Brisbane River Catchment Flood Studies – Hydrology Phase

Flood Frequency Analysis Report

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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 Project overview

The Brisbane River Catchment Flood Study (BRCFS) – hydrology project requires a comprehensive hydrologic assessment to be conducted of the Brisbane River Catchment in accordance with Recommendation 2.2 of the Final Report of the Queensland Floods Commission of Inquiry. The project parties are Aurecon, the overall study client, Department of State Development, Infrastructure and Planning, with the Department of Natural Resources and Mines being the nominated Project Manager for this phase of the study. Aurecon will be assisted in the delivery of this project by sub-consultants:

- Royal Haskoning-DHV
- Deltares
- Don Carroll Project Management Pty Ltd

1.2 Project objectives

The main objective of the BRCFS-hydrology project is to develop and apply up-to-date, consistent, and robust hydrologic models and analytical techniques for comprehensive hydrologic assessment within the study area to provide best estimates of the (design) flood flows corresponding to a range of Annual Exceedance Probabilities (AEPs), from 50% AEP to the Probable Maximum Flood (PMF) event across various sections of the entire Brisbane River system. The outputs of the project, including estimated flood flows and volumes, will be used in subsequent hydraulic modelling studies to determine flood levels, extent, velocity data and associated flood maps for the purpose of floodplain planning and risk management purposes.

The design flood flows will be derived through application of three different methods:

1. Standard flood frequency analysis, in which a statistical distribution function is derived directly from observed water levels and flows
2. Design event approach (ARR, 1987, 1998)
3. Joint Probability/Monte Carlo approach

The design flood flows will be derived for the following two states of the catchment:

1. 'No-dams conditions' (also referred to as pre-dam or 'without-dam' condition), that is, without Perseverance, Cressbrook, Somerset, Wivenhoe and Moogerah Dams in the Brisbane River catchment
2. 'With-dam conditions' (also referred to as post-dam or current condition) with all the above dams in place

1.3 Objective of this document

This document provides an outline of the methodology proposed for the assessment of standard flood frequency analysis for a number of locations within the Brisbane River catchment for the 'no-dams conditions'. The results of the flood frequency analysis for the 'no-dams conditions' will eventually provide the basis for validating the overall Monte Carlo simulation framework to ensure the probability based design flood estimates produced by it are unbiased.

1.4 Scope

The clients' request for proposals (DSDIP, 2013), describes a number of requirements for the flood frequency analysis for the 'no-dams conditions', which can be summarised as follows:

- Review the results of the Seqwater study conducted by SKM (October 2013) that summarised the outcomes the results of the preliminary flood frequency analyses for the 'no-dams conditions' at a limited number of sites as part of the WSDOS project
- Agree the key locations to be included in the overall assessment with the Technical Working Group and Steering Committee
- Conduct a flood frequency analysis in accordance with best practice principles on peak flood flows and volumes at all agreed key locations
- Assess the consistency of the flood frequency results using regional analysis techniques, considering the characteristics and responses of the whole catchment as well as different sub-catchments
- Compare outcomes of the flood frequency analysis with estimates derived from hydrologic (and hydraulic) modelling to provide a basis for model validation and corroboration of results from different methodologies
- Document all the assumptions made and limitations associated with all data used for the 'no-dams conditions' flood frequency analysis
- Produce best estimates of AEP peak flows and volumes, and 80%, 90% and 95% confidence intervals for each site and identify the credible limit of extrapolation of the derived frequency curve

This document describes the analyses that were carried out since project commencement and that are still on-going. Also discussed are next steps and analyses that are necessary to meet the requirements described above.

1.5 Outline

Chapter 2 provides an overview of the key locations within the Brisbane River catchment

Chapter 3 describes the standard techniques and methodologies used for conducting the flood frequency analyses

Chapter 4 describes the implemented methodology and analysis results

2 Available data and key locations

2.1 Seqwater key locations (Seqwater/SKM)

Seqwater (and SKM) recently undertook a preliminary flood frequency analysis for 'no-dams conditions' case as part of the WSDOS project. The final report was published on 8 October 2013. The analysis was based on observed heights converted to estimated peak flood flows and modelled historic event flood hydrographs for a fourteen locations, including Somerset Dam and Wivenhoe Dam. The analysed sites were:

- Somerset Dam (inflow)
- Brisbane River at Gregors Creek
- Wivenhoe Dam (inflow)
- Lockyer Creek at Gatton
- Lockyer Creek at Lyons Bridge
- Brisbane River at Savages Crossing
- Brisbane River at Mt Crosby
- Bremer River at Walloon
- Warrill Creek at Amberley
- Purga Creek at Loamside
- Bremer River at Ipswich
- Brisbane River at Moggill
- Brisbane River at Jindalee
- Brisbane River at Port Office

Refer to Figure 2-1 for the location of the sites. The results of this analysis are reviewed to determine whether or not the methodology and results of the investigation are supported and adequate for the purpose of the BRCFS.

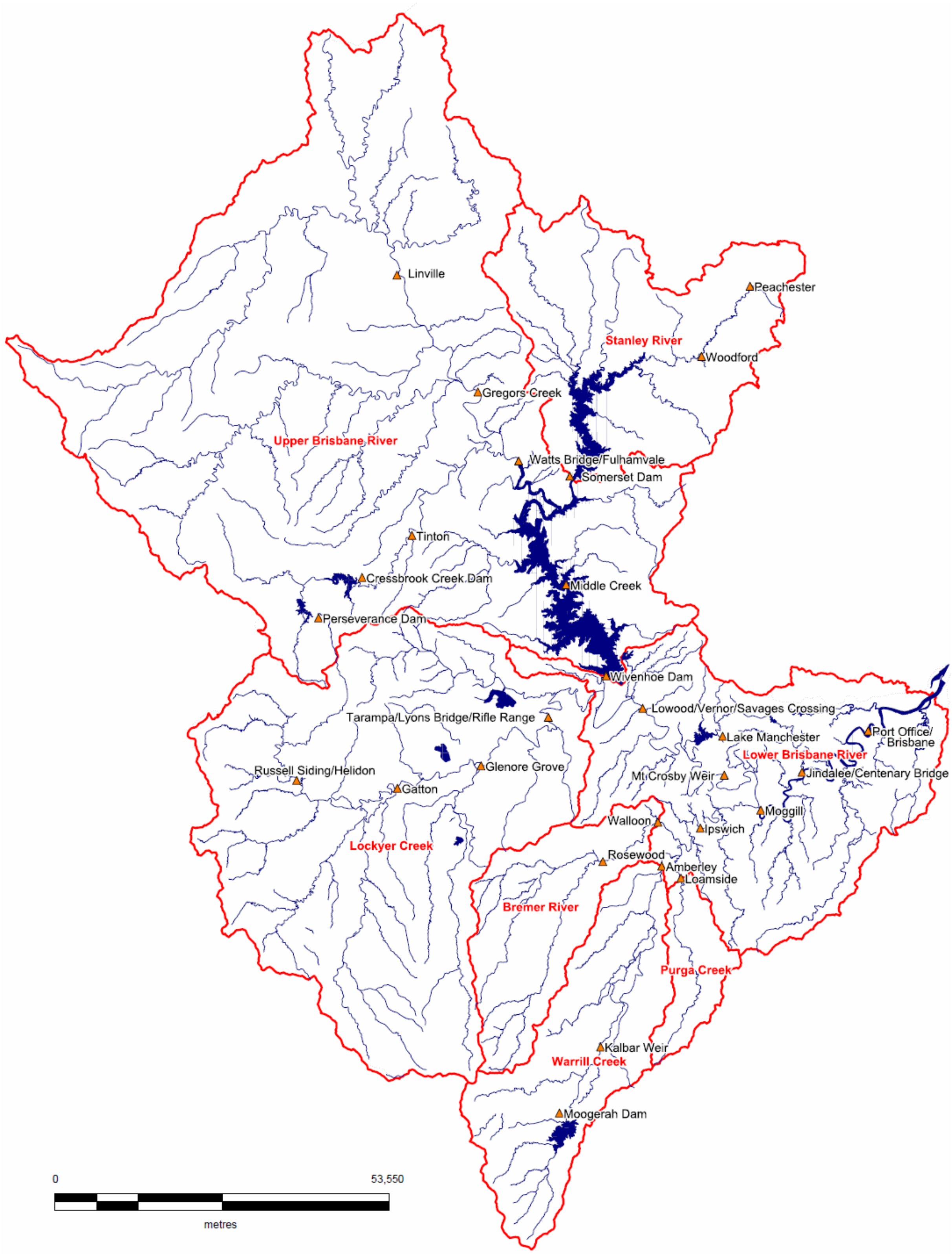

Figure 2-1 Brisbane River catchment stream gauge network (Seqwater)

2.2 Specified minimum locations (Brief)

The Project Brief specified a minimum list of 19 sites throughout catchment to be included in the flood frequency analysis for the BRCFS (subject to any adjustment necessary as a result of the above mentioned review):

- Brisbane River at Watts Bridge/Fulhamvale
- Brisbane River at Gregors Creek
- Brisbane River at Linville
- Stanley River at Peachester
- Stanley River at Silverton
- Cressbrook Creek at Tinton
- Brisbane River at Middle Creek
- Lockyer Creek at Tarampa/Lyons Bridge/Rifle Range
- Lockyer Creek at Russell Siding/Helidon
- Brisbane River at Lowood/Vernor/Savages Crossing
- Brisbane River at Mt Crosby
- Warrill Creek at Amberley
- Bremer River at Walloon
- Bremer River at Rosewood
- Purga Creek at Loamside
- Bremer River at Ipswich
- Brisbane River at Moggill
- Brisbane River at Jindalee/Centenary Bridge
- Brisbane River at Port Office/Brisbane City

Sites that were part of the Seqwater/SKM study, but are not included in the minimum list from the Brief, are:

- Somerset Dam (inflow)
- Wivenhoe Dam (inflow)
- Lockyer Creek at Gatton

Other sites that could be included in this study because of their relative long period of record, are:

- Stanley River at Woodford (94 year record)
- Lockyer Creek at Glenore Grove (58 year record)
- Warrill Creek at Kalbar Weir (65 + 14 year record)

These sites have additionally been included for consideration in this study, resulting in a total list of 25 key locations. However on review of data availability, site conditions and other criteria, several of the specified minimum and additional sites were considered to be unsuitable for reliable analysis. These sites are identified and discussed in Section 4.8.11.

2.3 Recommended locations

2.3.1 Stationary record sites

Stationary record sites are those sites not impacted by tide, or by dam or channel modification. See Table 2-1 for a summary of the sites and their general characteristics.

The tidal reaches of the Brisbane River extend to just downstream of My Crosby Weir. The tidal reaches of the Bremer River extend to approximately 17 km upstream from its confluence with the Brisbane River to the Ipswich CBD.

Locations on the Brisbane River that are not impacted any dam are those sites upstream of the confluence with the Stanley River (Somerset Dam), just upstream of Lake Wivenhoe. This includes the following sites:

- Watts Bridge/Fulhamvale
- Gregors Creek
- Linville

Locations on the Bremer River that are not impacted by any dam are those sites upstream of the confluence with Warrill Creek, which is influenced by Moogerah Dam. This includes the following sites:

- Walloon
- Rosewood

A tributary of the Bremer River that is not influenced by any dam is Purga Creek (eg Loamside) and tributaries of the Brisbane River that are not influenced by any dam are Emu and Cooyar Creek (Upper Brisbane) and Lockyer Creek. Key sites of Lockyer Creek include:

- Gatton
- Glenore Grove
- Tarampa/Lyons Bridge/Riffle Range
- Russell Siding/Helidon

Channel modifications (eg dredging) in the Lower Brisbane River, are assumed to effect river flow and water levels up to Moggill. Besides the construction of dams, other factors which influenced the historical flood record include:

- Dredging (mainly 1864 to 1940)
- Urbanisation and riverine infrastructure
- Extraction for water supply
- Changes in catchment vegetation

For the purpose of the flood frequency analysis, only the effect of dredging and riverine infrastructure will be accounted for.

Table 2-1 General characteristic of key gauge sites

Catchment	Site	Open or closed site?	Key locations Brief	Key locations Seqwater/SKM	Rating curve review BRCFS	Influenced by tide	Affected by channel mod	Influenced by dam(s)	Stationary site
Brisbane River	Linville	Open	X		x			No	Yes
Brisbane River	Gregors Creek	Open	X	X	X			No	Yes
Brisbane River	Watts Bridge/ Fulham Vale	Closed	X					No	Yes
Stanley River	Peachester	Open	X		X			No	Yes

Catchment	Site	Open or closed site?	Key locations Brief	Key locations Seqwater/SKM	Rating curve review BRCFS	Influenced by tide	Affected by channel mod	Influenced by dam(s)	Stationary site
Stanley River	Silverton	Closed	X					No	Yes
Stanley River	Woodford	Open			X			No	Yes
Somerset Dam	*(inflow)*	Open		X	X			Somerset	No
Cressbrook Creek	Tinton	Closed	X					Preserverance & Cressbrook	No
Wivenhoe Dam	*(inflow)*	Open		X	X			Wivenhoe	No
Brisbane River	Middle Creek	Closed	X					Somerset	No
Lockyer Creek	Gatton	Open		X	X			No	Yes
Lockyer Creek	Glenore Grove	Open			X			No	Yes
Lockyer Creek	Tarampa/ Lyons Bridge/ Rifle Range Rd	Closed/ closed /open	X	X	X			No	Yes
Lockyer Creek	Russell Siding/ Helidon	Closed/ open	X					No	Yes
Brisbane River	Lowood/ Vernor/ Savages Crossing	Closed/ closed /open	X	X	X			Wivenhoe	No
Brisbane River	Mt Crosby	Open	X	X	X			Wivenhoe	No
Bremer River	Rosewood	Open	X		X			No	Yes
Bremer River	Walloon	Open	X	X	X			No	Yes
Warrill Creek	Kalbar Weir	Open						Moogerah	No
Warrill Creek	Amberley	Open	X	X	X			Moogerah	No
Purga Creek	Loamside	Open	X	X	X			No	Yes
Bremer River	Ipswich	Open	X	X		x		Moogerah	No
Brisbane River	Moggill	Open	X	X	X	X	X	Wivenhoe	No
Brisbane River	Jindalee/ Centenary Bridge	Open/ Sporadic	X	X	X	X	X	Wivenhoe	No
Brisbane River	Port Office/ Brisbane City	Open	X	X	X	X	X	Wivenhoe	No

2.3.2 Non-stationary record sites

The following stations are influenced by tides, dams and historical channel modifications in the Lower Brisbane River:

- Moggill
- Jindalee/Centenary Bridge
- Port Office/Brisbane City

Ipswich is influenced by Moogerah Dam and by tides, but probably not by channel modifications in the Lower Brisbane River.

As can be seen in Figure 2-1, the following sites are additionally influenced by one or more dams:

- Somerset Dam (inflow)
- Tinton
- Wivenhoe Dam (inflow)
- Middle Creek
- Lowood/Vernor/Savages Crossing
- Mt Crosby
- Kalbar Weir
- Amberley
- Ipswich
- Moggill
- Centenary Bridge
- Port Office Gauge/Brisbane City Gauge

All other sites are considered to be stationary.

3 Flood frequency analysis techniques

3.1 Overview

Flood frequency analysis uses statistical analysis of recorded floods to estimate the magnitude of floods of a selected probability of exceedance. The procedures are typically applied to peak discharges. They may sometimes be applied to flood volumes or even maximum flows over some time period such as a month, although relatively little evidence is available on appropriate types of probability distributions in these cases. Flood frequency analysis is dependent upon the assumption that the variable being examined can be considered to be drawn randomly from a well-behaved statistical distribution.

General guidance on flood frequency analysis is provided in AR&R (1987 and its subsequent updates), however it must be noted that this document is not intended as a strict code of practice. A number of advancements in FFA techniques are addressed in the draft flood frequency chapter of the new version of AR&R (Kuczera and Franks 2006), although the status of this document is still identified as for ‘review purposes’. In 2011, Engineers Australia released a policy statement retracting a number of the specific recommendations in AR&R (1987) and advising that designers should be aware of current best practice standards and adopt the appropriate approach for the set of circumstances.

Flood frequency analysis may be a useful method at a site where streamflow records of at least moderate length are available. It is desirable to have at least 10 to 15 years of data, although situations may occur where short records may have to be used as there is no better alternative. Criteria for deciding if flood frequency analysis should be used are given in the guidelines in AR&R (2003) Book III Section 2.6. The accuracy of flood frequency estimates is indicated by the confidence limits, however factors other than length of record affect the accuracy of the estimate, and methods and formulae leading to the criteria in Book III Section 2.6 are also useful as indicating the likely accuracy of flood frequency estimates.

3.2 Types of flood series

3.2.1 Annual series

Annual Series data is comprised of the highest instantaneous value in each year of record. Where flows are highly seasonal, especially with a wet summer, use of a water year (year commencing at the end of the period of lowest average flow) is preferable to the calendar year. The highest flow in each year is selected whether it is a major flood or not, and all other floods are neglected, even though some will be much larger than the maximum discharges selected from some other years. The annual flood series will consist of the same number of values as the number of years of data.

Statistical analysis of the Annual Series returns the relationship for Annual Exceedance Probability (AEP), defined as the probability that an event of given magnitude (or greater) will occur within a one year period.

3.2.2 Partial series (Peak over threshold)

Partial Series data, also referred to as Peak Over Threshold, is comprised of all floods with peak discharges above a selected base value or threshold, regardless of the number of such floods occurring each year. The number of floods may be different to the number of years of record, and will depend on the selected base discharge. The American Society of Civil Engineers (1949) recommended that the base discharge should be selected so that the number of samples is greater than the number of years, but that there should not be more than 3 or 4 floods above the base in any one year. These two requirements can be incompatible. Recommended values for the number of samples vary from equal to the number of years for fitting of a Log Pearson III type distribution to between two and five times that for fitting of other distribution types.

Statistical analysis of the Partial Series returns the relationship for Average Recurrence Interval (ARI), defined as the average time period between events of a given magnitude (or greater).

3.2.3 Relationship between annual and partial series

As the values selected in the annual and partial series for a given catchment are different, the results of frequency analyses of the two series are different. Langbein (1949) used the binomial distribution to derive the theoretical relationship between the probabilities given by the two series as:

$$P = 1 - e^{-1/Y}$$

where *P* and *Y* are refer to the AEP from the annual series and ARI from the partial series respectively for a particular discharge.

It must be noted that this is a theoretical relationship only, and does not take into account seasonal variation (wet/dry season) or climatic variation (El Nino/La Nina) which will tend to concentrate the occurrence of flood events within the wet season of wet years, and thus increase the discrepancy.

3.2.4 Selection of preferred series

The Annual Series is easily and unambiguously extracted as the individual annual maximum flows are more likely to be separated by considerable intervals of time and are likely to be independent. The form of the frequency distribution of annual floods conforms with that of many bell shaped theoretical distributions, and thus statistical theory is readily applicable. The Annual Series is generally preferred for analysis of large to extreme flood events (AEP < 0.1; ARI > 10 year) as analyses of the two series theoretically give almost identical answers in this range. Annual series is generally used in design, as low AEPs in this range are generally required for estimation of a design flood for a structure or works at a particular site.

Partial series is generally preferred for analysis of small to moderate floods (AEP >0.1; ARI <10 year) as all floods are of interest in this range regardless of whether they are the highest in the particular year of record or not. The annual series may omit many floods of interest. The partial series is appropriate for estimating design floods of low ARI for diversion works, coffer dams and other temporary structures.

3.2.5 Peak flow

Annual series flow data is the easiest variable to extract, and is simply a matter of analysing the historical record to determine the highest value in each water year.

Partial series flow data requires analysing the historical record to extract all peaks above a given threshold. The analysis can be complicated as the analysis is based on the principle of statistically independent events, which requires physical independence of the causative factors of the flood, mainly rainfall and antecedent wetness (Laurenson 1987). Selection of appropriate criteria for determining independence of successive peaks is discussed at length in Sections 2.2.3 of AR&R (2003), which provides a wide but non-exhaustive list of criteria used in previous studies but ultimately concludes that the decision “requires subjective judgement by the designer or analyst in each case” and “It is inevitable that the adopted criterion will be arbitrary to some extent.”

- Bulletin 17B of the Interagency Advisory Committee on Water Data (1982) states that no general criterion can be recommended and the decision should be based on the intended use in each case, as discussed above. However in Appendix 14 of that document, a study by Beard (1974) is summarised where the criterion used is that independent flood peaks should be separated by five days plus the natural logarithm of the square miles of drainage area, with the additional requirement that intermediate flows must drop to below 75% of the lower of the two separate flood peaks. This may only be suitable for catchments larger than 1000 km^2. Jayasuriya and Mein (1985) used this criterion
- The UK Flood Studies Report (Natural Environment Research Council, 1975) used a criterion that flood peaks should be separated by three times the time to peak and that the flow should decrease between peaks to two thirds of the first peak
- McIllwraith (1953), in developing design rainfall data for flood estimation, used the following criteria based on the rainfall causing the floods:
  - For rainfalls of short duration up to two hours, only the one highest flood within a period of 24 hours
  - For longer rains, a period of 24 hours in which no more than 5 mm of rain could occur between rain causing separate flood events
- In a study of small catchments, Potter and Pilgrim (1971) used a criterion of three calendar days between separate flood events but lesser events could occur in the intervening period. This was the most satisfactory of five criteria tested on data from seven small catchments located throughout eastern New South Wales. It also gave the closest approximation to the above criteria used by McIllwraith (1953)
- Pilgrim and McDermott (1982) and McDermott and Pilgrim (1982) adopted monthly maximum peak flows to give an effective criterion of independence in developing a design procedure for small to medium sized catchments. This was based primarily on the assumption that little additional damage would be caused by floods occurring within a month, and thus closer floods would not be independent in terms of their effects. This criterion was also used by Adams and McMahon (1985) and Adams (1987)

The simplest method for assessing large amounts of data is to perform an initial automated selection based on flow threshold using a time threshold to determine independence of the events, as illustrated in Figure 3-1. Selection of flow threshold will be based on achieving the desired number of events, while time threshold will need to be based on catchment size and review of data characteristics. If events selected by this assessment are in close proximity, then they will need to be reviewed to determine if they should be considered as independent.

3.2.6 Flood volumes

Hydrological frequency analysis is usually focussed on flood peaks and there are significantly fewer studies into flood volumes despite these being required for design of structures such as dams. As well as less available data, several issues complicate the extraction of statistical flood volume data:

- Peak volume is not necessarily linked to peak flow, and high volume events may be caused by low flows of extended duration
- The inter-relationship of sequential events is much more complicated for flood volumes. It is necessary to not only determine independence of event, but to try to separate the volume of a particular event
- The inclusion or exclusion of base-flow in the volume

These issues apply for both annual and partial series data. Extraction of statistically independent flood volume data is therefore much more analysis intensive and potentially inaccurate than extraction of flood peaks. A number of assumptions can be made to simplify the assessment:

- Assessment only of events that that reach a minimum flow threshold
- Inclusion of total flow volume regardless of whether it came from an independent rainfall event, potentially through the use of a lower-bound flow threshold rather than a time threshold

An alternative assessment of flood volumes would be to use an approach similar to the assessment of rainfall, whereby the record is analysed to extract volumes that occur within a particular duration.

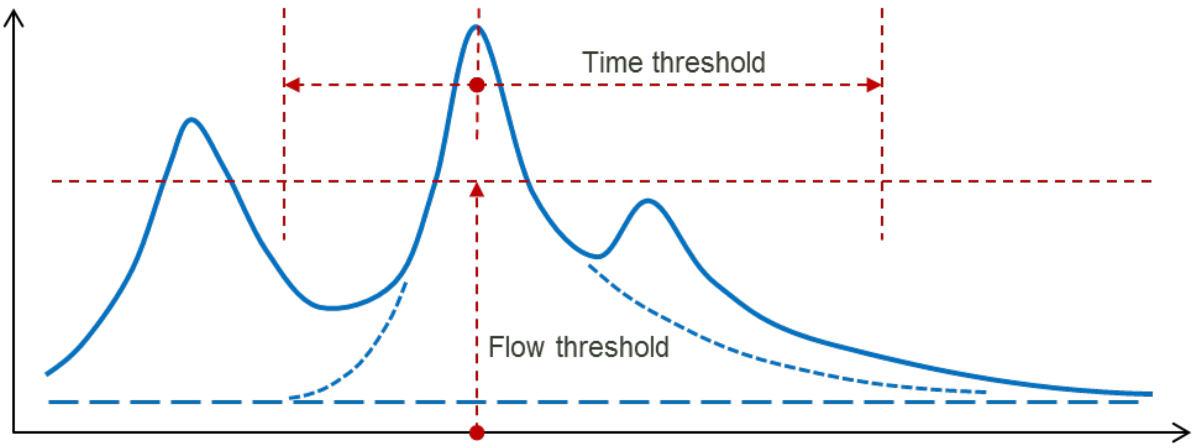

Figure 3-1 Selection of independent events

3.3 Data preparation

3.3.1 Data requirements

Flood frequency analysis is based on the assumption that the data provides a representative sample of a randomly distributed homogeneous data set. Book IV Section 2.2.1 of AR&R (2003) and Book IV Section 2.1.3 of AR&R (DRAFT 2006) identify a range of issues that may affect homogeneity of the data population that are addressed in Table 3-1. The historical record at each gauge location will be carefully examined to identify issues of homogeneity. Where such issues are encountered, they will be rectified as discussed in the sections below, highly qualified and given reduced priority in the flood frequency analysis, or removed from the record entirely.

Table 3-1 Factors affecting homogeneity of gauge data

Issue	Response
Daily readings, possibly with some intermediate readings during some floods for part of the record, and continuous recording through the remainder	Recent gauge records usually supply continuous level records, but data becomes more sparse (and less reliable) for older gauges. Review of historical gauge records will need to examine quantity and quality of available data Extraction of data, discussed in Sections 3.2.5 and 3.2.6 will depend on the type of flood record
Change of gauging station site	With a few exceptions, gauge locations have been relatively constant. Minor changes to the gauge location should have minimal impact on the gauge rating, however the gauge history will need to be carefully reviewed to identify changes in location and/or datum and impacts. Specific gauge site related issues are discussed in Section 4.6
Inability to allow for change of station rating curve, for example resulting from insufficient high-stage gaugings	The Rating Curve Review, particularly for primary gauges, has assessed ratings up to and beyond the largest recorded floods at the gauge. Extrapolation of the rating must be consistent with channel shape and properties
Construction of large storages, levees and channel improvements	The six major dams, in particular Wivenhoe and Somerset, represent significant changes to the catchment characteristics. The historical records will need to be adjusted to account for influence of the dams. This is discussed in Section 3.3.8
Growth in the number of farm dams on the catchment Changes in land use such as clearing, different farming practices, soil conservation works, reforestation, and urbanisation	AR&R states that the available evidence indicates that unless changes to the catchment involve large proportions of the total area or large changes in the storage on the catchment, the effects on flood magnitudes are likely to be low and effects are likely to be larger for small floods than for the large floods that are of interest in design The area of catchment impacted by urbanisation is only 2.5% of the total Brisbane River catchment. Aurecon has investigated the inclusion of urbanisation into the Seqwater URBS model and found that increases on peak flow rates of up to 2.5% changes to flood volumes of up to 4% were observed
Changes to rainfall and flood mechanisms including long-term climate change and pseudo-periodic shifts that persist over periods lasting from several years to several decades	Issues relating to periodic shifts in weather patterns have been related to climate indexes such as the Interdecadal Pacific Oscillation (IPO) have been identified and discussed in papers such as Micevski (2006), however the effects not well understood and there is little guidance on how to address the issues in a flood frequency analysis Period of gauge data record will be compared with IPO records to identify gauges that may be at risk of significant bias

3.3.2 Calculation of flows at rated gauges

Stream gauges record water levels that must be converted to a discharge. The Rating Curve Review has examined and identified preferred level-discharge relationships for each of the FFA gauge locations throughout the Brisbane River catchment. The ratings were developed as a 'best-fit' of a combination of flow gauging data, hydrologic and hydraulic modelling. Although variability of the data was generally observed, this was generally random scatter with no strong evidence of trends or historical variation (with the exception of Savages Crossing).

It is acknowledged that the use of a single rating curve does not necessarily predict the exact flow for any given event, but nevertheless the rating represents typical flow values for a given recorded water level and this is generally considered appropriate for use in flood frequency analysis. Further discussion on the effects of variability in the rating is provided in Section 3.5.1.

3.3.3 Calculation of flows at isolated unrated gauges

The Rating Curve Review has focused on improving confidence in gauges used for calibrating the hydrologic modelling, although most of these are also nominated as sites for flood frequency analysis. The most reliable method for determining flows at currently unrated gauges is through hydrologic modelling. Seqwater/SKM developed historical rainfall data for 48 flood events for the WSDOS study and it is understood that Seqwater has subsequently compiled rainfall data for additional flood events. These do not necessarily represent the largest events at each site or even a balanced distribution of frequencies, and it will be necessary to determine flows from levels recorded for other events. The hydrologic model flows and measured levels can be used to develop rating curves at each site. As discussed in Rating Curve Review, results of the hydrologic model are influenced by multiple factors, which include the model parameters, assumed losses and rainfall data. Significant scatter is therefore likely and the rating curve represents an averaged or expected value.

When conducting the flood frequency analysis there is the option of using either the modelled or rated flows for the available historical data. Although this may vary for each site, it is generally preferred that the latter option is used as this should help minimise any systematic bias or other uncertainties in the hydrologic model results

3.3.4 Translation of flows to unrated gauges

In the case where an unrated gauge is in relatively close proximity to a rated gauge and there is a reasonable period of overlap between the two gauge records then it can be possible to translate rated flows from the rated gauge to an estimate of flows at the unrated gauge by using the hydrologic model to determine a generic relationship between flows at the gauges. The accuracy of this method is dependent upon the proximity of the gauges and the strength of the correlation between flows at the gauges. Using a generic relationship reduces the uncertainties in the hydrologic modelling of specific events (eg reliability of rainfall data), although could potentially produce a less accurate prediction of specific events if the modelling is indeed reliable.

The translated flows can be used directly, or more practically can be matched to recorded levels to generate a rating curve. This rating allows the relationship to be used outside the period of record of the rated gauge and also potentially averages out translation error or other bias that may be present for specific events.

3.3.5 Translation of levels from unrated gauges

If an unrated gauge in relatively close proximity to a rated gauge has a longer period of record but with a reasonable period of overlap, then it can be possible to translate levels between the two gauges by developing a generic relationship from the overlapping period of gauge height data. If the gauge records do not overlap then a correlation could potentially be determined from hydraulic modelling or estimates of flood slope. A level-based correlation may be more complicated than the flow-based correlation as changes in cross section properties (ie discontinuities in the rating) may result in a non-linear or segmented relationship.

As with the translation of flows, the accuracy of the level translation is dependent on correlation between levels at the two gauges. AR&R (2003) identifies an approximate criterion for deciding whether the regression should be used as that the correlation coefficient of the relation should exceed 0.85 (Fiering 1963; Matalas and Jacobs 1964). More rigorous criteria are discussed in Book III Section 2.6.5.

3.3.6 Extension of records using rainfall-runoff

Book IV Section 2.2.6 of AR&R (2003) briefly discusses use of rainfall runoff routing methods to extend the flood record. Methods range from simple rainfall-runoff regressions to catchment models for estimating continuous runoff hydrographs from rainfall data. The procedure is advised as possible in some cases, but not recommended.

Considering that one of the primary purposes of the flood frequency analysis is to confirm the calibration of the hydrologic models and validity of the stochastic simulations, it is not intended to use this method except where a clear benefit can be identified.

3.3.7 Extension of records using historical floods

Book IV Section 2.2.6 of AR&R (2003) also briefly discusses use of historical events, typically large events prior to or after the period of gauged record for which level or other data is known. Procedures are provided in Sections 2.4.5 and 2.7.1. Use of historical flood data will be considered where reliable flood data is available and a clear benefit can be identified.

The use of paleofloods, major floods that have occurred outside the historical record, but which are evidenced by geological, geomorphological or botanical information, are discussed as a means potential means for extending the data base and providing information on the tail of the underlying flood distribution. Considering the limited data availability and stated uncertainty and risks, assessment of paleofloods is not considered likely to provide additional certainty and will not be assessed.

3.3.8 Elimination of dam influence

The flood mitigation provided by dams, particularly regulated structures such as Wivenhoe and Somerset, is not consistent for all events and therefore influences the flood probability distribution. The flood gauge records are unlikely to have sufficient data pre- and post- dam construction to allow independent analyses to be conducted, so a flood frequency analysis based on a standardised probability distribution will require the influence of the dams to be removed to produce a single consistent data set.

The best tool for estimating the influence of the dams is the URBS hydrologic model, which can be modified to reflect pre- and post-dam conditions and calibrated to historical data from each condition (provided such data exists). Historical rainfall data is currently available for 48 flood events, and the quickest option to determine no-dam flows is to simply use the flow predicted by the URBS model:

$$Q_{NoDams} = URBS_{NoDams} \quad (1)$$

where Q_{NoDams} is the adopted no-dam flow and $URBS_{NoDams}$ is the modelled flow. However, even with individual calibration to each event it is unlikely the URBS model can exactly match the measured flow. The second option is to scale the rated flow, Q_{NoDams}, proportional to the URBS results:

$$Q_{NoDams} = Q_{WithDams} \times \frac{URBS_{NoDams}}{URBS_{WithDams}} \quad (2)$$

These records do not represent the full flood history and do not necessarily match the key peak events for each gauge location. For other flood events it would be necessary to develop a generic relationship between pre- and post-dam conditions.

$$Q_{NoDams} = Q_{WithDams} \times f\left(Q_{WithDams}\right) \quad (3)$$

where f is a correction derived using the URBS model. This relationship could be based on the historical flood events, but may also use stochastic events to provide additional variability.

The generic relationship will provide an average or expected no-dam flow for an observed post-dam flow, and it is acknowledged that this may well not represent the actual flow that would have been observed. This does not necessarily detract significantly from the accuracy of the flood frequency analysis. Fitting a probability distribution is itself a process of averaging, and provided the sample size is adequately large and the generic relationship is averaged then any errors should be balanced out (ie for each event overestimated there should be a similar event underestimated).

Of greater concern are the regulated dam outlets, in particular Wivenhoe, the operation of which specifically target particular flows downstream (Rural and Urban Strategies). This greatly increases the variability in the relationship between released flow and the unrestricted flow that caused the flood. Greater attention to the Lower Brisbane River gauges downstream of Wivenhoe and Somerset will therefore be required. Fortunately, the historical URBS events should target this location meaning greater focus can be placed on specific event adjustment (Equation 2) rather than generic.

3.3.9 Modifications to data and fitting procedures

Section 2.7 of AR&R (2003) discusses methods for adjusting the data and statistical fitting procedures to allow for:

- Inclusion of historical data
- Zero and low flows
- Identification and treatment of high and low outliers
- Possible deletion of lower portion of flood series

The procedures in AR&R (2003) were developed for use with Log Pearson III type probability distribution, but presumably are also applicable to a GEV or other type of distribution. More recent methods are also available, including the multiple Grubbs and Beck low flow outlier test for multiple outliers, while Bayesian fitting methods provide flexibility for dealing with outliers.

3.4 Statistical distributions

3.4.1 Log-Pearson III

The distribution commonly referred to as the Log-Pearson III assumes that the logarithms of the flood flows are distributed in accordance with the Pearson III probability distribution. The Log-Pearson III was identified as the preferred flood frequency distribution in AR&R (2003), although as discussed in Section 3.1 this specific advice was retracted in 2011 leaving selection of an appropriate distribution at the discretion and responsibility of the designer. The original recommendation was made on the basis that:

- Use of a standard distribution and procedure contributes to consistency in design practice and equity in use of scarce resources, since no single distribution can be proved to be correct
- The Log-Pearson III distribution performed best of those that had been tested on data for Australian catchments (Conway 1970; Kopittke et al. 1976; McMahon 1979; McMahon and Srikanthan 1981)
- A large amount of theory and design methodology is available for the log Pearson III distribution, especially as it is the recommended procedure for the United States in Bulletin 17B of the Interagency Advisory Committee on Water Data (1982)

The Pearson III distribution is a three-parameter probability distribution related to the standard Gamma probability distribution. The parameters can be directly related to the mean, standard deviation and skew of the data sample.

3.4.2 Generalised extreme value (GEV)

Like the Pearson III distribution, the GEV distribution is a flexible three-parameter probability distribution. The GEV function combines three extreme-value distributions (the Gumbel, Frechet and Weibull) within a single framework. The parameters of the GEV distribution are different to those of the Pearson III distribution, but can nevertheless also be related to the mean, standard deviation and skew of the data sample.

3.4.3 Other distributions

A wide range of other probability distributions have been suggested for use in flood frequency analysis, particularly for assessment of partial series, including but not limited to:

- Gumbell Distribution (specific case of the GEV distribution)
- Generalised Pareto distribution
- The power transformation approach developed by Box and Cox (1964)
- The Wakeby distribution (eg Houghton, 1978)
- A compound model using a Poisson distribution of occurrences and a negative exponential distribution of magnitudes (Tavares and da Silva 1983; Jayasuriya and Mein 1985)
- Multi-component models where flooding is affected by different types of meteorological events that can be separated and analysed separately

Considering the objectives of the flood frequency analysis, it is not intended to investigate or adopt any of the lesser recognised methods unless the probability distribution cannot be adequately matched using the standard Log-Pearson III or GEV distributions.

3.4.4 Methods for fitting

There are numerous procedures for fitting the statistical distributions to data, including:

- Graphical fit
- Method of moments preserving the moments of the logarithms of flows
- Method of moments preserving the moments of the actual flow values
- Method of maximum likelihood
- Least squares
- Maximum Entropy
- Probability weighted moments
- Linear moments (L-moments)
- Bayesian maximum likelihood

AR&R (2003) provides standardised methodology for the first two methods. The method of moments preserving the moments of the logarithms of flows was recommended by AR&R (2003) primarily for reasons of simplicity, justifying the decision on the argument that it is at least as important to preserve the moments of the logarithms of the flood values as those of the actual discharges, and checking the fitted distribution against the plotted data reduces the importance of the method of fitting. As discussed in Section 3.1, the specific recommendation has since been retracted.

Fitting procedures is still a topic of active research, and contemporary distribution fitting is frequently associated with an L-moment approach. Conventional moments raise raw data to powers of 2, 3 and 4 to obtain estimates of standard deviation, skewness and kurtosis, whereas L-moments avoid non-linear transformations of data, which can help prevent distortions when there are outlying values in the data. Recent studies have preferred the use of L-moment or Bayesian methods. Bayesian methods in particular have been found to be very flexible in how they use incomplete data, including dealing with missing data in a continuous record, using historical information prior to the continuous record and censoring low flow data.

3.4.5 Use of regional skew

Flood frequency analysis involves calculation of statistical properties (generalised as mean, standard deviation and skew) from observed data. Of these properties, the skew can be sensitive to effects of random variations in the observed values. That is, it can be strongly influenced by the presence or absence of extreme events within the data sample, particularly if the sample is small. Accuracy can be improved by weighting the skew with generalised values from other sites in the region. Assessment of the multiple gauges within the Brisbane River catchment provides the opportunity for a region based assessment of skew to improve the reliability and consistency of the overall assessment. AR&R (2003) provides some discussion on the use of regional skew with the Log-Pearson III distribution, and a similar approach can also be adopted for the GEV distribution.

3.4.6 Preferred distribution

The Log-Pearson III distribution was adopted as the standard distribution in AR&R (1987) because it was found to consistently fit flood data as well, if not better than other probability families for Australian catchments, although the GEV distribution has been gaining popularity as a statistical distribution for flood frequency analysis. Engineers Australia currently does not specifically recommend either distribution as there is no conclusive reason that one distribution should or does consistently provide a better fit of the data. Care should be taken not to be overly influenced by international experience where the causal effects and resulting probability distributions may be different.

AR&R discusses two general approaches for design procedures, the first being to fit several different types of distribution to each catchment and adopt the distribution which gives the best fit, while the second (recommended) approach is to adopt a single distribution for all catchments in a region or for all Australia based on the best overall fit in many catchments. The GEV and Log-Pearson III profiles are both highly adaptive three-parameter distributions and it is the selection of these parameters that has the greatest influence. Given the current debate regarding Log-Pearson III versus GEV, it is proposed to fit both distributions to the data for each catchment but then, unless there is a significant and justifiable disparity between catchments, adopt a single distribution type for the final assessment based on whichever is considered to give the best representation of the region.

The AR&R (1987) standard methodology adopted the method of moments based on preserving the logarithms of flows, but acknowledged that other methods had been found by some studies to give better results. The method of L-moments has been espoused as giving better parameter estimates for data containing outlying values, while Bayesian methods are generally more flexible. Regardless of the method used, it must be demonstrated to provide a good fit of the data. Methods for improving the fit include:

- Use of regional skew characteristics to minimise overall influence of high and low-end outliers
- Identification of outliers through both statistical assessment and visual inspection
- Checking the fitted distribution against the plotted data and using engineering judgement to identify inconsistencies or other issues with the data and fit

3.5 Accuracy and confidence

3.5.1 FFA confidence limits

Flood frequency analysis is based on assessment of samples from an (assumed to be) randomly distrusted variable. Different sample sets would therefore result in different outcome. The uncertainty associated with flood frequency analysis is usually assessed by calculating confidence limits that define the range within which the actual population is expected to lie with a selected level of probability. The confidence limits about a flow are dependent upon the probability associated with the confidence limits (eg 90% probability), the frequency of the flow and the number of samples.

Numerous methods have been proposed for defining confidence limits and are dependent on the type of probability distribution. Procedures for fitting confidence limits to the Pearson III distribution are discussed and presented in AR&R (2003). Alternate methods are required for the GEV distribution. Although confidence intervals for a standard probability function can be estimated mathematically, they are not compatible with the advanced sampling techniques and Bayesian fitting methods implemented by FLIKE. Whilst the brief requested that 80%, 90% and 95% confidence limits be derived for each site, FLIKE currently only provides for the determination of 90% confidence limits. This is considered satisfactory for providing an indication of the uncertainty in the flood frequency estimates.

It should be noted that FFA confidence intervals only indicate the expected probabilities of the statistical analysis. They do not consider or identify confidence or potential errors in the underlying data.

3.5.2 Rating variability and error

Rating review identified a degree of scatter in the flow gauging and hydrologic model data. With the exception of Savages Crossing, which appears to exhibit a historical variation in the rating, the scatter appears to be relatively random with no discernible time or flow-based trends. Possible contributors to the data scatter include:

- Measurement error in level gaugings
- Measurement or interpretation error in flow gaugings (for flow gauging data)
- Uncertainty in rainfall records and hydrologic model calibration (for hydrologic model data)
- Hysteresis (difference between rising and falling limbs of the flood event)
- Variation in flow characteristics (eg roughness, channel shape etc)

Of these, only the last two represent ‘real’ variability of the gauge rating (ie an actual change in the level-discharge relationship). The others represent measurement error, and do not affect the accuracy of the rating provided that they are relatively unbiased.

Investigations into the effect of hysteresis on the gauge ratings identified no evidence of consistent effect on flow gauging used to develop the ratings, although it is noted that flow gauging is usually only available for smaller in-channel flows where storage effects and hysteresis should be minimal. The effects of hysteresis should therefore have minimal impact on calculation of the gauge rating and use of the gauge rating to convert peak flood levels to flows. However, hysteresis is known to be present, particularly in the lower Brisbane gauges with relatively flat grades and significant floodplain areas, which may be important if the rating is used to estimate non-peak flows for calculating flood volumes. Hysteresis is not consistent and is dependent on flowrate, duration and rate of change. Predicting the effects of hysteresis is therefore difficult without detailed event-specific investigation, however a reasonable estimate can often be obtained using the Jones formula and potentially second-order diffusion corrections (eg Fenton 2001).

It is considered likely that variation in flow characteristics will have some impact on the level-flow relationship for specific events, however separating this from the other factors is very difficult. Additionally it should be noted that, provided that this variation is unbiased, it does not necessarily represent a corresponding reduction in the accuracy of the rating or the flood frequency analysis, as the flood frequency analysis is itself a method for determining an averaged value from randomly distributed data.

Perhaps the greatest unknown and most difficult value to quantify is the accuracy of the upper rating curve where it is extrapolated using hydrologic or hydraulic models. While sensitivity testing can be performed by varying the hydraulic model roughness, hydrologic model parameters or just the rating levels, there is no obvious method for actually quantifying the probability and risk of such variation.

3.5.3 Limits of extrapolation

Large extrapolations of flood frequency analyses are not recommended. AR&R Book VI Section 1.2 recommends that the 1 in 100 AEP flood is the largest event that should be estimated by direct frequency analysis for important work, and the maximum flood that should be estimated by this means under any circumstances is the 1 in 500 AEP event.

Consistent with these recommendations, the preferred methodology is to use the results of the flood frequency analysis for assessment of moderate to large flood events (<1 in 500 AEP) and comparison with stochastic rainfall assessment within this range. The stochastic rainfall and other methods such as PMP/PMF calculations should be used for extrapolation to extreme flood frequencies.

3.6 Regional flood frequency analysis

A commonly encountered problem associated with estimating flood flows is estimating the flood flow of a given AEP at a location where the historical monitored information is inadequate for frequency analysis. Regional analysis techniques which draw upon (or transfer) better gauge records from nearby and/or hydrological similar sites can help improve or benchmark results derived by other methods. The application of regional frequency techniques may also result in improvements in terms of consistency (between the locations), robustness and reliability.

There are a number of regional flood frequency analysis (RFFA) techniques available for application. The recent AR&R Project 5 Stage 2 Report, (Rahman et al 2012), provides a summary of approaches that are available for application. Project 5 considered a number of RFFA methods which were then selected for detailed investigation. All RFFA methods use the results of at-site FFA as basic data. A RFFA method then essentially consists of two principal steps:

1. Formation of regions: This involves formation of regions from the available streamflow gauging stations
2. Development of regional estimation models: This involves development of prediction equations to estimate flood quantiles, based on the results of at-site FFA within the region

In RFFA, formation of regions can be based on proximity in geographic or catchment attributes space. A region can be fixed, having a definite boundary or it can be formed in geographic or catchment attributes space with respect to the ungauged catchment of interest. AR&R Project 5 examined the applications of the following RFFA methods:

1. Probabilistic Rational Method (PRM)
2. Quantile Regression Technique (QRT)
3. Parameter Regression Technique (PRT)
4. Index Flood Method
5. Probabilistic Model (PM)/Large Flood Regionalisation Model (LFRM)

The AR&R Project 5 report provided a summary of each of these techniques. The original intention was to apply the widely applied index flood method of Hosking and Wallis (1997), as it has proven to be suitable for a wide variety of applications, and then use the new ARR Project 5 Regional Analysis Tool which incorporates the Parameter Regression Technique (PRT) to validate the regional characteristics derived from the at-site frequency analysis. A brief explanation of each of these methods is provided below:

3.6.1 Index flood method

AR&R Project 5 summarised the Index Flood Method and reiterated that the key assumption in the method is that the distribution of floods at different sites within a homogeneous region is the same except for a site-specific scale, or index flood factor. Homogeneity with regard to the index flood relies on the concept that the standardised flood peaks from individual sites in the region follow a common probability distribution with identical parameter values. From all the methods examined in the AR&R Project 5, the Index Flood Method involves the strongest assumptions on homogeneity.

AR&R (Engineers Australia, 1987) did not favour the index flood method as a design flood estimation technique. The index flood method had been criticised on the grounds that the coefficient of variation of the flood series may vary approximately inversely with catchment area, thus resulting in flatter flood frequency curves for larger catchments. This had particularly been noticed in the case of humid catchments that differed greatly in size, such as is the case for the Brisbane River Catchment.

There have been recent studies carried out by Bates et al. (1998) and Rahman et al. (1999) where the development of an application for design flood estimation in ungauged catchments in south-east Australia was tested using the index flood method. The method involved the assignment of ungauged catchments to a particular homogenous group identified (through the use of L-moments) on the basis of catchment characteristics as opposed to geographical proximity. The relationships sought were developed by statistical procedures such as canonical correlation analysis, tree based modelling and other multivariate statistical techniques. This allowed for the development of a RFFA method using up to 12 independent catchment characteristics variables.

The limitation with this approach is the need to define so many characteristics to define the homogeneous regions. If a site is not classified appropriately, the estimation of flood quantiles can be affected significantly. Therefore it was decided not to proceed with the application of this approach.

3.6.2 ARR Project 5 regional analysis tool

Stage I and Stage II of AR&R Revision Project 5 have now been completed. Project 5 has undertaken a comprehensive review of gauging stations across Australia (up to 676 gauged catchment have been used), and undertaken a review of a number of regional flood frequency estimation (RFFE) approaches to determine the best approach for the determination of peak discharge estimates at ungauged or poorly gauged sites, or to be used as a comparison to at site Flood Frequency approaches, where only low quality site specific data is available.

The ARR Project 5 team have developed a software application tool which automates the preferred ARR RFFE 2012 method, with the user required to input just the latitude and longitude (to derive design rainfall intensities, and to determine the Regional of Influence) and the catchment area to the point where a flood quantile estimate is required. The tool takes out the need to derive Mean Annual Rainfall and Evapotranspiration (these have been sourced from BoM Tables) and Forest Cover (from Topographic mapping etc). The application also gives uncertainty estimates with 90th percentile confidence limits.

Unfortunately Aurecon were unable to apply the tool as the Beta version of the tool was withdrawn due to some problems being identified in its implementation. Therefore it was not possible to apply the tool to the current study, but this could be considered once it becomes available in the future.

4 Flood frequency analysis implementation

4.1 Adopted methodology

Flood frequency analysis of the Brisbane River catchment stream gauges involves compilation and analysis of a large amount of flood flow data from multiple sources including stream gauge and URBS modelling. This data is sometimes of uncertain quality, incomplete, or influenced by dams or other factors. The assessment methodology has been developed to use current best-practice techniques and taking advantage of automated Bayesian fitting techniques implemented in the FLIKE flood frequency analysis software developed by the University of Newcastle. The adopted procedure is to:

1. Compile available at-site flow data at each site (Section 4.2)
2. Correct for influence of dams to produce 'no-dams conditions' peak flow estimates (Section 4.2.4)
3. Extend or supplement the at-site data record using historical and/or translated flood records where appropriate (Section 4.3)
4. Identify and filter outliers and errors from the gauge records (Section 4.4)
5. Assess the data availability and quality to identify the likely reliability of the frequency estimates at each site (Section 4.5)
6. Conduct a primary assessment of the gauge sites considered to be most reliable (Section 4.6)
7. Assess the regional characteristics of the primary assessment sites (Section 4.7)
8. Analyse all stream gauges introducing a regional weighting of the flood frequency (Section 4.8)

4.2 Compilation of flood gauge records

Flood frequency analysis requires a consistent, homogeneous and statistically relevant record of flood flows. Historical river flows can be estimated from either:

- Hydrologic routing of recorded rainfall
- Estimation of flow corresponding to recorded river levels using a pre-determined gauge rating

Neither of these methods is without limitations and each has assumptions and a certain degree of uncertainty in its outputs. A significant component of the preparatory work for conducting the flood frequency analysis has been the compilation of a single combined historical record at each of the gauge locations from three available data sets – continuous gauge data, peak level records and URBS hydrologic modelling. The advantages and limitations of each method are discussed below.

4.2.1 Continuous gauge data

Most of the major gauges for which flood frequency analysis has been undertaken are sites at which a continuous stream gauge record has been recorded. Early records were usually read manually from gauge boards, recorded on a daily basis and sometimes (but not always) with more frequent readings during flood events. The gauge record does not necessarily record the peak level. The gauge records typically display a significant increase in the frequency of record during the 1950s (transition is not consistent for all gauges), as typified in Figure 4-1. Automatic gauge recorders may still be subject to error and even complete failure, so the gauge record for each event has been reviewed to identify obvious discrepancies.

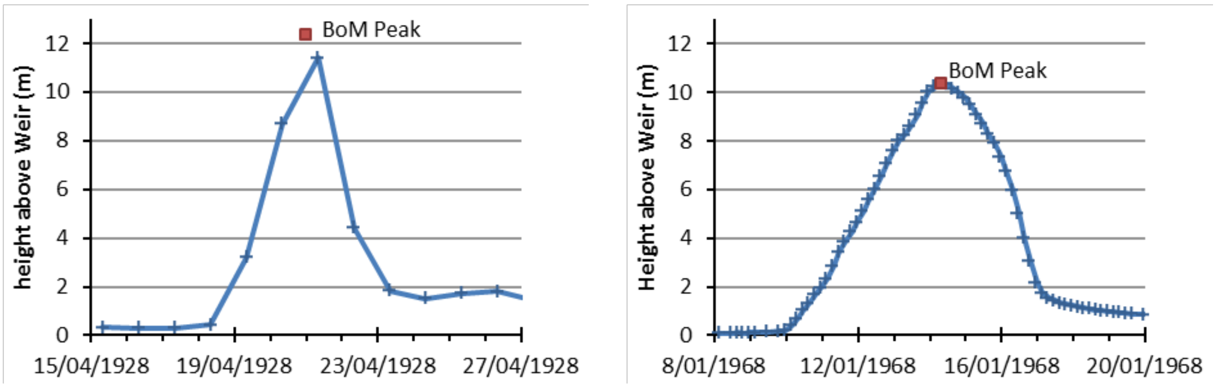

Figure 4-1 Typical Mt Crosby gauge records (a) prior to 1953 and (b) after 1953

4.2.2 Historical flood peak level data

In addition to continuous gauge records, the Bureau of Meteorology has compiled a summary of peak levels for most of the major gauges in the Brisbane River catchment. Where good quality continuous gauge record data is available, the peak level data is usually consistent with the continuous record (as shown in Figure 4-1b. For older records, the peak level data is relatively consistent but sometimes higher than the gauge record data, as demonstrated in Figure 4-1a. At a number of gauges the BoM peak level data record contains data from outside the available continuous data record, as well as flood marks for historical events.

A limitation of the peak level data is that it is not necessarily a complete or homogenous record. Usually only the larger floods have been identified, with no floods recorded in many years (which are theoretically required for an annual series analysis). There is also no record of the threshold below which floods are omitted, and it may not be consistent across the record. A second limitation of the peak level data is dynamic effects (hysteresis) cannot be accounted for from a single point. This is usually minimal, but can be present for flood events with a short, sharp flood peak in the lower Brisbane River (typically <5%).

4.2.3 URBS hydrologic modelling

URBS is a hydrologic routing tool developed primarily for flood forecasting and design flood hydrology, and can be used for generating flows from recorded historical rainfall. URBS has multiple calibration parameters – the storage lag parameters (alpha and beta), catchment non-linearity parameter (m) and the initial and continuing rainfall loss parameters. Due to the number of variable parameters, URBS must be calibrated against recorded flows to provide confidence in magnitude of the flow. Provided that the model has been calibrated, it can potentially provide useful flow information at gauges where no stream gauge data was recorded.

Seqwater has identified and prepared rainfall data for 38 flood events between 1955 and 2013, and an additional 10 historical events prior to 1955 dating back to 1887. Implementation of the URBS model results into the historic flood sequence has limitations and must be undertaken with care, particularly for smaller gauge locations in the upper catchment.

- The modelled flood events were selected based on their impact on flooding in the Lower Brisbane River. Since lower-Brisbane floods may result from rainfall concentrated in only part of the catchment, they do not necessarily represent a consistent or homogeneous data set in all parts of the catchment as major local rainfall events and floods may not have been identified
- It is not a complete annual record with many years not having modelled events, and the consistency of the threshold below which no data is available may not be consistent across the historical record
- The quality of the available data is not consistent, with many of the older rainfall data consisting primarily of daily rainfall records. This is especially important for analysing smaller catchments, which may have a critical storm duration of less than a day and therefore be strongly influenced by the rainfall temporal pattern (or lack thereof)

Despite these limitations, the URBS model is currently the only available method to model pre- and post-dam conditions and therefore assess dam influence.

4.2.4 Combined record adopted for analysis

Considering the strengths and limitations of each of the data sets discussed above, the available data sources have been combined to produce a single historical flood record then adopted for flood frequency analysis using the priorities summarised in Table 4-1 on the basis that:

- Prior to around 1955 (dependent on gauge), peak flow data is preferred to continuous data due to the limited frequency of recording evident in the gauge record. URBS data is implemented in the record with caution
- After 1955, continuous record is preferred as this allows inspection of continuity of the record to identify outliers and also potential correction for hysteresis where dynamic effects are present
- Where dam influence has a minor effect on the flood record, the peak flow without dams has been estimated by multiplying the rated flow at the gauge by a scaling factor, f, defined as the ratio between the URBS model flows without and with dams (Equation 2)
- Where dam influence has a major effect on the flood record, the peak flow without dams has been taken directly from the URBS model (Equation 1)

Minor and major effect on the flood record has been based on an arbitrarily threshold of whether the dams reduce the peak flow at a gauge by less or greater than 25%. This methodology for accounting for dam influence has been adopted to minimise dependence of the flow estimates on the reliability of the rainfall data and assumption of losses. It is acknowledged that gauge levels and ratings are also not perfectly reliable, however the hydrologic model should ideally be calibrated to the gauge rating. If the hydrologic model is well calibrated then the gauge and URBS model (with dams) flows should be virtually identical and using the direct URBS model data or a ratio will have negligible difference.

The scaling factor is individually calculated for each event for which URBS modelling is available. An average ratio has been used for other events where specific modelling is not available. The URBS modelling has identified the majority of significant flood events affecting the lower Brisbane River, particularly since 1983 when Wivenhoe has a significant influence on river flows. The average ratio is therefore typically only applied to minor flows. Low flows are generally filtered from the lower tail of the record, and assumptions related to the average ratio will therefore have minimal influence on the results of the flood frequency analysis.

Table 4-1 Combined record data priority

Priority	Pre-1950s	Post-1950s (No Dams)	Minor Dam Influence (1/*f* > 0.75)	Major Dam Influence (1/*f* < 0.75)
1	Peak Level	Continuous	Continuous × Factor	URBS (No Dams)
2	Continuous	Peak Level	Peak × Factor	Continuous × Factor
3	URBS (No Dams)	URBS (No Dams)	URBS (No Dams)	Peak × Factor

4.3 Extension of gauge records

Fitting of a flood frequency distribution to flood records is based on the assumption and consequently requirement that the data provides a homogeneous and statistically representative data sample. As the available data comes from a variety of sources and methods, the available data sample is not necessarily homogeneous. Figure 4-2(a) shows a typical data sample containing a well-populated period of recorded data (eg from continuous gauge records, typically available since the mid-1950s) supplemented by a more sparsely populated period of record (eg from water level records kept only for large floods above some arbitrary threshold). This historical data potentially provides a useful extension of the period of record, however the non-homogeneous nature of the combined record means that basic mathematical fitting methods cannot be applied.

Bayesian fitting methods, such as those implemented by FLIKE, provide a number of methods for including additional historical or censored data into a data record. Data can be included either as a given value or as an unknown value above or below a given threshold. This gives several methods for combining the additional historical record with the continuous data sample, illustrated in Figure 4-2:

Method 1 – Censoring of low flow data

All data below a given threshold, including both low-flow data from the continuous data sample and missing data from the additional historical data, is censored with the threshold adjusted upwards until there can be reasonable confidence that none of the missing data would have been above the flood threshold. The flood frequency analysis is therefore performed only using the largest data events.

Information from nearby stream gauges and/or representative rainfall stations in the catchment can be used to assist in setting the threshold by determining whether the catchment would likely have produced floods in excess of the threshold within the years with missing data, however depending on the density of samples in the historical record and threshold below which no data is available, a large proportion of the continuous data sample may potentially be excluded. This places a heavy emphasis on the accuracy of the estimates of the large flood events, which are usually derived from the least reliable part of the flow rating, and on the statistical representativeness of a limited number of events.

Method 2 – Correlation to nearby gauges

Flood data in missing years can sometimes be estimated by correlation of flood records at the site with flood data available in neighbouring sites or catchments that have closely related flood characteristics. The quality of the flow estimate is dependent on the strength of the correlation between the sites and this method therefore becomes less desirable as the correlation decreases or the dependence on the estimated flow magnitude increases.

Method 3 – Censoring of incomplete record low-flow data

The disadvantage of Method 1 is that a large part of the continuous record is potentially omitted, creating a heavy reliance on what is usually the least reliable range of the flood record. The Bayesian fitting method implemented in FLIKE allows the large events in the incomplete record to be combined with the continuous record and the rest of the incomplete record included as unknown values below a threshold.

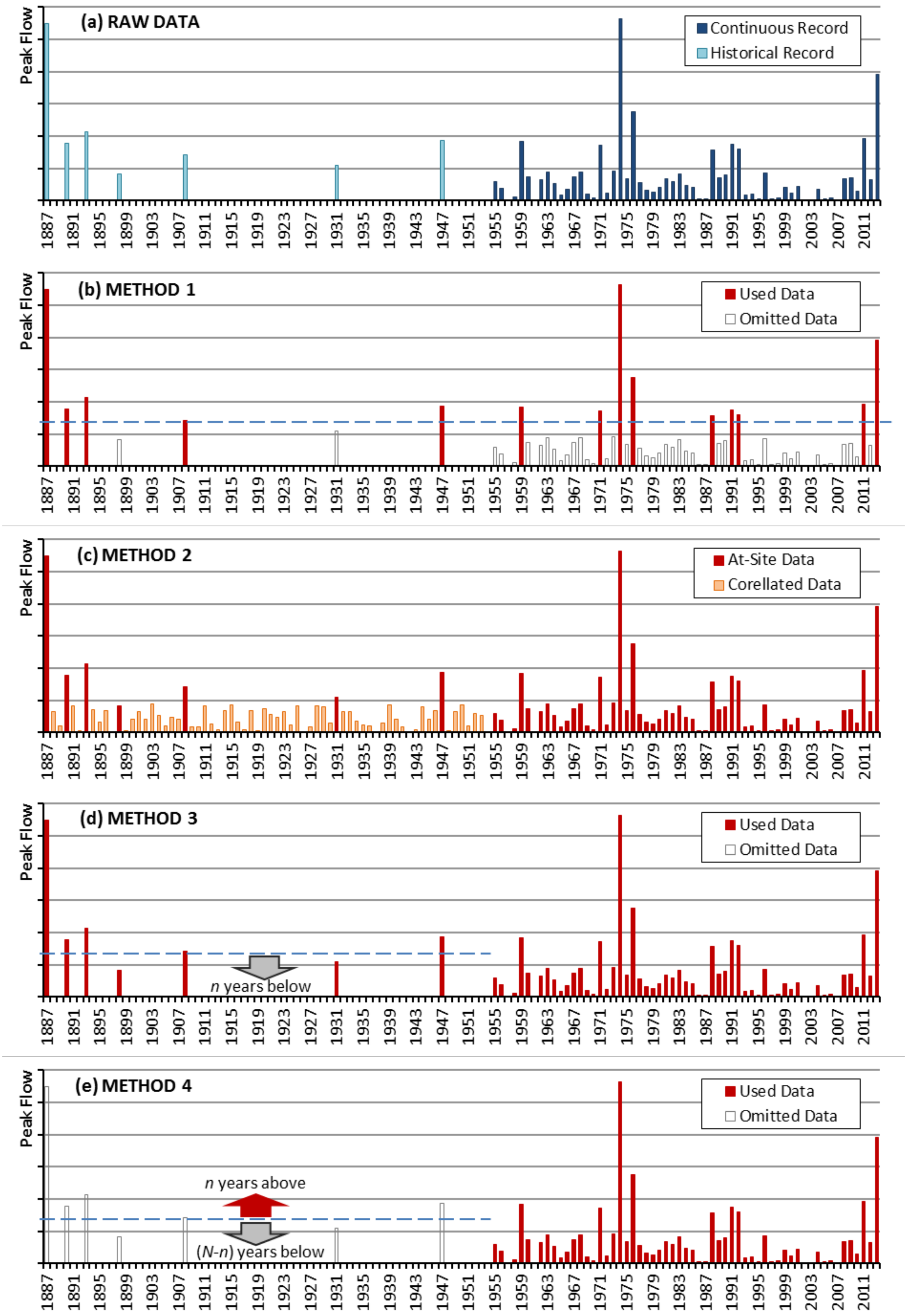

Figure 4-2 Methods of extending data record using historical data

Method 4 – Inclusion of incomplete record as censored data

Censored data consists solely of the number of floods above or below the threshold discharge. The largest records in the period of incomplete record can be treated as events that exceeded an appropriately selected upper threshold. This method is particularly useful if the exact magnitude of the historical events is less reliable or even unknown.

4.4 Filtering of gauge records and treatment of poor fits

Flood frequency analysis assumes that the available data fits a standard probability model, however an acceptable fit is not always obtained. Numerous factors can lead to a poor fit, including:

- Presence of outliers – because gauge data is a random sample, it is to be expected that some of the data samples will exhibit a poor fit of the selected probability model. The sample may contain one or more observed floods that are unusually rare (compared to the period of record) or conversely the record may not contain as many significant events as would be statistically expected. Outliers may also be observed
- Rating or measurement error – systematic or non-systematic discrepancy between the calculated and actual flows can result from a variety of causes including error in extension of the rating curve, changes in the rating over time
- Non-standard flood frequency distribution – the basic assumption that the flood frequency distribution fits a recognised standard three-parameter distribution may be flawed. Changes in the hydraulic properties (conveyance, storages, bypasses etc.) may affect the river or floodplain behaviour and consequently the shape of the frequency curve, or different meteorological mechanisms (eg convective storms vs tropical cyclones) may result in a mixed population that does not satisfy a standard three-parameter distribution

Goodness-of-fit can be assessed by:

- Comparing the recorded data against the fitted probability model and its confidence limits
- Comparing the characteristics of the fitted probability model with those of surrounding catchments or catchments where similar flow properties would be expected (ie regional comparison)
- Observing the influence of the upper and lower tail distributed data on the shape of the fitted probability model

Where outliers are observed in the upper or lower tail of the data, they can potentially be censored and replaced as undetermined values below or above a given threshold. This method is frequently applied if a data sample contains zero or low-flow values that significantly affect the fit of the probability model. Selection of a censor threshold is often done ‘by eye’ and is therefore reliant on the experience and opinion of the modeller. Numerical methods such as the Multiple Grubbs-Beck test (Lamontagne et al 2013) can be used to identify low outliers, although the method should be confirmed as producing a rational result. Where high outliers appear to be present, review of rainfall data or other records may provide justification for adoption of a high outlier threshold.

Systematic discrepancies are potentially more difficult to address. Review of gauge ratings, rainfall data or other available data may be able to identify a realistic explanation for the observed characteristics. In some circumstances a standard probability distribution may not be appropriate.

4.5 Gauge selection criteria

Reliable flood frequency analysis requires three criteria to be satisfied:

- The site must have a reasonable period of uninterrupted record, with the amount of confidence in the statistical analysis increasing with the length of the sample period
- The record must be homogeneous. It must consistently identify all floods (above a certain magnitude, see Sections 4.3 and 4.4) within the period of record, and if parts of the record are influenced by dams or other changes in catchment properties then this influence must be removed
- The flow estimates must themselves be reliable through the use of a reliable rating curve or other flow estimation method

Table 4-2 summarises how each of the selected FFA sites satisfy these criteria, identifying the suitability of the site for conducting a reliability analysis.

Table 4-2 Gauge suitability for flood frequency analysis

Catchment	Gauge	Period of Record	Homogeneous Data	Reliable Rating	Suitability for FFA
Stanley	Peachester	✓	✓	?	Limited
	Woodford	✓	✓	✓	Good
	Somerset	✓	?	✓	Limited
	Silverton	✓	×	?	Limited
Upper Brisbane	Cooyar Creek	✓	✓	?	Limited
	Linville	✓	✓	✓	Good
	Gregors Creek	✓	✓	✓	Good
	Tinton	?	×	×	Poor
	Fulham Vale	?	✓	?	Limited
	Watts Bridge	×	×	?	Poor
	Caboonbah	✓	×	?	Limited
	Middle Ck	?	×	?	Partial
	Wivenhoe	×	×	✓	Limited
Lockyer	Helidon	✓	✓	?	Limited
	Gatton	✓	✓	?	Limited
	Glenore Grove	✓	✓	✓	Good
	Rifle Range Rd	✓	✓	?	Partial
Bremer	Rosewood	✓	✓	?	Limited
	Walloon	✓	✓	✓	Good
	Ipswich	✓	×	×	Poor
Warrill	Kalbar Weir	✓	×	×	Poor
	Amberley	✓	×	✓	Good
Purga	Loamside	✓	✓	✓	Good

Catchment	Gauge	Period of Record	Homogeneous Data	Reliable Rating	Suitability for FFA
Lower	Savages Cr	✓	×	✓	Good
	Mt Crosby	✓	×	✓	Good
	Moggill	✓	×	✓	Good
	Centenary	×	×	✓	Poor
	City	✓	×	?	Limited

4.6 Initial at-site gauge assessment

Independent at-site flood frequency assessment was undertaken for ten primary gauge locations considered to have reliable gauge and rating information. These locations correlate to the sites at which independent hydraulic modelling was undertaken during the rating curve review process. This section presents results of the initial independent flood frequency analysis. Reassessment using catchment weighted parameters is discussed in Section 4.8. Adopted and censored data, censor thresholds and fit parameters have been provided in Appendix A.

4.6.1 Stanley River at Woodford

Woodford is located in the upper Stanley River catchment, gauging approximately 20% of the total catchment down to Somerset. Independent review and hydraulic modelling of the gauge site indicates that the control weir downstream of the gauge is submerged for flows greater than 20 m³/s to 50 m³/s, with the gauge level becoming dependent on the combined flows of the Stanley River and Monkeybong Creek, which merge just downstream of the weir. Since most of the peak flows are above this threshold, the reported gauge flows and resulting flood frequency analysis are for the combined river flow downstream of the gauge. The availability of gauge data is summarised in Table 4-3. The stream gauge has a long historical record, although continuous gauge data is only available since 2003. The annual peak flow record, shown in Figure 4-3, appears relatively consistent although the record prior to 1908 appears to lack low to moderate flows (nominally < 500 m³/s).

Flood frequency analysis was conducted using the full 127 years of record. 45 years of this data are either missing or zero, and multiple Grubbs Beck censoring of low flow data excluded a further 19 floods below 160 m³/s, leaving approximately half the data record. A higher threshold of 590 m³/s was adopted for the period between 1887 and 1908, as the gauge record does not appear to have identified minor flows during this period. Analysis was conducted for both the Log Pearson III and GEV distributions and both fit the data sample reasonably well, as shown in Figure 4-4.

4.6.2 Upper Brisbane River at Linville

Linville is located in the upper Brisbane Catchment between Cooyar Creek and Gregors Creek. The gauge rating review has treated Linville as a primary site with independent hydraulic modelling to confirm the gauge rating. The site has continuous gauge data recorded since 1965 giving 49 years of consistent record. The availability of gauge data is presented in Table 4-4 and the available annual peak record is shown in Figure 4-5. Multiple Grubbs Beck censoring did not remove any of the data, which may not be optimal and the automatic censoring method could possibly be affected by high-flow data discussed below. Eight low values below 20 m³/s were manually censored from the data.

Limited information on historical events is available from URBS hydraulic modelling. The selection of events for the URBS modelling focussed on known lower Brisbane River floods, and review of the flood record in Figure 4-5 suggests that these events do not necessarily represent either a statistically consistent sample or events of high significance. Given this uncertainty and the relatively low reliability of the modelled flows, inclusion in statistical analysis is not considered justifiable.

Table 4-3 Gauge record history for Stanley River at Woodford

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	2003 – 2013	11	11	0
Peak Gauge	1890 – 2013	123	72	51
Combined	1887 – 2013	127	82	45

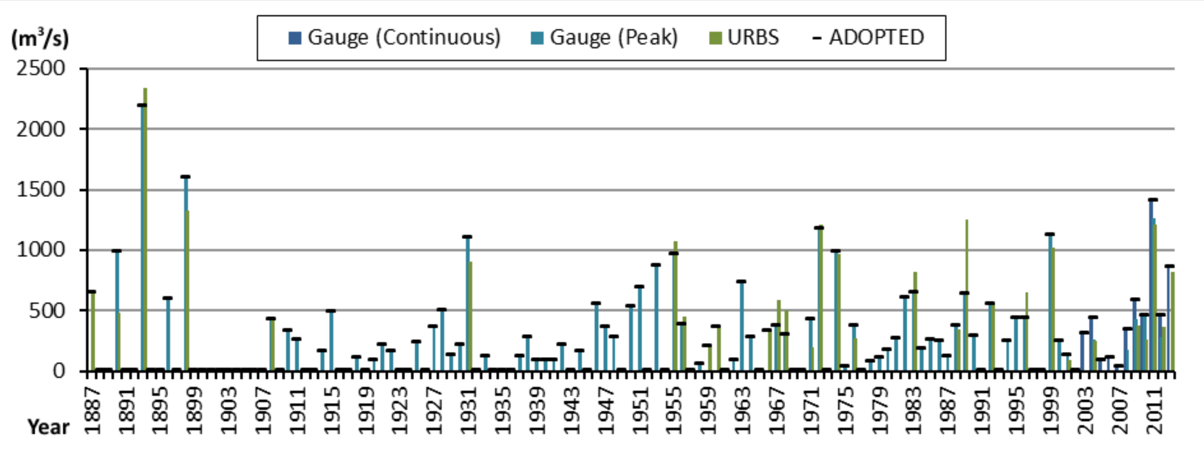

Figure 4-3 Annual peak flow record for Stanley River at Woodford

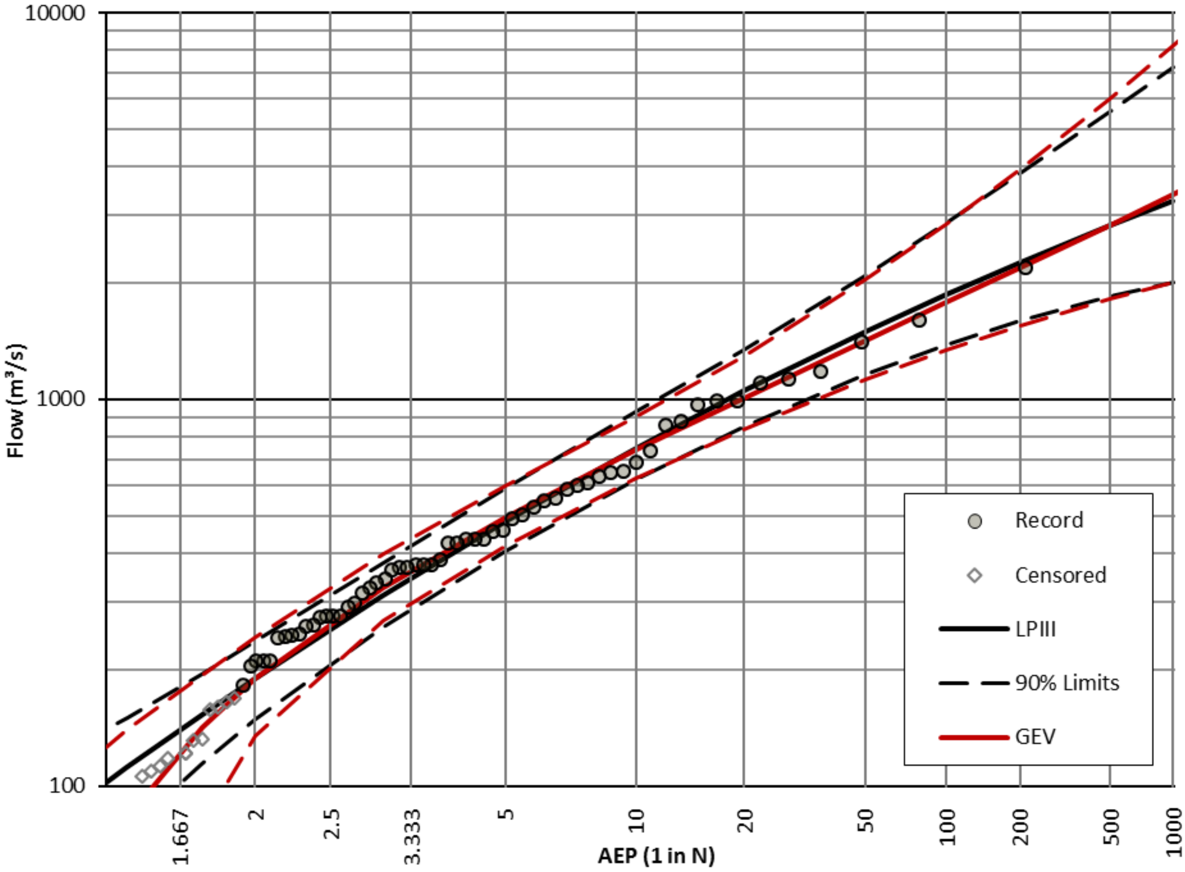

Figure 4-4 At-site flood frequency analysis at Woodford

Flood frequency analysis was initially conducted using the only the stream gauge data. Analysis was conducted for both the Log Pearson III and GEV distributions, shown in Figure 4-6, with the Log-Pearson III distribution visually having a reasonable fit but the GEV distribution having a significant positive skew that produces unrealistically high flows for large floods. An unusual phenomenon of the data record, evident in Figure 4-6, is that there have been 7 floods with rated flows between 1,600 and 4,000 m³/s, but none above that range and only one flow between 600 and 1600 m³/s, giving the upper tail of the data a distinct S-bend that appears to have a significant influence on the curve. This trend could be produced by numerous influences including:

- Issues with the stream gauge or gauge rating
- Floodplain flow or bypass characteristics
- Catchment shape or response
- Mixed rainfall mechanisms (eg convective storms vs east-coast lows)

Issues with the gauge rating and local stream characteristics are considered unlikely as the gauge is understood to be a reliable site and independent hydraulic modelling was conducted to derive the rating. Additionally, the downstream site at Gregors Creek exhibits exactly the same phenomenon with a completely independent gauge record and rating. Although rainfall mechanisms and catchment properties cannot be ruled out, the pattern may simply be a random sample. This influence of the upper tail on the frequency curve was investigated by using FLIKE's Bayesian fitting methods to include the larger floods as 'historical' data of significant but undefined flowrate. The resulting probability fit based on the remaining mid-range flood events, exhibits more pronounced curvature.

4.6.3 Upper Brisbane River at Gregors Creek

Gregors Creek is located in the upper Brisbane Catchment between Linville and Wivenhoe Dam. The gauge rating review has treated Gregors Creek as a secondary site, however the availability of stream gauging, modelling undertaken by DNRM and the presence of validation points at Linville upstream and Wivenhoe downstream give reasonable confidence in the rating. The site has a similar flood history to Linville, with continuous gauge data recorded since 1963 giving 51 years consistent record. The availability of gauge data is presented in Table 4-5 and the available annual peak record is shown in Figure 4-7. Multiple Grubbs Beck censoring removed only one low flow, which may not be optimal and the automatic censoring method could possibly be affected by high-flow data discussed below. Eight low values below 44 m³/s were manually censored from the data.

A historical flood level at the site is available at the site for one of the 1893 floods (date not specified). This is identified as a "flood mark" and the reliability of the level and rating at this level make the estimated flow unreliable. The rated flow is significantly higher than the flow predicted by URBS modelling however this is also not reliable due to reliance on daily rainfall data so the exact magnitude of this flood event is uncertain. Inclusion of this event as an historical event of undefined magnitude tends to produce slightly lower flows, but has negligible impact once regional parameters are introduced (see Section 4.8). As with Linville, the remaining historical floods available from the URBS modelling do not necessarily represent either a statistically consistent sample or events of high significance and inclusion in the statistical analysis is not considered justifiable.

Flood frequency analysis was conducted using the only the stream gauge data. Analysis was conducted for both the Log Pearson III and GEV distributions, shown in Figure 4-8. As with Linville, the Log-Pearson III distribution visually has a good fit while the GEV distribution demonstrates a significant positive skew that produces unrealistically high flows for large floods. Gregors Creek displays the same phenomenon of the data record that is present in the Linville record with 7 floods with rated flows between 3,000 and 6,200 m³/s, but none above that range and only one flow between 1,200 and 3,000 m³/s (see discussion in Section 4.6.2).

Table 4-4 Gauge record history for the upper Brisbane River at Linville

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1965 – 2013	49	49	0
Peak Gauge	1966 – 2012	47	21	26
Combined	1887 – 2013	127	60	67

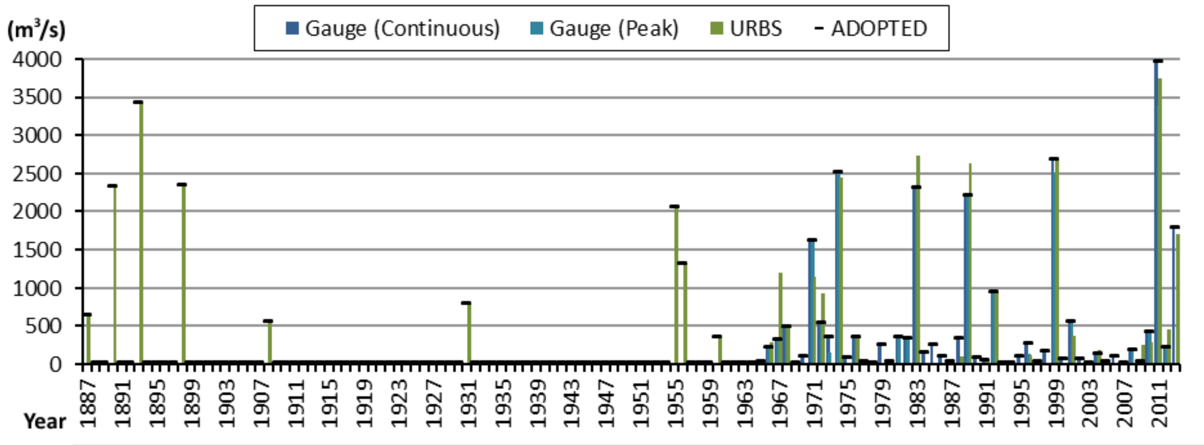

Figure 4-5 Annual peak flow record for the upper Brisbane River at Linville

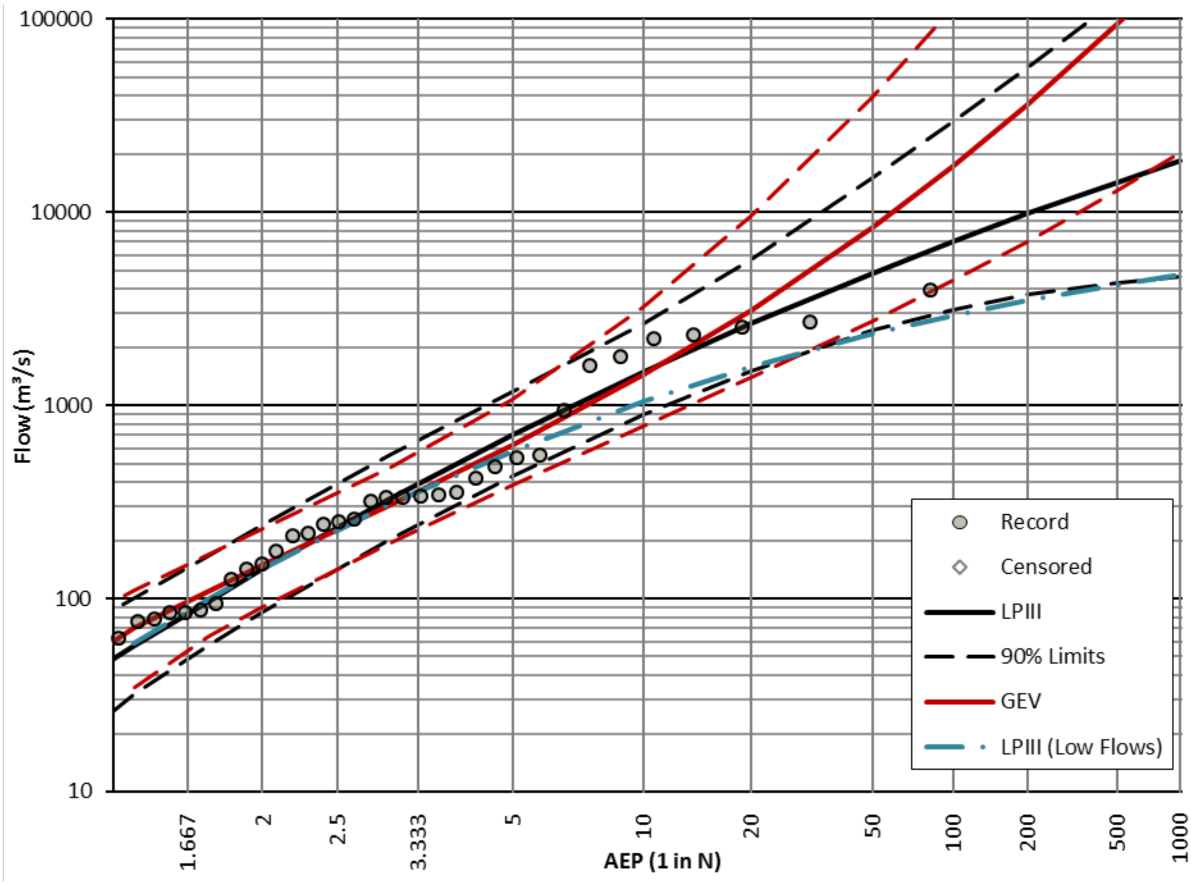

Figure 4-6 At-site flood frequency analysis at Linville

Table 4-5 Gauge record history for the upper Brisbane River at Gregors Creek

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1963 – 2013	51	49	0
Peak Gauge	1966 – 2012	49	19	30
Combined	1887 – 2013	127	62	65

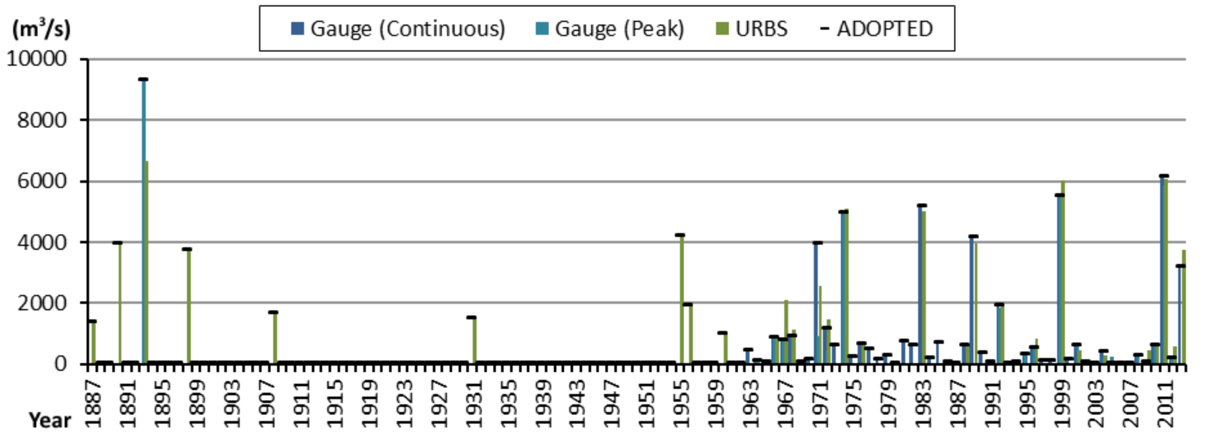

Figure 4-7 Annual peak flow record for the upper Brisbane River at Gregors Creek

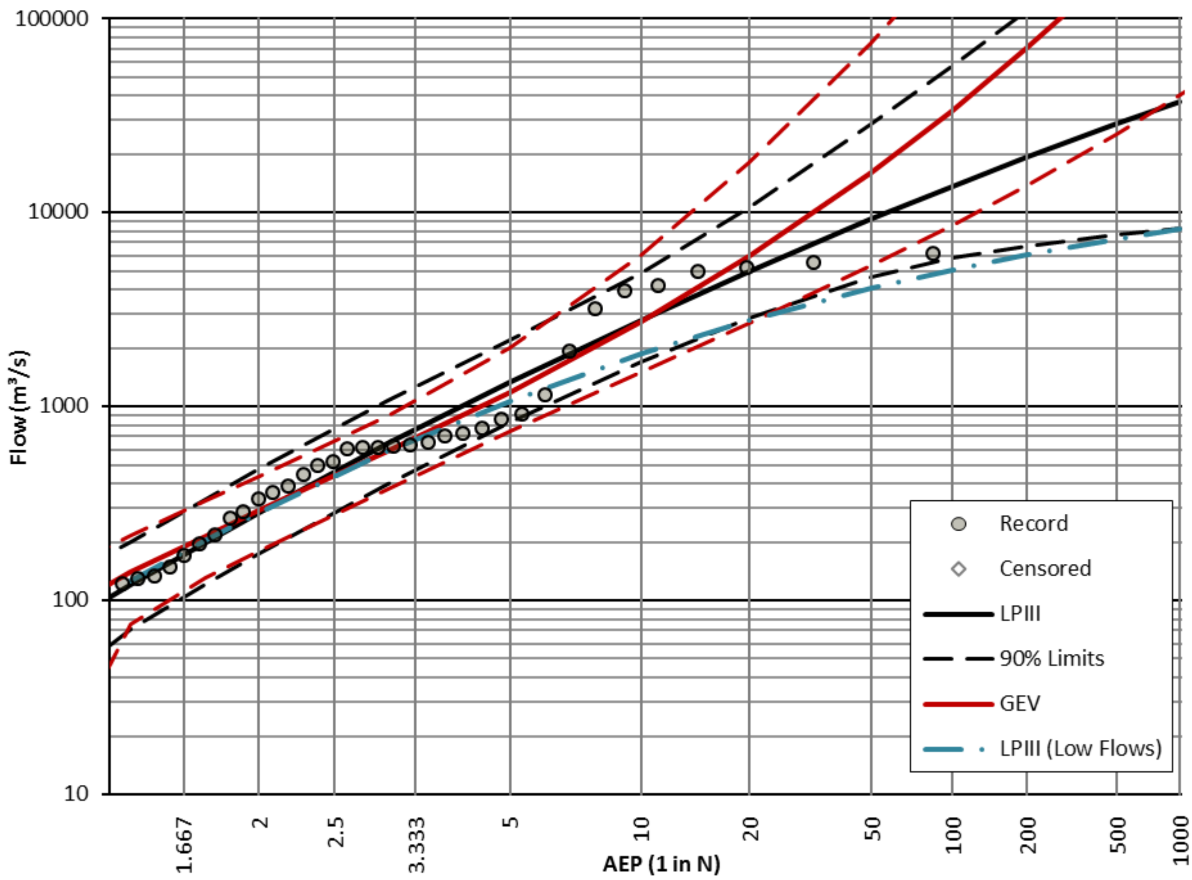

Figure 4-8 At site flood frequency analysis at Gregors Creek

As with Linville, these flows have a significant influence on the frequency curve, which was investigated by using FLIKE's Bayesian fitting methods to include the larger floods as 'historical' data of significant but undefined flowrate. The resulting frequency curve based on the remaining mid-range flood events, exhibits more pronounced curvature.

4.6.4 Lockyer Creek at Glenore Grove

Glenore Grove is located in the mid Lockyer Creek catchment at the junction of Lockyer and Laidley Creeks, gauging approximately 73% of the total catchment down to O'Reilly's Weir. The site is located at a key location where significant breakout occurs during large flood events. The main channel has a maximum capacity of less than 1,000 m³/s, with almost all additional flow spilling into the floodplain. In the lower Lockyer floodplain, perched channel blanks limit interaction between floodplain and main channel flows rendering gauges downstream of Glenore Grove incapable of recording the full flow. Because of this, the rating curve review identified Glenore Grove as a key site for measuring Lockyer Creek flows, with independent hydraulic modelling undertaken to determine the rating. The flow rating becomes very sensitive and high flows will have a high degree of uncertainty.

The availability of gauge data at Glenore Grove is summarised in Table 4-6 and the available annual peak record is shown in Figure 4-9. Peak level data is available at the gauge site since 1955, although nearly half of the years do not contain a recorded flood peak. This overlaps consistently with the URBS model data, which provided an additional 4 years of data for which no gauge level was available. Continuous gauge data is available since 1995, however the data contained significant errors and discontinuities. The continuous gauge data was therefore considered unreliable and not used. URBS modelling is available for a limited number of historical floods prior to 1955, however these do not appear to be particularly significant floods at Glenore Grove and are not necessarily a statistically consistent sample. Given this uncertainty and the relatively low reliability of the modelled flows, inclusion in statistical analysis is not considered justifiable.

Flood frequency analysis was conducted using the 59 years of record from 1955 to 2013. 23 years of this data are either missing or zero, and multiple Grubbs Beck censoring of low flow data excluded three further events, leaving approximately 55% of the data record. Analysis was conducted for both the Log Pearson III and GEV distributions, and Figure 4-10 shows that both fit the data sample reasonably well up to about 1 in 20 AEP, above which they begin to deviate significantly.

4.6.5 Bremer River at Walloon/Rosewood

Walloon is located on the Bremer River upstream of Ipswich and upstream of the junction with Warrill and Purga Creeks. The availability of gauge data at Walloon is summarised in Table 4-7 and the available annual peak record is shown in Figure 4-12. The Walloon gauge has a reasonable record length with 52 years of continuous gauge data available since 1962. Comparison of the pre-1955 URBS model flows with the post-1955 gauge record suggests that the modelled storm events (including 1893) are not particularly significant events in the Bremer River catchment. Inclusion as a historical data set is not recommended. Flood frequency analysis was conducted using the Walloon gauge data only. Multiple Grubbs Beck censoring of low flow data excluded 15 years where negligible flow was recorded, leaving 37 years of the data record.

Analysis was conducted for both the Log Pearson III and GEV distributions, and both appear to fit the data sample reasonably although they deviate noticeably above 1 in 100 AEP, as shown in Figure 4-13. Initial analysis identified that the two largest flood events (1974 and 2011) were having a significant effect on the flood frequency distribution. Review of recent TUFLOW modelling conducted by Brisbane City Council on behalf of DSDIP suggests that the Walloon gauge may be affected by backwater from Warrill Creek and the Brisbane River during major events. Additionally, the stream gauge did not record the 1974 flood event, the level for which is indicated in records as a 'flood mark'.

Table 4-6 Gauge record history for Lockyer Creek at Glenore Grove

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1995 – 2013	19	19	0
Peak Gauge	1955 – 2011	57	32	25
Combined	1887 – 2013	127	84	43

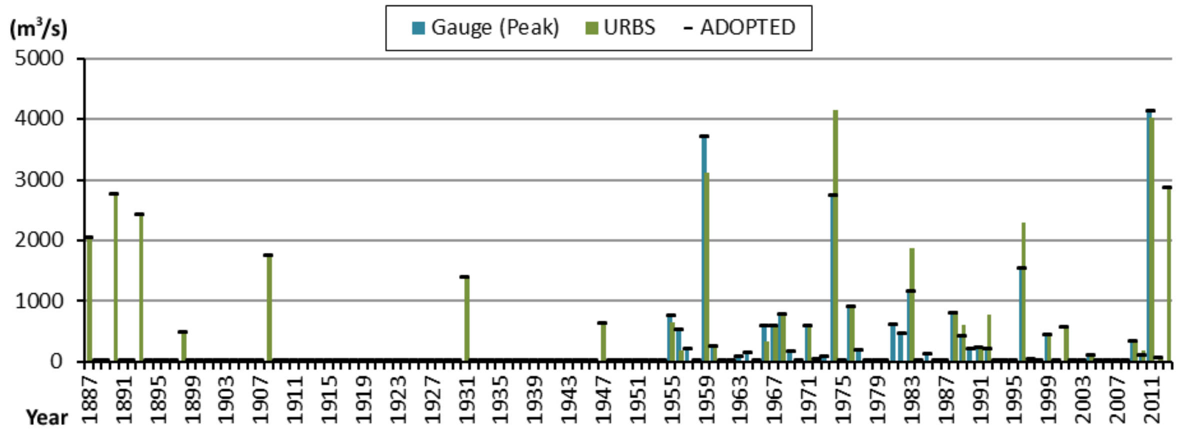

Figure 4-9 Annual peak flow record for Lockyer Creek at Glenore Grove

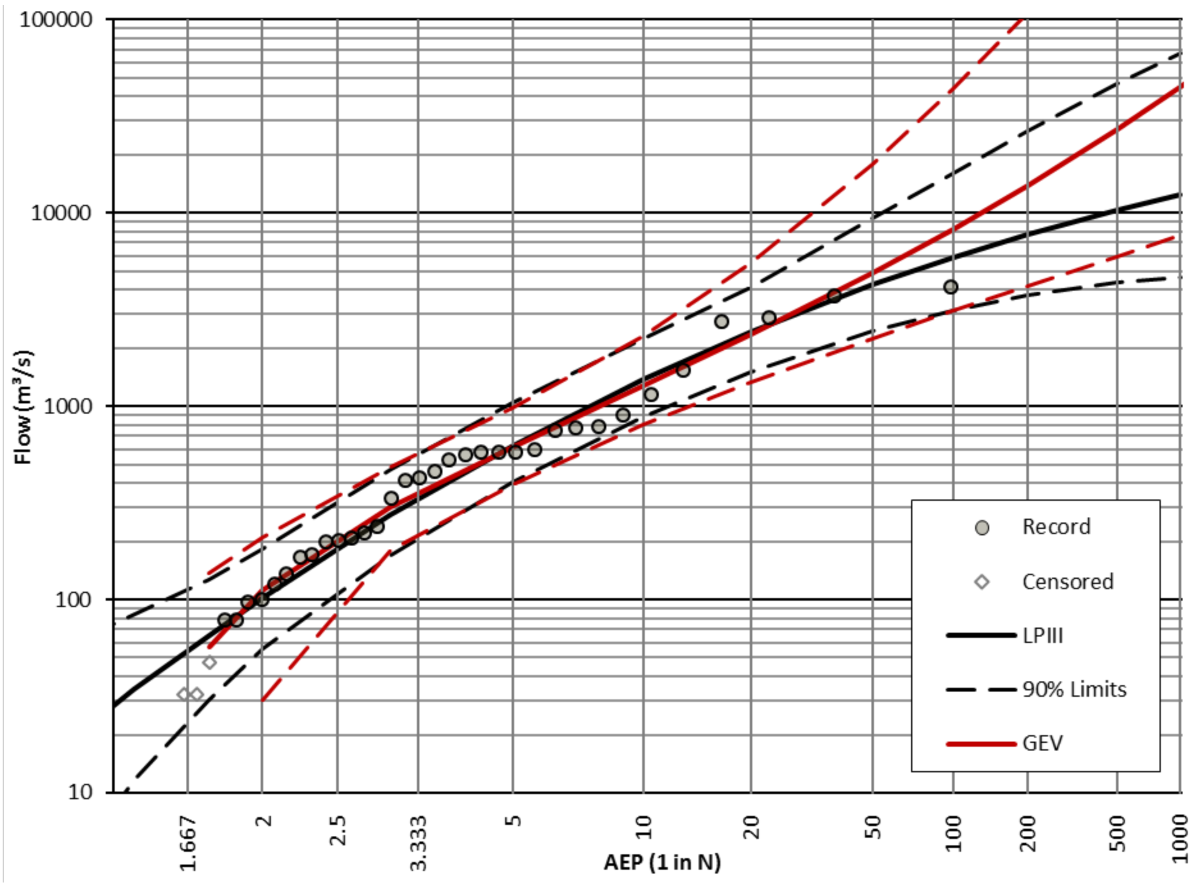

Figure 4-10 At site flood frequency analysis at Glenore Grove

Exaggerating these uncertainties in water level is that the gauge rating is also highly sensitive at high flood levels, with large changes in flow resulting from small changes in level. Due to the uncertainty regarding the flows for these events, they were included as undefined events above a threshold. Using the URBS model flows instead of undefined flows produced a similar curve with slightly less curvature (ie slightly higher flows for low AEP events) however the URBS model flows may themselves be overestimated as the calibration is influenced by the recorded gauge levels/flows). Comparison and/or inclusion of the Rosewood gauge and regional weighting (see Section 4.8) help improve confidence in the Walloon analysis.

The Bremer River gauge at Rosewood is situated in relatively close proximity to Walloon, located approximately 13 km upstream and sharing 85% of the catchment. Rosewood has a longer gauge history dating back to 1898, however the period prior to the 1920s appears to be inconsistently populated (Figure 4-12). The gauge has no official rating. Comparison of the overlapping period record allowed a correlation between the peak levels at the Rosewood and Walloon gauges to be developed, shown in Figure 4-11. This correlation was used to extend the Walloon record back to 1922 adding another 40 years of record. This period includes several large flood events, shown in Figure 4-14, serving to illustrate that the pre-1955 URBS modelling does not consistently identify all large floods, particularly when investigating the smaller Brisbane River tributaries. The correlation was also used to derive an independent estimate of the flows for the 1974 and 2011 events.

As shown in Figure 4-15, the frequency curve based on the combined record is relatively consistent with the curve based only on the at-site Walloon data. The difference is further reduced once catchment weighted skew parameters are applied (see Section 4.8), making it debatable whether benefit of the increased record length outweighs the uncertainty of the translation of levels from Rosewood to Walloon.

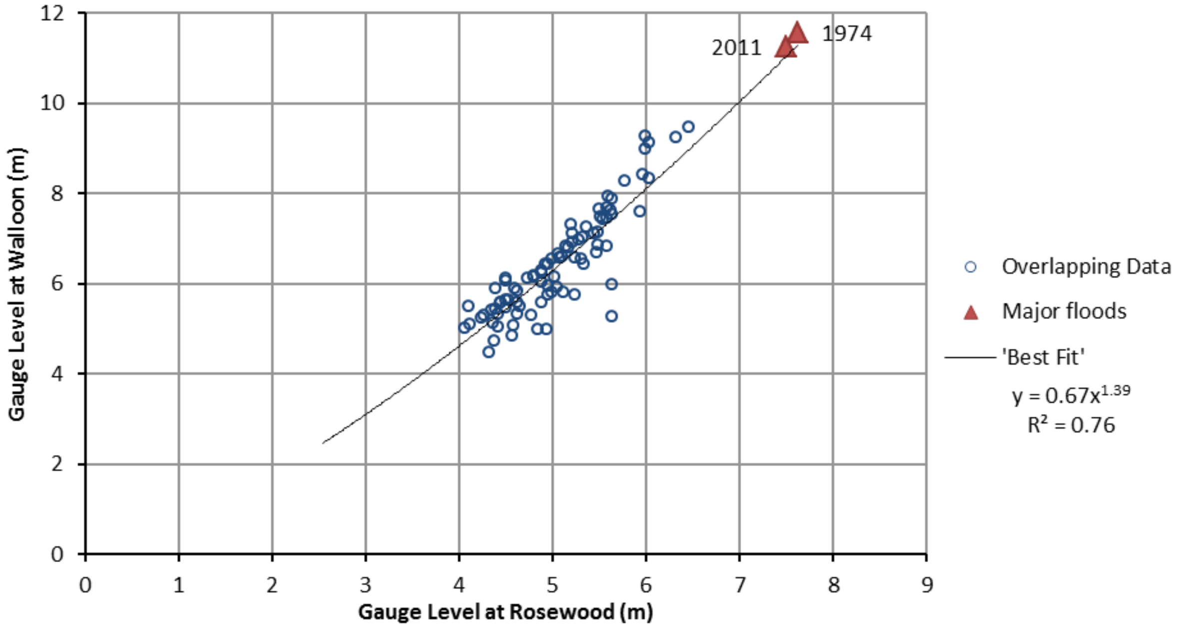

Figure 4-11 Correlation between Rosewood and Walloon gauge levels

Table 4-7 Gauge record history for the Bremer River at Walloon

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1962 – 2013	52	52	0
Peak Gauge	1898 – 2012	115	68	47
Combined	1887 – 2013	127	86	41

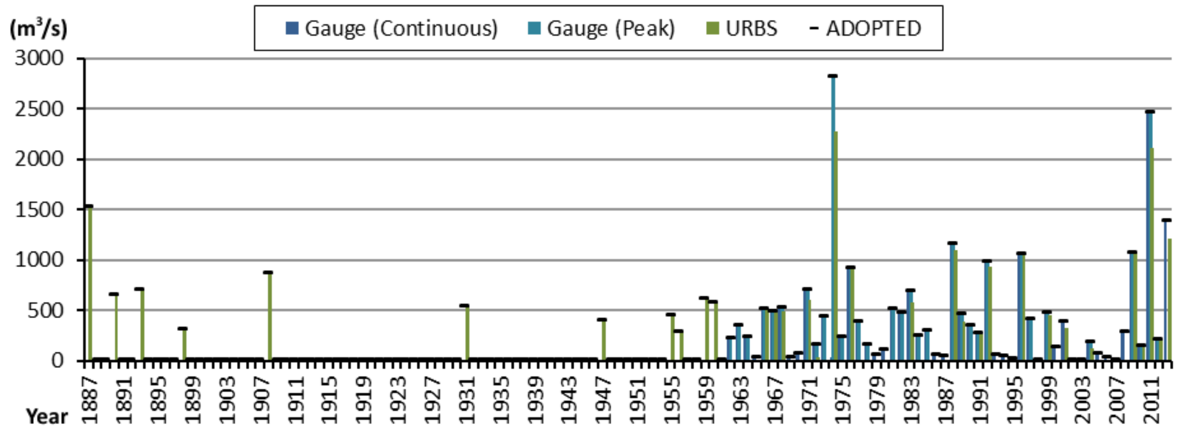

Figure 4-12 Annual peak flow record for the Bremer River at Walloon

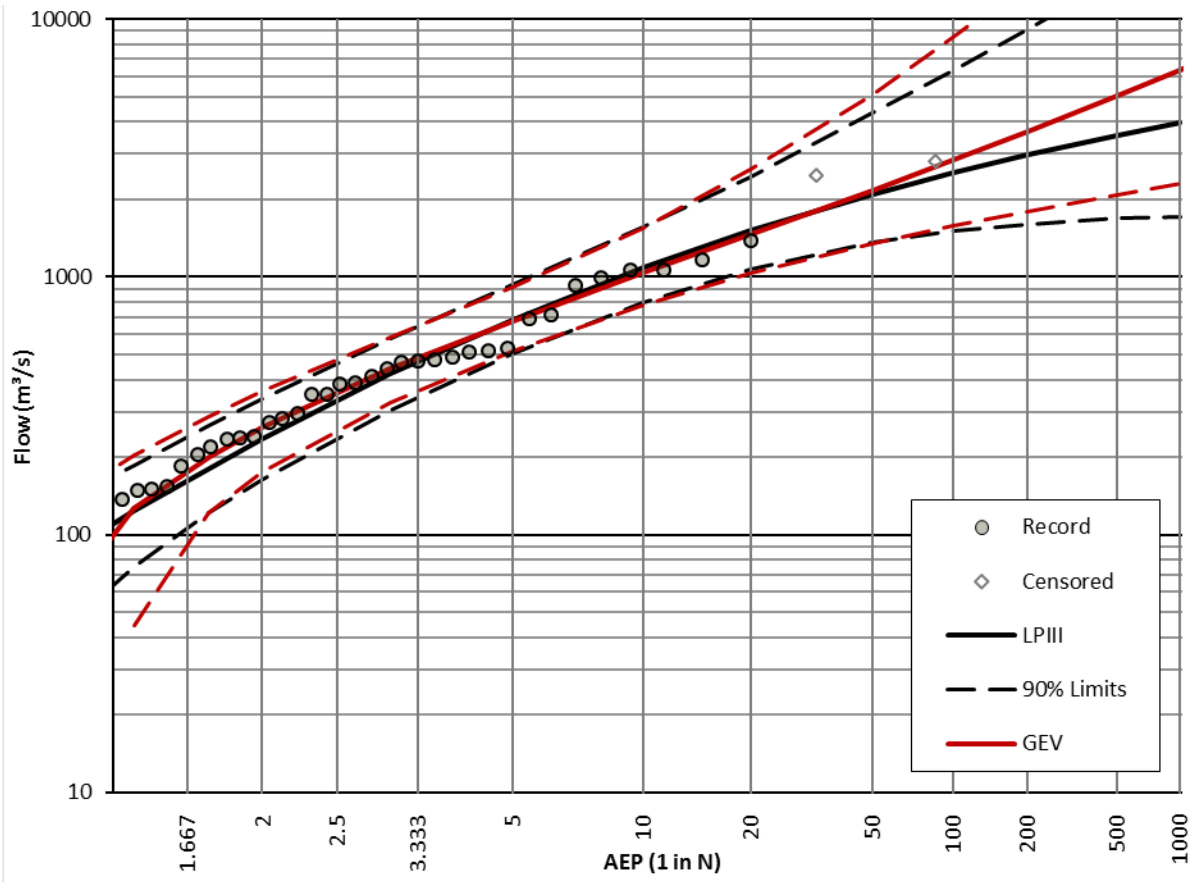

Figure 4-13 At-site flood frequency analysis at Walloon

Table 4-8 Gauge record history for the Bremer River at Walloon extended using Rosewood

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1962 – 2013	52	52	0
Peak Gauge	1962 – 2012	51	32	19
Combined	1887 – 2013	127	63	64

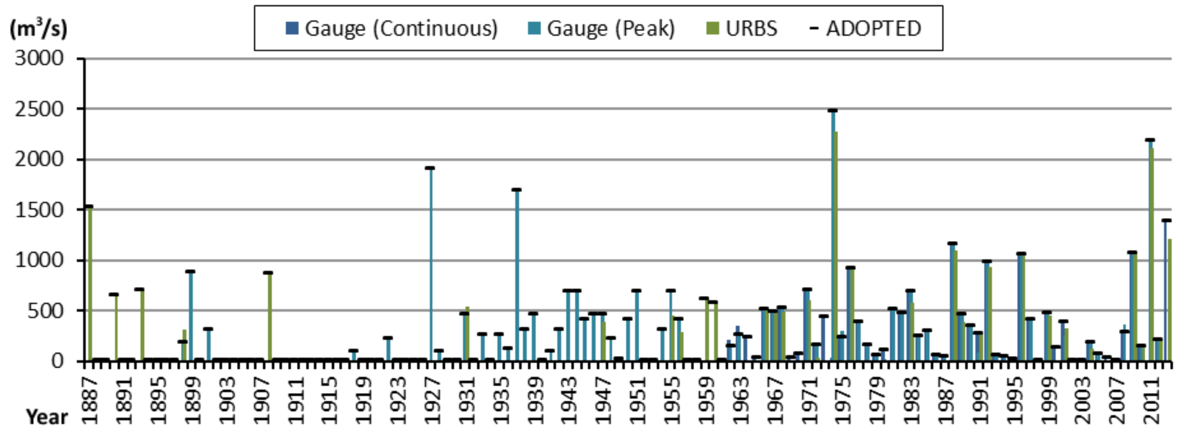

Figure 4-14 Annual peak flow record for the Bremer River at Walloon extended using Rosewood

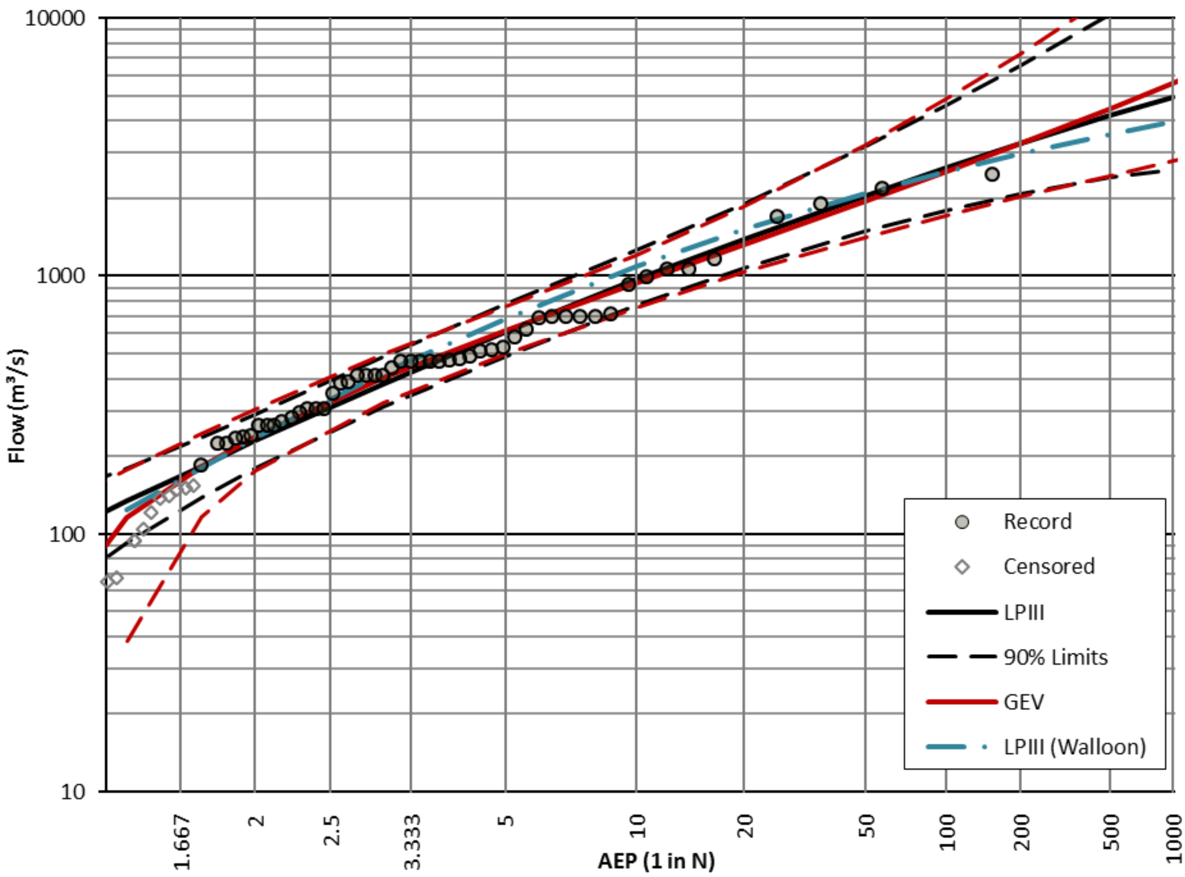

Figure 4-15 At-site flood frequency analysis at Walloon extended using Rosewood

4.6.6 Warrill Creek at Amberley

Amberley is located on Warrill Creek upstream of Ipswich and upstream of the junction with Purga Creek. Moogerah Dam is located in the upper catchment, so URBS modelling has been used to estimate and remove the influence of the dam from the gauge records. Additionally, the gauge rating becomes very sensitive during large flood events as flows break out of the Warrill Creek channel and bypass the gauge site into the adjacent Purga Creek (downstream of the Loamside gauge). Predicted flows during large events should be treated with caution.

The availability of gauge data at Amberley is summarised in Table 4-9 and the available annual peak record is shown in Figure 4-16. Amberley has the same period of record as the Bremer River Walloon gauge, with 52 years of continuous gauge data available since 1962. Flood frequency analysis was conducted using the Amberley gauge data. Multiple Grubbs Beck censoring of low flow data excluded 11 years where minor flow was recorded, leaving 41 years of the data record.

Comparison of the pre-1955 URBS model flows with the post-1955 gauge record suggests that most of the modelled storm events are not particularly significant events in the Warrill Creek catchment. Inclusion of the pre-1955 URBS model data as a complete historical record of flows above threshold is not recommended. Inclusion of 1893 could possibly be considered as a flood of interest (note that this is actually the second 1893 event, which is the smaller of the two floods in the Brisbane River), however the limited reliability of the pre-1955 URRBS modelling makes estimation of a flood peak difficult to determine making any influence dependent on an arbitrarily selected threshold. Inclusion of URBS results from 1955 to 1961 would add four years of data but also three years of unknown value, and is considered to be of little benefit.

Analysis was conducted for both the Log Pearson III and GEV distributions, and both appear to fit the data sample reasonably, as shown in Figure 4-17. The resulting frequency curves have a significantly higher slope than that of any other examined site. Three significant events (1974, 2013 and 1976 in order of descending magnitude) have a strong influence on the probability distribution. While this could indicate an issue with the flow rating, the rated flows for all three events are well matched by the URBS model, indicating a good consistency between the recorded rainfall and rated flows. Figure 4-18 shows a comparison between the peak catchment averaged rainfall depths for these events and the AR&R (2013) rainfall IFD. The 1974 and 2013 events both recorded 18 to 24 hour rainfall depths in excess of the AR&R 1 in 500 AEP rainfall. Although this strongly suggests an issue with the official AR&R IFD values for the Warrill Creek catchment, it also indicates that Warrill Creek has experienced a number of significant events in its recent flood history. Such a statistical anomaly would be very rare, but is nonetheless possible.

4.6.7 Purga Creek at Loamside

Loamside is located on Purga Creek upstream of Ipswich and upstream of the junction with Warrill Creek. Purga Creek is the smallest of the three models developed for the Bremer River and its tributaries. Overflow from Warrill Creek spills into Purga Creek downstream of the gauge site during large flood events. The rating review suggests that this has no significant impact at Loamside gauge. Nevertheless, Purga Creek has a relatively small channel in a wide floodplain, and the gauge rating becomes sensitive to changes in level during large flood events. Predicted flows during large events should be treated with caution.

The availability of gauge data at Loamside is summarised in Table 4-10 and the available annual peak record is shown in Figure 4-19. Loamside has a shorter record than the Walloon and Amberley gauges, with 40 years of continuous gauge data available since 1974. Flood frequency analysis was conducted using the Loamside gauge data. Multiple Grubbs Beck censoring of low flow data excluded 16 years where minor flow was recorded, leaving 24 years of the data record.

Table 4-9 Gauge record history for Warrill Creek at Amberley

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1962 – 2013	52	52	0
Peak Gauge	1962 – 2012	51	41	10
Combined	1887 – 2013	127	63	64

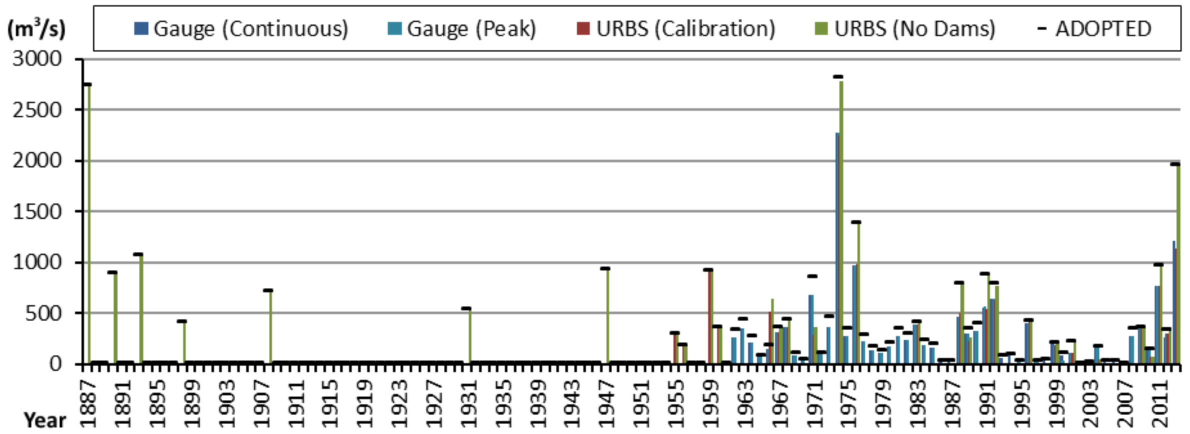

Figure 4-16 Annual peak flow record for Warrill Creek at Amberley

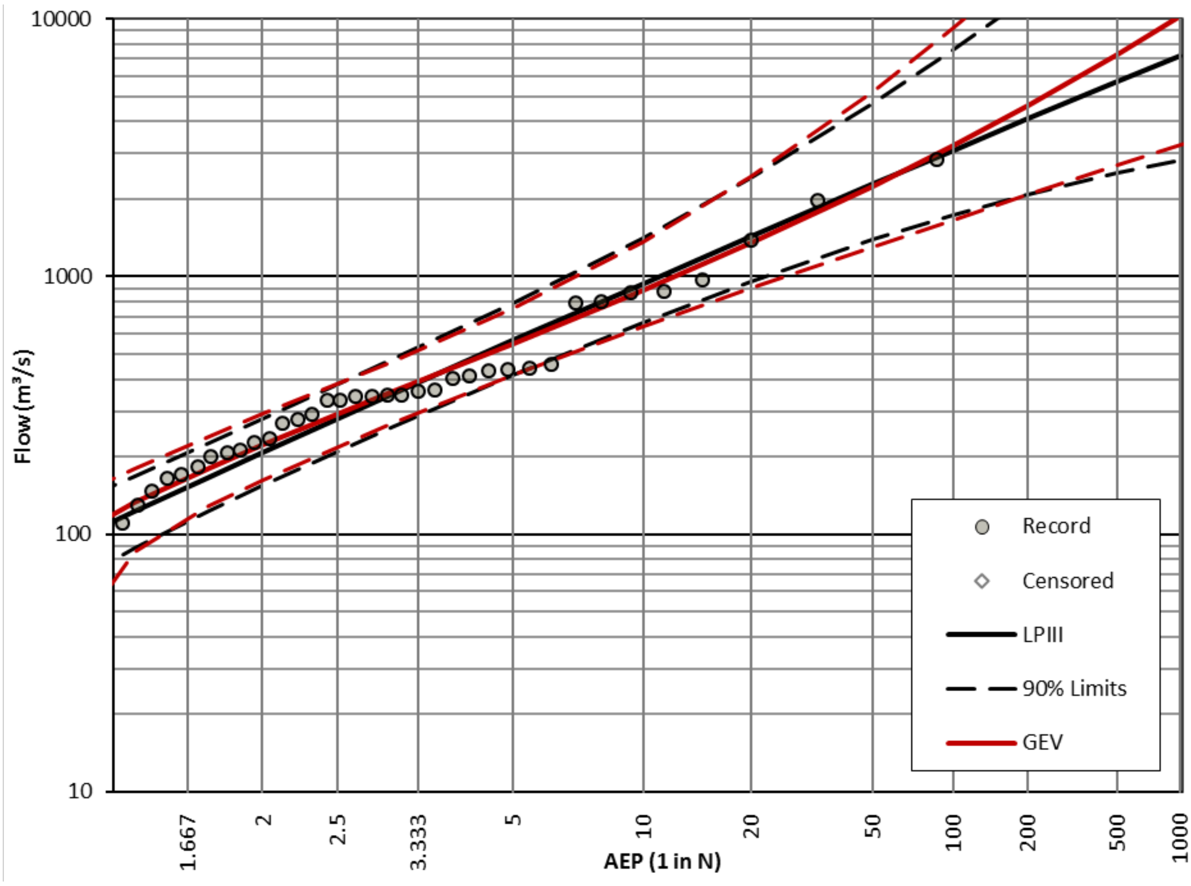

Figure 4-17 Flood frequency analysis at Amberley

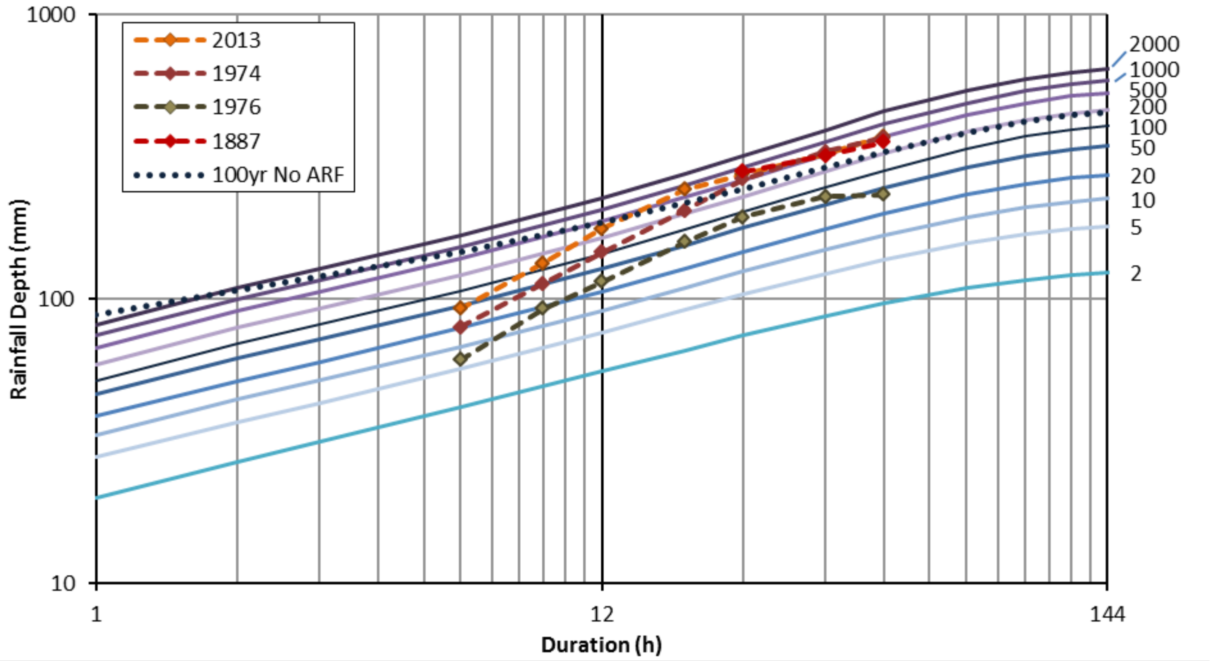

Figure 4-18 Catchment average rainfall depths at Amberley

As with the other Bremer River catchments, comparison of the URBS model flows with the gauge record suggests that most of the modelled storm events are not particularly significant events in the Purga Creek catchment. Inclusion of the URBS model data as a complete historical record of flows above threshold is not valid. Inclusion of URBS results from 1955 to 1973 would add 9 years of data (of unknown reliability) but also 10 years of unknown value, and is difficult to justify. The 1893 flood is a major event of similar magnitude to 1974 (note that this is actually the second major flood event in 1893, which is the smaller of the two floods in the Brisbane River), with both events being significantly (nearly 2.4 times) larger than any other known flood event, although the pre-1955 URBS modelling makes estimation of a flood peak uncertain. Influence of the 1893 flood on the frequency distribution was investigated, with three analysis techniques tested:

1. Omission (ie estimate based only on the gauged record from 1974 onwards)
2. Inclusion as an undefined historical event
3. Inclusion as a defined flood magnitude

Analysis was conducted for both the Log Pearson III and GEV distributions, with both methods providing a similar fit through the data, as shown in Figure 4-20. Methods 1 and 2 were found to produce very similar results. Method 3 produces slightly lower flows and is arguably preferable because, although the 1893 flow is uncertain, it is considered likely to be of similar magnitude to 1974 and this method prevents the fitting method from estimating an arbitrarily large flood. Regardless, the introduction of catchment weighting parameters, discussed in Section 4.7 and 4.8.1, significantly reconcile the difference between the methods.

Table 4-10 Gauge record history for Purga Creek at Loamside

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1974 – 2013	40	40	0
Peak Gauge	1974 – 2012	39	25	14
Combined	1887 – 2013	127	56	71

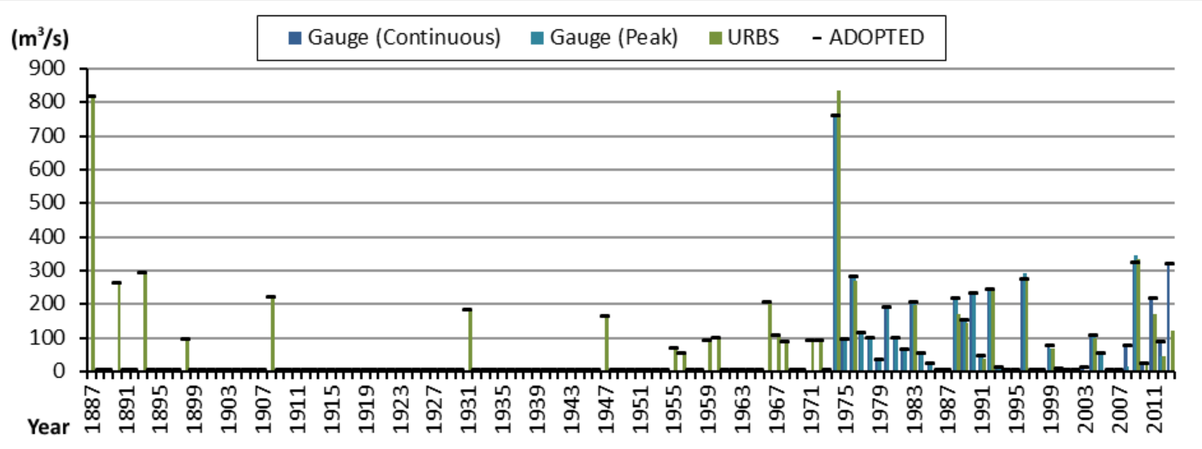

Figure 4-19 Annual peak flow record for Purga Creek at Loamside

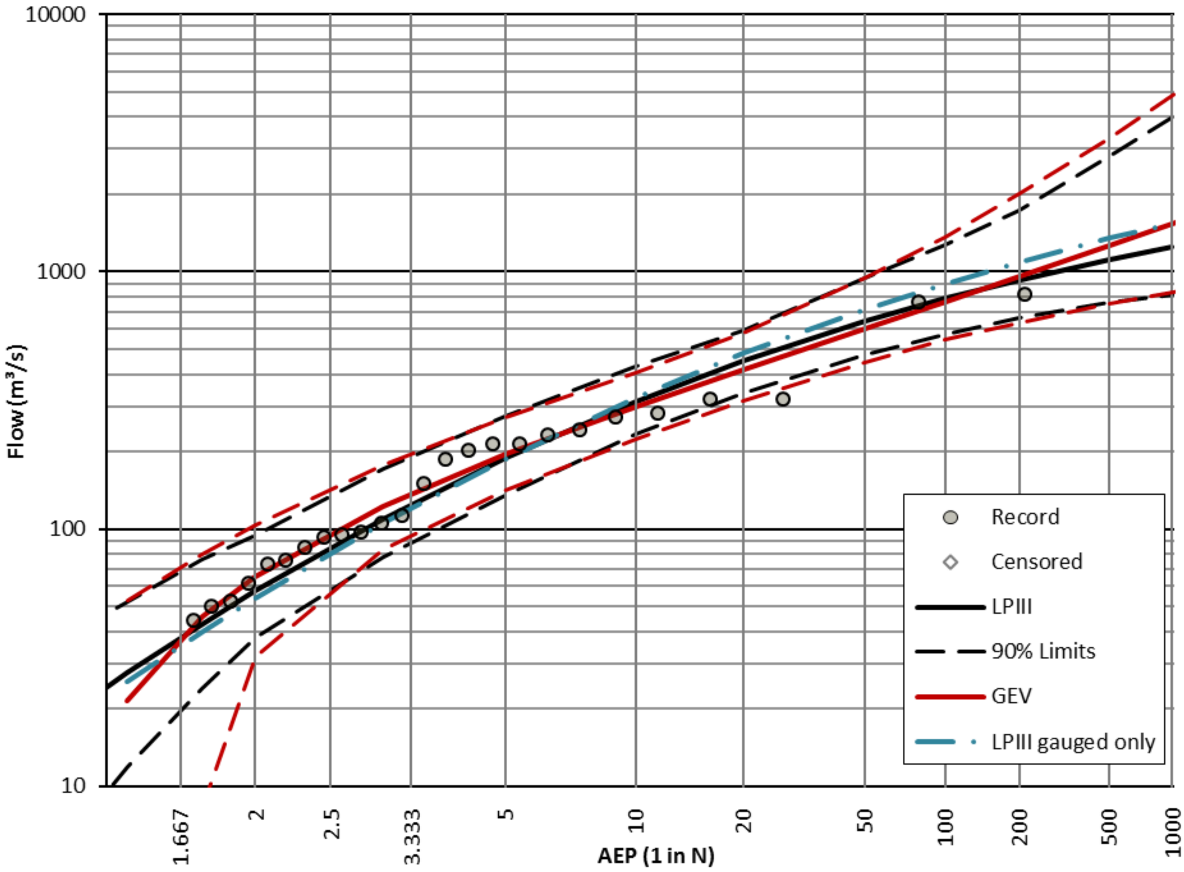

Figure 4-20 Flood frequency analysis at Loamside

4.6.8 Mid Brisbane River at Lowood/Verner/Savages Crossing

Savages Crossing is one of several gauging sites along what Seqwater refers to as the mid Brisbane River (between the Lockyer Creek and Bremer River confluences), but is considered to be the primary reference point for the upstream end of this reach and of importance for the operation of Wivenhoe Dam. The site at Savages Crossing has been operational since 1959. Other gauges with longer records in relatively close proximity are available, most notably the gauges at Lowood and Verner. Comparison of overlapping records shows a relatively strong correlation between gauge heights, shown in Figure 4-21. Using this correlation, equivalent flood heights at Savages Crossing were calculated from the gauge records at Lowood (1890-1950) and Verner (1951-1958). It is acknowledged that the correlation is not exact and that this method adds some uncertainty to the level prediction and hence rated flow for any particular event. However, much of this uncertainty is within the tolerances of gauge height record and gauge rating. Provided that the transfer relationship is averaged and unbiased the significant increase in record length should outweigh any added uncertainty when conducting the flood frequency analysis.

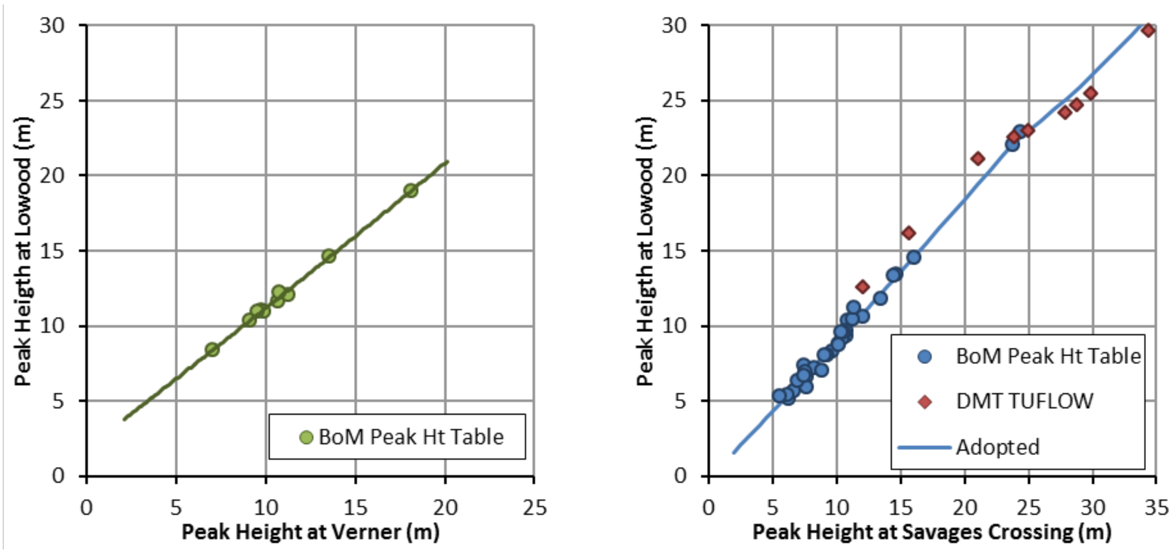

Figure 4-21 Correlation between Verner, Lowood and Savages Crossing gauge levels

The availability of gauge data for the combined records of Lowood, Verner and Savages Crossing is summarised in Table 4-11 and the available annual peak record is shown in Figure 4-22.

The combined flood record, including the gauged records at Savages Crossing, Lowood and Verner and URBS model results provides 127 years of data with only 17 years for which no data is available. Multiple Grubbs Beck censoring of low flow data excluded a further 35 years where flow was below a threshold of 240 m^3/s, leaving 75 years of the data record. The Savages Crossing gauge/rating has known issues with variability, which could be expected to be most prevalent at low flows, so a higher threshold was considered advisable, although visually the data and fit appears reasonable. The annual peak record in Figure 4-22 identifies that the record before 1910, for which continuous gauge data is not available, has clearly only registered the larger floods (above 4,700 m^3/s) and this part of the record has been included as a separate threshold.

Analysis was conducted for both the Log Pearson III and GEV distributions, shown in Figure 4-23, with both methods providing a similar fit through the data up to about 1 in 20 AEP, but diverging significantly for higher flows. The GEV distribution appears to predict unrealistically high flows for rare floods when compared to other gauges and flow estimation methods.

Table 4-11 Gauge record history for the mid Brisbane River at Savages Crossing (including Lowood and Verner)

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1910 – 2013	104	104	0
Peak Gauge	1890 – 2011	122	53	69
Combined	1887 – 2013	127	110	17

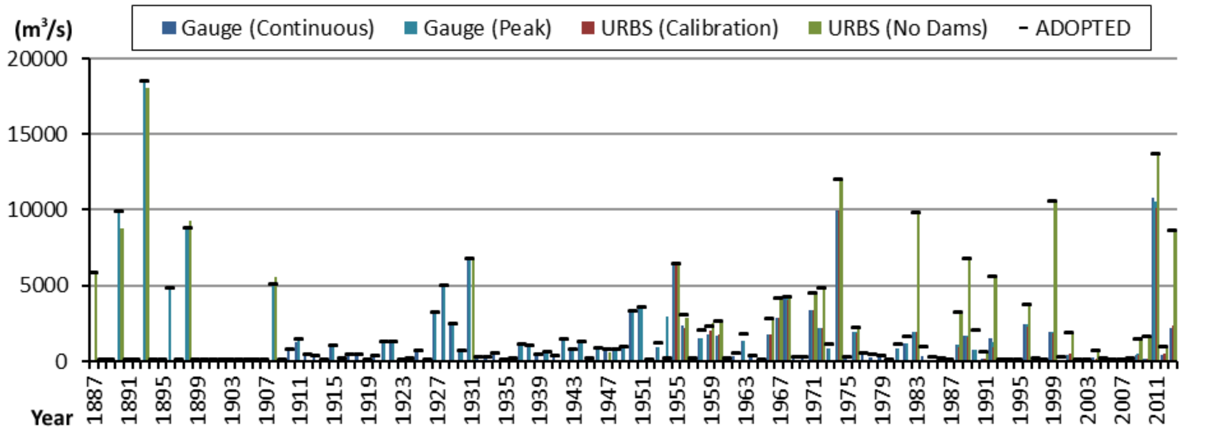

Figure 4-22 Annual peak flow record for the mid Brisbane River at Savages Crossing

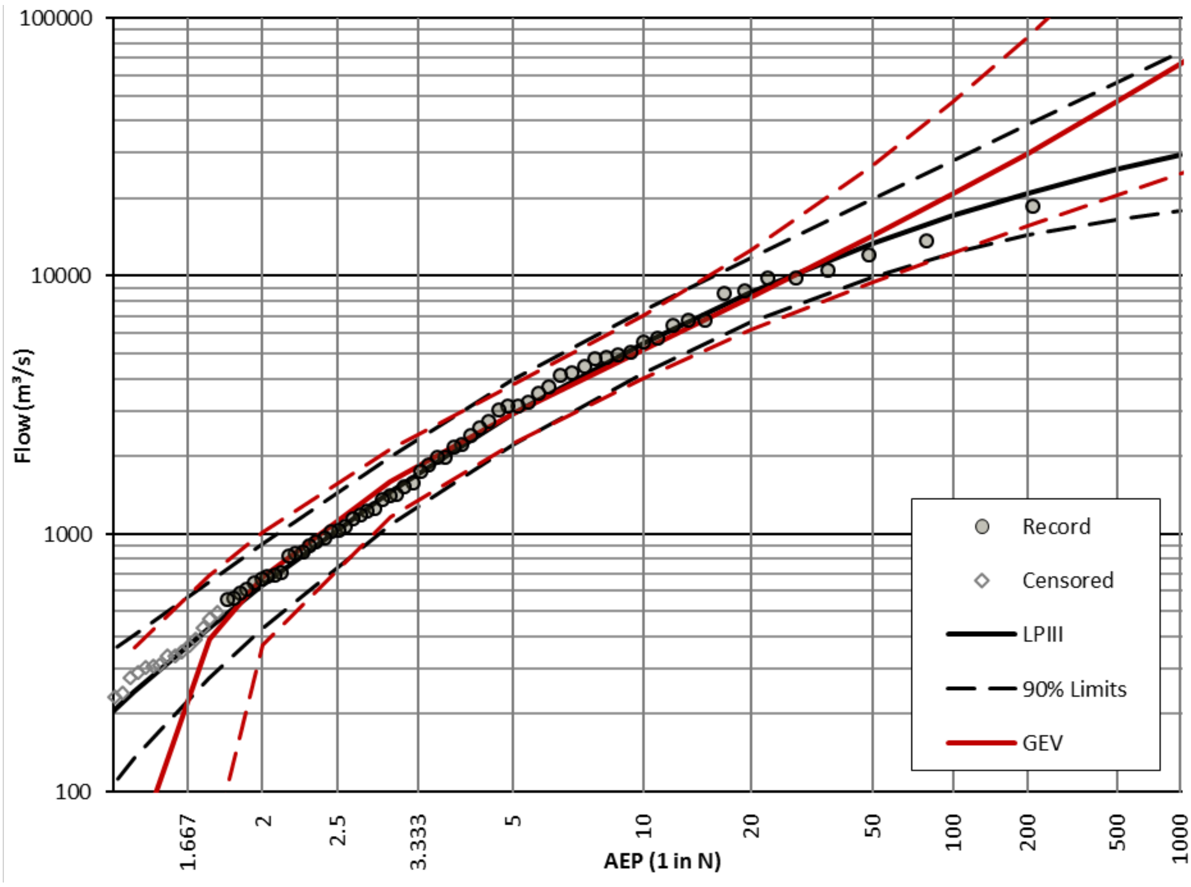

Figure 4-23 Flood frequency analysis at Savages Crossing

4.6.9 Mid Brisbane River at Mt Crosby Weir

Mt Crosby Weir is located in what Seqwater refers to as the mid Brisbane River (between the Lockyer Creek and Bremer River confluences), approximately 40 km downstream of Savages Crossing and 20 km upstream of Moggill. The availability of gauge data is summarised in Table 4-12 and the available annual peak record is shown in Figure 4-24. Mt Crosby Weir is a long-term gauging site with continuous gauge records from 1901. Peak flood height levels dating back to 1887, giving 127 years of history of which 29 have no available data. A single flood peak is available from 1864 however review of City gauge shows numerous moderate events not identified in intervening period so inclusion in the analysis is not considered statistically valid. Multiple Grubbs Beck censoring of low flow data excluded a further 55 years where flow was below a threshold of 750 m^3/s, leaving 72 years of the data record. Review of the plotted flow data, shown in Figure 4-25, demonstrates a noticeable 'bulge' between 1,000 and 2,000 m^3/s. The rating curve review identified significant variability in the recorded levels and flows within this range, most likely attributable to interaction between the water surface and the bridge deck. Consequently all flows less than 2,000 m^3/s were censored from the analysis, with a second threshold of 4,400 m^3/s used for the period prior to 1901.

Analysis was conducted for both the Log Pearson III and GEV distributions, with both methods providing a similar fit through the data up to about 1 in 100 AEP, but diverging for higher flows.

4.6.10 Lower Brisbane River at Moggill

There are several stream gauges in the lower reach of the Brisbane River, however all of these gauges have some degree of limitation when it comes to flood frequency analysis. Moggill is the first stream gauge in the lower reach of the Brisbane River, located just downstream of the Bremer River junction. The gauge site is tidally affected, and low flows (< 2,500 m^3/s) are unreliable. Useful continuous gauge data at the site is limited, but peak flood level data is available at the site as far back as 1893. Centenary Bridge, located approximately 20 km downstream of Moggill, is an infrequent flood record. Flood levels are available for several major floods but are insufficient for a statistically relevant flood frequency analysis. Nevertheless, flow measurement data collected during and at the peak of the 2011 flood provides an extremely useful reference point for flows throughout the lower Brisbane River.

The availability of gauge data at Moggill is summarised in Table 4-13 and the available annual peak record is shown in Figure 4-26. Flows below 2,600 m^3/s were censored from the data due to unreliability of the low flow rating. Examination of Figure 4-26 suggests visually that the combined gauge and URBS model record post-1955 is relatively well populated, but appears sparse prior to 1955. Most of the major flows have been identified, but there are no records below about 7,000 m^3/s.

The post-1955 record contains 27 years of data, of which 8 low flow years were censored, and another 32 years where no flood peak was recorded. The pre-1955 record contains only 7 years of data (of which one low flow was excluded). Analysis was conducted for both the Log Pearson III and GEV distributions, shown in Figure 4-27, with both methods providing a similar fit through the data up to about 1 in 50 AEP, but diverging for higher flows.

The Brisbane City gauge record was used to identify a further 5 large flood events estimated to exceed around 7,000 m^3/s dating back to 1841, which were included as historical events exceeding a threshold. Inclusion of this historical record results in minimal change to the FFA, exhibiting only a slight increase in the frequency curve for large floods. Since the correlation between the Brisbane City and Moggill gauges is not particularly reliable (see discussion in Section 4.8.10), inclusion of historic events does not appear to provide significant benefit.

Table 4-12 Gauge record history for the mid Brisbane River at Mt Crosby Weir

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1901 – 1974	75	75	0
Peak Gauge	1887 – 2011	125	43	82
Combined	1887 – 2013	127	98	29

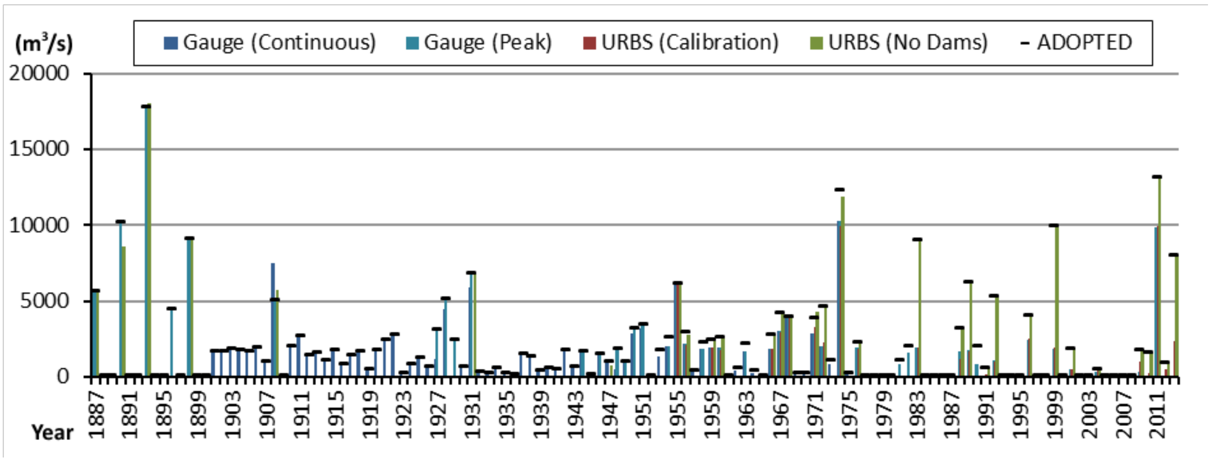

Figure 4-24 Annual peak flow record for the mid Brisbane River at Mt Crosby Weir

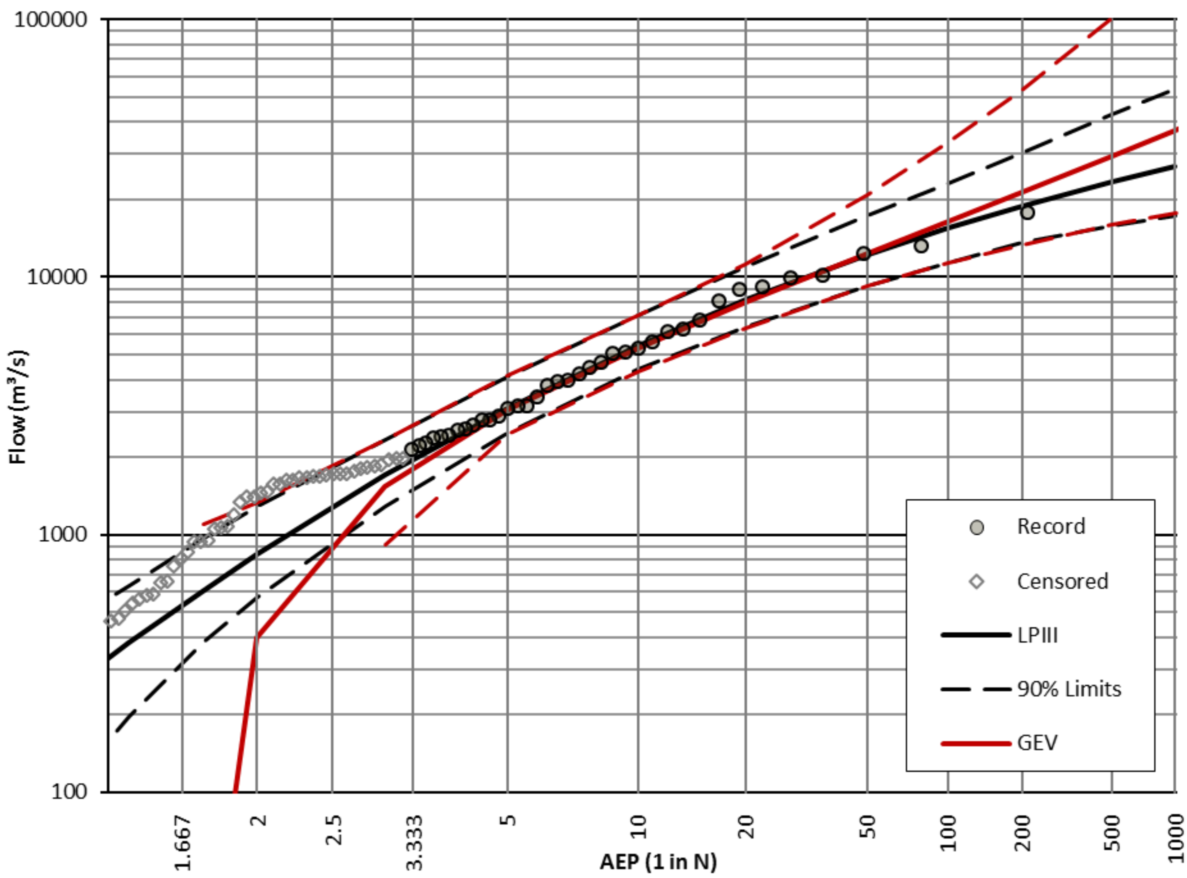

Figure 4-25 Flood frequency analysis at Mt Crosby Weir

Table 4-13 Gauge record history for the lower Brisbane River at Moggill

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1996 – 2013	18	3	15
Peak Gauge	1893 – 2011	119	20	99
Combined	1887 – 2013	127	34	93

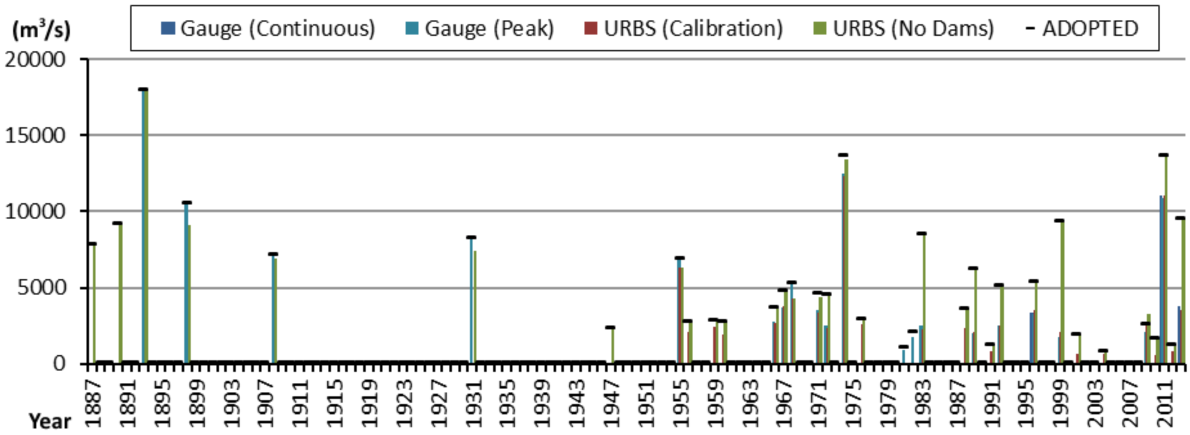

Figure 4-26 Annual peak flow record for the lower Brisbane River at Moggill

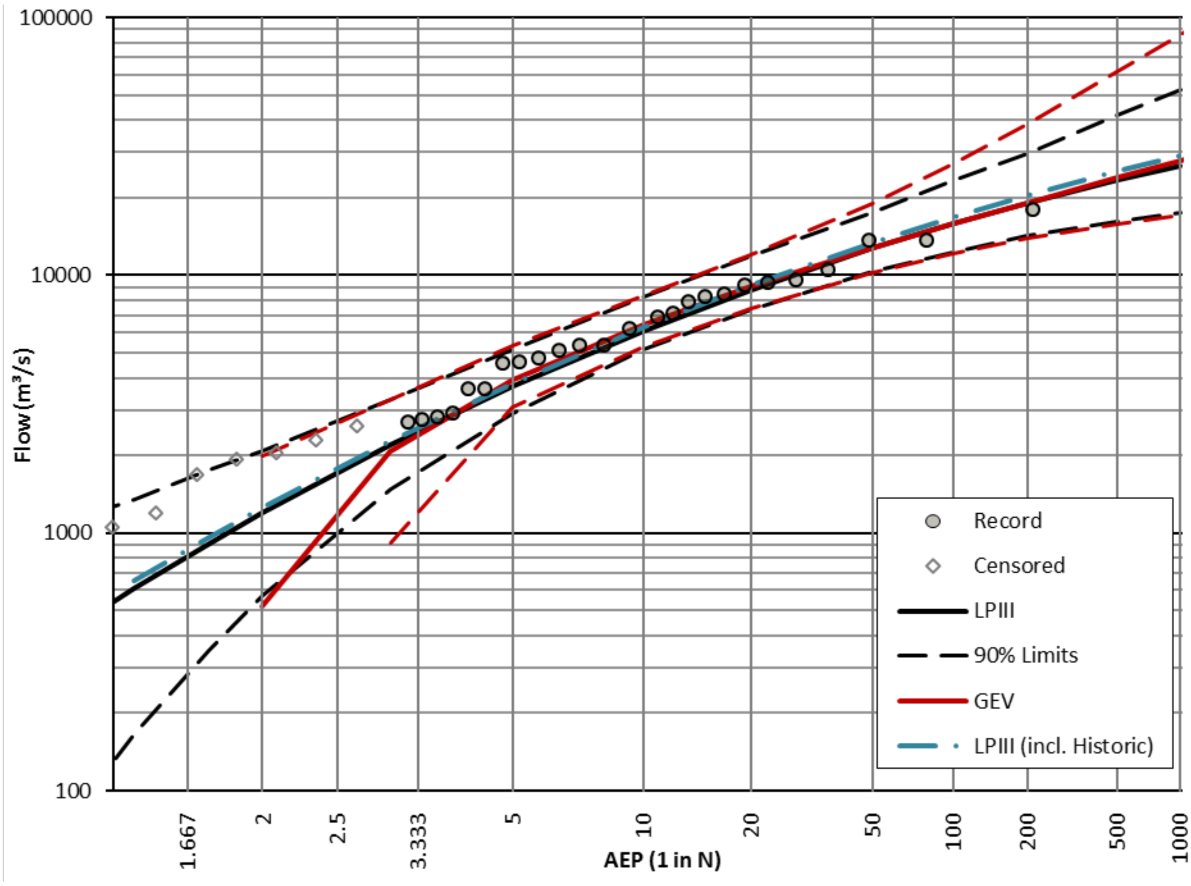

Figure 4-27 Flood frequency analysis at Moggill

4.7 Regional/catchment weighting method

As neither of the originally proposed methods discussed in Section 3.6 was considered appropriate to apply, an alternate approach was considered. It was noted that the accuracy of skew estimates based on single 'at-site' analysis, especially those with short gauge records, is often low. It is recognised that the accuracy can generally be improved by weighting the station skew with generalised values obtained from pooled information from other sites in the region AR&R (Engineers Australia,1987).

The Log-Pearson III and GEV distributions are the most common probability functions applied to flood frequency analysis in Australia. Analysis at the primary gauge sites identified that the GEV distribution could usually provide a reasonable representation of the upper or lower tails of the gauge data, however in most situations the Log-Pearson III distribution provided a better overall representation of the full data set, as well as being relatively consistent with the design event and Monte-Carlo simulation methodologies. Since the FFA is required to assess flows within the range of 1 in 2 to 1 in 100 AEP and reconcile with other methods at and above this range, the Log-Pearson III distribution was adopted as the standard probability function for all gauges.

The Log-Pearson III distribution is a three-parameter probability distribution related to the standard Gamma probability distribution defined by a mean, standard deviation and skew. These parameters roughly correspond to the magnitude, slope and curvature of the distribution when plotted on standard log-probability paper. Using regionally consistent parameters provides several advantages, including the ability to:

- Identify and/or reduce the influence of outliers at individual gauges
- Improve reliability of the fit and reduce confidence intervals, particularly at gauges with limited data
- Improve consistency between gauges, particularly when extrapolating to small or large AEP

However, the flood probability distribution is influenced by many factors including rainfall (intensity and variability), catchment response (routing, storage, coincidence of tributary flows etc) and infiltration (losses). These will not necessarily be consistent across the catchment. It is important that implementing regionalised parameters does not constrain the natural variation between different parts of the catchment. The Bayesian fitting methods available in the FLIKE software package allow the user to input pre-determined distribution parameters (Mean of log *Q*, ln[std dev of log *Q*] and Skew of log *Q*). These are input in the form of a mean and standard deviation for each parameter, with the smaller the standard deviation, the heavier the weighting applied to the specified parameter. Applying an appropriate standard deviation will allow the regional parameters to influence the fit, without completely overriding the natural characteristics of the catchment exhibited in the data.

The skew (curvature of the flood frequency distribution) tends to be sensitive to potential outliers in the lower or upper tail of the data, while also having a significant influence on forward projection of the probability curve to rare events. Examination of the skew of the ten primary gauges, shown in Figure 4-28, identified that with the exception of Amberley as a significant outlier (influenced by a number of extreme flood events as discussed in Section 4.6.6), and to a lesser degree Woodford (influenced by an extreme event in 1893), the primary gauges tend to have a skew in the range -0.7 to -0.9.

For the catchment weighting, a mean of -0.8 and standard deviation of 0.1 were adopted for the Skew of log *Q*. It is acknowledged that this skew is lower than values typically seen on the east coast of Australia, however application of these parameters appeared to produce a satisfactory outcome, with even gauges that had originally yielded significantly different unweighted skews readily conforming to the catchment skew. The resulting weighted flood frequency distributions were generally observed to be much more consistent with flow estimates produced by the Design Event and Monte-Carlo simulation methodologies.

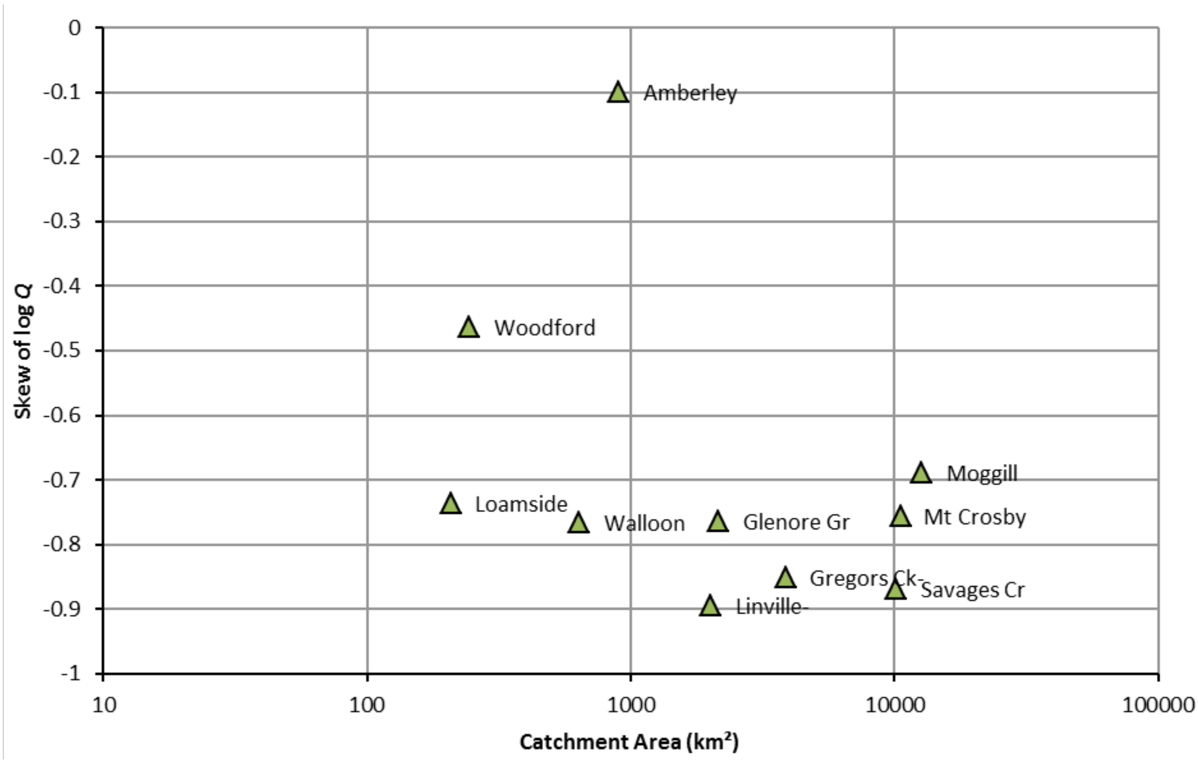

Figure 4-28 Comparison of Skew of log Q at primary gauges

A Log Pearson III distribution with negative skew is characterised by an upper bound or maximum value, which is presented by some authors as a failing, or at least a limitation. However, it is worth noting that the concepts of Probable Maximum Precipitation and Flood also imply that there is a maximum precipitation depth that is physically possible, hence the upper limit of the LPIII distribution should only be of significant concern if the upper bound is too low and not consistent with precipitation magnitudes. The relatively good agreement between FFA and rainfall based methods (Design Event and Monte Carlo simulation) suggests that this is not the case.

Figure 4-29 compares the upper bound with the PMF calculated using the Design Event approach (Monte Carlo estimates were similar). A good correlation is observed, with the LPIII upper bound typically slightly lower than the PMPDF (if Moggill is excluded, the best-fit of the primary sites is within 2%). This comparison is not intended to imply that there is or should be a direct relationship between the Log Pearson III upper bound and PMPDF, but rather to confirm that the relatively strong negative skew does not create practical upper bound problems. Probability distributions are chosen because they fit bulk of data, however there can be significant divergence in the upper tail. The focus of the flood frequency analysis is on frequent events (typically < 1 in 100 AEP) and the probability distribution should not be extrapolated to extreme events.

This assessment indicates that the upper limit is of the correct order of magnitude and does not artificially constrain the flow estimates within the recommended extrapolation range (ideally less than 1 in 50 AEP and not greater than 1 in 2000 AEP).

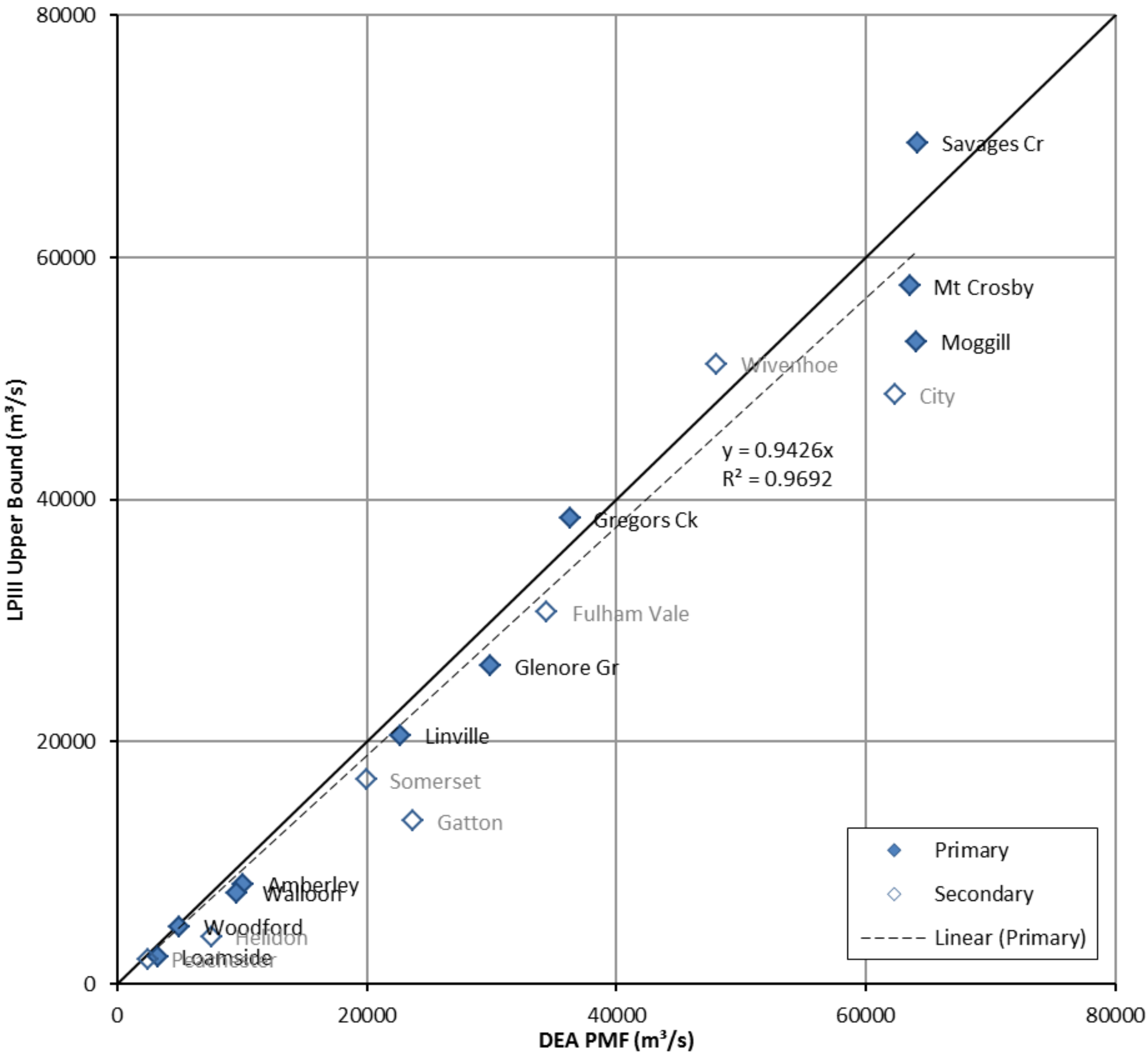

Figure 4-29 Comparison of LPIII Upper Bound and DEA PMF

Application of a regional skew is relatively well recognised, however the benefit of a regionally weighted standard deviation is somewhat more questionable. Each of the catchments was reassessed using the catchment weighted skew, and the resulting standard deviations examined to see if a correlating factor could be identified. Figure 4-30 shows the standard deviation after catchment weighted skew has been applied. These display a relatively weak correlation of increasing with increasing catchment area, however various catchment related trends can be readily identified. The Lockyer Creek sites (Glenore Grove, Gatton and Helidon) typically exhibit a higher standard deviation (and hence gradient of the FFA curve) for a given area than the Stanley River catchments (Peachester, Woodford and Somerset). Numerous correlating factors other than area were investigated however a single consistent factor could not be readily identified. An improved correlation between standard deviation and area was achieved by adjusting the standard deviation by a correction factor based on the dimensionless gradient of the rainfall intensity, given as:

$$C_{IG} = \ln\left(\frac{{}^{50}I_{24} - {}^{2}I_{24}}{{}^{2}I_{24}}\right)^{0.4} \quad (4)$$

where $^{2}I_{24}$ and $^{50}I_{24}$ are the 1 in 2 and 1 in 50 AEP catchment averaged 24 hour rainfall intensities upstream of each site.

These rainfall weighted standard deviations are also shown in Figure 4-30. Using this correction factor, the mean of the standard deviation was then estimated as:

$$\text{Mean of Standard Deviation of log } Q = \frac{1}{C_{IG}}\left(0.058\ln A + 0.63\right) \qquad (5)$$

where A is the catchment area. It is acknowledged that this is a purely empirical correlation and does not achieve a perfect correlation as flood magnitude is dependent on other factors besides area and rainfall intensity. A standard deviation of 0.12 of the ln[std dev of log Q] was applied based on the variation in the primary catchments.

Implementation of the weighted standard deviation in general has minor influence on sites with a reasonable set of consistent data. Most benefit is observed at sites with limited data or appearing to be affected by outliers. Benefit of applying regional standard deviation parameters is best demonstrated by application at the Wivenhoe site, discussed in Section 4.8.6.

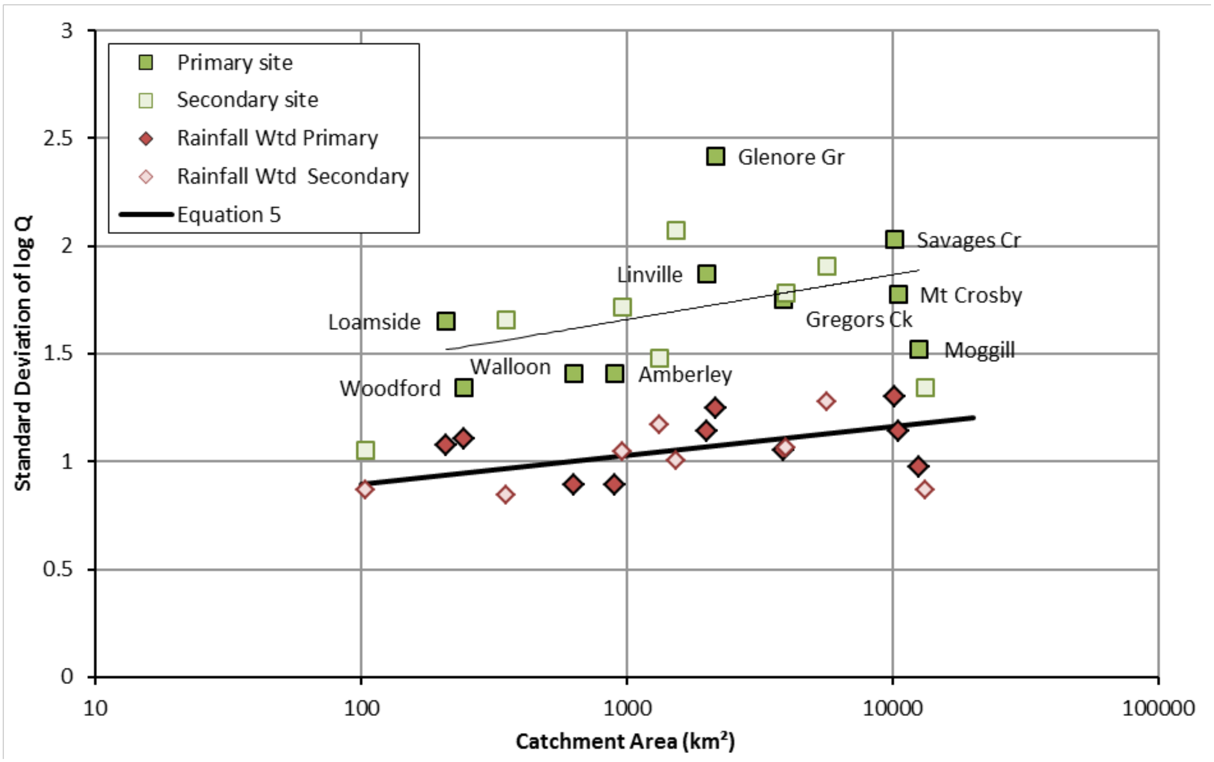

Figure 4-30 Comparison of Standard Deviation of Log Q (after catchment weighted skew applied)

4.8 Catchment weighted analysis

4.8.1 Catchment weighted reassessment of primary gauges

The primary analysis sites described in Section 4.6 were reassessed using FLIKE's Bayesian inference method with Gaussian prior distributions to include the weighted catchment skew and standard deviation parameters discussed in Section 4.7 above. The effects are shown in Figure 4-31 to Figure 4-40 and summarised in Table 4-14.

Table 4-14 Influence of catchment weighted parameters on primary site FFA

Location	Summary
Woodford Figure 4-31	Introduction of catchment weighted skew results in more pronounced curvature of the frequency curve. Visually this appears to provide a better fit of the upper tail with the exception of the flood of record. Considering that this is known to be an extreme event and the uncertainty associated with the estimate of this 1893 flow, this is not necessarily a bad outcome. Introduction of catchment weighted standard deviation results in a minor flattening of the curve
Linville Figure 4-32	The unweighted Linville frequency curve based on full range of data is strongly affected by the 'S' shape of the upper tail. Introduction of catchment weighted noticeably affects the curve through this upper tail, and visually appears to improve the fit through the largest values. The projection of the frequency curve is also much more consistent with flows produced by Design Event and Monte Carlo simulation methods
Gregors Creek Figure 4-33	As with Linville, the unweighted Gregors Creek frequency curve is strongly affected by the 'S' shape of the upper tail, and receives a similar improvement to the fit through the largest values and consistency with flows produced by Design Event and Monte Carlo simulation methods from introduction of the weighted catchment parameters
Glenore Grove Figure 4-34	The Glenore Grove frequency curve is significantly steeper than the other investigated sites. Introduction of catchment weighted skew and standard deviation increasingly tend to reduce the grade of the frequency curve. Visually, the weighted skew curve appears to provide a slightly better fit of the full data range. The weighted skew and standard deviation curve fits the largest recorded flow well but seems to overestimate the very frequent flows (>1 in 2 AEP). Considering that there is water harvesting of flows from the water course due to the large scale irrigation within the catchment, which may affect low flows, this may actually be more appropriate
Walloon Figure 4-35	Aside from the uncertain magnitude of the two largest flows, the Walloon frequency curve is relatively well behaved. Introduction of catchment weighted parameters have very little impact on the fit. The extended record including data from Rosewood produces a very similar but slightly lower frequency curve. Use of the at-site Walloon analysis is therefore conservative and recommended
Amberley Figure 4-36	The unweighted frequency curve at Amberley is strongly affected by what are believed to be several significant flood events in the catchment and the skew was identified as a significant outlier. Introduction of weighted catchment skew reduces the influence of the upper tail and increases the curvature resulting in lower flows above 1 in 20 AEP. The catchment weighted standard deviation has minimal impact on the curve. The weighted Amberley frequency curve and flows are very similar to that of Walloon, despite having 40% greater catchment area. This is consistent with Design Event flow predictions. Use of the catchment weighting parameters is therefore supported
Loamside Figure 4-37	Loamside has the shortest gauge record of the primary investigation sites, with the two largest flows (1893 and 1974) nearly 2.4 times the next highest known event. With the unweighted analysis, inclusion or omission of the historical 1893 produced a varied the flood frequency curve. Inclusion of catchment weighted parameters slightly flattens the frequency curve and reduces the discrepancy to a virtually negligible amount
Savages Crossing Figure 4-38	Savages Crossing has a long record that exhibits a very smooth frequency trend. Introduction of catchment weighted parameters have very minor influence on the frequency curve, appearing to slightly improve the fit of the upper tail and slightly worsen the fit of the lower tail (> 1 in 3 AEP)
Mt Crosby Figure 4-39	Mt Crosby has a long record but a noted variability in the gauge rating below 2,000 m^3/s. The catchment weighting parameters adjust the frequency curve slightly, appearing to produce a slightly better fit of the upper tail
Moggill Figure 4-40	Introduction of catchment weighted parameters have relatively little impact on the Moggill frequency curve. The weighted skew slightly flattens the curve, which is counterbalanced by the weighted standard deviation, with the final frequency curve virtually identical to the unweighted curve

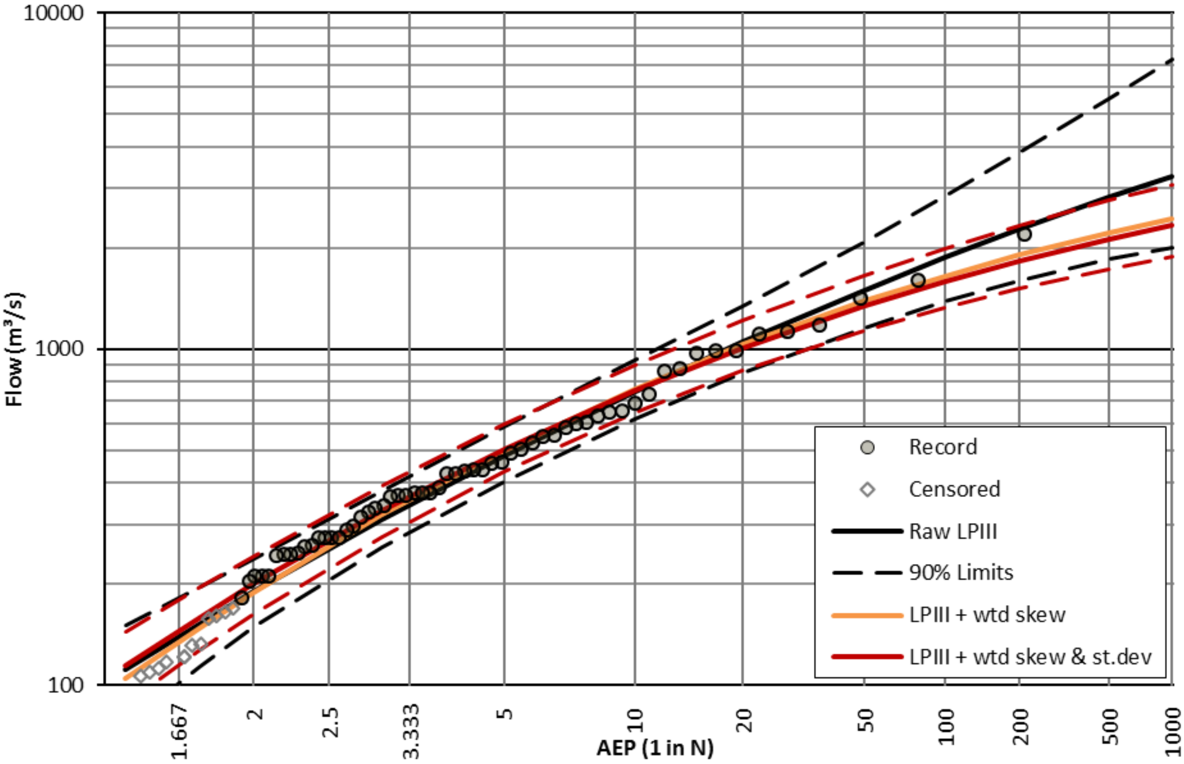

Figure 4-31 Catchment weighted flood frequency analysis at Woodford

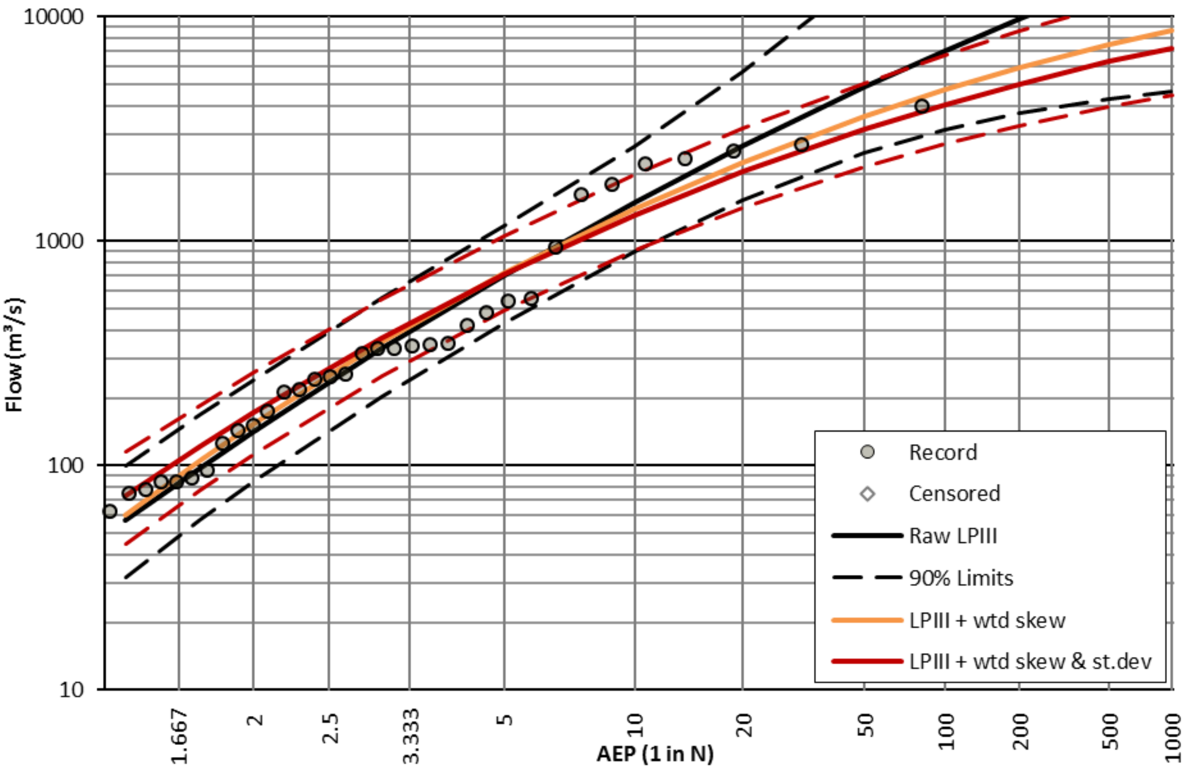

Figure 4-32 Catchment weighted flood frequency analysis at Linville

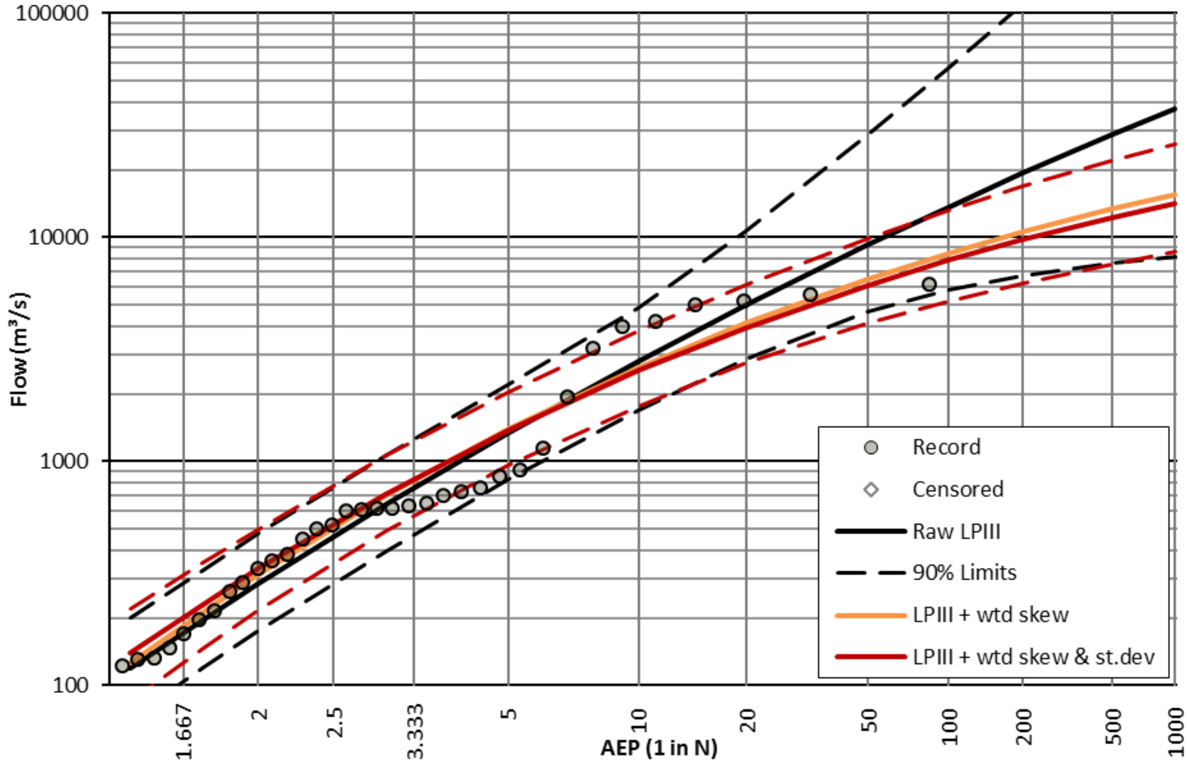

Figure 4-33 Catchment weighted flood frequency analysis at Gregors Creek

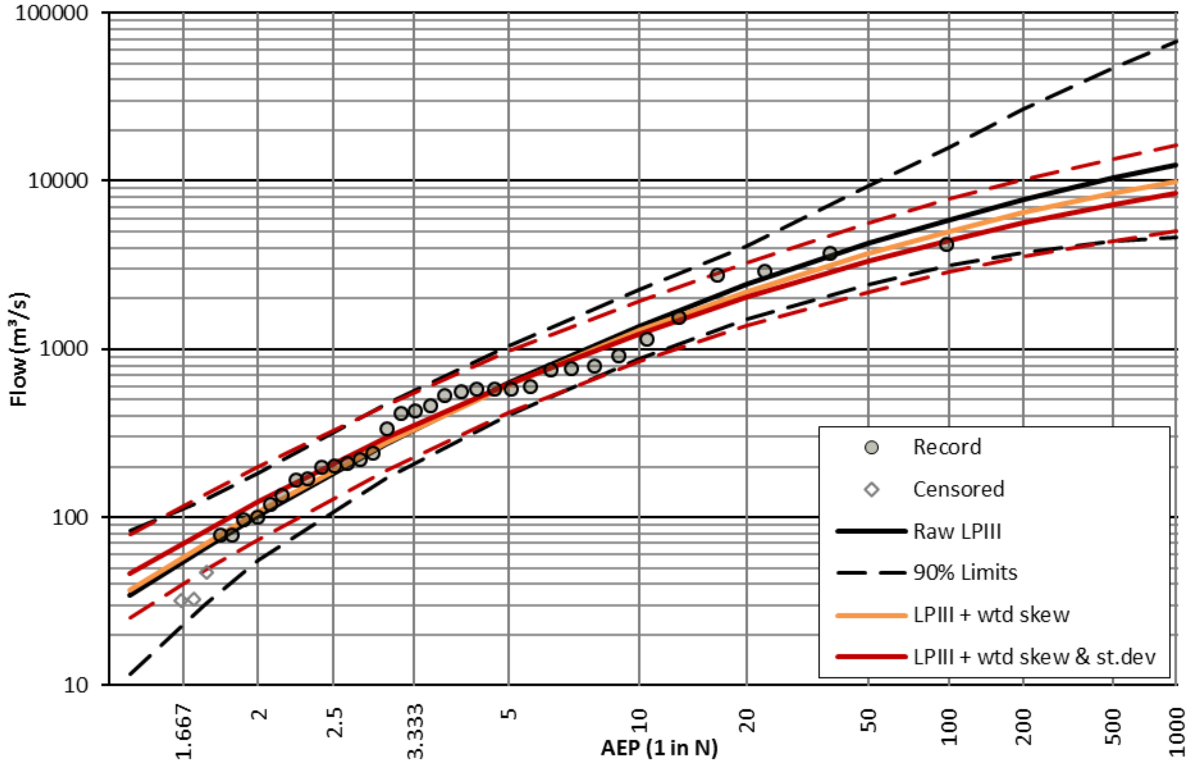

Figure 4-34 Catchment weighted flood frequency analysis at Glenore Grove

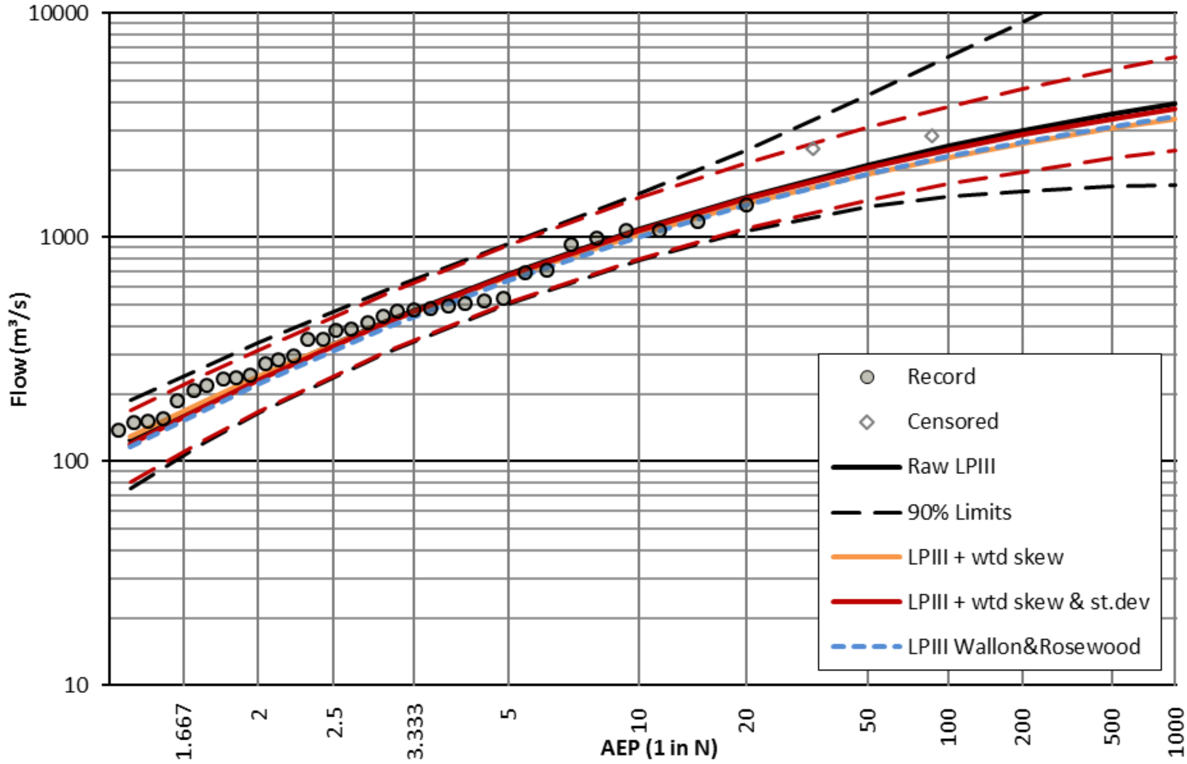

Figure 4-35 Catchment weighted flood frequency analysis at Walloon

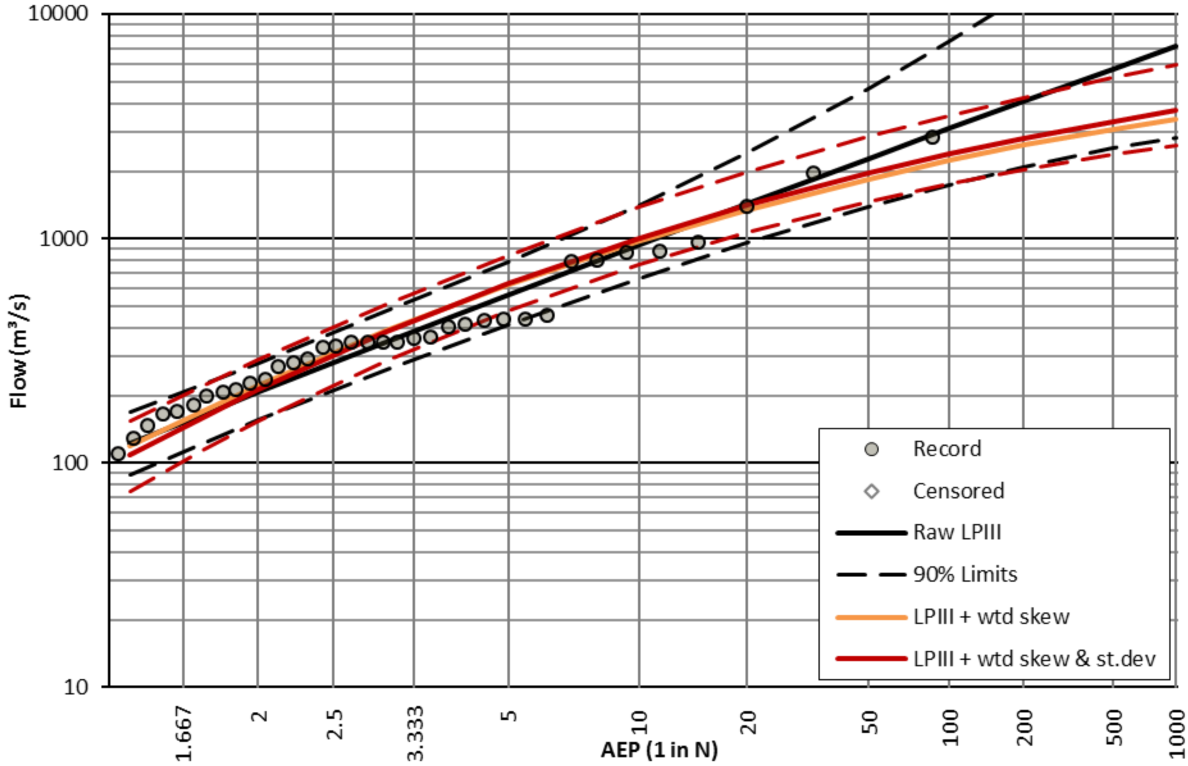

Figure 4-36 Catchment weighted flood frequency analysis at Amberley

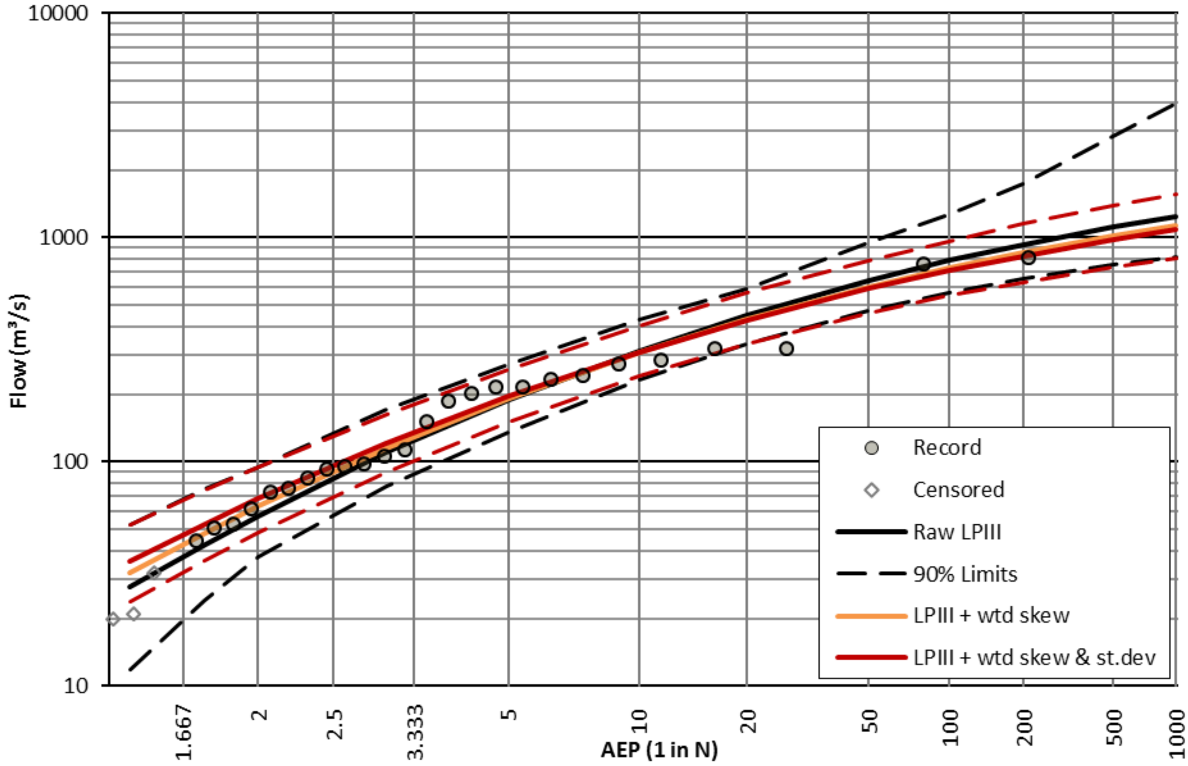

Figure 4-37 Catchment weighted flood frequency analysis at Loamside

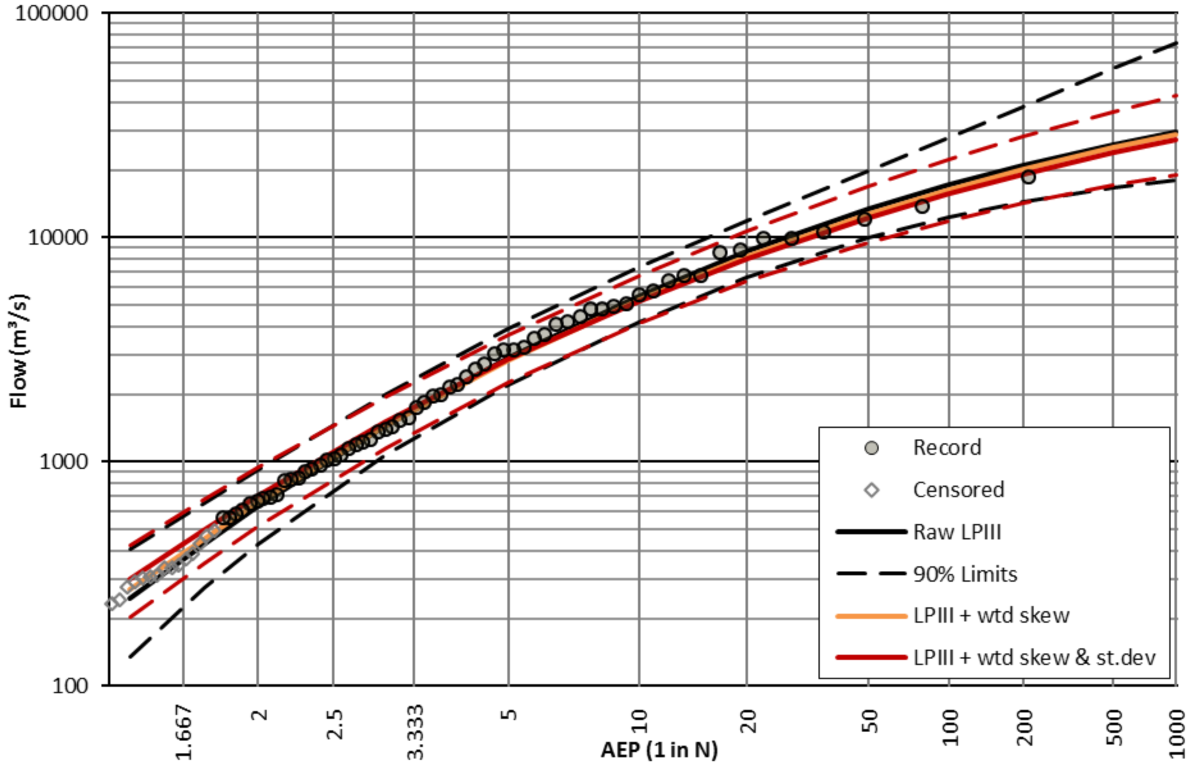

Figure 4-38 Catchment weighted flood frequency analysis at Savages Crossing

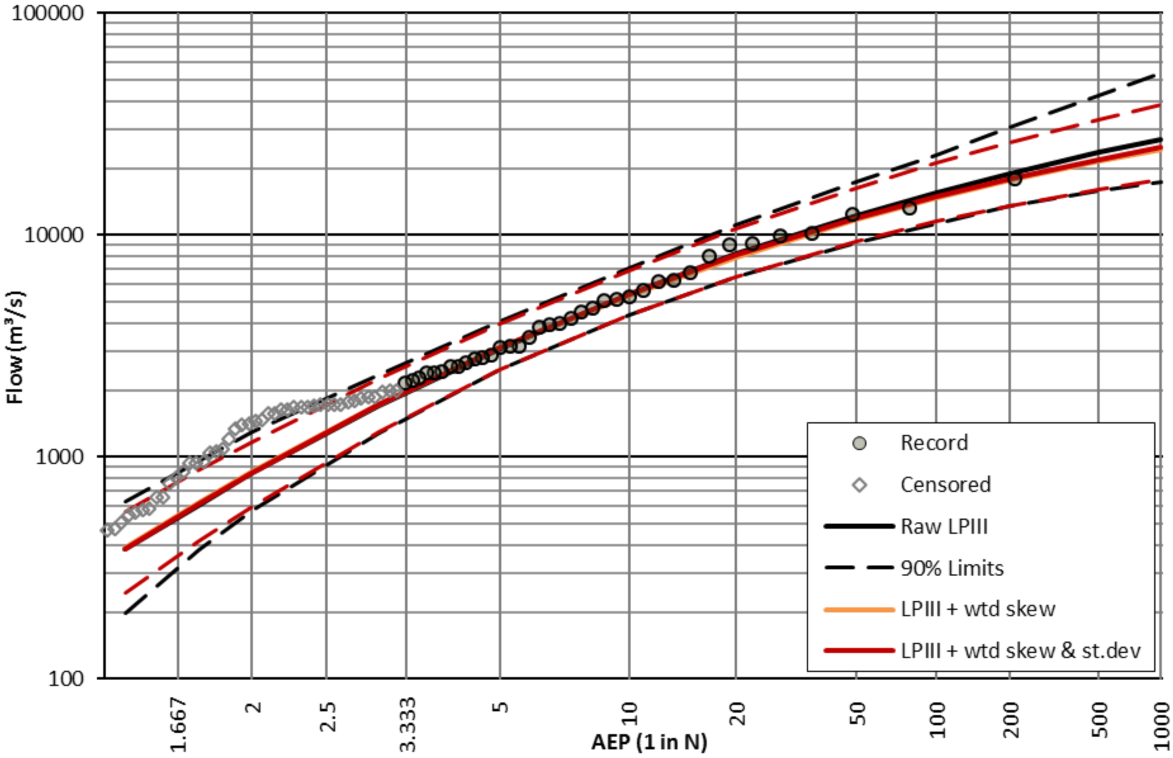

Figure 4-39 Catchment weighted flood frequency analysis at Mt Crosby

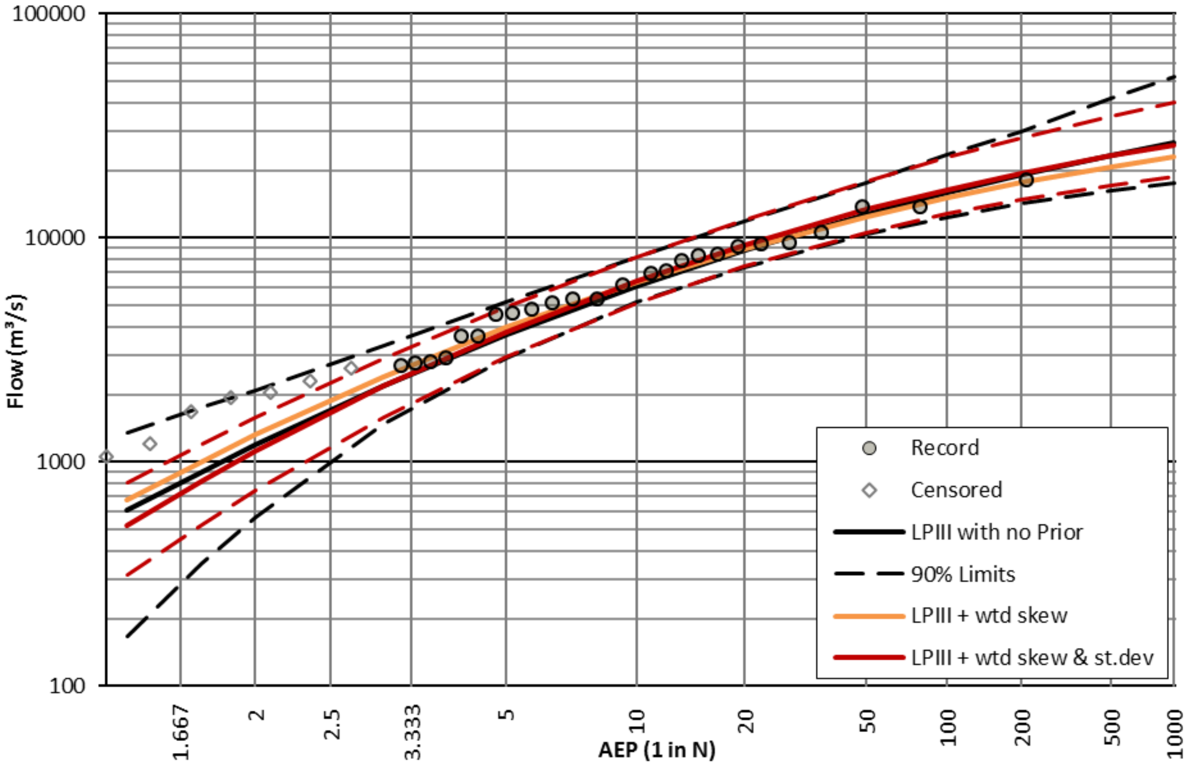

Figure 4-40 Catchment weighted flood frequency analysis at Moggill

4.8.2 Stanley River at Peachester

Peachester is located in the upper Stanley River catchment and experiences significantly higher rainfall intensities than the rest of the Brisbane River catchment. It has a relatively long gauge record dating back to 1928, but only gauges a small catchment. The availability of gauge data is presented in Table 4-15 and the available annual peak record is shown in Figure 4-41. The gauge rating review has identified Peachester as a secondary site with the high-flow rating determined using hydrologic model results. The rating also becomes very sensitive to changes in water levels at high flows. High flows should therefore be treated with caution. The 'flood of record' at the site is likely to have occurred in 1887, however there are no site records and only URBS model flow estimates are available. Considering that these are based on 24 hour rainfall records, the peak flow is not considered reliable. The remaining URBS model flows prior to the gauge record do not appear to be particularly significant events.

Flood frequency analysis was conducted using the period of gauged record, including the 1893 flood of record as a historical event greater than 875 m³/s. The multiple Grubbs Beck test did not identify any outliers. Sensitivity testing of censoring low-flow values showed no significant influence on the frequency curve. Flood frequency curves are presented in Figure 4-42. Analysis of the raw at-site data produces a very flat relationship with minimal skew that does not appear to fit the larger events particularly well. Introducing catchment weighted skew significantly improves the fit of the upper curve, at the expense of very frequent events (> 1 in 1.5 AEP). The catchment weighted standard deviation has negligible effect.

4.8.3 Stanley River at Somerset Dam/Silverton

Somerset Dam is located just upstream of the confluence with the Brisbane River. Construction on Somerset Dam began in 1935 but was suspended due to World War II and the dam was not completed until 1959. Flow estimates for major flood events since 1955 were calculated by reverse routing reservoir levels and outflows for use in the URBS model calibration. The availability of URBS model and reverse routed flow data is presented in Table 4-16 and the available annual peak record is shown in Figure 4-43.

A significant limitation of this data source is that flows are only available for specific events. These events were selected due to their impact on flooding in the lower Brisbane River and may therefore not consistently identify all significant events in the Stanley River. Additionally, since Somerset acts partly as a flood mitigation dam, events that caused significant inflow but not outflow may easily have been omitted. Correlation between Somerset and Woodford flows was used to identify the likely threshold below which Somerset floods were not identified. This correlation suggested that the threshold of missing floods was not consistent, making inclusion in analysis difficult. This resulted in the implementation of two thresholds – 20 years below 490 m³/s (the lowest significant recorded flood) and a further 15 years below 1500 m³/s. These thresholds are unconfirmed and therefore potentially affect the reliability of the flood frequency estimates.

Flood frequency analysis was conducted using the combined reverse routed and URBS model record since 1955. Frequency curves are presented in Figure 4-44. Notably, the Somerset record contains 5 events between 3240 m³/s and 3405 m³/s, which have a significant influence on the skew. Introducing catchment weighted skew and standard deviation seem to produce more realistic relationships that are consistent with the trends observed at the other Stanley River gauges of Woodford and Peachester.

Table 4-15 Gauge record history for the Stanley River at Peachester

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1928 – 2013	86	86	0
Peak Gauge	1933 – 2012	80	52	28
Combined	1887 – 2013	127	91	36

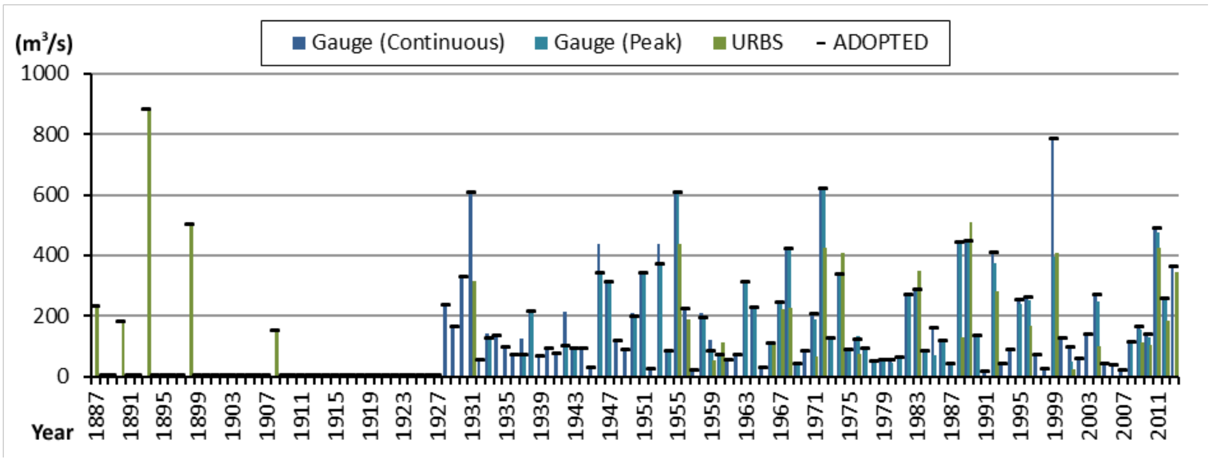

Figure 4-41 Annual peak flow record for the Stanley River at Peachester

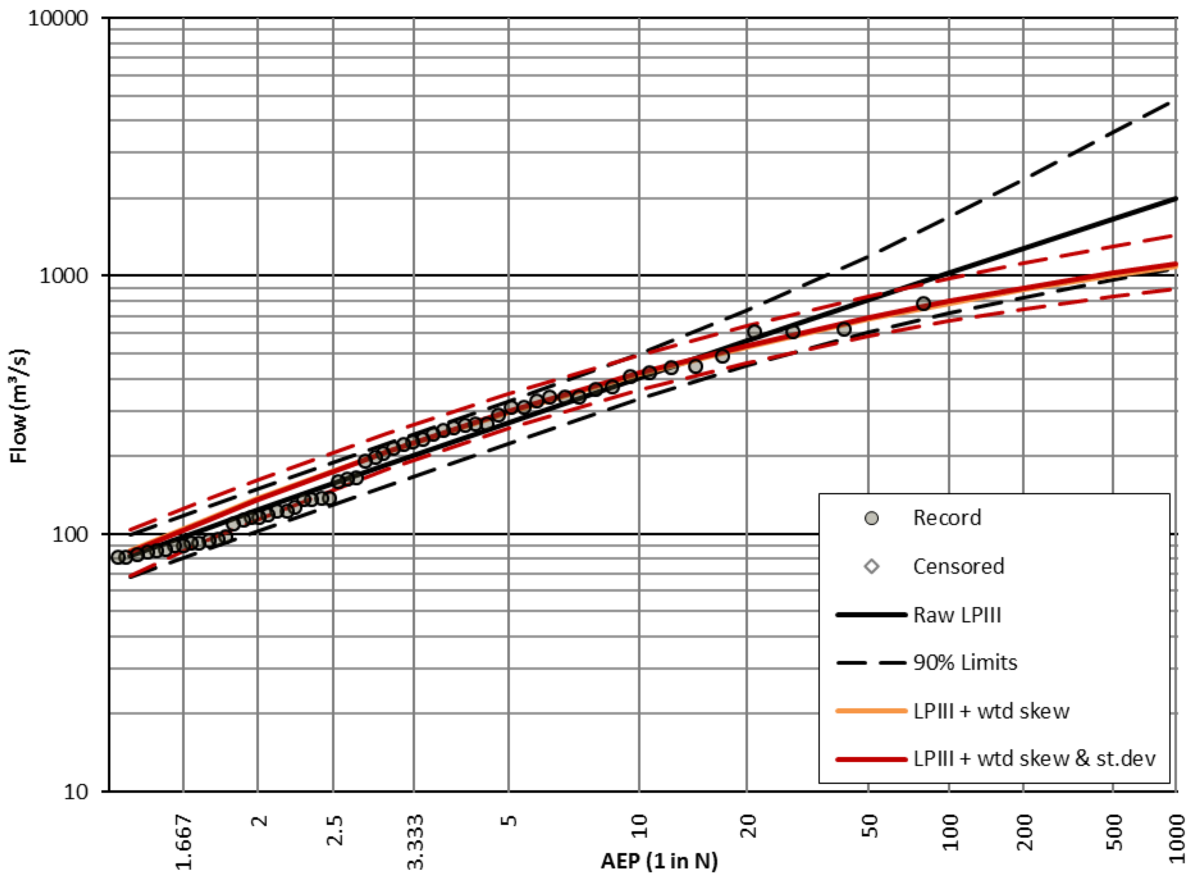

Figure 4-42 Flood frequency analysis at Peachester

Flood frequency analysis was conducted using the combined Somerset Dam and Silverton records. Frequency curves are presented in Figure 4-46, including comparison to the curve derived from Somerset Dam data only. The discharge data points clearly sit below the Somerset Dam frequency curve. Analysis of the raw data produces a frequency curve with very little skew (the opposite of the unweighted Somerset Dam curve). Introducing catchment weighted skew and standard deviation produce a more curved relationships that, while lower than the Somerset Dam curve at low flows, converges for high flows.

Construction on Somerset Dam commenced in 1935. Half of the Silverton gauge record is therefore potentially affected by the partially completed Somerset Dam. It is worth noting that between 1932 and 1954, only one flow in excess of 1000 m³/s is registered (1/23) compared to 4 between 1920 and 1931 (1/3) and at least 17 between 1955 and 2013 (~1/3.5). This may be natural climate variation, but it may be indicative of the impact of Somerset Dam.

Flood frequency analysis of the combined record of Silverton and Somerset Dam should therefore be treated with caution. Since the Somerset Dam record is itself dependent on unverified selection of threshold of missing floods, analysis of this site in general is considered to be relatively unreliable, particularly for high AEP events. The convergence of the frequency curves for low AEP's suggests that this may provide some confidence, although it is cautioned that this is to some extent dependent on weighed catchment parameters.

4.8.4 Upper Brisbane River at Cooyar Creek

The Cooyar Creek gauge is located in the upper Brisbane River catchment. It was not a site requested for flood frequency analysis, but was initially nominated as a site for inclusion in the Monte Carlo simulation trial study and is presented here for completeness. The gauge rating utilises hydrologic model results and is therefore potentially unreliable.

The availability of gauge data is presented in Table 4-18 and the available annual peak record is shown in Figure 4-47. Stream gauge data is only available since 1970. Flood frequency analysis was conducted using only the stream gauge data. Multiple Grubbs Beck censoring of low flow data excluded 5 flows below 13 m³/s, leaving a sample of 39 years data. Inclusion of URBS model flows back to 1955 would add another seven years of flow data to the record, but also eight years for which no flow data is known. These floods are not particularly significant compared to others within the continuous gauge data set. The statistical benefit of this inclusion is questionable. The flood record prior to 1955, which is solely based on URBS model results, is sparsely populated. The 1893 flood flows are not especially noteworthy at this location and of unknown reliability due to the quality of the rainfall data (daily record) and inclusion in the historical record cannot reasonably be justified.

Analysis of the raw gauge data, shown in Figure 4-48, reduces a frequency curve with a relatively small skew. Inclusion of a catchment weighted skew produces a curve that visually fits the data as well, is more consistent with stream gauges downstream and other flow estimation methods and significantly reduces the confidence limits. Catchment weighted standard deviation has negligible effect on the frequency curve.

4.8.5 Upper Brisbane River at Plainlands/Fulham Vale/Watts Bridge

Planlands, Fulham Vale and Watts Bridge are historical gauges in the upper Brisbane River prior to the construction of Wivenhoe. Plainlands (1920-1932) and Fulham Vale (1933-1966) were located in fairly close proximity just upstream of the confluence with Cressbrook Creek, while Watts Bridge (1952-1972) was located just downstream of the confluence.

Table 4-16 Gauge record history for the Stanley River at Somerset Dam

Record Type	Period	Total	Containing Data	Missing/Zero
Reverse Routed	1955 – 2013	59	19	40
Combined post-1955	1955 – 2012	59	24	35
Combined	1887 – 2013	127	32	95

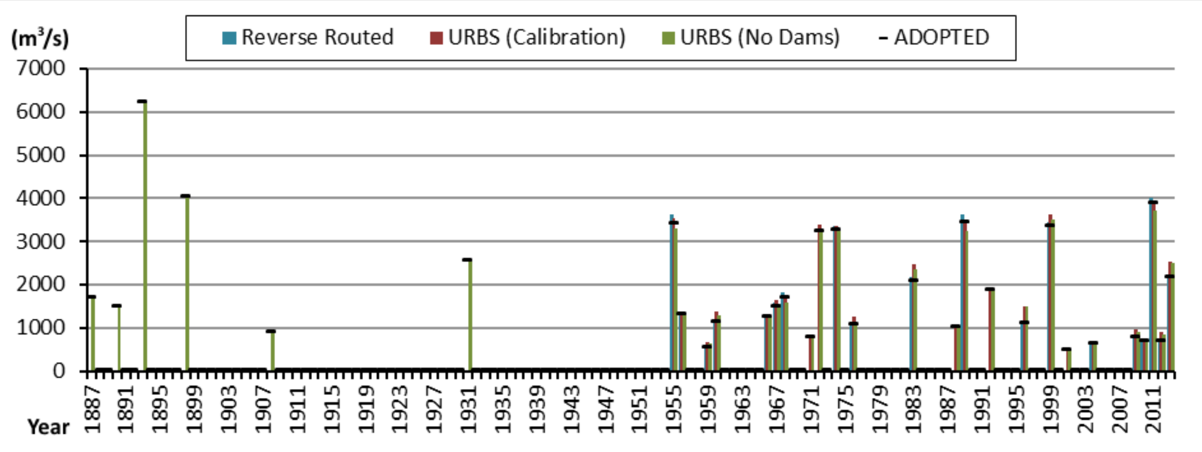

Figure 4-43 Annual peak flow record for the Stanley River at Somerset Dam

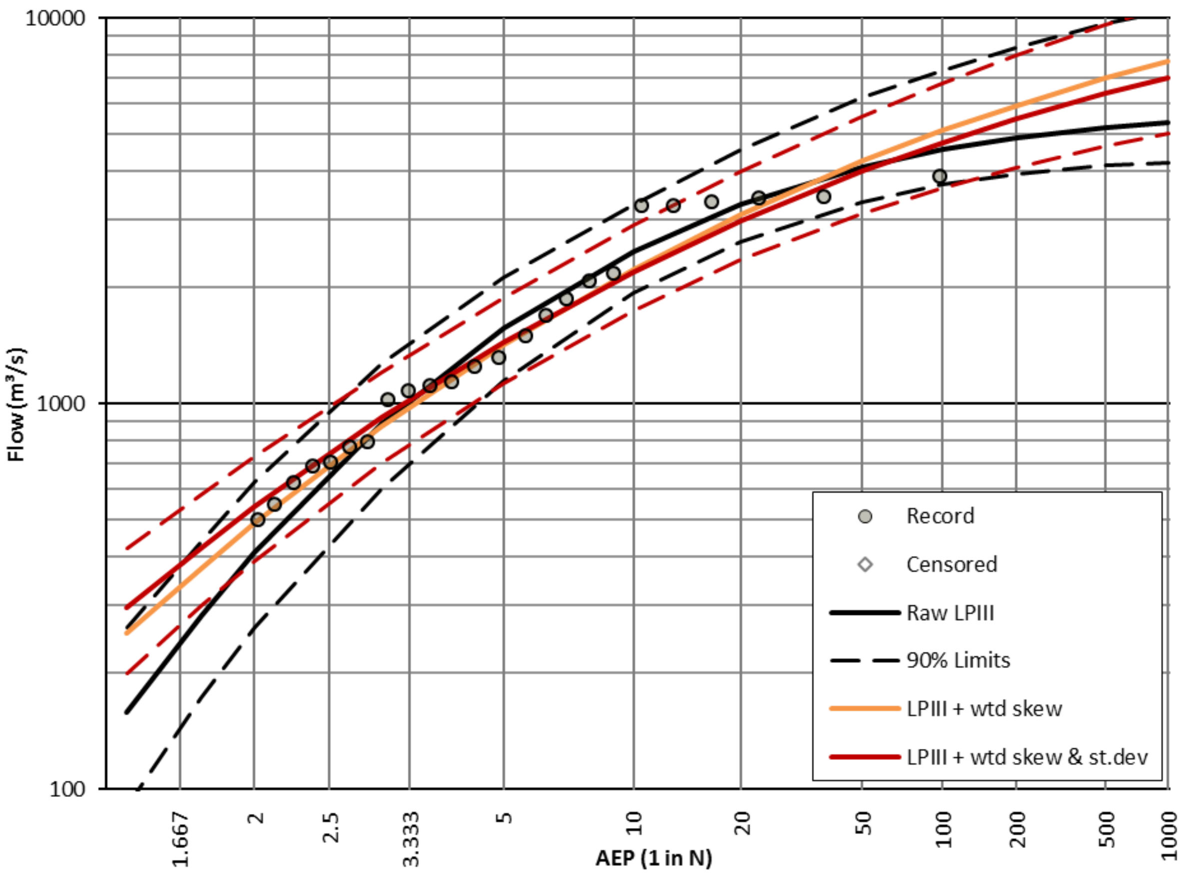

Figure 4-44 Flood frequency analysis at Somerset Dam

Table 4-17 Gauge record history for the Stanley River at Somerset Dam and Silverton

Record Type	Period	Total	Containing Data	Missing/Zero
Stream gauge	1920 – 1951	32	32	0
Reverse routed	1955 – 2013	59	19	40
Combined	1887 – 2013	127	32	95

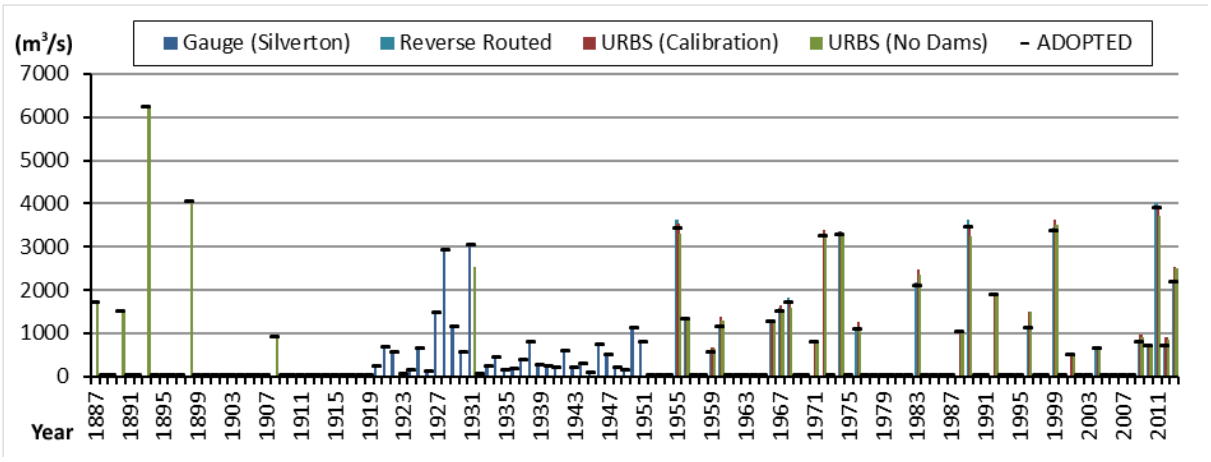

Figure 4-45 Annual peak flow record for the Stanley River at Somerset Dam and Silverton

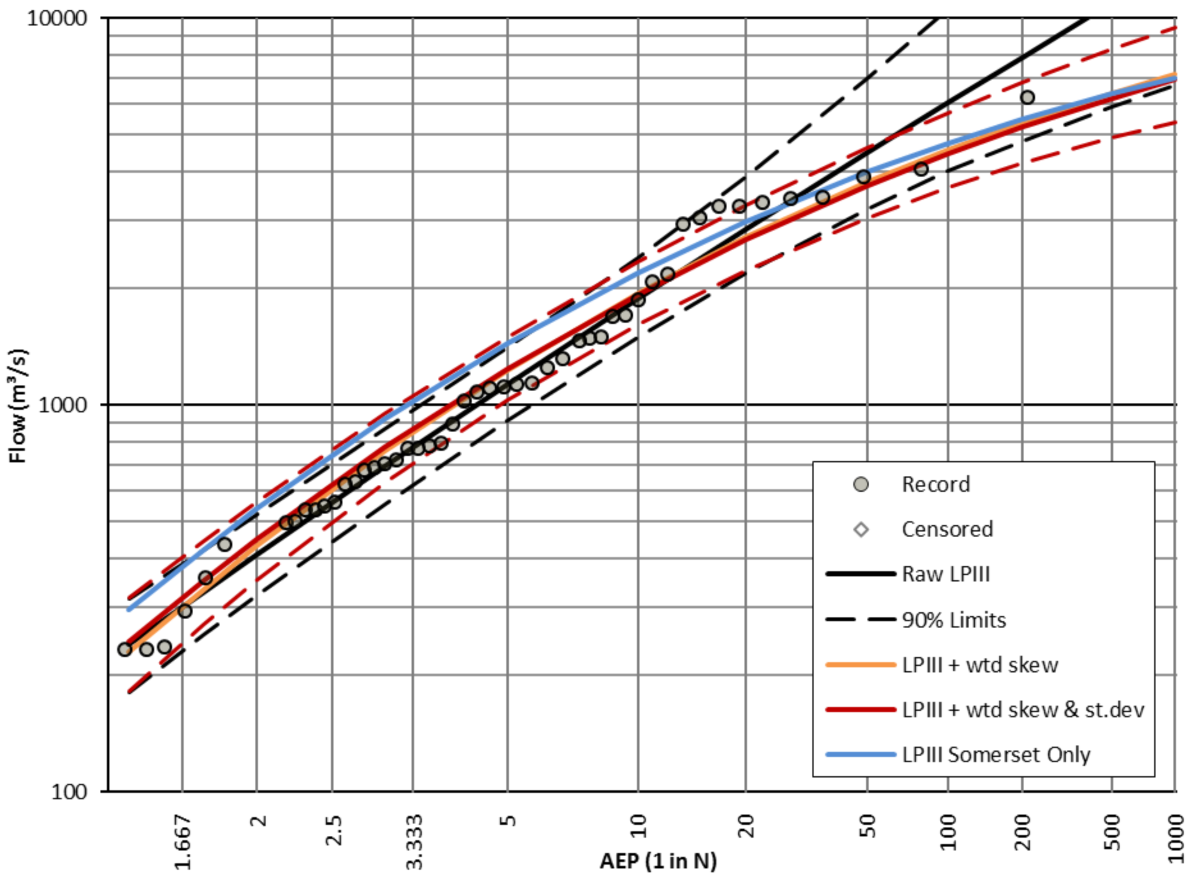

Figure 4-46 Flood frequency analysis of Somerset Dam and Silverton

Table 4-18 Gauge record history for the upper Brisbane River at Cooyar Creek

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1970 – 2013	44	44	0
Peak Gauge	1971 – 2011	41	16	25
Combined (post 1955)	1955 – 2013	59	51	8

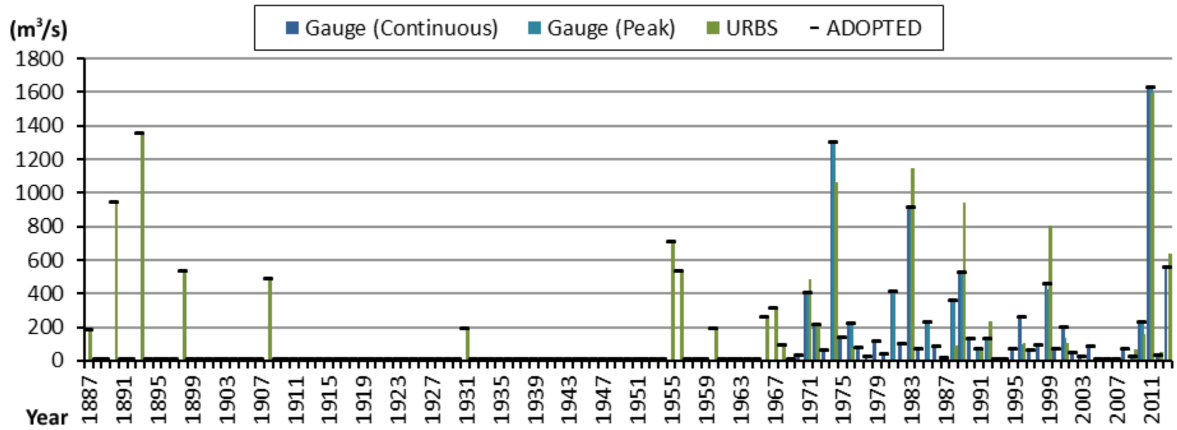

Figure 4-47 Annual peak flow record for the upper Brisbane River at Cooyar Creek

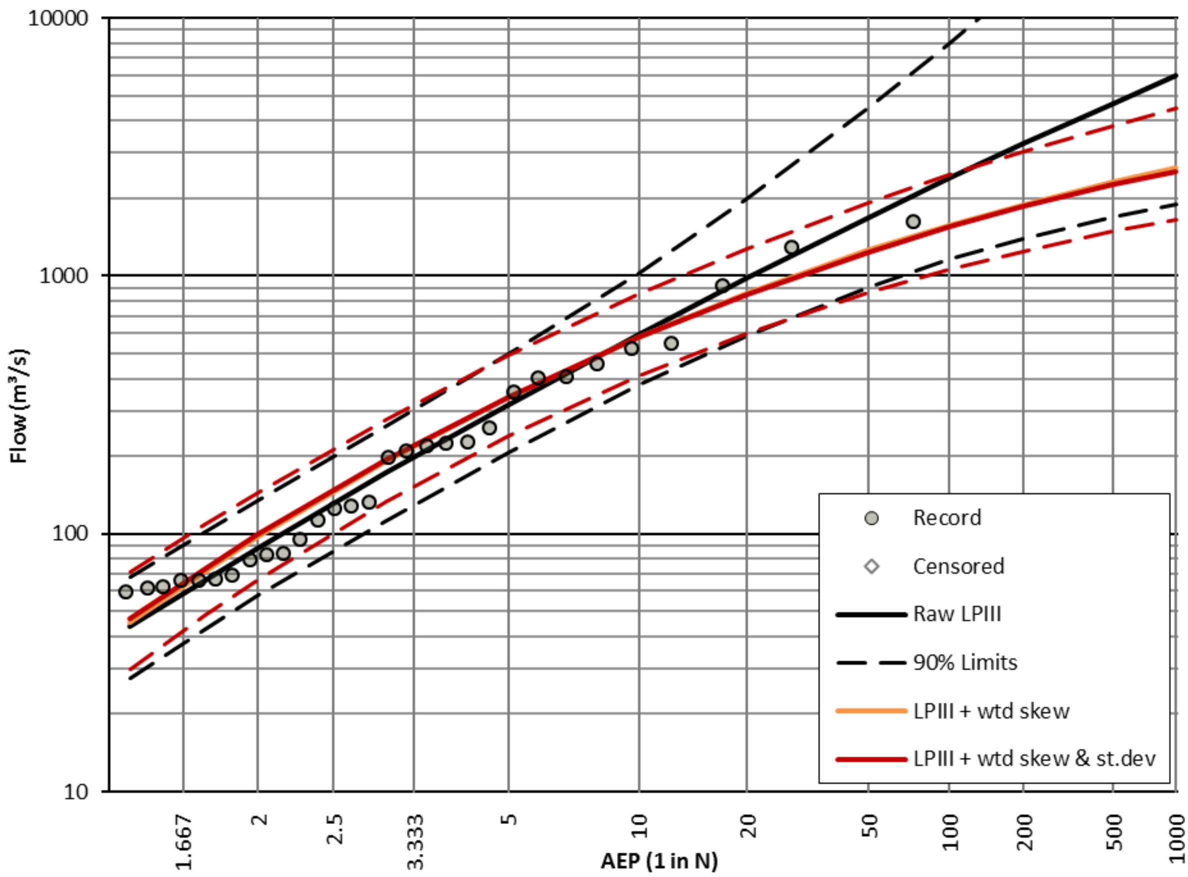

Figure 4-48 Flood frequency analysis at Cooyar Creek

A significant limitation is the lack of reliable gauge ratings at these sites. Fulham Vale as flow gauging only up to 200 m³/s and the rating has been extrapolated using limited URBS model flow data. Plainlands has no significant flow measurements. Watts Bridge has flow measurements up to 540 m³/s but the record is too short for a useful independent flood frequency analysis and the flows are not directly comparable as Watts Bridge includes the Cressbrook Creek catchment.

A combined flood record from the gauges has been compiled using:

- Gauge record and rating at Fulham Vale (1933-1966)
- Additional gauge record at Plainlands (1920-1932) assuming the same rating as Fulham Vale
- Additional record translated from Watts Bridge to Fulham Vale (1967-1972) using a gauge level correlation derived from overlapping period of record

The availability of gauge data is presented in Table 4-19 and the available annual peak record is shown in Figure 4-49. The gauge record covers a period of 53 years, with Multiple Grubbs Beck censoring of low flow data excluding 12 flows below 98 m³/s leaving a sample of 41 years data. The peak flow record shows that the gauge record misses the five largest flood events, identified by URBS modelling of major floods identified by downstream gauges. Post-1955 flows have been included as known historical events as these should be relatively well calibrated to Wivenhoe releases. The 1893 flood has been included as an undefined historical event as the URBS flow prediction is less reliable (gauge data at Gregors Creek suggests the actual flow may be higher than the modelled flow).

Flood frequency analysis using the unweighted flood record and catchment weighted parameters is shown in Figure 4-50. The catchment weighting has only a minor influence on the frequency curve. In general, analysis at this site is considered to have low reliability due to the gauge rating and complied nature of the gauge record. It does serve as a useful confirmation of the flows at Gregors Creek, which is located approximately 17 km upstream.

4.8.6 Upper Brisbane River at Wivenhoe

Wivenhoe Dam is located on the Brisbane River just upstream of the confluence with the Lockyer Creek. The dam was constructed between 1977 and 1985. Flow estimates for flood events since 1983 were calculated by reverse routing reservoir levels and outflows for use in the URBS model calibration. The availability of URBS model and reverse routed flow data is presented in Table 4-20 and the available annual peak record is shown in Figure 4-51. Only 14 flows are recorded within the period of Wivenhoe's operation and one of these is a minor inflow excluded from the sample, less than half the sample period. This period also includes the worst drought on record (the Millennium drought from 2001 to 2009) and several major inflows (1983, 1999 and 2013). The record does not contain a statistically distributed sample. Flood frequency analysis shown in Figure 4-52 demonstrates that unweighted frequency curve has a steep gradient that is strongly influenced by the inclusion of regional weighting parameters.

A long-term stream gauging station was operated at Caboonbah, upstream of Wivenhoe dam and downstream of the confluence of the Brisbane and Stanley rivers. The station has peak stream height records dating from 1890 until 1983. No flow gauging is available at the site, and a rating was developed based primarily by URBS model flow data to historical levels (assisted by some cross-correlation to Middle Creek). Pre-Wivenhoe stream records are also available at Middle Creek gauge downstream of Caboonbah, with continuous records from 1963 to 1982. Flow measurements up to 2,500 m³/s were recorded at this site, providing some confidence in the flow rating.

Table 4-19 Gauge record history for the upper Brisbane River at Fulham Vale

Record Type	Period	Total	Containing Data	Missing/Zero
Fulham Vale gauge	1933 – 1966	34	34	0
Extended Gauge	1920 – 1972	53	53	0
Combined	1887 – 2013	127	74	53

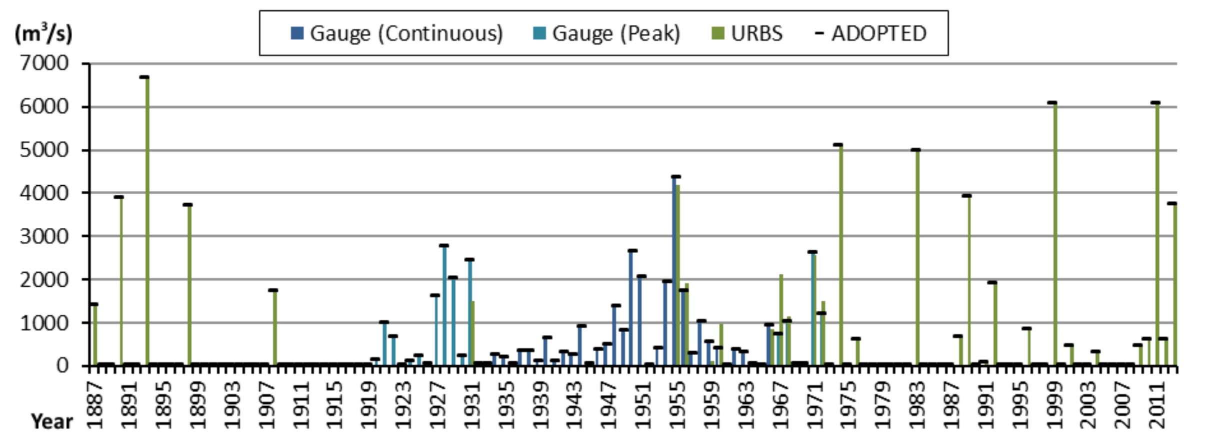

Figure 4-49 Annual peak flow record for the upper Brisbane River at Fulham Vale

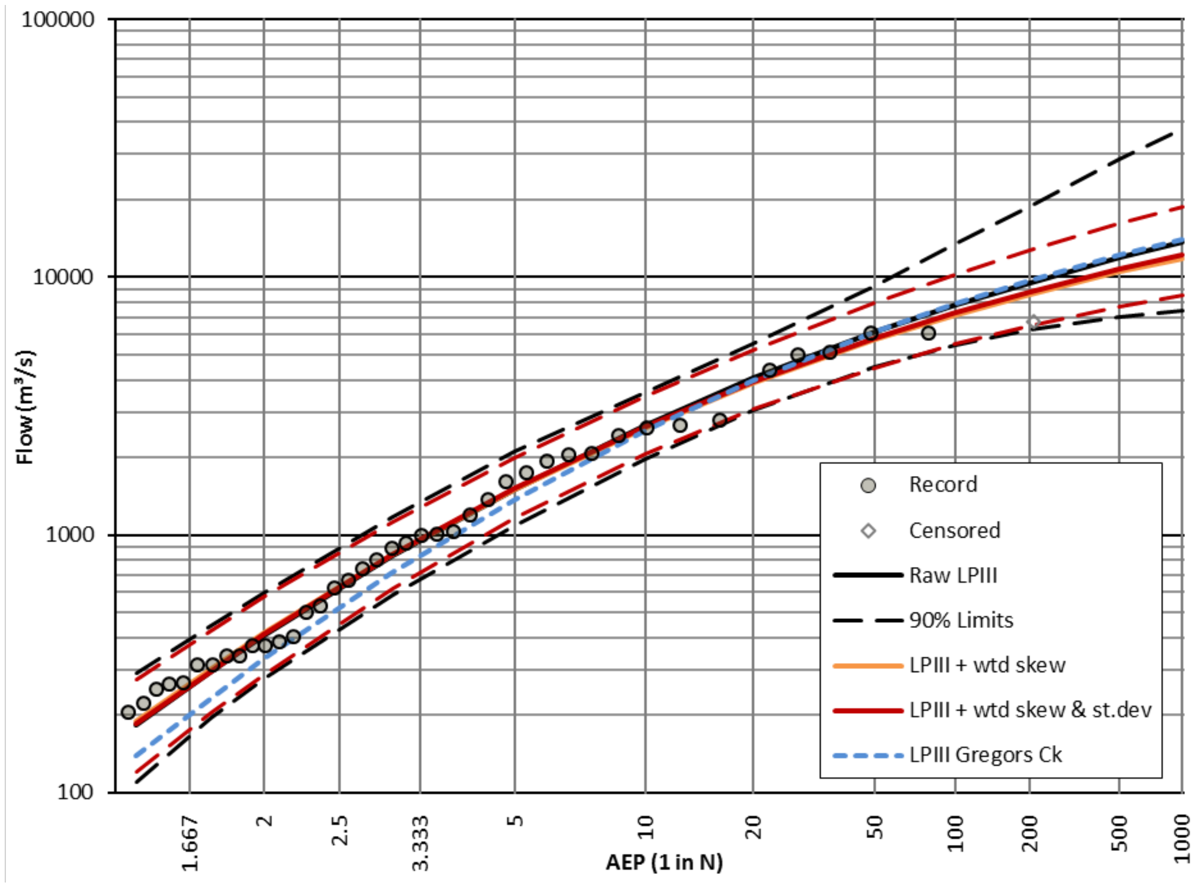

Figure 4-50 Flood frequency analysis at Fulham Vale

The combined records of these sites, summarised in Table 4-21 and shown in Figure 4-53, provide a long but somewhat unreliable and inconsistent record of flows in the reach between the Bremer River confluence and the Wivenhoe Dam site. Assessment of the data consistency resulted in the censoring of all flows below 1,800 m³/s and inclusion of a second higher threshold for missing flows prior to 1921. Flood frequency analysis of this data, shown in Figure 4-54, has a lower gradient. The inclusion of catchment weighted parameters visually appears to improve the fit of the data. Of significant note is that the catchment weighted frequency curve of the limited post-1983 Wivenhoe data shows very good consistency with the combined record data.

4.8.7 Lockyer Creek at Helidon

Helidon is located in the upper Lockyer Creek catchment. Stream gauge records at Helidon extend back to 1926, however this has been obtained at three separate sites and review of the data has identified issues with all three sites:

- Helidon No.1 (1926-1971) has only minor flow gauging and exhibits a number of minor drifts in datum. The rating has been extended using No.3, which it is closest to
- Helidon No.2 (1966-1988) has the highest flow gauging but both level record and flow gaugings display a significant datum shift in 1976
- Helidon No. 3 (1987-2013) has moderate flow gauging but contains the millennium drought and an extreme event in 2011, making it statistically unreliable

Helidon No. 1 and 3 are located within 0.2 km of each other, however Helidon No. 2 is 5.1 km downstream. Rating curves were developed at No. 2 and No. 3 using the flow gauging and extrapolation using URBS model flows where available. Due to the lack of available data, Helidon No.1 was assumed to have the same rating as No. 3.

The availability of gauge data is presented in Table 4-22 and the available annual peak record is shown in Figure 4-55. The combined gauge data provides a continuous record from 1927 to 2013. Some earlier URBS model flow estimates are available but are of unknown accuracy and unconfirmed statistical relevance and so have not been used in the analysis. The flood of record occurred in 2011. Although this is known to have been an extreme event, the rated flow for this event is highly inconsistent with the other data (including URBS flow modelling of the event) and is over 3.5 times larger than the next highest flow in 127 years. The automatic stream gauge is known to have failed during the 2011 flood, and the peak level is identified only as a flood mark. The 2011 event has been included in the analysis as a historical event of undefined size only due to uncertainty in recorded level and rating, and a strong influence on fit.

Flood frequency analysis results are shown in Figure 4-56. The plotted data appears relatively consistent and the unweighted frequency curve provides a good fit of the full range of data. Introduction of catchment weighted skew slightly increases the curvature and visually appears to slightly improve the fit of the upper tail. The catchment weighted standard deviation has little influence on the frequency curve. Although this appears to be a good outcome, the inconsistencies in the gauge datum, low reliability of the rating curves and combined nature of the record significantly limit the reliability of the analysis at this site.

Table 4-20 Gauge record history for the upper Brisbane River at Wivenhoe

Record Type	Period	Total	Containing Data	Missing/Zero
Reverse Routed	1983 – 2013	31	11	20
Combined post-1983	1983 – 2013	31	14	17
Combined	1887 – 2013	127	53	74

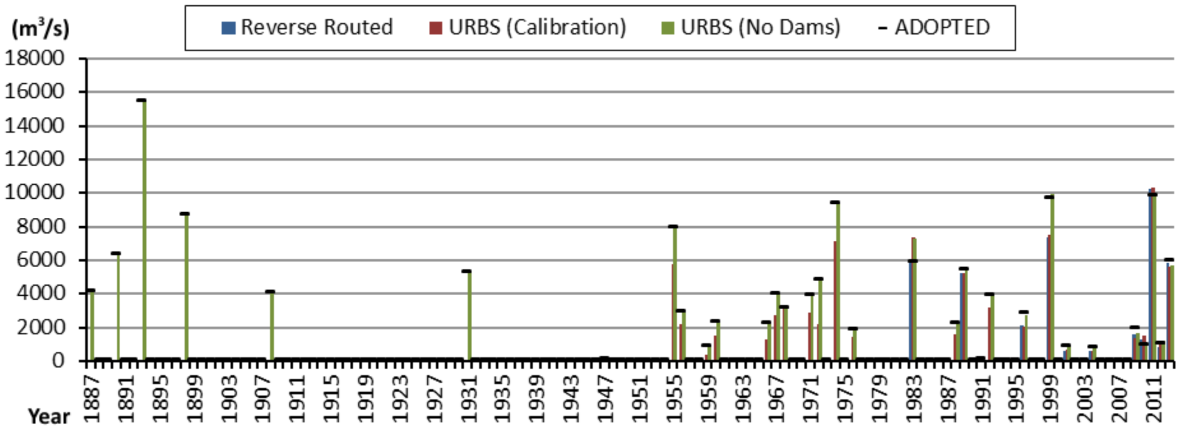

Figure 4-51 Annual peak flow record for the upper Brisbane River at Wivenhoe

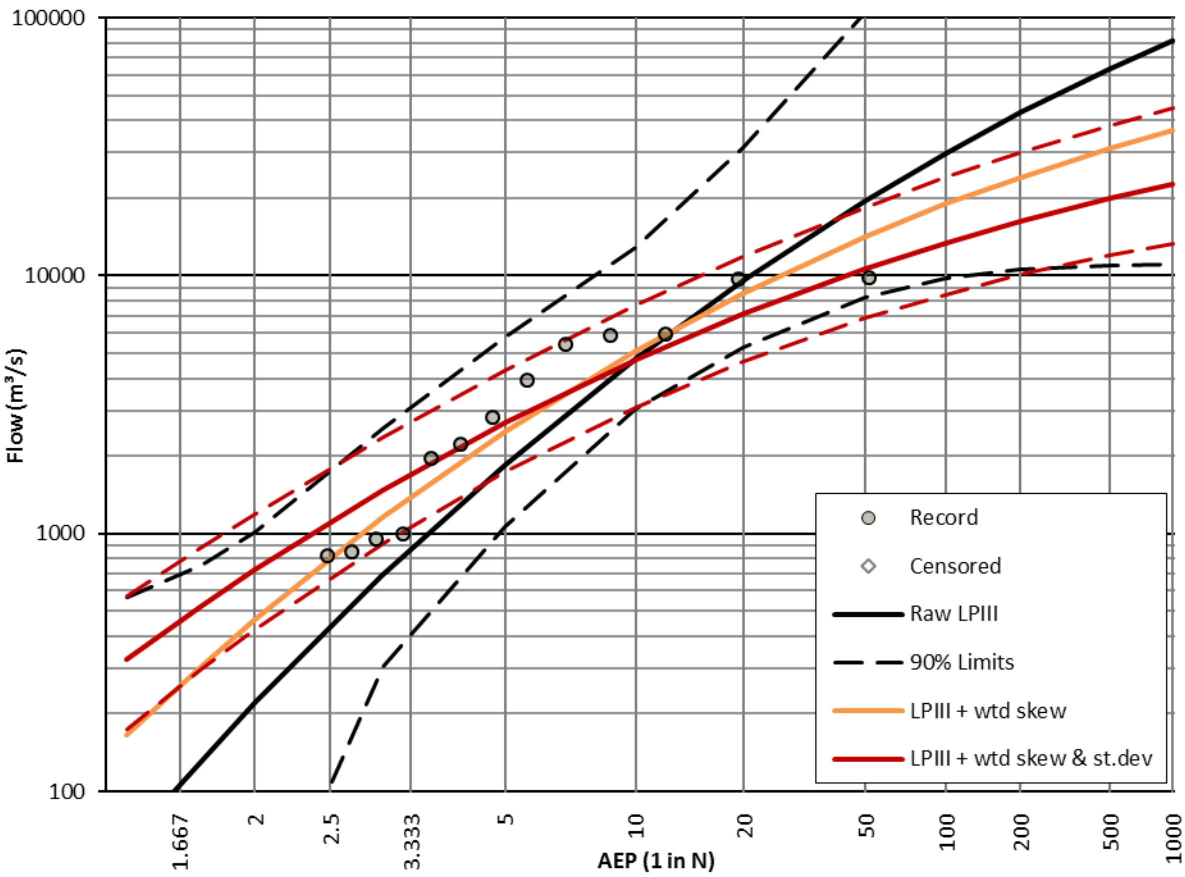

Figure 4-52 Flood frequency analysis at Wivenhoe

Table 4-21 Gauge record history for the upper Brisbane River at Caboonbah, Middle Creek and Wivenhoe

Record Type	Period	Total	Containing Data	Missing/Zero
Reverse Routed	1983 – 2013	31	11	20
Stream gauge	1890 – 1983	94	36	58
Combined	1887 – 2013	127	74	53

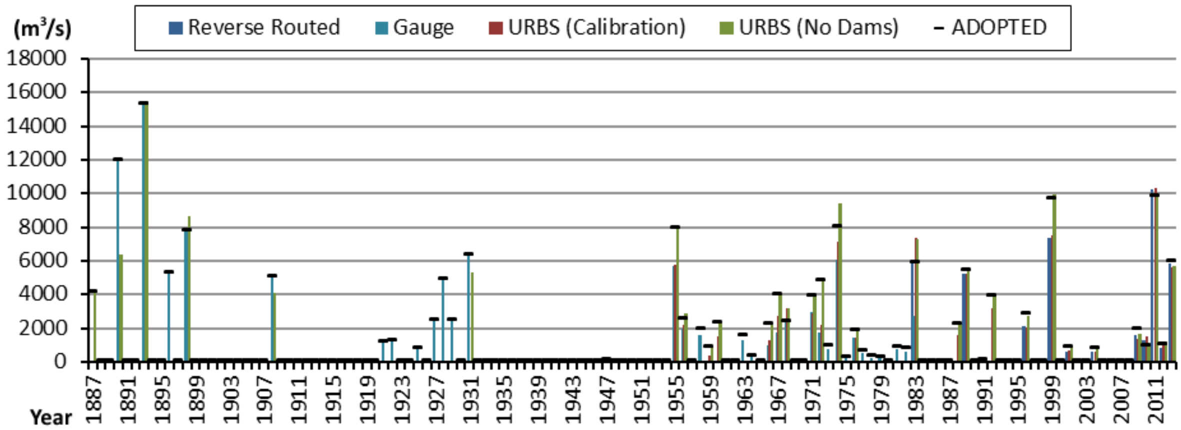

Figure 4-53 Annual peak flow record for the upper Brisbane River at Caboonbah, Middle Creek and Wivenhoe

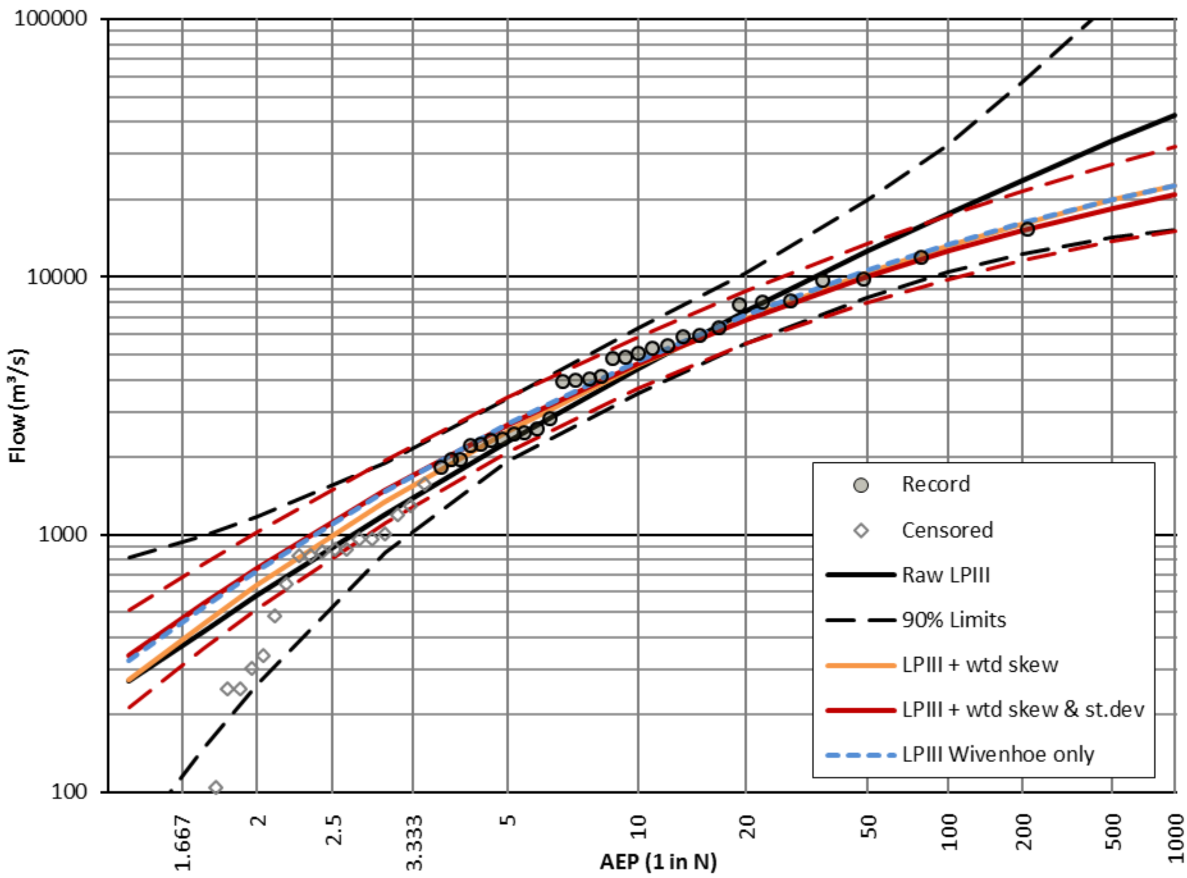

Figure 4-54 Flood frequency analysis at Caboonbah, Middle Creek and Wivenhoe

Table 4-22 Gauge record history for Lockyer Creek at Helidon

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1927 – 2013	87	87	0
Peak Gauge	1967 – 2011	45	18	27
Combined	1887 – 2013	127	92	35

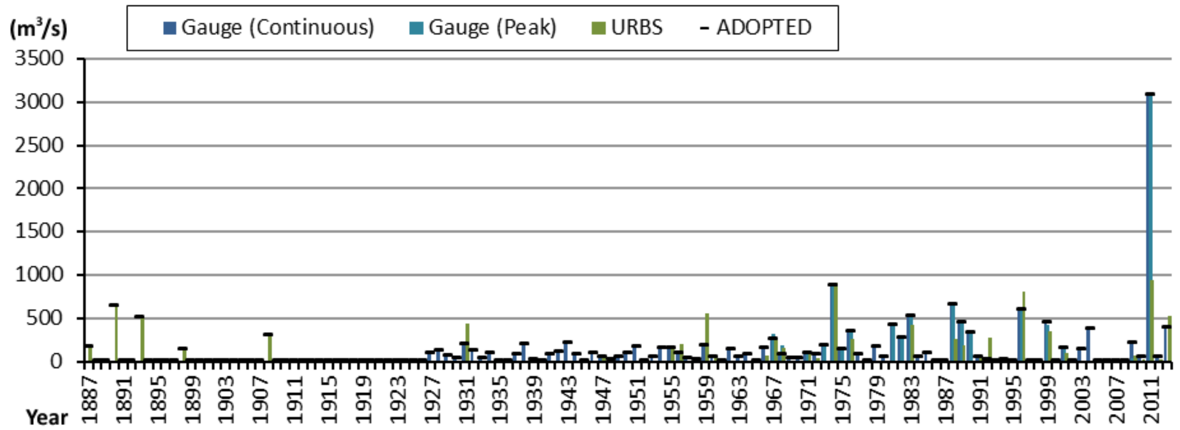

Figure 4-55 Annual peak flow record for Lockyer Creek at Helidon

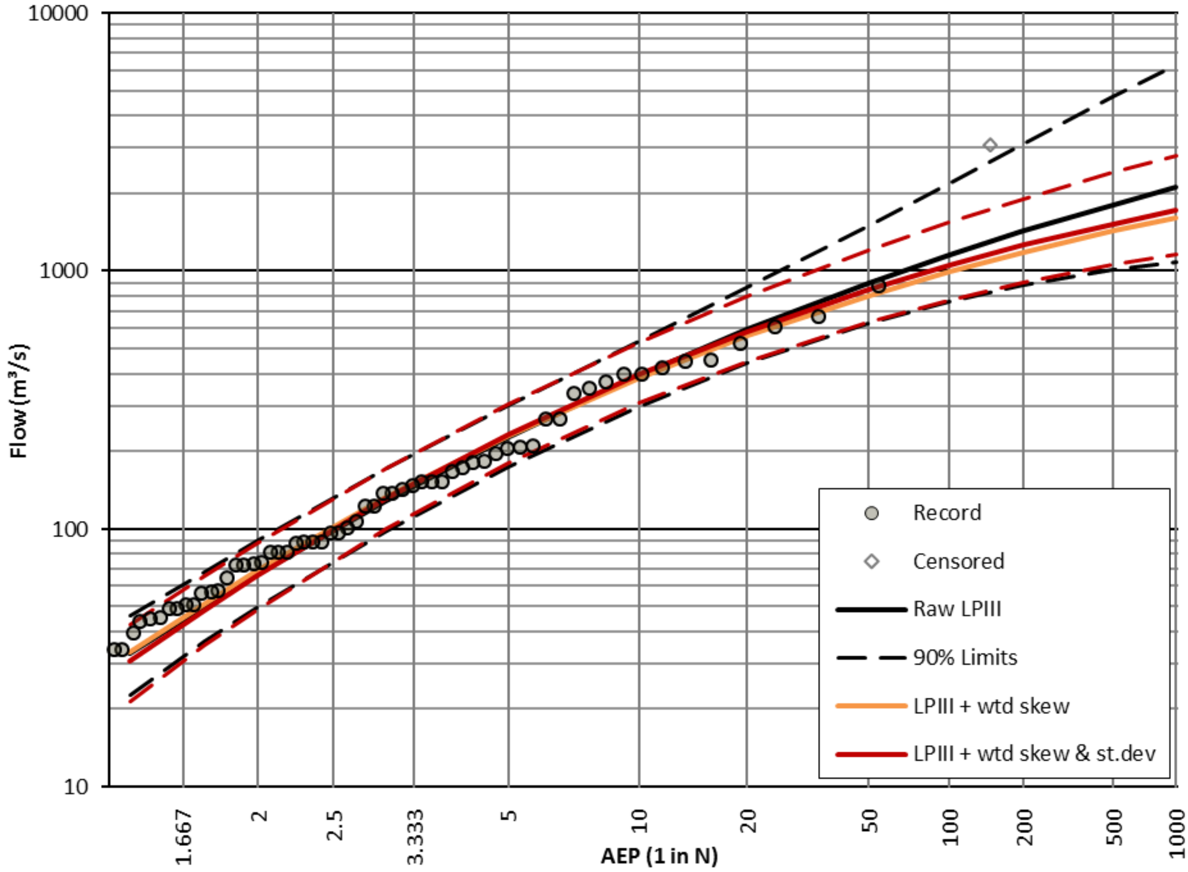

Figure 4-56 Flood frequency analysis at Helidon

4.8.8 Lockyer Creek at Gatton

Gatton is located on Lockyer Creek between Helidon and Glenore Grove. It has a long gauge history, with records dating back to 1890. Only peak flood level is available at the site. The availability of gauge data is presented in Table 4-23 and the available annual peak record is shown in Figure 4-57. Gatton is a flood warning gauge with no official flow rating. For the WSDOS project, Seqwater developed a rating at the site influenced by recorded flood peaks and estimated flows obtained from hydraulic modelling conducted and documented as part of the Lockyer Flood Study (SKM 2012). Although this theoretically should mean that the rating is relatively reliable, a number of significant issues with the rating have been identified:

- Comparison of the rated and URBS model flows for historical events shows a relatively good agreement for high flows (> 1,000 m^3/s) but the rating appears to overestimates mid-range events (150 – 700 m^3/s). (Review of Seqwater's report/modelling shows the same trend)
- Initial flood frequency analysis using this rating resulted in minor events (< 1 in 2 AEP) having a higher flow at Gatton than at Glenore Grove or Rifle Range Road downstream

Neither Aurecon nor Seqwater have obtained or reviewed the hydrologic or hydraulic modelling undertaken for the Lockyer Flood Study to verify what steps were taken to calibrate the model (beyond what is documented in the report), confirm the calibration/validity of the modelling for low flows or check for consistency with the hydrologic modelling undertaken for WSDOS or BRCFS. The lower rating was therefore modified slightly to improve consistency with the URBS modelling, which also reduced flows for the minor flood events.

Flood frequency analysis results are presented in Figure 4-58. Unweighted analysis of the data produces a relatively straight relationship. Introduction of catchment weighted skew increases the curvature of the frequency curve, while the catchment weighted standard deviation has negligible effect. The catchment weighted frequency curve using the Seqwater rating is shown for comparison, tending to produce similar flows for low AEP results but higher flows for high AEP events. Due to this uncertainty in the flow rating, the flood frequency analysis of the Gatton gauge has low confidence in the high AEP frequency curve.

4.8.9 Lockyer Creek at Rifle Range Rd/Lyons Bridge

Rifle Range Road is located in the lower Lockyer Creek downstream of Glenore Grove. The gauge has been in operation since 1966, with continuous record data from 1988. The station has stream flow measurements up to about bank-full level (~800 m^3/s), however the ratings become increasingly unreliable above about 600 m^3/s as flows break out of the creek channel upstream at Glenore Grove. Lockyer Creek has a perched channel as it cuts through the lower Lockyer floodplain, and the stream gauge cannot measure out of channel flows. The station at Lyons Bridge is located 2 km upstream and was operated by the State Government water resources agencies (now DNRM) from 1955 until 1988 when it was relocated to Rifle Range Road. Lyons Bridge also has reasonable stream measurement data. The availability of gauge data at Rifle Range Road is presented in Table 4-24 and the available annual peak record is shown in Figure 4-59. Rated flows in excess of bank-full capacity are highly unreliable, while the URBS model only reports main-channel flows. Rated flows from Lyons Bridge were used to extend the flow record back to 1955.

The Rifle Range Road and Lyons Bridge records were analysed using only the reliable in-channel flow range. This method of censoring out the high (>650 m^3/s) and low flows (<90 m^3/s) is considered unreliable and was undertaken solely for the purpose of cross-checking the Glenore Grove low flow range. Results of the flood frequency analysis are presented in Figure 4-60. The analysis is presented for information purposes only, and should not be used for estimating flood frequencies in the lower Lockyer floodplain.

Table 4-23 Gauge record history for Lockyer Creek at Gatton

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	-	-	-	-
Peak Gauge	1893 – 2011	119	47	72
Combined	1887 – 2013	127	60	67

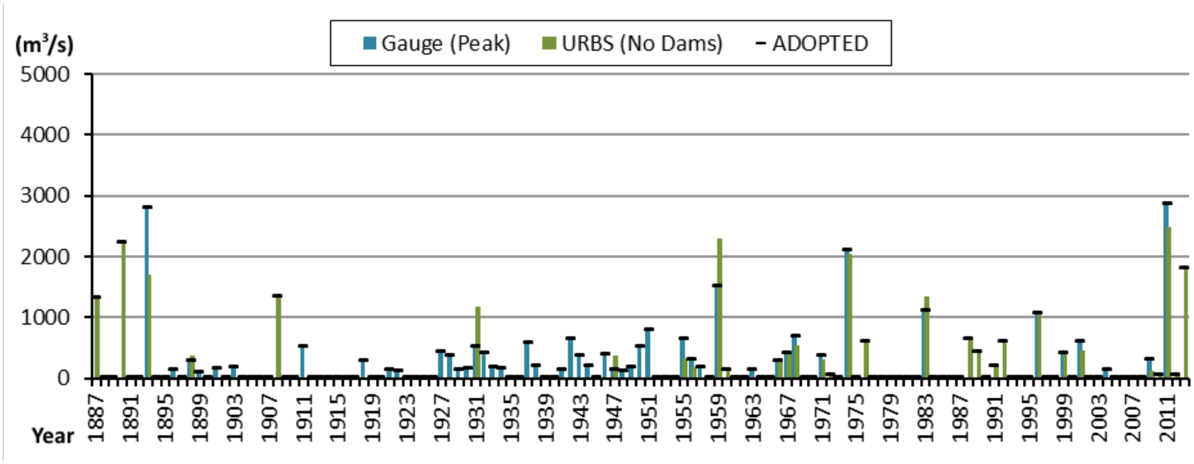

Figure 4-57 Annual peak flow record for Lockyer Creek at Gatton

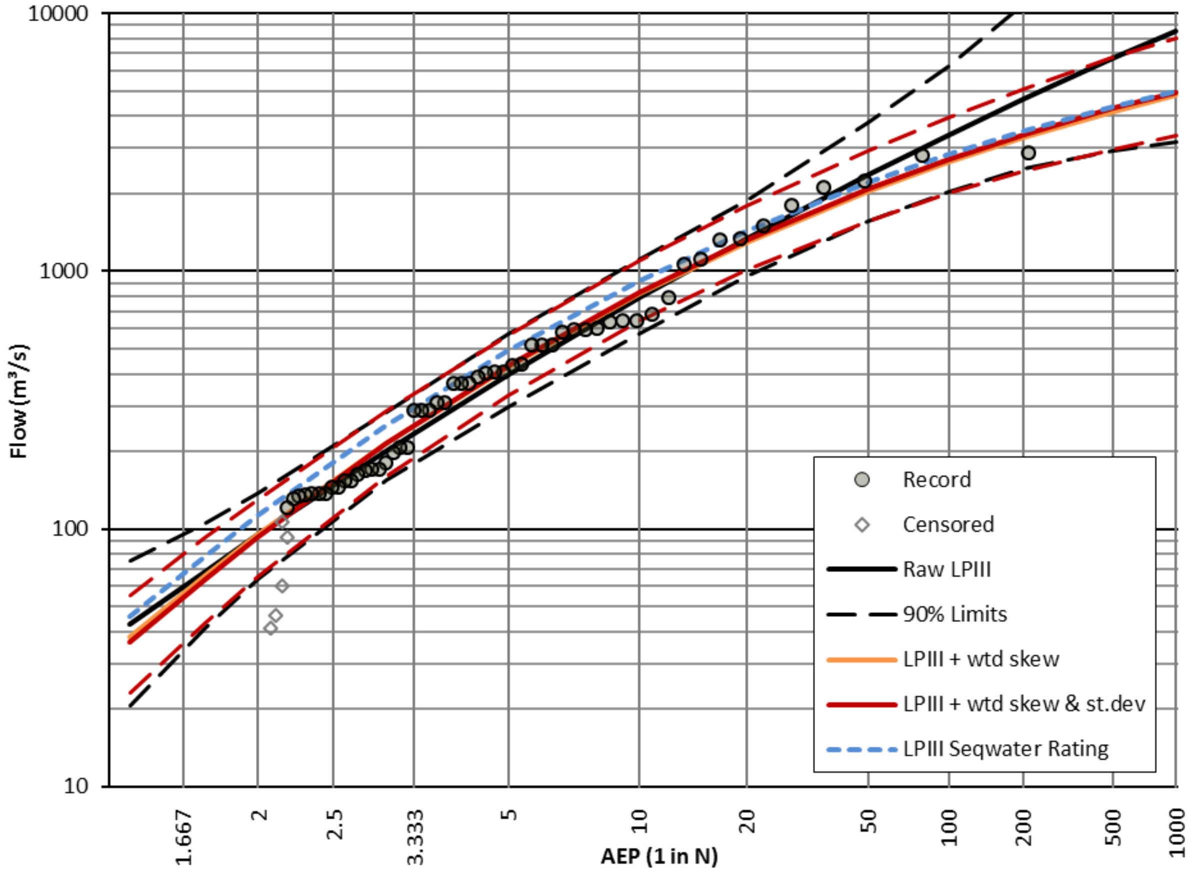

Figure 4-58 Flood frequency analysis at Gatton

Table 4-24 Gauge record history for Lockyer Creek at Rifle Range Rd

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	1989 – 2013	25	22	3
Peak Gauge	1966 – 2011	46	27	19
Combined	1887 – 2013	127	32	95

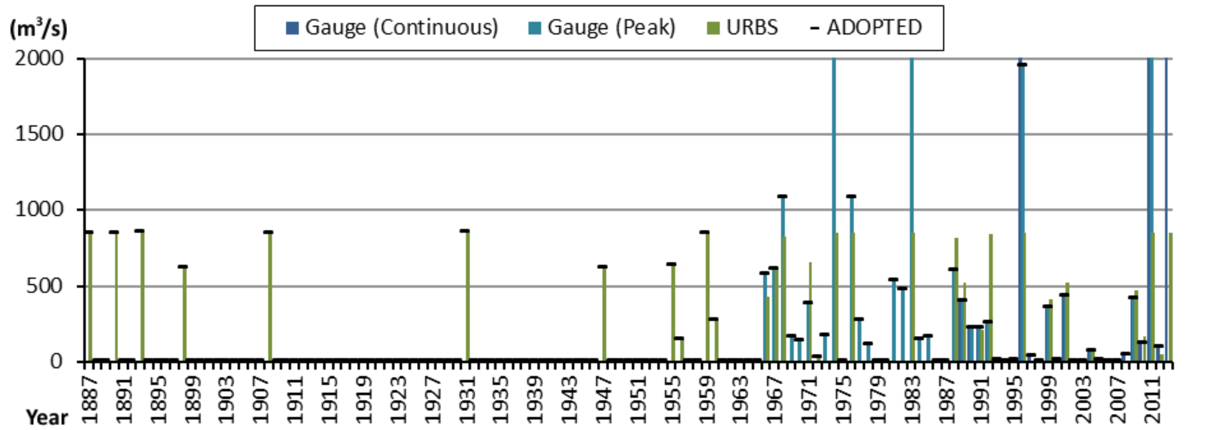

Figure 4-59 Annual peak flow record for Lockyer Creek at Rifle Range Rd

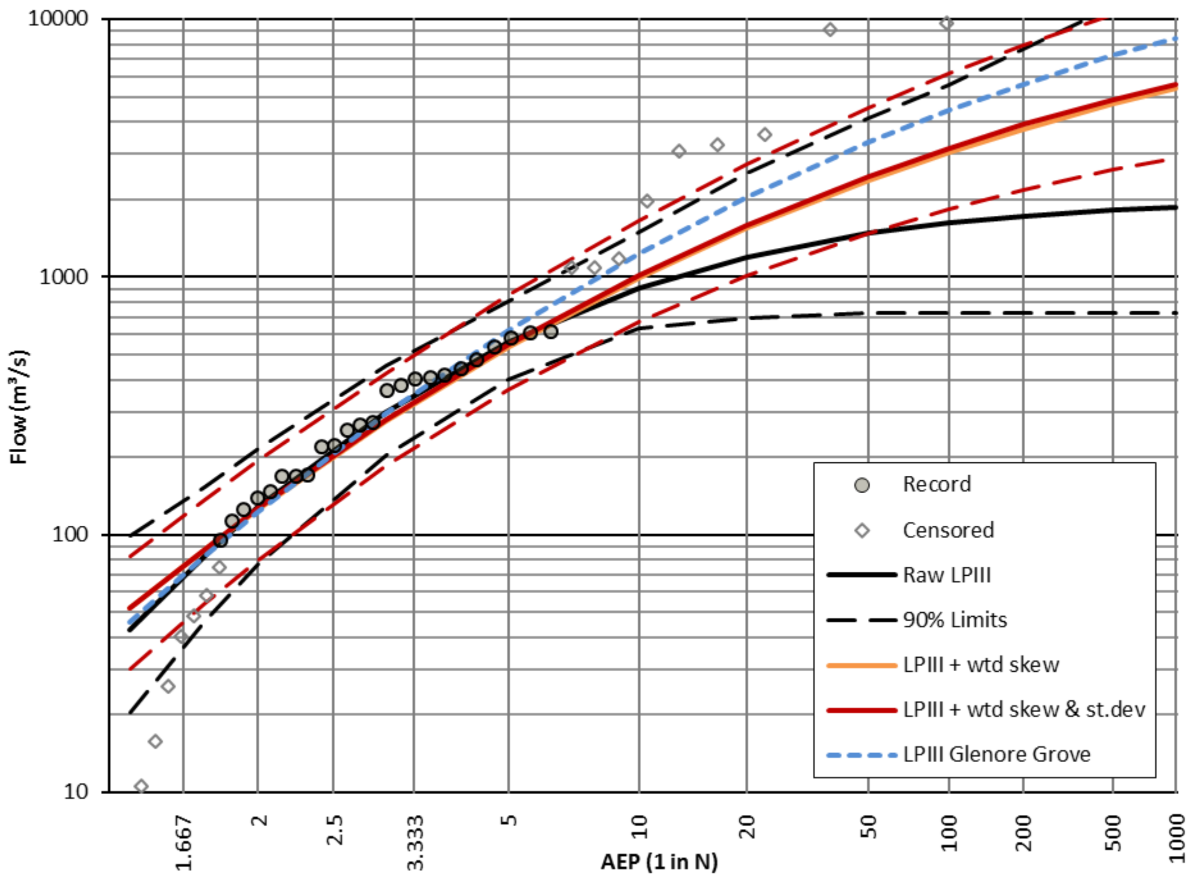

Figure 4-60 Flood frequency analysis at Rifle Range Rd

The unweighted analysis produces a very good fit of the data, but without control from the censored high end of the record results in a very high curvature. Introducing a catchment weighted skew produces a similar fit of the data range, while catchment weighted standard deviation has negligible impact. The high AEP range (< 1 in 5 AEP) is consistent with that of the Glenore Grove shown in Figure 4-60 for comparison, which is as expected as there is relatively little additional catchment between the sites (URBS model events simulation of historical events shows minor increases or decreases depending on the balance of local inflows against attenuation, while Design Event modelling actually shows a slight decrease between Glenore Grove and Rifle Range Road). The upper Rifle Range Road frequency curve projects lower than Glenore Grove. Although this is actually physically possible, given the significant floodplain area between the sites, this should not be considered to imply that the Rifle Range Road frequency curve derived from in-stream records is accurately predicting the floodplain attenuation.

4.8.10 Lower Brisbane River at Brisbane City

The Brisbane City gauge has a long flood record, particularly of notable historical flood events dating back to 1841, but reliable flood frequency analysis is disadvantaged by the lack of a reliable flow rating:

- Flood levels are strongly affected by tide, particular for minor to moderate flows up to 6,000 m^3/s but with some influence even for larger flows
- There is no flow gauging available at the site for independent confirmation of the rating, and steady releases from Wivenhoe used for validation of other lower Brisbane gauges are well within the tidally affected range
- The rating is potentially influenced by varying degrees of historical dredging, the extent and impact of which is difficult to reliably quantify

Previous attempts to account for dredging have been made by adjusting the gauge level, generally by applying a uniform shift which is not considered to be particularly realistic as the effects of dredging would be expected to vary with flow. The magnitude of the shift has little physical basis and has varied significantly. Other attempts to perform flood frequency analysis at the gauge have included developing synthetic flood histories based on flows at Moggill, flow volumes at Ipswich etc.

Several approaches have been considered to make use of the available gauge record at the City gauge and also estimate flows at that location:

Approach 1 – Assessment using a local rating

Calibration using a Local Rating – Assessment of recent TUFLOW modelling conducted by Brisbane City Council on behalf of DSDIP shows a level-flow relationship relatively free from hysteresis but displaying noticeable tidal variation/influence even for relatively high flows. (This is consistent with correlation of peak flow levels between Moggill and City gauges discussed below – note the negligible response in City tidal range for Moggill levels up to 10 m (~4,500 m^3/s) and still notable variation above 18 m (~ 10,000 m^3/s) in Figure 4-61). This model has been used to develop a rating at the City gauge however, as discussed above, there is no information to independently correlate the rating. The rating is therefore dependent entirely on the calibration of TUFLOW model used flows from Seqwater's WSDOS model that are not consistent with the current BRCFS URBS model calibration and flows. The presence of tidal influence and historical consistency of the gauge rating (eg dredging) also limit the reliability of the rating.

Approach 2 – Correlation of gauge heights to Moggill

There are relatively few inflows downstream of the Bremer River confluence. Figure 4-61 demonstrates that there is definite correlation between the peak flood levels at Moggill and at the Brisbane City gauge for larger flood events, nominally about 12.5 mAHD at Moggill, corresponding to a flowrate of around 6,000 m³/s

The relationship evident in Figure 4-61 can be used to translate levels at the City gauge to an equivalent level at Moggill. This provides a longer period of record, but the variability of the correlation introduces significant uncertainty into the exact magnitude of flow. Provided that the translation is average and unbiased, this nevertheless potentially provides a useful independent cross-check of the Moggill gauge record.

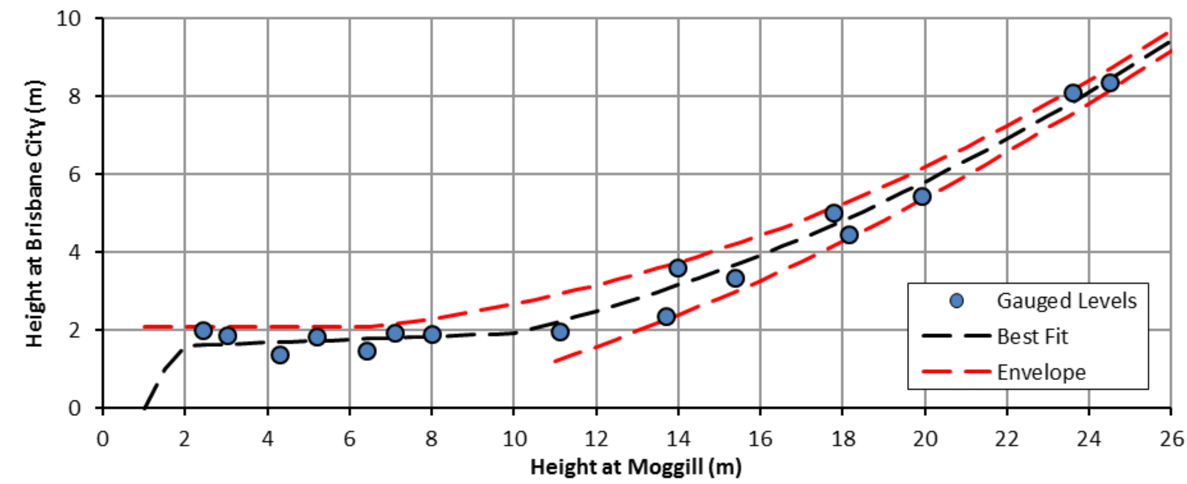

Figure 4-61 Relationship between peak flood levels at Moggill and Brisbane City gauges

Approach 3 – Correlation of flows from Moggill

Due to the lack of data to confirm the reliability of the rating at the City gauge, design flows at the city gauge could be obtained by correlating FFA results from a gauging location with a more reliable rating such as Moggill. Previous studies have assumed that flows remain relatively consistent in the lower reach although the recent TUFLOW modelling and hydrologic modelling conducted for the BRCFS indicates that there is some attenuation of peak flow as the flood progresses downstream.

The availability of gauge data at the Brisbane City gauge is presented in Table 4-26 and the available annual peak record estimated using the Brisbane City rating derived from the TUFLOW modelling is shown in Figure 4-62. Flood frequency analysis was performed for the combined record excluding all flows below 5600 m³/s due to significant uncertainty in the rating for lower flows. This leaves the analysis based on only 25 of 173 years of record (14%). Results of the analysis provided in Figure 4-63 show that the unweighted Log Pearson III curve fits the data relatively well and predicts low AEP flows slightly lower than at Moggill but noticeably larger high AEP flows. Inclusion of catchment weighted skew and standard deviation both have a noticeable influence due to the relatively small data sample. The weighted curve tends to be slightly lower than the Moggill frequency curve for low AEP events and still slightly higher than at Moggill for low AEP events. These predictions are slightly higher than suggested by other Design Event and Monte Carlo simulation methods, which typically show a reduction in flow between Moggill and Brisbane. Possible issues include the unverified rating curve, tidal influence and the limited data sample. It should be noted that flows below 1 in 5 AEP are within the tidal range and consequently have little value.

The correlation between levels at Moggill and Brisbane City was used to translate recorded levels at the City gauge to an equivalent level, and consequently flow, at Moggill. This method uses the flow rating at Moggill but an independent data sample from the City gauge. It should be noted that this analysis produces flows based on the Moggill rating and therefore the FFA estimates are applicable at the Moggill site. The combined stream gauge and URBS model contains 48 annual records out of 173 years. The analysis was conducted using 30 flood records greater than 5,000 m^3/s. The resulting frequency curves shown in Figure 4-64 show a very similar trend to the Moggill curve but slightly higher flows. The accuracy of the level correlation and small data sample limit the reliability of the flow estimates, so although this serves as a useful validation of the Moggill frequency curve, it should not override the at-site analysis.

Overall, the analysis of Brisbane City gauge data provides a useful indication of the flood frequency curves. However, limitations on the accuracy of the flow estimates correspondingly limit the reliability of the analysis. Hydraulic modelling component of BRCFS may improve confidence in Brisbane City rating, however the strong tidal influence will limit the availability of minor flood information. Currently the most reliable source for flow estimates at the City gauge is considered to be form hydrologic modelling calibrated at a more reliable site such as Moggill (ie Alternative 3).

4.8.11 Other gauge sites

In addition to the gauge sites discussed above, a number of other sites were specified for analysis in the Project Brief. A number of these sites are currently unrated or have ratings that are of unknown quality. Review of available data, records and ratings has identified three of the specified sites as being unsuitable for a reliable flood frequency analysis. Discussion of these sites is provided in Table 4-25.

Table 4-25 Nominated sites considered unsuitable for reliable FFA

Gauge Site	Remarks
Cressbrook Creek at Tinton	The gauge at Tinton has records from 1952 to 1986. The record could possibly be extended using data from other sites, such as Rosentrotters Crossing (1986-) located 12km downstream, however this would introduce correlation and datum issues. Neither site has significant flow gauging, making derivation of reliable ratings difficult. The gauge records are influenced by Cressbrook & Perseverance Dams. Overall, estimation of a reliable, unbiased flow record would be difficult
Warrill Creek at Kalbar & Junction Weir	Seqwater has developed a rating for Junction Weir based on hydraulic modelling, however the site is known to have complicated flow patterns and the rating is considered highly unreliable for moderate flows and above. Junction weir has a limited record, but could be combined the Kalbar gauge records although this correlation would add further uncertainty. Statistical analysis is not considered to be reliable and would have little benefit to the study
Bremer River at Ipswich	Ipswich is subject to flooding from both the Brisbane River and Bremer River. Flood levels may result from flows in either or both rivers and the causal system cannot be determined from gauge level alone. The current gauge rating is not considered reliable. Additionally, there is little evidence to support fitting of a probability distribution to data affected by multiple factors. Multi-component models have been used where the factors can be separated and analysed separately, but Bremer and Brisbane River flood is neither consistent nor separable Frequency analysis of gauge height could conceivably be performed and would give some indication of probability of reaching particular gauge heights, but there is no evidence to support a valid statistical level-depth relationship (particularly one with two sources of flooding), so projection of the relationship would be highly unreliable

Table 4-26 Gauge record history for the lower Brisbane River at Brisbane City

Record Type	Period	Total	Containing Data	Missing/Zero
Continuous Gauge	-	-	-	-
Peak Gauge	1841 – 2011	171	33	138
Combined	1841 – 2013	173	48	125

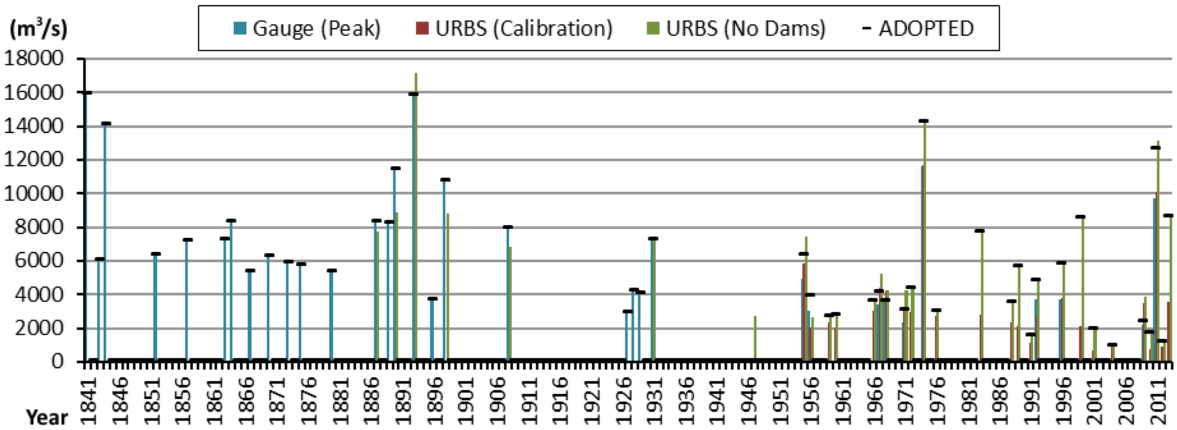

Figure 4-62 Annual peak flow record for the lower Brisbane River at Brisbane City

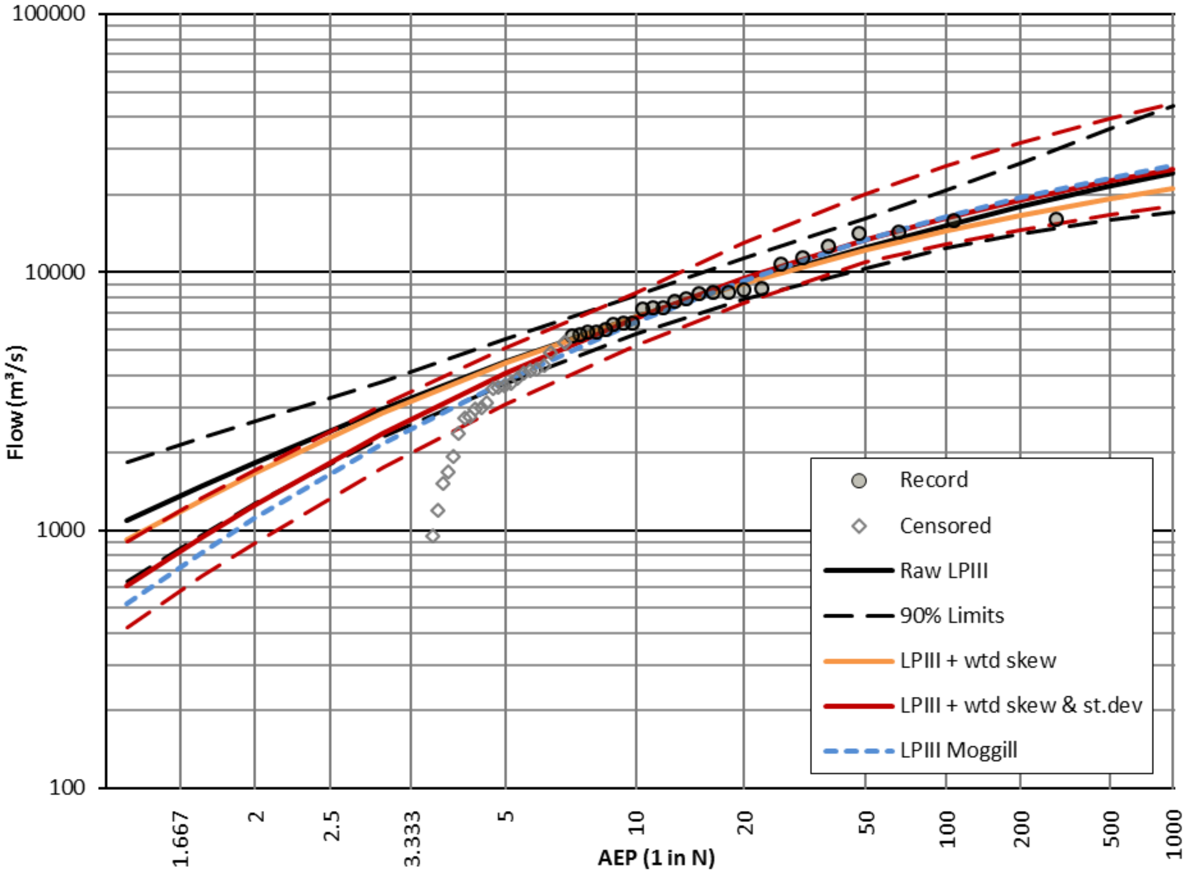

Figure 4-63 Flood frequency analysis at Brisbane City

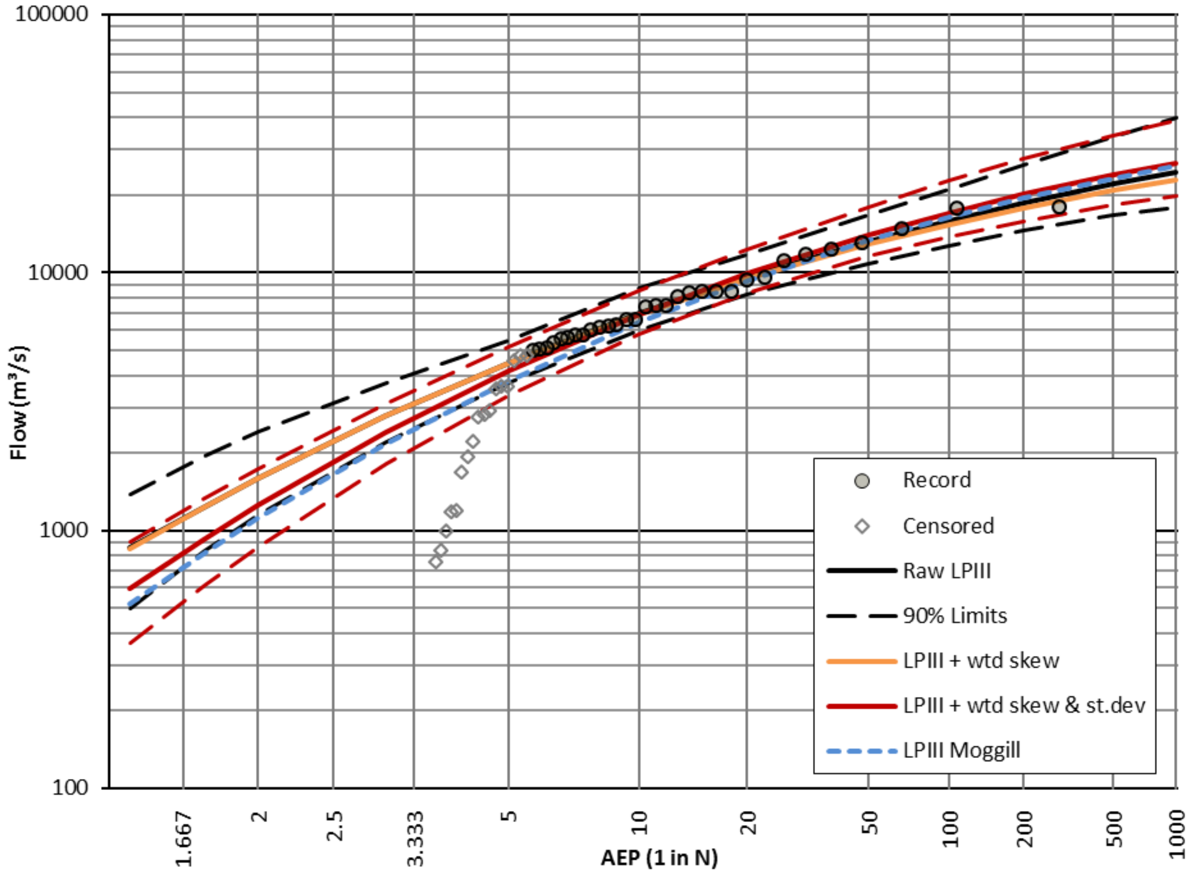

Figure 4-64 Flood frequency analysis of Brisbane City flows translated to Moggill

5 Volume frequency analysis

5.1 Assessment methodology

General principles and limitations associated with flood volume analysis are described in Section 3.2.6. Two fundamentally different approaches may be adopted – assessment of total event volumes or assessment of duration-based volumes. The former has several complicating factors primarily related to identification and separation of what constitutes an independent flood event. The volume frequency analysis has therefore focussed on volumes over a fixed duration. This approach is also more consistent with Design Event and Monte-Carlo simulation assessments which are based on simulation of rainfall bursts rather than complete flood events.

The volume frequency assessment methodology consists of:

1. Convert continuous stream-gauge records into flows using a rating curve
2. Divide the record into discrete sub-intervals smaller than the duration of interest and calculate the flow volume within each interval
3. Calculate the total volume over the duration of interest as the sum of the sub-interval volumes
4. Extract the highest annual volumes
5. Conduct frequency analysis of the annual volume

Using this methodology, the analysed volumes therefore include baseflow and in catchments where the response time is shorter than the duration of interest could conceivably include flows from independent rainfall events.

5.2 Selection of analysis sites

Flood frequency analysis has been conducted at 19 gauges using data compiled from a combination of different sources. The criteria required for reliable volume frequency analysis are significantly more stringent than for flood peak analysis

- The site must have a reasonable period of continuous stream-gauge record, not just peak flows
- The record must be homogeneous. It must consistently identify all floods within the period of record, and cannot be influenced by dams or other changes in catchment properties (even if full, dams will change the flow characteristics, which cannot be readily corrected)
- The flow estimates must be reliable through the use of a rating curve that is reliable across the full range of flows

As illustrated in Table 5-1, very few available gauges satisfy all these criteria. Volume frequency analysis has therefore been limited to the gauges at Linville, Gregors Creek and Walloon.

Table 5-1 Gauge suitability for volume frequency analysis

Catchment	Gauge	Period of Record	Homogeneous Data	Reliable Rating	Suitability for VFA
Stanley	Peachester	✓	✓	×	Limited
	Woodford	×	✓	✓	Poor
	Somerset	✓	×	✓	Poor
	Silverton	×	×	×	None
Upper Brisbane	Cooyar Creek	✓	✓	×	Limited
	Linville	✓	✓	✓	Good
	Gregors Creek	✓	✓	✓	Good
	Tinton	?	×	×	None
	Fulham Vale	?	✓	×	Poor
	Watts Bridge	×	×	×	Poor
	Caboonbah	×	×	×	None
	Middle Ck	×	×	×	Poor
	Wivenhoe	×	×	✓	Limited
Lockyer	Helidon	✓	×	×	Limited
	Gatton	×	✓	?	None
	Glenore Grove	×	✓	✓	None
	Rifle Range Rd	✓	✓	×	Poor
Bremer	Rosewood	×	✓	?	Limited
	Walloon	✓	✓	✓	Good
	Ipswich	×	×	×	None
Warrill	Kalbar Weir	✓	×	×	None
	Amberley	✓	×	✓	None
Purga	Loamside	?	✓	?	Limited
Lower	Savages Cr	✓	×	✓	None
	Mt Crosby	✓	×	✓	None
	Moggill	×	×	✓	None
	Centenary	×	×	✓	None
	City	×	×	×	None

5.3 Regional/catchment weighting

As discussed above, Linville, Gregors and Walloon are realistically the only three sites where the available gauge data is suitable for volume frequency analysis. However, as discussed in Sections 4.6.2, 4.6.3 and 4.6.5 respectively all these sites have issues at the high end of the flood frequency curve. The flood frequency analysis at these sites benefited from catchment weighted adjustment. Application of catchment weighting to the volume analysis is problematic as there is no reliable data to determine a regional relationship. Visually, the volume data appears to follow a similar trend to the flows so the same catchment weighted skew used for the flow frequency analysis (mean = -0.8, std deviation = 0.1) was applied to the volumes. The standard deviations calculated using catchment weighted skews were then analysed by comparing to the equivalent flow analysis standard deviation. The volume deviations are typically of similar order of magnitude (±5%), as shown Figure 5-1. Most of the data appears to show a slight decreasing trend with increasing duration however the amount of data is limited and the 72h value at Walloon suggests that this may be coincidental. The volume frequency assessment was therefore conducted using the same catchment weighted standard deviation as was used for the flow assessment. Due to the uncertainty associated with their application, the catchment weighted frequency curves have been calculated for interest but should be treated with caution.

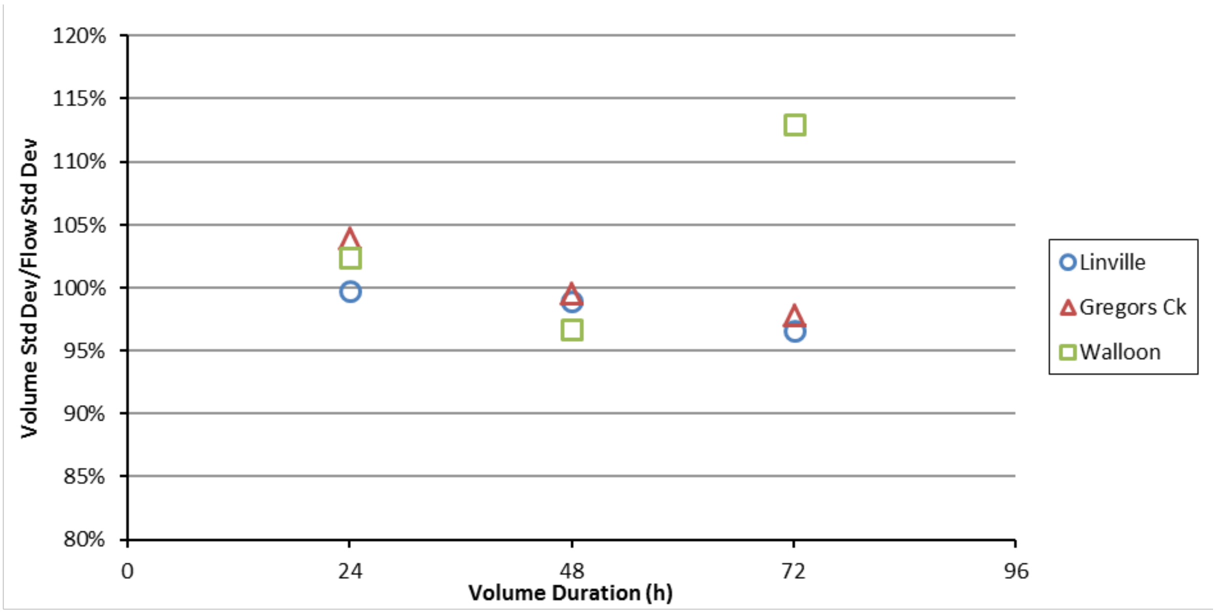

Figure 5-1 Relationship between volume and flow standard deviations

5.4 Annual peak volume frequency analysis

5.4.1 Upper Brisbane River at Linville

Linville is located in the upper Brisbane Catchment between Cooyar Creek and Gregors Creek. The gauge rating review conducted independent hydraulic modelling to confirm the gauge rating, which is considered to be reliable. The site has continuous gauge data recorded since 1965 giving 49 years of consistent record.

Flood frequency analysis was conducted using the volumes calculated from the stream gauge data. The flow volumes show the same distinct step or S-bend as the peak flows discussed in Section 4.6.2, with no 24 hour annual peak volumes between 43,000 and 82,000 m^3. The shape of the bend changes slightly with the different durations. Frequency analysis results for the 24, 48 and 72 hour flow volumes are provided in Figure 5-2, Figure 5-3 and Figure 5-4 respectively.

The influence of catchment weighted parameters on the volume frequency analysis parameters is similar to the flow analysis, with both the catchment weighted skew significantly increasing the curvature of frequency curve and the catchment weighted standard deviation slightly decreasing the slope. Visually, it is difficult to determine whether these parameters improve the fit, although it is noted that the shape of the fit becomes more consistent with volume frequency relationship calculated using the Design Event approach.

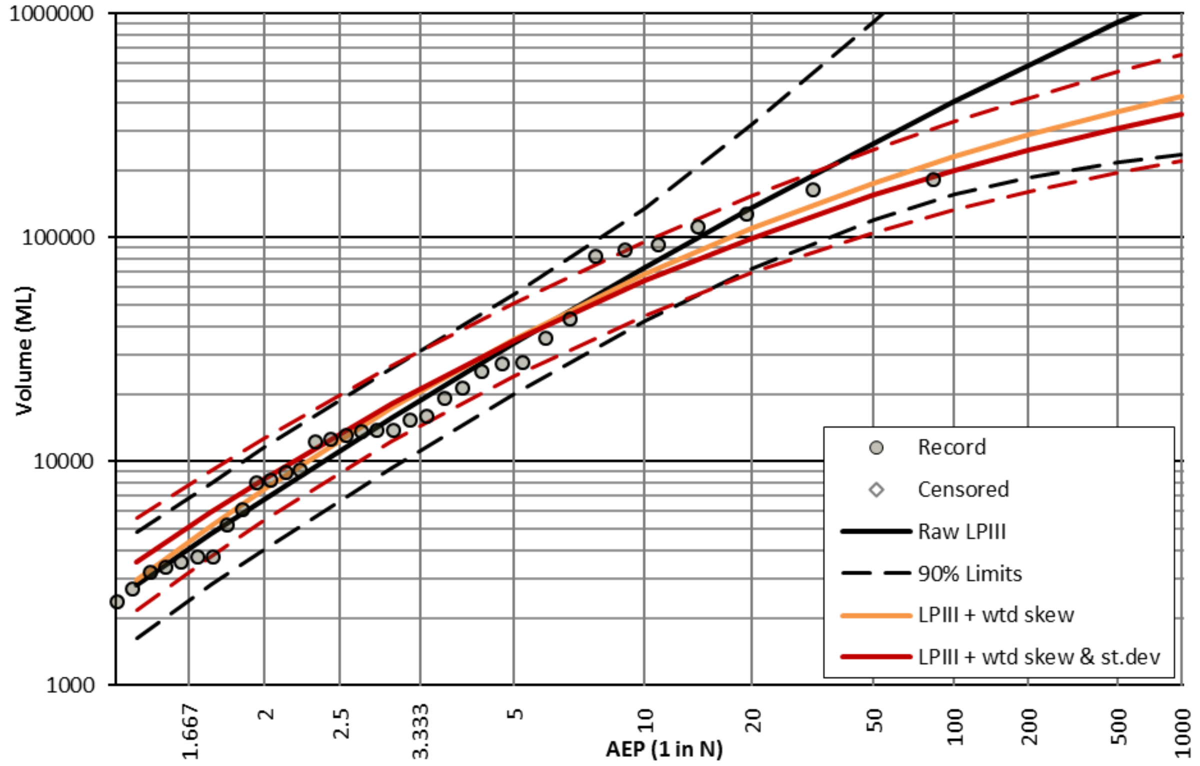

Figure 5-2 24h flow volume frequency analysis at Linville

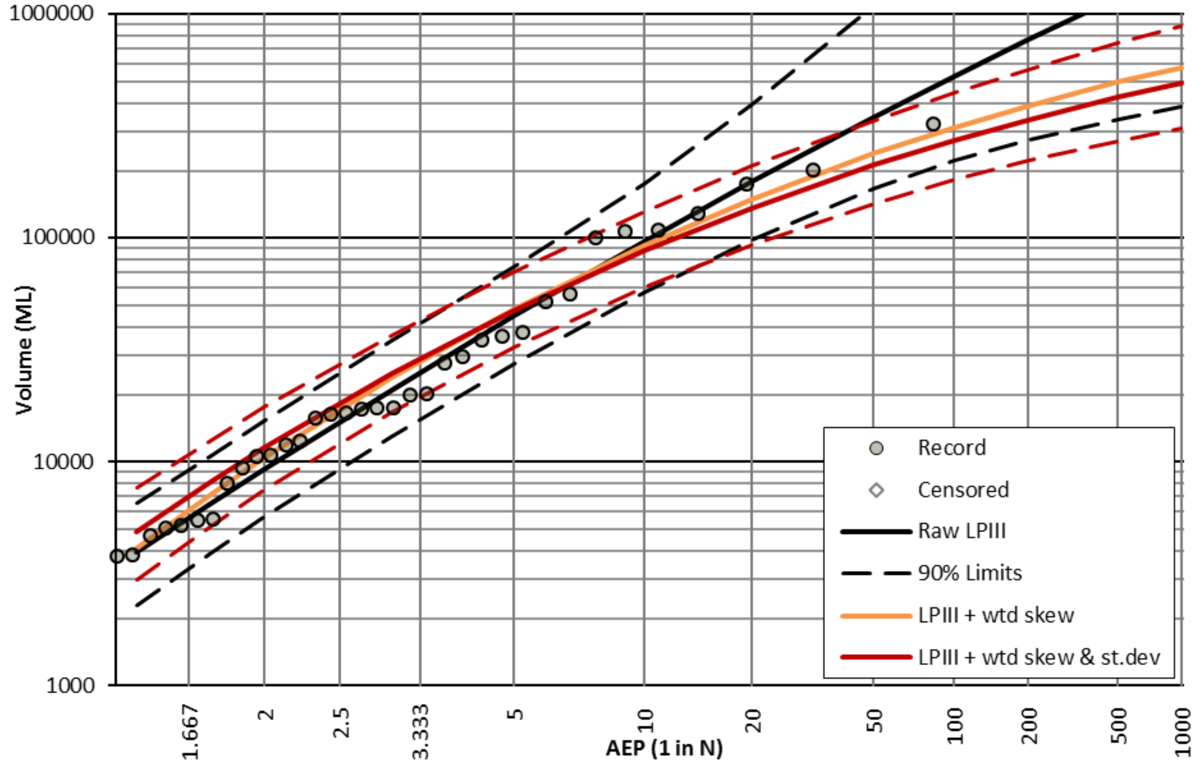

Figure 5-3 48h flow volume frequency analysis at Linville

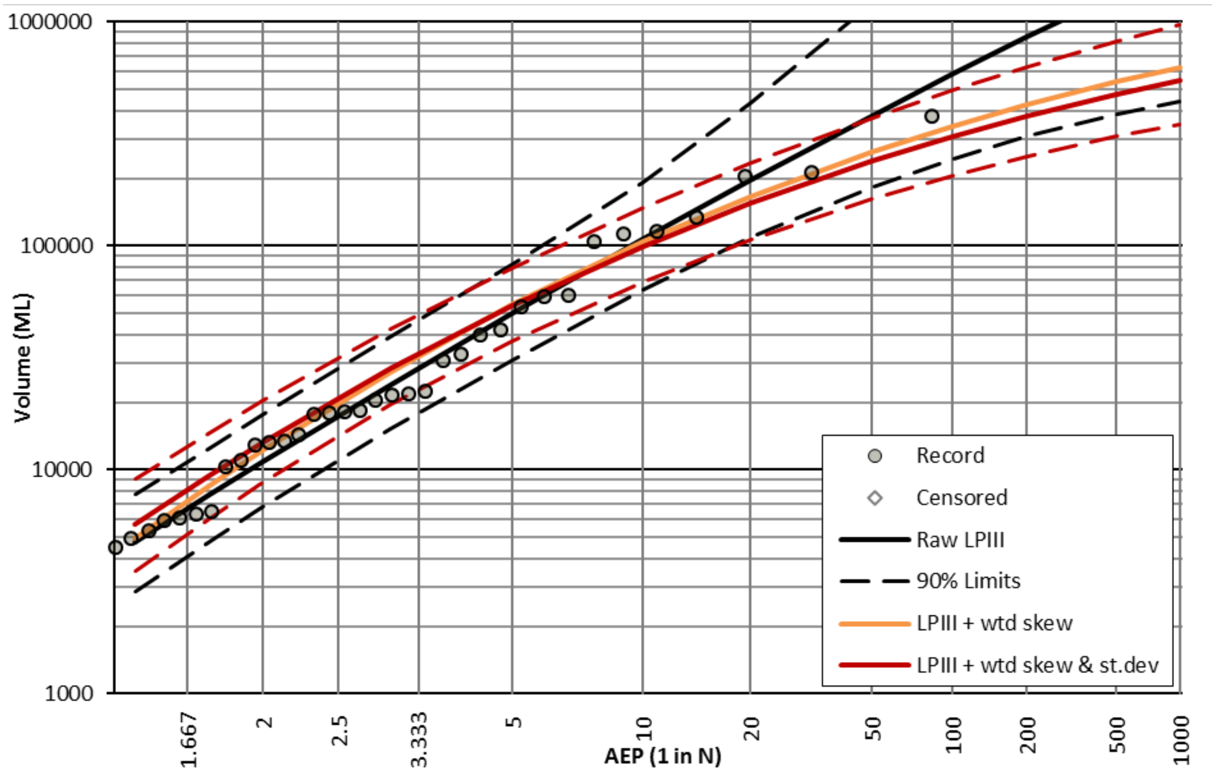

Figure 5-4 72h flow volume frequency analysis at Linville

5.4.2 Upper Brisbane River at Gregors Creek

Gregors Creek is located in the upper Brisbane Catchment between Linville and Wivenhoe Dam. The gauge rating review has treated Gregors Creek as a secondary site. The availability of stream gauging and modelling undertaken by DNRM give reasonable confidence in the rating, although it is noted that the site is potentially affected by bed changes and downstream sand extraction. The site has a similar flood history to Linville, with continuous gauge data recorded since 1963 giving 51 years consistent record.

Flood frequency analysis was conducted using the volumes calculated from the stream gauge data. The flow volumes show the same distinct step or S-bend as is observed at Linville and in the peak flows discussed in Section 4.6.3. The shape of the bend changes slightly with the different durations. Frequency analysis results for the 24, 48 and 72 hour flow volumes are provided in Figure 5-5, Figure 5-6 and Figure 5-7 respectively.

The influence of catchment weighted parameters on the volume frequency analysis parameters is similar to the flow analysis, with both the catchment weighted skew significantly increasing the curvature of frequency curve and the catchment weighted standard deviation slightly decreasing the slope. The influence appears to be slightly less than at Linville, particularly catchment weighted standard deviation which has decreasing effect with increasing duration. Visually, the catchment weighted frequency curves have a significantly different upper tail but appear to provide a reasonable fit to the data, and are typically more consistent with volume frequency relationship calculated using the Design Event approach.

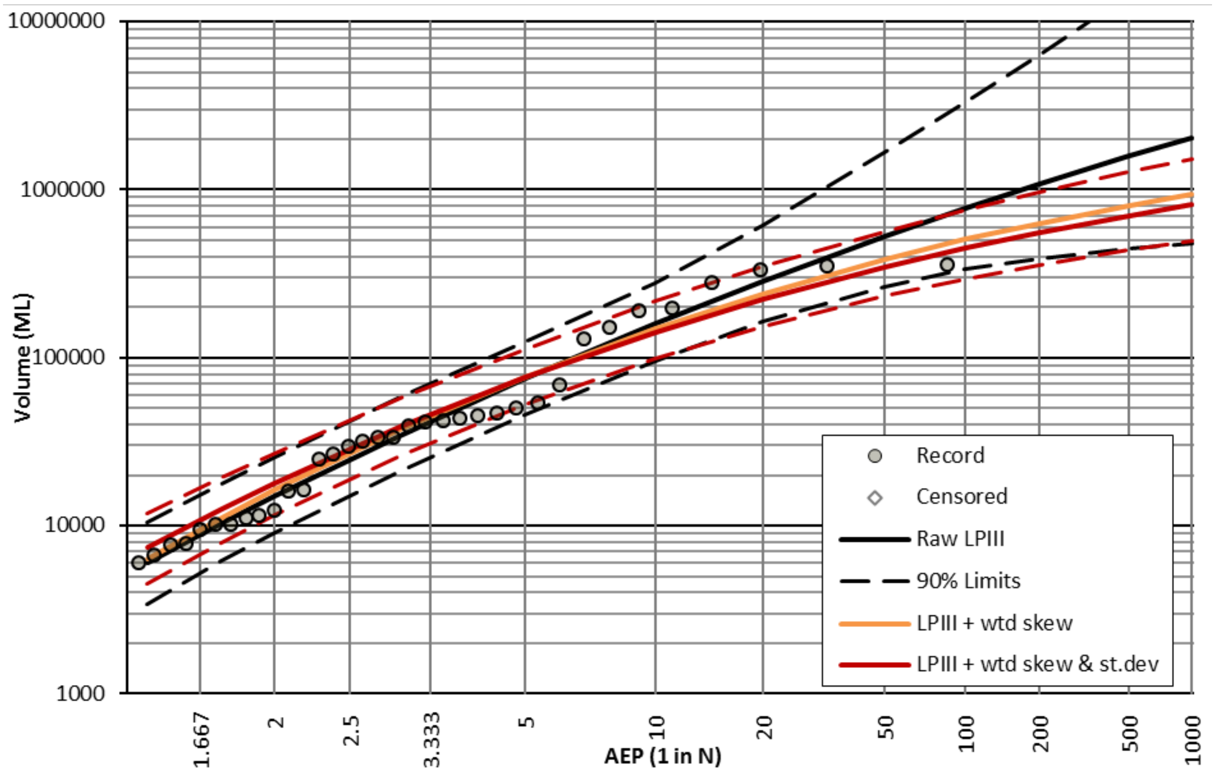

Figure 5-5 24h flow volume frequency analysis at Gregors Creek

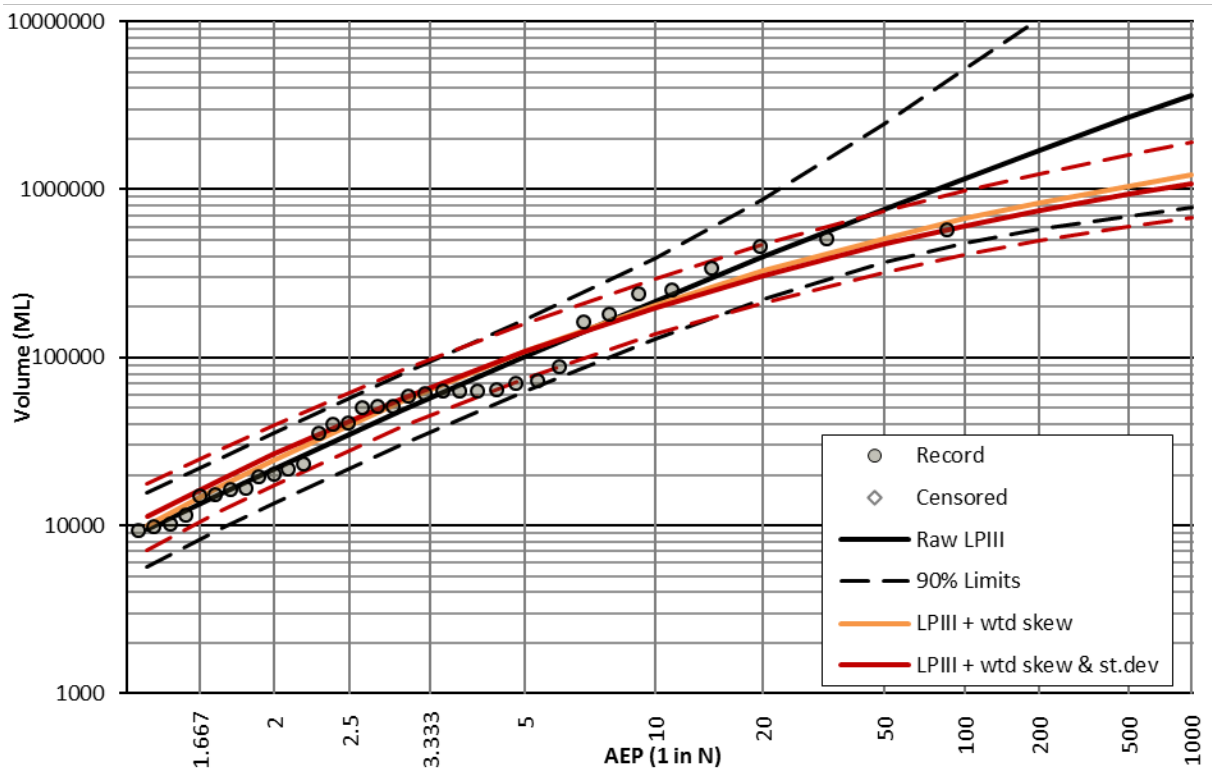

Figure 5-6 48h flow volume frequency analysis at Gregors Creek

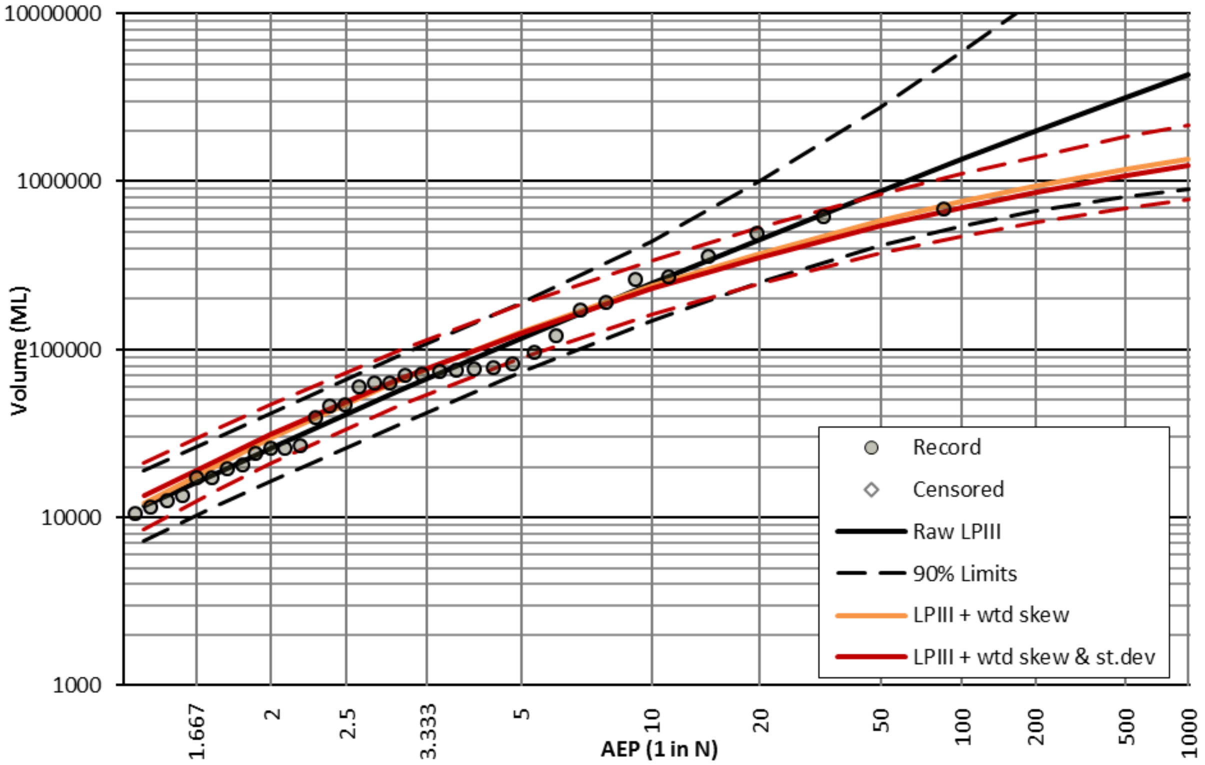

Figure 5-7 72h flow volume frequency analysis at Gregors Creek

5.4.3 Bremer River at Walloon

Walloon is located on the Bremer River upstream of Ipswich and upstream of the junction with Warrill and Purga Creeks. The Walloon gauge has a reasonable record length with 52 years of continuous gauge data available since 1962. The rating curve review treated Walloon as a primary gauge site, with the rating developed using independent hydraulic modelling calibrated to available stream flow measurements. The rating is generally considered to be reliable however it is noted that the gauge site may be affected by backwater during large flood events. Realistically, this potentially affects only two events during the continuous gauge history (1974 and 2011) and only during the flood peak. The gauge did not function during the 1974 flood so no volume data from this event is available. The 2011 event has been censored from the record to avoid influencing the analysis, with the two events included as the two largest historical events of unknown volume.

Flood frequency analysis was conducted using the volumes calculated from the stream gauge data. Frequency analysis results for the 24, 48 and 72 hour flow volumes are provided in Figure 5-8, Figure 5-9 and Figure 5-10 respectively. The unweighted frequency curves tend to exhibit relatively little curvature, with the 72 hour volume frequency curve actually having a slight positive skew. The introduction of the catchment weighted skew parameter significantly increases the curvature causing the unweighted and weighted relationships to diverge above 1 in 10 AEP. The influence of the catchment weighted standard deviation appears to be variable, having a noticeable effect on the 48 hour volume frequency curve but negligible effect for the 24 and 72 hour volume curves. It is difficult to determine whether the weighting parameters improve the overall fit as the fitting of the upper tail is unclear without the two largest floods.

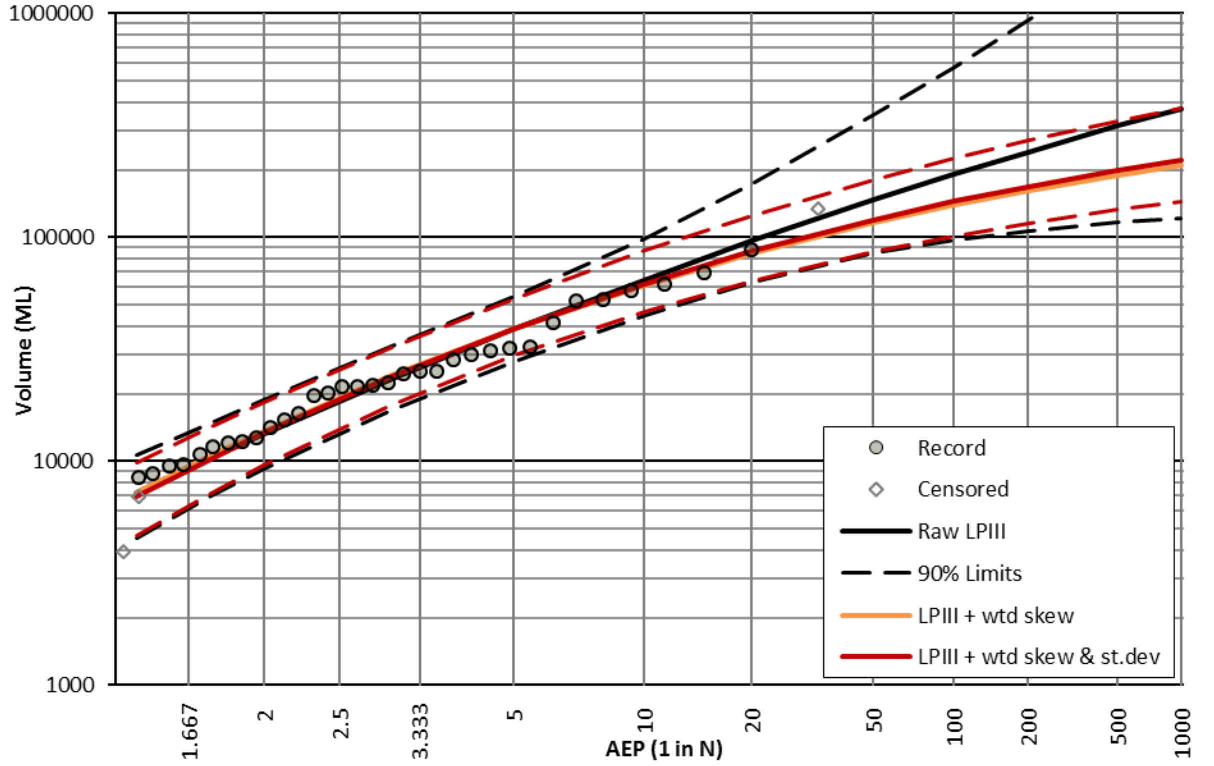

Figure 5-8 24h flow volume frequency analysis at Walloon

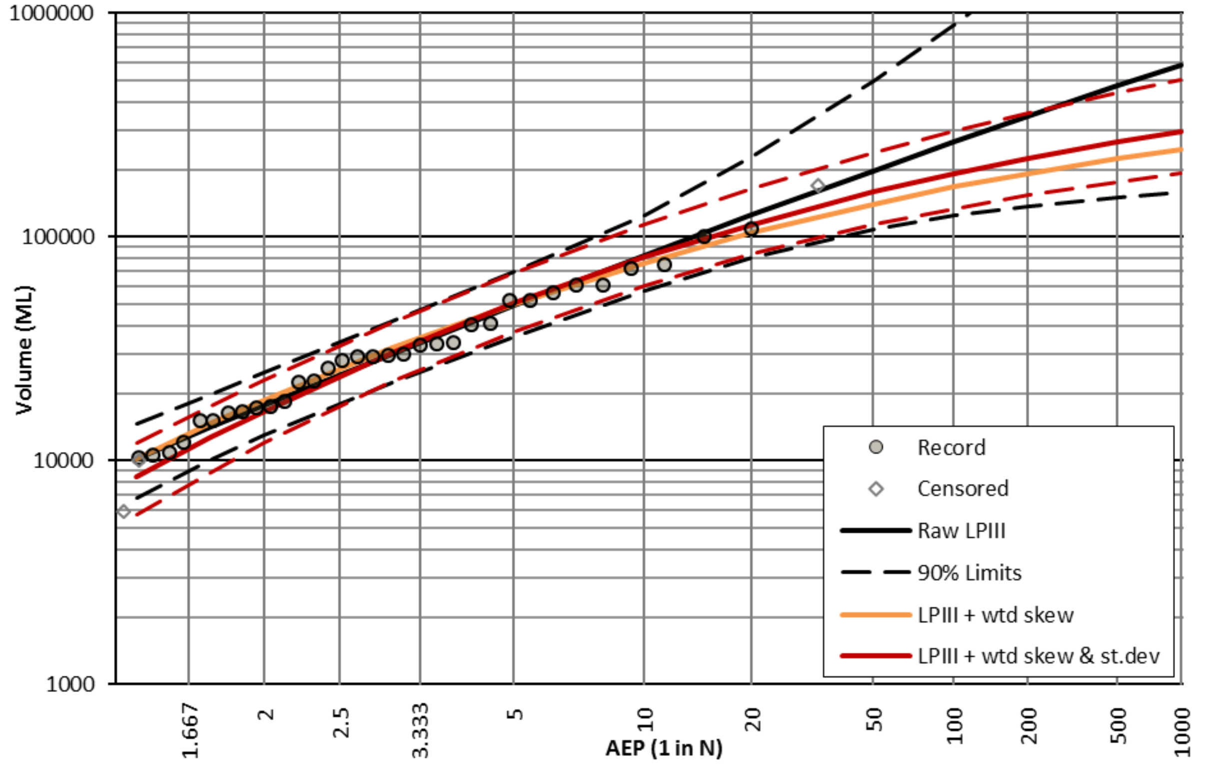

Figure 5-9 48h flow volume frequency analysis at Walloon

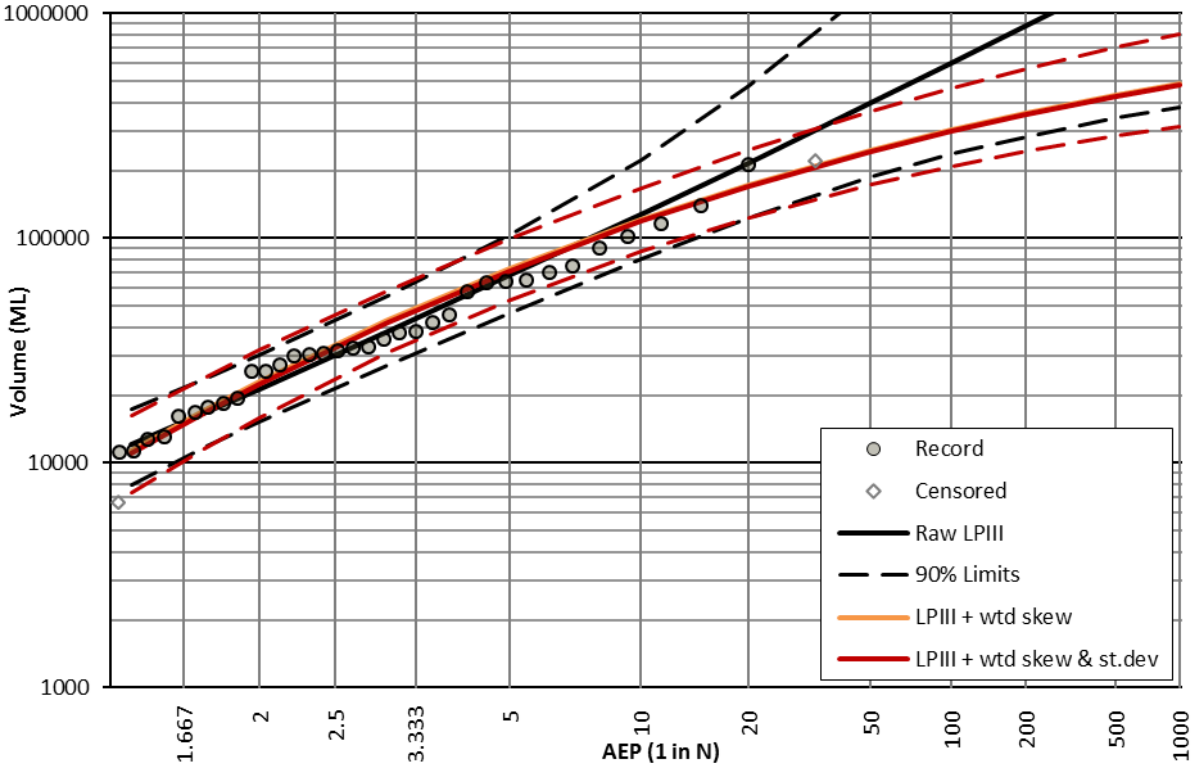

Figure 5-10 72h flow volume frequency analysis at Walloon

6 Conclusions and recommendations

6.1 Methodology

Flood frequency analysis of the Brisbane River catchment stream gauges involves compilation and statistical analysis of historic flow data. This flow data has been collected from multiple sources including stream gauge and URBS modelling and reliability of the data can vary significantly. The record at a number of the sites has been affected by construction of dams, and this effect must be removed to provide a homogenous sample representing 'no-dam conditions'. The assessment methodology has been developed to use current best-practice techniques and taking advantage of automated Bayesian fitting techniques implemented in the FLIKE flood frequency analysis software developed by the University of Newcastle. The adopted procedure consists of:

- Collection of available flow data from all sources and correction for influence of dams to produce 'no-dams conditions' peak flow estimates
- Identify and filter outliers and errors from the gauge records and/or extend or supplement the at-site data record using historical and/or translated flood records where appropriate to make optimum use of the available data
- Conduct a primary assessment of the gauge sites considered to be most reliable and assess the regional characteristics of the primary assessment sites
- Analyse all stream gauges introducing a regional weighting of the flood frequency

6.2 Probability function

The Log-Pearson III and GEV distributions are common probability functions applied to flood frequency analysis in Australia. The Log-Pearson III distribution was adopted as the standard distribution in AR&R (1987) because it was found to fit flood data for Australian catchments as well, if not better than other probability families. Engineers Australia currently does not specifically recommend a specific distribution, and the GEV distribution has been gaining popularity as a statistical distribution for flood frequency analysis.

Analysis at the Brisbane River catchment sites identified that the GEV distribution could usually provide a reasonable representation of the upper or lower tails of the gauge data, but in many cases when fitted to the full available range of data produced an upper tail that did not appear consistent with the expected frequency distribution. In most situations the Log-Pearson III distribution provided a good overall representation of the full data set, as well as being relatively consistent with the design event and Monte-Carlo simulation methodologies. Since the primary objective of the FFA is to provide a consistent assessment flows across the range of 1 in 2 to 1 in 100 AEP and to reconcile with other methods at and above this range, the Log-Pearson III distribution was adopted as the standard probability function for all gauges.

6.3 Regional weighting analysis

Regional analysis techniques that draw upon better gauge records from nearby and/or hydrological similar sites can help improve results derived at a location where the historical monitored information is inadequate for frequency analysis, or may result in improvements in terms of consistency (between the locations), robustness and reliability. The recent AR&R Project 5 Stage 2 Report (Rahman et al 2012) provides a summary of a number of regional flood frequency analysis techniques approaches that are available for application.

The BRCFS originally intended to utilise the new ARR Project 5 Regional Analysis Tool which incorporates the Parameter Regression Technique to validate the regional characteristics derived from the at-site frequency analysis, however the Beta version of the tool was withdrawn due to some problems being identified in its implementation. An alternative considered was the widely applied Index Flood Method of Hosking and Wallis (1997). A key assumption in this method is that the distribution of floods at different sites within a homogeneous region is the same except for a site-specific scale, which relies on the concept that the standardised flood peaks from individual sites in the region follow a common probability distribution with identical parameter values. The index flood method had been criticised on the grounds that the coefficient of variation of the flood series may vary approximately inversely with catchment area, thus resulting in flatter flood frequency curves for larger catchments. This had particularly been noticed in the case of humid catchments that differed greatly in size, such as is the case for the Brisbane River Catchment.

As neither of the originally proposed methods was considered appropriate to apply, an alternate approach loosely based on the Index Flood Method was adopted for the BRCFS analysis:

- An unbiased flood frequency assessment of a range of primary gauges considered to have reliable record length and flow estimates was undertaken
- The frequency distribution parameters (skew and standard deviation) were analysed to determine if consistent catchment-wide values or trends could be identified
- These catchment values were then returned back into the site analyses as Gaussian prior distribution parameters used with the Bayesian inference method adopted by the FLIKE flood frequency analysis software

Skew estimates based on single 'at-site' analysis, especially those with short gauge records, can be sensitive to the presence of outliers in the upper or lower tail of the data, and it is well recognised that the accuracy can generally be improved by weighting the station skew with generalised values obtained from pooled information from other sites in the region. Review of the preliminary at-site analysis identified a typical skew of around -0.8, with no discernible relationship to catchment area or other obvious catchment property. A catchment weighted skew with a mean of -0.8 and standard deviation of 0.1 was used for subsequent analysis at all gauge sites. The catchment weighted skew had a strong influence on the curvature of the frequency curve at a number of gauges, however in all cases this influence promoted greater consistency with both other gauges and with alternative flow estimation techniques based on rainfall data. Based on this evidence, use of a catchment weighted skew parameter is strongly endorsed.

Use of a regional standard deviation is a recognised technique, but the relationship is potentially more complicated and a standardised methodology is not appropriate or available. The primary gauges were reassessed using weighted skew. The standard deviation was found to display a weak relationship with catchment area. The correlation was slightly improved by adjusting the standard deviation by a correction factor based on the dimensionless gradient of the rainfall intensity, given by Equation 4. The relationship given in Equation 5 was derived from the adjusted data and introduced into the frequency analysis using a relatively loose standard deviation (of the ln[std dev of log Q]) of 0.12 to avoid unduly suppressing natural site characteristics. Introduction of catchment weighted standard deviation generally had a minor influence on the frequency curve. In cases where a strong influence was observed, comparison with other data suggests it has a positive benefit in promoting greater consistency with both other gauges and with alternative flow estimation techniques based on rainfall data. Use of catchment weighted standard deviation is therefore tentatively endorsed, but it is recommended that further investigation is undertaken, such as comparison with AR&R Project 5 when this becomes available.

Figure 6-1 and Figure 6-2 respectively show the skew and standard deviation of the frequency curves calculated using the catchment weighted skew and standard deviation. After application of catchment weighted parameters, the standard deviation is relatively consistent with Equation 5. The skew of log Q has a mean of -0.795 and a standard deviation of 0.025, significantly lower than the value of 0.1 applied. Note that Amberley, the most significant outlier in the unweighted skews (Figure 4-28) lies comfortably within the scatter. The weighted skew appears to show a slight relationship with catchment area where previously no consistent variation was observed. This variation is within the standard deviation applied (0.1). Application of an area-dependent skew could potentially be applied to future assessments, however it is cautioned that these values are catchment weighted and therefore not independent.

Application of regional analysis to volume frequency analysis would theoretically be beneficial, however there is currently too little information to allow catchment relationships to be determined. The volume frequency curves show similar traits to the flow frequency curves and catchment weighted analysis was therefore performed using the same parameters calculated for flow. The appropriateness of these parameters is difficult to confirm, although the method appears to show improved consistency with alternative volume frequency estimation techniques based on rainfall data. Catchment weighted values should be treated with caution and compared against other methods of calculation.

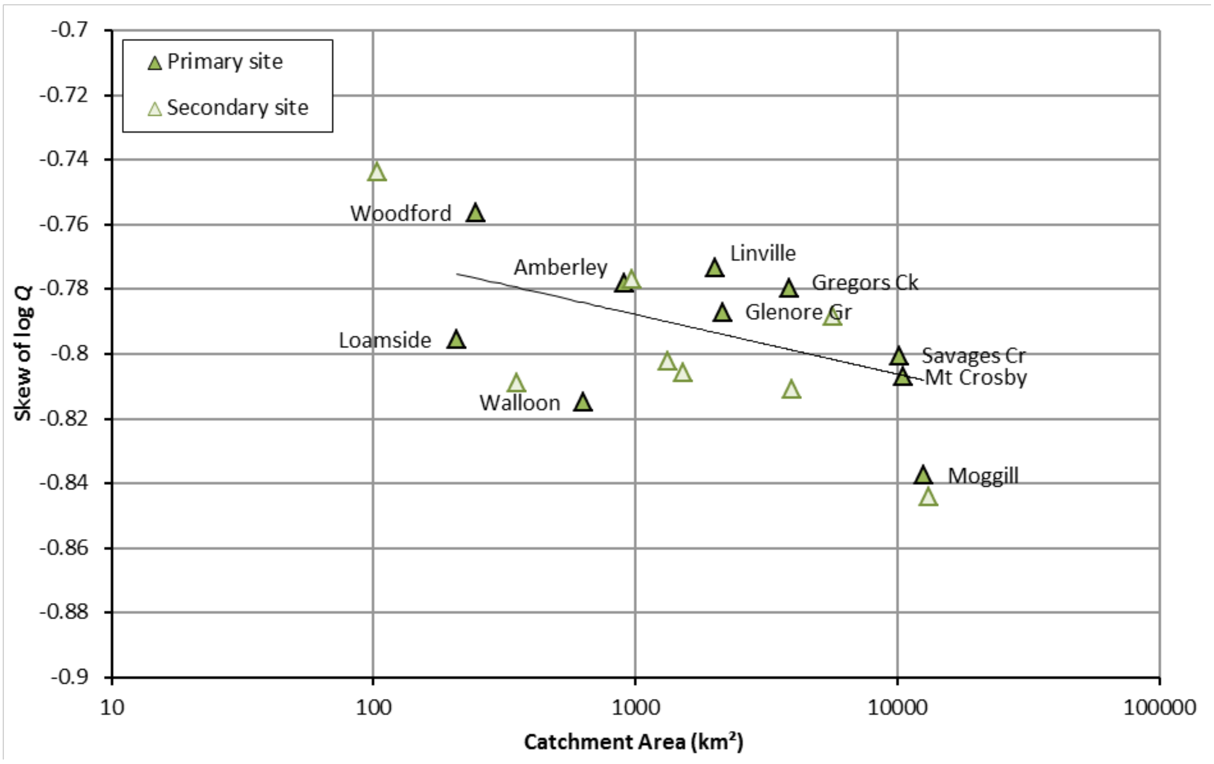

Figure 6-1 Skew of log Q after application of catchment weighted parameters

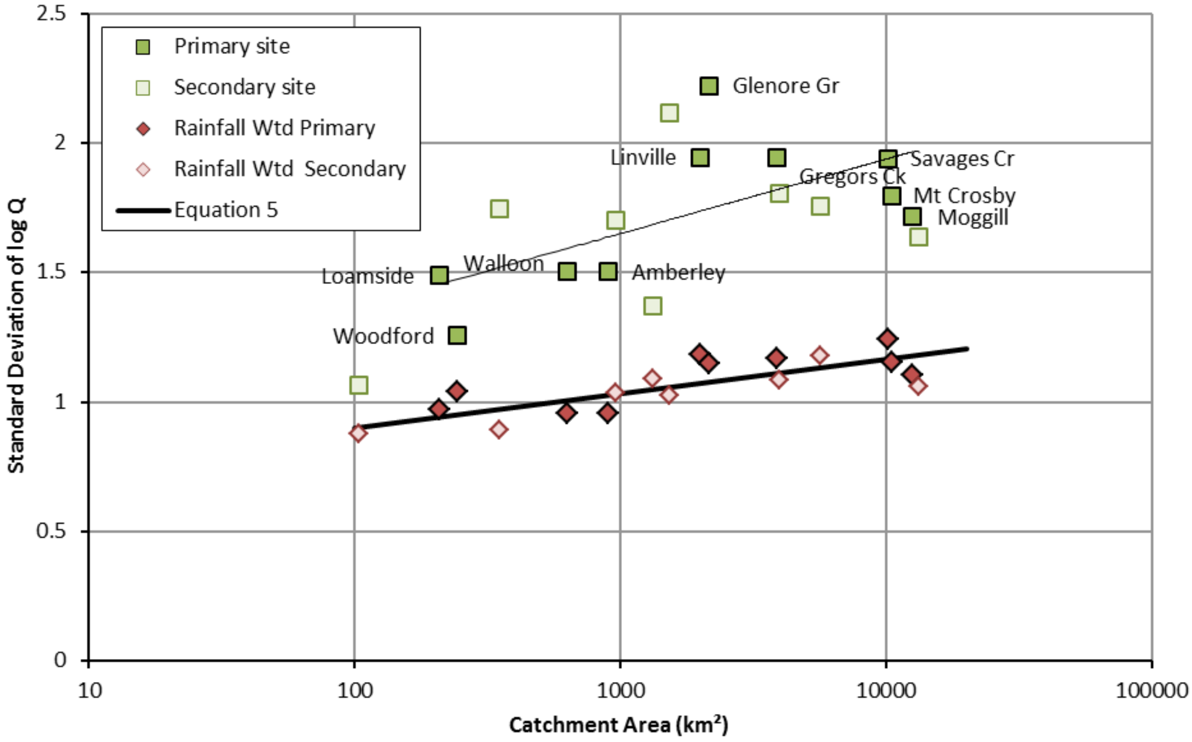

Figure 6-2 Standard Deviation of log Q after application of catchment weighted parameters

6.4 Flood frequency flow estimates

As discussed in the sections above a preliminary assessment of ten primary gauges was undertaken. The resulting flood frequency curves are shown in Figure 6-3 and display significant variation in magnitude, slope and curvature. Regional analysis was conducted to determine catchment weighting parameters. The catchment weighted frequency curves are shown in Figure 6-4 and display much greater consistency of curvature and slope while still maintaining individuality that is consistent with known behaviour of the catchments. Flow estimates for 1 in 2, 10 and 100 AEP from the catchment weighted frequency curves are shown in Figure 6-5 as function of catchment area. Flows generally show an increasing trend with catchment area as expected, and although there is significant variation consistent trends can be observed within and between catchments. Bremer River gauges (eg Peachester, Woodford, Somerset) consistently exhibit the highest flows relative to catchment area and the Lockyer Creek catchments (Helidon, Gatton, Glenore Grove) the lowest, which is consistent with rainfall intensity and loss characteristics of the catchments.

Raw and catchment weighted frequency curves are compared for the Stanley, upper Brisbane, Lockyer, Bremer and lower Brisbane catchments in Figure 6-6 to Figure 6-10. Flood frequency estimates are provided in Appendix A.

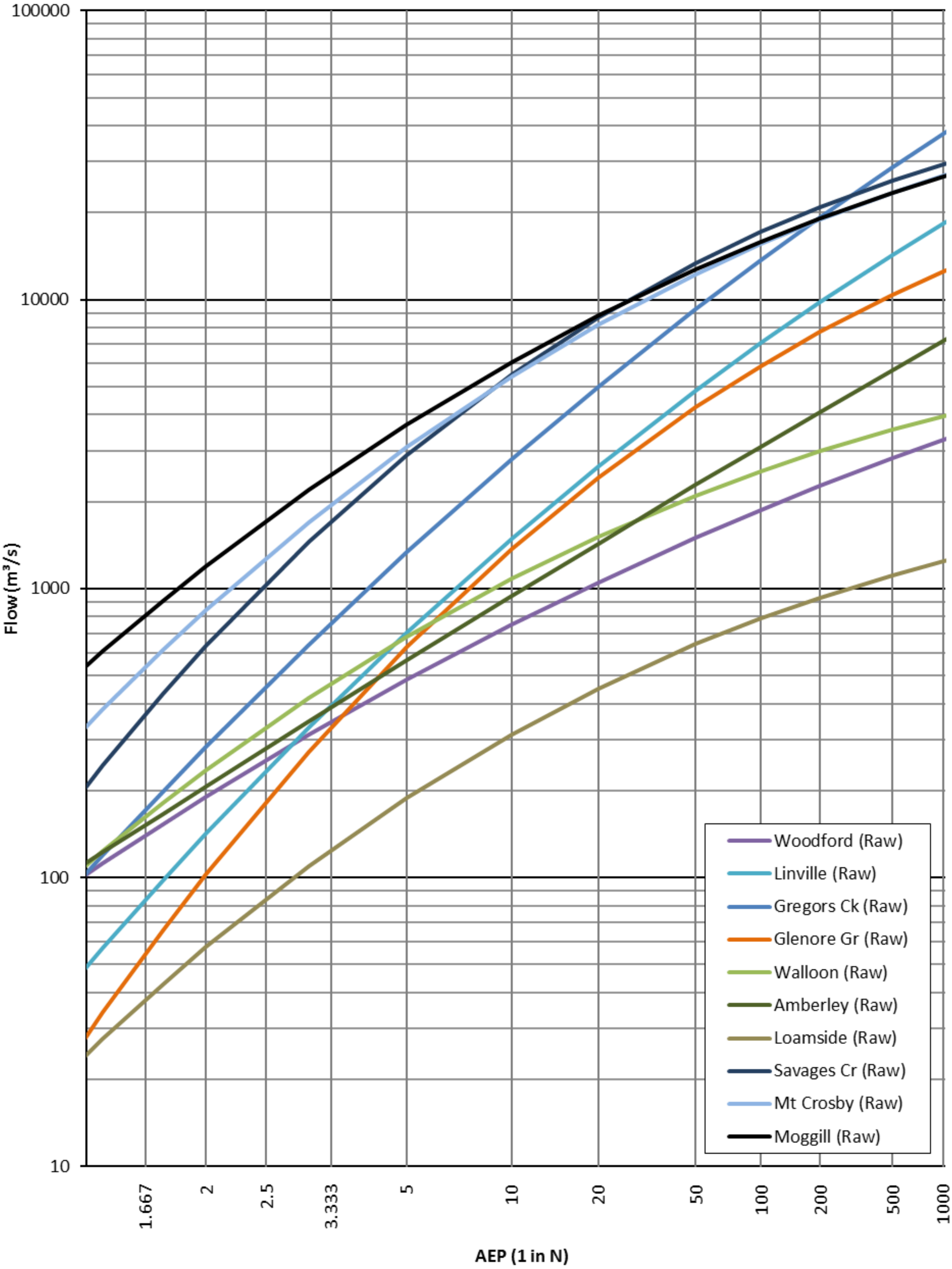

Figure 6-3 Raw (unweighted) frequency curves at primary gauges

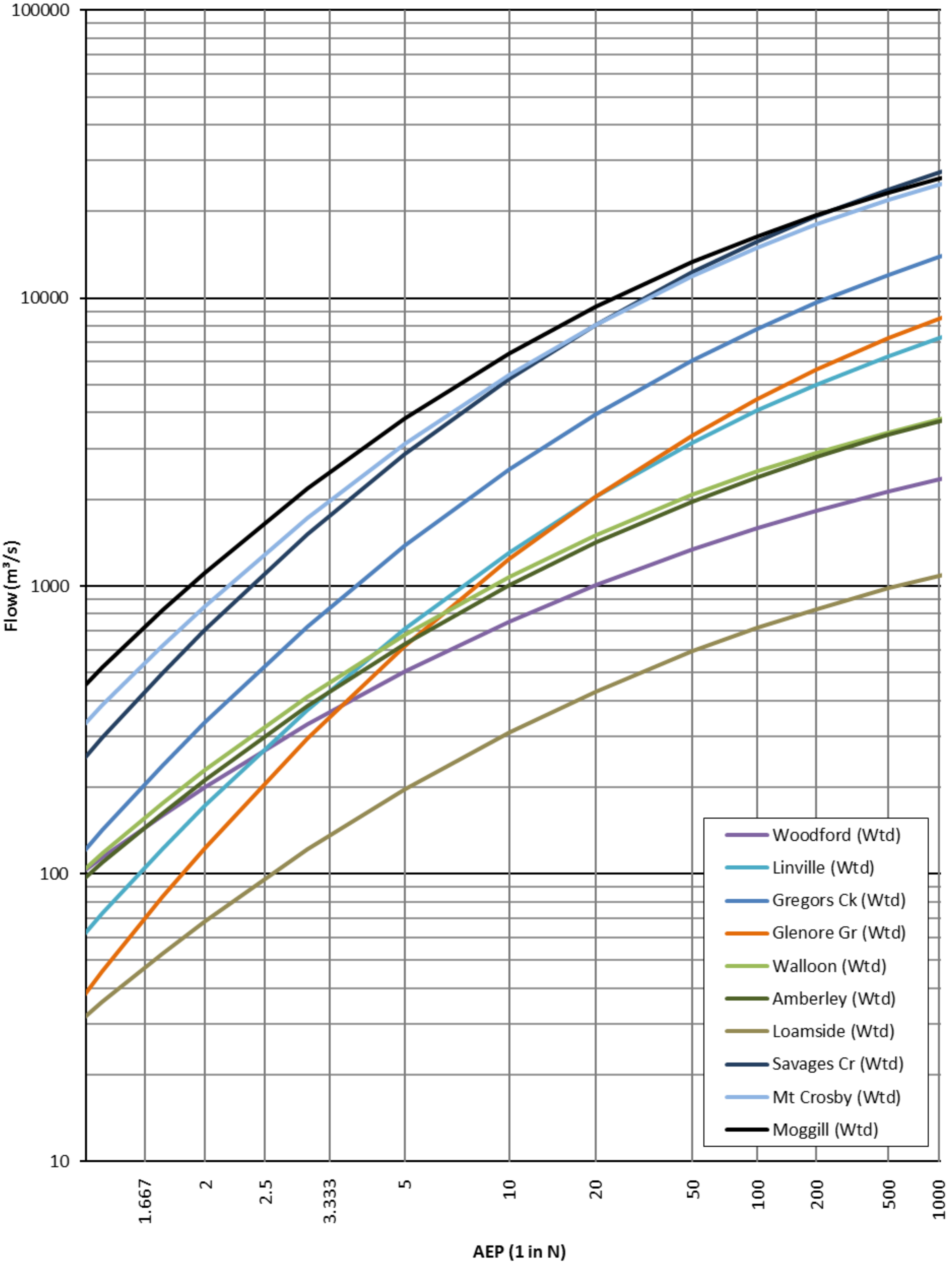

Figure 6-4 Catchment weighted frequency curves at primary gauges

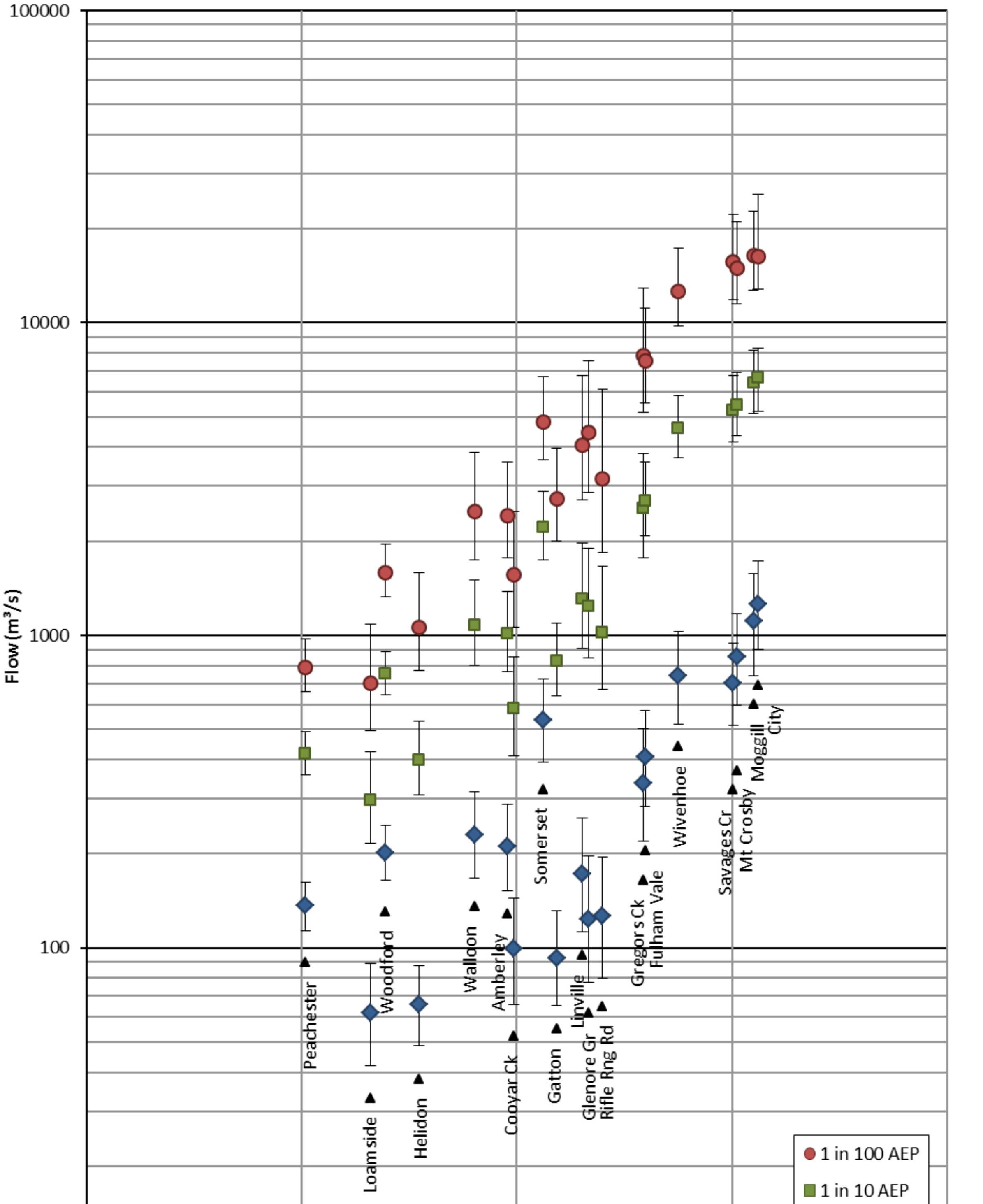

Figure 6-5 Key flood frequency flow estimates for all catchments

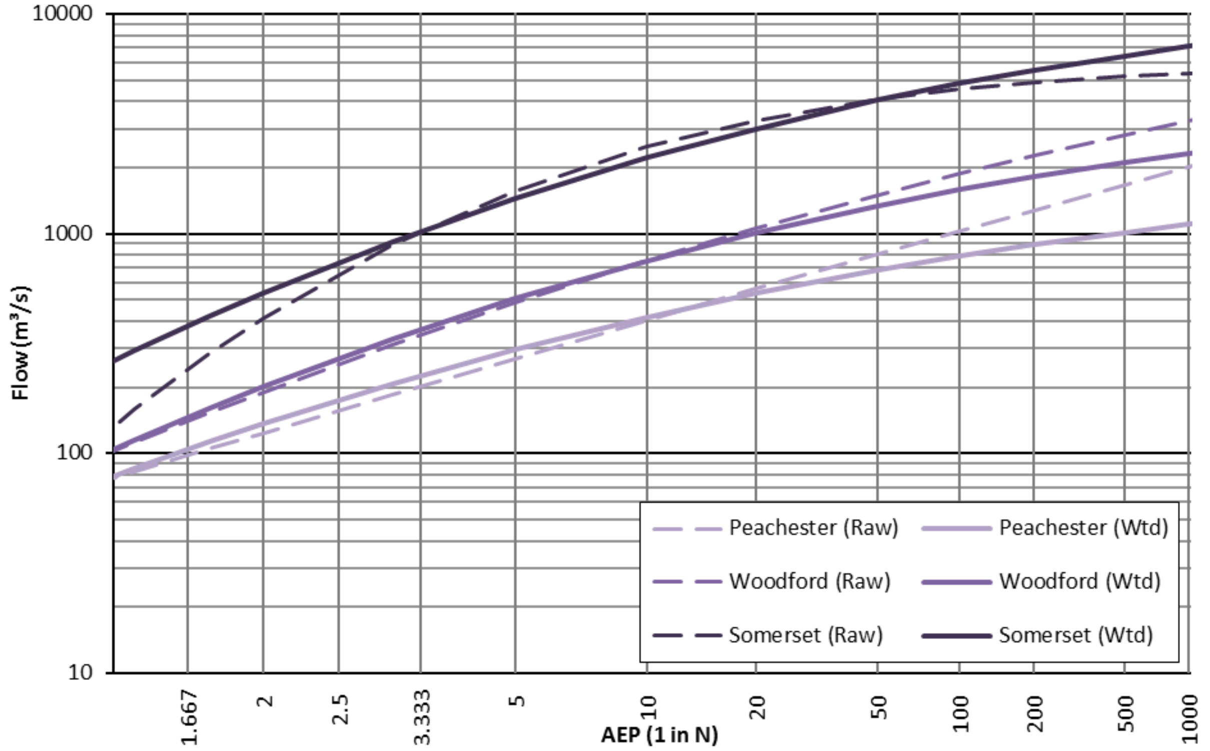

Figure 6-6 Raw and catchment weighted frequency curves for Stanley River catchments

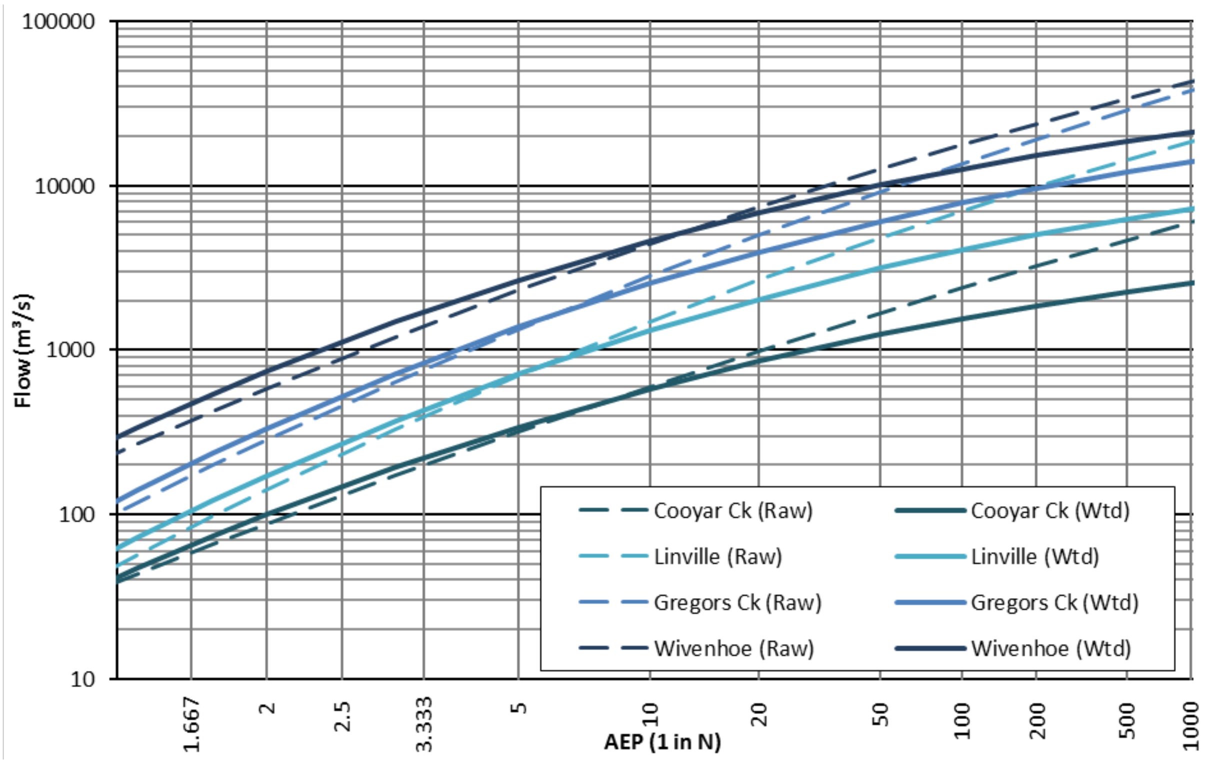

Figure 6-7 Raw and catchment weighted frequency curves for upper Brisbane River catchments

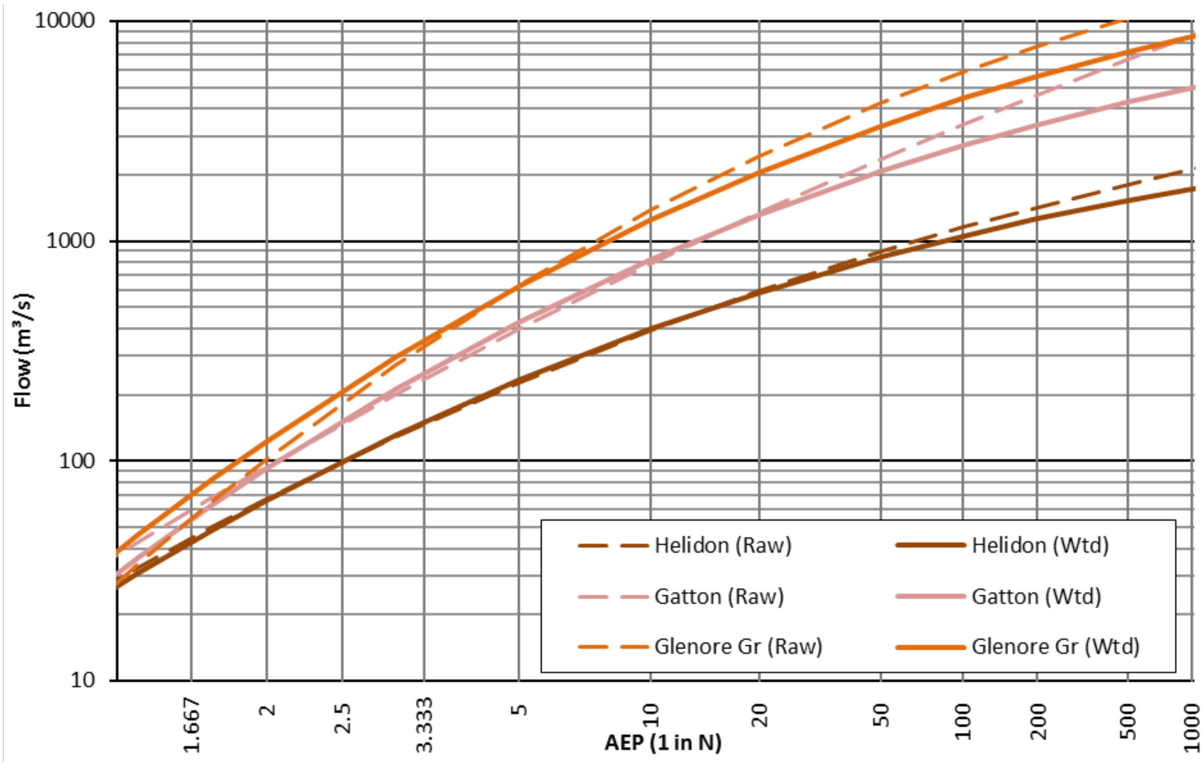

Figure 6-8 Raw and catchment weighted frequency curves for Lockyer Creek catchments

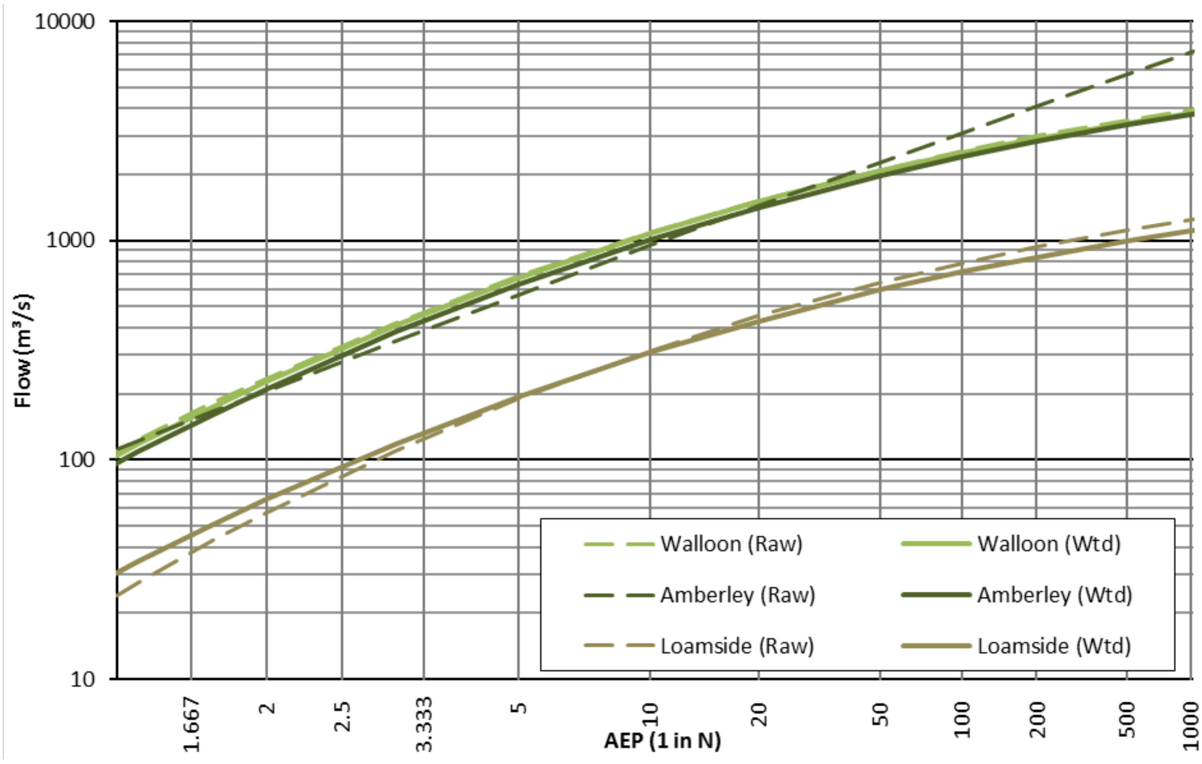

Figure 6-9 Raw and catchment weighted frequency curves for Bremer River catchments

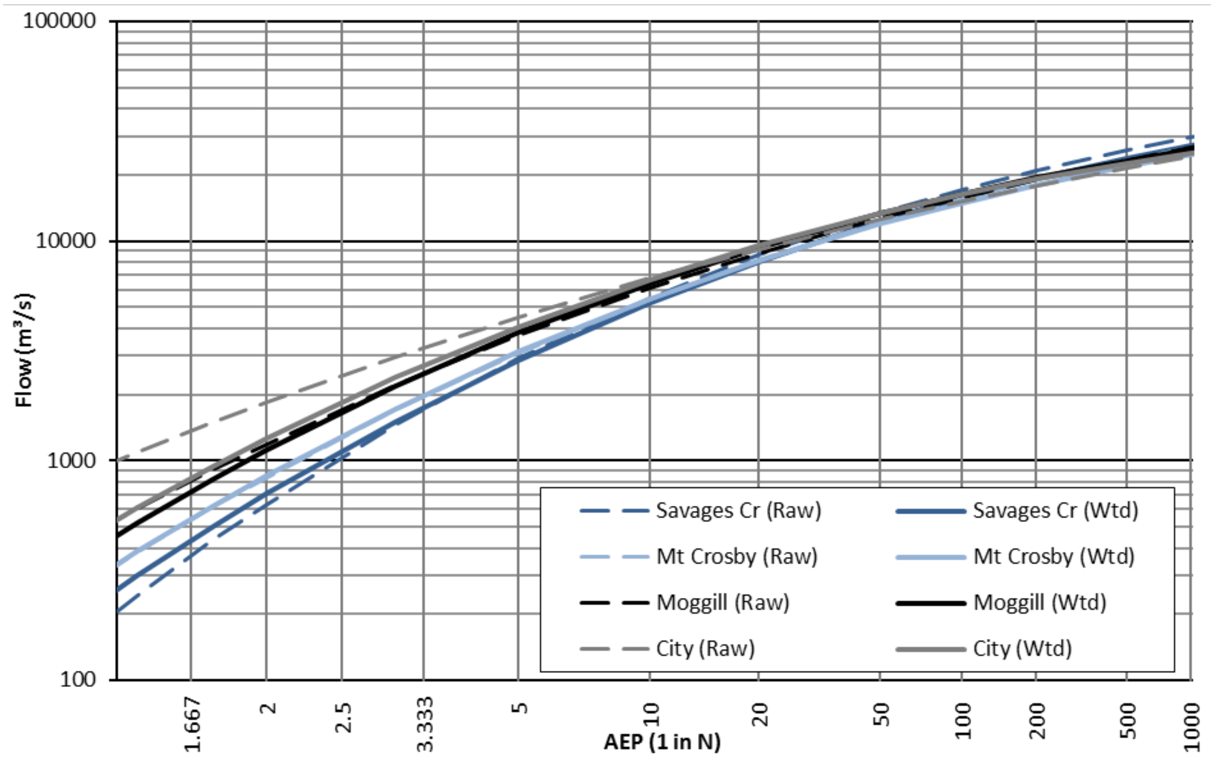

Figure 6-10 Raw and catchment weighted flow frequency curves for lower Brisbane River catchments

6.5 Volume frequency estimates

Volume frequency analysis was conducted for three sites where reliable flow ratings and continuous stream gauge record unaffected by dams were available. The volume analysis assessed volumes over a fixed duration rather than complete event volumes, which is more consistent with Design Event and Monte-Carlo simulation assessments based on simulation of rainfall bursts, but means that the analysed volumes include baseflow and potentially include flows from separate rainfall events.

Raw and catchment weighted 24, 48 and 72 hour volume frequency curves are provided for Linville, Gregors Creek and Walloon in Figure 6-11 to Figure 6-13. Volume frequency estimates are provided in Appendix B. Use of catchment weighting is recommended as all three of the investigated sites are noted to have issues at the high end of the flood frequency curve. Catchment weighting has been performed using the same skew and standard deviation parameters that were developed for the flood frequency analysis. The volume data visually appears to follow similar trends to the flows and application of the catchment parameters appears to produce a reasonable fit of the data that is more consistent with volume frequency relationship calculated using the Design Event approach. However it should be cautioned that there is insufficient data to confirm the validity of these parameters or to derive independent volume parameters.

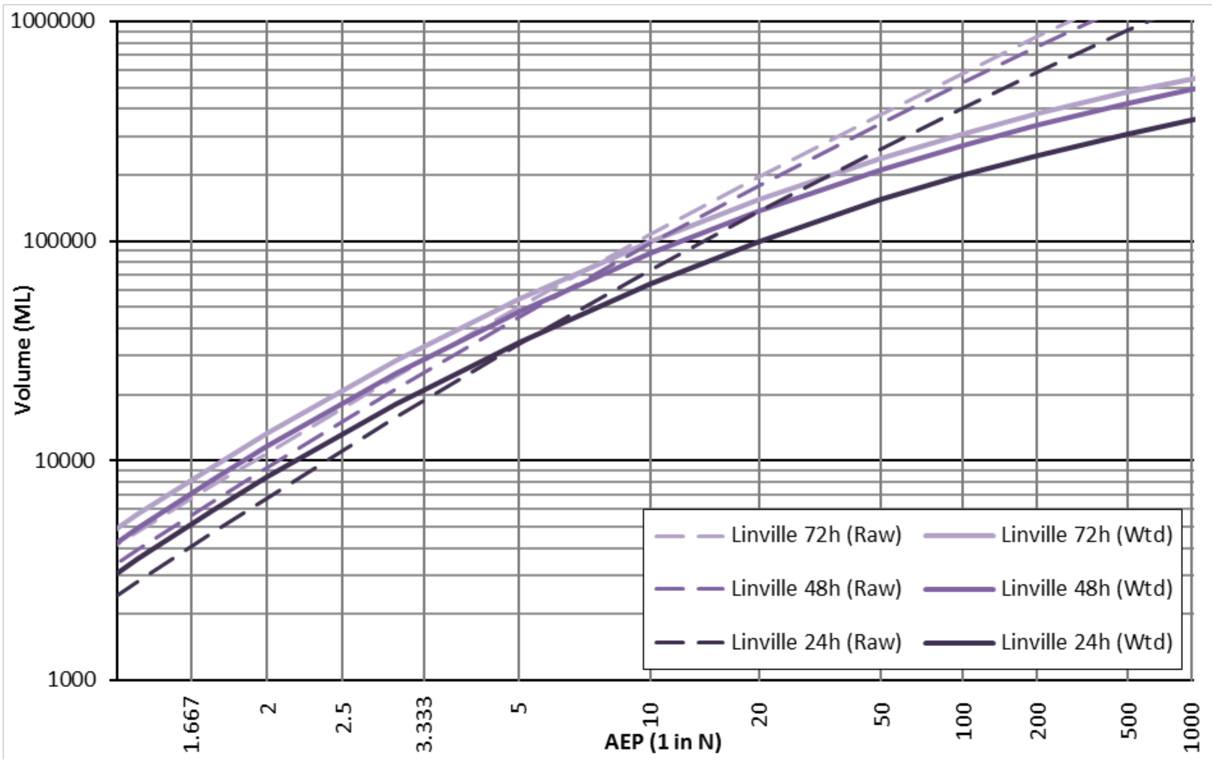

Figure 6-11 Raw and catchment weighted volume frequency curves for Linville

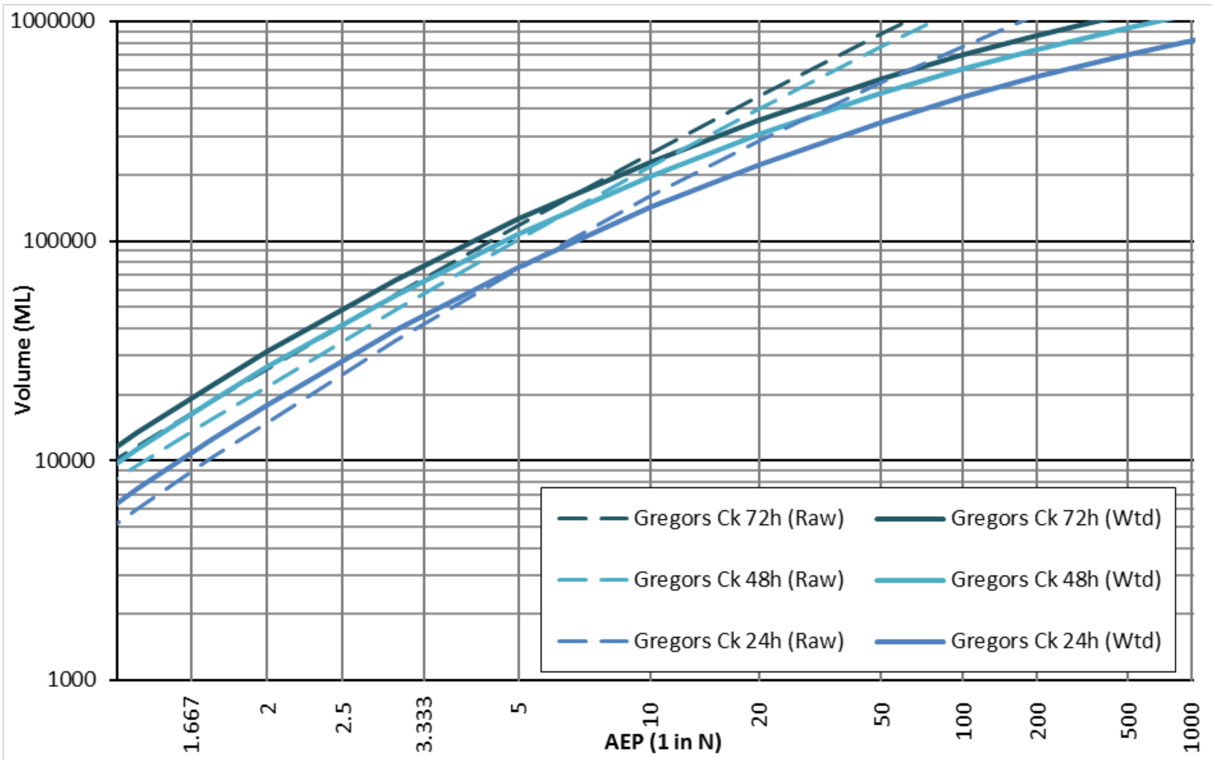

Figure 6-12 Raw and catchment weighted volume frequency curves for Gregors Creek

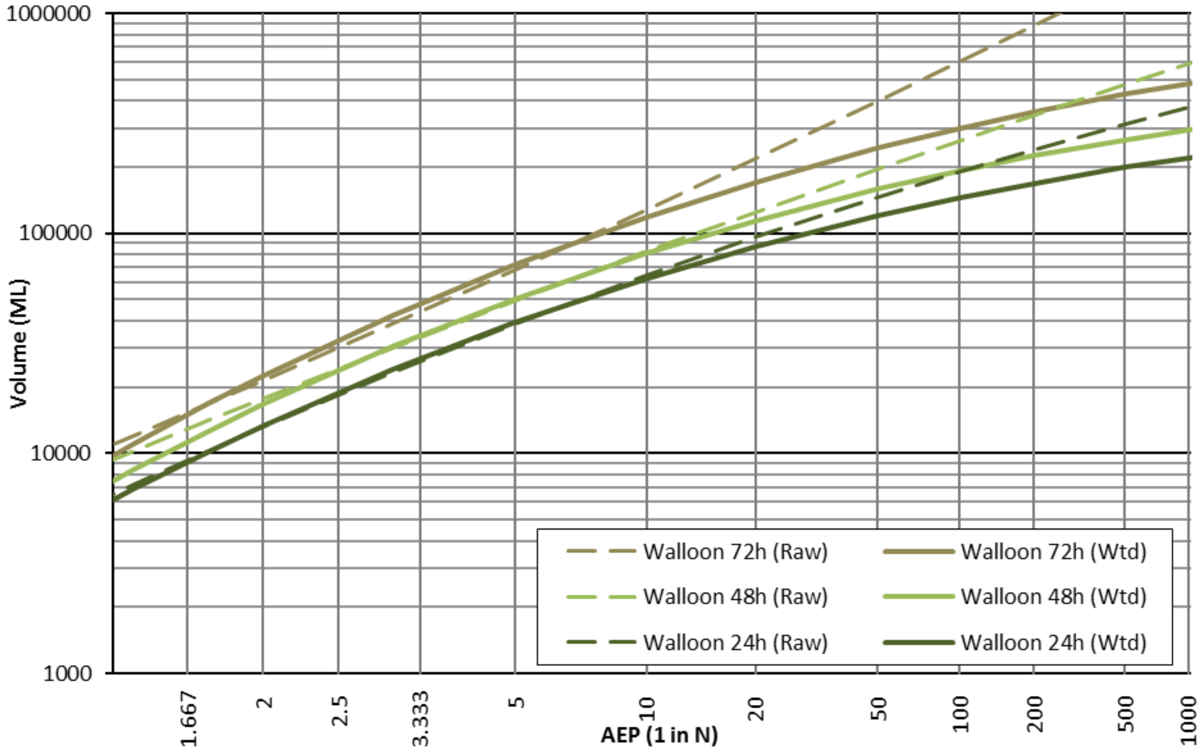

Figure 6-13 Raw and catchment weighted volume frequency curves for Walloon

6.6 Assumptions and limitations

Flood frequency analysis is based on statistical analysis of historical flow data. This historical data was compiled from numerous sources with varying degrees of accuracy and uncertainty. Even at its best, flood frequency analysis is associated with significant uncertainty in the frequency estimates. Although the integrated assessment has been conducted based on best currently available data using current best-practice techniques a number of limitations have been identified. Specific limitations include but are not restricted to:

- **Length of record** – analysis is based on a historical period assumed to represent a random but statistically balanced sample. The longer the record, the greater the statistical reliability of the sample, however the reliability of the data may decrease for older records. Where appropriate, the data record has been extended using additional data
- **Accuracy of gauge readings** – the primary data source for estimating flows has been stream gauge records. Factors affecting the accuracy of these records include:
  - ***Automatic vs. manual recording*** – recent gauge records usually supply instrument recorded continuous level records. Older gauges were typically manually recorded at 24 hour intervals, sometimes with more frequent recordings during flood events. The recordings may therefore miss flood peaks, particularly for short, minor events or at night
  - ***Reliability of records*** – Automatic instrument recordings are subject to jamming or malfunction and may not correctly record flood peaks. Where possible records have been correlated to other data sources, however if no correlating data exists it is often impossible to identify where ‘missing’ floods should have occurred

- *Flood peak records* – records of peak flood heights have been used at locations or in periods where continuous record is not available. Unless otherwise noted, it has been assumed that these records identify all significant floods above a certain magnitude within the period of record. This may not be correct as there is typically no record of what criteria were used to select specific events, nor whether these criteria are consistent across the period of record

- **Conversion of flows to levels** – rating curves are used to convert recorded stream gauge levels into flows. The Rating Curve Review worked to improve confidence in the gauge ratings however there are limitations on this assessment
  - ***Rating accuracy*** – primary gauges have been assessed using independent hydraulic modelling to generate rating curves. These models were calibrated to available flow measurements and other data, but extrapolation of the rating is still dependent upon the accuracy of the model. Ratings at secondary gauges were developed using flow measurements where available and extrapolation using URBS model results. These ratings are considered to have limited accuracy and results should be used with caution. Lower Brisbane gauge ratings were developed using results from the DMT TUFLOW model. This model was calibrated using flows based on Seqwater URBS modelling that has been superseded by the BRCFS hydrology
  - ***Rating consistency*** – rating curves assume a consistent relationship between flow and level. A number of sites exhibit variability in the relationship, which may be due to short or long-term changes to the channel bed, vegetation or other factors. The rating curves have been developed to represent typical or average conditions. Flow estimates for specific events may therefore have a certain margin of error. Several sites also displayed shifts in the gauge datum. Where possible these have been corrected, however it is often not readily apparent whether the change is simply a translation of the gauge zero or represents a more significant change in the channel properties
  - ***Rating sensitivity*** – flow across wide floodplains can exhibit significant sensitivity in the rating whereby small changes in level represent a large change in flow. These ratings may be particularly susceptible to changes in floodplain vegetation
- **URBS modelling** – flow records have in a number of cases been extended or modified using results of URBS hydrologic modelling. These models have been calibrated against available data, but flow estimates are dependent on the availability and accuracy of the calibration data
- **Homogeneity of data record** – analysis assumes that the available record represents a random sample taken from a homogeneous data set. Many factors can result in long-term changes to catchment characteristics including:
  - ***Dams*** – several gauge sites, primarily in the lower Brisbane River and Warrill Creek catchments are affected by dams. Where data records are available, URBS modelling has been undertaken to adjust the record to account for the dam influence. The accuracy of this adjustment is dependent upon the availability and accuracy of input data (eg rainfall, losses) and the ability of the model to represent 'with-dam conditions' and 'no-dam conditions'. Where data records are not available for a specific event, a generic relationship between 'no-dams conditions' and 'with-dams conditions' has been used to estimate 'no-dam conditions'. This provides an estimate of typical dam impacts, but does not necessarily represent the exact impact
  - ***Catchment and stream properties*** – changes in land use such as urbanisation, changes in land use and construction of farm dams affect the catchment runoff characteristics. The area of catchment impacted by urbanisation is only 2.5% of the total Brisbane River but inclusion of urbanisation into the Seqwater URBS model and was found to increase peak flow rates by up to 2.5%, which is minor but not negligible. The assessment has assumed that the catchment and stream conditions are consistent throughout the period of record

- *Climatic changes* – periodic shifts in weather patterns are noted to produce periods of drought or flood. Short records may be susceptible to significant bias if they span periods dominated by one extreme of the climatic cycle. Long-term climate change has also not been considered

- **Catchment weighting parameters** – regional/catchment analysis has been used to improve consistency and confidence of the flood frequency analysis. Details of this assessment are discussed in greater detail in Sections 4.7 and 6.3. Generally the results of the catchment weighting are consistent with expectations and other data, however parts of the methodology used are unique to the BRCFS assessment and therefore unconfirmed

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8 Glossary

8.1 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)

8.2 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
Flood frequency analysis results summary

Gauge Location:	**Stanley River at Peachester**
Catchment Area:	104 km³
Notes:	Continuous gauge data available from 1928. A small shift in datum appears to occur about 1971. Gauge rating becomes highly sensitive and uncertain above about 300m³/s. URBS modelling identifies additional 5 major floods from 1887-1898 including likely flood of record in 1893 that are included as historical data only due to uncertainty in magnitude.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution due to limited reliability gauge high level flow rating**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	123	102	145	124	103	149	137	114	163	136	113	162
5	258	215	310	271	224	326	297	255	348	298	254	349
10	392	318	502	404	332	499	415	357	492	418	357	493
20	571	436	806	561	447	738	531	455	639	535	456	637
50	905	620	1,480	809	601	1,190	678	572	832	683	577	828
100	1,260	789	2,340	1,030	715	1,690	783	654	975	790	661	971
200	1,750	983	3,710	1,280	827	2,360	882	729	1,110	890	737	1,110
500	2,660	1,290	6,780	1,670	970	3,590	1,010	819	1,300	1,010	827	1,300
1000	3,640	1,580	10,600	2,000	1,070	4,870	1,090	880	1,430	1,100	887	1,430
2000	4,970	1,910	16,800	2,380	1,170	6,540	1,170	936	1,560	1,180	940	1,560

Posterior	Location u	91.221	Mean (loge flow)	4.806	Mean (loge flow)	4.791	Mean (loge flow)	4.785
Expected	loge (Scale a)	4.358	loge [Std dev (loge flow)]	-0.062	loge [Std dev (loge flow)]	0.051	loge [Std dev (loge flow)]	0.061
Parameters	Shape k	-0.449	Skew (loge flow)	-0.080	Skew (loge flow)	-0.737	Skew (loge flow)	-0.744

ANNUAL DATA

Year	Value	Source	Used
1928	232.17	Gauge (continuous)	Y
1929	163.6	Gauge (continuous)	Y
1930	326.12	Gauge (continuous)	Y
1931	606.99	Gauge (continuous)	Y
1932	52.27	Gauge (continuous)	Y
1933	122.19	Gauge (peak)	Y
1934	134.35	Gauge (continuous)	Y
1935	94.41	Gauge (continuous)	Y
1936	67.58	Gauge (continuous)	Y
1937	69.06	Gauge (peak)	Y
1938	212.26	Gauge (peak)	Y
1939	65.53	Gauge (continuous)	Y
1940	91.61	Gauge (continuous)	Y
1941	73.3	Gauge (continuous)	Y
1942	97.21	Gauge (peak)	Y
1943	91.61	Gauge (continuous)	Y
1944	89.86	Gauge (continuous)	Y
1945	26.66	Gauge (continuous)	N[1]
1946	338.46	Gauge (peak)	Y
1947	308	Gauge (peak)	Y
1948	115.64	Gauge (continuous)	Y
1949	84.12	Gauge (continuous)	Y
1950	197.66	Gauge (peak)	Y
1951	338.46	Gauge (continuous)	Y
1952	20.8	Gauge (continuous)	N[1]

Year	Value	Source	Used
1953	369.33	Gauge (peak)	Y
1954	80.77	Gauge (peak)	Y
1955	606.99	Gauge (continuous)	Y
1956	221.55	Gauge (continuous)	Y
1957	16.56	Gauge (continuous)	N[1]
1958	191.02	Gauge (peak)	Y
1959	80.09	Gauge (peak)	Y
1960	70.75	Gauge (continuous)	Y
1961	52.27	Gauge (continuous)	Y
1962	69.69	Gauge (continuous)	Y
1963	308	Gauge (peak)	Y
1964	225.53	Gauge (continuous)	Y
1965	27.35	Gauge (continuous)	N[1]
1966	109.09	Gauge (peak)	Y
1967	243.14	Gauge (continuous)	Y
1968	419.87	Gauge (continuous)	Y
1969	38.13	Gauge (continuous)	Y
1970	80.77	Gauge (continuous)	Y
1971	204.29	Gauge (continuous)	Y
1972	616.13	Gauge (continuous)	Y
1973	125.47	Gauge (continuous)	Y
1974	336.41	Gauge (continuous)	Y
1975	86.65	Gauge (continuous)	Y
1976	118.26	Gauge (continuous)	Y
1977	89.63	Gauge (continuous)	Y

Year	Value	Source	Used
1978	49.85	Gauge (continuous)	Y
1979	53.03	Gauge (continuous)	Y
1980	51.71	Gauge (continuous)	Y
1981	59.85	Gauge (continuous)	Y
1982	266.42	Gauge (continuous)	Y
1983	286.38	Gauge (continuous)	Y
1984	83	Gauge (continuous)	Y
1985	158.38	Gauge (continuous)	Y
1986	115.64	Gauge (continuous)	Y
1987	38.89	Gauge (continuous)	Y
1988	440.01	Gauge (continuous)	Y
1989	445.04	Gauge (continuous)	Y
1990	134.35	Gauge (continuous)	Y
1991	12.75	Gauge (continuous)	N[1]
1992	404.77	Gauge (continuous)	Y
1993	37.6	Gauge (continuous)	Y
1994	85.5	Gauge (continuous)	Y
1995	251.45	Gauge (continuous)	Y
1996	260.93	Gauge (continuous)	Y
1997	67.33	Gauge (continuous)	Y
1998	22.98	Gauge (continuous)	N[1]
1999	780.76	Gauge (continuous)	Y
2000	122.19	Gauge (continuous)	Y
2001	93.08	Gauge (continuous)	Y
2002	56.81	Gauge (continuous)	Y

ANNUAL DATA

Year	Value	Source	Used
2003	136.86	Gauge (continuous)	Y
2004	266.42	Gauge (continuous)	Y
2005	40.32	Gauge (continuous)	Y
2006	36.57	Gauge (continuous)	Y
2007	19.39	Gauge (continuous)	N[1]
2008	112.04	Gauge (continuous)	Y
2009	162.45	Gauge (continuous)	Y
2010	136.97	Gauge (continuous)	Y
2011	487.33	Gauge (continuous)	Y
2012	256.11	Gauge (continuous)	Y
2013	362.33	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	36.53	0	7	1928 – 2013	Low outlier threshold determined using multiple Grubbs Beck test
2	800	1	40	1887 – 1927	Historical flood of record 1893, flow estimate from URBS modelling

Gauge Location:	**Stanley River at Woodford**
Catchment Area:	245 km³
Notes:	Primary rated site in Stanley River catchment, but low-flow rating potentially influenced by flow balance between Stanley River and Monkeybong Creek. Gauge record since 1890 with relatively consistent peak level data since 1908 but continuous data only since 2003. Additional 5 major floods from 1887-1898 no low-flows in this period. Separate censor thresholds applied pre- and post 1908.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods. **Preferred FFA site for Stanley River catchment**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	190	135	244	190	149	237	189	146	238	201	164	246
5	497	419	598	484	405	589	502	423	598	505	431	595
10	741	626	903	751	620	928	762	647	920	753	644	889
20	1,010	839	1,290	1,050	848	1,340	1,030	867	1,270	1,010	858	1,200
50	1,420	1,130	2,040	1,500	1,160	2,080	1,390	1,150	1,760	1,340	1,130	1,630
100	1,780	1,340	2,840	1,870	1,390	2,860	1,650	1,350	2,150	1,580	1,330	1,960
200	2,190	1,550	3,920	2,270	1,600	3,850	1,900	1,530	2,530	1,820	1,510	2,290
500	2,830	1,820	5,970	2,830	1,850	5,540	2,220	1,760	3,040	2,120	1,720	2,720
1000	3,390	2,020	8,210	3,270	2,010	7,240	2,440	1,910	3,410	2,330	1,870	3,050
2000	4,030	2,220	11,200	3,740	2,150	9,410	2,650	2,040	3,770	2,520	2,010	3,370

Posterior	Location u	103.728	Mean (loge flow)	5.154	Mean (loge flow)	5.069	Mean (loge flow)	5.148
Expected	loge (Scale a)	5.420	loge [Std dev (loge flow)]	0.183	loge [Std dev (loge flow)]	0.294	loge [Std dev (loge flow)]	0.229
Parameters	Shape k	-0.194	Skew (loge flow)	-0.463	Skew (loge flow)	-0.785	Skew (loge flow)	-0.756

ANNUAL DATA

Year	Value	Source	Used
1887	647.37	URBS model	Y
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	988.83	Gauge (peak)	Y
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	2187	Gauge (peak)	Y
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	596.11	Gauge (peak)	Y
1897	-	No data	N[2]
1898	1596.4	Gauge (peak)	Y
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	-	No data	N[2]
1902	-	No data	N[2]
1903	-	No data	N[2]
1904	-	No data	N[2]
1905	-	No data	N[2]
1906	-	No data	N[2]
1907	-	No data	N[2]
1908	425.1	Gauge (peak)	Y
1909	-	No data	N[1]
1910	326.07	Gauge (peak)	Y
1911	258.11	Gauge (peak)	Y

Year	Value	Source	Used
1912	-	No data	N[1]
1913	-	No data	N[1]
1914	157.42	Gauge (peak)	N[1]
1915	488.79	Gauge (peak)	Y
1916	-	No data	N[1]
1917	-	No data	N[1]
1918	112.27	Gauge (peak)	N[1]
1919	-	No data	N[1]
1920	90.82	Gauge (peak)	N[1]
1921	210.19	Gauge (peak)	Y
1922	164.43	Gauge (peak)	N[1]
1923	-	No data	N[1]
1924	-	No data	N[1]
1925	241.26	Gauge (peak)	Y
1926	-	No data	N[1]
1927	366.5	Gauge (peak)	Y
1928	502.01	Gauge (peak)	Y
1929	132.21	Gauge (peak)	N[1]
1930	210.19	Gauge (peak)	Y
1931	1103.8	Gauge (peak)	Y
1932	-	No data	N[1]
1933	121.25	Gauge (peak)	N[1]
1934	-	No data	N[1]
1935	-	No data	N[1]
1936	-	No data	N[1]

Year	Value	Source	Used
1937	121.25	Gauge (peak)	N[1]
1938	274.95	Gauge (peak)	Y
1939	90.82	Gauge (peak)	N[1]
1940	90.82	Gauge (peak)	N[1]
1941	90.82	Gauge (peak)	N[1]
1942	210.19	Gauge (peak)	Y
1943	-	No data	N[1]
1944	160.22	Gauge (peak)	N[1]
1945	-	No data	N[1]
1946	547.49	Gauge (peak)	Y
1947	366.5	Gauge (peak)	Y
1948	274.95	Gauge (peak)	Y
1949	-	No data	N[1]
1950	526.26	Gauge (peak)	Y
1951	687.35	Gauge (peak)	Y
1952	-	No data	N[1]
1953	872.87	Gauge (peak)	Y
1954	-	No data	N[1]
1955	964.11	Gauge (peak)	Y
1956	384.33	Gauge (peak)	Y
1957	-	No data	N[1]
1958	56.5	Gauge (peak)	N[1]
1959	203.48	URBS model	Y
1960	362.66	URBS model	Y
1961	-	No data	N[1]

ANNUAL DATA

Year	Value	Source	Used
1962	90.82	Gauge (peak)	N[1]
1963	732.97	Gauge (peak)	Y
1964	274.95	Gauge (peak)	Y
1965	-	No data	N[1]
1966	334.64	URBS model	Y
1967	371.59	Gauge (peak)	Y
1968	296	Gauge (peak)	Y
1969	-	No data	N[1]
1970	-	No data	N[1]
1971	425.1	Gauge (peak)	Y
1972	1174.8	Gauge (peak)	Y
1973	-	No data	N[1]
1974	985.4	Gauge (peak)	Y
1975	38.01	Gauge (peak)	N[1]
1976	371.59	Gauge (peak)	Y
1977	-	No data	N[1]
1978	78.57	Gauge (peak)	N[1]
1979	105.86	Gauge (peak)	N[1]
1980	168.63	Gauge (peak)	N[1]
1981	272.84	Gauge (peak)	Y
1982	605.23	Gauge (peak)	Y
1983	650.85	Gauge (peak)	Y
1984	181.43	Gauge (peak)	Y
1985	260.21	Gauge (peak)	Y
1986	247.58	Gauge (peak)	Y
1987	117.4	Gauge (peak)	N[1]
1988	371.59	Gauge (peak)	Y
1989	632.6	Gauge (peak)	Y
1990	289.68	Gauge (peak)	Y
1991	8.04	URBS model	N[1]
1992	553.55	Gauge (peak)	Y
1993	-	No data	N[1]
1994	245.47	Gauge (peak)	Y
1995	435.29	Gauge (peak)	Y
1996	435.29	Gauge (peak)	Y
1997	-	No data	N[1]
1998	-	No data	N[1]
1999	1125.1	Gauge (peak)	Y
2000	243.37	Gauge (peak)	Y
2001	130.81	Gauge (peak)	N[1]
2002	-	No data	N[1]
2003	314.73	Gauge (continuous)	Y
2004	432.54	Gauge (continuous)	Y
2005	83.27	Gauge (continuous)	N[1]
2006	109.06	Gauge (continuous)	N[1]
2007	38.14	Gauge (continuous)	N[1]
2008	341.77	Gauge (continuous)	Y
2009	582.79	Gauge (continuous)	Y
2010	458.41	Gauge (continuous)	Y
2011	1405.5	Gauge (continuous)	Y
2012	453.82	Gauge (continuous)	Y
2013	855.75	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	181.43	0	52	1908 – 2013	Low outlier threshold determined using multiple Grubbs Beck test
2	590	0	16	1887 – 1907	Low outlier threshold pre-1908 based on visual assessment of data record

Gauge Location:	**Stanley River at Somerset**
Catchment Area:	1324 km³
Notes:	Data since 1955 based on reverse-routed reservoir flows and URBS model results. Record contains 5 events between 3240m³/s and 3405m³/s which have a significant influence on skew. Threshold of missing floods appears to be inconsistent making inclusion in analysis difficult. Correlation to Woodford used to identify likely magnitude of missing floods.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution due to potential inconsistencies in the data record**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	379	-	729	411	262	624	488	308	717	536	391	722
5	1,480	1,110	2,080	1,570	1,140	2,120	1,420	1,090	1,900	1,450	1,130	1,880
10	2,300	1,780	3,200	2,480	1,940	3,280	2,230	1,740	3,070	2,210	1,740	2,880
20	3,160	2,450	5,010	3,280	2,620	4,540	3,090	2,370	4,470	3,000	2,350	3,970
50	4,400	3,200	9,340	4,100	3,320	6,220	4,250	3,150	6,550	4,040	3,100	5,520
100	5,430	3,600	15,200	4,550	3,710	7,290	5,110	3,680	8,200	4,810	3,640	6,740
200	6,550	3,910	24,400	4,890	3,940	8,400	5,940	4,180	9,990	5,540	4,120	7,950
500	8,190	4,180	45,100	5,200	4,130	9,660	6,970	4,750	12,300	6,460	4,690	9,570
1000	9,560	4,330	72,600	5,360	4,220	10,400	7,710	5,140	14,000	7,100	5,060	10,700
2000	11,100	4,440	117,000	5,480	4,260	11,100	8,390	5,480	15,800	7,690	5,390	12,000

Posterior	Location u	55.887	Mean (loge flow)	5.519	Mean (loge flow)	5.992	Mean (loge flow)	6.102
Expected	loge (Scale a)	6.759	loge [Std dev (loge flow)]	0.793	loge [Std dev (loge flow)]	0.390	loge [Std dev (loge flow)]	0.317
Parameters	Shape k	-0.126	Skew (loge flow)	-1.407	Skew (loge flow)	-0.812	Skew (loge flow)	-0.802

ANNUAL DATA

Year	Value	Source	Used
1955	3403.8	Reverse routed	Y
1956	1310.9	Reverse routed	Y
1957	-	No data	N[1-2]
1958	-	No data	N[1-2]
1959	544.16	Reverse routed	Y
1960	1138.6	Reverse routed	Y
1961	-	No data	N[1-2]
1962	-	No data	N[1-2]
1963	-	No data	N[1-2]
1964	-	No data	N[1-2]
1965	-	No data	N[1-2]
1966	1243.1	Reverse routed	Y
1967	1490.8	Reverse routed	Y
1968	1685.9	Reverse routed	Y
1969	-	No data	N[1-2]
1970	-	No data	N[1-2]
1971	791.93	URBS model	Y
1972	3244.4	URBS model	Y
1973	-	No data	N[1-2]
1974	3261	Reverse routed	Y
1975	-	No data	N[1-2]
1976	1073.5	Reverse routed	Y
1977	-	No data	N[1-2]
1978	-	No data	N[1-2]
1979	-	No data	N[1-2]
1980	-	No data	N[1-2]
1981	-	No data	N[1-2]
1982	-	No data	N[1-2]
1983	2073.7	Reverse routed	Y
1984	-	No data	N[1-2]
1985	-	No data	N[1-2]
1986	-	No data	N[1-2]
1987	-	No data	N[1-2]
1988	1019	URBS model	Y
1989	3438.9	Reverse routed	Y
1990	-	No data	N[1]
1991	21.59	URBS model	N[1]
1992	1860.2	URBS model	Y
1993	-	No data	N[1-2]
1994	-	No data	N[1-2]
1995	-	No data	N[1-2]
1996	1106	Reverse routed	Y
1997	-	No data	N[1-2]
1998	-	No data	N[1-2]
1999	3334.7	Reverse routed	Y
2000	-	No data	N[1-2]
2001	497.68	URBS model	Y
2002	-	No data	N[1-2]
2003	-	No data	N[1-2]
2004	622.89	Reverse routed	Y
2005	-	No data	N[1-2]
2006	-	No data	N[1-2]
2007	-	No data	N[1-2]
2008	-	No data	N[1-2]
2009	769.53	Reverse routed	Y
2010	683.48	Reverse routed	Y
2011	3868.5	Reverse routed	Y
2012	701.71	Reverse routed	Y
2013	2172.3	Reverse routed	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	495	0	20	1955 – 2013	Low outlier thresholds estimated from correlation to Woodford gauge which indicates inconsistent inclusion/omission of low flows from data record. Refer to Section 4.8.3 for further details.
2	1500	0	15	1955 – 2013	

Gauge Location:	**Upper Brisbane River at Cooyar Creek**
Catchment Area:	965 km³
Notes:	Gauge rating utilises hydrologic model results and has limited reliability. Continuous gauge data available from 1970. Some events pre-1969 available from URBS modelling but low reliability of peak and do not appear to be consistently significant. Influence dependent on arbitrary selection of threshold and inclusion in statistical analysis not justifiable.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution due to limited reliability gauge flow rating**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	92	61	131	88	58	135	97	64	145	99	66	145
5	292	196	465	318	206	498	339	242	498	341	240	492
10	566	347	1,120	597	377	1,020	582	415	884	581	410	852
20	1,040	551	2,620	983	584	1,980	859	600	1,360	854	601	1,280
50	2,230	939	7,950	1,690	900	4,450	1,260	857	2,110	1,250	864	1,930
100	3,920	1,360	18,800	2,390	1,150	7,890	1,580	1,050	2,760	1,560	1,060	2,480
200	6,850	1,940	44,000	3,250	1,390	13,900	1,900	1,240	3,420	1,870	1,250	3,060
500	14,300	3,050	136,000	4,670	1,680	27,900	2,310	1,470	4,360	2,270	1,490	3,860
1000	24,800	4,240	318,000	5,980	1,890	46,700	2,620	1,640	5,110	2,570	1,660	4,520
2000	43,100	5,880	749,000	7,510	2,060	76,500	2,920	1,780	5,870	2,860	1,810	5,170

Posterior	Location u	57.497	Mean (loge flow)	4.405	Mean (loge flow)	4.357	Mean (loge flow)	4.376
Expected	loge (Scale a)	4.394	loge [Std dev (loge flow)]	0.465	loge [Std dev (loge flow)]	0.541	loge [Std dev (loge flow)]	0.531
Parameters	Shape k	-0.796	Skew (loge flow)	-0.281	Skew (loge flow)	-0.776	Skew (loge flow)	-0.777

ANNUAL DATA

Year	Value	Source	Used
1970	27.34	Gauge (continuous)	Y
1971	399.76	Gauge (continuous)	Y
1972	208.76	Gauge (continuous)	Y
1973	58.95	Gauge (continuous)	Y
1974	1291.8	Gauge (continuous)	Y
1975	131.98	Gauge (continuous)	Y
1976	218.44	Gauge (continuous)	Y
1977	68.65	Gauge (continuous)	Y
1978	17.71	Gauge (continuous)	Y
1979	111.83	Gauge (continuous)	Y
1980	35.37	Gauge (continuous)	Y
1981	406.95	Gauge (continuous)	Y
1982	94.36	Gauge (continuous)	Y
1983	906.83	Gauge (continuous)	Y
1984	65.34	Gauge (continuous)	Y
1985	222.58	Gauge (continuous)	Y
1986	79.22	Gauge (continuous)	Y
1987	13.03	Gauge (continuous)	Y
1988	352.01	Gauge (continuous)	Y
1989	523.14	Gauge (continuous)	Y

Year	Value	Source	Used
1990	124.62	Gauge (continuous)	Y
1991	61.44	Gauge (continuous)	Y
1992	127.99	Gauge (continuous)	Y
1993	1.29	Gauge (continuous)	N[1]
1994	2.62	Gauge (continuous)	N[1]
1995	65.28	Gauge (continuous)	Y
1996	254.85	Gauge (continuous)	Y
1997	52.29	Gauge (continuous)	Y
1998	83.45	Gauge (continuous)	Y
1999	453.67	Gauge (continuous)	Y
2000	62.04	Gauge (continuous)	Y
2001	195.88	Gauge (continuous)	Y
2002	43.45	Gauge (continuous)	Y
2003	17.19	Gauge (continuous)	Y
2004	82.36	Gauge (continuous)	Y
2005	4.64	Gauge (continuous)	N[1]
2006	1.16	Gauge (continuous)	N[1]
2007	0.02	Gauge (continuous)	N[1]
2008	66.47	Gauge (continuous)	Y
2009	18.08	Gauge (continuous)	Y

Year	Value	Source	Used
2010	225.21	Gauge (continuous)	Y
2011	1619.2	Gauge (continuous)	Y
2012	29.29	Gauge (continuous)	Y
2013	546.92	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	13.03	0	5	1970 – 2013	Low outlier threshold determined using multiple Grubbs Beck test

Gauge Location:	**Upper Brisbane River at Linville**
Catchment Area:	2009 km³
Notes:	Reliable rating site. Continuous gauge data available from 1966. Some events pre-1965 available from URBS modelling but low reliability of peak and do not appear to be consistently significant. Influence dependent on arbitrary selection of threshold hence inclusion in statistical analysis not justifiable. Data upper and lower tails have significant impact on the frequency curve.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Other distributions should not be used due to strong influence of upper tail**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	150	91	229	142	86	240	154	92	246	172	112	260
5	624	388	1,070	702	427	1,170	721	481	1,140	711	492	1,050
10	1,440	782	3,190	1,490	899	2,630	1,400	934	2,310	1,310	909	1,980
20	3,110	1,390	9,490	2,650	1,510	5,650	2,250	1,470	3,920	2,040	1,410	3,160
50	8,340	2,730	39,300	4,850	2,450	15,000	3,590	2,260	6,740	3,150	2,130	5,060
100	17,400	4,410	115,000	7,070	3,130	29,500	4,710	2,890	9,270	4,060	2,700	6,750
200	36,000	7,000	336,000	9,810	3,720	55,300	5,890	3,510	12,200	5,010	3,270	8,580
500	93,900	12,900	1,360,000	14,300	4,280	124,000	7,490	4,300	16,500	6,290	3,980	11,200
1000	194,000	20,400	3,990,000	18,300	4,620	225,000	8,700	4,850	20,000	7,250	4,490	13,300
2000	400,000	31,900	11,600,000	22,900	4,920	393,000	9,880	5,370	23,600	8,190	4,960	15,500

Posterior	Location u	83.282	Mean (loge flow)	4.794	Mean (loge flow)	4.758	Mean (loge flow)	4.901
Expected	loge (Scale a)	5.004	loge [Std dev (loge flow)]	0.721	loge [Std dev (loge flow)]	0.756	loge [Std dev (loge flow)]	0.666
Parameters	Shape k	-1.045	Skew (loge flow)	-0.467	Skew (loge flow)	-0.793	Skew (loge flow)	-0.774

ANNUAL DATA

Year	Value	Source	Used
1965	15.65	Gauge (continuous)	N[1]
1966	217.1	Gauge (continuous)	Y
1967	314.23	Gauge (continuous)	Y
1968	478.63	Gauge (continuous)	Y
1969	1.96	Gauge (continuous)	N[1]
1970	94.1	Gauge (continuous)	Y
1971	1602.6	Gauge (continuous)	Y
1972	534.95	Gauge (continuous)	Y
1973	343.7	Gauge (continuous)	Y
1974	2501.8	Gauge (continuous)	Y
1975	74.97	Gauge (continuous)	Y
1976	350.18	Gauge (continuous)	Y
1977	14.99	Gauge (continuous)	N[1]
1978	10.7	Gauge (continuous)	N[1]
1979	241.72	Gauge (continuous)	Y
1980	27.77	Gauge (continuous)	Y
1981	337.22	Gauge (continuous)	Y
1982	330.74	Gauge (continuous)	Y
1983	2299.5	Gauge (continuous)	Y
1984	141.54	Gauge (continuous)	Y

Year	Value	Source	Used
1985	248.29	Gauge (continuous)	Y
1986	83.77	Gauge (continuous)	Y
1987	26.49	Gauge (continuous)	Y
1988	330.74	Gauge (continuous)	Y
1989	2198	Gauge (continuous)	Y
1990	77.57	Gauge (continuous)	Y
1991	36.05	Gauge (continuous)	Y
1992	932.32	Gauge (continuous)	Y
1993	11.42	Gauge (continuous)	N[1]
1994	7.9	Gauge (continuous)	N[1]
1995	84.54	Gauge (continuous)	Y
1996	254.85	Gauge (continuous)	Y
1997	23.78	Gauge (continuous)	Y
1998	150.39	Gauge (continuous)	Y
1999	2665.9	Gauge (continuous)	Y
2000	62.34	Gauge (continuous)	Y
2001	550.44	Gauge (continuous)	Y
2002	55.05	Gauge (continuous)	Y
2003	5.72	Gauge (continuous)	N[1]
2004	124.92	Gauge (continuous)	Y

Year	Value	Source	Used
2005	30.19	Gauge (continuous)	Y
2006	87	Gauge (continuous)	Y
2007	6.23	Gauge (continuous)	N[1]
2008	174.49	Gauge (continuous)	Y
2009	20.88	Gauge (continuous)	Y
2010	419.13	Gauge (continuous)	Y
2011	3949.7	Gauge (continuous)	Y
2012	210.38	Gauge (continuous)	Y
2013	1778.5	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	20	0	8	1965 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Gregors Creek**
Catchment Area:	3866 km³
Notes:	Relatively reliable rating site. Continuous gauge data available from 1963. Some events pre-1963 available from URBS modelling but low reliability of peak and do not appear to be consistently significant. Influence dependent on arbitrary selection of threshold hence inclusion in statistical analysis not justifiable. Upper and lower tails have significant impact on skew.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Other distributions should not be used due to strong influence of upper tail**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	290	180	437	283	176	476	313	190	490	335	219	503
5	1,190	747	2,010	1,330	826	2,190	1,390	938	2,120	1,380	954	2,040
10	2,740	1,500	5,990	2,800	1,690	4,850	2,630	1,780	4,210	2,540	1,760	3,800
20	5,960	2,680	17,900	5,000	2,850	10,600	4,160	2,760	6,990	3,940	2,710	6,060
50	16,100	5,290	74,800	9,250	4,620	28,600	6,540	4,190	11,700	6,070	4,100	9,680
100	33,700	8,590	218,000	13,700	5,790	56,300	8,500	5,300	15,900	7,820	5,180	12,900
200	70,100	13,700	637,000	19,200	6,710	110,000	10,600	6,410	20,700	9,630	6,240	16,500
500	185,000	25,300	2,600,000	28,600	7,700	265,000	13,300	7,800	27,500	12,100	7,550	21,600
1000	384,000	40,200	7,440,000	37,400	8,220	491,000	15,400	8,780	33,100	13,900	8,490	25,600
2000	796,000	62,800	21,600,000	47,700	8,720	878,000	17,400	9,630	38,900	15,600	9,350	29,800

Posterior	Location u	165.455	Mean (loge flow)	5.522	Mean (loge flow)	5.478	Mean (loge flow)	5.564
Expected	loge (Scale a)	5.632	loge [Std dev (loge flow)]	0.672	loge [Std dev (loge flow)]	0.719	loge [Std dev (loge flow)]	0.666
Parameters	Shape k	-1.054	Skew (loge flow)	-0.382	Skew (loge flow)	-0.790	Skew (loge flow)	-0.780

ANNUAL DATA

Year	Value	Source	Used
1963	445.07	Gauge (continuous)	Y
1964	111.71	Gauge (continuous)	Y
1965	67.09	Gauge (continuous)	Y
1966	854.9	Gauge (continuous)	Y
1967	761.87	Gauge (continuous)	Y
1968	905.48	Gauge (continuous)	Y
1969	44.37	Gauge (continuous)	Y
1970	129.67	Gauge (continuous)	Y
1971	3949.8	Gauge (continuous)	Y
1972	1137.9	Gauge (continuous)	Y
1973	606.73	Gauge (continuous)	Y
1974	4958.9	Gauge (continuous)	Y
1975	214.86	Gauge (continuous)	Y
1976	648.92	Gauge (continuous)	Y
1977	496.07	Gauge (continuous)	Y
1978	147.04	Gauge (continuous)	Y
1979	285.29	Gauge (continuous)	Y
1980	27.03	Gauge (continuous)	N[1]
1981	725.43	Gauge (continuous)	Y
1982	615.77	Gauge (continuous)	Y

Year	Value	Source	Used
1983	5159.2	Gauge (continuous)	Y
1984	194.73	Gauge (continuous)	Y
1985	698.93	Gauge (continuous)	Y
1986	72.45	Gauge (continuous)	Y
1987	30.11	Gauge (continuous)	N[1]
1988	609.75	Gauge (continuous)	Y
1989	4164.6	Gauge (continuous)	Y
1990	358.51	Gauge (continuous)	Y
1991	58.9	Gauge (continuous)	Y
1992	1914.5	Gauge (continuous)	Y
1993	16.2	Gauge (continuous)	N[1]
1994	38.05	Gauge (continuous)	N[1]
1995	331.97	Gauge (continuous)	Y
1996	518.33	Gauge (continuous)	Y
1997	81.34	Gauge (continuous)	Y
1998	121.11	Gauge (continuous)	Y
1999	5507.6	Gauge (continuous)	Y
2000	131.99	Gauge (continuous)	Y
2001	600.71	Gauge (continuous)	Y
2002	44.37	Gauge (continuous)	Y

Year	Value	Source	Used
2003	20.84	Gauge (continuous)	N[1]
2004	383.41	Gauge (continuous)	Y
2005	15.69	Gauge (continuous)	N[1]
2006	28.09	Gauge (continuous)	N[1]
2007	0.04	Gauge (continuous)	N[1]
2008	262.18	Gauge (continuous)	Y
2009	70.54	Gauge (continuous)	Y
2010	627.83	Gauge (continuous)	Y
2011	6115.6	Gauge (continuous)	Y
2012	168.99	Gauge (continuous)	Y
2013	3181.6	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	44	0	8	1965 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Plainlands/Fulham Vale/ Watts Bridge**
Catchment Area:	3950 km³
Notes:	Gauge is a compilation of Plainlands (1920-1932), Fulham Vale (1933-1966) and Watts Bridge (1967-1972, correlated levels). Flow rating and correlation have limited reliability. Gauge record misses 5 largest flood events, included as historical floods only.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Rating and record has low reliability. Provided for comparison with Gregors Creek only**.

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	455	299	653	406	278	600	417	281	594	410	285	571
5	1,390	1,030	1,870	1,510	1,090	2,100	1,510	1,160	1,990	1,510	1,150	1,980
10	2,430	1,810	3,360	2,670	1,980	3,590	2,620	2,060	3,460	2,640	2,040	3,450
20	3,920	2,790	6,140	4,050	3,040	5,500	3,890	3,040	5,280	3,940	3,050	5,230
50	7,000	4,440	13,600	6,120	4,460	9,250	5,720	4,380	8,090	5,810	4,440	7,990
100	10,600	6,000	24,700	7,800	5,440	13,400	7,160	5,380	10,500	7,280	5,460	10,300
200	15,900	7,910	45,200	9,540	6,250	18,700	8,610	6,330	13,000	8,760	6,430	12,800
500	26,900	11,100	99,300	11,900	7,000	28,600	10,500	7,490	16,500	10,700	7,620	16,200
1000	39,900	14,000	183,000	13,600	7,440	37,800	11,900	8,300	19,300	12,100	8,430	18,900
2000	59,000	17,700	331,000	15,400	7,720	49,000	13,200	9,010	22,000	13,400	9,170	21,600

Posterior	Location u	258.434	Mean (loge flow)	5.787	Mean (loge flow)	5.796	Mean (loge flow)	5.773
Expected	loge (Scale a)	6.181	loge [Std dev (loge flow)]	0.582	loge [Std dev (loge flow)]	0.577	loge [Std dev (loge flow)]	0.592
Parameters	Shape k	-0.556	Skew (loge flow)	-0.744	Skew (loge flow)	-0.804	Skew (loge flow)	-0.811

ANNUAL DATA

Year	Value	Source	Used
1887	1392.8	URBS model	N[2]
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	3883.0	URBS model	N[2]
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	6661.6	URBS model	N[3]
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	-	No data	N[2]
1897	-	No data	N[2]
1898	3700.9	URBS model	N[2]
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	-	No data	N[2]
1902	-	No data	N[2]
1903	-	No data	N[2]
1904	-	No data	N[2]
1905	-	No data	N[2]
1906	-	No data	N[2]
1907	-	No data	N[2]
1908	1710.1	URBS model	N[2]
1909	-	No data	N[2]
1910	-	No data	N[2]
1911	-	No data	N[2]

Year	Value	Source	Used
1912	-	No data	N[2]
1913	-	No data	N[2]
1914	-	No data	N[2]
1915	-	No data	N[2]
1916	-	No data	N[2]
1917	-	No data	N[2]
1918	-	No data	N[2]
1919	-	No data	N[2]
1920	128.22	Gauge (Plainlands)	Y
1921	994.98	Gauge (Plainlands)	Y
1922	661.36	Gauge (Plainlands)	Y
1923	9.5	Gauge (Plainlands)	N[1]
1924	98.73	Gauge (Plainlands)	Y
1925	220.29	Gauge (Plainlands)	Y
1926	30.42	Gauge (Plainlands)	N[1]
1927	1602	Gauge (Plainlands)	Y
1928	2761.2	Gauge (Plainlands)	Y
1929	2033.6	Gauge (Plainlands)	Y
1930	204.47	Gauge (Plainlands)	Y
1931	2421.2	Gauge (Plainlands)	Y
1932	52.63	Gauge (Plainlands)	N[1]
1933	31.15	Gauge (Fulham Vale)	N[1]
1934	262.02	Gauge (Fulham Vale)	Y
1935	178.57	Gauge (Fulham Vale)	Y
1936	29.7	Gauge (Fulham Vale)	N[1]

Year	Value	Source	Used
1937	337.27	Gauge (Fulham Vale)	Y
1938	339.71	Gauge (Fulham Vale)	Y
1939	111.35	Gauge (Fulham Vale)	Y
1940	623.51	Gauge (Fulham Vale)	Y
1941	107	Gauge (Fulham Vale)	Y
1942	310.93	Gauge (Fulham Vale)	Y
1943	251.95	Gauge (Fulham Vale)	Y
1944	882.73	Gauge (Fulham Vale)	Y
1945	51.51	Gauge (Fulham Vale)	N[1]
1946	369.07	Gauge (Fulham Vale)	Y
1947	496.29	Gauge (Fulham Vale)	Y
1948	1363.7	Gauge (Fulham Vale)	Y
1949	801.66	Gauge (Fulham Vale)	Y
1950	2654.8	Gauge (Fulham Vale)	Y
1951	2063.8	Gauge (Fulham Vale)	Y
1952	13.41	Gauge (Fulham Vale)	N[1]
1953	381.31	Gauge (Fulham Vale)	Y
1954	1930	Gauge (Fulham Vale)	Y
1955	4352.6	Gauge (Fulham Vale)	Y
1956	1735.8	Gauge (Fulham Vale)	Y
1957	266.33	Gauge (Fulham Vale)	Y
1958	1001.2	Gauge (Fulham Vale)	Y
1959	530.54	Gauge (Fulham Vale)	Y
1960	400.88	Gauge (Fulham Vale)	Y
1961	23.32	Gauge (Fulham Vale)	N[1]

ANNUAL DATA

Year	Value	Source	Used
1962	369.07	Gauge (Fulham Vale)	Y
1963	310.93	Gauge (Fulham Vale)	Y
1964	45.3	Gauge (Fulham Vale)	N[1]
1965	15.18	Gauge (Fulham Vale)	N[1]
1966	929.5	Gauge (Fulham Vale)	Y
1967	733.54	Gauge (Watts Bridge)	Y
1968	1026.8	Gauge (Watts Bridge)	Y
1969	31.93	Gauge (Watts Bridge)	N[1]
1970	54.36	Gauge (Watts Bridge)	N[1]
1971	2596.6	Gauge (Watts Bridge)	Y
1972	1193	Gauge (Watts Bridge)	Y
1973	-	No data	N[2]
1974	5089.4	URBS model	Y
1975	-	No data	N[2]
1976	602.0	URBS model	N[2]
1977	-	No data	N[2]
1978	-	No data	N[2]
1979	-	No data	N[2]

Year	Value	Source	Used
1980	-	No data	N[2]
1981	-	No data	N[2]
1982	-	No data	N[2]
1983	4977.5	URBS model	Y
1984	-	No data	N[2]
1985	-	No data	N[2]
1986	-	No data	N[2]
1987	-	No data	N[2]
1988	654.7	URBS model	N[2]
1989	3922.8	URBS model	N[2]
1990	-	No data	N[2]
1991	68.8	URBS model	N[2]
1992	1889.0	URBS model	N[2]
1993	-	No data	N[2]
1994	-	No data	N[2]
1995	-	No data	N[2]
1996	837.3	URBS model	N[2]
1997	-	No data	N[2]

Year	Value	Source	Used
1998	-	No data	N[2]
1999	6052.9	URBS model	Y
2000	-	No data	N[2]
2001	457.6	URBS model	N[2]
2002	-	No data	N[2]
2003	-	No data	N[2]
2004	296.4	URBS model	N[2]
2005	-	No data	N[2]
2006	-	No data	N[2]
2007	-	No data	N[2]
2008	-	No data	N[2]
2009	465.2	URBS model	N[2]
2010	595.3	URBS model	N[2]
2011	6056.2	URBS model	Y
2012	594.9	URBS model	N[2]
2013	3722.9	URBS model	N[2]

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	98.73	0	12	1920 – 1972	Low outlier threshold determined using multiple Grubbs Beck test
2	590	0	69	1887 – 2013	Low outlier threshold applied to pre-1920 and post-1973 URBS model data
3	6600	1	0	1893	Historical flood of record

Gauge Location:	**Upper Brisbane River at Wivenhoe (including Caboonbah and Middle Creek)**
Catchment Area:	5645 km³
Notes:	Data since 1983 based on reverse-routed reservoir flows and URBS model results. Record extended using Middle Creek (1963-1982 but missing 1971 & 1974 floods) and Caboonbah (1890-1983). Rating for Middle Creek is reasonable. Rating for Caboonbah is relatively unreliable.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution due to limited reliability gauge flow ratings**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	-	-	-	582	262	1,180	638	357	1,020	741	518	1,030
5	2,410	1,860	3,620	2,300	1,910	3,370	2,530	1,910	3,380	2,650	2,080	3,400
10	4,590	3,680	6,410	4,420	3,530	6,300	4,540	3,640	6,060	4,590	3,680	5,850
20	7,020	5,610	10,000	7,340	5,510	10,300	6,920	5,530	9,630	6,820	5,490	8,860
50	10,800	8,220	18,000	12,600	8,340	19,800	10,400	8,060	15,500	10,000	7,930	13,500
100	14,100	10,100	29,000	17,700	10,500	32,500	13,300	9,940	20,800	12,600	9,760	17,400
200	18,000	11,800	46,500	23,800	12,300	56,600	16,100	11,700	26,600	15,100	11,500	21,600
500	24,000	13,700	88,500	33,600	14,200	117,000	19,900	13,900	34,600	18,500	13,700	27,400
1000	29,400	15,000	145,000	42,400	15,300	192,000	22,600	15,500	40,900	21,000	15,200	31,900
2000	35,600	16,100	234,000	52,300	16,100	329,000	25,300	16,900	47,300	23,300	16,500	36,700

Posterior	Location u	-1020.52	Mean (loge flow)	6.250	Mean (loge flow)	6.204	Mean (loge flow)	6.379
Expected	loge (Scale a)	7.574	loge [Std dev (loge flow)]	0.554	loge [Std dev (loge flow)]	0.644	loge [Std dev (loge flow)]	0.564
Parameters	Shape k	-0.211	Skew (loge flow)	-0.402	Skew (loge flow)	-0.809	Skew (loge flow)	-0.788

ANNUAL DATA

Year	Value	Source	Used
1887	4103.9	URBS model	Y
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	11926	Gauge (Caboonbah)	Y
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	15274	Gauge (Caboonbah)	Y
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	5282.3	Gauge (Caboonbah)	Y
1897	-	No data	N[2]
1898	7789.2	Gauge (Caboonbah)	Y
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	-	No data	N[2]
1902	-	No data	N[2]
1903	-	No data	N[2]
1904	-	No data	N[2]
1905	-	No data	N[2]
1906	-	No data	N[2]
1907	-	No data	N[2]
1908	5021.1	Gauge (Caboonbah)	Y
1909	-	No data	N[2]
1910	-	No data	N[2]
1911	-	No data	N[2]

Year	Value	Source	Used
1912	-	No data	N[2]
1913	-	No data	N[2]
1914	-	No data	N[2]
1915	-	No data	N[2]
1916	-	No data	N[2]
1917	-	No data	N[2]
1918	-	No data	N[2]
1919	-	No data	N[2]
1920	-	No data	N[2]
1921	1176.3	Gauge (Caboonbah)	N[1]
1922	1279.1	Gauge (Caboonbah)	N[1]
1923	-	No data	N[1]
1924	-	No data	N[1]
1925	814.88	Gauge (Caboonbah)	N[1]
1926	-	No data	N[1]
1927	2454.3	Gauge (Caboonbah)	Y
1928	4852.8	Gauge (Caboonbah)	Y
1929	2486.7	Gauge (Caboonbah)	Y
1930	-	No data	N[1]
1931	6311.1	Gauge (Caboonbah)	Y
1932	-	No data	N[1]
1933	-	No data	N[1]
1934	-	No data	N[1]
1935	-	No data	N[1]
1936	-	No data	N[1]

Year	Value	Source	Used
1937	-	No data	N[1]
1938	-	No data	N[1]
1939	-	No data	N[1]
1940	-	No data	N[1]
1941	-	No data	N[1]
1942	-	No data	N[1]
1943	-	No data	N[1]
1944	-	No data	N[1]
1945	-	No data	N[1]
1946	-	No data	N[1]
1947	102.74	URBS model	N[1]
1948	-	No data	N[1]
1949	-	No data	N[1]
1950	-	No data	N[1]
1951	-	No data	N[1]
1952	-	No data	N[1]
1953	-	No data	N[1]
1954	-	No data	N[1]
1955	7914.4	URBS model	Y
1956	2548.4	Gauge (Caboonbah)	Y
1957	-	No data	N[1]
1958	1954	Gauge (Caboonbah)	Y
1959	867.41	URBS model	N[1]
1960	2298.7	URBS model	Y
1961	-	No data	N[1]

ANNUAL DATA

Year	Value	Source	Used
1962	-	No data	N[1]
1963	1550.3	Gauge (Middle Ck)	N[1]
1964	332.89	Gauge (Middle Ck)	N[1]
1965	39.65	Gauge (Middle Ck)	N[1]
1966	2230.5	URBS model	Y
1967	3987.5	URBS model	Y
1968	2350.5	Gauge (Middle Ck)	Y
1969	27.83	Gauge (Middle Ck)	N[1]
1970	56.11	Gauge (Middle Ck)	N[1]
1971	3938.9	URBS model	Y
1972	4794.9	URBS model	Y
1973	945.78	Gauge (Middle Ck)	N[1]
1974	8020.1	Gauge (Caboonbah)	Y
1975	249.56	Gauge (Middle Ck)	N[1]
1976	1818.2	Gauge (factored)	Y
1977	636.86	Gauge (Middle Ck)	N[1]
1978	298.3	Gauge (Middle Ck)	N[1]
1979	248.13	Gauge (Middle Ck)	N[1]
1980	32.56	Gauge (Middle Ck)	N[1]
1981	867	Gauge (Middle Ck)	N[1]

Year	Value	Source	Used
1982	476.34	Gauge (Middle Ck)	N[1]
1983	5856.6	Reverse routed	Y
1984	-	No data	N[1]
1985	-	No data	N[1]
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	2213.8	URBS model	Y
1989	5409.3	Reverse routed	Y
1990	-	No data	N[1]
1991	94.64	URBS model	N[1]
1992	3926.9	URBS model	Y
1993	-	No data	N[1]
1994	-	No data	N[1]
1995	-	No data	N[1]
1996	2811.9	Reverse routed	Y
1997	-	No data	N[1]
1998	-	No data	N[1]
1999	9685.5	Reverse routed	Y
2000	-	No data	N[1]
2001	845.61	Reverse routed	N[1]

Year	Value	Source	Used
2002	-	No data	N[1]
2003	-	No data	N[1]
2004	819.75	URBS model	N[1]
2005	-	No data	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	-	No data	N[1]
2009	1954	Reverse routed	Y
2010	944.86	Reverse routed	N[1]
2011	9792.4	Reverse routed	Y
2012	995.73	Reverse routed	N[1]
2013	5935.2	Reverse routed	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	1815	0	69	1921 – 2013	Low outlier threshold determined by visual inspection of data
2	4100	0	29	1887 – 1920	Low outlier threshold applied to pre-1921 data determined by visual inspection

Gauge Location:	**Lockyer Creek at Helidon**
Catchment Area:	351 km³
Notes:	Gauge record extends back to 1926, however record is a composite of three sites, none of which are particularly reliable. 2011 event has been included as historical event only due to uncertainty in recorded level and rating, and strong influence on fit. No.1 (1926-1971) has only minor flow gauging and exhibits a number of minor drifts in datum. Rating has been extended using data from No.3, which it is closest to. No.2 (1966-1988) has the highest flow gauging but displays a significant datum shift in 1976.No. 3 (1987-2013) has moderate flow gauging but contains the millennium drought and an extreme event in 2011, making it statistically unreliable.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution due to poor reliability of gauge flow ratings**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	74	55	97	67	50	90	69	51	91	66	49	88
5	215	168	278	227	173	302	230	181	297	232	180	304
10	366	275	515	393	299	535	384	302	512	398	308	533
20	577	403	929	591	437	861	558	431	769	585	448	806
50	1,000	610	1,960	896	626	1,490	802	604	1,150	853	636	1,230
100	1,480	801	3,450	1,150	761	2,180	992	730	1,470	1,060	773	1,580
200	2,170	1,040	6,050	1,430	879	3,090	1,180	852	1,810	1,270	903	1,950
500	3,560	1,410	12,700	1,810	1,010	4,710	1,420	1,000	2,260	1,540	1,060	2,460
1000	5,150	1,760	22,000	2,110	1,090	6,320	1,600	1,100	2,610	1,730	1,170	2,840
2000	7,430	2,180	38,200	2,420	1,160	8,400	1,770	1,190	2,970	1,910	1,270	3,230

Posterior	Location u	44.002	Mean (loge flow)	4.039	Mean (loge flow)	4.017	Mean (loge flow)	3.956
Expected	loge (Scale a)	4.321	loge [Std dev (loge flow)]	0.480	loge [Std dev (loge flow)]	0.505	loge [Std dev (loge flow)]	0.556
Parameters	Shape k	-0.520	Skew (loge flow)	-0.624	Skew (loge flow)	-0.791	Skew (loge flow)	-0.809

ANNUAL DATA

Year	Value	Source	Used
1927	88.4	Gauge (Helidon No.1)	Y
1928	121.7	Gauge (Helidon No.1)	Y
1929	64.34	Gauge (Helidon No.1)	Y
1930	34.0	Gauge (Helidon No.1)	Y
1931	204.29	Gauge (Helidon No.1)	Y
1932	121.7	Gauge (Helidon No.1)	Y
1933	29.77	Gauge (Helidon No.1)	Y
1934	96.3	Gauge (Helidon No.1)	Y
1935	7.8	Gauge (Helidon No.1)	N[1]
1936	9.68	Gauge (Helidon No.1)	N[1]
1937	72.2	Gauge (Helidon No.1)	Y
1938	194.7	Gauge (Helidon No.1)	Y
1939	25	Gauge (Helidon No.1)	Y
1940	9.68	Gauge (Helidon No.1)	N[1]
1941	72.2	Gauge (Helidon No.1)	Y
1942	106.34	Gauge (Helidon No.1)	Y
1943	209.1	Gauge (Helidon No.1)	Y
1944	80.58	Gauge (Helidon No.1)	Y
1945	11.98	Gauge (Helidon No.1)	N[1]
1946	88.44	Gauge (Helidon No.1)	Y
1947	44.44	Gauge (Helidon No.1)	Y
1948	18.4	Gauge (Helidon No.1)	Y
1949	56.48	Gauge (Helidon No.1)	Y
1950	96.3	Gauge (Helidon No.1)	Y
1951	164.92	Gauge (Helidon No.1)	Y
1952	2.9	Gauge (Helidon No.1)	N[1]
1953	57.01	Gauge (Helidon No.1)	Y
1954	151.47	Gauge (Helidon No.1)	Y
1955	151.47	Gauge (Helidon No.1)	Y
1956	100.49	Gauge (Helidon No.1)	Y
1957	39.2	Gauge (Helidon No.1)	Y
1958	19.41	Gauge (Helidon No.1)	Y
1959	180.28	Gauge (Helidon No.1)	Y
1960	44.96	Gauge (Helidon No.1)	Y
1961	4.28	Gauge (Helidon No.1)	N[1]
1962	137.07	Gauge (Helidon No.1)	Y
1963	48.63	Gauge (Helidon No.1)	Y
1964	80.58	Gauge (Helidon No.1)	Y
1965	12.28	Gauge (Helidon No.1)	N[1]
1966	151.47	Gauge (Helidon No.1)	Y
1967	263.94	Gauge (Helidon No.1)	Y
1968	80.58	Gauge (Helidon No.1)	Y
1969	32.91	Gauge (Helidon No.1)	Y
1970	33.96	Gauge (Helidon No.1)	Y
1971	87.39	Gauge (Helidon No.2)	Y
1972	72.63	Gauge (Helidon No.2)	Y
1973	181.63	Gauge (Helidon No.2)	Y
1974	874.69	Gauge (Helidon No.2)	Y
1975	141.71	Gauge (Helidon No.2)	Y
1976	350.59	Gauge (Helidon No.2)	Y
1977	73.5	Gauge (Helidon No.2)	Y
1978	10.06	Gauge (Helidon No.2)	N[1]
1979	170.93	Gauge (Helidon No.2)	Y
1980	50.41	Gauge (Helidon No.2)	Y
1981	417.14	Gauge (Helidon No.2)	Y
1982	264.99	Gauge (Helidon No.2)	Y
1983	521.01	Gauge (Helidon No.2)	Y
1984	43.71	Gauge (Helidon No.2)	Y
1985	88.3	Gauge (Helidon No.2)	Y
1986	4.53	Gauge (Helidon No.2)	N[1]
1987	11.19	Gauge (Helidon No.2)	N[1]
1988	660.77	Gauge (Helidon No.3)	Y
1989	446.44	Gauge (Helidon No.3)	Y
1990	334.37	Gauge (Helidon No.3)	Y
1991	55.96	Gauge (Helidon No.3)	Y
1992	27.02	Gauge (Helidon No.3)	Y
1993	1.31	Gauge (Helidon No.3)	N[1]
1994	19.75	Gauge (Helidon No.3)	Y
1995	2.47	Gauge (Helidon No.3)	N[1]
1996	600.86	Gauge (Helidon No.3)	Y
1997	0.5	Gauge (Helidon No.3)	N[1]
1998	4.32	Gauge (Helidon No.3)	N[1]
1999	442.26	Gauge (Helidon No.3)	Y
2000	3.63	Gauge (Helidon No.3)	N[1]
2001	146.96	Gauge (Helidon No.3)	Y

ANNUAL DATA

Year	Value	Source	Used
2002	5.51	Gauge (Helidon No.3)	N[1]
2003	136.11	Gauge (Helidon No.3)	Y
2004	368.07	Gauge (Helidon No.3)	Y
2005	10.37	Gauge (Helidon No.3)	N[1]
2006	2.11	Gauge (Helidon No.3)	N[1]
2007	0.82	Gauge (Helidon No.3)	N[1]
2008	1.32	Gauge (Helidon No.3)	N[1]
2009	206.31	Gauge (Helidon No.3)	Y
2010	50.57	Gauge (Helidon No.3)	Y
2011	3071.1	Gauge (Helidon No.3)	N[2]
2012	48.94	Gauge (Helidon No.3)	Y
2013	395.55	Gauge (Helidon No.3)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	18.36	0	20	1927 – 2013	Low outlier threshold determined using multiple Grubbs Beck
2	950	1	0	2011	Historical flood of record. Gauge data unreliable during this event.

Gauge Location:	**Lockyer Creek at Gatton**
Catchment Area:	1527 km³
Notes:	Gauge records available from 1893. Peak heights only. Flood warning gauge with no official flow rating. Rating based on hydraulic modelling conducted for Lockyer Flood Study (SKM 2012). Current rating of unknown reliability due to unknown consistency between modelling and BRCFS.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution due to unknown reliability gauge flow rating**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	93	45	141	95	64	138	96	64	138	93	65	131
5	401	305	543	397	299	570	428	332	563	430	331	564
10	762	574	1,070	786	573	1,110	814	636	1,080	826	639	1,090
20	1,310	932	2,120	1,340	954	1,870	1,290	993	1,780	1,320	1,010	1,790
50	2,490	1,530	5,360	2,360	1,570	3,760	2,030	1,510	2,930	2,090	1,570	2,940
100	3,950	2,080	10,800	3,380	2,030	6,250	2,650	1,920	3,970	2,730	2,000	3,960
200	6,190	2,740	22,000	4,640	2,480	10,800	3,290	2,330	5,120	3,390	2,430	5,100
500	11,100	3,800	55,700	6,680	2,930	21,100	4,150	2,850	6,760	4,290	2,960	6,740
1000	17,200	4,820	113,000	8,550	3,190	35,500	4,790	3,220	8,090	4,950	3,340	8,050
2000	26,500	6,020	230,000	10,700	3,400	54,700	5,420	3,570	9,450	5,610	3,690	9,430

Posterior	Location u	31.413	Mean (loge flow)	4.438	Mean (loge flow)	4.287	Mean (loge flow)	4.249
Expected	loge (Scale a)	5.007	loge [Std dev (loge flow)]	0.592	loge [Std dev (loge flow)]	0.728	loge [Std dev (loge flow)]	0.751
Parameters	Shape k	-0.619	Skew (loge flow)	-0.384	Skew (loge flow)	-0.796	Skew (loge flow)	-0.806

ANNUAL DATA

Year	Value	Source	Used
1887	1315.2	URBS model	Y
1888	-	No data	N[1]
1889	-	No data	N[1]
1890	2222.1	URBS model	Y
1891	-	No data	N[1]
1892	-	No data	N[1]
1893	2791.7	Gauge (peak)	Y
1894	-	No data	N[1]
1895	-	No data	N[1]
1896	137.09	Gauge (peak)	Y
1897	-	No data	N[1]
1898	286.41	Gauge (peak)	Y
1899	92.34	Gauge (peak)	N[1]
1900	-	No data	N[1]
1901	152.69	Gauge (peak)	Y
1902	-	No data	N[1]
1903	167.51	Gauge (peak)	Y
1904	-	No data	N[1]
1905	-	No data	N[1]
1906	-	No data	N[1]
1907	-	No data	N[1]
1908	1329.3	URBS model	Y
1909	-	No data	N[1]
1910	-	No data	N[1]
1911	513.17	Gauge (peak)	Y
1912	-	No data	N[1]
1913	-	No data	N[1]
1914	-	No data	N[1]
1915	-	No data	N[1]
1916	-	No data	N[1]
1917	-	No data	N[1]
1918	286.41	Gauge (peak)	Y
1919	-	No data	N[1]
1920	-	No data	N[1]
1921	137.09	Gauge (peak)	Y
1922	120.97	Gauge (peak)	Y
1923	-	No data	N[1]
1924	-	No data	N[1]
1925	-	No data	N[1]
1926	-	No data	N[1]
1927	428.21	Gauge (peak)	Y
1928	366.22	Gauge (peak)	Y
1929	137.09	Gauge (peak)	Y
1930	161.19	Gauge (peak)	Y
1931	513.17	Gauge (peak)	Y
1932	402.7	Gauge (peak)	Y
1933	170.38	Gauge (peak)	Y
1934	152.69	Gauge (peak)	Y
1935	-	No data	N[1]
1936	-	No data	N[1]
1937	577.47	Gauge (peak)	Y
1938	206.41	Gauge (peak)	Y
1939	-	No data	N[1]
1940	-	No data	N[1]
1941	144.89	Gauge (peak)	Y
1942	641.04	Gauge (peak)	Y
1943	366.22	Gauge (peak)	Y
1944	196.41	Gauge (peak)	Y
1945	-	No data	N[1]
1946	384.46	Gauge (peak)	Y
1947	135.53	Gauge (peak)	Y
1948	106.69	Gauge (peak)	N[1]
1949	170.38	Gauge (peak)	Y
1950	513.17	Gauge (peak)	Y
1951	783.25	Gauge (peak)	Y
1952	-	No data	N[1]
1953	-	No data	N[1]
1954	-	No data	N[1]
1955	641.04	Gauge (peak)	Y
1956	309.28	Gauge (peak)	Y
1957	178.99	Gauge (peak)	Y
1958	-	No data	N[1]
1959	1495.7	Gauge (peak)	Y
1960	133.56	URBS model	Y
1961	-	No data	N[1]

ANNUAL DATA

Year	Value	Source	Used
1962	-	No data	N[1]
1963	144.89	Gauge (peak)	Y
1964	-	No data	N[1]
1965	-	No data	N[1]
1966	286.41	Gauge (peak)	Y
1967	403.92	Gauge (peak)	Y
1968	677.49	Gauge (peak)	Y
1969	-	No data	N[1]
1970	-	No data	N[1]
1971	366.22	Gauge (peak)	Y
1972	40.88	URBS model	N[1]
1973	-	No data	N[1]
1974	2103.8	Gauge (peak)	Y
1975	-	No data	N[1]
1976	591.14	URBS model	Y
1977	-	No data	N[1]
1978	-	No data	N[1]
1979	-	No data	N[1]
1980	-	No data	N[1]
1981	-	No data	N[1]
1982	-	No data	N[1]
1983	1110.7	Gauge (peak)	Y
1984	-	No data	N[1]
1985	-	No data	N[1]
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	635.35	URBS model	Y
1989	431.31	URBS model	Y
1990	-	No data	N[1]
1991	206.63	URBS model	Y
1992	592.6	URBS model	Y
1993	-	No data	N[1]
1994	-	No data	N[1]
1995	-	No data	N[1]
1996	1060.1	Gauge (peak)	Y
1997	-	No data	N[1]
1998	-	No data	N[1]
1999	399.06	Gauge (peak)	Y
2000	-	No data	N[1]
2001	598.66	Gauge (peak)	Y
2002	-	No data	N[1]
2003	-	No data	N[1]
2004	130.33	Gauge (peak)	Y
2005	-	No data	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	-	No data	N[1]
2009	307.76	Gauge (peak)	Y
2010	59.77	URBS model	N[1]
2011	2865.5	Gauge (peak)	Y
2012	45.93	URBS model	N[1]
2013	1798.2	URBS model	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	120	0	62	1921 – 2013	Low outlier threshold determined by visual inspection of data
2	1060	0	10	1887 – 1920	Estimated number of larger flood events not identified by gauge record based on comparison with Helidon and Glenore Grove gauge records and URBS modelling

Gauge Location:	**Lockyer Creek at Glenore Grove**
Catchment Area:	2149 km³
Notes:	Relatively consistent gauge data since 1955. Pre-1955 URBS modelling available but low reliability of peak and do not appear to be consistent or represent significant Lockyer Creek floods. Influence dependent on arbitrary selection of threshold hence inclusion in statistical analysis not justifiable. Rating based on independent hydraulic modelling but becomes very sensitive for high flows.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Preferred FFA site for Lockyer Creek catchment**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	111	30	209	102	56	182	107	56	185	124	77	197
5	618	395	977	627	405	1,050	613	399	982	621	422	936
10	1,270	801	2,300	1,370	880	2,240	1,290	852	2,190	1,240	844	1,900
20	2,340	1,340	5,510	2,420	1,500	4,080	2,210	1,410	4,000	2,050	1,380	3,200
50	4,860	2,250	17,700	4,240	2,440	9,290	3,720	2,260	7,340	3,340	2,200	5,460
100	8,240	3,110	43,800	5,890	3,140	15,900	5,040	2,960	10,600	4,450	2,870	7,560
200	13,800	4,160	108,000	7,740	3,760	26,500	6,470	3,650	14,400	5,630	3,540	9,930
500	27,100	5,930	354,000	10,400	4,370	46,700	8,440	4,550	20,100	7,250	4,420	13,500
1000	44,900	7,670	865,000	12,500	4,650	67,200	9,960	5,180	24,900	8,490	5,050	16,300
2000	74,300	9,790	2,140,000	14,600	4,850	96,200	11,500	5,800	29,900	9,720	5,630	19,300

Posterior	Location u	17.483	Mean (loge flow)	4.316	Mean (loge flow)	4.351	Mean (loge flow)	4.528
Expected	loge (Scale a)	5.403	loge [Std dev (loge flow)]	0.909	loge [Std dev (loge flow)]	0.882	loge [Std dev (loge flow)]	0.799
Parameters	Shape k	-0.723	Skew (loge flow)	-0.763	Skew (loge flow)	-0.806	Skew (loge flow)	-0.787

ANNUAL DATA

Year	Value	Source	Used
1955	743.68	Gauge (peak)	Y
1956	524.62	Gauge (peak)	Y
1957	207.51	Gauge (peak)	Y
1958	-	No data	N[1]
1959	3707	Gauge (peak)	Y
1960	237.12	Gauge (peak)	Y
1961	-	No data	N[1]
1962	-	No data	N[1]
1963	78.06	Gauge (peak)	Y
1964	134.12	Gauge (peak)	Y
1965	-	No data	N[1]
1966	572.31	Gauge (peak)	Y
1967	572.31	Gauge (peak)	Y
1968	764.7	Gauge (peak)	Y
1969	163.73	Gauge (peak)	Y
1970	-	No data	N[1]
1971	572.31	Gauge (peak)	Y
1972	32.03	URBS model	N[1]
1973	78.06	Gauge (peak)	Y
1974	2739.1	Gauge (peak)	Y

Year	Value	Source	Used
1975	-	No data	N[1]
1976	898.35	Gauge (peak)	Y
1977	168.24	Gauge (peak)	Y
1978	-	No data	N[1]
1979	-	No data	N[1]
1980	-	No data	N[1]
1981	589.23	Gauge (peak)	Y
1982	455.88	Gauge (peak)	Y
1983	1141.9	Gauge (peak)	Y
1984	-	No data	N[1]
1985	118.67	Gauge (peak)	Y
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	781.51	Gauge (peak)	Y
1989	407.56	Gauge (peak)	Y
1990	198.5	Gauge (peak)	Y
1991	220.39	Gauge (peak)	Y
1992	201.72	Gauge (peak)	Y
1993	-	No data	N[1]
1994	-	No data	N[1]

Year	Value	Source	Used
1995	-	No data	N[1]
1996	1530.6	Gauge (peak)	Y
1997	32.35	Gauge (peak)	N[1]
1998	-	No data	N[1]
1999	422.27	Gauge (peak)	Y
2000	-	No data	N[1]
2001	555.81	URBS model	Y
2002	-	No data	N[1]
2003	-	No data	N[1]
2004	96.12	Gauge (peak)	Y
2005	-	No data	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	-	No data	N[1]
2009	331.93	Gauge (peak)	Y
2010	98.74	Gauge (peak)	Y
2011	4128.2	Gauge (peak)	Y
2012	46.7	URBS model	N[1]
2013	2864.5	URBS model	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	78.06	0	26	1955 – 2013	Low outlier threshold determined using multiple Grubbs Beck

Gauge Location:	**Lockyer Creek at Rifle Range Road/Lyons Bridge**
Catchment Area:	2521 km³
Notes:	Combined record of Lyons Bridge and Rifle Range Road. Gauge data available from 1955. Gauges cannot record floodplain flows and starts to become unreliable above 600 m³/s. High flows censored from record. Projection of FFA curve very sensitive due to omission of high tail.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve not to be used for flood estimation above 1 in 5 AEP due to unreliable gauge high flow rating**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	126	37	240	128	77	217	126	74	198	127	80	195
5	547	401	850	558	400	808	535	370	889	546	367	847
10	894	625	2,030	903	635	1,500	992	647	1,900	1,020	669	1,660
20	1,290	744	4,810	1,190	696	2,530	1,550	941	3,370	1,590	1,010	2,730
50	1,900	825	14,800	1,470	722	4,150	2,380	1,330	5,910	2,460	1,480	4,530
100	2,460	859	34,000	1,620	725	5,570	3,060	1,620	8,270	3,170	1,830	6,130
200	3,120	882	79,600	1,720	726	7,680	3,760	1,890	10,900	3,900	2,180	7,890
500	4,160	897	244,000	1,810	726	11,100	4,690	2,240	14,800	4,870	2,610	10,400
1000	5,110	902	573,000	1,860	726	14,200	5,380	2,460	17,800	5,580	2,890	12,500
2000	6,220	907	1,320,000	1,880	726	17,800	6,040	2,670	21,200	6,280	3,170	14,600

Posterior	Location u	12.230	Mean (loge flow)	4.231	Mean (loge flow)	4.570	Mean (loge flow)	4.571
Expected	loge (Scale a)	5.699	loge [Std dev (loge flow)]	0.932	loge [Std dev (loge flow)]	0.694	loge [Std dev (loge flow)]	0.705
Parameters	Shape k	-0.232	Skew (loge flow)	-1.521	Skew (loge flow)	-0.807	Skew (loge flow)	-0.811

ANNUAL DATA

Year	Value	Source	Used
1955	9615.3	Gauge (peak)	N[2]
1956	406.61	Gauge (peak)	Y
1957	-	No data	N[1]
1958	-	No data	N[1]
1959	1170.7	Gauge (peak)	N[2]
1960	264.6	URBS model	Y
1961	-	No data	N[1]
1962	-	No data	N[1]
1963	-	No data	N[1]
1964	58.13	Gauge (peak)	N[1]
1965	-	No data	N[1]
1966	577.83	Gauge (peak)	Y
1967	610.8	Gauge (peak)	Y
1968	1083.3	Gauge (peak)	N[2]
1969	167.64	Gauge (peak)	Y
1970	138.35	Gauge (peak)	Y
1971	379.17	Gauge (peak)	Y
1972	25.75	URBS model	N[1]
1973	168.88	Gauge (peak)	Y
1974	9099.4	Gauge (peak)	N[2]
1975	-	No data	N[1]
1976	1083.3	Gauge (peak)	N[2]
1977	272.27	Gauge (peak)	Y
1978	112.92	Gauge (peak)	Y
1979	-	No data	N[1]
1980	-	No data	N[1]
1981	533	Gauge (peak)	Y
1982	472.38	Gauge (peak)	Y
1983	3065.5	Gauge (peak)	N[2]
1984	146.18	Gauge (peak)	Y
1985	166.82	Gauge (peak)	Y
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	603.05	Gauge (peak)	Y
1989	399.46	Gauge (continuous)	Y
1990	219.8	Gauge (continuous)	Y
1991	219.03	Gauge (peak)	Y
1992	253.2	Gauge (peak)	Y
1993	7.58	Gauge (continuous)	N[1]
1994	1.53	Gauge (continuous)	N[1]
1995	7.78	Gauge (continuous)	N[1]
1996	1955.9	Gauge (peak)	N[2]
1997	40.32	Gauge (continuous)	N[1]
1998	1.03	Gauge (continuous)	N[1]
1999	360.76	Gauge (peak)	Y
2000	15.8	Gauge (continuous)	N[1]
2001	436.65	Gauge (peak)	Y
2002	1.19	Gauge (continuous)	N[1]
2003	-	No data	N[1]
2004	74.29	Gauge (peak)	N[1]
2005	10.57	Gauge (continuous)	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	48.1	Gauge (continuous)	N[1]
2009	416.36	Gauge (peak)	Y
2010	125.2	Gauge (continuous)	Y
2011	3262.5	Gauge (peak)	N[2]
2012	94.74	Gauge (continuous)	Y
2013	3558.2	Gauge (continuous)	N[2]

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	94.7	0	26	1955 – 2013	Low outlier threshold determined using multiple Grubbs Beck and visual inspection
2	620	9	0	1955 – 2013	High flow limit due to out-of-bank flow

Gauge Location:	**Bremer River at Walloon**
Catchment Area:	634 km³
Notes:	Continuous gauge data since 1962. High flow rating potentially affected by backwater uncertainty in 1974 level (flood mark) so 1974 and 2011 included only as 'historical' floods. Pre-1962 URBS modelling but low reliability of peak and do not appear to be consistent or represent significant Bremer River floods. Influence dependent on arbitrary selection of threshold hence inclusion in statistical analysis not justifiable. Rating based on independent hydraulic modelling but becomes very sensitive for high flows.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Preferred FFA site for Bremer River catchment**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	260	176	360	236	165	337	240	171	327	229	167	317
5	675	512	907	684	503	937	664	514	904	678	511	923
10	1,040	773	1,540	1,080	791	1,550	1,030	783	1,470	1,080	803	1,500
20	1,470	1,030	2,600	1,510	1,070	2,450	1,400	1,040	2,100	1,500	1,100	2,150
50	2,170	1,350	5,090	2,100	1,370	4,320	1,900	1,370	3,040	2,070	1,470	3,080
100	2,850	1,580	8,440	2,550	1,510	6,330	2,270	1,590	3,770	2,490	1,730	3,830
200	3,670	1,800	14,000	2,990	1,600	9,120	2,630	1,790	4,520	2,910	1,980	4,620
500	5,050	2,090	26,900	3,550	1,680	14,500	3,070	2,030	5,510	3,420	2,270	5,630
1000	6,370	2,300	43,800	3,960	1,720	20,500	3,380	2,200	6,260	3,790	2,450	6,410
2000	7,980	2,500	71,600	4,340	1,740	28,500	3,680	2,330	7,000	4,130	2,620	7,160

Posterior	Location u	153.033	Mean (loge flow)	5.277	Mean (loge flow)	5.293	Mean (loge flow)	5.231
Expected	loge (Scale a)	5.624	loge [Std dev (loge flow)]	0.378	loge [Std dev (loge flow)]	0.343	loge [Std dev (loge flow)]	0.409
Parameters	Shape k	-0.293	Skew (loge flow)	-0.766	Skew (loge flow)	-0.805	Skew (loge flow)	-0.815

ANNUAL DATA

Year	Value	Source	Used
1962	217.85	Gauge (continuous)	Y
1963	350.13	Gauge (continuous)	Y
1964	235.55	Gauge (continuous)	Y
1965	35.72	Gauge (continuous)	N[1]
1966	506.07	Gauge (continuous)	Y
1967	487.79	Gauge (continuous)	Y
1968	526.96	Gauge (continuous)	Y
1969	35.01	Gauge (continuous)	N[1]
1970	67.33	Gauge (continuous)	N[1]
1971	705.31	Gauge (continuous)	Y
1972	150.46	Gauge (continuous)	Y
1973	440.14	Gauge (continuous)	Y
1974	2809.8	Gauge (peak)	N[2]
1975	232.6	Gauge (continuous)	Y
1976	919.43	Gauge (continuous)	Y
1977	383.57	Gauge (continuous)	Y
1978	153.32	Gauge (continuous)	Y
1979	50.78	Gauge (continuous)	N[1]
1980	103.78	Gauge (continuous)	Y
1981	516.51	Gauge (continuous)	Y
1982	469.48	Gauge (continuous)	Y
1983	686.35	Gauge (continuous)	Y
1984	239.97	Gauge (continuous)	Y
1985	294.64	Gauge (continuous)	Y
1986	50.78	Gauge (continuous)	N[1]
1987	37.15	Gauge (continuous)	N[1]
1988	1160.4	Gauge (continuous)	Y
1989	465.29	Gauge (continuous)	Y
1990	347.09	Gauge (continuous)	Y
1991	270.94	Gauge (continuous)	Y
1992	982.32	Gauge (continuous)	Y
1993	58.09	Gauge (continuous)	N[1]
1994	40.08	Gauge (continuous)	N[1]
1995	15.9	Gauge (continuous)	N[1]
1996	1059.5	Gauge (continuous)	Y
1997	411.02	Gauge (continuous)	Y
1998	2.79	Gauge (continuous)	N[1]
1999	476.81	Gauge (continuous)	Y
2000	135.94	Gauge (continuous)	Y
2001	385.66	Gauge (continuous)	Y
2002	0.26	Gauge (continuous)	N[1]
2003	0.21	Gauge (continuous)	N[1]
2004	184.49	Gauge (continuous)	Y
2005	64.78	Gauge (continuous)	N[1]
2006	28.16	Gauge (continuous)	N[1]
2007	-	No data	N[1]
2008	281.56	Gauge (continuous)	Y
2009	1062.4	Gauge (continuous)	Y
2010	147.88	Gauge (continuous)	Y
2011	2465.7	Gauge (continuous)	N[2]
2012	204.51	Gauge (continuous)	Y
2013	1380.1	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	103.78	0	15	1962 – 2013	Low outlier threshold determined using multiple Grubbs Beck
2	1400	2	0	1974 & 2011	High flows censored due to uncertainty in level measurements

Gauge Location:	**Warrill Creek at Amberley**
Catchment Area:	902 km³
Notes:	Continuous gauge data since 1962. Pre-1962 URBS modelling but low reliability of peak and do not appear to be consistent or represent significant Warrill Creek floods. Influence dependent on arbitrary selection of threshold hence inclusion in statistical analysis not justifiable. Rating based on independent hydraulic modelling but becomes sensitive for high flows. Catchment appears to have experienced a disproportionate number of large flood events resulting in small skew compared to other catchments.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Other distributions should not be used due to strong influence of upper tail**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	223	163	293	207	155	280	222	160	302	211	153	287
5	551	416	750	564	415	789	622	479	830	630	478	845
10	890	642	1,360	943	664	1,410	971	751	1,330	1,010	765	1,380
20	1,350	905	2,430	1,430	955	2,400	1,340	1,020	1,900	1,420	1,070	1,990
50	2,250	1,310	5,210	2,280	1,390	4,660	1,850	1,380	2,720	1,980	1,470	2,860
100	3,230	1,660	9,220	3,100	1,730	7,530	2,230	1,650	3,380	2,410	1,760	3,580
200	4,600	2,070	16,300	4,090	2,080	12,100	2,600	1,900	4,050	2,830	2,040	4,300
500	7,270	2,710	34,800	5,710	2,520	22,000	3,080	2,210	4,940	3,370	2,380	5,270
1000	10,200	3,260	61,500	7,190	2,830	34,000	3,430	2,420	5,620	3,750	2,610	6,010
2000	14,300	3,910	110,000	8,940	3,120	53,000	3,760	2,620	6,290	4,120	2,830	6,750

Posterior	Location u	149.191	Mean (loge flow)	5.311	Mean (loge flow)	5.228	Mean (loge flow)	5.158
Expected	loge (Scale a)	5.210	loge [Std dev (loge flow)]	0.191	loge [Std dev (loge flow)]	0.341	loge [Std dev (loge flow)]	0.407
Parameters	Shape k	-0.479	Skew (loge flow)	-0.100	Skew (loge flow)	-0.757	Skew (loge flow)	-0.778

ANNUAL DATA

Year	Value	Source	Used
1962	328.9	Gauge (factored)	Y
1963	435.83	Gauge (factored)	Y
1964	268.19	Gauge (factored)	Y
1965	81.12	Gauge (factored)	Y
1966	181.34	Gauge (factored)	Y
1967	362.71	Gauge (factored)	Y
1968	436.74	Gauge (factored)	Y
1969	103.94	Gauge (factored)	Y
1970	44.6	Gauge (factored)	N[1]
1971	857.79	Gauge (factored)	Y
1972	109.84	Gauge (continuous)	Y
1973	455.06	Gauge (factored)	Y
1974	2820.9	Gauge (factored)	Y
1975	343.3	Gauge (factored)	Y
1976	1381.8	Gauge (factored)	Y
1977	277.1	Gauge (factored)	Y
1978	164.13	Gauge (factored)	Y
1979	128.83	Gauge (factored)	Y
1980	206.38	Gauge (factored)	Y
1981	341.48	Gauge (factored)	Y

Year	Value	Source	Used
1982	291.36	Gauge (factored)	Y
1983	411.42	Gauge (factored)	Y
1984	234.63	Gauge (factored)	Y
1985	198.51	Gauge (factored)	Y
1986	26.73	Gauge (factored)	N[1]
1987	25.09	Gauge (factored)	N[1]
1988	786.73	URBS model	Y
1989	345.75	Gauge (factored)	Y
1990	400.64	Gauge (factored)	Y
1991	875.92	URBS model	Y
1992	793.02	Gauge (factored)	Y
1993	80.43	Gauge (factored)	Y
1994	98.26	Gauge (factored)	Y
1995	24.51	Gauge (factored)	N[1]
1996	427.9	Gauge (factored)	Y
1997	32.36	Gauge (factored)	N[1]
1998	41.29	Gauge (factored)	N[1]
1999	210.14	Gauge (factored)	Y
2000	108.49	Gauge (factored)	Y
2001	225.28	URBS model	Y

Year	Value	Source	Used
2002	6.86	Gauge (factored)	N[1]
2003	11.43	Gauge (factored)	N[1]
2004	169.65	Gauge (continuous)	Y
2005	32.69	Gauge (factored)	N[1]
2006	33.94	Gauge (factored)	N[1]
2007	4.8	Gauge (factored)	N[1]
2008	341.84	Gauge (factored)	Y
2009	357.48	Gauge (continuous)	Y
2010	146.78	Gauge (continuous)	Y
2011	961.96	Gauge (factored)	Y
2012	327.74	Gauge (factored)	Y
2013	1955.3	URBS model	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	80.43	0	11	1962 – 2013	Low outlier threshold determined using multiple Grubbs Beck

Gauge Location:	**Purga Creek at Loamside**
Catchment Area:	209 km³
Notes:	Continuous gauge data since 1974. Pre-1974 URBS modelling available but low reliability of peak and do not appear to be consistent or represent significant Warrill Creek floods. Influence dependent on arbitrary selection of threshold hence inclusion in statistical analysis not justifiable, however flood of record (1893) has been included in the analysis. Rating based on independent hydraulic modelling but becomes very sensitive for high flows.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Preferred FFA site for Purga Creek catchment**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	66	32	104	57	38	95	63	40	94	66	47	92
5	195	141	271	189	134	273	191	143	257	194	148	255
10	300	224	406	313	233	428	307	238	408	308	238	402
20	419	316	580	451	336	592	432	335	581	430	335	566
50	603	443	945	642	473	946	602	462	836	595	459	794
100	767	542	1,370	788	570	1,270	731	554	1,040	719	554	981
200	959	633	2,000	931	659	1,730	856	639	1,250	840	636	1,160
500	1,260	747	3,290	1,110	757	2,810	1,010	742	1,540	993	737	1,390
1000	1,530	830	4,820	1,240	815	3,990	1,130	812	1,760	1,100	815	1,570
2000	1,850	910	7,020	1,370	858	5,580	1,230	875	1,970	1,200	879	1,740

Posterior	Location u	30.132	Mean (loge flow)	3.827	Mean (loge flow)	3.940	Mean (loge flow)	3.995
Expected	loge (Scale a)	4.530	loge [Std dev (loge flow)]	0.502	loge [Std dev (loge flow)]	0.429	loge [Std dev (loge flow)]	0.397
Parameters	Shape k	-0.219	Skew (loge flow)	-0.816	Skew (loge flow)	-0.805	Skew (loge flow)	-0.796

ANNUAL DATA

Year	Value	Source	Used
1887	812.5	URBS model	Y
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	260.8	URBS model	N[2]
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	289.4	URBS model	N[2]
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	-	No data	N[2]
1897	-	No data	N[2]
1898	93.58	URBS model	N[2]
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	-	No data	N[2]
1902	-	No data	N[2]
1903	-	No data	N[2]
1904	-	No data	N[2]
1905	-	No data	N[2]
1906	-	No data	N[2]
1907	-	No data	N[2]
1908	217.79	URBS model	N[2]
1909	-	No data	N[2]
1910	-	No data	N[2]
1911	-	No data	N[2]

Year	Value	Source	Used
1912	-	No data	N[2]
1913	-	No data	N[2]
1914	-	No data	N[2]
1915	-	No data	N[2]
1916	-	No data	N[2]
1917	-	No data	N[2]
1918	-	No data	N[2]
1919	-	No data	N[2]
1920	-	No data	N[2]
1921	-	No data	N[2]
1922	-	No data	N[2]
1923	-	No data	N[2]
1924	-	No data	N[2]
1925	-	No data	N[2]
1926	-	No data	N[2]
1927	-	No data	N[2]
1928	-	No data	N[2]
1929	-	No data	N[2]
1930	-	No data	N[2]
1931	180.22	URBS model	N[2]
1932	-	No data	N[2]
1933	-	No data	N[2]
1934	-	No data	N[2]
1935	-	No data	N[2]
1936	-	No data	N[2]

Year	Value	Source	Used
1937	-	No data	N[2]
1938	-	No data	N[2]
1939	-	No data	N[2]
1940	-	No data	N[2]
1941	-	No data	N[2]
1942	-	No data	N[2]
1943	-	No data	N[2]
1944	-	No data	N[2]
1945	-	No data	N[2]
1946	-	No data	N[2]
1947	159.91	URBS model	N[2]
1948	-	No data	N[2]
1949	-	No data	N[2]
1950	-	No data	N[2]
1951	-	No data	N[2]
1952	-	No data	N[2]
1953	-	No data	N[2]
1954	-	No data	N[2]
1955	67.23	URBS model	N[2]
1956	49.17	URBS model	N[2]
1957	-	No data	N[2]
1958	-	No data	N[2]
1959	88.35	URBS model	N[2]
1960	96.15	URBS model	N[2]
1961	-	No data	N[2]

ANNUAL DATA

Year	Value	Source	Used
1962	-	No data	N[2]
1963	-	No data	N[2]
1964	-	No data	N[2]
1965	-	No data	N[2]
1966	203	URBS model	N[2]
1967	103.65	URBS model	N[2]
1968	86.33	URBS model	N[2]
1969	-	No data	N[2]
1970	-	No data	N[2]
1971	89.18	URBS model	N[2]
1972	88.95	URBS model	N[2]
1973	-	No data	N[2]
1974	756.47	Gauge (continuous)	Y
1975	92.64	Gauge (continuous)	Y
1976	280.3	Gauge (continuous)	Y
1977	112.68	Gauge (continuous)	Y
1978	94.82	Gauge (continuous)	Y
1979	31.95	Gauge (continuous)	N[1]
1980	185.95	Gauge (continuous)	Y
1981	97.01	Gauge (continuous)	Y

Year	Value	Source	Used
1982	61.61	Gauge (continuous)	Y
1983	201.07	Gauge (continuous)	Y
1984	52.12	Gauge (continuous)	Y
1985	20.95	Gauge (continuous)	N[1]
1986	0.91	Gauge (continuous)	N[1]
1987	1.27	Gauge (continuous)	N[1]
1988	214.3	Gauge (continuous)	Y
1989	149.6	Gauge (continuous)	Y
1990	230.96	Gauge (continuous)	Y
1991	43.9	Gauge (continuous)	Y
1992	242.0	Gauge (continuous)	Y
1993	8.82	Gauge (continuous)	N[1]
1994	1.11	Gauge (continuous)	N[1]
1995	2.8	Gauge (continuous)	N[1]
1996	271.0	Gauge (continuous)	Y
1997	2.04	Gauge (continuous)	N[1]
1998	2.03	Gauge (continuous)	N[1]
1999	72.42	Gauge (continuous)	Y
2000	4.71	Gauge (continuous)	N[1]
2001	2.6	Gauge (continuous)	N[1]

Year	Value	Source	Used
2002	0.82	Gauge (continuous)	N[1]
2003	7.2	Gauge (continuous)	N[1]
2004	105.0	Gauge (continuous)	Y
2005	50.16	Gauge (continuous)	Y
2006	2.58	Gauge (continuous)	N[1]
2007	0.84	Gauge (continuous)	N[1]
2008	75.34	Gauge (continuous)	Y
2009	319.0	Gauge (continuous)	Y
2010	19.8	Gauge (continuous)	N[1]
2011	213.17	Gauge (continuous)	Y
2012	84.1	Gauge (continuous)	Y
2013	316.9	Gauge (continuous)	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	43.9	0	16	1974 – 2013	Low outlier threshold determined using multiple Grubbs Beck
2	810	0	86	1887 – 1974	Threshold applied for inclusion of flood of record (1887)

Gauge Location:	**Mid Brisbane River at Savages Crossing**
Catchment Area:	10146 km³
Notes:	Combined record of Lowood, Verner and Savages Crossing providing consistent gauge record since 1908. Minor flows <500m³/s excluded due to rating uncertainty. Pre-1908 record contains major floods but no minor events so higher historical threshold applied. Rating based on DMT TUFLOW modelling. Calibration of model may not be consistent with BRCFS. Level-flow relationship subject to dynamic effects.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution until rating confirmed or updated**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m^3/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	674	369	1,020	631	432	917	658	449	923	704	515	943
5	2,910	2,220	3,790	2,910	2,200	3,940	2,850	2,200	3,700	2,870	2,260	3,680
10	5,200	4,010	6,970	5,510	4,190	7,340	5,300	4,150	7,010	5,230	4,150	6,760
20	8,310	6,170	12,500	8,660	6,600	11,800	8,280	6,390	11,400	8,050	6,350	10,700
50	14,300	9,480	26,700	13,400	9,930	19,800	12,800	9,580	18,400	12,300	9,440	16,900
100	20,800	12,300	47,300	17,100	12,300	27,900	16,400	12,000	24,500	15,700	11,800	22,200
200	29,800	15,500	83,800	21,000	14,400	38,300	20,100	14,300	31,300	19,200	14,100	28,100
500	47,400	20,500	179,000	25,900	16,600	56,500	25,100	17,300	40,900	23,800	17,100	36,400
1000	66,600	24,900	314,000	29,500	17,900	73,600	28,700	19,200	48,600	27,300	19,000	42,800
2000	93,400	29,800	556,000	32,900	18,900	94,900	32,200	21,100	56,300	30,600	20,900	49,700

Posterior	Location u	172.041	Mean (loge flow)	6.141	Mean (loge flow)	4.791	Mean (loge flow)	4.785
Expected	loge (Scale a)	7.135	loge [Std dev (loge flow)]	0.763	loge [Std dev (loge flow)]	0.051	loge [Std dev (loge flow)]	0.061
Parameters	Shape k	-0.472	Skew (loge flow)	-0.869	Skew (loge flow)	-0.737	Skew (loge flow)	-0.744

ANNUAL DATA

Year	Value	Source	Used
1887	5732.9	URBS model	Y
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	9821	Gauge (peak)	Y
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	18453	Gauge (peak)	Y
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	4771.1	Gauge (peak)	Y
1897	-	No data	N[2]
1898	8697.5	Gauge (peak)	Y
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	-	No data	N[2]
1902	-	No data	N[2]
1903	-	No data	N[2]
1904	-	No data	N[2]
1905	-	No data	N[2]
1906	-	No data	N[2]
1907	-	No data	N[2]
1908	5046.2	Gauge (peak)	Y
1909	-	No data	N[2]
1910	688.79	Gauge (continuous)	Y
1911	1417.6	Gauge (peak)	Y

Year	Value	Source	Used
1912	334.2	Gauge (continuous)	N[1]
1913	300.68	Gauge (continuous)	N[1]
1914	44.58	Gauge (continuous)	N[1]
1915	922.51	Gauge (peak)	Y
1916	102.11	Gauge (continuous)	N[1]
1917	344.97	Gauge (continuous)	N[1]
1918	388.89	Gauge (continuous)	N[1]
1919	44.98	Gauge (continuous)	N[1]
1920	289.22	Gauge (continuous)	N[1]
1921	1244.8	Gauge (peak)	Y
1922	1217.5	Gauge (peak)	Y
1923	12.16	Gauge (continuous)	N[1]
1924	112.62	Gauge (continuous)	N[1]
1925	644.57	Gauge (continuous)	Y
1926	74.09	Gauge (continuous)	N[1]
1927	3123.6	Gauge (peak)	Y
1928	4914.7	Gauge (peak)	Y
1929	2380.2	Gauge (peak)	Y
1930	585.18	Gauge (peak)	Y
1931	6706	Gauge (peak)	Y
1932	232.42	Gauge (continuous)	N[1]
1933	224.84	Gauge (continuous)	N[1]
1934	464.45	Gauge (continuous)	N[1]
1935	58.69	Gauge (continuous)	N[1]
1936	85.42	Gauge (continuous)	N[1]

Year	Value	Source	Used
1937	1010.1	Gauge (peak)	Y
1938	958.57	Gauge (peak)	Y
1939	332.92	Gauge (continuous)	N[1]
1940	555.98	Gauge (peak)	Y
1941	307.58	Gauge (continuous)	N[1]
1942	1350.9	Gauge (peak)	Y
1943	705.39	Gauge (peak)	Y
1944	1178.1	Gauge (peak)	Y
1945	75.71	Gauge (continuous)	N[1]
1946	819.97	Gauge (peak)	Y
1947	665.64	Gauge (continuous)	Y
1948	678.5	Gauge (peak)	Y
1949	894.18	Gauge (peak)	Y
1950	3206.9	Gauge (peak)	Y
1951	3504	Gauge (peak)	Y
1952	3.85	Gauge (factored)	N[1]
1953	1138.4	Gauge (factored)	Y
1954	104.48	Gauge (factored)	N[1]
1955	6379.9	Gauge (continuous)	Y
1956	3014.6	Gauge (factored)	Y
1957	136.89	Gauge (factored)	N[1]
1958	1967.6	Gauge (factored)	Y
1959	2208.2	Gauge (factored)	Y
1960	2560.1	URBS model	Y
1961	94.5	Gauge (factored)	N[1]

ANNUAL DATA

Year	Value	Source	Used	Year	Value	Source	Used	Year	Value	Source	Used
1962	427.92	Gauge (factored)	N[1]	1982	1513.4	Gauge (factored)	Y	2002	46.53	Gauge (factored)	N[1]
1963	1733	Gauge (factored)	Y	1983	9776.8	URBS model	Y	2003	51.74	Gauge (factored)	N[1]
1964	275.61	Gauge (factored)	N[1]	1984	835.52	Gauge (factored)	Y	2004	603.77	URBS model	Y
1965	57.52	Gauge (factored)	N[1]	1985	239.84	Gauge (factored)	N[1]	2005	115.18	Gauge (factored)	N[1]
1966	2708.1	URBS model	Y	1986	144.13	Gauge (factored)	N[1]	2006	53.06	Gauge (factored)	N[1]
1967	4071.5	URBS model	Y	1987	65.89	Gauge (factored)	N[1]	2007	45.07	Gauge (factored)	N[1]
1968	4170.8	Gauge (factored)	Y	1988	3119.7	URBS model	Y	2008	129.77	Gauge (factored)	N[1]
1969	159.22	Gauge (factored)	N[1]	1989	6693.3	URBS model	Y	2009	1393	URBS model	Y
1970	171.81	Gauge (factored)	N[1]	1990	1961.8	Gauge (factored)	Y	2010	1566.5	URBS model	Y
1971	4430.6	Gauge (factored)	Y	1991	559.74	URBS model	Y	2011	13627	URBS model	Y
1972	4791.5	URBS model	Y	1992	5496.3	URBS model	Y	2012	845.29	URBS model	Y
1973	1029.5	Gauge (factored)	Y	1993	59.99	Gauge (factored)	N[1]	2013	8527.1	URBS model	Y
1974	11947	Gauge (factored)	Y	1994	56.84	Gauge (factored)	N[1]				
1975	209.53	Gauge (factored)	N[1]	1995	53.49	Gauge (factored)	N[1]				
1976	2151.6	Gauge (factored)	Y	1996	3674.5	URBS model	Y				
1977	491.15	Gauge (factored)	N[1]	1997	106.89	Gauge (factored)	N[1]				
1978	365.23	Gauge (factored)	N[1]	1998	48.03	Gauge (factored)	N[1]				
1979	306.05	Gauge (factored)	N[1]	1999	10513	URBS model	Y				
1980	59.3	Gauge (factored)	N[1]	2000	210.31	Gauge (factored)	N[1]				
1981	1062.4	Gauge (factored)	Y	2001	1828.6	URBS model	Y				

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	500	0	48	1910 – 2013	Low outlier threshold determined by visual inspection of data
2	4700	0	17	1887 – 1909	Low outlier threshold for historical data prior to continuous gauge record

Gauge Location:	**Lower Brisbane River at Mt Crosby Weir**
Catchment Area:	10527 km³
Notes:	Gauged record available from 1887, however record 1887-1900 contains no minor events so higher historical threshold applied. Flows <2000m³/s excluded due to anomaly in low-flow rating, most likely due to influence of bridge deck. Rating based on DMT TUFLOW modelling. Calibration of model may not be consistent with BRCFS. Level-flow relationship subject to dynamic effects.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution until rating confirmed or updated**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	401	-	1,340	841	574	1,290	855	536	1,250	852	597	1,170
5	3,040	2,450	4,150	3,090	2,460	4,090	3,090	2,440	3,990	3,120	2,460	3,980
10	5,310	4,270	7,130	5,430	4,370	7,090	5,360	4,380	6,980	5,430	4,360	6,930
20	7,970	6,330	11,200	8,180	6,420	11,000	7,960	6,430	10,700	8,090	6,460	10,600
50	12,300	9,220	20,700	12,300	9,170	17,200	11,700	9,200	16,700	11,900	9,370	16,200
100	16,400	11,400	33,200	15,600	11,300	22,900	14,700	11,200	21,800	14,900	11,500	21,000
200	21,300	13,400	53,100	18,900	13,600	30,300	17,600	13,100	27,300	18,000	13,600	26,000
500	29,500	15,900	100,000	23,400	15,900	42,600	21,500	15,500	34,800	21,900	16,100	33,000
1000	37,200	17,800	162,000	26,800	17,300	53,700	24,300	17,200	40,700	24,800	17,800	38,400
2000	46,500	19,500	262,000	30,100	18,100	66,500	27,000	18,700	46,400	27,500	19,300	43,900

Posterior	Location u	-290.20	Mean (loge flow)	6.513	Mean (loge flow)	6.516	Mean (loge flow)	6.508
Expected	loge (Scale a)	7.491	loge [Std dev (loge flow)]	0.576	loge [Std dev (loge flow)]	0.575	loge [Std dev (loge flow)]	0.586
Parameters	Shape k	-0.278	Skew (loge flow)	-0.756	Skew (loge flow)	-0.802	Skew (loge flow)	-0.807

ANNUAL DATA

Year	Value	Source	Used
1887	5584.9	Gauge (peak)	Y
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	10145	Gauge (peak)	Y
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	17739	Gauge (peak)	Y
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	4459.6	Gauge (peak)	Y
1897	-	No data	N[2]
1898	9068.2	Gauge (peak)	Y
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	1622.6	Gauge (continuous)	N[1]
1902	1670.8	Gauge (continuous)	N[1]
1903	1839.4	Gauge (continuous)	N[1]
1904	1705.9	Gauge (continuous)	N[1]
1905	1659.9	Gauge (continuous)	N[1]
1906	1853.5	Gauge (continuous)	N[1]
1907	935.3	Gauge (continuous)	N[1]
1908	5003.2	Gauge (peak)	Y
1909	67.21	Gauge (continuous)	N[1]
1910	1974	Gauge (continuous)	N[1]
1911	2641.5	Gauge (continuous)	Y
1912	1404.3	Gauge (continuous)	N[1]
1913	1560.2	Gauge (continuous)	N[1]
1914	1044.9	Gauge (continuous)	N[1]
1915	1750.9	Gauge (continuous)	N[1]
1916	805.2	Gauge (continuous)	N[1]
1917	1389.9	Gauge (continuous)	N[1]
1918	1665.8	Gauge (continuous)	N[1]
1919	472.38	Gauge (continuous)	N[1]
1920	1714.5	Gauge (continuous)	N[1]
1921	2367.4	Gauge (continuous)	Y
1922	2770.9	Gauge (continuous)	Y
1923	231.33	Gauge (continuous)	N[1]
1924	752.17	Gauge (continuous)	N[1]
1925	1195.5	Gauge (continuous)	N[1]
1926	584.54	Gauge (continuous)	N[1]
1927	3092.9	Gauge (peak)	Y
1928	5066.4	Gauge (peak)	Y
1929	2419.5	Gauge (peak)	Y
1930	651.62	Gauge (continuous)	N[1]
1931	6753.4	Gauge (peak)	Y
1932	314.64	Gauge (continuous)	N[1]
1933	221.42	Gauge (continuous)	N[1]
1934	542.83	Gauge (continuous)	N[1]
1935	161.19	Gauge (continuous)	N[1]
1936	145.72	Gauge (continuous)	N[1]
1937	1449.7	Gauge (continuous)	N[1]
1938	1332.3	Gauge (continuous)	N[1]
1939	328.94	Gauge (continuous)	N[1]
1940	576.6	Gauge (continuous)	N[1]
1941	462.84	Gauge (continuous)	N[1]
1942	1719.2	Gauge (continuous)	N[1]
1943	657.01	Gauge (continuous)	N[1]
1944	1628.8	Gauge (peak)	N[1]
1945	117.64	Gauge (continuous)	N[1]
1946	1464.7	Gauge (peak)	N[1]
1947	950.53	Gauge (continuous)	N[1]
1948	1790.1	Gauge (peak)	N[1]
1949	937.08	Gauge (peak)	N[1]
1950	3139.1	Gauge (peak)	Y
1951	3421.9	Gauge (peak)	Y
1952	12.54	Gauge (factored)	N[1]
1953	1685.2	Gauge (factored)	N[1]
1954	2542.2	Gauge (factored)	Y
1955	6133.2	Gauge (continuous)	Y
1956	2870.4	Gauge (factored)	Y
1957	367.46	Gauge (factored)	N[1]
1958	2264.3	Gauge (factored)	Y
1959	2385.3	Gauge (factored)	Y
1960	2551.4	URBS model	Y
1961	72.19	Gauge (factored)	N[1]

ANNUAL DATA

Year	Value	Source	Used
1962	506.14	Gauge (factored)	N[1]
1963	2143.8	Gauge (factored)	Y
1964	339.02	Gauge (factored)	N[1]
1965	41.33	Gauge (factored)	N[1]
1966	2763.2	URBS model	Y
1967	4165.5	URBS model	Y
1968	3931.1	Gauge (continuous)	Y
1969	179.16	Gauge (factored)	N[1]
1970	180.38	Gauge (factored)	N[1]
1971	3793.1	Gauge (factored)	Y
1972	4627.3	URBS model	Y
1973	1077.2	Gauge (factored)	N[1]
1974	12285	Gauge (factored)	Y
1975	242.44	Gauge (factored)	N[1]
1976	2195.5	Gauge (factored)	Y
1977	-	No data	N[1]
1978	-	No data	N[1]
1979	-	No data	N[1]
1980	-	No data	N[1]
1981	1056.5	Gauge (factored)	N[1]

Year	Value	Source	Used
1982	1952.4	Gauge (factored)	N[1]
1983	8955.9	URBS model	Y
1984	-	No data	N[1]
1985	-	No data	N[1]
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	3129.4	URBS model	Y
1989	6223.4	URBS model	Y
1990	1978.9	Gauge (factored)	N[1]
1991	556.93	URBS model	N[1]
1992	5257.9	URBS model	Y
1993	-	No data	N[1]
1994	-	No data	N[1]
1995	-	No data	N[1]
1996	3970.1	URBS model	Y
1997	-	No data	N[1]
1998	-	No data	N[1]
1999	9874.2	URBS model	Y
2000	-	No data	N[1]
2001	1818.5	URBS model	N[1]

Year	Value	Source	Used
2002	-	No data	N[1]
2003	-	No data	N[1]
2004	453.46	Gauge (factored)	N[1]
2005	-	No data	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	-	No data	N[1]
2009	1720.7	URBS model	N[1]
2010	1569.4	URBS model	N[1]
2011	13093	Gauge (factored)	Y
2012	851.44	URBS model	N[1]
2013	7996.2	URBS model	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	2000	0	81	1901 – 2013	Low outlier threshold determined by visual inspection of data
2	4400	0	9	1887 – 1900	Low outlier threshold for historical data prior to continuous gauge record

Gauge Location:	**Lower Brisbane River at Moggill**
Catchment Area:	12616 km³
Notes:	Stream gauge record with relatively consistent record from 1955 but also with major floods back to 1893. Separate censoring thresholds applied for pre- and post-1955 records. Rating based on DMT TUFLOW modelling. Calibration of model may not be consistent with BRCFS. Level-flow relationship subject to dynamic effects.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Frequency curve should be used with caution until rating confirmed or updated**

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m³/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	520	-	1,990	1,190	570	2,080	1,320	789	2,000	1,110	744	1,580
5	3,910	3,080	5,320	3,690	2,900	5,140	3,980	3,100	5,120	3,820	2,940	4,910
10	6,420	5,290	8,370	6,090	5,150	8,220	6,360	5,260	8,070	6,420	5,110	8,180
20	9,030	7,460	12,000	8,800	7,360	11,900	8,920	7,430	11,600	9,310	7,460	12,000
50	12,700	10,300	19,000	12,700	10,300	17,500	12,400	10,100	17,000	13,300	10,500	17,900
100	15,800	12,200	27,100	15,900	12,300	23,300	15,000	12,000	21,600	16,400	12,700	22,700
200	19,100	13,900	38,700	19,100	14,200	29,800	17,600	13,700	26,200	19,400	14,700	27,900
500	23,900	15,800	61,800	23,400	16,200	41,800	20,800	15,800	32,500	23,200	17,100	34,800
1000	27,800	17,000	86,300	26,600	17,500	52,200	23,100	17,200	37,300	26,000	18,700	40,200
2000	32,100	18,100	123,000	29,800	18,400	66,100	25,200	18,400	41,900	28,500	20,100	45,500

Posterior	Location u	-486.86	Mean (loge flow)	6.910	Mean (loge flow)	6.986	Mean (loge flow)	6.778
Expected	loge (Scale a)	7.897	loge [Std dev (loge flow)]	0.420	loge [Std dev (loge flow)]	0.420	loge [Std dev (loge flow)]	0.540
Parameters	Shape k	-0.115	Skew (loge flow)	-0.689	Skew (loge flow)	-0.805	Skew (loge flow)	-0.837

ANNUAL DATA

Year	Value	Source	Used
1887	7827.5	URBS model	Y
1888	-	No data	N[2]
1889	-	No data	N[2]
1890	9130.2	URBS model	Y
1891	-	No data	N[2]
1892	-	No data	N[2]
1893	17942	Gauge (peak)	Y
1894	-	No data	N[2]
1895	-	No data	N[2]
1896	-	No data	N[2]
1897	-	No data	N[2]
1898	10518	Gauge (peak)	Y
1899	-	No data	N[2]
1900	-	No data	N[2]
1901	-	No data	N[2]
1902	-	No data	N[2]
1903	-	No data	N[2]
1904	-	No data	N[2]
1905	-	No data	N[2]
1906	-	No data	N[2]
1907	-	No data	N[2]
1908	7084.4	Gauge (peak)	Y
1909	-	No data	N[2]
1910	-	No data	N[2]
1911	-	No data	N[2]

Year	Value	Source	Used
1912	-	No data	N[2]
1913	-	No data	N[2]
1914	-	No data	N[2]
1915	-	No data	N[2]
1916	-	No data	N[2]
1917	-	No data	N[2]
1918	-	No data	N[2]
1919	-	No data	N[2]
1920	-	No data	N[2]
1921	-	No data	N[2]
1922	-	No data	N[2]
1923	-	No data	N[2]
1924	-	No data	N[2]
1925	-	No data	N[2]
1926	-	No data	N[2]
1927	-	No data	N[2]
1928	-	No data	N[2]
1929	-	No data	N[2]
1930	-	No data	N[2]
1931	8238	Gauge (peak)	Y
1932	-	No data	N[2]
1933	-	No data	N[2]
1934	-	No data	N[2]
1935	-	No data	N[2]
1936	-	No data	N[2]

Year	Value	Source	Used
1937	-	No data	N[2]
1938	-	No data	N[2]
1939	-	No data	N[2]
1940	-	No data	N[2]
1941	-	No data	N[2]
1942	-	No data	N[2]
1943	-	No data	N[2]
1944	-	No data	N[2]
1945	-	No data	N[2]
1946	-	No data	N[2]
1947	2274.5	URBS model	N[2]
1948	-	No data	N[2]
1949	-	No data	N[2]
1950	-	No data	N[2]
1951	-	No data	N[2]
1952	-	No data	N[2]
1953	-	No data	N[2]
1954	-	No data	N[2]
1955	6865.4	Gauge (peak)	Y
1956	2692.9	URBS model	Y
1957	-	No data	N[1]
1958	-	No data	N[1]
1959	2799.8	URBS model	Y
1960	2745.7	URBS model	Y
1961	-	No data	N[1]

ANNUAL DATA

Year	Value	Source	Used
1962	-	No data	N[1]
1963	-	No data	N[1]
1964	-	No data	N[1]
1965	-	No data	N[1]
1966	3619.5	URBS model	Y
1967	4750.5	Gauge (factored)	Y
1968	5301.6	Gauge (factored)	Y
1969	-	No data	N[1]
1970	-	No data	N[1]
1971	4576	Gauge (factored)	Y
1972	4539.1	URBS model	Y
1973	-	No data	N[1]
1974	13581	Gauge (factored)	Y
1975	-	No data	N[1]
1976	2896.2	URBS model	Y
1977	-	No data	N[1]
1978	-	No data	N[1]
1979	-	No data	N[1]
1980	-	No data	N[1]
1981	1050.9	Gauge (factored)	N[1]

Year	Value	Source	Used
1982	2027.2	Gauge (factored)	N[1]
1983	8441.2	URBS model	Y
1984	-	No data	N[1]
1985	-	No data	N[1]
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	3602.2	URBS model	Y
1989	6153.4	URBS model	Y
1990	-	No data	N[1]
1991	1192.2	URBS model	N[1]
1992	5071.1	URBS model	Y
1993	-	No data	N[1]
1994	-	No data	N[1]
1995	-	No data	N[1]
1996	5314.5	URBS model	Y
1997	-	No data	N[1]
1998	-	No data	N[1]
1999	9287.8	URBS model	Y
2000	-	No data	N[1]
2001	1924.3	URBS model	N[1]

Year	Value	Source	Used
2002	-	No data	N[1]
2003	-	No data	N[1]
2004	754.22	URBS model	N[1]
2005	-	No data	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	-	No data	N[1]
2009	2589.4	Gauge (factored)	N[1]
2010	1671.5	URBS model	N[1]
2011	13648	Gauge (factored)	Y
2012	1174.9	URBS model	N[1]
2013	9494.3	URBS model	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	2600	0	40	1955 – 2013	Low outlier threshold determined by inspection of data and tidal influence on rating
2	7000	0	62	1887 – 1954	Low outlier threshold for historical data prior to gauge record

Gauge Location:	**Lower Brisbane River at Brisbane City**
Catchment Area:	13235 km³
Notes:	Gauge record of moderate to large floods from 1841.
	Rating based on DMT TUFLOW modelling. Calibration of model may not be consistent with BRCFS. Rating is highly influenced by tide at low to moderate flows. Threshold applied and FFA conducted on high flows only.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods
	City gauge is least reliable of the lower Brisbane ratings. Frequency curve should be used with caution until rating confirmed or updated

FLOOD FREQUENCY ANALYSIS: PEAK FLOW (m^3/s)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	425	-	2,750	1,840	1,270	2,650	1,680	1,090	2,430	1,260	899	1,720
5	3,990	3,210	5,530	4,490	3,710	5,530	4,440	3,510	5,450	4,070	3,090	5,070
10	6,470	5,750	8,130	6,740	5,780	8,140	6,730	5,690	8,120	6,680	5,220	8,300
20	8,930	7,960	11,300	9,160	7,850	11,300	9,090	7,890	11,200	9,500	7,580	13,000
50	12,300	10,500	16,900	12,500	10,400	16,100	12,200	10,500	15,600	13,400	10,900	20,100
100	14,800	12,400	22,700	15,200	12,400	20,900	14,500	12,200	19,200	16,300	12,800	25,800
200	17,500	14,000	31,000	17,900	14,100	26,500	16,600	13,700	22,900	19,100	14,600	31,700
500	21,200	15,800	46,000	21,600	16,000	35,800	19,300	15,500	27,800	22,600	16,700	39,600
1000	24,100	17,000	61,100	24,300	17,100	44,300	21,200	16,700	31,300	25,100	18,000	45,400
2000	27,100	17,800	81,100	27,100	17,800	54,100	23,000	17,800	34,700	27,400	19,300	51,000

Posterior	Location u	-686.07	Mean (loge flow)	7.404	Mean (loge flow)	7.247	Mean (loge flow)	6.910
Expected	loge (Scale a)	8.008	loge [Std dev (loge flow)]	0.160	loge [Std dev (loge flow)]	0.296	loge [Std dev (loge flow)]	0.494
Parameters	Shape k	-0.050	Skew (loge flow)	-0.577	Skew (loge flow)	-0.798	Skew (loge flow)	-0.844

ANNUAL DATA

Year	Value	Source	Used
1841	15923	Gauge (peak)	Y
1842	-	No data	N[1]
1843	5999.6	Gauge (peak)	Y
1844	14046	Gauge (peak)	Y
1845	-	No data	N[1]
1846	-	No data	N[1]
1847	-	No data	N[1]
1848	-	No data	N[1]
1849	-	No data	N[1]
1850	-	No data	N[1]
1851	-	No data	N[1]
1852	6308.5	Gauge (peak)	Y
1853	-	No data	N[1]
1854	-	No data	N[1]
1855	-	No data	N[1]
1856	-	No data	N[1]
1857	7152.6	Gauge (peak)	Y
1858	-	No data	N[1]
1859	-	No data	N[1]
1860	-	No data	N[1]
1861	-	No data	N[1]
1862	-	No data	N[1]
1863	7274.6	Gauge (peak)	Y
1864	8291.8	Gauge (peak)	Y
1865	-	No data	N[1]

Year	Value	Source	Used
1866	-	No data	N[1]
1867	5321.4	Gauge (peak)	N[1]
1868	-	No data	N[1]
1869	-	No data	N[1]
1870	6267.3	Gauge (peak)	Y
1871	-	No data	N[1]
1872	-	No data	N[1]
1873	5855.4	Gauge (peak)	Y
1874	-	No data	N[1]
1875	5690.7	Gauge (peak)	Y
1876	-	No data	N[1]
1877	-	No data	N[1]
1878	-	No data	N[1]
1879	-	No data	N[1]
1880	5321.4	Gauge (peak)	N[1]
1881	-	No data	N[1]
1882	-	No data	N[1]
1883	-	No data	N[1]
1884	-	No data	N[1]
1885	-	No data	N[1]
1886	-	No data	N[1]
1887	8291.8	Gauge (peak)	Y
1888	-	No data	N[1]
1889	8229.8	Gauge (peak)	Y
1890	11392	Gauge (peak)	Y

Year	Value	Source	Used
1891	-	No data	N[1]
1892	-	No data	N[1]
1893	15830	Gauge (peak)	Y
1894	-	No data	N[1]
1895	-	No data	N[1]
1896	3678.8	Gauge (peak)	N[1]
1897	-	No data	N[1]
1898	10762	Gauge (peak)	Y
1899	-	No data	N[1]
1900	-	No data	N[1]
1901	-	No data	N[1]
1902	-	No data	N[1]
1903	-	No data	N[1]
1904	-	No data	N[1]
1905	-	No data	N[1]
1906	-	No data	N[1]
1907	-	No data	N[1]
1908	7899.6	Gauge (peak)	Y
1909	-	No data	N[1]
1910	-	No data	N[1]
1911	-	No data	N[1]
1912	-	No data	N[1]
1913	-	No data	N[1]
1914	-	No data	N[1]
1915	-	No data	N[1]

ANNUAL DATA

Year	Value	Source	Used
1916	-	No data	N[1]
1917	-	No data	N[1]
1918	-	No data	N[1]
1919	-	No data	N[1]
1920	-	No data	N[1]
1921	-	No data	N[1]
1922	-	No data	N[1]
1923	-	No data	N[1]
1924	-	No data	N[1]
1925	-	No data	N[1]
1926	-	No data	N[1]
1927	2943	Gauge (peak)	N[1]
1928	4178.7	Gauge (peak)	N[1]
1929	4035.9	Gauge (peak)	N[1]
1930	-	No data	N[1]
1931	7274.6	Gauge (peak)	Y
1932	-	No data	N[1]
1933	-	No data	N[1]
1934	-	No data	N[1]
1935	-	No data	N[1]
1936	-	No data	N[1]
1937	-	No data	N[1]
1938	-	No data	N[1]
1939	-	No data	N[1]
1940	-	No data	N[1]

Year	Value	Source	Used
1941	-	No data	N[1]
1942	-	No data	N[1]
1943	-	No data	N[1]
1944	-	No data	N[1]
1945	-	No data	N[1]
1946	-	No data	N[1]
1947	-	No data	N[1]
1948	-	No data	N[1]
1949	-	No data	N[1]
1950	-	No data	N[1]
1951	-	No data	N[1]
1952	-	No data	N[1]
1953	-	No data	N[1]
1954	-	No data	N[1]
1955	6326.1	Gauge (factored)	Y
1956	3871.3	Gauge (factored)	N[1]
1957	-	No data	N[1]
1958	-	No data	N[1]
1959	2711.9	URBS model	N[1]
1960	2753.4	URBS model	N[1]
1961	-	No data	N[1]
1962	-	No data	N[1]
1963	-	No data	N[1]
1964	-	No data	N[1]
1965	-	No data	N[1]

Year	Value	Source	Used
1966	3579.1	URBS model	N[1]
1967	4145.2	Gauge (factored)	N[1]
1968	3605.2	Gauge (peak)	N[1]
1969	-	No data	N[1]
1970	-	No data	N[1]
1971	3101.5	Gauge (factored)	N[1]
1972	4352.9	URBS model	N[1]
1973	-	No data	N[1]
1974	14270	Gauge (factored)	Y
1975	-	No data	N[1]
1976	2970	URBS model	N[1]
1977	-	No data	N[1]
1978	-	No data	N[1]
1979	-	No data	N[1]
1980	-	No data	N[1]
1981	-	No data	N[1]
1982	-	No data	N[1]
1983	7667.9	URBS model	Y
1984	-	No data	N[1]
1985	-	No data	N[1]
1986	-	No data	N[1]
1987	-	No data	N[1]
1988	3511.5	URBS model	N[1]
1989	5630.7	URBS model	Y
1990	-	No data	N[1]

ANNUAL DATA

Year	Value	Source	Used
1991	1516.4	URBS model	N[1]
1992	4845.1	URBS model	N[1]
1993	-	No data	N[1]
1994	-	No data	N[1]
1995	-	No data	N[1]
1996	5827.6	URBS model	Y
1997	-	No data	N[1]
1998	-	No data	N[1]
1999	8514.9	URBS model	Y
2000	-	No data	N[1]
2001	1914.4	URBS model	N[1]
2002	-	No data	N[1]
2003	-	No data	N[1]
2004	942.44	URBS model	N[1]
2005	-	No data	N[1]
2006	-	No data	N[1]
2007	-	No data	N[1]
2008	-	No data	N[1]
2009	2364.8	Gauge (factored)	N[1]
2010	1680.2	URBS model	N[1]
2011	12622	Gauge (factored)	Y
2012	1192.5	URBS model	N[1]
2013	8628.8	URBS model	Y

CENSOR THRESHOLDS

No.	Threshold (m^3/s)	Years Above	Years Below	Period	Description
1	5630	0	148	1955 – 2013	Low outlier threshold determined by inspection of data and tidal influence on rating

Appendix B
Volume frequency analysis results summary

Gauge Location:	**Upper Brisbane River at Linville**
Catchment Area:	2009 km³
Notes:	Reliable rating site. Continuous gauge data available from 1966. Upper and lower tails have significant impact on the frequency curve.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods
	Other distributions should not be used due to strong influence of upper tail

VOLUME FREQUENCY ANALYSIS: 24 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	7	4	10	7	4	12	8	5	12	8	5	13
5	30	18	55	34	20	56	35	24	55	35	24	51
10	76	39	185	74	42	135	68	46	111	64	45	96
20	180	73	631	136	73	320	110	72	189	100	70	153
50	545	155	3,130	264	120	926	175	111	323	154	105	247
100	1,250	263	10,200	403	156	1,970	230	141	448	199	132	329
200	2,840	446	33,700	587	185	4,250	288	171	583	245	161	417
500	8,410	882	158,000	911	216	11,000	366	210	786	308	196	550
1000	19,100	1,470	518,000	1,230	235	22,600	426	237	951	356	220	653
2000	43,400	2,460	1,710,000	1,620	253	44,900	484	263	1,130	402	243	761

Posterior	Location u	3766.3	Mean (loge flow)	8.717	Mean (loge flow)	8.649	Mean (loge flow)	8.788
Expected	loge (Scale a)	8.767	loge [Std dev (loge flow)]	0.694	loge [Std dev (loge flow)]	0.753	loge [Std dev (loge flow)]	0.665
Parameters	Shape k	-1.182	Skew (loge flow)	-0.313	Skew (loge flow)	-0.789	Skew (loge flow)	-0.770

Note: FFA conducted in ML

ANNUAL DATA: 24 HOUR VOLUME (ML) (All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1965	1205	Y	1985	13736	Y	2005	1086.3	Y
1966	13575	Y	1986	3704.3	Y	2006	2347.4	Y
1967	18935	Y	1987	1387.2	Y	2007	275.45	N[1]
1968	27296	Y	1988	15721	Y	2008	8144.8	Y
1969	131.08	N[1]	1989	91943	Y	2009	1645.8	Y
1970	3189.8	Y	1990	5180.4	Y	2010	25055	Y
1971	87864	Y	1991	2020.7	Y	2011	179820	Y
1972	27092	Y	1992	42985	Y	2012	12477	Y
1973	12184	Y	1993	463.28	N[1]	2013	82177	Y
1974	126790	Y	1994	506.77	N[1]			
1975	2680.1	Y	1995	3348.7	Y			
1976	21166	Y	1996	12908	Y			
1977	845.09	N[1]	1997	1272	Y			
1978	435.58	N[1]	1998	8866.1	Y			
1979	9132.9	Y	1999	161240	Y			
1980	1687.2	Y	2000	3700.2	Y			
1981	15193	Y	2001	35082	Y			
1982	13639	Y	2002	3515.5	Y			
1983	111250	Y	2003	406.57	N[1]			
1984	7928.2	Y	2004	6029.9	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	1086	0	7	1965 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Linville**
Catchment Area:	2009 km³
Notes:	Reliable rating site. Continuous gauge data available from 1966. Upper and lower tails have significant impact on the frequency curve.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods
	Other distributions should not be used due to strong influence of upper tail

VOLUME FREQUENCY ANALYSIS: 48 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	10	6	15	9	6	15	10	6	17	12	7	18
5	41	25	69	45	28	75	48	32	75	48	33	70
10	94	51	208	97	58	175	93	62	150	88	60	131
20	206	92	620	178	99	395	149	98	255	137	94	210
50	561	184	2,610	345	167	1,100	238	151	431	211	143	335
100	1,180	301	7,690	526	223	2,300	312	193	595	273	182	446
200	2,480	483	22,400	766	276	4,580	391	236	776	338	221	566
500	6,580	898	91,200	1,190	340	10,900	497	290	1,050	425	272	745
1000	13,800	1,430	264,000	1,610	384	21,100	578	329	1,260	490	307	889
2000	28,700	2,250	771,000	2,120	422	39,300	658	363	1,490	555	340	1,040

Posterior	Location u	5500.9	Mean (loge flow)	9.039	Mean (loge flow)	8.977	Mean (loge flow)	9.110
Expected	loge (Scale a)	9.159	loge [Std dev (loge flow)]	0.673	loge [Std dev (loge flow)]	0.745	loge [Std dev (loge flow)]	0.661
Parameters	Shape k	-1.063	Skew (loge flow)	-0.293	Skew (loge flow)	-0.783	Skew (loge flow)	-0.764

Note: FFA conducted in ML

ANNUAL DATA: 48 HOUR VOLUME (ML)

(All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1965	1937.9	Y	1985	19936	Y	2005	1410.7	Y
1966	17379	Y	1986	5065.5	Y	2006	4641.1	Y
1967	27562	Y	1987	2097.8	Y	2007	389.53	N[1]
1968	36401	Y	1988	19765	Y	2008	10709	Y
1969	236.89	N[1]	1989	106710	Y	2009	2843.6	Y
1970	3818.2	Y	1990	7977.2	Y	2010	34972	Y
1971	108520	Y	1991	3323.9	Y	2011	323170	Y
1972	37678	Y	1992	55968	Y	2012	16288	Y
1973	15559	Y	1993	732.38	N[1]	2013	99236	Y
1974	173160	Y	1994	856.21	N[1]			
1975	3748.3	Y	1995	5457.5	Y			
1976	29435	Y	1996	17298	Y			
1977	1390	N[1]	1997	1845.4	Y			
1978	626.58	N[1]	1998	12374	Y			
1979	11843	Y	1999	199680	Y			
1980	2427.7	Y	2000	5508.1	Y			
1981	17194	Y	2001	51672	Y			
1982	16496	Y	2002	5137.5	Y			
1983	127990	Y	2003	769.44	N[1]			
1984	10514	Y	2004	9311.5	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	1460	0	7	1965 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Linville**
Catchment Area:	2009 km³
Notes:	Reliable rating site. Continuous gauge data available from 1966. Upper and lower tails have significant impact on the frequency curve.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods
	Other distributions should not be used due to strong influence of upper tail

VOLUME FREQUENCY ANALYSIS: 72 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	11	7	17	11	7	18	12	8	19	13	9	20
5	45	29	77	50	31	83	55	37	84	54	38	80
10	102	58	225	107	64	193	104	71	167	99	69	148
20	218	103	637	196	109	433	166	111	277	154	106	235
50	570	202	2,540	380	183	1,210	262	170	469	237	161	373
100	1,170	327	7,260	583	245	2,500	342	216	640	307	205	494
200	2,370	517	20,300	855	308	4,870	426	262	828	379	250	626
500	6,060	948	81,000	1,340	384	11,800	541	323	1,110	476	307	818
1000	12,300	1,480	232,000	1,830	438	22,800	628	365	1,340	549	347	967
2000	24,900	2,320	662,000	2,440	486	42,900	714	405	1,580	621	386	1,120

Posterior	Location u	6532.7	Mean (loge flow)	9.220	Mean (loge flow)	9.144	Mean (loge flow)	9.255
Expected	loge (Scale a)	9.302	loge [Std dev (loge flow)]	0.633	loge [Std dev (loge flow)]	0.721	loge [Std dev (loge flow)]	0.651
Parameters	Shape k	-1.020	Skew (loge flow)	-0.233	Skew (loge flow)	-0.777	Skew (loge flow)	-0.760

Note: FFA conducted in ML

ANNUAL DATA: 72 HOUR VOLUME (ML) (All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1965	2363.4	Y	1985	22391	Y	2005	1601.9	N[1]
1966	18250	Y	1986	6018.6	Y	2006	5314	Y
1967	30473	Y	1987	2866.8	Y	2007	483.24	N[1]
1968	52964	Y	1988	21568	Y	2008	13137	Y
1969	350.79	N[1]	1989	111470	Y	2009	3744.8	Y
1970	4390.8	Y	1990	10245	Y	2010	39616	Y
1971	115380	Y	1991	4460.1	Y	2011	376120	Y
1972	41785	Y	1992	60062	Y	2012	17800	Y
1973	21524	Y	1993	952.16	N[1]	2013	103940	Y
1974	203290	Y	1994	1153.1	N[1]			
1975	4931.2	Y	1995	6283.7	Y			
1976	32467	Y	1996	20376	Y			
1977	1793.3	Y	1997	2166.5	Y			
1978	762.42	N[1]	1998	14234	Y			
1979	13347	Y	1999	211070	Y			
1980	3053.1	Y	2000	6468.7	Y			
1981	18023	Y	2001	58745	Y			
1982	17515	Y	2002	5879.9	Y			
1983	133590	Y	2003	1111.3	N[1]			
1984	12890	Y	2004	10978	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	1793	0	7	1965 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Gregors Creek**
Catchment Area:	3866 km³
Notes:	Relatively reliable rating site. Continuous gauge data available from 1963. Upper and lower tails have significant impact on skew.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods
	Other distributions should not be used due to strong influence of upper tail

VOLUME FREQUENCY ANALYSIS: 24 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	15	9	23	15	9	26	16	10	26	18	12	27
5	66	41	116	75	46	124	77	51	120	76	53	113
10	157	84	356	160	96	279	149	100	244	142	98	216
20	353	155	1,070	286	164	614	241	157	414	223	152	348
50	992	319	4,510	527	265	1,650	384	242	705	348	233	565
100	2,140	534	13,400	773	335	3,300	505	309	970	451	295	761
200	4,600	877	39,900	1,080	391	6,310	632	376	1,270	559	358	972
500	12,600	1,690	170,000	1,580	450	14,500	804	461	1,710	704	437	1,280
1000	27,100	2,730	502,000	2,040	481	25,600	934	521	2,070	813	494	1,530
2000	58,000	4,440	1,520,000	2,560	508	46,800	1,060	574	2,440	921	547	1,790

Posterior	Location u	8540.3	Mean (loge flow)	9.459	Mean (loge flow)	9.425	Mean (loge flow)	9.537
Expected	loge (Scale a)	9.620	loge [Std dev (loge flow)]	0.724	loge [Std dev (loge flow)]	0.757	loge [Std dev (loge flow)]	0.688
Parameters	Shape k	-1.099	Skew (loge flow)	-0.456	Skew (loge flow)	-0.793	Skew (loge flow)	-0.776

Note: FFA conducted in ML

ANNUAL DATA: 24 HOUR VOLUME (ML) (All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1963	16191	Y	1983	280340	Y	2003	926.41	N[1]
1964	6683.3	Y	1984	12215	Y	2004	11495	Y
1965	1434.6	N[1]	1985	46070	Y	2005	1070.8	N[1]
1966	53285	Y	1986	4228.4	Y	2006	1890.5	N[1]
1967	40954	Y	1987	1212.6	N[1]	2007	3.17	N[1]
1968	49766	Y	1988	33035	Y	2008	9482.9	Y
1969	1681.1	N[1]	1989	195340	Y	2009	4416.9	Y
1970	4524.9	Y	1990	26706	Y	2010	45249	Y
1971	189010	Y	1991	4308.9	Y	2011	348280	Y
1972	68725	Y	1992	129150	Y	2012	11093	Y
1973	29287	Y	1993	940.62	N[1]	2013	149900	Y
1974	330250	Y	1994	2999.4	Y			
1975	10173	Y	1995	7574.6	Y			
1976	39051	Y	1996	31335	Y			
1977	24903	Y	1997	2843.2	Y			
1978	10130	Y	1998	7719.7	Y			
1979	15977	Y	1999	357770	Y			
1980	2019.4	Y	2000	5934.7	Y			
1981	41989	Y	2001	43516	Y			
1982	33115	Y	2002	3328	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	2000	0	8	1963 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Gregors Creek**
Catchment Area:	3866 km³
Notes:	Relatively reliable rating site. Continuous gauge data available from 1963. Upper and lower tails have significant impact on skew.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods
	Other distributions should not be used due to strong influence of upper tail

VOLUME FREQUENCY ANALYSIS: 48 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	22	14	34	22	14	36	25	15	39	27	18	40
5	92	57	162	101	63	167	109	74	166	108	74	159
10	216	117	482	217	130	386	206	140	329	198	137	295
20	477	212	1,450	397	221	873	327	218	546	307	212	467
50	1,320	427	6,190	765	366	2,450	513	331	913	472	320	740
100	2,800	702	18,800	1,170	479	5,170	668	419	1,240	607	407	981
200	5,940	1,150	56,300	1,710	577	10,300	831	508	1,610	748	492	1,240
500	16,000	2,160	238,000	2,670	695	26,000	1,050	621	2,150	937	600	1,620
1000	33,900	3,480	709,000	3,620	777	50,400	1,220	700	2,590	1,080	675	1,920
2000	71,500	5,600	2,180,000	4,810	840	98,600	1,380	770	3,050	1,220	746	2,230

Posterior	Location u	12751.0	Mean (loge flow)	9.912	Mean (loge flow)	9.849	Mean (loge flow)	9.945
Expected	loge (Scale a)	9.960	loge [Std dev (loge flow)]	0.641	loge [Std dev (loge flow)]	0.714	loge [Std dev (loge flow)]	0.654
Parameters	Shape k	-1.079	Skew (loge flow)	-0.252	Skew (loge flow)	-0.784	Skew (loge flow)	-0.771

Note: FFA conducted in ML

ANNUAL DATA: 48 HOUR VOLUME (ML)

(All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1963	21352	Y	1983	336200	Y	2003	1607.3	N[1]
1964	9182.4	Y	1984	19367	Y	2004	15088	Y
1965	2047.8	N[1]	1985	64018	Y	2005	1786.4	N[1]
1966	70027	Y	1986	5848.2	Y	2006	3636.9	Y
1967	62766	Y	1987	1939.6	N[1]	2007	6.35	N[1]
1968	72011	Y	1988	50257	Y	2008	16089	Y
1969	2201.4	N[1]	1989	248610	Y	2009	7412	Y
1970	5672.7	Y	1990	39440	Y	2010	63073	Y
1971	238750	Y	1991	7623.7	Y	2011	574100	Y
1972	87307	Y	1992	161140	Y	2012	16657	Y
1973	40275	Y	1993	1623.7	N[1]	2013	180150	Y
1974	503200	Y	1994	5556.8	Y			
1975	14968	Y	1995	9782.3	Y			
1976	60486	Y	1996	50565	Y			
1977	34926	Y	1997	4225.4	Y			
1978	20089	Y	1998	11382	Y			
1979	23119	Y	1999	457300	Y			
1980	3335.9	N[1]	2000	10094	Y			
1981	58323	Y	2001	62897	Y			
1982	50955	Y	2002	5273.6	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	3630	0	8	1963 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Upper Brisbane River at Gregors Creek**
Catchment Area:	3866 km³
Notes:	Relatively reliable rating site. Continuous gauge data available from 1963. Upper and lower tails have significant impact on skew.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Other distributions should not be used due to strong influence of upper tail**

VOLUME FREQUENCY ANALYSIS: 72 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	26	17	39	26	17	42	30	19	46	31	21	47
5	105	67	174	117	73	190	127	88	191	126	89	184
10	242	139	489	248	148	441	238	163	368	230	162	339
20	527	255	1,360	453	250	992	374	253	605	355	247	534
50	1,420	526	5,270	878	415	2,750	584	383	1,000	545	372	840
100	2,990	882	14,600	1,350	543	5,840	757	485	1,360	700	471	1,110
200	6,250	1,470	41,000	1,990	666	12,100	938	585	1,760	862	570	1,410
500	16,500	2,830	158,000	3,140	804	30,600	1,180	713	2,320	1,080	695	1,830
1000	34,400	4,610	441,000	4,310	902	60,100	1,370	804	2,790	1,240	782	2,170
2000	71,700	7,460	1,230,000	5,790	973	119,000	1,550	888	3,250	1,400	865	2,520

Posterior	Location u	15273.2	Mean (loge flow)	10.106	Mean (loge flow)	10.032	Mean (loge flow)	10.109
Expected	loge (Scale a)	10.103	loge [Std dev (loge flow)]	0.609	loge [Std dev (loge flow)]	0.697	loge [Std dev (loge flow)]	0.647
Parameters	Shape k	-1.058	Skew (loge flow)	-0.198	Skew (loge flow)	-0.781	Skew (loge flow)	-0.770

Note: FFA conducted in ML

ANNUAL DATA: 72 HOUR VOLUME (ML)

(All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1963	25589	Y	1983	354880	Y	2003	2011.8	N[1]
1964	10479	Y	1984	23709	Y	2004	17242	Y
1965	2962.8	N[1]	1985	73070	Y	2005	2279	N[1]
1966	75405	Y	1986	6773.2	Y	2006	4748.3	Y
1967	76702	Y	1987	2455.8	N[1]	2007	9.52	N[1]
1968	119820	Y	1988	62274	Y	2008	19364	Y
1969	2514.4	N[1]	1989	267100	Y	2009	8842.8	Y
1970	6631.7	Y	1990	46327	Y	2010	70563	Y
1971	261030	Y	1991	9494	Y	2011	677500	Y
1972	95630	Y	1992	169330	Y	2012	20475	Y
1973	45678	Y	1993	2130.3	N[1]	2013	189420	Y
1974	616610	Y	1994	7754.3	Y			
1975	17048	Y	1995	11366	Y			
1976	81841	Y	1996	62804	Y			
1977	38952	Y	1997	5177.6	Y			
1978	25787	Y	1998	13399	Y			
1979	26727	Y	1999	486710	Y			
1980	4354.4	N[1]	2000	12564	Y			
1981	74424	Y	2001	69799	Y			
1982	59179	Y	2002	6593.9	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	4740	0	8	1963 – 2013	Low outlier threshold determined by visual inspection of data

Gauge Location:	**Bremer River at Walloon**
Catchment Area:	634 km³
Notes:	Continuous gauge data since 1962. High flow rating potentially affected by backwater uncertainty in 1974 level (flood mark) so 1974 and 2011 included only as 'historical' floods. Rating based on independent hydraulic modelling but becomes very sensitive for high flows.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Preferred FFA site for Bremer River catchment**

VOLUME FREQUENCY ANALYSIS: 24 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	14	10	20	13	9	19	14	10	19	13	10	18
5	39	29	53	39	28	55	39	30	53	39	30	53
10	62	44	96	65	45	99	61	46	87	62	47	87
20	91	61	174	96	63	173	84	62	126	86	64	125
50	143	83	375	146	85	351	115	82	183	119	86	180
100	198	100	673	190	98	575	138	96	230	144	101	224
200	268	117	1,210	240	107	932	161	109	277	168	115	270
500	397	141	2,590	313	116	1,730	189	124	340	198	133	331
1000	529	160	4,620	375	122	2,720	210	135	386	220	144	378
2000	703	178	8,240	441	126	4,170	228	144	432	240	154	422

Posterior	Location u	8560.3	Mean (loge flow)	9.390	Mean (loge flow)	9.334	Mean (loge flow)	9.302
Expected	loge (Scale a)	9.593	loge [Std dev (loge flow)]	0.316	loge [Std dev (loge flow)]	0.366	loge [Std dev (loge flow)]	0.397
Parameters	Shape k	-0.391	Skew (loge flow)	-0.416	Skew (loge flow)	-0.795	Skew (loge flow)	-0.800

Note: FFA conducted in ML

ANNUAL DATA: 24 HOUR VOLUME (ML) (All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1962	8411.5	Y	1982	20023	Y	2002	18.85	N[1]
1963	21490	Y	1983	41373	Y	2003	16	N[1]
1964	14001	Y	1984	12145	Y	2004	8755.4	Y
1965	1801.5	N[1]	1985	15176	Y	2005	3929.3	N[1]
1966	24903	Y	1986	2180.4	N[1]	2006	1261.5	N[1]
1967	30887	Y	1987	1844	N[1]	2007	-	N[1]
1968	31860	Y	1988	57146	Y	2008	16241	Y
1969	1624.6	N[1]	1989	25085	Y	2009	51437	Y
1970	3328.7	N[1]	1990	21808	Y	2010	11467	Y
1971	29917	Y	1991	12012	Y	2011	133670	N[2]
1972	10704	Y	1992	52562	Y	2012	12658	Y
1973	21464	Y	1993	2860.9	N[1]	2013	87206	Y
1974	-	N[2]	1994	2040.6	N[1]			
1975	9580.8	Y	1995	718.25	N[1]			
1976	61008	Y	1996	68598	Y			
1977	22219	Y	1997	19613	Y			
1978	9449.3	Y	1998	182.05	N[1]			
1979	3171.1	N[1]	1999	32002	Y			
1980	3524.8	N[1]	2000	6884	N[1]			
1981	28020	Y	2001	24507	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	8411	0	17	1962 – 2013	Low outlier threshold determined using multiple Grubbs Beck
2	900000	2	0	1974 & 2011	High flows censored due to uncertainty in level measurements

Gauge Location:	**Bremer River at Walloon**
Catchment Area:	634 km³
Notes:	Continuous gauge data since 1962. High flow rating potentially affected by backwater uncertainty in 1974 level (flood mark) so 1974 and 2011 included only as 'historical' floods. Rating based on independent hydraulic modelling but becomes very sensitive for high flows.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Preferred FFA site for Bremer River catchment**

VOLUME FREQUENCY ANALYSIS: 48 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	19	13	26	18	13	25	19	13	26	17	12	23
5	49	36	69	49	36	69	50	39	68	50	38	69
10	80	57	132	83	57	125	77	58	108	81	60	114
20	122	79	254	125	80	228	104	78	154	114	84	164
50	203	109	616	196	108	495	140	101	220	158	113	238
100	293	132	1,220	264	125	886	167	117	272	191	134	296
200	417	157	2,360	344	138	1,590	192	132	325	224	153	357
500	658	191	5,680	472	151	3,320	224	150	395	265	176	439
1000	924	217	11,100	587	158	5,620	247	162	448	294	191	500
2000	1,290	245	21,800	719	164	9,640	268	172	499	322	205	561

Posterior	Location u	12065.1	Mean (loge flow)	9.737	Mean (loge flow)	9.655	Mean (loge flow)	9.515
Expected	loge (Scale a)	9.732	loge [Std dev (loge flow)]	0.229	loge [Std dev (loge flow)]	0.309	loge [Std dev (loge flow)]	0.427
Parameters	Shape k	-0.476	Skew (loge flow)	-0.193	Skew (loge flow)	-0.793	Skew (loge flow)	-0.809

Note: FFA conducted in ML

ANNUAL DATA: 48 HOUR VOLUME (ML) (All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1962	9927.4	N[1]	1982	29129	Y	2002	31.67	N[1]
1963	25756	Y	1983	51421	Y	2003	27.26	N[1]
1964	16463	Y	1984	14928	Y	2004	10253	Y
1965	2226.7	N[1]	1985	18186	Y	2005	5886.7	N[1]
1966	28788	Y	1986	2530.7	N[1]	2006	1532.2	N[1]
1967	51555	Y	1987	2226.9	N[1]	2007	-	N[1]
1968	60599	Y	1988	74999	Y	2008	22514	Y
1969	1879.7	N[1]	1989	29693	Y	2009	55835	Y
1970	3878.6	N[1]	1990	29354	Y	2010	17202	Y
1971	40180	Y	1991	16323	Y	2011	169320	N[2]
1972	14962	Y	1992	60731	Y	2012	17334	Y
1973	33200	Y	1993	3413.8	N[1]	2013	108410	Y
1974	-	N[2]	1994	2485.9	N[1]			
1975	10771	Y	1995	870.39	N[1]			
1976	71902	Y	1996	99584	Y			
1977	27655	Y	1997	22277	Y			
1978	11970	Y	1998	249.44	N[1]			
1979	3844.9	N[1]	1999	40514	Y			
1980	3946	N[1]	2000	10545	Y			
1981	32467	Y	2001	33446	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	10253	0	17	1962 – 2013	Low outlier threshold determined using multiple Grubbs Beck
2	110000	2	0	1974 & 2011	High flows censored due to uncertainty in level measurements

Gauge Location:	**Bremer River at Walloon**
Catchment Area:	634 km³
Notes:	Continuous gauge data since 1962. High flow rating potentially affected by backwater uncertainty in 1974 level (flood mark) so 1974 and 2011 included only as 'historical' floods. Rating based on independent hydraulic modelling but becomes very sensitive for high flows.
Recommendation:	Log Pearson III with catchment weighted skew & standard deviation gives best consistency with other gauges and methods **Preferred FFA site for Bremer River catchment**

VOLUME FREQUENCY ANALYSIS: 72 HOUR VOLUME (GL)

AEP	GEV			Unweighted LPIII			LPIII + wtd skew			LPIII + wtd skew & st.dev		
(1 in N)	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%	Exp. Flow	5%	95%
2	23	16	32	21	15	30	23	15	33	22	16	32
5	68	48	101	68	46	103	73	54	104	72	53	99
10	123	80	225	128	81	221	121	88	178	118	87	167
20	210	120	505	216	123	474	173	124	268	170	124	246
50	409	186	1,470	397	187	1,300	246	171	405	243	172	365
100	666	247	3,300	600	237	2,710	303	204	521	299	209	463
200	1,080	321	7,460	879	282	5,710	360	236	642	355	243	565
500	2,020	446	22,300	1,410	342	14,600	433	275	806	428	285	704
1000	3,250	562	50,100	1,960	383	30,000	486	302	932	481	312	811
2000	5,210	700	114,000	2,700	421	61,400	536	327	1,060	531	339	919

Posterior	Location u	14428.6	Mean (loge flow)	10.004	Mean (loge flow)	9.838	Mean (loge flow)	9.814
Expected	loge (Scale a)	9.921	loge [Std dev (loge flow)]	0.300	loge [Std dev (loge flow)]	0.464	loge [Std dev (loge flow)]	0.468
Parameters	Shape k	-0.679	Skew (loge flow)	0.161	Skew (loge flow)	-0.776	Skew (loge flow)	-0.775

Note: FFA conducted in ML

ANNUAL DATA: 72 HOUR VOLUME (ML) (All data sourced from continuous stream gauge record)

Year	Value	Used	Year	Value	Used	Year	Value	Used
1962	16663	Y	1982	32661	Y	2002	68.92	N[1]
1963	27062	Y	1983	63439	Y	2003	64.07	N[1]
1964	17457	Y	1984	29836	Y	2004	11096	Y
1965	2491.4	N[1]	1985	19288	Y	2005	6627	N[1]
1966	30151	Y	1986	2860.6	N[1]	2006	2351.2	N[1]
1967	69503	Y	1987	2567.2	N[1]	2007	-	N[1]
1968	100340	Y	1988	137910	Y	2008	31508	Y
1969	1996.4	N[1]	1989	41723	Y	2009	57275	Y
1970	4102.5	N[1]	1990	38253	Y	2010	25543	Y
1971	89929	Y	1991	18338	Y	2011	219550	N[2]
1972	15939	Y	1992	62979	Y	2012	25382	Y
1973	64640	Y	1993	4045.7	N[1]	2013	114490	Y
1974	-	N[1]	1994	3483	N[1]			
1975	11218	Y	1995	1071.7	N[1]			
1976	74299	Y	1996	210020	Y			
1977	30504	Y	1997	32080	Y			
1978	12929	Y	1998	325.45	N[1]			
1979	4054.7	N[1]	1999	45221	Y			
1980	4194.8	N[1]	2000	12663	Y			
1981	35493	Y	2001	37722	Y			

CENSOR THRESHOLDS

No.	Threshold (ML)	Years Above	Years Below	Period	Description
1	11095	0	17	1962 – 2013	Low outlier threshold determined using multiple Grubbs Beck
2	210020	2	0	1974 & 2011	High flows censored due to uncertainty in level measurements

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