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Brisbane River Catchment Flood Study – Comprehensive Hydrologic Assessment

Data, Rating Curve and Historical Flood Review Report

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

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Aurecon team

The Aurecon Team consists of Aurecon as lead consultant, supported by Deltares, Royal HaskoningDHV, and Don Carroll Project Management and Hydrobiology.

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1 Introduction

1.1 Brisbane River catchment

The Brisbane River catchment has a total catchment area of 13,750 km^2 to the Port Office Gauge which is located in the heart of Brisbane City. The catchment is bounded by the Great Dividing Range to the west and a number of smaller coastal ranges including the Brisbane, Jimna, D'Aguilar and Conondale Ranges to the north and east. Most of the Brisbane River catchment lies to the west of the coastal ranges. The catchment is complex in nature, combining urban and rural land, flood mitigation dams, tidal influences and numerous tributaries with the potential for individual or joint flooding.

The river system itself consists of the Brisbane River and a number of major tributaries. Cooyar Creek, Emu Creek and Cressbrook Creek are all major tributaries of the Upper Brisbane River. The Stanley River catchment is the only major tributary that flows from the Conondale and D'Aguilar Ranges. Lockyer Creek, incorporating Laidley Creek, flows from the escarpment of the Great Dividing Range and joins the Brisbane River just downstream of Wivenhoe Dam. The remaining tributary is the Bremer River which rises in the Little Liverpool Range and confluences with the Brisbane River at Ipswich. The Bremer River catchment includes the Warrill Creek and Purga Creek tributaries.

The Brisbane River is tidal to just below Mt Crosby Weir, which is located some 90 km from the mouth of the river. The Bremer River is also tidal in its lower reaches and it is affected by backwater when the Brisbane River is in flood.

The river system passes through numerous townships and two major cities. It also passes through rural and agricultural land. As such, flooding in the river has the potential to affect large numbers of residents and businesses.

The Brisbane River itself has two dams located in its upper reaches, both of which were built to supplement Brisbane's water supply and to provide flood mitigation. Wivenhoe Dam was built in 1984 and has a catchment area of approximately 7,020 km^2. Somerset Dam on Lake Somerset is located upstream of Lake Wivenhoe on the Stanley River near Kilcoy, and has a catchment area of 1,340 km^2. Therefore only around half the overall catchment is regulated. There are also numerous smaller dams located within the catchment on the tributaries to the Brisbane River.

1.2 Brisbane River Catchment Flood Study

The Queensland Floods Commission of Inquiry Final Report which was issued in March 2012 contained a recommendation (Recommendation 2.2) that required a flood study be conducted of the Brisbane River catchment. In accordance with this recommendation, the State of Queensland is managing the conduct of this study in a number of separate phases, namely:

- Phase 1: Data Collection, Collation, Review and Storage of Existing Data (complete)
- **Phase 2: Comprehensive Hydrologic Assessment (current)**
- Phase 3: Comprehensive Hydraulic Assessment
- Phase 4: Brisbane River Floodplain Management Study and Brisbane River Floodplain Management Plan

The Aurecon Team was commissioned to undertake the Comprehensive Hydrologic Assessment (CHA). This assessment needs to be comprehensive with a requirement for various methodologies to be utilised and for them to corroborate each other. The study needs to include a Monte Carlo framework that can account for the variability of nominated input parameters, including rainfall, both spatially and temporally, antecedent conditions and reservoir levels.

The main objective of the CHA is to develop and apply a state of the art process that produces consistent and robust hydrologic models and analytical techniques that will enable the CHA to provide best estimates of a range of flood flows across the entire Brisbane River system. The study needs to be able to account for two scenarios: the conditions referred as 'no-dams', and the conditions 'with-dams'. The dams referred to are the major water storages that exist within the catchment; these are Perseverance, Cressbrook, Somerset, Wivenhoe and Moogerah Dams.

The hydrologic assessment methodology also needs to be iterative, both within itself and in conjunction with the subsequent hydraulic study, so as to ensure consistency with the hydraulic modelling and its determination of flood levels in the Lower Brisbane River and its tributaries. The combined output from the hydrologic assessment and the hydraulic modelling assessment will be used to underpin the Brisbane River Floodplain Management Study (BRFMS) and the Brisbane River Floodplain Management Plan (BRFMP).

1.3 Comprehensive hydrologic assessment tasks

The CHA comprises of many key input datasets and tasks. The CHA process includes both tasks that are reliant on completion of previous tasks and tasks that are iterative. Figure 1-1 shows the key datasets and tasks, and the relationships between these and completion of the study. It can be inferred from this figure that there are three critical tasks which are required for commencement of the study:

- Collection of all required input datasets
- Understanding of historic events and datasets
- Adoption of first-pass rating curves. Figure 1-1 shows that there is an iterative process that involves the adoption of rating curves, the hydrologic modelling and the generation of model outputs. Therefore, first-pass curves are required to commence the study but will need to be reviewed in later stages of the study

These first three tasks are presented in this report. The review comments received from the Technical Working Group, the Independent Peer Review Panel and the Internal International Peer Review Panel are provided in Appendix D, along with the Aurecon Team's response to these comments.

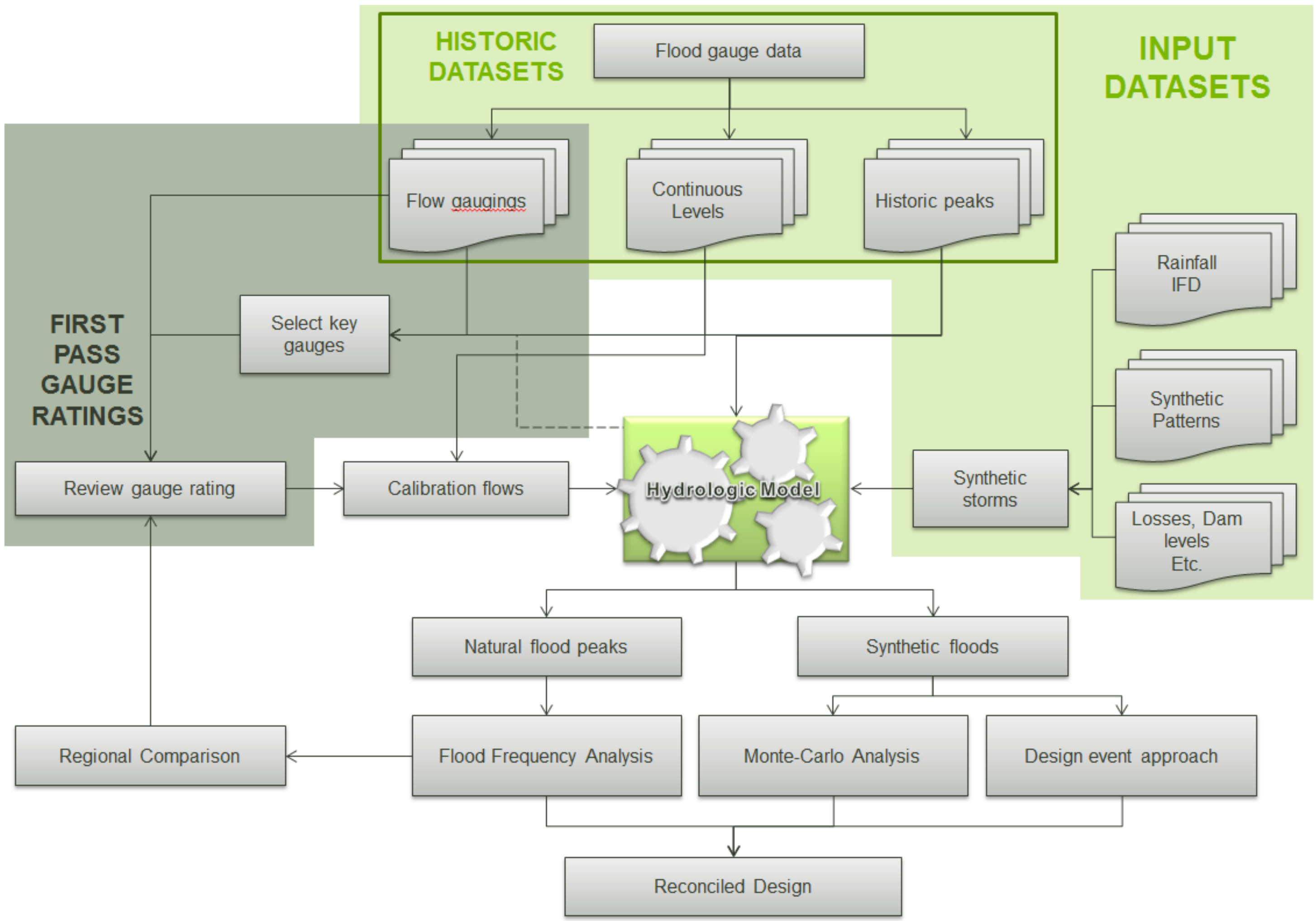


Figure 1-1 Interaction of key hydrologic study inputs and tasks

1.4 Data, rating curve and historical flood review

This report presents a review as the first stage of works in the CHA process. This review has focussed on three primary data sources, as identified in the brief (refer Section 1.5 below):

- Seqwater/SKM ongoing work on hydrology undertaken as part of the Wivenhoe Somerset Dam Optimisation Study (WSDOS) project
- Aurecon work on existing data compilation and review undertaken as part of the BRCFS
- Brisbane City Council (BCC) work on updating the Digital Terrain Model (DTM), bed sensitivity analysis and the review of rating curves

The review process has aimed to assess the available data, identify any data gaps and understand the impacts that each available dataset may have on the outcome of the CHA, including a detailed understanding and review of the adopted rating curves throughout the catchment. The review process is iterative and will not be completed until later in the project. This report presents the outcomes of the first-pass review process. This is presented as three separate focus areas:

- Data review: presents the outcomes of the overall data review, the identification of data gaps and the processes undertaken to fill these gaps (refer Section 2)
- Rating curve review: presents the work undertaken to date to review the rating curves and first pass recommendations for rating curves to be adopted (noting that these are first pass only and will be subject to change as the project progresses) (refer Section 4)
- Historical flood review: presents a summary of the key historical studies and the hydrologic model predictions from these studies as a point of reference for future stages of the CHA (refer Section 5)

1.5 BRCFS brief

This report aims to address Sections 3.6.2, 3.6.3 and 3.6.4 of the Brisbane River Catchment Flood Study (BRCFS) brief (dated 1 July 2013), as provided below:

3.6.2 General review of existing relevant data and information

The Consultant is required to consider the following related ongoing/completed works and the associated data sets, identified gaps and findings as the main basis and starting point for their assessment of data, critical gaps and related important issues:

1. *Seqwater/SKM ongoing work on hydrology undertaken as part of the Wivenhoe Somerset Dam Optimisation Study (WSDOS) project*
2. *Aurecon work on existing data compilation and review undertaken as part of the BRCFS*
3. *Brisbane City Council (BCC) work on updating the Digital Terrain Model (DTM), bed sensitivity analysis and the review of rating curves which has only recently commenced*

A briefing session by Seqwater will be organised in order to provide an overview of their work for the benefit of all interested Offerors. A copy of the final Aurecon report will be made available to the Offerors upon request. It is also proposed that an overview of the ongoing BCC work will be provided at the briefing session.

The Consultant will need to check that any specific BRCFS requirements related to this hydrologic assessment project will be satisfied.

The Consultant is required to undertake sufficient review of the data provided for this study to validate the completed works noted in paragraph 1 above and to identify any issues or further data gaps that may limit the study from meeting its objectives. This includes but is not limited to identification of limitations in availability or quality of rainfall, streamflow gauging measurements, recorded water level data, and applicable stream rating curves which may impact on the achievement of project objectives.

The Consultant is also required to develop a register of data survey datums and document all datum conversions used throughout the project. There is significant variation in the State Datum to Australian Height Datum conversion across the catchments and the study must be able to track that correct datum conversions are being used.

In the course of the project, where the Consultant identifies critical data gaps, the Consultant is to prepare a report for consideration by the Principal that details:

- *The data gaps and their importance to the project outcomes; and,*
- *Where obtaining additional data is feasible, an estimate of cost and time for this additional data to be sourced.*

Key data gaps include (but are not limited to) 2013 flood event, sediment movement (dredging/gravel extraction), rainfall, and bathymetry. The principal will review the report in consultation with the Consultant to quantify and confirm the additional work to be undertaken as soon as possible.

It is recognised that some of these limitations may not become obvious or clearly defined until later in the study. It is important to identify known issues up front and to maintain an up to date register of limitations and suggested improvements throughout the study.

The consultant is also required to consider relevant reports and studies (in addition to the data) identified and/or provided for this study.

3.6.3 Review of existing flood studies and relevant hydrologic models

There are numerous studies and reviews which have assessed flooding in the Brisbane River catchment.

A list (including sources) of key previous studies and reports/documents relevant to the BRCFS is provided in the Aurecon report. Exhibit 883 of the Queensland Floods Commission of Inquiry is an "Expert Reading List". It contains copies of many historical reports and documents relating to flood studies for the Brisbane River catchment, and the information therein should provide a good background to hydrologic investigations prior to the release of the QFCI Report. The documents comprising this exhibit can be downloaded from the QFCI website.

As this study is expected to build on the ongoing Seqwater/WSDOS work on hydrology and undertake necessary additional hydrologic assessment work to meet the requirements of the flood study and the floodplain management study/plan, a copy of the current Seqwater models and available documentation will be made available.

The Consultant is required to consider and be satisfied that the outcomes of the relevant studies and reports are appropriate to be utilised and/or determine to what extent these could be utilised, as part of this project. Any significant discrepancies are to be reported.

3.6.4 Detailed review of rating curves and historical flow estimates

A detailed review of existing rating curves at gauging stations located on the Brisbane River and tributaries is required to supplement Seqwater's review and revision of available rating curves as part of the WSDOS project. It is understood that Seqwater has carried out various levels of reviews and updates of the rating tables for at least the following 16 locations in the Brisbane River catchment:

- *Dam site*
- *Linville*
- *Boat Mountain*
- *Gregors Creek*
- *Rosentretters*
- *Helidon*
- *Tenthill*
- *Showground Weir*
- *Lyons Bridge*
- *Rifle Range Road*
- *Savages Crossing*
- *Mt Crosby Weir*
- *Adams Bridge*
- *Walloon*
- *Kalbar*
- *Amberley*

In its review of ratings under WSDOS, Seqwater have considered available gaugings from DNRM as well as BOM Data (e.g. peak heights). In addition to DNRM gauge data, Seqwater and BCC have separately undertaken gauging in recent events, which Seqwater have incorporated into their work to review rating curves. The Consultant would need to review the latest information from Seqwater as well as consider the latest related information from DNRM, BoM and BCC.

BCC is currently undertaking a hydraulic model review of rating curves at eight key regional gauges to support improved understanding of the rating relationships in conjunction with the updated development of preliminary 2-D hydraulic model for disaster management purposes. These regional gauges include:

- *O'Reilly's Weir,*
- *Lowood,*
- *Savages Crossing,*
- *Mt Crosby,*
- *Ipswich,*
- *Moggill;*
- *Jindalee/Centenary Bridge and*
- *Port Office/City Gauge*

BCC is also currently undertaking a bed level sensitivity analysis which would help to understand the historical effects of dredging and bar removal at the Brisbane River mouth on the rating curve and the sensitivity of ratings to such changes.

The Consultant is first required to review the Seqwater hydrology model calibration locations, together with the data and information to support the rating curve review to identify which stations are to be given priority. The 'priority locations' must then be agreed with the client and stakeholders through the Technical Working Group and the Steering Committee prior to the detailed review of the rating curves.

The Consultant is required to conduct a thorough review of the latest rating curves and associated information to come up with a comprehensive understanding of the available ratings and the issues at each priority location. The Consultant would need to consider all the key gauges which potentially will be used in hydrologic/hydraulic model development, and for each priority gauge, present relevant information which includes:

- *ratio of highest gauging measurement to highest flow from a recorded height;*
- *list of gauging measurements and quality code descriptors;*
- *gauge ownership;*
- *available cross-section survey data;*
- *suitability of location for stable and good quality rating;*
- *checks on gauge zero and gauge datum;*
- *significance of tidal and/or backwater effects, and whether dependent rating relationships can quantify these effects;*
- *anecdotal information about gauge/gauge history;*
- *record availability and quality for the major flood events;*
- *documentation of any changes to rating curves recommended by Seqwater in the course of hydrologic model development and the basis of the recommendations for these changes;*
- *documentation of any changes to rating curves recommended by BCC in the course of hydraulic model development and the basis of the recommendations for these changes;*
- *sensitivity of the rating curve to changes (within plausible range) in bathymetry;*
- *identification of key levels where significant changes in flow conveyance capacity may occur;*
- *stability of the channel (scour/deposition);*
- *extent, magnitude, and periods of historical dredging downstream of gauge locations and their potential impacts on the gauges' ratings. Key gauges include (but are not limited to) Port Office, Jindalee/Centenary Bridge, and Moggill)*
- *potential influences of variation in channel and floodplain vegetation conditions over time; and*
- *stability of low to high flow controls.*

The assessment of these factors could be used to assign a quality (accuracy) rating to the flood data from each gauge. For each gauge, the Consultant is required to provide an evaluation of the quality of the rating curves and the flood flow data should be given, as well as recommendations on any further actions which might improve the quality of the rating curve for each gauge, such as water balance calculations, peak flow comparison with upstream and downstream gauges, local hydraulic modelling or analysis; review of the rating curve extension methods and results.

Given the length of record and strategic locations of gauges along the Brisbane River downstream of Wivenhoe such as Port Office, Jindalee/Centenary Bridge and Moggill, whose ratings are potentially affected by dredging and other riverine changes, the Consultant is required to use the available *historical information on dredging, topography, and bathymetry to undertake hydraulic assessments/modelling with a view to improving the quality of ratings at these locations. The Consultant would need to check with BCC regarding progress with their sensitivity analyses of rating curves, and where feasible, share information and results. (see also Section 3.6.6.5).*

Following the detailed rating curve review, a review/reassessment of historical flow estimates is required and any significant departures from previously accepted historic flow rate estimates are to be documented and discussed with the Independent Panel of Experts and the Steering Committee. There needs to be consensus between parties (including Seqwater, Bureau of Meteorology, BOM and Councils) as to the magnitude of flows in historical events as this will be important in hydrologic and hydraulic model development and in frequency analyses.

It is expected that the Consultant would come up with a consistent, robust and agreed set of rating curves (and historical flows) to be available as the best data/information available for further use by all relevant parties in SEQ for flood management purposes. It is recognized that this work may be refined (if and when necessary) in the longer term based on the results from hydraulic modelling (including proposed detailed 2-D hydraulic modelling) to be undertaken at a later stage as part of the BRCFS. The Consultant is required to provide appropriate documentation to enable this refinement to occur on a transparent basis.

It is considered that the above three tasks (as detailed in Section 3.6.2, 3.6.3 and 3.6.4) together will lay the required solid foundation for the subsequent tasks of flood frequency analysis and hydrologic (and hydraulic) modelling calibration and validation.

The review of Seqwater's URBS model is presented in the Hydrologic Model Calibration and Validation Review Report.

2 Data review and additional data collection

This section presents a discussion of the data which has been collected as part of this CHA. This data has been identified as being required for the CHA, either during the Phase 1 Data Collection project or as the CHA start-up tasks have been undertaken. This section does not include a detailed description of the implications of each dataset on the study outcomes as these are yet to be determined and will be addressed in relevant reports throughout the course of the study.

2.1 Aurecon Team data collection, collation and review project

The Aurecon Team includes the key team members who delivered the Data Collection, Collation, Review and Storage of Existing Data project (Phase 1 of the BRCFS). Therefore, the Team already had a thorough knowledge of the data that was collected as part of the Phase 1 project, and of the data gaps which were identified on completion of the Phase 1 study.

The following list presents the key gaps in the hydrologic data as identified in the Phase 1 study and provides links to the sections of this report in which they are discussed further:

- Collection of final WSDOS study models and reports (refer to Section 2.2)
- Identification and collection of additional rating curves and flow gauging records (refer to Sections 2.7, 2.7.2 and 2.7.3)
- Review of all available rating curve and flow gauging data (refer to Section 3)
- Collection of continuous rainfall data (refer to Section 2.4.1)
- Collection of radar data (not collected)
- Collection of updated IFD and temporal patterns (refer to Section 2.5)

2.2 Seqwater WSDOS data

Seqwater has compiled extensive hydrologic data as part of the ongoing Wivenhoe Dam and Somerset Dam Optimisation Study (WSDOS). As part of the study Seqwater developed the Dam Optimisation Model, which is currently in the process of peer review. This is a GoldSim-based model for hydrologic routing of the Brisbane River system, including the simulation of complex dam interactions based on operation decision logic and algorithms. The model is set up to simulate 48 historical rainfall events using the URBS hydrologic model. The model is also being used to test operating scenarios under a range of design and synthetic events. Figure 2-1 shows the URBS model layout and extents and Figure 2-2 gives the GoldSim model's domain and inflows.

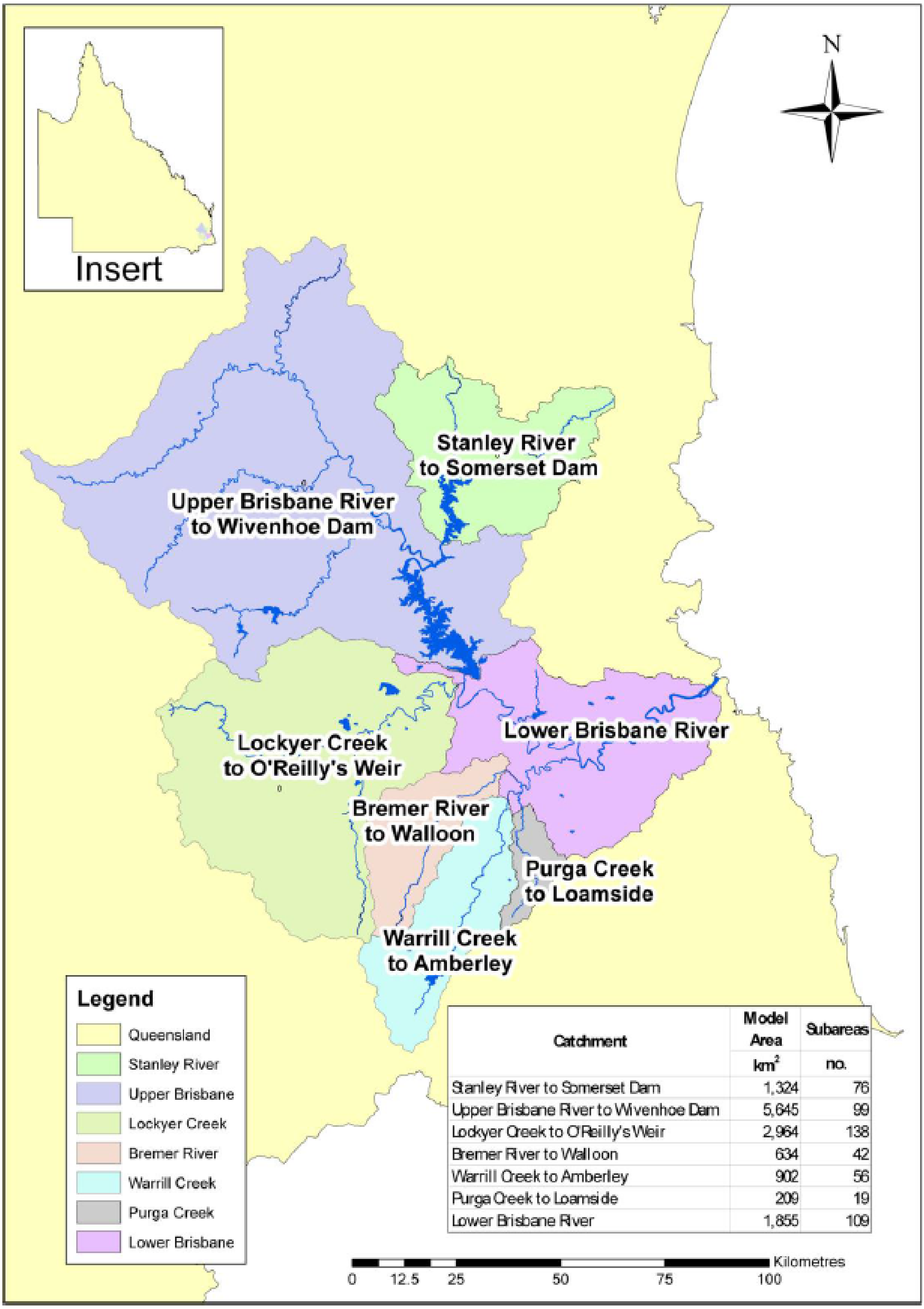


Figure 2-1 URBS hydrology model layout and extents (from Seqwater)

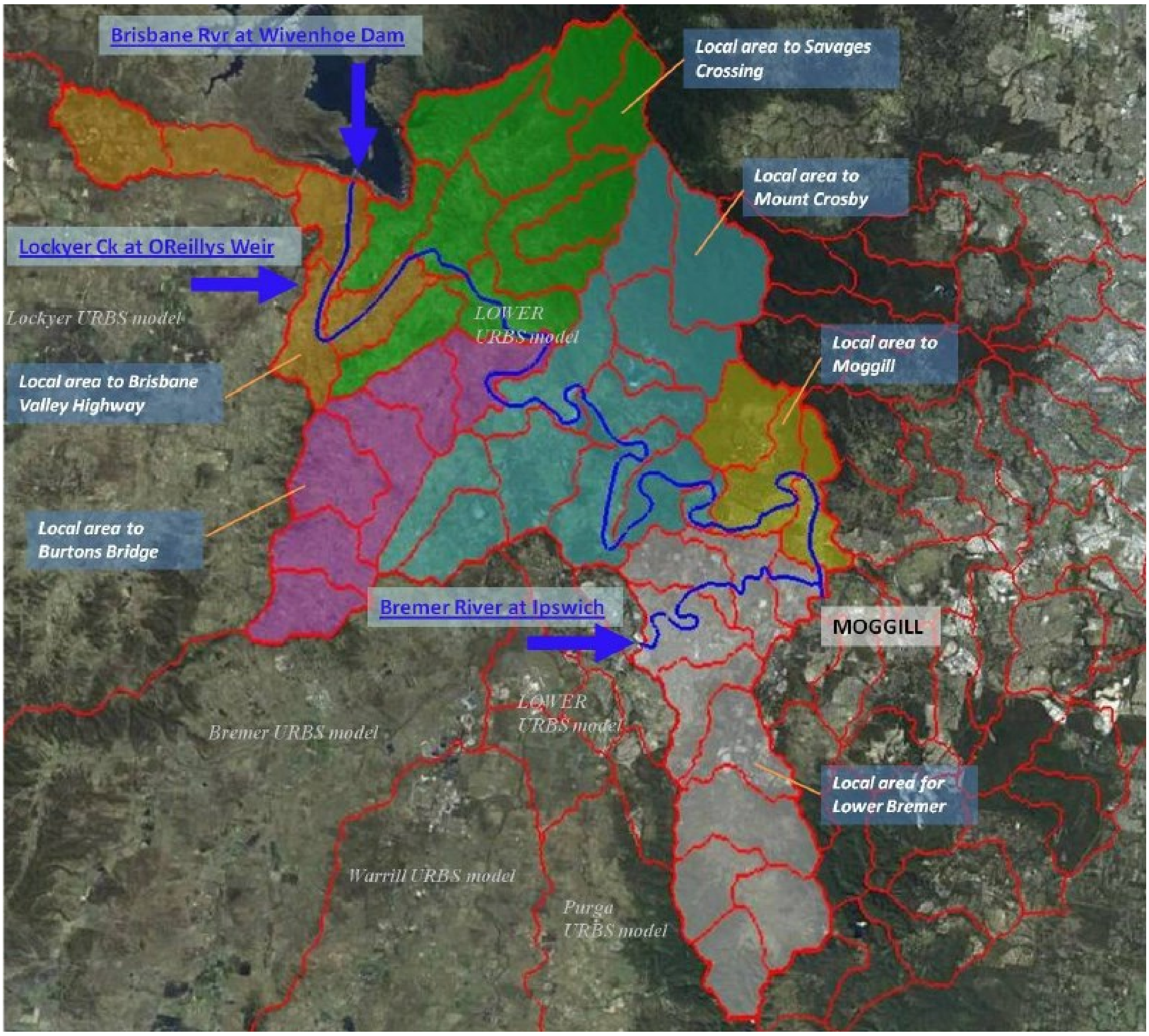


Figure 2-2 WSDOS project Dam Optimisation Model domain and inflows (from Seqwater)

Data that has been collected from Seqwater related to the WSDOS includes:

- Calibrated URBS model, including input and output data for all 48 calibration events
- Key input datasets and key data from previous studies
- Testing and analyses undertaken on input datasets including: rainfall, dam inflows, ratings, baseflow, conceptual storages and flood slopes
- CatchmentSIM data for URBS model sub-catchment delineation
- URBS model output analyses including calibration plots
- Seqwater's *Brisbane River Flood Hydrology Models* Report (December 2013, Final Version)
- SKM's *Generation of Inflow Hydrographs and Preliminary Flood Frequency Analysis Report* (Final Report, 8 October 2013)
- Information obtained during briefing sessions with Seqwater
- Information obtained from numerous queries which have been raised by the Aurecon Team

- Seqwater's Wivenhoe and Somerset Dam Operations Manual (Revision 10 – October 2012)

The review of Seqwater's Hydrologic (URBS) Model and related input and output data is presented in the Hydrologic Model Calibration and Validation Review Report.

2.3 BCC DMT, DEM, bed sensitivity and rating curve review

The BCC study is aimed at delivering the following outputs for the BRCFS:

- A Digital Elevation Model (DEM) of the river and overbanks between Wivenhoe Dam and the mouth using the best available topographic and bathymetric data
- Update and recalibration of the Disaster Management Tool (TUFLOW model) developed in 2009 (City Design, 2009) and assessment of a number of potential flood scenarios
- An assessment of the sensitivity of the model to variations in bed level and shape
- A review of the rating curves at key locations along the Brisbane and Bremer rivers

The BCC DMT final report was completed in November 2014 and the draft report was completed in June 2014. In advance of the June 2014 draft report, and at the request of the State/Aurecon, model outputs were made available to Aurecon in February 2014 based on DMT Mark II calibration. The DMT Mark II calibration remained unchanged from February 2014 to finalisation of the project in November 2014 and is consistent with model data/outputs provided to Aurecon. Since the issue of Interim Calibration Report (BCC, 2013), additional work and investigations have been undertaken with a view to improving the DMT hydraulic model calibration. Specifically, these investigations and sensitivity analyses have focused on rating curve consistency with the data derived from other agencies, and the concurrent BRCFS hydrology phase project, as well as matching the 2011 and 2013 ADCP (Acoustic Doppler Current Profiler) flow gaugings. Within the scope and limitations of the DMT project, these objectives were achieved with the development of the DMT Mark II hydraulic model. The DMT Mark II hydraulic model utilises a finer grid resolution of 20 m for model computations as compared to the DMT Mark I hydraulic model used to prepare the Interim Calibration Report (BCC, 2013) which utilised a 30 m grid.

The following data has been collected from BCC:

- *Brisbane River Catchment Flood Study Disaster Management Tool (DMT) Interim Calibration Report* (Oct 2013) and *Model Development and Calibration Outcomes Draft Final Report* (June 2014)
- The adopted 10 m grid DEM used in BCC's assessment
- Information obtained during briefing sessions
- Model output hydrographs and GIS data showing hydrograph locations

This data has been used to assist in the URBS model review and the rating curve review for the Lower Brisbane River model as described in the Hydrologic Model Calibration and Validation Review Report and Section 4.7 of this report.

2.4 Rainfall data

2.4.1 Continuous records for entire catchment

During the Phase 1 Data Collection Study, continuous rainfall records were requested from the Bureau of Meteorology (BoM); however, the provision of this data was considered a time consuming and costly exercise and was therefore put on hold until the CHA phase of the study. The collection of this data has been revisited with BoM and was again considered to be a time consuming and costly exercise.

Continuous rainfall records are not required for model calibration, as the event based data is already included in the URBS model files. Continuous rainfall records may be necessary for the Monte Carlo analyses, depending on the Monte Carlo approach that is adopted. A Pilot Study is currently underway to test these approaches; the outcomes of which will dictate whether continuous rainfall data is required for the entire catchment. On the understanding that it is more likely that this data will not be required we have not proceeded with its collection. This provides a large cost advantage to the project but has the potential risk that, if it is required, it could significantly delay the project schedule. This has been decided in conjunction with the Study Manager.

2.4.2 Continuous data for pilot catchment study

Continuous rainfall data for the Upper Brisbane catchment has been collected for use in the Pilot Study. Ideally, the Pilot Study would include continuous records from rainfall gauges within the catchment with longer than 30 years of sub-daily timestep rainfall records. Such data does not exist, therefore the following continuous rainfall datasets were collected:

- Boat Mountain gauge on Emu Creek with records from 1993 to present
- Ravensbourne gauge in the upper Perseverance Creek catchment with records from 1956 to 1997
- Kirkleagh gauge on Somerset Dam with records from 1959 to 1991

2.4.3 Synthetic storm data

The stochastically simulation space-time rainfall patterns prepared by SKM and BoM (SKM, 2013) for Seqwater's WSDOS study have been collected for use in the Monte Carlo analyses.

The stochastic flood simulations were produced using stochastically generated space-time rainfall patterns for the Brisbane River catchment. These synthetic flood events were produced using a technique for stochastic generation of space-time rainfall fields, which were generated from radar data observed during eight heavy rainfall events across the catchment (observed between 1996 and 2012 inclusive).

A multiplicative-random cascade approach was used to generate 90 replicates of stochastic space-time rainfall patterns across the Brisbane River catchment. The position of the catchment was moved around within the generated spatial domain of the stochastic space-time data to six different possible positions and different segments of time were selected from 10 of the longer replicates. This resulted in 600 space time patterns that were adopted for the stochastic simulation. The generated space time patterns were verified against spatial patterns observed in historical rainfall events that have occurred in the Brisbane River catchment between 1954 and 2012.

Following initial investigations and at request of the Steering Committee, Aurecon commissioned Jacobs to conduct an assessment of the January 2013 flood event using the same techniques, producing another 60 replicates.

2.5 Intensity-frequency-duration data

Intensity-frequency-duration (IFD) data is required for input to the design event and Monte Carlo analyses. This data is available for two separate IFD datasets: that produced for the 1987 version of Australian Rainfall and Runoff (AR&R); and that produced in 2013 for the current update of AR&R. This data was requested in gridded format from BoM: the 1987 dataset was available at a cost of $13,000 and was therefore not collected, and the 2013 dataset is unavailable until 2015.

WMAWater have these two gridded datasets available from information that they have extracted from the BoM website. These two gridded datasets were provided by WMAWater for the Brisbane River catchment extents. The 1987 dataset will be used to generate the design event IFD data and the 2013 dataset will be used for sensitivity testing.

2.6 Historical storage levels

Daily storage volumes from the historical inflow simulations from the Integrated Quantity Quality Model (IQQM) were provided by DSITIA. This includes data for the period 1889 to 30 June 2011 (120 years) from the following dams:

- Wivenhoe (full supply capacity = 1,165,238 ML)
- Somerset (full supply capacity = 379,849 ML)
- Moogerah (full supply capacity = 83,765 ML)
- Lake Manchester (full supply capacity = 26,217 ML)
- Cressbrook (full supply capacity = 81,842 ML)
- Perseverance (full supply capacity = 30,140 ML)

It is noted that the models assume current infrastructure, operations and full entitlement demands for the full period of simulation. Operations are as per Resource Operation Plan (ROP), which are assumed to be close to current operations. DSITIA indicated that the results are “fairly different to the current level of use for all systems, for the following reasons:

- Lake Manchester has an extractive demand of 5800 ML/a in the model. In practice, Lake Manchester was used in the recent drought to supplement supplies from Wivenhoe. To DSITIA’s knowledge, Lake Manchester has not been used since the drought
- Full entitlement demand for the Wivenhoe system is about 273 000 ML/a. Some recent work that DSITIA has completed for DEWS has indicated that 'current' use is about half of this value

2.7 Stream gauge data

2.7.1 Gauge details and history

A detailed list of all stream gauges, both open and closed, within the catchment was prepared. This list included basic gauge data such as:

- Station number and CBM number
- Station name and location
- Operating agency
- Latitude/longitude
- LL Datum
- Adopted Middle Thread Distance (AMTD)

- Open and closing dates
- Catchment area above gauging station
- Gauge zero
- What data is available at the station: height, flow, rainfall, water quality?

A copy of these tables is provided in Appendix A. A register of gauge data and datums is being collated as part of the BRCFS and will be included in the final deliverables for the study.

2.7.2 Recorded gauge levels

Up-to-date continuous gauge recordings for DNRM gauges have been collected from the DNRM website.

Limited continuous gauge recordings have been collected from BoM at this stage. Each data request to BoM has a data provision cost associated with it; therefore we are trying to limit the number of requests in order to limit costs to the project. We are currently identifying a list of gauges for which continuous gauge recording will be required for the Flood Frequency Assessment.

2.7.3 Rating curves and gaugings

A number of rating curve datasets was collected in the Phase 1 Data Collection Study. Additional to these, the following data has been collected:

- Details on DNRM gaugings and gauge reliabilities were collected during a meeting with DNRM
- Seqwater ratings have been collected from Seqwater
- Images showing BCC's ratings from the TUFLOW model have been included in BCC's Brisbane River Catchment Flood Study Disaster Management Tool (DMT) Interim Calibration Report and Draft Final Report (June 2014)

3 Rating curve review

3.1 Scope of assessment

Understanding the relationship between water level and flow at gauge stations and the derivation of accurate rating curves is a fundamental step to developing a robust catchment hydrologic assessment. Accurate high flow rating curves provide the basis for site specific flood frequency and historic event flow estimation.

As illustrated in Figure 1-1 above and Figure 3-1, review of the flood gauge rating curves is a complex and iterative process that is tied into other aspects of the hydrologic assessment, including calibration of hydrologic models and flood frequency analysis of gauges across the catchment. These processes are dependent upon the gauge ratings, but achieving catchment-wide consistency may require ongoing review and adjustment of the ratings.

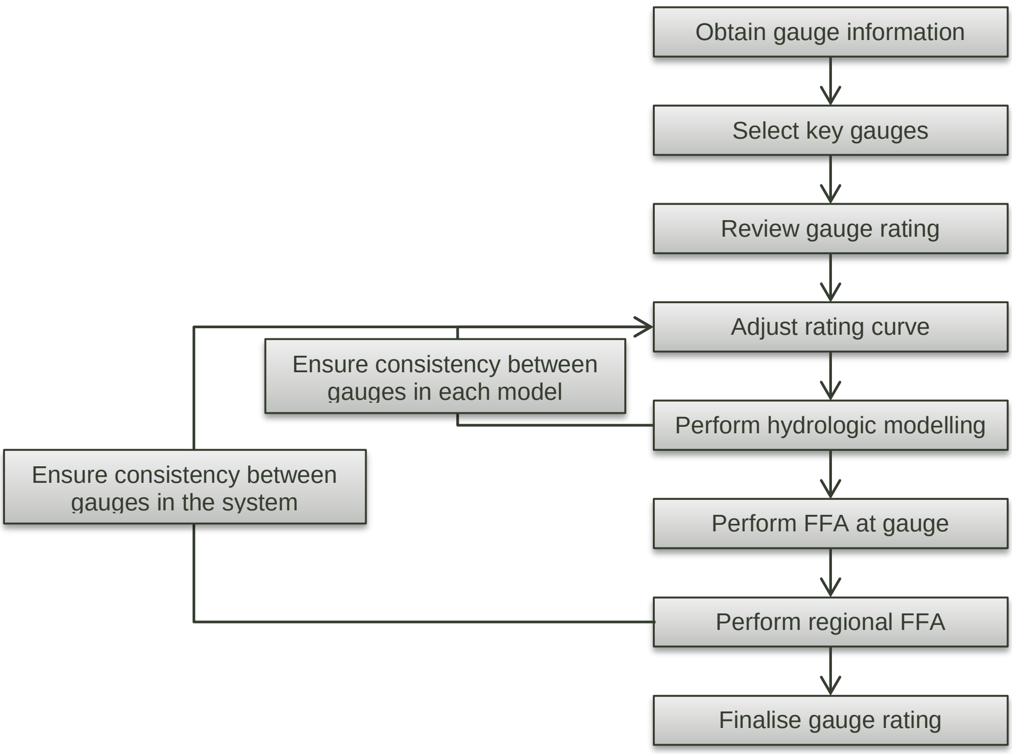


Figure 3-1 Overview of rating curve review methodology

The Brisbane River catchment contains over 70 currently active flood level gauges of widely varying quality, reliability and usefulness. It is considered impractical to conduct a detailed review of all these gauges, and indeed the usefulness of many gauges is limited by location, availability of data or other factors such that they will provide little benefit to the project. It is not within the scope of the BRCFS to review the rating of every gauge, or necessarily even gauges that may be considered important to particular agencies or departments for various reasons. The primary objectives of the BRCFS hydrologic assessment are to develop and calibrate reliable hydrologic models and to provide a best estimate of flood flows and probabilities within the Brisbane River system. Selection of gauges and review methods has been prioritised towards these objectives. It is recognised that different stakeholders (DNRM, Seqwater, BoM) have different priorities and use the rating curves for different purposes. Nevertheless it is anticipated that consensus can be reached that the methodology and ratings described in the following sections are fit for purpose and appropriate to satisfy the objectives of this study. Whether the ratings recommended in this review are adopted or modified by each stakeholder to suit their own needs will be up to the individual stakeholders.

The review procedure has therefore assessed the properties of the major gauges in the system, including gauge characteristics and availability of data to identify ‘key’ or primary gauges that will be used for review/calibration of the hydrologic models. Although it is stressed that the rating curve review is intended to be a review of existing available data, a detailed assessment of these primary gauges has been undertaken, including data review and independent hydraulic modelling, to identify any issues with the current ratings and provide consistency and an increased level of confidence in the gauge rating to be adopted for the Brisbane River Catchment Flood Study. This detailed assessment has been limited to typically one to two key gauges per catchment. Review of other major gauges has also been conducted to identify the level of confidence in the current rating. The modelling undertaken is described in greater detail in Section 3.5.

3.2 Gauge review priority criteria

Available gauge data has been reviewed to classify the flood gauges according to their proposed priority of usage for the Brisbane River Catchment Flood Study. Gauge review priority classifications are described in Table 3-1. Selection of gauge classification has been based on multiple criteria that are discussed in the sections below. Selection and classification of gauges in each catchment area are detailed in Section 4.

Note that this classification of ‘primary’ and ‘secondary’ in Sections 3 and 4 refers only to the importance and level of detail of the rating review, not necessarily to the overall importance of the gauge (although this is one of the selection criteria). A number of gauges that may otherwise be considered to be of high priority for purposes such as dam operations or flood warning, have nevertheless been identified as secondary for the rating review due to inconsistent or inadequate data, or other factors precluding the usefulness of detailed independent hydraulic analysis.

Table 3-1 Gauge review priority classifications

Classification	Description
Primary	Gauge is considered to be of high importance to the hydrologic analysis and has data of sufficient quality and quantity to allow independent assessment of the rating to be undertaken
Secondary	Gauge is generally considered to be of either moderate importance to the hydrologic analysis, or of high importance but with some factor limiting the benefit of a detailed assessment (eg the gauge may already have a high level of confidence, or may lack data). Review of existing data and ratings has been undertaken to identify level and range of confidence in the existing rating

Classification	Description
Other	Gauge is in a location of low priority or may have limited or conflicting data preventing reliable determination of a rating curve

3.2.1 Singularity/appropriateness of control

The gauge needs to provide a reliable and consistent rating (ie level-discharge relationship). Ideally this relationship will be singular, and gauges where the level is dependent upon multiple factors (such as flow and tide at Port Office, Brisbane River backwater around the Lockyer Creek and Bremer River confluences) will be difficult to calibrate. If the river conditions at or around the gauge are subject to change then the gauge rating will be unreliable both for historical records and future use, and there is little practical benefit in conducting a detailed assessment of the gauge. Alternatively, if the gauge location experiences widespread floodplain flows then small changes in water level may potentially represent large changes in flow, leading to increased uncertainty in the gauge readings. Although it may be possible to determine an in-stream gauge rating and identify the uncertainty associated with higher discharges, this may not be appropriate for a primary gauge.

3.2.2 Significance for the hydrologic modelling

One of the primary purposes of the gauge rating is to provide historical flows in the river reach to allow calibration of the hydrologic model. The review process has therefore attempted to conduct a detailed review of at least one gauge in each of the major tributaries and Brisbane River reaches. Primary gauges have been prioritised towards sites in the catchment conducive to hydrologic model calibration.

3.2.3 Type, length and quality of flood record

Calibration of the hydrologic models requires continuous flood data, which must be available at the gauge for flood events appropriate for calibration. Flood frequency analysis will also be conducted at the gauges for estimation of peak flows as well as to improve confidence in the gauge rating and consistency with other gauges in the catchment. Although it may be possible to supplement or replace flood record data with hydrologic model data, this means that the gauge would be calibrated to the hydrologic model rather than the other way around.

3.2.4 Availability/reliability of calculation data

The more reliable physical data there is regarding flow conditions at the site, the more reliable the calculation of the relationship between discharge and flood level. Key data includes survey data (cross-sections, channel slope etc), flood models (local stream models or Brisbane River floodplain TUFLOW model results), and calibration data (eg constant dam release, flow gaugings).

3.3 Sources of gauge rating data

Gauge rating curves form the link between recorded flood levels and discharge at the gauge. Gauge ratings may be based on a variety of methods ranging from physical measurements to numerical modelling. A brief summary of the typical data and methods is provided in the following sections. These sections are listed in order of perceived reliability, and thus the order of priority used when determining or reviewing reliability of the gauge ratings. It should be noted that no one method is considered completely reliable, and that the highest confidence can only be reached by comparison of and achieving consistency between all the available data. This is discussed further in Section 3.5 below.

3.3.1 Flow gauging

Flow gauging provides an estimate of discharge obtained from physically measured flow properties corresponding to measured water levels. Flow measurements may be obtained by a number of different methods, but are typically based on measured flow velocity and cross-section area. Accuracy of the flow estimate can therefore vary significantly depending on the data capture method. Nevertheless, flow gauging is the only method provides simultaneous flow and level measurement, and is thus independent of numerical modelling. Therefore, unless the data review has identified known or suspected reasons to discount a gauged record, the gauged flow records have been considered to be accurate. Flow gauging data is usually only available for low to mid-range flows.

3.3.2 Reverse reservoir routing

The Brisbane River catchment contains several reservoirs, of which six have been considered by Seqwater to have a significant influence on flood behaviour. These including the major Wivenhoe and Somerset Dams and the smaller Moogerah, Cressbrook Creek, Lake Manchester and Perseverance Dams. These reservoirs generally have a well-defined outlet control (either regulated gates or unregulated weir overflow). Provided that the relationships between reservoir level, volume and outflow are known, inflows into the reservoir can be back-calculated from the outflow and change in reservoir volume. Accuracy is dependent upon the reliability of the outflow and storage ratings, measurement accuracy, and assumptions of routing in the reservoir.

3.3.3 Hydraulic modelling

Hydraulic modelling provides a method for estimating water level for a known discharge. The reliability of the rating curve is dependent on the physical and numerical representation of the hydraulic model, boundary conditions and adopted loss parameters. Confidence in the hydraulic model can be improved by calibrating the model to flow gauging or other data. The model can then be used to extrapolate the rating to higher discharges, although the confidence in such extrapolation may decrease if the channel properties (shape or roughness) change above the calibrated range.

3.3.4 Hydrologic modelling

Derivation of a discharge rating curve through hydrologic modelling involves modelling known rainfall events to estimate discharge, then matching this discharge to recorded gauge levels. Results of the hydrologic model are influenced by multiple factors, which include the model parameters, assumed losses and rainfall data, which may vary significantly across the catchment and not be captured reliably by the rainfall gauges. Additionally, because this method is wholly dependent on the output of the hydrologic model, using rating curves derived in this manner to calibrate the hydrologic model can lead to a circular reasoning, and must therefore be treated with caution. As with the hydraulic model, the results can be calibrated to flow gauging data and used to extrapolate the rating to higher discharges, however this extrapolation is based on the catchment-wide properties and empirical formulations inherent in the hydrologic model rather than the more realistic and specific local site conditions of a hydraulic model.

3.3.5 Correlation of gauge data

Provided that the additional contributing catchment between the gauges is small, gauges in close proximity can be correlated to allow flows from a well-documented site to be translated to a less data rich site, or to potentially identify discrepancies or outliers in the data. However, because rainfall events may be localised in particular areas of the catchment, the reliability of the correlations would be expected to decrease as the distance between the gauges increases.

3.3.6 Flood frequency analysis

Flood frequency analysis involves the process of fitting recorded peak flood discharges (or flood event volumes) to a probability function. Water levels usually cannot be fitted to a standard probability distribution because changes in the channel shape lead to an inconsistent relationship between probability and level. Although flood frequency analysis cannot be used to directly determine the discharge rating curve, it can be used for:

- Identifying potential errors in the rating curve (eg discontinuities in the discharge-probability function, which would be expected to have a smooth fit of a recognised function such as a Log Pearson III or Generalised Extreme Value type distribution)
- Comparison of different gauge predictions to ensure consistency across the catchment

3.4 Overview of numerical modelling methods

In the absence of physically recorded data, numerical modelling must be used to determine the relationship between flood level and discharge. Hydraulic modelling is considered to be more reliable than hydrologic modelling for this task. A range of numerical model types are available, but all have limitations that can restrict their appropriateness for particular tasks. A brief summary of different model types is provided in the sections below. Limitations of hydraulic models are discussed in greater detail in '*Numerical Limitations of Hydraulic Models'* (Toombes & Chanson 2011). Modelling techniques were adopted for the review of each rating based on the priority of the gauge review, site conditions and characteristics, and the limitations and advantages of each model type.

3.4.1 One-dimensional hydraulic models

One-dimensional models assume that the flow is in one direction only, and there is no direct modelling of changes in flow distribution, cross-section shape, flow direction, or other two- and three-dimensional properties of the flow. The channel geometry is typically represented as a series of cross-sections at fixed (but not necessarily uniform) intervals. Although often considered to be relatively simplistic by modern standards, one-dimensional modelling remains a useful and valid tool for situations where the flow may be adequately approximated as one-dimensional.

3.4.2 Two-dimensional hydraulic models

Two-dimensional hydraulic models are commonly used for modelling of floodplains, coastal and marine situations where the flow path is variable or poorly defined. Two-dimensional models calculate water depths and velocities across a grid or mesh that defines the topographic information. The numerical solution used by two-dimensional hydraulic models is usually based on the Saint Venant equations, also commonly known as the shallow water equations. These are based on the assumption that the horizontal length scale is significantly greater than the vertical scale, implying that vertical velocities are negligible, vertical pressure gradients are hydrostatic, and horizontal pressure gradients are due to displacement of the free surface.

A significant restriction on the use of two-dimensional analysis for detailed systems or narrow channels is the ability to accurately define the geometry within the two-dimensional grid system. In addition to the increased computational requirements of smaller grids, grid size is limited by the assumptions inherent in the shallow water equations and the way they are discretised by the model. The formulations used to estimate the forces acting on each fluid component, such as viscous shear stresses and bed friction, can become distorted when the vertical length scale approaches or exceeds the horizontal scale.

3.4.3 Linked 1D-2D hydraulic models

Linked 1D-2D models are created by embedding a one-dimensional river network within a two-dimensional floodplain. The one-dimensional network is used to model the main river channel and overcome the limitations of the two-dimensional grid size, while the overbanks are linked into a two-dimensional matrix to overcome restrictions of a one-dimensional network. This theoretically adds flexibility and the ability to model small, narrow or sharply incised channels where the channel cannot be reasonably represented in the two-dimensional domain. However linked 1D-2D models are not appropriate in all situations and the linking of the 1D and 2D domains within current software packages still has significant limitations.

Firstly, the interface and transfer of flow between the 1D channel and 2D floodplain is usually based on a weir-type relationship that does not transfer momentum between the domains. This is adequate where the channel remains a dominant flowpath and transfer of shear forces is small. Braided channels, meandering channels where the high level floodplain flow direction may be across the channel, or other systems where there is a strong transfer of shear and/or momentum between the channel and floodplain are not appropriate cases for a linked 1D-2D model.

Secondly, the 1D and 2D networks are linked but numerically separate domains. Care must be taken to avoid duplication of conveyance where the domains overlap. This can potentially be resolved by blocking out or otherwise the channel area in the two-dimensional domain, however potential for overlap (or conversely omission) of conveyance can reduce model accuracy/confidence.

3.4.4 Normal or uniform flow depth

Normal depth is the depth of uniform, steady flow in a channel and can be calculated for a channel of regular cross-section and grade using Manning's Equation. Normal depth is not necessarily a reliable method for estimating a rating curve in an irregular channel, but as a measurement of the flow capacity of the channel (based on a single cross-section), it can provide an indication of the level and magnitude of changes in the flow rating.

3.4.5 Hydrologic modelling

Hydrologic models are used to convert rainfall into runoff hydrographs. While they may vary in terms of complexity of application, hydrologic models are traditionally based around an empirical relationship between storage and discharge assumed to follow a power law type distribution of the form $S = kQ^m$ where the exponent m is typically between 0.6 and 1.0 when representing the storage effects of channel reaches and between 1.0 and 1.5 for flood routing in major rivers and through reservoirs. The catchment response and consequently, the shape of the hydrograph at any location, is a function of storage attenuation and delays in the contributing reaches. Although the catchment may be subdivided into various sub-areas and reaches and different parameters applied to represent different characteristics, often producing a good representation of observed catchment response, there is not a robust link between the empirical model and physical catchment.

In addition to the model characteristics and calibration parameters, the hydrologic model results are dependent on the assumed losses and the input rainfall data, the reliability of which may vary significantly depending on the number and location of rainfall gauges and uniformity of rainfall across the site. Due to this variability, significant scatter in the model results can be expected and the rating must be based on best-fit through the data. Although emphasis can be placed on results that can be considered more reliable, estimation of the rating curve from hydrologic model results is typically less reliable than hydraulic modelling.

3.5 Gauge rating review methodology

As discussed in Section 3.3 above, numerous sources of gauge rating data are available, each with limitations on range and accuracy. Individually, none of these methods can determine the rating curves across the full range required. Several overlapping methods have therefore been used for each gauge to provide as high a level of confidence as possible in the gauge ratings. The level of detail used to confirm and/or determine rating curves for primary and secondary gauges is described in the following sections.

3.5.1 Seqwater review

As part of the development and calibration of the URBS hydrologic models of the Brisbane River catchment, Seqwater has undertaken a review a most of the major flow gauges within the catchment. With a few exceptions, the review primarily used existing flow gaugings and hydrologic modelling. Ratings were developed for each site, typically consisting of a low flow rating based on best-fit of flow gauging data (where available) and a high flow rating based on best-fit of the hydrologic model data. When developing the ratings, Seqwater also utilised gauge station cross-section survey data to identify where inflexion points would be expected in the ratings, and placed focus on ensuring continuity of peak flow estimates and flood volumes between upstream and downstream gauges.

Seqwater has typically used a power-law type equation when estimating best fit of flow gauge and hydrologic model data, in keeping with standard industry practice. A power-law relationship between discharge and depth is technically only observed if the channel characteristics (shape and roughness) fit a power law. Natural channels rarely fit this criterion across the full flow depth, but may exhibit relationships that may be approximated by a power law within certain ranges. Review of the Seqwater estimates indicates a power exponent typically between 2 and 3. In a number of situations a similar or better fit of the data could be obtained using a cubic relationship, although this is not standard practice. Any adopted relationship must be supported by the data and should be confirmed and potentially adjusted ‘by eye’. Cross-section shape or a normal-depth flow rating can be used as indicators of expected trends in the rating.

3.5.2 Analysis of primary gauge ratings

Primary gauges are considered to be of high importance for the hydrologic modelling. In addition to the review of existing data and ratings, this study has conducted an independent assessment of the rating curve for most of the primary gauges. Unless otherwise noted in Section 4, preliminary assessments of the primary gauge ratings have been performed using the following procedure:

1. Develop a hydraulic model of the gauge location. Considering the limitations discussed in Section 3.4, pure 2D modelling has been preferred as this should give the greatest reliability for mid- to high-level floodplain flows
2. Calibrate the hydraulic model to available flow gauging data
3. Use the calibrated model to model higher discharges and extend the gauge rating
4. Compare the modelled rating with other available data, including existing ratings and hydrologic model results (currently based on Seqwater calibration)

This procedure for analysis of the primary gauge ratings is based on utilising the most reliable data available, with an independent hydraulic model calibrated and validated to available data. As discussed in Section 3.6, the results and ratings currently presented in this report are the first stage of the rating review process for the primary purpose of calibrating the hydrologic models. The ratings will continue to be reviewed and updated throughout the assessment to ensure consistency of the data.

3.5.3 Analysis of secondary gauge ratings

Secondary gauges are those for which a reliable rating curve is:

- Already reasonably well defined and unlikely to be significantly increased by additional modelling
- Desirable but not essential for the hydrologic model calibration, or
- Limited by availability of data or other factors adversely affecting development of a reliable rating

Preliminary analysis of secondary gauge ratings has been limited to review of existing data, including flow gauging data, gauge ratings, and hydrologic model results. This data has been assessed to identify the range and reliability of the current rating. As discussed in Section 3.6, additional review will be undertaken once calibration of the hydrologic models has been undertaken.

3.5.4 Historic variation of the rating curves

Unless regulated by a permanent and well documented structure, gauge ratings may change over time. This can be a gradual long-term evolution, rapid flood incident driven scour, human driven change to stream or floodplain use, or even seasonal variation in vegetation density or agricultural use. Due to this variation it may not be appropriate to apply current ratings to historical flood events and even recent events may vary significantly from the rating. Conversely, the rating change may be driven by a better understanding of the flow characteristics at the site, such as additional or higher quality data, or different measurement or calculation methods. Using a historically derived rating does not guarantee a more reliable result unless it can be conclusively demonstrated that the historical rating was more accurate and that the differences are driven by changes to the site conditions.

The philosophy of this study is to assume that the gauging sites are reasonably stable with time and adopt a single consistent rating based on compilation of all available data. This means that the rating may not match the exact current site condition and may not be suitable for all purposes, however use of a single 'averaged' rating curve is considered appropriate for this study on the basis that:

- The accuracy of historical ratings cannot be guaranteed, and it is rarely feasible to try to reconstruct historical conditions to confirm or derive historical ratings
- Variation is usually greatest in the lower gauge range. It is acknowledged that this is not always the case, however there is usually significantly less reliable data in the upper range to confirm any trend. The primary purposes of this study are calibration of the hydrologic models and flood frequency analysis, both of which prioritise the importance of moderate to major flood events
- Hydrologic model calibration is dependent upon rainfall records and assumed losses. These are rarely of sufficient quality to exactly match recorded flood levels/discharges, and the influence and uncertainty of both have the greatest effect for small flows
- Flood Frequency Analysis is performed by fitting a probability distribution to randomly distributed samples and some scatter is expected. Unless there has been a consistent trend or abrupt change, or the flood frequency distribution is strongly influenced by a particular data point, then historical variation may increase the scatter and uncertainty, but does not necessarily cause an error

It is acknowledged that these assumptions may not be as appropriate for sites that exhibit a trend of historical variation. Where possible, selection of primary gauge sites has focussed on gauges that display relatively consistent flood gauging history. Flow gauging records and anecdotal evidence suggests that a number of gauge sites, specifically Gregors Creek and Savages Crossing, display signs of historical variation and these have been given a lower priority in the review in terms of additional modelling.

3.5.5 Reliability of flow estimates

Rating curves are derived for the purpose of estimating a discharge from an observed water level. The reliability of the flow estimate is therefore dependent upon the reliability of the rating curve, or how truthfully the rating curve represents the relationship between water level and discharge, and the accuracy to which the flow measurement can be read from the rating curve.

The rating curves have been derived based on a 'best fit' curve or hydraulic model calibrated to flow gauge and/or hydrologic model data. Two characteristics have been used to describe the variability of the data and how well it is represented by the rating curve. Scatter of the data has been assessed in the form of a 90% confidence interval for the percent deviation of the data from the rating, approximated from the normal standard deviation as:

$$CI_Z^{90\%} = 1.645\sqrt{\frac{1}{n}\sum\left(\frac{\Delta Z}{Z_{rating}} - \overline{\frac{\Delta Z}{Z_{rating}}}\right)^2} \quad \text{and} \quad CI_Q^{90\%} = 1.645\sqrt{\frac{1}{n}\sum\left(\frac{\Delta Q}{Q_{rating}} - \overline{\frac{\Delta Q}{Q_{rating}}}\right)^2}$$

where ΔZ and ΔQ are the residual difference between the are the elevation and flow of each data point, Z_{data} and Q_{data}, and the rated elevation and flow derived from the rating curve, $Z_{rating} = f(Q_{data})$ and $Q_{rating} = f(Z_{data})$, as defined in Figure 3-2 below.

The appropriateness of the rating curve shape has been quantified using a standard r-squared (R^2) correlation, which is the square of the Pearson product moment correlation coefficient. The r-squared value can be interpreted as the proportion of the variance in one variable attributable to the variance in the other. A low r-squared value between the rating curve value and the residual difference indicates that there is no trend or bias in the residual and that the curve shape is appropriate. The formulae used to calculate the r-squared values are:

$$R_Z^2 = \frac{\left(\sum\left(\Delta Z - \overline{\Delta Z}\right)\left(Z_{rating} - \overline{Z}_{rating}\right)\right)^2}{\sum\left(\Delta Z - \overline{\Delta Z}\right)^2\sum\left(Z_{rating} - \overline{Z}_{rating}\right)^2} \quad \text{and} \quad R_Q^2 = \frac{\left(\sum\left(\Delta Q - \overline{\Delta Q}\right)\left(Q_{rating} - \overline{Q}_{rating}\right)\right)^2}{\sum\left(\Delta Q - \overline{\Delta Q}\right)^2\sum\left(Q_{rating} - \overline{Q}_{rating}\right)^2}$$

It should be noted that these are assessments only of how well the rating fits the available data. The accuracy of the data itself is dependent upon the method and accuracy used to determine the data, typically either flow gauging, hydraulic modelling or hydrologic modelling.

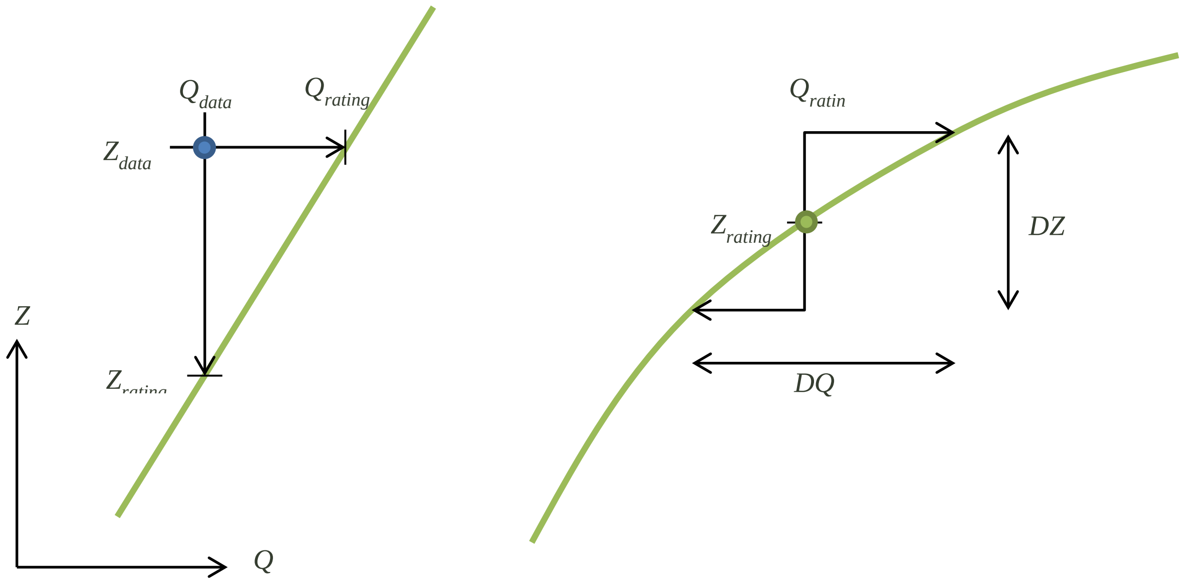


Figure 3-2 Definitions for rating reliability assessment

The sensitivity of the rating curve to differences in elevation has been assessed in the form of ratio between the change in elevation and the resulting change in flow (as a percentage of the elevation and flow at that location on the rating), given as:

$$S_{dQ/dZ} = \frac{DQ}{DZ}\frac{Z_{rating}}{Q_{rating}}$$

where ΔQ and ΔZ are defined in Figure 3-2. Calculation of $S_{dQ/dZ}$ in Section 4 has been based on a variation of ±5% of the gauge height and averaged across characteristic regions of the rating curve.

Hydraulic model ratings are typically a function of the channel conveyance, which is dependent upon the topography and assumed roughness. Assuming that the flow is well developed and quasi-steady, the sensitivity of the discharge and elevation to changes in roughness can be approximated as:

$$\frac{\Delta Q}{Q} = -\frac{\Delta n}{n + \Delta n}$$

$$\frac{\Delta Z}{Z} = -S_{dQ/dZ}^{-1}\frac{\Delta n}{n + \Delta n}$$

3.6 Continuing and future work

As discussed in Section 3.1, it is considered important to achieve consistency between all stages of the BRCFS. The rating curve development, including the hydraulic modelling conducted for the primary gauges, has been subject to continual review during the ongoing hydrologic model calibration and flood frequency analysis stages. They are based on the best available data but should continue to be reviewed throughout the hydraulic modelling and subsequent stages of the BRCFS, and ongoing gauging and refinement of the ratings should be continued as opportunity arises to continue improving the definition and confidence in the ratings for use in flood operations.

4 Gauge rating summary

4.1 Stanley River to Somerset

The Stanley River catchment is located in the Upper Brisbane River catchment covering an area of 1324 km² upstream of Somerset Dam. Major watercourses in the catchment include the Stanley River, Sheep Station Creek, Kilcoy Creek, Sandy Creek and Neurum Creek, which generally all converge in the vicinity of the reservoir of Somerset Dam.

4.1.1 Summary of available gauge data

The Stanley River catchment has only three gauging stations. Gauge locations are shown in Figure 4-1 and available data for the catchment is summarised in Table 4-1.

The Stanley River gauge at Peachester is considered to have an excellent history of gauging and data, with about 420 gaugings taken between 1927 and 2012, however the gauge represents less than 10% of the total catchment.

The Stanley River gauge at Woodford, located at the D'Aguilar Highway crossing, has a long history of water level data but more limited gauged flows. The Woodford gauge site represents approximately 20% of the total catchment to Somerset Dam. Seqwater has developed a one-dimensional HEC-RAS model of the Woodford gauge reach, achieving a relatively good match of the gauge data for the lower levels. They note however that there is likely flood storage and bypass issues at the higher levels.

The Mount Kilcoy weir site is located in the lower reaches of Kilcoy Creek north of Lake Somerset. There have been 132 flow gaugings taken since 1950 however the quality of the gauging data is uncertain, and the site does not have a long history of quality continuous data.

Table 4-1 Catchment gauge summary – Stanley River to Somerset

Gauge	Area (km²)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Stanley River @ Peachester	104 (8%)	7.0m 127m³/s	1927 -		<6.8 Good >6.8 Fair	n/a
Stanley River @ Woodford	250 (19%)	6.7m 298m³/s	1918 -		<5.2 Fair >5.2 Fair	Seqwater HEC-RAS
Kilcoy Creek @ Mt Kilcoy	131 (10%)	5.7m 153m³/s	1956 – 1971 2005 -		<5.0 Fair >5.0 Poor	n/a
Stanley River @ Somerset Dam	1330 (100%)	n/a	n/a	Y	n/a	Dam Inflow

Catchment	Model Area km²	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-1 Stanley River to Somerset Dam URBS model (from Seqwater 2013)

4.1.2 Gauge selection for the Stanley River catchment model

Based on the gauge characteristics, the most suitable site to achieve a good rating is considered to be the Peachester gauge, however the small catchment size limits the usefulness of the gauge. Similarly, Kilcoy Creek is also considered to be of limited use due to the small catchment size, limited continuous gauge data and proximity to Somerset Dam.

The gauge at Woodford has a long period of record and commands a larger percentage of the catchment compared to the other gauges, but is understood to have complicated flow issues affecting the high level rating. It is therefore the logical selection for further investigation to improve confidence in the rating. The most reliable source of calibration data for the catchment is Somerset Dam.

4.1.3 Primary calibration input – Somerset Dam inflow

Somerset Dam has been in operation since 1959 and therefore has a sizeable flood history. It has a regulated outflow control and well defined storage and outflow relationships. Details of the Somerset outflow and storage ratings have been provided by Seqwater and are summarised in the '*Brisbane River Flood Hydrology Models*' report (Seqwater 2013). These ratings have been assumed to be well defined, and a detailed review requiring three-dimensional CFD or physical modelling is outside the project scope. Reverse reservoir routing of the Somerset Dam inflows has been used to determine hydrographs at the outlet of the Stanley River model.

4.1.4 Primary gauge rating – Stanley River @ Woodford

The gauge location at Woodford on the Stanley River is a relatively complicated site, with several ponds adjacent to the channel and a road bridge approximately 20 m upstream of the gauge. The gauge control is an old concrete water supply weir located approximately 700 m downstream of the gauge site. Monkeybong Creek joins the Stanley River approximately 200 m downstream of this weir. Seqwater has identified suspected issues relating to flood storage and bypass around the gauge site at higher flows. Approximately 70 flow gaugings are available up to a maximum discharge of 539 m^3/s. A number of the older gaugings are significantly lower than the current ratings, suggesting that they may have been conducted prior to construction of the weir.

Review of the current ratings, flow gauge data and current hydrologic model results is provided in Figure 4-2 below. The Seqwater and DNRM ratings show good relatively good agreement with each other and the flow gaugings up to approximately 6 m gauge height, but diverge above this elevation with the Seqwater rating curve following selected hydrologic model data (from their assessment). Relatively high scatter was apparent in this hydrologic model data, particularly around the bridge deck level, and Seqwater consequently excluded a large number of events from their rating assessment. Seqwater also excluded the highest flow gauging from their rating assessment. DNRM has expressed confidence in this gauged discharge, and the DNRM rating is influenced by this discharge. Above 445 m^3/s the current DNRM rating appears to have been influenced by the Seqwater review and the rating trends up to join the Seqwater rating.

A two-dimensional MIKE 21 hydraulic model was developed to review the Woodford gauge rating. Details of the model are provided in Appendix B. The LIDAR survey does not include the channel invert due to water ponded upstream of the control weir, so a low-flow channel was derived by interpolating between the gauge section shown in Figure 4-2 and survey downstream of the weir. The gauging data and ratings show a distinct discontinuity between around 3.5 m and 4.5 m gauge height. The modelling suggests that it is at around this elevation that downstream tailwater drowns out the controlling influence of the weir. This discontinuity is present but less pronounced in the hydraulic model results, suggesting that the transition may not be as abrupt as in the current ratings.

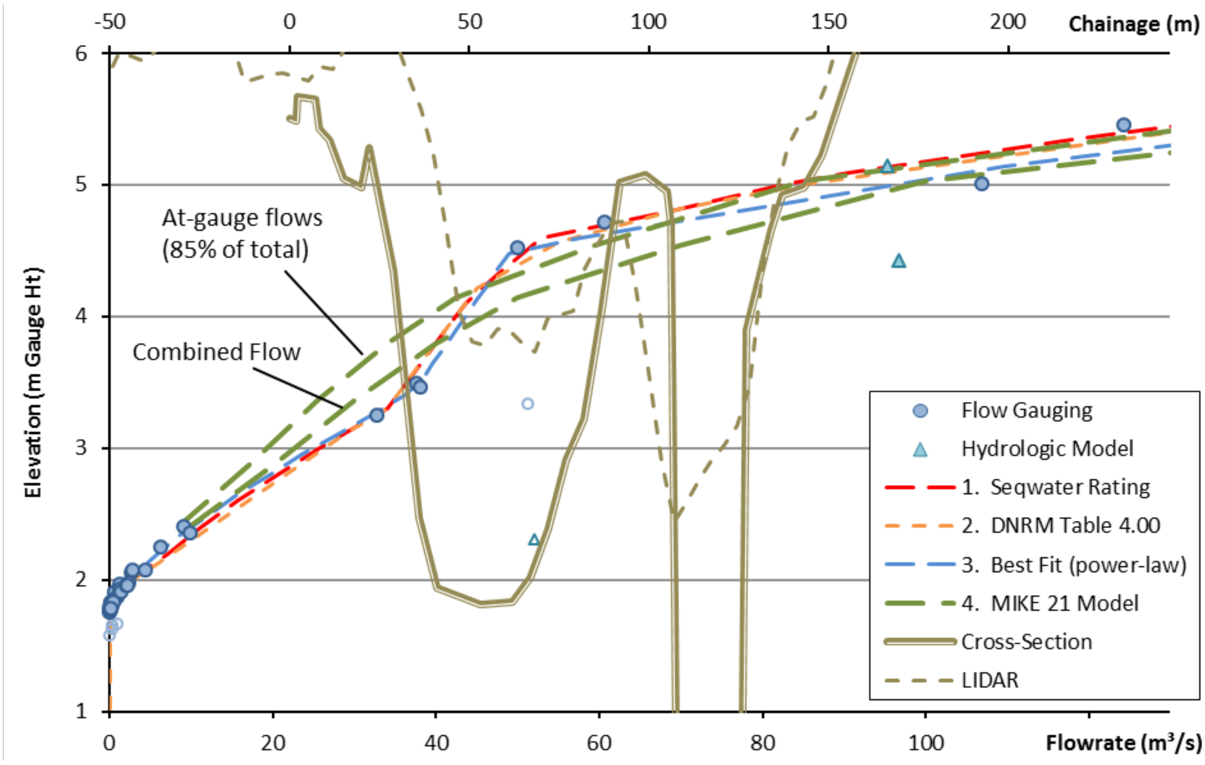


Figure 4-2(a) Rating Comparison – Stanley River @ Woodford (low – mid range)

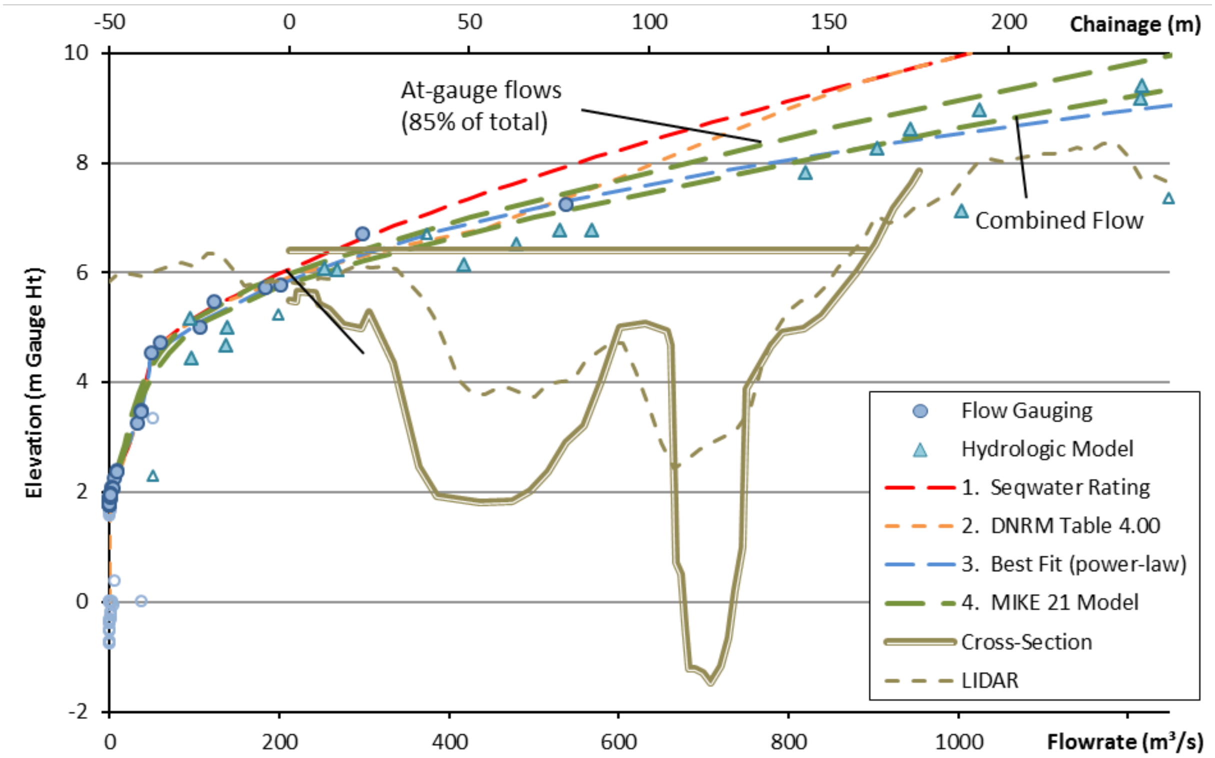


Figure 4-2(b) Rating Comparison – Stanley River @ Woodford (full range)

Review of the hydraulic characteristics of the site suggests that the effects of the weir are drowned out for relatively small flows (20 to 40 m³/s). The hydraulic control thereafter shifts to the reach downstream of the confluence with Monkeybong Creek, with the at gauge level becoming a function of combined Stanley River and Monkeybong Creek flows up to the confluence and at-site flows between the confluence and gauge site. This makes developing a single consistent rating difficult. Hydrologic modelling of the calibration flood events suggests that the contributions of Stanley River (at Woodford gauge site) and Monkeybong Creek are typically 85% and 15% respectively of the combined peak flow, although the actual ratio will vary during any particular event depending on the magnitude and timing of the rainfall across the catchment. The hydraulic modelling was conducted assuming this flow split and is therefore unreliable at low flows, but becomes increasingly independent of the actual ratio as the flow increases.

The hydraulic model was calibrated to match the flow gaugings using roughness parameters well within the expected range. The model is also considered at low flows due to lack of data to define the creek channel and weir, but provides a reasonable fit of flow gaugings and a good correlation with the DNRM rating curve for flows from around 100 m³/s up to 450 m³/s where the DNRM curve deviates back towards the Seqwater curve. A good correlation to the hydrologic model results is observed at high flows. Note that hydrologic model flows in Figure 4-2 are combined Stanley River and Monkeybong Creek flows, whereas flow gaugings, Seqwater and DNRM ratings are at-site flows.

Assessment of the data variability is provided in Table 4-2. Recommended flow ratings are:

- At low flows (< 20 to 30 m³/s) a local rating similar to Seqwater or DNRM rating is recommended
- At high flows (> 150 to 200 m³/s) a rating dependent on combined flows downstream of the Monkeybong Creek should be adopted
- For intermediate flows, the rating is considered uncertain due to variable coincident flows in Stanley River and Monkeybong creek

Temporal distribution of the deviation of the rated discharge from the measured/estimated is provided in Figure 4-3. It is noted that the DNRM rating generally gives higher flows than were recorded by a series of gaugings in 2003, but represents later measurements more evenly. There is no strong evidence of consistent long-term variation of the gauge, however there is potentially vegetation driven variation. In the high range (>4.6 m gauge height), a weighted rating based on all data gives higher discharges than the bulk of the hydrologic model results and lower discharges than the gauged discharges.

Table 4-2 Rating curve reliability assessment – Stanley River @ Woodford

Range (m)	Discharge (m³/s)	Number of samples		Basis for rating
		Gauged	Modelled	
1.8 - 3.4	0 - 36.2	14	1	Best fit of gauging
3.4 - 4.6	36.2 - 73.7	3	1	Interpolated transition
4.6 - 10	73.7 - 1409	7	19	MIKE 21 model

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dZ}$
1.8 - 3.4	-0.1%±16.9%	-3.2%±41.5%	0.011	0.003	1.5
3.4 - 4.6	-2.0%±12.7%	5.6%±29.1%	0.216	0.384	1.6
4.6 - 10	-2.9%±10.4%	6.2%±34.4%	0.115	0.001	2.8

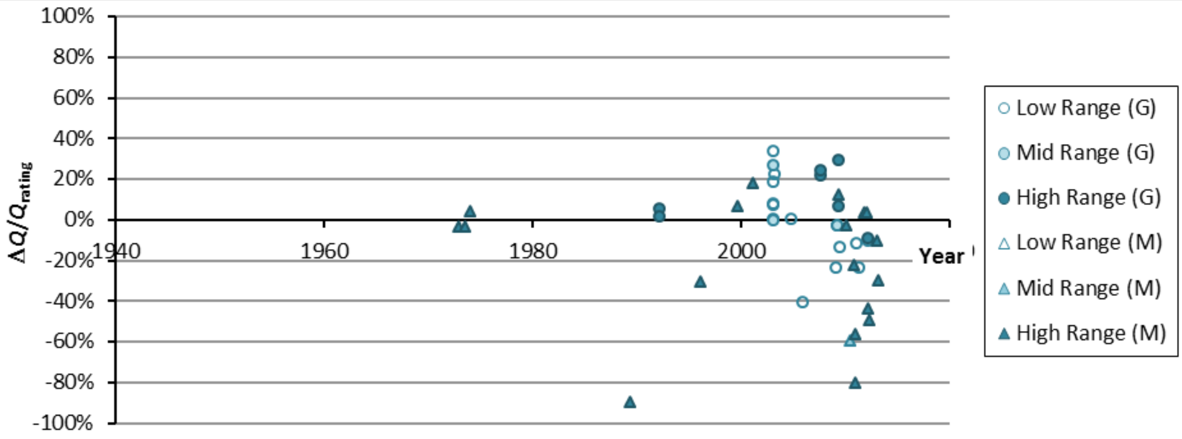


Figure 4-3 Relative variance of rated discharge – Stanley River @ Woodford

4.1.5 Secondary gauge rating – Stanley River @ Peachester

The Peachester gauge in the Stanley River has over 400 flow gaugings, although the majority of these are for very low discharges. The largest gauging is 7.9 m gauge height, corresponding to 299 m³/s. Available channel sections (provided by Seqwater) have a fairly wide channel base typically around 1.5 m to 2 m below the 'gauge zero', which is not consistent with zero flow of the flow gaugings and ratings. Possibilities include an inconsistency in the datum or a pooled channel, both of which add uncertainty to the gauge rating. No additional survey data (LIDAR) are currently available at the Peachester gauge location, so this cannot be confirmed.

Review of the current ratings, flow gauge data and current hydrologic model results is provided in Figure 4-4 below. The cross-section data shows an incised channel through a wider floodplain. Aerial photographs show minor channels and potential for 'short-cutting' across the floodplain, so a significant change in rating behaviour between in- and out-of-channel flows would be expected. The Seqwater and DNRM ratings both display this characteristic. The ratings are similar for in-channel flows, while the Seqwater rating is typically up to 0.4 m higher than the DNRM rating for floodplain flows. Visually, the DNRM rating is closer to the high flow gauging data, while the Seqwater rating displayed better agreement with their hydrologic model data, although it is again noted that the Seqwater rating omitted some model results that match well with the DNRM rating.

Generally a higher confidence would be placed on the validity of the flow gaugings. It is also important to consider that the Stanley River hydrologic model was calibrated with strong emphasis on Somerset Dam, while Peachester is a small gauge in the upper catchment, and the model calibration at this location may therefore be biased.

Following recalibration of the hydrologic model, the rating was reassessed using a three-stage power-law fit of available data. The resulting rating has a sharper transition near bank-full that appears to fit the flow gauging and hydraulic model data better. At low flows the rating is relatively consistent with the DNRM rating and flow gauging while at high flows it is relatively consistent with the Seqwater rating. Assessment of the data variability is provided in Table 4-3. The in-channel stages of the rating are considered to be relatively well rated and sensitive to changes in water level, but the high range of the rating (>7.5 m gauge height) becomes sensitive to changes in flow. It is noted that there is still significant scatter with a 90% confidence interval in the order of 10 to 20% across much of the gauge height. The temporal distribution of the deviation of the rated discharge from the measured/estimated, provided in Figure 4-5, shows no evidence of long-term variation of the gauge rating. Considering the low priority of this site, no additional hydraulic modelling is proposed at this site.

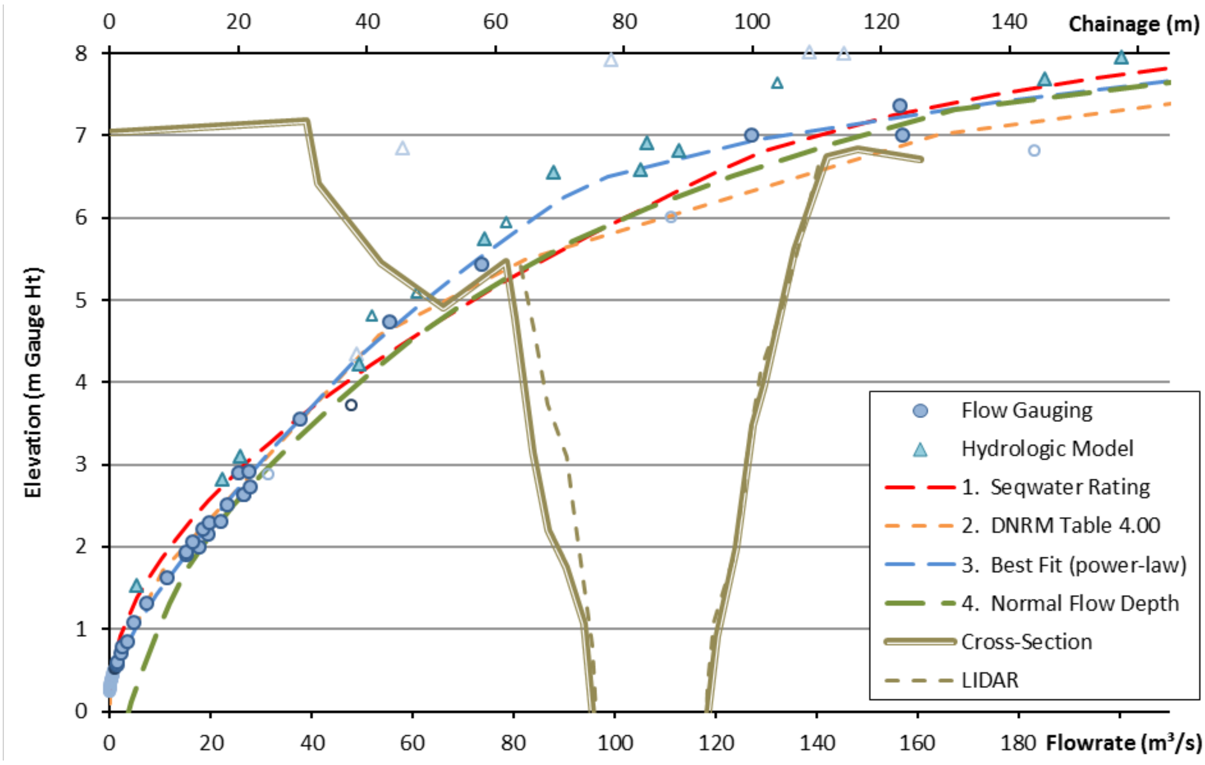


Figure 4-4(a) Rating Comparison – Stanley River @ Peachester (low – mid range)

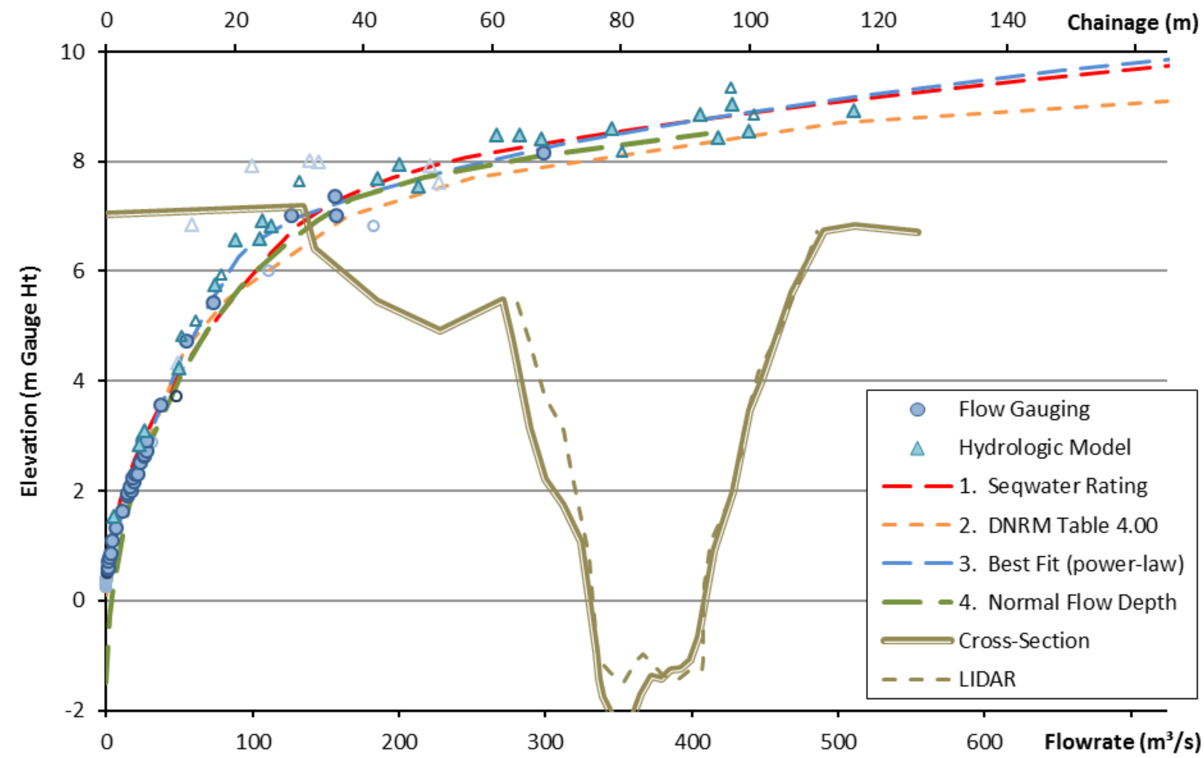


Figure 4-4(b) Rating Comparison – Stanley River @ Peachester (full range)

Table 4-3 Rating curve reliability assessment – Stanley River @ Peachester

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.2 - 4	0.01 - 44.3	50	3	Best fit of gauging and model data
4 - 6.5	44.3 - 100	3	6	Best fit of gauging and model data
6.5 - 10	100 - 781	5	26	Best fit of gauging and model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.2 - 4	0.0%±8.8%	-0.2%±13.0%	0.200	0.141	1.6
4 - 6.5	-0.3%±3.7%	0.3%±5.8%	0.344	0.170	1.8
6.5 - 10	-0.3%±4.4%	0.0%±21.1%	0.083	0.002	4.8

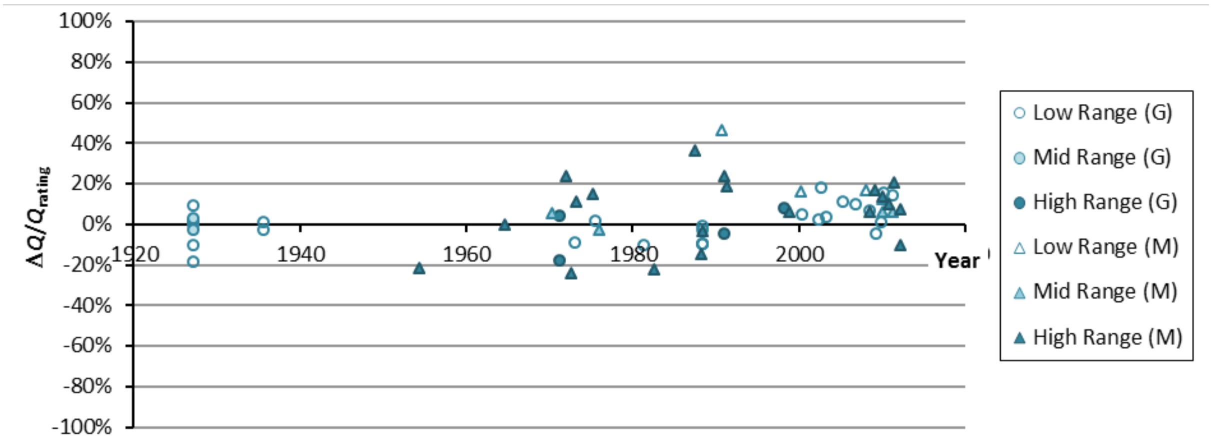


Figure 4-5 Relative variance of rated discharge – Stanley River @ Peachester

4.1.6 Secondary gauge rating – Kilcoy Creek @ Mt Kilcoy Weir

The Mt Kilcoy Weir gauge on Kilcoy Creek has over 160 flow gaugings, however many of these register negligible flow even with high water depth (possibly related to flows upstream of the weir) and are therefore inappropriate for the rating at the gauge location downstream of the weir. The highest reading is 5.7 m gauge height corresponding to 153 m^3/s, just below the bank full capacity. The DNRM rating up to 5.7 m is based on flow gauging data. The Seqwater rating is virtually identical to the DNRM rating up to this level, then fit to hydrologic model data for out-of-bank flows. The previous DNRM ratings (eg Table 4.00 shown in Figure 4-6) did not reflect the change in cross-section shape at the floodplain level, however the current Table 4-4 has been updated to follow the Seqwater rating.

The Seqwater rating appears to be consistent with the cross-section shape and conveyance, confirmed using Manning's normal flow depth calculations, although it is noted that the hydrologic model data displays significant scatter above top-of-bank level. Perched channel banks approximately 1 m above surrounding floodplain may have some impact on the gauged rating. Assessment of the data variability provided in Table 4-4 and Figure 4-7 displays a relatively high but consistent scatter.

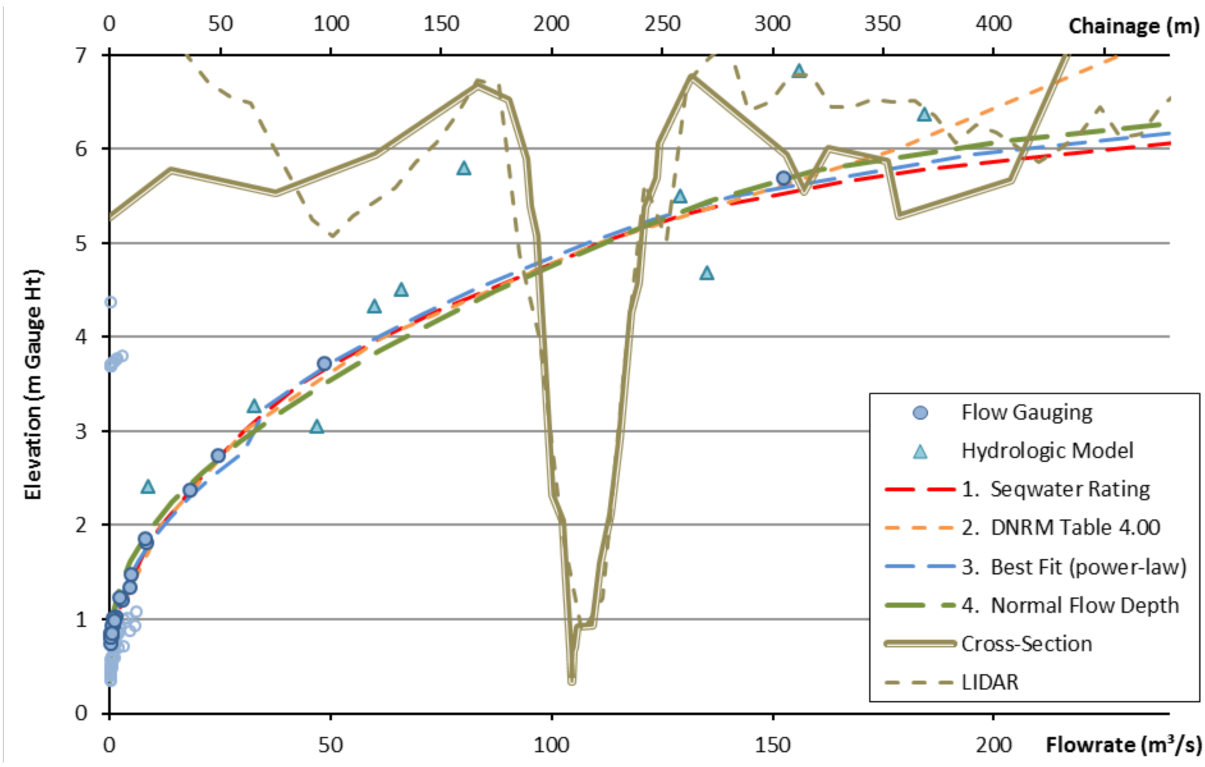


Figure 4-6(a) Rating Comparison – Stanley River @ Mt Kilcoy (low – mid range)

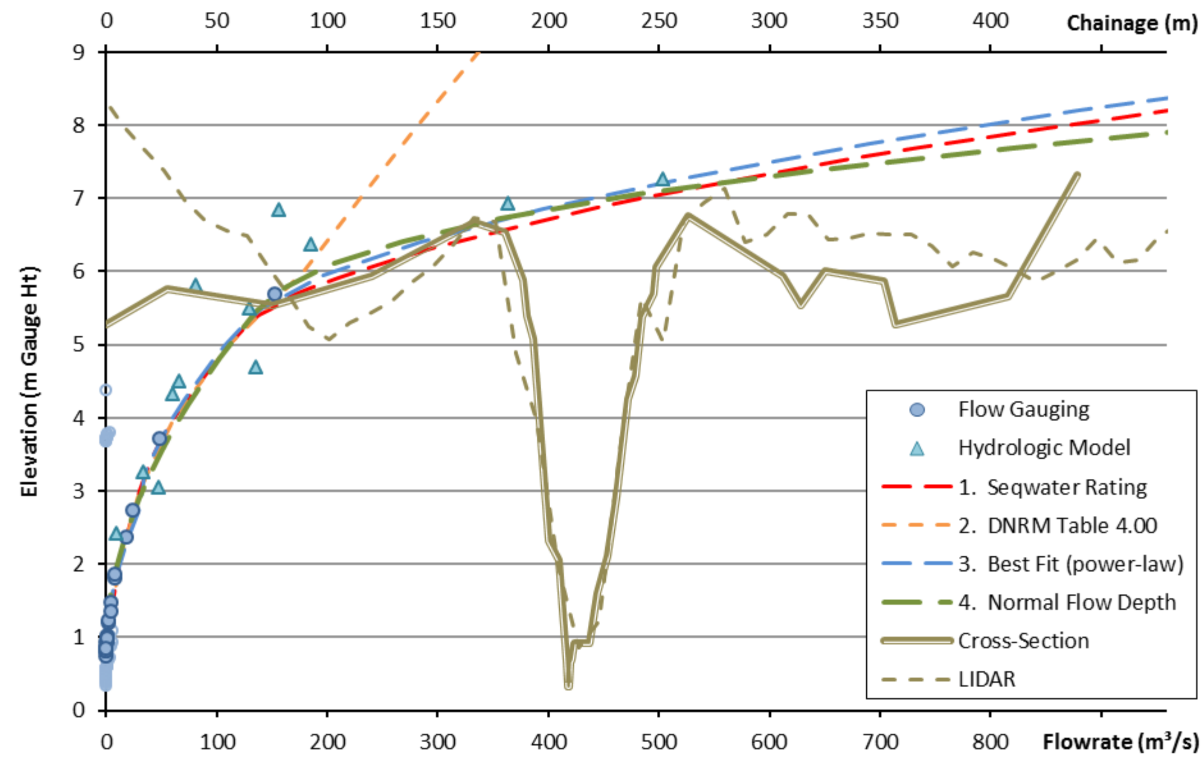


Figure 4-6(b) Rating Comparison – Stanley River @ Mt Kilcoy (full range)

Table 4-4 Rating curve reliability assessment – Stanley River @ Mt Kilcoy

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.7 - 3	0.137 - 32.8	36	1	Best fit of gauging and model data
3 - 5.5	32.8 - 143	18	6	Best fit of gauging and model data
5.5 - 10	143 - 1952	1	5	Best fit of gauging and model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.7 - 3	-6.6%±19.0%	9.5%±34.1%	0.052	0.001	2.0
3 - 5.5	-0.2%±15.7%	-2.7%±37.9%	0.077	0.021	2.3
5.5 - 10	-9.2%±18.8%	22.4%±35.3%	0.436	0.001	4.0

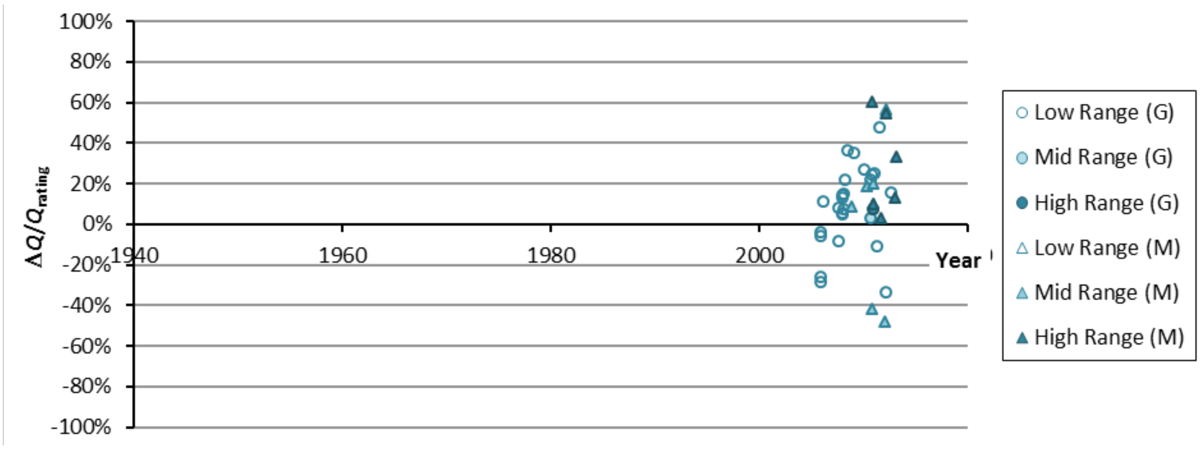


Figure 4-7 Relative variance of rated discharge – Stanley River @ Mt Kilcoy

Both Seqwater and DNRM ratings are considered to be reasonable and appear relatively reliable up to around 5.5 m gauge height. Based on available data the Seqwater rating appears reasonable above this level but cannot be guaranteed with any certainty. Following recalibration of the hydrologic model, which resulted in slightly different flows to Seqwater's modelling, a revised three-stage power-law rating was applied, producing slightly lower flows in the upper range. It is cautioned that this rating is dependent upon hydrologic model results. Considering the small proportion of the catchment serviced by the Mt Kilcoy gauge, no additional review or hydraulic modelling will be undertaken at this site.

4.2 Upper Brisbane River to Wivenhoe

The Upper Brisbane River is the major tributary in the catchment upstream of Wivenhoe Dam, and includes Cressbook Creek, Emu Creek, Cooyar Creek as well as several smaller tributaries. The combined catchment area is 5,645 km² to Wivenhoe Dam, making the Upper Brisbane River the largest of the seven URBS models. Cressbrook and Perseverance Dams are relatively small storages located within the catchment.

4.2.1 Summary of available gauge data

The Upper Brisbane River catchment has gauging stations on Brisbane River, Cooyar Creek, Emu Creek and Cressbrook Creek. Gauge locations are shown in Figure 4-8 and available data for the Brisbane River gauges is summarised in Table 4-5. The creek gauges typically have smaller catchment areas. Additional gauges in the lower catchment (Caboonbah, Middle Creek) are subject to inundation from Lake Wivenhoe.

The Brisbane River gauge at Linville has a reasonable history of gauging and data and is considered to be a useful site for water level monitoring in the upstream areas of the Upper Brisbane catchment. The Seqwater review of the DNRM rating showed good agreement, however high level flows were based on hydrologic model results.

The Brisbane River gauge at Gregors Creek is considered to be of high importance for dam operations. The gauge has a reasonable history of gauging and data. Seqwater has developed a one-dimensional HEC-RAS model of the Gregors Creek gauge reach, achieving a relatively good match of the flow gauge data. DNRM has raised concerns that the channel shape at the Gregors Creek gauge site has changed during and after the 2011 flood event and that the current rating is no longer valid.

Caboonbah was a long-term flood gauging station downstream of the confluence of Stanley and Brisbane Rivers. Caboonbah has a long record of flood levels, but no flow gaugings or official flow rating. The Caboonbah gauge site is inundated by Wivenhoe reservoir and is no longer in use.

Table 4-5 Catchment gauge summary – Brisbane River to WIvenhoe

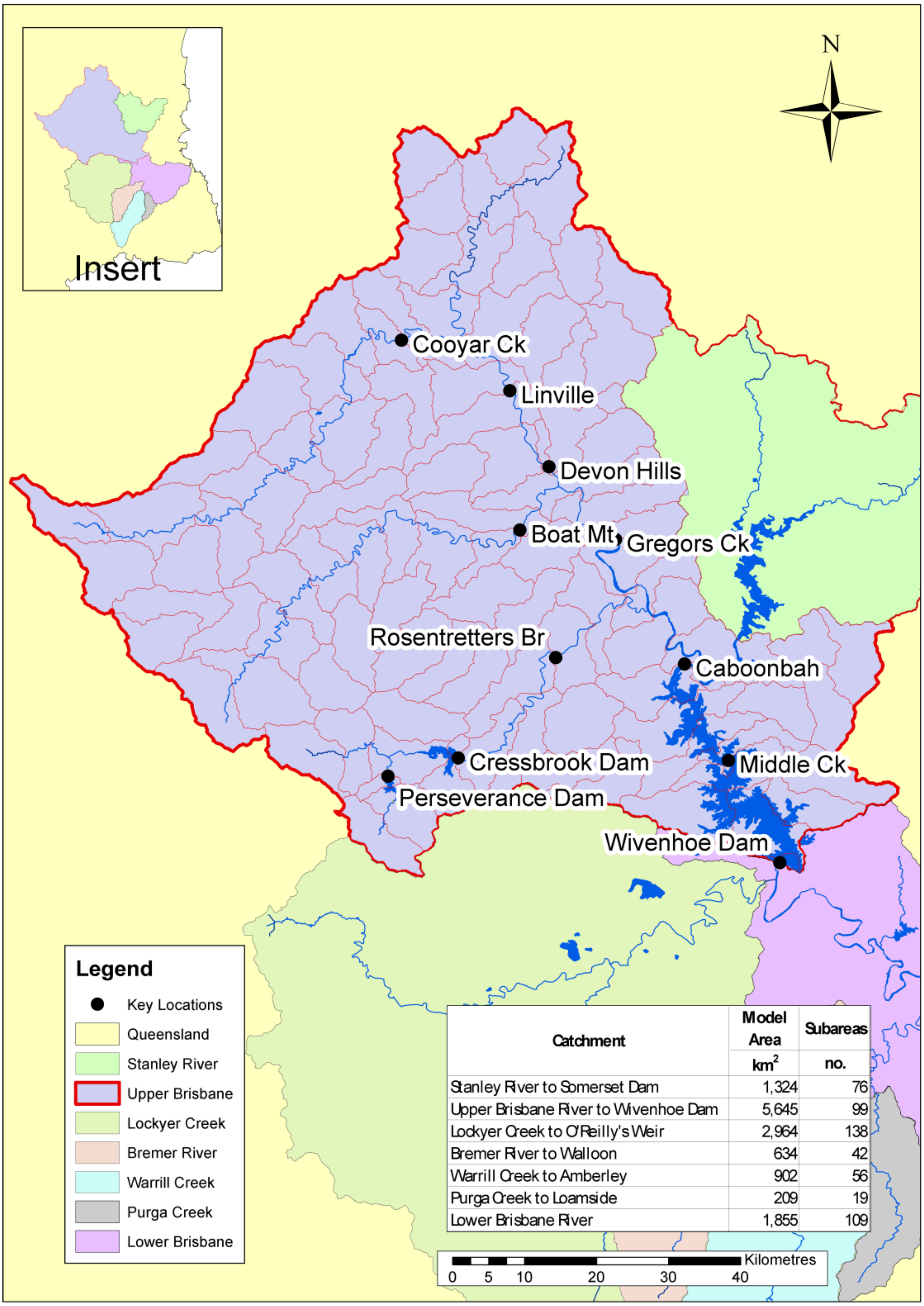
Gauge	Area (km^2)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Brisbane River @ Linville	2,009 (36%)	7.2m 1,486m^3/s	1967 -	Y	Fair - Good	n/a
Brisbane River @ Gregors Creek	3,866 (68%)	8.8m 2,198m^3/s	1962 -	Y	<2.36 Good >2.36 Good	DNRM HEC-RAS
Brisbane River @ Caboonbah	6,207[a] (89%)	22.63 16,000m^3/s	1905 - 1983	N	n/a	n/a
Brisbane River @ Wivenhoe	6,969[a] (100%)	n/a	n/a	Y	n/a	Dam Inflow

Notes: a Includes 5,645km^2 from the Upper Brisbane River and 1324km^2 from the Stanley River to Somerset dam

4.2.2 Gauge selection for the Upper Brisbane River catchment model

The Gregors Creek gauge is generally considered to be the most important site within the catchment due to its location in the lower part of the catchment, close to Wivenhoe Dam but not affected by backwater from the reservoir. It is considered to be a key gauge for dam operations. Although the site is generally well behaved and conducive to a good rating, the river channel around the Gregors Creek gauge has been affected by both floods and sand extraction. The other major Brisbane River gauge is at Linville, which commands around half the catchment area of the Gregors Creek gauge. Wivenhoe Dam should also provide a reliable source of calibration data.

Due to the uncertainty surrounding the Gregors Creek channel condition, it was decided to undertake a more detailed assessment of the Linville gauge to provide a representation of flows from the upper areas of the catchment, while using reverse-routed inflows into Lake Wivenhoe for flows at the model outlet. These should provide sufficient confidence in the calibration of the URBS model to inform a reasonably confident review of the Gregors Creek gauge based on hydrological model estimates.



Catchment	Model Area km²	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-8 Brisbane River to Wivenhoe Dam URBS model (from Seqwater 2013)

4.2.3 Primary calibration input – Wivenhoe Dam inflow

Wivenhoe Dam has been in operation since 1986. It has well defined storage and outflow relationships, making Wivenhoe a reliable but relatively short record. Details of the Wivenhoe outflow and storage ratings have been provided by Seqwater and are summarised in the '*Brisbane River Flood Hydrology Models*' report (Seqwater 2013). These ratings have been assumed to be well defined, and a detailed review requiring three-dimensional CFD or physical modelling is outside the project scope. Reverse reservoir routing of the Wivenhoe Dam inflows has been used to determine hydrographs at the outlet of the Upper Brisbane River model.

4.2.4 Primary gauge rating – Brisbane River @ Linville

The gauge on the Brisbane River at Linville is considered to be a reliable site and has 286 flow gaugings from between 1956 and 2011. The highest rating is 7.15 m gauge height corresponding to 1487 m^3/s. The Seqwater high flow rating is based on a power-law fit through the flow gauging and hydrologic model results. DNRM ratings Table 33 was very similar to the Seqwater rating, with both showing good agreement with the flow gaugings and hydrologic model results, however this rating has recently been updated and the current Table 34 now predicts higher discharges for much of the range. Table 34 does not appear to match the flow gauging particularly well, as shown in Figure 4-9, so the reason for this modification is unknown.

To improve confidence in the high level rating, a two-dimensional MIKE 21 hydraulic model has been prepared for the section of the Upper Brisbane River extending approximately 1 km upstream and 5 km downstream from the DNRM gauge at Linville. Details of the model are provided in Appendix B. The model was based on LIDAR survey data. Review of this survey shows relatively good agreement with the gauge cross-section obtained from Seqwater, however the LIDAR data appears to lack the channel invert, likely due to water in the channel when the LIDAR was flown. The hydraulic model results have been adjusted by scaling the model discharge by the ratio of the conveyance of the channel with and without the missing area. The roughness parameters were adjusted to achieve a best fit of the gauge data and the model then used to extend the rating curve.

A good agreement is achieved between the MIKE 21 model predictions, the current Seqwater ratings, and the calibration/validation data. The hydraulic model predicts slightly lower flows in the upper range. The preferred rating curve consists of a best-fit curve through the gauge data using the hydraulic model to extrapolate the rating curve to higher discharges.

Linville is a hydraulically consistent site, with a well constrained channel with no overbank areas up to and beyond the maximum observed flood levels. Assessment of the data variability provided in Table 4-6 shows a small confidence interval in upper range and comparatively low sensitivity across entire range. The deviation of the rated flows from the gauged and hydrologic model flows are provided in Figure 4-10. Comparison of the flow gaugings between1960 and 1980 with those gauged after 2000 potentially shows some evidence of a minor long-term shift in the low range rating. There is no evidence of this in the mid to upper range, with the deviation well distributed about the mean.

Overall, the review has concluded that Linville is a good and reliable flow measurement site with a high degree of confidence in the gauge rating across the full range of observed water levels. This conclusion supports its selection as a primary rating site for calibration of the URBS models.

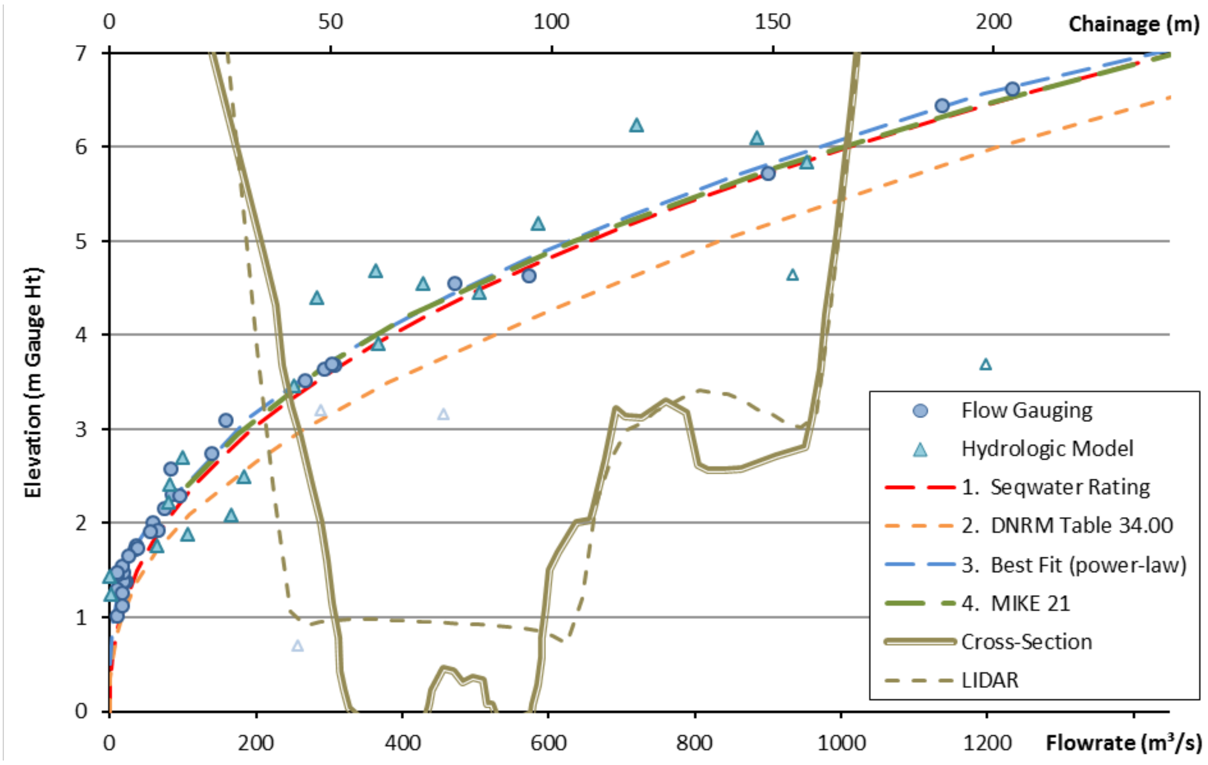


Figure 4-9(a) Rating Comparison – Brisbane River @ Linville (low – mid range)

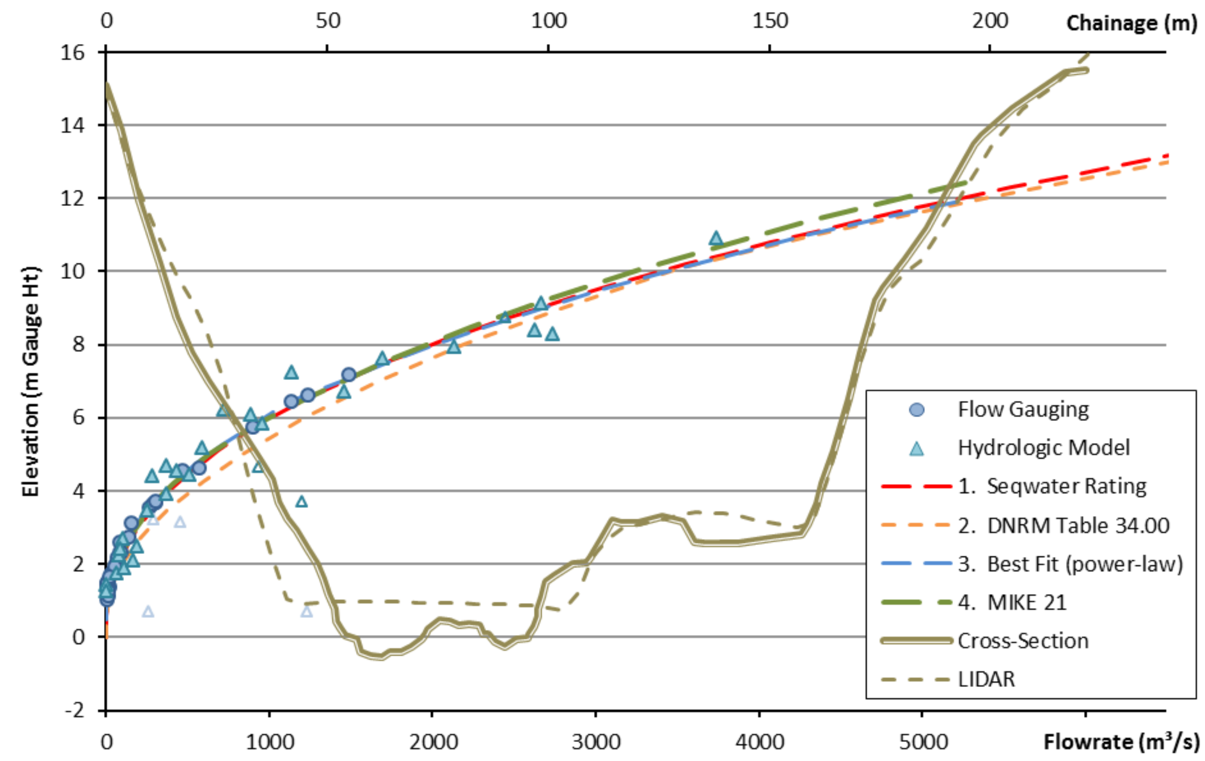


Figure 4-9(b) Rating Comparison – Brisbane River @ Linville (full range)

Table 4-6 Rating curve reliability assessment – Brisbane River @ Linville

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.7 - 2.7	0.7 - 144	25	11	Best fit of gauging and model data
2.7 - 7	144 - 1458	11	15	MIKE 21 model
7 - 10	1458 - 3232	1	8	MIKE 21 model

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.7 - 2.7	2.5%±18.2%	-16.5%±71.3%	0.001	0.002	3.3
2.7 - 7	0.0%±23.3%	-17.9%±142.0%	0.220	0.076	2.4
7 - 10	-1.6%±12.8%	1.7%±27.2%	0.434	0.062	2.2

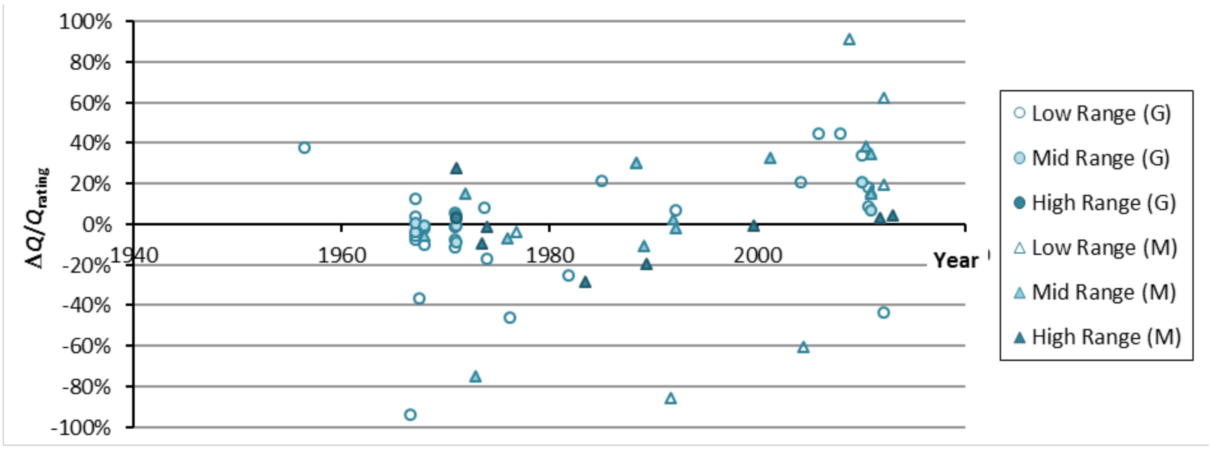


Figure 4-10 Relative variance of rated discharge – Brisbane River @ Linvlle

4.2.5 Secondary gauge rating – Brisbane River @ Gregors Creek

The Brisbane River gauge at Gregors Creek is an important gauge for dam operations. There are 273 flow gaugings up to a maximum of 8.76 m gauge height corresponding to 2198 m³/s. The Seqwater rating is a best-fit curve through the flow gauging for low-level and hydrologic model results for high-level flows, however it does not place much weight on the highest flow gauging. As with the Linville gauge, the current DNRM rating (Table 42) appears to predict flows across much of the range and does not provide a particularly good match of either the flow gauging or hydrologic model data, as shown in Figure 4-11. The DRNM Table 42 may therefore give a conservative estimate of discharge, but is considered unsuitable for the purposes of the BRCFS. The previous DNRM rating reviewed by Seqwater (Table 41) showed a better match of the gauged data and was relatively similar to the Seqwater rating for levels up to around 7 m gauge height.

It is understood that DNRM has developed a one-dimensional HEC-RAS model of the Gregors Creek gauge location. The HEC-RAS model results show a relatively good agreement with the DNRM rating, including the highest flow gaugings above which it deviates above the DNRM rating towards the hydrologic model results and the Seqwater rating. The hydrologic model was calibrated placing an emphasis on reverse-routed flows at Wivenhoe Dam downstream of the Gregors Creek gauge, so the results should have a reasonable level of confidence although there is still noticeable scatter.

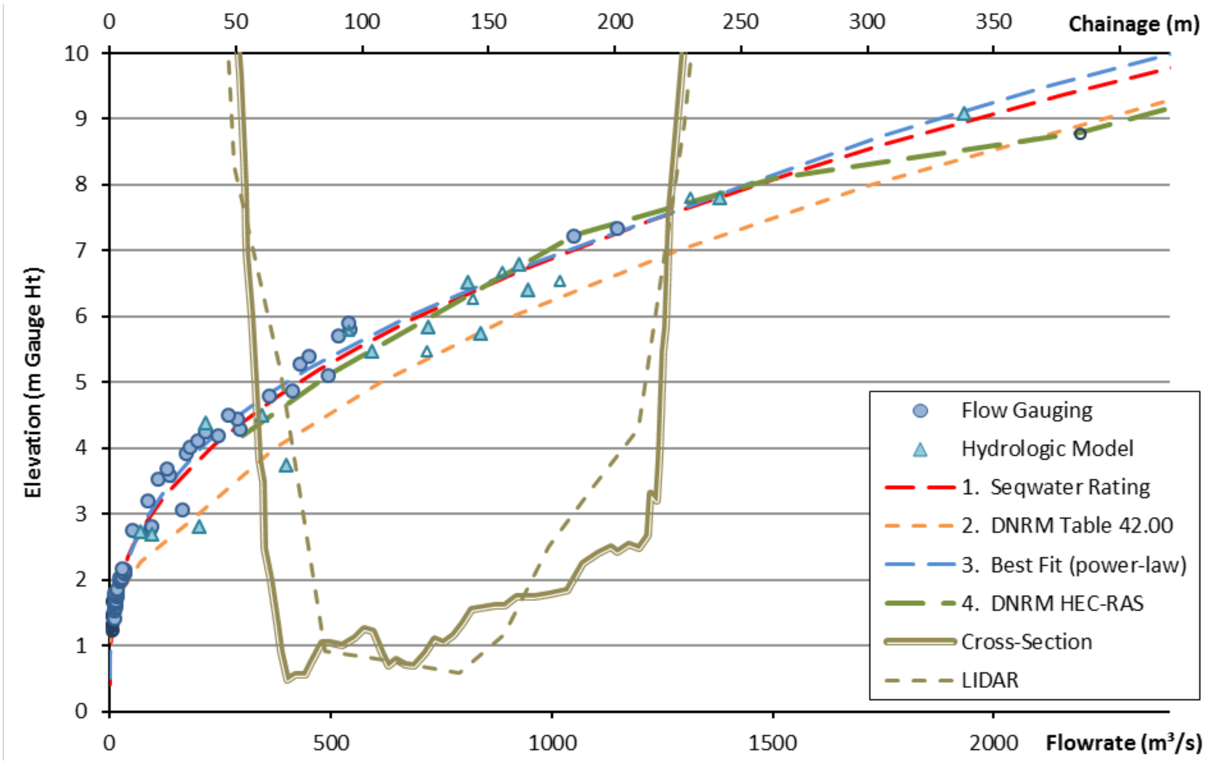


Figure 4-11(a) Rating Comparison – Brisbane River @ Gregors Creek (low – mid range)

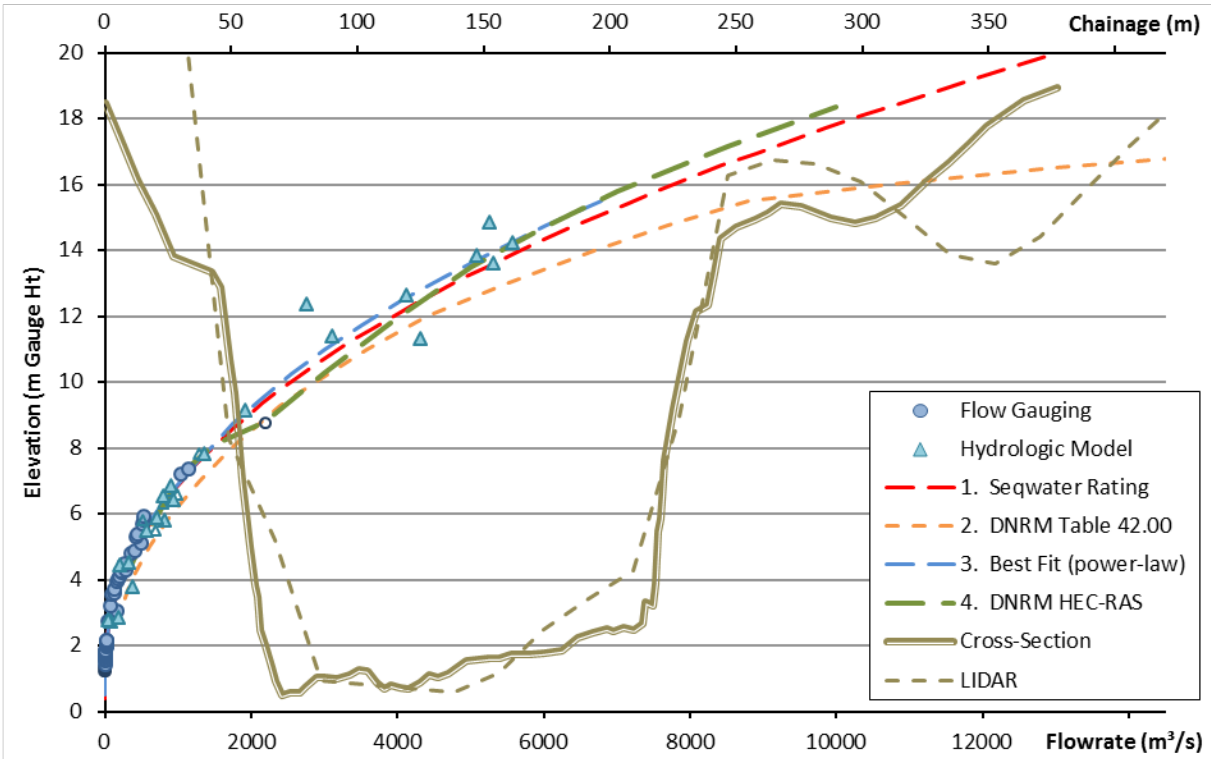


Figure 4-11(b) Rating Comparison – Brisbane River @ Gregors Creek (full range)

The flow gauging data appears to suggest a discontinuity in mid-range (around 8 to 9 m gauge height) that the Seqwater best-fit rating does not reflect, but shows in the DNRM HEC-RAS model results. The reason for this discontinuity is not clear as there is nothing evident in the channel section to cause a change of properties. The accuracy of this highest flow gauging, taken during the 2011 flood, is also uncertain. Applying a heavier weighting to the gauged data and adopting a three-stage power-law best-fit rating using the ranges described in Table 4-7 gives a good match of the flow gauging and hydrologic model data and the HEC-RAS model results (excluding mid-range). A discontinuity in the channel section above around 15 m gauge height could be expected to cause an inflection in the rating above this level. There is no data to predict the shape of this inflection, and the rating should not be used above this level. Hydraulic modelling would be the best alternative to extend the rating, however this is unnecessary for the objectives of the BRCFS rating review and is outside the scope.

Assessment of the reliability of the preferred rating curve, provided in Table 4-7, shows significant variability, particularly in the lower range, however the relative variability and sensitivity to depth change actually decreases with height. Despite the suspected issues regarding changes to the channel, Figure 4-12 shows no evidence of a consistent long-term trend. It is cautioned however that there is very limited data after 2011, when a noticeable change was observed, to confirm current conditions. Overall, Gregors Creek appears to be a good flow measurement site with a relatively high degree of confidence in the gauge rating across the full range of observed water levels.

Table 4-7 Rating curve reliability assessment – Brisbane River @ Gregors Creek

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0 - 4	0 - 205	55	4	Best fit of gauging and model data
4 - 8	205 - 1441	16	15	Best fit of gauging and model data
8 - 15.5	1441 - 6790	1	9	Best fit of gauging and model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0 - 4	-0.7%±12.4%	-1.5%±46.1%	0.060	0.001	3.8
4 - 8	-0.4%±6.5%	0.2%±19.7%	0.003	0.024	2.8
8 - 15.5	0.3%±11.3%	-2.4%±26.8%	0.008	0.222	2.3

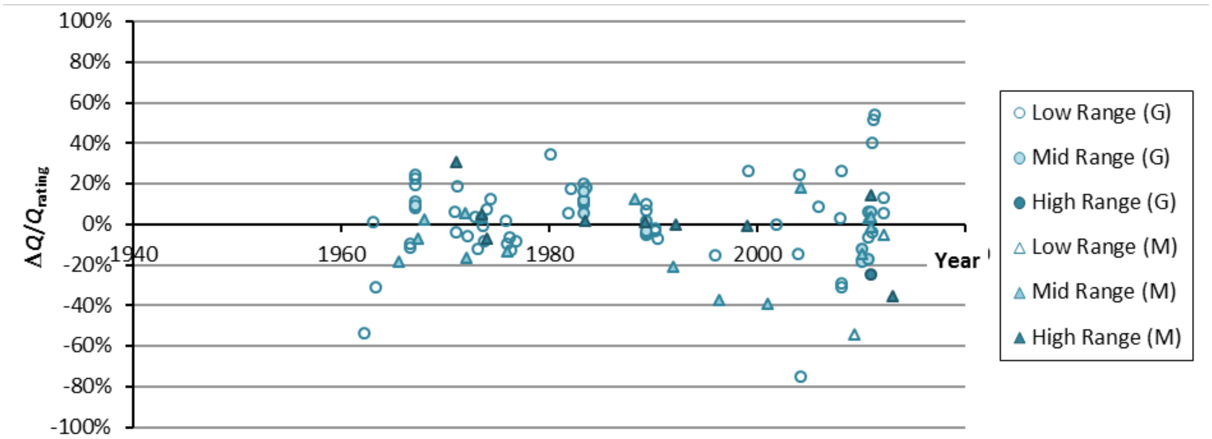


Figure 4-12 Relative variance of rated discharge – Brisbane River @ Gregors Creek

4.2.6 Secondary gauge rating – Brisbane River @ Caboonbah

The gauge at Caboonbah was considered a key gauge in Brisbane's flood warning network until the construction of Wivenhoe Dam. It has been nominated as an important gauge for assessing river conditions prior to the dam. The Caboonbah gauge is not currently in service. It had no official rating and no flow gauging data. Seqwater has estimated hydrologic model results for a number of events which, as shown in Figure 4-14, display a relatively high amount of scatter. The Seqwater rating is based on a single power-law type relationship through limited data, and follows the general trend but not with any level of confidence.

In order to improve confidence in the rating, particularly the low-flow range, a comparison was made with the Middle Creek gauge, which has a relatively well-defined low-flow rating. The URBS model was used to estimate a correlation between peak flows at Caboonbah and Middle Creek. Acknowledging that there may be inflow and storage attenuation effects between the gauges that are not perfectly represented by the model, a reasonable correlation was observed with flows at Caboonbah typically 1.5% higher than at Middle Creek, as shown in Figure 4-13. Recorded peak levels at Caboonbah were then matched with rated peak flows calculated from the Middle Creek gauge record and rating. A three-stage power-law best fit was used to define a rating for the Caboonbah gauge, having fairly good agreement with the Seqwater rating.

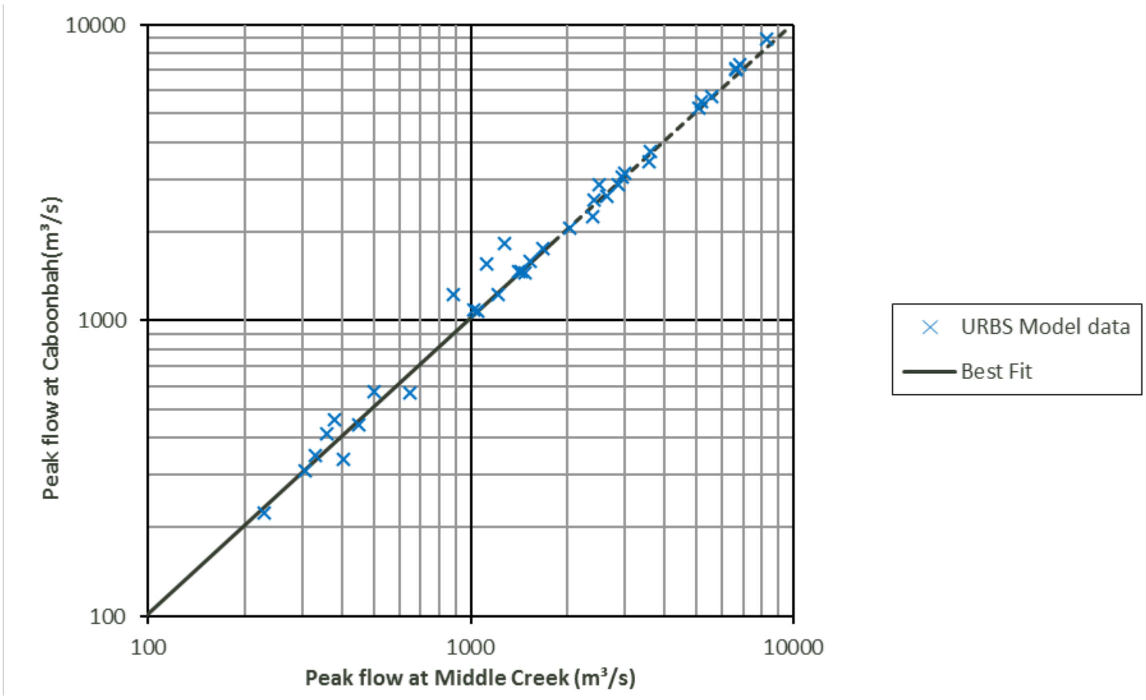


Figure 4-13 URBS calibration event peak flows between Middle Creek and Caboonbah

4.2.7 Secondary gauge rating – Brisbane River @ Middle Creek

Middle Creek was a stream gauge on the upper Brisbane River downstream of Caboonbah within the area submerged by the Wivenhoe Dam reservoir. The gauge was active between 1962 and 1982. Flow gauging is available up to over 2500 m³/s, making the low to mid-range rating relatively reliable. There is no data available for projection to high flow rates so extrapolation should be treated with caution, although the gauge record does not include the major flood in 1974 and most other events lie within the reliable range.

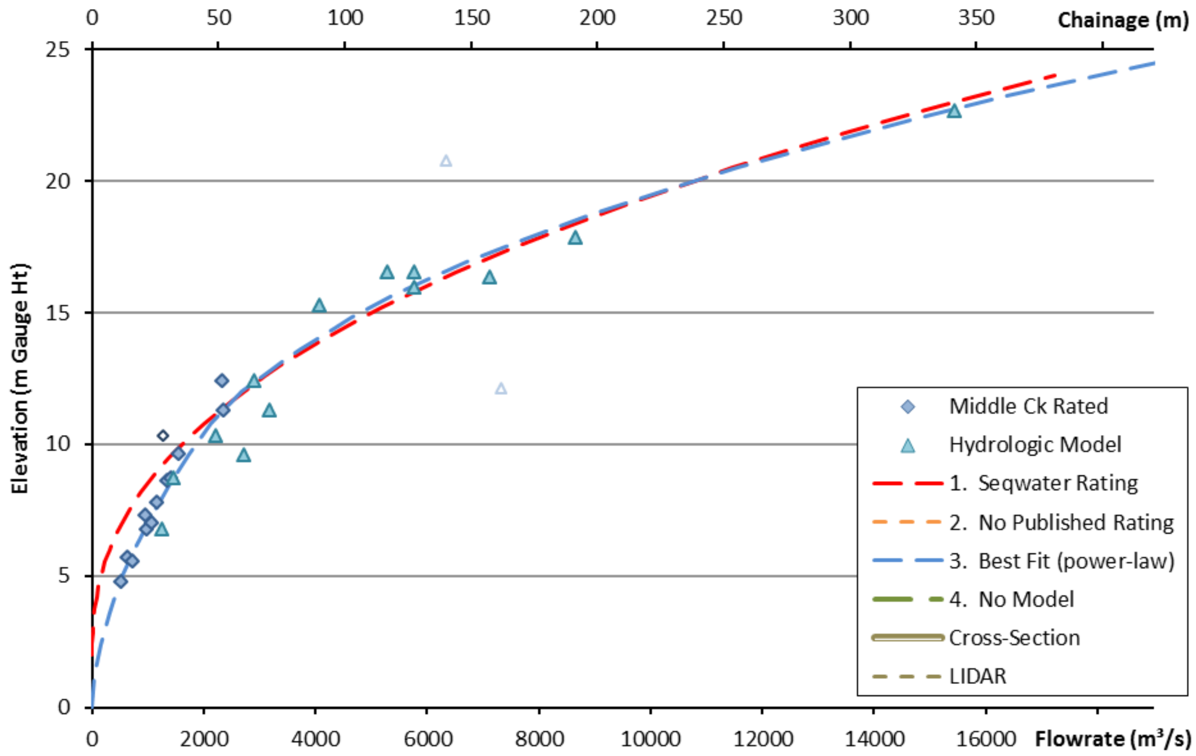


Figure 4-14 Rating Comparison – Brisbane River @ Caboonbah

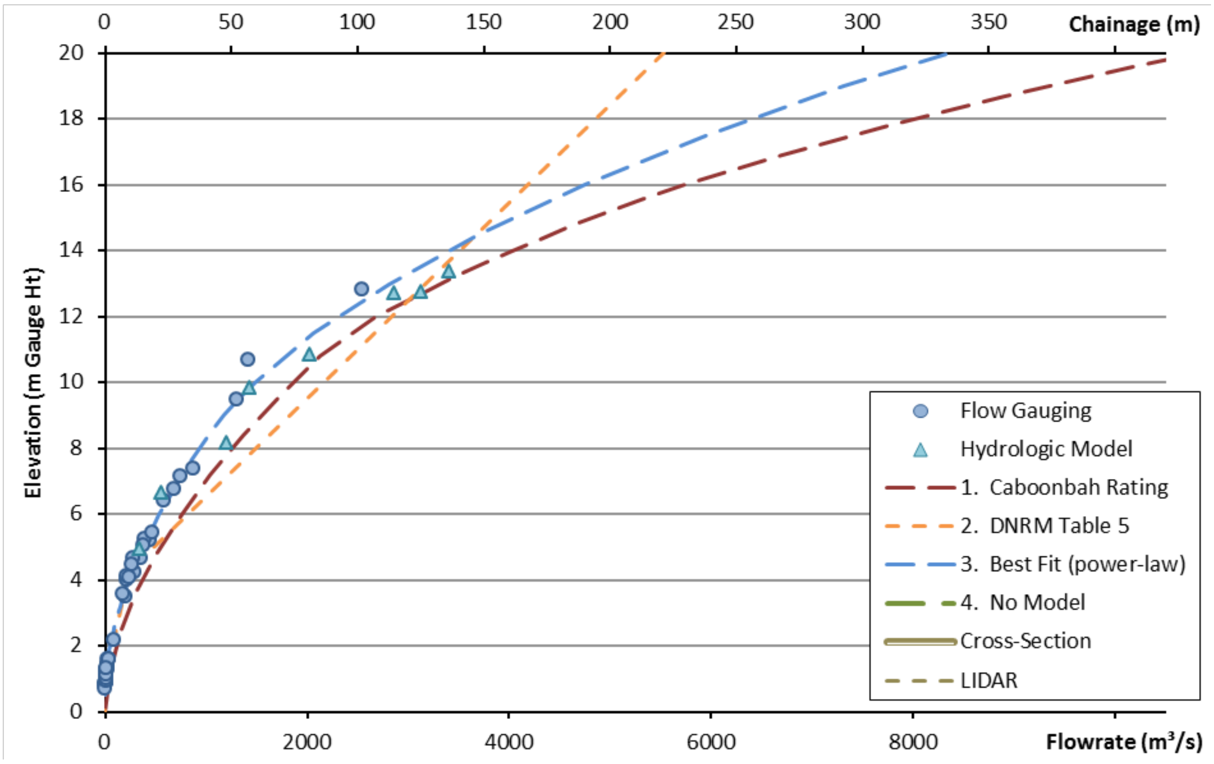


Figure 4-15 Rating Comparison – Brisbane River @ Middle Creek

4.3 Lockyer Creek to O'Reilly's Weir

The Lockyer Creek is a major tributary of the Brisbane River catchment, joining the Brisbane River a short distance downstream of Wivenhoe Dam. The total area of the Lockyer Creek catchment to O'Reillys Weir is 2,964 km². The catchment features numerous tributaries, including Fifteen Mile, Murphy's and Alice Creeks upstream of Helidon, Flagstone and Sandy Creeks upstream of Grantham, Ma Ma and Tenthill Creeks upstream of Gatton, and Laidley and Buraba Creeks between Gatton and the Brisbane River. The catchment varies significantly, with steep headwater areas and wide flat floodplain in the lower reaches.

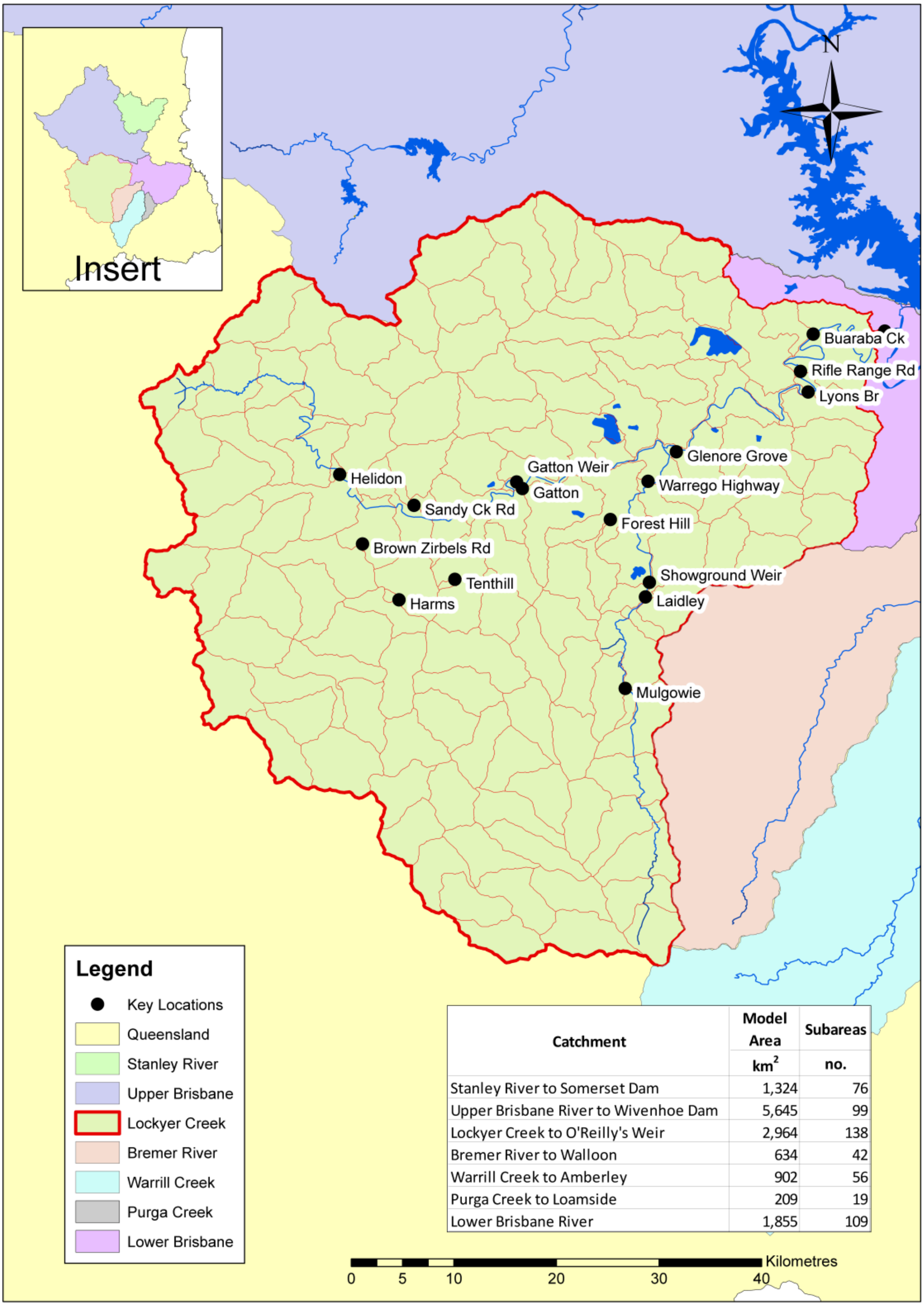
4.3.1 Summary of available gauge data

DNRM, Seqwater and BoM operate numerous gauges throughout the Lockyer Creek catchment, however the quality and usefulness of these gauges varies significantly. Gauge locations are shown in Figure 4-16 and available data for the major gauges are summarised in Table 4-8. Cross-sections of the main gauges are compared in Figure 4-17, highlighting the change in elevation and floodplain levels between the gauge sites.

Two flood gauges are located on Lockyer Creek in the vicinity of Gatton, covering approximately half the catchment area. The upstream gauge at Gatton Weir has only limited flood record and very limited flow gauging data, while the gauge at Gatton is a flood warning station with a long history but non-continuous records and no flow gauging. A rating for the Gatton gauge was derived from hydraulic modelling conducted as part of the Lockyer Flood Study (SKM 2013).The DNRM stream gauge on Laidley Creek at the Warrego Highway has a relatively short record length but is considered by DNRM to be a reliable rating with a good range of flow gaugings. A gauge is operated by BoM and Seqwater at Glenore Grove, near the confluence of Laidley Creek with Lockyer Creek, which covers over 70% of the catchment. Laidley Creek actually bifurcates to either side of the gauge site at the junction, which potentially complicates the discharge-level rating relationship.

Table 4-8 Lockyer Creek catchment gauge summary

Gauge	Area (km²)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Lockyer Creek @ Helidon	351 12%	3.4m 108m³/s	1926 -	Y	Fair	n/a
Lockyer Creek @ Gatton Weir	1527 52%	2.16m 26.5m³/s	2000 -		Good	n/a
Lockyer Creek @ Gatton	1527 52%	n/a	1893 -	N	Good	SKM Flood Study
Lockyer Creek @ Glenore Grove	2149 73%	n/a		Y		
Laidley Creek @ Warrego Hwy	469 16%	7.65m 985m³/s	1990 -	Y	<7.0 Good >7.0 Fair	n/a
Lockyer Creek @ Lyons Bridge	2432 82%	14.1m 595m³/s	1964 -1988	Y	<14 Good >14 Fair	
Lockyer Creek @ Rifle Range Rd	2521 85%	15.9m 829m³/s	1988 -	Y	<15 Good >15 Poor	



Catchment	Model Area km^2	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-16 Lockyer Creek to O'Reilly's Weir URBS model (from Seqwater 2013)

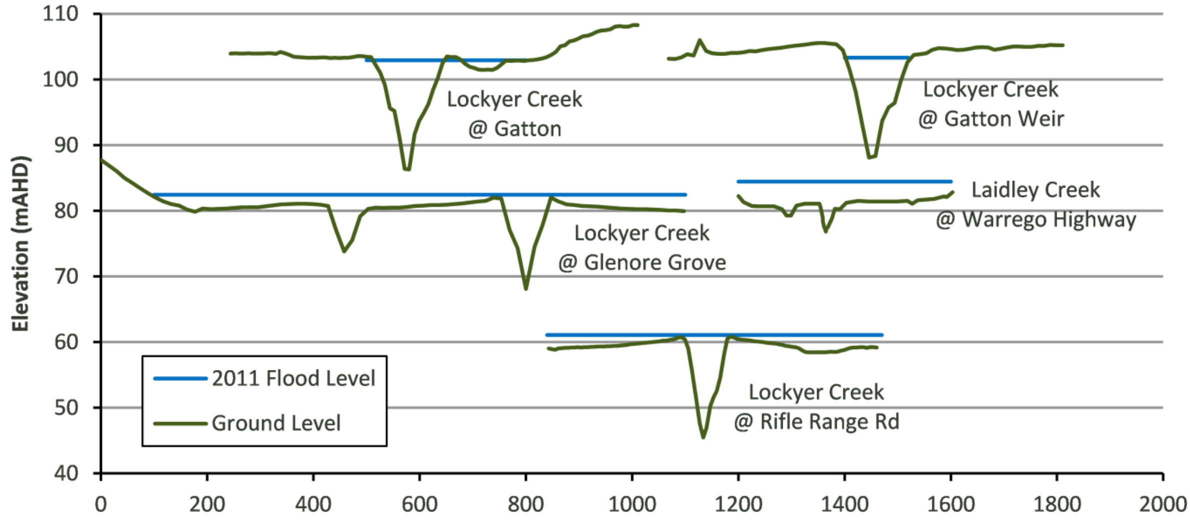


Figure 4-17 Lockyer catchment gauge location cross-sections

In the lower Lockyer Creek reach, a gauge was located at Lyons Bridge until 1988 when it was moved further downstream to the current location at Rifle Range Road. At these locations the creek forms an incised channel with the bank level perched above a very wide floodplain. Flow gaugings can define the in-channel rating with reasonable confidence, but complicated flow patterns and limited response significantly limit confidence in the depth-discharge relationship once breakout from the channel occurs. The Rifle Range Road gauge site is understood to be affected by Brisbane River flows during larger events. The furthest downstream gauge at O'Reilly's Weir is well rated for low flows but is subject to tailwater effects from Brisbane River floods.

4.3.2 Gauge selection for the Lockyer Creek catchment model

The best rated gauge in the Lockyer is currently considered to be the Laidley Creek gauge at Warrego Highway, however this only registers one tributary and 16% of the catchment and is potentially affected by backwater from Lockyer Creek. A good rating could potentially be achieved at one of the Gatton gauges, which command just over half the catchment. The Gatton Weir gauge has continuous records but only a short record length and very limited flow gaugings, while the Gatton gauge has a long flood history but does not have continuous flow records or any flow gauging. A model study has already been conducted at this site by SKM, but the limited gauge data available means that further improvement of the rating at this site may have limited benefit.

The preferred option for the Lockyer Creek catchment would be to develop a reliable rating further downstream in the catchment, however the currently rated gauges at Lyons Bridge, Rifle Range Road and O'Reilly's Weir are highly unreliable for large flood events due to numerous issues including perched channel geometry, flow breakouts bypassing the gauge sites, and backwater from Brisbane River floods.

Considering all these issues, the most benefit to the Brisbane River Catchment Flood Study was considered to lie in trying to develop a reliable rating at Glenore Grove. This site has a good flood history and commands the largest proportion of the catchment not affected by Brisbane River floods, but is complicated by the potentially complex flow patterns and lack of gauged flow data.

4.3.3 Primary gauge rating – Lockyer Creek @ Glenore Grove

The Glenore Grove gauge is a BoM flood warning site that does not have an official rating or any flow measurements. The Seqwater rating was based only on hydrologic model results. Although there are no official flow measurements, the hydrologic modelling suggests a close relationship between flows at Glenore Grove and Lyons Bridge, particularly for in-channel flows. Flow estimates for the Glenore Grove site were obtained by matching levels recorded at Glenore Grove with flows derived from Lyons Bridge, using both flow gauging and rated flows from flood event peaks. The Lyons Bridge rating is considered reliable up to the highest rated flow of 595 m^3/s. Higher flows will become increasingly less reliable, but provide an alternative source of data to the hydrologic modelling. The highest reported flow (rated) at Lyons Bridge is 2319 m^3/s, corresponding to a gauge height of 14.94 m at Glenore Grove. Significant out-of-bank flows and bypass issues would be expected at the Lyons Bridge site for this flow, so this is not considered reliable (and could be expected to under-estimate the actual flow).

A MIKE 21 two-dimensional hydraulic model has been prepared for the section of Lockyer Creek extending approximately 5.5 km upstream and 5.5 km downstream from the BoM gauge at Glenore Grove, including both Lockyer and Laidley Creeks. The model was based on a Digital Terrain Model (DTM) developed from the LiDAR survey data sourced as part of the BRCFS Data Collection phase. No cross-section data is available at the Glenore Grove site, however the LIDAR shows very good agreement with the gauge cross-section at Rifle Range Road (Figure 4-27) and reasonable agreement at Gatton Weir (Figure 4-21). A grid spacing of 10 m was adopted for the two-dimensional domain. Details of the model are provided in Appendix B.

The MIKE 21 model was developed as a steady-state model (constant flow) and used to assess a range of flows through Lockyer and Laidley Creeks in order to establish a rating curve at the Glenore Grove gauge. The gauge is located at a potentially complex site, with the Laidley Creek channel bifurcating at the junction to form an island. The gauge site is located on the Lockyer Creek channel between the confluences such that Laidley Creek flows may enter upstream and downstream of the gauge. Flow in the upstream bifurcation can also change direction depending on whether Lockyer or Laidley Creek is experiencing higher flows, such that Lockyer Creek flows can bypass around the gauge site. Due to these complicated flow patterns, the model was tested with 50/50 and 80/20 flow splits between Lockyer and Laidley Creeks (hydrologic modelling suggests that the peak discharge at the Warrego Highway gauge on Laidley Creek is typically between 20% and 60% of the peak flow at Gatton). The flow split was found to have negligible impact (<50 mm) on levels at the gauge location. It was therefore concluded that despite the bifurcation, flood levels are dominated by the behaviour of the combined channel downstream of the gauge and can therefore provide a reasonable rating of the total flows in Lockyer Creek downstream of the confluence.

In general the hydraulic model results show very good agreement with the translated Lyons Bridge flow data (with the possible exception of the highest rated flow) and also the hydrologic model results. This is considered a positive outcome and significant improvement in reliability of the gauge rating. Assessment of the gauge reliability in Table 4-9 shows significant scatter with a large confidence interval, although in this case it can be argued that this reflects the uncertainty of the calibration data rather than necessarily the variability of the rating. The gauge rating is considered reasonable up to around 13 m but becomes highly sensitive above this elevation, although the sensitivity appears to be less than further downstream at Rifle Range Road (see discussion in Section 4.3.7).

The relative variance of the rated discharge shown in Figure 4-19 shows consistent scatter and no significant trends in the in-channel rating (low to mid-range). The general trend in the upper rating, however, is to predict larger flows than are produced by the hydrologic modelling, although a reasonable agreement with the flow gauging is obtained. The 2011 flood event in particular, which is the highest recorded elevation event at the site, gives a rated flow of nearly 4400 m^3/s, or 30% higher than the hydrologic model.

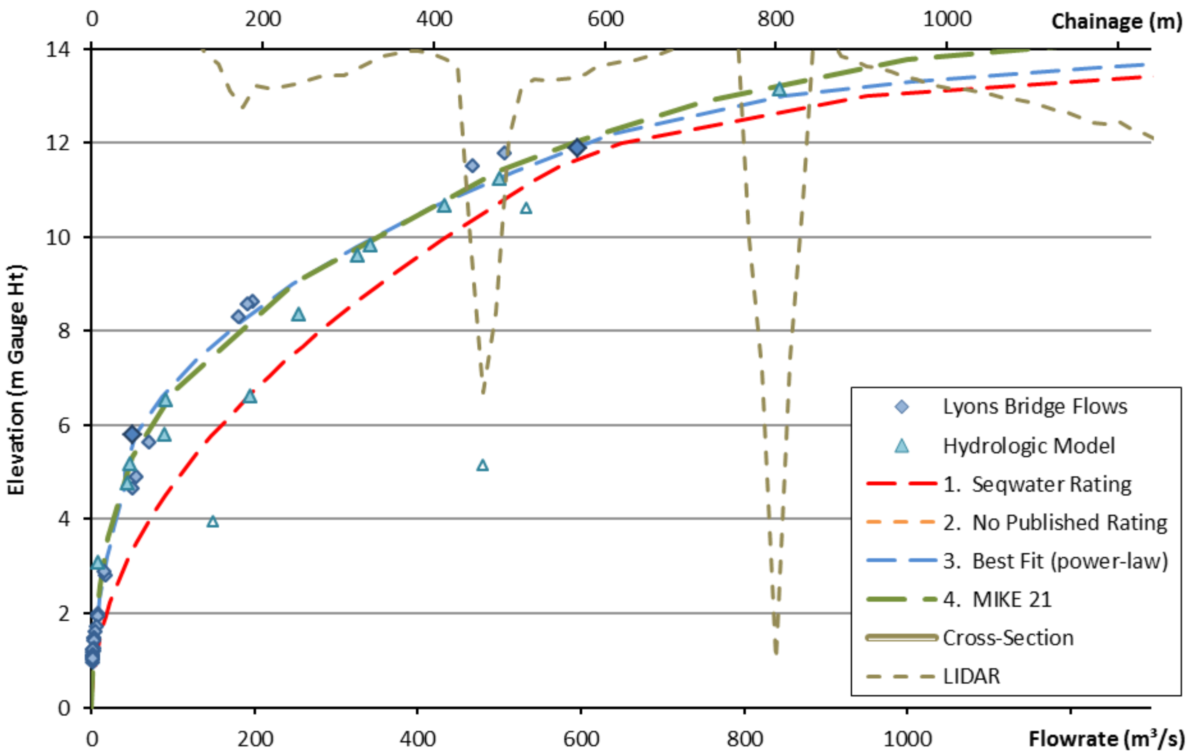


Figure 4-18(a) Rating Comparison – Lockyer Creek @ Glenore Grove (low – mid range)

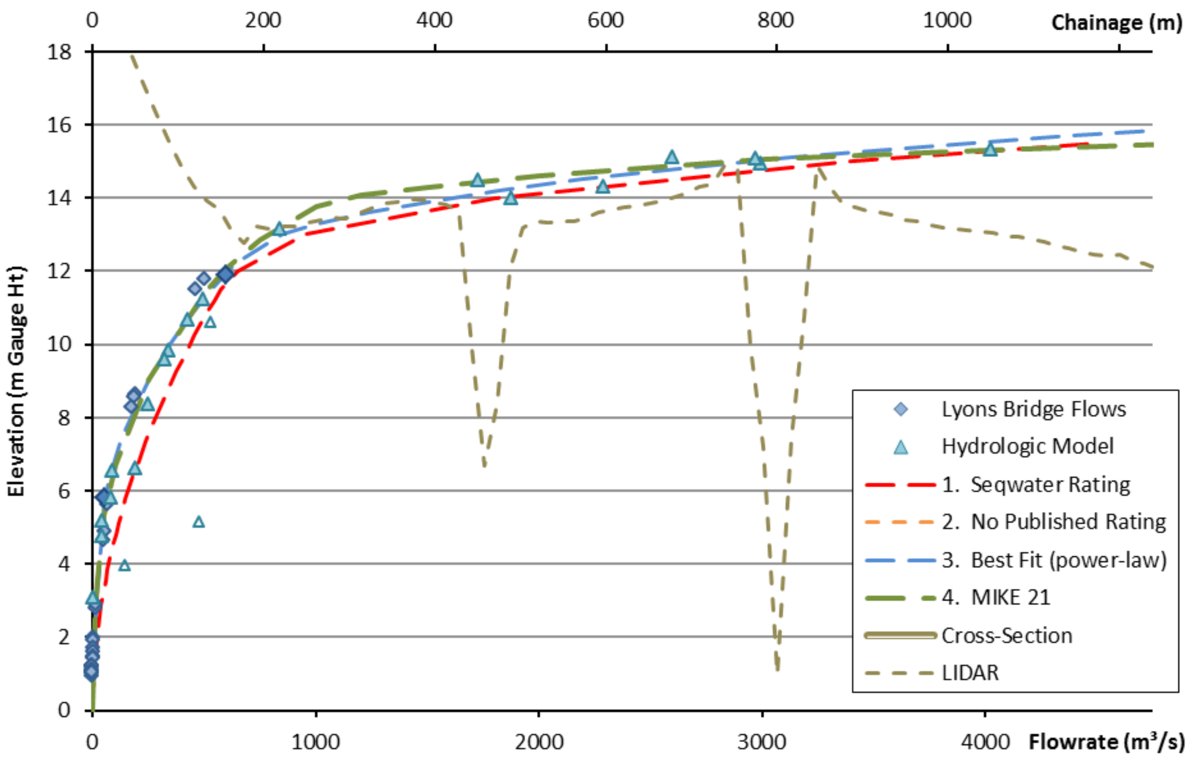


Figure 4-18(b) Rating Comparison – Lockyer Creek @ Glenore Grove (full range)

Table 4-9 Rating curve reliability assessment – Lockyer Creek @ Glenore Grove

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0 – 5	0 - 138	0 – 44.4	4	MIKE 21 model
5 - 13	138 - 915	44.4 - 786	9	MIKE 21 model
13 - 15.4	915 - 5690	786 - 4381	0	MIKE 21 model

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0 - 5	1.1%±32.3%	-11.5%±57.0%	0.417	0.187	2.0
5 - 13	-2.8%±10.4%	4.3%±62.9%	0.309	0.013	3.1
13 - 15.4	0.7%±2.7%	-12.0%±45.2%	0.022	0.332	11.5

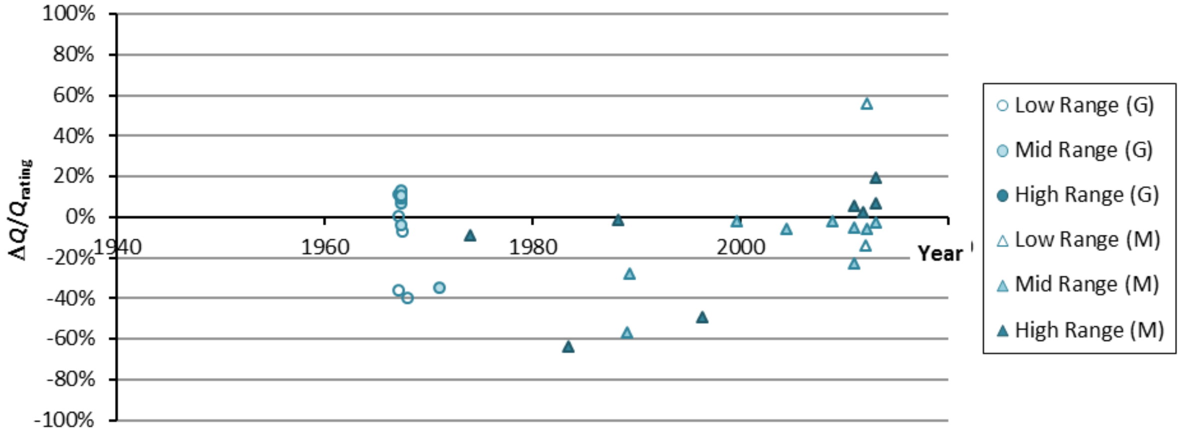


Figure 4-19 Relative variance of rated discharge – Lockyer Creek @ Glenore Grove

It is acknowledged that there is likely to be some roughness variation due to the rural nature of the site, and the discrepancy between the hydraulic and hydrologic model results could be reduced by increasing the roughness, although this would introduce greater discrepancy to the flow gaugings. Whether the discrepancy is a problem with the rating, the URBS model calibration in general, or specifically related to the 2011 event predictions has yet to be confirmed. Discussions with DSDIP/BCC regarding the ongoing development and calibration of the DMT TUFLOW model supports conclusions that the URBS flow predictions for the 2011 event are too low. This issue is discussed further in Section 4.7.6.

Overall, it is concluded that the Glenore Grove site is one of the most reliable of the lower Lockyer sites and is relatively well rated up to bank-full capacity, but that confidence in the gauge rating decreases significantly for out-of bank flows. The rating supports the inference that the peak flow of some large flood events may be underestimated by the current URBS model, and it is recommended that this is investigated further during the hydrologic model calibration review.

4.3.4 Secondary gauge rating – Lockyer Creek @ Gatton & Gatton Weir

Two gauges are located in relatively close proximity in the Gatton area. The BoM operates a flood warning gauge at Gatton while Seqwater owns and operates a gauge upstream at Gatton Weir. The Gatton gauge has non-continuous flood records dating as far back as 1893 but no official rating or flow gaugings, while Gatton Weir has a much shorter record and limited minor flow gaugings up to a maximum of 2.16 m gauge height corresponding to 26.5 m^3/s. A rating for the flood warning gauge at Gatton was derived from hydraulic modelling conducted by SKM in 2013 as part of the '*Lockyer Flood Study*'. The TUFLOW model has not been obtained from SKM, either by Seqwater or Aurecon, and the rating curve shown in the figures below has been reconstructed by Seqwater through comparison of recorded flood peaks and estimated flows from the documented results of the model.

Ratings for the Gatton and Gatton Weir gauges were derived by Seqwater from the SKM rating, limited flow gaugings at Gatton Weir and hydrologic model results. The ratings are provided in Figure 4-20 and Figure 4-21 respectively. The Seqwater rating at Gatton shows a shape consistent with the rating derived from the Lockyer Flood Study model. Overall, the review has concluded that Gatton and Gatton Weir are relatively good and consistent gauge sites up to the bank full capacity, but with limited calibration data to derive the ratings. It must be noted that the ratings do not extend above top of bank, where a significant change in cross-section and thus rating would be expected. The ratings therefore should not be extended above around 16 m gauge height.

During the hydrologic model calibration and flood frequency analysis processes, comparison of rated flows at Gatton with the gagues upstream (Helidon) and downstream (Glenore Grove, Lyons Bridge and Rifle Range Road) identified a potential issue with the low to mid-range of the Gatton rating, with Gatton producing higher flows than at Lyons Bridge/Rifle Range Road. The creek channel is relatively contained and the Lyons Bridge and Rifle Range Road ratings well defined at these flows. The Lockyer Flood Study model was not made available and the report provides insufficient data to validate the reliability of the calibration. It is noted that study jointly calibrated hydrologic and hydraulic models for the catchment, producing models that are consistent but not validated independent of each other. The primary source of calibration data appears to have been the major flood of 2011.

The Gatton rating was reassessed using a three-stage power-law best fit of hydrologic model data (calibrated primarily to the independently rated Glenore Grove gauge downstream). As shown in Figure 4-20, the rating has a different shape to the Seqwater and Lockyer Flood Study ratings in the lower range but a similar trend for high flows. Assessment of the data variability and sensitivity is provided in Table 4-10 and Figure 4-22.

Table 4-10 Rating curve reliability assessment – Lockyer Creek @ Gatton

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0 - 4	0 - 98.4	0	4	Best fit of hydrologic model data
4 - 8	98.4 - 344	0	7	Best fit of hydrologic model data
8 - 16	344 - 2651	0	7	Best fit of hydrologic model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0 - 4	8.7%±20.6%	-19.3%±41.1%	0.338	0.017	1.6
4 - 8	-31.5%±31.5%	35.3%±26.3%	0.434	0.057	1.9
8 - 16	1.1%±16.2%	-8.5%±53.4%	0.222	0.000	2.9

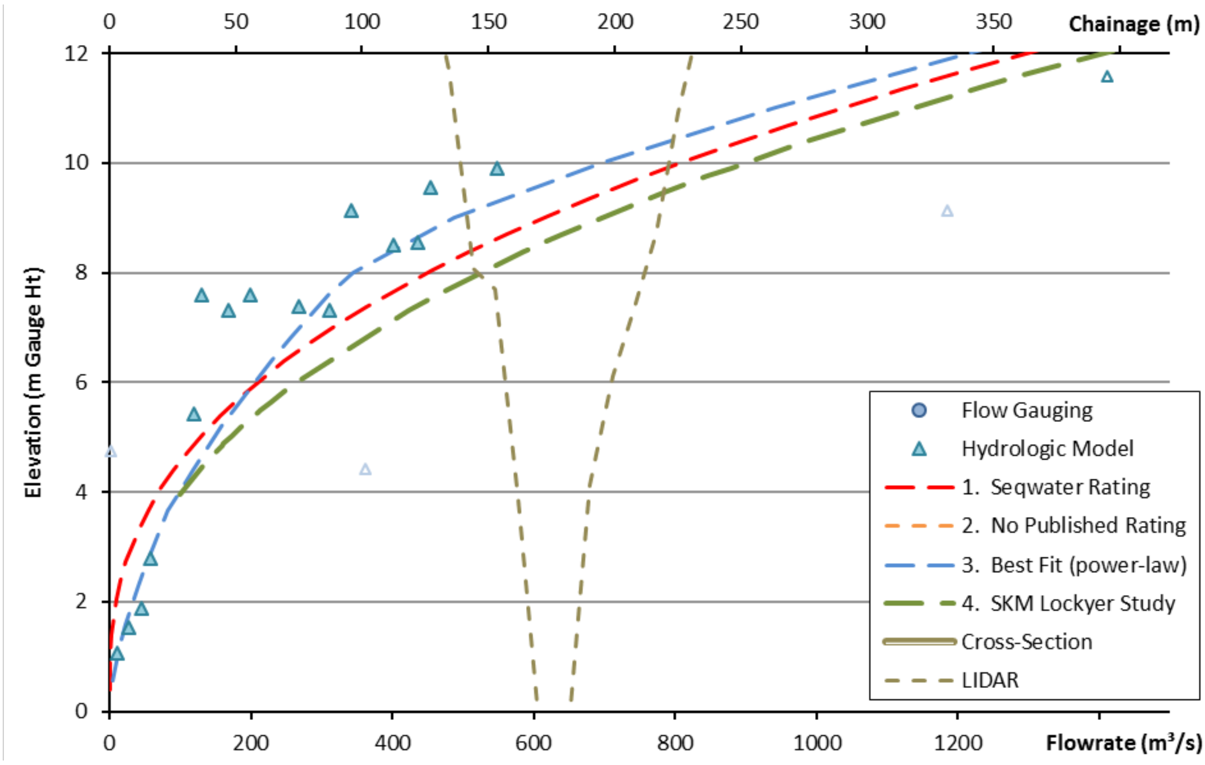


Figure 4-20(a) Rating Comparison – Lockyer Creek @ Gatton (low – mid range)

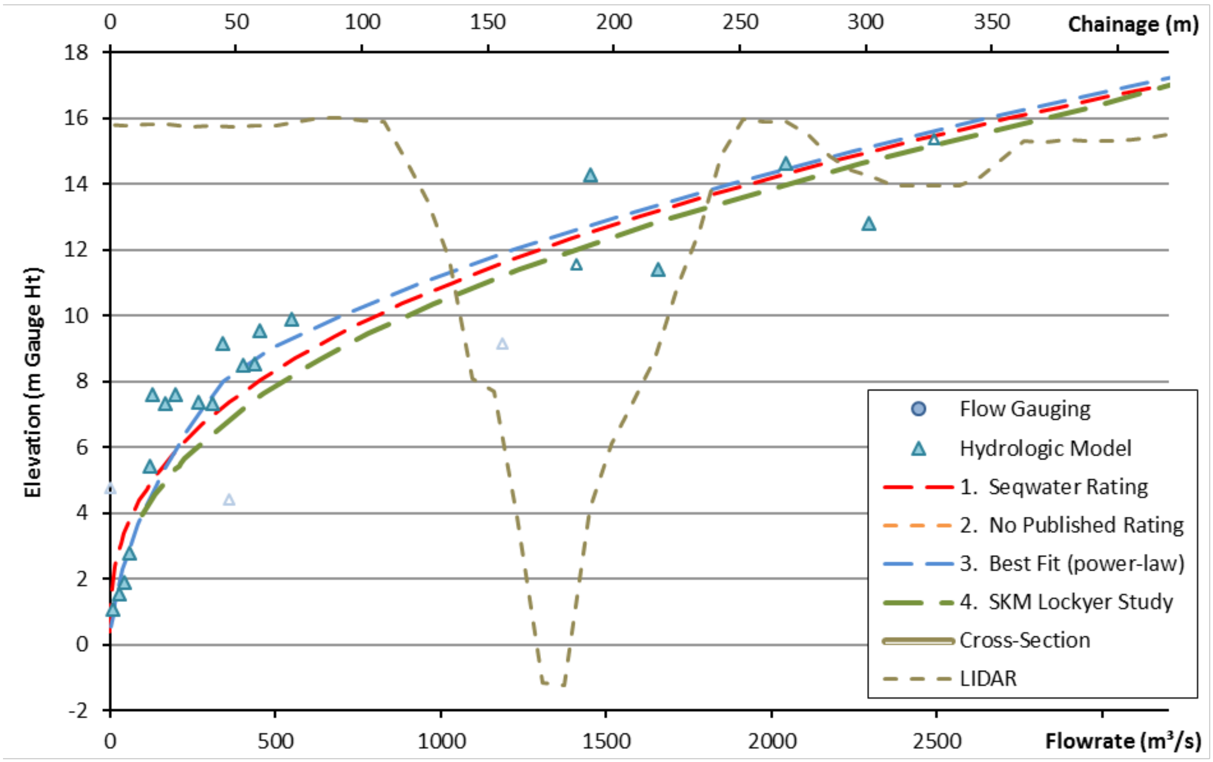


Figure 4-20(b) Rating Comparison – Lockyer Creek @ Gatton (full range)

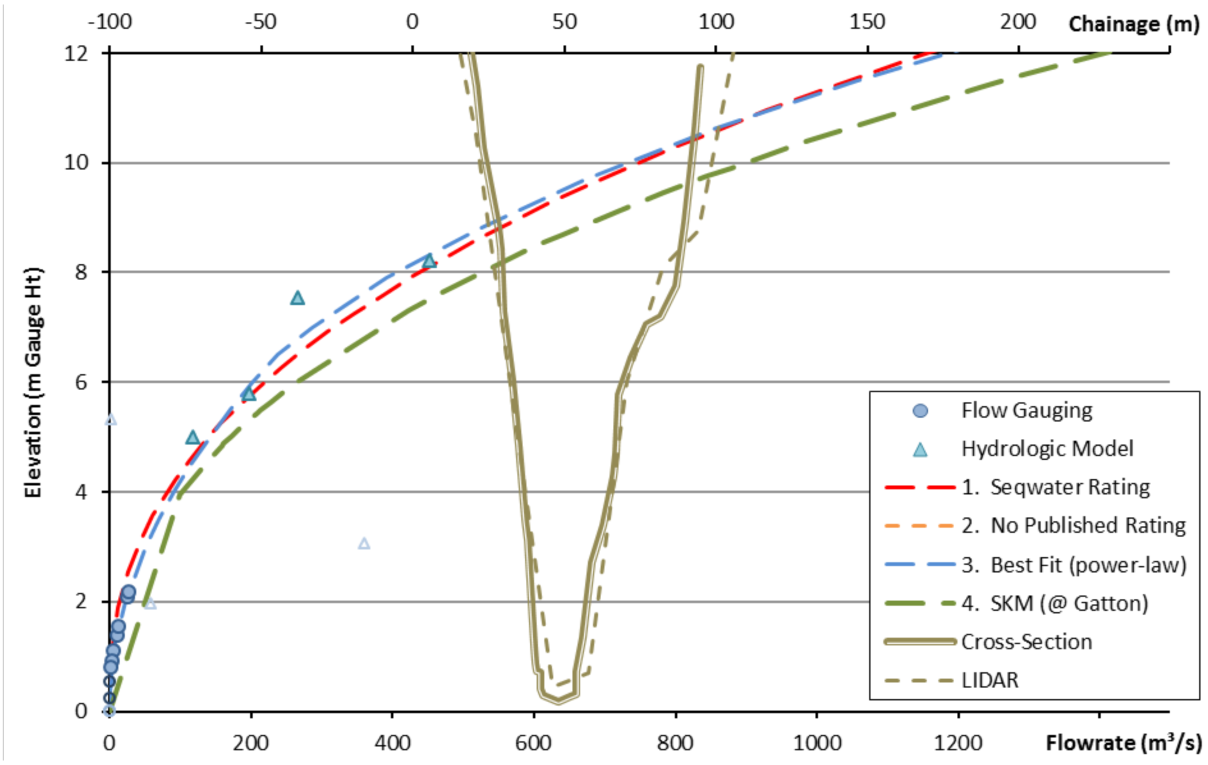


Figure 4-21(a) Rating Comparison – Lockyer Creek @ Gatton Weir (low – mid range)

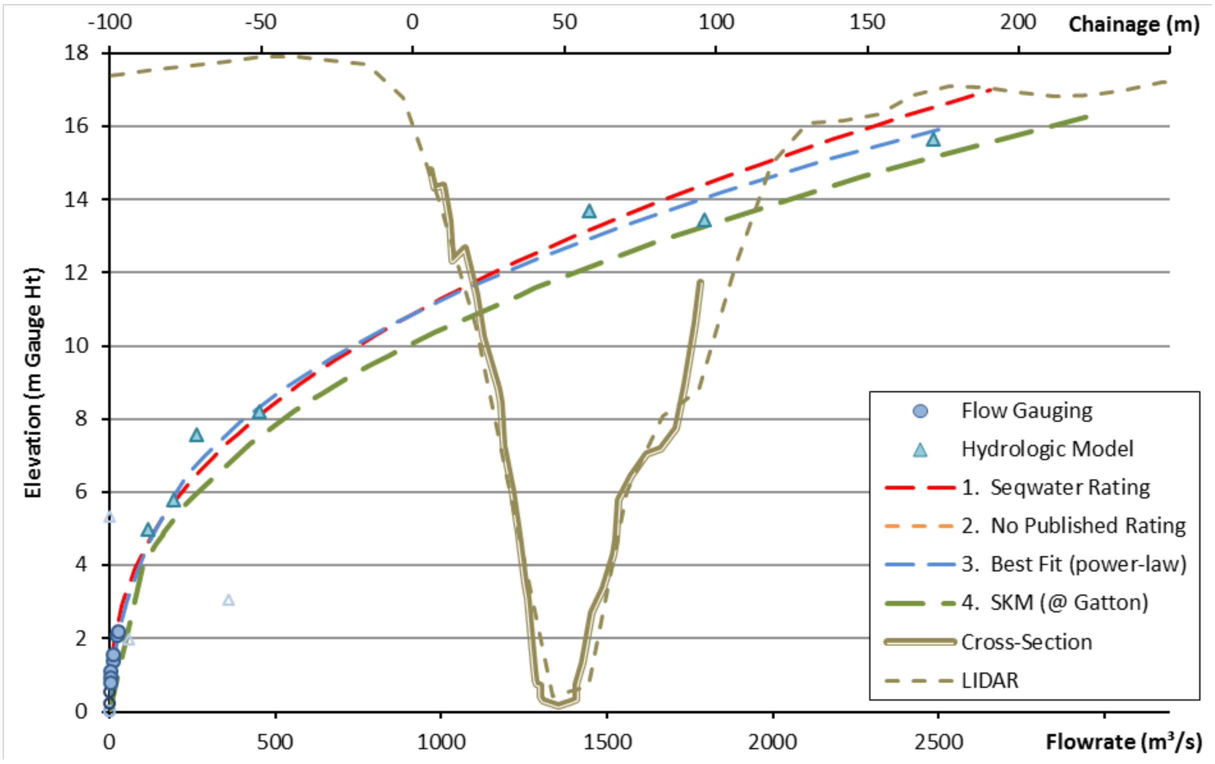


Figure 4-21(b) Rating Comparison – Lockyer Creek @ Gatton Weir (full range range)

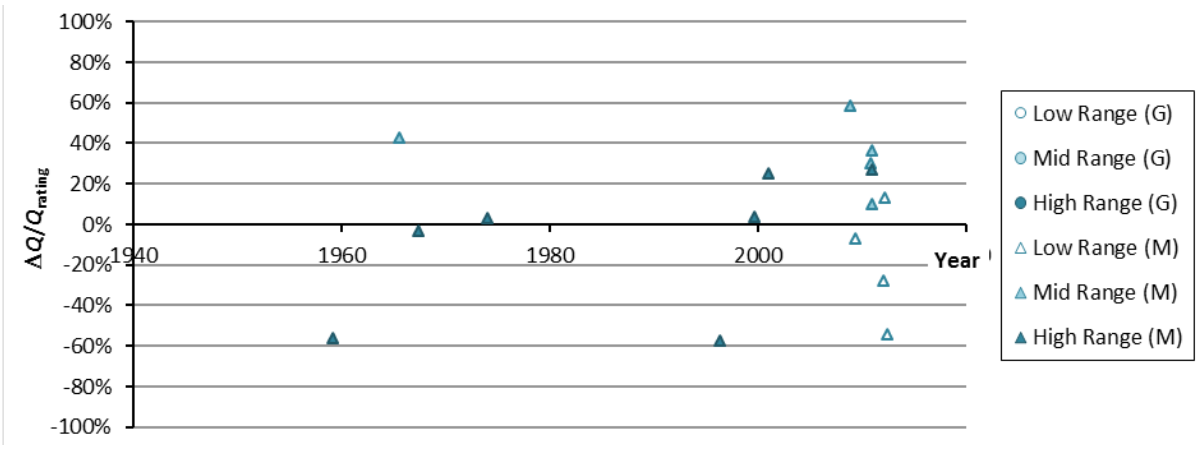


Figure 4-22 Relative variance of rated discharge – Lockyer Creek @ Gatton

Figure 4-21 suggests that the Seqwater rating provide a generally good match of the limited data available at Gatton Weir although a slightly better match of the gauged flows and recalibrated hydrologic model data could potentially be achieved, however there is currently insufficient data at this site to improve rating or provide significant value to model calibration or flood frequency analysis. No further review of the rating at this site has been undertaken.

4.3.5 Secondary gauge rating – Lockyer Creek @ Helidon

DNRM has historically operated three separate gauging sites at Helidon, located in the upper Lockyer Creek catchment. The Helidon No. 1 and No. 3 sites (1926-1971 and 1987 onwards respectively) are located within 0.2 km of each other, while the Helidon No. 2 site (1966-1988) is 5 km downstream. Although stream gauge records at Helidon extend back to 1926, review of the data has identified issues with the gauge data availability and consistency:

- Helidon No.1 has only minor flow gauging and exhibits a number of minor drifts in datum
- Helidon No.2 has the highest flow gauging but both level record and flow gaugings display a significant datum shift in 1976
- Helidon No.3 has limited flow gauging (up to 3.4 m and 110 m^3/s)

The Helidon No.3 rating was reassessed using a three-stage power-law best fit of stream flow measurement and hydrologic model data. As shown in Figure 4-23, the low to mid-stage rating shows good consistency with the DNRM rating up to around 3.5 m, consistent with the available flow gauging data. The high-flow rating, which is based solely on hydrologic model data deviates somewhat from the DNRM rating. Manning’s normal flow depth calculations indicate that the shape of the power-law rating is consistent with the cross-section profile at this site.

Assessment of the data variability in Table 4-11 and Figure 4-24 identifies a moderate amount of scatter in the gauged data. The hydrologic model data shows a high degree of variability, which is consistent with the model calibration weighted heavily towards the Glenore Grove site which has approximately six times the catchment area.

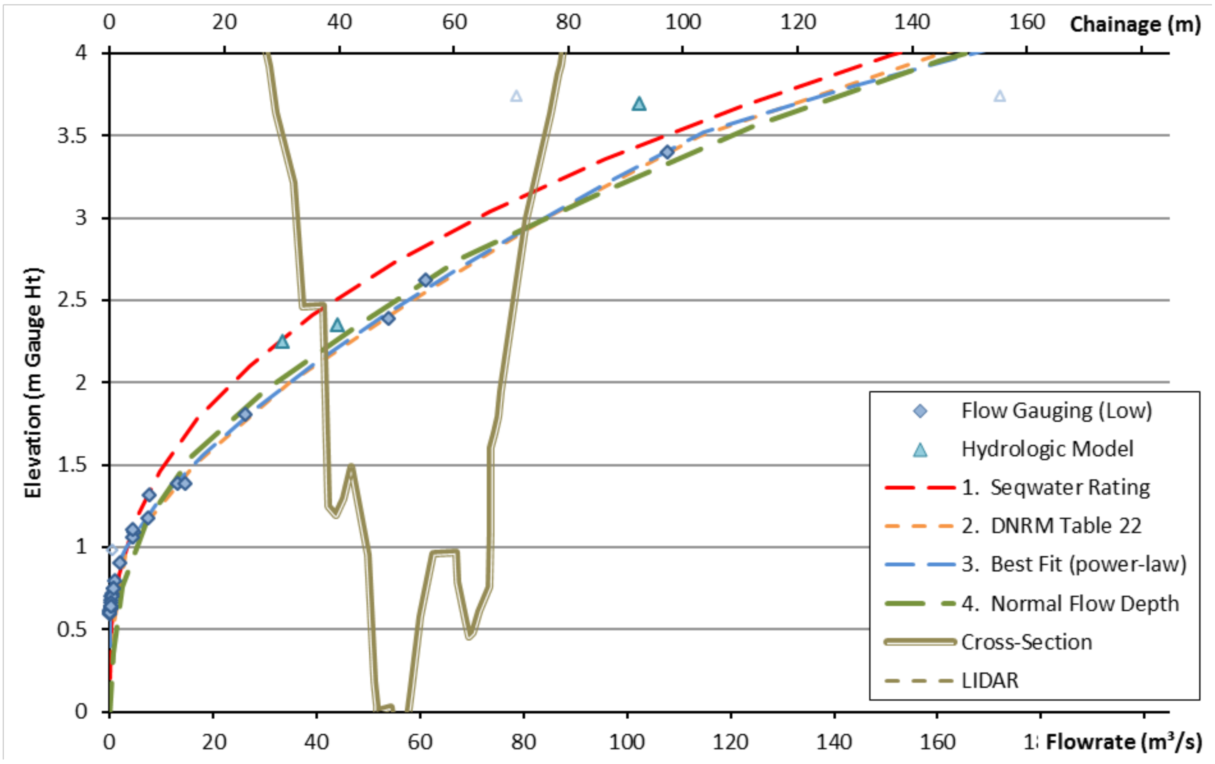


Figure 4-23(a) Rating Comparison – Lockyer Creek @ Helidon (low – mid range)

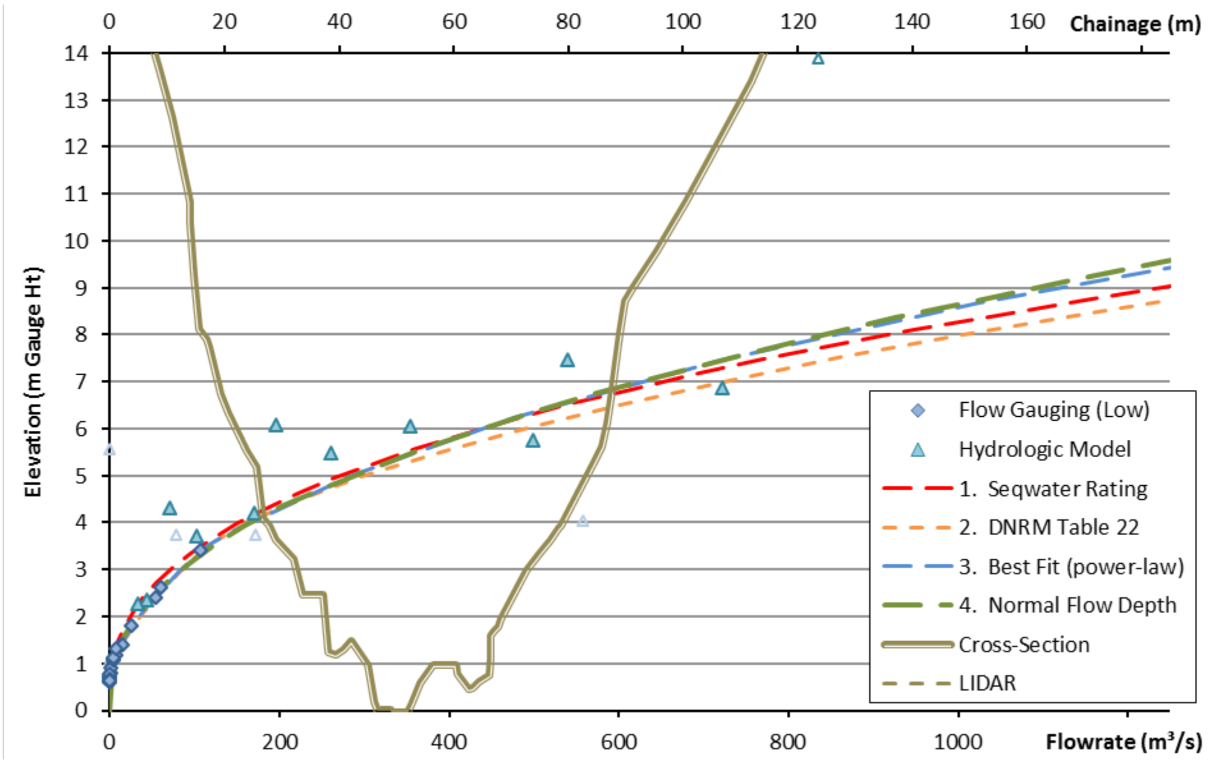


Figure 4-23(b) Rating Comparison – Lockyer Creek @ Helidon Highway (full range)

Table 4-11 Rating curve reliability assessment – Lockyer Creek @ Helidon

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.4 - 1	0.4 - 1	0 - 3.19	20	Best fit of gauging and model data
1 - 3.8	1 - 3.8	3.19 - 144	11	Best fit of gauging and model data
3.8 - 16	3.8 - 16	144 - 4260	0	Best fit of gauging and model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.4 - 1	-2.9%±5.1%	16.0%±26.6%	0.635	0.235	7.0
1 - 3.8	-8.7%±72.5%	-91.4%±602.7%	0.188	0.054	2.5
3.8 - 16	-55.3%±43.5%	54.0%±28.9%	0.087	0.115	2.8

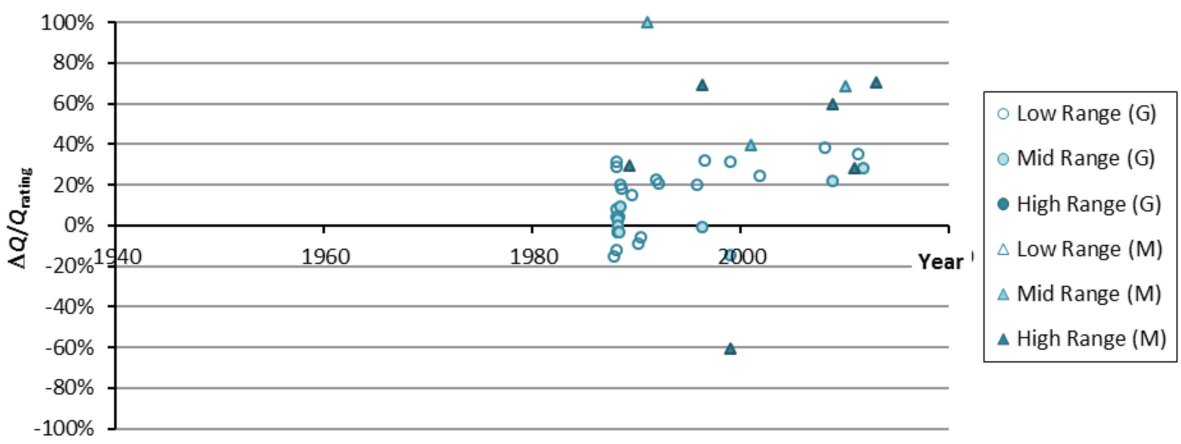


Figure 4-24 Relative variance of rated discharge – Lockyer Creek @ Helidon

4.3.6 Secondary gauge rating – Laidley Creek @ Warrego Highway

The Laidley Creek gauge at the Warrego Highway has a relatively short record but is well gauged up to a maximum of 7.6 m gauge height, corresponding to 985 m^3/s. The Seqwater rating appears to be based heavily on the flow gaugings and agrees closely with the DNRM rating up to around 7.5 m gauge height. The flow gaugings and ratings appear to be consistent with the cross-section shape, and were confirmed by a Manning's normal-depth flow calculation.

Assessment of the data variability in Table 4-12 and Figure 4-25 identifies a relatively large amount of scatter in the low-flow gauged data, and the DNRM rating also appears to over-predict discharges of the low-flow gaugings, which is not necessarily ideal BCRFS objectives, however these statistics are heavily weighted by a large number of very low flow ratings. The gauge rating appears relatively sensitive above 7 m gauge height and care should be taken when considering levels above the highest flow gauging. Seqwater has also identified that the gauge may be affected by backwater from the confluence with Lockyer Creek at Glenore Grove, and this concern may be justified by comparison of the channel levels in Figure 4-17, however flood levels at Glenore Grove plateau quickly above the floodplain level and the 2011 flood levels shows a reasonable change in elevation (approximately 2 m) between the Warrego Highway and Glenore Grove gauges. The gauge calibration data shows no conclusive evidence of any backwater effects.

The DNRM rating has been adopted for the Warrego Highway gauge site. The gauge is considered to be well rated and relatively reliable based on the range of flow gauging data available. The rating should be used with caution at high levels due to sensitivity of the rating to changes in depth. Backwater effects from Lockyer Creek are considered to be possible, however a significant imbalance between Laidley and Lockyer creek flows would be required so this should be rare. Considering the proportion of the catchment serviced by the Warrego Highway gauge and the range and reliability of the flow gaugings, no additional review or modelling is proposed.

Table 4-12 Rating curve reliability assessment – Laidley Creek @ Warrego Highway

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.505 - 3.4	0 - 17.2	20	1	DNRM Rating
3.4 - 5.5	17.2 - 156	3	10	DNRM Rating
5.5 - 8.2	156 - 1450	2	7	DNRM Rating

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dZ}$
0.505 - 3.4	-21.7%±16.7%	55.1%±47.8%	0.767	0.794	2.3
3.4 - 5.5	-1.8%±5.5%	3.8%±33.3%	0.093	0.009	4.9
5.5 - 8.2	-0.3%±4.0%	0.5%±20.8%	0.359	0.087	5.5

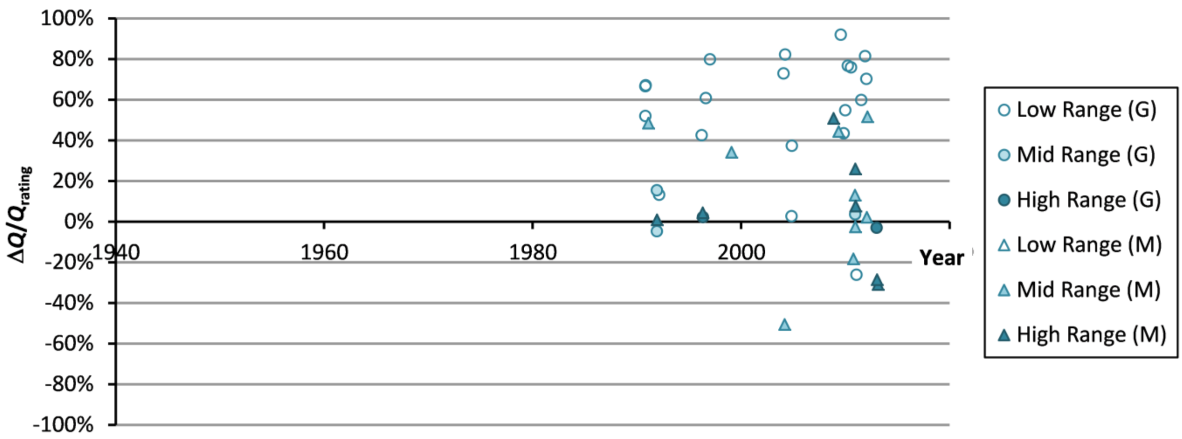


Figure 4-25 Relative variance of rated discharge – Laidley Creek @ Warrego Highway

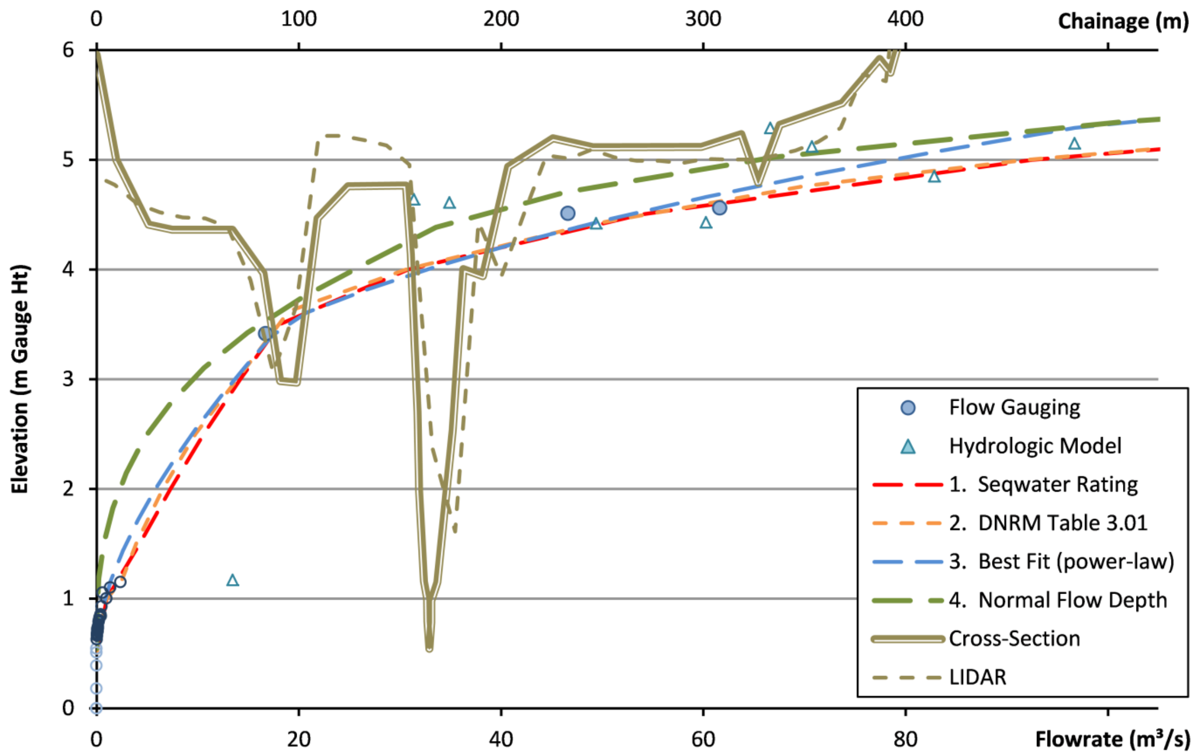


Figure 4-26(a) Rating Comparison – Laidley Creek @ Warrego Highway (low – mid range)

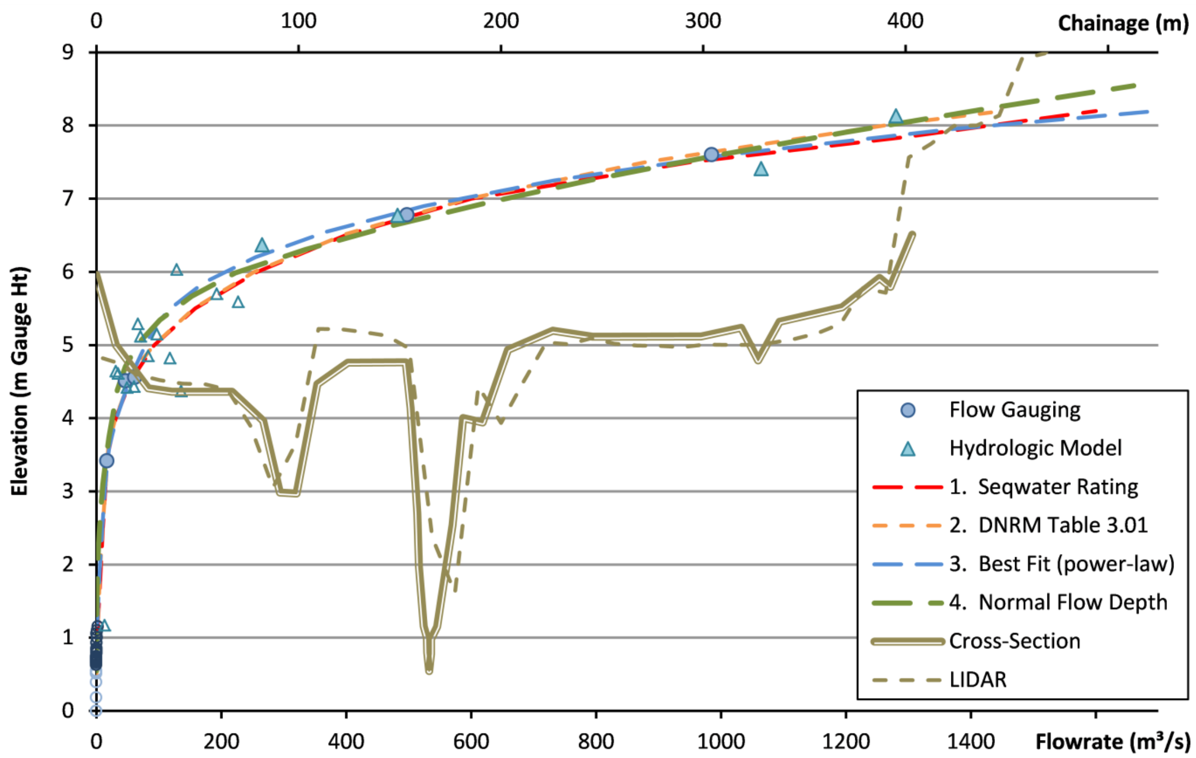


Figure 4-26(b) Rating Comparison – Laidley Creek @ Warrego Highway (full range)

4.3.7 Secondary gauge rating – Lockyer Creek @ Rifle Range Road

The Lockyer Creek gauge at Rifle Range Road has a relatively short historical record but over 130 flow gaugings up to a maximum of 15.85 m gauge height corresponding to 830 m³/s. For in-channel flows up to 15 m gauge height Seqwater has adopted the DNRM rating, which fits well with the flow gaugings. Above the bank height the Seqwater rating curve rapidly plateaus, with large changes in flow causing minimal change in level. The Seqwater rating, influenced by hydrologic model results predicts an increase of only 1 m for flows between 1000 m³/s and 5000 m³/s. The current DNRM rating (Table 2.00) does not extend above bank-full discharge.

As shown in Figure 4-27(a), there is a reasonable degree of scatter in the flow gauging data, which is likely contributed to by changes in vegetation in the channel, and the DNRM rating appears to align with the lower discharge side of the data. Consequently Aurecon has developed an independent best-fit of the data, which is preferred for the purposes of the BRCFS as it is considered more representative of average values. Variability of the data is summarised in Table 4-13 and Figure 4-28.

The lower reach of Lockyer Creek is a perched channel in very wide floodplain and as such the gauge site has a number of significant limitations including:

- The level on each floodplain may be different from each other and that in the channel, and cannot be measured by the gauge
- Due to the agricultural use of the floodplain, roughness may vary significantly and flood levels potentially exhibit strong seasonal behaviour
- The gauge site may be affected by backwater from Brisbane River

Because of these issues it is virtually impossible to develop a reliable rating for high flows. The proposed rating is considered reasonable of average values for in-channel flows, but the gauge is not recommended for use above bank full or around 15.5 m gauge height. No additional review or modelling is proposed at this site.

Table 4-13 Rating curve reliability assessment – Lockyer Creek @ Rifle Range Road

Range (m)	Discharge (m³/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.5 - 10	0.0208 - 179	70	10	Best fit of gauging and model data
10 - 16	179 - 1205	5	9	Best fit of gauging and model data
16 - 17	1205 - 5000	0	3	Best fit of gauging and model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.5 - 10	-11.0%±25.0%	20.4%±50.5%	0.246	0.169	2.1
10 - 16	-0.6%±3.3%	4.2%±19.5%	0.035	0.460	7.0
16 - 17	-0.7%±2.8%	11.9%±48.7%	0.921	0.094	12.9

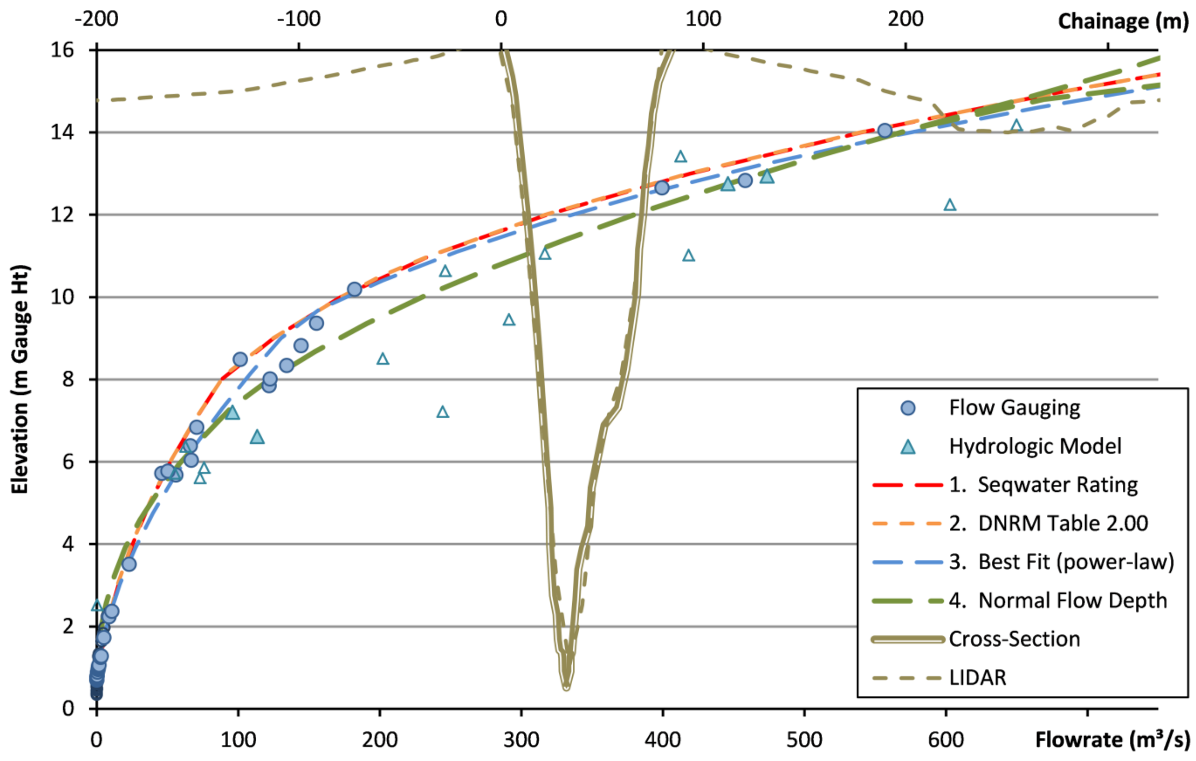


Figure 4-27(a) Rating Comparison – Lockyer Creek @ Rifle Range Road (low – mid range)

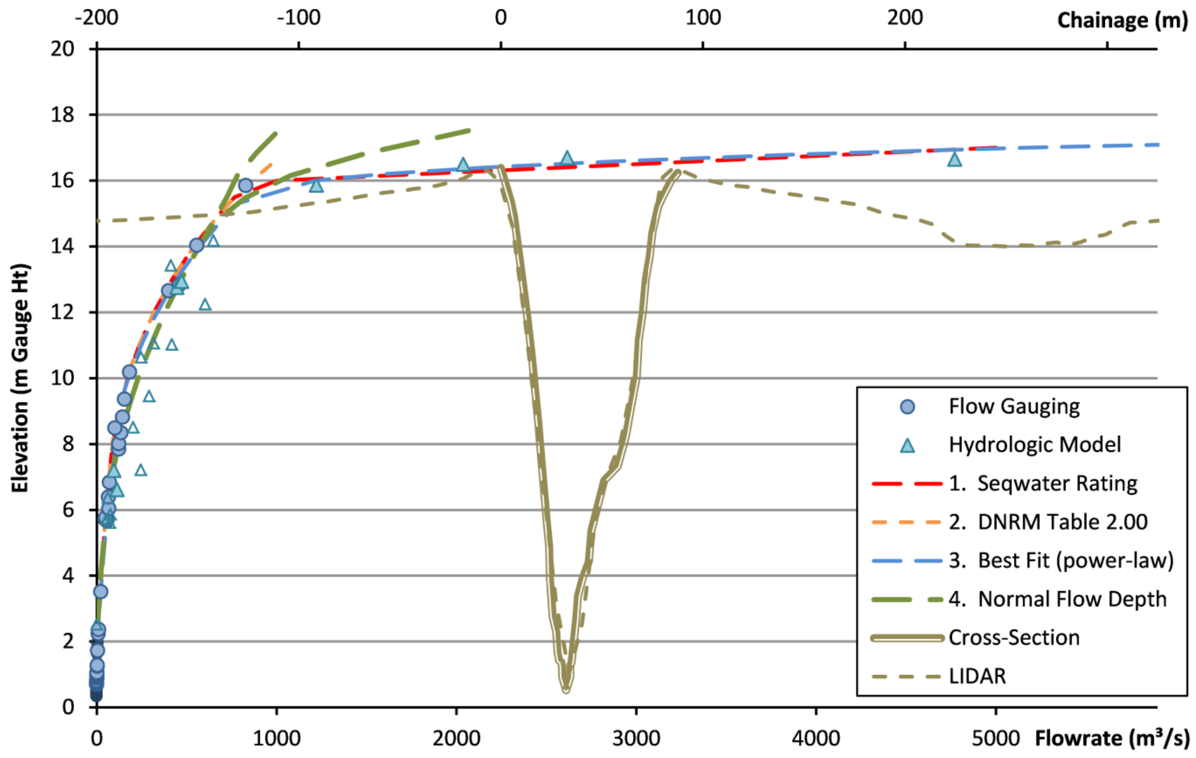


Figure 4-27(b) Rating Comparison – Lockyer Creek @ Rifle Range Road (full range)

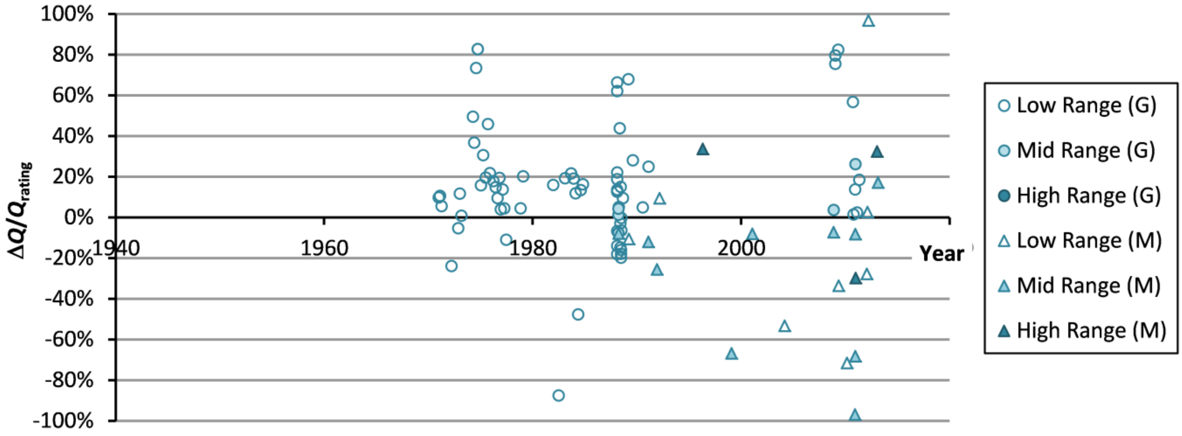


Figure 4-28 Relative variance of rated discharge – Lockyer Creek @ Rifle Range Road

4.4 Bremer River to Walloon

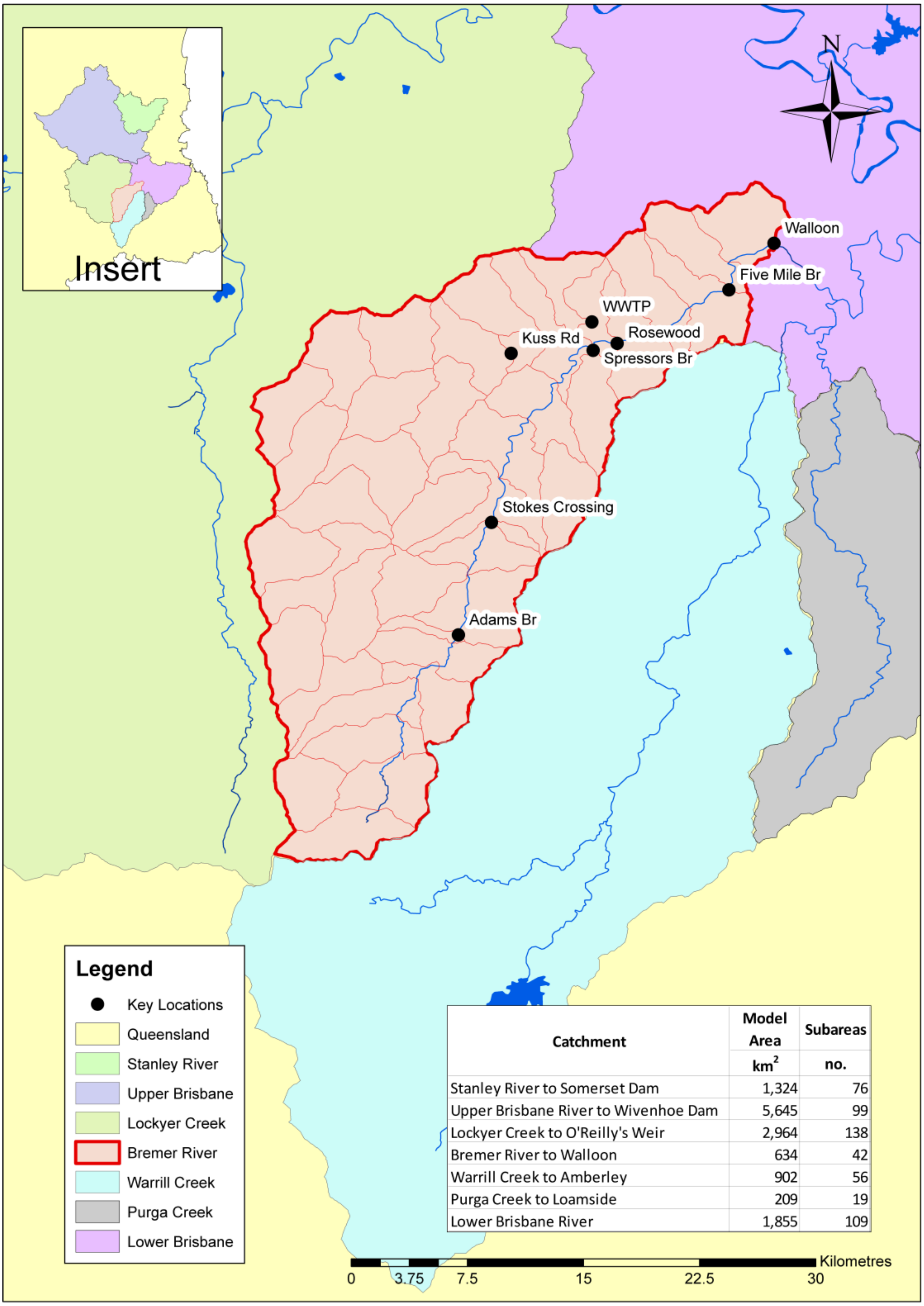
The Bremer River is a major tributary of the Brisbane River. The catchment has been subdivided into three separate URBS models – Bremer River to Walloon, Warrill Creek to Amberley and Purga Creek to Loamside. The Bremer River catchment to Walloon is the second largest of these three models with an area of 634 km². It includes the upper Bremer River and Western Creek. The lower Bremer River floodplain is included in the Lower Brisbane River model.

4.4.1 Summary of available gauge data

DNRM, Seqwater and BoM operate several gauges in the Bremer River catchment, primarily on the Bremer River. Gauge locations are shown in Figure 4-29 and available data for the major gauges are summarised in Table 4-14. Only the DNRM gauges currently have flow gauging and discharge rating curves. The DNRM gauges on the upper Bremer River gauge at Adams Bridge and at the model outlet at Walloon both have reasonable history of flood data and flow gaugings. BoM gauges at Rosewood and Five Mile Bridge have good historical data but are currently unrated.

Table 4-14 Bremer River catchment gauge summary

Gauge	Area (km²)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Bremer River @ Adams Bridge	126 20%	4.2m 173m³/s	1968 -	Y	Fair	n/a
Bremer River @ Rosewood	546 86%	n/a	1994-	Y	n/a	n/a
Bremer River @ Five Mile Br.	601 95%	n/a		Y	n/a	n/a
Bremer River @ Walloon	634 100%	9.0m 835m³/s	1961 -	Y	<9.1 Good >9.1 Fair	n/a



Catchment	Model Area km²	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-29 Bremer River to Walloon URBS model (from Seqwater 2013)

4.4.2 Gauge selection for the Bremer River catchment model

The number of viable gauges in the Bremer River catchment is limited. The gauge at Adams Bridge has reasonable data available but commands only 20% of the catchment, while the Rosewood and Five Mile Bridge gauges command much greater catchment area but are BoM flood warning sites with no rating or flow data. The gauge at Walloon is located at the end of the model and has reasonable history and flow gauging information, and is the logical selection for detailed investigation, although it has been identified that the gauge is potentially affected by some backwater effects from further downstream.

4.4.3 Primary gauge rating – Bremer River @ Walloon

The Bremer River gauge at Walloon has over 150 flow gaugings, although the majority are for relatively small discharges. The maximum recorded gauging is 8.96 m gauge height corresponding to 835 m^3/s. The current DNRM rating (Table 16.01) appears to match the gauging data well for elevations below around 5m gauge height, but tends to under-predict flows between 5 and 9 m gauge height. The Seqwater rating adopts the DNRM rating up to 4 m gauge height, a power-law best-fit equation between 4 m and 9.1 m, and a manual fit of hydrologic model results above this.

A MIKE 21 two-dimensional hydraulic model has been prepared for the section of the Bremer River extending approximately 2.5 km upstream and 5 km downstream from the DNRM gauge at Walloon. The model was based on a Digital Terrain Model (DTM) developed from the LIDAR survey data sourced as part of the BRCFS Data Collection phase using a grid spacing of 7.5 m for the two-dimensional domain. Details of the model are provided in Appendix B. The MIKE 21 model was developed as a steady-state model (constant flow) and used to assess a range of flows through the Bremer River in order to establish a rating curve at the Walloon gauge. The MIKE 21 roughness parameters were adjusted within reasonable limits to achieve a best fit rating curve comparison against the flow gaugings.

The hydraulic model lacks the fine-scale definition to accurately represent low-flow stages of the channel, but in general model results match very well with the flow gauging data and hydrologic model results above around 4 m gauge height. The model results are virtually identical to the Seqwater Rating between 4 m and 9 m gauge height, but tends to project slightly lower elevations (higher discharges) than the Seqwater rating above this level.

The preferred BRCFS rating curve adopts the DNRM rating for low flows up to 4 m gauge height and the hydraulic model results above this elevation. Variation of the data from the rating curve is assessed in Table 4-15 and Figure 4-31. The low stage (DNRM rating) shows a relatively high variability, and the rating also tends to over-predict discharges slightly but is considered reasonable. The mid and high-level ratings show good consistency of data. There is no strong evidence of long-term variation of the gauge rating.

Overall, Walloon is considered to be a good gauge site with a fairly reliable rating curve, particularly for small to moderate flood events. The gauge high flow rating is relatively sensitive to changes in elevation and may be subject to variability in floodplain vegetation. Additionally, review of DMT TUFLOW model results and Bremer River flood slopes during historical flood events (presented in Figure 7-51 of Seqwater 2013) suggests that during major floods a choke point develops in the downstream of the Bremer River and Warrill Creek confluence, which is itself subject to backwater from Brisbane River flooding. Due to the sensitivity of the rating even minor backwater influence can register as a large change in flow. Development and implementation of a multi-parameter rating (Bremer River and Warrill Creek flows, Brisbane River level) into the URBS model framework is difficult and outside the scope of the review. The rating is considered reliable for Bremer River catchment floods but should be treated with caution for major Warrill Creek/Brisbane River floods.

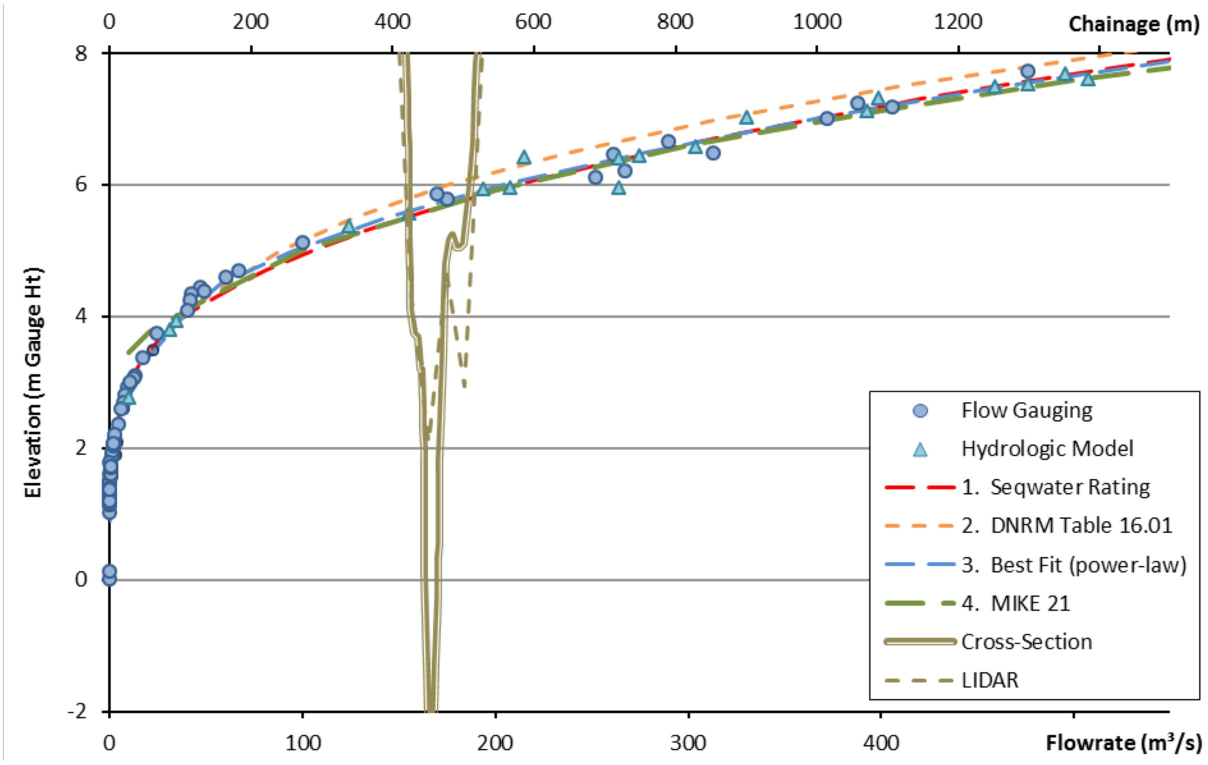


Figure 4-30(a) Rating Comparison – Bremer River @ Walloon (low – mid range)

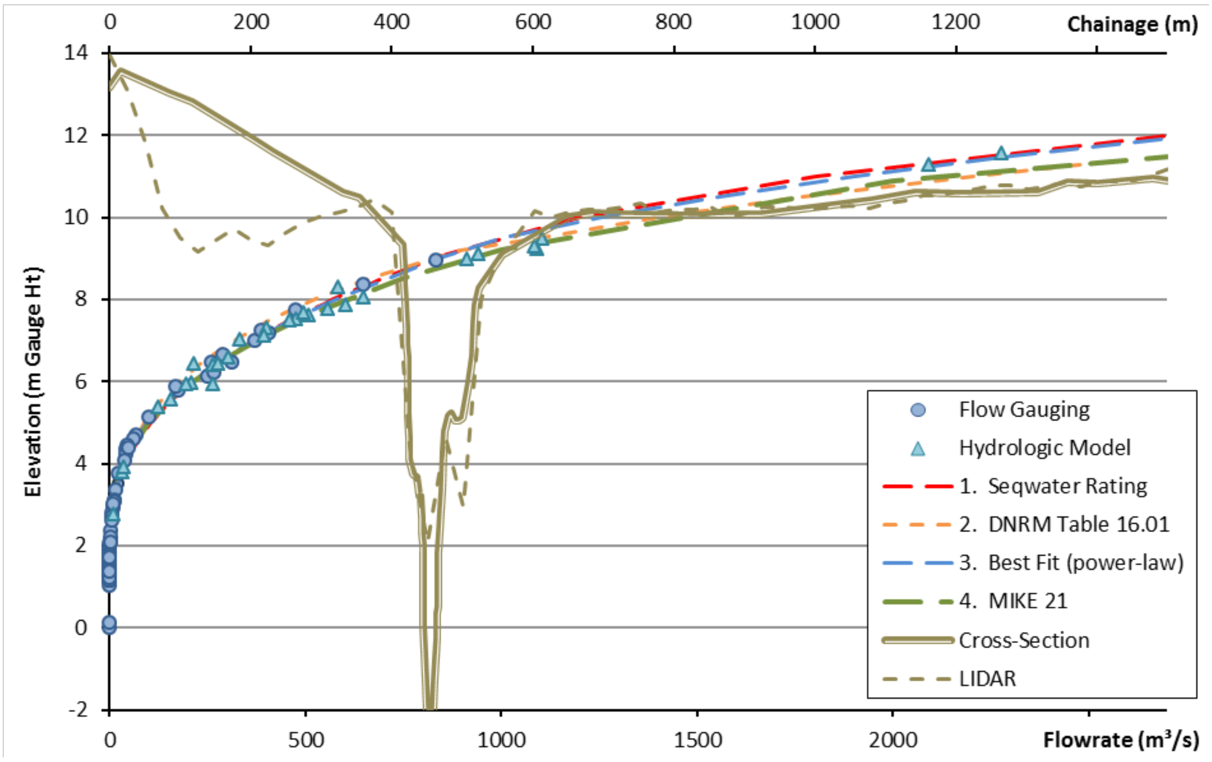


Figure 4-30(b) Rating Comparison – Bremer River @ Walloon (full range)

Table 4-15 Rating curve reliability assessment – Bremer River @ Walloon

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.99 - 4	0 - 38.2	64	4	DNRM Rating
4 - 9	38.2 - 923	21	22	MIKE 21 Model
9 - 12.5	923 - 4559	0	7	MIKE 21 Model

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.99 - 4	-20.8%±45.6%	26.2%±73.2%	0.409	0.080	3.5
4 - 9	-1.6%±4.6%	4.6%±14.5%	0.113	0.009	3.4
9 - 12.5	-1.6%±3.2%	6.8%±13.6%	0.594	0.745	4.7

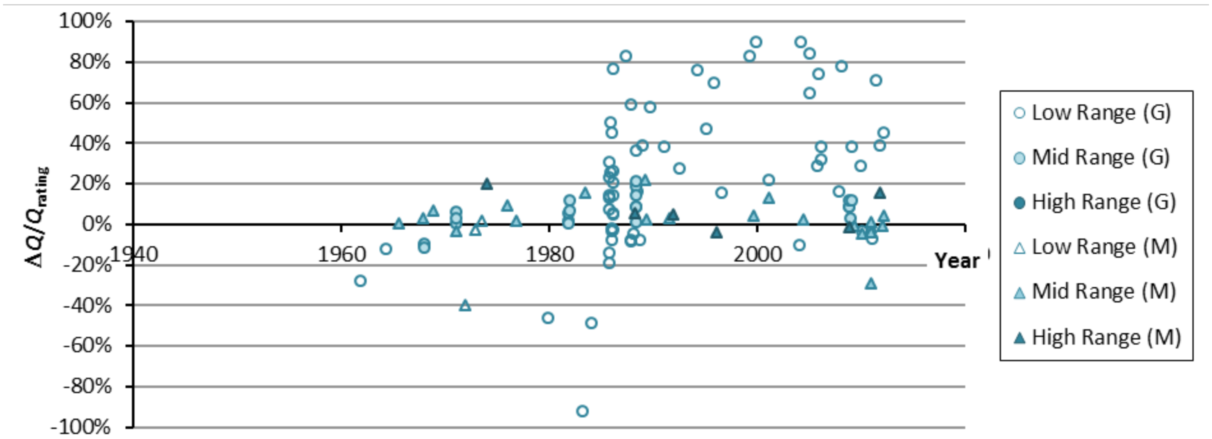


Figure 4-31 Relative variance of rated discharge – Bremer River @ Walloon

4.4.4 Secondary gauge rating – Bremer River @ Adams Bridge

The Bremer River gauge at Adams Bridge is relatively well rated although the majority of flow gaugings are for very small discharges. The highest recorded gauging is 4.18 m gauge height corresponding to 173 m^3/s. Seqwater has adopted the DNRM rating for this gauge even though the rating tends to give higher levels than predicted by the hydrologic model results.

Normal-depth discharge calculations were performed to assess the flow characteristics of the channel using a cross-section at the gauge location and LIDAR survey data. The gauge cross-section and LIDAR survey show significant difference in the depth of the main channel. The invert level of neither survey match the gauge zero, and neither of the normal-depth flow calculations performed with each section could match the gauge data. The normal-depth flow ratings nevertheless approach similar levels as the floodplain becomes the dominant conveyance mechanism, and this level is consistent with the DNRM and Seqwater rating projection, but not necessarily the best fit of the hydrologic model results which suggest that curve may flatten out more than predicted by the current rating. Conveyance calculations based on a single section are not conclusive, particularly considering the variability in section shape observed.

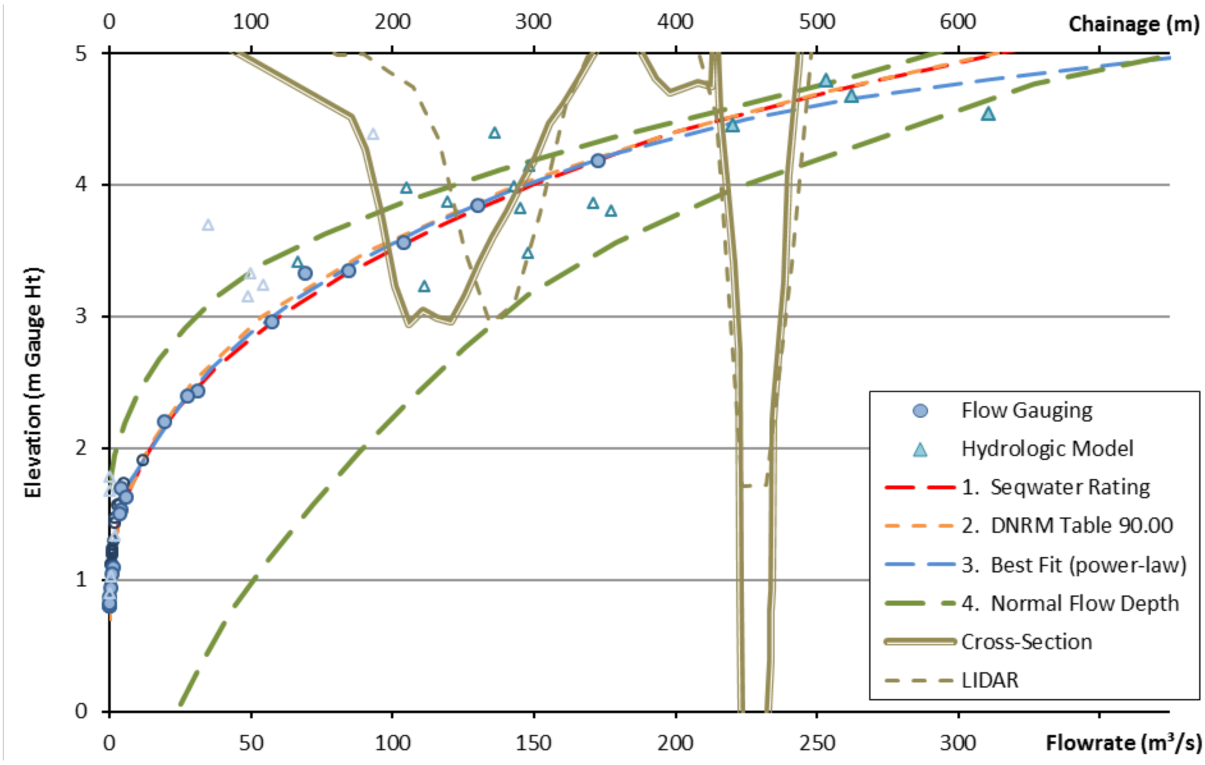


Figure 4-32(a) Rating Comparison – Bremer River @ Adams Bridge (low – mid range)

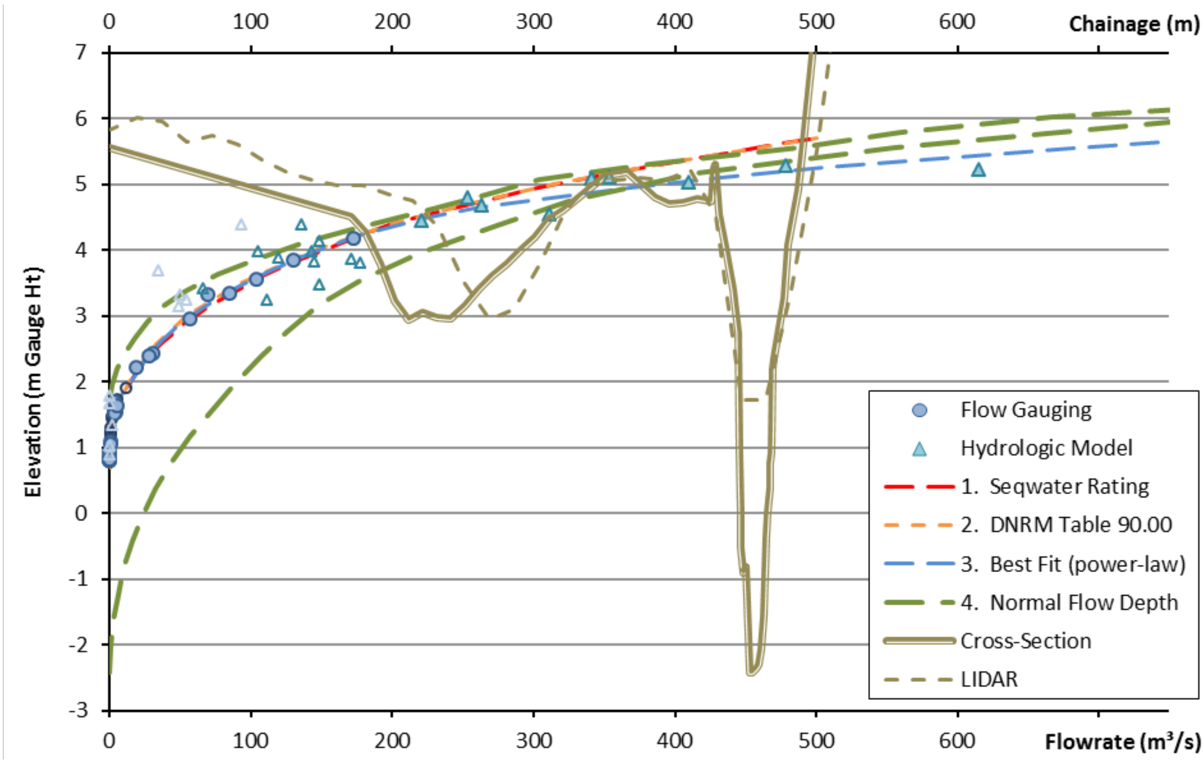


Figure 4-32(b) Rating Comparison – Bremer River @ Adams Brige (full range)

Based on this assessment, the current DNRM rating is considered to have reasonable reliability in the low to mid-range. The upper range of the DNRM curve has relatively poor match with the hydrologic modelling and the power-law best fit has been adopted, but should be used with caution. Due to the small catchment size, Adams Bridge is considered a low priority site so no additional work is proposed.

Table 4-16 Rating curve reliability assessment – Bremer River @ Adams Bridge

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.695 - 1.8	0 - 9.4	25	5	DNRM Rating
1.8 - 4.5	9.4 - 227	10	17	DNRM Rating
4.5 - 5.7	227 - 786	0	8	Best fit of hydrologic model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dZ}$
0.695 - 1.8	-8.6%±20.2%	17.0%±37.5%	0.003	0.007	3.4
1.8 - 4.5	1.5%±5.1%	-4.7%±14.7%	0.019	0.060	2.8
4.5 - 5.7	-0.2%±6.1%	-0.8%±29.5%	0.220	0.011	4.6

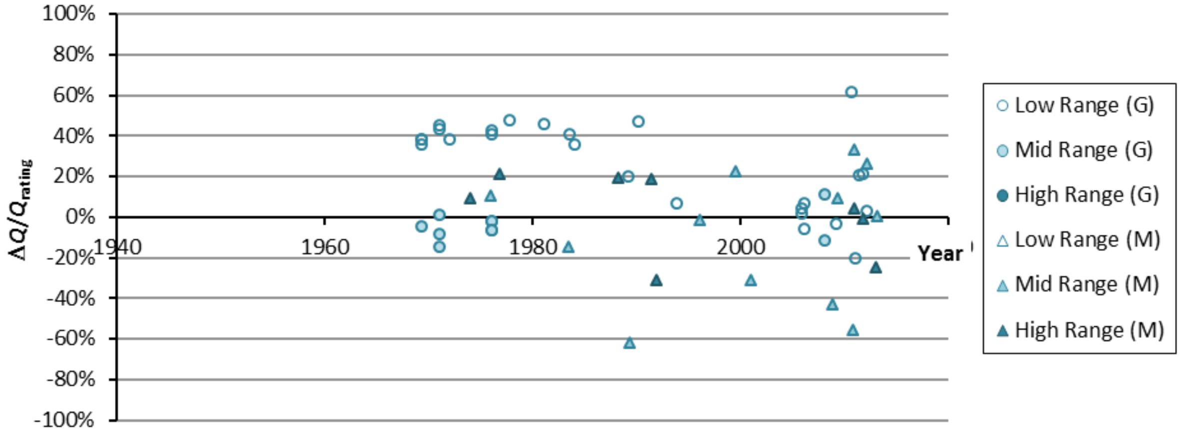


Figure 4-33 Relative variance of rated discharge – Bremer River @ Adams Bridge

4.4.5 Secondary gauge rating – Bremer River @ Rosewood

The BoM gauge on the Bremer River at Rosewood is a flood warning gauge with no rating or flow gaugings. Seqwater has developed a rating based solely on a power-law type best fit of hydrologic model results above 4.5 m gauge height. The hydrologic model should theoretically be reasonably reliable at the Rosewood site considering the proximity to Walloon, which was the primary basis for model calibration.

Normal-depth discharge calculations were performed to assess the flow characteristics of the channel using a cross-section extracted from the LIDAR survey at the gauge location. The normal-depth rating is relatively similar to the Seqwater rating but with a less abrupt transition between 3 m and 5.5 m gauge height. It is noted that the normal-depth flow estimates have been adjusted to fit the hydrologic model and are not considered a reliable check of absolute levels.

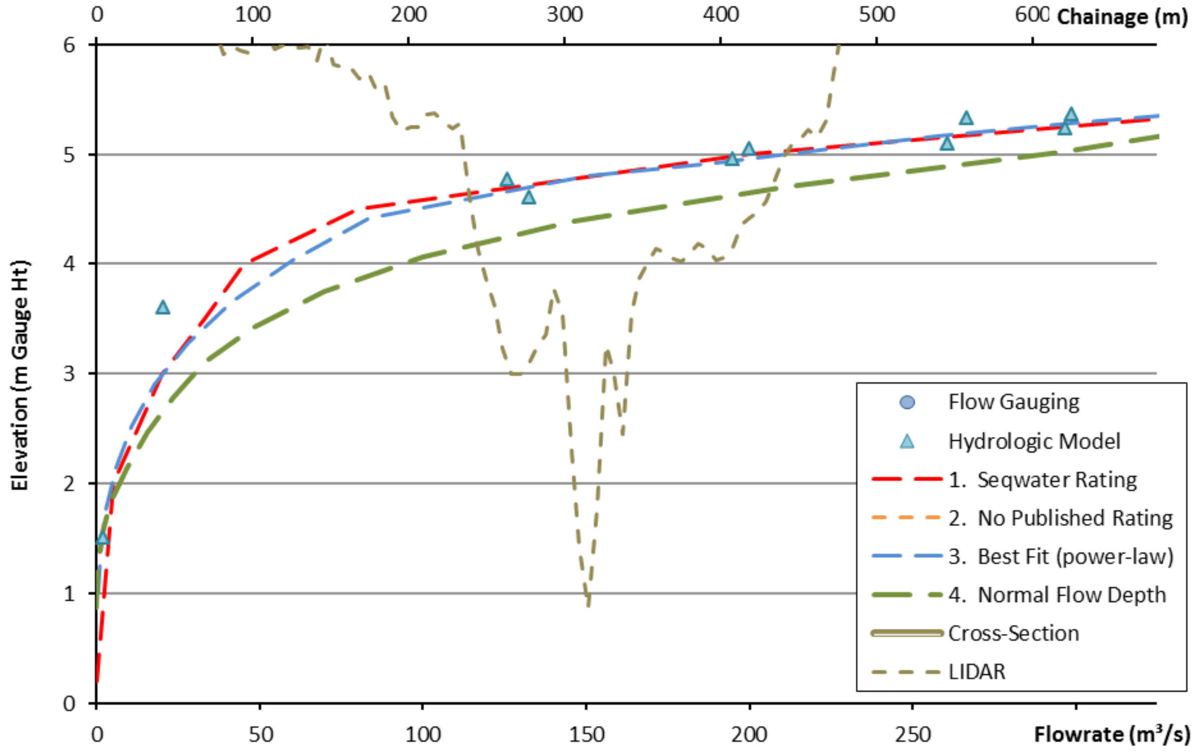


Figure 4-34(a) Rating Comparison – Bremer River @ Rosewood (low – mid range)

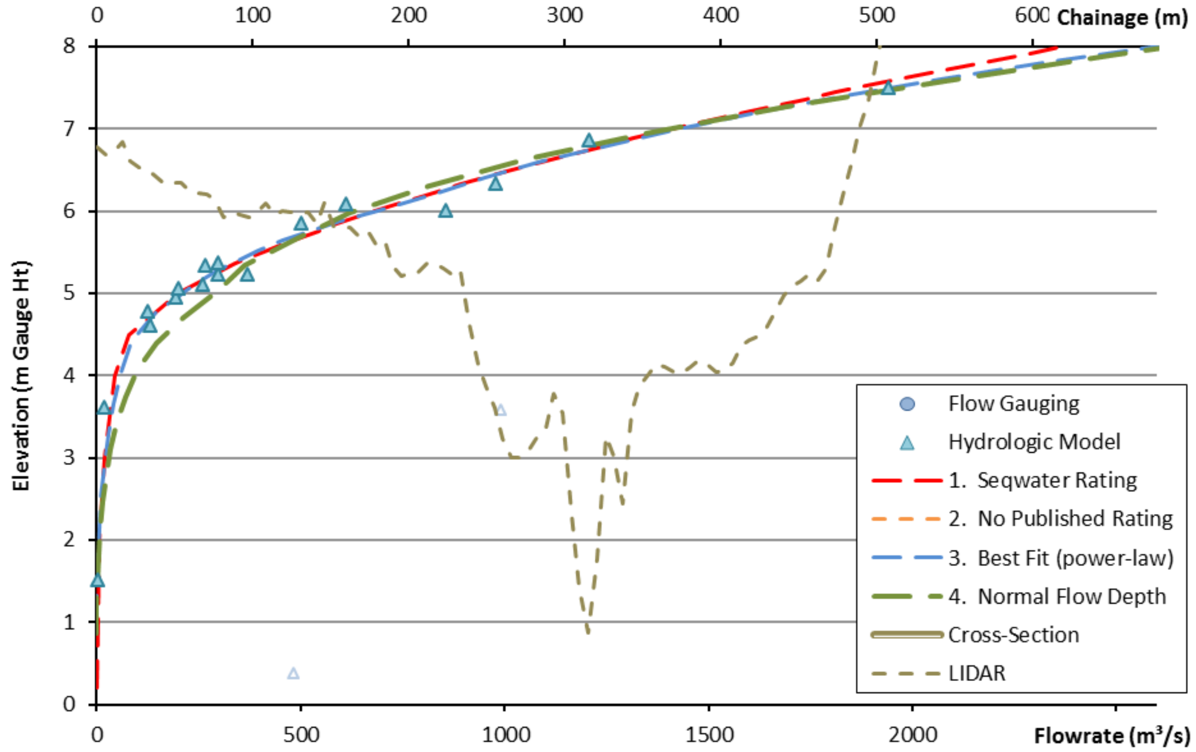


Figure 4-34(b) Rating Comparison – Bremer River @ Rosewood (full range)

The Rosewood site appears to be a reasonable gauge location, with relatively good consistency of data and no evidence of long-term variation of the gauge record. Review of the data reliability in Table 4-17 and Figure 4-35 indicates that the Seqwater rating provides a reasonable representation of the hydrologic model data. Following recalibration of the review of the URBS model, a slightly modified power-law distribution was adopted. The low flow rating up to around 4.5 m gauge height is considered uncertain, and a smoother transition between 3 m and 5 m gauge height could potentially be expected. Flow gauging at this site is recommended to improve the reliability of the low-flow rating. Confidence in the low-flow rating could potentially be improved by correlating the flows at Rosewood to flow gaugings at Walloon, but this would require good understanding of the relative discharges between the two sites. Variability is expected as minor catchment contributions downstream of Rosewood would have greater influence during small events.

Considering the low priority of the site for the purposes of the BRCFS, no additional review or modelling is proposed.

Table 4-17 Rating curve reliability assessment – Bremer River @ Rosewood

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.2 - 4.8	0 - 151	0	5	Best fit of hydrologic model data
4.8 - 6	151 - 688	0	9	Best fit of hydrologic model data
6 - 8	688 - 2604	0	4	Best fit of hydrologic model data

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg$_Z$ & $CI_Z^{90\%}$	Avg$_Q$ & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.2 - 4.8	-4.4%±15.0%	8.6%±42.8%	0.008	0.005	4.7
4.8 - 6	0.2%±4.0%	-2.4%±26.9%	0.245	0.028	6.5
6 - 8	-0.7%±3.1%	3.8%±15.8%	0.186	0.084	4.6

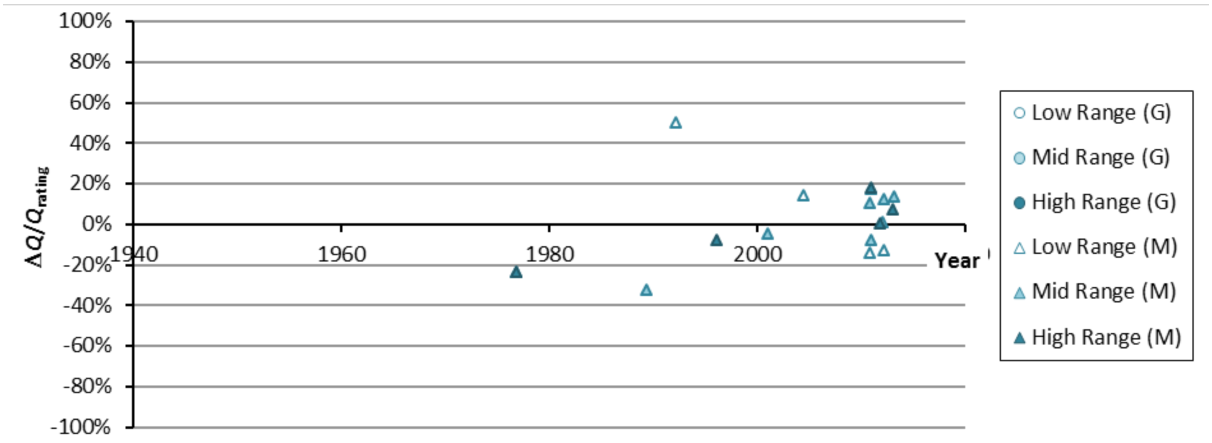


Figure 4-35 Relative variance of rated discharge – Bremer River @ Rosewood

4.5 Warrill Creek to Amberley

The Bremer River is a major tributary of the Brisbane River. The catchment has been subdivided into three separate URBS models – Bremer River to Walloon, Warrill Creek to Amberley and Purga Creek to Loamside. The Warrill Creek catchment is the largest of these models with an area of 902 km². The major streams in the catchment are Warrill Creek and Reynolds Creek. Other significant tributaries include Warrolaba, Mount Walker and Ebenezer Creeks. Moogerah Dam is a large water storage on Reynolds Creek. The lower Bremer River floodplain is included in the Lower Brisbane River model.

4.5.1 Summary of available gauge data

Gauge locations are shown in Figure 4-36 and available data for the major gauges in the Warrill Creek catchment are summarised in Table 4-18. Seqwater operated water resource assessment gauges are located at Moogerah Dam, Junction and Kalbar Weirs, and Churchbank Weirs. These are water level gauges and do not have flow gauging or flow ratings, although Seqwater has recently conducted an assessment of the Junction and Kalbar Weirs. BoM flood warning gauges are located at Kalbar, Harrisville and Green's Road. These also do not have flow gauging or ratings.

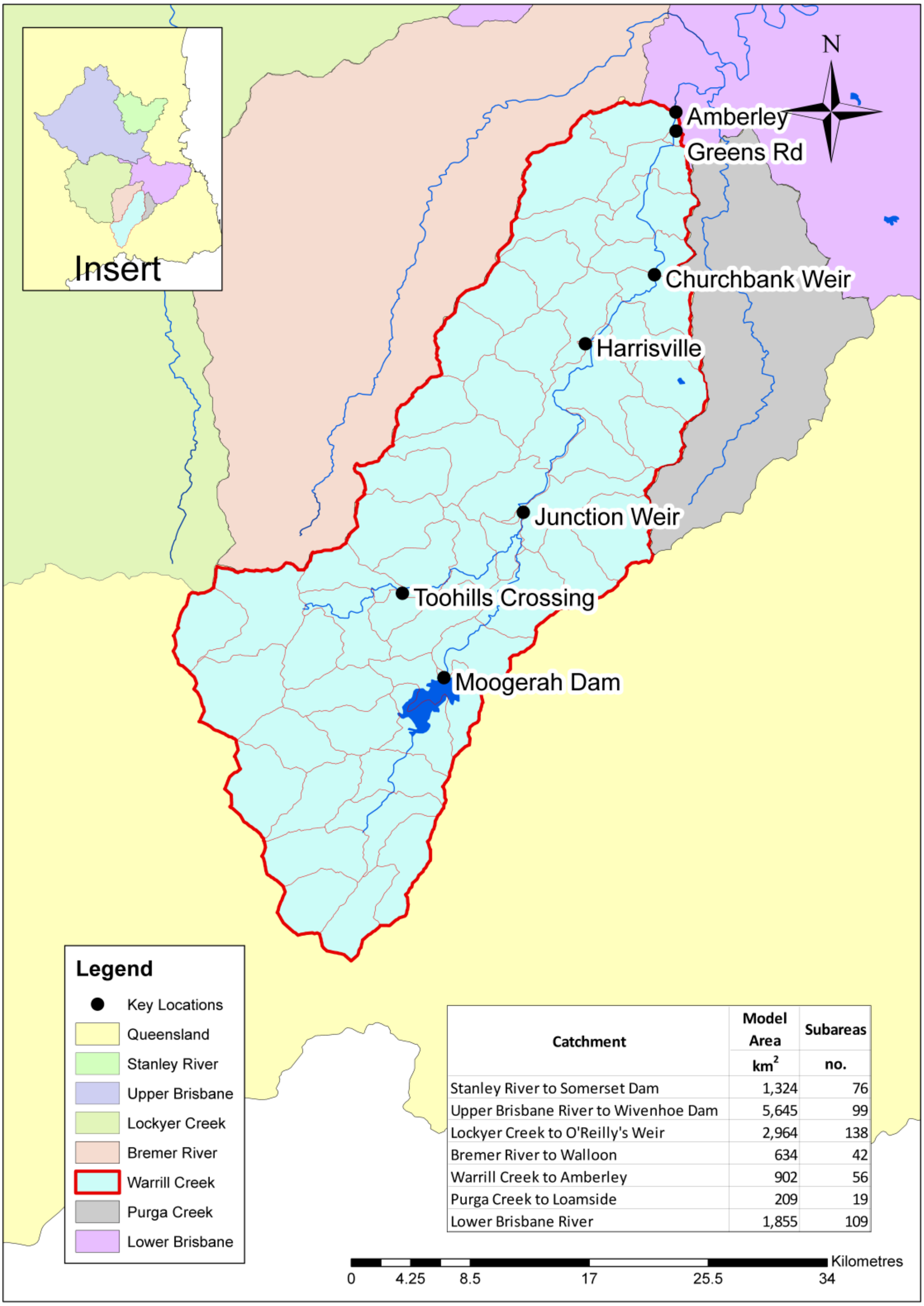
The Harrisville and Churchbank Weir stations are located in areas where floodplain conditions are complex (eg breakout flows, and multiple channels). The Churchbank Weir station does not have recorded water levels between 1960 and 1995 and Seqwater has identified issues with uncertain and changing gauge datum up until 1998. Then DNRM operated gauge at Amberley at the downstream end of the catchment is the only current gauge to have flow gauging and a published discharge rating.

Table 4-18 Warrill Creek catchment gauge summary

Gauge	Area (km²)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Reynolds Creek @ Moogerah Dam	226 (25%)	n/a	1967-	Y	n/a	Dam Inflow
Warrill Creek @ Junction Weir	458 (51%)	n/a	1997-	Y	n/a	Seqwater HEC-RAS
Warrill Creek @ Churchbank Wr	751 (83%)	n/a	1953-		n/a	n/a
Warrill Creek @ Green's Road	887 (98%)	n/a	1994-	N	n/a	n/a
Warrill Creek @ Amberley	902 (100%)	9.8m 914m³/s	1961 -	Y	<9.5 Good >9.5 Poor	Aurecon MIKE 21

4.5.2 Gauge selection for the Warrill Creek catchment model

Few of the gauges in the Warrill Creek catchment are currently of practical use for the Brisbane River Catchment Flood Study. The Amberley gauge has reasonable gauge history and flow gauging data available and has therefore been adopted as the primary focus of the review. Seqwater has undertaken hydraulic modelling of the Kalbar/Junction Weir area as part of the development and calibration of the URBS hydrologic models of the Brisbane River catchment. Other gauges in the catchment were considered to have insufficient reliable data for useful review. Moogerah Dam is located in the upper catchment of Warrill Creek and is considered a reliable data source and of importance for identifying the attenuating effect of the dam.



Catchment	Model Area km^2	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-36 Warrill Creek to Amberley URBS model (from Seqwater 2013)

4.5.3 Primary calibration input – Moogerah Dam inflow

Moogerah Dam has been in operation since 1960. It has well defined storage relationship. Outflow is via an uncontrolled ogee crest spillway. A detailed investigation of the dam was undertaken by Aurecon in 2013, which included three-dimensional CFD modelling of the spillway discharge characteristics. This modelling identified a discrepancy in the discharge rating curve. The level axis of the official discharge rating graph was divided into 1 ft intervals with 5×0.2 ft subintervals, however one interval contained only 4 subintervals (ie 0.8 ft instead of 1 ft). Correcting for this level difference resulted in excellent agreement between the CFD model and the discharge rating. It is recommended that this adjusted rating is used for outflow characteristics of the dam.

Reverse reservoir routing of the Moogerah Dam inflows has been used to determine hydrographs in Reynolds Creek upstream of the dam.

4.5.4 Primary gauge rating – Warrill Creek @ Amberley

The Warrill Creek gauge at Amberley has a good period of record and over 200 flow gaugings. The maximum gauged record is 9.81 m gauge height corresponding to 914 m^3/s. The DNRM rating appears to be based on the flow gaugings which are then extrapolated to higher discharges. Inspection of the DNRM rating suggests that it overestimates levels in the mid-range of the rating. The Seqwater rating is based on the DNRM rating up to 5 m gauge height, then a best-fit curve through the gauge ratings up to 9.5 m gauge height. Above this level the Seqwater rating is based on hydrologic model results as well as levels from an existing MIKE 21 model of Amberley Creek developed by Aurecon for the Cunningham Highway Amberley Interchange project for Transport and Main Roads.

The existing Aurecon MIKE 21 model has been restored and used to reassess the Amberley gauge rating. The model covers an area 5.9 km × 7.8 km that encompasses both Amberley and Purga Creek, extending downstream beyond the confluence of Warrill and Purga Creeks, which is 5.3 km downstream of the Amberleygauge, and approximately 6 km upstream of the Amberley gauge on Warrill Creek. Details of the model are provided in Appendix B. The MIKE 21 model was used to assess a range of flows in Warrill Creek in order to establish a rating curve at the Amberley gauge. The model roughness parameters were adjusted within reasonable limits to achieve a best fit rating curve comparison against the flow gauging data.

As shown in Figure 4-37, the hydraulic model results match very well with the flow gauging between 4 m and 8 m gauge height. Above around 8 m the hydraulic model results begin to deviate from the gauged data and predict lower water levels. The two-dimensional modelling identified a breakout of flow upstream of the gauge where flows transfer from Warrill Creek into Purga Creek. The proportion of breakout flow increases as the discharge increases. The discharge rating for the total catchment flow is therefore different from the local gauge flow rating. If the model rating plotted as a function of local flow at the gauge site only, then it agrees with the gauged data for the full range of available data. The final gauge rating has been assessed as a function of total flow as this is of greatest use for the purposes of the BRCFS.

The modelling identified that a combination of large flows in the Purga Creek system and small flows in the Warrill Creek system could potentially cause minor backwater influence at the Amberley gauge, however this is considered to be an unusual combination considering the sizes of the catchment and has not been considered in development of the rating curve. The preferred rating curve for the BRCFS adopts the DNRM rating up to 5 m gauge height (approximate best-fit curve through the gauge data) and the hydraulic model results above this elevation.

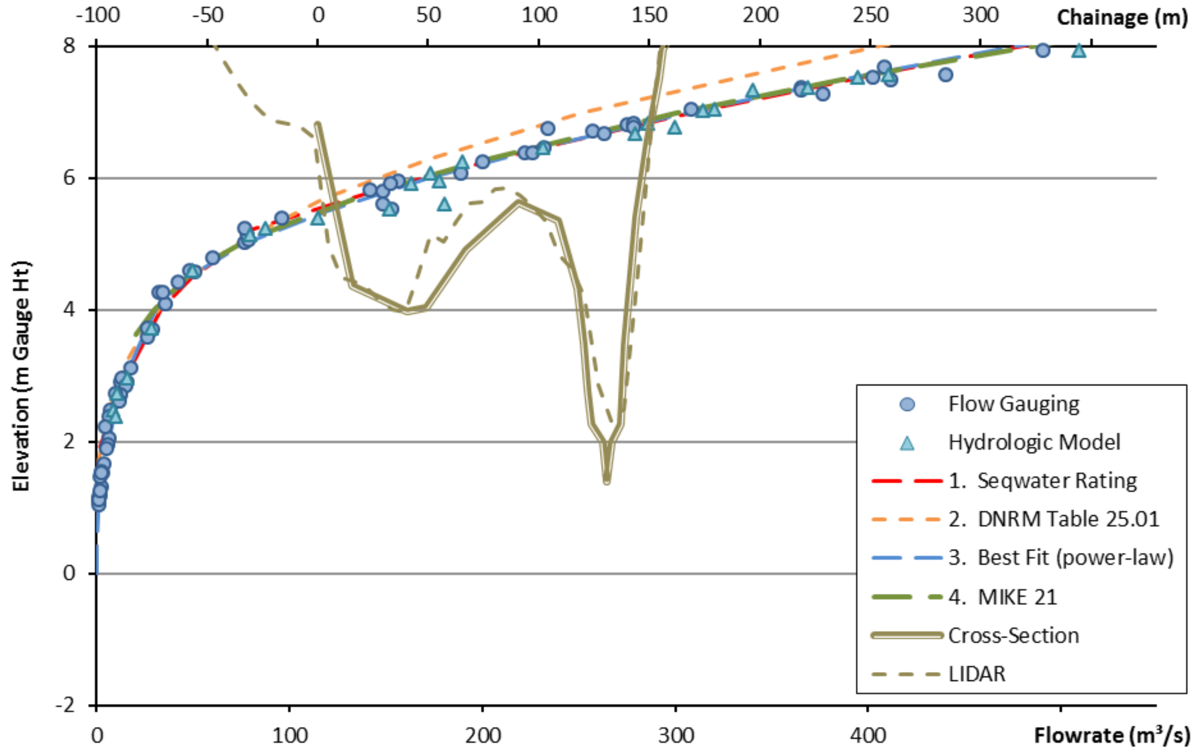


Figure 4-37(a) Rating Comparison – Warrill Creek @ Amberley (low – mid range)

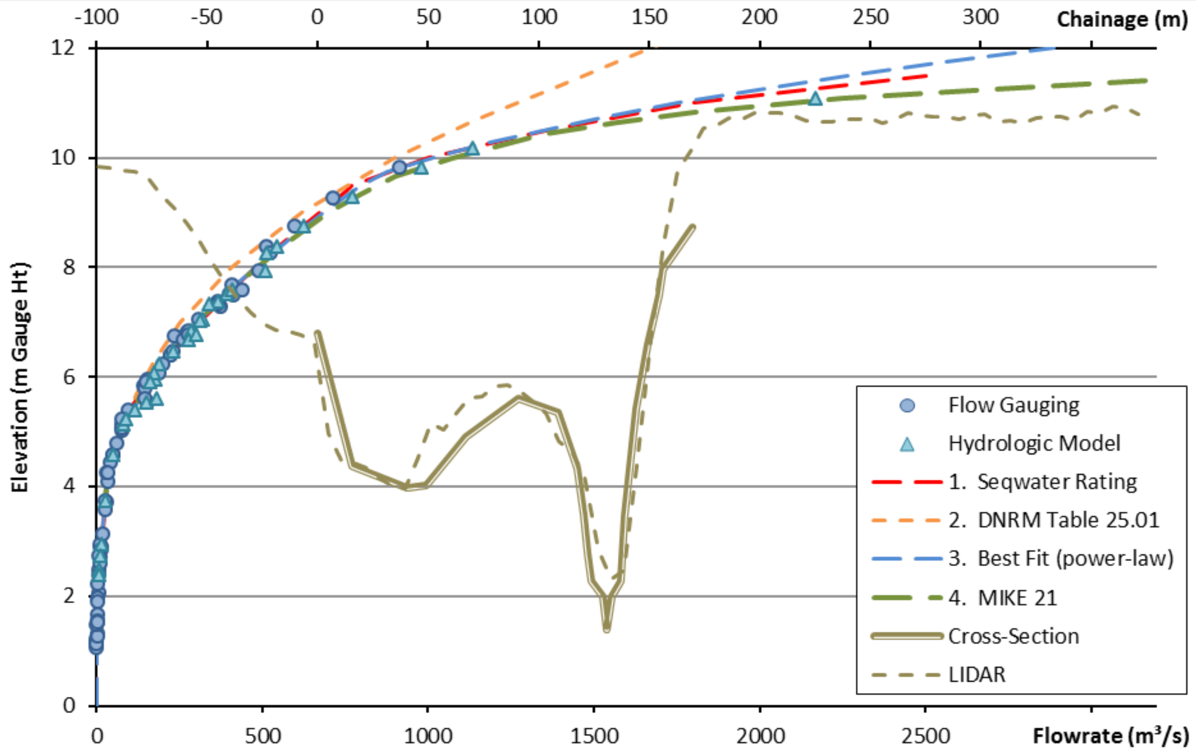


Figure 4-37(b) Rating Comparison – Warrill Creek @ Amberley (full range)

Table 4-19 and Figure 4-38 provide an assessment of the variability of the data and reliability of the rating curve. The data is considered to be very consistent with relatively little scatter and no evidence of long-term variation. The rating provides a consistently good match of the gauge data, but becomes relatively sensitive to changes in elevation in the upper range.

Like the other primary Lockyer Creek and Bremer River gauges, the hydraulic model rating predicts higher flows than were produced by the original Seqwater calibration of the hydrologic model for large flood events. Although this match could have been improved by increasing the roughness, the vegetation present in the Amberley floodplain did not justify a significant increase. Recalibration of the hydrologic model and review of flood frequency analysis and other data sources produced hydrologic model results that are consistent across the full range of the rating using parameters within expected ranges and consistent with other catchments.

Table 4-19 Rating curve reliability assessment – Warrill Creek @ Amberley

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0 - 4.5	0 - 46.9	35	5	Best fit
4.5 - 9.5	46.9 - 844	38	25	MIKE 21 Model
9.5 - 11.5	844 - 3453	1	3	MIKE 21 Model

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dZ}$
0 - 4.5	-5.5%±14.5%	7.6%±23.3%	0.344	0.095	2.8
4.5 - 9.5	0.1%±3.2%	-0.6%±14.0%	0.004	0.006	3.6
9.5 - 11.5	-0.9%±0.9%	4.5%±3.8%	0.227	0.001	7.7

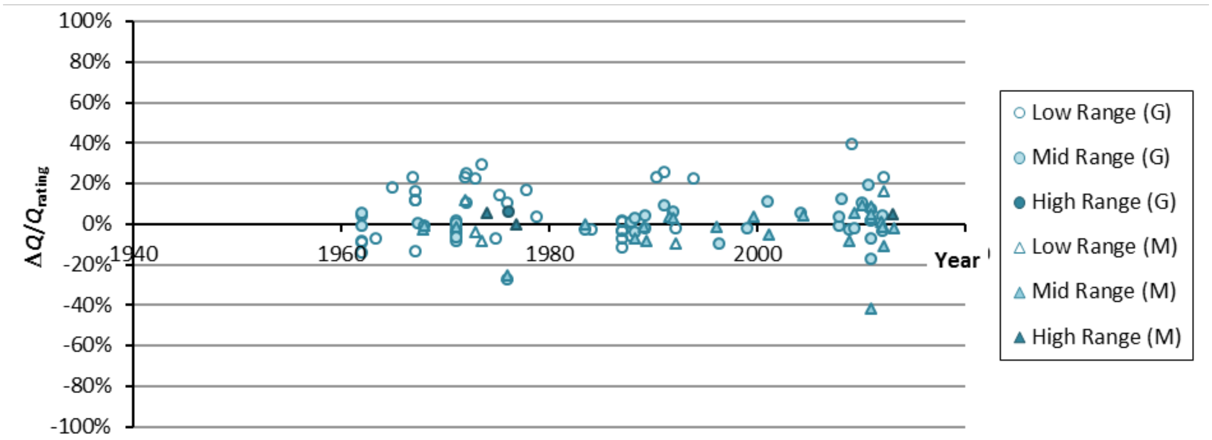


Figure 4-38 Relative variance of rated discharge – Warrill Creek @ Amberley

4.5.5 Secondary gauge rating – Warrill Creek @ Junction Weir

The Junction Weir and three Kalbar gauging stations are all in close proximity within a 1.5 km reach of Warrill Creek in proximity to Kalbar Connection Road. An integrated review of applicable ratings was undertaken by Seqwater due to the proximity of the gauges. Contrasting the lack of available flow data, survey data was considered to be of sufficient quantity and quality to allow a hydraulic analysis to be performed. A HEC-RAS model was established extending from 280 m downstream of the BoM Kalbar gauge to 20 m upstream of the Junction Weir crest corresponding to the location of the Junction weir headwater gauge. Details of the modelling is provided in "*Brisbane Basin Flood Hydrology Models Appendix B.7 Hydraulic Analysis for Junction Weir and Kalbar Gauge Ratings for Warrill Creek Model*' (Seqwater 2013). The headwater and tailwater ratings developed using the HEC-RAS model are presented in Figure 4-39 below.

The hydrologic model data shows significant scatter within the low-flow region, but relatively good agreement with the high-flow rating (>79 m). Considering the relative importance of the gauge rating and the level of detail of the Seqwater analysis, further analysis has not been undertaken.

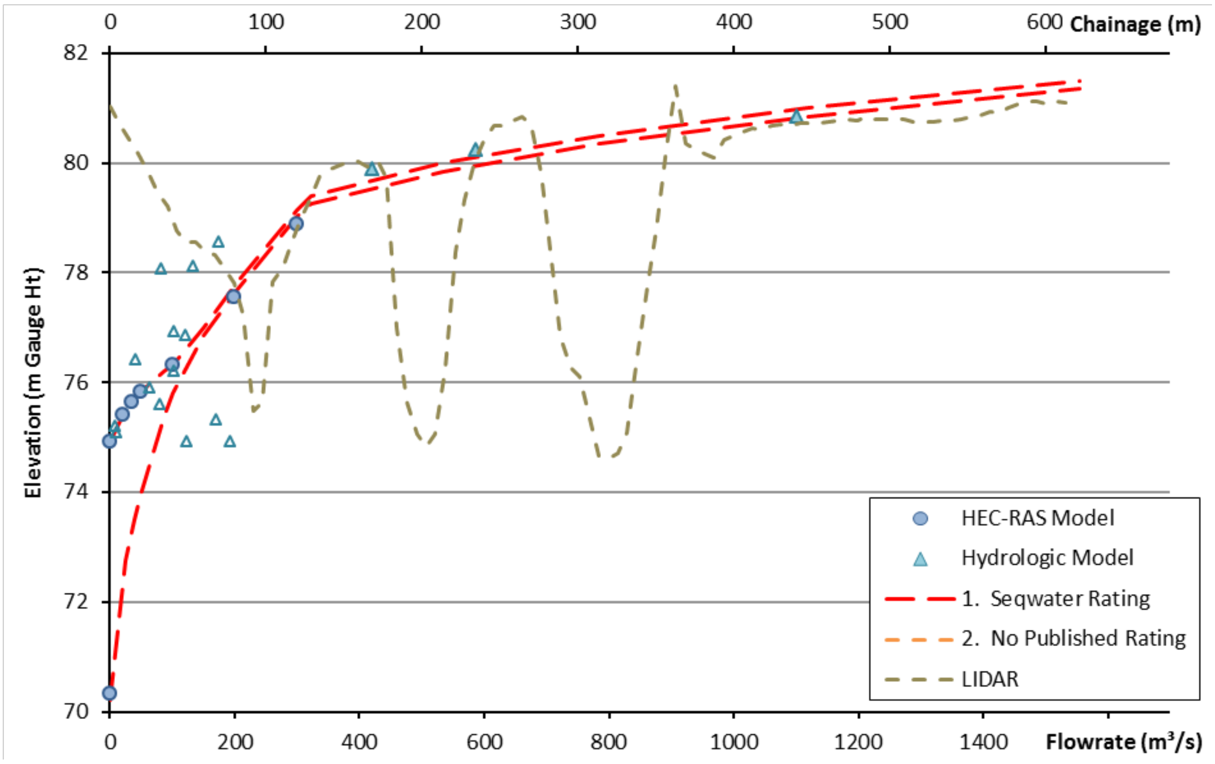
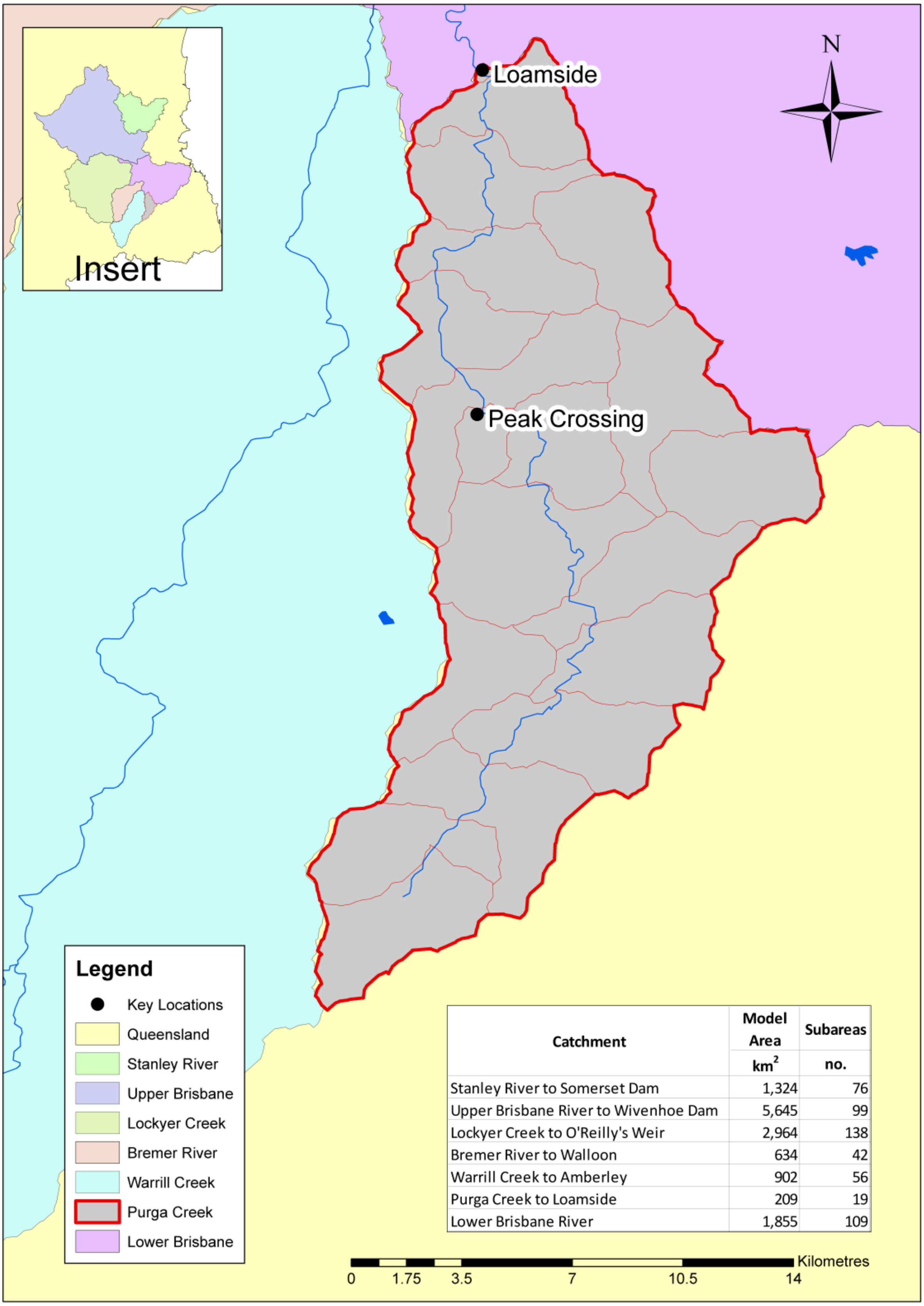


Figure 4-39 Rating Comparison – Warrill Creek @ Junction Weir

4.6 Purga Creek to Loamside

The Bremer River is a major tributary of the Brisbane River. The catchment has been subdivided into three separate URBS models – Bremer River to Walloon, Warrill Creek to Amberley and Purga Creek to Loamside. The Purga Creek catchment is the smallest of these models with an area of 209 km². Purga Creek is the only significant watercourse in the catchment.



Catchment	Model Area km²	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-40 Purga Creek to Loamside URBS model (from Seqwater 2013)

4.6.1 Summary of available gauge data

Gauge locations for the Purga Creek catchment are shown in Figure 4-40 above and available data for the major gauges in the Purga Creek catchment are summarised in Table 4-20. Peak Crossing is a relatively new flood warning gauge operated by BoM. It registers a reasonable proportion of the catchment but has no flow gauging or rating. The DNRM gauge at Loamside at the downstream end of the catchment has a reasonable historical record and some flow gauging.

Table 4-20 Purga Creek catchment gauge summary

Gauge	Area (km^2)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Purga Creek @ Peak Crossing	142 (68%)	n/a	1998-		n/a	n/a
Purga Creek @ Loamside	209 (100%)	5.59m 46.5m³/s	1973-	Y	<7.0 Good >7.0 Fair	Aurecon MIKE 21

4.6.2 Gauge selection for the Purga Creek catchment model

There are only two viable gauges in the Purga Creek catchment. The Loamside gauge is the only gauge with flow gauging data available and has therefore been adopted as the primary focus of the review. Only limited analysis is feasible at the Peak Crossing gauge.

4.6.3 Primary gauge rating – Purga Creek @ Loamside

The Purga Creek gauge at Loamside has a reasonable period of record and over 130 flow gaugings, although most of these are at low discharges. The maximum gauged record is 5.6 m gauge height corresponding to 46.5 m³/s. The DNRM rating appears to be based on the flow gaugings, but has been projected to higher discharges. The projection methodology is not identified. The Seqwater rating is based on the DNRM rating up to 6.5 m gauge height, then a 'by eye' extrapolation through the hydrologic model results. For this gauge the hydrologic model results show relatively good consistency with limited scatter.

An existing Aurecon MIKE 21 model (as discussed in Section 4.5.4) has been restored and used to reassess the Loamside gauge rating. The model covers an area 5.9 km × 7.8 km that encompasses both Amberley and Purga Creek, extending downstream beyond the confluence of Warrill and Purga Creeks. Details of the model are provided in Appendix B. The MIKE 21 model was used to assess a range of flows in Purga Creek in order to establish a rating curve at the Loamside gauge. The MIKE 21 roughness parameters were adjusted within reasonable limits to achieve a best fit rating curve comparison against the flow gauging data.

Purga Creek has a small narrow channel within a much wider floodplain. The MIKE 21 model was found to have insufficient detail to model low channel flows below approximately 4.5 m gauge height, but above that elevation the model results match well with the flow gauging data. The modelled profile matches well with the general shape of the Seqwater rating but with slightly lower water levels above the top of bank level of around 6 m gauge height. The rating predicted higher flows than were produced by the Seqwater calibrated hydrologic model for large flood events, consistent with the other Lockyer Creek and Bremer River gauges. As with the Amberley gauge, the match could be improved by increasing the roughness, although the observed vegetation condition does not justify a significant increase. The Loamside hydraulic model calibration and derived rating are therefore considered reasonable and were adopted as a review of the URBS model achieved good match and demonstrated no need for further modification.

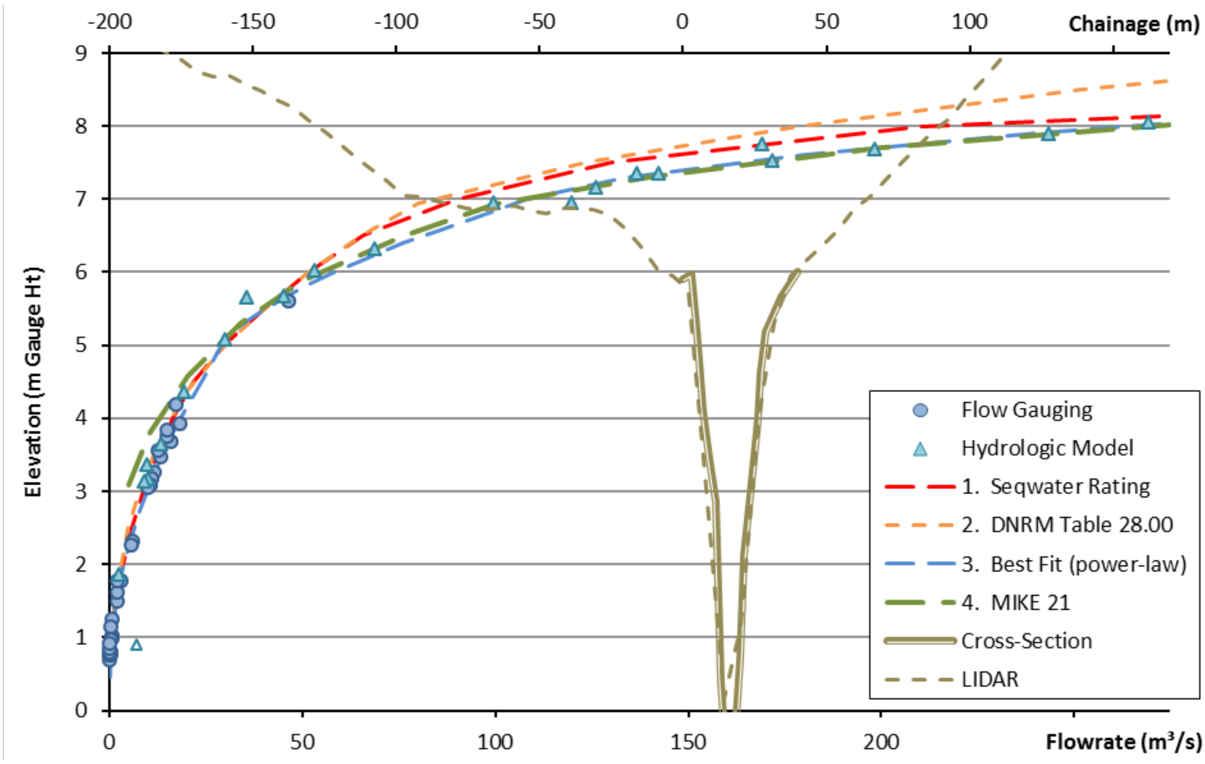


Figure 4-41(a) Rating Comparison – Purga Creek @ Loamside (low – mid range)

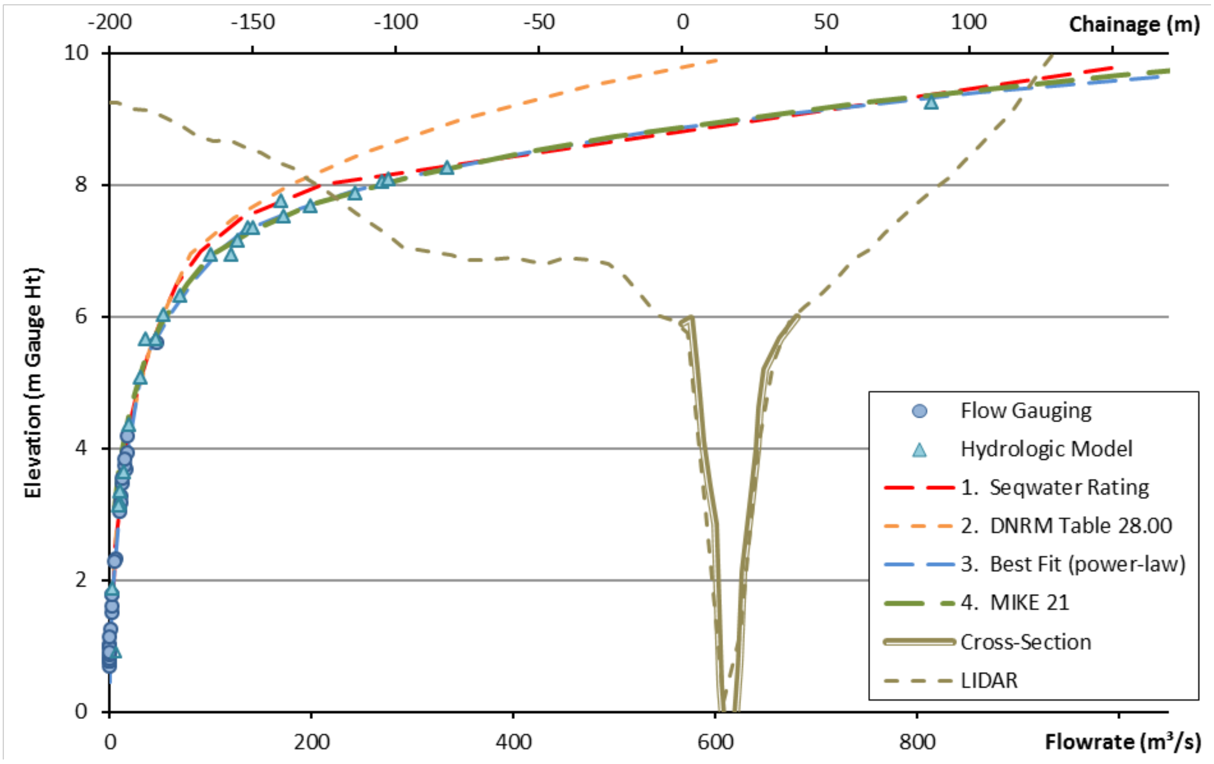


Figure 4-41(b) Rating Comparison – Purga Creek @ Loamside (full range)

The preferred rating curve for the BRCFS adopts the DNRM rating up to around 5 m gauge height and the hydraulic model rating above this elevation. Review of the data variability in Table 4-21 and Figure 4-42 indicates that the rating provides a good match of the average data, but that there is significant data scatter in the low level flow gaugings but the hydrologic model predictions are relatively consistent. There is no evidence of long-term changes to the rating, however short term variation due to changes in vegetation is possible considering the condition of the creek. The gauge rating becomes relatively sensitive to changes in depth above 7 m gauge height and care should be taken when considering levels above the highest flow gauging.

Table 4-21 Rating curve reliability assessment – Purga Creek @ Loamside

Range (m)	Discharge (m^3/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.52 - 5	0 - 29.5	32	7	DNRM Rating
5 - 7	29.5 - 107	1	7	MIKE 21 Model
7 - 10.7	107 - 1918	0	11	MIKE 21 Model

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.52 - 5	-5.1%±27.1%	5.5%±83.4%	0.479	0.108	2.6
5 - 7	0.5%±4.1%	-3.0%±15.1%	0.085	0.023	4.5
7 - 10.7	-0.4%±1.8%	2.7%±11.2%	0.212	0.208	6.8

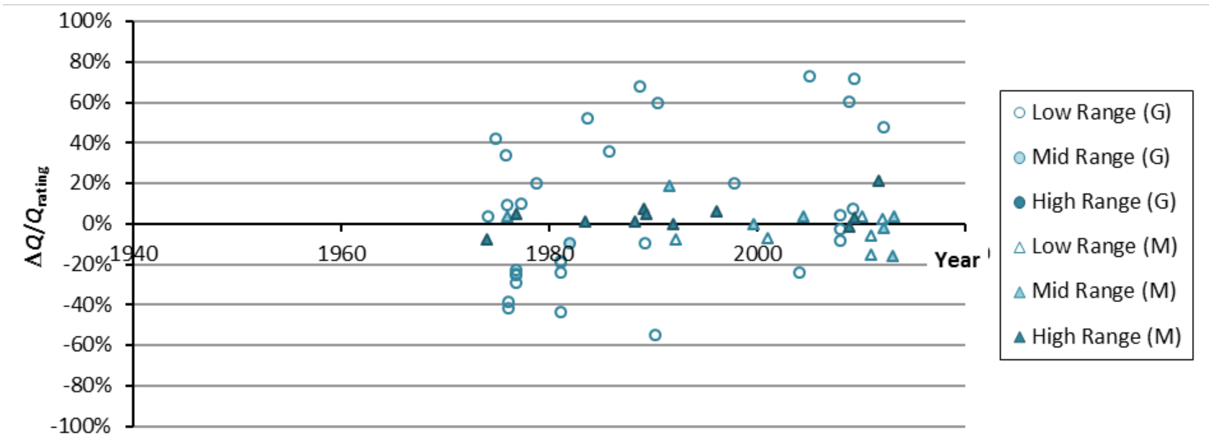


Figure 4-42 Relative variance of rated discharge – Purga Creek @ Loamside

The Loamside gauge is located approximately 1.5 km upstream of where breakout flows from Warrill Creek discussed in Section 4.5.4 enter Purga Creek. The Loamside gauge is located at a relatively constricted section of the channel that widens out further downstream. The hydrologic and hydraulic model results currently show no evidence of significant backwater effects from this overflow, but it nevertheless considered possible if there is a significant imbalance between flows in Purga and Warrill creeks.

4.6.4 Secondary gauge rating – Purga Creek @ Peak Crossing

The BoM gauge on Purga Creek at Peak Crossing is a flood warning gauge with no rating or flow gaugings. Seqwater has developed a rating based solely on a power-law type best fit of the full range of hydrologic model results. The hydrologic model displays good consistency at Loamside, and should have reasonable reliability considering the proximity of Peak Crossing to Loamside, but Peak Crossing has a short flood history and few model results available. Manning's normal-depth discharge calculations were performed to assess the flow characteristics of the channel using a cross-section extracted from the LIDAR survey at the gauge location, although the LIDAR does not appear to have particularly good definition of the main channel. The normal-depth rating displays a more rapid transition at the floodplain level than Seqwater rating. It is noted that the normal-depth flow calculations have been adjusted to fit the hydrologic model and are not considered a reliable check of absolute levels.

Overall, the Seqwater rating does not appear to fit the hydrologic model data particularly well, particularly after recalibration of the URBS model. An updated power-law distribution fits the hydrologic model data relatively well but does not transition above bank-full conditions as could be expected from the cross-section characteristics. On this basis the normal flow depth rating is preferred for but is not considered to be reliable. Considering the limited data available at the site, no additional modelling is proposed.

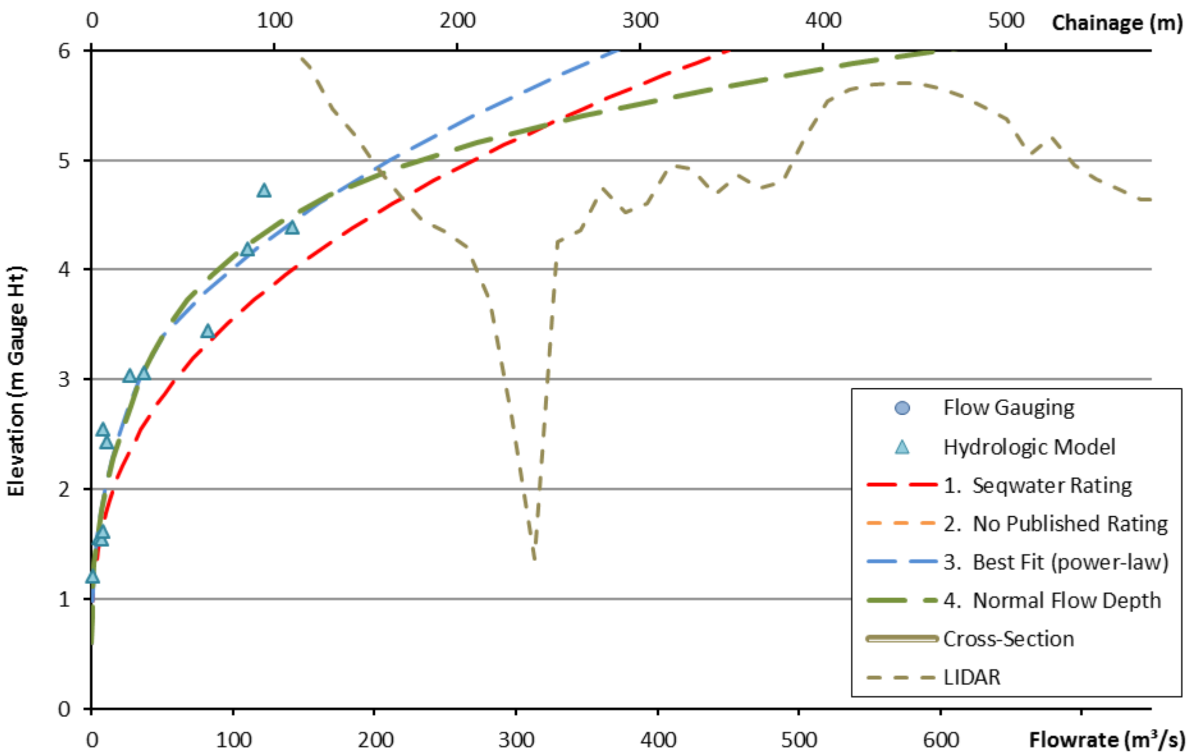


Figure 4-43 Rating Comparison – Purga Creek @ Peak Crossing

4.7 Lower Brisbane River

The URBS model of the lower Brisbane River catchment covers an area of 1,855 km², commencing downstream of Wivenhoe Dam. The model includes the lower Lockyer Creek area downstream of O'Reilly's Weir and lower Bremer River floodplain taking inflows from Bremer River at Walloon, Warrill Creek at Amberley and Purga Creek at Loamside. These catchments are modelled separately and are discussed in the sections above. The model includes numerous watercourses, including England Creek and other small creeks originating in the D'Aguilar Range near Mt Glorious, Black Snake Creek draining from headwater catchment areas near Marburg and Rosewood, Cabbage Tree Creek from the D'Aguilar Range around Mt Nebo, Bundamba Creek, and urban area creeks, the largest of which is Oxley Creek.

4.7.1 Summary of available gauge data

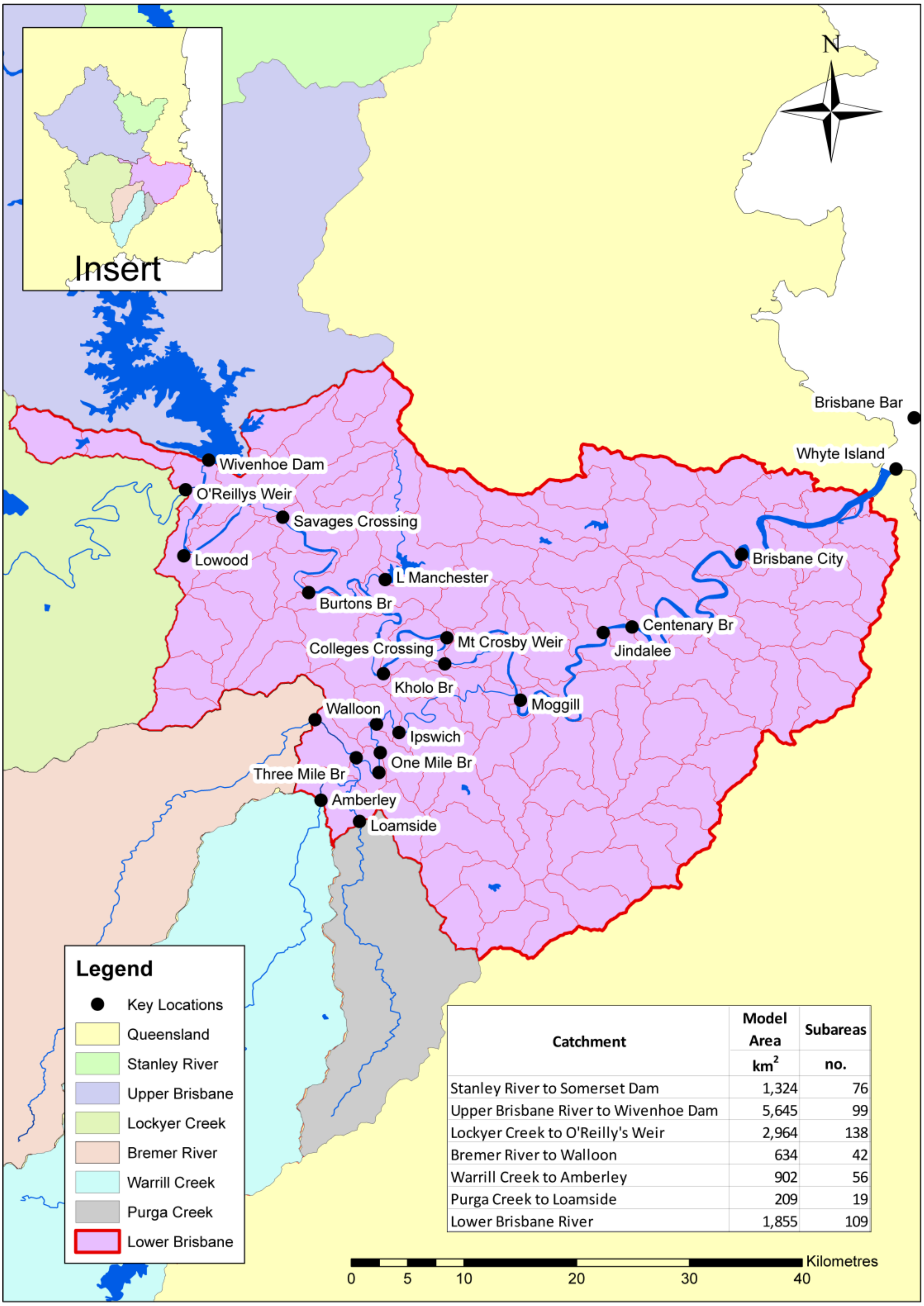
The Lower Brisbane catchment has numerous flood gauges with various purposes and reliability. The review has focussed on major river gauges. Available data for the major gauges along the Brisbane River downstream of Wivenhoe Dam are summarised inTable 4-22.

The DNRM gauge at Savages Crossing and Seqwater gauge at Mt Crosby Weir are situated in the Brisbane River reach between Lockyer Creek and Bremer River. Both gauges have a long historical record, however Savages Crossing has a significantly larger number of flow gaugings, although there appear to be inconsistencies between recent flow observations and older historical records at the Savages Crossing site, potentially due to changes in the channel and surrounding floodplain.

Three gauges operated by Seqwater and BoM are located in relatively close proximity downstream of the Bremer River confluence at Moggill, Jindalee and Centenary Bridge. All three gauges are currently unrated and have limited continuous height data available. Centenary Bridge is the only gauge with flow measurements available, with gauging undertaken during the 1974, 2011 and 2013 flood events.

Table 4-22 Lower Brisbane River catchment gauge summary

Gauge	Area (km²)	Flow Gauging	Historical Record	Continuous Record	Rating Quality	Numerical Model
Brisbane River @ Savages Crsg	10,146 (73%)	15.9m 3361m³/s		Y		DNRM HEC-RAS DMT Tuflow
Brisbane River @ Mt Crosby Weir	10,527 (75%)	11.7m 1671m³/s		Y		GHD MIKE 11 DMT Tuflow
Brisbane River @ Moggill	12,616 (90%)	n/a				DMT Tuflow
Brisbane River @ Jindalee	12,839 (92%)	n/a	1994-		n/a	DMT Tuflow
Brisbane River @ Centenary Br	12,916 (92%)	12.1m 9780m³/s			n/a	DMT Tuflow
Brisbane River @ Brisbane City	13,297 (95%)				n/a	DMT Tuflow



Catchment	Model Area km²	Subareas no.
Stanley River to Somerset Dam	1,324	76
Upper Brisbane River to Wivenhoe Dam	5,645	99
Lockyer Creek to O'Reilly's Weir	2,964	138
Bremer River to Walloon	634	42
Warrill Creek to Amberley	902	56
Purga Creek to Loamside	209	19
Lower Brisbane River	1,855	109

Figure 4-44 Purga Creek to Loamside URBS model (from Seqwater 2013)

4.7.2 Hydraulic modelling and review of the Lower Brisbane catchment

Although independent hydraulic models have been developed for the primary gauges in the other catchments, development of hydraulic models of the lower Brisbane River is considered a significant undertaking that overlaps with (or rather is the responsibility of) the hydraulic modelling component of the BRCFS. This task is considered outside the scope of the rating review.

BCC has developed a TUFLOW model of the lower Brisbane River on behalf of DSDIP for use as a disaster management tool, and DSDIP/BCC has provided results from this model to Aurecon for gauge comparison. Details of this model are provided in the '*Brisbane River Catchment Disaster Management Tool Model Development and Calibration Outcomes Final Report*' (BCC 2014).

4.7.3 Gauge selection for the Lower Brisbane River catchment model

The key differentiator between primary and secondary gauge assessment in the other catchments has been the development of the independent hydraulic models. The same methodology has been used to develop ratings for each of the gauges investigated. There is therefore little practical difference between the review of primary and secondary gauges in the lower Brisbane catchment, with the main differentiator being a perception of likely reliability of the rating for use in calibration of the hydrologic models.

In the reach between the Lockyer Creek and Bremer River confluences, the Savages Crossing and Mt Crosby Weir offer similar duration of flow record. Savages Crossing has greater availability of gauged flow data, however reviews by Seqwater and others have identified long-term inconsistencies in the gauge data and flow levels. These issues are discussed further in Section 4.7.7. On the basis of these inconsistencies, the gauge site at Mt Crosby Weir was considered to be more reliable and was selected as the primary gauge for this reach. Subsequent review of the Mt Crosby Weir rating, particularly with benefit of the DMT TUFLOW model analysis, identified consistency issues with part of the rating that are discussed further in Section 4.7.5. With this exception, the data at Mt Crosby is in general more consistent at the micro-scale than at Savages Crossing and it has been subsequently adopted as the primary gauging site. As discussed in the sections below, significant effort has gone into ensuring that the ratings are consistent at the macro-scale.

Seqwater identified Moggill as a key location for the WSDOS project, downstream of which peak Brisbane River flows are considered to be (relatively) uniform. Moggill also has the best period of record of the lower Brisbane River gauges (excluding the Port Office gauge). However the Moggill gauge has no flow measurements and the gauge site is considered to provide less reliable conditions than the other gauge locations. The Centenary Bridge gauge is the only site with flow measurement data available and is therefore a more reliable gauge location and has been considered to be the primary gauge site. However Centenary Bridge has only limited flood history making it less useful site for model calibration and flood frequency analysis.

The Brisbane City gauge has a very long period of record and is obviously considered to be of critical importance for flood warning. The gauge is subject to significant tidal influence across much of its range and the flood behaviour is also understood to have been affected by changes to the river channel, making it a very difficult gauge to assess without intensive study.

4.7.4 Gauge rating development

Ratings have been developed for the five main gauge locations in the Lower Brisbane River (Savages Crossing, Mt Crosby, Moggill, Centenary Bridge and Brisbane City) using results from the DMT TUFLOW modelling. Details of this modelling are documented in BCC (2014).

The DMT TUFLOW model results identify that much of the lower Brisbane River between Wivenhoe and Brisbane City is subject to noticeable dynamic effects (eg hysteresis) that generally become increasingly more pronounced with flood magnitude and with distance downstream. This effect can be related to notable floodplain storage at certain locations within the river system and causes a delayed response between changes in flow and water levels as illustrated Figure 4-45 where for the 2011 flood event there is a 4 hour lag between the peak flow and water level and an even longer delay in the receding flood.

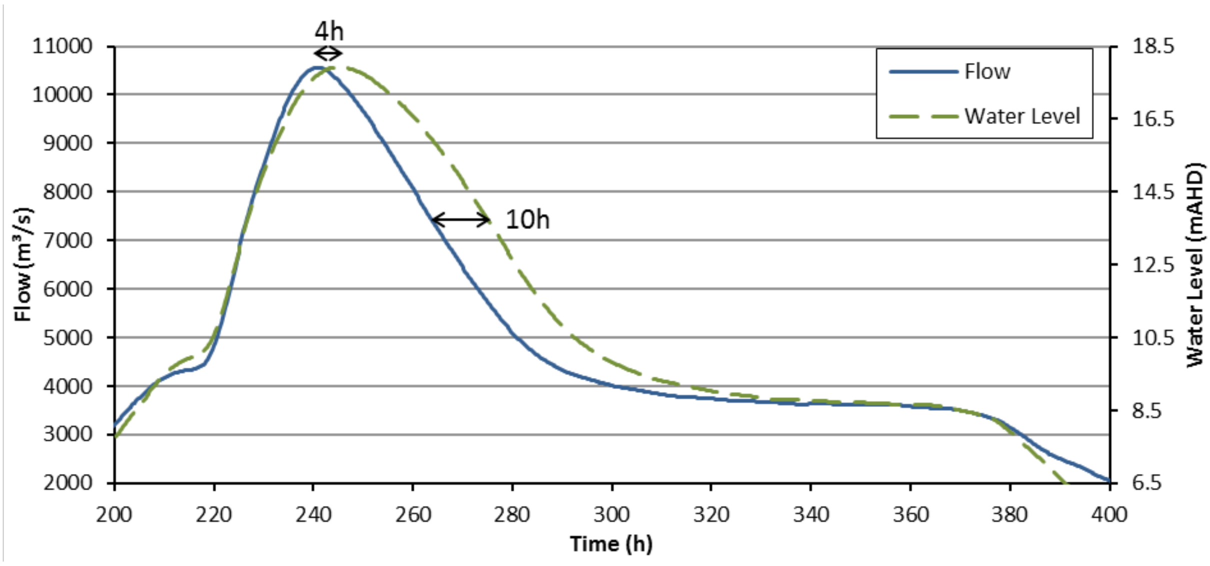


Figure 4-45 DMT TUFLOW model 2011 calibration – flow and water levels at Moggill

The dynamic response means that there is not a singular steady-state relationship between flow and water level, but rather the water level-flow relationship of a flood hydrograph displays a characteristic loop, as illustrated in Figure 4-46. The dynamic flow (Q) can often be related to a steady state rating flow (Q_r) using a correction factor known as the Jones Formula:

$$Q = Q_r(\eta)\sqrt{1 + \frac{1}{cS}\frac{d\eta}{dt}} \quad (1)$$

where $c = \frac{1}{B}\frac{dQ_r}{d\eta}$, η is the water surface level, B is the channel width, S is the channel slope.

Figure 4-46 shows the relationship between water level and flow at Savages Crossing from the DMT TUFLOW model for a range of flood events with and without correction using the Jones formula. This method was used to remove the dynamic influence and calculate a corrected 'steady-state' rating curve at each of the gauges.

Although the DMT TUFLOW model was calibrated against a number of historical flood events, it is important to recognise that this was accomplished within limits of available hydrology and other data. The results are therefore not necessarily consistent with the current BRCFS hydrology nor the forthcoming hydraulics phases. The ratings derived from the TUFLOW model were compared to available calibration data at each site, including flow measurements, steady-state Wivenhoe releases and BRCFS hydrologic model results. At each site, a small adjustment factor was generally required to conform the TUFLOW rating with available data (eg at Centenary Bridge an increase in flow approximately 3% was required to match observed level-flow values). This can be considered as an adjustment of the river conveyance of the calibrated model (eg a model calibrated with a too low flow would require higher roughness to match observed water levels).

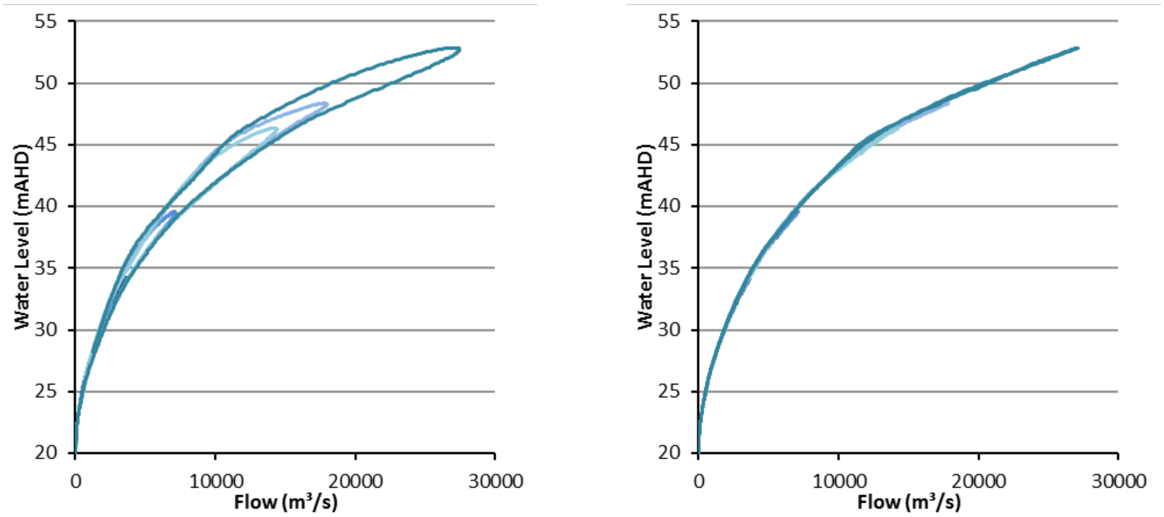


Figure 4-46 TUFLOW flow and water level relationship at Savages Creek with and without Jones correction

Hydrologic model and flood frequency results were also compared to ensure as much as possible consistency between the gauge ratings along the river. The resulting ratings are therefore consistent with the current hydrologic modelling but it is important to recognise that the only independent point of truthing in the high flow ratings is the flow gauging undertaken at Centenary Bridge, and that the uncertainty increases with distance from this site as storage attenuation and other effects may not be properly represented in the current models. This is particularly valid for the sites upstream of Bremer River confluence where the relationship between the flows at these sites and those downstream of the confluence can only be estimated within the limits of the available hydrologic modelling. Ongoing review of the ratings will be required, particularly following the BRCFS hydraulics phase.

4.7.5 Primary gauge rating – Brisbane River @ Mt Crosby Weir

Mount Crosby Weir has a fixed crest level of 6.9 m above the gauge zero datum, which is AHD. The gauging station operated by Seqwater, while not an official stream gauging site, was previously gauged by DNRM with 57 measurements between 1922 and 1999. The highest gauged record is 11.7 mAHD corresponding to 1671 m^3/s. In addition to the flow gaugings, on several occasions between 1989 and 2013 steady state releases have been made from Wivenhoe Dam, with the highest release being 3,500 m^3/s following the 2011 floods. These releases provide a well-defined discharge that can be matched to a recorded water level (assuming negligible inflows from catchments downstream of Wivenhoe).

Seqwater made use of a one-dimensional MIKE 11 model developed by SKM in defining the rating for Mount Crosby. The MIKE 11 model was refined and re-calibrated to the 2011 flood event as part of investigations for the Queensland Floods Commission of Inquiry. The MIKE 11 model was used to extrapolate the rating up to the level of 32 m recorded for the 1893 flood. The Bureau of Meteorology has also reviewed the Mount Crosby rating following the 2011 flood event. Both ratings are shown in Figure 4-48 and are very similar for levels up to 18 mAHD, with a slight deviation above that level. Both show good consistency with the steady release measurements and hydrologic model results.

The available data, shown in Figure 4-48, generally displays good consistency, however a distinctive cluster of data points between 10 m and 13 m gauge height show noticeable scatter. A number of these data points are steady-state releases from Wivenhoe (darker coloured triangles) and should have reasonable accuracy although there may be some additional inflows. These levels and flows correspond roughly to the road closure flow. Contact with and submergence of the deck, presence of debris and other factors may introduce significant variation in the observed water level. There is also a distinctive weir-flow type relationship below this level that is not present at higher levels, suggesting that submergence of the weir may also occur within this range. The rating derived from the TUFLOW modelling within this transition range is an approximate or typical value but generally shows good agreement with available data for lower and higher levels.

Figure 4-47 compares the historical variation of relative difference between the adopted rating and gauged/modelled discharge (note that modelled events shown as occurring in 1900 actually occurred prior to this time). Two clusters of flow gaugings where there is significant variation from the rating can be identified in 1922 and 1953. These are all very low discharges (<0.6 m above crest level). Excluding these clusters, the data appears to be reasonably well represented by the rating and no sign of consistent historical variation in the rating is evident.

The review concludes that Mt Crosby Weir is generally a good gauging location. The rating remains comparatively insensitive to changes in flow depth across most of its height and the rating appears relatively consistent and reliable. The rating should however be used with caution between around 10 and 12 m where the water level is in contact with the bridge deck. A noted limitation of the confidence in the rating is that most of the flow gauging is for relatively small discharges, with only 5 records above 250 m³/s.

Table 4-23 Rating curve reliability assessment – Brisbane River at Mt Crosby Weir

Range (m)	Discharge (m³/s)	Number of samples		Basis for rating
		Gauged	Modelled	
6.9 - 9	0 - 667	23	13	DMT TUFLOW
9 - 23	667 - 7540	5	35	DMT TUFLOW
23 - 33	7540 - 19980	0	6	DMT TUFLOW

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
6.9 - 9	-0.4%±8.6%	-0.9%±31.0%	0.002	0.017	3.4
9 - 23	-5.3%±20.8%	1.7%±14.6%	0.119	0.016	1.3
23 - 33	-3.8%±7.3%	4.9%±9.9%	0.334	0.124	2.2

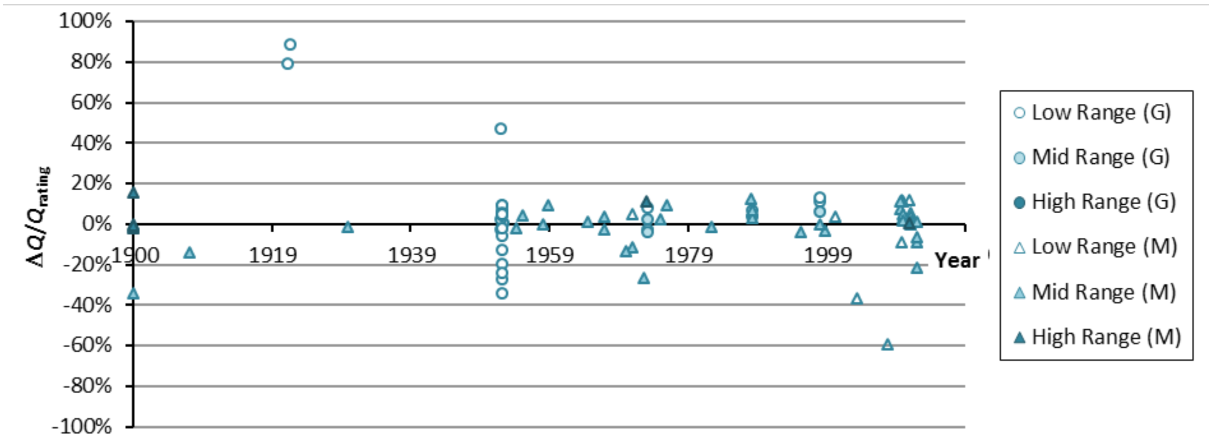


Figure 4-47 Relative variance of rated discharge – Brisbane River at Mt Crosby Weir

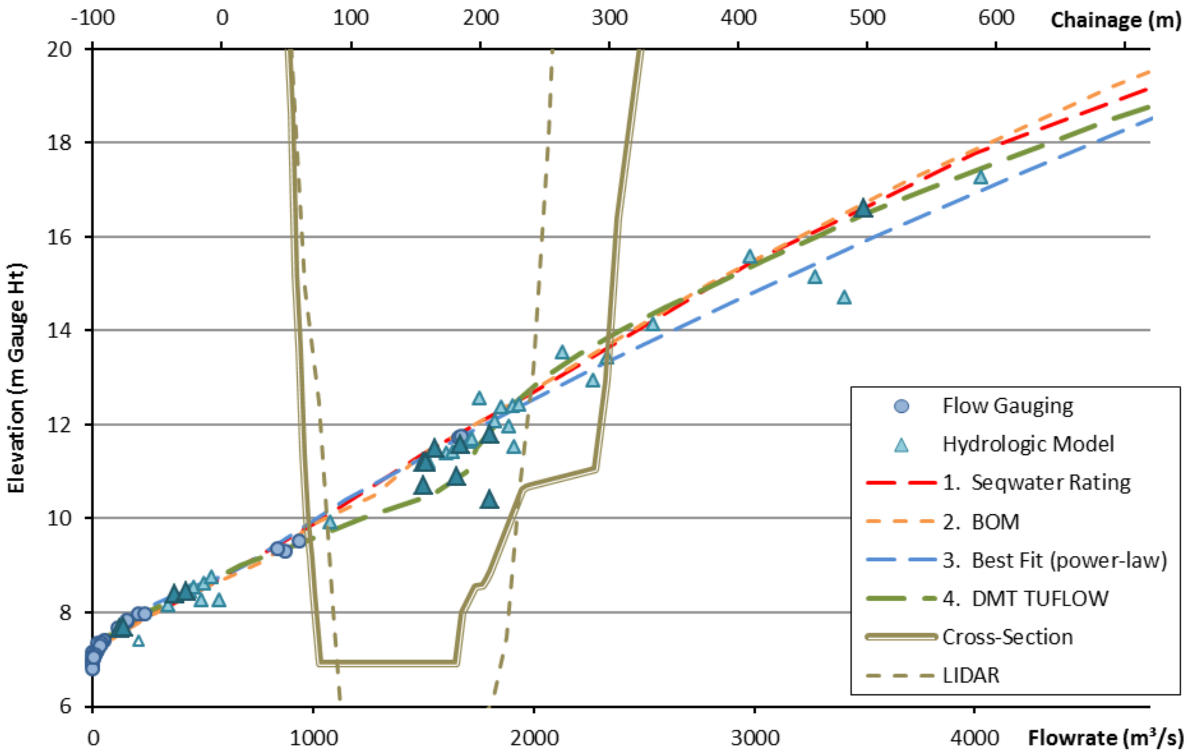


Figure 4-48(a) Rating Comparison – Brisbane River at Mt Crosby Weir (low – mid range)

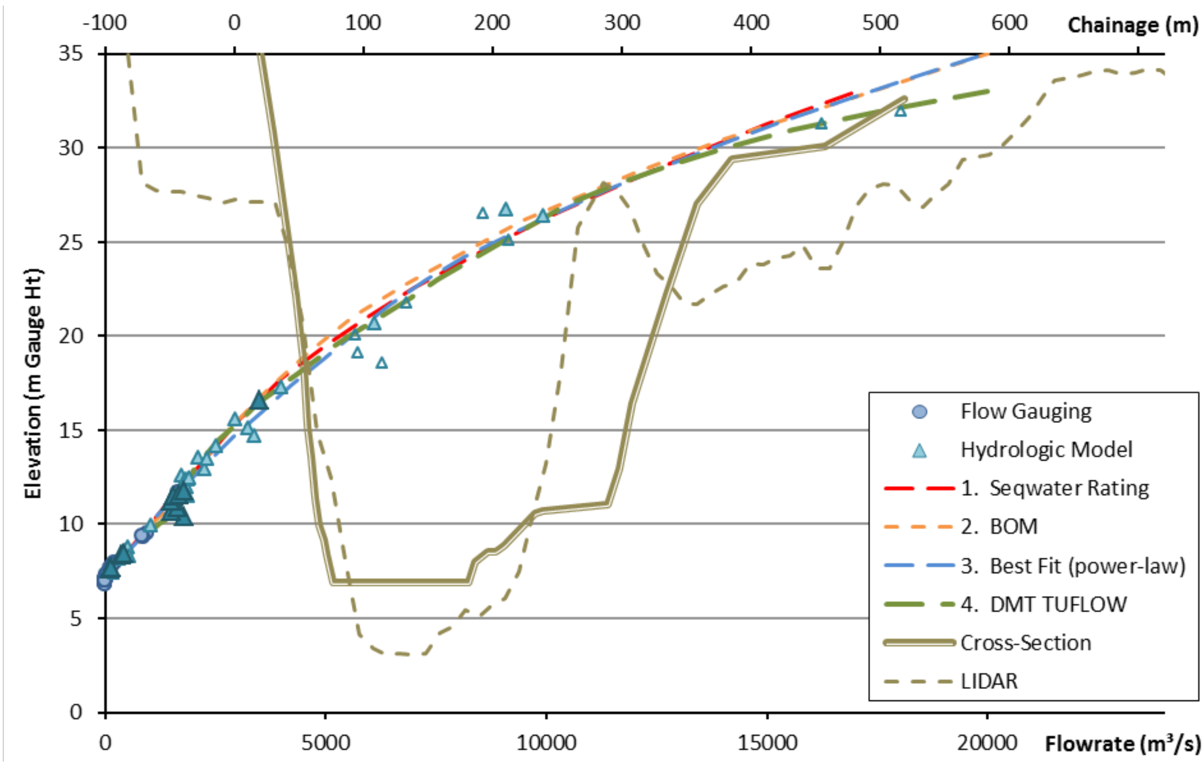


Figure 4-48(b) Rating Comparison – Brisbane River at Mt Crosby Weir (full range)

4.7.6 Primary gauge rating – Brisbane River @ Centenary Bridge

The Brisbane River gauge at Centenary Bridge is a flood warning gauge operated by BoM. The Centenary Bridge site has a much more limited historical record than Moggill, however some flow gauging information is available and flow conditions at the site are reported to be more suitable for a reliable rating than at Moggill. Flow gauging is limited, but covers a large range, up to 12.1 mAHD corresponding to around 9,780 to 10,085 m³/s during the 2011 flood event. Levels for the steady flow releases from Wivenhoe Dam between 1989 and 2013 are also available. Seqwater developed a rating based on flow gauging, steady state discharges and hydrologic model results. The rating is tide dependent at low discharges. The rating developed using the DMT TUFLOW model displays generally similar trend to the Seqwater rating up to about 15 mAHD (13,000 m³/s) but begins to diverge above this level with the TUFLOW rating tending to give higher flows.

Review of the reliability of the data in Table 4-24 and Figure 4-49 suggests that Centenary Bridge is a good gauging site with the available data showing remarkable consistency and no evidence of historical variation, although it is acknowledged that the amount of data is limited. The rating is also relatively insensitive to changes in flow depth. Overall, the Centenary Bridge rating is considered to be the most reliable of the Lower Brisbane River ratings, particularly in the high range where it is the only rating to have high flow measurements available.

Table 4-24 Rating curve reliability assessment – Brisbane River at Centenary Bridge

Range (m)	Discharge (m³/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.5 - 5	0 - 3959	13	5	DMT TUFLOW
5 - 15	3959 - 13099	5	7	DMT TUFLOW
15 - 25	13099 - 37632	0	2	DMT TUFLOW

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg$_Z$ & $CI_Z^{90\%}$	Avg$_Q$ & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
0.5 - 5	1.5%±10.1%	-1.7%±9.9%	0.051	0.000	1.0
5 - 15	-1.2%±7.0%	0.9%±7.2%	0.206	0.042	1.2
15 - 20	0.9%±0.8%	-1.3%±1.3%	1.000	1.000	1.7

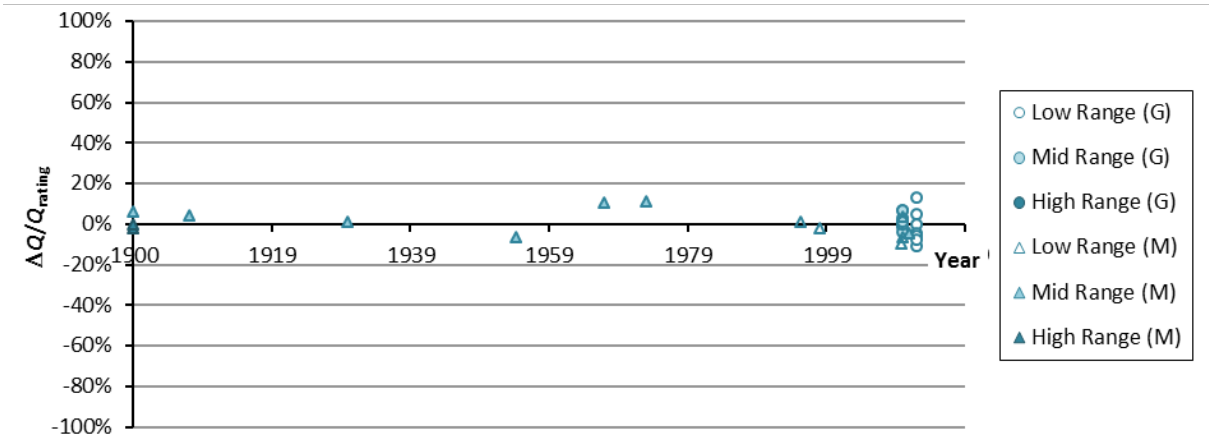


Figure 4-49 Relative variance of rated discharge – Brisbane River at Centenary Bridge

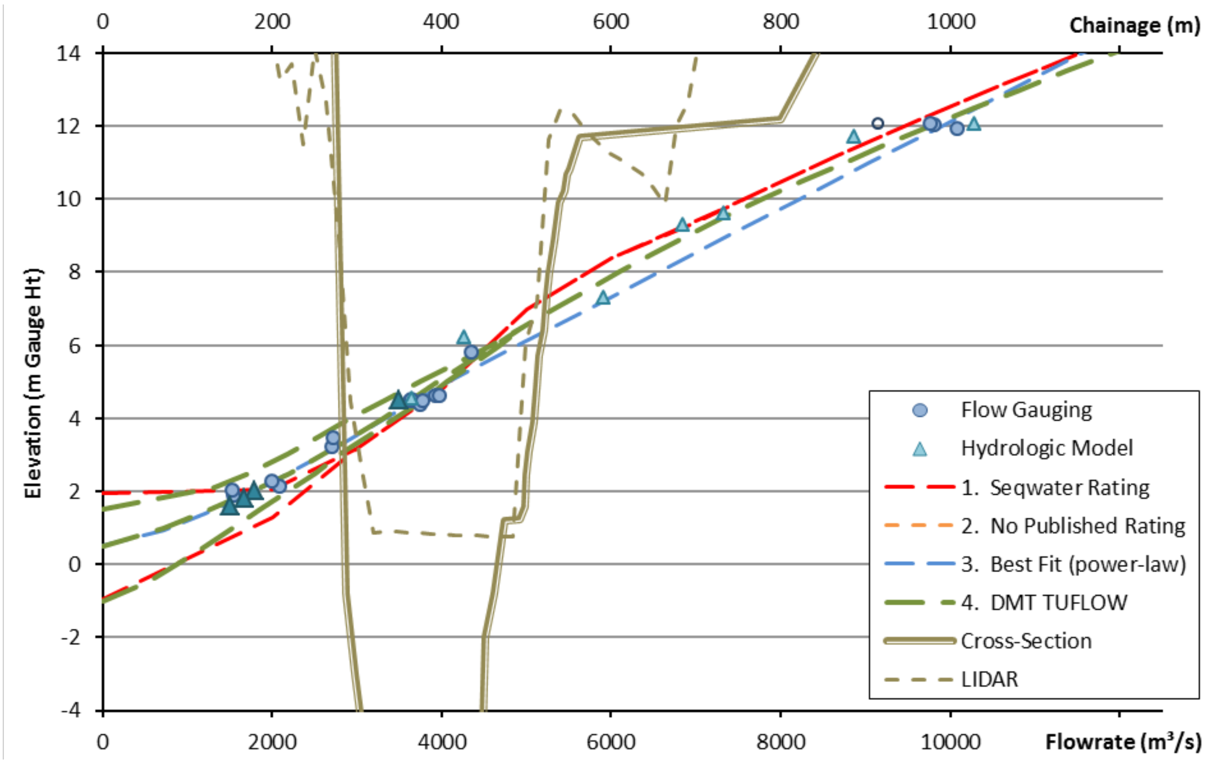


Figure 4-50(a) Rating Comparison – Brisbane River at Centenary Bridge (low – mid range)

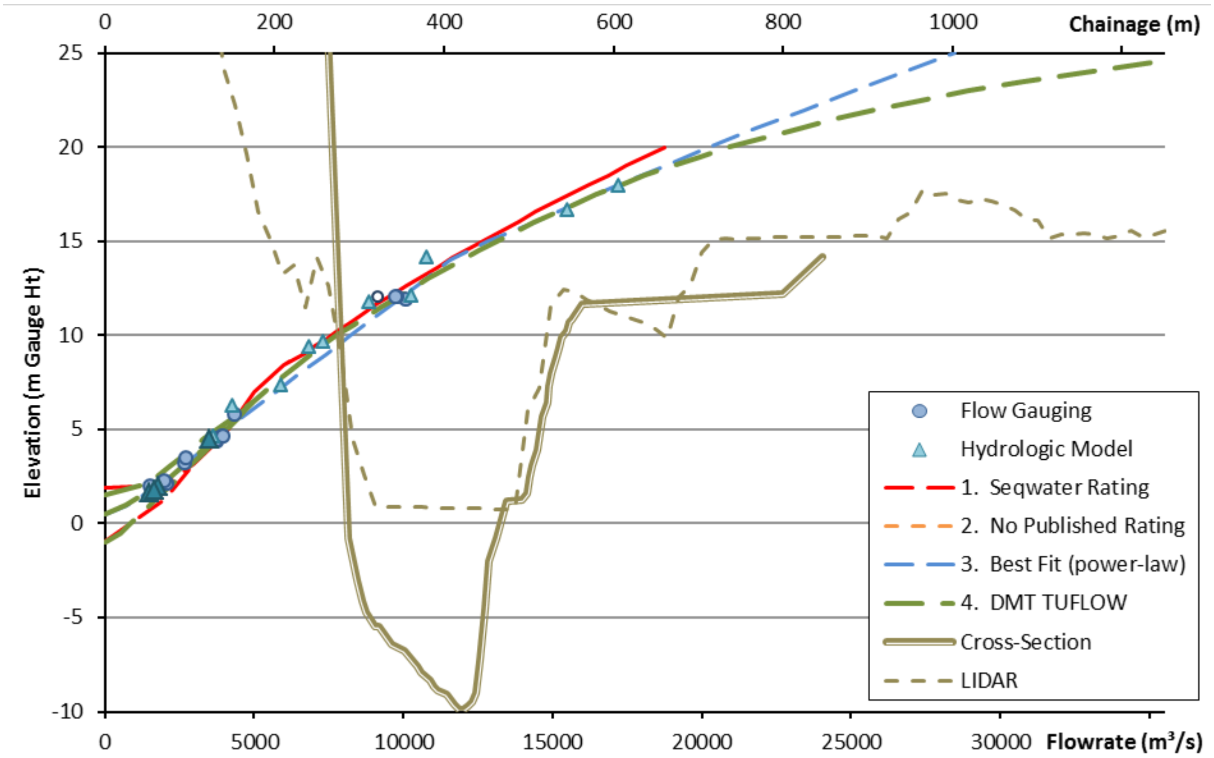


Figure 4-50(b) Rating Comparison – Brisbane River at Centenary Bridge (full range)

4.7.7 Secondary gauge rating – Brisbane River @ Savages Crossing

The Savages Crossing gauge is owned and operated by DNRM. The site has a large number of flow gaugings, with over 350 gaugings made between 1958 and 2013. The highest flow gauging measurement was during the January 1968 flood with a gauge height of 16 m corresponding to an estimated flow of 3360 m³/s. DNRM flow ratings at the site have varied significantly and examples are represented by Tables 32 (superseded) and 100 (current) in Figure 4-51. Examination of the flow gaugings shows significant scatter. While some of this may be attributable to inaccuracies or differences in the flow measurement technique, Seqwater has reported noticeable differences (>1 m) in the observed water level for similar releases prior to and after the 2011 flood event, suggesting that there have been changes in the channel conditions. Changes to high flow breakout patterns in the Fernvale area have also been observed, possibly due to recent changes in the floodplain. As shown in Figure 4-51(a), the current DNRM Table 100, which is the lower of the two DNRM curves shown, appears to over-estimate the discharge for much of the low to mid-range levels. It is therefore not considered suitable for the purposes of the BRCFS.

Seqwater has developed a rating based on a DNRM rating (understood to have been Table 100 although this appears to have been updated subsequent to the Seqwater assessment) for elevations less than 5 m gauge height, mathematical fit of steady flow release data between 5 m and 17 m, and extrapolation of the upper rating using a HEC-RAS model developed by DNRM to guide the shape of the extrapolation.

The rating derived from the DMT TUFLOW model generally shows reasonable agreement with the Seqwater and DNRM ratings and has been developed to provide an ‘average’ fit of the available data. It provides reasonable consistency with the flow gaugings (considering the scatter), steady flow release measurements and hydraulic and hydrologic modelling. Review of the data and rating reliability is provided in Table 4-25 and Figure 4-52, which suggest that the lower range is relatively variable but the variability decreases with flow depth. Importantly, Figure 4-52 appears to indicate temporal variation of the lower rating. This is not as pronounced but is still potentially present in the mid-range flows, although it is cautioned that there is less data available in this range.

Overall, it is concluded that Savages Crossing is a reasonable gauge site with a long and well documented flood history, and a rating that is relatively insensitive to changes in flow depth across a wide range. However the issues discussed above suggest the site is subject to ongoing changes. The ratings are therefore considered to be reasonable indication of discharge but are not overly reliable, particularly over long periods of time.

Table 4-25 Rating curve reliability assessment – Brisbane River at Savages Crossing

Range (m)	Discharge (m³/s)	Number of samples		Basis for rating
		Gauged	Modelled	
0.5 - 7	0.0 - 704	101	16	DMT TUFLOW
7 - 20	704 - 6111	24	33	DMT TUFLOW
20 - 35	6111 - 28669	0	6	DMT TUFLOW

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg_Z & $CI_Z^{90\%}$	Avg_Q & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dZ}$
0.5 - 7	-2.9%±10.9%	7.1%±29.2%	0.090	0.038	2.6
7 - 20	-0.8%±8.3%	1.0%±18.6%	0.162	0.018	2.2
20 - 35	1.1%±3.0%	-2.8%±7.7%	0.002	0.004	2.7

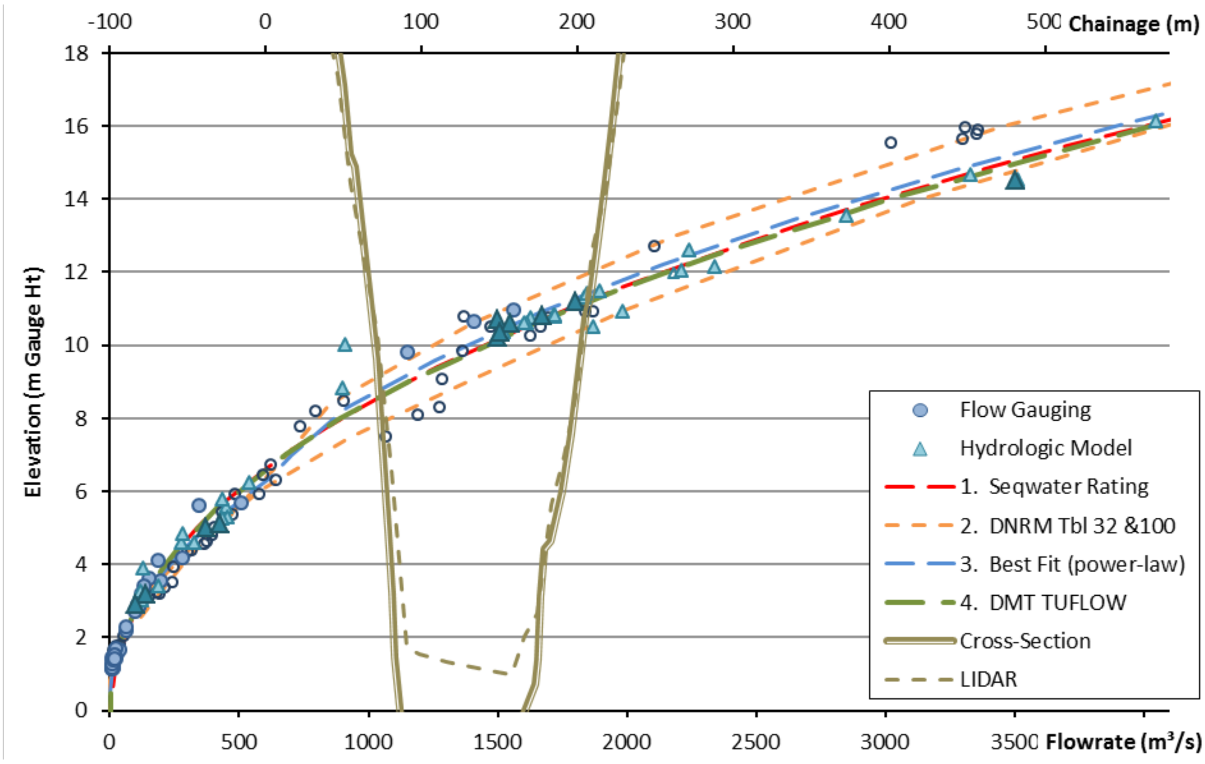


Figure 4-51(a) Rating Comparison – Brisbane River at Savages Crossing (low – mid range)

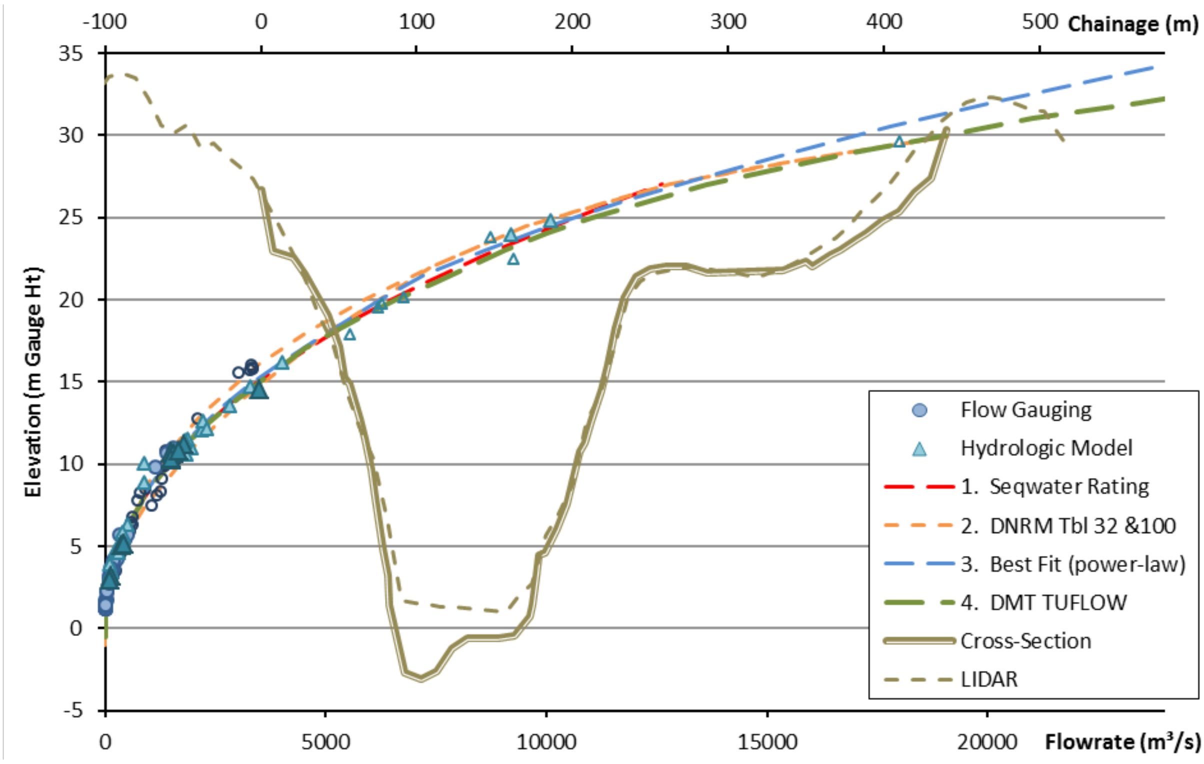


Figure 4-51(b) Rating Comparison – Brisbane River at Savages Crossing (full range)

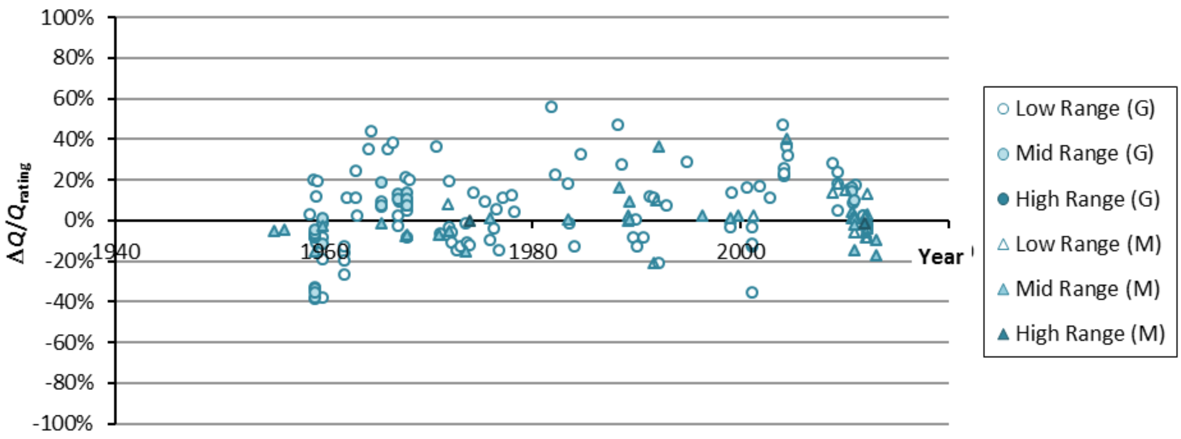


Figure 4-52 Relative variance of rated discharge – Brisbane River at Savages Crossing

4.7.8 Secondary gauge rating – Brisbane River @ Moggill

The Brisbane River gauge at Moggill is a flood warning gauge operated by BoM. The site has a long history of recorded peak heights for significant flood events and substantial continuous water level data, but is currently unrated. No flow gauging has been performed at the site, but recorded heights for several steady state releases from Wivenhoe Dam between 1989 and 2013 are available up to a maximum discharge of 3500 m³/s, providing a well-defined discharge that can be matched to a recorded water level.

The rating derived from the DMT TUFLOW modelling shows a similar trend but tends to produce slightly higher flows. Review of the data reliability is provided in Table 4-26 and Figure 4-54. The rating fits the data relatively well, although it is cautioned that there is relatively limited reliable data available. Overall, the rating review concludes that Moggill is a reasonable gauge site with a long history of flood levels and a rating that is relatively insensitive to changes in flow depth across a wide range, but with little data to develop complete confidence in the rating. The rating is currently considered to be reasonable indication of discharge but is not overly reliable.

Table 4-26 Rating curve reliability assessment – Brisbane River at Moggill

Range (m)	Discharge (m³/s)	Number of samples		Basis for rating
		Gauged	Modelled	
1 - 7	0 - 3259	0	30	DMT TUFLOW
7 - 15	3259 - 7825	0	9	DMT TUFLOW
15 - 28	7825 - 26327	0	7	DMT TUFLOW

Range (m)	Data Variability		Rating Bias		Sensitivity
	Avg$_Z$ & $CI_Z^{90\%}$	Avg$_Q$ & $CI_Q^{90\%}$	R_Z^2	R_Q^2	$S_{dQ/dz}$
1 - 7	6.7%±25.5%	-21.9%±86.9%	0.005	0.487	1.2
7 - 15	-2.9%±11.5%	2.6%±11.1%	0.211	0.489	1.2
15 - 28	-3.9%±9.7%	4.8%±13.2%	0.165	0.005	1.9

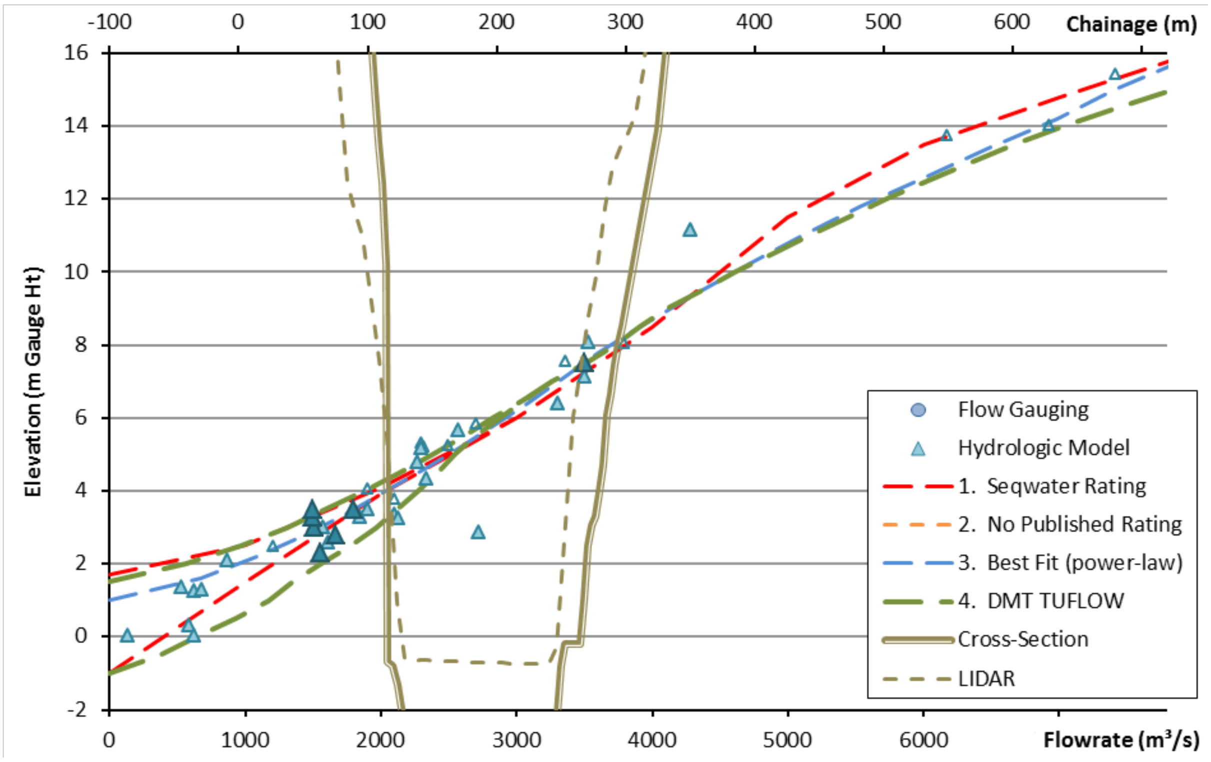


Figure 4-53(a) Rating Comparison – Brisbane River at Moggill (low – mid range)

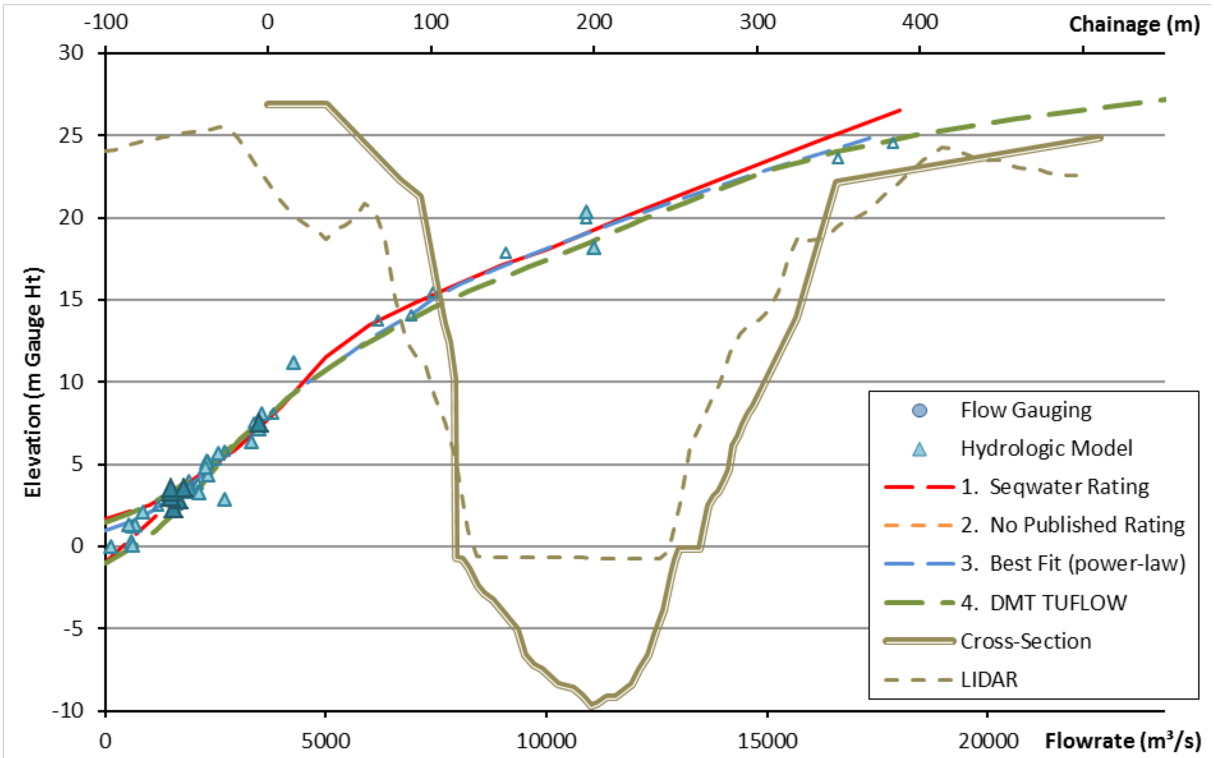


Figure 4-53(b) Rating Comparison – Brisbane River at Moggill (full range)

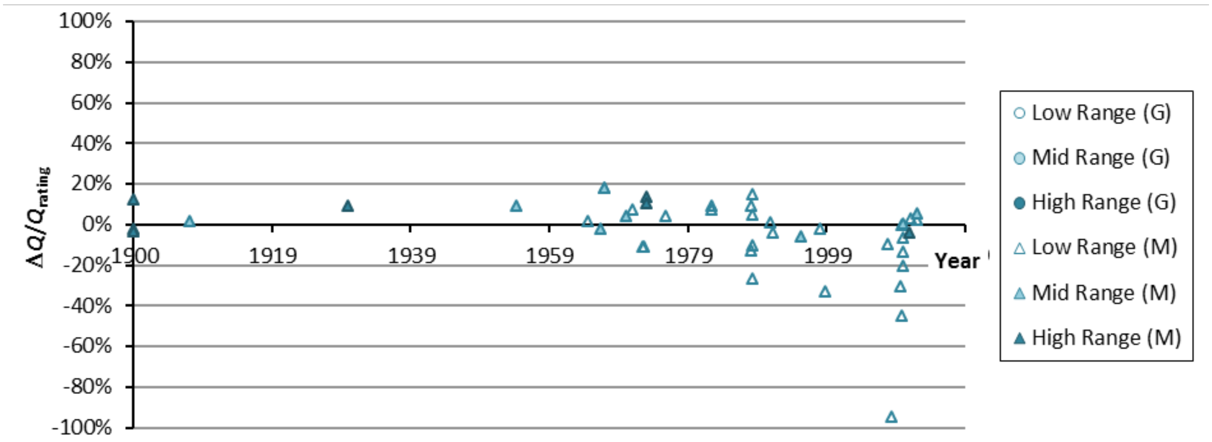


Figure 4-54 Relative variance of rated discharge – Brisbane River at Moggill

4.7.9 Secondary gauge rating – Brisbane River @ Brisbane City

The BRCFS scope has highlighted the Brisbane City gauge as being of key importance. In realistic terms, the Brisbane City gauge is not of high importance for the hydrologic model calibration as upstream gauges have better quality ratings. The main advantage of the Brisbane City gauge is its long period of record, dating back to the 1840s, which may make it of some use to the flood frequency analysis, but this usefulness is diminished if a reliable rating cannot be established. Derivation of a reliable flood rating at this site is considered to be a very complicated task. The '*Brisbane River Flood Hydrology Models*' report (Seqwater 2013) identifies:

> *A rating relationship for the Port Office gauge is particularly complex because there are no flow gauging data at the site and tidal influences are evident on nearly all recorded water level hydrographs. Compared to upstream gauge sites, the relatively small height range at the Port Office results in potential greater flow uncertainty as a small error in height measurements results in a larger difference in flow estimate.*

Figure 4-55, reproduced from the Seqwater report, highlights these issues. The condition of the river channel is also understood to be unstable due to dredging works and scour during flood events. The Seqwater review of currently available data at the Brisbane City gauge is included in their report and is considered to reflect the current understanding of the Brisbane City gauge characteristics.

It is considered extremely difficult to derive a joint probability rating based on hydrologic model data alone, and without any flow gauging or other reliable rating calibration data, the only practical way to improve confidence in the rating is through hydraulic modelling. A comprehensive assessment of the Brisbane City gauge rating would require a detailed and reliable hydraulic model of the lower Brisbane River. Development of this model lies outside the scope of the BRCFS hydrology study, however the results from the DSDIP/DMT TUFLOW model was used to develop a rating curve for this location. The revised rating is shown in Figure 4-56. Unlike the other lower Brisbane River gauges, the city gauge shows relatively little hysteresis due to limited storage area between the city and river mouth. Strong tidal influence is observed up to even up to high flows. Combined with the lack of independent data, the Brisbane City rating is considered to be unreliable. The hydrologic model calibration nevertheless identified the rating to be relatively consistent with the upstream gauges.

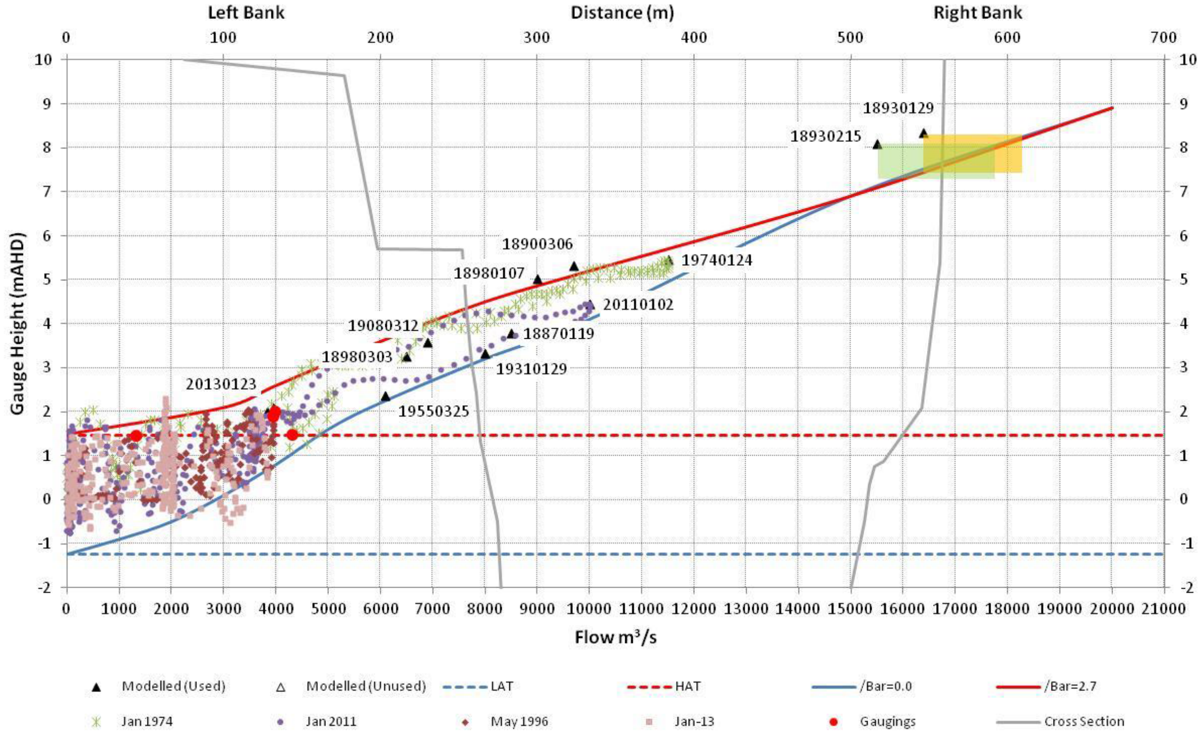


Figure 4-55 Rating Comparison – Brisbane River @ Brisbane City from Seqwater 2013

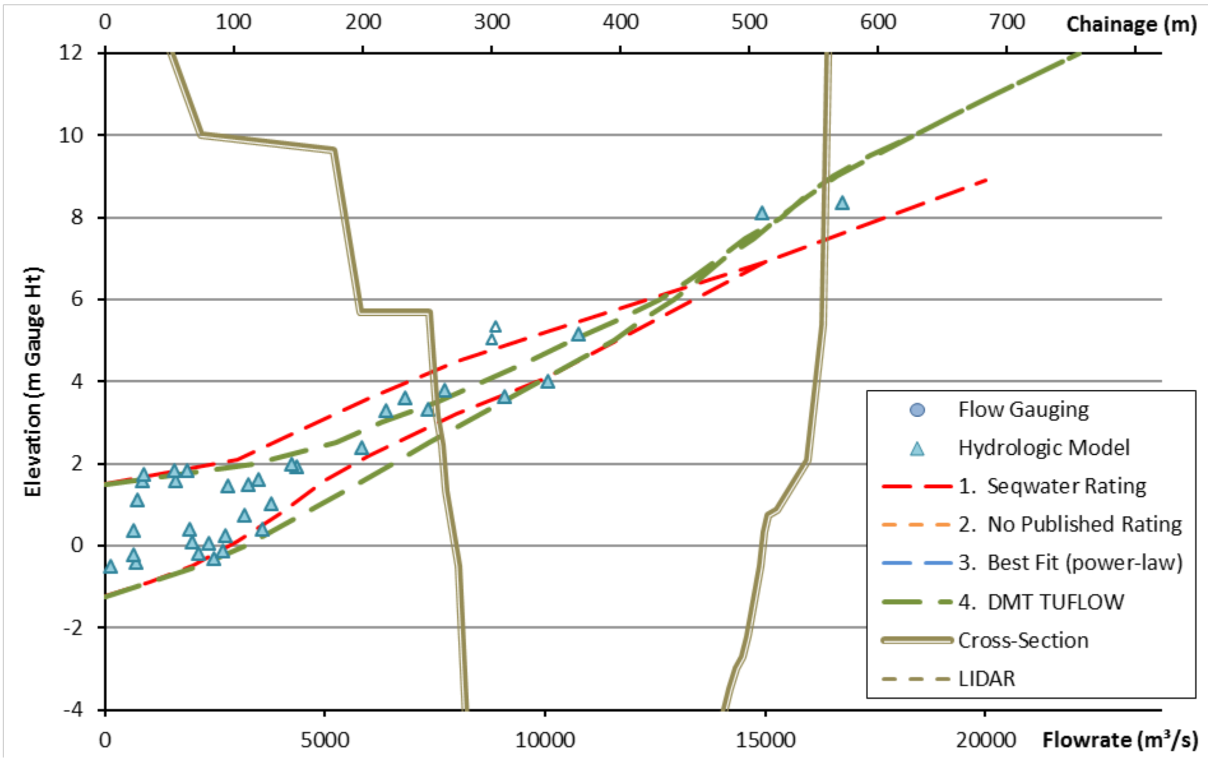


Figure 4-56 Rating Comparison – Brisbane River @ Brisbane City

4.7.10 Secondary gauge rating – Bremer River @ Ipswich

The Bremer River gauge at Ipswich is of considered to be of high importance to that city and has been identified as a key gauge site. However, flood levels at Ipswich are strongly affected by backwater from the Brisbane River. Seqwater has developed a co-dependent rating relating flows at Ipswich to levels at Ipswich and Moggill. Seqwater (2013) identifies that this was parameterised from recorded water levels and flow estimates derived from hydrologic modelling, but acknowledges that "ideally a dependent rating relationship would be informed by a well configured and calibrated hydraulic model".

The current rating was assessed using the results from the DMT TUFLOW model. As illustrated in Figure 4-57, using model water levels at Ipswich and Moggill, the rating predicted a flow significantly lower and peaking earlier than the actual flow. Overall the rating is considered to have relatively low accuracy.

Due to storage effects (hysteresis) in the Brisbane River and in the Bremer River both upstream and downstream of Ipswich, flood levels at Ipswich are potentially a complex function not only of the flow/level in the Brisbane Bremer Rivers but also the rate of change of each of those values. This could potentially be considered after completion of the BRCFS hydraulic modelling but is considered to like outside the scope of the BRCFS hydrology study.

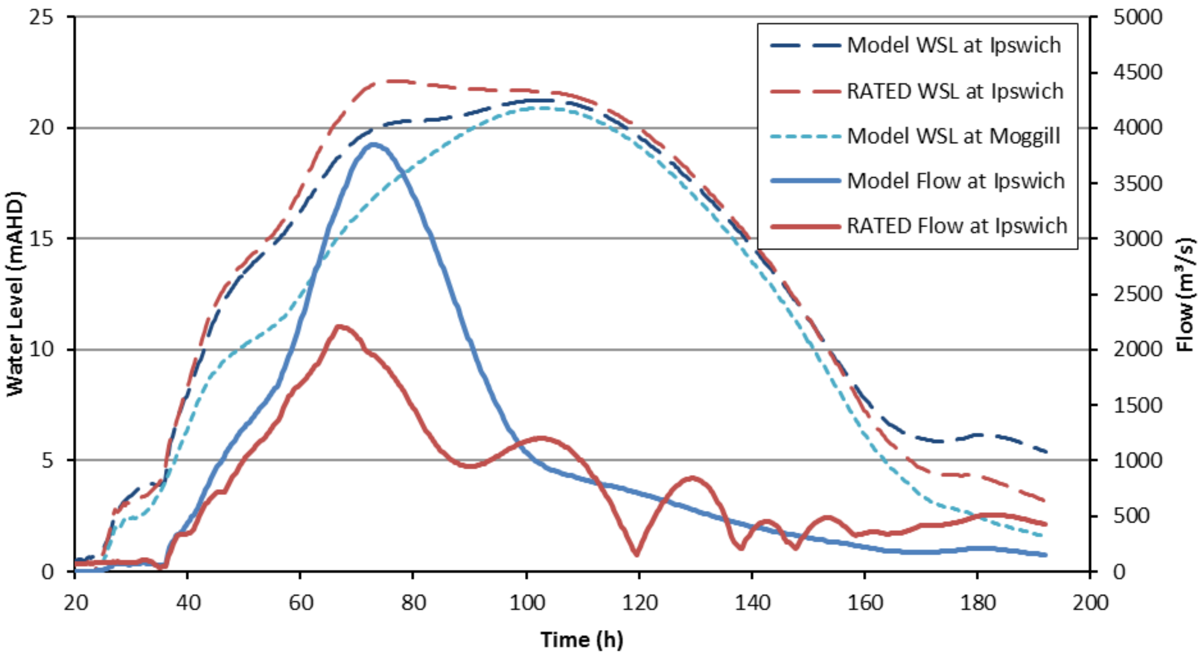


Figure 4-57 Comparison of rated flows and levels – Bremer River @ Ipswich

4.8 Summary of recommended ratings

A summary of current gauge rating recommendations is provided for the primary and secondary gauges in Table 4-27 and Table 4-28 respectively.

Table 4-27 Summary of Primary Gauge Rating recommendations

Gauge description	Recommended rating description
Catchment: Stanley River to Somerset **Stream:** Stanley River **Site:** Woodford **Gauge No:** 143901A **Owner:** DNRM	Power-law fit of data up to 2.5m then hydraulic model results Flows below 20m³/s weir controlled and dependent on local Stanley River flows only. Flows above 50m³/s dependent on combined flows from Stanley River (at gauge) and downstream tributary. Rating provides a good fit of revised hydrologic model results, however could be unreliable if flow distribution varies significantly from the ratio assumed by the hydraulic modelling
Catchment: Brisbane River to Wivenhoe **Stream:** Brisbane River **Site:** Linville **Gauge No:** 143007A **Owner:** DNRM	Power-law fit of data up to 2.7m then hydraulic model results Site is considered a good gauge location. Flow gauging and hydrologic model data are consistent and high flows are well contained. Rating provides a good fit of flow gaugings and hydrologic model data
Catchment: Lockyer Creek to O'Reilly's Weir **Stream:** Lockyer Creek **Site:** Glenore Grove **Gauge No:** 143807 **Owner:** BoM	Power-law fit of data up to 2.5m then hydraulic model results 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
Catchment: Bremer River to Walloon **Stream:** Bremer River **Site:** Walloon **Gauge No:** 143107A **Owner:** DNRM	DNRM rating up to 5m then hydraulic model results 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
Catchment: Warrill Creek to Amberley **Stream:** Warrill Creek **Site:** Amberley **Gauge No:** 143108A **Owner:** DNRM	Power-law fit of data up to 5m then hydraulic model results 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)
Catchment: Purga Creek to Loamside **Stream:** Purga Creek **Site:** Loamside **Gauge No:** 143113A **Owner:** DNRM	DNRM rating up to 6m then hydraulic model results 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)
Catchment: Lower Brisbane River **Stream:** Brisbane River **Site:** Mt Crosby Weir **Gauge No:** 430003A **Owner:** Seqwater	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

Gauge description		Recommended rating description
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	

Table 4-28 Summary of Secondary Gauge Rating recommendations

Gauge description		Recommended rating description
Catchment:	Stanley River to Somerset	3-stage best-fit of flow gauging and hydrologic model data Reasonable match of flow gauging and hydrologic model data below 6m. Gauge becomes sensitive to changes in level above 7m with limited reliable data available for calibration. Hydrologic model data shows noticeable scatter but consistent general trend
Stream:	Stanley River	
Site:	Peachester	
Gauge No:	143303A	
Owner:	DNRM	
Catchment:	Stanley River to Somerset	Seqwater Rating based on two-stage best-fit of flow gauging and hydrologic model data Reasonable match of flow gauging data up to 5.5m. Upper rating is based solely on hydrologic model data and significant scatter is observed in the results above 5m. Upper rating is also very sensitive to changes in level. Upper rating is therefore considered to be unreliable but of fairly low importance overall
Stream:	Kilcoy Creek	
Site:	Mt Kilcoy	
Gauge No:	143312A	
Owner:	DNRM	
Catchment:	Brisbane River to Wivenhoe	3-stage best-fit of flow gauging and hydrologic model data Good agreement with DNRM HEC-RAS model although details of model are not confirmed. Reasonable match of flow gauging data up to 9m and hydrologic model data above that level, however noticeable scatter is evident in the low level flow gauging data. Site is well confined but known to have issues with changes to section and sand extraction downstream. The rating is considered to be reasonable, but not necessarily consistent
Stream:	Brisbane River	
Site:	Gregors Creek	
Gauge No:	143009A	
Owner:	DNRM	
Catchment:	Brisbane River to Wivenhoe	3-stage best-fit of flow gauging and hydrologic model data Reasonable agreement with Seqwater rating. Flow measurements translated from Middle Creek gauge site to improve shape of low-flow rating. Gauge site has been closed since construction of Wivenhoe Dam
Stream:	Brisbane River	
Site:	Caboonbah	
Gauge No:	143900	
Owner:	BoM	
Catchment:	Brisbane River to Wivenhoe	3-stage best-fit of flow gauging and hydrologic model data Rating based on flow gauging up to 2,600 m³/s and is considered to be good within this range. Little data available for validation of rating above this range but few recorded higher levels and gauge site has been closed since construction of Wivenhoe Dam
Stream:	Brisbane River	
Site:	Middle Creek	
Gauge No:	143008A	
Owner:	DNRM	

Gauge description		Recommended rating description
Catchment:	Lockyer Creek to O'Reilly's Weir	3-stage best-fit of flow gauging and hydrologic model data Rating shows similar trend to Seqwater rating based on hydrologic model data and independent SKM hydraulic model, however consistency of this model to BRCFS hydrology not confirmed. Rating was adjusted to improve better match of hydrologic model results and improve consistency with downstream flows at Glenore Grove and Rifle Range Road No flow gauging data is available for comparison. Gauge location is well confined and should provide reasonable rating conditions up to bank-full condition, but is not rated above 16m (2700m³/s)
Stream:	Lockyer Creek	
Site:	Gatton	
Gauge No:	143904	
Owner:	BoM	
Catchment:	Lockyer Creek to O'Reilly's Weir	Seqwater rating Relatively close proximity to Gatton gauge. Very limited low-level flow gauging and limited hydrologic model data due to short gauge record. Gauge location is well confined and should provide reasonable rating conditions up to bank-full condition, but is not rated above 17m (2700m³/s)
Stream:	Lockyer Creek	
Site:	Gatton Weir	
Gauge No:	143236A	
Owner:	Seqwater	
Catchment:	Lockyer Creek to O'Reilly's Weir	3-stage best-fit of flow gauging and hydrologic model data Reasonable agreement with DNRM and Seqwater ratings. Stream flow gauging only available for low flows. Significant scatter in hydrologic model data as model calibration weighted heavily towards the Glenore Grove site which has six times the catchment area. Rating is considered to have limited reliability
Stream:	Lockyer Creek	
Site:	Helidon	
Gauge No:	143203C	
Owner:	BoM	
Catchment:	Lockyer Creek to O'Reilly's Weir	DNRM Rating Good agreement with flow gauging up to 7.6m so considered to be a relatively reliable rating, however rating becomes sensitive to changes in level above 5m
Stream:	Laidley Creek	
Site:	Warrego Hwy	
Gauge No:	143904	
Owner:	BoM	
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	
Catchment:	Bremer River to Walloon	DNRM Rating (Seqwater rating very similar) up to 4.4m gauge height then power law best-fit of hydrologic model data Good fit of flow gauging up to 4.3m. Basis of projection above this level unknown and appears to predict higher levels/lower flows than Seqwater hydrologic model results. Rating becomes sensitive to changes in level above 4m
Stream:	Bremer River	
Site:	Adams Bridge	
Gauge No:	143110A	
Owner:	DNRM	
Catchment:	Bremer River to Walloon	Best-fit of hydrologic model data Reasonable agreement with hydrologic model data but no independent confirmation data available. Poor detail below 4.5m. Higher emphasis should be placed on Walloon gauge rating
Stream:	Bremer River	
Site:	Rosewood	
Gauge No:	143909	
Owner:	BoM	

Gauge description	Recommended rating description
Catchment: Warrill Creek to Amberley **Stream:** Warrill Creek **Site:** Junction Weir **Gauge No:** 143118 **Owner:** Seqwater	Seqwater rating Based on hydraulic model up to around 200m³/s. Reportedly very low reliability above this but shows reasonable match of the limited hydrologic model data available
Catchment: Purga Creek to Loamside **Stream:** Purga Creek **Site:** Peak Crossing **Gauge No:** 143869 **Owner:** Seqwater	Best fit of hydrologic model data only Limited record length and no independent data. Generally low confidence in gauge rating magnitude
Catchment: Lower Brisbane River **Stream:** Brisbane River **Site:** Savages Crossing **Gauge No:** 143001C **Owner:** DNRM	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
Catchment: Lower Brisbane River **Stream:** Brisbane River **Site:** Moggill **Gauge No:** 143951 **Owner:** BoM/Seqwater	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
Catchment: Lower Brisbane River **Stream:** Brisbane River **Site:** Brisbane City **Gauge No:** 143838 **Owner:** Seqwater	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

5 Historical flood review

In addition to the work undertaken by Seqwater, there are numerous studies and reviews which have assessed flooding in the Brisbane River catchment. A brief summary of a number of these reports was provided in Appendix D of the Phase 1 Data Collection Study report. These reports have been reviewed in much greater detail to obtain key hydrologic information and an understanding of the flood history of the Brisbane River catchment. In particular, the documents which make up Exhibit 883 of the Queensland Floods Commission of Inquiry have provided the best source of historical information.

5.1 Summary of key predictions

The historical flood review included a review of the Common Expert Reading List – Exhibit 883 of the QFCoI. A summary of the main issues and results from the reports included in the Reading List is given in Appendix C. The review focussed in particular on the changes in Q100 and related peak flood levels for the Port Office/Brisbane City gauge over time (1977-2011). The table below gives a summary of this review.

Table 5-1 Changes in Q100 and related peak flood levels for the Port Office/Brisbane City gauge over time

Report Date	Author	Q100 Peak Flow at Port Office gauge (m3/s)	Q100 Peak Level at Port Office gauge (m AHD)	Comments
1977	Grigg			Grigg noted that based on FFA the probable frequency of the Brisbane City gauge reaching 8mAHD is 1 in 110 years (pre-Wivenhoe)
1977	Hausler and Porter			This study provided the original design estimates of Q100 for Wivenhoe Dam although it does not include flood estimates at Brisbane City gauge
Mar 1978	Hegarty	~12,800 (pre-Wiv); ~6800 (post-Wiv)	~7.8m (pre-Wiv); ~3.7 (post-Wiv)	Found that Wivenhoe Dam would reduce a 5.5m flood (of 50 yr ARI) to a 3m flood (of 55 yr ARI), and a 3m flood (23 yr ARI) to a 2.5m flood (25 yr ARI) compared to the 1978 conditions. Using Log Pearson III distribution for pre-Wiv and Boughton for post-Wiv. Looking at the Q100 peak flow and level on the Log Pearson III curve, gives very high values for the pre-Wiv estimates (~12800m^3/s and ~8m) and gives post-Wiv estimates of ~6800m^3/2 and ~3.7m using Boughton

Report Date	Author	Q100 Peak Flow at Port Office gauge (m3/s)	Q100 Peak Level at Port Office gauge (m AHD)	Comments
Nov 1984	Wivenhoe Dam flood manual committee	5510	-	Notes from the 13th-15th meeting of the Wivenhoe Dam flood manual committee, held Aug-Nov 1984, and related correspondence
1984	Weeks	5510		First study to establish design flows for the area downstream of Wivenhoe, built upon findings of his 1983 report on design floods at the dam. Design floods were calculated by using the design rainfalls as input into a calibrated runoff-routing model. Weeks estimated a Q100 flow of 5510m^3/s at the City gauge when Wivenhoe dam was in operation. This allowed for a peak outflow from the dam of 3500m^3/s
1984	"unknown"	6800	3.3	Used as a basis for flood levels for development control level. This report is referred to in the City Design [June 1999] report as being the "most recent study completed by Council's Water Supply and Sewerage Department"
Jan 1985	Hegarty and Weeks	6800	-	By January 1985, for the purpose of the Wivenhoe Dam Operations Manual, Hegarty and Weeks undertook a FFA of flooding in the lower Brisbane River catchment taking into account operation of the Somerset and Wivenhoe dams. Flood frequency plots suggest a Q100 peak flow of up to 6800m^3/s was derived for the Brisbane City gauge
May 1992	Greer	11500		A PMF peak of 54400m^3/s (by method RR) is obtained from CBM (GTM) study in 1984. 1% AEP and PMF estimates of multiple rivers and creeks in QLD are summarised in table
Sept 1992	SEQ Water Corporation	<8580		calibration of runoff-routing models
Mar 1993 (draft)	SEQ Water Corporation	8580	-	
Aug 1993	SEQ Water Corporation	9120/9380	-	It seems that the 9380m^3/s value has been referenced in City Design [1999] and CMC [2004]. 9120m^3/s was based on a storm over the whole Brisbane catchment, as this spatial pattern was critical for the PMF. However, a value of 9380m^3/s was also given for a storm in only the Upper Brisbane catchment
June 1998	SKM (for BCC)	9560	5.34	This study used hydrologic and hydraulic models that were calibrated to four events and verified against another four events to establish a post dam peak Q100 flow of 9560m^3/s at the Port Office

Report Date	Author	Q100 Peak Flow at Port Office gauge (m3/s)	Q100 Peak Level at Port Office gauge (m AHD)	Comments
Dec 1998	Mein	<9560		Mein (for BCC) reviewed SKM's 1998 report. Found that the approach was appropriate, but the magnitude of the Q100 peak flow was an overestimate. The review was concerned about the misclosure between FFA and the rainfall runoff approach, because of the use of zero losses and the absence of a real reduction factor to reduce the misclosure. The review considered that too much emphasis was given to historic events in the 1800's suggesting a higher emphasis should be placed on historic events from the 1900s. Also, the assumption that the dams were full prior to an event was questioned
June 1999	City Design	8600	5	The City Design report did not fully address Mein's [1998] review recommendations. It concluded that if current development control levels remained that these would have a return period of 1 in 55 years. The estimated Q100 is a 10% reduction compared to the SKM [1998] study
Dec 1999	City Design	8000	4.7	This study ("further investigation") was to fully incorporate Mein's recommendations, although they were again not fully addressed
Oct 2000	Brisbane River Flood Study Technical Workshop, held in October 2000.			Workshop identifies FORGE Study being undertaken by DNR and Seqwater Corporation. The continuous simulation study was due to be finalised December 2000 and was consistent with Mein's comments and the current approach by the CRC for Catchment Hydrology. The workshop concluded that the FORGE work needs to be taken into account, and suggested to take areal reduction factors into account (estimated to produce a 20% reduction in total rainfall at the Port Office gauge). Preliminary results showed the DNR Q100 level as closer to the BCC 1984 study (6800m^3/s) than the 1992 DNR study (9120m^3/s)
June 2003	Preliminary advice from DNRM to BCC	6000-7000		Preliminary advice that the Q100 flood flows at Port Office would be 6000-7000m^3/s
Sept 2003	Mein et al (Independent Review Panel)	6000 ± 1000	3.3 ±0.5	Based on the two SKM August 2003 reports, the independent review panel concluded that a Q100 peak flow of 6000m^3/s with dam with an estimated flood level of 3.3mAHD at the Port Office gauge was a more likely estimate than previous estimates of over 8000m^3/s. The review proposed a pre-dam flow of 12000m^3/s and that the dams reduced the flow by 50%

Report Date	Author	Q100 Peak Flow at Port Office gauge (m3/s)	Q100 Peak Level at Port Office gauge (m AHD)	Comments
Dec 2003	SKM	6500 ± 1500	3.51 (2.76-4.41)	SKM suggest that the peaks are lower than in their previous 1998 study as areal reduction factors were used, there was more consideration of variation in temporal and spatial characteristics of rainfall, better knowledge of dam operating procedures and inclusion of regional streamflow information in the statistical flood frequency analysis. SKM used the rainfall-runoff model developed as part of SKM's 1998 study with additional information and statistical techniques to reassess the plausible range of the Q100 flood
Feb 2004	SKM (for City Design)	6000	3.16	Re-calibration of the 1955 RAFTS Model (loss rates only) and 1998 Mike11 hydraulic model to determine 1% AEP flood levels. Extractions of hydrographs from the 1955 and 1974 RAFTS Model and input to Mike11. Predicted discharges at Port Office gauge: 9979m^3/s (1974) and 4364m^3/s (1955). For CRC FORGE event analysis, all hydrographs were scaled up with factor 1.117 and the Mike11 model run resulted in 5971m^3/s at Port Office Gauge
Mar 2011	Joint Flood Taskforce	-	4.46 (City) / 4.27 (Port Office)	No revisions of the Q100 estimate between 2004 and 2011. The report states that the current Q100 peak flow was last estimated in 2003 to be 6000m^3/s with a corresponding flood level of 3.3mAHD including the uncertainty bounds as recommended by the 2003 Independent Panel Review. The report also states that at the time of the 2011 flood, BCC had defined the Defined Flood Event (DFE) to be 6800m^3/s and the Defined Flood Level (DFL) to be 3.7mAHD. This was first set in 1978 and reconfirmed in 2003
Oct 2011	WMA2011	9500		Carried out FFA on Port Office gauge record with and for 1841-2011. 2011 event pre-dam: 13000m^3/s; post-dam 9500m^3/s (and 9000m^3/s without info on 2011 post-dam flow). FFA found the 2011 event to have 120yr ARI (post-dam) and 100yr ARI (pre-dams). WMAwater states that the Q100 line as adopted by BCC is significantly below the Q100 flood line estimated in WMAwater's study (~3m at Moggill and ~1m at PO)

Report Date	Author	Q100 Peak Flow at Port Office gauge (m3/s)	Q100 Peak Level at Port Office gauge (m AHD)	Comments
Oct 2011	Brisbane River Flood Frequency Panel			Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011. All experts, including Mr Babister (author of WMAwater 2011 report), agreed that the WMAwater Q100 estimate was not an appropriate flood level figure corresponding to the Q100 because he had not been able to complete a comprehensive flood study. The reports prepared by each expert were critiques of Mr Babister's methodology and results. The joint expert statement diverged significantly from that topic. The joint expert statement sets out a blueprint for a best practice flood study for the Brisbane River catchment

5.2 Future work

It is expected that further analysis and review of the historical flood reports will be required throughout the course of the CHA.

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7 Glossary

7.1 Hydrologic terms

AEP: Annual Exceedance Probability – is a measure of the likelihood (expressed as a probability) of a flood event reaching or exceeding a particular magnitude in any one year. A 1% (AEP) flood has a 1% (or 1 in 100) chance of occurring or being exceeded at a location in any year

AHD: Australian Height Datum (m), the standard reference level in Australia

AR&R: Australian Rainfall and Runoff (AR&R) is a national guideline document for the estimation of design flood characteristics in Australia. It is published by Engineers Australia. The current 2003 edition is now being revised. The revision process includes 21 research projects, which have been designed to fill knowledge gaps that have arisen since the 1987 edition

CHA: Comprehensive Hydrologic Assessment

CL: Continuing Loss (mm/hour). The amount of rainfall during the later stages of the event that infiltrates into the soil and is not converted to surface runoff in the hydrologic model

CRC-CH: Cooperative Research Centre – Catchment Hydrology. In this report, CRCH-CH usually refers to a Monte Carlo sampling method that was developed by the CRC-CH

CSS: Complete Storm Simulation. This is one of the proposed Monte Carlo sampling methods

Cumulative probability: The probability of an event occurring over a period of time, any time in that period. This probability increases over time

DEA: Design Event Approach. A semi-probabilistic approach to establish flood levels, which only accounts for the variability of the rainfall intensity

Design flood event: Hypothetical flood events based on a design rainfall event of a given probability of occurrence (ie AEP). The probability of occurrence for a design flood event is assumed to be the same as the probability of rainfall event upon which it is based (EA, 2003)

DMT: Disaster Management Tool. Work completed by BCC in 2014 for Queensland Government as part of the development of an interim disaster management tool until the completion of the BRCFS

DTM: Digital Terrain Model

EL (m AHD): Elevation (in metres) above the Australian Height Datum

FFA: Flood Frequency Analysis – a direct statistical assessment of flood characteristics

Flood mitigation manual (Flood Manual): A flood mitigation manual approved under section 371E(1)(a) or 372(3) of the Water Supply (Safety and Reliability) Act 2008 (QLD)

FOSM: Flood Operations Simulation Model (refer Seqwater 2014)

Floodplain: Area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by the PMF (CSIRO, 2000)

FSL: Full Supply Level - maximum normal water supply storage level of a reservoir behind a dam

FSV: Full Supply Volume – volume of the reservoir at FSL

GEV: Generalised Extreme Value statistical distribution

GIS: Geographic Information System

GL: Gigalitres This is a unit of volume used in reservoir studies. A Gigalitre = 1,000,000,000 litres or equivalently 1,000,000 m^3

GSDM: Generalised Short Duration Method of extreme precipitation estimation for storms of less than 6 hour duration and catchments of less than 1,000 km^2. Refer BoM, 2003

GTSMR: Revised Generalised Tropical Storm Method of extreme precipitation estimation for storms of tropical origin. Applicable to storm durations of up to 168 hours and catchments up to 150,000km^2. Refer BoM, 2003

IFD-curves: Intensity-Frequency-Duration curves, describing the point- or area-rainfall statistics. In the current report rainfall depth is generally used as an alternative to rainfall intensity. Rainfall depth is the product of duration and intensity. It was decided to maintain the term “IFD” as this is the terminology that the reader is most likely to be familiar with

IL: Initial Loss (mm). The amount of rainfall that is intercepted by vegetation or absorbed by the ground and is therefore not converted to runoff during the initial stages of the rainfall event

LOC: Loss of Communications dam operating procedure, refer Flood Manual (Seqwater 2013)

LPIII: Log-Pearson Type III statistical distribution

IQQM: Integrated Quantity and Quality Model for water resources planning

JPA: Joint Probability Approach. A general term for probabilistic methods to establish design flood levels

MCS: Monte Carlo Simulation

MHWS: Mean High Water Spring Tide level

ML: Megalitre. This is a unit of volume used in reservoir studies. A megalitre is equal to 1,000,000 litres or, equivalently, 1,000 m^3

m^3/s: Cubic metre per second – unit of measurement for instantaneous flow or discharge

PMF: Probable Maximum Flood – the largest flood that could conceivably occur at a particular location, resulting from the PMP (CSIRO, 2000) and Australia Rainfall and Runoff, 2003 (EA, 2003)

PMP: Probable Maximum Precipitation – the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of year, with no allowance made for long-term climatic trends (CSIRO, 2000; EA 2003)

PMP DF: Probable Maximum Precipitation Design Flood – the flood event that results from the PMP event

Quantiles: Values taken at regular intervals from the inverse of the cumulative distribution function (CDF) of a random variable

Stochastic flood event: Statistically generated synthetic flood event. Stochastic flood events include variability in flood input parameters (eg temporal and spatial rainfall patterns) compared to design flood events. Stochastic flood events by their method of generation exhibit a greater degree of variability and randomness compared to design flood events (See also Design flood event)

Synthetic flood event: See Stochastic flood event

TPT: Total Probability Theorem. This is one of the fundamental theorems in statistics. In this report, TPT refers to a Monte Carlo sampling method that is based on stratified sampling and, hence, makes use of the total probability theorem

URBS: Unified River Basin Simulator. A rainfall runoff routing hydrologic model (Carroll, 2012)

7.2 Study related terms

BCC: Brisbane City Council

BoM: Australian Bureau of Meteorology

BRCFS: Brisbane River Catchment Flood Study

BRCFM: Brisbane River Catchment Floodplain Management Study

BRCFMP: Brisbane River Catchment Floodplain Management Plan

Delft-FEWS: Flood Early Warning Systems, a software package developed by Deltares, initially for the purpose of real-time flood forecasting. Delft-FEWS is used all over the world, including by the Environment Agency (UK) and the National Weather Service (US). Currently, it is also being implemented by Deltares and BoM for flood forecasting in Australia. The Monte Carlo framework for the BRCFS-Hydrology Phase will be implemented in Delft-FEWS

DEWS: Department of Energy and Water Supply

DIG: Dams Implementation Group

DNRM: Department of Natural Resources and Mines

DSITIA: Department of Science Information Technology, Innovation and the Arts

DSDIP: Department of State Development and Infrastructure Planning

EA: Engineers Australia formally known as The Institute of Engineers, Australia

GA: General Adapter, an interface between the Delft-FEWS environment and an external module

IC: Implementation Committee of the BRCFS

ICC: Ipswich City Council

IPE: Independent panel of experts to the BRCFS

LVRC: Lockyer Valley Regional Council

ND: No-dams condition. This scenario represents the catchment condition without the influence of the dams and reservoirs. The reservoir reaches have effectively been returned to their natural condition

NPDOS: North Pine Dam Optimisation Study conducted in response to the QFCOI Final Report

PIG: Planning Implementation Group

QFCOI: Queensland Floods Commission of Inquiry

RTC: Real-Time Control. A software package for simulations of reservoir operation. RTC tools is used for the simulation of Wivenhoe and Somerset reservoirs

SC: Steering Committee of the BRCFS

SRC: Somerset Regional Council

TWG: Technical Working Group

WD: With-dams condition. This scenario represents the catchment condition with the influence of the dams and reservoirs represented in their current (2013) configuration

WSDOS: Wivenhoe and Somerset Dam Optimisation Study conducted in response to the QFCOI Final report

Appendices

Appendix A
Brisbane River catchment stream gauges

##	#	CBM No.	Station no.	Stream name	Station Name / location	Operating Agency	Latitude	Longitude	LL Datum	AMTD	RL of GZ	DATUM	DATES FROM	TO	Area km2	Station type	Height data	Flow data	Rainfall data	TS WQ data	MIN	Crops	MOD	Towns	MAJ	Data Source
252	49		143110A	Bremer River	Adams Bridge	DNRM	-27.82771	152.51156	GDA94	77.1	75.5	AHD	30/09/1968		125	GQ	H	F	R	-						DNRM
102	102	540157			ADAMS BRIDGE ALERT	Seqwater				77.1	75.5	AHD	30/09/1968		130						4		5		6	BoM
101	101	540068			ADAMS BRIDGE TM	DNRM				77.1	75.5	AHD	30/09/1968		130						4		5		6	BoM
199	199	540239			ALDERLEY ALERT	BCC															5.2		5.9		6.7	BoM
231	28		143023A	Small Catchment	Algester		-27.60889	153.02694	AGD84	0.7	16.1	BCC	8/06/1977	22/12/1981	1	G	H	-	-	-						DNRM
251	48		143108A	Warrill Creek	Amberley	DNRM	-27.66377	152.70001	GDA94	9	17.5	AHD	1/10/1961		914	GQ	H	F	R	Q						DNRM
138	138	540505			AMBERLEY (DNRM) AL	Seqwater				9	17.61	STATE	15/03/2011		920						4.5		6.5		7.5	BoM
139	139	40816			AMBERLEY (DNRM) TM	DNRM				9	17.61	STATE	1/10/1961		920						4.5		6.5		7.5	BoM
137	137	540180			AMBERLEY ALERT-P	BoM/Seqwater				10	19.87	AHD	1/10/1994		850						4		5.5		6.5	BoM
249	46		143106A	Warrill Creek	Aratula Weir		-27.97306	152.54694	AGD84	60.2	92.7	SD	12/09/1953	31/12/1960	122	G	H	F	-	-						DNRM
289	86		143222A	Atkinson Dam	Atkinson Creek Outlet		-27.43194	152.46417	AGD84	0	9.2	ASS	18/01/1983	1/07/2002	0	G	H	F	-	-						DNRM
78	78	540479			ATKINSON DAM ALERT	Seqwater									33											BoM
79	79	540547			ATKINSON DAM HW TM	Seqwater									33											BoM
276	73		143211A	Buaraba Creek	Atkinson Diversion Weir		-27.41222	152.4175	AGD84	16	63.8	SD	20/02/1967	12/07/1979	251	G	H	F	-	-						DNRM
225	22		143018A	Brisbane River	Avoca Vale		-26.7525	152.235	GDA94	292.1	129.8	AHD	1/09/1970	1/10/1990	1498	G	H	F	-	-						DNRM
316	113		143932A	Enoggera Creek	Bancroft Park		-27.445	153.00472	GDA94	9.3	1.4	SD	19/11/1971	28/10/1981	70	G	H	F	-	-						DNRM
173	173	40796			BEATTY ROAD ALERT	BCC									155						6.2		7		8.2	BoM
166	166	40985			BELLBIRD PARK ALERT	ICC					43.13	AHD	25/07/2007								14.5		16		17.5	BoM
210	7		143004A	Bulimba Creek	Belmont		-27.53556	153.10944	AGD84	27.1	27.4	ASS	9/12/1949	30/06/1971	51	G	H	F	-	-						DNRM
257	54		143115A	Bremer River	Berry's Lagoon	Seqwater	-27.64611	152.74306	AGD84	26.5	0	AHD	28/07/1994	1/07/2002	1807	G	H	-	-	-						DNRM
146	146	540502			BERRYS LAGOON AL	ICC															5		6.5		8	BoM
147	147	540550			BERRYS LAGOON ALERT-B	Seqwater															5		6.5		8	BoM
145	145	540216			BERRY'S LAGOON TM	Seqwater					0	AHD	28/07/1994								5		6.5		8	BoM
66	66	540472			BILL GUNN DAM ALERT	Seqwater									3											BoM
67	67	540563			BILL GUNN DAM TM	Seqwater									3											BoM
162	162	40872			BLACKSTONE BRIDGE ALERT	BoM/ICC					0	AHD	1/01/1993		97						19		20		21	BoM
288	85		143221A	Sandy Creek	Blenheim		-27.65194	152.32306	AGD84	13	23.7	ASS	1/01/1900	1/01/1900	62	G	H	F	-	-						DNRM
216	13		143010A	Emu Creek	Boat Mountain	DNRM	-26.98333	152.28333	GDA94	9.9	108.1	SD	21/11/1965	8/11/1976	914	G	H	F	-	-						DNRM
217	14		143010B	Emu Creek	Boat Mountain	DNRM	-26.97711	152.28566	GDA94	9.5	108.9	AHD	24/11/1976		915	GQ	H	F	R	Q						DNRM
20	20	540141			BOAT MOUNTAIN ALERT	Seqwater				9.3	107.84	STATE	10/01/1976		920						4.5		6		7.5	BoM
19	19	540045			BOAT MOUNTAIN TM	DNRM				9.3	107.84	STATE	10/01/1976		920						4.5		6		7.5	BoM
202	202	540130			BOWEN HILLS ALERT	BCC					0	AHD	1/01/1994								2.3		2.7		3.3	BoM
149	149	540250			BRASSALL(HANCOCKS BR) AL	BoM/ICC					0	AHD	30/09/1998								8		10		12	BoM
203	203	540286			BREAKFAST CREEK MOUTH AL	BCC					0	AHD	1/09/1999								1.7		2		2.3	BoM
269	66		143206A	Lockyer Creek	Brightview Weir		-27.49889	152.50028	AGD84	36.4	51.8	SD	1/10/1953	28/02/1973	2393	G	H	F	-	-						DNRM
158	158	40647			BRISBANE BAR TIDE TM	MSQ					-1.24	AHD									1.7		2.6		3.5	BoM
156	156	540198			BRISBANE CITY ALERT	Seqwater					0	AHD	30/06/1992		13559						1.7		2.6		3.5	BoM
155	155	40690			BRISBANE CITY TM	MSQ					0	AHD	30/06/1992		13559						1.7		2.6		3.5	BoM
168	168	40874			BRISBANE ROAD ALERT	BoM/ICC				1.2	0	AHD	8/02/2005								4		5		6	BoM
300	97		143233A	Flagstone Creek	Brown-Zirbels Road	DNRM	-27.6047	152.1327	GDA94	6.8	140.3	AHD	1/06/1993		157	GQ	H	F	-	Q						DNRM
80	80	540259			BUARABA CREEK ALERT	Seqwater					92.5	ASSUM														BoM
164	164	540249			BUNDAMBA (HANLON ST) AL	BoM/ICC					0	AHD	29/08/1996		109						14.5		16		17.5	BoM
163	163	40875			BUNDAMBA SCHOOL ALERT	BoM/ICC					0	AHD	3/02/1993		102						14.5		16		17.5	BoM
90	90	540257			BURTONS BRIDGE ALERT	Seqwater					15.06	AHD	30/07/2002													BoM
185	185	540128			CARINDALE ALERT	BCC															5.9		6.8		7.6	BoM
312	109		143307A	Byron Creek	Causeway		-27.1354	152.63883	GDA94	1.6	88.9	AHD	25/06/1975	10/01/2011	79	G	H	F	-	-						DNRM
248	45		143105A	Warrill Creek	Churchbank Weir	Seqwater	-27.77306	152.68361	AGD84	3.2	38.7	SD	5/09/1953	25/06/2002	149	G	H	F	-	-						DNRM
136	136	540316			CHURCHBANK WEIR ALERT	BoM/ICC					38.61	AHD	5/09/1953		740						1		2		3	BoM
135	135	540217			CHURCHBANK WEIR TM	Seqwater					38.61	AHD	5/09/1953		740						1		2		3	BoM
159	159	540248			CHURCHILL ALERT	BoM/ICC															2		4		6	BoM
298	95		143231A	Redbank Creek	Clarendon Number 2		-27.54417	152.31806	AGD84	0	0	AHD	9/12/1993	1/07/2002	0	G	H	-	-	-						DNRM
297	94		143230A	Redbank Creek	Clarendon Pump Station		-27.54	152.315	AGD84	0	0	AHD	7/10/1993	1/07/2002	64	G	H	-	-	-						DNRM
98	98	540063			COLLEGES CROSSING ALERT	BoM/ICC					0	AHD	27/08/1999													BoM
176	176	40791			COOPERS PLAINS ALERT	BCC									21						7		8		8.5	BoM
14	14	540146			COOYAR CREEK ALERT	Seqwater				12.2	158.88	STATE	10/01/1968		965						5		6.5		8	BoM
13	13	540044			COOYAR CREEK TM	DNRM				12.2	158.88	STATE	10/01/1968		965						5		6.5		8	BoM
178	178	540071			CORINDA HIGH ALERT	BCC					0	AHD	6/04/1992								3.5		4.5		6.1	BoM
278	75		143213A	Ma Ma Creek	Creek Harms	DNRM	-27.65442	152.16568	GDA94	13.7	147.2	SD	22/02/1972	10/01/1976	227	GQ	H	F	-	Q						DNRM
27	27	540142			CRESSBROOK DAM ALERT	Seqwater									315											BoM
313	110		143312A	Kilcoy Creek	d/s Kilcoy Weir	DNRM	-26.92101	152.57952	GDA94	15.3	105	AHD	16/06/2005		0	G	H	F	R	-						DNRM
271	68		143208A	Fifteen Mile Cree	Dam Site		-27.45861	152.09944	AGD84	2.1	26.4	ASS	28/06/1956	28/02/1989	87	G	H	F	-	-						DNRM
221	18		143015A	Cooyar Creek	Damsite	DNRM	-26.74111	152.13667	GDA94	13.2	158.9	SD	1/10/1968	10/12/1990	963	G	H	F	-	-						DNRM
18	18	540188			DEVON HILLS ALERT	Seqwater					99	AHD	1/10/1994		2160						2		6		7	BoM
290	87		143223A	Seven Mile Lagoo	Diversion Channel		-27.44528	152.43222	AGD84	0	9.2	ASS	18/01/1983	28/11/2006	0	G	H	F	-	-						DNRM

##	#	CBM No.	Station no.	Stream name	Station Name / location	Operating Agency	Latitude	Longitude	LL Datum	AMTD	RL of GZ	DATUM	DATES FROM	TO	Area km2	Station type	Height data	Flow data	Rainfall data	TS WQ data	MIN	Crops	MOD	Towns	MAJ	Data Source
291	88		143224A	Buaraba Creek	Diversion Channel		-27.41556	152.4275	AGD84	0	64.1	AHD	27/02/1984	1/07/2002	0	G	H	F	-	-						DNRM
304	101		143301B	Stanley River	Donnelly Dell		-27.02694	152.56389	AGD84	25.3	19.9	ASS	1/07/1915	31/12/1919	1227	G	H	F	-	-						DNRM
237	34		143031A	Water Street	Drain Exhibition Ground		-27.45278	153.03194	AGD84	0	5.6	BCC	24/12/1976	30/10/1981	0	G	H	-	-	-						DNRM
229	26		143021A	Ekibin Creek	Dudley Street		-27.51222	153.03778	AGD84	4.9	7.9	SD	1/08/1972	16/08/1973	13	G	H	F	-	-						DNRM
174	174	40789			DURACK KING AVE ALERT	BCC									28						8.2		8.8		9.2	BoM
182	182	540132			EAST BRISBANE ALERT	BCC					0	AHD	1/01/1994								2		2.8		3.5	BoM
195	195	140004			ELEANOR SCHONELL BRIDGE	BoM															2		3		4	BoM
197	197	540119			ENOGGERA DAM ALERT	Seqwater															75.5		77		79	BoM
196	196	540604			ENOGGERA DAM HW TM	Seqwater															2		3		4	BoM
31	31	540441			FALLS RD TM	DNRM															3		4		5	BoM
224	21		143017A	Esk Creek	Falls Road	DNRM	-27.23583	152.44528	GDA94	0	84.3	AHD	30/11/2007		184	GQ	H	F	-	Q						DNRM
45	45	540405			FLAGSTONE CK TM	DNRM				6.8	140.35	AHD	1/06/1993								4		6.5		8	BoM
46	46	540517			FLAGSTONE CREEK ALERT	LVRC															4		6.5		8	BoM
287	84		143220A	Sandy Creek	Forest Hill		-27.58861	152.34444	AGD84	3.4	19	ASS	4/10/1978	1/01/1985	102	G	H	F	-	-						DNRM
299	96		143232A	Sandy Creek	Forest Hill	DNRM	-27.58345	152.35022	GDA94	2.5	90.6	AHD	5/09/1995		94	GQ	H	F	-	Q						DNRM
57	57	540516			FOREST HILL ALERT	LVRC															2		4		5	BoM
58	58	540511			FOREST HILL TM	DNRM															2		4		5	BoM
208	5		143002B	Brisbane River	Fulham Vale		-27.07194	152.44222	AGD84	235.4	70.7	SD	1/10/1931	30/09/1965	3950	G	H	F	-	-						DNRM
54	54	40444			GATTON	BoM				72	87.54	AHD	1/09/1929		1550						7	13	10	18.3	15	BoM
55	55	540156			GATTON ALERT	Seqwater				72	87.54	AHD	1/09/1929		1550						7		10		15	BoM
53	53	540363			GATTON TM	Seqwater				72	29.27	ASSUM	4/02/2000								4.5		5		6.5	BoM
219	16		143012A	Cooyar Creek	Gilla		-26.89333	152.01722	AGD84	50.6	21	ASS	21/11/1965	2/01/1969	443	G	H	F	-	-						DNRM
223	20		143016A	Maronghi Creek	Glendale	DNRM	-26.9796	152.33269	GDA94	0	20.4	ASS	13/06/2008		203	GQ	H	F	R	Q						DNRM
21	21	540446			GLENDALE TM	DNRM															4.5		6		7.5	BoM
72	72	540149			GLENORE GROVE ALERT	BoM/Seqwater				51.8	67.11	AHD	1/01/1955		2230						8		11		13	BoM
192	192	540107			GOLD CK RESERVOIR ALERT	Seqwater																				BoM
191	191	540609			GOLD CK RESERVOIR HW TM	Seqwater															6		7.5		9	BoM
107	107	540064			GRANDCHESTER ALERT	BoM/ICC					82.3	AHD	30/10/2002													BoM
108	108	540064			GRANDCHESTER ALERT	BoM/ICC					0	AHD	27/08/1999	37559							3		4		5	BoM
24	24	540140			GREGOR CK ALERT-B	Seqwater				251.9	82.39	AHD	7/02/1962		3885						3.5		4.5		7.5	BoM
23	23	540139			GREGOR CK ALERT-P	Seqwater				251.7	82.39	AHD	2/07/1962		3885						3.5		4.5		7.5	BoM
22	22	40822			GREGOR CREEK TM	DNRM				251.7	82.39	AHD	2/07/1962		3885						3.5		4.5		7.5	BoM
215	12		143009A	Brisbane River	Gregors Creek	DNRM	-26.99556	152.41017	GDA94	251.9	82.4	AHD	7/02/1962		3866	GQ	H	F	-	Q						DNRM
106	106	540317			GREY'S PLAINS ROAD ALERT	BoM/ICC					0	ASSUM														BoM
161	161	40873			HARDING STREET ALERT	BoM/ICC					0	AHD	22/01/1993		96						24		25		26	BoM
280	77		143213C	Ma Ma Creek	Harms	DNRM	-27.654	152.1655	GDA94	13.6	146.7	AHD	25/08/1995		227	GQ	H	F	-	Q						DNRM
132	132	40445			HARRISVILLE	BoM				30.5	45.69	STATE	1/09/1956		725						3	5	4		5	BoM
134	134	540387			HARRISVILLE AL-B	BoM					45.69	STATE	3/08/2006		725						3	5	4		5	BoM
133	133	540154			HARRISVILLE ALERT	Seqwater					45.69	STATE	1/10/1994		725						3	5	4		5	BoM
303	100		143301A	Stanley River	Hazeldean		-27.03083	152.5625	AGD84	23.7	19.9	ASS	1/07/1912	28/02/1915	1242	G	H	F	-	-						DNRM
301	98		143234A	Atkinson Dam	Head Water	Seqwater	-27.43278	152.46278	GDA94	0	0	AHD	19/02/1997	1/07/2002	0	G	H	-	-							DNRM
302	99		143235A	Lake Clarendon	Head Water	Seqwater	-27.51556	152.35306	GDA94	0	0	AHD	20/02/1997	1/07/2002	0	G	H	-	-							DNRM
265	62		143203A	Lockyer Creek	Helidon	DNRM	-27.54111	152.11167	AGD84	99.5	132	SD	1/07/1926	31/08/1971	357	G	H	F	-	-						DNRM
44	44	540143			HELIDON ALERT	Seqwater				99	128.65	AHD	19/11/1987		350						4		6.5		8	BoM
266	63		143203B	Lockyer Creek	Helidon Number 2	DNRM	-27.56333	152.12083	AGD84	96.2	123.5	SD	1/10/1965	2/12/1989	382	G	H	F	-	-						DNRM
267	64		143203C	Lockyer Creek	Helidon Number 3	DNRM	-27.54228	152.1145	GDA94	99.3	128.7	AHD	19/11/1987		357	GQ	H	F	R	Q						DNRM
43	43	40829			HELIDON TM	DNRM				99	128.65	AHD	19/11/1987		350						4		6.5		8	BoM
186	186	540129			HEMMANT ALERT	BCC					0	AHD	1/01/1994								1.8		2.2		2.5	BoM
285	82		143218A	Redbank Creek	Holcomb		-27.51694	152.28361	AGD84	5.8	105	AHD	15/12/1975	21/09/1983	55	G	H	F	-	-						DNRM
181	181	540134			HOLLAND PARK WEST ALERT	BCC															17.5		17.9		18.3	BoM
236	33		143030A	Sandy Creek	Indooroopilly		-27.50194	152.98889	AGD84	1.7	4.6	AHD	15/02/1977	22/02/1999	0	G	H	F	-	-						DNRM
230	27		143022A	Stable Swamp Cre	Interstate Railway		-27.56389	153.02528	AGD84	6.6	4	SD	31/10/1971	6/01/1982	19	G	H	F	-	-						DNRM
150	150	40101			IPSWICH	BoM/ICC				16.8	1.02	AHD	1/03/1967	27403	1850											BoM
151	151	40101			IPSWICH	BoM/ICC				16.8	0	AHD	9/01/1975		1850						7	7	9	7.4	11.7	BoM
152	152	40831			IPSWICH ALERT	BoM/ICC				16.8	0	AHD	24/10/1990		1850						7	7	9	7.4	11.7	BoM
200	200	540116			ITHACA ALERT	BCC															15		16		17	BoM
201	201	540500			ITHACA CREEK TM	DNRM									10						15		16		17	BoM
235	32		143028A	Ithaca Creek	Jason Street	DNRM	-27.44893	152.99334	GDA94	1.8	14	SD	30/09/1972		10	G	H	F	R	-						DNRM
153	153	540192			JINDALEE ALERT	Seqwater					0	AHD	1/10/1994		12915						6		8		10	BoM
154	154	40713			JINDALEE BRIDGE	BCC									12915						6		8		10	BoM
50	50	540568			JUNCTION VIEW ALERT	LVRC					0	ASSUM	20/12/2012								1		2		3	BoM
258	55		143117A	Warrill Creek	Junction Weir Headwater	Seqwater	-27.93806	152.59639	AGD84	0	0	AHD	3/12/1998	1/07/2002	0	GQ	H	-	-	Q						DNRM
259	56		143118A	Warrill Creek	Junction Weir Tailwater	Seqwater	-27.93806	152.59639	AGD84	0	0	AHD	17/07/1997	1/07/2002	0	G	H	F	-	-						DNRM
131	131	40440			KALBAR	BoM				49.4	66.72	AHD	1/09/1958		470						6	7	7		9	BoM

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242	39		143102A	Warrill Creek	Kalbar Number 1		-27.93194	152.59917	AGD84	50.9	68.2	SD	25/10/1912	30/12/1958	465	G	H	F	-	-						DNRM
243	40		143102B	Warrill Creek	Kalbar Number 1		-27.92361	152.60056	AGD84	49.7	67.1	SD	1/10/1958	28/02/1971	468	G	H	F	-	-						DNRM
127	127	540151			KALBAR WEIR ALERT	Seqwater					74.6	AHD	11/09/1998	40405	470											BoM
128	128	540151			KALBAR WEIR ALERT	Seqwater					0	AHD	16/08/2010		470						76.8		77.8		78.8	BoM
129	129	540058			KALBAR WEIR HW TM	Seqwater				51.4	74.6	AHD	11/09/1998		470						76.8		77.8		78.8	BoM
130	130	540057			KALBAR WEIR TW TM	Seqwater				51.4	0	AHD	17/07/1997								6		7.5		9	BoM
198	198	540118			KELVIN GROVE ALERT	BCC															5.2		5.9		6.7	BoM
93	93	540256			KHOLO BRIDGE ALERT	Seqwater					12	AHD	30/07/2002													BoM
234	31		143027A	Blunder Creek	King Avenue Bridge		-27.595	152.99583	AGD84	4.2	4	SD	25/10/1973	18/11/1981	31	G	H	F	-	Q						DNRM
109	109	40701			KUSS ROAD	BoM					45.06	AHD	1/02/1982		200						6		7		8	BoM
260	57		143121A	Western Creek	Kuss Road	BoM	-27.66483	152.54202	GDA94	0	21.7	ASS	22/09/2011		0	G	H	-	R	-						DNRM
110	110	540194			KUSS ROAD ALERT	Seqwater					45.06	AHD	1/02/1982		200						6		7		8	BoM
111	111	540583			KUSS ROAD TM	DNRM									200						6		7		8	BoM
63	63	40716			LAIDLEY	BoM					101.5	AHD	1/01/1982		285						5	8.5	6	9	7	BoM
70	70	540473			LAKE CLARENDON ALERT	Seqwater																				BoM
71	71	540546			LAKE CLARENDON HW TM	Seqwater																				BoM
295	92		143228A	Bill Gunn Dam	Lake Dyer	Seqwater	-27.63167	152.37944	AGD84	0	100	AHD	20/12/1985	1/07/2002	3	G	H	-	-	-						DNRM
92	92	540028			LAKE MANCHESTER ALERT	Seqwater																				BoM
91	91	540606			LAKE MANCHESTER HW TM	Seqwater																				BoM
175	175	540535			LAKESIDE CRESCENT ALERT	BCC															8.2		8.8		9.2	BoM
17	17	40387			LINVILLE	BoM				278.2	111	STATE	1/09/1956		2005						3	9	7		8	BoM
213	10		143007A	Brisbane River	Linville	DNRM	-26.80409	152.27391	GDA94	282.4	115.3	AHD	16/10/1964		2009	GQ	H	F	R	Q						DNRM
16	16	540261			LINVILLE ALERT	Seqwater				282.4	115.3	AHD	16/10/1964		2005						2		5.5		6.5	BoM
15	15	540040			LINVILLE TM	DNRM				282.4	115.3	AHD	10/01/1964		2005						2		5.5		6.5	BoM
26	26	540272			LITTLE OAKEY CREEK ALERT	TRC															3.5		4.5		7.5	BoM
255	52		143113A	Purga Creek	Loamside	DNRM	-27.68304	152.72954	GDA94	6.8	18.4	AHD	23/11/1973		215	GQ	H	F	-	Q						DNRM
143	143	540062			LOAMSIDE ALERT	BoM/ICC				6.8	18.39	AHD	23/11/1973		215						5		6.5		8	BoM
144	144	540210			LOAMSIDE TM	DNRM				6.8	18.39	AHD	23/11/1973		215						5		6.5		8	BoM
104	104	540574			LOWER MT WALKER ALERT	ICC					0	UNKNOW	13/06/2012								4		5		6	BoM
85	85	40441			LOWOOD	BoM				140.4	23.68	AHD	1/09/1909		10062						8	18	15	21	20	BoM
204	1		143001A	Brisbane River	Lowood	DNRM	-27.47111	152.59222	AGD84	141.1	23.7	SD	13/07/1909	2/10/1950	10055	G	H	F	-	-						DNRM
86	86	540182			LOWOOD ALERT-P	Seqwater				139.9	22.74	STATE	1/10/1994		10062						8.6		15.9		21.2	BoM
83	83	540183			LOWOOD PUMP STN ALERT-B	Seqwater					23.07	AHD	1/01/1992	40935	10062											BoM
84	84	540183			LOWOOD PUMP STN ALERT-B	Seqwater					22.79	AHD	27/01/2012		10062						12		14		16	BoM
73	73	40662			LYONS BRIDGE	BoM				29.1	48.53	AHD	1/01/1955	27454	2530											BoM
74	74	40662			LYONS BRIDGE	BoM				29.1	47.53	AHD	1/03/1975		2530						10		11.5		13	BoM
274	71		143210A	Lockyer Creek	Lyons Bridge	DNRM	-27.46833	152.52722	AGD84	28.4	44.6	SD	20/04/1964	18/03/1988	2486	G	H	F	-	-						DNRM
75	75	540174			LYONS BRIDGE ALERT-P	BoM/Seqwater				29.1	47.53	AHD	1/10/1994		2530						10		11.5		13	BoM
48	48	540518			MA MA CREEK ALERT	LVRC															2		3		4	BoM
49	49	540406			MA MA CREEK TM	DNRM				13.6	146.71	AHD	25/08/1995								2		3		4	BoM
279	76		143213B	Ma Ma Creek	Ma Ma Weir	DNRM	-27.65778	152.16194	AGD84	14	153.1	SD	31/03/1977	3/03/1986	226	G	H	F	-	-						DNRM
240	37		143094A	Bulimba Creek	Mansfield		-27.53028	153.10583	AGD84	25.4	5.2	AHD	31/07/1971	1/01/1997	57	G	H	F	-	-						DNRM
184	184	540126			MANSFIELD ALERT	BCC															10.2		11.5		12.5	BoM
89	89	540312			MARBURG ALERT	BoM/ICC					79.14	AHD	1/09/2005													BoM
177	177	540432			MARSHALL RD AL	BCC															3		5		7	BoM
256	53		143114A	Bundamba Creek	Mary Street	Seqwater	-27.60389	152.80167	AGD84	4.3	5.5	SD	1/08/1972	28/01/1983	110	G	H	F	-	-						DNRM
214	11		143008A	Brisbane River	Middle Creek		-27.26694	152.54444	AGD84	187.5	42	SD	1/10/1962	11/08/1982	6704	G	H	F	-	-						DNRM
228	25		143020A	Moggill Creek	Misty Morn		-27.5125	152.92639	AGD84	3.8	4	SD	23/05/1972	22/10/1981	61	G	H	F	-	-						DNRM
193	193	540061			MISTY MORN ALERT	BCC									62						8.9		10.4		12.3	BoM
99	99	40812			MOGGILL ALERT	BoM				73	0	AHD	1/01/1977		12600						10		13		15.5	BoM
100	100	540200			MOGGILL ALERT-P	BoM/Seqwater				73	0	AHD	1/01/1977		12600						10		13		15.5	BoM
232	29		143024A	Pullen Pullen	Moggill Road		-27.55111	152.88972	AGD84	2.1	1.1	AHD	21/04/1977	22/10/1981	27	G	H	F	-	-						DNRM
244	41		143103A	Reynolds Creek	Moogerah		-28.03694	152.54556	AGD84	15.7	126.4	SD	1/10/1917	23/11/1954	190	G	H	F	-	-						DNRM
245	42		143103B	Reynolds Creek	Moogerah		-28.03806	152.54417	AGD84	15.9	126.8	SD	1/10/1954	30/09/1960	190	G	H	F	-	-						DNRM
121	121	40135			MOOGERAH DAM	Seqwater				15.3	100	AHD	10/01/1967		225						1		2		3	BoM
253	50		143111A	Reynolds Creek	Moogerah Dam Headwater	Seqwater	-28.03139	152.55	AGD84	15.3	100	AHD	1/10/1967	1/07/2002	226	G	H	-	-	-						DNRM
123	123	540474			MOOGERAH DAM HW ALERT	Seqwater					154.91	AHD	14/10/2009		228											BoM
122	122	540364			MOOGERAH DAM HW TM	Seqwater				15.3	154.93	AHD	1/10/1967		226											BoM
124	124	540513			MOOGERAH DAM TW TM	Seqwater									226											BoM
254	51		143112A	Reynolds Creek	Moogerah Tailwater	Seqwater	-28.02667	152.55139	AGD84	15.3	98.9	ASS	31/10/1980	21/06/2002	227	G	H	F	-	Q						DNRM
56	56	540567			MOON ROAD ALERT	LVRC					0	ASSUM	6/12/2012								2		4		5	BoM
209	6		143003A	Brisbane River	Mount Crosby Weir		-27.538	152.79819	AGD84	90.8	7	SD	1/01/1900	31/05/1975	10550	G	H	F	-	-						DNRM
307	104		143304A	Kilcoy Creek	Mount Kilcoy		-26.90056	152.58306	AGD84	17.5	109	SD	13/11/1935	31/08/1971	127	G	H	F	-	-						DNRM
308	105		143304B	Kilcoy Creek	Mount Kilcoy		-26.90694	152.58306	AGD84	16.3	108.3	SD	1/08/1956	31/08/1971	131	G	H	-	-	-						DNRM

##	#	CBM No.	Station no.	Stream name	Station Name / location	Operating Agency	Latitude	Longitude	LL Datum	AMTD	RL of GZ	DATUM	DATES FROM	TO	Area km2	Station type	Height data	Flow data	Rainfall data	TS WQ data	MIN	Crops	MOD	Towns	MAJ	Data Source
30	30	540560			MT BYRON TM	DNRM															3		4		5	BoM
94	94	40142			MT CROSBY	BoM/BCC				90.2	6.9	AHD	01/09/1864	27395	10600											BoM
95	95	40142			MT CROSBY	BoM/BCC				90.2	0	AHD	1/01/1975		10600						11	13	13		21	BoM
97	97	540199			MT CROSBY ALERT	Seqwater				90.2	0	AHD	1/10/1994		10600						11	13	13		21	BoM
96	96	40818			MT CROSBY TM	Seqwater				90.2	0	AHD	7/02/1975		10600						11	13	13		21	BoM
8	8	540482			MT KILCOY WEIR ALERT	Seqwater															5	5	6.1	10.7	8.5	BoM
7	7	540373			MT KILCOY WEIR TM	DNRM									131						5	5	6.1	10.7	8.5	BoM
273	70		143209B	Laidley Creek	Mulgowie	DNRM	-27.72996	152.36423	AGD84	31	132.7	AHD	6/03/1967		167	GQ	H	F	-	Q						DNRM
62	62	540528			MULGOWIE ALERT	LVRC									179						5	7	6	7.1	7	BoM
60	60	40835			MULGOWIE TM	DNRM				30.9	132.71	STATE	3/06/1967		179											BoM
61	61	40835			MULGOWIE TM	DNRM				30.9	132.62	AHD	31/12/2000		179						5	7	6	7.1	7	BoM
282	79		143215A	Laidley Creek	Mulgowie Weir		-27.75083	152.37278	AGD84	34	141.6	SD	20/07/1972	30/09/1986	154	G	H	F	-	-						DNRM
272	69		143209A	Laidley Creek	Mulgowie1	DNRM	-27.73139	152.36333	AGD84	30.9	133.3	SD	24/01/1957	30/12/1962	167	G	H	F	-	-						DNRM
179	179	540433			MURIEL AVE AL	City Council															4.2		6.3		7.8	BoM
241	38		143101A	Warrill Creek	Mutdapily		-27.74944	152.685	AGD84	21	31.5	SD	1/07/1914	12/07/1957	771	G	H	F	-	-						DNRM
239	36		143033A	Oxley Creek	New Beith	DNRM	-27.73111	152.94667	AGD66	45	25.4	ASS	10/12/1976		60	GQ	H	F	-	Q						DNRM
171	171	540097			NEW BEITH ALERT	BCC					48.85	AHD		38665												BoM
172	172	540097			NEW BEITH ALERT	BCC					0	AHD	9/11/2005								4		5		6	BoM
170	170	40719			NEW BEITH TM	DNRM									49						4		5		6	BoM
148	148	40836			ONE MILE BRIDGE ALERT	BoM/ICC					0	AHD	24/10/1990								10		12		14	BoM
167	167	40795			OPOSSUM ALERT	BoM/ICC					0	AHD	24/05/1989								21		22		23	BoM
270	67		143207A	Lockyer Creek	O'Reillys Weir	DNRM	-27.41855	152.59057	AGD84	1.6	23.6	AHD	12/01/1948		2965	GQ	H	F	R	Q						DNRM
82	82	540153			O'REILLY'S WEIR ALERT	Seqwater				1.4	23.62	AHD	1/12/1948		2980						12		14		16	BoM
294	91		143227A	Lockyer Creek	O'Reillys Weir Tail Water		-27.42028	152.59083	AGD84	1.3	23.5	SD	25/10/1984	19/04/1989	2965	G	H	F	-	-						DNRM
81	81	540051			O'REILLY'S WEIR TM	DNRM				1.4	23.62	AHD	1/12/1948		2980						12		14		16	BoM
180	180	540274			OXLEY CREEK MOUTH ALERT	BCC					0	AHD	1/09/1999								2.5		3.5		5.5	BoM
306	103		143303A	Stanley River	Peachester	DNRM	-26.8393	152.8403	GDA94	89.2	125	SD	1/07/1927		104	G	H	F	-	-						DNRM
2	2	540059			PEACHESTER ALERT	Seqwater				89.2	125.03	STATE	7/01/1927		104						5		8		9	BoM
1	1	540046			PEACHESTER WRC TM	DNRM				89.2	125.03	STATE	7/01/1927		104						5		8		9	BoM
141	141	540065			PEAK CROSSING ALERT	BoM/ICC					45.32	AHD	30/10/2002													BoM
142	142	540065			PEAK CROSSING ALERT	BoM/ICC					0	AHD	27/08/1999	37559							2		3.5		5	BoM
207	4		143002A	Brisbane River	Plainlands		-27.06972	152.44278	AGD84	235.6	13.2	ASS	1/01/1920	13/01/1932	3950	G	H	F	-	-						DNRM
190	190	540296			PULLEN PULLEN CREEK AL	BCC															6		7.5		9	BoM
218	15		143011A	Emu Creek	Raeburn		-27.06417	152.00444	GDA94	74	24.8	ASS	21/11/1965	8/06/1989	439	G	H	F	-	-						DNRM
187	187	540279			RANSOME ALERT	BCC															2.8		3.2		3.5	BoM
275	72		143210B	Lockyer Creek	Rifle Range Road	DNRM	-27.4536	152.517	GDA94	26.2	44.4	AHD	1/02/1988		2490	GQ	H	F	-	Q						DNRM
77	77	540544			RIFLE RANGE ROAD ALERT	Seqwater									2541						10.5		12		13.5	BoM
76	76	40817			RIFLE RANGE ROAD TM	DNRM				26.2	44.44	AHD	1/02/1988		2541						10.5		12		13.5	BoM
160	160	40792			RIPLEY ALERT	BoM/ICC					0	AHD	1/06/1989		35						52		53		54	BoM
29	29	540148			ROSENTRETERS BRIDGE AL	Seqwater				25.4	102	AHD	20/08/1986		477						3		4		5	BoM
28	28	40823			ROSENTRETERS BRIDGE TM	DNRM				25.4	102	AHD	20/08/1986		477						3		4		5	BoM
315	112		143921A	Cressbrook Creek	Rosentretters Crossing	DNRM	-27.13607	152.33002	GDA94	23.1	102	AHD	20/08/1986		447	GQ	H	F	R	Q						DNRM
246	43		143104A	Bremer River	Rosevale		-27.86	152.48556	AGD84	82.7	26.2	SD	15/02/1919	16/04/1953	77	G	H	F	-	-						DNRM
247	44		143104B	Bremer River	Rosevale		-27.86639	152.48556	AGD84	83.3	91.1	SD	1/10/1952	28/02/1973	67	G	H	F	-	-						DNRM
114	114	40549			ROSEWOOD	BoM									543						4	5	5		6	BoM
115	115	540388			ROSEWOOD AL-B	BoM									543						4	5	5		6	BoM
116	116	540193			ROSEWOOD ALERT	Seqwater				49.9	32.83	STATE	1/10/1994		543						4	5	5		6	BoM
113	113	540503			ROSEWOOD DETENTION BASIN	ICC															7.3		8.3	9.3	9.3	BoM
112	112	540313			ROSEWOOD WWTP ALERT	BoM/ICC					35.42	AHD	15/02/2001								7.3		8.3	9.3	9.3	BoM
263	60		143202A	Lockyer Creek	Russell Siding		-27.5375	152.09778	AGD84	101	140.2	SD	1/11/1919	30/06/1926	271	G	H	F	-	-						DNRM
264	61		143202B	Lockyer Creek	Russell Siding Number 2		-27.53333	152.08333	AGD84	101	140.2	SD	30/06/1926	3/12/1931	271	G	H	F	-	-						DNRM
47	47	540386			SANDY CREEK ROAD ALERT	LVRC					0	ASSUM	25/05/2006								2		3		4	BoM
206	3		143001C	Brisbane River	Savages Crossing	DNRM	-27.43917	152.6686	GDA94	131.1	18.5	AHD	1/10/1958		10172	GQ	H	F	-	Q						DNRM
88	88	540150			SAVAGES CROSSING ALERT	Seqwater				130.8	18.43	AHD	10/01/1958		10180						9		16		21	BoM
87	87	540066			SAVAGES CROSSING TM	DNRM				130.8	18.43	AHD	10/01/1958		10180						9		16		21	BoM
65	65	540158			SHOWGROUND WEIR ALERT	Seqwater				17.6	97	AHD	20/09/1984		241						6		7		7.8	BoM
64	64	540047			SHOWGROUND WEIR HW TM	Seqwater				17.6	97	AHD	20/09/1984		241						6		7		7.8	BoM
292	89		143225A	Laidley Creek	Showgrounds Weir Head Water	Seqwater	-27.63861	152.38417	GDA94	17.6	97	AHD	20/09/1984	1/07/2002	233	GQ	H	F	-	Q						DNRM
293	90		143226A	Laidley Creek	Showgrounds Weir Tailwater		-27.64	152.38361	AGD84	17.5	97	AHD	21/09/1984	2/07/1997	233	G	H	F	-	-						DNRM
305	102		143302A	Stanley River	Silverton		-27.12611	152.55056	AGD84	6.1	58	SD	1/11/1919	30/06/1968	1339	G	H	F	-	-						DNRM
309	106		143305A	Stanley River	Somerset Dam		-27.11667	152.55444	AGD84	7.2	60.7	SD	1/07/1935	21/09/1959	1336	G	H	F	-	-						DNRM
11	11	540160			SOMERSET DAM HW ALERT-B	Seqwater									1330						102		103		104	BoM
9	9	540159			SOMERSET DAM HW ALERT-P	BoM/Seqwater				7.2	0	AHD			1330											BoM
10	10	540471			SOMERSET DAM HW ALERT-P2	Seqwater									1330											BoM

##	#	CBM No.	Station no.	Stream name	Station Name / location	Operating Agency	Latitude	Longitude	LL Datum	AMTD	RL of GZ	DATUM	DATES FROM	TO	Area km2	Station type	Height data	Flow data	Rainfall data	TS WQ data	MIN	Crops	MOD	Towns	MAJ	Data Source
12	12	40820			SOMERSET DAM TM	Seqwater									1335						102		103		104	BoM
32	32	540260			SPLITYARD CREEK DAM AL	Seqwater															3		4		5	BoM
105	105	540314			SPRESSERS BRIDGE ALERT	BoM/ICC					35	AHD	11/02/2004								4		4.4		4.8	BoM
286	83		143219A	Murphys Creek	Spring Bluff	DNRM	-27.4688	151.9857	GDA94	129.9	380.8	AHD	1/10/1979		18	G	H	F	-	-						DNRM
41	41	540527			SPRING BLUFF ALERT	LVRC																				BoM
39	39	540589			SPRING BLUFF RADAR TM	MBS																				BoM
40	40	540507			SPRING BLUFF TM	DNRM																				BoM
165	165	540501			SPRINGFIELD LAKES AL	ICC															14.5		16		17.5	BoM
103	103	40702			STOKES CROSSING	BoM					56.67	AHD	1/02/1982		180						4		5		6	BoM
261	58		143201A	Lockyer Creek	Tarampa		-27.47194	152.52278	AGD84	29.8	12.9	ASS	1/10/1909	29/04/1926	2405	G	H	F	-	-						DNRM
262	59		143201B	Lockyer Creek	Tarampa Number 2		-27.47361	152.52056	AGD84	30	47.2	SD	1/10/1925	30/06/1947	2405	G	H	F	-	-						DNRM
222	19		143015B	Cooyar Creek	Taromeo Creek	DNRM	-26.73946	152.1376	GDA94	13.3	160.7	SD	20/12/1990		963	GQ	H	F	R	Q						DNRM
277	74		143212A	Tenthill Creek	Tenthill	DNRM	-27.63431	152.2154	GDA94	14.6	123.8	AHD	18/03/1968		447	GQ	H	F	R	Q						DNRM
52	52	540152			TENTHILL ALERT	Seqwater				14.6	123.84	AHD	18/03/1968		455						4.5		5		6.5	BoM
51	51	540067			TENTHILL TM	DNRM				14.6	123.84	AHD	18/03/1968		455						4.5		5		6.5	BoM
220	17		143013A	Cressbrook Creek	The Damsite		-27.26333	152.20528	AGD84	58.3	28.1	ASS	1/11/1965	13/05/1981	321	G	H	F	-	-						DNRM
59	59	40751			THORNTON	BoM/LVRC					162.84	AHD	24/01/1994								4.5	5.3	4.7		5.3	BoM
120	120	40838			THREE MILE BRIDGE ALERT	BoM/ICC					0	AHD	24/10/1990		1870						14		16		18	BoM
212	9		143006A	Cressbrook Creek	Tinton		-27.195	152.29833	GDA94	35.4	22.1	ASS	1/10/1952	15/06/1986	422	G	H	F	-	-						DNRM
125	125	540549			TOOHILLS CROSSING ALERT	Seqwater																				BoM
126	126	540365			TOOHILLS CROSSING TM	Seqwater																				BoM
311	108		143306B	Reedy Creek	Umount Byron	DNRM	-27.13491	152.6255	GDA94	9.5	20.7	AHD	20/09/2011		0	G	H	F	R	-						DNRM
238	35		143032A	Moggill Creek	Upper Brookfield	DNRM	-27.49	152.89083	AGD84	12.5	36.4	AHD	12/07/1976		23	G	H	F	-	-						DNRM
194	194	40813			UPPER BROOKFIELD TM	DNRM									22						2		3		4	BoM
25	25	540276			UPPER CRESSBROOK ALERT	TRC															3.5		4.5		7.5	BoM
42	42	540566			UPPER LOCKYER ALERT	LVRC					0	ASSUM	20/12/2012								2		4		6	BoM
226	23		143019A	Oxley Creek	Upstream Beatty Road		-27.58778	153.01111	AGD84	16.1	1.1	AHD	24/12/1971	29/12/1974	152	G	H	F	-	-						DNRM
227	24		143019B	Oxley Creek	Upstream Beatty Road		-27.58722	153.00944	AGD84	15.9	0.3	AHD	22/04/1975	18/11/1981	152	G	H	-	-	-						DNRM
310	107		143306A	Reedy Creek	Upstream Byron Creek Junction	DNRM	-27.13391	152.6405	GDA94	10.5	85.4	AHD	25/06/1975	10/01/2011	56	G	H	F	-	-						DNRM
205	2		143001B	Brisbane River	Vernor	DNRM	-27.4675	152.59917	AGD84	140.1	21.8	SD	1/10/1950	14/11/1958	10056	G	H	F	-	-						DNRM
284	81		143217A	Buaraba Creek	Vineyard		-27.41472	152.45333	AGD84	10.9	55.1	SD	10/08/1977	30/09/1987	347	G	H	F	-	-						DNRM
188	188	540477			WAKERLEY ALERT	BCC															2.8		3.2		3.5	BoM
250	47		143107A	Bremer River	Walloon	DNRM	-27.60178	152.69406	GDA94	36.9	16.4	AHD	1/10/1961		622	GQ	H	F	-	Q						DNRM
119	119	540504			WALLOON (DNRM) AL	Seqwater				36.9	16.4	AHD	15/03/2011		620						5		6.5		8.5	BoM
117	117	540147			WALLOON ALERT-P	BoM/Seqwater				41	22.97	AHD	1/10/1994		585						3.5		5.5		7	BoM
118	118	540081			WALLOON TM	DNRM				36.9	16.4	AHD	1/10/1961		620						5		6.5		8.5	BoM
296	93		143229A	Laidley Creek	Warrego Highway	DNRM	-27.55316	152.389	GDA94	0	76.3	AHD	8/11/1990		450	GQ	H	F	-	Q						DNRM
69	69	540529			WARREGO HIGHWAY ALERT	LVRC									445						4.5		5.2		5.5	BoM
68	68	540050			WARREGO HIGHWAY TM	DNRM				5	76.34	AHD	11/08/1990		445						4.5		5.2		5.5	BoM
140	140	540195			WASHPOOL ALERT	Seqwater									65						2.5		3.5		4.5	BoM
283	80		143216A	Redbank Creek	Water Treatment Works		-27.53417	152.30278	AGD84	3	94	AHD	15/12/1975	25/08/1986	60	G	H	F	-	-						DNRM
211	8		143005A	Brisbane River	Watts Bridge		-27.09056	152.46833	AGD84	230.9	66	SD	1/10/1952	31/10/1972	4602	G	H	F	-	-						DNRM
157	157	540495			WHYTE ISLAND ALERT	Seqwater															1.7		2.6		3.5	BoM
268	65		143204A	Lockyer Creek	Wilsons Weir		-27.53528	152.34083	AGD84	62	78.5	SD	1/10/1953	31/07/1982	1655	G	H	F	-	-						DNRM
281	78		143214A	Flagstone Creek	Windolfs		-27.61556	152.11333	AGD84	8.7	147.7	AHD	1/02/1972	31/12/1986	142	G	H	F	-	-						DNRM
183	183	540127			WISHART(GREENWOOD ST) AL	BCC															22		23		24	BoM
233	30		143026A	Brisbane River	Wivenhoe		-27.39639	152.60222	AGD84	150	25.7	SD	19/06/1974	5/04/1977	7023	G	H	F	-	-						DNRM
33	33	40763			WIVENHOE DAM	Seqwater									7020											BoM
35	35	540177			WIVENHOE DAM HW ALERT-B	Seqwater									7020											BoM
36	36	540302			WIVENHOE DAM HW ALERT-B2	Seqwater									7020											BoM
34	34	540049			WIVENHOE DAM HW TM	Seqwater				150.4	0	AHD	11/12/1986		7020											BoM
38	38	540178			WIVENHOE DAM TW ALERT-P	Seqwater				150	0	AHD	5/02/1986		7020											BoM
37	37	540069			WIVENHOE DAM TW TM	Seqwater				150	0	AHD	5/02/1986		7020											BoM
169	169	540378			WOLSTON CREEK ALERT	BCC															4		5		6	BoM
6	6	40627			WOODFORD	BoM				64.1	107.51	AHD	1/09/1918		250						5	5	6.1	10.7	8.5	BoM
314	111		143901A	Stanley River	Woodford	DNRM	-26.9356	152.7617	GDA94	64.9	107.5	AHD	6/02/2002		249	GQ	H	F	-	Q						DNRM
5	5	540338			WOODFORD ALERT-B	Seqwater				64.1	107.51	AHD	15/05/2002		250						5	5	6.1	10.7	8.5	BoM
4	4	540337			WOODFORD ALERT-P	Seqwater				64.1	107.51	AHD	15/05/2002		250						5	5	6.1	10.7	8.5	BoM
3	3	540485			WOODFORD TM	DNRM									250						5	5	6.1	10.7	8.5	BoM
189	189	540278			WYNNUM(BYRNESIDE TCE) AL	BCC															4.8		6		7	BoM

Appendix B
Hydraulic modelling details

Bremer River at Walloon

Table B1 Hydraulic model setup

Model Parameter	Value
Model Type:	MIKE21 2D
Model Width	3250m
Model Height	6000m
Origin	471,230**E** 6,942,120**N**
Rotation	-45°
Grid Resolution	7.5m
Mainstream Distance Between Gauge and Downstream Boundary	5km
Topography Data Source	LiDAR Survey (BRCFS Data Collection Phase)
Boundary Conditions	■ Inflow – steady state (constant flows) – Bremer River inflows – 10, 20, 50, 100, 200, 300, 400, 500, 750, 1000, 2000, 3000, 4000, 5000 m^3/s ■ Tailwater – refer to TW rating (Table B2)

Table B2 Tailwater rating

Discharge (m^3/s)	TW Level Channel (m AHD)	TW Level Floodplain (m AHD)
10	13.0	na
20	13.0	na
50	13.37	21.49
100	13.99	21.49
200	14.81	21.49
300	15.42	21.49
400	15.90	21.49
500	16.32	21.49
750	17.19	21.49
1000	17.91	21.49
2000	20.10	21.49
3000	21.49	21.49
4000	22.32	22.32
5000	22.85	22.85

The MIKE21 roughness parameters were based upon aerial photography. These parameters were then adjusted within the limits defined by each land use to achieve a best fit rating curve comparison against the stage-discharge gaugings developed by DNRM. The roughness values for the calibrated model are outlined in Table B3 below.

Table B3 Adopted Manning's n values

Land Use Type	Adopted Manning's n Values
Roads	0.027
Pasture / Parks	0.053
Channel (low flow)	0.030
Channel (bank flow)	0.120
Brush (light)	0.053
Brush (medium to dense)	0.067
Residential / Commercial	0.200

The model topography and typical flow patterns (water depths and surface elevations) are highlighted in Figure B1 to Figure B4.

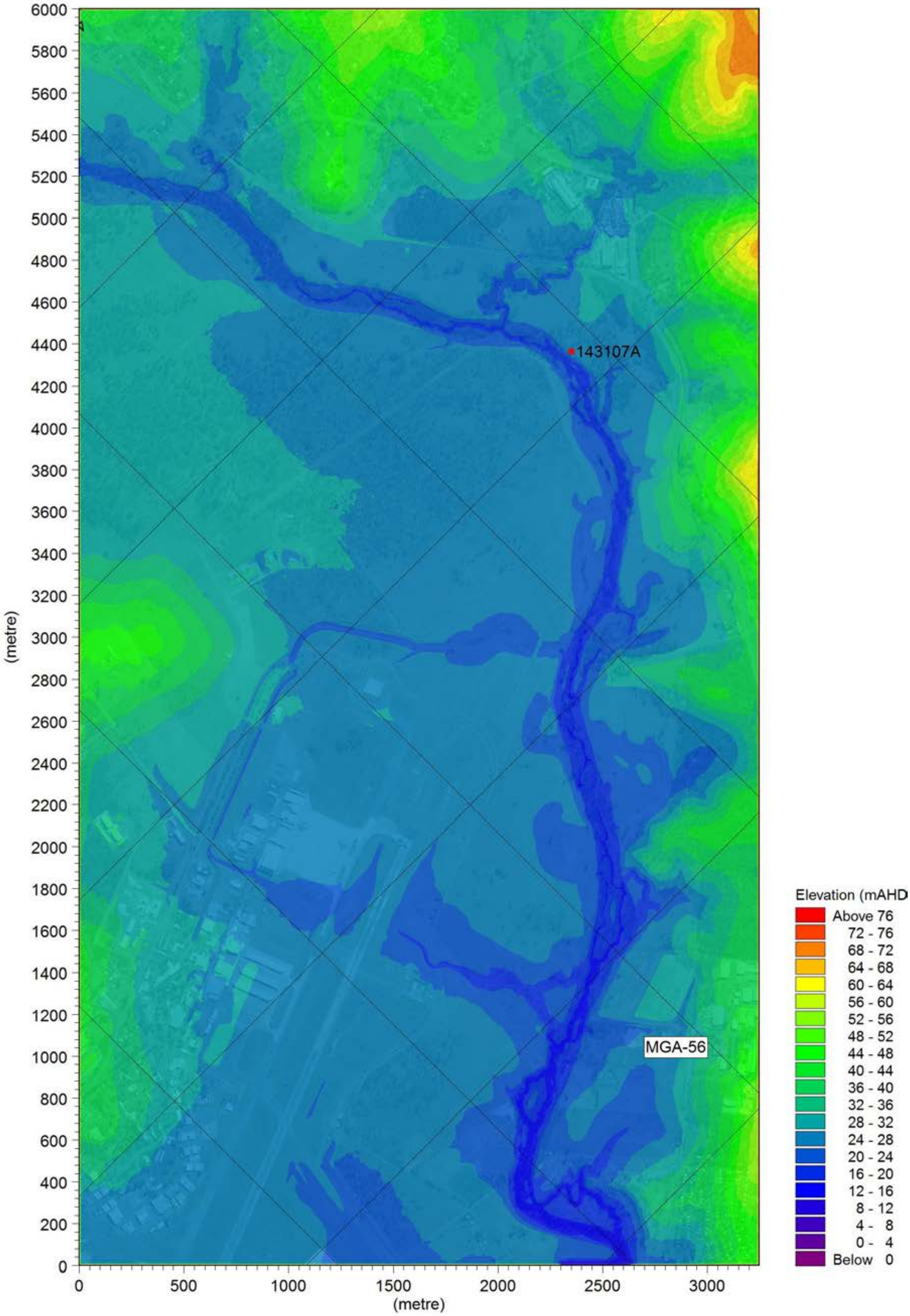

Figure B1 MIKE21 hydraulic model topography – Bremer River at Walloon (143107A)

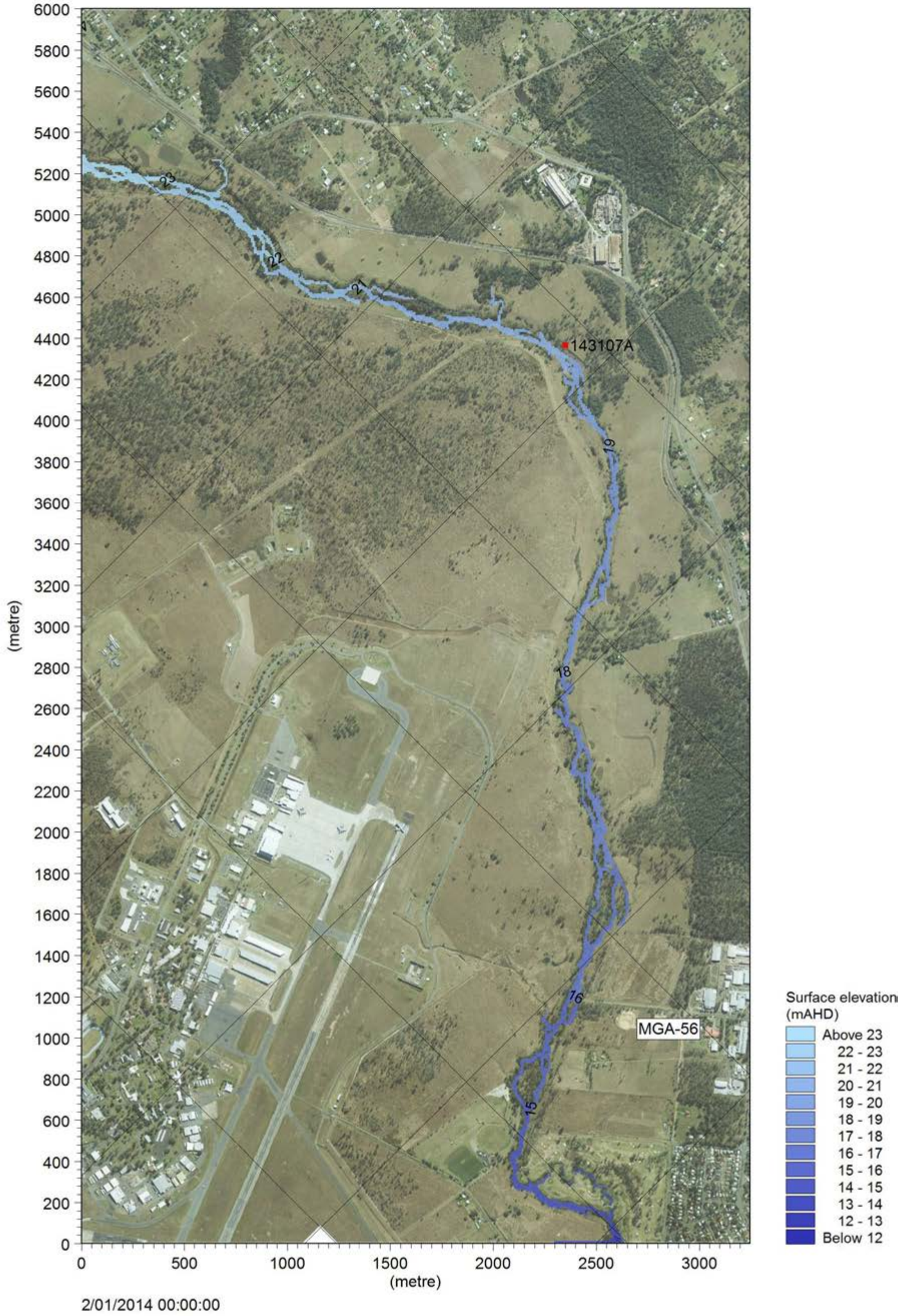

Figure B2 Bremer River at Walloon (143107A) – 20m³/s surface water levels

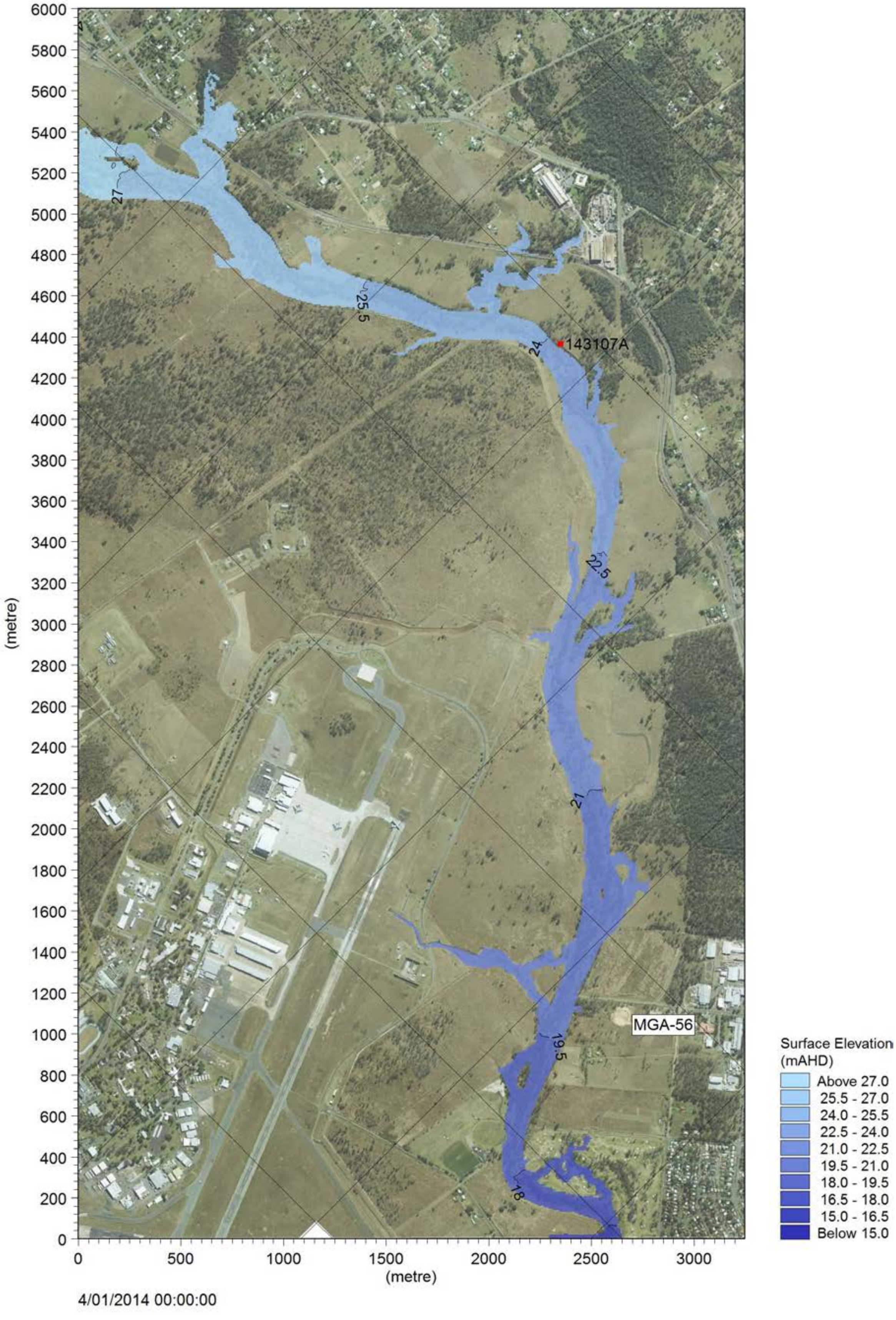

Figure B3 Bremer River at Walloon (143107A) – 500m^3/s surface water levels

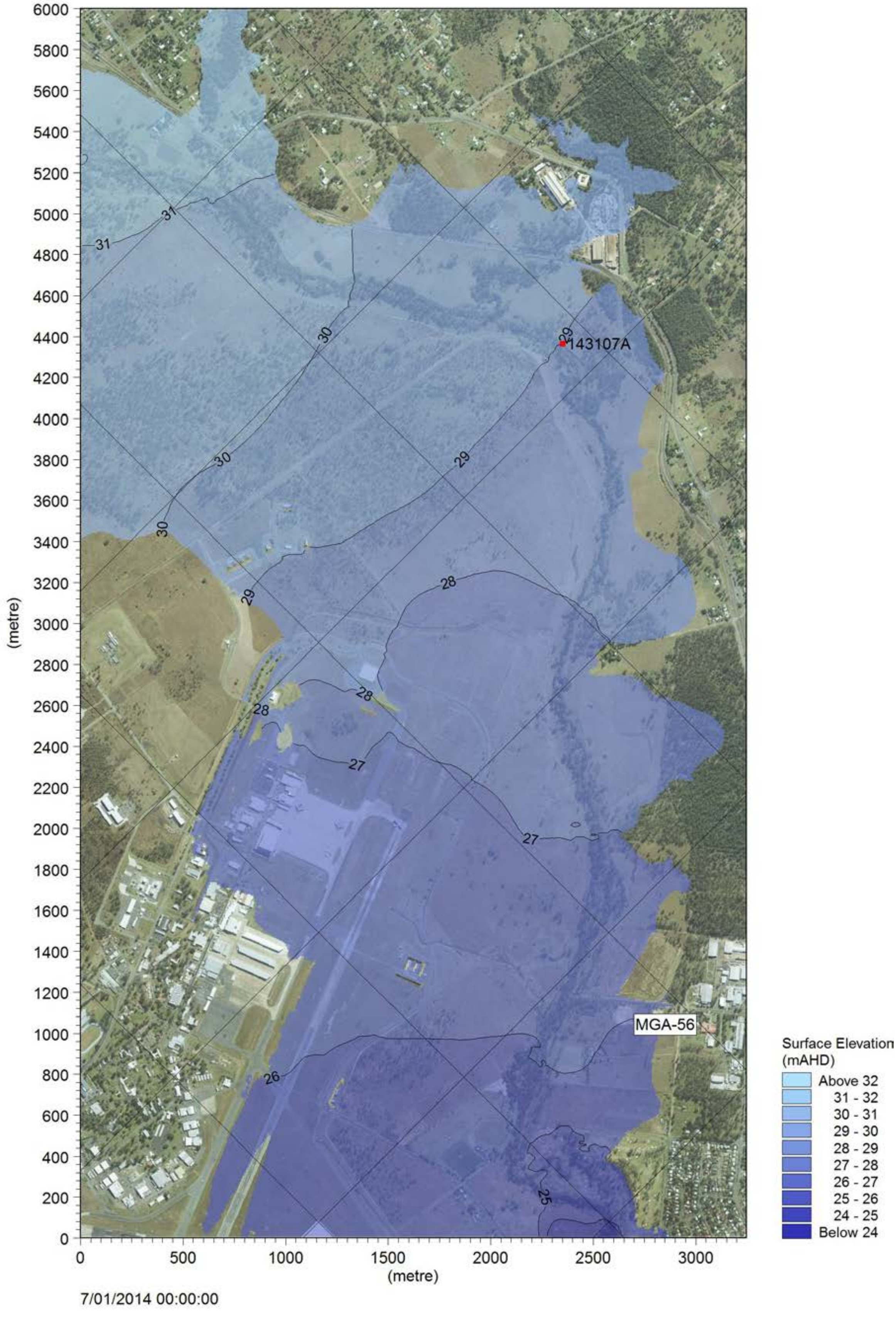

Figure B4 Bremer River at Walloon (143107A) – 5000m³/s surface water levels

Upper Brisbane River at Linville

Table B4 Hydraulic model setup

Model Parameter	Value
Model Type:	MIKE21 2D
Model Width	3000m
Model Height	5000m
Origin	427,000**E** 7,031,000**N**
Rotation	0°
Grid Resolution	10m
Mainstream Distance Between Gauge and Downstream Boundary	5km
Topography Data Source	LiDAR Survey (BRCFS Data Collection Phase)
Boundary Conditions	▪ Inflow – steady state (constant flows) – Brisbane River inflows – 50, 100, 200, 300, 500, 750, 1000, 1500, 2000, 3000, 4000, 5000 m^3/s ▪ Tailwater – refer to TW rating (Table B5)

Table B5 Tailwater rating

Discharge (m^3/s)	TW Level Channel (m AHD)
50	111.55
100	112.14
200	112.98
300	113.54
500	114.26
750	114.86
1000	115.33
1500	116.11
2000	116.77
3000	117.84
4000	118.71
5000	119.45

The MIKE21 roughness parameters were based upon aerial photography. These parameters were then adjusted within the limits defined by each land use to achieve a best fit rating curve comparison against the stage-discharge gaugings developed by DNRM. The roughness values for the calibrated model are outlined in Table B6 below.

Table B6 Adopted Manning's n values

Land Use Type	Adopted Manning's n Values
Pasture	0.040
Channel (low flow)	0.040
Channel (bank flow)	0.048 to 0.090
Brush (light)	0.050
Brush (medium to dense)	0.070
Residential / Commercial	0.200

The model topography is presented in Figure B5. Typical flow patterns (water depths and surface elevations) are presented in Figure B6 to Figure B8.

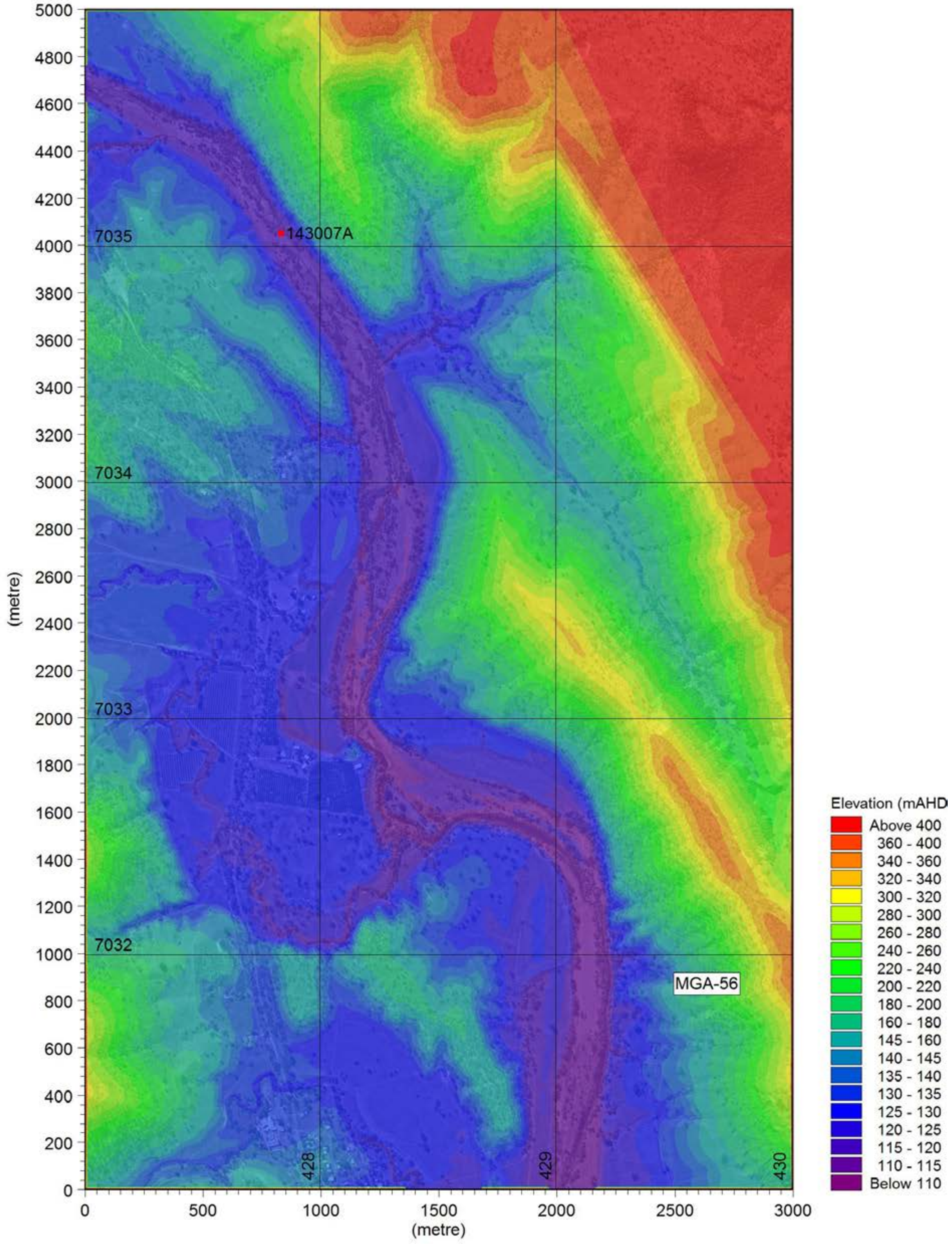

Figure B5 MIKE21 hydraulic model topography – Upper Brisbane River at Linville (143007A)

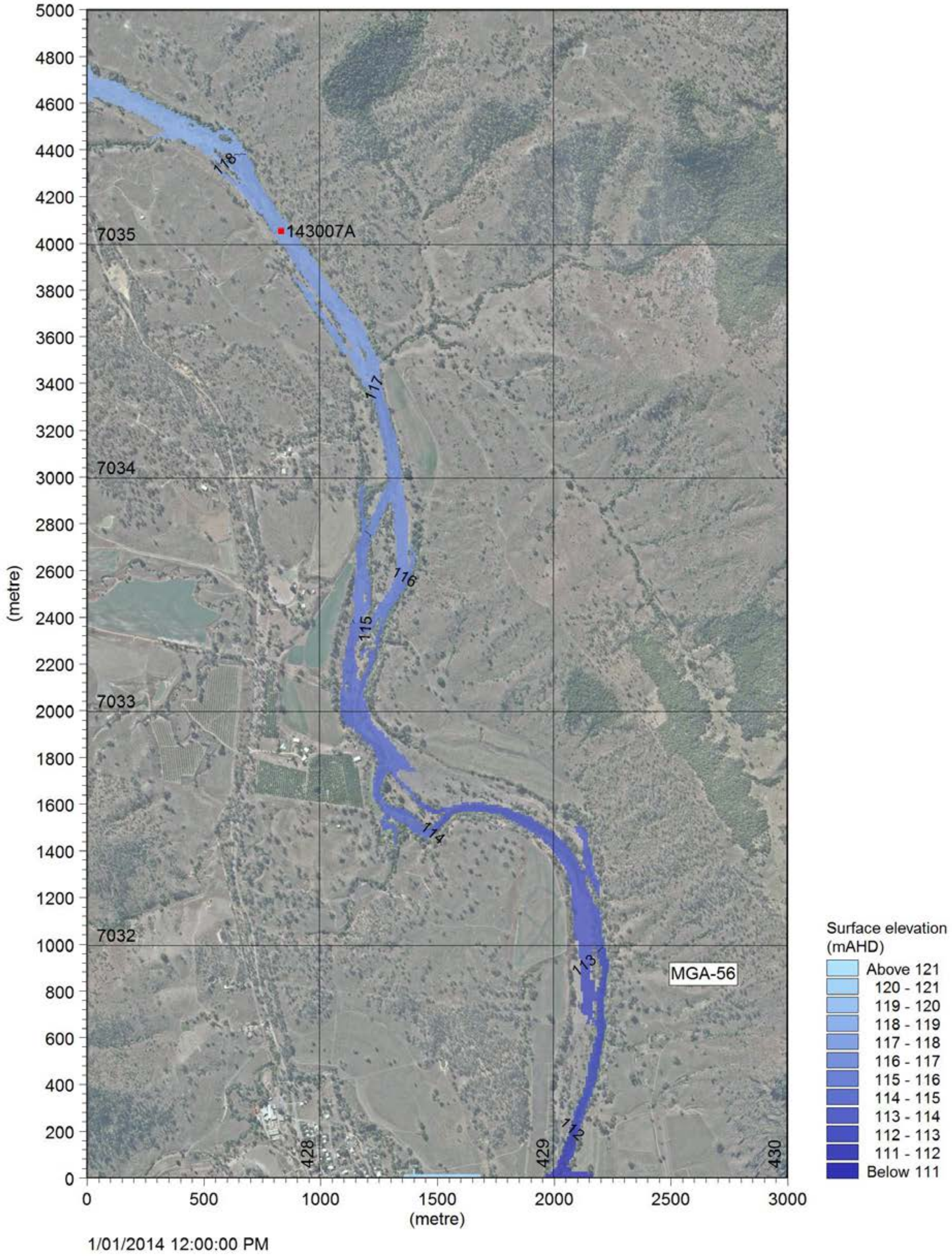

Figure B6 Upper Brisbane River at Linville (143007A) – 50m^3/s surface water levels

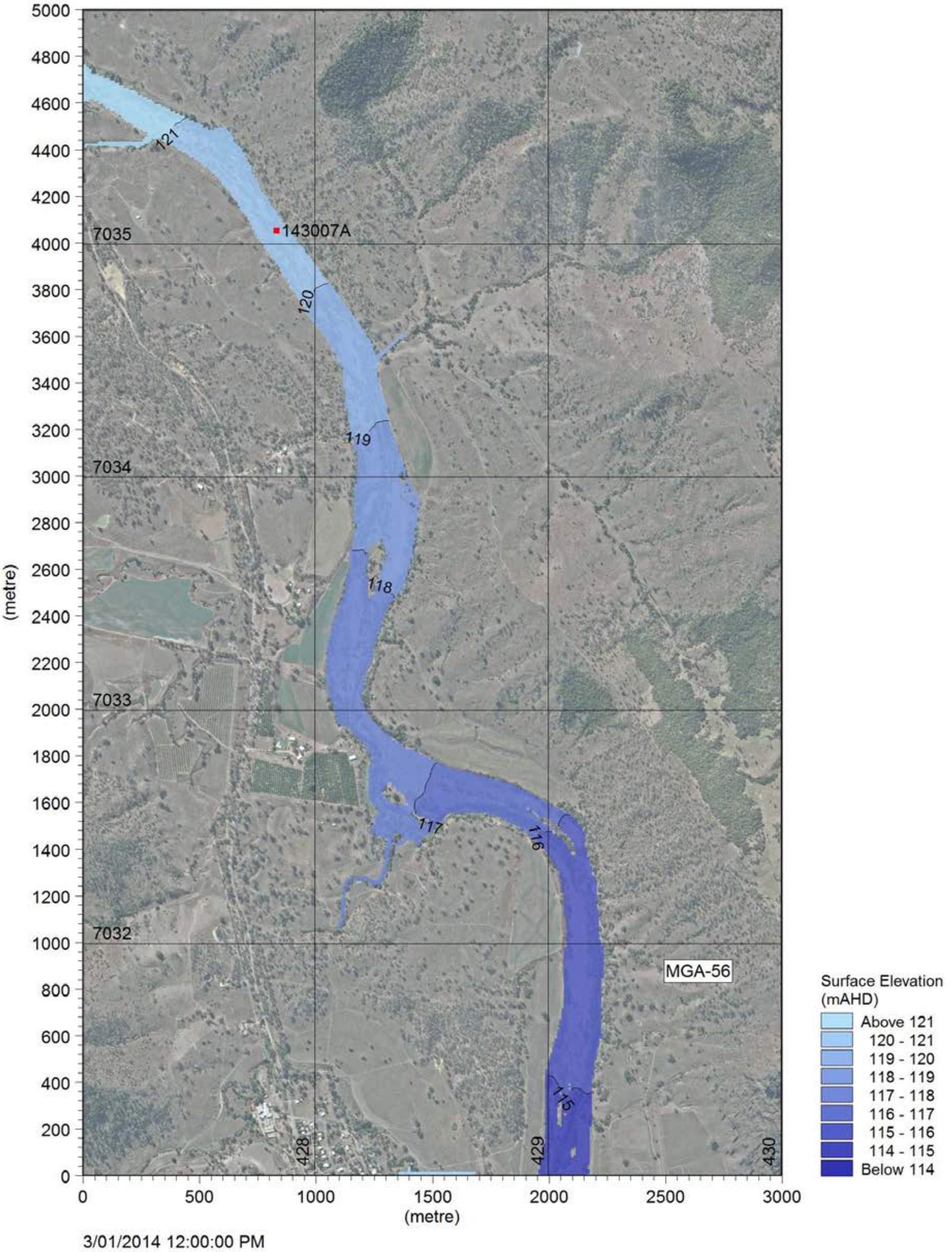

Figure B7 Upper Brisbane River at Linville (143007A) – 500m^3/s surface water levels

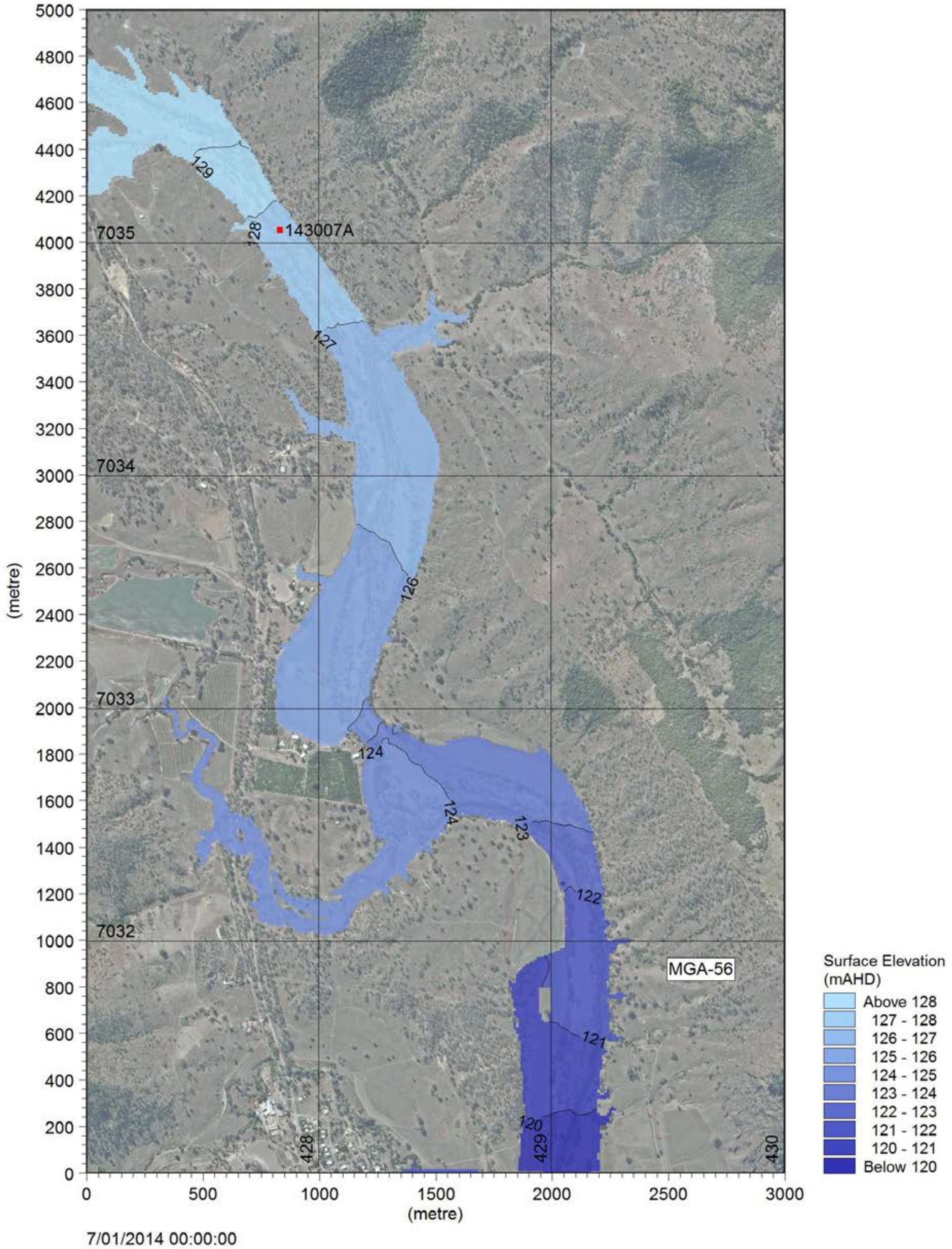

Figure B8 Upper Brisbane River at Linville (143007A) – 5000m^3/s surface water levels

Lockyer Creek at Glenore Grove

Table B7 Hydraulic model setup

Model Parameter	Value
Model Type:	MIKE21 2D
Model Width	7000m
Model Height	6000m
Origin	438,000**E** 6,953,000**N**
Rotation	0°
Grid Resolution	10m
Mainstream Distance Between Gauge and Downstream Boundary	5.5km
Topography Data Source	LiDAR Survey (BRCFS Data Collection Phase)
Boundary Conditions	▪ Inflow – steady state (constant flows) – Single source inflows for each of Lockyer and Laidley Creeks – refer to 4.3 – 50, 100, 250, 500, 600, 750, 1000, 2000, 3000, 4000, 5000 m^3/s ▪ Tailwater – refer to TW rating (Table B8)

Table B8 Tailwater rating

Total Discharge (m^3/s)	Lockyer Creek Inflow (m^3/s)	Laidley Creek Inflow (m^3/s)	TW Level Channel (m AHD)
50	40	10	66.20
100	80	20	66.20
250	200	50	66.63
500	400	100	67.18
600	480	120	67.18
750	600	150	67.18
1000	800	200	67.98
2000	1600	400	70.33
3000	2400	600	71.95
4000	3200	800	73.24
5000	4000	1000	74.36

The MIKE21 roughness parameters were developed off aerial photography. These parameters were then adjusted within the limits defined by each land use to achieve a best fit rating curve comparison against the stage-discharge gaugings developed by DNRM. The roughness values for the calibrated model are outlined in Table B9 below.

Table B9 Adopted Manning's n values

Land Use Type	Adopted Manning's n Values
Pasture / Cultivated Area	0.040
Channel (low flow)	0.035
Channel (bank flow)	0.060 to 0.110
Brush (light)	0.050
Residential / Commercial	0.150

Figure B9 presents the model topography and Figure B10 to Figure B12 present the typical flow patterns (water depths and surface elevations).

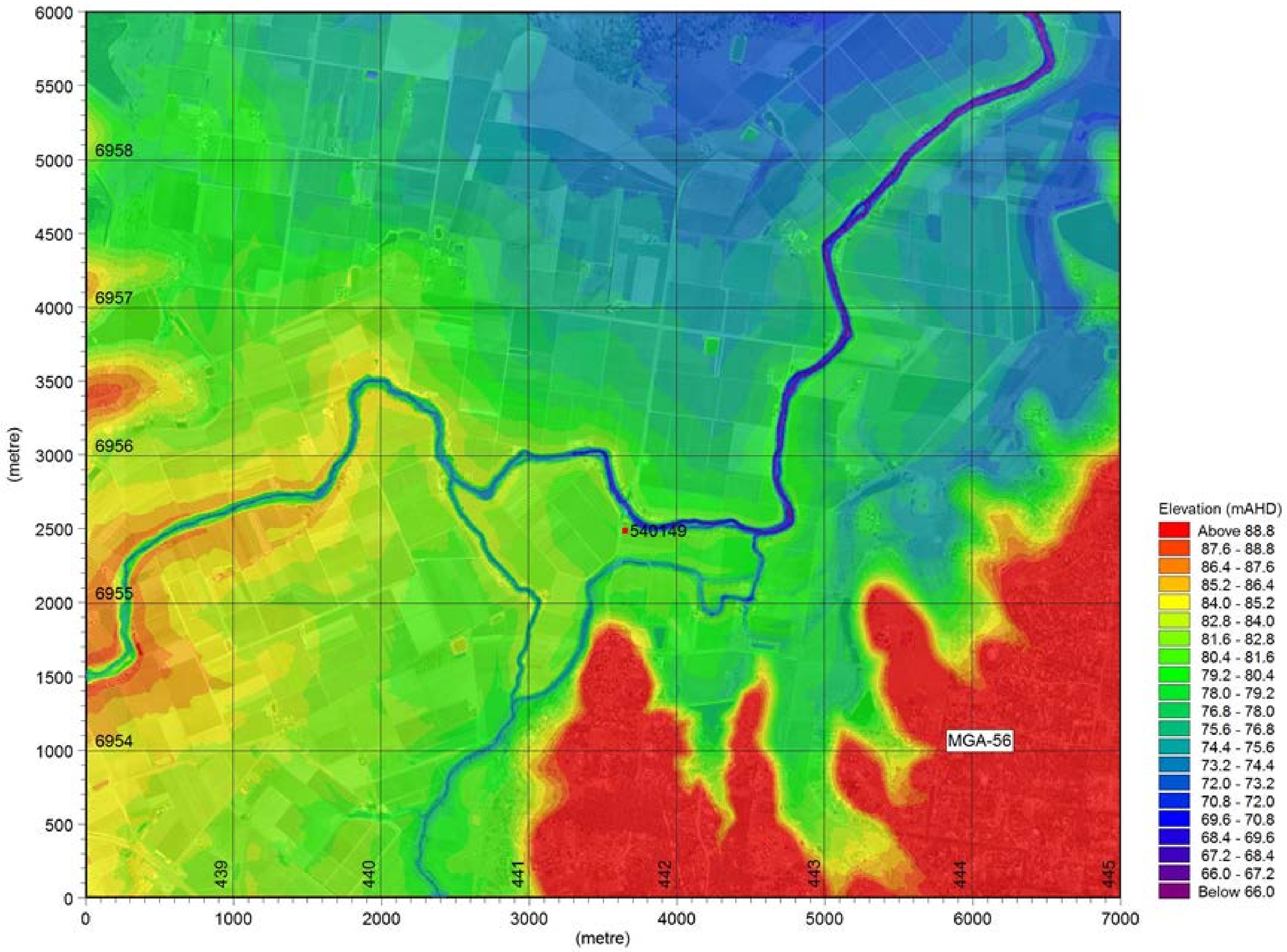

Figure B9 MIKE21 hydraulic model topography – Lockyer Creek at Glenore Grove (143807)

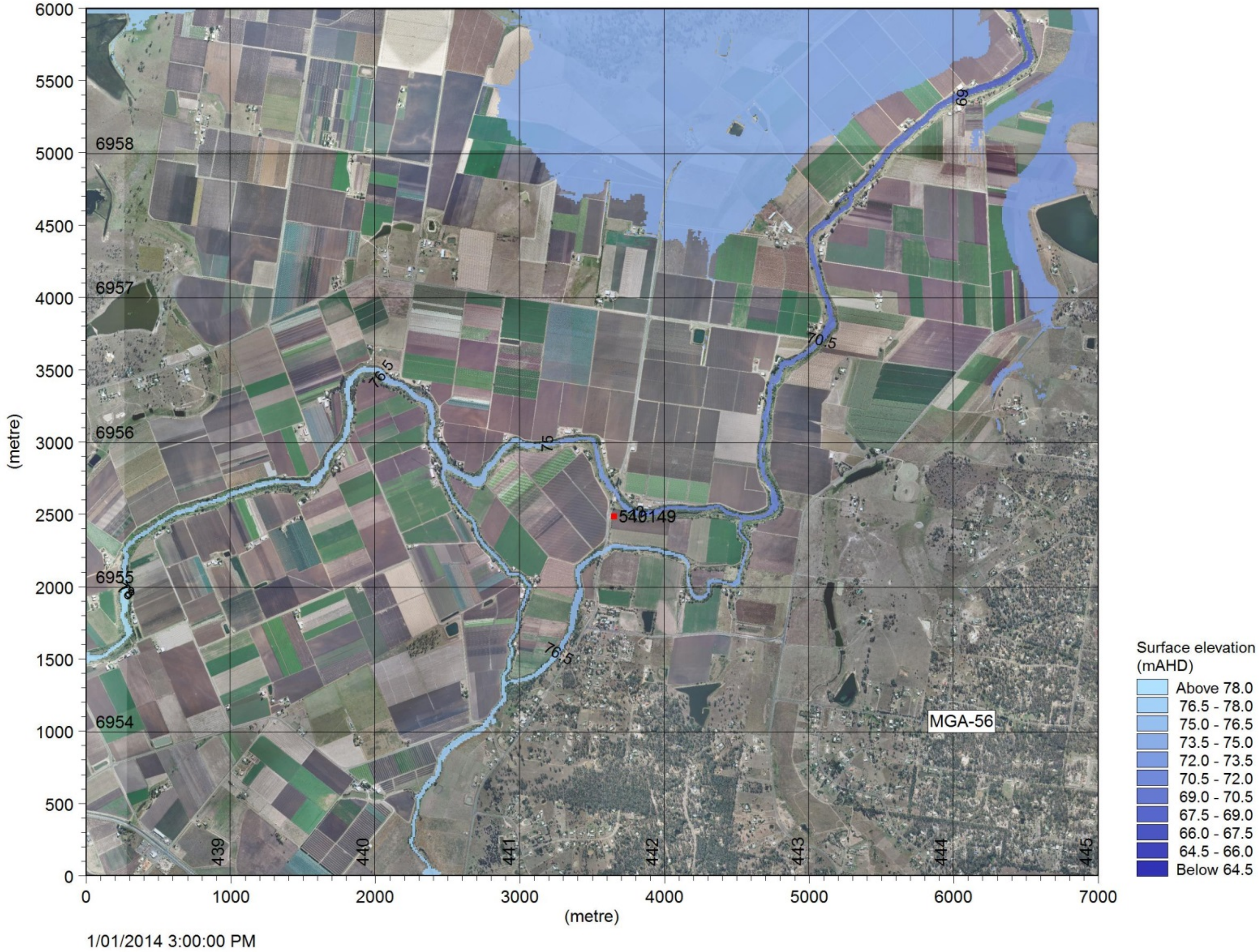

Figure B10 Lockyer Creek at Glenore Grove (143807) – 50m³/s surface water levels

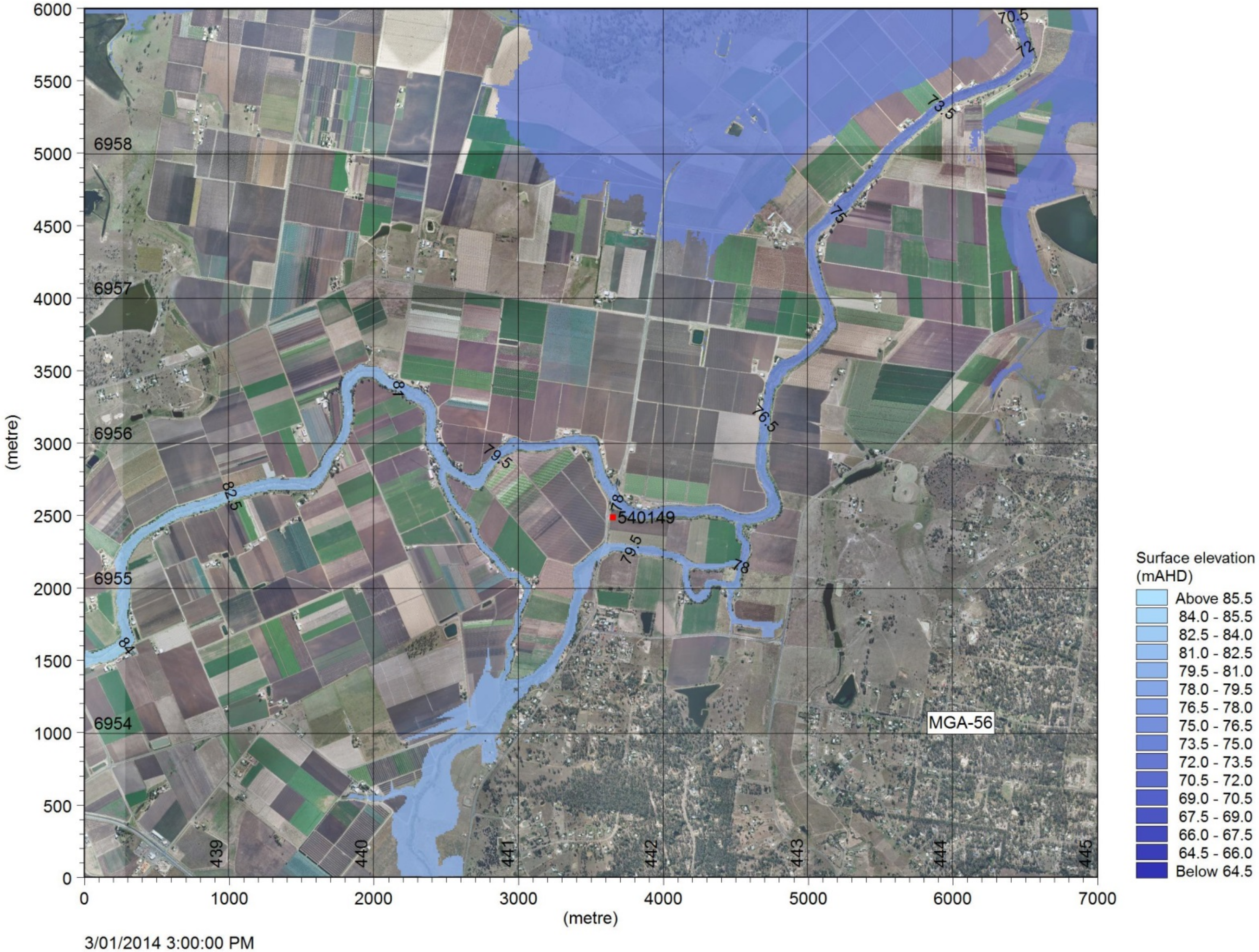

Figure B11 Lockyer Creek at Glenore Grove (143807) – 500m^3/s surface water levels

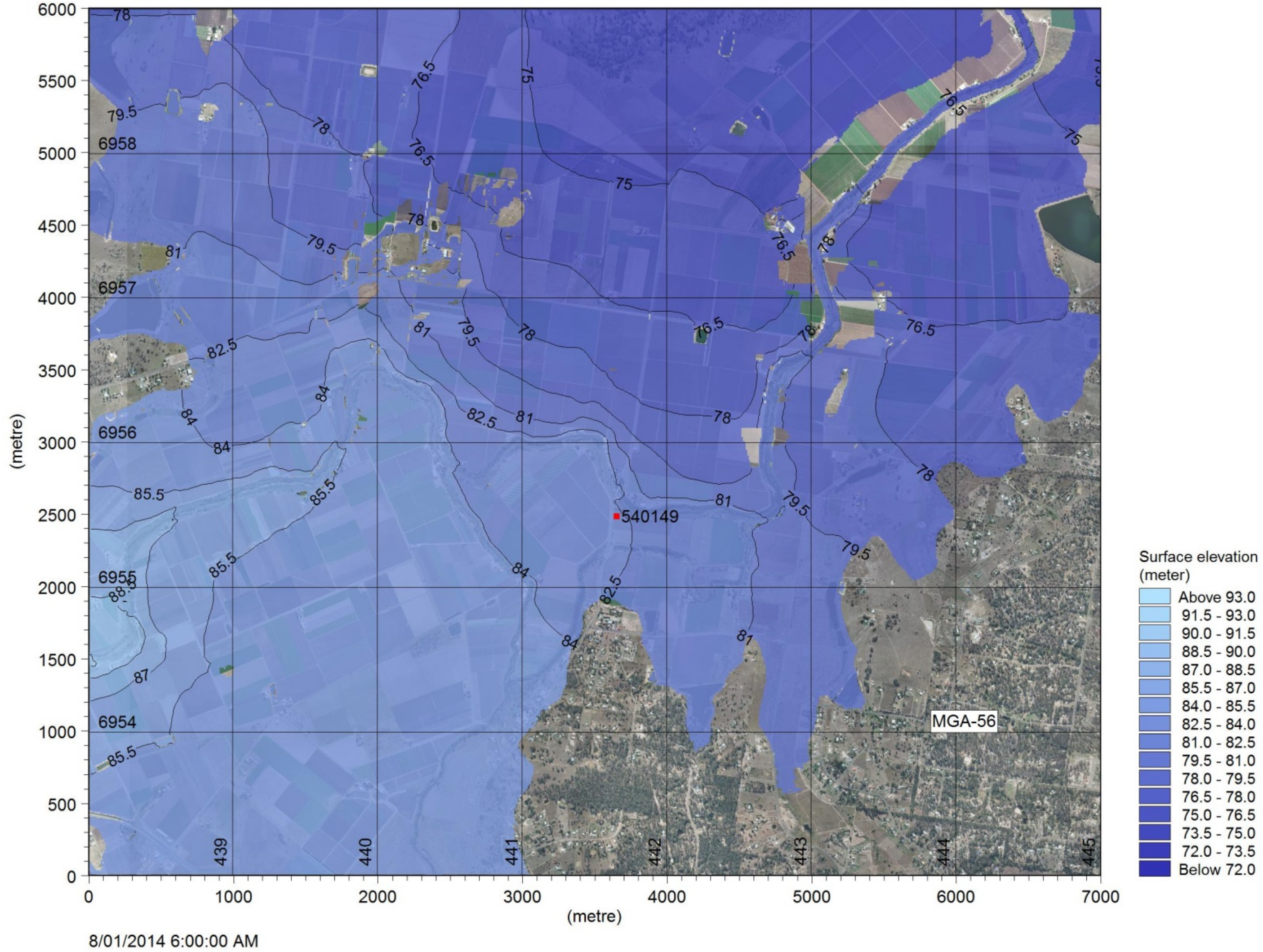

Figure B12 Lockyer Creek at Glenore Grove (143807) – 5000m^3/s surface water levels

Stanley River at Woodford

Table B10 Hydraulic model setup

Model Parameter	Value
Model Type:	MIKE21 2D
Model Width	3720m
Model Height	3220m
Origin	474,230**E** 7,018,430**N**
Rotation	0°
Grid Resolution	7.5m
Mainstream Distance Between Gauge and Downstream Boundary	3.5km
Topography Data Source	▪ LiDAR Survey (BRCFS Data Collection Phase) ▪ DTMR survey section at bridge used to account for poor channel definition in LiDAR
Boundary Conditions	▪ Inflow – steady state (constant flows) – Stanley River inflows – 10, 20, 40, 50, 60, 80, 100, 200, 300, 400, 500, 750, 1000 m^3/s ▪ Tailwater – refer to TW rating (Table B11)

Table B11 Tailwater rating

Discharge (m^3/s)	TW Level Channel (m AHD)
10	105.41
20	105.72
40	106.12
50	106.28
60	106.42
80	106.67
100	106.88
200	107.71
300	108.32
400	108.81
500	109.23
750	110.04
1000	110.76

The MIKE21 roughness parameters were developed off aerial photography. These parameters were then adjusted within the limits defined by each land use to achieve a best fit rating curve comparison against the stage-discharge gaugings developed by DNRM. The roughness values for the calibrated models are outlined in Table B12 below.

Table B12 Adopted Manning's n values

Land Use Type	Adopted Manning's n Values
Roads	0.020
Ponds	0.025
Pasture	0.050
Channel (low flow)	0.035
Channel (bank flow)	0.150
Brush (light)	0.060
Brush (dense)	0.150
Residential / Commercial	0.150

The model topography and typical flow patterns (water depths and surface elevations) are highlighted in Figure B13 to Figure B16.

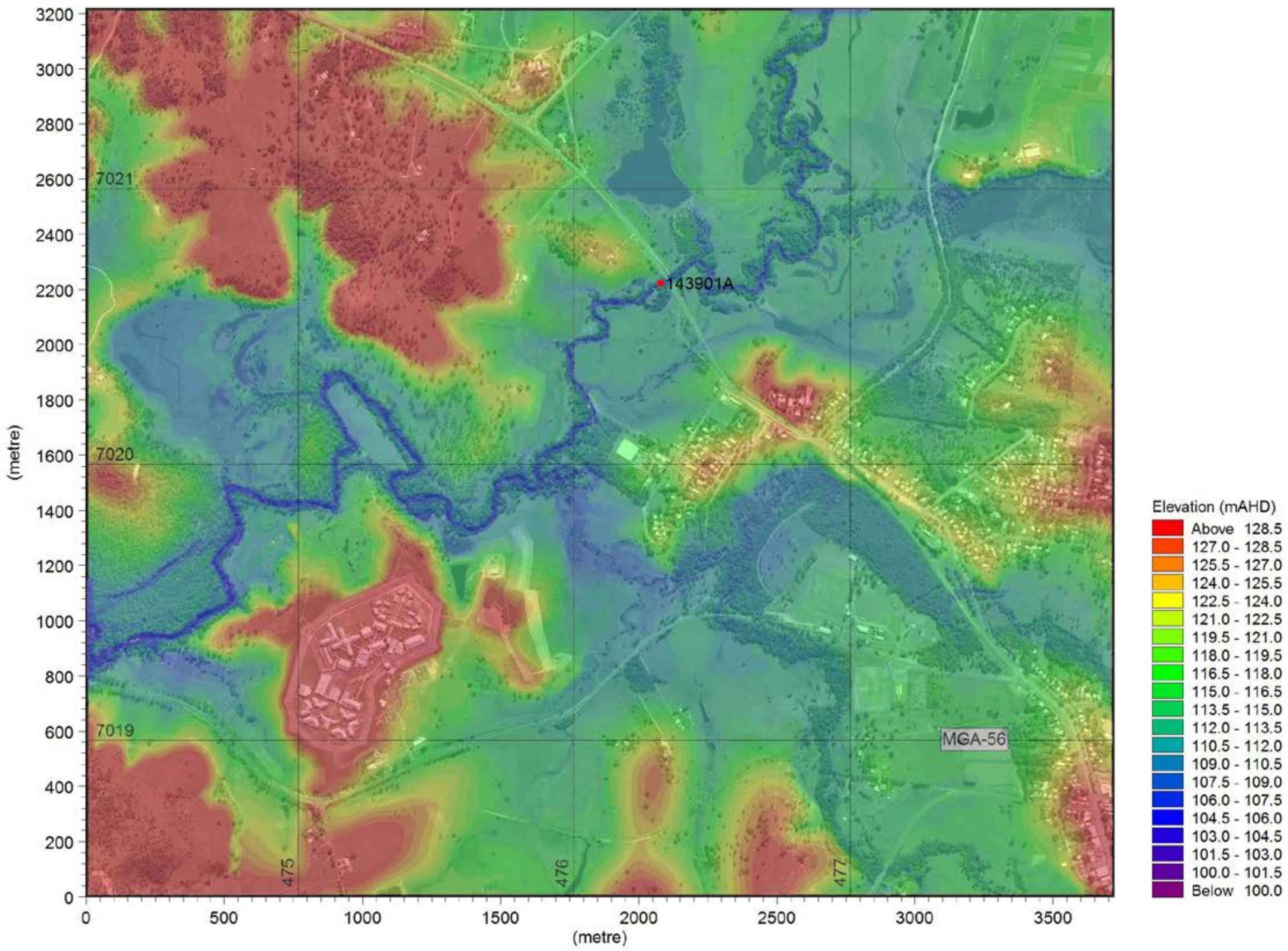

Figure B13 MIKE21 Hydraulic model topography – Stanley River at Woodford (143901A)

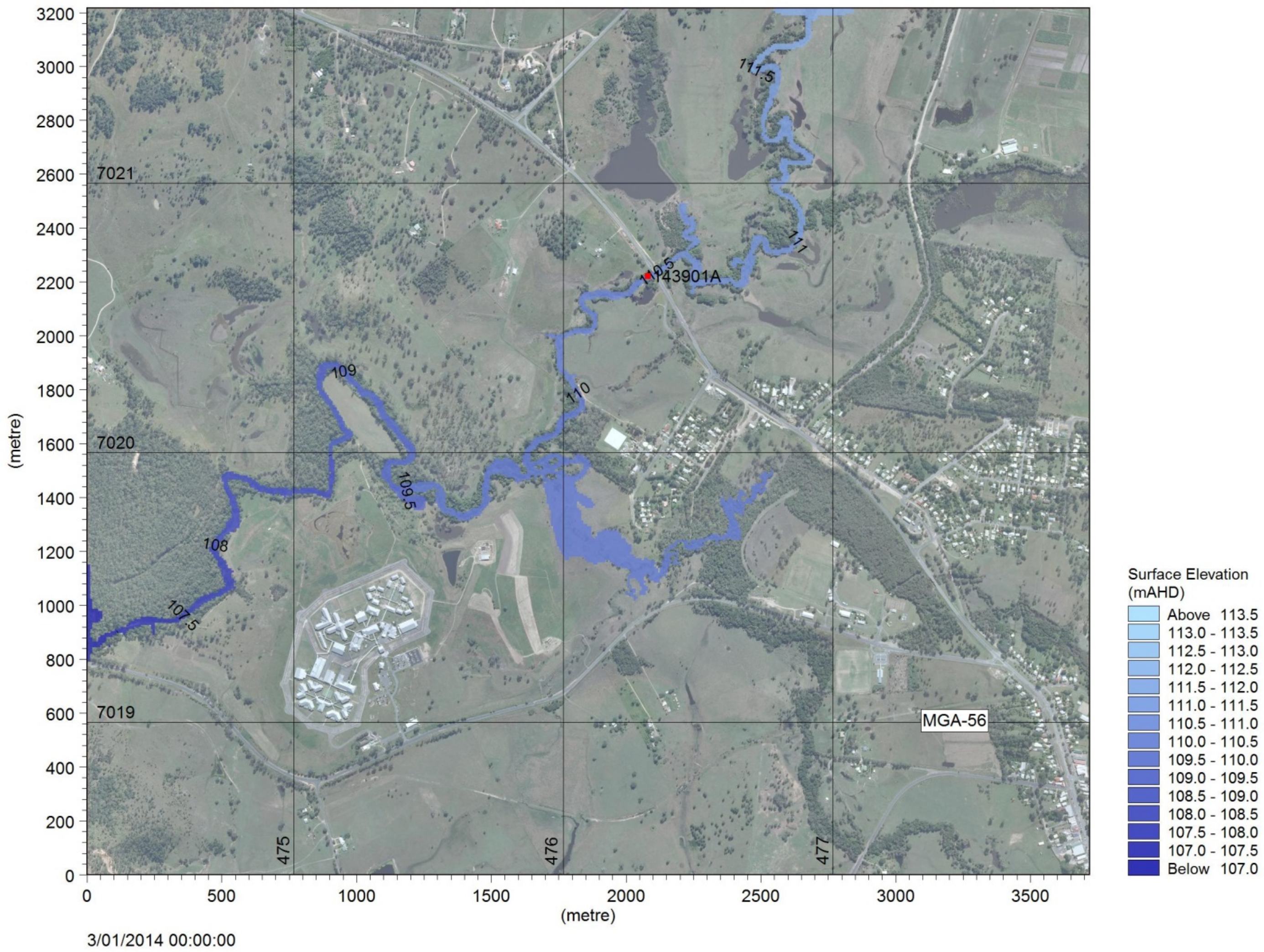

Figure B14 Stanley River at Woodford (143901A) – 60m^3/s surface water levels

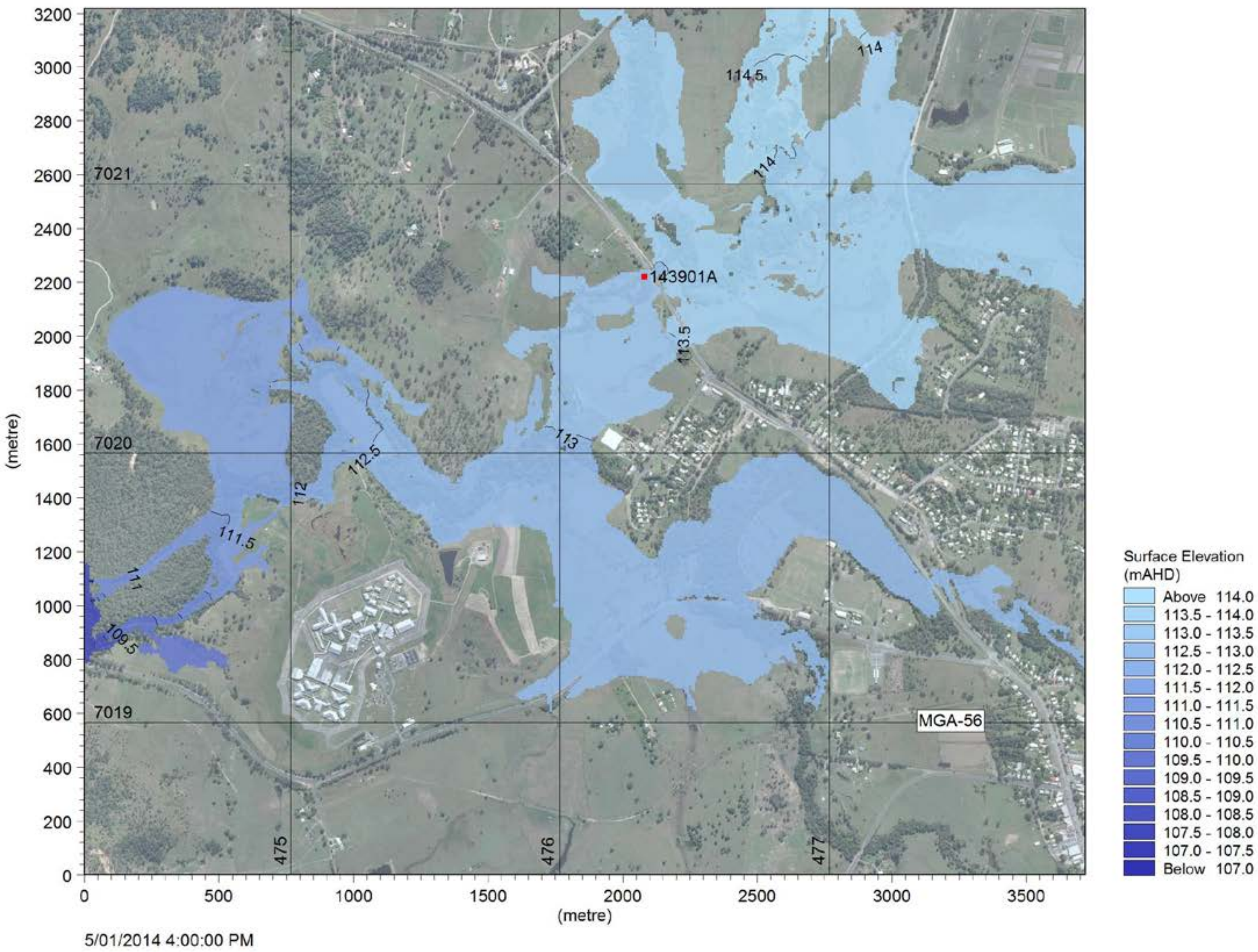

Figure B15 Stanley River at Woodford (143901A) – 200m³/s surface water levels

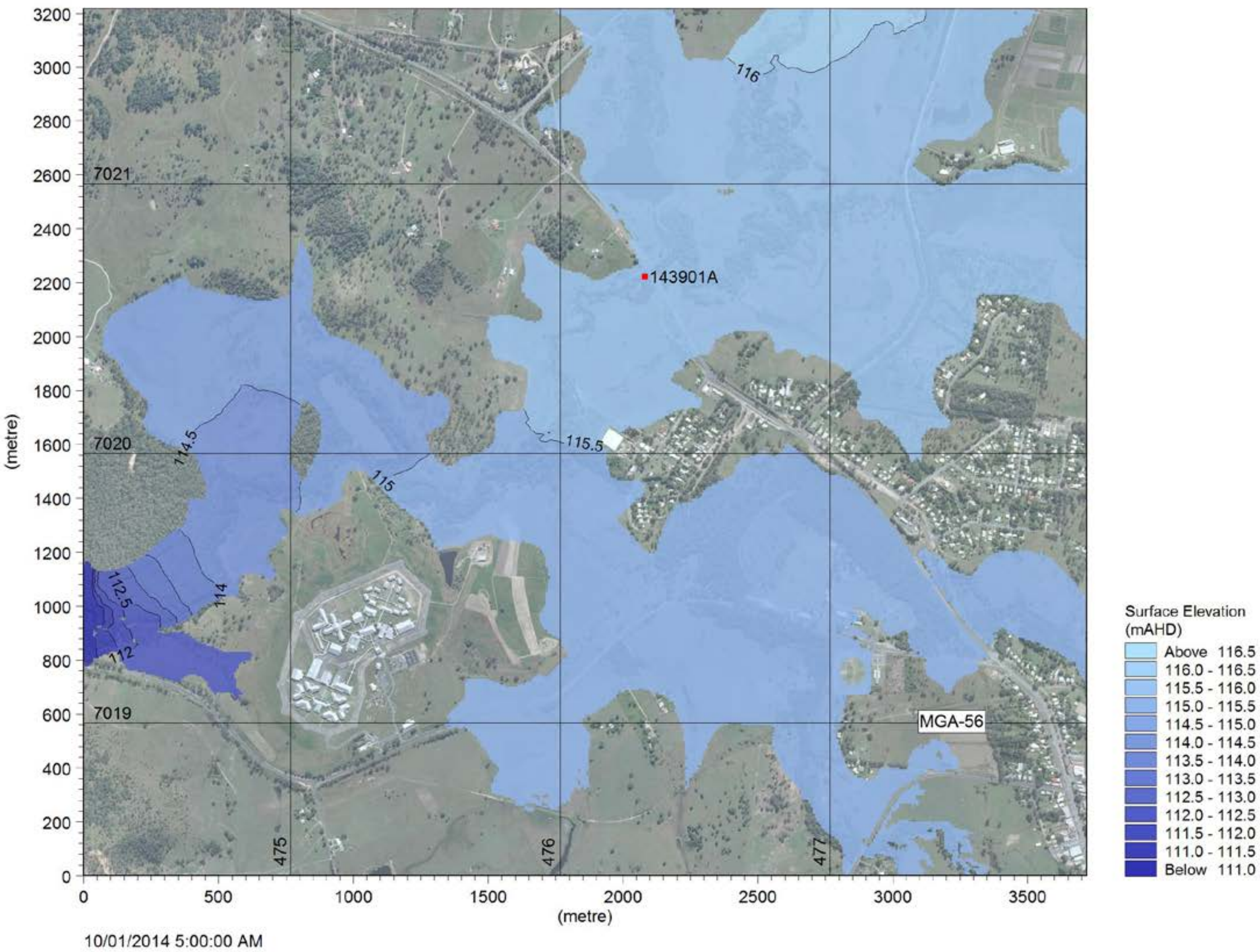

Figure B16 Stanley River at Woodford (143901A) – 1000m³/s surface water levels

Warrill Creek at Amberley and Purga Creek at Loamside

Table B13 Hydraulic model setup

Model Parameter	Value
Model Type:	MIKE21 2D
Model Width	5915m
Model Height	7890m
Origin	468,170**E** 6,934,815**N**
Rotation	0°
Grid Resolution	5m
Mainstream Distance Between Gauge and Downstream Boundary	7km (Amberley gauge); 8km (Loamside gauge)
Topography Data Source	LiDAR Survey (BRCFS Data Collection Phase)
Boundary Conditions	■ Inflow – steady state (constant flows) – Multiple source (two) inflows for Warrill Creek and a single source inflow for Purga Creek – refer to 4.5 – 25, 60, 120, 250, 400, 700, 1050, 1500, 2250, 3000, 4000, 5000m^3/s ■ Tailwater – refer to TW rating (Table B14)

Table B14 Tailwater rating

Total Discharge (m^3/s)	Warrill Creek Total Inflows (m^3/s)	Purga Creek Inflow (m^3/s)	TW Level Channel (m AHD)
25	20	5	13.08
60	50	10	14.20
120	100	20	15.19
250	200	50	16.25
400	300	100	17.10
700	500	200	18.36
1050	750	300	19.50
1500	1000	500	20.65
2250	1500	750	22.15
3000	2000	1000	23.17
4000	2500	1500	24.10
5000	3000	2000	24.78

The MIKE21 roughness parameters were developed off aerial photography. These parameters were then adjusted within the limits defined by each land use to achieve a best fit rating curve comparison against the stage-discharge gaugings developed by DNRM. The roughness values for the calibrated models are outlined in Table B15 below.

Table B15 Adopted Manning's n values

Land Use Type	Adopted Manning's n Values
Roads	0.020
Pasture	0.050
Ponds	0.033
Warrill Creek Channel (low flow)	0.033
Warrill Creek Channel (bank flow)	0.114
Purga Creek Channel (low flow)	0.028
Purga Creek Channel (bank flow)	0.100
Brush (light to medium)	0.067
Residential / Commercial	0.167

Figure B17 to Figure B20 present the model topography and typical flow patterns (water depths and surface elevations).

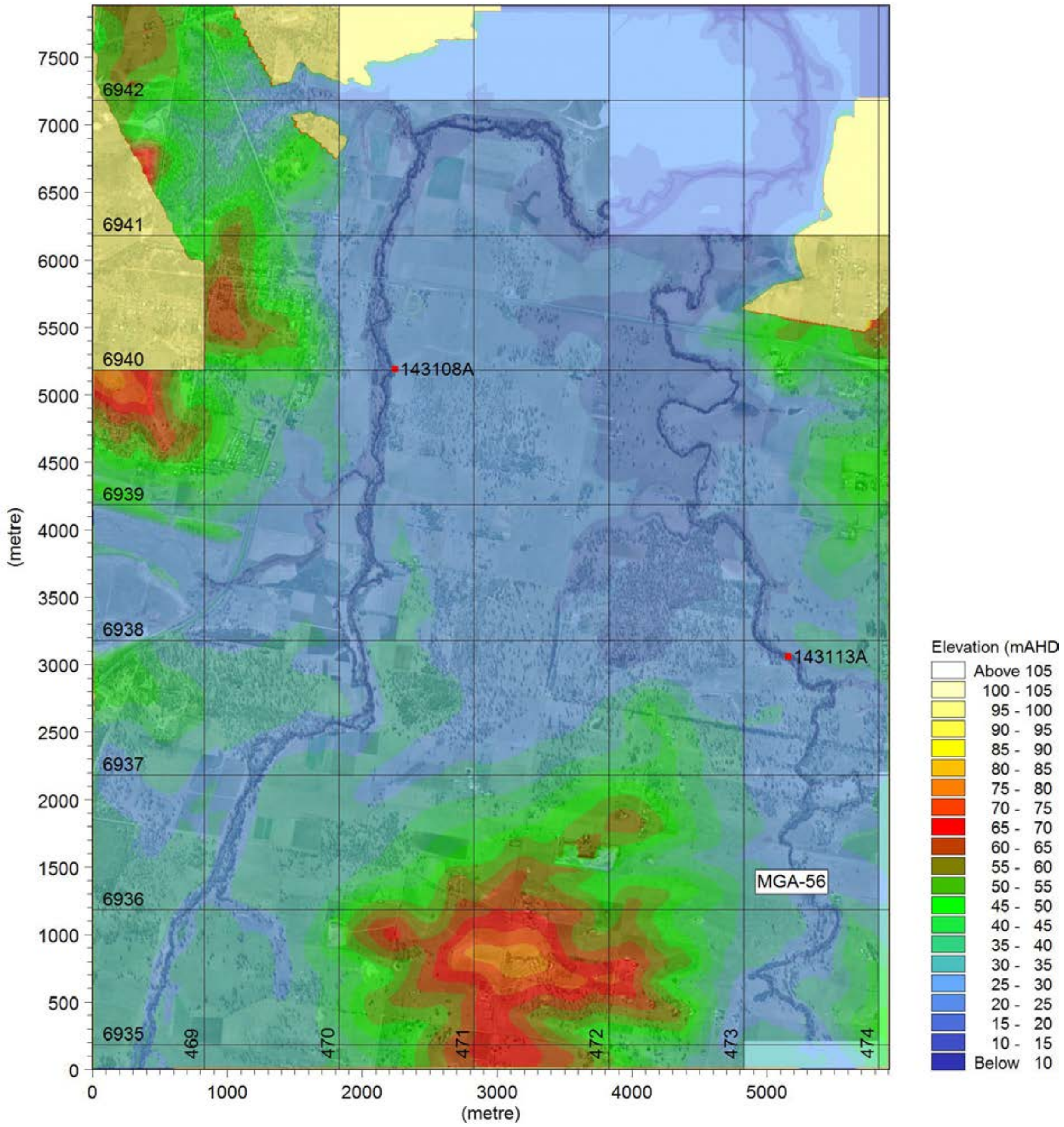

Figure B17 MIKE21 Hydraulic model topography – Warrill Creek at Amberley (143108A) & Purga Creek at Loamside (143113A)

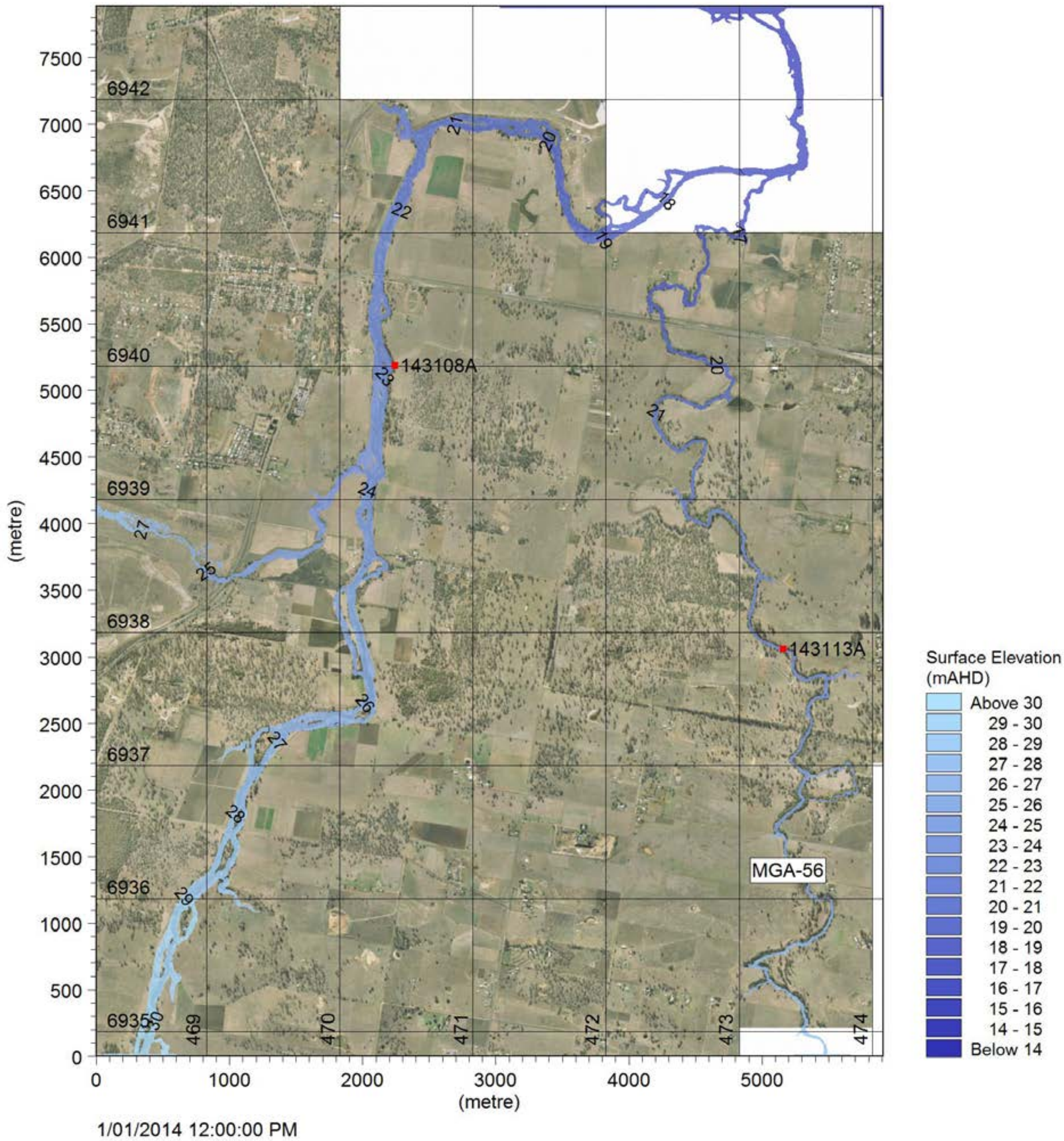

Figure B18 Warrill Creek at Amberley (143108A) & Purga Creek at Loamside (143113A) – 120m^3/s surface water levels

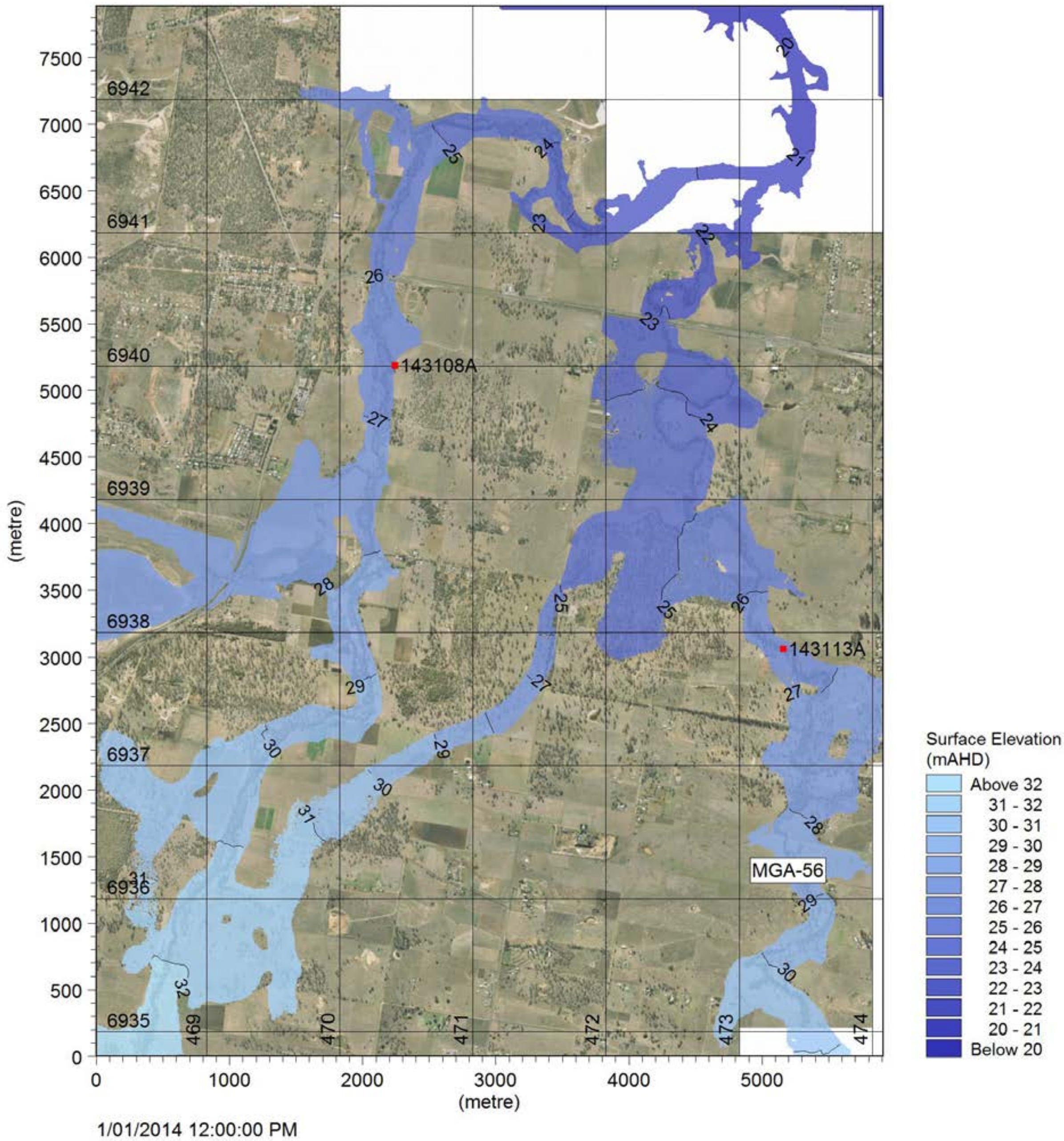

Figure B19 Warrill Creek at Amberley (143108A) & Purga Creek at Loamside (143113A) – 1050m^3/s surface water levels

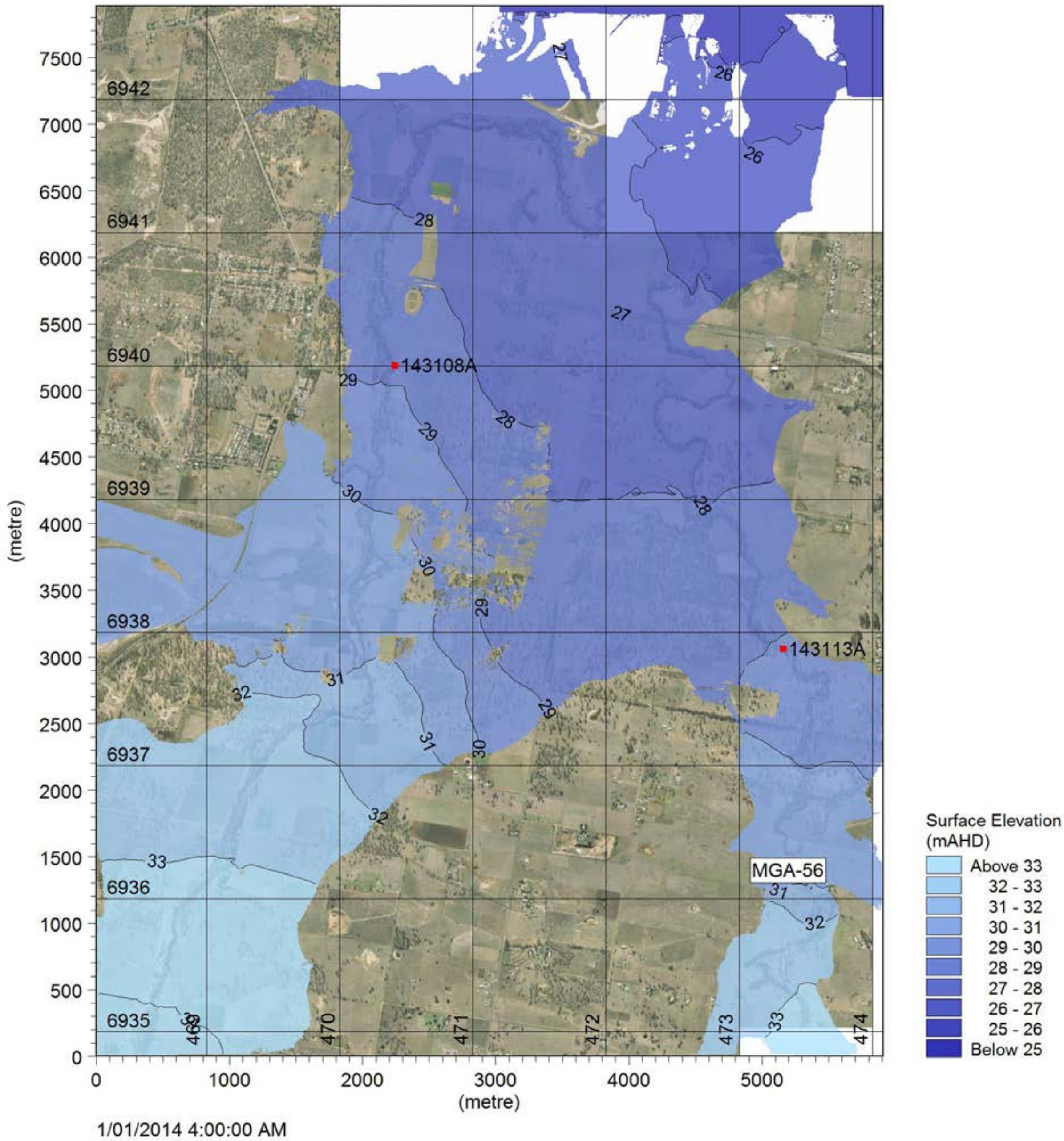

Figure B20 Warrill Creek at Amberley (143108A) & Purga Creek at Loamside (143113A) – 5000m^3/s surface water levels

Appendix C
Tabulated rating curves

Primary gauges

Stanley River at Woodford

Gauge level (m)	Flow (m^3/s)
0 (107.519 mAHD)	0.0
1.7	0.0
1.9	1.0
2	2.4
2.2	5.8
2.4	10.0
2.6	14.6
2.8	19.6
Flows below $20 m^3/s$ weir controlled and dependent on local Stanley River flows only. Flows above $50 m^3/s$ dependent on combined flows from Stanley River (at gauge) and downstream tributary	
4.2	53.0
4.4	63.0
4.6	73.7
4.8	85.9
5	98.2
5.2	123.8
5.4	151.8
5.6	179.8
5.8	211.8
6	253.9
6.2	296.0
6.4	346.1
6.6	397.1
6.8	448.0
7	499.0
7.2	559.6
7.4	620.4
7.6	681.3
7.8	742.1
8	802.9
8.2	863.7
8.4	924.6
8.6	985.4
8.8	1054.0
9	1125.1
9.2	1196.2
9.4	1267.2
9.6	1338.3
9.8	1409.4
10	1480.5

Brisbane River at Linville

Gauge level (m)	Flow (m^3/s)
0 (115.319 mAHD)	0
0.5	0.5
0.8	2.7
1	5.5
1.2	10.0
1.4	16.6
1.6	25.9
1.8	38.6
2	55.1
2.2	76.0
2.4	101.8
2.6	131.4
2.8	156.7
3	184.3
3.2	217.1
3.4	249.9
3.6	282.7
3.8	322.1
4	365.3
4.2	408.5
4.4	464.5
4.6	520.9
4.8	577.2
5	633.5
5.2	704.5
5.4	775.5
5.6	846.6
5.8	919.4

Gauge level (m)	Flow (m^3/s)
6	1002.7
6.2	1086.0
6.4	1169.3
6.6	1264.6
6.8	1361.2
7	1457.8
7.2	1554.3
7.4	1650.9
7.6	1753.5
7.8	1864.6
8	1975.7
8.2	2086.9
8.4	2198.0
8.6	2317.4
8.8	2440.3
9	2563.3
9.2	2686.2
9.4	2822.7
9.6	2959.2
9.8	3095.7
10	3232.2

Lockyer Creek at Glenore Grove

Gauge level (m)	Flow (m^3/s)
0 (67.12 mAHD)	0
2.5	12.1
5	44.4
5.5	56.5
6	74.5
6.5	92.4
7	118.7
7.5	150.9
8	183.0
8.5	215.2
9	247.4
9.5	298.3
10	350.8

Gauge level (m)	Flow (m^3/s)
10.5	403.4
11	455.9
11.5	512.3
12	589.2
12.5	680.6
13	785.7
13.2	840.7
13.4	895.6
13.6	950.5
13.8	1012.9
14	1141.9
14.2	1373.7
14.4	1687.5
14.6	2000.0
14.8	2434.8
15	2869.6
15.2	3538.5
15.4	4381.0

Bremer River at Walloon

Gauge level (m)	Flow (m^3/s)
0 (16.4 mAHD)	0.0
0.99	0.0
1.5	0.3
2	2.1
2.5	4.6
3	10.3
3.5	20.4
4	38.2
4.5	61.5
5	88.1
5.5	140.4
6	211.9
6.5	285.7
7	375.2
7.5	480.0
8	610.5

Gauge level (m)	Flow (m^3/s)
8.5	745.9
9	923.0
9.5	1170.3
10	1470.0
10.5	1769.8
11	2135.0
11.5	2717.1
12	3489.5
12.5	4559.0

Warrill Creek at Amberley

Gauge level (m)	Flow (m^3/s)
0 (17.535 mAHD)	0.0
0.5	0.3
1.5	3.1
2	6.1
2.5	10.2
3	15.6
3.5	22.4
4	30.6
4.5	46.9
5	75.4
5.5	117.4
6	168.2
6.2	191.8
6.4	218.4
6.6	246.4
6.8	274.5
7	303.1
7.2	336.2
7.4	369.4
7.6	405.9
7.8	445.8
8	485.6
8.2	525.4
8.4	565.0
8.6	607.1

Gauge level (m)	Flow (m^3/s)
8.8	651.5
9	695.9
9.2	752.8
9.4	812.4
9.6	876.1
9.8	966.1
10	1071.8
10.2	1196.4
10.4	1321.1
10.6	1514.9
10.8	1751.1
11	2097.9
11.2	2552.4
11.5	3453.1

Purga Creek at Loamside

Gauge level (m)	Flow (m^3/s)
0 (18.478 mAHD)	0.0
0.52	0.0
1.5	1.3
2	3.0
2.5	4.8
3	7.7
3.5	11.3
4	16.0
4.5	22.0
5	29.5
5.5	39.7
6	54.1
6.2	63.5
6.4	71.9
6.6	81.7
6.8	92.6
7	107.2
7.2	129.1
7.4	154.7
7.6	184.1

Gauge level (m)	Flow (m^3/s)
7.8	221.9
8	269.7
8.2	322.4
8.4	383.6
8.6	452.1
8.8	534.7
9	628.8
9.2	722.9
9.4	834.9
9.6	954.2
9.8	1092.0
10	1241.3
10.2	1418.4
10.4	1605.6
10.7	1918.2

Brisbane River at Mt Crosby Weir

Gauge level (m)	Flow (m^3/s)	*cS*
0.0 (0 mAHD)	0	0.00006
6.9	0	0.00006
7.0	5	0.00006
7.2	18	0.00005
7.5	75	0.00005
8.0	240	0.00029
8.5	462	0.00061
9.0	667	0.00071
9.5	954	0.00077
10.0	1224	0.00092
10.5	1540	0.00098
11.0	1692	0.00102
11.5	1742	0.00103
12.0	1827	0.00103
12.5	1920	0.00102
13.0	2049	0.00100
13.5	2204	0.00098
14.0	2394	0.00095
14.5	2597	0.00093
15.0	2821	0.00088
15.5	3050	0.00081
16.0	3280	0.00075
16.5	3498	0.00072
17.0	3780	0.00066
17.5	4049	0.00057
18.0	4346	0.00060
18.5	4620	0.00058
19.0	4935	0.00056
19.5	5198	0.00055
20.0	5539	0.00058
21.0	6195	0.00059
22.0	6897	0.00059
23.0	7540	0.00062
24.0	8240	0.00066
25.0	8976	0.00070
26.0	9747	0.00079
27.0	10441	0.00084
28.0	11475	0.00084
29.0	12700	0.00085
30.0	14076	0.00086
31.0	15600	0.00087
32.0	17655	0.00086
33.0	19980	0.00085

Brisbane River at Centenary Bridge

Gauge level (m)	Flow (m^3/s)		*cS*
	Tide=1.5m	Tide=-1m	
-1.0		0	0.00218
-0.5		536	0.00195
0 (0 mAHD)		876	0.00173
0.5		1205	0.00151
1.0		1524	0.00128
1.5	0	1854	0.00102
2.1	1318	2256	0.00087
2.5	1730	2503	0.00079
3.0	2173	2802	0.00071

Gauge level (m)	Flow (m³/s)		cS
	Tide=1.5m	Tide=-1m	
3.5	2554	3121	0.00066
4.0	2915	3451	0.00062
4.5	3317	3770	0.00060
5.0	3739	4069	0.00060
5.5	4161	4378	0.00060
6.0	4573	4687	0.00061
6.5	4972		0.00062
7.0	5333		0.00062
7.5	5708		0.00063
8.0	6095		0.00065
8.5	6494		0.00059
9.0	6899		0.00053
9.5	7306		0.00049
10.0	7782		0.00044
10.5	8258		0.00041
11.0	8746		0.00037
11.5	9246		0.00034
12.0	9757		0.00031
12.5	10280		0.00031
13.0	10815		0.00030
13.5	11362		0.00030
14.0	11924		0.00029
14.5	12502		0.00027
15.0	13099		0.00027
15.5	13718		0.00027
16.0	14361		0.00027
16.5	15032		0.00026
17.0	15737		0.00027
17.5	16478		0.00026
18.0	17262		0.00027
18.5	18093		0.00028
19.0	18978		0.00028
19.5	19923		0.00028
20.0	20934		0.00028
20.5	22062		0.00028
21.0	23210		0.00027
21.5	24452		0.00029
22.0	25804		0.00031
22.5	27289		0.00034
23.0	28930		0.00037
23.5	30754		0.00040
24.0	32791		0.00044
24.5	35072		0.00049
25.0	37632		0.00051

Secondary gauges

Grey values are considered less reliable.

Stanley River at Peachester

Gauge level (m)	Flow (m³/s)
0 (126.417 mAHD)	0
0.2	0.01
0.6	1.71
0.8	3.02
1.0	4.86
1.2	7.02
1.4	9.1
1.6	11.3
1.8	13.6
2.0	16.1
2.2	18.6
2.4	21.2
2.6	23.9
2.8	26.7
3.0	29.5
3.2	32.4
3.4	35.4
3.6	38.4
3.8	41.4
4.0	44.3
4.2	47.4
4.4	51.0
4.6	54.8
4.8	58.7

Gauge level (m)	Flow (m^3/s)
5.0	62.6
5.2	66.8
5.4	71.0
5.6	75.3
5.8	79.6
6.0	84.1
6.2	88.7
6.4	95.1
6.6	105
6.8	118
7.0	133
7.2	154
7.4	175
7.6	202
7.8	228
8.0	260
8.2	293
8.4	330
8.6	371
8.8	415
9.0	465
9.2	516
9.4	576
9.6	637
9.8	708
10.0	781

Kilcoy Creek at Mount Kilcoy

Gauge level (m)	Flow (m^3/s)
0 (105.017 mAHD)	0
0.7	0.1
0.8	0.4
1.0	1.1
1.2	2.3
1.4	3.9
1.6	6.1
1.8	8.8

Gauge level (m)	Flow (m^3/s)
2.0	12
2.2	16
2.4	20
2.6	26
2.8	31
3.0	33
3.2	35
3.4	40
3.6	46
3.8	53
4.0	60
4.2	69
4.4	78
4.6	87
4.8	97
5.0	108
5.2	120
5.4	134
5.6	153
5.8	177
6.0	205
6.5	309
7.0	440
7.5	601
8.0	795
8.5	1025
9.0	1293
9.5	1601
10.0	1952

Brisbane River at Gregors Creek

Gauge level (m)	Flow (m^3/s)
0 (82.42 mAHD)	0
0.5	0.1
0.8	1.0
1.0	2.6
1.2	4.5

Gauge level (m)	Flow (m^3/s)
1.4	8.3
1.6	13
1.8	19
2.0	26
2.2	35
2.4	46
2.6	58
2.8	73
3.0	89
3.2	109
3.4	130
3.6	153
3.8	179
4.0	205
4.2	237
4.4	268
4.6	311
4.8	353
5.0	402
5.2	450
5.4	504
5.6	559
5.8	619
6.0	679
6.2	745
6.4	812
6.6	884
6.8	956
7.0	1034
7.2	1113
7.4	1197
7.6	1281
7.8	1361
8.0	1441
8.2	1523
8.4	1605
8.6	1687
8.8	1774

Gauge level (m)	Flow (m^3/s)
9.0	1874
9.2	1975
9.4	2075
9.6	2181
9.8	2293
10.0	2405
10.5	2700
11.0	3010
11.5	3349
12.0	3705
12.5	4076
13.0	4479
13.5	4898
14.0	5333
14.5	5802
15.0	6287
15.5	6790

Lockyer Creek at Helidon (No. 3)

Gauge level (m)	Flow (m^3/s)
0 (128.625 mAHD)	0.0
0.4	0.0
0.6	0.1
0.8	0.8
1.0	3.2
1.2	7.6
1.4	13.1
1.6	19.5
1.8	26.8
2.0	34.9
2.2	43.6
2.4	52.8
2.6	62.8
2.8	73.2
3.0	84.1
3.2	95.5
3.4	107

Gauge level (m)	Flow (m^3/s)
3.6	123
3.8	144
4.0	167
4.5	225
5.0	283
5.5	360
6.0	437
6.5	527
7.0	627
7.5	730
8.0	854
8.5	979
9.0	1121
9.5	1271
10.0	1427
11.0	1782
12.0	2186
13.0	2635
14.0	3129
15.0	3671
16.0	4260

Lockyer Creek at Gatton

Gauge level (m)	Flow (m^3/s)
0 (87.54 mAHD)	0.0
0.6	5.1
1.0	11
1.5	21
2.0	33
2.5	46
3.0	61
3.5	78
4.0	98
4.5	123
5.0	148
5.5	176
6.0	205

Gauge level (m)	Flow (m^3/s)
6.5	236
7.0	269
7.5	304
8.0	344
8.5	416
9.0	488
9.5	593
10.0	698
10.5	820
11.0	942
11.5	1080
12.0	1219
12.5	1374
13.0	1529
13.5	1700
14.0	1871
14.5	2058
15.0	2245
15.5	2448
16.0	2651

Lockyer Creek at Gatton Weir

Gauge level (m)	Flow (m^3/s)
0 (87.68 mAHD)	0.0
0.5	0.2
1.0	2.2
1.5	6.5
2.0	14
2.5	25
3.0	39
3.5	58
4.0	81
4.5	108
5.0	140
5.5	176
6.0	218
6.5	264

Gauge level (m)	Flow (m^3/s)
7.0	317
7.5	374
8.0	437
8.5	506
9.0	580
9.5	661
10.0	748
10.5	841
11.0	940
11.5	1045
12.0	1157
12.5	1276
13.0	1401
13.5	1534
14.0	1672
14.5	1819
15.0	1972
15.5	2132
16.0	2299

Laidley Creek at Warrego Highway

Gauge level (m)	Flow (m^3/s)
0 (76.31 mAHD)	0.0
0.5	0.0
1.0	1.0
1.5	3.9
2.0	6.5
2.5	9.8
3.0	14
3.5	18
4.0	31
4.5	54
5.0	92
5.5	156
6.0	252
6.5	394
7.0	596

Gauge level (m)	Flow (m^3/s)
7.5	878
8.0	1262
8.2	1450

Lockyer Creek at Rifle Range Road

Gauge level (m)	Flow (m^3/s)
0 (44.435 mAHD)	0.0
0.5	0.0
1.0	1.7
1.5	3.6
2.0	7.3
2.5	11
3.0	17
3.5	23
4.0	30
4.5	37
5.0	46
5.5	55
6.0	65
6.5	76
7.0	87
7.5	99
8.0	111
8.5	125
9.0	139
9.5	159
10.0	179
10.5	210
11.0	247
11.5	289
12.0	336
12.5	387
13.0	443
13.5	506
14.0	575
14.5	650
15.0	730

Gauge level (m)	Flow (m^3/s)
15.5	866
16.0	~1200
17.0	~5000

Bremer River at Adams Bridge

Gauge level (m)	Flow (m^3/s)
0 (75.5 mAHD)	0.0
0.8	0.0
1.0	0.7
1.2	1.5
1.4	2.8
1.6	5.1
1.8	9.4
2.0	13
2.2	20
2.4	26
2.6	34
2.8	44
3.0	54
3.2	69
3.4	84
3.6	102
3.8	123
4.0	144
4.2	172
4.4	204
4.6	250
4.8	311
5.0	389
5.2	480
5.4	587
5.6	716
5.7	786

Bremer River at Rosewood

Gauge level (m)	Flow (m^3/s)
0 (32.83 m AHD)	0.0
1.0	0.3
1.5	1.7
2.0	4.7
2.5	10
3.0	20
3.5	36
4.0	58
4.2	70
4.4	82
4.6	115
4.8	151
5.0	211
5.2	271
5.4	345
5.6	436
5.8	546
6.0	688
6.2	824
6.4	951
6.6	1093
6.8	1250
7.0	1425
7.2	1618
7.4	1831
7.6	2066
7.8	2323
8.0	2604

Warrill Creek at Junction Weir

Upstream gauge level (m AHD)	Downstream gauge level (mAHD)	Flow (m^3/s)
74.92	70.22	0
75.49	72.75	25
75.74	73.49	39
75.82	73.98	50

Upstream gauge level (m AHD)	Downstream gauge level (mAHD)	Flow (m^3/s)
76.21	75.36	87
76.32	75.80	100
77.00	76.85	150
77.45	77.31	178
77.70	77.56	195
77.78	77.64	200
79.15	79.01	300
79.4	79.25	322
80	79.85	534
80.5	80.35	783
81	80.85	1117
81.5	81.35	1554

Purga Creek at Peak Crossing

Gauge level (m)	Flow (m^3/s)
0 (45.32 mAHD)	0.0
0.6	0.1
0.8	0.3
1.0	0.8
1.2	1.6
1.4	2.9
1.6	4.5
1.8	6.6
2.0	9.5
2.2	13
2.4	17
2.6	22
2.8	28
3.0	34
3.2	42
3.4	51
3.6	66
3.8	80
4.0	98
4.2	117
4.4	138

Gauge level (m)	Flow (m^3/s)
4.6	160
4.8	185
5.0	210
5.2	239
5.4	268
5.6	301
5.8	334
6.0	370

Brisbane River at Savages Crossing

Gauge level (m)	Flow (m^3/s)	*cS*
-0.5	0.0	0.00015
0.0 (18.481 mAHD)	1.0	0.00015
0.5	3.0	0.00015
1.0	7.5	0.00015
1.5	24	0.00015
2.0	48	0.00015
2.5	81	0.00015
3.0	120	0.00025
3.5	165	0.00033
4.0	216	0.00043
4.5	270	0.00049
5.0	338	0.00051
5.5	410	0.00058
6.0	502	0.00062
6.5	588	0.00061
7.0	682	0.00069
7.5	787	0.00074
8.0	888	0.00075
8.5	1017	0.00079
9.0	1155	0.00081
9.5	1307	0.00076
10.0	1458	0.00068
10.5	1609	0.00069
11.0	1787	0.00068
11.5	1955	0.00069
12.0	2160	0.00070

Gauge level (m)	Flow (m^3/s)	*cS*
12.5	2354	0.00067
13.0	2570	0.00068
13.5	2797	0.00063
14.0	3013	0.00063
14.5	3272	0.00062
15.0	3510	0.00060
16.0	4028	0.00055
17.0	4536	0.00051
18.0	5130	0.00051
19.0	5832	0.00049
20.0	6588	0.00048
21.0	7452	0.00049
22.0	8262	0.00048
23.0	9072	0.00048
24.0	9990	0.00045
25.0	11020	0.00046
26.0	12310	0.00046
27.0	13610	0.00048
28.0	15340	0.00047
29.0	17060	0.00046
30.0	19120	0.00048
31.0	21010	0.00047
32.0	23440	0.00047
33.0	25700	0.00045

Brisbane River at Moggill

Gauge level (m AHD)	Flow (m^3/s)		*cS*
	Tide=1.5m	Tide=-1m	
-1.0		0.0	0.00314
-0.5		364	0.00271
0.0		650	0.00228
0.5		924	0.00185
1.0		1170	0.00142
1.5	0.0	1350	0.00098
2.0	557	1560	0.00054
2.5	964	1773	0.00046
3.0	1304	1958	0.00042
3.5	1600	2125	0.00042
4.0	1877	2274	0.00041
4.5	2133	2413	0.00041
5.0	2386	2550	0.00042
5.5	2614	2701	0.00043
6.0	2820	2879	0.00044
6.5	3042	3051	0.00045
7.0	3259	3259	0.00046
7.5	3503		0.00045
8.0	3718		0.00043
8.5	3914		0.00041
9.0	4109		0.00039
9.5	4362		0.00037
10.0	4621		0.00038
10.5	4886		0.00035
11.0	5157		0.00032
11.5	5436		0.00032
12.0	5728		0.00032
12.5	6025		0.00029
13.0	6342		0.00029
13.5	6677		0.00029
14.0	7035		0.00028
14.5	7422		0.00027
15.0	7825		0.00025
15.5	8242		0.00027
16.0	8674		0.00026
16.5	9121		0.00028
17.0	9583		0.00026
17.5	10050		0.00026
18.0	10550		0.00026
18.5	10990		0.00026
19.0	11420		0.00024
19.5	11860		0.00023
20.0	12230		0.00024
20.5	12750		0.00023
21.0	13220		0.00024
21.5	13700		0.00019

Gauge level (m AHD)	Flow (m³/s)		cS
	Tide=1.5m	Tide=-1m	
22.0	14170		0.00021
22.5	14700		0.00020
23.0	15170		0.00021
23.5	15890		0.00021
24.0	16550		0.00022
24.5	17440		0.00019
25.0	18330		0.00019
26.0	20660		0.00022
27.0	23350		0.00023
28.0	26330		0.00023

Brisbane River at Brisbane City

Gauge level (m AHD)	Flow (m³/s)	
	Tide=1.5m	Tide=-1m
-1.0		0
-0.5		2120
0.0		3192
0.5		4036
1.0		4874
1.5	0	5709
2.0	3361	6542
2.5	5252	7374
3.0	6303	8208
3.5	7566	9045
4.0	8619	9887
4.5	9674	10735
5.0	10625	11591
5.5	11684	12220
6.0	12639	12953
6.5	13335	13546
7.0	13995	14118
7.5	14620	14823
8.0	15426	15364
8.5	15999	16056
9.0	16633	16746
9.5	17510	17627
10.0	18526	

Gauge level (m AHD)	Flow (m³/s)	
	Tide=1.5m	Tide=-1m
10.5	19445	
11.0	20385	
11.5	21348	
12.0	22333	

Appendix D
Review of historical reports

Reading list – QFCOI Exhibit 883: Common expert reading list – A

Tab	Report	Date
Key historical flood studies and reports		
1	*Review of Brisbane River Flood Study: Report to Brisbane City Council*. Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann)	3 September 2003
2	*City Design – Flood Modelling Services: Recalibration of the Mike11 Hydraulic Model and Determination of the 1 in 100 AEP Flood Levels (Final Report)*. Sinclair Knight Merz	5 February 2004
3	*Joint Flood Taskforce Report.* Brisbane City Council	March 2011
4	*Brisbane River Flood Study: Further Investigations of Hydrology & Hydraulics Incorporating Dam Operations and CRC Forge Rainfall Estimates (Draft)*. Sinclair Knight Merz	29 August 2003
5	*Flood Frequency Analysis for Brisbane River Catchment Summary Report: Flood Frequency Analysis of Brisbane River (Draft)*. Sinclair Knight Merz	8 August 2003
6	*Brisbane River Flood Study: Further Investigation of Flood Frequency Analysis Incorporation Dam Operations and CRC Forge rainfall estimates – Brisbane River (Final)*. Sinclair Knight Merz	18 December 2003
Concurrent evidence reports		
7	*Brisbane River 2011 Flood Event – Flood Frequency Analysis.* WMAwater (Mark Babister)	18 September 2011
8	*Review of Brisbane River 2011 Flood Frequency Analysis.* University of Adelaide (Dr Michael Leonard)	26 September 2011
9	*Brisbane River 2011 Flood Event – Flood Frequency Analysis: Review of Report by WMAwater.* Sinclair Knight Merz (Dr Rory Nathan)	28 September 2011
10	*Response to Peer Reviews of WMAwater's Brisbane River 2011 Flood Event – Flood Frequency Analysis (Sept 2011)*. WMAwater (Mark Babister & Monique Retallick)	7 October 2011
11	*Review of Aspects of the Report of WMAwater Report.* Bewsher Consulting (Drew Bewsher, Director)	14 October 2011
12	*Provision of expert advice in relation to a report provided by WMAwater.* Uniquest (Professor Colin Apelt)	13 October 2011
13	*Expert Comments on Final Report by WMAwater*. RJ Keller & Associates (Erwin Weinmann)	October 2011
14	*Technical Review of Flood Frequency Analysis Report.* BMT WBM (Neil Ian Collins)	14 October 2011
15	*Review of WMAwater Report.* WRM Water and Environment (Dr Sharmil Markar)	14 October 2011
16	*Memorandum to QFCI re Comment on Selected Issues Raised by WMAwater.* Sinclair Knight Merz (Rory Nathan)	21 October 2011
Other		
17	*Letter re additional comments on Flood Frequency Analysis.* Seqwater	19 October 2011
18	*Third Statement of Terence Alwyn Malone.* Seqwater	20 October 2011
19	*Wivenhoe Dam and Somerset Dam Optimisation Study (Draft)*. Sinclair Knight Merz	19 September 2011
20	*Fourth Statement of T Malone*	24 October 2011

Report summaries

Tab 1: Review of Brisbane River Flood Study, Independent Review Panel, 3 Sept 2003

- Expert Panel of Russell Mein, Colin Apelt, John McIntosh and Erwin Weinmann commissioned to review SKM's Q100 estimates from Aug 2000
- Paper discusses design flood estimation aims and best practice methodology
- Paper also discusses particular issues surrounding Brisbane River catchment, including: size of catchment and the resultant variability in rainfall; catchment characteristics and the variation in these with time; the influence of the dams; and tidal and storm surge effects
- Panel found that SKM's technical processes were appropriate
- Panel considers that SKM's FFA at Savages Crossing of no-dams Q100 = 12,000 m^3/s (± 2000) is appropriate
- Panel recognises that City Design has also done FFA which is not as rigorous as SKM's FFA, for which Q100 = 10,800 m^3/s at Savages Crossing
- Panel considers that SKM's RAFTS model Q100 of 10,000 m^3/s is low by 10-20%
- SKM's with-dams FFA is based on DNRM estimates of with-dam flows for 1890-2000. Generalised Pareto and LPIII do not fit well, therefore no FFA estimate was suitable
- SKM used RAFTS model to estimate post-dams Q100 of 5,400 $m^3.s$ at Savages Crossing. Panel considers that, given no-dam RAFTS is low, post-dam RAFTS will also be low by a similar magnitude
- Panel considers that Savages Crossing peak discharges are of a similar order to those at downstream locations
- Panel recommended that best estimate of Q100 (post dams) at Port Office Gauge is 6000 m^3/s which corresponds to RL 3.3 m AHD
- Panel recommended that plausible range of flow estimates is 5000-7000 m^3/s (2.8-3.8 m AHD)
- Panel acknowledged that extrapolation of rating curves provides significant uncertainty
- Panel recommended that Monte Carlo analysis is warranted
- Panel recommended that further investigation of the differences between FFA and RAFTS be undertaken

Report also has an appendix titled "Brisbane River Flood Study Chronology of Events" which is reproduced as follows:

1984 Reports for Brisbane City Council and Water Resources Commission. Q100 river flow set at 6,800 m^3/s (or cubic metres per second). This flow was used as the basis for flood levels for development control level

1993 DNR study undertaken for the (now) South East Queensland Water Corporation to examine operating rules for the dam. The study determined that Q100 flow was 9,380 m^3/s. The report recommended that further work be undertaken to determine areal reduction factors. DNR consider this flow volume was seen as an overestimation as it was not specifically produced for the Q100 event in Brisbane. This prompted Council to re-examine flood levels in the river and led to commissioning the SKM report, which commenced in November 1996

1998 Model developed and draft SKM report received by Council, proposing Q100 flow of 9,560 m^3/s

1998 Report and results reviewed by Council officers who determined that this flow was based on assumptions that equated to a lower probability of flooding than the Q100. This resulted in Council commissioning Professor Russell Mein, eminent hydrologist, to undertake an independent review of the work to date

1998 December, received Professor Mein's review of the draft SKM report. This review stated: "The overall approach for the hydrologic component of the study … is appropriate. However … conservative assumptions in key input variables point to the likelihood that the magnitude of the Q100 obtained in this Study is an over-estimate". Professor Mein made six recommendations for work needed to address the issues of concern

1999 June, draft review by City Design. Note that this revised downwards the Q100 flow to 8,600 m^3/s as a result of the additional analysis – a reduction of 10% on the SKM report (this draft report did not fully address Professor Mein's review recommendations). This is the report referred to by the Courier Mail in its stories on flooding which appeared in the newspaper form 24 June 2003 to 5 July 2003

2000 January to September, review of all these reports, discussions with external stakeholders, including South East Queensland Water Corporation, Department of Natural Resources, Bureau of Meteorology. Council continued to review the draft June and December reports as the peer review recommendations had not been fully addressed

2000 October, Brisbane River Flood Study Technical Workshop held. Purpose – to ensure that the definitive flood study report would be technically rigorous and adopt an approach/methodology that is consistent with the current practices, using the latest available information. Participants included Professor Mein, BCC Waterways and City Design, Department of Natural Resources, Bureau of Meteorology, South East Queensland Water Corporation, Institution of Engineers National Committee on Water Engineering and Ipswich City Council

Since 2000 Council has been in contact with DNRM every few months to check on the progress of the report. Officers of DNRM have consistently reassured us as to the probability of the Q100 flow figure being close to, or at the level of the 1984 Q100 figure.

Council has been taking other actions as well, for example, raising community awareness of flooding issues with tools such:

- Council's flood information system which predicts flood levels in the river during major flood events
- Upgraded system which will automate and improve the accuracy of Q100 on individual properties
- Fact sheets and articles in publications and information on Council's website

On 27 June 2003 BCC received preliminary advice from DNRM that the Q100 flood flows at the Brisbane Port Office would be between 6,000 and 7,000 m^3/s. This affirmed that the preliminary estimate from early reports was likely to be an over-estimate. This is consistent with their advice from the October 2000 workshop and from contact with DNRM since then.

Tab2: Recalibration of MIKE 11 Model, SKM (for City Design), 5 Feb 2004

- RAFTS and MIKE 11 models were originally developed for BCC in 1998. Models were then used for Ipswich Rivers Flood Study (IRFS) [SKM 2000] and additional rivers and creeks were added to M11 and sub-catchment definition to RAFTS. Recalibration was undertaken within the ICC boundary. In this study the models were recalibrated within the BCC boundary
- 1974 event calibration was not changed from IRFS and generally good agreement was reached
- 1974 discharge at Port Office gauge was predicted to be 9979 m^3/s
- 1955 event calibration generally matched peaks but timing of predicted flows was earlier than recorded, especially at Savages Crossing. Port Office gauge did not match but problems with the recorded data were expected due to inconsistencies with other gauges
- 1955 discharge at Port Office gauge was predicted to be 4364 m^3/s
- For design event analysis, RAFTS flows were scaled up to produce a peak discharge of 6000 m^3/s at the Port Office Gauge

Tab 3: Joint Flood Taskforce Report, BCC, March 2011

- Joint Flood Taskforce was appointed to answer the following questions:
  - How does Jan2011 event compare to pre-event Q100 and BCC DFE?
  - Does pre-event Q100 remain the best estimate of this event?
  - What standard should be used for new development and redevelopment?
- JFTF found that Jan 2011 was larger than the pre-defined Q100
- JFTF recommended that Q100 needs to be reviewed
- JFTF recommended interim development standards be set based on actual Jan 2011 event levels
- Limitations are:
  - Only considers BCC area
  - Doesn’t consider creek flooding, storm surge or climate change
  - Report timeframe was only one month, therefore analysis has been limited
  - Does not consider operation of Wivenhoe Dam

Tab 4: Further Investigations of H&H Incorporating Dam Ops and CRC Forge Rainfall Estimates (Draft), SKM, 29 August 2003

- CRC Forge rainfall depth estimates (incl ARFs) were applied to the IRFS RAFTS model
- A series of spatial patterns was analysed
- IL of 10mm and CL of 1mm/h were used
- RAFTS median no-dams flow at Savages Crossing was 10,000m^3/s
- FFA at Savages Crossing was 12,000 m^3/s
- RAFTS and FFA estimates could not be reconciled unless ARFs were increased or spatial/temporal patterns were combined
- For the with-dams case DNRM predicted the dam outflow hydrograph using CRC Forge rainfall depths, various spatial patterns and standard AR&R temporal patterns and this was used as an inflow to the RAFTS model
- The median RAFTS with-dams flow at Savages Crossing was 6,200 m^3/s

- A sensitivity test of the starting water level in the dam showed that a 13% reduction in peak flows at Port Office Gauge is obtained for a 75% full starting condition in the dam
- MIKE 11 was used to route the flows from Savages Crossing to the Port Office gauge and best estimate of peak flows at the Port Office Gauge was 6,500 m^3/s
- Peak flow estimates of with-dam 1893 and 1974 events were 9,500 and 6,800 m^3/s respectively
- Reasons for the reduction in peak flows from the 1998 study were: use of CRC Forge with ARFs; better representation of Dam Ops; and more reliable streamflow data

Tab 5: FFA of Brisbane River Catchment – Summary Report, SKM, 8 August 2003

- FFA of Savages Crossing was undertaken for the no-dams case using at-site and regional FFA approaches
- 4 cases were assessed, with a range of data subsets assessed under each case. The cases were: Pre-Wivenhoe and Somerset; Pre-Wivenhoe with no adjustments made for Somerset; "No dams" based on NRM adjusted estimates; and "Dams" based on NRM adjusted estimates
- The best estimate of no-dams Q100 at Savages Crossing is 12,000 m^3/s
- Uncertainty in the estimate comes from:
  - Maximum gauged flow being 35-40% of the 1974 peak flow
  - Scarcity of information on the magnitude of the 1893 event – this event has a significant impact on the Q100
  - Choice of distribution and appropriate parameters
  - Adjustment of the data for dam effects
- The RAFTS model was run with no losses and the Q100 at Savages Crossing was estimated to be 11,400 m^3/s, which inclusion of losses would more realistically reduce to 10,500 m^3/s
- No specific with-dams estimates were made

Tab 6: Further Investigations of FFA Incorporating Dam Ops and CRC Forge Rainfall Estimates (Final), SKM, 18 December 2003

- This is a combined report incorporating both the Tab 4 and Tab 5 reports.
- Recommendations are similar to the Tab 4 and Tab 5 reports
  - No-dams Q100 FFA at Savages Crossing was 12,000 m^3/s, with range of 10,000-14,000 m^3/s
  - No-dams Q100 RAFTS model at Savages Crossing was 10,000 m^3/s with range of 8,000-11,500 m^3/s
  - Estimated with-dams Q100 at Port Office gauge is 6,500 m^3/s

Tab 7: 2011 Flood Event FFA, WMAwater, Mark Babister, 18 September 2011

- FFA was undertaken to determine 1% AEP flood levels for up to 8 key locations on the Lower Brisbane and Bremer Rivers, including a review of SKM's previous work
- The above was repeated including the 2011 event data
- The magnitude of the 2011 event was assessed
- Identified 11 locations of interest were (estimates based on adjusted Mike 11 model to match observed data from 2011 Joint Taskforce [2011], using peak post dam flow of 9,500 m^3/s):

Location of interest to The Commission	Estimated 1% AEP Peak Flood Level (mAHD)*	Appr Jan 2011 Peak Flood Level (mAHD)
13 Bridge St, Redbank	16.81	17.21
Cnr Ryan & Woogaroo St, Goodna	15.96	16.37
Cnr Moggill & Birkin Rds, Bellbowrie	14.63	15.04
Cnr Thiesfield St & Sandringham Pl, Fig Tree Pocket	10.86	11.22
312 Long St East, Graceville	9.76	10.10
Brisbane Markets, Rocklea	9.51	9.84
Softstone St, Tennyson	9.58	9.90
15 Cansdale St, Yeronga	8.58	8.85
42 Ferry Rd, West End	6.55	6.75
81 Baroona Rd, Paddington	5.77	5.95
Brisbane City Gauge	4.32	4.46

** Sensitivity testing using the flow estimates from the 1841-2010 data set found that the 1% AEP (Q100) height estimate at Moggill and the Port Office would reduce by appr 0.5 m and 0.2 m respectively.*

- 13 Bridge St, Redbank
- Cnr Ryan & Woogaroo St, Goodna
- Cnr Moggill & Birkin Rds, Bellbowrie
- Cnr Thiesfield St & Sandringham Pl, Fig Tree Pocket
- 312 Long St East, Graceville
- Brisbane Markets, Rocklea
- Softstone St, Tennyson
- 15 Cansdale St, Yeronga
- 42 Ferry Rd, West End
- 81 Baroona Rd, Paddington
- Brisbane City Gauge

- Background discussion on design event flood level determination is provided:
  - While several floods occurred in 2010-2011 water year (in this report is defined from July to June), only the January flood (largest) would be considered in an annual series
  - A Bayesian maximum likelihood approach has been adopted
  - Flike FFA software developed by Kuczera was used
- Brisbane River flood history is provided
  - 1841, 1844 and 1825 were significant events. 1824, 1836 and 1893 were also mentioned in historical records, but are less significant, and there is not enough detailed evidence available
  - The effects of development on flood behaviour are not quantified in this study
  - The 1999 BRFS accounted for effects of dredging by adjusting flood heights for the initial bar dredging (reduced flood levels by 0.4 m) and the major dredging works completed in 1912 (reduced flood levels by 1.52 m). A table with key dredging dates is given

- Tab 39 investigated the impact of different dam levels on the Q100 discharge hydrographs at Port Office using a MIKE 11 model
- Three sets of bathymetric data have been used in different studies:
  - 1873: detailed survey from Victoria Bridge to Moreton Bay
  - Following 1974 flood: survey by Dept. Harbours and Marine
  - “newer” data used in SKM and BCC studies
- A brief description and a table summarising Q100 peak flow estimates at the Port Office Gauge from different studies is provided:

Report/Study Date	Q100 Peak Flow (m3/s)	Q100 Peak Level (m AHD)
Nov 1984	5510	-
1984	6800	3.3
Jan 1985	6800	-
Mar 1993	8580	-
Aug 1993	9120/9380	-
June 1998	9560	5.34
June 1999	8600	5.00
Dec 1999	8000	4.70
Sept 2003	6000 ± 1000	3.3 ±0.5
Dec 2003	6500 ± 1500	3.51 (2.76-4.41)
Feb 2004	6000	3.16
Mar 2011	-	4.46 (City) / 4.27 (Port Office)

- In many reports reviewed few details are given in regard to the rating curve used to convert historical stage observations (at Port Office) into associated peak discharges. Although sufficient details of the rating curves are not provided, various reports suggest that they have been provided by BoM, BCC, or developed based on modelling
- SMEC [1975] indicated that significant gauging of discharge had been carried out for events 1931, 1951, 1955 and 1968, although none of the original information relating to these gaugings had been found in any of the available reports
- SKM [1998], BCC [1999] and Mein et al [2003] show that in large floods the peak at Moggil, Jindalee and Port Office tend to remain appr constant. SKM [24 June 2011] found peak flow of ~ 9,600 m^3/s of the Jan 2001 event at Jindalee and assumed the same flow at Port Office
- City Design [June 1999] presents 5 estimates of flow ranging from 11,300 to 16,990 m^3/s for the 1983 event. WMA tested the impact of dredging with SKM’s Mike 11 model and found the same range. City Design [Dec 1999] estimated the peak flow at 11,6000 m3/s based on cross sections from 1873
- Plausible range of peak flows for 1975 are 9,800 to 10,900 m^3/s and peak heights of 5.45 mAHD (at Jindalee). WMA uses a flow of 9,600 m^3/s for the 2011 event with peak height range of 4.27 to 4.46 mAHD
- A rating curve was derived at the Port Office Gauge from the above mentioned studies, with lower end of the curve based on an average of the curves established in the 1998 and 1999 Flood Studies

- Extensive FFA were undertaken in 1985 [Weeks], 1993 {DNR], 1998/1999 [SKM and 2003 [SKM]
- Includes description of long record gauges: Port Office, Savages Crossing, Moggill and Mt Crosby Weir

Event	Recorded Level (as measured during the event)	Adjusted Level*	Pre Dam Current Conditions		Ranking (annual series)	Plotting position**	ARI
	(mAHD)	(mAHD)	Heights (mAHD)	Flow (m3/s)		(AEP) %	(1/PP)
1893 a	8.35	6.83	6.83	13,700	1	0.35	285
1893 b	8.09	6.57	6.57	12,600	-	-	-
1841	8.43	6.51	6.51	12,500	2	0.94	107
2011	4.27	4.27	6.40	12,400	3	1.52	66
1974	5.45	5.45	5.50	11,300	4	2.10	48
1844	7.03	5.11	5.11	10,400	5	2.69	37
1890	5.33	3.81	3.81	8,100	6	3.27	31
1898	5.02	3.50	3.50	7,500	7	3.86	26

** Includes 1.52 m prior to 1971 and an additional 0.4 m adjustment for prior to 1864*
*** The Cunnane formula was used to determine the plotting position*

Data set / case	Q100 (m^3/s)	
	GEV	LP3
1841-2011*	12,130	13,730
1841-2010*	11,740	13,900
1908-2011**	10,740	16,610
1908-2010**	9,510	13,900

** 141 censored flows lower than 2,000 m3/s (30 gauged floods)*
*** 90 censored flows lower than 2,000 m3/s (only 14 floods above 2,000 m3/s)*

- Design flows from FFA are given. A 1% AEP estimate of 13,000 m^3/s was adopted for the pre-dam case, and 9,500 m^3/s for post dam → 2011 event = 0.83% AEP (120 yr ARI) under current conditions, and 1% AEP (100 yr ARI) under pre-dam conditions
- Examination of misclose between flood frequency and rainfall estimates is given
- The current Q100 flood line used by BCC is significantly below the revised 1% AEP flood line calculated by this study, with a difference ranging from appr 3 m at Moggill to appr 1m at Port Office

Combined Tab 8, 9, 10 and 16

8. Review of Brisbane River 2011 FFA – University of Adelaide, Dr M. Leonard, 26 Sept 2011

9. Review of Brisbane River 2011 FFA – SKM, R. Nathan, 28 Sept 2011

10. Response to above two Peer Reviews – WMAwater, M. Babister & M. Retallick, 7 Oct 2011

16. Memorandum to QFCoI re Comment on Selected Issues Raised by WMAwater, SKM (Rory Nathan, 21 Oct 2011

- Both reviewers have in broad terms endorsed the:
  - methodology used to develop the high flow rating curve
  - approach used in the flood frequency analysis, and
  - pre dam Q100 estimate of 13,000 m^3/s (noting the uncertainty about the estimate)
- Dr Nathan has rejected the approach used to convert pre-dam flows to post-dam flows and hence the post-dam flood levels
- Dr Nathan has presented some additional observed debris marks for the 2011 event (Figure 3) that in some locations contradict the flood levels presented in the Joint Task Force 2011 report. WMA states*: "The data points used by Dr Nathan were not made available to WMAwater and no source is included in Dr Nathan's review. As a result further assessment was not possible as the data points have not been tabulated. However, if these data points prove to be more reliable than the Joint Task Force March 2011 levels then these data points would suggest that the calibration of the Mike 11 model was not as poor as originally thought. Figure 3 would suggest that within 10km up and downstream of Jindalee the Mike 11 model fits the observed data reasonably well. There are still some issues with the calibration between Oxley Creek and the Port Office"*
- Dr Nathan has raised questions, based on the debris marks, about the design flood profiles presented in our report
- Dr Leonard believes we have used implicit knowledge of the 2011 event to determine the post dam estimate. WMA says the estimates are still valid without being aware of this event
- Dr Leonard (Reference 10) has wrongly interpreted that WMAwater calibrated the Mike 11 model to fit the 2011 Joint Taskforce data (Reference 15) and used this revised model to determine the 1% AEP levels
- Both reviewers recommend the use of Monte Carlo (stochastic) analysis (as did WMAwater in their May 2011 report)
- Issues to the data and models used by SKM [2003] that have been documented by others:
  - Rainfall: Sargent [2006] found that the CRC Forge rainfall had been incorrectly input into the RAFTS model for the 24, 30, 36 and 48h durations. Also, he found that the input rainfalls were less than those applied in the CRC Forge spreadsheet. In SKM's Memorandum (Tab 16), Nathan explains the differences between the Sargent [2006] and SKM [2004] RAFST-XP model. Nathan gives differences in 30h flood estimates obtained by using the RAFTS-XP model for 22 locations
  - RAFTS modelling: Sargent [2006] found that the model has been set up in a very unorthodox way; this is disputed again by SKM in the Memorandum (Tab 16)
  - Hydraulic modelling: KBR [2002] found that the use of the resistance radius method in the Mike11 model developed by SKM was having major effects on the models behaviour for events that were not a similar order of magnitude to the calibration event. Similar to WMAwater [2001] findings. This is discussed/disputed again by SKM in the Memorandum (Tab 16)
- In its response, WMAwater addresses the issues raised by the two reviewers:
  - Dr. Nathan: "*It is not clear why WMAwater did not critically review the extensive flood frequency analysis undertaken by SKM (2003)"*

- Dr. Nathan: *"Why was the 1999 December City Design (Reference 4) Q100 estimate not included in the list of similar estimates?"*
- Footnote 2 of Dr Nathan's review (Reference 11) suggests the flood level data used in Appendix B of our report was incorrectly attributed to SKM and should be City Design June 1999
- Dr Nathan raised several questions about the assumptions behind some of the data used in the FFA

Tab 11: Review of aspects of the WMAwater Report, Bewsher Consulting, 14 Oct 2011

- WMAwater used a flood frequency approach to estimate pre-dam flow frequencies. This approach was used earlier by others (eg BCC, June 1999) which had been rejected by others due to uncertainties in available data that were not addressed by WMAwater:
  - No records before 1875 (or 1878) when Port Office was installed
  - WMAwater used 30 flood peak (excluding 1841, 1844 and 1845-Rank 6 flood according the BCC [June 1999]) but don't state which ones, only the largest ones. They might have used the same peaks as BCC [June 1999]
  - Brewsher mentions the Brisbane Notice Board from 1911, with good historical info: http://www.bom.gov.au/hydro/flood/qld/fld_history/brisbane_notice_board.shtml
- Brewsher believes that the 1% AEP level will be higher, but at other levels as estimated by WMAwater
- There are significant uncertainties (most acknowledged by WMAwater) associated with the preparation of the discharge estimates, which would impact directly on the 1% AEP discharge
- Would have been good practice to test the sensitivity of the 1% AEP discharge estimate to potential changes in the discharge used to prepare the FFA
- The 90% confidence limits for the derived 1% AEP discharges are already moderate (ie 10,000-22,000 m3/s), so will be higher than quoted
- Issues related to dredging adjustments (1.92 m prior to 1864; 1.52 between 1864-1917):
  - The following document provides a more complete description of the river changes (more than suggested two major ones) particularly over the 20th Century: http://www.marine.uq.edu.au/marbot/publications/CRC%20coastal%202003_HC%20report/Ch%209%20Appendices.pdf
  - Important changes in dredging and river bed are:
    - 1841 flood
    - Relocation of port to Fisherman's Island in the mid-late 70s → reduction in maintenance dredging upstream (from new port to the city), with likely aggradation of river beds since that time
  - Height adjustments assumed by BCC and used by WMAwater are tenuous and based on very old information of doubtful accuracy. The methodology of WMAwater's test of the 1.52 m adjustment estimate with MIKE11 is not given, and thus not testable
- Methodology of preparation of pre- to post-dam estimation line is not explained. Brewsher gives the limitations of the graph in this report
- Brewsher refers to Figure 2 of Cossins [1978]; a recorded stage hydrograph at Port Office during 1974 flood, including tidal and storm surge influence: *For example, when the flood height is say 1.5mAHD, at least ±0.5m or more could be due to normal tidal activity. Bigger ranges would likely occur if storm surges were present (as these often accompany floods) or spring tides. This tidal*

influence diminishes as the flood height rises but even at a flood level of 4mAHD, some tidal influence can be exerted

- Brewsher questions the shift in the upper section of the Port Office rating curve to the right. There are six data items included in WMAwater's Figure 8 (Port Office rating) which are discussed below. (The first two are listed under Item a):
  - SKM (June 1998) and SKM (June 1998) – these appear to be based on recorded levels from historical floods with flows estimated from the MIKE11 models used in those studies – but I can't be sure
  - SKM (2011) − appears to be obtained directly from the MIKE11 model, noting that this model was calibrated to the 2011 flood records
  - 1893 Event − the orange box on Figure 8 is based on flood heights ranging from 8.35 mAHD to 6.83 mAHD.12 The discharge range is 11,300 m^3/s to 16,900 m^3/s.13 As discussed in the footnotes, the most likely estimate of the 1893 event is 6.83 mAHD and 11,600 m^3/s – so the orange box should be centred on this point (which approximates the lower left hand corner of the existing box)
  - 1974 Event – 5.45 mAHD was the recorded height for this event. WMAwater states that previously the discharge was thought to be 9,800 m^3/s but this has been revised upwards to 10,900 m^3/s based on information learnt during the 2011 event
  - 2011 Event – due to time limitations I have not had time to check these values

Tab 12: Provision of expert advice in relation to the report provided by WMAwater, Uniquest (Prof. Colin Apelt), 13 Oct 2011

- In briefing material from City Design to the Independent Review Panel in 2003: “It is suggested that small floods reduced by 1.52 m but little effect on large floods”. WMAwater assumed a reduction of 1.52 for all floods
- BoM provided a chart relating Moggill Alert to Brisbane City Alert “to show that the adjustment of pre-dredging levels should only be by 0.6 m rather than 1.8 m assumed in the December 1999 review”
- The Independent Review Panel accepted the decision by Sinclair Knight Merz (SKM) to use the combined record from the gauges at Savages Crossing, Lowood and Vernor, referred to as “Savages Crossing” as the key site for FFA
- In an email to Ken Morris of Brisbane City Council dated 12 August 2003, Peter Baddiley of BoM provided a rating curve for Port Office/City Gauge that is linear
- Apelt suggests that the GEV estimates should be preferred, not averaged with LP3 estimates. If the estimate for Q100 is based on GEV alone it becomes 12,130 m^3/s
- Seqwater [March 2011]:
  - The first peak inflow was **10095 m^3/s** at 08:00 on 10 January. At that time the outflow was 1944 m^3/s; it increased slowly to 2087 m^3/s at 15:00; then more rapidly to 2695 m^3/s at 20:00; then slowly to 2753 m^3/s at 08:00 on 11 January; it then increased rapidly to 7464 m^3/s as the second peak inflow arrived
  - The minimum inflow between the peaks was 3594 m^3/s at 02:00 on 11 January At that time the outflow was **2721 m^3/s**, the dam level was 73.35 m AHD and the storage was 1,977,862 ML or 169.8% of FSV. The storage at FSL of 67.00 m AHD is 1,165,000 ML
  - From all of this one could argue that the attenuation of the first peak was 73.1%, corresponding to the peak outflow being 26.9% of peak inflow ie **2721/10095**. Even if one uses the initial

objective of limiting outflow to 4000 m^3/s the attenuation would have been 60%, corresponding to the peak outflow being 40% of peak inflow

  - The second peak inflow was **11561 m^3/s** at 13:00 on 11 January. The peak outflow rose to **7464 m^3/s** by 19:00 on the 11th. This gives an attenuation of 35.4%, corresponding to peak outflow being 64.6% of peak inflow. (WMA has 32-35%). But the dam was at 170% of FSV at the start of this second peak inflow

- The 2003 Review Panel made no recommendation for a 50% reduction, nor did it adopt it. It noted that for the period 1890 to 2000 the DNRM model simulation of dam operations had indicated that it should be possible to operate the dams to reduce peak flood flow rates by about 60% on average and that it indicated a January 1974 flood attenuation of nearly 50%. [Mein et al, 2003 – p15]. The panel did not have access to the DNRM model and it recommended that it should be peer reviewed [Mein et al, 2003 – p23]

Tab 13: Expert comments on Final Report by WMAwater, RJ Keller & Associates (Erwin Weinmann), Oct 2011

- Other floods reported for the period between 1824 and 1839 (including the 1825 referred to in the SKM 2003 report) have not been included in the analysis as they were judged to be either not significant or not reliably documented
- Weinmann compares annual pre-dam peakflow estimates from WMAwater 2011 (Port Office) and SKM 2003 (Savages Crossing, including simulated peak flows for the events that occurred after construction of the two Dams). He advises that it would be highly desirable for any future detailed flood study to use the available flood data from all four sites (Port Office, Lowood/Savages Crossing, Moggill, Mt Crosby Weir) in accordance with their special merits and limitations
- Weinmann questions the conversion of pre-dam design peak flows to post-dam peakflow
- Weinmann states that the peak flow estimate of 9500 m^3/s cannot be considered to represent a ‘best estimate’ of the 1% AEP peak flow for the lower Brisbane River under post-dam conditions. It will be necessary to use the combined results of a range of estimation methods (include rainfall based design flood simulation for the pre- and postdam conditions) based on all the relevant sources of flood data

Tab 14: Technical Review of FFA Report, BMT WBM (Neil Ian Collins) for ICC, 14 Oct 2011 (and supplementary report, September 2011)

- Advice from ICC as opposed to the estimates from the WMAwater [2011] Report (see also attachment of BMT WBM [2011] with extracts of ICC’s flood maps that supplement this data):

Event	13 Bridge Street, Redbank		20 Woogaroo Street (cnr Ryan St & Woogaroo St), Goodna	
	ICC Flood Level (mAHD)	WMA Water * Plotted flood level (mAHD)	ICC Flood Level (mAHD)	WMA Water * Plotted flood level (mAHD)
1% AEP	15.33	14	14.78	13.2
Recorded 2011 peak flood level	16.8	17.55	16.92	16.85
1974 flood level	19.22	-	17.67	-

- The specific issues for Ipswich City, which are considered in this Review, are as follows:
  1. Timing of dam releases as it may affect flooding in Ipswich and Bremer River flooding
  2. How satisfactory is the calibration of the models are for Lockyer Creek and the Bremer River and therefore how reliable are the predictions in the WMA report for Ipswich City
  3. The benefits or disadvantages of alternative dam operating strategies for Ipswich, such as avoiding coincident Wivenhoe Dam release peaks with Bremer River peaks in Ipswich
  4. Why the release strategies for Wivenhoe Dam were not adjusted when assessing the 75% full supply level strategy and what effect such an adjustment would have had on flooding in Ipswich and Bremer River flooding

Tab 15: Review of WMAwater Report, WMA Water and Environment (Sharmil Markar), 14 Oct 2011

- It appears that the flood events greater than 2,000 m^3/s have been classified as large and the remainder as small for the purposes of the FFA. The basis/justification for the selection of this threshold value is not known. Given that tidal influences affect flood levels for much higher discharges the adoption of a 2,000 m^3/s threshold appears unjustified
- The adopted flood threshold has resulted in 141 out of 171 values. (82.5%) and 90 out of 102 values (88%) being 'censored' for the 171 year (1841-2011) and 102 year (1908-2011) data sets respectively. It is not clear what 'censored' means but it appears that these values have been omitted from the analysis. The recorded discharges at the upstream gauges should have been used to derive a discharge data set at the Port Office
- The February 1999 flood upstream of Wivenhoe and Somerset dams was larger than the 1974 flood (Seqwater, 2011). Based on data presented in Appendix B of the WMAwater report, it appears that the 1999 flood is not appropriately taken into account in the pre dams FFA

Tab 17: Letter re additional comments on FFA – Seqwater, Allens Arthur Robinson, 19 Oct 2011

- Appendix A = Table of the floods which should be included in the data series; including Somerset and Wivenhoe peak outflows, recorded peaks at Moggill, Jindalee Br and Port Office and required adjustments to gauges
- The letter states that an incorrect assumption that Somerset Dam does not provide significant mitigation of floods emanating from the Stanley River. A figure shows the relationship between peak inflow and outflow at Somerset Dam since it was constructed. In all significant events, prior to and after construction of Wivenhoe Dam, the peak outflow from Somerset is significantly lower than the peak in the inflow. The 1974 flood peak could have been 0.9 m higher at Port Office
- The Port Office rating of WMAwater [2011] is concave – contrary to most ratings – which leads to an underestimation of flow (figure with comparison is given)

Tab 18 & 20: Third & Fourth Statement of Terence Alwyn Malone, Seqwater, In the matter of QFCoI, 20 & 24 Oct 2011

- This statement addresses the matter raised by WMAwater [2011] that there may have been mechanical failure with Seqwater's City Gauge during the 2011 flood event. The statement gives differences between Brisbane Port Office gauge (143919) operated by MSQ and Seqwater/BoM's Brisbane ALERT gauge (143838)

- There is an apparent difference of 190 mm between the peak water levels at the Port Office gauge and the ALERT gauge. My opinion is that the ALERT gauge readings were accurate during the 2011 flood event:
  - No mechanical failure of ALERT gauge
  - Manual readings confirm automatic readings
  - No wave setup or turbulence in area of ALERT gauge
  - No manual readings of Port Office gauge available
  - BCC survey data suggests Port Office gauge reading too low
  - Superelevation and Slope unlikely to be a reason for the difference
  - Port Office gauge may be affected by high velocity flows
- For these reasons, Seqwater has adopted the ALERT gauge reading of 4.46 m AHD as the peak of the 2011 flood event at Port Office
- Fourth Statement: MSQ explained in an email (20-10-2011) that, both before and after the 2011 flood event, there were discrepancies between the automated readings from the Port Office Gauge and the manual readings from the associated MSQ staff gauge. In each case the Port Office gauge recorded a lower water level than the water level shown on the associated manual gauge. (The Brisbane Port Office (and the tide board) is on Low Water Datum; the only gauge in QLD that is on LWD)

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