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12 January 2011

Mr. Barry Dennifen
CEO, SEQ Water Grid Manager
PO Box 16205
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Dear Barry,

This letter report:

- presents my final findings on a review of the operation of Wivenhoe Dam (including controlled releases) for compliance against the Flood Mitigation Manual for the period 12 December 2010 to date (Flood Event), and;
- provides advice on the prudence and appropriateness of the decisions and actions taken during the Flood Event regarding the operation of Wivenhoe Dam in light of the Flood Mitigation Manual's requirements and the circumstances of the Flood Event.

The report follows on from my preliminary report sent to you earlier today. The findings and advice are provided on the basis of information provided by SEQ Water Grid Manager which comprised the Flood Mitigation Manual and Technical Situation Reports. The latter were daily (sometimes twice daily) reports for the subject period. They gave a log of rainfall over the dam catchments and the downstream river (Lockyer Ck. and Bremer R.) catchments; inflows to Somerset and Wivenhoe Dams; storage levels; releases from the dams; details of the operation of gates and other outlets (gate openings/discharges); proposed changes in operating strategies and impacts on the various access crossings downstream of Wivenhoe Dam. In reviewing the Technical Situation Reports, I prepared a spreadsheet (see separate attachment of Excel spreadsheet *Tech Reports - Summary*, summarising the reports so that a timeline of the Flood Event could be seen at a glance. This provided a good overview of the Flood Event as it unfolded and showed what information may or may not have been included in a particular report. The Queensland Director Dam Safety (Water Supply) informed me that the Flood Operation Logs contain much more detailed information including details of the communications that were carried out and some of the more detailed information that is not necessarily included in the Technical Situation Reports. I have been provided with a draft of the "Protocol for the Communication of Flooding Information for the Brisbane River Catchment - Including Floodwater Releases from Wivenhoe and Somerset Dams" developed in October/November last year and currently being used. The Technical Situation Reports appear to have been an outcome of that Protocol.

The various requirements and required actions detailed in the Flood Mitigation Manual are summarised in the Table given in Attachment A. The Table also gives my comments (where appropriate) on whether there is evidence from the information presented to me, that there is satisfactory compliance with these requirements and actions.

The main aspects of the Flood Mitigation Manual are the various strategies for operating Wivenhoe Dam and Somerset Dam as well as a number of requirements relating to flood operations personnel, flood preparedness and flood training.

At Wivenhoe Dam there are four main strategies for operating the dam (W1 to W4) and at Dam there are three (S1 to S3). These strategies are hierarchical and are based on a number of flood objectives. These in descending order of importance, are:

- Ensure the structural safety of the dams;
- Provide optimum protection of urbanised areas from inundation;
- Minimise disruption to rural life in the valleys of the Brisbane and Stanley Rivers;
- Retain the storage at Full Supply Level (FSL) at the conclusion of the Flood Event, and;
- Minimise impacts to riparian flora and fauna during the drain down phase of the Flood Event.

Normal procedures require a return to FSL within 7 days of the flood event peak passing through the dams so that the potential effects of closely spaced Flood Events can be allowed for.

It is apparent from the Technical Situation Reports that emphasis has been given to communicating changes in flood operations strategies with local authorities and the Bureau of Meteorology (BOM).

Until the last day or so, Wivenhoe Dam has been below EL74.0 and accordingly, would be operating under Strategy W1 i.e. make releases such that bridges downstream of the dam do not have to be closed prematurely. For a few days at the end of December and for the last day or so before yesterday's big rise, Strategy W2 would be in place (restrain releases from Wivenhoe Dam such that Brisbane River flows are maintained within the upper limit of non-damaging floods at Lowood (3,500 m³/s)). At various times during the Flood Event some of the downstream bridges have been closed. However, it is evident that action has been taken to vary dam releases such that various bridges could be re-opened as soon as possible. This appears to have been done in accordance with the flood operating strategies. The operations then moved onto Strategy W4 when the storage in Wivenhoe Dam reached about EL 73.5 (before the W4 trigger level of EL 74) when yesterday's heavy rain came on and it was assessed that there was a chance that the first (central) fuse plug could be triggered. It was then a matter of juggling the radial gate openings in an attempt to circumvent any fuse plug triggering. A graph of storage levels for Wivenhoe and Somerset Dams (from information taken from the Technical Situation Reports) showing the limits for the various Wivenhoe Dam flood strategies is given in Attachment A. It is apparent from this graph, that the appropriate flood operation strategies were adopted. The Technical Situation Reports indicate that proposed changes in strategy were appropriately communicated with appropriate authorities in accordance with the new Communication Protocol.

Summary:

The Technical Situation Reports comply with the requirements of the new Communication Protocol. However, I feel that there could be more consistency in the information presented. There seem to be gaps in information presented such as storage levels (see spreadsheet and graph in Attachment A). It would be useful to specify the minimum information required to be presented in the Technical Situation Reports (storage levels, inflows, recent/current rainfall, forecast rainfall, releases from dams, estimated flows from downstream tributaries, current flood operating strategy for each dam and proposed change in strategy, gate and regulator operations, state of downstream road crossings etc). Most of the minimum information is already given, but not in a consistent manner. As a means of reviewing processes followed during a flood, it would be useful to present a timeline of the flood event showing graphs of storage levels and other data that can be easily presented in a graphical manner.

I am informed by the Queensland Director Dam Safety (Water Supply) that the various requirements of the Flood Mitigation Manual relating to requirements for flood operations personnel, flood preparedness and flood training have been adhered to. There are a number of other requirements however, that I am not able to say whether they were satisfied as I had insufficient information. These requirements (see Table in Attachment A) should be subject to a separate audit.

It appears to me that the decision to implement Strategy W4 was a prudent one. While it would cause some damage in the Brisbane River downstream, its implementation, considering forecast rainfalls and projected flows in Lockyer Ck. And the Bremer River, would allow reduction of the storage level in

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Wivenhoe Dam. This reduction in storage level would hopefully provide a sufficient buffer that would minimise the chance of a fuse plug triggering in the auxiliary spillway. Triggering of the first (central) fuse plug would cause a sudden increase of flow of some 2,000m³/s from Wivenhoe Dam. This increase in flow would cause significantly more flooding in the lower Brisbane River than that caused by early implementation of Strategy W4.

Conclusions:

The strategies as set out in the Flood Mitigation Manual have been followed, allowing for the discretion given to making variations in order to maximise flood mitigation effects. The actions taken and decisions made during the Flood Event appear to have been prudent and appropriate in the context of the available knowledge available to those responsible for flood operations and the way events unfolded.

There are a number of requirements where there was insufficient time given the urgency of this review, to source the necessary information for me to demonstrate compliance. However, satisfaction or otherwise of these requirements would have had little impact on the operation of the two dams during this particular Flood Event. It is intended that they be audited when time permits, after the Flood Event.

There are aspects of the Technical Situation Reports that could be improved and these have been discussed above.

Regards,



Brian Cooper

ATTACHMENT A

Action Requirements extracted from the Flood Mitigation Manual:

Action	Comment
The Flood Mitigation Manual contains the operational procedures for Wivenhoe Dam and Somerset Dam for the purposes of flood mitigation and must be used for the operation of the dams during flood events.	Appears to have been done
Sufficient numbers of suitably qualified personnel are available to operate the dams if a Flood Event occurs.	Director of Dam Safety is satisfied
The level of flooding as a result of emptying stored floodwaters after the peak has passed is to be less than the flood peak unless accelerated release is necessary to reduce the risk of overtopping.	See Note 1
A regular process of internal audit and management review must be maintained by Seqwater to achieve improvements in the operation of the RTFM.	See Note 1
Seqwater must maintain a log of the performance of the data collection network. The log must include all revised field calibrations and changes to the number, type and locations of gauges. Senior Flood Operations and Flood Operations Engineers are to be notified of all significant changes to the Log.	See Note 1
Seqwater must maintain a log of the performance of the RTFM. Any faults to the computer hardware or software are to be noted and promptly and appropriately attend to.	See Note 1
Seqwater must ensure that all available data and other documentation is appropriately collected and catalogued for future use.	See Note 1
Seqwater must ensure that information relevant to the calibration of its field stations is shared with appropriate agencies.	See Note 1
<p>Seqwater must liaise and consult with these agencies with a view to ensuring all information relative to the flood event is consistent and used in accordance with agreed responsibilities:</p> <ul style="list-style-type: none"> • Bureau of Meteorology (issue of flood warnings for Brisbane River basin); • Department of Environment and Resource Management (review of flood and discretionary powers); • Somerset Regional Council (flood level information for upstream of Somerset Dam and upstream and downstream of Wivenhoe Dam); • Ipswich City Council (flood level information for Ipswich), and; • Brisbane City Council (flood level information for Brisbane City). 	Required also by draft of Communications Protocol. Technical Situation Reports infer compliance
Seqwater must report to the Chief Executive by 30 September each year on the training and state of preparedness of operations personnel.	See Note 1
Seqwater must provide a report to the Chief Executive by 30 September each year on the state of the Flood Monitoring and Forecasting System and Communication Networks.	See Note 1

Action	Comment
After each significant flood event, Seqwater must report to the Chief Executive on the effectiveness of the operational procedures contained in this manual.	It is too early for this action to be implemented. Will be implemented when the Flood Event is finished
Prior to the expiry of the approval period, Seqwater must review the Manual pursuant to provisions of the Act.	It is too early for this action to be implemented
Strategies are changed in response to changing rainfall forecasts and stream flow conditions to maximise the flood mitigation benefits of the dams.	Technical Situation Reports indicate that this is done
When determining dam outflows within all strategies, peak outflow should generally not exceed peak inflow.	Information from Seqwater indicates that the requirement was satisfied
Protocol for use of discretionary powers (i.e. who gets told)	Director of Dam Safety is satisfied – I don't know whether Seqwater CEO or Chairperson approved – See Note 1

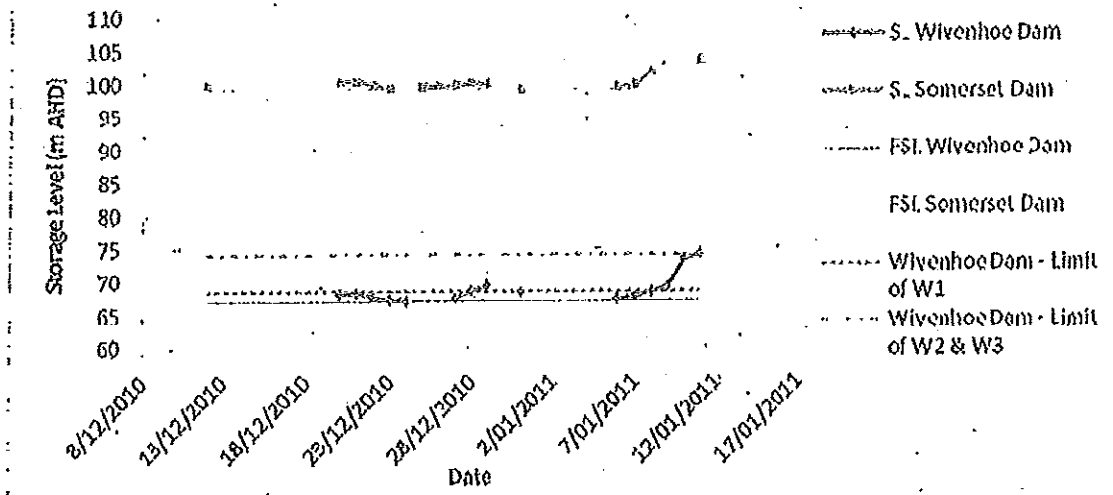
Note 1: For a number of the above actions, given the short time frame for the review on compliance of actual flood operations with the Flood Mitigation Manual, it was not possible to source some of the information required to confirm that requirements had been fulfilled. These actions will be audited separately, when time permits.

Action	Comment
Flood Strategies for Wivenhoe Dam:	
<p>The Intent of Strategy W1 is to not to submerge the bridges downstream of the dam prematurely (see Appendix I). The limiting condition for Strategy W1 is the submergence of Mt Crosby Weir Bridge that occurs at approximately 1,900 m³/s.</p> <p>For situations where flood rains are occurring on the catchment upstream of Wivenhoe Dam and only minor rainfall is occurring downstream of the dam, releases are to be regulated to limit, as much as appropriate in the circumstances, downstream flooding.</p>	<p>Technical Situation Reports indicate that every attempt was made to keep the specified road crossings open</p>
<p>The Intent of Strategy W2 is limit the flow in the Brisbane River to less than the naturally occurring peaks at Lowood and Moggill, while remaining within the upper limit of non-damaging floods at Lowood (3,500 m³/s). In these instances, the combined peak river flows should not exceed those shown in the following table:</p>	<p>Technical Situation Reports indicate that Wivenhoe Dam releases were made considering concurrent flows in the Bremer River & Lockyer Ck. To delay damaging floods as long as possible</p>
<p>The Intent of Strategy W3 is to limit the flow in the Brisbane River at Moggill to less than 4000 m³/s, noting that 4000 m³/s at Moggill is the upper limit of non-damaging floods downstream. The combined peak river flow targets for Strategy W3 are shown in the following table. In relation to these targets, it should be noted that depending on natural flows from the Lookyer and Bremer catchments, it may not be possible to limit the flow at Moggill to below 4000 m³/s. In these instances, the flow at Moggill is to be kept as low as possible.</p>	
<p>The Intent of Strategy W4 is to ensure the safety of the dam while limiting downstream impacts as much as possible.</p> <p>This strategy normally comes into effect when the water level in Wivenhoe Dam reaches EL74.0 m AHD. However the Senior Flood Operations Engineer may seek to invoke the discretionary powers of Section 2.8 if earlier commencement is able to prevent triggering of a fuse plug.</p> <p>There are no restrictions on gate opening increments or gate operating frequency once the storage level exceeds EL74.0 AHD, as the safety of the dam is of primary concern at these storage levels.</p>	<p>Technical Situation Reports indicate that Wivenhoe Dam releases were such as to delay adopting this strategy as long as possible</p>
<p>Where possible, total releases during closure should not produce greater flood levels downstream than occurred during the flood event.</p>	<p>Technical Situation Reports indicate that this requirement was satisfied</p>
<p>The aim should always be to empty stored floodwaters stored above EL 67.0m within seven days after the flood peak has passed through the dams.</p>	<p>Technical Situation Reports indicate that</p>

Action	Comment
	emphasis was given to satisfying this requirement
Flow in the spillway to be as symmetrical as possible with the centre gates opened first.	Technical Situation Reports indicate that this was done
The bottom edge of the radial gates must always be at least 500mm below the release flow surface.	See Note 1 above

Action	Comment
<i>Flood Strategies for Somerset Dam:</i>	
The Intent of Strategy S1 (Somerset Dam Level expected to exceed EL 99.0 and Wivenhoe Dam not expected to reach EL 67.0 (FSL) during the course of the Flood Event) is to return the dam to full supply level while minimising the impact on rural life upstream of the dam. Consideration is also given to minimising the downstream environmental impacts from the release.	Technical Situation Reports indicate that this was done
The Intent of Strategy S2 (Somerset Dam Level expected to exceed EL 99.0 and Wivenhoe Dam level expected to exceed EL 67.0 (FSL) but not exceed EL 75.5 (fuse plug inflation) during the course of the Flood Event). This to maximise the benefits of the flood storage capabilities of the dam while protecting the structural safety of both dams. The Flood Mitigation Manual contains a graph that shows the intended interaction of the Wivenhoe Dam and Somerset Dam storage levels.	Technical Situation Reports indicate that this was done - little information on the operation of the radial gates at Somerset Dam. How the graph was followed not really demonstrated
The Intent of Strategy S3 (Somerset Dam Level expected to exceed EL 99.0 and Wivenhoe Dam level expected to exceed EL 75.5 (fuse plug inflation) during the course of the Flood Event) is to maximise the benefits of the flood storage capabilities of the dam while protecting the structural safety of both dams.	Not relevant at this stage
The safety of Somerset Dam is the primary consideration and cannot be compromised and its peak level cannot exceed EL 109.7.	Maximum level only EL103.3

Wivenhoe & Somerset Dams – Storage Level Behaviour (as presented in Technical Situation Reports)



Date	Time	TSR	Wivenhoe Dam Release (m ³ /s)			Gate No.	Opening (m)	Storage level	Rainfall (mm)
			Regulators	Hydro	Gates				
12/12/2010	1400	W1							
13/12/2010	1300	W2		10	290		300		
15/12/2010	1300	W3							
16/12/2010	1600	W4			0				
17/12/2010	1200	W5						Large storms yesterday pm and night; 20-50 forecast tonight 20-50 forecast o/n	
17/12/2010	1300	W6	Closed	Opening Op. Initiated					
	1830			13	50	63	3	0.5	
18/12/2010	0700	W7						40-50 since 16/12/2010 20-30 upper Brisbane R.	
19/12/2010	0700	W8			350	350	3		2.5
19/12/2010	1800	W9			300	300	3	3	
20/12/2010	0700	W10							
20/12/2010	0900	W11						68 expected this afternoon	
20/12/2010	0900	W12							
21/12/2010	0730	W13				peak 1,220 (0500)		peak 68.24 (0400); currently 68.22 (112% cap.) falling slowly currently @ 67.61 (107% cap.) falling slowly	
22/12/2010	0530	W14						none since 300 on 20/12/2010	
22/12/2010	1600	W15		Closing sequence					
23/12/2010	0800	W16						When gates closed, will be 67.2 (0.2m > FSL) & 50mm < gate opening trigger level	
23/12/2010	1430	W17			350		3	3.5	
24/12/2010	0630	W18						67.07 expected when all gates closed	
24/12/2010	1530	W19	4,200Ml/day from reg. & Hydro	Radial gate ops ceased @ 1300			3	zero	10-30 in CA over last 24 hrs.; further heavy rain expected to start on 29/12/2010
25/12/2010	0930	W20						little or no rainfall	
								10-20 over last 24 hrs	

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26/12/2010	0800 W21				Rel. minor over last 24 hrs.
27/12/2010	0800 W22				40-50 over dam CA last 24 hrs.
28/12/2010	0700 W23		347 (initially) then back to 46		20-40 over dam CA's past 24 hrs
29/12/2010	0700 W24			69.26 (@ 0600) - sim is to return to FSL by 2/1/2011 69.33 peak yesterday @ 1200 (2.3m > FSL) 69.07 this am	No/very little in last 24 hrs.
30/12/2010	0700 W25		Wivenhoe-Lockyer @ 1,600m ³ /s		No/very little in last 24 hrs.
31/12/2010	0700 W26 W27		Wivenhoe-Lockyer @ 1,600m ³ /s		68.4 @ 0500 No/very little in last 24 hrs.
6/01/2011	1200 W28		Commence opening RG @ 1200 & ramp up to 300m ³ /s by 2200		20-30 widespread with up to 50 on dams CA's
7/01/2011	0700 W29				30-50 with isolated falls up to 75; signif. Rain on Lock. Cl.
7/01/2011	1500 W30		Release started 1500 to be incl. slowly to ~1,200m ³ /s by 1400 tomorrow		
8/01/2011	0700 W31		~890	All (5) RG's open	Widespread rain 20-40 over dam CA's since 0900 yesterday; further high rainfall predicted for next 4 days
9/01/2011	0700 W32 W33			1,343	Currently 68.58 (falling slowly) For last 12 hrs. av. of 40 for Somerset CA & <10 for Wivenhoe CA
9/01/2011	2100 W34			1,400	Very heavy rainfall - totals for 24 hrs 100-300; Severe weather warning for heavy rainfall Currently @ 69.1;

W25
W36
W37

11/01/2011

0630 W38

2,750 since 1990 on
10/1/2011

All (5) gates

73.51 rising @
25mm/hr.

20-60 last 12 hrs in Lockyer CA; 30 in
Bremer R.; Isol. Falls of 125 in upper
Brisbane R. & widespread falls of 40-70
in Somerset CA

11/01/2011

1200 W39

3,970

74.1 (179.5% cap.)
rising @ 25mm/hr.

Comments

Crossing Closures

45,000ML from Somerset; WL Somerset to peak at 99.7 on 13/12/2010; 150m³/s expected through Brisbane; 30,000ML expected into Wivenhoe from upper Brisbane R.; peak WL in Wivenhoe expected to be 67.6; Releases expected from Wivenhoe on afternoon of 12/12/2010 ramping up to 300m³/s; Reg. will be closed & Gate 3 opened to 3m to get WL back to 67.25; Incr. release will impact on 3 crossings; Dam Regulator informed

133m³/s from Somerset;

Releases from Wivenhoe will cease on 16/12/2010; Hydro will continue during fish recovery ops.

Gate closed 1000

Decision to commence a release tonight was made this am by Dry Flood Engineers to provide as much notice to impacted Councils as possible; 60,000ML needs to be released from Wivenhoe & Somerset to maintain FSL

Need to release >60,000ML from Wivenhoe & Somerset to achieve FSL

Releases could increase to 300m³/s;

100,000ML to be drained in next 4 days; Q| Brisbane R. to be maintained at 300-350m³/s; Transfer from Somerset via 2 reg.; Wivenhoe Q| incr. to 150m³/s o/n; WL incr. further to 300m³/s as Q| Lock Ck. Subside over next 24 hrs.; Q| Lock Ck. Currently 130m³/s 12,000ML/day from Somerset; Release expected until 22/12/2010;

Somerset rel. steady (Q| reg. ~140m³/s); Q| Wivenhoe to be maintained at 200m³/s (Lock Ck. Permitting) to allow Burtons Bridge to remain open; WL Wivenhoe expected to incr. to 67.4 over next 2 days;

Somerset risen to 100.2 - sluice gate releases to be made until am of 22/12/2010 when FSL expected; WL Wivenhoe at 68 expected this pm; Q| Wivenhoe expected to be >1,200m³/s - discuss with impacted Cncls. - strategy decision by 1000; Wivenhoe inflows excl. Q| Somerset peak tomorrow at 1800m³/s

Inflow to Somerset to peak today at 700m³/s; Somerset & Wivenhoe currently storing 140,000ML above FSL; further inflows occurring; releases to be incr. o/n to ~1,200m³/s; various Cncls. Given heads up; BOM advised

Same as WLL

410m³/s from Somerset sluice gates; Somerset peaked @100.43 (1300 on 20/12/2010), currently @ 100.23 (21.4% of cap.); 110,700ML

inflow to Somerset; 67,500ML discharged into Wivenhoe; Wivenhoe inflow (excl. Somerset releases) = 157,900ML; 103,000ML released;

Total inflow to both dams ~310,000ML; Continued gate operations may be necessary if forecast rainfall results in subsequent river rise

410m³/s from Somerset sluice gates; Somerset currently @ 99.65 (103% cap.); 121,500ML inflow to Somerset; 103,000ML released to Wivenhoe; Gate Ops. @ Wivenhoe; High tides expected to coincide with peak levels in Brisbane R.

BOM aware of all releases

1 sluice open @ Somerset to be closed @ 0900 - WL will be 0.1m > FSL; Est. inflow to Somerset 135,000ML, majority discharged into Wivenhoe; Gate closure ops @ Wivenhoe in progress; Wivenhoe inflow (excl. Somerset inflow) = 204,000ML; A total of 324,000ML has been released; Contd. gate ops may be necessary if forecast rain results in river rises; Gate closure ops sequence to be reviewed

Somerset gate ops ceased @ 0500, WL @ 99.1; Gate closure sequence extended to pm of 24/12/2010; Contd. Gate ops may be necessary if forecast rainfall gives incr. river levels

Gate ops @ Somerset ceased yesterday, reg. to be opened to bring lake to FSL; Gate ops continuing @ Wivenhoe - 1 gate incr. every 5-6 hrs to ensure Brisbane R. Q. not incr. due to incr. Lock. Ck. Outflows & maintain Burtons Bridge open;

Flood Centre to monitor o/n & consider options tomorrow am based on inflows & rainfall; further gate ops may be necessary in coming days

Somerset WL incr. from 99.15 yesterday @ 0600 to 99.33 @ 0730 today; 99.5 tomorrow if no gate ops; Wivenhoe currently ~2,200ML through hydro & reg.; 15,000ML expected just from upper Brisbane R. in next few days; WL cont. to fall in Lock. Ck; Small rises expected in Bremer & Warrill systems; WL in Wivenhoe incr. to 67.28 @ 600

Gate release will impact on 3 crossings

Would impact Twin Bridges, Savages Crossing, Colleges Crossing

Twin Bridges & Savages Crossing currently closed; Colleges Crossing to be impacted in afternoon

Twin Bridges, Savages Crossing, Colleges Crossing currently closed

Twin Bridges, Savages Crossing and Colleges Crossing are closed; closing of Burtons Bridge and Kholo Bridge will be considered if more rain or inflows

Both Burtons and Kholo bridges likely to be inundated

Wivenhoe releases reduced slightly to keep Burtons Bridge open - then incr. releases after Somerset Regal Cnd inform residents affected by Burtons Bridge

Kholo Bridge is also expected to be inundated by mid-morning; in accordance with the adopted operational strategy these bridges should be back in service by late Thursday and all bridges (with the possible exception of Twin Bridges) should be trafficable for Christmas providing no further rainfall occurs.

Burtons Bridge & Kholo Bridge expected to be back in service by 23-24/12/2010; All bridges expected to be trafficable by Xmas provided no further rain

Gate closing sequence to allow bridges to be accessible

Projected crossing openings: Burtons Bridge - 18:00 Thursday 23 December 2010.

Savages Crossing - 19:00 Thursday 23 December 2010

Kholo Bridge - 21:00 Thursday 23 December 2010

Colleges Crossing - 08:00 Friday 23 December 2010

Projected crossing openings: Burtons Bridge - 18:00 Thursday 23 December 2010, Kholo Bridge - 21:00 Thursday 23 December 2010; Other bridges expected to remain closed until Xmas Day

Twin Bridges, Savages Crossing and Colleges Crossing are currently closed and should remain so for some time due in part to current outflows into the Brisbane River from Lockyer Creek that will peak in excess of 200 cumecs late today.

Twin Bridges, Savages Crossing and Colleges Crossing may still be affected by flows from the Lockyer.

Twin Bridges, Savages and Colleges Crossing remain impacted by Wivenhoe releases and Lockyer and local runoff. Burtons and Kholo Bridges would be currently unaffected. Kholo will no doubt still be closed by Council regarding repairs.

BOM issued severe weather warning @ 0445; Somerset WL incr. to 99.46 (0.46m > FSL) - 2 regs. To be opened today (140m³/s); Wivenhoe WL incr. to 67.37 (0.37m > FSL); RG to be opened later today following discussions with local authorities; further gate ops may be necessary if rainfall incr. river levels

BOM continues with severe weather warning & widespread rainfall over dam CA's; 2 regs. @ Somerset giving 139m³/s release, lake contd. To rise to 99.6 (0.6m > FSL); RG ops @ Wivenhoe commenced yesterday @ 0900, WL contd. To rise to 67.57 (0.57m > FSL); Q| Wivenhoe reduced a/n because of incr. Q| Lockyer to ensure Burtons Bridge remains open; RG @ Wivenhoe wound back as Q| Lockyer incr. > 250m³/s; Q| Lockyer expected to peak > 500m³/s later today/tomorrow - will inundate Burtons Bridge; When this happens, Q| Wivenhoe will be incr. to get WL back to FSL; further gate ops may be necessary in coming days

Severe weather warning no longer current; Somerset release through regs' ~ 208m³/s; WL Somerset incr. to 99.96 (0.96m > FSL) - inflows decreasing; RG opening dependent on Q| Lockyer; Wivenhoe WL currently @ 68.55 (1.55m > FSL); Inflows to Wivenhoe decr.

Further 2 sluices opened @ Somerset; WL @ Somerset 99.33 & falling slowly; 2 sluices to be closed @ 1200; Intended to incr. Wivenhoe releases so Q| Wivenhoe + Q| Lockyer maintained @ 1,600m³/s (similar Q to mid Oct & mid Dec 2010)

2 sluices @ Somerset remain open (405m³/s) - FSL expected by 6/1/2011; RG closing sequence expected to start mid tomorrow - RG expected to be closed on 2/1/2011

WL @ Somerset 99.01 (falling from peak of 100.0 - 1200 22/12/2010) - currently 2 regs;

Somerset @ 99.24 (0.24m > FSL) & rising slowly; Wivenhoe 67.31 (0.31m > FSL) & rising slowly; Gates will be opened in next 24 hrs; Lockyer Cr peak of about 100m³/s Friday afternoon

100-200mm rain forecast for SE Qld next 5 days; Somerset WL @ 99.52 (0.52m > FSL) rising slowly - currently releasing 35m³/s; Wivenhoe WL @ 67.64 (0.64m > FSL & > gate trigger level) rising slowly; u/s of dam river levels peaked @ Urville and Gregors Cr gauges; A peak of about 470 cumecs is expected from Lockyer Creek by mid-afternoon; Wivenhoe gate releases will occur after the impact of Lockyer flows on Burtons Bridge has been ascertained and flood levels in the lower Lockyer subside Q| Wivenhoe may be as high as 1,200m³/s

Somerset releasing 35m³/s; 50,000ML into Somerset; Gate release @ Wivenhoe - strategy to be reviewed tomorrow (dependent on further rainfall)

Somerset WL @ 100.42 & rising (0500) - 1 open sluice gate; Water temp. held in Wivenhoe - strategy may need to be reviewed (depend. On confidence in estimates of Wivenhoe inflows); Intended to ramp Wivenhoe up to 1,200m³/s by 1200 - likely to be incr. next week since 2/1/2011, ~200,000ML has flowed into Wivenhoe (incl. Somerset releases), further 180,000ML expected based on recorded rainfall; ~50,000ML released via reg. & hydro @ 50m³/s

Somerset currently @ 100.27 - 60mm rain in last 2 hrs will cause significant inflow later today; 405m³/s being released into Wivenhoe; maintain combined Q of 1,600m³/s in mid-Brisbane R.

Not included

Somerset @ 101.62 rising quickly; 5 sluice gates open releasing ~1,100m³/s; WL expected to reach 103.5 by am 11/1/2011; River levels u/s Wivenhoe rising fast; Q| Brisbane R. @ Gregors Cr @ 6,700m³/s; Wivenhoe expected to reach 73.0 by 11/1/2011 - need to incr. Q| Wivenhoe am of 20/1/2011 - crank up to 2,500m³/s by am 11/1/2011; Attempt to keep combined Q < 3,500m³/s - < limit of urban damages in the City

Crossings downstream of the dam are currently impacted primarily by non-controlled river flows only (no RG releases from Wivenhoe). Lockyer Creek outflows into the Brisbane River are currently in the order of 60m³/s. Twin Bridges, Savages and Colleges Crossings will be inundated but the plan is to release around 300-350m³/s depending on flows downstream so as to not impact Burtons Bridge.

Twin Bridges, Savages Crossing and Colleges Crossing currently closed; Burtons Bridge is currently open, but will be closed later today/tomorrow; Kholo Bridge remains unserviceable due to flood damage; No current expectation that either Mt Crosby Weir Bridge or Fernvale Bridge will be impacted by the current event; An updated estimate of the time of closure of Burtons Bridge this afternoon will be provided to Council; RG discharge dropped back to 46m³/s to ensure Burtons Bridge can remain open; Twin Bridges, Savages Crossing, Colleges Crossing, Burtons Bridge and Kholo Bridge are currently closed; No current expectation that either Mt Crosby Weir Bridge or Fernvale Bridge will be impacted by the current event; Lockyer Creek outflows being closely monitored and may come close to impacting upon the Mt Crosby Weir Bridge; England Creek access is not impacted yet

Twin Bridges, Savages Crossing, Colleges Crossing, Burtons Bridge and Kholo Bridge are currently closed; no current expectation that Mt Crosby Weir Bridge or Fernvale Bridge will be impacted by current event. At this stage, estimated that the flow at Burtons Bridge will fall below the bridge deck on Sunday morning.

Twin Bridges, Savages Crossing, Colleges Crossing, Burtons Bridge and Kholo Bridge are currently closed
Twin Bridges, Savages Crossing, Colleges Crossing, Burtons Bridge and Kholo Bridge are currently closed due to inundation

Not included

Lockyer Cr peak of about 100m³/s Friday afternoon. This will take out twin bridges and nearly inundate Savages Crossing. Colleges Crossing could be taken out by a combined Lockyer and local runoff. Current strategy is to keep Burton Bridge free. Gate release would limit mid-Brisbane Q to 400m³/s ((Burtons capacity 450m³/s).

Q| Lockyer may be of sufficient magnitude to inundate Burtons Bridge; Somerset Regional Council, Ipswich City Council and Brisbane City Council have been advised of the potential for gate operations during the next 24 hours. The relatively high Lockyer flows will adversely impact upon Twin Bridges, Savages Crossing, and Colleges Crossing for several days, may also later impact upon Burtons Bridge & Kholo Bridge; not expected to be any adverse impacts upon Fernvale Bridge or Mt Crosby Weir Bridge; Councils have been advised of this strategy and are contacting residents

All of the crossings downstream of Wivenhoe with the exception of Fernvale and Mt Crosby Weir Bridge will be adversely impacted; Councils have been advised of this strategy and are contacting residents

The projected Wivenhoe release of 1,200m³/s combined with Lockyer flows and local runoff will mean that all crossings downstream of Wivenhoe (Twin Bridges, Savages Crossing, Burtons Bridge, Kholo Bridge and Colleges Crossing) will be adversely impacted for several days. At this stage Fernvale and Mt Crosby Weir Bridge are not expected to be affected but they could potentially be affected if the predicted rainfall totals eventuate.

The current Wivenhoe Dam release combined with Lockyer flows and local runoff will mean that all low level crossings downstream of Wivenhoe (Twin Bridges, Savages Crossing, Burtons Bridge, Kholo Bridge and Colleges Crossing) will be adversely impacted until at least Wednesday 12 January. At this stage Fernvale and Mt Crosby Weir Bridge are not expected to be affected, but this may be revised if the predicted rainfall totals eventuate and higher releases from Wivenhoe Dam are considered necessary. Councils advised of Wivenhoe op. strategy

The projected Wivenhoe Dam releases combined with Lockyer flows and local runoff will mean that all crossings downstream of Wivenhoe (Twin Bridges, Fernvale, Savages Crossing, Burtons Bridge, Kholo Bridge, Mt Crosby Weir and Colleges Crossing) will be adversely impacted until at least Saturday 15 January in varying degrees. Water levels in the lower Brisbane R will be impacted by the combined flows of Lockyer Cr, Bremer River, local runoff and releases from Wivenhoe Dam

Not included
Not included
Not included

Somerset WL @ 103.27 & falling slowly; currently 1,400m³/s released to Wivenhoe - to be reduced to 500m³/s later in the day - to ensure flood mitigation of Somerset & Wivenhoe are maximized; BOM provided advice on flash flooding in Lockyer Cr; WL in Wivenhoe will reach 74 by evening; May need to increase Q further - may result in Q lower Brisbane R. > 5,000m³/s

Somerset @ 103.3 & rising; Outflows into the Brisbane River from both Lockyer Creek and the Bremer River are also increasing; if no further rain, can hold @ 74.2 - aim is to prevent rope plug triggering; situation assessed every 3 hrs.; Heavy rainfall continues throughout South East Queensland and the situation could deteriorate over the next 24 hours. The flood operation centre will continue to monitor the situation and provide situation reports every six hours until the situation stabilizes.

The projected Wivenhoe Dam releases combined with Lockyer Creek flows and local runoff will mean that all crossings downstream of Wivenhoe (Twin Bridges, Fernvale, Savages Crossing, Burtons Bridge, Kholo Bridge, Mt Crosby Weir and Colleges Crossing) will be adversely impacted; Water levels in the lower Brisbane River will be impacted by the combined flows of Lockyer Creek, Bremer River, local runoff and releases from Wivenhoe Dam.

Brian Cooper

Dams Engineer

Qualifications & Affiliations

Short courses on finite element analysis, embankment dam engineering, earthquake engineering. Published technical papers – ICOLD, ANCOLD and I.E. Aust. Attended dam safety course at USBR (Denver, USA) in 2002

Bachelor of Engineering (B.E. Hons), 1968 and Master of Engineering Science (M.Eng.Sc.), 1971

University of New South Wales

Graduate Diploma of Engineering Management, 1994 Deakin University

F.I.E. Aust., C.P.Eng. RPEQ

Expertise

Brian has approximately 40 years experience in investigation and design of major dams, weirs and hydraulic structures, having started his career designing farm dams and small irrigation schemes. He retired from NSW Department of Commerce in 2005. Brian now works as a private consultant specialising in dams engineering and fish passage at dams and weirs. He has a special interest in risk assessment and computer modelling in general and the seismic analysis of dams in particular. Engineering software (concrete dam stability analysis and flood routing) written by Brian is still used extensively in the Dams & Civil Group of the Department of Commerce. He also has particular experience with concrete dams and the use of post tensioned ground anchors for strengthening those dams. He was a member of the Australian National Committee on Large Dams (ANCOLD) Working Group that developed guidelines for 'Design of Dams for Earthquakes' and a member of the Working Group that revised the guidelines for 'Risk Assessment for Dams'. He has been a guest lecturer for a number of years (most recently in 2009) on concrete dam engineering for the University of NSW post graduate Embankment Dam Engineering Course, and on the history of dams in NSW at Sydney University.

He has been the project director and project manager for a number of feasibility studies, design reviews, site investigations and detail design consultancies for major dams and weirs including the direction and coordination of all specialist services including dambreak studies, preparation of dam safety emergency plans and risk assessments. He is currently an expert reviewer for a number of Australian water authorities and consultants (State Water Corporation (NSW), Hydro Tasmania, SunWater (Queensland), Brisbane City Council, Goulburn-Murray Water, Goulburn Valley Water, WA Water Corporation, Southern Rural Water (Victoria), URS, GHD, Hobart Water, NT PowerWater, and TrustPower (NZ)). He has also worked as a sub-consultant for a number of consulting firms (URS, MWH, GHD).

Brian is the Engineers Australia representative for the NSW Dams Safety Committee (the dam safety regulator in NSW) and is currently the Chairman of that organisation. He has been a member of the Murray Darling Basin Authority's Fish Passage Task Force which advises inter alia on the installation of fishways on the Murray River as part of the Living Murray Program.

Brian is a registered engineer in Queensland (RPEQ No. 6819). He started his own consulting business in 2008, advising on dam safety, dam design and analysis, dam risk assessments and dam upgrades as well as fish passage for dams. He is providing specialist advice through *Brian Cooper Consulting* as a sole trader.

Professional Experience

2008 to Present: Principal of Brian Cooper Consulting

- 2010 Five yearly comprehensive dam safety inspection of Carcoar Dam (double curvature arch dam), Internal reviewer to URS (Melbourne) on concept design of regulator structures and associated fishways for the Hipwell Road project for watering the Gunbower Forest
Specialist adviser to Melbourne Water – valve behaviour on Sugarloaf Dam pipeline, structural behaviour of pumping station floor slab and pump bases at Cardinia Dam Pumping Station
Commenced work as member of ANCOLD working group re-writing the Earthquake Guidelines – responsible for re-writing sections relating to concrete dams.
Continuing involvement with Alluvium in the design of the weir upgrade and the new fishway for Boolgal Weir.
Continuing external peer review services to State Water Corporation for the detail design of new auxiliary fuse plug spillways for Copeton and Chaffey Dams, detail design of raising and post tensioned strengthening of Keepit Dam, detail design of upgrade works for Wyangala Dam, finite element analysis of Carcoar Dam (double curvature arch dam).
Further work with GHD (Perth) on risk assessment for Serpentine Dam.
Continuing involvement with Hydro Tasmania, as Chair of external review panel for Catagunya Dam.
- 2009 Part of URS' comprehensive inspection team for Melbourne Water's Maroondah Dam.
Part of URS' business risk assessment team for Southern Rural Water's Cowwarr and Maffra Weirs.
Part of Alluvium's design team upgrading Boolgal Weir and providing a fishway at the weir, for State Water Corporation.
Part of GHD's design team for Lower Fitzroy River Infrastructure Project designing fishways for Rookwood and Eden Bann Weirs near Rockhampton in Queensland.
Project Manager on behalf of SA Water and reviewer for study into vibration of a crane rail beam at Lock 5 on the River Murray.
Expert reviewer for State Water Corporation for 3D finite element analysis of Carcoar Dam (double curvature arch dam).
Internal reviewer for URS on Laanecoorie Dam Upgrade.
Expert reviewer for State Water Corporation for risk assessments for Oberon and Rydal Dams.
Member of GHD's Serpentine Dam risk assessment team for WA WaterCorp.
Expert reviewer for SunWater in Queensland for the comprehensive risk assessment undertaken for Fairbairn Dam and Coolmunda Dam.
Expert reviewer for State Water Corporation for major upgrade works at Keepit, Copeton, Chaffey and Wyangala Dams.
Appointed as Chairman of the NSW Dams Safety Committee (the dam safety regulator in NSW).
Provided external peer review for Goulburn Valley Water, on Nine Mile Creek Dam Upgrade.
Internal reviewer for URS (Adelaide) for Lake Victoria Outlet Regulator options studies.
Provided advice to URS (Melbourne) on the Mildura Weir Fishway design.
Member of expert panel advising State Water Corporation on revised dam surveillance regime.
Part of Ecosmart bid team - prepared concept designs for fish passage facility at proposed Wyalalong Dam in Queensland.
Continuing expert review role for Catagunya Dam upgrade.
- 2008 Started as a private specialist dams consultant - *Brian Cooper Consulting*.
Worked through the URS Corporation for the USBR and the USACE in developing a risk toolbox for lined spillways.
Advised TrustPower in New Zealand on replacement of post tensioned anchors at Mahinerangi No. 1 Dam.
Adviser to State Water Corporation and to URS on further upgrade works for Hume Dam.
Provided specialist advice to WA Water Corporation on Wellington Dam post tensioning.
Peer reviewer on behalf of URS for Warren Dam in South Australia.
Part of URS team carrying out portfolio risk assessment of Melbourne Water's dams.
Member of Expert Review Panel for Darwin River and Manton Dams for NT PowerWater.

1987 to 2008: Dams & Civil Section of NSW Department of Public Works and Services/NSW Department of Commerce.

- 2008 Carried out detailed 3D finite element analysis of radial gate at Wyangala Dam spillway for State Water Corporation.
Continuing review role for Tillegra Dam.
Continuing review role for Hinze and Lake Manchester Dams in Queensland and Catagunya Dam in Tasmania.
Prepared options report on Burrendong Dam spillway modifications for State Water Corporation.
- 2007 Continuing roles on Lake Manchester, Hinze, Catagunya and Redbank Ck. Dams.
Internal peer reviewer for NSW Dept. of Commerce regarding design of Tillegra Dam.
Advised State Water on feasibility of fish passage facilities at a number of their major irrigation dams.
Expert reviewer for GHD on a flood retarding basin in south west Sydney.
Part of expert panel for River Murray Water risk assessments for Hume and Dartmouth Dams, Torrumberry and Yarrowonga Weirs and Lake Victoria.
Re-elected as Deputy Chairman of the Dams Safety Committee
- 2006 Project director for 3D finite element analysis of Bendora Dam (double curvature arch dam)
Chair of external peer review panel for upgrading of Lake Manchester Dam (concrete gravity dam) in Queensland
Internal peer reviewer and senior consultant for the raising of Hinze Dam (earth and rockfill embankment) in Queensland
Project director for preliminary and detailed design of Redbank Creek Dam (single curvature arch dam) upgrading
Project director for Keepit Dam fish passage investigations
Part of expert panel for URS undertaking portfolio risk assessment for dams owned by River Murray Water
External peer reviewer for Hydro Tasmania for Catagunya Dam (concrete gravity dam) upgrading;
Project director for 3D finite element analysis of Upper Cordeaux No. 2 Dam (single curvature arch dam owned by SCA) for BHP Billiton
- 2005 Project design engineer for dam related aspects of Nepean Dam Deepwater Access Project:
Pipeline crossing end of spillway; outlet works for end of pipeline
Project design engineer for Avon Dam Deepwater Access Project: tunnel design through rockfill buttressing; new low level outlet works
- 2004 Internal reviewer to URS Australia for Pykes Ck Dam Investigations (Southern Rural Water, Victoria)
Internal reviewer to URS Australia for Lower Reservoir Dam (Hobart Water, Tasmania)
Member of expert review panel for the Melton Dam upgrade design (Southern Rural Water, Victoria)
- 2003/04 Designer for retrofitting multi-level offtake for Tallowa Dam (Sydney Catchment Authority).
Member of the Independent Technical Expert Panel for the Eildon Dam Upgrading in Victoria for Goulburn-Murray Water.
Currently the design director for the Wivenhoe Dam Alliance carrying out the flood capacity upgrading for Wivenhoe Dam in Queensland -- included directing major computational fluid dynamics modelling investigations of existing spillway
- 2003 Carried out options study for environmental upgrading works at Keepit Dam (selective withdrawal facility, additional outlet works and fish passage)
Carried out assessment of spillway capacity for Hume Dam using computational fluid dynamics modelling (by a sub-consultant)
Carried out detail design for anchoring Bellfield Dam (Victoria) Intake Tower
Carried out detailed finite element analysis of Keepit Dam radial gates
- 2002 Carried out review of large farm dam with seepage problems. Directed computational fluid dynamics modelling of drum gate and radial gates at Warragamba Dam together with structural analysis of gates (modelling carried out by sub-consultant) to ensure gates can handle more

rigorous operating conditions

Adviser to the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on civil engineering matters related to the replacement reactor project at Lucas Heights
Expert reviewer for Goulburn-Murray Water for remedial works at Cairn Curran Dam in Victoria
Project Director for Lerderberg Weir safety review and risk assessment for Southern Rural Water (Victoria). Carried out finite element analysis of radial gate

2001

Project Director for design of further remedial works at Hume Dam.
Technical director on behalf of NPWS for quantitative risk assessment for Snowy Mountains roads
Chairman of the committee producing a geotechnical response plan for the Alpine Way in the Snowy Region for NPWS
Carried out non-linear finite element analysis (earthquake loading) for outlet tower at Bellfield Dam for Wimmera-Mallee Water (Victoria)
Joined the MDBC's Fish Passage Reference Group and reviewed fishway designs
Consultant to DLWC for their portfolio risk assessment of thirty dams
Provided advice on the post tensioning system at Waitakere Dam in New Zealand.

Director of Dam Surveillance Group responsible for the surveillance of DLWC dams and participant of a number of 5 yearly surveillance inspections
Project Director of review of DLWC Intake Towers Earthquake Stability Review
Directed DPWS input into the Earthquake Stability of the structural elements of Yarrawonga Weir as sub-consultant to URS Australia - included detail design of anchoring system for the weir. Also provided design advice on design of stone columns to provide protection against liquefaction of alluvial foundations.
Member of the expert panel for the risk assessment studies being undertaken for Goulburn-Murray Water
Project Director for safety review and preliminary design of remedial options for Blowering Dam (DLWC)
Acted as reviewer for a number of projects carried out by URS (incl. Cardinia Dam outlet tower, Bellfield Dam embankment/spillway)
Directed functionality study (including business risk assessment) for Yallourn Weir for Southern Rural Water (Victoria)

2000

Project Director for design of further investigations and remedial works at Hume Dam.
Safety reviews for Bamarang and Flat Rock Dams
Director of Dam Surveillance Group responsible for the surveillance of DLWC dams and participant of a number of 5 yearly surveillance inspections.
Project Director for earthquake studies on Intake towers and appurtenant works at DLWC dams
Consultant to DLWC to manage their portfolio risk assessment
Project Director for a number of dambreak studies and preparation of dam safety emergency plans
Member of the consulting team carrying out risk assessments for Goulburn-Murray Water (Victoria) for Eppalook Dam
Carried out review of Earthquake Stability Review of the Outlet Tower at Eppalook Dam in Victoria for G-MW.
Reviewed URS Australia designs for Alpine Way remedial works

1999

Project Director of earthquake studies on Wyangala Dam
Project Director for design of further remedial works at Hume Dam. Included design of ground improvement works (stone columns) for protecting alluvial foundations against liquefaction
Peer reviewer of Leslie Dam (Queensland) Safety Report.
Peer reviewer of DLWC's Screening Level Risk Assessment

1998

Project Director for portfolio risk assessment for six dams owned by a Southern Rural Water in Victoria.
Directed structural analysis of spillway gates on Narracan Dam for Southern Rural Water
Project Director for concept design and DD&C contract documentation for Warragamba Dam auxiliary spillway. Dam to be upgraded the dam to cater for increased inflow flood estimates. Upgrading works estimated to cost \$135M. An auxiliary spillway is to be constructed adjacent to the existing dam - involves excavating some 2,000,000m³ of rock and constructing concrete lining, training walls, fuse plug embankments, large scale cement stabilised sandstone fill, a mull

span bridge across the spillway, post tensioned ground anchors for dissipator/training walls, modifications of existing spillway gates. Design involved extensive physical hydraulic model testing.

- 1997 Feasibility options study for remediation of Redbank Ck. Dam near Mudgee (NSW) Karapiro Dam, New Zealand - Part of international consulting team reviewing this concrete arch dam's security and determining appropriate remedial options (mass concrete, buttressing). Director of risk assessment studies for Tenterfield Dam
- 1993-1997 Hume Dam Investigations - Project Manager of Investigation and Design Studies for the embankments at the dam. Work involves:
- review of the stability of the embankments under static and earthquake loadings
 - investigation of liquefaction
 - potential of embankments' foundations
 - development of stabilising options
 - development of options to provide increased flood security including provision of new auxiliary spillways and modifications to existing works
- detail design and documentation of stabilising works for the embankments including a key trench into the dam's foundations, stabilising berms, slurry wall out-offs, drainage/filter curtains and strengthening of critical gravity training walls with both horizontal and vertical post tensioning.
- part of advisory and review team for the risk assessment of the dam and its components.
- 1990-1996 Warragamba Dam Upgrading for Sydney Water Corporation - Project Manager of Investigation Concept Design Studies for upgrading the dam to cater for increased inflow flood estimates and provide substantial flood mitigation. Upgrading works estimated to cost \$280M. The existing dam was to be strengthened with mass concrete buttressing - some 600,000m³.
- 1996 Project Director for Safety Review (including Finite Element Analysis) of Wellington Dam
- 1993-1996 Hume Dam Gates for Department of Water Resources - Project Manager for the design of new maintenance baulks and emergency closure gates. Involves development of proposals for underwater installation.
- 1995 Redbank Creek Dam and Lithgow No. 2 Dam for NSW Public Works Dams Surveillance - Project Manager for safety reviews and finite element analysis of two 16m high arch dams. Clarrie Hall Dam for NSW Public Works Dams Surveillance - Project Manager for dambreak studies.
- 1994 Burrinjuck Dam Gates for NSW Department of Water Resources - Project Manager for the design of new control and emergency closure gates. Involves underwater installation. Karangul Dam for Coffs Harbour City Water Project - Project Manager for dambreak studies.
- 1993 Mardil Dam for Wyong Council - Project Manager for safety review of earth embankment.
- 1988-1990 Nepean Dam Remedial Works for Sydney Water Corporation - Project Manager for investigation studies, design development and detail design. Work involved:
- initial flood security studies and development of options
 - co-ordination of hydraulic model studies
 - detail design and contract documentation for modified spillway, large size post-tensioned ground anchors and rockfill buttressing.
- 1987-1989 Boggabilla Weir for NSW Department of Water Resources - Project Manager for detail design and contract documentation of a large gated re-regulation weir with fishway. Involved liaison with fisheries expert in developing optimum geometry for fish ladder.

Chaffey Dam for NSW Department of Water Resources - Project Manager for upgrading of dam.
Work Involved:

- development of options and preliminary design
- finite element analyses for raised morning glory spillway
- stability analyses for raised earth/rockfill embankment
- co-ordination of hydraulic model studies for raised spillway.

1989-1987: *Water Resources Commission of NSW (WRC) (now Department of Land and Water Conservation).*

1986-1987 Flood Security studies for WRC - Project Design Engineer for investigation into flood security of Chaffey and Glennies Creek Dams. Involved co-ordinating dambreak studies, development of remedial options, economic risk studies.

1985-1987

Hume Dam Strengthening for WRC - Project Design Engineer for detail design and contract documentation. - Work Included:

- design of large size post-tensioned ground anchors including development of appropriate grouting procedures
- design of structural modifications to the concrete gravity dam
- design of a new road bridge over the dam.
- establishing the rationale for replacing the existing post tensioning system

Contact

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