401, 611 Alexander Street Vancouver British Columbia V6A 1E1 Canada Tel +1 604 683 5777 Fax +1 604 608 3232 Email vancouver@bmtwbm.com Web www.bmtwbm.com