THE CAPABILITIES OF PROFESSIONAL JUDGMENT VERSUS MODELLING IN THE ANALYSIS OF FLOODS AND FLOODING

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Abstract: A principal finding of the Queensland Flood Commission of Inquiry was that the operations of the Wivenhoe and Somerset Dams had not been conducted in accordance with the Manual for those operations.

The analyses undertaken by authorities and commentators, responding to this finding, may be characterized by two factors. Firstly, there appears to be an absence of any modelling, publicly reported, of the probable flooding outcome if the Dam operations had been undertaken in compliance with the Manual. Secondly, professional judgments have been offered by multiple professional organisations and professionals as to the impact of the operational rationale used during the flood in place of the operational requirements made by the Manual.

This paper describes the evaluation of those professional judgments made in the absence of relevant modelling. The evaluation was sought by flood victims seeking to reconcile the differences in advice coming to them from multiple legal firms and the professional judgments being offered by professional organisations and individual professionals. A judgment on whether the flood would have been contained within the River if the manual had been followed was also sought.

The capabilities of professional judgment are critical, because of the reliance on professional judgment by the current Revision of the Wivenhoe Manual.

The evaluation found that, where some component issues were available to qualitative and approximate quantitative judgment, the overall flood outcome could not be effectively judged without relevant modelling, in the opinion of the professionals assisting the flood victims. The paper recommends that a comprehensive study, independent of the adversarial circumstances associated with proposed legal action, be undertaken, to serve the public interest.

Introduction

A principal finding of the Queensland Flood Commission of Inquiry [QFCI] (2011;p57) was that the operations of the Wivenhoe and Somerset Dams had not been conducted in accordance with the Manual for those operations.

The analyses undertaken by authorities and commentators, responding to this finding, may be characterized by two factors. Firstly, there appears to be an absence of any modelling, publicly reported, of the probable flooding outcome if the Dam operations had been undertaken in compliance with the Manual. Secondly, in lieu of such modelling, professional judgments have been offered by multiple professional organisations and professionals as to the impact of the operational rationale actually used during the flood, in place of the operational requirements made by the Manual.

Householders and businesses located on the Brisbane River Floodplain, who experienced damages during the January 2011 Flood, have expressed measures of support for the litigators undertaking a class action against the State Government, for the Government's failure to comply with the Manual. The investigations being conducted by these legal firms are to test, in the courts, the performances of the State agencies which had responsibilities for managing flood controls along the Brisbane River.

It is noted from media releases by litigators that the basis for the class action claim may also concern actions or inactions by government bodies, both prior to the subject flood event, as well as actions or inactions during the flood event (Solomons, 2013;p4). It appears that modelling will be undertaken by the litigants, rather than an argument based upon experts offering competing professional judgments.

Method

This paper describes the evaluation of those professional judgments made, in the absence of relevant modelling, about the impacts on the flooding derived from the failure to adopt the practices set out in the Manual. The evaluation was sought by flood victims seeking to reconcile the differences in advice coming to them from multiple legal firms, and the professional judgments being offered by professional organisations and individual professionals. A judgment on whether the flood would have been contained within the River, if the manual had been followed, was also sought by the victims.

This paper looks at the case for and against the proposition that the January 2011 Brisbane Flood Event might have been substantially avoided altogether. A principal issue of public interest raised by victims was whether the flood may have been contained, if reasonable preparations and best practice methodologies had been applied in every respect, rather than just in some respects, to the task of controlling flood waters down the Brisbane River.

A selection was made from issues raised by [QFCI], and issues raised with the QFCI, that are relevant to the flood management outcome for that flood. These were (QFCI, 2011):

1. The releases from Wivenhoe Dam, and the impact of ignoring forecasts of future rainfall;
2. The sufficiency of rainfall and flow data measurement systems;
3. The operation of Somerset Dam;
4. The hydraulic modelling of flows; and,
5. The extent of training undertaken in the management of this water resource during major flooding.

The preparations and practices relevant to these five issues have been evaluated for any potential for effecting a reduced flood outcome. Distinctions are made, in exploring some possibilities for a better outcome, between what judgments regarding flooding may have been available using foresight before the flood event and during the event, versus, what lessons were learned using hindsight.

Important to the understanding of the flood management challenge at Wivenhoe Dam is the geography of the Brisbane Valley catchment, and the relative locations of Wivenhoe Dam and the city of Brisbane. This is illustrated on Figure 1.

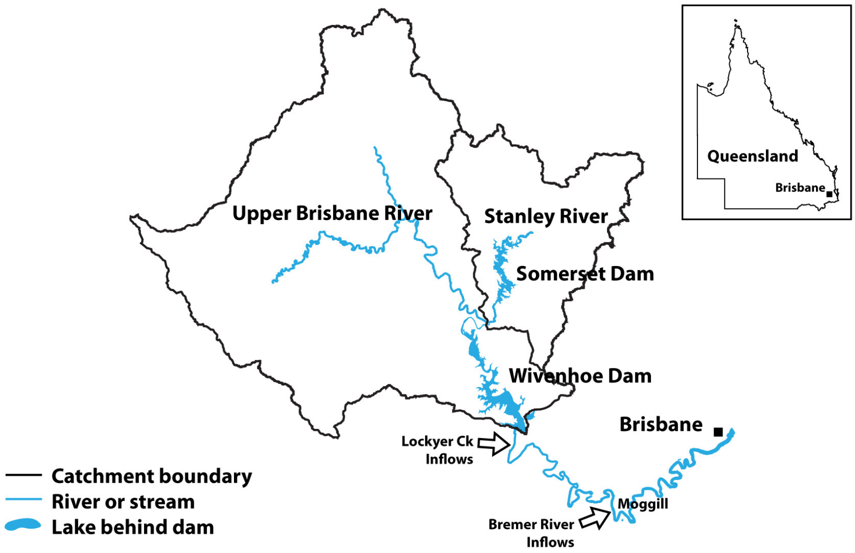

Figure 1: Brisbane and the Wivenhoe Catchment

Important are Lockyer Creek and Bremer River, which enter the Brisbane River from the West and South West a few kilometres / 80km, respectively, downstream of Wivenhoe Dam.

Discussion

Releases from Wivenhoe Dam.

Use of Rainfall Forecasts is the most commonly cited opportunity for reducing, in January 2011, the flood flows and flood heights in the Brisbane River downstream of Wivenhoe Dam.

The proposition here concerns the six hour peak release flow from Wivenhoe, of 7500 cumecs (reported by SEQWater 2011) and shown as the black line 'peak' feature in Figure 2. This peak release rate was decided by SEQWater during the flood, at point B on Figure 2, in order to protect the Dam after the water level in the Dam had reached the trigger level of RL 74.0m. Above this level, the rules for operating the Dam (termed W4 rules) required that release outflows from the Dam matched the inflows into the Dam. This 'W4' rule was established because, above this RL 74.0m level, a threat is posed to failure of the rockfill Dam by overtopping (or by failure of an activated fuse plug).

The peak wave in the actual outflows from the Dam (the black line peak on Figure 2) is attributed to the use by SEQWater, more than one day earlier at point A, of a No Further Rainfall [NFR] assumption. This NFR assumption was made when deciding to adopt the releases described by the green line on Figure 2. This NFR rationale led to a spike release from 2700 to 7500 cumecs (reported to SEQWater), or from 2700 to 11,561 cumecs claimed by the class action (Rodriguez, 2014).

If, however, the Best Available Rainfall Forecast (BARF) rationale had been used, as was required by the Manual according to QFCI, this spike release event would have been forecast (see purple broken line 'spike' on Figure 2). SEQWater operations may not have been surprised by the spike as they appeared to have been using the NFR analysis. Increasing the release rate, decided at point A, from 2700 to 3500 approx would have obviated the need for a spike release after point B, by preventing the water level from reaching RL74.00m at Point B, thereby avoiding application of the <u>outflow = inflow</u> W4 rule.

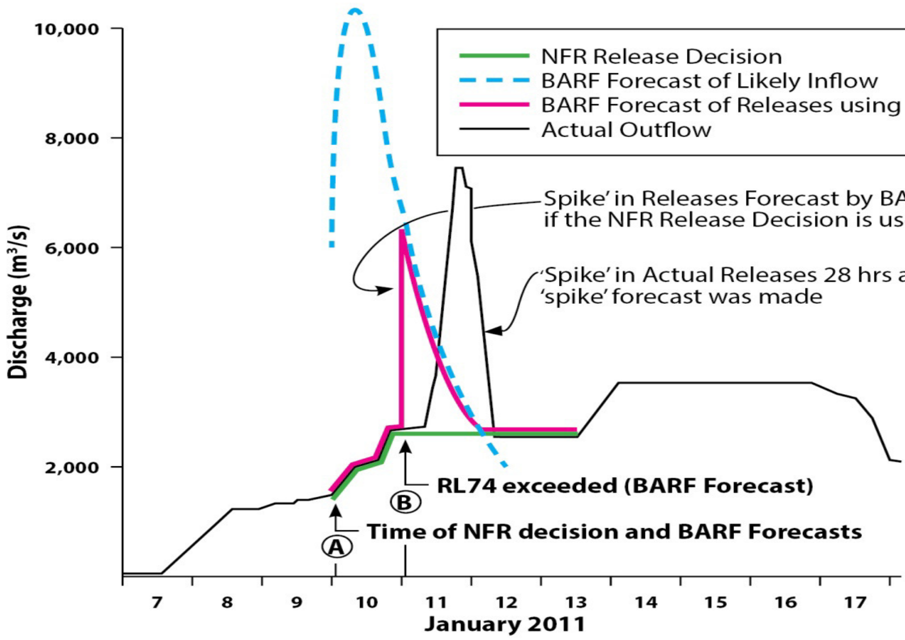

Figure 2: The NRF Decision on Releases, & What BARF Forecast would Actually be Released under the NFR Rationale

Professional judgment was available at point A (01.00 hours on 10 Jan 11) – that is, with foresight – that adoption of the BARF process, as was required by the Manual, would have reduced the Dam outflows from a max of 7500 cumecs (SEQWater, 2011), or 11561 cumecs (Rodriguez, 2014), to a max of 3500 cumecs approx.

The advantages and the disadvantages of the NFR rationale are analysed in the papers by Van den Honert & McAneney (2011) and McMahon (2012). Engineers Australia, however, have stipulated that the NFR approach must be used, because the predictions of rainfall are too inaccurate and unreliable to be used (Weeks, 2013). The NFR approach is essentially equivalent to a forecast of ZERO future rainfall.

The rationale of the BARF approach is based on risk management. Risk management methods are employed to handle such uncertainties in rainfall forecasts. The risk management approach was stipulated in the Manual for operating Wivenhoe and Somerset Dams at the time of the flood. The Manual required that forecasts be based on the 'best available rainfall forecast' [BARF]. However inaccurate or unreliable that BARF might be, it is likely to be much more 'accurate' for major flood events than making no forecast (or making a forecast of zero rainfall) for the period of the heavy rainfalls in such an event.

In the life of the Dam, NFR protects against higher likelihood, lower consequence flood events, that do not reach near to RL74m. NFR, however, aggravates the consequences for the lower likelihood, higher consequence events. In any individual event, when BARF forecasts that RL74m may be reached, BARF provides the best mitigation effect upon the higher consequence events (McMahon, 2014).

BARF proved its advantages, during January 2011. Figure 2 represents the decision point situation at 0100hrs on 10 January 2011. The NFR approach at this time did not forecast that the trigger level of RL74m would be reached, and SEQWater adopted a final release rate of 2700 cumecs (in green). The BARF, by comparison, did predict that RL74m would be reached if the NFR release rate of 2700 cumecs as used, and forecast that, when RL74m was reached, the operators would have to commit to a 'spike' release of 6200 cumecs. The BARF forecast was inaccurate with respect to the timing and the size of the 'spike' release (compare purple and black lines on Figure 2), but the BARF rationale did forecast the 'spike' event, and gave 28 hours warning of this 'spike' in likely release rates.

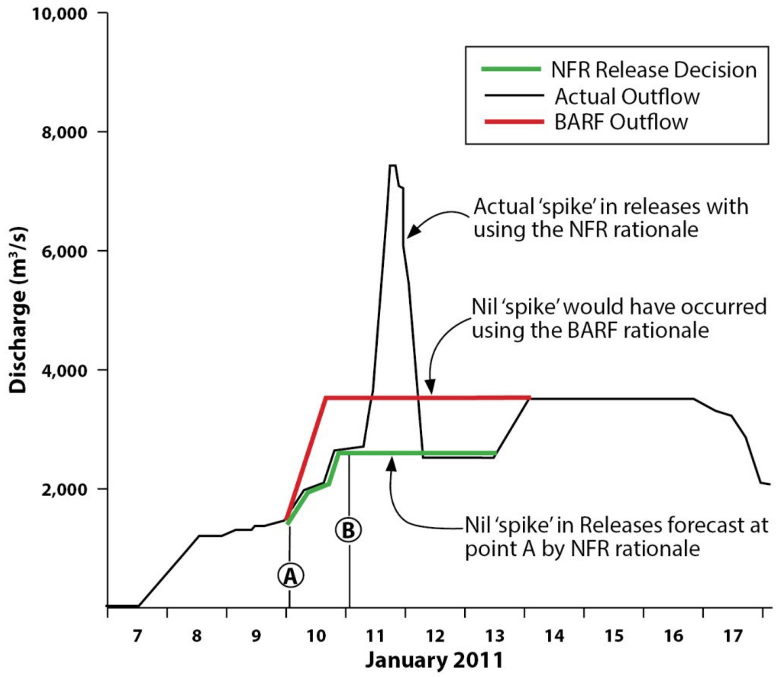

Figure 3: A Comparison of Outflows from Wivenhoe under NFR vs BARF Rationale

Figure 3 shows the alternative outcome. The 28 hour warning could have been used, with foresight, to increase releases such that RL74m would not be reached. This is represented in Figure 3. The BARF outflow in Figure 3, namely 3500 cumecs, is based on a one only volumetric calculation for the total relevant period, using hindsight. An hour by hour re-enactment of the flood event, using the BARF technique, would be necessary to demonstrate the true potential for achieving this BARF outcome. This analysis would be using the foresight provided by a time sequence of diagrams, like Figure 2, throughout the flood. Without such modelling, however, professional judgment can still determine that a peak release from the Dam would be reduced to a max of about 3500 cumecs.

Training

QFCI (2011;p57) reported that SEQWater had organised training for its staff, but that the training had not been with flood scenarios where RL74m had been reached. This may have been unfortunate, as the conduct of several exercises into this W4 flooding regime may have alerted the organisation to the advantages of the BARF procedure set out in their Manual. The early warning given by BARF, and the 'spike' releases that arise from using the NFR approach, may have presented themselves for evaluation during training exercises involving W4 scenarios, before the occasion of a real W4 flood.

Coinciding River Peaks.

Figure 4, from reporting by QFCI, indicates that the release of the 7500 cumecs (or 11561 cumecs) peak from Wivenhoe Dam coincided ***'near simultaneously'*** in timing with the peak of the flood flow joining the Brisbane River from the Bremer River (Babister, 2011a;p3).

The further possibility for reducing flood levels approaching Brisbane, would be to use the periods, prior to the time of arrival of the Bremer River peak flow into the Brisbane River, to release more water from Wivenhoe Dam. This would require less water to be released from Wivenhoe Dam during the passing of the peak of the Bremer River.

Figure 4, however, presents a hurdle to those who claim that the flood was substantially avoidable by the State Government. 'Substantially' means that urban damages would have been avoided, but not damage to rural properties, or delays on low level river crossings. This hurdle is the size of the flood peak of the Bremer River (the blue line on Figure 4).

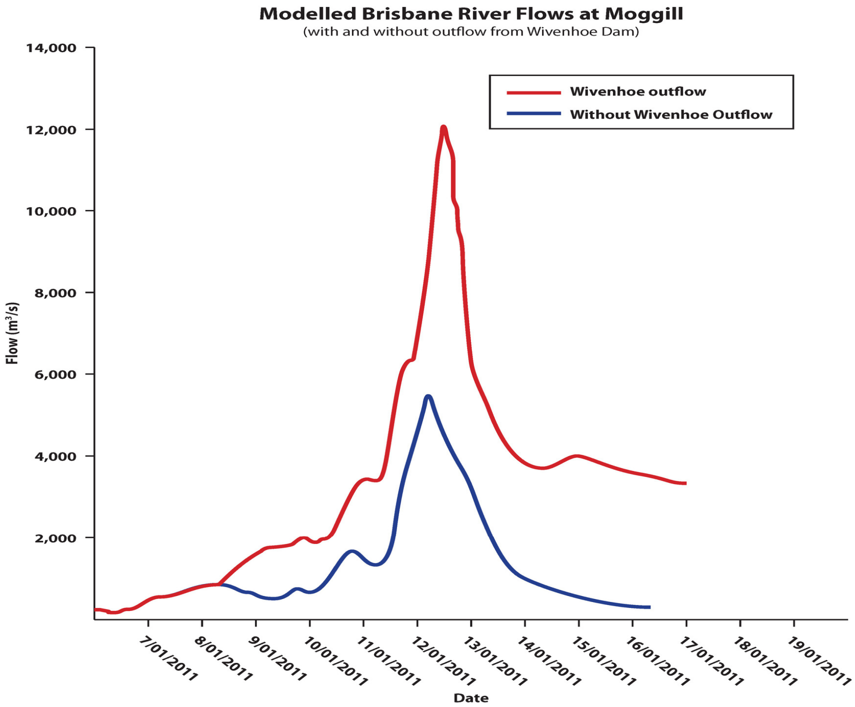

Figure 4: Actual Flooding at Moggill vs Modelled Flooding without Outflows from Wivenhoe

A flow at Moggill of 4000 cumecs was held to be ***the upper limit of non-damaging flows downstream*** (QFCI, 2012;p447). Accepting the validity of Figure 4, proponents of the ***'no flood'*** case would then need to:

1. Demonstrate, firstly, the capacity to reduce outflows from Wivenhoe Dam down to zero during the Period of Passing [PoP] of the peak flow of the Bremer River;
2. Demonstrate also an error in either or both the Moggill Flood Damage Indicator [FDI] flow of 4000 cumecs, and / or an error in the peak flow of the Bremer River.

If the Bremer peak at Moggill was 5400 cumecs, and the damage free limit was 4000 cumecs, urban damage would still have occurred even if Wivenhoe releases were able to be reduced to zero.

Essentially, the first requirement is to release more water earlier, so as to conserve a storage behind the Dam that will absorb a period of inflows into Wivenhoe while releases from Wivenhoe are reduced, during the PoP of the Bremer River peak.

Risk management has two planning rules that may assist here. The first principle is basing decision-making on the **most probable** outcome, determined here by the BARF. The supporting principle is to make provision for the **most dangerous** outcome. Both rules have the potential for assisting the operation of the Dam to release more water earlier, using foresight (McMahon, 2012).

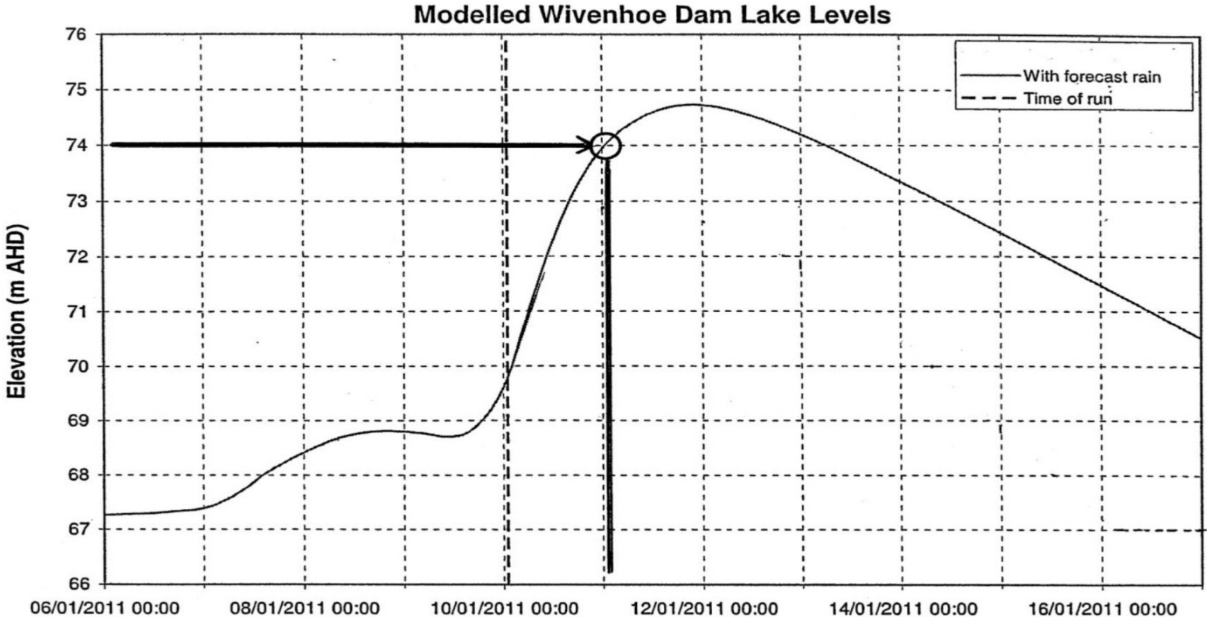

Figure 5 A

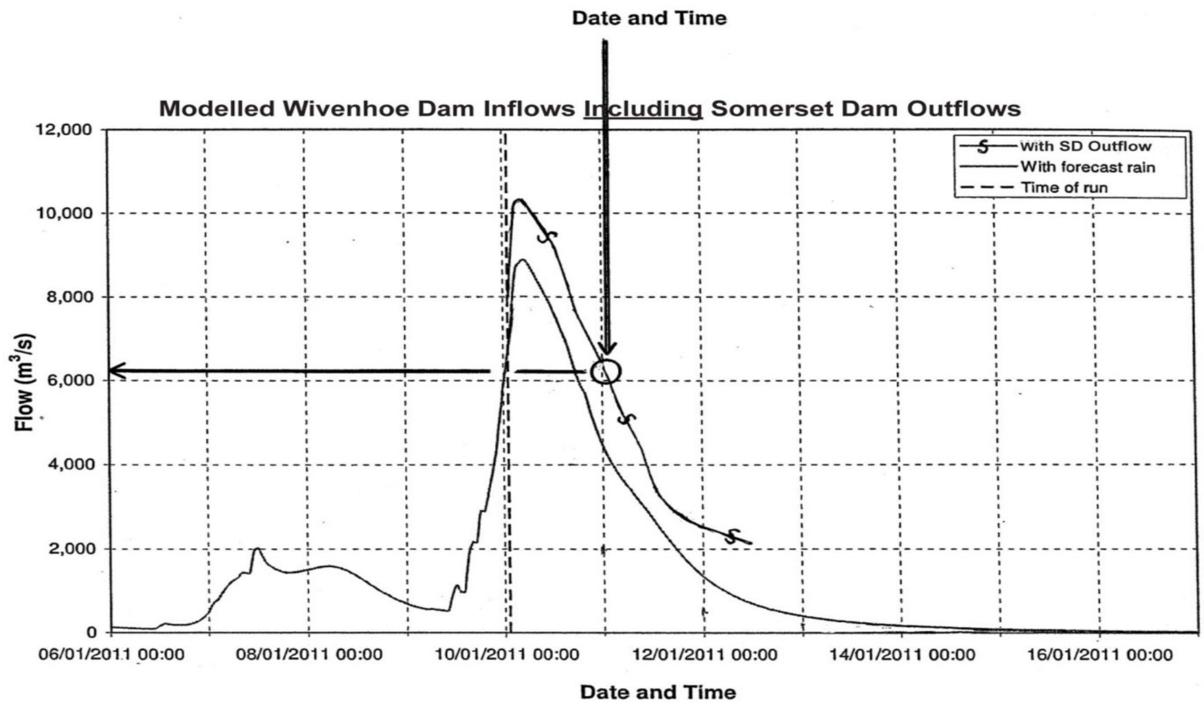

Figure 5 B

Figure 5: Forecasts of Releases Made from Modelling based on Forecast Rainfalls

Figure 5 from McMahon (2012) demonstrates the means to predicting the **most probable** outflow from Wivenhoe when the trigger level for W4 rules, RL74m, was reached. This is a forecast that does not appear to have been used by the flood operations authority during the

2011 event. It could have been used, say, for avoiding the coincidence of the spike release from Wivenhoe with the peak flow in the Bremer River. Using BARF was a requirement of the Manual, and the efficacy of the BARF approach was established in the developmental work that led to establishing that Manual. That development was completed away from any presence of any real flood or flood damage controversy and judicial inquiry.

Figure 5B also uses two tools not employed in analyses done by or for the QFCI:

- firstly, the plot of total inflows into Wivenhoe Dam (Upper Brisbane plus Somerset releases plus local runoff – and Splityard Creek if this outflow is part of the explanation of the mixture or mix-up of figures for Somerset Dam releases), and,
- the link from the forecast time when the W4 trigger level would be reached, to the forecast of total inflow into the Dam at that time, and then to the forecast of Dam releases required by W4 rules.

Figure 5 (like Figure 2) is only one demonstration of these tools and forecasts, offered in circumstances where the QFCI appeared not to be aware of these flood control foresight capabilities. Figure 5 has been subject to wide discussion and review (McMahon, 2012, 2013a,b,c,d).

A more expansive use of the technique demonstrated in Figure 5 would apply this BARF risk management approach for period forecasts longer than the 24 hour rainfall forecasts employed for Figure 5. The thinking that would prefer the NFR zero rainfall forecast would likely reject the use of a 2 day or 3 day rainfall forecast. This appears to be because the NFR advocates may misunderstand the BARF rationale to be a 'prediction' approach. NFR advocates would dismiss the BARF rationale because BARF provides *unreliable predictions*. BARF, however, does not have a primary prediction motif – BARF primarily has a 'strategy' motif, intending to determine the best strategy to adopt so as to best deal with the spectrum of rainfalls that could occur. Using, say, an integrated three (3) day BARF may have given earlier indications that the W4 trigger level would be crossed. This may have justified **an earlier start** to the BARF Dam release strategy demonstrated in Figure 3. This is as far as professional judgment can take the consideration, however. Data and modelling is needed to determine what the opportunities were. A forensic study that pursued the avoidability of the 2011 flood would need to use these longer integrated BARFs, to explore with foresight the risks with using earlier warning times for optimizing release strategies, if such earlier warning times were available.

This BARF approach is using the **most probable** rule for risk management. The subsidiary rule, making provision for the **most dangerous** outcome, can also assist in releasing more water earlier, when the RL74m trigger has been forecast.

The most dangerous outcome comes with actual rainfall occurring that is greater than the rainfall used in BARF. One provision for the most dangerous outcome suggested by McMahon (2012) was earliest use of the zero urban damage capacity of the Brisbane River. Releases from Wivenhoe based on this strategy, say 4000 cumecs at Moggill rather than 3500 cumecs out of Wivenhoe, may have been initiated earlier in the flood than Point A shown on Figure 3. This appears to be what Queensland authorities, two years later, may have decided to do in future flood operations along the Brisbane River (SEQWater, 2014).

It follows that a professional could reasonably judge that adherence to risk management may have provided a capacity to reduce releases during the PoP of the Bremer River. But by how much? – that answer required a forensic evaluation of the 2011 flood based on BARF. This QFCI did not do. QFCI adhered to the NFR rationale, and Queensland authorities appear to be continuing to adhere to NFR instead of returning to the BARF rationale incorporated into the Wivenhoe Manual in place in January 2011 (SEQWater, 2014).

Operation of Somerset Dam

Historically, the most intense rainfall areas above Wivenhoe Dam lie within the catchment of Somerset Dam, immediately upstream of Wivenhoe Dam, on the Stanley River. The system for flood control operations of Somerset Dam had the following features (SEQWater, 2011;s9, s10)::

A. The operating rules linked level and release controls to expectations of events in Wivenhoe Dam. These expectations concerning Wivenhoe Dam, of course, were being directed by the NFR rationale. The NFR rationale appears to have provided suboptimal expectations in risk management terms at Wivenhoe, and so may not have optimised the usefulness of Somerset ;
B. The operating rules for Somerset Dam, in all instances, had the crest (radial) **gates open**, so as to enable uncontrolled discharge. The use of **closed gates** to store additional water, say, during the PoP of Lockyer Creek or Bremer River peaks, was not contemplated by the operating rules;
C. The flood control Operating Target Line [OTL], for using Somerset and Wivenhoe Dam as an integrated flood control system, was derived directly, and only, from the failure criteria for both Dams – Wivenhoe by overtopping, Somerset by structural cracking. There was no link, say, to the PoP of the Bremer River peak. The OTL kept each Dam at a similar safety margin from structural failure. The failure level for Somerset Dam, on different assumptions, was at the high end of the operating range for the crest gates, or within the storage level behind the closed crest gates. The risk of structural failure of Somerset Dam may be a rationale for reducing the flood mitigation capability of the Dam, by vetoing, via the operating rules, any use of the crest gates – '***closing the crest gates … increases the risk of dam failure'*** (Babister, 2011b;para25).

During the 2011 flood, the operations needed to comply with the operating rules in force. Any argument for establishing the ***'avoidable flood'*** case would need to direct criticism at the pre-existing operating rules rather than with the January 2011 operations. The QFCI did inquire into whether any concerns about dam failure impacted upon the operational decisions made during January 2011 (QFCI 2012;s17.6). The impact at issue, however, was whether the cracks in the Dam had any effect on the determination of the operating rules made prior to the flood.

Within the rules for Somerset operations during 2011, the ***'no flood'*** case would need to focus upon:

A. The influence on Somerset Dam operations of the forecasts accepted about Wivenhoe Dam. The latter forecasts were formed using the NFR rationale, in lieu of the BARF rationale stipulated by the Manual. This may be beyond professional judgment - forensic modelling would be required;
B. During the rise in water levels at Wivenhoe above Wivenhoe's W4 trigger, the water level behind Somerset rose by two metres, absorbing inflow volumes. The same two metres, plus another 1-2 metres (plus storage behind the crest gates on a sound Dam structure), may have been used to store water at Somerset while the Bremer peak joined the Brisbane River, and may still have been in reasonable accord with the Operating Target Line - only modelling may confirm this.

There are other issues (SEQWater, 2011;s6). The reports on the 2011 Flood by the operator of both Dams provided three sets of varying figures for the outflows, over time, from Somerset into Wivenhoe Dam. The figures varied by up to 50%. It is not clear which, if any, were the actual flows from Somerset, nor which, if any, were used by the flood control operations body in decision-making during the flood event. Inquiry, not modelling or professional judgment, may be needed to resolve this issue.

Another major discrepancy occurred in the water storage levels at Wivenhoe Dam during the worst period of the flooding. No serious investigation into the operations of Somerset as the source of this anomaly in Wivenhoe Dam storage levels has been reported. Investigations of the Wivenhoe levels anomaly appear to have been limited to a ready acceptance of a ‘magic’ storm, of 1in2000 AEP, that dropped rain onto the Wivenhoe Lake to a pattern that missed all the rainfall gauges, including the gauges at Wivenhoe Dam. The storm explanation is a possibility not to be dismissed, but its improbability may merit a thorough investigation of alternative explanations, including the Somerset outflow anomaly. Inquiry, again, would lead the resolution of concerns here.

Any scope for improving the performance of Somerset Dam in the flood control role would extend the capacity of the Wivenhoe – Somerset flood control system to reduce releases during the Bremer River PoP. The forensic analyses necessary to test this capacity appear yet to have been reported.

Forecasting River Peaks

The poor state and spread of rainfall gauging stations, and the limitations of the stream gauging stations, within the Bremer and Lockyer catchments, may have denied water authorities confidence in their operating decisions and analyses made during the flood, concerning the contributions to flooding from these two catchments. This deficiency in forecasting flows appears to have been one of the **flood preparation** issues (QFCI, 2011;p43-44).

The obstacle to the **‘no flood’** proponents, posed by the 5400 cumecs peak on the Bremer at Moggill, shown on Figure 4, may be less of an obstacle once the origins of that hydrograph are evaluated.

The Bremer River hydrograph first appeared in SEQWater (2011;App1,p156). It carried a warning that it ***‘only approximates the actual flow’***. How it was derived has not been disclosed. If the 5400 cumecs figure was produced by Version 1 or 2 of SEQWater’s hydrodynamic model, it is highly questionable. QFCI withdrew from any endorsement that Version 2 of the model was ***“well configured”*** (Babister, 2012b;para79). QFCI identified the limitations of the model at the Bremer-Brisbane River ‘interaction’ (vicinity Moggill). The criticism of the modelling was continued, after the model was modified for particular deficiencies. O’Brien’s (2011) criticism that the calibration of Version 2 was 470mm above actuals at the Brisbane City Gauge, for example, was not answered by QFCI after QFCI undertook to provide a response. QFCI was just ***using the modelling tools available … Revision … to model this area … could not be undertaken within the time available’*** (Babister, 2011b;para21,22).

The criticism came from the firm that developed the hydrodynamic model used by QFCI:

> *The representation of the boundary conditions to the model is incorrect. The catchment inflows between Wivenhoe Dam and Moggill have been combined as a single inflow source at Moggill. Consequently the only river flow being modelled between Wivenhoe Dam and Moggill is the Dam release. The water levels in the model are therefore distorted and the storage and propagation of dam release flows in this approximately 80 km stretch of the river is incorrect …*
> *The “calibration” of the model has primarily been achieved by adjusting inflows to achieve a model “prediction” close to actual measured flows at various gauges along the river. … As such the model cannot be considered to be reliably calibrated to represent the river and floodplain behaviour*

Szylkarski & van Kalken, 2012;p1

The second criticism is major The first is of a *'distorting'* modelling practice applied to the reach of the Brisbane River of interest to this forensic. There are valid reasons for redoing the total analysis before accepting this Bremer River peak of 5400 cumecs at Moggill, during any zero outflow from Wivenhoe. Professional judgement may reject the peak, but modelling would be needed to give a new estimate.

Setting a Zero Urban Damage Indicator

Moggill has been listed as a site potentially affected by riverine changes. It had Priority 1 for study and analysis. The Moggill gauge was described by SEQWater's modellers as ***'less reliable than other gauges'***, due to the proximity to a major confluence (with the Bremer River). QFCI accepted the Moggill estimate only as ***'better than nothing'***, hardly an endorsement (Babister, 2011b;para44).

This raises the possibility that the 4000 cumec Flood Damage Indicator at Moggill could be in significant error. Any increase would allow a rise in BARF release rates from Wivenhoe.

Conclusion

The QFCI did not report an hour by hour re-enactment of the 2011 flood, based on risk management operating strategies for both Wivenhoe and Somerset Dams. QFCI also may not have allowed sufficient time to undertake a hydrodynamic modelling exercise that was fit for purpose in identifying the flood levels caused by the failure to operate the Dams in accordance with the Flood Manual. These decisions may act to deny any firm analysis of the merits of the ***'no flood'*** case. Any assertion that a questionable analysis is ***'better than nothing'*** assumes that the analysis provides useful information, rather than misinformation.

The forensic analysis indicates that a proper analysis of the **'no flood'** argument is merited. The prospects of reduced flooding for major floods with the use of rainfall forecasts applied using risk management appears to be strong. The analysis that derived the Bremer River peak appears to be questionable, but which way the results might turn with a comprehensive forensic is uncertain.

The ability to obtain such a forensic study will have its challenges. This is because of the great divide in technical positions adopted by opponents on the damages issue. That divide is currently a State Government versus a national enterprise, which enterprise appears to have decided to argue a reduction in flood levels rather than a ***'no flood'*** outcome. Commercial cum legal reasons rather than forensic analysis may be dictating this choice.

This paper shows the technical divide. The QFCI came to a rationale that the flood control operations achieved '***close to the best possible flood mitigation result'*** (QFCI, 2012;p524). An EA Group have opined to the media that the flood levels in the Brisbane CBD would have been 2 metres higher if the operations of the Dams had been different to what actually occurred in January 2011 (Bruesch, 2013). The 7500 or 11561 cumec flood wave released in Figure 2, and the coinciding peaks in Figure 4, render these claims of significant engineering interest. The EA Group opinion has come unaccompanied by the supporting analysis requested from the EA Group (McMahon, 2013a&b). The divergence in technical opinion with the expertise that wrote the Manual is in prominent evidence.

The call for an analysis into the ***‘no flood’*** case is outside of the current legal contest. Victims will find it hard, without access to a substantial data cum modelling exercise, to promote what appears to be a case with merit that should be resolved, in the public interest.

Recommendations

The management of water resources associated with controlling floods through dams, dams with both water supply and flood mitigation functions, will benefit strongly from

1. An understanding of risk management in dealing with rainfall forecasts;
2. A rainfall and flow monitoring system that provides timely and critical information during very large events;
3. Modelling software and model frameworks that support the provision of useful forecasts to responsible disaster authorities;
4. Training in the flood control operations for very large flood scenarios.

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