Lake Mokoan Hydrology – Response to Community Concerns (19/09/08)

Introduction

Following release of the Hydrology Report on Lake Mokoan (GHD, 2005) and the presentation of the Hydrology Report on Lake Mokoan, in Shepparton in September 2007, the community has raised a number of questions on aspects of the work undertaken. Responses to each question raised at the presentation of the Hydrology Report on Lake Mokoan are provided in Attachment 1. In general the questions asked related to several key issues, namely:

- Not using rainfall data held by local landholders in the area and surrounds;
- The assumptions made in the modelling;
- The extent of modelling undertaken; and
- Whether additional work could be undertaken to better inform the community about the accuracy of the results.

The questions listed above are addressed below in a generic sense in terms of data requirements for hydrological modelling, relevance of historical events and assumptions, approaches and modelling.

In addition, further information is provided on an analysis of the 1993 flood event in Attachment 2. This analysis was undertaken in response to the questions raised at the presentation.

Data Requirements

It is important to understand that the hydrology analysis undertaken required data for two key purposes, namely:

- To calibrate the hydrological model; and
- To use the model to simulate design storm events.

The hydrological model used in the study was RORB, which is the model of preference for this type of work. The model requires rainfall input to produce outputs in the form of flow hydrographs (flow plotted against time), which define the catchment response (e.g. catchment response includes such things as the amount and timing of runoff generated by rainfall across the catchment influenced by topography, soils types, when rain last fell etc.).

To do this accurately the model parameters have to be calibrated to historical data. The calibration process required flow hydrographs generated from historical data on rainfall across the catchment during a storm event to be matched against observed inflow hydrographs. The data requires measurements in hours rather than days.

There is no recorded streamflow data available in the Lake Mokoan catchment, to enable direct calibration of the hydrology model. The only suitable data available dated from 1970 (i.e. historical storage levels from which inflows to Lake Mokoan can be estimated). Further restrictions also applied to the pluviograph data (i.e. rainfall data measurement in time intervals less than one day), which was not available for all years. Of the four largest rainfall events on record in the last 30 years only two were found to have sufficient data for calibration purposes, the October 1993 and the November 1998 events.

Once the model was calibrated it was used to simulate flow behaviour for a range of design flows based on rainfall analysis. Rainfall frequency curves were developed using statistically derived rainfall data in Australian Rainfall and Runoff (1999).

It is important to note that the Australian Rainfall and Runoff data uses all available historical rainfall data to circa 1987 to assist in defining the intensity, duration and frequency of the rainfall frequency curves.

Relevance of Historical Events

The community has collective knowledge of historical storm events, particularly the more severe ones. It is the knowledge of these events (both recorded and anecdotal), their magnitude and frequency, that the community refers to when faced with the task of accepting results of an hydrological study. For example a flood in 1956 is alleged to have had significant impacts at Winton Swamp.

While the historical data for pre 1969 events was not able to be directly used in the study, we recognise that the direct use of these data could assist the community by obtaining a better understanding of how the modelling data compares to these events. For that reason we have extracted additional rainfall data from the BoM database and presented the data for discussion in terms of relevance to design data used in the study. Also rainfall depth data was supplied by the community, this data was compared to that recorded by the BoM for the 1993 event.

<u>Rainfall Data</u>

Attachment 3 presents the IFD design storm data for Benalla and Wangaratta from the Bureau of Meteorology. The information is derived from Australian Rainfall and Runoff (IE Aust. 1999). Tables 1, 2 and 3 summarise the total rainfall recorded by the Bureau of Meteorology at Benalla and Wangaratta for three events in 1956, 1974 and 1993 respectively and indicates the approximate ARI (years) for each event based on data in Attachment 3. These three events were chosen because, 1956 has been identified by the community as a significant event at Winton Swamp, 1993 is the most severe and recent flood event to affect the area and 1974 is another recognised significant event.

From Tables 1, 2 and 3, the estimated ARIs of the rainfall for the 1956, 1974 and 1993 events vary markedly. Given that the centroid of the Lake Mokoan catchment is about half way between the rainfall stations at Benalla and Wangaratta, an average rainfall depth between the two rainfall stations has been assumed to represent the rainfall over Lake Mokoan. However, it is likely that at best this will only provide a broad indication of the rainfall that fell over Lake Mokoan during these events. The results in Table 1 and 2 indicate that particularly for the 1956 and to a lesser degree the 1974 event the rainfall across the Lake Mokoan catchment was uniform. Table 3 indicates that for the 1993 event there was a large amount of variability in rainfall across the catchment.

Rainfall maps can provide an improved idea of where the rain fell spatially. Attachment 4 provides an example for the 1993 event. The map indicates that in 1993 the 24 hour rainfall for Lake Mokoan could be about 100 mm, which is lower than that given in Table 3. The approximate ARI for a 100 mm of rainfall in 24 hours at Lake Mokoan is 30 years. This is in contrast to the 10 year ARI value estimated using rainfall at the Glenrowan Post Office given in the GHD 2005 report. The above information highlights the large variability in rainfall across the Lake Mokoan catchment in the 1993 event.

As mentioned above, the community supplied rainfall depth data to G-MW at three locations, namely Casey Weir, Lima and Upper Ryans Creek Road. For the 1993 event the maximum 24 hour rainfall recorded by the community at each location was 75 mm, 90 mm and 130 mm respectively. These rainfall depths are consistent with those recorded by the BoM.

Table 1 Design Rainfall for Benalla

	7 July 1956 (24 hours)	
	Total Rainfall (mm)	**Approximate ARI**
Benalla	25.4	<1
Wangaratta	31.8	<1
Lake Mokoan*	28.6	2

Note: * Based on rainfall interpolated between Benalla and Wangaratta

Table 2 Summary of Design Rainfall for Benalla

	14 & 15 May 1974 (48 hours)	
	Total Rainfall (mm)	**Approximate ARI**
Benalla	95.5	8
Wangaratta	108.7	18
Lake Mokoan*	102.1	12

Note: * Based on rainfall interpolated between Benalla and Wangaratta

Table 3 Summary of Design Rainfall for Benalla

	4 October 1993 (24 hours)	
	Total Rainfall	**Approximate ARI**
Benalla	177.4	900
Wangaratta	71.3	5
Lake Mokoan*	124.35	100

Note: * Based on rainfall interpolated between Benalla and Wangaratta

Storm Losses

Figures 1, 2 and 3 show the mean monthly total rainfall at Benalla for the entire period of record compared with the total monthly rainfall for 1956, 1974 and 1993 respectively over a period of 12 months. These data are presented to provide an indication of the pre-storm catchment conditions for each of the historical storms referred to in Tables 1, 2 and 3. Higher than average rainfall pre-storm (i.e. in the months prior to the month of interest) will indicate a wetter catchment and hence the likelihood that storm losses will be lower, rather than higher, leading to greater runoff.

In 1956 the rainfall in the previous four month (i.e. March to June) was higher than average (see Figure 1). This suggests storm losses during the event would be lower than average.

In 1974 the rainfall in the previous month (i.e. April) was even higher than the rainfall for May and well above the average (see Figure 2). This suggests storm losses during the event would be lower than average, as was the case in 1956.

In 1993 significantly higher than average rainfall occurred in September, the month prior to the October event (see Figure 3). Again, storm losses during the 1993 event would tend to be lower than average. Further comment on the 1993 event is provided in Attachment 2 dealing with the impact of a repeat of the 1993 event with the proposed Winton Swamp in place.

It is concluded that, for the three flow events (1956, 1974 and 1993) analysed, significant rain fell prior to the rainfall that produced the floods, resulting in a wet catchment and more runoff than average. In these cases storm losses would probably be less than the average or median values appropriate for modelling design events. It should be noted that the guidelines for flood estimation embedded in Australian Rainfall and Runoff (IEAust 1999) are based on the assumption that the design peak discharge calculated will have the same ARI as the rainfall event used in the analysis. Reasons why this assumption might not apply include adopting rainfall losses that are biased towards either the low or high end of the possible range and adopting extreme temporal rainfall patterns and /or spatial patterns. If losses are chosen at the lower end (on the basis of wet antecedent conditions), then the flow result could be biased towards a higher ARI. Any comparison of historical storm events with design events needs to recognise this difference.

Figure 1 Monthly Rainfall in 1956

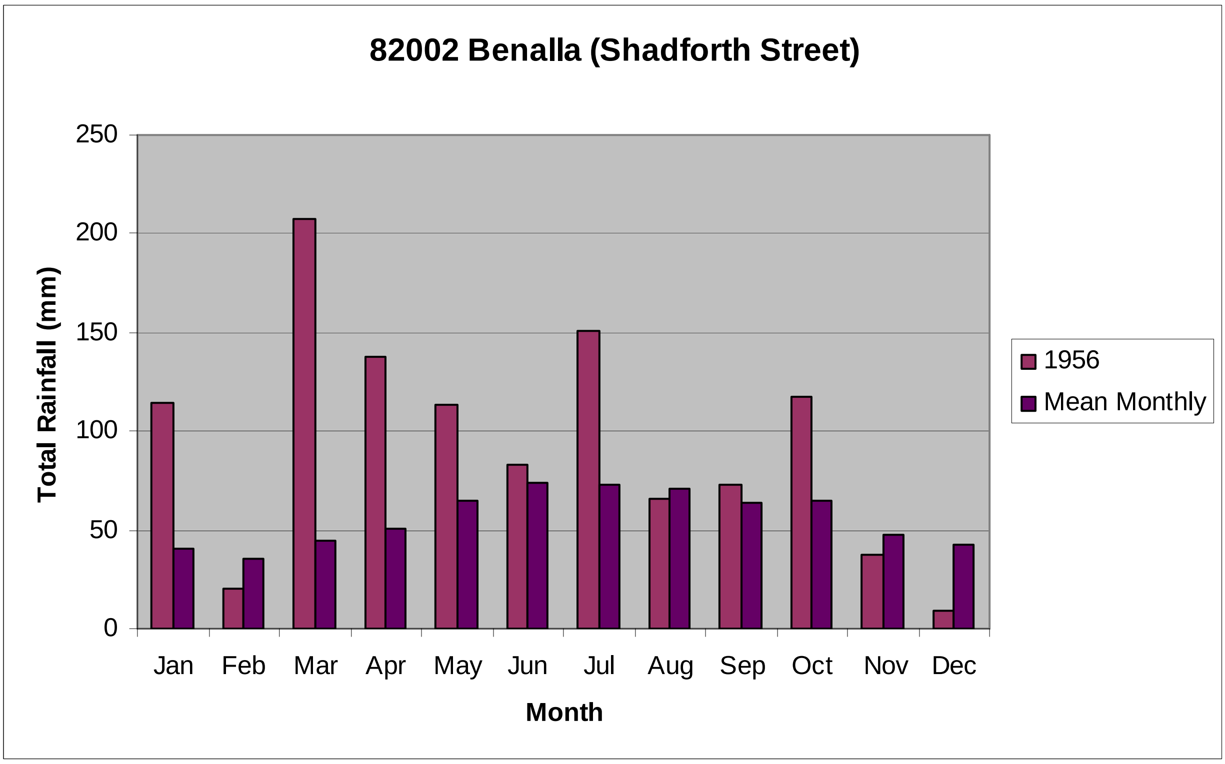


Figure 2 Monthly Rainfall in 1974

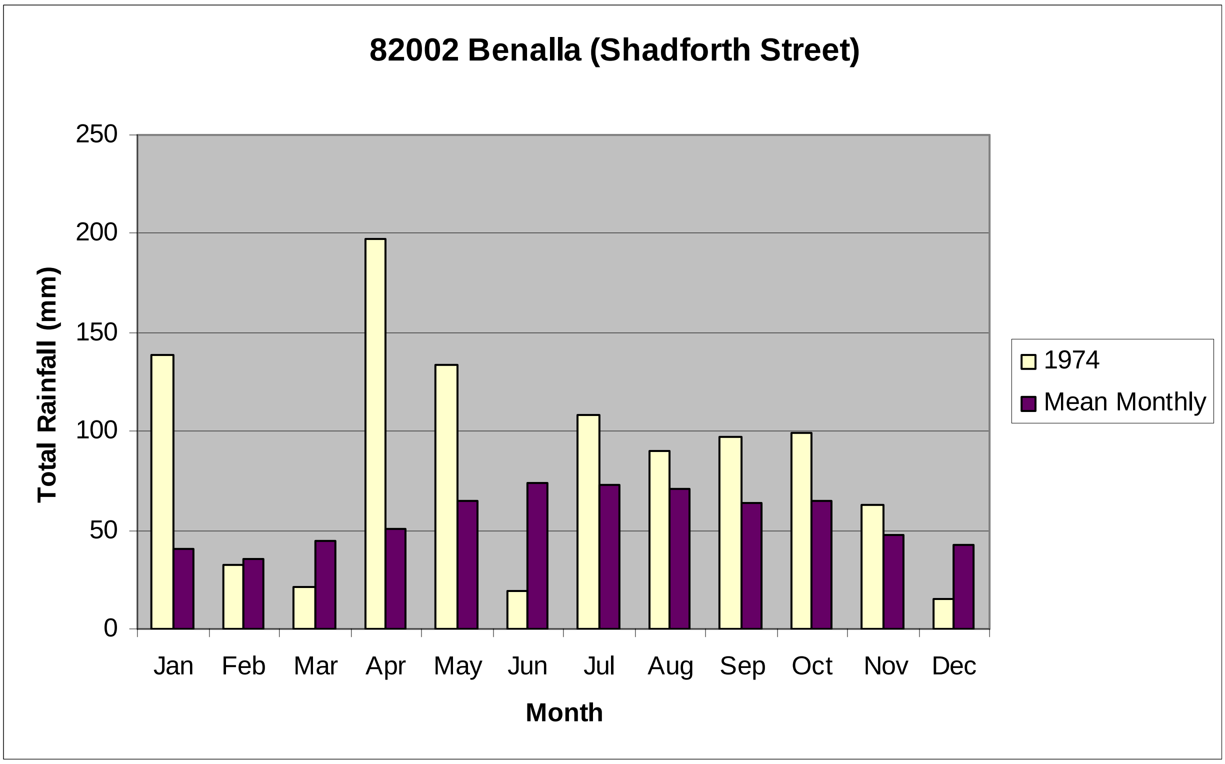
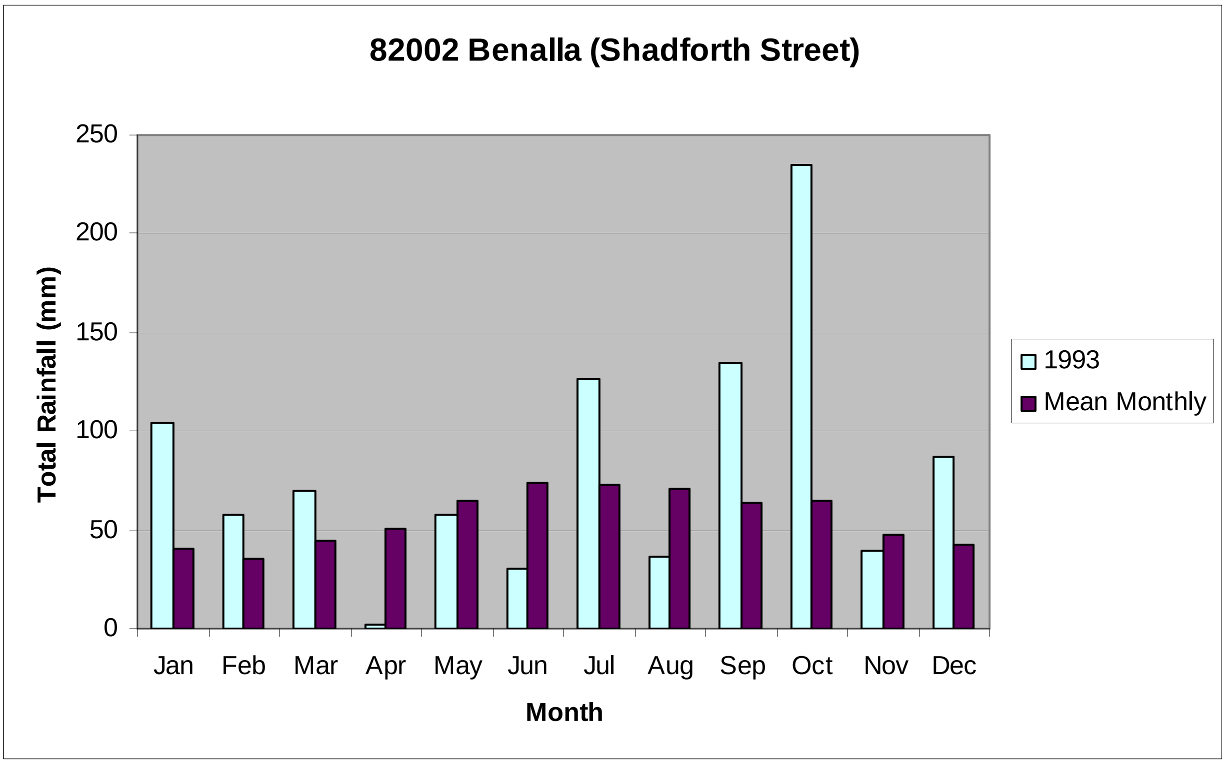


Figure 3 Monthly Rainfall in 1993



Assumptions, Approach and Models

The first point to note with regard to assumptions, approach and modelling is that the work was undertaken in accordance with Australian Rainfall & Runoff, A guide to flood estimation, prepared and published by the Institution of Engineers, Australia (1999). This publication, generally referred to as ARR1999, presents guidelines on the use of design data methods, techniques and models to estimate runoff resulting from storm rainfall. ARR1999 is not a "standard" as it provides guidelines on how to approach, analyse and present results with appropriate attention to assumptions and levels of uncertainty.

The GHD 2005 report documents the details of the study and presents the results in adequate detail and in line with acceptable practice.

ARR documents procedures for flood estimation and provides guidance for designers in their choice of methods. It also gives rainfall data recorded for the computation of design storms. The information provided in ARR represents the combined expertise and knowledge of Australian academics and practitioners in climatology, hydrology and hydraulics. Preparation of successive version of ARR has involved considerable individual efforts, an advisory panel of the Institutions National Committee on Hydrology and Water Resources, workshops and questionnaires.

ARR was used as the guide to the work undertaken and, as such, the work is current best practice for this type of feasibility / concept study.

Conclusion

It is concluded that:

- Historical rainfall and flood data used in the 2005 study were appropriate and relevant for the analysis undertaken given that historical storm rainfall prior to 1987 has been used to derive design storm rainfall and detailed historical rainfall and recorded data on the behaviour of Lake Mokoan used to calibrate the hydrological model; and
- The assumptions, approach and modelling undertaken were adequate for the purpose of the study given that acceptable practices were followed in accordance with the national guidelines (Australian Rainfall and Runoff 1999).

Attachment 1

Lake Mokoan Hydrology – Response to Community Concerns

Responses to Questions

Question 1:

What are the flow rates increases for level increases at Casey's of:

- 0.01m (1:100 event on Broken plus 1:100 from Mokoan);
- 0.04 m (1:100 event on Broken plus no diversion to Mokoan); and
- 0.08 m (1:5 event on Broken plus no diversion to Mokoan).

Answer:

6.7 m^3/s (GHD cannot corroborate this), 28 m^3/s and 28 m^3/s.

Question 2:

Does the modelling recognise pre 1969 floods?

Answer:

Not specifically however, design storm data used in the study was based on all major storm events up to circa 1987 given that this data has been used to prepare data incorporated into the design storm information in Australian Rainfall and Runoff (IEAust. 1999).

For calibration, data was sourced only from post Lake Mokoan (post 1969) because data on flows in the Lake Mokoan catchment, required for model calibration, is only available since the Lake Mokoan was constructed. Even then only reservoir level data is available and not flow data into the Lake Mokoan.

Question 3:

Are correlations with earlier Murray floods relevant and necessary?

Answer:

No, as it would be difficult to correlate Murray data with the situation at Lake Mokoan and therefore any results would not be reliable.

Question 4:

Does the modelling recognise precedent conditions in 1956 flood, which are reportedly higher than post 1969 events?

Answer:

If the model could have been calibrated against the 1956 flood event then the antecedent conditions would have been taken into account. However, this was not the case. In estimating design flows (as given in the report) average or median conditions are normally assumed to avoid producing a biased estimate.

Question 5:

What assumptions are made in the modelling?

Answer:

Some key assumptions were set out in the presentation and are given in the Hydrology Report on Lake Mokoan (GHD, 2005). Some of these assumptions are conditions identified by G-MW. The key assumptions detailed in the presentation were:

- Wetlands full at commencement of storm;
- Inlet channel not operating (i.e. no inflow from the inlet channel);
- Outlet works modified to have weir level of 161.14m AHD; and
- Breach in embankment wall at level of 161.14 m AHD.

Question 6:

How many model runs were undertaken?

Answer:

Numerous model runs are undertaken in the calibration process (an iterative process generally). Runs of the hydrology/hydraulic models undertaken to produce results involved at least the combination of about six storm durations for each ARI event (5 in total) for each of the possible scenarios analysed (e.g. 6 x 5 x 2 breach lengths x 2 outlet options = 144) that are reported. In addition, there are numerous trial runs and reruns to test the results are consistent. The number of specific conditions modelled by the RORB model, TUFLOW model and HEC-RAS model can be inferred from the information in the report.

Question 7:

What were the confidence limits around the model outputs?

Answer:

Confidence limits for the results were not determined in the study. It is not standard practice to estimate confidence limits for all modelling results such as those presented in the report. The results presented represent best estimates based on procedures / analysis undertaken in accordance with accepted guidelines, that is Australian Rainfall and Runoff (IEAust. 1999). The 1 in 1000 year AEP event modelling was undertaken to give some indication of a worse situation than the 1 in 100 year AEP event.

Question 8:

What coincident events have been assumed in the modelling?

Answer:

The coincident events are set out in the report.

Question 9:

What further work could be done to address community concerns re: quality of data & assumptions?

Answer:

Possible additional work that could be undertaken if considered necessary to allay community concerns would include:

- Examine daily rainfall that is available from records kept by local landowners to check the additional data available against that available from the Bureau of Meteorology to increase the collective knowledge of historical rainfall events (refer to explanatory text pg 2);
- Analyse the upstream and downstream impacts that could result from a repeat of the 1993 flood event with the proposed Winton Swamp arrangements in place (refer Attachment 2);
- Update model to incorporate possible inflow of local storm runoff from the Inlet Channel in design storm modelling;
- Undertake a more formalised sensitivity analysis to assess the impact of varying IL, CL and k_c in the hydrologic modelling (i.e. RORB). However, modelling historical events such as the 1993 event and assessing the impacts maybe a better way to allay community concerns (refer Attachment 2); and
- Undertake a more formalised sensitivity analysis to assess the impact of the status of wetlands prior to storm events commencing based on water balance modelling in the hydraulic modelling (i.e. TUFLOW modelling). This could include modelling the 1993 event in TUFLOW.

Question 10:

How have the uncertainties raised in the above points been addressed in the methodology adopted by GHD?

Answer:

The question is answered by the responses above. Further discussion would only lead to duplication. Suffice to say that GHD used the best information available at the time and applied analysis generally in accordance with guidelines without bias.

Question 11:

What are the impacts of decommissioning on flows downstream of Casey's Weir?

Answer:

Refer answer to Question 1. Impacts have only been defined in the Hydrology Report on Lake Mokoan (GHD, 2005) in indicative terms by estimating the potential peak water level increases under specific conditions.

Attachment 2

Lake Mokoan Hydrology – Draft Response to Community Concerns

Analysis of October 1993 Event

Introduction

Goulburn Murray Water (G-MW) commissioned GHD to determine, from modelling, what impact the 1993 event could have upstream and downstream if the proposed arrangement for Lake Mokoan i.e. a 10 metre breach in the embankment without the existing outlet, was in place.

Background

In October 1993 wide spread flooding was experienced over North East Victoria as a result of intense rainfall. The most intense rainfall was situated between Benalla and Harrietville and evidence suggests that extremely intense rainfall was also centred on the eastern edge of the Hollands Creek catchment. The rainfall gauge at Benalla recorded 177.4 mm in the 24 hours preceding 9:00am on 4 October 1993. The 24 hour rainfall at Benalla equates to an ARI of approximately 900 years. It is worth noting that rainfall at other gauges in the vicinity recorded rainfalls over the 24 hours that show ARI's of lower values.

The pluviographs available for the October 1993 event indicates that there were two main bursts of rainfall. At Lake Nillahcootie the first burst of most intense rainfall occurred around noon of Sunday, October 3 and the second burst occurred late in the evening (DCNR, 1995).

Prior to 1993 the two largest storms, which occurred in the past 25 years, are May 1974 and July 1981. The data indicates that the mean catchment rainfall in October 1993 far exceeded rainfall in the 1974 and 1981 events.

The then Department of Conservation and Natural Resources in 1995 stated the following,

> "rainfall depths alone do not convey the complete reason why so much more runoff was generated from the October 1993 storm. There were also differences in rainfall intensities. In October 1993, a high percentage of the total rainfall fell within 18 hours and most of the rain fell in the second storm burst over a period of about 8 hours from late afternoon on October 3. Although there was a burst of more intense rainfall for about 6 hours in the May 1974 storm, the rainfall was generally of lower intensity sustained over a storm duration of about 60 hours. In 1981, the rainfall occurred over the full three days, and in fact significant rainfall fell in the succeeding 24 hours to 0900 hours on July 24.
>
> Antecedent rainfall was significant prior to the July 1981 storm and, as noted above, was substantial prior to the October 1993 storm. In May 1974, however, there was relatively little antecedent rainfall. In summary therefore, not only was the depth of precipitation greater in October 1993, but the intensity of rainfall was higher and the antecedent catchment conditions were more saturated. These factors produced a very high rate of runoff."

Methodology

The methodology adopted to model the 1993 event was as follows:

- Set up a hydraulic model (SWMM) for the Outlet Channel from Lake Mokoan to Broken River at Casey Weir, with Lake Mokoan entered as a storage with the storage details (elevation versus storage) taken from data supplied by G-MW. An inflow hydrograph to Lake Mokoan from its catchment and the inlet channel was back calculated from the recorded storage levels during the 1993 event. The hydrograph was input back into the hydraulic model to check that the storage levels over time match that recorded during the 1993 event (a good match was not expected due to the error involved in back calculating the inflows). The inflow hydrograph was adjusted to achieve a match between the modelled and actual storage behaviour for Lake Mokoan (this corrected the back calculation errors and provided a match between modelled and actual volumes of the inflow event into Lake Mokoan). It is worth noting that there was no outflow recorded from Lake Mokoan during the 1993 event, therefore no outflow from Lake Mokoan was modelled for the calibration process;
- A modified hydraulic model (SWMM) was then established with the existing outlet channel in place, a storage representing Winton Swamp and the proposed arrangement of a 10 metre wide breach in the embankment with the outlet set at 161.14 mAHD. The inflow hydrograph established in the calibration process above, was entered into the hydraulic model with the 10 metre wide breach in the embankment in place. The levels at Casey Weir were determined in the hydraulic model for the 1993 event by using the rating curve for the Broken River at Casey Weir and inputting Broken River flows to 'mimic' what happened on the Broken River in 1993. It is worth noting that it was assumed that Winton Swamp started full i.e. 161.14 mAHD;
- The modelled levels in the outlet channel resulting from the Winton Swamp scenario described above were then compared to the levels in the outlet channel in 1993 (i.e. the recorded level at Casey Weir was assumed in the model to extend back up the outlet channel) at two locations (immediately downstream of the Mokoan embankment and at Casey Weir);
- The level upstream in Winton Swamp resulting from the calibrated 1993 hydrograph with the breach in place was then noted; and
- The design 100 year ARI inflow calculated in 2005 was entered into the hydraulic model to verify the hydraulic model against the previous hydraulic modelling.

Results

Figure 1 shows the calibrated reservoir levels versus the recorded reservoir level (existing conditions) with the calculated 1993 inflow hydrograph.

Figure 1 Calibration Results from October 1993 Event

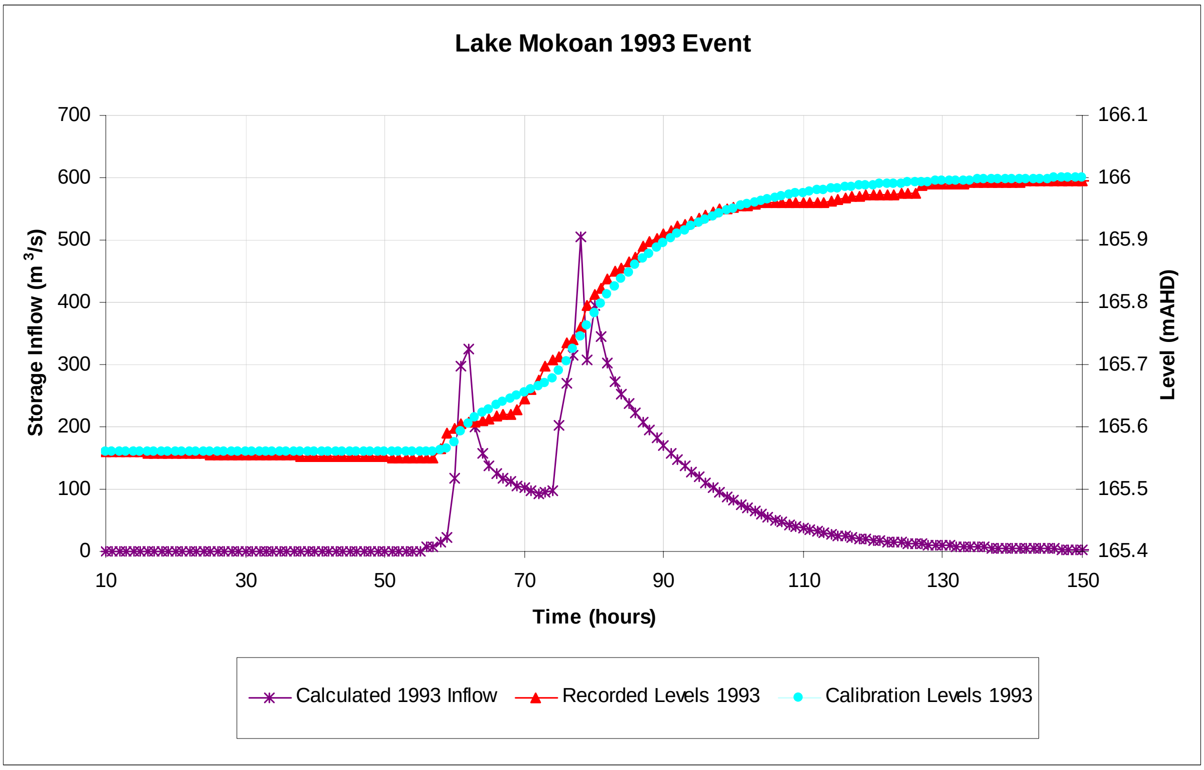


Figure 2 shows the assumed 1993 levels versus the Winton Swamp modelled levels in the outlet channel immediately downstream of the Mokoan embankment. As mentioned previously it was assumed in the model that the recorded level at Casey Weir extended back up the outlet channel. Figure 3 shows the recorded 1993 levels versus the Winton Swamp modelled levels in the outlet channel at Casey Weir. Table 1 shows a summary of peak levels at key locations along the outlet channel for the 1993 event.

Figure 2 Levels in Outlet Channel Immediately Downstream of Lake Mokoan

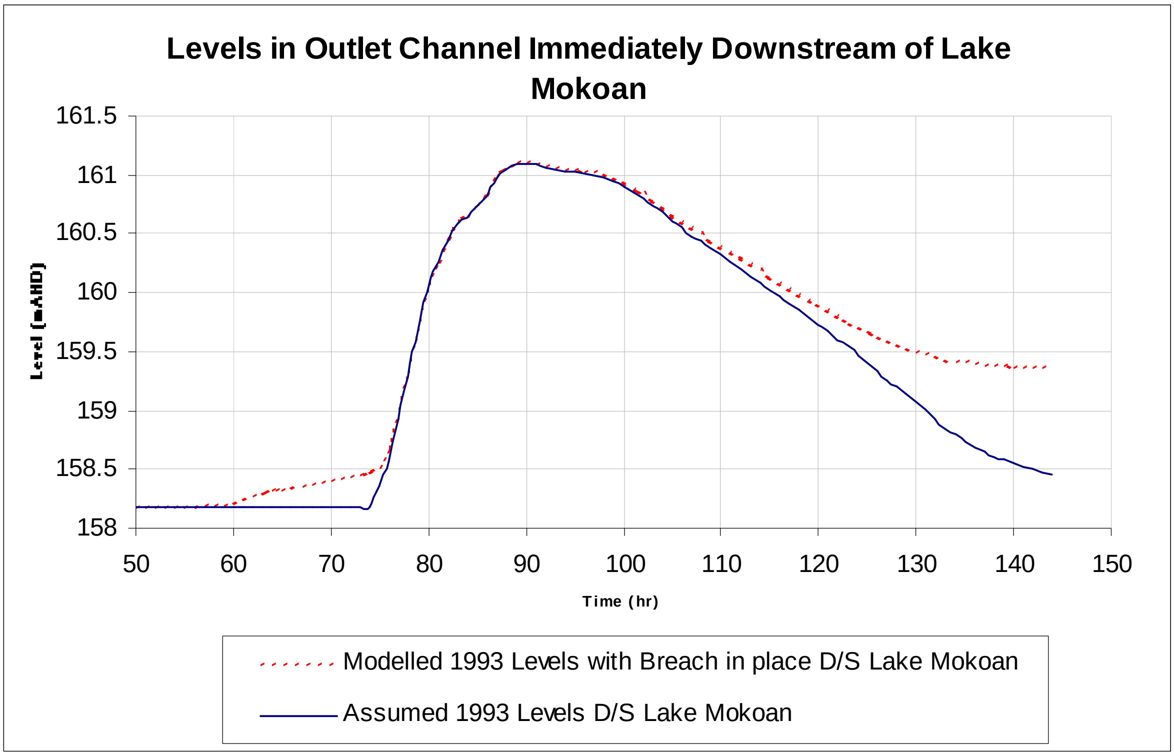


Figure 3 Levels in Outlet Channel at Casey Weir

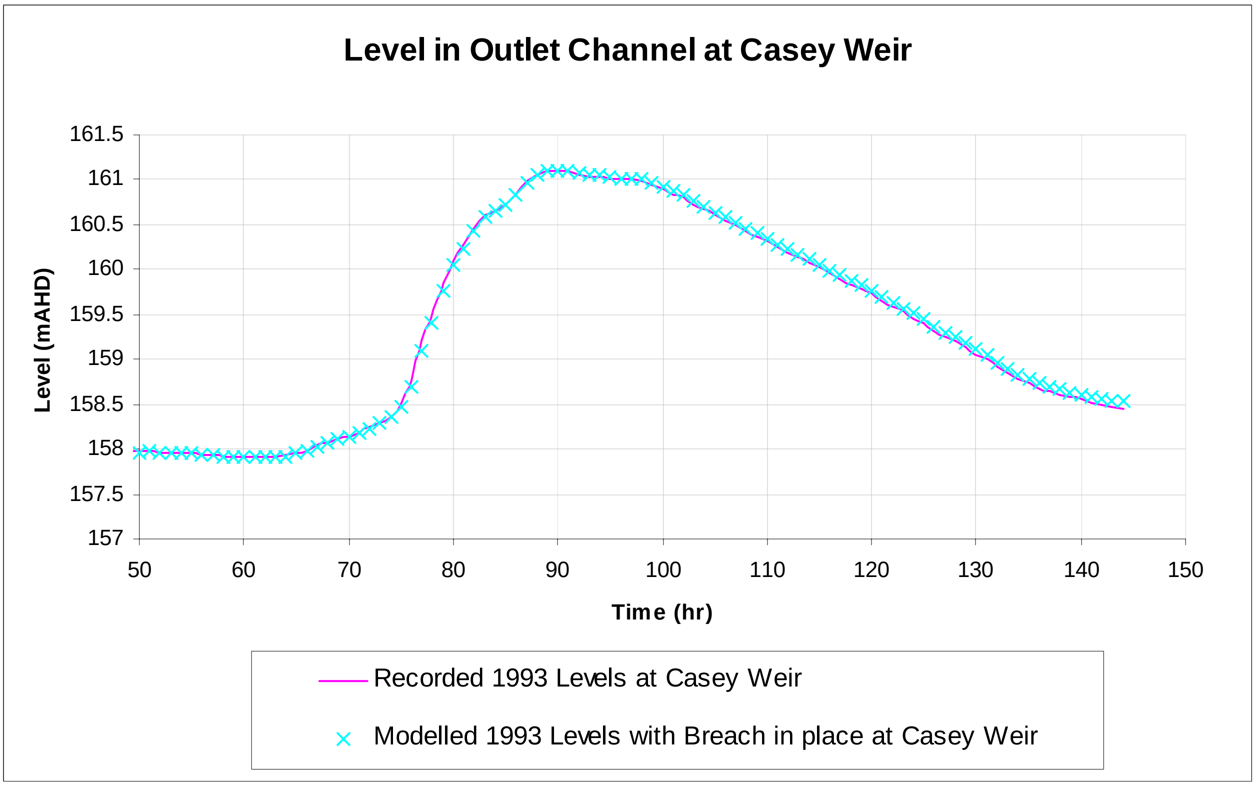


Table 1 Summary of Peak Level in the Outlet Channel – 1993 Event

Location Along Outlet Channel	Peak Recorded Level in Outlet Channel (mAHD)	Peak Modelled Level in Outlet Channel with Breach (mAHD)
Downstream of Lake Mokoan	161.1	161.12
Approximately 500 metres d/s of Lake Mokoan	161.1	161.11
Downstream End of Outlet Channel	161.1	161.11

From the hydraulic model (SWMM) the maximum level reached in Winton Swamp (i.e. upstream of the embankment) for the calibrated 1993 event was 162 mAHD.

Table 2 shows a summary of peak levels at key locations along the outlet channel for the critical 100 year ARI event from both the 2005 and current modelling.

Table 2 Summary of Peak Level in the Outlet Channel for 100 year ARI

Location	Peak Modelled Level in Outlet Channel (mAHD) from 2005 Report	Peak Modelled Level in Outlet Channel (mAHD) from Current Modelling
Lake Mokoan	161.1	161.1
Approximately 500 metres d/s of Lake Mokoan	161.1	161.1
Downstream End of Outlet Channel	161.1	161.1

From the hydraulic model (SWMM) the maximum level estimated to be reached in Winton Swamp (i.e upstream of the embankment) for the 100 year ARI event was 161.5 mAHD.

Discussion

Figure 1 shows that a good calibration against the recorded reservoir levels was achieved with the calculated 1993 inflow hydrograph. The 'double' peaked hydrograph, with the second peak being higher than the first reflects the pluviograph information that is available which suggest that for the October 1993 event there were two main bursts of rainfall with most of the rain fall in the second storm burst.

Figure 2 and 3 and Table 1 indicates that if the 1993 event was to occur with the 10 metre breach in place then the impact on peak water levels in the outlet channel would be minor (up to +20 mm immediately downstream of Lake Mokoan to +10 mm approximately 0.5 kilometres downstream of Lake Mokoan). Flood levels will however be higher for longer, as indicated in Figure 2. This is expected, given that in October 1993 the flood levels were determined by the levels at Casey Weir, whereas a 10 m breach will result in some outlet channel flows until the level in the proposed Winton Swamp drops.

It is worth noting that the estimated higher level of 159.4 mAHD, immediately downstream of Lake Mokoan, (see Figure 2) at the end of the hydrograph is below the level of the compacted banks. Also the Given the corresponding level (i.e. at the end of the hydrograph) at Casey Weir is about 158.5 mAHD (see Figure 1), the water levels in the outlet channel along its length would also be below the compacted banks at this stage in the flood event.

In order to see that the hydraulic model (SWMM) was consistent with the previous TUFLOW modelling in the 2005 GHD Report, the 100 year ARI design event was placed into the model and the same tailwater conditions as in 2005 were assumed i.e. 161.1 mAHD. The 24 hour storm only was modelled as this produced the peak outflow in the outlet channel. Table 2 shows that both models produce the same result. This is not unusual, given the high tailwater, which resulted in very little difference in flood level between the water level just downstream of the embankment and at Casey Weir.

In terms of upstream impacts the modelled maximum level reached within the proposed Winton Swamp for a repeat of the 1993 event was 162 mAHD and for the 100 year ARI, 24 hour event was 161.5 mAHD. The 100 year ARI level determined in 2005 using the TUFLOW (2 dimensional) model indicated a maximum level of 161.73 mAHD for Winton Swamp (10 metre breach without the outlet). This is 0.23 m higher than the SWMM (one dimensional) model value. The difference between these two levels (161.5 mAHD and 161.73 mAHD) represents a difference between the TUFLOW (2 dimensional) and SWMM (1 dimensional) models. Therefore extrapolating the difference between TUFLOW and SWMM could indicate that the estimated maximum level in Winton Swamp in a repeat of the 1993 event could be higher than 162.0 mAHD. However, any increase in levels in Winton Swamp will have minimal effect downstream of the embankment (due to the high tailwater levels, at Casey Weir, resulting from the 1993 flood).

Attachment 3

Lake Mokoan Hydrology

Design Storm Rainfall Depths

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180 Lonsdale Street Melbourne Vic 3000

G-MW - Lake Mokoan Hydrology
Design Storm Rainfall Depths

Attachment 3

Benalla

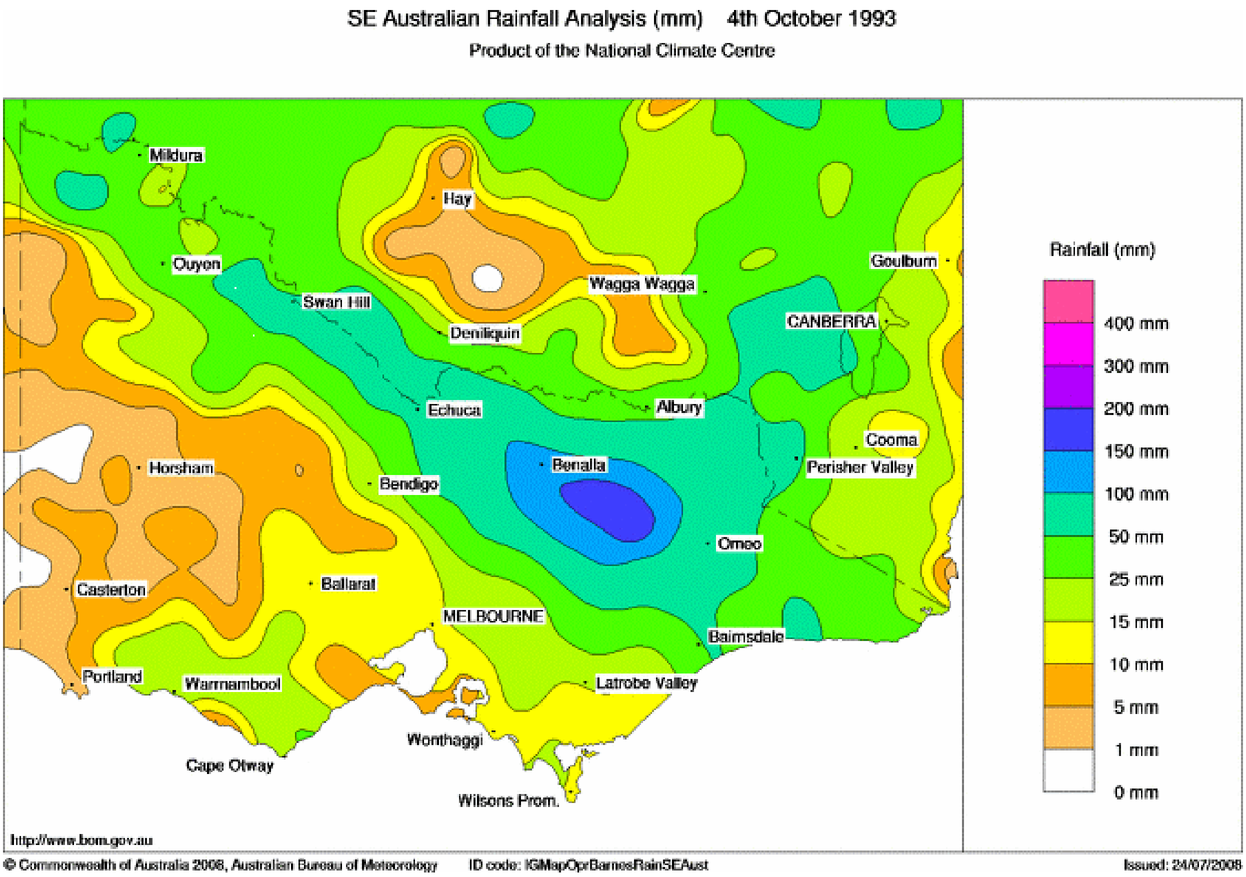
	ARI						
DURATION	**1 Year**	**2 years**	**5 years**	**10 years**	**20 years**	**50 years**	**100 years**
5Mins	4.4	5.8	7.9	9.3	11.1	13.6	15.6
6Mins	4.9	6.5	8.8	10.4	12.4	15.2	17.4
10Mins	6.6	8.8	11.9	13.9	16.6	20.3	23.2
20Mins	9.6	12.7	17.1	19.9	23.6	28.8	32.9
30Mins	11.7	15.3	20.6	23.9	28.3	34.5	39.4
1Hr	15.5	20.3	27.0	31.2	36.9	44.6	50.8
2Hrs	19.9	25.8	34.0	39.0	45.6	54.8	62.0
3Hrs	22.8	29.5	38.1	43.8	51.0	60.9	68.7
6Hrs	28.5	36.8	46.7	52.8	61.2	72.0	81.0
12Hrs	35.6	45.8	57.5	64.6	74.3	87.2	97.3
24Hrs	44.4	56.9	71.5	80.6	92.6	109.0	121.7
48Hrs	53.3	68.6	87.4	99.4	114.7	135.8	152.6
72Hrs	56.9	74.2	95.0	108.0	124.6	148.3	166.3

Wangaratta

	ARI						
DURATION	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5Mins	4.2	5.6	7.7	9.0	10.8	13.2	15.2
6Mins	4.7	6.3	8.6	10.0	12.0	14.7	16.9
10Mins	6.4	8.5	11.5	13.5	16.0	19.5	22.5
20Mins	9.3	12.2	16.4	19.1	22.7	27.6	31.5
30Mins	11.2	14.8	19.7	22.9	27.1	32.9	37.5
1Hr	15.0	19.6	25.9	29.9	35.2	42.4	48.2
2Hrs	19.3	25.0	32.8	37.4	43.8	52.4	59.4
3Hrs	22.1	28.7	37.2	42.3	49.2	58.8	66.3
6Hrs	28.0	36.1	45.9	51.8	60.0	70.8	79.2
12Hrs	35.3	45.4	57.0	64.0	73.6	86.5	96.5
24Hrs	44.4	56.9	71.0	79.7	91.2	106.8	119.0
48Hrs	54.2	69.1	86.9	97.0	110.9	130.1	145.0
72Hrs	59.0	75.6	94.3	105.1	120.2	141.1	156.2

Attachment 4

24 Hour Rainfall – 4 October 1993


SE Australian Rainfall Analysis (mm) 4th October 1993
Product of the National Climate Centre
Mildura
Hay
Ouyen
Swan Hill
Wagga Wagga
Goulburn
Deniliquin
CANBERRA
Echuca
Albury
Cooma
Perisher Valley
Horsham
Benalla
Bendigo
Omeo
Casterton
Ballarat
MELBOURNE
Bairnsdale
Portland
Warrnambool
Latrobe Valley
Wonthaggi
Cape Otway
Wilsons Prom.
http://www.bom.gov.au
Rainfall (mm)
400 mm
300 mm
200 mm
150 mm
100 mm
50 mm
25 mm
15 mm
10 mm
5 mm
1 mm
0 mm
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