SEQWater Dams

Wivenhoe Dam Comprehensive Inspection
July 2006

Surveillance Report Final Report

Report No: DC07063
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A division of the Department of Services, Technology & Administration
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1 CONCLUSIONS AND RECOMMENDATIONS

1.1 Conclusions

The Wivenhoe Dam Safety Committee, having reviewed the historical data and its performance and inspected the dam, has concluded that:

- The embankment dams and the two saddle dams are in a satisfactory condition and behaving satisfactorily;
- The primary spillway is in a satisfactory condition to pass discharges up to its current component of the design flood.
- The secondary spillway is in a satisfactory condition to pass discharges up to its current component of the current design flood.
- The outlet works are generally in a satisfactory condition.

Wivenhoe Dam has been assigned a “HIGH” hazard rating as outlined in GHD (1997). However, it is anticipated that the dam would be reclassified as “EXTREME” hazard based on the current ANCOLD Guidelines.

1.2 Recommendations

The Committee made the following recommendations based on the observations and review made on this inspection:

1.2.1 General Issues

1. Review the hazard category for the dam based on current ANCOLD Guidelines. Refer to Section 4.6.

2. Review and update the Dam Safety Management Program for Wivenhoe, Somerset and North Pine Dams to address items noted at Section 5.1.

3. An Emergency Action Plan (EAP) is in place for the dam. However, given the potential “Extreme” Consequence Category rating, a training exercise should be devised and tested to evaluate the performance of the EAP. Contact lists should be updated at 6 monthly intervals. Refer Section 5.2.

4. Finalise all outstanding dam safety compliance documents (e.g. Design Report for recent Stage 1 Upgrading Works). Refer Section 5.2.
1.2.2 Dam Surveillance Issues

5. Review and update the Standard Operating Procedures to address items noted at Section 5.2. For example, in the SOP for routine instrument surveillance, Appendix B refers to instrumentation which is no longer read, and other details may also be out of date.

6. Annual inspection reports should be updated to include a checklist for the earth embankments. Refer to Section 5.2.

7. Increase the frequency of reported routine inspections to daily in accordance with the ANCOLD (2003) for an EXTREME Consequence Category Dam. Pore pressures may be monitored at monthly to 3-monthly intervals. Refer to Section 6.3.

8. The saddle dams are currently inspected fortnightly. This frequency will need to be reviewed when the storage is near full (when water is above the upstream toe of the saddle dams). Refer to Section 7.2.7.

9. Maintain the gravel filled relief wells (located near the piezometer wells) at the toe of the embankment to ensure they function appropriately. Refer to Section 7.2.2.

10. Remove weeds including cumbungi from the channel downstream of the seepage monitoring points for both the left and right embankment sections. Remove slime growth in seepage pits. Refer to Sections 7.2.3, and 7.4.

11. Update Operations and Maintenance and Flood Operations Manuals to capture changes to the operation of the dam required from the Stage 1 Upgrading Works by the Wivenhoe Alliance. Refer Section 7.3.

12. Vegetation, silt and other rubbish should be cleaned from around pipes and drains formed in the left embankment crest wave wall. Refer to Section 7.4.

13. Repair rubber seal(s) as appropriate on “waterproof” gates installed in left embankment wave wall. Refer to Section 7.4.

14. Remove overgrown vegetation along the drainage channel downstream of the left embankment toe. Provide clearance under seepage pipe to allow placement of measurement container. Refer to Section 7.4.

15. Develop an inspection checklist for the new secondary fuse plug spillway for incorporation in the surveillance procedures. Refer to Section 7.4.

16. Clean out clay from the right side training wall disc drain located adjacent to the fuse bay. Refer to Section 7.4.

17. Remove tree saplings on the lower berm of the spillway discharge channel before they grow too large. Refer to Section 7.5.
18. Remove ant hill on downstream side of saddle dam 1 embankment crest. Refer to Section 7.6.

19. Saddle Dam 1 - clear long grass and other vegetation on downstream batter, at toe and within 5m of groins to enable effective surveillance. Refer to Section 7.6.

20. Saddle Dam 2 - take care not to over graze grass at toe of saddle dam 2. Remove small saplings on the upstream face and keep vegetation 5m away from groins. Refer to Section 7.7.

21. A length of 1.9m diameter penstock at the power station appears unsupported. The security of this section should be checked by a structural/mechanical engineering consultant. Refer to Section 7.9.

22. Monitoring data and plots should be kept up to date and older data (pre June 2001) included so that ongoing dam behaviour can be compared against past performance. If an anomalous incident or unusual data reading occurs in the future, then up to date comprehensive data/plotting information should be readily at hand and in a form facilitating rapid assessment. Refer to Section 6.1.

23. Ensure that the roles and responsibilities for the surveillance and monitoring processes are clearly defined from an organisational perspective and in terms of position (staff) accountabilities. Refer to Section 6.1.

24. Make sure that the monitoring data is regularly updated and reviewed by a dam surveillance engineer as it is collected and that the plots are regularly reviewed. Refer to Section 6.1.

25. Rainfall and storage level (versus time/date) should be incorporated on seepage plots. Refer to Section 6.1.

26. Ensure time series plots for dam surveillance instrumentation are kept up-to-date, and the full range of data (including the pre June 2001 data) be made available to allow rapid assessment in the event of an anomaly occurring. Refer to Section 6.2.1.

27. Merge the instrumentation data for pre- and post-July 2001 so that long-term plots can be examined for long-term behaviour and previous behaviour under similar storage conditions, as well as looking at short-term and medium-term behaviour. Comparison of older and newer data is difficult at present, because of presentational differences between available plots for the two sets of data. Refer to Section 6.2.1.

28. Prepare a one-page checklist for weekly surveillance inspection of the structures at the dam, rather than relying on written-in comments on the (essentially mechanical/electrical) monthly report. This would help to ensure that visual dam surveillance is appreciated as a separate distinct activity with a vital dam safety function, and ensure that all sections of the structures are regularly inspected. Refer to Section 6.1.
1.2.3 Dam Operations and Maintenance Issues

29. Provide a copy of the annual inspection report to the dam supervisor to ensure that items mentioned are attended to. Refer to Section 5.4.

30. As a general rule, keep vegetation (other than short grass) at least 5 metres away from dam structures, to ensure effective visual surveillance, and reduce the likelihood of damage through tree roots. Clearing or spraying of nuisance weeds and vegetation should typically be carried out at 3 to 6 monthly intervals. Refer to Sections 7.2, 7.4, 7.5, 7.6 and 7.7.

31. Clean the grass and debris from joints in the concrete dish drain on the crest adjacent to the wave wall, and clean out the pipe outlets from this drain. Refer to Section 7.4.

1.2.4 Dam Safety Investigation Studies

32. The dam hazard categories in the SEQWater Dam Safety Management Program of October 2002 should be reviewed to accord with the expanded range of categories in the revised ANCODEL guidelines as noted in Section 4.6.

33. Review and update the stability analysis of Somerset Dam to address issues noted at Section 4.2. Refer to the following recommendation.

34. Update the preliminary portfolio risk assessment carried out in 2000 to include the risk associated with cascade failure of Somerset and Wivenhoe dams. Refer to Section 4.2.

35. The current risk assessment studies are preliminary in nature only. It is recommended that the owner appraise the risk profile, and if deemed a concern, then a detailed risk assessment should be carried out that includes a detailed assessment of consequences, in particular loss of life; i.e. review the risk assessment studies for Somerset and Wivenhoe Dams and determine whether more detailed studies are warranted. Refer to Section 4.5.
2 INSPECTION METHODOLOGY

2.1 General

The Comprehensive Inspection of Wivenhoe Dam was carried out on 19th July 2006 by an Inspection Committee comprising:

- Barton Maher, Operations Engineer, SEQWater
- Roger Mail, Senior Engineer, Dam Surveillance, State Water Corporation
- Brian Cooper, Principal Contract Engineer, Department of Commerce, Dams & Civil.

The Inspection Committee was assisted by SEQWater and Sun Water personnel listed at Section 7.1. The previous Annual Inspection was in October 2004 (Appendix E2).

The methodology for this Comprehensive Inspection is based on the following four stages:

- A documentation review directed at dam failure modes, risk and consequence assessment;
- A performance review, reviewing the SEQWater dam safety management program and the documented surveillance data for instrumentation;
- A site inspection;
- Preparation of the final Report with recommendations based on the observations and review

2.2 Documentation Review

This work assesses the status of the dam in terms of Hazard Category and risk assessment studies and is reported at Section 4. Previous reviews and risk assessments include a series of reports produced by the Wivenhoe Alliance following the completion of the Stage 1 upgrade in 2005. Earlier studies include a preliminary risk assessment study by SKM and a safety review by GHD in 1997. Supplementary studies by Commerce for Somerset Dam are relevant due to the potential for a Somerset / Wivenhoe cascade failure.
2.3 Performance Review

The instrumentation data and plots on Excel spreadsheets supplied by SEQWater were reviewed and assessed for any disturbing trends, with particular emphasis on behaviour over the past five years. The following documents were examined:

- The SEQWater Dam Safety Management Program for Wivenhoe, Somerset, North Pine Dams, SEQWater (2005). This describes the overall arrangements and procedures for operation, maintenance and surveillance of the dam and lists recommendations from the previous reviews, risk assessments and other studies together with the Corporation’s assessment of these recommendations.

- The previous Annual Inspection Reports (check list reports) for the dam. These described the condition of the dam and its mechanical and electrical equipment, and made certain recommendations.

- Key drawings for the dam;

- Dam safety documentation, including:
  - Emergency Action Plan;
  - Standing Operating Procedures;
  - Detailed Operating and Maintenance Manuals;

The Corporation’s dam safety management system is outlined at Section 5. A review of dam instrumentation records is provided at Section 6, and comment on standard operating procedures, operation and maintenance manuals and emergency procedures is in the inspection checklist at Section 7.3. Recommendations resulting from previous inspections are outlined at Section 8. Refer to Section 1 for a summary of recommended actions resulting from this Comprehensive Dam Inspection.
2.4 Dam Inspection

A draft report was prepared prior to the inspection as background material for the Inspection Committee.

The documentation at the dam which relates to dam safety and surveillance was checked for currency and completeness, together with documentation on maintenance activities.

The dam was inspected guided by the annual inspection checklist. The comments made in the previous annual inspection reports by GHD and Commerce were also used as a reference. During the inspection, all major dam structures and monitoring installations and galleries were inspected, together with a brief inspection of mechanical and electrical equipment which has a bearing on dam safety, supplemented by discussions with dam staff. Photographs and videos were taken. The reservoir rim was viewed from accessible areas close to the dam, and from a boat. Various aspects of the findings of the inspection were discussed with dam staff.

2.5 Final Report

The final report describes the inspections and observations, reviews the instrumentation results, makes recommendations and reports on progress in addressing past recommendations. Photographs, and copies of selected instrumentation plots from spreadsheets provided by SEQWater are included, as well as the annotated annual inspection check list. Raw video footage of the inspection is held by SEQWater.
3 GENERAL INFORMATION

3.1 Background

Wivenhoe Dam, as originally constructed, is a 56 m high, zoned earth and rock embankment separated into two parts by a concrete gravity spillway, controlled by 5 radial gates, each 12.0 m wide by 16.0 m high. Two saddle dam embankments are located on the left side of the reservoir. The Brisbane Valley Highway was relocated to pass over the dam.

The dam has four main functions by providing:

- A 1,150 GL storage at full supply level (FSL EL 67.0) providing a safe water supply for Brisbane and surrounding areas;
- Flood mitigation in the Brisbane River with a dedicated flood storage volume of 1,450 GL up to EL77 (the MFL was increased to EL80m as part of the Wivenhoe Alliance Upgrade works in 2005 changing the flood storage volume to 2,000 GL at EL80m);
- The lower pool for the Split Yard Pumped Hydro-Electric power station which has a 500 MW generating capacity;
- A recreation area.

The dam was designed by the Queensland Water Resources Commission and a design report is provided at DPI, 1995. It was constructed by a consortium of contractors between 1977 and 1985, supervised by the Commission.

The dam has an EXTREME hazard classification (according to current ANCOLD guidelines) because of the significant development downstream in the Brisbane and Ipswich metropolitan areas, with the population at risk (PAR) numbering in the hundreds of thousands.

The first formal dam safety review was undertaken by Gutteridge, Haskins & Davey Pty Ltd in 1997 (GHD, 1977). A concurrent review of the mechanical and electrical equipment was undertaken by HECEC Pty Ltd and this Report is included at GHD (1997) as an Appendix. The base data for the original dam in this Report is largely taken from these references.

The original spillway capacity, with an Annual Exceedance Probability (AEP) of 1 in 22,000, was well below current standards for an Extreme hazard dam. The Wivenhoe Alliance was formed by SEQWater to improve the flood security with a long-term goal of providing adequate spillway capacity to pass the Probable Maximum Flood (PMF). Investigation studies concluded that the two-stage upgrade program outlined below would provide a cost-effective risk reduction program.
• **Stage 1 Upgrade Works**
  - Construction of a new secondary spillway on the right abutment that would enable the dam to handle an inflow flood with an AEP of 1 in 100,000 at a Maximum Flood Level (MFL) of EL 80. The spillway is to be controlled by three fuse plug embankments;
  - Upgrading of the embankment crest to retain a MFL of EL80 with zero freeboard;
  - Upgrading of associated structures as appropriate, including protection of the gates and spillway bridge and strengthening of the spillway gravity structure.

• **Stage 2 Upgrade Works**
  - Reconstruction of Saddle Dam 2 as a fuse plug spillway such that the dam can accommodate the PMF.

Plans for the upgraded dam and the original dam construction are all in metric units to Australian Height Datum and a local coordinate system established for the dam.

### 3.2 Hydrology

The dam failure analysis report, WA (2005) summarises the storage and spillway discharge data, the PMF inflow data and downstream flood parameters for the following PMF scenarios:

- Original dam with failure
- Stage 1 construction with failure (both fuse plug and main embankment)
- Stage 2 construction without failure
- Stage 2 construction with failure for comparison purposes.

The 36 hour PMP rainfall was found to produce the highest peak inflow and outflow at the dam. Details of the methodology used to derive the PMF hydrographs are described at WA (2004B).

The peak inflow for the PMF is 49,000 m3/s which includes outflows from Somerset Dam. This was derived using the latest GTSM-R PMP rainfall depths and temporal patterns provided by BOM (2003). The PMF has a flood volume is 5,993 GL and the peak outflow discharge following Stage 2 construction is 37,400 m3/s.

### 3.3 Main Embankment

The Wivenhoe main embankment is located on the right hand side of the centrally placed spillway. The 1.2 km embankment is a 56 m high central clay core embankment with both upstream and downstream filters supported by outer shells of compacted sandstone with river run gravel in the upper portion. The shoulder slopes are 2 horizontal to 1 vertical with a local

*Queensland Bulk Water Supply Authority – SEQWater*

SEQWater Dams Surveillance – Wivenhoe Dam Comprehensive Inspection, July 2006
steepening in the upper portion to 1.5 horizontal to 1 vertical. Riprap was provided on both upstream and downstream shoulders.

To the left of the spillway structure, the embankment has a sloping upstream core protected by both upstream and downstream filters and supported by a downstream shell of miscellaneous fill. Batter slopes are 3 horizontal to 1 vertical on the upstream face and 2 horizontal to 1 vertical on the downstream face. Riprap was provided on both upstream and downstream shoulders.

3.4 Saddle Dams

Two saddle dams close off low saddles on the left abutment of the dam. Saddle Dam 1 is a homogeneous embankment constructed from miscellaneous fill. Saddle Dam 2 is the higher of the two embankments and is constructed with a central clay core and random fill shoulders. Rip Rap is provided for both embankment on the upstream face for wave protection and the downstream slope is topsoiled and grassed. They have a crest level at EL 80 and have a maximum height of 10 m. The saddle dams only retain water during flood operation.

During the investigation undertaken by the Wivenhoe Alliance in 2003 it was proposed that a tertiary spillway be constructed through Saddle Dam 2. This was ultimately deferred as a second stage upgrade to be carried out at a later date. Initially, the upgrading works for Stage 1 works carried out by the Alliance in 2005 included minor works on the Saddle Dams to raise and strengthen them. This work was deleted from the project after discussion with the Peer Review Team. The Peer Review Team recommended that the Saddle Dams not be raised or strengthened to allow them to be overtopped prior to the main embankment during an extreme event as the Stage 1 works only allow the dam to pass the 1 in 100,000 AEP flood event. The rational behind this recommendation is that a breach of the Saddle Dams would result in significantly less downstream damage than a breach of the main embankment in the unlikely event of a flood with an AEP of less than 1 in 100,000. This is consistent with the proposed Stage 2 works.

The release of the Draft Acceptable Flood Capacity Guidelines for Dams by the QLD Department of Natural Resources and Mines in 2005 has a requirement for the Stage 2 works to be completed by October 2035. This will be confirmed by NRW following a review of dams in QLD.

3.5 Foundation

A single line grout curtain, 15 m to 35m deep and an 8 m deep grout blanket was installed under the core of the main embankment and the sloping core of the left embankment. Water losses were generally low at depth but high water losses were noted as appearing to "coincide with poorly consolidated sandstone, which is a primary structural feature and is not the result of weathering" (DPI 1995).

The foundation was cleaned off by removal of loose and shattered material and blasting with water - air jets. This was only done under the core and filter areas as the shoulders were founded on the alluvial materials. Foundation treatment generally comprised slush grout or
mortar to seal fractures, fill irregularities and fill fissures. Dental concrete was used where the contact fill could not readily be compacted and to fill cavities and smooth abrupt vertical faces. Areas where the foundation was likely to weather rapidly were mortar treated immediately following clean up.

The contact fill (Zone 1A) and filters (Zone 2) were placed while the slush grout or mortar was still plastic. The contact clay was compacted with rubber tyred construction machinery.

Excavation of the main embankment during the construction of the Stage 1 upgrade works by the Wivenhoe Alliance at the right hand side abutment of the dam found the construction tolerances to be excellent for the original dam construction. The zoning and material specifications noted from the excavation were as described by the original construction records.

3.6 Primary Spillway

The spillway is located in a low saddle between the two embankments and is controlled by 5 radial gates supported on a mass concrete ogee crest. The radial gates are 12 m wide by 16 m high and discharge via a flip bucket spillway to an unlined rock discharge channel.

The five 12 metre wide by 16 metre high radial gates in the Wivenhoe spillway structure are operated by hydraulic motor driven wire rope winches, one on each side of each gate. The power units (2) for the spillway gates and penstock gate are located in a winch room in the left abutment of the dam. Also located in this winch room is an auxiliary diesel operated hydraulic unit capable of operating the gates.

A left bank underground control complex in the dam comprises the winch room, water quality control room, main high voltage substation, main switchboard, fire control equipment, storeroom diesel alternator set, and ventilation system.

A 79 tonne travelling gantry crane on the service bridge over the spillway structure serves to handle the bulkhead gate used for maintenance of the radial gates. A smaller gantry over the intake structure is used for handling the trashracks and water quality baulks.

3.7 Outlet Works

The following information on the Outlet Works is obtained from the DPI (1995).

The outlet works extend over 4 monoliths LH11 to LH14 with the entrances to the penstock and river outlet being in Monolith 11 and the regulating valves in Monolith 14. At the entrance to the outlet works in Monolith 11 a 3.6m diameter penstock with a large capacity intake was installed to meet the demands of a proposed 30MW hydro-electric turbine, and a 1.905m diameter river outlet was installed directly above the 3.6m diameter penstock. A single fixed wheel bulkhead gate is provided to command either outlet (but not both outlets) to provide for emergency closure or dewatering.

The 3.6m diameter penstock was sealed off with a semi-ellipsoidal dome. A 1.5m offtake from this penstock provided one of the river outlets was controlled by a 1.5m diameter
stainless steel Fixed Dispersion Cone (FDC) regulating valve. The upper outlet, consisting of a 1.9m diameter pipe is located vertically above the 3.6m diameter penstock. This outlet was also controlled by a 1.5m diameter regulating valve.

In 2001/2002, a mini hydro Power Station was constructed at the outlet of the dam. A power station building was constructed housing a 4MW GE turbine at the end of the 3.6m diameter penstock. The 1.9m diameter penstock was extended through the new power station building and a new dissipator box provided for the FDC regulating Valve.

The power station was designed by Maunsell Australia for Stanwell Corporation. The power station is owned and operated by Stanwell Corporation under a Build Own Operate and Transfer agreement. The power station becomes SEQWater property after a thirty years lease. The SunWater operators at the dam are contracted by Stanwell to operate the power station.

Additional offtake are provided for town water supplies and possible local urban development.

The inlet transition is steel lined because of the high 10m/s flow velocity in the pipes. The internal surfaces of the outlet pipes were coated with coal tar epoxy to a minimum thickness of 500 microns.

A 4.1m wide by 5.25m high fixed wheel type emergency gate serves as a guard gate for the outlets through the dam (one 3.6m diameter penstock, and a 1.9m diameter outlet pipe).

Within the intake structure in the left abutment there is an arrangement of trashracks and six telescoping vertical lift gates to allow selective withdrawal of water for quality control purposes.

### 3.8 Electrical Equipment

The electrical power system consists of the following major components:

- 11kV supply system and transformer
- Main switchboard
- Diesel generator
- Load bank
- Distribution boards
- UPS power supplies.

The diesel generator is a self contained skid mounted unit with a six cylinder Mitsubishi engine and a 330kVA Stamford generator providing a three phase 415 volt AC alternative power supply for the main dam distribution board. The rating of the engine is a nominal 250kW, with a continuous rating of 90% and a one hour rating of 110%.

The diesel is automatically started at a pre-set time delay after the mains power fails and the entire site load is automatically connected to the diesel a short time later. Upon the restoration of the mains power there is a short delay and the diesel is shut down and the load reverted to
the mains supply. The instantaneous shutting down of the engine without any cooling down period would be detrimental on the diesel and would shorten its service life. The diesel is run weekly as part of the operations and maintenance program for the dam.

To ensure that the diesel is not operated for prolonged periods of time on light load an automatic load bank has been provided. When the diesel load is below a preset level, the load is connected in one step and once the total loading has increased to another preset loading the load bank is disconnected. Also the load bank is disabled when the 79 tonne gantry crane is operating from the diesel generator.

3.9 Supporting Services

There are several supporting services which influence the safety of the asset and the operators and therefore have the potential to indirectly compromise the gate operation. These services include:

- Fire detection
- Fire control and fighting
- Ventilation
- Security systems
- Communications
- Alarm systems
- Monitoring systems
- Access and material handling.

3.10 Stage 1 Upgrade Works

The stage 1 upgrade works carried out by the Wivenhoe Alliance in 2004/2005 comprised:

- Construction of a 164m wide secondary spillway through the right abutment of the existing dam in an excavated chute that included concrete works for a 3m ogee crest, apron slabs, chute lining and the divider walls to enable construction of three fuse plug embankments;
- Temporary diversion of the Brisbane Valley Highway and relocation of services to enable construction of a new road bridge across the new spillway;
- Upgrading of the existing crash barrier on the two main embankments to handle the new Maximum Flood Level (MFL) of EL 80;
- Strengthening of the primary spillway with post-tensioned anchors to cater for the increased loading due to the raised flood level.
• Provision of a steel deflection baffle upstream of the radial gates to ensure the gates clear the flow profile for the raised MFL.

• Associated works comprising spoil area, access roads, sediment and erosion controls, site facilities and landscaping.

• Refurbishment of the Visitors information Centre.

This Stage 1 upgrade changed the dam crest flood from a 1 in 22,000 AEP event to 1 in 100,000 AEP flood event. The initial trigger level for the first fuse plug embankment is at EL 75.7m (approximately the 1 in 6 000 AEP flood event).

3.11 Proposed Stage 2 Upgrade Works

Stage 2 works will involve the reconstruction of Saddle Dam 2 to incorporate a fully lined concrete chute spillway with a single fuse plug embankment. This 100 m wide spillway will provide full PMF protection with a conventional freeboard and will be triggered by the 1 in 50,000 AEP event. The concrete lining and flip bucket protects against erosion of the conglomerate foundation under the structure.

It is anticipated that Stage 2 will be constructed within a 10 to 15 year time frame and will increase the flood capacity to cater for the PMF.
3.12 Spillway Discharges at Fuse Plug Initiation

Table 3-1 shows lake water levels and discharges from the various spillways when each fuse plug initiates. The approximate flood (inflow) AEP’s at which the fuse plugs initiate are also shown. It has been assumed that a depth averaged water level of 0.1m over the fuse plug pilot channel crest is required to initiate the fuse plug. Spillway chute losses of 0.03m and 0.08 m have been assumed for bay 2 and bay 3 on the right abutment respectively. These losses were determined from the 3D CFD modeling of the spillway undertaken by Worley (2004).

<table>
<thead>
<tr>
<th>Fuse Plug No. Initiated</th>
<th>Approx. Inflow AEP (1 in X Years)</th>
<th>Gated Spillway</th>
<th>Total Right Abutment (RA) Spillway</th>
<th>Saddle Dam 2 (SD2) Spillway</th>
<th>Lake Water Level at Fuseplug Initiation (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6,000</td>
<td>10,600</td>
<td>1,650</td>
<td>0</td>
<td>75.80</td>
</tr>
<tr>
<td>2</td>
<td>11,500</td>
<td>11,200</td>
<td>5,400</td>
<td>0</td>
<td>76.33</td>
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<tr>
<td>3</td>
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<td>11,900</td>
<td>9,900</td>
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<td>76.88</td>
</tr>
<tr>
<td>4 (SD2)*</td>
<td>65,000</td>
<td>13,100</td>
<td>12,200</td>
<td>7,550</td>
<td>78.40</td>
</tr>
</tbody>
</table>

* This assumes Stage 2 construction

3.13 Geology

The following description of the site geology is taken from DPI (1995) and GHD (1997). Brief descriptions of the regional and rim geology are provided at GHD (1995).

The main dam is located wholly on the Helidon Sandstone (also known as the Wivenhoe Sandstone). The sandstone consists of quartz grains with minor dark chert fragments in a whitish kaolinitic matrix. Structurally, most of the rock foundation consisted of massive undulating layers of sandstone, sometimes cross bedded, which had dips between 2 and 10 degrees and strikes in the general ENE direction. Most of these units were separated by thin layers of shale, shale conglomerate or fine pebbly conglomerates containing minor amounts of fossilised plant material (coal).

An exception occurred on the right bank were up to 9 m of interbedded shales and fine sandstones were found. The sandstone unit above was fairly weathered and contained many thin layers of clay. A continuation of the shale / fine sandstone unit is thought to have been intersected on the left bank. This suggested that the unit was responsible for the incision of the...
river into the valley floor at the dam site and subsequent control of the alluvial deposition sequences upstream of the dam site.

Up to 20 m of alluvium / colluvium overburden was found to exist above the foundation rock.

3.14 Seismology

The Corporation has six stations throughout the three dam catchments with seismometers which measure seismic activity in x, y & z directions in real time. This data is transmitted via radio telemetry to the Wivenhoe Office where the information is analysed. Six triaxial accelerometers have been installed, two at each dam, one at the crest and one at the base of each dam, to measure the actual dam movement during earthquakes.

A review of earthquakes and earthquake hazard in the Somerset Dam area, northwest of Brisbane was undertaken by Gibson (RMIT 1995) using earthquake information published to December 1994. The study covers the area bounded by the Somerset and North Pine Dams and includes the Wivenhoe site.

No major earthquakes have occurred in the area since European settlement. The available data suggests the earthquake hazard in the area is above average for Queensland but below the average for eastern Australia.

The Report provides the annual exceedence probability (AEP) for peak ground accelerations as tabulated at Table 3-2.
Table 3-2 - Earthquake Risk for the Wivenhoe, Somerset, North Pine Area

<table>
<thead>
<tr>
<th>AEP</th>
<th>Peak Ground Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in 1</td>
<td>0.006 g</td>
</tr>
<tr>
<td>1 in 3</td>
<td>0.010 g</td>
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<tr>
<td>1 in 10</td>
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<td>1 in 10,000</td>
<td>0.392 g</td>
</tr>
<tr>
<td>1 in 20,000</td>
<td>0.505 g</td>
</tr>
</tbody>
</table>
4 RISK ASSESSMENT, FAILURE MODES AND CONSEQUENCE ASSESSMENTS

4.1 Risk Assessment Studies

A number of studies have been undertaken in recent years relating to various aspects of Wivenhoe and Somerset Dams. Somerset Dam is relevant in relation to the possibility of a cascade failure of the two dams. These include:

- Dam Safety Review of Wivenhoe Dam reported in GHD (1997);
- A preliminary risk assessment of Wivenhoe, Somerset and North Pine Dams by SKM, reported at SKM (2000);
- A detailed risk assessment for Somerset Dam by SMEC (2004);
- A review and updating of the Wivenhoe risk assessment report by the Wivenhoe Alliance, WA (2004C).
  ➢ These were based on a hydrology study by WRM Water and Environment, WRM (October 2004). It is understood that this Report has been revised and these revisions need to be incorporated in to the Commerce conclusions.

4.2 Cascade Failure

Wivenhoe Dam, following the completion of the Stage 1 Upgrade works, is designed to handle a 1 in 100,000 AEP flood event centred on the Wivenhoe catchment, assuming that Somerset Dam does not fail. A cascade failure of both Somerset and Wivenhoe Dams would only result from an extreme flood event as Wivenhoe reservoir has sufficient capacity to store the normal Somerset storage volume without initiating the secondary spillway fuse plugs.

The impact of a Somerset Dam failure on Wivenhoe Dam was detailed at Commerce (2004). The dominant risk associated with Somerset Dam is structural failure of the non-overflow units at the change in slope during a major flood event. Stability studies indicated with some reservations that the dam may satisfy normal stability criteria for the 1 in 100,000 AEP flood event centred on the Somerset catchment. On this basis it is argued (Commerce, 2005), that any upgrade to Somerset Dam should attract the same degree of urgency as Stage 2 Wivenhoe works.

The hydrology study used by Commerce (2004) was revised (WRM 2005). This revision resulted in an increased in the Maximum Flood Levels (MFL) for the range of flood investigated. This resulted in the stability of Somerset Dam for the 1 in 100,000 AEP event being marginal according to the stability analysis results. Therefore it is considered necessary...
that the risk associated with the cascade failure of Somerset and Wivenhoe be investigated by updating the Preliminary Portfolio Risk Assessment carried out in 2000.

There are several outstanding issues which may impact on the stability of Somerset that should be examined including:

2. Operation of the sector gates during an extreme flood event. If the gates were lowered into the flow during an extreme event this would induce significant load on the structure.

3. Cracking on the downstream side of the upper gallery. If similar cracking occurs above or below the gallery this has the potential to impact on the stability results for the upper part of the dam.

4. Flooding for the galleries for water levels above RL107.46. The impacts on the stability of the dam for these higher water levels need to be addressed.

### 4.3 Consequences of Failure for Wivenhoe Dam

#### 4.3.1 Loss of Life Assessments

SKM (2000) provided loss of life estimates for both day and night failures of Wivenhoe Dam for a variety of load cases. SMEC (2004) has used the SKM data for total loss of life at night and adopted the following loss of life figures for the risk assessment:

- IFF Failure (Main Embankment) 89
- Earthquake 36
- Normal Operating Condition (main embankment piping failure) 77

#### 4.3.2 Financial Loss Assessments

SKM (2000) has assessed the financial consequences associated with the failure of Wivenhoe Dam under three broad categories; third party damages, SEQWater direct damages and SEQWater loss of revenue. A major failure of Wivenhoe Dam was valued at $12 billion to $25 billion.

#### 4.3.3 Environmental & Intangible Consequences

The SKM (2000) study included an assessment of environmental and intangible consequences. SKM assessed the incremental environmental consequences for Wivenhoe dam as low while the incremental intangible consequences were assessed as high. It concluded that:

> “These environmental and intangible consequences were far outweighed by the significant life loss and financial consequences for this portfolio. As such they did not play a significant role in the development of the risk reduction strategy.”
4.4 Risk Analysis

The original risk analysis for Wivenhoe Dam was developed by SKM and is reported at SKM (2000).

WA (2004C) reviews the risk to life presented by Wivenhoe Dam in both its existing state and after flood security upgrading works. It is an extension of the risk assessment undertaken by SKM (2000) and starts with a review of the earlier risk analysis of Wivenhoe Dam. It then considers the effect of the latest (2003) flood hydrology on the dam’s risk profile.

The Wivenhoe Alliance further revised this work to incorporate the risks associated with a Somerset failure. The FN Charts for total loss of life is shown at Figure 4-1 and indicates that:

- The original Wivenhoe Dam plots well above the ANCOLD Limit Line;
- The Stage 1 Upgrade for Wivenhoe brings the risk below the ANCOLD Limit Line provided Somerset does not fail;
- If allowance is included for risks associated with Somerset, the plot rises just above the Limit Line;
- The Stage 2 Upgrade brings the risk well below the Limit Line.

The total risk to Wivenhoe Dam as a stand-alone construction following the Stage 1 Upgrade works is assessed at $0.84 \times 10^{-5}$ per annum. Introducing the risks associated with a Somerset failure increases these risks by a factor of 2.4 to $2.0 \times 10^{-5}$ per annum.

The risk to life matrix (F-N Chart) using the incremental loss of life figures is reproduced at Figure 4-2. This shows the Wivenhoe risks plotting below the ANCOLD Limit Line.

The report recommended that due to its relatively simplistic nature and the way in which judgement was used (in conjunction with deterministic analysis) to estimate conditional probabilities, the risk analysis should not be used to determine the satisfaction of ANCOLD risk criteria in an absolute sense.

However, the risk analysis was useful in comparing the relative risk presented by various states of the dam (existing dam, fully and partially upgraded dam, various levels of radial gate upgrading). It further recommended that consideration be given to further, slightly more rigorous risk analysis. However, the decision for doing this analysis should not be made until the final option is determined and the dambreak studies completed and the consequences reassessed.

4.5 Limitations of Risk Studies

The Wivenhoe Alliance study is a modification of the SKM study and as such is a Preliminary Risk Assessment. If the risk profile is a concern, a detailed risk analysis should be carried out, that includes a detailed assessment of the consequences, particularly loss of life. Previous consequence studies are dated and there has been considerable development along the Brisbane River Valley since the previous assessment.
4.6 Hazard Category

The Dam Safety Management Plan, SEQWater (2005) at Section 6.1 states that “The Corporation’s dams are classified under the ANCOLD classification guidelines as HIGH hazard because of the significant consequences of a dam failure”.

The basis for this classification is outlined at GHD (1997) and is based on:

- The significant development downstream in the Brisbane and Ipswich metropolitan areas, with the population at risk (PAR) numbering in the tens of thousands.
- The extensive residential and commercial development in the Brisbane along the river banks;
- The investment in infrastructure including key road and rail bridges.

The classification was based on an early version of ANCOLD (2000B). The current Guideline has a more extensive classification system and it is recommended that the Hazard Classification be reviewed using the current Guideline.

It is considered that Wivenhoe Dam would be re-classified as EXTREME Hazard based on application of the latest ANCOLD Guidelines and a more rigorous assessment of the population at risk (PAR) than that provided in GHD (1997).

4.7 Conclusions

The risk assessments for Wivenhoe Dam are Preliminary Assessments only. If the risk profile is a concern, a detailed risk analysis should be carried out, that includes a detailed assessment of the consequences, particularly loss of life. Previous consequence studies are dated and there has been considerable development along the Brisbane River Valley since the previous assessment. Consideration would also need to be given to the effects of a cascade failure initiated by failure of Somerset Dam.
Figure 4-1 - ANCOLD Total Societal Risk Assessment – from Wivenhoe Alliance, 2004

Wivenhoe Dam Total Societal Risk: Interim Spillway Upgrade

- Limit Line
- Existing Dam - Latest Fld.Freq.
- Full Upgrade
- Total Risk Interim Upgrade Considering Somerset Dam Failure
- Total Risk Interim Upgrade with No Failure of Somerset Dam

Queensland Bulk Water Supply Authority – SEQWater
SEQWater Dams Surveillance – Wivenhoe Dam Comprehensive Inspection, July 2006
Figure 4-2 - ANCOLD Incremental Societal Risk Assessment – from Wivenhoe Alliance, 2004

![Wivenhoe Dam Incremental Societal Risk: Interim Spillway Upgrade](image-url)

- **Limit Line**
- **Full Upgrade**
- **Incremental Risk Interim Upgrade Considering Somerset Dam Failure**
- **Incremental Risk Interim Upgrade with No Failure of Somerset Dam**
5 SEQWATER DAM SAFETY MANAGEMENT PROGRAM

5.1 Program Objectives

Dam Safety Legislation is contained within the Water Act 2000. The legislation defines an objective of protecting life and property and gives broad discretionary powers to the Chief Executive of the Department of Natural Resources and Mines who is responsible for dam safety in Queensland.

Requirements are now prescribed in Queensland Safety Management Guidelines for Referable Dams (2001).

SEQWater has a well developed Dam Safety Management Program designed to ensure that each dam is operated and maintained in a safe manner and that risks associated with dam failure are minimised. This management program is documented at SEQWater (2005), and details the management structure and policy of the Corporation ensuring dam safety and summarises the six functional levels of documentation listed below.

The Plan was comprehensively prepared in 2002 with some tracked updates for March to May 2005. It now requires further updating of details and clarification in some areas. In particular:

- Definition of the roles of the Operations Manager and Operations Engineer, with a clear statement of who is responsible for management and assessment of surveillance data;
- Definition of the respective roles and responsibilities of SEQWater and Sun Water;
- The statement concerning 5 Yearly surveillance inspections should be modified to reflect actual practice;
- Wivenhoe instrumentation on page 12 needs to be amended.

5.2 Dam Safety Documentation

Six functional levels of documentation are required by the Department of Natural Resources, Mines and Energy Safety Group require the following documentation for each dam. The requirements and the documentation available for Wivenhoe Dam are listed below:

- *Emergency Action Plan*. This is a short document that details procedures to be followed in the event of problems developing at a dam. The plan is completed and has control document status. No documentary evidence was sighted indicating the EAP had been tested during a training exercise. This should be considered to evaluate the performance of the EAP.
• **Standing Operating Procedures.** This document details procedures to be followed in the operation of the dam especially during periods of flooding or high risk operation. It should contain sufficient information to enable all safety equipment at the dam to be operated.

  - The plan is completed and has control document status. The title pages including the index were updated in December 2004.
  - The SOP documents were comprehensively prepared prior to 1998, but need updating of details and clarification in some areas. The SOPs don’t seem to be fully followed in practice as, at least in 2003; visual inspection sheets weren’t being filled in to document the surveillance being done.
  - The frequency of reading the instrumentation and the frequency of visual inspection should be reviewed. Weekly seepage readings should probably be more frequent.
  - The procedure flowchart at one stage does not say what to do if the instruments are not OK.
  - The procedures mention an Operations Engineer, but not an Operations Manager, and it is not clear who is responsible for updating the plots, reviewing the data and ensuring review is carried out. The documents require the Dam Supervisor to ensure this work is done but it is questioned whether he is in a position to do this.
  - The documentation mentions entering data into “the database” although it is understood that instrument readings are entered into a monthly report that is sent to SEQWater. The data is then downloaded into individual excel spreadsheets each month and the plots updated. These two steps are not well documented and there is confusion as to who is responsible.
  - There are several variations of the title Contract Manager;
  - The procedures refer to proformas for visual inspection that were not available in 2003. The inspecting engineer at annual inspections is required to confirm that the dam behaviour is within acceptable limits, but there is no explicit reference to examining instrumentation records or plots, and this is not included in the Flowchart.

• **Detailed Operating and Maintenance Manuals.** This documentation should contain general information detailing operating, maintenance and overhaul instructions for all equipment at the dam and the maintenance procedures.

  - The 17 volume plan is completed and has control document status;
  - The manuals are revised upon any refurbishment, replacement or modifications of any components of any of the equipment
  - This Manual is co-ordinated with the Corporation’s Planned Maintenance Program;
  - Flood operations are handled in accordance with the Flood Operation Manual for the Wivenhoe/Somerset system, developed in conjunction with the Department of Natural Resources and Water (NRW). The Manual is reviewed
after every flood event. The last flood release for Wivenhoe Dam occurred in 2001.

- **Inspection and Evaluation Reports.** This document records details of operations, surveillance data and the findings of inspection Engineers.
  - Annual inspection reports were reviewed. The reports need to be updated to include a checklist for the earth embankments as the current check list focuses mainly on the mechanical and electrical components of the dam.

- **Data Books.** A data book is an abbreviated, convenient source of information summarising all the pertinent records and history related to the safety of the dam. It will contain a complete set of as constructed plans of the dam. It may actually be a large set of documentation.
  - Completed with as much data as is available.

- **Dam Safety Review / Design Reports, Investigation Reports etc.** This collection of documents should detail all the technical information on the investigation, design and construction of a dam. They should include the basis for all design and operating criteria and be in sufficient detail that no further investigations are necessary to resolve any technical issues which may arise. In the absence of a design report, the dam safety review should cover those areas not adequately documented.
  - A series of studies forming a dam safety review have been completed as noted at Section 4.1.
  - A Design Report and a Construction Report for the original dam was produced in 1995. The Wivenhoe Alliance is responsible for producing design reports for the Stage 1 upgrade. These Reports are in draft form at this time.
  - It is recommended that all outstanding dam safety compliance documents be finalised.

### 5.3 Routine Monitoring and Inspections

For confirmation of satisfactory behaviour and identification of deficiencies, the Operation and Maintenance Contractor’s dam supervisors undertake routine inspections and instrument readings as part of their normal duties at each dam. Inspections are in accordance with the requirements of the relevant Standing Operating Procedures and Operation and Maintenance Manuals including maintaining records in the operating log and in the dam data book and instrument recording folders.

The dam supervisors ensure that all instruments are regularly maintained and tested at intervals not exceeding those recommended by the manufacturers of the instruments to ensure reliability of measurements carried out.
Instruments read include:

- V-notch weirs in lower gallery of spillway for seepage;
- Seepage measuring points in left and right embankment drainage systems;
- Piezometers (right embankment & spillway) for uplift pressure;
- Inclinometers (right embankment) for movement;
- Survey points on concrete structure and left and right embankments, for movement.

The on-site officers who carry out the routine inspections have the following length of experience in routine dam inspections:

- Doug Grigg, Dam Supervisor, over 15 years experience as a dam operator (10 years at Wivenhoe)
- Geoff Elliot, Electrical Officer, over 10 years at Wivenhoe Dam

### 5.4 Intermediate Inspections

Where ongoing dam surveillance or unusual flood or earthquake events indicate abnormal behaviour, the dam supervisors undertake an *Unplanned Inspection* at the direction of the Operations Manager. Follow-up inspections by the Operations Engineer and possibly dam specialist consultants may be required.

**Specific Inspections** involve the confirmation of satisfactory behaviour or identification of deficiencies by a thorough on-site inspection; by evaluating data; and by applying current criteria and state-of-the-art knowledge. Equipment is test operated to identify any deficiencies. Condition monitoring is undertaken on selected mechanical and electrical equipment every 6 months and recorded in the dam data books.

**Periodic (Annual) Dam Inspections** are performed by the Corporation’s Operations Engineer or consulting engineer by visual examination of the dams and review of surveillance data against prevailing knowledge.

The annual inspections require the review of maintenance records of equipment which is considered important for Dam Safety. This includes, but is not limited to spillway and sluice gates and emergency generating equipment.

Note that a copy of the annual inspection report should be provided to the dam supervisor to ensure that items mentioned are attended to.
5.5 Comprehensive (5-Yearly) Inspections

The documentation requires a comprehensive inspection to be carried out at five yearly intervals. The inspection committee issues a Comprehensive Surveillance Report which is submitted for review. The last Comprehensive Inspection for Wivenhoe Dam was completed in 1997.

5.6 Training

The basis for personnel training and the proficiencies required are detailed in the Dam Safety Management Program, SEQWater (2005). Education and training for the relevant Operations Section staff is gained through experience and formal education; experience with the current management of the dams (e.g. use of, and enhancement of the O&M Manuals, the Standing Operating Procedures, the Emergency Action Plans, analysis of surveillance data, etc); and relevant “formal” seminars, etc. (e.g. ANCOLD Conferences). Operations Section staff at Lake Wivenhoe Information Centre undertake Incident Response training for dissemination of information during a flood.

The contract for the Operation and Maintenance of the dams specifies the training requirements for contract staff. It also contains specific requirements for training in flood operations.

5.7 Scrutiny and Analysis

The results for the weekly surveillance inspection are collated by SunWater and presented to SEQWater on a monthly basis. The Dam Supervisor and Electrical Officer are trained internally by SunWater in Dam Surveillance. Any unusual readings or observations are notified to the SunWater Operations Manager and the SEQWater Operations Engineer.

The results of the surveillance are reviewed by the SEQWater Operations Engineer for long term trends. The plots of data are not continuous and do not necessary include all of the relevant data. It is recommended that the plots of surveillance data are combined and kept up to date to allow easy review of the ongoing behaviour of the dam.
### 5.8 Summary of Recent Reports

A large number of flood study Reports and Investigations are listed in SEQWater (2005). The following Reports have or are being produced by the Wivenhoe Alliance.

**Table 5-1 - Flood Study & Investigation Reports by Wivenhoe Alliance**

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<th>Title</th>
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<th>Author</th>
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<td>Completed</td>
<td>All Reports by Wivenhoe Alliance</td>
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<td>WIV-RP-HD-006</td>
<td>Dambreak Study Report</td>
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<tr>
<td>WIV-RP-DE-009</td>
<td>Option Selection and Concept Design Report</td>
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<tr>
<td>WIV-RP-GE-001</td>
<td>Phase 1 Geotechnical Report</td>
<td>Completed</td>
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</tr>
<tr>
<td>WIV-RP-GE-003</td>
<td>Phase 2 Geotechnical Report</td>
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<td>WIV-RP-DE-014</td>
<td>Operational and Maintenance Requirements</td>
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5.9 Summary of Modifications and Major Maintenance

These include:

- Sealing plates for Operations Room
- Modifications to hydraulic lines
- New mini-hydro power station constructed in 2002
- Access ramp from the bench on the left embankment to below the office

SEQWater (2005) provides a long list of recommendations for Wivenhoe Dam and a full listing of these is included at Appendix F. The great majority of these have been attended to while others are noted as requiring annual review. Table 8-1 lists a number of recommendations that may be relevant to this Comprehensive Inspection.

Table 8-2 lists three actions proposed by Consultants together with Corporate comment.
6 REVIEW OF PERFORMANCE

6.1 Inspection and Monitoring Procedures

The dam and the appurtenant works are generally in a satisfactory condition and the instrumentation recordings indicate the dam is behaving satisfactorily.

Prior to this surveillance inspection (July 2006), a comprehensive dam safety inspection was carried out in 1997 and is reported at GHD (1997). Annual inspections have been carried out in 2002, 2003 and 2004 and these are reported at GHD (2002 and 2004) and at Commerce, 2003. Copies of the 2003 and 2004 annual inspection reports are provided at Appendix E.

Based on the Inspection Committee’s review of procedures, the following general comments regarding data collection and review processes are made with respect to all 3 SEQWater dams (Wivenhoe, Somerset and North Pine):

- SunWater is currently responsible for carrying out routine visual inspections; collection of monitoring data and plotting of results; notification of any unusual readings or observations etc. The results are reported on and forwarded to SEQWater at monthly intervals.

- SEQWater is responsible for reviewing the monthly surveillance reports and monitoring data.

- The surveillance and monitoring data was not presented (2003 and 2006) in a form that could be readily assessed.

- Monitoring data and plots should be kept up to date and older data included so that ongoing dam behaviour can be compared against past performance. If an anomalous incident or unusual data reading occurs in the future, then up to date comprehensive data/plotting information should be readily at hand and in a form facilitating rapid assessment.

- Ensure that the roles and responsibilities for the surveillance and monitoring processes are clearly defined from an organisational perspective and in terms of position (staff) accountabilities.

- Make sure that the data is regularly updated and reviewed by a dam surveillance engineer as it is collected and that the plots are regularly reviewed.

- Rainfall and storage level (versus time/ date) should be incorporated on seepage plots

It is recommended that a one-page checklist be prepared for weekly surveillance inspection of the structures at the dam, rather than relying on written-in comments on the (essentially mechanical/electrical) monthly report. This would help to ensure that visual dam surveillance is appreciated as a separate distinct activity with a vital dam safety function, and ensure that all sections of the structures are regularly inspected.

Queensland Bulk Water Supply Authority – SEQWater

SEQWater Dams Surveillance – Wivenhoe Dam Comprehensive Inspection, July 2006
6.2 Monitoring Behaviour

6.2.1 Instrumentation

Instrumentation plots for leakage, piezometers, and inclinometers are attached at Appendix C. The Appendix is sub-divided as follows:

- Appendix C1 – Instrumentation Drawings
- Appendix C2 – Storage Level Behaviour and Rainfall
- Appendix C3 – Piezometric Data
- Appendix C4 – Leakage Data
- Appendix C5 – Inclinometer Data
- Appendix C6 - Surface Movement Survey

The instrumentation data was assessed by inspection team member Roger Mail.

It is noted that the surveillance plots presented at Appendix C were provided retrospectively by SEQWater. These plots therefore include monitoring data subsequent to the date of the inspection (July 2006). The dataset also incorporates revisions that reflect the comments and recommendations at Section 6.1 above; i.e. inclusion of storage level and rainfall plots and older data; improved presentation, anomalies fixed etc.

At the time of the inspection, instrumentation plots were generally only available from July 2001 to January 2006, however at the intermediate inspection in December 2003, leakage plots of weekly data from July 1997 to June 2001, and piezometer plots of monthly data from July 1996 to March 2001 (16 plots) were examined, along with selected plots of monthly piezometer data from Jun 1982 to Jun 1996. The comments from that report have been taken into account in the assessment below. Instrumentation readings up to end June 2007 which were not incorporated into the original plots at the time of the inspection have also been assessed. Inconsistencies found in the earlier dataset are not evident in the data presented at Appendix C.

It is recommended that time series plots for dam surveillance instrumentation are kept up-to-date, and the full range of data (including the pre June 2001 data) be made available to allow rapid assessment in the event of an anomaly occurring. The instrumentation data for pre- and post- July 2001 should be merged so that long-term plots can be examined for long–term behaviour and previous behaviour under similar storage conditions, as well as looking at short-term and medium-term behaviour. Comparison of older and newer data is difficult at present, because of presentational differences between available plots for the two sets of data.
6.2.2 Storage Level Behaviour

The storage level variation and rainfall data is shown graphically at Appendix C2.

The storage was near full in February 2001. The storage level dropped at a fairly constant rate from EL 66.49 on 4/7/01 when most current plots commenced to about 56.63 on 27th January 2006, except for an inflow about February 2004 which produced a 2m storage level rise. On the day of the inspection the storage had fallen to approximately 28% full (RL 55.1).

6.2.3 Piezometers

Piezometric data plots are presented at Appendix C3.

There are 65 piezometers, including 24 near Ch 1600 and 22 near Ch 1800 at two cross sections in the right earth embankment, and 14 in the concrete spillway section.

There are also 5 piezometers installed in the core of the diversion channel section of the main embankment. Three of these are installed in a cross section just above foundation level, and one to each side of the cut. The most downstream tip shows little variation, but the other four have reduced with storage water level over the past 4½ years.

At chainage 1600, there are three tips in the foundation, one in the downstream filter, one in the upstream alluvium and one in the downstream alluvium, as well as 18 tips in the core. At each level, the indicated levels reduce across the width of the core. There is about a 6m drop across the grout curtain,

Most piezometers do not change significantly, except for a fall with SWL in the more upstream piezometers, and those in the foundation (e.g. 1, 2, 3, 4, 10, 14, 18, and 23). Those installed at EL 65, above current water level, are reading below their installation level. Piezometer 22 may now have air in the lines, or a leak.

At chainage 1800, there are three tips in the foundation, and one in the downstream filter, as well as 18 tips in the core. At each level, the indicated levels reduce across the width of the core.

There is about a 20m drop across the grout curtain.

Most piezometers do not change significantly, except for a fall with SWL in some piezometers, usually the more upstream ones including those in the foundation (e.g. 28, 34, 35, 36, 38, 42, and 43). There is no significant change in piezometer behaviour, but those installed at EL 65, above current water level, are reading at or below their installation level. Piezometer 45 may now have air in the lines, or a leak.

Piezometers in the spillway section foundation have not showed a significant change in the four years up to about June 2005, but many of them have changed by a small amount since then.
Notes re 2006/ 2007 assessments by Roger Mail:

- Plots for piezometers at the old diversion channel (possibly piezometers 17 to 51) were not sighted.
- Piezometers 23 and 24 were plotted at chainage 1800 as well as their correct chainage (1600)

Overall, there is no significant change in piezometer behaviour.

6.2.4 Leakage

Leakage data plots are provided at Appendix C4

Plots of weekly data from July 01 to January 2006 were examined. There are four seepage points, west and east in the concrete dam lower gallery, one for the right embankment downstream of the old diversion section and another since February 2002 for the left embankment, monitoring flow from the toe drain. Typical dry weather seepage flows during this period are under 1000 L/hr for the Old Diversion area, under 200L/hr for the east toe, and under 200L/hr for the east and west gallery weirs. The east toe weir shows the most response to storage water level, and the most responsiveness to rainfall. Over the past year, the gallery weirs have been less than 100L/hr and 30L/hr respectively, showing the effect of the low storage level. There has been no significant change in seepage behaviour.

At the time of the inspection, storage water level and rainfall data was not incorporated on the seepage plots. Monitoring and presentation of this data has since been undertaken (refer Appendix C2).

6.2.5 Inclinometers

Inclinometer data plots are presented at Appendix C5

Four inclinometers are read, with inclinometers I1, I2 and I3 at Ch 1600 and inclinometer I4 at Ch 1800. Inclinometers I1 and I4 are generally read monthly, and I2 and I3 are generally read 3-monthly. Plots of the last five readings at each hole (pattern of displacements over the inclinometer height) since January 1990 for I3 and I4 and since August 1989 for I1 and I2 are attached.

Inclinometer I1, 6.5m downstream of the axis at CH 1600 shows a maximum downstream deformation of 14mm at a depth of 37m, and a downstream deformation of 4mm at the top of the hole. It shows a maximum 15 mm right movement over the top 10 metres of the hole.

Inclinometer I2, 40m downstream of the axis at CH 1600 shows a maximum downstream deformation of 7mm at the top of the hole. It shows a maximum 5 mm left movement over the top 7 metres of the hole.
Inclinometer I3, 68m downstream of the axis at CH 1600 shows a maximum downstream deformation of 17mm at the top of the hole. It shows a maximum 5 mm left movement at the top of the hole.

Inclinometer I4, 6.5m downstream of the axis at CH 1800 shows a maximum downstream deformation of 15mm over the top 8m of the hole. It shows a maximum 10 mm right movement over the top 16 metres of the hole.

The plots do not show any significant concentrated movement since the start of 1990, and apart from the normal variations between individual inclinometer readings, do not show any recent movements over the past five readings. Much larger overall movements appear to have been measured prior to 1990.

Confirmation of readings prior to 1990 should be provided given the noticeable change in trend.

For I2, only the top 17 metres are now being read out the original 33 metres, so figures before 1999 are not comparable.

Three additional inclinometers were installed on both the left and right side of the fuse plug spillway by the Wivenhoe Alliance to monitor movements during construction. Results from these inclinometers were not available and were not reviewed as part of this report.

6.2.6 Movement Survey

Surface movement plots are presented at Appendix C6.

There are 46 currently surveyed long-term stations on and near the main right embankment.

Results were provided some time after the inspection for surveys from 1984 to December 2007 in tabular and graphical form. The graphical time series plots showing movements for each individual point in the X, Y and Z directions over the period of record are a great improvement in presentation compared to the previously-available tabulations of coordinates and coordinate differences and made assessment of the trends much easier. No anomalous movements were shown by the deformation surveys. There is continuing settlement at some points since the previous comprehensive inspection, but at a reducing rate. Similarly some points show continuing small movements in the X and Y directions.

The total movement shown by the latest survey has a maximum of 132mm settlement (the Z direction) over 22years at point 8 on the upstream edge of the crest. Maximum recorded movements in the X (mainly right) and Y (mainly downstream) directions were 24mm and 87 mm, also at points on the upstream edge of the crest.
6.3 Inspection and Monitoring Frequency

The July 2006 inspection determined that the embankment was being inspected fortnightly and the concrete dam weekly. This frequency of inspection is inadequate.

In accordance with ANCOLD (2003) for an EXTREME Hazard Category dam, the frequency of routine inspections and monitoring for seepage, rainfall and storage level should be daily. Pore pressures may be monitored at monthly to 3-monthly intervals. Refer to Tables 5.2 and 5.3 of the above reference.

It is noted that the inspection frequencies in 2003 fell far short of the above guidelines for an EXTREME category dam.

The above recommendation anticipates reclassification of the hazard category to EXTREME (refer to Section 4.2). If the hazard category reassessment indicates a HIGH rating then the dam owner may undertake a review to determine if a reduced frequency of inspection is acceptable.
7 RECORD OF INSPECTION

7.1 General

7.1.1 Committee

The Wivenhoe Dam Safety Committee that inspected and reviewed the safety status of Wivenhoe Dam on 19 July 2006 comprised:

Committee:

Mr. Barton Maher  Operations Engineer  (SEQWater)
Mr. Roger Mail  Senior Engineer, Dam Surveillance (State Water)
Mr. Brian Cooper  Principal Contract Engineer (NSW Department of Commerce)

Assisted by:

Doug Grigg  Dam Supervisor, Wivenhoe Dam (SunWater)
Robert Gorian  Senior Technical Officer (SunWater, Ipswich)
Mark Granzien  SEQW Ranger (Boat Driver)

7.1.2 Storage and Conditions

On the days of the inspection:

- The storage level was EL 55.13
- The weather was fine and sunny
- The most recent rainfall was 3mm on the 17/7/2007
- Dam releases were:
  - Spillway - nil
  - Valves – nil
  - Power station - approximately 400ML/day
- The largest discharge that has passed over the spillway to date was 150,000 ML/d (1750m³/s) in 1999.
  - On that occasion, the storage water level was at approximately EL 70m, 3000 mm above FSL. This represents 14% of the design discharge. The spillway has not passed any flows since early 1999.
7.2 Inspection Details

7.2.1 General

The inspection pro-forma used at previous annual inspections was used as the basis for the site inspection and some detailed comments have been included in Sections 7.3 to 7.11. The 2003 and 2004 Annual Inspection Reports are attached at Appendix E.

7.2.2 Right (Main) Zoned Embankment

The right embankment section was inspected on foot along the downstream edge of the crest and from the wave wall on the upstream edge of the crest, at about 100m to 200m intervals, from the toe downstream of the junction with the concrete spillway section, and from the upstream right abutment near the end of the crest.

The upstream face and upstream right abutment were inspected by boat.

The downstream toe was inspected from a vehicle, stopping and inspecting the seepage monitoring point and the two piezometer installations. Two inclinometer installations were also seen at the crest. This embankment is inspected fortnightly under the routine inspection schedule. This frequency of inspection is inadequate for a dam likely to have an Extreme Hazard Rating.

The function of the gravel filled wells (located near the piezometer wells) at the toe of the embankment is to provide relief drainage – they are connected to the downstream filter/drainage system in the main embankment. It is recommended that the pipes be maintained to ensure the relief wells are functioning appropriately.

Based on this inspection the embankment is in a satisfactory condition.

7.2.3 Left Zoned Embankment

The left embankment section and the left abutment were inspected on foot along the downstream edge of the crest and from the wave wall on the upstream edge of the crest, at about 100m to 200m intervals, from the crest near the office and car park area, from a boat, and from the downstream groin and toe, including the seepage monitoring point. This embankment is inspected fortnightly under the routine inspection schedule. This frequency of inspection is inadequate for a dam likely to have an Extreme Hazard Rating.

Based on this inspection the embankment is in a satisfactory condition.

The channel downstream of the seepage monitoring point was overgrown with weeds including cumbungi. This vegetation should be cleaned out.
7.2.4 Concrete Spillway

The concrete spillway section of the dam, including the gates and the highway bridge, was viewed from a boat and from the spillway bridge, the highway bridge and other sections of the concrete crest and the embankment crest sections, and from the top of the pier to the left of gate 1. It was also inspected from the downstream embankment toe on the left and right hand side, from the tops of the downstream spillway training walls, and from the crest of the embankment adjacent to the left upstream spillway training wall. All galleries were inspected, including their instrumentation and the lower gallery drains.

The concrete dam is inspected weekly under the routine inspection schedule. This frequency of inspection is inadequate for a dam likely to have an Extreme Hazard Rating.

The concrete spillway section was in a satisfactory condition.

7.2.5 Outlet Works and Mechanical & Electrical Equipment

The outlet works were inspected from the operating level inside the intake structure and from the sump pump area and gallery, with a brief inspection of the low voltage switch room. The new power station on the left side of the spillway including the relocated cone valve and dissipator were also briefly inspected. The fixed gas monitoring facility for the power station has recently been recalibrated.

The power station was discharging during the inspection.

A stationary stand-by generator and hydraulic pump unit and connecting lines provide a backup to the mains powered system for the lifting of the radial gates, and can lift one gate at a time. A mobile hydraulic unit can also be connected to raise one gate at a time.

Sealing plates were ready for use to cover the window and cable entry to the hydraulic unit, winch and control area in the event of an extreme flood.

A power failure was simulated and the standby generator started up after a short delay. The uninterruptible power supply had maintained lighting. A radial gate was raised and lowered 200mm from the control room. Power was then turned back on.

No. 1 radial gate was later raised about 1.5m and lowered using mains power.

SunWater at Ipswich generates computer listings on a weekly basis of mechanical and electrical tasks including inspection, overhaul, and routine exercising of equipment, which include items required at various frequencies. Performance of these tasks is reported to SunWater at Ipswich monthly. These sheets are kept in the operating log. The overall impression is that this work is well performed, is generally up to date and the system works well.

The outlet works and equipment were in a satisfactory condition.
7.2.6  Secondary Spillway and Road Bridge

The secondary spillway and road bridge were inspected by walking beside the upstream
training walls and upstream part of the ogee crest, by walking along the crest of the fuse plug
embankments and by driving on the road downstream. The inclinometers in the spillway were
being read by Coffey’s at the time of the inspection.

7.2.7  Saddle Dams

Each of the two saddle dam embankments and their abutments were inspected on foot from
the crest and from the downstream toe. These dams are to be inspected fortnightly under the
routine inspection schedule. This frequency will need to be reviewed when the storage is near
full (when water is above the upstream toe of the saddle dams.

The saddle dam embankments were in a satisfactory condition.
7.3 Operational and Emergency Preparedness

*Standard Operating Procedures (SOP)*

1. Issue or revision date: November 2001
2. Is copy at dam current? Yes
3. Are Instructions adequate? Yes
4. Are Instructions understood? Yes
5. Any changes required? Yes

*Comments*

Standard Operating Procedures in need of revision as some procedures amended or out of date.

*Operations & Maintenance Manuals*

1. Issue or revision date: December 1992
2. Is copy at dam current? Yes
3. Are Instructions adequate? Yes
4. Are Instructions understood? Yes
5. Any changes required? Yes

*Comments*

The manuals should be updated to capture the changes to the operation of the dam required from the upgrading by the Wivenhoe Alliance.
**Emergency Action Plan**

1. Issue or revision date : December 2005
2. Is copy at dam current? Yes
3. Are Instructions adequate? Yes
4. Are Instructions understood? Yes
5. Any changes required? Update Contact list at 6 monthly intervals

**Comments**

Recently revised in December 2005

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**Flood Operations Manual**

1. Issue or revision date : December 2004
2. Is copy at dam current? Yes
3. Are Instructions adequate? Yes
4. Are Instructions understood? Yes
5. Any changes required? Yes

**Comments**

Manual to be updated to reflect post construction status.
Flood Operations

1. Flood Warning & Operations
   (a) Duty Engineer current? Check Flood Control Centre Answering machine (3227 7857)
      (a) Office phone - Number given on message
      (b) Home phone - Number given on message
      (c) Mobile phone - Number given on message
      (b) Date of last Flood Operations training.

2. Standby Operators
   (a) Last Training
   (b) Number Trained

Comments
Update contact details, operators names and status of training
General Emergency Operations

1. Communications
   (a) Normal
      Phone
      Fax
   (a) Standby
      Mobile phone
   (a) Emergency
      SEQWater two way radio

2. Warning Systems
   Alarms

3. Emergency Power
   (a) Test                      Last tested on 17/07/2007
   (b) Condition                Good
   (c) Adequacy                 Acceptable

4. Portable petrol generator
   (a) Test                      Generator last tested August 2005
   (b) Condition                Good

Comments
Update communications contacts and test operations protocols and systems; keep records of all tests carried out.
7.4 Main Dam – Checklist

**Left Embankment Crest**

a) Cracks None observed
b) Sinkholes None observed
c) Alignment No obvious misalignment observed. Wave wall and Armco barrier appear well aligned
d) Erosion None observed
e) Vegetation Grass growing on upstream side of wave wall. Some drains blocked with silt and rubbish. Some flaps on upstream ends of drainage pipes are jammed open. Vegetation should be cleaned from around pipes and drains should be cleaned out. Minor grass growth at downstream edge of roadway.
f) Depressions No obvious depressions observed
g) Settlement None observed
h) Wave wall Appears OK. Wave wall extended, with cutoff to clay core? Extended as embankment at left end, with "waterproof" gate and flap valves on drainage outlets. Another gate near intake crane area. Rubber is to be added to the sides of this gate.

**Left Embankment Downstream Slope**

a) Cracks None observed
b) Sinkholes None observed
c) Bulging None observed
d) Wet spots at toe from drainage None observed. Controlled clear seepage
e) Boils None observed
f) Depressions None observed
g) Vegetation Some overgrown vegetation along drainage channel downstream of the toe needs removing. Not much room for placing seepage measurement container under pipe.
h) Erosion None observed
i) Animal Burrows None observed
**Comment**
Frequency of seepage measurements should be reviewed.

**Left Embankment Abutment**
a)  Cracks            None observed (not closely observed upstream)
b)  Wet spots        None observed
c)  Vegetation       Trees and shrubs on upstream groin should be removed
          removed
d)  Slides           None observed

**Comment**
Drainage channel downstream of embankment seepage monitoring point is overgrown with vegetation including cumbungi, and should be cleaned out.

**Right Embankment Crest**
a)  Cracks            None observed
b)  Sinkholes        None observed
c)  Alignment        No obvious misalignment observed
d)  Erosion          None observed. Controlled clear seepage
e)  Vegetation       Very minor grass on downstream side of roadway
f)  Depressions      None observed
g)  Settlement       None observed
h)  Wave wall        Joint filler debonded/extruded in places.

**Comment**
Major auxiliary spillway upgrade works constructed at right hand end of embankment, comprising excavation and construction of a fuse plug auxiliary spillway. Wave wall extended and cutoff extension constructed. Guide wall extension near the road bridge.
**Right Embankment Downstream Slope**

a) Cracks  None observed  
b) Sinkholes  None observed  
c) Bulging  None observed  
d) Wet spots  None observed  
e) Boils  None observed  
f) Depressions  Change of slope midway between the reinforced rockfill toe and the embankment crest.  
g) Vegetation  Minor grass  
h) Erosion  None observed  
i) Animal Burrows  None observed  
j) Drainage System  Seepage measured weekly, frequency should be reviewed. Slime in seepage pit should be cleaned out. Vegetation including cumbungi should be cleaned from the channel downstream of the pit.

**Left Embankment Upstream Slope**

a) Slides  None observed  
b) Sinkholes  None observed  
c) Deterioration of slope protection  Riprap appears okay, except not placed to correct profile and is cast in concrete at crest. Uncertain whether this is settlement related during construction or if riprap just not placed correctly? Some dead grass on old construction ramp on riprap  
d) Beaching  None observed  
e) Erosion  None observed
**Left Embankment Abutment**

e) Cracks  Not closely observed upstream.
f) Wet spots  Appears ok
g) Vegetation removed  Okay
h) Slides  None obvious

**Comment**

Drainage channel downstream of embankment seepage monitoring point is overgrown with vegetation including cumbungi, and should be cleaned out.

**Right Embankment Abutment**
i) Cracks  Not closely observed upstream.
j) Wet spots  Appears ok
k) Vegetation removed  Okay
l) Slides  None obvious

**Comment**

Secondary spillway checklist is required.

Upstream bed - covered with cobbles. Some growth of grassy vegetation but dying off. LHS spillway training wall quite a lot of cracking, especially toward the base. No displacement or spalling.


Disk drain on top of right training wall adjacent to fuse has clay in it which needs cleaning out. Downstream channel looks good.

Coffey’s reading? Next reading in 6 months is the last.
7.5 Spillway – Checklist

**Spillway Gates**

a) General Condition  
   Appears good  

b) Hoist Equipment  
   Appears good  

c) Controls (control room)  
   Appears good  

d) Controls (local)  
   Appears good  

**Spillway Main Hydraulic Pumps**

a) General Condition  
   Appears good  

b) Last test date  
   June 2004  

**Spillway Emergency Pump & Hydraulic Unit**

a) General Condition of Pump  
   Appears good  

b) Last test date  
   June 2004  

c) General Condition of Hydraulic Unit  
   Not inspected, reportedly good  

d) Last test date  
   August 2005  

**Spillway Chute**

a) General Condition  
   Appears okay  

b) Cracking  
   Minor with calcite. Gate 5 cracking behind gate.  

c) Spalling  
   Left side of Gate 5 chute and centre behind gate  

d) Construction Joints  
   Appears okay  

e) Erosion  
   None observed  

**Flip Bucket**

a) General Condition  
   Appears good, with minor cracking  

b) Cracking  
   Minor, probably construction related  

c) Spalling  
   None observed
d) Construction Joints  
   Appearance okay

e) Erosion  
   None observed

**Left Bank Spillway Retaining Wall**

a) General Condition  
   Good

b) Cracking  
   Small crack in wall beside flip bucket. Minor seepage and calcite from crack above outlet works. Reportedly no change.

c) Spalling  
   None observed

d) Construction Joints  
   Appearance okay

e) Erosion  
   None observed

**Right Bank Spillway Retaining Wall**

a) General Condition  
   Appears good

b) Cracking  
   One crack full height of wall with minor calcite. Crack observed previous inspections.

c) Spalling  
   None observed

d) Construction Joints  
   Appearance okay

e) Erosion  
   None observed

**Spillway Discharge Channel**

a) General Condition  
   Appears good

b) Erosion  
   No significant erosion observed

c) Debris  
   Not significant

d) Loose rock  
   Not significant

e) Vegetation  
   Trees downstream could do with removing before they grow. Some trees on lower berm could pose maintenance issue/spalling of rock face problems if they grow much bigger. Consider removing

**Upper Gallery**

a) General Conditions  
   Appears good, with minor calcite on joints and cracks. Some drains and blocks had been numbered
b) Leakage
Mainly dry.

c) Formed drains
Formed drains appear okay, minor calcite

d) Gutter drains
Appear okay

e) Ventilation
Appears adequate

f) Electrical
Appear okay. Lighting seems adequate

(g) Movement
Minor cracking, generally no obvious movement. Access gallery from right abutment showed cracking and movement at two joints where the angled post-tensioning was stressed.

Lower Gallery

(a) General Conditions
Appears good

(b) Foundation drains
Wall drains and floor drains generally flowing small amounts. Calcite evident.

(c) Formed drains
Appears okay. 4 or 5 drains wholly or partly blocked by grouting during post-tensioning. One drilled out.

(d) Gutter drains
Appears okay. Partly wet.

(e) Sump pumps
Appears okay, not observed working.

(f) Metal Work
Appears okay

(g) Ventilation
Appears adequate

(h) Electrical
Appears okay. Lighting seems adequate.

Comment
Ramp to outlet works was significant calcite accumulation and some current seepage

Access Road

a) Pavement General Condition
Appears adequate

b) Guard Rails
Appears okay

c) Signs
Appears okay
7.6 Saddle Dam 1 – Checklist

**Embankment Crest**

a) cracks | none observed  
b) sinkholes | none observed  
c) alignment | no obvious misalignment  
d) erosion | none observed  
e) vegetation | some grass  
f) depressions | no significant depression obvious  
g) settlement | none observed  
h) animal burrows | one relatively large ant hill on downstream side of crest, which should be remediated  

**Embankment Downstream Slope**

a) cracks | none observed  
b) sinkholes | none observed  
c) bulging | none observed  
d) wet spots | none observed - water level of reservoir below toe of dam  
e) boils | none observed  
f) depressions | none observed  
g) vegetation | long grass on downstream batter and excessive grass and other vegetation at the toe makes effective surveillance impossible  
h) erosion | none observed  
i) animal burrows | none observed
**Embankment Upstream Slope**

a) Slides  
None observed

b) Sinkholes  
None observed

c) Deterioration of slope protection  
None observed

d) Beaching  
None observed

e) Erosion  
None observed

f) Vegetation  
Should be cleaned from within 5m of groins

**Embankment Abutments**

a) Cracks  
None observed

b) Wet spots  
None observed

c) Vegetation  
See above

d) Slides  
None observed
7.7 Saddle Dam 2 – Checklist

*Embankment Crest*

a) Cracks  None observed  
b) Sinkholes  None observed 
c) Alignment  None observed  
d) Erosion  None observed  
e) Vegetation  Some grass 
f) Depressions  None observed  
g) Settlement  None observed

*Embankment Downstream Slope*

a) Cracks  None observed  
b) Sinkholes  None observed  
c) Bulging  None observed  
d) Wet spots  None observed - water level of reservoir below toe of dam  
e) Boils  None observed  
f) Depressions  None observed  
g) Vegetation  Embankment has been grazed and the grass was very short. Care should be taken not to overgraze near downstream toe  
h) Erosion  None observed  
i) Animal Burrows  None observed

*Embankment Upstream Slope*

a) Slides  None observed  
b) Sinkholes  None observed  
c) Deterioration of slope protection  Protection does not extend to crest. Some riprap looks small in size at the left end, although somewhat protected by existing ground upstream
d) Beaching    None observed

e) Vegetation  Some small saplings on upstream face. These should be removed.

f) Erosion     None observed

**Embankment Abutments**

a) Cracks      None observed

b) Wet spots   None observed

c) Vegetation  Some grass cover (see above) vegetation should be kept 5m away from groin

d) Slides      None observed
7.8 Instrumentation - Checklist

**Collection of Data**

a) V-notch weirs in lower gallery (spillway):

b) Seepage measuring points in Main Dam drainage system:

c) Piezometers (main dam & spillway):

d) Inclinometers (main dam & spillway)

e) Settlement cross arms (main dam):

f) Pressure cells (main dam & spillway):

**Comments** Nil

**Review of Instrumentation Data**

a) V-notch weirs in lower gallery (spillway):

b) Seepage measuring points in Main Dam drainage system:

c) Piezometers (main dam & spillway):

d) Inclinometers (main dam & spillway)

e) Settlement cross arms (main dam):

f) Pressure cells (main dam & spillway):

**Comments** Nil
7.9 Mechanical Checklist

**Spillway Gates**

a) General Condition  
   Appear okay

b) Metalwork Condition  
   Appears good

c) Coatings  
   Appears good

d) Seals  
   Appear good, very little leakage from bottom seal on gates

e) Seal Seats  
   Appear okay

f) Cavitation damage  
   None observed

g) Hydraulic Winches  
   Appears good. Generally not inspected

h) Hydraulic Pipes, Hoses and Fittings  
   Appears good. Generally not inspected

i) Wire Ropes  
   Appear good

j) Access  
   Appears adequate

k) Control System  
   Appears okay

l) Security  
   Appears okay

m) Operation instructions  
   Not observed

n) Last Operation / Test  
   Exercised every 3 months to 150mm for 2 minutes, and 6 months through full range behind baulk gate

**Comment**

Trunnion seals cracking and falling off. Bearings under investigation.

**Spillway Baulk Gate**

a) General Condition  
   Appears good

b) Metal Work Condition  
   Appears good

c) Coatings  
   Appear okay

d) Seals  
   Appear okay

e) Seal Seat  
   Appear okay

f) Leakage  
   Appear okay

g) Access  
   Appears okay

h) Filling Valve  
   Not observed
i) Lifting provision  Appears okay, although hatch needs to be closed
j) Operation instructions  Not observed
k) Last Operation / Test  June 2004

**Penstock Gate**

a) General Condition  Appears good
b) Metal Work Condition  Appears good
c) Coatings  Appear good
d) Seals  Appear okay
e) Seal Seats
f) Leakage  Not observed
g) Lifting provision  Appears okay
h) Operation instructions  Not observed
i) Last Operation / Test  February 2004 large penstock, September 2004 small penstock

**Intake Trash Screens**

a) General Condition  Appear reasonable above water
b) Coatings
c) Metalwork Condition  Appear okay above water
d) Last Inspection  Not observed
**Intake - Selective Withdrawal Baulks**

a) General Condition  
Not inspected. No 4 recently repainted, with plans for one/year from hereon in.

b) Lifting Chains

c) Last Inspection  
February 2004

**79 tonne Gantry Crane**

a) General Condition  
Appears good, not inspected.

b) Mechanical

c) Electrical

d) Operating instructions  
Not observed

e) Storage/tie down area

f) Last Operation / Test  
October 2004

**3.2 tonne Gantry Crane**

g) General Condition  
Reportedly ok, not inspected.

h) Mechanical

i) Electrical

j) Operating instructions

k) Storage/tie down area

l) Last Operation / Test  
Run monthly
**Penstock Winch**

<table>
<thead>
<tr>
<th>Category</th>
<th>Condition</th>
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<tr>
<td>a) General Condition</td>
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<td>b) Mechanical</td>
<td></td>
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<tr>
<td>c) Electrical</td>
<td></td>
</tr>
<tr>
<td>d) Operating instructions</td>
<td></td>
</tr>
<tr>
<td>e) Last Operation / Test</td>
<td>September 2004</td>
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**3.6 m diameter Penstock**

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<tr>
<td>a) General Condition</td>
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<td>b) Surface protection</td>
<td></td>
</tr>
<tr>
<td>c) Operating instructions</td>
<td></td>
</tr>
<tr>
<td>d) Last Inspection</td>
<td>September 2004</td>
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**1.9 m diameter Penstock**

<table>
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<tbody>
<tr>
<td>a) General Condition</td>
<td>Not inspected</td>
</tr>
<tr>
<td>b) Surface protection</td>
<td>Vibration reported in the new section at the power station. A long length appears unsupported. The security of this section should be checked by a structural/mechanical engineering consultant.</td>
</tr>
<tr>
<td>c) Operating instructions</td>
<td></td>
</tr>
<tr>
<td>d) Last Inspection</td>
<td>August 2004</td>
</tr>
</tbody>
</table>
No.1 Regulating Valve (1500 mm cone dispersion valve)

a) General Condition  
   Appears okay. Relocated due to hydropower station construction. Used as bypass.

b) Coatings

c) Seals

d) Metalwork

e) Leakage

f) Access

g) Safety

h) Operation

i) Exercise Frequency

j) Security

k) Operating Instructions  N/A
No.2 Regulating Valve (1500 mm cone dispersion valve)

a) General Condition

   Removed and penstock blanked off as part of hydropower station construction. Valve not observed.

b) Coatings

c) Seals

d) Metalwork

e) Leakage

f) Access

g) Safety

h) Operation

i) Exercise Frequency

j) Security

k) Operating Instructions  N/A
**Gallery Sump Pump No 1 - Lower Gallery near outlet works**

a) General Condition  
Appears good. No problems reported

b) Coatings

c) Seals

d) Metalwork

e) Leakage

f) Access

g) Safety

h) Operation

i) Exercise Frequency  
Operates frequently. Manually operated weekly

j) Security

k) Operating Instructions  
Not observed
Gallery Sump Pump No 2 - Lower Gallery near outlet works

a) General Condition   Appears good. No problems reported
b) Coatings

c) Seals

d) Metalwork

e) Leakage
f) Lubrication
g) Access

h) Lifting Provision

i) Safety

j) Operation

k) Control System

l) Exercise Frequency   Operates frequently. Manually operated weekly

m) Security

n) Operating Instructions   Not observed

Comments

Equipment appears to be being well maintained and working areas kept clean and tidy.

Hydropower station in operation since February 2003
7.10 Electrical Checklist

*Gallery Regular Main Switchboard and Electrical Systems*

a) General condition Appears good, cursory inspection only. Motor protection relays planned for replacement

b) Protective coating

c) Metalwork

d) Access

e) Safety

f) Operation

g) Security

h) General condition

*High Voltage Electrical System*

a) General condition Not inspected

b) Protective coating

c) Metalwork

d) Access

e) Safety

f) Operation

g) Security

h) General condition Uncertain - SEQW responsibility
7.11 Outlet Works

Walls
a) Surface condition  Appears okay
b) Concrete  Appears okay
c) Joints  Appears okay
d) Cracks  Cracks in roof observed from below and above
e) Movement  Non observed
f) Seepage  Minor

Floor
a) Surface condition  Appears okay
b) Concrete  Appears okay
c) Joints  Appears okay
d) Cracks  Some minor cracks
e) Movement  Non observed
f) Seepage  Minor

General
a) Access  Appears adequate
b) Safety  Gas detection system and lock-out on doors in operation
c) Operation  Not observed
d) Security  Appears okay
e) Lighting  Appears adequate. Fused gas monitor recently calibrated
**Town Water Supply Pumps and Valves**

a) General condition  Appears okay

b) Protective coatings  Appears okay

c) Leakage  Minor leakage at seals

**Access Lift**

a) General condition  Appears okay. Lift was used

b) Service Frequency  6 monthly, due March 2005

**Access Lift Outlet Works Distribution Board**

a) General condition  Appears okay

**Comments**

Hydropower station was in operation during inspection.

Thicker stainless steel lining has been installed in the dissipator.
8 REVIEW OF DAM STATUS

8.1 Previous Recommendations from Annual Reports, 2002 to 2004

8.1.1 Standard Operating Procedures

- SOP DM4.2-10 needs minor revision to flowchart to follow logic if Instruments are Not OK after receipt of an unusual report on instrumentation results.

  Comment: This has not been done.

8.1.2 Operation and Maintenance Manuals

- Manuals revised and issued as SEQWC documents. Review in progress by Sun Water to ensure all aspects of previous documents are incorporated in the new documents. Drawings uncontrolled Water Board documents.

- Revisions to documents noted by SunWater in Site Monitoring Form Section 2.1 and previously submitted to David Gill of SEQWC for amendments to be issued.

- Revisions to electrical drawings have been made with a set of drawings at the site but no changes to the main set of drawings.

- Manuals have no reference in each file to the other manuals of which there are 17 manuals. Manual No 1 was not available to check the total number of manuals in the set. Recommend that each manual include a listing of the total set for reference.

- Controlled set of drawings needs to be issued with the O&M Manuals and updated when changes made to operating systems.

  Comment: Review now in progress by SEQWater. As built drawings have been re-issued on CD. Other comments still apply.

8.1.3 Emergency Preparedness – Emergency Action Plan

- Phone numbers for contacts and contact listing requires updating. Radio Channels required on listing.

  Comment: The contact list should be updated.
8.1.4 **Emergency Preparedness - General Emergency Operations**

- Some problems with the alarm being set off by fog and reprogrammed to avoid false alarms

*Comment:* This has been solved by adjustment of the system.

8.1.5 **Embankments**

- The wave walls do not run out to zero height at the ends of the embankments and in the event of extreme floods occurring, flow will be allowed to pass around the wave walls and down the abutment/embankment toe leading to potential erosion damage/failure of the embankment

*Comment:* This has been fixed as part of the Stage 1 upgrade works.

8.1.6 **Spillway**

- Minor seepage from rock on the left side of the spillway channel above the access road level.

- The right bank spillway retaining wall has no railing at the end to prevent personnel falling over the rock face at the end of the concrete section. It is recommended that the hand railing be taken perpendicular from the wall across the channel for OHSA requirements.

- Consideration should be given to monitoring seepage from the upper right gallery should this flow increase.

- A lot of calcite and cracking is present at the gallery exit to the outlet works on horizontal joints.

- There is no joint or drain numbering or crack identification in the galleries. It is recommended that joints and drains be numbered and the ends of prominent cracks be identified to evaluate any growth of the cracks.

*Comment:* Joint and foundation drain numbering has been added. A railing has been installed on the right spillway retaining wall. Other comments still apply.
8.1.7  **Saddle dams**

- No embankment chainage markers for dam safety surveillance where anomalies are noted.

  **Comment:** Chainage markers have been added

8.1.8  **Instrumentation**

- Recommend that the “V” notch readings be taken using a mounted gauge plate to provide consistency in taking readings.

  **Comment:** Still read manually with vernier callipers. Reasonable consistency obtained, so this method appears acceptable.

8.2  **Previous Recommendations and Actions Taken**

SEQWater (2005) provides a long list of recommendations for Wivenhoe Dam and a full listing of these is included at Appendix F. The great majority of these have been attended to while others are noted as requiring annual review. Table 8-1 lists a number of recommendations that may be relevant to this Comprehensive Inspection.

Table 8-2 lists three actions proposed by Consultants together with Corporate comment.

The right hand column of Table 8-1 includes comment from the Inspection.
Table 8-1 - Wivenhoe Dam Recommended Actions

<table>
<thead>
<tr>
<th>No.</th>
<th>Recommendation</th>
<th>Priority</th>
<th>Date Complete</th>
<th>SEQWater Comments</th>
<th>Review Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Embankment Generally</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>An investigation into the seepage profile through the embankment is required to determine the actual phreatic surface. This would include a review of the materials used in the downstream shoulder to determine the actual pore pressure profile (section 12.8.3.6).</td>
<td>L</td>
<td>yes</td>
<td>Investigation done</td>
<td>Monitor during annual inspections</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Piezometers do not indicate a raised phreatic surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.</td>
<td>The embankment is monitored closely following extensive drought periods. This will include monitoring of piezometric levels of the main embankment at least twice weekly during flood and visual inspection of the upstream shoulder (section 12.8.3.6).</td>
<td>L</td>
<td></td>
<td>Piezometric levels notionally read on monthly basis</td>
<td>While drought continues</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Right Bank Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>The seepage in the right bank of the diversion cut at the foundation contact be monitored with a V notch weir or similar (section 13.8.2).</td>
<td>H</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
<td>Regularly monitored</td>
</tr>
<tr>
<td>g.</td>
<td>The effectiveness of the drainage system downstream of the core is investigated in light of the increasing pore pressures in the filter at chainage 1800 (section 11.1.2.2).</td>
<td>H</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
<td>Pore pressure behaviour is acceptable – no visible seepage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mechanical Electrical – General Maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i.</td>
<td>Replacement oil be purchased in advance and stored on site as reserve oil for the system.</td>
<td>H</td>
<td>1997</td>
<td>Review during annual inspection in October each year</td>
<td>Oil is stored in drums</td>
</tr>
<tr>
<td>j.</td>
<td>Consideration be given to providing oil containment and oil clean up materials.</td>
<td>L</td>
<td></td>
<td></td>
<td>As above</td>
</tr>
</tbody>
</table>

Queensland Bulk Water Supply Authority – SEQWater
SEQWater Dams Surveillance – Wivenhoe Dam Comprehensive Inspection, July 2006
<table>
<thead>
<tr>
<th>No.</th>
<th><strong>Recommendation</strong></th>
<th><strong>Priority</strong></th>
<th><strong>Date Complete</strong></th>
<th><strong>SEQWater Comments</strong></th>
<th><strong>Review Comment</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Right Bank Section – General Maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. The erosion of the far right abutment section above the diversion cut is repaired and monitored after significant rainstorms. In the event that the erosion gets much worse rockfill or concrete drop structures may be required in the formed drain (section 13.8.2).</td>
<td>M</td>
<td>July 1999</td>
<td>Review during annual inspection in October each year</td>
<td>Not noted as being of concern</td>
</tr>
<tr>
<td></td>
<td>e. The seepage from the top of the shotcrete protection in the Brisbane River section be closely monitored and that the effect of this on the overall stability of the dam be investigated (section 13.8.2).</td>
<td>M</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
<td>None visible</td>
</tr>
<tr>
<td></td>
<td><strong>Left Bank Section – General Maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. The drainage of the seepage at the toe of the highest section in the left abutment section is improved by cleaning out and regrading the drainage bank. The installation of a monitoring weir for this seepage is also required (section 13.8.3).</td>
<td>M</td>
<td>July 1999</td>
<td>Completed and review during annual inspection in October each year</td>
<td>Seepage is monitored</td>
</tr>
<tr>
<td></td>
<td>d. The substantial open drain from the toe of the left abutment section is cleaned out. The inflows into this drain should be investigated and a monitoring weir should be installed if this drain conducts seepage from the dam (section 13.8.3).</td>
<td>M</td>
<td>July 1999</td>
<td>Completed and review during annual inspection in October each year</td>
<td>Seepage from pipe is monitored. Drain again full of vegetation</td>
</tr>
</tbody>
</table>
Table 8-2 - Preliminary Risk Assessment – Proposed “Fixes” with Corporate Comment

<table>
<thead>
<tr>
<th>Consultant’s Proposed “Fix”</th>
<th>Estimated Cost</th>
<th>Corporate Comments</th>
<th>Reviewer Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve reliability of Spillway Gates (GHD design)</td>
<td>$0.13m</td>
<td>Work Completed</td>
<td></td>
</tr>
<tr>
<td>Auxiliary Spillway to enable the dam to pass the PMF</td>
<td>$57.8m</td>
<td>Stage 1 completed</td>
<td></td>
</tr>
<tr>
<td>Develop Emergency Evacuation Plans</td>
<td>$0.50m</td>
<td>Discussions with Local Authorities and SES ongoing. Co-ordinating supply of Dam release information. Evacuation is responsibility of SES and Police.</td>
<td></td>
</tr>
</tbody>
</table>
8.3 Recommended Actions from this Inspection

Refer to Section 1 for a summary of recommended actions resulting from this Comprehensive Dam Inspection.
9 SIGNATURES

9.1 State Water Dam Safety Committee

Mr. Barton Maher
Operations Engineer,
SEQ Water

Mr. Roger Mail
Senior Engineer, Dam Surveillance,
Strategic Asset Services,
State Water Corporation

Mr. Brian Cooper
Principal Contract Engineer,
Dams and Civil Section,
Department of Commerce

9.2 Report Compilers

Mr. Phillip Carter
Principal Contract Engineer,
Dams and Civil Section,
Department of Commerce

Mr. Roger Mail
Senior Engineer, Dam Surveillance,
Strategic Asset Services,
State Water Corporation
10 REFERENCES

ANCOLD, 2000A  Guidelines on Selection of Acceptable Flood Capacity for Dams; prepared by the Australian National Committee on Large Dams, March 2000

ANCOLD, 2000B  Guidelines on the Assessment of the Consequences of Dam Failure; prepared by the Australian National Committee on Large Dams, May 2000

ANCOLD, 2003  Guidelines on Dam Safety Management


Commerce, 2004  Somerset & North Pine Dam, Dam Safety Review; prepared by Department of Commerce, December 2004

Commerce, 2005  Somerset Dam, Stability of Abutment Monoliths; prepared by Department of Commerce, May 2005


GHD, 1997  Wivenhoe Dam – Dam Safety Review

GHD, 2000  Safety Review of Somerset Dam, prepared by GHD Pty Ltd, September 2000. This Report is based on GHD, 1995 but includes geotechnical work completed in following years upgrades the Report to take into account the comments made at Russo (1996).

GHD, 2002  Somerset Dam Annual Inspection Report, prepared by GHD for inspection on 4 September 2002

GHD, 2004  Somerset Dam Annual Inspection Report, prepared by GHD, 28 October 2004

Queensland Bulk Water Supply Authority – SEQWater

SEQWater Dams Surveillance – Wivenhoe Dam Comprehensive Inspection, July 2006
<table>
<thead>
<tr>
<th>Author</th>
<th>Report Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMIT, 1995</td>
<td>Review of Seismicity, Somerset Dam and North Pine Dam; prepared by the Seismology Research centre at RMIT University, March 1995.</td>
</tr>
<tr>
<td>SKM, 2000</td>
<td>Preliminary Risk Assessment for Wivenhoe, Somerset and North Pine Dams; prepared by Sinclair Knight Merz in conjunction with Hydro Consulting, Hydro Electric Corporation, 2004</td>
</tr>
<tr>
<td>SMEC, 2004</td>
<td>Somerset Dam – Detailed Risk Assessment Stage 2; prepared by SMEC Australia Pty Ltd, March 2004</td>
</tr>
<tr>
<td>WA, 2005</td>
<td>Dam Failure Analysis of Wivenhoe Dam; prepared by Wivenhoe Alliance, Q1091, WIV-RP-HD-006, 2005</td>
</tr>
</tbody>
</table>
### Reservoir

Full Supply level (FSL) | EL 67.0  
Storage (at FSL) | 1,150,000 ML  
Reservoir Surface Area (at FSL) | 10,820 ha

### Dam

| Type | Zoned earth and rockfill dam with a concrete gravity spillway section and two earthfill saddle dams.  
Crest Level | EL 79.15m excluding the wave wall

### Main Dam

| Type | Earth and rockfill dam  
Crest Level | EL 79.15  
Wave Wall | EL 80.1m (top of wall)  
Dam length (including spillway section) | 2450m  
Dam height (maximum above downstream toe) |  
Right embankment | 53m Central core embankment  
Left embankment | 24m Sloping core embankment

### Saddle Dam 1

| Type | Earthfill embankment  
Crest Level | EL 80.0m  
Crest width | 4.0m  
Upstream slope | 3H:1V  
Downstream slope | 2.5H:1V  
Embankment height (maximum) | 6m  
Embarkment Length | 200m
Saddle Dam 2

Type
Crest Level
Crest width
Upstream slope
Downstream slope
Embankment height (maximum)
Embankment Length

Earthfill embankment.
EL 80m
4.0m
3H:1V
2.5H:1V
11m
265m

Outlet Works – Water Supply and Power Station Intake

Variable level drawoff facility
Penstocks
Penstock diameters

6 selective baulks placed in individual slots (each baulk is 6.3m high x 6m wide)
2
1.9m & 3.6m

Outlet Works – Regulators

Number of regulators
Type and size of regulators
Level of centreline of FDC regulator
Level of centreline of the 3.6m pipe entienring the turbine

1
1.5 m diameter fixed cone dispersion valve and a 4.5MW Frances turbine hydro power plant
EL 31.5
EL 26m
APPENDIX A
Description and Pertinent Data

**Spillway**

**Type**
Gated, concrete gravity section with flip bucket and flanking retaining walls.

**Number of radial gates**
5

**Size of each gate**
12.0m wide x 16.5m high

**Top of gates when closed**
EL 73.0

**Top of bridge deck**
EL 79.15

**Spillway width (clear width)**
60.0m

**Unlined stilling basin invert**
EL 17.0

**Peak water level as a result of PMF Embankment overtopped**

**Dam Crest Flood (DCF) - AEP**
1 in 100,000

**Maximum flood level (DCF)**
EL 80

**Peak discharge (DCF)**
13,100m$^3$/s

**Auxilliary Spillway**

**Type**
3 bay fuse plug embankments

**Average height of embankments**
13m

**Length of bays**
Bay 1 - 34m
Bay 2 – 64m
Bay 3 - 65m

**AEP’s of trigger levels**
Bay 1 - 1 in 6,000
Bay 2 – 1 in 11,500
Bay 3 – 1 in 22,500

**Discharge capacity at DCF level**
14,900m$^3$/s
Wivenhoe Dam Surveillance Inspection Photographs - Date of Inspection: 19th July 2006

Photograph No. 1: U/S of Spillway Showing Radial Gates

Photograph No. 2: New Baffle Structure Above and U/S of Radial Gate
Photograph No. 3: New Auxiliary Fuse Plug Spillway & Highway Bridge

Photograph No. 4: Auxiliary Spillway Left Hand Inlet Training Wall Showing Cracking
Photograph No. 5: Right Hand Auxiliary Spillway Abutment Wall Showing Debris Filled Gutter

Photograph No. 6: Auxiliary Spillway - D/S Side
Photograph No. 7: Discharge Area D/S of Auxiliary Spillway

Photograph No. 8: Main Embankment - Road Drains Discharging to U/S Side Showing Flap Valves
Photograph No. 9: Main Embankment U/S Road Drain Showing 'No-fines Concrete' Around Drainage Discharge Point

Photograph No. 10: "Watertight" Gate Adjacent to Spillway - Requires Rubber Seals
Photograph No. 11: Right Embankment - D/S Batter

Photograph No. 12: Left Embankment - D/S Batter
Photograph No. 13: Levee & Watertight Gate at Cormorant Bay

Photograph No. 14: Drainage/Seepage Collection D/S of Right Embankment
Photograph No. 15: Right Embankment Near Spillway - D/S Side

Photograph No. 16: Instrumentation Terminal Structure at Toe of Right Embankment
Photograph No. 17: Piezometers Showing Abandoned Electronic Transducers

Photograph No. 18: New Spillway Baffle From D/S
Photograph No. 19: Gallery Inside Spillway Crest

Photograph No. 20: No. 1 Radial Gate Being Raised
Photograph No. 21: No. 1 Saddle Dam - U/S Side

Photograph No. 22: No. 1 Saddle Dam - D/S Side
Photograph No. 23: No. 2 Saddle Dam
APPENDIX C
Supervision Data

Appendix C1 – Instrumentation Drawings
Appendix C2 – Storage Level Behaviour and Rainfall
Appendix C3 – Piezometric Data
Appendix C4 – Leakage Data
Appendix C5 – Inclinometer Data
Appendix C6 - Surface Movement Survey
APPENDIX C1
Instrumentation Drawings

Appendix C1 – Instrumentation Drawings
Figure C1.1 - Spillway Peizometer Locations

300 x 300 x 300 deep hole to be backfilled with dry pack.

Pipe clamp

Section A

Scale 1:50

Prior to placing gallery framework, pipe elbows to be turned to gallery end. Quadro-tubes threaded through pipe.

Control Board

Section B

Scale 1:250

Scale 1:500

Quadro-tubes to be carefuuly reamed and, if suitable, inserted in nits nose above EL 41500. These quadro-
tubes are to be adequately protected from damage by construction equipment during concreting operat-
ions below EL 41500.

Sections

Not to Scale

Notes:
1. All dimensions are in millimetres and all elevations are in m at B.E.
2. All materials and workmanship to the relevant Australian Standards.
**Total Pressure Cells (Scale 1:4)**

**Electric cables** (Earth wires omitted for clarity)

**Surface of placed fill**

**Cell A**

**Cell B**

**Cell C**

**Piezometer**

**Flexible hose**

**Bore Cap to be coated with grease before installation in mortar**

**3- M12 x 130 hex bolts (or 3/4 x 5 Whitworth bolts) with nuts and over-size washers**

**NOTES:**

1. UNLESS OTHERWISE STATED ALL DIMENSIONS ARE IN MILLIMETRES.
2. ALL MATERIALS AND WORKMANSHIP TO THE RELEVANT AUSTRALIAN STANDARD.
3. Trenches to be backfilled with compacted material similar to that excavated.
4. One dimensional Total Pressure Cells contain Cell A only.
5. Centreline of 100NB pipe and target point of surface movement point to be within one degree of vertical.
6. This drawing to be read in conjunction with detailed installation instructions for the total pressure cells.

**AS BUILT**

**All MS items to be galvanised**

**Section B-B**

**Detail Z** (Scale 1:4)

**Electric transducer**

**Piezometer**

**BRISBANE RIVER 150-3 km - WIVENHOE DAM INSTRUMENTATION-TOTAL PRESSURE CELL & SECONDARY SURFACE MOVEMENT POINT INSTALLATION DETAILS**

**Contract No** 2120

**Design**

**Recommended**

**Prep. #6**

**Ch. 31**

**Ch. 54/G**

**Super. M.U.C.**

**Approved**

**Submit**

**Executive Engineer**

**As Chief Designing Engineer**

**Date**

**Remarks**

**Co-ordinator General's Department**

**Brisbane River 150-3 km - Wivenhoe Dam Instrumentation - Total Pressure Cell & Secondary Surface Movement Point Installation Details**

**16-6-78 A2-53376 A**
APPENDIX C2

Storage Level Behaviour and Rainfall

Appendix C2 – Storage Level Behaviour and Rainfall
Wivenhoe Storage Height and Rainfall
Piezometers Chn 1800 RL15

Piezometric Data Plots

Sheet 7 of 14
Appendix C4 – Leakage Data
Wivenhoe Dam Surveillance Report June 2009

Wivenhoe Leakage - Gallery Weirs

Flow (l/hr)

Storage Level (m AHD)

Flow

Storage Level

Rainfall

East

West

Gallery Leakage Plot
Appendix C5 – Inclinometer Data
**WIVENHOE DAM**

Inclinometer I1 - Cumulative Displacement Report

Comparing the latest 5 readings with 30/08/1989

A axis faces Downstream  B axis is to the right

---

**WIVHOE I1, A-Axis**

- Depth in meters
- Cumulative Displacement (mm) from 30/08/1989

---

**WIVHOE I1, B-Axis**

- Depth in meters
- Cumulative Displacement (mm) from 30/08/1989
WIVENHOE DAM

Inclinometer I2

Comparing the latest 5 readings with 30/08/1989

A axis faces Downstream

B axis is to the right
WIVENHOE DAM
Inclinometer I3
Comparing the latest 5 readings with 12/01/1990
A axis faces Downstream B axis is to the right
WIVENHOE DAM
Inclinometer I3
Comparing the latest 5 readings with 12/01/1990
A axis faces downstream
B axis is to the right

WIVHOE I3, A-Axis

WIVHOE I3, B-Axis
WIVENHOE DAM
Inclinometer I1- Incremental Displacement Report
Comparing the last 5 readings with 30/08/1989
A axis faces downstream  B axis faces to the right
Wivenhoe Dam
Inclinometer I2
Comparing latest 5 readings with 30/08/1989
A axis faces downstream
B axis is to the right
WIVENHOE DAM
Inclinometer I4- Incremental Displacement Report
Comparing the last 5 readings with 09/01/1990
A axis faces downstream  B axis is to the right
Appendix C6 - Surface Movement Survey
Upstream Crest X Coordinate Change from Chn 1200 - 1600
Upstream Crest X Coordinate Change from Chn 2000 - 2400

Displacement (mm)

Movement Plots

WVSSS012  WVSSS013  WVSSS014  WVSSS015  WVSSS016

Sheet 3 of 30
Downstream Crest X Coordinate Change from Chn 1200 - 1600
Upstream Crest X Coordinate Change SS44, SS33, SS39, SS42

Displacement (mm)

Survey Date

WVSSS039
WVSSS033
WVSSS042
WVSSS044
Downstream Face RL69 - X Coordinate Change SS34, SS45

Displacement (mm)


Movement Plots
Downstream Face RL59 - X Coordinate Change SS35, SS40, SS43, SS46

Movement Plots
Upstream Crest Y Coordinate Change from Chn 1600 - 2000

Movement Plots

Sheet 12 of 30
Downstream Crest Y Coordinate Change from Chn 2000 - 2400
Upstream Crest Z Coordinate Change from Chn 1600 - 2000

Displacement (mm)

Storage Level (mAHd)

Survey Date

APPENDIX D
Selected Drawings

Appendix D1 - 1979 “As Built” Drawings (Original Dam)
Appendix D2 - 2005 “As Built” Drawings (Flood Security Upgrade)
APPENDIX D1
1979 “As Built” Drawings (Original Dam)

Appendix D1 - 1979 “As Built” Drawings (Original Dam)
Appendix D2 - 2005 “As Built” Drawings (Flood Security Upgrade)
TARGET LOCATION TABLE

<table>
<thead>
<tr>
<th>MOVEMENT TARGET</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTS01</td>
<td>TOP OF CONCRETE PANEL WALL</td>
</tr>
<tr>
<td>MTS02</td>
<td>TOP OF CONCRETE PANEL WALL</td>
</tr>
<tr>
<td>MTS03</td>
<td>PLACED IN TRIGGER SECTION</td>
</tr>
<tr>
<td>MTS04</td>
<td>TOP OF CONCRETE PLUG EMBANKMENT</td>
</tr>
<tr>
<td>MTS05</td>
<td>PLACED IN TRIGGER SECTION</td>
</tr>
<tr>
<td>MTS06</td>
<td>TOP OF CONCRETE PLUG EMBANKMENT</td>
</tr>
<tr>
<td>MTS07</td>
<td>PLACED IN TRIGGER SECTION</td>
</tr>
<tr>
<td>MTS08</td>
<td>TOP OF CONCRETE PANEL WALL</td>
</tr>
<tr>
<td>MTS09</td>
<td>TOP OF CONCRETE PANEL WALL</td>
</tr>
</tbody>
</table>

LEGEND

+ MTS01 SURVEY MOVEMENT TARGETS

CS110 SURVEY CONTROL STATION

NOTES

1. MOVEMENT TARGETS SHALL BE INSTALLED AFTER COMPLETION OF EMBANKMENTS AND CONCRETE WALLS
2. LOCATION OF SURVEY CONTROL STATION TO BE CONTINUED ON SITE BY SURVEYOR
3. REFER DRAWING FOR CONTROL STATION DETAILS.
WIVENHOE DAM UPGRADE
RIGHT ABUT SPILLWAY - FLOOR & DOEE STRUCTURE
GROUT CURTAIN ARRANGEMENT

WIV/DWG/C6/1011

EXCAVATION
乐

CONCRETE SCALE PLANNED AFTER GROUTING
LINE OF GROUT HOLES

LEGEND
P = PRIMARY HOLE
S = SECONDARY HOLE

1. REMOVE UNSTABLE MATERIAL AND REPLACE WITH CEMENT STABILIZED FILL PRIOR TO COMPLETION OF GROUT CURTAIN WORKS.
2. PRIMARY GROUT HOLES TO HAVE 8IN PUMPKIN DIAMETER AND NOMINAL DEPTH OF 20IN BELL BLOW A FLOOR, PRIMARY GROUT HOLES TO HAVE 6IN PUMPKIN DIAMETER AND NOMINAL DEPTH OF 25IN. SECONDARY GROUT HOLES TO HAVE 6IN PUMPKIN DIAMETER AND NOMINAL DEPTH OF 20IN.
3. STARTING GROUT MIX FOR PRIMARY HOLES TO BE AT CONCRETE SPECIFICATIONS, GROUT MIX TO VARY DEPENDING ON HOLES CONDITIONS ENCOUNTERED.
4. GUIDELINES FOR EFFECTIVE GROUTING LIMITS, NO FURTHER GROUTING IS RECOMMENDED:
   - WATER TEST VALUE FROM TUBE 20 DEGREES CDRS
   - LESS THAN 30% RESTRICTION IN DEGREE VALUE OR GROUT TAKES LESS THAN 10 MINUTES FROM PREVIOUS TAKING WHERE DEGREE VALUE FOR THE PREVIOUS TAKING IS LESS THAN 10 DEGREES
   - ALL GROUT TAKES LINES GROUTING ARE LESS THAN 25 DEGREES
   - GROUT HOLES SPACING LESS THAN 6.7M
5. REQUIREMENTS FOR SECONDARY AND TERTIARY HOLES OTHER THAN BULK GROUT HOLES TO BE DETERMINED BY THE ENGINEER.
6. IF SHORTCUTTING IS CARRIED OUT PRIOR TO GROUTING, A BLANK AREA 20 X 20 INCH SHALL BE LEFT AROUND THE GROUT HOLES.
Grading Limits
(After Placement / Compaction)

<table>
<thead>
<tr>
<th>ZONE</th>
<th>MATERIAL</th>
<th>PLACEMENT SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CORE</td>
<td>IMPERVIOUS SC OR SI MATERIAL, GRADE LIMITS AS SHOWN</td>
<td>COMPACTED IN 25mm LAYERS TO NOT LESS THAN 95% DESIGN DRY DENSITY; MOISTURE LIMITS FROM 0.4% TO 0.42%</td>
</tr>
<tr>
<td>2. FINE FILTER</td>
<td>WELL GRADED CLEAN, NON-COAGULANT SAND-GRAVEL, GRADE LIMITS AS SHOWN</td>
<td>COMPACTED IN 25mm LAYERS TO MIN 70% DENSITY INDEX</td>
</tr>
<tr>
<td>3. CHARGE FILTER</td>
<td>WELL GRADED CLEAN, CLEANED NATURAL GRAVEL, GRADE LIMITS AS SHOWN</td>
<td>AS PER ZONE 2A</td>
</tr>
<tr>
<td>4. ROCK FILL</td>
<td>FRESH HARD DURABLE ROCKFILL, GRADE LIMITS AS SHOWN</td>
<td>PLACED IN 650mm LAYERS WITH COMPACTION FROM TRAILED CONSTRUCTION EQUIPMENT OR EQUIVALENT</td>
</tr>
<tr>
<td>5. SUBBASE</td>
<td>FRESH HARD DURABLE ROCK</td>
<td>SPREAD TO FORM A UNIFORM DENSE AND STABLE LAYER</td>
</tr>
<tr>
<td>6. ROAD BASE</td>
<td>2:3 ROAD PAVEMENT MATERIAL</td>
<td>COMPACTED IN A SINGLE LAYER TO NOT LESS THAN PROPOSED DRY DENSITY; MOISTURE LIMITS FROM 0.4% TO 0.42%</td>
</tr>
</tbody>
</table>

NOTE: Wave wall to be constructed from treated hardwood as per specification.

Typical Bolted Connection Details

Wivenhoe Dam Upgrade
Right Abut Spillway - Fuse Plugs Embankments
Material Specification

Wivenhoe Alliance
PROVIDE PROTECTION TO CONTROL ROOM.
SEAL OFF PENETRATIONS TO AVOID
DAMAGE TO GATE OPERATION EQUIPMENT

PROVIDE CUT-OFF WALL TO CLAY CORE

PROVIDE CONCRETE PAVEMENT ON CREST
TO CONNECT TO THE CUT-OFF WALL
RAISE THE CRASH BARRIER
TO A MINIMUM OF RL 89.1

PLAN
SCALE 1:1

1/9/13 & 2/9/13 POST TENSIONING CABLES
REFER DRAW 12% FOR DETAILS

FSL 67.0

TOP OF GATES RL 57.0

SPILLWAY CREST

PROVIDE POST TENSIONING FOR
SPILLWAY MONOLITH

UPSTREAM LINE OF ANCHORS

SECTION
SCALE 1:1

WIVENHOE DAM UPGRADE
EXISTING DAM WORKS
GENERAL ARRANGEMENT

WIV/DWG/CG/1275
APPENDIX E

2003 and 2004 Annual Inspection Reports

Appendix E1 – Annual Inspection December 2003
Appendix E2 – Annual Inspection November 2004
Appendix E1 – Annual Inspection December 2003
# WIVENHOE DAM ANNUAL INSPECTION

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Photographs

Instrumentation Plots

Attachment 'A' Detailed inspection check list
WIVENHOE DAM ANNUAL INSPECTION

1.0 GENERAL
Senior Engineer, Dam Surveillance Roger Mail of the Dams and Civil section of the NSW Department of Commerce (previously the Department of Public Works and Services) carried out the Wivenhoe Dam Annual Surveillance Inspection on 10th December 2003, as part of the annual inspections of three SEQ Water dams (Wivenhoe, Somerset and North Pine). He was assisted by Doug Grigg and Jeff Elliott of SunWater. The previous Annual Inspection was in September 2002.

2.0 STORAGE CONDITIONS
The storage was at EL 60.90m, 6.1m below the Full Supply Level (FSL) of EL 67.0m. The weather was hot and humid, with occasional cloud cover. A total of 40.8mm of rain was recorded for the previous seven days, with no rain recorded for three days prior to the inspection.

3.0 BACKGROUND
Dam Details.
Wivenhoe Dam is a 2.3 km long, 56m high, zoned earth embankment on the Brisbane River with a gated concrete gravity spillway structure in the middle, containing five radial gates. Riprap is present on both the upstream and downstream shoulders of the embankment. It stores 1,165,000 megalitres, with a further 1,450,000 megalitres above FSL for the temporary storage of floodwaters. It also has two earthen saddle dams above FSL. It is now also used for the generation of 4.5 Megawatts of hydroelectric power.

The construction of the dam was completed in 1985.

Methodology.
The steps involved in the annual inspection of each of the three SEQ Water dams were:

- Prior to the inspection, the instrumentation data and plots on Excel spreadsheets supplied by SEQ Water were reviewed and assessed for any disturbing trends, with particular emphasis on behaviour over the past year, and the following documents were read:
  - The SEQ Water Dam Safety Management Program of October 2002. This described the overall arrangements and procedures for operation, maintenance and surveillance of the dam and listed recommendations from the GHD safety review of 1995 and from the risk assessment of 1999 by Sinclair Knight Merz and HECEC.
  - A copy of the previous Annual Inspection Report (check list completed by GHD) on the dam. This described the condition of the dam and its mechanical and electrical equipment, and made certain recommendations.
- Relevant sections of the risk assessment report, for additional background information and information on recommended actions.
- A diagram of the spillway section of the dam.
- A copy of the SOP for Routine Instrument Surveillance for Wivenhoe Dam.

- The documentation at the dam which relates to dam safety and surveillance was checked for currency and completeness, together with documentation on maintenance activities.

- The dam was inspected, often in conjunction with a dam supervisor or other dam staff member, guided by the annual inspection checklist. The comments made in the previous annual inspection report by GHD were also used as a reference. During the inspection, all major dam structures and monitoring installations and galleries were inspected, together with a brief inspection of mechanical and electrical equipment which has a bearing on dam safety, supplemented by discussions with dam staff. Photographs were taken. The reservoir rim was viewed from accessible areas close to the dam. Various aspects of the findings of the inspection were discussed with dam staff.

- Requesting additional information from SEQ Water on its progress in dealing with the recommendations of past surveillance inspections.

- Obtaining additional information and clarification from the dam operator.

- The reports on the inspection were prepared, to describe the inspections and what was observed, review the instrumentation results, make recommendations and report on progress in addressing past recommendations. Photographs and copies of selected instrumentation plots from spreadsheets provided by SEQ Water were included, as well as the annual inspection check list filled out as appropriate.

- Brian Cooper reviewed the reports.

- One copy of the draft report was submitted for review by SEQ Water, following which, the report was finalised.
4.0 RECORD OF INSPECTION

Detailed notes are given in the checklist at Attachment A. This section describes what was inspected and expands on some significant aspects and gives an overall comment on the condition of the structures.

4.1 Right (Main) Zoned Earth Embankment

The right embankment section was inspected on foot along the wave wall on the upstream edge of the crest, and from the downstream edge of the crest at about 100m intervals, from the toe downstream of the junction with the concrete spillway section, and from the upstream right abutment. The downstream toe was inspected from a vehicle, stopping and inspecting the seepage monitoring point and the two piezometer installations. Two inclinometer installations were also seen at the crest. This embankment is inspected fortnightly under the routine inspection schedule.

Based on this inspection the embankment is in a satisfactory condition.

4.2 Left Zoned Earth Embankment

The left embankment section was inspected on foot along the wave wall on the upstream edge of the crest, and from the downstream edge of the crest at about 100m intervals, from the crest near the office and car park area, from the abutment upstream of the junction with the concrete dam, and from the downstream toe, including the seepage monitoring point. This embankment is inspected fortnightly under the routine inspection schedule.

Based on this inspection the embankment is in a satisfactory condition.

4.3 Concrete Dam

The concrete spillway section of the dam was viewed from the spillway bridge, the highway bridge and other sections of the concrete crest and the embankment crest sections, from the top of the pier to the left of gate 1, and from the mesh floor on the machinery platform above all the spillway gates. It was also inspected from the downstream embankment toe on the left and right hand side, from the tops of the downstream spillway training walls, and from the left upstream abutment adjacent to the spillway training wall. All galleries were inspected, including their instrumentation and the lower gallery drains.

The concrete dam is inspected weekly under the routine inspection schedule.

The concrete spillway section was in a satisfactory condition.

4.4 Outlet Works and Mechanical & Electrical Equipment

The outlet works were inspected from the operating level inside the intake structure and from the sump pump area and gallery, with a brief inspection of switch rooms. The new
power station construction on the left side of the spillway including the relocated cone
valve and dissipator were also briefly inspected. The oxygen reading on the fixed gas
monitoring facility for the power station needed recalibration.

The power station was discharging during the inspection.

A stationary stand-by generator and hydraulic pump unit and connecting lines provide a
backup to the mains powered system for the lifting of the radial gates, and can lift one
gate at a time. A mobile hydraulic unit can also be connected to raise one gate at a time.
Sealing plates were ready for use to cover the window and cable entry to the hydraulic
unit, winch and control area in the event of an extreme flood.

SunWater at Ipswich generates computer listings on a weekly basis of mechanical and
electrical tasks including inspection, overhaul, and routine exercising of equipment,
which include items required at various frequencies. Performance of these tasks is
reported to SunWater at Ipswich monthly. These sheets are kept in the operating log.
The overall impression is that this work is well performed, is generally up to date and
the system works well.

The outlet works and equipment were in a satisfactory condition.

4.5 Saddle Dams

Each of the two saddle dam embankments and their abutments were inspected on foot
from the crest and from the downstream toe. These dams are to be inspected fortnightly
under the routine inspection schedule.

The saddle dam embankments were in a satisfactory condition.

5.0 REVIEW OF PERFORMANCE

Instrumentation plots for leakage, piezometers, and inclinometers are attached to this
report.

Storage Level Behaviour.

The storage level has dropped from EL 66.49 on 4/7/01 to 64.53 on 5/7/02 to 61.41 on
30/9/03. In the previous period covered by some plots of July 96 to June 01, the storage
level varied between EL 63 and 68, with a spill in February 1999.

Leakage

Plots of weekly data from July 1997 to June 01, and from July 01 to Sept 03 were
examined. There are four seepage points, west and east in the concrete dam lower
gallery, one for the right embankment downstream of the old diversion section and
another since February 2002 for the left embankment, monitoring flow from the toe
drain. There has been no significant change in seepage behaviour.

Piezometers

Plots of monthly data from July 96 to March 2001 (16 plots) and from July 01 to Sept 03
were examined, along with selected plots of monthly data from Jun 82 to Jun 96. There
are 65 piezometers, including 24 near Ch 1600 and 22 near Ch 1800 at two cross sections in the right earth embankment, and fourteen in the concrete dam.

Most piezometers do not change significantly, except for a fall with SWL in some piezometers, usually the more upstream ones (e.g. 1, 2, 3, 4, 10, 14, 18, 25, 28, 34, 35, 36, 38, 42, 43, 47, 48, 50, 51). There is no significant change in piezometer behaviour, but piezometers 45 and 46 showed a sudden drop in February 2003, possibly due to release of pressure at the piezometer well, and are now recovering.

Survey

There are 54 survey points installed on and near the main right embankment. Results were available for surveys in the years 1990, 2000, 2001, 2002 and 2003 in coordinate form. The results show some continuing settlement and some continuing downstream movement, but do not show any disturbing trends.

The maximum settlement of any point since 1990 is 46mm, with maximum movements to the right of 11mm and downstream of 30mm. All these movements were recorded at points on the upstream side of the crest.

Between the last two surveys in February 2002 and March 2003, the indicated vertical movements on the embankment were generally a rise, with a maximum rise of 10mm (probably indicating survey error in the 2002 survey) and the maximum indicated horizontal movements were 9mm and 8mm to the right and downstream.

Inclinometers

Four inclinometers are read, with inclinometers I1, I2 and I3 at Ch 1600 and inclinometer I4 at Ch 1800. Inclinometers I1 and I4 are generally read monthly, and I2 and I3 are generally read 3-monthly. Plots of the recent movements of the top of each hole (cumulative displacement over the inclinometer height) at 3-monthly intervals are attached. With the tools available, we were not able to assess the deformed shape of the inclinometer holes. The plots do not show any significant movement since the start of 2002, and are generally consistent with the overall cumulative displacement plotted in the late 1990s. For comparison, some continuing downstream movements were evident in the data from 1989 to 2001. The figures for I2 are not comparable as a shorter length of inclinometer hole is now being read.

6.0 SUMMARY

The dam and the appurtenant works are generally in a satisfactory condition and the instrumentation recordings indicate the dam is behaving satisfactorily.
### 7.0 RECOMMENDED ACTIONS FROM 1997 SAFETY REVIEW BY GHD

**WIVENHOE DAM SAFETY REVIEW – STATUS AS AT DECEMBER 2003 – CAPITAL WORKS**

<table>
<thead>
<tr>
<th>No.</th>
<th>Recommendation</th>
<th>Priority</th>
<th>Date Complete</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Mechanical/Electrical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The feasibility of converting the gates to automatic operation be investigated.</td>
<td></td>
<td></td>
<td>Automatic operation not considered economical</td>
</tr>
<tr>
<td>b.</td>
<td>That consideration be given to refurbishing the control system to provide condition monitoring.</td>
<td>H</td>
<td>1996</td>
<td>Completed 1996</td>
</tr>
<tr>
<td>c.</td>
<td>That means of improving the security of the hydraulic pipework be investigated.</td>
<td>M</td>
<td>2000</td>
<td>Completed 2000</td>
</tr>
<tr>
<td>d.</td>
<td>That a system of valving and quick connect oil pressure fittings be provided at each winch and thereby permit the connection of an emergency oil supply system.</td>
<td>M</td>
<td>2000</td>
<td>Completed 2000</td>
</tr>
<tr>
<td>e.</td>
<td>That the diesel hydraulic unit be relocated to the surface/or be converted to a mobile unit.</td>
<td>M</td>
<td>2000</td>
<td>Completed 2000</td>
</tr>
<tr>
<td>f.</td>
<td>That consideration be given to relocating the main hydraulic unit and control panels to a higher level in the building.</td>
<td>M</td>
<td>July 1999</td>
<td>The room containing this equipment has been waterproofed – no further action.</td>
</tr>
<tr>
<td>g.</td>
<td>That consideration be given to providing a sheltered control station or control room near the present control complex.</td>
<td></td>
<td></td>
<td>Not considered necessary</td>
</tr>
<tr>
<td>h.</td>
<td>That consideration be given to providing on-line alternative oil supplies, and improved drainage system including an oil separator.</td>
<td>M</td>
<td></td>
<td>Included with 1b, c, d.</td>
</tr>
<tr>
<td>k.</td>
<td>That the fuel system be upgraded to be more accessible, and to reduce the fire risk from leaks.</td>
<td>H</td>
<td>July 1999</td>
<td>Completed</td>
</tr>
<tr>
<td>l.</td>
<td>That the adequacy of the system be reviewed by a fire detection and control expert.</td>
<td>H</td>
<td>July 1999</td>
<td>Completed</td>
</tr>
<tr>
<td>m.</td>
<td>That consideration be given to upgrading the ventilation provisions of the underground control complex and running the system continuously.</td>
<td>M</td>
<td></td>
<td>Fire safety equipment upgraded in 2000.</td>
</tr>
<tr>
<td>n.</td>
<td>That consideration be given to improving the system for delivering fuel to the diesel operated oil pump.</td>
<td>M</td>
<td>1996</td>
<td>Completed 1996</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
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</tr>
<tr>
<td>o.</td>
<td>That the adequacy of the intruder detection system be reviewed and that the alarms be interconnected to a paging system which will alert operators, a security firm or the police.</td>
<td>M</td>
<td>Complete in 2001</td>
<td>Security system with dial out</td>
</tr>
<tr>
<td>p.</td>
<td>That operators be equipped with hand held radios for used while operating the spillway gates.</td>
<td>H</td>
<td>1997</td>
<td>Completed 1997</td>
</tr>
<tr>
<td>q.</td>
<td>That gate position indicators be investigated.</td>
<td>L</td>
<td>Installed 2000</td>
<td></td>
</tr>
<tr>
<td>r.</td>
<td>That tests be conducted to determine whether a single hoist would be capable of moving a gate safely under emergency conditions.</td>
<td>H</td>
<td>July 1999</td>
<td>Discussions held with DNR design staff – one winch will hold gate – no further action.</td>
</tr>
<tr>
<td>s.</td>
<td>Consideration be given to ensuring the duplicate hydraulic pumps be made flood proof.</td>
<td>H</td>
<td>August 1999</td>
<td>Included with 1b, c, d.</td>
</tr>
<tr>
<td>t.</td>
<td>That consideration be given to improving the fail safe nature of the Main Switchboard.</td>
<td>M</td>
<td></td>
<td>Inspections done during annual condition monitoring</td>
</tr>
<tr>
<td>u.</td>
<td>A review of the load bank size be undertaken.</td>
<td>L</td>
<td>Planned Mntce in plan to 2010.</td>
<td></td>
</tr>
<tr>
<td>v.</td>
<td>Review of the location for the outlet works distribution board be undertaken as it is below tailwater level and could be at risk if the dewatering pumps fail.</td>
<td>L</td>
<td>Regular inspection and operation is done on dewatering pumps</td>
<td></td>
</tr>
<tr>
<td>w.</td>
<td>A review of the UPS power supply standby time be undertaken to see if it is adequate.</td>
<td>H</td>
<td>Overhauled 2000</td>
<td></td>
</tr>
<tr>
<td>x.</td>
<td>The position sensors be installed on each side of each gate.</td>
<td>H</td>
<td>Position indicators connected to flood alert in 2001</td>
<td></td>
</tr>
</tbody>
</table>

2. Civil

<table>
<thead>
<tr>
<th>No.</th>
<th>Recommendation</th>
<th>Priority</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Block numbers are painted on each side of each spillway section block joint allow easy reference to location for all gallery joints, weeping drains or cracks in future inspections.</td>
<td>L</td>
<td>July 2003</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>The effectiveness of the spillway flip bucket drainage system be investigated further (section 11.1.1)</td>
<td>M</td>
<td>Review in comprehensive inspection 2005</td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>The radial gates, winches and bridges be checked for seismic loading. Radial gates of this size (16.5m high) have the potential to produce a significant flood wave if they breach (section 12.8.6)</td>
<td>M</td>
<td>Dec 1999</td>
<td>Structurally ok refer Report WS222-C1</td>
</tr>
<tr>
<td>e.</td>
<td>Data is obtained for the performance of the spillway, specifically the flows and gate openings with time during the 1991 event and any other data which</td>
<td>Nil</td>
<td>1999</td>
<td>Observed in Feb 99 flood</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------</td>
<td>---------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>may be of used such as video or photographs of spill (section 12.9.4).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>Vibration monitoring is installed on the radial gates and concrete structure to monitor any vortex formation and gate performance. This should be installed prior to the next spill event (section 12.9.4).</td>
<td>M</td>
<td>1999</td>
<td>Observed in Feb 99 flood. Not considered necessary.</td>
</tr>
<tr>
<td>g.</td>
<td>Surveys of the stilling basin before and after flood events are taken to quantify the amount of erosion. These surveys should include the upper level berms. Details on the repairs undertaken (if any) after the 1991 flood should be obtained (section 12.9.5).</td>
<td>M</td>
<td>Dec 1999</td>
<td>Will be resurveyed after each significant flood event.</td>
</tr>
<tr>
<td>h.</td>
<td>The flood immunity of the spillway gate control equipment is checked for extreme flood events (section 12.9.6).</td>
<td></td>
<td></td>
<td>As per 1f</td>
</tr>
<tr>
<td>i.</td>
<td>The spillway retaining wall monoliths are checked for stability, particularly in light of current earthquake and “at rest” pressure design methods (section 12.9.7).</td>
<td>L</td>
<td></td>
<td>Design check complete in 2001</td>
</tr>
<tr>
<td></td>
<td>3. Embankment General:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>Soil properties are confirmed using as placed strength data. This is particularly important for the rolled sandstone fill as the as placed properties will differ from the excavated properties because of particle breakdown (section 12.8.3.2).</td>
<td>L</td>
<td></td>
<td>Not considered necessary.</td>
</tr>
<tr>
<td>b.</td>
<td>The alluvium properties are obtained (section 12.8.3.2).</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>Soil properties are obtained for the actual core material used. It is possible that soil tests relate to borrow area not utilised in construction (section 12.8.2).</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>A review is made of all available soil strength tests and quality control records to determine the actual strength of the embankment as placed (section 12.8.3.6).</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>An investigation into the seepage profile through the embankment is required to determine the actual phreatic surface. This would include a review of the materials used in the downstream shoulder to determine the actual pore pressure profile (section</td>
<td>L</td>
<td>yes</td>
<td>Investigation done Monitor during annual inspections</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
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<td>----------</td>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td>12.8.3.6).</td>
<td>The embankment is monitored closely following extensive drought periods. This will include monitoring of piezometric levels of the main embankment at least twice weekly during flood and visual inspection of the upstream shoulder (section 12.8.3.6).</td>
<td>L</td>
<td></td>
<td>Piezometric levels read on monthly basis</td>
</tr>
<tr>
<td>4. <strong>Right Bank Section.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The reason for the presence of the fine zone in the rip rap on the upstream face approximately halfway between the spillway and the right abutment is investigated further (section 13.8.2).</td>
<td>M</td>
<td>1996 Complete</td>
<td>Material was from access ramp on top of the riprap</td>
</tr>
<tr>
<td>d.</td>
<td>The seepage in the right bank of the diversion cut at the foundation contact be monitored with a V notch weir or similar (section 13.8.2).</td>
<td>H</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
</tr>
<tr>
<td>f.</td>
<td>The reason for the zone of fine material in the rip rap half way between the right abutment and the spillway on the downstream face be investigated. It is also recommended that this area should be closely watched until appropriate remedial action is taken in the event that the fines have been washed out from the shoulder (section 13.8.2).</td>
<td>H</td>
<td>1996 Complete</td>
<td>Material was from access ramp on top of the riprap.</td>
</tr>
<tr>
<td>g.</td>
<td>The effectiveness of the drainage system downstream of the core is investigated in light of the increasing pore pressures in the filter at chainage 1800 (section 11.1.2.2).</td>
<td>H</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
</tr>
<tr>
<td>5. <strong>Left Bank Section</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>The concrete manholes installed at regular intervals along the left abutment section toe are investigated further to define where they drain from and whether they should be monitored (section 13.8.3).</td>
<td>H</td>
<td>2002 Complete</td>
<td></td>
</tr>
<tr>
<td>6. <strong>Saddle Dam 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>The unusual animal burrows over a large area of the lower part of the downstream shoulder of saddle dam 1 are dug out and recompacted to stop rainfall and runoff from entering the dam structure (section 13.8.4).</td>
<td>M</td>
<td>1998 Complete</td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>The bare patch on the downstream shoulder of saddle dam 1 is</td>
<td>M</td>
<td>1998 Complete</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>---------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>recompacted and sowed with grass (section 13.8.4).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>Soil testing be undertaken or that the construction testing is investigated to determine whether the soil used for saddle dam 1 is dispersive (section 13.8.4).</td>
<td>M</td>
<td></td>
<td>Complete refer Sunwater Reports</td>
</tr>
<tr>
<td>f.</td>
<td>Set wheel tracks on the downstream shoulder of saddle dam 1 be repaired so that an erosion gully does not form in them (section 13.8.4).</td>
<td>M</td>
<td>1998</td>
<td>Complete</td>
</tr>
<tr>
<td>7.</td>
<td><strong>Saddle Dam 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The long grass on saddle dam 2 (furthest from the main dam) be slashed or mowed to allow easy detection of seepage or erosion (section 13.8.5).</td>
<td>M</td>
<td>1998</td>
<td>Complete and on-going</td>
</tr>
<tr>
<td>b.</td>
<td>A zone of 10 meters or so should be cleared of trees on the upstream and downstream toe if saddle dam 2. This includes the large dead tree at the downstream toe (section 13.8.5).</td>
<td>M</td>
<td>1998</td>
<td>Complete</td>
</tr>
<tr>
<td>c.</td>
<td>The downstream shoulder and toe of saddle dam 2 is fenced off from vehicles and stock and the track graded in on the left abutment is removed. The original profile of the dam should be re-established and resown with grass (section 13.8.5).</td>
<td>M</td>
<td>1998</td>
<td>Complete</td>
</tr>
<tr>
<td>8.</td>
<td><strong>Outlet Works</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>It is recommended that a detailed inspection of the corrosion protection of the inside of the penstock be undertaken</td>
<td>M</td>
<td>May 1999</td>
<td>Complete</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>----------</td>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td>1.</td>
<td>Mechanical/Electrical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i.</td>
<td>Replacement oil be purchased in advance and stored on site as reserve oil for the system.</td>
<td>H</td>
<td>1997</td>
<td>Review during annual inspection in October each year</td>
</tr>
<tr>
<td>j.</td>
<td>Consideration be given to providing oil containment and oil clean up materials.</td>
<td>L</td>
<td></td>
<td>As above</td>
</tr>
<tr>
<td>2.</td>
<td>Civil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>The drain on the stairs of the upper gallery which is still filled with polystyrene foam (possibly from construction) is cleared out (section 13.8.1). The tree at the toe of left side spillway training wall should be removed (section 13.10)</td>
<td>L</td>
<td></td>
<td>As above</td>
</tr>
<tr>
<td>j.</td>
<td>Appropriate water safety buoys and booms be placed across the entrance to the spillway.</td>
<td>L</td>
<td></td>
<td>As above</td>
</tr>
<tr>
<td>3.</td>
<td>Spillway Section.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>The rip rap condition be monitored following significant wind storm events. (section 12.8.1)</td>
<td>M</td>
<td></td>
<td>As above</td>
</tr>
<tr>
<td>4.</td>
<td>Right Bank Section.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>One or two trees are removed on the downstream shoulder of the right abutment section (section 13.8.2).</td>
<td>M</td>
<td>Yes</td>
<td>As above</td>
</tr>
<tr>
<td>c.</td>
<td>The erosion of the far right abutment section above the diversion cut is repaired and monitored after significant rainstorms. In the event that the erosion gets much worse rockfill or concrete drop structures may be required in the formed drain (section 13.8.2).</td>
<td>M</td>
<td>July 1999</td>
<td>Review during annual inspection in October each year</td>
</tr>
<tr>
<td>e.</td>
<td>The seepage from the top of the shotcrete protection in the Brisbane River section be closely monitored and that the effect of this on the overall stability of the dam be investigated (section 13.8.2).</td>
<td>M</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
</tr>
<tr>
<td>5.</td>
<td>Left Bank Section</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>Removal of a few trees in a zone 10 meters from the toe of the left embankment section is undertaken (section 13.8.3)</td>
<td>M</td>
<td>1997</td>
<td>As above</td>
</tr>
<tr>
<td>b.</td>
<td>The creeper on the upstream face near the left abutment be poisoned so that</td>
<td>M</td>
<td>1997</td>
<td>As Above</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>the performance of the rip rap can be inspected and monitored and the reason for the undersized rip rap determined. Area of insufficient or undersized rip rap in this section will have to be repaired with a cover of suitable rock (section 13.8.3).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>The drainage of the seepage at the toe of the highest section in the left abutment section is improved by cleaning out and regrading the drainage bank. The installation of a monitoring weir for this seepage is also required (section 13.8.3).</td>
<td>M</td>
<td>July 1999</td>
<td>Completed and review during annual inspection in October each year. Seepage is monitored by timed pipe discharge.</td>
</tr>
<tr>
<td>d.</td>
<td>The substantial open drain from the toe of the left abutment section is cleaned out. The inflows into this drain should be investigated and a monitoring weir should be installed if this drain conducts seepage from the dam (section 13.8.3).</td>
<td>M</td>
<td>July 1999</td>
<td>Completed and review during annual inspection in October each year. This drain needs cleaning out again.</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Saddle Dam 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The long grass on saddle dam 1 (close to the main dam) be slashed or mowed to allow easy detection of seepage or erosion.</td>
<td>H</td>
<td>1997</td>
<td>As above</td>
</tr>
<tr>
<td>b.</td>
<td>A zone of 10 meters or so should be cleared of trees on the upstream and downstream toe of saddle dam 1 (section 13.8.4).</td>
<td>H</td>
<td>1997</td>
<td>As above</td>
</tr>
<tr>
<td>7.</td>
<td><strong>Saddle Dam 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>The erosion gully forming from the left abutment towards the toe of saddle dam 2 is backfilled and monitored following rain storms (section 13.8.5).</td>
<td>M</td>
<td>1997</td>
<td>As above</td>
</tr>
<tr>
<td>e.</td>
<td>The minor runoff erosion on the downstream shoulder of saddle dam 2 be monitored (section 13.8.5).</td>
<td>H</td>
<td>Yes</td>
<td>Completed and review during annual inspection in October each year</td>
</tr>
</tbody>
</table>

The priority in the Table was assigned prior to the risk assessment being undertaken. In this case the priority was given as either low (L), medium (M) or high (H).
8.0 RECOMMENDED ACTIONS FROM PRELIMINARY RISK ASSESSMENT

Table of Proposed ‘Fixes’ with Corporation Comments

<table>
<thead>
<tr>
<th>Dam</th>
<th>Consultant’s Proposed ‘Fix’</th>
<th>Estimated Cost</th>
<th>Corporation Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wivenhoe</td>
<td>Improve liability of Spillway Gates (GHD design)</td>
<td>$0.13m</td>
<td>Work Completed</td>
</tr>
<tr>
<td>Wivenhoe</td>
<td>Auxiliary Spillway to enable the dam to pass the PMF</td>
<td>$57.8m</td>
<td>Alliance formed. Design phase for new spillway due to be completed by February 2004.</td>
</tr>
<tr>
<td>Downstream of all dams</td>
<td>Develop Emergency Evacuation Plans</td>
<td>$1.50m</td>
<td>Discussions with Local Authorities and SES ongoing. Co-ordinating supply of Dam release information. Evacuation is responsibility of SES and Police.</td>
</tr>
</tbody>
</table>

9.0 RECOMMENDED ACTIONS (and some other comments) FROM 2002 ANNUAL INSPECTION

(SOP)
SOP DM4.1-10 needs minor revision to flowchart to follow logic if Instruments are Not OK after receipt of an unusual report on instrumentation results. 
This has not been done.

(O & M Manuals)
Manuals revised and issued as SEQWC documents. Review in progress by SunWater to ensure all aspects of previous documents are incorporated in the new documents. Drawings uncontrolled Water Board documents dated 1988. Revisions to documents noted by Sunwater in Site Monitoring Form Section 2.1 and submitted to David Gill of SEQWC for amendments to be issued. Revisions to electrical drawings have been made with a set of drawings at the site but no changes to the main set of drawings. Manuals have no reference in each file to the other manuals of which there are 17 manuals. Manual No 1 was not available to check the total number of manuals in the set. Recommend that each manual include a listing of the total set for reference. Controlled set of drawings needs to be issued with the O&M Manuals and updated when changes made to operating systems. 
Review has identified some omissions. Review now in progress by SEQW. As built drawings have been reissued on CD. New set of updated electrical drawings dated 25/11/03. Other comments still apply

(Emergency Preparedness – EAP)
Phone numbers for contacts and contact listing requires updating. Radio Channels required on listing.
Comments still apply

(General Emergency Operations)
Some problems with the alarm being set off by fog and reprogrammed to avoid false alarms
This has been solved by adjustment of the system.

(Embankments)
The wave walls do not run out to zero height at the ends of the embankments and in the event of extreme floods occurring, flow will be allowed to pass around the wave walls and down the abutment/embankment toe leading to potential erosion damage/failure of the embankment
This is still the case.

(Spillway)
Minor seepage from rock on the left side of the spillway channel above the access road level.
The right bank spillway retaining wall has no railing at the end to prevent personnel falling over the rock face at the end of the concrete section. It is recommended that the handrail be taken perpendicular from the wall across the channel for OHSA requirements.
Consideration should be given to monitoring seepage from the upper right gallery should this flow increase.
A lot of calcite and cracking is present at the gallery exit to the outlet works on horizontal joints.
There is no joint or drain numbering or crack identification in the galleries. It is recommended that joints and drains be numbered and the ends of prominent cracks be identified to evaluate any growth of the cracks.
Joint and foundation drain numbering has been added. A railing has been installed on the right spillway retaining wall. Other comments still apply.

(Saddle Dams)
No embankment chainage markers for dam safety surveillance where anomalies are noted.
Chainage markers have been added

(Instrumentation)
Recommend that the “V” notch readings be taken using a mounted gauge plate to provide consistency in taking readings.
Still read manually. Reasonable consistency obtained.
10.0 RECOMMENDED ACTIONS FROM THIS INSPECTION

Review the requirements for routine dam surveillance in the Standard Operating Procedures in the light of the recent release of the ANCOLD Guidelines on Dam Safety Management, August 2003. In the SOP for routine instrument surveillance, Appendix B refers to instrumentation which is no longer read, and other details may also be out of date.

Ensure time series plots for dam surveillance instrumentation are kept up-to-date, and the full range of plots given for the earlier data (pre June 2001) should be available to allow rapid assessment in the event of an anomaly occurring.

Merge the instrumentation data for pre- and post- July 2001 so that long-term plots can be examined for long–term behaviour and previous behaviour under similar storage conditions, as well as looking at short-term and medium-term behaviour. Comparison of older and newer data is difficult at present, because of presentational differences between available plots for the two sets of data.

Prepare a one-page checklist for weekly surveillance inspection of the structures at the dam, rather than relying on written–in comments on the (essentially mechanical/electrical) monthly report. This would help to ensure that visual dam surveillance is appreciated as a separate distinct activity with a vital dam safety function, and ensure that all sections of the structures are regularly inspected.

Provide a copy of the annual inspection report to the dam supervisor to ensure that items mentioned are attended to.

As a general rule, keep vegetation (other than short grass) at least 5 metres away from dam structures, to ensure effective visual surveillance, and reduce the likelihood of damage through tree roots.

A comprehensive dam inspection should be undertaken. The last detailed safety review was in 1997, and the Dam Safety Management Program indicates that comprehensive inspections have been undertaken at five yearly intervals. It also indicates an inspection is planned for 2005.

Remove the ant colonies evident at joints in the wave wall.

Clean the grass and debris from joints in the concrete dish drain on the crest adjacent to the wave wall, and clean out the pipe outlets from this drain.

The dam hazard categories in the SEQW Dam Safety Management Program of October 2002 should be reviewed to accord with the expanded range of categories in the revised ANCOLD guidelines.

The oxygen reading on the fixed gas monitoring facility for the power station needs to be recalibrated or the sensor replaced.

More detailed items are noted in the checklist in Attachment A.
Appendix E2 – Annual Inspection November 2004
WIVENHOE DAM
ANNUAL INSPECTION

Date of Inspection : 1 November 2004
Inspection Notes By : Richard Evans (GHD)

Field Conditions :

<table>
<thead>
<tr>
<th>Condition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>X</td>
</tr>
<tr>
<td>Cloudy</td>
<td></td>
</tr>
<tr>
<td>Overcast</td>
<td></td>
</tr>
<tr>
<td>Rain</td>
<td>Nil</td>
</tr>
<tr>
<td>Temperature</td>
<td>Max 32°C</td>
</tr>
<tr>
<td>Wind</td>
<td>Calm</td>
</tr>
</tbody>
</table>
**Contents**

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2 Operational and Emergency Preparedness 7
3 Main Dam Checklist 11
4 Spillway Checklist 14
5 Saddle Dam 1 Checklist 16
6 Saddle Dam 2 Checklist 17
7 Instrumentation Checklist 18
8 Mechanical Checklist 19
9 Electrical Checklist 23
10 Outlet Works 24
Description and Pertinent Data

Reservoir
Full Supply level (FSL) EL 67.0
Storage (at FSL) 1,150,000 ML
Reservoir Surface Area (at FSL) 10,820 ha

Dam
Type Zoned earth and rockfill dam with a concrete gravity spillway section and two earthfill saddle dams.
Crest Level EL 79.15m excluding the wave wall

Main Dam
Type Earth and rockfill dam
Crest Level EL 79.15
Wave Wall EL 79.7m (top of wall)
Dam length (including spillway section) 2260m
Dam height (maximum above downstream toe) 53m
Right embankment Central core embankment
Left embankment Sloping core embankment

Saddle Dam 1
Type Earthfill embankment
Crest Level EL 80.0m
Crest width 4.0m
Upstream slope 3H:1V
Downstream slope 2.5H:1V
Embankment height (maximum) 11m
Embankment Length 90 m
Saddle Dam 2

Type: Earthfill embankment.
Crest Level: EL 80m
Crest width: 4.0m
Upstream slope: 3H:1V
Downstream slope: 2.5H:1V
Embankment height (maximum): 6m
Embankment Length: 225m

Outlet Works - Water Supply Intake

Variable level drawoff facility
Penstocks: 2
Penstock diameters: 1.9m & 3.6m

Outlet Works - Regulators

Number of regulators: 2
Type and size of regulators: 1.5 m diameter fixed cone dispersion valves
Level of centreline of regulators: EL 31.5

Spillway

Type: Gated, concrete gravity section with flip bucket and flanking retaining walls.
Number of radial gates: 5
Size of each gate: 12.0m wide x 16.5m high
Top of gates when closed: EL 73.0
Top of bridge deck: EL 79.15
Spillway width: 60.0m
Unlined stilling basin invert: EL 17.0
Peak water level as a result of PMF Embankment overtopped
Imminent Failure Flood (IFF) - return period: 14,300 years
Maximum flood level (IFF): EL 79.15
Peak discharge (IFF): 14,000m³/s
### Operational Status at Time of Inspection

- **Reservoir water surface level:** 60.68m
- **Reservoir Storage:** $627,797 \times 10^6$ m$^3$ (53.9%)
- **Releases:**
  - Spillway: Nil
  - Regulators: Nil
  - Power station: 592 ML/d

**Inspected By:**
- Richard Evans - GHD
- Doug Grigg – Sunwater

**Report Prepared By:** Richard Evans

**Approved By:** Brian Forbes
1. **Inspection Team**

<table>
<thead>
<tr>
<th>Name</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richard Evans</td>
<td>GHD</td>
</tr>
<tr>
<td>Doug Grigg</td>
<td>Sunwater</td>
</tr>
</tbody>
</table>

Notes:
2. Operational and Emergency Preparedness

Standing Operating Procedures (SOP)

1. Issue or revision date : DMQD4.1 dated 2/11/2001. Controlled Copy No. 3
2. Is copy at dam current ? Yes
3. Are Instructions adequate ? Yes
4. Are Instructions understood ? Yes
5. Any changes required ? Yes - minor revision, see comments.

Comments:

- Refer to comments in 2002 report by GHD. Still not actioned

O & M Manuals

1. Issue or revision date : DMQD3.1 dated 18/3/2002. Controlled Copy No. 1
2. Is copy at dam current ? Yes
3. Are Instructions adequate ? No, see comments
4. Are Instructions understood ? Yes, however maintenance schedules prepared by Sunwater are used
5. Any changes required ? Yes, see comments.

Comments:

- Refer to comments in 2002 report by GHD. Still not actioned
- Drawings have been issued in hard copy
- Old manuals still referred to by supervisors. Supervisors have stopped suggesting modifications due to lack of action on updates.
- Will require incorporation of spillway upgrade works
### Emergency Preparedness

**EAP**

1. Issue or revision date: Controlled Copy No 3, dated 11/11/2001
2. Is copy at dam current? Yes
3. Are Instructions adequate? Yes
4. Are Instructions understood? Yes
5. Any changes required? *Yes, see comments*

Comments:
- Refer to comments in 2002 report by GHD. Still not actioned.
- Notification list needs to be updated and kept up to date on a regular basis. Supervisor has separate list of contacts.
- Confusion on the controlled copy number of on-site document. Sticker on cover says Copy 3, front cover says Copy 4.

### Flood Operations Manual

1. Issue or revision date: Controlled Copy 11 dated 6/9/2002
   Flood operations procedures FLX41101 (Sept 2003), Controlled Copy No. 10
2. Is copy at dam current? Yes
3. Are Instructions adequate? Yes
4. Are Instructions understood? Yes
5. Any changes required? *Yes - to take account of spillway upgrade works in progress*

Comments:
Flood Operations

1. Flood Warning & Operations
   (a) Duty Engineer current? Check Flood Control Centre Answering machine (3120 0290) Don Cock
   (b) Office phone - Number given on message Yes
   (c) Home phone - Number given on message Yes
   (d) Mobile phone - Number given on message Yes
   (e) Date of last Flood Operations training including loss of communications 19/8/2004 (loss of communications)

2. Standby Operators
   (a) Last Training Date 29/6/2004
   (b) Number Trained 12

General Emergency Operations

1. Communications Rob Ayre
   Normal
   Phone Listing of contacts. Phone communications primarily followed by confirmation by fax. E-mail not used.
   Fax
   Standby On contact listing.
   Mobile phone
   Emergency Channels 1-4 available. Still needs to be incorporated into EAP.
   SEQWB two way radio
2. Warning Systems

EDAC Auto-dialler regularly tested. In use for:

- High lake level
- Fire
- Diesel generator running for 1hr
- System valve failure
- Power failure
- Sump pump fault
- Sump high level
- Security
- 24volt dc supply level

Comments:
- Security system has been upgraded.

3. Emergency Power

(a) Test Weekly for 45 minutes
(b) Condition Appears good
(c) Adequacy Appears OK

Comments:
3. **Main Dam - Checklist**

1. **Left Embankment Crest**
   - (a) Crack ________________________ None observed
   - (b) Sinkholes ________________________ None observed
   - (c) Alignment ________________________ No obvious misalignment observed. Wave wall and Armco barrier appear well aligned
   - (d) Erosion ________________________ None observed
   - (e) Vegetation ________________________ Minor
   - (f) Depressions ________________________ No obvious observed
   - (g) Settlement ________________________ None observed
   - (h) Wave wall ________________________ Appears OK. Some minor ant activity observed in joints. Sand deposited on upstream side of wall is reportedly from clearing out of drains. Joint filler has debonded/ extruded in places.

2. **Left Embankment Downstream Slope**
   - (a) Cracks ________________________ None Observed
   - (b) Sinkholes ________________________ None Observed
   - (c) Bulging ________________________ None Observed
   - (d) Wet spots ________________________ None Observed. Controlled clear seepage at toe from drainage system observed (<1l/min).
   - (e) Boils ________________________ None Observed
   - (f) Depressions ________________________ None Observed
   - (g) Vegetation ________________________ Some overgrown vegetation along downstream toe/ toe drain needs controlling
   - (h) Erosion ________________________ None Observed
   - (i) Animal Burrows ________________________ None Observed

3. **Left Embankment Upstream Slope**
   - (a) Slides ________________________ None Observed
   - (b) Sinkholes ________________________ None Observed
   - (c) Deterioration of slope protection ___ Minor breakdown of weathered rip rap. Some vegetation growth, which should be controlled.
   - (d) Beaching ________________________ None Observed
   - (e) Erosion ________________________ None Observed

4. **Left Embankment Abutment**
   - (a) Cracks ________________________ None Observed
   - (b) Wet spots ________________________ None Observed
   - (c) Vegetation ________________________ No significant problems
   - (d) Slides ________________________ None Observed
5. Right Embankment Crest
   (a) Cracks ________________________ None observed.
   (b) Sinkholes _____________________ None observed
   (c) Alignment _____________________ No obvious misalignment observed.
   (d) Erosion ________________________ None Observed
   (e) Vegetation ____________________ Very minor grass
   (f) Depressions ____________________ None Observed
   (g) Settlement ____________________ None Observed
   (h) Wave wall _____________________ joint filler debonded/ extruded in places.

Comments: major spillway upgrade works under construction at right hand end of embankment, comprising excavation and construction of a fuse plug auxiliary spillway. Cofferdam in place protecting downstream works at time of inspection. Crest road/highway realigned temporarily upstream until bridge over new spillway constructed.

6. Right Embankment Downstream Slope
   (a) Crack ________________________ None observed
   (b) Sinkholes _____________________ None observed
   (c) Bulging ________________________ None observed
   (d) Wet spots____________________ Small seepage/ wet spot emerging from foundation rock in old diversion channel. Vegetation should be controlled to allow surveillance.
   (e) Boils ________________________ None observed
   (f) Depressions ____________________ Change of slope midway between the reinforced rockfill toe and the embankment crest.
   (g) Vegetation ____________________ Minor grass
   (h) Erosion ________________________ None observed
   (i) Animal Burrows _______________ None observed
   (j) Drainage System _______________ Seepage measured weekly.

7. Right Embankment Upstream Slope
   (a) Slides ________________________ None observed
   (b) Sinkholes _____________________ None observed
   (c) Deterioration of slope protection___ Rip rap appears OK, except not placed to correct profile and is cast in concrete at crest. Uncertain whether this is settlement related during construction or if riprap just not placed correctly? Some grasses near right hand side of spillway in riprap.
   (d) Beaching _____________________ None observed
   (e) Erosion ________________________ None observed

Comments: temporary works for auxiliary spillway do not appear protected with riprap to crest, with a grassed slope being used.

8. Right Embankment Abutment
   (a) Cracks ________________________ Spillway upgrade works – Alliance works area
   (b) Wet spots_____________________
   (c) Vegetation ____________________
   (d) Slides ________________________
Comments:

- Spillway upgrade in progress – Alliance work area
4. **Spillway - Checklist**

1. Spillway Gates
   (a) General Condition______________ Appears good, although trunnion seals under investigation for cracking. Some seals removed.
   (b) Hoist Equipment ______________ Appears good
   (c) Controls (control room)__________ Appears good
   (d) Controls (local) ________________ Appears good

2. Spillway Main Hydraulic Pump
   (a) General Condition______________ Appears good
   (b) Last test date __________________ June 2004

3a. Spillway Emergency Hydraulic Pump
   (a) General Condition______________ Appears good
   (b) Last test date __________________ June 2004

3b. Spillway Mobile Hydraulic Unit
   (c) General Condition______________ Not inspected, reportedly good
   (d) Last test date __________________ June 2004

4. Spillway Chute
   (a) General Condition______________ *Appears OK, some spalling of concrete in left side of Gate 5 chute, which needs closer inspection.*
   (b) Cracking _____________________ Minor with calcite. Gate 5 cracking behind gate.
   (c) Spalling _____________________ Left side of Gate 5 chute and centre behind gate
   (d) Construction Joints _____________ Appear OK
   (e) Erosion _____________________ None observed

5 Flip Bucket
   (a) General Condition______________ Appears good, with minor cracking
   (b) Cracking _____________________ Minor, probably construction related.
   (c) Spalling _____________________ None observed
   (d) Construction Joints _____________ Appear OK
   (e) Erosion _____________________ None observed

6 Left Bank Spillway Retaining Wall
   (a) General Condition______________ Good
   (b) Cracking _____________________ Small crack in wall beside flip bucket. Minor seepage and calcite from crack above outlet works. Reportedly no change.
   (c) Spalling _____________________ None observed
   (d) Joints ______________________ Appear OK
   (e) Deflection ________________ No obvious
7 Right Bank Spillway Retaining Wall
   (a) General Condition ______________ Appears good
   (b) Cracking ________________________ One crack full height of wall with minor calcite. Crack observed previous inspections.
   (c) Spalling ________________________ None observed
   (d) Joints __________________________ Appear OK
   (e) Deflection ______________________ No obvious

8 Spillway Discharge Channel
   (a) General Condition ______________ Appears good
   (b) Erosion _________________________ No significant erosion observed
   (c) Debris __________________________ No significant
   (d) Loose Rocks _____________________ No significant
   (e) Vegetation ______________________ Trees downstream could do with removing before they grow. Some trees on lower berm could pose maintenance issue/spalling of rock face problems if they grow much bigger. Consider removing.

9 Upper Gallery
   (a) General Conditions _____________ Appears good, with minor calcite on joints and cracks.
   (b) Leakage _________________________ Mainly dry, but with a few small seepages. Some minor calcite.
   (c) Formed drains _________________ Appear OK, minor calcite
   (d) Gutter drains ____________________ Appears OK
   (e) Ventilation____________________ Appears adequate
   (f) Electrical ______________________ Appears OK. Lighting seems adequate
   (g) Movement_______________________ Minor cracking, generally no obvious movement.

10 Lower Gallery
   (a) General Conditions _____________ Appears good
   (b) Foundation drains _______________ Wall drains and floor drains generally flowing small amounts. Calcite evident.
   (c) Formed drains _________________ Appears OK
   (d) Gutter drains ____________________ Appears OK
   (e) Sump pumps _____________________ Appear OK, not observed working
   (f) Metal Work ______________________ Appears OK
   (g) Ventilation____________________ Appears adequate
   (h) Electrical ______________________ Appears OK. Lighting seems adequate

11. Access Road
   (a) Pavement General Condition _____ Appears adequate
   (b) Guard Rails ______________________ Appear OK
   (c) Signs ____________________________ Appears OK

Comments:
5. **Saddle Dam 1 - Checklist**

1. **Embankment Crest**
   
   (a) Cracks ______________________ None observed
   (b) Sinkholes _____________________ None observed
   (c) Alignment ____________________ No obvious misalignment
   (d) Erosion ______________________ None observed
   (e) Vegetation ____________________ Some grass
   (f) Depressions ____________________ No significant depressions obvious
   (g) Settlement ____________________ None observed
   (h) Animal burrows________________ One relatively large ant hill on downstream side of crest, which should be remediated.

2. **Embankment Downstream Slope**
   
   (a) Crack ________________________ None observed
   (b) Sinkholes _____________________ None observed
   (c) Bulging ______________________ None observed
   (d) Wet spots_____________________ None observed - water level of reservoir below toe of dam
   (e) Boils _________________________ None observed
   (f) Depressions __________________ None observed
   (g) Vegetation ____________________ Good grass cover, greener at right hand toe area – no noticeable wet spot. Small saplings starting to grow, but are likely to be cut during next mowing
   (h) Erosion ______________________ None observed
   (i) Animal Burrows ________________ None observed

3. **Embankment Upstream Slope**
   
   (a) Slides ________________________ None observed
   (b) Sinkholes _____________________ None observed
   (c) Deterioration of slope protection__ None observed
   (d) Beaching ______________________ None observed
   (e) Erosion ________________________ None observed
   (f) Vegetation____________________ None observed

4. **Embankment Abutments**
   
   (a) Cracks ________________________ None observed
   (b) Wet spots_____________________ None observed
   (c) Vegetation____________________ Reasonable grass cover
   (d) Slides________________________ None observed
6. Saddle Dam 2 - Checklist

1. Embankment Crest
   (e) Cracks _______________________ None observed
   (f) Sinkholes____________________ None observed
   (g) Alignment____________________ None observed
   (h) Erosion_______________________ None observed
   (i) Vegetation___________________ Some grass
   (j) Depressions__________________ Nothing significant
   (k) Settlement___________________ None observed

2. Embankment Downstream Slope
   (a) Crack________________________ None observed
   (b) Sinkholes____________________ None observed
   (c) Bulging_______________________ None observed
   (d) Wet spots____________________ None observed – water level below toe.
   (e) Boils_________________________ None observed
   (f) Depressions___________________ None observed
   (g) Vegetation___________________ Good grass cover
   (h) Erosion_______________________ None observed
   (i) Animal Burrows_______________ None observed

3. Embankment Upstream Slope
   (a) Slides________________________ None observed
   (b) Sinkholes____________________ None observed
   (c) Deterioration of slope protection___ None observed. Riprap not to crest. Some riprap looks small in size at the left end, although somewhat protected by existing ground upstream.
   (d) Beaching_____________________ None observed
   (e) Vegetation___________________ Some small saplings on upstream face need removing
   (f) Erosion_______________________ None observed

4. Embankment Abutment
   (a) Cracks_______________________ None observed
   (b) Wet spots____________________ None observed
   (c) Vegetation___________________ Some grass cover
   (d) Slides_______________________ None observed

Comments:
7. **Instrumentation - Checklist**

1. **Collection of data**

   (a) V-notch weirs in lower gallery (spillway): Weekly readings

   (b) Seepage measuring points in Main Dam drainage system: Weekly readings

   (c) Piezometers (main dam & spillway): Monthly readings

   (d) Inclinometers (main dam & spillway): Read by Sunwater from Brisbane, possibly at 3 monthly intervals.

   (e) Settlement crossarms (main dam): *uncertain if still read, likely not.*

   (f) Pressure cells (main dam & spillway): *uncertain if still read, likely not.*

2. **Review of Instrumentation Data**

   (a) V-notch weirs in lower gallery (spillway): not observed

   (b) Seepage measuring points in Main Dam drainage system: not observed

   (c) Piezometers (main dam & spillway): not observed

   (d) Inclinometers (main dam & spillway): not observed

   (e) Settlement crossarms (main dam): not observed

   (f) Pressure cells (main dam & spillway): not observed

Comments:

- Refer to 2002 and 2003 annual inspection reports for comments, which still apply.
8. Mechanical Checklist

1. Spillway Gates
   (a) General Condition __________ Appear OK
   (b) Metal Work Condition ________ Appears good
   (c) Coatings____________________ Appears good
   (d) Seals _______________________ Appear good, very little leakage
   (e) Seal Seats___________________ Appear OK
   (f) Cavitation damage__________ None observed
   (g) Hydraulic Winches __________ Appears good
   (h) Hydraulic Pipes, Hoses and Fittings Appear good
   (i) Wire Ropes __________________ Appear good, Nobles check every 5 years
   (j) Access_______________________ Appears adequate
   (k) Control System ______________ Appears OK
   (l) Security____________________ Appears OK
   (m) Operation instructions________ Not observed
   (n) Last Operation / Test__________ June 2004. Exercised every 3 months to
      150 mm for 2 minutes, and 6 months through full range behind baulk gate

Comments: trunnion seals cracking and falling off. Bearings under investigation.

2. Spillway Baulk Gate
   (a) General Condition __________ Appears good
   (b) Metal Work Condition ________ Appears good
   (c) Wheels_______________________ Appear OK
   (d) Coatings____________________ Appears OK
   (e) Seals ________________________ Appear OK
   (f) Seal Seat____________________ Appears OK
   (g) Leakage ______________________ Not observed
   (h) Access_______________________ Appears OK
   (i) Filling Valve _________________ Not observed
   (j) Lifting provision ______________ Appears OK, although hatch needs to be
      closed
   (k) Operation instructions________ Not observed
   (l) Last Operation / Test__________ June 2004

3. Penstock Gate
   (a) General Condition __________ Appears good
   (b) Metal Work Condition ________ Appears good
   (c) Coatings____________________ Appears good
   (d) Seals ________________________ Appear OK
   (e) Seal Seats____________________
   (f) Leakage______________________ Not observed
   (g) Lifting provision _____________ Appears OK
   (h) Operation instructions________ Not observed
   (i) Last Operation / Test__________ February 2004 large penstock, September
      2004 small penstock
4. Intake Trashscreens
   (a) General Condition ___________ Appear reasonable above water. Poor fitting on left side.
   (b) Coatings _________________ Appear OK above water
   (c) Metalwork Condition _________ Not observed
   (d) Last Inspection _____________

5. Intake - Selective Withdrawal Baulks (6 no.)
   (a) General Condition ___________ Not inspected. No 4 recently repainted, with plans for one/year from hereonin
   (b) Lifting Chains ________________
   (c) Electrical ___________________
   (d) Last Operation / Test _____________ February 2004

6. 79 t Gantry Crane
   (a) General Condition ___________ Appears good
   (b) Mechanical _________________
   (c) Electrical _________________
   (d) Operating instructions __________ Not observed
   (e) Storage/tie down area _________ Rail drain holes blocked by Alliance for environmental control during construction
   (f) Last Operation / Test _____________ October 2004

7. 3.2 t Gantry Crane
   (a) General Condition ___________ Reportedly OK. Not inspected.
   (b) Mechanical _________________
   (c) Electrical _________________
   (d) Operating instructions __________
   (e) Storage/tie down area __________
   (f) Last Operation / Test ____________ Run monthly.

8. Penstock Winch
   (a) General Condition ___________ Appeared good
   (b) Mechanical _________________
   (c) Electrical _________________
   (d) Operating instructions __________
   (e) Last Operation / Test ____________ September 2004

9. 3.6 m diameter penstock
   (a) General Condition ___________ Appears OK, not inspected in detail
   (b) Surface protection ______________
   (c) Access Pipe into Penstock __________
   (d) Operating instructions __________
   (e) Last Inspection _________________ February 2004

10. 1.9 m diameter penstock
    (a) General Condition ___________ Appears OK, not inspected in detail
    (b) Surface protection ______________
    (c) Operating instructions __________
(d) Last Inspection __________________ August (?) 2004

11. No.1 Regulating Valve (1500 mm cone dispersion valve)
   (a) General Condition ______________ Appears OK. Relocated due to recent hydropower station construction. Used as bypass.
   (b) Coatings ________________________
   (c) Seals ____________________________
   (d) Metalwork ________________________
   (e) Leakage __________________________
   (f) Access ____________________________
   (g) Safety ____________________________
   (h) Operation _________________________
   (i) Exercise Frequency ________________
   (j) Security __________________________
   (k) Operating Instructions __________ Not observed

12. No.2 Regulating Valve (1500 mm cone dispersion valve)
   (a) General Condition ______________ Removed and penstock blanked off as part of hydropower station construction.
   (b) Coatings ________________________
   (c) Seals ____________________________
   (d) Metalwork ________________________
   (e) Leakage __________________________
   (f) Access ____________________________
   (g) Safety ____________________________
   (h) Operation _________________________
   (i) Exercise Frequency ________________
   (j) Security __________________________
   (k) Operating Instructions __________ N/A

13. Gallery Sump Pump No 1 - Lower Gallery
   (a) General Condition ______________ Appears good. No problems reported.
   (b) Coatings ________________________
   (c) Seals ____________________________
   (d) Metalwork ________________________
   (e) Leakage __________________________
   (f) Lubrication _________________________
   (g) Access ____________________________
   (h) Lifting Provision _________________
   (i) Safety ____________________________
   (j) Operation _________________________
   (k) Control System _____________________
   (l) Exercise Frequency ________________ Operates frequently. Manually operated weekly
   (m) Security __________________________
   (n) Operation Instructions ___________ Not observed

14. Gallery Sump Pump No 2 - Lower Gallery
   (a) General Condition ______________ Same as Pump No 1
(b) Coatings______________________
(c) Seals ________________________
(d) Metalwork ____________________
(e) Leakage ________________
(f) Lubrication ________________
(g) Access _______________________
(h) Lifting Provision ______________
(i) Safety_______________________
(j) Operation______________
(k) Control System _____________
(l) Exercise Frequency __________
(m) Security ______________________
(n) Operation Instructions__________

Comments:
- Equipment appears to be being well maintained and working areas kept clean and tidy.
- Hydropower station in operation since February 2003.
9. **Electrical Checklist**

1. Regular Main Switchboard and Electrical Systems
   (a) General condition ______________ Appears good. Motor protection relays planned for replacement.
   (b) Protective coating ______________
   (c) Metalwork ______________
   (d) Access ______________
   (e) Safety ______________
   (f) Operation ______________
   (g) Security ______________

2. High Voltage Electrical System
   (a) General condition ______________ Appears good.
   (b) Metalwork ______________
   (c) Access ______________
   (d) Safety ______________
   (e) Operation ______________
   (f) Security ______________
   (g) Operating instructions ______________
   (h) Last check ______________ Uncertain – SEQW responsibility

Comments:
10. Outlet Works

1. Walls
   (a) Surface condition _____________ Appears OK
   (b) Concrete ________________ Appears OK
   (c) Joints ________________ Appear OK
   (d) Cracks ________________ Cracks in roof observed from below and above
   (e) Movement ________________ None observed
   (f) Seepage ________________ No significant seepage observed. Some minor in right side wall, with calcite.

2. Floor
   (a) Surface condition _____________ Appears OK
   (b) Concrete ________________ Appears OK
   (c) Joints ________________ Appear OK
   (d) Cracks ________________ Some minor cracks
   (e) Movement ________________ None observed
   (f) Seepage ________________ Minor

3. General
   (a) Access ________________ Appears adequate
   (b) Safety ________________ Gas detection system and lock-out on doors in operation.
   (c) Operation ________________ Not observed
   (d) Security ________________ Appears OK
   (e) Lighting ________________ Appears adequate

4. Town Water Supply Pumps and Valves
   (a) General condition ____________ Appears OK
   (b) Protective coatings ____________ Appear OK
   (c) Leakage ________________ Minor leakage at seals.

5. Access Lift
   (a) General condition ____________ Appears OK
   (b) Service frequency ____________ 6 monthly, due March 2005

7. Outlet Works Distribution Board
   (a) General condition ____________ Appears OK

Comments: Hydropower station was in operation during inspection.
## APPENDIX F

### Recommended Actions from 1997 Safety Review by GHD

**WIVENHOE DAM SAFETY REVIEW – STATUS AS AT DECEMBER 2003 – CAPITAL WORKS**

<table>
<thead>
<tr>
<th>No.</th>
<th>Recommendation</th>
<th>Priority</th>
<th>Date Complete</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Mechanical/Electrical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The feasibility of converting the gates to automatic operation be investigated.</td>
<td></td>
<td></td>
<td>Automatic operation not considered economical</td>
</tr>
<tr>
<td>b.</td>
<td>That consideration be given to refurbishing the control system to provide condition monitoring.</td>
<td>H</td>
<td>1996</td>
<td>Completed 1996</td>
</tr>
<tr>
<td>c.</td>
<td>That means of improving the security of the hydraulic pipework be investigated.</td>
<td>M</td>
<td>2000</td>
<td>Completed 2000</td>
</tr>
<tr>
<td>d.</td>
<td>That a system of valving and quick connect oil pressure fittings be provided at each winch and thereby permit the connection of an emergency oil supply system.</td>
<td>M</td>
<td>2000</td>
<td>Completed 2000</td>
</tr>
<tr>
<td>e.</td>
<td>That the diesel hydraulic unit be relocated to the surface/or be converted to a mobile unit.</td>
<td>M</td>
<td>2000</td>
<td>Completed 2000</td>
</tr>
<tr>
<td>f.</td>
<td>That consideration be given to relocating the main hydraulic unit and control panels to a higher level in the building.</td>
<td>M</td>
<td>July 1999</td>
<td>The room containing this equipment has been waterproofed – no further action.</td>
</tr>
<tr>
<td>g.</td>
<td>That consideration be given to providing a sheltered control station or control room near the present control complex.</td>
<td></td>
<td></td>
<td>Not considered necessary</td>
</tr>
<tr>
<td>h.</td>
<td>That consideration be given to providing on-line alternative oil supplies, and improved drainage system including an oil separator.</td>
<td>M</td>
<td></td>
<td>Included with 1b, c, d.</td>
</tr>
<tr>
<td>k.</td>
<td>That the fuel system be upgraded to be more accessible, and to reduce the fire risk from leaks.</td>
<td>H</td>
<td>July 1999</td>
<td>Completed</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------</td>
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<td>-----------------------------------------------</td>
</tr>
<tr>
<td>l.</td>
<td>That the adequacy of the system be reviewed by a fire detection and control expert.</td>
<td>H</td>
<td>July 1999</td>
<td>Completed</td>
</tr>
<tr>
<td>m.</td>
<td>That consideration be given to upgrading the ventilation provisions of the underground control complex and running the system continuously.</td>
<td>M</td>
<td></td>
<td>Fire safety equipment upgraded in 2000.</td>
</tr>
<tr>
<td>n.</td>
<td>That consideration be given to improving the system for delivering fuel to the diesel operated oil pump.</td>
<td>M</td>
<td>1996</td>
<td>Completed 1996</td>
</tr>
<tr>
<td>o.</td>
<td>That the adequacy of the intruder detection system be reviewed and that the alarms be interconnected to a paging system which will alert operators, a security firm or the police.</td>
<td>M</td>
<td></td>
<td>Security system with dial out completed in 2001</td>
</tr>
<tr>
<td>p.</td>
<td>That operators be equipped with handheld radios for use while operating the spillway gates.</td>
<td>H</td>
<td>1997</td>
<td>Completed 1997</td>
</tr>
<tr>
<td>q.</td>
<td>That gate position indicators be investigated.</td>
<td>L</td>
<td></td>
<td>Installed 2000</td>
</tr>
<tr>
<td>r.</td>
<td>That tests be conducted to determine whether a single hoist would be capable of moving a gate safely under emergency conditions.</td>
<td>H</td>
<td>July 1999</td>
<td>Discussions held with DNR design staff – one winch will hold gate – no further action.</td>
</tr>
<tr>
<td>s.</td>
<td>Consideration be given to ensuring the duplicate hydraulic pumps be made flood proof.</td>
<td>H</td>
<td>August 1999</td>
<td>Included with 1b, c, d.</td>
</tr>
<tr>
<td>t.</td>
<td>That consideration be given to improving the fail safe nature of the Main Switchboard.</td>
<td>M</td>
<td></td>
<td>Inspections done during annual condition monitoring</td>
</tr>
<tr>
<td>u.</td>
<td>A review of the load bank size be undertaken.</td>
<td>L</td>
<td></td>
<td>Planned Mntce in plan to 2010.</td>
</tr>
<tr>
<td>v.</td>
<td>Review of the location for the outlet works distribution board be undertaken as it is below tailwater level and could be at risk if the dewatering pumps fail.</td>
<td>L</td>
<td></td>
<td>Regular inspection and operation is done on dewatering pumps</td>
</tr>
<tr>
<td>w.</td>
<td>A review of the UPS power supply standby time be undertaken to see if it is adequate.</td>
<td>H</td>
<td></td>
<td>Overhauled 2000</td>
</tr>
<tr>
<td>x.</td>
<td>The position sensors be installed on</td>
<td>H</td>
<td></td>
<td>Position indicators</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>each side of each gate.</strong></td>
<td></td>
<td></td>
<td>connected to flood alert in 2001</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Civil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>Block numbers are painted on each side of each spillway section block joint allow easy reference to location for all gallery joints, weeping drains or cracks in future inspections.</td>
<td>L</td>
<td>July 2003</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>The effectiveness of the spillway flip bucket drainage system be investigated further (section 11.1.1)</td>
<td>M</td>
<td></td>
<td>Review in comprehensive inspection 2005</td>
</tr>
<tr>
<td>d.</td>
<td>The radial gates, winches and bridges be checked for seismic loading. Radial gates of this size (16.5m high) have the potential to produce a significant flood wave if they breach (section 12.8.6)</td>
<td>M</td>
<td>Dec 1999</td>
<td>Structurally ok refer Report WS222-C1</td>
</tr>
<tr>
<td>e.</td>
<td>Data is obtained for the performance of the spillway, specifically the flows and gate openings with time during the 1991 event and any other data which may be of used such as video or photographs of spill (section 12.9.4).</td>
<td>Nil</td>
<td>1999</td>
<td>Observed in Feb 99 flood</td>
</tr>
<tr>
<td>f.</td>
<td>Vibration monitoring is installed on the radial gates and concrete structure to monitor any vortex formation and gate performance. This should be installed prior to the next spill event (section 12.9.4).</td>
<td>M</td>
<td>1999</td>
<td>Observed in Feb 99 flood. Not considered necessary.</td>
</tr>
<tr>
<td>g.</td>
<td>Surveys of the stilling basin before and after flood events are taken to quantify the amount of erosion. These surveys should include the upper level berms. Details on the repairs undertaken (if any) after the 1991 flood should be obtained (section 12.9.5).</td>
<td>M</td>
<td>Dec 1999</td>
<td>Will be resurveyed after each significant flood event.</td>
</tr>
<tr>
<td>h.</td>
<td>The flood immunity of the spillway gate control equipment is checked for extreme flood events (section 12.9.6).</td>
<td></td>
<td></td>
<td>As per 1f</td>
</tr>
<tr>
<td>i.</td>
<td>The spillway retaining wall monoliths are checked for stability, particularly in light of current earthquake and ”at rest” pressure design methods (section</td>
<td>L</td>
<td></td>
<td>Design check complete in 2001</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>----------</td>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Embankment General:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>Soil properties are confirmed using as placed strength data. This is particularly important for the rolled sandstone fill as the as placed properties will differ from the excavated properties because of particle breakdown (section 12.8.3.2).</td>
<td>L</td>
<td></td>
<td>Not considered necessary.</td>
</tr>
<tr>
<td>b.</td>
<td>The alluvium properties are obtained (section 12.8.3.2).</td>
<td>L</td>
<td></td>
<td>Report by GHD Review by Sunwater</td>
</tr>
<tr>
<td>c.</td>
<td>Soil properties are obtained for the actual core material used. It is possible that soil tests relate to borrow area not utilised in construction (section 12.8.2).</td>
<td>L</td>
<td></td>
<td>Report by GHD Review by Sunwater Strength is adequate.</td>
</tr>
<tr>
<td>e.</td>
<td>A review is made of all available soil strength tests and quality control records to determine the actual strength of the embankment as placed (section 12.8.3.6).</td>
<td>L</td>
<td></td>
<td>Report by GHD Review by Sunwater</td>
</tr>
<tr>
<td>f.</td>
<td>An investigation into the seepage profile through the embankment is required to determine the actual phreatic surface. This would include a review of the materials used in the downstream shoulder to determine the actual pore pressure profile (section 12.8.3.6).</td>
<td>L</td>
<td>yes</td>
<td>Investigation done Monitor during annual inspections</td>
</tr>
<tr>
<td>g.</td>
<td>The embankment is monitored closely following extensive drought periods. This will include monitoring of piezometric levels of the main embankment at least twice weekly during flood and visual inspection of the upstream shoulder (section 12.8.3.6).</td>
<td>L</td>
<td></td>
<td>Piezometric levels read on monthly basis</td>
</tr>
<tr>
<td>4.</td>
<td><strong>Right Bank Section.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The reason for the presence of the fine zone in the rip rap on the upstream</td>
<td>M</td>
<td>1996</td>
<td>Complete. Material was from access ramp on top of</td>
</tr>
<tr>
<td>No.</td>
<td>Recommendation</td>
<td>Priority</td>
<td>Date Complete</td>
<td>Comments</td>
</tr>
<tr>
<td>-----</td>
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<td>---------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>face approximately halfway between the spillway and the right abutment is investigated further (section 13.8.2).</td>
<td></td>
<td></td>
<td>the riprap</td>
</tr>
<tr>
<td>d.</td>
<td>The seepage in the right bank of the diversion cut at the foundation contact be monitored with a V notch weir or similar (section 13.8.2).</td>
<td>H</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
</tr>
<tr>
<td>f.</td>
<td>The reason for the zone of fine material in the rip rap half way between the right abutment and the spillway on the downstream face be investigated. It is also recommended that this area should be closely watched until appropriate remedial action is taken in the event that the fines have been washed out from the shoulder (section 13.8.2).</td>
<td>H</td>
<td>1996</td>
<td>Complete. Material was from access ramp on top of the riprap.</td>
</tr>
<tr>
<td>g.</td>
<td>The effectiveness of the drainage system downstream of the core is investigated in light of the increasing pore pressures in the filter at chainage 1800 (section 11.1.2.2).</td>
<td>H</td>
<td>Yes</td>
<td>Review during annual inspection in October each year</td>
</tr>
</tbody>
</table>

5. **Left Bank Section**

e. The concrete manholes installed at regular intervals along the left abutment section toe are investigated further to define where they drain from and whether they should be monitored (section 13.8.3). | H        | 2002          | Complete                                                                                          |

6. **Saddle Dam 1**

c. The unusual animal burrows over a large area of the lower part of the downstream shoulder of saddle dam 1 are dug out and recompacted to stop rainfall and runoff from entering the dam structure (section 13.8.4). | M        | 1998          | Complete                                                                                          |

d. The bare patch on the downstream shoulder of saddle dam 1 is recompacted and sowed with grass (section 13.8.4). | M        | 1998          | Complete                                                                                          |
e. Soil testing be undertaken or that the | M        |               | Complete refer Sunwater                                                                              |
<table>
<thead>
<tr>
<th>No.</th>
<th>Recommendation</th>
<th>Priority</th>
<th>Date Complete</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>f.</td>
<td>Set wheel tracks on the downstream shoulder of saddle dam 1 be repaired so that an erosion gully does not form in them (section 13.8.4).</td>
<td>M</td>
<td>1998</td>
<td>Complete</td>
</tr>
<tr>
<td>7.</td>
<td><strong>Saddle Dam 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>The long grass on saddle dam 2 (furthest from the main dam) be slashed or mowed to allow easy detection of seepage or erosion (section 13.8.5).</td>
<td>M</td>
<td>1998</td>
<td>Complete and on-going</td>
</tr>
<tr>
<td>b.</td>
<td>A zone of 10 meters or so should be cleared of trees on the upstream and downstream toe if saddle dam 2. This includes the large dead tree at the downstream toe (section 13.8.5).</td>
<td>M</td>
<td>1998</td>
<td>Complete</td>
</tr>
<tr>
<td>c.</td>
<td>The downstream shoulder and toe of saddle dam 2 is fenced off from vehicles and stock and the track graded in on the left abutment is removed. The original profile of the dam should be re-established and resown with grass (section 13.8.5).</td>
<td>M</td>
<td>1998</td>
<td>Complete</td>
</tr>
<tr>
<td>8.</td>
<td><strong>Outlet Works</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>It is recommended that a detailed inspection of the corrosion protection of the inside of the penstock be undertaken</td>
<td>M</td>
<td>May 1999</td>
<td>Complete</td>
</tr>
</tbody>
</table>