17 Other dam issues

This chapter deals with those aspects of the Commission's investigation into the operation of dams unrelated to the narrow issue canvassed in the February 2012 hearings.

The longer term review of the flood mitigation manuals relevant to Wivenhoe, Somerset and North Pine dams is dealt with in section 17.1 below. It was in part dealt with by the interim report, which set out scientific investigations that should be completed before such a review took place.[1] Those recommendations are now supplemented in this report with recommendations as to the procedure by which the review should take place.

The review and approval by the Department of Environment and Resource Management (DERM) of flood mitigation manuals is dealt with in section 17.2. DERM's review of flood event reports, a topic that takes on greater prominence given the questions raised about the veracity of Seqwater's March 2011 flood event report, is addressed in section 17.3.

The effect of the dams' operation in relation to the slumping of river banks upstream and downstream of the dams is the subject of section 17.4.

Three other topics related to Wivenhoe, Somerset and North Pine dams were raised on the material and submissions received by the Commission: the operation of the Wivenhoe Power Station by Tarong Energy, the presence of cracking in Somerset Dam and the impact of the operation of all three dams on nearby bridges and crossings. Those three matters should also be taken into account in the longer term review of the flood mitigation manuals.

The Commission also investigated dams in areas where regional hearings were held. Information on dams in the Fraser Coast, Maryborough, Gympie, Sunshine Coast, Bundaberg, North Burnett and South Burnett local government regions was collected and considered. Those dams included eight operated by each of Seqwater[2] and SunWater,[3] and eight dams operated by Wide Bay Water Corporation, South Burnett Regional Council, Newcrest Mining and Stanwell Corporation.[4] The evidence received on Lenthalls Dam, near Maryborough, warranted specific attention by the Commission; its operation is discussed at length in section 17.8 below.

Aspects of the detention basins in Toowoomba were raised in submissions which members of the public made to the Commission. Given the flash flooding of 10 January 2011, a consideration of those detention basins was appropriate and appears at section 17.9.

Finally, the Commission considered the role of DERM in the regulation of dams, outside of its involvement in the review of flood mitigation manuals and flood event reports. That involved a consideration of DERM's response to the Bureau of Meteorology forecast in October 2010, its process of review of emergency action plans, its interaction with disaster management personnel, its performance of dam safety audits and its management of non-commercial water assets. The consideration of those topics identified an unfortunate vacuum in responsibility for flood mitigation in Queensland.

17.1 Longer term review of the Wivenhoe and North Pine manuals

The Commission's interim report recommended reviews of the flood mitigation manuals applicable to Wivenhoe and Somerset dams and North Pine Dam on both an interim (before the 2011/2012 wet season) and a long term basis.[5] The interim report set out the scientific investigations that would be required to be undertaken as part of the longer term review of both manuals. It did not make recommendations about the procedure of the review, the policy decisions to be made by government at the end of it nor the approval of the manual by government; those were not tasks that could be completed before the onset of the 2011/2012 wet season. It was indicated in the interim report that those issues would be dealt with in the final report.[6] The first two of those topics will be addressed in this section; the approval of flood mitigation manuals is dealt with in section 17.2 below.

Seqwater has completed interim reviews of both manuals. The approval of Revision 8 of the Wivenhoe manual by the Director-General of DERM was gazetted on 1 October 2011.[7] Approval of Revision 6 of the *Manual of Operational Procedures for Flood Mitigation at North Pine Dam* ('North Pine manual') was gazetted on 11 October 2011.[8]

In response to the passage of the *Disaster Management and Other Legislation Amendment Act 2010*, and the subsequent declaration of a temporary full supply level at Wivenhoe Dam by the responsible Minister, Seqwater added a chapter to the Wivenhoe manual to deal with a drain down to a temporary full supply level. That chapter was added to the Wivenhoe manual and submitted to DERM for approval as Revision 9; approval of it was gazetted on 14 November 2011.[9]

Those interim reviews, and the steps taken to begin the scientific investigations required for the longer term review of the Wivenhoe and North Pine manual, have assisted the Commission in making further recommendations.

The Commission envisages that each longer term review will progress in three stages:

1. completion of the scientific investigations required for the review
2. decision by government as to the operating strategies to be adopted after consideration of options
3. creation of the new manual by Seqwater.

17.1.1 The structure for the completion of the scientific investigations

Seqwater has begun the task of conducting the scientific investigations necessary for the reviews. It has initiated the Wivenhoe Dam and Somerset Dam Optimisation Study and the North Pine Dam Optimisation Study. Both studies will draw upon three separate investigations: into dam operations, water supply and floodplain risk management.[10] For the Wivenhoe study, the three investigations (dam operations, water supply security and floodplain management) are to be conducted through a technical working group under the supervision of the steering committee. The dam operations group is to be chaired by Seqwater, the water supply security group by Queensland Water Commission and the floodplain management group by the Department of Local Government and Planning.[11] Activities relevant to the local government regions of the Brisbane City Council, Ipswich City Council and Somerset Regional Council will be led by those councils respectively.[12]

Both studies will conclude with the presentation to government of options for operating strategies for the dams.[13] The Wivenhoe Dam and Somerset Dam Optimisation Study will arrive at a range of options, informed by the effects of flooding, the balance of competing interests across dam operations, floodplain development and water supply, flood risk and flood behaviour and the economic, social and environmental impacts of a range of flood management measures.[14]

Each optimisation study has a steering committee, chaired by Seqwater, with overall responsibility for the project.[15] In addition to Seqwater, both steering committees include representatives of DERM, the Queensland Water Commission, the South East Queensland Water Grid Manager and Brisbane City Council. The Wivenhoe study steering committee also includes representatives of Queensland Treasury, the Department of Local Government and Planning, the Queensland Reconstruction Authority, the Department of Community Safety, the Bureau of Meteorology and Brisbane, Ipswich and Somerset councils.[16] The North Pine study also includes representatives of the Moreton Bay council.[17]

Despite the lack of a finalised scope of work for the floodplain management study in the Wivenhoe Optimisation Study, it is likely that the work to be completed will overlap with the comprehensive flood study recommended for the Brisbane River catchment in chapter 2 of this report. The two studies have different purposes: the Wivenhoe study to assess the impacts of different operating environments at the dam, the flood study to inform land use planning and emergency management procedures. Investigations about the impacts of the operation of the dams on the floodplain are connected to investigations required to inform land use planning and emergency management, and vice versa, but each set of investigations is only a subset of the other. Investigations of the sort required for a review of the manual appear to be smaller in scope than those required for a comprehensive flood study. That can be gleaned both from the draft scope of work of the floodplain management technical working group,[18] and the fact that the whole of the optimisation study is expected to be completed by the end of 2012,[19] whereas the flood study is estimated to take approximately three years.[20] Some work as to the effects of dam operation on the floodplain and possible mitigation measures will need to be done, by someone, as part of the manual review. The Commission's view, however, is that the flood study it has recommended for the Brisbane River catchment should be undertaken separately from the optimisation study.

Elementary notions of efficiency suggest that the removal of the water supply and floodplain management studies from the dam operations study would be beneficial. The steering committees would not have as much work to oversee; the expert review panels would neither require so many experts with varying expertise nor need to review as much work. Sinclair Knight Merz, the project managers of the Wivenhoe Dam and Somerset Dam Optimisation Study, would not be faced with such a large and multi-faceted project. In the short term, some work done to set up the studies might be lost. If there were to be separation, the links between agencies forged by the initiation of the optimisation studies, and the work so far completed, should be built upon in the new study.

The three streams of investigation included in the optimisation studies are topics relevant to the review of the Wivenhoe and North Pine manuals. The Queensland Government will need advice on all those topics when it considers options for the operation of the dams, but it is not necessary that the advice come from one source. In fact, it may be beneficial for advice on competing objectives to come from different sources. The government will be required to weigh up the benefits and disadvantages of different options and strike a balance for the people of Queensland. The process for that decision is discussed further below at section 17.1.2. One integrated study, like the Wivenhoe study, has the benefit that it will 'package' each option in terms of impacts on other areas and costs because it has, within it, expertise in all relevant areas. On the other hand, it might, because of that integration, discard possible options before the government is involved. It is not the role of those involved in the optimisation study to do that balancing exercise for the government.

These concerns support the removal of both the water supply and floodplain management investigations from both optimisation studies.

Nonetheless, there are also good reasons, including the integration of investigations and agencies, to maintain the structure that has been implemented. It is a matter for the steering committee of each study whether the floodplain management and water supply security investigation remains part of it, or are conducted separately. The Commission recommends in *2.2 Flood studies* that the steering committee of the Wivenhoe Dam and Somerset Dam Optimisation Study consider whether the floodplain management investigation, a subset of which would involve a flood study, should be removed from the confines of that study: see recommendation 2.1. A similar decision should be made by the steering committee of the North Pine Dam Optimisation Study. The responsibility for completing floodplain management investigations and flood studies, if outside of the Optimisation Study, will fall on councils and the Queensland Government in accordance with the recommendations made in *2.5 The performance of flood studies in Queensland.*

If the investigations in each optimisation study are to be separated, there will need to be a high level of co-operation between those completing the different investigations. In particular, the data collection and creation part of each investigation must be performed in a manner which ensures that all have access to the data and its analysis. Models and other materials may, where appropriate, be shared between groups conducting the investigations. The agencies involved in separate floodplain management and water supply investigations would maintain their membership on the dam operations steering committee and so be able to ensure that integration.

As a final point, the Commission's interim report set out a list of scientific investigations that should form part of the review of the Wivenhoe manual in recommendations 2.12 and 2.13. All those investigations were directed at dam operations. The Commission is unable to assess in this report whether the scientific investigations to be

undertaken as part of the study in respect of dam operations are in accordance with those recommendations. That is because the scope of the work to be done by each technical working group in the Wivenhoe Dam and Somerset Dam Optimisation Study has not yet been finalised; that preparation is expected to continue into early 2012.[21] The steering committee of the Wivenhoe Optimisation Study has resolved to deliver recommendation 2.10 to 2.13; history will judge whether they succeed.

Recommendations

17.1 The steering committees of the Wivenhoe Dam and Somerset Dam Optimisation Study and the North Pine Dam Optimisation Study should consider removing the water supply security investigation from each study.

17.2 The steering committee of the North Pine Dam Optimisation Study should consider whether it would be beneficial for the floodplain management investigation to be removed from the North Pine Dam Optimisation Study.

For recommendations relevant to the floodplain management investigation of the Wivenhoe Dam and Somerset Dam Optimisation Study, see recommendation 2.1 of this report.

17.1.2 Consideration of options for operating strategies by government

The expected outcome of the longer term review of the manual is that options for operating strategies will be considered by the Queensland Government. Each option should involve a nominal full supply level and set out the strategies to be employed during a flood event. The range of options should be wide enough, and explained well enough, for the government to understand:

- the flood mitigation benefits of each option, distinguishing between flood mitigation for rural and urban areas respectively, and between different urban areas
- the water supply security implications of the full supply level of each option
- the dam safety implications of the full supply level of each option, including the flood that the dam is able to pass safely and the likely cost of and loss of life from dam failure.

Other considerations include:

- the submergence of bridges affected by the lake levels, releases or flooding around Wivenhoe, Somerset and North Pine dams, including the costs associated with raising those bridges
- the slumping and erosion of banks
- the effects on riparian fauna and flora.

See also recommendations 17.15 and 17.26 of this report.

The results (in terms of those topics) for each option must be considered over a range of flood events occurring both upstream and downstream of the dam. Clearly, the government will have to be presented with a wide spectrum of options from which it can determine how it wishes to prioritise different considerations in floods of different severity. The government might choose to give further direction to the steering committees of the optimisation studies as to the options to be presented. It could indicate in advance the objectives to which it intends to accord priority.

Recommendation

17.3 The Queensland Government should ensure that, when it considers options for the operational strategies to be employed at Wivenhoe and Somerset dams, and North Pine Dam, it is presented with a wide range of options which prioritise differing objectives. The Queensland Government should determine the operational strategies by considering the implications of each option over a range of flood events for at least:

- inundation of urban and rural areas
- water supply security
- dam safety
- submerging of bridges
- bank slumping and erosion
- riparian fauna and flora.

17.1.3 Creation of the new manuals

Lessons from the interim review

The interim reviews of Seqwater's flood mitigation manuals resulted in Revision 9 of the Wivenhoe manual[22] and Revision 6 of the North Pine manual.[23] Both manuals were sent to an independent dam safety and risk consultant for a peer review before they were submitted to DERM. That review involved consideration of more than one iteration of the manuals. In the end, the peer reviewer was satisfied with the manual's content and structure as an instructional document for engineers.[24] The manual was also reviewed numerous times by DERM lawyers and engineers with experience in dam operations before it was approved. The result of those reviews was that DERM considered the manual satisfactory.[25]

The changes made to the manuals in the interim reviews were scrutinised by the Commission for the purpose of informing recommendations to be made about the longer term reviews of the manuals, which are continuing. The Commission, from that scrutiny, has identified some areas of concern.

The Commission considers that there are two bases on which the manual must be judged: first, as an instructional document to be used by engineers during floods; second, as a set of procedures which, if observed, will confer immunity on a dam operator for civil actions against it.[26]

As to the second basis, the manual could conceivably be the epicentre of important litigation. Consequently, it is essential that it is expressed so that a determination can be made, in a forensic context, as to whether there has been compliance. For this reason, any examination of its efficacy cannot be limited to a consideration of its usefulness as an instructional document.

A well-written manual will also assist in public understanding, a point emphasised in the Commission's interim report. Public understanding, though, is a secondary concern to the two primary roles the manual must fulfil.

'Judged likely'

Revision 9 of the Wivenhoe manual and Revision 6 of the North Pine manual introduced terms such as 'judged likely' into the conditions for the use of operational strategies. For example, Revision 7 of the Wivenhoe manual required that the predicted lake level 'be' between 68.5 metres and 74.0 metres for strategy W3 to apply, while Revision 9 says that the predicted lake level should be 'judged likely to be more than 2.5 metres above the [full supply level]'.[27] The same change has been made to strategies W1 and W2.[28] Strategy W4 now requires that the actual lake level 'exceed' 74.0 metres or the predicted level be 'judged very likely' to exceed 74.0 metres.[29]

The newly introduced terms have been defined as follows:

- 'judged likely' or 'judges it likely' means an event or circumstance being, in the professional engineering judgment of the duty flood operations engineer, sufficiently certain to occur given the likely consequences associated with any decision which depends upon the judgment
- 'judged unlikely' means an event or circumstance being, in the professional engineering judgment of the duty flood operations engineer, not sufficiently certain to occur given the likely consequences associated with any decision which depends upon the judgment
- 'judged very likely' means an event or circumstance being, in the professional engineering judgment of the duty flood operations engineer, certain or near certain to occur given the likely consequences associated with any decision which depends upon the judgment.[30]

For a court to be able to determine whether or not the dam operators complied with the manual without negligence,[31] it is necessary and appropriate for it to contain some objective standards. That was reflected in Revision 7 of the Wivenhoe manual by the requirement that certain states of affairs be likely or predicted.[32] The Commission's interim report recommended that such provisions be amended on the basis that they were expressed inconsistently, but not on the basis that they imported an objective standard of reckoning.[33] In fact, such a standard is important; if all that is required to operate the dams is the subjective judgment of an engineer, there is little for the manuals to do. It would be an unhappy result if all that was required to achieve immunity on the scale provided by section 374 of the *Water Supply (Safety and Reliability) Act 2008* was that engineers had used their own judgment.

Of course individual decisions as to whether or not a relevant state of affairs exists will ultimately be a matter for the subjective judgment of the flood engineers. But their decisions should be made by reference to an objective criterion. The introduction of terms such as 'judged likely', and their accompanying definitions, effectively removes the presence of any objective standard.

It may be that, by linking the concept of 'likelihood' with the consequences of the decision, the revision was seeking to introduce something like what is known as a 'Briginshaw' test in a legal context, which requires that the standard of the evidence required rises as the consequences of an adverse finding increase in seriousness. A test of that kind would seem to be contemplated in that part of section 4.2 of Revision 9 of the Wivenhoe manual which deals with the flood engineers' use of forecast rainfall.[34] That test has a place in the operation of the dams, but should be formulated in terms which are readily understandable.

Strategy flowcharts

A major structural change to the Wivenhoe manual in Revision 9 is the introduction of strategy flowcharts. There are a Wivenhoe strategy selection flowchart,[35] individual flowcharts for each of strategies W1, W2 and W3,[36] and a Somerset strategy flowchart.[37] Each flowchart presents as a series of decision points in a binary system. In each box is a question, which can only (according to the flowchart) be answered yes or no. Once answered, an arrow indicates the action that should be taken, or poses another question.

A flowchart is not an unreasonable way to present the information about strategies for the operation of Wivenhoe and Somerset dams. However, the Commission harbours concerns about aspects of these flowcharts.

Strategy selection flowchart

In the strategy selection flowchart, the threshold question is phrased in the negative: '[i]s it judged unlikely that the Wivenhoe Dam lake level will exceed the [full supply level]?'.[38] Answering such a question is difficult in a normal situation, let alone with the pressure of flood operations. Thought should be given to expressing the question in a form which asks whether the lake level is *likely to exceed* full supply level, accompanied by a rehearsal of the consequences according to whether the answer is yes or no.

In almost all cases, compound questions have been used: for example '[i]s the predicted Wivenhoe Dam lake level judged likely to exceed the [full supply level] by more than 3 metres within the next 24 hours *and* it is judged likely that drain down on the Dams will not commence within the next 48 hours?' (emphasis added) in the strategy W2 flowchart.[39] Such questions carry with them the difficulty of determining whether an answer of 'yes' means 'yes' to one or both parts of the question. There should be no need for such questions to be unravelled, especially when they might be addressed by individuals under pressure: it is poor drafting practice.

A third criterion, effectively a sidenote to the flowchart, has been added for the purposes of many of the decisions regarding flows that submerge bridges downstream of Wivenhoe Dam. The situation in which the drain down of the dams is 'judged likely' to commence in the next 24 to 48 hours is an overriding consideration which allows the flood engineers to consider keeping a bridge open when the flowchart requires them to no longer give consideration to that objective.[40] Its status suggests that it should be included in the flow chart, not marginalised as a side note.

Whether or not these concerns are shared by the flood engineers, they do little to substantiate Seqwater's claim (in its explanatory notes to the Wivenhoe manual provided to DERM) that 'the flowcharts should enable persons with limited knowledge of Brisbane Basin hydrology to develop a basic understanding of transition options'.[41]

Inconsistencies in the strategy W2 flowchart

The strategy W2 flowchart in Revision 9 of the Wivenhoe manual[42] has two apparent inconsistencies. On the bottom row of that flowchart, the middle box asks whether the predicted Wivenhoe lake level is judged likely to exceed the full supply level by more than three metres within 24 hours and whether it is judged likely that the drain down of the dams will not commence within the next 48 hours. The red cross in that box indicates that the sidenote already mentioned, concerning the keeping open of the downstream bridges if the drawdown is judged likely to commence in the next 24 to 48 hours, applies. But it is obvious that the first position is inconsistent with the second: if it has been judged likely that drain down will not commence in the next 48 hours, it cannot be judged likely that the drain down will commence in 24 to 48 hours. Secondly, if the answer to the first question is yes – the flood engineer has judged it likely that the drain down will not commence within 48 hours – the flowchart directs the reader to a result oval which states that no consideration will be given to bridges 'unless drain down of the dams is judged likely to commence in the next 24 to 48 hours'. Again, the inconsistency is obvious. Both inconsistencies should be rectified.

Minimum gate openings in strategy W4

It is unclear how the table of minimum gate openings in Strategy W4A in Revision 9 of the Wivenhoe manual[43] was determined. It is not the gate opening strategy used in the January 2011 event.[44] If it is not supported by modelling regarding different gate opening strategies in strategy W4 and their effects, this table should not be followed strictly by flood engineers nor replicated in further iterations of the manual.

Registration

Seqwater removed the requirement in both manuals that all flood engineers be registered as Professional Engineers in Queensland; only senior flood engineers are now required to be registered.[45] If that was a reaction to the Commission's finding that Seqwater was in breach of Revision 7 of the Wivenhoe manual for failing to ensure that all flood engineers were registered,[46] it is unfortunate. Registration is not a mere formality; it reflects a commitment to maintaining skills through continuing education. It is part of the way in which expertise is acknowledged. Both manuals contemplate the situation in which a single flood engineer might operate the dams; in fact, that occurred in the early, and late, stages of the January 2011 flood event.[47] The manual provides that, where possible, the senior flood operations engineer should be in charge of operations for the whole of a flood event.[48] It also provides that other flood engineers, when on shift, are to direct flood operations in accordance with the overall strategy of the senior flood engineer.[49] If circumstances were to change drastically during a shift, it would be expected that the flood engineer on duty would act to meet the new circumstances, whether or not he or she was designated as senior. As an example, in the January 2011 flood event, neither of the two flood engineers on shift when the decision was made to transition to strategy W4 was a senior flood engineer.[50] Flood engineers on shift in the absence of a senior flood engineer are not supervised by a senior flood engineer. For those reasons, registration should be required for all flood engineers.

Assessment of compliance in flood event report

The report produced by Seqwater after a flood event should include an assessment of whether the operation of the dam during the flood event complied with the manual.[51] In addition to explaining the use of operational strategies and whether they were adopted and applied in compliance with the manual, Seqwater should be required to consider its compliance with other requirements, such as training and registration, in addition to those related to the operational strategies employed during an event. This was not done in response to the 2011 flood.

Scaling of quantitative precipitation forecasts

Seqwater stated in the explanatory notes to the Wivenhoe manual submitted to DERM for approval that the flood engineers would continue 'scaling' up or down the quantitative precipitation forecasts when making predictions as to lake level.[52] If that is to occur, the process, and the reasons for it, should be explained in the manual.

Discretion of flood engineers

The Wivenhoe manual gives the flood engineers substantial discretion as to the way the dam is operated. For example, the strategies do not set out prescriptively the release rates to be implemented during each strategy. The senior flood engineer is also given discretion to depart from the terms of the manual to achieve the flood mitigation objectives in it.[53] There was no suggestion that the manual in force at the dam at the time of the January 2011 flood event gave too much or too little discretion. However, a consideration of the scope of the discretion would be a valuable part of a comprehensive review of the manual.

Pre-releases in response to weather forecasts

The North Pine manual stated that 'pre-releases' could be made outside the confines of the table of gate opening intervals in that manual to reduce the risk of the dam overtopping.[54] The scope of that allowance is not clear.[55] The idea of releasing water in advance of forecast rainfall is attractive. Seqwater has had work done in the past on the feasibility of pre-releases of water in response to rainfall forecasts.[56] That work has not supported the use of rainfall forecasts in operational decisions.[57] Seqwater has, however, clarified circumstances in which rainfall forecasts may be reliable and useful to flood engineers in Revision 9 of the Wivenhoe manual.[58] The time is ripe, then, for further consideration of the circumstances in which a pre-release might be employed.

'Transition' strategies

The flood engineers gave evidence in the February 2012 hearings of the Commission that, at the time of the 2011 flood, there was some confusion as to when and how strategy W2 should be implemented and as to how the choice between strategy W2 and W3 should be made.[59] Particularly some, if not all, of the flood engineers, did not appreciate at the time of the January 2011 flood that W2 was not a transition strategy between W1 and W3.[60] That misunderstanding is not surprising: W2 was described expressly as a transition strategy in Revision 7 of the Wivenhoe manual, and the flowchart contained in it indicated it should be used between W1 and W3. The clarification of this issue was part of recommendation 2.9 in the Commission's interim report. More recently, a submission the Commission received from a member of the public proposed an interpretation of the respective applications of W2 and W3 which was entirely different from the flood engineers', but which was open, at the least.[61] If strategies of the form of W2 or W3 in Revision 7 are chosen as part of the longer term review of the Wivenhoe manual, the criteria for their use and the conditions under which each of them should be used should be explained clearly and simply so as to avoid these problems in the future.

'Urban inundation'

The protection of urban areas from inundation, which is the second highest objective for flood mitigation in Revision 7 and Revision 9 of the Wivenhoe manual, has proved to pose some difficulty. In evidence in February 2012, Mr Malone accepted that the term could refer to a wide range of circumstances.[62] He said that he relied on the manual (then in force, Revision 7) which prescribed the limit of urban damage to be a flow in the Brisbane River of 4000 m^3/s.[63] Mr Tibaldi said that some urban damage occurs with flows as low as 1600 m^3/s or 1900 m^3/s, including the inundation of bike paths and inundation of low lying houses.[64] Mr Ayre described the impact of a flow of 1600 m^3/s in the Brisbane River on tide heights as a consideration relevant to the protection of urban areas.[65] It is undesirable if different flood engineers have different interpretations of this term, because it will affect what any of them tries to achieve in pursuance of the objective. If this term is to be used in the manual prepared as part of the longer term review, it should be precisely defined.

If the definition involves diverse concepts, then some attempt must be made to relate those concepts back to the strategies, so that flood engineers can reach a clear understanding of their objectives and primary considerations.

'Natural peak flow'

The concept of natural peak flow was relevant to the implementation of strategies W2 and W3 under Revision 7 of the Wivenhoe manual. For example: in W2, the target flow in the Brisbane River at Lowood was capped at the lesser of the 'natural peak flow at Lowood excluding Wivenhoe Dam releases, and 3500 m^3/s';[66] in W3, the target flow in the Brisbane River is dependent on the timing of the 'naturally occurring peak at Moggill (excluding Wivenhoe Dam releases)'.[67] (The concept is not used in the same way in Revision 9 of the Wivenhoe manual.)[68]

The engineers gave evidence that 'natural peak flow' for the purposes of W2 meant the estimated flow emanating from downstream tributaries and local Brisbane River flows downstream of the dam. For Lowood, that means the flows from the Lockyer Creek; for Moggill the flows from the Lockyer Creek and the Bremer River.[69] The submission from a member of the public referred to above suggested that the term meant instead the flow that would have occurred without artificial intervention; in other words, as though neither Somerset nor Wivenhoe dams had been built. The peak flow for Lowood would consist of the flows from the Stanley and Brisbane rivers in the absence of the dams, as well as the flow from Lockyer Creek.[70] Again, the interpretation is at the least arguable.

If the concept of natural peak flows is to be used in the new revision of the manual, it should be defined.

There are no transition strategies in the current version of the North Pine manual, nor is the protection of urban areas from inundation an objective at that dam. The concept of natural peak flow is not used. Nonetheless, these issues might become relevant in the longer term review of the North Pine manual depending on what strategies are chosen for that dam.

Recommendation

17.4 Seqwater should, in creating the new Wivenhoe and North Pine flood mitigation manuals, comprehensively consider:

- the amount of discretion that is able to be exercised by the flood engineers and the senior flood engineers, and the description of the circumstances in which such discretion may be exercised
- the circumstances in which it might be appropriate to release water in advance of an impending flood on the basis of forecasts from the Bureau of Meteorology
- if strategies of the form of strategy W2 and W3 in Revision 7 are included in the revised manual, or any strategy defined as a 'transition strategy', when and how those strategies should be implemented
- if the concept of 'urban inundation' is relevant to the operation of the dam, how it should be defined, and if the definition involves diverse concepts, how those concepts can be related back to the strategies, so that flood engineers can reach a clear understanding of their objectives and primary considerations
- if the concept of 'natural peak flow' is relevant, how it should be defined.

Writing the flood manuals

Seqwater did a substantial amount of work to revise the Wivenhoe and North Pine manuals in the short period between the Commission's interim report and the 2011/2012 wet season. The review resolved many inconsistencies and ambiguities that appeared in Revision 7 of the Wivenhoe manual. DERM did not identify any failings requiring it to withhold its approval of the new manual. It involved both lawyers and engineers in its review. It was satisfied by the extensive legal and technical reviews of wording and the clarification of strategies.[71]

The Commission considers, however, that the new Wivenhoe manual is attended by deficiencies which were not present in Revision 7. Some matters of concern, such as the structure of flowcharts, have been outlined above. Another concern is that the writing style has become more legalistic and complex. Definitions have been provided for words that are in common use, such as 'likely'.

The Commission recognises that a clear and precise expression of procedures used in the operation of a dam during flood is not an easy task. The writing required is different from that of engineers' reports or legal documents.

The Commission reiterates its view that the use of a technical writer could assist Seqwater in the preparation of the manuals. A technical writer is a professional writer, skilled in the art of preparing technical or instructional documents. There would be considerable benefit in having the final versions of the manuals written, in their entirety, by a technical writer, who was not bound to follow any particular structure or style adopted in previous iterations of the manuals. Such a technical writer should be independent of the flood engineers who will use the manuals in flood operations, although he or she would, of course, be required to engage substantially with the flood engineers in order to understand the procedures that are to be set out in the manual.

The immunity provided for by section 374 of the *Water Supply (Safety and Reliability) Act 2008* necessitates a legal review of the manuals. The purpose of the legal review should be, though, to confirm the manuals' terms are clear and unambiguous so that a court can determine compliance with them, if required. It should not be to over-define and legalise the document in a way that detracts from its other purposes.

The Wivenhoe and North Pine manuals are the only two flood mitigation manuals approved under the Act. The principles arising from this consideration of those two manuals should also be applied to any flood mitigation manual approved in the future for any dam in Queensland.

Recommendations

17.5 The conditions for the use of a particular strategy in all flood mitigation manuals should reflect objective standards.

17.6 The Queensland Government should ensure that all flood mitigation manuals include the requirement that those operating the dam during flood events hold current registrations as professional engineers.

17.7 Seqwater should consider engaging a technical writer to develop completely new manuals after the operational strategies for Wivenhoe, Somerset and North Pine dams are set by the Queensland Government.

17.8 Seqwater should ensure a legal review of the Wivenhoe manual and the North Pine manual is completed before the manual is submitted for approval.

17.1.4 A further consideration for the longer term review of the North Pine manual

North Pine Dam is located on the North Pine River, immediately upstream of urban areas that are within the boundaries of the Moreton Bay Regional Council. Its basic characteristics were outlined in the Commission's interim report in section 2.2.10 and the January 2011 flood event in section 2.10. Its full supply level is 39.6 metres.[72] The top of the embankment is 43.28 metres.[73] At Wivenhoe, the flood mitigation capacity of the dam is the volume able to be held between the full supply level and the top of the embankment.[74] Looking at North Pine Dam in the same way, its flood storage capacity is the volume of water able to be held between 39.6 and 43.28 metres.[75]

North Pine Dam is unique among the dams in Queensland which have flood mitigation manuals. It is operated in accordance with prescriptive tables of gate openings and, as operated, has insignificant flood mitigation capacity. Discretion such as that exercised by flood engineers at Wivenhoe is not a feature of the operation of North Pine Dam during flood events. The evidence was that it was built for water supply; flood mitigation was not a primary focus.[76]

However, the dam does have over two vertical metres of flood mitigation capacity.[77] The review of the North Pine manual should result in the Queensland Government's receiving options for operating strategies over a wide range of full supply levels. It should consider in that context whether North Pine should operate as a flood mitigation dam, and if so, whether strategies like those in the Wivenhoe manual should be employed to utilise North Pine Dam's flood mitigation capacity.

Recommendation

17.9 The Queensland Government should consider whether North Pine Dam should be operated as a flood mitigation dam when it considers possible operating strategies and full supply levels as part of the longer term review of the *Manual of Operational Procedures for Flood Mitigation at North Pine Dam*.

17.2 Review and approval of flood mitigation manuals

The *Water Supply (Safety and Reliability) Act* provides for flood mitigation manuals to be prepared by owners of dams. The government can, by regulation, require the owner of a particular dam to prepare a flood mitigation manual.[78] The Director-General is empowered to approve a manual submitted to DERM for a period of five years or less.[79] There is also provision for amendment of existing manuals.[80] Where there is a flood mitigation manual for a dam, the dam's owner, operator and employees are protected from civil liability for any act or omission done honestly and without negligence in observance of the procedures in the manual.[81]

The Commission examined the review and approval of manuals under the Act. The review and approval of Revision 7 of the Wivenhoe manual can be briefly described as an example. The dam safety regulator, Mr Allen, held a delegation to exercise the Director-General's power to approve a manual. He, in conjunction with other officers, assessed the manual and suggested changes to its terms to Seqwater, some of which were adopted in further drafts. He approved the manual in November 2009.

17.2.1 Identity of approver

The choice of operating strategies under flood mitigation manuals has the capacity to affect millions of people. The manual is produced after many competing interests have been balanced; it provides immunity from civil action for a dam operator under certain circumstances. It is the Minister, as the representative of the people, who should approve the manual for use by dam operators. DERM officers should maintain the role of assessing the manual and providing information and advice in order for the Minister to make the decision.

Recommendation

17.10 The Queensland Government should amend the *Water Supply (Safety and Reliability) Act 2008* to designate the Minister as the person who must approve a flood mitigation manual.

17.2.2 Independence of assessor

The assessment of flood mitigation manuals should be undertaken by a person who is independent of both the flood engineers and those who created the manual. Mr Allen approved Revision 7 of the Wivenhoe manual and assessed Revision 9 before it was approved by the Director-General.[82] Mr Allen has been involved for a long period in the operation of the dams, including in the development of the manuals over many years[83] and has, inevitably, a close professional relationship with the current flood engineers.[84] For reasons given elsewhere (see section 16.12 above), the Commission considers that it would not be appropriate for Mr Allen to review the flood event report prepared in respect of the January 2011 floods at Wivenhoe and Somerset dams. Equally, appointing Mr Allen to assess the new versions of the flood mitigation manuals may give rise to the appearance of a lack of independence and critical oversight by DERM of Seqwater and its manual. That oversight is required by the process of review and approval under the *Water Supply (Safety and Reliability) Act*. There is no suggestion that Mr Allen's previous review of the manual was compromised because of his involvement in the development of the manual or his relationship with the flood engineers. However, it would be appropriate in future that a clearly independent person be chosen to perform this role.

Mr Allen made the point that whoever is the assessor will need to understand how the dam is operated to assess the manual.[85] Expertise in dam operations is necessary, but knowledge of particular dams should not be needed.

The manual itself should clearly define the procedures to be followed. If a person who does not already know the procedures cannot understand them from the manual, it is clearly not fulfilling its purpose. See section 17.1, above, for the purposes of a flood mitigation manual.

Recommendation

17.11 The assessment of flood mitigation manuals should be completed by a person with appropriate expertise who has had no involvement in its development, at any stage, and who can be seen to be independent of all individuals who were so involved.

17.2.3 Work procedure

A work procedure was developed in 2010 for the assessment of flood mitigation manuals: DS 5.1 *Flood mitigation manual for a dam.*[86] That work procedure had a number of inadequacies that were explored during the Commission's first round of hearings:

- By way of information for action officers, the document[87] included the statement that '[t]he aim of the flood mitigation manual is to give the dam owners indemnity for flood release operations if they are conducted in accordance with the provisions of the approved manual'. The dam safety regulator, Mr Allen, who prepared DS 5.1,[88]agreed that this choice of words was poor.[89] Clearly the purpose of a flood mitigation manual is to set out the procedures by which a dam mitigates floods.
- The checklist against which manuals were to be judged did little more than mirror the contents of Revision 7 of the Wivenhoe manual.[90]
- The work procedure failed to deal with the competing aims that are involved in flood mitigation manuals, which will involve putting some people at some degree of risk for the overall benefit of the community. Mr John Bradley, then Director-General of DERM, agreed in the Commission's public hearings that the review of the manual should address this.[91] The question of whether the manual presented to DERM is consistent with the balance as struck by the executive was not posed in work procedure DS 5.1. That may be attributable to the fact the executive has not, in the past, clearly decided and communicated what that balance should be.

In 2011, DERM reviewed its work procedures for the review of flood mitigation manuals. It has created a new version of work procedure DS 5.1 *Flood mitigation manual for a dam*.[92] This is to be used for the assessment of a new flood mitigation manual; that is, for a dam that has never had a manual before. The new DS 5.3 *Processing a flood mitigation manual for a dam following review*[93] is the procedure to use for the assessment of a new revision of a manual that already exists. It is that procedure which was used for the assessment of Revisions 8 and 9 of the Wivenhoe manual and Revision 6 of the North Pine manual in 2011, and will be used relevant to the manuals for those dams in the future.

Both new procedures deal with the first point made above; the offending words have been removed. As to the second point, the checklist of factors still aligns closely with the content of the current Wivenhoe and North Pine manuals.[94] The Commission does not have evidence as to whether the work procedure includes consideration of all topics that should be considered in the assessment of a flood mitigation manual. It is not possible, on the evidence, to give unqualified endorsement to either of DS 5.1 or 5.3. The Queensland Government may consider it prudent to obtain independent expert advice about what should be contained in flood mitigation manuals to reflect this in its work procedures.

Neither DS 5.1 nor 5.3 deals with the final point made above. The most important consideration in an assessment of the manual by DERM, aside from compliance with the Act, is whether it reflects the decision as to the operating strategies and balance between objectives decided by the government. If the manual does not reflect the executive's will, it should be rejected. This does not mean that the executive's policy decisions must be inserted into the procedure, only that the assessor should confirm that the manual is consistent with the government's policy.

One question posed to the assessor by the work procedures is whether the manual complies with the outcomes of this Inquiry.[95] The Commission's recommendations have no status without executive commitment to implement

them. Even when such a commitment is given, the executive may vary or supplement the approach advocated by the Commission. It is the executive, not the Commission, to which DERM must look for the policy position that is reflected in flood mitigation manuals.

DERM should also ensure that the manual is in such a form that a ready determination can be made as to whether its procedures have been observed, so that the manual is capable of playing its role under section 374 of the *Water Supply (Safety and Reliability) Act 2008*. That requires it to provide objective standards by which decisions are to be made.

Recommendations

17.12 The Queensland Government should continue to assess and review the adequacy of work procedures DS 5.1 and 5.3, having regard to the need for flood mitigation manuals to reflect the will of the executive.

17.13 Prior to approving a flood mitigation manual, the Queensland Government should be satisfied that its terms are expressed in a manner that allows a determination of compliance with it to be made by reference to objective standards.

17.3 Review of flood event reports

When an emergency action plan for a dam is triggered by a flood, a flood event report must be prepared by the owner of the dam and submitted to DERM.[96] The content of the flood event report is specified in the emergency action plan for each referable dam. The emergency action plan will usually incorporate a provision requiring the dam owner to prepare a flood event report, within 30 days of a flood, that includes:[97]

- a description of the flood event
- instrument readings, where appropriate
- a description of any observed damage
- photographs
- details of communication and actions which took place during the flood
- a description of how the emergency action plan was implemented during the event
- comment on the adequacy of the emergency action plan and any changes proposed.

A similar requirement to produce flood event reports is imposed on the owners of referable dams that have flood mitigation manuals.[98] This requirement is triggered when there are flood releases from the dams.[99] The required content of these reports is set out in the flood mitigation manuals and usually involves the production of a more comprehensive report than that required under an emergency action plan.[100] (The operators of dams with both emergency action plans and flood mitigation manuals may have obligations under each; Seqwater, the operator of Wivenhoe Dam, for example, has an obligation under both the emergency action plan[101] and the manual[102] to write a report.)

In the 2010/2011 floods, 24 emergency action plans were activated and flood event reports submitted to DERM.[103] These were reviewed by a dam safety engineer.[104] Reports were also prepared and submitted under the Wivenhoe manual and the North Pine manual.[105] The only serious damage to dams identified in any of these reports was erosion in the Wivenhoe Dam spillway chute.[106] In the course of the flood event report being prepared for the North Pine Dam, a concern was raised regarding the design flood hydrology for North Pine Dam.[107] The Commission deals with the review of the Wivenhoe and Somerset dams flood event report in section 16.12, above.

The Commission is not in a position to assess the adequacy of the flood event reports DERM received and reviewed following the 2010/2011 floods. The level of detail in these reports varies considerably.[108] To the extent that DERM identified any inadequacies in the level of information provided in the flood event reports it should, if it has not done so already, raise those inadequacies with the relevant dam operators and require that all missing information be provided.

Flood event reports are only prepared if an emergency action plan is activated or flood releases are made under a flood mitigation manual. The triggers for the activation of the emergency action plan are not the same for all dams. Some dam owners elect to have their emergency action plans activated during relatively small floods, whereas others are triggered only in extreme floods.[109] While DERM does make some enquiries about whether an emergency action plan has been triggered if it has reason to believe this may have occurred, it is the responsibility of the dam owner to identify the need for a flood event report to be submitted.[110]

DERM does not have a formal work procedure for the review of the flood event reports.[111] The director of the dam safety unit within DERM said that while there may be some benefit to having such a procedure for the review of flood event reports produced under emergency action plans, it is unlikely to be helpful for reviewing the reports produced under flood mitigation manuals, given that only three dams have flood mitigation manuals and these manuals are under review.[112] The Commission is not aware of any particular issue arising out of DERM's review of the flood event reports following the 2010/2011 floods, but there appears to be an obvious advantage in developing a procedure for the review of flood event reports prepared following future floods. It would ensure that expectations of what is required by way of review are clear and that institutional knowledge is retained even if experienced individuals leave DERM. In particular, it would be useful for DERM to formalise a process for ascertaining which dams may require a flood event report to be submitted, reminding the owners of those dams of their obligation to submit a flood event report, and reviewing such reports.

The Commission notes the comments of the director of the dam safety unit that drafting formal work procedures for the review of flood event reports produced under flood mitigation manuals may not be an efficient use of time, as the reviewer would be a skilled engineer who would inevitably have to have reference to the flood mitigation manual itself. Drafting a work procedure that restates the flood mitigation manual may not, therefore, be a worthwhile exercise, particularly as the manuals are presently under review. However, there is a benefit to ensuring that there is a formal and transparent process for receiving and reviewing reports produced under flood mitigation manuals in the same way as those produced under emergency action plans.

Recommendation

17.14 The Department of Environment and Resource Management should prepare formal work procedures for the review of flood event reports created under emergency action plans and flood mitigation manuals. These should include procedures for:

- making enquiries with the owners of referable dams that have catchments that have been subject to heavy rainfall (or where there is other reason to believe the emergency action plan has been triggered) as to whether the emergency action plans have been triggered
- reminding owners of referable dams that have had emergency action plans triggered of their obligation to submit a flood event report
- upon receipt of a flood event report, reviewing it, identifying any dam safety or other issues or areas where insufficient detail has been provided, raising those matters with the dam owner or other affected party and identifying appropriate remedial steps
- raising any issues identified in the report that are beyond the expertise of the Department of Environment and Resource Management, or are likely to be of particular interest to another body, with the appropriate body
- keeping a record of the process and results of the review of the flood event report
- fixing an appropriate timeline for the completion of each of the above steps: the time required may depend on specific circumstances, but must allow for any potential safety issues to be identified and remedied efficiently.

17.4 Bank slumping

Before publication of the interim report, the Commission received several submissions from people whose property had suffered severe erosion or bank slumping (where chunks of riverbank become unstable and topple or slide into the river) during or immediately following the January 2011 flood event at Wivenhoe Dam. These submissions provided a stark reminder of the magnitude of the flood and the impact the river can have on land bordering it.

The majority of the submissions were received from people in the mid-Brisbane River region between Wivenhoe Dam and Mt Crosby Weir. Other submissions were received from landowners upstream of Wivenhoe Dam in and around the township of Harlin. Several of these landowners contended that releases from Somerset and Wivenhoe dams were at least partly to blame for the damage to riverbanks.[113]

In response, Seqwater submitted that the question of whether the operation of Wivenhoe and Somerset dams caused or contributed to erosion or slumping of the Brisbane River's banks was a matter for expert evidence. This view was supported by Mr Terry Wall, then acting Director-General of DERM, who indicated that a comprehensive geomorphological assessment was necessary to determine the cause of the bank slumping.[114]

The Commission accepted Seqwater's submissions on this point, and called for it to provide an expert report on the subject. DERM was also invited to provide expert evidence, but did not.

On 10 October 2011, the Commission received a report from Dr Bruce Abernethy, of Sinclair Knight Merz, an expert on fluvial geomorphology (the study of the behaviour of river channels and human impacts thereon).[115] Dr Abernethy's report included an assessment of riverbank erosion and slumping in the upper and mid-Brisbane River regions. It did not, however, include a consideration of the likely impact of different modes of operation of the Wivenhoe and Somerset dams on erosion, instability and slumping. Accordingly, the Commission asked Dr Abernethy to prepare a supplementary report that considered this issue and provided a more detailed analysis of the riverbank erosion and slumping process.

17.4.1 Riverbank erosion and slumping in January 2011

Both the upper and mid-Brisbane River regions experienced significant riverbank erosion and slumping. At Harlin, upstream of Wivenhoe Dam, for example, the river channel underwent a major transformation as large sections of the riverbank fell away.[116] One Harlin property holder's submission indicated that some 30 acres of his property had been lost as a result of the slumping.[117] Another reported the loss of approximately 4.5 acres.[118] A number of photographs vividly illustrating the dramatic effects of riverbank slumping have been provided to the Commission. The photograph to the right is just one of these. It shows a 3.9 metre sheer cliff created by the slumping of bank material into the river.

3.9 metres depth of land lost at Harlin (photo courtesy Jenny Moore)
Source: Exhibit 41, Statement of Jenny Moore, 7 April 2011 [p13]

The effects of riverbank slumping were equally dramatic in the mid-Brisbane River region downstream of Somerset Dam and Wivenhoe Dam, as illustrated in the following photograph, showing the loss of approximately 8 hectares of land from a farm in the mid-Brisbane River region.

Approximately eight hectares of farm washed away
Source: Mid Brisbane River Irrigators, Submission to the Queensland Floods Commission of Inquiry, 11 March 2011, Annexure 6

In many instances, the damage caused by the slumping cannot feasibly be repaired by landholders. While nature will eventually take its course, and restore the riverbanks to some extent, that process is likely to take many years.[119]

17.4.2 The causes of riverbank erosion and slumping

That the banks of the Brisbane River were damaged is uncontested. What is less certain is the cause of the damage, and the extent to which the operation of Wivenhoe and Somerset dams played a part.

The banks of rivers change over time, either through natural processes or human intervention.[120] The causes of bank erosion and slumping are many and varied. Some causes operate locally, while others are associated with wider changes to the river's flow, for example, by way of damming.[121] Changes to a river's flow caused by the construction of a dam may result in the complete readjustment of the river's channel over a period of up to 500 years.[122]

On a local level, a range of factors determines whether and how erosion or slumping occurs.[123] In river reaches subject to flooding, such as those in the upper and mid-Brisbane River regions, riverbanks are damaged primarily by a process of slumping.[124] Riverbank slumping generally occurs as a result of bank instability caused by either a reduction of a bank's internal strength initiated by complex processes occurring below the earth's surface, or a change in the form of the bank (usually as a result of scour – the direct removal of bank materials by the physical action of flowing water).[125] When the stability of a bank is compromised by these processes, whole blocks of material may slide or topple from the bank into the river channel.[126]

The instability that leads to riverbank slumping commonly occurs when an increase in a river's flow, which saturates the riverbank, is followed by a corresponding decrease in flow, which removes the support the water was providing to the saturated bank, leading it to collapse into the river under its own weight.[127] The rate of slumping in such circumstances depends on several factors, including bank composition and moisture content and the speed of water

flow.[128] Given that bank material may vary significantly from one part of a river to another nearby section, different failure modes may be observed in close proximity to each other.[129] These factors make it difficult to predict the occurrence of bank failure.[130] Generally speaking though, the faster a river's level falls following elevated flow, the greater the likelihood that slumping will occur.[131]

The riverbank erosion and slumping process is further complicated by landholder activity. The effect of floodwater on riverbanks may, for example, be mitigated considerably by vegetation growing on and around riverbanks. Where flooding occurs in areas where vegetation has been cleared, bank slumping is likely to be greater.[132]

Although the process is complex, it is possible to provide a broad summary of the circumstances in which bank slumping may occur. According to Dr Abernethy, the conditions necessary for slumping will arise where a flood:

- is large enough to wet the higher parts of the bank
- is of sufficient duration to allow water to seep into the bank
- recedes faster than the banks are able to drain.[133]

It is trite to say that the operation of a dam may have an impact on the size, duration and recession of a flood. The concern expressed by upper and mid-Brisbane River landholders regarding the impact of the operation of Wivenhoe Dam on their riverbanks is, therefore, entirely understandable.

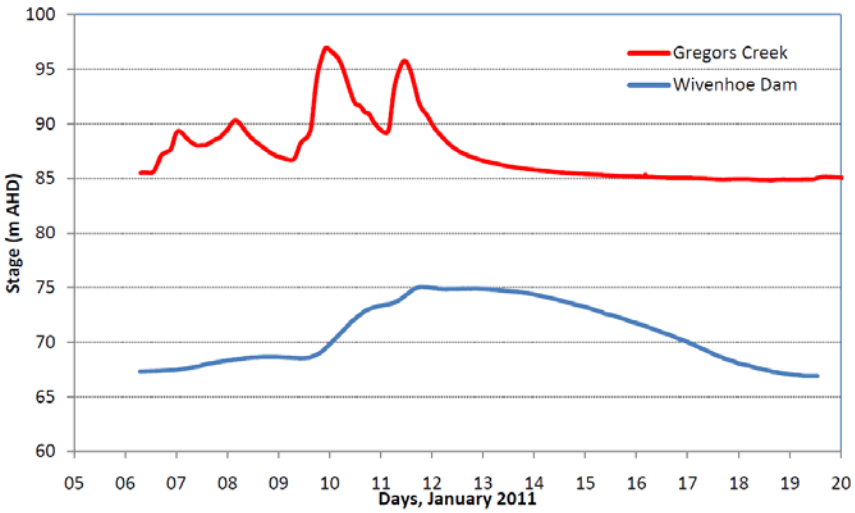
17.4.3 Slumping in the upper-Brisbane River

The first report provided by Dr Abernethy includes a review of the flood damage at Harlin[134]. Dr Abernethy's report echoes the observations of landholders in respect of the severity of bank slumping and assesses the likely impact of Wivenhoe Dam on it.

In doing so, Dr Abernethy reviews the river heights at the Gregors Creek gauge, which is downstream of Harlin and approximately 83 kilometres upstream of the Wivenhoe Dam wall. Figure 17(a) below sets out the water levels at both the Gregors Creek gauge and Wivenhoe Dam for the period between 6 and 20 January 2011. A review of Figure 17(a) reveals that between 8 and 13 January 2011, the water level at Gregors Creek gauge rose and fell on three separate occasions independently of the level of Lake Wivenhoe, which rose steadily from 8 January 2011 until 11 January 2011, levelled off, and then began falling towards the end of 13 January 2011.

The lack of correlation between the water levels at Gregors Creek and Wivenhoe Dam led Dr Abernethy to conclude that the river flow and, in turn, bank slumping at Harlin was controlled by local channel conditions; the operation of Wivenhoe Dam during the flood was not responsible for the damage to the riverbanks observed at and around Harlin.[135] The force of that reasoning is obvious, and the Commission accepts the conclusion as correct.

Figure 17(a)



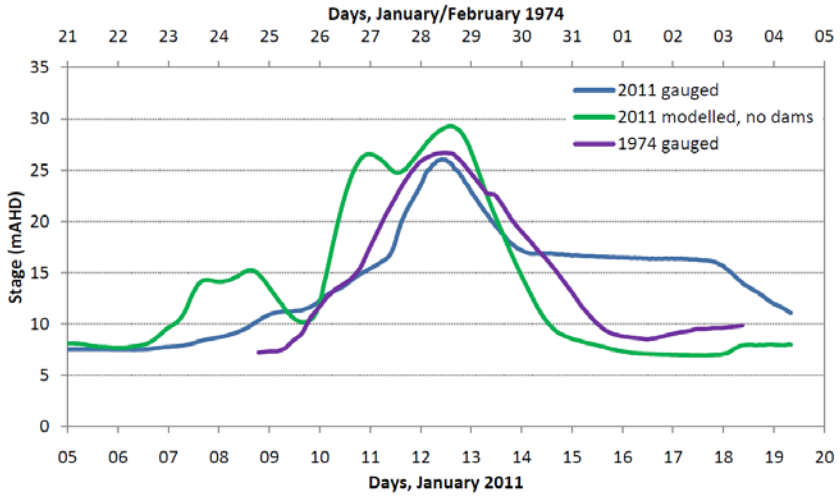
Stage heights at Gregors Creek and Wivenhoe Dam gauges
Source: Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p6].

17.4.4 Slumping in mid-Brisbane River

Again, Dr Abernethy's first report supports landholders' assertions that substantial riverbank slumping occurred in the mid-Brisbane River region as a result of the flooding. Dr Abernethy's report, however, diverges from the submission made by some landholders that, as a result of the pattern of releases from Wivenhoe Dam, the river flowed at a higher rate and receded faster in January 2011 than it did in 1974, thereby causing additional bank slumping.[136]

Figure 17(b) below sets out a comparison between the level of the Brisbane River at Mt Crosby Weir during the 2011 flooding as compared to the observed 1974 levels, and a calculation of the levels that would have been experienced in 2011 if Wivenhoe Dam had not been built. The graph demonstrates that the management of releases from Wivenhoe Dam in 2011 led to a lower peak and more gradual recession than would have occurred in the absence of the dam.[137] It also reveals that the process of drawing down Wivenhoe Dam to full supply level resulted in the river level remaining elevated for longer than it did in 1974. On those bases, Dr Abernethy concluded that the operation of the Wivenhoe and Somerset dams between 7 and 14 January 2011 did not exacerbate the riverbank damage reported in the mid-Brisbane River region.[138]

Figure 17(b)



Modelled and gauged hydrographs at Mt Crosby Reservoir
Source: Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p10].

This conclusion was founded on a comparison between observed flow rates and those that would have been experienced had the dams not existed, rather than a consideration of the likely impact of different modes of operation of the Wivenhoe and Somerset dams on erosion and slumping. With that in mind, it should be noted that Dr Abernethy's first report does observe that the maintenance of a higher water level between 14 and 18 January extended the period of riverbank inundation, potentially allowing water to seep further into the bank than it did during previous flooding.[139] As a result of this, and despite the fact that the second drawdown (from 18 January 2011) occurred at a slower than natural rate,[140] the banks may not have drained sufficiently.[141] While, in light of the great variation in bank and flow conditions at different locations, Dr Abernethy was not able to conclusively determine whether the slumping was attributable to the combination of the prolonged elevated flow between 14 and 18 January 2011 and the subsequent drawdown from 18 January 2011 onwards,[142] it is possible that this was the case.

In his second report,[143] Dr Abernethy gave a further explanation of his inability to reach a firm conclusion on this point. He noted that the complex interaction between the various factors involved in riverbank slumping means that a more conclusive assessment cannot be made without conducting an in-depth program of field testing of the bank properties at various locations.[144] In considering the factors involved in riverbank erosion, Dr Abernethy gave his opinion that significantly less slumping would have been observed in the mid-Brisbane River region if naturally occurring vegetation had not been cleared from the riverbanks.[145] On a general level, though, Dr Abernethy

confirmed that the longer a river is maintained at a high level, the slower the drawdown needs to be to minimise bank slumping.[146]

In summary, given the size of the flood, it is likely that substantial bank erosion and slumping would have occurred in the mid-Brisbane region regardless of the pattern of releases from Wivenhoe Dam.[147] Indeed, it should be noted that extending the drawdown longer than would have occurred naturally may, in some instances, have contributed to increased bank slumping. [148] Nevertheless, it is possible that had the drawdown phase been extended, particularly in the period from 18 January onwards, the extent of the bank slumping may have been reduced.

17.4.5 Riverbank slumping and dam operation strategies

Part 3.6 of the Wivenhoe manual as it stood in January 2011 (and in its present form) requires that consideration be given to reducing potential bank slumping. It notes that '[r]apid draw down of stream levels where banks are saturated should be avoided if this can be managed within the other flood mitigation objectives'.[149]

The ability of the flood engineers to draw down the lake level gradually so as to minimise bank slumping is constrained by all the higher ranked flood mitigation objectives in the Wivenhoe manual. Of particular relevance are the objectives to ensure dam safety and minimise disruption to rural life. Part 3.2 of the manual provides that the structural safety of the dams is of paramount importance and observes that, in view of the significant probability of two or more flood producing storms occurring in short succession, floodwaters should be emptied within seven days of the flood peak.[150] Dam operators are also required to read part 3.6 of the manual subject to the requirement in part 3.4 to minimise any disruption to rural areas, for example, by limiting the inundation of downstream bridges.

It appears that the operation of the dam during the January 2011 flooding accorded with part 3.6 of the manual (as circumscribed by part 3.2); the drawdown of the dam extended until the morning of 19 January 2011, approximately seven days after the peak of the flooding.[151] Releases from Wivenhoe Dam had remained stable at approximately 3500 m^3/s between 14 January and 17 January 2011 before decreasing progressively until the morning of 19 January 2011. This caused the river level at Mt Crosby Weir to remain stable between 14 and 18 January 2011 and, as noted above, may have resulted in parts of the riverbank becoming saturated and collapsing under their own weight in the subsequent drawdown phase.[152]

The manual allows for an extension of the drawdown because of downstream flood conditions. It does not, however, explicitly contemplate prolonging the drawdown beyond seven days in an attempt to limit the effects of riverbank slumping. Given that bank slumping may be reduced if the drawdown period is extended so that the mid-Brisbane River's level decreases more gradually,[153] this may be unduly inflexible.[154] As already observed, the longer a river flows at a high level, the slower the drawdown must be to minimise slumping.[155] Where there is no risk to Wivenhoe Dam's structural safety, and no significant danger to the safety of downstream communities and infrastructure,[156] it may be prudent to prolong the drawdown of the lake in an effort to reduce downstream bank slumping.

The same is true of the interaction between parts 3.6 and 3.4 of the manual. In certain circumstances, it may be appropriate to extend the inundation of a lower level crossing (provided lasting damage to that crossing is not likely to result), and the associated inconvenience to local residents, in order to reduce the likelihood of significant bank slumping.

Both assessments necessitate a balancing of competing interests that is best undertaken by the Queensland Government in the consideration of appropriate operating strategies for Wivenhoe and Somerset dams during the longer term review of the manual. See also recommendation 17.3 above.

Recommendation

17.15 As part of the longer term review of the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam* the Queensland Government should consider whether the dam operators should be able to extend the drawdown of the lake beyond seven days in order to reduce downstream bank slumping.

17.5 Wivenhoe Power Station

The Wivenhoe Power Station is a pumped storage hydroelectric power station located on the eastern side of Wivenhoe Dam. The power station has been operating since 1984.[157] On 1 July 2011, the State of Queensland transferred ownership and management of the power station from Tarong Energy Corporation to CS Energy Limited. Both companies are government-owned corporations.

In view of this change in ownership, this section refers to Tarong Energy in its consideration of the January 2011 flooding and the terms of documents developed or entered into by Tarong Energy. Recommendations for the future operation of the Wivenhoe Power Station, on the other hand, are made by reference to CS Energy.

17.5.1 Splityard Creek Dam

The Wivenhoe Power Station produces electricity by releasing water from Splityard Creek Dam into Wivenhoe Dam, which drives the power station's turbine generator. Splityard Creek Dam is an earth and rock fill dam with a capacity of approximately 28 700 megalitres. It is 76 metres high and 1120 metres long. The dam's embankment crest is at a level of EL (elevation above sea level) 168 metres[158] and its full supply level is 166.5 metres.

Splityard Creek Dam has a relatively small catchment area of 3.6 square kilometres. It is designed with a spillway capable of releasing 420 m^3/s, substantially greater than the largest inflows recorded during the January 2011 flooding and larger than the peak flow associated with the probable maximum flood.[159]

At full capacity, the dam allows the power station to operate for approximately 10 hours.[160] The dam can be re-filled via a pumping system that recycles water from Lake Wivenhoe into the dam.

17.5.2 Interaction between Splityard Creek Dam and Wivenhoe Dam

The storage capacity of Splityard Creek Dam pales in comparison with that of Wivenhoe Dam. When Splityard Creek Dam is full, its contents equate to less than two per cent of the water held by Wivenhoe Dam at full supply level, and less than one per cent of the water held when Wivenhoe Dam's flood compartment is also full.

Wivenhoe Dam is designed on the premise that, even in a flood with an average recurrence interval of 100 000 years, the water level will not exceed 80 metres.[161] That level is the crest of the embankment; if the water were to exceed 80 metres, the risk of dam collapse would rise dramatically. If closed, the radial gates in the dam wall are likely to experience a critical structural failure if the water level exceeds 79 metres.[162] At either of those levels, a release of the full capacity of Splityard Creek Dam would induce a rise in Wivenhoe Dam's level not exceeding 17 centimetres.[163] It follows that only in extraordinary circumstances could the operation of the Wivenhoe Power Station be significant to the structural integrity of Wivenhoe Dam. Similarly, it is unlikely that a release from Splityard Creek Dam would trigger one of Wivenhoe Dam's fuse plugs (located at 75.7, 76.2 and 76.7 metres).

That said, even small increases in the level of Wivenhoe Dam, such as those resulting from releases from Splityard Creek Dam, could affect the way the dam is operated by the flood engineers. For example, the engineers may:

- change strategy under the Wivenhoe manual if the dam level reaches a certain trigger height (for example, from W1 to W2 or W3 if the actual lake level rises above 1.5 metres above full supply level)[164]
- increase releases in a way that causes bridge closures downstream of Wivenhoe Dam as the lake level rises through different trigger levels under strategy W1[165]
- if not advised of changes to the Wivenhoe Dam level resulting from releases from Splityard Creek Dam, make errors in adjusting the hydrologic models used to predict likely dam levels (for example, by altering the runoff coefficient).[166]

The Wivenhoe manual recognises the impact of releases from Splityard Creek Dam by requiring personnel at Wivenhoe Dam to take the operation of the power station into account during a flood.[167] It should be noted that the manual observes that releases from Splityard Creek Dam can result in increases of up to 300 millimetres in the Wivenhoe Dam lake level.[168] The comment in the manual is not supported by any further data and is significantly larger than the figure Tarong Energy has calculated as representing the maximum impact of such releases.[169] It appears to have been included simply to draw attention to the necessity for Wivenhoe Dam operators to consider potential releases from Splityard Creek Dam. The reason for this discrepancy is unclear. It may, for example, have

arisen because the two calculations were premised on different Wivenhoe Dam levels. CS Energy and Seqwater should ensure that any confusion as to the impact of releases is resolved and amend the manual accordingly.

17.5.3 Wivenhoe Power Station during the January 2011 flooding

At the height of the January 2011 rainfall, inflow to Splityard Creek Dam over a four hour period averaged approximately 30 m^3/s,[170] substantially less than the spillway capacity of the dam.[171]

There are two transmitter devices at Splityard Creek Dam that provide remote measurements of its water level. At approximately 1.30 pm on 10 January 2011, one of these transmitters failed. Tarong Energy's usual practice in the event of transmitter failure is to have a staff member conduct a physical observation of the dam to ensure that the readings provided by the remaining transmitter are accurate. This was not possible during the flood event, because the access road to the dam had been obstructed by a number of landslides.[172] There were no surveillance cameras or other devices that would have allowed staff to conduct remote visual monitoring of dam levels.

Tarong Energy considered that there was little risk that the dam would be overtopped by water.[173] Nevertheless, there were concerns that the high rainfall and associated runoff might lead to erosion of the dam wall, slipping of the dam rim or rock movement.[174] In light of the transmitter failure and access difficulties, Tarong Energy decided to reduce the dam level by commencing power generation and, in doing so, releasing water into Wivenhoe Dam.[175] Splityard Creek Dam's water level at this time was EL 163.3 metres.[176] Power generation commenced at approximately 11.00 am on 11 January 2011 and continued until shortly before 7.00 pm,[177] by which time approximately 5262 megalitres of water had been released into Wivenhoe Dam.

When this release is considered together with smaller releases that occurred on 10 January 2011, a total of 8647 megalitres of water was released from Splityard Creek Dam into Wivenhoe Dam by the operation of the power station on 10 and 11 January 2011.[178] Accounting for the recycling of water back into Splityard Creek Dam before the 10 January 2011 release, the operation of Wivenhoe Power Station resulted in a net addition of approximately 5887 megalitres to Wivenhoe Dam during that period.[179]

The release that took place on 11 January 2011 cannot sensibly be considered in isolation from other inflows into Wivenhoe Dam. The total inflow into Wivenhoe Dam in the 24 hours from 12.00 am on 11 January 2011 was approximately 635 616 megalitres.[180] Releases from Splityard Creek Dam comprised less than one per cent of this amount. When releases from Splityard Creek Dam began, the water level at Wivenhoe Dam was approximately EL 74.10 metres. Releases continued until shortly before 7.00 pm, by which time Wivenhoe Dam had reached its peak level of EL 74.97 metres. In those circumstances, the release from Splityard Creek Dam on 11 January 2011 is likely to have resulted in the level of Wivenhoe Dam rising by approximately four centimetres.[181]

On Tarong Energy's calculations, even if it had elected to release approximately 23 500 megalitres, the full power generation capacity of the Splityard Creek Dam (and more than four times the actual release on 11 January 2011), Wivenhoe Dam's level would only have risen by 17 centimetres.[182]

At the time of the release, Wivenhoe Dam was already being operated in accordance with strategy W4, (that is to say that Seqwater's sole consideration was the safety of the dam).[183] Releases from Splityard Creek Dam did not, therefore, result in a change in the release strategy employed by Seqwater. Additionally, there was little danger that releases from Splityard Creek Dam would trigger any of Wivenhoe Dam's fuse plugs. This is fortunate, but no guarantee that releases in future flood events will be similarly inconsequential.

Recommendation

17.16 CS Energy should supplement physical monitoring of Splityard Creek Dam with visual monitoring by installing surveillance cameras or similar devices.

17.5.4 Communication about releases

Tarong Energy's (and now CS Energy's) right to take water from Wivenhoe Dam for the operation of the Wivenhoe Power Station is subject to the terms of a Deed of Practice for Wivenhoe Dam and Wivenhoe Power Station entered into by the predecessors of Tarong Energy and Seqwater on 22 October 1987. Among other things, the deed requires Wivenhoe Power Station to be operated in a manner that, as far as practicable, assists Seqwater in its attempts to mitigate flooding of the Brisbane River.[184]

The deed of practice also includes an acknowledgment by both parties of the Wivenhoe Manual[185] and requires Tarong Energy to assist Seqwater in its implementation.[186]

The deed of practice contains an express requirement that Seqwater notify Tarong Energy once it forms an intention to act in a manner that may result in a variation of the level of Wivenhoe Dam. It does not, however, impose any corresponding obligation on Tarong Energy. Notwithstanding the absence of such an obligation, a communication protocol was established on 7 October 2010. This protocol requires Tarong Energy to inform Seqwater of any movement of water between Splityard Creek Dam and Wivenhoe Dam once the Wivenhoe Dam level exceeds EL 67 metres.[187]

Tarong Energy's adherence to this protocol in the period immediately following its adoption appears to have been somewhat variable; a number of releases in October and November 2010 occurred in the absence of any notification.[188] The same is true of the January 2011 flood event at Wivenhoe Dam. Tarong Energy provided notice via email of the release of approximately 3385 megalitres on 10 January 2011,[189] but did not adhere to the protocol on 11 January 2011, when it released 5262 megalitres without notifying Seqwater.[190]

As at 11 January 2011, Wivenhoe Power Station was being controlled remotely by Tarong Energy employees situated at the Tarong Power Station, 180 kilometres north-west of Brisbane. Personnel at the Tarong Power Station, rather than at the Wivenhoe Power Station, were primarily responsible for notifying Seqwater of the releases.[191] Wivenhoe Power Station personnel, for their part, were engaged in attempts to prevent the influx of water into the power station machine hall.[192] Because of access difficulties, both power stations were operating under a skeleton staffing arrangement.[193]

From approximately 5.00 pm on 11 January 2011, Tarong Energy personnel experienced a loss of both telephone and email communications.[194] This loss of communications was caused by a power outage in the Brisbane central business district, where Tarong Energy's corporate network is based.[195] The impact of the corporate network outage was compounded by difficulties with mobile phone reception. Personnel at the Wivenhoe Power Station also reported difficulties with mobile phone reception throughout the flood event.[196]

These factors do not, of themselves, provide a satisfactory explanation for the failure to advise Seqwater of the releases before they occurred. The release began several hours before the corporate network outage. And although the reduced staff numbers undoubtedly placed additional burdens on the personnel who were able to attend work, at both Wivenhoe Power Station and Tarong Power Station, the protocol for notification of water movements is not onerous. It is unlikely that the preparation of a brief email outlining estimated flow rates, releases and pumping times would have significantly impinged upon the ability of Tarong Energy personnel at either power station to perform their other functions.

In the absence of any other communication, Seqwater's flood operations centre directed its operations manager to telephone an employee at Wivenhoe Power Station. Shortly before 6.00 pm on 11 January 2011, Seqwater's operations manager left a voice message requesting that no releases be made from Splityard Creek Dam.[197] Because of poor mobile phone reception, this message was not received for approximately 45 minutes.[198] Tarong Energy ceased power generation on receipt of the message; Seqwater was advised accordingly at approximately 6.41 pm.[199]

For clarity, the interactions between Tarong Energy and Seqwater regarding releases on 11 January 2011 can be summarised as follows (note that times are approximations only):

11.00 am	Releases from Splityard Creek Dam into Wivenhoe Dam commence
5.00 pm	Tarong Energy's corporate communication network fails as a result of a power outage
6.00 pm	Seqwater leaves a voice message requesting that no releases be made from Wivenhoe Power Station
6.41 pm	Seqwater's message is received and releases from the power station are stopped

Again, there is no evidence that Tarong Energy's failure to notify Seqwater of the releases created any risk that Wivenhoe Dam's fuse plugs would be triggered.[200] Tarong Energy personnel were subject to a number of important, competing demands and successfully ensured that the power station did not suffer significant flood damage. Nevertheless, the failure to notify Seqwater of the release should not be ignored. A similar breakdown in communications in future flood events could have damaging consequences.

While the failure to adhere to the protocol regarding dam releases cannot be attributed to the failure of internet and telephone communications from 5.00 pm on 11 January 2011, similar technological difficulties may have a greater impact in future flood events. The communication protocol, for example, relies on email communication. Mobile phone reception is regularly poor at the power station.[201] Experience in the January 2011 flooding demonstrates that these methods of communication may not be readily available when they are needed most. CS Energy has acknowledged that two-way radios, independent of any corporate communications network, would assist in ensuring the maintenance of appropriate communications with Seqwater.[202] The protocol should be updated to remove any ambiguity as to how and when information about releases is communicated and to ensure that, in circumstances where advice as to releases cannot be transmitted by email, CS Energy and Seqwater are able to communicate by phone or, if that is not possible, radio. The necessary radio equipment should be made available to relevant personnel. Arrangements should also be made to ensure that telephone and email communications at the power station are not entirely dependent on a network located off-site: possible means of doing so include installing a conventional land line telephone service, obtaining access to mobile internet and/or improving mobile phone reception.

As observed above, during the 2011 flooding Wivenhoe Power Station was operated by personnel who were not physically present at the power station. The protocol should ensure that, irrespective of whether Wivenhoe Power Station is being operated remotely or on-site, a direct line of communication is established between CS Energy personnel physically located at the power station and Seqwater employees at the Flood Operations Centre.

Recommendations

17.17 CS Energy and Seqwater should agree upon and adhere to a formal communication protocol that requires CS Energy personnel to advise Seqwater, through the Flood Operations Centre, of water movements between Splityard Creek Dam and Wivenhoe Dam or Pryde Creek once a flood event is declared under the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*. The protocol should ensure that a direct line of communication is established between CS Energy personnel physically located at the power station and the Flood Operations Centre.

17.18 The protocol should make provision for the use of telephone and/or radio where communication by email is not possible. Where necessary, CS Energy and Seqwater should make additional radio equipment available to relevant personnel.

17.19 CS Energy should put in place contingency measures to ensure email and telephone communications at Wivenhoe Power Station are not entirely dependent on a network located off-site.

17.5.5 Flood emergency planning

Tarong Energy has developed an emergency action plan in respect of Splityard Creek Dam. The emergency action plan provides guidance to Wivenhoe Power Station personnel in the event of an earthquake, which is regarded as the most likely threat to the dam's structural integrity.[203] The emergency action plan does not address high rainfall events. This is said to be because the design of the dam's spillway means that the dam wall cannot be overtopped by high rainfall events.[204] Similarly, the general business procedure, WIV-MAN-13: Emergency Response and Business Continuity Plan, which provides an overview of emergency response and business continuity planning in respect of the Wivenhoe Power Station, does not include flooding among its list of 'Credible Emergency Incidents'.[205] This omission is surprising.

There is a further business procedure designed to provide guidance to personnel at Wivenhoe Power Station in the event that Wivenhoe Dam exceeds its full supply level of EL 67.0 metres: WIV-OPS-15: Wivenhoe – High Rainfall,

High Dam Water Levels. WIV-OPS-15 makes repeated reference to the necessity to consider the emergency action plan. There is, however, nothing in the plan to indicate that it is triggered by high rainfall and rising lake levels, the circumstances that give rise to the operation of WIV-OPS-15. This apparent inconsistency may give rise to confusion in flood emergencies.

WIV-OPS-15 also requires staff at Wivenhoe Power Station to 'establish close contact' with Seqwater and monitor their predictions in relation to likely changes in dam levels.[206] No explanation as to what is involved in the establishment of 'close contact' is provided. As discussed above, the ramifications of a breakdown in communications between Seqwater and CS Energy could be significant. For this reason, it is important that any ambiguity in relation to communications between Seqwater and CS Energy be removed. As part of this, WIV-OPS-15 should be amended to make express reference to the formal communications protocol regarding releases.

Recommendations

17.20 CS Energy should review its emergency action plan and business procedures to ensure they are wholly consistent and give appropriate consideration to flooding as a possible emergency event.

17.21 CS Energy should amend its business procedure to remove any ambiguity as to the establishment of communications with Seqwater and to acknowledge the formal communications protocol regarding releases.

17.5.6 Condition of Splityard Creek Dam

As considered above, Wivenhoe Power Station personnel were concerned that the high rainfall and associated runoff might compromise Splityard Creek Dam's structural integrity. This concern played a significant part in their decision to release water into Wivenhoe Dam. On Wednesday 19 January 2011, dam safety engineers from SunWater carried out a physical inspection of the dam. They concluded that the dam was in good condition, and no structural issues required further attention.[207]

Another major factor in the decision to release water from Splityard Creek Dam was the failure of one of the dam's two water level transmitters. This concern appears to have been addressed since the flooding; the transmitter that failed on 11 January 2011 was repaired in late January 2011. Both water level transmitters are now fully operational.[208]

17.5.7 Control of Splityard Creek Dam operations during flooding

Mr John Tibaldi, Seqwater's current principal engineer, Dam Safety, has submitted that it would be sensible for the Wivenhoe Power Station and Splityard Creek Dam to operate under the direction of the flood operations centre once the level of Wivenhoe Dam exceeds 72 metres.[209] Mr Robert Ayre, one of the senior flood engineers under the Wivenhoe manual until mid-2011, contended that Seqwater should be able to direct the cessation of releases where Wivenhoe Dam's lake level exceeds 67 metres.[210] Mr Ayre's submission is in line with the recommendation he made to the Seqwater board following flooding in 1999.[211] This recommendation was not implemented. CS Energy, for its part, has expressed concern that an agreement requiring it to follow directions from Seqwater in relation to the release of water from Splityard Creek Dam may conflict with the statutory authority of the Australian Energy Market Operator to direct CS Energy to operate, or refrain from operating, assets such as the Wivenhoe Power Station that are connected to the National Electricity Market. [212]

Under the National Electricity Rules the Australian Energy Market Operator has power, for the purpose of ensuring security of electricity supply, to give directions to power generators.[213] Putting to one side, for the moment, that role of the Australian Energy Market Operator as it might affect the interactions between Seqwater and CS Energy, the relatively small storage capacity of Splityard Creek Dam means that the operation of the Wivenhoe Power Station is unlikely to have a significant impact on the storage capacity or structural integrity of Wivenhoe Dam. Wivenhoe Power Station personnel are also familiar with the operation of both the Splityard Creek Dam and the power station itself and, accordingly, are best placed to monitor and direct the operation of Splityard Creek Dam. In those circumstances, it is unnecessary for control of the power station to devolve completely to Seqwater.

However, there is a strong argument for Seqwater to be given a more limited power of direction. As discussed above in *17.5.2 Interaction between Splityard Creek Dam and Wivenhoe Dam*, it is conceivable that a 40 millimetre increase in Wivenhoe Dam's level could require the dam operators to transition from one strategy to the next under the manual or result in the closing of a bridge downstream of Wivenhoe Dam under strategy W1: events which might not have taken place in the absence of the release. These potential effects underscore the need for a clearly defined protocol regarding releases, and militate in favour of granting Seqwater (through the flood engineers) some power to direct CS Energy to stop or delay releases from Splityard Creek Dam during flood events.

The Australian Energy Market Operator has indicated that it would have no objection to such an arrangement.[214] In any event, it is likely that Rule 4.8.9(c) of the National Electricity Rules would resolve any conflict between a direction of the Australian Energy Market Operator and one made by Seqwater. Rule 4.8.9(c) provides that a power generator is not required to comply with a direction from the Australian Energy Market Operator where to do so would be a hazard to public safety or contravene any law. The operation of Wivenhoe Power Station at a time when Seqwater has requested that releases be stopped because of Lake Wivenhoe's elevated level appears likely to constitute a hazard to public safety for the purpose of the National Electricity Rules.

It is, however, important to note the need to balance dam safety and flood mitigation considerations against the implications of shutting down Wivenhoe Power Station. In certain circumstances, the power generation benefits associated with operating the power station may be such as to justify additional releases into Wivenhoe Dam (provided no risk to the dam's structural integrity results).[215] Determining precisely how the balance between these competing interests should be struck is a matter for the Queensland Government.

Recommendation

17.22 The Queensland Government should consider whether to empower Seqwater, through the flood operations centre, to direct CS Energy to stop or delay releases from Splityard Creek Dam where a flood event is declared under the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*.

17.6 Somerset Dam cracks

Somerset Dam is a 47 metre high concrete gravity dam with a 308 metre long embankment. It is situated upstream of Wivenhoe Dam on the Stanley River. Somerset Dam's concrete structure includes two internal galleries (enclosed passageways within the dam wall): an upper inspection gallery positioned at a level of EL (elevation above sea level) 88.9 metres and a lower drainage gallery at EL 66.0 metres.[216]

Construction of Somerset Dam began in 1935 and was completed in 1953. The prolonged duration of construction is partly attributable to the suspension of work between 1942 and 1948 because of the Second World War.[217] For further information about Somerset Dam generally see section 2.2.7 of the interim report.

There was some suggestion, in media reports following the 2011 flood event, that Somerset Dam's flood mitigation capacity may have been reduced by cracks in the dam's wall, with implications for the way in which Somerset Dam and Wivenhoe Dam were operated. The matter was also raised by submissions which members of the public made to the Commission.

In light of these suggestions, the Commission has conducted a review of several reports relating to the structural integrity of Somerset Dam prepared between 1995 and 2010. The Commission has also had reference to the view of Mr Tibaldi, Seqwater's principal engineer, Dam Safety. This part of the report constitutes the Commission's findings consequent upon that review.

In short, the reports considered by the Commission, and the evidence of Mr Tibaldi, indicate that cracks in Somerset Dam do not presently have any material impact on its structural integrity. In saying that, it must be noted that the Commission has not independently investigated the stability of the dam and had no input into the scope of, or methodology adopted in, the reports considered.

17.6.1 Investigating the cracks

Like most mass concrete structures, Somerset Dam is susceptible to cracking. The majority of concrete cracking is caused by tensile stress which occurs when the material is subjected to pulling or stretching forces as a result of volume change. Such volume change is generally caused by:

- changes in the moisture content of the concrete
- chemical reactions within the concrete
- changes in concrete temperature
- irregularities in construction procedures, including, for example, significant delays
- stress from the application of loads.[218]

The presence of cracking in concrete reduces its tensile strength (making it more likely to be pulled apart).[219] Depending on its nature and location, cracking in a dam wall may make it more susceptible to the upward pressure generated by water in the dam and, in turn, likely to collapse at a lower water level than would otherwise be the case.

Cracks have been observed in a number of parts of Somerset Dam since at least 1939, well before the conclusion of construction.[220] The majority of these are hairline cracks that are unlikely to have any meaningful impact on the structural integrity of the dam. That said, potentially significant cracking has occurred in the concrete structure. Of particular note are two cracks observed on the downstream side of the upper gallery wall. The first of these cracks is located approximately 0.4 metres above the gallery floor; the other sits at approximately 1.6 to 1.8 metres above the floor. The latter crack extends for most of the length of the gallery.[221]

The cracks in the gallery wall have been the subject of a number of investigations in recent years.[222] The most recent of these was undertaken in 2008 by SMEC, an independent engineering consultancy firm. The report produced by SMEC revealed that the cracking is evident in a number of areas across the downstream face of the dam and, accordingly, is likely to extend uninterrupted from the gallery to certain parts of the dam face.[223] No significant cracking was identified on the upstream side of the gallery wall.[224]

On a more general level, the SMEC report echoed previous findings that the most likely cause of the cracking is a change in concrete volume resulting from the dissipation of heat following the completion of construction.[225] It also demonstrated that the concrete above and around the upper gallery is of good quality. There were no indications of alkali aggregate reaction (a chemical reaction that can reduce concrete strength) in the concrete structure and little evidence of air bubbles in the concrete.[226]

The SMEC report concluded that there was little, if any, movement of the concrete in the area around the cracks downstream of the gallery[227] and that the cracks do not appear to have any negative impact on the overall structural stability or operation of Somerset Dam.[228] The report did not provide an in-depth explanation as to how this conclusion was reached. To the contrary, it appears that the investigation conducted by SMEC was limited to a localised analysis of the cracks and the surrounding concrete. It did not evaluate the impact of the cracking on structural integrity in light of dam levels or other relevant factors.

Previous investigations, however, have included a more detailed analysis of Somerset Dam's stability. The dam is presently operated in accordance with the findings set out in the New South Wales Department of Commerce's 2005 report entitled Somerset Dam: Stability of Abutment Monoliths.[229] This report included an assessment of previous studies undertaken by SMEC and a further two independent engineering consultancy firms: Sinclair Knight Merz and GHD. It concluded that Somerset Dam would maintain structural integrity at the storage level likely to be reached during a flood with an average recurrence interval of 100 000 years (which, it stated, would produce a dam level of EL 109.75 metres).[230]

The Department of Commerce report observed that the cracks in the dam wall drain into the gallery.[231] This minimises the impact of water pressure on the dam wall and, in turn, reduces stability concerns. Cracking above or below the gallery, however, was identified as a 'critical unknown'.[232] Such cracking, it was said, would become a 'plane of weakness' that may be subject to substantial water pressure.[233]

While the Department of Commerce report indicated that Somerset Dam was likely to remain stable at a level of EL 109.7 metres,[234] the presence of cracks above or below the upper gallery would reduce stability at higher water levels and result in the concrete structure failing at a lower level than would otherwise be the case. The report

estimates that, if such cracking is present, the dam would fail at a level of EL 110.1 metres, below the probable maximum flood level of EL 110.7 metres.[235] Importantly then, the SMEC report did not locate any significant cracking above the upper gallery. There has not been any comprehensive investigation, whether by SMEC in 2008 or otherwise, into the existence of further cracking below the upper gallery.

In 2009, Seqwater's annual dam safety inspection report (prepared by Mr Tibaldi, Seqwater's current principal engineer, Dam Safety) included the following reference to the cracking:

> This issue was last examined several years ago and it is recommended that the issue be revisited to fully understand any dam safety issues associated with this cracking.[236]

Seqwater's 2011 annual dam safety inspection was conducted by a dam safety engineer reporting to Mr Tibaldi. The 2011 inspection report included a reference to the cracking in precisely the same terms:

> This issue was last examined several years ago and it is recommended that the issue be revisited to fully understand any dam safety issues associated with this cracking.[237]

Notwithstanding the comments in the 2011 inspection report, Mr Tibaldi has stated that, having reviewed in detail the engineering reports into the cracking as part of the five year comprehensive dam safety inspection report in September 2010, and having considered the issue again in response to a requirement sent by the Commission on 20 December 2011, he considers that the crack is not presently an 'issue of structural concern'.[238]

The non-overflow crest level of Somerset Dam is EL 107.46 metres. Above this level, water will overtop part of the dam wall and be discharged onto its downstream face. The analysis contained in the Commerce report is predicated on an assumption that such overtopping will not result in the flooding of the gallery. If the gallery is flooded during overtopping, the stability of the dam will be markedly reduced.[239] In view of this, the Department of Commerce report recommended that the dam layout and waterproofing be reviewed to confirm that the gallery systems will not be flooded by an overtopping event. Seqwater should ensure that this is the case.

The material before the Commission tends towards a conclusion that the cracking in the Somerset Dam wall is not presently a threat to the dam's structural integrity. Given, however, the significant implications of a collapse of the Somerset Dam wall, the dam safety regulator may, as part of a review of the dam's safety under sections 353 to 355 of the *Water Supply (Safety and Reliability) Act 2008*, wish to review the materials on which this conclusion is based and consider whether any further investigations are necessary to ensure that the cracking does not compromise dam safety. From the perspective of ensuring that the cracking does not affect the operation of the dam, it may be prudent for Seqwater to commission an investigation into the extent of cracking below the level of the upper gallery and the impact of any such cracking.

Recommendations

17.23 Seqwater should consider commissioning an investigation into the extent of cracking below the level of the upper gallery of Somerset Dam and the impact of any such cracking on the dam's stability and, in turn, its operation.

17.24 Seqwater should ensure that the Somerset Dam gallery is not susceptible to flooding during overtopping events.

17.6.2 Monitoring the cracking

Between 1969 and 1984, instruments were installed at 22 measurement points to monitor movement of the larger crack in the upper gallery.[240] The SMEC report recommended that the crack in the upper gallery continue to be monitored at least every four months. Since receiving that report, Seqwater has monitored the cracking on a monthly basis.[241]

Cracking recorded at each of the 22 measurement points was also assessed as part of the Five Year Comprehensive Dam Safety Inspection Report in September 2010. The safety report detailed the changes at each measurement point over the previous 11 years. It indicated that the crack opened between 0.5 millimetres and 1.1 millimetres at

each point during that period. After averaging the measurements observed at each of the points, the safety report concluded that the crack has opened at a rate of 0.064 millimetres per year for the past 11 years.[242]

The SMEC report also recommended that the cracking be inspected immediately following any significant inflows into the dam. During the course of the January 2011 flood, the cracking was monitored at least daily.[243] Additionally, the cracking has been reviewed following all significant inflows into the dam since the flooding.[244] Monitoring during and since the flooding has not revealed any significant change in the cracking.[245]

17.6.3 Impact of the cracking on the operation of Somerset Dam during floods

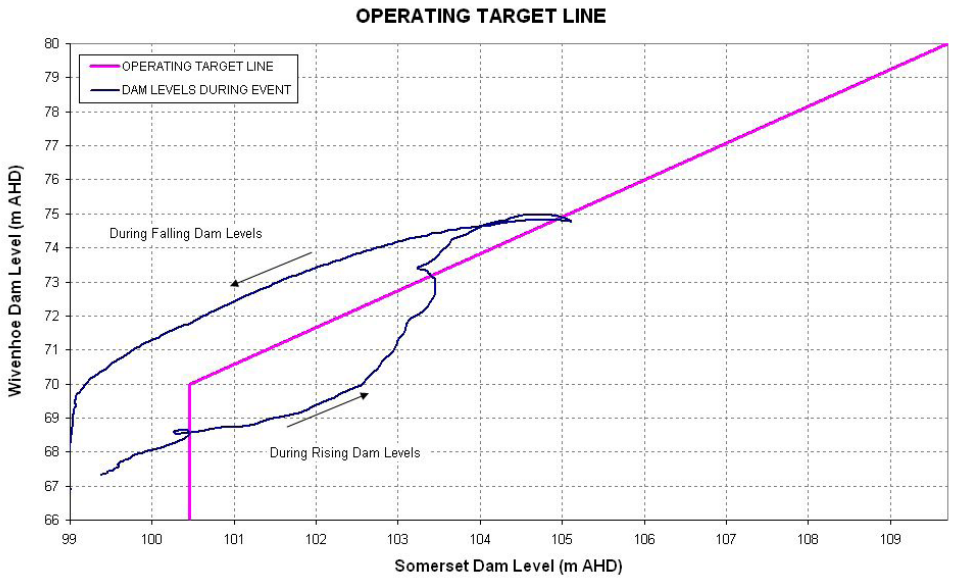
The peak water level at Somerset Dam in January 2011 was EL 105.11 metres.[246] This is significantly below the level identified by the Department of Commerce report as the point at which the structural stability of the dam may be compromised.

No comprehensive investigation into the impact of the cracking on the stability of the dam during and after the flooding has been undertaken. There is, however, no indication that the presence of the cracking posed any risk to the dam's structural integrity.

Seqwater has submitted that the presence of the cracks did not alter the way the dam was operated during the January 2011 flooding.[247] Neither the manual nor the flood event report contains any mention of the cracking or other stability concerns in relation to Somerset Dam.[248]

The manual includes an operating target line that provides guidance as to what the dam level at Somerset Dam should be when Wivenhoe Dam is at a particular storage level and vice versa: see Figure 17(c) below, which sets out the operating target line relative to the water levels at Wivenhoe and Somerset dams during the flood event.[249] This target line was developed on the basis of an assumption that the maximum storage capacity prior to dam collapse at Wivenhoe is EL 80 metres and at Somerset Dam it is EL 109.7 metres.[250] The critical level adopted for the purposes of Somerset Dam accords with the findings of the Department of Commerce report; it has not been reduced, at least since 2005, on account of stability concerns. It should be noted that the Commission has not investigated whether Seqwater has ever considered the water level at which the dam will fail to have been higher or lower than EL 109.7.

Figure 17(c)



Wivenhoe/Somerset Operating Target Line throughout the January 2011 Flood Event
Source: Exhibit 24, January 2011 Flood Event Report on the Operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p203].

The target line indicates that when Wivenhoe Dam is operating at 75 metres, Somerset Dam should be operated in such a way that its water level is approximately 105 metres. Wivenhoe Dam's lake level peaked at 74.97 metres Australian Height Datum at 7.00 pm on 11 January 2011. At that time, Somerset Dam's level was 104.6 metres. Somerset Dam's peak level of 105.11 metres was observed between 6.00 am and 9.00 am on 12 January 2011, at which time Wivenhoe Dam's level ranged between 74.77 and 74.78 metres Australian Height Datum.[251] As is apparent from the figure above, the water levels at Somerset were maintained at levels that accord fairly closely with the operating target line. There is nothing to suggest that the cracks in the dam wall led the operators of Somerset Dam to release more water than would otherwise have been the case.

17.7 Bridges and crossings near Wivenhoe, Somerset and North Pine dams

17.7.1 Crossings downstream of Wivenhoe, Somerset and North Pine dams

The January 2011 flooding and consequent dam releases resulted in the inundation and closure of a number of bridges downstream of Wivenhoe Dam. Two crossings downstream of North Pine Dam were also affected by floodwaters released from dams: Youngs Crossing and the A J Wyllie Bridge.[252]

Bridge closures are often inconvenient, forcing people to take alternative routes that extend their travel time. In some instances, their impact is more critical, restricting residents' access to essential supplies and hampering the efforts of emergency services personnel to provide needed assistance, including medical treatment or evacuation.[253] The Commission received a number of submissions from people expressing concern as to the frequency with which particular bridges downstream of the dams were closed.[254]

The impact of bridge closures is taken into account in the Wivenhoe manual.[255] When releases from Wivenhoe Dam first commence, dam operators make use of strategy W1, which aims to minimise disruption to downstream rural life by limiting releases so that particular bridges and crossings are not submerged.[256] The manual also notes that, following flood events, the operation of the dams should not unnecessarily prolong the inundation of the bridges.[257]

The Wivenhoe manual identifies seven bridges downstream of Wivenhoe Dam that may be affected by releases during flood events:[258]

- Twin Bridges on Wivenhoe Pocket Road
- Fernvale Bridge on Brisbane Valley Highway
- Savages Crossing on Banks Creek Road
- Burtons Bridge on Summerville Road
- Kholo Bridge on Kholo Road
- Mr Crosby Weir Bridge on Allawah Road
- Colleges Crossing on Mt Crosby Road.

Several of these bridges are submerged at relatively low flow rates. Twin Bridges, for example, is inundated when Brisbane River flows exceed 50 m^3/s. Colleges Crossing, which is used by a significant number of vehicles, is submerged when river flows are between 175 m^3/s and 200 m^3/s.[259]

The seven bridges fall under the control of the Department of Transport and Main Roads (Colleges Crossing and Fernvale Bridge), Somerset Regional Council (Burtons Bridge, Twin Bridges, and Savages Crossing) or Brisbane City Council (Mt Crosby Weir and Kholo Bridge).

Youngs Crossing and AJ Wyllie Bridge, both at Petrie, cross the North Pine River. The Moreton Bay Regional Council controls Youngs Crossing, while A J Wyllie Bridge is under the control of the Queensland Government. As the Commission's interim report described,[260] Youngs Crossing was closed 18 times during the 2010/11 wet season because of releases from the North Pine Dam. Seqwater concluded in its flood event report that if Youngs Crossing were raised so that it was not submerged by flows under 300 m^3/s, 16 of the 18 closures could probably have been avoided.[261]

17.7.2 Upgrading bridges and influence on dam operations

Potential to upgrade bridges

The height and positioning of downstream bridges is of importance not only for the people who regularly travel over them, but also for the operation of Wivenhoe, Somerset and North Pine dams. Upgrading particular bridges to make them less susceptible to closure would, for example, provide additional flexibility to Seqwater in managing releases from Wivenhoe Dam under strategy W1, and in the drawdown of the lake level following a flood event.[262]

The Department of Transport and Main Roads has indicated that it works with local councils in considering bridge construction and upgrades.[263]

A range of matters needs to be taken into account in determining whether, how and where to upgrade (or build) river crossings, not least of which is the significant cost likely to be involved in such projects.[264] An in-depth cost-benefit analysis will be necessary before any decision can be made.

The possibility of upgrading crossings downstream of North Pine Dam was considered in the Commission's interim report.[265] After reviewing the impact of flooding between 10 October 2010 and 5 March 2011 on both Youngs Crossing and the AJ Wyllie Bridge, the Commission recommended that that Moreton Bay Regional Council undertake a cost-benefit analysis of options for the upgrade of Youngs Crossing to determine an outcome which best serves the public interest.[266]

In relation to river crossings downstream of Wivenhoe Dam, the Commission notes that the Department of Transport and Main Roads is presently undertaking a planning study to investigate options for an additional Brisbane River crossing in the Moggill/Ipswich West region. As part of this study, which it expects to complete by early 2012,[267] the department is investigating upgrades to a number of surrounding roads in an attempt to improve flood immunity. The study is confined to the Moggill/Ipswich West Region and does not consider upgrades to other downstream bridges and surrounding roads.[268] The Commission is not aware of any other plans to upgrade or create new bridge crossings downstream of Wivenhoe Dam.

The decision as to whether the upgrade of any bridge is justified is one for the Queensland Government, together with the relevant council. Seqwater will, following its review of the Wivenhoe manual, present the Government with options for release strategy and supply levels (see the discussion below and section *17.1 Longer term review of the Wivenhoe and North Pine manuals*); any decision as to bridge upgrade should be made with the benefit of that information.

Recommendation

17.25 The Department of Transport and Main Roads, in conjunction with Brisbane City Council and Somerset Regional Council, should investigate options for the upgrade of Brisbane River crossings between Wivenhoe Dam and Colleges Crossing and undertake a cost-benefit analysis of these to determine the outcome which best serves the public interest.

The impact of bridge upgrades on dam operating strategies

As observed above, any upgrade of existing bridges or development of new bridges on the Brisbane and North Pine rivers is likely to be relevant to the operation of the relevant dams.

Accordingly, the longer term review of the Wivenhoe manual and the North Pine manual ought to consider any plans for the upgrade of both upstream and downstream bridges affected by the operation of, respectively, Wivenhoe and Somerset dams or North Pine Dam. See also recommendation 17.3 above.

Seqwater has confirmed that it proposes to consider raising or upgrading of downstream bridges as part of the Wivenhoe Dam and Somerset Dam Optimisation Study.[269] The Commission considers that Seqwater should take any possible upgrade of the bridges into account when it performs modelling over a range of operating strategies as part of this study. It should design strategies that do not limit flows by reference to the need to keep some or all of the bridges open, and model the flood mitigation benefits of removing that restriction. Having done so, Seqwater

should give clear advice to the Queensland Government and relevant local councils as to the flood mitigation effects of upgrading each of the bridges. The same process should be followed in modelling strategies for the operation of North Pine Dam, and advice given accordingly as to the effects of upgrading the affected bridges. See also recommendation 17.4, above.

These processes should, as far as possible, occur concurrently with Department of Transport and Main Roads and local council investigations into the costs associated with upgrading each bridge.

Recommendation

17.26 As part of the longer term review of the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, the Queensland Government should consider the impact of possible upgrades of bridges downstream of Wivenhoe Dam on different operating strategies for the dam.

17.7.3 Communication of bridge closures

Both the Wivenhoe and North Pine manuals provide that, prior to the closure of a bridge because of releases of water from the dams, the flood engineer on duty should notify the government agency responsible for the particular bridge so that it is able to make arrangements for its orderly closure.[270] Neither manual makes provision for such advice to be given directly to the Department of Community Safety or emergency services agencies.

There is also no such provision in the Wivenhoe Dam Emergency Action Plan[271] or the North Pine Dam Emergency Action Plan,[272] despite the fact that each includes an appendix entitled 'Road Closure/Public Notification Arrangements During Flood Events' which includes contact details for, respectively, representatives of the Somerset and Moreton Bay councils.[273]

The earlier emergency services and other agencies are notified of likely bridge closures, the better they are able to adjust accordingly; for example, by relocating personnel and amending response protocols.[274] Seqwater should, therefore, aim to expedite the communication of information regarding releases from all three dams, where possible providing such information directly to relevant emergency services agencies.

These considerations appear to have been addressed in the draft Dam Release Communications Protocol for the Brisbane River Catchment. This document contemplates the provision of advice regarding floodwater releases to, among others, Emergency Management Queensland, the Queensland Police Service and relevant local councils. The advice is to be provided in the form of a dam situation report. The template for the dam situation report appended to the protocol includes a range of information about dam levels, releases, the impact of releases on bridges downstream, and rainfall forecasts.[275]

In making these comments about communication arrangements, the Commission reaffirms the recommendations made in the interim report to the effect that:

- Seqwater consider creating a designated communications position within the flood operations centre[276]
- Seqwater consider consolidating its communication arrangements in a single document for each dam it operates.[277]

17.8 Lenthalls Dam

Lenthalls Dam is located in the Fraser Coast Regional Council area, on the Burrum River close to the town of Howard, and is owned and operated by Wide Bay Water Corporation.[278] The dam is referable (one which poses a risk to the safety of two or more people should it fail)[279] and has a population at risk of 270 people.[280]

The Commission's investigation has been primarily concerned with the fact that, since their installation on the dam in February 2007, different gates have operated at varying levels of effectiveness during a number of floods.

The dam came to the attention of the Commission through a submission made by a concerned member of the public. The submitter's family owns and resides at a property upstream of the dam. Flooding on this property has been worsened on a number of occasions since 2008 by backwater resulting from the inoperability of some of the dam's gates during floods.[281]

The Commission has considered the communications since 2008 between Wide Bay Water and residents about the operation of the dam; the issues raised are described, in a general sense, in section 4.1.4 of the Commission's interim report and are dealt with by the recommendations contained in that section.

17.8.1 Installation and design of the crest gates

In February 2007, Lenthalls Dam's embankment was raised by 60 centimetres and five crest gates were installed on the existing spillway of the dam to increase the dam's full supply level by two metres to 26.0 metres.[282] The crest gates used had been successfully installed as part of new dam projects elsewhere but had never before been used to raise the full supply level of an existing dam, or installed on a dam with a curved crest, like Lenthalls Dam.[283]

The gates comprise four 14.8 metre wide gates (gates 1, 2, 4 and 5) and one 9.8 metre wide gate (gate 3) which is centrally positioned between the other gates.[284]

Automatic operation

The gates are designed to open automatically as the water level of the dam rises.[285] Their automatic operation is triggered by water filling buoyancy tanks inside the gates as the dam level rises; as the weight of a gate increases it drops and opens to allow greater flood releases.[286] As the dam's water level lowers, the buoyancy tanks drain, allowing the gates to lift and close, stopping the discharge of water.[287] Gate 3 is designed to open first, when the dam's full supply level is exceeded by 150 millimetres, followed by the others in succession, at 50 millimetre intervals.[288]

Manual operation

The crest gates can also be operated manually, in two ways. Each gate has a manual inlet valve which allows the tank in the gate to fill with water and open.[289] Opening the inlet valves allows for testing of the gates, or for the dam operator to lower the level of the dam at their discretion.[290] This procedure was codified in September 2008.[291] In instances where opening the inlet valve has not worked, a hydraulic jack has been used on some of the gates to make them operate.[292] Both means of manual operation have been used when gates have failed to open automatically during floods at the dam.

Testing

The automatic opening and closing of the gates, dependent as it is on water entering and leaving the buoyancy tanks, can only be observed as the water level of the dam rises and falls.[293] The ability of the gates to be manually opened and closed can be tested when the water level is low.[294] Being able to successfully open a gate manually does not mean that the gate will open automatically in flood as designed. That restriction on testing automatic operation explains in some part the sometimes lengthy intervals between identifying a solution and testing it. To better monitor the gates, Wide Bay Water has advised the Commission that it is considering, with a view to installation as soon as practicable, the use of closed circuit television cameras and gauges to measure the opening position of each gate.[295]

Crest gates on the spillway of Lenthalls Dam (photo courtesy Wide Bay Water)

17.8.2 Chronology of floods since installation of the gates

Since the installation of the gates in 2007, there have been seven floods that have exceeded the 'trigger event', defined in the emergency action plan, at which the gates are expected to operate.[296] Different gates have performed to varying levels of effectiveness during these floods; at times they have failed to operate as designed.

February 2008 flood

On 29 January 2008, in the lead up to the February 2008 flooding, Wide Bay Water staff manually opened gate 3 at a lake level of 25.44 metres.[297] Heavy rainfall commenced on 5 February 2008, causing the dam level to peak on 12 February 2008 at 27.41 metres.[298] The crest gates should have begun to open automatically at 26.15 metres.[299] In correspondence between Wide Bay Water and DERM on 10 March 2008,[300] the former gave this account of the gate openings from 5 February 2008:

- gate 3 opened automatically for a period on 16 February 2008, and
- gate 1 was opened by a hydraulic jack on 18 February 2008.[301]

The failure of most of the gates to operate as designed during the flood worsened flooding upstream of the dam.[302]

GHD, the designer of the crest gates for Lenthalls Dam, was engaged to prepare a report investigating the impact of the February flood on upstream properties.[303] GHD's investigations confirmed that most of the gates failed to operate as designed during the flood and that this increased river heights near these properties.[304] GHD also identified excess pressure on the gates' lintel seals as a likely cause of the gates' failure.[305] This issue and the work undertaken to rectify it are discussed at section *17.8.3 Observed problems and solutions implemented.*

May/June 2008 flood

Another flood occurred over May and June 2008. As with the February 2008 flood, some of the gates did not operate as designed.[306] Gate 1 was manually opened with a hydraulic jack on 30 May 2008, and gate 3 opened automatically on 5 June 2008, although this opening occurred later than anticipated according to its design sequence.[307]

March 2010 flood

Rainfall commenced in the catchment on 1 March 2010, and the dam level peaked at 26.45 metres on 6 March 2010.[308] During this flood a number of gates opened, some automatically, and some with manual assistance.

Gate 2 opened automatically as designed three times over the course of the flood.[309] Gate 4 opened automatically on 6 March 2010.[310] Gate 3 did not initially open as designed, but on 9 March it opened automatically after the level of the dam had begun to fall.[311]

Unsuccessful attempts were made to open both gates 1 and 5 manually by opening their inlet valves on 6 March 2010.[312] Gate 1 was opened with the use of a hydraulic jack that day, and was opened manually by using the inlet valve on 7 March.[313] All attempts to open gate 5 failed.[314]

First December 2010 flood

The trigger event of 26.10 metres was reached early on 12 December 2010.[315] At this time, attempts to open gate 5 manually, first by using the inlet valve, and then with a hydraulic jack, failed.[316] Gate 1 was manually opened that morning, although it closed for a few hours when the dam level was 550 millimetres above full supply level, and opened again as the dam levels continued to fall.[317] According to Wide Bay Water, gate 1 should have stayed open until the level of the dam reached 350 millimetres above the full supply level.[318]

Gate 4 was also manually opened on 12 December, while gate 2 operated as designed by opening automatically.[319] The peak of the dam was reached late in the evening on 12 December 2010.[320] Neither gate 3 nor gate 5 opened at all, either automatically or manually, throughout the course of this flood.[321]

As a result of this flood, a second possible cause of the gate failures emerged: a problem with the air venting system in the gates.[322] This is discussed further at section *17.8.3 Observed problems and solutions implemented*.

Second December 2010 flood

On 15 December 2010, the chief operating officer of Wide Bay Water made a decision based on forecast rain to the dam catchment area to open gate 1 to control the rate at which the dam level was rising.[323] After some difficulty, the gate was opened manually on 16 December 2010.[324]

After gate 1 was opened, the chief operating officer came to the decision that the level of the dam could not be adequately controlled with only one gate open.[325] Consequently, on 17 December 2010, attempts were made to open both gates 4 and 5 manually, using a hydraulic jack. These attempts failed.[326] Gate 1 was the only crest gate open at this stage, even though the dam level was 26.54 metres and all of the gates should have been operating.[327]

The level of the dam peaked on 17 December 2010 at 26.78 metres.[328] At the time of the peak, operational staff observed that gate 1 had partially closed.[329] The dam level fell for a period, but started to rise once again on 18 December 2010, reaching another peak on 20 December 2010.[330]

An attempt to open gate 2 manually was proposed on 19 December 2010; Wide Bay Water's chief operating officer rejected the suggestion because both the weather and the dam levels meant that the procedure could not be completed safely.[331]

The dam level began to fall after peaking on 20 December 2010 at 26.89 metres.[332] Early on the morning of 21 December 2010, gate 2 was opened manually; the lake level was 26.46 metres and all gates should have been open.[333] After the successful manual operation of gate 2, the inlet valves of all other gates were opened manually; as a result, gate 1 opened.[334] For the second time during this flood, attempts were made to open gates 4 and 5 with a hydraulic jack:[335] again, these attempts were unsuccessful.

Third December 2010 flood

During this flood, the dam peaked at 28.12 metres on 28 December 2010, at a level higher than that of the February 2008 flood.[336] With the exception of gates 1 and 5, all gates opened automatically at times.[337] Gate 1 was opened manually with the assistance of a hydraulic jack.[338] Gate 5 failed to open at any time.[339] The chief operating officer had concerns that gates 2, 3 and 4, which did open automatically during the flood, were not remaining open as designed.[340] Specifically, he could not be sure if gates 2, 3 and 4 were closing entirely, or partially closing, during the flood.[341]

This generated a third possible reason for the inability of the gates to operate as designed: hydrodynamic forces may have been causing the gates to rise during a flood.[342] This issue is discussed further at section *17.8.3 Observed problems and solutions implemented.*

January 2011 flood

After the floods experienced during December 2010, some of the gates were kept open to lower the level of the dam.[343] Rainfall began to fall in the catchment on 3 January 2011, with levels in the dam peaking on 8 January at 26.94 metres.[344]

The chief operating officer recalled that gates 2, 3 and 4 opened automatically during the flood; there is no event log for this flood to confirm this.[345] Gate 5 did not open at all during the flood.[346] Gate 1 closed on 11 January 2011 after its manual valve was closed.[347] The manual valve on gate 2 was left open until 12 January, to manage the inflows into the dam.[348]

17.8.3 Observed problems and solutions implemented

The seven floods that have occurred at Lenthalls Dam since the installation of the crest gates have exposed problems with the gates' operation but have also allowed Wide Bay Water, the gate designers, and associated external consultants, to identify possible reasons for the varying levels of effectiveness of the gates during floods. This is because the capability of the crest gates, and the efficacy of possible solutions, cannot be tested until the water level rises to the relevant threshold, which generally requires the occurrence of a flood.[349]

Three problems with the gates' operation have been identified:

- pressure on the lintel seals of the gates, which has proved so great that the weight of the gates during floods has not been enough to make them drop as designed
- problems with the air venting system inside the gates
- hydrodynamic forces causing the gates to close or partially close, after opening, as the dam level rises.

Excess pressure on the gate lintel seals

At the time of installation, each crest gate was fitted with a seal to prevent water leaking out of the gate or beside the gate.[350]

As a result of the February 2008 flood, GHD, the designer of the crest gates, identified these seals as a likely cause of the failure of the gates to open; the seals proved so effective that the pressure on the gates during flood events was excessive and prevented them lowering as intended.[351]

In response to the gate failures during the February 2008 flood, and subsequently during the May/June 2008 flood, a site inspection and testing were carried out by Wide Bay Water; it was established that the gate seals needed modification.[352] GHD prepared a report outlining various options to address this problem.[353] A program of works to adjust the gate seals to reduce their friction loads, titled 'Seal Improvement Program', was carried out by Wide Bay Water between December 2008 and February 2009, on advice from GHD.[354]

Following the completion of the 'Seal Improvement Program', Wide Bay Water carried out testing on the gates to assess the operability of the crest gates.[355] This testing involved manual opening of the gates at water levels below 26.0 metres and revealed that the gates were operational following the improvement program;[356] the automatic opening of the gates was not able to be tested at that water level.

An external consultant engaged by Wide Bay Water found that the seal modifications had been effective in dramatically reducing the high lintel seal friction forces, which were now consistent with expectations.[357]

Problems with the air venting system

Following the first December 2010 flood, Wide Bay Water's chief operating officer discussed with GHD a perceived problem with the air venting in the crest gates.[358] The solution suggested was drilling an 11 millimetre hole on top of the access hatch of each of the gates, enabling air trapped in them to be released.[359] This solution was initially tested on 21 December 2010 on gate 1, and manual tests confirmed the gate would operate with the holes in place.[360] The same procedure was adopted for the remaining gates on 22 December 2010.[361]

GHD undertook work to identify a permanent solution relating to the air venting system that would improve the performance of the gates.[362] In its June 2011 report, GHD stated that air becoming trapped in the gates' pipework caused a water lock preventing the gates from working.[363] GHD suggested modifying the vent system to allow the release of water trapped in the pipework after the gates had been lowered and raised.

To achieve this, snorkels have been installed on top of the holes in the gate access hatches to help release trapped air.[364] Since the addition of the snorkels, Wide Bay Water has been able to open all crest gates manually, except gate 5.[365]

An external consultant engaged by Wide Bay Water to peer review the snorkel solution regarded it as a successful arrangement, which could be adopted in a permanent form.[366]

Hydrodynamic forces and the 'rising' behaviour of the gates

Dam operation staff witnessed one of the gates partially closing during the second flood at the dam in December 2010,[367] a problem again observed by Wide Bay Water's chief operating officer during the third December 2010 flood.[368] GHD, in a report completed after that flood, confirmed that although gates 2, 3 and 4 operated automatically during the early stages of the flood, they closed as the dam levels continued to rise.[369] Once the dam levels began to drop again, the gates appeared to open as designed.[370]

As with the other problems previously identified, Wide Bay Water has been working closely with GHD to arrive at a solution for the 'rising' behaviour of the gates observed during December 2010.[371] The first solution GHD proposed involved the installation of a hydraulic spoiler to the crest gates, but after modelling it was deemed not workable.[372]

The other solution proffered by GHD involved building a flow deflector upstream of the crest gates; computer modelling and concept development of this device is currently being carried out to test its efficacy. If this solution is found to be workable, it will be subject to a peer review by external consultants engaged by Wide Bay Water.[373] Following that review, the solution will be provided to DERM for comment, before submission to Wide Bay Water's board of directors for consideration. Wide Bay Water anticipates that it will be able to make a recommendation to the board in the first quarter of 2012.[374] A detailed design needs to be devised before the project can be put out to tender; Wide Bay Water has already commenced preparing a shortlist of contractors to save time in the event that the proposed solution proves workable.[375]

Two external consultants engaged by Wide Bay Water are currently conducting a peer review of the solution proposed by GHD in relation to the 'rising' behaviour of the gates.[376]

17.8.4 Current status of gate operability

Although the manual opening procedure has proved invaluable during the floods that have occurred at the dam, it cannot be relied on in every instance. This has been demonstrated by the floods where some of the gates, not just gate 5, have failed to open manually either through opening the inlet valve or with hydraulic assistance.[377]

The solutions implemented by Wide Bay Water to counter the pressure on the lintel seals and the air vent issues have improved the functioning of most of the gates. Following the installation of snorkels on the inlet valve, all gates except for gate 5 can be manually operated by opening their inlet valve.[378]

Wide Bay Water's chief operating officer was of the view in October 2010 that all crest gates, excepting gate 5, are capable of automatic operation.[379] The accuracy of that view cannot be confirmed until the onset of another flood.

The inoperability of gate 5 has been a recurrent problem. The gate was opened manually with a hydraulic jack on 12 October 2011,[380] 25 October 2011 and 3 November 2011.[381] The current expectation is that it will continue to be operable with the assistance of a hydraulic jack.[382]

Despite four years of work and investigation by Wide Bay Water and its external consultants, Wide Bay Water's chief operating officer cannot confirm that all the gates will work as designed.[383] If the solutions currently under review prove ineffective or impracticable, Wide Bay Water should investigate the feasibility of replacing the existing gates, or removing them altogether.

17.8.5 Dam safety implications

It might be thought that a failure of dam gates to open is a dam safety concern. Certainly, the failure of some of the gates in floods has caused water to back up more than is usual.

However, at their worst (if all spillway gates could not open), the problems with the gates do not prevent the dam from passing a flood of the capacity required by DERM's Guidelines on Acceptable Flood Capacity for Dams.[384] The dam spillway can pass a flood with an average recurrence interval of 2 000 000 years, if all gates operate as designed,[385] and a flood with an average recurrence interval of 50 000 years if none of the spillway gates were to open.[386] Additionally, given the current functionality of gates 1, 2, 3 and 4, DERM considers that there is 'not a very high risk' that failure of the gates to fully open will cause failure of the dam.[387]

The Commission asked DERM whether it has considered taking compliance action in respect of the dam and is advised that, although such action has been considered in respect of the operation of the spillway gates, it presently considers compliance action unsuitable because Wide Bay Water is doing 'as much as they can to correct the gate operational problems'.[388]

17.8.6 Preparing for wet seasons

In the lead up to the 2010/2011 wet season, Wide Bay Water:

- undertook a disaster simulation to test its response to the occurrence of a tropical cyclone[389]
- prompted by media coverage of the possible active wet season, held informal discussions with key staff about gate operations (no minutes were taken)[390]
- tested the ability of each gate to open and close and cleared the air venting system and pipework in the gates.[391]

In early December 2010, Wide Bay Water provided DERM with an annual report demonstrating compliance with its dam safety conditions. This report included specific advice on the operability of the crest gates.

Prior to the 2011/2012 wet season, Wide Bay Water opened the gates on a rotating basis to ensure their operability, and to release water from the dam.[392] In accordance with the standard operating procedures and operating and maintenance manual, general maintenance has been carried out, including clearing air vents and pipework.[393]

As part of its wet season preparedness more generally, Wide Bay Water tests the gates annually at the 'time of the first spring rains', generally through October and November.[394]

The Commission considers that Wide Bay Water's wet season preparation could be improved if it were to:

- conduct a flood simulation exercise which includes implementing contingency plans for the situation in which one or more of the gates fails to open automatically and/or manually
- hold meetings with key staff about gate operations and keep minutes of these meetings to provide a complete record for staff of the current strategy or procedures proposed for gate operations and floods.

In addition, given the persisting difficulties with the crest gates, DERM should seek to confirm the operability of the gates at Lenthalls Dam prior to all wet seasons until their operating problems are completely rectified.

Recommendations

17.27 Wide Bay Water should, in addition to its usual wet season preparations and maintenance, undertake the following activities in advance of each wet season:

- conduct training for personnel on dam operation, including contingency plans for the situation in which one or more of the gates is inoperable
- hold meetings of key personnel of Wide Bay Water involved in the operation of the dam during floods, which:
  - in addition to any other matters, inform staff about the current status of the gates, dam operation strategies and contingency plans for the situation in which one or more of the gates is inoperable
  - are recorded in minutes which document the information provided and are made available to all operational staff.

17.28 The Department of Environment and Resource Management should require Wide Bay Water, in advance of every wet season, to provide details of its expectation as to the operability of the crest gates if a flood occurs, until such time as all gates have been demonstrated to work as designed.

17.9 Detention basins in Toowoomba city

The Commission received a number of submissions from residents of the Toowoomba Regional Council area calling upon the council to mitigate the flood risks associated with East Creek, West Creek and Gowrie Creek.[395]

In response, the Commission investigated the council's and the Queensland Government's actions in respect of creek works, including detention basins,[396] designed to alleviate the impacts of flood in East and West creeks.

East and West creeks flow from the south, meeting to the north of the Toowoomba central business district to form the Gowrie Creek system.[397] The waterways and catchments of both creeks are steep, and the water runs quickly down the slopes. This contributes to swift rainfall runoff.[398] A full description of the Toowoomba catchments is contained in the Commission's interim report at section 7.1.1.

17.9.1 Flood mitigation actions by Toowoomba Regional Council

The former Toowoomba City Council investigated the need for creek works, including detention basins, to minimise the flood impacts of the Gowrie Creek system and to improve the capacity of the creeks to accommodate these flood mitigation measures.[399]

Following these investigations and community consultation, the council adopted the Gowrie Creek Catchment Management Strategy on 13 October 1998.[400] The strategy's suggested implementation period is 20 to 25 years.[401] The Toowoomba Regional Council has continued to implement this strategy since amalgamation in 2008.[402]

The strategy recommends structural measures, including detention basins, changing the profile and alignment of the creek channel,[403] and non-structural measures, such as town planning controls, to minimise flooding.[404] Initially the works proposed included 22 detention basins, 10.5 kilometres of channel improvements, 53 pool/riffle structures and 18 kilometres of revegetation.[405] These measures were calculated to provide protection against a 1% AEP flood.[406] However, the Toowoomba City Council reduced the number of basins, but increased their size on the basis of expert engineering and landscaping investigations coupled with detailed design plans and reports.[407] The final proposal under the strategy is for the construction of six detention basins on West Creek and three on East Creek.[408] The Commission's consideration is confined to the detention basins, proposed and existing.

The construction of the basins is not yet complete. The method of construction has been sequential, starting at the top of West Creek and working downstream. The aim is an accrued mitigation affect on flooding in Toowoomba city.[409]

As at 21 October 2011, five detention basins along West Creek and one on East Creek were in place.[410] The final basin for West Creek will be built once the land designated for it reverts to council control after the expiry of private leases in March 2012.[411]

WBM Engineering and Environmental Consultants were engaged by Toowoomba City Council in early 2005 to review the contents of the 1998 strategy.[412] As a result, the Gowrie Creek System Flood Risk and Mapping Study was presented to the Toowoomba City Council in mid-2007.[413] Focussing on flood risk and the accurate mapping of design floods,[414] the study confirmed that the existing detention basins, and those yet to be built, were necessary to minimise the number of properties affected by a 1% AEP flood in the creek catchments.[415] Further design work for two detention basins to be built along East Creek was recommended as part of this study.[416]

The Toowoomba City Council's last capital works plan, produced in 2007, did not allocate any funding over following financial years for the works suggested under the 1998 strategy and the subsequent 2007 study, and no further basins have been built.[417] The general manager of the Toowoomba Regional Council's Water and Waste Services Group has explained that the former council's decision not to allocate more funding for the financial years up to and including 2010/2011 was the result of the need for investigation in relation to the East Creek basins and the unavailability, pending the expiration of the relevant leases, of the land for the West Creek basin.[418]

Prior to the January 2011 flooding, the Toowoomba Regional Council considered the detention basins and channel improvements to have substantially increased the stormwater capacity of West Creek.[419]

The 10 January 2011 flooding in Toowoomba exceeded 1% AEP flood levels.[420] A technical report prepared by BMT WBM for the purpose of assessing the flooding found that the magnitude of the event meant that even if all mitigation measures had been complete, overtopping of crossings and damage to property would still have occurred.[421] Despite this, the presence of the structural flood mitigation measures in the Gowrie Creek catchment did assist in easing the flooding on 10 January 2011.[422]

Toowoomba Regional Council is continuing the 20 to 25 year implementation of the 1998 strategy to achieve the 'ultimate catchment development design goal' of containing a 1% AEP flood.[423] Further works in accordance with this strategy are planned, with funds allocated in the 2011/2012 council budget to continue work on two East Creek basins, and to commence work on the final West Creek basin once the requisite land reverts to the council.[424]

The Toowoomba Regional Council has relied on assistance from the Queensland and Commonwealth governments to implement this program. Its most recent application to the Commonwealth Government for funds was unsuccessful.[425] The council has advised the Commission that it does not have the means to accelerate or expand the program without financial assistance.[426]

17.9.2 DERM's dam safety and failure impact assessment

DERM, which is responsible for dam safety regulation, has considered assessing the East Creek and West Creek detention basins to ascertain whether they are referable dams. A referable dam is a dam assessed as posing a risk to the safety of two or more people should it fail.[427] The dam safety regulator can impose dam safety conditions on referable dams to reduce the risk of dam failure.[428] Under the *Water Supply (Safety and Reliability) Act 2008,* a failure impact assessment is required to assess and identify the population at risk, in order to determine whether a dam should be considered referable.[429] A preliminary failure impact assessment report was prepared in May 2004 for four of the detention basins along West Creek.[430] The report commented that assessing the failure impacts of the basins was complex but, on the basis of the available data, concluded that one or more of the four basins were likely to be referable dams.[431] The report recommended further hydraulic and hydrologic modelling be done to confirm the status of these basins.[432] It also suggested the basins might need to be investigated as a system, capable of failure individually or in series with others.[433]

The then Department of Natural Resources and Water carried out further investigations on the West Creek detention basins as a response to this report. A 2005 report by the department identified the need to complete a full failure impact assessment accompanied by further surveying work. It also pointed to the need for a sophisticated hydraulic model, and an assessment of the cascade failure risk of the other basins further upstream in West Creek.[434] This report also suggested that the Alderley Street detention basin was a referable dam under the Act.[435] It is unclear what further assessment of these detention basins, if any, was carried out in the period between these investigations in 2005 and the January 2011 flood.

DERM commenced investigations after the flooding of 10 January 2011 to assess the flood mitigation structures serving the relevant Toowoomba catchments and their performance during the flood. Inspections of the detention basins determined that none failed during the event, although many of the basins and associated ponds were overtopped, with some minor erosion.[436] The inspection report recommended that DERM reassess whether a failure impact assessment, including an examination of the risk of cascade failure, should be carried out for any one, or all, of the structures.[437]

Toowoomba council has engaged engineers to undertake a failure impact assessment for the West Creek detention basins.[438] DERM has advised the Commission this assessment indicates no person's safety would be at risk if the West Creek detention basins failed.[439] DERM has commenced a review of this assessment and indicates discussions with Toowoomba council will occur once the review is complete.[440]

Recommendations

17.29 Toowoomba Regional Council should engage external consultants to carry out failure impact assessments on the detention basins along East Creek.

17.30 Toowoomba Regional Council and the Department of Environment and Resource Management should continue to co-operate to assess the referable dam status of existing detention basins and any future detention basins constructed in the West Creek and East Creek catchment areas.

17.10 Other DERM dam functions

DERM is the department responsible for the administration of the *Water Supply (Safety and Reliability) Act 2008*,[441] the Act which regulates referable dams (dams which pose a risk to the safety of two or more people should they fail).[442] Two of their important dam-related functions, the review and approval of flood mitigation manuals and the review of flood event reports are dealt with in sections 17.2 and 17.3 above, respectively. Others are dealt with below.

17.10.1 Response to Bureau of Meteorology forecast

The Bureau of Meteorology provided a seasonal forecast to the Queensland Cabinet in October 2010, warning of a 75 per cent chance of above average rainfall in south-east Queensland and an active cyclone season.[443] DERM's Director-General was also briefed in that month as a member of the state disaster management group.[444] He discussed the weather outlook with the DERM executive management group in a meeting on 25 October 2010.[445] DERM officers took steps to update the department's disaster management plan and ensure key staff were available over the holiday period.[446]

Each division of DERM was invited to nominate issues to include in a summer issues briefing paper being prepared by the Department of Premier and Cabinet.[447] DERM chose five issues to include in its part of the briefing note, which was endorsed by the executive management group of DERM on 22 November 2010.[448] The five issues were the discharge of poor quality water from mines and other water storages; damage to national parks; downstream flooding in south-east Queensland; failure of dams resulting in loss of life and loss of water supply; and environmental damage.[449]

In response to the summer issues briefing, two actions were taken which were the subject of examination in the Commission's interim report:

- Water agencies, on request of the Minister, considered the possibility of lowering the full supply level of Wivenhoe and Somerset dams to 75 per cent and North Pine Dam to 95 per cent to assist in flood mitigation. In the result, the Minister decided not to lower the water level of either dam in mid-December 2010. This issue was discussed in detail in the Commission's interim report in section *2.4 Temporary alteration of full supply level.*
- Communication procedures between participants in the South East Queensland Water Grid regarding releases from Wivenhoe and Somerset dams were formalised through the production of a draft communication protocol. For further details, see section *2.6.10 Communications* in the Commission's interim report.

The summer issues briefing identified an audit of the currency of emergency action plans at all referable dams as an appropriate response to the risk of dam failure.[450] The Minister signed correspondence to all dam operators requesting that they assure DERM of the currency of their emergency action plan by 30 November 2010.[451] In the event that an assurance was not provided, compliance action was foreshadowed.[452] Seven dams failed to produce current emergency action plans by the required date.[453] Discussions between DERM and the owners of these seven dams have continued, and a show cause notice was issued to one.[454] The audit and follow-up actions undertaken by DERM prior to the 2010/2011 wet season[455] were appropriate.

The Commission considers that the summer issues briefing did not capture some critical issues. DERM should have taken steps to consider:

- Seqwater's ability to comply with the flood mitigation manuals relevant to Wivenhoe, Somerset and North Pine dams. (In fact, Seqwater's schedule of authorities[456] included an unregistered engineer, in breach of the manuals, a point which would have been readily discoverable by DERM. See section *2.5.6 Registration of flood engineers* of the Commission's interim report.)
- whether the operators of referable dams around the state were able to comply with their emergency action plans
- whether communication procedures between referable dam operators and local disaster management groups were adequate to enable local groups to perform their role and warn communities
- the flood mitigation capacities of referable dams around the state, to determine if any action should be taken at any dam, for example the lowering of a full supply level.

Dam operators are primarily responsible for ensuring that their dams comply with applicable manuals and emergency procedures and that their communication protocols are adequate. However, as the regulator of referable dams under the *Water Supply (Safety and Reliability) Act 2008*, it was incumbent upon DERM to consider the preparedness of those dams and ensure operators were meeting their responsibilities.

In respect of the last point, the State of Queensland has submitted that DERM has responsibility only for dam safety and providing data from gauges to assist in flood warning, not for ensuring dams provide appropriate flood mitigation.[457] If that is correct, it points to an unfortunate hiatus in government oversight of the issue. All dams, even those without gates, provide some measure of flood mitigation. It would be appropriate for DERM to consider the efficacy of the operation of those dams in terms of flood mitigation. See section 17.10.6 below, for discussion about responsibility for flood mitigation across the Queensland Government.

17.10.2 Review and approval of emergency action plans

Emergency action plans have no status in the legislation governing referable dams in Queensland.[458] The dam safety conditions set by DERM for each dam contain a requirement that the dam have an emergency action plan.[459] The conditions also require a twelve-monthly review of the plan and a five yearly comprehensive review.[460] DERM must be informed of amendments, or that no amendments are required after review.[461]

DERM requires dam owners to submit copies of their emergency action plans to it, but it does not perform a substantive review of them. It reviews the parties listed in the plan, the scope of emergencies addressed, and the currency of the document,[462] and keeps a copy on file.[463] The audit of emergency action plans undertaken in advance of the 2010/2011 wet season, discussed above in section 16.8.1, was similarly limited.

DERM advised the Commission that all referable dams have emergency action plans, except in cases where: a dam is yet to have safety conditions applied; where the due date for a dam's provision of its emergency action plan is yet to occur; where a dam is currently being decommissioned;[464] or where the dam owner's property contains the whole of the population at risk.[465]

However, a case brought to the attention of the Commission, that of Gordonbrook Dam, demonstrated that DERM processes have not always ensured that all dams had emergency action plans. Reports prepared by independent engineers in 2008 in respect of dam safety and spillway adequacy indicated that the dam did not have key documentation, including an emergency action plan, standard operating procedures, an operating and maintenance manual or a data book.[466] There was a disaster management plan, but it lacked the information essential in an emergency action plan.[467] Other issues were raised in the reports, and DERM engaged with the dam operator to resolve them from 2008 to 2010. DERM did not, however, take steps to ensure Gordonbrook Dam had

the necessary operational and emergency documentation until October 2010. Gordonbrook Dam is a referable dam with a population at risk of about 10.[468] It should maintain an emergency action plan; DERM should have taken action to remedy the situation earlier.

The Commission made recommendations about the content of the warnings procedures in emergency action plans in section 4.1.4 of its interim report. The plans reviewed by the Commission approached the matter of warnings in varying ways;[469] implementation of the recommendations may assist in providing some consistency in the future. The *Water Supply (Safety and Reliability) Act 2008* has been amended since the interim report to allow the Director-General to impose safety conditions that include requirements about giving information about flow to the local community immediately downstream of a dam.[470]

The Gordonbrook Dam example, and the varied approach to warnings, indicates that it would be appropriate for the existence and content of emergency action plans to be regulated by legislation and reviewed by government departments. In particular, the Commission considers it would be appropriate for there to be:

- a legislative obligation on referable dam owners to have an emergency action plan approved by an appropriate government agency, and to review it periodically
- substantive reviews of referable dams' emergency action plans completed by an appropriate government agency.

The government should, in consultation with dam owners and operators, consider the administrative arrangements surrounding this obligation to establish an efficient scheme for the submission and approval of plans.

Reviews should be substantive in the sense of considering the effectiveness of each plan's procedures as a response to emergencies. This would considerably extend the scope of DERM's current review. The government agency given the responsibility for review might be assisted by the production of guidelines to dam owners about what must be included. There are some guidelines in the Dam Safety Management Guidelines produced by DERM[471] and the Australian Government publication Emergency Management Planning for Floods Affected by Dams.[472] More guidance might be required. The criteria for the substantive review of emergency action plans should be determined by the agency which is charged with their review and approval in consultation with DERM, Emergency Management Queensland and dam operators. The criteria for warnings procedures should be informed by the Commission's interim report, section *4.1.4 Warnings about dam spillway outflow.* Whatever criteria are established, the reviewer must assess the plan against them and against its purpose: to deal effectively with emergencies.

The dam safety regulator does not consider DERM to be the appropriate agency to review and approve emergency action plans; he suggests that Emergency Management Queensland approve them, and local disaster management groups conduct reviews.[473] The Queensland Government submitted that DERM would be the most appropriate agency, with Emergency Management Queensland providing advice and input.[474] The important thing is that the substance of the plans is reviewed by persons with the relevant expertise. That would include at least dam safety and emergency management considerations. The Queensland Government should determine which agency is appropriate to perform the review and approval of emergency action plans.

Recommendations

17.31 The Queensland Government should legislate to oblige each owner of a referable dam to have an emergency action plan approved by the appropriate Queensland Government agency. Such plans should be reviewed periodically.

17.32 The Queensland Government should, in consultation with the Department of Environment and Resource Management and Emergency Management Queensland, determine which agency is appropriate to review and approve emergency action plans for referable dams.

17.33 Prior to each wet season, the Department of Environment and Resource Management should audit the compliance of each owner of a referable dam with the obligation to have an emergency action plan approved by the Queensland Government.

17.10.3 Dam safety audits

Section 354 of the *Water Supply (Safety and Reliability) Act 2008* empowers the Director-General of DERM to impose dam safety conditions. DERM has imposed conditions for most referable dams in Queensland. Referable dam owners have a number of responsibilities under their respective dam safety conditions, including five-yearly inspections of their dam by registered engineers.[475]

DERM conducts desktop audits of referable dam owners' compliance with dam safety conditions. DERM considers that compliance demonstrates preparedness for future wet seasons.[476] An example of the type of matter considered in a dam safety audit is whether a current emergency action plan exists.[477] If any deficiencies are detected during the dam safety audit process, it is then the responsibility of the dam owner to rectify these deficiencies.[478]

The number of audits that can be conducted in any one year is limited by resource and budget constraints.[479] Over the last few years between 11 and 13 audits have been completed each year.[480] Eighty-five of Queensland's 106 referable dams have been the subject of a dam safety audit since 2007.[481] The dam safety regulator considers that such audits should be conducted every three to five years.[482] He indicated that DERM would perform more frequent audits on dams which had 'inexperienced or recalcitrant' owners.[483]

According to the dam safety regulator, the dam safety audits were originally targeted at the major dam owners whose dams presented particular hazards to downstream communities, or put high populations at risk.[484] Once it had established that these owners were generally in compliance with dam safety conditions, DERM turned its attention to smaller dams.[485] These smaller dams generally have a lower population at risk.[486] The smaller dams are, however, generally older and built to lower standards, with owners generally less familiar with dam safety requirements.[487]

DERM has applied a system of prioritisation to determine which dams to audit since the inception of the dam safety audit program in 2007. This prioritisation has been based entirely on the size of the population at risk and hazards for downstream communities in the event of dam failure.[488]

The Commission considers that DERM should conduct a risk assessment, using its results to make decisions about when each referable dam will be audited. A number of relevant factors should be considered in determining the order of these audits.

Recommendation

17.34 The Department of Environment and Resource Management should prioritise dam safety audits according to risk. The risk assessment should be informed by criteria including:

- structure and materials used in construction
- age of the dam
- time since last inspection
- occurrence of a flood event since last audit and the size of that flood event
- population at risk if the dam were to fail
- experience and capability of dam owner
- dam owner compliance history
- time since last audit.

17.10.4 Interaction between DERM and disaster management personnel

DERM links with various levels of Queensland's disaster management hierarchy. For example, the Director-General of DERM and the director of dam safety at DERM sit on the state disaster co-ordination committee and provide information to this body as required.

In 2010/2011, DERM ensured Emergency Management Queensland had copies of all emergency action plans for dams.[489] That was appropriate, and should occur for every wet season.

DERM staff have previously presented papers to Emergency Management Queensland at various conferences or workshops, and visited local disaster management groups to educate them on dam safety issues.[490] These discussions can usefully inform local groups of the possible consequences of dam failure for downstream communities, and appropriate emergency responses to such an eventuality. Such education may lead to faster, more integrated responses when flooding occurs.

It appears that DERM has not made presentations to Emergency Management Queensland or local disaster management groups for some time. The dam safety regulator stated that these activities should be conducted again.[491] It is particularly surprising that such presentations were not considered or conducted prior to the 2010/2011 wet season, given the severity of the seasonal forecast provided by the Bureau of Meteorology to the Queensland Government in October 2010. DERM should make those presentations before each wet season, particularly if a wet season is forecast with a greater than 50 per cent change of above median rainfall.

Recommendations

17.35 The Department of Environment and Resource Management and Emergency Management Queensland should ensure that each has copies of current emergency action plans for all dams in Queensland.

17.36 The Department of Environment and Resource Management should conduct periodic dam safety information and education sessions with emergency management personnel including those from Emergency Management Queensland, local and district disaster management groups and local councils. Priority should be given to sessions if the Bureau of Meteorology forecasts a wet season with a greater than 50 per cent chance of above median rainfall.

17.10.5 Management of non-commercial water assets

DERM owns and is responsible for managing a group of 'non-commercial water assets'. These are typically items of water infrastructure, such as dams, weirs and pipelines, over which the Queensland Government has retained ownership following the corporatisation of SunWater in 2000, or which have reverted to state control upon the cessation of mining tenements.[492]

DERM's current portfolio of non-commercial water assets comprises 10 dams, 12 weirs, one pipeline and a system of levees on the lower Mary River near Maryborough.[493] The Commission has made enquiries of DERM as to the effect of flooding during the 2010/2011 wet season on these assets. Specifically, the department was asked whether flooding of the assets increased the level of flooding on any nearby property, whether any of the assets pose a risk to life or property when affected by flooding and whether DERM has taken or will take steps to manage those risks.[494]

DERM has advised the Commission that, in all cases, its non-commercial water assets experienced increased water levels during the 2010/2011 wet season, but functioned normally.[495] No adverse impacts, such as structural damage, were caused to the assets during the 2010/2011 wet season.[496]

The only reported consequence of flooding associated with the non-commercial water assets was with respect to the Mary River levees; on 25 January 2011 an owner of property adjacent to the Mary River advised DERM that water from the Mary River had flooded his cane fields on 20 January.[497] DERM inspected the area on 27 January 2011 and found that the inundation was not caused by a malfunction of the levee system. DERM advised the Commission it would continue monitoring the levees.[498]

One non-commercial water asset, Ibis Dam at Irvinebank in far north Queensland, is in breach of current safety standards and poses a risk to life and safety.[499] Specifically, the dam is assessed as being capable of safely handling only seven per cent of its acceptable flood capacity. It has a population at risk of 75 people.[500] The dam is within DERM's very high risk category.[501]

On 19 September 2011, the Office of the Water Safety Regulator (a different division of DERM) issued an information notice that had the effect of requiring DERM in its capacity as dam owner and manager to either upgrade or 'decommission' the dam by 1 October 2012.[502] (Decommissioning a dam involves removing or otherwise modifying parts of its structure to make it incapable of storing water, either temporarily or permanently.[503])

DERM is currently considering options for the long term management of Ibis Dam.[504] In the interim, DERM has:

- revised the dam's emergency action plan
- reviewed the dam's operating requirements
- held community information sessions to make the public aware of the safety concerns
- engaged independent engineers to review the dam's stability, structural integrity and spillway capacity so as to ascertain and mitigate the dam's safety risks.[505]

Four of DERM's other non-commercial water assets are referable dams, like Ibis Dam. DERM inspects these dams, being Crooks Dam, Wyndham Dam, Copperfield Dam and Corella Dam, on a weekly basis.[506] DERM has also advised the Commission that it has recently reviewed the emergency action plans for each of these dams in accordance with the Commission's interim report recommendations about communication with downstream communities.[507]

There is no evidence that DERM's non-commercial water assets functioned other than as expected during the 2010/2011 floods or that DERM's management of these assets is in any way deficient.

17.10.6 A broader flood mitigation responsibility?

It appears that no Queensland Government agency has wide ranging responsibility for flood mitigation. Such responsibility would include oversight of structural measures such as dams, levees and vegetation as a complement to non-structural measures such as land planning systems and emergency management. The Queensland Flood Risk Management Activities Audit completed in November 2010 indicated that flood risk management activities are spread across a multitude of agencies and departments. The fact that no single agency has overarching responsibility is likely to lead to inconsistency and gaps in policy.

The audit tried to address gaps it perceived in flood risk responsibility. However, the audit was silent on key flood mitigation issues such as the ability of Seqwater to comply with its flood mitigation manuals in respect of Wivenhoe, Somerset and North Pine dams.

The Queensland Government submitted that it had, as a result of that audit, designated the Department of Local Government and Planning as its lead agency for flood mitigation issues. To support that claim, it provided correspondence between relevant Ministers and Directors-General of that department, DERM and the Department of Community Safety.[508] It is not immediately apparent from that correspondence that there is a single lead agency; it merely indicates that the Department of Local Government and Planning has agreed to be the Queensland representative on the National Flood Risk Advisory Group and lead the current review of State Planning Policy 1/03.

The Commission's terms of reference did not permit this potentially important issue to be taken further in the course of this inquiry. It may be that government should consider a separate investigation directed at determining whether one agency should be responsible for flood mitigation.

(Endnotes)

1 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, section 2.5.8 and 2.10.6.

2 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, section 2.1.4.

3 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, section 2.1.5.

4 Seqwater – Baroon Pocket Dam, Cedar Pocket Dam, Borumba Dam, Cooloolabin Dam, Ewen Maddock Dam, Lake MacDonald/Six Mile Creek Dam, Poona Dam, Wappa Dam; SunWater – Boondooma Dam, Fred Haigh Dam, Paradise Dam, Wuruma Dam, Bjelke-Petersen Dam, Cania Dam, Isis Balancing Storage, Woongarra Balancing Storage; Wide Bay Water Corporation – Lenthalls Dam; South Burnett Regional Council – Gordonbrook Dam; Newcrest Mining – Perry River Dam; Stanwell Corporation – Meandu Creek Dam, Cooling Water Dam, Ash Dam, Black Creek Dam, Drains Reclaim Dam.

5 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 2.5 [p52]; Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 2.10 [p88].

6 Queensland Floods Commission of Inquiry, *Interim Report*, 2011 [p60].

7 *Approval of Flood Mitigation Manual Notice (No 01) 2011*, Vol 358, No 40, Queensland Government Gazette, 1 October 2011.

8 *Approval of Flood Mitigation Manual Notice (No 02) 2011*, Vol 358, No 46, Queensland Government Gazette, 11 October 2011.

9 *Approval of Flood Mitigation Manual Notice (No 03) 2011*, Vol 358, No 75, Queensland Government Gazette, 14 November 2011.

10 Statement of James Pruss, 21 November 2011 [p2: para 12]; Statement of James Pruss, 21 November 2011, Annexure JP4 [p17]; Statement of James Pruss, 21 November 2011 [p2: para 8].

11 Statement of James Pruss, 21 November 2011 [p2-3: para 12(b)].

12 Statement of James Pruss, 21 November 2011, Annexure JP4 [p22].

13 Statement of James Pruss, 21 November 2011 [p5: para 23(b)]; Statement of James Pruss, 21 November 2011 [p4: para 19(d)].

14 Statement of James Pruss, 21 November 2011 [p5: para 23(b)].

15 Statement of James Pruss, 21 November 2011 [p2: para 12]; Statement of James Pruss, 21 November 2011, Annexure JP4 [p13]; Statement of James Pruss, 21 November 2011 [p2: para 6].

16 Statement of James Pruss, 21 November 2011 [p5: para 24(a)]; Statement of James Pruss, 21 November 2011 [p2: para 5].

17 Statement of James Pruss, 21 November 2011 [p2: para 6].

18 Which focuses on flood damages in downstream areas. See Statement of James Pruss, 21 November 2011, Annexure JP4 [pA-8].

19 Seqwater, Wivenhoe Dam and Somerset Dam Optimisation Study Progress Report, Revision 4, 12 December 2011 [p12].

20 See section *2.3.2 A comprehensive study of the Brisbane River catchment*.

21 Statement of James Pruss, 21 November 2011, Annexure JP4 [pA-2]; Seqwater, Wivenhoe Dam and Somerset Dam Optimisation Study Progress Report, Revision 4, 12 December 2011 [p12].

22 November 2011.

23 October 2011.

24 Statement of Peter Allen, 24 November 2011, Annexures PHA-48g; PHA-50g.

25 See Statement of Peter Allen, 24 November 2011, Annexures PHA-48, PHA-50.

26 See section 374 of the *Water Supply (Safety and Reliability) Act 2008*.

27 Amongst other requirements. Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p30].

28 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p26, 28].

29 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p32].

30 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p8]. Only

'judged likely' is used in the North Pine Manual: Seqwater, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 6, October 2011 [p6].

31 Section 374 of the *Water Supply (Safety and Reliability) Act 2008*.

32 For example: Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p23, 24].

33 Queensland Floods Commission of Inquiry, *Interim Report,* Recommendation 2.9, 2011 [p59].

34 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p21].

35 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p25].

36 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p27, 29, 31].

37 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p42].

38 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p25].

39 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p29].

40 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p27, 29].

41 Statement of Peter Allen, 24 November 2011, Attachment PHA-48e [p5].

42 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p29].

43 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p33].

44 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p158-159].

45 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p14]; Seqwater, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 6, October 2011 [p12].

46 Queensland Floods Commission of Inquiry, *Interim Report*, section 2.5.6, 2011 [p58].

47 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p33-35].

48 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [14: section 2.4].

49 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p 14: section 2.5].

50 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p33-35].

51 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p17]; Seqwater, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 6, October 2011 [p15].

52 Statement of Peter Allen, 24 November 2011, Attachment PHA 48-e [p4]. For a description of this use of quantitative precipitation forecasts, see section *2.6.5 'With forecast' and 'without forecast' model runs* in the Commission's Interim Report: Queensland Floods Commission of Inquiry, *Interim Report,* Section 2.6.5, 2011 [p64].

53 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p7-8].

54 Exhibit 29. Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 5, August 2010 [p19: section 8.4].

55 Queensland Floods Commission of Inquiry, *Interim Report*, 2011 [p92].

56 Exhibit 17, Statement of Robert Ayre, 23 March 2011 [p45: para 210 – p47: para 220].

57 Exhibit 17, Statement of Robert Ayre, 23 March 2011 [p46: para 217 – 218].

58 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p21].

59 See for example Transcript, John Tibaldi, 2 February 2012, Brisbane [p5055: lines 10-55]; Transcript, John Ruffini, 11 February 2012, Brisbane [p6073: line 30]; [p6074: line 1 - p6075: line 35]; Transcript, Terrence Malone, 11 February 2012, Brisbane [p6094: line 35-55]; Transcript, Rob Ayre, 11 February 2012, Brisbane [p6105: line 21 – p6106: line 5].

60 See, for example, Mr Tibaldi's difficulty in determining whether the flood engineers had used strategy W2 section *16.10.2 Mr Tibaldi's methodology*. See also Transcript, John Ruffini, 11 February 2012, Brisbane [p6074: line 1 – p6075: line 35]; Transcript, Rob Ayre, 11 February 2012, Brisbane [p6111: line 25 – p6112: line 32]; Transcript, John Tibaldi, 11 February 2012, Brisbane [p6126: line 45 – p6127: line 40].

61 Submission of John Craigie, 14 February 2012.

62 Transcript, Terrence Malone, 5 February 2012, Brisbane [p5316: line 38 – p5317: line 30].

63 Transcript, Terrence Malone, 5 February 2012, Brisbane [p5316: line 38 – p5317: line 30].

64 Transcript, John Tibaldi, 2 February 2012, Brisbane [p5124: line 4].

65 Transcript, Robert Ayre, 3 February 2012, Brisbane [p5190: line 55 – p5191: line 10].

66 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p27].

67 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p28].

68 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011.

69 See, for example, Exhibit 1036, Statement of John Tibaldi, 1 February 2012 [p4: para 28 – p6: para 29] and Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix A; Transcript, John Tibaldi, 2 February 2012, Brisbane [p5054: line 2]; Transcript, John Tibaldi, 3 February 2012, Brisbane [p5166: line 12]; [p5171: line 5]; Transcript, Robert Ayre, 4 February 2012, Brisbane [p5250: line 5-30]; Transcript, Terrence Malone, 6 February 2012, Brisbane [p5400: line 12]; Transcript, John Ruffini, 6 February 2012, Brisbane [p5444: line 13]; Transcript, John Ruffini, 11 February 2012, Brisbane [p6083: line 20]; Transcript, Terrence Malone, 11 February 2012, Brisbane [p6098: line 23]; Transcript, Robert Ayre, 12 February 2012, Brisbane [p6108: line 12 – p6109: line 11].

70 Submission of John Craigie, 14 February 2012 [p4-6].

71 Statement of Peter Allen, 24 November 2011, Attachment PHA-48a.

72 Australian Height Datum. See Exhibit 396, Department of Environment and Resource Management, Moreton Resources Operations Plan 2009, December 2009 [p99]; Seqwater, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 6, September 2011 [p5].

73 Australian Height Datum.

74 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p3].

75 To describe the flood storage compartment in this fashion is consistent with the manner in which the flood storage compartment of Wivenhoe Dam has been described (see Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011). The January 2011 Flood Event Report on the operation of North Pine Dam, (see Exhibit 30, Seqwater, January 2011 Flood Event Report on the operation of North Pine Dam, March 2011) [p4], however, describes the flood storage compartment as the volume of water between full supply level and the radial gate opening trigger level (p4), which, under Revision 5 of the North Pine manual, is a vertical height of five centimetres. The same description was used by then senior flood operations engineer, Robert Ayre, in his first statement: Exhibit 17, Statement of Robert Ayre, 23 March 2011 [p19: para 96].

76 Transcript, Peter Allen, 18 May 2011, Brisbane [p2076: line 21].

77 Note that at a water level of 42.047 metres, water will escape through the spillway above the gates. See: Seqwater, *Manual of Operational Procedures for Flood Mitigation at North Pine Dam*, Revision 6, October 2011, Appendix C.

78 Section 370, *Water Supply (Safety and Reliability) Act 2008*.

79 Section 371(2),(3), *Water Supply (Safety and Reliability) Act 2008*.

80 Section 372, 373, *Water Supply (Safety and Reliability) Act 2008*.

81 Section 374, *Water Supply (Safety and Reliability) Act 2008*.

82 Statement of Peter Allen, 24 November 2011 [p28: para 155 – p29: para 158; p30: para 165-168].

83 Transcript, Peter Allen, 16 May 2011, Brisbane [p2083: line 37].

84 Transcript, Peter Allen, 16 May 2011, Brisbane [p2088: line 38].

85 Transcript, Peter Allen, 16 May 2011, Brisbane [p2088: line 55].

86 Exhibit 391, DS 5.1 Flood Mitigation for a Dam, Version 1, 28 October 2010 [p2].

87 Exhibit 391, DS 5.1 Flood mitigation manual for a dam, 28 October 2010, Attachment C [p1].

88 Transcript, John Bradley, 16 May 2011, Brisbane [p2029: line 28]; Transcript, Peter Allen, 16 May 2011, Brisbane [p2082: line 42].

89 Transcript, Peter Allen, 16 May 2011, Brisbane [p2083: line 49]; see also Transcript, John Bradley, 16 May 2011, Brisbane [p2026: line 32].

90 Exhibit 391, DS 5.1 Flood mitigation manual for a dam, 28 October 2010, Attachment C [p2]; Transcript, John Bradley, 16 May 2011, Brisbane [p2029: line 13].

91 Transcript, John Bradley, 16 May 2011, Brisbane [p2028: line 8].

92 Department of Environment and Resource Management, DS 5.1 Flood mitigation manual for a dam, Version 2, 16 September 2011, www.derm.qld.gov.au/about/policy/documents/3991/wir_2009_3991.pdf.

93 Department of Environment and Resource Management, DS 5.3 Processing a flood mitigation manual for a dam following review, Version 1, 16 September 2011, www.derm.qld.gov.au/about/policy/documents/4884/wir_2011_4884.pdf

94 Department of Environment and Resource Management, DS 5.1 Flood mitigation manual for a dam, Version 2, 16 September 2011, www.derm.qld.gov.au/about/policy/documents/3991/wir_2009_3991.pdf, Attachment C; Department of Environment and Resource Management, DS 5.3 Processing a flood mitigation manual for a dam following review, Version 1, 16 September 2011, www.derm.qld.gov.au/about/policy/documents/4884/wir_2011_4884.pdf, Attachment C.

95 Department of Environment and Resource Management, DS 5.1 Flood mitigation manual for a dam, Version 2, 16 September 2011, www.derm.qld.gov.au/about/policy/documents/3991/wir_2009_3991.pdf, Attachment C [p6]; Department of Environment and Resource Management, DS 5.3 Processing a flood mitigation manual for a dam following review, Version 1, 16 September 2011, www.derm.qld.gov.au/about/policy/documents/4884/wir_2011_4884.pdf, Attachment C [p7].

96 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p1: para 5].

97 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p1: para 5]; Queensland Dam Safety Management Guidelines, 26 February 2002, Chapter 9, 9.5.

98 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p3: para 9].

99 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p3: para 9].

100 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p3: para 9].

101 Exhibit 327, Wivenhoe Dam Emergency Action Plan [p9].

102 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p8].

103 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p3: para 8(c)]; Attachment PHA-19.

104 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p3: para 8(d)].

105 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p4: para 12]. See Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam; Exhibit 30, Seqwater, January 2011 Flood Event Report on the operation of North Pine Dam.

106 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p3: para 8(d), (f)]; Attachment PHA-20.

107 See section 2.10.3 of the Commission's interim report.

108 Exhibit 1128, Statement of Peter Allen, 12 September 2011, Attachment PHA-19.

109 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p2: para 7]; Statement of Peter Allen, 24 November 2011 [p25: para 128].

110 Statement of Peter Allen, 24 November 2011 [p5: para 30].

111 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [p2: para 8; p3: para 10].

112 Statement of Peter Allen, 24 November 2011 [p22: para 120; p23: para 121].

113 For example, Submission of the Mid Brisbane River Irrigators, 11 March 2011; Submission of Ms Jocelyn Bailey, undated; Exhibit 41, Statement of Ms Jenny Moore, 7 April 2011.

114 Statement of Terry Wall, 9 June 2011 [p7; para 24].

115 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p1].

116 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p4].

117 Submission of Barrie Dunning, 24 February 2011 [p3].

118 Exhibit 41, Statement of Jenny Moore, 7 April 2011, Annexure 1.

119 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p6].

120 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p3].

121 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p3].

122 Statement of Dr Bruce Abernethy, 16 November, Annexure BA-1 [p3].

123 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p3].

124 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p4].

125 Statement of Terry Wall, 9 June 2011, Annexure TWW-7.

126 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p4].

127 Statement of Terry Wall, 9 June 2011, Annexure TWW-7.

128 Statement of Terry Wall, 9 June 2011, Annexure TWW-7; Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p4].

129 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p7].

130 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p7].

131 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p4].

132 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p3]; Office of the Chief Scientist, Understanding Floods: Questions and Answers, July 2011, Question 3.

133 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p4].

134 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p4-6].

135 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p6].

136 Statement of Graham Bell, 29 October 2011 [p1: para 4-5], Statement of Jocelyn Bailey, 24 October 2011 [p3: para 23].

137 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p11].

138 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p11].

139 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p11].

140 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p11].

141 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 26].

142 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p12].

143 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1.

144 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 27].

145 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p4: para 12].

146 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 27].

147 Statement of Dr Bruce Abernethy, 7 October 2011, Annexure BA-1 [p11].

148 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8].

149 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p11: section 3.6]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p20: section 3.6].

150 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p19: section 3.2]; Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p10: section 3.2].

151 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, March 2011, table 9.1.1 [p166].

152 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 26].

153 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 27].

154 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 27].

155 Statement of Dr Bruce Abernethy, 16 November 2011, Annexure BA-1 [p8: para 27].

156 Statement of Terry Wall, 9 June 2011 [p8: para 31]; Submission of Seqwater, 25 November 2011 [p3].

157 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p8].

158 All references to metres in this section 16.3 are references to elevation level unless otherwise stated.

159 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p18].

160 Statement of Andrew Krotewicz, 13 September 2011 [para 13(ii)].

161 Exhibit 426, Statement of Barton Maher, 1 April 2011 [p3: para 14].

162 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p81]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 8, September 2011, Appendix G [p80]; Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009, Appendix E [p61].

163 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6, Appendix 10.

164 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p25]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 8, September 2011 [p28]; Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p27].

165 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011 [p27]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 8, September 2011 [p27]; Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p25-26].

166 For background on the real time flood model used by the flood engineers during the January 2011 event, see section *2.6.4 The real time flood model* of the Commission's interim report.

167 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011[p23]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 8, September 2011 [p23]; Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p19].

168 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 9, November 2011[p23]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 8, September 2011 [p23]; Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p19].

169 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6, Appendix 10.

170 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p18].

171 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p18].

172 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p18].

173 Statement of Andrew Krotewicz, 13 September 2011 [para 3].

174 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p18].

175 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p18].

176 Statement of Andrew Krotewicz, 3 November 2011 [para 8.1].

177 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p12].

178 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6, Appendix 10.

179 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p4].

180 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p158-159].

181 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p4]. Statement of Andrew Krotewicz dated 13 September 2011, Annexure ATK-6, Appendix 10.

182 Again assuming a level of EL 75 metres. Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6, Appendix 10.

183 For a consideration of the operation of Wivenhoe Dam in strategy W4, see section 2.7.8 of the interim report.

184 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-1 [clause 3.1(a), 3.2].

185 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-1 [clause 7.2].

186 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-1 [clause 7.2].

187 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-2.

188 Statement of Andrew Krotewicz, 3 November 2011 [para 4.5-4.7], Statement of John Tibaldi, 12 September 2011 [para 6].

189 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-10. Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6, Appendix 10.

190 Statement of Andrew Krotewicz, 3 November 2011 [para 4.7]; Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p5].

191 Statement of Andrew Krotewicz, 3 November 2011 [para 5.1-5.3].

192 Statement of Andrew Krotewicz, 3 November 2011 [para 5.4].

193 Statement of Andrew Krotewicz, 3 November 2011 [para 5.1-5.3]; Statement of Andrew Krotewicz, 13 September 2011, Annexures ATK-6, ATK-9.

194 Statement of Andrew Krotewicz, 3 November 2011 [para 6.2-6.6].

195 Statement of Andrew Krotewicz, 3 November 2011 [para 6.31].

196 Statement of Andrew Krotewicz, 3 November 2011 [para 6.2-6.6].

197 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011; Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p13].

198 Statement of Andrew Krotewicz, 3 November 2011 [para 6.6].

199 Exhibit 24, Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011; Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6 [p13].

200 At its peak, Wivenhoe Dam's level was more than 70cm below that required to trigger the first of the fuse plugs.

201 Statement of Andrew Krotewicz, 3 November 2011 [para 6.6].

202 Statement of Andrew Krotewicz, 3 November 2011 [para 7.1].

203 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-4 [p10].

204 Statement of Andrew Krotewicz, 13 September 2011 [para 3.1].

205 Submission of Tarong Energy, 8 April 2011, Appendix 4 [clause 2.1].

206 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-5 [clause 3.2.1].

207 Statement of Andrew Krotewicz, 13 September 2011, Annexure ATK-6, Appendix 11.

208 Statement of Andrew Krotewicz, 3 November 2011 [para 9.1-9.3].

209 Statement of John Tibaldi, 12 September 2011 [para 9].

210 Statement of Robert Ayre, 7 September 2011 [p6; para 5].

211 Statement of Robert Ayre, 7 September 2011 [p2; para 5].

212 Statement of Andrew Krotewicz, 13 September 2011 [para 12-13].

213 National Electricity Rules, November 2011, Chapter 4.

214 Submission of Australian Energy Market Operator, 16 December 2011.

215 Exhibit 1128, Statement of Peter Allen, 12 September 2011 [para 76].

216 GHD Report: South East Queensland Water Board – Safety Review, Somerset Dam, Annexure BM-1, Document no. 24 [p3] to Statement of Barton Maher, 12 September 2011.

217 Exhibit 397, Statement of Peter Allen, 4 April 2011 [p5: para 19].

218 GHD Report, South East Queensland Water Board – Safety Review – Somerset Dam, September 1995, Document no. 24, Annexure BM-1 [p48] to Statement of Barton Maher, 12 September 2011.

219 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p11] to Statement of Barton Maher, 12 September 2011.

220 GHD Report, South East Queensland Water Board – Safety Review – Somerset Dam, September 1995, Document no. 24, Annexure BM-1 [p46] to Statement of Barton Maher, 12 September 2011.

221 GHD Report, South East Queensland Water Board – Safety Review – Somerset Dam, September 1995, Document no. 24, Annexure BM-1 [p32-33] to Statement of Barton Maher, 12 September 2011.

222 See, for example, the reports of GHD, SMEC and the New South Wales Department of Commerce, Document nos. 24, 33, 38, Annexure BM-1 to Statement of Barton Maher, 12 September 2011.

223 SMEC Report, Somerset Dam Investigation, July 2008, Document no. 38, Annexure BM-1 [p3] to Statement of Barton Maher, 12 September 2011.

224 SMEC Report, Somerset Dam Investigation, July 2008, Document no. 38, Annexure BM-1 [p9] to Statement of Barton Maher, 12 September 2011.

225 GHD Report, SMEC Report and New South Wales Department of Commerce Report, Document nos. 24, 33, 38, Annexure BM-1 to Statement of Barton Maher, 12 September 2011.

226 GHD Report, SMEC Report and New South Wales Department of Commerce Report, Document nos. 24, 33, 38, Annexure BM-1 to Statement of Barton Maher, 12 September 2011.

227 SMEC Report, Somerset Dam Investigation, July 2008, Document no. 38, Annexure BM-1 [p10] to Statement of Barton Maher, 12 September 2011.

228 SMEC Report, Somerset Dam Investigation, July 2008, Document no. 38, Annexure BM-1 [p10] to Statement of Barton Maher, 12 September 2011.

229 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 to Statement of Barton Maher, 12 September 2011.

230 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p3] to Statement of Barton Maher, 12 September 2011.

231 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p2] to Statement of Barton Maher, 12 September 2011.

232 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p10] to Statement of Barton Maher, 12 September 2011.

233 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33,

Annexure BM-1 [p10] to Statement of Barton Maher, 12 September 2011.

234 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p22] to Statement of Barton Maher, 12 September 2011.

235 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p19] to Statement of Barton Maher, 12 September 2011.

236 Seqwater, Somerset Dam Annual Dam Safety Inspection, November 2009, Document no. 40, Annexure BM-1 [p17] to Statement of Barton Maher, 12 September 2011.

237 Seqwater, Somerset Dam Annual Dam Safety Inspection 2011, October 2011. See also Tenth Statement of John Tibaldi, 22 December 2011 [para 5].

238 See also Tenth Statement of John Tibaldi, 22 December 2011 [para 4(f)].

239 New South Wales Department of Commerce Report, Somerset Dam – Stability of Abutment Monoliths, May 2005, Document no. 33, Annexure BM-1 [p21] to Statement of Barton Maher, 12 September 2011.

240 Statement of Barton Maher, 12 September 2011 [p2: para 13].

241 Statement of Barton Maher, 12 September 2011 [p3].

242 Somerset Dam: Five Year Comprehensive Dam Safety Inspection Report, Annexure BM-1 [Document no. 41: p22] to Statement of Barton Maher, 12 September 2011.

243 Statement of Barton Maher, 12 September 2011 [p3: para 21].

244 Statement of Barton Maher, 12 September 2011 [p3: para 20].

245 Statement of Barton Maher, 12 September 2011 [p4: para 23].

246 Exhibit 24, Seqwater, January 2011 Flood Event Report on the Operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p172].

247 Statement of Barton Maher, 12 September 2011 [p2: para 7].

248 Similarly, the cracking in Somerset Dam was not mentioned in the evidence of flood engineers about the operation of Somerset Dam. See Transcripts, 11 April 2011, Brisbane [p77] – 15 April 2011, Brisbane [p467].

249 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p40]; Exhibit 24, January 2011 Flood Event Report on the Operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p219].

250 Exhibit 21, Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, November 2009 [p40]; Somerset – Wivenhoe Interaction Study, October 2009 [p7].

251 Exhibit 24, Seqwater, January 2011 Flood Event Report on the Operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p159, 172].

252 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 2.10.7 [p93-94]. There is also a crossing at Grant St, Whiteside; however, it appears to serve only a small local population.

253 Submission of State of Queensland, 7 November 2011 [p11].

254 See for example, Statement of Daryl Brown [p1]; Submission of Jocelyn Bailey [p1]; Submission of Bruce and Cheryl McDade [p2]; Submission of Merven Hoppner [p4]; Submission of Darren Zanow [p9]; Exhibit 310, Statement of Dr Peter Hackney, 10 April 2011, Attachment 1; Transcript, Dr Peter Hackney, 9 May 2011, Brisbane [p1515: line 26].

255 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* Revision 9, November 2011 [p26].

256 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* Revision 9, November 2011 [p26].

257 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* Revision 9, November 2011 [p20].

258 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* Revision 9, November 2011 [p26].

259 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* Revision 9, November 2011 [p26].

260 Queensland Floods Commission of Inquiry, *Interim Report*, 2.10.7: North Pine River Crossings, 2011 [p93].

261 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, 2011 [p76].

262 Submission of State of Queensland, 7 November 2011 [p9].

263 Submission of State of Queensland, 7 November 2011 [p4].

264 The Department of Transport and Main Roads has indicated that the cost of improving flood immunity in the Moggill and Ipswich West region through the construction of a new bridge and road upgrades is likely to be between $134 and $380 million: Submission of State of Queensland, 7 November 2011 [p3].

265 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, *2.10.7: North Pine River Crossings*, 2011.

266 Queensland Floods Commission of Inquiry, *Interim Report*, Recommendation 2.29, 2011 [p94].

267 Submission of State of Queensland, 7 November 2011 [p3]; Exhibit 1010, Statement of Miles Vass, 8 September 2011, Annexure G [p3].

268 Submission of State of Queensland, 7 November 2011 [p3]; Exhibit 1010, Statement of Miles Vass, 8 September 2011, Annexure G [p3].

269 Submission of Seqwater, 9 September 2011 [p1].

270 Seqwater, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* Revision 9, November 2011 [p22, 27]; Seqwater, *Manual of Operational Procedures for Flood Mitigation at North Pine Dam,* Revision 6, October 2011 [p20].

271 Exhibit 327, Wivenhoe Dam Emergency Action Plan, September 2010.

272 Exhibit 314, North Pine Dam Emergency Action Plan, September 2010.

273 Exhibit 327, Wivenhoe Dam Emergency Action Plan, September 2010, Appendix C; Exhibit 314, North Pine Dam Emergency Action Plan, September 2010, Appendix C.

274 Submission of State of Queensland, 7 November 2011 [p12].

275 The situation report accords with the template the Commission recommended should be adopted: Queensland Floods Commission of Inquiry, *Interim Report*, 2.6.10: Communications, 2011.

276 Queensland Floods Commission of Inquiry, *Interim Report*, Recommendation 2.23, 2011 [p70].

277 Queensland Floods Commission of Inquiry, *Interim Report*, Recommendation 4.19, 2011 [p139].

278 Transcript, Peter Care, 12 October 2011, Maryborough [p3974: line 30]. Wide Bay Water Corporation is wholly owned by the Fraser Coast Regional Council: Exhibit 787, Statement of Peter Care, 14 September 2011 [p4: para 7].

279 Section 341, *Water Supply (Safety and Reliability) Act 2008*.

280 Statement of Peter Allen, 24 November 2011 [p20: para 110].

281 Submission of Esther Allan.

282 Transcript, Peter Care, 12 October 2011, Maryborough [p3974: line 38]; Statement of Peter Allen, 24 November 2011 [p20: para 111]; Exhibit 787, Statement of Peter Care, 14 September 2011 [p6: para 16 and 17].

283 Exhibit 787, Statement of Peter Care, 14 September 2011 [p7: para 21].

284 Exhibit 787, Statement of Peter Care, 14 September 2011 [p8: para 27].

285 Exhibit 787, Statement of Peter Care, 14 September 2011 [p8: para 27]; Transcript, Peter Care, 12 October 2011, Maryborough [p3974: line 57].

286 Statement of Peter Allen, 24 November 2011 [p20: para 112].

287 Statement of Peter Allen, 24 November 2011 [p20: para 112].

288 Exhibit 787, Statement of Peter Care, 14 September 2011 [p8: para 27, 28]; Transcript, Peter Care, 12 October 2011, Maryborough [p3975: line 1].

289 Transcript, Peter Care, 12 October 2011, Maryborough [p3975: line 7]; Statement of Peter Care, 24 November 2011 [p1: para 4].

290 Transcript, Peter Care, 12 October 2011, Maryborough [p3975: line 7].

291 Exhibit 787, Statement of Peter Care, 14 September 2011 [p12: para 58].

292 Statement of Peter Care, 24 November 2011 [p2: para 6].

293 Exhibit 787, Statement of Peter Care, 14 September 2011 [p9: para 37].

294 SunWater, Options for the Raising of Lenthalls Dam – Supplementary Report, December 2000, Appendix D [p3]; Statement of Peter Care, 24 November 2011 [p1: para 4].

295 Statement of Peter Care, 24 November 2011 [p4: para 23].

296 The 'trigger event' in the emergency action plan revision in effect during the 2010/2011 wet seasons is defined as the point at which the lake level is approaching RL 26.10 metres and either further rain is forecast or the lake level is rising: Exhibit 787, Statement of Peter Care, 14 September 2011 [p9: para 38].

297 Exhibit 787, Statement of Peter Care, 14 September 2011, Annexure 3.

298 Exhibit 787, Statement of Peter Care, 14 September 2011, Annexure 3.

299 Exhibit 787, Statement of Peter Care, 14 September 2011 [p10: para 42].

300 Exhibit 787, Statement of Peter Care, 14 September 2011, Annexure 3.

301 Exhibit 787, Statement of Peter Care, 14 September 2011, Annexure 3.

302 Transcript, Peter Care, 12 October 2011, Maryborough [p3976: line 23]; Exhibit 788, GHD, Lenthalls Dam Flooding Draft Report, February 2009 [p28].

303 Exhibit 788, GHD, Lenthalls Dam Flooding Draft Report, February 2009.

304 Exhibit 788, GHD, Lenthalls Dam Flooding Draft Report, February 2009 [p28].

305 Exhibit 787, Statement of Peter Care, 14 September 2011 [p10: para 46].

306 Exhibit 787, Statement of Peter Care, 14 September 2011 [p13: para 62]; Annexure 4.

307 Exhibit 787, Statement of Peter Care, 14 September 2011, Annexure 9.

308 Exhibit 787, Statement of Peter Care, 14 September 2011 [p13: para 66].

309 On 6 March 2010, 8 March 2010 and 9 March 2010.

310 Lenthalls Dam Event Log, March 2010.

311 Exhibit 787, Statement of Peter Care, 14 September 2011 [p13: para 66].

312 Lenthalls Dam Event Log, March 2010.

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396 See definition of detention basin in Glossary.

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