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Further Investigations for the Brisbane River Flood Study

December 1999

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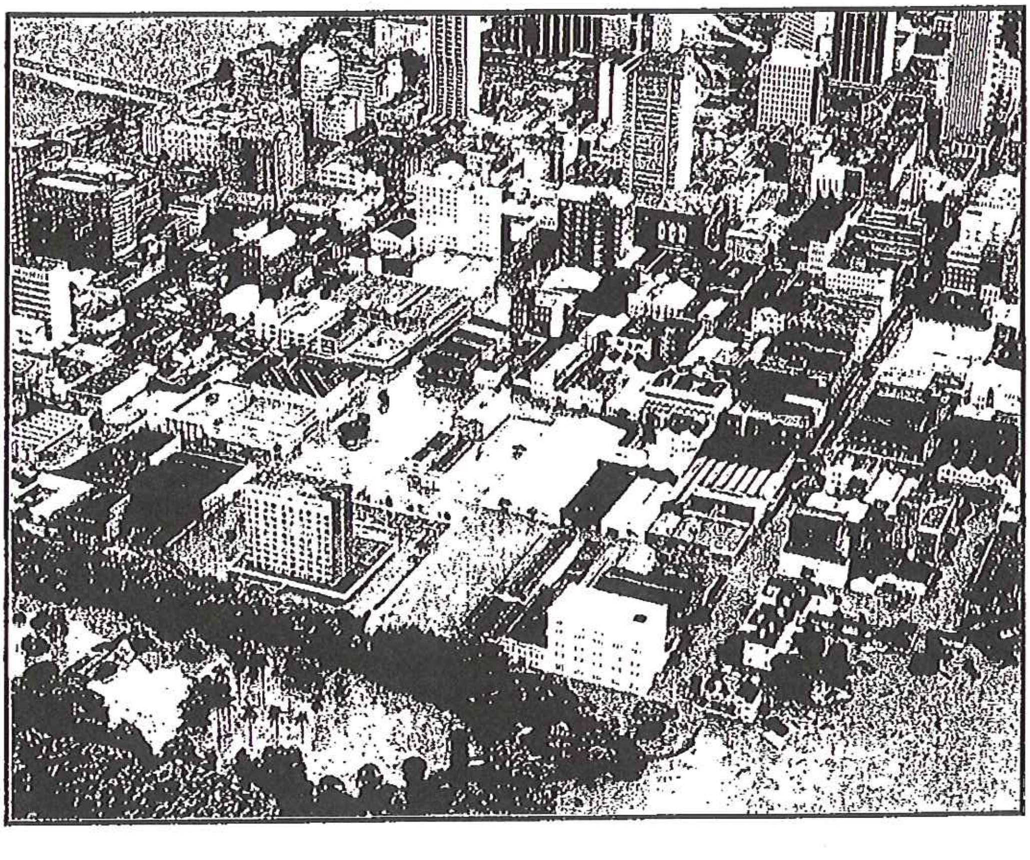

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Executive Summary

The Brisbane River Flood Study, June 1999, highlighted further study that could impact on the estimate of the Q100 flood. The flood frequency analysis is highly dependent on the assumed flood discharge of the 1893 flood. This report provided further research to gain a better understanding of this flood. Included in this report is further work on the assumptions pertaining to the state of the Dam and its effect on flood levels.

Analysis of the 1893 flood discharge was undertaken. Flood discharge hydrographs were produced by hydrologic modelling using 1893 recorded rainfall records. Survey data from the Victoria Bridge to Moreton Bay, surveyed in 1873, was used to augment the existing cross-sections in the Brisbane River MIKE11 hydraulic model. Using MIKE11 it was possible to determine the peak flood flows which produced flood levels similar to those recorded in 1893.

It was concluded that the best estimate of the discharge of the 1893 flood was 11 600 m^3/s. The estimate of the discharge of the 1893 flood, used in the flood frequency analysis for the Brisbane River Flood Study in June 1999, was 14 600 m^3/s.

The revised estimate of the 1893 flood discharge reduces the estimate of the Q100 flood by 600 m^3/s. Q100 discharge is 8000 m^3/s. The peak flood level at the Port Office Gauge is reduced by 0.3m. Q100 flood height is 4.7 m AHD at the Port Office Gauge.

Is this comparing the original SKM report?
• How this compares with existing Q100 FL.?

A report containing the original flood operation procedures and a copy of the current release procedures for Wivenhoe and Somerset Dams was obtained from the DNR. Careful analysis of these procedures revealed that there is little difference between original and current operating procedures.

Even though the operating procedures have changed very little since Wivenhoe Dam was constructed, the magnitude of the Probable Maximum Flood (PMF) and the magnitude of the Q100 flood event have increased.

The current operating procedures have less impact the larger the flood event. This means that the dam has less impact on reducing the peak of the revised Q100 flood. Wivenhoe Dam's operating procedures have more impact on the smaller flood events (Q2-10) than larger flood events, (Q100).

The sensitivity of a Q100 flood to the water level in Wivenhoe Dam was investigated. Q100 design rainfall was applied to the RAFTS model of the Brisbane River catchment. Wivenhoe Dam water levels were set at 100%, 90%, 75% and 50%. The resultant hydrographs at the Port Office Gauge were plotted.

It was calculated that a Q100 event with Wivenhoe Dam at 50% storage will reduce the peak of the flood by 1800 m^3/s. The probability of the dam being 50% full at the start of a Q100 rainfall event was also investigated.

The DNR supplied a daily simulation of Wivenhoe Dam storage for 96 years using recorded rainfall data. The storage levels in the dam *just proceeding* a historic flood event were measured. Seven out of the nine historic flood events are at or above the Full Supply Level.

The probability of the volume of the dam being greater than 90%, 75% and 50% full supply level was found to be 0.8, 0.95 and 0.98 respectively. The Wivenhoe Dam storage never fell below 65% in the simulation. It fells to 75% storage only twice in 95 years of simulation.

The years where the dam storage is around 75% are the result of low rainfall summers and very dry winters. A Q100 event never occurs in a very dry season. It generally occurs in a season of wet winters and high rainfall summers.

The probability that the dam is at 50% storage at the start of a Q100 event would mean that the dam would need to be almost empty at the start of the wet season. The probability of the dam being almost empty at the start of the wet season is zero.

1.0 Introduction

City Design completed a Final Report of the Brisbane River Flood Study in June 1999. This further work has been commissioned by Waterways Program to gain further understanding of the 1893 flood events and on Wivenhoe Dam's impact on Brisbane River flooding.

2.0 Scope of Work

The scope of the work is detailed as follows:

a) Analyse the 1893 flood. Use the cross sections surveyed in the 1870's and the measured hyetographs to determine the peak flood flows and the peak flood levels for the largest flood of 1893. Compare this with the recorded flood flows and flood levels.

b) Investigate the effects of the changing operating rules for Wivenhoe Dam. Find the original estimates of the impact of Wivenhoe Dam on the Flood Levels.

c) Investigate the sensitivity of dam storage. Analyse the impact on Q100 flood levels when the dam is:
   - 90% full;
   - 75% full; and
   - 50% full.

d) Develop a probability matrix to identify the risks associated with events occurring simultaneously. For example, the dam being full and a Q100 rainfall event occurring.

Each section of the work has a direct effect on the estimate of the Q100 flood in the Brisbane River. Section (a) will potentially have the most dramatic effect.

3.0 The 1893 Floods

3.1 Hydrology

During research on the Brisbane River Flood Study we found rainfall records of 22 rainfall stations in the Brisbane River catchment, for the period containing the first 1893 flood event. Each rainfall station had recorded totals (in inches), at 24-hour intervals. The rainfall station at Cromanhurst recorded 35.71 inches in 24 hours, from 8:00am 2nd February 1893 to 8:00am 3rd February 1893. The rainfall station at Yandina, (close to the catchment), had rainfall totals at varying intervals, (2 to 8 hours), for the 48 hours starting 9:00am 1 February 1893. A map showing rainfall depth contours across the Brisbane River catchment for 96 hours, beginning 4th February 1893 was used.

The temporal pattern of the rainfall at Cromanhurst and Yandina were used as typical temporal patterns for the catchment. The original temporal pattern at Cromanhurst is in 24-hour totals and thus removes many of the peaks and troughs of the rainfall. Combining the 96hr temporal pattern of Cromanhurst and including within it the intermediate 48 hour temporal pattern recordings from the Yandina rainfall station produced another temporal pattern, "Cromanhurst Peaked". This was done to give a temporal pattern which would contain the "peaks and troughs" of the rainfall.

Using HYDCON, (a software program written for the Brisbane River Flood Study), rainfall files were generated which simulated the rainfall across the catchment 1893. Each of the three different temporal patterns produced a different rainfall file.

A RAFTS model of the Brisbane River catchment used the rainfall file produced and flows at the Port Office gauge were calculated.

3.1.1 Initial and Continuing Loss

Losses in the RAFTS model have a major effect, particularly on long duration rainfall events. It is practice to put in an initial loss and a continuing loss.

Initial loss is used to simulate initial catchment wetting when no runoff is produced. There were widespread rainfalls in the 2 days proceeding our simulated rainfalls therefore a zero initial loss was modelled.

Continuing loss accounts for infiltration once the catchment is saturated and is expressed in mm/hr. Modelling began by using a standard 2.5mm/hr continuing loss. This meant that the total loss for the 24hrs amounted to 60mm and to 240mm for 96hrs. It was found that discharge at the Port Office Gauge was lower than historical measurements.

3.1.2 Results

Table 3.1 shows the results of each of the eight model simulations, each time varying the temporal pattern and continuing loss. The discharge calculated is at the Port Office Gauge.

Table 3.1 – Modelled Discharge at Port Office gauge

Losses – Initial and Continuing (mm, mm/hr)	Cromanhurst Temporal Pattern	Cromanhurst Peaked Temporal Pattern	Yandina Temporal Pattern
0 & 2.5	9,146 m^3/s	9,360 m^3/s	7,977 m^3/s
0 & 1.0	11,196 m^3/s	11,361 m^3/s	10,281 m^3/s
0 & 0.5	12,577 m^3/s	12,758 m^3/s	11,351 m^3/s
0 & 0	18,310 m^3/s	19,014 m^3/s	12,959 m^3/s
Calibrated 1974 model losses	9,644 m^3/s	9,894 m^3/s	8,607 m^3/s

what are they?

In the Brisbane River Flood Study, June 1999, Appendix A10 contains *Table 10.2 –Measurements of the 1893 Flood Event*. This table is reproduced below.

Source	Flow Estimate
Henderson's report to Parliament 1896 – 24000000cubic feet/minute	11,300 m^3/s
Using the adjusted level and look up on the port office gauge stage discharge curve (a circular reference to the item above) – (done 1999)	11,600 m^3/s
Using a measured level at the Moggill gauge and look-up the Moggill Stage discharge curve (there is little flood flow reduction between Moggill and Brisbane) – (done 1999)	14,600 m^3/s
Flood Velocity measurements at Indooroopilly Bridge calculated a flood flow of 600,000 cubic feet/sec. – (done 1893)	16,990 m^3/s
Flood Velocity measurements at Victoria Bridge gives a flow as "494,000 cubic feet/sec excluding the flow through South Brisbane" - (done 1893)	14,000 m^3/s +

These five sources in the above table indicate that the discharge for the 1893 flood lies between 11,000 and 17,000 m^3/s. Of the fifteen peak discharges calculated in Table 3.1 above, only six lie within this range. It can be noted that the Yandina Temporal pattern produced lower discharges despite having similar losses in the RAFTS model. A continuing loss of zero millimetres per hour was considered unrealistic and with Yandina falling outside the Brisbane River catchment it was concluded that the Yandina temporal patterns would not be trialed in the hydraulic model. Therefore four hydrographs, *Cromanhurst* and *Cromanhurst Peaked*, with continuing losses of 0.5 and 1.0 mm/hr were trialed in the hydraulic model.

3.2 Hydraulics

3.2.1 Geometric data

Survey data from the Victoria Bridge to Moreton Bay, surveyed by Staff Commander Bedwell and Navel Lieutenant Connor R.N. in 1873, was used to augment the existing cross-sections in the Brisbane River MIKE11 hydraulic model. Essentially the channel of the Brisbane River was replaced by this data for cross sections from the Victoria Bridge to the mouth of the River. No cross sections upstream of the Victoria Bridge were modified.

The bed resistance used in the "1893" MIKE11model was the same as the bed resistance used in the Brisbane River Flood Study MIKE 11 model.

3.2.2 Flood Hydrographs

Hydrographs generated in RAFTS were subsequently "routed" through the "1893" MIKE 11 model. As an initial trial four hydrographs were selected. The four hydrographs correspond to the *Cromanhurst* and *Cromanhurst Peaked* temporal patterns with continuing losses of 1.0 mm/hr and 0.5 mm/hr. Peak water levels were then compared to recorded water levels in 1893.

3.2.3 Tailwater Level

While tidal records have been found at the state archives for the years 1884 – 1973, these were not used in the analysis. Instead the Mean High Water Springs level (MHWS) of 0.92 m AHD was used.

The sensitivity of the tailwater level was investigated. The tailwater level was reduced to 0.0 m AHD, (a change of 920mm), to investigate what effects this may on results upstream. The results of the modelling indicated a change of 30mm at the Newstead Park Gauge and a change of 2mm at the Port Office Gauge. It can be concluded that the model is not very sensitive to changes in the tailwater level during large flood events such as the 1893 flood.

3.2.4 Results

The hydrographs that produce results closest to the recorded flood heights in 1893 are *Cromanhurst* and *Cromanhurst Peaked* temporal patterns with a continuing loss of 1mm/hr. These results compare well with measured values downstream of the Victoria Bridge.

Table 3.2 summarises the results of the hydraulic modelling. Detailed tabular results are contained in Table 3.4 and illustrated in Figure 3.1. It may be seen that the calculated values differ slightly to the recorded flood heights upstream of the Yeronga Street Gauge. Changes to the river may have occurred upstream of the Victoria Bridge but no attempt to quantify this has been taken in this investigation.

Table 3.2 – Comparison of Flood Peak Heights with Discharge at the Port Office Gauge

Peak Flood Heights at Port Office			Peak Discharge at Port Office	
Recorded in 1893	Cromanhurst Cont Loss1.0 mm/hr	Cromanhurst Peaked Cont Loss1.0 mm/hr	Cromanhurst Cont Loss1.0 mm/hr	Cromanhurst Peaked Cont Loss1.0 mm/hr
8.35	8.263	8.366	11 426 m^3/s	11 635 m^3/s

It can be concluded from this study that the best estimate of the discharge of the 1st flood in February 1893 is 11 600 m^3/s.

The estimate of the discharge of the February 1893 flood, used in the Brisbane River Flood Study in June 1999, was 14 600 m^3/s.

3.2.4 Effect on the Q100 Flood Discharge

The effect on the original estimate of the Q100 flood is shown below in Table 3.3.

Table 3.3 – Effect on Q100 Flood Discharge

	Discharge at Port Office Gauge (m^3/s)	Water Level at Port Office Gauge (m AHD)
Brisbane River Flood Study – June 1999	8600	5.0
Brisbane River Flood Study – Further Investigations – November 1999	8000	4.7

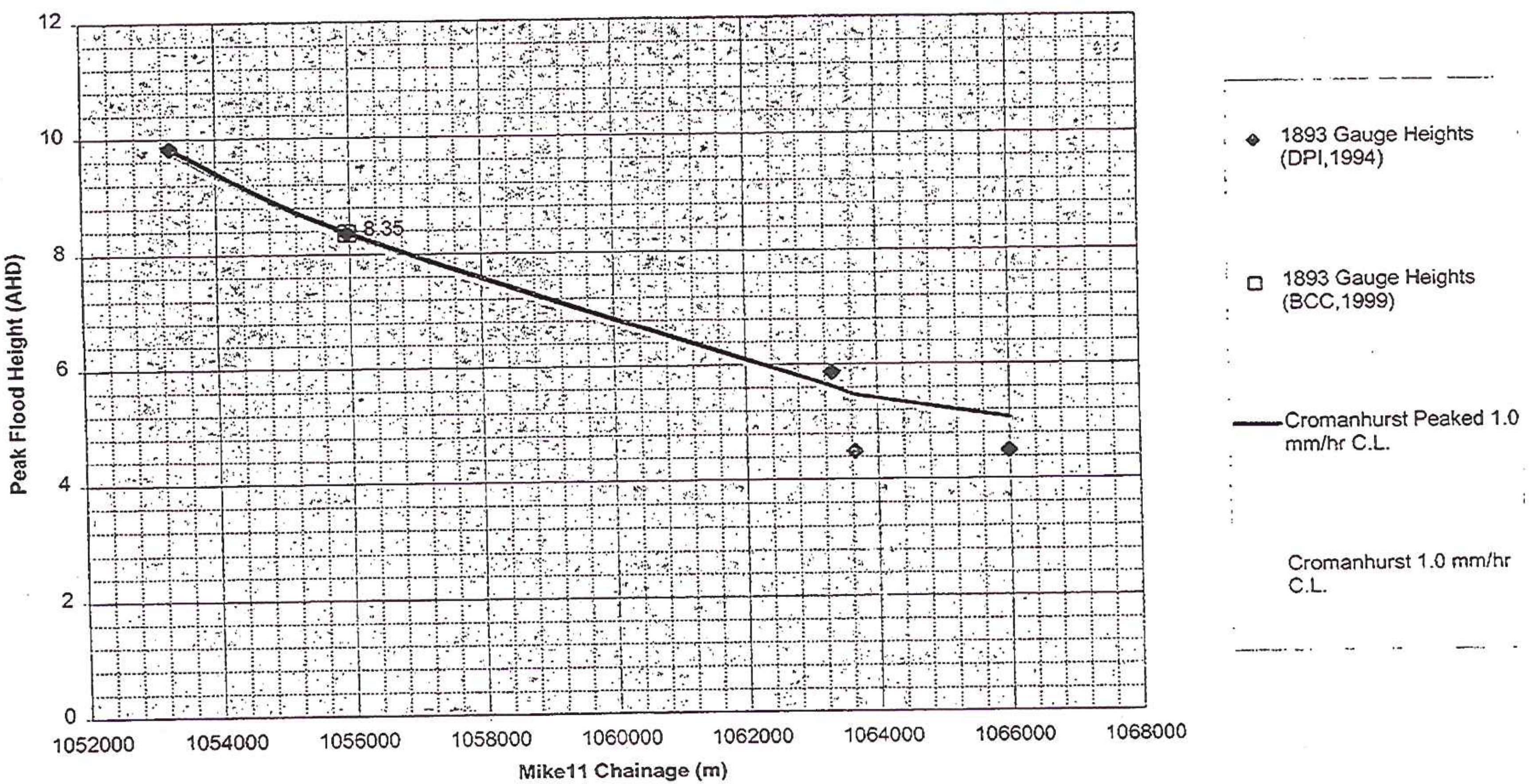
- SKM Report 9560 m^3/s.
- 1984 Report 6800 m^3/s (current Flood level)

Table 3.4 - Comparison of Recorded Peak Flood Heights to Modelled Peak Flood Heights

MIKE11 Chainage (m)	AMTD Chainage (km)	Brisbane River Cross Section Label	Location	Peak Flood Heights (m AHD)					
				Measured Gauge Data		Model Run #1	Model Run #2	Model Run #3	Model Run #4
				Source - DPI 1994†	Source – BCC 1999‡	Cromanhurst Peaked Temporal Pattern Continuing Loss 1.0 mm/hr	Cromanhurst Peaked Temporal Pattern Continuing Loss 0.5 mm/hr	Cromanhurst Recorded Temporal Pattern Continuing Loss 1.0 mm/hr	Cromanhurst Recorded Temporal Pattern Continuing Loss 0.5 mm/hr
1053320	25.304	BN 640	Victoria Bridge	9.82		9.804	10.413	9.667	10.313
1055960	22.7	BN 530	Port Office Gauge	8.351	8.35	8.366	8.892	8.263	8.822
1063310	15.35	BN 320	Newstead Park Gauge	5.86		5.605	5.94	5.546	5.891
1063645	15.015	BN 310	Crescent Road Gauge	4.49		5.46	5.775	5.403	5.728
1065990	12.67	BN 260	Cairncross Dock Gauge	4.49		5.056	5.36	5.002	5.315

† - Brisbane River Flood Study, Department of Primary Industries 1994
‡ - Brisbane River Flood Study, Brisbane City Council 1999

Figure 3.1 - Peak Flood Heights



4.0 Operating Rules for Wivenhoe Dam

The Department of Natural Resources holds a number of documents about the design and construction of Wivenhoe dam. A copy was obtained of Hydrology Report No:143005.PR/4. This document was titled, Report on Downstream Flooding, Queensland Water Resources Commission, November 1984. Chapter 7 of this report contains the flood operation procedures for Wivenhoe and Somerset Dams. This chapter was originally provided by Mr K. Hegerty from the Brisbane City Council.

A copy of the current release procedures for Wivenhoe Dam was obtained. These two procedures were compared to find the differences between them and the impact it would have on a Q100 flood.

Appendix A contains a copy of the original flood operation procedures for Wivenhoe Dam and a copy of the current operating rules for Wivenhoe Dam.

Careful analysis of these procedures reveals that there is little difference between previous and current operating procedures. The current procedures are a little more prescriptive for small dam releases. However, the governing principles of each step of the releases are the same.

Even though the operating procedures have changed very little since Wivenhoe Dam was constructed, the magnitude of the Probable Maximum Flood (PMF) and the magnitude of the Q100 flood event have increased.

It is perceived that the current operating procedures have less impact on the Q100 flood event but in actuality the Q100 flood event has increased in magnitude which means that the dam has less impact on reducing the peak of the flood.

Wivenhoe Dam's operating procedures have more impact on the smaller flood events (Q2-10) than larger flood events, (Q100).

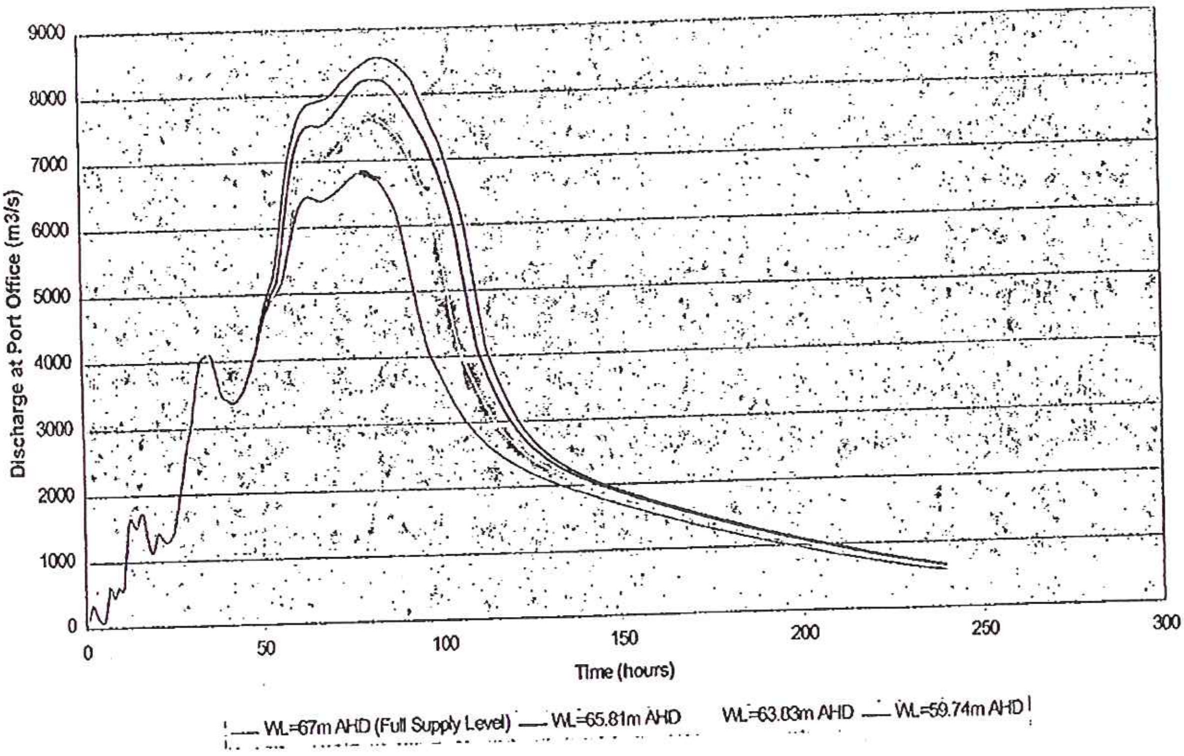
5.0 Investigation of the Sensitivity of Initial Dam Storage.

The Department of Natural Resources had previously supplied Wivenhoe Dam's Stage-Storage curve. This curve was used to determine what water level in the dam corresponded to it being 90%, 75%, and 50% full. The XP-RAFTS model of the Brisbane River catchment contained a model of Wivenhoe Dam. It is possible to represent the Dam being 90%, 75% and 50% full by changing the starting water level in the dam. The Q100 rainfall event was run using the model and the resultant hydrographs at the Port Office Gauge were plotted.

The Brisbane River MIKE11 model was used to see the effects of the varying discharge on water levels along the Brisbane River. The effects at the Port Office Gauge were plotted.

Figure 5.1 shows the difference between discharge hydrographs at the Port Office Gauge, due to varying initial water levels in Wivenhoe Dam. It can be seen from these results that a Q100 event with Wivenhoe Dam at 50% will reduce the peak of the flood by 1800 m^3/s. The probability of the dam being 50% full is examined in section 6.0.

Figure 5.1 Discharge Hydrographs at the Port Office Gauge - varying initial water levels in Wivenhoe Dam



6.0 Determination of Probabilities

In Appendix A10.2 of the Brisbane River Flood Study, June 1999, information on simulated storage volumes in Wivenhoe Dam can be found. The Department of Natural Resources used 96 years of daily rainfall data in the Wivenhoe Dam catchment and daily storage volumes in Wivenhoe Dam since its construction to compile a simulated daily storage volume.

These volumes were interrogated to find the storage levels in the dam *just proceeding* a historic flood event. Table 6.1gives these results.

Table 6.1 - Simulated and Recorded Volumes in the Wivenhoe Dam before Historic Flood Events.

Date	Volume in Wivenhoe Dam (ML)
15/3/1908	1 188 766
1/2/1931	1 128 075
26/3/1955	1 223 844
1/6/1973	1 146 020
24/1/1974	1 258 450
19/6/1983	1 194 462
3/3/1989	1 163 961
23/4/1989	1 230 573
30/4/1996	1 020 308

The average volume in Wivenhoe Dam, just proceeding a historic flood event is 1 171 916 ML. Full Supply Level is at 1 151 000 ML. Figure 6.1 shows a detailed graph of the simulated period and plots these proceeding volumes on the graph. **Seven out of the nine historic flood events are at or above the Full Supply Level.**

Figure 10.1, from the Brisbane River Flood Study, shows the Dam Storage vrs Percentage of Time Exceeded. Using this graph, the probability of the volume of the dam being greater than 90%, 75% and 50% full supply level was determined and tabulated in Table 6.2.

Table 6.2 – Probability of Dam Storage Exceedance

Wivenhoe Dam Storage	Probability of Dam Exceeding Storage
90%	80%
75%	95%
50%	98%

This table demonstrates that the probability of the dam being less than 75% full is very low. Figure 6.1 shows that once the dam initially fills, it never again falls below being 65% full for the rest of the simulation. It falls to being 75% full only twice in 95 years of simulation.

The years where the dam supply is around 75% are the result of low rainfall summers and very dry winters. These years are typical of "El Nino" events.

A Q100 event never occurs in a very dry season. It generally occurs in a season of wet winters and high rainfall summers. These years are typical of "La Nina" events.

The probability curve (Figure 10.1) could be deemed to apply at the start of a wet season. The probability that the dam is at 50% supply at the start of a Q100 event would mean that the dam would need to be almost empty at the start of the wet season. The probability of the dam being almost empty at the start of the wet season is zero.

The effect for Q100 discharge estimates is zero.

Figure 6.1 - Wivenhoe Dam - Simulated Water Levels, 1900 - 1996

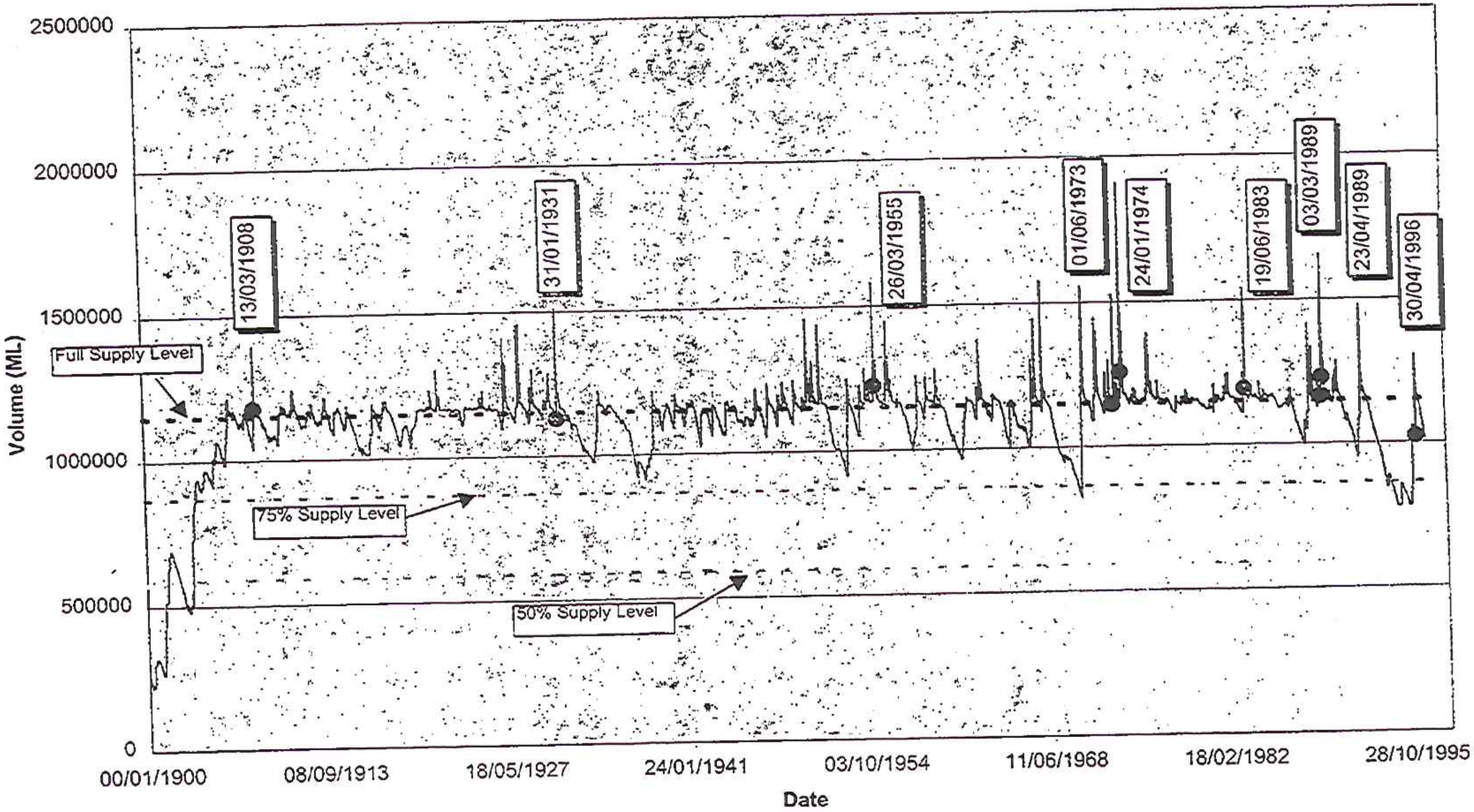
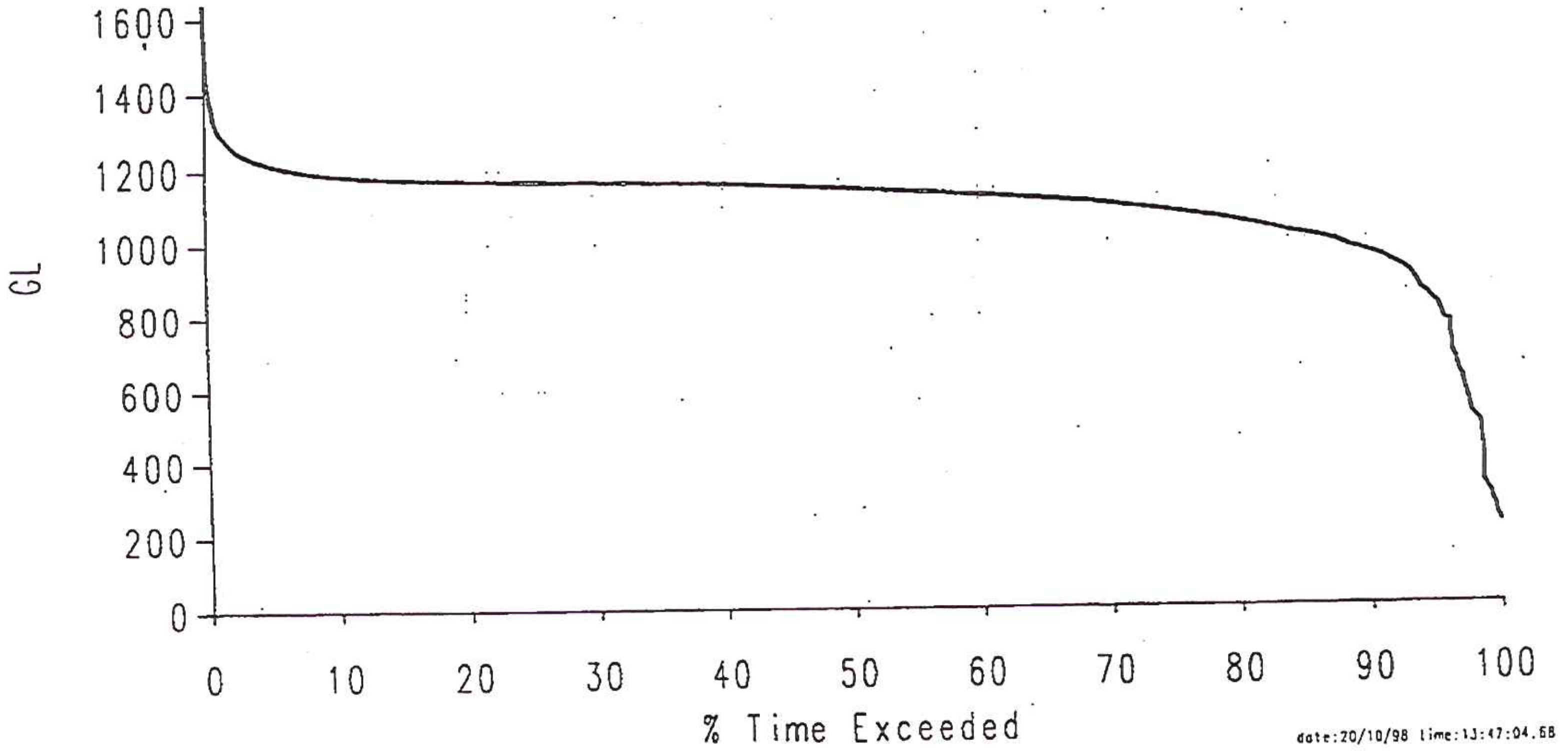


Figure 10.1 – Dam Storage vrs % of time Exceeded



Appendix A

A1 Contains the revised Flood Frequency data for the Port Office Gauge.

A2 Contains Chapter 7 from Hydrology Report No:143005.PR/4, Report on Downstream Flooding, Queensland Water Resources Commission, November 1984. It contains the original flood operation procedures for Wivenhoe and Somerset Dams.

Also contained is a graph and table of the current release procedures for Wivenhoe Dam.

A2 Contains Brisbane River Cross section, which are a combination of survey conducted in 1873 and survey conducted in 1997. The cross sections are located from the Victoria Bridge to the mouth of the Brisbane River

Figure A1- Revised Flood Frequency Curve at Port Office Gauge - No Dams Effective