Contents

Document History and Status

Issue	Rev.	Issued To	Qty	Date	Reviewed	Approved
Draft	1	G Tierney, A Campbell	1	8/10/2002	D Sheehan	Mike Edwards
Draft	2	G Tierney, A Campbell	1	5/02/2003		Mike Edwards

Printed: Wednesday, 26 March 2008
Last Saved: Wednesday, 26 March 2008
File Name: I:\WCMS\Wc99082\REP02_06.26\R02mbe.Doc
Author: Mike Edwards
Project Manager: Mike Edwards
Name of Organisation: Benalla Rural City Council
Name of Project: Jamieson Flood Scoping Study
Name of Document: Flood Study Report
Document Version: Final Draft
Project Number: WC99082

1. Introduction

Sinclair Knight Merz has been commissioned by Delatite Shire Council to undertake a scoping study for the township of Jamieson. The purpose of the study is to:

- investigate and gain an understanding of the nature of flooding through Jamieson;
- identify flood impacts and flood risk to the community;
- identify gaps in existing information and the need for improved information;
- undertake a preliminary damage assessment, and
- scope mitigation measures.

This report presents the findings of the scoping study as three main outcomes:

- examination of historic floods and impacts to establish the context for further works or measures if required as a subsequent stage;
- preparation of flood inundation maps and 100-year ARI[1] flood levels for statutory planning purposes; and
- identifying potential flood damages, issues and potential solutions that can be addressed in a detailed Floodplain Management Study if the potential benefits of such a study justify its need.

This study has been prepared under the Commonwealth Natural Disaster Risk Management Studies Program.

1.1 Background

Located at the head of the Goulburn River, where the Upper Goulburn and Jamieson Rivers join Lake Eildon, Jamieson had its origins a supply town for sending supplies to the more remote mine workings, after gold was discovered in the area in 1854.

At its peak Jamieson had a population of 3000 to 4000. Today the permanent population averages around 100 to 125. Many of its historic buildings still remain including the Court House Hotel, which is an elegant reminder of a town that supported fourteen hotels and several breweries in its heyday.

Today, Jamieson is a quiet rural town known for its local trout fishing and gold panning for holiday fossickers (Ref. http://home.vicnet.net.au/~jdhs/5jamieson.htm – home page).

Jamieson has experienced numerous floods, although little documentary evidence is available. Details of historic floods are discussed in **Section 2**.

[1] This is the likelihood of occurrence of flooding expressed in terms of the long-term average number of years between the occurrence of a flood of equal or greater magnitude to the flood being considered. For example, a flood with a discharge equal or greater than the 100-year ARI flood will occur on average every 100 years.

Flood behaviour at Jamieson has been influenced by the formation of Lake Eildon (3,390 GL capacity) in the 1950s, which, when full, will affect flood levels in the lower reaches of the Upper Goulburn and Jamieson Rivers. Prior to 1950, a smaller lake existed behind the current lake - Sugarloaf Reservoir (377,000 ML capacity) constructed after the 1912-1914 drought.

The comparatively recent September 1998 flood was the largest flood in recent times. Fortuitously, a number of flood levels were pegged and surveyed. Among other things this study extends this work to provide estimates of 100-year ARI flood levels and the flood extent at Jamieson.

1.2 Scope

The scope of work is summarised from the Study Brief in **Table 1-1**.

■ **Table 1-1 Summary of Scope**

Terms of Reference	Description
1	History of Flooding and Review of Information: • Research studies, reports and any historic newspaper articles and photographs. • Identify available streamflow, rainfall, flood behaviour, level and extent information • Contact stakeholders for flood data • Document findings.
2	Flood Level Survey and General Flood Information: • Interview residents for details of nature of flooding, community perception and awareness of flooding • Locate and survey additional flood levels • Survey cross sections at key locations.
3	1998 Flood Profile Analysis: • Determine the average recurrence interval for the 1998 flood • Determine peak flow rates for Jamieson.
4	1998 Flood Profile Analysis: • Estimate 100-year ARI flood flow and levels • Prepare 100-year ARI flood level contours.
5	Flood Maps: • Carry out trace survey for the 100-year ARI flood extent and the 1% flood extent less 500 mm • Prepare flood maps for this information • Describe the nature of flooding throughout Jamieson and estimate frequency of chosen historic floods.
6	Preliminary Flood Risk Assessment: • Carry out a preliminary flood damage assessment including damage estimates for the 100-year ARI event and the Average Annual Damage.
7	Future Studies: • Identify gaps in existing information • Identify possible risk treatment options • Make recommendations and justifications regarding any future studies or detailed floodplain management study.

1.3 Consultation

Consultation was undertaken with relevant agencies and other stakeholders information, as summarised in **Table 1-2**.

■ Table 1-2 Consultation

Date	Persons/Agencies Consulted	Notes/Issues
26/06/02	Guy Tierney, GBCMA	Guy handed over flood data and files at inception meeting held at the Sinclair Knight Merz Armadale Office.
26/06/02	Barbara Bateson, Secretary, Jamieson & District Historic Society	Barbara advised that no data was available. Flood photographs may be available at the museum, but these were not inspected. They are of limited value to the study.
25/09/02	Matthew Woodward, Senior Planning Officer, Delatite Shire	Provided flood information.
31/07/02 & 29/08/02	Ian Barry & Lynne Maxwell, VicRoads	Ian and Lynne were contacted for bridge information.
3/02/2003	Bill Viney, Goulburn-Murray Water	No information available.
17-19/07/02 & 20-22/11/03	Local residents	Provided flood marks for survey.

2. Flood Information

2.1 Hydrological Data

Available rainfall and streamflow data for the upper part of the Goulburn River is presented in **Figure 2-1**. There are two gauge stations of relevance to Jamieson, Upper Goulburn River at Dohertys (405219) and Jamieson River at Gerrans Bridge (405218). Both gauge stations were installed in 1954, and one needs to go to the Goulburn River gauge stations at Eildon (405203) or Trawool (405201) for a longer record. Details of these four gauge stations are listed in **Table 2-1**.

- **Figure 2-1 Data Collection Network**

Source Bureau of Meteorology

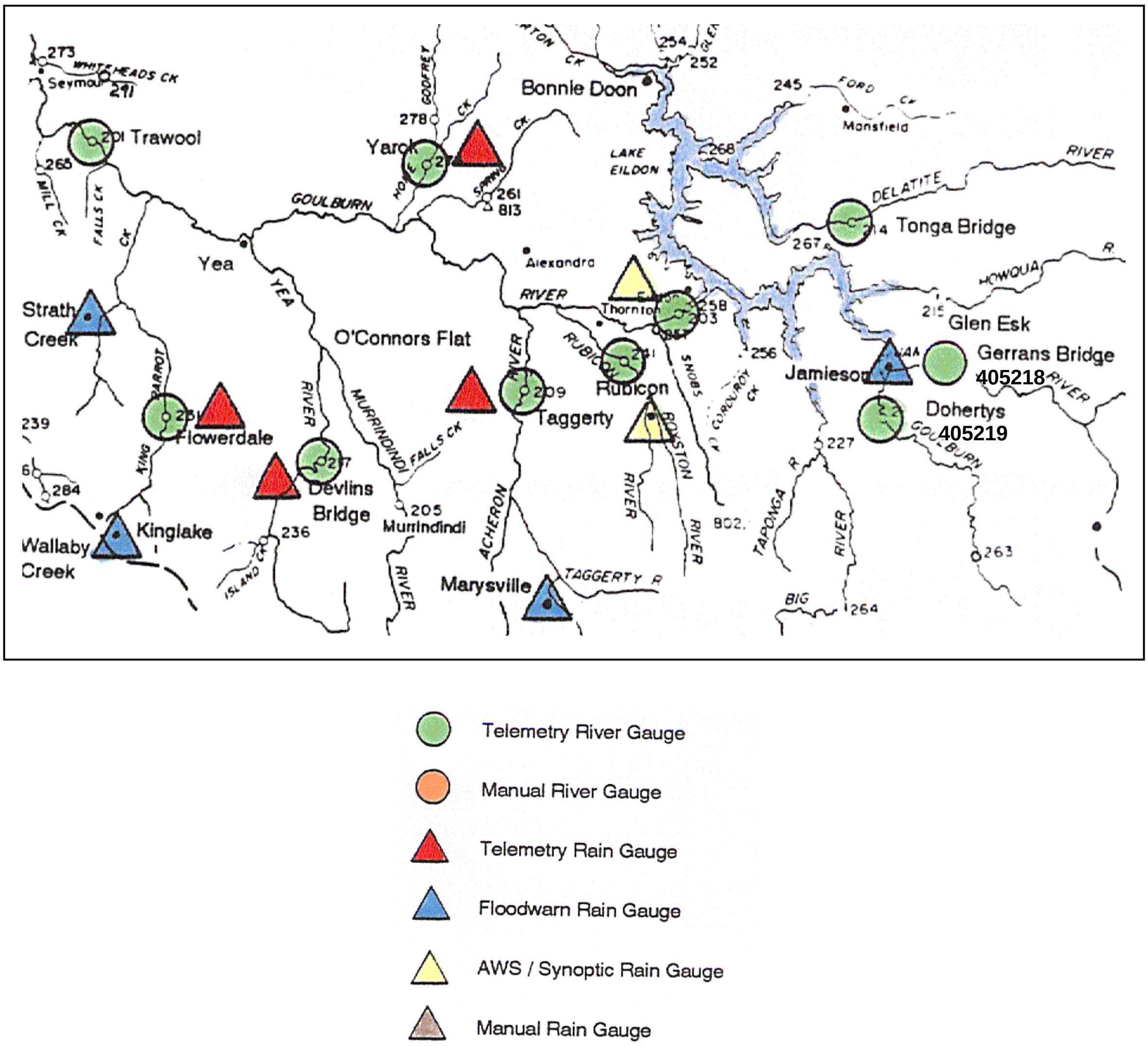


Table 2-1 Gauge Stations

River	Gauge Station Number & Location	Period of Observation	Gauge Station Area (km^2)
Upper Goulburn River	405219, Dohertys	Aug. 1954 to date	694
Jamieson River	405218, Gerrans Bridge	Jul. 1954 to date	368
Goulburn River	405203, Eildon	Jan. 1916 to date	3,911
Goulburn River	405201, Trawool	Jan. 1908 to date	7,335

Details of major floods for the Upper Goulburn River and Jamieson River, from 1954 to June 2002 are listed in **Table 2-2**, along with flood frequencies, expressed as the "Average Recurrence Interval" (ARI).

Corresponding data for the Goulburn River at Eildon is also listed for comparison. It should be noted that inflows from other tributaries, and the operation of Eildon Weir itself, could affect the timing and magnitude of peak flows out of Lake Eildon.

The results from **Table 2-2** indicate that Lake Eildon can have a significant effect in mitigating floods.

Table 2-2 Significant Floods

Month, Year	Jamieson 405218			Upper Goulburn 405219			Goulburn @ Eildon 405203		
	Flow ML/d	Gauge Height (m)	ARI[1]	Flow ML/d	Gauge Height (m)	ARI[1]	Flow ML/d	Gauge Height (m)	ARI[2]
August 1955	9,650	3.57	4.5	12,000	3.11	4	11,460	2.66	1.3
April 1956	8,400	3.35	4	8,600	2.35	2	3,150	1.47	<1
August 1956	10,400	3.71	7	15,600	3.89	8.5	34,500	4.66	4
August 1958	8,600	3.37	4	15,800	3.93	10	6,500	2.05	1
July 1964	11,200	3.85	8	14,500	3.65	6	6,150	2.01	1
October 1968	12,900	4.16	25	15,400	3.84	8.5	3,750	1.59	1
July 1974	11,100	3.92	8	14,200	3.58	6	15,350	3.06	1.3
May 1975	12,300	4.05	19	1,550	0.94	<1	4,650	1.76	1
July 1975	10,600	3.74	7	9,000	2.43	2	3,950	1.63	<1
July 1986	10,300	3.69	7	14,100	3.57	6	170	0.55	<1
September 1993	4,850[3]	2.66	1.4	15,500	3.86	8.5	36,800	4.82	5
October 1993	10,316	3.69	7	7,400	2.07	1.6	40,130	5.05	6
June 1995	12,000	4.00	18	13,000	3.33	5	485	0.74	<1
October 1996	12,350	4.06	20	14,800	3.71	8	17,225	3.24	2
September 1998	15,306[4]	4.47	80	19,300	4.66	40	2,300	1.29	<1

Notes

1. Refer to Section 4 for flood frequency analyses
2. Approximate only, based on Thiess Environmental Services Pty Ltd : *Flood Warning Station Information Manual*, February 1999.
3. While the September 1993 flood was not as significant along the Jamieson River as the Upper Goulburn River, flooding still occurred at Jamieson.
4. Largest flood at Jamieson since at least 1955.

2.2 Existing Flood Data

A requirement of this project was to research potential sources of flood data. As indicated in **Table 2-3**, a number of flood levels obtained as a result of a flood reconnaissance by the Goulburn Broken Catchment Management Authority shortly after the September 1998 flood, provided the best source of flood information. These were surveyed in June 2001, during which a number of flood levels from earlier events were also picked up.

- **Table 2-3 Flood Data**

Type	Comments
Flood Photography	A number of flood levels were obtained from a copy of a 1912 flood photo supplied by the Jamieson & District Historic Society.
Flood levels	Flood reconnaissance and survey in 1998 and 2001 identified a number of historic flood levels for the 1912, 1986, 1993 and 1998 floods.
Flood Maps	The flood map prepared as part of NRE's "Flood Data Transfer" Project pre-dates the September 1998 flood and was based on very limited information. An approximate 1998 flood extent was compiled in June 2002 (FPM/01/018).
Flood Structures	A review of bridge details from a database compiled by LICS for West Gippsland CMA revealed no documented flood information.
Flood Studies	None available.
Historic newspapers	An article on the September 1912 flood appeared in the September 1912 edition of the Jamieson Chronicle. No specific mention of flooding was found in a search of other editions of this paper or a similar search of the Mansfield Courier for details of floods at Jamieson.

Further details of information sources are given in **Appendix A**.

2.3 Newspaper Records of Floods

Anecdotal evidence points to a number of large floods at Jamieson prior to 1955, including 1912, 1934 and 1939. All three events preceded the construction of Lake Eildon in the 1950's.

Newspaper records indicate that the 1912 event was the largest flood since Jamieson was settled up to that date. No information was found for the August 1939 flood, although the *Mansfield Courier* (August 25 edition) observed that, while there was exceptionally heavy rain that month, floods in the region were not as severe as other areas. The 21 December 1934 edition of this newspaper mentioned that a "Jamieson Flood Fund" had been set up, but no details of the flood were provided.

Comparison with flow records at Eildon indicated large regional floods (in addition to the December 1934 and August 1939 events) occurred in August/September 1916, June to October 1917, May to July 1918, September 1921, October 1923, July 1942, July 1952, and October 1953.

The *Mansfield Courier* provided a few details of floods in the Mansfield/Lake Eildon area (July 1917, September 1921 and October 1923). However no specific details of floods at Jamieson could be found.

2.4 Review of Available Information

Having regard to the limited information and the results of further flood level reconnaissance and survey (described in **Section 3**) the following comments are made in respect of the accuracy and reliability of the information:

- A reasonable number of flood levels have been surveyed, including high reliability flood levels associated with the September 1998 flood. As this was a large event (40-year ARI) the 100 year flood levels can be estimated with a reasonable degree of confidence.
- There is a need for greater documentation of flood impacts for Jamieson, particularly the duration of flooding and the possible impacts of flowpaths. One flow path passes through the centre of the town, and while blocked at a number of roads, localised flooding and/or stormwater drainage may affect some houses.
- Detailed ground survey, and also possibly floor level survey, is desirable in the long term to fully determine flood impacts.
- The hydrology is not fully understood for the area, especially the inter-relationship between flows along the Upper Jamieson and Goulburn Rivers and at Lake Eildon. Further comments on hydrology are given in **Section 4**.

3. Flood Survey

As part of this scoping study, LICS Pty Ltd undertook a survey of Jamieson and its surrounds, in two stages.

3.1 Stage 1

This comprised of survey across the Jamieson River at four locations and a reconnaissance and survey of flood levels. Key residents were interviewed to establish the nature of flooding and to identify any flood marks from these landowner discussions.

Plan 540227 – Sheet 2 (**Appendix B**) shows the location of four cross sections, established in consultation with Mr Guy Tierney, Goulburn Broken CMA. The information was used to derive a margin between the September 1998 flood levels and the estimated 100-year ARI flood levels in **Section 5**.

Plan 540227 – Sheet 1 – incorporates 21 newly surveyed flood levels with 22 from an earlier survey.

All newly surveyed flood levels were documented with an interview sheet, site description, photograph, level reference number and reliability rating, and have been incorporated into GBCMA file FPM01018 containing information from a previous survey.

3.2 Stage 2

In **Section 5.4**, estimated 100 year ARI flood levels were determined and were used in conjunction with a trace survey to produce a flood inundation map showing:

- the 100 –year ARI flood extent;
- a flood extent corresponding to an event producing flood levels 0.5 m below the 100 year ARI event;
- flood contours for the above events; and
- the approximate location of dwellings within the inundated areas.

A reduced copy of the map is included in **Appendix B**.

4. Hydrology

Flood frequency analyses were undertaken to estimate the magnitude of the 100-year ARI floods for the Jamieson and Upper Goulburn Rivers at Jamieson, based on results from their stream gauges at Gerrans Bridge and Dohertys.

4.1 Jamieson River

A daily instantaneous flow record was available on the Jamieson River at Gerrans Bridge (405218), approximately 5 km upstream of Jamieson. Data was available between February 1959 and May 2002, with only one day of missing data during this period.

This daily flow record was transposed downstream to coincide with the catchment at Jamieson, using a regionally-based formula derived from Grayson et al, (1996):

$Q1/Q2 = (A1/A2)^{0.763}$ where

Q1 and A1 are the flow rate and catchment area at Jamieson (385.9 km^2); and
Q2 and A2 are the flow rate and catchment area at Gerrans Bridge (368 km^2).

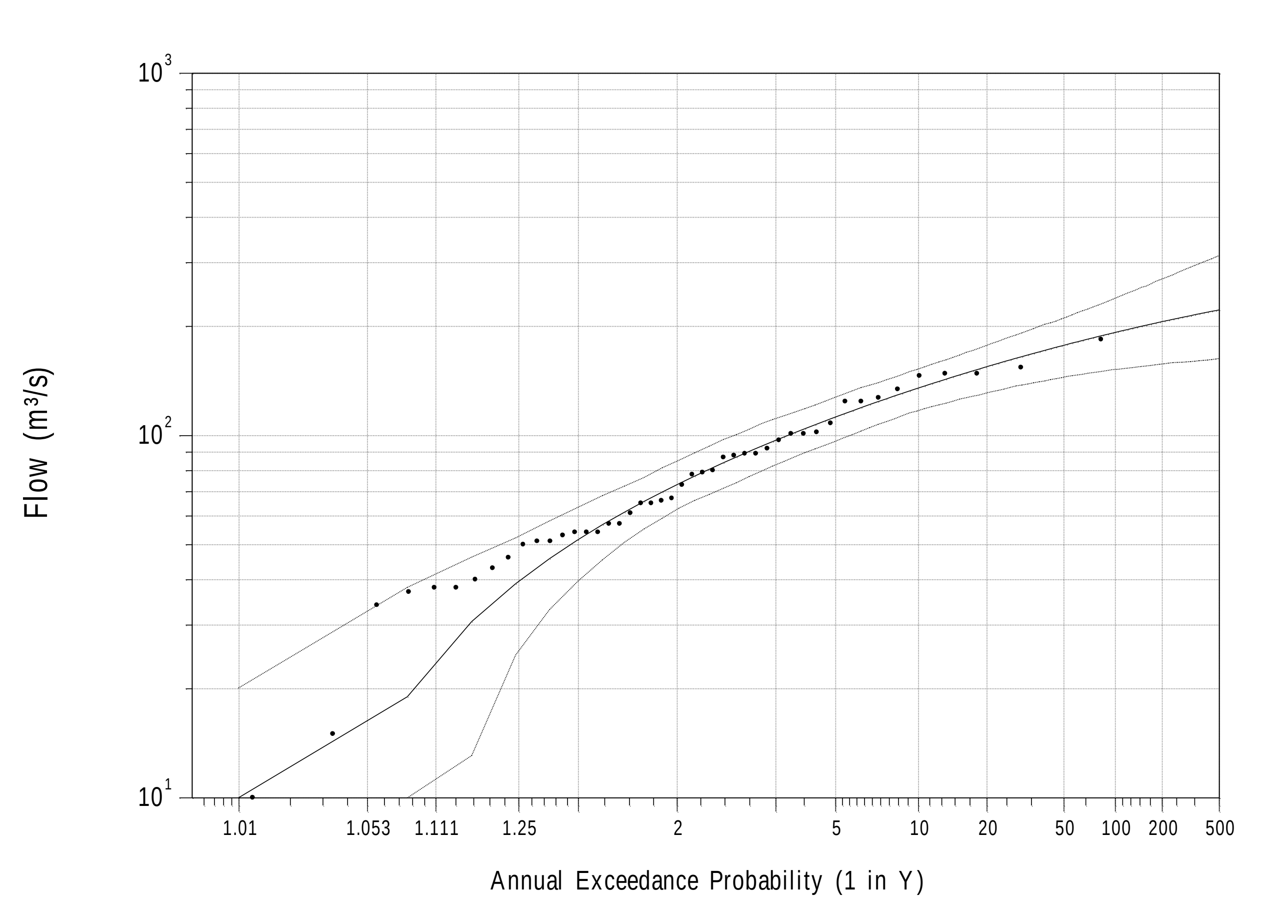
A Generalised Extreme Value (GEV) theoretical distribution was then fitted by the method of higher order L-moments (Wang, 1997) to the annual series of peak flows (the largest peak flow in each year of record). This method has the advantage that it gives greater weight to the larger peak flows and is thus less influenced by low (or zero) values in the annual series. The use of GEV / LH-moments is to be recommended in the revised flood frequency chapter of Australian Rainfall and Runoff. Confidence limits (90%) of the fit were also generated using a boot strapping technique.

The results of the flood frequency analysis are illustrated in **Figure 4-1**.

The estimated magnitude of the 1 in 100 year flood of the Jamieson River at Jamieson is 192 m^3/s (16,600 ML/d). The upper and lower limits of the 90% confidence interval are 157 m^3/s (13,600 ML/d) and 235 m^3/s (20,300 ML/d) respectively.

It should be noted that this low rate is substantially below that estimated from an empirical equation developed by N Nikolaou and Roel von't Steen, which compared the results of a large number of floods along the Great Dividing Range (DCNR, 1994):

$Q = 4.67\ Area^{0.763}$,
where the catchment area is 385.9 km^2. This yields a flow rate of 439.3 m^3/s (38,000 ML/d).



- **Figure 4-1 Flood Frequency Relationship for the Jamieson River**

4.2 Upper Goulburn River

The analysis was repeated for the Goulburn River at Jamieson.

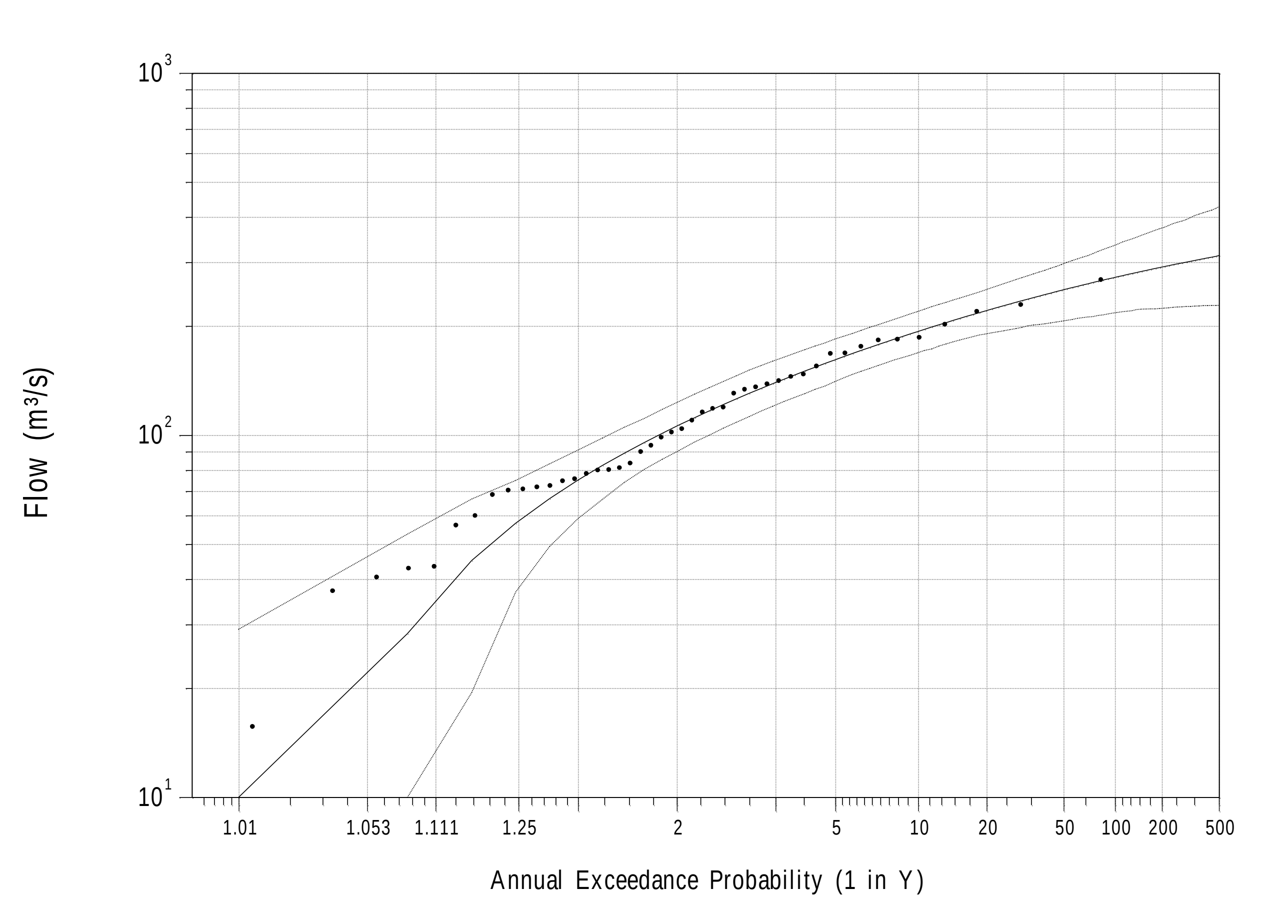
Recorded data was available at Dohertys (405219), 6 km upstream of Jamieson, between August 1954 and June 2002. This data was transposed to Jamieson using the same formula in **Section 4.1** (the catchment areas being 718.8 km^2 and 694 km^2 respectively).

A flood frequency analysis was undertaken using the same methodology for the Jamieson River. Results are illustrated in **Figure 4-2**.

The magnitude of the 100-year ARI flood event for the Goulburn River at Jamieson is 273 m^3/s (23,600 ML/d), with upper and lower 90% confidence limits of 220 m^3/s (19,000 ML/d) and 329 m^3/s (28,000 ML/d) respectively.

As with the Jamieson River at Jamieson, this flow rate is substantially below that estimated from an equation curve developed by N Nikolaou and Roel von't Steen (DCNR, 1994):

$Q = 4.67\ Area^{0.763}$, where the catchment area is 718.8 km2. This yields a flow rate of 706.2 m^3/s (61,000 ML/d).



- **Figure 4-2 Flood Frequency Relationship for the Goulburn River at Jamieson**

4.3 Flow Correlations

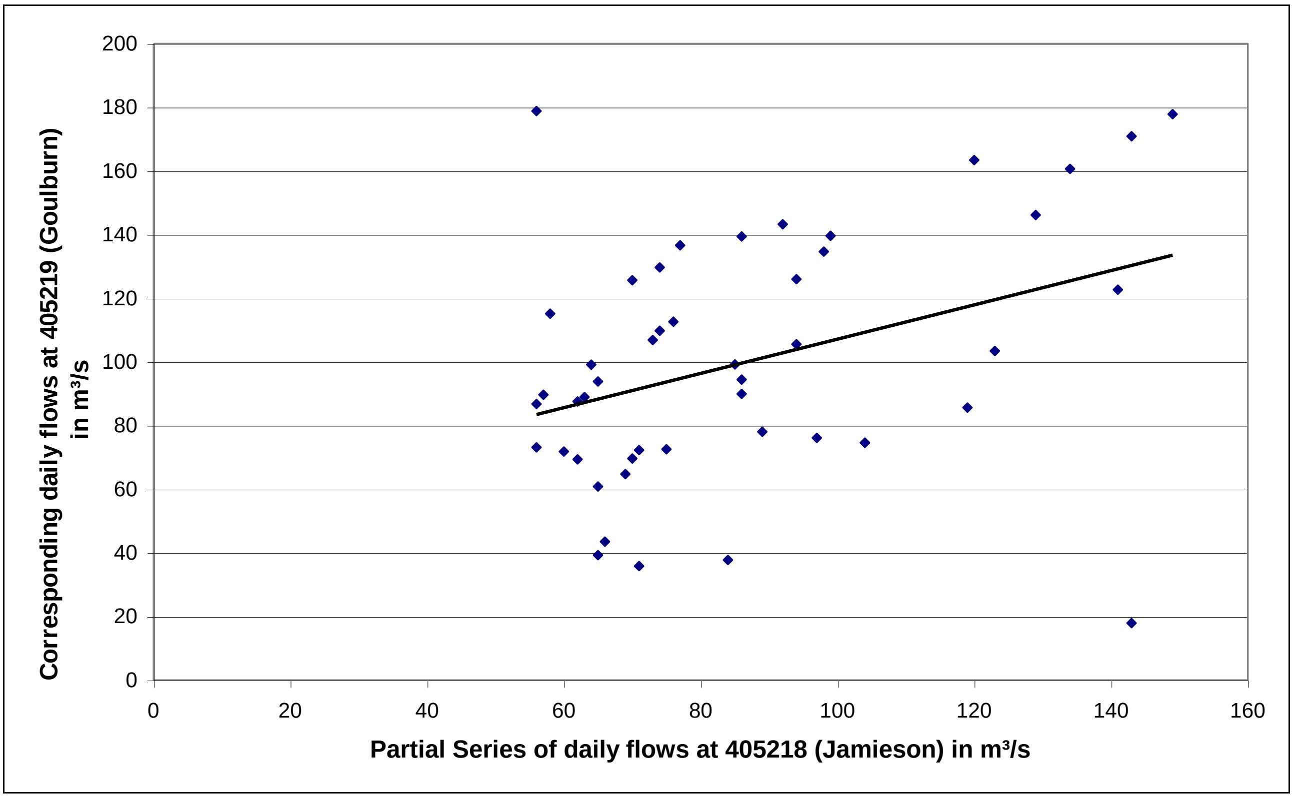
To see if there was a pattern between flows in the Upper Goulburn River and Jamieson River catchments, the 48 largest instantaneous flows for the Jamieson River at Gerrans Bridge was plotted against Upper Goulburn River flows, as a partial series[2].

The x-axis of this plot shows the magnitude of the 48 largest instantaneous flow events recorded for the Jamieson River. The y-axis is the corresponding flow on the Upper Goulburn River. For example, on the 4th of October 1993 a peak flow of 199 m³/s was recorded on the Jamieson River and a flow of 86 m³/s was recorded on the Goulburn River.

As illustrated in **Figure 4-3** the flows in the Goulburn River and Jamieson River are reasonably correlated, indicating that when flows along the Jamieson River are high, so too are flows along the Upper Goulburn.

[2] A "partial series" is one in which only flood peaks greater than a threshold flood (in this case the flow just below the 49th largest flood) are analysed. The flood frequency analyses undertaken in **Sections 4.1 and 4.2** were based on an "annual series" in which only the maximum flood peak for each year was considered.

If or when a detailed Flood Study is undertaken for Jamieson, it is recommended that a more detailed joint probability analysis of the two rivers be undertaken in conjunction with investigations into the level of Lake Eildon. For this study a simplified approach has been adopted to estimate 100-year ARI flood levels at Jamieson, as described in **Section 5**.



■ **Figure 4-3 Correlations of high flow events between the Jamieson River and the Goulburn River.**

5. Determination of Flood Levels

The following approach was adopted to estimate 1 in 100-year ARI flood levels:

1) A flood profile for Jamieson River at Jamieson was prepared, based on September 1998 flood levels. This was the largest flood for which flow records are available and was approximately a 1 in 40-year ARI event (refer **Table 2-2**).

2) A steady state hydraulic model was developed using the 4 surveyed cross sections. The model was calibrated to the September 1998 peak flow rates. The measured peak 1998 flow at the Gerrans Bridge gauge station was 177.15 m^3/s (15,306 ML/d), and this was transposed to Jamieson using the technique described in **Section 4.1**. The peak 1998 flow at Jamieson was calculated as 183.7 m^3/s (15,900 ML/d).

3) The results were validated against recorded flood levels for the July 1986 and October 1993 floods. The measured flows at Gerrans Bridge for these two events were 119.54 m^3/s (10,330 ML/d) and 119.40 m^3/s (10,320 ML/d) respectively. Transposed to Jamieson the flows were 123.96 m^3/s (10,710 ML/d) and 123.81 m^3/s (10,700 ML/d) respectively.

4) The model was then run for 100 year ARI flood conditions at Jamieson.

It should be noted that a surveyed cross section across both the Jamieson and Upper Goulburn Rivers showed that the bed of the Jamieson River was approximately 0.57 m higher than the bed of the Upper Goulburn River. River levels differed by 1.38 m at the time of the survey, (the Jamieson River having the higher level) strongly indicating that the effect of the Upper Goulburn River on flood levels at Jamieson will be marginal, particularly since both river longitudinal gradients are large. Notwithstanding this, the level of Lake Eildon will have an effect on flood levels for the lower reaches of the township.

5.1 Flood Profile

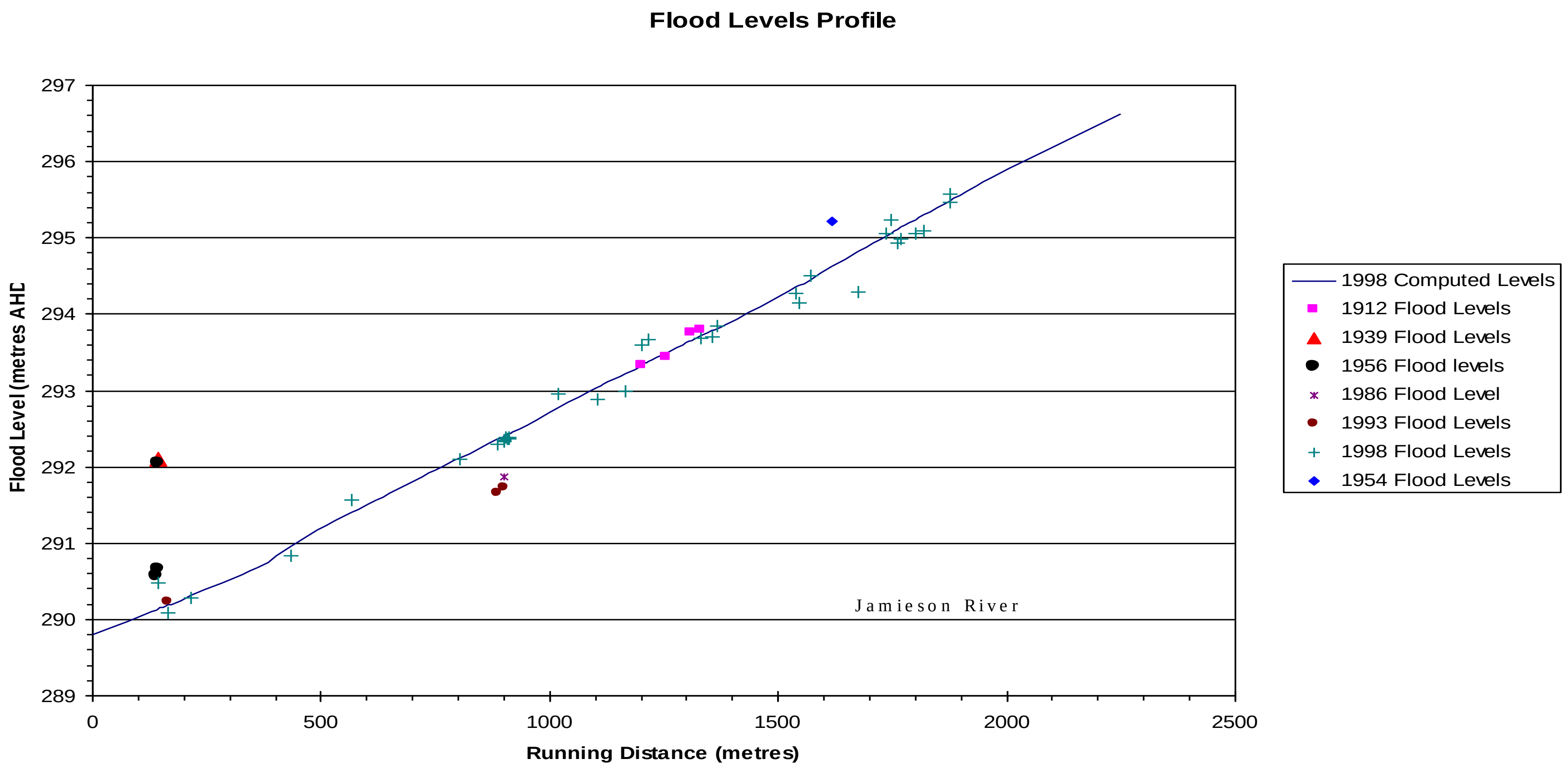
A plot of historic levels versus river distance is shown in **Figure 5-1**, along with results from the hydraulic model for the September 1998 flood. It is interesting to note that the 1912 flood (at the time the flood photo from which the flood levels were extracted) produces similar flood levels to the September 1998 event, which suggests this flood may have had similar average recurrence intervals. However the difference in timing between the flood peak and the time of the photography is not known.

A 1939 flood level and three 1956 flood levels at RD 145 m do not appear consistent with current trends. No reason could be found for the discrepancies. All came from the same source.

Likewise a 1954 flood level at RD 1620 m was well above more recent flood levels. And is considered to be an anomaly.

These levels are likely to precede the filling of Lake Eildon.

■ Figure 5-1 Flood Profile



5.2 Model Calibration

As indicated previously, a hydraulic model was developed to simulate flood conditions at Jamieson. The four surveyed cross sections formed the basis for determining the geometric parameters of the model, with cross sections estimated at the upstream and downstream extents of the model and adjusted to mimic the expected characteristics of the bed and river slope.

The industry standard HECRAS software was used to produce the model. This had the capability of automatically generating interpolated cross sections. The model was calibrated to the 1998 peak flood flow of 183.7 m^3/s (15,870 ML/d) and results are shown in **Table 5-1**.

- **Table 5-1 Model Parameters**

River Chainage (m)	Minimum Bed Level (m AHD)	Computed Water Surface Elevation (m AHD)	Average Channel Velocity (m/s)	Flow Area (m^2)	Manning's "n"	
					Channel	Overbank
2250**	292.07	296.63	1.76	127.61	0.058	0.09
2092*	291.8	296.17	1.84	119.15	0.058	0.09
1933*	291.54	295.68	1.86	116.93	0.058	0.09
1775	291.07	295.16	1.91	112.45	0.058	0.09
1617*	290.76	294.63	1.94	114.49	0.055	0.09
1458*	290.44	294.09	1.93	119.27	0.055	0.09
1300	290.13	293.63	1.61	174.42	0.058	0.09
1117*	289.32	293.08	1.69	148.56	0.058	0.08
933*	288.51	292.50	1.80	136.86	0.058	0.08
750	287.71	291.95	1.96	125.08	0.050	0.08
620*	287.36	291.56	2.10	121.04	0.050	0.08-0.09
490*	287.01	291.17	2.16	115.62	0.050	0.07
360	286.67	290.68	2.41	102.16	0.050	0.07
180*	286.04	290.22	1.95	127.37	0.050	0.06
0**	285.67	289.80	1.93	123.11	0.050	0.05

Notes
* Interpolated cross section
** Extrapolated cross section

Calculated 1998 flood levels from the model are plotted against recorded flood levels in **Figure 5-1**. Generally results are within +/- 0.15 m, which is considered reasonable having regard to natural fluctuations in the levels.

When the flood levels are averaged out by plotting out a best fit curve of flood level versus river distance, the margins between the levels calculated from the model and the "best fit" flood levels generally range from –0.02 m to 0.06 m, as can be seen from **Table 5-2**.

■ **Table 5-2 Calibration Against Best Fit 1998 Flood levels**

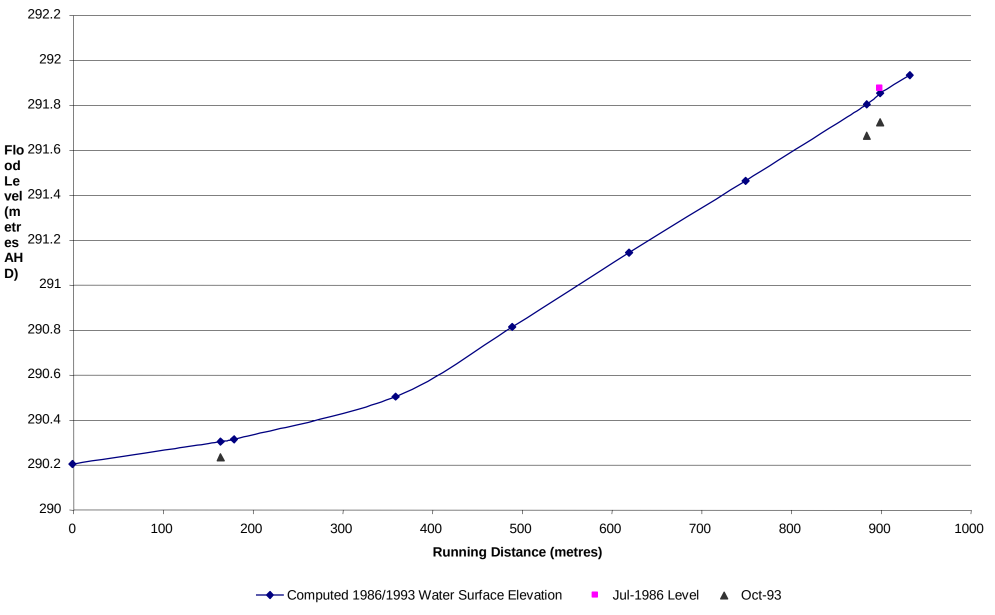
River Chainage (m)	Best Fit 1998 Flood level (m AHD)	Computed 1998 Flood Level (m AHD)	Difference (m)
1775	295.10	295.16	0.06
1617*	294.60	294.63	0.03
1458*	294.10	294.09	-0.01
1300	293.60	293.63	0.03
1117*	293.10	293.08	-0.02
933*	292.55	292.50	-0.05
750	291.95	291.95	0.00
620*	291.55	291.56	0.01
490*	291.10	291.17	0.07
360	290.70	290.68	-0.02
180*	290.10	290.22	0.12
0**	289.80	289.80	0.00
Notes			
*	Interpolated cross section		
**	Extrapolated cross section		

5.3 Validation Against July 1986 and October 1993 Floods

The peak flood flows at Jamieson for the July 1986 and October 1993 flood events were estimated to be 123.95 m^3/s and 123.81 m^3/s, based on recorded flows for Jamieson River at Gerrans Bridge, transposed according to the relevant formula in **Section 4.1**.

The HECRAS model was run for a design flow of 123.9 m^3/s (10,700 ML/d), and the results are plotted against recorded flood levels for these two events in **Figure 5-2**. It should be noted that a high downstream flood level was retained to simulate conditions that occurred in October 1993, in which the level of Lake Eildon was well above the full supply level.

■ **Figure 5-2 Validation Plot**



The results show the model generally overestimates the October 1993 flood levels by up to 0.15 m.

5.4 Modelling the 1% Flood

The calibrated and validated model was used to calculate flood levels for three possible 1 in 100 year flood scenarios:

- the mean 100 year ARI flow derived from the frequency analysis (192 m^3/s or 16,600 ML/d);

- the upper 90% confidence limit of the 1 in 100 year flow derived from the frequency analysis (235 m^3/s or 20,300 ML/d); and

- 439.3 m^3/s (38,000 ML/d), being an indicative estimate of the 1 in 100 year flood flow from an equation developed from a study of a large number of floods along and adjacent to the Great Dividing Range in Victoria (DCNR, 1994 – refer to **Section 4.1**).

Lake Levels

The largest level at Lake Eildon in recent times occurred in October 1993, when flood levels were allowed to encroach into the freeboard reserved for extreme floods, ie those approaching the probable maximum design flood event (Bill Viney, pers comm.). The normal operational procedures that generally prevented this occurring were not followed as inflows into the lake had already peaked and the forecast was for fine weather. This meant the probability of an extreme flood was virtually non existent.

Accordingly 1993 levels at the Eildon Weir rose to a maximum of 0.58 metres above the full supply level of 288.90 m AHD.

A check of the peak lake levels for the September 1993 flood at Lake Eildon Head Gauge (RD 445 km) and Goughs Bay (RD 464km) revealed the lake level peaked on 16 September. The level was at the same level at both locations ie. 289.48 m AHD. Therefore no flood gradient was detected at the two locations.

A relatively high September 1993 flood level close to the confluence of the Jamieson and Goulburn Rivers suggested a flood levels at Lake Eildon of the order of 290.1 m AHD. This is 0.62 m higher that the level at Goughs Bay and Eildon Head gauge.

The level of the Jamieson River at its junction with the Goulburn River is affected by complex factors such as wind effects, the likelihood of the lake being above full supply level and any local effects of floodwaters entering Goulburn Inlet. It should be noted that the width of the Goulburn Inlet (into Lake Eildon) is of the order of 50 to 100 metres, and one would expect local flood surge effects.

In the absence of a detailed investigation a downstream level of 290.1 m AHD has been assumed for modelling purposes, based on the observed flood behaviour that occurred in September 1993.

Model Runs
Results for the three scenarios discussed earlier are shown in **Table 5-3**.

- **Table 5-3 Possible 1 in 100 Year Flood Levels**

River Chainage (m)	Computed 1 in 100 Yr ARI Levels for Flows of: Scenario 1 192 (m^3/s)	Scenario 2 235 (m^3/s)	Scenario 3 439 (m^3/s)	Computed 1998 Level (m AHD)	Difference Scenario 1 (m)	Scenario 2 (m)	Scenario 3 (m)
2250	296.70	297.01	298.0	296.63	0.07	0.38	1.37
2091.66	296.23	296.54	297.52	296.17	0.06	0.37	1.35
1933.33	295.74	296.04	297.00	295.68	0.06	0.36	1.32
1775	295.22	295.50	296.41	295.16	0.06	0.34	1.25
1617	294.69	294.93	295.79	294.63	0.06	0.30	1.16
1458	294.14	294.35	295.14	294.09	0.05	0.26	1.05
1300	293.68	293.91	294.81	293.63	0.05	0.28	1.18
1117	293.13	293.38	294.39	293.08	0.05	0.30	1.31
933	292.56	292.83	293.93	292.50	0.06	0.33	1.43
750	292.01	292.28	293.32	291.95	0.06	0.33	1.37
620	291.62	291.88	292.85	291.56	0.06	0.32	1.29
490	291.24	291.50	292.46	291.17	0.07	0.33	1.29
360	290.78	290.99	291.88	290.68	0.10	0.31	1.20
180	290.40	290.53	291.32	290.22	0.18	0.31	1.10
0	290.10	290.10	290.10	289.80	0.30	0	0.30
Rows highlighted in yellow correspond to the surveyed cross sections							

Discounting the lowermost sections where the flood depths are influenced by the starting flood level, **Scenario 1** provides a margin of only 0.05 to 0.06 m above 1998 flood levels. This is considered too low, especially considering the observed fluctuations in the 1998 recorded flood levels.

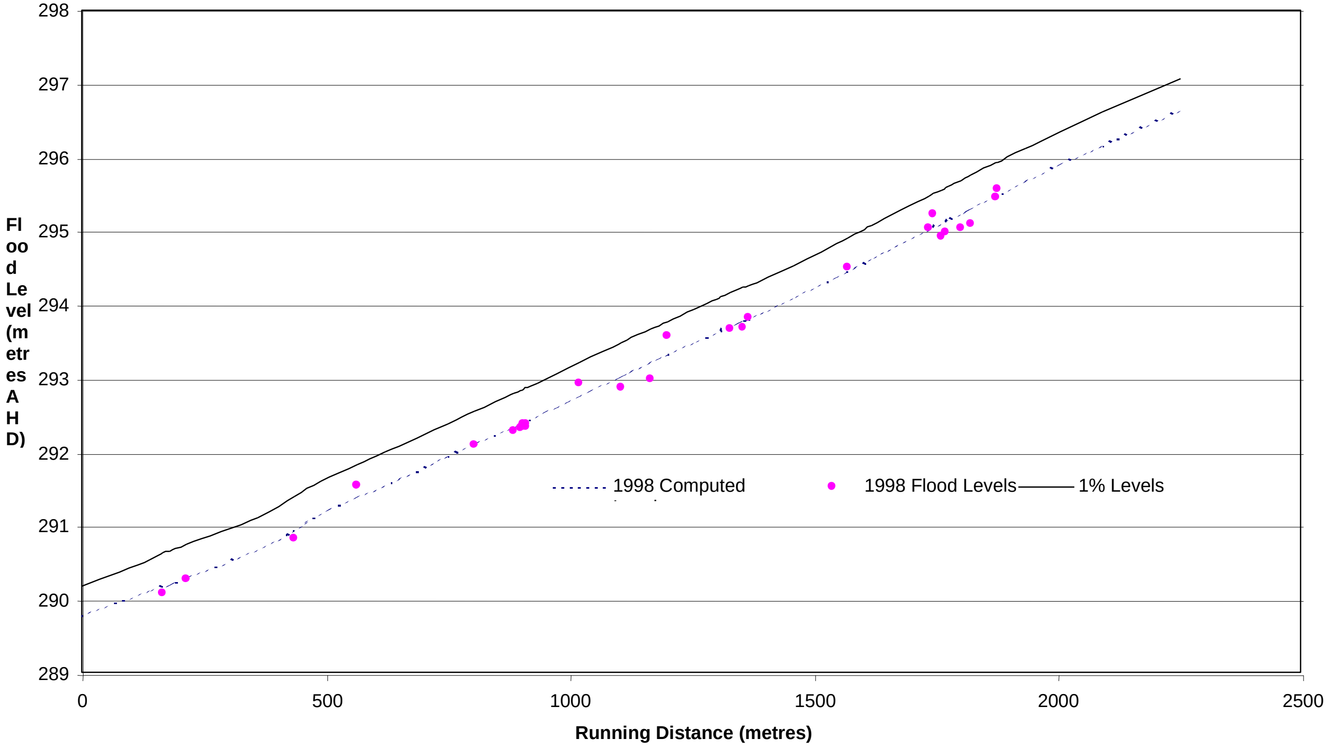
Scenario 3 is not considered realistic as it produces flood levels considerably higher than any that have previously observed. From **Figure 4-1** a flood flow of 439 m^3/s corresponds to that which will occur on average every 1,000 years or more.

Scenario 2 is based on the upper 90% confidence limit flow derived from the frequency analysis and it seems appropriate to adopt this as a reasonably conservative approximation of the 1 in 100 year flood, given that the period of record is only 42 years.

Based on a margin of 0.35m (from **Table 5-3**) plus an additional allowance of 0.1 m to accommodate the fluctuations in flood levels (as per **Table 5-2**) it would seem appropriate to adopt a margin of 0.45 m above 1998 flood levels for the 1 in 100-year ARI flood.

Adopted 100-year flood levels are shown in **Figure 5-3**. At the downstream end, levels have been adjusted to accommodate a level of 290.2 m AHD at the confluence of the Jamieson and Upper Goulburn Rivers.

■ **Figure 5-3 100-Year ARI Flood Levels for Jamieson**



5.5 Flood Levels for a Range of Events

In order to estimate how flood levels vary for a range of floods, the hydraulic model was run for a series of statistical floods. Results are shown in **Table 5-4**, for the 4 surveyed cross sections.

■ Table 5-4 Flood Levels for a Range of Floods

	Cross Section Running Distance (metres)			
	1775	**1300**	**750**	**360**
Flood Levels (m AHD)				
July 1986 (123.95 m^3/s) 7 year ARI	294.65	293.15	291.46	290.45
October 1993 (123.81 m^3/s) 7 year ARI	294.65	293.15	291.46	290.45
Sep 1998 (183.7 m^3/s) 20 year ARI*	295.16	293.63	291.95	290.68
2 year ARI (73 m^3/s)	293.97	292.52	290.67	289.57
5 year ARI (115 m^3/s)	294.55	293.06	291.33	290.13
10 year ARI (140 m^3/s)	294.81	293.30	291.59	290.35
20 year ARI (180 m^3/s)	295.13	293.61	291.92	290.65
50 year ARI* (210 m^3/s)	295.34	293.78	292.12	290.85
100 year ARI* (235 m^3/s)	295.50	293.91	292.28	290.99
200 year ARI* (275 m^3/s)	295.71	294.11	292.51	291.21
500 year ARI * (315 m^3/s)	295.91	294.29	292.72	291.41
* Used the upper 90 percentile curve in Figure 4-1 for the larger flows.				
Increase (Decrease) in Flood Level above 1998 level (metres)				
July 1986 (123.95 m^3/s) 7.5 year ARI	(0.51)	(0.48)	(0.49)	(0.23)
October 1993 (123.81 m^3/s) 7.5 year ARI	(0.51)	(0.48)	(0.49)	(0.23)
Sep 1998 (183.7 m^3/s) 20 year ARI	0	0	0	0
2 year ARI (73 m^3/s)	(1.19)	(1.11)	(1.28)	(1.11)
5 year ARI (115 m^3/s)	(0.61)	(0.57)	(0.62)	(0.55)
10 year ARI (140 m^3/s)	(0.35)	(0.33)	(0.36)	(0.33)
20 year ARI (180 m^3/s)	(0.03)	(0.02)	(0.03)	(0.03)
50 year ARI (210 m^3/s)	0.18	0.15	0.17	0.17
100 year ARI (235 m^3/s)	0.34	0.28	0.33	0.31
200 year ARI (275 m^3/s)	0.55	0.48	0.56	0.53
500 year ARI (315 m^3/s)	0.75	0.66	0.77	0.73

6. Economic, Social and Environmental Impacts

In order to justify the need for further studies or activities, a means of assessing economic, social and environmental impacts is desirable.

In May 2000, Read Sturgess and Associates, Consulting Economists, completed a "Rapid Appraisal Method (RAM) to assist the rapid evaluation of floodplain management projects in economic, social and environmental terms (NRE, 2000). The RAM has been designed to provide a set of simple and rapid evaluation tools, useful for estimating flood damages and determining the benefits and costs of certain types of works and measures.

6.1 Economic Assessment

The RAM methodology was used to determine the flood damages within Jamieson for areas delineated as land subject to inundation in a 100 year ARI flood, and land that would be inundated from a 20 year ARI event approximately. The latter event corresponded to a flood that produced flood levels 500 mm below the 100 year ARI flood levels.

From the flood inundation map included in **Appendix B** the number of dwellings affected and the cumulative length of sealed and unsealed roads were determined. Information was obtained for the Caravan Park to enable the number of caravans, cabins and ablutions blocks affected to be estimated.

This raw data was then multiplied by appropriate CPI adjusted unit rates and factors (listed in **Table 6-1**). These were derived from the RAM or were estimated having regard for a study of flood impacts for a caravan park at Chinaman's Bridge near Nagambie (SKM, 2000).

- **Table 6-1 Flood Damage Rates**

Item	Rate
Dwellings	$22,550 per property
Agricultural damages	Not applicable
Sealed roads per km	$20,350 per km
Other roads - per km	$9,185 per km
Caravans and annexes	$7,500 each
Cabins in the caravan park	$8,500 each
Caravan park ablutions block	$6,000 each
Notes	
The rates for dwellings and roads have been CPI adjusted from NRE, 2000.	
The rates for caravans, cabins and ablutions blocks have been estimated from information obtained from SKM, 2000	
The rates for dwellings, caravans, cabins and ablutions blocks are potential damages. An adjustment has been made to estimate direct damages, assuming the community has little experience of flooding and the flood warning time is 2 hours. Direct damages have been assumed to be 90% of the potential damages, in accordance with the RAM.	

In this way the direct flood damages were calculated for the areas inundated in a 100 year ARI and 20 year ARI flood event. Indirect damages were assumed to be 30% of the direct damages, as suggested in the RAM.

Flood damages were assumed to be zero for floods less than or equal to the flood at which floodwaters commence to affect low lying areas. By considering the cross section information in **Appendix B** and the flood frequency analysis this was estimated to be a 2 year ARI event.

The "average annual damage" (AAD) for Jamieson was estimated by plotting the frequency of the three threshold events (2 year ARI, 20 year ARI and 100 year ARI events) against the estimated damages for each event, and calculating the area under the graph. A similar exercise was undertaken to assess the "average annual population affected" (see **Section 6.2** below). Results are summarised in **Table 6-2**.

- **Table 6-2 Estimated Flood Damages**

Item	Items Inundated	Direct Damages $	Indirect Damages $	Total Damages $	Estimated Population Affected
Land Inundated in a 20 Year ARI Flood					
Buildings	19 properties	385,605			48
Roads (Incl. Caravan park)	0.33 km sealed 0.64 km unsealed	12,594			
Caravan Park	70 caravans 8 cabins 1 ablutions block	539,100			100
	Total	**937,299**	**281,190**	**1,218,489**	**148**
Land Inundated in a 100 Year ARI Flood					
Buildings	27 properties	547,965			68
Roads	0.42 km sealed 0.75 km unsealed	15,436			
Caravan Park	70 caravans 8 cabins 1 ablutions block	539,100			100
	Total	**1,102,501**	**330,750**	**1,433,251**	**168**
Average Annual Damages		**$341,800 per annum**			
Average Annual Population Affected		**41 people per anum**			

6.2 Social Assessment

The RAM provides a means of assessing social impacts by considering the "average annual population affected" (AAPA) which is the average number of people exposed to the effects of flooding each year. This is an indicator of the effects of flooding on the health and safety of the community and is determined in a similar manner to the AAD, by preparing a graph of population affected by flooding against probability of the flood occurring and integrating the area below the curve.

For buildings. the population affected by the 100 year ARI and 20 year ARI flood events was estimated by multiplying the number of dwellings affected by 2.5. To this was added an estimate of the number of residents from the Caravan park affected.

The AAPA has been included in **Table 6-2**.

6.3 Environmental Assessment

While the RAM provides a method for assessing environmental effects of proposed works, the method is not particularly useful for flood studies, unless they are likely to lead to structural works.

A measure of environmental benefits can be obtained by considering specific works and measures that could result from a study or implementation of a floodplain management plan.

The preparation of flood inundation maps and their incorporation into municipal planning schemes will have some environmental benefit, as they provide a mechanism for ensuring proposed works are consistent with the flood risk. In doing so, there is a greater likelihood of preserving the natural functions of floodplains to convey and store floodwater, together with their inherent environmental benefits.

On the other hand, works such as levees and raised earthworks, that isolate sections of the floodplain in order to provide flood protection are likely to have an adverse affect on environmental values.

The environmental impacts of proposed works and measures for mitigating flood damages should be investigated as part of any future floodplain management plan.

7. Assessment of the Need for Further Studies

It is considered that the estimated 100 year flood extent and levels provide a sound basis for ensuring that future development on the floodplain at Jamieson is compatible with the flood risk.

However this information has been based on limited ground contour information, and no floor level survey has been undertaken of structures in the floodplain.

In the longer term (and subject to the availability of funding) further work could be undertaken to improve the flood risk assessment, in particular:

- ground level and floor level survey;
- a joint probability analysis of the two rivers be undertaken in conjunction with investigations into the level of Lake Eildon;
- hydraulic modelling to improve 100 year flood estimates; and
- a review of flood control overlays (Floodway and Land subject to inundation) when better data is available.

Structural works such as levees and retardation basins are not considered appropriate for Jamieson because of their expense and ongoing maintenance costs, the fact that comparatively few people would benefit, and the potentially adverse environmental affects. While structural works could be perhaps justified economically for some areas (eg the Caravan Park) there is likely to be strong community opposition, because of the visual impacts.

It is considered that at the present time, the preparation of a detailed floodplain management plan for Jamieson is not warranted at this point in time.

8. Recommendation

It is recommended that:

- the flood levels and flood extent map be adopted for planning purposes and incorporated into the municipal planning scheme;
- floodway areas be adopted, based on a margin of 0.5 m below the estimated 100 year ARI flood levels; and
- improvements to emergency response arrangements for the Caravan Park are undertaken because of the flood risk.

The results of this study should be reviewed when better survey information becomes available, or when a major flood provides additional information.

A flowpath passes through the centre of the town, and has the potential to pass into the town drainage system at Cobham Street. It is recommended that the Shire monitors the performance of floods in this area, to ensure that this potential flow path does not become active.

9. References

Grayson,R.B., Argent, R.M., Nathan, R.J., McMahon,T.A., & Mein,R.G. 1996, *Hydrological Recipes: Estimation Techniques in Australian Hydrology,* Cooperative Research Centre for Catchment Hydrology, Clayton, Australia.

Wang, Q.J., (1997) LH moments for statistical analysis of extreme events. Water Resources Research. 33(12) pp2841-2848.

DCNR (1994): *Regression of Flood Flows Versus Catchment Areas in Victoria for Urban and Rural Catchments along and adjacent to the Great Dividing Range*. Developed by Nick Nikolaou and Roel von't Steen, Floodplain Management Unit, Department of Conservation and Natural Resources.

Sinclair Knight Merz (2000): *Chinaman's Bridge Caravan Park Feasibility Study*.

Appendix A Flood Information

A review of flood information was undertaken as part of this project. The following sections provide a brief overview of the consultation and review process undertaken.

A.1 Goulburn Broken CMA

Goulburn Broken CMA was the main source of flood data for this project. Mr Guy Tierney, the Authority's Floodplain Manager, supplied a background file containing information used for a flood reconnaissance and survey project initiated after the September 1998 floods. This included a photograph taken in 1912, which showed flooding along parts of Cobham Street, Perkins Road and surrounding areas. A number of flood levels were extracted from the photograph as part of this earlier flood level survey.

Drawing (No. 540216) was also supplied, dated 13/06/2001. The showed the 1998 flood extent and surveyed flood levels, and also contained a longitudinal profile of the 1998 flood levels.

A.2 Delatite Shire Council

Delatite Shire provided information comprising:

- Correspndence from the Rural waterCommission of Victoria date 24 October 1991, providing flood advice for a dwelling to be errected at No. 16 Bridge Street Jamieson.
- An approximate 1934 flood extent, shown on a Parish map. This was similar to the 1998 flood extent.
- A copy of a flood map for Jamieson, part of NRE's "Flood Data Transfer" Project. This was based on information that predated the 1998 flood extent.

A.3 VicRoads

There are two road bridges at Jamieson (Structures 8703 and 5404). VicRoads were contacted for details but were unable to advise whether useful flood information or cross section information was available without a substantial searching fee. Therefore an alternative option was pursued.

In a project for the West Gippsland CMA, LICS Pty Ltd collated information on bridges for Victoria and compiled a database. They were therefore able to provide information on the design level for each bridge, the bed level, the date of construction, and design information. No flood information was detected.

LICS surveyed the underside of the two bridges and confirmed that they were both well above the 100-year ARI flood levels.

A.4 G-M Water

G-M Water were contacted and confirmed they had no information of use to the project.

A.5 Jamieson and District Historical Society

The Secretary of the Jamieson and District Historical Society was contacted for flood information but advised that no information was available on its files.

A museum located at Jamieson was inspected and was found to contain historic photographs of previous flood events. These were not followed up, as sufficient flood marks were available from other sources.

Appendix B Survey Details

B.1 Cross Section Locations

Insert Plan 540227 Sheet 2

B.2 Flood Level Locations

Insert Plan 540227 sheet 1

B.3 Flood Extents

Insert Plan 540228