SINCLAIR KNIGHT MERZ–(SKM)
Req#1720883 Roderic Nathan –
SM#1745348 & Annexures #1745615
File 540953
Volume 1 of 2 ORIGINAL

In the matter of the Queensland Floods Commission of Inquiry 2011
A Commission of Inquiry under the *Commissions of Inquiry Act* 1950
And Pursuant to the *Commissions of Inquiry Order (No. 1)* 2011

Statement of Roderic John Nathan

with Annexures RJN1 – RJN6

Volume 1 of 2

QFCI

Date: 26/10/11 JM

Exhibit Number: 884

In the matter of the Queensland Floods Commission of Inquiry 2011

A Commission of Inquiry under the Commissions of Inquiry Act 1950

And Pursuant to the Commissions of Inquiry Order (No. 1) 2011

Statement of Roderic John Nathan

On 4 October 2011, I, Dr Roderic ("Rory") John Nathan, of Level 11, 452 Flinders Street, Melbourne, in the State of Victoria, say as follows:

Introduction

1 I am currently employed by Sinclair Knight Merz Pty Limited (**SKM**) as General Manager Technology and Practice, and the Practice Leader for Hydrology. I have held this role for approximately 5 years.

2 SKM is an engineering, sciences and project delivery firm based in Australia but with offices in New Zealand, Europe, the Middle East, South America and Asia. I have been employed by SKM since 1995.

3 As a direct report to the Chief Executive Officer of SKM, I assist with developments in SKM's technology and delivery capabilities, technical leadership, investment in research and development, the quality of service delivery, knowledge management, and our information systems.

4 As the Practice Leader for Hydrology at SKM, I provide leadership within the specialist technical field of hydrology, so that projects are undertaken with the appropriate level of technical review and input. I am also responsible for improving knowledge sharing and networking across the firm within the hydrological community of practice.

5 In 2003, I had the title of "Principal Hydrologist". In that role, I was SKM's lead technical reviewer for the hydrological investigations into flood behaviour commissioned by the Brisbane City Council.

6 Prior to 1995, I held various roles including five years with the Rural Water Commission of Victoria, three years with the water, energy and resources consultancy GHD Australia, and several years with Cementation International in London. I also undertook research at the University of Melbourne for submission of a Doctorate of Philosophy (for 3 years), and at the University of London for partial fulfilment of a Master of Science degree.

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Qualifications and Experience

7 I hold the following academic qualifications:

(1) Bachelor of Engineering (Agriculture) from the University of Melbourne (1980);

(2) Master of Science (in Engineering Hydrology) from the University of London (1985);

(3) Diploma of Imperial College, University of London (1985); and

(4) Doctor of Philosophy, University of Melbourne (1990).

8 I hold the following professional affiliations:

(1) Fellow, Institute of Engineers, Australia;

(2) Australian Representative, Floods Committee, International Committee on Large Dams;

(3) Member Hydrology Sub-committee, NSW Dams Safety Committee;

(4) Honorary Fellow, Department. Civil Engineering., Monash University; and

(5) Past Honorary Fellow, Dept. Civil and Environmental Engin., University of Melbourne.

9 I have over thirty years experience in various organisations in Australia and overseas, covering academia, public service, and private industry. I was the lead author of the current Australian guidelines for the estimation of large to extreme floods, and I am on Engineers Australia's Technical Steering Committee for the ongoing revision of the general guidelines for design flood estimation. I have worked on numerous projects concerned with the assessment of flood risk across Australia, in every State and Territory. I have performed consulting and advisory services and carried out independent technical reviews for the majority of major dam owning and other water resource agencies in Australia as well as participated in expert panels in formal flood risk assessment processes. I have also performed consulting and advisory services for several U.S. agencies providing input for the development of flood estimation practice and related guidelines on the characterisation of flood risk.

10 I have published over 150 research papers on engineering and environmental hydrology in refereed journals, books, and conference proceedings, and have won several national and international awards for my contribution to professional practice, including:

(1) Named as member of "Top 100 Most Influential Engineers" in Australia, 2009;

(2) National Civil Engineer of the Year, awarded by the Institution of Engineers, 2000;

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(3) Engineers Australia "W.H. Warren Medal" for the best paper in Civil Engineering (awarded three times in 1992, 1998, and 2005);

(4) American Society Civil Engineering Journal of Irrigation and Drainage Engineering "Best Research Paper Award" (1997); and,

(5) G.N. Alexander Medal (1998) for the best paper in Hydrology and Water Resources, (Engineers Australia).

11 For convenience, I have attached my curriculum vitae as **Annexure RJN1**.

This statement

12 This statement is provided in response to a notice issued by the Queensland Floods Commission of Inquiry (**Commission**) to me pursuant section 5(1) of the *Commission of Inquiry Act* 1950 (QLD) dated 22 September 2011 (**Request for Information**). Attached as **Annexure RJN2** is a copy of the Request for Information. I note that the Commission has confirmed that paragraph number 1 in the Request relates only to Brisbane River flood related studies performed for the Brisbane City Council during the relevant period.

13 The statements I make below in paragraphs 14 to 43 are my best recollection of the matters referred to in the Request for Information. I have also refreshed my memory by reviewing the documents referred to below.

Response to Request for Information

A brief overview of the work done for the Brisbane City Council by SKM during the period 2000 - 2004, and a list of reports (draft and final) prepared by SKM

14 Between July and December 2003, SKM conducted an investigation for Brisbane City Council (**BCC**) into the likely 1 in 100 annual exceedance probability (AEP) peak flow rate (the "Q100" event) at Savages Crossing and the Brisbane Port Office Gauge (defined below as the **2003 Study**). Further details of the 2003 Study are provided below at paragraph 27 and following.

15 As far as I am aware, the 2003 Study was the first Brisbane River flood related study undertaken by SKM for BCC during the period 2000 to 2004.

16 Prior to finalising the 2003 Study, a number of draft reports were issued to BCC and the Independent Review Panel (as defined below) for review, as follows:

(1) Flood Frequency Analysis of Brisbane River: Draft B (dated 8 August 2003 and issued on 22 August 2003) – a copy of which is attached to this statement as **Annexure RJN3**;

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(2) Brisbane River Flood Study: Further investigations of hydrology incorporating dam operations and CRC-FORGE rainfall estimates: Draft B (dated and issued on 29 August 2003) – a copy of which is attached to this statement as **Annexure RJN4**;

(3) Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates: Final (dated 7 October 2003) – a copy of which is attached to this statement as **Annexure RJN5**; and

(4) Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates: Final (dated and issued on 13 November 2003) – a copy of which is attached to this statement as **Annexure RJN6**; and

(5) Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates: Final Issue (compiled 9 December 2003) – a copy of which is attached to this statement as **Annexure RJN7**.

17 The final complied version of the 2003 Study is entitled "Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates: Final Issue (compiled 18 December 2003) – a copy of which is attached to this statement as **Annexure RJN8**.

18 I note that the final version of the 2003 Study refers to two additional documents issued during the course of the study (at page iii of the report under the heading "Document history and status"), namely:

(1) Statistical Flood Frequency: Draft A (issued 13 August 2003); and

(2) Hydrological modelling: Draft A (issued 22 August 2003).

19 As at the date of affirming this statement, I have not been able to locate those documents.

20 During the period November 2003 – February 2004, SKM was engaged by BCC to re-calibrate the section of the MIKE-11 hydraulic model that lay within the Brisbane City boundary. The study provided an estimate of the Q100 *flood level* based on the Q100 *peak flow value* recommended by the Independent Review Panel (i.e. 6000 m^3/s). In essence, this report describes the refinement of the hydraulic model used in 2003 (**Annexure RJN8**), but using the (slightly lower) Q100 estimate as recommended by Independent Review Panel. I was not directly involved in this study but was aware that it was being undertaken. I understand that the following draft and final reports were issued by SKM to BCC:

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(1) Recalibration of the MIKE-11 hydraulic model and determination of the 1 in 100 AEP flood levels: Draft dated 23 December 2003 – a copy of which is attached to this statement as **Annexure RJN9**; and

(2) Recalibration of the MIKE-11 hydraulic model and determination of the 1 in 100 AEP flood levels: Final (dated and issued 5 February 2004) – a copy of which is attached to this statement as **Annexure RJN10**.

21 I note that the final version of report referred to above indicates that two additional documents were issued during the course of the study (at page ii of the report under the heading "Document history and status"), being:

(1) Recalibration of the MIKE-11 hydraulic model and determination of the 1 in 100 AEP flood levels: Draft 0 (issued 16 January 2004); and

(2) Recalibration of the MIKE-11 hydraulic model and determination of the 1 in 100 AEP flood levels: Draft 1 (issued 29 January 2004).

22 As at the date of affirming this statement, I have not been able to locate those documents.

23 In July 2004, SKM was also engaged by BCC to calculate flood peaks and levels for exceedance probabilities of 10%, 5%, 2%, and 0.05% - these were provided to complement the Q100 (1%) estimates provided in February 2004 as discussed in the preceding paragraph. I was not directly involved in this study but was aware that it was being undertaken. I understand that the following draft and final reports were issued by SKM to BCC:

(1) Calculation of the Floods of Various Return periods on the Brisbane River: Q10, Q20, Q50 & Q2000 Events: Draft dated 3 March 2004 – a copy of which is attached to this statement as **Annexure RJN11**; and

(2) Calculation of the Floods of Various Return periods on the Brisbane River: Q10, Q20, Q50 & Q2000 Events: Final dated 6 July 2004 – a copy of which is attached to this statement as **Annexure RJN12**.

24 Also attached are documents (including correspondence and file notes dated between 14 February 2004 and 18 March 2004) which I understand that the 2004 studies referred to in paragraphs 20 and 23 above (bundle attached as **Annexure RJN13**).

25 I understand that SKM does not have any record of any further report or study being produced for BCC in 2004.

26 As I was not involved in the further work undertaken by SKM for BCC following the 2003 study, I do not comment on that subsequent work any further in this statement (except as noted in paragraph 58, below).

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Instructions/brief from Brisbane City Council (both at the start of the study and any further instructions or clarifications given during the study)

27 To the best of my recollection, the BCC approached SKM to review the Brisbane River catchment hydrology estimates in or about July 2003 (**2003 Study**).

28 The instructions/brief for the 2003 Study were developed jointly between BCC and SKM as a result of two meetings between representatives of BCC and SKM on or about 30 June and 8 July 2003.

29 The outcomes of those meetings are summarised in letters from the SKM Project Manager, Mark Salisbury, to Peter Barnes of the Water Resources Department of BCC, dated 1 July 2003 and 8 July 2003 respectively. Attached to this statement are copies of those letters along with additional documents relating to the 2003 Study, all of which are listed at paragraph 42.

30 By a letter dated 12 August 2003, BCC confirmed its engagement of SKM to review the Brisbane River hydrologic and hydraulic models. I have assumed that the reference in the letter of engagement to a fax from SKM to BCC "dated 4 July 2003" is a typographical error and is intended to refer to the letter from SKM to BCC dated 8 July 2003 which sets out a proposed scope of works. Attached below as **Annexure RJN28** is a copy of the letter of engagement from BCC to SKM dated 12 August 2003.

31 In brief, the scope of work for the 2003 Study comprised:

(1) Collection and collation of streamflow data;

(2) At-site and regional flood frequency analyses of flood maxima (i.e. the statistical analysis of historic flood peaks to characterise flood risk under "pre-dam" conditions);

(3) Configuration of flood event model (RAFTS) and review of associated inputs to allow comparison of results with flood frequency analysis (i.e. this allows reconciliation of flood estimates with two independent estimates); and

(4) Use of RAFTS model to characterise flood risk under various operating scenarios with the prime aim of estimating the Q100 flow and level at the Port Office under current conditions.

In this regard, I refer to scope of work outlined in letter from SKM to BCC dated 8 July 2003.

32 The BCC set a timeframe to complete the study. SKM was required to undertake and deliver the results of the study by 30 September 2003.

33 The data, assumptions and information used by SKM in carrying out the 2003 Study included:

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(1) stream gauge information supplied by the Department of Natural Resources and Mines (**DNRM**) and the Commonwealth Bureau of Meteorology (referred to in final version of the 2003 Study dated 18 December 2003 at page 9, section 2, a copy of which is attached as **Annexure RJN8**);

(2) information on the characteristics of large rainfalls supplied by Co-operative Research Centre for Catchment Hydrology (referred to at section 4.3.1 in final version of the 2003 Study dated 18 December 2003, a copy of which is attached as **Annexure RJN8**);

(3) spatial distribution data supplied by BCC (referred to at Section 4.3.2 in final version of the 2003 Study dated 18 December 2003, a copy of which is attached as **Annexure RJN8**).

34 DNRM provided SKM with synthetic data estimates of "no dams" and "with dams" flood peaks at Savages Crossing (both to include and exclude the influences of the dams where appropriate) (referred to in the final version of the 2003 Study dated 18 December 2003 at page 9, section 2 and Appendix D, a copy of which is attached as **Annexure RJN8**).

35 DNRM also provided SKM with the dam operations model to determine outflows from Wivenhoe and Somerset Dams (referred to at Section 4.1 in final version of the 2003 Study dated 18 December 2003, a copy of which is attached as **Annexure RJN8**).

36 At the first meeting held with representatives of BCC on 1 July 2003, BCC indicated that it intended to create and engage an independent expert review panel (**Independent Review Panel**) to review the methodology used by SKM to determine the Q100 flow at the Brisbane Port Office, and to produce a report summarising their opinions and recommendations. In this regard I refer to the Terms of Reference for Brisbane River Flood Study Independent Expert Review Panel, which is an Appendix to the document entitled "Review of Brisbane River Flood Study" Report to Brisbane City Council, Independent Review Panel, dated 3 September 2003, a copy of which is attached as **Annexure RJN14**).

37 The Independent Review Panel was engaged directly by BCC and comprised [redacted] (as Chair), Colin Apelt, [redacted] and Erwin Weinmann.

38 The Independent Review Panel met for the first time on 31 July 2003. I also attended that meeting by telephone. A number of representatives from BCC (including Barry Ball and Gavin Blakey) also attended the meeting. At that meeting, I briefed the Independent Review Panel on the work that SKM was presently undertaking.

39 As the study progressed during July and August 2003, issues of technical detail were discussed in formal meetings held between all or a combination of BCC, SKM, DNRM and the Independent Review Panel. These formal meetings were supplemented by informal

exchanges between SKM project team members and representatives of BCC, DNRM and the Independent Review Panel. I recall that the general tone of all such discussions was constructive, and at no point were any additional instructions or clarifications given that materially departed from the original brief.

40 Drafts of the 2003 Study were produced to the Independent Review Panel as noted in paragraph 16 above. Attached to this statement and marked **Annexure RJN5A**, **Annexure RJN5B** and **Annexure RJN5C** respectively are copies or extracts of the Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates: Final (dated 7 October 2003) (the document identified as **Annexure RJN5**), containing various handwritten notes (none of the annotations appear to be in my handwriting).

41 As noted above, the final version of the 2003 Study is dated 18 December 2003, a copy of which is attached as **Annexure RJN8**. Successive draft reports provide an increasing level of detail and clarity around the investigations undertaken, but I do not believe that there were any material changes to the flood flow (or level) estimates provided over this review period.

42 Attached to this statement are also the following additional documents relating to the 2003 Study:

(1) Document entitled "Action Plan for Tasks from 1 July 2003" – a copy of which is attached to this statement as **Annexure RJN15**;

(2) Letter from SKM [redacted] to BCC (Peter Barnes) dated 1 July 2003 – a copy of which is attached to this statement as **Annexure RJN16**;

(3) Document entitled "Brisbane River Flood Study Meeting - Notes from Meeting 1 dated 8 July 2003" – a copy of which is attached to this statement as **Annexure RJN17**;

(4) Letter from SKM [redacted] to BCC – Waterways (Peter Barnes) dated 8 July 2003 – a copy of which is attached to this statement as **Annexure RJN18**;

(5) Progress report from Gavin Blakey (Water Resources) to Barry Ball (Water Resources) copied to project team dated 11 July 2003 – a copy of which is attached to this statement as **Annexure RJN19**;

(6) Document entitled "Brisbane River Flood Study Meeting - Notes from Meeting 2 dated 14 July 2003" – a copy of which is attached to this statement as **Annexure RJN20**;

(7) Letter from SKM (Mark Salisbury) to BCC (Gavin Blakey) dated 18 July 2003 – a copy of which is attached to this statement as **Annexure RJN21**;

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(8) Letter from SKM [redacted] to BCC (Gavin Blakey) dated 25 July 2003– a copy of which is attached to this statement as **Annexure RJN22**;

(9) Document entitled "Brisbane River Flood Study – Expert Review Panel: Notes from Meeting 1 dated 31 July 2003" – a copy of which is attached to this statement as **Annexure RJN23**;

(10) Letter from SKM ([redacted] to Brisbane City Council (Gavin Blakey) dated 25 July 2003 concerning the week ending 3 August 2003 – a copy of which is attached to this statement as **Annexure RJN24**;

(11) Document entitled "Brisbane River Flood Study Meeting - Notes from Meeting 3 dated 6 August 2003" – a copy of which is attached to this statement as **Annexure RJN25**;

(12) Progress report from Gavin Blakey (Water Resources) to Barry Ball (Water Resources) copied to project team dated 8 August 2003 – a copy of which is attached to this statement as **Annexure RJN26**;

(13) Letter from SKM [redacted] to Brisbane City Council (Gavin Blakey) dated 25 July 2003 concerning the week ending 10 August 2003 – a copy of which is attached to this statement as **Annexure RJN27**;

(14) Letter of engagement from BCC (Don Carroll) to SKM dated 12 August 2003 – a copy of which is attached to this statement as **Annexure RJN28**;

(15) Progress report from Ken Wood (Water Resources) to Barry Ball (Water Resources) copied to project team dated 15 August 2003 – a copy of which is attached to this statement as **Annexure RJN29**;

(16) Letter from SKM ([redacted] to Brisbane City Council (Gavin Blakey) dated 25 July 2003 concerning the week ending 17 August 2003 – a copy of which is attached to this statement as **Annexure RJN30**.

Input parameters provided by Brisbane City Council to SKM

43 I do not recall BCC providing any specific input parameters that were required to be used in the 2003 Study. As noted above, a number of matters of technical detail arose during the course of the study as results were progressively provided, and these were discussed as between SKM, BCC and the Independent Review Panel and resolved and/or incorporated on the basis of technical merit.

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Opinion as to whether those instructions/brief and input parameters are likely to yield the best estimate of the 1% AEP flood (Q100)

44 I believe the instructions/brief developed at the commencement of the 2003 Study, and the refinement of the approach developed during the course of the work, were suited to providing a sound estimate of the Q100 based on information available as at July 2003 and given the time constraints imposed upon completion of the 2003 Study. Had more information been available and had there been more time to undertake further analysis, then it would have been possible to improve upon the estimate provided (that is, reduce the level of uncertainty involved, which may or may not have resulted in a different "best estimate").

45 I had discussions with representatives of BCC and Professor [redacted] and Mr Weinmann concerning the desirability of using a Monte Carlo approach to estimating the Q100 flow at the Brisbane Port Office in or about August 2003. I also understand that this issue was raised at a meeting with the Independent Expert Panel on 14 August 2003 (attached at **Annexure RJN31** is a copy of the minutes of that meeting – I did not attend the meeting). While in concept, adoption of this approach would have yielded an improved estimate of the Q100 (with a reduced level of uncertainty), its implementation could not have been completed within the required timeframe.

Opinion as to whether the results of studies during 2000-2004 were an underestimate or overestimate of the 1% AEP flood (Q100) and why

46 It is truly difficult to assess whether the 2003 Study yielded an underestimate or overestimate of the Q100 flood. On the basis of the information available within the time and practical constraints that applied and accepted hydrologic practice at the time, I consider that the estimate of the Q100 provided in 2003, along with the notional range of uncertainty, to be based on a sound hydrological approach that was appropriate within the constraints that applied to the project.

47 However, events recorded since 2003, and advances in relevant design information and professional practice would lead to an improved estimate of the Q100 if the same analysis were undertaken today (again, by "improved", I mean provision of an estimate with reduced uncertainty bounds, which may or may not result in a different "best estimate"). Before proffering an opinion it is necessary to provide some hydrological context for why the opinion sought by the Commission, without analysis, is inherently speculative.

48 Flood levels in the lower Brisbane River (both historic and the Q100) are heavily dependent on both "stochastic" and "deterministic" influences. The former relate to the capricious variability of Mother Nature, and the latter mainly relate to the impacts of dam operation associated with flood control and water supply decisions over previous years, as well as the influence of downstream floodplain storage. It is relatively straightforward to examine history to make

inferences about the impacts of stochastic factors, but the analysis of combined "stochastic-deterministic" systems is highly complex and requires rigorous methods of analysis to resolve.

49 I recognise that it is tempting to conclude that the occurrence of three major floods such as 1893, 1974, and 2011 might suggest that the current Q100 is underestimated. However, there are number of factors that confound such an inference, specifically:

(1) changing river bathymetry in the lower Brisbane River and land-use conditions in the entire catchment (deterministic);

(2) construction and operation of the upstream dams (deterministic);

(3) the complexity with which the flood producing factors combine (stochastic); and,

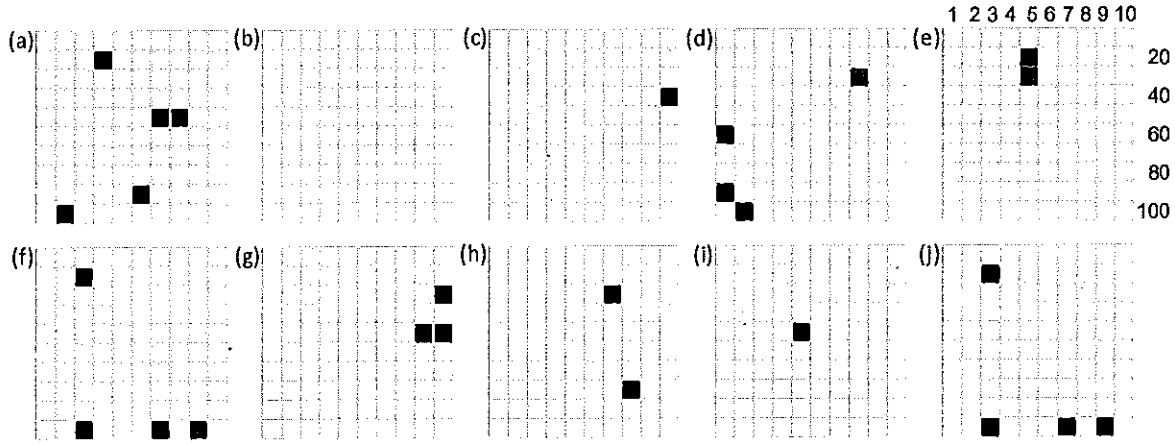
(4) the arrival probability (ie likelihood) of extreme rainfalls (stochastic).

50 The first above factor would tend to cause flood levels to increase within the City of Brisbane, and the second factor would obviously work to reduce flood impacts. With respect to the third factor, the manner in which flood producing factors combine in a catchment as large and complex as Brisbane River is highly complicated, and this greatly confounds the ability to assess flood risks based on the short historic periods over which flood behaviour can be assumed to be constant. By comparison with the first three, the statistical likelihood of extreme rainfalls is reasonably straightforward to characterise, though by its nature is hard to predict over a given time period. All these influences have a material impact on flood likelihoods, and accordingly any professional opinion of value needs to be underpinned by careful analysis.

51 It needs to be recognised that the term "Q100" is easily misunderstood, and it is worth clarifying its use for assessing flood risks. Most non-specialists would assume that the Q100 refers to a flood that occurs once every 100 years. This is a misleading interpretation, and it is more accurate to treat the Q100 as a flood that has a *1 in 100 chance of being exceeded in any one year*; that is, it has the same chance that a ball lands on one particular number in a roulette wheel with a hundred pockets. The likelihood that *one or more* "Q100" events occur in a 100 year period is around 2 in 3 (a little over 60%); to continue with the roulette metaphor, this is analogous to the likelihood that the ball lands on a particular number one or more times after one hundred spins of the wheel.

52 By way of simple illustration, the following diagram represents 10 different 100 year periods selected from one hundred such simulations; each panel (*a* to *j*) contains 100 small squares each of which represent a single year, and the solid squares illustrate those years in which the Q100 was equalled or exceeded. The ten selected periods shown in this diagram were selected for illustration purposes, and do not represent equally likely outcomes. These flood simulations were undertaken using a rigorous mathematical technique to generate flood exceedances; the details of the statistics involved are not important here, but it is sufficient to

note that the likelihood of exceeding the Q100 in any one year is 1 in 100, and that the patterns observed from one year to the next are the same as that found in nature. It is seen that in one of the 100 year periods that the Q100 was never exceeded (panel *b*); in another it was exceeded just the once (panel *d*). In another 100 year period (panel *g*) it is seen that the Q100 was exceeded three times in the first 50 years but no exceedances were observed in the latter half of the century; after the last two exceedances which occurred in successive years, one could be forgiven for suspecting that the Q100 was underestimated. There is even one century (panel *a*) in which the Q100 was exceeded five times. It should be stressed that these patterns are all generated from the same distribution of annual floods: they just represent different possible outcomes that might be observed in a 100-year sequence.



53 The point of the above illustration is merely to stress that observing a flood bigger than the Q100 event two or more times in a hundred year period doesn't necessarily mean that the estimate of the Q100 is wrong or an under or over estimate; it is just less likely than if we observed only one exceedance.

54 To comment on more event-specific matters, it is evident from recent analysis[1] that for the January 2011 event the annual exceedance probability of the *rainfalls* over the whole catchment above Brisbane is around 1 in 100 to 1 in 200, though the annual exceedance probability of the most extreme point rainfalls that occurred in the centre of the Brisbane River catchment (downstream of the dam) is likely to be between 1 in 500 and 1 in 2000. We can be much more confident in our assessment of rainfall probabilities than we can floods for the reasons touched upon in paragraph 48 above. I am thus reasonably confident in stating that the catchment rainfalls associated with the January 2011 event are rarer than 1 in 100.

55 The implication of the preceding paragraph is that if the rainfalls are rarer than 1 in 100, then the associated flood might also be rarer than 1 in 100. This implication is not as obvious as a

[1] *January 2011 Flood Event: Report on the operation of Somerset Dam and Wivenhoe Dam. Review of Hydrological Issues.* Report prepared by SKM for Seqwater, March 2011.

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non-hydrologist might think, but it is not unreasonable. If this implication is accepted, then it necessarily follows that the January 2011 flood level is higher than the Q100. In other words, the fact that the January 2011 floods were larger than the Q100 does not necessarily lead me to assume that the estimates provided in 2003 were under-estimated.

56 In summary of the above points, it is thus my view that:

(1) This is a complex "stochastic-deterministic" system, and without rigorous analysis it is truly difficult to assess whether the 2003 study yielded an underestimate or overestimate of the Q100 flood;

(2) the occurrence of perhaps three floods greater than the Q100 in the past 120 years is not sufficiently improbable to allow me to conclude that the current Q100 estimate is low especially given that the first two events occurred prior to the construction of Wivenhoe Dam; and

(3) rainfalls associated with the January 2011 event were rarer than 1 in 100, and thus it is likely that the associated floods were also larger than the Q100 at Brisbane.

57 In short, I believe that a system as complex as the Brisbane River requires careful analysis of modelling inputs and outcomes. That said, taking into account the further information that is now available, I would be surprised if a revised estimate of the Q100 proves to be lower than that estimated in 2003; conversely, I would not be surprised if it proved to be higher. Based on the information available at the time, I consider the estimate of the Q100 in the 2003 Study is based on a sound hydrological approach that was appropriate within the constraints that applied to the project.

58 Subsequent advice provided to BCC in 2004 (as documented in **Annexures RJN10** and **RJN12**) was based on the Q100 estimate recommended by the Independent Review Panel (namely 6000 m^3/s) and not that originally recommended by SKM (namely, 6500 m^3/s). I was comfortable at the time that the lower estimate recommended by the Independent Review Panel was adopted for these subsequent studies as this represented the outcomes of a formal review process, and the difference lay well within the reported uncertainty inherent in these estimates. I do not think this difference is sufficient to be considered an "underestimate" in comparison to the estimate provided by SKM in 2003.

An explanation of how techniques used to estimate the 1% AEP flood (Q100) changed between 1996 and 2004

59 The studies undertaken by SKM in 1998 and 2003 used both "flood frequency" and "rainfall-based flood event" modelling to estimate the Q100. The former approach involves the statistical analysis of a (preferably) long period of historic floods, and the second generally

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involves the inputting of "1 in 100" rainfalls into a computer model that represents the flood response of a catchment to extreme rainfalls. While both studies used broadly similar approaches, they differed markedly in the emphasis given to each.

60 The 2003 Study was able to take advantage of information that was not previously available, namely:

(1) Additional information on historical floods that was prepared by DNRM using observed and modelled data; this information primarily related to Savages Crossing under "no dam" conditions, and was important in understanding the stochastic nature of flood behaviour in the catchment.

(2) New research into the characteristics of large rainfalls, provided by the Cooperative Research Centre for Catchment Hydrology, which provided the primary input to the flood event model adopted; the effective rainfalls used to estimate the Q100 event in 2003 were lower than that used in the 1998 model.

(3) Improvements in the hydrodynamic model (used to route flows along the Brisbane River) arising from a study undertaken for Ipswich City Council.

(4) Revised operating procedures for Wivenhoe and Somerset Dams (also provided by DNRM)

61 The availability of additional flood maxima in 2003 allowed a more robust and sophisticated statistical approach to be used in the flood frequency analysis. To this end, the study made use of software developed by Prof [redacted] of Newcastle University which was only made available in 1999.

62 The new information available in 2003 allowed:

(1) greater emphasis to be given to the statistical analysis of historical floods; and,

(2) more refined modelling of the factors that influence the conversion of extreme rainfalls to floods.

63 In 2001 I developed and implemented a Monte Carlo (or joint probability) simulation framework for the assessment of flood risks. This technique recognises that any design flood characteristics (e.g. peakflow) may result from a variety of combinations of flood producing factors, rather than from a single combination; the approach mimics natural flood processes in that the influence of all probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes. This was an innovation at the time, and while the work was used successfully to assess the flood risks for a dam in Victoria and submitted for peer review in a research publication, this approach did not

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represent accepted hydrologic practice in 2003. Strictly speaking this approach represented a change in available technique between 1998 and 2003, but it was not practical to implement it within the required project timeframe.

Opinion as to whether the approach taken or results derived by the Independent Expert Panel (Professor Mein, Colin Apelt et al) in their September 2003 review was an underestimate or overestimate of the 1% AEP flood (Q100) and why

64 I was, and still remain, in broad agreement with the opinions expressed by the Independent Expert Panel in 2003, including all matters of substance related to the assessment of the conceptual framework adopted, its implementation, the hydrologic inferences made, and the Panel's recommendations.

65 As noted in paragraph 58 above, the Panel adopted a final Q100 that was 500 m^3/s lower than that recommended by SKM. Given the stated range of uncertainty I do not think this difference represents a material difference from SKM's "best estimate" (as identified in Table 6-2 of **Annexure RJN8**), and thus I do not think their adopted Q100 was necessarily either an under-estimate or an over-estimate.

Opinion as to whether the results of the flood study completed in 1998 was an underestimate or overestimate of the 1% AEP flood (Q100) and why

66 While I consider the overall approach followed in 1998 to be reasonable, the inputs used to derive the estimate of Q100 were based on conservatively high assumptions. As may be inferred from my comments in paragraphs 59 to 63 above, the main factors that resulted in the 1998 estimate of the Q100 being higher than the 2003 estimate were as follows:

(1) the catchment rainfalls used in 1998 as inputs to the flood-event model were higher than those in 2003 (the later study used information developed by the Co-operative Research Centre for Catchment Hydrology that was not previously available);

(2) the adopted (initial) loss rates were lower;

(3) different dam operating rules were adopted;

(4) revision of the flood operations manual for Wivenhoe and Somerset dams; and,

(5) additional information on historical floods was provided by DNRM which provided an improved understanding of flood behaviour in the catchment.

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Opinion as to the opinions expressed by Professor Mein in his review of the 1998 study, in particular whether you agree that the result produced by SKM's study was an overestimate of the Q100

67 I was, and still remain, in broad agreement with the opinions expressed by [redacted] in his review of the 1998 study.

68 For the reasons discussed above in paragraph 66, I believe that the estimate of the Q100 provided by SKM in 1998 was based on conservatively high assumptions. It would be expected that such assumptions would lead to the Q100 being over-estimated, but at the time of the study consideration may have been given to other compensating factors that suggested otherwise. From the perspective provided by the information available to me in 2003, I believe the result produced in 1998 was an over-estimate.

A brief overview of opinion as to how a flood study should be conducted in 2011 to obtain a best estimate of the 1% AEP flood (Q100)

69 In brief, a revised estimate of the Q100 should be undertaken by giving consideration to:

(1) Hydroclimatic observations collected since 2003;

(2) Review of rating curve information at selected key streamflow gauges;

(3) Review of catchment routing parameters used in hydrologic model;

(4) Refinement of hydroclimatic design inputs;

(5) Adoption of a Monte Carlo (joint probability) framework;

(6) Reconciliation of peak and volume flood exceedance probabilities against independent estimates based on historical observations;

(7) Incorporation of current data on river bathymetry and floodplain storage; and,

(8) Further improvement in the hydrodynamic model of the Brisbane River.

These points are expanded upon briefly below.

70 The data collected during the January 2011 event represents the most comprehensive coverage of a severe event that I know of, and this, in combination with information on other events that has been collected since 2003, would provide an immensely valuable data set for calibration and testing.

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71 The rating tables developed for key flow gauges on the Brisbane River are subject to appreciable uncertainty for a variety of reasons; while their accuracy has been improved in recent times by the use of a hydrodynamic model, further review and improvement of this information would be desirable.

72 Hydroclimatic information collected on major flood events since 2003 should be prepared and used to refine the calibration (and validation) of the routing parameters of the hydrologic flood model (ie, the parameters that control the flood response of the catchment for a given input of rainfall).

73 I understand that the Bureau of Meteorology is currently in the process of refining estimates of the 1 in 100 rainfalls (and for other exceedance probabilities) and this information should be used to update the rainfall inputs used to derive the required design floods. In addition, historic data sets should be carefully examined to derive inputs necessary for input to the Monte Carlo simulation framework.

74 The rainfall-based estimation of floods should be undertaken using a Monte Carlo framework in which the joint probabilities of the different temporal and spatial patterns of rainfall, antecedent conditions, initial and event infiltration losses, storage level, gate operation, and possibly tidal influences can be explicitly considered. This approach is based on multiple model simulations (involving several thousands of runs) where all the possible combinations of inputs are considered in a manner that reflects the likelihood of their occurrence. The magnitude of the flood exceedance probabilities can then be determined through a careful statistical analysis of the modelled outputs.

75 The flood level in the reservoirs and floodplain inundations below the dam are the *combined* result of both the *peak* and the *volume* (ie the whole shape) of the influent flood hydrographs and the tide. The shape of the simulated flood hydrographs are dependent on routing parameters adopted in the model (paragraph 72), the manner in which the different rainfall inputs and associated flood influencing factors come together in any particular event (paragraph 74), and the gate operations. As discussed above (in paragraphs 48 to 53), this represents a complex "stochastic-deterministic" system, and the best way that confidence can be had in the estimated flood exceedances of such a system is if the *exceedance probabilities of both the modelled flood peaks and volumes* are reconciled with corresponding metrics inferred from historical data sets. Thus, in addition to being able to compare the modelled and observed hydrographs for a significant flood event (eg January 2011), it is important that the exceedance probabilities of the salient flood characteristics are reconciled with the historical record. This is a significant body of work, yet it is the only practical means that I know of to derive a rigorous assessment of the flood risks involved.

76 The bathymetry of the Brisbane River downstream of Wivenhoe Dam may have changed appreciably following the events of January 2011, and thus it would be important to ensure

that any such changes are correctly represented in the hydrodynamic model. This should extend to the incorporation of any additional, or suspected modified, information on floodplain conditions to help ensure that the overbank storage represented in the hydrodynamic (and possibly the hydrologic) models are correctly represented.

77 The nature of flooding downstream of Somerset and Wivenhoe Dams is heavily dependent on how the dams are operated during flood conditions. Any revision of the flood operating procedures thus needs to be incorporated into the study so that the impact on flood exceedance probabilities is correctly represented.

78 The hydrodynamic model is an important tool that allows the estimates of *flood flows* to be converted to *flood levels* along the lower reaches of the Brisbane River. This model should be refined to take advantage of additional survey information that may be available (see previous point), where particular attention needs to be given to the representation of the Lockyer and Bremmer inflow tributaries. Once these refinements have been incorporated, the model should be validated against a number of historic flood events for which suitable information can be obtained.

Affirmed by the deponent)
at Melbourne)
in Victoria) [redacted]
on 4 October 2011) Signature of Dr Roderic John Nathan, F.I.E.Aust.
Before me:)

[redacted]
Signature of witness

[redacted]
452 Flinders St, Melbourne 3000
An Australian Legal Practitioner
within the meaning of the
Legal Profession Act 2004

[redacted]
Signature: Roderic John Nathan

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Signature: Witness

In the matter of the Queensland Floods Commission of Inquiry 2011

A Commission of Inquiry under the Commissions of Inquiry Act 1950

And Pursuant to the Commissions of Inquiry Order (No. 1) 2011

Statement of Roderic John Nathan

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Annexure	Details	Paragraph/s
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RJN26	Progress Report from Gavin Blakey to Barry Ball dated 8 August 2003	42(12)
RJN27	Letter from [redacted] (SKM) to Gavin Blakey (BCC) dated 25 July 2003 – Progress Report Week Ending 10 August 2003	42(13)
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Curriculum Vitae



Dr Rory Nathan

Practice Leader Hydrology

Qualifications

- B.E.(Agr), University of Melbourne, 1980
- M.Sc., D.I.C., University of London, 1984
- Ph.D., University of Melbourne, 1990

Affiliations

- Fellow, Institution of Engineers, Australia
- Australian Representative, Floods Committee, International Committee on Large Dams
- Member Hydrology Sub-committee, NSW Dams Safety Council
- Honorary Fellow, Department. Civil Engineering., Monash University
- Past Honorary Fellow, Dept. Civil and Environmental Engin., University of Melbourne

Awards

- Named as member of "Top 100 Most Influential Engineers" in Australia, 2009
- National Civil Engineer of the Year, awarded by the Institution of Engineers, 2000
- W.H. Warren Medal (1992, 1998, and 2005) for the best paper in Civil Engineering (national award by the Engineers Australia).
- ASCE Journal of Irrigation and Drainage Engineering Best Research Paper Award (1997)
- G.N. Alexander Medal (1998) for the best paper in Hydrology and Water Resources, (national award by the Engineers Australia)
- Best presentation of a technical paper at the Hydrology & Water Resources Conf. (1993)
- ACEA Award of Excellence (1998).
- Victorian Engineering Excellence Award (2003).

Fields of Special Competence

Dr Rory Nathan has around 30 years experience in engineering hydrology in both the academic and consulting fields. He is actively involved in a number of research projects under the auspices of Engineers Australia and with the University of Melbourne. While he has generally worked in areas of flood estimation, hydrological processes, regionalisation, and catchment hydrology, he has developed specialist skills in the following areas:

- Estimation of extreme hydrologic events (floods and low flows)
- Characterisation of risk for dam safety
- Hydrologic estimation in ungauged catchments
- Regionalisation of hydrologic information
- Characterisation of flow regimes for environmental flows
- Modelling and simulation of hydrologic processes
- Hydrologic model development and application

Relevant experience

- Convenor and senior author of the national guidelines for the estimation of large to extreme floods published by the Institution of Engineers Australia.

SKM

- Contracted by the U.S. Bureau of Reclamation to provide input to the development of guidelines on the characterisation of hydrologic inputs for risk analysis
- Contracted by the U.S. Army Corps of Engineers to help formulate research directions to be undertaken in the area of hydrologic risk using federal agency funding
- Contracted by the Murray Darling Basin Commission to oversee and review the flood risk assessment of Hume Dam being undertaken by NSW State Water (and SMEC).
- Member of panel undertaking risk review of the Dam Safety Program for Western Australia's South-West Irrigation Dams
- Member, Expert Review Panel for the Preliminary Risk Assessment of the portfolio of dams owned by the Hydro-Electric Authority, Tasmania
- Member, Expert Review Panel for the Preliminary Risk Assessment of Somerset, Wivenhoe, and North Pine Dams owned by the South East Queensland Water Board
- Member, Expert Review Panel for the upgrading of Rosslynne Dam owned by the Southern Rural Water
- Project Manager consequence assessment and risk characterisation of Dartmouth Dam (Goulburn-Murray Water)
- Project Director for the consequence assessment and risk characterisation of Hume Dam (DLWC, NSW)
- Variously Project Manager and Project Director for the estimation of hydrologic loads, risk characterisation, and consequence assessment of several dams owned by Goulburn-Murray Water (and its predecessor the Rural Water Corporation); Dartmouth, Eildon, Cairn-Curran, Nillhacootie, Laanacoorie, Mokoan, Waranga, Buffalo, Fyans, Bellfield, Rocklands,
- The estimation of hydrologic loads and review of spillway adequacy for many major water storages owned by the (then) Rural Water Corporation (Eildon, Dartmouth, Laanacoorie, Wartook, Bellfield, Fyans, Waranga, Lonsdale, Rocklands, Pine, Taylors, Cairn-Curran, Tullaroop, Upper Coliban, Lauriston, Malmsbury, Buffalo, and Pykes Creek).
- Responsible for event tree development and risk characterisation of hydrologic inputs to the Preliminary Risk Assessment of all dams owned by the Snowy Mountain Hydro-Electric Authority.
- Responsible for the derivation and characterisation of hydrologic and hydraulic inputs to the Preliminary Risk Assessment of all dams owned by South Australia Water.
- Use of quantitative risk analysis for evaluation of floodplain development options for AMP
- Provision of advice to ACTEW/AGL on how to best account for climatic variability in the development of options for their future water supply options (ongoing)
- Assessment of the vulnerability to climate change and variability for the water resources of the Fitzroy River
- Project Director for the consequence assessment of four major dams owned by the Dept. of Land and Water Conservation, NSW (Blowering, Burrinjuck, Split Rock and Keepit)
- Project Director for the consequence assessment and risk characterisation of the Kiewa Hydroelectric Scheme (Southern Hydro)
- Expert reviewer of extreme event hydrologic studies undertaken by Melbourne Water (Upper Yarra and Devils Bend reservoirs)
- The estimation of hydrologic loads and review of spillway adequacy for O'Shannassy Reservoir (Melbourne Water).

SKM

Refereed Journal and Book Publications

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REQUIREMENT TO PROVIDE STATEMENT TO COMMISSION OF INQUIRY

I, Justice Catherine E Holmes, Commissioner of Inquiry, pursuant to section 5(1)(d) of the *Commissions of Inquiry Act 1950* (Qld), require Dr Rory Nathan to provide a written statement, under oath or affirmation, to the Queensland Floods Commission of Inquiry, in which the said Dr Nathan provides the following:

1. a brief overview of the work done for the Brisbane City Council by SKM during the period 2000 – 2004, and a list of reports (draft and final) prepared by SKM;

2. the instructions/brief from Brisbane City Council (both at the start of each study and any further instructions or clarifications given during the study);

3. the input parameters provided by Brisbane City Council to SKM;

4. his opinion as to whether those instructions/brief and input parameters are likely to yield the best estimate of the 1% AEP flood (Q100);

5. his opinion as to whether the results of studies during 2000 – 2004 were an underestimate or overestimate of the 1% AEP flood (Q100) and why;

6. an explanation of how techniques used to estimate the 1% AEP flood (Q100) changed between 1996 and 2004;

7. his opinion as to whether the approach taken or results derived by the Independent Expert Panel (Professor Mein, Colin Apelt et al) in their September 2003 review was an underestimate or overestimate of the 1% AEP flood (Q100) and why;

8. his opinion as to whether the results of the flood study completed by SKM in 1998 was an underestimate or overestimate of the 1% AEP flood (Q100) and why;

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9. his opinion as to the opinions expressed by Professor Mein in his review of the 1998 study, in particular whether you agree that the result produced by SKM's study was an overestimate of the Q100; and

10. a brief overview of his opinion as to how a flood study should be conducted in 2011 to obtain a best estimate of the 1% AEP flood (Q100).

Dr Nathan should attach relevant documents such as instructions, draft reports, final reports and correspondence including instructions, comments or directions to his statement.

In addressing these matters, Dr Nathan is to:

- provide all information in his possession and identify the source or sources of that information;
- make commentary and provide opinions he is qualified to give as to the appropriateness of particular actions or decisions and the basis of that commentary or opinion.

Dr Nathan may also address other topics relevant to the Terms of Reference of the Commission in the statement, if he wishes.

The statement is to be provided to the Queensland Floods Commission of Inquiry by 4pm, Tuesday 4 October 2011.

The statement can be provided by post, email or by arranging delivery to the Commission by emailing info@floodcommission.qld.gov.au.

[redacted]

Commissioner
Justice C E Holmes

Flood Frequency Analysis for Brisbane River Catchment Summary Report

FLOOD FREQUENCY ANALYSIS OF BRISBANE RIVER

- Draft
- 8/08/2003

Flood Frequency Analysis of Brisbane River

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1. Introduction

1.1 Background

An Expert Panel has been appointed to review the flood studies undertaken for the Brisbane River in SE Queensland, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for SKM were to:

- Undertake flood frequency analysis, and to
- Update the rainfall – runoff modelling results

The details of the tasks are presented in Appendix A.

1.2 Scope of Report

The subject of this report covers the first two points in Appendix A, namely to,

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.

This report gives an assessment of the flood frequency analysis undertaken with the available data.

The report has been prepared for expert reviewers and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, is assumed.

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2. Sources of Data

Gauging station data were obtained from the Department of Natural Resources and Mining (NRM) and the Commonwealth Bureau of Meteorology (BOM). Data of various typed was collected, including:

- recorded water elevation above the gauge datum,
- flow data estimated from a rating relationship and
- rating tables

were obtained. In some instances the data had been processed in some additional manner as discussed below.

A number of reports on large flood events and the analysis thereof have also been made available.

2.1 Selection of Data for Analysis

2.1.1 Department of Natural Resources and Mining Data

There are two sources of data from NRM:

- Recorded water elevation data and associated flow estimates
- Estimates of "no dams" flood peaks at Savages Crossing that adjusted to exclude the influence of the dam(s) where appropriate.
- Estimates of "no dams" flood peaks at Savages Crossing that adjusted to exclude the influence of the dam(s) where appropriate

Both data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.1.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in Appendix C (along with other sources of gauged data). The primary reasons for omission were:

- short record length,
- small catchment area, and/or
- uncertainty in the rating curve.

The latter reason included either very low gauged flow or the rating curve had been changed to a "calibration curve" for use in real time flood forecasting. It may be possible to include some of this



flow data for future analysis when questions regarding the adjustment made to the calibration curves have been resolved.

Elevation data for a number of sites of direct interest to this study, such as Moggill (40545), Brisbane City (40690) and the Port Office (040690) were also obtained.

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3. Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that SKM undertake flood frequency analysis of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (ie peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in Section 2.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- Adjustment of data for the influence of the dams
- Uncertainty in the rating curves that relate recorded river level to flow rate
- The magnitude of historic data (especially 1893 and 1825)
- The period of record associated with the historic data
- Choice of distribution
- Selection of parameters for the distribution
- Method of including historical data

NRM provided a series of data (1890 – 2000) that was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had existed over the entire period. A frequency analysis of this data was also undertaken.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The regional method is reported in Appendix D.

The analyses to determine the "best" estimate from flood frequency analysis and a plausible range is summarised in Table 3.1. FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets an SKM program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte-Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

The results of these analyses are recorded with selected frequency distributions in the Sections 3.2 - 3.5 and the results summarised in Table 3.7.

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Table 3.1 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distribn	Prior informn (regional)	Main Objective
Case 1 Pre -Wivenhoe and Somerset							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

Case 2 **Pre Wivenhoe, no adjustments made for Somerset**							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3 **"No Dams" based on NRM adjusted estimates**							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by NRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4 **"Dams" based on NRM estimates**							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on NRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

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3.2 Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the NRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in Table 3.2 with specific influence on curves plotted in Figures 3.1 – 3.3 so that the influence of specific assumptions can be compared graphically..

Table 3.2 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative..

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	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post-Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.

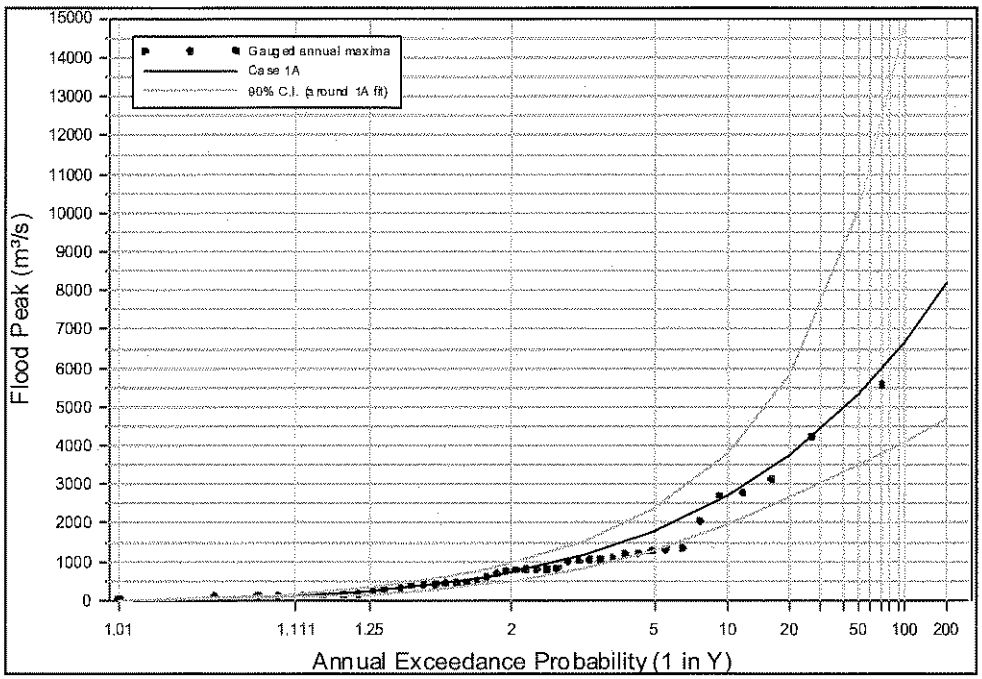

Figure 3.1 Generalised Pareto Distribution fitted to the 1909-1951 pre dams data at Savages Crossing.

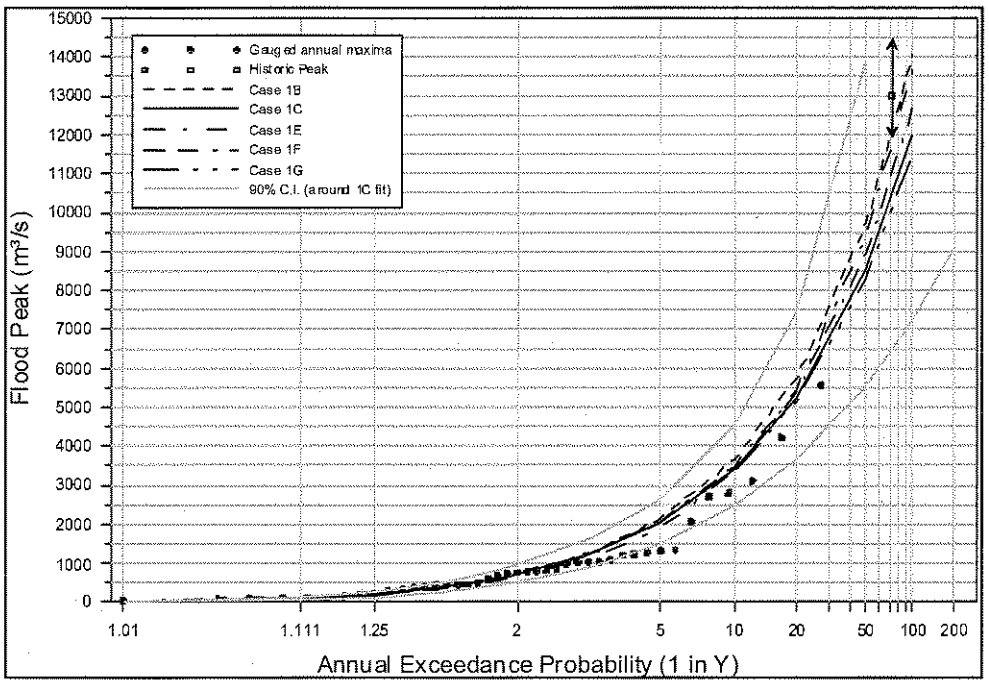

Figure 3.2 Comparisons of variations in flood frequency for various assumptions on pre-dams data for Savages Crossing.

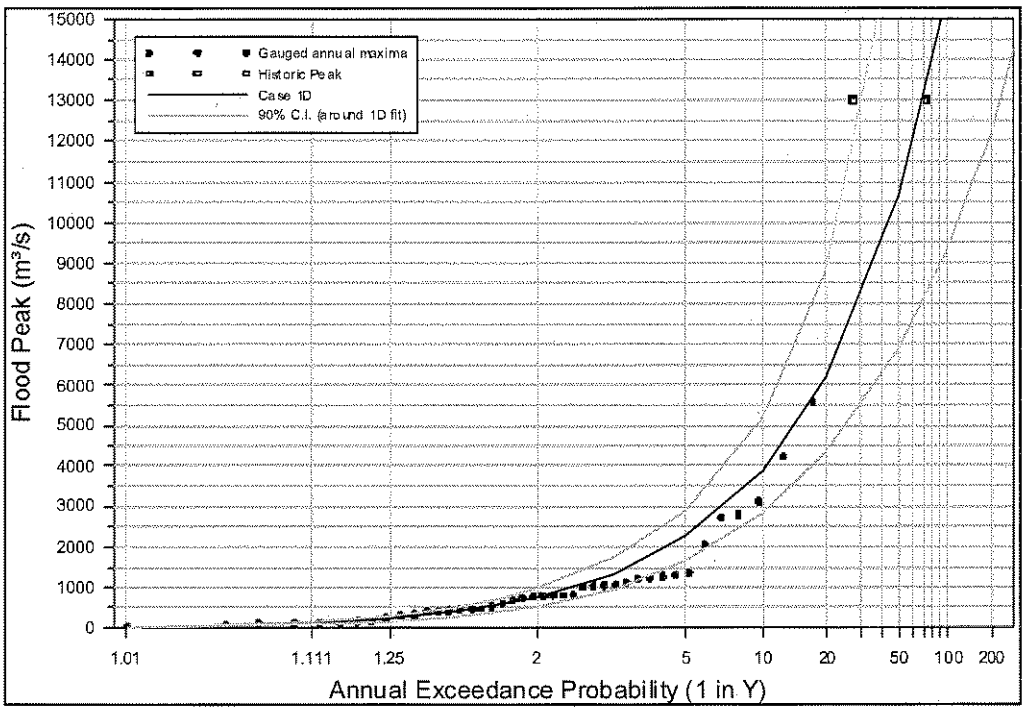

Figure 3.3 Assessment of the inclusion of a 1925 estimate of a flood possibly of the same magnitude as the 1893 event.

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3.3 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

Table 3.3 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

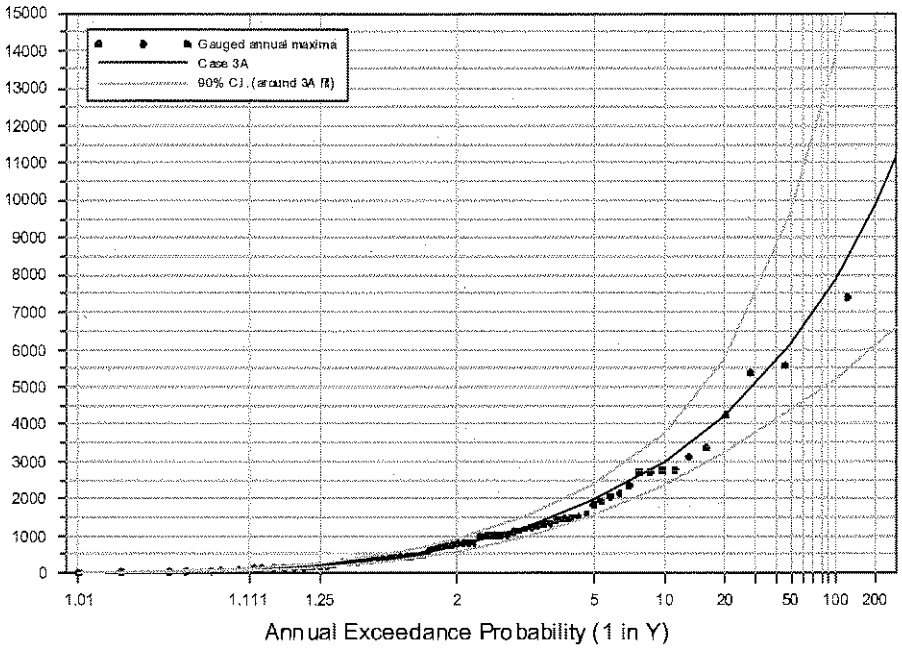

Figure 3.4 Assessment of the pre-Wivenhoe gauged data without 1893 event.

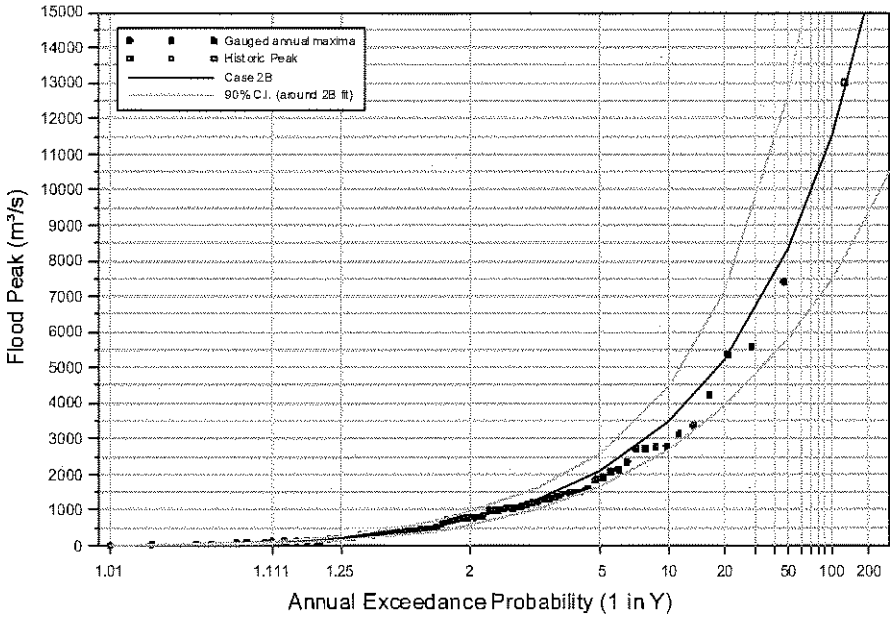

Figure 3.5 Assessment of the pre-Wivenhoe gauged data with 1893 event..

3.4 Analysis of "No Dams" Data Estimated by NRM

Note effect of Somerset is highly variable depending on the operation. NRM has indicated that they have spent significant resources assessing the effect of Somerset on the flood series. The data

series has been provided without documentation as to the method used to adjust the data. SKM has taken this series and analysed the statistics without investigation of derivation.

Table 3.4 Summary of Case 3 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 "No Dams" based on NRM adjusted estimates								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by NRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.

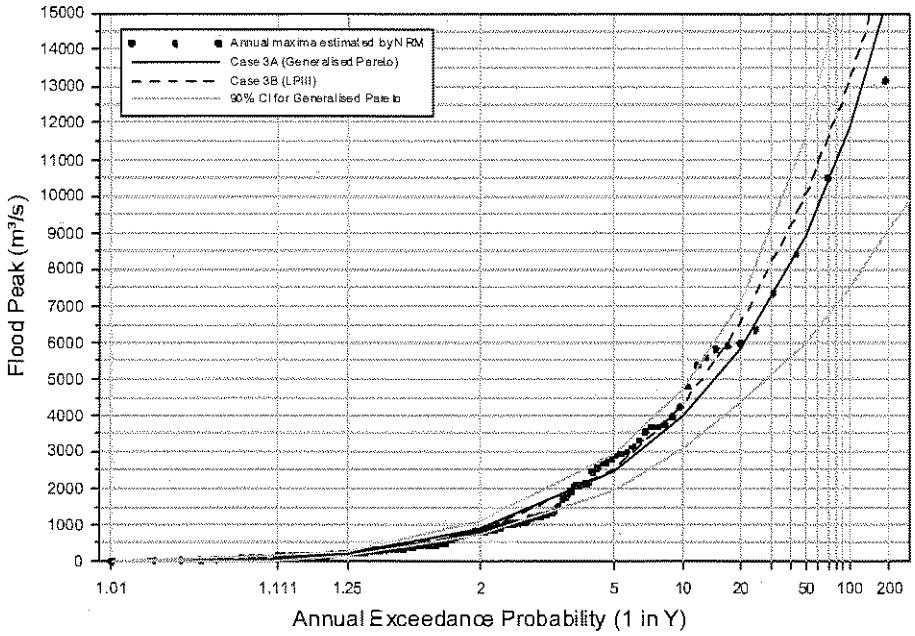

Figure 3.6 Assessment of the "no –dams" annual maxima series provided by NRM using both GP and LPIII distributions.

3.5 Analysis of Post-Dam Data Estimated by NRM

These analyses were based on "post-dam" data set provided by NRM. As with the analyses reported in Section 3.4, no assessment of the manner in which this data set was derived was undertaken.

Table 3.5 Summary of Case 4: Post Dam Data - flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m³/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 4 **"Dams" based on NRM estimates**								

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on NRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

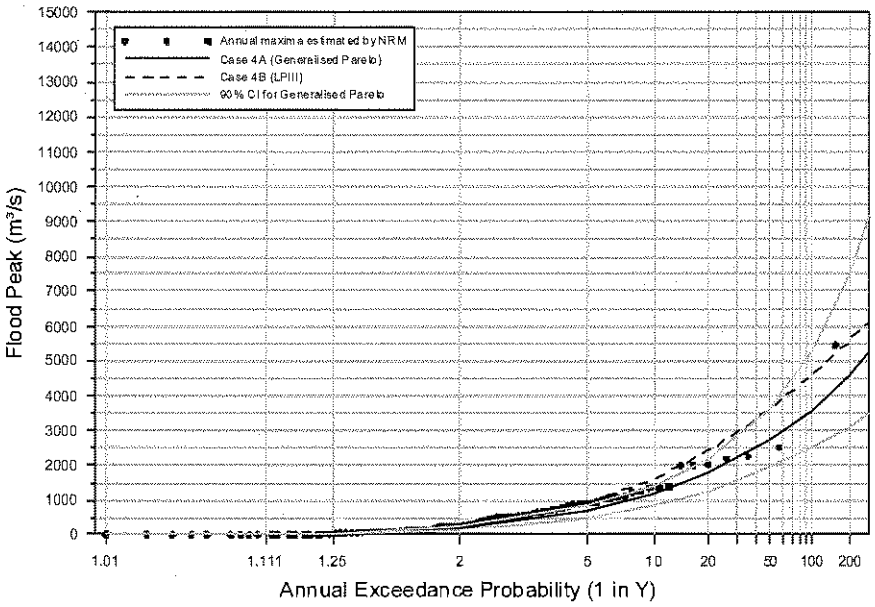

Figure 3.7 Assessment of the "post-dams" annual maxima series provided by NRM using both GP and LPIII distributions.

3.6 Summary of analysis results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) at Savages Crossing. The analyses are summarised in Table 3.7.

A regional frequency analysis was conducted to assist in the estimation of flood frequency at Savages Creek (GS143001). The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane catchment, including the site at Savages Crossing (GS143001). The Generalised Pareto probability distribution was selected for the flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency

distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value;
- its prior standard deviation; and,
- its correlation with other parameters.

The prior mean and standard deviation of the scale (?) and shape (?) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in Table 1.

Table 3.6 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001).

Value	Scale parameter, ?	Shape parameter, ?
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

SKM

Table 3.7 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 **Pre -Wivenhoe and Somerset**								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative..
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 8179m^3/s if the historical data is excluded.
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

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Case 3 "No Dams" based on NRM adjusted estimates								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by NRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.
Case 4 "Dams" based on NRM estimates								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on NRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

3.6.1 Best Estimates from flood frequency assessment

SKM has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are speculative, and do not take into consideration information that may be available from other independent sources (such as rainfall-based flood event modelling).

An additional assessment of the "current" scenario, ie with Somerset and Wivenhoe dams present and operated using current operating procedures is also provided. This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by NRM. Note that no assessment of the plausible range for this estimate is possible as the method for adjusting the data series is not currently available.

The results are presented in Table 3.8.

Table 3.8 Most plausible estimates of the Q100 peak flow at Savages Crossing.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), NRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m^3/s); as no allowance made for Somerset dam, the Q100 could be expected to be higher than 11 500m^3/s.
- the "No dams" series from NRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3A).

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100.
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty)
- choice of distribution and the appropriate parameters; and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500m³/s and 11 000m³/s.

3.7 Comparison ofQ100 estimates from flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated RAFTS model
- CRC FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

gave a Q100 at Savages Crossing of 11400m³/s. It would be reasonable to expect some losses with a 1in 100 AEP event and hence the hydrological modelling results could be expected to be lower, say in the order of 10, 500m³/s.

The difference between the results requires more detailed assessment than is available in the scope and timing of the current assessments. Potential factors influencing the difference in Q100 estimates include:

- potential for partial area storms
- variation in temporal patterns
- variation in spatial patterns
- variation in losses
- adjustment of data for influence of dams

- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.



4. Future proposed work



5. Conclusions

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6. References

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane River flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the Flood Frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the Flood Frequency Analysis Outcomes. An allowance of one face-to-face meeting has been allowed for in the fee estimate.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC Forge Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 100 year ARI event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the NRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine 100 year ARI flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQB (?) and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time



available and nature of the starting level information will dictate the level of sophistication appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.



Appendix B Flow Gauging Stations Omitted from Consideration

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STATION	RIVER	STATNAME	CATCH AREA (km²)	LENGTH_ OF RECORD	WHY N
143222A	Atkinson_Dam	Atkinson_Creek_Outlet		20	Small c
143234A	Atkinson_Dam_Hea			6	Small c
143228A	Bill_Gunn_Dam	Lake_Dyer	3	18	Catchn
143027A	Blunder_Ck	King_Avenue_Bridge	31	8	Urban
2121	Blunder_Ck	King_Ave-_Durack		14	Urban
1594	Breakfast_Ck	Opposite_Newstead_House		5	Urban
1579	Breakfast_Ck	Sedgley_Park_Retention_Basin-_New_Market		6	Urban
1525	Breakfast_Ck	Opposite_Mann_Park-_Bowen_Hills		9	Urban
143104B	Bremer	Rosevale	67	21	Catchn
143104A	Bremer	Rosevale	77	34	Catchn
143110A	Bremer	Adams_Bridge	125	35	Catchn
143940	Bremer	Stokes_Crossing	180	21	ALERT
143909	Bremer	Rosewood	543	-99	ALERT
143833	Bremer	Rosewood_Alert	543	9	ALERT
143908	Bremer	Rosewood_TM	543	25	ALERT
143934	Bremer	Walloon_Bvrt	585	-99	ALERT
143805	Bremer	Walloon_Alert-P	585	9	ALERT
143911	Bremer	Ipswich	1850	-99	ALERT

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143956	Bremer	Three_Mile_Bridge_Alert	1870	-99 ALERT
143954	Bremer	Ipswich_Alert		-99 ALERT
143953	Bremer	One_Mile_Bridge_Alert		-99 ALERT
143852	Bremer	Brassall(Hancocks_Br)_Al		5 ALERT
143115A	Bremer	Berry's_Lagoon		9 Recorc
143831	Brisbane	Devon_Hills_Alert	2160	9 ALERT
143922	Brisbane	Devon_Hills_Bvrt	2190	-99 ALERT
143002A	Brisbane	Plainlands	3950	12 Recorc
143005A	Brisbane	Watts_Bridge	4602	20 Recorc
143008A	Brisbane	Middle_Creek	6704	20 Recorc
143026A	Brisbane	Wivenhoe	7023	3 Recorc
143036A	Brisbane	Wivenhoe_Headwater	7023	17 Recorc
143035A	Brisbane	Wivenhoe_Tailwater	7023	17 Recorc
143907	Brisbane	Lowood	10062	-99 ALERT
143941	Brisbane	Lowood_Bvrt	10062	-99 ALERT
143827	Brisbane	Lowood_Alert-P	10062	9 ALERT
143916	Brisbane	Mt_Crosby	10600	-99 ALERT
143839	Brisbane	Mt_Crosby_Alert	10600	9 ALERT
143925	Brisbane	Mt_Crosby_TM	10600	28 ALERT
143951	Brisbane	Moggill_Alert	12600	-99 ALERT
143915	Brisbane	Moggill_Bvrt	12600	-99 ALERT
143924	Brisbane	Moggill_TM	12600	-99 ALERT

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143900	Brisbane	Caboonbah		-99 ALERT
143914	Brisbane	Gregor_Creek		-99 ALERT
143920	Brisbane	Gregor_Creek_Bvrt		-99 ALERT
143902	Brisbane	Murrumba		-99 ALERT
143005	Brisbane	Watts_Bridge		-99 ALERT
143903	Brisbane	Wivenhoe		-99 ALERT
143868	Brisbane	Colleges_Crossing_Alert		4 ALERT
143918	Brisbane_Estuary	Bishop_Island		-99 ALERT
143217A	Buaraba_Ck	Vineyard	63	10 Catchn
143211A	Buaraba_Ck	15.8km	251	12 Catchn
143224A	Buaraba_Ck	Diversion_Channel		19 Catchn
143094A	Bulimba_Ceek	Mansfield	57	26 Urban
143004A	Bulimba_Ck	Belmont	51	22 Urban
1591	Bulimba_Ck	End_of_Aquarium_Ave._Hemmant		5 Urban
1528	Bulimba_Ck	Doughboy_Pde-_Hemmant		9 Urban
1804	Bulimba_Ck	Greenwood_St-_Wishart		9 Urban
1831	Bulimba_Ck	Merion_Pl-_Carindale		9 Urban
1707	Bulimba_Ck	Old_Cleveland_Rd-_Carindale		9 Urban
143926	Bundamba_Ck	Ripley_Alert	35	-99 Urban
143959	Bundamba_Ck	Harding_Street_Alert	96	-99 Urban
143958	Bundamba_Ck	Blackstone_Bridge_Alert	97	10 Urban
143955	Bundamba_Ck	Bundamba_School_Alert	102	-99 Urban

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143854	Bundamba_Ck	Bundamba_(Hanlon_St)_Al	109	7 Urban
143114A	Bundamba_Ck	Mary_Street	110	11 Urban
143307A	Byron_Ck	Causeway	79	28 Catchn
143012A	Cooyar_Ck	51.5km.	443	4 Recorc
143015B	Cooyar_Ck	Damsite	963	13 Recorc
143015A	Cooyar_Ck	Damsite	963	22 Recorc
143013A	Cressbrook_Ck	The_Damsite	321	16 Recorc
143952	Cressbrook_Ck	Rosentreters_Bridge	440	-99 ALERT
143921A	Cressbrook_Ck	Rosentretters_Bridge	447	17 Recorc
143921	Cressbrook_Ck	Rosentreters_Bridge_TM	477	-99 ALERT
143806	Cressbrook_Ck	Rosentreters_Bridge_Al	477	9 ALERT
143857	Deebing_Ck	Churchill_Alert		-99 ALERT
143021A	Ekibin_Ck	Dudley_Street.	13	1 Urban
143011A	Emu_Ck	Raeburn	439	24 Catchn
143932A	Ennogera_Ck	Bancroft_Park	70	10 Urban
143932	Enoggera_Ck	Bancroft_Park_TM	67	-99 Urban
1531	Enoggera_Ck	100_M_U/S_From_Original_E_e529		6 Urban
1532	Enoggera_Ck	Enoggera_Dam-_The_Gap		9 Urban
1529	Enoggera_Ck	Kelvin_Grove_Rd-_Kelvin_Grove		9 Urban
143208A	Fifteen_Mile_Ck	Dam_Site	87	33 Catchn
143214A	Flagstone_Ck	Windolfs	142	14 Catchn
143233A	Flagstone_Ck	Brown-Zirbels_Road		10 Catchn

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1717	Gold_Ck	Reservoir-_Brookfield_(Brisbane_Water)		-99 Urban
143028A	Ithaca_Ck	Jason_Street	10	31 Urban
1535	Ithaca_Ck	Jason_St-_Ithaca		9 Urban
143304A	Kilcoy_Ck	Mount_Kilcoy	127	36 Catchn
143304B	Kilcoy_Ck	Mount_Kilcoy_Weir	131	15 Catchn
143235A	L_Clarendon_Head			6 Offstre
143215A	Laidley_Ck	Mulgowie_Weir	154	14 Catchn
143209A	Laidley_Ck	Mulgowie1	167	5 Catchn
143209B	Laidley_Ck	Mulgowie2	167	36 Catchn
143225A	Laidley_Ck	Showgrounds_Weir_Head_Wat e	233	19 Catchn
143226A	Laidley_Ck	Showgrounds_Weir_Tail_Wate	233	19 Catchn
143943	Laidley_Ck	Laidley	285	-99 Catchn
143923	Laidley_Ck	Thornton		-99 Catchn
143229A	Laidley_Ck	Warrego_Highway		13 Catchn
143202A	Lockyer_Ck	Russell_Siding	271	7 Catchn
143203C	Lockyer_Ck	Helidon_Number_3	357	16 Catchn
143203A	Lockyer_Ck	Helidon	357	45 Catchn
143203B	Lockyer_Ck	Helidon_No.2	382	24 Catchn
143904	Lockyer_Ck	Gatton	1550	-99 ALERT
143204A	Lockyer_Ck	Wilsons_Weir	1655	29 Catchn
143905	Lockyer_Ck	Glenore_Grove	2230	-99 ALERT
143906	Lockyer_Ck	Glenore_Grove_Bvrt	2230	-99 ALERT

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143807	Lockyer_Ck	Glenore_Grove_Alert	2230	9 ALERT
143206A	Lockyer_Ck	Brightview_Weir	2393	20 Catchn
143917	Lockyer_Ck	Lyons_Bridge	2530	-99 ALERT
143913	Lockyer_Ck	Lyons_Bridge_Bvrt	2530	-99 ALERT
143819	Lockyer_Ck	Lyons_Bridge_Alert-P	2530	9 ALERT
2142	Lota_Ck	Rickertt_Rd_Ransome		4 Urban
143213B	Ma_Ma_Ck	Ma_Ma_Weir	226	9 Catchn
143213A	Ma_Ma_Ck	Harms	227	4 Catchn
143213C	Ma_Ma_Ck	Harm's		8 Catchn
143032A	Moggill_Ck	Upper_Brookfield	23	27 Urban
143020A	Moggill_Ck	Misty_Morn	61	9 Urban
143020	Moggill_Ck	Misty_Morn_TM		-99 Urban
1722	Moggill_Ck	Fortrose_St-_Kenmore		8 Urban
2143	Moolabin_Ck	Brisbane_Golf_Club-_Tennyson		14 Urban
143219A	Murphys_Ck	Spring_Bluff	18	24 Urban
1549	Norman_Ck	Joachim_St-_Holland_Park_West		9 Urban
1552	Norman_Ck	South_East_Freeway-_Greenslopes		9 Urban
1555	Norman_Ck	Caswell_St-_East_Brisbane		10 Urban
143033A	Oxley_Ck	New_Beith	60	27 Urban
143019A	Oxley_Ck	Upstream_Beatty_Road	152	3 Urban
143019B	Oxley_Ck	Downstream_Beatty_Road	152	6 Urban
143019	Oxley_Ck	Beatty_Road_TM		-99 Urban

1588	Oxley_Ck	Mouth_of_Oxley_Creek		5 Urban
1727	Oxley_Ck	New_Beith_(DNR)+F31		8 Urban
2023	Oxley_Ck	Corinda_High_School-_Corinda		12 Urban
2125	Oxley_Ck	Beatty_Rd-_Acacia_Ridge		14 Urban
2111	Oxley_Ck	Johnson_Rd-_Forestdale		14 Urban
143024A	Pullen_Pullen_Ck	Moggill_Road	27	4 Urban
1745	Pullen_Pullen_Ck	Pinjarra_Rd-_Pinjarra_Hills		6 Urban
143983	Purga_Ck	Loamside_Alert	215	8 ALERT
143869	Purga_Ck	Peak_Crossing_Alert		4 ALERT
143218A	Redbank_Ck	Holcomb	55	8 Urban
143216A	Redbank_Ck	Water_Treatment_Works	60	11 Urban
143231A	Redbank_Ck	Clarendon_Number_2		10 Urban
143230A	Redbank_Ck	Clarendon_Pump_Station		10 Urban
143306A	Reedy_Ck	Upstream_Byron_Creek_Junct	56	28 Catchn
143111A	Reynolds_Ck	Moogerah_Dam_Headwater	226	36 Head g
143112A	Reynolds_Ck	Moogerah_Tailwater	227	23 Tail ga
143220A	Sandy_Ck	Forest_Hill	102	7 Urban
143232A	Sandy_Ck	Forest_Hill		8 Urban
143030A	Sandy_Ck	Indooroopilly		22 Urban
143223A	Seven_Mile_Lagoo	Diversion_Channel		20 Diversi
143023A	Small_Catchment	Algester	1	4 Urban
143022A	Stable_Swamp_Ck	Interstate_Railway	19	11 Urban

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2129	Stable_Swamp_Ck	Musgrave_Rd-_Coopers_Plains		14 Urban
143303A	Stanley	Peachester	104	76 Catchn
143938	Stanley	Woodford_TM	220	-99 ALERT
143829	Stanley	Woodford_Alert-P	220	9 ALERT
143901	Stanley	Woodford	250	-99 ALERT
143301B	Stanley	Donnelly_Dell	1227	4 Recorc
143301A	Stanley	Hazeldean	1242	3 Recorc
143305	Stanley	Somerset_Dam	1330	-99 ALERT
143818	Stanley	Somerset_Dam_Hw_Alert-B	1330	9 ALERT
143817	Stanley	Somerset_Dam_Hw_Alert-P	1330	9 ALERT
143305A	Stanley	Somerset_Dam	1336	24 Head g
143960	Stanley	Peachester		-99 ALERT
143106A	Warrill_Ck	Aratula_Weir	122	7 Catchn
143102A	Warrill_Ck	Kalbar_No.1	465	46 Catchn
143102B	Warrill_Ck	Kalbar_No.2	468	13 Catchn
143937	Warrill_Ck	Kalbar	470	-99 ALERT
143910	Warrill_Ck	Harrisville	725	-99 ALERT
143912	Warrill_Ck	Harrisville_TM	725	-99 ALERT
143825	Warrill_Ck	Amberley_Alert-P	850	9 ALERT
143933	Warrill_Ck	Amberley_Bvrt	862	-99 ALERT
143117A	Warrill_Ck	Junction_Weir_H/W		5 Recorc
143118A	Warrill_Ck	Junction_Weir_Tailwater		6 Recorc

143116A	Warrill_Ck	Toohill's_Crossing		6 Recorc
143105A	Warrill_Ck_East	Churchbank_Weir	149	50 Catchn
143031A	Water_St._Drain	Exhibition_Ground		5 Urban
143939	Western_Ck	Kuss_Road	200	21 Urban
143861	Western_Ck	Grandchester_Alert		4 Urban
1583	Wolston_Ck	700m_U/S_Wacol_Station_Rd-_Wacol		6 Urban
143962	Woogaroo_Ck	Brisbane_Road_Alert		-99 Urban
143927	Woogaroo_Ck	Opossum_Alert		-99 Urban
143961	Woogaroo_Ck	Alice_Street_Alert		7 Urban

Appendix C Location of select stream gauges



Insert figure 3.1 from skm BR Fs report here.

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Appendix D Regional Flood Frequency Information

D.1 Introduction

The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

D.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in Section 2.1 only NRM gauge flow data was both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in Table D.1.

The location of the gauges can be seen in the catchment map in Appendix C.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in Table D.1 were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in Section D.3.

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Table D.1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods.

River	Station Name	Station Number	Years of Record	C'ment Area (km^2)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

D.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in Table D.1. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. Figure 3.1 shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (eg Peel et al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

Also shown on Figure D.1 is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that BremerR @Walloon (143107A) and BrisbaneR @ Gregor's Ck (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (Appendix E) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.

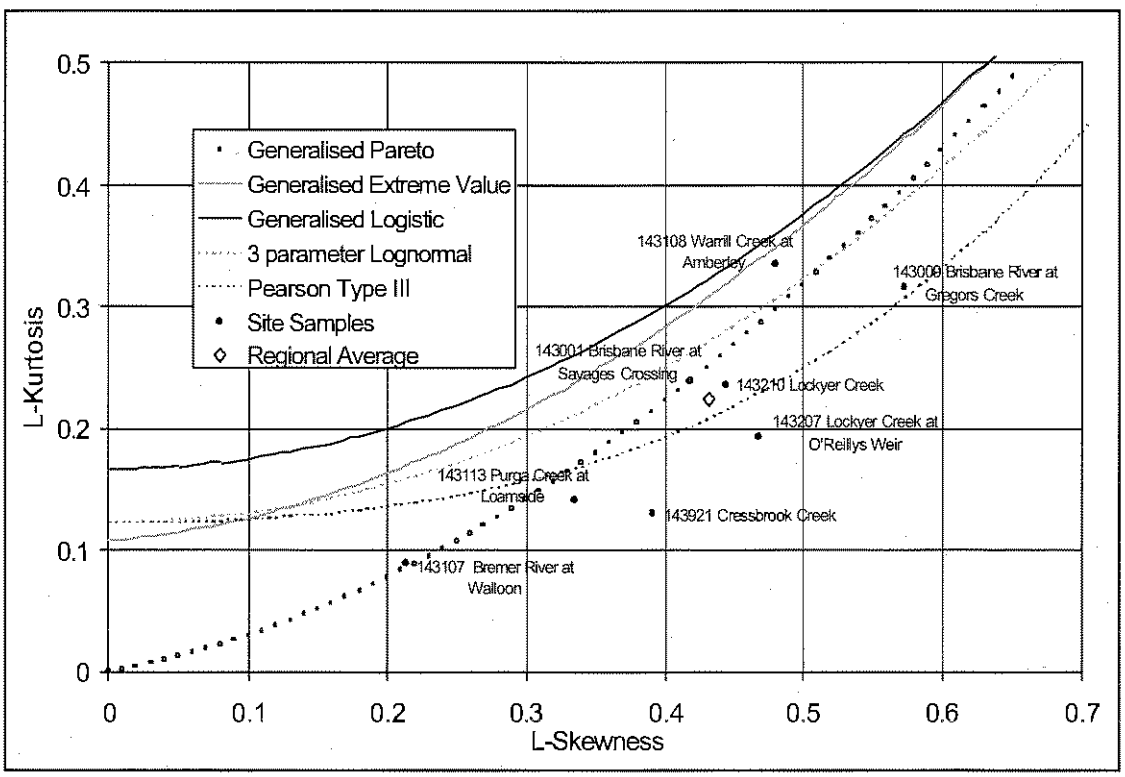

Figure D.1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500km^2), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (Figure D.2) supports the adoption of the Generalised Pareto distribution.

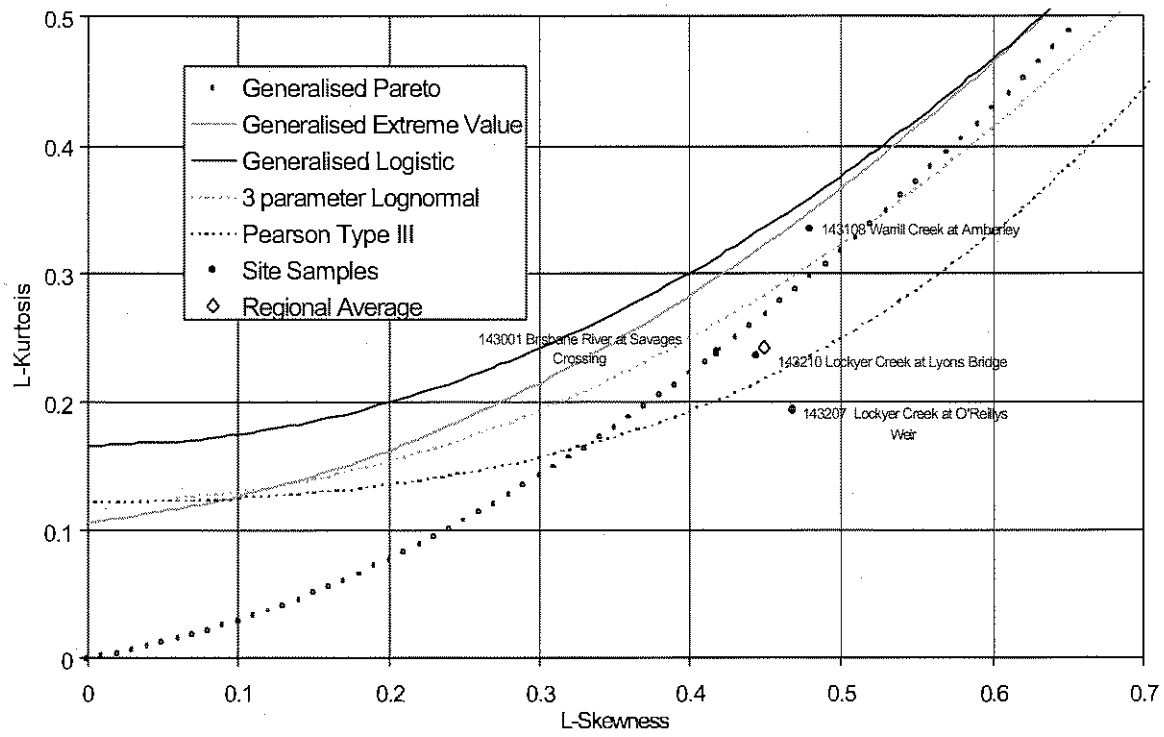

Figure D.2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in Table D.2.

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Table D.2 Regional parameter values of the adopted Generalised Pareto distribution

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter, ?	-0.062	-0.096
Scale parameter, ?	0.811	0.795
Shape parameter, ?	-0.230	-0.275

D.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation,
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale (?) and shape (?) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of Table D.2. The scale parameter (?) from the regional analysis shown in Table D.2 is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$? _{143001} ? L^1_{143001} ? ^{CV}_{\text{Regional}} ? 1181 ? 0.795 ? 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in Table D.3. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$? _{?,143001} ? L^1_{143001} ? ^{CV}_{?,\text{Regional}} ? 1181 ? 0.388 ? 458$$

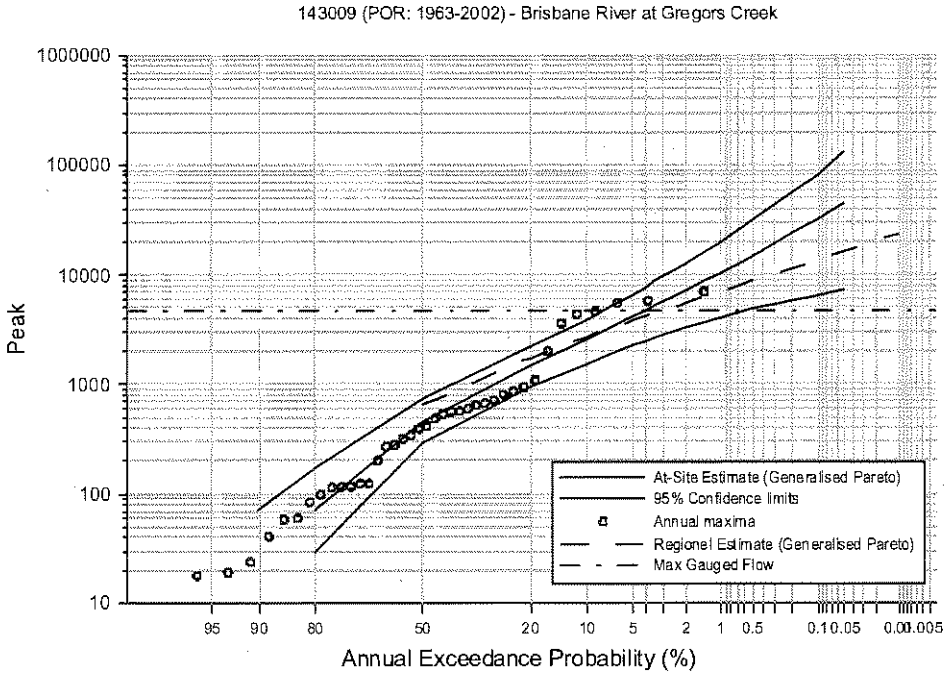
The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information

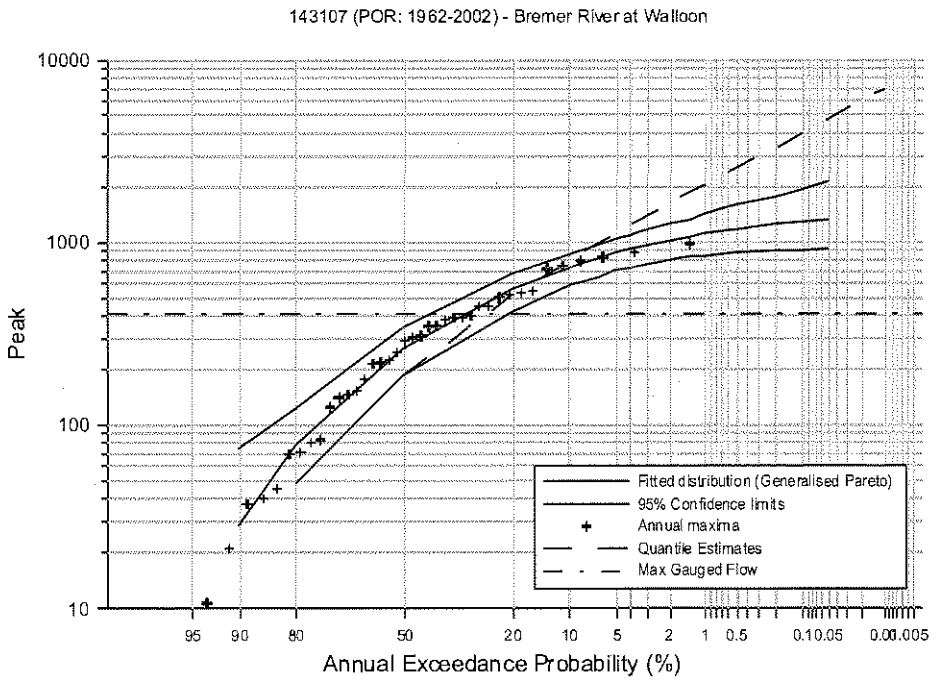
was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

Table D.3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution

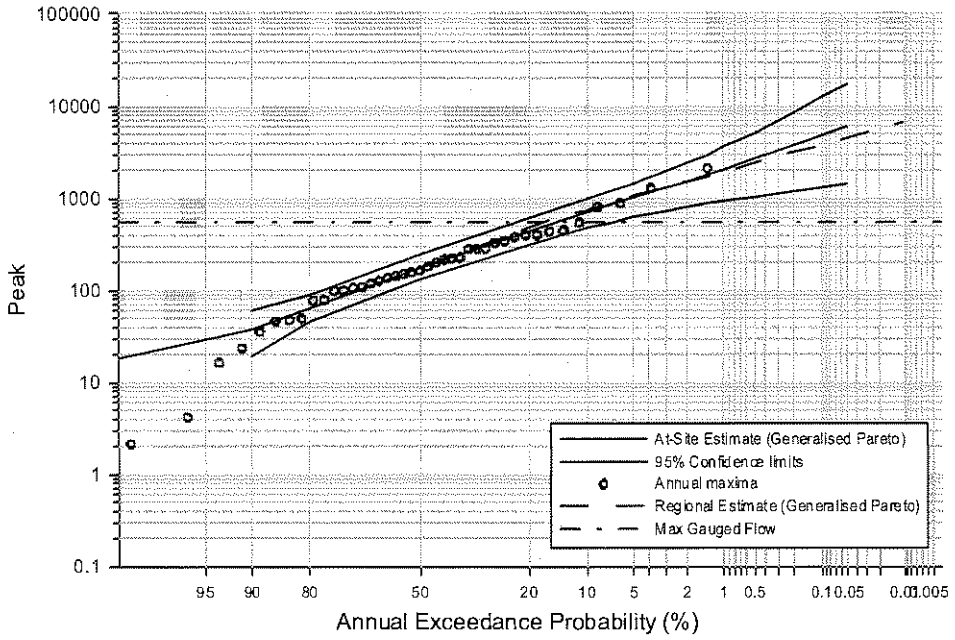
Site Number	Gauging Station Name	Scale parameter, ?	Shape parameter, ?
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		0.388	0.297

At-Site/Regional Analysis of Selected Gauges

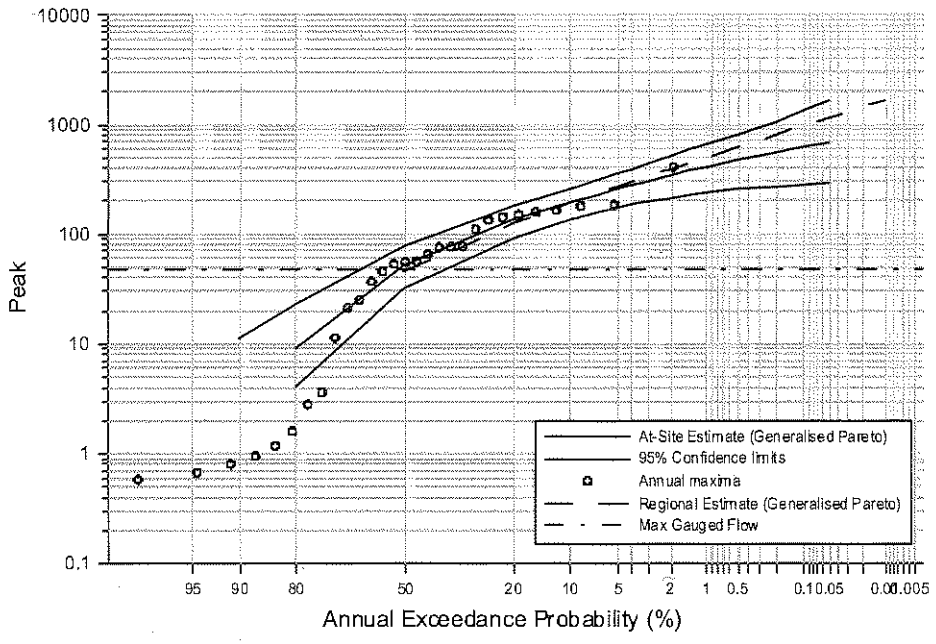


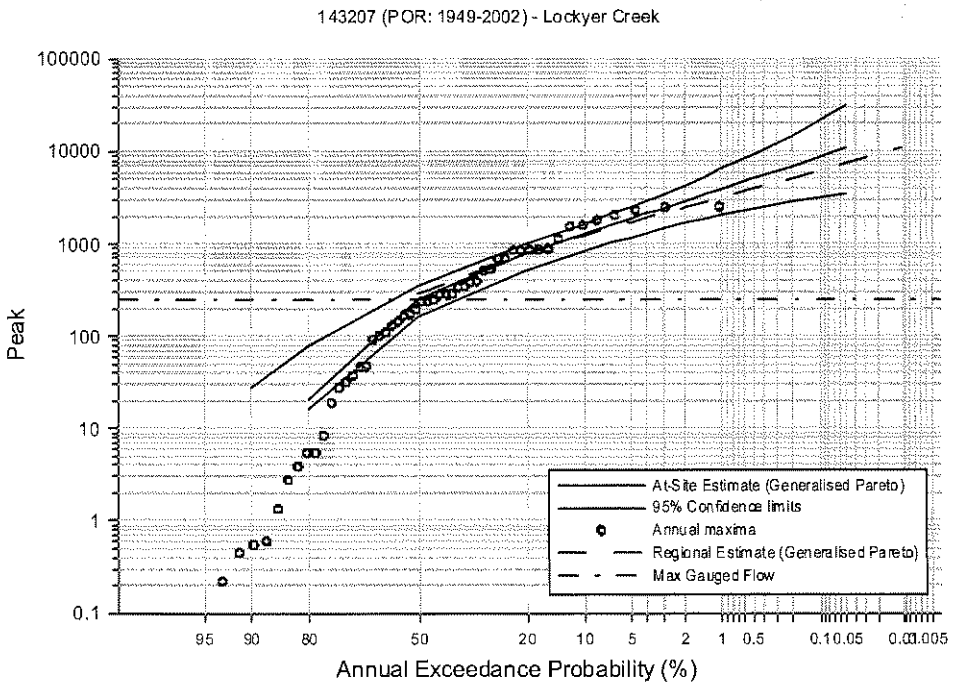


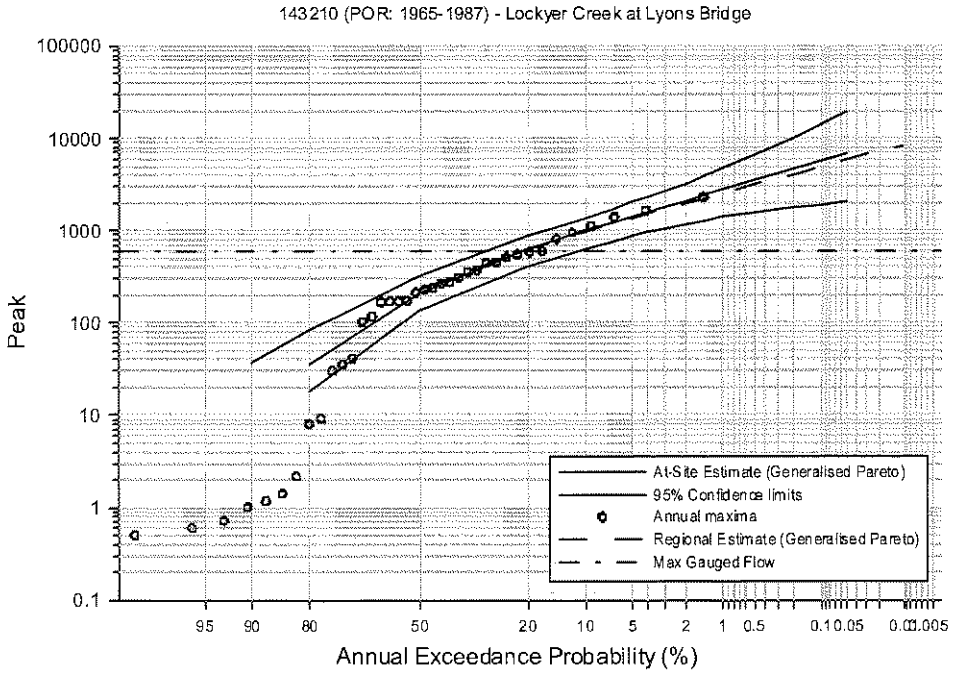
143108 (POR: 1962-2002) - Warrill Creek at Amberley

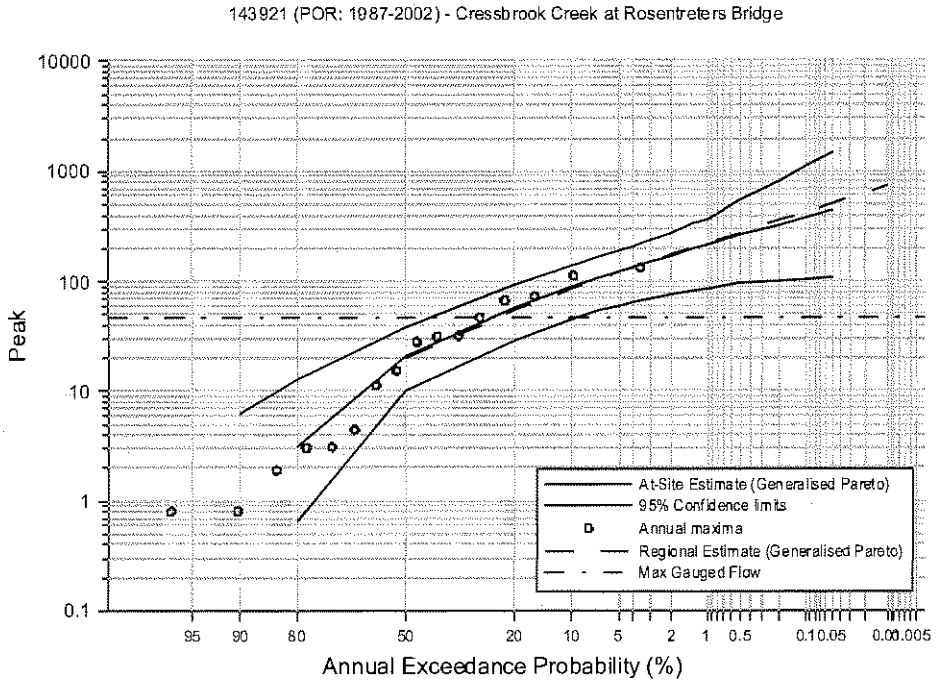


143113 (POR: 1974-2002) - Purga Creek at Loamside

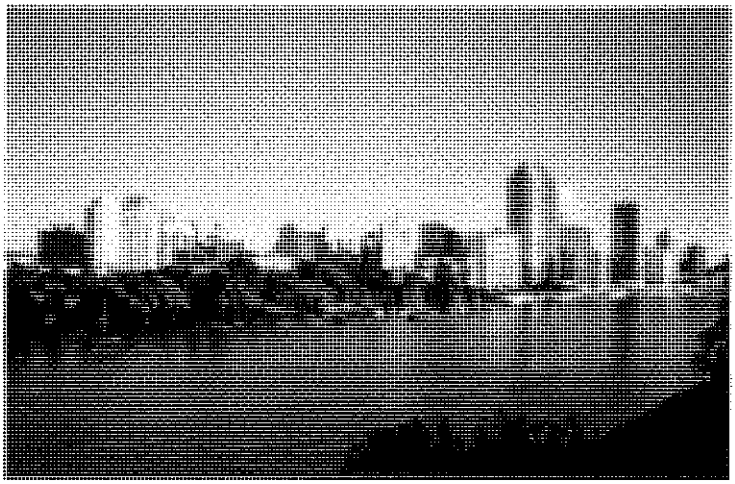



143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
Peak
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow

Brisbane River Flood Study



FURTHER INVESTIGATIONS OF HYDROLOGY & HYDRAULICS INCORPORATING DAM OPERATIONS AND CRC FORGE RAINFALL ESTIMATES

- Further Investigations
- Draft
- 29 Aug 2003



Brisbane River Flood Study

FURTHER INVESTIGATIONS OF HYDROLOGY INCORPORATING DAM OPERATIONS AND CRC FORGE RAINFALL ESTIMATES

- Draft
- 29 Aug 2003

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1. Executive Summary

The Brisbane River Catchment is approximately 13500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7000 km^2 and therefore there is potential for flood mitigation to areas below the dams. The potential for flood mitigation is dependent on the following factors:

- Dam Operating Procedures.
- Dam levels at the start of a flood event.
- Spatial and Temporal Patterns.

The most appropriate way assess the above factors is by Monte Carlo Analysis however given the restrictions on time, this analysis was not able to be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Investigation of dam operations was not undertaken as part of this study.

The Department of Natural Resources and Mines (DNRM) provided 1%AEP CRC Forge rainfall estimates. These estimates included Areal Reduction Factors (ARF) which accounts for spatial distribution of rainfall over a catchment. ARF's were not available for catchments of this size when the previous Brisbane River Flood Study (SKM 1998) was undertaken.

CRC Rainfall depths were input into the RAFTS hydrological model (SKM 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. The flood frequency estimate was determined to be 12000 m^3/s (SKM 2003).

Using a catchment average 48 hour CRC Forge rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for predams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s.

This shows that by using a combination of spatial and temporal patterns, reconciliation between the FFA estimate and the RAFTS estimate could be achieved.

The CRC Forge estimates for various spatial patterns with a standard AR&R temporal pattern were run through the DNRM Dam Operations model. This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model

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and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of the spatial pattern for post dams conditions was estimated to be 6200 m^3/s.

A temporal pattern sensitivity analysis for post dam conditions was not undertaken.

Using the 1% AEP 72 hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr, a dam starting water level sensitivity analysis was undertaken. If the dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

The main objective of the report was to determine 1% peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (SKM 2000) was used to account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is difficult to provide a single estimate of the 1% AEP flood event at Port Office. **Table 1** provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

Table 1 Range of Estimates at Moggill and the Port Office for the 1% AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

As a check of the peak flows predicted by the design events, two historical flood events were run through the RAFTS model. The 1893 and 1974 flood events were run through the RAFTS model for the pre and post dam conditions. For post dam conditions, the estimated peak flow at the Port Office for the 1893 and 1974 flood events were 9500 m^3/s and 6800 m^3/s respectively. Flood flows predicted for the 1893 flood event are outside the range presented in **Table 1**. While this is of some concern, the reliability of the measured historical data for this event is questionable.

Conversely, the predicted post dam peak flow for the 1974 flood event matches well with the 'best estimate flow. Measured historical data for this flood is much more reliable and a reasonable amount of confidence can be placed on the estimate.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (SKM 1998). The primary reasons for the reduction in peak flows are due to:

- Introduction CRC Forge Rainfall depths with Areal Reduction Factors.
- Better representation of Dam Operating Procedures.
- More reliable streamflow data.

It is recommended that the following actions be undertaken:

- Undertake a Monte Carlo Analysis
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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2. Introduction

The introduction of CRC Forge Rainfall estimates for Queensland requires that further investigations be undertaken to determine potential impacts along the lower reach of the Brisbane River within the bounds of Brisbane City.

Furthermore, there have been modifications to Operation Procedures for Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, June 1998) was completed and inclusion of the latest procedures will be included in this investigation.

After a number of meetings with Council Officers, the following methodology was adopted:

- Review previous reports, CRC Forge rainfall estimates and historical streamflow data.
- Undertake a Regional Flood Frequency Analysis (pre dams).
- Undertake hydrologic modelling (pre dams).
- Undertake hydrologic modelling (dams in place).
- Analyse catchment sensitivity using various temporal patterns.
- Undertake a check with historical flood events.
- Undertake hydraulic modelling
- Reporting and documentation.

As part of the review process, an external Expert Review Panel was formed to comment on the methodology and to review the outcomes of this investigation. The findings of this panel will be presented in a separate report.

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3. Hydrological Modelling

Hydrologic Modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS hydrological model developed for the Ipswich Rivers Flood Studies was used for this investigation. The Ipswich River Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows.

- Initial Loss Rate (IL) = 10 mm
- Continuing Loss (CL) = 1.0 mm/h
- All model runs were undertaken for the 1% AEP flood event only.

3.1 Assumptions

- The Ipswich Rivers Flood Studies (SKM 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM 2003) Wivenhoe and Somerset Dam Operations Model was used to determine Dam outflows.

3.2 Methodology

The following Methodology describes the process that was used to determine 1% AEP flood flows at Moggill and the Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model
- Input CRC FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1% AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the NRM Dam Operations Model.
- The NRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the NRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1% AEP flows at Moggill and the Port Office Gauge.
- A sensitivity analysis was then performed to using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wivenhoe and Somerset Dams at the start of the flood event.

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3.3 Pre Dams RAFTS Modelling

The object of the pre dams modelling was to achieve reconciliation between the Flood Frequency Estimates and the flow estimates produced by RAFTS. CRC Forge rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine affects that temporal patterns have on peak flows.

3.3.1 CRC Rainfall Estimates – Standard CRC Forge Distribution

CRC Forge Rainfall Estimates for varying duration's were input into the model with Areal Reduction Factors (ARF) applied. **Table 2 CRC Forge Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors** – 1%AEP presents the rainfalls and ARF's used.

Table 2 CRC Forge Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC Forge Rainfall	247	268	285	317	358	385	402
CRC Forge Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC Forge rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in **Appendix A**. Standard Temporal Patterns were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/hr was adopted.

The CRC Forge rainfall estimates with ARF's applied are presented in **Table 3 Peak Flows for CRC Forge Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Pre-dams**.

Table 3 Peak Flows for CRC Forge Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Pre-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Port Office should be considered indicative only.

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3.3.2 Spatial Pattern Sensitivity

To determine the impact of spatial patterns, seven historical spatial patterns were assessed. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC Forge Rainfall Depths (ARF applied) for each duration.

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane Catchment.
- April 1996 – rainfalls produce were high in the Lockyer and Lower Brisbane Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in **Appendix A**.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/h was applied.

Peak flows are presented in **Table 4 Pre- dams 1% AEP Peak Flows for Historical Spatial Distribution**. Note that for all spatial distributions the 30 hour flood is the critical duration storm at Savages Crossing and the 72 hour flood is the critical duration at Moggill and Port Office. Flows presented at Moggill and the Port Office in **Table 4** should be considered indicative only. More accurate flows will be determined during the hydraulic modelling.

« Table 4 Pre- dams 1% AEP Peak Flows for Historical Spatial Distributions.

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: - Bold values indicate the median flow at each location
- Flows at Moggill and Port Office should be considered indicative only.

A full listing of peak discharges at Savages Crossing, Moggill and Port Office are present in **Appendix B**.

3.3.3 Temporal Pattern Sensitivity

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC Forge Rainfall 48 hour storm duration. An I.L of 0 mm and a C.L of 0 mm/hr was applied.

The temporal patterns assess are as follows:

- AVM – Mark Pearse
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event.
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event.
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event.
- AR&R 1987 – Standard temporal pattern outlined in Australian Rainfall and Runoff.

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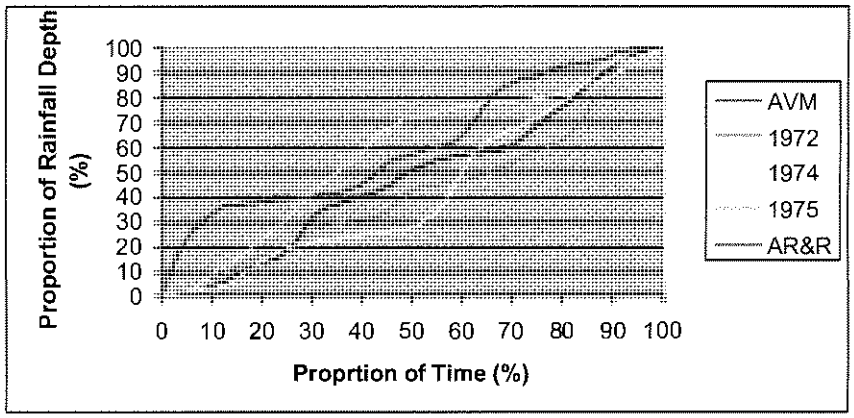
Figure 1 Temporal Patterns for the 1% AEP 48 Hour Storm Event



The resulting peak flow estimates using the temporal patterns described above are presented in **Table 5 48 Hour Temporal Pattern Sensitivity.**

Table 5 48 Hour Temporal Pattern Sensitivity

	48 hour Temporal Pattern				
Location	AR&R	AVM	1972	1974	1975
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Port Office	12817	13464	13287	14115	13634

3.3.4 Discussion

Table 4 and **Table 5** show that spatial and temporal patterns have a significant affect on peak flows. Given the size of the catchment and the variability that spatial and temporal patterns have on peak flows, it is evident that a Monte Carlo Analysis would be appropriate. A Monte Carlo Analysis was not possible within specified time frame for this report and therefore the sensitivity analyses was undertaken to investigate potential effects of this phenomenon.

The pre-dams historical spatial distributions produce peak flows at Savages Crossing that range from 11500 m^3/s to 8000 m^3/s with the median peak flow being 10046 m^3/s. The estimated peak flow at savages using the CRC Forge Spatial Pattern was estimated to be 9607 m^3/s.

If an IL of 0 mm and CL of 0 mm/h is applied to the CRC Forge 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11278 m^3/s. It should be noted that the 'best estimate' of peak flow at Savages Crossing from the Flood Frequency Analysis was estimated to be 12000 m^3/s. This means that the RAFTS peak flow estimates and the FFA

estimates cannot be reconciled unless ARF's are increased or spatial and temporal patterns are combined.

3.4 Post Dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and run through the DNRM Dam Operations Model. These inflows were based on the outputs presented in **Appendix B** and included an IL of 10 mm and CL of 1.0 mm/hour.

The outflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC Forge and historical spatial patterns to determine flows at Savages Crossing, Moggill and Port Office.

3.4.1 CRC Rainfall Estimates – Standard CRC Forge Distribution

The parameters described in **Section 3.3.1** were used for the Post Dams RAFTS modelling.

The CRC Forge rainfall estimates with ARF's applied are presented in **Table 6 Peak Flows for CRC Forge Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Post Dams**.

» Table 6 Peak Flows for CRC Forge Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Post Dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	**5368**	2335	2502
Moggill	3017	3690	2999	3302	**5043**	3811	3990
Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Port Office should be considered indicative only.

3.4.2 Spatial Pattern Sensitivity

The parameters described in **Section 3.3.2** were used for the Post Dams RAFTS modelling. Peak flows are presented in **Table 7 Post Dams 1% AEP Peak Flows for Historical Spatial Distributions**. Note that the critical duration storm at Savages Crossing, Moggill and Port Office range from 72 to 120 hours for Post Dam Conditions. Flows presented at Moggill and the Port Office in **Table 7** should be considered indicative only. More accurate flows will be determined during the hydraulic modelling.

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Table 7 Post Dams 1% AEP Peak Flows for Historical Spatial Distributions

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: - (120hr) denotes the critical storm duration
- Bold values indicate the median flow at each location
-Flows at Moggill and Port Office should be considered indicative only.

3.4.3 Dam Sensitivity

Full supply level of Wivenhoe Dam is at RL 67.0 m AHD and has a storage capacity of 1,165E6 m^3 of storage. The crest level of Wivenhoe Dam is at RL 79 m AHD with a corresponding storage capacity of 2,934E6 m^3. The maximum flood mitigation volume of Wivenhoe Dam is 1,769E6 m^3.

It is unlikely that Dam Operators would ever allow this amount of flood storage volume to be used as Wivenhoe Dam is an earth fill dam and overtopping is likely to cause dam failure.

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1% AEP flood (average CRC Forge rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in **Table 8 Flood Runoff Volumes for the 1% AEP above Wivenhoe Dam**.

Table 8 Flood Runoff Volumes for the 1% AEP above Wivenhoe Dam

Storm Duration (hours)	CRC Rainfall Depth wit ARF Applied (mm)	Runoff Volume ($m^3 \times 10^6$)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

Table 8 shows that if Wivenhoe Dam is at FSL, the 1%AEP 36 hour flood runoff volume can be fully stored between FSL and Crest Level without release. For 1%AEP events with longer

durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the crest level is over, topped (no releases).

Given current operational procedure, it is unlikely that no releases would occur during a flood event, particularly if Wivenhoe Dam is at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs have been done for the 1% AEP 72 hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in **Table 9 Dam Starting Water Levels Sensitivity Analysis for the 1% AEP 72 Hour Storm.**

Table 9 Dam Starting Water Levels Sensitivity Analysis for the 1% AEP 72 Hour Storm

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Port Office	5044	4402	4402

Note: - Flows at Moggill and Port Office should be considered indicative only.

Table 10 shows that the reduction in flow is approximately 13% at the Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

3.4.4 1893 and 1974 Historical Flood Events

As a check on design flows, the 1893 and 1974 historical flood events were input into the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post Dam flows are presented in **Table 11 Predicted Post Dam Flows for the 1893 and 1974 Historical Flood Events**.

Table 11 Predicted Post Dam Flows for the 1893 and 1974 Historical Flood Events

	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
Location	No Dams (m^3/s)	Som and Wiv in Place (m^3/s)	Somerset in Place (m^3/s)	Som and Wiv in Place (m^3/s)
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Port Office	13869	9519	9874	6801

Table 11 shows that the peak flows for the historical events at the Port Office are above the 1%AEP CRC Forge Estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1893 event however more confidence can be placed in the predicted 1974 flow estimate. The 1974 peak flow is within the range of flows predicted by varying spatial distributions whereas the 1893 flood is outside the predicted range.

3.4.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. This further suggests that Monte Carlo Analysis would be an appropriate way to investigate the complexities of Dams, spatial and temporal patterns to obtain the best estimate of the 1%AEP flood event.

The CRC Forge spatially distributed peak flow at Savages Crossing was estimated to be 5368 m^3/s for the post dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow being 6241 m^3/s.

Based on the preceding information it is difficult to specify a single estimate for the 1% AEP flood at the Port Office. Given the current information, the 'best estimate' of peak flow at the Port Office would be 6500 m^3/s with an upper and lower limit of 8000 m^3/s and 5000 m^3/s respectively.

It is recommended that Monte Carlo Analysis be undertaken as there many uncertainties associated with the above best estimate.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (SKM 1998). The primary reasons are that the DNRM Dam operations model was provided allowing an accurate representation of release procedures. The previous study (SKM 1998), assumed emergency operating procedures which minimise the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River.

Derivation of the Areal Reduction Factors as part of CRC Forge estimates since the 1998 study have also had an impact on the flows estimates. For catchments of this size, ARF's were not available in 1998.

Another factor is that the reliability of the streamflow at Moggill and Port Office is questionable as these gauges are height read gauges and tidal effects make it difficult to derive reliable rating curves at these locations. In the 1998 study, the emphasis was to match Flood Frequency Estimates at Moggill and the Port Office. After discussions with DNRM, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and flood frequency estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing.

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4. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Port Office is good, other sections of the reach within Brisbane City has not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

4.1 Assumptions

- Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane Bar.

4.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from the Brisbane Bar to approximately 10km downstream of Savages Crossing. The model also includes Bremer River and other smaller tributaries which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1% AEP spatially distributed over the catchment. Duration's ranging from 24 to 120 hours were assessed.

4.3 Results

The peak Discharges and Flood Levels for at Moggill and Port Office are presented in **Table 12 1% AEP Peak Flood Levels and Flows for the CRC Forge Spatial Distributed Rainfall.**

Table 12 1% AEP Peak Flood Levels and Flows for the CRC Forge Spatial Distributed Rainfall

	Moggill		Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

4.4 Discussion

Table 6 and **Table 12** show that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Port Office.

Using the 'best estimate and upper and lower limits of peak flows at the Port Office presented in **Section 3.4.5**, a rating curve was used to predict flood levels at the Port Office for the 1%AEP flood event. Peak flood levels and corresponding flows are presented in **Table 13 Peak Flood Level and Peak Flow Estimates for the 1%AEP Flood Event at Port Office.**

Table 13 Peak Flood Level and Peak Flow Estimates for the 1%AEP Flood Event at Port Office.

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

Note that these estimates should be considered indicative because the actual tide level may vary for an actual flood event. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918) at the Brisbane Bar.



5. References

Department of Natural Resources & Mines - CRC Forge Rainfall Estimates 2003

Department of Natural Resources & Mines - Wivenhoe and Somerset Dams Operational Mode 2003

Brisbane River Flood Study - Sinclair Knight Merz June 1998

Ipswich Rivers Flood Studies - Sinclair Knight Merz July 2000

Australian Rainfall and Runoff - A guide to Flood Estimation Volume 2 IEAust 1988

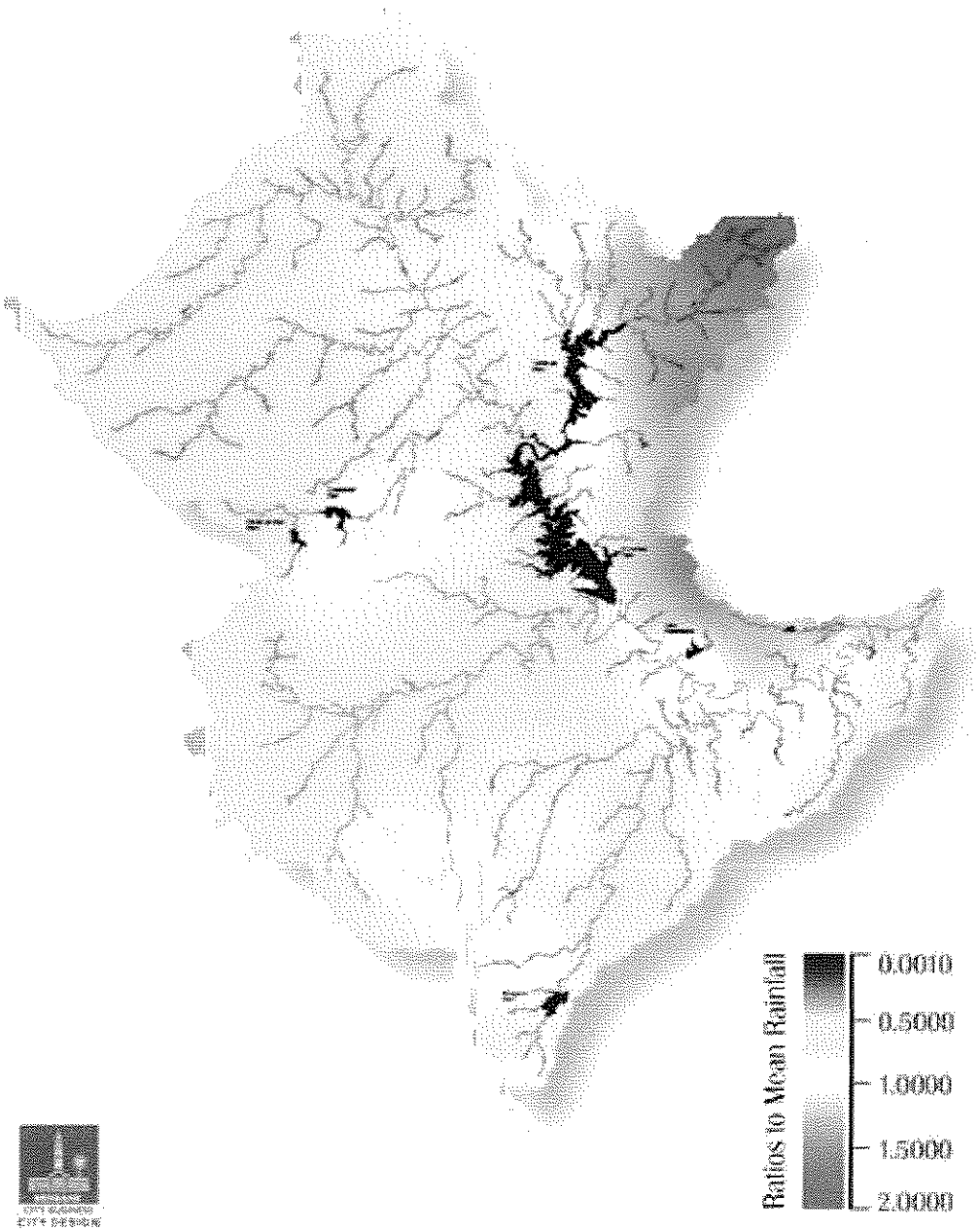
Appendix A Historical Spatial Distributions

SKM

CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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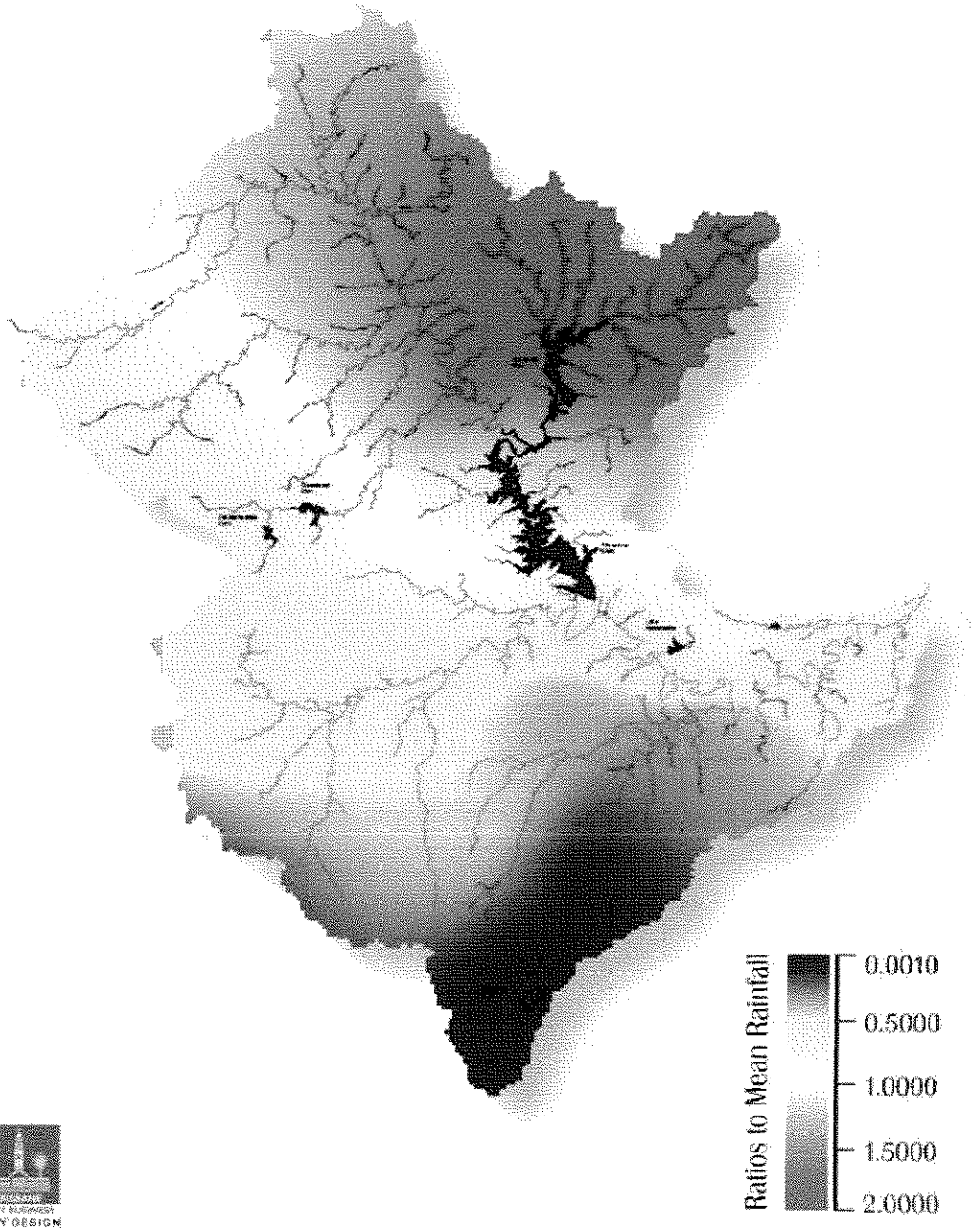
JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

SINCLAIR KNIGHT MERZ

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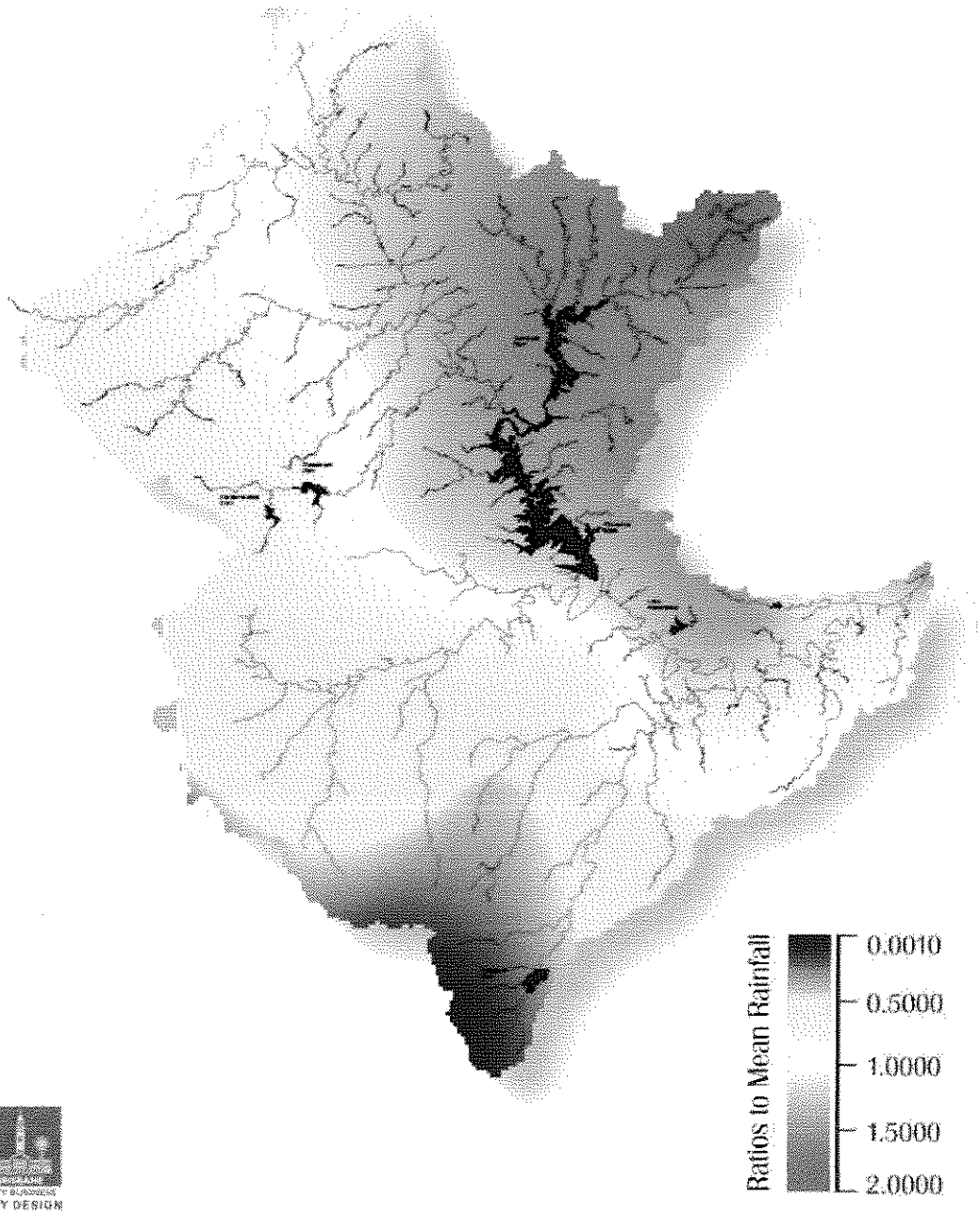
FEBRUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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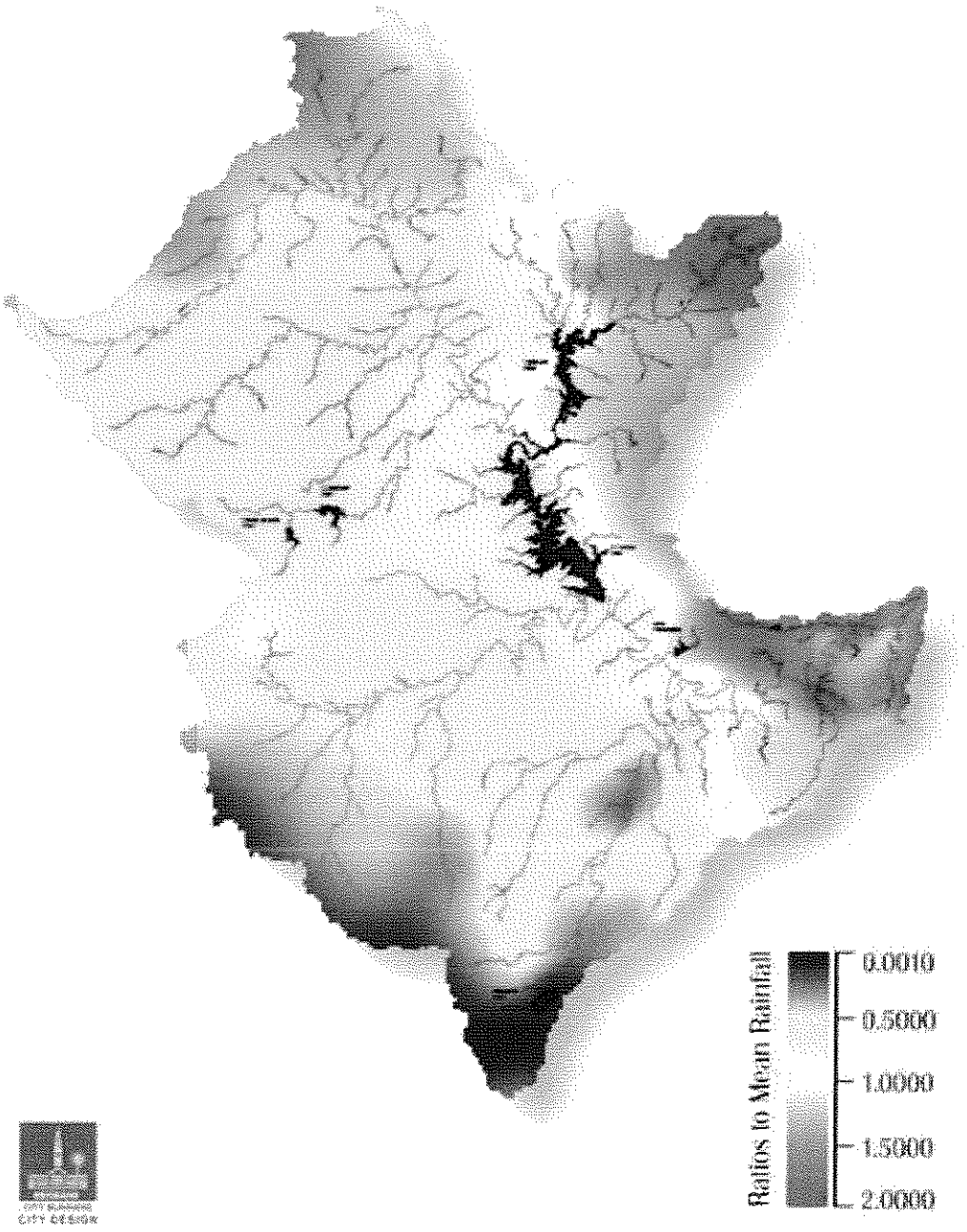
JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

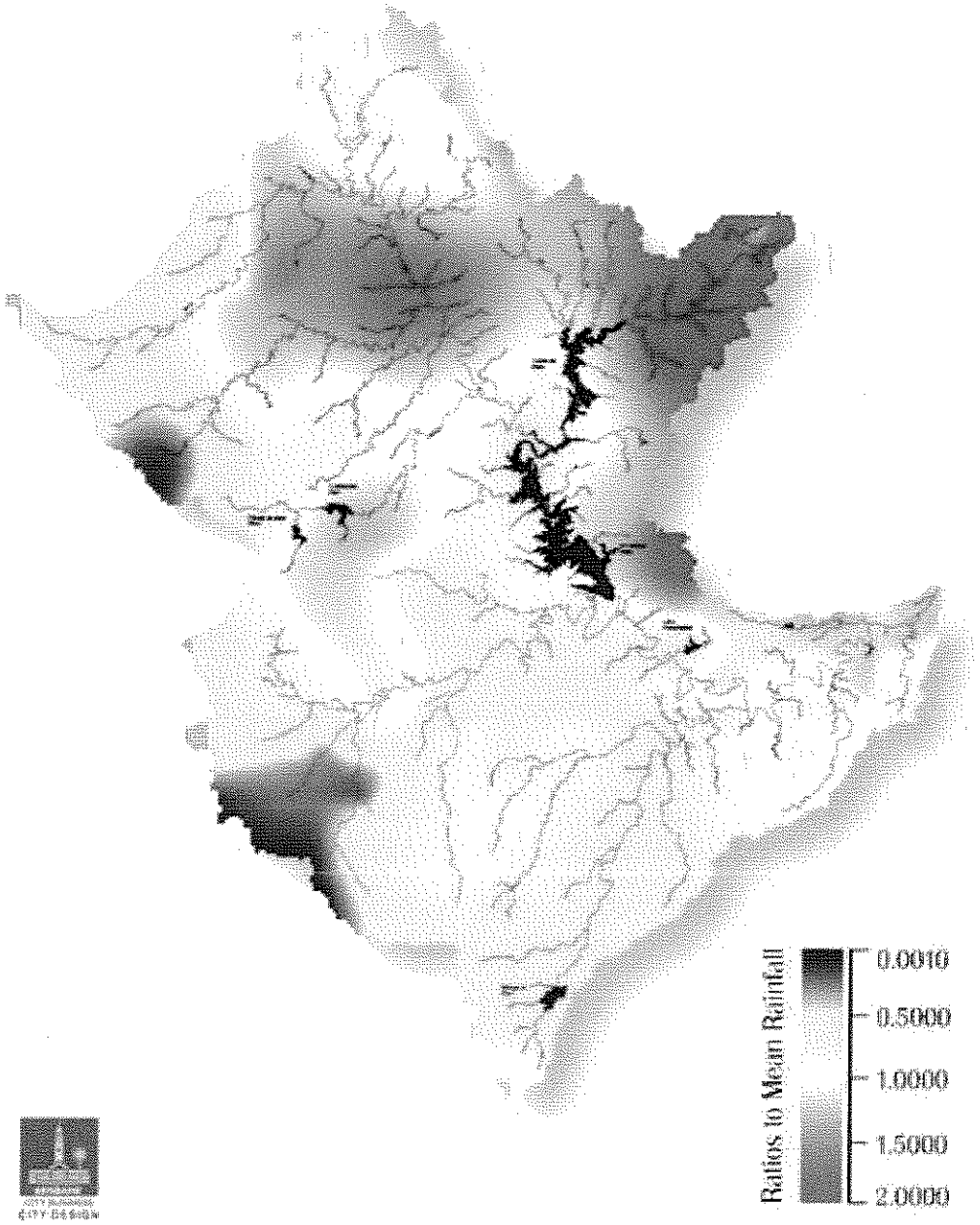
BRISBANE RIVER CATCHMENT



MARCH 1955 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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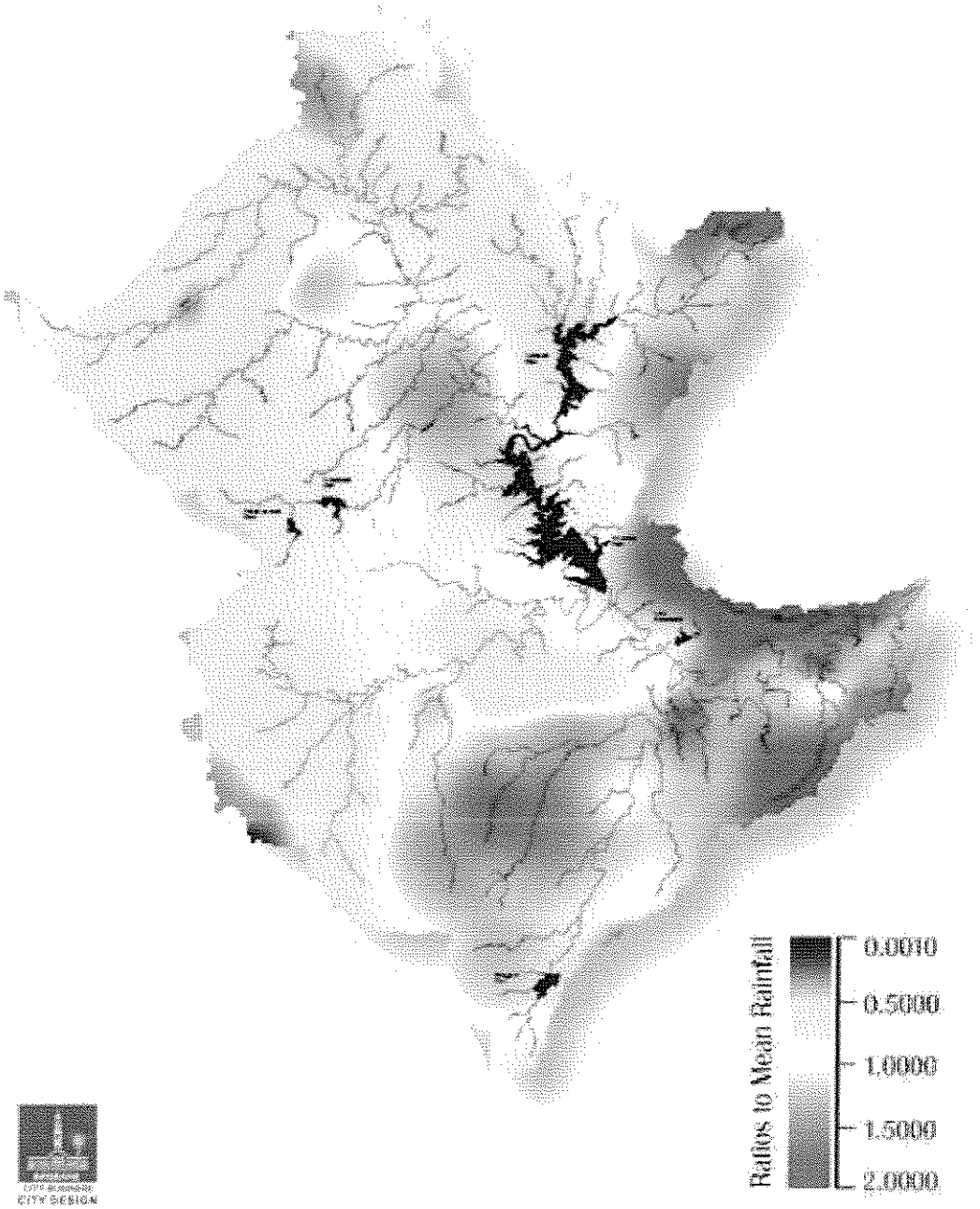
JANUARY 1974 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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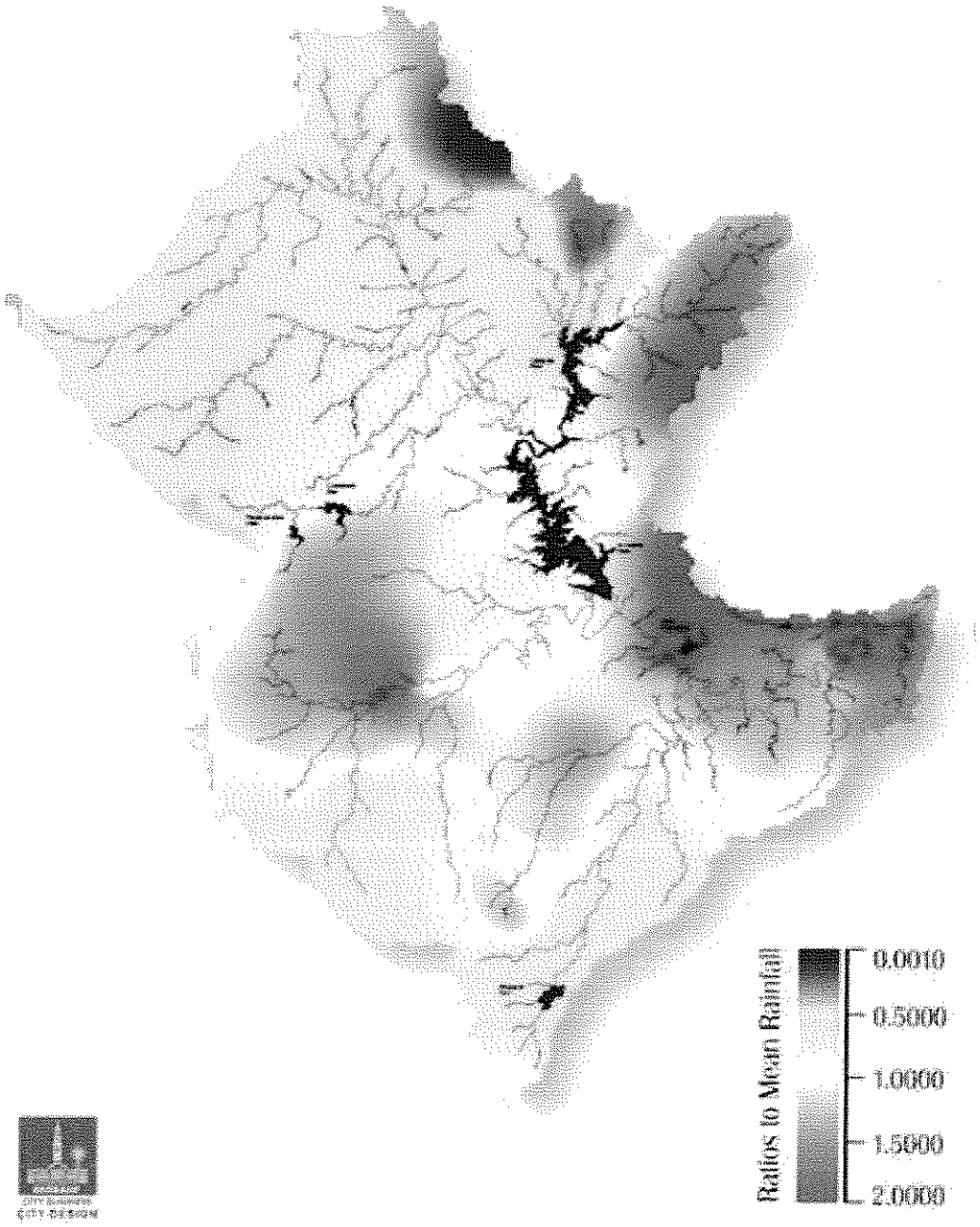
APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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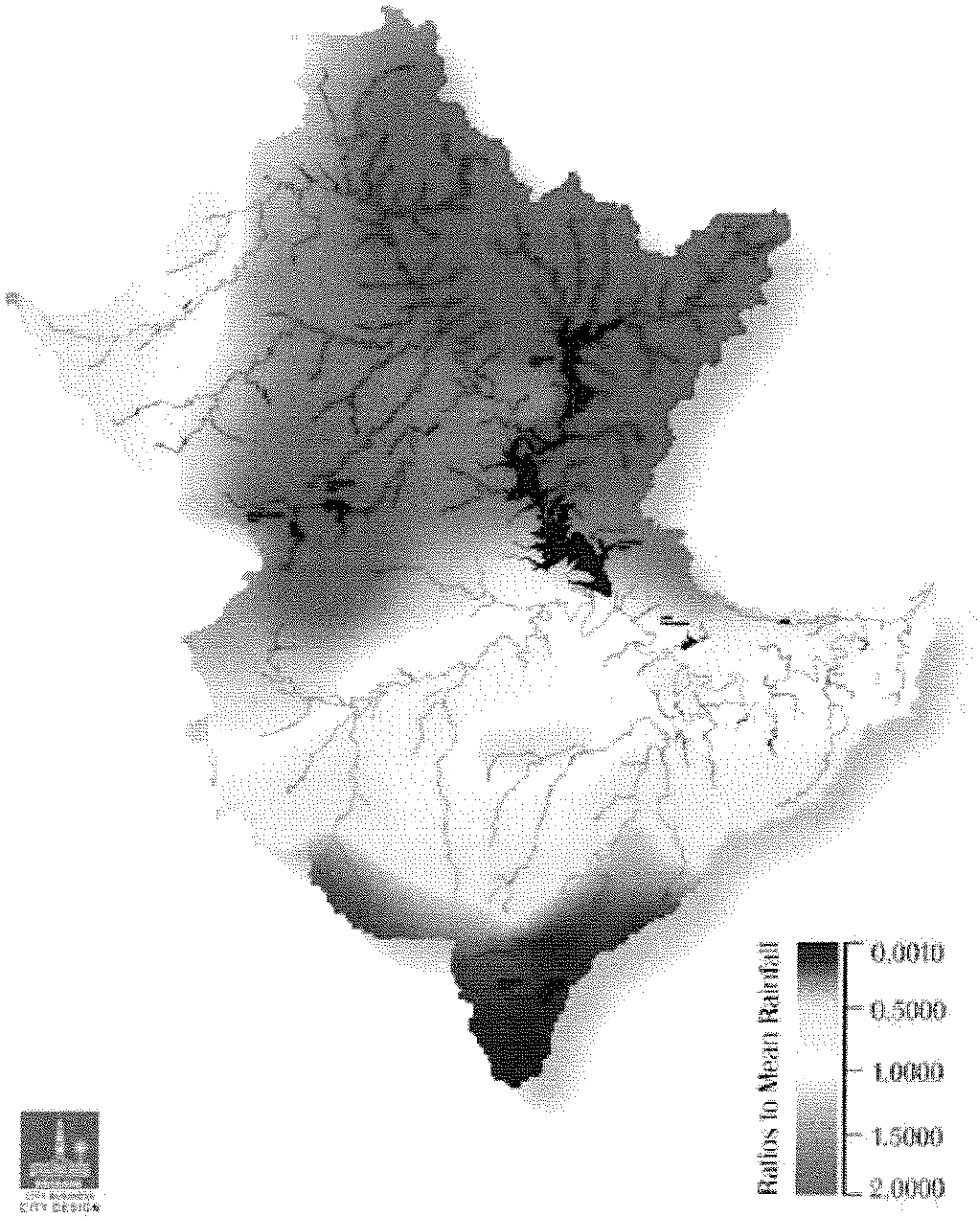
FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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Appendix B Pre and Post Dam RAFTS Model Results

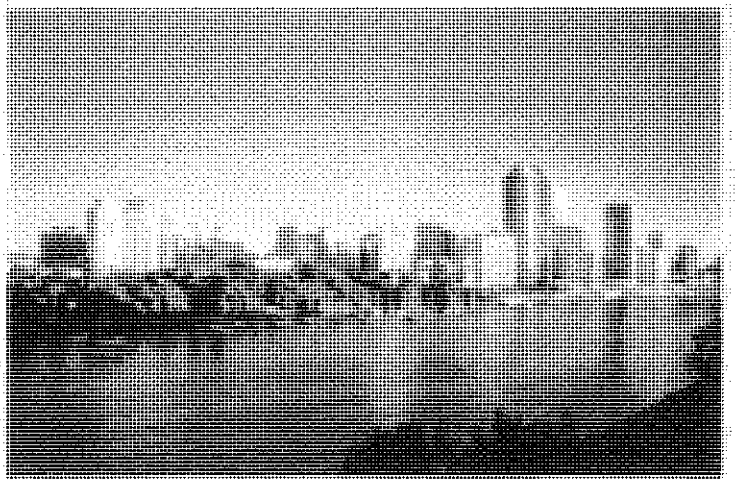
BRISBANE FLOOD STUDY - RESULTS
NO DAMS

	DURATION	SAV-OUT	POG-OUT	JIN###
JAN 1893	24	9861	7927	7927
	30	**11507**	9793	9792
	36	9810	7932	7932
	48	10238	8535	8534
	72	10911	**10198**	**10196**
	96	9774	9394	9392
	120	10074	9641	9639
FEB 1893	24	8698	7502	7502
	30	**10062**	8789	8788
	36	8682	7512	7512
	48	9012	7866	7865
	72	9634	**9504**	**9501**
	96	8568	8636	8632
	120	8804	8904	8898
JAN 1931	24	7505	6745	6745
	30	**8543**	7648	7648
	36	7476	6776	6775
	48	7712	7191	7190
	72	8183	**8030**	**8026**
	96	7140	7610	7514
	120	7360	7713	7630
MAR 1955	24	8671	7537	7536
	30	**10046**	8925	8925
	36	8689	7554	7553
	48	8955	7916	7915
	72	9563	**9623**	**9619**
	96	8376	8750	8745
	120	8635	9002	8997
JAN 1974	24	7058	7203	7202
	30	**8005**	8049	8046
	36	7049	7073	7072
	48	7227	7528	7527
	72	7714	**9117**	**9112**
	96	6729	8161	8154
	120	6879	8454	8432
APR 1996	24	7531	7068	7067
	30	**8621**	7966	7966
	36	7549	7079	7078
	48	7748	7427	7425
	72	8287	**8922**	**8917**
	96	7184	8043	8034
	120	7399	8182	8170
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7894	7893
	48	9981	8444	8443
	72	10642	**10200**	**10197**
	96	9512	9387	9384
	120	9809	9629	9626

BRISBANE FLOOD STUDY - RESULTS
WITH DAMS

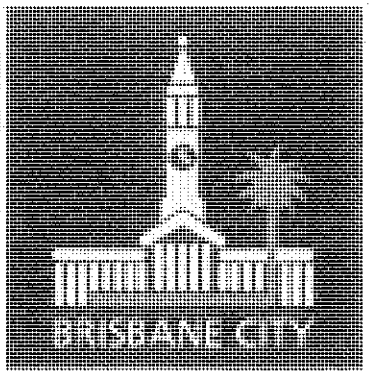
	DURATION	SAV-OUT	POG-OUT	JIN###
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7121**	**7120**
FEB 1893	24	1877	2070	2061
	30	3818	3449	3449
	36	1935	2211	2203
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5596	5595
	120	**6568**	**5851**	**5850**
JAN 1931	24	1872	2319	2051
	30	1926	3314	2708
	36	1884	2836	2452
	48	1758	2580	2382
	72	3079	3968	3146
	96	3170	3383	2940
	120	**3279**	**3411**	**3218**
MAR 1955	24	1925	2350	2345
	30	3524	3433	3433
	36	2063	2544	2541
	48	3272	3013	3013
	72	**6241**	**5710**	**5709**
	96	5926	5340	5339
	120	6151	5585	5584
JAN 1974	24	1753	3326	3324
	30	2467	3989	3987
	36	1871	3350	3279
	48	1943	3633	3627
	72	3307	4965	4418
	96	**4771**	**5852**	**5841**
	120	2911	3662	3656
APR 1996	24	3554	3400	3399
	30	4067	4138	4137
	36	3535	3260	3260
	48	3605	3691	3690
	72	**4162**	**5035**	**5019**
	96	3492	4417	4378
	120	3509	4663	4571
FEB 1999	24	3424	2887	2886
	30	5789	4442	4442
	36	3575	3147	3150
	48	4604	3495	3494
	72	6879	6448	6447
	96	7217	6624	6623
	120	**7431**	**6819**	**6819**

Brisbane River Flood Study



FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Further Investigations
- Final
- 7 Oct 2003



Brisbane River Flood Study

FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Final
- 7 Oct 2003

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Document history and status

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Flood Frequency Draft A	13/08/2003	R. Nathan	[redacted]	13/08/2003	
Flood Frequency Draft B	22/08/2003	R. Nathan		22/08/2003	Major Update
Hydrological Modelling Draft A	22/08/2003	[redacted]		22/08/2003	
Hydrological Modelling Draft B	29/08/2003			29/08/2003	
Final	25/09/2003				Merge Two Reports and Finalise

Distribution of copies

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Flood Frequency Draft B	PDF	PDF	Barry Ball (Brisbane City Council)
Hydrological Modelling Draft A	Electronic	Electronic	Peter Barnes (Brisbane City Council)
Hydrological Modelling Draft B	Electronic	Electronic	Peter Barnes (Brisbane City Council)
Final			

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Executive Summary

An Expert Panel has been appointed to review the flood investigations undertaken for the Brisbane River. Sinclair Knight Merz was approached to assist the Expert Panel with their review. The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a "best" estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event.

The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

This technical report has been prepared for expert technical reviewers and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, hydrological terminology and abbreviations is generally assumed.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table E1.

Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100.
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty)
- choice of frequency distribution and the appropriate parameters; and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m³/s and 11 000 m³/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by

vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures;
- dam levels at the start of a flood event; and,
- spatial and temporal patterns of the storm.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment. ARFs were not available for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knight Merz 1998) was undertaken.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

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Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

Q100 estimate at the Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The information for the two historical flood events (1893 and 1974) were run through the RAFTS model for the pre and post-dam conditions. For post-dam conditions, the estimated peak flow at the Port Office for the 1893 and 1974 flood events were 9500 m^3/s and 6800 m^3/s respectively. It should be noted that the uncertainty of the historical data, 1893 in particular, is considerable.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

SKM

1. Introduction

1.1 Background

Sinclair Knight Merz prepared a flood study for the Brisbane River in 1998. Since this time, there have been changes to the information used in assessing the flood levels along the lower reaches of the Brisbane River. This includes:

- CRC-FORGE rainfall estimates that have been prepared for the Brisbane River catchment (Department of Natural Resources and Mines, 2003a) and
- Modifications to procedures for flood operations at Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, 1998) was completed.
- Additional and/or revised flood flow data

An Expert Panel has been appointed to review the flood studies undertaken for the Brisbane River in the light of this new information, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for Sinclair Knight Merz were to:

- Undertake flood frequency analysis, and to
- Update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The details of the tasks that were agreed to are presented in Appendix A.

1.2 Scope of Report

This report addresses the tasks presented in Appendix A, namely to,

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document the findings of the flood frequency analysis, stating assumptions and outcomes;
4) Review previous reports, CRC-FORGE rainfall estimates and historical streamflow data.
5) Undertake a Regional Flood Frequency Analysis (pre-dams).
6) Undertake hydrologic modelling (pre-dams).
7) Undertake hydrologic modelling (dams in place).

8) Analyse catchment sensitivity using various temporal patterns.

9) Undertake a check with historical flood events.

10) Perform hydraulic modelling to produce flood frequency estimates at Moggill and the Port Office.

11) Report on the findings of the rainfall-runoff and hydraulic modelling.

SKM

2. Sources of Data for Flood Frequency Analysis

Gauging station data were obtained from the Department of Natural Resources and Mining (DNRM) and the Commonwealth Bureau of Meteorology (BoM). Different types of data were collected, including:

- recorded water elevation above the gauge datum,
- flow data estimated from a rating relationship and
- rating tables

In some instances the data had been processed in some additional manner, as discussed below.

A number of reports on large flood events and the analysis thereof have also been made available.

2.1 Department of Natural Resources and Mining Data

There are two sources of data from DNRM:

- Recorded water elevation data and associated flow estimates
- Estimates of "no dams" flood peaks at Savages Crossing that had been adjusted to exclude the influence of the dam(s) where appropriate.

Both data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in **Appendix B** (along with other sources of gauged data). The primary reasons for omission were:

- short record length,
- small catchment area, and/or
- uncertainty in the rating curve.

The latter reason included either very low gauged flow or the rating curve had been changed to a "calibration curve" for use in real time flood forecasting. It may be possible to include some of this flow data for future analysis when questions regarding the adjustment made to the calibration curves have been resolved.

Elevation data for a number of sites of direct interest to this study, such as Moggill, Brisbane City and the Port Office were also obtained.

Appendix C shows the location of the stream gauges that were used in the flood frequency analysis.

SKM

3. Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (ie peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in Section 2.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- Adjustment of data for the influence of the dams
- Uncertainty in the rating curves that relate recorded river level to flow rate
- The magnitude of historic data (especially 1893 and 1825)
- The period of record associated with the historic data
- Choice of frequency distribution
- Selection of parameters for the distribution
- Method of including historical data

DNRM provided a series of data (1890 – 2000) that was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had existed over the entire period. Frequency analysis of this data was undertaken along with various unadjusted data.

The frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by Assoc Prof George Kuczera in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix D**.

The analyses undertaken to determine the "best" estimate from flood frequency analysis and a plausible range is summarised in Table 3.1. FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets an Sinclair Knight Merz program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte-Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

The results of these analyses are recorded with selected frequency distributions in Sections 3.3 - 3.6 and the results summarised in Table 3.7. As noted previously, this report has been prepared for expert reviewers with a high level of understanding. The explanations, comments and discussion are as concise as possible to enable the broad range of analyses to be succinctly presented for ease of comparison.

SKM

Table 3.1 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m³/s)	Historic Period	Distribution	Model for fitting distribn	Prior Informn (regional)	Main Objective
Case 1 **Pre -Wivenhoe and Somerset**							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

Case 2 **Pre Wivenhoe, no adjustments made for Somerset**							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3 **"No Dams" based on DNRM adjusted estimates**							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by DNRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4 **"Dams" based on DNRM estimates**							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

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3.2 Regional Frequency Analysis

A regional frequency analysis was conducted to assist in the estimation of flood frequency at Savages Creek (GS143001). The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane River catchment, including the site at Savages Crossing (GS143001). The Generalised Pareto probability distribution was selected for the flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value;
- its prior standard deviation; and,
- its correlation with other parameters.

The prior mean and standard deviation of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in Table 3.2.

Table 3.2 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001).

Value	Scale parameter, α	Shape parameter, κ
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

Greater detail of the regional analyses is provided in Appendix D.

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3.3 Case 1: Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the DNRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in Table 3.3 with specific influence on curves plotted in Figures 3.1 – 3.3 so that the influence of specific assumptions can be compared graphically.

Table 3.3 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Gauge Data Record	Historic Data (m³/s)	Historic Period	Distn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.

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	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1C	1909-1951	1893 (Qp= 13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post-Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825 (Qp= 13200) 1893 (Qp= 13 200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp= 14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.

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	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1G	1909-1951	1893 (Qp= 12 000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp= 13 000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.

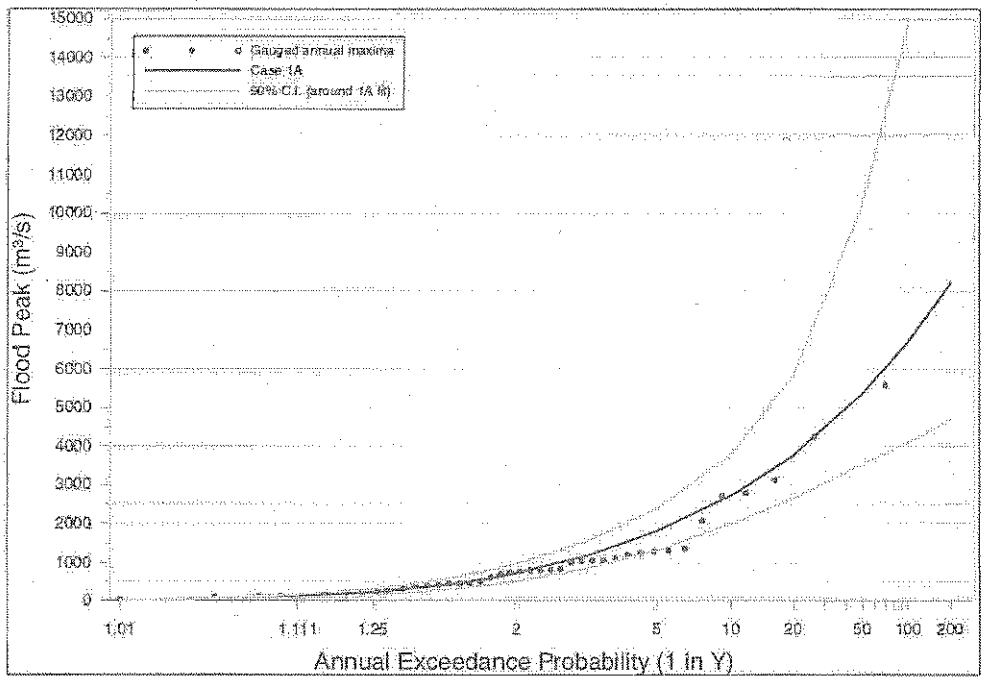

Figure 3.1 Generalised Pareto Distribution fitted to the 1909-1951 pre-dams data at Savages Crossing.

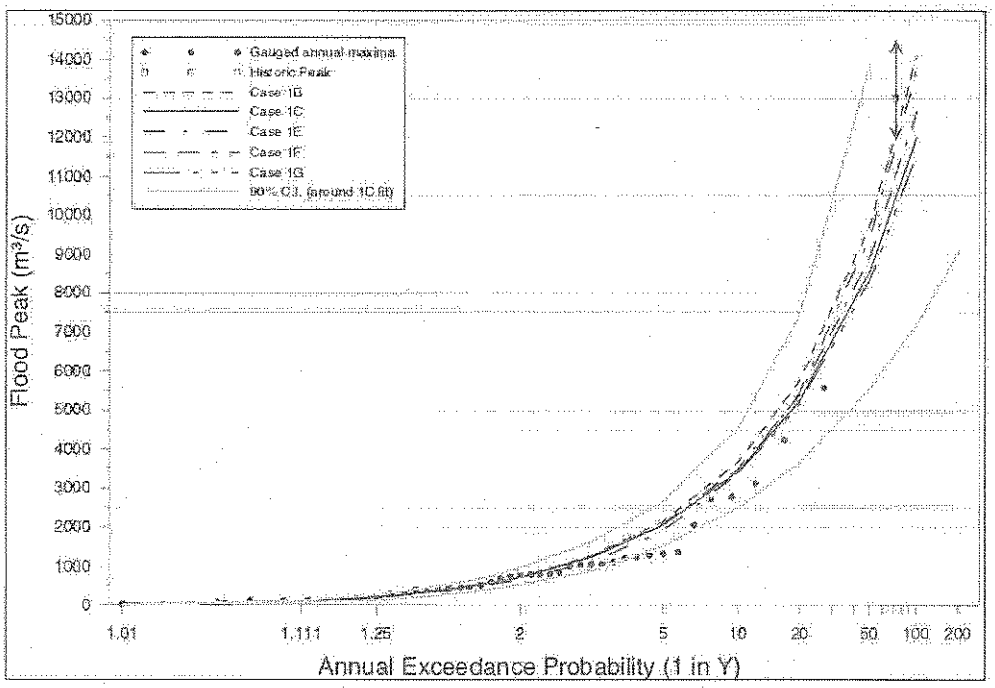

Figure 3.2 Comparisons of variations in flood frequency for various assumptions on pre-dams data for Savages Crossing.

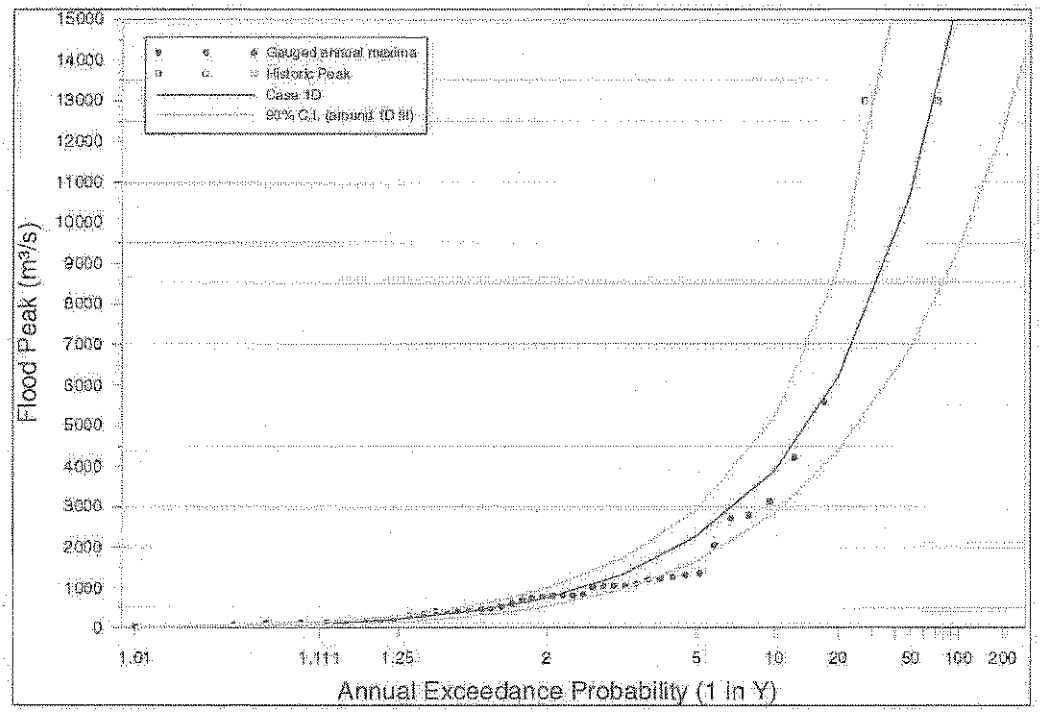

Figure 3.3 Assessment of the inclusion of a 1825 estimate of a flood possibly of the same magnitude as the 1893 event.

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3.4 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

- Table 3.4 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Cont'n Data Record	Historic Data (m³/s)	Historic Period	Distbn	Prior Info (reg-ional)	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

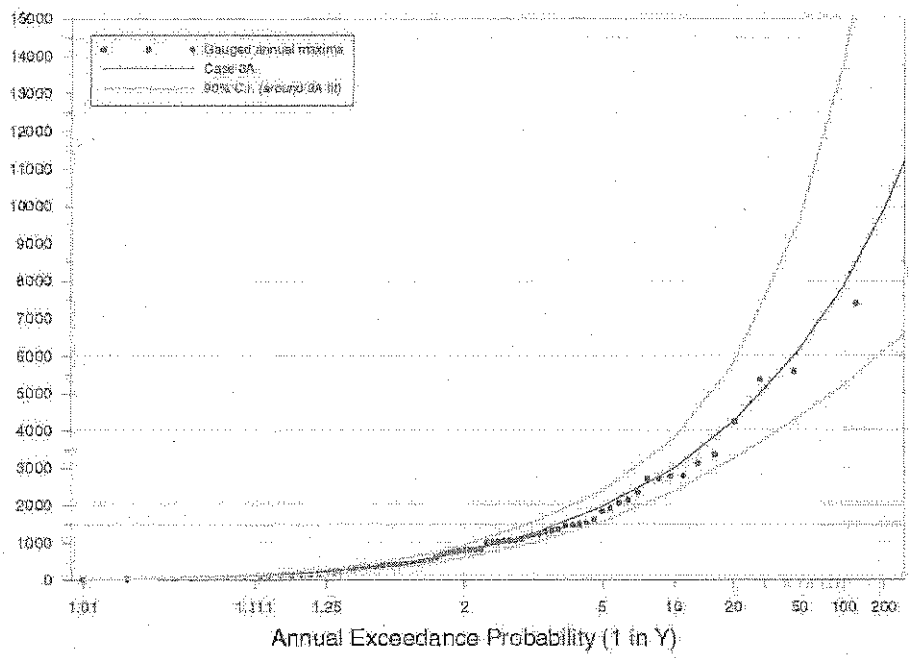

Figure 3.4 Assessment of the pre-Wivenhoe gauged data without 1893 event.

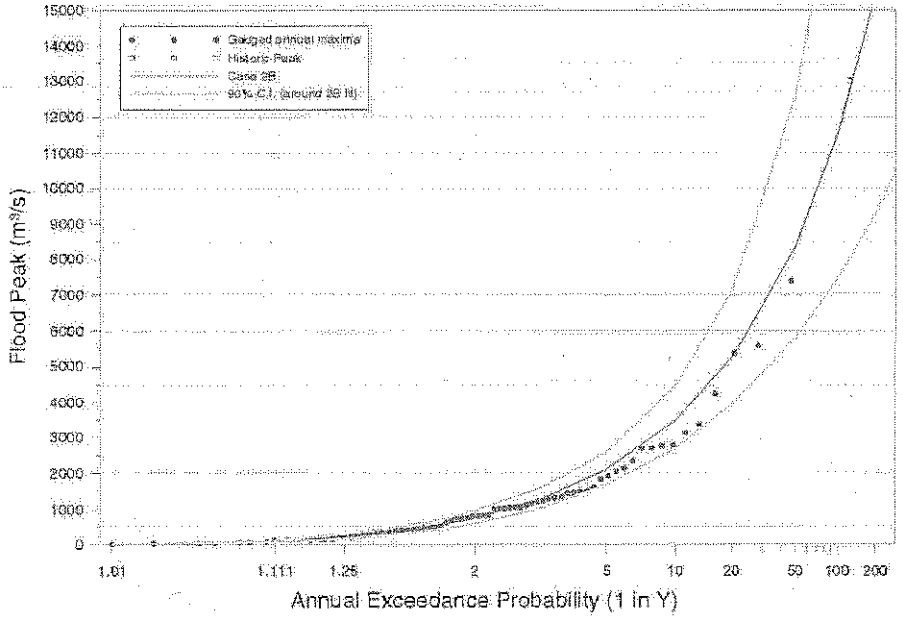

Figure 3.5 Assessment of the pre-Wivenhoe gauged data with 1893 event.

3.5 Case 3: Analysis of "No Dams" Data Estimated by DNRM

Note effect of Somerset dam is highly variable depending on its operation. DNRM has indicated that they have spent significant resources assessing the effect of Somerset on the flood series. The data series has been provided without documentation as to the method used to adjust the data. Sinclair Knight Merz has taken this series and analysed the statistics without investigation of its derivation.

Table 3.5 Summary of Case 3 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Contiguous Record	Historic Data (m³/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.

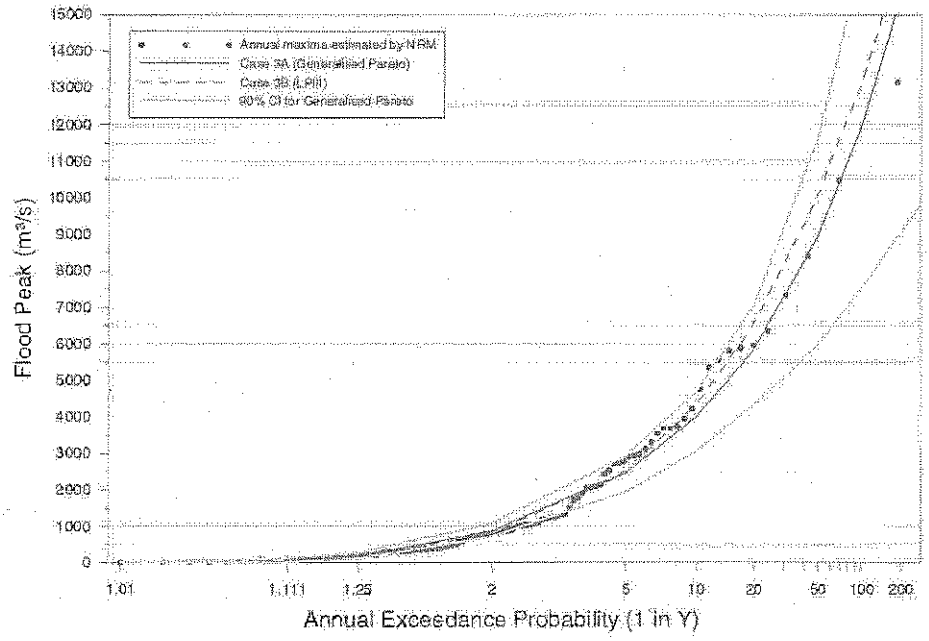

Figure 3.8 Assessment of the "no –dams" annual maxima series provided by DNRM using both GP and LPIII distributions.

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3.6 Case 4: Analysis of Post-Dam Data Estimated by DNRM

These analyses were based on "post-dam" data set provided by DNRM. As with the analyses reported in Section 3.4, no assessment of the manner in which this data set was derived was undertaken.

- Table 3.6 Summary of Case 4: Post-dam Data - flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m³/s)	Historic Period	Distn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 4 "Dams" based on DNRM estimates								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

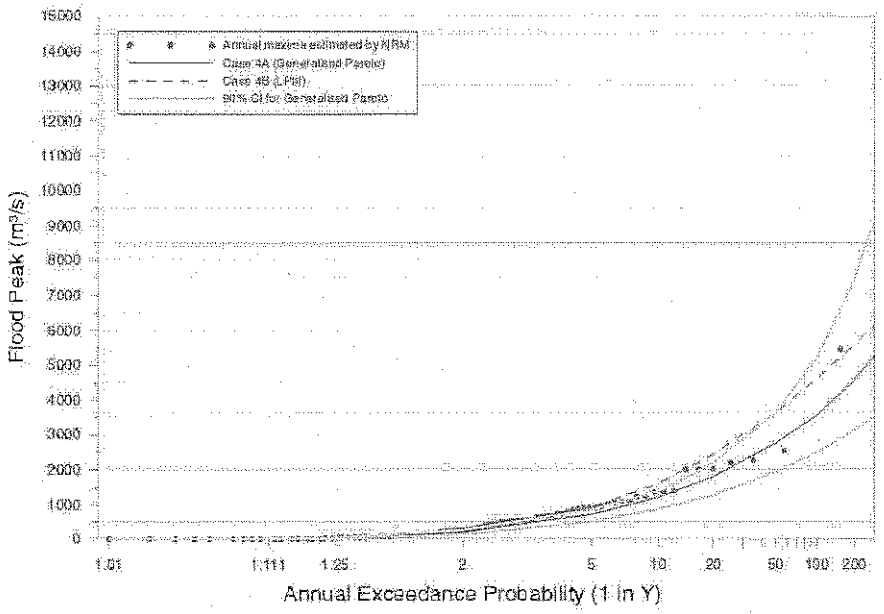

Figure 3.7 Assessment of the "post-dams" annual maxima series provided by DNRM using both GP and LPIII distributions.

3.7 Summary of analysis results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) estimate at Savages Crossing. The analyses are summarised in Table 3.7. As noted above, the summary is intended to succinctly present the broad range of sensitivity analyses for expert reviewers who are familiar with the concepts, common discipline abbreviations and analysis methods.

SKM

Table 3.2 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m³/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 1 **Pre -Wivenhoe and Somerset**								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information.	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825(Qp=1320 0) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m³/s if the historical data is excluded.
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

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Table 3.7 cont. Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m³/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

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3.8 Best Estimates from flood frequency assessment

Sinclair Knight Merz has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling reported in the subsequent chapters). The results are presented in Table 3.8.

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), DNRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m³/s); as no allowance made for Somerset dam, the Q100 could be expected to be higher than 11 500m³/s.
- the "No dams" series from DNRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3A).

Table 3.8 Most plausible estimates of the Q100 peak flow at Savages Crossing.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),
- choice of distribution and the appropriate parameters; and

- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500m³/s and 11 000m³/s.

An additional assessment of the "current" scenario, ie with Somerset and Wivenhoe dams present and operated using current operating procedures is also provided (Case 4 – above). This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by DNRM. Note that no assessment of the plausible range for this estimate is possible, as the method for adjusting the data series is not currently available.

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4. Rainfall-Runoff Modelling

Rainfall-runoff modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS rainfall-runoff model developed for the Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) was used for this investigation. The Ipswich River Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model.

4.1 Assumptions

- The Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM, 2003) Wivenhoe and Somerset Dam Operations Model was used to determine Dam outflows.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows.

- Initial Loss Rate (IL) = 10 mm
- Continuing Loss (CL) = 1.0 mm/h
- All model runs were undertaken for the 1 in 100 (1%) AEP flood event only.

4.2 Methodology

The following Methodology describes the process that was used to determine 1 in 100 AEP flood flows at Moggill and the Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model
- Input CRC-FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1% AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the DNRM Dam Operations Model.
- The DNRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the DNRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1% AEP flows at Moggill and the Port Office Gauge.

- A sensitivity analysis was then performed to using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wivenhoe and Somerset Dams at the start of the flood event.

4.3 Pre-dams RAFTS Modelling

The object of the pre-dams modelling was to achieve reconciliation between the Flood Frequency Estimates and the flow estimates produced by RAFTS. CRC-FORGE rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine affects that temporal patterns have on peak flows.

4.3.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

CRC-FORGE Rainfall Estimates for varying duration's were input into the model with Areal Reduction Factors (ARF) applied (Department of Natural Resources and Mines, 2003a). Table 4.1 presents the rainfalls and ARF's used.

- Table 4.1 CRC-FORGE Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC-FORGE Rainfall	247	268	285	317	358	385	402
CRC-FORGE Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC-FORGE rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in Appendix E. Standard Temporal Patterns were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/hr was adopted.

The CRC-FORGE rainfall estimates with ARF's applied are presented in Table 4.2.

- Table 4.2 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Pre-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Port Office should be considered indicative only.

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4.3.2 Sensitivity to Spatial Pattern of Rainfall

To determine the impact of spatial patterns, seven historical spatial patterns were assessed. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC-FORGE Rainfall Depths (ARF applied) for each duration.

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane River and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane River Catchment.
- April 1996 - high rainfalls in the Lockyer and Lower Brisbane River Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in Appendix F.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/h was applied.

Peak flows are presented in Table 4.3.Note that for all spatial distributions the 30 hour flood is the critical duration storm at Savages Crossing and the 72 hour flood is the critical duration at Moggill and Port Office. Flows presented at Moggill and the Port Office in Table 4.3 should be considered indicative only. More reliable estimates of design floods at the lower gauges are produced by the hydraulic model, as discussed in **Chapter 5**.

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- Table 4.3 Pre- dams 1% AEP Peak Flows for Historical Spatial Distributions.

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: - Bold values indicate the median flow at each location
- Flows at Moggill and Port Office should be considered indicative only.

A full listing of peak discharges at Savages Crossing, Moggill and Port Office are present in Appendix G.

4.3.3 Sensitivity to Temporal Pattern of Rainfall

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC-FORGE Rainfall 48 hour storm duration. An I.L. of 0 mm and a C.L. of 0 mm/hr was applied.

The temporal patterns that were used in the sensitivity analysis were:

- AVM – Average Variability Method
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event.
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event.
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event.
- AR&R 1987 – Standard temporal pattern outlined in Australian Rainfall and Runoff.

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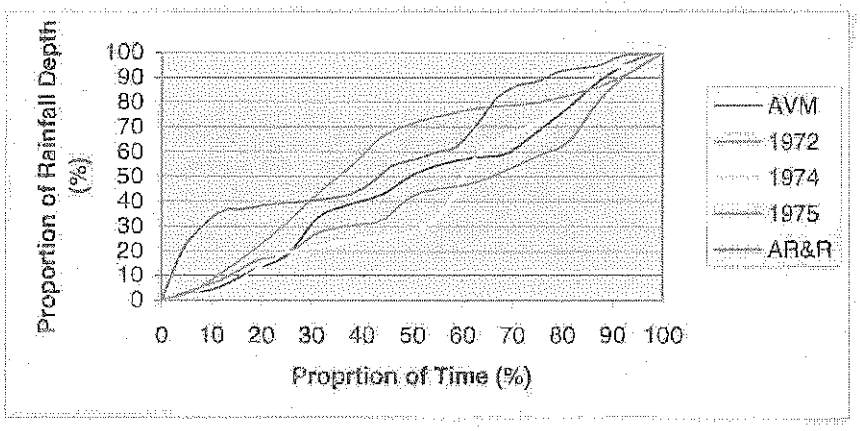
Figure 4.1 Temporal Patterns for the 1% AEP 48 Hour Storm Event



The resulting peak flow estimates using the temporal patterns described above are presented in Table 4.5

Table 4.4 48 Hour Temporal Pattern Sensitivity

	48 hour Temporal Pattern				
Location	AR&R	AVM	1972	1974	1975
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Port Office	12817	13464	13287	14115	13634

4.3.4 Discussion

Table 4.3 and Table 4.4 show that spatial and temporal patterns have a significant affect on peak flows. Given the size of the catchment and the variability that spatial and temporal patterns have on peak flows, it is evident that a Monte-Carlo analysis would be appropriate. A Monte-Carlo analysis was not possible within specified time frame for this report and therefore the sensitivity analyses was undertaken to investigate potential effects of this phenomenon.

The pre-dams historical spatial distributions produce peak flows at Savages Crossing that range from 11500 m^3/s to 8000 m^3/s with the median peak flow being 10046 m^3/s. The estimated peak flow at savages using the CRC-FORGE Spatial Pattern was estimated to be 9607 m^3/s.

If an IL of 0 mm and CL of 0 mm/h is applied to the CRC-FORGE 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11278 m^3/s. It should be noted that the 'best estimate' of peak flow at Savages Crossing from the Flood Frequency Analysis was estimated to be 12000 m^3/s. This means that the RAFTS peak flow

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estimates and the FFA estimates cannot be reconciled unless further work is undertaken on the manner in which the various flood-producing factors can be combined.

4.4 Comparison of Q100 estimates from flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated RAFTS model
- CRC-FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

produced a Q100 at Savages Crossing of 11278 m^3/s. It would be reasonable to expect some losses with a 1 in 100 AEP event and hence the hydrological modelling results, using typical design parameters, could be expected to be lower, say in the order of 10, 500m^3/s.

The difference between the results and those from the statistical frequency analysis of flood records (Chapter 3) indicates that there are underlying factors that have not been adequately addressed to date. This would require more detailed assessment than is available in the scope and timing of the current assessment. Potential factors influencing the difference in Q100 estimates include:

- potential for partial area storms
- variation in temporal patterns
- variation in spatial patterns
- variation in losses
- adjustment of data for influence of dams
- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.

The development of a Monte-Carlo framework for analysing the factors affecting flood magnitude would enable the natural variation in the first four factors to be explicitly modelled. This would give insights necessary to resolve the discrepancy between the two independent sources of the Q100 estimate.

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4.5 Post-dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and run through the DNRM Dam Operations Model (Department of Natural Resources and Mines, 2003b). These inflows were based on the outputs presented in Appendix G and included an IL of 10 mm and CL of 1.0 mm/hour.

The outflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the hydrograph volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC-FORGE and historical spatial patterns to determine flows at Savages Crossing, Moggill and Port Office.

4.5.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

The parameters described in Section 4.3.1 were used for the Post-dams RAFTS modelling.

The CRC-FORGE rainfall estimates with ARF's applied are presented in Table 4.5.

Table 4.5 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Post-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	**5368**	2335	2502
Moggill	3017	3690	2999	3302	**5043**	3811	3990
Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Port Office should be considered indicative only.

4.5.2 Sensitivity to Spatial Pattern of Rainfall

The parameters described in Section 4.3.2 were used for the Post-dams RAFTS modelling. Peak flows are presented in Table 4.6. Note that the critical duration storm at Savages Crossing, Moggill and Port Office range from 72 to 120 hours for Post-dam Conditions. Flows presented at Moggill and the Port Office in Table 4.6 should be considered indicative only. More accurate flows will be determined during the hydraulic modelling.

Table 4.6 Post-dams 1% AEP Peak Flows for Historical Spatial Distributions

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: **- (120hr) denotes the critical storm duration**
- Bold values indicate the median flow at each location
-Flows at Moggill and Port Office should be considered indicative only.

4.5.3 Sensitivity to Starting Water Level in Wivenhoe Dam

Full supply level of Wivenhoe Dam is at RL 67.0 m AHD and has a storage capacity of 1165×10^6 m^3 of storage. The crest level of Wivenhoe Dam is at RL 79 m AHD with a corresponding storage capacity of 2934×10^6 m^3. The maximum flood mitigation volume of Wivenhoe Dam is 1769×10^6 m^3.

It is unlikely that Dam Owners would choose to utilise the full volume of flood as Wivenhoe Dam is an earth fill dam they would be unwilling to risk overtopping of the dam that could lead to dam failure.

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1% AEP flood (average CRC-FORGE rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in Table 4.7

Table 4.7 Flood Runoff Volumes for the 1% AEP above Wivenhoe Dam

Storm Duration (hours)	CRC Rainfall Depth with ARF Applied (mm)	Runoff Volume ($m^3 \times 10^6$)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

Table 4.7 shows that if Wivenhoe Dam is at FSL, the 1% AEP 36-hour flood runoff volume can be fully stored between FSL and Crest Level without release. For 1% AEP events with longer

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durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the crest level is over, topped (no releases).

Given current operational procedure, it is unlikely that no releases would occur during a flood event, particularly if Wivenhoe Dam is at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs have been done for the 1% AEP 72 hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in Table 4.8.

Table 4.8 Dam Starting Water Levels Sensitivity Analysis for the 1% AEP 72 Hour Storm

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Port Office	5044	4402	4402

Note: - Flows at Moggill and Port Office should be considered indicative only.

Table 4.9 shows that the reduction in flow is approximately 13% at the Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

4.5.4 1893 and 1974 Historical Flood Events

The information from the two historical flood events (1893 and 1974) were run through the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post-dam flows are presented in Table 4.10.

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Table 4.10 Predicted Post-dam Flows for the 1893 and 1974 Historical Flood Events

	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
Location	No Dams (m^3/s)	Somerset and Wivenho' in Place (m^3/s)	Somerset in Place (m^3/s)	Somerset and Wivenho' in Place (m^3/s)
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Port Office	13869	9519	9874	6801

Table 4.10 indicates that the peak flows for the historical events at the Port Office are above the 1 in 100 AEP CRC-FORGE estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1974 peak flow estimate and even more with the 1893 event. However, it is clear that the effect of the dams on events of such magnitude can be significant.

4.5.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. This again indicates that Monte-Carlo analysis would be an appropriate way to investigate the complex interactions between dams and variations in losses, spatial and temporal patterns to obtain the best estimate of the 1%AEP flood event.

The CRC-FORGE spatially distributed peak flow at Savages Crossing was estimated to be 5368 m^3/s for the post-dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow being 6241 m^3/s.

Based on the preceding investigations, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate. Given the current information, the 'best estimate' of peak flow at the Port Office would be 6500 m^3/s with an upper and lower limit of 8000 m^3/s and 5000 m^3/s respectively.

It is recommended that Monte-Carlo analysis be undertaken as there many uncertainties associated with the above best estimate.

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The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flow estimates are:

- inclusion of the lower CRC-FORGE rainfall depths with areal reduction factors (ARF's were not available for catchments of this size in 1998),
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures (the previous study (Sinclair Knight Merz 1998), assumed emergency operating procedures which minimised the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River),
- In the 1998 study, the emphasis was to match Flood Frequency Estimates at Moggill and the Port Office. The reliability of the streamflow at Moggill and Port Office is questionable as these gauges are height read gauges and tidal effects are difficult to account for at these locations. After discussions with DNRM, who have just developed a new composite flood series at Savages Crossing, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and flood frequency estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing, as discussed in Chapter 3.
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that rainfall-runoff modelling be undertaken in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.

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5. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Port Office is good, other sections of the reach within Brisbane City has not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

5.1 Assumptions

- Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane River Bar.

5.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from approximately 10km downstream of Savages Crossing to the Brisbane River Bar. The model also includes Bremer River and other smaller tributaries which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1% AEP spatially distributed over the catchment. Duration's ranging from 24 to 120 hours were assessed.

5.3 Results

The peak Discharges and Flood Levels for at Moggill and Port Office are presented in **Table 5.1 1% AEP Peak Flood Levels and Flows for the CRC-FORGE Spatial Distributed Rainfall.**

- Table 5.1 1% AEP Peak Flood Levels and Flows for the CRC-FORGE Spatial Distributed Rainfall

	Moggill		Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

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5.4 Discussion

Table 4.5 and Table 5.1 show that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Port Office.

Using the 'best estimate and upper and lower limits of peak flows at the Port Office presented in Section 4.5.5, a rating curve was used to predict flood levels at the Port Office for the 1%AEP flood event. Peak flood levels and corresponding flows are presented in Table 5.2.

Table 5.2 Peak Flood Level and Peak Flow Estimates for the 1%AEP Flood Event at Port Office.

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

Note that these estimates should be considered indicative because the actual tide level may vary for an actual flood event. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918) at the Brisbane River Bar.

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6. Conclusions

Detailed investigations have been undertaken to assist the Expert Review Panel to assess the likelihood of floods in the lower reaches of the Brisbane River. The assistance has been centred on the two tasks of

- undertaking statistical flood frequency analysis, and
- updating the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table E1.

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Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the significant sources of uncertainty in the recorded data, length of record, choice of distribution and adjustment of the data for the effect of the dams. As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m^3/s and 11 000 m^3/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment. ARFs were not available for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knight Merz 1998) was undertaken.

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Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1% AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

Q100 estimate at the Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to

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account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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7. References

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane *River* flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the Flood Frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the Flood Frequency Analysis Outcomes.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC-FORGE Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 1 in 100 AEP event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the DNRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine the 1 in 100 AEP flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQB and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of sophistication



appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.

Appendix B Flow Gauging Stations Omitted from Consideration

Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143222A	Atkinson Dam	Atkinson Creek Outlet		20	Small catchment area, offstream storage	DNRM
143234A	Atkinson Dam Hea			6	Small catchment area, offstream storage	DNRM
143228A	Bill Gunn Dam	Lake Dyer	3	18	Catchment area too small	DNRM
143027A	Blunder Creek	King Avenue Bridge	31	8	Urban creek in Brisbane area, Small catchment	DNRM
2121	Blunder Creek	King Ave- Durack		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1594	Breakfast Creek	Opposite Newstead House		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1579	Breakfast Creek	Sedgley Park Retention Basin- New Market		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1525	Breakfast Creek	Opposite Mann Park- Bowen Hills		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143104B	Bremer River	Rosevale	67	21	Catchment area too small	DNRM
143104A	Bremer River	Rosevale	77	34	Catchment area too small	DNRM
143110A	Bremer River	Adams Bridge	125	35	Catchment area too small	DNRM
143940	Bremer River	Stokes Crossing	180	21	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143909	Bremer River	Rosewood	543		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143833	Bremer River	Rosewood Alert	543	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143908	Bremer River	Rosewood TM	543	25	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143934	Bremer River	Walloon Bvrt	585		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143805	Bremer River	Walloon Alert-P	585	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143911	Bremer River	Ipswich	1850		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143956	Bremer River	Three Mile Bridge Alert	1870		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143954	Bremer River	Ipswich Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143953	Bremer River	One Mile Bridge Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143852	Bremer River	Brassall(Hancocks Br) Al		5	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143115A	Bremer River	Berry's Lagoon		9	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143944	Brisbane River	Linville	2005	47	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143007A	Brisbane River	Linville	2009	39	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143831	Brisbane River	Devon Hills Alert	2160	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143922	Brisbane River	Devon Hills Bvrt	2190		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143002A	Brisbane River	Plainlands	3950	12	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143002B	Brisbane River	Fulham Vale	3950	34	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143005A	Brisbane River	Watts Bridge	4602	20	Record length too short	DNRM
143008A	Brisbane River	Middle Creek	6704	20	Record length too short	DNRM
143026A	Brisbane River	Wivenhoe	7023	3	Record length too short	DNRM
143036A	Brisbane River	Wivenhoe Headwater	7023	17	Record length too short	DNRM
143035A	Brisbane River	Wivenhoe Tailwater	7023	17	Record length too short	DNRM
143907	Brisbane River	Lowood	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143941	Brisbane River	Lowood Bvrt	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143827	Brisbane River	Lowood Alert-P	10062	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143916	Brisbane River	Mt Crosby	10600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143839	Brisbane River	Mt Crosby Alert	10600	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143925	Brisbane River	Mt Crosby TM	10600	28	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143951	Brisbane River	Moggill Alert	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143915	Brisbane River	Moggill Bvrt	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143924	Brisbane River	Moggill TM	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143900	Brisbane River	Caboonbah			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143914	Brisbane River	Gregor Creek			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143920	Brisbane River	Gregor Creek Bvrt			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143902	Brisbane River	Murrumba			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143005	Brisbane River	Watts Bridge			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143903	Brisbane River	Wivenhoe			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143018A	Brisbane River	Avoca Vale	1498	20	Record length too short (post Wivenhoe)	DNRM
143868	Brisbane River	Colleges Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143918	Brisbane River Estuary	Bishop Island			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143217A	Buaraba Creek	Vineyard	63	10	Catchment area too small	DNRM
143211A	Buaraba Creek	15.8km	251	12	Catchment area too small	DNRM
143224A	Buaraba Creek	Diversion Channel		19	Catchment area too small	DNRM
143094A	Bulimba Ceek	Mansfield	57	26	Urban creek in Brisbane area, Small catchment	DNRM
143004A	Bulimba Creek	Belmont	51	22	Urban creek in Brisbane area, Small catchment	DNRM
1591	Bulimba Creek	End of Aquarium Ave. Hemmant		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1528	Bulimba Creek	Doughboy Pde- Hemmant		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1804	Bulimba Creek	Greenwood St- Wishart		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1831	Bulimba Creek	Merion Pl- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1707	Bulimba Creek	Old Cleveland Rd- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143926	Bundamba Creek	Ripley Alert	35		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143959	Bundamba Creek	Harding Street Alert	96		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143958	Bundamba Creek	Blackstone Bridge Alert	97	10	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143955	Bundamba Creek	Bundamba School Alert	102		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143854	Bundamba Creek	Bundamba (Hanlon St) Al	109	7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143114A	Bundamba Creek	Mary Street	110	11	Urban creek in Ipswich area, Small catchment	DNRM
143307A	Byron Creek	Causeway	79	28	Catchment area too small	DNRM
143012A	Cooyar Creek	51.5km.	443	4	Record length too short	DNRM
143015B	Cooyar Creek	Damsite	963	13	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143015A	Cooyar Creek	Damsite	963	22	Record length too short	DNRM
143013A	Cressbrook Creek	The Damsite	321	16	Record length too short	DNRM
143952	Cressbrook Creek	Rosentreters Bridge	440		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143921A	Cressbrook Creek	Rosentretters Bridge	447	17	Record length too short	DNRM
143921	Cressbrook Creek	Rosentreters Bridge TM	477		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143806	Cressbrook Creek	Rosentreters Bridge Al	477	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143857	Deebing Creek	Churchill Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143021A	Ekibin Creek	Dudley Street.	13	1	Urban creek in Brisbane area, Small catchment	DNRM
143011A	Emu Creek	Raeburn	439	24	Catchment area too small	DNRM
143010A	Emu Creek	Boat Mountain	915	11	Catchment area too small	DNRM
143010B	Emu Creek	Boat Mountain	915	27	Catchment area too small	DNRM
143932A	Ennogera Creek	Bancroft Park	70	10	Urban creek in Brisbane area, Small catchment	DNRM
143932	Enoggera Creek	Bancroft Park TM	67		Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1531	Enoggera Creek	100 M U/S From Original E e529		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1532	Enoggera Creek	Enoggera Dam- The Gap		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1529	Enoggera Creek	Kelvin Grove Rd- Kelvin Grove		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143208A	Fifteen Mile Creek	Dam Site	87	33	Catchment area too small	DNRM
143214A	Flagstone Creek	Windolfs	142	14	Catchment area too small	DNRM
143233A	Flagstone Creek	Brown-Zirbels Road		10	Catchment area too small	DNRM
1717	Gold Creek	Reservoir- Brookfield (Brisbane Water)			Urban creek in Brisbane area, Small catchment	South East Queensland Water
143028A	Ithaca Creek	Jason Street	10	31	Urban creek in Brisbane area, Small catchment	DNRM
1535	Ithaca Creek	Jason St- Ithaca		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143304A	Kilcoy Creek	Mount Kilcoy	127	36	Catchment area too small	DNRM
143304B	Kilcoy Creek	Mount Kilcoy Weir	131	15	Catchment area too small	DNRM
143235A	Lake Clarendon Head			6	Offstream storage	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143215A	Laidley Creek	Mulgowie Weir	154	14	Catchment area too small	DNRM
143209A	Laidley Creek	Mulgowie1	167	5	Catchment area too small	DNRM
143209B	Laidley Creek	Mulgowie2	167	36	Catchment area too small	DNRM
143225A	Laidley Creek	Showgrounds Weir Head Wate	233	19	Catchment area too small	DNRM
143226A	Laidley Creek	Showgrounds Weir Tail Wate	233	19	Catchment area too small	DNRM
143943	Laidley Creek	Laidley	285		Catchment area too small	BoM, Queensland Regional Office
143923	Laidley Creek	Thornton			Catchment area too small	BoM, Queensland Regional Office
143229A	Laidley Creek	Warrego Highway		13	Catchment area too small	DNRM
143202A	Lockyer Creek	Russell Siding	271	7	Catchment covered by other gauges DS	DNRM
143203C	Lockyer Creek	Helidon Number 3	357	16	Catchment covered by other gauges DS	DNRM
143203A	Lockyer Creek	Helidon	357	45	Catchment covered by other gauges DS	DNRM
143203B	Lockyer Creek	Helidon No.2	382	24	Catchment covered by other gauges DS	DNRM
143904	Lockyer Creek	Gatton	1550		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143204A	Lockyer Creek	Wilsons Weir	1655	29	Catchment covered by other gauges DS	DNRM
143905	Lockyer Creek	Glenore Grove	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143906	Lockyer Creek	Glenore Grove Bvrt	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143807	Lockyer Creek	Glenore Grove Alert	2230	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143206A	Lockyer Creek	Brightview Weir	2393	20	Catchment covered by other gauges DS	DNRM
143201A	Lockyer Creek	Tarampa	2405	17	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143201B	Lockyer Creek	Tarampa Number 2	2405	22	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143917	Lockyer Creek	Lyons Bridge	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143913	Lockyer Creek	Lyons Bridge Bvrt	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143819	Lockyer Creek	Lyons Bridge Alert-P	2530	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143227A	Lockyer Creek	O'Reilly's Weir Tailwater	2965	5	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
2142	Lota Creek	Rickertt Rd Ransome		4	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143213B	Ma Ma Creek	Ma Ma Weir	226	9	Catchment area too small	DNRM
143213A	Ma Ma Creek	Harms	227	4	Catchment area too small	DNRM
143213C	Ma Ma Creek	Harm's		8	Catchment area too small	DNRM
143032A	Moggill Creek	Upper Brookfield	23	27	Urban creek in Brisbane area, Small catchment	DNRM
143020A	Moggill Creek	Misty Morn	61	9	Urban creek in Brisbane area, Small catchment	DNRM
143020	Moggill Creek	Misty Morn TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1722	Moggill Creek	Fortrose St- Kenmore		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2143	Moolabin Creek	Brisbane River Golf Club- Tennyson		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143219A	Murphys Creek	Spring Bluff	18	24	Urban creek in Brisbane area, Small catchment	DNRM
1549	Norman Creek	Joachim St- Holland Park West		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1552	Norman Creek	South East Freeway- Greenslopes		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1555	Norman Creek	Caswell St- East Brisbane River		10	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143033A	Oxley Creek	New Beith	60	27	Urban creek in Brisbane area, Small catchment	DNRM
143019A	Oxley Creek	Upstream Beatty Road	152	3	Urban creek in Brisbane area, Small catchment	DNRM
143019B	Oxley Creek	Downstream Beatty Road	152	6	Urban creek in Brisbane area, Small catchment	DNRM
143019	Oxley Creek	Beatty Road TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1588	Oxley Creek	Mouth of Oxley Creek		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1727	Oxley Creek	New Beith (DNR)+F31		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2023	Oxley Creek	Corinda High School- Corinda		12	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2125	Oxley Creek	Beatty Rd- Acacia Ridge		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2111	Oxley Creek	Johnson Rd- Forestdale		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143024A	Pullen Pullen Creek	Moggill Road	27	4	Urban creek in Brisbane area, Small catchment	DNRM
1745	Pullen Pullen Creek	Pinjarra Rd- Pinjarra Hills		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143983	Purga Creek	Loamside Alert	215	8	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143113A	Purga Creek	Loamside	215	30	Catchment area too small	DNRM
143869	Purga Creek	Peak Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143218A	Redbank Creek	Holcomb	55	8	Urban creek in Ipswich area, Small catchment	DNRM
143216A	Redbank Creek	Water Treatment Works	60	11	Urban creek in Ipswich area, Small catchment	DNRM
143231A	Redbank Creek	Clarendon Number 2		10	Urban creek in Ipswich area, Small catchment	DNRM
143230A	Redbank Creek	Clarendon Pump Station		10	Urban creek in Ipswich area, Small catchment	DNRM
143306A	Reedy Creek	Upstream Byron Creek Junct	56	28	Catchment area too small	DNRM
143103A	Reynolds Creek	Moogerah	190	37	Catchment area too small	DNRM
143103B	Reynolds Creek	Moogerah	190	6	Catchment area too small	DNRM
143111A	Reynolds Creek	Moogerah Dam Headwater	226	36	Head gauge affected by dam site	DNRM
143112A	Reynolds Creek	Moogerah Tailwater	227	23	Tail gauge affected by dam site	DNRM
143220A	Sandy Creek	Forest Hill	102	7	Urban creek in Brisbane area, Small catchment	DNRM
143232A	Sandy Creek	Forest Hill		8	Urban creek in Brisbane area, Small catchment	DNRM
143030A	Sandy Creek	Indooroopilly		22	Urban creek in Brisbane area, Small catchment	DNRM
143223A	Seven Mile Lagoo	Diversion Channel		20	Diversion channel	DNRM
143023A	Small Catchment	Algester	1	4	Urban creek in Brisbane area, Small catchment	DNRM
143022A	Stable Swamp Creek	Interstate Railway	19	11	Urban creek in Brisbane area, Small catchment	DNRM
2129	Stable Swamp Creek	Musgrave Rd- Coopers Plains		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143303A	Stanley River	Peachester	104	76	Catchment area too small	DNRM
143938	Stanley River	Woodford TM	220		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143829	Stanley River	Woodford Alert-P	220	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143901	Stanley River	Woodford	250		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143301B	Stanley River	Donnelly Dell	1227	4	Record length too short	DNRM
143301A	Stanley River	Hazeldean	1242	3	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143305	Stanley River	Somerset Dam	1330		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143818	Stanley River	Somerset Dam Hw Alert-B	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143817	Stanley River	Somerset Dam Hw Alert-P	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143305A	Stanley River	Somerset Dam	1336	24	Head gauge affected by dam site	DNRM
143302A	Stanley River	Silverton	1339	49	Data obtained, but uncertainty as to appropriate rating	DNRM
143960	Stanley River	Peachester			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143212A	Tenthill Creek	Tenthill	447	35	Catchment area too small	DNRM
143106A	Warrill Creek	Aratula Weir	122	7	Catchment covered by other gauges DS	DNRM
143102A	Warrill Creek	Kalbar No.1	465	46	Catchment covered by other gauges DS	DNRM
143102B	Warrill Creek	Kalbar No.2	468	13	Catchment covered by other gauges DS	DNRM
143937	Warrill Creek	Kalbar	470		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143910	Warrill Creek	Harrisville	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143912	Warrill Creek	Harrisville TM	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143101A	Warrill Creek	Mutdapily	771	43	Catchment covered by other gauges DS	DNRM
143825	Warrill Creek	Amberley Alert-P	850	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143933	Warrill Creek	Amberley Bvrt	862		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143117A	Warrill Creek	Junction Weir H/W		5	Record length too short	DNRM
143118A	Warrill Creek	Junction Weir Tailwater		6	Record length too short	DNRM
143116A	Warrill Creek	Toohill's Crossing		6	Record length too short	DNRM
143105A	Warrill Creek East	Churchbank Weir	149	50	Catchment covered by other gauges DS	DNRM
143031A	Water St. Drain	Exhibition Ground		5	Urban creek in Brisbane area, Small catchment	DNRM
143939	Western Creek	Kuss Road	200	21	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
143861	Western Creek	Grandchester Alert		4	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1583	Wolston Creek	700m U/S Wacol Station Rd- Wacol		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143962	Woogaroo Creek	Brisbane River Road Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143927	Woogaroo Creek	Opossum Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143961	Woogaroo Creek	Alice Street Alert		7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

Appendix C Location of select stream gauges

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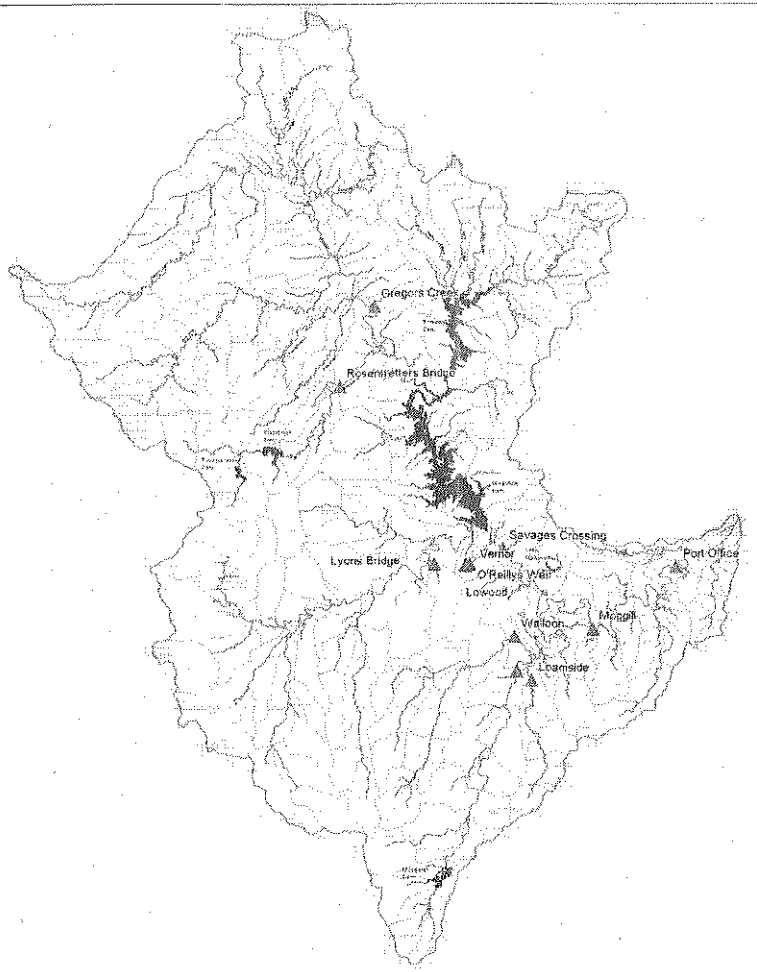
- Location of stream gauge sites that were used in flood frequency analysis



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Appendix D Regional Flood Frequency Information

D.1 Introduction

The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

D.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in Section 2.2 only DNRM gauge flow data were both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in Table D.1.

The location of the gauges can be seen in the catchment map in Appendix C.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in Table D.1 were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in Section D.3.

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- Table D.1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods.

River	Station Name	Station Number	Years of Record	C'ment Area (km²)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

D.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in Table D.1. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. Figure 3.1 shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (eg Peel et al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

Also shown on Figure D.1 is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that Bremer River @Walloon (143107A) and Brisbane @ Gregor's Creek (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (Appendix E) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.

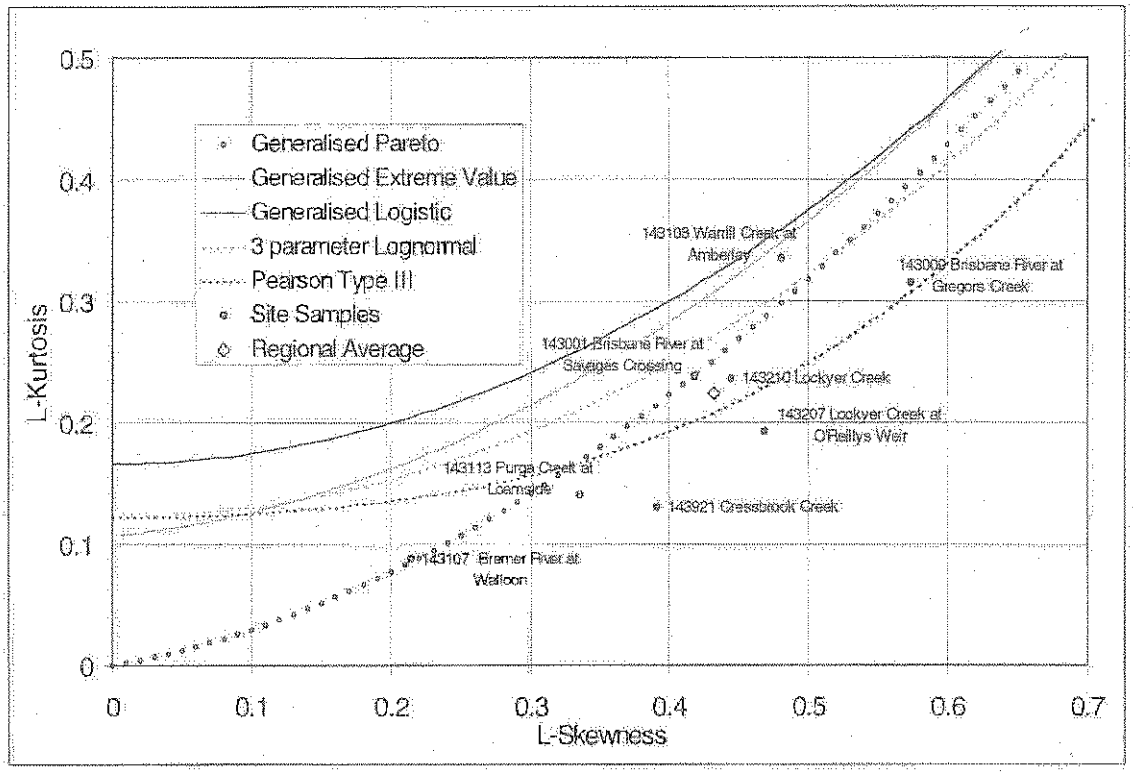

Figure D.1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500km²), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (Figure D.2) supports the adoption of the Generalised Pareto distribution.

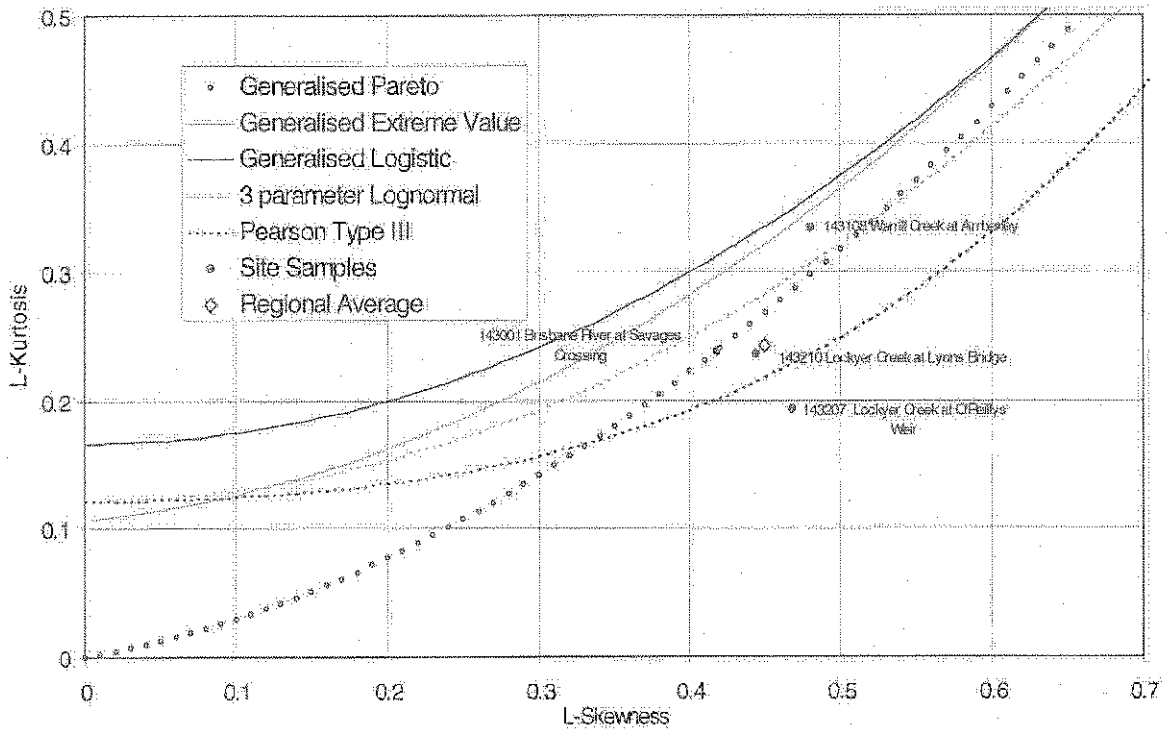

Figure D.2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in Table D.2.

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- Table D.2 Regional parameter values of the adopted Generalised Pareto distribution

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter, ξ	-0.062	-0.096
Scale parameter, α	0.811	0.795
Shape parameter, κ	-0.230	-0.275

D.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation,
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of Table D.2. The scale parameter (α) from the regional analysis shown in Table D.2 is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\hat{\alpha}_{143001} = L^1_{143001}\alpha^{CV}_{\text{Regional}} = 1181 \times 0.795 = 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in Table D.3. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\sigma_{\alpha,143001} = L^1_{143001}\sigma^{CV}_{\alpha,\text{Regional}} = 1181 \times 0.388 = 458$$

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information

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was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

- Table D.3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution

Site Number	Gauging Station Name	Scale parameter, α	Shape parameter, κ
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		0.388	0.297

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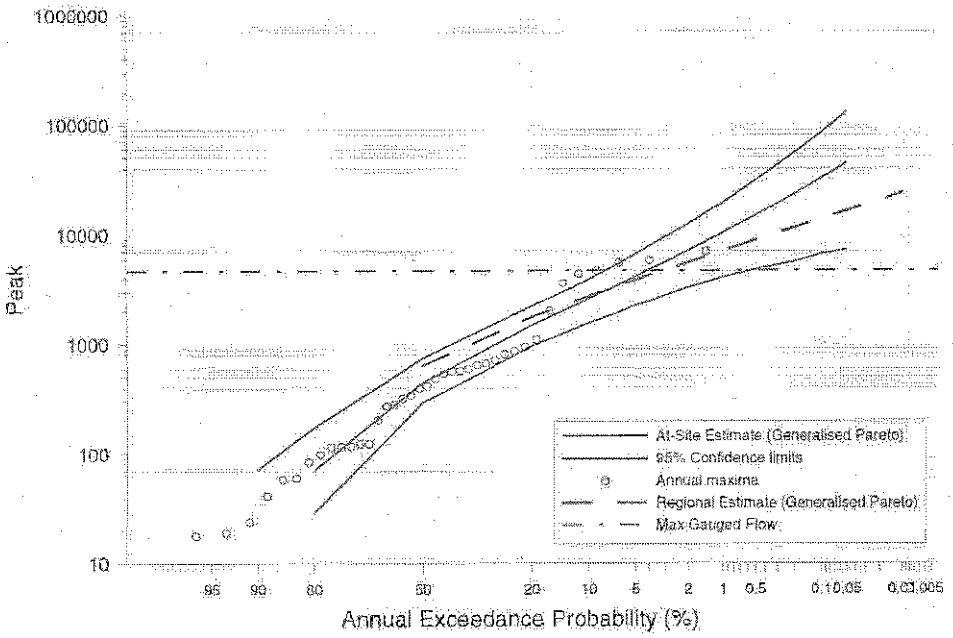
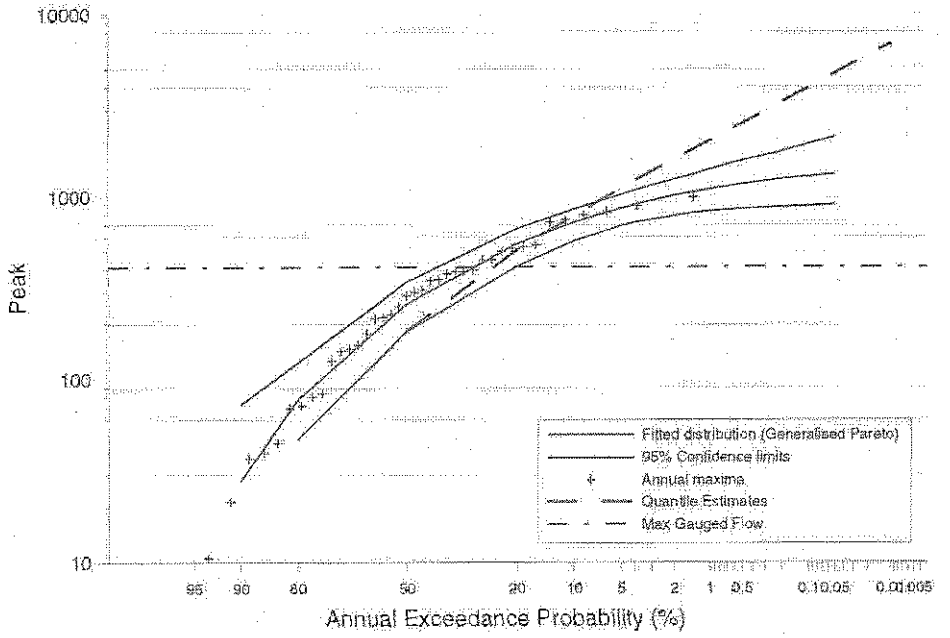
Appendix E At-Site/Regional Analysis of Selected Gauges

143009 (POR: 1963-2002) - Brisbane River at Gregors Creek



143107 (POR: 1962-2002) - Bremer River at Walloon



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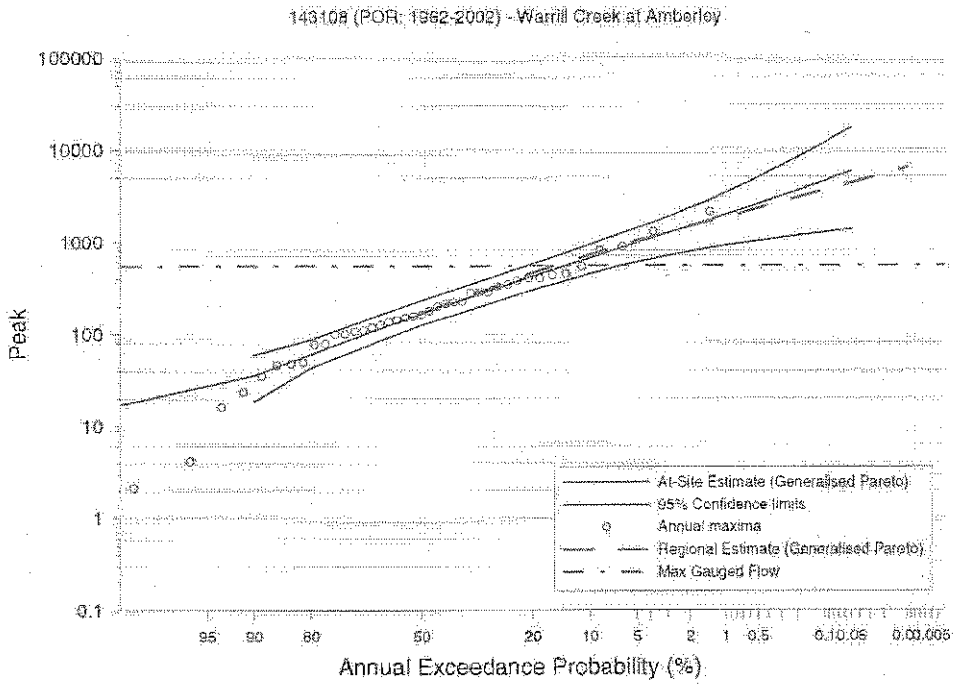
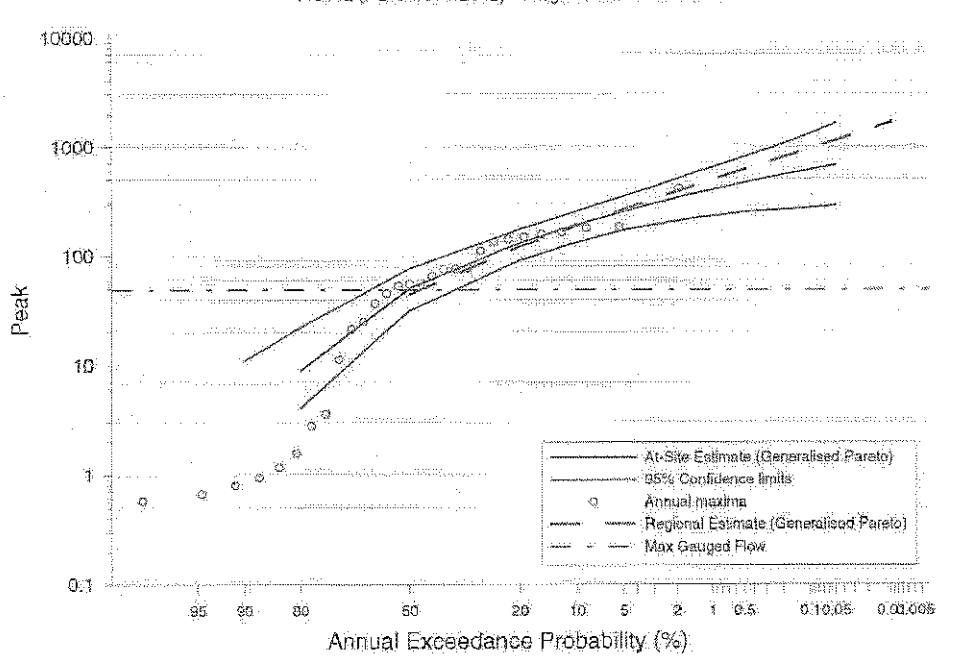
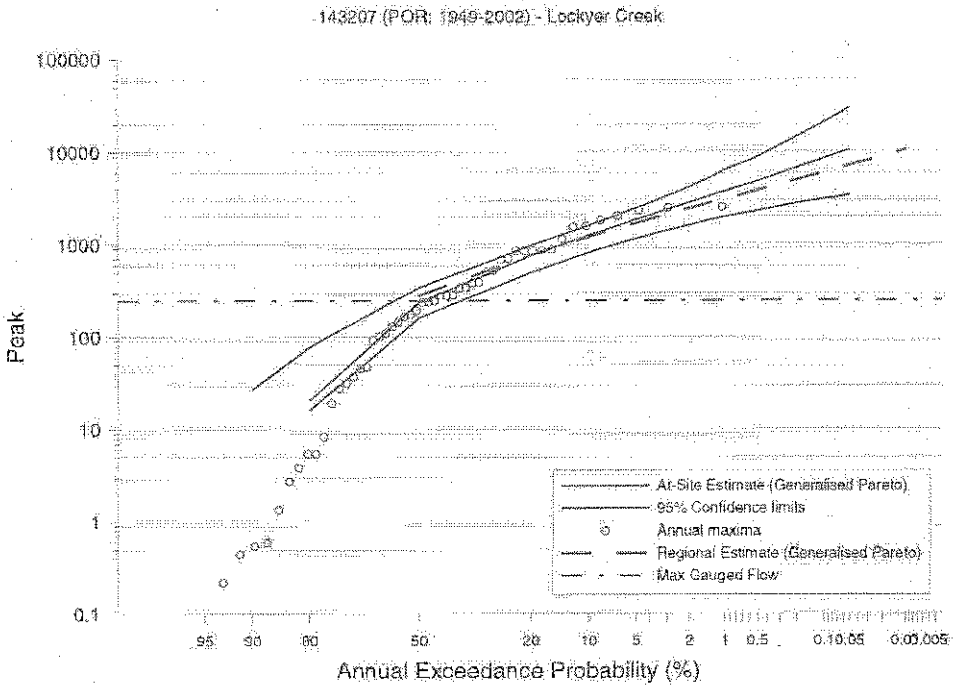
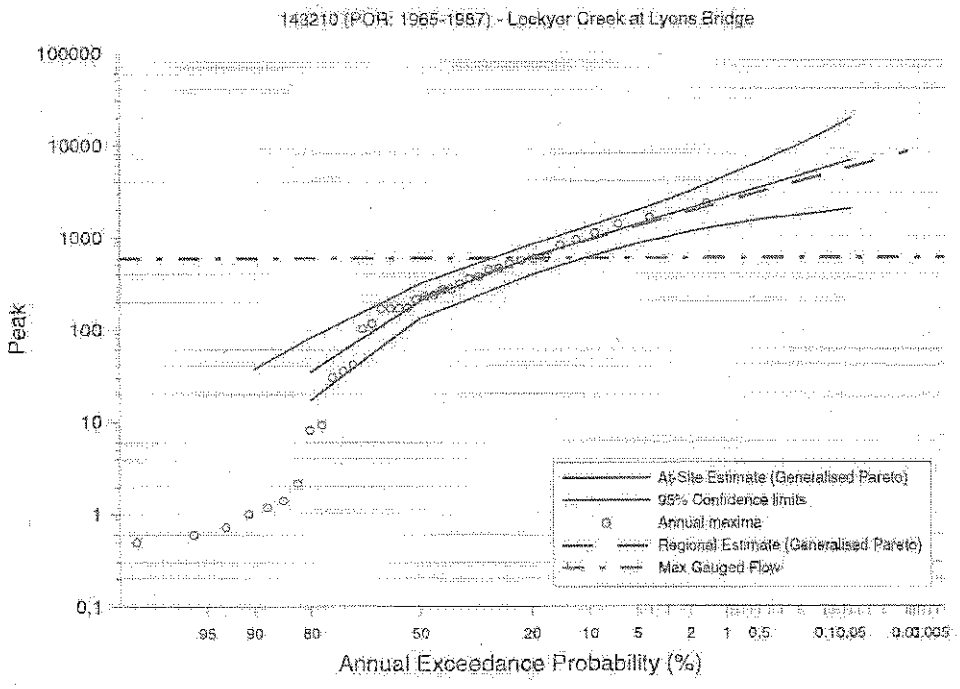
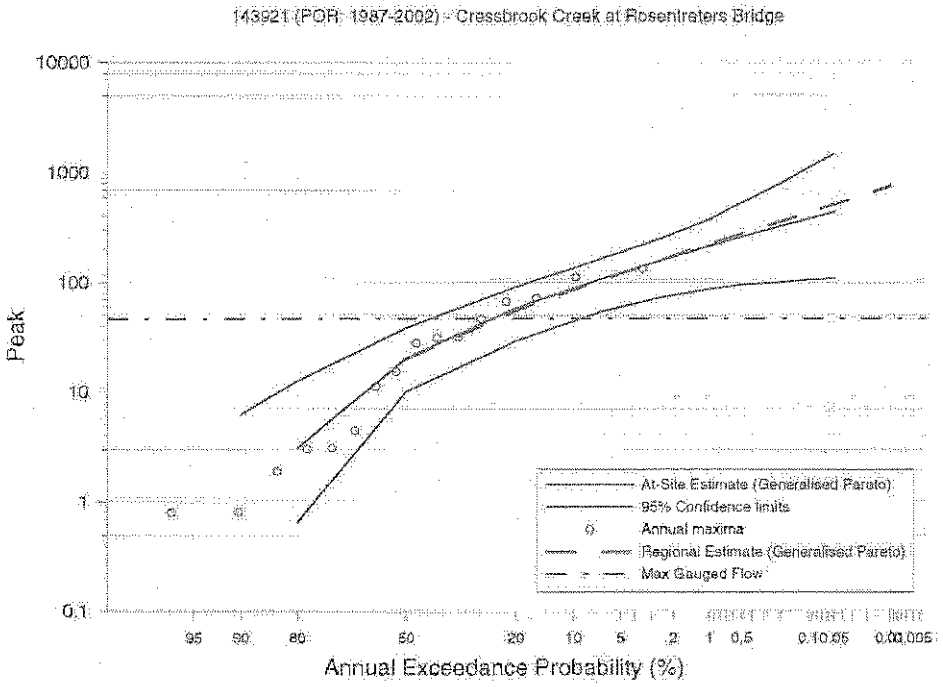

143108 (POR: 1962-2002) - Warrill Creek at Amberley
Peak
100000
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143113 (POR: 1974-2002) - Purga Creek at Loamside
Peak
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.10.05
0.03.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0,1
95
90
80
50
20
10
5
2
1
0.5
0.10.05
0.03.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow

Appendix F Historical Spatial Distributions

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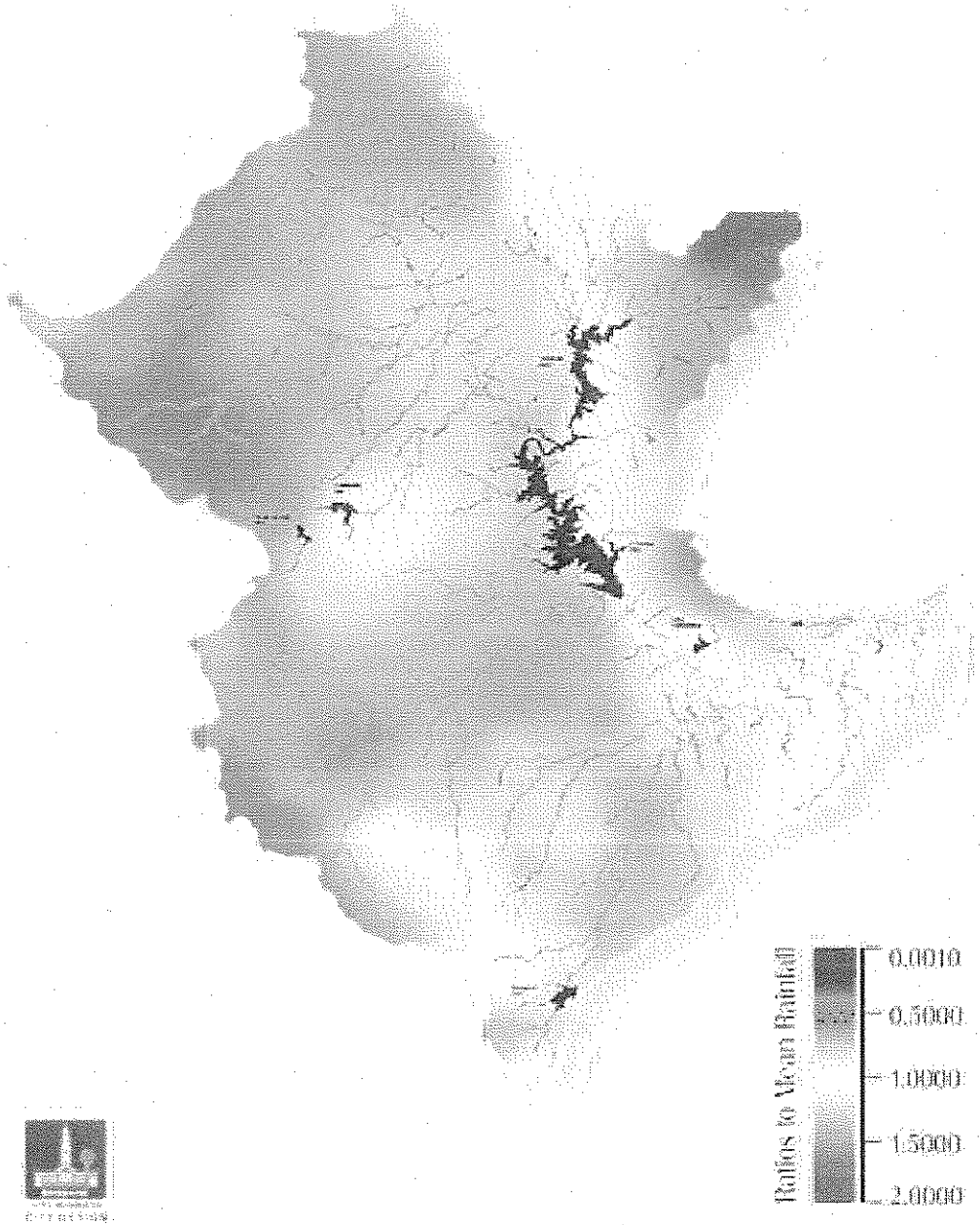
CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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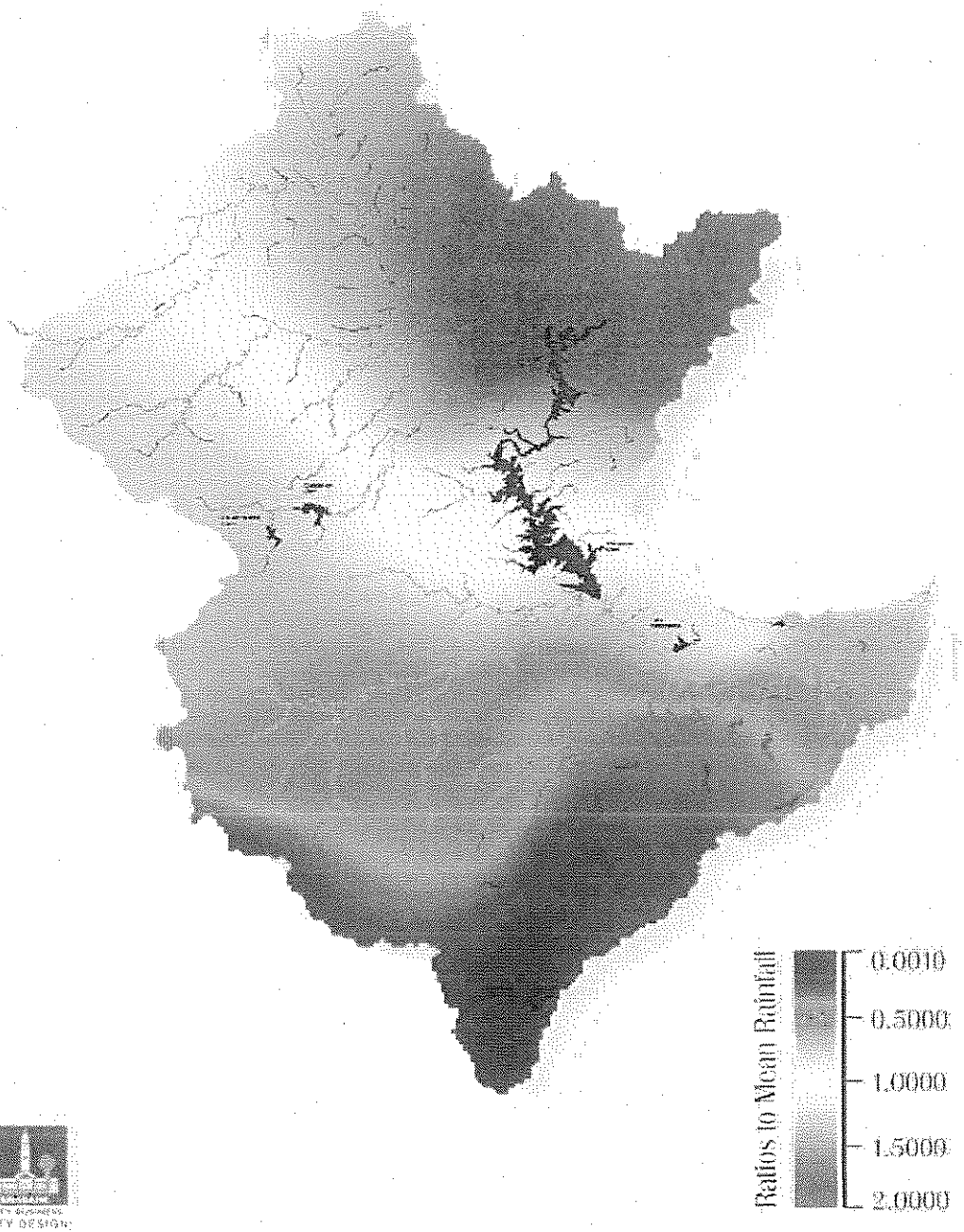
JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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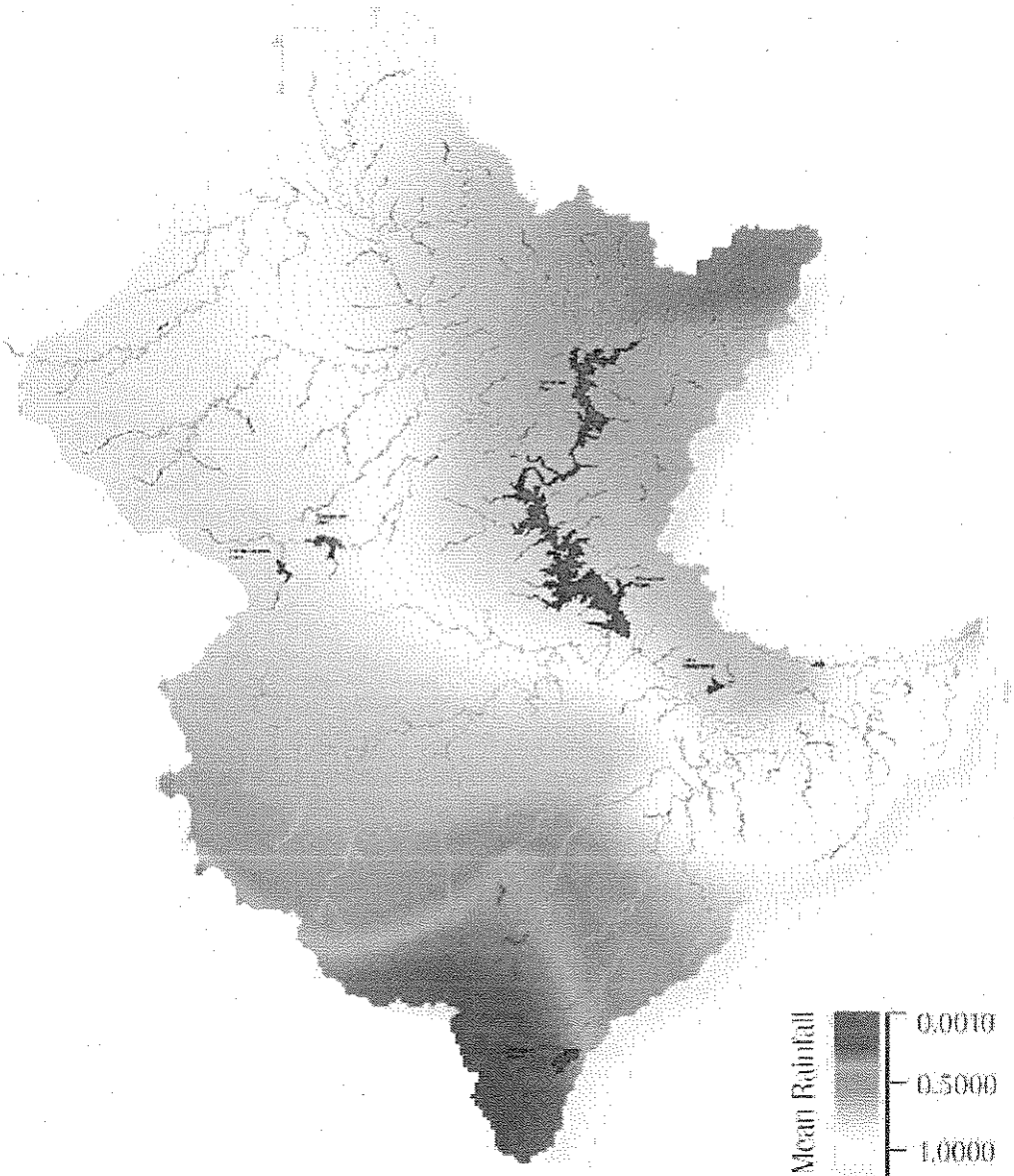
FEBRUARY 1893 SPATIAL DISTRIBUTION
Maximum 24Hr Storm Burst
BRISBANE RIVER CATCHMENT



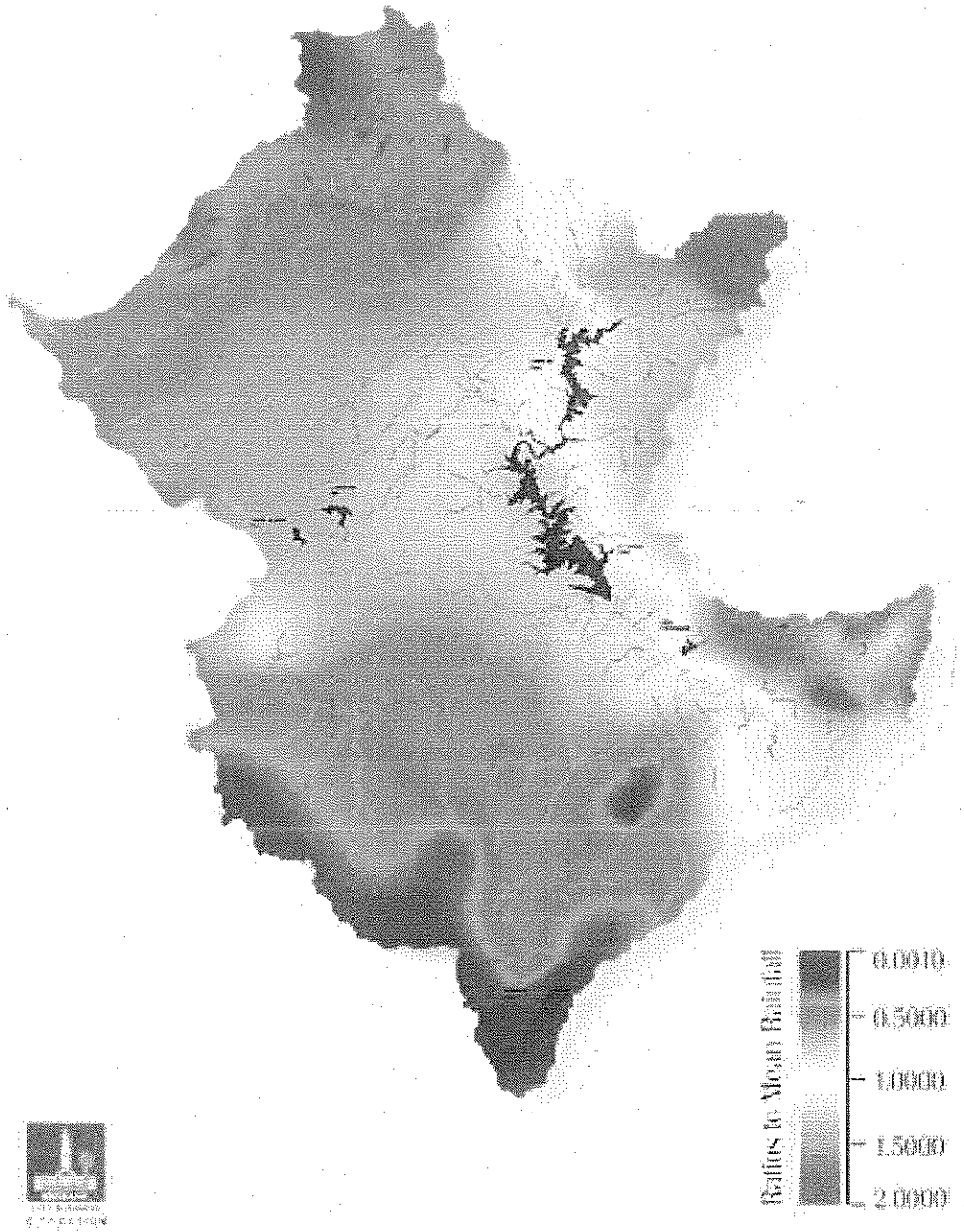
SINCLAIR KNIGHT MERZ

SKM

JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



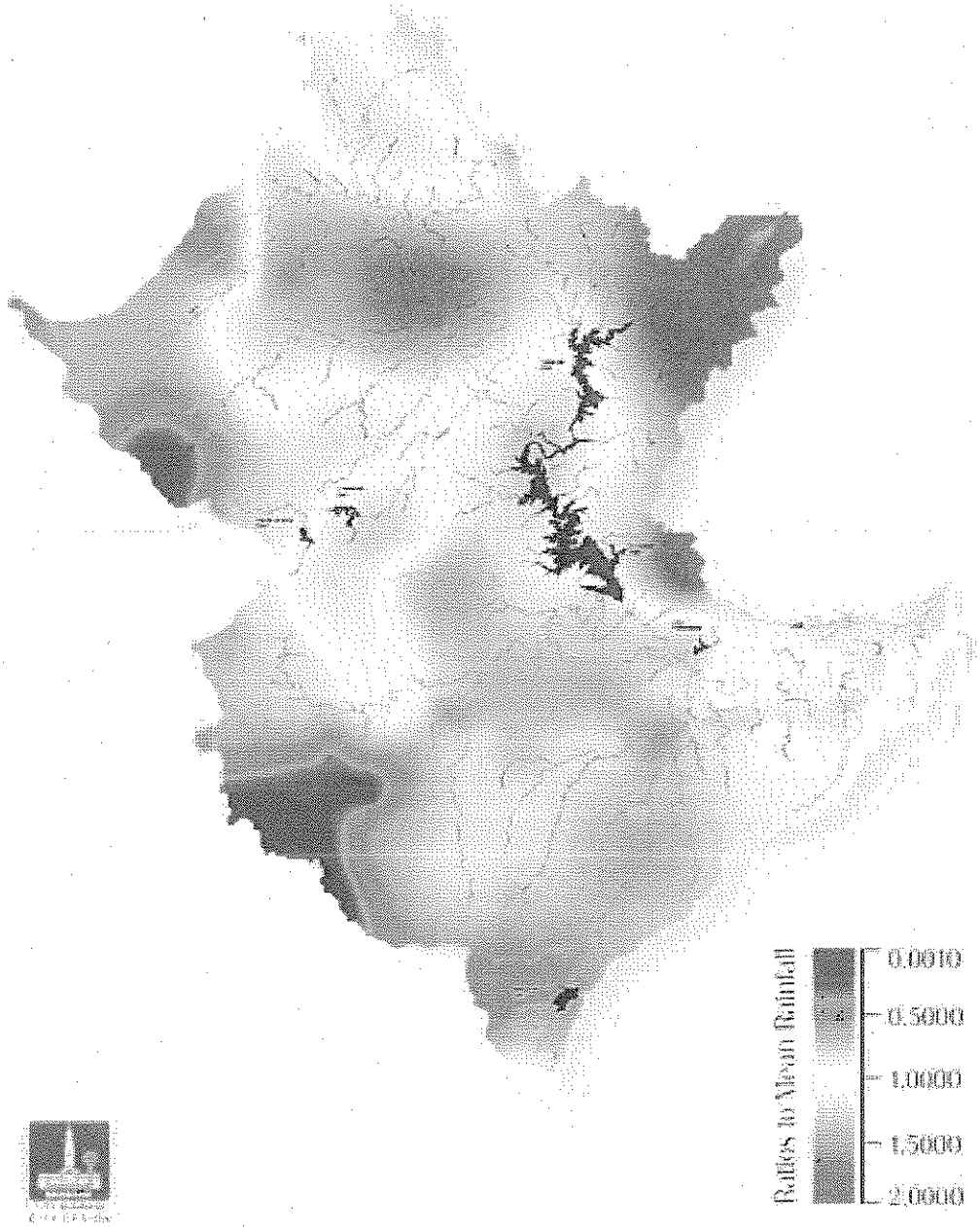
SINCLAIR KNIGHT MERZ

SKM

MARCH 1955 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



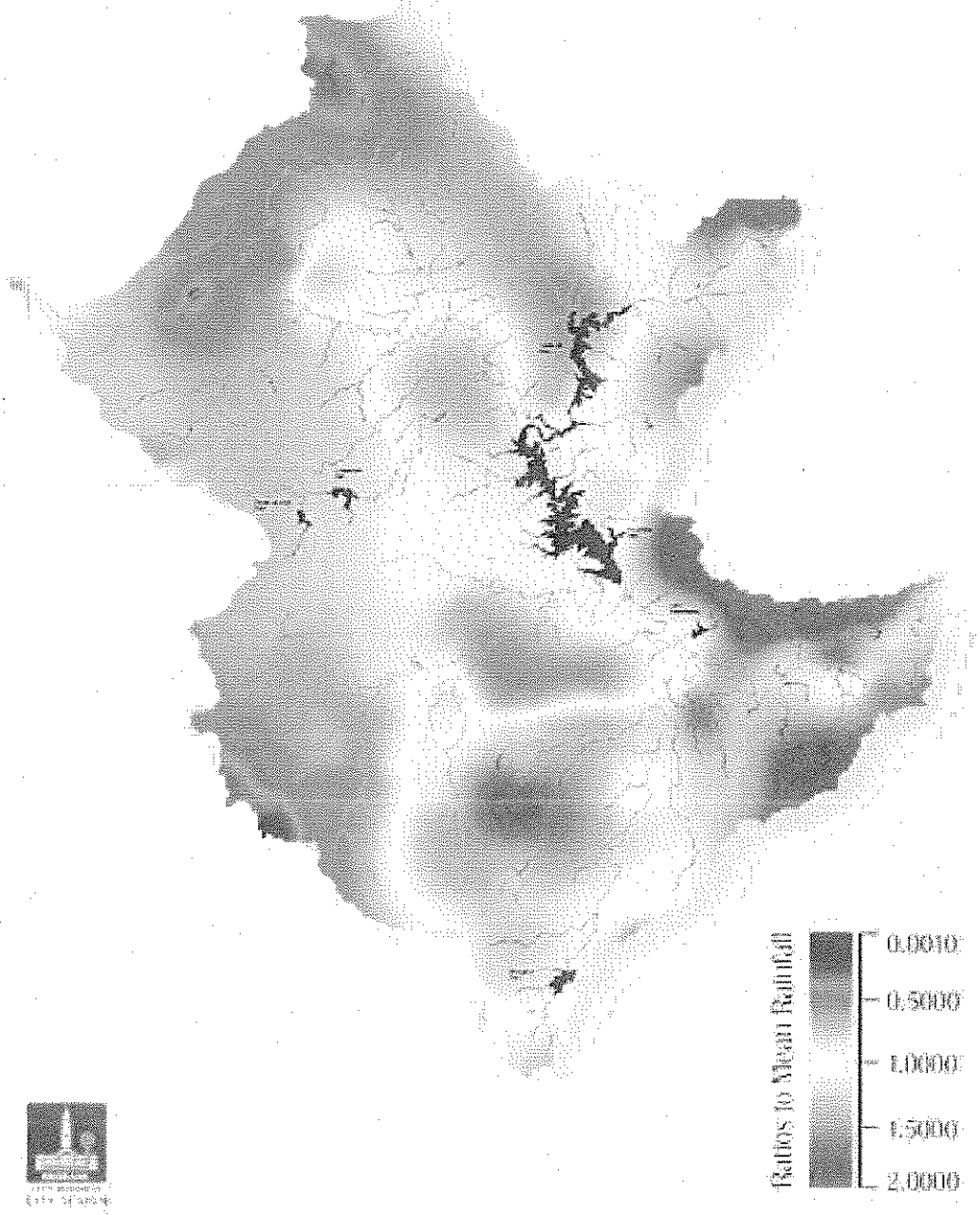
SINCLAIR KNIGHT MERZ

SKM

JANUARY 1974 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



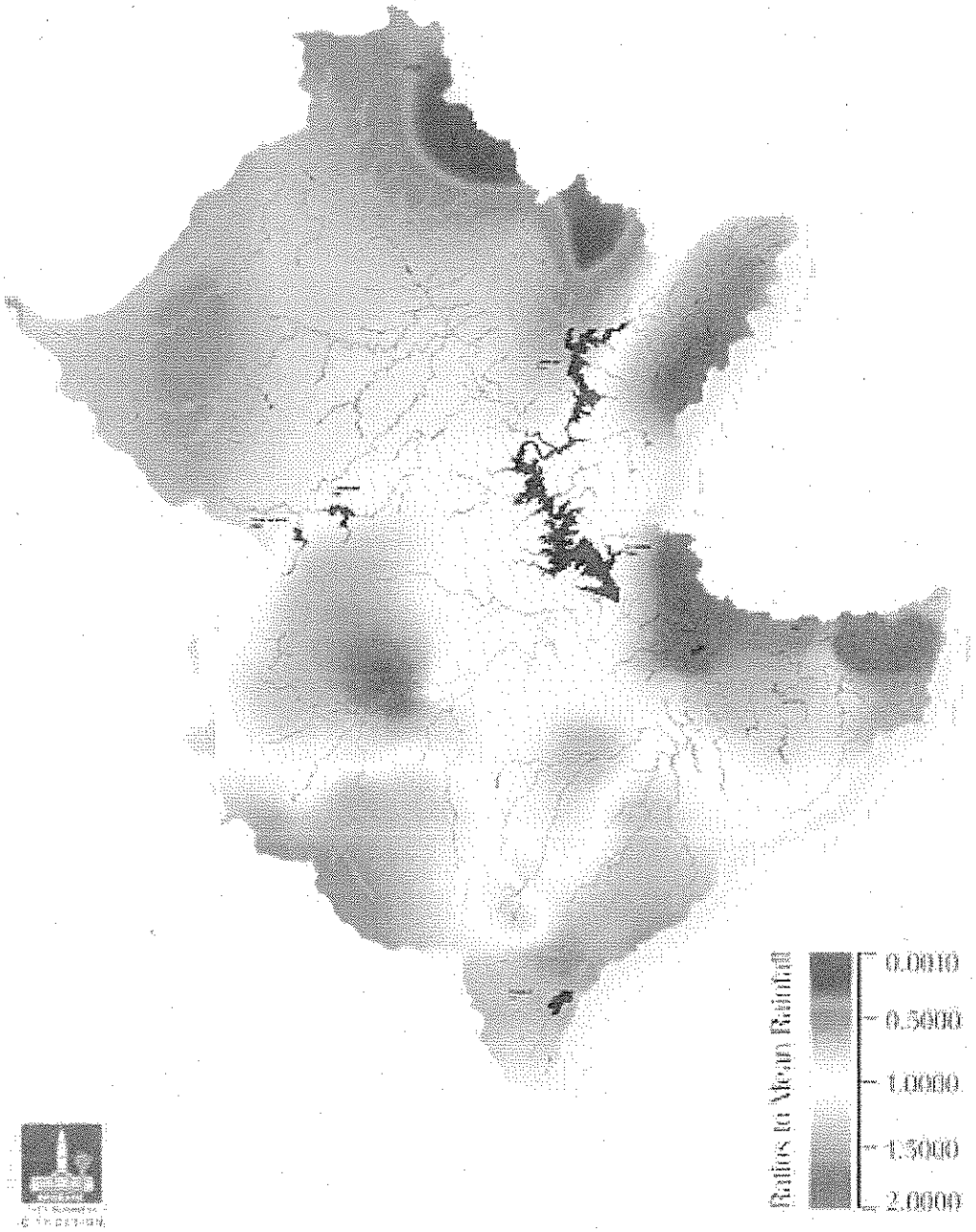
SINCLAIR KNIGHT MERZ

SKM

APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



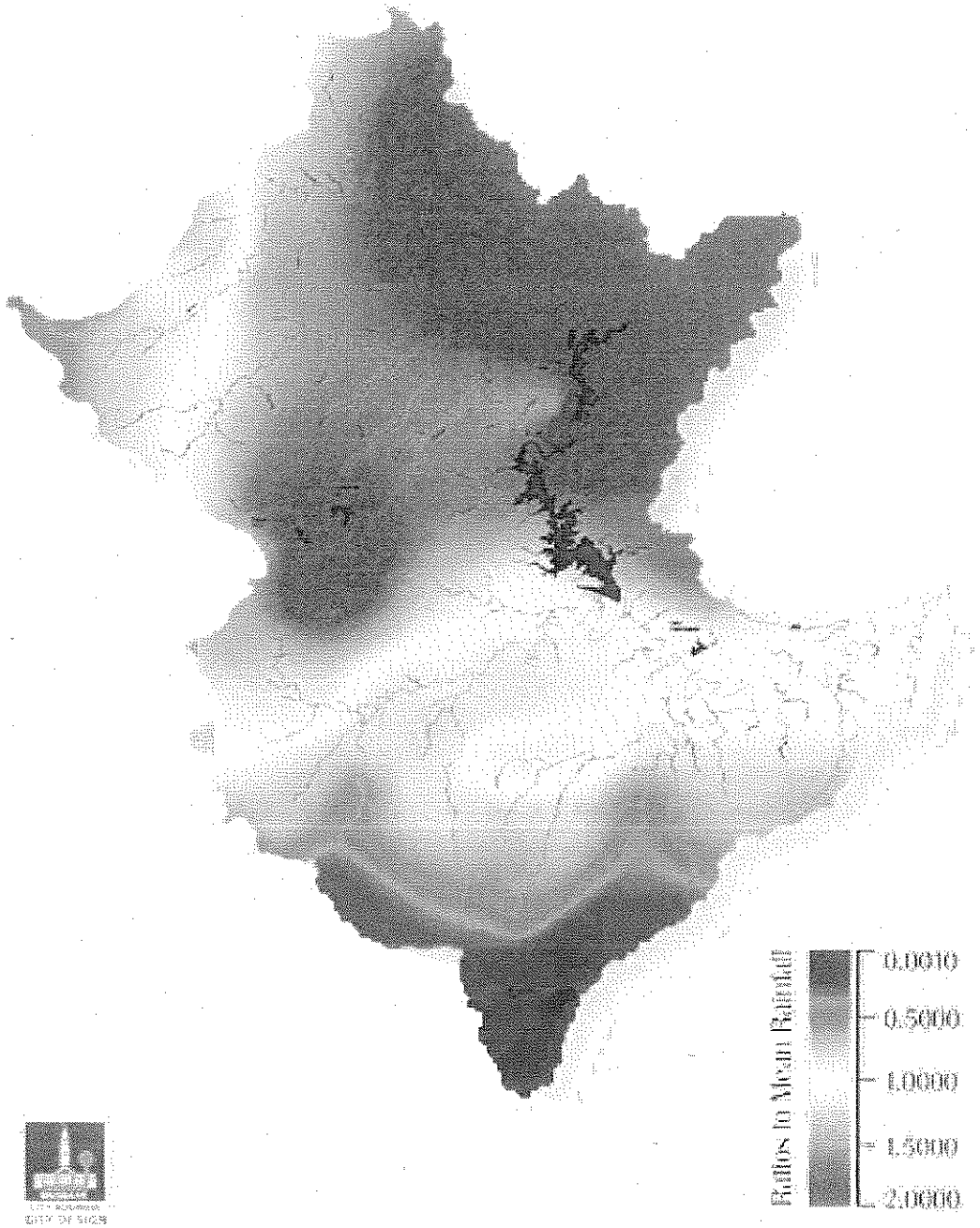
SINCLAIR KNIGHT MERZ

SKM

FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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Appendix G Pre- and Post-dams RAFTS Model Results

- Q100 Peak Flows for RAFTS Model, Pre-Dams

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
JAN 1893	24	9861	7927	7927
	30	**11507**	9793	9792
	36	9810	7932	7932
	48	10238	8535	8534
	72	10911	**10198**	**10196**
	96	9774	9394	9392
	120	10074	9641	9639
FEB 1893	24	8698	7502	7502
	30	**10062**	8789	8788
	36	8682	7512	7512
	48	9012	7866	7865
	72	9634	**9504**	**9501**
	96	8568	8636	8632
	120	8804	8904	8896
JAN 1931	24	7505	6745	6745
	30	**8543**	7648	7648
	36	7476	6776	6775
	48	7712	7191	7190
	72	8183	**8030**	**8026**
	96	7140	7610	7514
	120	7360	7713	7630
MAR 1955	24	8671	7537	7536
	30	**10046**	8925	8925
	36	8689	7554	7553
	48	8955	7916	7915
	72	9563	**9623**	**9619**
	96	8376	8750	8745
	120	8635	9002	8997
JAN 1974	24	7058	7203	7202
	30	**8005**	8049	8046
	36	7049	7073	7072
	48	7227	7528	7527
	72	7714	**9117**	**9112**
	96	6729	8161	8154
	120	6879	8454	8432

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Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
APR 1996	24	7531	7068	7067
	30	**8621**	7966	7966
	36	7549	7079	7078
	48	7748	7427	7425
	72	8287	**8922**	**8917**
	96	7184	8043	8034
	120	7399	8182	8170
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7894	7893
	48	9981	8444	8443
	72	10642	**10200**	**10197**
	96	9512	9387	9384
	120	9809	9629	9626

Note: Critical flows at each location are shown in **bold**.

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- Q100 Peak Flows for RAFTS Model, Post-Dams

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7121**	**7120**
FEB 1893	24	1877	2070	2061
	30	3816	3449	3449
	36	1935	2211	2203
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5596	5595
	120	**6568**	**5851**	**5850**
JAN 1931	24	1872	2319	2051
	30	1926	3314	2708
	36	1884	2836	2452
	48	1758	2580	2382
	72	3079	3968	3146
	96	3170	3883	2940
	120	**3279**	**3411**	**3218**
MAR 1955	24	1925	2350	2345
	30	3524	3433	3433
	36	2063	2544	2541
	48	3272	3013	3013
	72	**6241**	**5710**	**5709**
	96	5926	5340	5339
	120	6151	5585	5584
JAN 1974	24	1753	3326	3324
	30	2467	3989	3987
	36	1871	3350	3279
	48	1943	3633	3627
	72	3307	4965	4418
	96	**4771**	**5852**	**5841**
	120	2911	3662	3656

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Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
APR 1996	24	3554	3400	3399
	30	4067	4138	4137
	36	3535	3260	3260
	48	3605	3691	3690
	72	**4162**	**5035**	**5019**
	96	3492	4417	4378
	120	3509	4663	4571
FEB 1999	24	3424	2887	2886
	30	5789	4442	4442
	36	3575	3147	3150
	48	4604	3495	3494
	72	6879	6448	6447
	96	7217	6624	6623
	120	**7431**	**6819**	**6819**

Note: Critical flows at each location are shown in **bold**.

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SINCLAIR KNIGHT MERZ
SKM

BRISBANE CITY

Brisbane River Flood Study



FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Further Investigations
- Final
- 7 Oct 2003

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Blue - [redacted]
Black -

Red - [redacted]

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BRISBANE CITY

Brisbane River Flood Study

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FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES BRISBANE RIVER

- Final
- 7 Oct 2003

1

Compiled

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Executive Summary

~~An Expert Panel has been~~ appointed to review the flood investigations undertaken for the Brisbane River. Sinclair Knight Merz was approached to assist the Expert Panel with their review. The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a "best" estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event.

The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

This technical report has been prepared for expert technical reviewers and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, hydrological terminology and abbreviations is generally assumed.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

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Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table E1.

Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100.
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty)
- choice of frequency distribution and the appropriate parameters; and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m³/s and 11 000 m³/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by

not true !

The Monte-Carlo methodology is a research tool that is not currently used ~~day~~ in ~~offices~~ standard practice.

vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures;
- dam levels at the start of a flood event; and,
- spatial and temporal patterns of the storm.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment. ARFs were not available for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knight Merz 1998) was undertaken.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

Zero losses not practical →

~~Peter~~ What is the commensurate flow at the Brisbane Post Office ? →

SKM

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

Q100 estimate at the Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate', upper estimate and lower estimate.

Does this mean that 1974 was > 8100 ?

SKM

- Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The information for the two historical flood events (1893 and 1974) were run through the RAFTS model for the pre and post-dam conditions. For post-dam conditions, the estimated peak flow at the Port Office for the 1893 and 1974 flood events were 9500 m^3/s and 6800 m^3/s respectively. It should be noted that the uncertainty of the historical data, 1893 in particular, is considerable.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

~~It is recommended that~~ the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that ~~correctly~~ reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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1. Introduction

1.1 Background

Sinclair Knight Merz prepared a flood study for the Brisbane River in 1998. Since this time, there have been changes to the information used in assessing the flood levels along the lower reaches of the Brisbane River. This includes:

- CRC-FORGE rainfall estimates that have been prepared for the Brisbane River catchment (Department of Natural Resources and Mines, 2003a) and
- Modifications to procedures for flood operations at Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, 1998) was completed.
- Additional and/or revised flood flow data

An Expert Panel has been appointed to review the flood studies undertaken for the Brisbane River in the light of this new information, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for Sinclair Knight Merz were to:

- Undertake flood frequency analysis, and to
- Update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The details of the tasks that were agreed to are presented in Appendix A.

1.2 Scope of Report

This report addresses the tasks presented in Appendix A, namely to,

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document the findings of the flood frequency analysis, stating assumptions and outcomes;
4) Review previous reports, CRC-FORGE rainfall estimates and historical streamflow data.
5) Undertake a Regional Flood Frequency Analysis (pre-dams).
6) Undertake hydrologic modelling (pre-dams).
7) Undertake hydrologic modelling (dams in place).

8) Analyse catchment sensitivity using various temporal patterns.
9) Undertake a check with historical flood events.
10) Perform hydraulic modelling to produce flood frequency estimates at Moggill and the Port Office.
11) Report on the findings of the rainfall-runoff and hydraulic modelling.

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2. Sources of Data for Flood Frequency Analysis

Gauging station data were obtained from the Department of Natural Resources and Mining (DNRM) and the Commonwealth Bureau of Meteorology (BoM). Different types of data were collected, including:

- recorded water elevation above the gauge datum,
- flow data estimated from a rating relationship and
- rating tables

In some instances the data had been processed in some additional manner, as discussed below.

A number of reports on large flood events and the analysis thereof have also been made available.

2.1 Department of Natural Resources and Mining Data

There are two sources of data from DNRM:

- Recorded water elevation data and associated flow estimates
- Estimates of "no dams" flood peaks at Savages Crossing that had been adjusted to exclude the influence of the dam(s) where appropriate.

Both data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in **Appendix B** (along with other sources of gauged data). The primary reasons for omission were:

- short record length,
- small catchment area, and/or
- uncertainty in the rating curve.

The latter reason included either very low gauged flow or the rating curve had been changed to a "calibration curve" for use in real time flood forecasting. It may be possible to include some of this flow data for future analysis when questions regarding the adjustment made to the calibration curves have been resolved.

same gauge ?

Elevation data for a number of sites of direct interest to this study, such as Moggill, Brisbane City and the Port Office were also obtained.

Appendix C shows the location of the stream gauges that were used in the flood frequency analysis.

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3. Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (ie peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in Section 2.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- Adjustment of data for the influence of the dams
- Uncertainty in the rating curves that relate recorded river level to flow rate
- The magnitude of historic data (especially 1893 and 1825)
- The period of record associated with the historic data
- Choice of frequency distribution
- Selection of parameters for the distribution
- Method of including historical data

DNRM provided a series of data (1890 – 2000) that was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had existed over the entire period. Frequency analysis of this data was undertaken along with various unadjusted data.

The frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by Assoc Prof George Kuczera in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix D**.

The analyses undertaken to determine the "best" estimate from flood frequency analysis and a plausible range is summarised in Table 3.1. FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets an Sinclair Knight Merz program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte-Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

The results of these analyses are recorded with selected frequency distributions in Sections 3.3 - 3.6 and the results summarised in Table 3.7. As noted previously, this report has been prepared for expert reviewers with a high level of understanding. The explanations, comments and discussion are as concise as possible to enable the broad range of analyses to be succinctly presented for ease of comparison.

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Table 3.1 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

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	Continuous Record	Historic Data (m³/s)	Historic Period	Distribution	Model for fitting distribn	Prior Informn (regional)	Main Objective
Case 1 Pre -Wivenhoe and Somerset							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

X

GP = Generalised Pareto Distribution
LPIII = Log-Pearson III Distribution

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Case 2 **Pre Wivenhoe, no adjustments made for Somerset**							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3 **"No Dams" based on DNRM adjusted estimates**							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by DNRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4 **"Dams" based on DNRM estimates**							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

3.2 Regional Frequency Analysis

A regional frequency analysis was conducted to assist in the estimation of flood frequency at Savages Creek (GS143001). The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane River catchment, including the site at Savages Crossing (GS143001). The Generalised Parcto probability distribution was selected for the flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value;
- its prior standard deviation; and,
- its correlation with other parameters.

The prior mean and standard deviation of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in Table 3.2.

Table 3.2 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001).

Value	Scale parameter, α	Shape parameter, κ
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

Greater detail of the regional analyses is provided in Appendix D.

SKM

3.3 Case 1: Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the DNRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in Table 3.3 with specific influence on curves plotted in Figures 3.1 – 3.3 so that the influence of specific assumptions can be compared graphically.

Table 3.3 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m³/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m³/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1C	1909-1951	1893 (Qp= 13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post-Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825 (Qp= 13200) 1893 (Qp= 13 200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp= 14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from ~~P Baddiley~~ "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1G	1909-1951	1893 (Qp= 12 000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp= 13 000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.

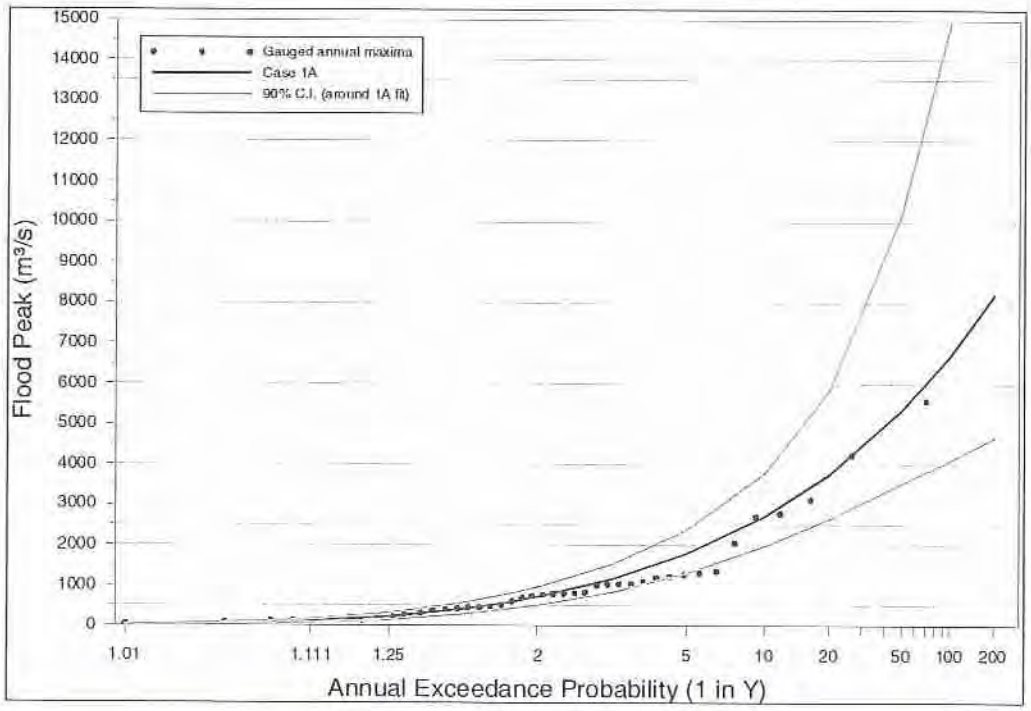

Figure 3.1 Generalised Pareto Distribution fitted to the 1909-1951 pre-dams data at Savages Crossing.

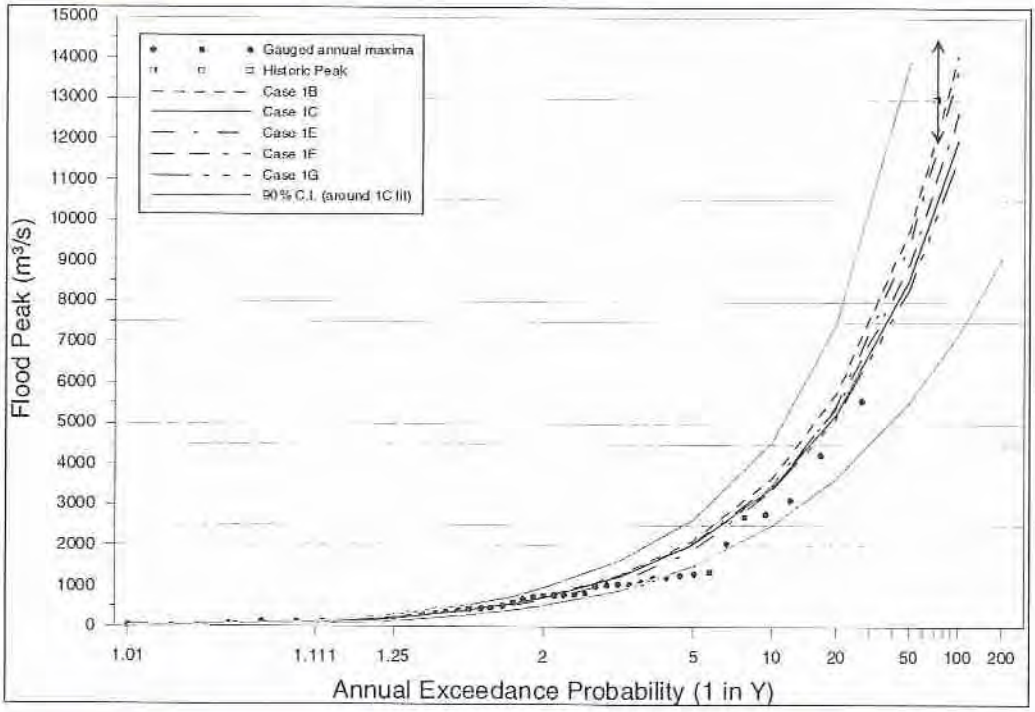

Figure 3.2 Comparisons of variations in flood frequency for various assumptions on pre-dams data for Savages Crossing.

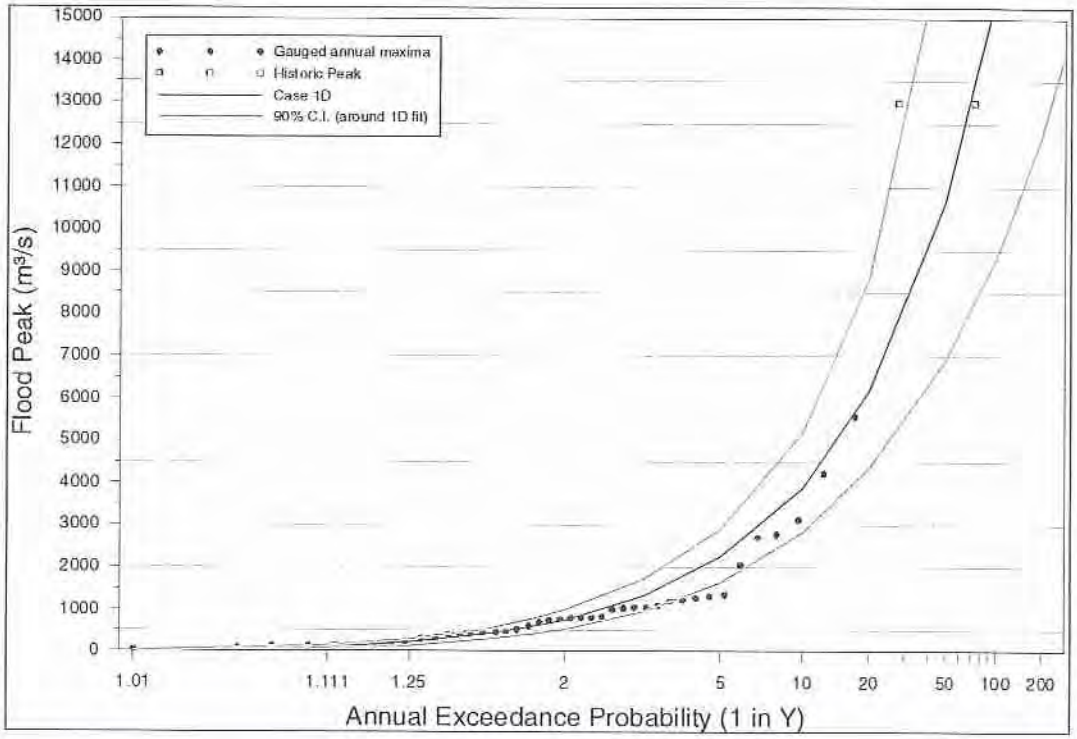

Figure 3.3 Assessment of the inclusion of a 1925 estimate of a flood possibly of the same magnitude as the 1893 event.

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3.4 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

Table 3.4 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

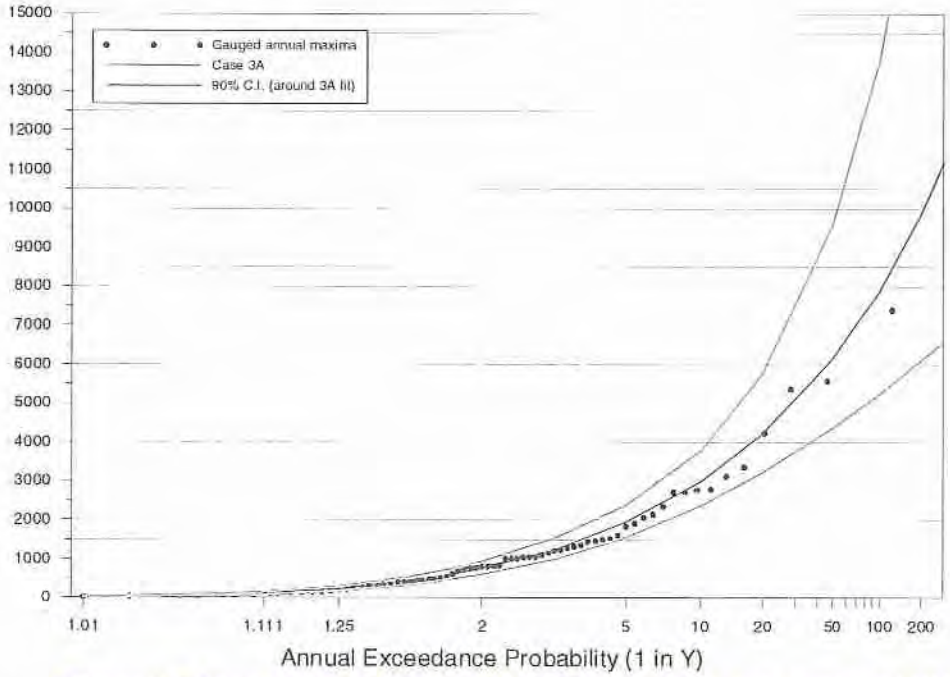

Figure 3.4 Assessment of the pre-Wivenhoe gauged data without 1893 event

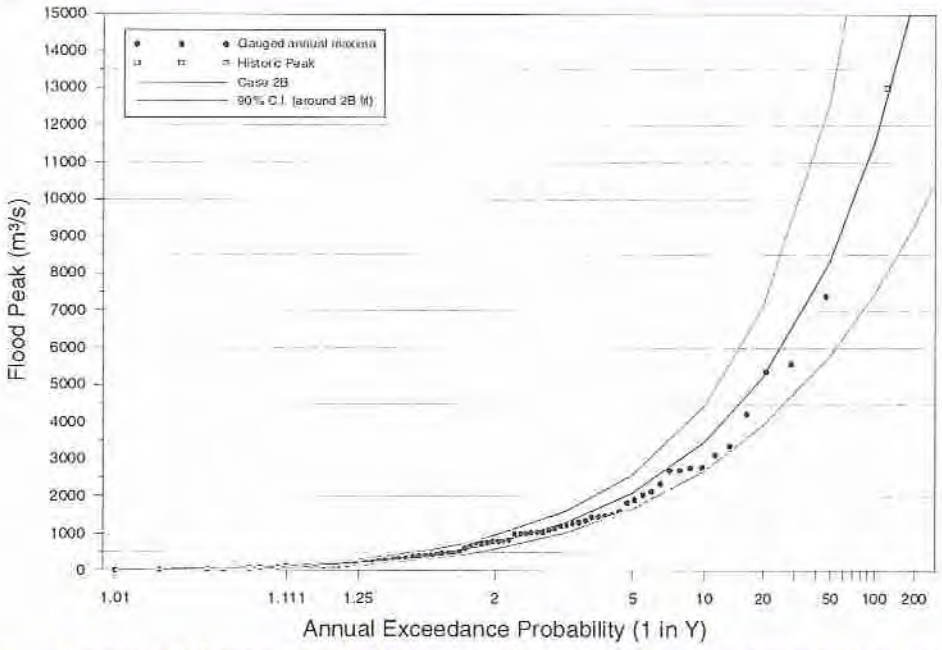

Figure 3.5 Assessment of the pre-Wivenhoe gauged data with 1893 event..

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3.5 Case 3: Analysis of "No Dams" Data Estimated by DNRM

Note effect of Somerset dam is highly variable depending on its operation. DNRM has indicated that they have spent significant resources assessing the effect of Somerset on the flood series. The data series has been provided without documentation as to the method used to adjust the data. Sinclair Knight Merz has taken this series and analysed the statistics without investigation of its derivation.

Table 3.5 Summary of Case 3 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.

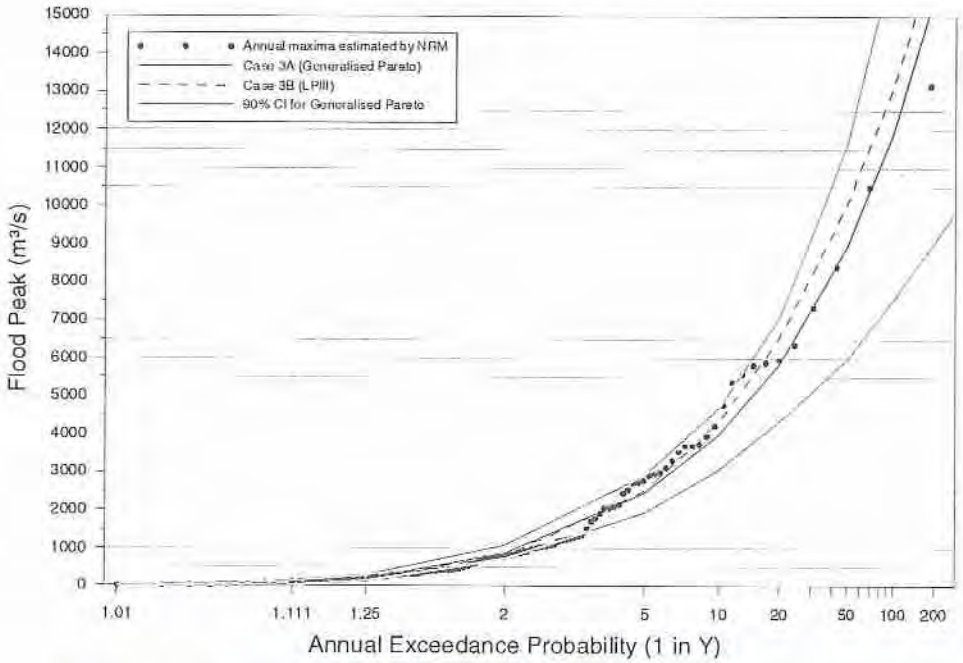

Figure 3.6 Assessment of the "no –dams" annual maxima series provided by DNRM using both GP and LPIII distributions.

3.6 Case 4: Analysis of Post-Dam Data Estimated by DNRM

These analyses were based on "post-dam" data set provided by DNRM. As with the analyses reported in Section 3.4, no assessment of the manner in which this data set was derived was undertaken.

Table 3.6 Summary of Case 4: Post-dam Data - flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

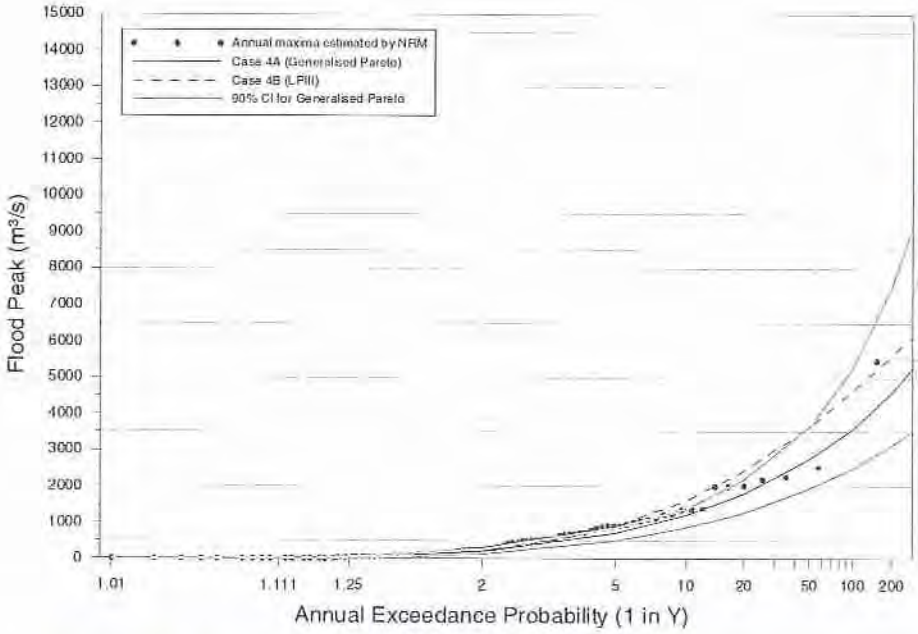

Figure 3.7 Assessment of the "post-dams" annual maxima series provided by DNRM using both GP and LPIII distributions.

3.7 Summary of analysis results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) estimate at Savages Crossing. The analyses are summarised in Table 3.7. As noted above, the summary is intended to succinctly present the broad range of sensitivity analyses for expert reviewers who are familiar with the concepts, common discipline abbreviations and analysis methods.

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Table 3.7 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Date (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 **Pre -Wivenhoe and Somerset**								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

Table 3.7cont. Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

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3.8 Best Estimates from flood frequency assessment

Sinclair Knight Merz has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling reported in the subsequent chapters). The results are presented in Table 3.8.

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), DNRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m³/s); as no allowance made for Somerset dam, the Q100 could be expected to be higher than 11 500m³/s.
- the "No dams" series from DNRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3A).

Table 3.8 Most plausible estimates of the Q100 peak flow at Savages Crossing.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),
- choice of distribution and the appropriate parameters; and

- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500m³/s and 11 000m³/s.

An additional assessment of the "current" scenario, ie with Somerset and Wivenhoe dams present and operated using current operating procedures is also provided (Case 4 – above). This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by DNRM. Note that no assessment of the plausible range for this estimate is possible, as the method for adjusting the data series is not currently available.

4. Rainfall-Runoff Modelling

Rainfall-runoff modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS rainfall-runoff model developed for the Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) was used for this investigation. The Ipswich River Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model.

4.1 Assumptions

- The Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM, 2003) Wivenhoe and Somerset Dam Operations Model was used to determine Dam outflows.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows.

- Initial Loss Rate (IL) = 10 mm
- Continuing Loss (CL) = 1.0 mm/h
- All model runs were undertaken for the 1 in 100 (1%) AEP flood event only.

4.2 Methodology

The following Methodology describes the process that was used to determine 1 in 100 AEP flood flows at Moggill and the Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model
- Input CRC-FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1% AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the DNRM Dam Operations Model.
- The DNRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the DNRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1% AEP flows at Moggill and the Port Office Gauge.

- A sensitivity analysis was then performed to using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wivenhoe and Somerset Dams at the start of the flood event.

4.3 Pre-dams RAFTS Modelling

The object of the pre-dams modelling was to achieve reconciliation between the Flood Frequency Estimates and the flow estimates produced by RAFTS. CRC-FORGE rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine affects that temporal patterns have on peak flows.

4.3.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

CRC-FORGE Rainfall Estimates for varying durations were input into the model with Areal Reduction Factors (ARF) applied (Department of Natural Resources and Mines, 2003a). Table 4.1 presents the rainfalls and ARF's used.

- Table 4.1 CRC-FORGE Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC-FORGE Rainfall	247	268	285	317	358	385	402
CRC-FORGE Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC-FORGE rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in Appendix F. Standard Temporal Patterns were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/hr was adopted.

The CRC-FORGE rainfall estimates with ARF's applied are presented in Table 4.2.

- Table 4.2 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Pre-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: **- Bold values indicate the critical duration at each location**
- Flows at Moggill and Port Office should be considered indicative only.

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4.3.2 Sensitivity to Spatial Pattern of Rainfall

To determine the impact of spatial patterns, seven historical spatial patterns were assessed. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC-FORGE Rainfall Depths (ARF applied) for each duration.

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane River and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane River Catchment.
- April 1996 - high rainfalls in the Lockyer and Lower Brisbane River Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in Appendix F.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/h was applied.

Peak flows are presented in Table 4.3.Note that for all spatial distributions the 30 hour flood is the critical duration storm at Savages Crossing and the 72 hour flood is the critical duration at Moggill and Port Office. Flows presented at Moggill and the Port Office in Table 4.3 should be considered indicative only. More reliable estimates of design floods at the lower gauges are produced by the hydraulic model, as discussed in **Chapter 5**.

Table 4.3 Pre- dams 1% AEP Peak Flows for Historical Spatial Distributions.

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: **- Bold values indicate the median flow at each location**
- Flows at Moggill and Port Office should be considered indicative only.

A full listing of peak discharges at Savages Crossing, Moggill and Port Office are present in Appendix G.

4.3.3 Sensitivity to Temporal Pattern of Rainfall

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC-FORGE Rainfall 48 hour storm duration. An I.L. of 0 mm and a C.L. of 0 mm/hr was applied.

The temporal patterns that were used in the sensitivity analysis were:

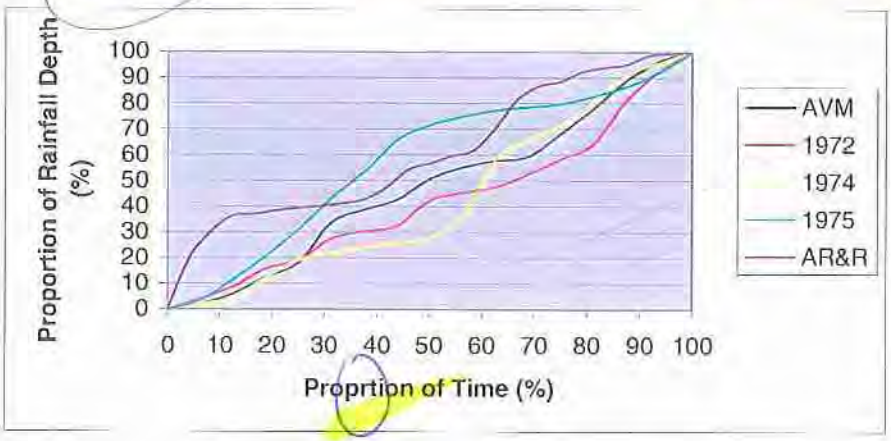
- AVM – Average Variability Method
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event.
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event.
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event.
- AR&R 1987 – Standard temporal pattern outlined in Australian Rainfall and Runoff.

not true



is currently a research tool which would require considerable time and resources

Figure 4.1 Temporal Patterns for the 1% AEP 48 Hour Storm Event



The resulting peak flow estimates using the temporal patterns described above are presented in Table 4.5

Table 4.5 48 Hour Temporal Pattern Sensitivity

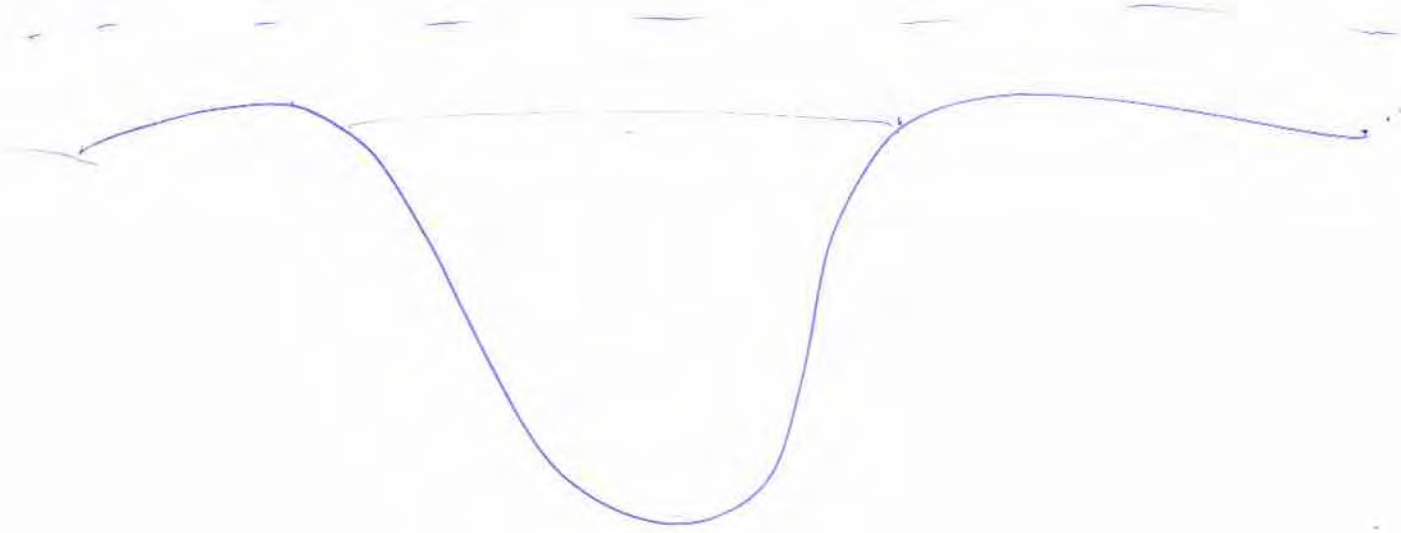
	48 hour Temporal Pattern				
Location	AR&R (m3/s)	AVM (m3/s)	1972 (m3/s)	1974 (m3/s)	1975 (m3/s)
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Port Office	12817	13464	13287	14115	13634

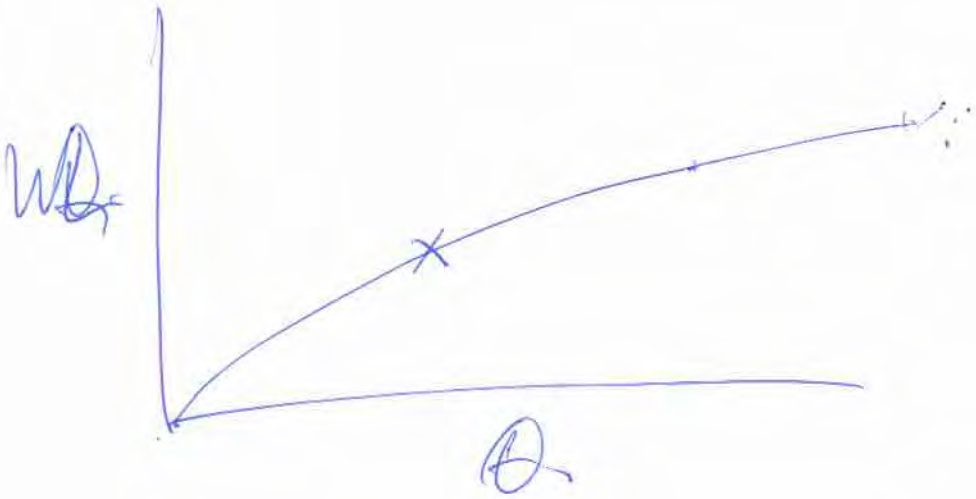
4.3.4 Discussion

Table 4.3 and Table 4.4 show that spatial and temporal patterns have a significant affect on peak flows. Given the size of the catchment and the variability that spatial and temporal patterns have on peak flows, it is evident that a Monte-Carlo analysis would be appropriate. Monte-Carlo analysis was not possible within specified time frame for this report and therefore the sensitivity analyses was undertaken to investigate potential effects of this phenomenon.

The pre-dams historical spatial distributions produce peak flows at Savages Crossing that range from 11500 m^3/s to 8000 m^3/s with the median peak flow being 10046 m^3/s. The estimated peak flow at savages using the CRC-FORGE Spatial Pattern was estimated to be 9607 m^3/s.

If an IL of 0 mm and CL of 0 mm/h is applied to the CRC-FORGE 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11278 m^3/s. It should be noted that the 'best estimate' of peak flow at Savages Crossing from the Flood Frequency Analysis was estimated to be 12000 m^3/s. This means that the RAFTS peak flow





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estimates and the FFA estimates cannot be reconciled unless further work is undertaken on the manner in which the various flood-producing factors can be combined.

4.4 Comparison of Q100 estimates from flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated RAFTS model
- CRC-FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

produced a Q100 at Savages Crossing of 11278 m³/s. It would be reasonable to expect some losses with a 1 in 100 AEP event and hence the hydrological modelling results, using typical design parameters, could be expected to be lower, say in the order of 10, 500m³/s.

The difference between the results and those from the statistical frequency analysis of flood records (Chapter 3) indicates that there are underlying factors that have not been adequately addressed to date. This would require more detailed assessment than is available in the scope and timing of the current assessment. Potential factors influencing the difference in Q100 estimates include:

- potential for partial area storms
- variation in temporal patterns
- variation in spatial patterns
- variation in losses
- adjustment of data for influence of dams
- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.

The development of a Monte-Carlo framework for analysing the factors affecting flood magnitude would enable the natural variation in the first four factors to be explicitly modelled. This would give insights necessary to resolve the discrepancy between the two independent sources of the Q100 estimates.

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4.5 Post-dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and run through the DNRM Dam Operations Model (Department of Natural Resources and Mines, 2003b). These inflows were based on the outputs presented in Appendix G and included an IL of 10 mm and CL of 1.0 mm/hour.

The outflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the hydrograph volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC-FORGE and historical spatial patterns to determine flows at Savages Crossing, Moggill and Port Office.

4.5.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

The parameters described in Section 4.3.1 were used for the Post-dams RAFTS modelling.

The CRC-FORGE rainfall estimates with ARF's applied are presented in Table 4.5.

Table 4.5 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Post-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	**5368**	2335	2502
Moggill	3017	3690	2999	3302	**5043**	3811	3990
Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Port Office should be considered indicative only.

4.5.2 Sensitivity to Spatial Pattern of Rainfall

The parameters described in Section 4.3.2 were used for the Post-dams RAFTS modelling. Peak flows are presented in Table 4.6. Note that the critical duration storm at Savages Crossing, Moggill and Port Office range from 72 to 120 hours for Post-dam Conditions. Flows presented at Moggill and the Port Office in Table 4.6 should be considered indicative only. More accurate flows will be determined during the hydraulic modelling.

Flood Mitigation - Board's Dams

The maximum level at which water is stored in the Board's dams for water supply purposes is referred to as the Full Supply Level. Somerset and Wivenhoe Dams each have space above this Full Supply Level which is normally empty, and can be used to temporarily store flood waters, when required. North Pine Dam has virtually no flood storage space above its Full Supply Level.

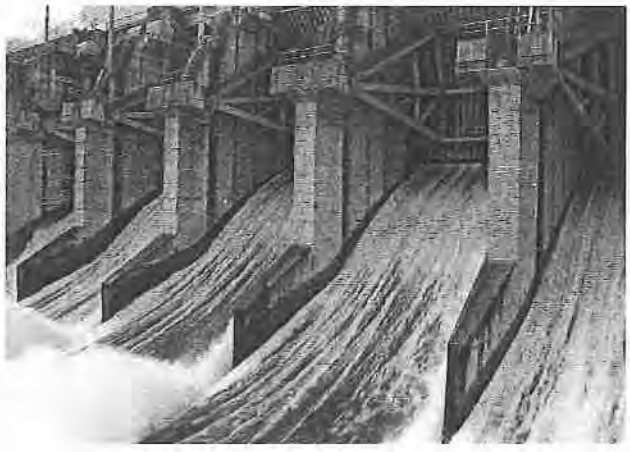
The concept of flood storage is illustrated by the following:

- **Wivenhoe Dam** has 1,165,000 megalitres of storage capacity for water supply purposes up to its Full Supply Level of EL67 metres AHD (Australian Height Datum). A further 1,450,000 megalitres of storage capacity is available above the Full Supply Level, up to a level of EL75 metres AHD for the temporary storage of flood waters, ie. the total capacity of Wivenhoe Dam is 2,615,000 megalitres. The flood storage is held empty, except when required to store flood waters.
- **Somerset Dam** has 380,000 megalitres of storage capacity for water supply purposes up to its Full Supply Level of EL99 metres. A further 524,000 megalitres of storage capacity is available above the Full Supply Level, up to a level of EL107 metres, for the temporary storage of flood waters, i.e. the total capacity of Somerset Dam is 904,000 megalitres.
- **North Pine Dam** has 215,000 megalitres of storage capacity for water supply purposes up to its Full Supply Level of EL39.6 metres. While there is virtually no space above this dam's Full Supply Level for flood storage, the spillway gates are operated in such a way as to minimise the effects of flooding.

On the spillway crest of each dam, steel gates are operated (raised or lowered) to regulate the discharge of flood waters downstream. The main principles for gate operation are that a dam should not be overtopped, and flood releases should be regulated to minimise upstream and downstream flood effects, to the extent possible. The procedures for the operation of the gates are set out in the approved Flood Operations Manual for each dam. Flood operations are undertaken by the Department of Natural Resources, as the Board's Headworks Operator.

Review of Spillway Capabilities

Following reassessment by the Bureau of Meteorology of the probable maximum rainfall events, which are used in designing dams, the Board has carried out a review of the spillway capacity of its dams, to assess whether each dam could safely pass the reassessed "probable maximum flood". The studies show that with the new (higher) rainfall estimations, Wivenhoe Dam requires further investigation. Accordingly, the Board has commissioned consultants to undertake a risk management study of the likely impact of these new rainfall predictions, together with a pre-feasibility study of options to upgrade the flood passing capacity of Wivenhoe Dam. The study will identify feasible options and broad cost estimates. It is proposed that a more detailed feasibility study will then proceed.



Wivenhoe Dam flood gates / spillway

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Table 4.6 Post-dams 1% AEP Peak Flows for Historical Spatial Distributions

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: **- (120hr) denotes the critical storm duration**
- Bold values indicate the median flow at each location
-Flows at Moggill and Port Office should be considered indicative only.

4.5.3 Sensitivity to Starting Water Level in Wivenhoe Dam

Full supply level of Wivenhoe Dam is at RL 67.0 m AHD and has a storage capacity of 1165×10^6 m^3 of storage. The crest level of Wivenhoe Dam is at RL 79 m AHD with a corresponding storage capacity of 2934×10^6 m^3. The maximum flood mitigation volume of Wivenhoe Dam is 1769×10^6 m^3.

It is unlikely that Dam Owners would choose to utilise the full volume of flood as Wivenhoe Dam is an earth fill dam they would be unwilling to risk overtopping of the dam that could lead to dam failure.

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1% AEP flood (average CRC-FORGE rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in Table 4.7

Table 4.7 Flood Runoff Volumes for the 1% AEP above Wivenhoe Dam

Storm Duration (hours)	CRC Rainfall Depth with ARF Applied (mm)	Runoff Volume ($m^3 \times 10^5$)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

Table 4.7 shows that if Wivenhoe Dam is at FSL, the 1% AEP 36-hour flood runoff volume can be fully stored between FSL and Crest Level without release. For 1% AEP events with longer

durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the crest level is over, topped (no releases).

Given current operational procedure, it is unlikely that no releases would occur during a flood event, particularly if Wivenhoe Dam is at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs have been done for the 1% AEP 72 hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in Table 4.8.

Table 4.8 Dam Starting Water Levels Sensitivity Analysis for the 1% AEP 72 Hour Storm

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Port Office	5044	4402	4402

Note: - Flows at Moggill and Port Office should be considered indicative only.

Table 4.9 shows that the reduction in flow is approximately 13% at the Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

4.5.4 1893 and 1974 Historical Flood Events

The information from the two historical flood events (1893 and 1974) were run through the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post-dam flows are presented in Table 4.10.

Underlying M.C. analysis would ens

A. M.C. analysis would provide a more defensible ~~robust~~ estimate of the Q100 + reduce the overall uncertainty in the flood estimates.

MNR

(change in exec summary as well).

No focus

Surely, this estimate should be carried to Savage. as directed by the Expert Panel. Should be para be here - as it is discussed in the next section?

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Table 4.10 Predicted Post-dam Flows for the 1893 and 1974 Historical Flood Events

Location	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
	No Dams (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)	Somerset in Place (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Port Office	13869	9519	9874	6801

Table 4.10 indicates that the peak flows for the historical events at the Port Office are above the 1 in 100 AEP CRC-FORGE estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1974 peak flow estimate and even more with the 1893 event. However, it is clear that the effect of the dams on events of such magnitude can be significant.

4.5.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. This again indicates that Monte-Carlo analysis would be an appropriate way to investigate the complex interactions between dams and variations in losses, spatial and temporal patterns to obtain the best estimate of the 1%AEP flood event.

The CRC-FORGE spatially distributed peak flow at Savages Crossing was estimated to be 5368 m^3/s for the post-dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow being 6241 m^3/s.

Based on the preceding investigations, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate. Given the current information, the 'best estimate' of peak flow at the Port Office would be 6500 m^3/s with an upper and lower limit of 8000 m^3/s and 5000 m^3/s respectively.

It is recommended that Monte-Carlo analysis be undertaken as there many uncertainties associated with the above best estimate.

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The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flow estimates are:

- inclusion of the lower CRC-FORGE rainfall depths with areal reduction factors (ARF's were not available for catchments of this size in 1998),
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures (the previous study (Sinclair Knight Merz 1998), assumed emergency operating procedures which minimised the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River),
- In the 1998 study, the emphasis was to match Flood Frequency Estimates at Moggill and the Port Office. The reliability of the streamflow at Moggill and Port Office is questionable as these gauges are height read gauges and tidal effects are difficult to account for at these locations. After discussions with DNRM, who have just developed a new composite flood series at Savages Crossing, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and flood frequency estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing, as discussed in Chapter 3.
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that rainfall-runoff modelling be undertaken in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.

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5. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Port Office is good, other sections of the reach within Brisbane City has not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

[redacted]

5.1 Assumptions

- Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane River Bar.

5.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from approximately 10km downstream of Savages Crossing to the Brisbane River Bar. The model also includes Bremer River and other smaller tributaries which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1% AEP spatially distributed over the catchment. Duration's ranging from 24 to 120 hours were assessed.

5.3 Results

The peak Discharges and Flood Levels for at Moggill and Port Office are presented in **Table 5.1 1% AEP Peak Flood Levels and Flows for the CRC-FORGE Spatial Distributed Rainfall.**

Table 5.1 1% AEP Peak Flood Levels and Flows for the CRC-FORGE Spatial Distributed Rainfall

	Moggill		Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

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5.4 Discussion

Table 4.5 and Table 5.1 show that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Port Office.

Using the 'best estimate and upper and lower limits of peak flows at the Port Office presented in Section 4.5.5, a rating curve was used to predict flood levels at the Port Office for the 1%AEP flood event. Peak flood levels and corresponding flows are presented in Table 5.2.

Table 5.2 Peak Flood Level and Peak Flow Estimates for the 1%AEP Flood Event at Port Office.

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	~~6500~~ 6000	3.51 X 3.3
Upper Estimate	~~8000~~ 7000	4.41 X

Note that these estimates should be considered indicative because the actual tide level may vary for an actual flood event. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918) at the Brisbane River Bar.

[redacted]

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6. Conclusions

Detailed investigations have been undertaken to assist the Expert Review Panel to assess the likelihood of floods in the lower reaches of the Brisbane River. The assistance has been centred on the two tasks of

- undertaking statistical flood frequency analysis, and
- updating the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event: firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table ~~E1~~. 6-1

compare to statement on Page 2 & see P63.

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- Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the significant sources of uncertainty in the recorded data, length of record, choice of distribution and adjustment of the data for the effect of the dams. As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m³/s and 11 000 m³/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment. ARFs were not available for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knight Merz 1998) was undertaken.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1% AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

Q100 estimate at the Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to

To reduce the uncertainty in the advance estimates

In order to ~~to improve the defensibility of the Q100 estimate~~

Adaptation of

The following actions would serve to increase the defensibility of the Q100 estimate [redacted]

account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

[redacted]

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane *River* flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the Flood Frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the Flood Frequency Analysis Outcomes.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC-FORGE Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 1 in 100 AEP event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the DNRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine the 1 in 100 AEP flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQB and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of sophistication



appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.

Appendix B Flow Gauging Stations Omitted from Consideration

Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143222A	Atkinson Dam	Atkinson Creek Outlet		20	Small catchment area, offstream storage	DNRM
143234A	Atkinson Dam Hea			6	Small catchment area, offstream storage	DNRM
143228A	Bill Gunn Dam	Lake Dyer	3	18	Catchment area too small	DNRM
143027A	Blunder Creek	King Avenue Bridge	31	8	Urban creek in Brisbane area, Small catchment	DNRM
2121	Blunder Creek	King Ave- Durack		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1594	Breakfast Creek	Opposite Newstead House		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1579	Breakfast Creek	Sedgley Park Retention Basin- New Market		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1525	Breakfast Creek	Opposite Mann Park- Bowen Hills		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143104B	Bremer River	Rosevale	67	21	Catchment area too small	DNRM
143104A	Bremer River	Rosevale	77	34	Catchment area too small	DNRM
143110A	Bremer River	Adams Bridge	125	35	Catchment area too small	DNRM
143940	Bremer River	Stokes Crossing	180	21	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143909	Bremer River	Rosewood	543		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143833	Bremer River	Rosewood Alert	543	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143908	Bremer River	Rosewood TM	543	25	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143934	Bremer River	Walloon Bvrt	585		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143805	Bremer River	Walloon Alert-P	585	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143911	Bremer River	Ipswich	1850		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143956	Bremer River	Three Mile Bridge Alert	1870		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143954	Bremer River	Ipswich Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143953	Bremer River	One Mile Bridge Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143852	Bremer River	Brassall(Hancocks Br) Al		5	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143115A	Bremer River	Berry's Lagoon		9	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143944	Brisbane River	Linville	2005	47	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143007A	Brisbane River	Linville	2009	39	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143831	Brisbane River	Devon Hills Alert	2160	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143922	Brisbane River	Devon Hills Bvrt	2190		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143002A	Brisbane River	Plainlands	3950	12	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143002B	Brisbane River	Fulham Vale	3950	34	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143005A	Brisbane River	Watts Bridge	4602	20	Record length too short	DNRM
143008A	Brisbane River	Middle Creek	6704	20	Record length too short	DNRM
143026A	Brisbane River	Wivenhoe	7023	3	Record length too short	DNRM
143036A	Brisbane River	Wivenhoe Headwater	7023	17	Record length too short	DNRM
143035A	Brisbane River	Wivenhoe Tailwater	7023	17	Record length too short	DNRM
143907	Brisbane River	Lowood	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143941	Brisbane River	Lowood Bvrt	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143827	Brisbane River	Lowood Alert-P	10062	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143916	Brisbane River	Mt Crosby	10600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143839	Brisbane River	Mt Crosby Alert	10600	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143925	Brisbane River	Mt Crosby TM	10600	28	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143951	Brisbane River	Moggill Alert	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143915	Brisbane River	Moggill Bvrt	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143924	Brisbane River	Moggill TM	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143900	Brisbane River	Caboonbah			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143914	Brisbane River	Gregor Creek			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143920	Brisbane River	Gregor Creek Bvrt			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143902	Brisbane River	Murrumba			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143005	Brisbane River	Watts Bridge			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143903	Brisbane River	Wivenhoe			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143018A	Brisbane River	Avoca Vale	1498	20	Record length too short (post Wivenhoe)	DNRM
143868	Brisbane River	Colleges Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143918	Brisbane River Estuary	Bishop Island			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143217A	Buaraba Creek	Vineyard	63	10	Catchment area too small	DNRM
143211A	Buaraba Creek	15.8km	251	12	Catchment area too small	DNRM
143224A	Buaraba Creek	Diversion Channel		19	Catchment area too small	DNRM
143094A	Bulimba Ceek	Mansfield	57	26	Urban creek in Brisbane area, Small catchment	DNRM
143004A	Bulimba Creek	Belmont	51	22	Urban creek in Brisbane area, Small catchment	DNRM
1591	Bulimba Creek	End of Aquarium Ave. Hemmant		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1528	Bulimba Creek	Doughboy Pde- Hemmant		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1804	Bulimba Creek	Greenwood St- Wishart		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1831	Bulimba Creek	Merion Pl- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1707	Bulimba Creek	Old Cleveland Rd- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143926	Bundamba Creek	Ripley Alert	35		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143959	Bundamba Creek	Harding Street Alert	96		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143958	Bundamba Creek	Blackstone Bridge Alert	97	10	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143955	Bundamba Creek	Bundamba School Alert	102		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143854	Bundamba Creek	Bundamba (Hanlon St) Al	109	7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143114A	Bundamba Creek	Mary Street	110	11	Urban creek in Ipswich area, Small catchment	DNRM
143307A	Byron Creek	Causeway	79	28	Catchment area too small	DNRM
143012A	Cooyar Creek	51.5km.	443	4	Record length too short	DNRM
143015B	Cooyar Creek	Damsite	963	13	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143015A	Cooyar Creek	Damsite	963	22	Record length too short	DNRM
143013A	Cressbrook Creek	The Damsite	321	16	Record length too short	DNRM
143952	Cressbrook Creek	Rosentreters Bridge	440		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143921A	Cressbrook Creek	Rosentretters Bridge	447	17	Record length too short	DNRM
143921	Cressbrook Creek	Rosentreters Bridge TM	477		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143806	Cressbrook Creek	Rosentreters Bridge Al	477	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143857	Deebing Creek	Churchill Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143021A	Ekibin Creek	Dudley Street.	13	1	Urban creek in Brisbane area, Small catchment	DNRM
143011A	Emu Creek	Raeburn	439	24	Catchment area too small	DNRM
143010A	Emu Creek	Boat Mountain	915	11	Catchment area too small	DNRM
143010B	Emu Creek	Boat Mountain	915	27	Catchment area too small	DNRM
143932A	Ennogera Creek	Bancroft Park	70	10	Urban creek in Brisbane area, Small catchment	DNRM
143932	Enoggera Creek	Bancroft Park TM	67		Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1531	Enoggera Creek	100 M U/S From Original E e529		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1532	Enoggera Creek	Enoggera Dam- The Gap		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1529	Enoggera Creek	Kelvin Grove Rd- Kelvin Grove		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143208A	Fifteen Mile Creek	Dam Site	87	33	Catchment area too small	DNRM
143214A	Flagstone Creek	Windolfs	142	14	Catchment area too small	DNRM
143233A	Flagstone Creek	Brown-Zirbels Road		10	Catchment area too small	DNRM
1717	Gold Creek	Reservoir- Brookfield (Brisbane Water)			Urban creek in Brisbane area, Small catchment	South East Queensland Water
143028A	Ithaca Creek	Jason Street	10	31	Urban creek in Brisbane area, Small catchment	DNRM
1535	Ithaca Creek	Jason St- Ithaca		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143304A	Kilcoy Creek	Mount Kilcoy	127	36	Catchment area too small	DNRM
143304B	Kilcoy Creek	Mount Kilcoy Weir	131	15	Catchment area too small	DNRM
143235A	Lake Clarendon Head			6	Offstream storage	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143215A	Laidley Creek	Mulgowie Weir	154	14	Catchment area too small	DNRM
143209A	Laidley Creek	Mulgowie1	167	5	Catchment area too small	DNRM
143209B	Laidley Creek	Mulgowie2	167	36	Catchment area too small	DNRM
143225A	Laidley Creek	Showgrounds Weir Head Wate	233	19	Catchment area too small	DNRM
143226A	Laidley Creek	Showgrounds Weir Tail Wate	233	19	Catchment area too small	DNRM
143943	Laidley Creek	Laidley	285		Catchment area too small	BoM, Queensland Regional Office
143923	Laidley Creek	Thornton			Catchment area too small	BoM, Queensland Regional Office
143229A	Laidley Creek	Warrego Highway		13	Catchment area too small	DNRM
143202A	Lockyer Creek	Russell Siding	271	7	Catchment covered by other gauges DS	DNRM
143203C	Lockyer Creek	Helidon Number 3	357	16	Catchment covered by other gauges DS	DNRM
143203A	Lockyer Creek	Helidon	357	45	Catchment covered by other gauges DS	DNRM
143203B	Lockyer Creek	Helidon No.2	382	24	Catchment covered by other gauges DS	DNRM
143904	Lockyer Creek	Gatton	1550		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143204A	Lockyer Creek	Wilsons Weir	1655	29	Catchment covered by other gauges DS	DNRM
143905	Lockyer Creek	Glenore Grove	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143906	Lockyer Creek	Glenore Grove Bvrt	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143807	Lockyer Creek	Glenore Grove Alert	2230	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143206A	Lockyer Creek	Brightview Weir	2393	20	Catchment covered by other gauges DS	DNRM
143201A	Lockyer Creek	Tarampa	2405	17	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143201B	Lockyer Creek	Tarampa Number 2	2405	22	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143917	Lockyer Creek	Lyons Bridge	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143913	Lockyer Creek	Lyons Bridge Bvrt	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143819	Lockyer Creek	Lyons Bridge Alert-P	2530	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143227A	Lockyer Creek	O'Reilly's Weir Tailwater	2965	5	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
2142	Lota Creek	Rickertt Rd Ransome		4	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143213B	Ma Ma Creek	Ma Ma Weir	226	9	Catchment area too small	DNRM
143213A	Ma Ma Creek	Harms	227	4	Catchment area too small	DNRM
143213C	Ma Ma Creek	Harm's		8	Catchment area too small	DNRM
143032A	Moggill Creek	Upper Brookfield	23	27	Urban creek in Brisbane area, Small catchment	DNRM
143020A	Moggill Creek	Misty Morn	61	9	Urban creek in Brisbane area, Small catchment	DNRM
143020	Moggill Creek	Misty Morn TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1722	Moggill Creek	Fortrose St- Kenmore		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2143	Moolabin Creek	Brisbane River Golf Club- Tennyson		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143219A	Murphys Creek	Spring Bluff	18	24	Urban creek in Brisbane area, Small catchment	DNRM
1549	Norman Creek	Joachim St- Holland Park West		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1552	Norman Creek	South East Freeway- Greenslopes		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1555	Norman Creek	Caswell St- East Brisbane River		10	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143033A	Oxley Creek	New Beith	60	27	Urban creek in Brisbane area, Small catchment	DNRM
143019A	Oxley Creek	Upstream Beatty Road	152	3	Urban creek in Brisbane area, Small catchment	DNRM
143019B	Oxley Creek	Downstream Beatty Road	152	6	Urban creek in Brisbane area, Small catchment	DNRM
143019	Oxley Creek	Beatty Road TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1588	Oxley Creek	Mouth of Oxley Creek		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1727	Oxley Creek	New Beith (DNR)+F31		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2023	Oxley Creek	Corinda High School- Corinda		12	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2125	Oxley Creek	Beatty Rd- Acacia Ridge		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2111	Oxley Creek	Johnson Rd- Forestdale		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143024A	Pullen Pullen Creek	Moggill Road	27	4	Urban creek in Brisbane area, Small catchment	DNRM
1745	Pullen Pullen Creek	Pinjarra Rd- Pinjarra Hills		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143983	Purga Creek	Loamside Alert	215	8	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143113A	Purga Creek	Loamside	215	30	Catchment area too small	DNRM
143869	Purga Creek	Peak Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143218A	Redbank Creek	Holcomb	55	8	Urban creek in Ipswich area, Small catchment	DNRM
143216A	Redbank Creek	Water Treatment Works	60	11	Urban creek in Ipswich area, Small catchment	DNRM
143231A	Redbank Creek	Clarendon Number 2		10	Urban creek in Ipswich area, Small catchment	DNRM
143230A	Redbank Creek	Clarendon Pump Station		10	Urban creek in Ipswich area, Small catchment	DNRM
143306A	Reedy Creek	Upstream Byron Creek Junct	56	28	Catchment area too small	DNRM
143103A	Reynolds Creek	Moogerah	190	37	Catchment area too small	DNRM
143103B	Reynolds Creek	Moogerah	190	6	Catchment area too small	DNRM
143111A	Reynolds Creek	Moogerah Dam Headwater	226	36	Head gauge affected by dam site	DNRM
143112A	Reynolds Creek	Moogerah Tailwater	227	23	Tail gauge affected by dam site	DNRM
143220A	Sandy Creek	Forest Hill	102	7	Urban creek in Brisbane area, Small catchment	DNRM
143232A	Sandy Creek	Forest Hill		8	Urban creek in Brisbane area, Small catchment	DNRM
143030A	Sandy Creek	Indooroopilly		22	Urban creek in Brisbane area, Small catchment	DNRM
143223A	Seven Mile Lagoo	Diversion Channel		20	Diversion channel	DNRM
143023A	Small Catchment	Algester	1	4	Urban creek in Brisbane area, Small catchment	DNRM
143022A	Stable Swamp Creek	Interstate Railway	19	11	Urban creek in Brisbane area, Small catchment	DNRM
2129	Stable Swamp Creek	Musgrave Rd- Coopers Plains		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143303A	Stanley River	Peachester	104	76	Catchment area too small	DNRM
143938	Stanley River	Woodford TM	220		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143829	Stanley River	Woodford Alert-P	220	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143901	Stanley River	Woodford	250		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143301B	Stanley River	Donnelly Dell	1227	4	Record length too short	DNRM
143301A	Stanley River	Hazeldean	1242	3	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143305	Stanley River	Somerset Dam	1330		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143818	Stanley River	Somerset Dam Hw Alert-B	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143817	Stanley River	Somerset Dam Hw Alert-P	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143305A	Stanley River	Somerset Dam	1336	24	Head gauge affected by dam site	DNRM
143302A	Stanley River	Silverton	1339	49	Data obtained, but uncertainty as to appropriate rating	DNRM
143960	Stanley River	Peachester			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143212A	Tenthill Creek	Tenthill	447	35	Catchment area too small	DNRM
143106A	Warrill Creek	Aratula Weir	122	7	Catchment covered by other gauges DS	DNRM
143102A	Warrill Creek	Kalbar No.1	465	46	Catchment covered by other gauges DS	DNRM
143102B	Warrill Creek	Kalbar No.2	468	13	Catchment covered by other gauges DS	DNRM
143937	Warrill Creek	Kalbar	470		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143910	Warrill Creek	Harrisville	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143912	Warrill Creek	Harrisville TM	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143101A	Warrill Creek	Mutdapily	771	43	Catchment covered by other gauges DS	DNRM
143825	Warrill Creek	Amberley Alert-P	850	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143933	Warrill Creek	Amberley Bvrt	862		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143117A	Warrill Creek	Junction Weir H/W		5	Record length too short	DNRM
143118A	Warrill Creek	Junction Weir Tailwater		6	Record length too short	DNRM
143116A	Warrill Creek	Toohill's Crossing		6	Record length too short	DNRM
143105A	Warrill Creek East	Churchbank Weir	149	50	Catchment covered by other gauges DS	DNRM
143031A	Water St. Drain	Exhibition Ground		5	Urban creek in Brisbane area, Small catchment	DNRM
143939	Western Creek	Kuss Road	200	21	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
143861	Western Creek	Grandchester Alert		4	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1583	Wolston Creek	700m U/S Wacol Station Rd- Wacol		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143962	Woogaroo Creek	Brisbane River Road Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143927	Woogaroo Creek	Opossum Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143961	Woogaroo Creek	Alice Street Alert		7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

Appendix C Location of select stream gauges

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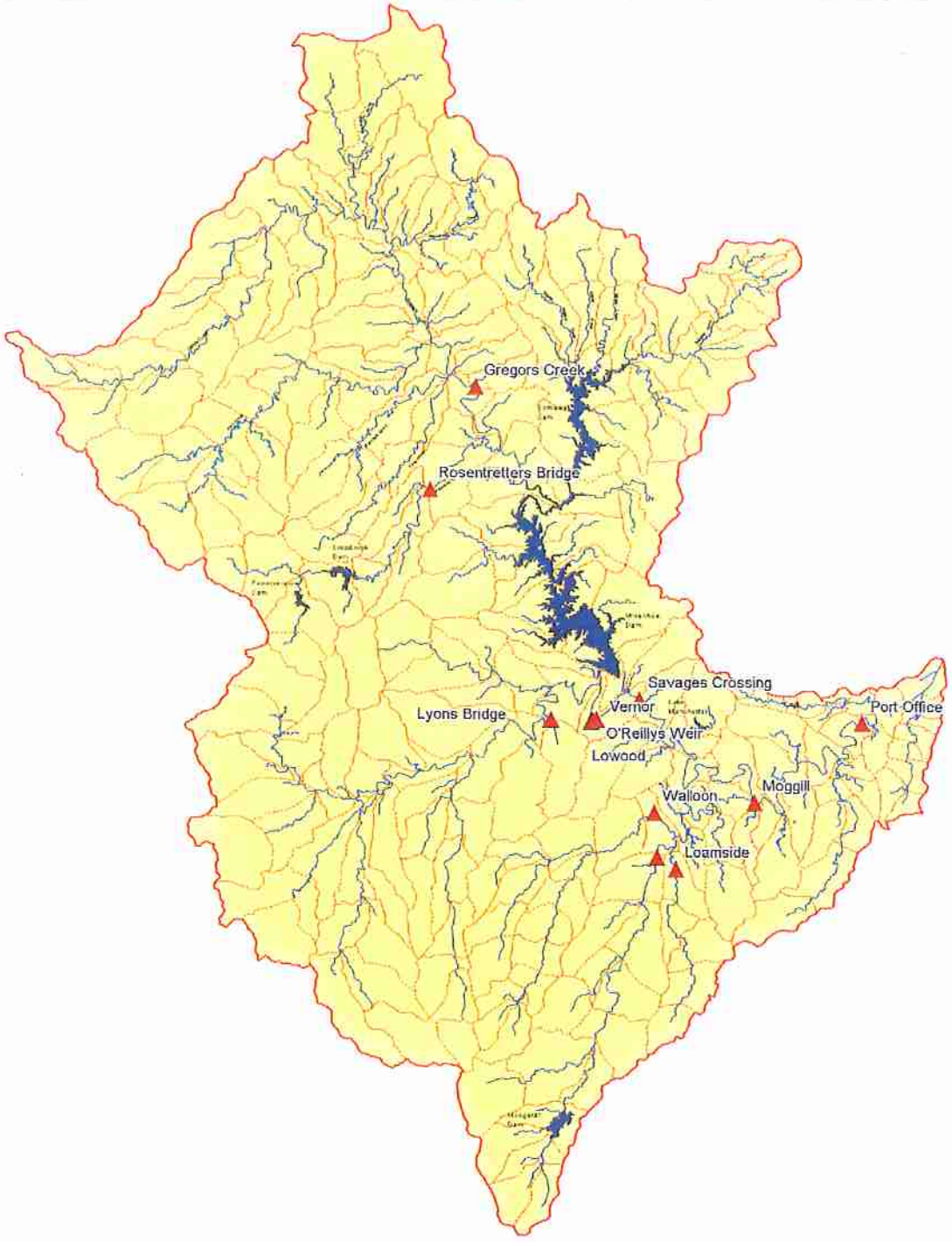
- Location of stream gauge sites that were used in flood frequency analysis



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Appendix D Regional Flood Frequency Information

D.1 Introduction

The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

D.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in Section 2.2 only DNRM gauge flow data were both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in Table D.1.

The location of the gauges can be seen in the catchment map in Appendix C.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in Table D.1 were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in Section D.3.

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Table D.1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods.

River	Station Name	Station Number	Years of Record	Catchment Area (km²)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

D.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in Table D.1. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. Figure D.1 shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (eg Peel et al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

Also shown on Figure D.1 is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that Bremer River @Walloon (143107A) and Brisbane @ Gregor's Creek (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (Appendix E) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.

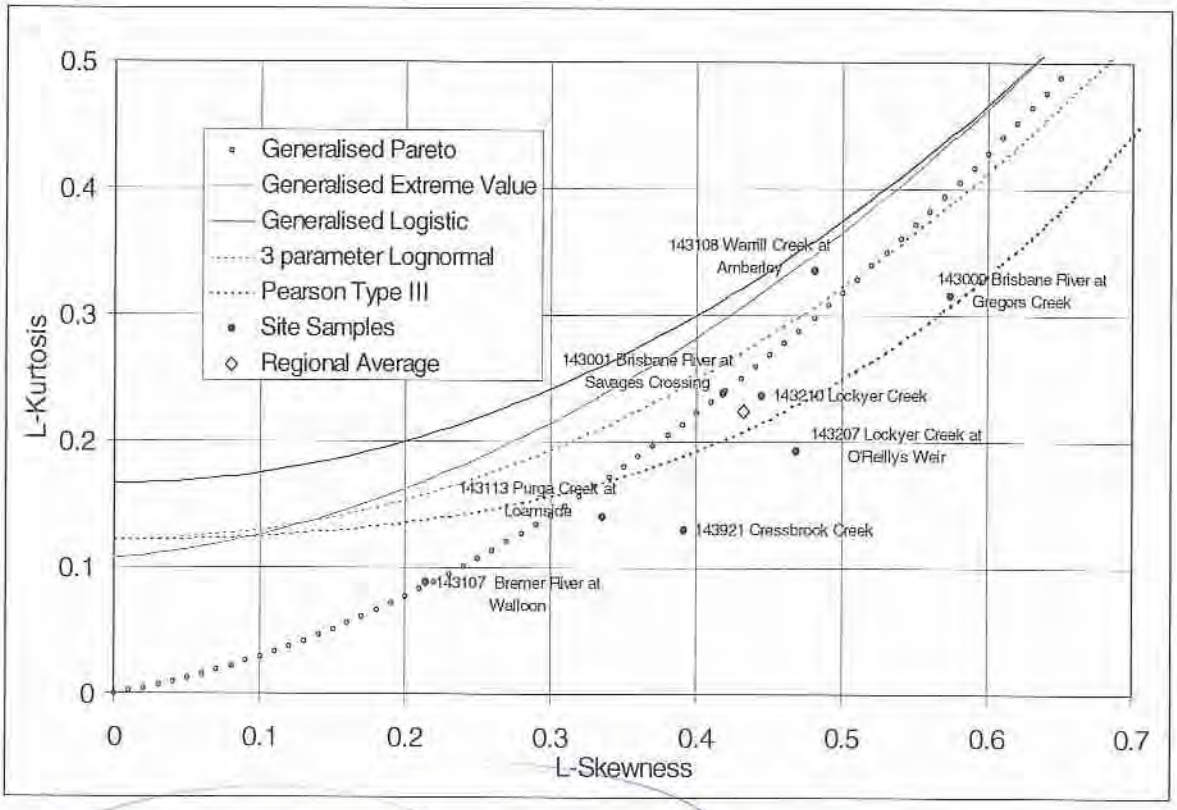


Figure D.1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500km²), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (Figure D.2) supports the adoption of the Generalised Pareto distribution.

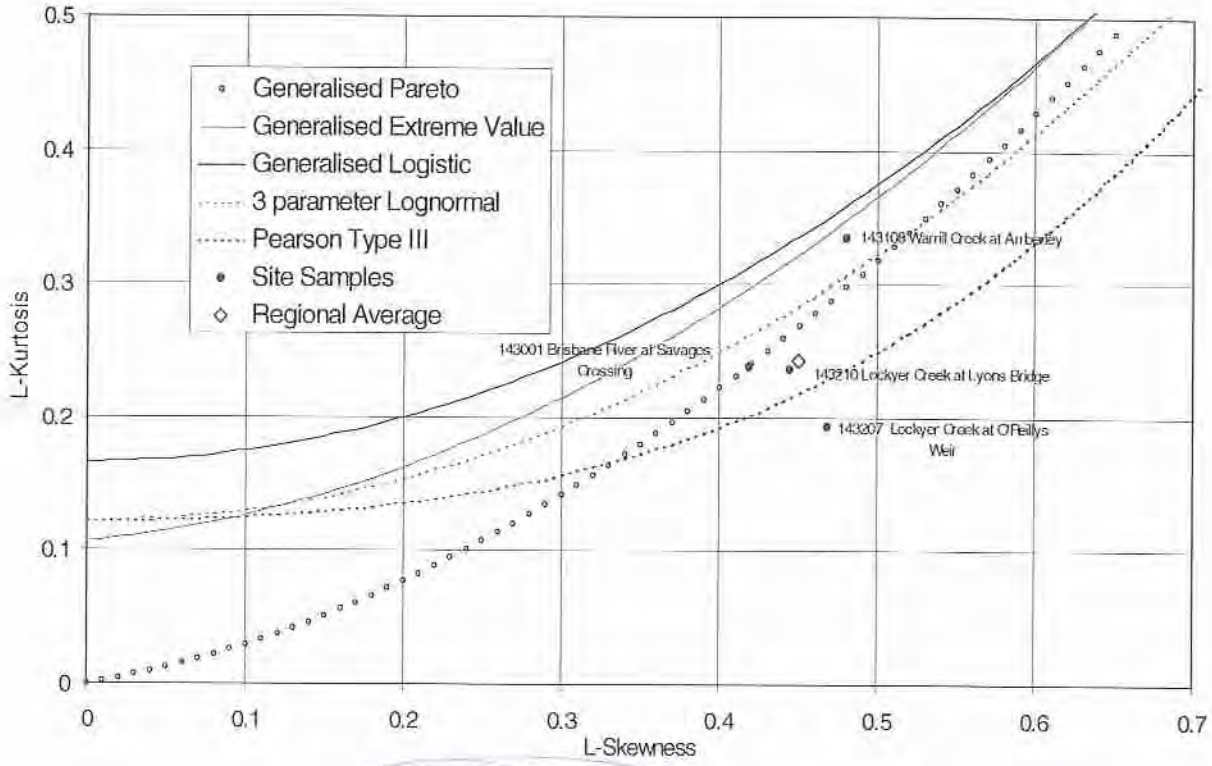


Figure D.2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in Table D.2.

Table D.2 Regional parameter values of the adopted Generalised Pareto distribution

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter, ξ	-0.062	-0.096
Scale parameter, α	0.811	0.795
Shape parameter, κ	-0.230	-0.275

D.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation,
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of Table D.2. The scale parameter (α) from the regional analysis shown in Table D.2 is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\hat{\alpha}_{143001} = L^1_{143001}\alpha^{CV}_{\text{Regional}} = 1181 \times 0.795 = 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in Table D.3. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\sigma_{\alpha,143001} = L^1_{143001}\sigma^{CV}_{\alpha,\text{Regional}} = 1181 \times 0.388 = 458$$

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information

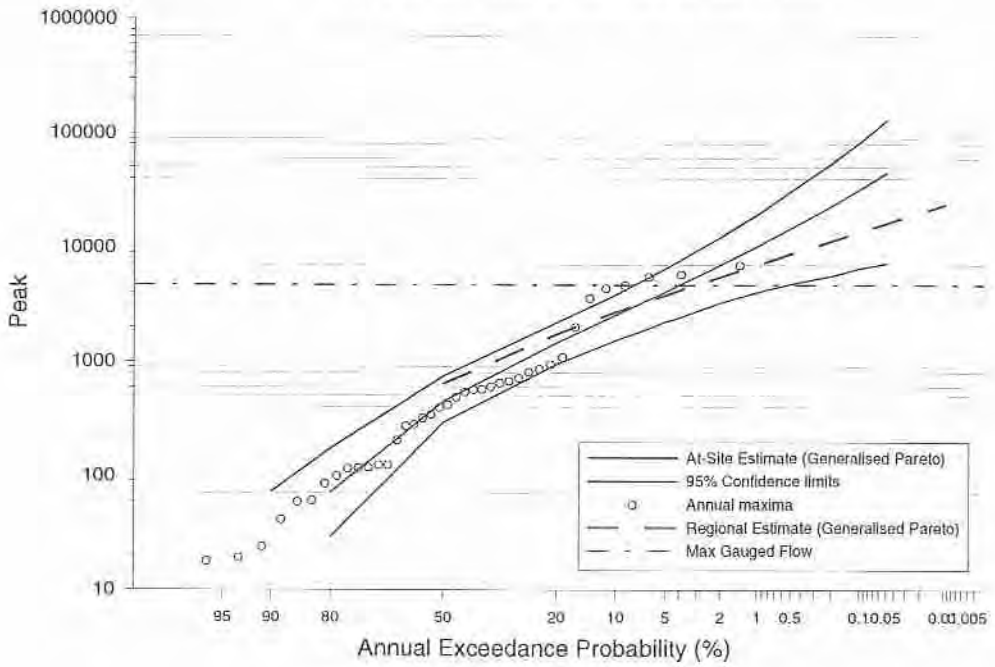
was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

Table D.3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution

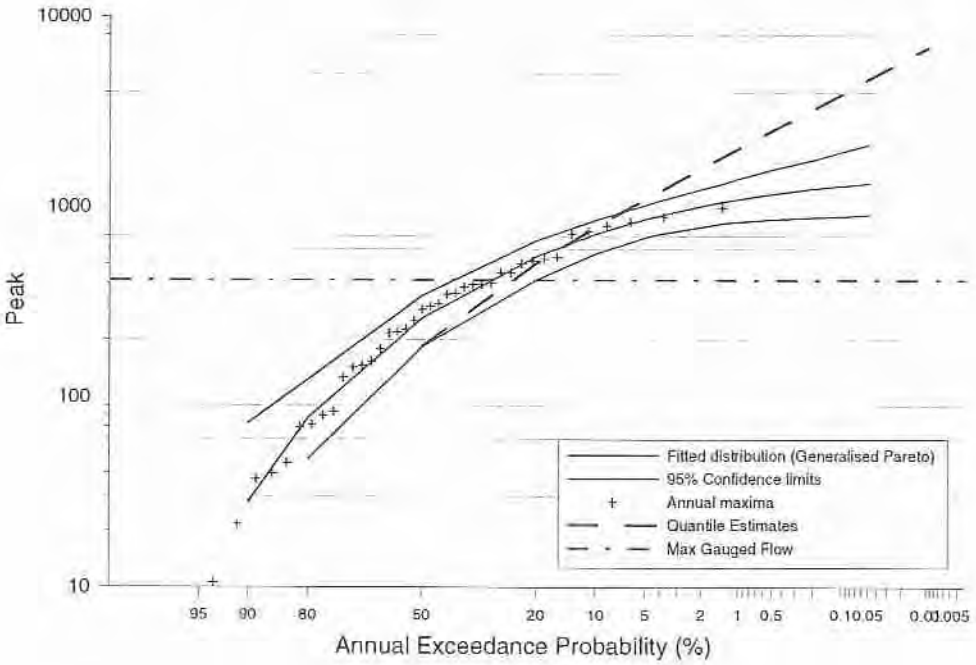
Site Number	Gauging Station Name	Scale parameter, α	Shape parameter, κ
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		0.388	0.297

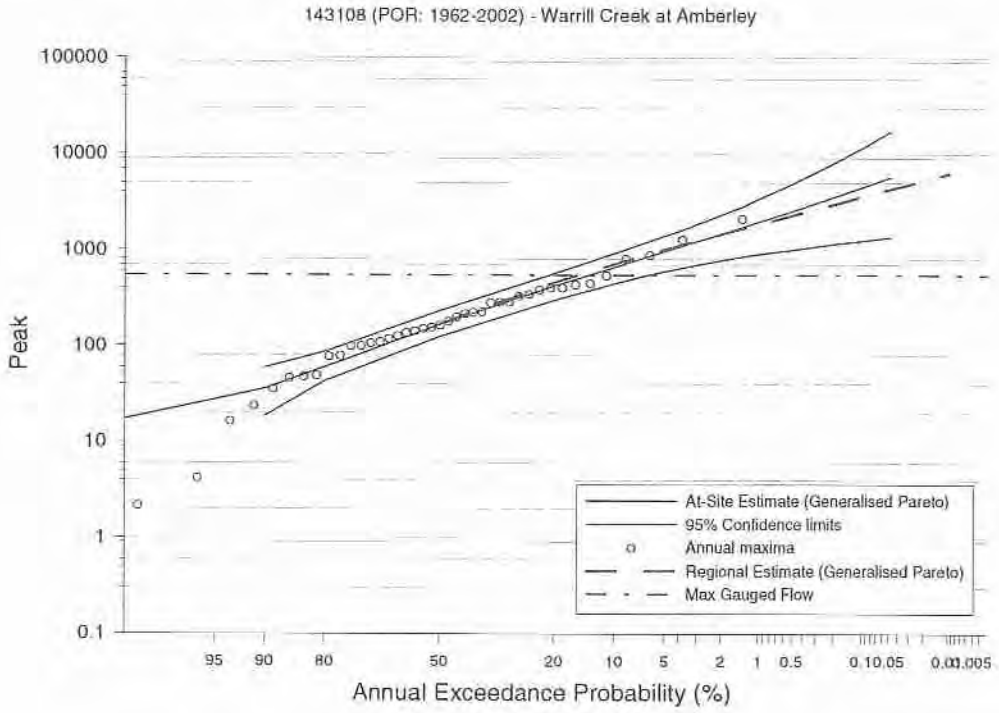
Appendix E At-Site/Regional Analysis of Selected Gauges

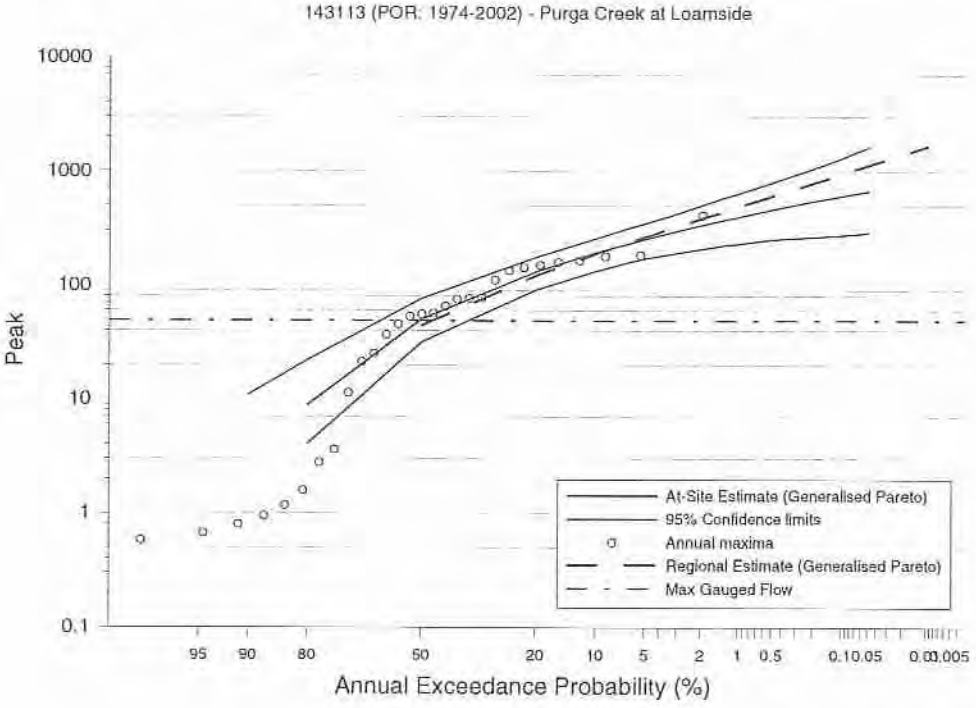
143009 (POR: 1963-2002) - Brisbane River at Gregors Creek

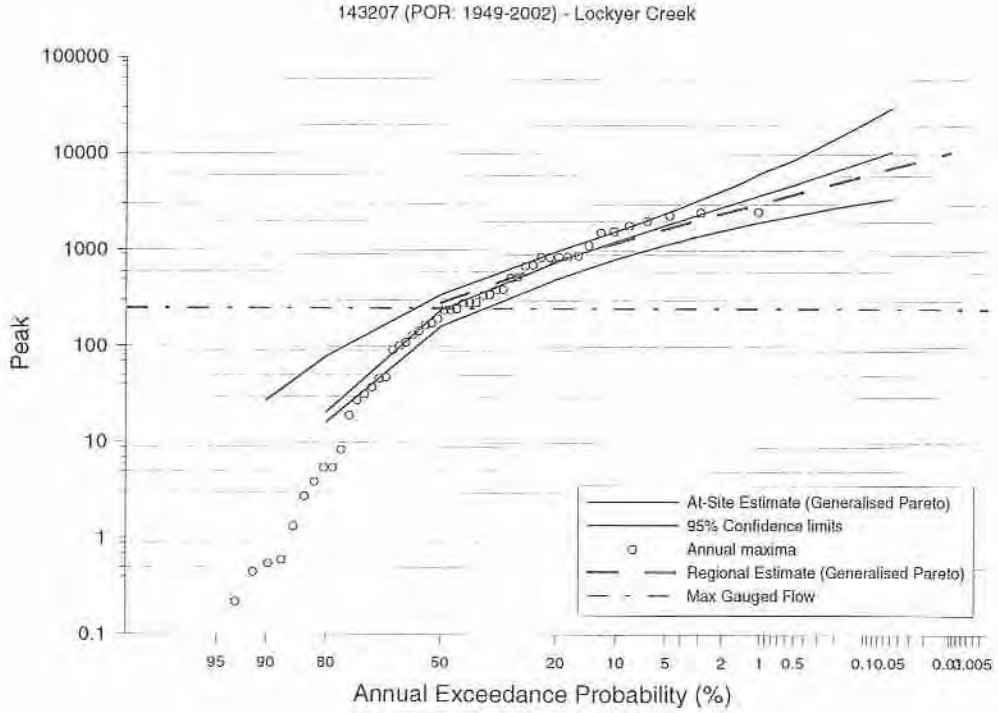


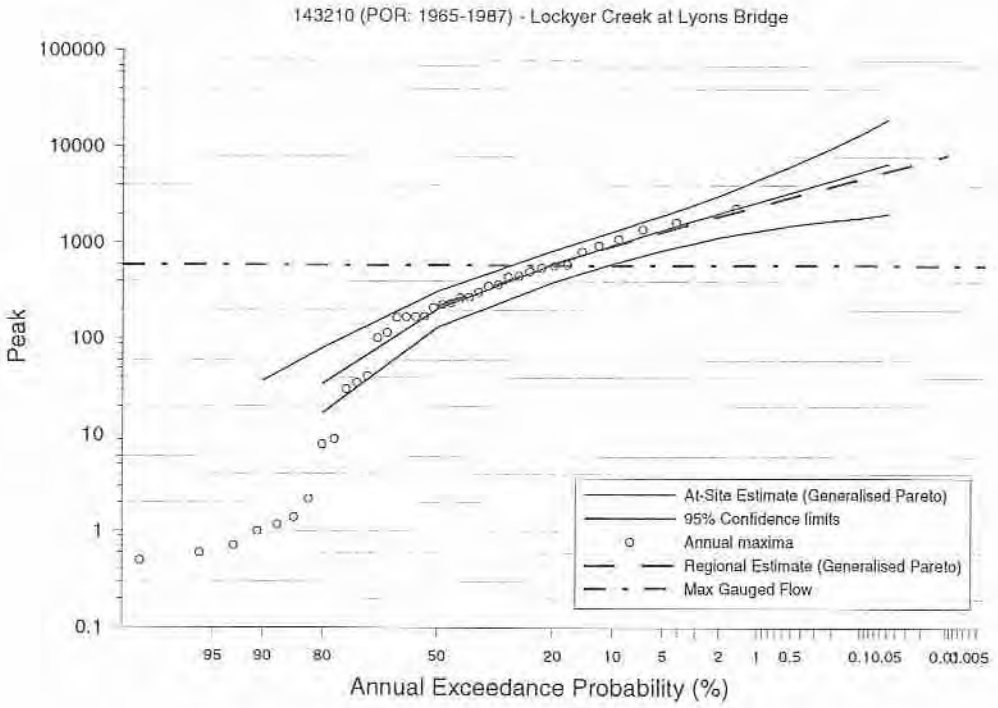
143107 (POR: 1962-2002) - Bremer River at Walloon

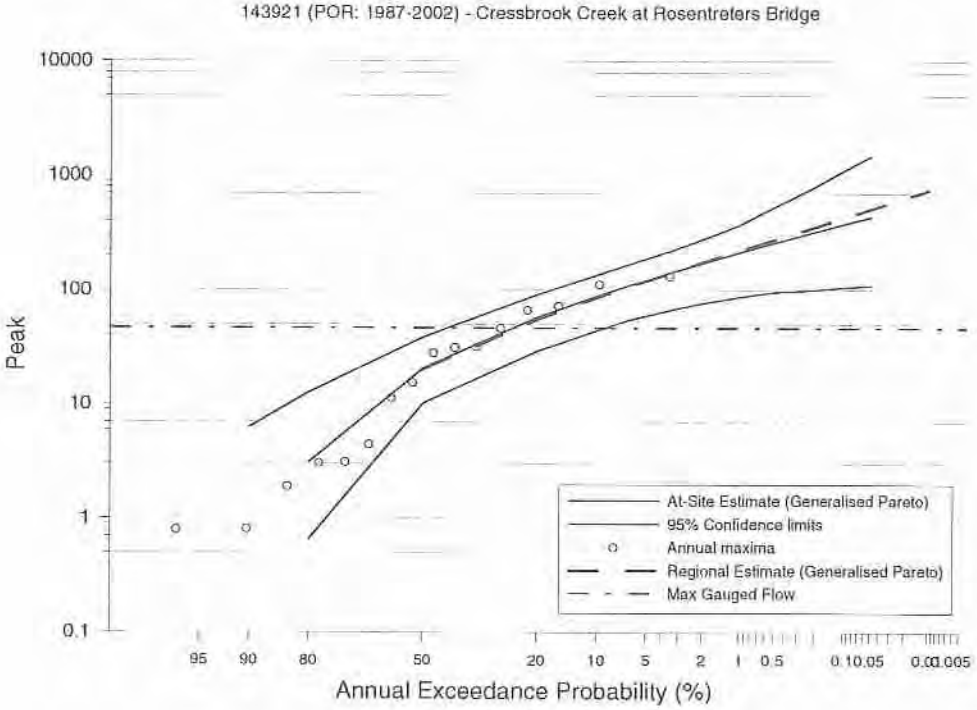



143108 (POR: 1962-2002) - Warrill Creek at Amberley
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143113 (POR: 1974-2002) - Purga Creek at Loamside
Peak
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow



Appendix F Historical Spatial Distributions

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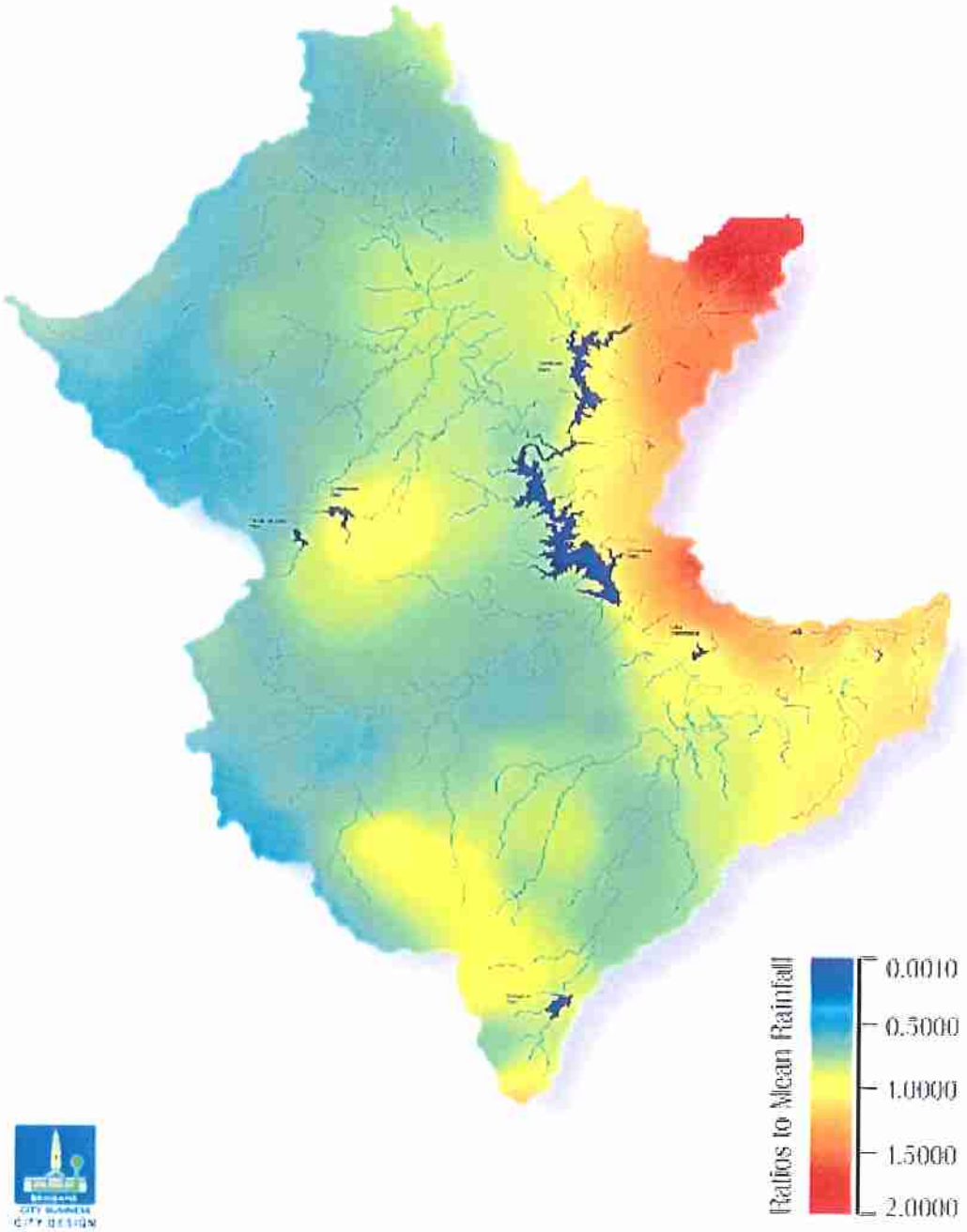
CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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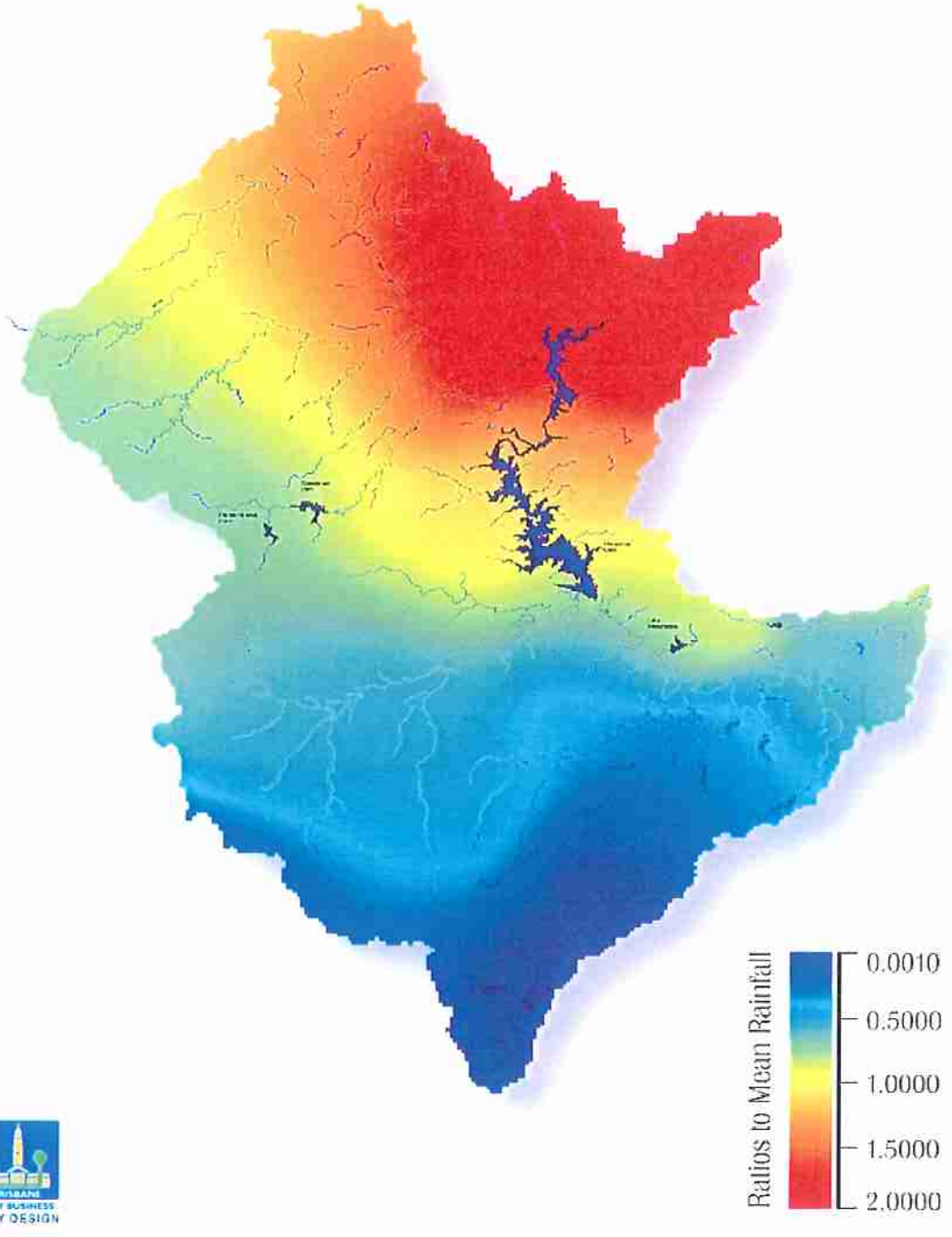
JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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SINCLAIR KNIGHT MERZ

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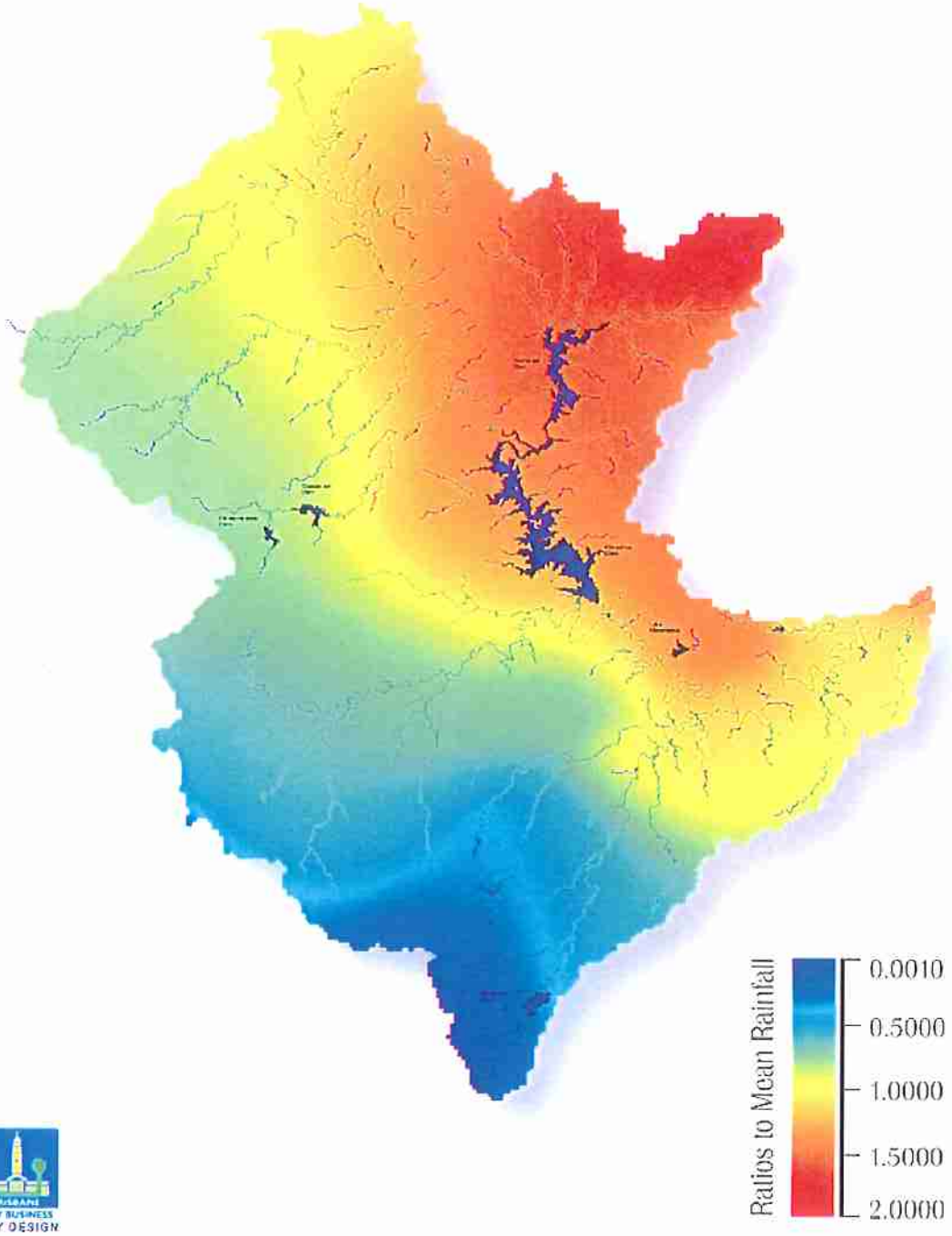
FEBRUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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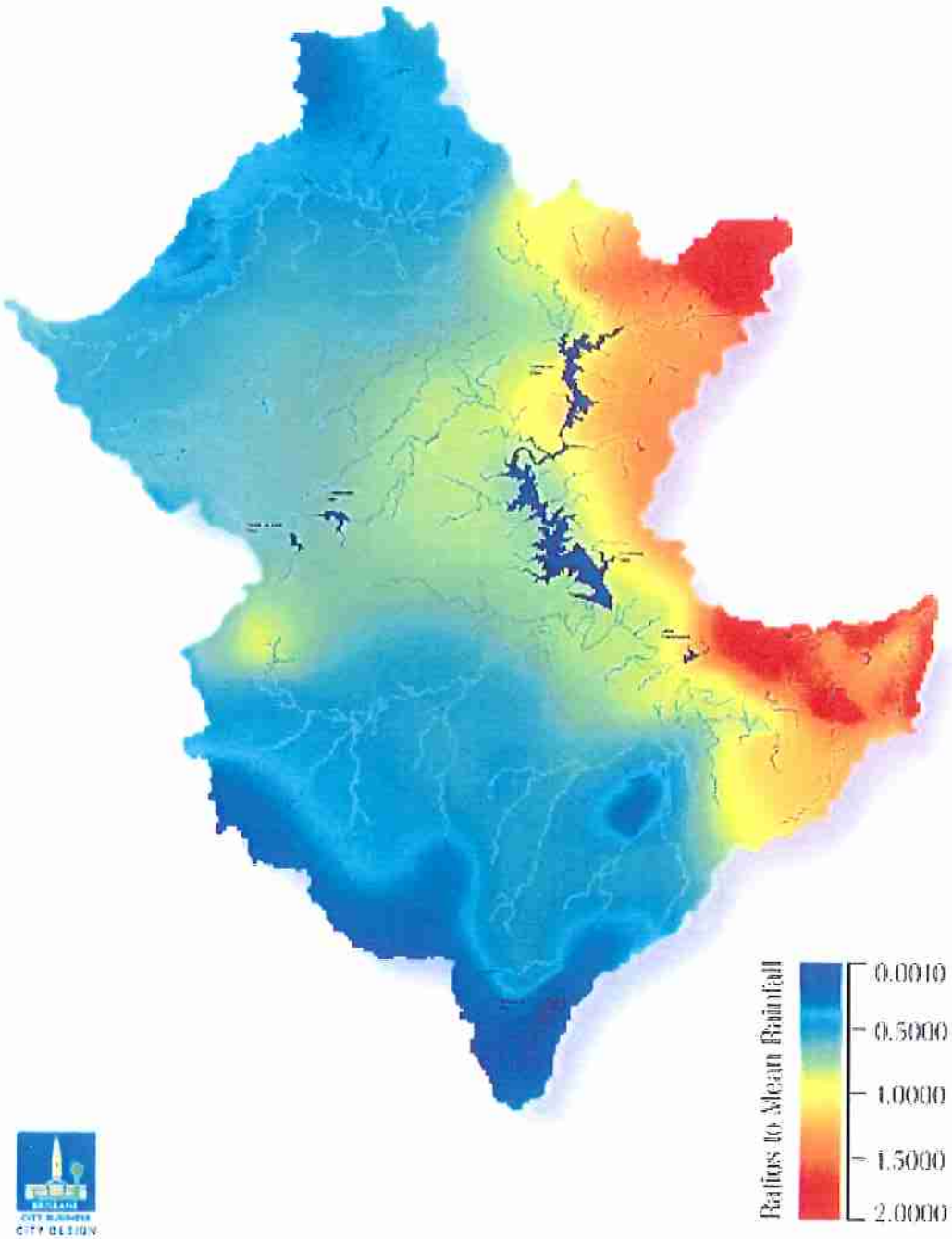
JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



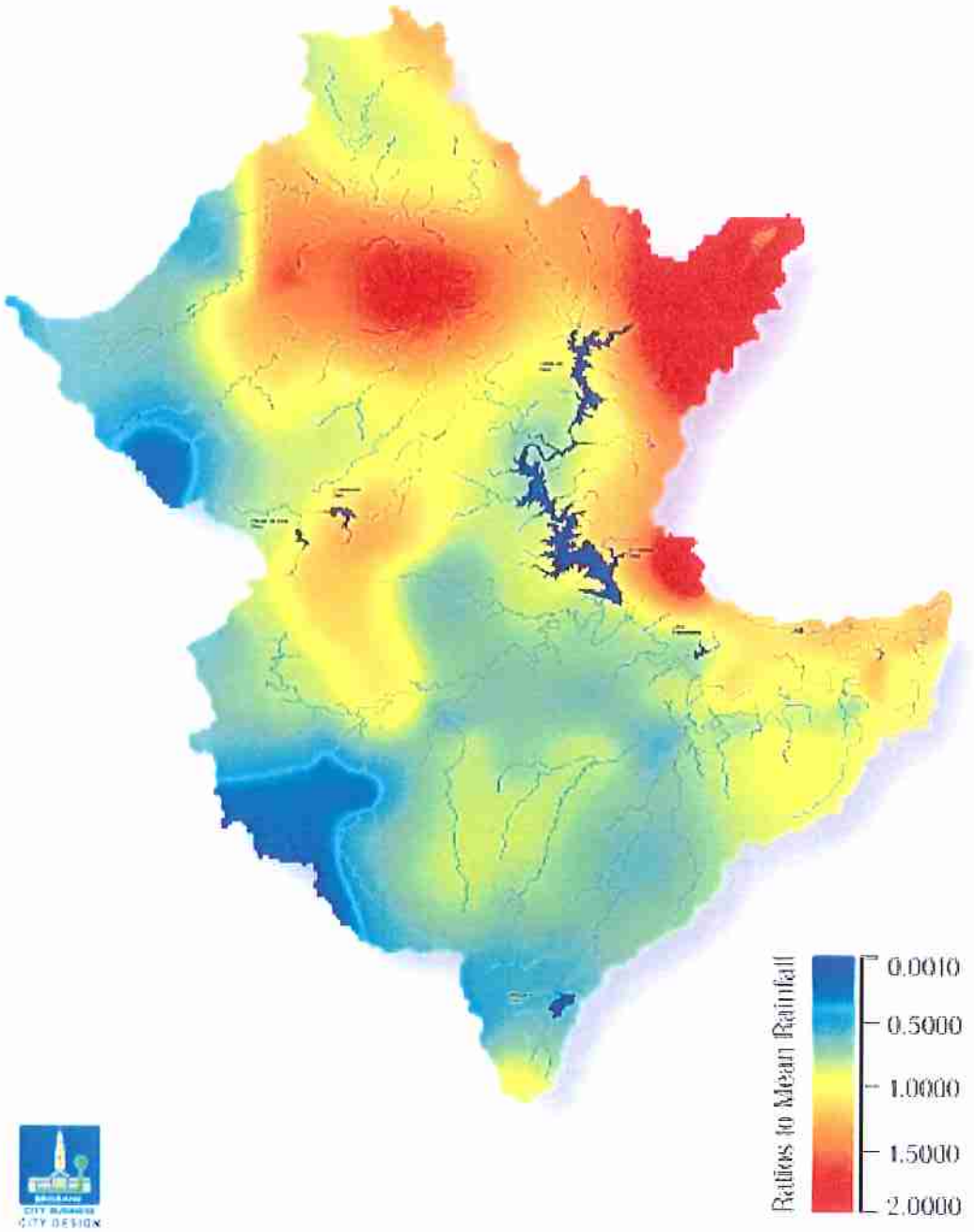
BRISBANE CITY COUNCIL CITY DESIGN

SINCLAIR KNIGHT MERZ

MARCH 1955 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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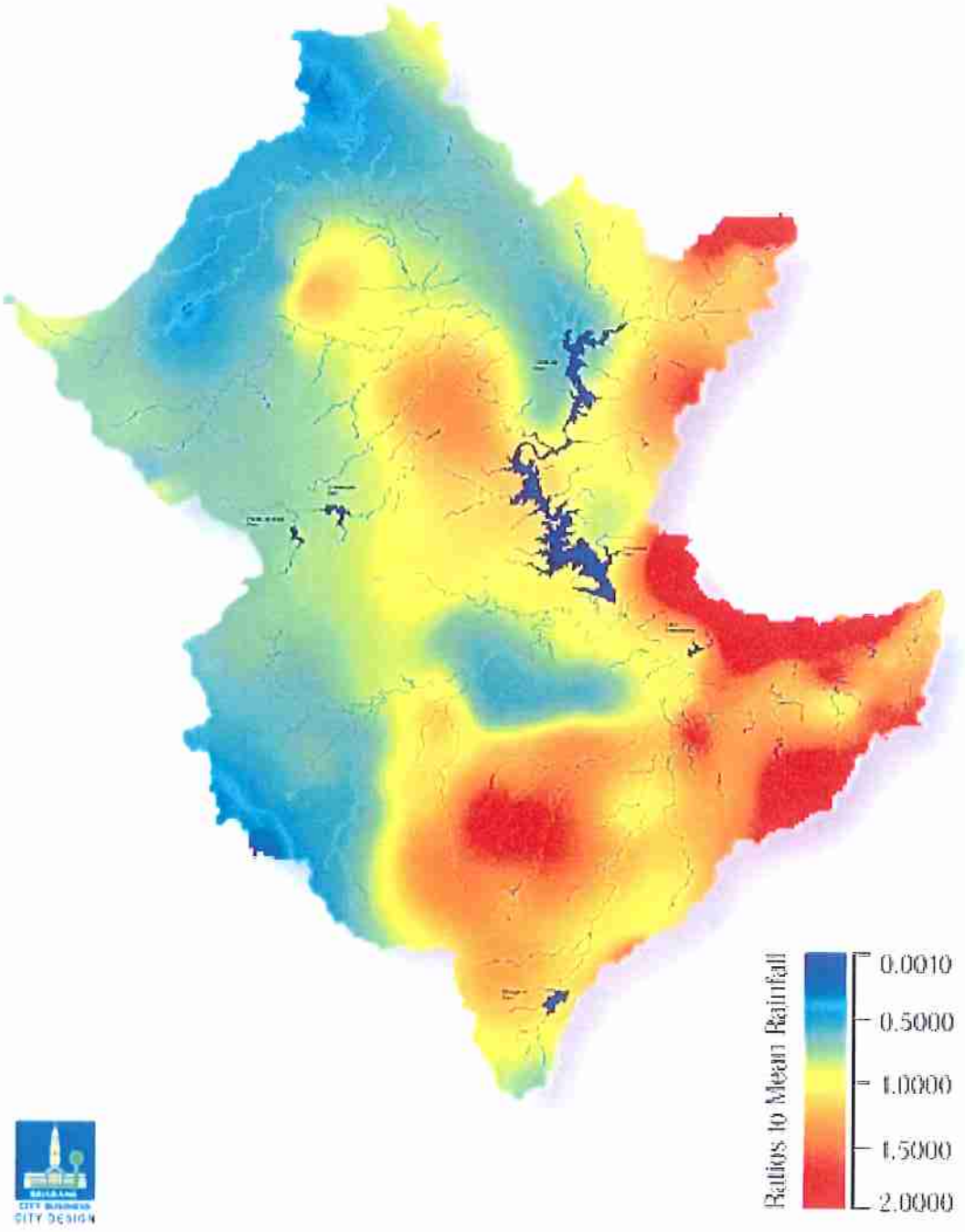
JANUARY 1974 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



BRISBANE CITY BUSINESS CITY DESIGN

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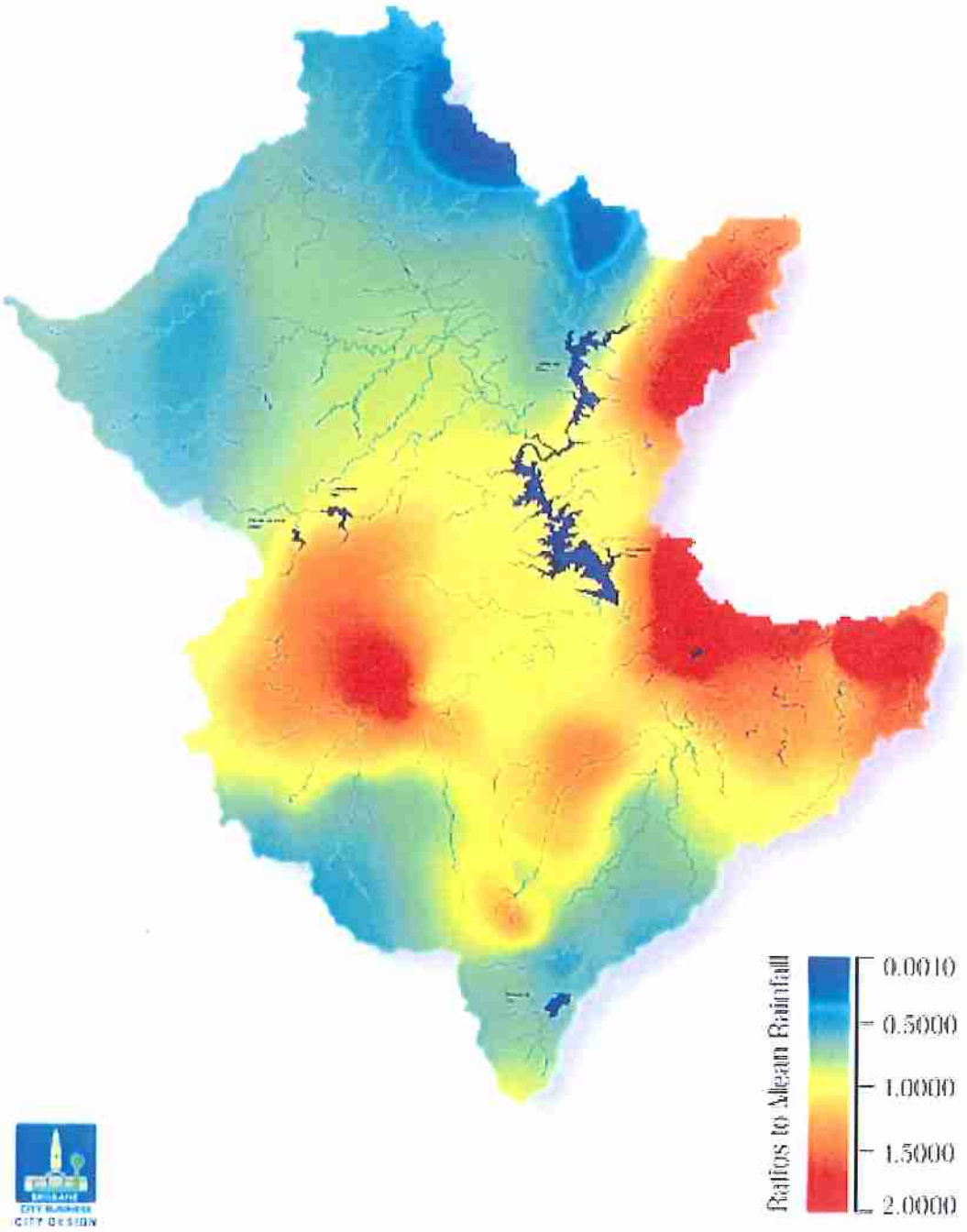
APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



BRISBANE CITY BUSINESS CITY DESIGN

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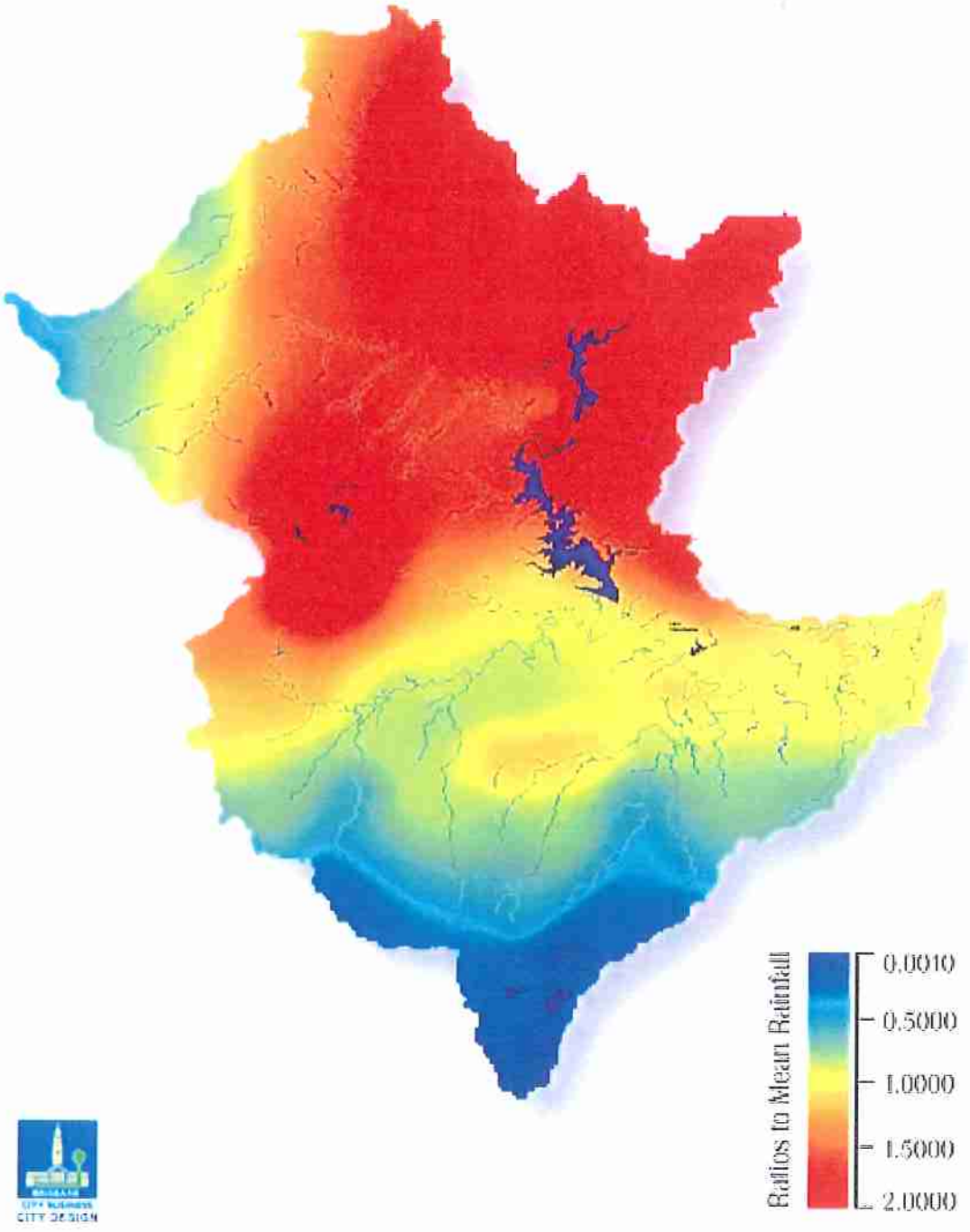
FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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Appendix G Pre- and Post-dams RAFTS Model Results

(8)

- ~~Q100~~ Peak Flows for RAFTS Model, Pre-Dams

Spatial Pattern from Event	Rainfall Event Duration(hours)	~~1 in 100 AEP~~ Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
JAN 1893	24	9861	7927	7927
	30	**11507**	9793	9792
	36	9810	7932	7932
	48	10238	8535	8534
	72	10911	**10198**	**10196**
	96	9774	9394	9392
	120	10074	9641	9639
FEB 1893	24	8698	7502	7502
	30	**10062**	8789	8788
	36	8682	7512	7512
	48	9012	7866	7865
	72	9634	**9504**	**9501**
	96	8568	8636	8632
	120	8804	8904	8898
JAN 1931	24	7505	6745	6745
	30	**8543**	7648	7648
	36	7476	6776	6775
	48	7712	7191	7190
	72	8183	**8030**	**8026**
	96	7140	7610	7514
	120	7360	7713	7630
MAR 1955	24	8671	7537	7536
	30	**10046**	8925	8925
	36	8689	7554	7553
	48	8955	7916	7915
	72	9563	**9623**	**9619**
	96	8376	8750	8745
	120	8635	9002	8997
JAN 1974	24	7058	7203	7202
	30	**8005**	8049	8046
	36	7049	7073	7072
	48	7227	7528	7527
	72	7714	**9117**	**9112**
	96	6729	8161	8154
	120	6879	8454	8432

for 1 in 100 AEP Rainfall

always go order in logical.

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(8)

Spatial Pattern from Event	Rainfall Event Duration(hours)	~~1 in 100 AEP~~ Peak Flow in m³/s for 1 in 100 AEP Rainfall		
		Savages Crossing	Port Office	Moggill
APR 1996	24	7531	7068	7067
	30	**8621**	7966	7966
	36	7549	7079	7078
	48	7748	7427	7425
	72	8287	**8922**	**8917**
	96	7184	8043	8034
	120	7399	8182	8170
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7894	7893
	48	9981	8444	8443
	72	10642	**10200**	**10197**
	96	9512	9387	9384
	120	9809	9629	9626

Note: Critical flows at each location are shown in **bold**.

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(8)

D100 Peak Flows for RAFTS Model, Post-Dams

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s for 1 in 100 AEP Rainfall		
		Savages Crossing	Port Office	Moggill
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7121**	**7120**
FEB 1893	24	1877	2070	2061
	30	3818	3449	3449
	36	1935	2211	2203
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5596	5595
	120	**6568**	**5851**	**5850**
JAN 1931	24	1872	2319	2051
	30	1926	3314	2708
	36	1884	2836	2452
	48	1758	2580	2382
	72	3079	3968	3146
	96	3170	3383	2940
	120	**3279**	**3411**	**3218**
MAR 1955	24	1925	2350	2345
	30	3524	3433	3433
	36	2063	2544	2541
	48	3272	3013	3013
	72	**6241**	**5710**	**5709**
	96	5926	5340	5339
	120	6151	5585	5584
JAN 1974	24	1753	3326	3324
	30	2467	3989	3987
	36	1871	3350	3279
	48	1943	3633	3627
	72	3307	4965	4418
	96	**4771**	**5852**	**5841**
	120	2911	3662	3656

Spatial Pattern from Event	Rainfall Event Duration(hours)	~~1 in 100 AEP~~ Peak Flow in m³/s for 1 in 100 AEP Rainfall		
		Savages Crossing	Port Office	Moggill
APR 1996	24	3554	3400	3399
	30	4067	4138	4137
	36	3535	3260	3260
	48	3605	3691	3690
	72	**4162**	**5035**	**5019**
	96	3492	4417	4378
	120	3509	4663	4571
FEB 1999	24	3424	2887	2886
	30	5789	4442	4442
	36	3575	3147	3150
	48	4604	3495	3494
	72	6879	6448	6447
	96	7217	6624	6623
	120	**7431**	**6819**	**6819**

Note: Critical flows at each location are shown in **bold**.

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Brisbane River Flood Study



FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Further Investigations
- Final
- 7 Oct 2003

DRAFT

Brisbane River Flood Study

FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Final
- 7 Oct 2003

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Document history and status

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Flood Frequency Draft B	22/08/2003	R. Nathan		22/08/2003	Major Update
Hydrological Modelling Draft A	22/08/2003	[redacted]	S. Abbey	22/08/2003	
Hydrological Modelling Draft B	29/08/2003		S. Abbey	29/08/2003	
Final	25/09/2003				Merge Two Reports and Finalise

Distribution of copies

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Flood Frequency Draft B	PDF	PDF	Barry Ball (Brisbane City Council)
Hydrological Modelling Draft A	Electronic	Electronic	Peter Barnes (Brisbane City Council)
Hydrological Modelling Draft B	Electronic	Electronic	Peter Barnes (Brisbane City Council)
Final			

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Executive Summary

An Expert Panel has been appointed to review the flood investigations undertaken for the Brisbane River. Sinclair Knight Merz was approached to assist the Expert Panel with their review. The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a "best" estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event.

The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

This technical report has been prepared for expert technical reviewers and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, hydrological terminology and abbreviations is generally assumed.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table E1.

Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100.
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty)
- choice of frequency distribution and the appropriate parameters; and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m³/s and 11 000 m³/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by



vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures;
- dam levels at the start of a flood event; and,
- spatial and temporal patterns of the storm.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment. ARFs were not available for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knight Merz 1998) was undertaken.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

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Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

Q100 estimate at the Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The information for the two historical flood events (1893 and 1974) were run through the RAFTS model for the pre and post-dam conditions. For post-dam conditions, the estimated peak flow at the Port Office for the 1893 and 1974 flood events were 9500 m^3/s and 6800 m^3/s respectively. It should be noted that the uncertainty of the historical data, 1893 in particular, is considerable.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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1. Introduction

1.1 Background

Sinclair Knight Merz prepared a flood study for the Brisbane River in 1998. Since this time, there have been changes to the information used in assessing the flood levels along the lower reaches of the Brisbane River. This includes:

- CRC-FORGE rainfall estimates that have been prepared for the Brisbane River catchment (Department of Natural Resources and Mines, 2003a) and
- Modifications to procedures for flood operations at Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, 1998) was completed.
- Additional and/or revised flood flow data

An Expert Panel has been appointed to review the flood studies undertaken for the Brisbane River in the light of this new information, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for Sinclair Knight Merz were to:

- Undertake flood frequency analysis, and to
- Update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The details of the tasks that were agreed to are presented in Appendix A.

1.2 Scope of Report

This report addresses the tasks presented in Appendix A, namely to,

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document the findings of the flood frequency analysis, stating assumptions and outcomes;
4) Review previous reports, CRC-FORGE rainfall estimates and historical streamflow data.
5) Undertake a Regional Flood Frequency Analysis (pre-dams).
6) Undertake hydrologic modelling (pre-dams).
7) Undertake hydrologic modelling (dams in place).

8) Analyse catchment sensitivity using various temporal patterns.
9) Undertake a check with historical flood events.
10) Perform hydraulic modelling to produce flood frequency estimates at Moggill and the Port Office.
11) Report on the findings of the rainfall-runoff and hydraulic modelling.

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2. Sources of Data for Flood Frequency Analysis

Gauging station data were obtained from the Department of Natural Resources and Mining (DNRM) and the Commonwealth Bureau of Meteorology (BoM). Different types of data were collected, including:

- recorded water elevation above the gauge datum,
- flow data estimated from a rating relationship and
- rating tables

In some instances the data had been processed in some additional manner, as discussed below.

A number of reports on large flood events and the analysis thereof have also been made available.

2.1 Department of Natural Resources and Mining Data

There are two sources of data from DNRM:

- Recorded water elevation data and associated flow estimates
- Estimates of "no dams" flood peaks at Savages Crossing that had been adjusted to exclude the influence of the dam(s) where appropriate.

Both data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in **Appendix B** (along with other sources of gauged data). The primary reasons for omission were:

- short record length,
- small catchment area, and/or
- uncertainty in the rating curve.

The latter reason included either very low gauged flow or the rating curve had been changed to a "calibration curve" for use in real time flood forecasting. It may be possible to include some of this flow data for future analysis when questions regarding the adjustment made to the calibration curves have been resolved.

Elevation data for a number of sites of direct interest to this study, such as Moggill, Brisbane City and the Port Office were also obtained.

Appendix C shows the location of the stream gauges that were used in the flood frequency analysis.

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3. Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (ie peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in Section 2.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- Adjustment of data for the influence of the dams
- Uncertainty in the rating curves that relate recorded river level to flow rate
- The magnitude of historic data (especially 1893 and 1825)
- The period of record associated with the historic data
- Choice of frequency distribution
- Selection of parameters for the distribution
- Method of including historical data

DNRM provided a series of data (1890 – 2000) that was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had existed over the entire period. Frequency analysis of this data was undertaken along with various unadjusted data.

The frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by Assoc Prof George Kuczera in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix D**.

The analyses undertaken to determine the "best" estimate from flood frequency analysis and a plausible range is summarised in Table 3.1. FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets an Sinclair Knight Merz program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte-Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

The results of these analyses are recorded with selected frequency distributions in Sections 3.3 - 3.6 and the results summarised in Table 3.7. As noted previously, this report has been prepared for expert reviewers with a high level of understanding. The explanations, comments and discussion are as concise as possible to enable the broad range of analyses to be succinctly presented for ease of comparison.

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Table 3.1 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distribn	Prior Informn (regional)	Main Objective
Case 1 Pre -Wivenhoe and Somerset							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

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Case 2 **Pre Wivenhoe, no adjustments made for Somerset**							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3 **"No Dams" based on DNRM adjusted estimates**							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by DNRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4 **"Dams" based on DNRM estimates**							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

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3.2 Regional Frequency Analysis

A regional frequency analysis was conducted to assist in the estimation of flood frequency at Savages Creek (GS143001). The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane River catchment, including the site at Savages Crossing (GS143001). The Generalised Pareto probability distribution was selected for the flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value;
- its prior standard deviation; and,
- its correlation with other parameters.

The prior mean and standard deviation of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in Table 3.2.

Table 3.2 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001).

Value	Scale parameter, α	Shape parameter, κ
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

Greater detail of the regional analyses is provided in Appendix D.

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3.3 Case 1: Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the DNRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in Table 3.3 with specific influence on curves plotted in Figures 3.1 – 3.3 so that the influence of specific assumptions can be compared graphically.

Table 3.3 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1C	1909-1951	1893 (Qp= 13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post-Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825 (Qp= 13200) 1893 (Qp= 13 200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp= 14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1G	1909-1951	1893 (Qp= 12 000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp= 13 000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.

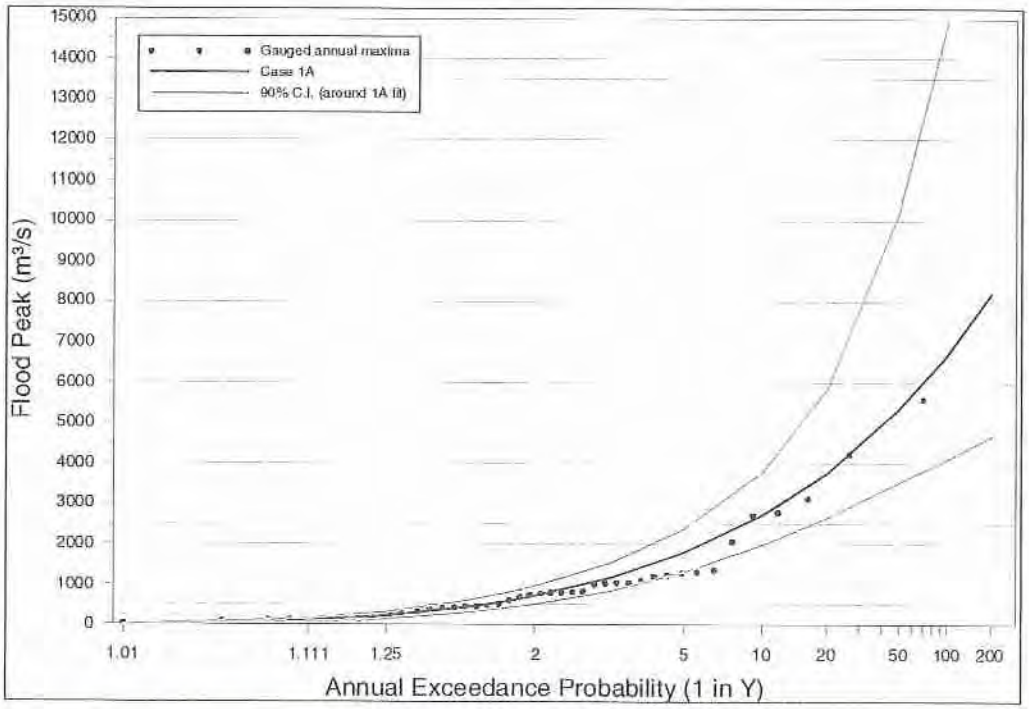

Figure 3.1 Generalised Pareto Distribution fitted to the 1909-1951 pre-dams data at Savages Crossing.

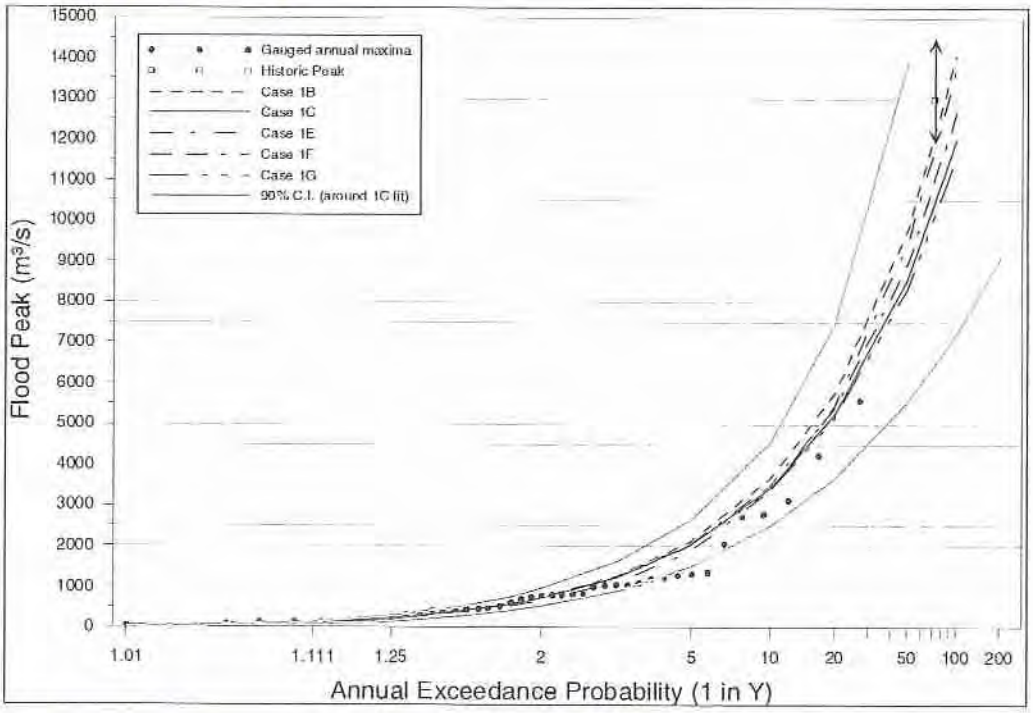

Figure 3.2 Comparisons of variations in flood frequency for various assumptions on pre-dams data for Savages Crossing.

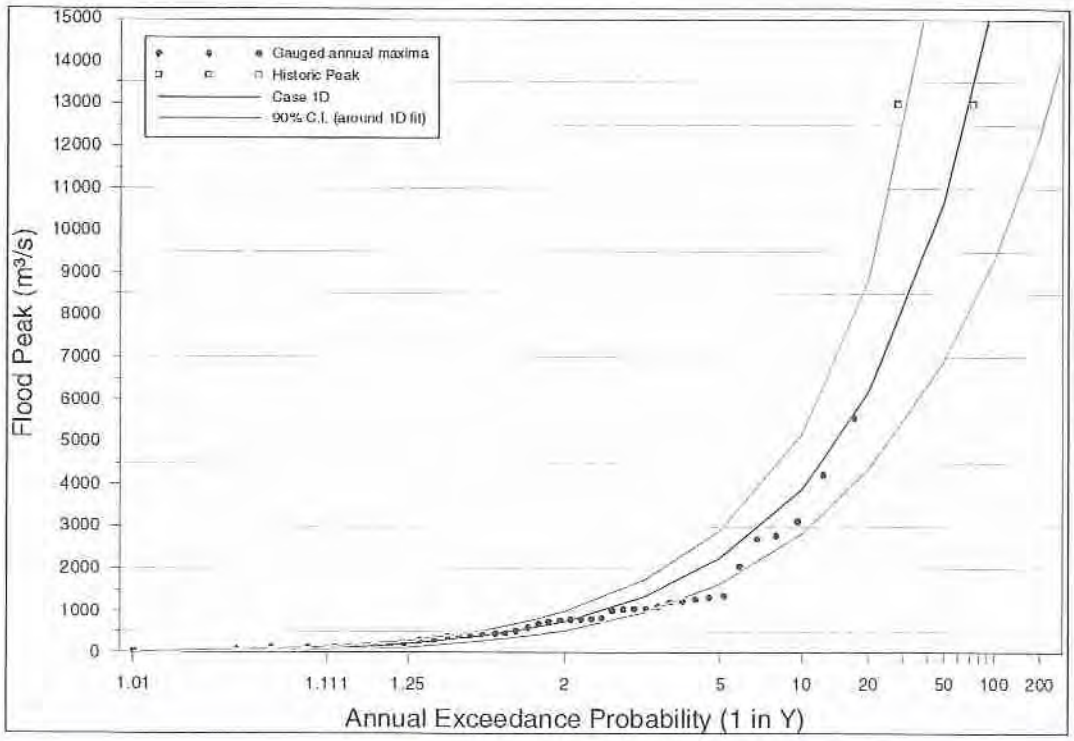

Figure 3.3 Assessment of the inclusion of a 1925 estimate of a flood possibly of the same magnitude as the 1893 event.

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3.4 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

Table 3.4 Summary of Case 1 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

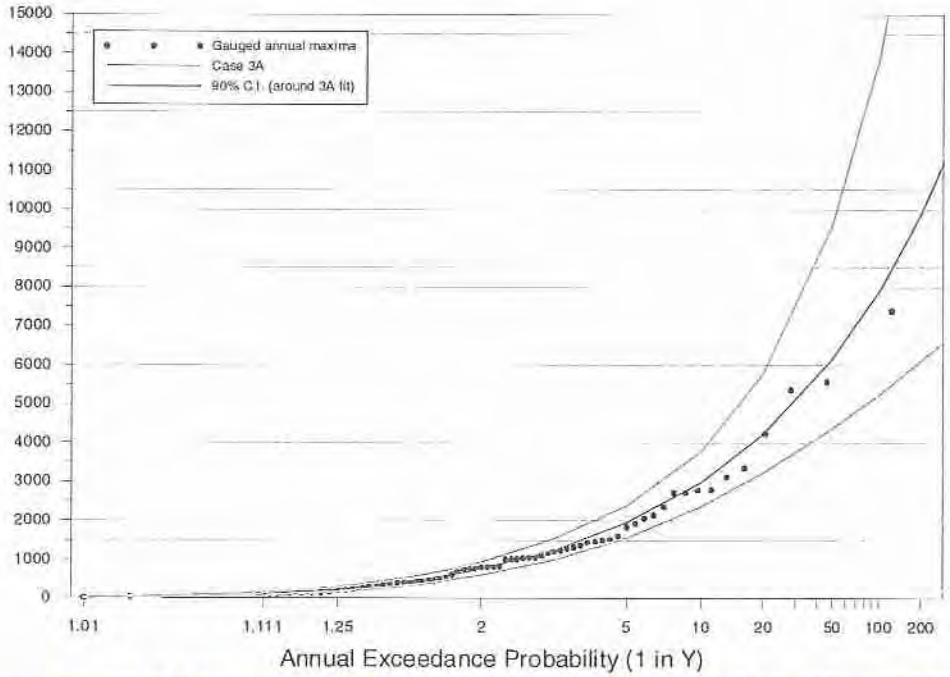

Figure 3.4 Assessment of the pre-Wivenhoe gauged data without 1893 event.

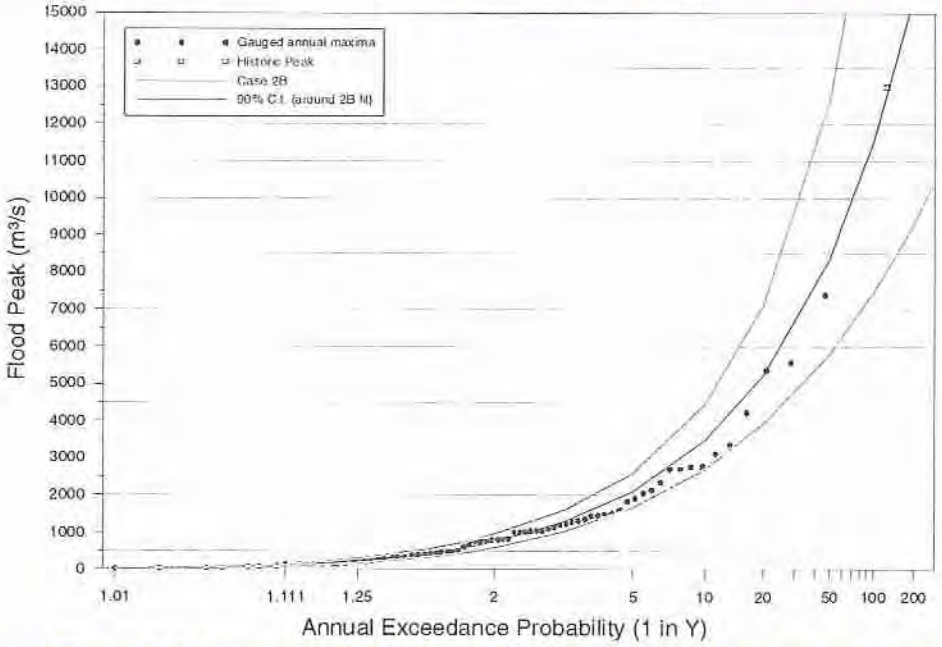

Figure 3.5 Assessment of the pre-Wivenhoe gauged data with 1893 event..

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3.5 Case 3: Analysis of "No Dams" Data Estimated by DNRM

Note effect of Somerset dam is highly variable depending on its operation. DNRM has indicated that they have spent significant resources assessing the effect of Somerset on the flood series. The data series has been provided without documentation as to the method used to adjust the data. Sinclair Knight Merz has taken this series and analysed the statistics without investigation of its derivation.

Table 3.5 Summary of Case 3 flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.

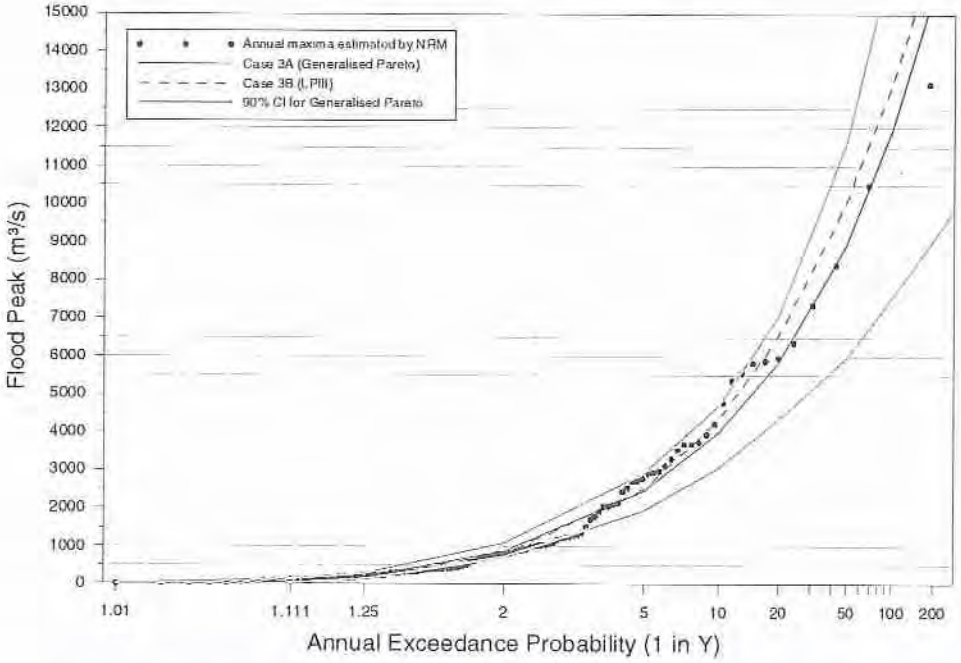

Figure 3.6 Assessment of the "no –dams" annual maxima series provided by DNRM using both GP and LPIII distributions.

3.6 Case 4: Analysis of Post-Dam Data Estimated by DNRM

These analyses were based on "post-dam" data set provided by DNRM. As with the analyses reported in Section 3.4, no assessment of the manner in which this data set was derived was undertaken.

Table 3.6 Summary of Case 4: Post-dam Data - flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

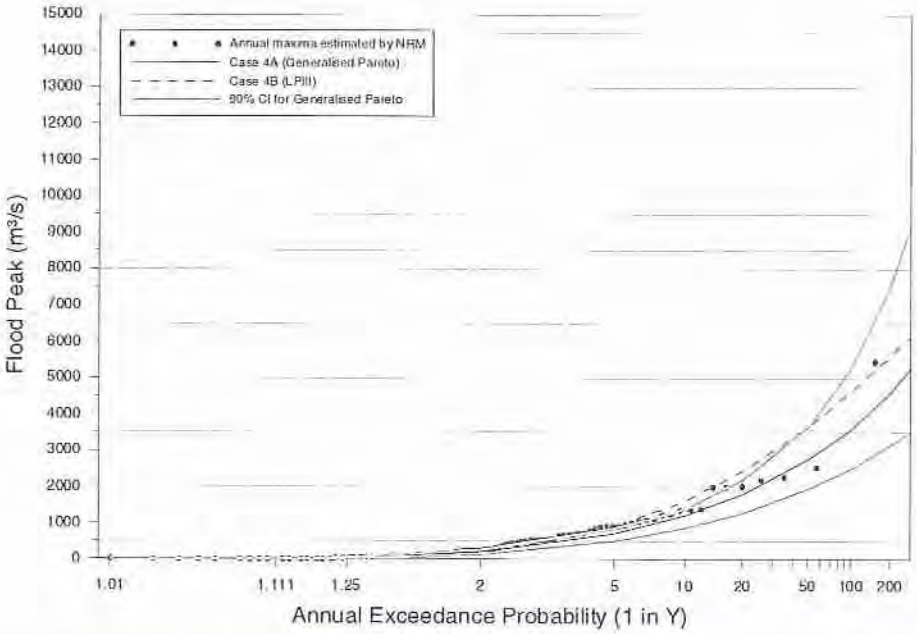

Figure 3.7 Assessment of the "post-dams" annual maxima series provided by DNRM using both GP and LPIII distributions.

3.7 Summary of analysis results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) estimate at Savages Crossing. The analyses are summarised in Table 3.7. As noted above, the summary is intended to succinctly present the broad range of sensitivity analyses for expert reviewers who are familiar with the concepts, common discipline abbreviations and analysis methods.

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Table 3.7 Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 **Pre -Wivenhoe and Somerset**								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from P Baddiley "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from P Baddiley URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.

Table 3.7cont. Summary of flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

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3.8 Best Estimates from flood frequency assessment

Sinclair Knight Merz has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling reported in the subsequent chapters). The results are presented in Table 3.8.

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), DNRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m³/s); as no allowance made for Somerset dam, the Q100 could be expected to be higher than 11 500m³/s.
- the "No dams" series from DNRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3A).

Table 3.8 Most plausible estimates of the Q100 peak flow at Savages Crossing.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),
- choice of distribution and the appropriate parameters; and

- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500m³/s and 11 000m³/s.

An additional assessment of the "current" scenario, ie with Somerset and Wivenhoe dams present and operated using current operating procedures is also provided (Case 4 – above). This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by DNRM. Note that no assessment of the plausible range for this estimate is possible, as the method for adjusting the data series is not currently available.

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4. Rainfall-Runoff Modelling

Rainfall-runoff modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS rainfall-runoff model developed for the Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) was used for this investigation. The Ipswich River Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model.

4.1 Assumptions

- The Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM, 2003) Wivenhoe and Somerset Dam Operations Model was used to determine Dam outflows.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows.

- Initial Loss Rate (IL) = 10 mm
- Continuing Loss (CL) = 1.0 mm/h
- All model runs were undertaken for the 1 in 100 (1%) AEP flood event only.

4.2 Methodology

The following Methodology describes the process that was used to determine 1 in 100 AEP flood flows at Moggill and the Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model
- Input CRC-FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1% AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the DNRM Dam Operations Model.
- The DNRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the DNRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1% AEP flows at Moggill and the Port Office Gauge.

- A sensitivity analysis was then performed to using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wivenhoe and Somerset Dams at the start of the flood event.

4.3 Pre-dams RAFTS Modelling

The object of the pre-dams modelling was to achieve reconciliation between the Flood Frequency Estimates and the flow estimates produced by RAFTS. CRC-FORGE rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine affects that temporal patterns have on peak flows.

4.3.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

CRC-FORGE Rainfall Estimates for varying duration's were input into the model with Areal Reduction Factors (ARF) applied (Department of Natural Resources and Mines, 2003a). Table 4.1 presents the rainfalls and ARF's used.

- Table 4.1 CRC-FORGE Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC-FORGE Rainfall	247	268	285	317	358	385	402
CRC-FORGE Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC-FORGE rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in Appendix F. Standard Temporal Patterns were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/hr was adopted.

The CRC-FORGE rainfall estimates with ARF's applied are presented in Table 4.2.

- Table 4.2 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Pre-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: **- Bold values indicate the critical duration at each location**
- Flows at Moggill and Port Office should be considered indicative only.

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4.3.2 Sensitivity to Spatial Pattern of Rainfall

To determine the impact of spatial patterns, seven historical spatial patterns were assessed. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC-FORGE Rainfall Depths (ARF applied) for each duration. (3)

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane River and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane River Catchment.
- April 1996 - high rainfalls in the Lockyer and Lower Brisbane River Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in Appendix F.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/h was applied.

Peak flows are presented in Table 4.3.Note that for all spatial distributions the 30 hour flood is the critical duration storm at Savages Crossing and the 72 hour flood is the critical duration at Moggill and Port Office. Flows presented at Moggill and the Port Office in Table 4.3 should be considered indicative only. More reliable estimates of design floods at the lower gauges are produced by the hydraulic model, as discussed in **Chapter 5**.

Table 4.3 Pre- dams 1% AEP Peak Flows for Historical Spatial Distributions.

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: - Bold values indicate the median flow at each location
- Flows at Moggill and Port Office should be considered indicative only.

A full listing of peak discharges at Savages Crossing, Moggill and Port Office are present in Appendix G.

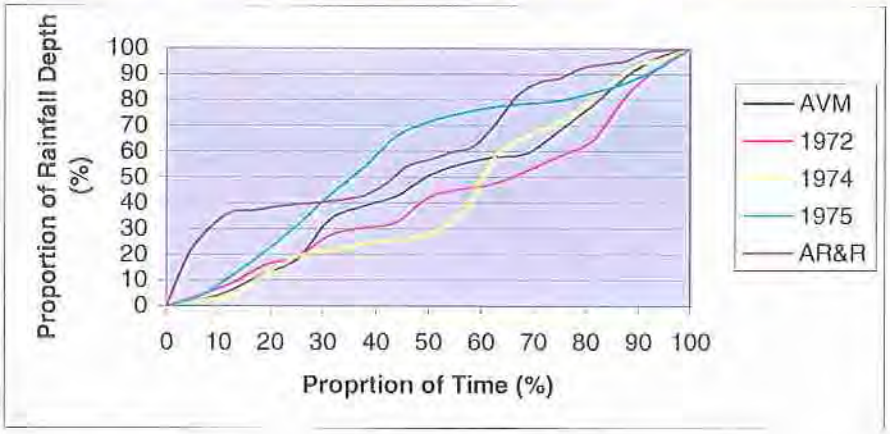
4.3.3 Sensitivity to Temporal Pattern of Rainfall

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC-FORGE Rainfall 48 hour storm duration. An I_L of 0 mm and a C_L of 0 mm/hr was applied.

The temporal patterns that were used in the sensitivity analysis were:

- AVM – Average Variability Method
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event.
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event.
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event.
- AR&R 1987 – Standard temporal pattern outlined in Australian Rainfall and Runoff.

Figure 4.1 Temporal Patterns for the 1% AEP 48 Hour Storm Event



The resulting peak flow estimates using the temporal patterns described above are presented in Table 4.5

Table 4.4 48 Hour Temporal Pattern Sensitivity

	48 hour Temporal Pattern				
Location	AR&R	AVM	1972	1974	1975
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Port Office	12817	13464	13287	14115	13634

4.3.4 Discussion

Table 4.3 and Table 4.4 show that spatial and temporal patterns have a significant affect on peak flows. Given the size of the catchment and the variability that spatial and temporal patterns have on peak flows, it is evident that a Monte-Carlo analysis would be appropriate. A Monte-Carlo analysis was not possible within specified time frame for this report and therefore the sensitivity analyses was undertaken to investigate potential effects of this phenomenon.

The pre-dams historical spatial distributions produce peak flows at Savages Crossing that range from 11500 m^3/s to 8000 m^3/s with the median peak flow being 10046 m^3/s. The estimated peak flow at savages using the CRC-FORGE Spatial Pattern was estimated to be 9607 m^3/s.

If an IL of 0 mm and CL of 0 mm/h is applied to the CRC-FORGE 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11278 m^3/s. It should be noted that the 'best estimate' of peak flow at Savages Crossing from the Flood Frequency Analysis was estimated to be 12000 m^3/s. This means that the RAFTS peak flow



estimates and the FFA estimates cannot be reconciled unless further work is undertaken on the manner in which the various flood-producing factors can be combined.

4.4 Comparison of Q100 estimates from flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated RAFTS model
- CRC-FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

produced a Q100 at Savages Crossing of 11278 m³/s. It would be reasonable to expect some losses with a 1 in 100 AEP event and hence the hydrological modelling results, using typical design parameters, could be expected to be lower, say in the order of 10, 500m³/s.

The difference between the results and those from the statistical frequency analysis of flood records (Chapter 3) indicates that there are underlying factors that have not been adequately addressed to date. This would require more detailed assessment than is available in the scope and timing of the current assessment. Potential factors influencing the difference in Q100 estimates include:

- potential for partial area storms
- variation in temporal patterns
- variation in spatial patterns
- variation in losses
- adjustment of data for influence of dams
- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.

The development of a Monte-Carlo framework for analysing the factors affecting flood magnitude would enable the natural variation in the first four factors to be explicitly modelled. This would give insights necessary to resolve the discrepancy between the two independent sources of the Q100 estimate.

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4.5 Post-dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and run through the DNRM Dam Operations Model (Department of Natural Resources and Mines, 2003b). These inflows were based on the outputs presented in Appendix G and included an IL of 10 mm and CL of 1.0 mm/hour.

The outflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the hydrograph volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC-FORGE and historical spatial patterns to determine flows at Savages Crossing, Moggill and Port Office.

4.5.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

The parameters described in Section 4.3.1 were used for the Post-dams RAFTS modelling.

The CRC-FORGE rainfall estimates with ARF's applied are presented in Table 4.5.

Table 4.5 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1% AEP Flood – Post-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	**5368**	2335	2502
Moggill	3017	3690	2999	3302	**5043**	3811	3990
Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Port Office should be considered indicative only.

4.5.2 Sensitivity to Spatial Pattern of Rainfall

The parameters described in Section 4.3.2 were used for the Post-dams RAFTS modelling. Peak flows are presented in Table 4.6. Note that the critical duration storm at Savages Crossing, Moggill and Port Office range from 72 to 120 hours for Post-dam Conditions. Flows presented at Moggill and the Port Office in Table 4.6 should be considered indicative only. More accurate flows will be determined during the hydraulic modelling.

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Table 4.6 Post-dams 1% AEP Peak Flows for Historical Spatial Distributions

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: **- (120hr) denotes the critical storm duration**
- Bold values indicate the median flow at each location
-Flows at Moggill and Port Office should be considered indicative only.

4.5.3 Sensitivity to Starting Water Level in Wivenhoe Dam

Full supply level of Wivenhoe Dam is at RL 67.0 m AHD and has a storage capacity of 1165×10^6 m^3 of storage. The crest level of Wivenhoe Dam is at RL 79 m AHD with a corresponding storage capacity of 2934×10^6 m^3. The maximum flood mitigation volume of Wivenhoe Dam is 1769×10^6 m^3.

It is unlikely that Dam Owners would choose to utilise the full volume of flood as Wivenhoe Dam is an earth fill dam they would be unwilling to risk overtopping of the dam that could lead to dam failure.

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1% AEP flood (average CRC-FORGE rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in Table 4.7

Table 4.7 Flood Runoff Volumes for the 1% AEP above Wivenhoe Dam

Storm Duration (hours)	CRC Rainfall Depth with ARF Applied (mm)	Runoff Volume ($m^3 \times 10^6$)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

Table 4.7 shows that if Wivenhoe Dam is at FSL, the 1% AEP 36-hour flood runoff volume can be fully stored between FSL and Crest Level without release. For 1% AEP events with longer

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durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the crest level is over, topped (no releases).

Given current operational procedure, it is unlikely that no releases would occur during a flood event, particularly if Wivenhoe Dam is at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs have been done for the 1% AEP 72 hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in Table 4.8.

Table 4.8 Dam Starting Water Levels Sensitivity Analysis for the 1% AEP 72 Hour Storm (6)

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Port Office	5044	4402	4402

Note: - Flows at Moggill and Port Office should be considered indicative only.

Table 4.9 shows that the reduction in flow is approximately 13% at the Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

4.5.4 1893 and 1974 Historical Flood Events

The information from the two historical flood events (1893 and 1974) were run through the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post-dam flows are presented in Table 4.10.

Table 4.10 Predicted Post-dam Flows for the 1893 and 1974 Historical Flood Events

	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
Location	No Dams (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)	Somerset in Place (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Port Office	13869	9519	9874	6801

Table 4.10 indicates that the peak flows for the historical events at the Port Office are above the 1 in 100 AEP CRC-FORGE estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1974 peak flow estimate and even more with the 1893 event. However, it is clear that the effect of the dams on events of such magnitude can be significant.

4.5.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. This again indicates that Monte-Carlo analysis would be an appropriate way to investigate the complex interactions between dams and variations in losses, spatial and temporal patterns to obtain the best estimate of the 1%AEP flood event.

The CRC-FORGE spatially distributed peak flow at Savages Crossing was estimated to be 5368 m^3/s for the post-dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow being 6241 m^3/s.

Based on the preceding investigations, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate. Given the current information, the 'best estimate' of peak flow at the Port Office would be 6500 m^3/s with an upper and lower limit of 8000 m^3/s and 5000 m^3/s respectively.

It is recommended that Monte-Carlo analysis be undertaken as there many uncertainties associated with the above best estimate.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flow estimates are:

- inclusion of the lower CRC-FORGE rainfall depths with areal reduction factors (ARF's were not available for catchments of this size in 1998),
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures (the previous study (Sinclair Knight Merz 1998), assumed emergency operating procedures which minimised the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River),
- In the 1998 study, the emphasis was to match Flood Frequency Estimates at Moggill and the Port Office. The reliability of the streamflow at Moggill and Port Office is questionable as these gauges are height read gauges and tidal effects are difficult to account for at these locations. After discussions with DNRM, who have just developed a new composite flood series at Savages Crossing, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and flood frequency estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing, as discussed in Chapter 3.
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that rainfall-runoff modelling be undertaken in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.

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5. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Port Office is good, other sections of the reach within Brisbane City has not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

5.1 Assumptions

- Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane River Bar.

5.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from approximately 10km downstream of Savages Crossing to the Brisbane River Bar. The model also includes Bremer River and other smaller tributaries which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1% AEP spatially distributed over the catchment. Duration's ranging from 24 to 120 hours were assessed.

5.3 Results

The peak Discharges and Flood Levels for at Moggill and Port Office are presented in **Table 5.1 1% AEP Peak Flood Levels and Flows for the CRC-FORGE Spatial Distributed Rainfall.**

- Table 5.1 1% AEP Peak Flood Levels and Flows for the CRC-FORGE Spatial Distributed Rainfall

	Moggill		Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

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5.4 Discussion

Table 4.5 and Table 5.1 show that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Port Office.

Using the 'best estimate and upper and lower limits of peak flows at the Port Office presented in Section 4.5.5, a rating curve was used to predict flood levels at the Port Office for the 1%AEP flood event. Peak flood levels and corresponding flows are presented in Table 5.2.

Table 5.2 Peak Flood Level and Peak Flow Estimates for the 1%AEP Flood Event at Port Office.

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

Note that these estimates should be considered indicative because the actual tide level may vary for an actual flood event. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918) at the Brisbane River Bar.

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6. Conclusions

Detailed investigations have been undertaken to assist the Expert Review Panel to assess the likelihood of floods in the lower reaches of the Brisbane River. The assistance has been centred on the two tasks of

- undertaking statistical flood frequency analysis, and
- updating the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table E1.

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Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the significant sources of uncertainty in the recorded data, length of record, choice of distribution and adjustment of the data for the effect of the dams. As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m^3/s and 11 000 m^3/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment. ARFs were not available for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knight Merz 1998) was undertaken.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8000 m^3/s and 11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3000 m^3/s to 8000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12000 m^3/s and 13800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1% AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing was estimated to be 5400 m^3/s. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing was reduced to 3500 m^3/s.

Q100 estimate at the Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to

account for routing effects from Savages Crossing to the Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Port Office. Table E2 provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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7. References

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane *River* flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the Flood Frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the Flood Frequency Analysis Outcomes.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC-FORGE Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 1 in 100 AEP event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the DNRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine the 1 in 100 AEP flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQB and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of sophistication



appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.



Appendix B Flow Gauging Stations Omitted from Consideration

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143222A	Atkinson Dam	Atkinson Creek Outlet		20	Small catchment area, offstream storage	DNRM
143234A	Atkinson Dam Hea			6	Small catchment area, offstream storage	DNRM
143228A	Bill Gunn Dam	Lake Dyer	3	18	Catchment area too small	DNRM
143027A	Blunder Creek	King Avenue Bridge	31	8	Urban creek in Brisbane area, Small catchment	DNRM
2121	Blunder Creek	King Ave- Durack		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1594	Breakfast Creek	Opposite Newstead House		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1579	Breakfast Creek	Sedgley Park Retention Basin- New Market		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1525	Breakfast Creek	Opposite Mann Park- Bowen Hills		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143104B	Bremer River	Rosevale	67	21	Catchment area too small	DNRM
143104A	Bremer River	Rosevale	77	34	Catchment area too small	DNRM
143110A	Bremer River	Adams Bridge	125	35	Catchment area too small	DNRM
143940	Bremer River	Stokes Crossing	180	21	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143909	Bremer River	Rosewood	543		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143833	Bremer River	Rosewood Alert	543	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143908	Bremer River	Rosewood TM	543	25	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143934	Bremer River	Walloon Bvrt	585		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143805	Bremer River	Walloon Alert-P	585	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143911	Bremer River	Ipswich	1850		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143956	Bremer River	Three Mile Bridge Alert	1870		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143954	Bremer River	Ipswich Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143953	Bremer River	One Mile Bridge Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143852	Bremer River	Brassall(Hancocks Br) Al		5	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143115A	Bremer River	Berry's Lagoon		9	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143944	Brisbane River	Linville	2005	47	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143007A	Brisbane River	Linville	2009	39	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143831	Brisbane River	Devon Hills Alert	2160	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143922	Brisbane River	Devon Hills Bvrt	2190		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143002A	Brisbane River	Plainlands	3950	12	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143002B	Brisbane River	Fulham Vale	3950	34	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143005A	Brisbane River	Watts Bridge	4602	20	Record length too short	DNRM
143008A	Brisbane River	Middle Creek	6704	20	Record length too short	DNRM
143026A	Brisbane River	Wivenhoe	7023	3	Record length too short	DNRM
143036A	Brisbane River	Wivenhoe Headwater	7023	17	Record length too short	DNRM
143035A	Brisbane River	Wivenhoe Tailwater	7023	17	Record length too short	DNRM
143907	Brisbane River	Lowood	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143941	Brisbane River	Lowood Bvrt	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143827	Brisbane River	Lowood Alert-P	10062	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143916	Brisbane River	Mt Crosby	10600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143839	Brisbane River	Mt Crosby Alert	10600	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143925	Brisbane River	Mt Crosby TM	10600	28	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143951	Brisbane River	Moggill Alert	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143915	Brisbane River	Moggill Bvrt	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143924	Brisbane River	Moggill TM	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143900	Brisbane River	Caboonbah			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143914	Brisbane River	Gregor Creek			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143920	Brisbane River	Gregor Creek Bvrt			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143902	Brisbane River	Murrumba			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143005	Brisbane River	Watts Bridge			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143903	Brisbane River	Wivenhoe			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143018A	Brisbane River	Avoca Vale	1498	20	Record length too short (post Wivenhoe)	DNRM
143868	Brisbane River	Colleges Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143918	Brisbane River Estuary	Bishop Island			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143217A	Buaraba Creek	Vineyard	63	10	Catchment area too small	DNRM
143211A	Buaraba Creek	15.8km	251	12	Catchment area too small	DNRM
143224A	Buaraba Creek	Diversion Channel		19	Catchment area too small	DNRM
143094A	Bulimba Ceek	Mansfield	57	26	Urban creek in Brisbane area, Small catchment	DNRM
143004A	Bulimba Creek	Belmont	51	22	Urban creek in Brisbane area, Small catchment	DNRM
1591	Bulimba Creek	End of Aquarium Ave. Hemmant		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1528	Bulimba Creek	Doughboy Pde- Hemmant		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1804	Bulimba Creek	Greenwood St- Wishart		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1831	Bulimba Creek	Merion Pl- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1707	Bulimba Creek	Old Cleveland Rd- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143926	Bundamba Creek	Ripley Alert	35		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143959	Bundamba Creek	Harding Street Alert	96		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143958	Bundamba Creek	Blackstone Bridge Alert	97	10	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143955	Bundamba Creek	Bundamba School Alert	102		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143854	Bundamba Creek	Bundamba (Hanlon St) Al	109	7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143114A	Bundamba Creek	Mary Street	110	11	Urban creek in Ipswich area, Small catchment	DNRM
143307A	Byron Creek	Causeway	79	28	Catchment area too small	DNRM
143012A	Cooyar Creek	51.5km.	443	4	Record length too short	DNRM
143015B	Cooyar Creek	Damsite	963	13	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143015A	Cooyar Creek	Damsite	963	22	Record length too short	DNRM
143013A	Cressbrook Creek	The Damsite	321	16	Record length too short	DNRM
143952	Cressbrook Creek	Rosentreters Bridge	440		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143921A	Cressbrook Creek	Rosentretters Bridge	447	17	Record length too short	DNRM
143921	Cressbrook Creek	Rosentreters Bridge TM	477		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143806	Cressbrook Creek	Rosentreters Bridge Al	477	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143857	Deebing Creek	Churchill Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143021A	Ekibin Creek	Dudley Street.	13	1	Urban creek in Brisbane area, Small catchment	DNRM
143011A	Emu Creek	Raeburn	439	24	Catchment area too small	DNRM
143010A	Emu Creek	Boat Mountain	915	11	Catchment area too small	DNRM
143010B	Emu Creek	Boat Mountain	915	27	Catchment area too small	DNRM
143932A	Ennogera Creek	Bancroft Park	70	10	Urban creek in Brisbane area, Small catchment	DNRM
143932	Enoggera Creek	Bancroft Park TM	67		Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1531	Enoggera Creek	100 M U/S From Original E e529		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1532	Enoggera Creek	Enoggera Dam- The Gap		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1529	Enoggera Creek	Kelvin Grove Rd- Kelvin Grove		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143208A	Fifteen Mile Creek	Dam Site	87	33	Catchment area too small	DNRM
143214A	Flagstone Creek	Windolfs	142	14	Catchment area too small	DNRM
143233A	Flagstone Creek	Brown-Zirbels Road		10	Catchment area too small	DNRM
1717	Gold Creek	Reservoir- Brookfield (Brisbane Water)			Urban creek in Brisbane area, Small catchment	South East Queensland Water
143028A	Ithaca Creek	Jason Street	10	31	Urban creek in Brisbane area, Small catchment	DNRM
1535	Ithaca Creek	Jason St- Ithaca		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143304A	Kilcoy Creek	Mount Kilcoy	127	36	Catchment area too small	DNRM
143304B	Kilcoy Creek	Mount Kilcoy Weir	131	15	Catchment area too small	DNRM
143235A	Lake Clarendon Head			6	Offstream storage	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143215A	Laidley Creek	Mulgowie Weir	154	14	Catchment area too small	DNRM
143209A	Laidley Creek	Mulgowie1	167	5	Catchment area too small	DNRM
143209B	Laidley Creek	Mulgowie2	167	36	Catchment area too small	DNRM
143225A	Laidley Creek	Showgrounds Weir Head Wate	233	19	Catchment area too small	DNRM
143226A	Laidley Creek	Showgrounds Weir Tail Wate	233	19	Catchment area too small	DNRM
143943	Laidley Creek	Laidley	285		Catchment area too small	BoM, Queensland Regional Office
143923	Laidley Creek	Thornton			Catchment area too small	BoM, Queensland Regional Office
143229A	Laidley Creek	Warrego Highway		13	Catchment area too small	DNRM
143202A	Lockyer Creek	Russell Siding	271	7	Catchment covered by other gauges DS	DNRM
143203C	Lockyer Creek	Helidon Number 3	357	16	Catchment covered by other gauges DS	DNRM
143203A	Lockyer Creek	Helidon	357	45	Catchment covered by other gauges DS	DNRM
143203B	Lockyer Creek	Helidon No.2	382	24	Catchment covered by other gauges DS	DNRM
143904	Lockyer Creek	Gatton	1550		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143204A	Lockyer Creek	Wilsons Weir	1655	29	Catchment covered by other gauges DS	DNRM
143905	Lockyer Creek	Glenore Grove	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143906	Lockyer Creek	Glenore Grove Bvrt	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143807	Lockyer Creek	Glenore Grove Alert	2230	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143206A	Lockyer Creek	Brightview Weir	2393	20	Catchment covered by other gauges DS	DNRM
143201A	Lockyer Creek	Tarampa	2405	17	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143201B	Lockyer Creek	Tarampa Number 2	2405	22	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143917	Lockyer Creek	Lyons Bridge	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143913	Lockyer Creek	Lyons Bridge Bvrt	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143819	Lockyer Creek	Lyons Bridge Alert-P	2530	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143227A	Lockyer Creek	O'Reilly's Weir Tailwater	2965	5	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
2142	Lota Creek	Rickertt Rd Ransome		4	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143213B	Ma Ma Creek	Ma Ma Weir	226	9	Catchment area too small	DNRM
143213A	Ma Ma Creek	Harms	227	4	Catchment area too small	DNRM
143213C	Ma Ma Creek	Harm's		8	Catchment area too small	DNRM
143032A	Moggill Creek	Upper Brookfield	23	27	Urban creek in Brisbane area, Small catchment	DNRM
143020A	Moggill Creek	Misty Morn	61	9	Urban creek in Brisbane area, Small catchment	DNRM
143020	Moggill Creek	Misty Morn TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1722	Moggill Creek	Fortrose St- Kenmore		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2143	Moolabin Creek	Brisbane River Golf Club- Tennyson		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143219A	Murphys Creek	Spring Bluff	18	24	Urban creek in Brisbane area, Small catchment	DNRM
1549	Norman Creek	Joachim St- Holland Park West		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1552	Norman Creek	South East Freeway- Greenslopes		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1555	Norman Creek	Caswell St- East Brisbane River		10	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143033A	Oxley Creek	New Beith	60	27	Urban creek in Brisbane area, Small catchment	DNRM
143019A	Oxley Creek	Upstream Beatty Road	152	3	Urban creek in Brisbane area, Small catchment	DNRM
143019B	Oxley Creek	Downstream Beatty Road	152	6	Urban creek in Brisbane area, Small catchment	DNRM
143019	Oxley Creek	Beatty Road TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1588	Oxley Creek	Mouth of Oxley Creek		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1727	Oxley Creek	New Beith (DNR)+F31		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2023	Oxley Creek	Corinda High School- Corinda		12	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2125	Oxley Creek	Beatty Rd- Acacia Ridge		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2111	Oxley Creek	Johnson Rd- Forestdale		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143024A	Pullen Pullen Creek	Moggill Road	27	4	Urban creek in Brisbane area, Small catchment	DNRM
1745	Pullen Pullen Creek	Pinjarra Rd- Pinjarra Hills		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143983	Purga Creek	Loamside Alert	215	8	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143113A	Purga Creek	Loamside	215	30	Catchment area too small	DNRM
143869	Purga Creek	Peak Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143218A	Redbank Creek	Holcomb	55	8	Urban creek in Ipswich area, Small catchment	DNRM
143216A	Redbank Creek	Water Treatment Works	60	11	Urban creek in Ipswich area, Small catchment	DNRM
143231A	Redbank Creek	Clarendon Number 2		10	Urban creek in Ipswich area, Small catchment	DNRM
143230A	Redbank Creek	Clarendon Pump Station		10	Urban creek in Ipswich area, Small catchment	DNRM
143306A	Reedy Creek	Upstream Byron Creek Junct	56	28	Catchment area too small	DNRM
143103A	Reynolds Creek	Moogerah	190	37	Catchment area too small	DNRM
143103B	Reynolds Creek	Moogerah	190	6	Catchment area too small	DNRM
143111A	Reynolds Creek	Moogerah Dam Headwater	226	36	Head gauge affected by dam site	DNRM
143112A	Reynolds Creek	Moogerah Tailwater	227	23	Tail gauge affected by dam site	DNRM
143220A	Sandy Creek	Forest Hill	102	7	Urban creek in Brisbane area, Small catchment	DNRM
143232A	Sandy Creek	Forest Hill		8	Urban creek in Brisbane area, Small catchment	DNRM
143030A	Sandy Creek	Indooroopilly		22	Urban creek in Brisbane area, Small catchment	DNRM
143223A	Seven Mile Lagoo	Diversion Channel		20	Diversion channel	DNRM
143023A	Small Catchment	Algester	1	4	Urban creek in Brisbane area, Small catchment	DNRM
143022A	Stable Swamp Creek	Interstate Railway	19	11	Urban creek in Brisbane area, Small catchment	DNRM
2129	Stable Swamp Creek	Musgrave Rd- Coopers Plains		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143303A	Stanley River	Peachester	104	76	Catchment area too small	DNRM
143938	Stanley River	Woodford TM	220		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143829	Stanley River	Woodford Alert-P	220	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143901	Stanley River	Woodford	250		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143301B	Stanley River	Donnelly Dell	1227	4	Record length too short	DNRM
143301A	Stanley River	Hazeldean	1242	3	Record length too short	DNRM

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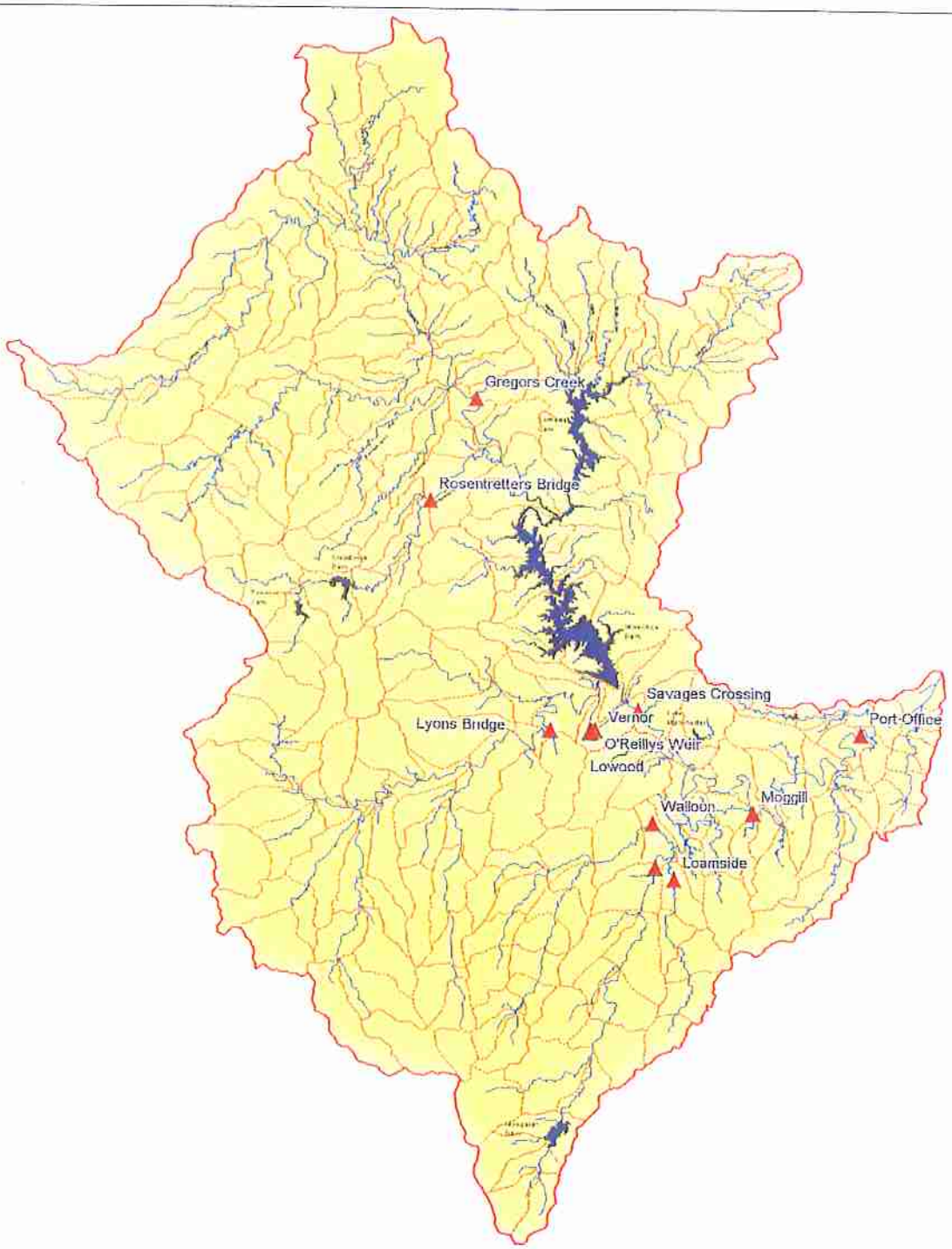
Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143305	Stanley River	Somerset Dam	1330		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143818	Stanley River	Somerset Dam Hw Alert-B	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143817	Stanley River	Somerset Dam Hw Alert-P	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143305A	Stanley River	Somerset Dam	1336	24	Head gauge affected by dam site	DNRM
143302A	Stanley River	Silverton	1339	49	Data obtained, but uncertainty as to appropriate rating	DNRM
143960	Stanley River	Peachester			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143212A	Tenthill Creek	Tenthill	447	35	Catchment area too small	DNRM
143106A	Warrill Creek	Aratula Weir	122	7	Catchment covered by other gauges DS	DNRM
143102A	Warrill Creek	Kalbar No.1	465	46	Catchment covered by other gauges DS	DNRM
143102B	Warrill Creek	Kalbar No.2	468	13	Catchment covered by other gauges DS	DNRM
143937	Warrill Creek	Kalbar	470		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143910	Warrill Creek	Harrisville	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143912	Warrill Creek	Harrisville TM	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143101A	Warrill Creek	Mutdapily	771	43	Catchment covered by other gauges DS	DNRM
143825	Warrill Creek	Amberley Alert-P	850	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143933	Warrill Creek	Amberley Bvrt	862		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143117A	Warrill Creek	Junction Weir H/W		5	Record length too short	DNRM
143118A	Warrill Creek	Junction Weir Tailwater		6	Record length too short	DNRM
143116A	Warrill Creek	Toohill's Crossing		6	Record length too short	DNRM
143105A	Warrill Creek East	Churchbank Weir	149	50	Catchment covered by other gauges DS	DNRM
143031A	Water St. Drain	Exhibition Ground		5	Urban creek in Brisbane area, Small catchment	DNRM
143939	Western Creek	Kuss Road	200	21	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
143861	Western Creek	Grandchester Alert		4	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1583	Wolston Creek	700m U/S Wacol Station Rd- Wacol		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143962	Woogaroo Creek	Brisbane River Road Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in flood frequency analysis	Data Provider
143927	Woogaroo Creek	Opossum Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143961	Woogaroo Creek	Alice Street Alert		7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office



Appendix C Location of select stream gauges

- Location of stream gauge sites that were used in flood frequency analysis



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Appendix D Regional Flood Frequency Information

D.1 Introduction

The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

D.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in Section 2.2 only DNRM gauge flow data were both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in Table D.1.

The location of the gauges can be seen in the catchment map in Appendix C.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in Table D.1 were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in Section D.3.

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Table D.1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods.

River	Station Name	Station Number	Years of Record	C'ment Area (km²)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

D.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in Table D.1. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. Figure 3.1 shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (eg Peel et al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

Also shown on Figure D.1 is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that Bremer River @Walloon (143107A) and Brisbane @ Gregor's Creek (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (Appendix E) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.

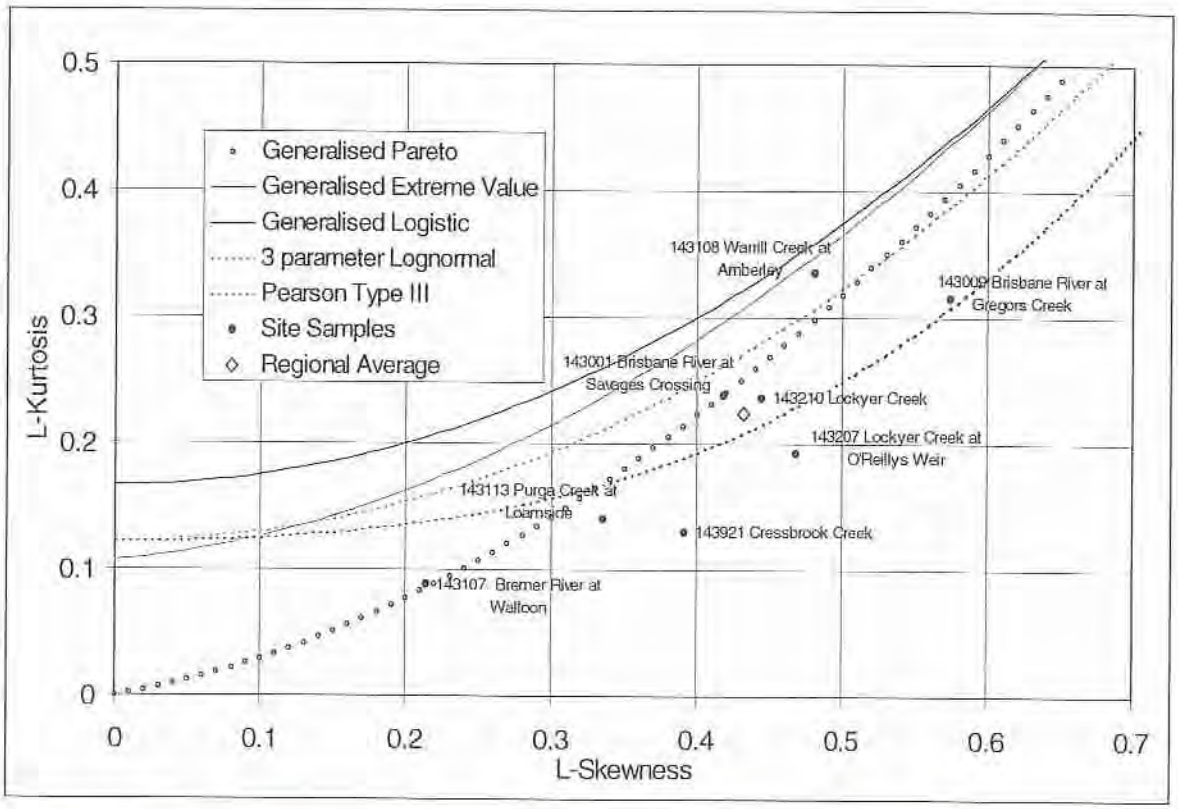

Figure D.1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500km²), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (Figure D.2) supports the adoption of the Generalised Pareto distribution.

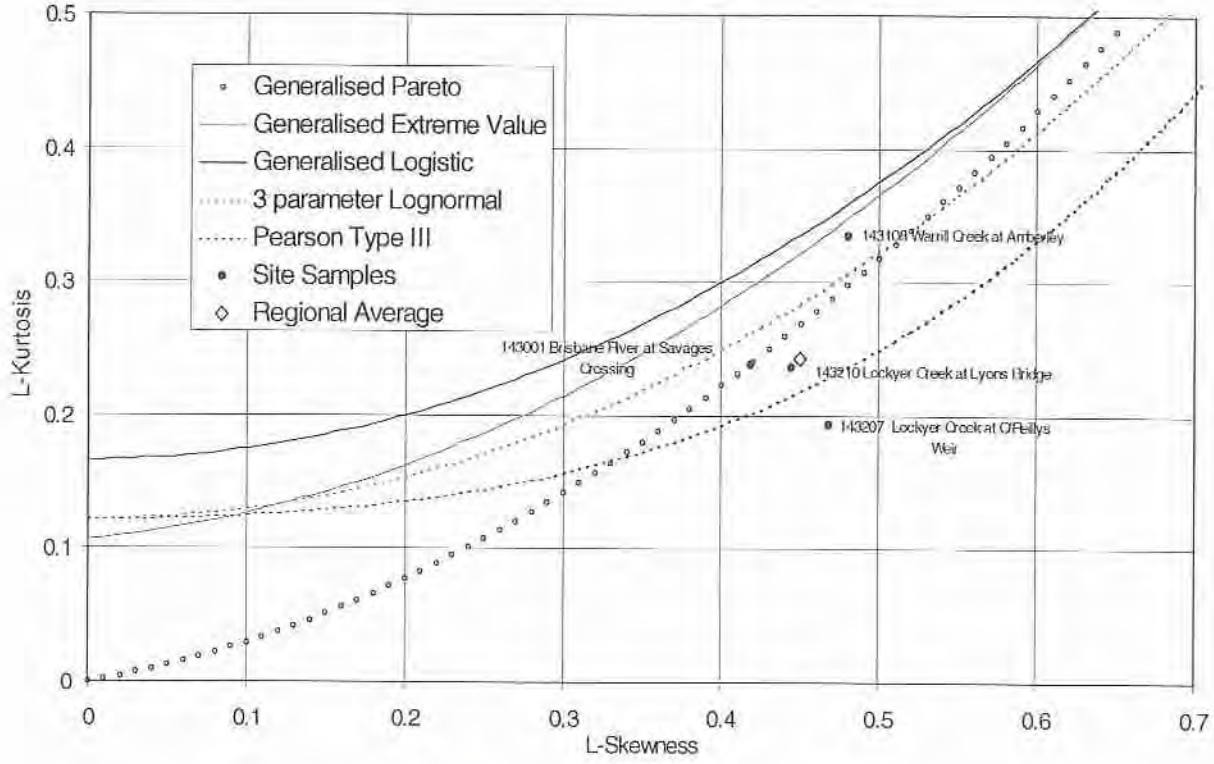

Figure D.2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in Table D.2.

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Table D.2 Regional parameter values of the adopted Generalised Pareto distribution

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter, ξ	-0.062	-0.096
Scale parameter, α	0.811	0.795
Shape parameter, κ	-0.230	-0.275

D.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation,
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of Table D.2. The scale parameter (α) from the regional analysis shown in Table D.2 is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\hat{\alpha}_{143001} = L^1_{143001}\alpha^{CV}_{\text{Regional}} = 1181 \times 0.795 = 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in Table D.3. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\sigma_{\alpha,143001} = L^1_{143001}\sigma^{CV}_{\alpha,\text{Regional}} = 1181 \times 0.388 = 458$$

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information



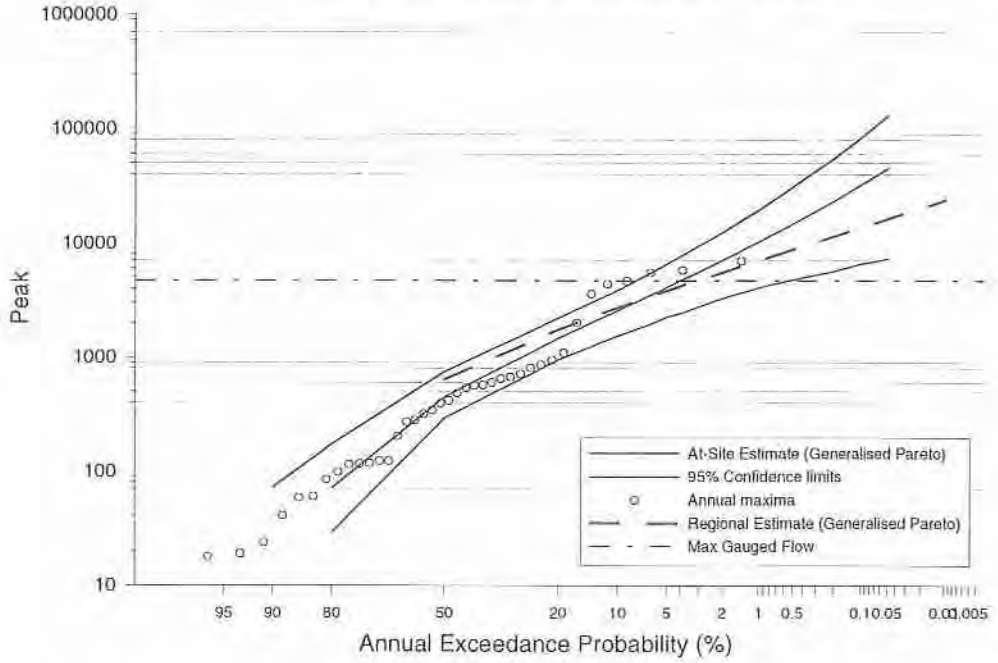
was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

- Table D.3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution

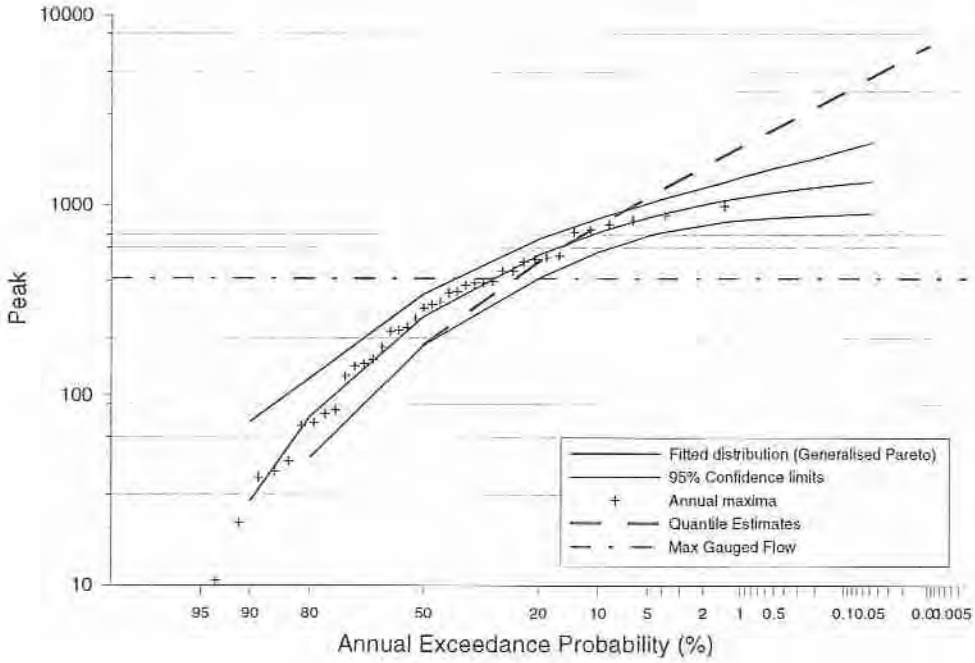
Site Number	Gauging Station Name	Scale parameter, α	Shape parameter, κ
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		0.388	0.297

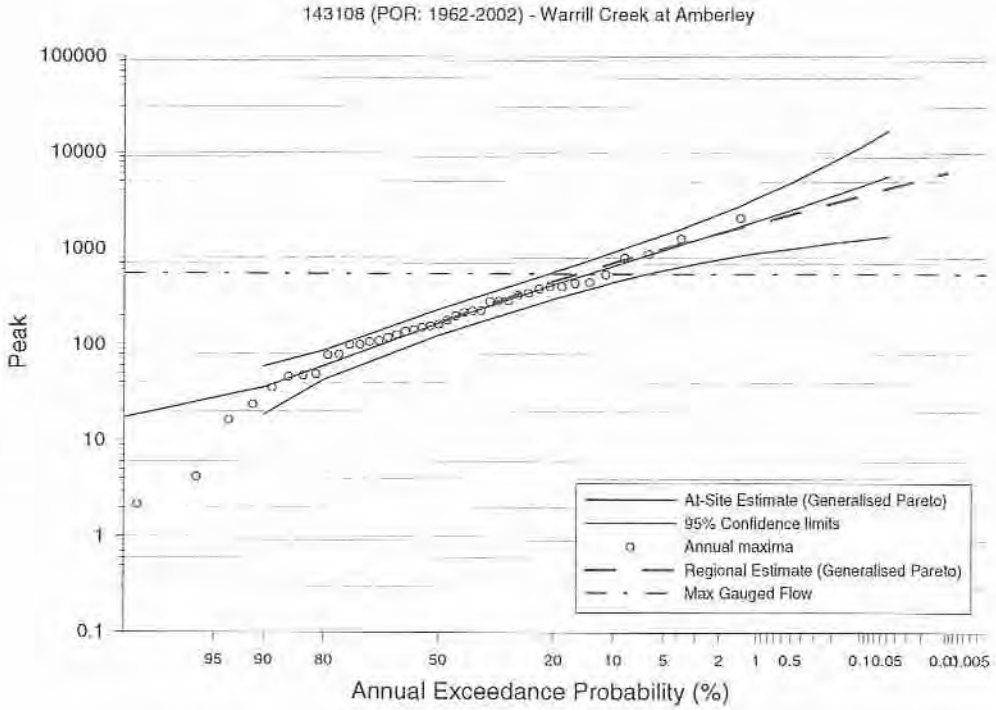
Appendix E At-Site/Regional Analysis of Selected Gauges

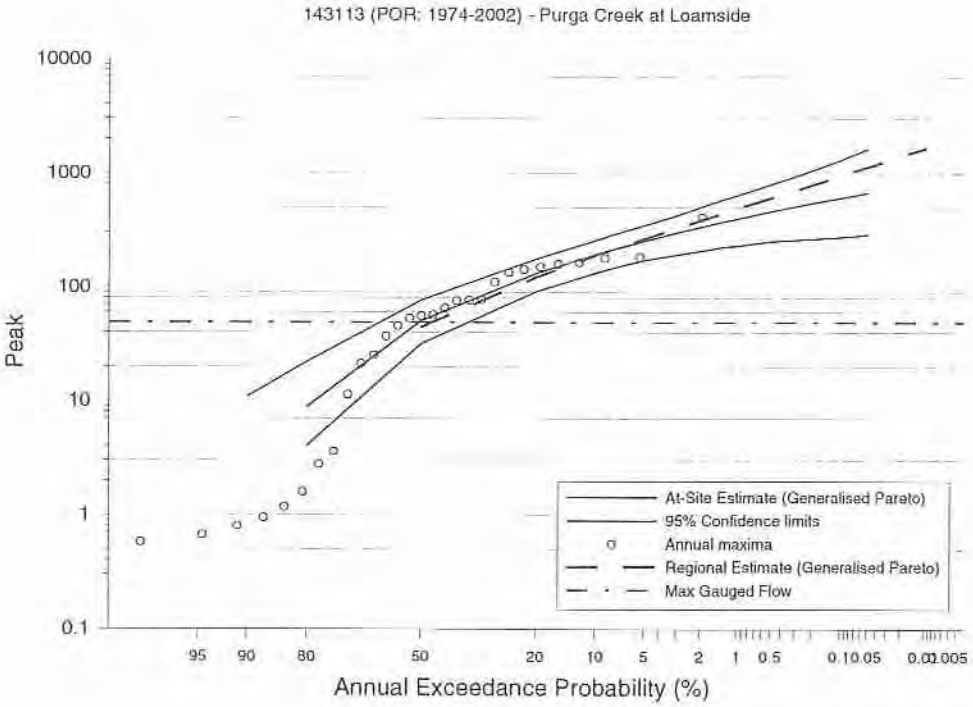
143009 (POR: 1963-2002) - Brisbane River at Gregors Creek

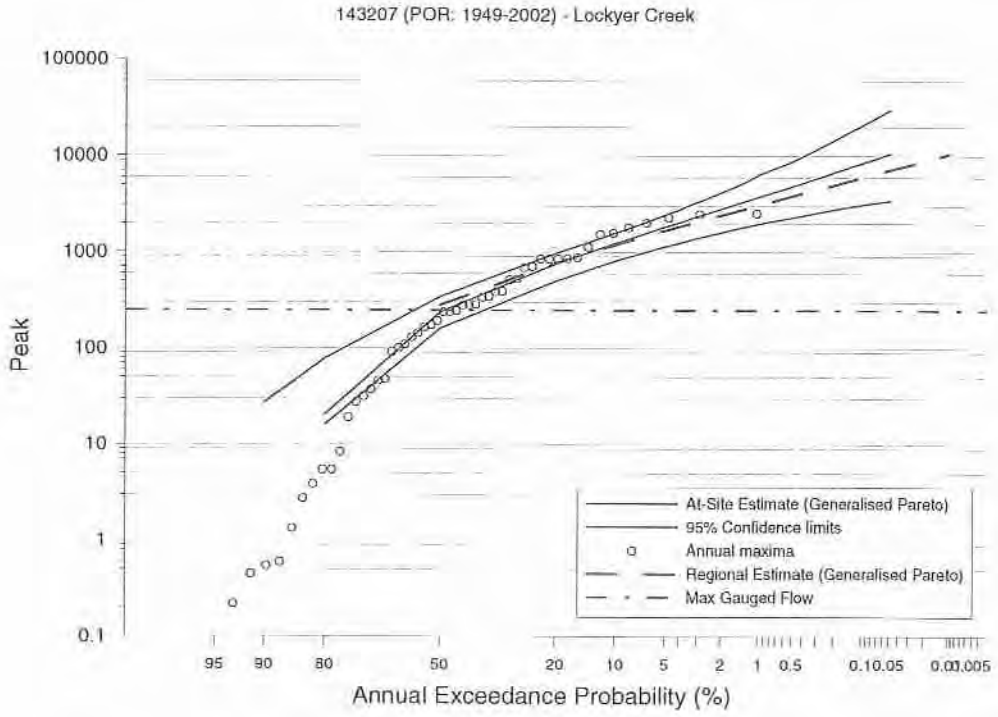


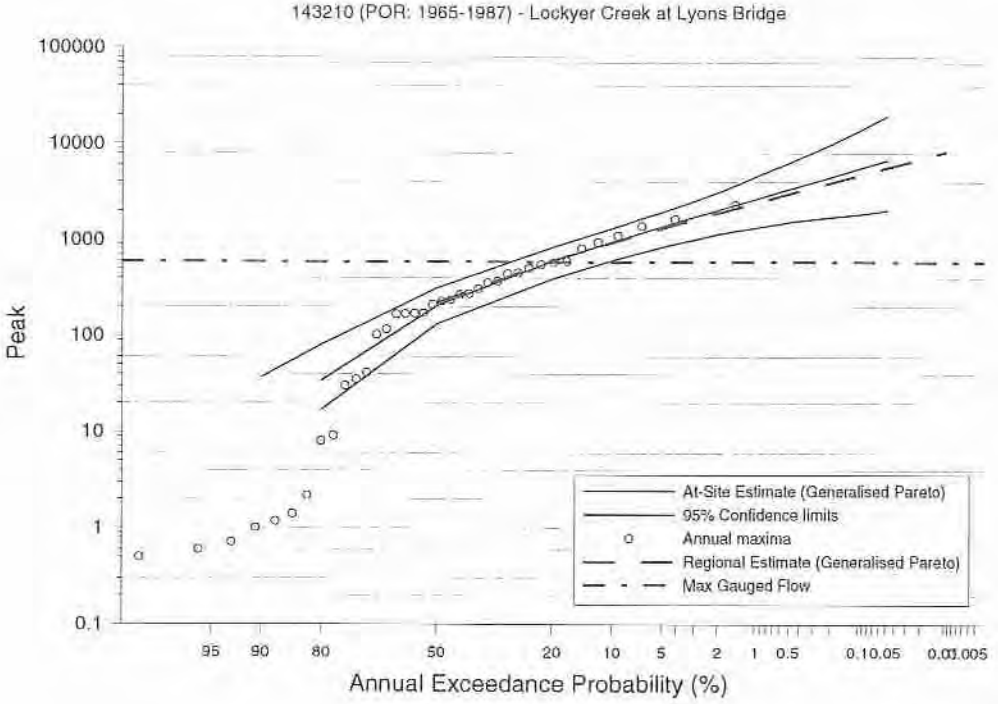
143107 (POR: 1962-2002) - Bremer River at Walloon

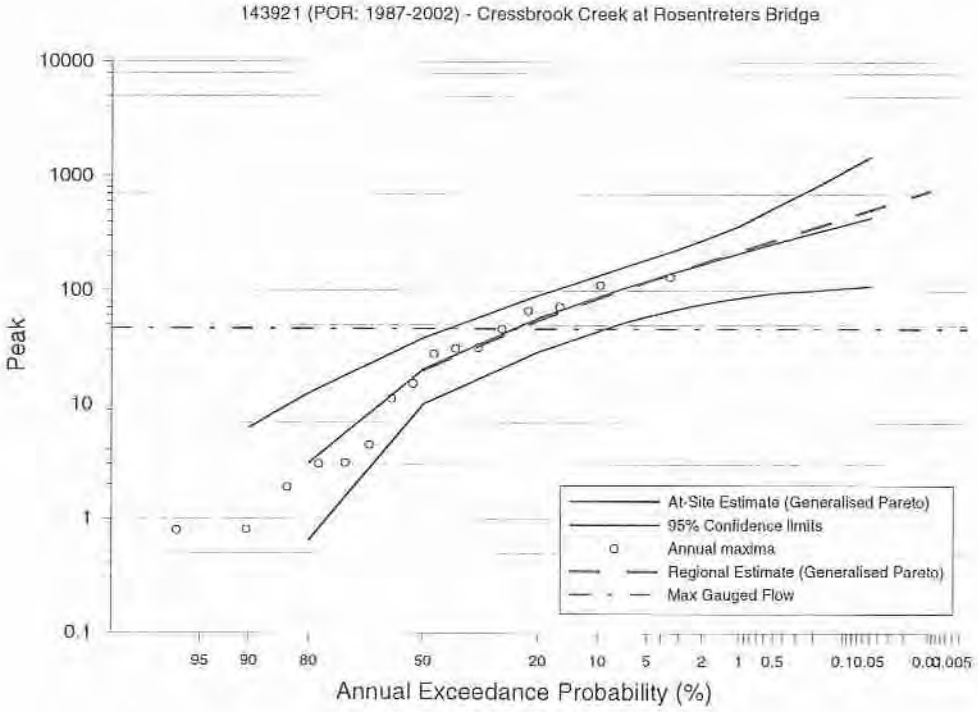



143108 (POR: 1962-2002) - Warrill Creek at Amberley
100000
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143113 (POR: 1974-2002) - Purga Creek at Loamside
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow

Appendix F Historical Spatial Distributions

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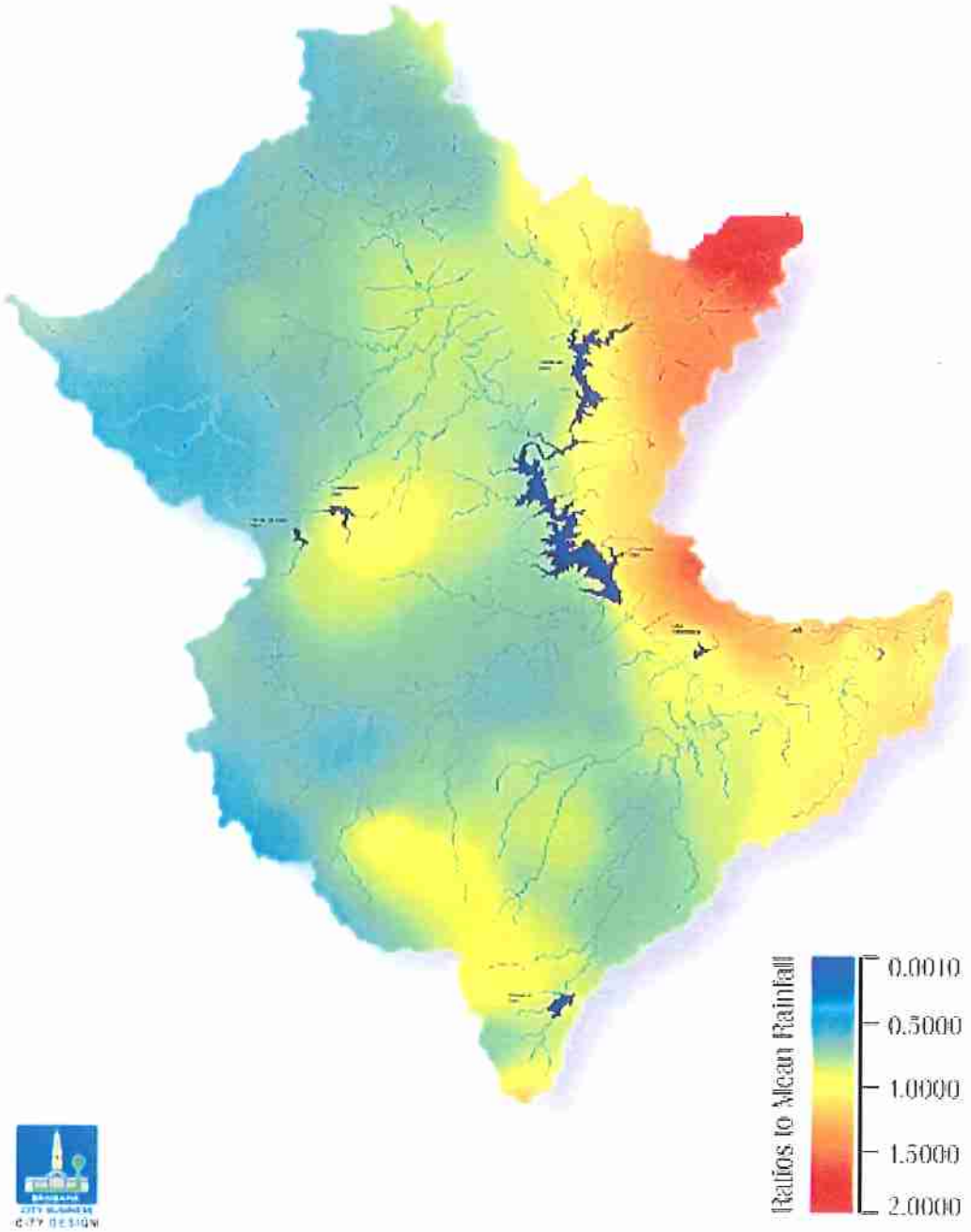
CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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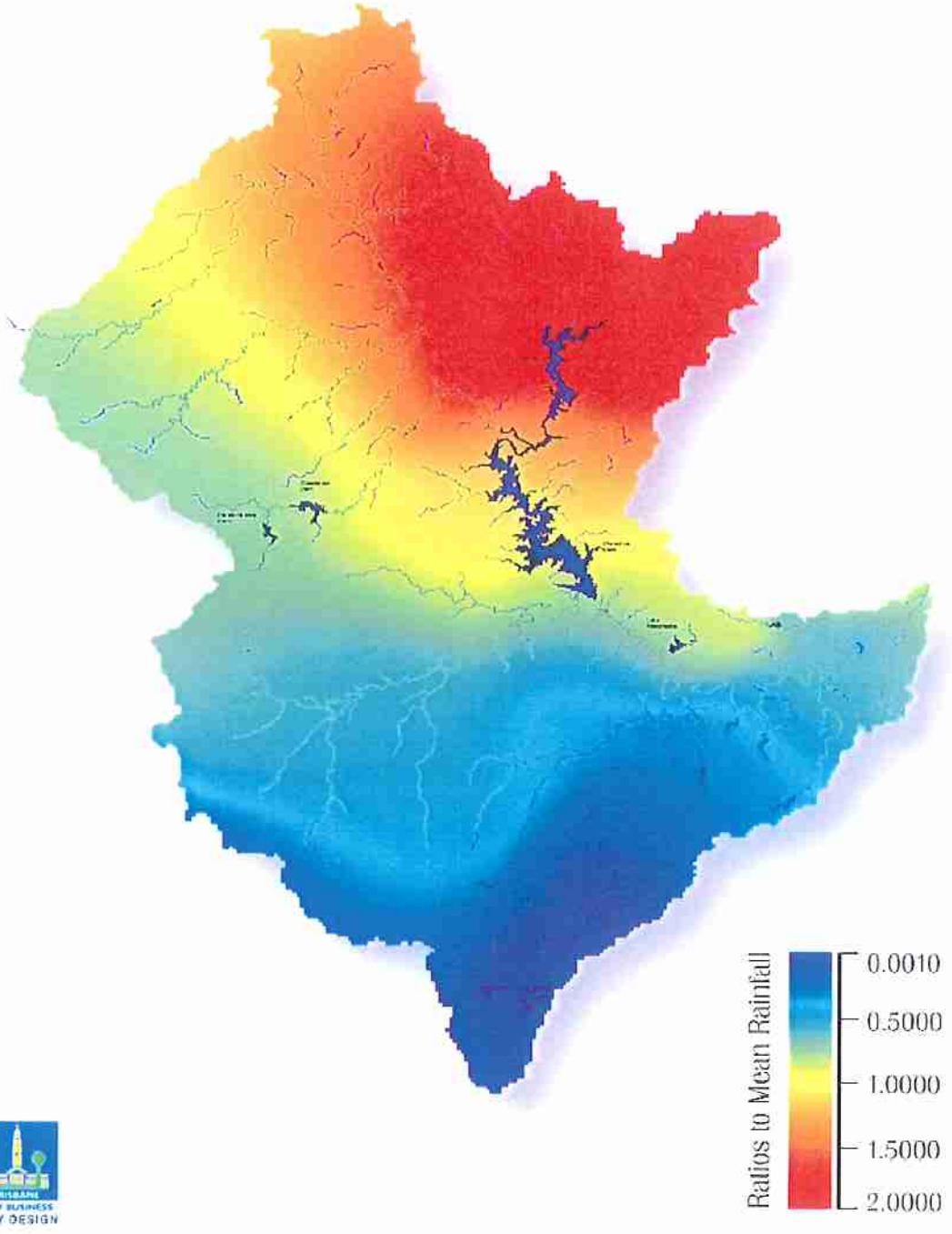
JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



BRISBANE CITY BUSINESS CITY DESIGN

SINCLAIR KNIGHT MERZ

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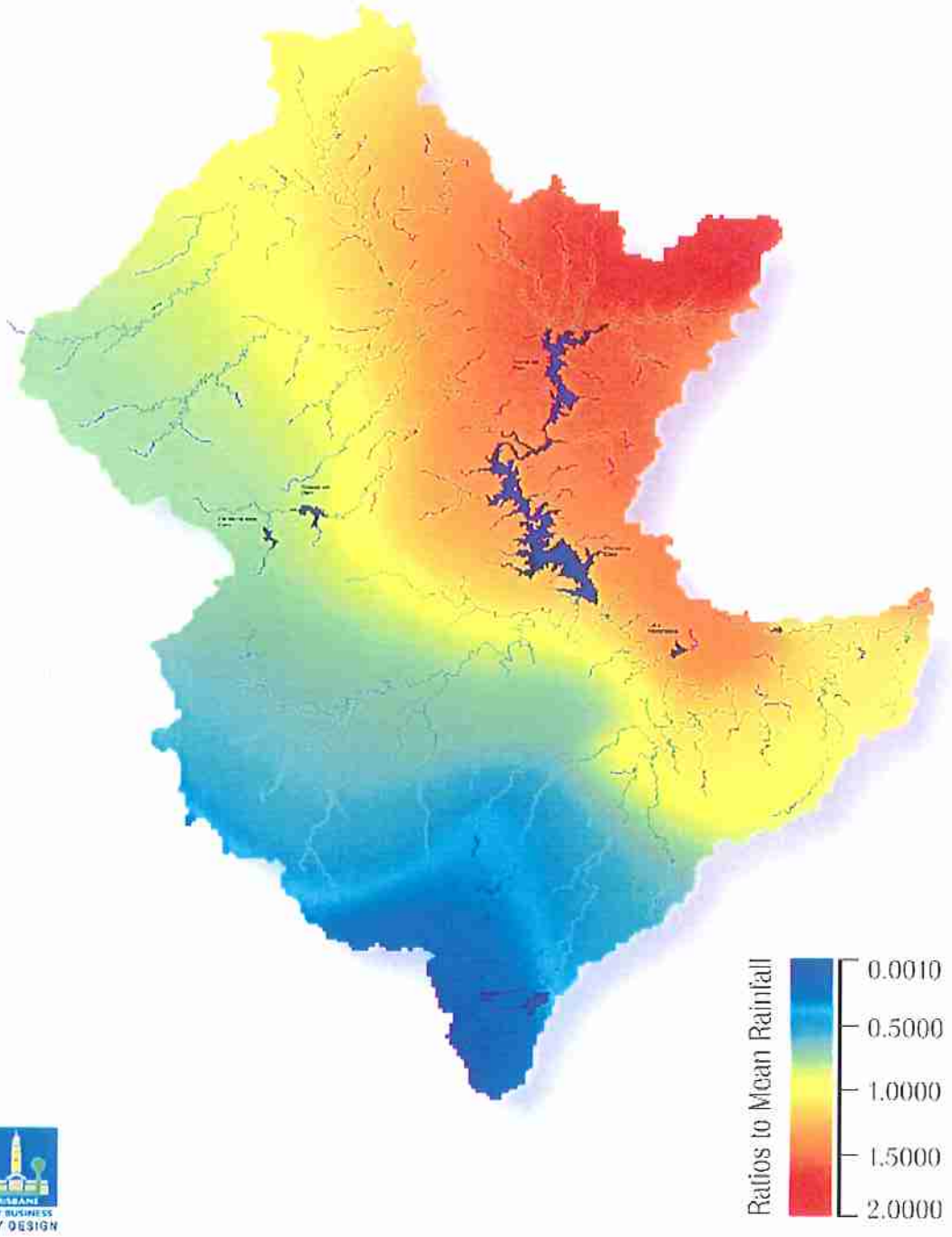
FEBRUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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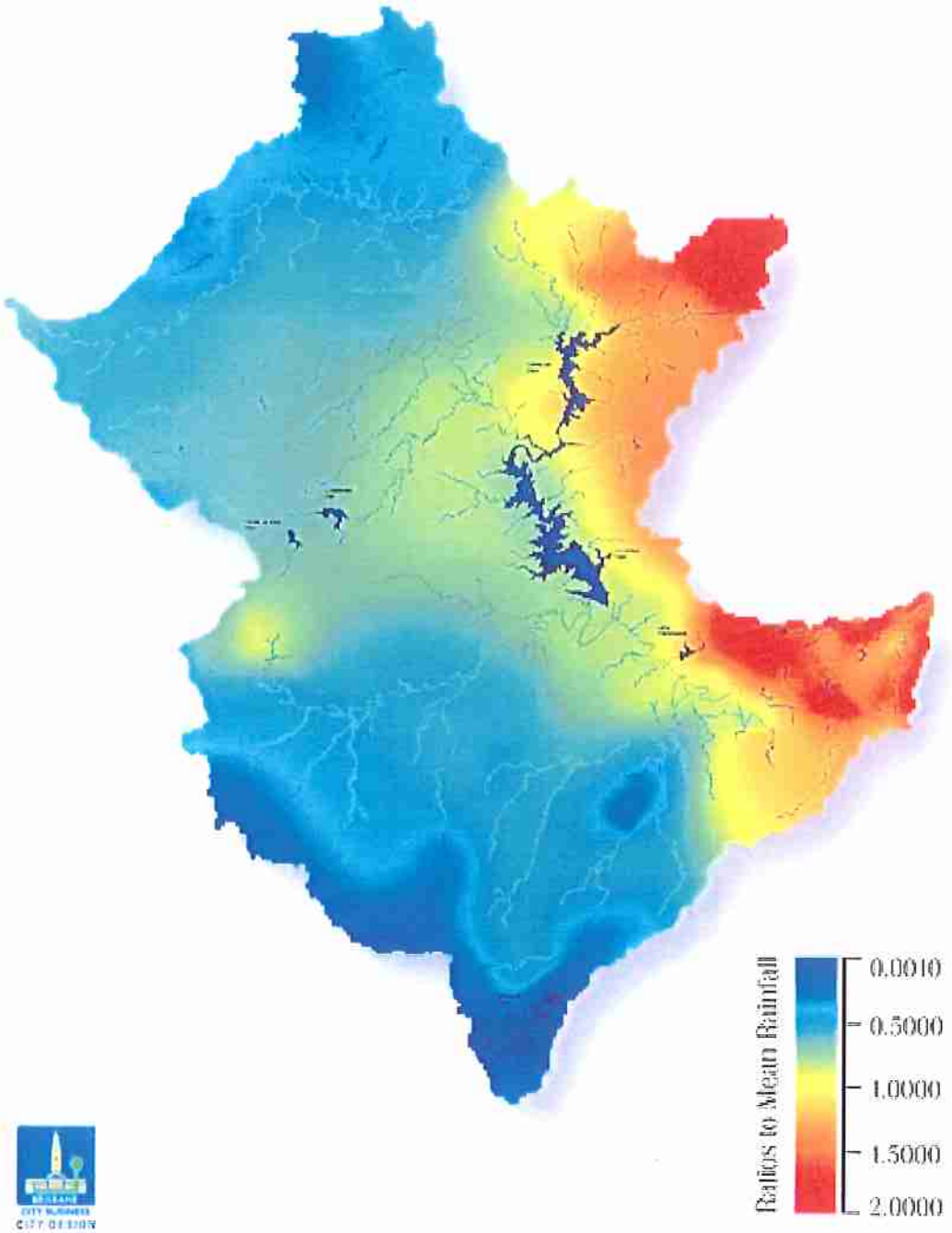
JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



MARCH 1955 SPATIAL DISTRIBUTION

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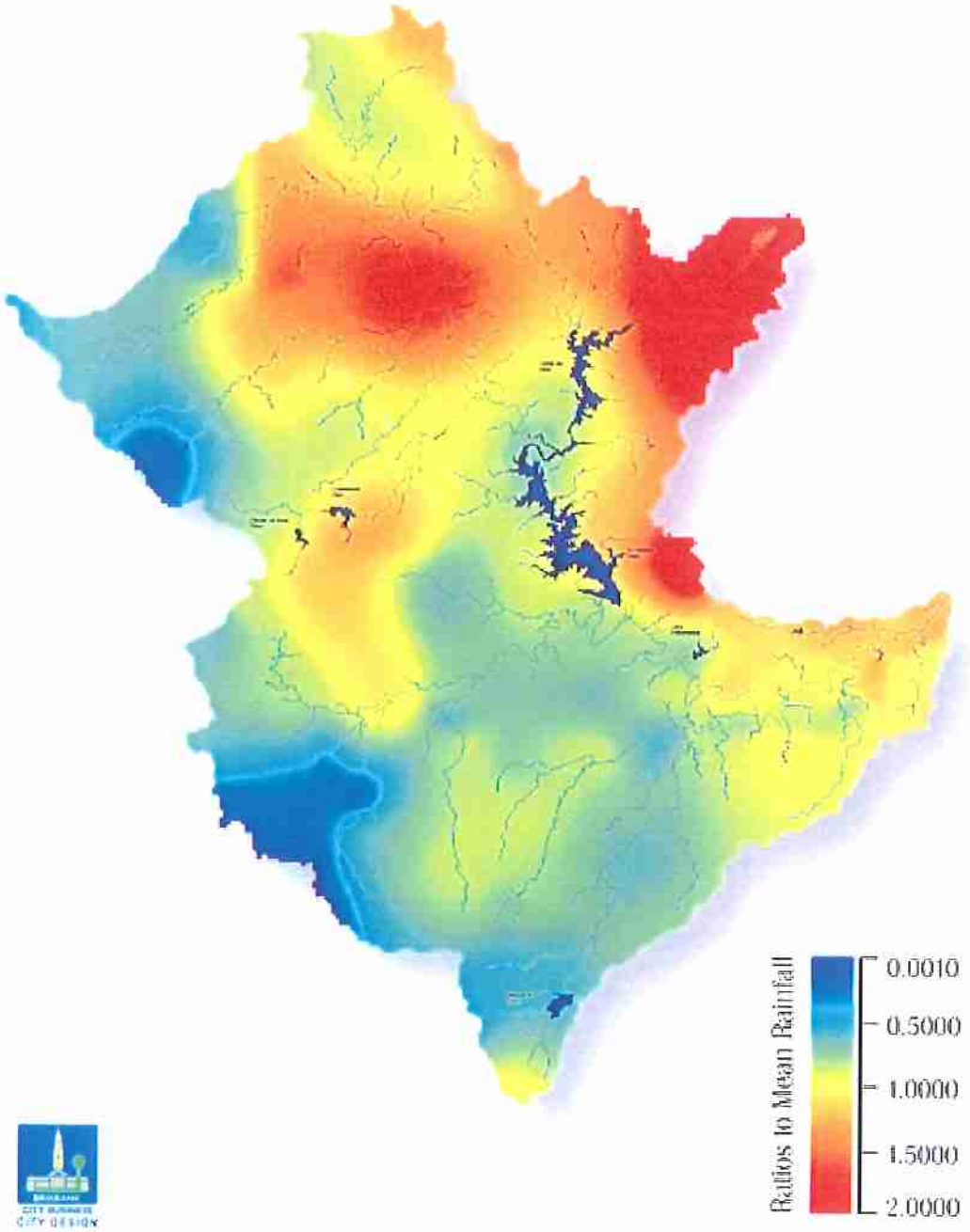

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JANUARY 1974 SPATIAL DISTRIBUTION

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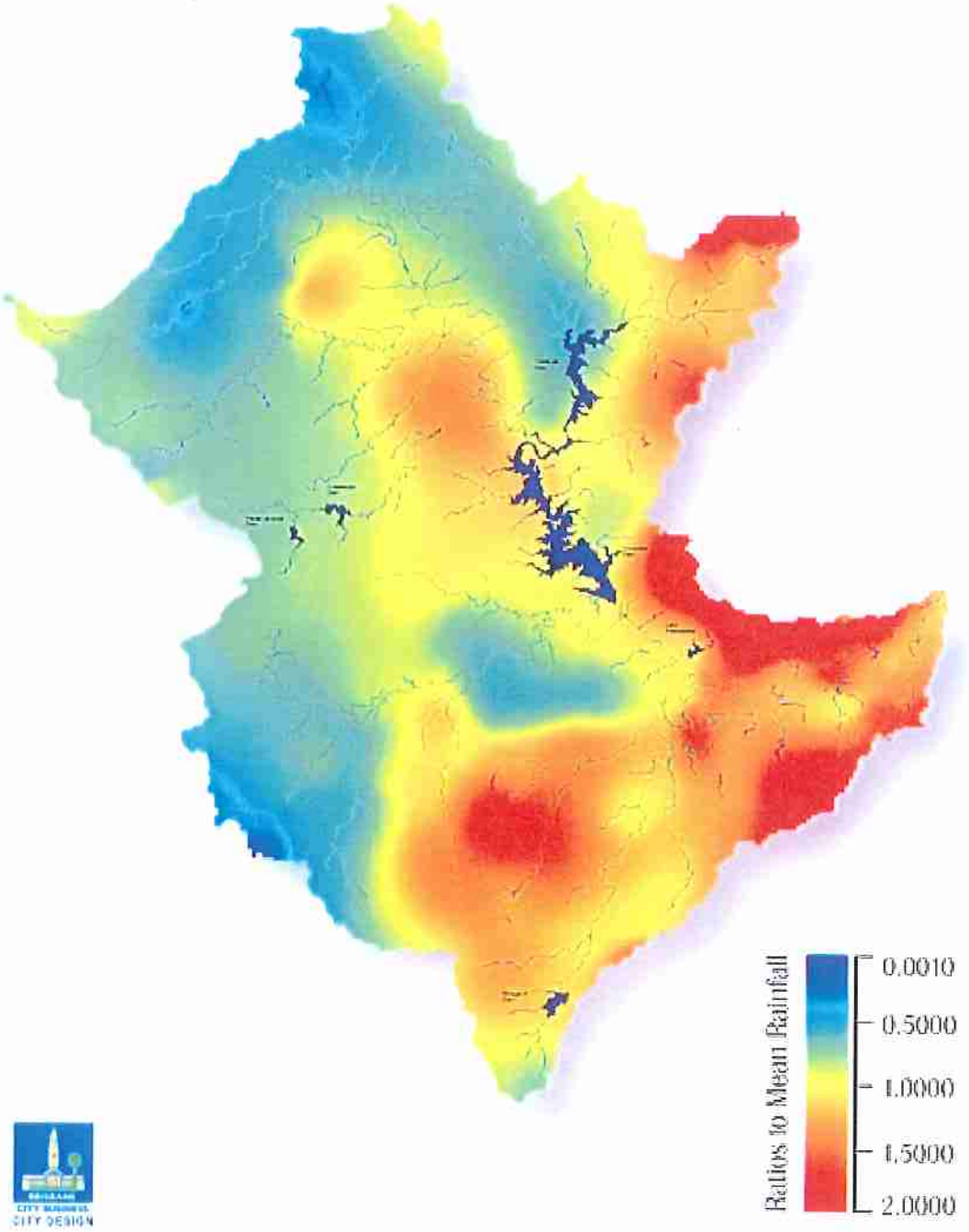

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APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

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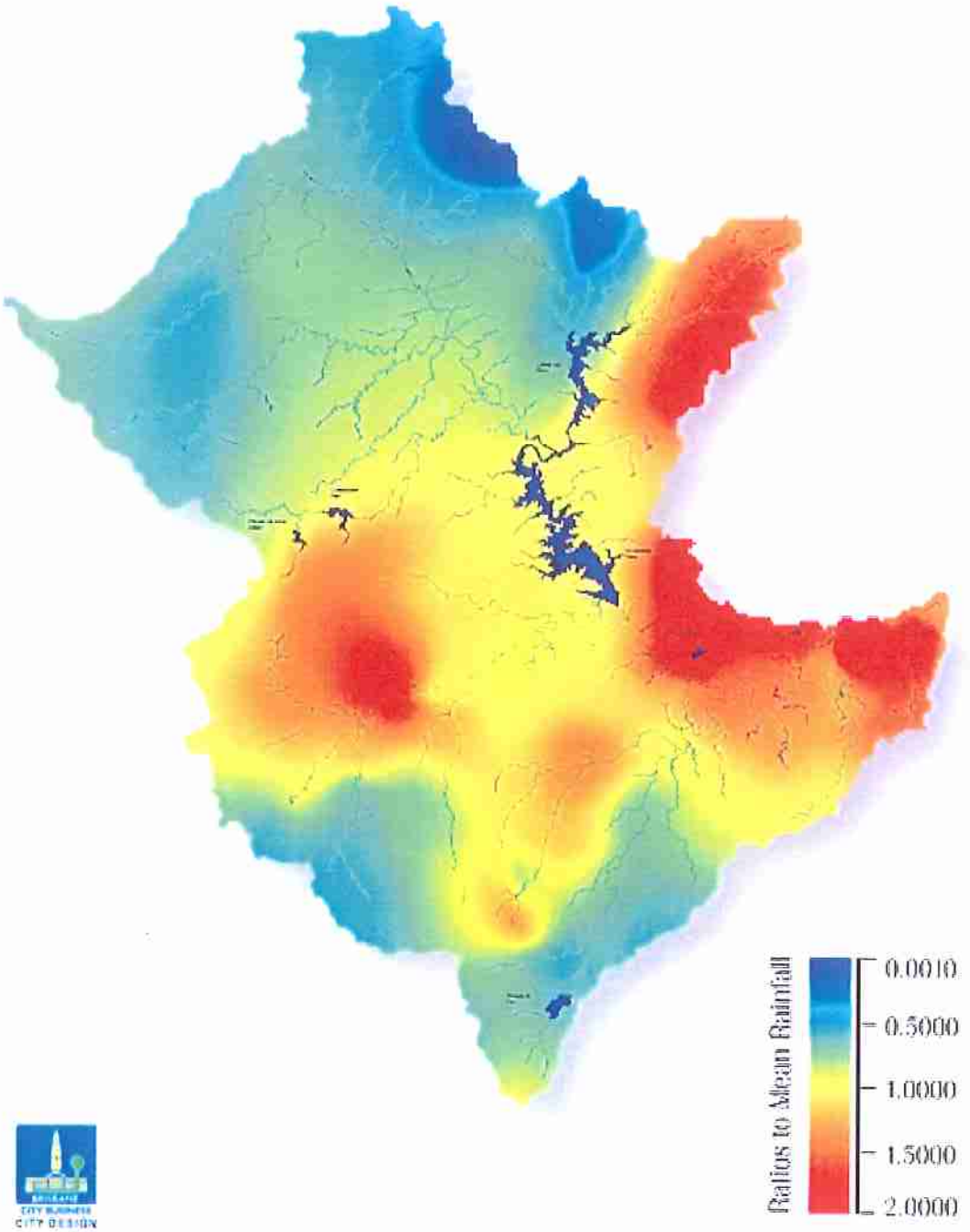

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FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

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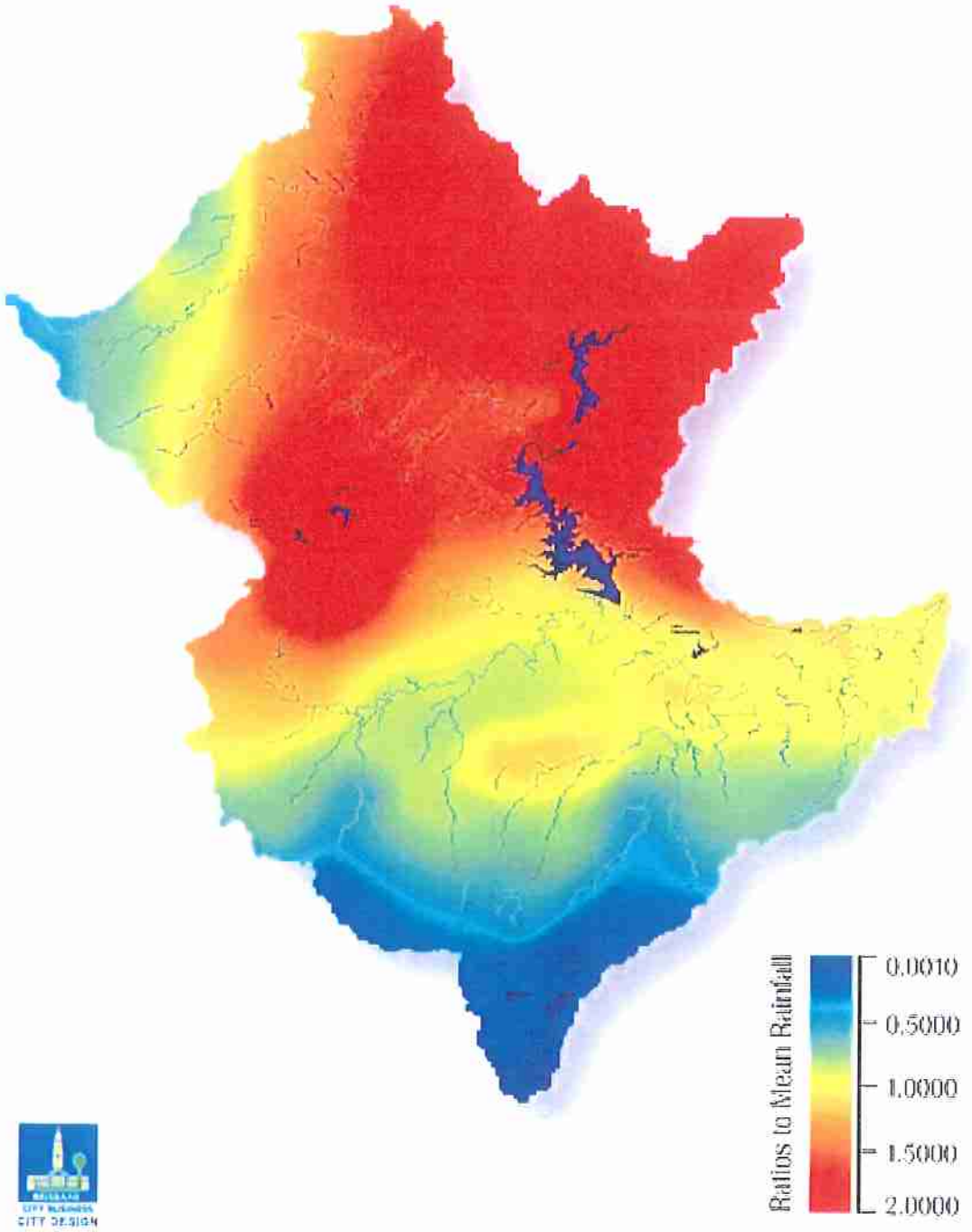

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Appendix G Pre- and Post-dams RAFTS Model Results

- Q100 Peak Flows for RAFTS Model, Pre-Dams

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
JAN 1893	24	9861	7927	7927
	30	**11507**	9793	9792
	36	9810	7932	7932
	48	10238	8535	8534
	72	10911	**10198**	**10196**
	96	9774	9394	9392
	120	10074	9641	9639
FEB 1893	24	8698	7502	7502
	30	**10062**	8789	8788
	36	8682	7512	7512
	48	9012	7866	7865
	72	9634	**9504**	**9501**
	96	8568	8636	8632
	120	8804	8904	8898
JAN 1931	24	7505	6745	6745
	30	**8543**	7648	7648
	36	7476	6776	6775
	48	7712	7191	7190
	72	8183	**8030**	**8026**
	96	7140	7610	7514
	120	7360	7713	7630
MAR 1955	24	8671	7537	7536
	30	**10046**	8925	8925
	36	8689	7554	7553
	48	8955	7916	7915
	72	9563	**9623**	**9619**
	96	8376	8750	8745
	120	8635	9002	8997
JAN 1974	24	7058	7203	7202
	30	**8005**	8049	8046
	36	7049	7073	7072
	48	7227	7528	7527
	72	7714	**9117**	**9112**
	96	6729	8161	8154
	120	6879	8454	8432

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
APR 1996	24	7531	7068	7067
	30	**8621**	7966	7966
	36	7549	7079	7078
	48	7748	7427	7425
	72	8287	**8922**	**8917**
	96	7184	8043	8034
	120	7399	8182	8170
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7894	7893
	48	9981	8444	8443
	72	10642	**10200**	**10197**
	96	9512	9387	9384
	120	9809	9629	9626

Note: Critical flows at each location are shown in **bold**.

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- Q100 Peak Flows for RAFTS Model, Post-Dams

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7121**	**7120**
FEB 1893	24	1877	2070	2061
	30	3818	3449	3449
	36	1935	2211	2203
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5596	5595
	120	**6568**	**5851**	**5850**
JAN 1931	24	1872	2319	2051
	30	1926	3314	2708
	36	1884	2836	2452
	48	1758	2580	2382
	72	3079	3968	3146
	96	3170	3383	2940
	120	**3279**	**3411**	**3218**
MAR 1955	24	1925	2350	2345
	30	3524	3433	3433
	36	2063	2544	2541
	48	3272	3013	3013
	72	**6241**	**5710**	**5709**
	96	5926	5340	5339
	120	6151	5585	5584
JAN 1974	24	1753	3326	3324
	30	2467	3989	3987
	36	1871	3350	3279
	48	1943	3633	3627
	72	3307	4965	4418
	96	**4771**	**5852**	**5841**
	120	2911	3662	3656

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Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Port Office	Moggill
APR 1996	24	3554	3400	3399
	30	4067	4138	4137
	36	3535	3260	3260
	48	3605	3691	3690
	72	**4162**	**5035**	**5019**
	96	3492	4417	4378
	120	3509	4663	4571
FEB 1999	24	3424	2887	2886
	30	5789	4442	4442
	36	3575	3147	3150
	48	4604	3495	3494
	72	6879	6448	6447
	96	7217	6624	6623
	120	**7431**	**6819**	**6819**

Note: Critical flows at each location are shown in **bold**.

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FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Further Investigations
- Final
- 7 Oct 2003

DRAFT



Brisbane River Flood Study

FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES

- Final Draft
- 7 Oct 2003

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Executive Summary

An Expert Panel has been appointed to review the flood investigations undertaken for the Brisbane River. Sinclair Knight Merz was approached to assist the Expert Panel with their review. The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a "best" estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event.

The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

This technical report has been prepared for expert technical reviewers and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, hydrological terminology and abbreviations is generally assumed.

Statistical Flood Frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (ie, the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, ie assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in Table E1.

Table E1. Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis.

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100.
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses etc). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty)
- choice of frequency distribution and the appropriate parameters; and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7 500 m³/s and 11 000 m³/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q!00 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (eg the soil, interception by

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vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures;
- dam levels at the start of a flood event; and,
- spatial and temporal patterns of the storm.

The most appropriate way to jointly assess the above factors (along with other factors variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate failure) is by Monte-Carlo analysis. Given the restrictions on time for this current inve analysis could not be undertaken. To account for the above factors, sensitivity analys undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increased catchment area. The rainfall estimates as supp contained the design spatial distribution of rainfall over the catchment. ARFs were not a for catchments of this size when the previous Brisbane River Flood Study (Sinclair Knig 1998) was undertaken.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (S Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were mode range of peak flows were determined at Savages Crossing and these varied between 80(11500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10000 m^3/s using an Initial Loss (IL) of 10 mm and a Continuing Loss (CL) of 1.0 mm/hr. This compares to the statistical frequency estimate (ie analysis of recorded flow data) of 12000 m^3/s.

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Table E2. Range of Estimates at the Port Office for the 1 in 100 AEP Flood

Condition	Peak Flow (m^3/s)	Peak Flood Level (m A
Lower Estimate	5000	2.7
Best Estimate	6500	3.5
Upper Estimate	8000	4.4

The information for the two historical flood events (1893 and 1974) were run through model for the pre and post-dam conditions. For post-dam conditions, the estimated p the Port Office for the 1893 and 1974 flood events were 9500 m^3/s and 6800 m^3/s res should be noted that the uncertainty of the historical data, 1893 in particular, is consi

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz ,1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and,
- inclusion of regional streamflow information in the flood frequency analysis.

It is recommended that the following actions be undertaken:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

8) Analyse catchment sensitivity using various temporal patterns.
9) Undertake a check with historical flood events.
10) Perform hydraulic modelling to produce flood frequency estimates at Moggill a Office.
11) Report on the findings of the rainfall-runoff and hydraulic modelling.

9. undertake a check using the spatial patterns of historic flood events?

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3. Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake flood frequency ana available data and come up with a best estimate of the likely 1 in 100 annual exceeda probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also refe Q100 event. An estimate of the Q100 for the "no dams" case (ie peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in Section 2.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- Adjustment of data for the influence of the dams
- Uncertainty in the rating curves that relate recorded river level to flow rate
- The magnitude of historic data (especially 1893 and 1825)
- The period of record associated with the historic data
- Choice of frequency distribution
- Selection of parameters for the distribution
- Method of including historical data

DNRM provided a series of data (1890 – 2000) that was adjusted so as to represent tl rates expected if Somerset and Wivenhoe dams had existed over the entire period. Fr analysis of this data was undertaken along with various unadjusted data.

The frequency analysis was undertaken using a range of at-site and regional methods benefit of adopting a regional approach to flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 45% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by Assoc Prof George Kuczera in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix D**.

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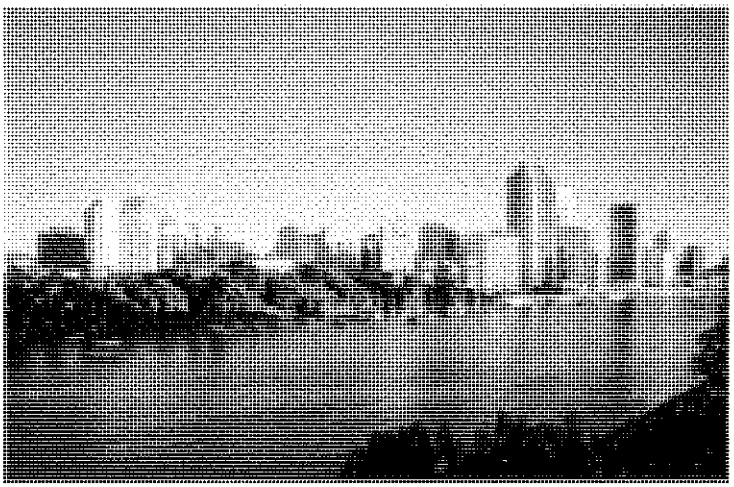

FURTHER INVESTIGATION OF STATISTICAL FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES – BRISBANE RIVER

- Further Investigations
- Final Issue
- Compiled 13 Nov 2003



Brisbane River Flood Study

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Document history and status

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Hydrological Modelling Draft A	22/08/2003	[redacted]	S. Abbey	22/08/2003	
Hydrological Modelling Draft B	29/08/2003		S. Abbey	29/08/2003	
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Final Issue	13/11/2003				Final Issue

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The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (e.g. the soil, interception by vegetation, etc.), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13,500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7,000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures;
- dam levels at the start of a flood event; and,
- spatial and temporal patterns of the storm.

The most sophisticated way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. A Monte Carlo analysis would provide a more accurate estimate of the Q100 and reduce the overall uncertainty in the flood estimates. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increasing catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows was determined at Savages Crossing and these are presented in **Table 2.**

- **Table 2 Pre dams 1 in 100 AEP Flow Estimates at Savages Crossing**

Scenario	Median (m^3/s)	Lower Estimate (m^3/s)	Upper Estimate (m^3/s)
No Dams	10,000	8,000	11,500

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10,000 m^3/s using an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h. This compares to the statistical frequency estimate (i.e. analysis of recorded flow data) of 12,000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3,000 m^3/s to 8,000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6,200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12,000 m^3/s and 13,800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis. While zero loss rates are not realistic, the objective of this sensitivity analysis was to show that temporal patterns can have an impact on the magnitude of flows. A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/h. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing and Brisbane Port Office was estimated to be 5,400 m^3/s and 5,000 m^3/s respectively. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing and Brisbane Port Office was reduced to 3,500 m^3/s and 4,400 m^3/s respectively.

SKM

Q100 estimate at the Brisbane Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Brisbane Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Brisbane Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Brisbane Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Brisbane Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 3** provides a range of estimates with a 'best estimate', upper estimate and lower estimate.

- **Table 3 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood with Dams**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The information for the two historical flood events (1893 and 1974) was run through the RAFTS model for the pre and post-dam conditions. For post-dam conditions, the estimated peak flow at the Brisbane Port Office for the 1893 and 1974 flood events were 9,500 m^3/s and 6800 m^3/s respectively. It should be noted that the uncertainty in some of the historical data, 1893 in particular, is considerable.

The best estimate of 6,500 m^3/s was adopted after consideration of the RAFTS modelling for current design spatial pattern, various historical patterns and the performance of the model in reproducing flows at Savages Crossing for pre-dam flows. The estimate of the lower end of the plausible range of the Q100 estimate is 5,000 m^3/s. It was adopted with particular consideration to the range of results from the sensitivity to the spatial patterns. The estimate of the upper end of the plausible range was taken to be 8,000 m^3/s. This upper bound was adopted after particular consideration of the variation in the spatial patterns; the sensitivity to temporal patterns; and the 1974 peak flow results for the Somerset only then Somerset and Wivenhoe dams scenarios.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;

- better representation of dam operating procedures; and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

The following actions could be undertaken to further refine this analysis:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that accurately reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich City Council's MIKE 11 hydraulic model within the Brisbane City Council Boundary.

SKM

1. Introduction

1.1 Background

Sinclair Knight Merz prepared a flood study for the Brisbane River in 1998. Since this time, there have been changes to the information used in assessing the flood levels along the lower reaches of the Brisbane River. These include:

- CRC-FORGE rainfall estimates that have been prepared for the Brisbane River catchment (Department of Natural Resources and Mines, 2003a);
- Modifications to procedures for flood operations at Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, 1998) was completed; and
- Additional and/or revised flood flow data.

An Expert Panel was appointed by Brisbane City Council to review the flood studies undertaken for the Brisbane River in the light of this new information, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for Sinclair Knight Merz were to:

- Undertake statistical flood frequency analysis, and to
- Update the estimates of statistical flood frequency from rainfall-runoff modelling with the new information.

The details of the tasks that were agreed to are presented in **Appendix A**.

1.2 Scope of Report

This report addresses the tasks presented in **Appendix A**, namely to:

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations.
2) Undertake a regional and at-site statistical flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document the findings of the statistical flood frequency analysis, stating assumptions and outcomes.
4) Review previous reports, CRC-FORGE rainfall estimates and historical streamflow data.



5) Undertake a Regional Statistical Flood Frequency Analysis (pre-dams).
6) Undertake hydrologic modelling (pre-dams).
7) Undertake hydrologic modelling (dams in place).
8) Analyse catchment sensitivity using various temporal patterns and historical spatial patterns.
9) Undertake a sensitivity analysis of starting reservoir levels.
10) Perform hydraulic modelling to produce flood frequency estimates at Moggill and the Brisbane Port Office.
11) Report on the findings of the rainfall-runoff and hydraulic modelling.

2. Sources of Data for Statistical flood frequency Analysis

Gauging station data were obtained from the Department of Natural Resources and Mining (DNRM) and the Commonwealth Bureau of Meteorology (BoM). Different types of data were collected, including:

- recorded water elevation above the gauge datum;
- flow data estimated from a rating relationship; and
- rating tables.

In some instances the data were processed in some additional manner, as discussed below.

A number of reports on large flood events and the analysis thereof were made available.

2.1 Department of Natural Resources and Mining Data

There are two sources of data from DNRM:

- Recorded water elevation data and associated flow estimates
- Estimates of "no dams" flood peaks at Savages Crossing that had been adjusted to exclude the influence of the dam(s) where appropriate.

Both data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in **Appendix B** (along with other sources of gauged data). The primary reasons for omission were:

- short record length;
- small catchment area; and/or
- uncertainty in the rating curve.

The last reason included either very low gauged flow or the rating curve was changed by BoM to a "calibration curve" for use in real time flood forecasting.

Elevation data for a number of sites of direct interest to this study, such as Moggill, and the Brisbane Port Office were also obtained.

Appendix C shows the location of the stream gauges that were used in the statistical flood frequency analysis.

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3. Statistical flood frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analyse of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (i.e. peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in **Section 2**.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- Adjustment of data for the influence of the dams;
- Uncertainty in the rating curves that relate recorded river level to flow rate;
- The magnitude of historic data (especially 1893 and 1825);
- The period of record associated with the historic data;
- Choice of frequency distribution;
- Selection of parameters for the distribution; and
- Method of including historical data.

DNRM provided three series of data. The series are provided in **Appendix D**. The first was the "gauged flows at Savages Crossing" (1909-200). This was a composite series from Savages Crossing/Lowood/Vernor stations. The second series was for "both dams working" in which they made some adjustments that they considered appropriate for the effect on the flow rates if the dams had been in place for the entire period. The precise method for adjusting the data has not been detailed; the method as provided is included with the data series in **Appendix D**. The third series of data (1890 - 2000) was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had not existed over the entire period. Frequency analysis of this data was undertaken along with various unadjusted data.

The statistical frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 55% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by Assoc Prof George Kuczera in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto (GP) distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix E** and **Appendix F**.

The analyses undertaken to determine the "best" estimate from statistical flood frequency analysis and a plausible range is summarised in **Table 3-1**. FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets a Sinclair Knight Merz program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte-Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

The results of these analyses are recorded with selected frequency distributions in **Sections 3.3 - 3.6** and the results summarised in **Table 3-7**. As noted previously, this report has been prepared for expert reviewers with a high level of understanding. The explanations, comments and discussion are as concise as possible to enable the broad range of analyses to be succinctly presented for ease of comparison.

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- **Table 3-1 Summary of statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distribn	Prior Informn (regional)	Main Objective
Case 1 Pre -Wivenhoe and Somerset							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

GP = Generalised Pareto Distribution

LPIII = Log-Pearson III Distribution

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distribn	Prior Informn (regional)	Main Objective
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3 **"No Dams" based on DNRM adjusted estimates**							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by DNRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4 **"Dams" based on DNRM estimates**							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

GP = Generalised Parts Distribution

LPIII = Log-Pearson III Distribution

3.2 Regional Frequency Analysis

A regional statistical frequency analysis was conducted to assist in the estimation of statistical flood frequency at Savages Crossing (GS143001). The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 55% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane River catchment, including the site at Savages Crossing (GS143001). The Generalised Pareto probability distribution was selected for the statistical flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value;
- its prior standard deviation; and
- its correlation with other parameters.

The prior mean and standard deviation of the scale ( ) and shape ( ) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in **Table 3-2**.

- **Table 3-2 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001).**

Value	Scale parameter,	Shape parameter,
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

The Expert Panel was interested in understanding how the statistical flood frequency analysis results varied with the addition of dams to the catchment, the inclusion of various gauged and historical data and various statistical techniques. The analyses have been grouped into four cases as listed below.

Case 1. Analysis of pre-Somerset and pre-Wivenhoe data; data that was unaffected by Somerset and Wivenhoe dams were assessed. Data prior to 1951 were analysed.

Case 2. Analysis of pre-Wivenhoe data with no correction for Somerset dam; consideration given to all data as recorded or estimated with no attempt made to assess the effect of Somerset dam on the flow magnitudes.

Case 3. Analysis of "no dams" data as estimated by DNRM; the data set that contained the flows that DNRM estimate would have occurred in the absence of Somerset and Wivenhoe dams was assessed.

Case 4. Analysis of post-dam data estimated by DNRM; assessment of the data set that contained the flows that DNRM estimate would have occurred if Somerset and Wivenhoe dams were present for the entire period of record.

The individual analyses including the data, techniques, the objective and comments on the results of each analysis are included in **Table 3-3** to **Table 3-6** and summarised in **Table 3-7**. The effects on the statistical flood frequency curves of each of the analyses are shown in **Figures 3.1-3.7**.

Greater detail of the regional analyses is provided in **Appendix E** and **Appendix F**.

3.3 Case 1: Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the DNRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in **Table 3-3** with specific influence on curves plotted in **Figures 3.1–3.3** so that the influence of specific assumptions can be compared graphically.

SKM

- **Table 3-3 Summary of Case 1 statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative..
1C	1909-1951	1893 (Qp= 13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825 (Qp= 13200) 1893 (Qp= 13 200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)

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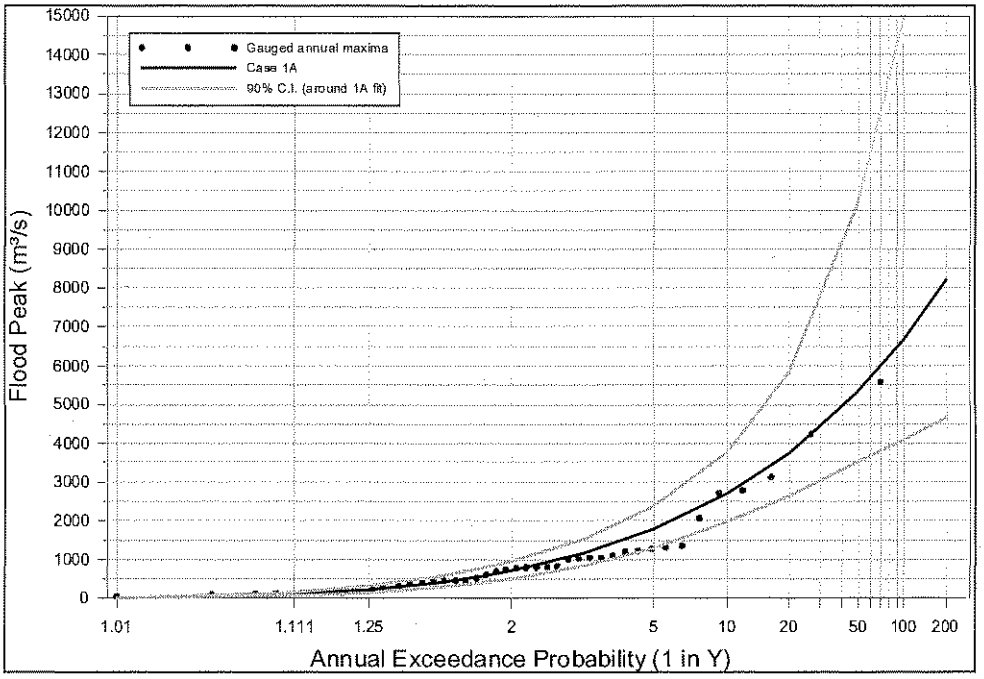
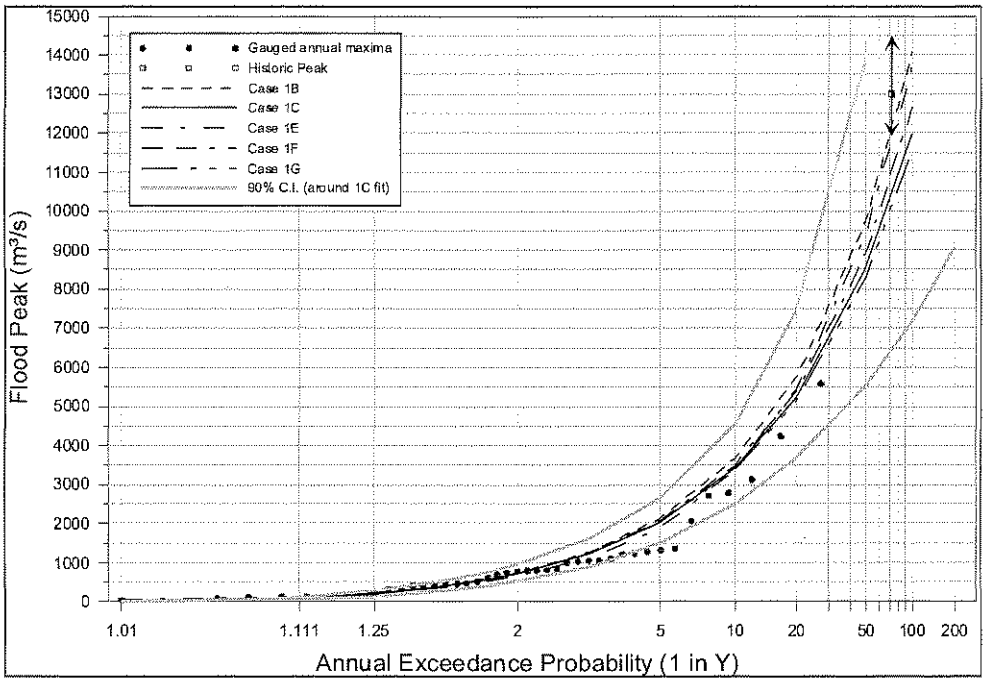
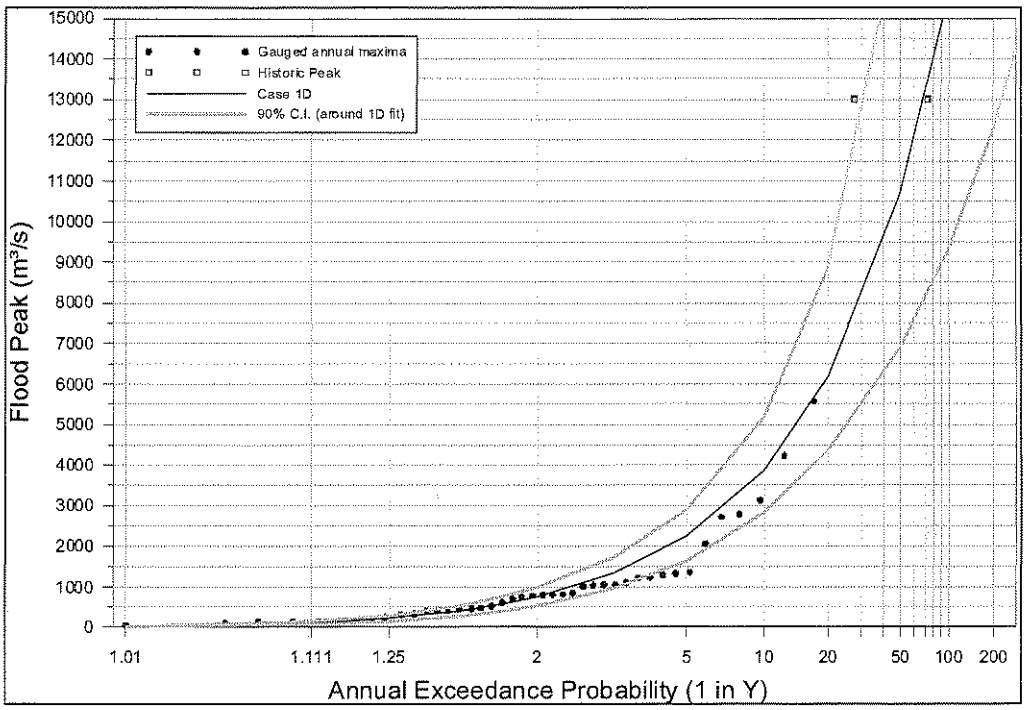
	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1F	1909-1951	1893 (Qp= 14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from BoM "not unreasonable" estimate of 1893 peak. (BoM 2003) Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp= 12 000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from BoM URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. (BoM 2003) Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp= 13 000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.



- **Figure 3-1 Generalised Pareto Distribution fitted to the 1909-1951 pre-dams data at Savages Crossing**



- **Figure 3-2 Comparisons of variations in statistical flood frequency for various assumptions on pre-dams data for Savages Crossing**



- **Figure 3-3 Assessment of the inclusion of a 1825 estimate of a flood possibly of the same magnitude as the 1893 event**

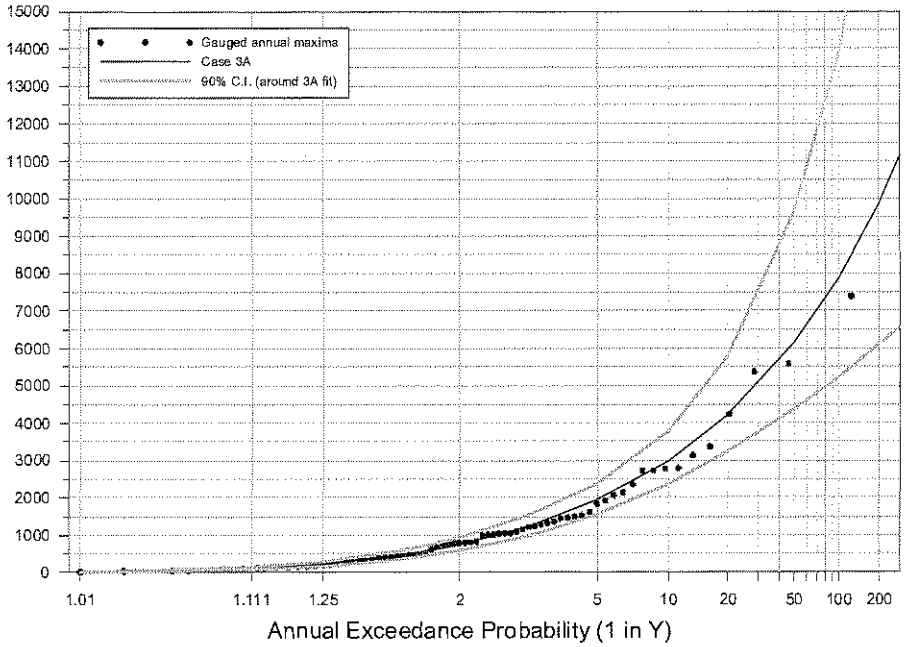
SKM

3.4 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

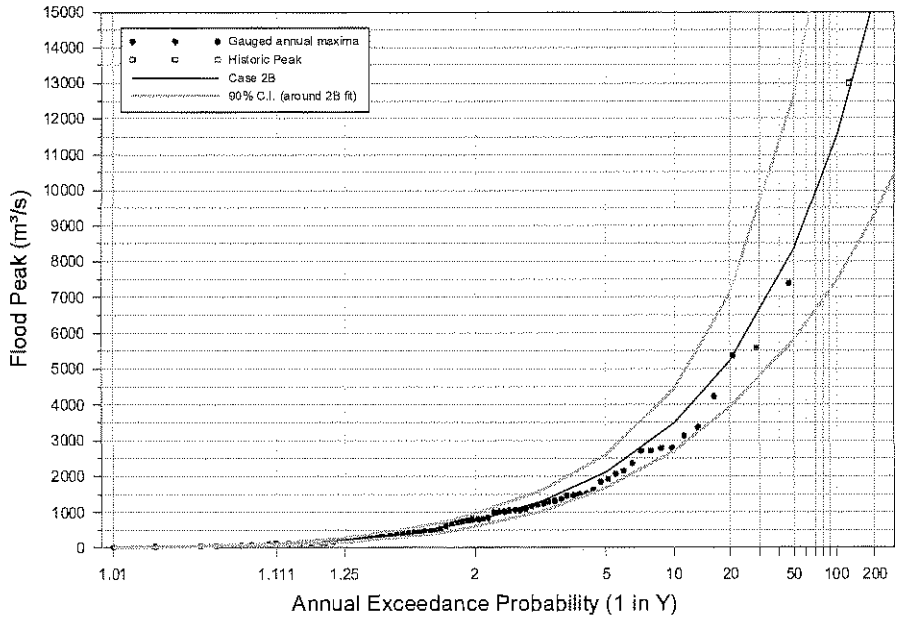
These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

- **Table 3-4 Summary of Case 1 statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.



- **Figure 3-4 Assessment of the pre-Wivenhoe gauged data without 1893 event**



- **Figure 3-5 Assessment of the pre-Wivenhoe gauged data with 1893 event**

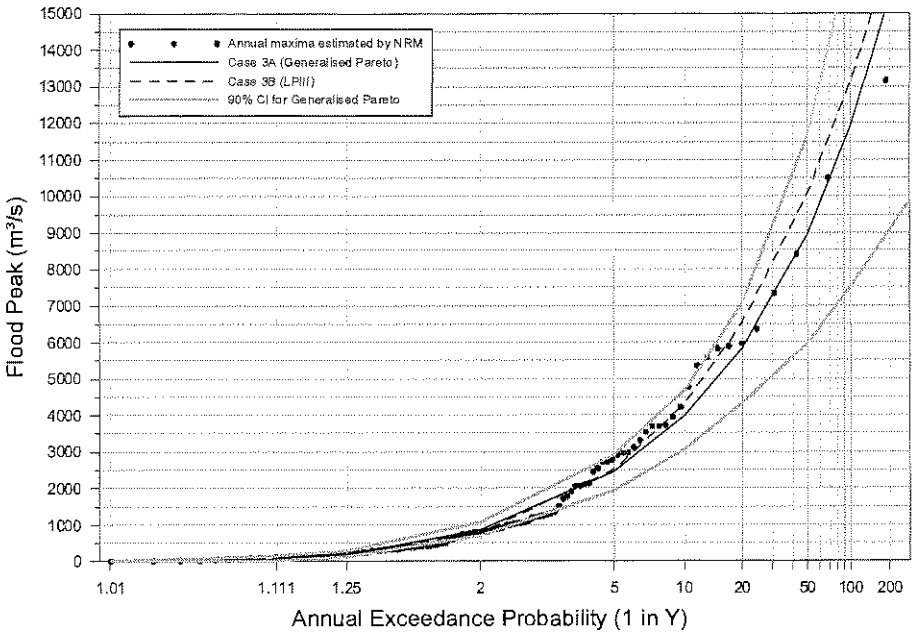
SKM

3.5 Case 3: Analysis of "No Dams" Data Estimated by DNRM

Note effect of Somerset dam is highly variable depending on its operation. DNRM has assessed the effect of Somerset dam on the flood data series. Sinclair Knight Merz has taken this series "as provided" and analysed the statistics.

- **Table 3-5 Summary of Case 3 statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.



- **Figure 3-6 Assessment of the "no –dams" annual maxima series provided by DNRM using both GP and LPIII distributions**

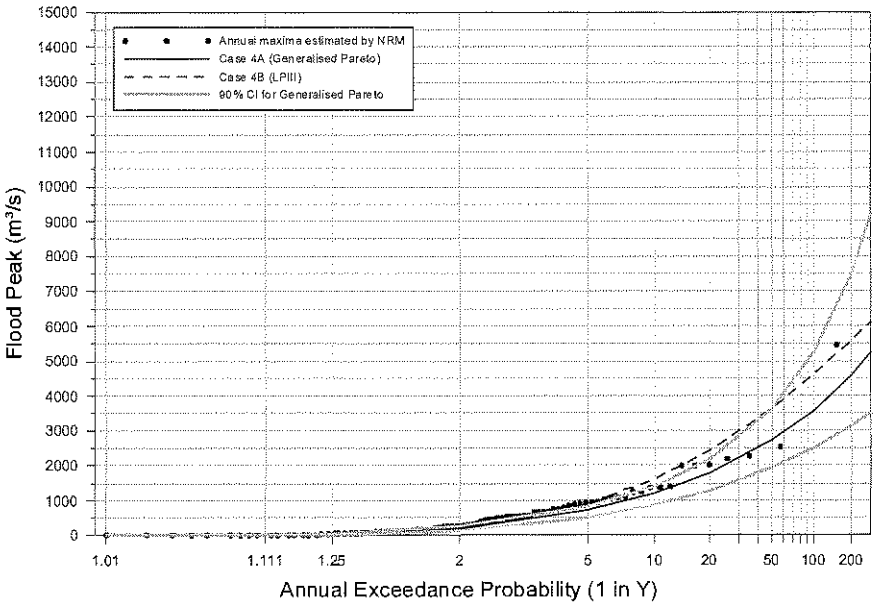
SKM

3.6 Case 4: Analysis of Post-Dam Data Estimated by DNRM

These analyses were based on the "post-dam" data set provided by DNRM. As noted in Section 3.4 the data has been taken and analysed on an "as provided" basis.

- **Table 3-6 Summary of Case 4: Post-dam Data - statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distbn	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 "Dams" based on DNRM estimates								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)



- **Figure 3-7 Assessment of the "post-dams" annual maxima series provided by DNRM using both GP and LPIII distributions.**

3.7 Summary of analysis results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) estimate at Savages Crossing. The analyses are summarised in **Table 3-7**. As noted above, the summary is intended to succinctly present the broad range of sensitivity analyses for expert reviewers who are familiar with the concepts, common discipline abbreviations and analysis methods.

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- **Table 3-7 Summary of statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from BoM "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.(BoM 2003)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from BoM URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. (BoM 2003) Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.
Case 2 Pre Wivenhoe, no adjustments made for Somerset								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.
Case 3 "No Dams" based on DNRM adjusted estimates								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.

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	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 "Dams" based on DNRM estimates								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to parallel SKM report on the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

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3.8 Best Estimates from statistical flood frequency assessment

Sinclair Knight Merz has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling reported in the subsequent chapters). The results are presented in **Table 3-8**.

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970 m^3/s)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), DNRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m^3/s); as no allowance made for Somerset dam, the pre dams Q100 could be expected to be higher than 11 500m^3/s.
- the "No dams" series from DNRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3AQ100 = 11,500 m^3/s).

- **Table 3-8 Most plausible estimates of the Pre dams Q100 peak flow at Savages Crossing**

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the statistical flood frequency assessment in the range of the Q100;
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scaree data on key event characteristics such as temporal pattern, losses, etc.). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty);

- choice of distribution and the appropriate parameters; and
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7,500 m^3/s and 11,000 m^3/s at Savages Crossing.

An additional assessment of the "current" scenario, i.e. with Somerset and Wivenhoe dams in place and operated using current operating procedures is also provided (Case 4 – refer **Section 3.6**). This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by DNRM. Note that an assessment of the plansible range for this estimate is not possible, as DNRM has not provided documentation for the method for adjusting the data series.

The lower bound of this range is based on assuming the reported flow from the actual event of 7,393 m^3/s as a lower bound estimate, which allows for the substantial uncertainty in the rating curve for the site. The higher bound is based on two sources: (i) report from BoM (August 2003) in which 10,800 m^3/s was estimated based on rainfall runoff routing and (ii) the DNRM assessment of 10,500 m^3/s for the "no dams" peak.

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4. Rainfall-Runoff Modelling

Rainfall-runoff modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS rainfall-runoff model developed for the Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) was used for this investigation. The Ipswich Rivers Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model prepared for Brisbane City Council.

4.1 Assumptions

- The Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM, 2003) Wivenhoe and Somerset Dam Operations Model was used to determine dam outflows.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows:

- Initial Loss Rate = 10 mm
- Continuing Loss Rate = 1.0 mm/h
- All model runs were undertaken for the 1 in 100 (1%) AEP flood event only.

4.2 Methodology

The following Methodology describes the process that was used to determine 1 in 100 AEP peak flows at Moggill and the Brisbane Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model.
- Input CRC-FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1 in 100 AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the DNRM Dam Operations Model.
- The DNRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the DNRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1 in 100 AEP flows at Savages Crossing, Moggill and the Brisbane Port Office Gauge.

- A sensitivity analysis was then performed using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wivenhoe and Somerset Dams at the start of the flood event.

4.3 Pre-dams RAFTS Modelling

The object of the pre-dams modelling was to compare statistical flood frequency estimates and the flow estimates produced by RAFTS. Good agreement between the flow estimates resulting from the statistical FFA and RAFTS provides a robust flood flow estimate. CRC-FORGE rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine the effects that temporal patterns have on variation of peak flows.

4.3.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

CRC-FORGE rainfall estimates for varying durations were input into the model with Areal Reduction Factors (ARF) applied (Department of Natural Resources and Mines, 2003a). **Table 4-1** presents the rainfalls depths and adjusted rainfall depths (ARF's applied) used in the RAFTS model.

- **Table 4-1 CRC-FORGE Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP**

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC-FORGE Rainfall	247	268	285	317	358	385	402
CRC-FORGE Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC-FORGE rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in **Appendix G**. Standard temporal patterns (ARR 1987) were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continning Loss of 1.0 mm/h was adopted.

The peak flows for Savages Crossing using the CRC-FORGE rainfall estimates with ARF's applied are presented in **Table 4-2**.

Table 4-2 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1 in 100 AEP Flood – Pre-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Brisbane Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.3.2 Sensitivity to Spatial Pattern of Rainfall

To determine the impact spatial patterns have on peak flows, seven historical spatial patterns were used. These spatial patterns were selected as they were significant flood events and data were readily available. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC-FORGE Rainfall Depths (ARF applied) for each duration.

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane River and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane River Catchment.
- April 1996 - high rainfalls in the Lockyer and Lower Brisbane River Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in **Appendix G**.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h was applied.

Peak flows are presented in **Table 4-3**. Note that for all spatial distributions the 30 hour rainfall duration is the critical duration storm at Savages Crossing and the 72 hour flood is the critical

duration at Moggill and Brisbane Port Office. Flows presented at Moggill and the Brisbane Port Office in **Table 4-3** should be considered indicative only. More reliable estimates of design floods at the lower gauges are produced by the hydraulic model, as discussed in **Chapter 5**.

- **Table 4-3 Pre- dams Peak Flows for 1 in 100 AEP Rainfall and Historical Spatial Distributions**

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Brisbane Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: - Bold values indicate the median flow at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

A full listing of peak flow rates at Savages Crossing, Moggill and Brisbane Port Office are present in **Appendix H**.

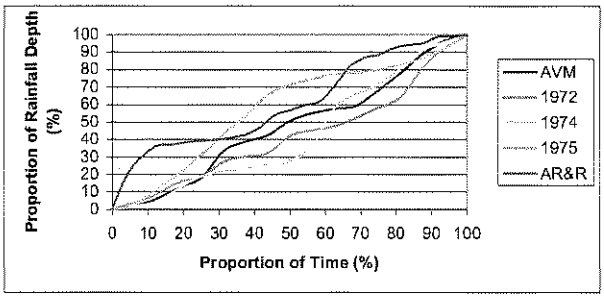
4.3.3 Sensitivity to Temporal Pattern of Rainfall

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC-FORGE Rainfall 48 hour storm duration. An Initial Loss of 0 mm and a Continuing Loss of 0 mm/h was applied.

The temporal patterns that were used in the sensitivity analysis were:

- AVM – Average Variability Method; **[MARK PEARSE TO SUPPLY INFORMATION]**
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event;
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event;
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event; and
- AR&R 1987 – Standard temporal pattern outlined in Australian Rainfall and Runoff.

These temporal patterns are shown in **Figure 4-1**.



- **Figure 4-1 Temporal Patterns for the 1% AEP 48 Hour Storm Event**

The resulting peak flow estimates using the temporal patterns described above are presented in **Table 4-4**.

- **Table 4-4 Sensitivity to Peak Flow to Temporal Pattern of Rainfall**

	48 hour Temporal Pattern				
Location	**AR&R (m^3/s)**	**AVM (m^3/s)**	**1972 (m^3/s)**	**1974 (m^3/s)**	**1975 (m^3/s)**
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Brisbane Port Office	12817	13464	13287	14115	13634

4.3.4 Discussion

Table 4-3 and **Table 4-4** show that spatial and temporal patterns have a significant effect on peak flows. The works undertaken show that by varying spatial and temporal patterns, the peak flow estimates at Savages Crossing can vary considerably. A Monte-Carlo analysis could be undertaken to improve the accuracy of the Q100 flow estimate and help to reduce the uncertainties arising from the work undertaken so far. The pre-dams historical spatial distributions produce peak flows at Savages Crossing that range from 11,500 m^3/s to 8,000 m^3/s with the median peak flow of 10,046 m^3/s. The estimated peak flow at Savages Crossing using the CRC-FORGE spatial pattern was estimated to be 9607 m^3/s.

If an Initial Loss of 0 mm and Continuing Loss of 0 mm/h is applied to the CRC-FORGE 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11,278 m^3/s. It should be noted that the 'best estimate' of peak flow at Savages Crossing from the Statistical flood frequency Analysis was estimated to be 12,000 m^3/s. This means that in order to

reconcile peak flow estimates between RAFTS and FFA, further work could be undertaken. These works would involve investigation of specific combinations of spatial and temporal patterns an application of acceptable loss rates to the RAFTS model. It is anticipated that this investigation would result in the reconciliation of flow estinates at Savages Crossing.

4.4 Comparison of Q100 estimates from statistical flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated Brisbane River Catchment RAFTS model
- CRC-FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

produced a Q100 at Savages Crossing of 11278 m³/s. It would be reasonable to expect some losses with a 1 in 100 AEP event and hence the hydrological modelling results, using typical design parameters, could be expected to be lower, say in the order of 10, 500m³/s.

The difference between the results and those from the statistical freqnency analysis of flood records (**Chapter 3**) indicates that there are underlying faetors that have not been adequately addressed to date. This would require more detailed assessment than is available in the scope and timing of the current assessment. Potential factors influencing the difference in Q100 estimates inclnde:

- potential for partial area storms
- variation in temporal patterns
- variation in spatial patterns
- variation in losses
- adjnstment of data for influence of dams
- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.

The development of a Monte-Carlo framework for analysing the factors affecting flood magnitude would enable the natural variation in the first four factors to be explicitly modelled. This would provide better insight necessary to understand the differences in the two methodologies.

4.5 Post-dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and rnn through the DNRM Dam Operations Model (Department of Natural Resources and Mines, 2003b). These inflows were based on the outputs presented in **Appendix H** and included an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/h.

The ontflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the hydrograph volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC-FORGE and historical spatial patterns to determine flows at Savages Crossing, Moggill and Brisbane Port Office.

4.5.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

The parameters described in **Section 4.3.1** were used for the Post-dams RAFTS modelling.

The CRC-FORGE rainfall estimates with ARF's applied are presented in **Table 4-5**.

- **Table 4-5 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for the 1 in 100 AEP Rainfall – Post-dams**

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	**5368**	2335	2502
Moggill	3017	3690	2999	3302	**5043**	3811	3990
Brisbane Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.5.2 Sensitivity to Spatial Pattern of Rainfall

The parameters described in **Section 4.3.2** were used for the Post-dams RAFTS modelling. Peak flows are presented in **Table 4-6**. Note that the critical duration storm at Savages Crossing, Moggill and Brisbane Port Office range from 72 to 120 hours for Post-dam Conditions. Flows presented at Moggill and the Brisbane Port Office in **Table 4-6** should be considered as indicative only. More accurate flows will be determined during the hydraulic modelling.

- **Table 4-6 Post-dams Peak Flows for the 1 in 100 AEP Rainfall and Historical Spatial Distributions**

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Brisbane Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: - (120hr) denotes the critical storm duration
- Bold values indicate the median flow at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.5.3 Sensitivity to Starting Water Level in Wivenhoe Dam

Wivenhoe Dam has 1,165 gigalitres (GL) of storage capacity for water supply purposes up to its full supply level of EL 67.0 m AHD (Australian Height Datum). A further 1,450 GL of storage capacity is available above the Full Supply Level, up to a level of EL 75.0 m AHD for the temporary storage of flood waters, i.e. the total capacity of Wivenhoe Dam is 2,615 GL. The flood storage is held empty, except when required, to store flood waters.

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1 IN 100 AEP flood (average CRC-FORGE rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in **Table 4-7**.

- **Table 4-7 Flood Runoff Volumes from the 1 in 100 AEP Rainfall Events above Wivenhoe Dam**

Storm Duration (hours)	CRC Rainfall Depth with ARF Applied (mm)	Runoff Volume (Gigalitres)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

Table 4-7 shows that if Wivenhoe Dam is at FSL, the 1 in 100 AEP 36-hour flood runoff volume can be fully stored between FSL and Crest Level without release. For 1 in 100 AEP events with

longer durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the crest level is over, topped (no releases).

Given the current operational procedures, it is unlikely that releases would not occur during a flood event, particularly if Wivenhoe Dam is at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs were done for the 1 in 100 AEP 72 hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in **Table 4-8**.

- **Table 4-8 Flows for Dam Starting Water Levels Sensitivity Analysis for the 1 in 100 AEP 72 Hour Storm**

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Brisbane Port Office	5044	4402	4402

Note: - Flows at Moggill and Brisbane Port Office should be considered indicative only.

Table 4-8 shows that the reduction in flow is approximately 13% at the Brisbane Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

4.5.4 1893 and 1974 Historical Flood Events

The information from the two historical flood events (1893 and 1974) were run through the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post-dam flows are presented in **Table 4-9**.

- **Table 4-9 Predicted Post-dam Flows for the 1893 and 1974 Historical Flood Events**

	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
Location	No Dams (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)	Somerset in Place (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Brisbane Port Office	13869	9519	9874	6801

Table 4-9 indicates that the peak flows for the historical events at the Brisbane Port Office are above the 1 in 100 AEP CRC-FORGE estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1974 peak flow estimate and even more with the 1893 event. However, it is clear from **Table 4-9** that the effect of the dams on events of such magnitude is significant. While flows predicted by the RAFTS model at the Brisbane Port Office are only indicative, they provide a reasonable estimate as calibration of this model has been undertaken. The most accurate way to assess flows at the Brisbane Port Office Gauge would be to use a hydraulic model.

4.5.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. Monte-Carlo analysis would be an appropriate way to investigate the complex interactions between dams and variations in losses, spatial and temporal patterns to obtain the best possible estimate of the 1 in 100 AEP flood event.

The CRC-FORGE spatially distributed peak flow at Savages Crossing was estimated to be 5,368 m^3/s for the post-dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow of 6,241 m^3/s.

Based on the preceding investigations, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 4-10** provides a range of estimates with a 'best estimate' upper estimate and lower estimate. Given the current information, the 'best estimate' of peak flow at the Brisbane Port Office would be 6500 m^3/s with an upper and lower limit of 8,000 m^3/s and 5,000 m^3/s respectively. While the estimates predicted by RAFTS at Moggill and the Brisbane Port Office should be considered indicative, previous modelling shows that flows predicted by RAFTS are consistent with flows predicted by the MIKE11 hydraulic model.

- **Table 4-10 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood with Dams**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The best estimate of 6,500 m^3/s was adopted after consideration of the RAFTS modelling for current design spatial pattern, various historical patterns and the performance of the model in reproducing flows at Savages Crossing for pre-dam flows. The estimate of the lower end of the plausible range of the Q100 estimate is 5,000 m^3/s. It was adopted with particular consideration to the range of results from the sensitivity to the spatial patterns. The estimate of the upper end of the plausible range was taken to be 8,500 m^3/s. This upper bound was adopted after particular consideration of the variation in the spatial patterns; the sensitivity to temporal patterns; and the 1974 peak flow results for the Somerset only then Somerset and Wivenhoe dams scenarios.

It should be noted that the predicted flow at the Brisbane Port Office Gange is 6,800 m3/s which is larger than the 'best estimate' 1 in 100 AEP event at the Brisbane Port Office (6,500 m3/s). This is primarily due to the 1974 spatial pattern (see **Appendix G**) where the majority of rainfall fell within the Lower Brisbane and Bremer River Catchment. For rainfall events where the majority of rainfall falls below the dams, the 1 in 100 AEP flow predicted in **Table 4-10** may be exceeded. This study did not investigate 100 year rainfalls being concentrated in the lower catchment (i.e. Below Wivenhoe dam). The 1974 flood event was a partial case however should a 100 year rainfall occur over the Lower Brisbane, Bremer and Lockyer catchments occur, flows at the Brisbane Port Office could be expected to be larger than the 1974 event. It was therefore considered appropriate to adopt an upper limit of 8,000 m^3/s.

A Monte-Carlo analysis would improve the accuracy of the 1 in 100 AEP flood event and reduce the uncertainty in the flood estimates.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flow estimates are:

- inclusion of the lower CRC-FORGE rainfall depths with areal reduction factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures (the previous study Sinclair Knight Merz 1998), assumed emergency operating procedures which minimised the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River);
- In the 1998 study, the emphasis was to match statistical flood frequency estimates at Moggill and the Brisbane Port Office. The reliability of the streamflow at Moggill and Brisbane Port Office is questionable as these gauges are river level gauges and tidal effects are difficult to account for at these locations. After discussions with DNRM, who have just developed a new composite flood series at Savages Crossing, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and statistical flood frequency



estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing, as discussed in **Chapter 3**; and

- inclusion of regional streamflow information in the statistical flood frequency analysis.

Rainfall-runoff modelling using a Monte Carlo framework could be undertaken to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This would improve the accuracy of the Q100 flood estimate and correctly reflect the combined influences of these stochastic factors. It would also reduce the uncertainty of the 1 in 100 AEP flood estimates.

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5. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Brisbane Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Brisbane Port Office is good, other sections of the reach within Brisbane City have not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Brisbane Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

5.1 Assumptions

- Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane River Bar.

5.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from approximately 10 km downstream of Savages Crossing to the Brisbane River Bar. The model also includes Bremer River and other smaller tributaries which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1 in 100 AEP spatially distributed over the catchment. Rainfall durations ranging from 24 to 120 hours were assessed.

5.3 Results

The peak flow rates and flood levels for at Moggill and Brisbane Port Office are presented in **Table 5-1**.

- **Table 5-1 Peak Flood Levels and Flows for the 1 in 100 AEP CRC-FORGE Spatial Distributed Rainfall**

	Moggill		Brisbane Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

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5.4 Discussion

Table 4-5 and **Table 5-1** show that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Brisbane Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Brisbane Port Office.

Using the 'best estimate and upper and lower limits of peak flows at the Brisbane Port Office presented in **Section 4.5.5**, a rating curve was used to predict flood levels at the Brisbane Port Office for the 1 in 100 AEP flood event. Peak flood levels and corresponding flows are presented in **Table 5-2**.

- **Table 5-2 Peak Flood Level and Peak Flow Estimates for the 1 in 100 AEP Flood Event at Brisbane Port Office**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

Note that these estimates should be considered indicative because the tide level variation during flood events may vary. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918 m AHD) at the Brisbane River Bar.

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6. Conclusions

Detailed investigations have been undertaken to assist the Expert Review Panel to assess the likelihood of floods in the lower reaches of the Brisbane River. The assistance has been centred on the two tasks of:

- nndertaking statistical flood frequency analysis, and
- updating thc estimates of statistical flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing thc plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

Statistical flood frequency Analysis

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frcquency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (i.e. the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequeney analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. at Savages Crossing 55% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in **Table 6-1**.

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- **Table 6-1 Most plausible estimates of the Q100 peak flow at Savages Crossing based on statistical flood frequency analysis**

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12,000	10,000	14,000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the significant sources of uncertainty in the recorded data, length of record, choice of distribution and adjustment of the data for the effect of the dams. As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7,500 m^3/s and 11,000 m^3/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method that SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, losses (e.g. the soil, interception by vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels behind the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increasing catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows were determined at Savages Crossing and these varied between 8,000 m^3/s and 11,500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10,000 m^3/s using an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h. This compares to the statistical frequency estimate (i.e. analysis of recorded flow data) of 12,000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3,000 m^3/s to 8,000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6,200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12,000 m^3/s and 13,800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken for variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing and the Brisbane Port Office was estimated to be 5,400 m^3/s and 5,000 m^3/s respectively. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing and the Brisbane Port Office was reduced to 3,500 m^3/s and 4,400 m^3/s respectively.

Q100 estimate at the Brisbane Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Brisbane Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Brisbane Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Brisbane Port Office.

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A rating curve from the hydraulic model was used to predict flood levels at the Brisbane Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 6-2** provides a range of estimates with a 'best estimate' upper estimate and lower estimate.

- **Table 6-2 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;
- better representation of dam operating procedures; and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

To reduce the uncertainty in the above estimates, the following actions would serve to increase the accuracy of the 1 in 100 AEP flow estimates.

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that correctly reflect the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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7. References

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane River flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site statistical flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the Statistical flood frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the Statistical flood freqnency Analysis Outcomes.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC-FORGE Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 1 in 100 AEP event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previons milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the DNRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine the 1 in 100 AEP flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long-term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQWB and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of



sophistication appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.

Appendix B Flow Gauging Stations Omitted from Consideration

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143222A	Atkinson Dam	Atkinson Creek Outlet		20	Small catchment area, offstream storage	DNRM
143234A	Atkinson Dam Hea			6	Small catchment area, offstream storage	DNRM
143228A	Bill Gunn Dam	Lake Dyer	3	18	Catchment area too small	DNRM
143027A	Blunder Creek	King Avenue Bridge	31	8	Urban creek in Brisbane area, Small catchment	DNRM
2121	Blunder Creek	King Ave- Durack		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1594	Breakfast Creek	Opposite Newstead House		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1579	Breakfast Creek	Sedgley Park Retention Basin- New Market		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1525	Breakfast Creek	Opposite Mann Park- Bowen Hills		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143104B	Bremer River	Rosevale	67	21	Catchment area too small	DNRM
143104A	Bremer River	Rosevale	77	34	Catchment area too small	DNRM
143110A	Bremer River	Adams Bridge	125	35	Catchment area too small	DNRM
143940	Bremer River	Stokes Crossing	180	21	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143909	Bremer River	Rosewood	543		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143833	Bremer River	Rosewood Alert	543	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143908	Bremer River	Rosewood TM	543	25	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143934	Bremer River	Walloon Bvrt	585		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143805	Bremer River	Walloon Alert-P	585	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143911	Bremer River	Ipswich	1850		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143956	Bremer River	Three Mile Bridge Alert	1870		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143954	Bremer River	Ipswich Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143953	Bremer River	One Mile Bridge Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143852	Bremer River	Brassall(Hancocks Br) Al		5	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143115A	Bremer River	Berry's Lagoon		9	Record length too short	DNRM
143944	Brisbane River	Linville	2005	47	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143007A	Brisbane River	Linville	2009	39	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143831	Brisbane River	Devon Hills Alert	2160	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143922	Brisbane River	Devon Hills Bvrt	2190		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143002A	Brisbane River	Plainlands	3950	12	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143002B	Brisbane River	Fulham Vale	3950	34	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143005A	Brisbane River	Watts Bridge	4602	20	Record length too short	DNRM
143008A	Brisbane River	Middle Creek	6704	20	Record length too short	DNRM
143026A	Brisbane River	Wivenhoe	7023	3	Record length too short	DNRM
143036A	Brisbane River	Wivenhoe Headwater	7023	17	Record length too short	DNRM
143035A	Brisbane River	Wivenhoe Tailwater	7023	17	Record length too short	DNRM
143907	Brisbane River	Lowood	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143941	Brisbane River	Lowood Bvrt	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143827	Brisbane River	Lowood Alert-P	10062	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143916	Brisbane River	Mt Crosby	10600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143839	Brisbane River	Mt Crosby Alert	10600	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143925	Brisbane River	Mt Crosby TM	10600	28	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143951	Brisbane River	Moggill Alert	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143915	Brisbane River	Moggill Bvrt	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143924	Brisbane River	Moggill TM	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143900	Brisbane River	Caboonbah			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143914	Brisbane River	Gregor Creek			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143920	Brisbane River	Gregor Creek Bvrt			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143902	Brisbane River	Murrumba			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143005	Brisbane River	Watts Bridge			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143903	Brisbane River	Wivenhoe			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143018A	Brisbane River	Avoca Vale	1498	20	Record length too short (post Wivenhoe)	DNRM
143868	Brisbane River	Colleges Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143918	Brisbane River Estuary	Bishop Island			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143217A	Buaraba Creek	Vineyard	63	10	Catchment area too small	DNRM
143211A	Buaraba Creek	15.8km	251	12	Catchment area too small	DNRM
143224A	Buaraba Creek	Diversion Channel		19	Catchment area too small	DNRM
143094A	Bulimba Creek	Mansfield	57	26	Urban creek in Brisbane area, Small catchment	DNRM
143004A	Bulimba Creek	Belmont	51	22	Urban creek in Brisbane area, Small catchment	DNRM
1591	Bulimba Creek	End of Aquarium Ave. Hemmant		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1528	Bulimba Creek	Doughboy Pde- Hemmant		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1804	Bulimba Creek	Greenwood St- Wishart		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1831	Bulimba Creek	Merion Pl- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1707	Bulimba Creek	Old Cleveland Rd- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143926	Bundamba Creek	Ripley Alert	35		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143959	Bundamba Creek	Harding Street Alert	96		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143958	Bundamba Creek	Blackstone Bridge Alert	97	10	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143955	Bundamba Creek	Bundamba School Alert	102		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143854	Bundamba Creek	Bundamba (Hanlon St) Al	109	7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143114A	Bundamba Creek	Mary Street	110	11	Urban creek in Ipswich area, Small catchment	DNRM
143307A	Byron Creek	Causeway	79	28	Catchment area too small	DNRM
143012A	Cooyar Creek	51.5km.	443	4	Record length too short	DNRM
143015B	Cooyar Creek	Damsite	963	13	Record length too short	DNRM
143015A	Cooyar Creek	Damsite	963	22	Record length too short	DNRM
143013A	Cressbrook Creek	The Damsite	321	16	Record length too short	DNRM
143952	Cressbrook Creek	Rosentreters Bridge	440		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143921A	Cressbrook Creek	Rosentreters Bridge	447	17	Record length too short	DNRM
143921	Cressbrook Creek	Rosentreters Bridge TM	477		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143806	Cressbrook Creek	Rosentreters Bridge AI	477	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143857	Deebing Creek	Churchill Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143021A	Ekibin Creek	Dudley Street	13	1	Urban creek in Brisbane area, Small catchment	DNRM
143011A	Emu Creek	Raeburn	439	24	Catchment area too small	DNRM
143010A	Emu Creek	Boat Mountain	915	11	Catchment area too small	DNRM
143010B	Emu Creek	Boat Mountain	915	27	Catchment area too small	DNRM
143932A	Enoggera Creek	Bancroft Park	70	10	Urban creek in Brisbane area, Small catchment	DNRM
143932	Enoggera Creek	Bancroft Park TM	67		Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1531	Enoggera Creek	100 M U/S From Original E e529		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1532	Enoggera Creek	Enoggera Dam- The Gap		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1529	Enoggera Creek	Kelvin Grove Rd- Kelvin Grove		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143208A	Fifteen Mile Creek	Dam Site	87	33	Catchment area too small	DNRM
143214A	Flagstone Creek	Windolfs	142	14	Catchment area too small	DNRM
143233A	Flagstone Creek	Brown-Zirbels Road		10	Catchment area too small	DNRM
1717	Gold Creek	Reservoir- Brookfield (Brisbane Water)			Urban creek in Brisbane area, Small catchment	South East Queensland Water
143028A	Ithaca Creek	Jason Street	10	31	Urban creek in Brisbane area, Small catchment	DNRM
1535	Ithaca Creek	Jason St- Ithaca		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143304A	Kilcoy Creek	Mount Kilcoy	127	36	Catchment area too small	DNRM
143304B	Kilcoy Creek	Mount Kilcoy Weir	131	15	Catchment area too small	DNRM
143235A	Lake Clarendon Head			6	Offstream storage	DNRM
143215A	Laidley Creek	Mulgowie Weir	154	14	Catchment area too small	DNRM
143209A	Laidley Creek	Mulgowie1	167	5	Catchment area too small	DNRM
143209B	Laidley Creek	Mulgowie2	167	36	Catchment area too small	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143225A	Laidley Creek	Showgrounds Weir Head Water	233	19	Catchment area too small	DNRM
143226A	Laidley Creek	Showgrounds Weir Tail Water	233	19	Catchment area too small	DNRM
143943	Laidley Creek	Laidley	285		Catchment area too small	BoM, Queensland Regional Office
143923	Laidley Creek	Thornton			Catchment area too small	BoM, Queensland Regional Office
143229A	Laidley Creek	Warrego Highway		13	Catchment area too small	DNRM
143202A	Lockyer Creek	Russell Siding	271	7	Catchment covered by other gauges DS	DNRM
143203C	Lockyer Creek	Helidon Number 3	357	16	Catchment covered by other gauges DS	DNRM
143203A	Lockyer Creek	Helidon	357	45	Catchment covered by other gauges DS	DNRM
143203B	Lockyer Creek	Helidon No.2	382	24	Catchment covered by other gauges DS	DNRM
143904	Lockyer Creek	Gatton	1550		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143204A	Lockyer Creek	Wilsons Weir	1655	29	Catchment covered by other gauges DS	DNRM
143905	Lockyer Creek	Glenore Grove	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143906	Lockyer Creek	Glenore Grove Bvrt	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143807	Lockyer Creek	Glenore Grove Alert	2230	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143206A	Lockyer Creek	Brightview Weir	2393	20	Catchment covered by other gauges DS	DNRM
143201A	Lockyer Creek	Tarampa	2405	17	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143201B	Lockyer Creek	Tarampa Number 2	2405	22	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143917	Lockyer Creek	Lyons Bridge	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143913	Lockyer Creek	Lyons Bridge Bvrt	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143819	Lockyer Creek	Lyons Bridge Alert-P	2530	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143227A	Lockyer Creek	O'Reilly's Weir Tailwater	2965	5	Record length too short	DNRM
2142	Lota Creek	Rickertt Rd Ransome		4	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143213B	Ma Ma Creek	Ma Ma Weir	226	9	Catchment area too small	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143213A	Ma Ma Creek	Harms	227	4	Catchment area too small	DNRM
143213C	Ma Ma Creek	Harm's		8	Catchment area too small	DNRM
143032A	Moggill Creek	Upper Brookfield	23	27	Urban creek in Brisbane area, Small catchment	DNRM
143020A	Moggill Creek	Misty Morn	61	9	Urban creek in Brisbane area, Small catchment	DNRM
143020	Moggill Creek	Misty Morn TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1722	Moggill Creek	Fortrose St- Kenmore		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2143	Moolabin Creek	Brisbane River Golf Club- Tennyson		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143219A	Murphys Creek	Spring Bluff	18	24	Urban creek in Brisbane area, Small catchment	DNRM
1549	Norman Creek	Joachim St- Holland Park West		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1552	Norman Creek	South East Freeway- Greenslopes		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1555	Norman Creek	Caswell St- East Brisbane River		10	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143033A	Oxley Creek	New Beith	60	27	Urban creek in Brisbane area, Small catchment	DNRM
143019A	Oxley Creek	Upstream Beatty Road	152	3	Urban creek in Brisbane area, Small catchment	DNRM
143019B	Oxley Creek	Downstream Beatty Road	152	6	Urban creek in Brisbane area, Small catchment	DNRM
143019	Oxley Creek	Beatty Road TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1588	Oxley Creek	Mouth of Oxley Creek		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1727	Oxley Creek	New Beith (DNR)+F31		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2023	Oxley Creek	Corinda High School- Corinda		12	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2125	Oxley Creek	Beatty Rd- Acacia Ridge		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2111	Oxley Creek	Johnson Rd- Forestdale		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143024A	Pullen Pullen Creek	Moggill Road	27	4	Urban creek in Brisbane area, Small catchment	DNRM
1745	Pullen Pullen Creek	Pinjarra Rd- Pinjarra Hills		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143983	Purga Creek	Loamside Alert	215	8	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143113A	Purga Creek	Loamside	215	30	Catchment area too small	DNRM
143869	Purga Creek	Peak Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143218A	Redbank Creek	Holcomb	55	8	Urban creek in Ipswich area, Small catchment	DNRM
143216A	Redbank Creek	Water Treatment Works	60	11	Urban creek in Ipswich area, Small catchment	DNRM
143231A	Redbank Creek	Clarendon Number 2		10	Urban creek in Ipswich area, Small catchment	DNRM
143230A	Redbank Creek	Clarendon Pump Station		10	Urban creek in Ipswich area, Small catchment	DNRM
143306A	Reedy Creek	Upstream Byron Creek Junct	56	28	Catchment area too small	DNRM
143103A	Reynolds Creek	Moogerah	190	37	Catchment area too small	DNRM
143103B	Reynolds Creek	Moogerah	190	6	Catchment area too small	DNRM
143111A	Reynolds Creek	Moogerah Dam Headwater	226	36	Head gauge affected by dam site	DNRM
143112A	Reynolds Creek	Moogerah Tailwater	227	23	Tail gauge affected by dam site	DNRM
143220A	Sandy Creek	Forest Hill	102	7	Urban creek in Brisbane area, Small catchment	DNRM
143232A	Sandy Creek	Forest Hill		8	Urban creek in Brisbane area, Small catchment	DNRM
143030A	Sandy Creek	Indooroopilly		22	Urban creek in Brisbane area, Small catchment	DNRM
143223A	Seven Mile Lagoon	Diversion Channel		20	Diversion channel	DNRM
143023A	Small Catchment	Algester	1	4	Urban creek in Brisbane area, Small catchment	DNRM
143022A	Stable Swamp Creek	Interstate Railway	19	11	Urban creek in Brisbane area, Small catchment	DNRM
2129	Stable Swamp Creek	Musgrave Rd- Coopers Plains		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143303A	Stanley River	Peachester	104	76	Catchment area too small	DNRM
143938	Stanley River	Woodford TM	220		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143829	Stanley River	Woodford Alert-P	220	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143901	Stanley River	Woodford	250		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143301B	Stanley River	Donnelly Dell	1227	4	Record length too short	DNRM
143301A	Stanley River	Hazeldean	1242	3	Record length too short	DNRM
143305	Stanley River	Somerset Dam	1330		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143818	Stanley River	Somerset Dam Hw Alert-B	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Why data was not used in statistical flood frequency analysis	Data Provider
143817	Stanley River	Somerset Dam Hw Alert-P	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143305A	Stanley River	Somerset Dam	1336	24	Head gauge affected by dam site	DNRM
143302A	Stanley River	Silverton	1339	49	Data obtained, but uncertainty as to appropriate rating	DNRM
143960	Stanley River	Peachester			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143212A	Tenthill Creek	Tenthill	447	35	Catchment area too small	DNRM
143106A	Warrill Creek	Aratula Weir	122	7	Catchment covered by other gauges DS	DNRM
143102A	Warrill Creek	Kalbar No.1	465	46	Catchment covered by other gauges DS	DNRM
143102B	Warrill Creek	Kalbar No.2	468	13	Catchment covered by other gauges DS	DNRM
143937	Warrill Creek	Kalbar	470		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143910	Warrill Creek	Harrisville	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143912	Warrill Creek	Harrisville TM	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143101A	Warrill Creek	Mutdapily	771	43	Catchment covered by other gauges DS	DNRM
143825	Warrill Creek	Amberley Alert-P	850	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143933	Warrill Creek	Amberley Bvrt	862		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143117A	Warrill Creek	Junction Weir H/W		5	Record length too short	DNRM
143118A	Warrill Creek	Junction Weir Tailwater		6	Record length too short	DNRM
143116A	Warrill Creek	Toohill's Crossing		6	Record length too short	DNRM
143105A	Warrill Creek East	Churchbank Weir	149	50	Catchment covered by other gauges DS	DNRM
143031A	Water St. Drain	Exhibition Ground		5	Urban creek in Brisbane area, Small catchment	DNRM
143939	Western Creek	Kuss Road	200	21	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
143861	Western Creek	Grandchester Alert		4	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1583	Wolston Creek	700m U/S Wacol Station Rd- Wacol		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143962	Woogaroo Creek	Brisbane River Road Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143927	Woogaroo Creek	Opossum Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143961	Woogaroo Creek	Alice Street Alert		7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

Appendix C Location of select stream gauges

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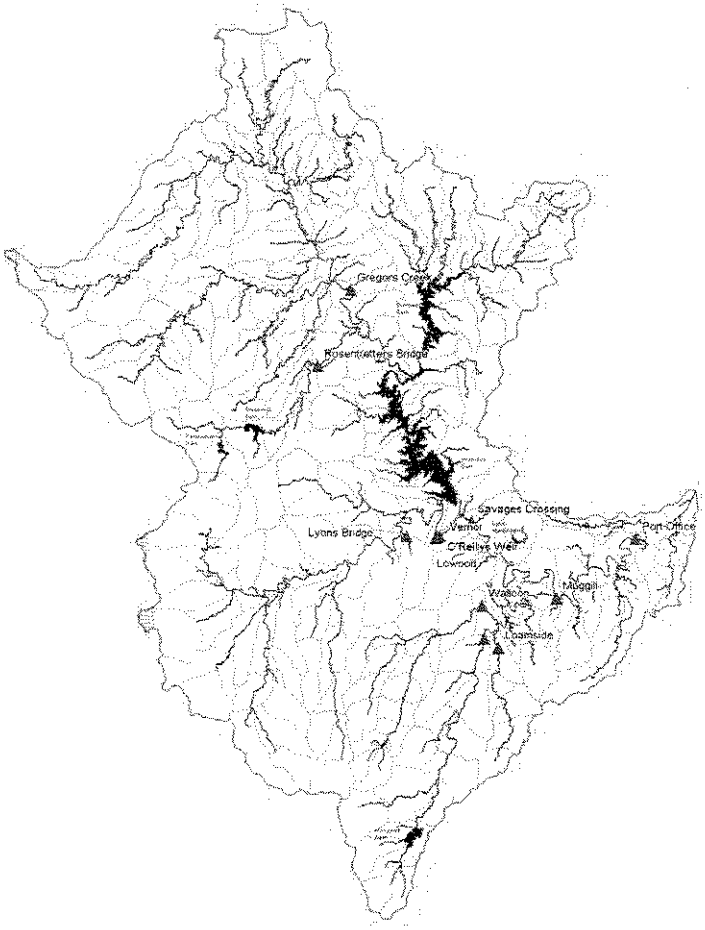
- **Location of stream gauge sites that were used in statistical flood frequency analysis**



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Appendix D Flood Data Series for Savages Crossing from DNRM

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	Gauged flow at Savages Crossing/Lowood Recorded Values	No Dams	Both Dams Working	Date*	
11/03/1890		7343			* Peak occurred at a different time according to operational rules in with dams case
09/06/1891		1790			
04/04/1892		3953			Generated using IQQM model of catchment with calibrated 6 six hourly disaggregation.
03/02/1893		13156			
21/04/1894		1060			Gauged Flow at Savages Crossing/Lowood/Vernor
26/01/1895		1194			
12/02/1896		3699			Gauged Flows affected by Somerset
02/03/1897		432			
11/01/1898		5889			Gauged flows affect by Somerset and Wivenhoe
30/01/1899		211			
23/05/1900		313			Flows adjusted to remove the impact of Somerset removed.
21/03/1901		885			
15/10/1901		142			Flows adjusted to remove the effect of Somerset and Wivenhoe
1/06/1903		1717			
18/04/1904		351			Flows routed through WIVOPS program using inflows into Somerset and Wivenhoe.
19/01/1905		816			
14/03/1906		745			
1/06/1907		302			
15/03/1908		6356			
17/07/1909		325			
28/12/1909	814	814	501	16/01/1910	
13/01/1911	1317	1317	535		
4/03/1912	461	461	251	25/06/1912	
23/06/1913	416	416	133		
27/02/1914	234	234	8		
11/02/1915	1035	1035	51		
12/04/1916	159	159	60		
29/01/1917	475	475	93		
13/12/1917	522	522	386		
8/05/1919	91	91	8		
22/01/1920	402	402	8		
11/06/1921	1237	1237	260		
30/12/1921	1280	1280	745		
16/10/1922	46	46	8		
12/02/1924	173	173	125		
21/06/1925	778	778	111		
6/01/1926	126	126	73		
27/01/1927	2715	2715	1029		
20/04/1928	4225	4225	927		
21/01/1929	2064	2064	682	4/04/1929	
30/06/1930	749	749	332	1/06/1930	
6/02/1931	5575	5575	1114		
10/12/1931	328	328	257		
20/01/1933	312	312	300		
23/02/1934	614	614	241	6/01/1934	
26/02/1935	120	120	38	18/01/1935	
24/03/1936	139	139	8		
17/03/1937	1103	1103	527		
28/05/1938	1052	1052	218		
17/03/1939	460	460	251		
3/03/1940	697	697	106		
25/01/1941	425	425	291		
10/02/1942	1360	1360	557		
31/12/1942	833	833	529		
31/12/1943	1208	1208	461		
13/06/1945	140	140	140		
26/03/1946	1052	1052	484	23/01/1946	
2/03/1947	803	803	270		
11/12/1947	796	796	796		
4/03/1949	1013	1013	542		
1/03/1950	2788	2788	2530		
1/02/1951	3125	3125	2270		
18/06/1952	18	18	8		
24/03/1953	1002	1002	76		
14/07/1954	1922	1922	1091	13/02/1954	
30/03/1955	5363	5363	667		
12/03/1956	2141	2141	890		
23/12/1956	214	214	61		
11/06/1958	1520	1520	922		
19/02/1959	1494	2550	1234		
14/11/1959	1451	2730	656		

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Appendix E Regional Statistical flood frequency Information

E.1 Introduction

The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (eg. at Savages Crossing 55% of the peak flows lie beyond the maximum rating) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Brisbane Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

E.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in **Section 2.2** only DNRM gauge flow data were both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in **Table E.1**.

The location of the gauges can be seen in the catchment map in **Appendix C**.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in **Table E.1** were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in **Section E.3**.

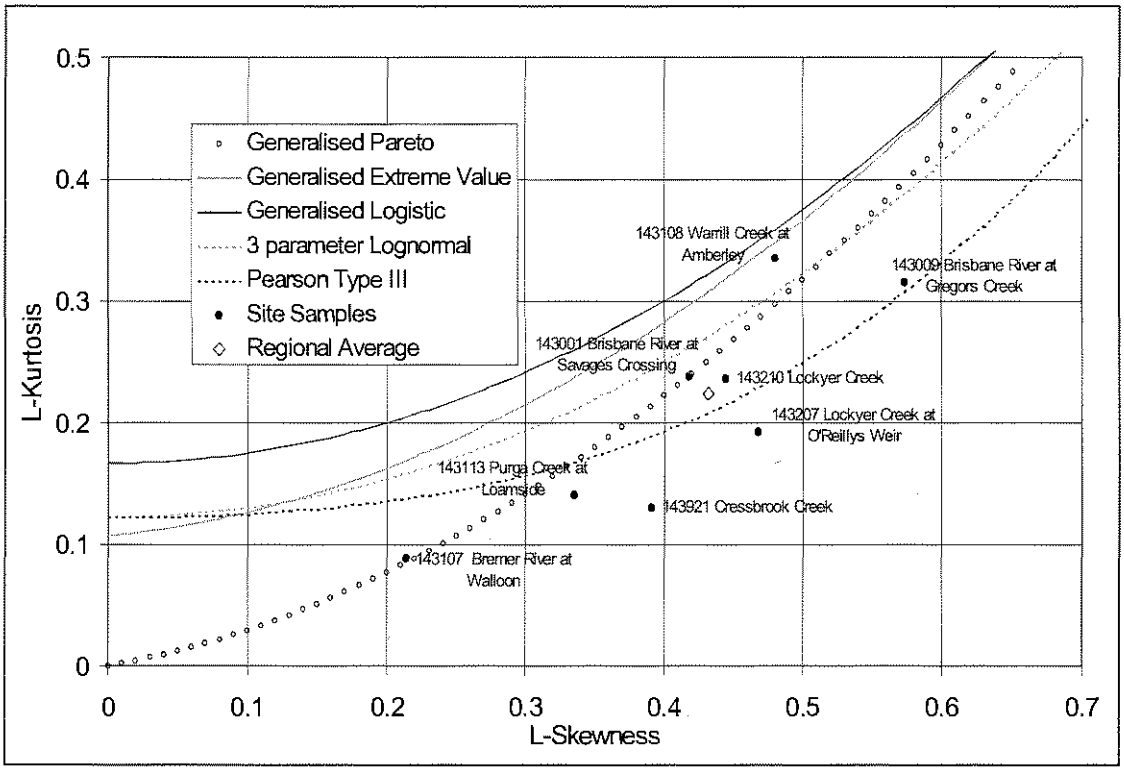
- **Table E.1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods**

River	Station Name	Station Number	Years of Record	C'ment Area (km^2)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

E.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in **Table E.1**. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. **Figure E.1** shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (e.g. Peel et al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

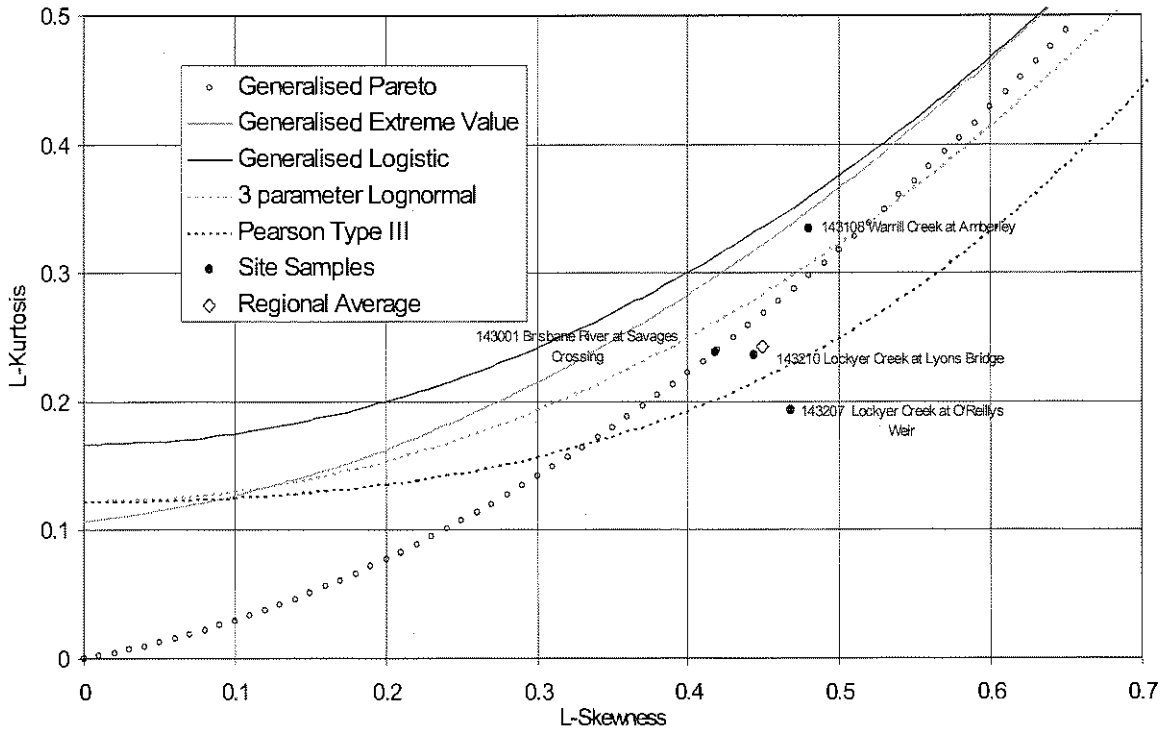
Also shown on **Figure E.1** is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that Bremer River @Walloon (143107A) and Brisbane @ Gregor's Creek (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (**Appendix F**) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.



- **Figure E.1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment**

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500 km^2), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (**Figure E.2**) supports the adoption of the Generalised Pareto distribution.



- **Figure E.2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)**

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in **Table E.2**.

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- **Table E.2 Regional parameter values of the adopted Generalised Pareto distribution**

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter,	-0.062	-0.096
Scale parameter,	0.811	0.795
Shape parameter,	-0.230	-0.275

E.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the statistical flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value;
- its prior standard deviation; and
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale ( ) and shape ( ) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of **Table E.2**. The scale parameter ( ) from the regional analysis shown in **Table E.2** is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\hat{\alpha}_{143001} = L^1_{143001}\alpha^{CV}_{\text{Regional}} = 1181 \times 0.795 = 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in **Table E.3**. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\sigma_{\alpha,143001} = L^1_{143001}\sigma^{CV}_{\alpha,\text{Regional}} = 1181 \times 0.388 = 458$$

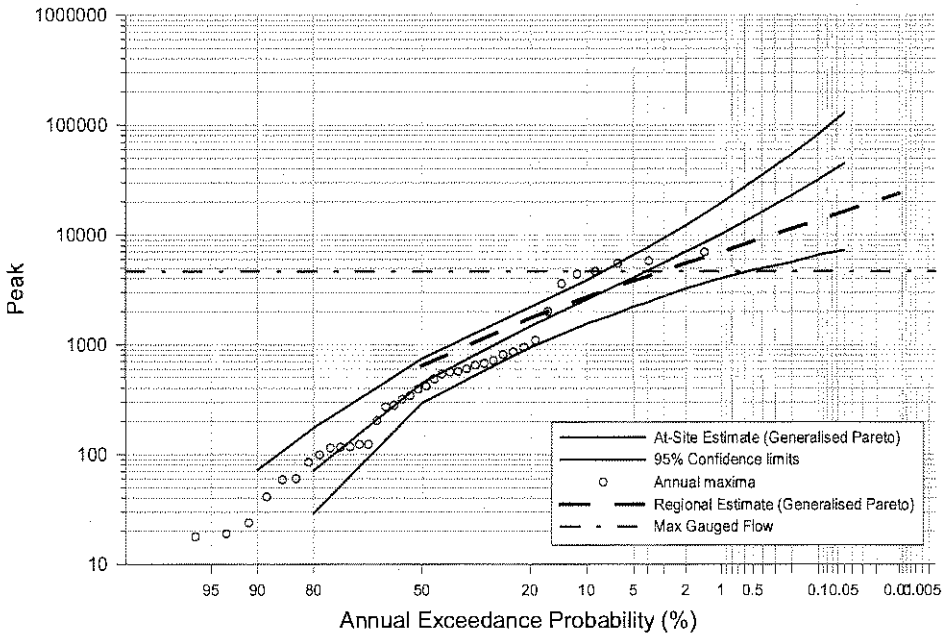
The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

- **Table E.3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution**

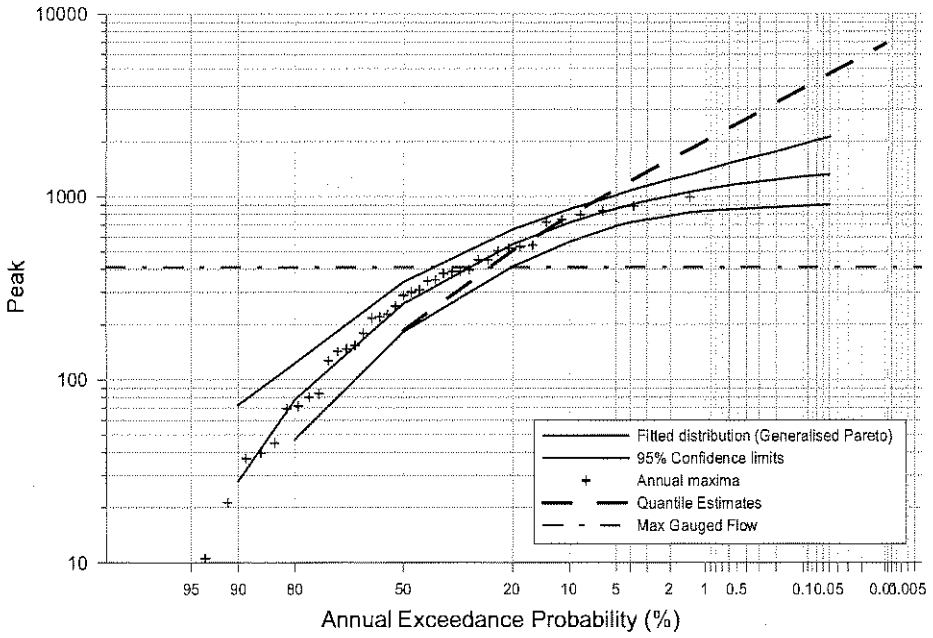
Site Number	Gauging Station Name	Scale parameter,	Shape parameter,
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		**0.388**	**0.297**

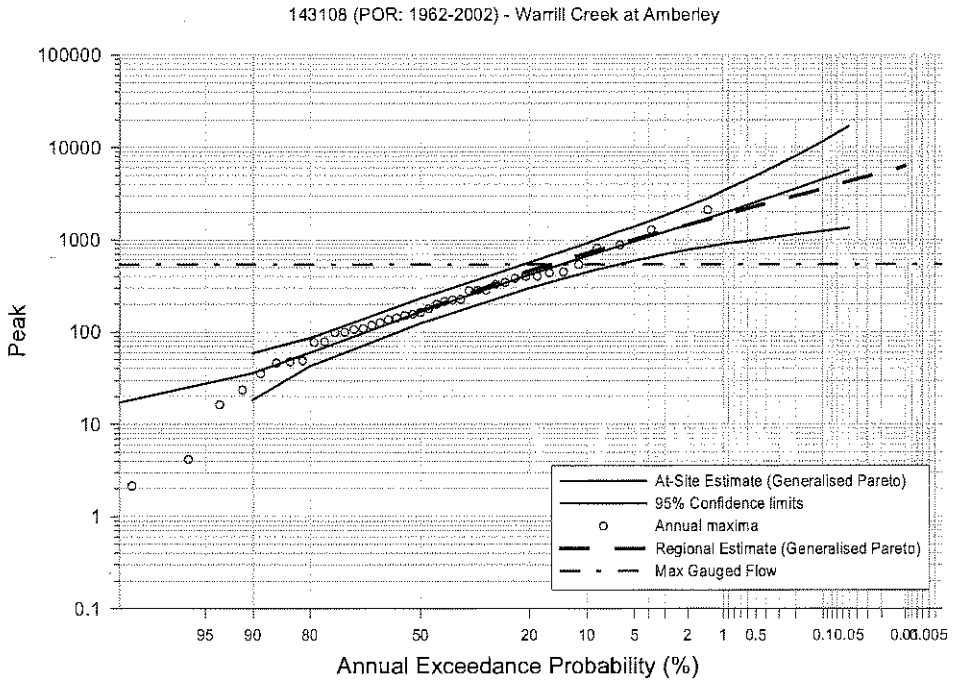
Appendix F At-Site/Regional Analysis of Selected Gauges

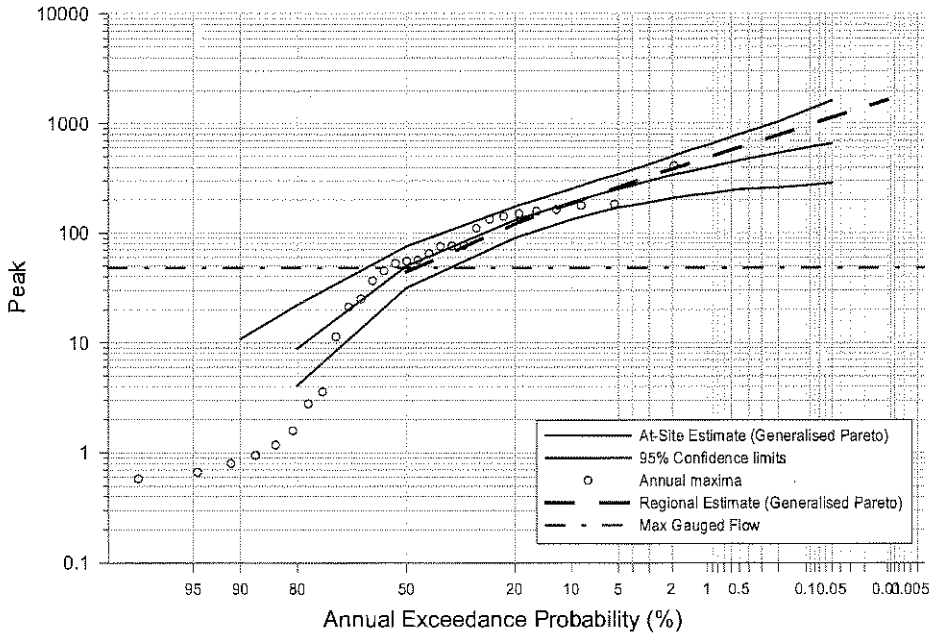
143009 (POR: 1963-2002) - Brisbane River at Gregors Creek

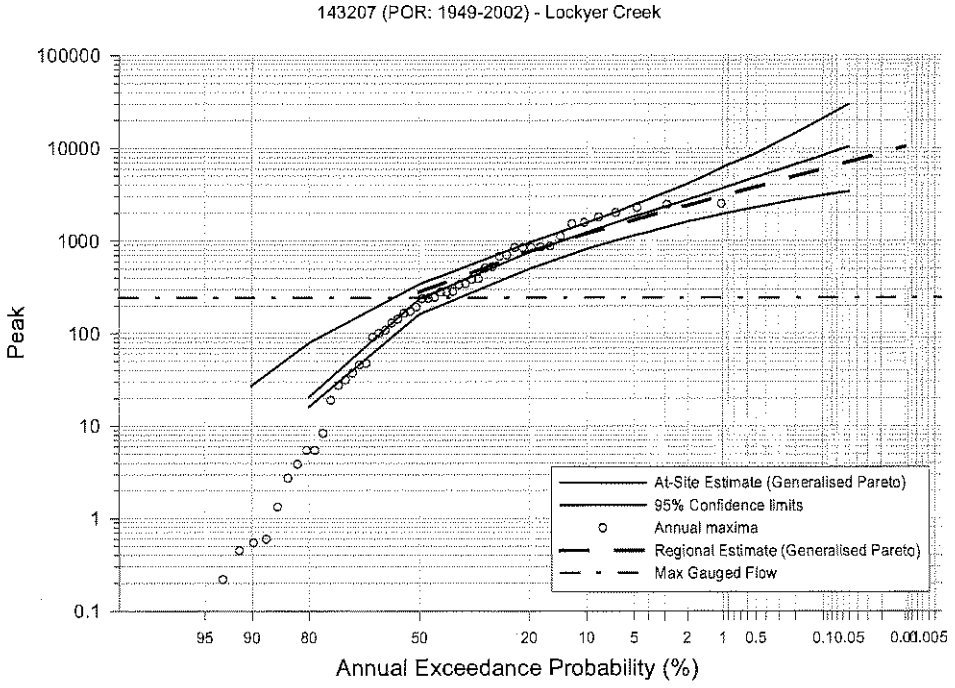


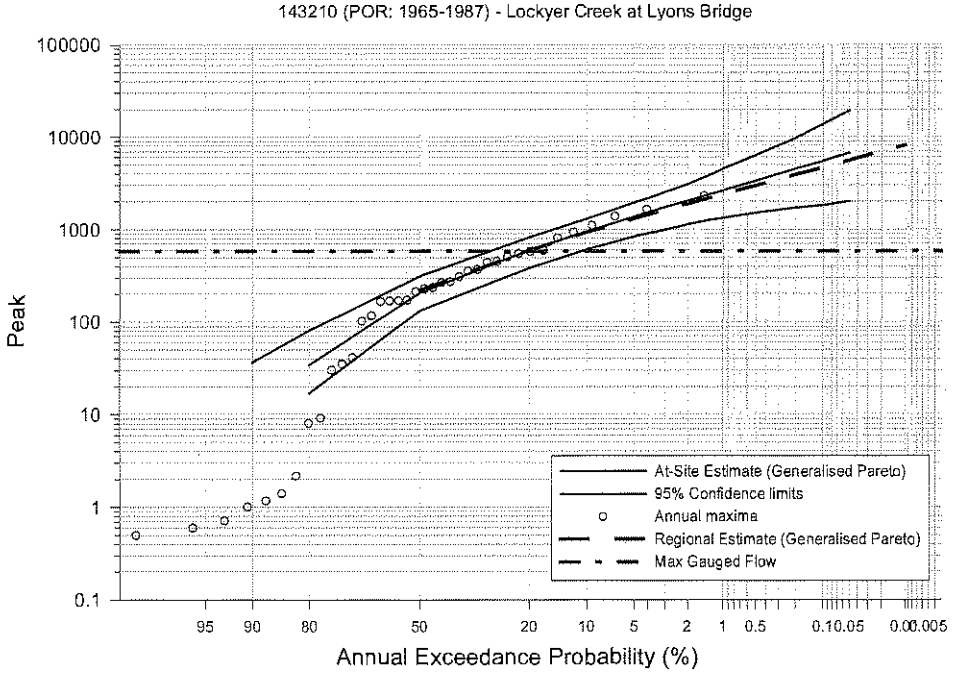
143107 (POR: 1962-2002) - Bremer River at Walloon

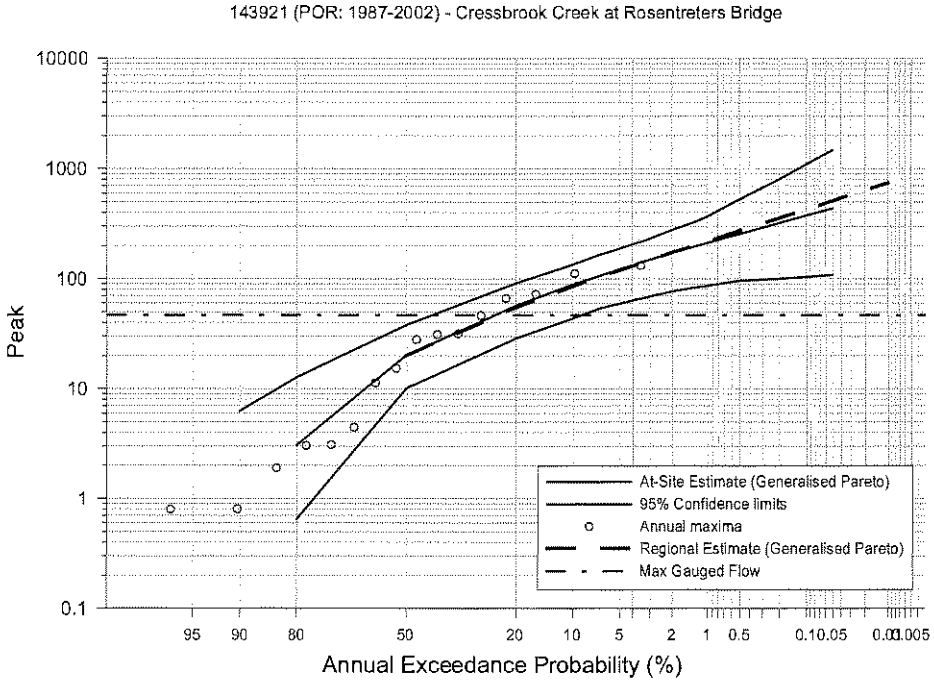



143108 (POR: 1962-2002) - Warrill Creek at Amberley
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143113 (POR: 1974-2002) - Purga Creek at Loamside
Peak
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow



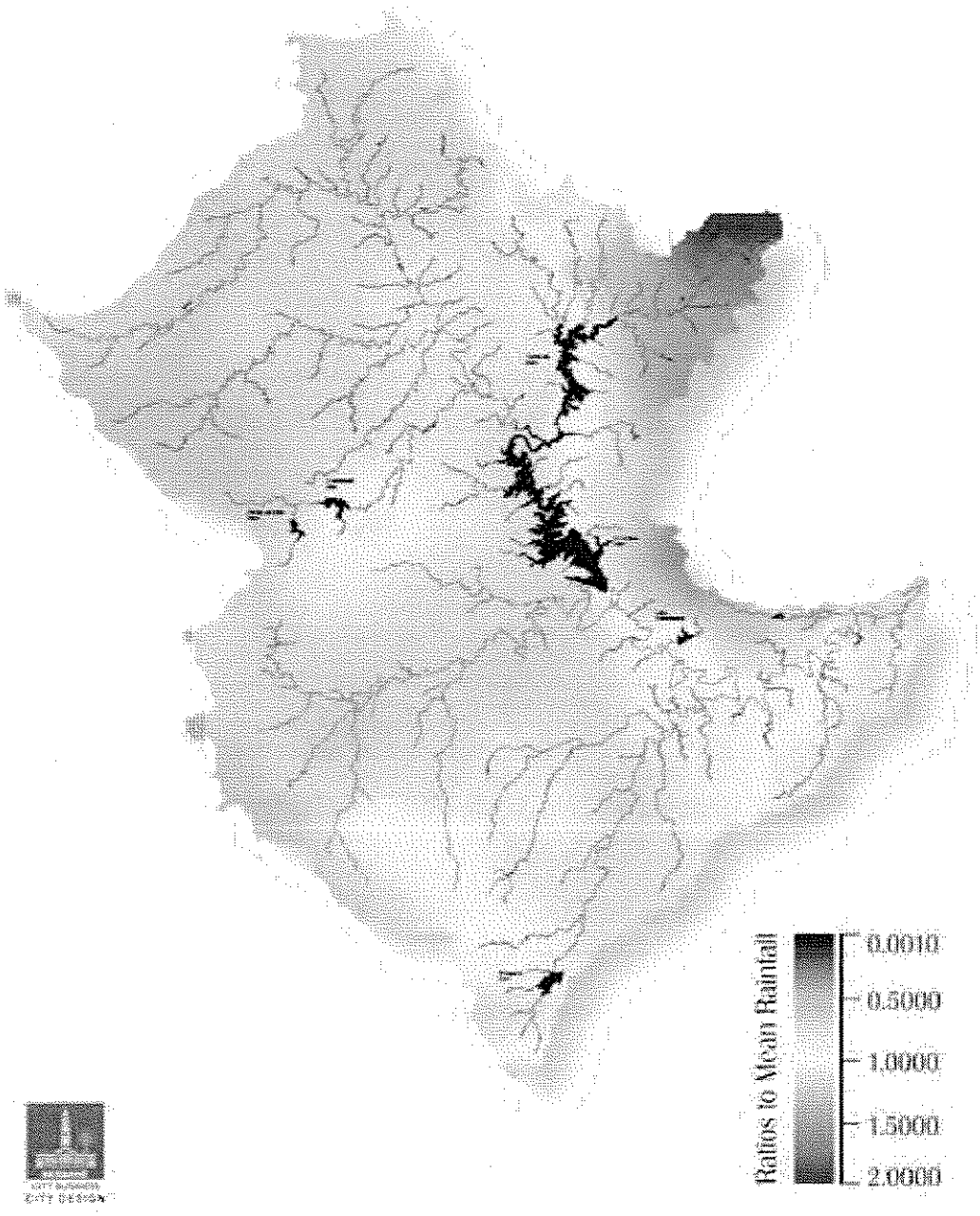
Appendix G Historical Spatial Distributions

SKM

CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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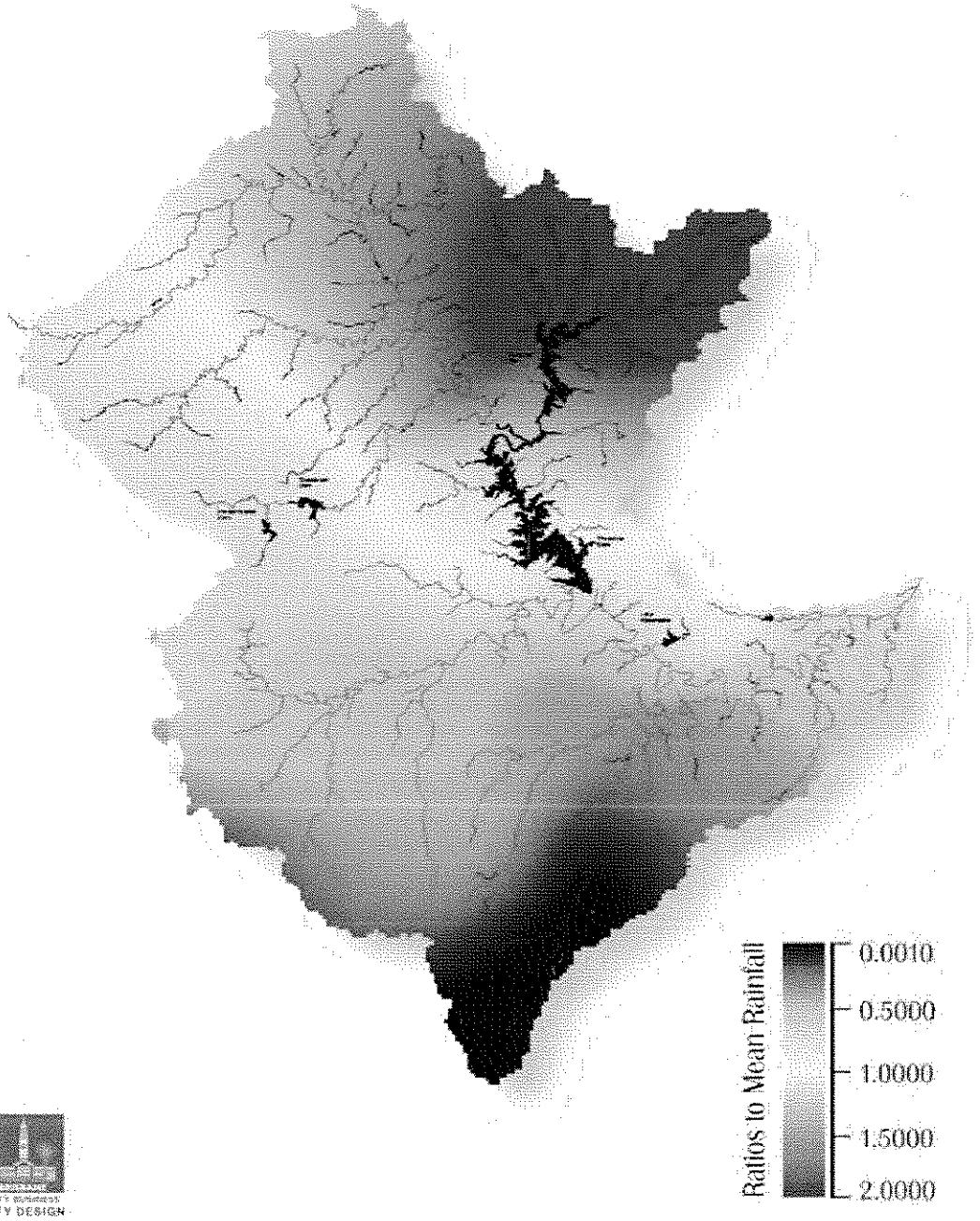
JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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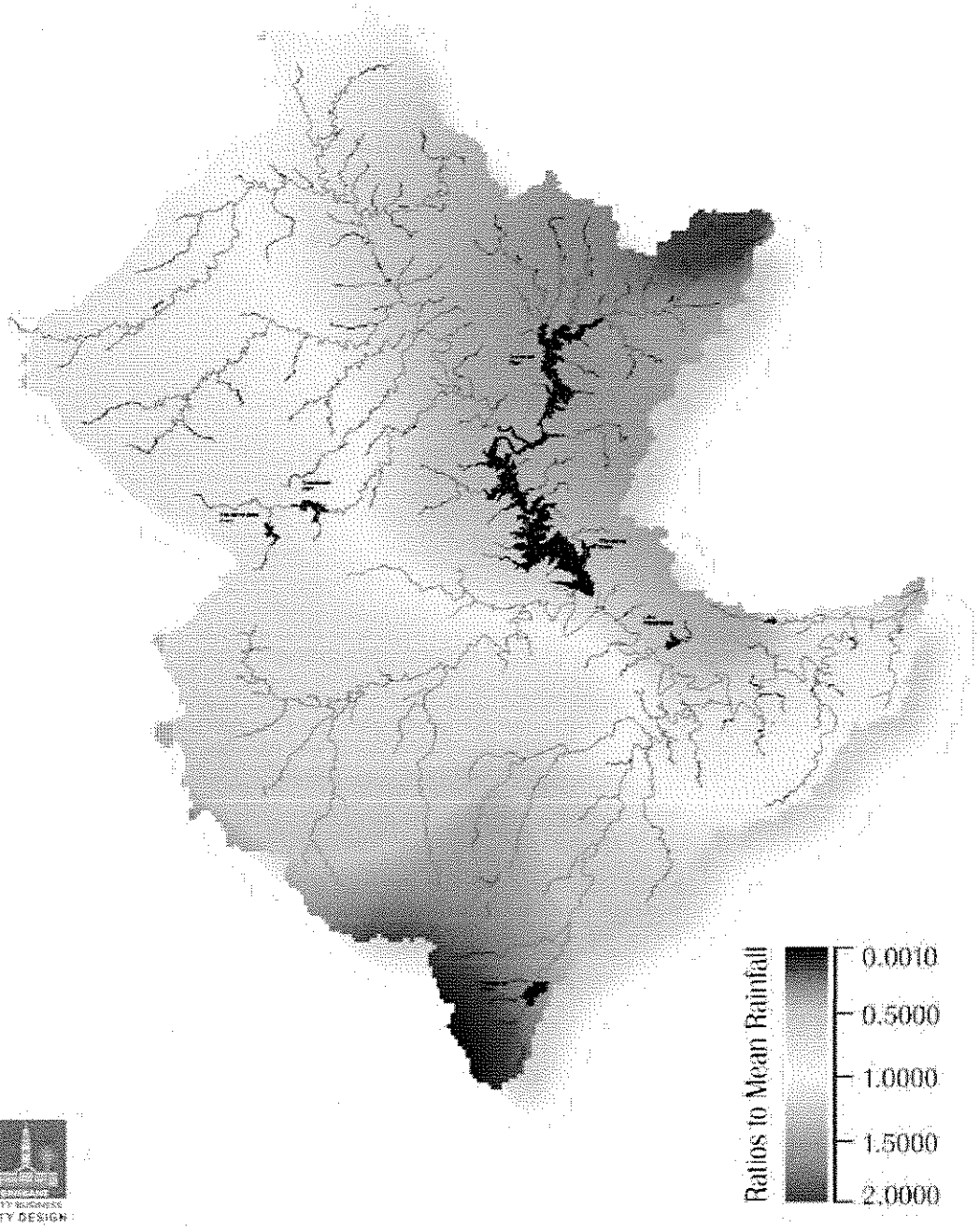
FEBRUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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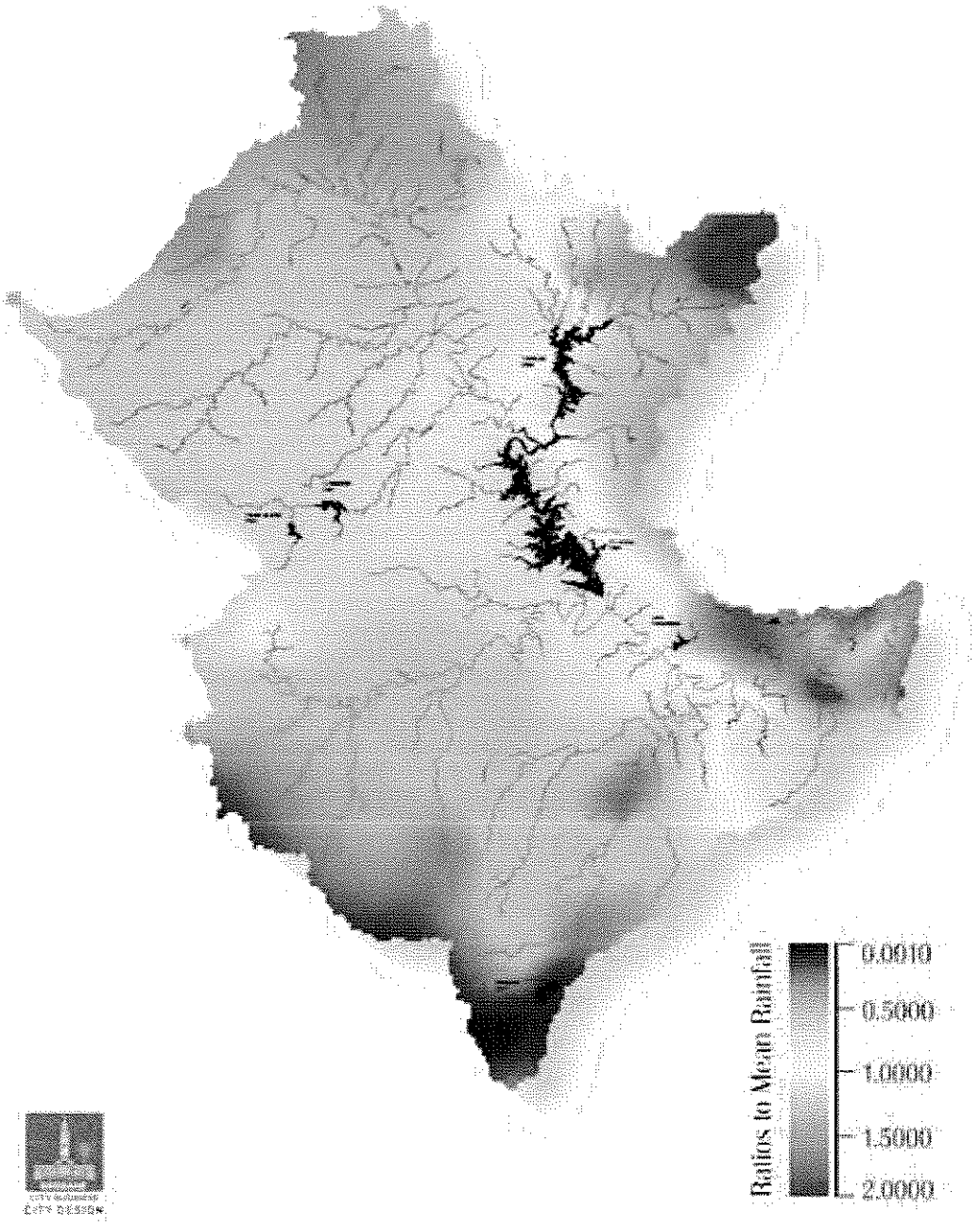
JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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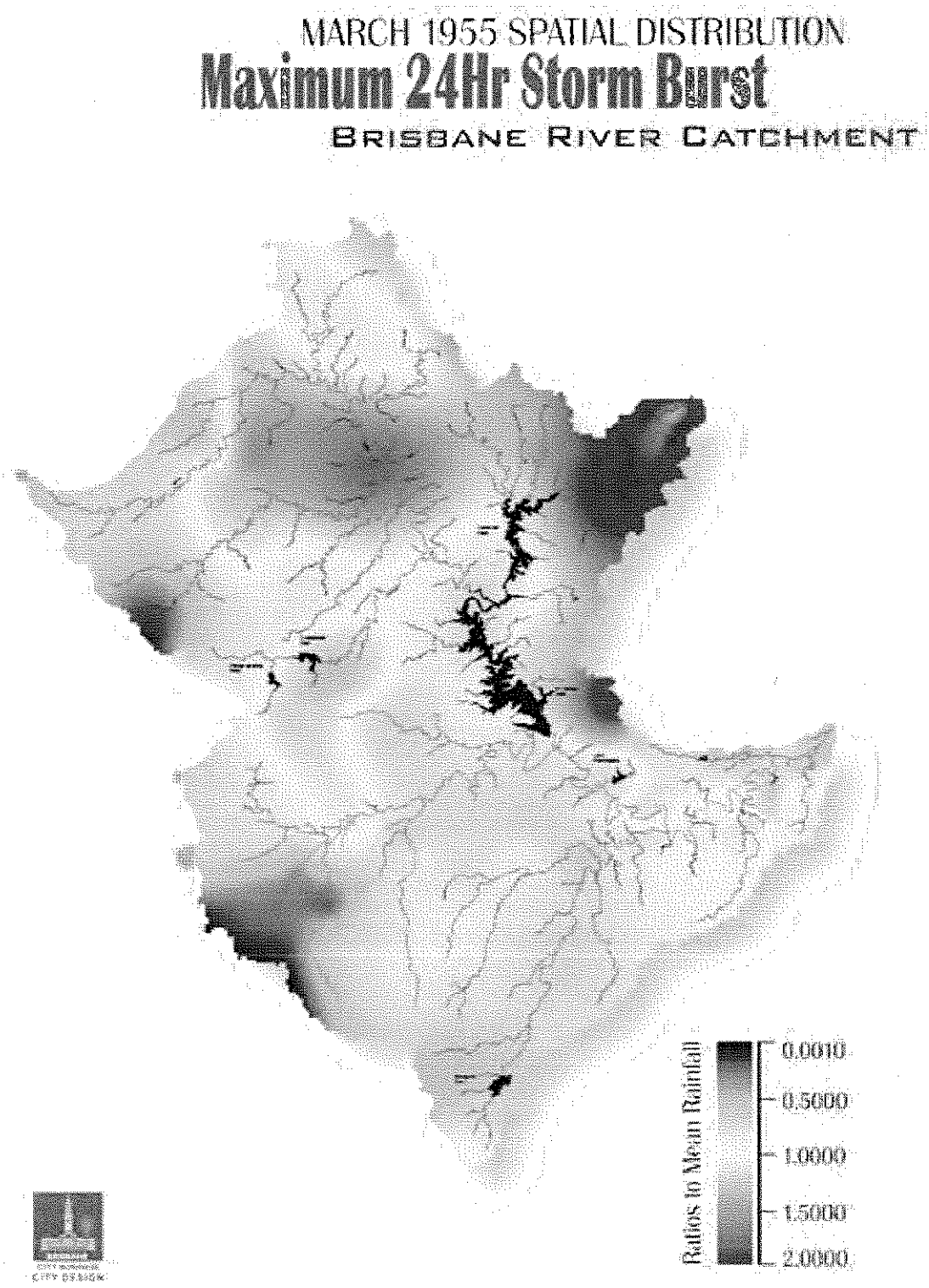
MARCH 1955 SPATIAL DISTRIBUTION
Maximum 24Hr Storm Burst
BRISBANE RIVER CATCHMENT
Ratios to Mean Rainfall
0.0010
0.5000
1.0000
1.5000
2.0000

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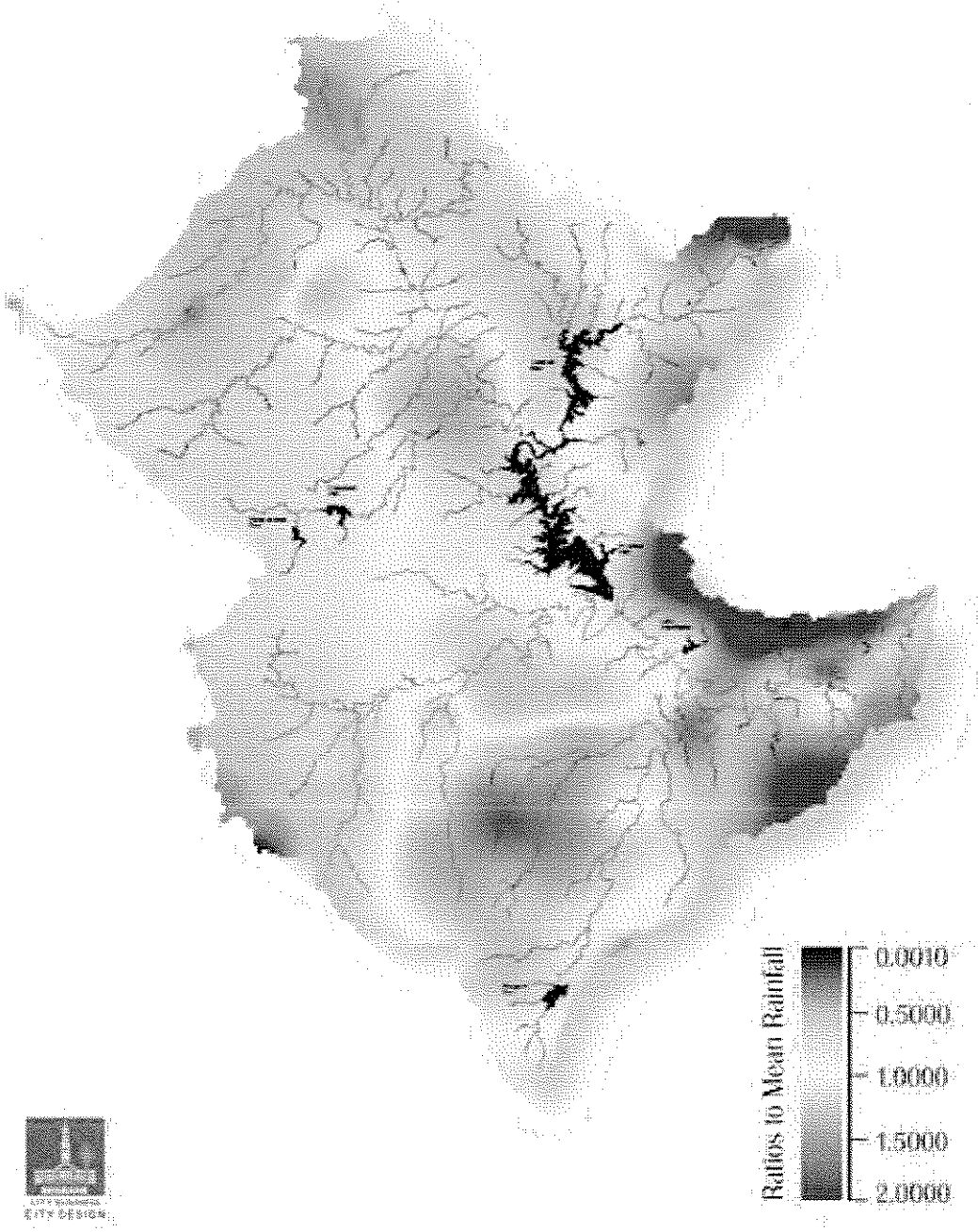
JANUARY 1974 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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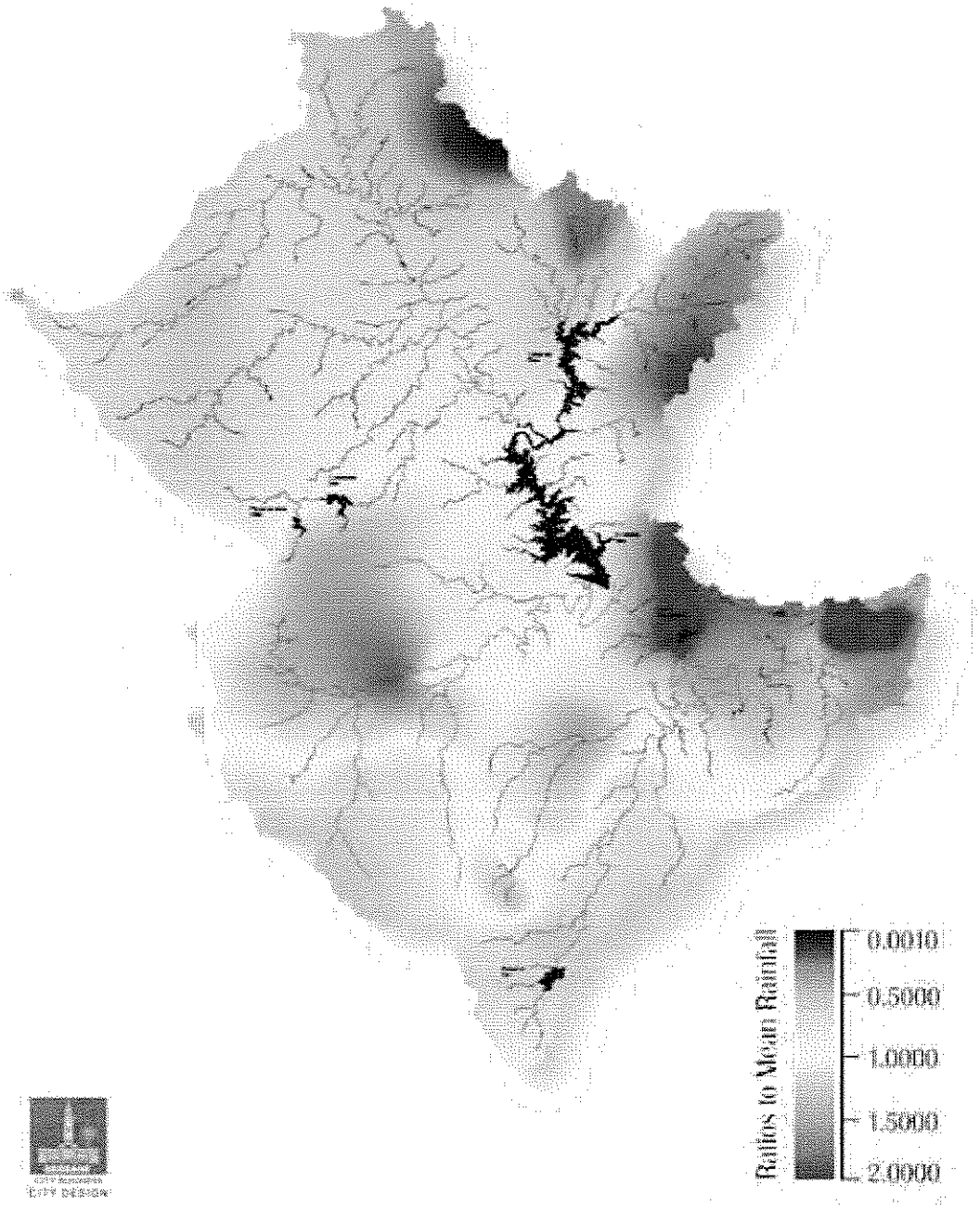
APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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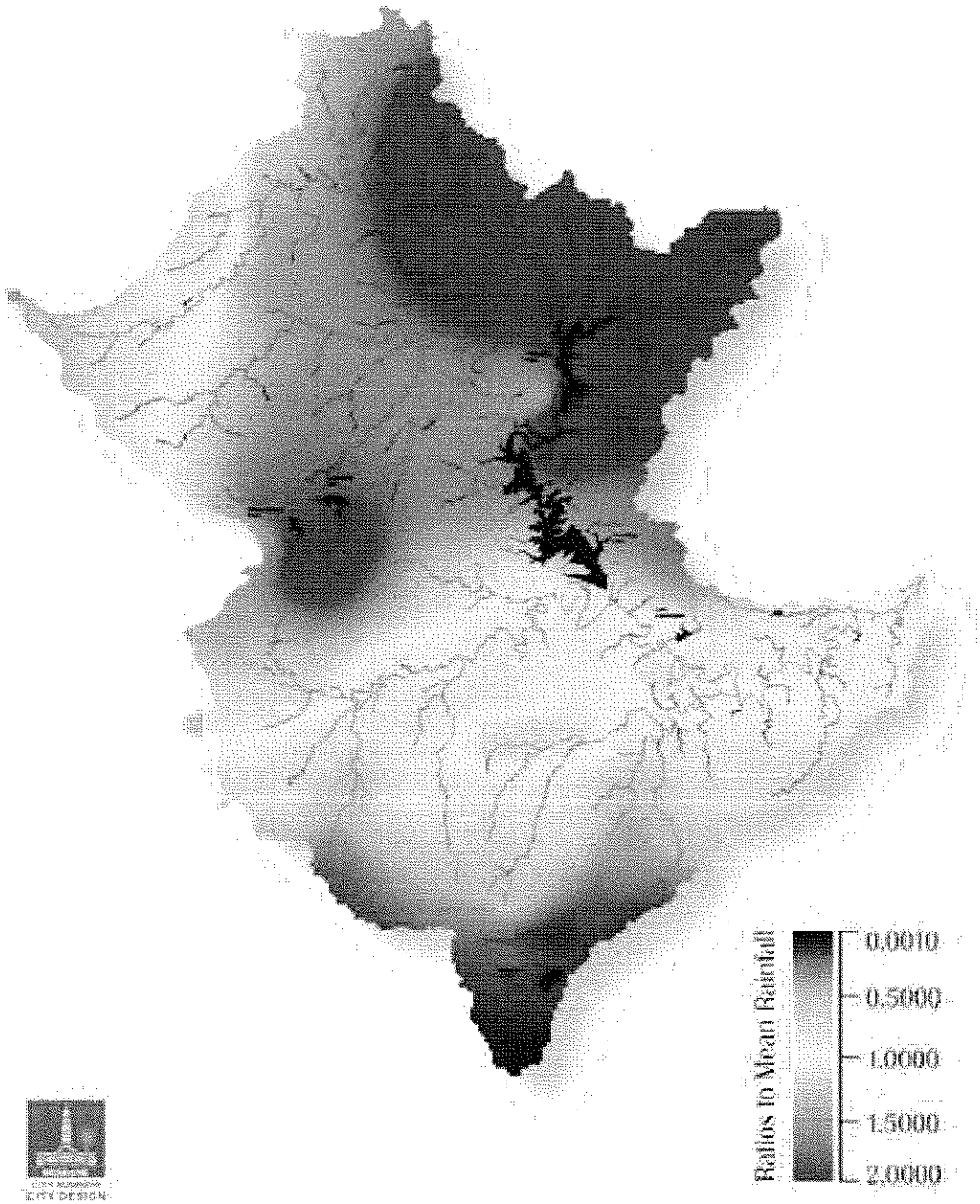
FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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Appendix H Pre- and Post-dams RAFTS Model Results

- **Peak Flows for RAFTS Model, Pre-Dams for 1 in 100 AEP Rainfall**

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
JAN 1893	24	9861	7927	7927
	30	**11507**	9792	9793
	36	9810	7932	7932
	48	10238	8534	8535
	72	10911	**10196**	**10198**
	96	9774	9392	9394
	120	10074	9639	9641
FEB 1893	24	8698	7502	7502
	30	**10062**	8788	8789
	36	8682	7512	7512
	48	9012	7865	7866
	72	9634	**9501**	**9504**
	96	8568	8632	8636
	120	8804	8898	8904
JAN 1931	24	7505	6745	6745
	30	**8543**	7648	7648
	36	7476	6775	6776
	48	7712	7190	7191
	72	8183	**8026**	**8030**
	96	7140	7514	7610
	120	7360	7630	7713
MAR 1955	24	8671	7536	7537
	30	**10046**	8925	8925
	36	8689	7553	7554
	48	8955	7915	7916
	72	9563	**9619**	**9623**
	96	8376	8745	8750
	120	8635	8997	9002
JAN 1974	24	7058	7202	7203
	30	**8005**	8046	8049
	36	7049	7072	7073
	48	7227	7527	7528
	72	7714	**9112**	**9117**
	96	6729	8154	8161

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
	120	6879	8432	8454
APR 1996	24	7531	7067	7068
	30	**8621**	7966	7966
	36	7549	7078	7079
	48	7748	7425	7427
	72	8287	**8917**	**8922**
	96	7184	8034	8043
	120	7399	8170	8182
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7893	7894
	48	9981	8443	8444
	72	10642	**10197**	**10200**
	96	9512	9384	9387
	120	9809	9626	9629

Note: Critical flows at each location are shown in **bold**.

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- **Peak Flows for RAFTS Model, Post-Dams for 1 in 100 AEP Rainfall**

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7120**	**7121**
FEB 1893	24	1877	2061	2070
	30	3818	3449	3449
	36	1935	2203	2211
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5595	5596
	120	**6568**	**5850**	**5851**
JAN 1931	24	1872	2051	2319
	30	1926	2708	3314
	36	1884	2452	2836
	48	1758	2382	2580
	72	3079	3146	3968
	96	3170	2940	3383
	120	**3279**	**3218**	**3411**
MAR 1955	24	1925	2345	2350
	30	3524	3433	3433
	36	2063	2541	2544
	48	3272	3013	3013
	72	**6241**	**5709**	**5710**
	96	5926	5339	5340
	120	6151	5584	5585
JAN 1974	24	1753	3324	3326
	30	2467	3987	3989
	36	1871	3279	3350
	48	1943	3627	3633
	72	3307	4418	4965
	96	**4771**	**5841**	**5852**
	120	2911	3656	3662
APR 1996	24	3554	3399	3400
	30	4067	4137	4138

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
	36	3535	3260	3260
	48	3605	3690	3691
	72	**4162**	**5019**	**5035**
	96	3492	4378	4417
	120	3509	4571	4663
FEB 1999	24	3424	2886	2887
	30	5789	4442	4442
	36	3575	3150	3147
	48	4604	3494	3495
	72	6879	6447	6448
	96	7217	6623	6624
	120	**7431**	**6819**	**6819**

Note: Critical flows at each location are shown in **bold**.

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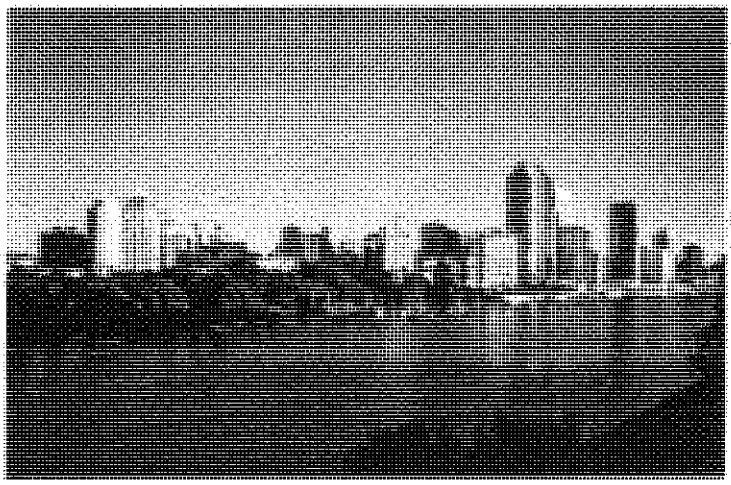
Brisbane River Flood Study



FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES – BRISBANE RIVER

- Further Investigations
- Final Issue
- Compiled 9 Dec 2003



Brisbane River Flood Study

FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES – BRISBANE RIVER

- Final Issue
- Compiled 9 Dec 2003

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Final Issue	13/11/2003	[redacted]			Include additional explanations for lay people

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Hydrological Modelling Draft B	Electronic	Electronic	Peter Barnes (Brisbane City Council)
Draft Final	Hard Copies	5	Peter Barnes (Brisbane City Council)
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Final Issue	Hard Copies	5 hard copies, 1 unbound copy, 1 PDF and 1 digital copy of the Executive Summary.	Gavin Blakey (Brisbane City Council)

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Executive Summary

Brisbane City Council (BCC) appointed an Expert Panel to review the flood investigations undertaken for the Brisbane River. Sinclair Knight Merz was approached to assist the Expert Panel with their review. The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analyse of the available data and provide a "best" estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing and the Brisbane Port Office Gauge. This peak flow rate is also referred to as the Q100 event.

The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

This technical report has been prepared for expert technical reviewers, and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, hydrological terminology and abbreviations is generally assumed.

Statistical flood frequency analysis

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (i.e. the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Statistical frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional

information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in **Table ES1**.

- **Table ES1 Most Plausible Estimates of the Q100 Peak Flow at Savages Crossing Based on Statistical Flood Frequency Analysis**

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12,000	10,000	14,000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this introduces considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there are scarce data on key event characteristics such as temporal pattern, losses, etc.). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),
- choice of frequency distribution and the appropriate parameters, and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence that the 1974 "no dams" peak flow rate is somewhere between 7,500 m^3/s and 11,000 m^3/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

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Rainfall-runoff modelling

The second method with which SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (e.g. the soil, interception by vegetation, etc.), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13,500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7,000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures,
- dam levels at the start of a flood event, and,
- spatial and temporal patterns of the storm.

The most sophisticated way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte Carlo analysis. Monte Carlo analysis would provide a more accurate estimate of the Q100 and reduce the overall uncertainty in the flood estimates. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increasing catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows was determined at Savages Crossing and these are presented in **Table ES2**.

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Table ES2 Pre dams 1 in 100 AEP Flow Estimates at Savages Crossing from Rainfall-Runoff Modelling

Scenario	Median (m^3/s)	Lower Estimate (m^3/s)	Upper Estimate (m^3/s)
No Dams	10,000	8,000	11,500

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10,000 m^3/s using an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h. This compares to the statistical frequency estimate (i.e. analysis of recorded flow data) of 12,000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3,000 m^3/s to 8,000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6,200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12,000 m^3/s and 13,800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis. While zero loss rates are not realistic, the objective of this sensitivity analysis was to show that temporal patterns can have an impact on the magnitude of flows. A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an IL of 10 mm and CL of 1.0 mm/h. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing and Brisbane Port Office was estimated to be 5,400 m^3/s and 5,000 m^3/s respectively. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing and Brisbane Port Office was reduced to 3,500 m^3/s and 4,400 m^3/s respectively.

SKM

Q100 estimate at the Brisbane Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Brisbane Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Brisbane Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Brisbane Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Brisbane Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table ES3** provides a range of estimates with a 'best estimate', upper estimate and lower estimate.

- **Table ES3 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood with Dams**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The information for the two historical flood events (1893 and 1974) was run through the RAFTS model for the pre and post-dam conditions. For post-dam conditions, the estimated peak flow at the Brisbane Port Office for the 1893 and 1974 flood events were 9,500 m^3/s and 6800 m^3/s respectively. It should be noted that the uncertainty in some of the historical data, 1893 in particular, is considerable.

The best estimate of 6,500 m^3/s was adopted after consideration of the RAFTS modelling for current design spatial pattern, various historical patterns and the performance of the model in reproducing flows at Savages Crossing for pre-dam flows. The estimate of the lower end of the plausible range of the Q100 estimate is 5,000 m^3/s. It was adopted with particular consideration to the range of results from the sensitivity to the spatial patterns. The estimate of the upper end of the plausible range was taken to be 8,000 m^3/s. This upper bound was adopted after particular consideration of the variation in the spatial patterns, the sensitivity to temporal patterns, and the 1974 peak flow results for the 'Somerset only' then 'Somerset and Wivenhoe' dams scenarios.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;

- better representation of dam operating procedures, and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

The following actions could be undertaken to further improve this analysis:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that accurately reflect the combined influences of these stochastic factors.

  It is noted that while undertaking rainfall-runoff modelling in a Monte Carlo framework is an accepted method, it is not a standard method for flood studies.

- Re-calibrate the Ipswich City Council's MIKE 11 hydraulic model within the Brisbane City Council Boundary.

SKM

1. Introduction

1.1 Background

Sinclair Knight Merz prepared a flood study for the Brisbane River in 1998. Since this time, there have been changes to the information used in assessing the flood levels along the lower reaches of the Brisbane River. These include:

- CRC-FORGE rainfall estimates that have been prepared for the Brisbane River catchment (Department of Natural Resources and Mines, 2003a),
- modifications to procedures for flood operations at Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, 1998) was completed, and
- additional and/or revised flood flow data.

An Expert Panel was appointed by Brisbane City Council to review the flood studies undertaken for the Brisbane River in the light of this new information, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- Update the flood frequency estimates from rainfall-runoff modelling with the new information.

The details of the tasks that were originally agreed are presented in **Appendix A.**

1.2 Scope of Report

This report addresses the tasks presented in **Appendix A**, namely to:

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document the findings of the flood frequency analysis, stating assumptions and outcomes.
4) Review previous reports, CRC-FORGE rainfall estimates and historical streamflow data.
5) Undertake a Regional Flood Frequency Analysis (pre-dams).
6) Undertake hydrologic modelling (pre-dams).



7) Undertake hydrologic modelling (dams in place).
8) Analyse catchment sensitivity using various temporal patterns and historical spatial patterns.
9) Undertake a sensitivity analysis of starting reservoir levels.
10) Perform hydraulic modelling to produce flood frequency estimates at Moggill and the Brisbane Port Office.
11) Report on the findings of the statistical flood frequency analyses and the rainfall-runoff and hydraulic modelling.

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2. Sources of Data for Statistical Flood Frequency Analysis

Gauging station data were obtained from the Department of Natural Resources and Mining (DNRM) and the Commonwealth Bureau of Meteorology (BoM). Different types of data were collected, including:

- recorded water elevation above the gauge datum,
- flow data estimated from a rating relationship, and
- rating tables.

In some instances the data were processed in some additional manner, as discussed below.

A number of reports on large flood events and the analysis thereof were made available.

2.1 Department of Natural Resources and Mining Data

There are two sources of data from DNRM:

- Recorded water elevation data and associated flow estimates,
- Estimates of "no dams" flood peaks at Savages Crossing that had been adjusted to *exclude* the influence of the dam(s) where appropriate.
- Estimates of "with dams" flood peaks at Savages Crossing that had been adjusted to *include* the influence of one or more of the dam(s) where appropriate.

All data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in **Appendix B** (along with other sources of gauged data). The primary reasons for omission were:

- short record length,
- small catchment area, and/or
- uncertainty in the rating curve.

The last reason included either very low gauged flow or the rating curve was changed by BoM to a "calibration curve" for use in real time flood forecasting.

Elevation data for a number of sites of direct interest to this study, such as Moggill, and the Brisbane Port Office were also obtained.

Appendix C shows the location of the stream gauges that were used in the statistical flood frequency analysis.

SKM

3. Statistical Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analyse of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (i.e. peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have been documented in **Section 2**.

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- adjustment of data for the influence of the dams,
- uncertainty in the rating curves that relate recorded river level to flow rate,
- the magnitude of historic data (especially 1893 and 1825),
- the period of record associated with the historic data,
- choice of frequency distribution,
- selection of parameters for the distribution, and
- method of including historical data.

DNRM provided three series of data. The series are provided in **Appendix D**. The first was the "gauged flows at Savages Crossing" (1909-200). This was a composite series from Savages Crossing/Lowood/Vernor stations. The second series was for "both dams working" in which they made some adjustments that they considered appropriate for the effect on the flow rates if the dams had been in place for the entire period. The precise method for adjusting the data has not been detailed; the method as provided is included with the data series in **Appendix D**. The third series of data (1890 - 2000) was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had not existed over the entire period. Frequency analysis of this data was undertaken along with various unadjusted data.

The statistical frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by [redacted] in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto (GP) distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix E** and **Appendix F**.

The Expert Panel was interested in understanding how the statistical flood frequency analysis results were affected by the addition of dams, the inclusion of various gauged/historical data and use of various statistical techniques. Four cases as listed below were developed to meet the Expert Panel's requirements.

Case 1. Analysis of pre-Somerset and pre-Wivenhoe data ie. data that was unaffected by Somerset and Wivenhoe dams were assessed. Data prior to 1951 were analysed.

Case 2. Analysis of pre-Wivenhoe data with no correction for Somerset dam; consideration given to all data as recorded or estimated with no attempt made to assess the effect of Somerset dam on the flow magnitudes.

Case 3. Analysis of "no dams" data as estimated by DNRM; the data set that contained the flows that DNRM estimate would have occurred in the absence of Somerset and Wivenhoe dams was assessed.

Case 4. Analysis of post-dam data estimated by DNRM; assessment of the data set that contained the flows that DNRM estimate would have occurred if Somerset and Wivenhoe dams were present for the entire period of record.

The analyses undertaken to determine the "best" estimate from statistical flood frequency analysis and a plausible range are summarised in **Table 3-1**.

The individual analyses including the data, techniques, the objective and comments on the results of each analysis are included in **Table 3-3** to **Table 3-6** and summarised in **Table 3-7**. The effects on the flood frequency curves of each of the analyses are shown in **Figures 3-1** to **3-7**.

As noted previously, this report has been prepared for expert reviewers with a high level of understanding. The explanations, comments and discussion are as concise as possible to enable the broad range of analyses to be succinctly presented for ease of comparison.

SKM

- **Table 3-1 Summary of statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distrib'n	Prior Inform'n (regional)	Main Objective
Case 1 Pre -Wivenhoe and Somerset							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

GP = Generalised Pareto Distribution

LPIII = Log-Pearson III Distribution

SKM

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distribn	Prior inform'n (regional)	Main Objective
Case 2							
Pre Wivenhoe, no adjustments made for Somerset							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3							
"No Dams" based on DNRM adjusted estimates							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by DNRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4							
"Dams" based on DNRM estimates							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

GP = Generalised Parts Distribution

LPIII = Log-Pearson III Distribution

SKM

3.2 Regional Frequency Analysis

A regional statistical frequency analysis was conducted to assist in the estimation of flood frequency at Savages Crossing (GS143001). The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane River catchment, including the site at Savages Crossing (GS143001). The Generalised Pareto probability distribution was selected for the statistical flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation, and
- its correlation with other parameters.

The prior mean and standard deviation of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in **Table 3-2**.

- **Table 3-2 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001)**

Value	Scale parameter, α	Shape parameter, κ
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets a Sinclair Knight Merz program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

Greater detail of the regional analyses is provided in **Appendix E** and **Appendix F**.

3.3 Case 1: Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the DNRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in **Table 3-3** with specific influence on curves plotted in **Figures 3-1** to **3-3** so that the influence of specific assumptions can be compared graphically.

SKM

- **Table 3-3 Summary of Case 1 statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative..
1C	1909-1951	1893 (Qp= 13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825 (Qp= 13200) 1893 (Qp= 13 200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)

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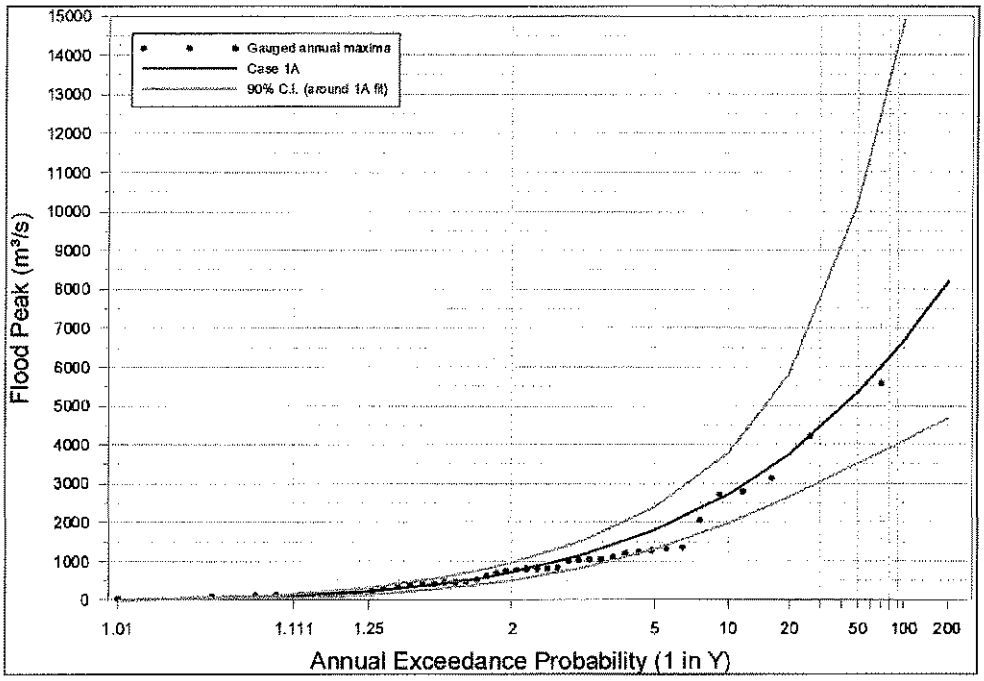
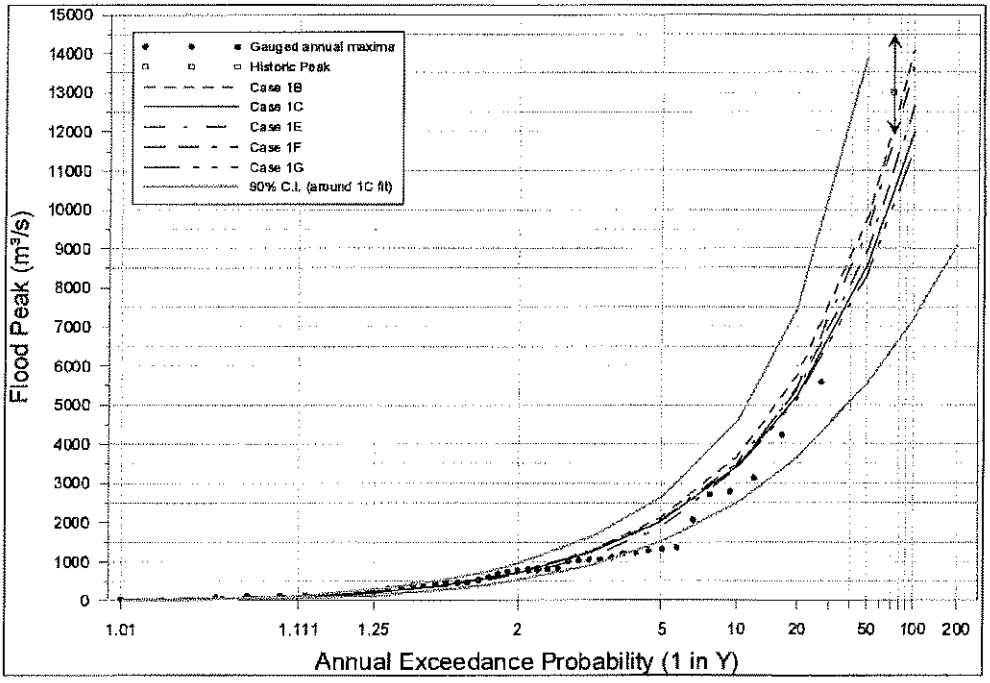
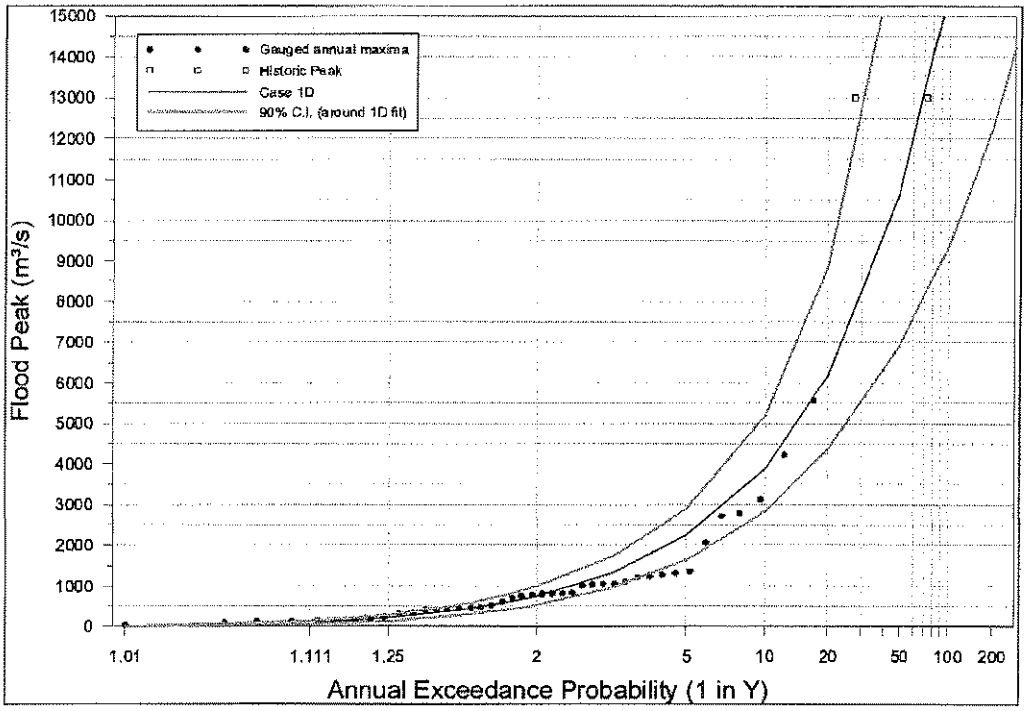
	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1F	1909-1951	1893 (Qp= 14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from BoM "not unreasonable" estimate of 1893 peak. (BoM 2003) Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp= 12 000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from BoM URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5 mm/hr. (BoM 2003) Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp= 13 000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.



- **Figure 3-1 Generalised Pareto Distribution fitted to the 1909-1951 pre-dams data at Savages Crossing**



- **Figure 3-2 Comparisons of variations in statistical flood frequency for various assumptions on pre-dams data for Savages Crossing**



- **Figure 3-3 Assessment of the inclusion of a 1825 estimate of a flood possibly of the same magnitude as the 1893 event**

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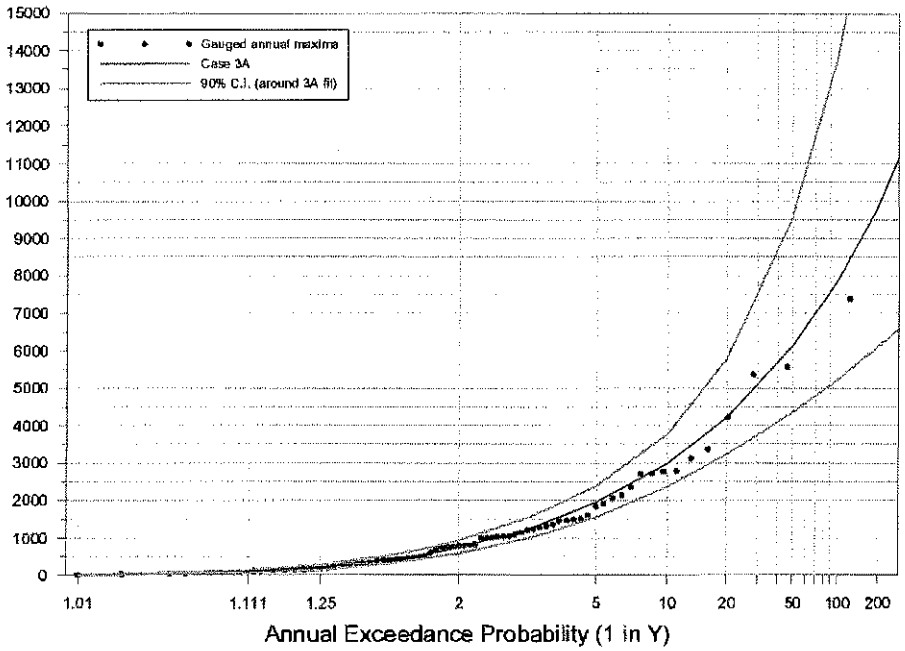
3.4 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

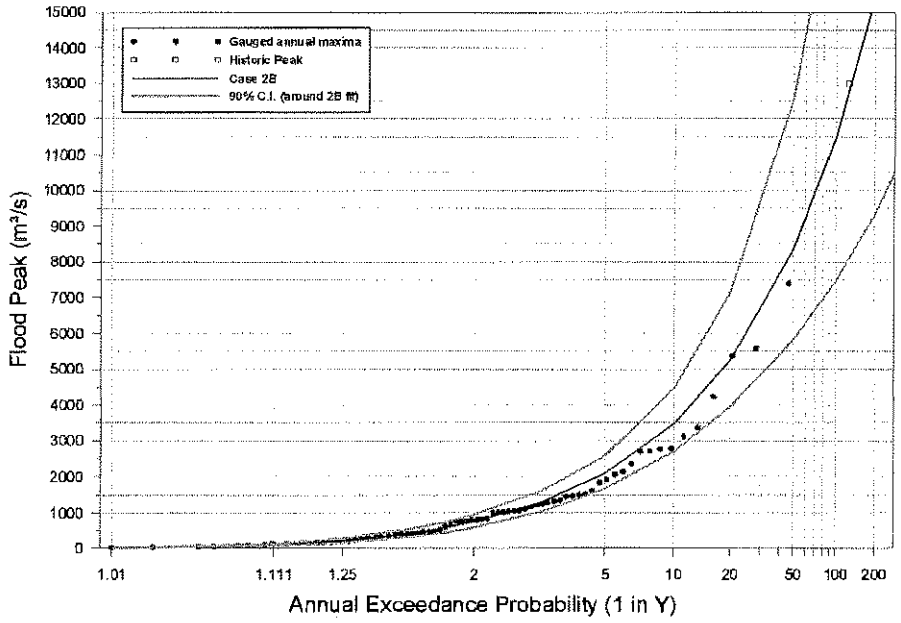
These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

- **Table 3-4 Summary of Case 1: statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.



- **Figure 3-4 Assessment of the pre-Wivenhoe gauged data without 1893 event**



- **Figure 3-5 Assessment of the pre-Wivenhoe gauged data with 1893 event**

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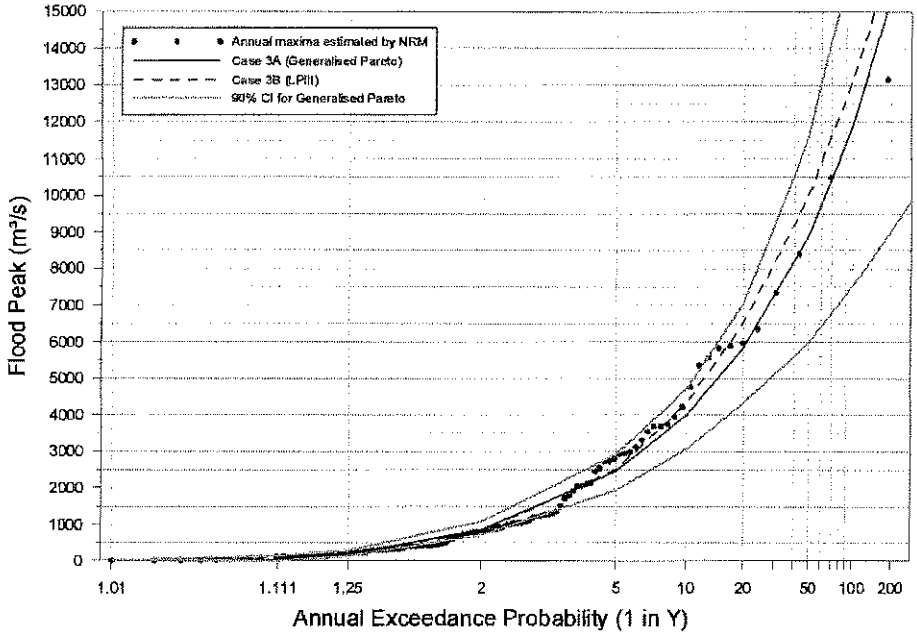
3.5 Case 3: Analysis of "No Dams" Data Estimated by DNRM

Note effect of Somerset dam is highly variable depending on its operation. DNRM has assessed the effect of Somerset dam on the flood data series. Sinclair Knight Merz has taken this series "as provided" and analysed the statistics.

- **Table 3-5 Summary of Case 3: statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.



- **Figure 3-6 Assessment of the "no –dams" annual maxima series provided by DNRM using both GP and LPIII distributions**

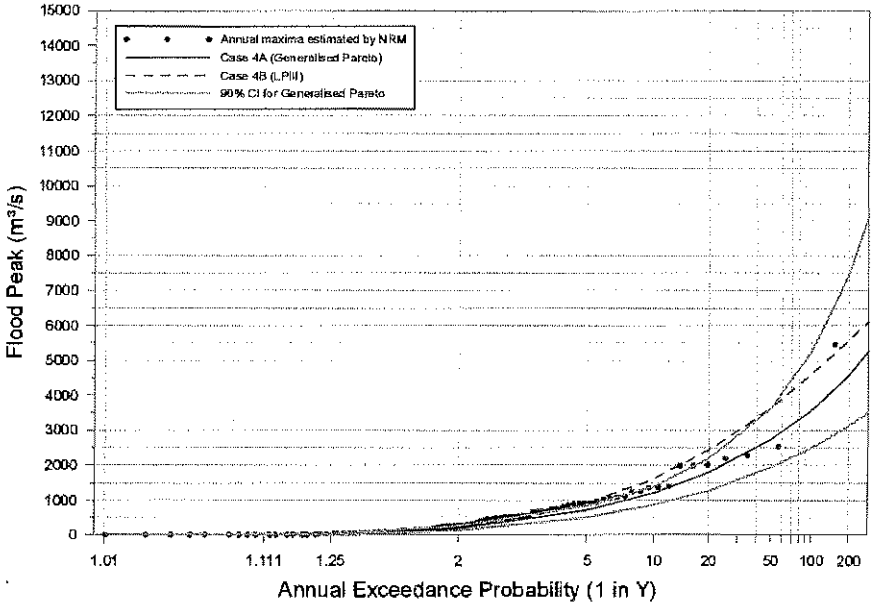
SKM

3.6 Case 4: Analysis of Post-Dam Data Estimated by DNRM

These analyses were based on the "post-dam" data set provided by DNRM. As noted in Section 3.4 the data has been taken and analysed on an "as provided" basis.

- **Table 3-6 Summary of Case 4: Post-dam Data - statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to later sections for the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)



- **Figure 3-7 Assessment of the "post-dams" annual maxima series provided by DNRM using both GP and LPIII distributions.**

3.7 Summary of Analysis Results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) estimate at Savages Crossing. The analyses are summarised in **Table 3-7**. As noted above, the summary is intended to succinctly present the broad range of sensitivity analyses for expert reviewers who are familiar with the concepts, common discipline abbreviations and analysis methods.

SKM

Table 3-7 Summary of statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detaile

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comr
Case 1 **Pre -Wivenhoe and Somerset**								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignor dam a Also e
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By ex overe
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The r partia simila pre-W
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The p magn
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relat Paret
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magn Q100
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magn patter Q100
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This r Note:
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 data i
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset	Inclus Q100 least Q100

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	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comr
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	Accor Wiver Note: Refer persp
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 than (

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3.8 Best Estimates from statistical flood frequency assessment

Sinclair Knight Merz has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling reported in the subsequent chapters). The results are presented in **Table 3-8**.

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970 m^3/s)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), DNRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m^3/s); as no allowance made for Somerset dam, the pre dams Q100 could be expected to be higher than 11 500m^3/s.
- the "No dams" series from DNRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3AQ100 = 11,500 m^3/s).

- **Table 3-8 Most plausible estimates of the Pre dams Q100 peak flow at Savages Crossing**

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the statistical flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristies sueh as temporal pattern, losses, etc.). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),

- choice of distribution and the appropriate parameters, and
- adjustment of data for the effect of the dams.

[redacted]

An additional assessment of the "current" scenario, i.e. with Somerset and Wivenhoe dams in place and operated using current operating procedures is also provided (Case 4 – refer **Section 3.6**). This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by DNRM. Note that an assessment of the plausible range for this estimate is not possible, as DNRM has not provided documentation for the method for adjusting the data series.

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4. Rainfall-Runoff Modelling

Rainfall-runoff modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS rainfall-runoff model developed for the Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) was used for this investigation. The Ipswich Rivers Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model prepared for Brisbane City Council.

4.1 Assumptions

- The Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM, 2003) Wivenhoe and Somerset Dam Operations Model was used to determine dam outflows.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows:

- Initial Loss Rate = 10 mm
- Continuing Loss Rate = 1.0 mm/h
- All model runs were undertaken for the 1 in 100 (1%) AEP flood event only.

4.2 Methodology

The following Methodology describes the process that was used to determine 1 in 100 AEP peak flows at Moggill and the Brisbane Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model.
- Input CRC-FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1 in 100 AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the DNRM Dam Operations Model.
- The DNRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the DNRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1 in 100 AEP flows at Savages Crossing, Moggill and the Brisbane Port Office Gauge.

- A sensitivity analysis was then performed using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wivenhoe and Somerset Dams at the start of the flood event.

4.3 Pre-dams RAFTS Modelling

The object of the pre-dams modelling was to compare statistical flood frequency estimates and the flow estimates produced by RAFTS. Good agreement between the flow estimates resulting from the statistical flood frequency analysis and RAFTS provides a robust flood flow estimate. CRC-FORGE rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine the effects that temporal patterns have on variation of peak flows.

4.3.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

CRC-FORGE rainfall estimates for varying durations were input into the model with Areal Reduction Factors (ARF) applied (Department of Natural Resources and Mines, 2003a). **Table 4-1** presents the rainfalls depths and adjusted rainfall depths (ARF's applied) used in the RAFTS model.

- **Table 4-1 CRC-FORGE Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP**

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC-FORGE Rainfall	247	268	285	317	358	385	402
CRC-FORGE Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC-FORGE rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in **Appendix G**. Standard temporal patterns (ARR 1987) were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h was adopted.

The peak flows for Savages Crossing using the CRC-FORGE rainfall estimates with ARF's applied are presented in **Table 4-2**.

- **Table 4-2 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1 in 100 AEP Flood – Pre-dams**

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Brisbane Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: - Bold values indicate the critical duration at each location

- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.3.2 Sensitivity to Spatial Pattern of Rainfall

To determine the impact spatial patterns have on peak flows, seven historical spatial patterns were used. These spatial patterns were selected as they were significant flood events and data were readily available. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC-FORGE Rainfall Depths (ARF applied) for each duration.

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February 1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane River and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane River Catchment.
- April 1996 - high rainfalls in the Lockyer and Lower Brisbane River Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in **Appendix G**.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h was applied.

Peak flows are presented in **Table 4-3**. Note that for all spatial distributions the 30 hour rainfall duration is the critical duration storm at Savages Crossing and the 72 hour flood is the critical

duration at Moggill and Brisbane Port Office. Flows presented at Moggill and the Brisbane Port Office in **Table 4-3** should be considered indicative only. More reliable estimates of design floods at the lower gauges are produced by the hydraulic model, as discussed in **Chapter 5**.

- **Table 4-3 Pre- dams Peak Flows for 1 in 100 AEP Rainfall and Historical Spatial Distributions**

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Brisbane Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: - Bold values indicate the median flow at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

A full listing of peak flow rates at Savages Crossing, Moggill and Brisbane Port Office are present in **Appendix H**.

4.3.3 Sensitivity to Temporal Pattern of Rainfall

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC-FORGE Rainfall 48 hour storm duration. An Initial Loss of 0 mm and a Continuing Loss of 0 mm/h was applied.

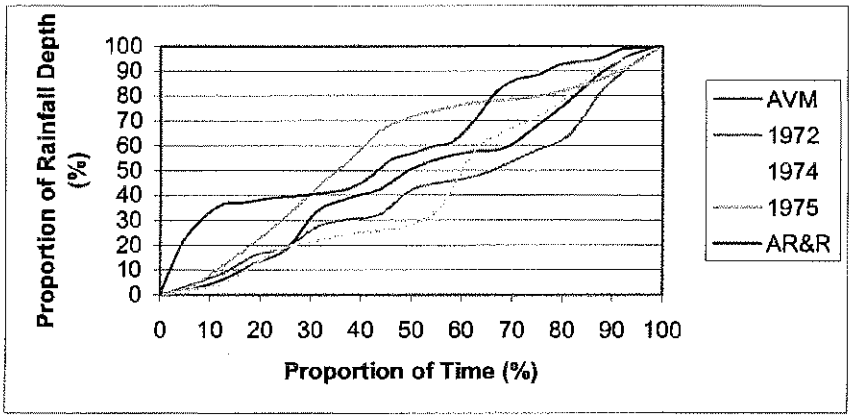
The temporal patterns that were used in the sensitivity analysis were:

- AVM – Average Variability Method,
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event,
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event,
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event, and
- AR&R 1987 – Standard temporal pattern as provided in the 1987 edition of Australian Rainfall and Runoff.

These temporal patterns are shown in **Figure 4-1**. Note that the AVM pattern was developed from temporal patterns used in the BoM development of the recently revised Generalised Tropical Storm Method (GTSM-R). In summary, the method involves:

- ranking the rainfall depths in descending order for each period,
- the percentage of the total storm rainfall occurring in the period of each rank is found,
- the average rank for each period and the average percentage of the rainfall depth in the period of each rank are then calculated, then
- to obtain the temporal pattern, the period with the lowest average rank is assigned the average percentage of rain for the rank 1 periods, the second lowest average rank is assigned the average percentage of rain for the rank 2 periods, and so on for all selected periods.

The AVM method is described in greater detail in Pilgrim et al. (1969).



- **Figure 4-1 Temporal Patterns for the 1% AEP 48 Hour Storm Event**

The resulting peak flow estimates using the temporal patterns described above are presented in **Table 4-4**.

- **Table 4-4 Sensitivity to Peak Flow to Temporal Pattern of Rainfall**

	48 hour Temporal Pattern				
Location	**AR&R** (m^3/s)	**AVM** (m^3/s)	**1972** (m^3/s)	**1974** (m^3/s)	**1975** (m^3/s)
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Brisbane Port Office	12817	13464	13287	14115	13634

4.3.4 Discussion

Table 4-3 and **Table 4-4** show that spatial and temporal patterns have a significant effect on peak flows. The works undertaken show that by varying spatial and temporal patterns, the peak flow



estimates at Savages Crossing can vary considerably. A Monte Carlo analysis could be undertaken to improve the accuracy of the Q100 flow estimate and help to reduce the uncertainties arising from the work undertaken so far. The historical spatial distributions produce pre-dams peak flows at Savages Crossing that range from 11,500 m^3/s to 8,000 m^3/s with the median peak flow of 10,050 m^3/s. The estimated peak flow at Savages Crossing using the CRC-FORGE spatial pattern was estimated to be 9600 m^3/s.

If an Initial Loss of 0 mm and Continuing Loss of 0 mm/h are applied to the CRC-FORGE 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11,278 m^3/s. It should be noted that the "best estimate" of peak flow at Savages Crossing from the statistical flood frequency analysis was estimated to be 12,000 m^3/s. This means that in order to reconcile peak flow estimates between RAFTS rainfall runoff modelling and the statistical flood frequency analysis, further work would need to be undertaken. This work would involve investigation of specific combinations of spatial and temporal patterns and application of acceptable loss rates to the RAFTS model. It is anticipated that this investigation would result in the reconciliation of flow estimates at Savages Crossing.

4.4 Comparison of Q100 estimates from statistical flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated Brisbane River Catchment RAFTS model
- CRC-FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

produced a Q100 at Savages Crossing of 11278 m^3/s. It would be reasonable to expect some losses with such an event and hence the hydrological modelling results, using typical design parameters, could be expected to be lower, say in the order of 10, 500m^3/s.

The difference between the results and those from the statistical frequency analysis of flood records (**Chapter 3**) indicates that there are underlying factors that have not been adequately addressed to date. This would require more detailed assessment than is available in the scope and timing of the current assessment. Potential factors influencing the difference in Q100 estimates include:

- potential for partial area storms
- variation in temporal patterns

- variation in spatial patterns
- variation in losses
- adjustment of data for influence of dams
- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.

The development of a Monte Carlo framework for analysing the factors affecting flood magnitude would enable the natural variation in the first four factors to be explicitly modelled. This would provide the insights necessary to resolve the differences between the two independent Q100 estimates.

4.5 Post-dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and run through the DNRM Dam Operations Model (Department of Natural Resources and Mines, 2003b). These inflows were based on the outputs presented in **Appendix H** and included an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/h.

The outflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the hydrograph volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC-FORGE and historical spatial patterns to determine flows at Savages Crossing, Moggill and Brisbane Port Office.

4.5.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

The parameters described in **Section 4.3.1** were used for the Post-dams RAFTS modelling.

The CRC-FORGE rainfall estimates with ARF's applied are presented in **Table 4-5**.

Table 4-5 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for the 1 in 100 AEP Rainfall – Post-dams

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	5368	2335	2502
Moggill	3017	3690	2999	3302	5043	3811	3990

Brisbane Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.5.2 Sensitivity to Spatial Pattern of Rainfall

The parameters described in **Section 4.3.2** were used for the Post-dams RAFTS modelling. Peak flows are presented in **Table 4-6**. Note that the critical duration storm at Savages Crossing, Moggill and Brisbane Port Office range from 72 to 120 hours for Post-dam Conditions. Flows presented at Moggill and the Brisbane Port Office in **Table 4-6** should be considered as indicative only. More accurate flows have been determined from the hydraulic modelling (**Chapter 5**).

Table 4-6 Post-dams Peak Flows for the 1 in 100 AEP Rainfall and Historical Spatial Distributions

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Brisbane Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: - (120hr) denotes the critical storm duration
- Bold values indicate the median flow at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.5.3 Sensitivity to Starting Water Level in Wivenhoe Dam

Wivenhoe Dam has 1,165 gigalitres (GL) of storage capacity for water supply purposes up to its full supply level of EL 67.0 m AHD (Australian Height Datum). A further 1,450 GL ref of storage capacity is available above the Full Supply Level, up to a level of EL 75.0 m AHD for the temporary storage of flood waters, i.e. the total capacity of Wivenhoe Dam is 2,615 GL. The flood storage is held empty, except when required, to store flood waters.

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1 in 100 AEP flood (average CRC-FORGE rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in **Table 4-7**.

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- **Table 4-7 Flood Runoff Volumes from the 1 in 100 AEP Rainfall Events above Wivenhoe Dam**

Storm Duration (hours)	CRC Rainfall Depth with ARF Applied (mm)	Runoff Volume (Gigalitres)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

almost

EL 75 m AHD

Table 4-7 shows that if Wivenhoe Dam is at FSL, the 1 in 100 AEP 30 hour (flood runoff volume can be fully stored between FSL and ~~Crest Level~~ without release. For 1 in 100 AEP events with longer durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the ~~crest level~~ is overtopped (no releases).

EL 75 m AHD

Given the current operational procedures, it is unlikely that releases would not occur during a flood event, particularly if Wivenhoe Dam were at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs were done for the 1 in 100 AEP 72-hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in Table 4-8.

- **Table 4-8 Flows for Dam Starting Water Levels Sensitivity Analysis for the 1 in 100 AEP 72 Hour Storm**

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Brisbane Port Office	5044	4402	4402

Note: - Flows at Moggill and Brisbane Port Office should be considered indicative only.

Table 4-8 shows that the reduction in flow is approximately 13% at the Brisbane Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

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4.5.4 1893 and 1974 Historical Flood Events

The information from the two historical flood events (1893 and 1974) were run through the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post-dam flows are presented in **Table 4-9**.

- **Table 4-9 Predicted Post-dam Flows for the 1893 and 1974 Historical Flood Events**

	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
Location	**No Dams (m^3/s)**	**Somerset and Wivenhoe in Place (m^3/s)**	**Somerset in Place (m^3/s)**	**Somerset and Wivenhoe in Place (m^3/s)**
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Brisbane Port Office	13869	9519	9874	6801

Table 4-9 indicates that the peak flows for the historical events at the Brisbane Port Office are above the 1 in 100 AEP CRC-FORGE estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1974 peak flow estimate and even more with the 1893 event. However, it is clear from **Table 4-9** that the effect of the dams on events of such magnitude is significant. While flows predicted by the RAFTS model at the Brisbane Port Office are only indicative, they provide a reasonable estimate as calibration of this model has been undertaken. The most accurate way to assess flows at the Brisbane Port Office Gauge would be to use a hydraulic model.

It should be noted that the predicted flow for the 1974 event, assuming that Wivenhoe dam had been in place, is 6,800 m^3/s at the Brisbane Port Office Gauge. This is larger than the 'best' estimate of the 1 in 100 AEP event at the Brisbane Port Office of 6,500 m^3/s. This is thought to be due to the 1974 spatial pattern (see **Appendix G**) where the majority of rainfall fell within the Lower Brisbane and Bremer River Catchment. For rainfall events where the majority of rainfall falls below the dams, the resultant flood will have a lower associated probability (i.e. will be expected to happen less often) after post Wivenhoe compared to prior to the construction of Wivenhoe. This study did not further investigate partial catchment storms on the over the Lower Brisbane, Bremer and Lockyer catchments apart from the overall sensitivity of spatial patterns (**Section 4.5.2**) The magnitude of the modelled 1974 event 'with dams' was a strong influence on the selection of the values proposed as the 'best estimate' and the notional 'upper limit' of the Q100 at the Port Office (**Section 4.5.5**).

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4.5.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. Monte-Carlo analysis would be an appropriate way to investigate the complex interactions between dams and variations in losses, spatial and temporal patterns to obtain the best possible estimate of the 1 in 100 AEP flood event.

The CRC-FORGE spatially distributed peak flow at Savages Crossing was estimated to be 5,368 m^3/s for the post-dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow of 6,241 m^3/s.

Based on the preceding investigations, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 4-10** provides a range of estimates with a 'best estimate,' upper estimate and lower estimate. Given the current information, the 'best estimate' of peak flow at the Brisbane Port Office would be 6500 m^3/s with an upper and lower limit of 8,000 m^3/s and 5,000 m^3/s respectively. While the estimates predicted by RAFTS at Moggill and the Brisbane Port Office should be considered indicative, previous modelling shows that flows predicted by RAFTS are consistent with flows predicted by the MIKE11 hydraulic model.

Table 4-10 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood with Dams

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The 'best estimate' of 6,500 m^3/s was adopted after consideration of the RAFTS modelling for current design spatial pattern, various historical patterns, the performance of the model in reproducing flows at Savages Crossing for pre-dam flows and the modelling of the 1974 event with Wivenhoe dam in place (**Section 4.5.4**). The estimate of the lower end of the plausible range of the Q100 estimate is 5,000 m^3/s. It was adopted with particular consideration to the range of results from the sensitivity to the spatial patterns. The estimate of the upper bound of the plausible range was taken to be 8,000 m^3/s. This upper bound was adopted after particular consideration of the variation in the spatial patterns, the sensitivity to temporal patterns, and the 1974 peak flow results for the 'Somerset only' then 'Somerset and Wivenhoe' dams scenarios.

A Monte-Carlo analysis would improve the accuracy of the 1 in 100 AEP flood estimate and reduce the uncertainty in plausible range of the flood estimates.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flow estimates are:

- inclusion of the lower CRC-FORGE rainfall depths with areal reduction factors,
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures (the previous study Sinclair Knight Merz 1998), assumed emergency operating procedures which minimised the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River),
- In the 1998 study, the emphasis was to match statistical flood frequency estimates at Moggill and the Brisbane Port Office. The reliability of the streamflow at Moggill and Brisbane Port Office is questionable as these gauges are river level gauges and tidal effects are difficult to account for at these locations. After discussions with DNRM, who have just developed a new composite flood series at Savages Crossing, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and statistical flood frequency estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing, as discussed in **Chapter 3**, and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

Rainfall-runoff modelling using a Monte Carlo framework could be undertaken to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This would correctly reflect the combined influences of these stochastic factors and improve the accuracy of the estimated Q100 flood magnitude. It would also reduce the uncertainty of the Q100 flood estimates.

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5. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Brisbane Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Brisbane Port Office is good, other sections of the reach within Brisbane City have not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Brisbane Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

5.1 Assumptions

Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane River Bar.

5.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from approximately 10 km downstream of Savages Crossing to the Brisbane River Bar. The model also includes Bremer River and other smaller tributaries, which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1 in 100 AEP spatially distributed over the catchment. Rainfall durations ranging from 24 to 120 hours were assessed.

5.3 Results

The peak flow rates and flood levels at Moggill and Brisbane Port Office are presented in **Table 5-1**.

- **Table 5-1 Peak Flood Levels and Flows for the 1 in 100 AEP CRC-FORGE Spatial Distributed Rainfall**

	Moggill		Brisbane Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

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5.4 Discussion

Comparison of Table 4-5 and **Table 5-1** indicates that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Brisbane Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Brisbane Port Office.

Using the 'best estimate' and upper and lower limits of peak flows at the Brisbane Port Office presented in **Section 4.5.5**, a rating curve was used to predict flood levels at the Brisbane Port Office for the 1 in 100 AEP flood event. Peak flood levels and corresponding flows are presented in **Table 5-2**.

- **Table 5-2 Peak Flood Level and Peak Flow Estimates for the 1 in 100 AEP Flood Event at Brisbane Port Office**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

Note that these estimates should be considered indicative because the tide level variation during flood events may vary. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918 m AHD) at the Brisbane River Bar.

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6. Conclusions

Detailed investigations have been undertaken to assist the Expert Review Panel to assess the likelihood of floods in the lower reaches of the Brisbane River. The assistance has been centred on the two tasks of:

- undertaking statistical flood frequency analysis, and
- updating the estimates of flood frequency from rainfall-runoff modelling with new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the 1 in 100 annual exceedance probability (AEP) flood, which is also referred to as the Q100 flood.

The two tasks provide independent assessments of the Q100 event, firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

Statistical flood frequency analysis

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (i.e. the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in **Table 6-1**.

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- **Table 6-1 Most plausible estimates of the Q100 peak flow and its plausible range at Savages Crossing based on statistical flood frequency analysis**

Scenario	"Best" estimate	Likely lower estimate	Likely uUpper estimate
"No dams"	12,000	10,000	14,000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the significant sources of uncertainty in the recorded data, length of record, choice of distribution and adjustment of the data for the effect of the dams. As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7,500 m^3/s and 11,000 m^3/s (**Section 3.8**). Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method by which SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by utilising design depth, temporal and spatial patterns of the storm, losses (e.g. the soil, interception by vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels behind the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increasing catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A

range of peak flows were determined at Savages Crossing and these varied between 8,000 m^3/s and 11,500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10,000 m^3/s using an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h. This compares to the statistical frequency estimate (i.e. analysis of recorded flow data) of 12,000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3,000 m^3/s to 8,000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6,200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12,000 m^3/s and 13,800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it should be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken for variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing and the Brisbane Port Office was estimated to be 5,400 m^3/s and 5,000 m^3/s respectively. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing and the Brisbane Port Office was reduced to 3,500 m^3/s and 4,400 m^3/s respectively.

Q100 Estimate at the Brisbane Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Brisbane Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was



used to account for routing effects from Savages Crossing to the Brisbane Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Brisbane Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Brisbane Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 6-2** provides a 'best estimate and the associated plausible range within which the Q100 estimate lies.

- **Table 6-2 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors,
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures, and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

To reduce the uncertainty in the above estimates, the following actions would serve to increase the accuracy of the 1 in 100 AEP flow estimates.

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimate of Q100 that correctly reflects the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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7. References

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane River flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the flood frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the flood frequency Analysis Outcomes.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC-FORGE Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 1 in 100 AEP event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the DNRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine the 1 in 100 AEP flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long-term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQWB and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of



sophistication appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.

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Appendix B Flow Gauging Stations Omitted from Consideration

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143222A	Atkinson Dam	Atkinson Creek Outlet		20	Small catchment area, offstream storage	DNRM
143234A	Atkinson Dam Hea			6	Small catchment area, offstream storage	DNRM
143228A	Bill Gunn Dam	Lake Dyer	3	18	Catchment area too small	DNRM
143027A	Blunder Creek	King Avenue Bridge	31	8	Urban creek in Brisbane area, Small catchment	DNRM
2121	Blunder Creek	King Ave- Durack		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1594	Breakfast Creek	Opposite Newstead House		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1579	Breakfast Creek	Sedgley Park Retention Basin-New Market		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1525	Breakfast Creek	Opposite Mann Park- Bowen Hills		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143104B	Bremer River	Rosevale	67	21	Catchment area too small	DNRM
143104A	Bremer River	Rosevale	77	34	Catchment area too small	DNRM
143110A	Bremer River	Adams Bridge	125	35	Catchment area too small	DNRM
143940	Bremer River	Stokes Crossing	180	21	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143909	Bremer River	Rosewood	543		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143833	Bremer River	Rosewood Alert	543	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143908	Bremer River	Rosewood TM	543	25	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143934	Bremer River	Walloon Bvrt	585		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143805	Bremer River	Walloon Alert-P	585	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143911	Bremer River	Ipswich	1850		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143956	Bremer River	Three Mile Bridge Alert	1870		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143954	Bremer River	Ipswich Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143953	Bremer River	One Mile Bridge Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143852	Bremer River	Brassall(Hancocks Br) Al		5	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143115A	Bremer River	Berry's Lagoon		9	Record length too short	DNRM
143944	Brisbane River	Linville	2005	47	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143007A	Brisbane River	Linville	2009	39	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143831	Brisbane River	Devon Hills Alert	2160	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143922	Brisbane River	Devon Hills Bvrt	2190		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143002A	Brisbane River	Plainlands	3950	12	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143002B	Brisbane River	Fulham Vale	3950	34	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143005A	Brisbane River	Watts Bridge	4602	20	Record length too short	DNRM
143008A	Brisbane River	Middle Creek	6704	20	Record length too short	DNRM
143026A	Brisbane River	Wivenhoe	7023	3	Record length too short	DNRM
143036A	Brisbane River	Wivenhoe Headwater	7023	17	Record length too short	DNRM
143035A	Brisbane River	Wivenhoe Tailwater	7023	17	Record length too short	DNRM
143907	Brisbane River	Lowood	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143941	Brisbane River	Lowood Bvrt	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143827	Brisbane River	Lowood Alert-P	10062	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143916	Brisbane River	Mt Crosby	10600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143839	Brisbane River	Mt Crosby Alert	10600	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143925	Brisbane River	Mt Crosby TM	10600	28	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143951	Brisbane River	Moggill Alert	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143915	Brisbane River	Moggill Bvrt	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143924	Brisbane River	Moggill TM	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143900	Brisbane River	Caboonbah			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143914	Brisbane River	Gregor Creek			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143920	Brisbane River	Gregor Creek Bvrt			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143902	Brisbane River	Murrumba			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143005	Brisbane River	Watts Bridge			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143903	Brisbane River	Wivenhoe			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143018A	Brisbane River	Avoca Vale	1498	20	Record length too short (post Wivenhoe)	DNRM
143868	Brisbane River	Colleges Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143918	Brisbane River Estuary	Bishop Island			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143217A	Buaraba Creek	Vineyard	63	10	Catchment area too small	DNRM
143211A	Buaraba Creek	15.8 km	251	12	Catchment area too small	DNRM
143224A	Buaraba Creek	Diversion Channel		19	Catchment area too small	DNRM
143094A	Bulimba Creek	Mansfield	57	26	Urban creek in Brisbane area, Small catchment	DNRM
143004A	Bulimba Creek	Belmont	51	22	Urban creek in Brisbane area, Small catchment	DNRM
1591	Bulimba Creek	End of Aquarium Ave. Hemmant		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1528	Bulimba Creek	Doughboy Pde- Hemmant		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1804	Bulimba Creek	Greenwood St- Wishart		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1831	Bulimba Creek	Merion Pl- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1707	Bulimba Creek	Old Cleveland Rd- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143926	Bundamba Creek	Ripley Alert	35		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143959	Bundamba Creek	Harding Street Alert	96		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143958	Bundamba Creek	Blackstone Bridge Alert	97	10	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143955	Bundamba Creek	Bundamba School Alert	102		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143854	Bundamba Creek	Bundamba (Hanlon St) Al	109	7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143114A	Bundamba Creek	Mary Street	110	11	Urban creek in Ipswich area, Small catchment	DNRM
143307A	Byron Creek	Causeway	79	28	Catchment area too small	DNRM
143012A	Cooyar Creek	51.5km.	443	4	Record length too short	DNRM
143015B	Cooyar Creek	Damsite	963	13	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143015A	Cooyar Creek	Damsite	963	22	Record length too short	DNRM
143013A	Cressbrook Creek	The Damsite	321	16	Record length too short	DNRM
143952	Cressbrook Creek	Rosentreters Bridge	440		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143921A	Cressbrook Creek	Rosentreters Bridge	447	17	Record length too short	DNRM
143921	Cressbrook Creek	Rosentreters Bridge TM	477		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143806	Cressbrook Creek	Rosentreters Bridge Al	477	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143857	Deebing Creek	Churchill Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143021A	Ekibin Creek	Dudley Street.	13	1	Urban creek in Brisbane area, Small catchment	DNRM
143011A	Emu Creek	Raeburn	439	24	Catchment area too small	DNRM
143010A	Emu Creek	Boat Mountain	915	11	Catchment area too small	DNRM
143010B	Emu Creek	Boat Mountain	915	27	Catchment area too small	DNRM
143932A	Enoggera Creek	Bancroft Park	70	10	Urban creek in Brisbane area, Small catchment	DNRM
143932	Enoggera Creek	Bancroft Park TM	67		Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1531	Enoggera Creek	100 M U/S From Original E e529		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1532	Enoggera Creek	Enoggera Dam- The Gap		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1529	Enoggera Creek	Kelvin Grove Rd- Kelvin Grove		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143208A	Fifteen Mile Creek	Dam Site	87	33	Catchment area too small	DNRM
143214A	Flagstone Creek	Windolfs	142	14	Catchment area too small	DNRM
143233A	Flagstone Creek	Brown-Zirbels Road		10	Catchment area too small	DNRM
1717	Gold Creek	Reservoir- Brookfield (Brisbane Water)			Urban creek in Brisbane area, Small catchment	South East Queensland Water
143028A	Ithaca Creek	Jason Street	10	31	Urban creek in Brisbane area, Small catchment	DNRM
1535	Ithaca Creek	Jason St- Ithaca		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143304A	Kilcoy Creek	Mount Kilcoy	127	36	Catchment area too small	DNRM
143304B	Kilcoy Creek	Mount Kilcoy Weir	131	15	Catchment area too small	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143235A	Lake Clarendon Head			6	Offstream storage	DNRM
143215A	Laidley Creek	Mulgowie Weir	154	14	Catchment area too small	DNRM
143209A	Laidley Creek	Mulgowie1	167	5	Catchment area too small	DNRM
143209B	Laidley Creek	Mulgowie2	167	36	Catchment area too small	DNRM
143225A	Laidley Creek	Showgrounds Weir Head Water	233	19	Catchment area too small	DNRM
143226A	Laidley Creek	Showgrounds Weir Tail Water	233	19	Catchment area too small	DNRM
143943	Laidley Creek	Laidley	285		Catchment area too small	BoM, Queensland Regional Office
143923	Laidley Creek	Thornton			Catchment area too small	BoM, Queensland Regional Office
143229A	Laidley Creek	Warrego Highway		13	Catchment area too small	DNRM
143202A	Lockyer Creek	Russell Siding	271	7	Catchment covered by other gauges DS	DNRM
143203C	Lockyer Creek	Helidon Number 3	357	16	Catchment covered by other gauges DS	DNRM
143203A	Lockyer Creek	Helidon	357	45	Catchment covered by other gauges DS	DNRM
143203B	Lockyer Creek	Helidon No.2	382	24	Catchment covered by other gauges DS	DNRM
143904	Lockyer Creek	Gatton	1550		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143204A	Lockyer Creek	Wilsons Weir	1655	29	Catchment covered by other gauges DS	DNRM
143905	Lockyer Creek	Glenore Grove	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143906	Lockyer Creek	Glenore Grove Bvrt	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143807	Lockyer Creek	Glenore Grove Alert	2230	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143206A	Lockyer Creek	Brightview Weir	2393	20	Catchment covered by other gauges DS	DNRM
143201A	Lockyer Creek	Tarampa	2405	17	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143201B	Lockyer Creek	Tarampa Number 2	2405	22	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143917	Lockyer Creek	Lyons Bridge	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143913	Lockyer Creek	Lyons Bridge Bvrt	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143819	Lockyer Creek	Lyons Bridge Alert-P	2530	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143227A	Lockyer Creek	O'Reilly's Weir Tailwater	2965	5	Record length too short	DNRM
2142	Lota Creek	Rickertt Rd Ransome		4	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143213B	Ma Ma Creek	Ma Ma Weir	226	9	Catchment area too small	DNRM
143213A	Ma Ma Creek	Harms	227	4	Catchment area too small	DNRM
143213C	Ma Ma Creek	Harm's		8	Catchment area too small	DNRM
143032A	Moggill Creek	Upper Brookfield	23	27	Urban creek in Brisbane area, Small catchment	DNRM
143020A	Moggill Creek	Misty Morn	61	9	Urban creek in Brisbane area, Small catchment	DNRM
143020	Moggill Creek	Misty Morn TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1722	Moggill Creek	Fortrose St- Kenmore		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2143	Moolabin Creek	Brisbane River Golf Club-Tennyson		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143219A	Murphys Creek	Spring Bluff	18	24	Urban creek in Brisbane area, Small catchment	DNRM
1549	Norman Creek	Joachim St- Holland Park West		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1552	Norman Creek	South East Freeway-Greenslopes		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1555	Norman Creek	Caswell St- East Brisbane River		10	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143033A	Oxley Creek	New Beith	60	27	Urban creek in Brisbane area, Small catchment	DNRM
143019A	Oxley Creek	Upstream Beatty Road	152	3	Urban creek in Brisbane area, Small catchment	DNRM
143019B	Oxley Creek	Downstream Beatty Road	152	6	Urban creek in Brisbane area, Small catchment	DNRM
143019	Oxley Creek	Beatty Road TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1588	Oxley Creek	Mouth of Oxley Creek		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1727	Oxley Creek	New Beith (DNR)+F31		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2023	Oxley Creek	Corinda High School- Corinda		12	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2125	Oxley Creek	Beatty Rd- Acacia Ridge		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
2111	Oxley Creek	Johnson Rd- Forestdale		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143024A	Pullen Pullen Creek	Moggill Road	27	4	Urban creek in Brisbane area, Small catchment	DNRM
1745	Pullen Pullen Creek	Pinjarra Rd- Pinjarra Hills		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143983	Purga Creek	Loamside Alert	215	8	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143113A	Purga Creek	Loamside	215	30	Catchment area too small	DNRM
143869	Purga Creek	Peak Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143218A	Redbank Creek	Holcomb	55	8	Urban creek in Ipswich area, Small catchment	DNRM
143216A	Redbank Creek	Water Treatment Works	60	11	Urban creek in Ipswich area, Small catchment	DNRM
143231A	Redbank Creek	Clarendon Number 2		10	Urban creek in Ipswich area, Small catchment	DNRM
143230A	Redbank Creek	Clarendon Pump Station		10	Urban creek in Ipswich area, Small catchment	DNRM
143306A	Reedy Creek	Upstream Byron Creek Junct	56	28	Catchment area too small	DNRM
143103A	Reynolds Creek	Moogerah	190	37	Catchment area too small	DNRM
143103B	Reynolds Creek	Moogerah	190	6	Catchment area too small	DNRM
143111A	Reynolds Creek	Moogerah Dam Headwater	226	36	Head gauge affected by dam site	DNRM
143112A	Reynolds Creek	Moogerah Tailwater	227	23	Tail gauge affected by dam site	DNRM
143220A	Sandy Creek	Forest Hill	102	7	Urban creek in Brisbane area, Small catchment	DNRM
143232A	Sandy Creek	Forest Hill		8	Urban creek in Brisbane area, Small catchment	DNRM
143030A	Sandy Creek	Indooroopilly		22	Urban creek in Brisbane area, Small catchment	DNRM
143223A	Seven Mile Lagoon	Diversion Channel		20	Diversion channel	DNRM
143023A	Small Catchment	Algester	1	4	Urban creek in Brisbane area, Small catchment	DNRM
143022A	Stable Swamp Creek	Interstate Railway	19	11	Urban creek in Brisbane area, Small catchment	DNRM
2129	Stable Swamp Creek	Musgrave Rd- Coopers Plains		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143303A	Stanley River	Peachester	104	76	Catchment area too small	DNRM
143938	Stanley River	Woodford TM	220		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143829	Stanley River	Woodford Alert-P	220	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143901	Stanley River	Woodford	250		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143301B	Stanley River	Donnelly Dell	1227	4	Record length too short	DNRM
143301A	Stanley River	Hazeldean	1242	3	Record length too short	DNRM
143305	Stanley River	Somerset Dam	1330		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143818	Stanley River	Somerset Dam Hw Alert-B	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143817	Stanley River	Somerset Dam Hw Alert-P	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143305A	Stanley River	Somerset Dam	1336	24	Head gauge affected by dam site	DNRM
143302A	Stanley River	Silverton	1339	49	Data obtained, but uncertainty as to appropriate rating	DNRM
143960	Stanley River	Peachester			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143212A	Tenthill Creek	Tenthill	447	35	Catchment area too small	DNRM
143106A	Warrill Creek	Aratula Weir	122	7	Catchment covered by other gauges DS	DNRM
143102A	Warrill Creek	Kalbar No.1	465	46	Catchment covered by other gauges DS	DNRM
143102B	Warrill Creek	Kalbar No.2	468	13	Catchment covered by other gauges DS	DNRM
143937	Warrill Creek	Kalbar	470		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143910	Warrill Creek	Harrisville	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143912	Warrill Creek	Harrisville TM	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143101A	Warrill Creek	Mutdapilly	771	43	Catchment covered by other gauges DS	DNRM
143825	Warrill Creek	Amberley Alert-P	850	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143933	Warrill Creek	Amberley Bvrt	862		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143117A	Warrill Creek	Junction Weir H/W		5	Record length too short	DNRM
143118A	Warrill Creek	Junction Weir Tailwater		6	Record length too short	DNRM
143116A	Warrill Creek	Toohill's Crossing		6	Record length too short	DNRM
143105A	Warrill Creek East	Churchbank Weir	149	50	Catchment covered by other gauges DS	DNRM
143031A	Water St. Drain	Exhibition Ground		5	Urban creek in Brisbane area, Small catchment	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143939	Western Creek	Kuss Road	200	21	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
143861	Western Creek	Grandchester Alert		4	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1583	Wolston Creek	700m U/S Wacol Station Rd-Wacol		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143962	Woogaroo Creek	Brisbane River Road Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143927	Woogaroo Creek	Opossum Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143961	Woogaroo Creek	Alice Street Alert		7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office

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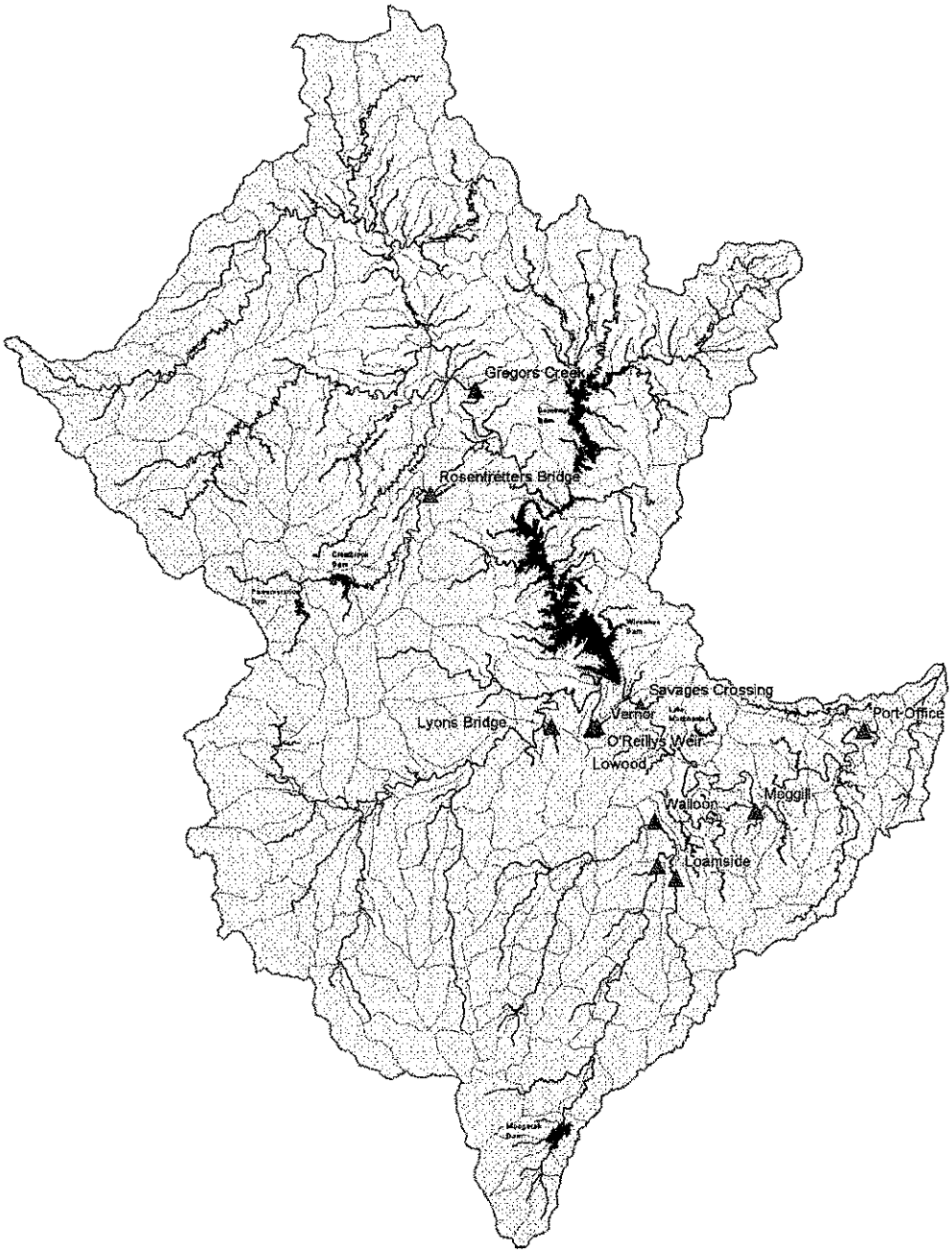
Appendix C Location of select stream gauges

- **Location of stream gauge sites that were used in flood frequency analysis**



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Appendix D Flood Data Series for Savages Crossing from DNRM

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Date	Gauged flow at Savages Crossing/Lowood Recorded Values	No Dams	Both Dams Working	Date*
11/03/1890		7343		
09/06/1891		1790		
04/04/1892		3953		
03/02/1893		13156		
21/04/1894		1080		
26/01/1895		1194		
12/02/1896		3699		
02/03/1897		432		
11/01/1898		5889		
30/01/1899		211		
23/05/1900		313		
21/03/1901		885		
15/10/1901		142		
1/06/1903		1717		
18/04/1904		351		
19/01/1905		816		
14/03/1906		745		
1/06/1907		302		
15/03/1908		6356		
17/07/1909		325		
28/12/1909	814	814	501	16/01/1910
13/01/1911	1317	1317	525	
4/03/1912	491	491	251	25/06/1912
23/05/1913	416	416	133	
27/02/1914	234	234	8	
11/02/1915	1035	1035	51	
12/04/1916	150	150	60	
29/01/1917	476	476	83	
13/12/1917	522	522	385	
8/05/1919	91	91	9	
22/01/1920	402	402	6	
11/06/1921	1237	1237	283	
30/12/1921	1280	1280	745	
16/10/1922	46	46	6	
12/02/1924	173	173	125	
21/06/1925	778	778	111	
6/01/1926	126	126	73	
27/01/1927	2715	2715	1029	
20/04/1928	4225	4225	927	
21/01/1929	2084	2084	682	4/04/1929
30/06/1930	749	749	332	1/06/1930
6/02/1931	5575	5575	1114	
10/12/1931	326	326	257	
20/01/1933	312	312	300	
23/02/1934	614	614	241	6/01/1934
26/02/1935	120	120	38	18/01/1935
24/03/1936	139	139	6	
17/03/1937	1103	1103	527	
28/05/1938	1052	1052	216	
17/03/1939	460	460	251	
3/03/1940	597	597	106	
25/01/1941	426	426	291	
10/02/1942	1060	1060	557	

* Peak occurred at a different time according to operational rules in with dams case

Generated using IQQM model of catchment with calibrated 6 six hourly disaggregation.

Gauged Flow at Savages Crossing/Lowood/Vernor

Gauged Flows affected by Somerset

Gauged flows affect by Somerset and Wivenhoe

Flows adjusted to remove the impact of Somerset removed.

Flows adjusted to remove the effect of Somerset and Wivenhoe

Flows routed through WIVOPS program using inflows into Somerset and Wivenhoe.

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Appendix E Regional statistical flood frequency Information

E.1 Introduction

The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (eg. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Brisbane Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

E.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in **Section 2.2** only DNRM gauge flow data were both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in **Table E-1**.

The location of the gauges can be seen in the catchment map in **Appendix** C.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in **Table E-1** were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in **Section E.3**.

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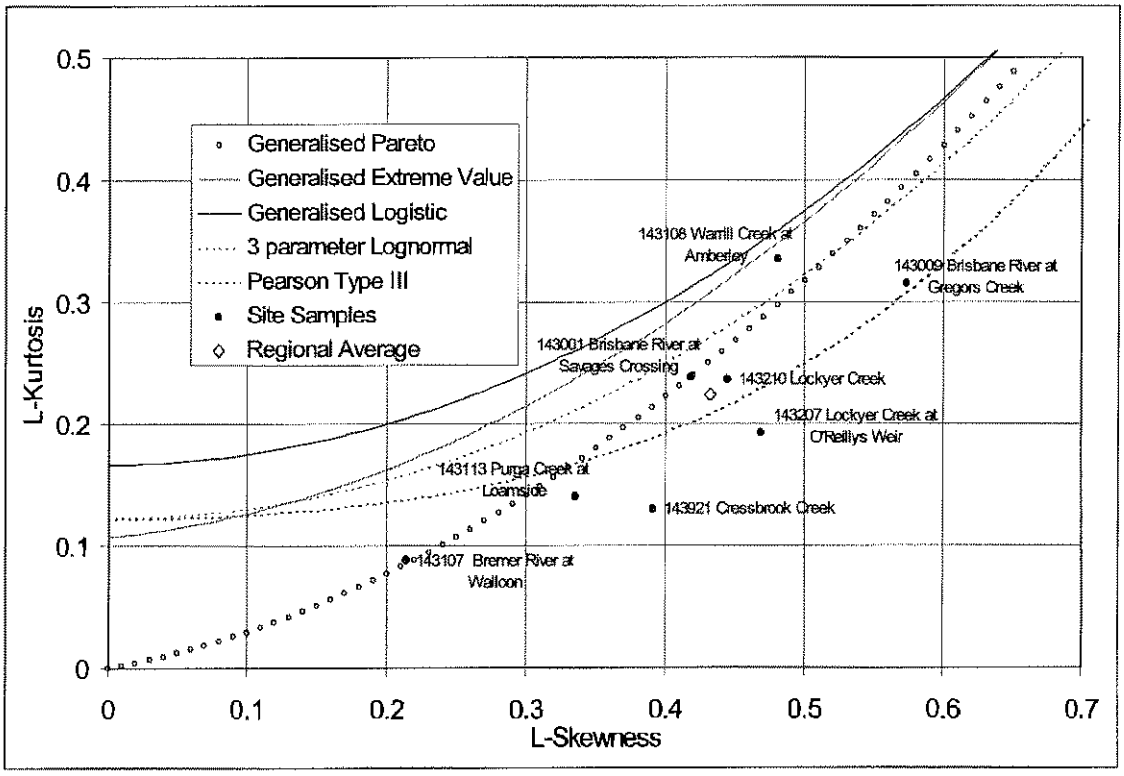
Table E-1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods

River	Station Name	Station Number	Years of Record	C'ment Area (km^2)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

E.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in **Table E-1**. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. **Figure E-1** shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (e.g. Peel et. al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

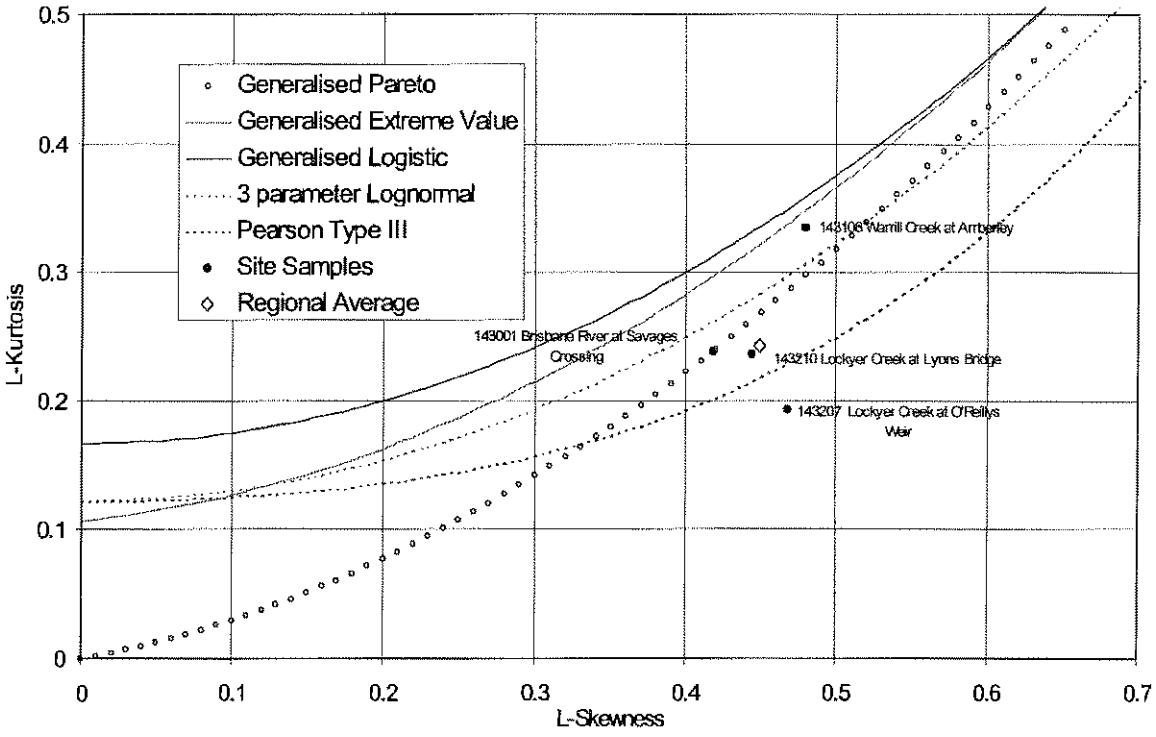
Also shown on **Figure E-1** is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that Bremer River @Walloon (143107A) and Brisbane @ Gregor's Creek (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (**Appendix F**) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.



- **Figure E-1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment**

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500 km²), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (**Figure E-2**) supports the adoption of the Generalised Pareto distribution.



- **Figure E-2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)**

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in **Table E-2**.

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- **Table E-2 Regional parameter values of the adopted Generalised Pareto distribution**

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter, ξ	-0.062	-0.096
Scale parameter, α	0.811	0.795
Shape parameter, κ	-0.230	-0.275

E.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation, and
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of **Table E-2**. The scale parameter (α) from the regional analysis shown in **Table E-2** is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\hat{\alpha}_{143001} = L^1_{143001}\alpha^{CV}_{\text{Regional}} = 1181 \times 0.795 = 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in **Table E-3**. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\sigma_{\alpha,143001} = L^1_{143001}\sigma^{CV}_{\alpha,\text{Regional}} = 1181 \times 0.388 = 458$$

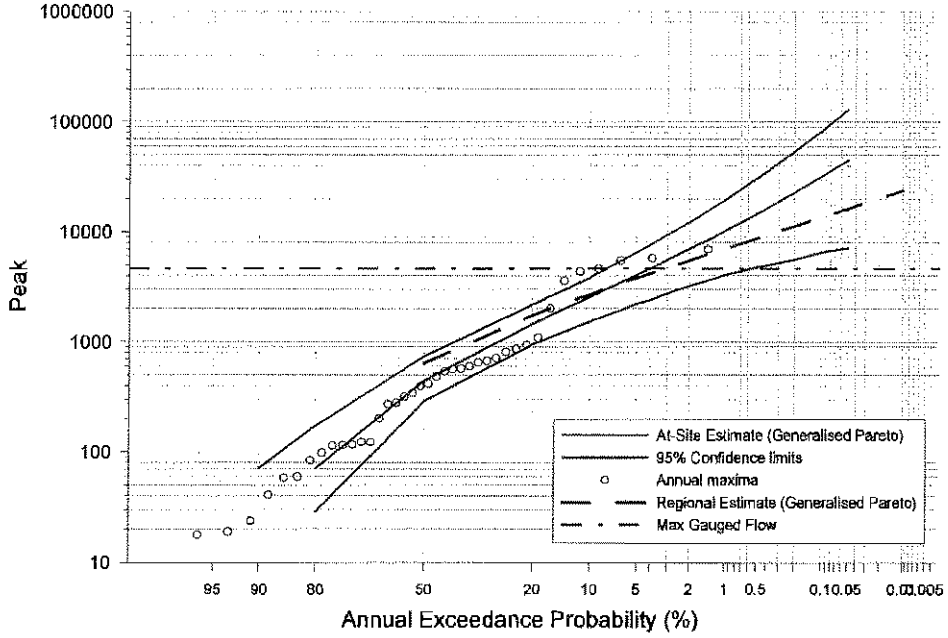
The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

- **Table E-3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution**

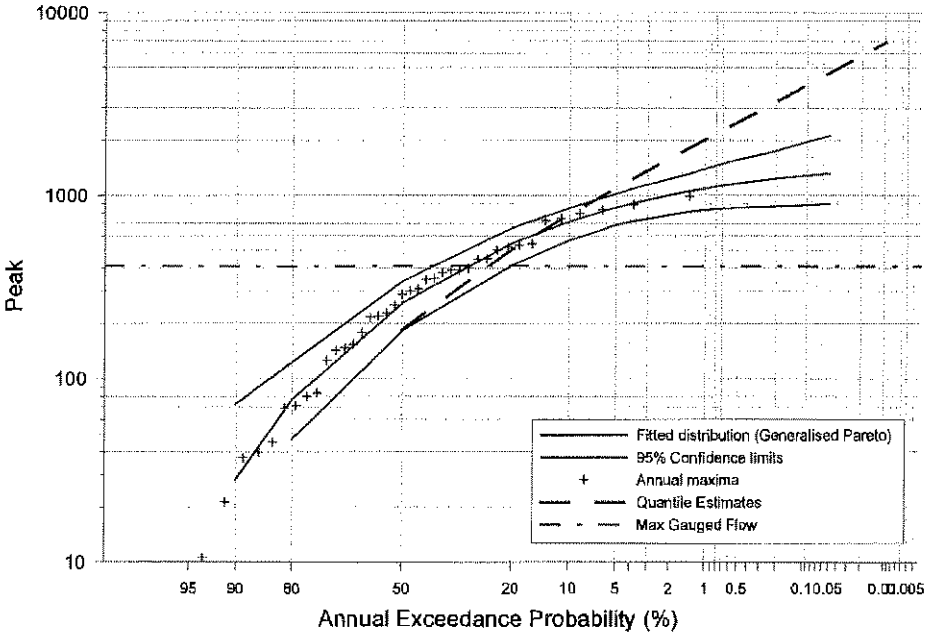
Site Number	Gauging Station Name	Scale parameter, α	Shape parameter, κ
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		**0.388**	**0.297**

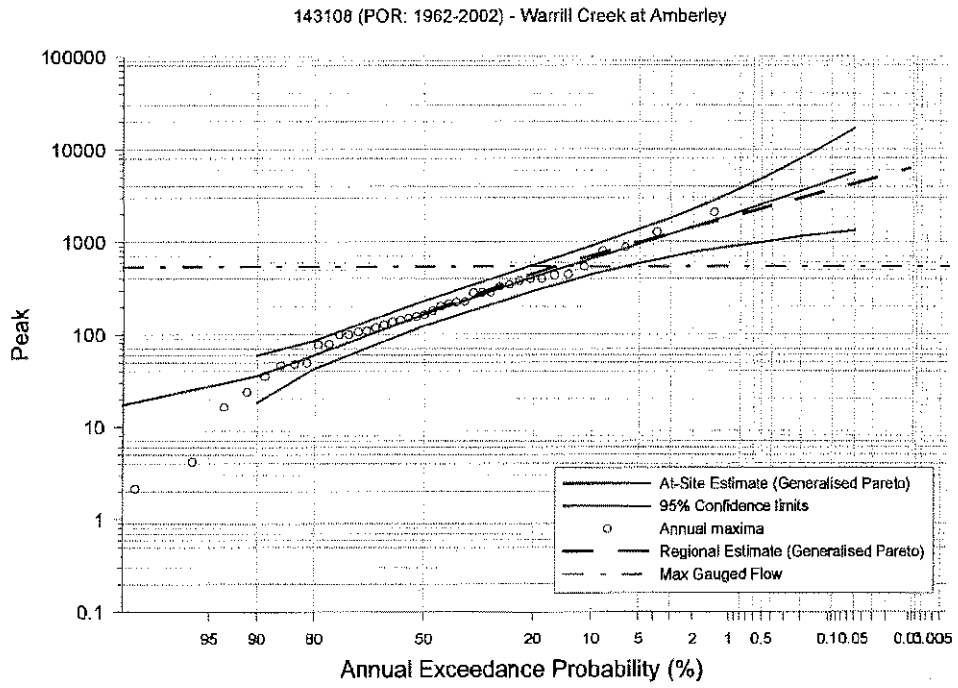
Appendix F At-Site/Regional Analysis of Selected Gauges

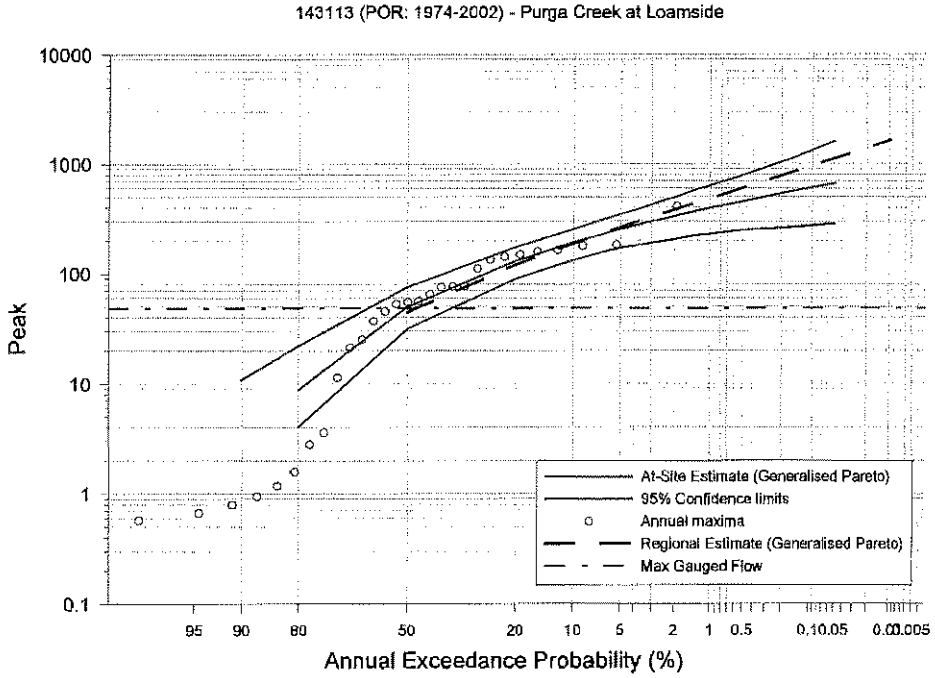
143009 (POR: 1963-2002) - Brisbane River at Gregors Creek

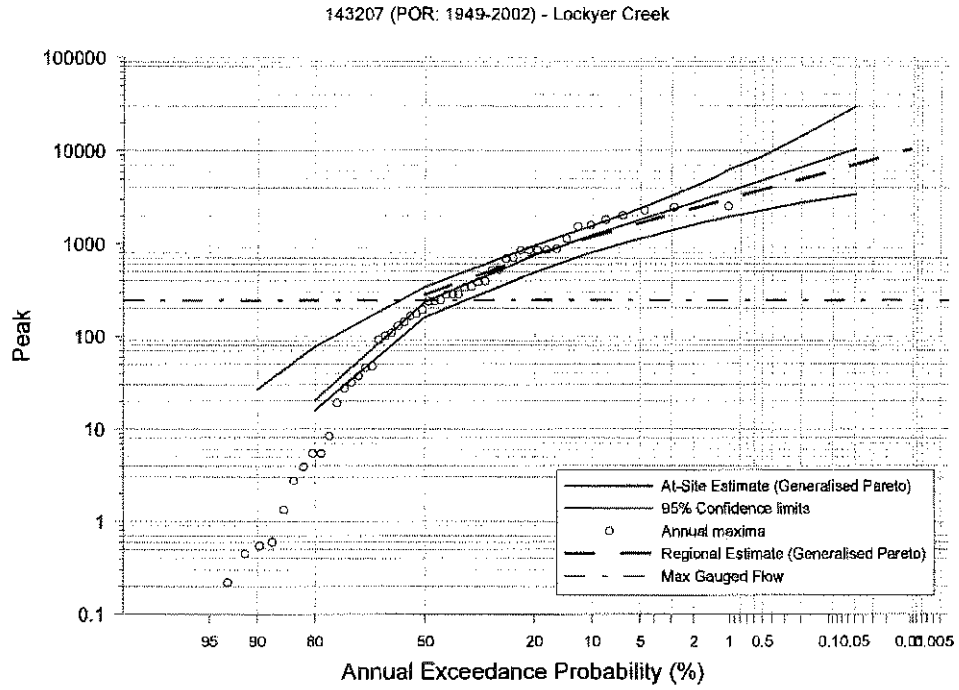


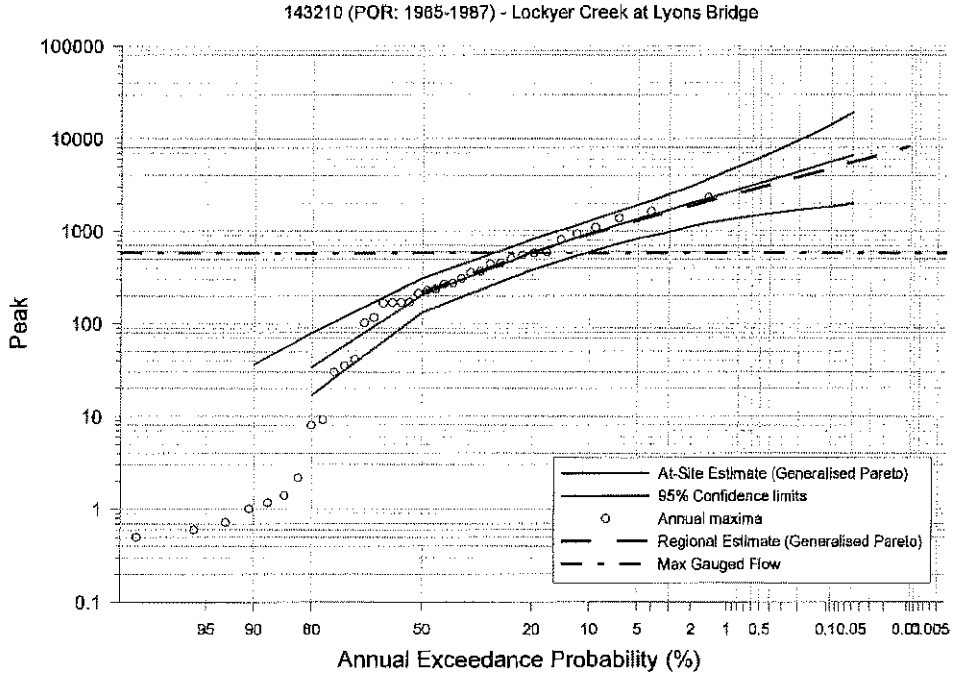
143107 (POR: 1962-2002) - Bremer River at Walloon

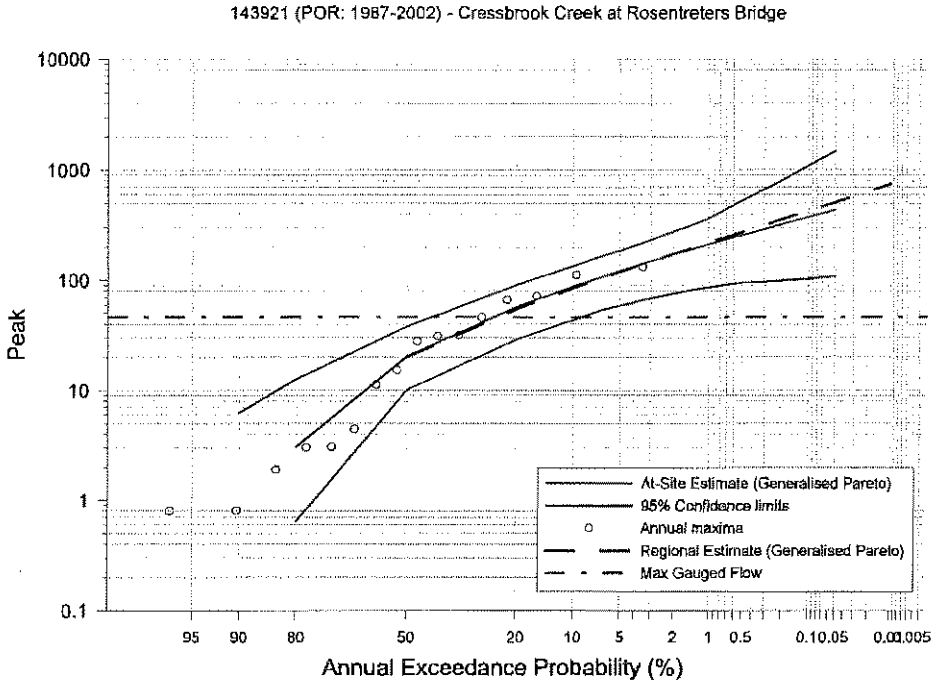



143108 (POR: 1962-2002) - Warrill Creek at Amberley
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143113 (POR: 1974-2002) - Purga Creek at Loamside
Peak
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
10000
1000
100
10
1
0.1
Peak
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidance limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow

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Appendix G Historical Spatial Distributions

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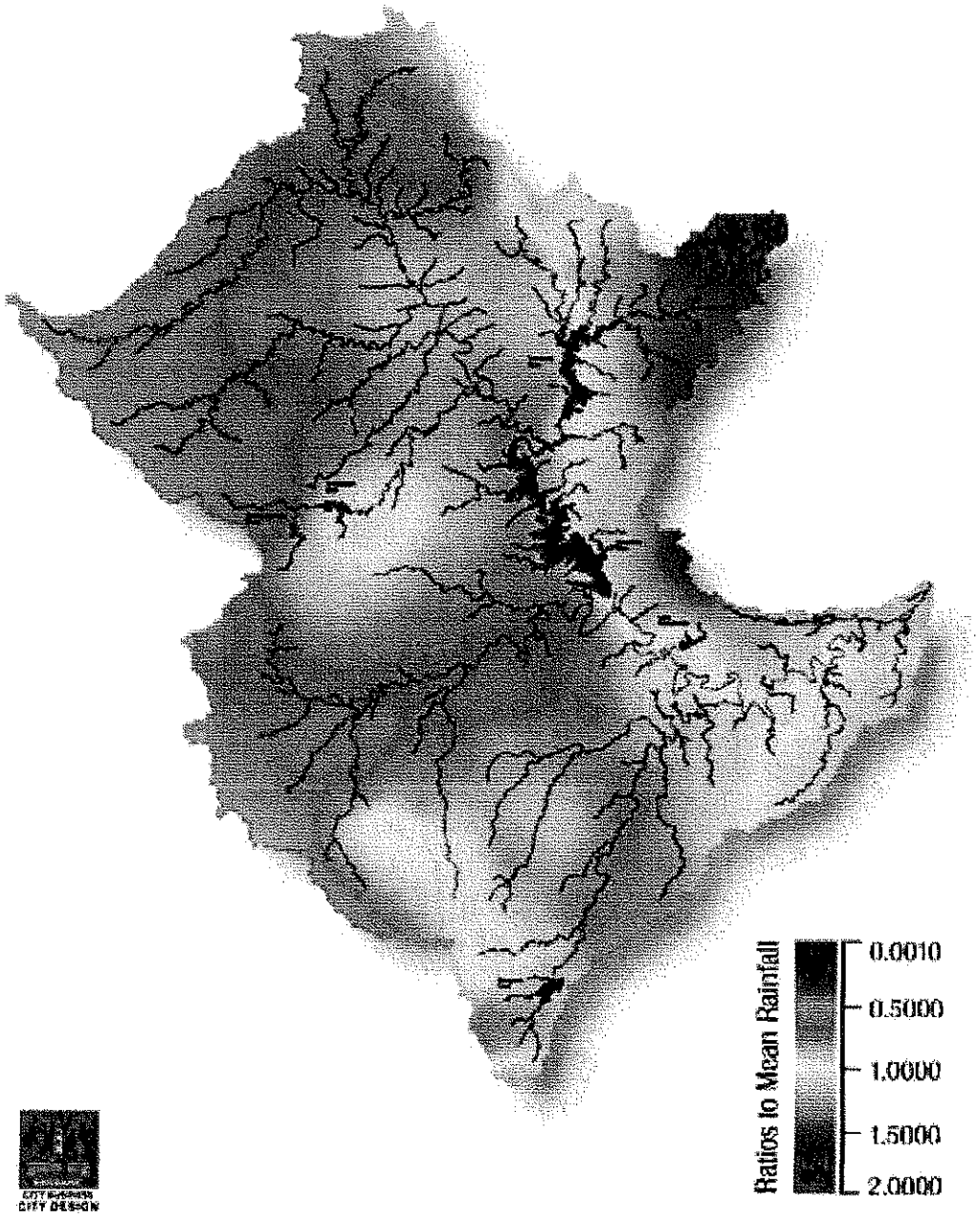
CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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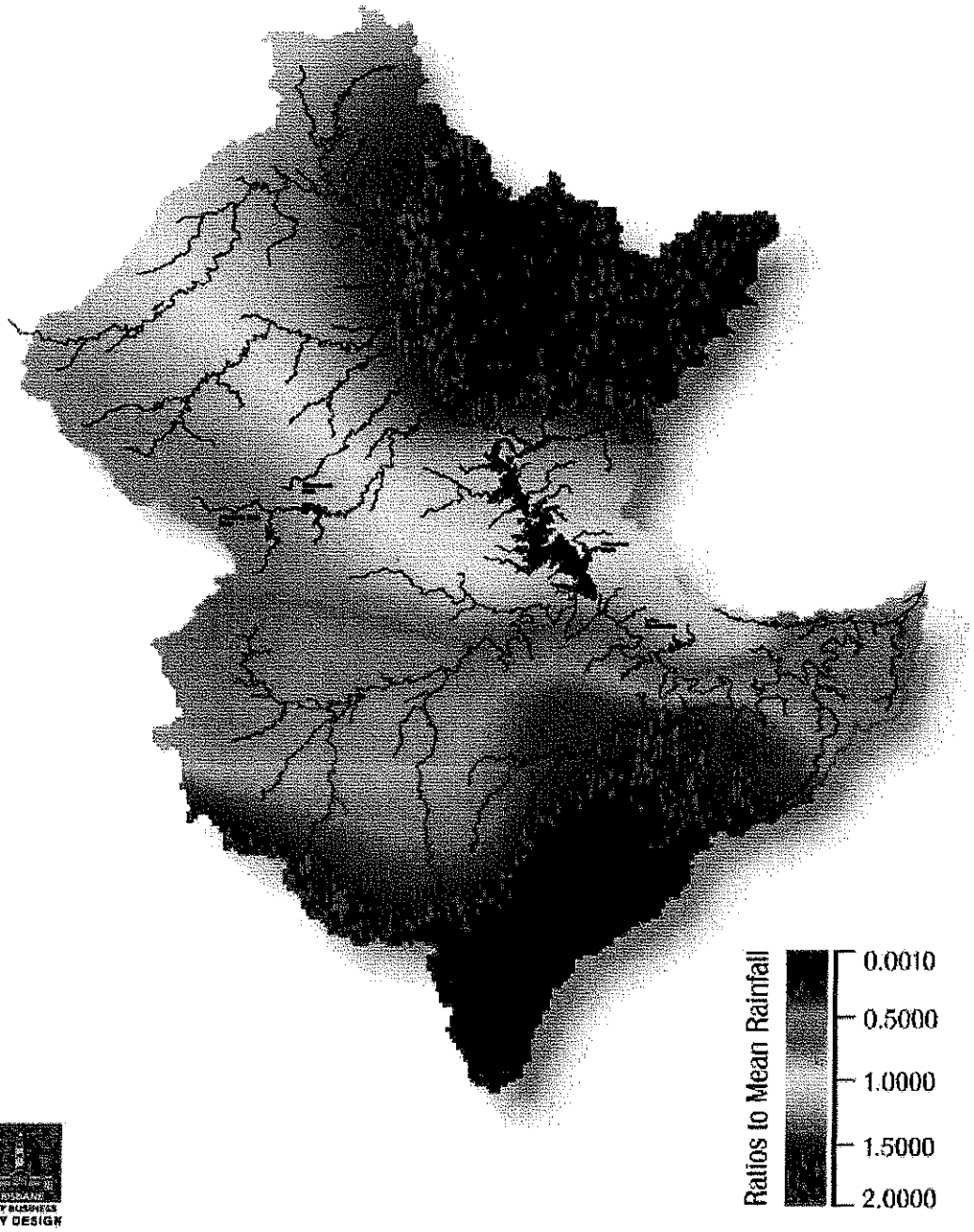
JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



BRISBANE CITY BUSINESS CITY DESIGN

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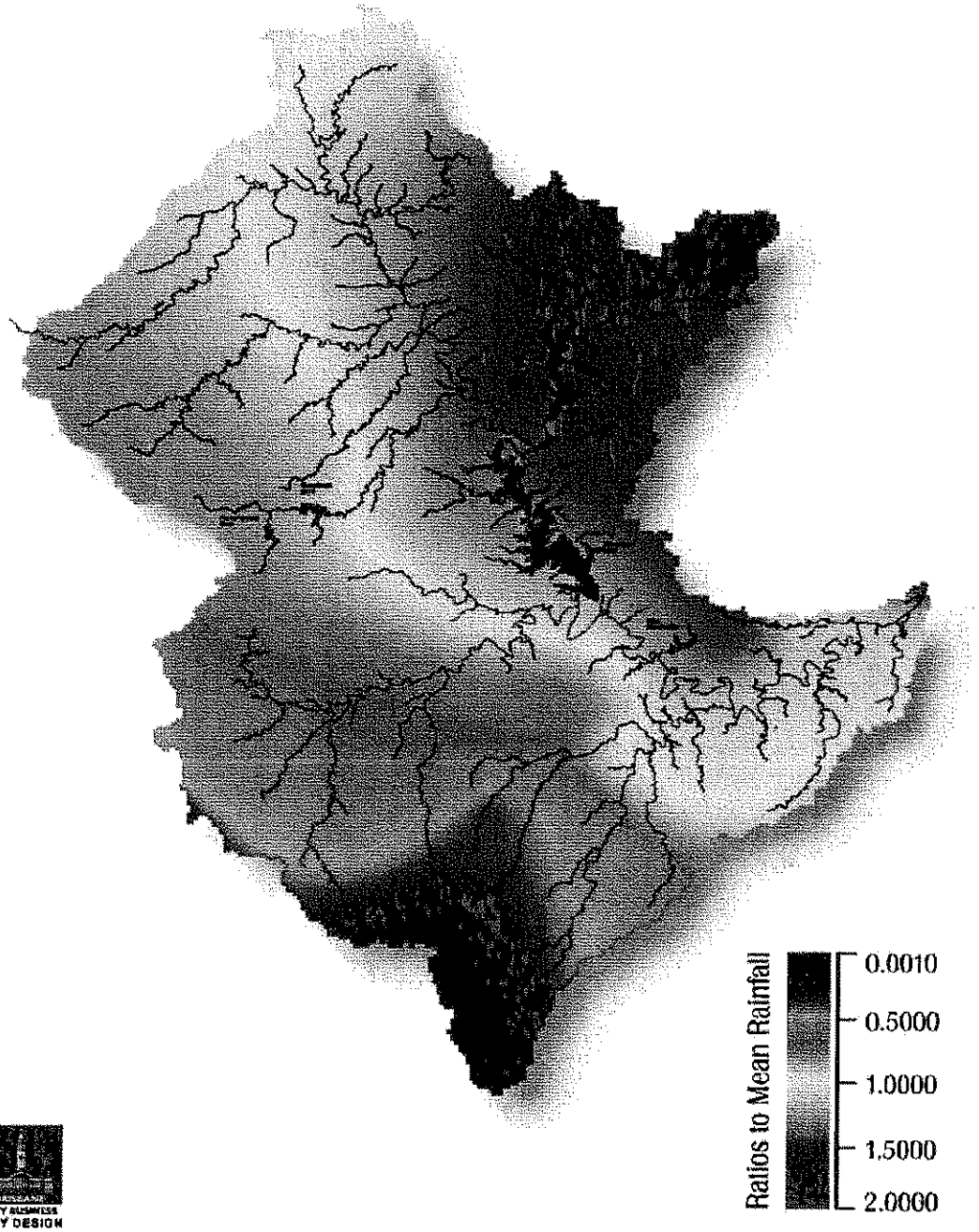
FEBRUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY BUSINESS
CITY DESIGN

SINCLAIR KNIGHT MERZ

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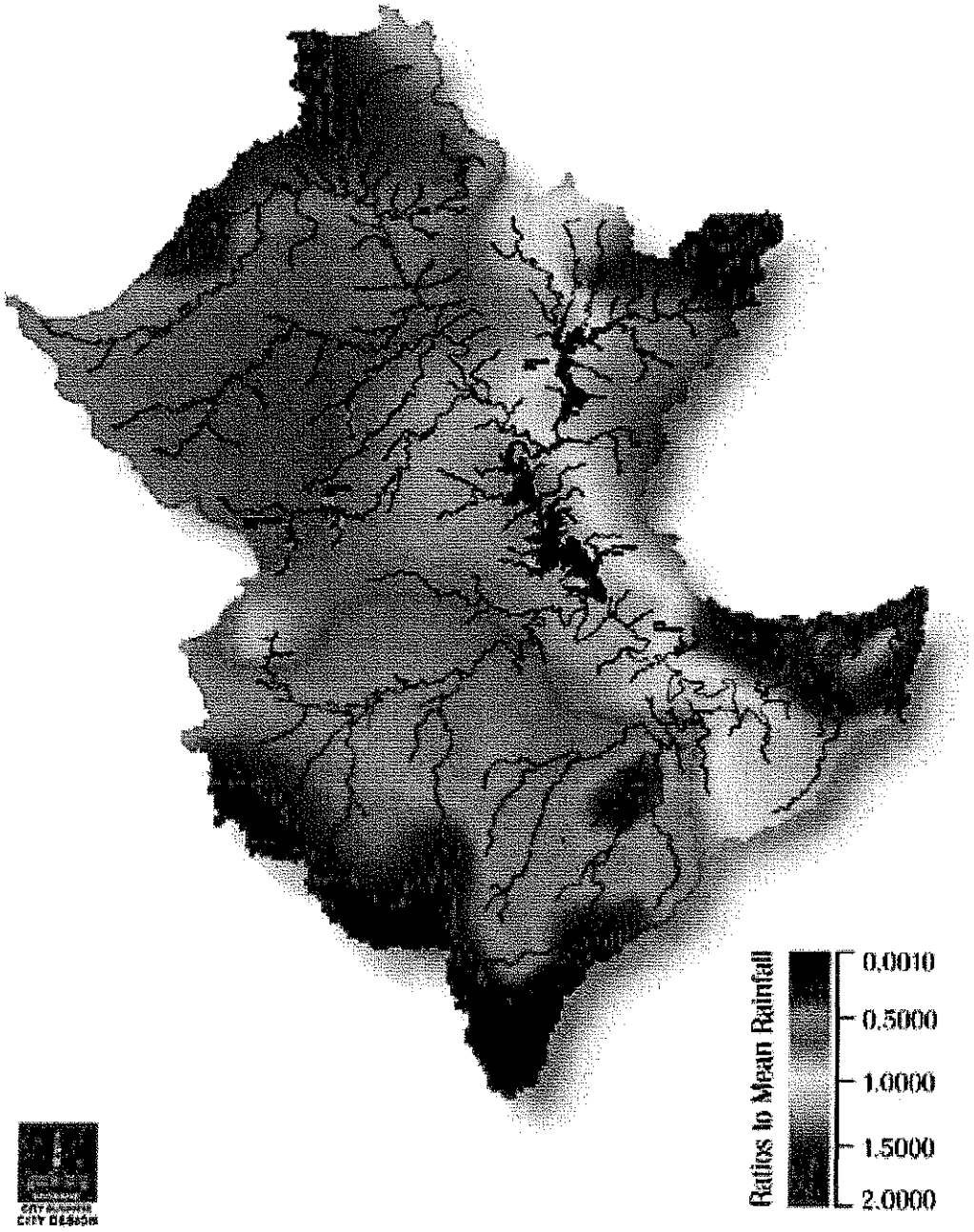
JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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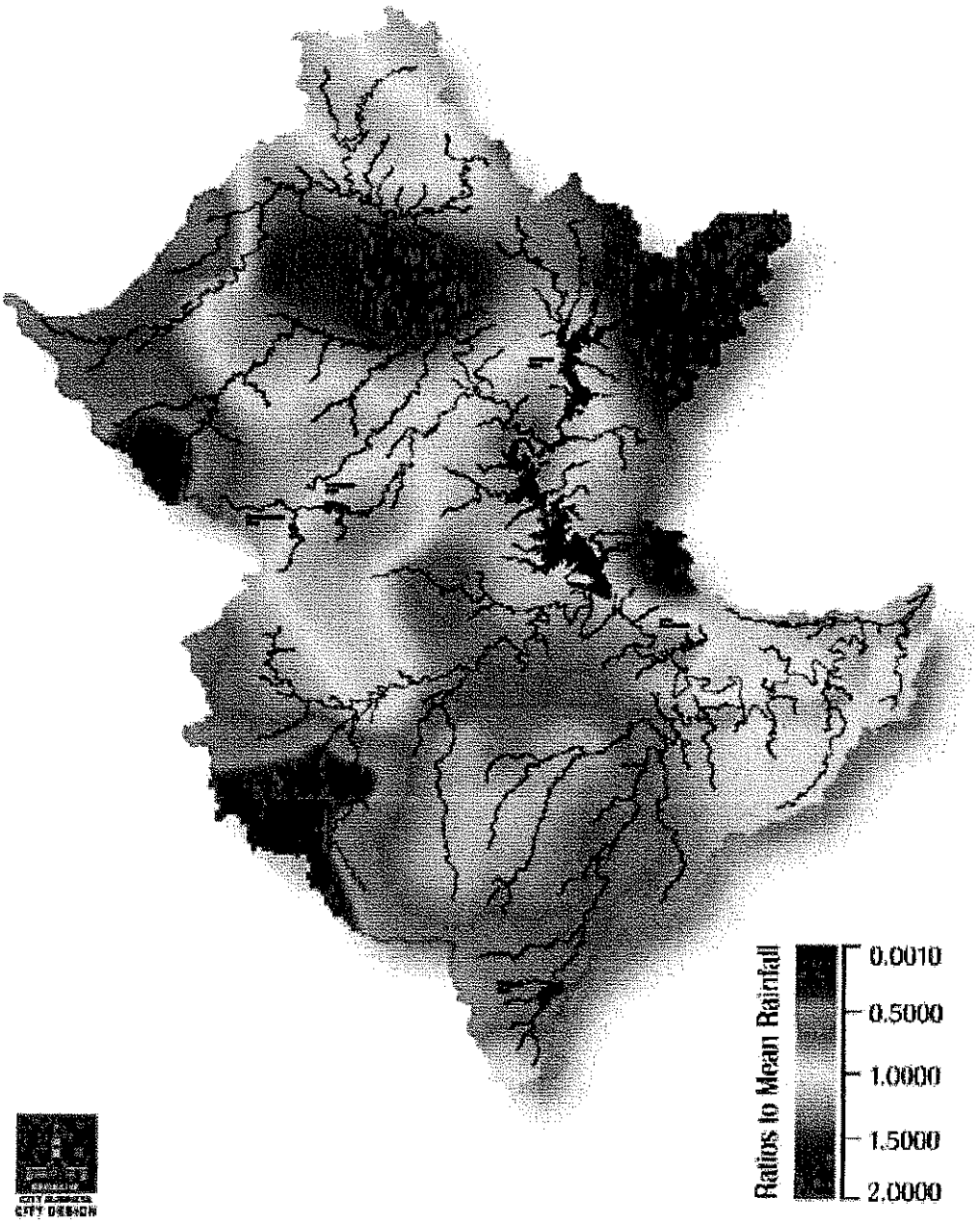
MARCH 1955 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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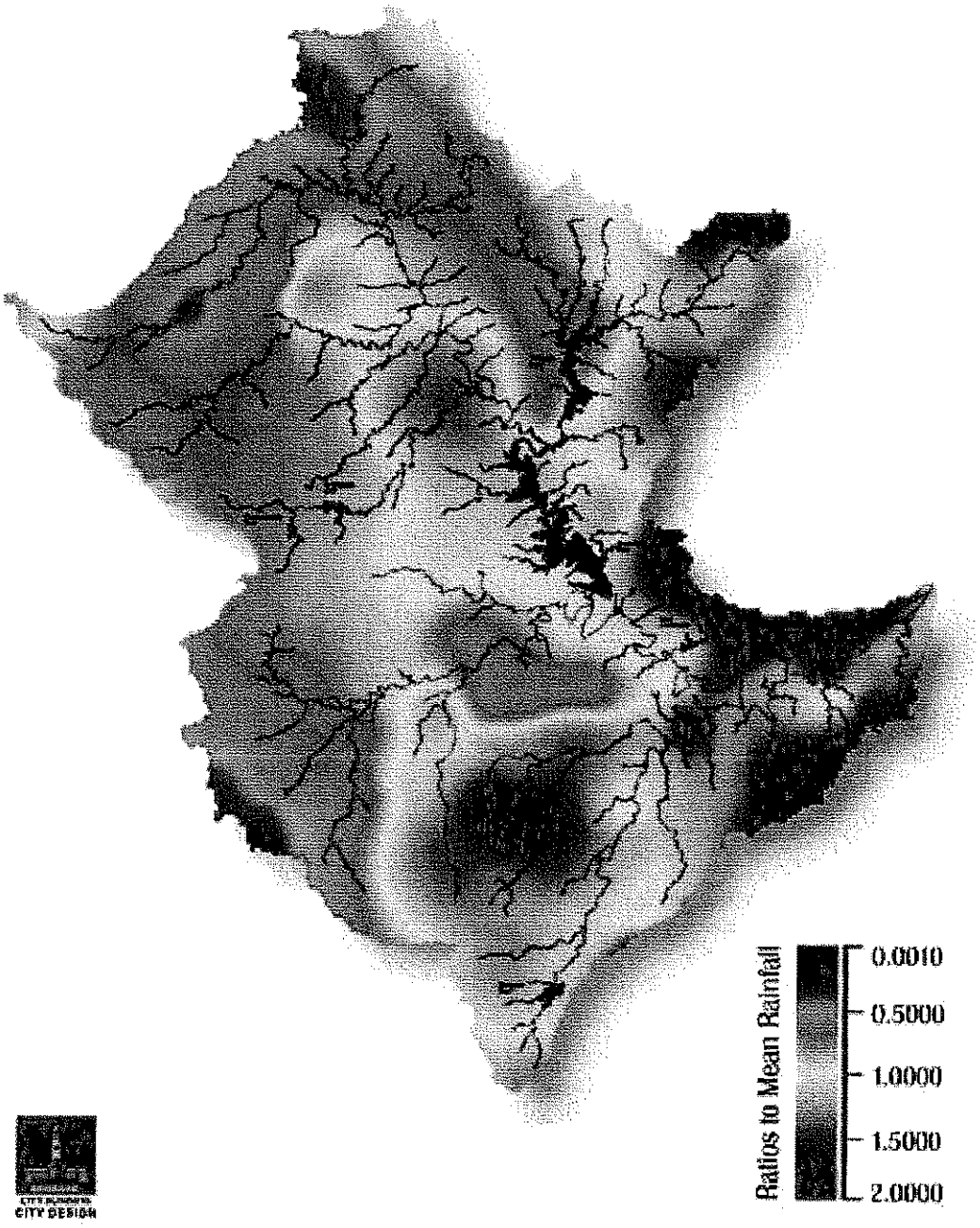
JANUARY 1974 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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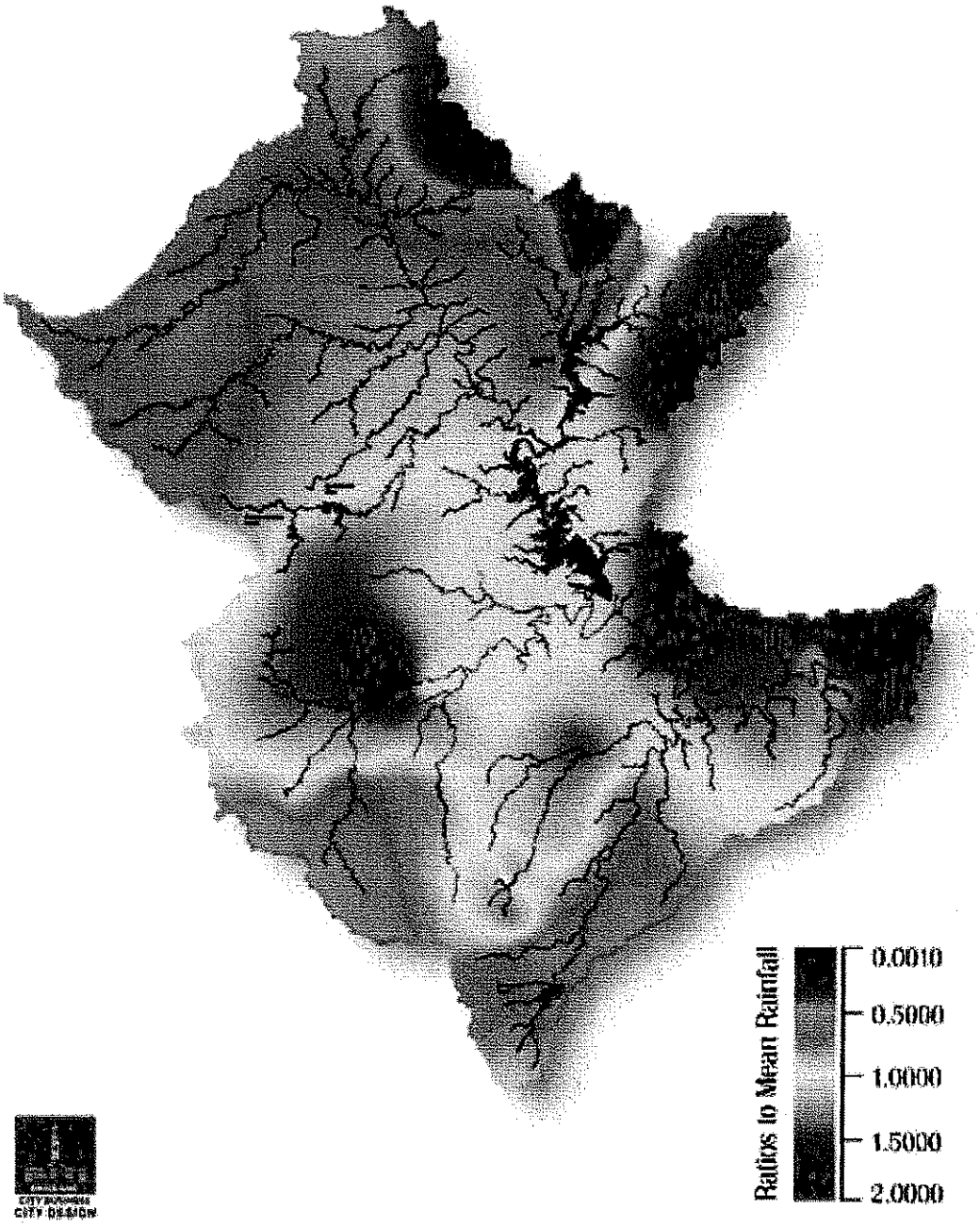
APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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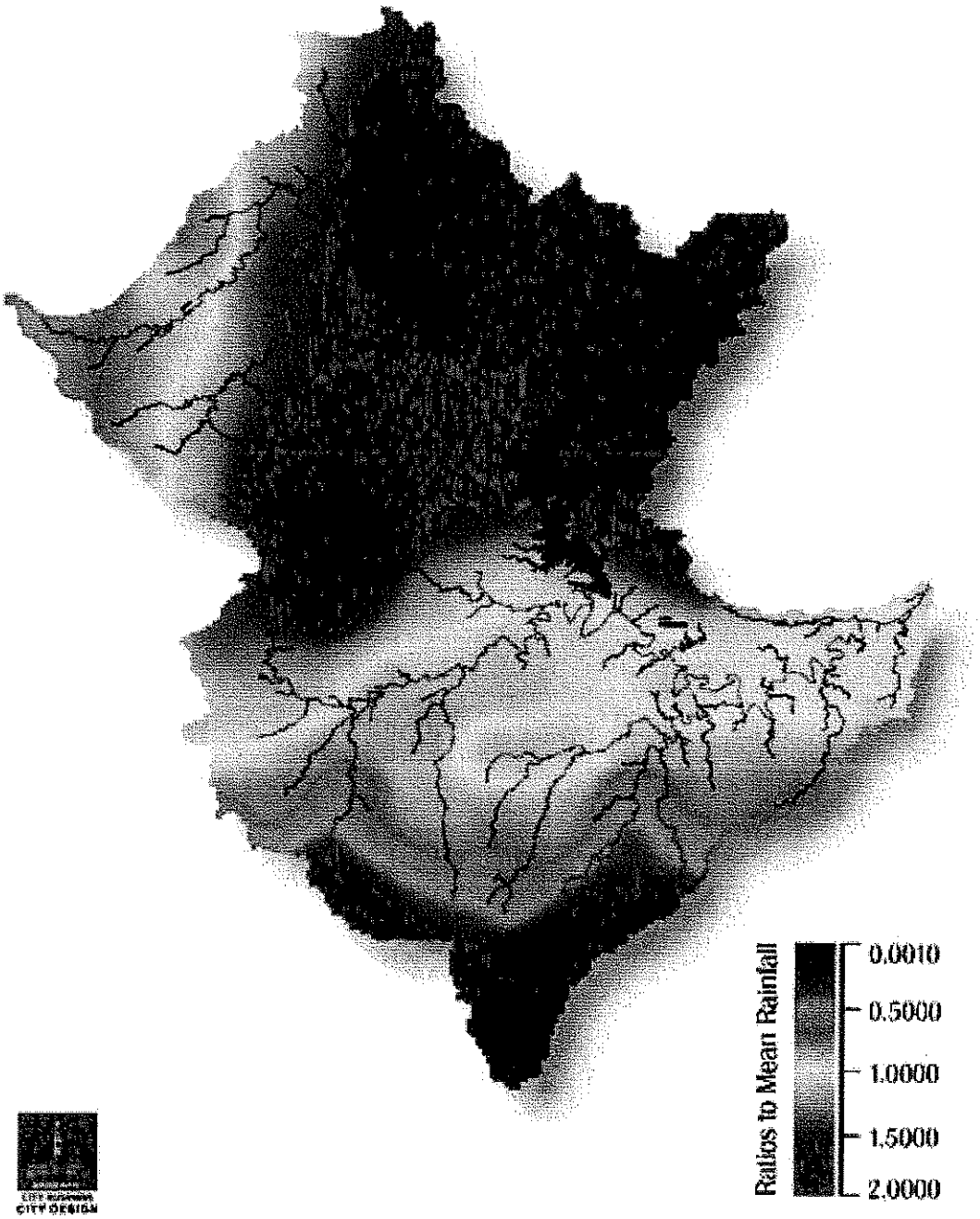
FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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Appendix H Pre- and Post-dams RAFTS Model Results

- **Peak Flows for RAFTS Model, Pre-Dams for 1 in 100 AEP Rainfall**

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
JAN 1893	24	9861	7927	7927
	30	**11507**	9792	9793
	36	9810	7932	7932
	48	10238	8534	8535
	72	10911	**10196**	**10198**
	96	9774	9392	9394
	120	10074	9639	9641
FEB 1893	24	8698	7502	7502
	30	**10062**	8788	8789
	36	8682	7512	7512
	48	9012	7865	7866
	72	9634	**9501**	**9504**
	96	8568	8632	8636
	120	8804	8898	8904
JAN 1931	24	**7505**	6745	6745
	30	**8543**	7648	7648
	36	7476	6775	6776
	48	7712	7190	7191
	72	8183	**8026**	**8030**
	96	7140	7514	7610
	120	7360	7630	7713
MAR 1955	24	8671	7536	7537
	30	**10046**	8925	8925
	36	8689	7553	7554
	48	8955	7915	7916
	72	9563	**9619**	**9623**
	96	8376	8745	8750
	120	8635	8997	9002
JAN 1974	24	7058	7202	7203
	30	**8005**	8046	8049
	36	7049	7072	7073
	48	7227	7527	7528
	72	7714	**9112**	**9117**
	96	6729	8154	8161

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
	120	6879	8432	8454
APR 1996	24	7531	7067	7068
	30	**8621**	7966	7966
	36	7549	7078	7079
	48	7748	7425	7427
	72	8287	**8917**	**8922**
	96	7184	8034	8043
	120	7399	8170	8182
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7893	7894
	48	9981	8443	8444
	72	10642	**10197**	**10200**
	96	9512	9384	9387
	120	9809	9626	9629

Note: Critical flows at each location are shown in **bold**.

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- **Peak Flows for RAFTS Model, Post-Dams for 1 in 100 AEP Rainfall**

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7120**	**7121**
FEB 1893	24	**1877**	2061	2070
	30	3818	3449	3449
	36	1935	2203	2211
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5595	5596
	120	**6568**	**5850**	**5851**
JAN 1931	24	1872	2051	2319
	30	1926	2708	3314
	36	1884	2452	2836
	48	1758	2382	2580
	72	3079	3146	3968
	96	3170	2940	3383
	120	**3279**	**3218**	**3411**
MAR 1955	24	1925	2345	2350
	30	3524	3433	3433
	36	2063	2541	2544
	48	3272	3013	3013
	72	**6241**	**5709**	**5710**
	96	5926	5339	5340
	120	6151	5584	5585
JAN 1974	24	1753	3324	3326
	30	2467	3987	3989
	36	1871	3279	3350
	48	1943	3627	3633
	72	3307	4418	4965
	96	**4771**	**5841**	**5852**
	120	**2911**	3656	3662
APR 1996	24	3554	3399	3400
	30	4067	4137	4138

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
	36	3535	3260	3260
	48	3605	3690	3691
	72	**4162**	**5019**	**5035**
	96	3492	4378	4417
	120	3509	4571	4663
FEB 1999	24	3424	2886	2887
	30	5789	4442	4442
	36	3575	3150	3147
	48	4604	3494	3495
	72	6879	6447	6448
	96	7217	6623	6624
	120	**7431**	**6819**	**6819**

Note: Critical flows at each location are shown in **bold**.

Brisbane River Flood Study



FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES – BRISBANE RIVER

- Further Investigations
- Final Issue
- Compiled 18 December 2003



Brisbane River Flood Study

FURTHER INVESTIGATION OF FLOOD FREQUENCY ANALYSIS INCORPORATING DAM OPERATIONS AND CRC-FORGE RAINFALL ESTIMATES – BRISBANE RIVER

- Final Issue
- Compiled 18 December 2003

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Executive Summary

Brisbane City Council (BCC) appointed an Expert Panel to review the flood investigations undertaken for the Brisbane River. Sinclair Knight Merz was approached to assist the Expert Panel with their review. The Expert Panel requested that Sinclair Knight Merz undertake flood frequency analyse of the available data and provide a "best" estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing and the Brisbane Port Office Gauge. This peak flow rate is also referred to as the Q100 event.

The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- update the estimates of flood frequency from rainfall-runoff modelling with the new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the Q100 flood.

The two tasks provide independent assessments of the Q100 event; firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

This technical report has been prepared for expert technical reviewers, and familiarity with the flood frequency techniques adopted, such as regional analysis and Bayesian techniques, hydrological terminology and abbreviations is generally assumed.

Statistical flood frequency analysis

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (i.e. the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Statistical frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional



information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in **Table ES1**.

- **Table ES1 Most Plausible Estimates of the Q100 Peak Flow at Savages Crossing Based on Statistical Flood Frequency Analysis**

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12,000	10,000	14,000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this introduces considerable uncertainty on the flow estimates for the large flows that influence the flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there are scarce data on key event characteristics such as temporal pattern, losses, etc.). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),
- choice of frequency distribution and the appropriate parameters, and,
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, there is reasonable evidence that the 1974 "no dams" peak flow rate is somewhere between 7,500 m^3/s and 11,000 m^3/s. Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

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Rainfall-runoff modelling

The second method with which SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by simulating the depth, temporal and spatial patterns of the storm, subsequent losses (e.g. the soil, interception by vegetation, etc.), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The Brisbane River Catchment is approximately 13,500 km^2 and includes Wivenhoe and Somerset Dams. The catchment area upstream of these dams is approximately 7,000 km^2 and therefore there is potential for flood mitigation benefits for areas below the dams. The potential for flood mitigation is dependent on the following factors:

- dam operating procedures,
- dam levels at the start of a flood event, and,
- spatial and temporal patterns of the storm.

The most sophisticated way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte Carlo analysis. Monte Carlo analysis would provide a more accurate estimate of the Q100 and reduce the overall uncertainty in the flood estimates. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels in the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised rainfall estimates and dam operating procedures have been included in this investigation to determine new flow estimates.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increasing catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A range of peak flows was determined at Savages Crossing and these are presented in **Table ES2**.

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- **Table ES2 Pre dams 1 in 100 AEP Flow Estimates at Savages Crossing from Rainfall-Runoff Modelling**

Scenario	Median (m^3/s)	Lower Estimate (m^3/s)	Upper Estimate (m^3/s)
No Dams	10,000	8,000	11,500

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10,000 m^3/s using an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h. This compares to the statistical frequency estimate (i.e. analysis of recorded flow data) of 12,000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3,000 m^3/s to 8,000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6,200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12,000 m^3/s and 13,800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it might be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis. While zero loss rates are not realistic, the objective of this sensitivity analysis was to show that temporal patterns can have an impact on the magnitude of flows. A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken to variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/h. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing and Brisbane Port Office was estimated to be 5,400 m^3/s and 5,000 m^3/s respectively. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing and Brisbane Port Office was reduced to 3,500 m^3/s and 4,400 m^3/s respectively.

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Q100 estimate at the Brisbane Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Brisbane Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was used to account for routing effects from Savages Crossing to the Brisbane Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Brisbane Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Brisbane Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table ES3** provides a range of estimates with a 'best estimate', upper estimate and lower estimate.

- **Table ES3 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood with Dams**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The information for the two historical flood events (1893 and 1974) was run through the RAFTS model for the pre and post-dam conditions. For post-dam conditions, the estimated peak flow at the Brisbane Port Office for the 1893 and 1974 flood events were 9,500 m^3/s and 6800 m^3/s respectively. It should be noted that the uncertainty in some of the historical data, 1893 in particular, is considerable.

The best estimate of 6,500 m^3/s was adopted after consideration of the RAFTS modelling for current design spatial pattern, various historical patterns and the performance of the model in reproducing flows at Savages Crossing for pre-dam flows. The estimate of the lower end of the plausible range of the Q100 estimate is 5,000 m^3/s. It was adopted with particular consideration to the range of results from the sensitivity to the spatial patterns. The estimate of the upper end of the plausible range was taken to be 8,000 m^3/s. This upper bound was adopted after particular consideration of the variation in the spatial patterns, the sensitivity to temporal patterns, and the 1974 peak flow results for the 'Somerset only' then 'Somerset and Wivenhoe' dams scenarios.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors;
- consideration of variation in temporal and spatial characteristics of rainfall;

- better representation of dam operating procedures, and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

The following actions could be undertaken to further improve this analysis:

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimates of Q100 that accurately reflect the combined influences of these stochastic factors.

  It is noted that while undertaking rainfall-runoff modelling in a Monte Carlo framework is an accepted method, it is not a standard method for flood studies.

- Re-calibrate the Ipswich City Council's MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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1. Introduction

1.1 Background

Sinclair Knight Merz prepared a flood study for the Brisbane River in 1998. Since this time, there have been changes to the information used in assessing the flood levels along the lower reaches of the Brisbane River. These include:

- CRC-FORGE rainfall estimates that have been prepared for the Brisbane River catchment (Department of Natural Resources and Mines, 2003a),
- modifications to procedures for flood operations at Wivenhoe and Somerset Dams since the initial Brisbane River Flood Study Report (Sinclair Knight Merz, 1998) was completed, and
- additional and/or revised flood flow data.

An Expert Panel was appointed by Brisbane City Council to review the flood studies undertaken for the Brisbane River in the light of this new information, with particular emphasis on the flood flows and associated levels in the lower reaches including Brisbane City.

Sinclair Knight Merz was approached to assist the Expert Panel with their review. The primary tasks for Sinclair Knight Merz were to:

- undertake statistical flood frequency analysis, and to
- Update the flood frequency estimates from rainfall-runoff modelling with the new information.

The details of the tasks that were originally agreed are presented in **Appendix A**.

1.2 Scope of Report

This report addresses the tasks presented in **Appendix A**, namely to:

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document the findings of the flood frequency analysis, stating assumptions and outcomes.
4) Review previous reports, CRC-FORGE rainfall estimates and historical streamflow data.
5) Undertake a Regional Flood Frequency Analysis (pre-dams).
6) Undertake hydrologic modelling (pre-dams).



7) Undertake hydrologic modelling (dams in place).
8) Analyse catchment sensitivity using various temporal patterns and historical spatial patterns.
9) Undertake a sensitivity analysis of starting reservoir levels.
10) Perform hydraulic modelling to produce flood frequency estimates at Moggill and the Brisbane Port Office.
11) Report on the findings of the statistical flood frequency analyses and the rainfall-runoff and hydraulic modelling.

SKM

2. Sources of Data for Statistical Flood Frequency Analysis

Gauging station data were obtained from the Department of Natural Resources and Mining (DNRM) and the Commonwealth Bureau of Meteorology (BoM). Different types of data were collected, including:

- recorded water elevation above the gauge datum,
- flow data estimated from a rating relationship, and
- rating tables.

In some instances the data were processed in some additional manner, as discussed below.

A number of reports on large flood events and the analysis thereof were made available.

2.1 Department of Natural Resources and Mining Data

There are two sources of data from DNRM:

- Recorded water elevation data and associated flow estimates,
- Estimates of "no dams" flood peaks at Savages Crossing that had been adjusted to *exclude* the influence of the dam(s) where appropriate.
- Estimates of "with dams" flood peaks at Savages Crossing that had been adjusted to *include* the influence of one or more of the dam(s) where appropriate.

All data sets have been analysed without assessment as to the method of obtaining the peak flow rates. That is the data sets were taken "as provided."

A significant amount of recorded data was not selected for the reasons discussed in relation to the BoM data below.

2.2 Bureau of Meteorology Data

Stations from the BoM have generally been omitted at this stage for a number of reasons. The reason for each site being omitted is stated in **Appendix B** (along with other sources of gauged data). The primary reasons for omission were:

- short record length,
- small catchment area, and/or
- uncertainty in the rating curve.

The last reason included either very low gauged flow or the rating curve was changed by BoM to a "calibration curve" for use in real time flood forecasting.

Elevation data for a number of sites of direct interest to this study, such as Moggill, and the Brisbane Port Office were also obtained.

Appendix C shows the location of the stream gauges that were used in the statistical flood frequency analysis.

SKM

3. Statistical Flood Frequency Analyses

3.1 Introduction

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analyse of the available data and come up with a best estimate of the likely 1 in 100 annual exceedance probability (AEP) peak flow rate at Savages Crossing. This peak flow rate is also referred to as the Q100 event. An estimate of the Q100 for the "no dams" case (i.e. peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

The sources of data have heen documented in **Section 2.**

The sources of uncertainty that could affect the Q100 estimate at Savages Crossing include:

- adjustment of data for the influence of the dams,
- uncertainty in the rating curves that relate recorded river level to flow rate,
- the magnitude of historic data (especially 1893 and 1825),
- the period of record associated with the historic data,
- choice of frequency distribution,
- selection of parameters for the distribution, and
- method of including historical data.

DNRM provided three series of data. The series are provided in **Appendix D**. The first was the "gauged flows at Savages Crossing" (1909-2000). This was a composite series from Savages Crossing/Lowood/Vernor stations. The second series was for "both dams working" in which they made some adjustments that they considered appropriate for the effect on the flow rates if the dams had been in place for the entire period. The precise method for adjusting the data has not been detailed; the method as provided is included with the data series in **Appendix D**. The third series of data (1890 - 2000) was adjusted so as to represent the peak flow rates expected if Somerset and Wivenhoe dams had not existed over the entire period. Frequency analysis of this data was undertaken along with various unadjusted data.

The statistical frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at tbe one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional information was incorporated in the Bayesian analysis of flood peaks that was performed using the FLIKE program (v4.5 as supplied by Assoc Prof George Kuczera in June 2003). The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto (GP) distribution. Some preliminary relevant information is contained in the next section and greater detail of the regional method is reported in **Appendix E** and **Appendix F**.

The Expert Panel was interested in understanding how the statistical flood frequency analysis results were affected by the addition of dams, the inclusion of various gauged/historical data and use of various statistical techniques. Four cases as listed below were developed to meet the Expert Panel's requirements.

Case 1. Analysis of pre-Somerset and pre-Wivenhoe data ie. data that was unaffected by Somerset and Wivenhoe dams were assessed. Data prior to 1951 were analysed.

Case 2. Analysis of pre-Wivenhoe data with no correction for Somerset dam; consideration given to all data as recorded or estimated with no attempt made to assess the effect of Somerset dam on the flow magnitudes.

Case 3. Analysis of "no dams" data as estimated by DNRM; the data set that contained the flows that DNRM estimate would have occurred in the absence of Somerset and Wivenhoe dams was assessed.

Case 4. Analysis of post-dam data estimated by DNRM; assessment of the data set that contained the flows that DNRM estimate would have occurred if Somerset and Wivenhoe dams were present for the entire period of record.

The analyses undertaken to determine the "best" estimate from statistical flood frequency analysis and a plausible range are summarised in **Table 3-1**.

The individual analyses including the data, techniques, the objective and comments on the results of each analysis are included in **Table 3-3** to **Table 3-6** and summarised in **Table 3-7**. The effects on the flood frequency curves of each of the analyses are shown in **Figures 3-1** to **3-7**.

As noted previously, this report has been prepared for expert reviewers with a high level of understanding. The explanations, comments and discussion are as concise as possible to enable the broad range of analyses to be succinctly presented for ease of comparison.

SKM

- **Table 3-1 Summary of statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Model for fitting distrib'n	Prior Inform'n (regional)	Main Objective
Case 1 Pre -Wivenhoe and Somerset							
1A	1909-1951	Excluded	1909-1951	GP	FLIKE	Excluded	Assess the continuous record of Savages Crossing Data that is unaffected by large dams
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Excluded	As for 1A except includes the best estimate of the 1893 historic peak
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	FLIKE	Included	As for 1B except includes regional information
1D	1909-1951	1825 (Qp=13200) 1893 (Qp=13200	1825-1951	GP	FLIKE	Excluded	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)
1E	1909-1951	1893	1847-1951	LPIII	FLIKE	Excluded	Test the difference re LPIII distribution instead of GP
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	FLIKE	Included	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII	ARR87 incl historic data	Excluded	Determine Q100 using ARR87 method for including historical data.

GP = Generalised Pareto Distribution

LPIII = Log-Pearson III Distribution

SKM

	Continuous Record	Historic Data (m³/s)	Historic Period	Distribution	Model for fitting distribn	Prior Inform'n (regional)	Main Objective
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**							
2A	1909-1982	Excluded	1909-1982	GP	FLIKE	Included	Test inclusion of additional 31 years of record.
2B	1909-1982	1893	1847-1982	GP	FLIKE	Included	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate
Case 3 **"No Dams" based on DNRM adjusted estimates**							
3A	1890-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess Q100 from "no dams" adjusted data series produced by DNRM.
3B	1890-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.
Case 4 **"Dams" based on DNRM estimates**							
4A	1909-2000	Excluded	1890-2000	GP	GetDat	Excluded	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.
4B	1909-2000	Excluded	1890-2000	LPIII	GetDat	Excluded	Assess impact of LPIII as an alternative distribution for this series.

GP = Generalised Parts Distribution

LPIII = Log-Pearson III Distribution

3.2 Regional Frequency Analysis

A regional statistical frequency analysis was conducted to assist in the estimation of flood frequency at Savages Crossing (GS143001). The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates.

Flood peaks were available at eight relevant sites in the Brisbane River catchment, including the site at Savages Crossing (GS143001). The Generalised Pareto probability distribution was selected for the statistical flood frequency analysis on the basis of the L-Moment ratios at eight sites.

Regional information was incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information was incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the Generalised Pareto distribution. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation, and
- its correlation with other parameters.

The prior mean and standard deviation of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that excluded Savages Crossing. The prior parameter values that were adopted for the Bayesian analysis are shown in **Table 3-2**.

Table 3-2 Prior parameters for Bayesian analysis of flood peaks at Savages Crossing (GS143001)

Value	Scale parameter, α	Shape parameter, κ
Mean	939	-0.274
Standard Deviation	458	0.297

The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

FLIKE was used to derive quantile estimates for Cases 1 and 2, but due to difficulties with the data sets a Sinclair Knight Merz program *GetDat* was used to assess Cases 3 and 4. The *GetDat* program is based on Hosking and Wallis' L-Moments routines, and includes Monte Carlo simulation for estimation of confidence limits. No prior or regional information was assessed in Cases 3 and 4.

Greater detail of the regional analyses is provided in **Appendix E** and **Appendix F**.

3.3 Case 1: Analysis of Pre-Somerset and Pre-Wivenhoe Data

The data set for these runs was the DNRM unadjusted gauge data (1909-1951) supplemented by historical data as noted in the table below.

The Case 1 analyses investigate the primary sources of uncertainty in the data apart from adjustments for the influence of the dams.

The results are tabulated with comments in **Table 3-3** with specific influence on curves plotted in **Figures 3-1** to **3-3** so that the influence of specific assumptions can be compared graphically.

SKM

- **Table 3-3 Summary of Case 1 statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 Pre -Wivenhoe and Somerset								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative..
1C	1909-1951	1893 (Qp= 13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included.
1D	1909-1951	1825 (Qp= 13200) 1893 (Qp= 13 200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)

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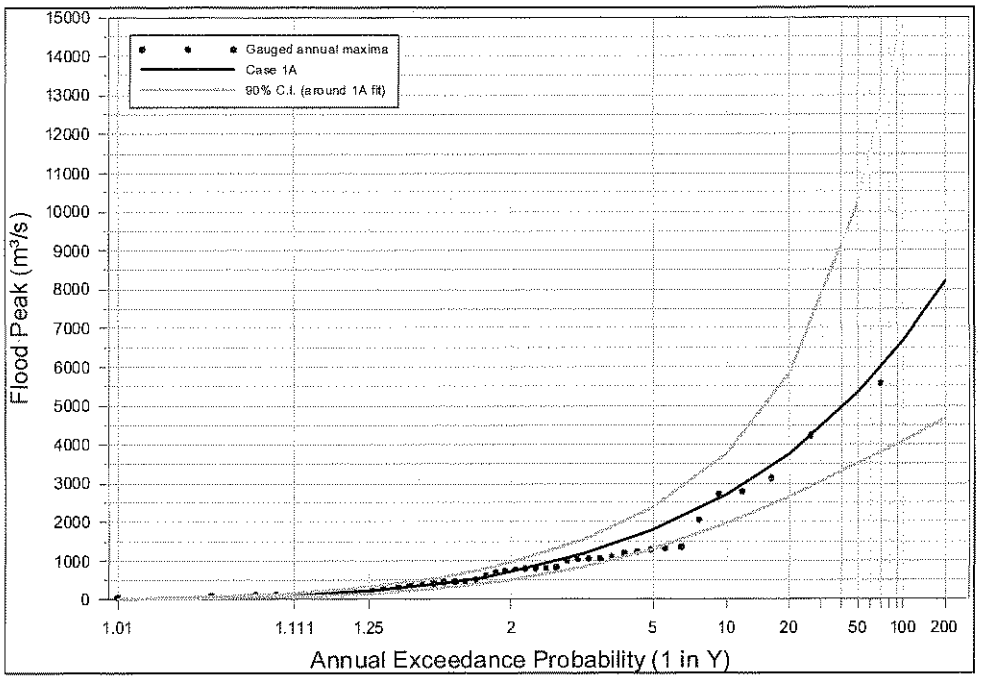
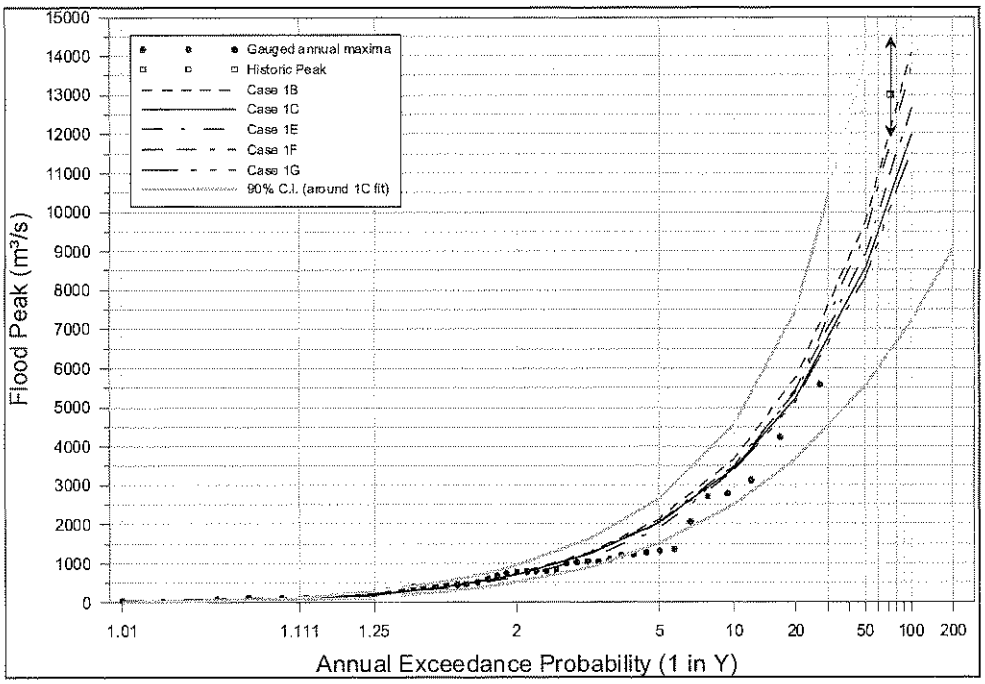
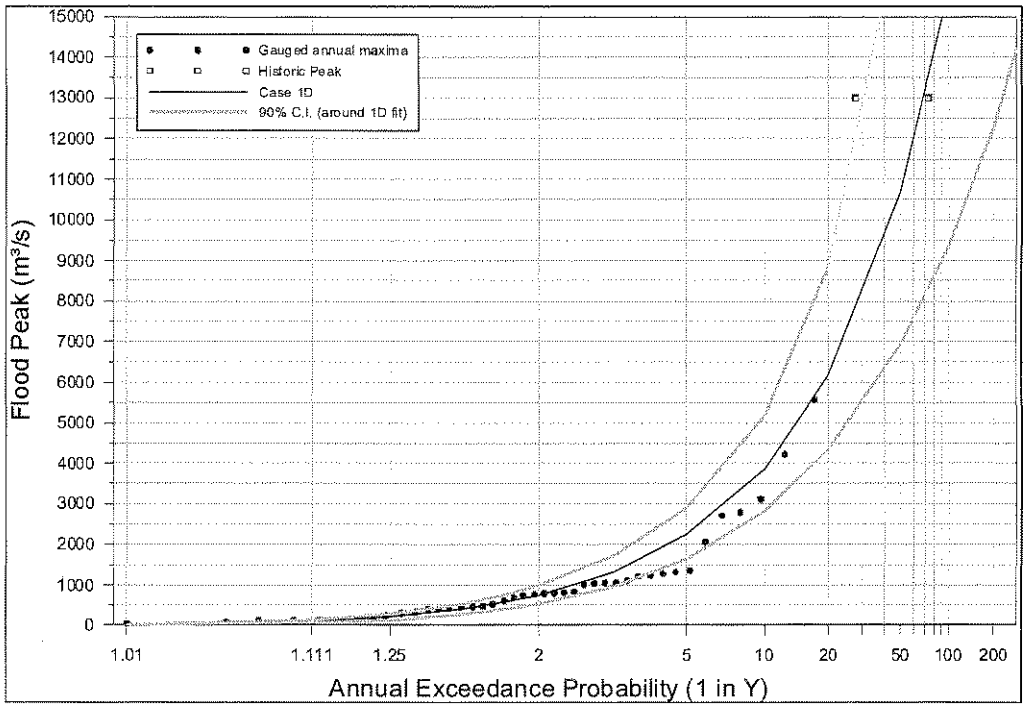
	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
1F	1909-1951	1893 (Qp= 14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from BoM "not unreasonable" estimate of 1893 peak. (BoM 2003) Q100 at Savages Crossing is influenced but not overly sensitive.
1G	1909-1951	1893 (Qp= 12 000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from BoM URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5 mm/hr. (BoM 2003) Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp= 13 000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of 6179m^3/s if the historical data is excluded.



- **Figure 3-1 Generalised Pareto Distribution fitted to the 1909-1951 pre-dams data at Savages Crossing**



- **Figure 3-2 Comparisons of variations in statistical flood frequency for various assumptions on pre-dams data for Savages Crossing**



- **Figure 3-3 Assessment of the inclusion of a 1825 estimate of a flood possibly of the same magnitude as the 1893 event**

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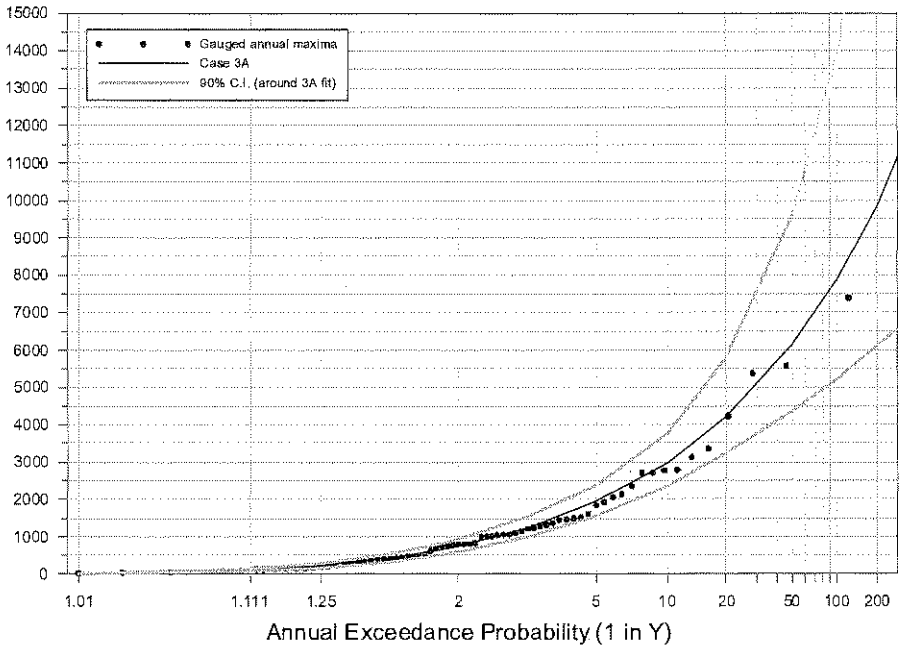
3.4 Case 2: Analysis of Pre-Wivenhoe Data With No Correction for Somerset Dam

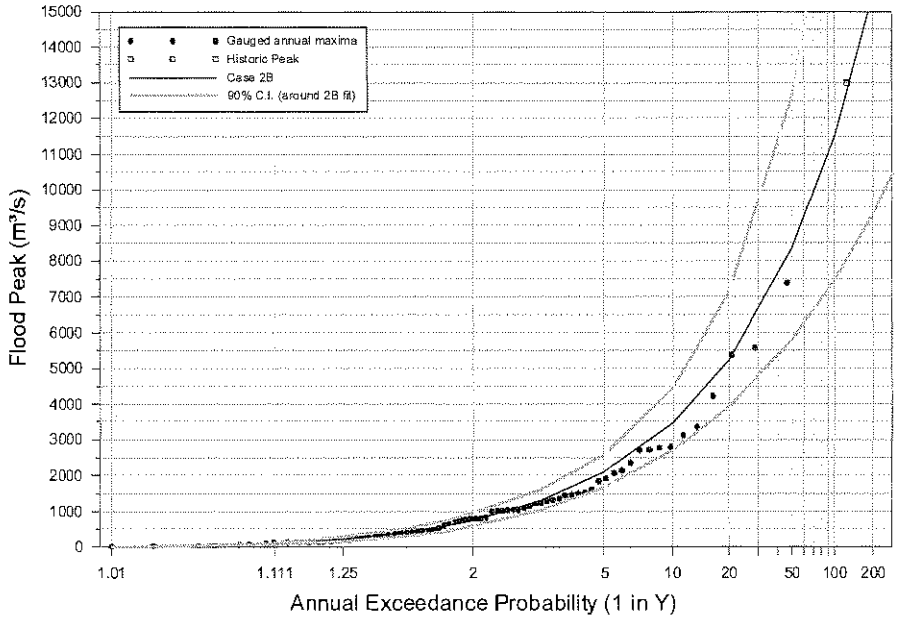
These analyses were based on gauged flows up to 1982, with no corrections made for the influence of Somerset Dam.

- **Table 3-4 Summary of Case 1: statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.



- **Figure 3-4 Assessment of the pre-Wivenhoe gauged data without 1893 event**



- **Figure 3-5 Assessment of the pre-Wivenhoe gauged data with 1893 event**

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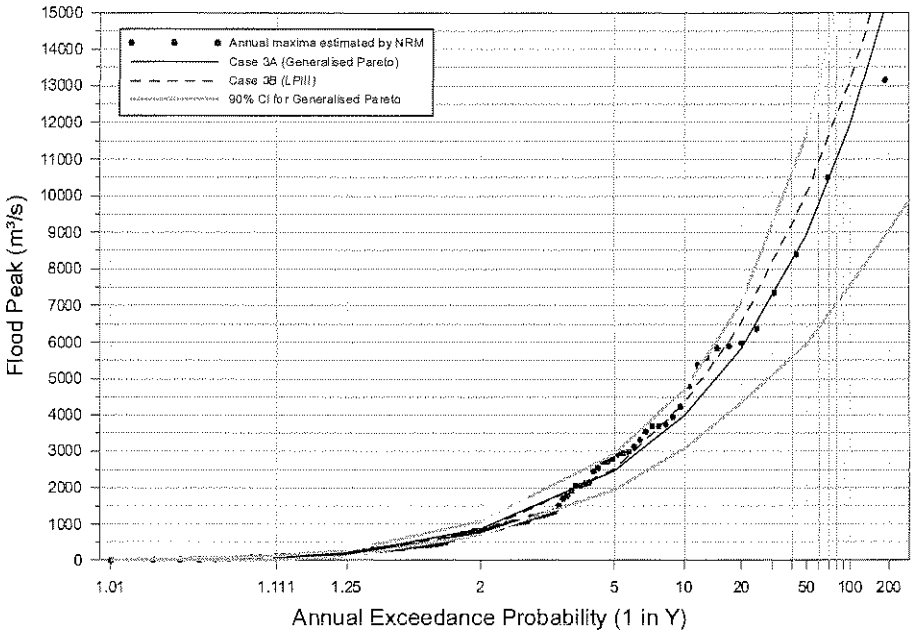
3.5 Case 3: Analysis of "No Dams" Data Estimated by DNRM

Note effect of Somerset dam is highly variable depending on its operation. DNRM has assessed the effect of Somerset dam on the flood data series. Sinclair Knight Merz has taken this series "as provided" and analysed the statistics.

- **Table 3-5 Summary of Case 3: statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.



- **Figure 3-6 Assessment of the "no –dams" annual maxima series provided by DNRM using both GP and LPIII distributions**

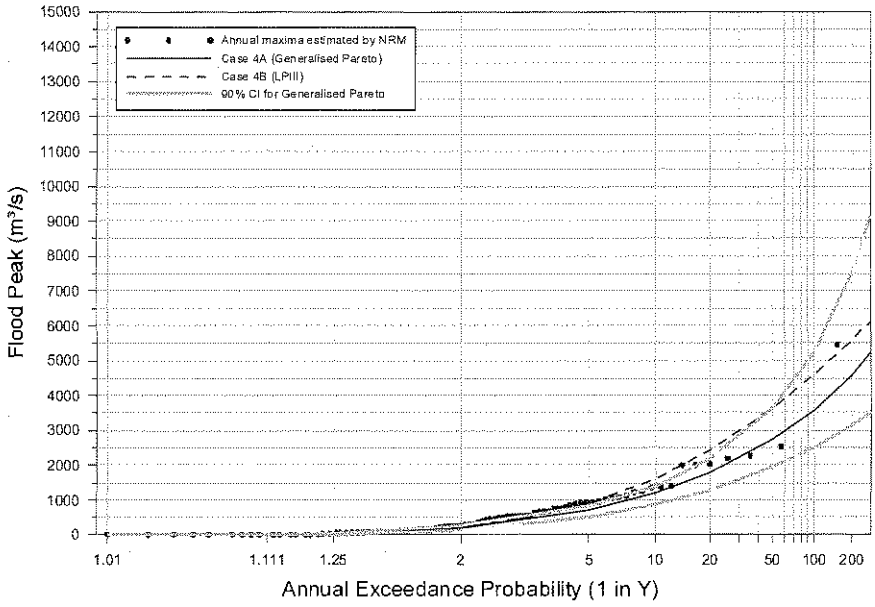
SKM

3.6 Case 4: Analysis of Post-Dam Data Estimated by DNRM

These analyses were based on the "post-dam" data set provided by DNRM. As noted in Section 3.4 the data has been taken and analysed on an "as provided" basis.

- **Table 3-6 Summary of Case 4: Post-dam Data - statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)**

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distrib-ution	Prior Info (regional)	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 **"Dams" based on DNRM estimates**								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to later sections for the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)



- **Figure 3-7 Assessment of the "post-dams" annual maxima series provided by DNRM using both GP and LPIII distributions.**

3.7 Summary of Analysis Results

The analyses in the preceding subsections indicate that there is considerable variation in the Q100 (1 in 100 AEP peak flow rate) estimate at Savages Crossing. The analyses are summarised in **Table 3-7**. As noted above, the summary is intended to succinctly present the broad range of sensitivity analyses for expert reviewers who are familiar with the concepts, common discipline abbreviations and analysis methods.

SKM

Table 3-7 Summary of statistical flood frequency analyses for peak flows at Savages Crossing (refer to text for abbreviations and more detailed comments)

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 1 **Pre -Wivenhoe and Somerset**								
1A	1909-1951	No	1909-1951	GP	No	6 690	Assess the continuous record of Savages Crossing Data that is unaffected by large dams	Ignores all information in the fifty years of data post Somerset (and post-Wivenhoe) dam and the historic 1893 event. Also excludes prior information from regional analysis
1B	1909-1951	1893 (Qp=13000)	1847-1951	GP	No	14 070	As for 1A except includes the best estimate of the 1893 historic peak	By excluding the data post Somerset dam the frequency of the 1893 event is overestimated, consequently the Q100 estimate is judged to be conservative.
1C	1909-1951	1893 (Qp=13000)	1847-1951	GP	Yes	11 970	As for 1B except includes regional information	The regional information has a significant influence on the Q100 estimate and partially compensates for the impact of the frequency of the 1893 event in 1B. Note similarity of Q100 estimate to that for 2B where the unadjusted post- Somerset but pre-Wivenhoe data was included
1D	1909-1951	1825(Qp=13200) 1893 (Qp=13200	1825-1951	GP	No	15 690	As for 1B with the addition of the historical event of circa 1825 (diary notes from early explorers with heights in the order of the 1893 event)	The plotting position of this event is outside the 90% confidence interval. Hence the magnitude is highly questionable and should be excluded from consideration.
1E	1909-1951	1893	1847-1951	LPIII	No	13 720	Test the difference re LPIII distribution instead of GP	Relatively minor difference to 1B (the equivalent data fitted with the Generalised Pareto distribution)
1F	1909-1951	1893 (Qp=14500)	1847-1951	GP	Yes	12 660	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable higher estimate)	Magnitude taken from BoM "not unreasonable" estimate of 1893 peak. Q100 at Savages Crossing is influenced but not overly sensitive.(BoM 2003)
1G	1909-1951	1893 (Qp=12000)	1847-1951	GP	Yes	11 560	Test the impact of uncertainty in the magnitude of historic 1893 peak (reasonable lower estimate)	Magnitude taken from BoM URBS modelling calibrated to 1974, daily temporal pattern and cont loss of 2.5mm/hr. (BoM 2003) Q100 at Savages Crossing is influenced but reasonably insensitive.
1H	1909-1951	1893 (Qp=13000)	1847-1951	LPIII (ARR87 incl historic data)	No	7667	Determine Q100 using ARR87 method for including historical data.	This method gives a significantly lower Q100 for Savages Crossing. Note: the ARR87 method gives a Q100 of $6179 m^3/s$ if the historical data is excluded.
Case 2 **Pre Wivenhoe, no adjustments made for Somerset**								
2A	1909-1982	No	1909-1982	GP	Yes	7 870	Test inclusion of additional 31 years of record.	Q100 estimate increases (note record includes 1974 event) but excludes the historic data including the flood of record (1893) so Q100 is underestimated.
2B	1909-1982	1893	1847-1982	GP	Yes	11 500	As for 2A plus historic data. Indicate sensitivity to effect of Somerset on Q100 estimate	Inclusion of historic data is very important (cf 2A). Q100 estimate is not overly sensitive to the influence of Somerset in the record (at least prior to Wivenhoe dam) Q100 estimate at Savages Crossing is likely to be greater than Q100 estimate here as data has *not* been adjusted for effect of Somerset dam. Refer to 3a for analysis of data adjusted for dams. Consistent with 1C and 3A Q100 estimates.
Case 3 **"No Dams" based on DNRM adjusted estimates**								
3A	1890-2000	No	1890-2000	GP	No	11 900	Assess Q100 from "no dams" adjusted data series produced by DNRM.	Q100 estimate is consistent with 1C and 2B. Note: method used to obtain adjusted data series not assessed by SKM.
3B	1890-2000	No	1890-2000	LPIII	No	13 150	Assess impact of LPIII as an alternative distribution for this series.	Q100 is more sensitive to choice of distribution for this data set than observed between 1B and 1E above.

SKM

	Continuous Record	Historic Data (m^3/s)	Historic Period	Distribution	Prior Information	Q100 Estimate at Savages Crossing (m^3/s)	Main Objective	Comments
Case 4 "Dams" based on DNRM estimates								
4A	1909-2000	No	1890-2000	GP	No	3590	Assess the impact of dams on Q100 at Savages Crossing based on DNRM's assessment of flows if dams had been in place for the historic period of record.	According to this series, the Q100 is reduced to about 30% of that expected without Wivenhoe and Somerset dams. Note: method used to obtain adjusted data series not assessed by SKM. Refer to later sections for the impact of dams from a hydrological routing perspective.
4B	1909-2000	No	1890-2000	LPIII	No	4920	Assess impact of LPIII as an alternative distribution for this series.	Q100 estimate is sensitive to choice of distribution (Q100 is approx. 30% higher than GP estimate in 4A)

SKM

3.8 Best Estimates from statistical flood frequency assessment

Sinclair Knight Merz has assessed the information and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower range of estimates are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling reported in the subsequent chapters). The results are presented in **Table 3-8**.

The best estimate for the "no dams" scenario was adopted after consideration of all the analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series, namely:

- the inclusion of all unadjusted Savages Crossing records (1909-1951) , the best estimate of the 1893 flood of record, the inclusion of prior information from the regional analysis and the adoption of the Generalised Pareto distribution (refer 1C, Q100=11 970 m^3/s)
- pre-Wivenhoe Savages Crossing records consisting of unadjusted peaks (1909-1982), DNRM estimated peaks (1890-1908) which included the 1893 flood of record (refer 2B, Q100= 11 500m^3/s); as no allowance made for Somerset dam, the pre dams Q100 could be expected to be higher than 11 500m^3/s.
- the "No dams" series from DNRM which included estimates of peak flows for Savages Crossing from 1890-2000 (refer 3AQ100 = 11,500 m^3/s).

Table 3-8 Most plausible estimates of the Pre dams Q100 peak flow at Savages Crossing

Scenario	"Best" estimate	Likely lower estimate	Likely Upper estimate
"No dams"	12 000	10 000	14 000

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the following significant sources of uncertainty:

- the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum estimated 1974 peak flow; this causes considerable uncertainty on the flow estimates for the large flows that influence the statistical flood frequency assessment in the range of the Q100,
- scarcity of information regarding the 1893 event in terms of its flow magnitude (there is considerable uncertainty in rainfall –runoff modelling results as there is scarce data on key event characteristics such as temporal pattern, losses, etc.). This event has a significant influence on the Q100 estimate (although inclusion of regional information lessens the impact of the uncertainty),

- choice of distribution and the appropriate parameters, and
- adjustment of data for the effect of the dams.

As an example of some of the above uncertainties, it is plausible that the 1974 "no dams" peak flow rate was somewhere between 9 000 m^3s-1 and 11 000 m^3s-1.

The lower bound of this range is based on assuming the reported flow from the actual event of 7393 m^3s-1 as a minimum estimate. Adoption of this as a lower bound estimate would assume that there was a gauge/rating error in the order of the attenuation attributable to Somerset Dam. Discussions with BoM staff indicated that their modelling of the event suggested that 2350 m^3/s of additional peak flow could have occurred from Somerset if the dam had not been present. Given some attenuation of this peak between Somerset Dam and Savages Crossing and some allowance for uncertainty in the rating curve, a value in the order of 9 000 m^3/s is considered to be a reasonable lower estimate of the plausible range of the peak flow of the 1974 event assuming "no dams."

The higher bound is based on two sources: (i) report from BoM (August 2003) in which 10 800m^3/s was estimated based on rainfall runoff routing and (ii) the DNRM assessment of 10 500 m^3s-1 for the "no dams" peak.

An additional assessment of the "current" scenario, i.e. with Somerset and Wivenhoe dams in place and operated using current operating procedures is also provided (Case 4 – refer **Section 3.6**). This is based on the data series that has values adjusted for the effect of the dams as assessed and provided by DNRM. Note that an assessment of the plausible range for this estimate is not possible, as DNRM has not provided documentation for the method for adjusting the data series.

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4. Rainfall-Runoff Modelling

Rainfall-runoff modelling was undertaken to determine flows within the lower reach of the Brisbane River with Wivenhoe Dam and Somerset Dam in place. The RAFTS rainfall-runoff model developed for the Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) was used for this investigation. The Ipswich Rivers Flood Studies RAFTS model is based on the original Brisbane River Flood Study RAFTS model prepared for Brisbane City Council.

4.1 Assumptions

- The Ipswich Rivers Flood Studies (Sinclair Knight Merz, 2000) RAFTS model was used for the investigation.
- The Department of Natural Resources and Mines (DNRM, 2003) Wivenhoe and Somerset Dam Operations Model was used to determine dam outflows.

Unless otherwise stated, the parameter set used for the RAFTS modelling was as follows:

- Initial Loss Rate = 10 mm
- Continuing Loss Rate = 1.0 mm/h
- All model runs were undertaken for the 1 in 100 (1%) AEP flood event only.

4.2 Methodology

The following Methodology describes the process that was used to determine 1 in 100 AEP peak flows at Moggill and the Brisbane Port Office.

- Remove Wivenhoe Dam and Somerset Dam from the RAFTS model.
- Input CRC-FORGE Rainfalls in the RAFTS model using various historical rainfall distributions.
- Run the RAFTS hydrologic model (pre-dams) for the 1 in 100 AEP flood event for a series of duration's spatial and temporal patterns to determine the critical duration storm.
- Inflow hydrographs were then extracted from the RAFTS model and input into the DNRM Dam Operations Model.
- The DNRM Dam operations model was then run and an outflow hydrograph from Wivenhoe Dam was generated.
- Upstream of Wivenhoe Dam was removed from the RAFTS model and the outflow hydrograph generated by the DNRM dam operations model was used at this location.
- The RAFTS model was then re-run to determine 1 in 100 AEP flows at Savages Crossing, Moggill and the Brisbane Port Office Gauge.

- A sensitivity analysis was then performed using Wivenhoe and Somerset Dam operating procedures assuming different starting water levels in Wiveuhoe and Somerset Dams at the start of the flood event.

4.3 Pre-dams RAFTS Modelling

The object of the pre-dams modelling was to compare statistical flood frequency estimates and the flow estimates produced by RAFTS. Good agreement between the flow estimates resulting from the statistical flood frequency analysis and RAFTS provides a robust flood flow estimate. CRC-FORGE rainfall estimates were input into the RAFTS model using various spatial distributions. A sensitivity analysis was also undertaken to determine the effects that temporal patterns have on variation of peak flows.

4.3.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

CRC-FORGE rainfall estimates for varying durations were input into the model with Areal Reduction Factors (ARF) applied (Department of Natural Resources and Mines, 2003a). **Table 4-1** presents the rainfalls depths and adjusted rainfall depths (ARF's applied) used in the RAFTS model.

- **Table 4-1 CRC-FORGE Rainfall Depths for Brisbane River Catchment with Applied Areal Reduction Factors – 1%AEP**

	24 Hour (mm)	30 Hour (mm)	36 Hour (mm)	48 Hour (mm)	72 Hour (mm)	96 Hour (mm)	120 Hour (mm)
CRC-FORGE Rainfall	247	268	285	317	358	385	402
CRC-FORGE Rainfall with ARF applied	188	209	229	263	308	338	358

The CRC-FORGE rainfall estimates were spatially distributed across the catchment. Maps of the 24 hour spatial pattern are presented in **Appendix G**. Standard temporal patterns (ARR 1987) were then applied and the RAFTS model was run for a range of durations. An Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h was adopted.

The peak flows for Savages Crossing using the CRC-FORGE rainfall estimates with ARF's applied are presented in **Table 4-2**.

- **Table 4-2 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for 1 in 100 AEP Flood – Pre-dams**

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	8387	**9607**	8379	8626	9192	8128	8384
Moggill	7607	9015	7588	8004	**10101**	9180	9446
Brisbane Port Office	7608	9015	7589	8005	**10106**	9190	9463

Note: - Bold values indicate the critical duration at each location

- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.3.2 Sensitivity to Spatial Pattern of Rainfall

To determine the impact spatial patterns have on peak flows, seven historical spatial patterns were used. These spatial patterns were selected as they were significant flood events and data were readily available. The 24 hour rainfall spatial pattern for each historical event were determined and a ratio was applied to rainfall depth until the catchment average rainfall depth matched the CRC-FORGE Rainfall Depths (ARF applied) for each duration.

The seven historical spatial patterns assessed are:

- January 1893 – most of the rainfall occurred on the north-west portion of the catchment upstream of Wivenhoe and Somerset Dams.
- February 1893 – the majority of the rainfall fell on the eastern half of the catchment.
- January 1931 – high rainfalls occurred along the eastern catchment boundary
- March 1955 – high rainfalls were experienced upstream of Wivenhoe dams on the Brisbane River and Stanley Rivers.
- January 1974 – this event produced high rainfalls along the eastern boundary and Lower Brisbane River Catchment.
- April 1996 - high rainfalls in the Lockyer and Lower Brisbane River Catchments.
- February 1999 – high rainfalls fell upstream of Wivenhoe Dam.

Maps of each of the above historical spatial patterns are presented in **Appendix G**.

Each of the historical spatial patterns were applied with standard temporal patterns (AR&R 1987). RAFTS was then run (pre-dams) with an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h was applied.

Peak flows are presented in **Table 4-3**. Note that for all spatial distributions the 30 hour rainfall duration is the critical duration storm at Savages Crossing and the 72 hour flood is the critical

duration at Moggill and Brisbane Port Office. Flows presented at Moggill and the Brisbane Port Office in **Table 4-3** should be considered indicative only. More reliable estimates of design floods at the lower gauges are produced by the hydraulic model, as discussed in **Chapter 5**.

- **Table 4-3 Pre- dams Peak Flows for 1 in 100 AEP Rainfall and Historical Spatial Distributions**

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Brisbane Port Office (m^3/s)
January 1893	11507	10196	10198
February 1893	10062	**9501**	**9504**
January 1931	8543	8026	8030
March 1955	**10046**	9619	9623
January 1974	8005	9112	9117
April 1996	8621	8917	8922
February 1999	11205	10197	10200

Note: - Bold values indicate the median flow at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

A full listing of peak flow rates at Savages Crossing, Moggill and Brisbane Port Office are present in **Appendix H**.

4.3.3 Sensitivity to Temporal Pattern of Rainfall

To assess the sensitivity of the catchment with respect to temporal patterns, a series of patterns were applied for the catchment average CRC-FORGE Rainfall 48 hour storm duration. An Initial Loss of 0 mm and a Continuing Loss of 0 mm/h was applied.

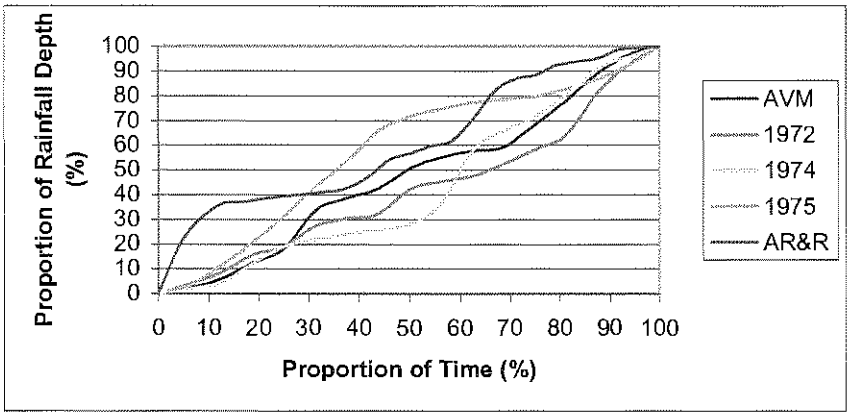
The temporal patterns that were used in the sensitivity analysis were:

- AVM – Average Variability Method,
- 1972 – This is a back loaded temporal pattern extracted from the January 1972 flood event,
- 1974 – A mid loaded temporal pattern extracted from the January 1974 flood event,
- 1975 – This is a front loaded temporal pattern extracted from the December 1975 flood event, and
- AR&R 1987 – Standard temporal pattern as provided in the 1987 edition of Australian Rainfall and Runoff.

These temporal patterns are shown in **Figure 4-1**. Note that the AVM patteru was developed from temporal patterns used in the BoM development of the recently revised Generalised Tropical Storm Method (GTSM-R). In summary, the method involves:

- ranking the rainfall depths in descending order for each period,
- the percentage of the total storm rainfall occurring in the period of each rank is found,
- the average rank for each period and the average percentage of the rainfall depth in the period of each rank are then calculated, then
- to obtain the temporal pattern, the period with the lowest average rank is assigned the average percentage of rain for the rank 1 periods, the second lowest average rank is assigned the average percentage of rain for the rank 2 periods, and so on for all selected periods.

The AVM method is described in greater detail in Pilgrim et al. (1969).



- **Figure 4-1 Temporal Patterns for the 1% AEP 48 Hour Storm Event**

The resulting peak flow estimates using the temporal patterns described above are presented in **Table 4-4**.

- **Table 4-4 Sensitivity to Peak Flow to Temporal Pattern of Rainfall**

	48 hour Temporal Pattern				
Location	**AR&R (m^3/s)**	**AVM (m^3/s)**	**1972 (m^3/s)**	**1974 (m^3/s)**	**1975 (m^3/s)**
Savages Crossing	11967	12635	12858	13864	13032
Moggill	12817	13464	13287	14115	13634
Brisbane Port Office	12817	13464	13287	14115	13634

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4.3.4 Discussion

Table 4-3 and **Table 4-4** show that spatial and temporal patterns have a significant effect on peak flows. The works undertaken show that by varying spatial and temporal patterns, the peak flow estimates at Savages Crossing can vary considerably. A Monte Carlo analysis could be undertaken to improve the accuracy of the Q100 flow estimate and help to reduce the uncertainties arising from the work undertaken so far. The historical spatial distributions produce pre-dams peak flows at Savages Crossing that range from 11,500 m^3/s to 8,000 m^3/s with the median peak flow of 10,050 m^3/s. The estimated peak flow at Savages Crossing using the CRC-FORGE spatial pattern was estimated to be 9600 m^3/s.

If an Initial Loss of 0 mm and Continuing Loss of 0 mm/h are applied to the CRC-FORGE 30 hour storm (critical at Savages Crossing), the peak flow from the RAFTS model was predicted to be 11,278 m^3/s. It should be noted that the 'best estimate' of peak flow at Savages Crossing from the statistical flood frequency analysis was estimated to be 12,000 m^3/s. This means that in order to reconcile peak flow estimates between RAFTS rainfall runoff modelling and the statistical flood frequency analysis, further work would need to be undertaken. This work would involve investigation of specific combinations of spatial and temporal patterns and application of acceptable loss rates to the RAFTS model. It is anticipated that this investigation would result in the reconciliation of flow estimates at Savages Crossing.

4.4 Comparison of Q100 estimates from statistical flood frequency analysis and hydrological modelling

Modelling of the Q100 event using:

- Calibrated Brisbane River Catchment RAFTS model
- CRC-FORGE 1 in 100 AEP rainfall estimates (with areal reduction factors and spatial distribution)
- 30 hr (critical duration for Savages Crossing) ARR87 temporal pattern
- zero initial and continuing losses
- no dams in the model

produced a Q100 at Savages Crossing of 11278 m^3/s. It would be reasonable to expect some losses with such an event and hence the hydrological modelling results, using typical design parameters, could be expected to be lower, say in the order of 10, 500m^3/s.

The difference between the results and those from the statistical frequency analysis of flood records (**Chapter 3**) indicates that there are underlying factors that have not been adequately addressed to date. This would require more detailed assessment than is available in the scope and timing of the current assessment. Potential factors influencing the difference in Q100 estimates include:



- potential for partial area storms
- variation in temporal patterns
- variation in spatial patterns
- variation in losses
- adjustment of data for influence of dams
- estimation of the 1893 flood peak
- estimation of the 1974 flood peak
- uncertainty in the rating curve at Savages Crossing and hence estimation of the flood peaks above the maximum gauged flood.

The development of a Monte Carlo framework for analysing the factors affecting flood magnitude would enable the natural variation in the first four factors to be explicitly modelled. This would provide the insights necessary to resolve the differences between the two independent Q100 estimates.

4.5 Post-dams RAFTS Modelling

Inflows to Somerset Dam and Wivenhoe Dam and outflows at Lockyer Creek and Bremer River were extracted from the pre-dams RAFTS model results and run through the DNRM Dam Operations Model (Department of Natural Resources and Mines, 2003b). These inflows were based on the outputs presented in **Appendix H** and included an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/h.

The outflow volume from Wivenhoe Dam produced by the DNRM Dam Operations model was compared to the total inflow volume into Wivenhoe and Somerset Dams. The comparison found good consistency between the hydrograph volumes.

Outflow hydrographs at Wivenhoe Dam were determined using the DNRM Dam Operations model and then used in RAFTS for the CRC-FORGE and historical spatial patterns to determine flows at Savages Crossing, Moggill and Brisbane Port Office.

4.5.1 CRC Rainfall Estimates – Standard CRC-FORGE Distribution

The parameters described in **Section 4.3.1** were used for the Post-dams RAFTS modelling.

The CRC-FORGE rainfall estimates with ARF's applied are presented in **Table 4-5**.

- **Table 4-5 Peak Flows for CRC-FORGE Spatially Distributed with Areal Reduction Factors for the 1 in 100 AEP Rainfall – Post-dams**

Location	24 Hour (m^3/s)	30 Hour (m^3/s)	36 Hour (m^3/s)	48 Hour (m^3/s)	72 Hour (m^3/s)	96 Hour (m^3/s)	120 Hour (m^3/s)
Savages Crossing	2069	3356	2186	2399	**5368**	2335	2502
Moggill	3017	3690	2999	3302	**5043**	3811	3990
Brisbane Port Office	3020	3691	3001	3305	**5044**	4073	4177

Note: - Bold values indicate the critical duration at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.5.2 Sensitivity to Spatial Pattern of Rainfall

The parameters described in **Section 4.3.2** were used for the Post-dams RAFTS modelling. Peak flows are presented in **Table 4-6**. Note that the critical duration storm at Savages Crossing, Moggill and Brisbane Port Office range from 72 to 120 hours for Post-dam Conditions. Flows presented at Moggill and the Brisbane Port Office in **Table 4-6** should be considered as indicative only. More accurate flows have been determined from the hydraulic modelling (**Chapter 5**).

- **Table 4-6 Post-dams Peak Flows for the 1 in 100 AEP Rainfall and Historical Spatial Distributions**

Spatial Distribution	Savages Crossing (m^3/s)	Moggill (m^3/s)	Brisbane Port Office (m^3/s)
January 1893	7847 (120hr)	7120 (120hr)	7121 (120hr)
February 1893	6568 (120hr)	5850 (120hr)	**5851** (120hr)
January 1931	3279 (120hr)	3218 (120hr)	3411(120hr)
March 1955	**6241** (72hr)	5709 (72 hr)	5710 (72hr)
January 1974	4771 (96hr)	**5841** (96hr)	5852 (96hr)
April 1996	4162 (72hr)	5019 (72hr)	5035 (96hr)
February 1999	7431 (120hr)	6819 (120hr)	6819 (120)

Note: - (120hr) denotes the critical storm duration
- Bold values indicate the median flow at each location
- Flows at Moggill and Brisbane Port Office should be considered indicative only.

4.5.3 Sensitivity to Starting Water Level in Wivenhoe Dam

Wivenhoe Dam has 1,165 gigalitres (GL) of storage capacity for water supply purposes up to its full supply level of EL 67.0 m AHD (Australian Height Datum). A further 1,450 GL ref of storage capacity is available above the Full Supply Level, up to a level of EL 75.0 m AHD for the temporary storage of flood waters, i.e. the total capacity of Wivenhoe Dam is 2,615 GL. The flood storage is held empty, except when required, to store flood waters (SEQWB 1998 –1999).

The catchment area above Wivenhoe Dam is approximately 7,080 km^2. Assuming no losses, the total runoff volume for the 1 in 100 AEP flood (average CRC-FORGE rainfalls with ARF applied) for durations ranging from 24 hours to 120 hours are presented in **Table 4-7**.

- **Table 4-7 Flood Runoff Volumes from the 1 in 100 AEP Rainfall Events above Wivenhoe Dam**

Storm Duration (hours)	CRC Rainfall Depth with ARF Applied (mm)	Runoff Volume (Gigalitres)
24	188	1331
30	209	1480
36	229	1621
48	263	1862
72	308	2180
96	338	2393
120	358	2534

Table 4-7 shows that if Wivenhoe Dam is at FSL, the 1 in 100 AEP 30 hour (flood runoff volume can almost be fully stored between FSL and EL 75.0 m without release. For 1 in 100 AEP events with longer durations, Wivenhoe Dam would have to be lower than FSL to store the entire flood runoff volume before the EL 75.0 m is exceeded (no releases).

Given the current operational procedures, it is unlikely that releases would not occur during a flood event, particularly if Wivenhoe Dam were at FSL at the start of the flood event. To determine the impacts starting water level have on flood flows downstream, a number of sensitivity runs were done for the 1 in 100 AEP 72-hour storm. Dam Starting Water Levels (SWL) have been assumed at 75% full and 50% full with current Operating Procedures.

Peak flows assuming different Wivenhoe Dam starting water levels are presented in **Table 4-8**.

- **Table 4-8 Flows for Dam Starting Water Levels Sensitivity Analysis for the 1 in 100 AEP 72 Hour Storm**

Location	FSL - RL 67 m AHD (m^3/s)	SWL 75% - RL 64 m AHD (m^3/s)	SWL 50% - RL 60 m AHD (m^3/s)
Savages Crossing	5368	3486	3334
Moggill	5043	4376	4376
Brisbane Port Office	5044	4402	4402

Note: - Flows at Moggill and Brisbane Port Office should be considered indicative only.

Table 4-8 shows that the reduction in flow is approximately 13% at the Brisbane Port Office Gauge between the dam being at FSL and 75% full. It is interesting to note that flows do not change significantly between the 75% and 50% starting water levels.

4.5.4 1893 and 1974 Historical Flood Events

The information from the two historical flood events (1893 and 1974) were run through the RAFTS model and flows at Savages Crossing were reconciled with measured estimates. Wivenhoe and Somerset Dams were then input into the model and operating procedures were applied.

The resulting Post-dam flows are presented in **Table 4-9**.

- **Table 4-9 Predicted Post-dam Flows for the 1893 and 1974 Historical Flood Events**

	1893 (IL = 0 and CL = 0.5mm/h)		1974 (IL =0mm and CL = 2.5mm/h)	
Location	No Dams (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)	Somerset in Place (m^3/s)	Somerset and Wivenhoe in Place (m^3/s)
Savages Crossing	13258	9563	7554	3882
Moggill	13856	9517	9850	6639
Brisbane Port Office	13869	9519	9874	6801

Table 4-9 indicates that the peak flows for the historical events at the Brisbane Port Office are above the 1 in 100 AEP CRC-FORGE estimate (5044 m^3/s), and the median spatial pattern estimate of 5851 m^3/s.

There are many uncertainties associated with the 1974 peak flow estimate and even more with the 1893 event. However, it is clear from **Table 4-9** that the effect of the dams on events of such magnitude is significant. While flows predicted by the RAFTS model at the Brisbane Port Office are only indicative, they provide a reasonable estimate as calibration of this model has been undertaken. The most accurate way to assess flows at the Brisbane Port Office Gauge would be to use a hydraulic model.

It should be noted that the predicted flow for the 1974 event, assuming that Wivenhoe dam had been in place, is 6,800 m^3/s at the Brisbane Port Office Gauge. This is larger than the 'best estimate' of the 1 in 100 AEP event at the Brisbane Port Office of 6,500 m^3/s. This is thought to be due to the 1974 spatial pattern (see **Appendix G**) where the majority of rainfall fell within the Lower Brisbane and Bremer River Catchment. For rainfall events where the majority of rainfall falls below the dams, the resultant flood will have a lower associated probability (i.e. will be expected to happen less often) after post Wivenhoe compared to prior to the construction of Wivenhoe. This study did not further investigate partial catchment storms on the over the Lower

Brisbane, Bremer and Lockyer catchments apart from the overall sensitivity of spatial patterns (**Section 4.5.2)** The magnitude of the modelled 1974 event 'with dams' was a strong influence on the selection of the values proposed as the 'best estimate' and the notional 'upper limit' of the Q100 at the Port Office (**Section 4.5.5**).

4.5.5 Discussion

The variability of flows predicted for the post-dams catchment is further affected by the introduction of Wivenhoe and Somerset Dams. Monte-Carlo analysis would be an appropriate way to investigate the complex interactions between dams and variations in losses, spatial and temporal patterns to obtain the best possible estimate of the 1 in 100 AEP flood event.

The CRC-FORGE spatially distributed peak flow at Savages Crossing was estimated to be 5,368 m^3/s for the post-dams case. The historical spatial distributions produce peak flows at Savages Crossing that range from 7847 m^3/s to 3279 m^3/s with the median peak flow of 6,241 m^3/s.

Based on the preceding investigations, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 4-10** provides a range of estimates with a 'best estimate,' upper estimate and lower estimate. Given the current information, the 'best estimate' of peak flow at the Brisbane Port Office would be 6500 m^3/s with an upper and lower limit of 8,000 m^3/s and 5,000 m^3/s respectively. While the estimates predicted by RAFTS at Moggill and the Brisbane Port Office should be considered indicative, previous modelling shows that flows predicted by RAFTS are consistent with flows predicted by the MIKE11 hydraulic model.

- **Table 4-10 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood with Dams**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The best estimate of 6,500 m^3/s was adopted after consideration of the RAFTS modelling for current design spatial pattern, various historical patterns, the performance of the model in reproducing flows at Savages Crossing for pre-dam flows and the modelling of the 1974 event with Wivenhoe dam in place (**Section 4.5.4**). The estimate of the lower end of the plausible range of the Q100 estimate is 5,000 m^3/s. It was adopted with particular consideration to the range of results from the sensitivity to the spatial patterns. The estimate of the upper bound of the plausible range was taken to be 8,000 m^3/s. This upper bound was adopted after particular consideration of the

variation in the spatial patterns, the sensitivity to temporal patterns, and the 1974 peak flow results for the 'Somerset only' then 'Somerset and Wivenhoe' dams scenarios.

A Monte-Carlo analysis would improve the accuracy of the 1 in 100 AEP flood estimate and reduce the uncertainty in plausible range of the flood estimates.

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flow estimates are:

- inclusion of the lower CRC-FORGE rainfall depths with areal reduction factors,
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures (the previous study Sinclair Knight Merz 1998), assumed emergency operating procedures which minimised the mitigation affects that Wivenhoe and Somerset Dams have on the lower Brisbane River),
- In the 1998 study, the emphasis was to match statistical flood frequency estimates at Moggill and the Brisbane Port Office. The reliability of the streamflow at Moggill and Brisbane Port Office is questionable as these gauges are river level gauges and tidal effects are difficult to account for at these locations. After discussions with DNRM, who have just developed a new composite flood series at Savages Crossing, it was concluded that the most appropriate location to reconcile flows between rainfall based methods and statistical flood frequency estimates was at Savages Crossing. For this investigation the focus was placed on Savages Crossing, as discussed in **Chapter 3**, and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

Rainfall-runoff modelling using a Monte Carlo framework could be undertaken to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This would correctly reflect the combined influences of these stochastic factors and improve the accuracy of the estimated Q100 flood magnitude. It would also reduce the uncertainty of the Q100 flood estimates.

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5. Hydraulic Modelling

The MIKE11 hydraulic model developed for the Ipswich Rivers Flood Studies was used to determine peak flood levels at the Brisbane Port Office Gauge. It should be noted that this model is an extension of the Brisbane River Flood Study MIKE11 hydraulic model and that the model was re-calibrated as part of the Ipswich Rivers Flood Studies work.

While the calibration at the Moggill and Brisbane Port Office is good, other sections of the reach within Brisbane City have not been calibrated, as the main focus was to calibrate the model within the Ipswich City Boundary. For the purposes of this investigation this model will provide good flood level estimates at Moggill and Brisbane Port Office, however care should be taken when flood level estimates are derived in other areas of Brisbane City.

5.1 Assumptions

Hydraulic modelling was undertaken assuming MHWS tide at the Brisbane River Bar.

5.2 MIKE11 Modelling

The Ipswich Rivers Flood Studies MIKE11 hydraulic model was used for the assessment. This model routes flows from approximately 10 km downstream of Savages Crossing to the Brisbane River Bar. The model also includes Bremer River and other smaller tributaries, which accounts for most of the major tributaries in the downstream reaches of the Brisbane River. The hydraulic modelling was undertaken for the 1 in 100 AEP spatially distributed over the catchment. Rainfall durations ranging from 24 to 120 hours were assessed.

5.3 Results

The peak flow rates and flood levels at Moggill and Brisbane Port Office are presented in **Table 5-1**.

- **Table 5-1 Peak Flood Levels and Flows for the 1 in 100 AEP CRC-FORGE Spatial Distributed Rainfall**

	Moggill		Brisbane Port Office	
Duration (hours)	Q (m^3/s)	WL (m AHD)	Q (m^3/s)	WL (m AHD)
24	3269	9.41	3337	1.79
30	4117	11.27	4047	2.15
36	3317	9.61	3331	1.79
48	3647	10.36	3717	2.00
72	**5195**	**13.24**	**5059**	**2.68**
96	4103	11.54	4472	2.42
120	4231	11.77	4853	2.48

Note: - Bold values indicate the critical duration at each location

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5.4 Discussion

Comparison of Table 4-5 and **Table 5-1** indicates that there is good consistency between the peak flows estimated by RAFTS and the peak flows estimated by MIKE 11 at the Brisbane Port Office. Some confidence can therefore be taken in using RAFTS flow outputs and rating curves produced by MIKE11 at the Brisbane Port Office.

Using the 'best estimate and upper and lower limits of peak flows at the Brisbane Port Office presented in **Section 4.5.5**, a rating curve was used to predict flood levels at the Brisbane Port Office for the 1 in 100 AEP flood event. Peak flood levels and corresponding flows are presented in **Table 5-2**.

- **Table 5-2 Peak Flood Level and Peak Flow Estimates for the 1 in 100 AEP Flood Event at Brisbane Port Office**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

Note that these estimates should be considered indicative because the tide level variation during flood events may vary. The levels presented in the above table are based on a Mean High Water Spring Tide (0.918 m AHD) at the Brisbane River Bar.

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6. Conclusions

Detailed investigations have been undertaken to assist the Expert Review Panel to assess the likelihood of floods in the lower reaches of the Brisbane River. The assistance has been centred on the two tasks of:

- undertaking statistical flood frequency analysis, and
- updating the estimates of flood frequency from rainfall-runoff modelling with new information.

The rainfall-runoff modelling utilised models developed as part of the Brisbane River Flood Study (Sinclair Knight Merz, 1998). Additional information and statistical techniques have been included in reassessing the plausible range of the 1 in 100 annual exceedance probability (AEP) flood, which is also referred to as the Q100 flood.

The two tasks provide independent assessments of the Q100 event, firstly a statistical assessment of the streamflow data and secondly a rainfall-runoff modelling assessment.

Statistical flood frequency analysis

The Expert Panel requested that Sinclair Knight Merz undertake statistical flood frequency analysis of the available data and come up with a best estimate of the likely Q100 at Savages Crossing. An estimate of the Q100 for the "no dams" case (i.e. the peak flow that would occur if the dams were not present) was requested with an indication of the sensitivity of the estimate to the various sources of uncertainty leading to a plausible range for the Q100 estimate.

Frequency analysis was undertaken using a range of at-site and regional methods. The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (e.g. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates. The regional information was incorporated using Bayesian theory.

Sinclair Knight Merz has assessed the flood series data and provided a "best" estimate and a plausible range for the "no dams" scenario, i.e. assuming that Somerset and Wivenhoe dams were not present. It should be noted that the upper and lower estimates of the range are notional, and do not take into consideration information that is available from other independent sources (such as rainfall-based flood event modelling).

The results are presented in **Table 6-1**.

- **Table 6-1 Most plausible estimates of the Q100 peak flow and its plausible range at Savages Crossing based on statistical flood frequency analysis**

Scenario	"Best" estimate	Likely lower estimate	Likely uUpper estimate
"No dams"	12,000	10,000	14,000

The best estimate for the "no dams" scenario was adopted after consideration of substantial sensitivity analyses, with particular attention paid to the convergence of the Q100 estimates based on the three most relevant data series.

The boundaries of the plausible range of flow estimates are reasonably broad. This reflects the significant sources of uncertainty in the recorded data, length of record, choice of distribution and adjustment of the data for the effect of the dams. As an example of some of the above uncertainties, there is reasonable evidence for 1974 "no dams" peak flow rate to be somewhere between 7,500 m^3/s and 11,000 m^3/s (**Section 3.8**). Such uncertainty has a direct bearing on the uncertainty in the "best" estimate of the Q100 event.

Rainfall-runoff modelling

The second method by which SKM was requested to assess the Q100 flow was rainfall-runoff modelling. This method takes design rainfall information and routes it through the catchment by utilising design depth, temporal and spatial patterns of the storm, losses (e.g. the soil, interception by vegetation, etc), movement through the streams, rivers and dams until it reaches the Brisbane Port Office.

The most appropriate way to jointly assess the above factors (along with other factors such as variability in rainfall spatial and temporal patterns, loss rates, reservoir level and gate operation failure) is by Monte-Carlo analysis. Given the restrictions on time for this current investigation, this analysis could not be undertaken. To account for the above factors, sensitivity analysis was undertaken separately for spatial patterns, temporal patterns and starting water levels behind the dams. Sensitivity to dam operation procedures was not undertaken as part of this study.

Revised Rainfall Depths

The Department of Natural Resources and Mines (DNRM) provided 1 in 100 AEP CRC-FORGE rainfall estimates. These estimates included Areal Reduction Factors (ARF) which account for the reduction in rainfall depth with increasing catchment area. The rainfall estimates as supplied also contained the design spatial distribution of rainfall over the catchment.

Rainfall depths from CRC-FORGE were input into the RAFTS rainfall-runoff model (Sinclair Knight Merz, 2000) for pre-dams conditions, and a series of spatial patterns were modelled. A

range of peak flows were determined at Savages Crossing and these varied between 8,000 m^3/s and 11,500 m^3/s.

The median peak flow produced by the RAFTS model for the range of spatial patterns using a standard temporal pattern was approximately 10,000 m^3/s using an Initial Loss of 10 mm and a Continuing Loss of 1.0 mm/h. This compares to the statistical frequency estimate (i.e. analysis of recorded flow data) of 12,000 m^3/s.

Sensitivity to Spatial Pattern of Rainfall

The CRC-FORGE estimates for various spatial patterns with a standard AR&R 1987 temporal pattern were run through the DNRM Dam Operations model (Department of Natural Resources and Mines, 2003). This model predicts an outflow hydrograph from Wivenhoe Dam. The Wivenhoe Dam outflow hydrograph was then input into the RAFTS model and peak flow estimates were calculated at Savages Crossing. Peak flows ranged approximately from 3,000 m^3/s to 8,000 m^3/s. The median value of peak flow for post-dam conditions with variation in spatial pattern was estimated to be 6,200 m^3/s.

Sensitivity to Temporal Pattern of Rainfall

Using a catchment average 48-hour CRC-FORGE rainfall depth (ARF applied), the RAFTS model was then re-run using various temporal patterns for pre-dams conditions. When zero losses were applied, the range of flows was between 12,000 m^3/s and 13,800 m^3/s. This indicates that by incorporating the natural variation in spatial and temporal patterns it should be possible to reconcile the results obtained using statistical methods and rainfall-runoff modelling analysis.

A sensitivity analysis to variation in rainfall temporal pattern was not undertaken for post-dam conditions.

Sensitivity to Wivenhoe Reservoir Level

A sensitivity analysis was undertaken for variations in the starting water level in Wivenhoe Dam. The analysis used the 1 in 100 AEP 72-hour storm with standard temporal patterns and an Initial Loss of 10 mm and Continuing Loss of 1.0 mm/hr. If Wivenhoe Dam is assumed full at the start of the event, the peak flow at Savages Crossing and the Brisbane Port Office was estimated to be 5,400 m^3/s and 5,000 m^3/s respectively. If the dam was assumed to be at 75% full, the peak flow at Savages Crossing and the Brisbane Port Office was reduced to 3,500 m^3/s and 4,400 m^3/s respectively.

Q100 Estimate at the Brisbane Port Office

The main objective of the report was to determine 1 in 100 AEP peak flows and flood levels at the Brisbane Port Office. To do this, the MIKE11 hydraulic model (Sinclair Knight Merz, 2000) was



used to account for routing effects from Savages Crossing to the Brisbane Port Office. The flows predicted by MIKE11 compared well to the flows predicted by RAFTS at the Brisbane Port Office. A rating curve from the hydraulic model was used to predict flood levels at the Brisbane Port Office.

Based on the current level of investigation, it is clear there is uncertainty in any estimate of the 1 in 100 AEP flood event at the Brisbane Port Office. **Table 6-2** provides a 'best estimate and the associated plausible range within which the Q100 estimate lies.

- **Table 6-2 Range of Estimates at the Brisbane Port Office for the 1 in 100 AEP Flood**

Condition	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
Lower Estimate	5000	2.76
Best Estimate	6500	3.51
Upper Estimate	8000	4.41

The peak flows presented in this report are less than those predicted in the Brisbane River Flood Study (Sinclair Knight Merz, 1998). The factors that influence the changes in peak flows are:

- inclusion of the lower CRC-FORGE rainfall depths with Areal Reduction Factors,
- consideration of variation in temporal and spatial characteristics of rainfall,
- better representation of dam operating procedures, and
- inclusion of regional streamflow information in the statistical flood frequency analysis.

To reduce the uncertainty in the above estimates, the following actions would serve to increase the accuracy of the 1 in 100 AEP flow estimates.

- Undertake rainfall-runoff modelling in a Monte Carlo framework to explicitly consider the natural variations in spatial and temporal patterns of rainfall and variations in initial dam storage levels (other variables such as variable rainfall losses and gate failure likelihood can also be incorporated). This will provide the most robust estimate of Q100 that correctly reflects the combined influences of these stochastic factors.
- Re-calibrate the Ipswich Rivers MIKE 11 hydraulic model within the Brisbane City Council Boundary.

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7. References

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South East Queensland Water Board (1998 – 1999) South East Queensland Water Board Annual Report

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Appendix A Original Scope of Work

The original scope of work proposed for assisting in the review of the Brisbane River flood studies was as follows:

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the flood frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the flood frequency Analysis Outcomes.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC-FORGE Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 1 in 100 AEP event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the DNRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine the 1 in 100 AEP flows at Moggill.
7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long-term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQWB and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of



sophistication appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.



Appendix B Flow Gauging Stations Omitted from Consideration

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143222A	Atkinson Dam	Atkinson Creek Outlet		20	Small catchment area, offstream storage	DNRM
143234A	Atkinson Dam Hea			6	Small catchment area, offstream storage	DNRM
143228A	Bill Gunn Dam	Lake Dyer	3	18	Catchment area too small	DNRM
143027A	Blunder Creek	King Avenue Bridge	31	8	Urban creek in Brisbane area, Small catchment	DNRM
2121	Blunder Creek	King Ave- Durack		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1594	Breakfast Creek	Opposite Newstead House		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1579	Breakfast Creek	Sedgley Park Retention Basin- New Market		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1525	Breakfast Creek	Opposite Mann Park- Bowen Hills		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143104B	Bremer River	Rosevale	67	21	Catchment area too small	DNRM
143104A	Bremer River	Rosevale	77	34	Catchment area too small	DNRM
143110A	Bremer River	Adams Bridge	125	35	Catchment area too small	DNRM
143940	Bremer River	Stokes Crossing	180	21	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143909	Bremer River	Rosewood	543		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143833	Bremer River	Rosewood Alert	543	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143908	Bremer River	Rosewood TM	543	25	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143934	Bremer River	Walloon Bvrt	585		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143805	Bremer River	Walloon Alert-P	585	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143911	Bremer River	Ipswich	1850		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143956	Bremer River	Three Mile Bridge Alert	1870		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143954	Bremer River	Ipswich Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143953	Bremer River	One Mile Bridge Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143852	Bremer River	Brassall(Hancocks Br) Al		5	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143115A	Bremer River	Berry's Lagoon		9	Record length too short	DNRM
143944	Brisbane River	Linville	2005	47	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143007A	Brisbane River	Linville	2009	39	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143831	Brisbane River	Devon Hills Alert	2160	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143922	Brisbane River	Devon Hills Bvrt	2190		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143002A	Brisbane River	Plainlands	3950	12	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143002B	Brisbane River	Fulham Vale	3950	34	Gauge ignored as record length below initial threshold. Possibly useful for future studies.	DNRM
143005A	Brisbane River	Watts Bridge	4602	20	Record length too short	DNRM
143008A	Brisbane River	Middle Creek	6704	20	Record length too short	DNRM
143026A	Brisbane River	Wivenhoe	7023	3	Record length too short	DNRM
143036A	Brisbane River	Wivenhoe Headwater	7023	17	Record length too short	DNRM
143035A	Brisbane River	Wivenhoe Tailwater	7023	17	Record length too short	DNRM
143907	Brisbane River	Lowood	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143941	Brisbane River	Lowood Bvrt	10062		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143827	Brisbane River	Lowood Alert-P	10062	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143916	Brisbane River	Mt Crosby	10600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143839	Brisbane River	Mt Crosby Alert	10600	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143925	Brisbane River	Mt Crosby TM	10600	28	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143951	Brisbane River	Moggill Alert	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143915	Brisbane River	Moggill Bvrt	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143924	Brisbane River	Moggill TM	12600		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143900	Brisbane River	Caboonbah			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143914	Brisbane River	Gregor Creek			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143920	Brisbane River	Gregor Creek Bvrt			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143902	Brisbane River	Murrumba			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143005	Brisbane River	Watts Bridge			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143903	Brisbane River	Wivenhoe			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143018A	Brisbane River	Avoca Vale	1498	20	Record length too short (post Wivenhoe)	DNRM
143868	Brisbane River	Colleges Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143918	Brisbane River Estuary	Bishop Island			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143217A	Buaraba Creek	Vineyard	63	10	Catchment area too small	DNRM
143211A	Buaraba Creek	15.8 km	251	12	Catchment area too small	DNRM
143224A	Buaraba Creek	Diversion Channel		19	Catchment area too small	DNRM
143094A	Bulimba Creek	Mansfield	57	26	Urban creek in Brisbane area, Small catchment	DNRM
143004A	Bulimba Creek	Belmont	51	22	Urban creek in Brisbane area, Small catchment	DNRM
1591	Bulimba Creek	End of Aquarium Ave. Hemmant		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1528	Bulimba Creek	Doughboy Pde- Hemmant		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1804	Bulimba Creek	Greenwood St- Wishart		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1831	Bulimba Creek	Merion Pl- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1707	Bulimba Creek	Old Cleveland Rd- Carindale		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143926	Bundamba Creek	Ripley Alert	35		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143959	Bundamba Creek	Harding Street Alert	96		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143958	Bundamba Creek	Blackstone Bridge Alert	97	10	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143955	Bundamba Creek	Bundamba School Alert	102		Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143854	Bundamba Creek	Bundamba (Hanlon St) Al	109	7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143114A	Bundamba Creek	Mary Street	110	11	Urban creek in Ipswich area, Small catchment	DNRM
143307A	Byron Creek	Causeway	79	28	Catchment area too small	DNRM
143012A	Cooyar Creek	51.5km.	443	4	Record length too short	DNRM
143015B	Cooyar Creek	Damsite	963	13	Record length too short	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143015A	Cooyar Creek	Damsite	963	22	Record length too short	DNRM
143013A	Cressbrook Creek	The Damsite	321	16	Record length too short	DNRM
143952	Cressbrook Creek	Rosentreters Bridge	440		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143921A	Cressbrook Creek	Rosentreters Bridge	447	17	Record length too short	DNRM
143921	Cressbrook Creek	Rosentreters Bridge TM	477		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143806	Cressbrook Creek	Rosentreters Bridge Al	477	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143857	Deebing Creek	Churchill Alert			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143021A	Ekibin Creek	Dudley Street.	13	1	Urban creek in Brisbane area, Small catchment	DNRM
143011A	Emu Creek	Raeburn	439	24	Catchment area too small	DNRM
143010A	Emu Creek	Boat Mountain	915	11	Catchment area too small	DNRM
143010B	Emu Creek	Boat Mountain	915	27	Catchment area too small	DNRM
143932A	Enoggera Creek	Bancroft Park	70	10	Urban creek in Brisbane area, Small catchment	DNRM
143932	Enoggera Creek	Bancroft Park TM	67		Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1531	Enoggera Creek	100 M U/S From Original E e529		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1532	Enoggera Creek	Enoggera Dam- The Gap		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1529	Enoggera Creek	Kelvin Grove Rd- Kelvin Grove		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143208A	Fifteen Mile Creek	Dam Site	87	33	Catchment area too small	DNRM
143214A	Flagstone Creek	Windolfs	142	14	Catchment area too small	DNRM
143233A	Flagstone Creek	Brown-Zirbels Road		10	Catchment area too small	DNRM
1717	Gold Creek	Reservoir- Brookfield (Brisbane Water)			Urban creek in Brisbane area, Small catchment	South East Queensland Water
143028A	Ithaca Creek	Jason Street	10	31	Urban creek in Brisbane area, Small catchment	DNRM
1535	Ithaca Creek	Jason St- Ithaca		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143304A	Kilcoy Creek	Mount Kilcoy	127	36	Catchment area too small	DNRM
143304B	Kilcoy Creek	Mount Kilcoy Weir	131	15	Catchment area too small	DNRM

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143235A	Lake Clarendon Head			6	Offstream storage	DNRM
143215A	Laidley Creek	Mulgowie Weir	154	14	Catchment area too small	DNRM
143209A	Laidley Creek	Mulgowie1	167	5	Catchment area too small	DNRM
143209B	Laidley Creek	Mulgowie2	167	36	Catchment area too small	DNRM
143225A	Laidley Creek	Showgrounds Weir Head Water	233	19	Catchment area too small	DNRM
143226A	Laidley Creek	Showgrounds Weir Tail Water	233	19	Catchment area too small	DNRM
143943	Laidley Creek	Laidley	285		Catchment area too small	BoM, Queensland Regional Office
143923	Laidley Creek	Thornton			Catchment area too small	BoM, Queensland Regional Office
143229A	Laidley Creek	Warrego Highway		13	Catchment area too small	DNRM
143202A	Lockyer Creek	Russell Siding	271	7	Catchment covered by other gauges DS	DNRM
143203C	Lockyer Creek	Helidon Number 3	357	16	Catchment covered by other gauges DS	DNRM
143203A	Lockyer Creek	Helidon	357	45	Catchment covered by other gauges DS	DNRM
143203B	Lockyer Creek	Helidon No.2	382	24	Catchment covered by other gauges DS	DNRM
143904	Lockyer Creek	Gatton	1550		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143204A	Lockyer Creek	Wilsons Weir	1655	29	Catchment covered by other gauges DS	DNRM
143905	Lockyer Creek	Glenore Grove	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143906	Lockyer Creek	Glenore Grove Bvrt	2230		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143807	Lockyer Creek	Glenore Grove Alert	2230	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143206A	Lockyer Creek	Brightview Weir	2393	20	Catchment covered by other gauges DS	DNRM
143201A	Lockyer Creek	Tarampa	2405	17	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143201B	Lockyer Creek	Tarampa Number 2	2405	22	Gauge ignored as catchment area below initial threshold. Possibly useful for future studies.	DNRM
143917	Lockyer Creek	Lyons Bridge	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143913	Lockyer Creek	Lyons Bridge Bvrt	2530		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

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Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143819	Lockyer Creek	Lyons Bridge Alert-P	2530	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143227A	Lockyer Creek	O'Reilly's Weir Tailwater	2965	5	Record length too short	DNRM
2142	Lota Creek	Rickertt Rd Ransome		4	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143213B	Ma Ma Creek	Ma Ma Weir	226	9	Catchment area too small	DNRM
143213A	Ma Ma Creek	Harms	227	4	Catchment area too small	DNRM
143213C	Ma Ma Creek	Harm's		8	Catchment area too small	DNRM
143032A	Moggill Creek	Upper Brookfield	23	27	Urban creek in Brisbane area, Small catchment	DNRM
143020A	Moggill Creek	Misty Morn	61	9	Urban creek in Brisbane area, Small catchment	DNRM
143020	Moggill Creek	Misty Morn TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1722	Moggill Creek	Fortrose St- Kenmore		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2143	Moolabin Creek	Brisbane River Golf Club-Tennyson		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143219A	Murphys Creek	Spring Bluff	18	24	Urban creek in Brisbane area, Small catchment	DNRM
1549	Norman Creek	Joachim St- Holland Park West		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1552	Norman Creek	South East Freeway-Greenslopes		9	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1555	Norman Creek	Caswell St- East Brisbane River		10	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143033A	Oxley Creek	New Beith	60	27	Urban creek in Brisbane area, Small catchment	DNRM
143019A	Oxley Creek	Upstream Beatty Road	152	3	Urban creek in Brisbane area, Small catchment	DNRM
143019B	Oxley Creek	Downstream Beatty Road	152	6	Urban creek in Brisbane area, Small catchment	DNRM
143019	Oxley Creek	Beatty Road TM			Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1588	Oxley Creek	Mouth of Oxley Creek		5	Urban creek in Brisbane area, Small catchment	Brisbane City Council
1727	Oxley Creek	New Beith (DNR)+F31		8	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2023	Oxley Creek	Corinda High School- Corinda		12	Urban creek in Brisbane area, Small catchment	Brisbane City Council
2125	Oxley Creek	Beatty Rd- Acacia Ridge		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council

SKM

Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
2111	Oxley Creek	Johnson Rd- Forestdale		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143024A	Pullen Pullen Creek	Moggill Road	27	4	Urban creek in Brisbane area, Small catchment	DNRM
1745	Pullen Pullen Creek	Pinjarra Rd- Pinjarra Hills		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143983	Purga Creek	Loamside Alert	215	8	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143113A	Purga Creek	Loamside	215	30	Catchment area too small	DNRM
143869	Purga Creek	Peak Crossing Alert		4	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143218A	Redbank Creek	Holcomb	55	8	Urban creek in Ipswich area, Small catchment	DNRM
143216A	Redbank Creek	Water Treatment Works	60	11	Urban creek in Ipswich area, Small catchment	DNRM
143231A	Redbank Creek	Clarendon Number 2		10	Urban creek in Ipswich area, Small catchment	DNRM
143230A	Redbank Creek	Clarendon Pump Station		10	Urban creek in Ipswich area, Small catchment	DNRM
143306A	Reedy Creek	Upstream Byron Creek Junct	56	28	Catchment area too small	DNRM
143103A	Reynolds Creek	Moogerah	190	37	Catchment area too small	DNRM
143103B	Reynolds Creek	Moogerah	190	6	Catchment area too small	DNRM
143111A	Reynolds Creek	Moogerah Dam Headwater	226	36	Head gauge affected by dam site	DNRM
143112A	Reynolds Creek	Moogerah Tailwater	227	23	Tail gauge affected by dam site	DNRM
143220A	Sandy Creek	Forest Hill	102	7	Urban creek in Brisbane area, Small catchment	DNRM
143232A	Sandy Creek	Forest Hill		8	Urban creek in Brisbane area, Small catchment	DNRM
143030A	Sandy Creek	Indooroopilly		22	Urban creek in Brisbane area, Small catchment	DNRM
143223A	Seven Mile Lagoon	Diversion Channel		20	Diversion channel	DNRM
143023A	Small Catchment	Algester	1	4	Urban creek in Brisbane area, Small catchment	DNRM
143022A	Stable Swamp Creek	Interstate Railway	19	11	Urban creek in Brisbane area, Small catchment	DNRM
2129	Stable Swamp Creek	Musgrave Rd- Coopers Plains		14	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143303A	Stanley River	Peachester	104	76	Catchment area too small	DNRM
143938	Stanley River	Woodford TM	220		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office

SKM

Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143829	Stanley River	Woodford Alert-P	220	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143901	Stanley River	Woodford	250		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143301B	Stanley River	Donnelly Dell	1227	4	Record length too short	DNRM
143301A	Stanley River	Hazeldean	1242	3	Record length too short	DNRM
143305	Stanley River	Somerset Dam	1330		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143818	Stanley River	Somerset Dam Hw Alert-B	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143817	Stanley River	Somerset Dam Hw Alert-P	1330	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143305A	Stanley River	Somerset Dam	1336	24	Head gauge affected by dam site	DNRM
143302A	Stanley River	Silverton	1339	49	Data obtained, but uncertainty as to appropriate rating	DNRM
143960	Stanley River	Peachester			ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143212A	Tenthill Creek	Tenthill	447	35	Catchment area too small	DNRM
143106A	Warrill Creek	Aratula Weir	122	7	Catchment covered by other gauges DS	DNRM
143102A	Warrill Creek	Kalbar No.1	465	46	Catchment covered by other gauges DS	DNRM
143102B	Warrill Creek	Kalbar No.2	468	13	Catchment covered by other gauges DS	DNRM
143937	Warrill Creek	Kalbar	470		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143910	Warrill Creek	Harrisville	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143912	Warrill Creek	Harrisville TM	725		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143101A	Warrill Creek	Mutdapily	771	43	Catchment covered by other gauges DS	DNRM
143825	Warrill Creek	Amberley Alert-P	850	9	ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143933	Warrill Creek	Amberley Bvrt	862		ALERT Gauge - likely to be poor data	BoM, Queensland Regional Office
143117A	Warrill Creek	Junction Weir H/W		5	Record length too short	DNRM
143118A	Warrill Creek	Junction Weir Tailwater		6	Record length too short	DNRM
143116A	Warrill Creek	Toohill's Crossing		6	Record length too short	DNRM
143105A	Warrill Creek East	Churchbank Weir	149	50	Catchment covered by other gauges DS	DNRM
143031A	Water St. Drain	Exhibition Ground		5	Urban creek in Brisbane area, Small catchment	DNRM

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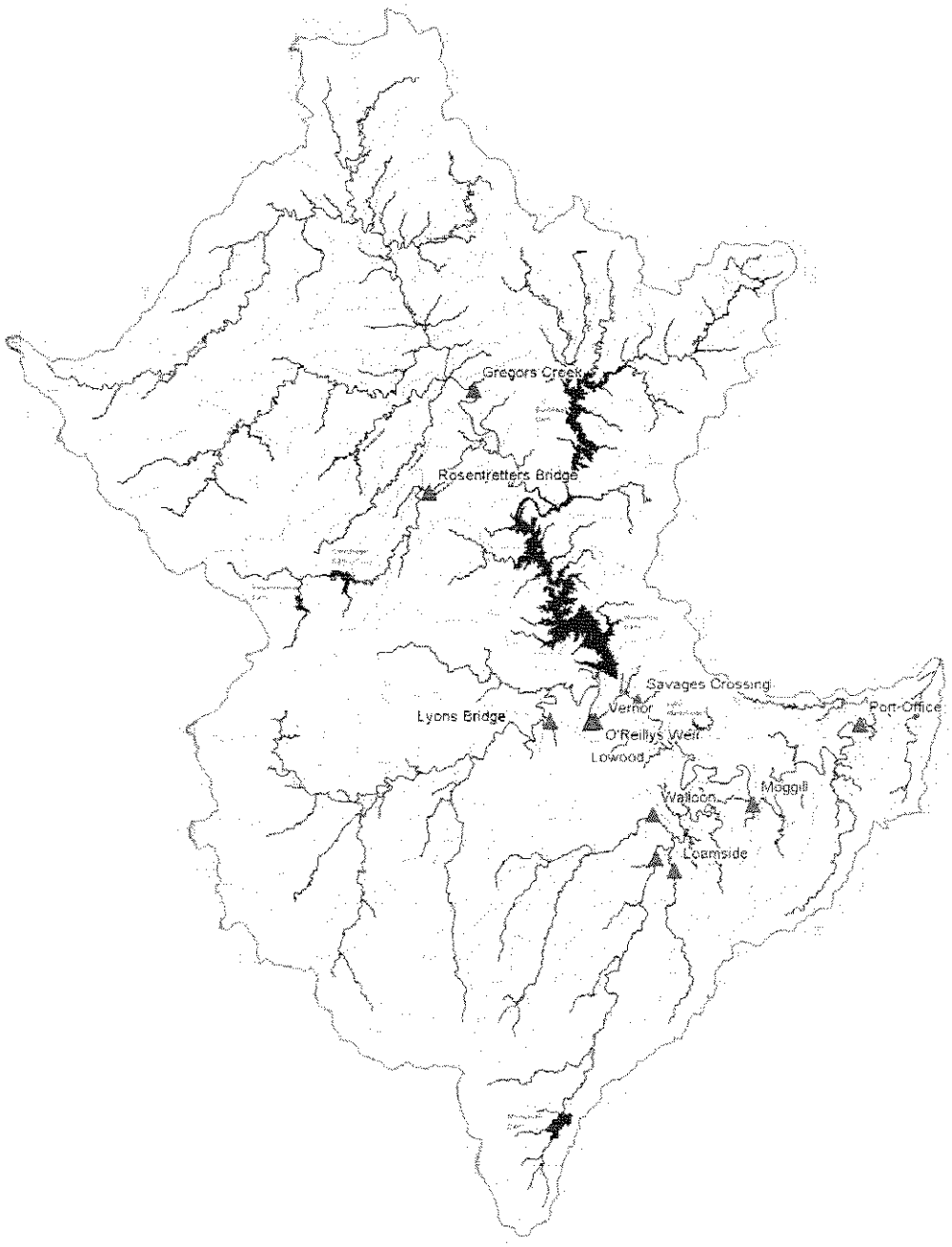
Station Number	Stream Name	Site Name	Catchment Area (km²)	Years of Record	Reason data was not used in statistical flood frequency analysis	Data Provider
143939	Western Creek	Kuss Road	200	21	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
143861	Western Creek	Grandchester Alert		4	Urban creek in Brisbane area, Small catchment	BoM, Queensland Regional Office
1583	Wolston Creek	700m U/S Wacol Station Rd-Wacol		6	Urban creek in Brisbane area, Small catchment	Brisbane City Council
143962	Woogaroo Creek	Brisbane River Road Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143927	Woogaroo Creek	Opossum Alert			Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office
143961	Woogaroo Creek	Alice Street Alert		7	Urban creek in Ipswich area, Small catchment	BoM, Queensland Regional Office



Appendix C Location of select stream gauges

- **Location of stream gauge sites that were used in flood frequency analysis**





Appendix D Flood Data Series for Savages Crossing from DNRM

SKM

Date	Gauged flow at Savages Crossing/Lowood Recorded Values	No Dams	Both Dams Working	Date'
11/03/1890		7343		
09/06/1891		1790		
04/04/1892		3953		
03/02/1893		13156		
21/04/1894		1060		
26/01/1895		1194		
12/02/1896		3699		
02/03/1897		432		
11/01/1898		5889		
30/01/1899		211		
23/05/1900		313		
21/03/1901		885		
15/10/1901		142		
1/06/1903		1717		
18/04/1904		351		
19/01/1905		816		
14/03/1906		745		
1/06/1907		302		
15/03/1908		6356		
17/07/1908		325		
28/12/1909	814	814	501	16/01/1910
13/01/1911	1317	1317	535	
4/03/1912	481	481	251	25/06/1912
23/06/1913	416	416	133	
27/02/1914	234	234	8	
11/02/1915	1035	1035	51	
12/04/1918	159	159	60	
29/01/1917	475	475	83	
13/12/1917	522	522	386	
6/05/1919	91	91	8	
22/01/1920	402	402	8	
11/06/1921	1237	1237	260	
30/12/1921	1280	1280	745	
16/10/1922	46	46	8	
12/02/1924	173	173	125	
21/06/1925	778	778	111	
6/01/1926	128	128	73	
27/01/1927	2715	2715	1028	
20/04/1928	4225	4225	927	
21/01/1929	2064	2064	682	4/04/1929
30/06/1930	749	749	332	1/06/1930
6/02/1931	5575	5575	1114	
10/12/1931	328	328	257	
20/01/1933	312	312	300	
23/02/1934	614	614	241	6/01/1934
28/02/1935	120	120	38	18/01/1935
24/03/1936	139	139	8	
17/03/1937	1103	1103	527	
28/05/1938	1052	1052	218	
17/03/1939	460	460	251	
3/03/1940	697	697	106	
25/01/1941	425	425	281	
10/02/1942	1360	1360	557	
31/12/1942	833	833	529	
31/12/1943	1208	1208	481	
13/06/1945	140	140	140	
26/03/1946	1052	1052	484	23/01/1946
2/03/1947	803	803	270	
11/12/1947	796	796	796	
4/03/1949	1013	1013	542	
1/03/1950	2789	2789	2530	
1/02/1951	3125	3125	2270	
18/06/1952	18	18	8	
24/03/1953	1002	1002	76	
14/07/1954	1922	1922	1091	13/02/1954
30/03/1955	5363	5363	667	
12/03/1956	2141	2141	890	
23/12/1956	214	214	61	
11/06/1958	1520	1520	922	
19/02/1959	1494	2550	1234	
14/11/1959	1451	2730	656	

' Peak occurred at a different time according to operational rules in with dams case

Generated using IQQM model of catchment with calibrated 6 six hourly disaggregation

Gauged Flow at Savages Crossing/Lowood/Vernor

Gauged Flows affected by Somerset

Gauged flows affect by Somerset and Wivenhoe

Flows adjusted to remove the impact of Somerset removed

Flows adjusted to remove the effect of Somerset and Wivenhoe

Flows routed through WIVOPS program using inflows into Somerset and Wivenhoe

SKM

Appendix E Regional statistical flood frequency Information

E.1 Introduction

The main benefit of adopting a regional approach to statistical flood frequency analysis is that it incorporates additional information that is not available at the one gauge. Where there are doubts about the reliability of the extrapolated flood estimates at the gauge (eg. the maximum gauged flow at Savages Crossing is in the order of 30-45% of the maximum peak flow) then the regional information provides useful information on the appropriateness of the at-site estimates.

Regional analysis also provides a means to transpose flood peaks from one location to another. For example, examination of the manner in which flood peak varies with catchment area allows peak flows estimated at Savages Crossing to be transposed down to the Brisbane Port Office.

This Appendix describes the regional information used to help inform the analysis undertaken at Savages Crossing.

E.2 Selection of Data

Given the time constraints of this review, the only data that could be incorporated was that which was readily available and for which there was a reasonable level of confidence in its consistency and quality.

As noted in **Section 2.2** only DNRM gauge flow data were both immediately available and of sufficient quality for the regional analysis. Annual maxima instantaneous flow rates were extracted for 8 stations in the Brisbane River catchment in Southern Queensland. The stations that were assessed in the analysis are listed in **Table E-1**.

The location of the gauges can be seen in the catchment map in **Appendix C**.

The composite record for Brisbane River at Lowood / Vernor / Savages Creek has the longest period of record prior to the construction of Wivenhoe Dam. It is reasonably close to the start of the hydraulic model set up to determine flood elevations and to route design floods along the most downstream reaches of the Brisbane River. It is the natural point to determine the key flood quantiles for use in estimating the appropriate design losses and performance of the rainfall runoff model.

The eight sites in **Table E-1** were adopted initially to assist in the selection of the distribution to fit to the flood data as discussed in **Section E.3**.

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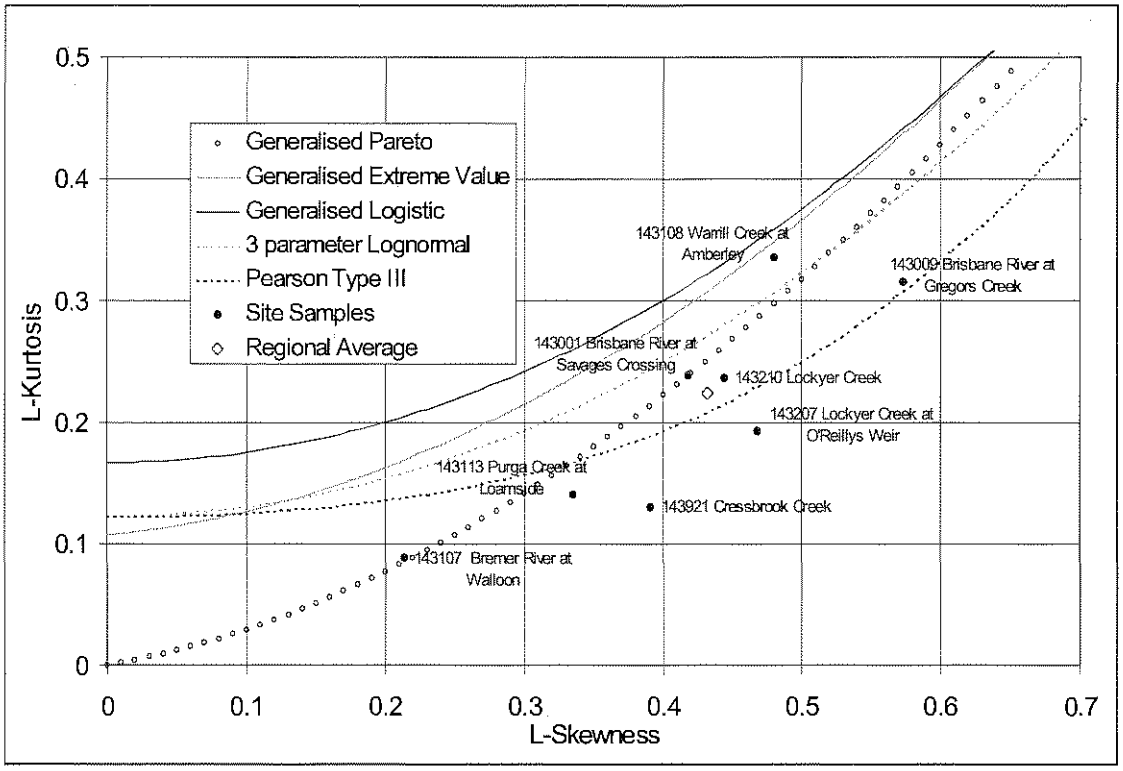
- **Table E-1 Flow gauging stations used in the regional analysis of pre-Wivenhoe Dam floods**

River	Station Name	Station Number	Years of Record	C'ment Area (km^2)	Max gauged flow as % of max estimated flow
Brisbane River	Brisbane River @ Savages Crossing	143001	72	10172	45%
Bremer River	Bremer River @ Walloon	143107	40	622	42%
Cressbrook Creek	Cressbrook Creek @ Rosentreters Bridge	143921	15	447	35%
Lockyer Creek	Lockyer Creek @ Lyons Bridge	143210	22	2486	25%
Lockyer Creek	Lockyer Creek	143207	53	2965	10%
Brisbane River	Brisbane River @ Gregors Creek	143009	39	3866	67%
Warrill Creek	Warrill Creek @ Amberley	143108	40	914	26%
Purga Creek	Purga Creek @ Loamside	143113	28	215	12%

E.3 Selection of Frequency Distribution and Parameters

The first four L-Moments of the maxima samples were computed at each of the eight sites in **Table E-1**. An L-moment diagram was constructed to assist in the choice of distribution appropriate to the flow data. **Figure E-1** shows that there is some scatter among the eight sites in the plot of L-Kurtosis v L-Skew (4th v 3rd L-Moment). This scatter is typical of such analyses and it is often difficult on the basis of such plots to make a definitive choice of distribution (e.g. Peel et. al., 1999). Either the Pearson III or Generalised Pareto distributions could be chosen.

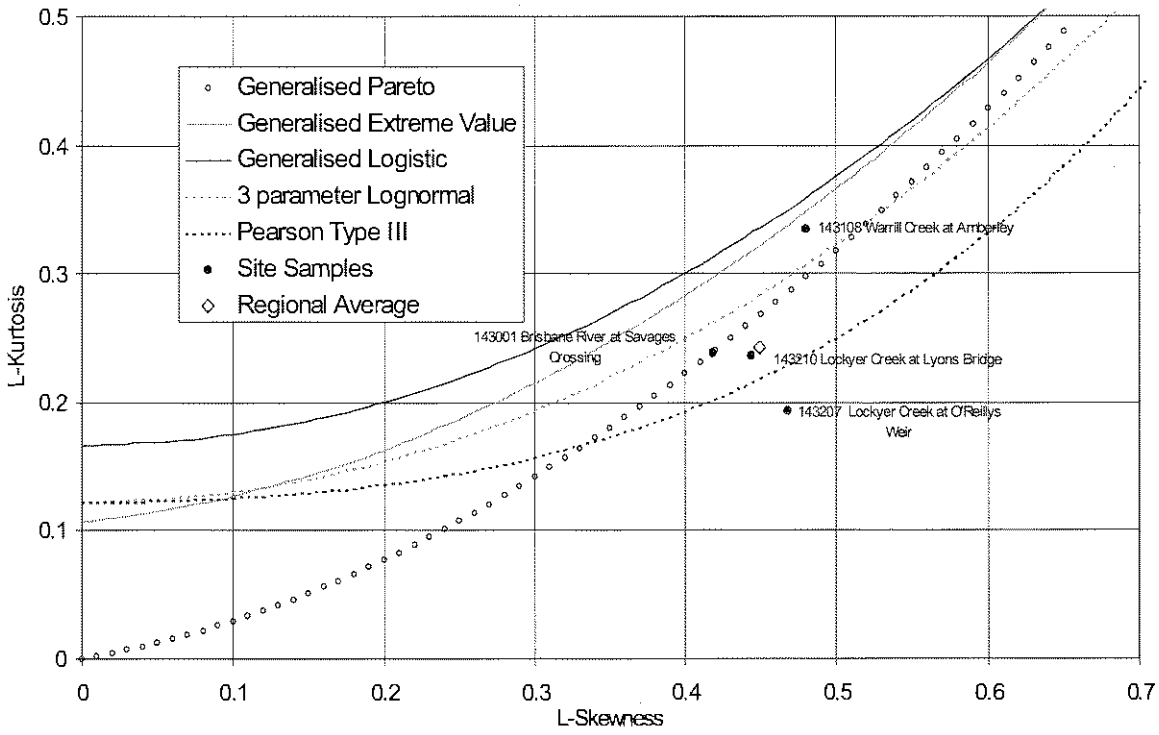
Also shown on **Figure E-1** is the regional average L-moments obtained from all eight sites (and weighted by their length of record). It is evident that Bremer River @Walloon (143107A) and Brisbane @ Gregor's Creek (143009A) are two sites most dissimilar to the regional average, an inspection of the at-site records (**Appendix F**) indicate considerable differences between the distribution of the annual maxima and the regional Generalised Pareto quantiles. Accordingly, these two stations were excluded from subsequent analysis.



- **Figure E-1 L-Moment Ratio diagram for six flow gauging stations in the Brisbane River catchment**

For assessment of peak flows at the lower reaches of the major Brisbane River system (approximately 13,500 km^2), the response of small tributaries is less relevant than that of the larger tributaries and sub-catchments. Consequently the remaining stations with small catchment areas were excluded. They were Purga Creek @ Loamside (143113) and Cressbrook Creek @ Rosentreters Bridge (143921).

The average regional L-moments were recalculated for the remaining data. The position of the catchment average L-moments on the L-moment ratio diagram (**Figure E-2**) supports the adoption of the Generalised Pareto distribution.



- **Figure E-2 L-Moment Ratio diagram for the most relevant and reliable flow gauging stations in the Brisbane River catchment (pre- Wivenhoe Dam)**

The Generalised Pareto distribution was adopted for the regional analysis on the basis that the regional average L-Moment values lie closest to this distribution, and the L-Moments of the individual sites are scattered around the theoretical curve.

The Generalised Pareto distribution was adopted with parameters given in **Table E-2**.

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- **Table E-2 Regional parameter values of the adopted Generalised Pareto distribution**

Parameter	Values obtained including information at Savages Crossing	Values obtained excluding information at Savages Crossing
Location parameter, ξ	-0.062	-0.096
Scale parameter, α	0.811	0.795
Shape parameter, κ	-0.230	-0.275

E.4 Parameters of Prior Distribution for Bayesian Analysis of Flood Peaks

Regional information can be incorporated in the Bayesian analysis of flood peaks that is performed by FLIKE. The regional information is incorporated into the Bayesian analysis as prior frequency distributions of the parameters of the flood frequency distribution that has been selected. The Bayesian analysis requires for each parameter:

- its prior mean (or expected) value,
- its prior standard deviation, and
- its cross-correlation with the other parameter(s) of the distribution.

The prior mean values of the scale (α) and shape (κ) parameters were obtained from the regional average L-moments of the seven sites that exclude Savages Crossing. These values are listed in the right column of **Table E-2**. The scale parameter (α) from the regional analysis shown in **Table E-2** is computed from the L^{CV} ($=L^2/L^1$). The prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\hat{\alpha}_{143001} = L^1_{143001}\alpha^{CV}_{\text{Regional}} = 1181 \times 0.795 = 939$$

The prior standard deviations of the scale and shape parameters were obtained by computing the parameter values from the L-moments at each of the seven sites, excluding Savages Crossing. The prior estimate of the standard deviation for each parameter was computed as the standard deviation of the parameter value from the seven sites. This computation is shown in **Table E-3**. The standard deviation for the scale parameter is computed from the L^{CV}. The standard deviation of the prior estimate of the scale parameter for gauging station 143001 is therefore computed from:

$$\sigma_{\alpha,143001} = L^1_{143001}\sigma^{CV}_{\alpha,\text{Regional}} = 1181 \times 0.388 = 458$$

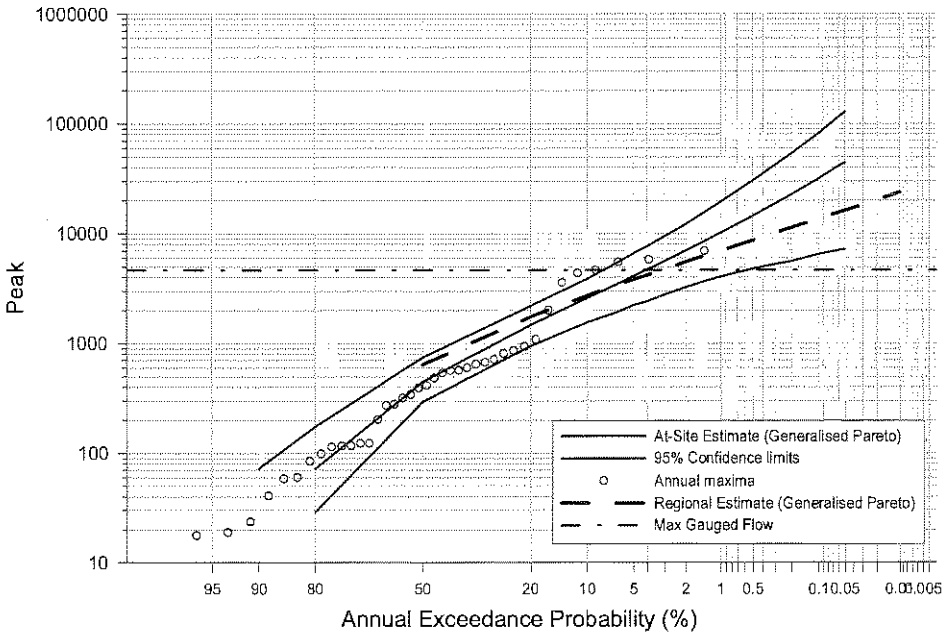
The cross-correlation between the scale and shape parameters was simply assumed to be the same as found from the parameter inference statistics computed by FLIKE ($r = 0.6$). This information was used rather than the sample statistics from the regional parameter set as it was considered that correlation between parameters from the one river system was likely to over-estimate the actual degree of correlation.

- **Table E-3 Estimates of prior standard deviation and cross-correlation in parameter values of the adopted Generalised Pareto distribution**

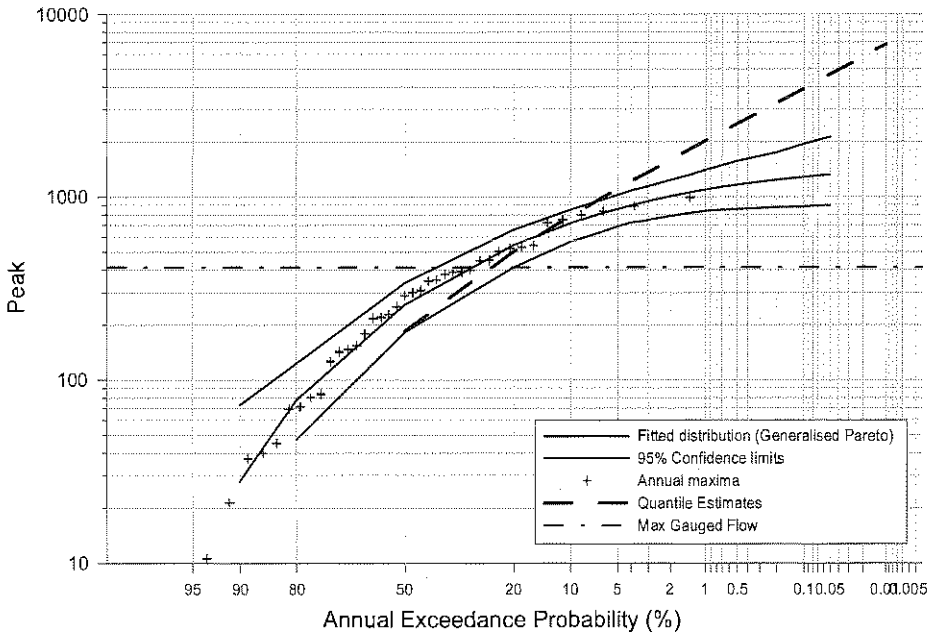
Site Number	Gauging Station Name	Scale parameter, α	Shape parameter, κ
143009	Brisbane River @ Gregors Creek	0.573	-0.467
143107	Bremer River @ Walloon	1.502	0.300
143108	Warrill Creek @ Amberley	0.724	-0.268
143113	Purga Creek @ Loamside	1.573	0.279
143207	Lockyer Creek	0.833	-0.279
143210	Lockyer Creek @ Lyons Bridge	0.815	-0.275
143921	Cressbrook Creek @ Rosentreters Bridge	0.948	-0.185
Standard Deviation of Parameter		**0.388**	**0.297**

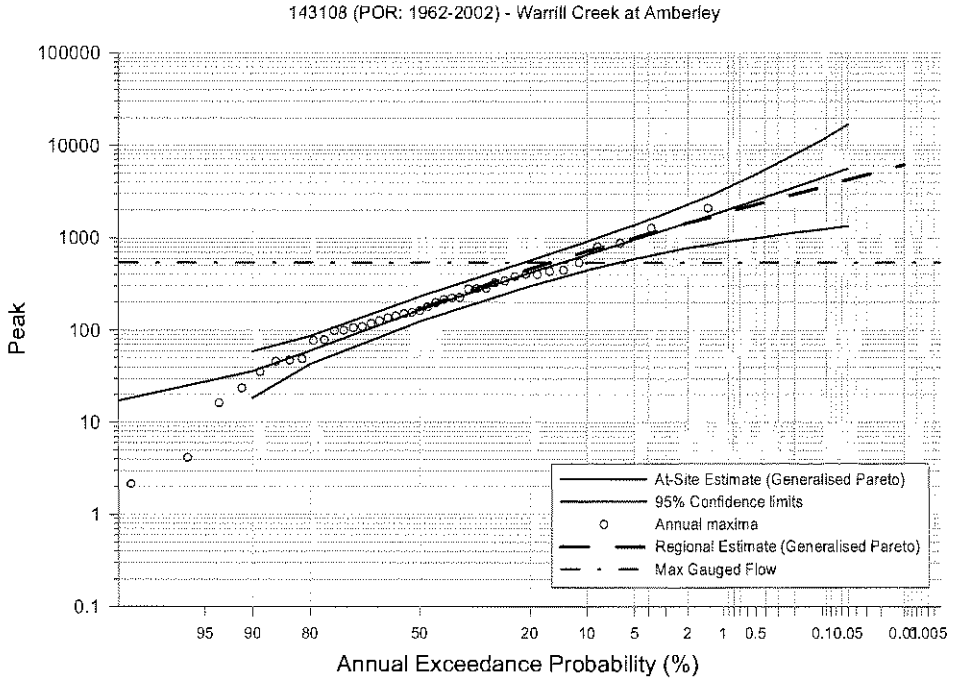
Appendix F At-Site/Regional Analysis of Selected Gauges

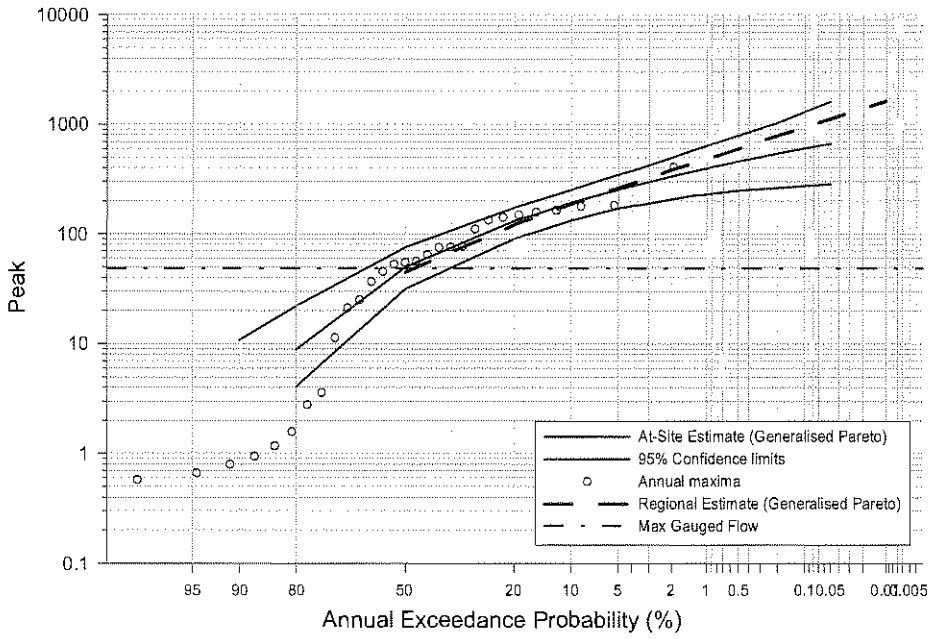
143009 (POR: 1963-2002) - Brisbane River at Gregors Creek

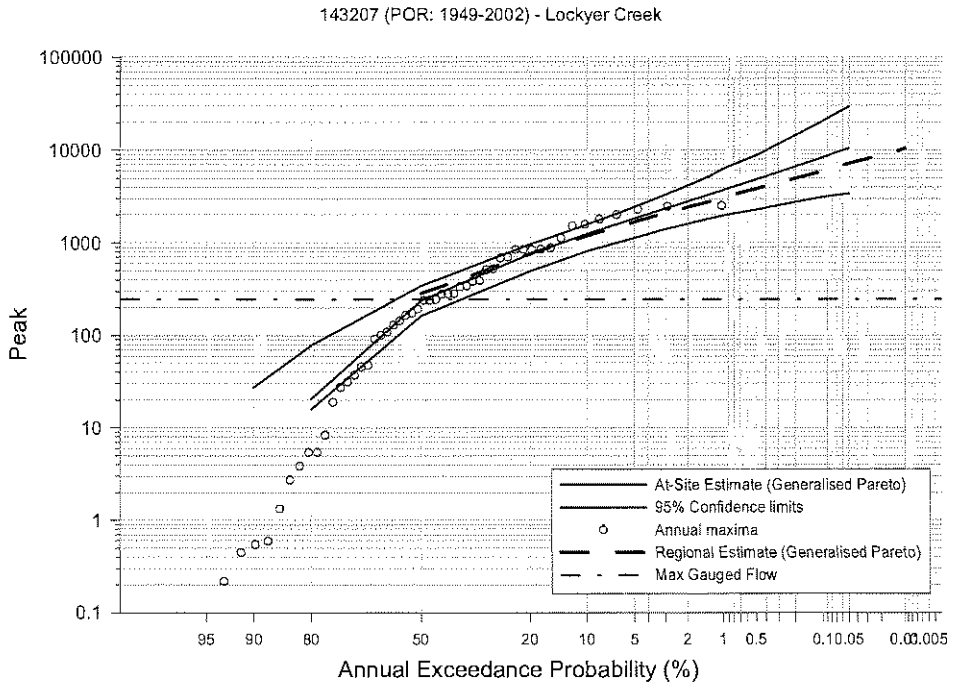


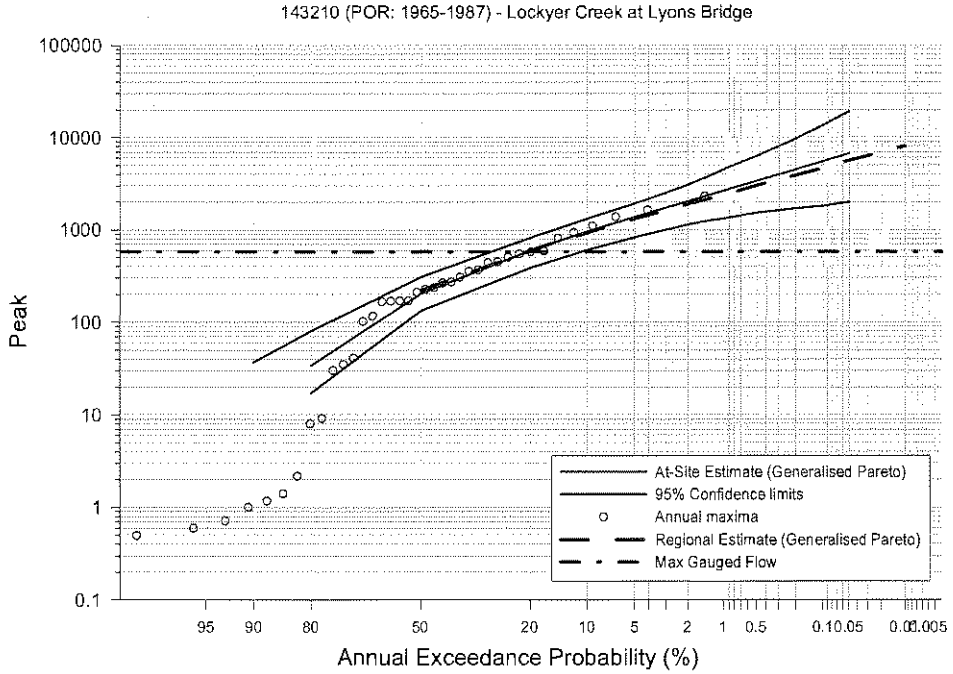
143107 (POR: 1962-2002) - Bremer River at Walloon

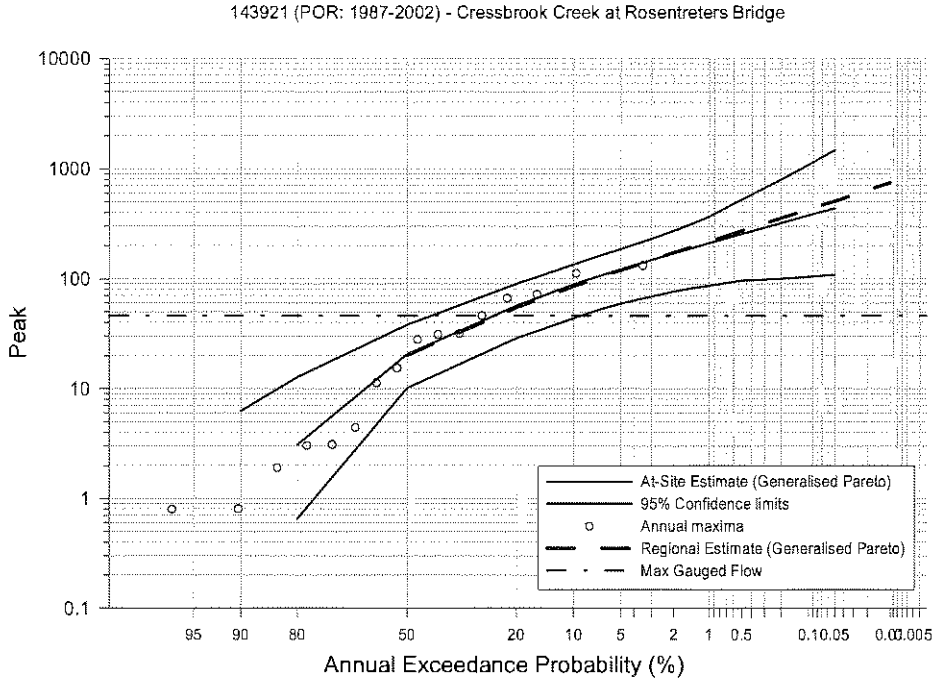



143108 (POR: 1962-2002) - Warrill Creek at Amberley
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143113 (POR: 1974-2002) - Purga Creek at Loamside
Peak
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143207 (POR: 1949-2002) - Lockyer Creek
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143210 (POR: 1965-1987) - Lockyer Creek at Lyons Bridge
Peak
100000
10000
1000
100
10
1
0.1
95 90 80 50 20 10 5 2 1 0.5 0.1 0.05 0.01 0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow


143921 (POR: 1987-2002) - Cressbrook Creek at Rosentreters Bridge
Peak
10000
1000
100
10
1
0.1
95
90
80
50
20
10
5
2
1
0.5
0.1
0.05
0.01
0.005
Annual Exceedance Probability (%)
At-Site Estimate (Generalised Pareto)
95% Confidence limits
Annual maxima
Regional Estimate (Generalised Pareto)
Max Gauged Flow

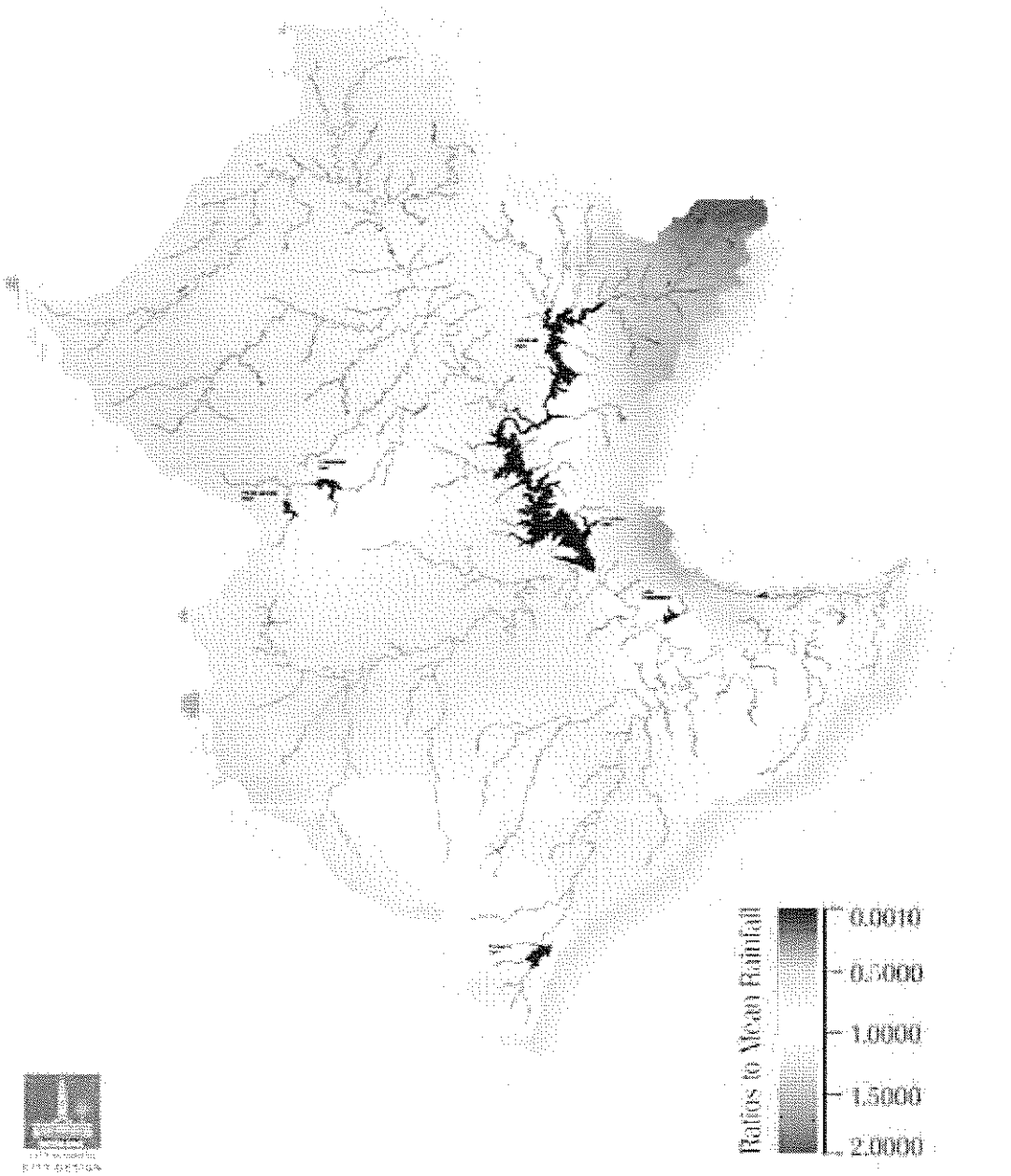
Appendix G Historical Spatial Distributions

SKM

CFC FORGE SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT

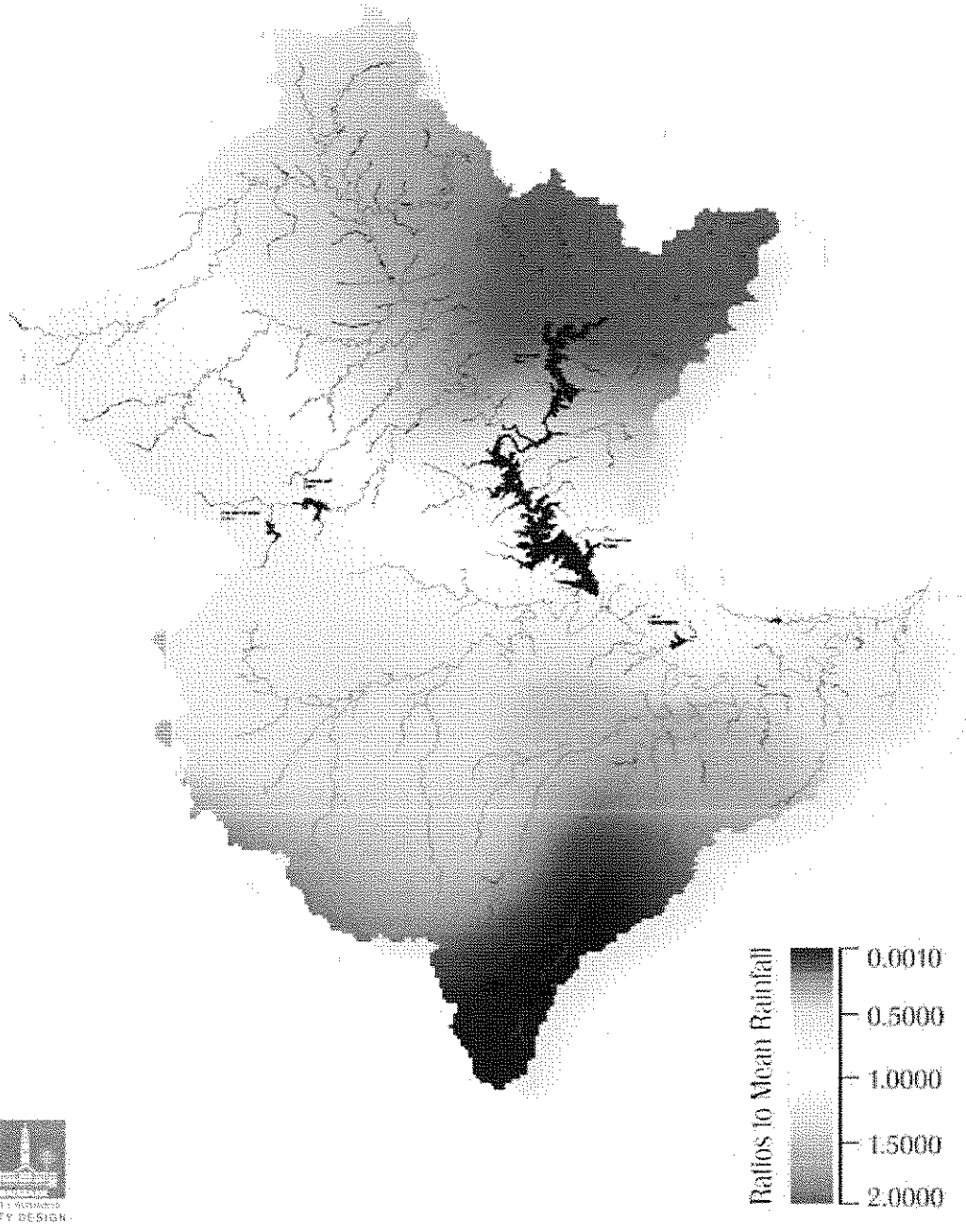


SKM

JANUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT

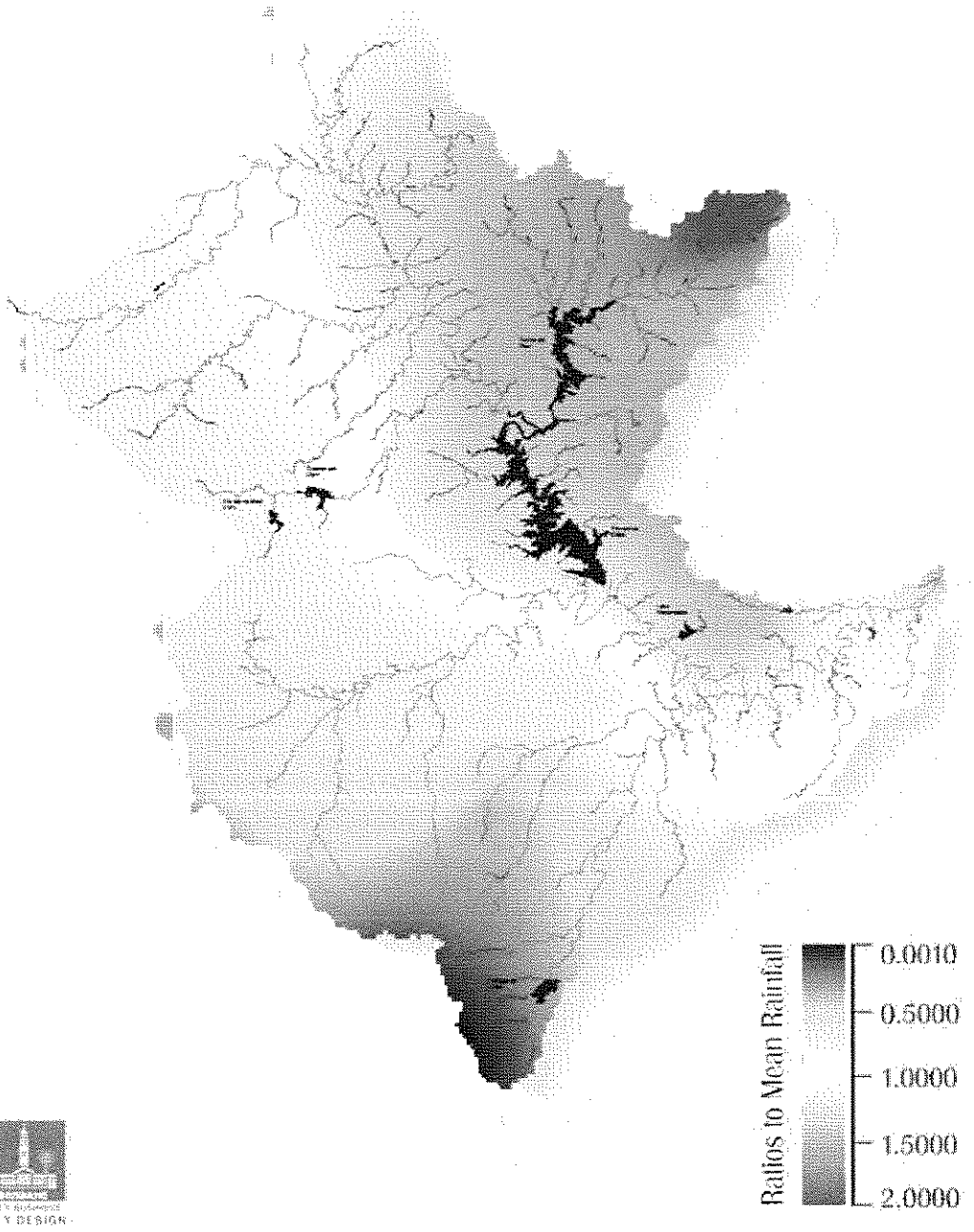


CITY DESIGN

FEBRUARY 1893 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



CITY DESIGN

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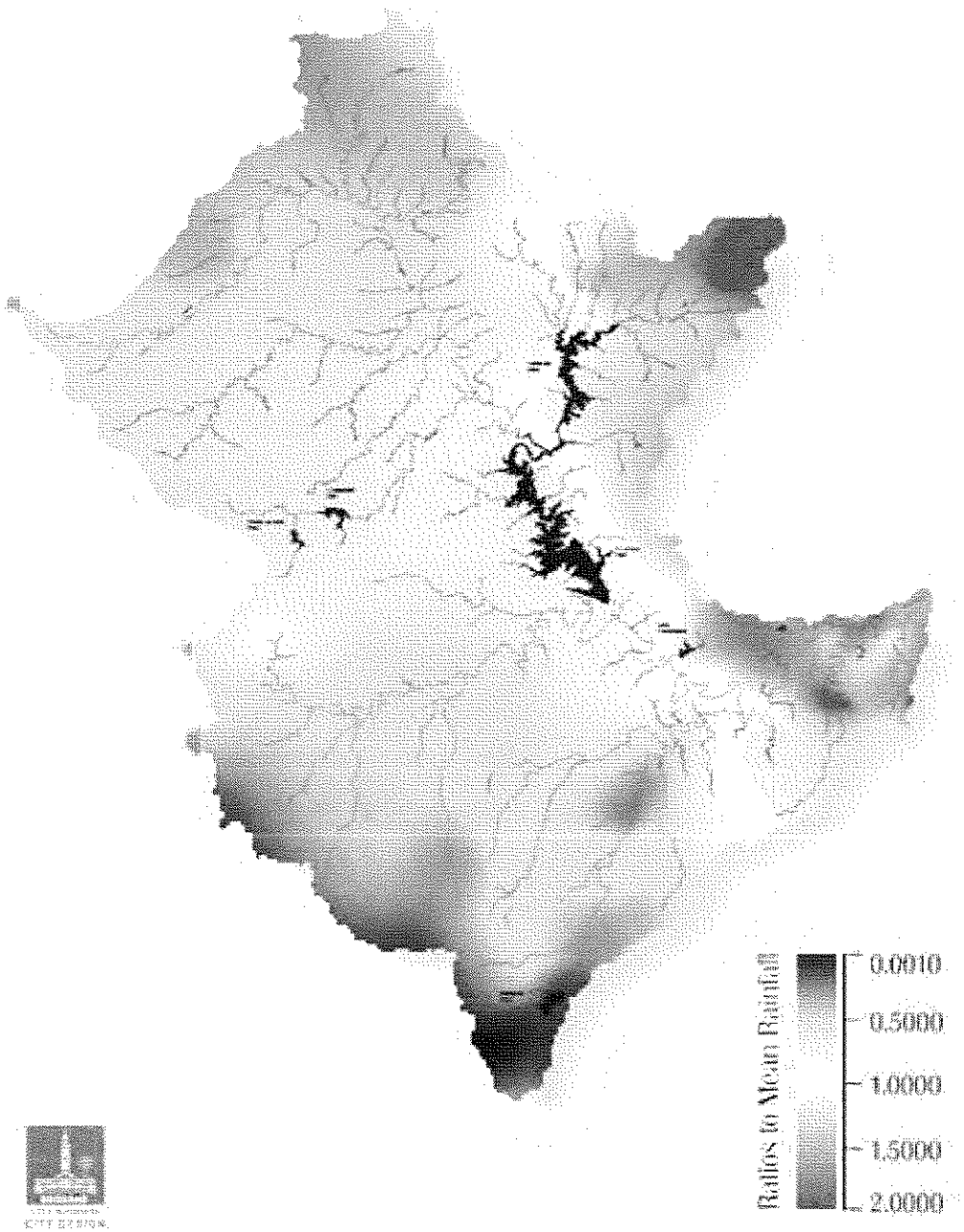
JANUARY 1931 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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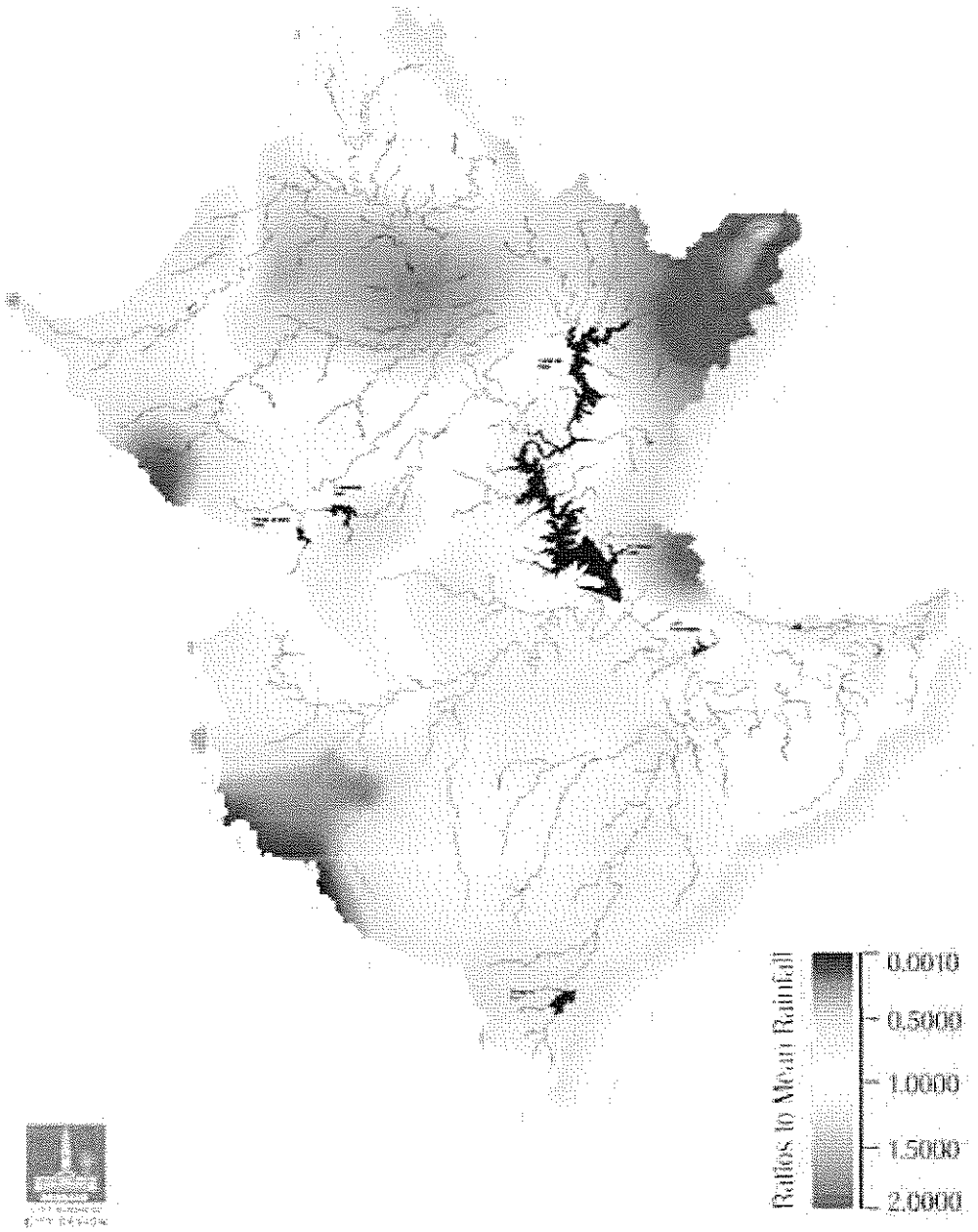
MARCH 1955 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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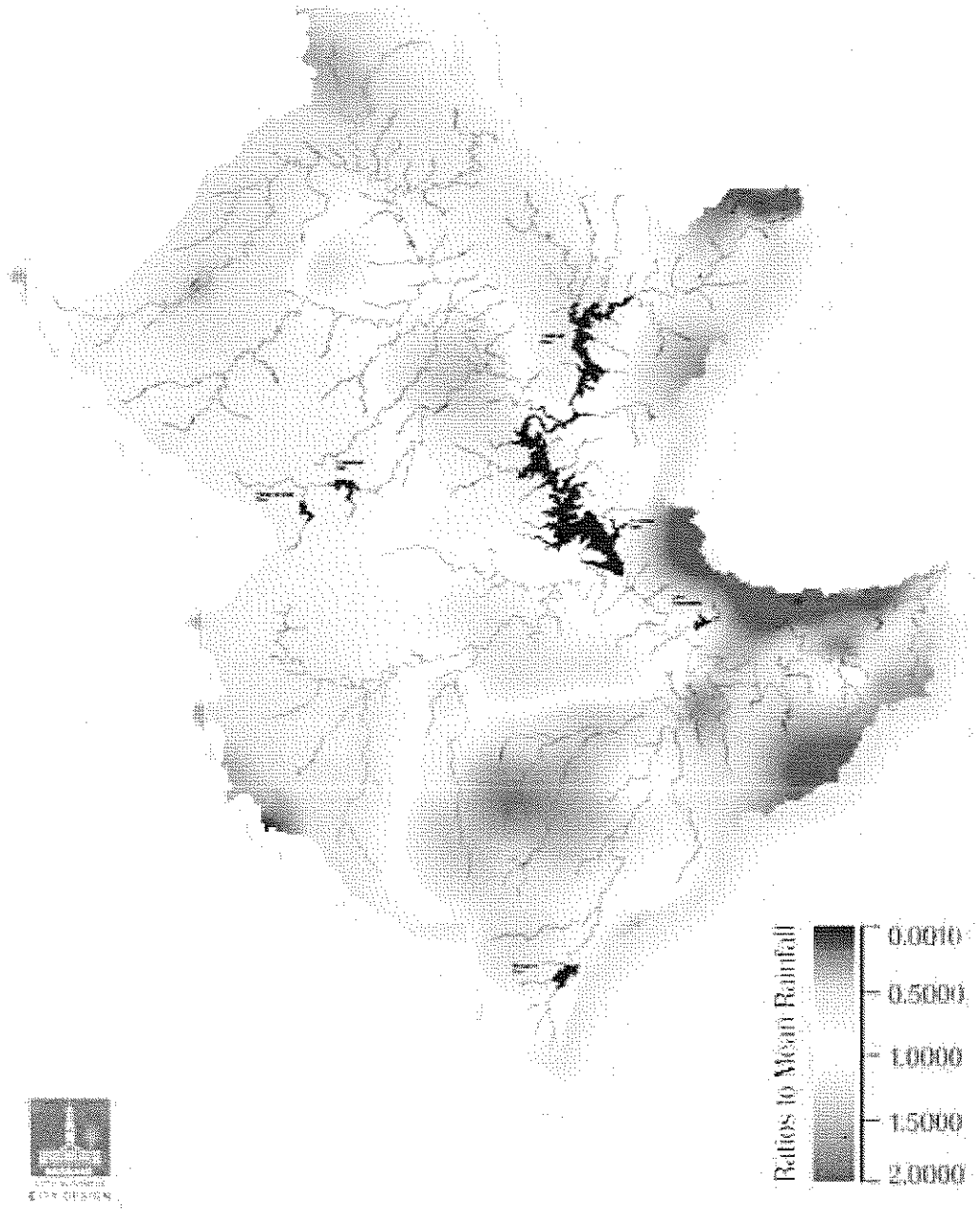
JANUARY 1974 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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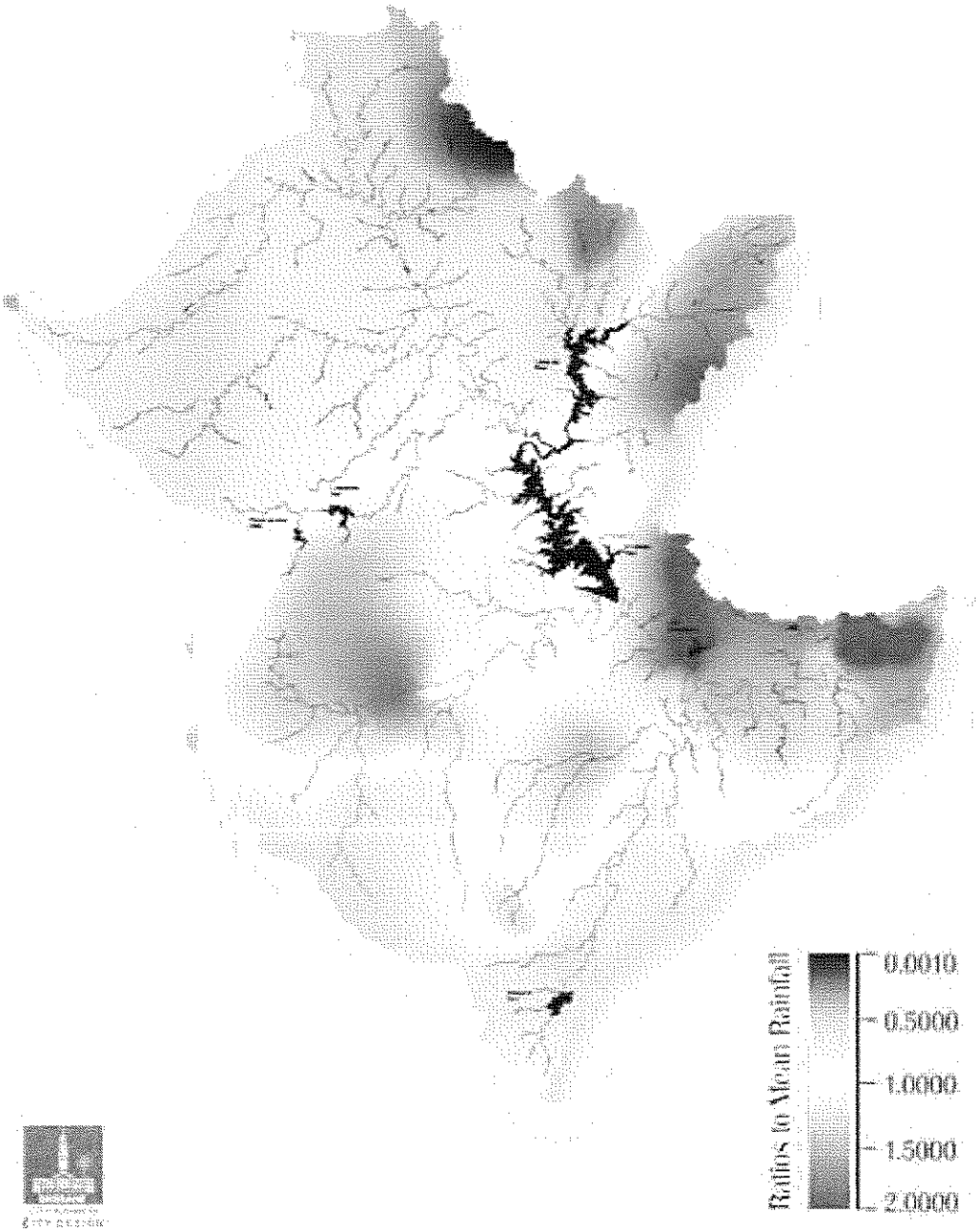
APRIL 1996 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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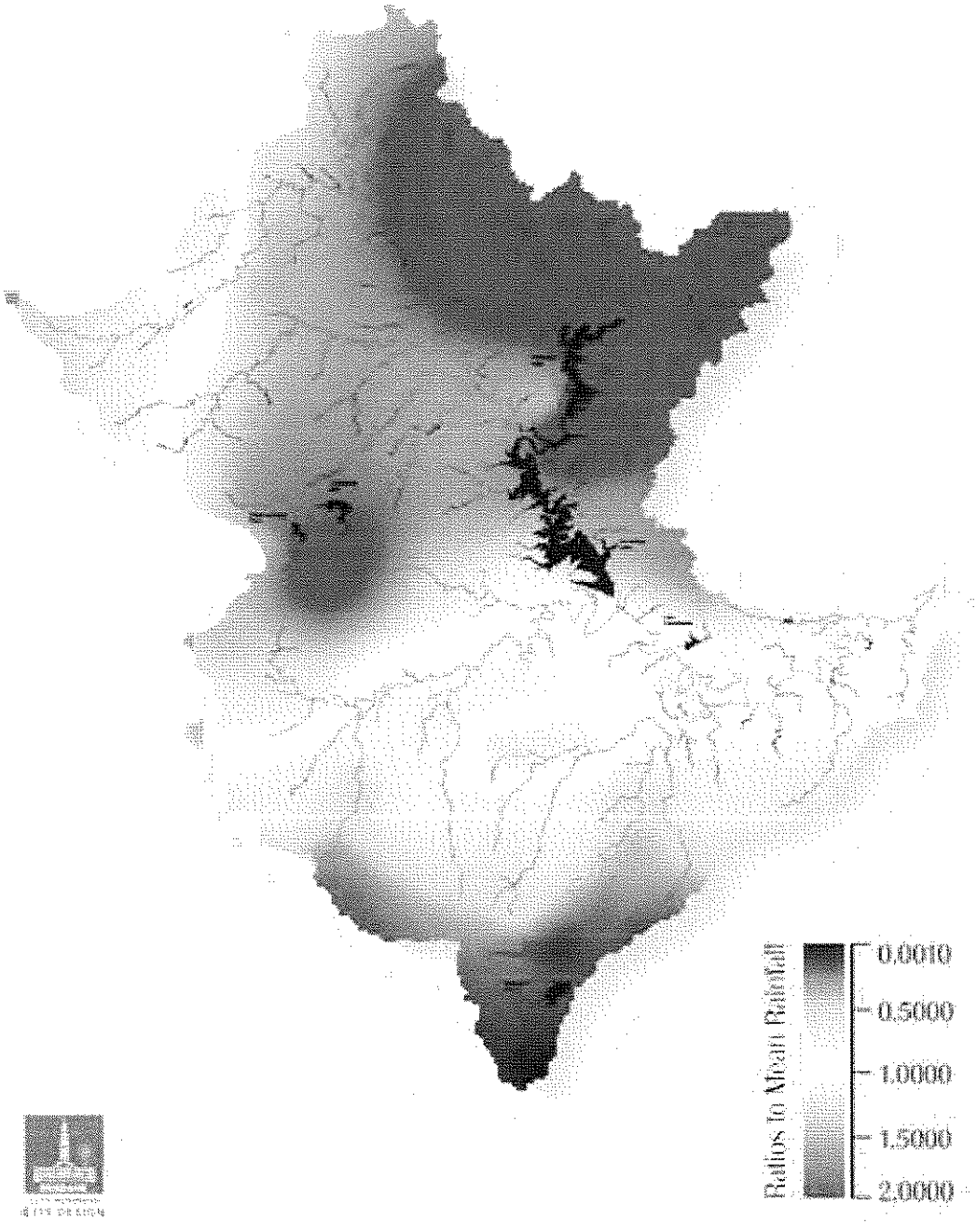
FEBRUARY 1999 SPATIAL DISTRIBUTION

Maximum 24Hr Storm Burst

BRISBANE RIVER CATCHMENT



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Appendix H Pre- and Post-dams RAFTS Model Results

- **Peak Flows for RAFTS Model, Pre-Dams for 1 in 100 AEP Rainfall**

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
JAN 1893	24	9861	7927	7927
	30	**11507**	9792	9793
	36	9810	7932	7932
	48	10238	8534	8535
	72	10911	**10196**	**10198**
	96	9774	9392	9394
	120	10074	9639	9641
FEB 1893	24	8698	7502	7502
	30	**10062**	8788	8789
	36	8682	7512	7512
	48	9012	7865	7866
	72	9634	**9501**	**9504**
	96	8568	8632	8636
	120	8804	8898	8904
JAN 1931	24	7505	6745	6745
	30	**8543**	7648	7648
	36	7476	6775	6776
	48	7712	7190	7191
	72	8183	**8026**	**8030**
	96	7140	7514	7610
	120	7360	7630	7713
MAR 1955	24	8671	7536	7537
	30	**10046**	8925	8925
	36	8689	7553	7554
	48	8955	7915	7916
	72	9563	**9619**	**9623**
	96	8376	8745	8750
	120	8635	8997	9002
JAN 1974	24	7058	7202	7203
	30	**8005**	8046	8049
	36	7049	7072	7073
	48	7227	7527	7528
	72	7714	**9112**	**9117**
	96	6729	8154	8161

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
	120	6879	8432	8454
APR 1996	24	7531	7067	7068
	30	**8621**	7966	7966
	36	7549	7078	7079
	48	7748	7425	7427
	72	8287	**8917**	**8922**
	96	7184	8034	8043
	120	7399	8170	8182
FEB 1999	24	9631	7884	7884
	30	**11205**	9708	9708
	36	9578	7893	**7894**
	48	9981	8443	8444
	72	10642	**10197**	**10200**
	96	9512	9384	9387
	120	9809	9626	9629

Note: Critical flows at each location are shown in **bold**.

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- **Peak Flows for RAFTS Model, Post-Dams for 1 in 100 AEP Rainfall**

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
JAN 1893	24	3026	2909	2909
	30	6008	4705	4705
	36	3474	3284	3284
	48	5366	3880	3880
	72	7323	6699	6699
	96	7596	6892	6892
	120	**7847**	**7120**	**7121**
FEB 1893	24	1877	2061	2070
	30	3818	3449	3449
	36	1935	2203	2211
	48	3471	3148	3148
	72	6197	5615	5615
	96	6310	5595	5596
	120	**6568**	**5850**	**5851**
JAN 1931	24	1872	2051	2319
	30	1926	2708	3314
	36	1884	2452	2836
	48	1758	2382	2580
	72	3079	3146	3968
	96	3170	2940	3383
	120	**3279**	**3218**	**3411**
MAR 1955	24	1925	2345	2350
	30	3524	3433	3433
	36	2063	2541	2544
	48	3272	3013	3013
	72	**6241**	**5709**	**5710**
	96	5926	5339	5340
	120	6151	5584	5585
JAN 1974	24	1753	3324	3326
	30	2467	3987	3989
	36	1871	3279	3350
	48	1943	3627	3633
	72	3307	4418	4965
	96	**4771**	**5841**	**5852**
	120	2911	3656	3662
APR 1996	24	3554	3399	3400
	30	4067	4137	4138

Spatial Pattern from Event	Rainfall Event Duration(hours)	1 in 100 AEP Peak Flow in m³/s		
		Savages Crossing	Moggill	Brisbane Port Office
	36	3535	3260	3260
	48	3605	3690	3691
	72	**4162**	**5019**	**5035**
	96	3492	4378	4417
	120	3509	4571	4663
FEB 1999	24	3424	2886	2887
	30	5789	4442	4442
	36	3575	3150	3147
	48	4604	3494	3495
	72	6879	6447	6448
	96	7217	6623	6624
	120	**7431**	**6819**	**6819**

Note: Critical flows at each location are shown in **bold**.

City Design - Flood Modelling Services

RECALIBRATION OF THE MIKE11 HYDRAULIC MODEL AND DETERMINATION OF THE 1 IN 100 AEP FLOOD LEVELS

- Draft
- 23/12/2003



- Draft
- 23/12/2003

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SKM

Executive Summary

In June 1998 SKM developed a MIKE11 hydraulic model as part of the Brisbane River Flood Study for Brisbane City Council. This model was then used as a base model for the model developed for the Ipswich Rivers Flood Studies (SKM 2000). During the Ipswich Study, many additional rivers and creeks were added to the hydraulic model.

These additional rivers/creeks changed the Brisbane River routing characteristics, consequently the model needed to be re-calibrated. Re-calibration was only performed within the Ipswich City Council boundary.

Further work was therefore required to re-calibrate the hydraulic model within the Brisbane City boundary. The purpose of this report is to present the findings of the re-calibration of the Brisbane River model.

The 1974 and 1955 flood events were used to calibrate the hydraulic model. These events were chosen because they provide an adequate calibration envelope so that the 1 in 100 year design event can be accurately modelled.

Calibration was generally achieved to within the general specification tolerances.

A design 1 in 100 AEP event was run based on a flow of 6000 m^3/s at the Brisbane Port Office Gauge. This corresponds to the 'best guess' report by the expert panel (IRP 2003).

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1. Introduction

The purpose of this report is to present the findings of the re-calibration of the Brisbane River Hydraulic Model. This model was calibrated using the 1974 and 1955 flood events.

The Calibration process involved

- Updating and re-running the 1955 RAFTS Model
- Re-calibrating the 1955 RAFTS Model (loss rates only)
- Extraction of hydrographs from the 1955 RAFTS model and input into MIKE11
- Extraction of hydrographs from the 1974 RAFTS model and input into MIKE11
- Adjusting roughness values in the 1974 and 1955 MIKE11 model. Iterating until the best match between predicted water levels and recorded water levels was achieved.

The 1974 and 1955 events were chosen because there is reliable historical flood level data for flood events. The flows for these events in the subject reach of the river are approximately 10 000 m^3/s (1974) and 4400 m^3/s (1955). This provides an envelope in which the design event can be accurately predicted. A design 1 in 100 AEP event was run based on a flow of 6000 m^3/s at the Brisbane Port Office Gauge. This corresponds to the 'best guess' report by the expert panel (IRP 2003).

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2. Hydrology

2.1 General

A RAFTS hydrologic model was developed as part of the Brisbane River Flood Study (SKM 1998). This study required that hydrologic model calibration/verification be undertaken for a total of 8 historical flood events. These events are presented in **Table 1**.

- **Table 1 Brisbane River Flood Study Calibration/Verification Events**

Calibration Events	Verification Events
January 1974	February 1931
June 1983	March 1955
Late April 1989	July 1973
May 1996	Early April 1989

In June 2000, the Ipswich Rivers Flood Studies (SKM 2000) was completed. All rivers within the study area fell within the Brisbane River Catchment and thus the Brisbane River RAFTS model was used as a basis of the Studies. Sub-catchment areas were refined in order to better represent the river network within the study area and therefore model re-calibration had to be undertaken. The re-calibration was performed on 4 events for the Ipswich Rivers Flood Studies. These calibration events are presented in **Table 2**.

- **Table 2 Ipswich River Flood Studies Calibration Events**

Calibration Events
January 1974
June 1983
Late April 1989
May 1996

Verification events were not re-run for the Ipswich River Flood Studies.

For this investigation, it was considered that the 1974 and 1955 historical flood events would provide the best calibration range for the 1 in 100 AEP flood event. It was therefore necessary to rerun the 1974 and 1955 historical flood events and extract the hydrographs for use in the MIKE11 hydraulic model.

2.2 1974 Historical Flood Event

The 1974 event was originally modelled using RAFTS as part of the Brisbane River Flood Study (SKM 1998). As part of the Ipswich Rivers Flood Studies (SKM 2000) the Brisbane River RAFTS

model was updated and re-calibrated. Re-calibration of the 1974 hydrologic model was not required. A comparison of the RAFTS predicted hydrographs and recorded hydrographs for the 1974 flood event have been provided in Appendix A. These hydrographs have been directly taken from the Ipswich Rivers Flood Studies Report (SKM 2000).

2.3 1955 Historical Flood Event

The 1995 event was not re-run as part of the Ipswich Rivers Flood Studies and subsequently the 1955 had to be run through the updated Brisbane River RAFTS model. As a result, loss rates reported in the Brisbane River Flood Study Report (SKM 1998) were adjusted to provide a better calibration. **Table 3** presents the adopted loss rates.

- Table 3 Rainfall Losses March 1955 calibration

Catchment Location	New Model Initial Loss	New Model Continuing Loss	Old Model Initial Loss	Old Model Continuing Loss
Brisbane	100	2.5	100	2.5
Bremer	50	1.5	50	1.5
Lockyer	90	1.8	85	2.5
Somerset	130	2.5	130	2.5
Wivenhoe	60	2.0	20	1.8

A comparison of the RAFTS predicted hydrographs and recorded hydrographs for the 1955 flood event have been provided in **Appendix A**. The magnitude of the discharge was matched for the key locations. Generally a good match was achieved however the timing of the peak discharge predicted by the RAFTS model for the Vernor gauging station was earlier than that of the recorded hydrograph. One possible explanation for the delay in the recorded hydrograph at Vernor Gauge is the storage of runoff by Somerset Dam. Although the dam was not completed, some storage was available. This storage could have resulted in delaying flows from the upstream portion of the catchment. This explanation would seem reasonable as the remainder of the hydrographs provide good agreement with timing.

The only catchment parameters adjusted for the 1955 event were loss rates. Various loss regimes were trialed in order to match the timing of the hydrograph at Vernor Gauge. The adopted loss regime presented in **Table 3** provides the best overall match.

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3. Hydraulic Model Calibration

3.1 General

The hydraulic model MIKE developed for the Brisbane River Flood Study (SKM 1998) was used as a base model for the model developed for the Ipswich Rivers Flood Studies (SKM 2000). During the Ipswich Study, many additional rivers and creeks were added to the hydraulic model.

These additional rivers/creeks changed the Brisbane River routing characteristics, consequently the model needed to be re-calibrated. Re-calibration was only performed within the Ipswich City Council boundary, and therefore further work was required to re-calibrate the hydraulic model within the Brisbane City boundary.

Generally, the upper reach of the Brisbane River from MIKE11 model chainage BNE 964km to BNE 990 km consists of mainly open grassed and treed floodplains with severe meanders at various locations. Rural properties are located at various levels along this reach.

The reach of the Brisbane river from MIKE11 model chainage BNE 990 km to BNE 1040 km consists of mainly open grassed and treed floodplains with severe meanders at various locations. Residential properties are located at various intervals and levels along this reach. These residential properties could be described as low density areas.

From chainage BNE 1040 km to BNE 1070 km the reach could be described as medium to high density residential areas which include the inner city area. The general shape of the river could be described as severely meandering.

The lower reach of the Brisbane River from BNE 1070 km to BNE 10788.66 km is relatively uniform with no major bends. Industry and residential properties line the banks along with mangrove swamps close to the river outlet.

The hydraulic model used for this assessment extends outside the Brisbane City Boundary however for completeness all results have been provided. Chainage 967.41 kms and downstream fall within the Brisbane City Boundary.

Model calibration involves the selection of appropriate model schematisatisation and model parameters in order to match simulated and recorded water levels and discharges. This involves an iterative process and the careful selection of roughness parameters which reflect channel and floodplain conditions and an accurate description of flow movement.

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3.2 Channel Roughness

Channel roughness values (Mannings 'n') selected were initially based on site visits, examination of aerial photographs and past experience from other flood studies. In order to achieve a reasonable match between recorded and predicted flood levels, roughness values were modified in some locations to better reflect the hydraulic behaviour of the flood.

The model has been re-calibrated against the 1974 and 1955 flood events. This was achieved by matching the water levels predicted by the MIKE11 hydraulic model with actual recorded data by altering the channel roughness values in the MIKE11 model.

The hydraulic model was first calibrated for the 1974 event. The same roughness values were then used for the 1955 event. The figure in **Appendix C** compares the roughness parameters used in the previous model and that of the new model.

Generally, acceptable calibration is considered to be achieved when predicted levels are within general calibration tolerances of 150 mm of maximum height records. 100 mm of continuous flood level records and 200 mm of other sources of flood levels.

3.3 January 1974 Flood Event

The January 1974 flood event was the largest flood event that has occurred in the Brisbane River System in recent times. This event was considered to be the primary calibration event because a large amount of recorded flood level information was available.

At the time of this flood Wivenhoe dam had not been constructed and this enabled good calibration of the discharge hydrographs to be achieved. The Merivale Bridge was not constructed until 1975 and therefore not modelled for the 1974 calibration.

3.4 March 1955 Flood Event

The 1955 flood event commenced on the 26 March 1955 and was the third largest recorded flood event this century. The event continued over a period of three days. Although Somerset Dam was not fully completed for the 1955 its storage had been constructed. At the time of the flood, the only structures on the Brisbane River downstream of Mt Crosby weir were Indooroopilly Bridge, William Jolly Bridge, Victoria Bridge and the Story Bridge.

The adopted tailwater level at the Western Inner Bar for this event was 1.3 m AHD which is consistent with the tailwater adopted for the Brisbane River Flood Study (SKM 1998).

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4. Results

For gauging stations with continuous records it was possible to compare the recorded hydrograph with hydrographs predicted by the model. For the 1974 event, predicted and recorded hydrographs generally good agreement (Refer **Appendix B**).

For the 1955 event, the peak water levels for the predicted hydrographs generally matched the peak of the recorded hydrographs. The timing for predicted hydrographs occurs earlier than the recorded hydrograph, this appears to be caused by the same problem that affected the RAFTS hydrographs already mentioned in **section 2.3.** The hydrographs for the Port Office Gauge did not match, however it appears that there are errors in the recorded hydrograph, as it is not consistent with the rest of the hydrographs.

For both events the recorded spot levels varied significantly depending on whether the level was taken on the outside or inside of the bend. The predicted levels outside the maximum allowable tolerance of 0.2m were checked and in most cases were deemed to be likely due to superelevation at bends or incorrect recorded level information. This was primarily decided by looking at surrounding levels and identifying outliers in the recorded levels.

In some reaches of the Brisbane River, higher than expected roughness values were required to achieve calibration. After checking the locations where high values were required, it was found that high roughness values corresponded to bends in the river. A plot of bend locations and corresponding roughness are presented in **Appendix C.**

4.1 Flood Levels

Table 4 & 5 outline the peak flood levels predicted by the model at the gauging stations for both the 1974 and 1955 flood events. A complete record can be found in **Appendix D.** For the 1974 event, predicted flood levels were generally within 100mm of the recorded levels at continuous flood level gauges.

Table 4 Peak Flood Levels 1974

Chainage	Predicted Flood Level	Recorded Flood Level		Difference
		Left Bank	Right Bank	
Mt. Crosby Weir (43003A)	26.81	26.74		0.07
Mt. Crosby (040142/040818)	26.75	26.83		-0.08
Moggill Gauge	19.91	19.93	20.04	-0.08
Goodna Hospital Gauge	18.44		18.43	0.01
Mt Ommaney Gauge	14.67	14.55	14.58	0.10
Darra Wharf Gauge	13.52	13.36	13.79	-0.05

Sherwood Gauge	12.43		12.52	-0.09
Clarence Road Gauge	11.14		11.20	-0.06
Oxley Creek Gauge	11.15		11.01	0.14
King Authur Terrace Gauge	11.11		11.04	0.07
Tennyson Power House Gauge	10.93		10.83	0.10
Yeronga Street Gauge	10.77		10.83	-0.06
Sandy Creek Gauge	9.81		9.81	0.00
Dutton Park Cemetery Gauge	9.50		9.57	-0.08
Highgate Hill Gauge	8.29		8.36	-0.07
St Lucia Ferry Gauge	8.15		8.09	0.06
Montague Road Gauge	6.46		6.56	-0.10
Port Office Gauge	5.28	4.95	5.44	0.09
Newstead Park Gauge	2.88	2.60	3.30	-0.07
Cresent Road Gauge	2.61	2.63	2.63	-0.02
Cairncross Dock Gauge	2.47		2.49	-0.02
Bulimba Power House Gauge	1.83		1.90	-0.07
Western Inner Bar Gauge	1.55		1.55	-0.01

Predicted flood levels for the 1955 event were generally within 150 mm of the recorded levels. Water Levels toward the lower end of the Brisbane River were higher in the Mike11 model than the recorded levels; this could be a result of

- less development along the river bank than the 1974 case
- changes in river bathymetry due to erosion sedimentation and or dredging
- for this event only the Story, Victoria, William Jolly and Indooroopilly bridges had been constructed.
- for this event the majority of gauging stations were only manually read as opposed to automatic readings for the 1974 flood

Nevertheless a good calibration was achieved for the 1974 event and a reasonable calibration was achieved for the 1955 event. The 1974 event is considered to be the primary calibration event because it better reflects current river conditions and because more historical data is available.

Table 5 Peak Flood Levels 1955

Chainage	Predicted Flood Level	Recorded Flood Level	Difference
Clarence Road Gauge	5.30	5.56	-0.26
King Authur Terrace Gauge	5.18	5.10	0.08
Yeronga Street Gauge	4.98	4.95	0.03
Sandy Creek Gauge	4.41	4.65	-0.25
Dutton Park Cemetery Gauge	4.22	4.12	0.09
Highgate Hill Gauge	3.62	3.82	-0.20
Port Office Gauge	2.50	2.28	0.22
Newstead Park Gauge	1.72	1.75	-0.03
Western Inner Bar Gauge	1.30	1.30	0.00

4.2 Peak Flows

Predicted discharges for the Port Office Gauge were 9979 m^3/s (1974) and 4364 m^3/s (1955). A complete record of peak flows predicted by the model can be found in **Appendix D.**

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5. Design Event Modelling

5.1 Background

In October 2003 a review was undertaken of the Brisbane River catchment hydrology. As part of this review, it was decided that the design 1 in 100 AEP event would be based on a flow of 6000 m^3/s at the Brisbane Port Office Gauge. This corresponds to the 'best guess' report by the expert panel (IRP 2003).

Because no events that corresponded to 6000 m^3/s at the Port Office Gauge had previously been modelled, it was decided that a CRC FORGE event (modelled as part of the SKM 2003 review) would be used as a base model for the 1 in 100 AEP design event. Hydrographs for the CRC-FORGE event would be scaled accordingly to give a discharge of 6000 m^3/s at the Port Office Gauge.

The 1% AEP CRC-FORGE event is spatially distributed with areal reduction factors using a standard AR&R (1987) temporal pattern. It was run using the 'Post Dams' case with a critical duration of 72 hours (Refer Brisbane River Flood Study Review, SKM, Oct 2003). The discharges predicted by this event are presented in **Table 6**. It should be noted that these discharges were calculated before the model was fully calibrated.

Table 6 CRC-FORGE event – RAFTS Model – Discharges

Gauge Location	Chainage	Discharge
Savages crossing	Ch 948270 m	5368 m^3/s
Moggill	Ch 1006300 m	5043 m^3/s
Port Office	Ch 1055690 m	5044 m^3/s

This CRC-FORGE event was chosen because it was the only event that gave a reasonably consistent discharge throughout the Brisbane River.

5.2 Results

Hydrographs were extracted from the RAFTS model and input into the calibrated MIKE 11 model. This produced a peak at the Port Office Gauge discharge of 5273 m^3/s (refer **Table 7**).

Table 7 CRC-FORGE event – MIKE 11 Model – Discharges

Gauge Location	Chainage	Discharge
Savages crossing	Ch 948270 m	5084 m^3/s
Moggill	Ch 1006300 m	5298 m^3/s
Port Office	Ch 1055690 m	5273 m^3/s

The difference between the values in **Table 6** and **Table** 7 are the result of routing affects.

The expert review panel (IRP 2003) recommended a discharge of 6 000 m^3/s at the Port Office Gauge for the 1% AEP event. During the work SKM undertook there was no RAFTS run that produced this flow and hence a factored event was derived.

To achieve the desired discharge at the Port Office Gauge, all the input hydrographs were scaled up by a factor of 1.117 (ie 6000m^3/s / 5273m^3/s = 1.117) and the MIKE 11 model re-run. The resulting discharge at the Port Office Gauge was 5971 m^3/s (refer **Table 8**). This is only 0.5% less then 6000 m^3/s and therefore considered acceptable. A full record of discharges is presented in **Appendix E.**

- Table 8 CRC-FORGE event – MIKE 11 Model – Discharges (with scaled up hydrographs)

Gauge Location	Chainage	Discharge
Savages crossing	Ch 948270 m	5775 m^3/s
Moggill	Ch 1006300 m	6011 m^3/s
Port Office	Ch 1055690 m	5971 m^3/s

Flood levels for the 1 in 100 year AEP event are outlined in **Table 9,** a full record of flood levels are presented in **Appendix E.**

- Table 9 CRC-FORGE event – MIKE 11 Model – Flood Levels (with scaled up hydrographs)

Gauge Location	Chainage	Level
Savages crossing	Ch 948270 m	39.34 m
Moggill	Ch 1006300 m	14.36 m
Port Office	Ch 1055690 m	3.16 m

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Bibliography

Sinclair Knight Merz (1998) *Brisbane River Flood Study*, report for Brisbane City Council, June 1998.

Sinclair Knight Merz (2000) *Ipswich River Flood Study*, report for Ipswich City Council, July 2000.

Sinclair Knight Merz (2003) *Brisbane River Flood Study – Further Investigation of Flood Frequency Analysis Incorporating Dam Operations and CRC-FORGE Rainfall Estimates-Brisbane River*, Report for Brisbane City Council, December 2003.

Independent Review Panel (2003) *Review of Brisbane River Flood Study*, Report for Brisbane City Council, September 2003.

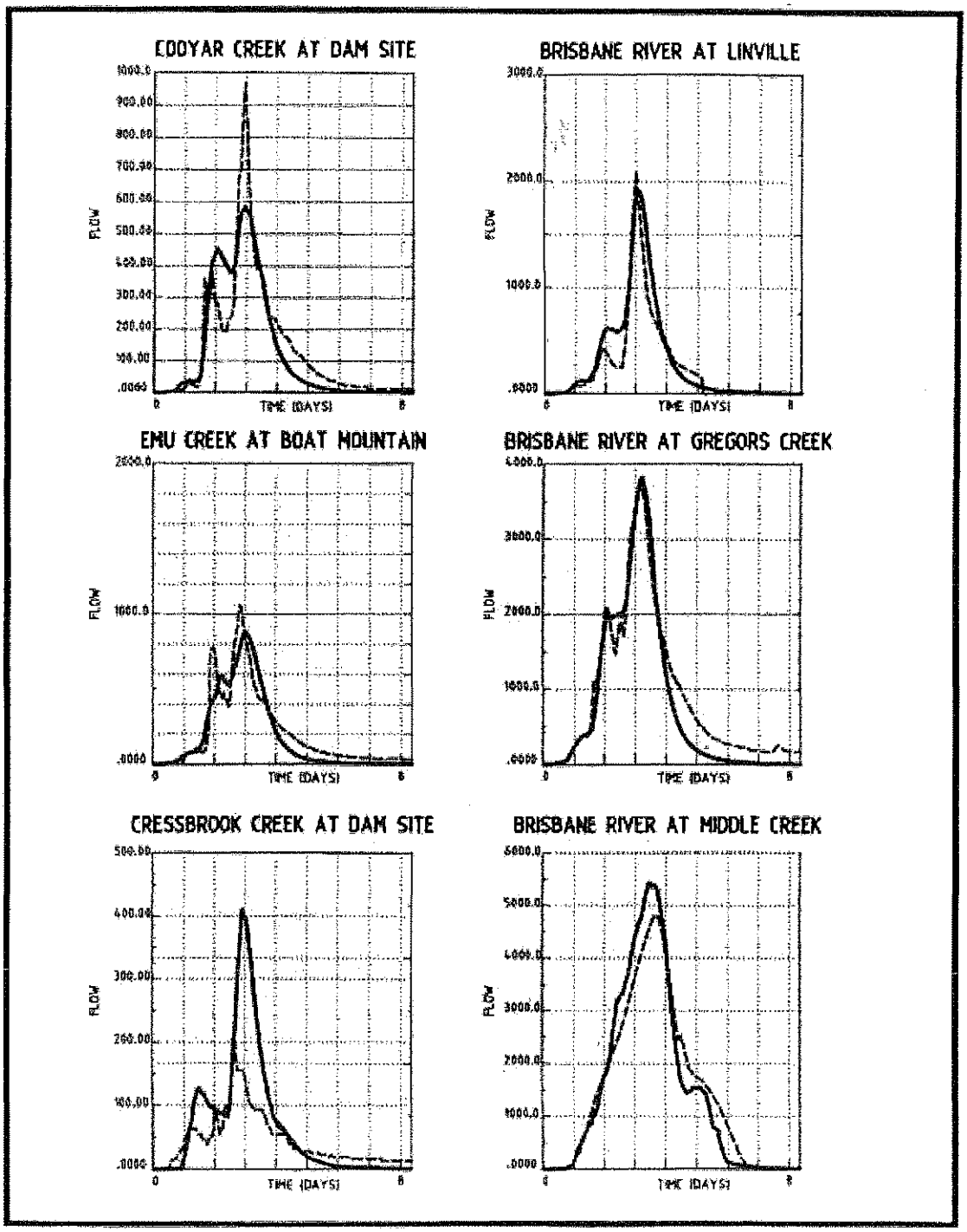
SKM

Appendix A Hydrological Hydrograph Comparison

SINCLAIR KNIGHT MERZ

FIGURE C-2a

IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

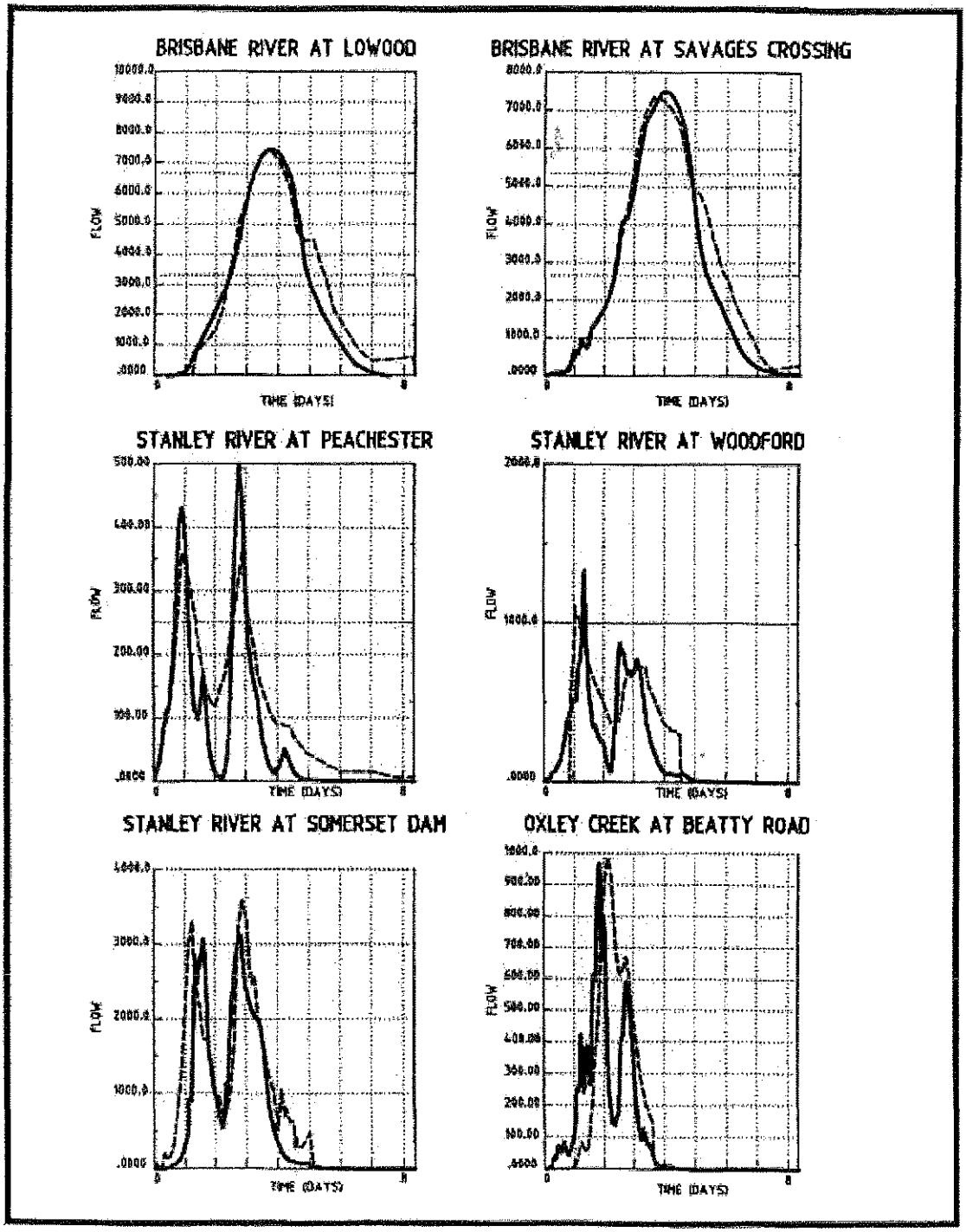
RECORDED DISCHARGE

PREDICTED DISCHARGE

FILE NAME: 04390-22
PLOT SCALE: 1:100
DISK No: U:\FMUD
JOB No: TD04390
DATE: 20-05-99

SINCLAIR KNIGHT MERZ

FIGURE C-2b
IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

RECORDED DISCHARGE

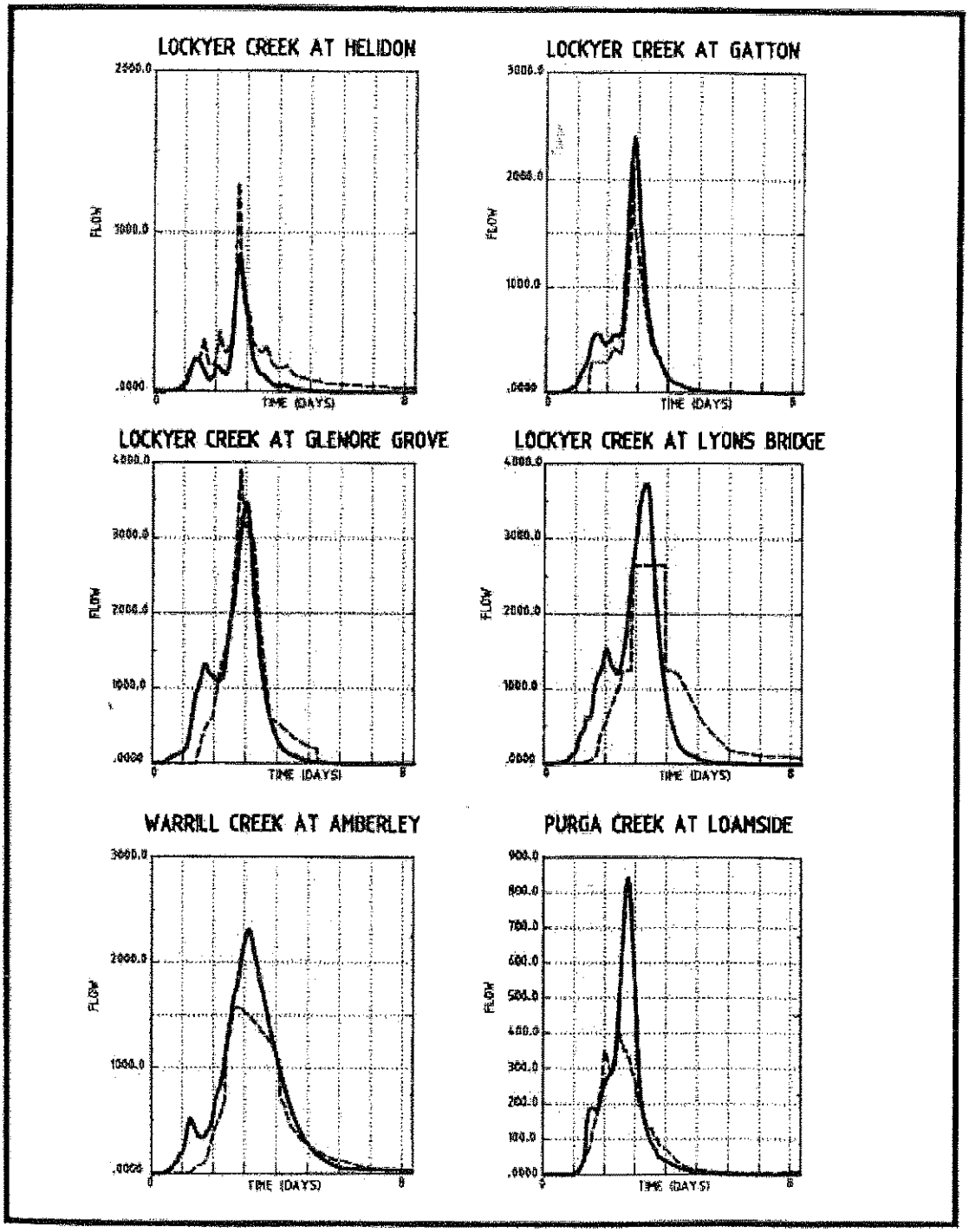
PREDICTED DISCHARGE

FILE NAME: 04390-22 DISK NO: LOWOOD JOB NO: T0004390 DATE: 20-05-99
PLOT SCALE: 1:100

SINCLAIR KNIGHT MERZ

FIGURE C-2c

IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

- - - - - - RECORDED DISCHARGE

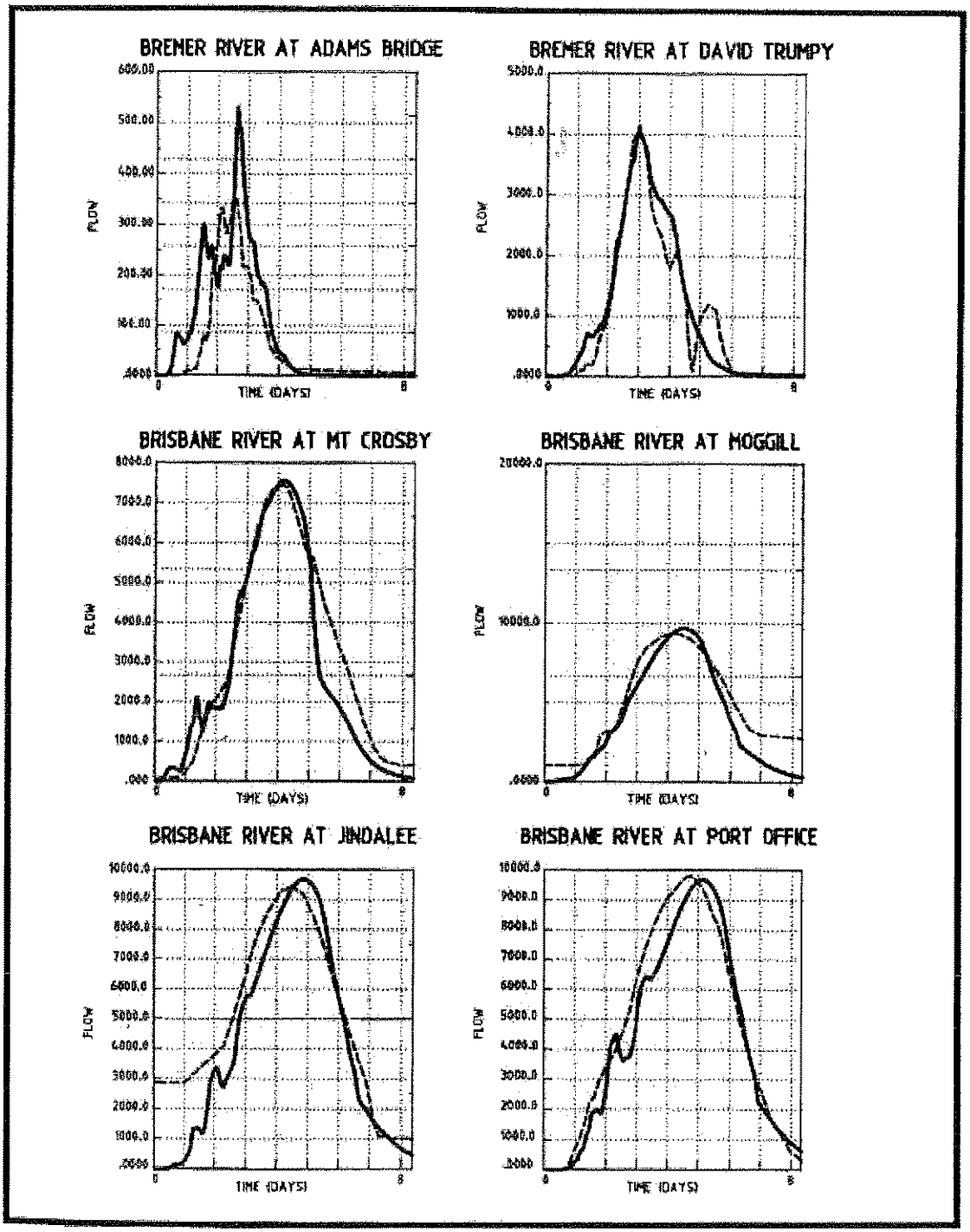
——— PREDICTED DISCHARGE

FILE NAME: 04390-27 DISK N°: U:\FWUD JOB N°: T004390 DATE: 20-05-99
PLOT SCALE: 1:100

SINCLAIR KNIGHT MERZ

FIGURE C-2d

IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

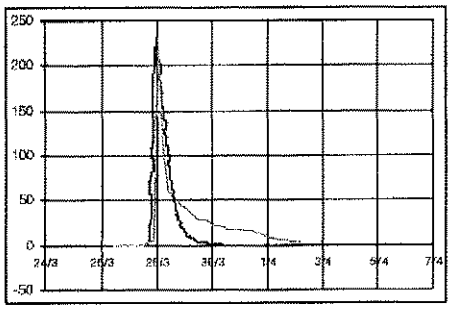
RECORDED DISCHARGE

PREDICTED DISCHARGE

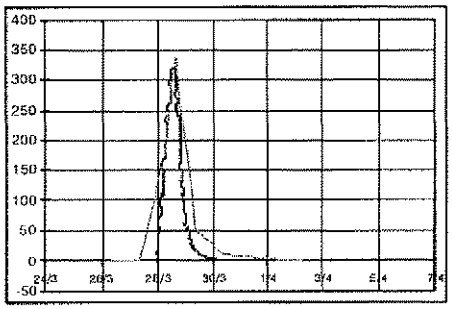
FILE NAME: 04390-22 DISK No: U:\FWUD JOB No: T004390 DATE: 20-15-99
PLOT SCALE: 1:100

1955 Historical Event Comparison

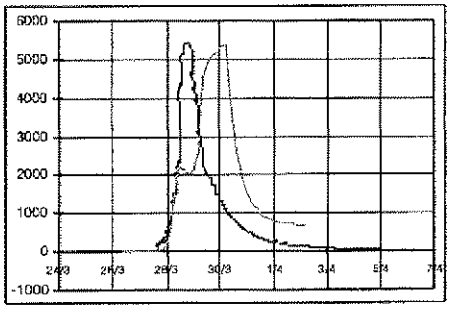
143203A Lockyer Creek AMTD 99.5
HEL-OUT Helidon Predicted
DISCHARGE (m^3/S) Recorded



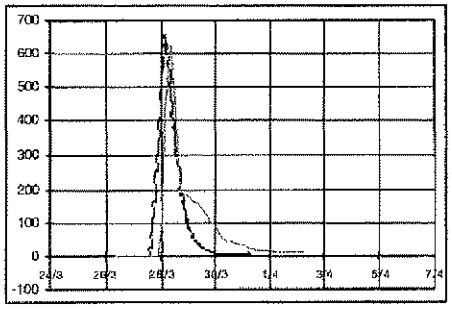
143102A Warrill Creek AMTD 50.9
KAL-OUT Kalbar Predicted
DISCHARGE (m^3/S) Recorded



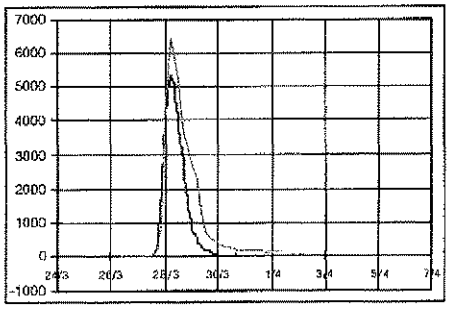
143001B Brisbane River AMTD 140.1
SAV11 Vernor Predicted
DISCHARGE (m^3/S) Recorded



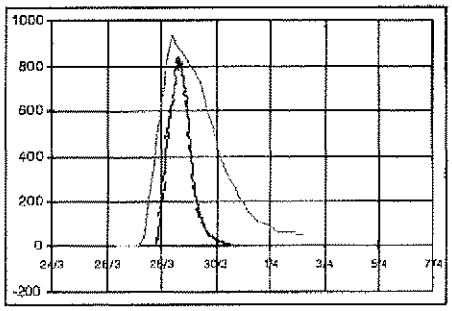
143204A Lockyer Creek AMTD 62.0
LYO+ Wilsons Weir Predicted
DISCHARGE (m^3/S) Recorded



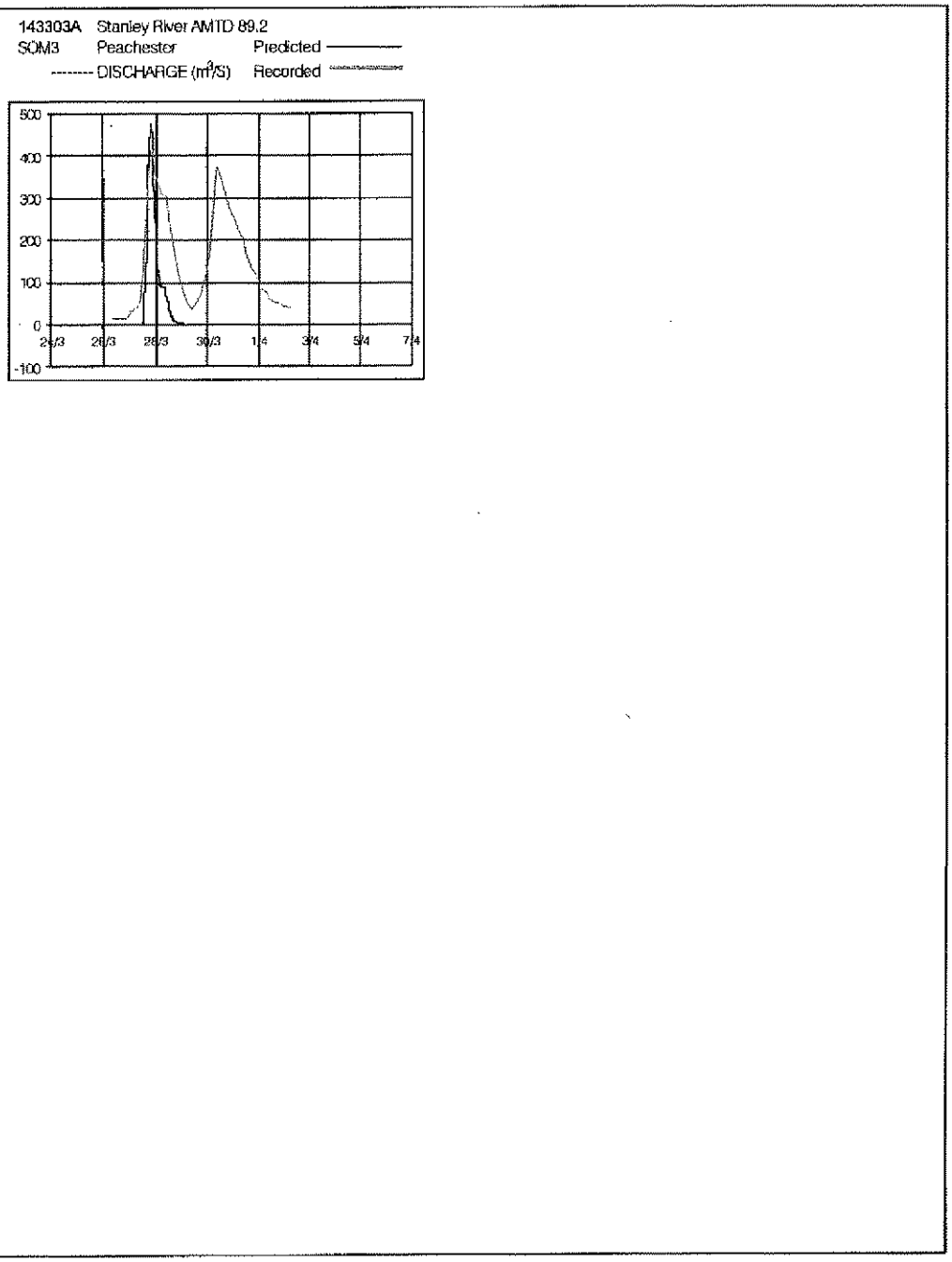
143005A Brisbane River AMTD 230.9
WIV8 Watts Bridge Predicted
DISCHARGE (m^3/S) Recorded



143206A Lockyer Creek AMTD 36.4
LYO-OUT Brightview Weir Predicted
DISCHARGE (m^3/S) Recorded



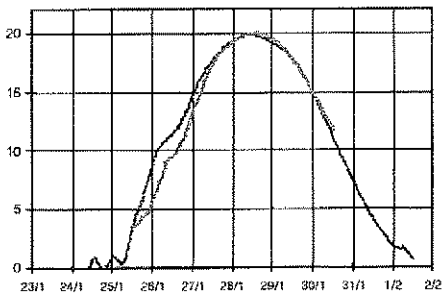
1955 Historical Event Comparison



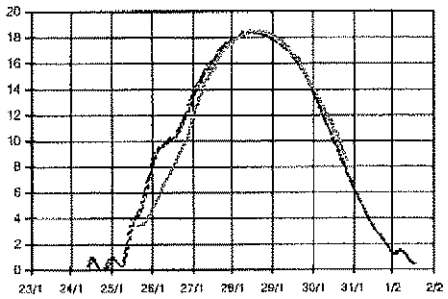
Appendix B Hydraulic Hydrograph Comparison

Predicted & Recorded Hydrograph Comparison - January 1974

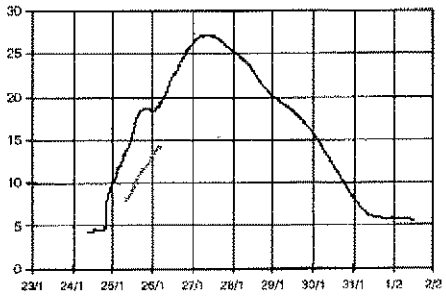
1974 MOGGILL GAUGE
Brisbane 1006.300 Predicted
------- WATER LEVEL (m) Recorded



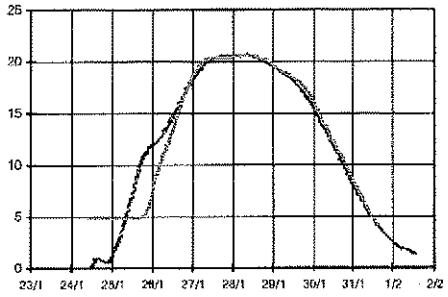
1974 GOODNA HOSPITAL GAUGE
Brisbane 1014.610 Predicted
------- WATER LEVEL (m) Recorded



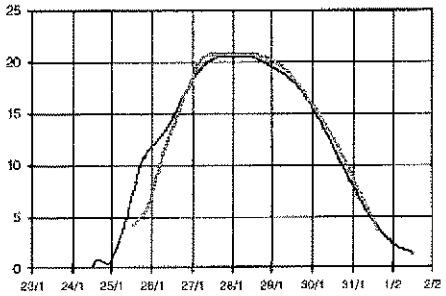
1974 BERRYS LAGOON GAUGE
Bremer 1002.300 Predicted
------- WATER LEVEL (m) Recorded



1974 DAVID TRUMPY GAUGE
Bremer 1012.050 Predicted
------- WATER LEVEL (m) Recorded

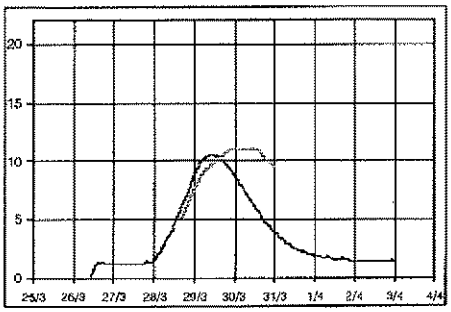


1974 MARSDEN PARADE GAUGE
Bremer 1012.070 Predicted
------- WATER LEVEL (m) Recorded

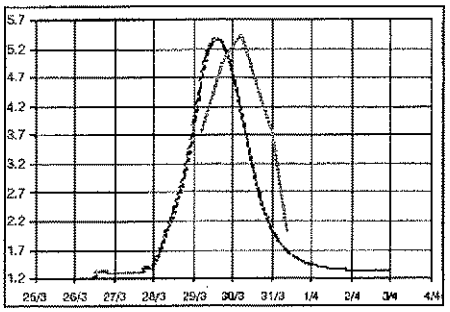


Predicted & Recorded Hydrograph Comparison - March 1955

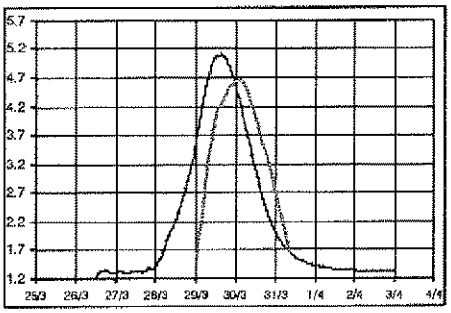
1955 GOODNA HOSPITAL GAUGE
BRISBANE 1014610 Predicted
WATER LEVEL (m) Recorded



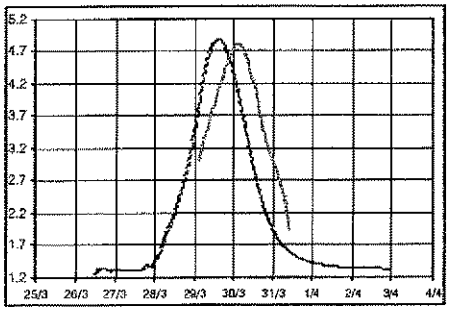
1955 INDOOROOPILLY BRIDGE GAUGE
BRISBANE 1037175 Predicted
WATER LEVEL (m) Recorded



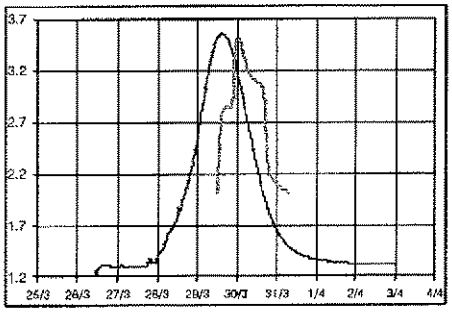
1955 TENNYSON GAUGE
BRISBANE1041460 Predicted
WATER LEVEL (m) Recorded



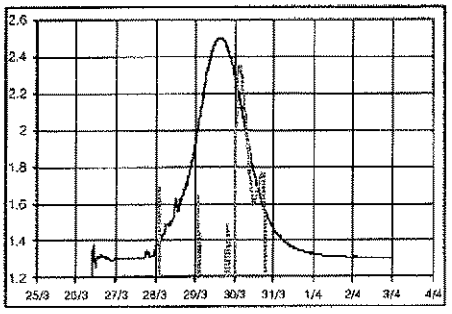
1955 SANDY CREEK GAUGE
BRISBANE 1042515 Predicted
WATER LEVEL (m) Recorded



1955 ST LUCIA FERRY GAUGE
BRISBANE 1048890 Predicted
WATER LEVEL (m) Recorded



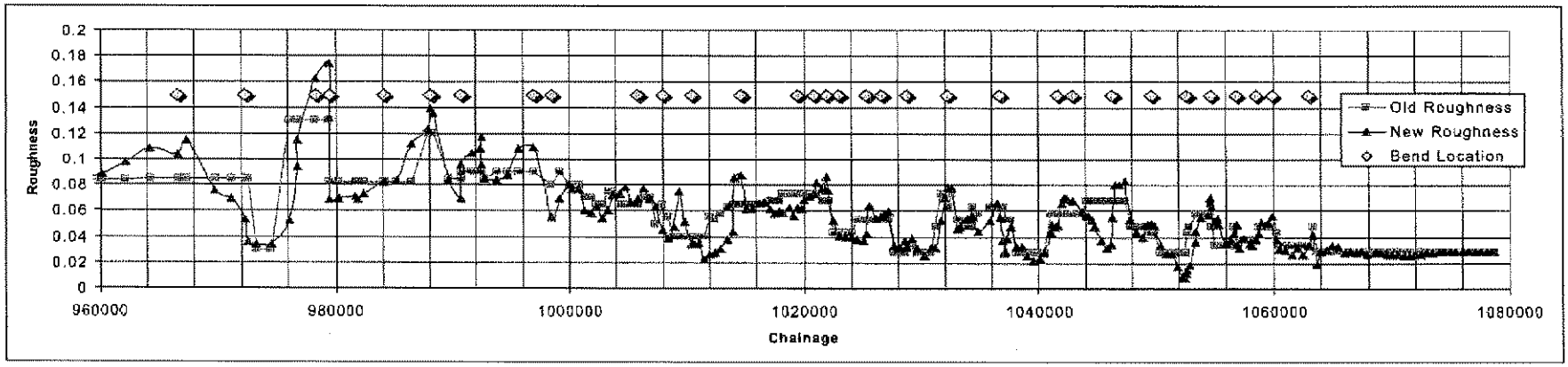
1955 PORT OFFICE GAUGE
BRISBANE 1055960 Predicted
WATER LEVEL (m) Recorded



Appendix C Roughness Parameters

SKM

Comparison of Roughness Values for New Model and Previous Model



SKM

Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference		Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
931570	0.084	0.086	0.002		980330	0.082	0.069	-0.013
933670	0.084	0.086	0.002		981660	0.082	0.071	-0.011
934270	0.084	0.086	0.002		981960	0.082	0.069	-0.013
934620	0.084	0.086	0.002		982460	0.082	0.073	-0.009
936070	0.084	0.086	0.002		984160	0.082	0.082	0.000
936820	0.084	0.086	0.002		985260	0.082	0.083	0.001
939770	0.084	0.086	0.002		986480	0.082	0.112	0.030
942320	0.084	0.086	0.002		987960	0.120	0.123	0.003
943570	0.084	0.086	0.002		988160	0.120	0.139	0.019
944120	0.084	0.086	0.002		988360	0.120	0.135	0.015
945570	0.084	0.086	0.002		989700	0.085	0.084	-0.001
947170	0.084	0.086	0.002		990700	0.085	0.070	-0.015
950270	0.084	0.086	0.002		990760	0.090	0.095	0.005
952320	0.084	0.086	0.002		991710	0.090	0.105	0.015
953870	0.084	0.086	0.002		992420	0.090	0.108	0.018
954920	0.084	0.086	0.002		992450	0.090	0.117	0.027
955970	0.084	0.086	0.002		992470	0.090	0.095	0.005
958770	0.084	0.086	0.002		992670	0.085	0.085	0.000
960170	0.084	0.088	0.004		993760	0.090	0.084	-0.006
962070	0.084	0.097	0.013		994760	0.090	0.087	-0.003
964170	0.085	0.108	0.023		995690	0.090	0.108	0.018
966610	0.085	0.104	0.019		996980	0.090	0.109	0.019
967410	0.085	0.115	0.030		998460	0.080	0.055	-0.025
969790	0.085	0.075	-0.010		999160	0.090	0.069	-0.021
971160	0.085	0.070	-0.015		1000000	0.080	0.081	0.001
972260	0.085	0.053	-0.032		1000285	0.080	0.077	-0.003
972600	0.085	0.036	-0.049		1000775	0.080	0.077	-0.003
973260	0.030	0.034	0.004		1001315	0.070	0.061	-0.009
974580	0.030	0.034	0.004		1001865	0.070	0.057	-0.013
976020	0.130	0.052	-0.078		1002350	0.065	0.063	-0.002
976750	0.130	0.094	-0.036		1002785	0.065	0.054	-0.011
976750	0.130	0.114	-0.016		1003275	0.075	0.060	-0.015
978280	0.130	0.162	0.032		1003775	0.075	0.072	-0.003
979507	0.130	0.174	0.044		1004300	0.065	0.073	0.008
979513	0.130	0.132	0.002		1004810	0.065	0.078	0.013
979530	0.082	0.069	-0.013		1005325	0.065	0.067	0.002

Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference		Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
1005870	0.065	0.070	0.005		1021539	0.068	0.076	0.008
1006300	0.070	0.078	0.008		1021715	0.068	0.078	0.010
1006910	0.070	0.069	-0.001		1021895	0.068	0.086	0.018
1007410	0.050	0.063	0.013		1022105	0.068	0.075	0.007
1007920	0.065	0.045	-0.020		1022575	0.043	0.052	0.009
1008445	0.055	0.039	-0.016		1023040	0.043	0.041	-0.002
1008925	0.040	0.048	0.008		1023570	0.043	0.040	-0.003
1009400	0.040	0.075	0.035		1024080	0.043	0.040	-0.003
1009820	0.040	0.052	0.012		1024563	0.053	0.037	-0.016
1010490	0.040	0.034	-0.006		1025070	0.053	0.037	-0.016
1010725	0.040	0.034	-0.006		1025360	0.053	0.042	-0.011
1010980	0.040	0.035	-0.005		1025590	0.053	0.064	0.011
1011510	0.040	0.022	-0.018		1026170	0.053	0.054	0.001
1011980	0.055	0.026	-0.029		1026680	0.053	0.056	0.003
1012475	0.053	0.028	-0.025		1026900	0.053	0.058	0.005
1012935	0.058	0.031	-0.027		1027160	0.053	0.059	0.006
1013445	0.063	0.038	-0.025		1027680	0.028	0.033	0.005
1013920	0.065	0.044	-0.021		1028180	0.028	0.031	0.003
1014110	0.065	0.086	0.021		1028680	0.028	0.037	0.009
1014610	0.065	0.088	0.023		1028760	0.033	0.032	-0.001
1015090	0.065	0.061	-0.004		1029200	0.033	0.039	0.006
1015560	0.065	0.062	-0.003		1029680	0.028	0.031	0.003
1016140	0.065	0.066	0.001		1030220	0.028	0.025	-0.003
1016640	0.065	0.067	0.002		1030870	0.028	0.032	0.004
1017130	0.068	0.061	-0.007		1031260	0.048	0.031	-0.017
1017610	0.068	0.058	-0.010		1031700	0.073	0.052	-0.021
1017920	0.068	0.060	-0.008		1031995	0.073	0.071	-0.002
1018200	0.073	0.058	-0.015		1032230	0.063	0.078	0.015
1018725	0.073	0.062	-0.011		1032585	0.073	0.077	0.004
1019095	0.073	0.056	-0.017		1033080	0.053	0.046	-0.007
1019490	0.073	0.062	-0.011		1033370	0.053	0.048	-0.005
1019865	0.073	0.061	-0.012		1033900	0.048	0.054	0.006
1020115	0.073	0.068	-0.005		1034370	0.048	0.055	0.007
1020525	0.073	0.071	-0.002		1034414	0.063	0.056	-0.007
1020830	0.073	0.073	0.000		1034890	0.058	0.044	-0.014
1021095	0.073	0.082	0.009		1035900	0.063	0.052	-0.011

Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference	Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
1036460	0.063	0.066	0.003	1049120	0.048	0.049	0.001
1036770	0.063	0.055	-0.008	1049370	0.048	0.050	0.002
1036915	0.063	0.037	-0.026	1049590	0.043	0.049	0.006
1037090	0.063	0.028	-0.035	1049870	0.043	0.049	0.006
1037175	0.053	0.028	-0.025	1050430	0.028	0.033	0.005
1037285	0.053	0.039	-0.014	1050860	0.028	0.027	-0.001
1037625	0.053	0.048	-0.005	1051360	0.028	0.027	-0.001
1038085	0.028	0.032	0.004	1051895	0.028	0.017	-0.011
1038600	0.028	0.033	0.005	1052310	0.028	0.010	-0.018
1039100	0.028	0.025	-0.003	1052390	0.028	0.008	-0.020
1039565	0.028	0.022	-0.006	1052595	0.028	0.012	-0.016
1040090	0.028	0.024	-0.004	1052640	0.043	0.014	-0.029
1040490	0.028	0.028	0.000	1052865	0.048	0.018	-0.030
1041010	0.058	0.044	-0.014	1053320	0.058	0.036	-0.022
1041230	0.058	0.050	-0.008	1053385	0.058	0.044	-0.014
1041460	0.058	0.048	-0.010	1053900	0.058	0.055	-0.003
1041700	0.058	0.049	-0.009	1054490	0.058	0.057	-0.001
1041960	0.058	0.065	0.007	1054640	0.058	0.066	0.008
1042235	0.058	0.070	0.012	1054680	0.058	0.071	0.013
1042515	0.058	0.069	0.011	1054760	0.048	0.063	0.015
1042910	0.058	0.068	0.010	1054970	0.033	0.052	0.019
1043725	0.058	0.059	0.001	1055280	0.033	0.054	0.021
1044060	0.068	0.056	-0.012	1055420	0.033	0.049	0.016
1044340	0.068	0.056	-0.012	1055960	0.033	0.035	0.002
1044605	0.068	0.053	-0.015	1056400	0.033	0.038	0.005
1044860	0.068	0.048	-0.020	1056695	0.048	0.042	-0.006
1045400	0.068	0.037	-0.031	1056865	0.038	0.050	0.012
1045885	0.068	0.031	-0.037	1056950	0.038	0.034	-0.004
1046180	0.068	0.034	-0.034	1057090	0.038	0.032	-0.006
1046340	0.068	0.055	-0.013	1057530	0.038	0.039	0.001
1046580	0.068	0.080	0.012	1058040	0.038	0.035	-0.003
1046900	0.068	0.080	0.012	1058230	0.038	0.034	-0.004
1047350	0.068	0.083	0.015	1058530	0.038	0.037	-0.001
1047915	0.048	0.053	0.005	1058735	0.048	0.042	-0.006
1048375	0.048	0.043	-0.005	1059035	0.048	0.051	0.003
1048890	0.048	0.040	-0.008	1059540	0.048	0.051	0.003

Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference	Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
1059990	0.048	0.056	0.008	1069535	0.029	0.026	-0.003
1060345	0.043	0.038	-0.005	1070025	0.029	0.026	-0.003
1060535	0.033	0.031	-0.002	1070530	0.029	0.026	-0.003
1061015	0.033	0.030	-0.003	1071040	0.029	0.025	-0.004
1061530	0.033	0.026	-0.007	1071520	0.029	0.025	-0.004
1062020	0.033	0.032	-0.001	1072015	0.029	0.026	-0.003
1062535	0.033	0.026	-0.007	1072515	0.029	0.027	-0.002
1062940	0.033	0.033	0.000	1072995	0.029	0.028	-0.001
1063310	0.048	0.042	-0.006	1073485	0.029	0.028	-0.001
1063645	0.029	0.019	-0.010	1074000	0.029	0.029	0.000
1064000	0.029	0.029	0.000	1074460	0.029	0.029	0.000
1064490	0.029	0.029	0.000	1074985	0.029	0.029	0.000
1065010	0.029	0.033	0.004	1075480	0.029	0.029	0.000
1065503	0.029	0.032	0.003	1076000	0.029	0.029	0.000
1065990	0.029	0.028	-0.001	1076495	0.029	0.029	0.000
1066505	0.029	0.029	0.000	1077010	0.029	0.029	0.000
1067020	0.029	0.028	-0.001	1077510	0.029	0.029	0.000
1067485	0.029	0.029	0.000	1078040	0.029	0.029	0.000
1067965	0.029	0.026	-0.003	1078525	0.029	0.029	0.000
1068660	0.029	0.028	-0.001	1078660	0.029	0.029	0.000
1069045	0.029	0.028	-0.001				

SKM

Appendix D MIKE11 Results

Figure D-2a Flood Calibration Profile - January 1974
Brisbane River

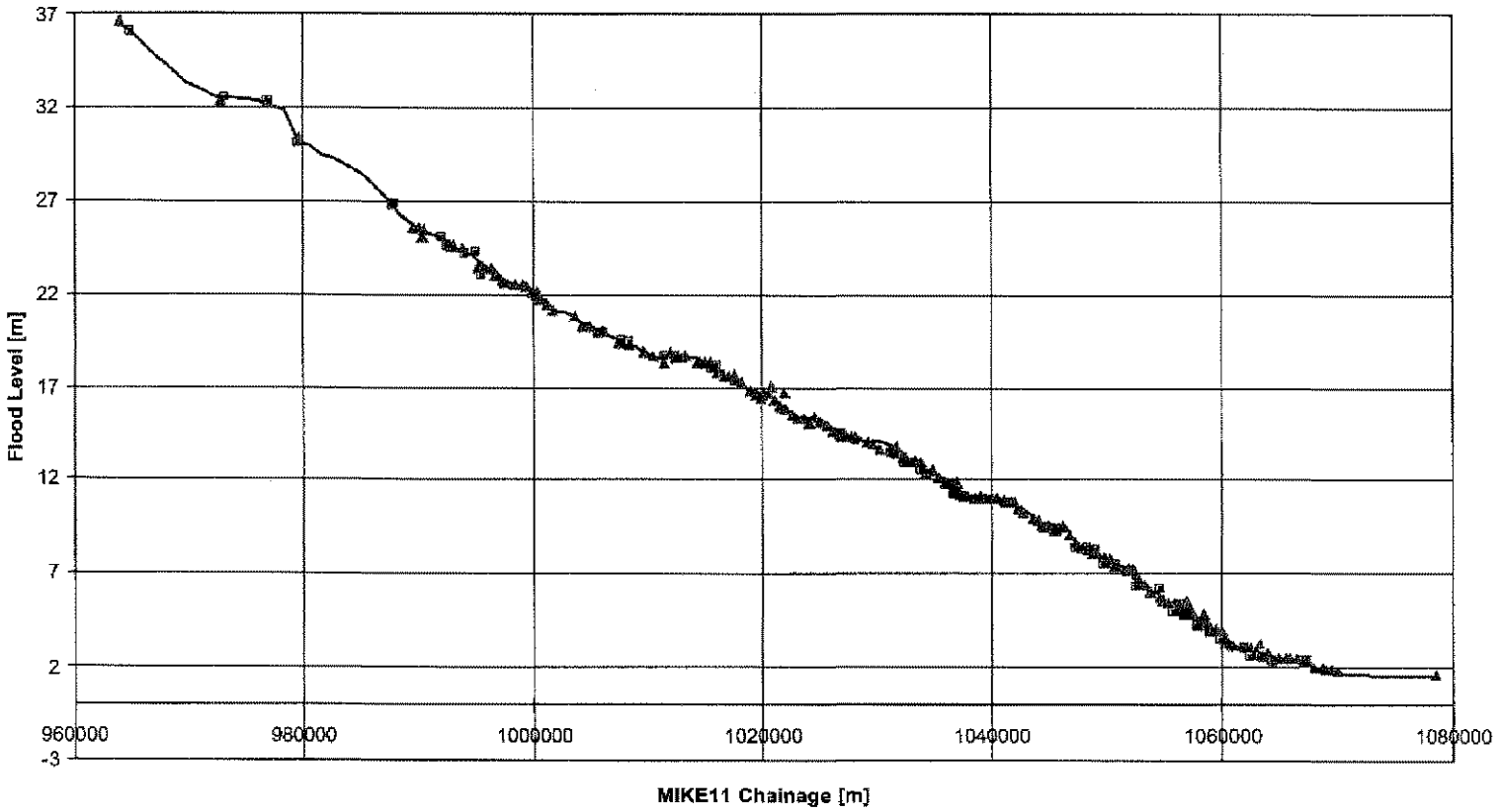
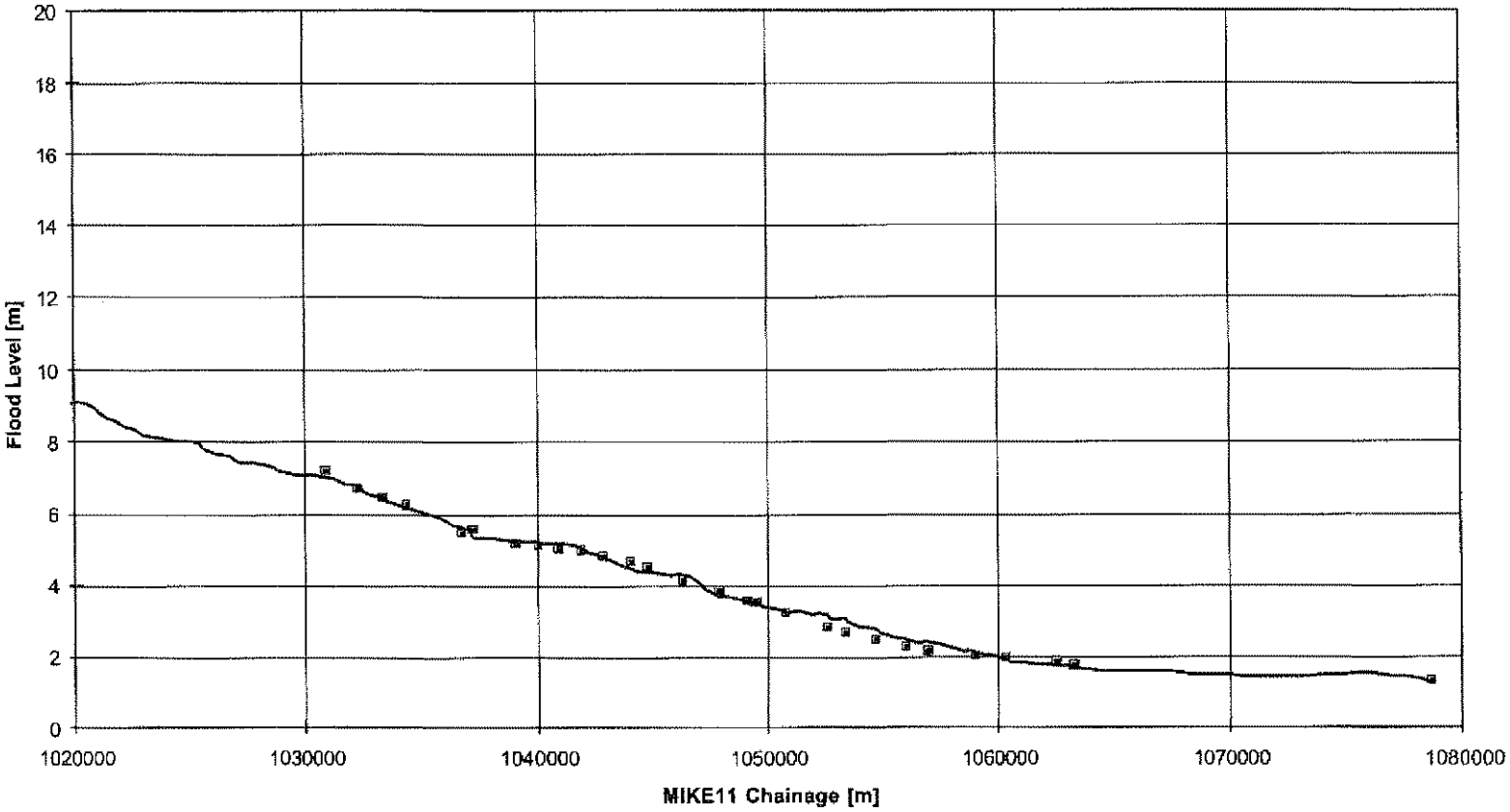


Figure D-2a Flood Calibration Profile - March 1955
Brisbane River



MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
		36.60		36.69	-0.09	31.51		
964170		36.49				31.37		
		36.06	36.08		-0.02	30.87		
966610		35.17				29.81		
967410		34.63				29.32		
	Cabbage Tree Crk.	34.50				29.20		
969790		33.36				28.16		
971160		32.89				27.68		
972260		32.62				27.44		
		32.62		32.3	0.32	27.42		
973260		32.61	32.49		0.12	27.41		
974580		32.38				27.24		
976020		32.31				27.15		
		32.14		32.23	-0.09	26.89		
		32.10	32.31		-0.21	26.84		
978280		31.82				26.41		
979507		30.10	30		0.10	24.40		
979513		30.03				24.36		
979530		30.09				24.36		
		30.06		30.25	-0.19	24.32		
980330		29.91				24.14		
981660		29.48				23.71		
982460		29.31				23.50		
984160		28.79				23.01		
985260		28.37				22.57		
986480		27.67				21.83		
	Mt. Crosby Weir (43003A)	26.81	26.74		0.07	20.84		
987960	Mt. Crosby (040142/040818)	26.75	26.826		-0.08	20.77		
988160		26.49				20.46		
988360		26.29				20.19		
		25.68		25.55	0.13	19.40		
989700		25.63				19.34		
		25.49		25.55	-0.06	19.19		
		25.47		25.52	-0.05	19.16		
		25.38		25.03	0.35	19.06		
		25.36		25.43	-0.07	19.03		
990700		25.30				18.97		
990760		25.26				18.93		
991710		25.08				18.67		
		24.99	25.06		-0.07	18.56		
992420		24.92				18.48		
992450	Colleges Crossing	24.86				18.43		
992470		24.82				18.41		
992670		24.76	24.61		0.15	18.31		
		24.64		24.58	0.06	18.16		
		24.53		24.58	-0.05	18.01		
993760		24.28				17.68		
		24.23		24.45	-0.22	17.59		
		24.19	24.21		-0.02	17.52		
994760		24.06				17.30		
		23.88	24.3		-0.42	17.07		
		23.81		23.45	0.36	16.98		
		23.70		23.51	0.19	16.83		
		23.64	23.02	23.51	0.37	16.75		
995690		23.62				16.73		
		23.52				16.57		
		23.13		23.45	-0.32	15.96		
		23.05				15.84		
		22.98		22.96	0.02	15.73		
996980		22.84				15.52		
		22.83		22.99	-0.16	15.49		
		22.81				15.46		
		22.79				15.43		
		22.78		22.72	0.06	15.40		
		22.72		22.53	0.19	15.31		
998460		22.54				14.99		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L.	Difference
		22.51		22.47	0.04	14.95		
999160		22.37				14.76		
		22.36		22.44	-0.08	14.75		
		22.26		22.38	-0.12	14.64		
		22.18		22.11	0.07	14.55		
1000000		22.14				14.51		
1000285		21.95		21.92	0.03	14.34		
		21.88		22.17	-0.29	14.27		
1000775		21.69		21.68	0.01	14.08		
1001315		21.60		21.5	0.10	13.93		
1001865		21.23		21.1	0.13	13.58		
1002350		21.12				13.37		
1002785		21.12				13.34		
1003275		20.92				13.11		
1003775		20.76		20.83	-0.07	12.94		
1004300		20.42		20.25	0.17	12.53		
1004810		20.40	20.25	20.25	0.15	12.43		
1005325		20.25				12.22		
1005870		20.03	19.93	19.97	0.07	11.94		
1006200		19.95				11.86		
1006200		19.95				11.86		
1006300	Moggill Gauge	19.91	19.93	20.04	-0.08	11.82		
1006300		19.91				11.82		
1006910		19.69				11.61		
1007410		19.61		19.33	0.28	11.50		
1007780		19.40				11.34		
1007780		19.40				11.34		
1007920		19.29	19.6	19.33	-0.18	11.26		
1008445		19.21	19.46	19.21	-0.13	11.24		
1008925		19.16				11.19		
1009400		19.03				11.08		
1009720		18.96		18.88	0.08	11.00		
1010490		18.59		18.69	-0.10	10.80		
1010725		18.64				10.83		
1010980		18.60				10.80		
1011510		18.67	18.63	18.3	0.21	10.80		
1011980		18.71		18.8	-0.10	10.80		
1012475		18.70	18.63	18.6	0.08	10.79		
1012475		18.70				10.79		
1012935		18.66		18.6	0.06	10.76		
1013190		18.65				10.74		
1013190		18.65				10.74		
1013445		18.63		18.63	0.00	10.73		
1013680		18.62				10.72		
1013680		18.62				10.72		
1013910		18.61				10.70		
1014310		18.55		18.3	0.25	10.62		
1014610	Goodna Hospital Gauge	18.44		18.43	0.01	10.49		
1014610		18.44				10.49		
1015090		18.26		18.3	-0.05	10.37		
1015560		18.08	17.96	18.33	-0.07	10.26		
1015850		18.01				10.20		
1015850		18.01				10.20		
1016140		17.94	18.15	17.78	-0.03	10.14		
1016640		17.78		17.63	0.15	9.97		
1016890		17.65				9.84		
1016890		17.65				9.84		
1017130		17.51		17.54	-0.03	9.72		
1017610		17.42	17.29	17.66	-0.05	9.58		
1017920		17.28				9.47		
1018200		17.24		17.26	-0.02	9.46		
1018725		16.96				9.30		
1019095		16.89		16.83	0.06	9.22		
1019490		16.84		16.65	0.19	9.18		
1019490		16.84				9.18		
1019865		16.57		16.47	0.10	9.03		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
1020115		16.71	16.56	16.71	0.07	9.06		
1020525		16.69				9.03		
1020830		16.53		17.02	-0.49	8.94		
1021095		16.30		16.26	0.04	8.80		
1021539		16.06		16.04	0.02	8.61		
1021715		16.08		15.98	0.10	8.58		
1021895		15.97		16.74	-0.77	8.51		
1022105		15.81		15.86	-0.05	8.42		
1022575		15.70		15.52	0.18	8.31		
1023040		15.42		15.31	0.11	8.14		
1023570		15.34		15.31	0.03	8.10		
1024080		15.31		15.13	0.18	8.05		
1024563		15.27		15.4	-0.13	8.00		
1025070		15.26		15.19	0.07	7.97		
1025360		15.14				7.90		
1025590		14.98		14.94	0.04	7.81		
1026170		14.77		14.64	0.13	7.67		
1026680	Mt Ommaney Gauge	14.67	14.55	14.58	0.10	7.56		
1026900		14.52	14.24	14.55	0.12	7.48		
1027160		14.35	14.24	14.46	0.00	7.40		
1027680		14.39		14.32	0.07	7.37		
1028180		14.40	14.12	14.3	0.19	7.35		
1028680		14.26				7.25		
	Centenary Bridge	14.21				7.20		
1028760		14.16				7.15		
1029200		14.03		14.09	-0.06	7.05		
1029680		14.04		13.97	0.07	7.04		
1030220		14.05		13.63	0.42	7.04		
1030870		13.99				6.99	7.17	-0.18
1031260		13.82	13.51	13.73	0.20	6.92		
1031700	Darra Wharf Gauge	13.52	13.36	13.79	-0.05	6.79		
1031995		13.66				6.80		
1032230		13.55		13.18	0.37	6.71	6.7	0.01
1032585		13.23	12.9	13.33	0.11	6.55		
1033080		13.07		12.99	0.08	6.43		
1033370		12.97	12.9	13.02	0.01	6.37	6.41	-0.04
1033900		12.73	12.57	12.96	-0.04	6.24		
1034370		12.51		12.26	0.25	6.11	6.23	-0.12
1034890	Sherwood Gauge	12.43		12.52	-0.09	6.04		
1035414		12.26		12.14	0.12	5.94		
1035900		12.03		11.87	0.16	5.80		
1036460		11.78	11.74	11.77	0.02	5.65		
1036770		11.73	11.24	11.59	0.31	5.57	5.47	0.10
1036915		11.58	11.32	11.65	0.10	5.53		
1037090		11.60	11.2	11.84	0.08	5.54		
	Indooroopilly Bridge	11.50				5.50		
1037175		11.19	11.13	11.47	-0.11	5.34		
1037285	Clarence Road Gauge	11.14		11.2	-0.06	5.30	5.56	-0.26
1037625		11.18	11.07	11.1	0.09	5.29		
1038085		11.22		11.1	0.12	5.27		
1038600		11.19		11.04	0.15	5.22		
1039100		11.16		11.07	0.09	5.18	5.16	0.02
1039200		11.16				5.18		
1039200		11.16				5.18		
1039565	Oxley Creek Gauge	11.15		11.01	0.14	5.18		
1039670		11.15				5.18		
1039670		11.15				5.18		
1039828		11.14				5.18		
1039828		11.14				5.18		
1040090	King Authur Terrace Gauge	11.11		11.04	0.07	5.18	5.1	0.08
1040250		11.07				5.16		
1040250		11.07				5.16		
1040490		10.97		11.01	-0.04	5.11		
1041010		11.03		10.89	0.14	5.13	5.02	0.11
1041230		11.01		10.83	0.18	5.10		
1041460	Tennyson Power House Gauge	10.93		10.83	0.10	5.07		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
1041700		10.92		10.83	0.08	5.07		
1041960	Yeronga Street Gauge	10.77		10.83	-0.06	4.98	4.95	0.03
1042235		10.57		10.42	0.15	4.89		
1042500		10.53				4.85		
1042500		10.53				4.85		
1042515		10.52		10.43	0.09	4.85		
1042910		10.41	10.16	10.25	0.20	4.71	4.8	-0.09
1043010		10.35				4.67		
1043010		10.35				4.67		
1043080		10.30				4.64		
1043110		10.29				4.63		
1043110		10.29				4.63		
1043725		9.97		9.95	0.02	4.46		
1044060	Sandy Creek Gauge	9.81		9.81	0.00	4.41	4.65	-0.25
1044340		9.67		9.61	0.06	4.34		
1044605		9.66		9.49	0.17	4.31		
1044860		9.67		9.55	0.12	4.30	4.49	-0.19
1045400		9.59		9.31	0.28	4.24		
1045885		9.54	9.15	9.46	0.23	4.20		
1046180		9.55		9.49	0.06	4.23		
1046340	Dutton Park Cemetery Gauge	9.50		9.57	-0.08	4.22	4.12	0.09
1046580		9.46				4.19		
1046900		9.21		9.03	0.18	4.05		
1047350		8.66	8.36	8.61	0.18	3.79		
1047915	Highgate Hill Gauge	8.29		8.36	-0.07	3.62	3.82	-0.20
1048375		8.37	8.36	8.3	0.04	3.63		
1048890	St Lucia Ferry Gauge	8.15		8.09	0.06	3.50		
1049120		8.10	8.27	8.24	-0.15	3.49	3.55	-0.06
1049370		7.89				3.40	3.51	-0.11
1049590		7.86				3.39	3.50	-0.11
1049870		7.71	7.57	7.9	-0.02	3.32		
1050430		7.63		7.75	-0.12	3.24		
1050860		7.47	7.57	7.48	-0.05	3.18	3.19	-0.01
1051360		7.48				3.19		
1051895		7.30	7.14	7.29	0.09	3.09		
1052310		7.49	7.08	7.17	0.36	3.16		
	Merivale Bridge	7.38				3.13		
1052390		7.35		7.23	0.12	3.12		
1052595		7.28				3.11		
	William Jolly Bridge	7.08				3.07		
1052640		6.53	6.35	7.05	-0.17	2.97	2.81	0.16
1052865	Montague Road Gauge	6.46		6.56	-0.10	2.96		
1053320		6.57		6.44	0.13	2.98		
	Victoria Bridge	6.45				2.95		
1053385		6.36		6.44	-0.08	2.93	2.66	0.27
1053900		6.08		6.04	0.04	2.79		
1054640		6.00				2.75		
	Captain Cook Bridge	5.96				2.75		
1054680		5.92	6.26	5.77	-0.10	2.75	2.43	0.32
1054970		5.61		5.59	0.02	2.64		
1055280		5.46				2.58		
1055420		5.40		5.44	-0.04	2.55		
1055960	Port Office Gauge	5.28	4.95	5.44	0.09	2.50	2.28	0.22
1056400		4.99	5.31	5.31	-0.32	2.39		
1056695		4.92				2.37		
1056865		5.16	4.76	5.4	0.08	2.44		
	Story Bridge	5.08				2.41		
1056950		5.04	4.8	5.47	-0.10	2.40	2.15	0.25
1057090		4.86	4.8	5.28	-0.18	2.35		
1057530		4.73		4.86	-0.13	2.31		
1058040		4.46	4.21	4.4	0.15	2.21		
1058230		4.39				2.18		
1058530		4.26	4.49	4.79	-0.38	2.15		
1058735		4.31	4.22	4.58	-0.09	2.16		
1059035		4.02	3.85	4.03	0.07	2.08	1.98	0.10
1059540		3.95	3.91	4.09	-0.05	2.04		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
1059990		3.68	3.48	4	-0.06	1.95		
1060345		3.35		3.27	0.08	1.86	1.96	-0.10
1060535		3.21	3.21	3.33	-0.06	1.83		
1061015		3.20		3.18	0.02	1.82		
1061530		3.01				1.77		
1062020		2.99	3.06	3.15	-0.12	1.76		
1062535		2.98	2.6	3.15	0.11	1.75	1.82	-0.07
1062940		3.00				1.75		
1063125		2.95				1.74		
1063125		2.95				1.74		
1063310	Newstead Park Gauge	2.88	2.6	3.3	-0.07	1.72	1.75	-0.03
1063645	Cresent Road Gauge	2.61	2.63	2.63	-0.02	1.65		
1064000		2.61		2.78	-0.17	1.65		
1064490		2.47	2.39	2.42	0.07	1.61		
1065010		2.49		2.48	0.01	1.62		
1065503		2.44		2.51	-0.07	1.61		
1065990	Cairncross Dock Gauge	2.47		2.49	-0.02	1.61		
1066505		2.37		2.51	-0.14	1.59		
1067020		2.34	2.42	2.36	-0.05	1.58		
1067485		2.22	2.42	2.36	-0.17	1.55		
1067965		2.10		2.02	0.08	1.52		
1068660		1.94		2.02	-0.08	1.49		
1069045		1.87		1.9	-0.03	1.47		
1069535	Bulimba Power House Gauge	1.83		1.9	-0.07	1.46		
1070025		1.79		1.85	-0.06	1.45		
1070530		1.71				1.43		
1071040		1.65				1.42		
1071520		1.70				1.44		
1072015		1.64				1.41		
1072020		1.64				1.41		
1072020		1.64				1.41		
1072515		1.63				1.40		
1072995		1.62				1.42		
1073485		1.61				1.43		
1074000		1.60				1.45		
1074460		1.60				1.46		
1074985		1.59				1.47		
1075480		1.58				1.49		
1076000		1.57				1.49		
1076495		1.56				1.46		
1077010		1.56				1.44		
1077510		1.55				1.41		
1078040		1.55				1.36		
1078525		1.55				1.30		
1078660	Western Inner Bar Gauge	1.55		1.55	-0.01	1.30	1.3	0.00

Chainage [m]	Discharge [m³/s]	
	1974 Flood Event	1955 Flood Event
BNE 931575.00	7600	5400
BNE 932625.00	7595	5395
BNE 933970.00	7587	5380
BNE 934445.00	7581	5368
BNE 935345.00	7577	5359
BNE 936445.00	7561	5308
BNE 938295.00	7553	5282
BNE 941045.00	7524	5254
BNE 942945.00	7483	5165
BNE 943845.00	7435	5068
BNE 944845.00	7419	4947
BNE 946370.00	7410	4888
BNE 947720.00	7406	4869
BNE 949270.00	7402	4850
BNE 951295.00	7397	4829
BNE 953095.00	7396	4820
BNE 954395.00	7392	4802
BNE 955445.00	7389	4788
BNE 957370.00	7383	4762
BNE 959470.00	7379	4742
BNE 961120.00	7362	4691
BNE 963120.00	7354	4676
BNE 965390.00	7351	4643
BNE 967010.00	7349	4621
BNE 968600.00	7348	4608
BNE 970475.00	7347	4592
BNE 971710.00	7346	4581
BNE 972760.00	7345	4573
BNE 973920.00	7343	4560
BNE 975300.00	7343	4551
BNE 976385.00	7344	4542
BNE 977515.00	7348	4521
BNE 978893.50	7347	4504
BNE 979510.00	7459	4611
BNE 979521.50	7456	4608
BNE 979930.00	7352	4493
BNE 980995.00	7348	4485
BNE 982060.00	7349	4480
BNE 983310.00	7347	4473
BNE 984710.00	7349	4468
BNE 985870.00	7350	4463
BNE 987220.00	7351	4457
BNE 988060.00	7352	4453
BNE 988165.00	7353	4452
BNE 988265.00	7353	4452
BNE 989030.00	7354	4448
BNE 990200.00	7358	4439
BNE 990730.00	7360	4438
BNE 991235.00	7361	4436
BNE 992065.00	7376	4427
BNE 992435.00	7364	4421
BNE 992460.00	7364	4419
BNE 992570.00	7365	4440
BNE 993215.00	7373	4423

Chainage [m]	Discharge [m^3/s]	
	1974 Flood Event	1955 Flood Event
BNE 994260.00	7373	4424
BNE 995225.00	7379	4420
BNE 996335.00	7383	4418
BNE 997720.00	7390	4414
BNE 998810.00	7398	4412
BNE 999580.00	7401	4411
BNE 1000142.50	8056	4466
BNE 1000530.00	8054	4465
BNE 1001045.00	8053	4464
BNE 1001590.00	8050	4463
BNE 1002107.50	8048	4462
BNE 1002567.50	8047	4461
BNE 1003030.00	8046	4460
BNE 1003525.00	8044	4459
BNE 1004037.50	8043	4458
BNE 1004555.00	8042	4457
BNE 1005067.50	8041	4455
BNE 1005597.50	8039	4452
BNE 1006035.00	7293	3997
BNE 1006250.00	9971	4691
BNE 1006605.00	10279	4689
BNE 1007160.00	10276	4683
BNE 1007595.00	10273	4678
BNE 1007850.00	10261	4663
BNE 1008182.50	10260	4661
BNE 1008685.00	10258	4658
BNE 1009162.50	10257	4655
BNE 1009560.00	10256	4652
BNE 1010105.00	10253	4646
BNE 1010607.50	10251	4644
BNE 1010852.50	10250	4642
BNE 1011245.00	10249	4640
BNE 1011745.00	10247	4635
BNE 1012227.50	10244	4630
BNE 1012705.00	10218	4608
BNE 1013062.50	10216	4605
BNE 1013317.50	9936	4603
BNE 1013562.50	9934	4601
BNE 1013795.00	9803	4599
BNE 1014110.00	9798	4596
BNE 1014460.00	9794	4591
BNE 1014850.00	9760	4567
BNE 1015325.00	9758	4565
BNE 1015705.00	9756	4564
BNE 1015995.00	9892	4563
BNE 1016390.00	9891	4561
BNE 1016765.00	9888	4559
BNE 1017010.00	10176	4558
BNE 1017370.00	10174	4555
BNE 1017765.00	10171	4553
BNE 1018060.00	10169	4552
BNE 1018462.50	10168	4550
BNE 1018910.00	10166	4548
BNE 1019292.50	10166	4547

Chainage [m]	Discharge [m³/s]	
	1974 Flood Event	1955 Flood Event
BNE 1019677.50	10162	4545
BNE 1019990.00	10161	4544
BNE 1020320.00	10159	4541
BNE 1020677.50	10157	4539
BNE 1020962.50	10157	4538
BNE 1021317.00	10156	4537
BNE 1021627.00	10155	4536
BNE 1021805.00	10155	4535
BNE 1022000.00	10154	4534
BNE 1022340.00	10154	4533
BNE 1022807.50	10155	4532
BNE 1023305.00	10153	4531
BNE 1023825.00	10152	4529
BNE 1024321.50	10151	4528
BNE 1024816.50	10150	4526
BNE 1025215.00	10148	4524
BNE 1025475.00	10148	4523
BNE 1025880.00	10147	4522
BNE 1026425.00	10145	4521
BNE 1026790.00	10144	4520
BNE 1027030.00	10144	4519
BNE 1027420.00	10142	4518
BNE 1027930.00	10138	4516
BNE 1028430.00	10141	4514
BNE 1028720.00	10051	4513
BNE 1028980.00	10164	4512
BNE 1029440.00	10141	4510
BNE 1029950.00	10127	4508
BNE 1030545.00	10125	4503
BNE 1031065.00	10122	4502
BNE 1031480.00	10121	4500
BNE 1031847.50	10120	4500
BNE 1032112.50	10119	4499
BNE 1032407.50	10117	4497
BNE 1032832.50	10116	4496
BNE 1033225.00	10114	4495
BNE 1033635.00	10113	4494
BNE 1034135.00	10111	4492
BNE 1034630.00	10110	4491
BNE 1035152.00	10107	4489
BNE 1035657.00	10106	4487
BNE 1036180.00	10104	4485
BNE 1036615.00	10102	4484
BNE 1036842.50	10101	4483
BNE 1037002.50	10101	4482
BNE 1037110.00	10101	4482
BNE 1037230.00	10101	4482
BNE 1037455.00	10100	4481
BNE 1037855.00	10098	4479
BNE 1038342.50	10091	4477
BNE 1038850.00	10084	4473
BNE 1039150.00	10080	4470
BNE 1039382.50	9867	4467
BNE 1039617.50	9864	4465

Chainage [m]	Discharge [m³/s]	
	1974 Flood Event	1955 Flood Event
BNE 1039749.00	9617	4464
BNE 1039959.00	9395	4368
BNE 1040170.00	9396	4368
BNE 1040370.00	9253	4368
BNE 1040750.00	9254	4367
BNE 1041120.00	9254	4367
BNE 1041345.00	9255	4367
BNE 1041580.00	9255	4367
BNE 1041830.00	9255	4367
BNE 1042097.50	9255	4366
BNE 1042367.50	9256	4366
BNE 1042507.50	9399	4366
BNE 1042712.50	9399	4366
BNE 1042960.00	9399	4366
BNE 1043045.00	9692	4366
BNE 1043095.00	9692	4366
BNE 1043417.50	9952	4366
BNE 1043892.50	9953	4366
BNE 1044200.00	9953	4365
BNE 1044472.50	9953	4365
BNE 1044732.50	9954	4365
BNE 1045130.00	9955	4365
BNE 1045642.50	9956	4365
BNE 1046032.50	9957	4365
BNE 1046260.00	9958	4365
BNE 1046460.00	9958	4365
BNE 1046740.00	9958	4365
BNE 1047125.00	9959	4365
BNE 1047632.50	9960	4365
BNE 1048145.00	9961	4364
BNE 1048632.50	9963	4364
BNE 1049005.00	9964	4364
BNE 1049245.00	9964	4364
BNE 1049480.00	9965	4364
BNE 1049730.00	9965	4364
BNE 1050150.00	9966	4364
BNE 1050645.00	9967	4364
BNE 1051110.00	9968	4364
BNE 1051627.50	9970	4364
BNE 1052102.50	9971	4364
BNE 1052350.00	9972	4363
BNE 1052492.50	9972	4362
BNE 1052625.00	9972	4354
BNE 1052752.50	9972	4363
BNE 1053092.50	9973	4364
BNE 1053355.00	9973	4364
BNE 1053642.50	9974	4364
BNE 1054270.00	9976	4364
BNE 1054660.00	9977	4364
BNE 1054825.00	9977	4364
BNE 1055125.00	9978	4364
BNE 1055350.00	9978	4364
BNE 1055690.00	9979	4364
BNE 1056180.00	9981	4364

Chainage [m]	Discharge [m³/s]	
	1974 Flood Event	1955 Flood Event
BNE 1056547.50	9982	4364
BNE 1056780.00	9982	4364
BNE 1056920.00	9983	4364
BNE 1057020.00	9983	4364
BNE 1057310.00	9984	4364
BNE 1057785.00	9985	4364
BNE 1058135.00	9986	4364
BNE 1058380.00	9986	4364
BNE 1058632.50	9987	4364
BNE 1058885.00	9988	4364
BNE 1059287.50	9989	4364
BNE 1059765.00	9991	4364
BNE 1060167.50	9993	4364
BNE 1060440.00	9994	4364
BNE 1060775.00	9995	4364
BNE 1061272.50	9998	4364
BNE 1061775.00	10000	4364
BNE 1062277.50	10003	4364
BNE 1062737.50	10009	4364
BNE 1063032.50	10013	4364
BNE 1063217.50	10065	4365
BNE 1063477.50	10068	4365
BNE 1063822.50	10072	4365
BNE 1064245.00	10077	4365
BNE 1064750.00	10083	4365
BNE 1065256.50	10091	4365
BNE 1065746.50	10101	4365
BNE 1066247.50	10113	4365
BNE 1066762.50	10123	4365
BNE 1067252.50	10138	4365
BNE 1067725.00	10153	4365
BNE 1068312.50	10166	4365
BNE 1068852.50	10180	4365
BNE 1069290.00	10192	4365
BNE 1069780.00	10207	4365
BNE 1070277.50	10222	4365
BNE 1070785.00	10239	4365
BNE 1071280.00	10257	4365
BNE 1071767.50	10274	4365
BNE 1072017.50	10284	4365
BNE 1072267.50	10521	4366
BNE 1072755.00	10541	4366
BNE 1073240.00	10561	4366
BNE 1073742.50	10585	4366
BNE 1074230.00	10608	4366
BNE 1074722.50	10633	4366
BNE 1075232.50	10661	4366
BNE 1075740.00	10706	4366
BNE 1076247.50	10765	4366
BNE 1076752.50	10817	4366
BNE 1077260.00	10896	4366
BNE 1077775.00	10953	4366
BNE 1078282.50	10997	4366
BNE 1078592.50	11014	4366

Appendix E DESIGN EVENT Results

1% AEP Design Event	
Chainage [m]	Water Level [m]
BNE 931570.00	44.512
BNE 931580.00	44.5
BNE 933670.00	42.678
BNE 934270.00	42.551
BNE 934620.00	42.309
BNE 936070.00	42.116
BNE 936820.00	42.043
BNE 939770.00	41.435
BNE 942320.00	40.405
BNE 943570.00	40.197
BNE 944120.00	40.168
BNE 945570.00	40.055
BNE 947170.00	39.691
BNE 948270.00	39.336
BNE 950270.00	38.765
BNE 952320.00	37.926
BNE 953870.00	37.503
BNE 954920.00	37.124
BNE 955970.00	36.713
BNE 958770.00	35.479
BNE 960170.00	35.189
BNE 962070.00	34.431
BNE 964170.00	33.322
BNE 966610.00	31.842
BNE 967410.00	31.313
BNE 969790.00	30.09
BNE 971160.00	29.587
BNE 972260.00	29.335
BNE 973260.00	29.311
BNE 974580.00	29.115
BNE 976020.00	29.029
BNE 976750.00	29.024
BNE 978280.00	28.384
BNE 979507.00	26.448
BNE 979513.00	26.385
BNE 979530.00	26.404
BNE 980330.00	26.203
BNE 981660.00	25.76
BNE 982460.00	25.547
BNE 984160.00	25.028
BNE 985260.00	24.579
BNE 986480.00	23.812
BNE 987960.00	22.744
BNE 988160.00	22.429
BNE 988170.00	22.387
BNE 988360.00	22.177
BNE 989700.00	21.355
BNE 990700.00	20.973
BNE 990760.00	20.931
BNE 991710.00	20.676
BNE 992420.00	20.489
BNE 992450.00	20.438
BNE 992470.00	20.398
BNE 992670.00	20.306
BNE 993760.00	19.673
BNE 994760.00	19.314
BNE 995690.00	18.74
BNE 996980.00	17.529
BNE 998460.00	17
BNE 999160.00	16.757
BNE 1000000.00	16.501

Chainage [m]	Water Level [m]
BNE 1000285.00	16.314
BNE 1000775.00	16.033
BNE 1001315.00	15.895
BNE 1001865.00	15.533
BNE 1002350.00	15.401
BNE 1002785.00	15.383
BNE 1003275.00	15.218
BNE 1003775.00	15.099
BNE 1004300.00	14.821
BNE 1004810.00	14.768
BNE 1005325.00	14.637
BNE 1005870.00	14.457
BNE 1005870.00	14.457
BNE 1006200.00	14.397
BNE 1006200.00	14.397
BNE 1006300.00	14.363
BNE 1006300.00	14.363
BNE 1006910.00	14.148
BNE 1007410.00	14.053
BNE 1007780.00	13.882
BNE 1007780.00	13.882
BNE 1007920.00	13.791
BNE 1008445.00	13.764
BNE 1008925.00	13.714
BNE 1009400.00	13.595
BNE 1009720.00	13.523
BNE 1010490.00	13.277
BNE 1010725.00	13.31
BNE 1010980.00	13.275
BNE 1011510.00	13.302
BNE 1011980.00	13.311
BNE 1012475.00	13.289
BNE 1012475.00	13.289
BNE 1012935.00	13.262
BNE 1013190.00	13.244
BNE 1013190.00	13.244
BNE 1013445.00	13.223
BNE 1013680.00	13.215
BNE 1013680.00	13.215
BNE 1013910.00	13.201
BNE 1014310.00	13.129
BNE 1014610.00	13.007
BNE 1014610.00	13.007
BNE 1015090.00	12.869
BNE 1015560.00	12.735
BNE 1015850.00	12.673
BNE 1015850.00	12.673
BNE 1016140.00	12.609
BNE 1016640.00	12.435
BNE 1016890.00	12.313
BNE 1016890.00	12.313
BNE 1017130.00	12.183
BNE 1017610.00	12.052
BNE 1017920.00	11.932
BNE 1018200.00	11.919
BNE 1018725.00	11.73
BNE 1019095.00	11.642
BNE 1019490.00	11.605
BNE 1019490.00	11.605
BNE 1019865.00	11.431
BNE 1020115.00	11.485
BNE 1020525.00	11.459

Chainage [m]	Water Level [m]
BNE 1020830.00	11.351
BNE 1021095.00	11.189
BNE 1021539.00	10.987
BNE 1021715.00	10.971
BNE 1021895.00	10.893
BNE 1022105.00	10.785
BNE 1022575.00	10.67
BNE 1023040.00	10.461
BNE 1023570.00	10.421
BNE 1024080.00	10.371
BNE 1024563.00	10.331
BNE 1025070.00	10.302
BNE 1025360.00	10.219
BNE 1025590.00	10.101
BNE 1026170.00	9.952
BNE 1026680.00	9.838
BNE 1026900.00	9.738
BNE 1027160.00	9.637
BNE 1027680.00	9.626
BNE 1028180.00	9.616
BNE 1028680.00	9.493
BNE 1028760.00	9.423
BNE 1029200.00	9.301
BNE 1029680.00	9.287
BNE 1030220.00	9.297
BNE 1030870.00	9.238
BNE 1031260.00	9.148
BNE 1031700.00	8.977
BNE 1031995.00	9.014
BNE 1032230.00	8.923
BNE 1032585.00	8.713
BNE 1033080.00	8.573
BNE 1033370.00	8.51
BNE 1033900.00	8.342
BNE 1034370.00	8.189
BNE 1034890.00	8.101
BNE 1035414.00	7.986
BNE 1035900.00	7.819
BNE 1036460.00	7.634
BNE 1036770.00	7.561
BNE 1036915.00	7.49
BNE 1037090.00	7.505
BNE 1037175.00	7.246
BNE 1037285.00	7.2
BNE 1037625.00	7.197
BNE 1038085.00	7.175
BNE 1038600.00	7.135
BNE 1039100.00	7.1
BNE 1039200.00	7.099
BNE 1039200.00	7.099
BNE 1039565.00	7.096
BNE 1039670.00	7.099
BNE 1039670.00	7.099
BNE 1039828.00	7.099
BNE 1039828.00	7.099
BNE 1040090.00	7.091
BNE 1040250.00	7.06
BNE 1040250.00	7.06
BNE 1040490.00	6.991
BNE 1041010.00	7.017
BNE 1041230.00	6.989
BNE 1041460.00	6.939

Chainage [m]	Water Level [m]
BNE 1041700.00	6.935
BNE 1041960.00	6.82
BNE 1042235.00	6.681
BNE 1042500.00	6.635
BNE 1042500.00	6.635
BNE 1042515.00	6.633
BNE 1042910.00	6.479
BNE 1043010.00	6.426
BNE 1043010.00	6.426
BNE 1043080.00	6.389
BNE 1043110.00	6.376
BNE 1043110.00	6.376
BNE 1043725.00	6.158
BNE 1044060.00	6.075
BNE 1044340.00	5.98
BNE 1044605.00	5.956
BNE 1044860.00	5.942
BNE 1045400.00	5.875
BNE 1045885.00	5.822
BNE 1046180.00	5.848
BNE 1046340.00	5.831
BNE 1046580.00	5.795
BNE 1046900.00	5.611
BNE 1047350.00	5.246
BNE 1047915.00	5.007
BNE 1048375.00	5.03
BNE 1048890.00	4.865
BNE 1049120.00	4.841
BNE 1049370.00	4.715
BNE 1049590.00	4.691
BNE 1049870.00	4.595
BNE 1050430.00	4.499
BNE 1050860.00	4.409
BNE 1051360.00	4.414
BNE 1051895.00	4.28
BNE 1052310.00	4.395
BNE 1052390.00	4.273
BNE 1052595.00	4.243
BNE 1052640.00	3.966
BNE 1052865.00	3.928
BNE 1053320.00	3.97
BNE 1053385.00	3.821
BNE 1053900.00	3.62
BNE 1054640.00	3.553
BNE 1054680.00	3.502
BNE 1054970.00	3.326
BNE 1055280.00	3.244
BNE 1055420.00	3.201
BNE 1055960.00	3.121
BNE 1056400.00	2.954
BNE 1056695.00	2.918
BNE 1056865.00	3.031
BNE 1056950.00	2.969
BNE 1057090.00	2.89
BNE 1057530.00	2.82
BNE 1058040.00	2.665
BNE 1058230.00	2.624
BNE 1058530.00	2.571
BNE 1058735.00	2.582
BNE 1059035.00	2.447
BNE 1059540.00	2.396
BNE 1059990.00	2.245

Chainage [m]	Water Level [m]
BNE 1060345.00	2.103
BNE 1060535.00	2.043
BNE 1061015.00	2.023
BNE 1061530.00	1.937
BNE 1062020.00	1.917
BNE 1062535.00	1.903
BNE 1062940.00	1.907
BNE 1063125.00	1.874
BNE 1063125.00	1.874
BNE 1063310.00	1.845
BNE 1063645.00	1.705
BNE 1064000.00	1.705
BNE 1064490.00	1.636
BNE 1065010.00	1.647
BNE 1065503.00	1.62
BNE 1065990.00	1.636
BNE 1066505.00	1.589
BNE 1067020.00	1.574
BNE 1067485.00	1.51
BNE 1067965.00	1.454
BNE 1068660.00	1.375
BNE 1069045.00	1.343
BNE 1069535.00	1.322
BNE 1070025.00	1.302
BNE 1070530.00	1.26
BNE 1071040.00	1.23
BNE 1071520.00	1.26
BNE 1072015.00	1.208
BNE 1072020.00	1.208
BNE 1072020.00	1.208
BNE 1072515.00	1.187
BNE 1072995.00	1.172
BNE 1073485.00	1.122
BNE 1074000.00	1.09
BNE 1074460.00	1.067
BNE 1074985.00	1.078
BNE 1075480.00	1.089
BNE 1076000.00	1.089
BNE 1076495.00	1.071
BNE 1077010.00	1.045
BNE 1077510.00	1.012
BNE 1078040.00	0.972
BNE 1078525.00	0.921
BNE 1078660.00	0.918

Chainage [m]	Discharge [m3/s]
BNE 931575.00	6144
BNE 932625.00	6141
BNE 933970.00	6125
BNE 934445.00	6114
BNE 935345.00	6107
BNE 936445.00	6074
BNE 938295.00	6057
BNE 941045.00	6028
BNE 942945.00	5963
BNE 943845.00	5886
BNE 944845.00	5821
BNE 946370.00	5787
BNE 947720.00	5779
BNE 949270.00	5770
BNE 951295.00	5758
BNE 953095.00	5752
BNE 954395.00	5739
BNE 955445.00	5732
BNE 957370.00	5716
BNE 959470.00	5704
BNE 961120.00	5640
BNE 963120.00	5617
BNE 965390.00	5595
BNE 967010.00	5582
BNE 968600.00	5575
BNE 970475.00	5567
BNE 971710.00	5560
BNE 972760.00	5555
BNE 973920.00	5548
BNE 975300.00	5544
BNE 976385.00	5539
BNE 977515.00	5527
BNE 978893.50	5524
BNE 979510.00	5447
BNE 979521.50	5446
BNE 979930.00	5514
BNE 980995.00	5508
BNE 982060.00	5505
BNE 983310.00	5502
BNE 984710.00	5499
BNE 985870.00	5497
BNE 987220.00	5494
BNE 988060.00	5492
BNE 988165.00	5492
BNE 988265.00	5492
BNE 989030.00	5490
BNE 990200.00	5487
BNE 990730.00	5486
BNE 991235.00	5485
BNE 992065.00	5491
BNE 992435.00	5516
BNE 992460.00	5519
BNE 992570.00	5506
BNE 993215.00	5486
BNE 994260.00	5478

Chainage [m]	Discharge [m3/s]
BNE 995225.00	5479
BNE 996335.00	5481
BNE 997720.00	5480
BNE 998810.00	5478
BNE 999580.00	5478
BNE 1000142.50	5491
BNE 1000530.00	5491
BNE 1001045.00	5491
BNE 1001590.00	5491
BNE 1002107.50	5490
BNE 1002567.50	5490
BNE 1003030.00	5490
BNE 1003525.00	5490
BNE 1004037.50	5490
BNE 1004555.00	5490
BNE 1005067.50	5490
BNE 1005597.50	5489
BNE 1006035.00	4795
BNE 1006250.00	6011
BNE 1006605.00	6010
BNE 1007160.00	6008
BNE 1007595.00	6005
BNE 1007850.00	5998
BNE 1008182.50	5997
BNE 1008685.00	5995
BNE 1009162.50	5994
BNE 1009560.00	5993
BNE 1010105.00	5990
BNE 1010607.50	5989
BNE 1010852.50	5988
BNE 1011245.00	5987
BNE 1011745.00	5985
BNE 1012227.50	5983
BNE 1012705.00	5971
BNE 1013062.50	5969
BNE 1013317.50	5968
BNE 1013562.50	5967
BNE 1013795.00	5967
BNE 1014110.00	5965
BNE 1014460.00	5964
BNE 1014850.00	5956
BNE 1015325.00	5956
BNE 1015705.00	5955
BNE 1015995.00	5955
BNE 1016390.00	5955
BNE 1016765.00	5953
BNE 1017010.00	5953
BNE 1017370.00	5951
BNE 1017765.00	5949
BNE 1018060.00	5947
BNE 1018462.50	5946
BNE 1018910.00	5946
BNE 1019292.50	5946
BNE 1019677.50	5945
BNE 1019990.00	5945

Chainage [m]	Discharge [m3/s]
BNE 1020320.00	5945
BNE 1020677.50	5945
BNE 1020962.50	5945
BNE 1021317.00	5945
BNE 1021627.00	5945
BNE 1021805.00	5945
BNE 1022000.00	5945
BNE 1022340.00	5945
BNE 1022807.50	5950
BNE 1023305.00	5950
BNE 1023825.00	5951
BNE 1024321.50	5952
BNE 1024816.50	5955
BNE 1025215.00	5958
BNE 1025475.00	5960
BNE 1025880.00	5961
BNE 1026425.00	5957
BNE 1026790.00	5958
BNE 1027030.00	5960
BNE 1027420.00	5963
BNE 1027930.00	5971
BNE 1028430.00	5992
BNE 1028720.00	6048
BNE 1028980.00	6003
BNE 1029440.00	5980
BNE 1029950.00	5971
BNE 1030545.00	5961
BNE 1031065.00	5957
BNE 1031480.00	5955
BNE 1031847.50	5958
BNE 1032112.50	5960
BNE 1032407.50	5961
BNE 1032832.50	5961
BNE 1033225.00	5958
BNE 1033635.00	5956
BNE 1034135.00	5954
BNE 1034630.00	5952
BNE 1035152.00	5949
BNE 1035657.00	5948
BNE 1036180.00	5948
BNE 1036615.00	5949
BNE 1036842.50	5950
BNE 1037002.50	5950
BNE 1037110.00	5950
BNE 1037230.00	5950
BNE 1037455.00	5950
BNE 1037855.00	5950
BNE 1038342.50	5949
BNE 1038850.00	5948
BNE 1039150.00	5947
BNE 1039382.50	5947
BNE 1039617.50	5946
BNE 1039749.00	5946
BNE 1039959.00	5977
BNE 1040170.00	5977

Chainage [m]	Discharge [m3/s]
BNE 1040370.00	5977
BNE 1040750.00	5976
BNE 1041120.00	5976
BNE 1041345.00	5975
BNE 1041580.00	5975
BNE 1041830.00	5974
BNE 1042097.50	5974
BNE 1042367.50	5974
BNE 1042507.50	5974
BNE 1042712.50	5974
BNE 1042960.00	5974
BNE 1043045.00	5974
BNE 1043095.00	5974
BNE 1043417.50	5975
BNE 1043892.50	5975
BNE 1044200.00	5975
BNE 1044472.50	5975
BNE 1044732.50	5975
BNE 1045130.00	5974
BNE 1045642.50	5974
BNE 1046032.50	5973
BNE 1046260.00	5973
BNE 1046460.00	5973
BNE 1046740.00	5973
BNE 1047125.00	5973
BNE 1047632.50	5973
BNE 1048145.00	5973
BNE 1048632.50	5972
BNE 1049005.00	5972
BNE 1049245.00	5972
BNE 1049480.00	5972
BNE 1049730.00	5972
BNE 1050150.00	5972
BNE 1050645.00	5972
BNE 1051110.00	5972
BNE 1051627.50	5972
BNE 1052102.50	5973
BNE 1052370.00	5977
BNE 1052492.50	5978
BNE 1052625.00	5998
BNE 1052752.50	5973
BNE 1053092.50	5971
BNE 1053355.00	5971
BNE 1053642.50	5972
BNE 1054270.00	5972
BNE 1054660.00	5971
BNE 1054825.00	5971
BNE 1055125.00	5971
BNE 1055350.00	5971
BNE 1055690.00	5971
BNE 1056180.00	5971
BNE 1056547.50	5971
BNE 1056780.00	5971
BNE 1056920.00	5971
BNE 1057020.00	5971

Chainage [m]	Discharge [m3/s]
BNE 1057310.00	5971
BNE 1057785.00	5971
BNE 1058135.00	5971
BNE 1058380.00	5971
BNE 1058632.50	5971
BNE 1058885.00	5971
BNE 1059287.50	5971
BNE 1059765.00	5971
BNE 1060167.50	5971
BNE 1060440.00	5971
BNE 1060775.00	5971
BNE 1061272.50	5971
BNE 1061775.00	5971
BNE 1062277.50	5972
BNE 1062737.50	5972
BNE 1063032.50	5972
BNE 1063217.50	6242
BNE 1063477.50	6252
BNE 1063822.50	6253
BNE 1064245.00	6252
BNE 1064750.00	6250
BNE 1065256.50	6244
BNE 1065746.50	6235
BNE 1066247.50	6225
BNE 1066762.50	6223
BNE 1067252.50	6225
BNE 1067725.00	6222
BNE 1068312.50	6221
BNE 1068852.50	6221
BNE 1069290.00	6221
BNE 1069780.00	6225
BNE 1070277.50	6228
BNE 1070785.00	6230
BNE 1071280.00	6236
BNE 1071767.50	6239
BNE 1072017.50	6240
BNE 1072267.50	6497
BNE 1072755.00	6497
BNE 1073240.00	6496
BNE 1073742.50	6495
BNE 1074230.00	6493
BNE 1074722.50	6493
BNE 1075232.50	6495
BNE 1075740.00	6498
BNE 1076247.50	6504
BNE 1076752.50	6509
BNE 1077260.00	6514
BNE 1077775.00	6517
BNE 1078282.50	6518
BNE 1078592.50	6518

City Design - Flood Modelling Services

RECALIBRATION OF THE MIKE11 HYDRAULIC MODEL AND DETERMINATION OF THE 1 IN 100 AEP FLOOD LEVELS

- Final Report
- 05/02/2004



- Final Report
- 05/02/04

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Executive Summary

In June 1998 SKM developed a MIKE11 hydraulic model as part of the Brisbane River Flood Study for Brisbane City Council. This model was then used as a base model for the model developed for the Ipswich Rivers Flood Studies (SKM 2000). During the Ipswich Study, many additional rivers and creeks were added to the hydraulic model.

These additional rivers/creeks changed the Brisbane River routing characteristics, consequently the model needed to be re-calibrated. Re-calibration was only performed within the Ipswich City Council boundary.

Further work was therefore required to re-calibrate the hydraulic model within the Brisbane City boundary. The purpose of this report is to present the findings of the re-calibration of the Brisbane River model.

The 1974 and 1955 flood events were used to calibrate the hydraulic model. These events were chosen because they provide an adequate calibration envelope so that the 1 in 100 year design event can be accurately modelled.

Calibration was generally achieved to within the general specification tolerances.

A design 1 in 100 AEP event was run based on a flow of 6000 m^3/s at the Brisbane Port Office Gauge. This corresponds to the 'best guess' report by the expert panel (IRP 2003).

1. Introduction

The purpose of this report is to present the findings of the re-calibration of the Brisbane River Hydraulic Model. This model was calibrated using the 1974 and 1955 flood events.

The Calibration process involved

- Updating and re-running the 1955 RAFTS Model
- Re-calibrating the 1955 RAFTS Model (loss rates only)
- Extraction of hydrographs from the 1955 RAFTS model and input into MIKE11
- Extraction of hydrographs from the 1974 RAFTS model and input into MIKE11
- Adjusting roughness values in the 1974 and 1955 MIKE11 model. Iterating until the best match between predicted water levels and recorded water levels was achieved.

The 1974 and 1955 events were chosen because there is reliable historical flood level data for flood events. The flows for these events in the subject reach of the river are approximately 10 000 m^3/s (1974) and 4400 m^3/s (1955). This provides an envelope in which the design event can be accurately predicted. A design 1 in 100 AEP event was run based on a flow of 6000 m^3/s at the Brisbane Port Office Gauge. This corresponds to the 'best guess' report by the expert panel (IRP 2003).

2. Hydrology

2.1 General

A RAFTS hydrologic model was developed as part of the Brisbane River Flood Study (SKM 1998). This study required that hydrologic model calibration/verification be undertaken for a total of 8 historical flood events. These events are presented in **Table 1**.

Table 1 Brisbane River Flood Study Calibration/Verification Events

Calibration Events	Verification Events
January 1974	February 1931
June 1983	March 1955
Late April 1989	July 1973
May 1996	Early April 1989

In June 2000, the Ipswich Rivers Flood Studies (SKM 2000) was completed. All rivers within the study area fell within the Brisbane River Catchment and thus the Brisbane River RAFTS model was used as a basis of the Studies. Sub-catchment areas were refined in order to better represent the river network within the study area and therefore model re-calibration had to be undertaken. The re-calibration was performed on 4 events for the Ipswich Rivers Flood Studies. These calibration events are presented in **Table 2**.

Table 2 Ipswich River Flood Studies Calibration Events

Calibration Events
January 1974
June 1983
Late April 1989
May 1996

Verification events were not re-run for the Ipswich River Flood Studies.

For this investigation, it was considered that the 1974 and 1955 historical flood events would provide the best calibration range for the 1 in 100 AEP flood event. It was therefore necessary to rerun the 1974 and 1955 historical flood events and extract the hydrographs for use in the MIKE11 hydraulic model.

2.2 1974 Historical Flood Event

The 1974 event was originally modelled using RAFTS as part of the Brisbane River Flood Study (SKM 1998). As part of the Ipswich Rivers Flood Studies (SKM 2000) the Brisbane River RAFTS

model was updated and re-calibrated. Re-calibration of the 1974 hydrologic model was not required. A comparison of the RAFTS predicted hydrographs and recorded hydrographs for the 1974 flood event have been provided in Appendix A. These hydrographs have been directly taken from the Ipswich Rivers Flood Studies Report (SKM 2000).

2.3 1955 Historical Flood Event

The 1995 event was not re-run as part of the Ipswich Rivers Flood Studies and subsequently the 1955 had to be run through the updated Brisbane River RAFTS model. As a result, loss rates reported in the Brisbane River Flood Study Report (SKM 1998) were adjusted to provide a better calibration. **Table 3** presents the adopted loss rates.

Table 3 Rainfall Losses March 1955 calibration

Catchment Location	New Model Initial Loss	New Model Continuing Loss	Old Model Initial Loss	Old Model Continuing Loss
Brisbane	100	2.5	100	2.5
Bremer	50	1.5	50	1.5
Lockyer	90	1.8	85	2.5
Somerset	130	2.5	130	2.5
Wivenhoe	60	2.0	20	1.8

A comparison of the RAFTS predicted hydrographs and recorded hydrographs for the 1955 flood event have been provided in **Appendix A**. The magnitude of the discharge was matched for the key locations. Generally a good match was achieved however the timing of the peak discharge predicted by the RAFTS model for the Vernor gauging station was earlier than that of the recorded hydrograph. One possible explanation for the delay in the recorded hydrograph at Vernor Gauge is the storage of runoff by Somerset Dam. Although the dam was not completed, some storage was available. This storage could have resulted in delaying flows from the upstream portion of the catchment. This explanation would seem reasonable as the remainder of the hydrographs provide good agreement with timing.

The only catchment parameters adjusted for the 1955 event were loss rates. Various loss regimes were trialed in order to match the timing of the hydrograph at Vernor Gauge. The adopted loss regime presented in **Table 3** provides the best overall match.

3. Hydraulic Model Calibration

3.1 General

The hydraulic model MIKE developed for the Brisbane River Flood Study (SKM 1998) was used as a base model for the model developed for the Ipswich Rivers Flood Studies (SKM 2000). During the Ipswich Study, many additional rivers and creeks were added to the hydraulic model.

These additional rivers/creeks changed the Brisbane River routing characteristics, consequently the model needed to be re-calibrated. Re-calibration was only performed within the Ipswich City Council boundary, and therefore further work was required to re-calibrate the hydraulic model within the Brisbane City boundary.

Generally, the upper reach of the Brisbane River from MIKE11 model chainage BNE 964km to BNE 990 km consists of mainly open grassed and treed floodplains with severe meanders at various locations. Rural properties are located at various levels along this reach.

The reach of the Brisbane river from MIKE11 model chainage BNE 990 km to BNE 1040 km consists of mainly open grassed and treed floodplains with severe meanders at various locations. Residential properties are located at various intervals and levels along this reach. These residential properties could be described as low density areas.

From chainage BNE 1040 km to BNE 1070 km the reach could be described as medium to high density residential areas which include the inner city area. The general shape of the river could be described as severely meandering.

The lower reach of the Brisbane River from BNE 1070 km to BNE 10788.66 km is relatively uniform with no major bends. Industry and residential properties line the banks along with mangrove swamps close to the river outlet.

The hydraulic model used for this assessment extends outside the Brisbane City Boundary however for completeness all results have been provided. Chainage 967.41 kms and downstream fall within the Brisbane City Boundary.

Model calibration involves the selection of appropriate model schematisatisation and model parameters in order to match simulated and recorded water levels and discharges. This involves an iterative process and the careful selection of roughness parameters which reflect channel and floodplain conditions and an accurate description of flow movement.

3.2 Channel Roughness

Channel roughness values (Mannings 'n') selected were initially based on site visits, examination of aerial photographs and past experience from other flood studies. In order to achieve a reasonable match between recorded and predicted flood levels, roughness values were modified in some locations to better reflect the hydraulic behaviour of the flood.

The model has been re-calibrated against the 1974 and 1955 flood events. This was achieved by matching the water levels predicted by the MIKE11 hydraulic model with actual recorded data by altering the channel roughness values in the MIKE11 model.

The hydraulic model was first calibrated for the 1974 event. The same roughness values were then used for the 1955 event. The figure in **Appendix C** compares the roughness parameters used in the previous model and that of the new model.

Generally, acceptable calibration is considered to be achieved when predicted levels are within general calibration tolerances of 150 mm of maximum height records. 100 mm of continuous flood level records and 200 mm of other sources of flood levels.

3.3 January 1974 Flood Event

The January 1974 flood event was the largest flood event that has occurred in the Brisbane River System in recent times. This event was considered to be the primary calibration event because a large amount of recorded flood level information was available.

At the time of this flood Wivenhoe dam had not been constructed and this enabled good calibration of the discharge hydrographs to be achieved. The Merivale Bridge was not constructed until 1975 and therefore not modelled for the 1974 calibration.

3.4 March 1955 Flood Event

The 1955 flood event commenced on the 26 March 1955 and was the third largest recorded flood event last century. The event continued over a period of three days. Although Somerset Dam was not fully completed for the 1955 its storage had been constructed. At the time of the flood, the only structures on the Brisbane River downstream of Mt Crosby weir were Indooroopilly Bridge, William Jolly Bridge, Victoria Bridge and the Story Bridge.

The adopted tailwater level at the Western Inner Bar for this event was 1.3 m AHD which is consistent with the tailwater adopted for the Brisbane River Flood Study (SKM 1998).

4. Results

For gauging stations with continuous records it was possible to compare the recorded hydrograph with hydrographs predicted by the model. For the 1974 event, predicted and recorded hydrographs generally good agreement (Refer **Appendix B**).

For the 1955 event, the peak water levels for the predicted hydrographs generally matched the peak of the recorded hydrographs. The timing for predicted hydrographs occurs earlier than the recorded hydrograph, this appears to be caused by the same problem that affected the RAFTS hydrographs already mentioned in **section 2.3.** The hydrographs for the Port Office Gauge did not match, however it appears that there are errors in the recorded hydrograph, as it is not consistent with the rest of the hydrographs.

For both events the recorded spot levels varied significantly depending on whether the level was taken on the outside or inside of the bend. The predicted levels outside the maximum allowable tolerance of 0.2m were checked and in most cases were deemed to be likely due to superelevation at bends or incorrect recorded level information. This was primarily decided by looking at surrounding levels and identifying outliers in the recorded levels.

In some reaches of the Brisbane River, higher than expected roughness values were required to achieve calibration. After checking the locations where high valnes were required, it was found that high roughness values corresponded to bends in the river. A plot of bend locations and corresponding roughness are presented in **Appendix C.**

4.1 Flood Levels

Table 4 & 5 outline the peak flood levels predicted by the model at the gauging stations for both the 1974 and 1955 flood events. A complete record can be found in **Appendix D.** For the 1974 event, predicted flood levels were generally within 100mm of the recorded levels at continuous flood level gauges.

« Table 4 Peak Flood Levels 1974

Chainage	Predicted Flood Level	Recorded Flood Level		Difference
		Left Bank	Right Bank	
Mt. Crosby Weir (43003A)	26.81	26.74		0.07
Mt. Crosby (040142/040818)	26.75	26.83		-0.08
Moggill Gauge	19.91	19.93	20.04	-0.08
Goodna Hospital Gauge	18.44		18.43	0.01
Mt Ommaney Gauge	14.67	14.55	14.58	0.10
Darra Wharf Gauge	13.52	13.36	13.79	-0.05

Sherwood Gauge	12.43		12.52	-0.09
Clarence Road Gauge	11.14		11.20	-0.06
Oxley Creek Gauge	11.15		11.01	0.14
King Authur Terrace Gauge	11.11		11.04	0.07
Tennyson Power House Gauge	10.93		10.83	0.10
Yeronga Street Gauge	10.77		10.83	-0.06
Sandy Creek Gauge	9.81		9.81	0.00
Dutton Park Cemetery Gauge	9.50		9.57	-0.08
Highgate Hill Gauge	8.29		8.36	-0.07
St Lucia Ferry Gauge	8.15		8.09	0.06
Montague Road Gauge	6.46		6.56	-0.10
Port Office Gauge	5.28	4.95	5.44	0.09
Newstead Park Gauge	2.88	2.60	3.30	-0.07
Cresent Road Gauge	2.61	2.63	2.63	-0.02
Cairncross Dock Gauge	2.47		2.49	-0.02
Bulimba Power House Gauge	1.83		1.90	-0.07
Western Inner Bar Gauge	1.55		1.55	-0.01

Predicted flood levels for the 1955 event were generally within 150 mm of the recorded levels. Water Levels toward the lower end of the Brisbane River were higher in the Mike11 model than the recorded levels; this could be a result of

- less development along the river bank than the 1974 case
- changes in river bathymetry due to erosion sedimentation and or dredging
- for this event only the Story, Victoria, William Jolly and Indooroopilly bridges had been constructed.
- for this event the majority of gauging stations were only manually read as opposed to automatic readings for the 1974 flood

Nevertheless a good calibration was achieved for the 1974 event and a reasonable calibration was achieved for the 1955 event. The 1974 event is considered to be the primary calibration event because it better reflects current river conditions and because more historical data is available.

Table 5 Peak Flood Levels 1955

Chainage	Predicted Flood Level	Recorded Flood Level	Difference
Clarence Road Gauge	5.30	5.56	-0.26
King Authur Terrace Gauge	5.18	5.10	0.08
Yeronga Street Gauge	4.98	4.95	0.03
Sandy Creek Gauge	4.41	4.65	-0.25
Dutton Park Cemetery Gauge	4.22	4.12	0.09
Highgate Hill Gauge	3.62	3.82	-0.20
Port Office Gauge	2.50	2.28	0.22
Newstead Park Gauge	1.72	1.75	-0.03
Western Inner Bar Gauge	1.30	1.30	0.00

4.2 Peak Flows

Predicted discharges for the Port Office Gauge were 9979 m^3/s (1974) and 4364 m^3/s (1955). A complete record of peak flows predicted by the model can be found in **Appendix D.**

5. Design Event Modelling

5.1 Background

In October 2003 a review was undertaken of the Brisbane River catchment hydrology. As part of this review, it was decided that the design 1 in 100 AEP event would be based on a flow of 6000 m^3/s at the Brisbane Port Office Gauge. This corresponds to the 'best guess' report by the expert panel (IRP 2003).

Because no events that corresponded to 6000 m^3/s at the Port Office Gauge had previously been modelled, it was decided that a CRC FORGE event (modelled as part of the SKM 2003 review) would be used as a base model for the 1 in 100 AEP design event. Hydrographs for the CRC-FORGE event would be scaled accordingly to give a discharge of 6000 m^3/s at the Port Office Gauge.

The 1% AEP CRC-FORGE event is spatially distributed with areal reduction factors using a standard AR&R (1987) temporal pattern. It was run using the 'Post Dams' case with a critical duration of 72 hours (Refer Brisbane River Flood Study Review, SKM, Oct 2003). The discharges predicted by this event are presented in **Table 6**. It should be noted that these discharges were calculated before the model was fully calibrated.

Table 6 CRC-FORGE event – RAFTS Model – Discharges

Gauge Location	Chainage	Discharge
Savages crossing	Ch 948270 m	5368 m^3/s
Moggill	Ch 1006300 m	5043 m^3/s
Port Office	Ch 1055690 m	5044 m^3/s

This CRC-FORGE event was chosen because it was the only event that gave a reasonably consistent discharge throughout the Brisbane River.

5.2 Results

Hydrographs were extracted from the RAFTS model and input into the calibrated MIKE 11 model. This produced a peak at the Port Office Gauge discharge of 5273 m^3/s (refer **Table 7**).

Table 7 CRC-FORGE event – MIKE 11 Model – Discharges

Gauge Location	Chainage	Discharge
Savages crossing	Ch 948270 m	5084 m^3/s
Moggill	Ch 1006300 m	5298 m^3/s
Port Office	Ch 1055690 m	5273 m^3/s

The difference between the values in **Table 6** and **Table 7** are the result of routing affects.

The expert review panel (IRP 2003) recommended a discharge of 6 000 m^3/s at the Port Office Gauge for the 1% AEP event. During the work SKM undertook there was no RAFTS run that produced this flow and hence a factored event was derived.

To achieve the desired discharge at the Port Office Gauge, all the input hydrographs were scaled up by a factor of 1.117 (ie 6000m^3/s / 5273m^3/s = 1.117) and the MIKE 11 model re-run. The resulting discharge at the Port Office Gauge was 5971 m^3/s (refer **Table 8**). This is only 0.5% less then 6000 m^3/s and therefore considered acceptable. A full record of discharges is presented in **Appendix E.**

- Table 8 CRC-FORGE event – MIKE 11 Model – Discharges (with scaled up hydrographs)

Gauge Location	Chainage	Discharge
Savages crossing	Ch 948270 m	5775 m^3/s
Moggill	Ch 1006300 m	6011 m^3/s
Port Office	Ch 1055690 m	5971 m^3/s

Flood levels for the 1 in 100 year AEP event are outlined in **Table 9,** a full record of flood levels are presented in **Appendix E.**

- Table 9 CRC-FORGE event – MIKE 11 Model – Flood Levels (with scaled up hydrographs)

Gauge Location	Chainage	Level
Savages crossing	Ch 948270 m	39.34 m
Moggill	Ch 1006300 m	14.36 m
Port Office	Ch 1055690 m	3.16 m

Bibliography

Sinclair Knight Merz (1998) *Brisbane River Flood Study*, report for Brisbane City Council, June 1998.

Sinclair Knight Merz (2000) *Ipswich River Flood Study*, report for Ipswich City Council, July 2000.

Sinclair Knight Merz (2003) *Brisbane River Flood Study – Further Investigation of Flood Frequency Analysis Incorporating Dam Operations and CRC-FORGE Rainfall Estimates-Brisbane River*, Report for Brisbane City Council, December 2003.

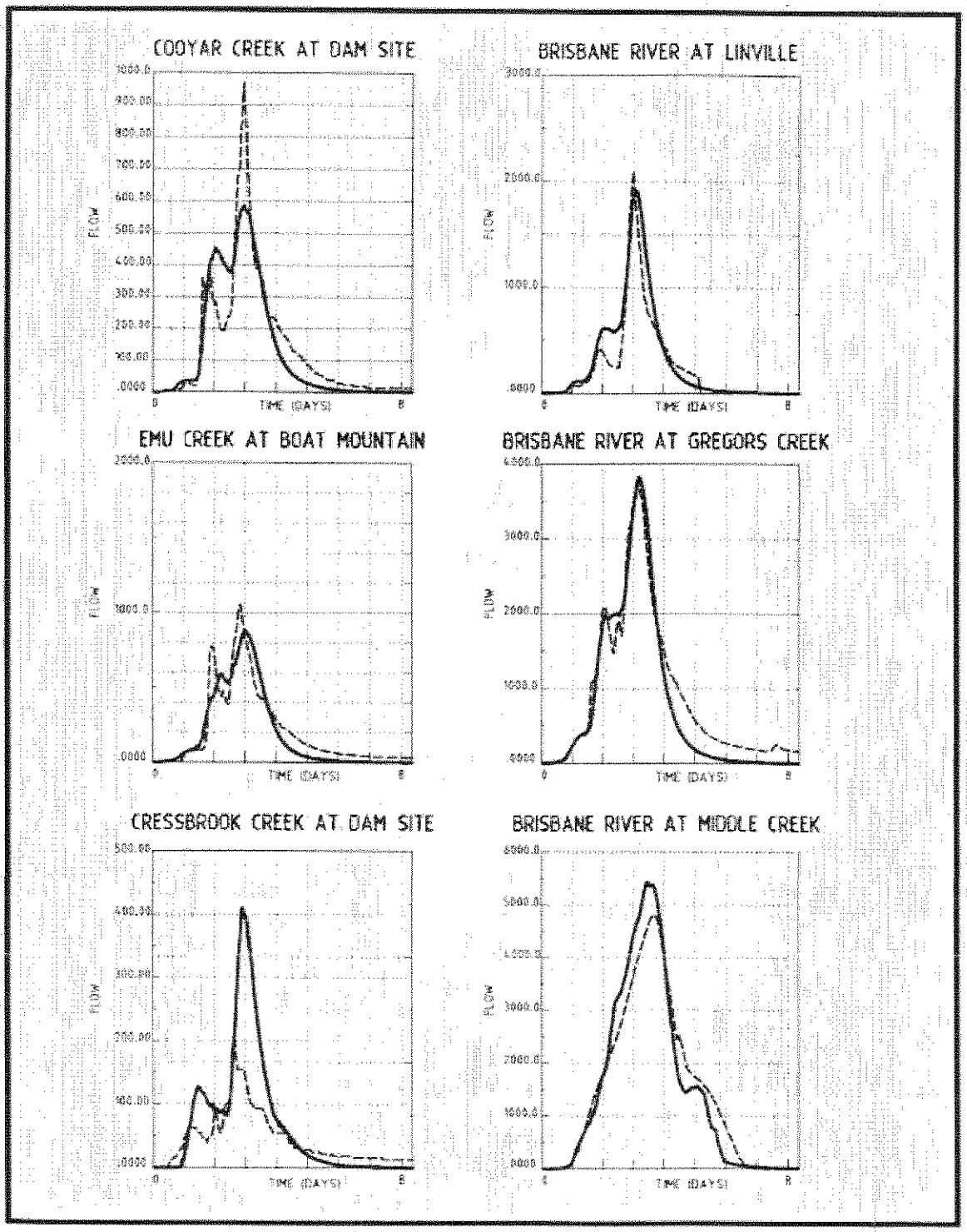
Independent Review Panel (2003) *Review of Brisbane River Flood Study*, Report for Brisbane City Council, September 2003.

Appendix A Hydrological Hydrograph Comparison

SINCLAIR KNIGHT MERZ

FIGURE C-2a

IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

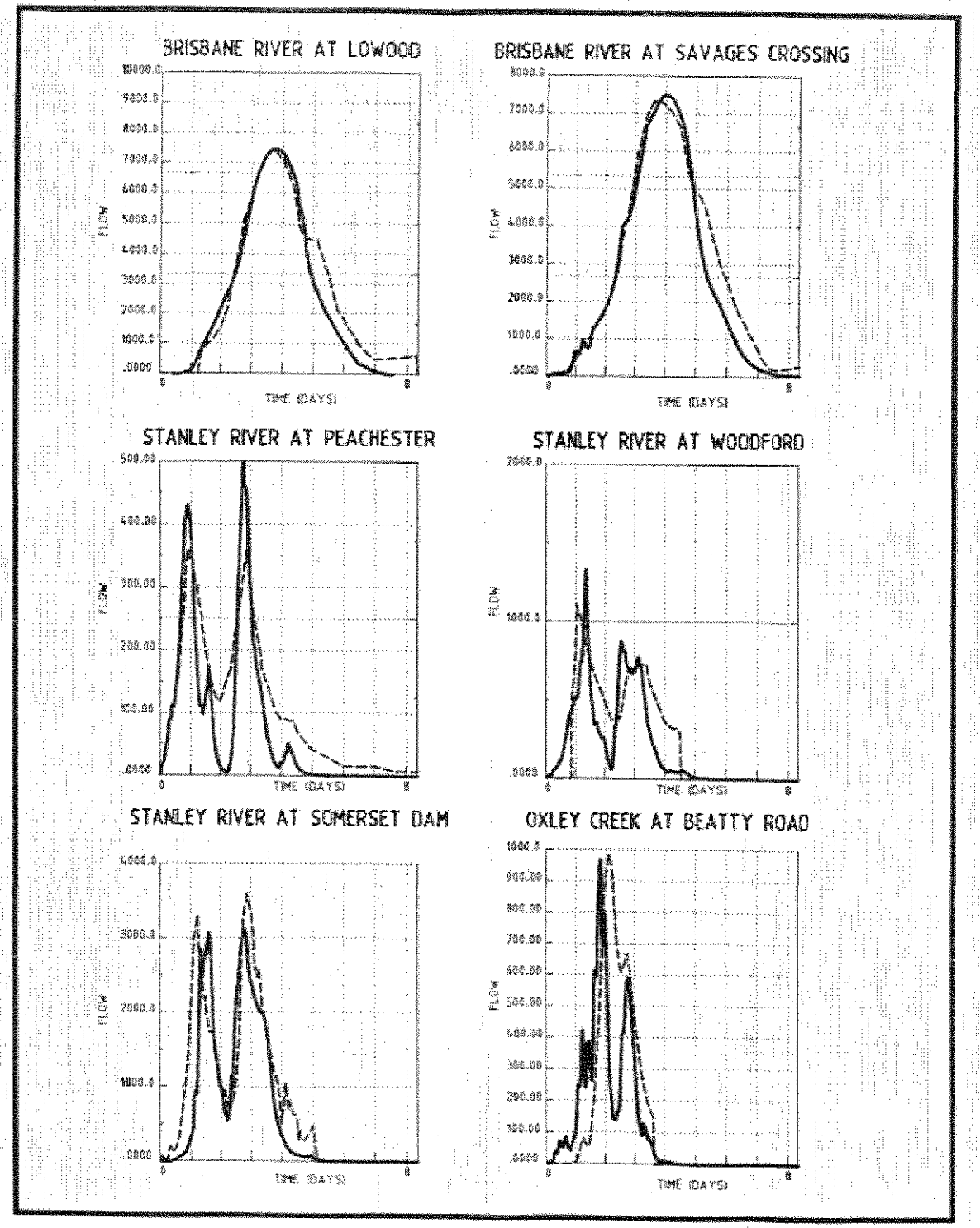
- - - - - - - - RECORDED DISCHARGE

———— PREDICTED DISCHARGE

FILE NAME 04390-22 DISK N° UNFWUD JOB N° 7004390 DATE 20-05-99
PLOT SCALE 1:100

SINCLAIR KNIGHT MERZ

FIGURE C-2b
IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



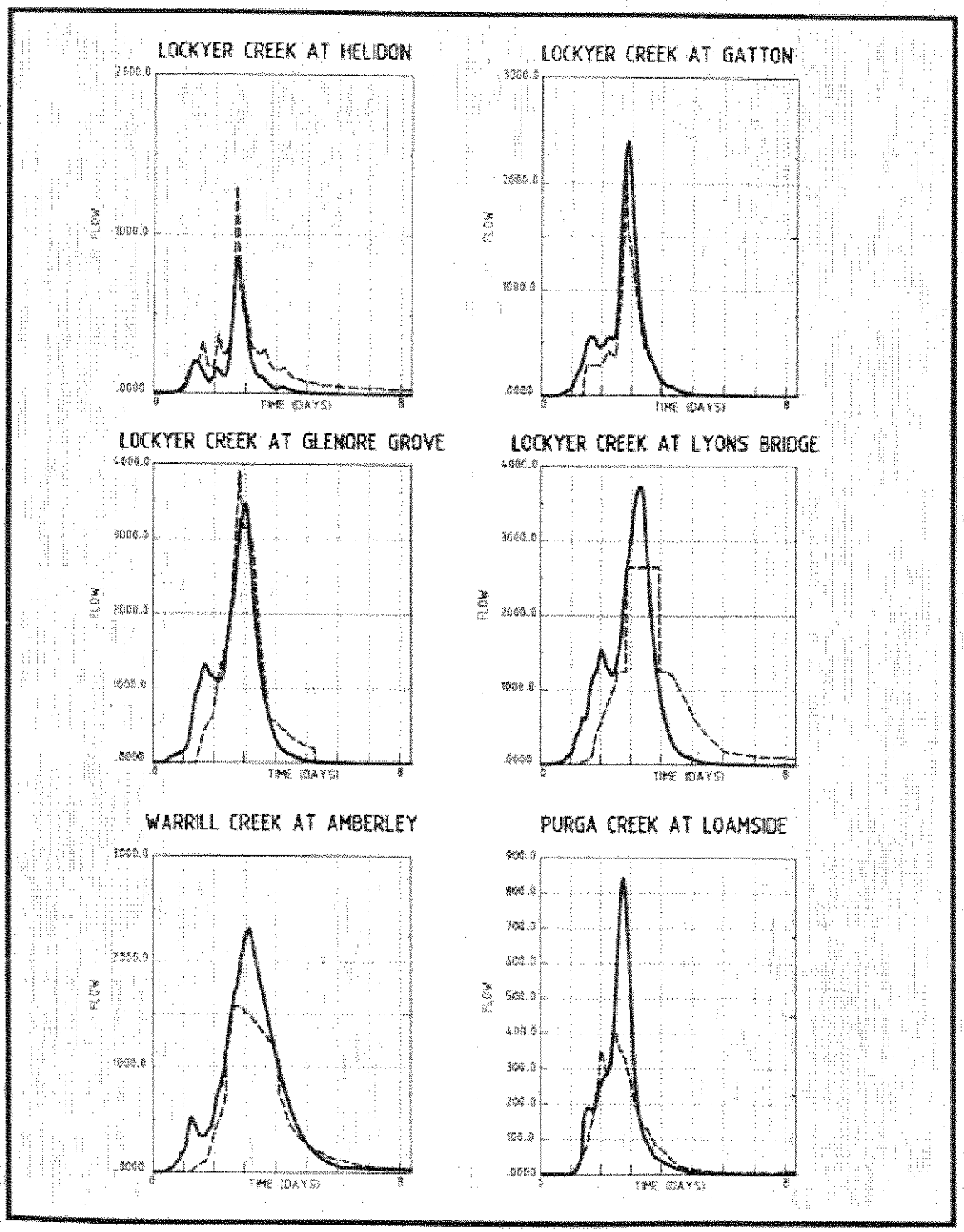
LEGEND
- - - - - - - RECORDED DISCHARGE
——— PREDICTED DISCHARGE

FILE NAME 04390-22 DISK N° U:\FWUD JOB N° 1004390 DATE 20-05-99
PLOT SCALE 1:100

SINCLAIR KNIGHT MERZ

FIGURE C-2c

IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

- - - - - - RECORDED DISCHARGE

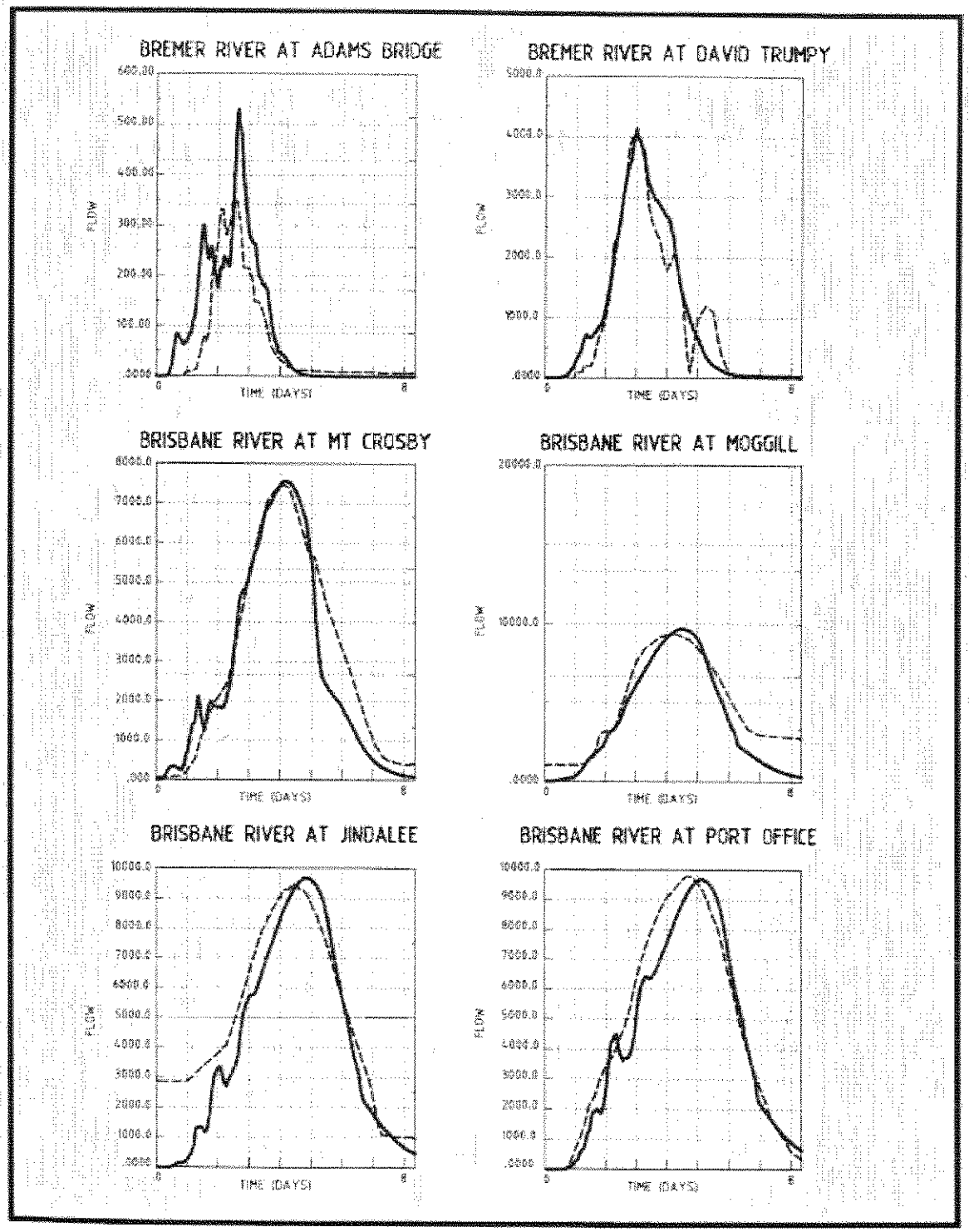
——— PREDICTED DISCHARGE

FILE NAME: 04399-22 DISK N°: U:\FWUD JOB N°: T004390 DATE: 20-05-99
PLOT SCALE: 1:100

SINCLAIR KNIGHT MERZ

FIGURE C-2d

IPSWICH RIVERS FLOOD STUDY
JANUARY 1974 FLOOD HYDROGRAPHS



LEGEND

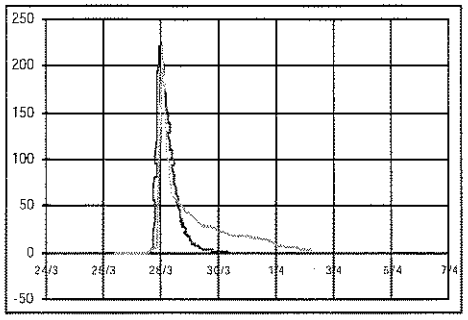
- - - - - - - RECORDED DISCHARGE

———— PREDICTED DISCHARGE

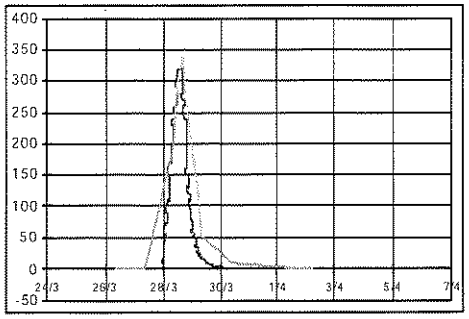
FILE NAME 04395-22 DISK NO. U:\FWUD JOB NO. T004390 DATE 20-15-99
PLOT SCALE 1:100

1955 Historical Event Comparison

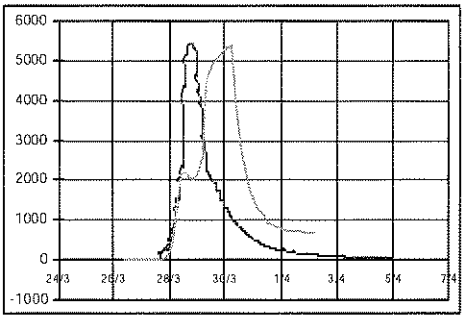
143203A Lockyer Creek AMTD 99.5
HEL-OUT Helidon Predicted
DISCHARGE (m^3/S) Recorded



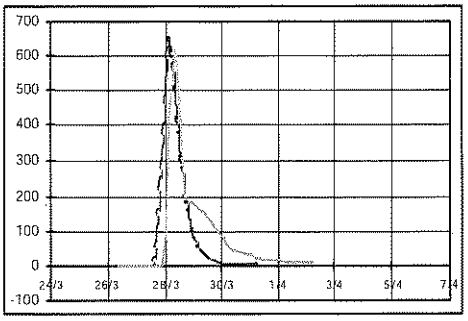
143102A Warrill Creek AMTD 50.9
KAL-OUT Kalbar Predicted
DISCHARGE (m^3/S) Recorded



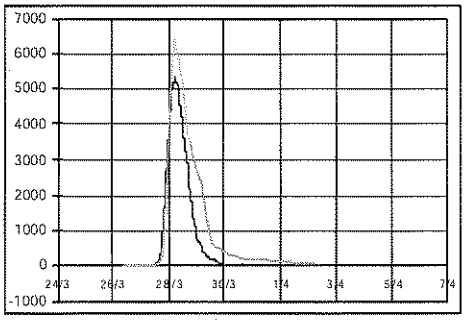
143001B Brisbane River AMTD 140.1
SAV11 Vernor Predicted
DISCHARGE (m^3/S) Recorded



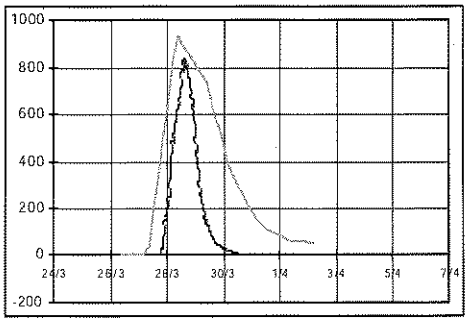
143204A Lockyer Creek AMTD 62.0
LYO+ Wilsons Weir Predicted
DISCHARGE (m^3/S) Recorded

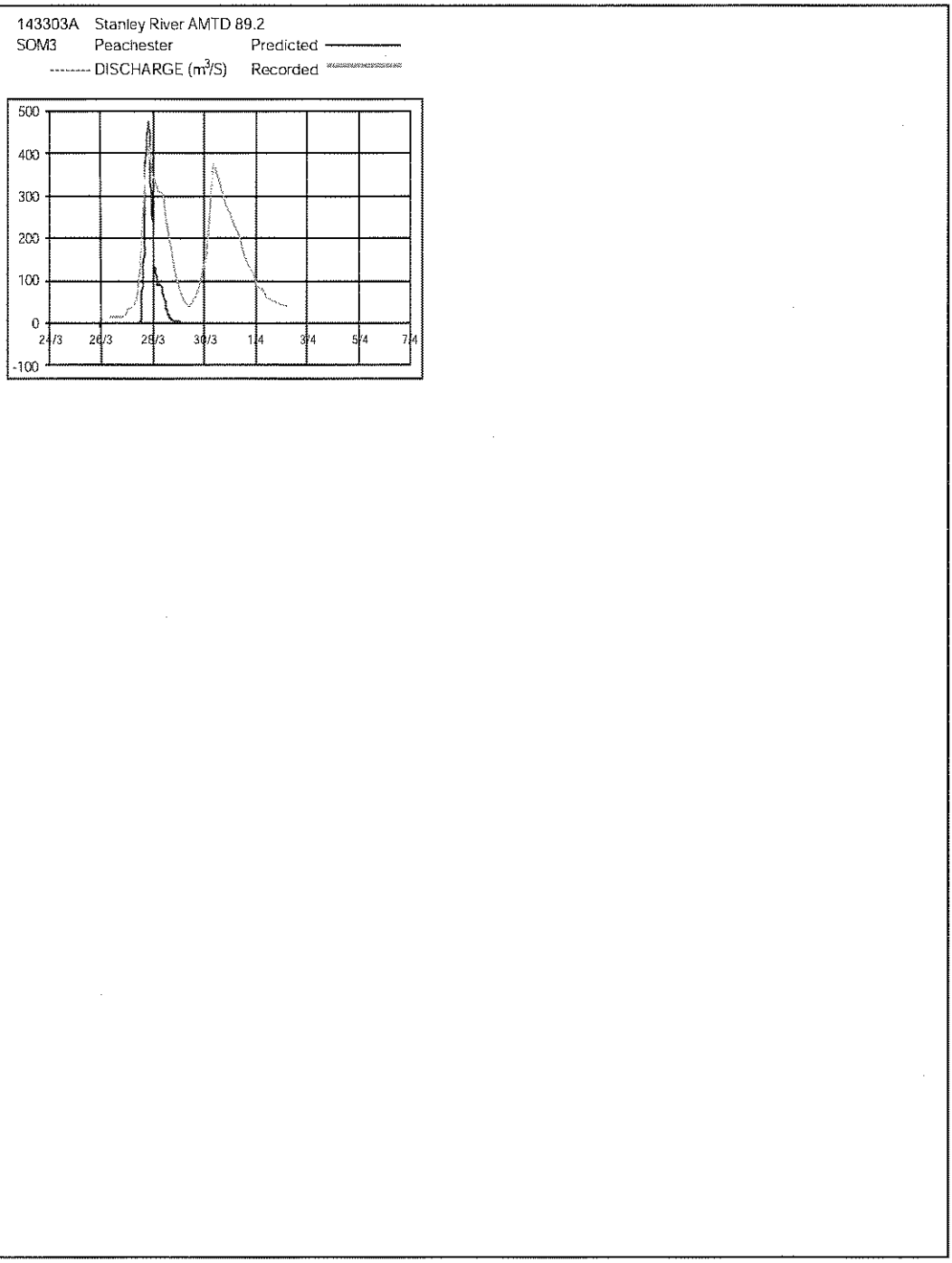


143005A Brisbane River AMTD 230.9
WIV8 Watts Bridge Predicted
DISCHARGE (m^3/S) Recorded



143206A Lockyer Creek AMTD 36.4
LYO-OUT Brightview Weir Predicted
DISCHARGE (m^3/S) Recorded

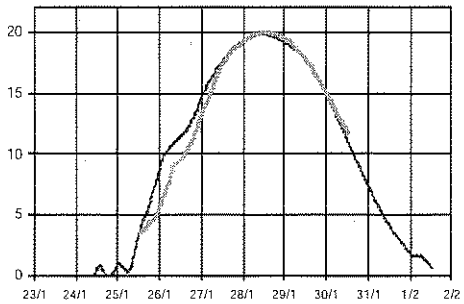



143303A Stanley River AMTD 89.2
SOM3 Peachester Predicted
DISCHARGE (m3/S) Recorded
500
400
300
200
100
0
-100
24/3
26/3
28/3
30/3
1/4
3/4
5/4
7/4

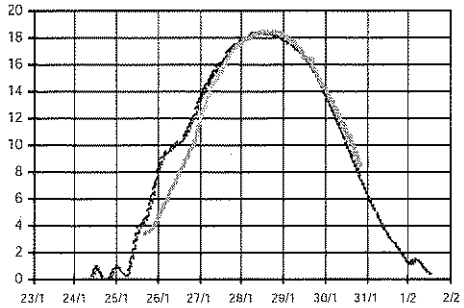
Appendix B Hydraulic Hydrograph Comparison

Predicted & Recorded Hydrograph Comparison - January 1974

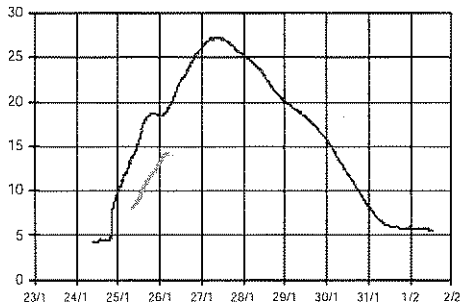
1974 MOGGILL GAUGE
Brisbane 1006.300 Predicted
-------- WATER LEVEL (m) Recorded



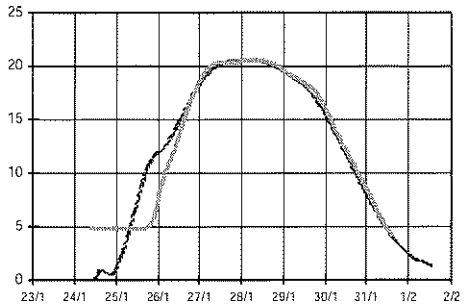
1974 GOODNA HOSPITAL GAUGE
Brisbane 1014.610 Predicted
-------- WATER LEVEL (m) Recorded



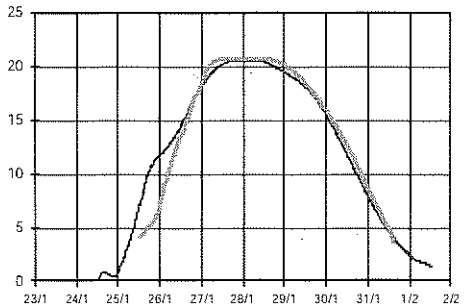
1974 BERRY'S LAGOON GAUGE
Bremer 1002.300 Predicted
-------- WATER LEVEL (m) Recorded



1974 DAVID TRUMPY GAUGE
Bremer 1012.050 Predicted
-------- WATER LEVEL (m) Recorded

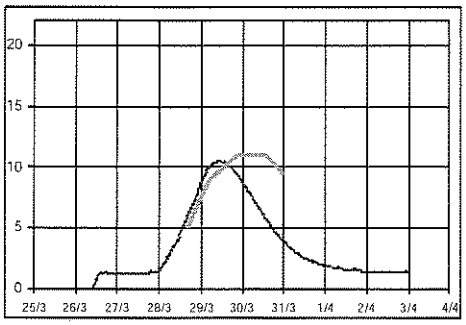


1974 MARSDEN PARADE GAUGE
Bremer 1012.070 Predicted
-------- WATER LEVEL (m) Recorded

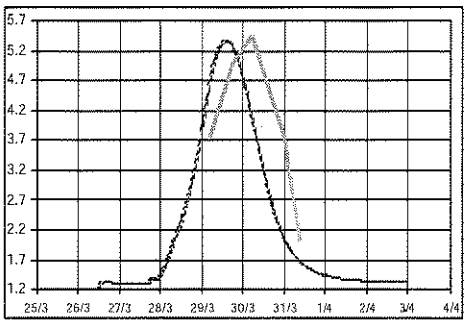


Predicted & Recorded Hydrograph Comparison - March 1955

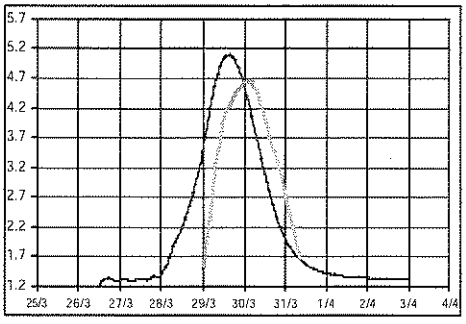
1955 GOODNA HOSPITAL GAUGE
BRISBANE 1014610 Predicted
WATER LEVEL (m) Recorded



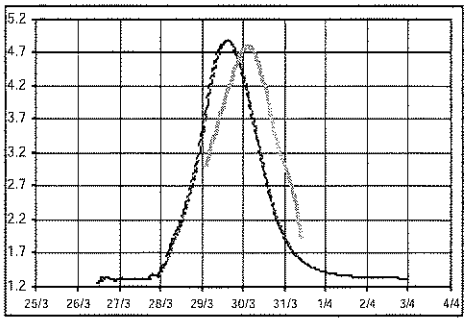
1955 INDOOROOPILLY BRIDGE GAUGE
BRISBANE 1037175 Predicted
WATER LEVEL (m) Recorded



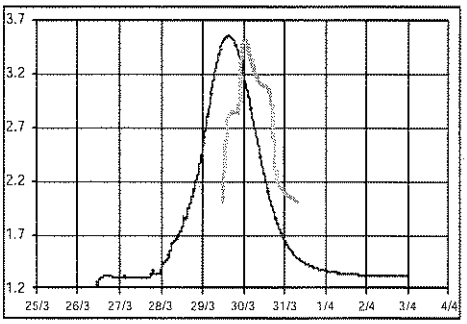
1955 TENNYSON GAUGE
BRISBANE1041460 Predicted
WATER LEVEL (m) Recorded



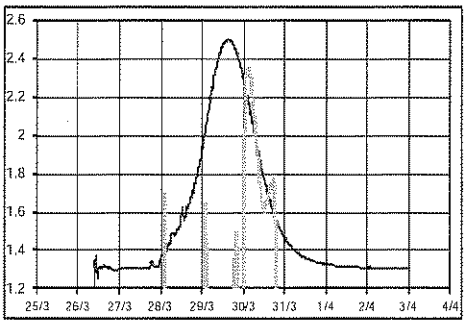
1955 SANDY CREEK GAUGE
BRISBANE 1042515 Predicted
WATER LEVEL (m) Recorded



1955 ST LUCIA FERRY GAUGE
BRISBANE 1048890 Predicted
WATER LEVEL (m) Recorded

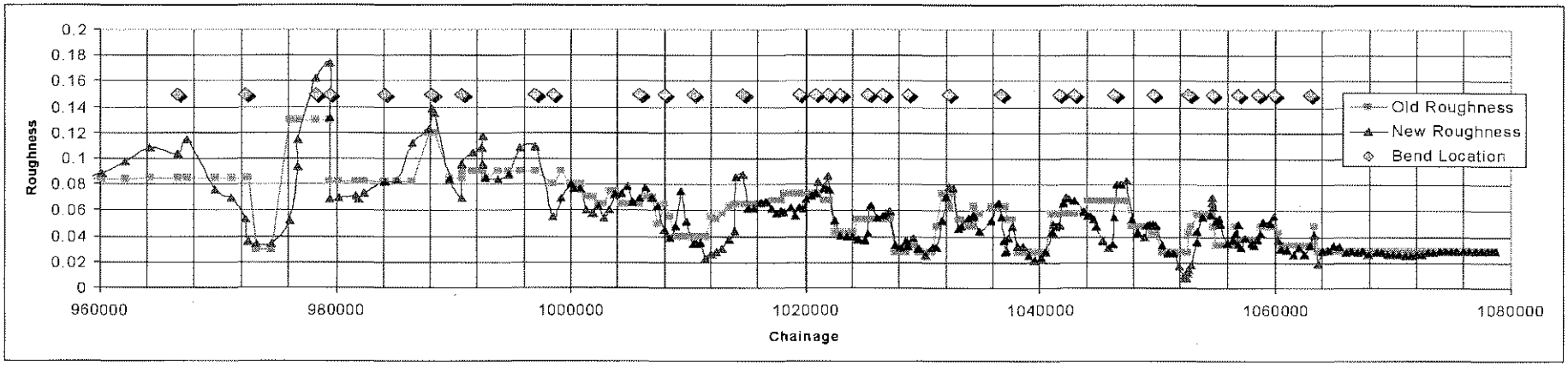


1955 PORT OFFICE GAUGE
BRISBANE 1055960 Predicted
WATER LEVEL (m) Recorded



Appendix C Roughness Parameters

Comparison of Roughness Values for New Model and Previous Model



Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference		Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
931570	0.084	0.086	0.002		980330	0.082	0.069	-0.013
933670	0.084	0.086	0.002		981660	0.082	0.071	-0.011
934270	0.084	0.086	0.002		981960	0.082	0.069	-0.013
934620	0.084	0.086	0.002		982460	0.082	0.073	-0.009
936070	0.084	0.086	0.002		984160	0.082	0.082	0.000
936820	0.084	0.086	0.002		985260	0.082	0.083	0.001
939770	0.084	0.086	0.002		986480	0.082	0.112	0.030
942320	0.084	0.086	0.002		987960	0.120	0.123	0.003
943570	0.084	0.086	0.002		988160	0.120	0.139	0.019
944120	0.084	0.086	0.002		988360	0.120	0.135	0.015
945570	0.084	0.086	0.002		989700	0.085	0.084	-0.001
947170	0.084	0.086	0.002		990700	0.085	0.070	-0.015
950270	0.084	0.086	0.002		990760	0.090	0.095	0.005
952320	0.084	0.086	0.002		991710	0.090	0.105	0.015
953870	0.084	0.086	0.002		992420	0.090	0.108	0.018
954920	0.084	0.086	0.002		992450	0.090	0.117	0.027
955970	0.084	0.086	0.002		992470	0.090	0.095	0.005
958770	0.084	0.086	0.002		992670	0.085	0.085	0.000
960170	0.084	0.088	0.004		993760	0.090	0.084	-0.006
962070	0.084	0.097	0.013		994760	0.090	0.087	-0.003
964170	0.085	0.108	0.023		995690	0.090	0.108	0.018
966610	0.085	0.104	0.019		996980	0.090	0.109	0.019
967410	0.085	0.115	0.030		998460	0.080	0.055	-0.025
969790	0.085	0.075	-0.010		999160	0.090	0.069	-0.021
971160	0.085	0.070	-0.015		1000000	0.080	0.081	0.001
972260	0.085	0.053	-0.032		1000285	0.080	0.077	-0.003
972600	0.085	0.036	-0.049		1000775	0.080	0.077	-0.003
973260	0.030	0.034	0.004		1001315	0.070	0.061	-0.009
974580	0.030	0.034	0.004		1001865	0.070	0.057	-0.013
976020	0.130	0.052	-0.078		1002350	0.065	0.063	-0.002
976750	0.130	0.094	-0.036		1002785	0.065	0.054	-0.011
976750	0.130	0.114	-0.016		1003275	0.075	0.060	-0.015
978280	0.130	0.162	0.032		1003775	0.075	0.072	-0.003
979507	0.130	0.174	0.044		1004300	0.065	0.073	0.008
979513	0.130	0.132	0.002		1004810	0.065	0.078	0.013
979530	0.082	0.069	-0.013		1005325	0.065	0.067	0.002

Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference		Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
1005870	0.065	0.070	0.005		1021539	0.068	0.076	0.008
1006300	0.070	0.078	0.008		1021715	0.068	0.078	0.010
1006910	0.070	0.069	-0.001		1021895	0.068	0.086	0.018
1007410	0.050	0.063	0.013		1022105	0.068	0.075	0.007
1007920	0.065	0.045	-0.020		1022575	0.043	0.052	0.009
1008445	0.055	0.039	-0.016		1023040	0.043	0.041	-0.002
1008925	0.040	0.048	0.008		1023570	0.043	0.040	-0.003
1009400	0.040	0.075	0.035		1024080	0.043	0.040	-0.003
1009820	0.040	0.052	0.012		1024563	0.053	0.037	-0.016
1010490	0.040	0.034	-0.006		1025070	0.053	0.037	-0.016
1010725	0.040	0.034	-0.006		1025360	0.053	0.042	-0.011
1010980	0.040	0.035	-0.005		1025590	0.053	0.064	0.011
1011510	0.040	0.022	-0.018		1026170	0.053	0.054	0.001
1011980	0.055	0.026	-0.029		1026680	0.053	0.056	0.003
1012475	0.053	0.028	-0.025		1026900	0.053	0.058	0.005
1012935	0.058	0.031	-0.027		1027160	0.053	0.059	0.006
1013445	0.063	0.038	-0.025		1027680	0.028	0.033	0.005
1013920	0.065	0.044	-0.021		1028180	0.028	0.031	0.003
1014110	0.065	0.086	0.021		1028680	0.028	0.037	0.009
1014610	0.065	0.088	0.023		1028760	0.033	0.032	-0.001
1015090	0.065	0.061	-0.004		1029200	0.033	0.039	0.006
1015560	0.065	0.062	-0.003		1029680	0.028	0.031	0.003
1016140	0.065	0.066	0.001		1030220	0.028	0.025	-0.003
1016640	0.065	0.067	0.002		1030870	0.028	0.032	0.004
1017130	0.068	0.061	-0.007		1031260	0.048	0.031	-0.017
1017610	0.068	0.058	-0.010		1031700	0.073	0.052	-0.021
1017920	0.068	0.060	-0.008		1031995	0.073	0.071	-0.002
1018200	0.073	0.058	-0.015		1032230	0.063	0.078	0.015
1018725	0.073	0.062	-0.011		1032585	0.073	0.077	0.004
1019095	0.073	0.056	-0.017		1033080	0.053	0.046	-0.007
1019490	0.073	0.062	-0.011		1033370	0.053	0.048	-0.005
1019865	0.073	0.061	-0.012		1033900	0.048	0.054	0.006
1020115	0.073	0.068	-0.005		1034370	0.048	0.055	0.007
1020525	0.073	0.071	-0.002		1034414	0.063	0.056	-0.007
1020830	0.073	0.073	0.000		1034890	0.058	0.044	-0.014
1021095	0.073	0.082	0.009		1035900	0.063	0.052	-0.011

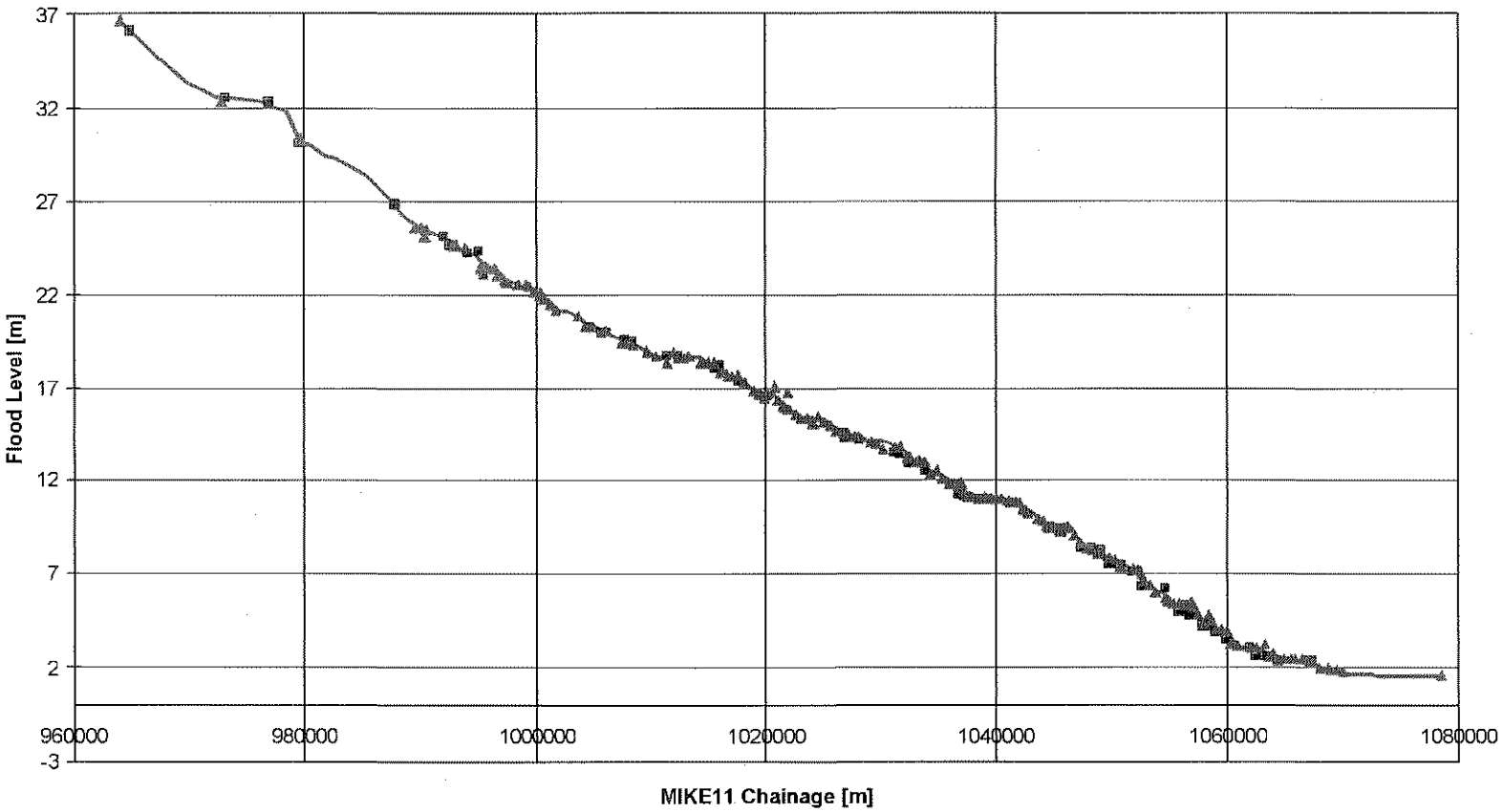
Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference		Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
1036460	0.063	0.066	0.003		1049120	0.048	0.049	0.001
1036770	0.063	0.055	-0.008		1049370	0.048	0.050	0.002
1036915	0.063	0.037	-0.026		1049590	0.043	0.049	0.006
1037090	0.063	0.028	-0.035		1049870	0.043	0.049	0.006
1037175	0.053	0.028	-0.025		1050430	0.028	0.033	0.005
1037285	0.053	0.039	-0.014		1050860	0.028	0.027	-0.001
1037625	0.053	0.048	-0.005		1051360	0.028	0.027	-0.001
1038085	0.028	0.032	0.004		1051895	0.028	0.017	-0.011
1038600	0.028	0.033	0.005		1052310	0.028	0.010	-0.018
1039100	0.028	0.025	-0.003		1052390	0.028	0.008	-0.020
1039565	0.028	0.022	-0.006		1052595	0.028	0.012	-0.016
1040090	0.028	0.024	-0.004		1052640	0.043	0.014	-0.029
1040490	0.028	0.028	0.000		1052865	0.048	0.018	-0.030
1041010	0.058	0.044	-0.014		1053320	0.058	0.036	-0.022
1041230	0.058	0.050	-0.008		1053385	0.058	0.044	-0.014
1041460	0.058	0.048	-0.010		1053900	0.058	0.055	-0.003
1041700	0.058	0.049	-0.009		1054490	0.058	0.057	-0.001
1041960	0.058	0.065	0.007		1054640	0.058	0.066	0.008
1042235	0.058	0.070	0.012		1054680	0.058	0.071	0.013
1042515	0.058	0.069	0.011		1054760	0.048	0.063	0.015
1042910	0.058	0.068	0.010		1054970	0.033	0.052	0.019
1043725	0.058	0.059	0.001		1055280	0.033	0.054	0.021
1044060	0.068	0.056	-0.012		1055420	0.033	0.049	0.016
1044340	0.068	0.056	-0.012		1055960	0.033	0.035	0.002
1044605	0.068	0.053	-0.015		1056400	0.033	0.038	0.005
1044860	0.068	0.048	-0.020		1056695	0.048	0.042	-0.006
1045400	0.068	0.037	-0.031		1056865	0.038	0.050	0.012
1045885	0.068	0.031	-0.037		1056950	0.038	0.034	-0.004
1046180	0.068	0.034	-0.034		1057090	0.038	0.032	-0.006
1046340	0.068	0.055	-0.013		1057530	0.038	0.039	0.001
1046580	0.068	0.080	0.012		1058040	0.038	0.035	-0.003
1046900	0.068	0.080	0.012		1058230	0.038	0.034	-0.004
1047350	0.068	0.083	0.015		1058530	0.038	0.037	-0.001
1047915	0.048	0.053	0.005		1058735	0.048	0.042	-0.006
1048375	0.048	0.043	-0.005		1059035	0.048	0.051	0.003
1048890	0.048	0.040	-0.008		1059540	0.048	0.051	0.003

Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference		Chainage [m]	Roughness (Previous Model)	Roughness (New Model)	Difference
1059990	0.048	0.056	0.008		1069535	0.029	0.026	-0.003
1060345	0.043	0.038	-0.005		1070025	0.029	0.026	-0.003
1060535	0.033	0.031	-0.002		1070530	0.029	0.026	-0.003
1061015	0.033	0.030	-0.003		1071040	0.029	0.025	-0.004
1061530	0.033	0.026	-0.007		1071520	0.029	0.025	-0.004
1062020	0.033	0.032	-0.001		1072015	0.029	0.026	-0.003
1062535	0.033	0.026	-0.007		1072515	0.029	0.027	-0.002
1062940	0.033	0.033	0.000		1072995	0.029	0.028	-0.001
1063310	0.048	0.042	-0.006		1073485	0.029	0.028	-0.001
1063645	0.029	0.019	-0.010		1074000	0.029	0.029	0.000
1064000	0.029	0.029	0.000		1074460	0.029	0.029	0.000
1064490	0.029	0.029	0.000		1074985	0.029	0.029	0.000
1065010	0.029	0.033	0.004		1075480	0.029	0.029	0.000
1065503	0.029	0.032	0.003		1076000	0.029	0.029	0.000
1065990	0.029	0.028	-0.001		1076495	0.029	0.029	0.000
1066505	0.029	0.029	0.000		1077010	0.029	0.029	0.000
1067020	0.029	0.028	-0.001		1077510	0.029	0.029	0.000
1067485	0.029	0.029	0.000		1078040	0.029	0.029	0.000
1067965	0.029	0.026	-0.003		1078525	0.029	0.029	0.000
1068660	0.029	0.028	-0.001		1078660	0.029	0.029	0.000
1069045	0.029	0.028	-0.001					

Appendix D MIKE11 Results

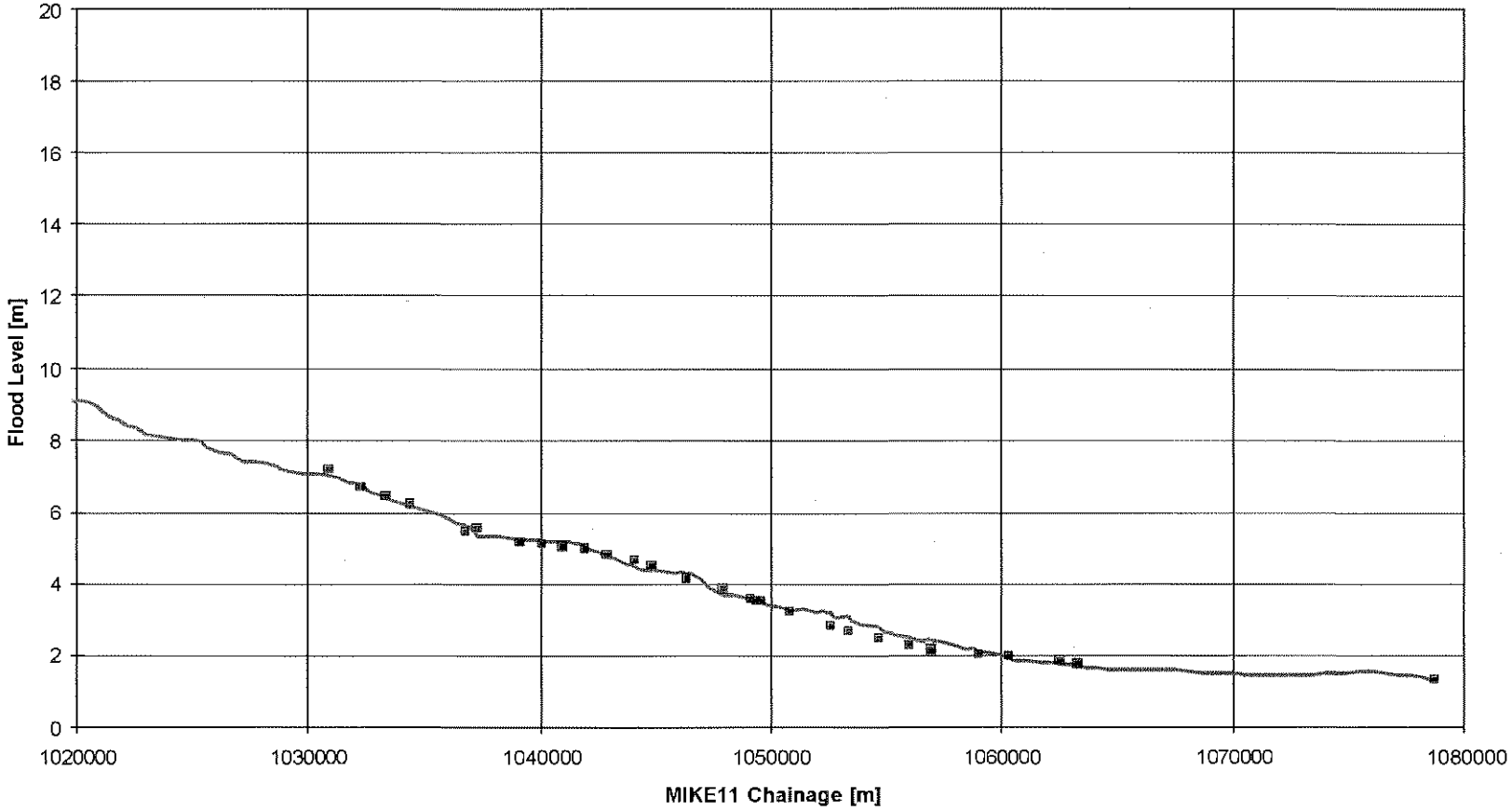
SKM

Figure D-2a Flood Calibration Profile - January 1974
Brisbane River



SKM

Figure D-2a Flood Calibration Profile - March 1955
Brisbane River



MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
		36.60		36.69	-0.09	31.51		
964170		36.49				31.37		
		36.06	36.08		-0.02	30.87		
966610		35.17				29.81		
967410		34.63				29.32		
	Cabbage Tree Crk.	34.50				29.20		
969790		33.36				28.16		
971160		32.89				27.68		
972260		32.62				27.44		
		32.62		32.3	0.32	27.42		
973260		32.61	32.49		0.12	27.41		
974580		32.38				27.24		
976020		32.31				27.15		
		32.14		32.23	-0.09	26.89		
		32.10	32.31		-0.21	26.84		
978280		31.82				26.41		
979507		30.10	30		0.10	24.40		
979513		30.03				24.36		
979530		30.09				24.36		
		30.06		30.25	-0.19	24.32		
980330		29.91				24.14		
981660		29.48				23.71		
982460		29.31				23.50		
984160		28.79				23.01		
985260		28.37				22.57		
986480		27.67				21.83		
	Mt. Crosby Weir (43003A)	26.81	26.74		0.07	20.84		
987960	Mt. Crosby (040142/040818)	26.75	26.826		-0.08	20.77		
988160		26.49				20.46		
988360		26.29				20.19		
		25.68		25.55	0.13	19.40		
989700		25.63				19.34		
		25.49		25.55	-0.06	19.19		
		25.47		25.52	-0.05	19.16		
		25.38		25.03	0.35	19.06		
		25.36		25.43	-0.07	19.03		
990700		25.30				18.97		
990760		25.26				18.93		
991710		25.08				18.67		
		24.99	25.06		-0.07	18.56		
992420		24.92				18.48		
992450	Colleges Crossing	24.86				18.43		
992470		24.82				18.41		
992670		24.76	24.61		0.15	18.31		
		24.64		24.58	0.06	18.16		
		24.53		24.58	-0.05	18.01		
993760		24.28				17.68		
		24.23		24.45	-0.22	17.59		
		24.19	24.21		-0.02	17.52		
994760		24.06				17.30		
		23.88	24.3		-0.42	17.07		
		23.81		23.45	0.36	16.98		
		23.70		23.51	0.19	16.83		
		23.64	23.02	23.51	0.37	16.75		
995690		23.62				16.73		
		23.52				16.57		
		23.13		23.45	-0.32	15.96		
		23.05				15.84		
		22.98		22.96	0.02	15.73		
996980		22.84				15.52		
		22.83		22.99	-0.16	15.49		
		22.81				15.46		
		22.79				15.43		
		22.78		22.72	0.06	15.40		
		22.72		22.53	0.19	15.31		
998460		22.54				14.99		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
		22.51		22.47	0.04	14.95		
999160		22.37				14.76		
		22.36		22.44	-0.08	14.75		
		22.26		22.38	-0.12	14.64		
		22.18		22.11	0.07	14.55		
1000000		22.14				14.51		
1000285		21.95		21.92	0.03	14.34		
		21.88		22.17	-0.29	14.27		
1000775		21.69		21.68	0.01	14.08		
1001315		21.60		21.5	0.10	13.93		
1001865		21.23		21.1	0.13	13.58		
1002350		21.12				13.37		
1002785		21.12				13.34		
1003275		20.92				13.11		
1003775		20.76		20.83	-0.07	12.94		
1004300		20.42		20.25	0.17	12.53		
1004810		20.40	20.25	20.25	0.15	12.43		
1005325		20.25				12.22		
1005870		20.03	19.93	19.97	0.07	11.94		
1006200		19.95				11.86		
1006200		19.95				11.86		
1006300	Moggill Gauge	19.91	19.93	20.04	-0.08	11.82		
1006300		19.91				11.82		
1006910		19.69				11.61		
1007410		19.61		19.33	0.28	11.50		
1007780		19.40				11.34		
1007780		19.40				11.34		
1007920		19.29	19.6	19.33	-0.18	11.26		
1008445		19.21	19.46	19.21	-0.13	11.24		
1008925		19.16				11.19		
1009400		19.03				11.08		
1009720		18.96		18.88	0.08	11.00		
1010490		18.59		18.69	-0.10	10.80		
1010725		18.64				10.83		
1010980		18.60				10.80		
1011510		18.67	18.63	18.3	0.21	10.80		
1011980		18.71		18.8	-0.10	10.80		
1012475		18.70	18.63	18.6	0.08	10.79		
1012475		18.70				10.79		
1012935		18.66		18.6	0.06	10.76		
1013190		18.65				10.74		
1013190		18.65				10.74		
1013445		18.63		18.63	0.00	10.73		
1013680		18.62				10.72		
1013680		18.62				10.72		
1013910		18.61				10.70		
1014310		18.55		18.3	0.25	10.62		
1014610	Goodna Hospital Gauge	18.44		18.43	0.01	10.49		
1014610		18.44				10.49		
1015090		18.26		18.3	-0.05	10.37		
1015560		18.08	17.96	18.33	-0.07	10.26		
1015850		18.01				10.20		
1015850		18.01				10.20		
1016140		17.94	18.15	17.78	-0.03	10.14		
1016640		17.78		17.63	0.15	9.97		
1016890		17.65				9.84		
1016890		17.65				9.84		
1017130		17.51		17.54	-0.03	9.72		
1017610		17.42	17.29	17.66	-0.05	9.58		
1017920		17.28				9.47		
1018200		17.24		17.26	-0.02	9.46		
1018725		16.96				9.30		
1019095		16.89		16.83	0.06	9.22		
1019490		16.84		16.65	0.19	9.18		
1019490		16.84				9.18		
1019865		16.57		16.47	0.10	9.03		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
1020115		16.71	16.56	16.71	0.07	9.06		
1020525		16.69				9.03		
1020830		16.53		17.02	-0.49	8.94		
1021095		16.30		16.26	0.04	8.80		
1021539		16.06		16.04	0.02	8.61		
1021715		16.08		15.98	0.10	8.58		
1021895		15.97		16.74	-0.77	8.51		
1022105		15.81		15.86	-0.05	8.42		
1022575		15.70		15.52	0.18	8.31		
1023040		15.42		15.31	0.11	8.14		
1023570		15.34		15.31	0.03	8.10		
1024080		15.31		15.13	0.18	8.05		
1024563		15.27		15.4	-0.13	8.00		
1025070		15.26		15.19	0.07	7.97		
1025360		15.14				7.90		
1025590		14.98		14.94	0.04	7.81		
1026170		14.77		14.64	0.13	7.67		
1026680	Mt Ommaney Gauge	14.67	14.55	14.58	0.10	7.56		
1026900		14.52	14.24	14.55	0.12	7.48		
1027160		14.35	14.24	14.46	0.00	7.40		
1027680		14.39		14.32	0.07	7.37		
1028180		14.40	14.12	14.3	0.19	7.35		
1028680		14.26				7.25		
	Centenary Bridge	14.21				7.20		
1028760		14.16				7.15		
1029200		14.03		14.09	-0.06	7.05		
1029680		14.04		13.97	0.07	7.04		
1030220		14.05		13.63	0.42	7.04		
1030870		13.99				6.99	7.17	-0.18
1031260		13.82	13.51	13.73	0.20	6.92		
1031700	Darra Wharf Gauge	13.52	13.36	13.79	-0.05	6.79		
1031995		13.66				6.80		
1032230		13.55		13.18	0.37	6.71	6.7	0.01
1032585		13.23	12.9	13.33	0.11	6.55		
1033080		13.07		12.99	0.08	6.43		
1033370		12.97	12.9	13.02	0.01	6.37	6.41	-0.04
1033900		12.73	12.57	12.96	-0.04	6.24		
1034370		12.51		12.26	0.25	6.11	6.23	-0.12
1034890	Sherwood Gauge	12.43		12.52	-0.09	6.04		
1035414		12.26		12.14	0.12	5.94		
1035900		12.03		11.87	0.16	5.80		
1036460		11.78	11.74	11.77	0.02	5.65		
1036770		11.73	11.24	11.59	0.31	5.57	5.47	0.10
1036915		11.58	11.32	11.65	0.10	5.53		
1037090		11.60	11.2	11.84	0.08	5.54		
	Indooroopilly Bridge	11.50				5.50		
1037175		11.19	11.13	11.47	-0.11	5.34		
1037285	Clarence Road Gauge	11.14		11.2	-0.06	5.30	5.56	-0.26
1037625		11.18	11.07	11.1	0.09	5.29		
1038085		11.22		11.1	0.12	5.27		
1038600		11.19		11.04	0.15	5.22		
1039100		11.16		11.07	0.09	5.18	5.16	0.02
1039200		11.16				5.18		
1039200		11.16				5.18		
1039565	Oxley Creek Gauge	11.15		11.01	0.14	5.18		
1039670		11.15				5.18		
1039670		11.15				5.18		
1039828		11.14				5.18		
1039828		11.14				5.18		
1040090	King Authur Terrace Gauge	11.11		11.04	0.07	5.18	5.1	0.08
1040250		11.07				5.16		
1040250		11.07				5.16		
1040490		10.97		11.01	-0.04	5.11		
1041010		11.03		10.89	0.14	5.13	5.02	0.11
1041230		11.01		10.83	0.18	5.10		
1041460	Tennyson Power House Gauge	10.93		10.83	0.10	5.07		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L	Difference
1041700		10.92		10.83	0.08	5.07		
1041960	Yeronga Street Gauge	10.77		10.83	-0.06	4.98	4.95	0.03
1042235		10.57		10.42	0.15	4.89		
1042500		10.53				4.85		
1042500		10.53				4.85		
1042515		10.52		10.43	0.09	4.85		
1042910		10.41	10.16	10.25	0.20	4.71	4.8	-0.09
1043010		10.35				4.67		
1043010		10.35				4.67		
1043080		10.30				4.64		
1043110		10.29				4.63		
1043110		10.29				4.63		
1043725		9.97		9.95	0.02	4.46		
1044060	Sandy Creek Gauge	9.81		9.81	0.00	4.41	4.65	-0.25
1044340		9.67		9.61	0.06	4.34		
1044605		9.66		9.49	0.17	4.31		
1044860		9.67		9.55	0.12	4.30	4.49	-0.19
1045400		9.59		9.31	0.28	4.24		
1045885		9.54	9.15	9.46	0.23	4.20		
1046180		9.55		9.49	0.06	4.23		
1046340	Dutton Park Cemetery Gauge	9.50		9.57	-0.08	4.22	4.12	0.09
1046580		9.46				4.19		
1046900		9.21		9.03	0.18	4.05		
1047350		8.66	8.36	8.61	0.18	3.79		
1047915	Highgate Hill Gauge	8.29		8.36	-0.07	3.62	3.82	-0.20
1048375		8.37	8.36	8.3	0.04	3.63		
1048890	St Lucia Ferry Gauge	8.15		8.09	0.06	3.50		
1049120		8.10	8.27	8.24	-0.15	3.49	3.55	-0.06
1049370		7.89				3.40	3.51	-0.11
1049590		7.86				3.39	3.50	-0.11
1049870		7.71	7.57	7.9	-0.02	3.32		
1050430		7.63		7.75	-0.12	3.24		
1050860		7.47	7.57	7.48	-0.05	3.18	3.19	-0.01
1051360		7.48				3.19		
1051895		7.30	7.14	7.29	0.09	3.09		
1052310		7.49	7.08	7.17	0.36	3.16		
	Merivale Bridge	7.38				3.13		
1052390		7.35		7.23	0.12	3.12		
1052595		7.28				3.11		
	William Jolly Bridge	7.08				3.07		
1052640		6.53	6.35	7.05	-0.17	2.97	2.81	0.16
1052865	Montague Road Gauge	6.46		6.56	-0.10	2.96		
1053320		6.57		6.44	0.13	2.98		
	Victoria Bridge	6.45				2.95		
1053385		6.36		6.44	-0.08	2.93	2.66	0.27
1053900		6.08		6.04	0.04	2.79		
1054640		6.00				2.75		
	Captain Cook Bridge	5.96				2.75		
1054680		5.92	6.26	5.77	-0.10	2.75	2.43	0.32
1054970		5.61		5.59	0.02	2.64		
1055280		5.46				2.58		
1055420		5.40		5.44	-0.04	2.55		
1055960	Port Office Gauge	5.28	4.95	5.44	0.09	2.50	2.28	0.22
1056400		4.99	5.31	5.31	-0.32	2.39		
1056695		4.92				2.37		
1056865		5.16	4.76	5.4	0.08	2.44		
	Story Bridge	5.08				2.41		
1056950		5.04	4.8	5.47	-0.10	2.40	2.15	0.25
1057090		4.86	4.8	5.28	-0.18	2.35		
1057530		4.73		4.86	-0.13	2.31		
1058040		4.46	4.21	4.4	0.15	2.21		
1058230		4.39				2.18		
1058530		4.26	4.49	4.79	-0.38	2.15		
1058735		4.31	4.22	4.58	-0.09	2.16		
1059035		4.02	3.85	4.03	0.07	2.08	1.98	0.10
1059540		3.95	3.91	4.09	-0.05	2.04		

MIKE11 Chainage [m]	Comments	1974 Flood Event				1955 Flood Event		
		Flood Levels	F.L Left	F.L. Right	Difference	Flood Levels	F.L.	Difference
1059990		3.68	3.48	4	-0.06	1.95		
1060345		3.35		3.27	0.08	1.86	1.96	-0.10
1060535		3.21	3.21	3.33	-0.06	1.83		
1061015		3.20		3.18	0.02	1.82		
1061530		3.01				1.77		
1062020		2.99	3.06	3.15	-0.12	1.76		
1062535		2.98	2.6	3.15	0.11	1.75	1.82	-0.07
1062940		3.00				1.75		
1063125		2.95				1.74		
1063125		2.95				1.74		
1063310	Newstead Park Gauge	2.88	2.6	3.3	-0.07	1.72	1.75	-0.03
1063645	Cresent Road Gauge	2.61	2.63	2.63	-0.02	1.65		
1064000		2.61		2.78	-0.17	1.65		
1064490		2.47	2.39	2.42	0.07	1.61		
1065010		2.49		2.48	0.01	1.62		
1065503		2.44		2.51	-0.07	1.61		
1065990	Cairncross Dock Gauge	2.47		2.49	-0.02	1.61		
1066505		2.37		2.51	-0.14	1.59		
1067020		2.34	2.42	2.36	-0.05	1.58		
1067485		2.22	2.42	2.36	-0.17	1.55		
1067965		2.10		2.02	0.08	1.52		
1068660		1.94		2.02	-0.08	1.49		
1069045		1.87		1.9	-0.03	1.47		
1069535	Bulimba Power House Gauge	1.83		1.9	-0.07	1.46		
1070025		1.79		1.85	-0.06	1.45		
1070530		1.71				1.43		
1071040		1.65				1.42		
1071520		1.70				1.44		
1072015		1.64				1.41		
1072020		1.64				1.41		
1072020		1.64				1.41		
1072515		1.63				1.40		
1072995		1.62				1.42		
1073485		1.61				1.43		
1074000		1.60				1.45		
1074460		1.60				1.46		
1074985		1.59				1.47		
1075480		1.58				1.49		
1076000		1.57				1.49		
1076495		1.56				1.46		
1077010		1.56				1.44		
1077510		1.55				1.41		
1078040		1.55				1.36		
1078525		1.55				1.30		
1078660	Western Inner Bar Gauge	1.55		1.55	-0.01	1.30	1.3	0.00

Chainage [m]	Discharge [m³/s]	
	1974 Flood Event	1955 Flood Event
BNE 931575.00	7600	5400
BNE 932625.00	7595	5395
BNE 933970.00	7587	5380
BNE 934445.00	7581	5368
BNE 935345.00	7577	5359
BNE 936445.00	7561	5308
BNE 938295.00	7553	5282
BNE 941045.00	7524	5254
BNE 942945.00	7483	5165
BNE 943845.00	7435	5068
BNE 944845.00	7419	4947
BNE 946370.00	7410	4888
BNE 947720.00	7406	4869
BNE 949270.00	7402	4850
BNE 951295.00	7397	4829
BNE 953095.00	7396	4820
BNE 954395.00	7392	4802
BNE 955445.00	7389	4788
BNE 957370.00	7383	4762
BNE 959470.00	7379	4742
BNE 961120.00	7362	4691
BNE 963120.00	7354	4676
BNE 965390.00	7351	4643
BNE 967010.00	7349	4621
BNE 968600.00	7348	4608
BNE 970475.00	7347	4592
BNE 971710.00	7346	4581
BNE 972760.00	7345	4573
BNE 973920.00	7343	4560
BNE 975300.00	7343	4551
BNE 976385.00	7344	4542
BNE 977515.00	7348	4521
BNE 978893.50	7347	4504
BNE 979510.00	7459	4611
BNE 979521.50	7456	4608
BNE 979930.00	7352	4493
BNE 980995.00	7348	4485
BNE 982060.00	7349	4480
BNE 983310.00	7347	4473
BNE 984710.00	7349	4468
BNE 985870.00	7350	4463
BNE 987220.00	7351	4457
BNE 988060.00	7352	4453
BNE 988165.00	7353	4452
BNE 988265.00	7353	4452
BNE 989030.00	7354	4448
BNE 990200.00	7358	4439
BNE 990730.00	7360	4438
BNE 991235.00	7361	4436
BNE 992065.00	7376	4427
BNE 992435.00	7364	4421
BNE 992460.00	7364	4419
BNE 992570.00	7365	4440
BNE 993215.00	7373	4423

Chainage [m]	Discharge [m^3/s]	
	1974 Flood Event	1955 Flood Event
BNE 994260.00	7373	4424
BNE 995225.00	7379	4420
BNE 996335.00	7383	4418
BNE 997720.00	7390	4414
BNE 998810.00	7398	4412
BNE 999580.00	7401	4411
BNE 1000142.50	8056	4466
BNE 1000530.00	8054	4465
BNE 1001045.00	8053	4464
BNE 1001590.00	8050	4463
BNE 1002107.50	8048	4462
BNE 1002567.50	8047	4461
BNE 1003030.00	8046	4460
BNE 1003525.00	8044	4459
BNE 1004037.50	8043	4458
BNE 1004555.00	8042	4457
BNE 1005067.50	8041	4455
BNE 1005597.50	8039	4452
BNE 1006035.00	7293	3997
BNE 1006250.00	9971	4691
BNE 1006605.00	10279	4689
BNE 1007160.00	10276	4683
BNE 1007595.00	10273	4678
BNE 1007850.00	10261	4663
BNE 1008182.50	10260	4661
BNE 1008685.00	10258	4658
BNE 1009162.50	10257	4655
BNE 1009560.00	10256	4652
BNE 1010105.00	10253	4646
BNE 1010607.50	10251	4644
BNE 1010852.50	10250	4642
BNE 1011245.00	10249	4640
BNE 1011745.00	10247	4635
BNE 1012227.50	10244	4630
BNE 1012705.00	10218	4608
BNE 1013062.50	10216	4605
BNE 1013317.50	9936	4603
BNE 1013562.50	9934	4601
BNE 1013795.00	9803	4599
BNE 1014110.00	9798	4596
BNE 1014460.00	9794	4591
BNE 1014850.00	9760	4567
BNE 1015325.00	9758	4565
BNE 1015705.00	9756	4564
BNE 1015995.00	9892	4563
BNE 1016390.00	9891	4561
BNE 1016765.00	9888	4559
BNE 1017010.00	10176	4558
BNE 1017370.00	10174	4555
BNE 1017765.00	10171	4553
BNE 1018060.00	10169	4552
BNE 1018462.50	10168	4550
BNE 1018910.00	10166	4548
BNE 1019292.50	10166	4547

Chainage [m]	Discharge [m³/s]	
	1974 Flood Event	1955 Flood Event
BNE 1019677.50	10162	4545
BNE 1019990.00	10161	4544
BNE 1020320.00	10159	4541
BNE 1020677.50	10157	4539
BNE 1020962.50	10157	4538
BNE 1021317.00	10156	4537
BNE 1021627.00	10155	4536
BNE 1021805.00	10155	4535
BNE 1022000.00	10154	4534
BNE 1022340.00	10154	4533
BNE 1022807.50	10155	4532
BNE 1023305.00	10153	4531
BNE 1023825.00	10152	4529
BNE 1024321.50	10151	4528
BNE 1024816.50	10150	4526
BNE 1025215.00	10148	4524
BNE 1025475.00	10148	4523
BNE 1025880.00	10147	4522
BNE 1026425.00	10145	4521
BNE 1026790.00	10144	4520
BNE 1027030.00	10144	4519
BNE 1027420.00	10142	4518
BNE 1027930.00	10138	4516
BNE 1028430.00	10141	4514
BNE 1028720.00	10051	4513
BNE 1028980.00	10164	4512
BNE 1029440.00	10141	4510
BNE 1029950.00	10127	4508
BNE 1030545.00	10125	4503
BNE 1031065.00	10122	4502
BNE 1031480.00	10121	4500
BNE 1031847.50	10120	4500
BNE 1032112.50	10119	4499
BNE 1032407.50	10117	4497
BNE 1032832.50	10116	4496
BNE 1033225.00	10114	4495
BNE 1033635.00	10113	4494
BNE 1034135.00	10111	4492
BNE 1034630.00	10110	4491
BNE 1035152.00	10107	4489
BNE 1035657.00	10106	4487
BNE 1036180.00	10104	4485
BNE 1036615.00	10102	4484
BNE 1036842.50	10101	4483
BNE 1037002.50	10101	4482
BNE 1037110.00	10101	4482
BNE 1037230.00	10101	4482
BNE 1037455.00	10100	4481
BNE 1037855.00	10098	4479
BNE 1038342.50	10091	4477
BNE 1038850.00	10084	4473
BNE 1039150.00	10080	4470
BNE 1039382.50	9867	4467
BNE 1039617.50	9864	4465

Chainage [m]	Discharge [m^3/s]	
	1974 Flood Event	1955 Flood Event
BNE 1039749.00	9617	4464
BNE 1039959.00	9395	4368
BNE 1040170.00	9396	4368
BNE 1040370.00	9253	4368
BNE 1040750.00	9254	4367
BNE 1041120.00	9254	4367
BNE 1041345.00	9255	4367
BNE 1041580.00	9255	4367
BNE 1041830.00	9255	4367
BNE 1042097.50	9255	4366
BNE 1042367.50	9256	4366
BNE 1042507.50	9399	4366
BNE 1042712.50	9399	4366
BNE 1042960.00	9399	4366
BNE 1043045.00	9692	4366
BNE 1043095.00	9692	4366
BNE 1043417.50	9952	4366
BNE 1043892.50	9953	4366
BNE 1044200.00	9953	4365
BNE 1044472.50	9953	4365
BNE 1044732.50	9954	4365
BNE 1045130.00	9955	4365
BNE 1045642.50	9956	4365
BNE 1046032.50	9957	4365
BNE 1046260.00	9958	4365
BNE 1046460.00	9958	4365
BNE 1046740.00	9958	4365
BNE 1047125.00	9959	4365
BNE 1047632.50	9960	4365
BNE 1048145.00	9961	4364
BNE 1048632.50	9963	4364
BNE 1049005.00	9964	4364
BNE 1049245.00	9964	4364
BNE 1049480.00	9965	4364
BNE 1049730.00	9965	4364
BNE 1050150.00	9966	4364
BNE 1050645.00	9967	4364
BNE 1051110.00	9968	4364
BNE 1051627.50	9970	4364
BNE 1052102.50	9971	4364
BNE 1052350.00	9972	4363
BNE 1052492.50	9972	4362
BNE 1052625.00	9972	4354
BNE 1052752.50	9972	4363
BNE 1053092.50	9973	4364
BNE 1053355.00	9973	4364
BNE 1053642.50	9974	4364
BNE 1054270.00	9976	4364
BNE 1054660.00	9977	4364
BNE 1054825.00	9977	4364
BNE 1055125.00	9978	4364
BNE 1055350.00	9978	4364
BNE 1055690.00	9979	4364
BNE 1056180.00	9981	4364

Chainage [m]	Discharge [m^3/s]	
	1974 Flood Event	1955 Flood Event
BNE 1056547.50	9982	4364
BNE 1056780.00	9982	4364
BNE 1056920.00	9983	4364
BNE 1057020.00	9983	4364
BNE 1057310.00	9984	4364
BNE 1057785.00	9985	4364
BNE 1058135.00	9986	4364
BNE 1058380.00	9986	4364
BNE 1058632.50	9987	4364
BNE 1058885.00	9988	4364
BNE 1059287.50	9989	4364
BNE 1059765.00	9991	4364
BNE 1060167.50	9993	4364
BNE 1060440.00	9994	4364
BNE 1060775.00	9995	4364
BNE 1061272.50	9998	4364
BNE 1061775.00	10000	4364
BNE 1062277.50	10003	4364
BNE 1062737.50	10009	4364
BNE 1063032.50	10013	4364
BNE 1063217.50	10065	4365
BNE 1063477.50	10068	4365
BNE 1063822.50	10072	4365
BNE 1064245.00	10077	4365
BNE 1064750.00	10083	4365
BNE 1065256.50	10091	4365
BNE 1065746.50	10101	4365
BNE 1066247.50	10113	4365
BNE 1066762.50	10123	4365
BNE 1067252.50	10138	4365
BNE 1067725.00	10153	4365
BNE 1068312.50	10166	4365
BNE 1068852.50	10180	4365
BNE 1069290.00	10192	4365
BNE 1069780.00	10207	4365
BNE 1070277.50	10222	4365
BNE 1070785.00	10239	4365
BNE 1071280.00	10257	4365
BNE 1071767.50	10274	4365
BNE 1072017.50	10284	4365
BNE 1072267.50	10521	4366
BNE 1072755.00	10541	4366
BNE 1073240.00	10561	4366
BNE 1073742.50	10585	4366
BNE 1074230.00	10608	4366
BNE 1074722.50	10633	4366
BNE 1075232.50	10661	4366
BNE 1075740.00	10706	4366
BNE 1076247.50	10765	4366
BNE 1076752.50	10817	4366
BNE 1077260.00	10896	4366
BNE 1077775.00	10953	4366
BNE 1078282.50	10997	4366
BNE 1078592.50	11014	4366

Appendix E DESIGN EVENT Results

1% AEP Design Event	
Chainage [m]	Water Level [m]
BNE 931570.00	44.512
BNE 931580.00	44.5
BNE 933670.00	42.678
BNE 934270.00	42.551
BNE 934620.00	42.309
BNE 936070.00	42.116
BNE 936820.00	42.043
BNE 939770.00	41.435
BNE 942320.00	40.405
BNE 943570.00	40.197
BNE 944120.00	40.168
BNE 945570.00	40.055
BNE 947170.00	39.691
BNE 948270.00	39.336
BNE 950270.00	38.765
BNE 952320.00	37.926
BNE 953870.00	37.503
BNE 954920.00	37.124
BNE 955970.00	36.713
BNE 958770.00	35.479
BNE 960170.00	35.189
BNE 962070.00	34.431
BNE 964170.00	33.322
BNE 966610.00	31.842
BNE 967410.00	31.313
BNE 969790.00	30.09
BNE 971160.00	29.587
BNE 972260.00	29.335
BNE 973260.00	29.311
BNE 974580.00	29.115
BNE 976020.00	29.029
BNE 976750.00	29.024
BNE 978280.00	28.384
BNE 979507.00	26.448
BNE 979513.00	26.385
BNE 979530.00	26.404
BNE 980330.00	26.203
BNE 981660.00	25.76
BNE 982460.00	25.547
BNE 984160.00	25.028
BNE 985260.00	24.579
BNE 986480.00	23.812
BNE 987960.00	22.744
BNE 988160.00	22.429
BNE 988170.00	22.387
BNE 988360.00	22.177
BNE 989700.00	21.355
BNE 990700.00	20.973
BNE 990760.00	20.931
BNE 991710.00	20.676
BNE 992420.00	20.489
BNE 992450.00	20.438
BNE 992470.00	20.398
BNE 992670.00	20.306
BNE 993760.00	19.673
BNE 994760.00	19.314
BNE 995690.00	18.74
BNE 996980.00	17.529
BNE 998460.00	17
BNE 999160.00	16.757
BNE 1000000.00	16.501

Chainage [m]	Water Level [m]
BNE 1000285.00	16.314
BNE 1000775.00	16.033
BNE 1001315.00	15.895
BNE 1001865.00	15.533
BNE 1002350.00	15.401
BNE 1002785.00	15.383
BNE 1003275.00	15.218
BNE 1003775.00	15.099
BNE 1004300.00	14.821
BNE 1004810.00	14.768
BNE 1005325.00	14.637
BNE 1005870.00	14.457
BNE 1005870.00	14.457
BNE 1006200.00	14.397
BNE 1006200.00	14.397
BNE 1006300.00	14.363
BNE 1006300.00	14.363
BNE 1006910.00	14.148
BNE 1007410.00	14.053
BNE 1007780.00	13.882
BNE 1007780.00	13.882
BNE 1007920.00	13.791
BNE 1008445.00	13.764
BNE 1008925.00	13.714
BNE 1009400.00	13.595
BNE 1009720.00	13.523
BNE 1010490.00	13.277
BNE 1010725.00	13.31
BNE 1010980.00	13.275
BNE 1011510.00	13.302
BNE 1011980.00	13.311
BNE 1012475.00	13.289
BNE 1012475.00	13.289
BNE 1012935.00	13.262
BNE 1013190.00	13.244
BNE 1013190.00	13.244
BNE 1013445.00	13.223
BNE 1013680.00	13.215
BNE 1013680.00	13.215
BNE 1013910.00	13.201
BNE 1014310.00	13.129
BNE 1014610.00	13.007
BNE 1014610.00	13.007
BNE 1015090.00	12.869
BNE 1015560.00	12.735
BNE 1015850.00	12.673
BNE 1015850.00	12.673
BNE 1016140.00	12.609
BNE 1016640.00	12.435
BNE 1016890.00	12.313
BNE 1016890.00	12.313
BNE 1017130.00	12.183
BNE 1017610.00	12.052
BNE 1017920.00	11.932
BNE 1018200.00	11.919
BNE 1018725.00	11.73
BNE 1019095.00	11.642
BNE 1019490.00	11.605
BNE 1019490.00	11.605
BNE 1019865.00	11.431
BNE 1020115.00	11.485
BNE 1020525.00	11.459

Chainage [m]	Water Level [m]
BNE 1020830.00	11.351
BNE 1021095.00	11.189
BNE 1021539.00	10.987
BNE 1021715.00	10.971
BNE 1021895.00	10.893
BNE 1022105.00	10.785
BNE 1022575.00	10.67
BNE 1023040.00	10.461
BNE 1023570.00	10.421
BNE 1024080.00	10.371
BNE 1024563.00	10.331
BNE 1025070.00	10.302
BNE 1025360.00	10.219
BNE 1025590.00	10.101
BNE 1026170.00	9.952
BNE 1026680.00	9.838
BNE 1026900.00	9.738
BNE 1027160.00	9.637
BNE 1027680.00	9.626
BNE 1028180.00	9.616
BNE 1028680.00	9.493
BNE 1028760.00	9.423
BNE 1029200.00	9.301
BNE 1029680.00	9.287
BNE 1030220.00	9.297
BNE 1030870.00	9.238
BNE 1031260.00	9.148
BNE 1031700.00	8.977
BNE 1031995.00	9.014
BNE 1032230.00	8.923
BNE 1032585.00	8.713
BNE 1033080.00	8.573
BNE 1033370.00	8.51
BNE 1033900.00	8.342
BNE 1034370.00	8.189
BNE 1034890.00	8.101
BNE 1035414.00	7.986
BNE 1035900.00	7.819
BNE 1036460.00	7.634
BNE 1036770.00	7.561
BNE 1036915.00	7.49
BNE 1037090.00	7.505
BNE 1037175.00	7.246
BNE 1037285.00	7.2
BNE 1037625.00	7.197
BNE 1038085.00	7.175
BNE 1038600.00	7.135
BNE 1039100.00	7.1
BNE 1039200.00	7.099
BNE 1039200.00	7.099
BNE 1039565.00	7.096
BNE 1039670.00	7.099
BNE 1039670.00	7.099
BNE 1039828.00	7.099
BNE 1039828.00	7.099
BNE 1040090.00	7.091
BNE 1040250.00	7.06
BNE 1040250.00	7.06
BNE 1040490.00	6.991
BNE 1041010.00	7.017
BNE 1041230.00	6.989
BNE 1041460.00	6.939

Chainage [m]	Water Level [m]
BNE 1041700.00	6.935
BNE 1041960.00	6.82
BNE 1042235.00	6.681
BNE 1042500.00	6.635
BNE 1042500.00	6.635
BNE 1042515.00	6.633
BNE 1042910.00	6.479
BNE 1043010.00	6.426
BNE 1043010.00	6.426
BNE 1043080.00	6.389
BNE 1043110.00	6.376
BNE 1043110.00	6.376
BNE 1043725.00	6.158
BNE 1044060.00	6.075
BNE 1044340.00	5.98
BNE 1044605.00	5.956
BNE 1044860.00	5.942
BNE 1045400.00	5.875
BNE 1045885.00	5.822
BNE 1046180.00	5.848
BNE 1046340.00	5.831
BNE 1046580.00	5.795
BNE 1046900.00	5.611
BNE 1047350.00	5.246
BNE 1047915.00	5.007
BNE 1048375.00	5.03
BNE 1048890.00	4.865
BNE 1049120.00	4.841
BNE 1049370.00	4.715
BNE 1049590.00	4.691
BNE 1049870.00	4.595
BNE 1050430.00	4.499
BNE 1050860.00	4.409
BNE 1051360.00	4.414
BNE 1051895.00	4.28
BNE 1052310.00	4.395
BNE 1052390.00	4.273
BNE 1052595.00	4.243
BNE 1052640.00	3.966
BNE 1052865.00	3.928
BNE 1053320.00	3.97
BNE 1053385.00	3.821
BNE 1053900.00	3.62
BNE 1054640.00	3.553
BNE 1054680.00	3.502
BNE 1054970.00	3.326
BNE 1055280.00	3.244
BNE 1055420.00	3.201
BNE 1055960.00	3.121
BNE 1056400.00	2.954
BNE 1056695.00	2.918
BNE 1056865.00	3.031
BNE 1056950.00	2.969
BNE 1057090.00	2.89
BNE 1057530.00	2.82
BNE 1058040.00	2.665
BNE 1058230.00	2.624
BNE 1058530.00	2.571
BNE 1058735.00	2.582
BNE 1059035.00	2.447
BNE 1059540.00	2.396
BNE 1059990.00	2.245

Chainage [m]	Water Level [m]
BNE 1060345.00	2.103
BNE 1060535.00	2.043
BNE 1061015.00	2.023
BNE 1061530.00	1.937
BNE 1062020.00	1.917
BNE 1062535.00	1.903
BNE 1062940.00	1.907
BNE 1063125.00	1.874
BNE 1063125.00	1.874
BNE 1063310.00	1.845
BNE 1063645.00	1.705
BNE 1064000.00	1.705
BNE 1064490.00	1.636
BNE 1065010.00	1.647
BNE 1065503.00	1.62
BNE 1065990.00	1.636
BNE 1066505.00	1.589
BNE 1067020.00	1.574
BNE 1067485.00	1.51
BNE 1067965.00	1.454
BNE 1068660.00	1.375
BNE 1069045.00	1.343
BNE 1069535.00	1.322
BNE 1070025.00	1.302
BNE 1070530.00	1.26
BNE 1071040.00	1.23
BNE 1071520.00	1.26
BNE 1072015.00	1.208
BNE 1072020.00	1.208
BNE 1072020.00	1.208
BNE 1072515.00	1.187
BNE 1072995.00	1.172
BNE 1073485.00	1.122
BNE 1074000.00	1.09
BNE 1074460.00	1.067
BNE 1074985.00	1.078
BNE 1075480.00	1.089
BNE 1076000.00	1.089
BNE 1076495.00	1.071
BNE 1077010.00	1.045
BNE 1077510.00	1.012
BNE 1078040.00	0.972
BNE 1078525.00	0.921
BNE 1078660.00	0.918

Chainage [m]	Discharge [m3/s]
BNE 931575.00	6144
BNE 932625.00	6141
BNE 933970.00	6125
BNE 934445.00	6114
BNE 935345.00	6107
BNE 936445.00	6074
BNE 938295.00	6057
BNE 941045.00	6028
BNE 942945.00	5963
BNE 943845.00	5886
BNE 944845.00	5821
BNE 946370.00	5787
BNE 947720.00	5779
BNE 949270.00	5770
BNE 951295.00	5758
BNE 953095.00	5752
BNE 954395.00	5739
BNE 955445.00	5732
BNE 957370.00	5716
BNE 959470.00	5704
BNE 961120.00	5640
BNE 963120.00	5617
BNE 965390.00	5595
BNE 967010.00	5582
BNE 968600.00	5575
BNE 970475.00	5567
BNE 971710.00	5560
BNE 972760.00	5555
BNE 973920.00	5548
BNE 975300.00	5544
BNE 976385.00	5539
BNE 977515.00	5527
BNE 978893.50	5524
BNE 979510.00	5447
BNE 979521.50	5446
BNE 979930.00	5514
BNE 980995.00	5508
BNE 982060.00	5505
BNE 983310.00	5502
BNE 984710.00	5499
BNE 985870.00	5497
BNE 987220.00	5494
BNE 988060.00	5492
BNE 988165.00	5492
BNE 988265.00	5492
BNE 989030.00	5490
BNE 990200.00	5487
BNE 990730.00	5486
BNE 991235.00	5485
BNE 992065.00	5491
BNE 992435.00	5516
BNE 992460.00	5519
BNE 992570.00	5506
BNE 993215.00	5486
BNE 994260.00	5478

Chainage [m]	Discharge [m3/s]
BNE 995225.00	5479
BNE 996335.00	5481
BNE 997720.00	5480
BNE 998810.00	5478
BNE 999580.00	5478
BNE 1000142.50	5491
BNE 1000530.00	5491
BNE 1001045.00	5491
BNE 1001590.00	5491
BNE 1002107.50	5490
BNE 1002567.50	5490
BNE 1003030.00	5490
BNE 1003525.00	5490
BNE 1004037.50	5490
BNE 1004555.00	5490
BNE 1005067.50	5490
BNE 1005597.50	5489
BNE 1006035.00	4795
BNE 1006250.00	6011
BNE 1006605.00	6010
BNE 1007160.00	6008
BNE 1007595.00	6005
BNE 1007850.00	5998
BNE 1008182.50	5997
BNE 1008685.00	5995
BNE 1009162.50	5994
BNE 1009560.00	5993
BNE 1010105.00	5990
BNE 1010607.50	5989
BNE 1010852.50	5988
BNE 1011245.00	5987
BNE 1011745.00	5985
BNE 1012227.50	5983
BNE 1012705.00	5971
BNE 1013062.50	5969
BNE 1013317.50	5968
BNE 1013562.50	5967
BNE 1013795.00	5967
BNE 1014110.00	5965
BNE 1014460.00	5964
BNE 1014850.00	5956
BNE 1015325.00	5956
BNE 1015705.00	5955
BNE 1015995.00	5955
BNE 1016390.00	5955
BNE 1016765.00	5953
BNE 1017010.00	5953
BNE 1017370.00	5951
BNE 1017765.00	5949
BNE 1018060.00	5947
BNE 1018462.50	5946
BNE 1018910.00	5946
BNE 1019292.50	5946
BNE 1019677.50	5945
BNE 1019990.00	5945

Chainage [m]	Discharge [m3/s]
BNE 1020320.00	5945
BNE 1020677.50	5945
BNE 1020962.50	5945
BNE 1021317.00	5945
BNE 1021627.00	5945
BNE 1021805.00	5945
BNE 1022000.00	5945
BNE 1022340.00	5945
BNE 1022807.50	5950
BNE 1023305.00	5950
BNE 1023825.00	5951
BNE 1024321.50	5952
BNE 1024816.50	5955
BNE 1025215.00	5958
BNE 1025475.00	5960
BNE 1025880.00	5961
BNE 1026425.00	5957
BNE 1026790.00	5958
BNE 1027030.00	5960
BNE 1027420.00	5963
BNE 1027930.00	5971
BNE 1028430.00	5992
BNE 1028720.00	6048
BNE 1028980.00	6003
BNE 1029440.00	5980
BNE 1029950.00	5971
BNE 1030545.00	5961
BNE 1031065.00	5957
BNE 1031480.00	5955
BNE 1031847.50	5958
BNE 1032112.50	5960
BNE 1032407.50	5961
BNE 1032832.50	5961
BNE 1033225.00	5958
BNE 1033635.00	5956
BNE 1034135.00	5954
BNE 1034630.00	5952
BNE 1035152.00	5949
BNE 1035657.00	5948
BNE 1036180.00	5948
BNE 1036615.00	5949
BNE 1036842.50	5950
BNE 1037002.50	5950
BNE 1037110.00	5950
BNE 1037230.00	5950
BNE 1037455.00	5950
BNE 1037855.00	5950
BNE 1038342.50	5949
BNE 1038850.00	5948
BNE 1039150.00	5947
BNE 1039382.50	5947
BNE 1039617.50	5946
BNE 1039749.00	5946
BNE 1039959.00	5977
BNE 1040170.00	5977

Chainage [m]	Discharge [m3/s]
BNE 1040370.00	5977
BNE 1040750.00	5976
BNE 1041120.00	5976
BNE 1041345.00	5975
BNE 1041580.00	5975
BNE 1041830.00	5974
BNE 1042097.50	5974
BNE 1042367.50	5974
BNE 1042507.50	5974
BNE 1042712.50	5974
BNE 1042960.00	5974
BNE 1043045.00	5974
BNE 1043095.00	5974
BNE 1043417.50	5975
BNE 1043892.50	5975
BNE 1044200.00	5975
BNE 1044472.50	5975
BNE 1044732.50	5975
BNE 1045130.00	5974
BNE 1045642.50	5974
BNE 1046032.50	5973
BNE 1046260.00	5973
BNE 1046460.00	5973
BNE 1046740.00	5973
BNE 1047125.00	5973
BNE 1047632.50	5973
BNE 1048145.00	5973
BNE 1048632.50	5972
BNE 1049005.00	5972
BNE 1049245.00	5972
BNE 1049480.00	5972
BNE 1049730.00	5972
BNE 1050150.00	5972
BNE 1050645.00	5972
BNE 1051110.00	5972
BNE 1051627.50	5972
BNE 1052102.50	5973
BNE 1052370.00	5977
BNE 1052492.50	5978
BNE 1052625.00	5998
BNE 1052752.50	5973
BNE 1053092.50	5971
BNE 1053355.00	5971
BNE 1053642.50	5972
BNE 1054270.00	5972
BNE 1054660.00	5971
BNE 1054825.00	5971
BNE 1055125.00	5971
BNE 1055350.00	5971
BNE 1055690.00	5971
BNE 1056180.00	5971
BNE 1056547.50	5971
BNE 1056780.00	5971
BNE 1056920.00	5971
BNE 1057020.00	5971

Chainage [m]	Discharge [m3/s]
BNE 1057310.00	5971
BNE 1057785.00	5971
BNE 1058135.00	5971
BNE 1058380.00	5971
BNE 1058632.50	5971
BNE 1058885.00	5971
BNE 1059287.50	5971
BNE 1059765.00	5971
BNE 1060167.50	5971
BNE 1060440.00	5971
BNE 1060775.00	5971
BNE 1061272.50	5971
BNE 1061775.00	5971
BNE 1062277.50	5972
BNE 1062737.50	5972
BNE 1063032.50	5972
BNE 1063217.50	6242
BNE 1063477.50	6252
BNE 1063822.50	6253
BNE 1064245.00	6252
BNE 1064750.00	6250
BNE 1065256.50	6244
BNE 1065746.50	6235
BNE 1066247.50	6225
BNE 1066762.50	6223
BNE 1067252.50	6225
BNE 1067725.00	6222
BNE 1068312.50	6221
BNE 1068852.50	6221
BNE 1069290.00	6221
BNE 1069780.00	6225
BNE 1070277.50	6228
BNE 1070785.00	6230
BNE 1071280.00	6236
BNE 1071767.50	6239
BNE 1072017.50	6240
BNE 1072267.50	6497
BNE 1072755.00	6497
BNE 1073240.00	6496
BNE 1073742.50	6495
BNE 1074230.00	6493
BNE 1074722.50	6493
BNE 1075232.50	6495
BNE 1075740.00	6498
BNE 1076247.50	6504
BNE 1076752.50	6509
BNE 1077260.00	6514
BNE 1077775.00	6517
BNE 1078282.50	6518
BNE 1078592.50	6518

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Brisbane River Flood Study: Further investigations of hydrology incorporating dam operations and CRC-FORGE rainfall estimates. Draft A (issued 22 August 2003)	Issued version cannot be located
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Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates. Draft Final (issued 25 September 2003)	Brisbane_River_Flood_Study_Draft_Final_25Sep03.pdf
Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates. Final (issued 13 November 2003)	Brisbane_River_Flood_Study_Final_Isse_13Nov03.pdf
Brisbane River Flood Study: Further investigations of flood frequency analysis incorporating dam operations and CRC-FORGE rainfall estimates. Final Issue (compiled 18 December 2003)	Brisbane_River_Flood_Study_ Final_Issue_18Dec03.pdf
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Recalibration of the MIKE-11 hydraulic model and determination of the 1 in 100 AEP flood levels. Final (issued 5th February 2004)	Brisbane_River_Flood_Study_Recalibration_Final_Report_05Feb04.pdf
Calculation of floods of various return periods on the Brisbane River Q10, Q20, Q50 & Q2000 events (issued 6th July 2004)	Brisbane_River_Flood_Study_Calculation_of_Floods_Various_ARI_06Jul04.pdf

City Design – Flood Modelling Services

CALCULATION OF FLOODS OF VARIOUS RETURN PERIODS ON THE BRISBANE RIVER

- Q10, Q20, Q50 & Q2000 EVENTS
- Draft
- 3/03/2004

City Design – Flood Modelling Services

CALCULATION OF FLOODS OF VARIOUS RETURN PERIODS ON THE BRISBANE RIVER

- Draft
- 3/03/2004

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SKM

1. Introduction

Council requires calculation of discharges and flood levels for the Brisbane River for return intervals of 10, 20, 50 and 2000 years. This work follows on from SKM's recent work on developing Q100 flood levels and discharges based on a re-calibrated model.

This report details assumptions, methodology and results for these storm events

2. Assumptions

The assumptions used to predict discharges are as follows.

- Rainfall based on data received from City Design on 11 February 2004
- Rainfall based on CRCFORGE rainfall with Areal Reduction Factors.
- An Initial loss of 10 mm and a Continuing loss of 1 mm/hr used in the RAFTS models
- A tail water level of 0.918m AHD at the Western Inner Bar used for each event

For the Q2000 event

- Storm durations of 24, 48, 96 and 120 hrs were modelled
- PMP temporal pattern 'a' used for all durations

For the Q10, Q20 and Q50 events

- Standard temporal patterns (AR&R 1987) were used for 24, 30, 36, 48 and 72 hr storm durations
- PMP temporal pattern 'a' used for 96 and 120 hr storm durations

SKM

3. Methodology

The methodology used to produce results for the Q10, Q20, Q50 and Q2000 events are as follows:

Rainfall

- Rainfall depths for the Q50 and Q200 flood events were based on data provided by Council. Data was produced using CRC FORGE rainfall with Areal Reduction Factors (ARF's) applied.
- Rainfall depths for the Q10 and Q20 flood events were based on depths calculated for the Brisbane River Flood Study (SKM 1998) with ARF's applied.
- There was a conversion process required to link rainfall data from Council to the current RAFTS model. This was because Council data was in the format of the original Brisbane River Flood Study (BRFS) and required updating to the more complex model used in the Ipswich Rivers Flood Study (IRFS)
- Rainfall intensities for each of the subcatchments were then temporally distributed using the program HYDCON.
- HYDCON outputs a *.his file that is compatible with RAFTS. This enables each subcatchment to have a unique 'local' storm depending on its position within the catchment

RAFTS [no dams]

- The RAFTS model was run for the each of the seven durations, Rainfall losses of 10 mm (initial) and 1 mm/hr (continuing) were applied. The RAFTS model was set up so that neither Wivenhoe nor Somerset Dams were active.
- This enables a hydrograph of the Wivenhoe and Somerset catchments to be calculated without contributing any storm water detention as a result of the dam. Dams were modelled separately using NR&M's Program DAMS.
- Hydrographs were extracted from RAFTS for nodes WIV27 (Wivenhoe) Som32 (Somerset) SAV8 (Lockyer) and 1B (Bremer).

DAMS

- The Dams program requires the RAFTS hydrographs be converted to a *.prn file format This was achieved using a combination of spreadsheet tools.
- The Dams program models the Wivenhoe and Somerset Dams using current operating rules for water releases. It required input hydrographs from RAFTS at four locations, namely WIV27 (Wivenhoe) Som32 (Somerset) SAV8 (Lockyer) and 1B (Bremer).
- The hydrograph for Wivenhoe was manipulated so that discharge from Somerset was not included, as this was modelled separately.

- The DAMS program was run for each of the seven storm durations.
- DAMS outputs hydrograph data for the Wivenhoe Dam release as a *.dat file. To enable compatibility with RAFTS, the *.dat file was converted into a suitable format using a spreadsheet tool. This was done for each storm durations

Rafts [with dams]

- The output from the DAMS model (ie. Wivenhoe Dam releases) was then input into the RAFTS model
- The RAFTS model was truncated so that all nodes above Wivenhoe Dam were removed, this was replaced with the direct inflow hydrograph extracted from DAMS.
- The RAFTS model was re-run for each of the seven storm durations.
- Results were recorded for several key locations and the critical duration was determined.
- Hydrographs were extracted for key locations on the Bremer, Brisbane River and associated tributaries for hydraulic modelling in MIKE11.
- RAFTS hydrographs were converted into a text ASCII format and imported into MIKE11.

MIKE11

- MIKE 11 Simulation, Boundary, and Time Series files were set up.
- Network and Parameter files were taken from the current Brisbane River MIKE 11 model (re-calibrated case).
- The MIKE 11 model was then run for the critical duration using the re-calibrated model
- Results were extracted for discharge and water levels for every cross section in the model. Results at key locations were also noted.

SKM

4. Results - RAFTS

Table 1 presents the results of the Rafts modelling with no dams

- Table 1 Discharges at Port Office Gauge (no dams)

Storm Duration	Q10	Q20	Q50	Q2000
24	4805.3	5868.4	7069.9	13966
30	**6090.0**	**7062.6**	7897.9	-
36	4828.4	5876.6	7043.7	-
48	4950.2	6107.1	7375.2	**17126**
72	4890.0	6187.9	**8613.6**	17026
96	-	-	7849.8	16417
120	-	-	7983.1	16897

Table 2 presents the results of the Rafts modelling with no dams

- Table 2 Discharges at Port Office Gauge (with dams)

Storm Duration	Q10	Q20	Q50	Q2000
24	1655.9	2054.8	2718.6	7202.8
30	**2343.9**	**2774.3**	3337.1	-
36	1691.8	2160.8	2734.5	-
48	1786.2	2323.1	3035.4	10157
72	1940.2	2426.1	**3972.8**	11605
96	-	-	3817.3	12347
120	-	-	3927.2	**12814**

5. Results - MIKE 11

Table 3 presents the results of the MIKE11 modelling with dams

- Table 3 Discharges and WSL at the Port Office Gauge (with dams)

	Q10	Q20	Q50	Q2000
Storm Duration [hrs]	30	30	72	120
WSL [m AHD]	1.529	1.791	2.416	6.368
Discharge [m^3/s]	2834	3447	4591	11698

It should be noted that differences in discharges in the RAFTS and MIKE11 models are due to river routing affects.

Appendix A Mike11 Results Q10

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q10 event CRCFORGE rainfall with ARF's

30hr Storm Duration

DRAFT

Chainage [m]	Water Level	Chainage [m]	Discharge	Chainage [m]	Velocity [m/s]	Chainage [m]	Velocity [m/s]
BNE 931570.00	36.154	BNE 931575.00	2000	BNE 931570.00	1.462	BNE 1027420.00	1.355
BNE 931580.00	36.149	BNE 932625.00	1985	BNE 931575.00	1.463	BNE 1027680.00	1.261
BNE 933670.00	35.094	BNE 933970.00	1974	BNE 931580.00	1.463	BNE 1027930.00	1.21
BNE 934270.00	34.958	BNE 934445.00	1964	BNE 932625.00	1.486	BNE 1028180.00	1.163
BNE 934620.00	34.773	BNE 935345.00	1954	BNE 933670.00	1.472	BNE 1028430.00	1.286
BNE 936070.00	34.525	BNE 936445.00	1922	BNE 933970.00	1.032	BNE 1028680.00	1.44
BNE 936820.00	34.496	BNE 937295.00	1903	BNE 934270.00	1.640	BNE 1028720.00	1.816
BNE 939770.00	34.214	BNE 941045.00	1899	BNE 934445.00	1.891	BNE 1028760.00	1.454
BNE 942320.00	33.125	BNE 942945.00	1899	BNE 934620.00	2.524	BNE 1028980.00	1.518
BNE 943570.00	32.702	BNE 943845.00	1899	BNE 935345.00	0.801	BNE 1029200.00	1.584
BNE 944120.00	32.488	BNE 944845.00	1898	BNE 936070.00	0.516	BNE 1029440.00	1.476
BNE 945570.00	31.992	BNE 946370.00	1898	BNE 936445.00	0.495	BNE 1029680.00	1.382
BNE 947170.00	31.488	BNE 947720.00	1898	BNE 936820.00	3.612	BNE 1029950.00	1.361
BNE 948270.00	31.04	BNE 949270.00	1898	BNE 936295.00	0.664	BNE 1030220.00	1.34
BNE 950270.00	30.454	BNE 951295.00	1897	BNE 939770.00	1.409	BNE 1030545.00	1.337
BNE 952320.00	29.85	BNE 953095.00	1897	BNE 941045.00	1.186	BNE 1030870.00	1.334
BNE 953870.00	29.444	BNE 954395.00	1897	BNE 942320.00	1.298	BNE 1031065.00	1.397
BNE 954920.00	29.058	BNE 955445.00	1897	BNE 942945.00	1.004	BNE 1031260.00	1.467
BNE 955970.00	28.544	BNE 957370.00	1896	BNE 943570.00	0.816	BNE 1031460.00	1.562
BNE 958770.00	27.377	BNE 959470.00	1896	BNE 943845.00	0.944	BNE 1031700.00	1.669
BNE 960170.00	26.944	BNE 961120.00	1896	BNE 944120.00	1.141	BNE 1031847.50	1.464
BNE 962070.00	25.979	BNE 963120.00	1895	BNE 944845.00	0.92	BNE 1031995.00	1.303
BNE 964170.00	24.494	BNE 965390.00	1895	BNE 945570.00	1.286	BNE 1032112.50	1.273
BNE 966610.00	22.823	BNE 967010.00	1894	BNE 946370.00	0.995	BNE 1032230.00	1.245
BNE 967410.00	22.449	BNE 968600.00	1894	BNE 947170.00	1.15	BNE 1032407.50	1.279
BNE 969790.00	21.635	BNE 970475.00	1894	BNE 947720.00	1.187	BNE 1032585.00	1.316
BNE 971160.00	21.278	BNE 971710.00	1893	BNE 948270.00	1.228	BNE 1032832.50	1.295
BNE 972260.00	21.059	BNE 972760.00	1893	BNE 949270.00	0.99	BNE 1033080.00	1.276
BNE 973260.00	21.017	BNE 973920.00	1893	BNE 950270.00	0.829	BNE 1033225.00	1.315
BNE 974580.00	20.918	BNE 975300.00	1893	BNE 951295.00	0.978	BNE 1033370.00	1.357
BNE 976020.00	20.834	BNE 976385.00	1892	BNE 952320.00	1.191	BNE 1033635.00	1.394
BNE 976750.00	20.749	BNE 977515.00	1892	BNE 953095.00	1.001	BNE 1033900.00	1.434
BNE 978280.00	19.79	BNE 978893.50	1892	BNE 953870.00	0.862	BNE 1034135.00	1.435
BNE 979507.00	17.837	BNE 979510.00	1914	BNE 954395.00	1.001	BNE 1034370.00	1.437
BNE 979513.00	17.807	BNE 979521.50	1912	BNE 954920.00	1.492	BNE 1034630.00	1.378
BNE 979530.00	17.777	BNE 979930.00	1894	BNE 955445.00	1.241	BNE 1034890.00	1.324
BNE 980330.00	17.485	BNE 980995.00	1891	BNE 955970.00	1.291	BNE 1035152.00	1.359
BNE 981660.00	17.111	BNE 982060.00	1891	BNE 957370.00	1.206	BNE 1035414.00	1.396
BNE 982460.00	16.953	BNE 983310.00	1890	BNE 958770.00	1.134	BNE 1035857.00	1.432
BNE 984160.00	16.559	BNE 984710.00	1890	BNE 959470.00	0.917	BNE 1035900.00	1.47
BNE 985260.00	16.167	BNE 985870.00	1890	BNE 960170.00	0.785	BNE 1036180.00	1.444
BNE 986480.00	15.533	BNE 987220.00	1890	BNE 961120.00	1.01	BNE 1036460.00	1.419
BNE 987960.00	14.619	BNE 988060.00	1890	BNE 962070.00	1.483	BNE 1036615.00	1.375
BNE 988160.00	14.355	BNE 988165.00	1890	BNE 963120.00	1.159	BNE 1036770.00	1.333
BNE 988170.00	14.315	BNE 988265.00	1890	BNE 964170.00	0.996	BNE 1036842.50	1.333
BNE 988360.00	14.057	BNE 989030.00	1890	BNE 965390.00	1.146	BNE 1036915.00	1.334
BNE 989700.00	13.047	BNE 990200.00	1889	BNE 966610.00	1.466	BNE 1037002.50	1.255
BNE 990700.00	12.692	BNE 990730.00	1889	BNE 967010.00	1.185	BNE 1037090.00	1.184
BNE 990760.00	12.664	BNE 991235.00	1889	BNE 967410.00	0.995	BNE 1037110.00	1.502
BNE 991710.00	12.383	BNE 992065.00	1889	BNE 968600.00	1.102	BNE 1037175.00	1.188
BNE 992420.00	12.201	BNE 992435.00	1889	BNE 969790.00	1.235	BNE 1037230.00	1.271
BNE 992450.00	12.175	BNE 992460.00	1889	BNE 970475.00	1.217	BNE 1037285.00	1.365
BNE 992470.00	12.163	BNE 992570.00	1889	BNE 971160.00	1.2	BNE 1037455.00	1.303
BNE 992670.00	12.07	BNE 993215.00	1888	BNE 971710.00	1.182	BNE 1037625.00	1.246
BNE 993760.00	11.491	BNE 994260.00	1888	BNE 972260.00	1.819	BNE 1037855.00	1.153
BNE 994760.00	11.023	BNE 995225.00	1888	BNE 972760.00	0.904	BNE 1038085.00	1.072
BNE 995690.00	10.459	BNE 996335.00	1888	BNE 973260.00	0.738	BNE 1038342.50	1.149
BNE 996980.00	9.619	BNE 997720.00	1887	BNE 973920.00	0.942	BNE 1038600.00	1.236
BNE 998460.00	9.407	BNE 998810.00	1887	BNE 974580.00	1.301	BNE 1038850.00	1.237
BNE 999160.00	9.348	BNE 999580.00	1887	BNE 975300.00	1.159	BNE 1039100.00	1.238
BNE 1000000.00	9.268	BNE 1000142.50	1887	BNE 976020.00	1.045	BNE 1039150.00	1.222
BNE 1000285.00	9.203	BNE 1000530.00	1887	BNE 976385.00	0.911	BNE 1039200.00	1.207
BNE 1000775.00	9.114	BNE 1001045.00	1887	BNE 976750.00	1.034	BNE 1039200.00	1.207
BNE 1001315.00	9.049	BNE 1001590.00	1886	BNE 977515.00	0.979	BNE 1039382.50	1.157
BNE 1001865.00	8.949	BNE 1002107.50	1886	BNE 978280.00	1.242	BNE 1039565.00	1.111
BNE 1002350.00	8.872	BNE 1002567.50	1886	BNE 978893.50	1.187	BNE 1039617.50	1.083
BNE 1002785.00	8.852	BNE 1003030.00	1886	BNE 979507.00	1.146	BNE 1039670.00	1.056
BNE 1003275.00	8.789	BNE 1003525.00	1886	BNE 979510.00	1.375	BNE 1039670.00	1.056
BNE 1003775.00	8.735	BNE 1004037.50	1886	BNE 979513.00	1.189	BNE 1039749.00	1.025
BNE 1004300.00	8.629	BNE 1004565.00	1886	BNE 979521.50	1.252	BNE 1039828.00	0.995
BNE 1004810.00	8.587	BNE 1005067.50	1886	BNE 979530.00	1.314	BNE 1039828.00	0.989
BNE 1005325.00	8.526	BNE 1005597.50	1885	BNE 979930.00	1.249	BNE 1039959.00	0.96
BNE 1005870.00	8.449	BNE 1006035.00	1885	BNE 980330.00	1.251	BNE 1040090.00	0.933
BNE 1005870.00	8.449	BNE 1006250.00	2935	BNE 980995.00	1.187	BNE 1040170.00	0.983
BNE 1006200.00	8.42	BNE 1006605.00	2934	BNE 981660.00	1.175	BNE 1040250.00	1.039
BNE 1006200.00	8.42	BNE 1007180.00	2930	BNE 982060.00	1.152	BNE 1040250.00	1.039
BNE 1006300.00	8.395	BNE 1007595.00	2926	BNE 982460.00	1.13	BNE 1040370.00	1.129
BNE 1006300.00	8.395	BNE 1007850.00	2923	BNE 983310.00	1.087	BNE 1040490.00	1.237
BNE 1006910.00	8.206	BNE 1008182.50	2922	BNE 984160.00	1.047	BNE 1040750.00	1.108
BNE 1007410.00	8.094	BNE 1008685.00	2920	BNE 984710.00	1.099	BNE 1041010.00	1.003
BNE 1007780.00	7.96	BNE 1009162.50	2918	BNE 985260.00	1.157	BNE 1041120.00	1.015
BNE 1007780.00	7.96	BNE 1009560.00	2916	BNE 985870.00	1.206	BNE 1041230.00	1.027
BNE 1007920.00	7.899	BNE 1010105.00	2914	BNE 986480.00	1.26	BNE 1041345.00	1.043
BNE 1008445.00	7.888	BNE 1010607.50	2912	BNE 987220.00	1.116	BNE 1041460.00	1.06
BNE 1008925.00	7.841	BNE 1010852.50	2911	BNE 987960.00	1.002	BNE 1041580.00	0.962
BNE 1009400.00	7.752	BNE 1011245.00	2909	BNE 988060.00	1.225	BNE 1041700.00	0.88
BNE 1009720.00	7.684	BNE 1011745.00	2907	BNE 988160.00	1.577	BNE 1041830.00	1.016
BNE 1010490.00	7.541	BNE 1012227.50	2904	BNE 988165.00	3.452	BNE 1041960.00	1.2
BNE 1010725.00	7.569	BNE 1012705.00	2899	BNE 988170.00	1.585	BNE 1042097.50	1.232
BNE 1010980.00	7.537	BNE 1013082.50	2897	BNE 988265.00	1.307	BNE 1042235.00	1.266
BNE 1011510.00	7.529	BNE 1013317.50	2896	BNE 988360.00	1.112	BNE 1042367.50	1.188
BNE 1011980.00	7.52	BNE 1013562.50	2895	BNE 989030.00	1.047	BNE 1042500.00	1.119
BNE 1012475.00	7.504	BNE 1013795.00	2894	BNE 989700.00	0.989	BNE 1042500.00	1.119

BNE 1012475.00	7.504			BNE 1014110.00	2891		BNE 990200.00	1.07		BNE 1042507.50	1.115
BNE 1012935.00	7.481			BNE 1014460.00	2889		BNE 990700.00	1.166		BNE 1042515.00	1.111
BNE 1013190.00	7.471			BNE 1014850.00	2885		BNE 990730.00	1.19		BNE 1042712.50	1.172
BNE 1013190.00	7.471			BNE 1015325.00	2884		BNE 990760.00	1.216		BNE 1042910.00	1.24
BNE 1013445.00	7.458			BNE 1015705.00	2883		BNE 991235.00	0.879		BNE 1042960.00	1.242
BNE 1013680.00	7.445			BNE 1015995.00	2882		BNE 991710.00	0.688		BNE 1043010.00	1.244
BNE 1013680.00	7.445			BNE 1016390.00	2882		BNE 992065.00	0.714		BNE 1043010.00	1.244
BNE 1013910.00	7.425			BNE 1016765.00	2880		BNE 992420.00	0.743		BNE 1043045.00	1.245
BNE 1014310.00	7.351			BNE 1017010.00	2879		BNE 992435.00	0.816		BNE 1043080.00	1.246
BNE 1014610.00	7.225			BNE 1017370.00	2878		BNE 992450.00	0.907		BNE 1043095.00	1.242
BNE 1014610.00	7.225			BNE 1017765.00	2877		BNE 992460.00	1.029		BNE 1043110.00	1.238
BNE 1015090.00	7.142			BNE [illegible]8060.00	2876		BNE 992470.00	0.908		BNE 1043110.00	1.238
BNE 1015560.00	7.058			[illegible]8462.50	2875		BNE 992570.00	0.991		BNE 1043417.50	1.151
BNE 1015850.00	7.012			BNE 1018910.00	2875		BNE 992670.00	1.09		BNE 1043725.00	1.075
BNE 1015850.00	7.012			BNE 1019292.50	2875		BNE 993215.00	1.256		BNE 1043892.50	1.044
BNE 1016140.00	6.967			BNE 1019677.50	2874		BNE 993760.00	1.482		BNE 1044060.00	1.014
BNE 1016640.00	6.81			BNE 1019990.00	2874		BNE 994260.00	1.214		BNE 1044200.00	1.077
BNE 1016890.00	6.697			BNE 1020320.00	2873		BNE 994760.00	1.028		BNE 1044340.00	1.149
BNE 1016890.00	6.697			BNE 1020677.50	2871		BNE 995225.00	1.136		BNE 1044472.50	1.098
BNE 1017130.00	6.585			BNE 1020962.50	2870		BNE 995690.00	1.269		BNE 1044605.00	1.052
BNE 1017610.00	6.468			BNE 1021317.00	2870		BNE 996335.00	1.333		BNE 1044732.50	1.015
BNE 1017920.00	6.378			BNE 1021627.00	2869		BNE 996980.00	1.403		BNE 1044860.00	0.981
BNE 1018200.00	6.37			BNE 1021805.00	2869		BNE 997720.00	0.974		BNE 1045130.00	0.981
BNE 1018725.00	6.257			BNE 1022000.00	2868		BNE 998460.00	0.745		BNE 1045400.00	0.98
BNE 1019095.00	6.195			BNE 1022340.00	2868		BNE 998810.00	0.991		BNE 1045642.50	1.009
BNE 1019490.00	6.151			BNE 1022807.50	2873		BNE 999160.00	1.478		BNE 1045885.00	1.04
BNE 1019490.00	6.151			BNE 1023305.00	2873		BNE 999680.00	1.2		BNE 1046032.50	0.886
BNE 1019865.00	6.053			BNE 1023825.00	2872		BNE 1000000.00	1.01		BNE 1046180.00	0.771
BNE 1020115.00	6.049			BNE 1024321.50	2872		BNE 1000142.50	1.145		BNE 1046260.00	0.781
BNE 1020525.00	6.01			BNE 1024816.50	2871		BNE 1000285.00	1.323		BNE 1046340.00	0.791
BNE 1020830.00	5.948			BNE 1025215.00	2870		BNE 1000530.00	1.328		BNE 1046460.00	0.813
BNE 1021095.00	5.852			BNE 1025475.00	2870		BNE 1000775.00	1.334		BNE 1046580.00	0.837
BNE 1021539.00	5.701			BNE 1025880.00	2869		BNE 1001045.00	1.27		BNE 1046740.00	0.957
BNE 1021715.00	5.666			BNE 1026425.00	2868		BNE 1001315.00	1.212		BNE 1046900.00	1.117
BNE 1021895.00	5.61			BNE 1026790.00	2868		BNE 1001590.00	1.409		BNE 1047125.00	1.181
BNE 1022105.00	5.551			BNE 1027030.00	2867		BNE 1001865.00	1.683		BNE 1047350.00	1.252
BNE 1022575.00	5.457			BNE 1027420.00	2867		BNE 1002107.50	1.685		BNE 1047632.50	1.201
BNE 1023040.00	5.346			BNE 1027930.00	2866		BNE 1002350.00	1.688		BNE 1047915.00	1.155
BNE 1023570.00	5.309			BNE 1028430.00	2864		BNE 1002567.50	1.425		BNE 1048145.00	1.01
BNE 1024080.00	5.26			BNE 1028720.00	2864		BNE 1002785.00	1.233		BNE 1048375.00	0.897
BNE 1024563.00	5.216			BNE 1028980.00	2864		BNE 1003030.00	1.357		BNE 1048632.50	1.055
BNE 1025070.00	5.189			BNE 1029440.00	2863		BNE 1003275.00	1.51		BNE 1048890.00	1.279
BNE 1025360.00	5.142			BNE 1029950.00	2862		BNE 1003525.00	1.423		BNE 1049005.00	1.179
BNE 1025590.00	5.076			BNE 1030545.00	2861		BNE 1003775.00	1.346		BNE 1049120.00	1.093
BNE 1026170.00	4.967			BNE 1031065.00	2860		BNE 1004037.50	1.484		BNE 1049245.00	1.166
BNE 1026680.00	4.878			BNE 1031480.00	2860		BNE 1004300.00	1.654		BNE 1049370.00	1.248
BNE 1026900.00	4.824			BNE 1031847.50	2859		BNE 1004555.00	1.343		BNE 1049480.00	1.193
BNE 1027160.00	4.772			BNE 1032112.50	2859		BNE 1004810.00	1.131		BNE 1049590.00	1.142
BNE 1027680.00	4.735			BNE 1032407.50	2858		BNE 1005067.50	1.195		BNE 1049730.00	1.19
BNE 1028180.00	4.716			BNE 1032832.50	2858		BNE 1005325.00	1.266		BNE 1049870.00	1.243
BNE 1028680.00	4.644			BNE 1033225.00	2857		BNE 1005597.50	1.35		BNE 1050150.00	1.224
BNE 1028760.00	4.567			BNE 1033635.00	2857		BNE 1005870.00	1.446		BNE 1050430.00	1.205
BNE 1029200.00	4.503			BNE 1034135.00	2856		BNE 1006870.00	1.446		BNE 1050645.00	1.237
BNE 1029680.00	4.493			BNE 1034630.00	2856		BNE 1006035.00	1.292		BNE 1050860.00	1.271
BNE 1030220.00	4.476			BNE 1035152.50	2855		BNE 1006200.00	1.168		BNE 1051110.00	1.176
BNE 1030870.00	4.444			BNE 1035657.50	2854		BNE 1006200.00	1.484		BNE 1051360.00	1.094
BNE 1031260.00	4.397			BNE 1036180.00	2854		BNE 1006250.00	1.45		BNE 1051627.50	1.245
BNE 1031700.00	4.319			BNE 1036615.00	2853		BNE 1006300.00	1.418		BNE 1051895.00	1.443
BNE 1031995.00	4.305			BNE 1036842.50	2853		BNE 1006300.00	1.418		BNE 1052102.50	1.24
BNE 1032230.00	4.242			BNE 1037002.50	2853		BNE 1006605.00	1.43		BNE 1052310.00	1.087
BNE 1032585.00	4.133			BNE 1037110.00	2853		BNE 1006910.00	1.441		BNE 1052370.00	1.79
BNE 1033080.00	4.056			BNE 1037230.00	2853		BNE 1007160.00	1.368		BNE 1052390.00	1.271
BNE 1033370.00	4.015			BNE 1037455.00	2853		BNE 1007410.00	1.381		BNE 1052492.50	1.282
BNE 1033900.00	3.925			BNE 1037855.00	2852		BNE 1007595.00	1.448		BNE 1052595.00	1.292
BNE 1034370.00	3.842			BNE 1038342.50	2851		BNE 1007780.00	1.633		BNE 1052625.00	1.613
BNE 1034890.00	3.787			BNE 1038850.00	2850		BNE 1007780.00	1.631		BNE 1052640.00	1.121
BNE 1035414.00	3.717			BNE 1039150.00	2850		BNE 1007850.00	1.717		BNE 1052752.50	1.143
BNE 1035900.00	3.63			BNE 1039382.50	2849		BNE 1007920.00	1.814		BNE 1052865.00	1.165
BNE 1036460.00	3.524			BNE 1039617.50	2848		BNE 1008182.50	1.583		BNE 1053092.50	1.098
BNE 1036770.00	3.459			BNE 1039749.00	2848		BNE 1008445.00	1.405		BNE 1053320.00	1.038
BNE 1036915.00	3.436			BNE 1039959.00	2835		BNE 1008685.00	1.413		BNE 1053355.00	1.364
BNE 1037090.00	3.45			BNE 1040170.00	2834		BNE 1008925.00	1.421		BNE 1053365.00	1.255
BNE 1037175.00	3.322			BNE 1040370.00	2834		BNE 1009162.50	1.419		BNE 1053642.50	1.228
BNE 1037285.00	3.296			BNE 1040750.00	2834		BNE 1009400.00	1.417		BNE 1053900.00	1.203
BNE 1037625.00	3.279			BNE 1041120.00	2834		BNE 1009560.00	1.399		BNE 1054270.00	0.841
BNE 1038085.00	3.264			BNE 1041345.00	2834		BNE 1009720.00	1.382		BNE 1054640.00	0.647
BNE 1038600.00	3.22			BNE 1041680.00	2834		BNE 1010105.00	1.515		BNE 1054660.00	0.983
BNE 1039100.00	3.187			BNE 1041830.00	2834		BNE 1010490.00	1.676		BNE 1054680.00	0.612
BNE 1039200.00	3.187			BNE 1042097.50	2834		BNE 1010807.50	1.548		BNE 1054825.00	0.784
BNE 1039200.00	3.187			BNE 1042367.50	2834		BNE 1010725.00	1.437		BNE 1054970.00	1.093
BNE 1039565.00	3.186			BNE 1042507.50	2834		BNE 1010852.50	1.463		BNE 1055125.00	1.076
BNE 1039670.00	3.189			BNE 1042712.50	2834		BNE 1010980.00	1.49		BNE 1055280.00	1.06
BNE 1039670.00	3.189			BNE 1042960.00	2833		BNE 1011245.00	1.432		BNE 1055350.00	1.07
BNE 1039828.00	3.192			BNE 1043045.00	2833		BNE 1011510.00	1.377		BNE 1055420.00	1.081
BNE 1039828.00	3.192			BNE 1043095.00	2833		BNE 1011745.00	1.358		BNE 1055690.00	1.026
BNE 1040090.00	3.193			BNE 1043417.50	2833		BNE 1011980.00	1.338		BNE 1055960.00	0.976
BNE 1040250.00	3.18			BNE 1043892.50	2833		BNE 1012227.50	1.324		BNE 1056180.00	1.094
BNE 1040250.00	3.18			BNE 1044200.00	2833		BNE 1012475.00	1.309		BNE 1056400.00	1.243
BNE 1040490.00	3.152			BNE 1044472.50	2833		BNE 1012475.00	1.307		BNE 1056547.50	1.179
BNE 1041010.00	3.159			BNE 1044732.50	2833		BNE 1012705.00	1.313		BNE 1056695.00	1.121
BNE 1041230.00	3.141			BNE 1045130.00	2833		BNE 1012935.00	1.32		BNE 1056780.00	0.432
BNE 1041460.00	3.117			BNE 1045642.50	2833		BNE 1013062.50	1.307		BNE 1056865.00	0.268
BNE 1041700.00	3.121			BNE 1046032.50	2833		BNE 1013190.00	1.293		BNE 1056920.00	1.264
BNE 1041960.00	3.071			BNE 1046260.00	2833		BNE 1013190.00	1.293		BNE 1056950.00	0.277
BNE 1042235.00	3.015			BNE 1046460.00	2833		BNE 1013317.50	1.282		BNE 1057020.00	0.413
BNE 1042500.00	2.989			BNE 1046740.00	2833		BNE 1013445.00	1.271		BNE 1057090.00	0.816
BNE 1042500.00	2.989			BNE 1047125.00	2833		BNE 1013562.50	1.252		BNE 1057310.00	0.883
BNE 1042515.00	2.987			BNE 1047632.50	2833		BNE 1013680.00	1.232		BNE 1057630.00	0.961
BNE 1042910.00	2.898			BNE 1048145.00	2833		BNE 1013680.00	1.232		BNE 1057785.00	1.058

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BNE 1043010.00	2.868		BNE 1048632.50	2833		BNE 1013795.00	1.223		BNE 1058040.00	1.177
BNE 1043010.00	2.868		BNE 1049005.00	2833		BNE 1013910.00	1.214		BNE 1058135.00	1.175
BNE 1043080.00	2.848		BNE 1049245.00	2833		BNE 1014110.00	1.235		BNE 1058230.00	1.173
BNE 1043110.00	2.841		BNE 1049480.00	2833		BNE 1014310.00	1.257		BNE 1058380.00	1.156
BNE 1043110.00	2.841		BNE 1049730.00	2833		BNE 1014460.00	1.27		BNE 1058530.00	1.14
BNE 1043725.00	2.73		BNE 1050150.00	2833		BNE 1014610.00	1.282		BNE 1058632.50	1.082
BNE 1044060.00	2.697		BNE 1050645.00	2833		BNE 1014810.00	1.28		BNE 1058735.00	1.029
BNE 1044340.00	2.657		BNE 1051110.00	2833		BNE 1014850.00	1.118		BNE 1058885.00	1.095
BNE 1044605.00	2.641		BNE 1051627.50	2833		BNE 1015090.00	0.994		BNE 1059035.00	1.171
BNE 1044860.00	2.627		BNE 1052102.50	2833		BNE 1015325.00	1.119		BNE 1059287.50	1.025
BNE 1045400.00	2.593		BNE 1052370.00	2833		BNE 1015560.00	1.281		BNE 1059540.00	0.912
BNE 1045885.00	2.564		BNE 1052492.50	2833		BNE 1015705.00	1.266		BNE 1059765.00	0.926
BNE 1046180.00	2.581		BNE 1052625.00	2833		BNE 1015850.00	1.251		BNE 1059990.00	0.941
BNE 1046340.00	2.576		BNE 1052752.50	2833		BNE 1015850.00	1.251		BNE 1060167.50	0.981
BNE 1046580.00	2.559		BNE [illegible]3092.50	2833		BNE 1015995.00	1.235		BNE 1060345.00	1.026
BNE 1046900.00	2.476		BNE [illegible]3355.00	2833		BNE 1016140.00	1.219		BNE 1060440.00	1.067
BNE 1047350.00	2.321		BNE 053642.50	2833		BNE 1016390.00	1.33		BNE 1060535.00	1.111
BNE 1047915.00	2.228		BNE 054270.00	2833		BNE 1016640.00	1.465		BNE 1060775.00	1.064
BNE 1048375.00	2.227		BNE 054660.00	2833		BNE 1016765.00	1.502		BNE 1061015.00	1.021
BNE 1048890.00	2.149		BNE 1054825.00	2833		BNE 1016890.00	1.541		BNE 1061272.50	1.048
BNE 1049120.00	2.142		BNE 1055125.00	2833		BNE 1016890.00	1.541		BNE 1061530.00	1.076
BNE 1049370.00	2.097		BNE 1055350.00	2834		BNE 1017010.00	1.6		BNE 1061775.00	1.02
BNE 1049590.00	2.088		BNE 1055690.00	2834		BNE 1017130.00	1.664		BNE 1062020.00	0.97
BNE 1049870.00	2.049		BNE 1056180.00	2834		BNE 1017370.00	1.574		BNE 1062277.50	0.906
BNE 1050430.00	1.998		BNE 1056547.50	2834		BNE 1017610.00	1.493		BNE 1062535.00	0.851
BNE 1050860.00	1.966		BNE 1056780.00	2834		BNE 1017765.00	1.545		BNE 1062737.50	0.765
BNE 1051380.00	1.971		BNE 1056920.00	2834		BNE 1017920.00	1.599		BNE 1062940.00	0.695
BNE 1051695.00	1.914		BNE 1057020.00	2834		BNE 1018060.00	1.402		BNE 1063032.50	0.704
BNE 1052310.00	1.952		BNE 1057310.00	2834		BNE 1018200.00	1.248		BNE 1063125.00	0.713
BNE 1052390.00	1.912		BNE 1057785.00	2834		BNE 1018462.50	1.325		BNE 1063125.00	0.713
BNE 1052595.00	1.908		BNE 1058135.00	2834		BNE 1018725.00	1.413		BNE 1063217.50	0.729
BNE 1052840.00	1.853		BNE 1058380.00	2834		BNE 1018910.00	1.396		BNE 1063310.00	0.745
BNE 1052865.00	1.846		BNE 1058632.50	2834		BNE 1019095.00	1.38		BNE 1063477.50	0.883
BNE 1053320.00	1.853		BNE 1058885.00	2834		BNE 1019292.50	1.291		BNE 1063645.00	1.023
BNE 1053385.00	1.789		BNE 1059287.50	2834		BNE 1019490.00	1.213		BNE 1063822.50	0.99
BNE 1053900.00	1.711		BNE 1059765.00	2834		BNE 1019490.00	1.213		BNE 1064000.00	0.958
BNE 1054640.00	1.681		BNE 1060167.50	2834		BNE 1019677.50	1.312		BNE 1064245.00	0.969
BNE 1054680.00	1.664		BNE 1060440.00	2834		BNE 1019865.00	1.428		BNE 1064490.00	0.98
BNE 1054970.00	1.607		BNE 1060775.00	2834		BNE 1019990.00	1.219		BNE 1064750.00	0.867
BNE 1055280.00	1.579		BNE 1061272.50	2834		BNE 1020115.00	1.063		BNE 1065010.00	0.777
BNE 1055420.00	1.561		BNE 1061775.00	2834		BNE 1020320.00	0.896		BNE 1065256.50	0.744
BNE 1055960.00	1.529		BNE 1062277.50	2834		BNE 1020525.00	0.775		BNE 1065503.00	0.714
BNE 1056400.00	1.471		BNE 1062737.50	2834		BNE 1020677.50	0.88		BNE 1065746.50	0.625
BNE 1056695.00	1.459		BNE 1063032.50	2834		BNE 1020830.00	1.018		BNE 1065990.00	0.555
BNE 1056865.00	1.493		BNE 1063217.50	2834		BNE 1020962.50	1.167		BNE 1066247.50	0.596
BNE 1056850.00	1.474		BNE 1063477.50	2834		BNE 1021095.00	1.386		BNE 1066505.00	0.644
BNE 1057090.00	1.451		BNE 1063822.50	2834		BNE 1021317.00	1.349		BNE 1066762.50	0.628
BNE 1057530.00	1.428		BNE 1064245.00	2835		BNE 1021539.00	1.332		BNE 1067020.00	0.613
BNE 1058040.00	1.375		BNE 1064750.00	2835		BNE 1021627.00	1.236		BNE 1067252.50	0.67
BNE 1058230.00	1.362		BNE 1065256.50	2835		BNE 1021715.00	1.153		BNE 1067485.00	0.739
BNE 1058530.00	1.348		BNE 1065746.50	2835		BNE 1021805.00	1.15		BNE 1067725.00	0.761
BNE 1058735.00	1.349		BNE 1065247.50	2835		BNE 1021895.00	1.146		BNE 1067965.00	0.786
BNE 1059035.00	1.311		BNE 1066762.50	2835		BNE 1022000.00	1.17		BNE 1068312.50	0.814
BNE 1059540.00	1.292		BNE 1067252.50	2835		BNE 1022105.00	1.194		BNE 1068660.00	0.844
BNE 1059990.00	1.241		BNE 1067725.00	2835		BNE 1022340.00	1.232		BNE 1068852.50	0.832
BNE 1060345.00	1.2		BNE 1068312.50	2835		BNE 1022575.00	1.274		BNE 1069045.00	0.821
BNE 1060535.00	1.188		BNE 1068852.50	2835		BNE 1022807.50	1.418		BNE 1069290.00	0.787
BNE 1061015.00	1.182		BNE 1069290.00	2835		BNE 1023040.00	1.596		BNE 1069535.00	0.756
BNE 1061530.00	1.17		BNE 1069780.00	2835		BNE 1023305.00	1.534		BNE 1069780.00	0.731
BNE 1062020.00	1.167		BNE 1070277.50	2836		BNE 1023570.00	1.477		BNE 1070025.00	0.707
BNE 1062535.00	1.166		BNE 1070785.00	2836		BNE 1023825.00	1.455		BNE 1070277.50	0.716
BNE 1062940.00	1.168		BNE 1071280.00	2836		BNE 1024080.00	1.433		BNE 1070530.00	0.724
BNE 1063125.00	1.177		BNE 1071767.50	2836		BNE 1024321.50	1.401		BNE 1070785.00	0.713
BNE 1063125.00	1.177		BNE 1072017.50	2836		BNE 1024563.00	1.37		BNE 1071040.00	0.702
BNE 1063310.00	1.156		BNE 1072267.50	3030		BNE 1024816.50	1.296		BNE 1071280.00	0.592
BNE 1063645.00	1.127		BNE 1072755.00	3040		BNE 1025070.00	1.23		BNE 1071520.00	0.511
BNE 1064000.00	1.128		BNE 1073240.00	3050		BNE 1025215.00	1.308		BNE 1071767.50	0.57
BNE 1064490.00	1.114		BNE 1073742.50	3060		BNE 1025360.00	1.397		BNE 1072015.00	0.644
BNE 1065010.00	1.116		BNE 1074230.00	3068		BNE 1025475.00	1.49		BNE 1072017.50	0.644
BNE 1065503.00	1.11		BNE 1074722.50	3073		BNE 1025590.00	1.596		BNE 1072020.00	0.644
BNE 1065990.00	1.112		BNE 1075232.50	3076		BNE 1025880.00	1.493		BNE 1072020.00	0.686
BNE 1066505.00	1.102		BNE 1075740.00	3076		BNE 1026170.00	1.402		BNE 1072267.50	0.673
BNE 1067020.00	1.098		BNE 1076247.50	3073		BNE 1026425.00	1.38		BNE 1072515.00	0.659
BNE 1067485.00	1.084		BNE 1076752.50	3069		BNE 1026680.00	1.359		BNE 1072755.00	0.643
BNE 1067965.00	1.072		BNE 1077260.00	3063		BNE 1026790.00	1.402		BNE 1072995.00	0.626
BNE 1068660.00	1.054		BNE 1077775.00	3060		BNE 1026900.00	1.448		BNE 1073240.00	0.659
BNE 1069045.00	1.046		BNE 1078282.50	3058		BNE 1027030.00	1.456		BNE 1073485.00	0.694
BNE 1069535.00	1.039		BNE 1078592.50	3058		BNE 1027160.00	1.464		BNE 1073742.50	0.684
BNE 1070025.00	1.031								BNE 1074000.00	0.674
BNE 1070530.00	1.018								BNE 1074230.00	0.67
BNE 1071040.00	1.007								BNE 1074460.00	0.665
BNE 1071520.00	1.009								BNE 1074722.50	0.7
BNE 1072015.00	0.994								BNE 1074985.00	0.738
BNE 1072020.00	0.994								BNE 1075232.50	0.67
BNE 1072020.00	0.994								BNE 1075480.00	0.613
BNE 1072515.00	0.989								BNE 1075740.00	0.514
BNE 1072995.00	1.005								BNE 1076000.00	0.443
BNE 1073485.00	1.019								BNE 1076247.50	0.501
BNE 1074000.00	1.038								BNE 1076495.00	0.578
BNE 1074460.00	1.053								BNE 1076752.50	0.475
BNE 1074985.00	1.066								BNE 1077010.00	0.404
BNE 1075480.00	1.079								BNE 1077260.00	0.346
BNE 1076000.00	1.081								BNE 1077510.00	0.303
BNE 1076495.00	1.065								BNE 1077775.00	0.311
BNE 1077010.00	1.041								BNE 1078040.00	0.32
BNE 1077510.00	1.009								BNE 1078282.50	0.384
BNE 1078040.00	0.97								BNE 1078525.00	0.482
BNE 1078525.00	0.92								BNE 1078592.50	0.107
BNE 1078660.00	0.918								BNE 1078660.00	0.06

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Appendix B Mike11 Results Q20

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q20 event CRCFORGE rainfall with ARF's

30hr Storm Duration

DRAFT

Chainage [m]	Water Level	Chainage [m]	Discharge	Chainage [m]	Velocity [m/s]	Chainage [m]	Velocity [m/s]
BNE 931570.00	36.092	BNE 931575.00	1900	BNE 931570.00	1.43	BNE 1031995.00	1.466
BNE 931580.00	36.086	BNE 932625.00	1900	BNE 931575.00	1.431	BNE 1032112.50	1.434
BNE 933670.00	35.012	BNE 933970.00	1899	BNE 931580.00	1.43	BNE 1032230.00	1.403
BNE 934270.00	34.872	BNE 934445.00	1898	BNE 932625.00	1.434	BNE 1032407.50	1.453
BNE 934620.00	34.682	BNE 935345.00	1897	BNE 933670.00	1.443	BNE 1032585.00	1.507
BNE 936070.00	34.425	BNE 936445.00	1892	BNE 933970.00	1.036	BNE 1032832.50	1.485
BNE 936820.00	34.396	BNE 937295.00	1888	BNE 934270.00	1.587	BNE 1033080.00	1.463
BNE 938770.00	34.112	BNE 938045.00	1884	BNE 934445.00	1.981	BNE 1033225.00	1.501
BNE 942320.00	33.011	BNE 942945.00	1882	BNE 934620.00	2.748	BNE 1033370.00	1.54
BNE 943570.00	32.583	BNE 943845.00	1879	BNE 935345.00	1.021	BNE 1033635.00	1.588
BNE 944120.00	32.358	BNE 944845.00	1875	BNE 936070.00	0.512	BNE 1033900.00	1.639
BNE 945570.00	31.847	BNE 946370.00	1870	BNE 936445.00	0.491	BNE 1034135.00	1.643
BNE 947170.00	31.331	BNE 947720.00	1867	BNE 936820.00	1.532	BNE 1034370.00	1.646
BNE 948270.00	30.878	BNE 949270.00	1863	BNE 938295.00	0.656	BNE 1034630.00	1.581
BNE 950270.00	30.291	BNE 951295.00	1859	BNE 939770.00	1.551	BNE 1034890.00	1.521
BNE 952320.00	29.686	BNE 953095.00	1858	BNE 941045.00	1.172	BNE 1035152.00	1.554
BNE 953870.00	29.278	BNE 954395.00	1855	BNE 942320.00	1.282	BNE 1035414.00	1.589
BNE 954920.00	28.889	BNE 955445.00	1853	BNE 942945.00	0.992	BNE 1035657.00	1.635
BNE 955970.00	28.37	BNE 957370.00	1852	BNE 943570.00	0.883	BNE 1035900.00	1.684
BNE 958770.00	27.199	BNE 959470.00	1849	BNE 943845.00	0.935	BNE 1036180.00	1.655
BNE 960170.00	26.762	BNE 961120.00	1846	BNE 944120.00	1.123	BNE 1036460.00	1.627
BNE 962070.00	25.787	BNE 963120.00	1844	BNE 944845.00	0.973	BNE 1036615.00	1.564
BNE 964170.00	24.273	BNE 965390.00	1839	BNE 945570.00	1.283	BNE 1036770.00	1.507
BNE 966610.00	22.579	BNE 967010.00	1837	BNE 946370.00	1.029	BNE 1036842.50	1.525
BNE 967410.00	22.209	BNE 968600.00	1834	BNE 947170.00	1.142	BNE 1036915.00	1.543
BNE 969790.00	21.405	BNE 970475.00	1832	BNE 947720.00	1.181	BNE 1037002.50	1.459
BNE 971160.00	21.052	BNE 971710.00	1831	BNE 948270.00	1.222	BNE 1037090.00	1.384
BNE 972260.00	20.835	BNE 972760.00	1829	BNE 949270.00	0.984	BNE 1037110.00	1.729
BNE 973260.00	20.792	BNE 973920.00	1827	BNE 950270.00	0.828	BNE 1037175.00	1.391
BNE 974580.00	20.686	BNE 975300.00	1826	BNE 951295.00	0.976	BNE 1037230.00	1.478
BNE 976020.00	20.612	BNE 976385.00	1824	BNE 952320.00	1.199	BNE 1037285.00	1.578
BNE 976750.00	20.525	BNE 977515.00	1823	BNE 953095.00	0.997	BNE 1037455.00	1.498
BNE 978280.00	19.563	BNE 978893.50	1823	BNE 953870.00	0.858	BNE 1037625.00	1.426
BNE 979507.00	17.623	BNE 979510.00	1845	BNE 954395.00	0.998	BNE 1037855.00	1.323
BNE 979513.00	17.594	BNE 979521.50	1843	BNE 954920.00	1.435	BNE 1038085.00	1.233
BNE 979530.00	17.561	BNE 979930.00	1822	BNE 955445.00	1.236	BNE 1038342.50	1.305
BNE 980330.00	17.275	BNE 980995.00	1820	BNE 955970.00	1.285	BNE 1038600.00	1.387
BNE 981660.00	16.907	BNE 982060.00	1819	BNE 957370.00	1.202	BNE 1038850.00	1.384
BNE 982460.00	16.754	BNE 983310.00	1819	BNE 958770.00	1.131	BNE 1039100.00	1.381
BNE 984160.00	16.369	BNE 984710.00	1818	BNE 959470.00	0.814	BNE 1039150.00	1.364
BNE 985260.00	15.964	BNE 985870.00	1818	BNE 960170.00	0.793	BNE 1039200.00	1.347
BNE 986480.00	15.366	BNE 987220.00	1818	BNE 961120.00	1.008	BNE 1039200.00	1.347
BNE 987960.00	14.481	BNE 988060.00	1818	BNE 962070.00	1.479	BNE 1039382.50	1.265
BNE 988160.00	14.227	BNE 988165.00	1818	BNE 963120.00	1.169	BNE 1039565.00	1.247
BNE 988170.00	14.188	BNE 988285.00	1818	BNE 964170.00	1.002	BNE 1039617.50	1.219
BNE 988360.00	13.939	BNE 989030.00	1818	BNE 965390.00	1.156	BNE 1039670.00	1.193
BNE 989700.00	12.966	BNE 990200.00	1818	BNE 966610.00	1.459	BNE 1039670.00	1.193
BNE 990700.00	12.738	BNE 990730.00	1818	BNE 967010.00	1.177	BNE 1039749.00	1.162
BNE 990760.00	12.721	BNE 991235.00	1819	BNE 967410.00	0.987	BNE 1039828.00	1.132
BNE 991710.00	12.557	BNE 992065.00	1819	BNE 968600.00	1.092	BNE 1039828.00	1.117
BNE 992420.00	12.444	BNE 992435.00	1820	BNE 969790.00	1.225	BNE 1039959.00	1.091
BNE 992450.00	12.429	BNE 992460.00	1820	BNE 970475.00	1.206	BNE 1040090.00	1.066
BNE 992470.00	12.419	BNE 992570.00	1820	BNE 971160.00	1.189	BNE 1040170.00	1.124
BNE 992670.00	12.365	BNE 993215.00	1821	BNE 971710.00	1.174	BNE 1040250.00	1.188
BNE 993760.00	12.047	BNE 994260.00	1821	BNE 972260.00	1.931	BNE 1040250.00	1.188
BNE 994760.00	11.824	BNE 995225.00	1823	BNE 972760.00	0.908	BNE 1040370.00	1.293
BNE 995690.00	11.569	BNE 996335.00	1825	BNE 973260.00	0.73	BNE 1040490.00	1.418
BNE 996980.00	11.111	BNE 997720.00	1828	BNE 973920.00	0.931	BNE 1040750.00	1.268
BNE 998460.00	10.919	BNE 998810.00	1833	BNE 974580.00	1.285	BNE 1041010.00	1.147
BNE 999160.00	10.86	BNE 999580.00	1835	BNE 975300.00	1.144	BNE 1041120.00	1.156
BNE 1000000.00	10.773	BNE 1000142.50	1939	BNE 976020.00	1.03	BNE 1041230.00	1.17
BNE 1000285.00	10.699	BNE 1000530.00	1937	BNE 976385.00	0.907	BNE 1041345.00	1.189
BNE 1000775.00	10.602	BNE 1001045.00	1935	BNE 976750.00	1.023	BNE 1041460.00	1.209
BNE 1001315.00	10.536	BNE 1001590.00	1931	BNE 977515.00	0.973	BNE 1041580.00	1.11
BNE 1001865.00	10.42	BNE 1002107.50	1929	BNE 978280.00	1.222	BNE 1041700.00	1.025
BNE 1002350.00	10.339	BNE 1002567.50	1927	BNE 978893.50	1.173	BNE 1041830.00	1.178
BNE 1002785.00	10.32	BNE 1003030.00	1924	BNE 979507.00	1.138	BNE 1041960.00	1.386
BNE 1003275.00	10.249	BNE 1003525.00	1922	BNE 979510.00	1.355	BNE 1042097.50	1.426
BNE 1003775.00	10.192	BNE 1004037.50	1920	BNE 979513.00	1.178	BNE 1042235.00	1.468
BNE 1004300.00	10.071	BNE 1004555.00	1918	BNE 979521.50	1.24	BNE 1042367.50	1.377
BNE 1004810.00	10.032	BNE 1005067.50	1915	BNE 979530.00	1.309	BNE 1042500.00	1.297
BNE 1005325.00	9.967	BNE 1005597.50	1910	BNE 979930.00	1.236	BNE 1042500.00	1.297
BNE 1005870.00	9.885	BNE 1006035.00	2104	BNE 980330.00	1.305	BNE 1042507.50	1.292
BNE 1005870.00	9.885	BNE 1006250.00	3606	BNE 980995.00	1.167	BNE 1042515.00	1.287
BNE 1006200.00	9.849	BNE 1006605.00	3604	BNE 981660.00	1.151	BNE 1042712.50	1.348
BNE 1006200.00	9.849	BNE 1007160.00	3599	BNE 982060.00	1.128	BNE 1042910.00	1.415
BNE 1006300.00	9.82	BNE 1007595.00	3595	BNE 982460.00	1.107	BNE 1042960.00	1.418
BNE 1006300.00	9.82	BNE 1007850.00	3588	BNE 983310.00	1.066	BNE 1043010.00	1.42
BNE 1006910.00	9.618	BNE 1008182.50	3587	BNE 984160.00	1.027	BNE 1043010.00	1.42
BNE 1007410.00	9.509	BNE 1008685.00	3584	BNE 984710.00	1.078	BNE 1043045.00	1.422
BNE 1007780.00	9.364	BNE 1009162.50	3582	BNE 985260.00	1.134	BNE 1043080.00	1.423
BNE 1007780.00	9.364	BNE 1009560.00	3581	BNE 985870.00	1.181	BNE 1043095.00	1.419
BNE 1007920.00	9.295	BNE 1010105.00	3577	BNE 986480.00	1.231	BNE 1043110.00	1.414
BNE 1008445.00	9.282	BNE 1010607.50	3575	BNE 987220.00	1.09	BNE 1043110.00	1.414
BNE 1008925.00	9.232	BNE 1010852.50	3574	BNE 987960.00	0.978	BNE 1043417.50	1.319
BNE 1009400.00	9.133	BNE 1011245.00	3572	BNE 988060.00	1.187	BNE 1043725.00	1.236
BNE 1009720.00	9.058	BNE 1011745.00	3568	BNE 988160.00	1.542	BNE 1043892.50	1.209
BNE 1010480.00	8.892	BNE 1012227.50	3564	BNE 988185.00	3.447	BNE 1044060.00	1.182
BNE 1010725.00	8.915	BNE 1012705.00	3555	BNE 988170.00	1.55	BNE 1044200.00	1.254
BNE 1010980.00	8.889	BNE 1013062.50	3552	BNE 988285.00	1.276	BNE 1044340.00	1.335
BNE 1011510.00	8.887	BNE 1013317.50	3551	BNE 988360.00	1.064	BNE 1044472.50	1.274
BNE 1011980.00	8.881	BNE 1013562.50	3549	BNE 989030.00	1.019	BNE 1044605.00	1.219
BNE 1012475.00	8.864	BNE 1013795.00	3547	BNE 989700.00	0.962	BNE 1044732.50	1.172

BNE 1012475.00	8.864			BNE 1014110.00	3544		BNE 990200.00	1.039		BNE 1044860.00	1.129
BNE 1012935.00	8.838			BNE 1014460.00	3542		BNE 990700.00	1.129		BNE 1045130.00	1.128
BNE 1013190.00	8.826			BNE 1014850.00	3532		BNE 990730.00	1.153		BNE 1045400.00	1.126
BNE 1013190.00	8.826			BNE 1015325.00	3530		BNE 990760.00	1.178		BNE 1045642.50	1.159
BNE 1013445.00	8.812			BNE 1015705.00	3530		BNE 991235.00	0.851		BNE 1045885.00	1.195
BNE 1013680.00	8.8			BNE 1015995.00	3529		BNE 991710.00	0.667		BNE 1046032.50	1.029
BNE 1013680.00	8.8			BNE 1016390.00	3528		BNE 992065.00	0.692		BNE 1046180.00	0.904
BNE 1013910.00	8.782			BNE 1016765.00	3527		BNE 992420.00	0.72		BNE 1046260.00	0.917
BNE 1014310.00	8.704			BNE 1017010.00	3526		BNE 992435.00	0.791		BNE 1046340.00	0.931
BNE 1014610.00	8.574			BNE 1017370.00	3524		BNE 992450.00	0.878		BNE 1046460.00	0.952
BNE 1014610.00	8.574			BNE 1017765.00	3523		BNE 992460.00	1.136		BNE 1046580.00	0.975
BNE 1015090.00	8.479			BNE 1018060.00	3522		BNE 992470.00	0.879		BNE 1046740.00	1.11
BNE 1015560.00	8.381			BNE 1018462.50	3520		BNE 992570.00	0.959		BNE 1046900.00	1.29
BNE 1015850.00	8.331			BNE 1018910.00	3519		BNE 992670.00	1.055		BNE 1047125.00	1.372
BNE 1015850.00	8.331			BNE 1019292.50	3519		BNE 993215.00	1.214		BNE 1047350.00	1.464
BNE 1016140.00	8.279			BNE 1019677.50	3518		BNE 993760.00	1.429		BNE 1047632.50	1.411
BNE 1016640.00	8.112			BNE 1019990.00	3518		BNE 994260.00	1.169		BNE 1047915.00	1.362
BNE 1016890.00	7.995			BNE 1020320.00	3516		BNE 994760.00	0.99		BNE 1048145.00	1.186
BNE 1016890.00	7.995			BNE 1020677.50	3514		BNE 995225.00	1.092		BNE 1048375.00	1.05
BNE 1017130.00	7.876			BNE 1020962.50	3514		BNE 995690.00	1.218		BNE 1048632.50	1.225
BNE 1017610.00	7.749			BNE 1021317.00	3513		BNE 996335.00	1.271		BNE 1048890.00	1.47
BNE 1017920.00	7.649			BNE 1021627.00	3512		BNE 996980.00	1.33		BNE 1049005.00	1.366
BNE 1018200.00	7.642			BNE 1021805.00	3512		BNE 997720.00	0.919		BNE 1049120.00	1.275
BNE 1018725.00	7.51			BNE 1022000.00	3511		BNE 998460.00	0.704		BNE 1049245.00	1.363
BNE 1019095.00	7.44			BNE 1022340.00	3510		BNE 998810.00	0.936		BNE 1049370.00	1.463
BNE 1019490.00	7.395			BNE 1022807.50	3510		BNE 999160.00	1.396		BNE 1049480.00	1.401
BNE 1019490.00	7.395			BNE 1023305.00	3517		BNE 999580.00	1.135		BNE 1049590.00	1.344
BNE 1019865.00	7.278			BNE 1023825.00	3516		BNE 1000000.00	0.959		BNE 1049730.00	1.398
BNE 1020115.00	7.285			BNE 1024321.50	3515		BNE 1000142.50	1.086		BNE 1049870.00	1.456
BNE 1020525.00	7.248			BNE 1024816.50	3514		BNE 1000285.00	1.254		BNE 1050150.00	1.429
BNE 1020830.00	7.174			BNE 1025215.00	3513		BNE 1000530.00	1.259		BNE 1050430.00	1.403
BNE 1021095.00	7.061			BNE 1025475.00	3512		BNE 1000775.00	1.264		BNE 1050645.00	1.444
BNE 1021539.00	6.892			BNE 1025880.00	3512		BNE 1001045.00	1.2		BNE 1050860.00	1.488
BNE 1021715.00	6.859			BNE 1026425.00	3511		BNE 1001315.00	1.142		BNE 1051110.00	1.382
BNE 1021895.00	6.797			BNE 1026790.00	3510		BNE 1001590.00	1.33		BNE 1051360.00	1.29
BNE 1022105.00	6.726			BNE 1027030.00	3510		BNE 1001865.00	1.592		BNE 1051627.50	1.461
BNE 1022575.00	6.622			BNE 1027420.00	3509		BNE 1002107.50	1.591		BNE 1051895.00	1.685
BNE 1023040.00	6.487			BNE 1027930.00	3508		BNE 1002350.00	1.59		BNE 1052102.50	1.445
BNE 1023570.00	6.449			BNE 1028430.00	3506		BNE 1002567.50	1.341		BNE 1052310.00	1.264
BNE 1024080.00	6.397			BNE 1028720.00	3506		BNE 1002785.00	1.159		BNE 1052370.00	2.083
BNE 1024663.00	6.351			BNE 1028980.00	3505		BNE 1003030.00	1.277		BNE 1052390.00	1.486
BNE 1025070.00	6.323			BNE 1029440.00	3504		BNE 1003275.00	1.422		BNE 1052492.50	1.503
BNE 1025360.00	6.265			BNE 1029950.00	3503		BNE 1003525.00	1.339		BNE 1052595.00	1.52
BNE 1025590.00	6.186			BNE 1030545.00	3500		BNE 1003775.00	1.265		BNE 1052625.00	1.921
BNE 1026170.00	6.062			BNE 1031085.00	3499		BNE 1004037.50	1.395		BNE 1052640.00	1.324
BNE 1026680.00	5.962			BNE 1031480.00	3499		BNE 1004300.00	1.555		BNE 1052752.50	1.353
BNE 1026900.00	5.897			BNE 1031847.50	3498		BNE 1004555.00	1.258		BNE 1052865.00	1.384
BNE 1027160.00	5.834			BNE 1032112.50	3498		BNE 1004810.00	1.057		BNE 1053092.50	1.298
BNE 1027680.00	5.797			BNE 1032407.50	3497		BNE 1005067.50	1.112		BNE 1053320.00	1.222
BNE 1028180.00	5.78			BNE 1032832.50	3497		BNE 1005325.00	1.173		BNE 1053355.00	1.592
BNE 1028680.00	5.694			BNE 1033225.00	3496		BNE 1005597.50	1.25		BNE 1053385.00	1.463
BNE 1028760.00	5.605			BNE 1033635.00	3495		BNE 1005870.00	1.338		BNE 1053642.50	1.438
BNE 1029200.00	5.526			BNE 1034135.00	3495		BNE 1005870.00	1.338		BNE 1053900.00	1.414
BNE 1029680.00	5.516			BNE 1034630.00	3494		BNE 1006035.00	1.201		BNE 1054270.00	0.992
BNE 1030220.00	5.503			BNE 1035152.00	3493		BNE 1006200.00	1.09		BNE 1054640.00	0.764
BNE 1030870.00	5.465			BNE 1035657.00	3492		BNE 1006200.00	1.636		BNE 1054660.00	1.153
BNE 1031260.00	5.408			BNE 1036180.00	3491		BNE 1006250.00	1.604		BNE 1054680.00	0.727
BNE 1031700.00	5.308			BNE 1036615.00	3490		BNE 1006300.00	1.573		BNE 1054825.00	0.931
BNE 1031995.00	5.3			BNE 1036842.50	3490		BNE 1006300.00	1.573		BNE 1054970.00	1.295
BNE 1032230.00	5.227			BNE 1037002.50	3490		BNE 1006605.00	1.675		BNE 1055125.00	1.276
BNE 1032585.00	5.094			BNE 1037110.00	3490		BNE 1006910.00	1.578		BNE 1055280.00	1.257
BNE 1033080.00	4.999			BNE 1037230.00	3490		BNE 1007160.00	1.477		BNE 1055350.00	1.268
BNE 1033370.00	4.951			BNE 1037455.00	3489		BNE 1007410.00	1.388		BNE 1055420.00	1.278
BNE 1033900.00	4.841			BNE 1037655.00	3488		BNE 1007595.00	1.555		BNE 1055690.00	1.214
BNE 1034370.00	4.74			BNE 1038342.50	3487		BNE 1007780.00	1.768		BNE 1055980.00	1.156
BNE 1034890.00	4.674			BNE 1038850.00	3486		BNE 1007780.00	1.764		BNE 1056180.00	1.295
BNE 1035414.00	4.591			BNE 1039150.00	3483		BNE 1007850.00	1.864		BNE 1056400.00	1.474
BNE 1035900.00	4.483			BNE 1039382.50	3482		BNE 1007920.00	1.977		BNE 1056547.50	1.4
BNE 1036460.00	4.354			BNE 1039617.50	3482		BNE 1008182.50	1.752		BNE 1056695.00	1.333
BNE 1036770.00	4.282			BNE 1039749.00	3481		BNE 1008445.00	1.574		BNE 1056780.00	0.518
BNE 1036915.00	4.252			BNE 1039959.00	3450		BNE 1008685.00	1.575		BNE 1056865.00	0.321
BNE 1037090.00	4.266			BNE 1040170.00	3450		BNE 1008925.00	1.575		BNE 1056920.00	1.504
BNE 1037175.00	4.106			BNE 1040370.00	3449		BNE 1009162.50	1.579		BNE 1056950.00	0.332
BNE 1037285.00	4.075			BNE 1040750.00	3449		BNE 1009400.00	1.583		BNE 1057020.00	0.496
BNE 1037625.00	4.056			BNE 1041120.00	3449		BNE 1009560.00	1.56		BNE 1057090.00	0.977
BNE 1038085.00	4.04			BNE 1041345.00	3449		BNE 1009720.00	1.537		BNE 1057310.00	1.055
BNE 1038600.00	3.99			BNE 1041580.00	3449		BNE 1010105.00	1.688		BNE 1057530.00	1.147
BNE 1039100.00	3.954			BNE 1041830.00	3448		BNE 1010490.00	1.874		BNE 1057785.00	1.261
BNE 1039200.00	3.954			BNE 1042097.50	3448		BNE 1010607.50	1.738		BNE 1058040.00	1.401
BNE 1039200.00	3.954			BNE 1042367.50	3448		BNE 1010725.00	1.62		BNE 1058135.00	1.399
BNE 1039565.00	3.952			BNE 1042507.50	3448		BNE 1010852.50	1.648		BNE 1058230.00	1.398
BNE 1039670.00	3.956			BNE 1042712.50	3448		BNE 1010980.00	1.676		BNE 1058380.00	1.381
BNE 1039670.00	3.956			BNE 1042960.00	3448		BNE 1011245.00	1.597		BNE 1058530.00	1.365
BNE 1039828.00	3.959			BNE 1043045.00	3448		BNE 1011510.00	1.523		BNE 1058632.50	1.294
BNE 1039828.00	3.959			BNE 1043095.00	3448		BNE 1011745.00	1.49		BNE 1058735.00	1.23
BNE 1040090.00	3.96			BNE 1043417.50	3448		BNE 1011980.00	1.458		BNE 1058885.00	1.311
BNE 1040250.00	3.943			BNE 1043892.50	3448		BNE 1012227.50	1.441		BNE 1059035.00	1.404
BNE 1040250.00	3.943			BNE 1044200.00	3448		BNE 1012475.00	1.424		BNE 1059287.50	1.228
BNE 1040490.00	3.906			BNE 1044472.50	3447		BNE 1012475.00	1.419		BNE 1059540.00	1.092
BNE 1041010.00	3.917			BNE 1044732.50	3447		BNE 1012705.00	1.432		BNE 1059765.00	1.108
BNE 1041230.00	3.895			BNE 1045130.00	3447		BNE 1012935.00	1.445		BNE 1059990.00	1.126
BNE 1041460.00	3.865			BNE 1045642.50	3447		BNE 1013062.50	1.434		BNE 1060167.50	1.178
BNE 1041700.00	3.868			BNE 1046032.50	3447		BNE 1013190.00	1.422		BNE 1060345.00	1.236
BNE 1041960.00	3.804			BNE 1046260.00	3447		BNE 1013190.00	1.422		BNE 1060440.00	1.285
BNE 1042235.00	3.731			BNE 1046460.00	3447		BNE 1013317.50	1.41		BNE 1060535.00	1.339
BNE 1042500.00	3.698			BNE 1046740.00	3447		BNE 1013445.00	1.398		BNE 1060775.00	1.281
BNE 1042500.00	3.698			BNE 1047125.00	3447		BNE 1013562.50	1.371		BNE 1061015.00	1.227
BNE 1042515.00	3.697			BNE 1047632.50	3447		BNE 1013680.00	1.344		BNE 1061272.50	1.26
BNE 1042910.00	3.584			BNE 1048145.00	3447		BNE 1013680.00	1.344		BNE 1061530.00	1.295

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BNE 1043010.00	3.549		BNE 1048632.50	3446		BNE 1013795.00	1.328		BNE 1061775.00	1.228	
BNE 1043010.00	3.549		BNE 1049005.00	3446		BNE 1013910.00	1.311		BNE 1062020.00	1.167	
BNE 1043080.00	3.524		BNE 1049245.00	3446		BNE 1014110.00	1.337		BNE 1062277.50	1.089	
BNE 1043110.00	3.516		BNE 1049480.00	3446		BNE 1014310.00	1.364		BNE 1062535.00	1.021	
BNE 1043110.00	3.516		BNE 1049730.00	3446		BNE 1014460.00	1.367		BNE 1062737.50	0.919	
BNE 1043725.00	3.379		BNE 1050150.00	3446		BNE 1014610.00	1.371		BNE 1062940.00	0.835	
BNE 1044060.00	3.337		BNE 1050645.00	3446		BNE 1014610.00	1.365		BNE 1063032.50	0.846	
BNE 1044340.00	3.284		BNE 1051110.00	3447		BNE 1014850.00	1.23		BNE 1063125.00	0.858	
BNE 1044605.00	3.265		BNE 1051627.50	3447		BNE 1015090.00	1.121		BNE 1063125.00	0.858	
BNE 1044860.00	3.248		BNE 1052102.50	3447		BNE 1015325.00	1.257		BNE 1063217.50	0.677	
BNE 1045400.00	3.206		BNE 1052370.00	3447		BNE 1015560.00	1.43		BNE 1063310.00	0.898	
BNE 1045885.00	3.17		BNE 1052492.50	3447		BNE 1015705.00	1.412		BNE 1063477.50	1.039	
BNE 1046180.00	3.19		BNE 1052625.00	3447		BNE 1015850.00	1.394		BNE 1063645.00	1.234	
BNE 1046340.00	3.184		BNE 1052752.50	3447		BNE 1015850.00	1.394		BNE 1063822.50	1.194	
BNE 1046580.00	3.162		BNE 1053092.50	3447		BNE 1015995.00	1.377		BNE 1064000.00	1.166	
BNE 1046900.00	3.055		BNE 1053355.00	3447		BNE 1016140.00	1.361		BNE 1064245.00	1.17	
BNE 1047350.00	2.863		BNE 1053642.50	3447		BNE 1016390.00	1.462		BNE 1064490.00	1.183	
BNE 1047915.00	2.729		BNE 1054270.00	3447		BNE 1016640.00	1.58		BNE 1064750.00	1.047	
BNE 1048375.00	2.73		BNE 1054660.00	3447		BNE 1016765.00	1.623		BNE 1065010.00	0.939	
BNE 1048890.00	2.631		BNE 1054825.00	3447		BNE 1016890.00	1.668		BNE 1065256.50	0.9	
BNE 1049120.00	2.621		BNE 1055125.00	3447		BNE 1016890.00	1.668		BNE 1065503.00	0.863	
BNE 1049370.00	2.56		BNE 1055350.00	3447		BNE 1017010.00	1.732		BNE 1065746.50	0.755	
BNE 1049590.00	2.548		BNE 1055690.00	3447		BNE 1017130.00	1.802		BNE 1065990.00	0.671	
BNE 1049870.00	2.496		BNE 1056180.00	3447		BNE 1017370.00	1.719		BNE 1066247.50	0.721	
BNE 1050430.00	2.433		BNE 1056547.50	3447		BNE 1017610.00	1.643		BNE 1066505.00	0.779	
BNE 1050860.00	2.387		BNE 1056780.00	3447		BNE 1017765.00	1.698		BNE 1066762.50	0.759	
BNE 1051360.00	2.393		BNE 1056920.00	3447		BNE 1017920.00	1.756		BNE 1067020.00	0.741	
BNE 1051895.00	2.319		BNE 1057020.00	3447		BNE 1018060.00	1.546		BNE 1067252.50	0.809	
BNE 1052310.00	2.371		BNE 1057310.00	3447		BNE 1018200.00	1.382		BNE 1067485.00	0.892	
BNE 1052390.00	2.315		BNE 1057785.00	3447		BNE 1018462.50	1.475		BNE 1067725.00	0.921	
BNE 1052595.00	2.309		BNE 1058135.00	3447		BNE 1018725.00	1.582		BNE 1067965.00	0.951	
BNE 1052640.00	2.226		BNE 1058380.00	3447		BNE 1018910.00	1.565		BNE 1068312.50	0.985	
BNE 1052865.00	2.215		BNE 1058632.50	3447		BNE 1019095.00	1.548		BNE 1068660.00	1.021	
BNE 1053320.00	2.226		BNE 1058885.00	3447		BNE 1019292.50	1.438		BNE 1068852.50	1.007	
BNE 1053385.00	2.144		BNE 1059287.50	3447		BNE 1019490.00	1.342		BNE 1069045.00	0.994	
BNE 1053900.00	2.038		BNE 1059765.00	3447		BNE 1019490.00	1.342		BNE 1069290.00	0.963	
BNE 1054640.00	1.999		BNE 1060167.50	3447		BNE 1019677.50	1.461		BNE 1069535.00	0.915	
BNE 1054680.00	1.976		BNE 1060440.00	3447		BNE 1019865.00	1.604		BNE 1069780.00	0.885	
BNE 1054970.00	1.887		BNE 1060775.00	3447		BNE 1019990.00	1.343		BNE 1070025.00	0.857	
BNE 1055280.00	1.858		BNE 1061272.50	3447		BNE 1020115.00	1.154		BNE 1070277.50	0.867	
BNE 1055420.00	1.834		BNE 1061775.00	3447		BNE 1020320.00	0.973		BNE 1070530.00	0.877	
BNE 1055960.00	1.791		BNE 1062277.50	3447		BNE 1020525.00	0.841		BNE 1070785.00	0.864	
BNE 1056400.00	1.71		BNE 1062737.50	3447		BNE 1020677.50	0.969		BNE 1071040.00	0.851	
BNE 1056695.00	1.693		BNE 1063032.50	3447		BNE 1020830.00	1.143		BNE 1071280.00	0.717	
BNE 1056865.00	1.742		BNE 1063217.50	3449		BNE 1020962.50	1.306		BNE 1071520.00	0.62	
BNE 1056950.00	1.715		BNE 1063477.50	3449		BNE 1021095.00	1.523		BNE 1071767.50	0.691	
BNE 1057090.00	1.681		BNE 1063822.50	3449		BNE 1021317.00	1.501		BNE 1072015.00	0.781	
BNE 1057530.00	1.65		BNE 1064245.00	3449		BNE 1021539.00	1.479		BNE 1072017.50	0.781	
BNE 1058040.00	1.576		BNE 1064750.00	3449		BNE 1021627.00	1.363		BNE 1072020.00	0.781	
BNE 1058230.00	1.557		BNE 1065256.50	3449		BNE 1021715.00	1.263		BNE 1072020.00	0.795	
BNE 1058530.00	1.537		BNE 1065746.50	3449		BNE 1021805.00	1.267		BNE 1072257.50	0.781	
BNE 1058735.00	1.539		BNE 1066247.50	3449		BNE 1021895.00	1.271		BNE 1072515.00	0.765	
BNE 1059035.00	1.484		BNE 1066762.50	3449		BNE 1022000.00	1.309		BNE 1072755.00	0.747	
BNE 1059540.00	1.458		BNE 1067252.50	3450		BNE 1022105.00	1.35		BNE 1072995.00	0.728	
BNE 1059990.00	1.387		BNE 1067725.00	3450		BNE 1022340.00	1.374		BNE 1073240.00	0.766	
BNE 1060345.00	1.327		BNE 1068312.50	3450		BNE 1022575.00	1.402		BNE 1073485.00	0.807	
BNE 1060535.00	1.302		BNE 1068852.50	3449		BNE 1022807.50	1.579		BNE 1073742.50	0.797	
BNE 1061015.00	1.291		BNE 1069290.00	3449		BNE 1023040.00	1.805		BNE 1074000.00	0.786	
BNE 1061530.00	1.269		BNE 1069780.00	3449		BNE 1023305.00	1.727		BNE 1074230.00	0.782	
BNE 1062020.00	1.261		BNE 1070277.50	3449		BNE 1023570.00	1.656		BNE 1074460.00	0.777	
BNE 1062535.00	1.254		BNE 1070785.00	3449		BNE 1023825.00	1.622		BNE 1074722.50	0.818	
BNE 1062940.00	1.252		BNE 1071280.00	3449		BNE 1024080.00	1.589		BNE 1074985.00	0.863	
BNE 1063125.00	1.232		BNE 1071767.50	3449		BNE 1024321.50	1.55		BNE 1075232.50	0.784	
BNE 1063125.00	1.232		BNE 1072017.50	3450		BNE 1024563.00	1.512		BNE 1075480.00	0.718	
BNE 1063310.00	1.232		BNE 1072267.50	3535		BNE 1024816.50	1.436		BNE 1075740.00	0.603	
BNE 1063645.00	1.189		BNE 1072755.00	3548		BNE 1025070.00	1.366		BNE 1076000.00	0.52	
BNE 1064000.00	1.186		BNE 1073240.00	3563		BNE 1025215.00	1.459		BNE 1076247.50	0.591	
BNE 1064490.00	1.165		BNE 1073742.50	3578		BNE 1025360.00	1.566		BNE 1076495.00	0.682	
BNE 1065010.00	1.166		BNE 1074230.00	3591		BNE 1025475.00	1.671		BNE 1076752.50	0.563	
BNE 1065503.00	1.156		BNE 1074722.50	3602		BNE 1025590.00	1.791		BNE 1077010.00	0.479	
BNE 1065990.00	1.158		BNE 1075232.50	3609		BNE 1025880.00	1.674		BNE 1077260.00	0.412	
BNE 1066505.00	1.144		BNE 1075740.00	3618		BNE 1026170.00	1.572		BNE 1077510.00	0.361	
BNE 1067020.00	1.139		BNE 1076247.50	3629		BNE 1026425.00	1.545		BNE 1077775.00	0.372	
BNE 1067485.00	1.12		BNE 1076752.50	3639		BNE 1026680.00	1.519		BNE 1078040.00	0.382	
BNE 1067965.00	1.104		BNE 1077260.00	3654		BNE 1026790.00	1.574		BNE 1078282.50	0.46	
BNE 1068660.00	1.082		BNE 1077775.00	3662		BNE 1026900.00	1.632		BNE 1078525.00	0.577	
BNE 1069045.00	1.073		BNE 1078282.50	3665		BNE 1027030.00	1.646		BNE 1078592.50	0.128	
BNE 1069535.00	1.067		BNE 1078592.50	3666		BNE 1027160.00	1.661		BNE 1078660.00	0.072	
BNE 1070025.00	1.061					BNE 1027420.00	1.519				
BNE 1070530.00	1.049					BNE 1027680.00	1.4				
BNE 1071040.00	1.039					BNE 1027930.00	1.338				
BNE 1071520.00	1.046					BNE 1028180.00	1.28				
BNE 1072015.00	1.03					BNE 1028430.00	1.425				
BNE 1072020.00	1.03					BNE 1028680.00	1.608				
BNE 1072020.00	1.03					BNE 1028720.00	2.009				
BNE 1072515.00	1.02					BNE 1028760.00	1.616				
BNE 1072995.00	1.012					BNE 1028980.00	1.695				
BNE 1073485.00	1.023					BNE 1029200.00	1.782				
BNE 1074000.00	1.041					BNE 1029440.00	1.667				
BNE 1074460.00	1.055					BNE 1029680.00	1.565				
BNE 1074985.00	1.068					BNE 1029950.00	1.518				
BNE 1075480.00	1.08					BNE 1030220.00	1.473				
BNE 1076000.00	1.082					BNE 1030545.00	1.476				
BNE 1076495.00	1.065					BNE 1030870.00	1.479				
BNE 1077010.00	1.041					BNE 1031065.00	1.56				
BNE 1077510.00	1.009					BNE 1031260.00	1.651				
BNE 1078040.00	0.97					BNE 1031480.00	1.768				
BNE 1078525.00	0.92					BNE 1031700.00	1.904				
BNE 1078660.00	0.918					BNE 1031847.50	1.657				

DRAFT

Appendix C Mike11 Results Q50

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q50 event CRCFORGE rainfall with ARF's

72hr Storm Duration

DRAFT

Chainage [m]	Water Level
BNE 931570.00	40.156
BNE 931580.00	40.149
BNE 933670.00	38.746
BNE 934270.00	38.621
BNE 934620.00	38.409
BNE 936070.00	38.206
BNE 936820.00	38.159
BNE 939770.00	37.757
BNE 942320.00	36.598
BNE 943570.00	36.195
BNE 944120.00	36.12
BNE 945570.00	35.879
BNE 947170.00	35.467
BNE 948270.00	35.105
BNE 950270.00	34.566
BNE 952320.00	33.9
BNE 953870.00	33.495
BNE 954920.00	33.101
BNE 955970.00	32.626
BNE 958770.00	31.381
BNE 960170.00	30.971
BNE 962070.00	30.034
BNE 964170.00	28.816
BNE 966810.00	27.278
BNE 967410.00	26.85
BNE 969790.00	25.826
BNE 971160.00	25.399
BNE 972260.00	25.171
BNE 973260.00	25.137
BNE 974580.00	24.995
BNE 976020.00	24.908
BNE 976750.00	24.861
BNE 978280.00	24.056
BNE 979507.00	22.053
BNE 979513.00	22.021
BNE 979530.00	22
BNE 980330.00	21.759
BNE 981660.00	21.352
BNE 982460.00	21.157
BNE 984160.00	20.699
BNE 985260.00	20.281
BNE 986480.00	19.574
BNE 987960.00	18.547
BNE 988160.00	18.248
BNE 988170.00	18.207
BNE 988360.00	17.978
BNE 989700.00	17.084
BNE 990700.00	16.725
BNE 990760.00	16.691
BNE 991710.00	16.421
BNE 992420.00	16.234
BNE 992460.00	16.196
BNE 992470.00	16.175
BNE 992670.00	16.074
BNE 993760.00	15.442
BNE 994760.00	15.025
BNE 995690.00	14.461
BNE 996980.00	13.519
BNE 998460.00	13.234
BNE 999160.00	13.129
BNE 1000000.00	12.99
BNE 1000285.00	12.877
BNE 1000775.00	12.724
BNE 1001315.00	12.631
BNE 1001865.00	12.438
BNE 1002350.00	12.317
BNE 1002785.00	12.293
BNE 1003275.00	12.172
BNE 1003775.00	12.079
BNE 1004300.00	11.866
BNE 1004810.00	11.811
BNE 1005325.00	11.703
BNE 1005870.00	11.563
BNE 1005870.00	11.563
BNE 1006200.00	11.511
BNE 1006200.00	11.511
BNE 1006300.00	11.482
BNE 1006300.00	11.482
BNE 1006910.00	11.281
BNE 1007410.00	11.181
BNE 1007780.00	11.033
BNE 1007780.00	11.033
BNE 1007920.00	10.963
BNE 1008445.00	10.949
BNE 1008925.00	10.902
BNE 1009400.00	10.806
BNE 1009720.00	10.74
BNE 1010490.00	10.566
BNE 1010725.00	10.59
BNE 1010980.00	10.564
BNE 1011510.00	10.57
BNE 1011950.00	10.569
BNE 1012475.00	10.553

Chainage [m]	Discharge
BNE 931575.00	3400
BNE 932625.00	3400
BNE 933970.00	3400
BNE 934445.00	3400
BNE 935345.00	3400
BNE 936445.00	3400
BNE 937295.00	3399
BNE 941045.00	3399
BNE 942845.00	3399
BNE 943845.00	3398
BNE 944845.00	3397
BNE 946370.00	3396
BNE 947720.00	3396
BNE 949270.00	3396
BNE 951295.00	3396
BNE 953095.00	3396
BNE 954395.00	3395
BNE 955445.00	3395
BNE 957370.00	3395
BNE 959470.00	3394
BNE 961120.00	3394
BNE 963120.00	3394
BNE 965390.00	3393
BNE 967010.00	3393
BNE 968600.00	3392
BNE 970475.00	3392
BNE 971710.00	3392
BNE 972760.00	3392
BNE 973920.00	3391
BNE 975300.00	3391
BNE 976385.00	3391
BNE 977515.00	3390
BNE 978893.50	3391
BNE 979510.00	3427
BNE 979521.50	3424
BNE 979930.00	3390
BNE 980995.00	3389
BNE 982060.00	3389
BNE 983310.00	3389
BNE 984710.00	3389
BNE 985870.00	3388
BNE 987220.00	3388
BNE 988060.00	3388
BNE 988165.00	3388
BNE 988265.00	3388
BNE 989030.00	3388
BNE 990200.00	3388
BNE 990730.00	3388
BNE 991235.00	3388
BNE 992065.00	3391
BNE 992435.00	3397
BNE 992460.00	3397
BNE 992570.00	3397
BNE 993215.00	3387
BNE 994260.00	3387
BNE 995725.00	3386
BNE 996335.00	3386
BNE 997720.00	3386
BNE 998810.00	3385
BNE 999580.00	3385
BNE 1000142.50	3386
BNE 1000530.00	3386
BNE 1001045.00	3386
BNE 1001590.00	3386
BNE 1002107.50	3386
BNE 1002567.50	3386
BNE 1003030.00	3386
BNE 1003525.00	3386
BNE 1004037.50	3386
BNE 1004555.00	3386
BNE 1005067.50	3385
BNE 1005597.50	3385
BNE 1006035.00	3181
BNE 1006250.00	4395
BNE 1006605.00	4394
BNE 1007160.00	4390
BNE 1007595.00	4385
BNE 1007850.00	4379
BNE 1008182.50	4376
BNE 1008685.00	4375
BNE 1009152.50	4374
BNE 1009560.00	4372
BNE 1010105.00	4368
BNE 1010607.50	4366
BNE 1010852.50	4365
BNE 1011245.00	4363
BNE 1011745.00	4359
BNE 1012227.50	4355
BNE 1012795.00	4342
BNE 1013052.50	4339
BNE 1013317.50	4337
BNE 1013562.50	4337
BNE 1013795.00	4335

Chainage [m]	Velocity [m/s]
BNE 931570.00	1.897
BNE 931575.00	1.898
BNE 931580.00	1.898
BNE 932625.00	1.859
BNE 933670.00	1.83
BNE 933970.00	1.236
BNE 934270.00	1.693
BNE 934445.00	2.258
BNE 934620.00	3.422
BNE 935345.00	0.982
BNE 936070.00	0.5
BNE 936445.00	0.583
BNE 936820.00	2.481
BNE 936295.00	0.878
BNE 939770.00	1.358
BNE 941045.00	1.384
BNE 942320.00	1.429
BNE 942945.00	1.107
BNE 943570.00	0.901
BNE 943845.00	0.874
BNE 944120.00	1.046
BNE 944845.00	0.998
BNE 945570.00	1.33
BNE 946370.00	1.006
BNE 947170.00	1.159
BNE 947720.00	1.194
BNE 948270.00	1.233
BNE 949270.00	1.088
BNE 950270.00	0.995
BNE 951295.00	1.194
BNE 952320.00	1.494
BNE 953095.00	1.172
BNE 953870.00	0.965
BNE 954395.00	1.145
BNE 954920.00	1.844
BNE 955445.00	1.381
BNE 955970.00	1.366
BNE 957370.00	1.359
BNE 958770.00	1.408
BNE 959470.00	1.077
BNE 960170.00	0.872
BNE 961120.00	1.153
BNE 962070.00	1.701
BNE 963120.00	1.265
BNE 964170.00	1.006
BNE 965390.00	1.291
BNE 966610.00	1.809
BNE 967010.00	1.492
BNE 967410.00	1.27
BNE 968600.00	1.409
BNE 969790.00	1.582
BNE 970475.00	1.556
BNE 971160.00	1.53
BNE 971710.00	1.465
BNE 972260.00	2.512
BNE 972760.00	1.173
BNE 973260.00	0.949
BNE 973920.00	1.209
BNE 974580.00	1.667
BNE 975300.00	1.485
BNE 976020.00	1.339
BNE 976385.00	0.992
BNE 976750.00	1.02
BNE 977515.00	1.029
BNE 978280.00	1.457
BNE 978893.50	1.384
BNE 979507.00	1.325
BNE 979510.00	1.366
BNE 979513.00	1.372
BNE 979521.50	1.417
BNE 979530.00	1.422
BNE 979930.00	1.35
BNE 980330.00	1.803
BNE 980995.00	1.397
BNE 981660.00	1.52
BNE 982060.00	1.48
BNE 982460.00	1.442
BNE 983310.00	1.371
BNE 984160.00	1.307
BNE 984710.00	1.367
BNE 985260.00	1.433
BNE 985870.00	1.509
BNE 986480.00	1.594
BNE 987220.00	1.366
BNE 987960.00	1.195
BNE 988060.00	1.442
BNE 988160.00	1.82
BNE 988165.00	3.606
BNE 988170.00	1.827
BNE 988265.00	1.541
BNE 988360.00	1.333
BNE 989030.00	1.215
BNE 989700.00	1.117

Chainage [m]	Velocity [m/s]
BNE 1031995.00	1.631
BNE 1032112.50	1.598
BNE 1032230.00	1.565
BNE 1032407.50	1.636
BNE 1032585.00	1.713
BNE 1032832.50	1.688
BNE 1033080.00	1.663
BNE 1033225.00	1.695
BNE 1033370.00	1.729
BNE 1033635.00	1.79
BNE 1033900.00	1.855
BNE 1034135.00	1.861
BNE 1034370.00	1.866
BNE 1034630.00	1.795
BNE 1034890.00	1.728
BNE 1035152.00	1.756
BNE 1035414.00	1.784
BNE 1035557.00	1.843
BNE 1035900.00	1.905
BNE 1036180.00	1.871
BNE 1036460.00	1.838
BNE 1036615.00	1.751
BNE 1036770.00	1.671
BNE 1036842.50	1.715
BNE 1036915.00	1.775
BNE 1037002.50	1.708
BNE 1037090.00	1.633
BNE 1037110.00	1.989
BNE 1037175.00	1.643
BNE 1037230.00	1.732
BNE 1037285.00	1.831
BNE 1037455.00	1.724
BNE 1037625.00	1.628
BNE 1037855.00	1.516
BNE 1038085.00	1.418
BNE 1038342.50	1.47
BNE 1038600.00	1.526
BNE 1038850.00	1.517
BNE 1039100.00	1.507
BNE 1039150.00	1.489
BNE 1039200.00	1.47
BNE 1039200.00	1.47
BNE 1039382.50	1.423
BNE 1039565.00	1.376
BNE 1039617.50	1.352
BNE 1039670.00	1.327
BNE 1039670.00	1.327
BNE 1039749.00	1.297
BNE 1039828.00	1.268
BNE 1039828.00	1.285
BNE 1039959.00	1.288
BNE 1040090.00	1.251
BNE 1040170.00	1.322
BNE 1040250.00	1.4
BNE 1040250.00	1.4
BNE 1040370.00	1.528
BNE 1040490.00	1.681
BNE 1040750.00	1.503
BNE 1041010.00	1.359
BNE 1041120.00	1.366
BNE 1041230.00	1.373
BNE 1041345.00	1.401
BNE 1041460.00	1.429
BNE 1041580.00	1.337
BNE 1041700.00	1.256
BNE 1041830.00	1.434
BNE 1041960.00	1.671
BNE 1042097.50	1.727
BNE 1042235.00	1.786
BNE 1042367.50	1.674
BNE 1042500.00	1.576
BNE 1042500.00	1.576
BNE 1042507.50	1.57
BNE 1042515.00	1.565
BNE 1042712.50	1.605
BNE 1042910.00	1.648
BNE 1042960.00	1.652
BNE 1043010.00	1.655
BNE 1043010.00	1.655
BNE 1043045.00	1.658
BNE 1043080.00	1.661
BNE 1043095.00	1.655
BNE 1043110.00	1.65
BNE 1043110.00	1.65
BNE 1043417.50	1.559
BNE 1043725.00	1.478
BNE 1043892.50	1.463
BNE 1044060.00	1.449
BNE 1044200.00	1.533
BNE 1044340.00	1.627
BNE 1044472.50	1.548
BNE 1044605.00	1.477
BNE 1044732.50	1.409

BNE 1012475.00	10.553			BNE 1014110.00	4332		BNE 990200.00	1.268		BNE 1044860.00	1.347
BNE 1012935.00	10.529			BNE 1014460.00	4329		BNE 990700.00	1.467		BNE 1045130.00	1.346
BNE 1013190.00	10.516			BNE 1014850.00	4323		BNE 990730.00	1.5		BNE 1045400.00	1.344
BNE 1013190.00	10.516			BNE 1015325.00	4321		BNE 990760.00	1.535		BNE 1045642.50	1.384
BNE 1013445.00	10.5			BNE 1015705.00	4320		BNE 991235.00	1.088		BNE 1045885.00	1.425
BNE 1013680.00	10.491			BNE 1015995.00	4319		BNE 991710.00	0.843		BNE 1046032.50	1.253
BNE 1013680.00	10.491			BNE 1016390.00	4317		BNE 992065.00	0.861		BNE 1046180.00	1.118
BNE 1013910.00	10.476			BNE 1016765.00	4316		BNE 992420.00	0.88		BNE 1046260.00	1.138
BNE 1014310.00	10.466			BNE 1017010.00	4313		BNE 992435.00	0.987		BNE 1046340.00	1.159
BNE 1014610.00	10.292			BNE 1017370.00	4311		BNE 992450.00	1.122		BNE 1046460.00	1.176
BNE 1014610.00	10.292			BNE 1017765.00	4308		BNE 992460.00	1.227		BNE 1046580.00	1.193
BNE 1015090.00	10.19			BNE 1018060.00	4306		BNE 992470.00	1.123		BNE 1046740.00	1.349
BNE 1015560.00	10.085			BNE 1018462.50	4304		BNE 992570.00	1.209		BNE 1046900.00	1.553
BNE 1015850.00	10.034			BNE 1018910.00	4303		BNE 992670.00	1.304		BNE 1047125.00	1.669
BNE 1015850.00	10.034			BNE 1019292.50	4329		BNE 993215.00	1.512		BNE 1047350.00	1.803
BNE 1016140.00	9.981			BNE 1019677.50	4336		BNE 993760.00	1.8		BNE 1047632.50	1.751
BNE 1016640.00	9.822			BNE 1019990.00	4335		BNE 994260.00	1.407		BNE 1047915.00	1.701
BNE 1016890.00	9.711			BNE 1020320.00	4333		BNE 994760.00	1.154		BNE 1048145.00	1.467
BNE 1016890.00	9.711			BNE 1020677.50	4331		BNE 995225.00	1.34		BNE 1048375.00	1.29
BNE 1017130.00	9.598			BNE 1020962.50	4330		BNE 995690.00	1.597		BNE 1048632.50	1.484
BNE 1017610.00	9.476			BNE 1021317.00	4329		BNE 996335.00	1.614		BNE 1048890.00	1.749
BNE 1017920.00	9.375			BNE 1021627.00	4328		BNE 996980.00	1.631		BNE 1049005.00	1.647
BNE 1018200.00	9.368			BNE 1021805.00	4327		BNE 997720.00	1.157		BNE 1049120.00	1.557
BNE 1018725.00	9.226			BNE 1022000.00	4327		BNE 998460.00	0.896		BNE 1049245.00	1.672
BNE 1019095.00	9.15			BNE 1022348.00	4326		BNE 998810.00	1.192		BNE 1049370.00	1.806
BNE 1019490.00	9.109			BNE 1022807.50	4396		BNE 999160.00	1.783		BNE 1049480.00	1.736
BNE 1019490.00	9.109			BNE 1023305.00	4396		BNE 999580.00	1.518		BNE 1049590.00	1.671
BNE 1019865.00	8.978			BNE 1023825.00	4395		BNE 1000000.00	1.323		BNE 1049730.00	1.73
BNE 1020115.00	9.001			BNE 1024321.50	4394		BNE 1000142.50	1.481		BNE 1049870.00	1.794
BNE 1020525.00	8.97			BNE 1024816.50	4393		BNE 1000285.00	1.882		BNE 1050150.00	1.749
BNE 1020830.00	8.887			BNE 1025215.00	4392		BNE 1000530.00	1.711		BNE 1050430.00	1.706
BNE 1021095.00	8.763			BNE 1025475.00	4392		BNE 1000775.00	1.74		BNE 1050645.00	1.765
BNE 1021539.00	8.591			BNE 1025880.00	4391		BNE 1001045.00	1.608		BNE 1050880.00	1.829
BNE 1021715.00	8.586			BNE 1026425.00	4390		BNE 1001315.00	1.494		BNE 1051110.00	1.714
BNE 1021895.00	8.502			BNE 1026790.00	4390		BNE 1001580.00	1.78		BNE 1051360.00	1.611
BNE 1022105.00	8.421			BNE 1027030.00	4390		BNE 1001865.00	2.201		BNE 1051627.50	1.809
BNE 1022575.00	8.315			BNE 1027420.00	4389		BNE 1002107.50	2.162		BNE 1051895.00	2.061
BNE 1023040.00	8.148			BNE 1027930.00	4388		BNE 1002350.00	2.124		BNE 1052102.50	1.76
BNE 1023570.00	8.112			BNE 1028430.00	4386		BNE 1002567.50	1.798		BNE 1052310.00	1.535
BNE 1024080.00	8.062			BNE 1028720.00	4386		BNE 1002785.00	1.558		BNE 1052370.00	2.52
BNE 1024563.00	8.018			BNE 1028980.00	4385		BNE 1003030.00	1.732		BNE 1052390.00	1.822
BNE 1025070.00	7.991			BNE 1029440.00	4384		BNE 1003275.00	1.95		BNE 1052492.50	1.857
BNE 1025360.00	7.924			BNE 1029950.00	4382		BNE 1003525.00	1.839		BNE 1052595.00	1.886
BNE 1025590.00	7.833			BNE 1030545.00	4379		BNE 1003775.00	1.74		BNE 1052625.00	2.441
BNE 1026170.00	7.703			BNE 1031065.00	4378		BNE 1004037.50	1.939		BNE 1052640.00	1.559
BNE 1026680.00	7.599			BNE 1031480.00	4377		BNE 1004300.00	2.189		BNE 1052752.50	1.707
BNE 1026900.00	7.522			BNE 1031847.50	4376		BNE 1004555.00	1.733		BNE 1052865.00	1.752
BNE 1027160.00	7.447			BNE 1032112.50	4375		BNE 1004810.00	1.435		BNE 1053092.50	1.629
BNE 1027680.00	7.42			BNE 1032407.50	4375		BNE 1005067.50	1.484		BNE 1053320.00	1.521
BNE 1028180.00	7.407			BNE 1032832.50	4374		BNE 1005325.00	1.536		BNE 1053355.00	1.951
BNE 1028680.00	7.308			BNE 1033225.00	4373		BNE 1005597.50	1.654		BNE 1053385.00	1.787
BNE 1028760.00	7.22			BNE 1033635.00	4372		BNE 1005870.00	1.782		BNE 1053642.50	1.769
BNE 1029200.00	7.132			BNE 1034135.00	4371		BNE 1005870.00	1.686		BNE 1053900.00	1.752
BNE 1029680.00	7.122			BNE 1034630.00	4370		BNE 1006035.00	1.557		BNE 1054270.00	1.237
BNE 1030220.00	7.12			BNE 1035152.00	4369		BNE 1006200.00	1.446		BNE 1054640.00	0.956
BNE 1030870.00	7.077			BNE 1035657.00	4368		BNE 1006200.00	1.775		BNE 1054650.00	1.424
BNE 1031260.00	7.007			BNE 1036180.00	4367		BNE 1006250.00	1.745		BNE 1054680.00	0.921
BNE 1031700.00	6.887			BNE 1036615.00	4367		BNE 1006300.00	1.716		BNE 1054825.00	1.176
BNE 1031995.00	6.895			BNE 1036842.50	4366		BNE 1006300.00	1.716		BNE 1054970.00	1.628
BNE 1032230.00	6.817			BNE 1037002.50	4438		BNE 1006605.00	1.704		BNE 1056125.00	1.607
BNE 1032585.00	6.663			BNE 1037110.00	4438		BNE 1006910.00	1.682		BNE 1056280.00	1.587
BNE 1033080.00	6.555			BNE 1037230.00	4438		BNE 1007160.00	1.568		BNE 1056350.00	1.595
BNE 1033370.00	6.504			BNE 1037455.00	4437		BNE 1007410.00	1.461		BNE 1056420.00	1.604
BNE 1033900.00	6.379			BNE 1037855.00	4436		BNE 1007595.00	1.645		BNE 1056690.00	1.523
BNE 1034370.00	6.266			BNE 1038342.50	4434		BNE 1007780.00	1.884		BNE 1056960.00	1.45
BNE 1034890.00	6.194			BNE 1038850.00	4430		BNE 1007780.00	1.879		BNE 1056180.00	1.627
BNE 1035414.00	6.105			BNE 1039150.00	4427		BNE 1007850.00	1.992		BNE 1056400.00	1.853
BNE 1035900.00	5.982			BNE 1039382.50	4425		BNE 1007920.00	2.119		BNE 1056547.50	1.767
BNE 1036460.00	5.841			BNE 1039617.50	4423		BNE 1008182.50	1.909		BNE 1056695.00	1.689
BNE 1036770.00	5.774			BNE 1039749.00	4421		BNE 1008445.00	1.739		BNE 1056780.00	0.667
BNE 1036915.00	5.73			BNE 1039959.00	4576		BNE 1008685.00	1.731		BNE 1056865.00	0.416
BNE 1037090.00	5.743			BNE 1040170.00	4576		BNE 1008925.00	1.723		BNE 1056920.00	1.906
BNE 1037175.00	5.551			BNE 1040370.00	4576		BNE 1009162.50	1.733		BNE 1056950.00	0.43
BNE 1037285.00	5.515			BNE 1040750.00	4576		BNE 1009400.00	1.743		BNE 1057020.00	0.64
BNE 1037625.00	5.504			BNE 1041120.00	4576		BNE 1009560.00	1.702		BNE 1057090.00	1.256
BNE 1038085.00	5.486			BNE 1041346.00	4576		BNE 1009720.00	1.663		BNE 1057310.00	1.352
BNE 1038600.00	5.441			BNE 1041580.00	4576		BNE 1010105.00	1.841		BNE 1057530.00	1.464
BNE 1039100.00	5.408			BNE 1041830.00	4576		BNE 1010490.00	2.066		BNE 1057785.00	1.606
BNE 1039200.00	5.408			BNE 1042097.50	4576		BNE 1010607.50	1.925		BNE 1058040.00	1.778
BNE 1039200.00	5.408			BNE 1042367.50	4576		BNE 1010725.00	1.802		BNE 1058135.00	1.778
BNE 1039565.00	5.405			BNE 1042507.50	4576		BNE 1010852.50	1.831		BNE 1058230.00	1.778
BNE 1039670.00	5.408			BNE 1042712.50	4576		BNE 1010980.00	1.861		BNE 1058380.00	1.769
BNE 1039670.00	5.408			BNE 1042960.00	4576		BNE 1011245.00	1.752		BNE 1058530.00	1.757
BNE 1039828.00	5.411			BNE 1043045.00	4576		BNE 1011510.00	1.655		BNE 1058632.50	1.661
BNE 1039828.00	5.411			BNE 1043095.00	4577		BNE 1011745.00	1.606		BNE 1058735.00	1.575
BNE 1040090.00	5.409			BNE 1043417.50	4577		BNE 1011980.00	1.559		BNE 1058885.00	1.686
BNE 1040250.00	5.386			BNE 1043892.50	4577		BNE 1012227.50	1.543		BNE 1059035.00	1.814
BNE 1040250.00	5.386			BNE 1044200.00	4577		BNE 1012475.00	1.527		BNE 1059287.50	1.582
BNE 1040490.00	5.334			BNE 1044472.50	4577		BNE 1012475.00	1.521		BNE 1059540.00	1.403
BNE 1041010.00	5.351			BNE 1044732.50	4577		BNE 1012705.00	1.533		BNE 1059765.00	1.423
BNE 1041230.00	5.325			BNE 1045130.00	4577		BNE 1012935.00	1.545		BNE 1059990.00	1.444
BNE 1041460.00	5.286			BNE 1045642.50	4577		BNE 1013062.50	1.541		BNE 1060167.50	1.521
BNE 1041700.00	5.286			BNE 1046032.50	4577		BNE 1013190.00	1.538		BNE 1060345.00	1.906
BNE 1041980.00	5.197			BNE 1046260.00	4577		BNE 1013190.00	1.538		BNE 1060440.00	1.573
BNE 1042235.00	5.095			BNE 1046460.00	4577		BNE 1013317.50	1.53		BNE 1060535.00	1.745
BNE 1042500.00	5.054			BNE 1046740.00	4577		BNE 1013445.00	1.523		BNE 1060775.00	1.665
BNE 1042500.00	5.054			BNE 1047125.00	4578		BNE 1013562.50	1.488		BNE 1061015.00	1.592
BNE 1042615.00	5.052			BNE 1047632.50	4578		BNE 1013680.00	1.454		BNE 1061272.50	1.538
BNE 1042910.00	4.914			BNE 1048145.00	4578		BNE 1013680.00	1.454		BNE 1061530.00	1.586

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BNE 1043010.00	4.87			BNE 1048632.50	4578		BNE 1013795.00	1.429		BNE 1061775.00	1.597
BNE 1043010.00	4.87			BNE 1049005.00	4578		BNE 1013910.00	1.406		BNE 1062020.00	1.518
BNE 1043080.00	4.839			BNE 1049245.00	4578		BNE 1014110.00	1.43		BNE 1062277.50	1.413
BNE 1043110.00	4.828			BNE 1049480.00	4579		BNE 1014310.00	1.456		BNE 1062535.00	1.322
BNE 1043110.00	4.828			BNE 1049730.00	4579		BNE 1014460.00	1.447		BNE 1062737.50	1.191
BNE 1043725.00	4.652			BNE 1050150.00	4579		BNE 1014610.00	1.436		BNE 1062940.00	1.086
BNE 1044060.00	4.592			BNE 1050545.00	4579		BNE 1014610.00	1.43		BNE 1063032.50	1.108
BNE 1044340.00	4.519			BNE 1051110.00	4589		BNE 1014850.00	1.334		BNE 1063125.00	1.122
BNE 1044605.00	4.496			BNE 1051627.50	4588		BNE 1015090.00	1.255		BNE 1063125.00	1.178
BNE 1044860.00	4.478			BNE 1052102.50	4590		BNE 1015325.00	1.396		BNE 1063217.50	1.204
BNE 1045400.00	4.423			BNE 1052370.00	4591		BNE 1015560.00	1.574		BNE 1063310.00	1.236
BNE 1045885.00	4.377			BNE 1052492.50	4592		BNE 1015705.00	1.555		BNE 1063477.50	1.434
BNE 1046180.00	4.403			BNE 1052625.00	4602		BNE 1015850.00	1.536		BNE 1063645.00	1.708
BNE 1046340.00	4.392			BNE 1052752.50	4590		BNE 1015850.00	1.536		BNE 1063822.50	1.554
BNE 1046580.00	4.383			BNE 1053092.50	4589		BNE 1015995.00	1.519		BNE 1064000.00	1.604
BNE 1046900.00	4.217			BNE 1053355.00	4589		BNE 1016140.00	1.501		BNE 1064245.00	1.623
BNE 1047350.00	3.939			BNE 1053642.50	4590		BNE 1016390.00	1.589		BNE 1064490.00	1.643
BNE 1047915.00	3.759			BNE 1054270.00	4590		BNE 1016640.00	1.687		BNE 1064750.00	1.456
BNE 1048375.00	3.768			BNE 1054860.00	4590		BNE 1016765.00	1.735		BNE 1065010.00	1.307
BNE 1048890.00	3.637			BNE 1054825.00	4590		BNE 1016890.00	1.786		BNE 1065256.50	1.254
BNE 1049120.00	3.621			BNE 1055125.00	4590		BNE 1016890.00	1.786		BNE 1065503.00	1.206
BNE 1049370.00	3.532			BNE 1055350.00	4591		BNE 1017010.00	1.853		BNE 1065746.50	1.055
BNE 1049590.00	3.515			BNE 1055690.00	4591		BNE 1017130.00	1.926		BNE 1065990.00	0.937
BNE 1049870.00	3.442			BNE 1056180.00	4591		BNE 1017370.00	1.844		BNE 1066247.50	1.009
BNE 1050430.00	3.361			BNE 1056547.50	4591		BNE 1017610.00	1.768		BNE 1066505.00	1.092
BNE 1050860.00	3.295			BNE 1056780.00	4591		BNE 1017765.00	1.825		BNE 1066762.50	1.065
BNE 1051360.00	3.301			BNE 1056920.00	4591		BNE 1017920.00	1.886		BNE 1067020.00	1.04
BNE 1051895.00	3.198			BNE 1057020.00	4591		BNE 1018060.00	1.678		BNE 1067252.50	1.137
BNE 1052310.00	3.276			BNE 1057310.00	4592		BNE 1018200.00	1.511		BNE 1067485.00	1.252
BNE 1052390.00	3.192			BNE 1057785.00	4592		BNE 1018462.50	1.622		BNE 1067725.00	1.297
BNE 1052595.00	3.176			BNE 1058135.00	4592		BNE 1018725.00	1.752		BNE 1067965.00	1.343
BNE 1052640.00	3.033			BNE 1058380.00	4602		BNE 1018910.00	1.734		BNE 1068312.50	1.394
BNE 1052865.00	3.012			BNE 1058632.50	4602		BNE 1019095.00	1.718		BNE 1068660.00	1.447
BNE 1053320.00	3.034			BNE 1058885.00	4602		BNE 1019292.50	1.587		BNE 1068852.50	1.429
BNE 1053385.00	2.921			BNE 1059287.50	4602		BNE 1019490.00	1.472		BNE 1069045.00	1.411
BNE 1053900.00	2.774			BNE 1059765.00	4602		BNE 1019490.00	1.472		BNE 1069290.00	1.353
BNE 1054640.00	2.723			BNE 1060167.50	4603		BNE 1019677.50	1.613		BNE 1069535.00	1.3
BNE 1054880.00	2.688			BNE 1060440.00	4603		BNE 1019865.00	1.783		BNE 1069780.00	1.257
BNE 1054970.00	2.57			BNE 1060775.00	4603		BNE 1019990.00	1.465		BNE 1070025.00	1.218
BNE 1055280.00	2.511			BNE 1061272.50	4603		BNE 1020115.00	1.243		BNE 1070277.50	1.231
BNE 1055420.00	2.477			BNE 1061775.00	4603		BNE 1020320.00	1.047		BNE 1070530.00	1.245
BNE 1055960.00	2.416			BNE 1062277.50	4608		BNE 1020525.00	0.904		BNE 1070785.00	1.224
BNE 1056400.00	2.297			BNE 1062737.50	4615		BNE 1020677.50	1.056		BNE 1071040.00	1.205
BNE 1056695.00	2.271			BNE 1063032.50	4647		BNE 1020830.00	1.27		BNE 1071280.00	1.017
BNE 1056865.00	2.347			BNE 1063217.50	4901		BNE 1020962.50	1.447		BNE 1071520.00	0.88
BNE 1056950.00	2.305			BNE 1063477.50	4911		BNE 1021095.00	1.68		BNE 1071767.50	0.979
BNE 1057090.00	2.253			BNE 1063822.50	4912		BNE 1021317.00	1.653		BNE 1072015.00	1.103
BNE 1057530.00	2.204			BNE 1064245.00	4914		BNE 1021539.00	1.626		BNE 1072017.50	1.103
BNE 1058040.00	2.095			BNE 1064750.00	4917		BNE 1021627.00	1.487		BNE 1072020.00	1.103
BNE 1058230.00	2.067			BNE 1065256.50	4922		BNE 1021715.00	1.37		BNE 1072020.00	1.141
BNE 1058530.00	2.034			BNE 1065746.50	4929		BNE 1021805.00	1.382		BNE 1072267.50	1.118
BNE 1058735.00	2.039			BNE 1066247.50	4938		BNE 1021895.00	1.394		BNE 1072515.00	1.097
BNE 1059035.00	1.951			BNE 1066762.50	4946		BNE 1022000.00	1.449		BNE 1072765.00	1.067
BNE 1059540.00	1.914			BNE 1067252.50	4958		BNE 1022105.00	1.509		BNE 1072995.00	1.04
BNE 1059990.00	1.808			BNE 1067725.00	4970		BNE 1022340.00	1.516		BNE 1073240.00	1.092
BNE 1060345.00	1.713			BNE 1068312.50	4978		BNE 1022575.00	1.528		BNE 1073485.00	1.15
BNE 1060535.00	1.673			BNE 1068852.50	4980		BNE 1022807.50	1.747		BNE 1073742.50	1.133
BNE 1061015.00	1.657			BNE 1069290.00	4979		BNE 1023040.00	2.03		BNE 1074000.00	1.117
BNE 1061630.00	1.601			BNE 1069780.00	4974		BNE 1023305.00	1.933		BNE 1074230.00	1.109
BNE 1062020.00	1.586			BNE 1070277.50	4966		BNE 1023570.00	1.844		BNE 1074460.00	1.103
BNE 1062535.00	1.575			BNE 1070785.00	4956		BNE 1023825.00	1.796		BNE 1074722.50	1.16
BNE 1062940.00	1.578			BNE 1071280.00	4948		BNE 1024080.00	1.75		BNE 1074985.00	1.224
BNE 1063125.00	1.553			BNE 1071767.50	4939		BNE 1024321.50	1.702		BNE 1075232.50	1.111
BNE 1063125.00	1.553			BNE 1072017.50	4935		BNE 1024563.00	1.657		BNE 1075480.00	1.017
BNE 1063310.00	1.535			BNE 1072267.50	5089		BNE 1024816.50	1.578		BNE 1075740.00	0.854
BNE 1063645.00	1.442			BNE 1072755.00	5095		BNE 1025070.00	1.507		BNE 1076000.00	0.736
BNE 1064000.00	1.441			BNE 1073240.00	5101		BNE 1025215.00	1.615		BNE 1076247.50	0.835
BNE 1064490.00	1.393			BNE 1073742.50	5107		BNE 1025360.00	1.739		BNE 1076495.00	0.964
BNE 1065010.00	1.399			BNE 1074230.00	5111		BNE 1025475.00	1.857		BNE 1076752.50	0.794
BNE 1065503.00	1.379			BNE 1074722.50	5115		BNE 1025590.00	1.992		BNE 1077010.00	0.675
BNE 1065990.00	1.387			BNE 1075232.50	5119		BNE 1025880.00	1.863		BNE 1077260.00	0.58
BNE 1066505.00	1.355			BNE 1075740.00	5124		BNE 1026170.00	1.75		BNE 1077510.00	0.508
BNE 1067020.00	1.342			BNE 1076247.50	5130		BNE 1026425.00	1.716		BNE 1077775.00	0.522
BNE 1067485.00	1.297			BNE 1076752.50	5134		BNE 1026680.00	1.663		BNE 1078040.00	0.537
BNE 1067965.00	1.259			BNE 1077260.00	5140		BNE 1026790.00	1.752		BNE 1078282.50	0.646
BNE 1068660.00	1.205			BNE 1077775.00	5142		BNE 1026900.00	1.827		BNE 1078525.00	0.813
BNE 1069045.00	1.184			BNE 1078282.50	5144		BNE 1027030.00	1.85		BNE 1078592.50	0.18
BNE 1069535.00	1.172			BNE 1078592.50	5144		BNE 1027160.00	1.873		BNE 1078660.00	0.101
BNE 1070025.00	1.161						BNE 1027420.00	1.689			
BNE 1070530.00	1.136						BNE 1027680.00	1.538			
BNE 1071040.00	1.119						BNE 1027930.00	1.463			
BNE 1071520.00	1.141						BNE 1028180.00	1.395			
BNE 1072015.00	1.109						BNE 1028430.00	1.563			
BNE 1072020.00	1.109						BNE 1028680.00	1.779			
BNE 1072020.00	1.109						BNE 1028720.00	2.177			
BNE 1072515.00	1.095						BNE 1028760.00	1.776			
BNE 1072995.00	1.084						BNE 1028980.00	1.872			
BNE 1073485.00	1.053						BNE 1029200.00	1.977			
BNE 1074000.00	1.046						BNE 1029440.00	1.855			
BNE 1074460.00	1.06						BNE 1029680.00	1.746			
BNE 1074985.00	1.073						BNE 1029950.00	1.665			
BNE 1075480.00	1.085						BNE 1030220.00	1.59			
BNE 1076000.00	1.086						BNE 1030545.00	1.605			
BNE 1076495.00	1.069						BNE 1030870.00	1.621			
BNE 1077010.00	1.044						BNE 1031065.00	1.723			
BNE 1077510.00	1.011						BNE 1031260.00	1.837			
BNE 1078040.00	0.971						BNE 1031480.00	1.984			
BNE 1078525.00	0.92						BNE 1031700.00	2.155			
BNE 1078650.00	0.918						BNE 1031847.50	1.857			

DRAFT

Appendix D Mike11 Results Q2000

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q2000 event CRCFORGE rainfall with ARF's

120hr Storm Duration

DRAFT

Chainage [m]	Water Level
BNE 931570.00	50.124
BNE 931580.00	50.117
BNE 933670.00	48.898
BNE 934270.00	48.859
BNE 934620.00	48.707
BNE 936070.00	48.483
BNE 936820.00	48.357
BNE 939770.00	47.74
BNE 942320.00	47.246
BNE 943570.00	47.194
BNE 944120.00	47.184
BNE 945570.00	47.12
BNE 947170.00	46.775
BNE 948270.00	46.371
BNE 950270.00	45.744
BNE 952320.00	44.758
BNE 953870.00	44.268
BNE 954920.00	43.921
BNE 955970.00	43.608
BNE 958770.00	42.448
BNE 960170.00	42.322
BNE 962070.00	42.056
BNE 964170.00	41.26
BNE 966610.00	40.017
BNE 967410.00	39.454
BNE 968790.00	37.99
BNE 971160.00	37.546
BNE 972260.00	37.22
BNE 973260.00	37.212
BNE 974580.00	36.971
BNE 976020.00	36.934
BNE 976750.00	36.948
BNE 978280.00	36.475
BNE 979507.00	34.654
BNE 979513.00	34.529
BNE 979530.00	34.649
BNE 980330.00	34.459
BNE 981660.00	34.001
BNE 982460.00	33.839
BNE 984160.00	33.198
BNE 986260.00	32.735
BNE 986480.00	31.674
BNE 987960.00	30.827
BNE 988160.00	30.565
BNE 988170.00	30.531
BNE 988360.00	30.329
BNE 989700.00	29.57
BNE 990700.00	29.172
BNE 990780.00	29.089
BNE 991710.00	28.876
BNE 992420.00	28.684
BNE 992450.00	28.578
BNE 992470.00	28.533
BNE 992670.00	28.451
BNE 993760.00	27.842
BNE 994760.00	27.58
BNE 995690.00	26.959
BNE 996980.00	25.807
BNE 998460.00	25.351
BNE 999160.00	25.06
BNE 1000000.00	24.756
BNE 1000285.00	24.514
BNE 1000775.00	24.142
BNE 1001315.00	24.04
BNE 1001865.00	23.515
BNE 1002350.00	23.382
BNE 1002785.00	23.392
BNE 1003275.00	23.101
BNE 1003775.00	22.866
BNE 1004300.00	22.371
BNE 1004810.00	22.351
BNE 1005325.00	22.133
BNE 1005870.00	21.804
BNE 1005870.00	21.804
BNE 1006200.00	21.701
BNE 1006200.00	21.701
BNE 1006300.00	21.659
BNE 1006300.00	21.659
BNE 1006910.00	21.436
BNE 1007410.00	21.365
BNE 1007780.00	21.148
BNE 1007780.00	21.148
BNE 1007920.00	21.027
BNE 1008445.00	20.935
BNE 1008925.00	20.874
BNE 1009400.00	20.742
BNE 1009720.00	20.682
BNE 1010490.00	20.261
BNE 1010725.00	20.326
BNE 1010980.00	20.265
BNE 1011510.00	20.36
BNE 1011980.00	20.403
BNE 1012475.00	20.407

Chainage [m]	Discharge
BNE 931575.00	12000
BNE 932625.00	11975
BNE 933970.00	11957
BNE 934445.00	11944
BNE 935345.00	11915
BNE 936445.00	11878
BNE 937295.00	11862
BNE 941045.00	11786
BNE 942945.00	11696
BNE 943845.00	11582
BNE 944845.00	11491
BNE 946370.00	11469
BNE 947720.00	11460
BNE 949270.00	11447
BNE 951295.00	11413
BNE 953095.00	11384
BNE 954395.00	11359
BNE 955445.00	11341
BNE 957370.00	11318
BNE 959470.00	11238
BNE 961120.00	11151
BNE 963120.00	11105
BNE 965390.00	11102
BNE 967010.00	11088
BNE 968600.00	11077
BNE 970475.00	11074
BNE 971710.00	11067
BNE 972760.00	11063
BNE 973920.00	11057
BNE 975300.00	11054
BNE 976385.00	11055
BNE 977515.00	11059
BNE 978893.50	11079
BNE 979510.00	11380
BNE 979521.50	11378
BNE 979930.00	11072
BNE 980995.00	11051
BNE 982060.00	11050
BNE 983310.00	11052
BNE 984710.00	11052
BNE 985870.00	11053
BNE 987220.00	11054
BNE 988060.00	11055
BNE 988165.00	11055
BNE 988265.00	11055
BNE 989030.00	11058
BNE 990200.00	11064
BNE 990730.00	11058
BNE 991235.00	11059
BNE 992065.00	11096
BNE 992435.00	11114
BNE 992460.00	11114
BNE 992570.00	11157
BNE 993215.00	11071
BNE 994260.00	11066
BNE 995225.00	11069
BNE 996335.00	11068
BNE 997720.00	11070
BNE 998810.00	11071
BNE 999580.00	11072
BNE 1000142.50	11159
BNE 1000530.00	11160
BNE 1001045.00	11160
BNE 1001580.00	11161
BNE 1002107.50	11161
BNE 1002567.50	11162
BNE 1003030.00	11162
BNE 1003525.00	11163
BNE 1004037.50	11163
BNE 1004565.00	11164
BNE 1005067.50	11165
BNE 1005597.50	11165
BNE 1006035.00	9594
BNE 1006250.00	11272
BNE 1006605.00	11876
BNE 1007160.00	11874
BNE 1007585.00	11872
BNE 1007850.00	11861
BNE 1008182.50	11859
BNE 1008685.00	11857
BNE 1009162.50	11857
BNE 1009560.00	11856
BNE 1010105.00	11853
BNE 1010607.50	11852
BNE 1010852.50	11851
BNE 1011245.00	11851
BNE 1011745.00	11849
BNE 1012227.50	11847
BNE 1012705.00	11834
BNE 1013062.50	11833
BNE 1013317.50	10847
BNE 1013562.50	10845
BNE 1013795.00	10244

Chainage [m]	Velocity [m/s]
BNE 931570.00	2.529
BNE 931575.00	2.531
BNE 931580.00	2.532
BNE 932625.00	2.359
BNE 933670.00	2.2
BNE 933970.00	1.423
BNE 934270.00	1.533
BNE 934445.00	1.878
BNE 934620.00	2.491
BNE 935345.00	0.918
BNE 936070.00	0.632
BNE 936445.00	0.865
BNE 936820.00	3.394
BNE 938295.00	1.419
BNE 939770.00	1.775
BNE 941045.00	1.387
BNE 942320.00	1.334
BNE 942945.00	1.007
BNE 943570.00	0.8
BNE 943845.00	0.769
BNE 944120.00	0.971
BNE 944845.00	0.878
BNE 945570.00	1.183
BNE 946370.00	1.027
BNE 947170.00	1.647
BNE 947720.00	1.667
BNE 948270.00	1.889
BNE 949270.00	1.59
BNE 950270.00	1.501
BNE 951295.00	1.846
BNE 952320.00	2.429
BNE 953095.00	1.71
BNE 953870.00	1.341
BNE 954395.00	1.45
BNE 954920.00	1.96
BNE 955445.00	1.448
BNE 955970.00	1.351
BNE 957370.00	1.652
BNE 958770.00	2.143
BNE 959470.00	1.111
BNE 960170.00	0.886
BNE 961120.00	1.172
BNE 962070.00	1.868
BNE 963120.00	1.376
BNE 964170.00	1.304
BNE 965390.00	1.55
BNE 966610.00	1.96
BNE 967010.00	1.916
BNE 967410.00	1.923
BNE 968600.00	2.127
BNE 968790.00	2.38
BNE 970475.00	2.155
BNE 971160.00	1.986
BNE 971710.00	2.044
BNE 972260.00	2.128
BNE 972760.00	1.8
BNE 973260.00	1.559
BNE 973920.00	1.907
BNE 974580.00	2.502
BNE 975300.00	2.13
BNE 976020.00	1.88
BNE 976385.00	1.098
BNE 976750.00	0.994
BNE 977515.00	1.023
BNE 978280.00	1.56
BNE 978893.50	1.801
BNE 979507.00	2.138
BNE 979510.00	2.163
BNE 979513.00	2.219
BNE 979521.50	1.798
BNE 979530.00	1.461
BNE 979930.00	1.516
BNE 980330.00	1.577
BNE 980995.00	1.815
BNE 981660.00	2.14
BNE 982060.00	1.886
BNE 982460.00	1.706
BNE 983310.00	1.848
BNE 984160.00	2.098
BNE 984710.00	2.074
BNE 985260.00	2.061
BNE 985870.00	2.192
BNE 986480.00	2.353
BNE 987220.00	1.908
BNE 987960.00	1.605
BNE 988060.00	1.784
BNE 988160.00	2.007
BNE 988165.00	3.537
BNE 988170.00	2.014
BNE 988265.00	1.88
BNE 988360.00	1.763
BNE 989030.00	1.616
BNE 989700.00	1.491

Chainage [m]	Velocity [m/s]
BNE 1031995.00	2.547
BNE 1032112.50	2.52
BNE 1032230.00	2.495
BNE 1032407.50	2.709
BNE 1032585.00	2.963
BNE 1032832.50	2.833
BNE 1033080.00	2.714
BNE 1033225.00	2.767
BNE 1033370.00	2.823
BNE 1033635.00	2.975
BNE 1033900.00	3.146
BNE 1034135.00	3.184
BNE 1034370.00	3.224
BNE 1034630.00	3.011
BNE 1034890.00	2.825
BNE 1035152.00	2.904
BNE 1035414.00	2.983
BNE 1035657.00	3.089
BNE 1035900.00	3.198
BNE 1036180.00	3.155
BNE 1036460.00	3.112
BNE 1036615.00	2.872
BNE 1036770.00	2.667
BNE 1036842.50	2.878
BNE 1036915.00	3.127
BNE 1037002.50	3.076
BNE 1037090.00	3.027
BNE 1037110.00	3.235
BNE 1037175.00	3.104
BNE 1037230.00	3.176
BNE 1037285.00	3.251
BNE 1037455.00	2.963
BNE 1037625.00	2.721
BNE 1037855.00	2.29
BNE 1038085.00	1.978
BNE 1038342.50	1.955
BNE 1038600.00	1.932
BNE 1038850.00	1.896
BNE 1039100.00	1.861
BNE 1039150.00	1.852
BNE 1039200.00	1.843
BNE 1039200.00	1.758
BNE 1039382.50	1.726
BNE 1039565.00	1.694
BNE 1039617.50	1.697
BNE 1039670.00	1.701
BNE 1039670.00	1.652
BNE 1039749.00	1.665
BNE 1039828.00	1.678
BNE 1039828.00	1.624
BNE 1039958.00	1.67
BNE 1040090.00	1.72
BNE 1040170.00	1.821
BNE 1040250.00	1.934
BNE 1040250.00	1.902
BNE 1040370.00	2.089
BNE 1040490.00	2.318
BNE 1040750.00	2.023
BNE 1041010.00	1.794
BNE 1041120.00	1.76
BNE 1041230.00	1.728
BNE 1041345.00	1.829
BNE 1041460.00	1.945
BNE 1041580.00	1.898
BNE 1041700.00	1.854
BNE 1041830.00	2.06
BNE 1041960.00	2.319
BNE 1042097.50	2.453
BNE 1042235.00	2.604
BNE 1042367.50	2.426
BNE 1042500.00	2.271
BNE 1042500.00	2.312
BNE 1042507.50	2.303
BNE 1042515.00	2.295
BNE 1042712.50	2.122
BNE 1042910.00	2.003
BNE 1042960.00	2.008
BNE 1043010.00	2.014
BNE 1043010.00	2.05
BNE 1043045.00	2.055
BNE 1043080.00	2.059
BNE 1043095.00	2.057
BNE 1043110.00	2.055
BNE 1043110.00	2.125
BNE 1043417.50	2.175
BNE 1043725.00	2.241
BNE 1043892.50	2.395
BNE 1044060.00	2.572
BNE 1044200.00	2.68
BNE 1044340.00	2.798
BNE 1044472.50	2.601
BNE 1044605.00	2.431
BNE 1044732.50	2.234

BNE 1012475.00	20.407		BNE 1014110.00	10238	BNE 990200.00	1.742	BNE 1044860.00	2.068
BNE 1012935.00	20.363		BNE 1014460.00	10232	BNE 990700.00	2.093	BNE 1045130.00	2.028
BNE 1013190.00	20.358		BNE 1014850.00	10197	BNE 990730.00	2.213	BNE 1045400.00	1.991
BNE 1013190.00	20.356		BNE 1015325.00	10193	BNE 990760.00	2.347	BNE 1045642.50	1.994
BNE 1013445.00	20.345		BNE 1015705.00	10191	BNE 991235.00	1.585	BNE 1045885.00	1.997
BNE 1013680.00	20.336		BNE 1015995.00	10814	BNE 991710.00	1.198	BNE 1046032.50	1.932
BNE 1013680.00	20.336		BNE 1016390.00	10812	BNE 992065.00	1.236	BNE 1046180.00	1.871
BNE 1013910.00	20.326		BNE 1016765.00	10810	BNE 992420.00	1.271	BNE 1046260.00	1.999
BNE 1014310.00	20.271		BNE 1017010.00	11817	BNE 992435.00	1.518	BNE 1046340.00	2.145
BNE 1014610.00	20.182		BNE 1017370.00	11815	BNE 992450.00	1.87	BNE 1046460.00	2.086
BNE 1014610.00	20.182		BNE 1017765.00	11814	BNE 992460.00	1.969	BNE 1046580.00	2.029
BNE 1015090.00	20.025		BNE 1018080.00	11813	BNE 992470.00	1.874	BNE 1046740.00	2.208
BNE 1015560.00	19.867		BNE 1018462.50	11812	BNE 992570.00	1.82	BNE 1046900.00	2.422
BNE 1015850.00	19.807		BNE 1018910.00	11811	BNE 992670.00	1.743	BNE 1047125.00	2.702
BNE 1015860.00	19.807		BNE 1019292.50	11812	BNE 993215.00	1.967	BNE 1047350.00	3.055
BNE 1016140.00	19.747		BNE 1019677.50	11810	BNE 993760.00	2.259	BNE 1047632.50	2.981
BNE 1016640.00	19.609		BNE 1019990.00	11810	BNE 994260.00	1.736	BNE 1047915.00	2.91
BNE 1016890.00	19.498		BNE 1020320.00	11809	BNE 994760.00	1.41	BNE 1048145.00	2.373
BNE 1016890.00	19.498		BNE 1020677.50	11808	BNE 995225.00	1.802	BNE 1048375.00	2.003
BNE 1017130.00	19.36		BNE 1020962.50	11807	BNE 995690.00	2.494	BNE 1048632.50	2.265
BNE 1017610.00	19.293		BNE 1021317.00	11807	BNE 996335.00	2.324	BNE 1048890.00	2.806
BNE 1017920.00	19.139		BNE 1021627.00	11806	BNE 996980.00	2.176	BNE 1049005.00	2.577
BNE 1018200.00	19.094		BNE 1021805.00	11806	BNE 997720.00	1.866	BNE 1049120.00	2.549
BNE 1018725.00	18.793		BNE 1022000.00	11806	BNE 998460.00	1.349	BNE 1049245.00	2.796
BNE 1019095.00	18.726		BNE 1022340.00	11805	BNE 998810.00	1.743	BNE 1049370.00	3.095
BNE 1019480.00	18.671		BNE 1022807.50	11813	BNE 999160.00	2.46	BNE 1049480.00	2.986
BNE 1019490.00	18.671		BNE 1023305.00	11812	BNE 999580.00	2.315	BNE 1049590.00	2.884
BNE 1019865.00	18.369		BNE 1023825.00	11812	BNE 1000000.00	2.192	BNE 1049730.00	2.963
BNE 1020115.00	18.545		BNE 1024321.50	11811	BNE 1000142.50	2.393	BNE 1049870.00	3.047
BNE 1020525.00	18.538		BNE 1024816.50	11810	BNE 1000285.00	2.833	BNE 1050150.00	2.838
BNE 1020830.00	18.354		BNE 1025215.00	11809	BNE 1000530.00	2.763	BNE 1050430.00	2.656
BNE 1021095.00	18.098		BNE 1025475.00	11808	BNE 1000775.00	2.907	BNE 1050645.00	2.811
BNE 1021535.00	17.857		BNE 1025890.00	11808	BNE 1001045.00	2.597	BNE 1050860.00	2.986
BNE 1021715.00	17.889		BNE 1026425.00	11807	BNE 1001315.00	2.347	BNE 1051110.00	2.865
BNE 1021895.00	17.77		BNE 1026790.00	11806	BNE 1001590.00	2.814	BNE 1051360.00	2.754
BNE 1022105.00	17.584		BNE 1027030.00	11806	BNE 1001865.00	3.513	BNE 1051627.50	2.971
BNE 1022575.00	17.488		BNE 1027420.00	11805	BNE 1002107.50	3.266	BNE 1051895.00	3.224
BNE 1023040.00	17.189		BNE 1027930.00	11804	BNE 1002350.00	3.052	BNE 1052102.50	2.734
BNE 1023570.00	17.091		BNE 1028430.00	11803	BNE 1002567.50	2.66	BNE 1052310.00	2.373
BNE 1024080.00	17.071		BNE 1028720.00	11802	BNE 1002785.00	2.356	BNE 1052370.00	3.8
BNE 1024583.00	17.042		BNE 1028860.00	11802	BNE 1003030.00	2.599	BNE 1052390.00	3.041
BNE 1025070.00	17.037		BNE 1029440.00	11800	BNE 1003275.00	2.898	BNE 1052492.50	3.185
BNE 1025360.00	16.898		BNE 1029950.00	11798	BNE 1003525.00	2.858	BNE 1052595.00	3.344
BNE 1025590.00	16.731		BNE 1030545.00	11795	BNE 1003775.00	2.82	BNE 1052625.00	5.361
BNE 1026170.00	16.506		BNE 1031065.00	11794	BNE 1004037.50	3.039	BNE 1052640.00	3.129
BNE 1026680.00	16.413		BNE 1031480.00	11793	BNE 1004300.00	3.294	BNE 1052752.50	3.255
BNE 1026900.00	16.248		BNE 1031847.50	11793	BNE 1004555.00	2.61	BNE 1052865.00	3.391
BNE 1027160.00	16.059		BNE 1032112.50	11792	BNE 1004810.00	2.161	BNE 1053092.50	3.058
BNE 1027680.00	16.113		BNE 1032407.50	11792	BNE 1005067.50	2.205	BNE 1053320.00	2.785
BNE 1028180.00	16.145		BNE 1032832.50	11791	BNE 1005325.00	2.25	BNE 1053355.00	3.459
BNE 1028680.00	15.972		BNE 1033225.00	11790	BNE 1005597.50	2.443	BNE 1053385.00	2.99
BNE 1028760.00	15.938		BNE 1033635.00	11789	BNE 1005870.00	2.672	BNE 1053642.50	2.997
BNE 1029200.00	15.797		BNE 1034135.00	11789	BNE 1005870.00	2.292	BNE 1053900.00	3.005
BNE 1029680.00	15.83		BNE 1034630.00	11788	BNE 1006035.00	2.238	BNE 1054270.00	2.212
BNE 1030220.00	15.827		BNE 1035152.00	11787	BNE 1006200.00	2.188	BNE 1054640.00	1.75
BNE 1030870.00	15.756		BNE 1035657.00	11786	BNE 1006200.00	2.586	BNE 1054660.00	2.371
BNE 1031260.00	15.563		BNE 1036180.00	11785	BNE 1006250.00	2.567	BNE 1054680.00	1.768
BNE 1031700.00	15.219		BNE 1036615.00	11784	BNE 1006300.00	2.549	BNE 1054825.00	2.23
BNE 1031995.00	15.402		BNE 1036842.50	11784	BNE 1006300.00	2.679	BNE 1054970.00	3.02
BNE 1032230.00	15.282		BNE 1037002.50	11786	BNE 1006605.00	2.528	BNE 1055125.00	3.007
BNE 1032585.00	14.927		BNE 1037110.00	11786	BNE 1006910.00	2.393	BNE 1055280.00	2.993
BNE 1033080.00	14.765		BNE 1037230.00	11786	BNE 1007160.00	2.16	BNE 1055350.00	2.965
BNE 1033370.00	14.661		BNE 1037455.00	11785	BNE 1007410.00	1.968	BNE 1055420.00	2.938
BNE 1033900.00	14.385		BNE 1037855.00	11785	BNE 1007595.00	2.221	BNE 1055690.00	2.765
BNE 1034370.00	14.15		BNE 1038342.50	11781	BNE 1007780.00	2.548	BNE 1055960.00	2.811
BNE 1034880.00	14.083		BNE 1038850.00	11778	BNE 1007780.00	2.543	BNE 1056180.00	2.945
BNE 1035414.00	13.889		BNE 1039150.00	11776	BNE 1007850.00	2.696	BNE 1056400.00	3.375
BNE 1035900.00	13.643		BNE 1039382.50	10776	BNE 1007920.00	2.868	BNE 1056547.50	3.275
BNE 1036460.00	13.377		BNE 1039617.50	10774	BNE 1008182.50	2.831	BNE 1056695.00	3.181
BNE 1036770.00	13.335		BNE 1039749.00	10200	BNE 1008445.00	2.795	BNE 1056780.00	1.383
BNE 1036916.00	13.164		BNE 1039959.00	10029	BNE 1008685.00	2.745	BNE 1056865.00	0.884
BNE 1037090.00	13.168		BNE 1040170.00	10028	BNE 1008925.00	2.697	BNE 1056920.00	3.465
BNE 1037175.00	12.704		BNE 1040370.00	9566	BNE 1009162.50	2.668	BNE 1056950.00	0.912
BNE 1037285.00	12.646		BNE 1040750.00	9564	BNE 1009400.00	2.639	BNE 1057020.00	1.344
BNE 1037625.00	12.708		BNE 1041120.00	9560	BNE 1009560.00	2.496	BNE 1057090.00	2.552
BNE 1038085.00	12.794		BNE 1041345.00	9558	BNE 1009720.00	2.369	BNE 1057310.00	2.709
BNE 1038600.00	12.755		BNE 1041580.00	9557	BNE 1010105.00	2.759	BNE 1057530.00	2.888
BNE 1039100.00	12.729		BNE 1041830.00	9556	BNE 1010490.00	3.305	BNE 1057785.00	3.115
BNE 1039200.00	12.727		BNE 1042097.50	9555	BNE 1010607.50	3.128	BNE 1058040.00	3.381
BNE 1039200.00	12.727		BNE 1042367.50	9554	BNE 1010725.00	2.969	BNE 1058135.00	3.38
BNE 1039565.00	12.72		BNE 1042507.50	10024	BNE 1010852.50	3.015	BNE 1058230.00	3.379
BNE 1039670.00	12.714		BNE 1042712.50	10024	BNE 1010980.00	3.062	BNE 1058380.00	3.46
BNE 1039670.00	12.714		BNE 1042960.00	10023	BNE 1011245.00	2.77	BNE 1058530.00	3.545
BNE 1039828.00	12.704		BNE 1043045.00	10641	BNE 1011510.00	2.528	BNE 1058632.50	3.3
BNE 1039828.00	12.704		BNE 1043095.00	10641	BNE 1011745.00	2.379	BNE 1058735.00	3.088
BNE 1040090.00	12.678		BNE 1043417.50	11701	BNE 1011980.00	2.247	BNE 1058885.00	3.381
BNE 1040250.00	12.636		BNE 1043892.50	11701	BNE 1012227.50	2.172	BNE 1059035.00	3.736
BNE 1040250.00	12.636		BNE 1044280.00	11701	BNE 1012475.00	2.103	BNE 1059287.50	3.199
BNE 1040490.00	12.546		BNE 1044472.50	11701	BNE 1012475.00	2.096	BNE 1059540.00	2.798
BNE 1041010.00	12.61		BNE 1044732.50	11700	BNE 1012705.00	2.134	BNE 1059765.00	2.809
BNE 1041230.00	12.598		BNE 1045130.00	11700	BNE 1012935.00	2.173	BNE 1059990.00	2.822
BNE 1041460.00	12.527		BNE 1045642.50	11700	BNE 1013062.50	2.143	BNE 1060167.50	3.096
BNE 1041700.00	12.509		BNE 1046032.50	11700	BNE 1013190.00	2.113	BNE 1060345.00	3.429
BNE 1041960.00	12.386		BNE 1046260.00	11699	BNE 1013190.00	1.975	BNE 1060440.00	3.59
BNE 1042235.00	12.217		BNE 1046460.00	11699	BNE 1013317.50	1.958	BNE 1060535.00	3.758
BNE 1042500.00	12.183		BNE 1046740.00	11699	BNE 1013445.00	1.945	BNE 1060775.00	3.513
BNE 1042500.00	12.183		BNE 1047125.00	11699	BNE 1013562.50	1.901	BNE 1061015.00	3.291
BNE 1042515.00	12.181		BNE 1047632.50	11699	BNE 1013680.00	1.881	BNE 1061272.50	3.428
BNE 1042910.00	12.114		BNE 1048145.00	11699	BNE 1013680.00	1.851	BNE 1061530.00	3.578

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BNE 1043010.00	12.065		BNE 1048632.50	11699		BNE 1013795.00	1.813		BNE 1061775.00	3.365	
BNE 1043010.00	12.065		BNE 1049005.00	11698		BNE 1013910.00	1.776		BNE 1062020.00	3.176	
BNE 1043080.00	12.027		BNE 1049245.00	11698		BNE 1014110.00	1.76		BNE 1062277.50	2.886	
BNE 1043110.00	12.011		BNE 1049480.00	11698		BNE 1014310.00	1.744		BNE 1062535.00	2.642	
BNE 1043110.00	12.011		BNE 1049730.00	11698		BNE 1014460.00	1.706		BNE 1062737.50	2.388	
BNE 1043725.00	11.664		BNE 1050150.00	11698		BNE 1014610.00	1.67		BNE 1062940.00	2.179	
BNE 1044060.00	11.465		BNE 1050645.00	11698		BNE 1014610.00	1.672		BNE 1063032.50	2.232	
BNE 1044340.00	11.312		BNE 1051110.00	11698		BNE 1014850.00	1.775		BNE 1063125.00	2.288	
BNE 1044605.00	11.316		BNE 1051627.50	11698		BNE 1015090.00	1.894		BNE 1063125.00	2.289	
BNE 1044860.00	11.336		BNE 1052102.50	11698		BNE 1015325.00	2.067		BNE 1063217.50	2.368	
BNE 1045400.00	11.287		BNE 1052370.00	11698		BNE 1015560.00	2.278		BNE 1063310.00	2.454	
BNE 1045885.00	11.216		BNE 1052492.50	11698		BNE 1015705.00	2.254		BNE 1063477.50	2.869	
BNE 1046180.00	11.219		BNE 1052625.00	11698		BNE 1015850.00	2.232		BNE 1063645.00	3.454	
BNE 1046340.00	11.149		BNE 1052752.50	11698		BNE 1015850.00	2.299		BNE 1063822.50	3.346	
BNE 1046580.00	11.115		BNE 1053092.50	11698		BNE 1015995.00	2.257		BNE 1064000.00	3.245	
BNE 1046900.00	10.852		BNE 1053355.00	11698		BNE 1016140.00	2.216		BNE 1064245.00	3.291	
BNE 1047350.00	10.27		BNE 1053642.50	11698		BNE 1016390.00	2.186		BNE 1064490.00	3.339	
BNE 1047915.00	9.885		BNE 1054270.00	11698		BNE 1016640.00	2.166		BNE 1064750.00	2.969	
BNE 1048375.00	9.984		BNE 1054660.00	11698		BNE 1016765.00	2.227		BNE 1065010.00	2.673	
BNE 1048890.00	9.748		BNE 1054825.00	11698		BNE 1016890.00	2.291		BNE 1065256.50	2.583	
BNE 1049120.00	9.692		BNE 1055125.00	11698		BNE 1016890.00	2.442		BNE 1065503.00	2.499	
BNE 1049370.00	9.451		BNE 1055350.00	11698		BNE 1017010.00	2.513		BNE 1065746.50	2.175	
BNE 1049590.00	9.424		BNE 1055690.00	11698		BNE 1017130.00	2.588		BNE 1065990.00	1.926	
BNE 1049870.00	9.267		BNE 1056180.00	11698		BNE 1017370.00	2.345		BNE 1066247.50	2.078	
BNE 1050430.00	9.198		BNE 1056547.50	11698		BNE 1017610.00	2.144		BNE 1066505.00	2.256	
BNE 1050860.00	9.034		BNE 1056780.00	11698		BNE 1017765.00	2.261		BNE 1066762.50	2.189	
BNE 1051360.00	9.037		BNE 1056920.00	11698		BNE 1017920.00	2.393		BNE 1067020.00	2.125	
BNE 1051895.00	8.856		BNE 1057020.00	11698		BNE 1018060.00	2.297		BNE 1067252.50	2.291	
BNE 1052310.00	9.061		BNE 1057310.00	11698		BNE 1018200.00	2.209		BNE 1067485.00	2.486	
BNE 1052390.00	8.798		BNE 1057785.00	11698		BNE 1018482.50	2.46		BNE 1067725.00	2.614	
BNE 1052595.00	8.701		BNE 1058135.00	11698		BNE 1018725.00	2.775		BNE 1067965.00	2.757	
BNE 1052640.00	7.772		BNE 1058380.00	11698		BNE 1018910.00	2.846		BNE 1068312.50	2.881	
BNE 1052865.00	7.679		BNE 1058632.50	11698		BNE 1019095.00	2.529		BNE 1068660.00	3.016	
BNE 1053320.00	7.818		BNE 1058885.00	11698		BNE 1019292.50	2.389		BNE 1068852.50	2.992	
BNE 1053385.00	7.569		BNE 1059287.50	11698		BNE 1019490.00	2.262		BNE 1069045.00	2.959	
BNE 1053900.00	7.263		BNE 1059765.00	11698		BNE 1019490.00	2.261		BNE 1069290.00	2.851	
BNE 1054640.00	7.187		BNE 1060167.50	11698		BNE 1019677.50	2.561		BNE 1069535.00	2.742	
BNE 1054680.00	7.094		BNE 1060440.00	11698		BNE 1019865.00	2.951		BNE 1069780.00	2.678	
BNE 1054970.00	6.719		BNE 1060775.00	11698		BNE 1019990.00	2.231		BNE 1070025.00	2.618	
BNE 1055280.00	6.551		BNE 1061272.50	11698		BNE 1020115.00	1.793		BNE 1070277.50	2.651	
BNE 1055420.00	6.487		BNE 1061775.00	11698		BNE 1020320.00	1.524		BNE 1070530.00	2.685	
BNE 1055980.00	6.368		BNE 1062277.50	11698		BNE 1020525.00	1.325		BNE 1070785.00	2.649	
BNE 1056400.00	6.022		BNE 1062737.50	11698		BNE 1020677.50	1.619		BNE 1071040.00	2.613	
BNE 1056895.00	5.943		BNE 1063032.50	11698		BNE 1020830.00	2.08		BNE 1071280.00	2.233	
BNE 1056865.00	6.235		BNE 1063217.50	11703		BNE 1020962.50	2.35		BNE 1071520.00	1.95	
BNE 1056950.00	6.092		BNE 1063477.50	11703		BNE 1021096.00	2.7		BNE 1071767.50	2.162	
BNE 1057090.00	5.872		BNE 1063822.50	11703		BNE 1021317.00	2.624		BNE 1072015.00	2.425	
BNE 1057530.00	5.713		BNE 1064245.00	11702		BNE 1021539.00	2.552		BNE 1072017.50	2.425	
BNE 1058040.00	5.392		BNE 1064750.00	11702		BNE 1021627.00	2.261		BNE 1072020.00	2.424	
BNE 1058230.00	5.315		BNE 1065256.50	11702		BNE 1021715.00	2.03		BNE 1072020.00	2.425	
BNE 1058530.00	5.147		BNE 1065746.50	11702		BNE 1021805.00	2.11		BNE 1072267.50	2.395	
BNE 1058735.00	5.211		BNE 1066247.50	11702		BNE 1021895.00	2.196		BNE 1072515.00	2.385	
BNE 1059035.00	4.84		BNE 1066762.50	11702		BNE 1022000.00	2.357		BNE 1072755.00	2.304	
BNE 1059540.00	4.781		BNE 1067252.50	11702		BNE 1022105.00	2.543		BNE 1072995.00	2.247	
BNE 1059990.00	4.465		BNE 1067725.00	11703		BNE 1022340.00	2.394		BNE 1073240.00	2.364	
BNE 1060345.00	4.051		BNE 1068312.50	11703		BNE 1022575.00	2.264		BNE 1073485.00	2.493	
BNE 1060535.00	3.868		BNE 1068852.50	11703		BNE 1022807.50	2.594		BNE 1073742.50	2.466	
BNE 1061015.00	3.87		BNE 1069290.00	11703		BNE 1023040.00	3.034		BNE 1074000.00	2.44	
BNE 1061530.00	3.626		BNE 1069780.00	11703		BNE 1023305.00	3.002		BNE 1074230.00	2.434	
BNE 1062020.00	3.603		BNE 070277.50	11703		BNE 1023570.00	2.97		BNE 1074460.00	2.428	
BNE 1062535.00	3.615		BNE 070785.00	11703		BNE 1023825.00	2.819		BNE 1074722.50	2.573	
BNE 1062940.00	3.643		BNE 071280.00	11703		BNE 1024080.00	2.682		BNE 1074985.00	2.735	
BNE 1063125.00	3.578		BNE 071767.50	11703		BNE 1024321.50	2.577		BNE 1075232.50	2.478	
BNE 1063125.00	3.578		BNE 072017.50	11703		BNE 1024563.00	2.481		BNE 1075480.00	2.265	
BNE 1063310.00	3.484		BNE 072267.50	11708		BNE 1024816.50	2.347		BNE 1075740.00	1.903	
BNE 1063645.00	3.131		BNE 072755.00	11708		BNE 1025070.00	2.227		BNE 1076000.00	1.64	
BNE 1064000.00	3.134		BNE 072995.00	11708		BNE 1025215.00	2.412		BNE 1076247.50	1.874	
BNE 1064490.00	2.956		BNE 073742.50	11708		BNE 1025360.00	2.63		BNE 1076495.00	2.186	
BNE 1065010.00	2.984		BNE 074230.00	11708		BNE 1025475.00	2.603		BNE 1076752.50	1.797	
BNE 1065503.00	2.911		BNE 074722.50	11708		BNE 1025590.00	3		BNE 1077010.00	1.525	
BNE 1065990.00	2.96		BNE 075232.50	11708		BNE 1025680.00	2.911		BNE 1077260.00	1.311	
BNE 1066505.00	2.833		BNE 075740.00	11708		BNE 1026170.00	2.828		BNE 1077510.00	1.15	
BNE 1067020.00	2.796		BNE 076247.50	11708		BNE 1026425.00	2.666		BNE 1077775.00	1.183	
BNE 1067485.00	2.046		BNE 076752.50	11708		BNE 1026680.00	2.523		BNE 1078040.00	1.219	
BNE 1067965.00	2.462		BNE 077260.00	11708		BNE 1026790.00	2.677		BNE 1078282.50	1.47	
BNE 1068660.00	2.259		BNE 077775.00	11708		BNE 1026900.00	2.852		BNE 1078525.00	1.853	
BNE 1069045.00	2.168		BNE 078282.50	11708		BNE 1027030.00	2.976		BNE 1078592.50	0.41	
BNE 1069535.00	2.112		BNE 078592.50	11708		BNE 1027160.00	3.11		BNE 1078669.00	0.231	
BNE 1070025.00	2.047					BNE 1027420.00	2.684				
BNE 1070530.00	1.93					BNE 1027680.00	2.36				
BNE 1071040.00	1.845					BNE 1027930.00	2.17				
BNE 1071520.00	1.927					BNE 1028180.00	2.009				
BNE 1072015.00	1.779					BNE 1028430.00	2.254				
BNE 1072020.00	1.778					BNE 1028680.00	2.569				
BNE 1072020.00	1.778					BNE 1028720.00	3.081				
BNE 1072515.00	1.717					BNE 1028760.00	2.47				
BNE 1072995.00	1.675					BNE 1028980.00	2.611				
BNE 1073485.00	1.537					BNE 1029200.00	2.769				
BNE 1074000.00	1.441					BNE 1029440.00	2.551				
BNE 1074460.00	1.348					BNE 1029680.00	2.366				
BNE 1074985.00	1.142					BNE 1029950.00	2.252				
BNE 1075480.00	1.114					BNE 1030220.00	2.161				
BNE 1076000.00	1.137					BNE 1030545.00	2.218				
BNE 1076495.00	1.063					BNE 1030870.00	2.278				
BNE 1077010.00	1.041					BNE 1031065.00	2.544				
BNE 1077510.00	1.009					BNE 1031260.00	2.88				
BNE 1078040.00	0.97					BNE 1031480.00	3.236				
BNE 1078525.00	0.92					BNE 1031700.00	3.682				
BNE 1078660.00	0.918					BNE 1031847.50	3.014				

DRAFT

City Design – Flood Modelling Services

CALCULATION OF FLOODS OF VARIOUS RETURN PERIODS ON THE BRISBANE RIVER

- Q10, Q20, Q50 & Q2000 EVENTS
- Final
- 6/07/2004

City Design – Flood Modelling Services

CALCULATION OF FLOODS OF VARIOUS RETURN PERIODS ON THE BRISBANE RIVER

- Final
- 6/07/2004

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1. Introduction

Council requires calculation of discharges and flood levels for the Brisbane River for return intervals of 10, 20, 50 and 2000 years. This work follows on from SKM's recent work on developing Q100 flood levels and discharges based on a re-calibrated model.

This report details assumptions, methodology and results for these storm events

2. Assumptions

The assumptions used to predict discharges are as follows.

- Rainfall based on data received from City Design on 11 February 2004
- Rainfall based on CRCFORGE rainfall with Areal Reduction Factors.
- An Initial loss of 10 mm and a Continuing loss of 1 mm/hr used in the RAFTS models
- A tail water level of 0.918m AHD at the Western Inner Bar used for each event

For the Q2000 event

- Storm durations of 24, 48, 96 and 120 hrs were modelled
- PMP temporal pattern 'a' used for all durations

For the Q10, Q20 and Q50 events

- Standard temporal patterns (AR&R 1987) were used for 24, 30, 36, 48 and 72 hr storm durations
- PMP temporal pattern 'a' used for 96 and 120 hr storm durations

3. Methodology

The methodology used to produce results for the Q10, Q20, Q50 and Q2000 events are as follows:

Rainfall

- Rainfall depths for the Q50 and Q200 flood events were based on data provided by Council. Data was produced using CRC FORGE rainfall with Areal Reduction Factors (ARF's) applied.
- Rainfall depths for the Q10 and Q20 flood events were based on depths calculated for the Brisbane River Flood Study (SKM 1998) with ARF's applied.
- There was a conversion process required to link rainfall data from Council to the current RAFTS model. This was because Council data was in the format of the original Brisbane River Flood Study (BRFS) and required updating to the more complex model used in the Ipswich Rivers Flood Study (IRFS)
- Rainfall intensities for each of the subcatchments were then temporally distributed using the program HYDCON.
- HYDCON outputs a *.his file that is compatible with RAFTS. This enables each subcatchment to have a unique 'local' storm depending on its position within the catchment

RAFTS [no dams]

- The RAFTS model was run for the each of the seven durations, Rainfall losses of 10 mm (initial) and 1 mm/hr (continuing) were applied. The RAFTS model was set up so that neither Wivenhoe nor Somerset Dams were active.
- This enables a hydrograph of the Wivenhoe and Somerset catchments to be calculated without contributing any storm water detention as a result of the dam. Dams were modelled separately using NR&M's Program DAMS.
- Hydrographs were extracted from RAFTS for nodes WIV27 (Wivenhoe) Som32 (Somerset) SAV8 (Lockyer) and 1B (Bremer).

DAMS

- The Dams program requires the RAFTS hydrographs be converted to a *.prn file format This was achieved using a combination of spreadsheet tools.
- The Dams program models the Wivenhoe and Somerset Dams using current operating rules for water releases. It required input hydrographs from RAFTS at four locations, namely WIV27 (Wivenhoe) Som32 (Somerset) SAV8 (Lockyer) and 1B (Bremer).
- The hydrograph for Wivenhoe was manipulated so that discharge from Somerset was not included, as this was modelled separately.

- The DAMS program was run for each of the seven storm durations.
- DAMS outputs hydrograph data for the Wivenhoe Dam release as a *.dat file. To enable compatibility with RAFTS, the *.dat file was converted into a suitable format using a spreadsheet tool. This was done for each storm durations

Rafts [with dams]

- The output from the DAMS model (ie. Wivenhoe Dam releases) was then input into the RAFTS model
- The RAFTS model was truncated so that all nodes above Wivenhoe Dam were removed, this was replaced with the direct inflow hydrograph extracted from DAMS.
- The RAFTS model was re-run for each of the seven storm durations.
- Results were recorded for several key locations and the critical duration was determined.
- Hydrographs were extracted for key locations on the Bremer, Brisbane River and associated tributaries for hydraulic modelling in MIKE11.
- RAFTS hydrographs were converted into a text ASCII format and imported into MIKE11.

MIKE11

- MIKE 11 Simulation, Boundary, and Time Series files were set up.
- Network and Parameter files were taken from the current Brisbane River MIKE 11 model (re-calibrated case).
- The MIKE 11 model was then run for the critical duration using the re-calibrated model
- Results were extracted for discharge and water levels for every cross section in the model. Results at key locations were also noted.

4. Results - RAFTS

Table 1 presents the results of the Rafts modelling with no dams

* Table 1 Discharges at Port Office Gauge (no dams)

Storm Duration	Q10	Q20	Q50	Q2000
24	4805.3	5868.4	7069.9	13966
30	**6090.0**	**7062.6**	7897.9	-
36	4828.4	5876.6	7043.7	-
48	4950.2	6107.1	7375.2	**17126**
72	4890.0	6187.9	**8613.6**	17026
96	-	-	7849.8	16417
120	-	-	7983.1	16897

Table 2 presents the results of the Rafts modelling with no dams

* Table 2 Discharges at Port Office Gauge (with dams)

Storm Duration	Q10	Q20	Q50	Q2000
24	1655.9	2054.8	2718.6	7202.8
30	**2343.9**	**2774.3**	3337.1	-
36	1691.8	2160.8	2734.5	-
48	1786.2	2323.1	3035.4	10157
72	1940.2	2426.1	**3972.8**	11605
96	-	-	3817.3	12347
120	-	-	3927.2	**12814**

5. Results - MIKE 11

Table 3 presents the results of the MIKE11 modelling with dams

Table 3 Discharges and WSL at the Port Office Gauge (with dams)

	Q10	Q20	Q50	Q2000
Storm Duration [hrs]	30	30	72	120
WSL [m AHD]	1.529	1.791	2.416	6.368
Discharge [m^3/s]	2834	3447	4591	11698

It should be noted that differences in discharges in the RAFTS and MIKE11 models are due to river routing affects.

Appendix A Mike11 Results Q10

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q10 event CRCFORGE rainfall with ARF's

30hr Storm Duration

Chainage [m]	Water Level	Chainage [m]	Discharge	Chainage [m]	Velocity [m/s]	Chainage [m]	Velocity [m/s]
BNE 931570.00	36.154	BNE 931575.00	2000	BNE 931570.00	1.462	BNE 1027420.00	1.355
BNE 931580.00	36.149	BNE 932625.00	1985	BNE 931575.00	1.463	BNE 1027680.00	1.261
BNE 933670.00	35.094	BNE 933970.00	1974	BNE 931580.00	1.463	BNE 1027930.00	1.21
BNE 934270.00	34.958	BNE 934445.00	1964	BNE 932625.00	1.466	BNE 1028180.00	1.163
BNE 934620.00	34.773	BNE 935345.00	1954	BNE 933670.00	1.472	BNE 1028430.00	1.286
BNE 936070.00	34.525	BNE 936445.00	1922	BNE 933970.00	1.032	BNE 1028680.00	1.44
BNE 936820.00	34.496	BNE 938295.00	1903	BNE 934270.00	1.649	BNE 1028720.00	1.816
BNE 939770.00	34.214	BNE 941045.00	1899	BNE 934445.00	1.891	BNE 1028760.00	1.454
BNE 942320.00	33.125	BNE 942945.00	1899	BNE 934620.00	2.524	BNE 1028980.00	1.516
BNE 943570.00	32.702	BNE 943845.00	1899	BNE 935345.00	0.801	BNE 1029200.00	1.584
BNE 944120.00	32.488	BNE 944845.00	1898	BNE 936070.00	0.516	BNE 1029440.00	1.476
BNE 945570.00	31.992	BNE 946370.00	1898	BNE 936445.00	0.495	BNE 1029680.00	1.382
BNE 947170.00	31.488	BNE 947720.00	1898	BNE 936820.00	3.612	BNE 1029950.00	1.361
BNE 948270.00	31.04	BNE 949270.00	1898	BNE 938295.00	0.664	BNE 1030220.00	1.34
BNE 950270.00	30.454	BNE 951295.00	1897	BNE 939770.00	1.409	BNE 1030545.00	1.337
BNE 952320.00	29.85	BNE 953095.00	1897	BNE 941045.00	1.186	BNE 1030870.00	1.334
BNE 953870.00	29.444	BNE 954395.00	1897	BNE 942320.00	1.298	BNE 1031065.00	1.397
BNE 954920.00	29.058	BNE 955445.00	1897	BNE 942945.00	1.004	BNE 1031260.00	1.467
BNE 955970.00	28.544	BNE 957370.00	1896	BNE 943570.00	0.816	BNE 1031480.00	1.562
BNE 958770.00	27.377	BNE 959470.00	1896	BNE 943845.00	0.944	BNE 1031700.00	1.669
BNE 960170.00	26.944	BNE 961120.00	1896	BNE 944120.00	1.141	BNE 1031847.50	1.464
BNE 962070.00	25.979	BNE 963120.00	1895	BNE 944845.00	0.92	BNE 1031995.00	1.303
BNE 964170.00	24.494	BNE 965390.00	1895	BNE 945570.00	1.286	BNE 1032112.50	1.273
BNE 966610.00	22.823	BNE 967010.00	1894	BNE 946370.00	0.995	BNE 1032230.00	1.245
BNE 967410.00	22.449	BNE 968600.00	1894	BNE 947170.00	1.15	BNE 1032407.50	1.279
BNE 969790.00	21.635	BNE 970475.00	1894	BNE 947720.00	1.187	BNE 1032585.00	1.315
BNE 971160.00	21.278	BNE 971710.00	1893	BNE 948270.00	1.228	BNE 1032832.50	1.295
BNE 972260.00	21.059	BNE 972760.00	1893	BNE 949270.00	0.99	BNE 1033080.00	1.276
BNE 973260.00	21.017	BNE 973920.00	1893	BNE 950270.00	0.829	BNE 1033225.00	1.315
BNE 974580.00	20.918	BNE 975300.00	1893	BNE 951295.00	0.978	BNE 1033370.00	1.357
BNE 976020.00	20.834	BNE 976385.00	1892	BNE 952320.00	1.191	BNE 1033635.00	1.394
BNE 976750.00	20.749	BNE 977515.00	1892	BNE 953095.00	1.001	BNE 1033900.00	1.434
BNE 978280.00	19.79	BNE 978893.50	1892	BNE 953870.00	0.862	BNE 1034135.00	1.435
BNE 979507.00	17.837	BNE 979510.00	1914	BNE 954395.00	1.001	BNE 1034370.00	1.437
BNE 979513.00	17.807	BNE 979521.50	1912	BNE 954920.00	1.492	BNE 1034630.00	1.378
BNE 979530.00	17.777	BNE 979930.00	1894	BNE 955445.00	1.241	BNE 1034890.00	1.324
BNE 980330.00	17.485	BNE 980995.00	1891	BNE 955970.00	1.291	BNE 1035152.00	1.359
BNE 981660.00	17.111	BNE 982060.00	1891	BNE 957370.00	1.206	BNE 1035414.00	1.396
BNE 982460.00	16.953	BNE 983310.00	1890	BNE 958770.00	1.134	BNE 1035657.00	1.432
BNE 984160.00	16.559	BNE 984710.00	1890	BNE 959470.00	0.917	BNE 1035900.00	1.47
BNE 985260.00	16.167	BNE 985870.00	1890	BNE 960170.00	0.785	BNE 1036180.00	1.444
BNE 986480.00	15.533	BNE 987220.00	1890	BNE 961120.00	1.01	BNE 1036460.00	1.419
BNE 987960.00	14.619	BNE 988060.00	1890	BNE 962070.00	1.483	BNE 1036615.00	1.375
BNE 988160.00	14.355	BNE 988165.00	1890	BNE 963120.00	1.159	BNE 1036770.00	1.333
BNE 988170.00	14.315	BNE 988265.00	1890	BNE 964170.00	0.996	BNE 1036842.50	1.333
BNE 988360.00	14.057	BNE 989030.00	1890	BNE 965390.00	1.146	BNE 1036915.00	1.334
BNE 989700.00	13.047	BNE 990200.00	1889	BNE 966610.00	1.466	BNE 1037002.50	1.255
BNE 990700.00	12.692	BNE 990730.00	1889	BNE 967010.00	1.185	BNE 1037090.00	1.184
BNE 990760.00	12.664	BNE 991235.00	1889	BNE 967410.00	0.995	BNE 1037110.00	1.502
BNE 991710.00	12.393	BNE 992065.00	1889	BNE 968600.00	1.102	BNE 1037175.00	1.188
BNE 992420.00	12.201	BNE 992435.00	1889	BNE 969790.00	1.235	BNE 1037230.00	1.271
BNE 992450.00	12.175	BNE 992460.00	1889	BNE 970475.00	1.217	BNE 1037285.00	1.365
BNE 992470.00	12.163	BNE 992570.00	1889	BNE 971160.00	1.2	BNE 1037455.00	1.303
BNE 992670.00	12.07	BNE 993215.00	1888	BNE 971710.00	1.182	BNE 1037625.00	1.246
BNE 993760.00	11.491	BNE 994260.00	1888	BNE 972260.00	1.819	BNE 1037855.00	1.153
BNE 994760.00	11.023	BNE 995225.00	1888	BNE 972760.00	0.904	BNE 1038085.00	1.072
BNE 995690.00	10.459	BNE 996335.00	1888	BNE 973260.00	0.738	BNE 1038342.50	1.149
BNE 996980.00	9.619	BNE 997720.00	1887	BNE 973920.00	0.942	BNE 1038600.00	1.236
BNE 998460.00	9.407	BNE 998810.00	1887	BNE 974580.00	1.301	BNE 1038850.00	1.237
BNE 999160.00	9.348	BNE 999580.00	1887	BNE 975300.00	1.159	BNE 1039100.00	1.238
BNE 1000000.00	9.268	BNE 1000142.50	1887	BNE 976020.00	1.045	BNE 1039150.00	1.222
BNE 1000285.00	9.203	BNE 1000530.00	1887	BNE 976385.00	0.911	BNE 1039200.00	1.207
BNE 1000775.00	9.114	BNE 1001045.00	1887	BNE 976750.00	1.034	BNE 1039200.00	1.207
BNE 1001315.00	9.049	BNE 1001590.00	1886	BNE 977515.00	0.979	BNE 1039382.50	1.157
BNE 1001865.00	8.949	BNE 1002107.50	1886	BNE 978280.00	1.242	BNE 1039565.00	1.111
BNE 1002350.00	8.872	BNE 1002567.50	1886	BNE 978893.50	1.187	BNE 1039617.50	1.083
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BNE 1004300.00	8.629	BNE 1004555.00	1886	BNE 979521.50	1.252	BNE 1039828.00	0.995
BNE 1004810.00	8.587	BNE 1005067.50	1886	BNE 979530.00	1.314	BNE 1039828.00	0.989
BNE 1005325.00	8.526	BNE 1005597.50	1885	BNE 979930.00	1.249	BNE 1039959.00	0.96
BNE 1005870.00	8.449	BNE 1006035.00	1885	BNE 980330.00	1.251	BNE 1040090.00	0.933
BNE 1005870.00	8.449	BNE 1006250.00	2935	BNE 980995.00	1.187	BNE 1040170.00	0.983
BNE 1006200.00	8.42	BNE 1006605.00	2934	BNE 981660.00	1.175	BNE 1040250.00	1.039
BNE 1006200.00	8.42	BNE 1007160.00	2930	BNE 982060.00	1.152	BNE 1040250.00	1.039
BNE 1006300.00	8.395	BNE 1007595.00	2926	BNE 982460.00	1.13	BNE 1040370.00	1.129
BNE 1006300.00	8.395	BNE 1007850.00	2923	BNE 983310.00	1.087	BNE 1040490.00	1.237
BNE 1006910.00	8.206	BNE 1008182.50	2922	BNE 984160.00	1.047	BNE 1040750.00	1.108
BNE 1007410.00	8.094	BNE 1008685.00	2920	BNE 984710.00	1.099	BNE 1041010.00	1.003
BNE 1007780.00	7.96	BNE 1009162.50	2918	BNE 985260.00	1.157	BNE 1041120.00	1.015
BNE 1007780.00	7.96	BNE 1009560.00	2916	BNE 985870.00	1.206	BNE 1041230.00	1.027
BNE 1007920.00	7.899	BNE 1010105.00	2914	BNE 986480.00	1.26	BNE 1041345.00	1.043
BNE 1008445.00	7.888	BNE 1010607.50	2912	BNE 987220.00	1.116	BNE 1041460.00	1.06
BNE 1008925.00	7.841	BNE 1010852.50	2911	BNE 987960.00	1.002	BNE 1041580.00	0.962
BNE 1009400.00	7.752	BNE 1011245.00	2909	BNE 988060.00	1.225	BNE 1041700.00	0.88
BNE 1009720.00	7.684	BNE 1011745.00	2907	BNE 988160.00	1.577	BNE 1041830.00	1.016
BNE 1010490.00	7.541	BNE 1012227.50	2904	BNE 988165.00	3.452	BNE 1041960.00	1.2
BNE 1010725.00	7.559	BNE 1012705.00	2899	BNE 988170.00	1.585	BNE 1042097.50	1.232
BNE 1010980.00	7.537	BNE 1013062.50	2897	BNE 988265.00	1.307	BNE 1042235.00	1.266
BNE 1011510.00	7.529	BNE 1013317.50	2896	BNE 988360.00	1.112	BNE 1042367.50	1.188
BNE 1011980.00	7.52	BNE 1013562.50	2895	BNE 989030.00	1.047	BNE 1042500.00	1.119
BNE 1012475.00	7.504	BNE 1013795.00	2894	BNE 989700.00	0.989	BNE 1042500.00	1.119

BNE 1012475.00	7.504	BNE 1014110.00	2891	BNE 990200.00	1.07	BNE 1042507.50	1.115
BNE 1012935.00	7.481	BNE 1014460.00	2889	BNE 990700.00	1.166	BNE 1042515.00	1.111
BNE 1013190.00	7.471	BNE 1014850.00	2885	BNE 990730.00	1.19	BNE 1042712.50	1.172
BNE 1013190.00	7.471	BNE 1015325.00	2884	BNE 990760.00	1.216	BNE 1042910.00	1.24
BNE 1013445.00	7.458	BNE 1015705.00	2883	BNE 991235.00	0.879	BNE 1042960.00	1.242
BNE 1013680.00	7.445	BNE 1015995.00	2882	BNE 991710.00	0.688	BNE 1043010.00	1.244
BNE 1013680.00	7.445	BNE 1016390.00	2882	BNE 992065.00	0.714	BNE 1043010.00	1.244
BNE 1013910.00	7.425	BNE 1016765.00	2880	BNE 992420.00	0.743	BNE 1043045.00	1.245
BNE 1014310.00	7.351	BNE 1017010.00	2879	BNE 992435.00	0.816	BNE 1043080.00	1.246
BNE 1014610.00	7.225	BNE 1017370.00	2878	BNE 992450.00	0.907	BNE 1043095.00	1.242
BNE 1014610.00	7.225	BNE 1017765.00	2877	BNE 992460.00	1.029	BNE 1043110.00	1.238
BNE 1015090.00	7.142	BNE 1018060.00	2876	BNE 992470.00	0.908	BNE 1043110.00	1.238
BNE 1015560.00	7.058	BNE 1018462.50	2875	BNE 992570.00	0.991	BNE 1043417.50	1.151
BNE 1015850.00	7.012	BNE 1018910.00	2875	BNE 992670.00	1.09	BNE 1043725.00	1.075
BNE 1015850.00	7.012	BNE 1019292.50	2875	BNE 993215.00	1.256	BNE 1043892.50	1.044
BNE 1016140.00	6.967	BNE 1019677.50	2874	BNE 993760.00	1.482	BNE 1044060.00	1.014
BNE 1016640.00	6.81	BNE 1019990.00	2874	BNE 994260.00	1.214	BNE 1044200.00	1.077
BNE 1016890.00	6.697	BNE 1020320.00	2873	BNE 994760.00	1.028	BNE 1044340.00	1.149
BNE 1016890.00	6.697	BNE 1020677.50	2871	BNE 995225.00	1.136	BNE 1044472.50	1.098
BNE 1017130.00	6.585	BNE 1020962.50	2870	BNE 995690.00	1.269	BNE 1044605.00	1.052
BNE 1017610.00	6.468	BNE 1021317.00	2870	BNE 996335.00	1.333	BNE 1044732.50	1.015
BNE 1017920.00	6.378	BNE 1021627.00	2869	BNE 996980.00	1.403	BNE 1044860.00	0.981
BNE 1018200.00	6.37	BNE 1021805.00	2869	BNE 997720.00	0.974	BNE 1045130.00	0.981
BNE 1018725.00	6.257	BNE 1022000.00	2868	BNE 998460.00	0.745	BNE 1045400.00	0.98
BNE 1019095.00	6.195	BNE 1022340.00	2868	BNE 998810.00	0.991	BNE 1045642.50	1.009
BNE 1019490.00	6.151	BNE 1022807.50	2873	BNE 999160.00	1.478	BNE 1045885.00	1.04
BNE 1019490.00	6.151	BNE 1023305.00	2873	BNE 999580.00	1.2	BNE 1046032.50	0.886
BNE 1019865.00	6.053	BNE 1023825.00	2872	BNE 1000000.00	1.01	BNE 1046180.00	0.771
BNE 1020115.00	6.049	BNE 1024321.50	2872	BNE 1000142.50	1.145	BNE 1046260.00	0.781
BNE 1020525.00	6.01	BNE 1024816.50	2871	BNE 1000285.00	1.323	BNE 1046340.00	0.791
BNE 1020830.00	5.948	BNE 1025215.00	2870	BNE 1000530.00	1.328	BNE 1046460.00	0.813
BNE 1021095.00	5.852	BNE 1025475.00	2870	BNE 1000775.00	1.334	BNE 1046580.00	0.837
BNE 1021539.00	5.701	BNE 1025880.00	2869	BNE 1001045.00	1.27	BNE 1046740.00	0.957
BNE 1021715.00	5.666	BNE 1026425.00	2868	BNE 1001315.00	1.212	BNE 1046900.00	1.117
BNE 1021895.00	5.61	BNE 1026790.00	2868	BNE 1001590.00	1.409	BNE 1047125.00	1.181
BNE 1022105.00	5.551	BNE 1027030.00	2867	BNE 1001865.00	1.683	BNE 1047350.00	1.252
BNE 1022575.00	5.457	BNE 1027420.00	2867	BNE 1002107.50	1.685	BNE 1047632.50	1.201
BNE 1023040.00	5.346	BNE 1027930.00	2866	BNE 1002350.00	1.688	BNE 1047915.00	1.155
BNE 1023570.00	5.309	BNE 1028430.00	2864	BNE 1002567.50	1.425	BNE 1048145.00	1.01
BNE 1024080.00	5.26	BNE 1028720.00	2864	BNE 1002785.00	1.233	BNE 1048375.00	0.897
BNE 1024563.00	5.216	BNE 1028980.00	2864	BNE 1003030.00	1.357	BNE 1048632.50	1.055
BNE 1025070.00	5.189	BNE 1029440.00	2863	BNE 1003275.00	1.51	BNE 1048890.00	1.279
BNE 1025360.00	5.142	BNE 1029950.00	2862	BNE 1003525.00	1.423	BNE 1049005.00	1.179
BNE 1025590.00	5.076	BNE 1030545.00	2861	BNE 1003775.00	1.346	BNE 1049120.00	1.093
BNE 1026170.00	4.967	BNE 1031065.00	2860	BNE 1004037.50	1.484	BNE 1049245.00	1.166
BNE 1026680.00	4.878	BNE 1031480.00	2860	BNE 1004300.00	1.654	BNE 1049370.00	1.248
BNE 1026900.00	4.824	BNE 1031847.50	2859	BNE 1004555.00	1.343	BNE 1049480.00	1.193
BNE 1027160.00	4.772	BNE 1032112.50	2859	BNE 1004810.00	1.131	BNE 1049590.00	1.142
BNE 1027680.00	4.735	BNE 1032407.50	2858	BNE 1005067.50	1.195	BNE 1049730.00	1.19
BNE 1028180.00	4.716	BNE 1032832.50	2858	BNE 1005325.00	1.266	BNE 1049870.00	1.243
BNE 1028680.00	4.644	BNE 1033225.00	2857	BNE 1005597.50	1.35	BNE 1050150.00	1.224
BNE 1028760.00	4.567	BNE 1033635.00	2857	BNE 1005870.00	1.446	BNE 1050430.00	1.205
BNE 1029200.00	4.503	BNE 1034135.00	2856	BNE 1005870.00	1.446	BNE 1050645.00	1.237
BNE 1029680.00	4.493	BNE 1034630.00	2856	BNE 1006035.00	1.292	BNE 1050860.00	1.271
BNE 1030220.00	4.476	BNE 1035152.00	2855	BNE 1006200.00	1.168	BNE 1051110.00	1.176
BNE 1030870.00	4.444	BNE 1035657.00	2854	BNE 1006200.00	1.484	BNE 1051360.00	1.094
BNE 1031260.00	4.397	BNE 1036180.00	2854	BNE 1006250.00	1.45	BNE 1051627.50	1.245
BNE 1031700.00	4.319	BNE 1036615.00	2853	BNE 1006300.00	1.418	BNE 1051895.00	1.443
BNE 1031995.00	4.305	BNE 1036842.50	2853	BNE 1006300.00	1.418	BNE 1052102.50	1.24
BNE 1032230.00	4.242	BNE 1037002.50	2853	BNE 1006605.00	1.43	BNE 1052310.00	1.087
BNE 1032585.00	4.133	BNE 1037110.00	2853	BNE 1006910.00	1.441	BNE 1052370.00	1.79
BNE 1033080.00	4.056	BNE 1037230.00	2853	BNE 1007160.00	1.368	BNE 1052390.00	1.271
BNE 1033370.00	4.015	BNE 1037455.00	2853	BNE 1007410.00	1.301	BNE 1052492.50	1.282
BNE 1033900.00	3.925	BNE 1037855.00	2852	BNE 1007595.00	1.448	BNE 1052595.00	1.292
BNE 1034370.00	3.842	BNE 1038342.50	2851	BNE 1007780.00	1.633	BNE 1052625.00	1.613
BNE 1034890.00	3.787	BNE 1038850.00	2850	BNE 1007780.00	1.631	BNE 1052640.00	1.121
BNE 1035414.00	3.717	BNE 1039150.00	2850	BNE 1007850.00	1.717	BNE 1052752.50	1.143
BNE 1035900.00	3.63	BNE 1039382.50	2849	BNE 1007920.00	1.814	BNE 1052865.00	1.165
BNE 1036460.00	3.524	BNE 1039617.50	2848	BNE 1008182.50	1.583	BNE 1053092.50	1.098
BNE 1036770.00	3.459	BNE 1039749.00	2848	BNE 1008445.00	1.405	BNE 1053320.00	1.038
BNE 1036915.00	3.438	BNE 1039959.00	2835	BNE 1008685.00	1.413	BNE 1053355.00	1.364
BNE 1037090.00	3.45	BNE 1040170.00	2834	BNE 1008925.00	1.421	BNE 1053385.00	1.255
BNE 1037175.00	3.322	BNE 1040370.00	2834	BNE 1009162.50	1.419	BNE 1053642.50	1.228
BNE 1037285.00	3.296	BNE 1040750.00	2834	BNE 1009400.00	1.417	BNE 1053900.00	1.203
BNE 1037625.00	3.279	BNE 1041120.00	2834	BNE 1009560.00	1.399	BNE 1054270.00	0.841
BNE 1038085.00	3.264	BNE 1041345.00	2834	BNE 1009720.00	1.382	BNE 1054640.00	0.647
BNE 1038600.00	3.22	BNE 1041580.00	2834	BNE 1010105.00	1.515	BNE 1054660.00	0.983
BNE 1039100.00	3.187	BNE 1041830.00	2834	BNE 1010490.00	1.676	BNE 1054680.00	0.612
BNE 1039200.00	3.187	BNE 1042097.50	2834	BNE 1010607.50	1.548	BNE 1054825.00	0.784
BNE 1039200.00	3.187	BNE 1042367.50	2834	BNE 1010725.00	1.437	BNE 1054970.00	1.093
BNE 1039565.00	3.186	BNE 1042507.50	2834	BNE 1010852.50	1.463	BNE 1055125.00	1.076
BNE 1039670.00	3.189	BNE 1042712.50	2834	BNE 1010980.00	1.49	BNE 1055280.00	1.06
BNE 1039670.00	3.189	BNE 1042960.00	2833	BNE 1011245.00	1.432	BNE 1055350.00	1.07
BNE 1039828.00	3.192	BNE 1043045.00	2833	BNE 1011510.00	1.377	BNE 1055420.00	1.081
BNE 1039828.00	3.192	BNE 1043095.00	2833	BNE 1011745.00	1.358	BNE 1055690.00	1.026
BNE 1040090.00	3.193	BNE 1043417.50	2833	BNE 1011980.00	1.338	BNE 1055960.00	0.976
BNE 1040250.00	3.18	BNE 1043892.50	2833	BNE 1012227.50	1.324	BNE 1056180.00	1.094
BNE 1040250.00	3.18	BNE 1044200.00	2833	BNE 1012475.00	1.309	BNE 1056400.00	1.243
BNE 1040490.00	3.152	BNE 1044472.50	2833	BNE 1012475.00	1.307	BNE 1056547.50	1.179
BNE 1041010.00	3.159	BNE 1044732.50	2833	BNE 1012705.00	1.313	BNE 1056695.00	1.121
BNE 1041230.00	3.141	BNE 1045130.00	2833	BNE 1012935.00	1.32	BNE 1056780.00	0.432
BNE 1041460.00	3.117	BNE 1045642.50	2833	BNE 1013062.50	1.307	BNE 1056865.00	0.268
BNE 1041700.00	3.121	BNE 1046032.50	2833	BNE 1013190.00	1.293	BNE 1056920.00	1.264
BNE 1041960.00	3.071	BNE 1046260.00	2833	BNE 1013190.00	1.293	BNE 1056950.00	0.277
BNE 1042235.00	3.015	BNE 1046460.00	2833	BNE 1013317.50	1.282	BNE 1057020.00	0.413
BNE 1042500.00	2.989	BNE 1046740.00	2833	BNE 1013445.00	1.271	BNE 1057090.00	0.816
BNE 1042500.00	2.989	BNE 1047125.00	2833	BNE 1013562.50	1.252	BNE 1057310.00	0.883
BNE 1042515.00	2.987	BNE 1047632.50	2833	BNE 1013680.00	1.232	BNE 1057530.00	0.961
BNE 1042910.00	2.896	BNE 1048145.00	2833	BNE 1013680.00	1.232	BNE 1057785.00	1.058

BNE 1043010.00	2.868			BNE 1048632.50	2833		BNE 1013795.00	1.223		BNE 1058040.00	1.177
BNE 1043010.00	2.868			BNE 1049005.00	2833		BNE 1013910.00	1.214		BNE 1058135.00	1.175
BNE 1043080.00	2.848			BNE 1049245.00	2833		BNE 1014110.00	1.235		BNE 1058230.00	1.173
BNE 1043110.00	2.841			BNE 1049480.00	2833		BNE 1014310.00	1.257		BNE 1058380.00	1.156
BNE 1043110.00	2.841			BNE 1049730.00	2833		BNE 1014460.00	1.27		BNE 1058530.00	1.14
BNE 1043725.00	2.73			BNE 1050150.00	2833		BNE 1014610.00	1.282		BNE 1058632.50	1.082
BNE 1044060.00	2.697			BNE 1050645.00	2833		BNE 1014610.00	1.28		BNE 1058735.00	1.029
BNE 1044340.00	2.657			BNE 1051110.00	2833		BNE 1014850.00	1.118		BNE 1058885.00	1.095
BNE 1044605.00	2.641			BNE 1051627.50	2833		BNE 1015090.00	0.994		BNE 1059035.00	1.171
BNE 1044860.00	2.627			BNE 1052102.50	2833		BNE 1015325.00	1.119		BNE 1059287.50	1.025
BNE 1045400.00	2.593			BNE 1052370.00	2833		BNE 1015560.00	1.281		BNE 1059540.00	0.912
BNE 1045885.00	2.564			BNE 1052492.50	2833		BNE 1015705.00	1.266		BNE 1059765.00	0.926
BNE 1046180.00	2.581			BNE 1052625.00	2833		BNE 1015850.00	1.251		BNE 1059990.00	0.941
BNE 1046340.00	2.576			BNE 1052752.50	2833		BNE 1015850.00	1.251		BNE 1060167.50	0.981
BNE 1046580.00	2.559			BNE 1053092.50	2833		BNE 1015995.00	1.235		BNE 1060345.00	1.026
BNE 1046900.00	2.476			BNE 1053355.00	2833		BNE 1016140.00	1.219		BNE 1060440.00	1.067
BNE 1047350.00	2.321			BNE 1053642.50	2833		BNE 1016390.00	1.33		BNE 1060535.00	1.111
BNE 1047915.00	2.228			BNE 1054270.00	2833		BNE 1016640.00	1.465		BNE 1060775.00	1.064
BNE 1048375.00	2.227			BNE 1054660.00	2833		BNE 1016765.00	1.502		BNE 1061015.00	1.021
BNE 1048890.00	2.149			BNE 1054825.00	2833		BNE 1016890.00	1.541		BNE 1061272.50	1.048
BNE 1049120.00	2.142			BNE 1055125.00	2833		BNE 1016890.00	1.541		BNE 1061530.00	1.076
BNE 1049370.00	2.097			BNE 1055350.00	2834		BNE 1017010.00	1.6		BNE 1061775.00	1.02
BNE 1049590.00	2.088			BNE 1055690.00	2834		BNE 1017130.00	1.664		BNE 1062020.00	0.97
BNE 1049870.00	2.049			BNE 1056180.00	2834		BNE 1017370.00	1.574		BNE 1062277.50	0.906
BNE 1050430.00	1.999			BNE 1056547.50	2834		BNE 1017610.00	1.493		BNE 1062535.00	0.851
BNE 1050860.00	1.966			BNE 1056780.00	2834		BNE 1017765.00	1.545		BNE 1062737.50	0.765
BNE 1051360.00	1.971			BNE 1056920.00	2834		BNE 1017920.00	1.599		BNE 1062940.00	0.695
BNE 1051895.00	1.914			BNE 1057020.00	2834		BNE 1018060.00	1.402		BNE 1063032.50	0.704
BNE 1052310.00	1.952			BNE 1057310.00	2834		BNE 1018200.00	1.248		BNE 1063125.00	0.713
BNE 1052390.00	1.912			BNE 1057785.00	2834		BNE 1018462.50	1.325		BNE 1063125.00	0.713
BNE 1052595.00	1.908			BNE 1058135.00	2834		BNE 1018725.00	1.413		BNE 1063217.50	0.729
BNE 1052640.00	1.853			BNE 1058380.00	2834		BNE 1018910.00	1.396		BNE 1063310.00	0.745
BNE 1052865.00	1.846			BNE 1058632.50	2834		BNE 1019095.00	1.38		BNE 1063477.50	0.863
BNE 1053320.00	1.853			BNE 1058885.00	2834		BNE 1019292.50	1.291		BNE 1063645.00	1.023
BNE 1053385.00	1.789			BNE 1059287.50	2834		BNE 1019490.00	1.213		BNE 1063822.50	0.99
BNE 1053900.00	1.711			BNE 1059765.00	2834		BNE 1019490.00	1.213		BNE 1064000.00	0.958
BNE 1054640.00	1.681			BNE 1060167.50	2834		BNE 1019677.50	1.312		BNE 1064245.00	0.969
BNE 1054680.00	1.664			BNE 1060440.00	2834		BNE 1019865.00	1.428		BNE 1064490.00	0.98
BNE 1054970.00	1.607			BNE 1060775.00	2834		BNE 1019990.00	1.219		BNE 1064750.00	0.867
BNE 1055280.00	1.579			BNE 1061272.50	2834		BNE 1020115.00	1.063		BNE 1065010.00	0.777
BNE 1055420.00	1.561			BNE 1061775.00	2834		BNE 1020320.00	0.896		BNE 1065256.50	0.744
BNE 1055960.00	1.529			BNE 1062277.50	2834		BNE 1020525.00	0.775		BNE 1065503.00	0.714
BNE 1056400.00	1.471			BNE 1062737.50	2834		BNE 1020677.50	0.88		BNE 1065746.50	0.625
BNE 1056695.00	1.459			BNE 1063032.50	2834		BNE 1020830.00	1.018		BNE 1065990.00	0.555
BNE 1056865.00	1.493			BNE 1063217.50	2834		BNE 1020962.50	1.167		BNE 1066247.50	0.596
BNE 1056950.00	1.474			BNE 1063477.50	2834		BNE 1021095.00	1.366		BNE 1066505.00	0.644
BNE 1057090.00	1.451			BNE 1063822.50	2834		BNE 1021317.00	1.349		BNE 1066762.50	0.628
BNE 1057530.00	1.428			BNE 1064245.00	2835		BNE 1021539.00	1.332		BNE 1067020.00	0.613
BNE 1058040.00	1.375			BNE 1064750.00	2835		BNE 1021627.00	1.236		BNE 1067252.50	0.67
BNE 1058230.00	1.362			BNE 1065256.50	2835		BNE 1021715.00	1.153		BNE 1067485.00	0.738
BNE 1058530.00	1.348			BNE 1065746.50	2835		BNE 1021805.00	1.15		BNE 1067725.00	0.761
BNE 1058735.00	1.349			BNE 1066247.50	2835		BNE 1021895.00	1.146		BNE 1067965.00	0.786
BNE 1059035.00	1.311			BNE 1066762.50	2835		BNE 1022000.00	1.17		BNE 1068312.50	0.814
BNE 1059540.00	1.292			BNE 1067252.50	2835		BNE 1022105.00	1.194		BNE 1068660.00	0.844
BNE 1059990.00	1.241			BNE 1067725.00	2835		BNE 1022340.00	1.232		BNE 1068852.50	0.832
BNE 1060345.00	1.2			BNE 1068312.50	2835		BNE 1022575.00	1.274		BNE 1069045.00	0.821
BNE 1060535.00	1.188			BNE 1068852.50	2835		BNE 1022807.50	1.418		BNE 1069290.00	0.787
BNE 1061015.00	1.182			BNE 1069290.00	2835		BNE 1023040.00	1.596		BNE 1069535.00	0.756
BNE 1061530.00	1.17			BNE 1069780.00	2835		BNE 1023305.00	1.534		BNE 1069780.00	0.731
BNE 1062020.00	1.167			BNE 1070277.50	2836		BNE 1023570.00	1.477		BNE 1070025.00	0.707
BNE 1062535.00	1.166			BNE 1070785.00	2836		BNE 1023825.00	1.455		BNE 1070277.50	0.716
BNE 1062940.00	1.168			BNE 1071280.00	2836		BNE 1024080.00	1.433		BNE 1070530.00	0.724
BNE 1063125.00	1.177			BNE 1071767.50	2836		BNE 1024321.50	1.401		BNE 1070785.00	0.713
BNE 1063125.00	1.177			BNE 1072017.50	2836		BNE 1024563.00	1.37		BNE 1071040.00	0.702
BNE 1063310.00	1.156			BNE 1072267.50	3030		BNE 1024816.50	1.296		BNE 1071280.00	0.592
BNE 1063645.00	1.127			BNE 1072755.00	3040		BNE 1025070.00	1.23		BNE 1071520.00	0.511
BNE 1064000.00	1.128			BNE 1073240.00	3050		BNE 1025215.00	1.308		BNE 1071767.50	0.57
BNE 1064490.00	1.114			BNE 1073742.50	3060		BNE 1025360.00	1.397		BNE 1072015.00	0.644
BNE 1065010.00	1.116			BNE 1074230.00	3068		BNE 1025475.00	1.49		BNE 1072017.50	0.644
BNE 1065503.00	1.11			BNE 1074722.50	3073		BNE 1025590.00	1.596		BNE 1072020.00	0.644
BNE 1065990.00	1.112			BNE 1075232.50	3076		BNE 1025880.00	1.493		BNE 1072020.00	0.686
BNE 1066505.00	1.102			BNE 1075740.00	3076		BNE 1026170.00	1.402		BNE 1072267.50	0.673
BNE 1067020.00	1.098			BNE 1076247.50	3073		BNE 1026425.00	1.38		BNE 1072515.00	0.659
BNE 1067485.00	1.084			BNE 1076752.50	3069		BNE 1026680.00	1.359		BNE 1072755.00	0.643
BNE 1067965.00	1.072			BNE 1077260.00	3063		BNE 1026790.00	1.402		BNE 1072995.00	0.626
BNE 1068660.00	1.054			BNE 1077775.00	3060		BNE 1026900.00	1.448		BNE 1073240.00	0.659
BNE 1069045.00	1.046			BNE 1078282.50	3058		BNE 1027030.00	1.456		BNE 1073485.00	0.694
BNE 1069535.00	1.039			BNE 1078592.50	3058		BNE 1027160.00	1.464		BNE 1073742.50	0.684
BNE 1070025.00	1.031									BNE 1074000.00	0.674
BNE 1070530.00	1.018									BNE 1074230.00	0.67
BNE 1071040.00	1.007									BNE 1074460.00	0.665
BNE 1071520.00	1.009									BNE 1074722.50	0.7
BNE 1072015.00	0.994									BNE 1074985.00	0.738
BNE 1072020.00	0.994									BNE 1075232.50	0.67
BNE 1072020.00	0.994									BNE 1075480.00	0.613
BNE 1072515.00	0.989									BNE 1075740.00	0.514
BNE 1072995.00	1.005									BNE 1076000.00	0.443
BNE 1073485.00	1.019									BNE 1076247.50	0.501
BNE 1074000.00	1.038									BNE 1076495.00	0.578
BNE 1074460.00	1.053									BNE 1076752.50	0.475
BNE 1074985.00	1.066									BNE 1077010.00	0.404
BNE 1075480.00	1.079									BNE 1077260.00	0.346
BNE 1076000.00	1.081									BNE 1077510.00	0.303
BNE 1076495.00	1.065									BNE 1077775.00	0.311
BNE 1077010.00	1.041									BNE 1078040.00	0.32
BNE 1077510.00	1.009									BNE 1078282.50	0.384
BNE 1078040.00	0.97									BNE 1078525.00	0.482
BNE 1078525.00	0.92									BNE 1078592.50	0.107
BNE 1078660.00	0.918									BNE 1078660.00	0.06

Appendix B Mike11 Results Q20

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q20 event CRCFORGE rainfall with ARF's

30hr Storm Duration

Chainage [m]	Water Level	Chainage [m]	Discharge	Chainage [m]	Velocity [m/s]	Chainage [m]	Velocity [m/s]
BNE 931570.00	36.092	BNE 931575.00	1900	BNE 931570.00	1.43	BNE 1031995.00	1.466
BNE 931580.00	36.086	BNE 932625.00	1900	BNE 931575.00	1.431	BNE 1032112.50	1.434
BNE 933670.00	35.012	BNE 933970.00	1899	BNE 931580.00	1.43	BNE 1032230.00	1.403
BNE 934270.00	34.872	BNE 934445.00	1898	BNE 932625.00	1.434	BNE 1032407.50	1.453
BNE 934620.00	34.682	BNE 935345.00	1897	BNE 933670.00	1.443	BNE 1032585.00	1.507
BNE 936070.00	34.425	BNE 936445.00	1892	BNE 933970.00	1.036	BNE 1032832.50	1.485
BNE 936820.00	34.396	BNE 938295.00	1888	BNE 934270.00	1.587	BNE 1033080.00	1.463
BNE 939770.00	34.112	BNE 941045.00	1884	BNE 934445.00	1.981	BNE 1033225.00	1.501
BNE 942320.00	33.011	BNE 942945.00	1882	BNE 934620.00	2.748	BNE 1033370.00	1.54
BNE 943570.00	32.583	BNE 943845.00	1879	BNE 935345.00	1.021	BNE 1033635.00	1.588
BNE 944120.00	32.358	BNE 944845.00	1875	BNE 936070.00	0.512	BNE 1033900.00	1.639
BNE 945570.00	31.847	BNE 946370.00	1870	BNE 936445.00	0.491	BNE 1034135.00	1.643
BNE 947170.00	31.331	BNE 947720.00	1867	BNE 936820.00	1.532	BNE 1034370.00	1.646
BNE 948270.00	30.878	BNE 949270.00	1863	BNE 938295.00	0.656	BNE 1034630.00	1.581
BNE 950270.00	30.291	BNE 951295.00	1859	BNE 939770.00	1.551	BNE 1034890.00	1.521
BNE 952320.00	29.686	BNE 953095.00	1858	BNE 941045.00	1.172	BNE 1035152.00	1.554
BNE 953870.00	29.278	BNE 954395.00	1855	BNE 942320.00	1.282	BNE 1035414.00	1.589
BNE 954920.00	28.889	BNE 955445.00	1853	BNE 942945.00	0.992	BNE 1035657.00	1.635
BNE 955970.00	28.37	BNE 957370.00	1852	BNE 943570.00	0.883	BNE 1035900.00	1.684
BNE 958770.00	27.199	BNE 959470.00	1849	BNE 943845.00	0.935	BNE 1036180.00	1.655
BNE 960170.00	26.762	BNE 961120.00	1846	BNE 944120.00	1.123	BNE 1036460.00	1.627
BNE 962070.00	25.787	BNE 963120.00	1844	BNE 944845.00	0.973	BNE 1036615.00	1.564
BNE 964170.00	24.273	BNE 965390.00	1839	BNE 945570.00	1.283	BNE 1036770.00	1.507
BNE 966610.00	22.579	BNE 967010.00	1837	BNE 946370.00	1.029	BNE 1036842.50	1.525
BNE 967410.00	22.209	BNE 968600.00	1834	BNE 947170.00	1.142	BNE 1036915.00	1.543
BNE 969790.00	21.405	BNE 970475.00	1832	BNE 947720.00	1.181	BNE 1037002.50	1.459
BNE 971160.00	21.052	BNE 971710.00	1831	BNE 948270.00	1.222	BNE 1037090.00	1.384
BNE 972260.00	20.835	BNE 972760.00	1829	BNE 949270.00	0.984	BNE 1037110.00	1.729
BNE 973260.00	20.792	BNE 973920.00	1827	BNE 950270.00	0.828	BNE 1037175.00	1.391
BNE 974580.00	20.696	BNE 975300.00	1826	BNE 951295.00	0.976	BNE 1037230.00	1.478
BNE 976020.00	20.612	BNE 976385.00	1824	BNE 952320.00	1.189	BNE 1037285.00	1.578
BNE 976750.00	20.525	BNE 977515.00	1823	BNE 953095.00	0.997	BNE 1037455.00	1.498
BNE 978280.00	19.563	BNE 978893.50	1823	BNE 953870.00	0.858	BNE 1037625.00	1.426
BNE 979507.00	17.623	BNE 979510.00	1845	BNE 954395.00	0.998	BNE 1037855.00	1.323
BNE 979513.00	17.594	BNE 979521.50	1843	BNE 954920.00	1.435	BNE 1038085.00	1.233
BNE 979530.00	17.561	BNE 979930.00	1822	BNE 955445.00	1.236	BNE 1038342.50	1.305
BNE 980330.00	17.275	BNE 980995.00	1820	BNE 955970.00	1.285	BNE 1038600.00	1.387
BNE 981660.00	16.907	BNE 982060.00	1819	BNE 957370.00	1.202	BNE 1038850.00	1.384
BNE 982460.00	16.754	BNE 983310.00	1819	BNE 958770.00	1.131	BNE 1039100.00	1.381
BNE 984160.00	16.369	BNE 984710.00	1818	BNE 959470.00	0.914	BNE 1039150.00	1.364
BNE 985260.00	15.984	BNE 985870.00	1818	BNE 960170.00	0.793	BNE 1039200.00	1.347
BNE 986480.00	15.366	BNE 987220.00	1818	BNE 961120.00	1.008	BNE 1039200.00	1.347
BNE 987960.00	14.481	BNE 988060.00	1818	BNE 962070.00	1.479	BNE 1039382.50	1.295
BNE 988160.00	14.227	BNE 988165.00	1818	BNE 963120.00	1.169	BNE 1039565.00	1.247
BNE 988170.00	14.188	BNE 988265.00	1818	BNE 964170.00	1.002	BNE 1039617.50	1.219
BNE 988360.00	13.939	BNE 989030.00	1818	BNE 965390.00	1.156	BNE 1039670.00	1.193
BNE 989700.00	12.966	BNE 990200.00	1818	BNE 966610.00	1.459	BNE 1039670.00	1.193
BNE 990700.00	12.738	BNE 990730.00	1818	BNE 967010.00	1.177	BNE 1039749.00	1.162
BNE 990760.00	12.721	BNE 991235.00	1819	BNE 967410.00	0.987	BNE 1039828.00	1.132
BNE 991710.00	12.557	BNE 992065.00	1819	BNE 968600.00	1.092	BNE 1039828.00	1.117
BNE 992420.00	12.444	BNE 992435.00	1820	BNE 969790.00	1.225	BNE 1039959.00	1.091
BNE 992450.00	12.429	BNE 992460.00	1820	BNE 970475.00	1.206	BNE 1040090.00	1.066
BNE 992470.00	12.419	BNE 992570.00	1820	BNE 971160.00	1.189	BNE 1040170.00	1.124
BNE 992670.00	12.365	BNE 993215.00	1821	BNE 971710.00	1.174	BNE 1040250.00	1.188
BNE 993760.00	12.047	BNE 994260.00	1821	BNE 972260.00	1.931	BNE 1040250.00	1.188
BNE 994760.00	11.824	BNE 995225.00	1823	BNE 972760.00	0.908	BNE 1040370.00	1.293
BNE 995690.00	11.569	BNE 996335.00	1825	BNE 973260.00	0.73	BNE 1040490.00	1.418
BNE 996980.00	11.111	BNE 997720.00	1828	BNE 973920.00	0.931	BNE 1040750.00	1.268
BNE 998460.00	10.919	BNE 998810.00	1833	BNE 974580.00	1.285	BNE 1041010.00	1.147
BNE 999160.00	10.86	BNE 999580.00	1835	BNE 975300.00	1.144	BNE 1041120.00	1.158
BNE 1000000.00	10.773	BNE 1000142.50	1939	BNE 976020.00	1.03	BNE 1041230.00	1.17
BNE 1000285.00	10.699	BNE 1000530.00	1937	BNE 976385.00	0.907	BNE 1041345.00	1.189
BNE 1000775.00	10.602	BNE 1001045.00	1935	BNE 976750.00	1.023	BNE 1041460.00	1.209
BNE 1001315.00	10.536	BNE 1001590.00	1931	BNE 977515.00	0.973	BNE 1041580.00	1.11
BNE 1001865.00	10.42	BNE 1002107.50	1929	BNE 978280.00	1.222	BNE 1041700.00	1.025
BNE 1002350.00	10.339	BNE 1002567.50	1927	BNE 978893.50	1.173	BNE 1041830.00	1.178
BNE 1002785.00	10.32	BNE 1003030.00	1924	BNE 979507.00	1.138	BNE 1041960.00	1.386
BNE 1003275.00	10.249	BNE 1003525.00	1922	BNE 979510.00	1.355	BNE 1042097.50	1.426
BNE 1003775.00	10.192	BNE 1004037.50	1920	BNE 979513.00	1.178	BNE 1042235.00	1.468
BNE 1004300.00	10.071	BNE 1004555.00	1918	BNE 979521.50	1.24	BNE 1042367.50	1.377
BNE 1004810.00	10.032	BNE 1005067.50	1915	BNE 979530.00	1.309	BNE 1042500.00	1.297
BNE 1005325.00	9.967	BNE 1005597.50	1910	BNE 979930.00	1.236	BNE 1042500.00	1.297
BNE 1005870.00	9.885	BNE 1006035.00	2104	BNE 980330.00	1.305	BNE 1042507.50	1.292
BNE 1005870.00	9.885	BNE 1006250.00	3606	BNE 980995.00	1.167	BNE 1042515.00	1.287
BNE 1006200.00	9.849	BNE 1006605.00	3604	BNE 981660.00	1.151	BNE 1042712.50	1.348
BNE 1006200.00	9.849	BNE 1007160.00	3599	BNE 982060.00	1.128	BNE 1042910.00	1.415
BNE 1006300.00	9.82	BNE 1007595.00	3595	BNE 982460.00	1.107	BNE 1042960.00	1.418
BNE 1006300.00	9.82	BNE 1007850.00	3588	BNE 983310.00	1.066	BNE 1043010.00	1.42
BNE 1006910.00	9.618	BNE 1008182.50	3587	BNE 984160.00	1.027	BNE 1043010.00	1.42
BNE 1007410.00	9.509	BNE 1008685.00	3584	BNE 984710.00	1.078	BNE 1043045.00	1.422
BNE 1007780.00	9.364	BNE 1009162.50	3582	BNE 985260.00	1.134	BNE 1043080.00	1.423
BNE 1007780.00	9.364	BNE 1009560.00	3581	BNE 985870.00	1.181	BNE 1043095.00	1.419
BNE 1007920.00	9.295	BNE 1010105.00	3577	BNE 986480.00	1.231	BNE 1043110.00	1.414
BNE 1008445.00	9.282	BNE 1010607.50	3575	BNE 987220.00	1.09	BNE 1043110.00	1.414
BNE 1008925.00	9.232	BNE 1010852.50	3574	BNE 987960.00	0.978	BNE 1043417.50	1.319
BNE 1009400.00	9.133	BNE 1011245.00	3572	BNE 988060.00	1.197	BNE 1043725.00	1.236
BNE 1009720.00	9.058	BNE 1011745.00	3568	BNE 988160.00	1.542	BNE 1043892.50	1.209
BNE 1010490.00	8.892	BNE 1012227.50	3564	BNE 988165.00	3.447	BNE 1044060.00	1.182
BNE 1010725.00	8.915	BNE 1012705.00	3555	BNE 988170.00	1.55	BNE 1044200.00	1.254
BNE 1010980.00	8.889	BNE 1013062.50	3552	BNE 988265.00	1.276	BNE 1044340.00	1.335
BNE 1011510.00	8.887	BNE 1013317.50	3551	BNE 988360.00	1.084	BNE 1044472.50	1.274
BNE 1011980.00	8.881	BNE 1013562.50	3549	BNE 989030.00	1.019	BNE 1044605.00	1.219
BNE 1012475.00	8.864	BNE 1013795.00	3547	BNE 989700.00	0.962	BNE 1044732.50	1.172

BNE 1012475.00	8.864			BNE 1014110.00	3544			BNE 990200.00 \	1.039			BNE 1044860.00 \	1.129
BNE 1012935.00	8.838			BNE 1014460.00	3542			BNE 990700.00 \	1.129			BNE 1045130.00 \	1.128
BNE 1013190.00	8.826			BNE 1014850.00	3532			BNE 990730.00 \	1.153			BNE 1045400.00 \	1.126
BNE 1013190.00	8.826			BNE 1015325.00	3530			BNE 990760.00 \	1.178			BNE 1045642.50 \	1.159
BNE 1013445.00	8.812			BNE 1015705.00	3530			BNE 991235.00 \	0.851			BNE 1045885.00 \	1.195
BNE 1013680.00	8.8			BNE 1015995.00	3529			BNE 991710.00 \	0.667			BNE 1046032.50 \	1.029
BNE 1013680.00	8.8			BNE 1016390.00	3528			BNE 992065.00 \	0.692			BNE 1046180.00 \	0.904
BNE 1013910.00	8.782			BNE 1016765.00	3527			BNE 992420.00 \	0.72			BNE 1046260.00 \	0.917
BNE 1014310.00	8.704			BNE 1017010.00	3526			BNE 992435.00 \	0.791			BNE 1046340.00 \	0.931
BNE 1014610.00	8.574			BNE 1017370.00	3524			BNE 992450.00 \	0.878			BNE 1046460.00 \	0.952
BNE 1014610.00	8.574			BNE 1017765.00	3523			BNE 992460.00 \	1.136			BNE 1046580.00 \	0.975
BNE 1015090.00	8.479			BNE 1018060.00	3522			BNE 992470.00 \	0.879			BNE 1046740.00 \	1.11
BNE 1015560.00	8.381			BNE 1018462.50	3520			BNE 992570.00 \	0.959			BNE 1046900.00 \	1.29
BNE 1015850.00	8.331			BNE 1018910.00	3519			BNE 992670.00 \	1.055			BNE 1047125.00 \	1.372
BNE 1015850.00	8.331			BNE 1019292.50	3519			BNE 993215.00 \	1.214			BNE 1047350.00 \	1.464
BNE 1016140.00	8.279			BNE 1019677.50	3518			BNE 993760.00 \	1.429			BNE 1047632.50 \	1.411
BNE 1016640.00	8.112			BNE 1019990.00	3518			BNE 994260.00 \	1.169			BNE 1047915.00 \	1.362
BNE 1016890.00	7.995			BNE 1020320.00	3516			BNE 994760.00 \	0.99			BNE 1048145.00 \	1.186
BNE 1016890.00	7.995			BNE 1020677.50	3514			BNE 995225.00 \	1.092			BNE 1048375.00 \	1.05
BNE 1017130.00	7.876			BNE 1020962.50	3514			BNE 995690.00 \	1.218			BNE 1048632.50 \	1.225
BNE 1017610.00	7.749			BNE 1021317.00	3513			BNE 996335.00 \	1.271			BNE 1048890.00 \	1.47
BNE 1017920.00	7.649			BNE 1021627.00	3512			BNE 996980.00 \	1.33			BNE 1049005.00 \	1.366
BNE 1018200.00	7.642			BNE 1021805.00	3512			BNE 997720.00 \	0.919			BNE 1049120.00 \	1.275
BNE 1018725.00	7.51			BNE 1022000.00	3511			BNE 998460.00 \	0.704			BNE 1049245.00 \	1.363
BNE 1019095.00	7.44			BNE 1022340.00	3510			BNE 998810.00 \	0.936			BNE 1049370.00 \	1.463
BNE 1019490.00	7.395			BNE 1022807.50	3518			BNE 999160.00 \	1.396			BNE 1049480.00 \	1.401
BNE 1019490.00	7.395			BNE 1023305.00	3517			BNE 999580.00 \	1.135			BNE 1049590.00 \	1.344
BNE 1019865.00	7.278			BNE 1023825.00	3516			BNE 1000000.00	0.959			BNE 1049730.00 \	1.398
BNE 1020115.00	7.285			BNE 1024321.50	3515			BNE 1000142.50	1.088			BNE 1049870.00 \	1.456
BNE 1020525.00	7.248			BNE 1024816.50	3514			BNE 1000285.00	1.254			BNE 1050150.00 \	1.429
BNE 1020830.00	7.174			BNE 1025215.00	3513			BNE 1000530.00	1.259			BNE 1050430.00 \	1.403
BNE 1021095.00	7.061			BNE 1025475.00	3512			BNE 1000775.00	1.264			BNE 1050645.00 \	1.444
BNE 1021539.00	6.892			BNE 1025880.00	3512			BNE 1001045.00	1.2			BNE 1050860.00 \	1.488
BNE 1021715.00	6.859			BNE 1026425.00	3511			BNE 1001315.00	1.142			BNE 1051110.00 \	1.382
BNE 1021895.00	6.797			BNE 1026790.00	3510			BNE 1001590.00	1.33			BNE 1051360.00 \	1.29
BNE 1022105.00	6.726			BNE 1027030.00	3510			BNE 1001865.00	1.592			BNE 1051627.50 \	1.461
BNE 1022575.00	6.622			BNE 1027420.00	3509			BNE 1002107.50	1.591			BNE 1051895.00 \	1.685
BNE 1023040.00	6.487			BNE 1027930.00	3508			BNE 1002350.00	1.59			BNE 1052102.50 \	1.445
BNE 1023570.00	6.449			BNE 1028430.00	3506			BNE 1002567.50	1.341			BNE 1052310.00 \	1.264
BNE 1024080.00	6.397			BNE 1028720.00	3506			BNE 1002785.00	1.159			BNE 1052370.00 \	2.083
BNE 1024563.00	6.351			BNE 1028980.00	3505			BNE 1003030.00	1.277			BNE 1052390.00 \	1.486
BNE 1025070.00	6.323			BNE 1029440.00	3504			BNE 1003275.00	1.422			BNE 1052492.50 \	1.503
BNE 1025360.00	6.265			BNE 1029950.00	3503			BNE 1003525.00	1.339			BNE 1052595.00 \	1.52
BNE 1025590.00	6.186			BNE 1030545.00	3500			BNE 1003775.00	1.265			BNE 1052625.00 \	1.921
BNE 1026170.00	6.062			BNE 1031065.00	3499			BNE 1004037.50	1.395			BNE 1052640.00 \	1.324
BNE 1026680.00	5.962			BNE 1031480.00	3499			BNE 1004300.00	1.555			BNE 1052752.50 \	1.353
BNE 1026900.00	5.897			BNE 1031847.50	3498			BNE 1004555.00	1.258			BNE 1052865.00 \	1.384
BNE 1027160.00	5.834			BNE 1032112.50	3498			BNE 1004810.00	1.057			BNE 1053092.50 \	1.298
BNE 1027680.00	5.797			BNE 1032407.50	3497			BNE 1005067.50	1.112			BNE 1053320.00 \	1.222
BNE 1028180.00	5.78			BNE 1032832.50	3497			BNE 1005325.00	1.173			BNE 1053355.00 \	1.592
BNE 1028680.00	5.694			BNE 1033225.00	3496			BNE 1005597.50	1.25			BNE 1053385.00 \	1.463
BNE 1028760.00	5.605			BNE 1033635.00	3495			BNE 1005870.00	1.338			BNE 1053642.50 \	1.438
BNE 1029200.00	5.526			BNE 1034135.00	3495			BNE 1005870.00	1.338			BNE 1053900.00 \	1.414
BNE 1029680.00	5.516			BNE 1034630.00	3494			BNE 1006035.00	1.201			BNE 1054270.00 \	0.992
BNE 1030220.00	5.503			BNE 1035152.00	3493			BNE 1006200.00	1.09			BNE 1054640.00 \	0.764
BNE 1030870.00	5.465			BNE 1035657.00	3492			BNE 1006200.00	1.636			BNE 1054660.00 \	1.153
BNE 1031260.00	5.406			BNE 1036180.00	3491			BNE 1006250.00	1.604			BNE 1054680.00 \	0.727
BNE 1031700.00	5.308			BNE 1036615.00	3490			BNE 1006300.00	1.573			BNE 1054825.00 \	0.931
BNE 1031995.00	5.3			BNE 1036842.50	3490			BNE 1006300.00	1.573			BNE 1054970.00 \	1.295
BNE 1032230.00	5.227			BNE 1037002.50	3490			BNE 1006605.00	1.575			BNE 1055125.00 \	1.276
BNE 1032585.00	5.094			BNE 1037110.00	3490			BNE 1006910.00	1.578			BNE 1055280.00 \	1.257
BNE 1033080.00	4.999			BNE 1037230.00	3490			BNE 1007160.00	1.477			BNE 1055350.00 \	1.268
BNE 1033370.00	4.951			BNE 1037455.00	3489			BNE 1007410.00	1.388			BNE 1055420.00 \	1.278
BNE 1033900.00	4.841			BNE 1037855.00	3488			BNE 1007595.00	1.555			BNE 1055690.00 \	1.214
BNE 1034370.00	4.74			BNE 1038342.50	3487			BNE 1007780.00	1.768			BNE 1055960.00 \	1.156
BNE 1034890.00	4.674			BNE 1038850.00	3485			BNE 1007780.00	1.764			BNE 1056180.00 \	1.295
BNE 1035414.00	4.591			BNE 1039150.00	3483			BNE 1007850.00	1.864			BNE 1056400.00 \	1.474
BNE 1035900.00	4.483			BNE 1039382.50	3482			BNE 1007920.00	1.977			BNE 1056547.50 \	1.4
BNE 1036460.00	4.354			BNE 1039617.50	3482			BNE 1008182.50	1.752			BNE 1056695.00 \	1.333
BNE 1036770.00	4.282			BNE 1039749.00	3481			BNE 1008445.00	1.574			BNE 1056780.00 \	0.518
BNE 1036915.00	4.252			BNE 1039959.00	3450			BNE 1008685.00	1.575			BNE 1056865.00 \	0.321
BNE 1037090.00	4.266			BNE 1040170.00	3450			BNE 1008925.00	1.575			BNE 1056920.00 \	1.504
BNE 1037175.00	4.106			BNE 1040370.00	3449			BNE 1009162.50	1.579			BNE 1056950.00 \	0.332
BNE 1037285.00	4.075			BNE 1040750.00	3449			BNE 1009400.00	1.583			BNE 1057020.00 \	0.496
BNE 1037625.00	4.058			BNE 1041120.00	3449			BNE 1009560.00	1.56			BNE 1057090.00 \	0.977
BNE 1038085.00	4.04			BNE 1041345.00	3449			BNE 1009720.00	1.537			BNE 1057310.00 \	1.055
BNE 1038600.00	3.99			BNE 1041580.00	3449			BNE 1010105.00	1.688			BNE 1057530.00 \	1.147
BNE 1039100.00	3.954			BNE 1041830.00	3448			BNE 1010490.00	1.874			BNE 1057785.00 \	1.261
BNE 1039200.00	3.954			BNE 1042097.50	3448			BNE 1010607.50	1.738			BNE 1058040.00 \	1.401
BNE 1039200.00	3.954			BNE 1042367.50	3448			BNE 1010725.00	1.62			BNE 1058135.00 \	1.399
BNE 1039565.00	3.952			BNE 1042507.50	3448			BNE 1010852.50	1.648			BNE 1058230.00 \	1.398
BNE 1039670.00	3.956			BNE 1042712.50	3448			BNE 1010980.00	1.676			BNE 1058380.00 \	1.381
BNE 1039670.00	3.956			BNE 1042960.00	3448			BNE 1011245.00	1.597			BNE 1058530.00 \	1.365
BNE 1039828.00	3.959			BNE 1043045.00	3448			BNE 1011510.00	1.523			BNE 1058632.50 \	1.294
BNE 1039828.00	3.959			BNE 1043095.00	3448			BNE 1011745.00	1.49			BNE 1058735.00 \	1.23
BNE 1040090.00	3.96			BNE 1043417.50	3448			BNE 1011980.00	1.458			BNE 1058885.00 \	1.311
BNE 1040250.00	3.943			BNE 1043892.50	3448			BNE 1012227.50	1.441			BNE 1059035.00 \	1.404
BNE 1040250.00	3.943			BNE 1044200.00	3448			BNE 1012475.00	1.424			BNE 1059287.50 \	1.228
BNE 1040490.00	3.906			BNE 1044472.50	3447			BNE 1012475.00	1.419			BNE 1059540.00 \	1.092
BNE 1041010.00	3.917			BNE 1044732.50	3447			BNE 1012705.00	1.432			BNE 1059765.00 \	1.108
BNE 1041230.00	3.895			BNE 1045130.00	3447			BNE 1012935.00	1.445			BNE 1059990.00 \	1.126
BNE 1041460.00	3.865			BNE 1045642.50	3447			BNE 1013062.50	1.434			BNE 1060167.50 \	1.178
BNE 1041700.00	3.868			BNE 1046032.50	3447			BNE 1013190.00	1.422			BNE 1060345.00 \	1.235
BNE 1041960.00	3.804			BNE 1046260.00	3447			BNE 1013190.00	1.422			BNE 1060440.00 \	1.285
BNE 1042235.00	3.731			BNE 1046460.00	3447			BNE 1013317.50	1.41			BNE 1060535.00 \	1.339
BNE 1042500.00	3.698			BNE 1046740.00	3447			BNE 1013445.00	1.398			BNE 1060775.00 \	1.281
BNE 1042500.00	3.698			BNE 1047125.00	3447			BNE 1013562.50	1.371			BNE 1061015.00 \	1.227
BNE 1042515.00	3.697			BNE 1047632.50	3447			BNE 1013680.00	1.344			BNE 1061272.50 \	1.26
BNE 1042910.00	3.584			BNE 1048145.00	3447			BNE 1013680.00	1.344			BNE 1061530.00 \	1.295

BNE_1043010.00	3.549			BNE_1048632.50	3446		BNE_1013795.00	1.328		BNE_1061775.00 \	1.228
BNE_1043010.00	3.549			BNE_1049005.00	3446		BNE_1013910.00	1.311		BNE_1062020.00 \	1.167
BNE_1043080.00	3.524			BNE_1049245.00	3446		BNE_1014110.00	1.337		BNE_1062277.50 \	1.089
BNE_1043110.00	3.516			BNE_1049480.00	3446		BNE_1014310.00	1.364		BNE_1062535.00 \	1.021
BNE_1043110.00	3.516			BNE_1049730.00	3446		BNE_1014460.00	1.367		BNE_1062737.50 \	0.919
BNE_1043725.00	3.379			BNE_1050150.00	3446		BNE_1014610.00	1.371		BNE_1062940.00 \	0.835
BNE_1044060.00	3.337			BNE_1050645.00	3446		BNE_1014610.00	1.365		BNE_1063032.50 \	0.846
BNE_1044340.00	3.284			BNE_1051110.00	3447		BNE_1014850.00	1.23		BNE_1063125.00 \	0.858
BNE_1044605.00	3.265			BNE_1051627.50	3447		BNE_1015090.00	1.121		BNE_1063125.00 \	0.858
BNE_1044860.00	3.248			BNE_1052102.50	3447		BNE_1015325.00	1.257		BNE_1063217.50 \	0.877
BNE_1045400.00	3.206			BNE_1052370.00	3447		BNE_1015560.00	1.43		BNE_1063310.00 \	0.898
BNE_1045885.00	3.17			BNE_1052492.50	3447		BNE_1015705.00	1.412		BNE_1063477.50 \	1.039
BNE_1046180.00	3.19			BNE_1052625.00	3447		BNE_1015850.00	1.394		BNE_1063645.00 \	1.234
BNE_1046340.00	3.184			BNE_1052752.50	3447		BNE_1015850.00	1.394		BNE_1063822.50 \	1.194
BNE_1046580.00	3.162			BNE_1053092.50	3447		BNE_1015995.00	1.377		BNE_1064000.00 \	1.156
BNE_1046900.00	3.055			BNE_1053355.00	3447		BNE_1016140.00	1.361		BNE_1064245.00 \	1.17
BNE_1047350.00	2.853			BNE_1053642.50	3447		BNE_1016390.00	1.462		BNE_1064490.00 \	1.183
BNE_1047915.00	2.729			BNE_1054270.00	3447		BNE_1016640.00	1.58		BNE_1064750.00 \	1.047
BNE_1048375.00	2.73			BNE_1054660.00	3447		BNE_1016765.00	1.623		BNE_1065010.00 \	0.939
BNE_1048890.00	2.631			BNE_1054825.00	3447		BNE_1016890.00	1.668		BNE_1065256.50 \	0.9
BNE_1049120.00	2.621			BNE_1055125.00	3447		BNE_1016890.00	1.668		BNE_1065503.00 \	0.863
BNE_1049370.00	2.56			BNE_1055350.00	3447		BNE_1017010.00	1.732		BNE_1065746.50 \	0.755
BNE_1049590.00	2.548			BNE_1055690.00	3447		BNE_1017130.00	1.802		BNE_1065990.00 \	0.671
BNE_1049870.00	2.496			BNE_1056180.00	3447		BNE_1017370.00	1.719		BNE_1066247.50 \	0.721
BNE_1050430.00	2.433			BNE_1056547.50	3447		BNE_1017610.00	1.643		BNE_1066505.00 \	0.779
BNE_1050860.00	2.387			BNE_1056780.00	3447		BNE_1017765.00	1.698		BNE_1066762.50 \	0.759
BNE_1051360.00	2.393			BNE_1056920.00	3447		BNE_1017920.00	1.756		BNE_1067020.00 \	0.741
BNE_1051895.00	2.319			BNE_1057020.00	3447		BNE_1018060.00	1.546		BNE_1067252.50 \	0.809
BNE_1052310.00	2.371			BNE_1057310.00	3447		BNE_1018200.00	1.382		BNE_1067485.00 \	0.892
BNE_1052390.00	2.315			BNE_1057785.00	3447		BNE_1018462.50	1.475		BNE_1067725.00 \	0.921
BNE_1052595.00	2.309			BNE_1058135.00	3447		BNE_1018725.00	1.582		BNE_1067965.00 \	0.951
BNE_1052640.00	2.226			BNE_1058380.00	3447		BNE_1018910.00	1.565		BNE_1068312.50 \	0.985
BNE_1052865.00	2.215			BNE_1058632.50	3447		BNE_1019095.00	1.548		BNE_1068660.00 \	1.021
BNE_1053320.00	2.226			BNE_1058885.00	3447		BNE_1019292.50	1.438		BNE_1068852.50 \	1.007
BNE_1053385.00	2.144			BNE_1059287.50	3447		BNE_1019490.00	1.342		BNE_1069045.00 \	0.994
BNE_1053900.00	2.038			BNE_1059765.00	3447		BNE_1019490.00	1.342		BNE_1069290.00 \	0.953
BNE_1054640.00	1.999			BNE_1060167.50	3447		BNE_1019677.50	1.461		BNE_1069535.00 \	0.915
BNE_1054680.00	1.976			BNE_1060440.00	3447		BNE_1019865.00	1.604		BNE_1069780.00 \	0.885
BNE_1054970.00	1.897			BNE_1060775.00	3447		BNE_1019990.00	1.343		BNE_1070025.00 \	0.857
BNE_1055280.00	1.858			BNE_1061272.50	3447		BNE_1020115.00	1.154		BNE_1070277.50 \	0.867
BNE_1055420.00	1.834			BNE_1061775.00	3447		BNE_1020320.00	0.973		BNE_1070530.00 \	0.877
BNE_1055960.00	1.791			BNE_1062277.50	3447		BNE_1020525.00	0.841		BNE_1070785.00 \	0.864
BNE_1056400.00	1.71			BNE_1062737.50	3447		BNE_1020677.50	0.969		BNE_1071040.00 \	0.851
BNE_1056695.00	1.693			BNE_1063032.50	3447		BNE_1020830.00	1.143		BNE_1071280.00 \	0.717
BNE_1056865.00	1.742			BNE_1063217.50	3449		BNE_1020962.50	1.306		BNE_1071520.00 \	0.62
BNE_1056950.00	1.715			BNE_1063477.50	3449		BNE_1021095.00	1.523		BNE_1071767.50 \	0.691
BNE_1057090.00	1.681			BNE_1063822.50	3449		BNE_1021317.00	1.501		BNE_1072015.00 \	0.781
BNE_1057530.00	1.65			BNE_1064245.00	3449		BNE_1021539.00	1.479		BNE_1072017.50 \	0.781
BNE_1058040.00	1.576			BNE_1064750.00	3449		BNE_1021627.00	1.363		BNE_1072020.00 \	0.781
BNE_1058230.00	1.557			BNE_1065256.50	3449		BNE_1021715.00	1.263		BNE_1072020.00 \	0.795
BNE_1058530.00	1.537			BNE_1065746.50	3449		BNE_1021805.00	1.267		BNE_1072267.50 \	0.781
BNE_1058735.00	1.539			BNE_1066247.50	3449		BNE_1021895.00	1.271		BNE_1072515.00 \	0.765
BNE_1059035.00	1.484			BNE_1066762.50	3449		BNE_1022000.00	1.309		BNE_1072755.00 \	0.747
BNE_1059540.00	1.458			BNE_1067252.50	3450		BNE_1022105.00	1.35		BNE_1072995.00 \	0.728
BNE_1059990.00	1.387			BNE_1067725.00	3450		BNE_1022340.00	1.374		BNE_1073240.00 \	0.766
BNE_1060345.00	1.327			BNE_1068312.50	3450		BNE_1022575.00	1.402		BNE_1073485.00 \	0.807
BNE_1060535.00	1.302			BNE_1068852.50	3449		BNE_1022807.50	1.579		BNE_1073742.50 \	0.797
BNE_1061015.00	1.291			BNE_1069290.00	3449		BNE_1023040.00	1.805		BNE_1074000.00 \	0.786
BNE_1061530.00	1.269			BNE_1069780.00	3449		BNE_1023305.00	1.727		BNE_1074230.00 \	0.782
BNE_1062020.00	1.261			BNE_1070277.50	3449		BNE_1023570.00	1.656		BNE_1074460.00 \	0.777
BNE_1062535.00	1.254			BNE_1070785.00	3449		BNE_1023825.00	1.622		BNE_1074722.50 \	0.818
BNE_1062940.00	1.252			BNE_1071280.00	3449		BNE_1024080.00	1.589		BNE_1074985.00 \	0.863
BNE_1063125.00	1.232			BNE_1071767.50	3449		BNE_1024321.50	1.55		BNE_1075232.50 \	0.784
BNE_1063125.00	1.232			BNE_1072017.50	3450		BNE_1024563.00	1.512		BNE_1075480.00 \	0.718
BNE_1063310.00	1.232			BNE_1072267.50	3535		BNE_1024816.50	1.436		BNE_1075740.00 \	0.603
BNE_1063645.00	1.189			BNE_1072755.00	3548		BNE_1025070.00	1.366		BNE_1076000.00 \	0.52
BNE_1064000.00	1.188			BNE_1073240.00	3563		BNE_1025215.00	1.459		BNE_1076247.50 \	0.591
BNE_1064490.00	1.165			BNE_1073742.50	3578		BNE_1025360.00	1.566		BNE_1076495.00 \	0.682
BNE_1065010.00	1.166			BNE_1074230.00	3591		BNE_1025475.00	1.671		BNE_1076752.50 \	0.563
BNE_1065503.00	1.156			BNE_1074722.50	3602		BNE_1025590.00	1.791		BNE_1077010.00 \	0.479
BNE_1065990.00	1.158			BNE_1075232.50	3609		BNE_1025880.00	1.674		BNE_1077260.00 \	0.412
BNE_1066505.00	1.144			BNE_1075740.00	3618		BNE_1026170.00	1.572		BNE_1077510.00 \	0.361
BNE_1067020.00	1.139			BNE_1076247.50	3629		BNE_1026425.00	1.545		BNE_1077775.00 \	0.372
BNE_1067485.00	1.12			BNE_1076752.50	3639		BNE_1026680.00	1.519		BNE_1078040.00 \	0.382
BNE_1067965.00	1.104			BNE_1077260.00	3654		BNE_1026790.00	1.574		BNE_1078282.50 \	0.46
BNE_1068660.00	1.082			BNE_1077775.00	3662		BNE_1026900.00	1.632		BNE_1078525.00 \	0.577
BNE_1069045.00	1.073			BNE_1078282.50	3665		BNE_1027030.00	1.646		BNE_1078592.50 \	0.128
BNE_1069535.00	1.067			BNE_1078592.50	3666		BNE_1027160.00	1.661		BNE_1078660.00 \	0.072
BNE_1070025.00	1.061						BNE_1027420.00	1.519			
BNE_1070530.00	1.049						BNE_1027680.00	1.4			
BNE_1071040.00	1.039						BNE_1027930.00	1.338			
BNE_1071520.00	1.046						BNE_1028180.00	1.28			
BNE_1072015.00	1.03						BNE_1028430.00	1.425			
BNE_1072020.00	1.03						BNE_1028680.00	1.608			
BNE_1072020.00	1.03						BNE_1028720.00	2.009			
BNE_1072515.00	1.02						BNE_1028760.00	1.616			
BNE_1072995.00	1.012						BNE_1028980.00	1.695			
BNE_1073485.00	1.023						BNE_1029200.00	1.782			
BNE_1074000.00	1.041						BNE_1029440.00	1.667			
BNE_1074460.00	1.055						BNE_1029680.00	1.565			
BNE_1074985.00	1.068						BNE_1029950.00	1.518			
BNE_1075480.00	1.08						BNE_1030220.00	1.473			
BNE_1076000.00	1.082						BNE_1030545.00	1.476			
BNE_1076495.00	1.065						BNE_1030870.00	1.479			
BNE_1077010.00	1.041						BNE_1031065.00	1.56			
BNE_1077510.00	1.009						BNE_1031260.00	1.651			
BNE_1078040.00	0.97						BNE_1031480.00	1.768			
BNE_1078525.00	0.92						BNE_1031700.00	1.904			
BNE_1078660.00	0.918						BNE_1031847.50	1.657			

Appendix C Mike11 Results Q50

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q50 event CRCFORGE rainfall with ARF's

72hr Storm Duration

Chainage [m]	Water Level	Chainage [m]	Discharge	Chainage [m]	Velocity [m/s]	Chainage [m]	Velocity [m/s]
BNE_931570.00	40.156	BNE_931575.00	3400	BNE_931570.00	1.897	BNE_1031995.00	1.631
BNE_931580.00	40.149	BNE_932625.00	3400	BNE_931575.00	1.898	BNE_1032112.50	1.598
BNE_933670.00	38.746	BNE_933970.00	3400	BNE_931580.00	1.898	BNE_1032230.00	1.565
BNE_934270.00	38.621	BNE_934445.00	3400	BNE_932625.00	1.859	BNE_1032407.50	1.636
BNE_934620.00	38.409	BNE_935345.00	3400	BNE_933670.00	1.83	BNE_1032585.00	1.713
BNE_936070.00	38.206	BNE_936445.00	3400	BNE_933970.00	1.236	BNE_1032832.50	1.688
BNE_936820.00	38.159	BNE_938295.00	3399	BNE_934270.00	1.693	BNE_1033080.00	1.663
BNE_939770.00	37.757	BNE_941045.00	3399	BNE_934445.00	2.258	BNE_1033225.00	1.695
BNE_942320.00	36.598	BNE_942945.00	3399	BNE_934620.00	3.422	BNE_1033370.00	1.729
BNE_943570.00	36.195	BNE_943845.00	3398	BNE_935345.00	0.982	BNE_1033635.00	1.79
BNE_944120.00	36.12	BNE_944845.00	3397	BNE_936070.00	0.5	BNE_1033900.00	1.855
BNE_945570.00	35.879	BNE_946370.00	3396	BNE_936445.00	0.583	BNE_1034135.00	1.861
BNE_947170.00	35.467	BNE_947720.00	3396	BNE_936820.00	2.481	BNE_1034370.00	1.866
BNE_948270.00	35.105	BNE_949270.00	3396	BNE_938295.00	0.878	BNE_1034630.00	1.795
BNE_950270.00	34.566	BNE_951295.00	3396	BNE_939770.00	1.358	BNE_1034890.00	1.728
BNE_952320.00	33.9	BNE_953095.00	3396	BNE_941045.00	1.384	BNE_1035152.00	1.756
BNE_953870.00	33.495	BNE_954395.00	3395	BNE_942320.00	1.429	BNE_1035414.00	1.784
BNE_954920.00	33.101	BNE_955445.00	3395	BNE_942945.00	1.107	BNE_1035657.00	1.843
BNE_955970.00	32.626	BNE_957370.00	3395	BNE_943570.00	0.901	BNE_1035900.00	1.905
BNE_958770.00	31.381	BNE_959470.00	3394	BNE_943845.00	0.874	BNE_1036180.00	1.871
BNE_960170.00	30.971	BNE_961120.00	3394	BNE_944120.00	1.046	BNE_1036460.00	1.838
BNE_962070.00	30.034	BNE_963120.00	3394	BNE_944845.00	0.998	BNE_1036615.00	1.751
BNE_964170.00	28.816	BNE_965390.00	3393	BNE_945570.00	1.33	BNE_1036770.00	1.671
BNE_966610.00	27.278	BNE_967010.00	3393	BNE_946370.00	1.006	BNE_1036842.50	1.715
BNE_967410.00	26.85	BNE_968600.00	3392	BNE_947170.00	1.159	BNE_1036915.00	1.775
BNE_969790.00	25.826	BNE_970475.00	3392	BNE_947720.00	1.194	BNE_1037002.50	1.708
BNE_971160.00	25.399	BNE_971710.00	3392	BNE_948270.00	1.233	BNE_1037090.00	1.633
BNE_972260.00	25.171	BNE_972760.00	3392	BNE_949270.00	1.088	BNE_1037110.00	1.989
BNE_973260.00	25.137	BNE_973920.00	3391	BNE_950270.00	0.995	BNE_1037175.00	1.643
BNE_974580.00	24.995	BNE_975300.00	3391	BNE_951295.00	1.194	BNE_1037230.00	1.732
BNE_976020.00	24.908	BNE_976385.00	3391	BNE_952320.00	1.494	BNE_1037285.00	1.831
BNE_976750.00	24.861	BNE_977515.00	3390	BNE_953095.00	1.172	BNE_1037455.00	1.724
BNE_978280.00	24.056	BNE_978893.50	3391	BNE_953870.00	0.965	BNE_1037625.00	1.628
BNE_979507.00	22.053	BNE_979510.00	3427	BNE_954395.00	1.145	BNE_1037855.00	1.516
BNE_979513.00	22.021	BNE_979521.50	3424	BNE_954920.00	1.844	BNE_1038085.00	1.418
BNE_979530.00	22	BNE_979930.00	3390	BNE_955445.00	1.381	BNE_1038342.50	1.47
BNE_980330.00	21.759	BNE_980995.00	3389	BNE_955970.00	1.366	BNE_1038600.00	1.526
BNE_981660.00	21.352	BNE_982060.00	3389	BNE_957370.00	1.359	BNE_1038850.00	1.517
BNE_982460.00	21.157	BNE_983310.00	3389	BNE_958770.00	1.408	BNE_1039100.00	1.507
BNE_984160.00	20.699	BNE_984710.00	3389	BNE_959470.00	1.077	BNE_1039150.00	1.489
BNE_985260.00	20.281	BNE_985870.00	3388	BNE_960170.00	0.872	BNE_1039200.00	1.47
BNE_986480.00	19.574	BNE_987220.00	3388	BNE_961120.00	1.153	BNE_1039200.00	1.47
BNE_987960.00	18.547	BNE_988060.00	3388	BNE_962070.00	1.701	BNE_1039382.50	1.423
BNE_988160.00	18.248	BNE_988165.00	3388	BNE_963120.00	1.265	BNE_1039565.00	1.378
BNE_988170.00	18.207	BNE_988265.00	3388	BNE_964170.00	1.006	BNE_1039617.50	1.352
BNE_988360.00	17.978	BNE_989030.00	3388	BNE_965390.00	1.291	BNE_1039670.00	1.327
BNE_989700.00	17.084	BNE_990200.00	3388	BNE_966610.00	1.809	BNE_1039670.00	1.327
BNE_990700.00	16.725	BNE_990730.00	3388	BNE_967010.00	1.492	BNE_1039749.00	1.297
BNE_990760.00	16.691	BNE_991235.00	3388	BNE_967410.00	1.27	BNE_1039828.00	1.268
BNE_991710.00	16.421	BNE_992065.00	3391	BNE_968600.00	1.409	BNE_1039828.00	1.285
BNE_992420.00	16.234	BNE_992435.00	3397	BNE_969790.00	1.582	BNE_1039959.00	1.268
BNE_992450.00	16.196	BNE_992460.00	3397	BNE_970475.00	1.556	BNE_1040090.00	1.251
BNE_992470.00	16.175	BNE_992570.00	3397	BNE_971160.00	1.53	BNE_1040170.00	1.322
BNE_992670.00	16.074	BNE_993215.00	3387	BNE_971710.00	1.485	BNE_1040250.00	1.4
BNE_993760.00	15.442	BNE_994260.00	3387	BNE_972260.00	2.512	BNE_1040250.00	1.4
BNE_994760.00	15.025	BNE_995225.00	3386	BNE_972760.00	1.173	BNE_1040370.00	1.528
BNE_995690.00	14.461	BNE_996335.00	3386	BNE_973260.00	0.949	BNE_1040490.00	1.681
BNE_996980.00	13.519	BNE_997720.00	3386	BNE_973920.00	1.209	BNE_1040750.00	1.503
BNE_998460.00	13.234	BNE_998810.00	3385	BNE_974580.00	1.667	BNE_1041010.00	1.359
BNE_999160.00	13.129	BNE_999580.00	3385	BNE_975300.00	1.485	BNE_1041120.00	1.366
BNE_1000000.00	12.99	BNE_1000142.50	3386	BNE_976020.00	1.339	BNE_1041230.00	1.373
BNE_1000285.00	12.877	BNE_1000530.00	3386	BNE_976385.00	0.992	BNE_1041345.00	1.401
BNE_1000775.00	12.724	BNE_1001045.00	3386	BNE_976750.00	1.02	BNE_1041460.00	1.429
BNE_1001315.00	12.631	BNE_1001590.00	3386	BNE_977515.00	1.029	BNE_1041580.00	1.337
BNE_1001865.00	12.438	BNE_1002107.50	3386	BNE_978280.00	1.457	BNE_1041700.00	1.256
BNE_1002350.00	12.317	BNE_1002567.50	3386	BNE_978893.50	1.384	BNE_1041830.00	1.434
BNE_1002785.00	12.293	BNE_1003030.00	3386	BNE_979507.00	1.325	BNE_1041960.00	1.671
BNE_1003275.00	12.172	BNE_1003525.00	3386	BNE_979510.00	1.366	BNE_1042097.50	1.727
BNE_1003775.00	12.079	BNE_1004037.50	3386	BNE_979513.00	1.372	BNE_1042235.00	1.786
BNE_1004300.00	11.866	BNE_1004555.00	3386	BNE_979521.50	1.417	BNE_1042367.50	1.674
BNE_1004810.00	11.811	BNE_1005067.50	3385	BNE_979530.00	1.422	BNE_1042500.00	1.576
BNE_1005325.00	11.703	BNE_1005597.50	3385	BNE_979930.00	1.35	BNE_1042500.00	1.576
BNE_1005870.00	11.563	BNE_1006035.00	3181	BNE_980330.00	1.803	BNE_1042507.50	1.57
BNE_1005870.00	11.563	BNE_1006250.00	4395	BNE_980995.00	1.397	BNE_1042515.00	1.565
BNE_1006200.00	11.511	BNE_1006605.00	4394	BNE_981660.00	1.52	BNE_1042712.50	1.605
BNE_1006200.00	11.511	BNE_1007160.00	4390	BNE_982060.00	1.48	BNE_1042910.00	1.648
BNE_1006300.00	11.482	BNE_1007595.00	4385	BNE_982460.00	1.442	BNE_1042960.00	1.652
BNE_1006300.00	11.482	BNE_1007850.00	4379	BNE_983310.00	1.371	BNE_1043010.00	1.655
BNE_1006910.00	11.281	BNE_1008182.50	4378	BNE_984160.00	1.307	BNE_1043010.00	1.655
BNE_1007410.00	11.181	BNE_1008685.00	4375	BNE_984710.00	1.367	BNE_1043045.00	1.658
BNE_1007780.00	11.033	BNE_1009162.50	4374	BNE_985260.00	1.433	BNE_1043080.00	1.661
BNE_1007780.00	11.033	BNE_1009560.00	4372	BNE_985870.00	1.509	BNE_1043095.00	1.655
BNE_1007920.00	10.963	BNE_1010105.00	4368	BNE_986480.00	1.594	BNE_1043110.00	1.65
BNE_1008445.00	10.949	BNE_1010607.50	4366	BNE_987220.00	1.366	BNE_1043110.00	1.65
BNE_1008925.00	10.902	BNE_1010852.50	4365	BNE_987960.00	1.195	BNE_1043417.50	1.559
BNE_1009400.00	10.806	BNE_1011245.00	4363	BNE_988060.00	1.442	BNE_1043725.00	1.478
BNE_1009720.00	10.74	BNE_1011745.00	4359	BNE_988160.00	1.82	BNE_1043892.50	1.463
BNE_1010490.00	10.566	BNE_1012227.50	4355	BNE_988165.00	3.606	BNE_1044060.00	1.449
BNE_1010725.00	10.59	BNE_1012705.00	4342	BNE_988170.00	1.827	BNE_1044200.00	1.533
BNE_1010980.00	10.564	BNE_1013062.50	4339	BNE_988265.00	1.541	BNE_1044340.00	1.627
BNE_1011510.00	10.57	BNE_1013317.50	4337	BNE_988360.00	1.333	BNE_1044472.50	1.548
BNE_1011980.00	10.569	BNE_1013562.50	4337	BNE_989030.00	1.215	BNE_1044605.00	1.477
BNE_1012475.00	10.553	BNE_1013795.00	4335	BNE_989700.00	1.117	BNE_1044732.50	1.409

BNE 1012475.00	10.553			BNE 1014110.00	4332		BNE 990200.00	1.268		BNE 1044860.00	1.347
BNE 1012935.00	10.529			BNE 1014460.00	4329		BNE 990700.00	1.467		BNE 1045130.00	1.346
BNE 1013190.00	10.516			BNE 1014850.00	4323		BNE 990730.00	1.5		BNE 1045400.00	1.344
BNE 1013190.00	10.516			BNE 1015325.00	4321		BNE 990760.00	1.535		BNE 1045642.50	1.384
BNE 1013445.00	10.5			BNE 1015705.00	4320		BNE 991235.00	1.088		BNE 1045885.00	1.425
BNE 1013680.00	10.491			BNE 1015995.00	4319		BNE 991710.00	0.843		BNE 1046032.50	1.253
BNE 1013680.00	10.491			BNE 1016390.00	4317		BNE 992065.00	0.861		BNE 1046180.00	1.118
BNE 1013910.00	10.476			BNE 1016765.00	4315		BNE 992420.00	0.88		BNE 1046260.00	1.138
BNE 1014310.00	10.406			BNE 1017010.00	4313		BNE 992435.00	0.987		BNE 1046340.00	1.159
BNE 1014610.00	10.292			BNE 1017370.00	4311		BNE 992450.00	1.122		BNE 1046460.00	1.176
BNE 1014610.00	10.292			BNE 1017765.00	4308		BNE 992460.00	1.227		BNE 1046580.00	1.193
BNE 1015090.00	10.19			BNE 1018060.00	4306		BNE 992470.00	1.123		BNE 1046740.00	1.349
BNE 1015560.00	10.085			BNE 1018462.50	4304		BNE 992570.00	1.209		BNE 1046900.00	1.553
BNE 1015850.00	10.034			BNE 1018910.00	4303		BNE 992670.00	1.304		BNE 1047125.00	1.669
BNE 1015850.00	10.034			BNE 1019292.50	4329		BNE 993215.00	1.512		BNE 1047350.00	1.803
BNE 1016140.00	9.981			BNE 1019677.50	4336		BNE 993760.00	1.8		BNE 1047632.50	1.751
BNE 1016640.00	9.822			BNE 1019990.00	4335		BNE 994260.00	1.407		BNE 1047915.00	1.701
BNE 1016890.00	9.711			BNE 1020320.00	4333		BNE 994760.00	1.154		BNE 1048145.00	1.467
BNE 1016890.00	9.711			BNE 1020677.50	4331		BNE 995225.00	1.34		BNE 1048375.00	1.29
BNE 1017130.00	9.598			BNE 1020962.50	4330		BNE 995690.00	1.597		BNE 1048632.50	1.484
BNE 1017610.00	9.476			BNE 1021317.00	4329		BNE 996335.00	1.614		BNE 1048890.00	1.749
BNE 1017920.00	9.375			BNE 1021627.00	4328		BNE 996980.00	1.631		BNE 1049005.00	1.647
BNE 1018200.00	9.368			BNE 1021805.00	4327		BNE 997720.00	1.157		BNE 1049120.00	1.557
BNE 1018725.00	9.226			BNE 1022000.00	4327		BNE 998460.00	0.896		BNE 1049245.00	1.672
BNE 1019095.00	9.15			BNE 1022340.00	4326		BNE 998810.00	1.192		BNE 1049370.00	1.806
BNE 1019490.00	9.109			BNE 1022807.50	4396		BNE 999160.00	1.783		BNE 1049480.00	1.736
BNE 1019490.00	9.109			BNE 1023305.00	4396		BNE 999580.00	1.518		BNE 1049590.00	1.671
BNE 1019865.00	8.978			BNE 1023825.00	4395		BNE 1000000.00	1.323		BNE 1049730.00	1.73
BNE 1020115.00	9.001			BNE 1024321.50	4394		BNE 1000142.50	1.481		BNE 1049870.00	1.794
BNE 1020525.00	8.97			BNE 1024816.50	4393		BNE 1000285.00	1.682		BNE 1050150.00	1.749
BNE 1020830.00	8.887			BNE 1025215.00	4392		BNE 1000530.00	1.711		BNE 1050430.00	1.706
BNE 1021095.00	8.763			BNE 1025475.00	4392		BNE 1000775.00	1.74		BNE 1050645.00	1.765
BNE 1021539.00	8.591			BNE 1025880.00	4391		BNE 1001045.00	1.608		BNE 1050860.00	1.829
BNE 1021715.00	8.566			BNE 1026425.00	4390		BNE 1001315.00	1.494		BNE 1051110.00	1.714
BNE 1021895.00	8.502			BNE 1026790.00	4390		BNE 1001590.00	1.78		BNE 1051360.00	1.611
BNE 1022105.00	8.421			BNE 1027030.00	4390		BNE 1001865.00	2.201		BNE 1051627.50	1.809
BNE 1022575.00	8.315			BNE 1027420.00	4389		BNE 1002107.50	2.162		BNE 1051895.00	2.061
BNE 1023040.00	8.148			BNE 1027930.00	4388		BNE 1002350.00	2.124		BNE 1052102.50	1.76
BNE 1023570.00	8.112			BNE 1028430.00	4386		BNE 1002567.50	1.798		BNE 1052310.00	1.535
BNE 1024080.00	8.062			BNE 1028720.00	4386		BNE 1002785.00	1.558		BNE 1052370.00	2.52
BNE 1024563.00	8.018			BNE 1028980.00	4385		BNE 1003030.00	1.732		BNE 1052390.00	1.822
BNE 1025070.00	7.991			BNE 1029440.00	4384		BNE 1003275.00	1.95		BNE 1052492.50	1.857
BNE 1025360.00	7.924			BNE 1029950.00	4382		BNE 1003525.00	1.839		BNE 1052595.00	1.886
BNE 1025590.00	7.833			BNE 1030545.00	4379		BNE 1003775.00	1.74		BNE 1052625.00	2.441
BNE 1026170.00	7.703			BNE 1031065.00	4378		BNE 1004037.50	1.939		BNE 1052640.00	1.659
BNE 1026680.00	7.599			BNE 1031480.00	4377		BNE 1004300.00	2.189		BNE 1052752.50	1.707
BNE 1026900.00	7.522			BNE 1031847.50	4376		BNE 1004555.00	1.733		BNE 1052865.00	1.752
BNE 1027160.00	7.447			BNE 1032112.50	4375		BNE 1004810.00	1.435		BNE 1053092.50	1.629
BNE 1027680.00	7.42			BNE 1032407.50	4375		BNE 1005067.50	1.484		BNE 1053320.00	1.521
BNE 1028180.00	7.407			BNE 1032832.50	4374		BNE 1005325.00	1.536		BNE 1053355.00	1.951
BNE 1028680.00	7.308			BNE 1033225.00	4373		BNE 1005597.50	1.654		BNE 1053385.00	1.787
BNE 1028760.00	7.22			BNE 1033635.00	4372		BNE 1005870.00	1.792		BNE 1053642.50	1.769
BNE 1029200.00	7.132			BNE 1034135.00	4371		BNE 1005870.00	1.686		BNE 1053900.00	1.752
BNE 1029680.00	7.122			BNE 1034630.00	4370		BNE 1006035.00	1.557		BNE 1054270.00	1.237
BNE 1030220.00	7.12			BNE 1035152.00	4369		BNE 1006200.00	1.446		BNE 1054640.00	0.956
BNE 1030870.00	7.077			BNE 1035657.00	4368		BNE 1006200.00	1.775		BNE 1054660.00	1.424
BNE 1031260.00	7.007			BNE 1036180.00	4367		BNE 1006250.00	1.745		BNE 1054680.00	0.921
BNE 1031700.00	6.887			BNE 1036615.00	4367		BNE 1006300.00	1.716		BNE 1054825.00	1.176
BNE 1031995.00	6.895			BNE 1036842.50	4366		BNE 1006300.00	1.716		BNE 1054970.00	1.628
BNE 1032230.00	6.817			BNE 1037002.50	4438		BNE 1006605.00	1.704		BNE 1055125.00	1.607
BNE 1032585.00	6.663			BNE 1037110.00	4438		BNE 1006910.00	1.692		BNE 1055280.00	1.587
BNE 1033080.00	6.555			BNE 1037230.00	4438		BNE 1007160.00	1.568		BNE 1055350.00	1.595
BNE 1033370.00	6.504			BNE 1037455.00	4437		BNE 1007410.00	1.461		BNE 1055420.00	1.604
BNE 1033900.00	6.379			BNE 1037855.00	4436		BNE 1007595.00	1.645		BNE 1055690.00	1.523
BNE 1034370.00	6.266			BNE 1038342.50	4434		BNE 1007780.00	1.884		BNE 1055960.00	1.45
BNE 1034890.00	6.194			BNE 1038850.00	4430		BNE 1007780.00	1.879		BNE 1056180.00	1.627
BNE 1035414.00	6.105			BNE 1039150.00	4427		BNE 1007850.00	1.992		BNE 1056400.00	1.853
BNE 1035900.00	5.982			BNE 1039382.50	4425		BNE 1007920.00	2.119		BNE 1056547.50	1.767
BNE 1036460.00	5.841			BNE 1039617.50	4423		BNE 1008182.50	1.909		BNE 1056695.00	1.689
BNE 1036770.00	5.774			BNE 1039749.00	4421		BNE 1008445.00	1.739		BNE 1056780.00	0.667
BNE 1036915.00	5.73			BNE 1039959.00	4576		BNE 1008685.00	1.731		BNE 1056865.00	0.416
BNE 1037090.00	5.743			BNE 1040170.00	4576		BNE 1008925.00	1.723		BNE 1056920.00	1.906
BNE 1037175.00	5.551			BNE 1040370.00	4576		BNE 1009162.50	1.733		BNE 1056950.00	0.43
BNE 1037285.00	5.515			BNE 1040750.00	4576		BNE 1009400.00	1.743		BNE 1057020.00	0.64
BNE 1037625.00	5.504			BNE 1041120.00	4576		BNE 1009560.00	1.702		BNE 1057090.00	1.256
BNE 1038085.00	5.486			BNE 1041345.00	4576		BNE 1009720.00	1.663		BNE 1057310.00	1.352
BNE 1038600.00	5.441			BNE 1041580.00	4576		BNE 1010105.00	1.841		BNE 1057530.00	1.464
BNE 1039100.00	5.408			BNE 1041830.00	4576		BNE 1010490.00	2.066		BNE 1057785.00	1.606
BNE 1039200.00	5.408			BNE 1042097.50	4576		BNE 1010607.50	1.925		BNE 1058040.00	1.778
BNE 1039200.00	5.408			BNE 1042367.50	4576		BNE 1010725.00	1.802		BNE 1058135.00	1.778
BNE 1039565.00	5.405			BNE 1042507.50	4576		BNE 1010852.50	1.831		BNE 1058230.00	1.778
BNE 1039670.00	5.408			BNE 1042712.50	4576		BNE 1010980.00	1.861		BNE 1058380.00	1.769
BNE 1039670.00	5.408			BNE 1042960.00	4576		BNE 1011245.00	1.752		BNE 1058530.00	1.757
BNE 1039828.00	5.411			BNE 1043045.00	4576		BNE 1011510.00	1.655		BNE 1058632.50	1.661
BNE 1039828.00	5.411			BNE 1043095.00	4577		BNE 1011745.00	1.606		BNE 1058735.00	1.575
BNE 1040090.00	5.409			BNE 1043417.50	4577		BNE 1011980.00	1.559		BNE 1058885.00	1.686
BNE 1040250.00	5.386			BNE 1043892.50	4577		BNE 1012227.50	1.543		BNE 1059035.00	1.814
BNE 1040250.00	5.386			BNE 1044200.00	4577		BNE 1012475.00	1.527		BNE 1059287.50	1.582
BNE 1040490.00	5.334			BNE 1044472.50	4577		BNE 1012475.00	1.521		BNE 1059540.00	1.403
BNE 1041010.00	5.351			BNE 1044732.50	4577		BNE 1012705.00	1.533		BNE 1059765.00	1.423
BNE 1041230.00	5.325			BNE 1045130.00	4577		BNE 1012935.00	1.545		BNE 1059990.00	1.444
BNE 1041460.00	5.286			BNE 1045642.50	4577		BNE 1013062.50	1.541		BNE 1060167.50	1.521
BNE 1041700.00	5.286			BNE 1046032.50	4577		BNE 1013190.00	1.538		BNE 1060345.00	1.606
BNE 1041960.00	5.197			BNE 1046260.00	4577		BNE 1013190.00	1.538		BNE 1060440.00	1.673
BNE 1042235.00	5.095			BNE 1046460.00	4577		BNE 1013317.50	1.53		BNE 1060535.00	1.745
BNE 1042500.00	5.054			BNE 1046740.00	4577		BNE 1013445.00	1.523		BNE 1060775.00	1.665
BNE 1042500.00	5.054			BNE 1047125.00	4578		BNE 1013562.50	1.488		BNE 1061015.00	1.592
BNE 1042515.00	5.052			BNE 1047632.50	4578		BNE 1013680.00	1.454		BNE 1061272.50	1.638
BNE 1042910.00	4.914			BNE 1048145.00	4578		BNE 1013680.00	1.454		BNE 1061530.00	1.686

BNE 1043010.00	4.87			BNE 1048632.50	4578		BNE 1013795.00	1.429		BNE 1061775.00	1.597
BNE 1043010.00	4.87			BNE 1049005.00	4578		BNE 1013910.00	1.406		BNE 1062020.00	1.518
BNE 1043080.00	4.839			BNE 1049245.00	4578		BNE 1014110.00	1.43		BNE 1062277.50	1.413
BNE 1043110.00	4.828			BNE 1049480.00	4579		BNE 1014310.00	1.456		BNE 1062535.00	1.322
BNE 1043110.00	4.828			BNE 1049730.00	4579		BNE 1014460.00	1.447		BNE 1062737.50	1.191
BNE 1043725.00	4.652			BNE 1050150.00	4579		BNE 1014610.00	1.438		BNE 1062940.00	1.086
BNE 1044060.00	4.592			BNE 1050645.00	4579		BNE 1014610.00	1.43		BNE 1063032.50	1.108
BNE 1044340.00	4.519			BNE 1051110.00	4589		BNE 1014850.00	1.334		BNE 1063125.00	1.122
BNE 1044605.00	4.496			BNE 1051627.50	4589		BNE 1015090.00	1.255		BNE 1063125.00	1.178
BNE 1044860.00	4.478			BNE 1052102.50	4590		BNE 1015325.00	1.396		BNE 1063217.50	1.204
BNE 1045400.00	4.423			BNE 1052370.00	4591		BNE 1015560.00	1.574		BNE 1063310.00	1.236
BNE 1045885.00	4.377			BNE 1052492.50	4592		BNE 1015705.00	1.555		BNE 1063477.50	1.434
BNE 1046180.00	4.403			BNE 1052625.00	4602		BNE 1015850.00	1.536		BNE 1063645.00	1.708
BNE 1046340.00	4.392			BNE 1052752.50	4590		BNE 1015850.00	1.536		BNE 1063822.50	1.654
BNE 1046580.00	4.363			BNE 1053092.50	4589		BNE 1015995.00	1.519		BNE 1064000.00	1.604
BNE 1046900.00	4.217			BNE 1053355.00	4589		BNE 1016140.00	1.501		BNE 1064245.00	1.623
BNE 1047350.00	3.939			BNE 1053642.50	4590		BNE 1016390.00	1.589		BNE 1064490.00	1.643
BNE 1047915.00	3.759			BNE 1054270.00	4590		BNE 1016640.00	1.687		BNE 1064750.00	1.456
BNE 1048375.00	3.768			BNE 1054660.00	4590		BNE 1016765.00	1.735		BNE 1065010.00	1.307
BNE 1048890.00	3.637			BNE 1054825.00	4590		BNE 1016890.00	1.786		BNE 1065256.50	1.254
BNE 1049120.00	3.621			BNE 1055125.00	4590		BNE 1016890.00	1.786		BNE 1065503.00	1.206
BNE 1049370.00	3.532			BNE 1055350.00	4591		BNE 1017010.00	1.853		BNE 1065746.50	1.055
BNE 1049590.00	3.515			BNE 1055690.00	4591		BNE 1017130.00	1.926		BNE 1065990.00	0.937
BNE 1049870.00	3.442			BNE 1056180.00	4591		BNE 1017370.00	1.844		BNE 1066247.50	1.009
BNE 1050430.00	3.361			BNE 1056547.50	4591		BNE 1017610.00	1.768		BNE 1066505.00	1.092
BNE 1050860.00	3.295			BNE 1056780.00	4591		BNE 1017765.00	1.825		BNE 1066762.50	1.065
BNE 1051360.00	3.301			BNE 1056920.00	4591		BNE 1017920.00	1.886		BNE 1067020.00	1.04
BNE 1051895.00	3.198			BNE 1057020.00	4591		BNE 1018060.00	1.678		BNE 1067252.50	1.137
BNE 1052310.00	3.276			BNE 1057310.00	4592		BNE 1018200.00	1.511		BNE 1067485.00	1.252
BNE 1052390.00	3.192			BNE 1057785.00	4592		BNE 1018462.50	1.622		BNE 1067725.00	1.297
BNE 1052595.00	3.176			BNE 1058135.00	4592		BNE 1018725.00	1.752		BNE 1067965.00	1.343
BNE 1052640.00	3.033			BNE 1058380.00	4602		BNE 1018910.00	1.734		BNE 1068312.50	1.394
BNE 1052865.00	3.012			BNE 1058632.50	4602		BNE 1019095.00	1.718		BNE 1068660.00	1.447
BNE 1053320.00	3.034			BNE 1058885.00	4602		BNE 1019292.50	1.587		BNE 1068852.50	1.429
BNE 1053385.00	2.921			BNE 1059287.50	4602		BNE 1019490.00	1.472		BNE 1069045.00	1.411
BNE 1053900.00	2.774			BNE 1059765.00	4602		BNE 1019490.00	1.472		BNE 1069290.00	1.353
BNE 1054640.00	2.723			BNE 1060167.50	4603		BNE 1019677.50	1.613		BNE 1069535.00	1.3
BNE 1054680.00	2.688			BNE 1060440.00	4603		BNE 1019865.00	1.783		BNE 1069780.00	1.257
BNE 1054970.00	2.57			BNE 1060775.00	4603		BNE 1019990.00	1.465		BNE 1070025.00	1.218
BNE 1055280.00	2.511			BNE 1061272.50	4603		BNE 1020115.00	1.243		BNE 1070277.50	1.231
BNE 1055420.00	2.477			BNE 1061775.00	4603		BNE 1020320.00	1.047		BNE 1070530.00	1.245
BNE 1055960.00	2.416			BNE 1062277.50	4608		BNE 1020525.00	0.904		BNE 1070785.00	1.224
BNE 1056400.00	2.297			BNE 1062737.50	4615		BNE 1020677.50	1.056		BNE 1071040.00	1.205
BNE 1056695.00	2.271			BNE 1063032.50	4647		BNE 1020830.00	1.27		BNE 1071280.00	1.017
BNE 1056865.00	2.347			BNE 1063217.50	4901		BNE 1020962.50	1.447		BNE 1071520.00	0.88
BNE 1056950.00	2.305			BNE 1063477.50	4911		BNE 1021095.00	1.68		BNE 1071767.50	0.979
BNE 1057090.00	2.253			BNE 1063822.50	4912		BNE 1021317.00	1.653		BNE 1072015.00	1.103
BNE 1057530.00	2.204			BNE 1064245.00	4914		BNE 1021539.00	1.626		BNE 1072017.50	1.103
BNE 1058040.00	2.095			BNE 1064750.00	4917		BNE 1021627.00	1.487		BNE 1072020.00	1.103
BNE 1058230.00	2.067			BNE 1065256.50	4922		BNE 1021715.00	1.37		BNE 1072020.00	1.141
BNE 1058530.00	2.034			BNE 1065746.50	4929		BNE 1021805.00	1.382		BNE 1072267.50	1.118
BNE 1058735.00	2.039			BNE 1066247.50	4938		BNE 1021895.00	1.394		BNE 1072515.00	1.097
BNE 1059035.00	1.951			BNE 1066762.50	4946		BNE 1022000.00	1.449		BNE 1072755.00	1.067
BNE 1059540.00	1.914			BNE 1067252.50	4959		BNE 1022105.00	1.509		BNE 1072995.00	1.04
BNE 1059990.00	1.808			BNE 1067725.00	4970		BNE 1022340.00	1.516		BNE 1073240.00	1.092
BNE 1060345.00	1.713			BNE 1068312.50	4978		BNE 1022575.00	1.528		BNE 1073485.00	1.15
BNE 1060535.00	1.673			BNE 1068852.50	4980		BNE 1022807.50	1.747		BNE 1073742.50	1.133
BNE 1061015.00	1.657			BNE 1069290.00	4979		BNE 1023040.00	2.03		BNE 1074000.00	1.117
BNE 1061530.00	1.601			BNE 1069780.00	4974		BNE 1023305.00	1.933		BNE 1074230.00	1.109
BNE 1062020.00	1.586			BNE 1070277.50	4966		BNE 1023570.00	1.844		BNE 1074460.00	1.103
BNE 1062535.00	1.575			BNE 1070785.00	4956		BNE 1023825.00	1.796		BNE 1074722.50	1.16
BNE 1062940.00	1.578			BNE 1071280.00	4948		BNE 1024080.00	1.75		BNE 1074985.00	1.224
BNE 1063125.00	1.553			BNE 1071767.50	4939		BNE 1024321.50	1.702		BNE 1075232.50	1.111
BNE 1063125.00	1.553			BNE 1072017.50	4935		BNE 1024563.00	1.657		BNE 1075480.00	1.017
BNE 1063310.00	1.535			BNE 1072267.50	5089		BNE 1024816.50	1.578		BNE 1075740.00	0.854
BNE 1063645.00	1.442			BNE 1072755.00	5095		BNE 1025070.00	1.507		BNE 1076000.00	0.736
BNE 1064000.00	1.441			BNE 1073240.00	5101		BNE 1025215.00	1.615		BNE 1076247.50	0.835
BNE 1064490.00	1.393			BNE 1073742.50	5107		BNE 1025360.00	1.739		BNE 1076495.00	0.964
BNE 1065010.00	1.399			BNE 1074230.00	5111		BNE 1025475.00	1.857		BNE 1076752.50	0.794
BNE 1065503.00	1.379			BNE 1074722.50	5115		BNE 1025590.00	1.992		BNE 1077010.00	0.675
BNE 1065990.00	1.387			BNE 1075232.50	5119		BNE 1025880.00	1.863		BNE 1077260.00	0.58
BNE 1066505.00	1.355			BNE 1075740.00	5124		BNE 1026170.00	1.75		BNE 1077510.00	0.508
BNE 1067020.00	1.342			BNE 1076247.50	5130		BNE 1026425.00	1.716		BNE 1077775.00	0.522
BNE 1067485.00	1.297			BNE 1076752.50	5134		BNE 1026680.00	1.683		BNE 1078040.00	0.537
BNE 1067965.00	1.259			BNE 1077260.00	5140		BNE 1026790.00	1.752		BNE 1078282.50	0.646
BNE 1068660.00	1.205			BNE 1077775.00	5142		BNE 1026900.00	1.827		BNE 1078525.00	0.811
BNE 1069045.00	1.184			BNE 1078282.50	5144		BNE 1027030.00	1.85		BNE 1078592.50	0.18
BNE 1069535.00	1.172			BNE 1078592.50	5144		BNE 1027160.00	1.873		BNE 1078660.00	0.101
BNE 1070025.00	1.161						BNE 1027420.00	1.689			
BNE 1070530.00	1.136						BNE 1027680.00	1.538			
BNE 1071040.00	1.119						BNE 1027930.00	1.463			
BNE 1071520.00	1.141						BNE 1028180.00	1.395			
BNE 1072015.00	1.109						BNE 1028430.00	1.563			
BNE 1072020.00	1.109						BNE 1028680.00	1.779			
BNE 1072020.00	1.109						BNE 1028720.00	2.177			
BNE 1072515.00	1.095						BNE 1028760.00	1.776			
BNE 1072995.00	1.084						BNE 1028980.00	1.872			
BNE 1073485.00	1.053						BNE 1029200.00	1.977			
BNE 1074000.00	1.046						BNE 1029440.00	1.855			
BNE 1074460.00	1.06						BNE 1029680.00	1.746			
BNE 1074985.00	1.073						BNE 1029950.00	1.665			
BNE 1075480.00	1.085						BNE 1030220.00	1.59			
BNE 1076000.00	1.086						BNE 1030545.00	1.605			
BNE 1076495.00	1.069						BNE 1030870.00	1.621			
BNE 1077010.00	1.044						BNE 1031065.00	1.723			
BNE 1077510.00	1.011						BNE 1031260.00	1.837			
BNE 1078040.00	0.971						BNE 1031480.00	1.984			
BNE 1078525.00	0.92						BNE 1031700.00	2.155			
BNE 1078660.00	0.918						BNE 1031847.50	1.857			

Appendix D Mike11 Results Q2000

MIKE 11 RESULTS - BRISBANE RIVER MODEL

Q2000 event CRCFORGE rainfall with ARF's

120hr Storm Duration

Chainage [m]	Water Level	Chainage [m]	Discharge	Chainage [m]	Velocity [m/s]	Chainage [m]	Velocity [m/s]
BNE 931570.00	50.124	BNE 931575.00	12000	BNE 931570.00	2.529	BNE 1031995.00	2.547
BNE 931580.00	50.117	BNE 932625.00	11975	BNE 931575.00	2.531	BNE 1032112.50	2.52
BNE 933670.00	48.898	BNE 933970.00	11957	BNE 931580.00	2.532	BNE 1032230.00	2.495
BNE 934270.00	48.859	BNE 934445.00	11944	BNE 932625.00	2.359	BNE 1032407.50	2.709
BNE 934620.00	48.707	BNE 935345.00	11915	BNE 933670.00	2.2	BNE 1032585.00	2.963
BNE 936070.00	48.483	BNE 936445.00	11878	BNE 933970.00	1.423	BNE 1032832.50	2.833
BNE 936820.00	48.357	BNE 938295.00	11862	BNE 934270.00	1.533	BNE 1033080.00	2.714
BNE 939770.00	47.74	BNE 941045.00	11786	BNE 934445.00	1.878	BNE 1033225.00	2.767
BNE 942320.00	47.246	BNE 942945.00	11696	BNE 934620.00	2.491	BNE 1033370.00	2.823
BNE 943570.00	47.194	BNE 943845.00	11582	BNE 935345.00	0.918	BNE 1033635.00	2.975
BNE 944120.00	47.184	BNE 944845.00	11491	BNE 936070.00	0.632	BNE 1033900.00	3.146
BNE 945570.00	47.12	BNE 946370.00	11469	BNE 936445.00	0.865	BNE 1034135.00	3.184
BNE 947170.00	46.775	BNE 947720.00	11460	BNE 936820.00	3.394	BNE 1034370.00	3.224
BNE 948270.00	46.371	BNE 949270.00	11447	BNE 938295.00	1.419	BNE 1034630.00	3.011
BNE 950270.00	45.744	BNE 951295.00	11413	BNE 939770.00	1.775	BNE 1034890.00	2.825
BNE 952320.00	44.758	BNE 953095.00	11384	BNE 941045.00	1.387	BNE 1035152.00	2.904
BNE 953870.00	44.268	BNE 954395.00	11359	BNE 942320.00	1.334	BNE 1035414.00	2.988
BNE 954920.00	43.921	BNE 955445.00	11341	BNE 942945.00	1.007	BNE 1035657.00	3.089
BNE 955970.00	43.608	BNE 957370.00	11318	BNE 943570.00	0.8	BNE 1035900.00	3.198
BNE 958770.00	42.448	BNE 959470.00	11238	BNE 943845.00	0.769	BNE 1036180.00	3.155
BNE 960170.00	42.322	BNE 961120.00	11151	BNE 944120.00	0.971	BNE 1036460.00	3.112
BNE 962070.00	42.056	BNE 963120.00	11105	BNE 944845.00	0.878	BNE 1036615.00	2.872
BNE 964170.00	41.26	BNE 965390.00	11102	BNE 945570.00	1.183	BNE 1036770.00	2.667
BNE 966610.00	40.017	BNE 967010.00	11088	BNE 946370.00	1.027	BNE 1036842.50	2.878
BNE 967410.00	39.454	BNE 968600.00	11077	BNE 947170.00	1.647	BNE 1036915.00	3.127
BNE 969790.00	37.99	BNE 970475.00	11074	BNE 947720.00	1.667	BNE 1037002.50	3.076
BNE 971160.00	37.546	BNE 971710.00	11067	BNE 948270.00	1.689	BNE 1037090.00	3.027
BNE 972260.00	37.22	BNE 972760.00	11063	BNE 949270.00	1.59	BNE 1037110.00	3.235
BNE 973260.00	37.212	BNE 973920.00	11057	BNE 950270.00	1.501	BNE 1037175.00	3.104
BNE 974580.00	36.971	BNE 975300.00	11054	BNE 951295.00	1.846	BNE 1037230.00	3.176
BNE 976020.00	36.934	BNE 976385.00	11055	BNE 952320.00	2.429	BNE 1037285.00	3.251
BNE 976750.00	36.948	BNE 977515.00	11059	BNE 953095.00	1.71	BNE 1037455.00	2.963
BNE 978280.00	36.475	BNE 978893.50	11079	BNE 953870.00	1.341	BNE 1037625.00	2.721
BNE 979507.00	34.654	BNE 979510.00	11380	BNE 954395.00	1.45	BNE 1037855.00	2.29
BNE 979513.00	34.529	BNE 979521.50	11378	BNE 954920.00	1.96	BNE 1038085.00	1.978
BNE 979530.00	34.649	BNE 979930.00	11072	BNE 955445.00	1.448	BNE 1038342.50	1.955
BNE 980330.00	34.459	BNE 980995.00	11051	BNE 955970.00	1.351	BNE 1038600.00	1.932
BNE 981660.00	34.001	BNE 982060.00	11050	BNE 957370.00	1.652	BNE 1038850.00	1.896
BNE 982460.00	33.839	BNE 983310.00	11052	BNE 958770.00	2.143	BNE 1039100.00	1.861
BNE 984160.00	33.198	BNE 984710.00	11052	BNE 959470.00	1.111	BNE 1039150.00	1.852
BNE 985260.00	32.735	BNE 985870.00	11053	BNE 960170.00	0.886	BNE 1039200.00	1.843
BNE 986480.00	31.874	BNE 987220.00	11054	BNE 961120.00	1.172	BNE 1039200.00	1.758
BNE 987960.00	30.827	BNE 988060.00	11055	BNE 962070.00	1.868	BNE 1039382.50	1.725
BNE 988160.00	30.565	BNE 988165.00	11055	BNE 963120.00	1.376	BNE 1039565.00	1.694
BNE 988170.00	30.531	BNE 988265.00	11055	BNE 964170.00	1.304	BNE 1039617.50	1.697
BNE 988360.00	30.329	BNE 989030.00	11058	BNE 965390.00	1.55	BNE 1039670.00	1.701
BNE 989700.00	29.57	BNE 990200.00	11064	BNE 966610.00	1.96	BNE 1039670.00	1.652
BNE 990700.00	29.172	BNE 990730.00	11058	BNE 967010.00	1.916	BNE 1039749.00	1.665
BNE 990760.00	29.089	BNE 991235.00	11059	BNE 967410.00	1.923	BNE 1039828.00	1.678
BNE 991710.00	28.876	BNE 992065.00	11096	BNE 968600.00	2.127	BNE 1039828.00	1.624
BNE 992420.00	28.684	BNE 992435.00	11114	BNE 969790.00	2.38	BNE 1039959.00	1.67
BNE 992450.00	28.578	BNE 992460.00	11114	BNE 970475.00	2.155	BNE 1040090.00	1.72
BNE 992470.00	28.533	BNE 992570.00	11157	BNE 971160.00	1.986	BNE 1040170.00	1.821
BNE 992670.00	28.451	BNE 993215.00	11071	BNE 971710.00	2.044	BNE 1040250.00	1.934
BNE 993760.00	27.842	BNE 994260.00	11066	BNE 972260.00	2.128	BNE 1040250.00	1.902
BNE 994760.00	27.58	BNE 995225.00	11069	BNE 972760.00	1.8	BNE 1040370.00	2.089
BNE 995690.00	26.959	BNE 996335.00	11068	BNE 973260.00	1.559	BNE 1040490.00	2.318
BNE 996980.00	25.807	BNE 997720.00	11070	BNE 973920.00	1.907	BNE 1040750.00	2.023
BNE 998460.00	25.351	BNE 998810.00	11071	BNE 974580.00	2.502	BNE 1041010.00	1.794
BNE 999160.00	25.06	BNE 999580.00	11072	BNE 975300.00	2.13	BNE 1041120.00	1.76
BNE 1000000.00	24.756	BNE 1000142.50	11159	BNE 976020.00	1.88	BNE 1041230.00	1.728
BNE 1000285.00	24.514	BNE 1000530.00	11160	BNE 976385.00	1.098	BNE 1041345.00	1.829
BNE 1000775.00	24.142	BNE 1001045.00	11160	BNE 976750.00	0.994	BNE 1041460.00	1.945
BNE 1001315.00	24.04	BNE 1001590.00	11161	BNE 977515.00	1.023	BNE 1041580.00	1.898
BNE 1001865.00	23.515	BNE 1002107.50	11161	BNE 978280.00	1.56	BNE 1041700.00	1.854
BNE 1002350.00	23.382	BNE 1002567.50	11162	BNE 978893.50	1.801	BNE 1041830.00	2.06
BNE 1002785.00	23.392	BNE 1003030.00	11162	BNE 979507.00	2.138	BNE 1041960.00	2.319
BNE 1003275.00	23.101	BNE 1003525.00	11163	BNE 979510.00	2.163	BNE 1042097.50	2.453
BNE 1003775.00	22.866	BNE 1004037.50	11163	BNE 979513.00	2.219	BNE 1042235.00	2.604
BNE 1004300.00	22.371	BNE 1004555.00	11164	BNE 979521.50	1.798	BNE 1042367.50	2.426
BNE 1004810.00	22.351	BNE 1005067.50	11165	BNE 979530.00	1.461	BNE 1042500.00	2.271
BNE 1005325.00	22.133	BNE 1005597.50	11165	BNE 979930.00	1.516	BNE 1042500.00	2.312
BNE 1005870.00	21.804	BNE 1006035.00	9594	BNE 980330.00	1.577	BNE 1042507.50	2.303
BNE 1005870.00	21.804	BNE 1006250.00	11272	BNE 980995.00	1.815	BNE 1042515.00	2.295
BNE 1006200.00	21.701	BNE 1006605.00	11876	BNE 981660.00	2.14	BNE 1042712.50	2.122
BNE 1006200.00	21.701	BNE 1007160.00	11874	BNE 982060.00	1.886	BNE 1042910.00	2.003
BNE 1006300.00	21.659	BNE 1007595.00	11872	BNE 982460.00	1.706	BNE 1042960.00	2.008
BNE 1006300.00	21.659	BNE 1007850.00	11861	BNE 983310.00	1.848	BNE 1043010.00	2.014
BNE 1006910.00	21.436	BNE 1008182.50	11859	BNE 984160.00	2.098	BNE 1043010.00	2.05
BNE 1007410.00	21.365	BNE 1008685.00	11857	BNE 984710.00	2.074	BNE 1043045.00	2.055
BNE 1007780.00	21.148	BNE 1009162.50	11857	BNE 985260.00	2.051	BNE 1043080.00	2.059
BNE 1007780.00	21.148	BNE 1009560.00	11856	BNE 985870.00	2.192	BNE 1043095.00	2.057
BNE 1007920.00	21.027	BNE 1010105.00	11853	BNE 986480.00	2.353	BNE 1043110.00	2.055
BNE 1008445.00	20.935	BNE 1010607.50	11852	BNE 987220.00	1.908	BNE 1043110.00	2.125
BNE 1008925.00	20.874	BNE 1010852.50	11851	BNE 987960.00	1.605	BNE 1043417.50	2.175
BNE 1009400.00	20.742	BNE 1011245.00	11851	BNE 988060.00	1.784	BNE 1043725.00	2.241
BNE 1009720.00	20.682	BNE 1011745.00	11849	BNE 988160.00	2.007	BNE 1043892.50	2.395
BNE 1010490.00	20.261	BNE 1012227.50	11847	BNE 988165.00	3.537	BNE 1044060.00	2.572
BNE 1010725.00	20.326	BNE 1012705.00	11834	BNE 988170.00	2.014	BNE 1044200.00	2.68
BNE 1010980.00	20.265	BNE 1013062.50	11833	BNE 988265.00	1.88	BNE 1044340.00	2.798
BNE 1011510.00	20.36	BNE 1013317.50	10847	BNE 988360.00	1.763	BNE 1044472.50	2.601
BNE 1011980.00	20.403	BNE 1013562.50	10845	BNE 989030.00	1.616	BNE 1044605.00	2.431
BNE 1012475.00	20.407	BNE 1013795.00	10244	BNE 989700.00	1.491	BNE 1044732.50	2.234

BNE 1012475.00	20.407			BNE 1014110.00	10238		BNE 990200.00 \	1.742		BNE 1044860.00 \	2.066
BNE 1012935.00	20.363			BNE 1014460.00	10232		BNE 990700.00 \	2.093		BNE 1045130.00 \	2.028
BNE 1013190.00	20.356			BNE 1014850.00	10197		BNE 990730.00 \	2.213		BNE 1045400.00 \	1.991
BNE 1013190.00	20.356			BNE 1015325.00	10193		BNE 990760.00 \	2.347		BNE 1045642.50 \	1.994
BNE 1013445.00	20.345			BNE 1015705.00	10191		BNE 991235.00 \	1.585		BNE 1045885.00 \	1.997
BNE 1013680.00	20.336			BNE 1015995.00	10814		BNE 991710.00 \	1.198		BNE 1046032.50 \	1.932
BNE 1013680.00	20.336			BNE 1016390.00	10812		BNE 992065.00 \	1.236		BNE 1046180.00 \	1.871
BNE 1013910.00	20.326			BNE 1016765.00	10810		BNE 992420.00 \	1.271		BNE 1046260.00 \	1.999
BNE 1014310.00	20.271			BNE 1017010.00	11817		BNE 992435.00 \	1.518		BNE 1046340.00 \	2.145
BNE 1014610.00	20.182			BNE 1017370.00	11815		BNE 992450.00 \	1.87		BNE 1046460.00 \	2.086
BNE 1014610.00	20.182			BNE 1017765.00	11814		BNE 992460.00 \	1.969		BNE 1046580.00 \	2.029
BNE 1015090.00	20.025			BNE 1018060.00	11813		BNE 992470.00 \	1.874		BNE 1046740.00 \	2.208
BNE 1015560.00	19.867			BNE 1018462.50	11812		BNE 992570.00 \	1.82		BNE 1046900.00 \	2.422
BNE 1015850.00	19.807			BNE 1018910.00	11811		BNE 992670.00 \	1.743		BNE 1047125.00 \	2.702
BNE 1015850.00	19.807			BNE 1019292.50	11812		BNE 993215.00 \	1.967		BNE 1047350.00 \	3.055
BNE 1016140.00	19.747			BNE 1019677.50	11810		BNE 993760.00 \	2.259		BNE 1047632.50 \	2.981
BNE 1016640.00	19.609			BNE 1019990.00	11810		BNE 994260.00 \	1.736		BNE 1047915.00 \	2.91
BNE 1016890.00	19.498			BNE 1020320.00	11809		BNE 994760.00 \	1.41		BNE 1048145.00 \	2.373
BNE 1016890.00	19.498			BNE 1020677.50	11808		BNE 995225.00 \	1.802		BNE 1048375.00 \	2.003
BNE 1017130.00	19.36			BNE 1020962.50	11807		BNE 995690.00 \	2.494		BNE 1048632.50 \	2.265
BNE 1017610.00	19.293			BNE 1021317.00	11807		BNE 996335.00 \	2.324		BNE 1048890.00 \	2.606
BNE 1017920.00	19.139			BNE 1021627.00	11806		BNE 996980.00 \	2.176		BNE 1049005.00 \	2.577
BNE 1018200.00	19.094			BNE 1021805.00	11806		BNE 997720.00 \	1.666		BNE 1049120.00 \	2.549
BNE 1018725.00	18.793			BNE 1022000.00	11806		BNE 998460.00 \	1.349		BNE 1049245.00 \	2.796
BNE 1019095.00	18.726			BNE 1022340.00	11805		BNE 998810.00 \	1.743		BNE 1049370.00 \	3.095
BNE 1019490.00	18.671			BNE 1022807.50	11813		BNE 999160.00 \	2.46		BNE 1049480.00 \	2.986
BNE 1019490.00	18.671			BNE 1023305.00	11812		BNE 999580.00 \	2.315		BNE 1049590.00 \	2.884
BNE 1019865.00	18.369			BNE 1023825.00	11812		BNE 1000000.00	2.192		BNE 1049730.00 \	2.963
BNE 1020115.00	18.545			BNE 1024321.50	11811		BNE 1000142.50	2.393		BNE 1049870.00 \	3.047
BNE 1020525.00	18.538			BNE 1024816.50	11810		BNE 1000285.00	2.633		BNE 1050150.00 \	2.838
BNE 1020830.00	18.354			BNE 1025215.00	11809		BNE 1000530.00	2.763		BNE 1050430.00 \	2.656
BNE 1021095.00	18.098			BNE 1025475.00	11808		BNE 1000775.00	2.907		BNE 1050645.00 \	2.811
BNE 1021539.00	17.857			BNE 1025880.00	11808		BNE 1001045.00	2.597		BNE 1050860.00 \	2.986
BNE 1021715.00	17.889			BNE 1026425.00	11807		BNE 1001315.00	2.347		BNE 1051110.00 \	2.865
BNE 1021895.00	17.77			BNE 1026790.00	11806		BNE 1001590.00	2.814		BNE 1051360.00 \	2.754
BNE 1022105.00	17.584			BNE 1027030.00	11806		BNE 1001865.00	3.513		BNE 1051627.50 \	2.971
BNE 1022575.00	17.488			BNE 1027420.00	11805		BNE 1002107.50	3.266		BNE 1051895.00 \	3.224
BNE 1023040.00	17.189			BNE 1027930.00	11804		BNE 1002350.00	3.052		BNE 1052102.50 \	2.734
BNE 1023570.00	17.091			BNE 1028430.00	11803		BNE 1002567.50	2.66		BNE 1052310.00 \	2.373
BNE 1024080.00	17.071			BNE 1028720.00	11802		BNE 1002785.00	2.356		BNE 1052370.00 \	3.8
BNE 1024563.00	17.042			BNE 1028980.00	11802		BNE 1003030.00	2.599		BNE 1052390.00 \	3.041
BNE 1025070.00	17.037			BNE 1029440.00	11800		BNE 1003275.00	2.898		BNE 1052492.50 \	3.185
BNE 1025360.00	16.898			BNE 1029950.00	11798		BNE 1003525.00	2.858		BNE 1052595.00 \	3.344
BNE 1025590.00	16.731			BNE 1030545.00	11795		BNE 1003775.00	2.82		BNE 1052625.00 \	5.361
BNE 1026170.00	16.506			BNE 1031065.00	11794		BNE 1004037.50	3.039		BNE 1052640.00 \	3.129
BNE 1026680.00	16.413			BNE 1031480.00	11793		BNE 1004300.00	3.294		BNE 1052752.50 \	3.255
BNE 1026900.00	16.248			BNE 1031847.50	11793		BNE 1004555.00	2.61		BNE 1052865.00 \	3.391
BNE 1027160.00	16.059			BNE 1032112.50	11792		BNE 1004810.00	2.161		BNE 1053092.50 \	3.058
BNE 1027680.00	16.113			BNE 1032407.50	11792		BNE 1005067.50	2.205		BNE 1053320.00 \	2.785
BNE 1028180.00	16.145			BNE 1032832.50	11791		BNE 1005325.00	2.25		BNE 1053355.00 \	3.459
BNE 1028680.00	15.972			BNE 1033225.00	11790		BNE 1005597.50	2.443		BNE 1053385.00 \	2.99
BNE 1028760.00	15.938			BNE 1033635.00	11789		BNE 1005870.00	2.672		BNE 1053642.50 \	2.997
BNE 1029200.00	15.797			BNE 1034135.00	11789		BNE 1005870.00	2.292		BNE 1053900.00 \	3.005
BNE 1029680.00	15.83			BNE 1034630.00	11788		BNE 1006035.00	2.238		BNE 1054270.00 \	2.212
BNE 1030220.00	15.827			BNE 1035152.00	11787		BNE 1006200.00	2.188		BNE 1054640.00 \	1.75
BNE 1030870.00	15.756			BNE 1035657.00	11786		BNE 1006200.00	2.586		BNE 1054660.00 \	2.371
BNE 1031260.00	15.563			BNE 1036180.00	11785		BNE 1006250.00	2.567		BNE 1054680.00 \	1.768
BNE 1031700.00	15.219			BNE 1036615.00	11784		BNE 1006300.00	2.549		BNE 1054825.00 \	2.23
BNE 1031995.00	15.402			BNE 1036842.50	11784		BNE 1006300.00	2.679		BNE 1054970.00 \	3.02
BNE 1032230.00	15.282			BNE 1037002.50	11786		BNE 1006605.00	2.528		BNE 1055125.00 \	3.007
BNE 1032585.00	14.927			BNE 1037110.00	11786		BNE 1006910.00	2.393		BNE 1055280.00 \	2.993
BNE 1033080.00	14.765			BNE 1037230.00	11786		BNE 1007160.00	2.16		BNE 1055350.00 \	2.965
BNE 1033370.00	14.661			BNE 1037455.00	11785		BNE 1007410.00	1.968		BNE 1055420.00 \	2.938
BNE 1033900.00	14.385			BNE 1037855.00	11785		BNE 1007595.00	2.221		BNE 1055690.00 \	2.765
BNE 1034370.00	14.15			BNE 1038342.50	11781		BNE 1007780.00	2.548		BNE 1055960.00 \	2.611
BNE 1034890.00	14.083			BNE 1038850.00	11778		BNE 1007780.00	2.543		BNE 1056180.00 \	2.945
BNE 1035414.00	13.889			BNE 1039150.00	11776		BNE 1007850.00	2.696		BNE 1056400.00 \	3.375
BNE 1035900.00	13.643			BNE 1039382.50	10776		BNE 1007920.00	2.868		BNE 1056547.50 \	3.275
BNE 1036460.00	13.377			BNE 1039617.50	10774		BNE 1008182.50	2.831		BNE 1056695.00 \	3.181
BNE 1036770.00	13.335			BNE 1039749.00	10200		BNE 1008445.00	2.795		BNE 1056780.00 \	1.383
BNE 1036915.00	13.164			BNE 1039959.00	10029		BNE 1008685.00	2.745		BNE 1056865.00 \	0.884
BNE 1037090.00	13.168			BNE 1040170.00	10028		BNE 1008925.00	2.697		BNE 1056920.00 \	3.465
BNE 1037175.00	12.704			BNE 1040370.00	9566		BNE 1009162.50	2.668		BNE 1056950.00 \	0.912
BNE 1037285.00	12.646			BNE 1040750.00	9564		BNE 1009400.00	2.639		BNE 1057020.00 \	1.344
BNE 1037625.00	12.708			BNE 1041120.00	9560		BNE 1009560.00	2.496		BNE 1057090.00 \	2.552
BNE 1038085.00	12.794			BNE 1041345.00	9558		BNE 1009720.00	2.369		BNE 1057310.00 \	2.709
BNE 1038600.00	12.755			BNE 1041580.00	9557		BNE 1010105.00	2.759		BNE 1057530.00 \	2.888
BNE 1039100.00	12.729			BNE 1041830.00	9556		BNE 1010490.00	3.305		BNE 1057785.00 \	3.115
BNE 1039200.00	12.727			BNE 1042097.50	9555		BNE 1010607.50	3.128		BNE 1058040.00 \	3.381
BNE 1039200.00	12.727			BNE 1042367.50	9554		BNE 1010725.00	2.969		BNE 1058135.00 \	3.38
BNE 1039565.00	12.72			BNE 1042507.50	10024		BNE 1010852.50	3.015		BNE 1058230.00 \	3.379
BNE 1039670.00	12.714			BNE 1042712.50	10024		BNE 1010980.00	3.062		BNE 1058380.00 \	3.46
BNE 1039670.00	12.714			BNE 1042960.00	10023		BNE 1011245.00	2.77		BNE 1058530.00 \	3.545
BNE 1039828.00	12.704			BNE 1043045.00	10641		BNE 1011510.00	2.528		BNE 1058632.50 \	3.3
BNE 1039828.00	12.704			BNE 1043095.00	10641		BNE 1011745.00	2.379		BNE 1058735.00 \	3.088
BNE 1040090.00	12.678			BNE 1043417.50	11701		BNE 1011980.00	2.247		BNE 1058885.00 \	3.381
BNE 1040250.00	12.636			BNE 1043892.50	11701		BNE 1012227.50	2.172		BNE 1059035.00 \	3.736
BNE 1040250.00	12.636			BNE 1044200.00	11701		BNE 1012475.00	2.103		BNE 1059287.50 \	3.199
BNE 1040490.00	12.546			BNE 1044472.50	11701		BNE 1012475.00	2.096		BNE 1059540.00 \	2.796
BNE 1041010.00	12.61			BNE 1044732.50	11700		BNE 1012705.00	2.134		BNE 1059765.00 \	2.809
BNE 1041230.00	12.598			BNE 1045130.00	11700		BNE 1012935.00	2.173		BNE 1059990.00 \	2.822
BNE 1041460.00	12.527			BNE 1045642.50	11700		BNE 1013062.50	2.143		BNE 1060167.50 \	3.096
BNE 1041700.00	12.509			BNE 1046032.50	11700		BNE 1013190.00	2.113		BNE 1060345.00 \	3.429
BNE 1041960.00	12.386			BNE 1046260.00	11699		BNE 1013190.00	1.975		BNE 1060440.00 \	3.59
BNE 1042235.00	12.217			BNE 1046460.00	11699		BNE 1013317.50	1.958		BNE 1060535.00 \	3.768
BNE 1042500.00	12.183			BNE 1046740.00	11699		BNE 1013445.00	1.945		BNE 1060775.00 \	3.513
BNE 1042500.00	12.183			BNE 1047125.00	11699		BNE 1013562.50	1.901		BNE 1061015.00 \	3.291
BNE 1042515.00	12.181			BNE 1047632.50	11699		BNE 1013680.00	1.861		BNE 1061272.50 \	3.428
BNE 1042910.00	12.114			BNE 1048145.00	11699		BNE 1013680.00	1.851		BNE 1061530.00 \	3.578

BNE 1043010.00	12.065			BNE 1048632.50	11699		BNE 1013795.00	1.813		BNE 1061775.00	3.365
BNE 1043010.00	12.065			BNE 1049005.00	11698		BNE 1013910.00	1.776		BNE 1062020.00	3.176
BNE 1043080.00	12.027			BNE 1049245.00	11698		BNE 1014110.00	1.76		BNE 1062277.50	2.885
BNE 1043110.00	12.011			BNE 1049480.00	11698		BNE 1014310.00	1.744		BNE 1062535.00	2.642
BNE 1043110.00	12.011			BNE 1049730.00	11698		BNE 1014460.00	1.706		BNE 1062737.50	2.388
BNE 1043725.00	11.664			BNE 1050150.00	11698		BNE 1014610.00	1.67		BNE 1062940.00	2.179
BNE 1044060.00	11.465			BNE 1050645.00	11698		BNE 1014610.00	1.672		BNE 1063032.50	2.232
BNE 1044340.00	11.312			BNE 1051110.00	11698		BNE 1014850.00	1.775		BNE 1063125.00	2.288
BNE 1044605.00	11.316			BNE 1051627.50	11698		BNE 1015090.00	1.894		BNE 1063125.00	2.289
BNE 1044860.00	11.336			BNE 1052102.50	11698		BNE 1015325.00	2.067		BNE 1063217.50	2.368
BNE 1045400.00	11.267			BNE 1052370.00	11698		BNE 1015560.00	2.276		BNE 1063310.00	2.454
BNE 1045885.00	11.216			BNE 1052492.50	11698		BNE 1015705.00	2.254		BNE 1063477.50	2.869
BNE 1046180.00	11.219			BNE 1052625.00	11698		BNE 1015850.00	2.232		BNE 1063645.00	3.454
BNE 1046340.00	11.149			BNE 1052752.50	11698		BNE 1015850.00	2.299		BNE 1063822.50	3.346
BNE 1046580.00	11.115			BNE 1053092.50	11698		BNE 1015995.00	2.257		BNE 1064000.00	3.245
BNE 1046900.00	10.852			BNE 1053355.00	11698		BNE 1016140.00	2.216		BNE 1064245.00	3.291
BNE 1047350.00	10.27			BNE 1053642.50	11698		BNE 1016390.00	2.186		BNE 1064490.00	3.339
BNE 1047915.00	9.885			BNE 1054270.00	11698		BNE 1016640.00	2.166		BNE 1064750.00	2.969
BNE 1048375.00	9.984			BNE 1054660.00	11698		BNE 1016765.00	2.227		BNE 1065010.00	2.673
BNE 1048890.00	9.748			BNE 1054825.00	11698		BNE 1016890.00	2.291		BNE 1065256.50	2.583
BNE 1049120.00	9.692			BNE 1055125.00	11698		BNE 1016890.00	2.442		BNE 1065503.00	2.499
BNE 1049370.00	9.451			BNE 1055350.00	11698		BNE 1017010.00	2.513		BNE 1065746.50	2.175
BNE 1049590.00	9.424			BNE 1055690.00	11698		BNE 1017130.00	2.588		BNE 1065990.00	1.926
BNE 1049870.00	9.267			BNE 1056180.00	11698		BNE 1017370.00	2.345		BNE 1066247.50	2.078
BNE 1050430.00	9.198			BNE 1056547.50	11698		BNE 1017610.00	2.144		BNE 1066505.00	2.256
BNE 1050860.00	9.034			BNE 1056780.00	11698		BNE 1017765.00	2.261		BNE 1066762.50	2.189
BNE 1051360.00	9.037			BNE 1056920.00	11698		BNE 1017920.00	2.393		BNE 1067020.00	2.125
BNE 1051895.00	8.856			BNE 1057020.00	11698		BNE 1018060.00	2.297		BNE 1067252.50	2.291
BNE 1052310.00	9.061			BNE 1057310.00	11698		BNE 1018200.00	2.209		BNE 1067485.00	2.486
BNE 1052390.00	8.798			BNE 1057785.00	11698		BNE 1018462.50	2.46		BNE 1067725.00	2.614
BNE 1052595.00	8.701			BNE 1058135.00	11698		BNE 1018725.00	2.775		BNE 1067965.00	2.757
BNE 1052640.00	7.772			BNE 1058380.00	11698		BNE 1018910.00	2.646		BNE 1068312.50	2.881
BNE 1052865.00	7.679			BNE 1058632.50	11698		BNE 1019095.00	2.529		BNE 1068660.00	3.016
BNE 1053320.00	7.818			BNE 1058885.00	11698		BNE 1019292.50	2.389		BNE 1068852.50	2.992
BNE 1053385.00	7.569			BNE 1059287.50	11698		BNE 1019490.00	2.262		BNE 1069045.00	2.969
BNE 1053900.00	7.263			BNE 1059765.00	11698		BNE 1019490.00	2.261		BNE 1069290.00	2.851
BNE 1054640.00	7.187			BNE 1060167.50	11698		BNE 1019677.50	2.561		BNE 1069535.00	2.742
BNE 1054680.00	7.094			BNE 1060440.00	11698		BNE 1019865.00	2.951		BNE 1069780.00	2.678
BNE 1054970.00	6.719			BNE 1060775.00	11698		BNE 1019990.00	2.231		BNE 1070025.00	2.618
BNE 1055280.00	6.551			BNE 1061272.50	11698		BNE 1020115.00	1.793		BNE 1070277.50	2.651
BNE 1055420.00	6.487			BNE 1061775.00	11698		BNE 1020320.00	1.524		BNE 1070530.00	2.685
BNE 1055960.00	6.368			BNE 1062277.50	11698		BNE 1020525.00	1.325		BNE 1070785.00	2.649
BNE 1056400.00	6.022			BNE 1062737.50	11698		BNE 1020677.50	1.619		BNE 1071040.00	2.613
BNE 1056695.00	5.943			BNE 1063032.50	11698		BNE 1020830.00	2.08		BNE 1071280.00	2.233
BNE 1056865.00	6.235			BNE 1063217.50	11703		BNE 1020962.50	2.35		BNE 1071520.00	1.95
BNE 1056950.00	6.092			BNE 1063477.50	11703		BNE 1021095.00	2.7		BNE 1071767.50	2.162
BNE 1057090.00	5.872			BNE 1063822.50	11703		BNE 1021317.00	2.624		BNE 1072015.00	2.425
BNE 1057530.00	5.713			BNE 1064245.00	11702		BNE 1021539.00	2.552		BNE 1072017.50	2.425
BNE 1058040.00	5.392			BNE 1064750.00	11702		BNE 1021627.00	2.261		BNE 1072020.00	2.424
BNE 1058230.00	5.315			BNE 1065256.50	11702		BNE 1021715.00	2.03		BNE 1072020.00	2.425
BNE 1058530.00	5.147			BNE 1065746.50	11702		BNE 1021805.00	2.11		BNE 1072267.50	2.395
BNE 1058735.00	5.211			BNE 1066247.50	11702		BNE 1021895.00	2.196		BNE 1072515.00	2.365
BNE 1059035.00	4.84			BNE 1066762.50	11702		BNE 1022000.00	2.357		BNE 1072755.00	2.304
BNE 1059540.00	4.781			BNE 1067252.50	11702		BNE 1022105.00	2.543		BNE 1072995.00	2.247
BNE 1059990.00	4.465			BNE 1067725.00	11703		BNE 1022340.00	2.394		BNE 1073240.00	2.364
BNE 1060345.00	4.051			BNE 1068312.50	11703		BNE 1022575.00	2.264		BNE 1073485.00	2.493
BNE 1060535.00	3.868			BNE 1068852.50	11703		BNE 1022807.50	2.594		BNE 1073742.50	2.466
BNE 1061015.00	3.87			BNE 1069290.00	11703		BNE 1023040.00	3.034		BNE 1074000.00	2.44
BNE 1061530.00	3.626			BNE 1069780.00	11703		BNE 1023305.00	3.002		BNE 1074230.00	2.434
BNE 1062020.00	3.603			BNE 1070277.50	11703		BNE 1023570.00	2.97		BNE 1074460.00	2.428
BNE 1062535.00	3.615			BNE 1070785.00	11703		BNE 1023825.00	2.819		BNE 1074722.50	2.573
BNE 1062940.00	3.643			BNE 1071280.00	11703		BNE 1024080.00	2.682		BNE 1074985.00	2.735
BNE 1063125.00	3.578			BNE 1071767.50	11703		BNE 1024321.50	2.577		BNE 1075232.50	2.478
BNE 1063125.00	3.578			BNE 1072017.50	11703		BNE 1024563.00	2.481		BNE 1075480.00	2.265
BNE 1063310.00	3.484			BNE 1072267.50	11708		BNE 1024816.50	2.347		BNE 1075740.00	1.903
BNE 1063645.00	3.131			BNE 1072755.00	11708		BNE 1025070.00	2.227		BNE 1076000.00	1.64
BNE 1064000.00	3.134			BNE 1073240.00	11708		BNE 1025215.00	2.412		BNE 1076247.50	1.874
BNE 1064490.00	2.956			BNE 1073742.50	11708		BNE 1025360.00	2.63		BNE 1076495.00	2.186
BNE 1065010.00	2.984			BNE 1074230.00	11708		BNE 1025475.00	2.803		BNE 1076752.50	1.797
BNE 1065503.00	2.911			BNE 1074722.50	11708		BNE 1025590.00	3		BNE 1077010.00	1.525
BNE 1065990.00	2.96			BNE 1075232.50	11708		BNE 1025880.00	2.911		BNE 1077260.00	1.311
BNE 1066505.00	2.833			BNE 1075740.00	11708		BNE 1026170.00	2.628		BNE 1077510.00	1.15
BNE 1067020.00	2.796			BNE 1076247.50	11708		BNE 1026425.00	2.666		BNE 1077775.00	1.183
BNE 1067485.00	2.646			BNE 1076752.50	11708		BNE 1026680.00	2.523		BNE 1078040.00	1.219
BNE 1067965.00	2.482			BNE 1077260.00	11708		BNE 1026790.00	2.677		BNE 1078282.50	1.47
BNE 1068660.00	2.259			BNE 1077775.00	11708		BNE 1026900.00	2.852		BNE 1078525.00	1.853
BNE 1069045.00	2.168			BNE 1078282.50	11708		BNE 1027030.00	2.976		BNE 1078592.50	0.41
BNE 1069535.00	2.112			BNE 1078592.50	11708		BNE 1027160.00	3.11		BNE 1078660.00	0.231
BNE 1070025.00	2.047						BNE 1027420.00	2.684			
BNE 1070530.00	1.93						BNE 1027680.00	2.36			
BNE 1071040.00	1.845						BNE 1027930.00	2.17			
BNE 1071520.00	1.927						BNE 1028180.00	2.009			
BNE 1072015.00	1.779						BNE 1028430.00	2.254			
BNE 1072020.00	1.778						BNE 1028680.00	2.569			
BNE 1072020.00	1.778						BNE 1028720.00	3.081			
BNE 1072515.00	1.717						BNE 1028760.00	2.47			
BNE 1072995.00	1.675						BNE 1028980.00	2.611			
BNE 1073485.00	1.537						BNE 1029200.00	2.769			
BNE 1074000.00	1.441						BNE 1029440.00	2.551			
BNE 1074460.00	1.348						BNE 1029680.00	2.366			
BNE 1074985.00	1.142						BNE 1029950.00	2.252			
BNE 1075480.00	1.114						BNE 1030220.00	2.161			
BNE 1076000.00	1.137						BNE 1030545.00	2.218			
BNE 1076495.00	1.063						BNE 1030870.00	2.278			
BNE 1077010.00	1.041						BNE 1031065.00	2.544			
BNE 1077510.00	1.009						BNE 1031260.00	2.88			
BNE 1078040.00	0.97						BNE 1031480.00	3.236			
BNE 1078525.00	0.92						BNE 1031700.00	3.692			
BNE 1078660.00	0.918						BNE 1031847.50	3.014			

Brisbane City Council
ABN 72 002 765 795

City Design
Level 3 TC Beirne Centre
315 Brunswick Street Mall
Fortitude Valley 4006
Locked Mail Bag 6996
Albion Qld 4010
Telephone 07 3403 3849
Facsimile 07 3403 0551

Contact: [redacted]
Phone:
Fax:
Your Ref:
Our Ref: *Brisbane River/Green Bridge*

14 February, 2004

[redacted]
Sinclair Knight Merz Pty Ltd
369 Ann Street
BRISBANE QLD 4004

Dear [redacted]

RE: Brief to Calculate Floods of Various Return Periods on the Brisbane River

An urgent request has been made for flood frequency information for the proposed tender documentation of the Green Bridge.

We require estimates of flows, with the following frequencies Q10, Q20, Q50 and Q2000, using the Australian Rainfall and Runoff techniques and the design storms from the latest CRC Forge analysis combined with Aerial Reduction Factors and the latest Wivenhoe Dam operating rules.

The CRC Forge data provides 50 year and 2,000 year rainfall duration's of 24, 48, 96 and 120 hour. City Design will carry out the rainfall extraction for you to apply to your model's sub-catchments using our GIS techniques.

Should you have any queries about this brief or wish to discuss it in detail, please do not hesitate to contact me on the above number.

Yours faithfully

[redacted]
Mary Shortland
Manager
CITY DESIGN

Sinclair Knight Merz
369 Ann Street, Brisbane 4000
PO Box 246
Spring Hill QLD 4004 Australia

Tel: +61 7 3244 7100
Fax: +61 7 3244 7307
Web: www.skmconsulting.com

Ken Morris
City Design
Locked Mail Bag 6996
Albion QLD 4010

17/02/2004

040217_Q2000_event.doc
QE09169

Dear Sir

Calculation of Floods of Various Return Periods on the Brisbane River

Q2000 Event

In response to your letter dated 28 January 2004 please find herewith results for Q2000 event. Results for the other return intervals will follow shortly.

Assumptions

The assumptions used to predict Q2000 discharges are as follows.

- Rainfall was based on data received from City Design on 11 February 2004
- Rainfall based on CRCFORGE rainfall with 1 in 2000 year ARI and Areal Reduction Factors.
- Storm durations of 24, 48, 96 and 120 hrs were modelled
- PMP temporal pattern 'a' used for all durations
- An Initial loss of 10 mm and a Continuing loss of 1 mm/hr were used in the RAFTS models

Methodology

The methodology used to produce the Q2000 event results is as follows:

- Convert BCC Rainfall to RAFTS nodes
- Create *.csv file for use in HYDCON program
- Use HYDCON to create *.his file
- Run RAFTS [no dams]
- Output hydrographs from RAFTS for nodes WIV27 (Wivenhoe) Som32 (Somerset) SAV8 (Lockyer) and 1B (Bremer).

SKM

- Convert hydrographs to *.prn file for use in NR&M Dams program
- Convert *.dat file to direct hydrograph in RAFTS
- Run RAFTS [with dams]
- Determine critical duration
- Import RAFTS hydrographs into MIKE 11
- Run MIKE 11 using re-calibrated model

Results Q2000

The Critical duration for the Q2000 event is the 48hr storm. A full table of results is presented in **Appendix A.**

Storm Duration	RAFTS Discharge at Port Office
24	11746
48	**14219**
96	13481
120	13958

Should you have any queries, please call to discuss.

Regards

[redacted]
Project Manager
Phone:
Fax:
E-mail: [redacted]

Contact name: [redacted]
Phone:
Fax *direct*:
Your Reference:
Our Reference: CD040015

Brisbane City Council
ABN 72 002 765 795

City Design
Level 3 TC Beirne Centre
315 Brunswick Street Mall
Fortitude Valley 4006
Locked Mail Bag 6996
Albion Qld 4010
Telephone 07 3403 3849
Facsimile 07 3403 0551

SINCLAIR KNIGHT MERZ
JOB No. 0209169
RECEIVED 27 FEB 2004
TO | DATE
[redacted] | 3/2/04

23 February 2004

The Manager
Sinclair Knight Merz Pty Ltd
P.O. Box 246
SPRING HILL QLD 4004

Dear Sir,

Re: Provision of Hydraulic Engineering Services

1. Provision of Services

Subject to your signing and returning a duplicate of this letter, the Brisbane City Council through City Design will engage Sinclair Knight Merz Pty Ltd to provide hydraulic engineering services as described in paragraph 2 of this letter.

The entire contract between you and the Council for the provision of the Services is comprised of the terms of this letter together with the attached terms and conditions marked "Attachment A" and entitled "General Conditions for Services" and all other attachments to this letter (**"the Contract"**).

When you sign the duplicate letter, you need to also initial each page of the attached documentation and return the document and its attachments to the Council Liaison Officer named at the end of this letter.

If you disagree with any of the attached terms, please do not unilaterally amend any of the terms and conditions of the Contract. Instead, please contact the Council Liaison Officer as a matter of urgency. Any unilateral amendment by you of the terms and conditions will not be construed by Council as an amendment or variation to this Contract unless the Council agrees in writing to such amendments.

2. Nature of the Services

The scope of work to be undertaken through this contract includes the provision of hydraulic engineering services in relation to:

a) Review of the Brisbane River Q2000,Q50 and other items as specified in the **Brief to Calculate Floods of Various Return Periods on the Brisbane River (letter dated 14/2/04)**, and as directed by the Council liaison officer.

3. Timing

The Contractor shall:

(a) commence work on the Services on 1 February 2004; and;

(b) ensure that all of the Services are duly performed and delivered to the Council in accordance with this Contract on or before 30 March 2004.

[redacted]

Our Business - A Better Brisbane

4. **Specified Personnel**

The Contractor shall ensure that the Services are performed by the officers specified in the proposal (**"the Specified Personnel"**). If at any time:

(i) the Specified Personnel is not available for any reason (whether within the control of the Contractor or not); or

(ii) the Council is of the reasonable opinion that the Specified Personnel **either** does not have the capacity to undertake the Services to the level required **or** is responsible for any disruption in the delivery of the Services;

then the Contractor shall replace the Specified Personnel in question with another suitably qualified and experienced person who is acceptable to Council. Such person shall be included within the term "Specified Personnel" and the substitution shall be:

A. undertaken at the earliest opportunity but not later than seven (7) days (or such later date as the Council may agree) from the date the Specified Personnel in question has ceased to be available; and

B. at no additional cost to Council.

5. **Fees**

Subject to clauses 5, 6 and 7 of the General Conditions for Services, the fees payable by the Council for the provision of the Services (**"the Fees"**) shall be charged at no more than the following rates (which includes all cost and expenses associated with the provision of the Services):

Table of Fees

Person to perform the Service	**Fee exclusive of GST**
[redacted]	***$130/hr***
	$86/hr

These Fees shall be charged per hour up to an initial maximum value of $9,312 (incl. GST) and will not be charged on a pro-rata basis. Additional hours are to be agree with Council prior to proceeding.

Please also note that:

(a) these Fees shall be invoiced on a fortnightly basis and shall be only payable pursuant to clause 5 of the General Conditions. The provisions of clause 5 of the General Conditions also specify that these Fees will **only** be payable on the receipt by Council of a properly rendered invoice. See clause 5 for what will constitute a properly rendered invoice and also for when Council will be paying these Fees; and

(b) the amount of GST applicable to Services will be determined in accordance with the GST Laws as amended from time to time.

6. **Indemnity**

(a) Upon demand being made by the Council, the Contractor shall fully indemnify the Council and its officers and employees:

(i) from and against any claim made by any of the Contractor's officers, employees, agents, Specified Personnel or its authorised sub-contractors (if any) in relation to the performance of the Services that they are employees (as commonly defined) of Council or "workers" of the Council under the *WorkCover Act 1996* of Queensland (as amended from time to time); and

[redacted]

(ii) from and against any loss or liability whatsoever (including, but not limited to, legal costs and expenses on a solicitor/own client basis) arising out of or in connection with any claim that the performance of the Services (including the creation, preparation or delivery of any Deliverable) has or is infringing (either wholly or partially, directly or indirectly) the Intellectual Property Rights of any person; and

(iii) in relation to any costs, losses, or damages of any kind suffered or incurred by the Council or its officers or employees where such costs, losses or damages arise in any manner out of:

A. any negligent, wilful, unlawful or wrongful act or omission by the Contractor or any of the Contractor's officers, employees, agents, Specified Personnel or its authorised sub-contractors (if any) in relation to the performance of the Services in relation to the provision of the Services; or

B. any breach of this Contract by the Contractor or any of the Contractor's officers, employees, agents, Specified Personnel or its authorised sub-contractors (if any).

(b) Notwithstanding paragraph (a), the Contractor's liability for any claim arising out of any personal injury to or the death of any person or loss of or damage to property shall be reduced to the extent that such claim is a direct result of **either** any breach by the Council of any provision of this Contract which causes delay to the Contractor performing the Services as required by this Contract **or** any negligent act or omission of the Council, its employees, agents, contractors or sub-contractors.

(c) If the Contractor fails to comply with its obligations under this Contract and fails to rectify such breach as and when requested to do so by the Council in accordance with this Contract, the Council may engage another Contractor to provide the Services in question and shall be able to recover such costs of engaging the other Contractor from the Contractor. The Council shall use its best endeavours to ensure that the Services in question are carried out in the most cost effective manner and shall provide the Contractor with written documentation of the actual costs incurred by the Council. The Contractor shall pay such costs to the Council within 14 days of being requested to do so by Council.

7. Notices

Please note that notices under the Contract may be delivered by hand, by mail or by facsimile to our respective offices. In the case of the Council, any such notices must be addressed to Mr Ken Morris, Principal Engineer Flood Management, City Design, Locked Bag 6996, ALBION, QLD 4010 or by facsimile to 07 3403 0438.

In the case of the Contractor, any such notices must be addressed to Sinclair Knight Merz, PO Box 246 Spring Hill Q 4004, or by facsimile to 07 3244 7306.

If there are any changes to a party's postal address, facsimile number and/or person to whom notices are to be addressed, these changes will only be effective as and from the date the other party receives written advice of such change.

Notices between Council and the Contractor shall be deemed to be given:

(a) in the case of hand delivery – upon written acknowledgment of receipt by an officer or other duly authorised employee, agent or representative of the receiving party;

(b) in the case of posting – 3 days after dispatch; and

(c) in the case of a facsimile – upon receipt of the answerback transmission or other proof of completion of transmission.

[redacted]

8. **Council Liaison Officer**

The person holding, occupying or performing the duties of Principal Engineer Flood Management shall be the Council Liaison Officer with responsibility for supervision of the Contract on behalf of the Brisbane City Council and shall have authority to act on behalf of the Council and issue and receive any written notification under the Contract. This person shall act reasonably in the exercise of this authority.

Yours faithfully

[redacted]

Don Carroll
Group Manager
Water and Environment

Dated this 23 day of 2 2004

Attachments:

Attachment A. General Conditions for Services

FORM OF ACCEPTANCE TO BE SIGNED AND RETURNED BY CONTRACTOR

As a person duly authorised to act for and on behalf of Sinclair Knight Merz Pty Ltd, I agree on behalf of Sinclair Knight Merz Pty Ltd to the provision of the abovementioned Services in accordance with the terms and conditions set out in and attached to this letter.

Signed for and on behalf of Sinclair Knight Merz Pty Ltd by

[redacted] (print name and title of signatory)

Signature

in the presence of: [redacted] (print name and title of Witness)

[redacted]

Signature of Witness

Date: 4/3/04

[redacted]

ATTACHMENT A

General Conditions for Services

1. Interpretation and Applicable Law

In the Contract, the definitions in the attached letter and the following definitions and rules of interpretation apply:

"**the Contractor**" includes the assignees of the Contractor.

"**Contract Material**" means the originals and copies of materials, papers, reports, books, memoranda, accounting records, files, texts, data, computer printouts, computer data (including, but without limiting the generality thereof, financial models of all types) however recorded, stored or embodied in any document or other form of media (electronic or otherwise) and being material etc that is ***either*** provided by the Council to the Contractor (or any of its staff, contractors or Specified Personnel (if any)) for the provision or the performance of the Services (including each and every outcome or Deliverable) ***or*** created or prepared by the Contractor or any of its staff or contractors in or incidental to the provision of the Services.

"**Contractor's GST Liability**" means the GST the Contractor is required by the GST Laws to pay or remit in relation to the supply of the Services to the Council under this Contract.

"**Council's Consent**" means prior written consent (which shall not be unreasonably withheld) of the Council which may be given subject to such terms and conditions as the Council may see fit to impose.

"**GST**" means the goods and services tax payable pursuant to the GST Laws.

"**GST Laws**" means the GST law (as defined by *A New Tax System (Goods and Services Tax) Act 1999* of the Commonwealth) together with all other laws and regulations which impose or regulate the implementation and operation of GST and all laws and regulations dealing with price exploitation and excessive profit taking as a result of the transition to the New Tax System.

"**Intellectual Property Rights**" means all forms of patent, copyright, trade mark (whether registered or not), trade name, trade secret, knowhow, discovery, invention, secret process, design, improvement in procedure, innovation or confidential information and any right to register or claim any type of intellectual property.

Words importing a gender include any other gender. Words in the singular number include the plural and works in the plural number include the singular.

This Contract shall be governed by and construed in accordance with the law for the time being in the State of Queensland and the parties submit to the jurisdiction of the courts of that State.

2. Provision of the Services

In providing the Services, the Contractor:

(a) shall provide and complete the Services with reasonable care and skill and act professionally at all times in the performance of the Services and shall provide and complete the Services (including the Deliverables) in accordance with the requirements of the Documentation (including timetables (if any)) and the terms and conditions of this Contract;

(b) shall consult regularly with and keep the Council Liaison Officer informed as to the progress and delivery of the Services;

(c) shall comply with all laws, licences, industrial awards, permits and all other lawful requirements that from time to time are applicable to the proper provision of the Services by the Contractor, its staff, contractors, sub-contractors and assignees (including, but not limited to, the *Environment Protection Act 1994* (Qld) and the *Workplace Health and Safety Act 1995* (Qld);

(d) shall, if the Services involve works that require excavation or boring (either manually or through the use of machinery), contact Dial Before You Dig ("**DBYD**") on telephone number 1100 (or such other number as is assigned from time to time to that service or its replacement service) to request utility plans of underground services in the areas requiring excavation and further, shall ensure that any excavation work undertaken as part of the Services does not adversely impact the proper operation of any utility services as identified by DBYD. All of the cost of contacting DBYD and any damages to such utility services as a direct result of the Contractor providing the Services will be the sole and absolute responsibility of the Contractor;

(e) shall not assign, sub-contract or transfer any of its rights under this Contract without the Council's Consent. Such consent shall be subject to such terms and conditions as the Council deems appropriate to protect its interests;

(f) shall at all times keep and maintain accurate records of the time spent in the provision of the Services. Where required by the Council to verify the fees and expenses invoiced by the Contractor, the Contractor shall provide the Council with free access to such records; and

(g) shall ensure that at all times during the term of this Contract each member of its staff, contractors or sub-contractors (including Specified Personnel) does not take any step which will lead to the Contractor being in breach of its obligations under this Contract.

[redacted]

3. Variation of Contract

No variation to the nature or scope of the Services (including the manner of providing the Services) (**"the Variation"**) shall be binding on either party unless and until agreed in writing by both parties. The prices applicable to any such Variation shall be as agreed to by the parties but cannot be proceeded with if the Fees and the prices for the Variation will, in aggregate, exceed $100,000 (exclusive of GST).

4. Contract Material

4.1 The title to and ownership of intellectual property (including copyright) in all Contract Material shall vest in the Council immediately upon its creation. The Contractor shall do all things necessary to perfect the vesting of the intellectual property rights attaching to the Contract Material in the Council.

4.2 On the expiration or earlier termination of the Contract, the Contractor shall deliver all copies of the Contract Material (irrespective of the form in which such material has been copied, stored, written, recorded by any means whether electronic or encrypted) to the Council Liaison Officer.

4.3 The Contractor shall not use the Contract Material for any purpose other than performance of the Services. Further, the Contractor shall take all reasonable steps to treat and keep such Contract Material as strictly confidential and shall ensure no unauthorised persons or any third party (including any member of the public) have access to any part of the Contract Material during or after the completion of the Services without the Council's Consent.

5. Fees and Invoice procedure

5.1 The Contractor shall provide the Services for the Fees specified in the attached letter. The parties agree that the Contractor shall not charge the Council for any additional fees nor incur such additional fees without first obtaining the Council's Consent.

5.2 No monies shall be paid to the Contractor until such time as the Council Liaison Officer has received an properly rendered invoice that meets the requirements of clause 5.3 **and** the Council Liaison Officer has not exercised the provisions of clause 5.4.

All such invoices must be invoiced on the basis specified in the attached letter (unless otherwise agreed in writing with the Council Liaison Officer). Except where clause 5.4 applies, the Fees invoiced shall be paid 30 days from receipt of a correctly rendered invoice by the Council.

5.3 An invoice will be deemed to not have been properly rendered unless it:

(a) specifies the title of the Service, the name of the relevant business unit within Council, name of the Council Liaison Officer and the Contract number or purchase order number (if any); and

(b) provides such details of the Fees invoiced as the Council Liaison Officer may from time to time require (and which may include the attachment of receipts, the number of hours involved and the amounts of GST (if any)); and

and is a valid tax invoice (as defined by the GST Laws) that also specifies the amount of GST payable in respect of the Services invoiced.

5.4 If at any time before the delivery of an correctly rendered invoice for Services or within 21 days of receipt by the Council Liaison Officer of a correctly rendered invoice, the Council Liaison Officer advises the Contractor that he or she is not satisfied with the standard and progress of all or any of the Services in question (**"Disputed Services"**), then:

(a) the Contractor shall promptly re-perform or re-deliver such Disputed Services until such time as the Council Liaison Officer is satisfied that the Disputed Services have been satisfactorily performed or provided in accordance with this Contract; and

(b) within 30 days of receipt of a correctly rendered invoice, the Council shall pay the Fees for the Services that are not Disputed Services.

The Council shall only be legally required to pay the Fees for any Disputed Services if the Council Liaison Officer is satisfied that the Disputed Services have been satisfactorily re-performed or re-provided to meet the requirements of this Contract. In such a case, payment shall be within 30 days of the Council Liaison Officer being satisfied with the re-performance and re-delivery of such Disputed Services.

6. Goods and Services Tax

6.1 Where the Council is legally obliged to pay an invoice pursuant to this Contract, the Contractor shall also be entitled to claim from the Council the amount of the Contractor's GST Liability for any Services to which the invoice relates **provided that** GST is applicable to those Services **and** the invoice is a properly rendered invoice that complies with the requirements of clause 5.3.

6.2 Except as expressly provided by this clause:

(a) the Contractor shall have no other claim against the Council that arises from or is in connection with any GST payable in respect of the Services;

(b) no other provision of this Contract shall operate to provide for any adjustment of the Fees or give rise to any other claim by the Contractor in connection with any GST payable in respect of the Services; and

(c) where any payment by the Council under this Contract is determined by referer[redacted]osts,

expenses, liabilities or damages incurred by the Contractor, the payment shall exclude any amount for which the Contractor is entitled to claim an input tax credit under the GST Laws.

7. Conflict of Interest

The Contractor warrants that, as of the date of entering into this Contract, no conflict of interest exists or is likely to arise in the performance of their obligations under this Contract. If during the term of this Contract, a conflict or risk of conflict of interest arises, the Contractor undertakes to notify the Council immediately in writing of that conflict or risk.

8. Negation of employment, agency and partnership

The Contractor shall not represent itself as being an employee, agent or partner of the Council and acknowledges that there is no relationship of employment, agency or partnership with the Council.

9. Termination of this Contract

9.1 The Council may:

(a) suspend the scope of the Services at any time during the term of this Contract by the provision of a written notice to the Contractor specifying the extent to which the scope of the Services are to be suspended and the date from which such suspension is to take effect (a "**Suspension Notice**"); or

(b) at any time terminate this Contract due to the Contractor:

(i) failing to comply with a Default Notice as required by clause 9.2;

(ii) having engaged in conduct or practice that is detrimental or harmful to the good name, reputation or interests of the Council;

(iii) entering into any form of insolvency administration or breaching paragraph 7 of the attached letter or clauses 2.2(e) or 4 of these General Conditions; or

(iv) having offered or given any gratuity, bribe, bonus or discount of any sort to any member of the Brisbane City Council or any officer, employee or agent of the Council.

Such termination shall be effected by the Council giving the Contractor a written notice terminating this Contract and specifying the date of termination (a "**Termination Notice**").

9.2 Where the Contractor has failed to comply with the provisions of paragraphs 4, 6 or 7 of the attached letter or clauses 2, 4, 7 or 8 of these General Conditions, the Council may give the Contractor a written notice specifying the breach and requiring the Contractor to rectify the breach within the Specified Time ("**Default Notice**").

For the purposes of this clause, the "**Specified Time**" in relation to any breach of paragraph 6 of the attached letter or clauses 2, 4, 7 or 8 shall be 14 days from the date of the Default Notice (or such longer time period as specified by the Council in the Default Notice) and in relation to a breach of paragraphs 4 or 7 of the attached letter, shall be 7 days from the date of the Default Notice (or such longer time period as specified by the Council in the Default Notice).

9.3 Upon receipt of a Termination Notice or a Suspension Notice pursuant to clause 9.1, the Contractor shall immediately:

(a) where the Contract has been terminated – cease work in accordance with the Termination Notice; or

(b) where the scope of work has been suspended – suspend work in accordance with the Suspension Notice;

and take all steps necessary to minimise the loss suffered by it as a result of either notice and continue to provide Services that are not affected by any such notice. Any termination or suspension of all or part of the Services shall not affect any right or entitlement which either party is entitled to claim under this Contract.

9.4 Upon the termination or suspension of Services, the Council's liability (if any) to the Contractor shall be limited to:

(a) in relation to termination – payments for any Services (or any part) performed in accordance with the Contract before the date of termination as specified in the Termination Notice;

(b) in relation to suspension of the Services – payments for any Services (or any part) performed in accordance with the Contract before the date of suspension as specified in the Suspension Notice; and

(c) any reasonable costs properly incurred by the Contractor which are directly attributable to the termination of the Contract or the suspension of Services (whichever is applicable) but which shall not include loss of prospective profits;

and payments for any Services not affected by either a Termination Notice or a Suspension Notice **provided always** that the maximum amount of the Council's liability to the Contractor under this clause shall be capped at the amount of the Fees (as varied pursuant to clause 3 or abated pursuant to clause 9.4(a)). The Contractor shall **not** be entitled to loss of profits.

9.5 This Contract can be terminated by mutual written agreement of the parties.

[redacted]

5030

TELEPHONE MESSAGE

JOB Brisbane River Flood Study FILE

PHONE CALL TO/FROM [redacted] TIME

OF BCC PHONE [redacted] DATE 15/03/04

DETAILS OF MESSAGE: Questions About Brisbane River Flood Model

- Asked about Scenic Rim upstream of [redacted]
  - Advised that this was for future job
- Asked if upstream boundary was Savages crossing
  - Advised that ch 91320 was Savages crossing
- Asked why there were 60 inflow points in model and this need to be ≈6
  - Advised that with the IRFS new tributaries were added
- Asked whether the DSFD file contained all hydrographs from calib
  - Advised that they would not contain all but would contain extras not called up in mike boundary file
- Asked if model took into account dam operating procedures.
  - Advised that [redacted] imported to dams → Paths → MIKE
- Asked what T & L represented - advised that this was Total & Local Hydros
- Asked about operation rules - advised that I would be sure and to ask Sally.

BY: [redacted]

CIRCULATION & ACTION

NAME	ACTION REQUIRED	INIT'	DATE
[redacted]	Note & Return call		

5030

TELEPHONE MESSAGE

JOB _____ FILE _____

PHONE CALL TO/FROM _____ TIME _____

OF _____ PHONE _____ DATE _____

DETAILS OF MESSAGE:

- Asked what version I was running
- advised MIKE II 1999 b
- He asked about 30 s timestep & if it varied
- Advised that I didn't think it changed but wasn't certain

BY: _____

CIRCULATION & ACTION

NAME	ACTION REQUIRED	INIT'	DATE

5030

TELEPHONE MESSAGE

JOB Brisbane River Flood Study

FILE

PHONE CALL TO/FROM [redacted]

TIME 1:00

OF BCC

PHONE

DATE 18/3/04

DETAILS OF MESSAGE:

[redacted] wanted to know about shutdown errors that come up at the start of runs. (Do you have them too?)
I Advised that we also had these errors they were investigated but we decided to leave as is. & for more info on errors speak to Rob.
He advised that this was ok he just wanted to check if we had errors too

BY: [redacted]

CIRCULATION & ACTION

NAME	ACTION REQUIRED	INIT'	DATE
[redacted]	Note	✓	

Review of

BRISBANE RIVER FLOOD STUDY

Report to Brisbane City Council

Independent Review Panel

Russell Mein (Chair), Colin Apelt, [redacted] Erwin Weinmann

3 September 2003

Executive Summary

This review was commissioned by the Brisbane City Council, so as to obtain independent and expert advice as to 'whether the August 2003 estimates of the Q100 flow and level at the Brisbane Port Office are reasonable'. [Q100 designates the peak discharge that can be expected to be equalled or exceeded once every 100 years on average].

In the conduct of the review, the Panel had two presentation/discussion sessions with representatives of the prime consultant (Sinclair Knight Merz), City Design, and the Department of Natural Resources and Mines (one session). Two draft reports (SKM, dated 8 and 28 August 2003, respectively) with the latest estimates of the Q100 values were the key documents.

It should be stated at the outset that the estimation of Q100 for a catchment of this size (nearly 14000 sq. km) is a challenging task. The extreme variability of rainfall, the change in catchment response due to the construction of dams, and the variable conditions in the tidal section of the river, are some of the factors which complicate the application of 'standard' flood methodologies. The advent of new techniques for flood frequency analysis and for extreme rainfall estimates, together with much improved hydraulic routing methods for estuaries, has added much to the technologies now available for flood estimation.

The Panel:

(i) have reviewed the methodology used by SKM to determine the Q100 river flow and level

(ii) believe that the appropriate technical processes have been followed in this study

(iii) based on the evidence available to it, is of the view that, for the Brisbane Port Office, the best current estimates for

- the Q100 flow is 6000 m^3/s
- the Q100 level is 3.3 m AHD

There is an inevitable degree of uncertainty in any estimates of this kind; in this case, heightened by the variable influence of the Somerset and Wivenhoe Dams on different storm events on the Brisbane River Catchment. A quite plausible range for the Q100 flow is 5000 to 7000 m^3/s and for the Q100 level, 2.8 to 3.8 m AHD. It seems certain that the position of the best estimates in the respective ranges can be more precisely determined, and the width of these ranges could be significantly reduced, with further investigation as outlined in Section 5.2 of this report.

The Panel notes that the current 'best estimates' of Q100 and the corresponding flood level at the Port Office provide a sufficient basis for a decision on whether the currently adopted flood levels are broadly acceptable. However, for general flood risk assessments and risk-based flood management decisions, more refined flood frequency estimates will ultimately be required.

Acknowledgment

The provision of material from representatives of the Brisbane City Council, City Design, Department of Natural Resources and Mines, and Sinclair Knight Merz greatly helped the Panel in the conduct of this review. It is a pleasure to acknowledge the high level of cooperation accorded to the Panel by these organisations in responses to questions and requests for information. In doing so, it is important to stress that the Panel has reached its conclusions independently, based on its own interpretations of the material supplied to it.

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1. Introduction

1.1 Purpose of report.

The Brisbane City Council (BCC) appointed a Review Panel in July 2003 to provide independent advice to, and make expert assessment of, a study being conducted by Sinclair Knight Merz (SKM) on design flood flows and levels in the Brisbane River. This report provides the Panel's determination as to whether the SKM estimates of the Q100 flow and level (ie. those likely to be equalled or exceeded on an average once in 100 years) are reasonable.

1.2 Background

A number of studies have been carried out in recent years to estimate the risk of flooding of areas of Brisbane from the Brisbane River. Given the size and complexity of the catchment, exacerbated by tidal effects in the downstream river reaches, the task is a challenging one; it is not surprising that there has been considerable variability in the design estimates of both flow and level. These are documented in the "Chronology of Events" prepared by Council (Appendix 1).

There have been major advances in the last five years in the methodology used to estimate extreme floods from rainfall, including design data that was not previously available for large catchments. The 2003 SKM Study was commissioned to provide an updated estimate of design flood with the new technologies, with the Panel providing an independent review role (see Appendix for Terms of Reference). The Panel met with the consultants and others for progress presentations on 31 July and 14 August 2003, and received draft copies of the relevant sections of the SKM report on 22 August.

1.3 Guide to this report

This review begins with a general overview of what can be termed best practice in flood hydrology (Chapter 2). It then highlights the particular characteristics of the catchment and estuarine zone of the Brisbane River which affect flood flows and levels (Chapter 3). Chapter 4 gives the Panel's assessment of the methodology used in the most recent Brisbane Flood Study (SKM, 2003 (a) and (b)), with comments on the results obtained. The Conclusion (Chapter 5) provides a statement as the most likely value of the Q100 flood and level at the Port Office in Brisbane, and the uncertainty that exists in these estimates. Recommendations for the work required to reduce this remaining uncertainty are included.

2. Design flood estimation – aims and best practice methodology

2.1 Introduction

Design flood estimation is not a simple process of following clearly defined standards and guidelines but it involves a considerable degree of judgement by the investigator. Before assessing the different studies and comparing their results, it is therefore useful to discuss more broadly what design flood estimation aims to achieve, what methods are available to achieve these aims and what issues are involved in applying the methods.

This section starts by explaining the aims of design flood estimation and introducing the most important principles and technical terms used in design flood estimation. The introductory description of best practice methodology is divided into three parts: flood frequency analysis, rainfall-based approaches for estimating design flood flows and hydraulic methods for converting design flood flows to design flood levels. The section concludes with a discussion of uncertainty in design flood estimates and its implications.

2.2 Aims and principles of design flood estimation

Flooding is a natural part of the flow regime of the Brisbane River and its tributaries. Its major cause is heavy storm rainfall over parts or all of the Brisbane River catchment. The nature and magnitude of flooding resulting from heavy storms depends also on catchment conditions, with the worst floods occurring when a heavy rainfall occurs over an already wet catchment. Major land use changes in the catchment have the potential to modify the flood response to storm rainfall, as do major storage developments such as the construction of Somerset and Wivenhoe Dams. For planning and floodplain management, design flood estimation must therefore relate to the *current or expected future catchment conditions*.

The distribution of flood events over time is almost random; there is no clearly discernible or predictable pattern of how flood flow periods occur. Similarly, the magnitude of flood events also varies randomly. It is therefore not possible to predict the actual occurrence of the next flood but only to estimate the *average flood frequency*, expressed as the average number of years between occurrences of floods of a given magnitude and referred to as the Average Recurrence Interval (or ARI). The aim of design flood estimation is to establish the *flood frequency curve* for a site of interest, or the relationship between flood magnitude and flood frequency.

The observations from *historic flood events* provide the main source of information for design flood estimation. Because of the great variability of climate and catchment conditions producing floods, each observed flood event differs from the next one with respect to one or several flood characteristics. For the purpose of flood management and design it is therefore necessary to define representative flood events which reflect the most likely combinations of the different flood characteristics for different magnitudes of events. These *defined flood events (DFE)* or *design flood events* are derived from historic flood data by means of statistical frequency analysis or by hydrologic modelling methods.

For a particular flood event, the maximum flood levels reached at different locations along the river are the characteristics of most direct interest to floodplain management. However, these are closely related to the peak flows experienced at those locations, which lend themselves better to frequency analysis. Design flood estimation therefore involves two steps. In the first step, *hydrologic* estimation methods are applied to estimate *design flood flows*, specifically peak flow rates for given ARIs, expressed in m^3/s. In the case of the Brisbane River Flood Study, the design flow of specific interest is Q100, the estimated peak flood flow with an ARI of 100 years. In the second step, *hydraulic* methods are then applied to convert the design flood flows to *design flood levels*. In the case of the lower Brisbane River, which is subject to tidal influences, there is no unique relationship between flood flows and flood levels, and a set of representative design conditions have to be assumed in the hydraulic analysis.

The methods applied in design flood estimation should follow best practice guidelines, to the extent that these have been formulated and are applicable to a specific situation. In Australia, the adopted guidelines for design flood estimation are documented in 'Australian Rainfall and Runoff – a Guide to Design Flood Estimation' (ARR, IEAust, 1999). These guidelines are not prescriptive, and in more complex flood estimation situations such as the Brisbane River catchment, they allow for a substantial degree of subjective interpretation by the designer, based on experience and professional judgement.

While designers and decision makers generally require a "best estimate" of the flood magnitude for a given ARI, it must be recognised that usually such estimates involve a considerable degree of uncertainty which may need to be allowed for in the decision making process. An indicative range of uncertainty is provided by confidence limits around the best estimate.

A range of different methods is available to the designer for both the hydrologic and hydraulic analysis components. In each specific case, the selection of the most appropriate method depends on the amount and quality of the data available, the particular characteristics of the catchment and the intended use and importance of the flood estimates. In situations where the design flood estimates are used to support decisions with far-reaching consequences, the approach should make best use of all relevant sources of data and information, and comparative analysis using a number of methods would be desirable. In the case of the Brisbane River Flood Study, the various investigators have followed two main approaches in the hydrologic analysis:

- frequency analysis of flood events extracted from streamflow records, and
- hydrologic modelling approaches to derive simulated design flood events from design rainfall events.

In the following, these two approaches are described in more detail.

2.3 Frequency analysis of observed flood data

The expected frequency of floods of different magnitudes can be assessed by a statistical frequency analysis of observed flood events. For this purpose, a series of

annual maximum flood events is extracted from an essentially complete record of streamflow data at a stream gauging station that has operated over a sufficiently long period of time. For this analysis to be meaningful, the data in the flood series have to reasonably satisfy the following basic assumptions:

- the occurrence of flood events is *random* and the events used in the analysis are *independent* of each other
- the events in the flood series are *homogeneous* (from the same population of events), *stationary* (free of any significant time trend) and *consistent* (not affected by any changes in the methods of measuring the data)
- the flood data being analysed are *representative* of the flood conditions of interest

In considering these assumptions it must be recognised that flood flows are not directly observed, but are estimated from observed water levels at the gauging site by means of a rating curve. The rating curve is established from flow velocity measurements (gaugings) for different flow magnitudes, but often the range of gaugings does not extend to the largest observed floods. Flood flow estimates for these larger events thus need to be based on extrapolated rating curves and are of lower accuracy.

Where the flood data do not readily satisfy some of the basic assumptions of statistical frequency analysis, because of changed catchment conditions or different methods of observation, adjustments need to be applied to some data points to render the series more homogeneous. In some cases, additional data on large historical floods may also be available, but these are generally based on less accurate forms of flood observations. Decisions on the use of adjusted and possibly lower quality data involve a trade-off between the benefit of potentially useful additional information and the danger of contaminating a reliable data series with "noise" from lower quality data.

Another potentially useful source of flood data is from other stream gauging stations in the same catchment or from stations in neighbouring catchments that have similar flood characteristics. If the flood data from these stations, after some form of standardisation, satisfy the assumption of homogeneity, they can be combined to undertake a regional flood frequency analysis. Again the balance between additional information and noise introduced by regional data needs to be carefully assessed.

For each data series to be analysed, a theoretical probability distribution is fitted which should reflect the characteristics of the empirical flood frequency distribution defined by the observed floods. The fitted distribution can then be used to estimate flood magnitudes over the full range of ARIs of interest; this often involves some degree of extrapolation beyond the range of observed floods. Many different probability distributions and parameter estimation methods are available for this fitting process, but only a relatively small number of these are used in standard Australian practice. In more complex flood estimation situations, such as the Brisbane River catchment, the choice of distribution and parameter estimation method can have a significant bearing on the resulting design flood estimates.

In practice, the dilemma involved in the selection of the most appropriate data set and analysis method from a range of alternatives is often addressed by undertaking flood

frequency analyses for a number of different flood series using a range of methods. The results of these analyses are then carefully evaluated, and the estimates considered to be most plausible and reliable selected as a design basis.

Since the preparation of the current version of the Australian guidelines on flood frequency analysis (ARR, IEAust, 1999), which were originally published in 1987, a number of important developments in flood frequency analysis methodology have taken place. In addition to the Log-Pearson 3 (LP3) distribution recommended in ARR, a range of other generalised distributions are now available for fitting, and the traditional product moment method for determining distribution parameters has been supplemented by the more robust L-moment and LH-moment methods. Bayesian methods of flood frequency analysis (Kuczera, 1999) allow different weights to be assigned to different forms of flood data, so that their influence on the final design flood estimate reflects the different levels of information content. These newer developments not only provide analysts with more powerful and flexible tools for flood frequency analysis, they also give a clearer indication of the uncertainties in design flood estimates (see Section 2.6). The guidelines on flood frequency analysis in Book IV of ARR (IEAust, 1999) are currently being revised, and the revision team has indicated that these newer developments will form an integral part of the new guidelines.

2.4 Rainfall-based approaches

Since floods are generally produced by heavy rainfall, an alternative to flood frequency analysis is to focus the attention on storm rainfalls and their transformation to flood events. Rainfall-based approaches overcome the lack of direct flood observations for the conditions of interest by incorporating knowledge of physical hydrologic and hydraulic processes into models that simulate how floods are generated. Because of the complex nature and high degree of temporal and spatial variability of processes, the models are forced to adopt a simplified, conceptual representation of the catchment and the governing processes. To the extent that the model structure reflects the key catchment characteristics, and the model parameters can be validated against observations, the models provide a reliable and flexible tool to derive design floods for a significantly broader range of conditions than is directly reflected in the observed flood data. However, the reliability of the design flood estimates reduces with increasing degree of extrapolation beyond the range of direct observations.

The basic input to flood estimation models is design rainfall data for the specific catchment and the ARI of interest. The most important design rainfall characteristics for storms of different durations are the average rainfall intensity over the catchment, and the likely distribution of rainfall in time and space. These design rainfall characteristics have been derived from analysis of data from many rainfall stations in a region and are available from design rainfall databases (e.g. ARR99, CRC-FORGE). The different design rainfall characteristics are combined to define a design storm event for a given rainfall duration and ARI.

Design storm events provide the basic probability input to the procedure. The "design event approach" adopted in Australia assumes that the 100-year ARI flood is produced by a 100-year design storm event. For this assumption to be satisfied, all

intermediate steps in the transformation of design rainfall to design flood need to be effected in a "probability-neutral" fashion; this means that parameters such as rainfall losses, initial storage contents and other flood modifying factors need to be selected in such a way that they are not biasing the probability of the simulated design flood.

The selection of a representative design storm and associated other design assumptions should be supported by the analysis of catchment-specific data, but in a catchment as large and complex as the Brisbane River catchment, the selection of these design inputs may still involve a considerable degree of professional judgement. In such situations it is desirable to check the appropriateness of the assumptions made by applying the model first to reproduce floods for catchment conditions for which reliable results of flood frequency analysis are available. In the case of the lower Brisbane River under current conditions, special complexity is introduced into the modelling process by the presence of Somerset and Wivenhoe Dams and their operation under flood conditions. It is therefore advisable to apply the hydrologic model to the pre-dam situation first and validate the results against the results of flood frequency analysis for pre-dam conditions.

2.5 Converting design flood flows to design flood levels

Hydraulic calculations are necessary to determine the design flood levels associated with a design flood. These calculations take account of the flow carrying capacity of the river channel and of the resistance to flow, including boundary shear and energy losses due to channel bends, bridges and other obstructions. The effects of tributary streams and of over-bank flooding must also be taken into account.

An appropriate water level must be specified at the downstream end of the river system. This is often referred to as the tailwater level.

The flood travels down the river system as a flood wave and it is modified as it progresses. The changes in the flood wave must be calculated correctly to establish the peak flood levels at different locations along the river.

In current practice, the hydraulic calculations are carried out with a computer software system that takes full account of the dynamics of the flood wave. This is described as the 'hydraulic model'. A number of well established hydraulic model systems are in use currently. The MIKE11 system was used by SKM and the RUBICON system was used by DNRM for the Brisbane River Flood Studies. Each of these hydraulic models is well established and is consistent with current best practice.

It is essential for the hydraulic model to be calibrated before it can be used to calculate design flood levels. In the process of calibration, the model is made to reproduce the observed flood levels for one or more historic floods for which sufficient data have been measured. This is achieved by adjusting the resistance and energy loss parameters in the model until satisfactory agreement is obtained between the flood levels calculated with the hydraulic model and the measured flood data.

2.6 Uncertainty

While designers and decision makers generally require a single valued "best estimate" of the design flood magnitude for a given ARI, it must be recognised that, by necessity, design flood estimates involve a considerable degree of uncertainty which may need to be allowed for in the decision making process.

A substantial degree of uncertainty in flood frequency estimates is inherent from the high degree of variability of hydrologic factors producing floods and the limited sample available from the total population of floods. Additional uncertainty may arise from the following sources of error in the basic data and in the methods of design flood estimation:

- systematic errors and inconsistencies in the basic rainfall and water level observations at gauging sites (e.g. for early historical data and very large events)
- uncertainty in the rating curves used to convert water level observations to flow estimates (particularly for large floods and for sites affected by tidal influences)
- errors introduced by the adjustment of flood data for the effects of changes in hydrologic and hydraulic catchment conditions (e.g. dams and changes to lower Brisbane River cross-sections)
- uncertainty in the choice of the correct model (distribution) for flood frequency analysis and in the estimation of its parameters
- uncertainty introduced by simplified representation of catchment characteristics in hydrologic models and estimation of model parameters

The confidence limits around the 'best estimates' obtained from flood frequency analysis give an indication of how some of these uncertainties affect the resulting design flood estimates, but they generally do not reflect all the uncertainty factors involved in the flood estimation process.

While the band of uncertainty around the 'best estimate' of a design flood may be so large that the decisions made using a lower bound estimate or an upper bound estimate would be substantially different, it should also be recognised that the adopted standards for floodplain management allow for some degree of uncertainty. In situations of unavoidable large uncertainty, consistency of approach in terms of current-best-practice may become the overriding consideration in determining the design basis.

3. The Brisbane River - particular issues for design flood estimation

3.1 Introduction

Chapter 2 set out to explain flood estimation techniques in general. For a specific catchment, it is important to choose techniques suitable for the task in hand, as well as to identify the features that will have a bearing on the flood response.

In the case of the Brisbane River, its large area is of considerable import. Its land-use has changed over the period of record. There are two very large water supply dams that are also operated so as to mitigate floods. In the lower reaches of the Brisbane River, the ocean levels affect flood levels. These aspects are each discussed further in respective sections below, followed by a discussion of the available data of relevance for a flood study.

3.2 Size of catchment

ARR99 defines any catchment that commands an area in excess of 1,000km^2 as being 'large'. The Brisbane River commands a catchment area of approximately 14,000km^2 and clearly sits within the large catchment category.

The variability of rainfall over the catchment is a key influence on floods in the Brisbane River. Differentials in excess of 1,000mm have been observed within the catchment for historical events. Similar gradients are also evident in design rainfall estimates by CRC FORGE estimates of design rainfalls.

Investigations by SKM (2003 (a)), for example, have found that spatial variability in rainfall distribution about the catchment alone can be responsible for variability in design discharges of the order of ±2,000m^3/s under 1% AEP design rainfall conditions. The problem is exacerbated when large dams exist on the catchment, and when rainfall may be centred above or below the dams

Variability of rainfall temporal pattern over the catchment is an added complication, but of lesser importance than spatial variability.

3.3 Catchment characteristics

Within any catchment, runoff response to rainfall is largely controlled by characteristics that fall into the following three general categories: Topography (draining system structure, catchment area, grades etc); Land classification (land use, soil type, vegetation etc); Waterway capacity (conveyance and storage).

These characteristics serve to dictate a catchment's response to rainfall, that is, the depth of rainfall that reports as runoff, the rate of runoff, and its duration of occurrence.

In many instances it is not necessary to explicitly account for key catchment characteristics in detail, as their influences can be adequately defined within a simplified scope of modelling parameters that are determined through a process of calibration against historical records.

Characteristics within the Brisbane River catchment have been continually changing, primarily as a result of progressive settlement and development. These changes will have had an effect on runoff characteristics (flood flow rates and levels), but one considered small in relation to the impact of the large dams, Wivenhoe and Somerset.

Investigations by both BCC and SKM have assumed that the only change in catchment characteristic of importance has been the construction of these dams. Under the circumstances this assumption is considered reasonable, given that most other key catchment characteristics can be considered to have largely remained unchanged over the years. It is noted that although development of the major regional centres of Brisbane and Ipswich Cities will have resulted in substantial change to local runoff characteristics, the overall impact on Brisbane River flooding is expected to be relatively small on account of the relatively small area of the overall catchment occupied. Catchment change has therefore been presented with respect to two scenarios: "No Dams"; and "With Dams".

3.4 Position and size of major storages

As noted previously, there are two major dams located within the catchment that provide both water supply and flood attenuation service:

- Wivenhoe Dam:
  - Completed: 1985
  - Water supply storage capacity: 1,150,000ML (approximately)
  - Regulated temporary flood storage capacity: 1,450,000ML (approximately)
  - Location: Brisbane River upstream from confluence with Bremer River
  - Catchment: approx. 7,000km^2

- Somerset Dam:
  - Completed: 1959
  - Water supply storage capacity: 370,000ML (approximately)
  - Regulated temporary flood storage capacity: 524,000ML (approximately)
  - Location: Stanley River upstream from confluence with Brisbane River

[information extracted from SKM 2003 (b)]

Clearly, the amount of flood storage is these dams is very significant relative to the design runoff volumes, so the correct simulation of these dams (and their operation during events) is of paramount importance.

3.5 Effect of tides and storm surge on flood levels

Brisbane River remains tidally affected up to around Colledge's Crossing, or approximately 86km upstream from its mouth in Moreton Bay. Mean High Water Spring Tide (MHWS) in the bay is at approximately 0.9mAHD. The potential for storm surge effect in the bay is relatively significant (BCC, Discrepancy in Predicted Flow Rate in Brisbane River, undated):

- MHWS 0.9mAHD
- January 1974 Storm Surge: 1.6mAHD
- May 1996 Storm Surge: 2.8mAHD

Sensitivity investigations undertaken by BCC to assess the likely effect of bay water levels on flood levels at Brisbane Port Office found the following:

- It appears the tidal and storm surge fluctuations can account for approximately a ±2m range in bay levels (ie –0.9mAHD to +2.8mAHD).
- The effects of tidal and/or storm surge influences in the bay diminish as discharges increase:
  - ±2m at zero flow;
  - ±0.8m at around 5,000 m^3/s;
  - ±0.5m at around 10,000 m^3/s (close to BCC estimate of January 1974 flow); and
  - nil (ie. completely drown out) at discharges greater than approximately 14,000 m^3/s.

The stage discharge curve was computed using the calibrated Mike11 Model developed in the 1998 and 2000 flood studies. It was compared with the Bureau of Meteorology data and found to be different. The Bureau of Meteorology discharge-stage information was derived to suit the Bureau of Meteorology flood forecasting model and has not yet been adequately verified.

Forensic investigations by BCC have also attempted to quantify the likely effect of historic dredging and excavation works about the entrance of the river. This work was undertaken to aid with their adjustment historic flood level estimates for an alternative FFA of flood data at river gauge stations to the downstream of Colledge's Crossing.:

- Removal of a bar at the mouth of Brisbane River in around 1864 is estimated to have resulted in lowering "large" flood levels at Port Office by approximately 0.4m;
- Dredging about the port in around 1917 is estimated to have resulted in lowering "small" floods by approximately 1.5m, with little effect on "large" floods. (According to the Bureau of Meteorology, this lowering should be only 0.6 m.)

3.6 Data available

A considerable amount of rainfall and stream flow data is available, and has been accessed in the conduct of the various investigations by BCC, SKM, BOM and DNRM.

Key data sources include:

- AEP 1 in 100 Rainfall Depths, Temporal and Spatial Patterns, Areal Reduction Factors for the Brisbane River Catchment CRC FORGE analysis undertaken by DNRM.
- Long-term daily rainfall totals from a significant number (around 130) of stations through the catchment.
- Daily stage height data and rating curves, utilised by SKM:
    - Brisbane River @ Savages Crossing (143001) – 72 years
    - Warrill Creek @ Amberley (143108) – 40 years
    - Lockyer Creek @ Lyons Bridge (143210) – 22 years
    - Lockyer Creek @ O'Reilly's Weir (143207) – 53 years
    - Daily stage height data and rating curves (calibration), utilised by BCC:
        - Brisbane River @ Brisbane Port Office – data from 1841
        - Brisbane River @ Moggill – data from 1893
        - Brisbane River @ Mt Crosby – data from 1864
        - Brisbane River @ Lowood – data from 1890
- Historic flood levels and estimated flow rates at Lowood, 1893 and 1825
- Peak annual flow series data for Savages Crossing (1890-2000) for assessed adjustments "No Dams" and "With Dams" scenarios.

It is also understood that relatively detailed waterway cross-sectional / bathymetry information is available for Brisbane River from around Moggill Gauge to the entrance.

4. Evaluation of recent studies

4.1 Introduction

Chapters 3 & 4 set out the current best-practice methodology for flood estimation, and the characteristics of the Brisbane River catchment that need special consideration. They thus provide the context for the review of the techniques adopted for, and the results from, the SKM 2003 study.

This chapter looks first at the flood frequency analysis of the flows at Savages crossing (Sect. 4.2), then at the results for the same location (pre-dams) obtained using the rainfall-based method (4.3), before comparing the two (4.4). It then considers the simulation of the catchment response to large storms with the Wivenhoe and Somerset Dams in place, as used to estimate the current Q100 for the Port Office (4.5). The conversion of this design flow to a design level is examined next (4.6). The chapter concludes with consideration of the uncertainty in the estimates (4.7), and a statement of the Panel's views on the recommended values of flood level at the Port Office (4.8).

4.2 Flood frequency analyses (pre-dam)

Among the several stream gauging stations located along the Brisbane River between Wivenhoe Dam and the Brisbane Port Office, the combined record from the gauges at Savages Crossing, Lowood and Vernor (from here on referred to as Savages Crossing) provides the longest record of high quality flood data, and has therefore been adopted by SKM as the key site for flood frequency analysis.

Four different flood data sets have been prepared for the Savages Crossing site and have been used for separate flood frequency analyses by SKM. Data Sets 1 to 3 relate to the pre-dam situation, while Data Set 4 attempts to represent the current situation with Somerset and Wivenhoe Dams providing a substantial degree of flood mitigation for the lower Brisbane River. The continuous record period represented by these data sets varies from 42 to 111 years, with the historical record period extended in some cases to include the large flood of January 1893, and in one case also the similarly large flood thought to have occurred in 1825.

For the *pre-dam* situation, the SKM draft report presents the results from a total of 12 different cases analysed to assess the sensitivity of the Q100 estimates to variations in the following factors:

- Inclusion or omission of January 1893 and 1825 historical floods
- Extension of recorded flood data set by inclusion of the following additional periods:
    - from 1890 to 1909 (extended by DNRM using IQQM model)
    - from 1959 to 1982 (with and without DNRM adjustment for impact of Somerset Dam)
    - from 1983 to 2000 (with DNRM adjustment for impact of Wivenhoe Dam)
- Inclusion or omission of information from regional flood frequency analysis
- Fitting of Generalised Pareto (GP) or Log-Pearson 3 (LP3) distribution

- Application of FLIKE or GetDat flood frequency analysis packages which use different parameter estimation methods

The Q100 estimates obtained from these 12 separate analyses varied from 6,700 m^3/s to 15,700 m^3/s, with the most plausible range given by SKM as 10,000 to 14,000 m^3/s. Based on the results of the two most plausible cases, SKM adopt the 'best estimate' of Q100 as 12,000 m^3/s.

The Panel considers the flood frequency analysis approach taken by SKM to be appropriate and agrees with the conclusion that the 'best estimate' of Q100 for the pre-dam case at Savages Crossing is approximately 12,000 m^3/s. While the 90% confidence limits around the best-case distributions are somewhat wider, the plausible range of uncertainty for the Q100 estimate is about 10,000 to 14,000 m^3/s.

Additional flood frequency analysis work was also undertaken by City Design for a range of sites between Savages Crossing and Brisbane Port Office. For each site, available information from various sources was combined to derive a most plausible rating curve for the full range of flood magnitudes of interest. While this work is not as rigorous in terms of the quality and consistency of the data used and the methods of frequency analysis applied, it nevertheless provides useful confirmation of the SKM estimates. City Design's 'best estimate' of Q100 at Savages Crossing for the pre-dam case is 10,800 m^3/s.

Based on these results, it is of interest to note that, in the absence of Somerset Dam, the January 1974 storm would have produced about a 70-year flood at Savages Crossing, while the January 1893 flood is estimated as having an ARI of 100 to 150 years.

4.3 Rainfall-based flood estimates (pre-dam)

To estimate the runoff generated by rain falling on the catchment, SKM used the RAFTS runoff routing model. They had calibrated this model satisfactorily during previous studies on the catchment of the Brisbane River, so that further calibration effort was considered unnecessary. The Panel were willing to accept the adequacy of the calibrated RAFTS model without specific review.

Design values of 10 mm initial loss and 1 mm/h continuing loss, distributed uniformly over the catchment, were used to estimate the Q100 event. The Panel considers these values acceptable for an extreme event on the Brisbane River catchment. (The assumption of zero losses would increase the Q100 estimate by about 15%).

As explained in Sect. 3.2, a particular challenge for design flood estimation on large catchments is the appropriate depth and variability of rainfall to use in the calculation. SKM adopted the recent CRC-FORGE work to get the average depth for each storm duration – with appropriate areal reduction factors (Sect. 3.6). The Panel endorse this.

The critical storm durations of 30 h at Savages Crossing and 72 h at Moggill/Port Office seem reasonable, and accord with other studies. Representative patterns in accordance with ARR (IEAust, 1998) were adopted. To assess sensitivity to temporal patterns, five patterns were applied to the catchment average CRC Forge rainfall 48

hour storm duration. The RAFTS model was used with nil losses. At Savages Crossing and at the Port Office, the ARR standard temporal pattern produced the smallest peak flows. The largest peak flows at these locations were produced by the 1974 historic temporal patterns, these being larger than the ARR peaks by 15% at Savages Crossing and by 10% at the Port Office.

Spatial distribution is a factor which can have a significant effect (especially for the post-dams case – Section 4.5). The Panel suggested using patterns from a number of large storms on the catchment, and SKM have done this for seven events. The result gives an approximate indication of the influence of spatial pattern on flood peaks of the 100 year ARI event (8000 to 11500 m^3/s, pre-dam case at Savages Crossing). The median value (of about 10000 m^3/s) is an appropriate vale for comparison with the flood frequency study (see next section).

4.4 Comparison of FFA and rainfall-based estimates (pre-dam)

The comparison of results from frequency analysis and rainfall-based estimates is a form of check undertaken to assess the degree of consistency in the results using different data sources, methods and assumptions. In the evaluation of the comparative results, allowance has to be made for the different degrees of reliability attached to the estimates from different approaches.

The most recent SKM studies produced the following Q100 estimates for the pre-dam situation at Savages Crossing:

Table 4.1 Summary of Q100 estimates at Savages Crossing (pre-dam conditions)

Method	Q100 estimates [m^3/s]		
	Best Estimate	Plausible Range	
		Lower Bound	Upper Bound
Flood Frequency Analysis	12,000	10,000	14,000
RAFTS Modelling	10,000	8,000	11,500

The comparison indicates that, while the plausible ranges of estimates from the two approaches overlap to some degree, the RAFTS modelling produces estimates that are significantly lower.

In the Panel's judgement, the flood frequency analysis estimates are based on relatively long streamflow records at a number of sites, and while there is considerable doubt on the reliability of large floods at individual sites, there is sufficient confirming information from flood observations at other sites to lend credence to the adopted Q100 estimate.

For the rainfall-based estimates, the design rainfall depths used to define design storms for the catchment are also based on the analysis of a large database of long-term rainfall records from many stations within and around the catchment. However, the RAFTS model converting these design rainfalls to design storms requires many assumptions regarding model parameters and secondary design inputs, such as spatial/temporal patterns of design rainfall and losses, and their variation with storm

magnitude. The uncertainty involved in these assumptions may introduce bias into the estimation of the 100-year flood from a 100-year storm rainfall depth.

The Panel therefore considers that the pre-dam Q100 estimate at Savages Crossing from RAFTS modelling estimate may be low by 10 to 20%. It would be desirable to assess, if the tendency for underestimation of peak flows also affects the estimate of flood volumes associated with Q100 in a similar fashion, as the post-dam flood peaks at Brisbane are largely determined by the inflow volumes to the dams. However, at this stage the information available does not allow this to be confirmed.

The expected tendency for underestimation in the rainfall-based approach should be taken into account when the RAFTS model is used to estimate design floods for the lower Brisbane River catchment under post-dam conditions.

4.5 Calculation of the post-dam flood discharges

Both the Somerset and Wivenhoe storages are capable of significantly modifying flood flows from their commanded catchments. The amount of flood attenuation that can be achieved by the structures is dependent upon a range of conditions, including:

- The antecedent storage inventory
- The volume and duration of the flood inflow hydrograph
- The rate of controlled discharge from the storage.

Under flood conditions both storages are operated in accordance with predefined rules controlling discharge to the downstream waterway. It is understood that these rules have been established with the objective of mitigating the potential impact of flooding on downstream communities and infrastructure. These rules are relatively complex and are not amenable to simplification.

In consideration of the significant impact that Wivenhoe and Somerset Dams can potentially have on the timing and magnitude of downstream flood flows it is necessary that proper account be taken of dam operation in any hydrological assessment. To this end, DNRM have established a hydrological model of the Brisbane River catchment for the purpose of simulating the expected performance of dam operation. It is understood that the model functions on a continuous simulation basis and utilised historical time series rainfall data to simulate an associated time series of waterway and dam flows. Although DNRM have made available the outputs from this model, no other details have been documented. This being the case, the Panel cannot comment on the efficacy of the model.

Review of historical dam routing results from the DNRM model for the period 1890 to 2000 has indicated that it should be possible to operate the dams to reduce peak flood flow rates by about ~~35~~60% on average, ~~with a maximum factor of approximately 50%~~. It is interesting to note that the model indicates a January 1974 flood attenuation of nearly 50%, with a peak inflow rate of 10,500m^3/s and outflow rate of 5,500m^3/s.

Flood frequency analysis by SKM of the DNRM dam routing time series showed that standard frequency distributions, such as the *Generalised Pareto* and *Log Pearson*

Type III, do not fit the data well. It is expected that this occurrence is largely due to the highly modified and non-linear nature of the flood hydrograph transformation by the dams. The Panel therefore considers the Q100 estimate from this analysis to be unreliable and not suitable as a basis for checking the results of hydrologic modelling for the post-dam case.

Hydrological modelling of the catchment has also been undertaken by SKM. This work has used the RAFTS program to undertake the basic rainfall-runoff-routing process, and a program from DNRM to simulate the routing of flow hydrographs (generated using RAFTS in this instance) through the Somerset and Wivenhoe storages under post-dam scenario conditions. SKM used the models to generate design flood flow rates from synthetically generated design storm events – in this case 1 in 100 AEP design CRC FORGE rainfall events.

The SKM application of the RAFTS hydrological model was used to both make estimates of:

- Design Q100 flow rates at Savages Crossing under both pre- and post-dam conditions
- Typical variability in Q100 flow rates that might reasonably be attributed to differences in the spatial distribution of rainfall across the catchment during the course of the driving storm event.

As noted above, SKM used the CRC FORGE method to establish the design 1 in 100 AEP storm event - comprising total rainfall depth, temporal and spatial rainfall distributions, and associated areal reduction factors. Typical "real event" spatial distributions for rainfall were also extracted from 7 historical storms events of significance. No specific criterion was applied to the selection of events, other than that the data was readily available for utilisation within the relatively limited time constraints afforded by the scope of current investigations.

It is noted that CRC FORGE rainfall was applied to the 7 historical spatial distributions, and not the actual rainfall associated with the event. This approach satisfied the investigation objective that was to sample the typical variability in runoff flow rates as might be produced by different spatial distributions of rainfall under both pre- and post-dams development scenarios.

Outcomes of SKM investigations are summarised in the following tabulation. In reviewing this information it should be noted that the base estimate is derived from RAFTS modelling using the CRC FORGE rainfall spatial distribution (eg 9,600 m^3/s at Savages Crossing for the pre-dams case). An indication of plausible range was obtained from calculation of the difference between the median valuation of the seven historical spatial distributions, and the second highest and second lowest bounding values (ie values at rank positions 2 and 6, with the median being at rank position 4). These ranges were then superimposed upon the RAFTS based estimates to give the plausible ranges listed in Table 4.2.

Table 4.2 RAFTS based Pre- and Post-Dam Q100 flow estimates (m^3/s) with indication of plausible range of variability

Location	Pre-Dams			Post-Dams			Reduction (%)
	RAFTS Q100	Plausible Bound		RAFTS Q100	Plausible Bound		
		Lower	Upper		Lower	Upper	
Savages Crossing	9,600	8,100	10,800	5,400	3,900	6,600	40
Moggill	10,100	9,500	10,800	5,000	4,200	6,000	50
Port Office	10,100	9,500	10,800	5,000	4,200	6,000	50

Review of the above outcomes indicates:

- The pre-dams best estimate of peak discharge at Savages Crossing (9,600 m^3/s) is 20% lower than that derived by SKM using FFA (see Section 4.2). This being the case it is probable that the estimate of post-dams peak discharge is also low.
- The variability indicated by analysis of historical spatial rainfall distributions appears to be generally consistent with that concluded by SKM on the basis of FFA work. This may be taken to indicate that the noted variance is probably physically realistic.
- Variability in post-dam flow estimates is significant, being of the order of 40% of the design base discharge value.
- The attenuated peak flood flow rate factors are generally consistent with that reflected in the source DNRM data.
- There appears to be little attenuation of flood flow rates between Moggill and Port Office. This characteristic is totally consistent with independent observations as reported by BCC.
- Savages Crossing peak discharges are of the same order as those further downstream.

The issue of variance between FFA and RAFTS model results has not yet been fully addressed by SKM. Nevertheless, SKM have investigated the sensitivity of estimated Q100 flow rates to assumed loss rates. The key outcome of this sensitivity appraisal was that the noted variance could not be fully explained by the influence of assumed rainfall losses. The cause for this variance warrants further investigation.

SKM also undertook investigations to assess the effect of antecedent dam storage inventory levels on the attenuation of flood flow rate. Analyses using antecedent inventories of 50% and 75% full supply volume indicated significant impact. However, prior analysis by BCC of the likelihood of the occurrence of antecedent drawdown was small, and that a FSL assumption is justified.

As a check on design flows, SKM used the RAFTS model to simulate the 1893 and 1974 historical flood events with both dams in place and with dam operating procedures applied. The peak flow calculated at the Port Office for the 1974 flood event was 6800 m^3/s. It is difficult to relate this result with those obtained from systematic study of 1 in 100 AEP rainfall events discussed above.

The Panel considers that flow estimates based on flood frequency analyses (Section 4.2) presents a fair assessment of *Best Estimates* under pre-dam conditions (ie Q100 of 12,000m^3/s with a plausible range between 10,000m^3/s and 14,000m^3/s). As noted above, RAFTS flow estimates are considered low, around 20% under pre-dam conditions. Under post-dam conditions the Panel would expect Q100 flows downstream of Wivenhoe dam to be of the order of 50% of those under pre-dam (as found by RAFTS, Table 4.3) – that is, 50% of 12,000m^3/s, or 6,000m^3/s.

In consideration of the above, the Panel considers that Q100 flow values presented in Table 4.3 below presents a fair and reasonable assessment of Q100 flow rates for design purposes – *on the basis of information currently made available to the Panel.*

Table 4.3 Panel Recommended Pre- and Post-Dam Q100 flow estimates (m^3/s) with indication of plausible range of variability

Location	Pre-Dams			Post-Dams		
	Q100	Plausible Bound		Q100	Plausible Bound	
		Lower	Upper		Lower	Upper
Savages Crossing	12,000	10,000	14,000	6,000	4,000	8,000
Moggill	12,000	11,000	13,000	6,000	5,000	7,000
Port Office	12,000	11,000	13,000	6,000	5,000	7,000

4.6 Estimation of design flood levels

Flood levels along the Brisbane River were calculated with the MIKE11 hydraulic model. The model extends upstream from the Brisbane bar to approximately 15km downstream from Savages Crossing. The inflow hydrograph at the upstream end was provided from a RAFTS hydrological model that has its output approximately 2 km upstream from the end of the MIKE11 model. The DNRM dam operations have been applied in producing this hydrograph and it includes Lockyer Creek flows. Downstream from this point, there are approximately 150 inflow locations in the MIKE11 model. At the downstream end the water level was set at MHWS (0.92 m AHD) and held constant throughout the entire flood simulation.

The MIKE11 hydraulic model that was developed for the Ipswich Rivers Flood Studies was used to calculate design flood levels in the Brisbane River. The Panel has not examined the calibration of the model. SKM reports that the calibration at the Port Office and at Moggill is considered good but that calibration has not been done at other locations along the Brisbane River within Brisbane City. Consequently, flood levels estimated for locations other than at the Port Office and at Moggill must be treated with care. It is noted also that the need to extrapolate the rating curves causes some uncertainty in the calibration of the hydraulic model, because of the uncertainty that attaches to the estimates of the flows of large floods used in calibration.

The hydraulic model was run with input flows calculated from CRC Forge rainfall estimates, spatially distributed with areal reduction factors, for the 1% AEP design rainfall, for seven durations. The critical duration was 72 hours and, for this case, the

peak flow calculated at the Port Office is 5060 m^3/s and the peak flood level is 2.68 m AHD.

The peak flow at the Port Office calculated with the hydraulic model is similar to that calculated with the RAFTS model (5,000 m^3/s, Section 4.5). However, the Panel considers that the values of Q100 estimated from RAFTS modelling may be low by 10 to 20% (see Sections 4.4, 4.5) and it has formed the opinion that the current best estimate for the Q100 flow at the Port Office is 6,000 m^3/s, as explained in section 4.8. It follows that the flood level, 2.68 m AHD, may be low and it would be desirable to calculate the flood level corresponding to a peak flow of 6,000 m^3/s. From simple interpolation in an approximate rating based on the MIKE11 results in the 2003 SKM study, the flood level for this flow is estimated at 3.3 m AHD.

The use of a constant water level at MHWS at the downstream end of the hydraulic model is consistent with what was adopted for the original Brisbane River Study. This may appear to result in slightly high estimates of flood levels in the tidally affected reaches of the river. However, the flood hydrograph is of long duration and the flow in the tidal reaches will be very close to the peak for a time interval similar to or greater than the interval between low tide and high tide. Therefore, the use of a constant water level at MHWS may not be conservative. It is known also that storm surges are often associated with the severe large weather patterns that produce large flood events. The Panel considers that a Monte Carlo analysis to examine the joint probabilities of flow rates and tide levels, including influences of storm surges, is required to resolve this issue.

4.7 Sources of remaining uncertainty

Rating curve extrapolation

At all of the flow gauging stations the maximum gauged flow is substantially smaller than the maximum estimated flow. For example, at Savages the maximum gauged flow is of order 30 - 45% of the estimated 1974 peak flow (SKM, 2003 (b)). Extrapolation of the rating curve to such an extent is a source of considerable uncertainty in the estimates of the larger flows that influence the FFA in the range of the Q100.

The need to extrapolate the rating curves also causes uncertainty in the calibration of the hydraulic model, because of the uncertainty that attaches to the estimates of the flows of large floods used in the calibration.

Unfortunately, little can be done to reduce these uncertainties until gaugings can be obtained during larger flood events.

Spatial and temporal pattern variability

The results obtained with seven historical spatial distributions of rainfall in the hydrological modelling show that the estimate of Q100 is substantially affected by the spatial distribution used. At Savages, the pre-dams estimates of Q100 ranged from 11507 to 8005 m^3/s and the post-dams estimates ranged from 7847 to 3279 m^3/s (SKM, 2003 (a)).

The results from a limited assessment of the effects of different temporal patterns for the pre-dam case showed variations in peak flows of 15% at Savages Crossing and of 10% at the Port Office.

Larger estimates of Q100 may result from spatial and temporal patterns of rainfall other than those modelled. This question could be resolved by a full Monte Carlo analysis.

Correlation of losses with storm occurrence

In the hydrological modelling the initial loss was set at 10mm and the continuing loss at 1.0mm/hr (SKM, 2003 (a)). These losses are within the ranges that are considered reasonable for eastern Queensland. It has been stated that 'A Q100 event ... generally occurs in a season of wet winters and high rainfall summers' (BCC, 1999). This has provided the basis for the use of relatively low losses in the hydrological modelling. Nevertheless, this has not been examined rigorously. Further, it is uncertain whether pre-event wetting of the catchment prior to large storm events may result in even smaller losses and larger peak flows.

These issues would be clarified by a correlation analysis of pre-event catchment soil moisture levels with storm occurrences.

Correlation of pre-event dam levels with storm occurrence

The set of post-dams estimates of flows downstream from Wivenhoe dam were calculated with the assumption that the dam was at FSL, RL 67.0 m AHD, in all cases. Sensitivity tests showed that the estimated peak flow at the Port Office Gauge is reduced by about 13% if Wivenhoe dam is 75% full with SWL at RL 64.0 m AHD at the start of the flood event (SKM, 2003 (a)). Data sets are available that would enable a correlation analysis to establish the most likely pre-event dam level.

Calibration of hydraulic model

The MIKE11 hydraulic model that was developed for the Ipswich Rivers Flood Studies was used to calculate design flood levels in the Brisbane River. The model calibration at the Port Office and at Moggill is considered good but it has not been calibrated at other locations along the Brisbane River within Brisbane City. The model should be calibrated throughout the length of the river within Brisbane City to provide good estimates of flood levels throughout.

4.8 Best estimates of the 100 year ARI at the Port Office

As noted in previous section, the spatial distribution of the design storm used to calculate the Q100 is critical. For this reason, the Panel requested SKM to calculate Q100 estimates using the spatial distributions from seven historical large storms. The range of Q100 for the Port Office was 3400 to 7121 m^3/s. The Panel considers this to be an extreme range, it is unlikely to be a fair indication of the likely uncertainty of the Q100 flood flow.

If the outermost two are 'dropped', the range reduces to 5000 to 6800 m^3/s, with the median being 5900 m^3/s (SKM, 2003(a), Table 7). After rounding these values in recognition of their approximate nature, the Panel regard 6000 m^3/s as the best current estimate of the Q100 flow-rate, with 5000 m^3/s being the lower estimate of Q100, and 7000 m^3/s being the upper. [As noted in the Conclusion, further work is needed to refine the position of this estimate in the range, and to reduce the size of the range itself]

The Q100 level calculated at the Port Office with the hydraulic model is 2.68 m AHD. However, the flow associated with this level is 5060 m^3/s, while the Panel regard 6000 m^3/s as the best current estimate of the Q100 flow. The best estimate of the Q100 level corresponding to this flow is 3.3 m AHD, with 2.8 and 3.8 m AHD being the levels corresponding to the lower and upper estimates of flow.

5. Conclusion

5.1 Panel findings

The estimation of Q100 for a catchment of this size (13570 sq. km) is a challenging task. The extreme variability of rainfall, the change in catchment response due to the construction of dams, and the variable conditions in the tidal section of the river, are some of the factors which complicate the application of 'standard' flood methodologies. The advent of new techniques for flood frequency analysis and for extreme rainfall estimates, together with much improved hydraulic routing methods for estuaries, has added much to the technologies now available for flood estimation. The Panel notes that the further studies done by SKM, in conjunction with City Design, took advantage of these new techniques.

With respect to its Terms of Reference, the Panel:

(i) have reviewed the methodology used by SKM to determine the Q100 river flow and level;

(ii) believe that the appropriate technical processes have been followed in this study;

(iii) based on the evidence available, is of the view that, for the Brisbane Port Office, the best current estimates for

- the Q100 flow is 6000 m^3/s
- the Q100 level is 3.3 m AHD

There is an inevitable degree of uncertainty in any estimates of this kind. The Panel believes the possible range for flow to be 5000 to 7000 m^3/s; for level to be 2.8 to 3.8 m AHD.

The Panel notes that the current 'best estimates' of Q100 and of the corresponding flood level at the Port Office, provide a sufficient basis for a decision on whether the currently adopted flood levels are broadly acceptable. However, for general flood risk assessments and risk-based flood management decisions, more refined flood frequency estimates will ultimately be required.

5.2 Recommendations for Further Work

a) The SKM 2003 study has demonstrated the very significant effect of assumed storm variability on the estimated post-dams flows at the Port Office. The Panel believes that this variability could be reduced if a similar study was conducted, but using Monte Carlo methodology to simulate the possible combinations of storm temporal and spatial patterns (instead of seven observed storms). Such a study could also properly estimate and account for the correlations between event occurrence, losses and reservoir drawdown (instead of using fixed average values). The Panel strongly recommends that such a study be done as Council moves towards a risk-based approach to flood management.

b) More confidence would be engendered in the results if there was a better match between the flood frequency analysis of observed data and the estimates obtained

from the rainfall-based RAFTS model. The current variance of around 20% is not desirable. Given the importance of runoff volume in a situation involving large dams, the Panel recommend that:

(i) Calibration of the RAFTS model be re-visited with the view to reducing the variance with FFA outcomes to within acceptable bounds.

(ii) Frequency analysis of event volumes be carried out, and compared with runoff volumes predicted by the RAFTS model from design rainfalls of corresponding frequency.

c) The MIKE11 model of the Brisbane River should be calibrated throughout the length of the river within Brisbane City to provide good estimates of flood levels throughout.

d) Consideration should be given to including the effect of tidal variation on flood levels in the estuarine zone. This would involve a Monte Carlo type analysis to examine the joint probabilities of flow-rates and tide height.

e) The DNRM model for simulating the expected operation and effect of Wivenhoe and Somerset Dams on flood flows, and associated data, should be independently reviewed when the DNRM final report is made available.

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6. References

BCC (1999) Report, Further Investigations for the Brisbane River Flood Study (Draft), December 1999.

IEAust (1999) Australian Rainfall and Runoff – A Guide to Flood Estimation, (Reprinted Edition), Institution of Engineers, Australia, Barton ACT.

Kuczera, G. (1999) Comprehensive at-site flood frequency analysis using Monte Carlo Bayesian inference, Water Resources Research, 35(5), 1551-1558.

SKM (2003(a)) Report, Further Investigations of Hydrology & Hydraulics Incorporating Dam Operations and CRC Forge Rainfall Estimated (Draft), 28 August 2003.

SKM (2003(b)) Report, Flood Frequency Analysis of Brisbane River (Draft), 8 August 2003.

Appendix – Terms of Reference and Chronology of Events
(Documents from Brisbane City Council)

TERMS OF REFERENCE

for

Brisbane River Flood Study

Independent Expert Review Panel

Background

A chronology of events to date has been included at the end of this document. It outlines the work undertaken so far to determine the Q100 Brisbane River flood level. The Brisbane City Plan 2000 uses the Q100 as the key input in the determination of development control levels adjacent to the river. The Q100 currently used is based on a study that was completed about the same time as Wivenhoe Dam was constructed. This 1984 figure of 6,800 m^3/s has been used as the basis for setting development control levels for nearly twenty years.

Council commenced extensive work into hydrologic and hydraulic aspects of the catchment after the 1993 DNR study indicated that the Q100 flow at the Brisbane Port Office may be as high as 9,380 m^3/s. The 1998 study undertaken for Council by SKM recommended a Q100 of 9,560 m^3/s. In June and December 1999 BCC's City Design produced draft reports that recommended Q100's of 8,600 m^3/s and 8,000 m^3/s respectively.

Preliminary results from the 2003 DNRM study on flows in the Brisbane River indicate a Q100 of 6,000-7,000 m^3/s at the Brisbane Port Office. BCC is undertaking further work to assess the results of the various methods.

BCC and SKM are now using updated information (including the DNRM results) to review the flood frequency analysis and determine the revised Q100 flood level at the Brisbane Port Office.

Even if the Q100 changes from 6,800 m^3/s, it is likely that the Development Control Level will remain the same as is currently used in the Brisbane City Plan.

Role

The role of this expert panel is to determine whether the August 2003 estimates of Q100 flow and level at the Brisbane Port Office are reasonable.

Objectives

1. Review the methodology that has been used to calculate estimates of Q100 river flow (1998 – 2003)
2. Ensure that the appropriate technical process has been followed for the 2003 Q100 river flow / level at the Brisbane Port Office.
3. If required, provide specific recommendations on further work be undertaken
4. Assess the suitability of the 2003 Q100 river flow / level for design purposes..

Outcome sought

It is expected that the expert panel will produce a report providing opinions, recommendations and advice on the technical process followed and the estimated Q100 river flow / level at the Brisbane Port Office

Membership of Panel

- Professor **Russell Mein** (Chair) – Experience: Former CEO of CRC for Catchment Hydrology and former Chairman of ARR Advisory Panel
- Professor **Colin Apelt** – Experience: Former Head of the Department of Civil Engineering, University of Queensland
- [redacted] – Experience: Chairman Engineers Australia National Committee on Water Engineering, and Director / Principal Water Engineer with consultants Water Solutions Pty Ltd
- **Erwin Weinmann** – Experience: Deputy Director CRC for Catchment Hydrology (Monash Node), Senior Lecturer in water subjects at Monash University and Co-author of Book VI (Estimation of Large and Extreme Floods)

Responsibilities of Members

- To read briefing materials provided prior to meetings.
- To attend and participate in meetings of the expert panel.
- To assess and report on the methodology and process used to determine the Q100 flow / level at the Brisbane Port Office.

Timing

It is initially anticipated that there will be two meetings of the expert panel:

- Thursday 31 July – to review the work done to date and agree on the process to finalise the Q100.
- Mid August – to consider the findings of the Q100 investigation and to critically assess the Q100 determined at the Brisbane Port Office

The objective is to deliver a brief report to the Manager Water Resources outlining the findings by 25 August 2003.

Brisbane River Flood Study
Chronology of Events

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

1993 DNR study undertaken for the (now) South East Queensland Water Corporation to examine operating rules for the dam. The study determined that Q100 flow was 9,380 m^3/s. The report recommended that further work be undertaken to determine areal reduction factors. DNR consider this flow volume was seen as an overestimation as it was not specifically produced for the Q100 event in Brisbane. This prompted Council to re-examine flood levels in the river and led to commissioning the SKM report, which commenced in November1996.

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

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

1998 December, received Professor Mein's review of the draft SKM report. This review stated;

> "The overall approach for the hydrologic component of the study ... is appropriate. However ... conservative assumptions in key input variables point to the likelihood

that the magnitude of the Q100 obtained in this Study is an over-estimate." Professor Mein made six recommendations for work needed to address the issues of concern.

1999 June, draft review by City Design. Note that this revised downwards the Q100 flow to 8,600 m3/s as a result of the additional analysis–a reduction of 10% on the SKM report (This draft report did not fully address Professor Mein's review recommendations). This is the report referred to by the Courier Mail in its stories on flooding which appeared in the newspaper from 24 June 2003 to 5 July 2003.

1999 December, review by City Design. This draft report entitled "Further Investigations for the Brisbane River Flood Study" was to fully incorporate Professor Mein's recommendations and revised the Q100 flood discharge down again to 8,000 m^3/s as the analysis was refined. It should be noted that this report again did not fully address Professor Mein's peer review analysis.

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

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

Action plan arising from October workshop identifies FORGE Study being undertaken by DNR for SEQ Water Corporation. At this time, the continuous simulation study was due to be finalised by December 2000 and was consistent with Professor Mein's comments, as well as the current approach by the CRC for Catchment Hydrology.

Preliminary results showed the DNR Q100 level as closer to the BCC 1984 study than the 1992 DNR study, which reinforced our position on the over-estimation of the Q100 flood flows. The workshop concluded that the FORGE work being done would need to be taken into account. In addition, the workshop suggested that we take into account the areal reduction factors, which it was estimated may produce a 20% reduction in total rainfall at the Brisbane Port Office gauge.

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

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

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

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

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ACTION PLAN for Tasks from 1 July 2003

No.	WHAT	WHO	WHEN	COMMENTS
1	List information on CD ROM provided by NRM	CD	Tuesday 1 July	
2	Determine what additional information is required from NRM (if any)	CD and SKM	Wed 2 July	
3	Obtain 1893 rain data from John Ruffini and its relationship to other rain records	CD	Fri 4 July	
4	Develop "road map" for the way ahead	SKM	Fri 4 July	
5	Review need for BCC/ICC model updating and provision to SKM	CD	Fri 4 July	
6	Review the NRM data for "FORGE" method	SKM	Tues 8 July	
7	Meet with or ask NRM for their list of assumptions (if not included on the CD ROM)	WR, CD	Tues 8 July	Confirm assumptions (WR)
8	Review Flood Level Records with comments on accuracy (eg origin) for Flood Frequency Analysis		Tues 8th July	
9	Develop Terms of Reference for Panel members	CD/SKM	Fri 11 July	For review by WR and forwarding to panel Advise expert panel of the process and actions being taken and ask them to let us know as quickly as possible if they have any comments
10	Create expert panel			Prof. Russell Mein; NRM: (Barry to contact), BoM Terry Malone; IEAust Water Panel: [redacted], SEQWCo: [redacted] City Design, Water Resources Barry Ball/Gavin Blakey, UNSW: [redacted] UniQuest: Collin Apelt, CRCCH: Erwin Weinman.
11	Stakeholders kept up to date (eg ICC)		ongoing	
12	Prepare a preliminary report on findings, including a checklist to ensure that all issues identified in Professor Mein's 1998 report have been adequately addressed in the 2003	CD, SKM	Fri 18 July	Need to list assumptions / parameters used in the June and December 1999 and July 2003 report and ensure that all of Professor Mein's recommendations have been addressed. WR to review this

No.	WHAT	WHO	WHEN	COMMENTS
	results			assessment.
13	Develop fact booklet for panel members as background for first meeting		Thur 24 July	Send to panel members
14	Develop steps to align flood record data with rainfall data (follow procedures in ARR book 6)	Panel	Thur 31 July	Agenda for first panel meeting
15	Carry out work resulting from the panel session		After 31 July	
16	Review the assumptions in the NRM report to see how they might differ from the assumptions / parameters used in the CD June and December 1999 reports	CD, SKM, WR	After 31 July	
17	Re-Convene the panel to assess the results	WR	End July	

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Mr Peter Barnes
Brisbane City Council - Waterways
GPO Box 1434
Brisbane 4001

1/07/2003 *BCC.doc*

Dear Sir

BRISBANE RIVER FLOOD STUDY – FURTHER INVESTIGATIONS

After yesterday's meeting we have discussed the issues raised in relation to reviewing the Brisbane River Catchment Hydrology estimates with Dr Rory Nathan in our Melbourne Office

As we stated in today's meeting, we consider it necessary to investigate both Flood Frequency Analysis and CRC Forge rainfall based estimates. It would be difficult to validate the rainfall based estimate without undertaking a Flood Frequency Analysis (FFA).

To undertake modelling using the revised rainfall based estimates, we need to adopt loss rates in our hydrological model. Best practice is to apply loss rates until rainfall based flow estimates, match well with flood frequency estimates. If loss rates are within acceptable limits (determined previously during model calibration), then we can adopt river flows with some degree of confidence. This methodology was previously adopted and has been reviewed and accepted. We believe that this methodology should be adopted again using the new information.

To proceed we consider the most appropriate way is as follows:

Phase 1

Review the Flood Frequency Estimate at Moggill Gauge – Review the FFA estimate work undertaken by BCC. This work includes reduction in flow estimates at Port Office and Moggill Stream Gauges due to dredging and the Brisbane River Bar. In order to investigate the 1893 flood event, we would also require information collated by NRM for the Generalised Tropical Storm Method work.

Review the CRC Forge Rainfall provided by NRM – review of the revised rainfall estimates derived by NRM. To undertake this review we require a plan of the CRC Forge Stations within the catchment, growth curves with sample rainfalls and maxima at each of these stations.

Once we have undertaken the FFA and reviewed the CRC Forge Rainfall, we will then discuss the findings with the review panel and decide if we continue with hydrologic/hydraulic modelling.

Expert Panel – Given the extensive panel of experts that have been proposed, we consider that it would be beneficial to have Dr Rory Nathan present at Expert Panel Meetings. Dr Nathan's role at these meetings would be to ensure that an expedient agreement can be achieved, and also to clarify any technical matters that may arise during the meeting.

Phase 2

If Phase 2 of the project proceeds, both hydrologic and hydraulic models will be supplied by BCC to SKM. This will ensure that the most up to date models are used for the investigation.

Re-run the RAFTS model using the CRC Forge rainfalls – this work can only be undertaken after a review of the Flood Frequency Analysis and the CRC Forge rainfall estimates have been completed. Running the hydrological model is intended to validate finding of the FFA.

Hydraulic modelling – During the Ipswich Rivers Flood Studies we found that adding tributaries (i.e Bremer River) to the Brisbane River Model reduced flood levels in the Brisbane River. Given that Brisbane City Council has undertaken flood modelling on other tributaries (i.e Oxley Creek), we consider that it would be beneficial to expand the Brisbane River Model to include these tributaries. This may not be required in the short term, however this could provide another means of reducing flood levels in Brisbane River. The logic behind this is that flows from the major tributaries have a shorter time of concentration than does the Brisbane River. The peak flood flows from the lower Brisbane River Tributaries could be finished by the time the upper Brisbane Flows reach the lower Brisbane River. The tributaries could therefore provide storage and thus reduce flood levels.

We propose that for the initial Phase 1 of the project be undertaken on a time and expenses basis. Once the panel has made a decision whether or not to proceed with Phase 2, we could proceed on either time an expense or a fixed fee. We have provided charge out rates for key personnel below. The rates provided below are exclusive of GST.

Dr Rory Nathan - [redacted]

All work will be conducted in accordance with Sinclair Knight Merz Standard Terms of Agreement for Consultancy. A copy has been attached for your information.

If you would like us to proceed on this basis please provide written confirmation.

If you could provide the information we have requested as soon as possible, we can commence investigations. Rory Nathan will be in Brisbane next Tuesday afternoon and would like to meet with Council representatives and John Ruffini to discuss a way forward. Can you please organise a meeting with the relevant people from BCC and John Ruffini and advise us of the time and place. Given the discussions we need to commence the meeting early afternoon (say 1:00 PM).

I trust this scope of work meets your requirements however should you have any questions, please contact me at this office.

Yours sincerely

[redacted]
Project Manager
Phone:
Fax:
E-mail:

BRISBANE RIVER FLOOD STUDY MEETING
Notes from Meeting 1

Sustainable Water Resources
Water Resources Branch
Urban Management Division

Meeting Description: Technical aspects of flood study to determine Q100
Purpose of Meeting: To confirm technical aspects of the flood study and specific actions to determine Q100
Date: 8 July 2003 Time: 1:00pm Location: BAC 5 conference room

People Attending		
1	Rory Nathan	SKM Melbourne
2	[redacted]	SKM Brisbane
3	John Ruffini	DNRM
4	Don Carroll	City Design, BCC
5	Ken Morris	City Design, BCC
6	Evan Caswell	City Design, BCC
7	Gavin Blakey	Water Resources, BCC
8	Peter Barnes	Water Resources, BCC
9	[redacted]	Water Resources, BCC

Items Discussed			
1	Agreed on agenda and time		
2	Discussed process to be used to incorporate DNRM's data into the BCC model	The Flood Frequency Analysis is will be refined by reviewing assumptions to date as some may be conservative, and others may now be modified given the information that has become available since the SKM / BCC / ICC model was completed.	
3	Agreed specific actions to be taken to determine revised Q100	See actions listed below	
4	Discussed role of Expert Panel and Stakeholders groups	Gavin Blakey handed out the Draft Terms of Reference for the Expert Panel and asked the group to provide feedback in the next day or two. There was discussion about whether the Expert Panel should sign off on Q100 or a range and about membership of the panel.	
	See Page 2 for Notes and Actions		

	Notes		
	John Ruffini advised that a sensitivity analysis had been undertaken during the rainfall analysis to see the effects of inclusion / removal of 1893 event. This had limited effect on the outputs of the study.		
	Mark Salisbury advised that based on preliminary investigations using rainfall from the 1998 study, insertion of the new Dam Operating Rules in the BCC (SKM) model has reduced the Q100 flow at the Port Office. Based on this information it is likely that using the ARF with the CRC Forge will reduce flows. Reduction yet to be quantified. Will be able to take into account water level in the dam at the time of a major rainfall event (eg Wivenhoe 90% full at the start of the event).		
	Rory Nathan advised that: 1. Preliminary assessment confirmed that the DNRM FORGE estimates of rainfall seem reasonable. 2. The FORGE methodology takes into account tropical storm scenarios. 3. Now need to review the Flood Frequency Analysis conducted by BCC / SKM to ensure it is based on the latest available information. 4. This work should list the confidence levels in data / methodology and if further work is required. Also need to list assumptions made in analyses. 5. SKM will download river gauge data from the DNRM and BoM sites as the data used in the 1998 and 1999 reports may now be out of date. 6. There may be some conservatism in some of the earlier assumptions - given the information that is now available assumptions should be checked. 7. Need to check balance of skills on the proposed expert panel – may not be necessary to have five panel members.		
	ACTIONS	BY WHOM	BY WHEN
1	Outline steps and timeframes and approximate $ to undertake work discussed at the meeting	[redacted]	Wednesday 9 July pm
2	Source gauging station data from BoM and DNRM (if any snags in obtaining information contact Ken Morris to assist in procurement)		Over next week or two
3	Update Gantt Chart with new and amended activities and timelines		Thursday 10 July

Prepared by Gavin Blakey

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Mr Peter Barnes
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Brisbane 4001

8/07/2003

L002.doc
RE09148

Dear Peter

BRISBANE RIVER FLOOD STUDY - FURTHER INVESTIGATIONS PROPOSAL

At our meeting yesterday, [redacted] requested that we prepare a scope of work, timeline and fee estimate to proceed with further investigations of the Brisbane River Flood Study.

Scope of Work

1) Collect and Collate Data. This task involves the collection of stream gauge information and discussions with hydrographers from various Stream Gauge Authorities to determine the reliability of readings at individual Gauging Stations. The amount of time available will dictate the degree to which the quality of the annual maxima can be assessed, and any caveats on the remaining uncertainty will be noted in the report.
2) Undertake a regional and at-site flood frequency analyses (FFA) for the Brisbane River Catchment under 'No Dams' conditions for selected sites.
3) Document findings of the Flood Frequency Analysis stating assumptions and outcomes of the investigation.
4) Meet with the Expert Panel to discuss the Flood Frequency Analysis Outcomes. An allowance of one face-to-face meeting has been allowed for in the fee estimate.
5) Remove Wivenhoe and Somerset Dams from the RAFTS model. Input the CRC Forge Rainfall Estimates into the RAFTS model and apply Areal Reduction Factors. Adjust loss rates to the RAFTS model for the 100 year ARI event until flows match those predicted by the FFA. The loss rates will then be assessed to determine whether they are within acceptable limits for the catchment. Note that this is a milestone for the investigation. Should the loss rates not be within acceptable limits, other factors will have to be investigated extending time and costs associated with the investigation, or else appropriate caveats noted in the report.
6) Assuming the previous milestone has been satisfied, Wivenhoe and Somerset Dams will be reintroduced into the RAFTS model along with the adopted loss rates. Hydrograph information from the RAFTS model would then be used as input into the NRM Dam Operation's model to determine an outflow hydrograph from Wivenhoe Dam. This

outflow hydrograph would reflect Dam Operation release procedures. The Outflow hydrograph will then be input into the RAFTS model and the RAFTS model will be re-run to determine 100 year ARI flows at Moggill.

7) Assess importance of Starting Water Level (SWL) of Wivenhoe and Somerset Dams. To this end, long term synthetic data on water levels (corresponding to current operating conditions) will be obtained from SEQB (?) and used to assess the range of starting levels likely to be associated with floods of differing severity. Depending on the outcome of this analysis, either a fixed starting level will be adopted or else a joint probability approach will be used. The time available and nature of the starting level information will dictate the level of sophistication appropriate to the joint probability approach (if required), and discussions will be held with BCC prior to tackling this aspect of the problem.

8) Prepare a report documenting the findings of the FFA and the RAFTS modelling.

A work program has been prepared and is attached for your information.

It is proposed that all work performed will be conducted in accordance with Sinclair Knight Merz Standard Terms and Conditions and a copy of this has been attached.

The estimate of the fee (GST Exclusive) required to complete the above works is around $45,000. This fee does not include work undertaken to this point. This work will be conducted on a time and expenses basis outlined in our letter of 1/7/2003. We will provide you with short reports on a weekly basis that outlines progress and expenditure to date, thus any required changes to scope and direction can be accommodated during the course of the project.

I trust this proposal meets your requirements however should you have any further questions, please contact me at this office.

Yours sincerely

[redacted]

Project Manager

Phone: [redacted]
Fax:
E-mail:
Encl.

Brisbane City Council

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Telephone 3403 6639
Facsimile 3403 9456

TO: Barry Ball, Manager Water Resources

COPY TO: Project team

FROM: Gavin Blakey,
Principal Officer Sustainable Water Resources

DATE: 11 July 2003

PROJECT: Brisbane River Flood Study

FLOOD STUDY

Actions to date:

- Project team has met on two occasions since meeting chaired by CEO Jude Munro. Specific actions required to deliver the project have been identified and commenced.
- SKM have been engaged to undertake this work with City Design
- Dr Rory Nathan of SKM has undertaken a preliminary assessment of the rainfalls determined by DNRM and has confirmed that they are reasonable. Based on this preliminary information it is likely that using the Areal Reduction Factors with the CRC Forge rainfalls will reduce flows produced using the BCC model (this is to be confirmed with model enhancement work to be undertaken over the next few weeks).
- Expert panel members have been approached. We have not been able to contact Professor Mein yet as he will be overseas on holidays until late July. Terms of Reference for the group have been drafted and will be sent to the group for their review.

Proposed actions over next few days:

- Collect new stream gauge data from State and Commonwealth agencies to validate final methodology assumptions.
- Use all available information to review BCC's Flood Frequency Analysis.
- Finalise engagement of Expert Panel

Proposed actions over next few weeks:

- Expert Panel to be asked to review methodology used to determine Q100
- Determine Q100 to be adopted by BCC using Flood Frequency Analysis, RAFTS modelling, joint probability analysis
- Expert Panel to meet and consider BCC and DNRM methodologies and results and determine if Q100 flow calculated using BCC methodology is reasonable.
- Current timelines are for an initial meeting of the Expert Panel in late July, with a draft report and second Expert panel meeting for mid-August, and final report by the end of August. These timelines will be dependent on Professor Mein's availability.

Key issues:

- Engaging Professor Mein for the Expert Panel
- Running the BCC model which needs to be updated with latest data and recalibrated

Key successes:

- BCC model can be updated with latest information over next few weeks

- Three of the four expert panel members have agreed to be on the panel

If you have any questions regarding this report, please call me on [redacted]

Gavin Blakey
Principal Officer Sustainable Water Resources
URBAN MANAGEMENT DIVISION

BRISBANE RIVER FLOOD STUDY MEETING
Notes from Meeting 2

Sustainable Water Resources
Water Resources Branch
Urban Management Division

Meeting Description: Methodology being used to determine Q100
Purpose of Meeting: To discuss technical aspects and methodology and identify specific actions to determine Q100
Date: Monday 14 July 2003 **Time:** 9:30-11:15am **Location:** BAC 5 conference room

People Attending		
1	[redacted]	SKM Brisbane
2	Don Carroll	City Design, BCC
3	Ken Morris	City Design, BCC
4	Barry Ball (last part of meeting)	Water Resources, BCC
5	Gavin Blakey	Water Resources, BCC
6	Peter Barnes	Water Resources, BCC
7	[redacted]	Water Resources, BCC

Items to Discuss			
1	Agreed on agenda and time		
2	Discussed process to be used to incorporate DNRM's data into the BCC model and methodology we are using to determine revised Q100	BCC / SKM will be using CRC FORGE rainfall data and areal reduction factors and review the Flood Frequency Analysis then determine Q100.	
3	Discuss assumptions / parameters used in studies to date	Ken Morris still collating assumptions / parameters	
4	Discuss Terms of Reference for Independent Expert Review Panel	SKM's 8/7/03 proposal to be sent to *Independent Expert Review Panel* for consideration	
5	Agree specific actions to be taken to determine revised Q100	See below	

	Notes
1	SKM will undertake hydrological analysis. City Design will undertake hydraulic analysis (eg determine Q100 flood level based on Q100 flood flow)
2	If needed BCC can call DNRM to ask that they provide stream gauge data to SKM. [redacted] can provide [redacted] contact details.
3	Barry Ball has asked the waterways partnership to see how a modified version of their model could be used to present the findings of the Brisbane River Flood Study (eg to show the catchment and anticipated flows at specific times during a Q100 event).

4	Barry Ball asked that we talk to SEQWCo to find out how their dam operating rules could be changed to better manage downstream flooding. [redacted] said given the proposed upgrade to the Wivenhoe Dam wall that he would do a run of the hydrologic model to see the effect of no outflow from the dam.

	ACTIONS	BY WHOM	BY WHEN
1	Update table of assumptions / parameters and return to Gavin Blakey for circulation to working group.	Ken Morris	Tuesday 15 July
2	Commence hydraulic analysis (ie have model ready for SKM inputs)	Ken Morris	End of July
3	Provide dam operating information (eg water levels in dams) to SKM for their yield analysis. [redacted] may need to confirm details with John Ruffini.	Ken Morris	Thursday 17 July
4	Attach SKM's proposal to the Terms of Reference to be sent to Independent Expert Review Panel	Gavin Blakey	Thursday 17 July
5	SKM to undertake a sensitivity analysis for dam water level at the beginning of the Q100 event, ie 100%, 90%, 80% and 70% full.	[redacted]	See work program
6	Prepare and send a weekly report on progress to Gavin Blakey. Gavin will use this report as the basis for updating within BCC.		On Friday mornings
7	Update Gantt chart with tasks and circulate to working group members.		Tuesday 15 July
8	Contact SEQWCo to discuss how their Dam Operating Rules could be changed to more effectively manage downstream flooding.	Gavin Blakey	Friday 25 July
9	Contact DNRM to find out if their report will be completed by the end of August 2003	Gavin Blakey	Friday 25 July
10	Confirm that the dam operating rules can be included in the BCC model and are likely to reduce outflows from the dam in a Q100 event	[redacted]	Tuesday 15 July

Prepared by Gavin Blakey

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Mr Gavin Blakey
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18/07/2003

L003.doc
RE09148

Dear Gavin

BRISBANE RIVER FLOOD STUDY - PROGRESS REPORT WEEK ENDING 20 JULY 2003

This letter provides our progress for the week ending 20 July 2003.

Actions to date:

- Reviewed the City Design 1999 Report
- Contacted NRM, BOM amd BCC to obtain stream gauge information. We have not received any data as yet but are expecting to have all data by Tuesday of next week.
- Discussed reliability of various stream gauge sites with NRM and BOM officers.
- Commenced writing the final report

Proposed actions over next few days:

- Continue to procure data from NRM, BOM and BCC.
- When data is received we will review and manipulate data for use in FFA.
- Continue writing the final report.

Proposed actions over next few weeks:

- Undertake Flood Frequency Analysis at sites where data is considered reliable
- Undertake RAFTS modelling.
- Determine the sensitivity of assuming different starting water levels in the dams.

Key issues:

- At the moment we can not continue with significant works as we still have not received stream Gauge information.
- Before Tuesday next week, we require the GTSM information held by John Ruffini in NRM. This information will give us more confidence in flows estimated for the 1893 flood event. As you are aware, this event has a major impact on Flood Frequency Analysis estimates and we need to get this right.

Key successes:

- The program showed that we were supposed to have all data by Tuesday this week and at this stage we have been promised this day by Tuesday next week. This means we are currently one week behind schedule. We may be able to make up this time however further delays are definitely going to cause delays to the finish date.

I trust this report is acceptable. If you have any questions regarding this report, please contact me at this office.

Regards

[redacted]
Project Manager
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Fax:
Mobile:
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25/07/2003

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RE09148

Dear Gavin

BRISBANE RIVER FLOOD STUDY - PROGRESS REPORT WEEK ENDING 27 JULY 2003

This letter provides our progress for the week ending 27 July 2003.

Actions to date:

- Went to NRM Office and extracted stream gauge information
- Input CRC rainfall into the RAFTS model.
- Reviewed the City Design 1999 Report
- Contacted NRM, BOM amd BCC to obtain stream gauge information. We have received almost all of the data but require a few more details from BoM.
- Discussed reliability of various stream gauge sites with NRM and BOM officers.
- Continue writing the final report

Proposed actions over next few days:

- Review stream gauge data.
- Meet with Ken Morris of BCC to discuss outcomes of the 1999 report.
- Commence Flood Frequency Analysis
- Meet with the expert panel
- Continue writing the final report.

Proposed actions over next few weeks:

- Complete Flood Frequency Analysis at sites where data is considered reliable
- Undertake RAFTS modelling.
- Determine the sensitivity of assuming different starting water levels in the dams.

Key issues:

- Obtaining the 1893 rainfalls and temporal patterns from BCC. I hope to get this data from Ken Morris at our meeting on Monday.

Key successes:

- We are 7 days behind the programmed schedule due to delays associated with the supply of data. We will try to make up this time however this wil depend on the data review. If data needs a lot of evaluation/manipulation, we may not be able to make this time up.

I trust this report is acceptable. If you have any questions regarding this report, please contact me at this office.

Regards

[redacted]
Project Manager
Phone:
Fax:
Mobile:
E-mail:
[redacted]

Brisbane River Flood Study
EXPERT REVIEW PANEL
Notes from Meeting 1

Meeting Description: Review methodology being used to determine Q100

Purpose of Meeting: To discuss technical aspects and methodology and identify specific actions to determine Q100

Date: Thursday, 31 July 2003 **Time:** 8:30am - 4:00pm **Location:** SKM Board Room

Participants	
Professor Russell Mein – Expert Review Panel Chairman	Barry Ball – Water Resources, BCC
Professor Colin Apelt – Expert Review Panel	Gavin Blakey - Water Resources, BCC
[redacted] – Expert Review Panel	Peter Barnes - Water Resources, BCC
Erwin Weinmann – Expert Review Panel	Don Carroll – City Design, BCC
Mary Shortland – City Design, BCC	Ken Morris – City Design, BCC
John Ruffini – Dept of Natural Resources & Mines, Qld	[redacted] – SKM, Brisbane
[redacted] - SKM, Brisbane	Dr Rory Nathan – SKM, Melbourne (by phone)
	[redacted] – SKM, Melbourne (by phone)

Agenda items			
1	Introduced participants	Russell Mein	8.30
2	Discussed and agree on agenda items	Russell Mein	8.40
3	Discussed and agreed Terms of Reference for Expert Review Panel	Barry Ball	8.50
4	Overview of Brisbane River and Peer Review	Russell Mein	9.10
5	**Discussion of methodology / assumptions / parameters used in studies to date**		9.30
5a	SKM 1998	[redacted]	9.30
	Discussed and clarified issues	All	
5b	City Design June 1999 and December 1999	Ken Morris	10.00
	Discussed and clarified issues	All	
	Morning Tea		10.45
5c	DNRM work on Forge, ARF, Dam Operating Rules, Loss rates etc	John Ruffini	11.00
	Discussed and clarified issues	All	
5d	SKM 2003 – work currently being undertaken	[redacted] Rory Nathan, [redacted]	11.45
	Discussed and clarified issues	All	
	Lunch		12.30
6	General discussion, contract details	Panel Members, Barry Ball	1.00
7	Agreed on what needs to be covered in afternoon and recapped on outstanding issues	Panel Members	1.15
8	Discussed methodology presented, assessed appropriateness of methodology being used, recommend actions still required.	Panel Members	1.30

9	Outlined specific actions to be taken to determine revised Q100	Panel Members and others	2.45
10	Closing comments and close meeting	Russell Mein	3.45

	Notes
4	**Overview – Russell Mein** • Russell provided an overview of the two methodologies (Flood Frequency Analysis and rainfall based estimates) and the importance of considering both. •
5a	**1998 SKM Report –** [redacted] • [redacted]utlined key aspects of 1998 study, including calibration, verification, isoheytal maps, calibration / rating curves. The hydrologic model developed for "no dams" case. 350 nodes for rainfall events. Assumed free release from dam and dam full at start of flood event. Since the 1998 study two bridges have been raised (and the operating rules changed) so there is more flexibility in managing flood events using the mitigating properties of the dams. • Fit by eye curve was used for FFA as this was preferred by BCC. • John Ruffini: BoM rating curves are really 'calibration curves; NRM Brisbane Port Office is a water height gauge only. First gauging station out of the tidal zone with good data is at Savages Crossing (covers about 10,000 km^2). Only rating done on Mt Crosby weir was done during the 1999 event. Limited ratings were done at Jindalee Bridge in 1974 (mainly water surface velocity measurements). • Erwin asked about length of records: Lowood since 1910, but on a bend, so moved to Savages. [redacted]said he would not class Moggill or Brisbane Port Office as gauging stations. Mt Trampia (Lockyer Creek) since 1909. Warrill Creek on Bremer catchment in place since 1961.

5b	**June and December 1999 Reports – Ken Morris** • Ken delivered a PowerPoint presentation on the June and December 1999 report. *June 1999 Report:* • John Ruffini: No flow information for the 1893 flood anywhere, only peak heights. • Panel noted that the re-analysis of the 1893 event was broad brush – required a number of assumptions. • [redacted] asked about "design rainfall" used in June 1999 report (refer Para 3 on Page 8 of the report). Ken Morris said that for expediency used this methodology to determine Q100. Fundamental assumption is that the flood frequency curve is correct (Page 7). • City Design assumed that the dam is full because this is generally the case before a major flood event. • Russell Mein: Noted that spatial distribution of rainfall is important. *December 1999 Report:* • Ken Morris said key issues were 1893 event and dam operating rules. 1893 Cromanhurst pattern based on 76 rainfall stations around catchment. Cromanhurst just outside the catchment. Yandina is outside catchment. This report included all 160 years of records (since 1841). • Erwin Weinmann commented that the measurements for the 1893 event appeared to be based on surface velocities. • John Ruffini: Transport Department can generate profiles of tide and storm surge for specified events. • Ken Morris: Some work done on dam operating rules – but did not believe it would have much influence at the larger flows in Brisbane. • John Ruffini: Somerset is drained into Wivenhoe, so operation of both dams needs to be taken into account in future assessments. • Russell Mein: Seemed reasonable to assume dam full at time report was done. • Ken Morris showed FFA curve with 160 years of data. Dropping out 1840's events only marginally changes FFA curve. Fit by eye and Log Pearson III very similar.

5c	**2003 NRM Report - John Ruffini** • 1993 study – to review dam operations, look at Probable Maximum Flood etc. • 1999 commenced work on rainfall distribution, areal reduction factors etc. • CRC Forge extends rainfall up to 2,000 years and determines Areal Reduction Factors (ARF). Information from NRM study was used to upgrade Dam Operating Rules. • NRM study a collaborative project with 11 partners. Study has cost over $3M. Queensland wide study. • PMP has changed as a result of recent revision of Generalised Tropical Storm Model (GTSM). Work has been internationally reviewed. That segment of work was completed in April 2003. • Study for SEQWC was not focussed on flooding in Brisbane, but provides useful input to Brisbane River Flood Study. • Barry Ball advised that he has had preliminary discussions with the CEO of the Water Corporation about possible need to modify dam operations so that the flood mitigation effect of the dam can be enhanced. • ~500 mm of runoff would completely fill both dams. • To saturate the catchment requires about 100mm of rainfall over a two day period. • 1893 (whole of catchment rainfall) AEP (5 day event?) = 260 years (needs to be read in context of rest of OHT). • John showed table that summarised outcomes of ARF analysis which compares CRC FORGE and ARF applied to ARR rainfalls – good consistency. • 1893 was an upper catchment rainfall event. 1974 rainfall spread across the catchment. • Loss rates of 1.0 and 1.5 mm/hr used across different parts of catchment. Lowest loss rates used were 0.5 and 1.5 mm/hr respectively. • NRM's study assumed uniform rainfall depth across catchment. • Estimates provided to Council (on 27 June 2003) are probably conservative. • John Ruffini has more confidence in his rainfall based estimates of flow than his FFA (uses Log Pearson III). • Brief discussion on types of rainfall events, eg storm and cyclonic, as this will affect rainfall distributions. • Work being done by NRM on soil moisture content across the catchment.
5d	**SKM 2003 – Rory Nathan, [redacted] [redacted] Lauren __** (via phone hook up to Melbourne) • General approach: 'mining' stream gauge info to get better estimate of flow during flood events. • Still waiting on some data, but has done first cut on eight gauges. • Analysis being done on pre-dams. • First assessment has been done on Savages Crossing (73 years of records pre-Wivenhoe). Has not yet done Moggill. • Hard to get good handle on quality of data within time available. • Aiming to get Q100 at top end of hydraulic model. • John Ruffini said that Wivenhoe and Somerset Dams have a significant flood mitigating effect on flood flows. • Brief discussion on the apparent discrepancy between early estimations of flow at Moggill between NRM report and SKM's 2003 estimate – factor of 2!!. **Action**: Rory Nathan and John Ruffini to discuss to see if comparable. • Warned that BoM calibration curves are not rating curves.

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Spring Hill QLD 4004 Australia

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Web: www.skmconsulting.com

Mr Gavin Blakey
Brisbane City Council
GPO Box 1434
Brisbane 4001

25/07/2003

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Dear Gavin

BRISBANE RIVER FLOOD STUDY - PROGRESS REPORT WEEK ENDING 3 AUGUST 03

This letter provides our progress for the week ending 03 August 03.

Actions to date:

- Met with Expert Review Panel to discuss actions to date, methodology and future works
- Undertake preliminary FFA at Savages Crossing
- Reviewed gauging station data
- Met with Ken Morris of BCC to discuss BCC December 1999 Report.
- Went to NRM Office and extracted stream gauge information
- Input CRC rainfall into the RAFTS model.
- Reviewed the City Design 1999 Report
- Contacted NRM, BOM amd BCC to obtain stream gauge information. We have received almost all of the data but require a few more details from BoM.
- Discussed reliability of various stream gauge sites with NRM and BOM officers.
- Continue writing the final report

Proposed actions over next few days:

- Rory Nathan to discuss outcomes of Expert Panel meeting
- Rory Nathan to discuss NRM FFA results and ensure that compatable data sets are being used.
- Continue reviewing stream gauge data.
- Continue with FFA
- Continue writing the final report.

Proposed actions over next few weeks:

- Complete Flood Frequency Analysis at sites where data is considered reliable
- Undertake RAFTS modelling.
- Determine the sensitivity of assuming different starting water levels in the dams.

Key issues:

- Agreement between SKM and Expert Panel over flood frequency analysis.

Key successes:

- Ability to gain access to data presented by NRM at the Expert Panel Meeting.

I trust this report is acceptable. If you have any questions regarding this report, please contact me at this office.

Regards

[redacted]
Project Manager
Phone:
Fax:
Mobile:
E-mail:

BRISBANE RIVER FLOOD STUDY MEETING
Notes from Meeting 3

Sustainable Water Resources
Water Resources Branch
Urban Management Division

Meeting Description: Methodology and actions to determine Q100

Purpose of Meeting: To discuss actions being taken and identify specific actions still required

Date: Wednesday 6 August 2003 **Time:** 11:30am - 1:40pm **Location:** BAC 5 Meeting room

People Attending		
1	Mark Salisbury	SKM Brisbane
2	Don Carroll	City Design, BCC
3	Ken Morris	City Design, BCC
4	Barry Ball	Water Resources, BCC
5	Gavin Blakey	Water Resources, BCC
6	Peter Barnes	Water Resources, BCC

Items to Discuss			
1	Agreed on agenda and time		
2	Discussed actions being taken and issues that need to be resolved (referred to Action lists from Meeting No.2 and Expert Panel Meeting)	Checked off action items from Meeting No.2 of Working Group. Assigned names and dates to action items identified by Expert Review Panel on 31 July 2003.	
3	Agreed specific actions still to be taken	See below	

	ACTIONS	BY WHOM	BY WHEN
1	Ask John Ruffini for time commitment provision of information by NRM (even if NRM has qualifiers eg on quality of information provided) as we need to update LMO and CEO on progress	Gavin B	Friday 8 August
2	Find out from John Ruffini the assumptions NRM has made in spatial distribution of rainfall events	[redacted] Ken Morris	Friday 8 August
3	Undertake rainfall runoff estimate using CRC Forge rainfall depths for 24, 36, 48, 60, 72, 84, 96, 108 hour events distributed in accordance with AR&R temporal pattern (as there isn't a CRC Forge distribution)	[redacted]	Thursday 14 August
4	To enable an understanding of the effects of spatial variation use 1974 (ie rainfall distributed across whole catchment) and 1893 (predominantly an upper catchment) rainfall events	[redacted]	Thursday 14 August
5	Sensitivity analysis: Adjust point rainfalls for 1974 and 1893 so that the average catchment rainfall is equal to the ARI 100 rainfall across the catchment. Run for 7 or 8 durations for pre and post dams scenarios	[redacted]	Thursday 14 August

Prepared by Gavin Blakey

Brisbane City Council

Water Resources Branch
Urban Management Division
Floor 5 69 Ann Street
Brisbane Qld
GPO Box 1434
Brisbane Qld 4001

Telephone 3403 6639
Facsimile 3403 9456

TO: Barry Ball, Manager Water Resources

COPY TO: Project team

FROM: Gavin Blakey,
Principal Officer Sustainable Water Resources

DATE: 8 August 2003

PROJECT: Brisbane River Flood Study

Progress Report

Actions this week:

- Actions required for analysis of flood flow and level confirmed by Expert Review Panel.
- Contract documents signed with expert panel members.
- Organised second expert review panel meeting for Thursday 14 August 2003
- Discussed Bridge Design Standards for river structures (eg for Goodwill Bridge, Floating RiverWalk, Green Bridge) with Doug Yuille of LMO. Doug prepared a draft presentation in consultation with Water Resources and City Design.
- Prepared spatial distribution of design and historical rainfall events. Appropriate temporal patterns for rainfall determined.
- Commenced assessment of tidal influence on flows in lower sections of the river.
- Requested and obtained key data from current NRM study to enable assessment of flood frequency analysis and design rainfall.
- RAFTS model modified ready to accept spatial patterns.

Proposed actions over next week:

- Compare flood frequency analyses undertaken by SKM and NRM to ensure that compatible data sets are being used.
- Undertake actions arising out of Expert Review Panel meeting.
- Reviewing stream gauge data, check compatibility of data sets.
- Conduct expert panel meeting No.2 to review progress so to date and confirm specific actions required to determine flows and levels.

Proposed actions over next few weeks:

- Determine Q100 using Flood Frequency Analysis, undertake RAFTS modelling and sensitivity analysis of dam starting water levels
- Expert Panel to meet in late August to consider BCC and DNRM methodologies and results and determine if Q100 flow calculated using BCC methodology is reasonable.

Key issues:

- Securing stream flow data from external agencies has taken longer than expected, so all effort is being made to ensure that the project stays on target. Some flexibility may be required in the timeline to ensure that an adequate level of analysis can be undertaken prior to determination of the Q100.
- Keep the Expert Review Panel in the loop to ensure that their recommendations are addressed and they can assess the Q100 flood flows and levels.

- While I am away [redacted] and Peter Barnes will be looking after the project coordination.

Key successes:

- Panel affirmed direction being taken by BCC and SKM and recommended specific actions to be taken to finalise Q100
- Started to run BCC / SKM models with NRM information so that the Flood Frequency Analysis can be checked and compared to CRC Forge results.

If you have any questions regarding this report, please call me on [redacted]

Gavin Blakey
Principal Officer Sustainable Water Resources
URBAN MANAGEMENT DIVISION

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Mr Gavin Blakey
Brisbane City Council
GPO Box 1434
Brisbane 4001

25/07/2003

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Dear Gavin

BRISBANE RIVER FLOOD STUDY - PROGRESS REPORT WEEK ENDING 10 AUGUST 03

This letter provides our progress for the week ending 10 August 03.

Actions to date:

- Continued with Regional FFA
- Attended meeting at NRM to discuss how to get data requested by Expert Panel
- Attend meeting with BCC and meet with Don Carrol to review spatial distribution works undertaken by BCC
- Received some spatial distribution data from BCC
- Currently modifying RAFTS model to accept BCC spatial patterns
- Met with Expert Review Panel to discuss actions to date, methodology and future works
- Undertake preliminary FFA at Savages Crossing
- Reviewed gauging station data
- Met with Ken Morris of BCC to discuss BCC December 1999 Report.
- Went to NRM Office and extracted stream gauge information
- Input CRC rainfall into the RAFTS model.
- Reviewed the City Design 1999 Report
- Contacted NRM, BOM and BCC to obtain stream gauge information. We have received almost all of the data but require a few more details from BoM.
- Discussed reliability of various stream gauge sites with NRM and BOM officers.
- Continue writing the final report

Proposed actions over next few days:

- Present results of Regional FFA to Expert Panel for comment
- Undertake RAFTS modelling to match FFA
- Rory Nathan to discuss outcomes of Expert Panel meeting
- Rory Nathan to discuss NRM FFA results and ensure that compatible data sets are being used.
- Continue reviewing stream gauge data.
- Continue with FFA
- Continue writing the final report.

Proposed actions over next few weeks:

- Complete RAFTS modelling
- Complete FFA
- Determine the sensitivity of assuming different starting water levels in the dams.

Key issues:

- Agreement between SKM and Expert Panel over flood frequency analysis.

Key successes:

- Ability to gain access to data presented by NRM at the Expert Panel Meeting.

I trust this report is acceptable. If you have any questions regarding this report, please contact me at this office.

Regards

[redacted]
Project Manager
Phone:
Fax:
Mobile:
E-mail:
[redacted]

Contact name: [redacted]
Phone:
Fax *direct*:
Your Reference:
Our Reference: CD040015

Brisbane City Council
ABN 72 002 765 795

City Design
Level 3 TC Beirne Centre
315 Brunswick Street Mall
Fortitude Valley 4006
Locked Mail Bag 6996
Albion Qld 4010
Telephone 07 3403 3849
Facsimile 07 3403 0551

12 August 2003

The Manager
Sinclair Knight Merz Pty Ltd
P.O. Box 246
SPRING HILL QLD 4004

Dear Sir,

Re: Provision of Hydraulic Engineering Services

1. Provision of Services

Subject to your signing and returning a duplicate of this letter, the Brisbane City Council through City Design will engage Sinclair Knight Merz Pty Ltd to provide hydraulic engineering services as described in paragraph 2 of this letter.

The entire contract between you and the Council for the provision of the Services is comprised of the terms of this letter together with the attached terms and conditions marked "Attachment A" and entitled "General Conditions for Services" and all other attachments to this letter (**"the Contract"**).

When you sign the duplicate letter, you need to also initial each page of the attached documentation and return the document and its attachments to the Council Liaison Officer named at the end of this letter.

If you disagree with any of the attached terms, please do not unilaterally amend any of the terms and conditions of the Contract. Instead, please contact the Council Liaison Officer as a matter of urgency. Any unilateral amendment by you of the terms and conditions will not be construed by Council as an amendment or variation to this Contract unless the Council agrees in writing to such amendments.

2. Nature of the Services

The scope of work to be undertaken through this contract includes the provision of hydraulic engineering services in relation to:

a) Review of the Brisbane River hydrologic and hydraulic models as outlined in the fax from Sinclair Knight Merz received 4 July 2003, and as directed by the Council liaison officer.

3. Timing

The Contractor shall:

(a) commence work on the Services on 7 July 2003; and;

(b) ensure that all of the Services are duly performed and delivered to the Council in accordance with this Contract on or before 30 September 2003.

[redacted]

Our Business - A Better Brisbane

4. **Specified Personnel**

The Contractor shall ensure that the Services are performed by the officers specified in the proposal ("**the Specified Personnel**"). If at any time:

(i) the Specified Personnel is not available for any reason (whether within the control of the Contractor or not); or

(ii) the Council is of the reasonable opinion that the Specified Personnel either does not have the capacity to undertake the Services to the level required or is responsible for any disruption in the delivery of the Services;

then the Contractor shall replace the Specified Personnel in question with another suitably qualified and experienced person who is acceptable to Council. Such person shall be included within the term "Specified Personnel" and the substitution shall be:

A. undertaken at the earliest opportunity but not later than seven (7) days (or such later date as the Council may agree) from the date the Specified Personnel in question has ceased to be available; and

B. at no additional cost to Council.

5. **Fees**

Subject to clauses 5, 6 and 7 of the General Conditions for Services, the fees payable by the Council for the provision of the Services ("**the Fees**") shall be charged at no more than the following rates (which includes all cost and expenses associated with the provision of the Services):

Table of Fees

Person to perform the Service	Fee exclusive of GST
Dr Rory Nathan	[redacted]
[redacted]	

These Fees shall be charged per hour up to an initial maximum value of $45,000 (incl. GST) and will not be charged on a pro-rata basis. Additional hours are to be agree with Council prior to proceeding.

Please also note that:

(a) these Fees shall be invoiced on a fortnightly basis and shall be only payable pursuant to clause 5 of the General Conditions. The provisions of clause 5 of the General Conditions also specify that these Fees will only be payable on the receipt by Council of a properly rendered invoice. See clause 5 for what will constitute a properly rendered invoice and also for when Council will be paying these Fees; and

(b) the amount of GST applicable to Services will be determined in accordance with the GST Laws as amended from time to time.

6. **Indemnity**

(a) Upon demand being made by the Council, the Contractor shall fully indemnify the Council and its officers and employees:

(i) from and against any claim made by any of the Contractor's officers, employees, agents, Specified Personnel or its authorised sub-contractors (if any) in relation to the performance of the Services that they are employees (as commonly defined) of Council or "workers" of the Council under the *WorkCover Act 1996* of Queensland (as amended from time to time); and

[redacted]

(ii) from and against any loss or liability whatsoever (including, but not limited to, legal costs and expenses on a solicitor/own client basis) arising out of or in connection with any claim that the performance of the Services (including the creation, preparation or delivery of any Deliverable) has or is infringing (either wholly or partially, directly or indirectly) the Intellectual Property Rights of any person; and

(iii) in relation to any costs, losses, or damages of any kind suffered or incurred by the Council or its officers or employees where such costs, losses or damages arise in any manner out of:

A. any negligent, wilful, unlawful or wrongful act or omission by the Contractor or any of the Contractor's officers, employees, agents, Specified Personnel or its authorised sub-contractors (if any) in relation to the performance of the Services in relation to the provision of the Services; or

B. any breach of this Contract by the Contractor or any of the Contractor's officers, employees, agents, Specified Personnel or its authorised sub-contractors (if any).

(b) Notwithstanding paragraph (a), the Contractor's liability for any claim arising out of any personal injury to or the death of any person or loss of or damage to property shall be reduced to the extent that such claim is a direct result of either any breach by the Council of any provision of this Contract which causes delay to the Contractor performing the Services as required by this Contract or any negligent act or omission of the Council, its employees, agents, contractors or sub-contractors.

(c) If the Contractor fails to comply with its obligations under this Contract and fails to rectify such breach as and when requested to do so by the Council in accordance with this Contract, the Council may engage another Contractor to provide the Services in question and shall be able to recover such costs of engaging the other Contractor from the Contractor. The Council shall use its best endeavours to ensure that the Services in question are carried out in the most cost effective manner and shall provide the Contractor with written documentation of the actual costs incurred by the Council. The Contractor shall pay such costs to the Council within 14 days of being requested to do so by Council.

7. Notices

Please note that notices under the Contract may be delivered by hand, by mail or by facsimile to our respective offices. In the case of the Council, any such notices must be addressed to Mr Ken Morris, Principal Engineer Flood Management, City Design, Locked Bag 6996, ALBION, QLD 4010 or by facsimile to 07 3403 0438.

In the case of the Contractor, any such notices must be addressed to Sinclair Knight Merz, PO Box 246 Spring Hill Q 4004, or by facsimile to 07 3244 7306.

If there are any changes to a party's postal address, facsimile number and/or person to whom notices are to be addressed, these changes will only be effective as and from the date the other party receives written advice of such change.

Notices between Council and the Contractor shall be deemed to be given:

(a) in the case of hand delivery – upon written acknowledgment of receipt by an officer or other duly authorised employee, agent or representative of the receiving party;

(b) in the case of posting – 3 days after dispatch; and

(c) in the case of a facsimile – upon receipt of the answerback transmission or other proof of completion of transmission.

8. **Council Liaison Officer**

The person holding, occupying or performing the duties of Principal Engineer Flood Management shall be the Council Liaison Officer with responsibility for supervision of the Contract on behalf of the Brisbane City Council and shall have authority to act on behalf of the Council and issue and receive any written notification under the Contract. This person shall act reasonably in the exercise of this authority.

Yours faithfully

[redacted]

Don Carroll
Group Manager
Water and Environment

Dated this 15 day of August 2003

Attachments:

Attachment A. General Conditions for Services

FORM OF ACCEPTANCE TO BE SIGNED AND RETURNED BY CONTRACTOR

As a person duly authorised to act for and on behalf of Sinclair Knight Merz Pty Ltd, I agree on behalf of Sinclair Knight Merz Pty Ltd to the provision of the abovementioned Services in accordance with the terms and conditions set out in and attached to this letter.

Signed for and on behalf of Sinclair Knight Merz Pty Ltd by

[redacted]

PRINCIPAL

.....
Signature

in the presence of [redacted] (print name and title of Witness)

.....
Signature of Witness

Date: [redacted]

[redacted]

ATTACHMENT A

General Conditions for Services

1. Interpretation and Applicable Law

In the Contract, the definitions in the attached letter and the following definitions and rules of interpretation apply:

"**the Contractor**" includes the assignees of the Contractor.

"**Contract Material**" means the originals and copies of materials, papers, reports, books, memoranda, accounting records, files, texts, data, computer printouts, computer data (including, but without limiting the generality thereof, financial models of all types) however recorded, stored or embodied in any document or other form of media (electronic or otherwise) and being material etc that is *either* provided by the Council to the Contractor (or any of its staff, contractors or Specified Personnel (if any)) for the provision or the performance of the Services (including each and every outcome or Deliverable) *or* created or prepared by the Contractor or any of its staff or contractors in or incidental to the provision of the Services.

"**Contractor's GST Liability**" means the GST the Contractor is required by the GST Laws to pay or remit in relation to the supply of the Services to the Council under this Contract.

"**Council's Consent**" means prior written consent (which shall not be unreasonably withheld) of the Council which may be given subject to such terms and conditions as the Council may see fit to impose.

"**GST**" means the goods and services tax payable pursuant to the GST Laws.

"**GST Laws**" means the GST law (as defined by *A New Tax System (Goods and Services Tax) Act 1999* of the Commonwealth) together with all other laws and regulations which impose or regulate the implementation and operation of GST and all laws and regulations dealing with price exploitation and excessive profit taking as a result of the transition to the New Tax System.

"**Intellectual Property Rights**" means all forms of patent, copyright, trade mark (whether registered or not), trade name, trade secret, knowhow, discovery, invention, secret process, design, improvement in procedure, innovation or confidential information and any right to register or claim any type of intellectual property.

Words importing a gender include any other gender. Words in the singular number include the plural and works in the plural number include the singular.

This Contract shall be governed by and construed in accordance with the law for the time being in the State of Queensland and the parties submit to the jurisdiction of the courts of that State.

2. Provision of the Services

In providing the Services, the Contractor:

(a) shall provide and complete the Services with reasonable care and skill and act professionally at all times in the performance of the Services and shall provide and complete the Services (including the Deliverables) in accordance with the requirements of the Documentation (including timetables (if any)) and the terms and conditions of this Contract;

(b) shall consult regularly with and keep the Council Liaison Officer informed as to the progress and delivery of the Services;

(c) shall comply with all laws, licences, industrial awards, permits and all other lawful requirements that from time to time are applicable to the proper provision of the Services by the Contractor, its staff, contractors, sub-contractors and assignees (including, but not limited to, the *Environment Protection Act 1994* (Qld) and the *Workplace Health and Safety Act 1995* (Qld);

(d) shall, if the Services involve works that require excavation or boring (either manually or through the use of machinery), contact Dial Before You Dig ("**DBYD**") on telephone number 1100 (or such other number as is assigned from time to time to that service or its replacement service) to request utility plans of underground services in the areas requiring excavation and further, shall ensure that any excavation work undertaken as part of the Services does not adversely impact the proper operation of any utility services as identified by DBYD. All of the cost of contacting DBYD and any damages to such utility services as a direct result of the Contractor providing the Services will be the sole and absolute responsibility of the Contractor;

(e) shall not assign, sub-contract or transfer any of its rights under this Contract without the Council's Consent. Such consent shall be subject to such terms and conditions as the Council deems appropriate to protect its interests;

(f) shall at all times keep and maintain accurate records of the time spent in the provision of the Services. Where required by the Council to verify the fees and expenses invoiced by the Contractor, the Contractor shall provide the Council with free access to such records; and

(g) shall ensure that at all times during the term of this Contract each member of its staff, contractors or sub-contractors (including Specified Personnel) does not take any step which will lead to the Contractor being in breach of its obligations under this Contract.

[redacted]

3. **Variation of Contract**

No variation to the nature or scope of the Services (including the manner of providing the Services) ("the Variation") shall be binding on either party unless and until agreed in writing by both parties. The prices applicable to any such Variation shall be as agreed to by the parties but cannot be proceeded with if the Fees and the prices for the Variation will, in aggregate, exceed $100,000 (exclusive of GST).

4. **Contract Material**

4.1 The title to and ownership of intellectual property (including copyright) in all Contract Material shall vest in the Council immediately upon its creation. The Contractor shall do all things necessary to perfect the vesting of the intellectual property rights attaching to the Contract Material in the Council.

4.2 On the expiration or earlier termination of the Contract, the Contractor shall deliver all copies of the Contract Material (irrespective of the form in which such material has been copied, stored, written, recorded by any means whether electronic or encrypted) to the Council Liaison Officer. The Contractor will be permitted to retain one (1) copy of the Contract Material for archival purposes.

4.3 The Contractor shall not use the Contract Material for any purpose other than performance of the Services. Further, the Contractor shall take all reasonable steps to treat and keep such Contract Material as strictly confidential and shall ensure no unauthorised persons or any third party (including any member of the public) have access to any part of the Contract Material during or after the completion of the Services without the Council's Consent.

5. **Fees and invoice procedure**

5.1 The Contractor shall provide the Services for the Fees specified in the attached letter. The parties agree that the Contractor shall not charge the Council for any additional fees nor incur such additional fees without first obtaining the Council's Consent.

5.2 No monies shall be paid to the Contractor until such time as the Council Liaison Officer has received an properly rendered invoice that meets the requirements of clause 5.3 and the Council Liaison Officer has not exercised the provisions of clause 5.4.

All such invoices must be invoiced on the basis specified in the attached letter (unless otherwise agreed in writing with the Council Liaison Officer). Except where clause 5.4 applies, the Fees invoiced shall be paid 30 days from receipt of a correctly rendered invoice by the Council.

5.3 An invoice will be deemed to not have been properly rendered unless it:

(a) specifies the title of the Service, the name of the relevant business unit within Council, name of the Council Liaison Officer and the Contract number or purchase order number (if any); and

(b) provides such details of the Fees invoiced as the Council Liaison Officer may from time to time require (and which may include the attachment of receipts, the number of hours involved and the amounts of GST (if any)); and

and is a valid tax invoice (as defined by the GST Laws) that also specifies the amount of GST payable in respect of the Services invoiced.

5.4 If at any time before the delivery of an correctly rendered invoice for Services or within 21 days of receipt by the Council Liaison Officer of a correctly rendered invoice, the Council Liaison Officer advises the Contractor that he or she is not satisfied with the standard and progress of all or any of the Services in question ("**Disputed Services**"), then:

(a) the Contractor shall promptly re-perform or re-deliver such Disputed Services until such time as the Council Liaison Officer is satisfied that the Disputed Services have been satisfactorily performed or provided in accordance with this Contract; and

(b) within 30 days of receipt of a correctly rendered invoice, the Council shall pay the Fees for the Services that are not Disputed Services.

The Council shall only be legally required to pay the Fees for any Disputed Services if the Council Liaison Officer is satisfied that the Disputed Services have been satisfactorily re-performed or re-provided to meet the requirements of this Contract. In such a case, payment shall be within 30 days of the Council Liaison Officer being satisfied with the re-performance and re-delivery of such Disputed Services.

6. **Goods and Services Tax**

6.1 Where the Council is legally obliged to pay an invoice pursuant to this Contract, the Contractor shall also be entitled to claim from the Council the amount of the Contractor's GST Liability for any Services to which the invoice relates **provided that** GST is applicable to those Services and the invoice is a properly rendered invoice that complies with the requirements of clause 5.3.

6.2 Except as expressly provided by this clause:

(a) the Contractor shall have no other claim against the Council that arises from or is in connection with any GST payable in respect of the Services;

(b) no other provision of this Contract shall operate to provide for any adjustment of the Fees or give rise to any other claim by the Contractor in connection with any GST payable in respect of the Services; and

(c) where any payment by the Council under this Contract is determined by reference to a

expenses, liabilities or damages incurred by the Contractor, the payment shall exclude any amount for which the Contractor is entitled to claim an input tax credit under the GST Laws.

7. **Conflict of Interest**

The Contractor warrants that, as of the date of entering into this Contract, no conflict of interest exists or is likely to arise in the performance of their obligations under this Contract. If during the term of this Contract, a conflict or risk of conflict of interest arises, the Contractor undertakes to notify the Council immediately in writing of that conflict or risk.

8. **Negation of employment, agency and partnership**

The Contractor shall not represent itself as being an employee, agent or partner of the Council and acknowledges that there is no relationship of employment, agency or partnership with the Council.

9. **Termination of this Contract**

9.1 The Council may:

(a) suspend the scope of the Services at any time during the term of this Contract by the provision of a written notice to the Contractor specifying the extent to which the scope of the Services are to be suspended and the date from which such suspension is to take effect (a "**Suspension Notice**"); or

(b) at any time terminate this Contract due to the Contractor:

(i) failing to comply with a Default Notice as required by clause 9.2;

(ii) having engaged in conduct or practice that is detrimental or harmful to the good name, reputation or interests of the Council;

(iii) entering into any form of insolvency administration or breaching paragraph 7 of the attached letter or clauses 2.2(e) or 4 of these General Conditions; or

(iv) having offered or given any gratuity, bribe, bonus or discount of any sort to any member of the Brisbane City Council or any officer, employee or agent of the Council.

Such termination shall be effected by the Council giving the Contractor a written notice terminating this Contract and specifying the date of termination (a "**Termination Notice**").

9.2 Where the Contractor has failed to comply with the provisions of paragraphs 4, 6 or 7 of the attached letter or clauses 2, 4, 7 or 8 of these General Conditions, the Council may give the Contractor a written notice specifying the breach and requiring the Contractor to rectify the breach within the Specified Time ("**Default Notice**").

For the purposes of this clause, the "**Specified Time**" in relation to any breach of paragraph 6 of the attached letter or clauses 2, 4, 7 or 8 shall be 14 days from the date of the Default Notice (or such longer time period as specified by the Council in the Default Notice) and in relation to a breach of paragraphs 4 or 7 of the attached letter, shall be 7 days from the date of the Default Notice (or such longer time period as specified by the Council in the Default Notice).

9.3 Upon receipt of a Termination Notice or a Suspension Notice pursuant to clause 9.1, the Contractor shall immediately:

(a) where the Contract has been terminated – cease work in accordance with the Termination Notice; or

(b) where the scope of work has been suspended – suspend work in accordance with the Suspension Notice;

and take all steps necessary to minimise the loss suffered by it as a result of either notice and continue to provide Services that are not affected by any such notice. Any termination or suspension of all or part of the Services shall not affect any right or entitlement which either party is entitled to claim under this Contract.

9.4 Upon the termination or suspension of Services, the Council's liability (if any) to the Contractor shall be limited to:

(a) in relation to termination – payments for any Services (or any part) performed in accordance with the Contract before the date of termination as specified in the Termination Notice;

(b) in relation to suspension of the Services – payments for any Services (or any part) performed in accordance with the Contract before the date of suspension as specified in the Suspension Notice; and

(c) any reasonable costs properly incurred by the Contractor which are directly attributable to the termination of the Contract or the suspension of Services (whichever is applicable) but which shall not include loss of prospective profits;

and payments for any Services not affected by either a Termination Notice or a Suspension Notice **provided always** that the maximum amount of the Council's liability to the Contractor under this clause shall be capped at the amount of the Fees (as varied pursuant to clause 3 or abated pursuant to clause 9.4(a)). The Contractor shall not be entitled to loss of profits.

9.5 This Contract can be terminated by mutual written agreement of the parties.

[redacted]

Brisbane City Council

Water Resources Branch
Urban Management Division
Floor 5 69 Ann Street
Brisbane Qld
GPO Box 1434
Brisbane Qld 4001

Telephone 3403 6639
Facsimile 3403 9456

TO: Barry Ball, Manager Water Resources

COPY TO: Project team

FROM: [redacted]
A/ Principal Officer Water Resources

DATE: 15 August 2003

PROJECT: Brisbane River Flood Study

Flood Study

Actions this week:

- Contract documents signed with expert panel members.
- Preparation by City Design of presentations for the Expert Panel
- Expert Panel meeting held successfully on Thursday

Proposed actions over next week:

- Receive and pass on CD's of NRM data to analysis teams
- Receive and distribute final Assessment and Actions list from Panel
- Undertake actions arising out of Expert Review Panel meeting.
- Hold a working team meeting later in the week.

Proposed actions over next few weeks:

- Determine Q100 using Flood Frequency Analysis, undertake RAFTS modelling and sensitivity analysis of dam starting water levels
- Expert Panel to meet in late August to consider BCC and DNRM methodologies and results and determine if Q100 flow calculated using BCC methodology is reasonable.
- Panel to prepare draft report. Current timing anticipated to be no earlier than 27 August.

Key issues:

- Obtaining copies of CD's with the NRM data required by the analysis teams and using this data. This is anticipated to be available late Friday or first thing Monday. The comment in the last report regarding flexibility in timeline is still applicable

Key successes:

- Second Expert Panel meeting held on Thursday. Draft notes and 'assessment and actions' sent for comments.

If you have any questions regarding this report, please call me on 36848.

[redacted]
A/Principal Officer Water Resources
URBAN MANAGEMENT DIVISION

Brisbane City Council

Water Resources Branch
Urban Management Division
Floor 5 69 Ann Street
Brisbane Qld
GPO Box 1434
Brisbane Qld 4001

Telephone 3403 6639
Facsimile 3403 9456

TO: Barry Ball, Manager Water Resources

COPY TO: Project team

FROM: [redacted]
A/ Principal Officer Water Resources

DATE: 22 August 2003

PROJECT: Brisbane River Flood Study

Actions this week:

- Finalising information for Expert Panel.
- Sought further data and information from NRM

Proposed actions over next week:

- Completion of information for Expert Panel
- Expert Panel preparing Report

Proposed actions over next few weeks:

- Receive report from Expert Panel.
- Currently anticipate that this will be mid to late next week ie by Friday 29 August

Key issues:

- Finalising information for Panel
- Finalising data from NRM
- Expert Panel drafting report

Key successes:

- Completion of investigation currently anticipated to be on time

If you have any questions regarding this report, please call me on 36848.

[redacted]
A/Principal Officer Water Resources
URBAN MANAGEMENT DIVISION

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369 Ann Street, Brisbane 4000
PO Box 246
Spring Hill QLD 4004 Australia

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Fax: +61 7 3244 7306
Web: www.skmconsulting.com

Mr Gavin Blakey
Brisbane City Council
GPO Box 1434
Brisbane 4001

25/07/2003

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RE09148

Dear Gavin

BRISBANE RIVER FLOOD STUDY - PROGRESS REPORT WEEK ENDING 17 AUGUST 03

This letter provides our progress for the week ending 17 August 03.

Actions to date:

- Met with Expert Panel
- Completed Preliminary FFA and presented to Expert Panel.
- Completed CRC Forge Model Runs and presented to Expert Panel
- Attended meeting at NRM to discuss how to get data requested by Expert Panel
- Attend meeting with BCC and meet with Don Carrol to review spatial distribution works undertaken by BCC
- Received some spatial distribution data from BCC
- Currently modifying RAFTS model to accept BCC spatial patterns
- Met with Expert Review Panel to discuss actions to date, methodology and future works
- Undertake preliminary FFA at Savages Crossing
- Reviewed gauging station data
- Met with Ken Morris of BCC to discuss BCC December 1999 Report.
- Went to NRM Office and extracted stream gauge information
- Input CRC rainfall into the RAFTS model.
- Reviewed the City Design 1999 Report
- Contacted NRM, BOM and BCC to obtain stream gauge information. We have received almost all of the data but require a few more details from BoM.
- Discussed reliability of various stream gauge sites with NRM and BOM officers.
- Continue writing the final report

SKM

Proposed actions over next few days:

- Continued with RAFTS modelling for 7 historical spatial distributions
- Continued with Regional FFA based on outcomes of Expert Panel Meeting
- Complete works by Friday 18 Aug 2003 and provide Draft Report to Expert Panel and BCC.

Proposed actions over next few weeks:

- Complete Investigation.

Key issues:

- Agreement between SKM and Expert Panel over flood frequency analysis.

Key successes:

- Input of historical rainfalls into existing RAFTS model.

I trust this report is acceptable. If you have any questions regarding this report, please contact me at this office.

Regards

[redacted]
Project Manager
Phone:
Fax:
Mobile:
E-mail:
[redacted]

Brisbane River Flood Study: EXPERT REVIEW PANEL
Notes from Meeting 2: 14 August 2003

Meeting Description: Review methodology to determine Q100

Purpose of Meeting: To review progress and direct further investigations

Date: Thursday, 14 August 2003 **Time:** 8:30am - 4:15pm **Location:** Flinders Room Level 28 Chifley Hotel

Participants	
Professor Russell Mein – Expert Review Panel Chairman	Barry Ball – Water Resources, BCC
Professor Colin Apelt – Expert Review Panel	[redacted] Water Resources, BCC
[redacted] – Expert Review Panel	Peter Barnes - Water Resources, BCC
Erwin Weinmann – Expert Review Panel	Don Carroll – City Design, BCC
	Ken Morris – City Design, BCC
	[redacted] – SKM, Brisbane
	[redacted] – SKM, Melbourne

Items Discussed			
1	Introduced new participants & Discussed on agenda items	Russell Mein	8.30
2	Brief overview of presentation topics	Russell Mein	8.40
3	[redacted]pres'n on FFA investigations of river flood records	[redacted]	9.00
4	Ken Morris pres'n : FFA for certain river stations	Ken Morris	10.15
	Morning tea		10.45
5	[redacted]pres'n: Rafts & FFA	[redacted]	11.00
6	Don Carrol pres'n: Spatial variation for historic events	Don Carrol	12.00
7	Discussion	All	12.30
	Lunch		12.45
8	Expert Panel discussion	Panel members	1.00
9	Discussion on Assessments and Actions	All	2.45
10	Closing comments and close meeting	Russell Mein	4.15

	Notes
3	[redacted]presentation Plot of the 3 day rainfalls from 1909 to present shows no significant difference between pre and post Somerset dam. The most reliable stations, which have BoM rating curves were used. Using this rating curve without assessment (time limits), flows determined for the recorded levels. Get the feeling for best curve to fit the data eg LP3, Pareto etc. Assessed with "L-Moments". Take out the stations which seem to be less reliable and re-plot. The General Pareto seem to give best fit. Period of data 1909-82 at Savages for a 'regional assessment'. Using this gives Q100 Savages 7,900 and Port Office (PO) 9,300. Acknowledge that there is some previous historic information in the 1840's & 1890's and want to increase the data sets accordingly so use 'Bayesian' methods. 'On-site' assessment for Savages (General Pareto curve) yields Q100 = 8,000. Bayesian analysis --> 9,200 using an 1893 flow of 12,000 though BoM think this is too low. Also comment that bringing in 1893 increase the curve and puts 1974 outside the confidence limits. It is likely the hydrologic model was used to determine flows post Wivenhoe and Somerset. The rated values should have been used at Savages/Lowood particularly before Somerset Dam was constructed. [redacted]comment: need NRM information as they don't see a way of getting Savages flow to be the 15,000 which John mentioned last meeting.

	SKM preliminary values 7,900 to 11,000 best guess 10,000.
4	**Ken Morris' presentation** NOTE that all flows which are affected by Somerset dam were increase by 20% to simulate the no-dams situation. This is generally in line with previous estimates. Frequency analysis was carried out on a number of different measuring stations all having 1893 in the period of record These are • Lowood (which is very close to Savages), • Mt Crosby (which is on the Brisbane river downstream of Lowood and upstream of the junction of the Bremer River), • Moggill (which is on the Brisbane River downstream of the Bremer river junction) and finally • Brisbane Port Office. Used existing ratings at Savages and flood levels at Lowood to plot part of the Stage Discharge Curve for Lowood. Then extrapolated the curve using nominated flows for 1893 = 13,500. This was derived from the Moggill Stage Discharge curve. On the basis that the flow at Lowood could not be less than at Moggill because of the rainfall spatial pattern and confirmed by BoM modelling, the lowest estimate of 13,500 was adopted. This gave Lowood Q100 = 10,800. Next look at Mt Crosby using the skm model stage discharge curve with a small adjustment to fit the measured 1893 flood (which didn't affect any other flood in the series). The flood series gave Q100=10,700 Moggill used the SKM model's Stage Discharge curve to develop flows from the BOM measured flood level series. The level measured at Moggill and the flow measured at Jindalee at the peak of the 1974 flood plots onto this Stage Discharge curve and gives credence to its adoption as a reliable curve. The flood series gave Q100= 11,900. BoM has produced a plot showing different levels for pre & post dredging which shows that the reduction due to dredging = 0.6m. This had been thought to be 1.8m previously. Adjusting floods that occurred prior to Dredging by this amount shows the adjusted level and assumed flow of 1893 to plot on the SKM model's Stage Discharge curve. The 1974 flood level and the flow gauging done at Jindalee also plots on this curve. The flood series gave Port Office Q100 = 12,200. Summary: Lowood (records from 1890+) + adopting the lowest estimate of the 1893 flood as 13,500 --> Q100 = 10,800 Mt Crosby (records 1864+) Q100 = 10,700 Moggill (1893+) Q100 = 11,900 Port Office (1841+) Q100= 12,200.
5	[redacted] **presentation** Rafts - CRC-FORGE + application of loss rates + temporal patterns Tables with lots of investigated options. For IL of 40 mm, + 2.5 mm/hr gave a 7,905m3/s (same as flood frequency analysis) & Critical duration of 30 hours SKM FFA 1998- 9,300 at Port cf 8,200 from Rafts Model The peak flow from skm RAFTS model at Savages Crossing with no dams, no loss rates applied was prediced to be 12,000 m3/s. Therefore skm do not have enough rainfall in RAFTS to be consistent with the FFA flow rate of 15500m3/s (no Dams) estimated by NRM. Skm then applied a series of Temporal patterns and the conclusion is that these increase flow rate by 1000 m3/s. An average patterns seems to be worse than the spatial based on 1988 ARR.1988 + spatial + higher rain Vs CRC + FORGE Russell's comment : Need to assess the effect of losses, 20 mm IL + 1mm/hr will give to 10,000 - can live with that. Spatial distribution may account for differences for Port Office between reg FFA and Rafts Model (Rafts model is less) Erwin: conclude FFA for Savages 9,000-12,000, Hydrologic model can get there - shared rating curves Colin: RAFTS model gives little difference from Savages - but FFA regional analysis shows

	significant difference Dilemma for panel - is that DNRM data presented is plausible, now SKM seems to be plausible John: spatial info needed to assess the dam Timing is critical - releases from dam is way after - thus the initial dam level is relatively insensitive Latest CRC-FORGE data - 5,500 at Port Office - Loss rates by DNRM 0.5 to 1.5 mm/hr - compared to 2.5 mm/hr by SKM
6	Don Carrol's presentation Spatial rainfall distributions show that in 1893 event there is a factor of 5 between rain depth experienced in the Stanley catchment (top north east corner) compared to rain at bottom of catchment. In 1974 there were high peaks in areas below the dam. Similarly there are significant differences in other events. The distributions examples lovingly coloured to 'paint the picture'. Much discussion as to how this can be developed to assist in the main task. Comment that the differences point to the possibility of using Monte-Carlo approach but this needs the Hydrologic model converted from Rafts to Urbs and app 6 weeks ieTOO LONG.
7	Discussion Skm's FFA range middle ~10,000 (query affect of somerset in 1974 as different suggestions as to the impact of flood storage) Ken's FF yields ~11,000 at Lowood *Note that some might say this is close agreement.* SKM Rafts matches the FFA so 'we can sleep at night'. HOWEVER we need NRM information so the losses can be calibrated. Russel will try to contact John Ruffini. Pre-dam there are somewhat consistent values. What is outstanding is the spatial distribution and how to handle it. Averaging the spatial effect seems the way to go. Discrepancy between SKM& NRM is significant. Russel will see John after work today if possible.