Queensland Bulk Water Supply Authority

SEQWater

SEQWATER DAMS

WIVENHOE DAM COMPREHENSIVE INSPECTION JULY 2006

SURVEILLANCE REPORT FINAL REPORT

Report No: DC07063

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NSW GOVERNMENT | Public Works
NSW Water Solutions

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Dams & Civil

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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instrument surveillance, Appendix B refers to instrumentation which is no longer read, and other details may also be out of date.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 ANCOLD 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 Section5 . 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

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 3-1 - Peak Outflows and Maximum Lake Levels at Fuse Plug Initiation

Fuse Plug No. Initiated	Approx. Inflow AEP (1 in X Years)	Peak Outflow (m3/s)			Lake Water Level at Fuseplug Initiation (m AHD)
		Gated Spillway	Total Right Abutment (RA) Spillway	Saddle Dam 2 (SD2) Spillway	
1	6,000	10,600	1,650	0	75.80
2	11,500	11,200	5,400	0	76.33
3	22,500	11,900	9,900	0	76.88
4 (SD2)*	65,000	13,100	12,200	7,550	78.40

* 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

AEP	Peak Ground Acceleration
1 in 1	0.006 g
1 in 3	0.010 g
1 in 10	0.017 g
1 in 30	0.030 g
1 in 100	0.052 g
1 in 300	0.088 g
1 in 1,000	0.152 g
1 in 3,000	0.24 g
1 in 10,000	0.392 g
1 in 20,000	0.505 g

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).
- Two short studies for Somerset Dam by Commerce, Commerce (2004 and 2005).
    - 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 in to the flow during an extreme event this would induce significant load on the structure.

3. Cracking on the downstream side of the upper galley. 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 $0.84*10^{-5}$ per annum. Introducing the risks associated with a Somerset failure increases these risks by a factor of 2.4 to $2.0*10^{-5}$ 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 re-assessed.

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

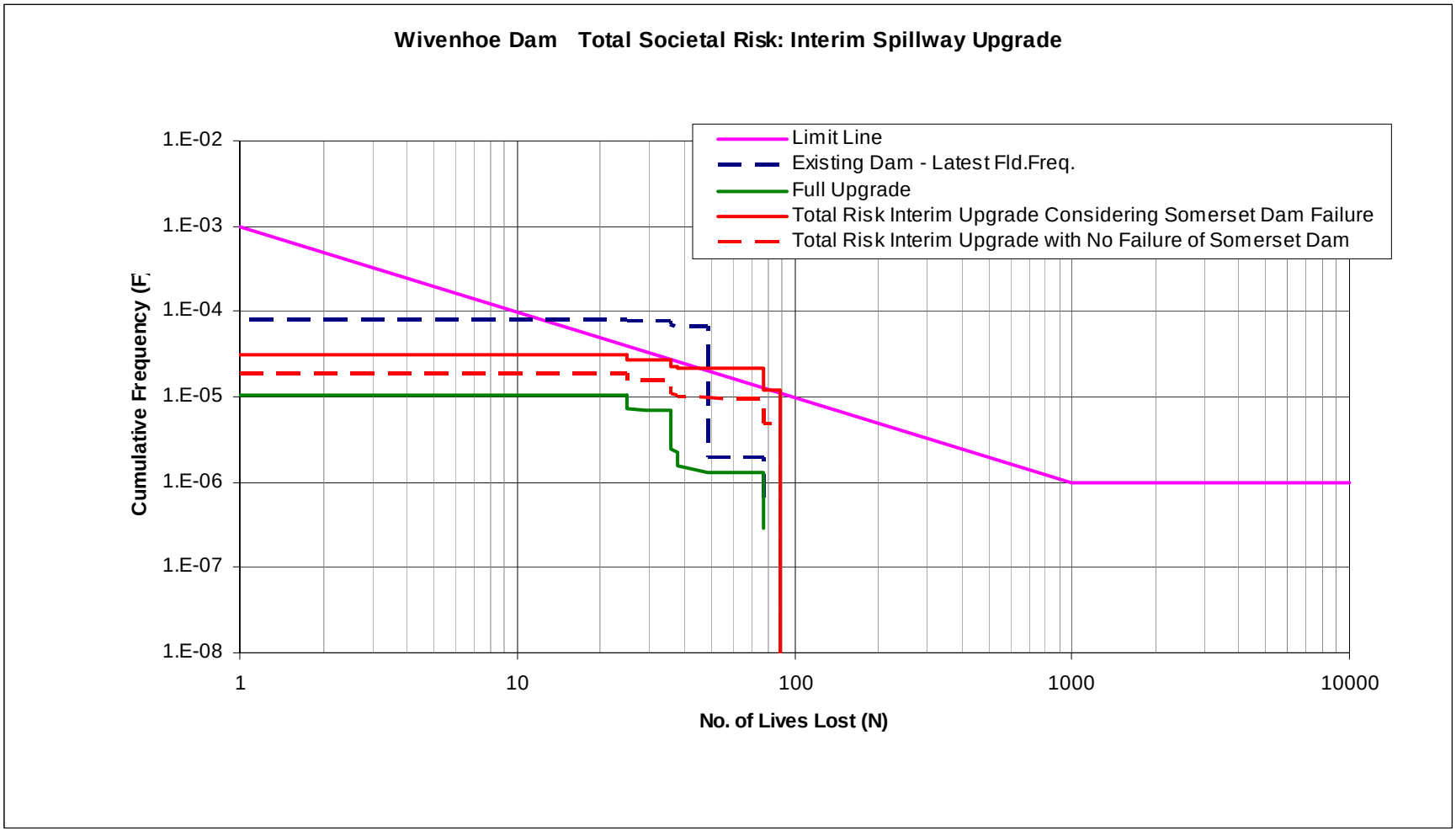
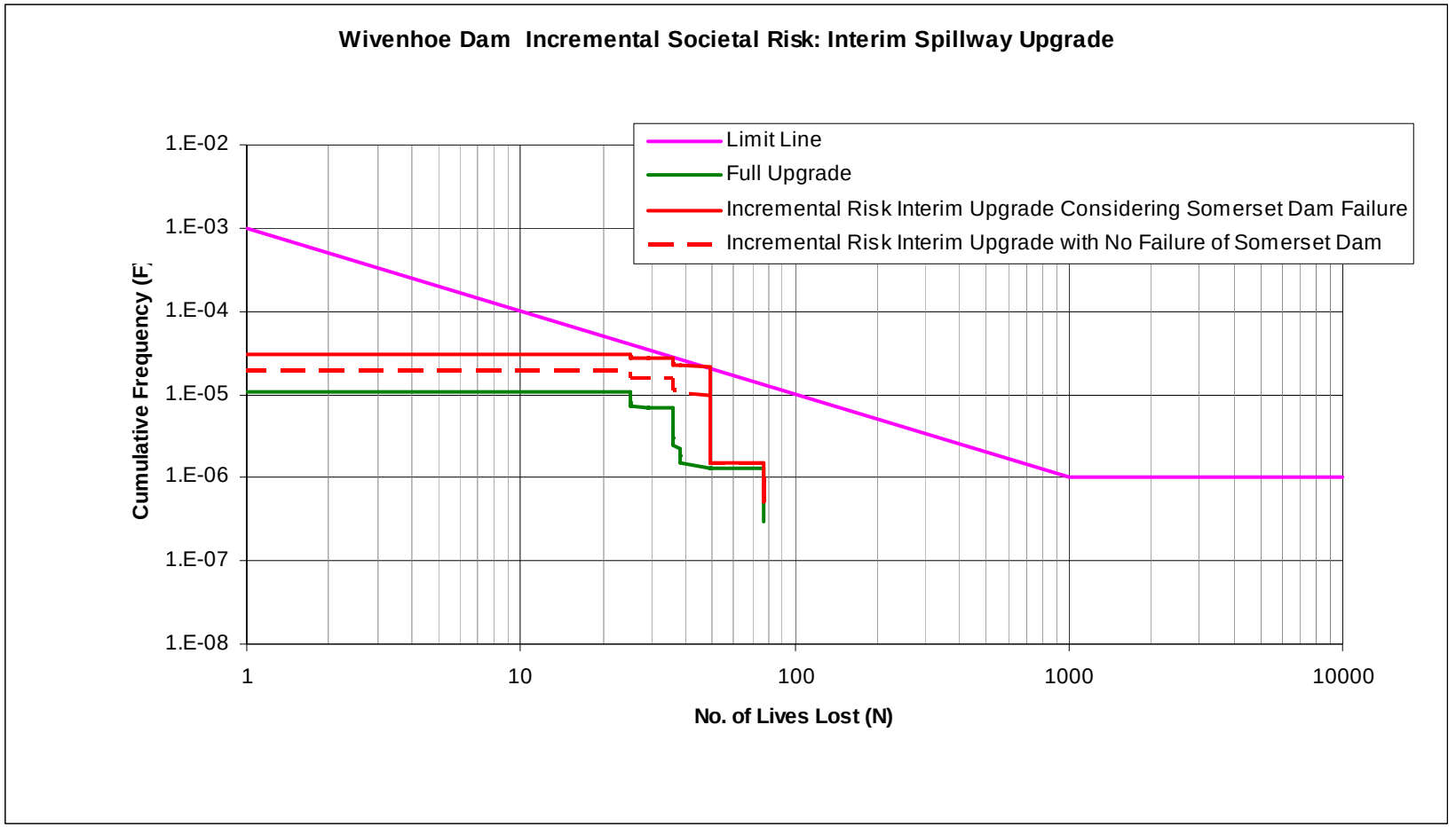


Figure 4-2 - ANCOLD Incremental Societal Risk Assessment – from Wivenhoe Alliance, 2004



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

Classification No	Title	Status	Author
	Reports and Investigations		All Reports by Wivenhoe Alliance
WIV-RP-HD-004	Design Discharges and Downstream Impacts Report	Completed	
WIV-RP-HD-006	Dambreak Study Report	Completed	
WIV-RP-DE-009	Option Selection and Concept Design Report	Completed	
WIV-RP-GE-001	Phase 1 Geotechnical Report	Completed	
WIV-RP-GE-003	Phase 2 Geotechnical Report	Completed	
WIV-RP-GE-006	Borrow Materials Investigation Report	Completed	
WIV-RP-DE-010	Right Abutment Secondary Spillway Design and Construction Report	Draft	
WIV-RP-GE-005	Phase 3 Geotechnical Report	Completed	
WIV-RP-DE-011	Existing Embankment Crest Works Design and Construction Report	Draft	
WIV-RP-DE-012	Existing Spillway Design and Construction Report	Completed	
WIV-RP-DE-013	As Constructed Drawing Set	Completed	
WIV-RP-DE-014	Operational and Maintenance Requirements	Draft	

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.

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 (1750m^3/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

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 removed	Trees and shrubs on upstream groin should be 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.

RHS training wall good. Little cracking. Bridge and piers from underneath okay. Fuse sections. Very good condition. Dividing walls very good.

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	Appear 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	Appear 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	Appear 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	Appear okay
e) Ventilation Appears adequate	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

a) General Condition — Appears okay

b) Mechanical

c) Electrical

d) Operating instructions

e) Last Operation / Test — September 2004

3.6 m diameter Penstock

a) General Condition — Not inspected

b) Surface protection

c) Operating instructions

d) Last Inspection — September 2004

1.9 m diameter Penstock

a) General Condition — Not inspected

b) Surface protection — 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.

c) Operating instructions

d) Last Inspection — August 2004

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.*

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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

No.	Recommendation	Priority	Date Complete	SEQWater Comments	Review Comment
	Embankment Generally				
f.	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).	L	yes	Investigation done Monitor during annual inspections	Piezometers do not indicate a raised phreatic surface
g.	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).	L		Piezometric levels notionally read on monthly basis	While drought continues
	Right Bank Section				
d.	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).	H	Yes	Review during annual inspection in October each year	Regularly monitored
g.	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).	H	Yes	Review during annual inspection in October each year	Pore pressure behaviour is acceptable – no visible seepage
	Mechanical Electrical – General Maintenance				
i.	Replacement oil be purchased in advance and stored on site as reserve oil for the system.	H	1997	Review during annual inspection in October each year	Oil is stored in drums
j.	Consideration be given to providing oil containment and oil clean up materials.	L		As above	

No.	Recommendation	Priority	Date Complete	SEQWater Comments	Review Comment
	Right Bank Section – General Maintenance				
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).	M	July 1999	Review during annual inspection in October each year	Not noted as being of concern
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).	M	Yes	Review during annual inspection in October each year	None visible
	Left Bank Section – General Maintenance				
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).	M	July 1999	Completed and review during annual inspection in October each year	Seepage is monitored
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).	M	July 1999	Completed and review during annual inspection in October each year	Seepage from pipe is monitored. Drain again full of vegetation

Table 8-2 - Preliminary Risk Assessment – Proposed "Fixes" with Corporate Comment

Consultant's Proposed "Fix"	Estimated Cost	Corporate Comments	Reviewer Comment
Improve reliability of Spillway Gates (GHD design)	$0.13m	Work Completed	
Auxiliary Spillway to enable the dam to pass the PMF	$57.8m	Stage 1 completed	
Develop Emergency Evacuation Plans	$0.50m	Discussions with Local Authorities and SES ongoing. Co-ordinating supply of Dam release information. Evacuation is responsibility of SES and Police.	

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, 2003	Somerset Dam Annual Inspection Report, prepared by Department of Commerce, 9 December 2003
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, 1995	Safety Review of Somerset Dam, prepared by GHD Pty Ltd, September 1995.
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

RMIT, 1995	Review of Seismicity, Somerset Dam and North Pine Dam; prepared by the Seismology Research centre at RMIT University, March 1995.
Russo, 1996	1996 GHD Somerset Dam Safety Review, Comments by R. Russo, prepared by R. Russo, August 1996
SEQWater, 2005	The Dam Safety Management Program for Wivenhoe, Somerset, North Pine Dams; prepared by SEQWater, March 2005
SKM, 2000	Preliminary Risk Assessment for Wivenhoe, Somerset and North Pine Dams; prepared by Sinclair Knight Merz in conjunction with Hydro Consulting, Hydro Electric Corporation, 2004
SMEC, 2004	Somerset Dam – Detailed Risk Assessment Stage 2; prepared by SMEC Australia Pty Ltd, March 2004
WA, 2004A	Somerset Dam – Maximum Flood Level Estimates for Various Gate Operation Scenarios; prepared by Wivenhoe Alliance, February 2004.
WA, 2004B	Design Discharges and Downstream Impacts of the Wivenhoe Dam Upgrade; prepared by Wivenhoe Alliance, 2004.
WA, 2004C	Wivenhoe Dam Spillway, Augmentation Works: Review and Updating of Risk Assessment, prepared by Wivenhoe Alliance, 2004.
WA, 2005	Dam Failure Analysis of Wivenhoe Dam; prepared by Wivenhoe Alliance, Q1091, WIV-RP-HD-006, 2005

APPENDIX A

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 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
Embankment Length	200m

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)	11m
Embankment Length	265m

Outlet Works – Water Supply and Power Station Intake

Variable level drawoff facility	6 selective baulks placed in individual slots (each baulk is 6.3mhigh x 6m wide)
Penstocks	2
Penstock diameters	1.9m & 3.6m

Outlet Works – Regulators

Number of regulators	1
Type and size of regulators	1.5 m diameter fixed cone dispersion valve and a 4.5MW Frances turbine hydro power plant
Level of centreline of FDC regulator	EL 31.5
Level of centreline of the 3.6m pipe entienring the turbine	EL26m

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	14,900m3/s

APPENDIX B

Photographs

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 Auxilliary Fuse Plug Spillway & Highway Bridge

Photograph No. 4: Auxilliary Spillway Left Hand Inlet Training Wall Showing Cracking

Photograph No. 5: Right Hand Auxilliary Spillway Abutment Wall Showing Debris Filled Gutter

Photograph No. 6: Auxilliary Spillway - D/S Side

Photograph No. 7: Discharge Area D/S of Auxilliary 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

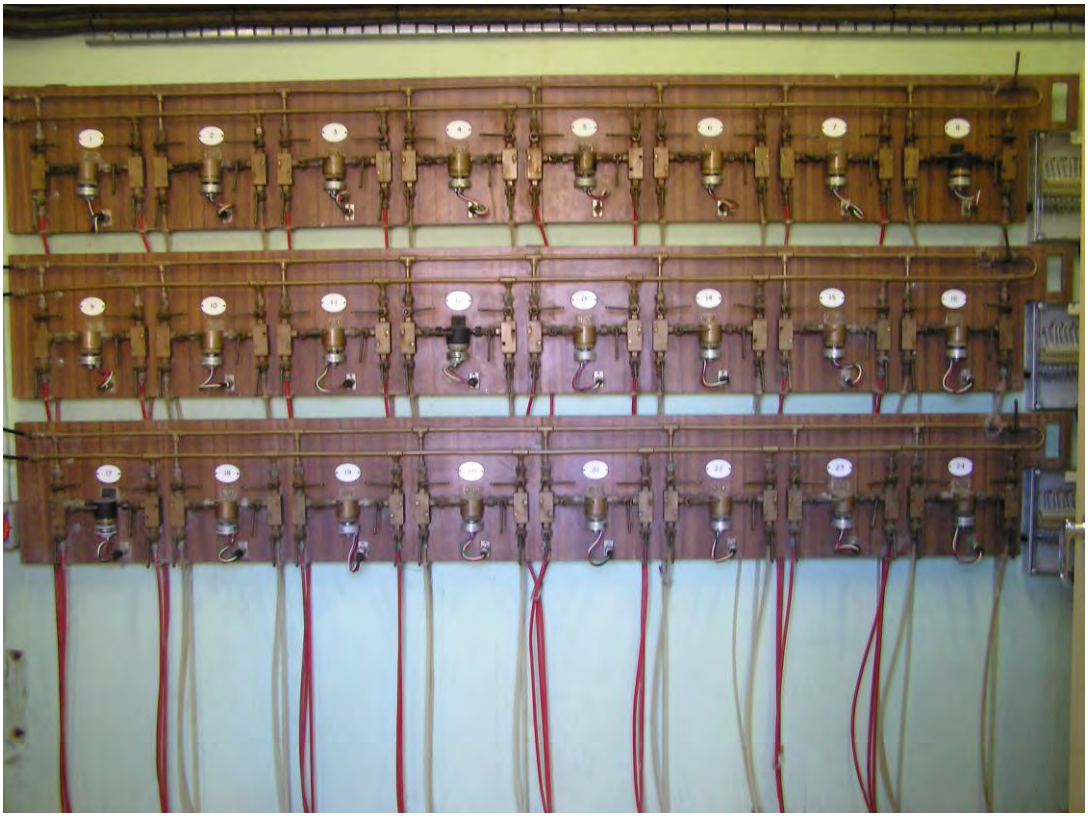
Photograph No. 12: Left Embankment - D/S Batter

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

Surveillance Data

Appendix C1 – Instrumentation Drawings

Appendix C2 – Storage Level Behaviour and Rainfall

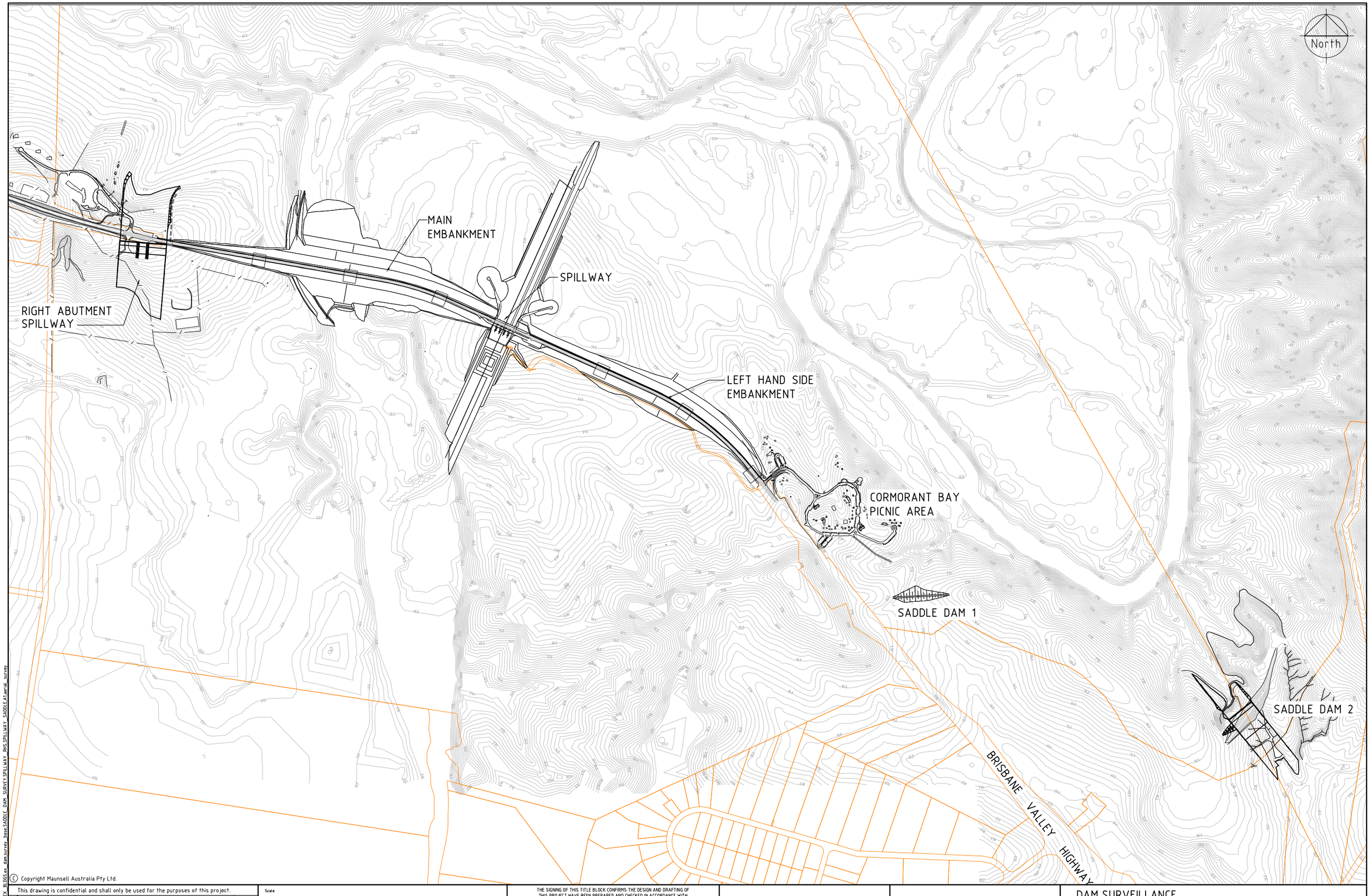
Appendix C3 – Piezometric Data

Appendix C4 – Leakage Data

Appendix C5 – Inclinometer Data

Appendix C6 - Surface Movement Survey

Appendix C1 – Instrumentation Drawings



This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

50 0 100 200m

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DETAIL\60020162-100.dwg
Last modified: 23 Nov 06 - 13:20

MAUNSELL AECOM

Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

WIVENHOE DAM
COVER SHEET

Status

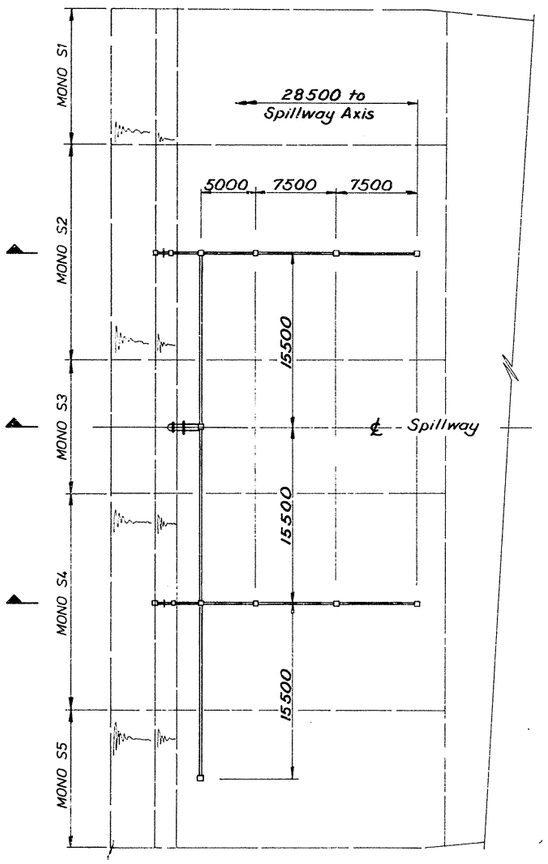
Drg No. 60020162-100

Rev.

Xref's content: DAM_CADASTRAL_EX_BLDGS_ex_dam survey_bas SADDLE_DAM_SURVEY SPILLWAY_RHS SPILLWAY_SADDLE1A aerial_survey

Figure C1.1 - Spillway Piezometer Locations

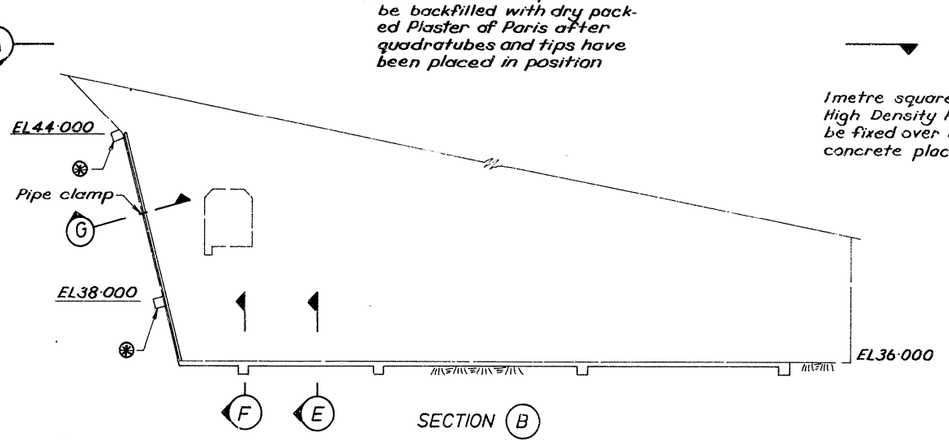
A1-56230



Gallery omitted for clarity

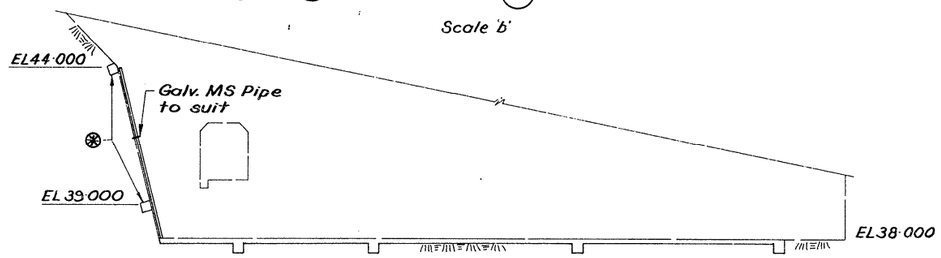
SECTIONAL PLAN (A)

Scale 'a'



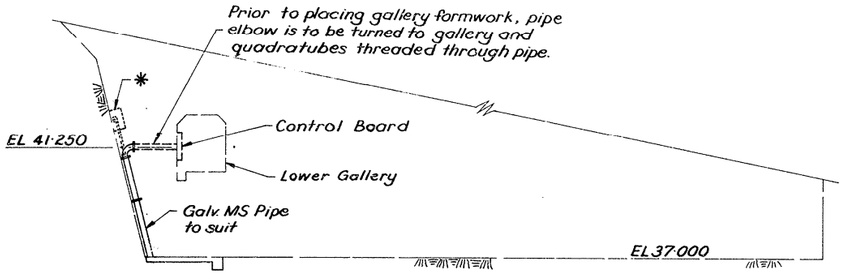
SECTION (B)

Scale 'b'



SECTION (C)

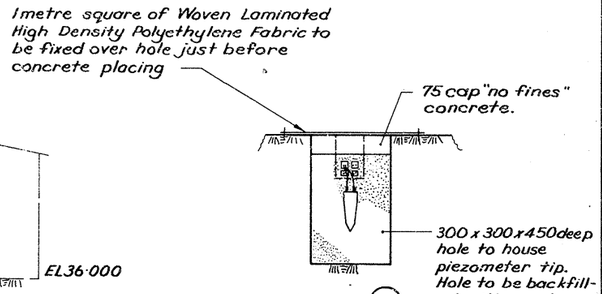
Scale 'b'



SECTION (D)

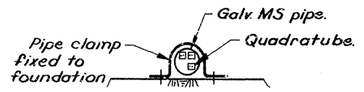
Scale 'b'

* Following setting of piezometer tips the pipe elbow in section (D) is to be set parallel with rock face. Quadratubes to be carefully coiled and suitably secured to rock face above EL42·000. These quadratubes are to be adequately protected from damage by construction equipment during concreting operations below EL41·00



SECTION (F)

Not to Scale



SECTION (G)

Not to Scale

SECTION (E)

Not to Scale

Notes:

1. All dimensions are in millimetres and all elevations are in metres.
2. All materials and workmanship to the relevant Australian Standards.

AS BUILT
By
Class
Date 31/10/85

Revision					Drawing Schedule
Oct '85	A	As Built			
Date		Remarks	Ckd	Psd	

Scale 'a' (1:250) 0 5 10 15 20m

Scale 'b' (1:100) 0 5 10m

Scales Before Reduction

QUEENSLAND WATER RESOURCES COMMISSION

Design	Drafting	Recommended
Prep	Dr	
Ckd	Ckd R.D.	Senior Engineer Designs
Supv	Supv R.D.	Approved
Submitted		
Executive Engineer		Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km — WIVENHOE DAM

SPILLWAY

FOUNDATION INSTRUMENTATION

12-10-79 | A1-56230 | A

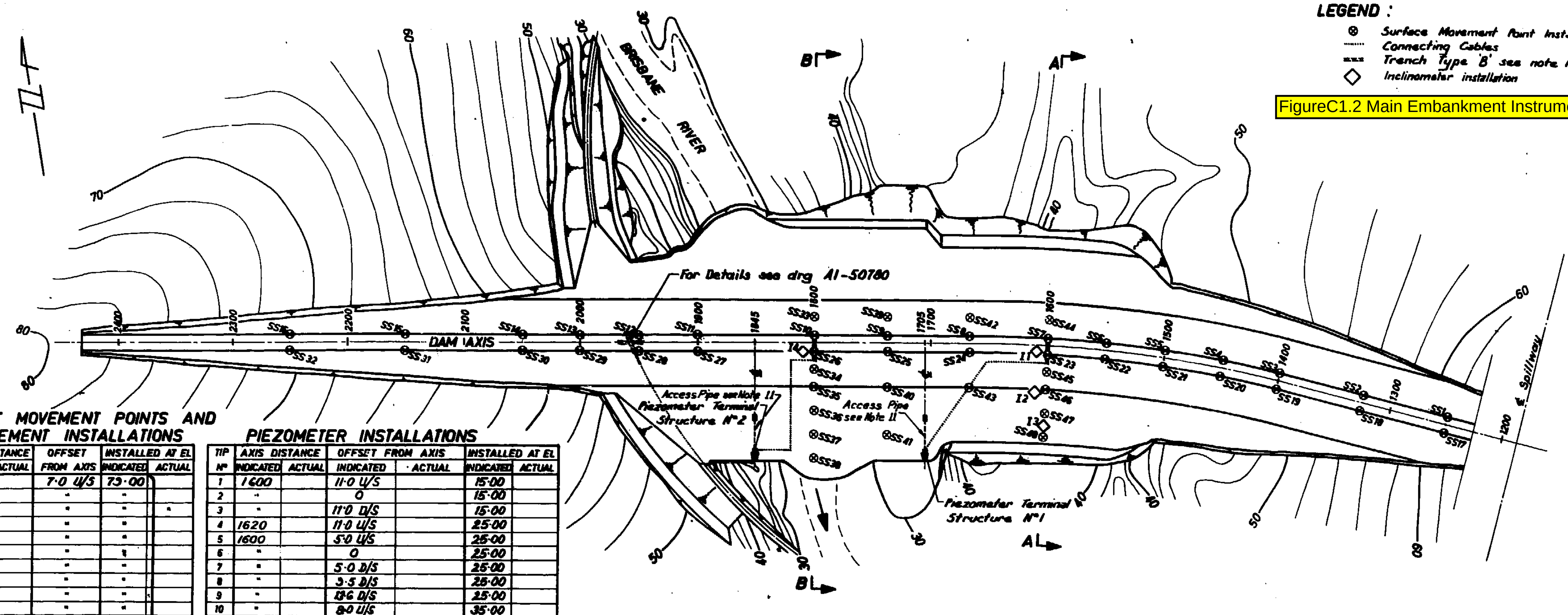
DWG 56230A.tif

LEGEND :

- ⊗ Surface Movement Point Installation
- ------ Connecting Cables
- ▪▪▪ Trench Type 'B' see note 10
- ◇ Inclinometer installation

FigureC1.2 Main Embankment Instrumentation Dwg 1 of 2

A1-53374



PLAN

SURFACE MOVEMENT POINTS AND SETTLEMENT INSTALLATIONS

Nº	AXIS DISTANCE INDICATED	AXIS DISTANCE ACTUAL	OFFSET FROM AXIS	INSTALLED AT EL INDICATED	INSTALLED AT EL ACTUAL	
SS1	1250		7·0 U/S	73·00		
SS2	1325		"	"		
SS3	1400		"	"		
SS4	1450		"	"		
SS5	1500		"	"		
SS6	1550		"	"		
SS7	1600		"	"		
SS8	1667		"	"		
SS9	1733		"	"		
SS10	1800		"	"		
SS11	1900		"	"		
SS12	1950		"	"		
SS13	2000		"	"		
SS14	2050		"	"		
SS15	2150		"	"		
SS16	2250		"	"		
SS17	1250		7·0 D/S	"		
SS18	1325		"	"		*
SS19	1400		"	"		
SS20	1450		"	"		
SS21	1500		"	"		
SS22	1550		"	"		
SS23	1600		"	"		
SS24	1667		"	"		
SS25	1733		"	"		
SS26	1800		"	"		
SS27	1900		"	"		
SS28	1950		"	"		
SS29	2000		"	"		
SS30	2050		"	"		
SS31	2150		"	"		
SS32	2250		"	"		
SS33	1800		22·0 U/S	63·00		
SS34	1800		22·0 D/S	63·00		
SS35	"		37·0 D/S	53·00		
SS36	"		57·0 D/S	43·00		
SS37	"		77·0 D/S	33·00		
SS38	"		97·0 D/S	23·00		
SS39	1733		22·0 U/S	63·00		*
SS40	1733		37·0 D/S	53·00		
SS41	1733		77·0 D/S	33·00		
SS42	1667		22·0 U/S	63·00		
SS43	1667		37·0 D/S	53·00		
SS44	1600		22·0 U/S	63·00		*
SS45	"		22·0 D/S	63·00		
SS46	"		37·0 D/S	53·00		
SS47	"		57·0 D/S	43·00		
SS48	"		77·0 D/S	33·00		

Note: Surface movement points to be as shown on drg A2-43361

PIEZOMETER INSTALLATIONS

TIP Nº	AXIS DISTANCE INDICATED	AXIS DISTANCE ACTUAL	OFFSET FROM AXIS INDICATED	OFFSET FROM AXIS ACTUAL	INSTALLED AT EL INDICATED	INSTALLED AT EL ACTUAL	
1	1600		11·0 U/S		15·00		
2	"		0		15·00		
3	"		11·0 D/S		15·00		
4	1620		11·0 U/S		25·00		
5	1600		5·0 U/S		25·00		
6	"		0		25·00		
7	"		5·0 D/S		25·00		
8	"		3·5 D/S		25·00		
9	"		13·6 D/S		25·00		
10	"		8·0 U/S		35·00		
11	"		3·0 U/S		35·00		
12	"		3·0 D/S		35·00		
13	"		8·0 D/S		35·00		
14	1620		7·5 U/S		45·00		
15	1600		2·5 U/S		45·00		
16	"		2·5 D/S		45·00		
17	"		6·0 D/S		45·00		
18	"		4·0 U/S		55·00		
19	"		0		55·00		
20	"		4·0 D/S		55·00		*
21	"		3·0 U/S		65·00		
22	"		0		65·00		
23	"		42·0 U/S		32·00		
24	"		42·0 D/S		32·00		
25	1800		11·0 U/S		15·00		
26	"		0		15·00		
27	"		11·0 D/S		15·00		
28	1820		11·0 U/S		25·00		
29	1800		5·0 U/S		25·00		
30	"		0		25·00		
31	"		5·0 D/S		25·00		
32	"		3·5 D/S		25·00		
33	"		13·6 D/S		25·00		
34	"		8·0 U/S		35·00		
35	"		3·0 U/S		35·00		
36	"		3·0 D/S		35·00		
37	"		8·0 D/S		35·00		
38	1820		7·5 U/S		45·00		
39	1800		2·5 U/S		45·00		
40	"		2·5 D/S		45·00		
41	"		6·0 D/S		45·00		
42	"		4·0 U/S		55·00		*
43	"		0		55·00		
44	"		4·0 D/S		55·00		
45	"		3·0 U/S		65·00		
46	"		0		65·00		
47	1970		10·5 U/S		28·00		
48	1965		0		28·00		
49	1960		10·5 D/S		28·00		
50	⊘		0		⊘		
51	⊘		0		⊘		

TOTAL PRESSURE CELL INSTALLATIONS

Nº	ORIENTATION	AXIS DISTANCE INDICATED	AXIS DISTANCE ACTUAL	OFFSET FROM AXIS INDICATED	OFFSET FROM AXIS ACTUAL	INSTALLED AT EL INDICATED	INSTALLED AT EL ACTUAL	
TP1		1620		14·5 U/S		25·00		
TP2		"		11·0 U/S		25·00		
TP3		1600		0		25·00		
TP4		"		3·5 D/S		25·00		
TP5		"		13·5 D/S		25·00		
TP6		1620		10·5 U/S		45·00		
TP7		"		7·5 U/S		45·00		
TP8		1600		0		45·00		
TP9		"		6·0 D/S		45·00		
TP10		"		9·5 D/S		45·00		
TP11		"		0		65·00		*
TP12		1820		14·5 U/S		25·00		
TP13		"		11·0 U/S		25·00		
TP14		1800		0		25·00		
TP15		"		3·5 D/S		25·00		
TP16		"		13·5 D/S		25·00		
TP17		1820		10·5 U/S		45·00		
TP18		"		7·5 U/S		45·00		
TP19		1800		0		45·00		
TP20		"		6·0 D/S		45·00		*
TP21		"		9·5		45·00		
TP22		"		0		65·00		
TP23		1960		0		28·00		
TP24		⊘		0		⊘		
TP25		⊘		0		⊘		

* REQUIRED THIS CONTRACT

Note: For definition of existing embankment see drg A1-53376

⊘ See drg A1-50780

INCLINOMETER INSTALLATIONS

	Nº	AXIS DISTANCE INDICATED	AXIS DISTANCE ACTUAL	OFFSET FROM AXIS INDICATED	OFFSET FROM AXIS ACTUAL	EL ACTUAL
*	I1	1600		6·5 D/S		
*	I2	"		40·0 D/S		
	I3	"		68·0 D/S		
*	I4	1800		6·5 D/S		

NOTES :

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES
2. Levels Datum : All levels to AHD (PSM Nº 34242 · EL 74·784)
3. Azimuth Datum : AMG
4. All installations to be carried out as per specification
5. Piezometers, Total Pressure Cells and associated tubes and wiring to be furnished and installed by the Principal but the associated protective surrounds shall be provided by the Contractor
6. Embankment Settlement and Inclinometer Installations to be furnished and installed by the Principal but the associated trenches and drilled holes and subsequent backfilling shall be provided by the Contractor
7. Surface Movement Points to be supplied and installed by the Contractor
8. Location of all embedded instruments and settlement installations to be recorded to the nearest two millimetres at the time of installation by the Engineer
9. Actual locations of instruments may vary depending on site conditions and will be determined by the Engineer
10. Trench Type 'B' (refer drg A1-50780) to be excavated to enable placement of connecting cables. After placement of cables is completed trench to be backfilled with 15 MPa concrete
11. For details of Piezometer Terminal Structure access pipes refer to drg A1-56232.

FOR SECTIONS A-A AND B-B AND LOCATION OF INSTRUMENT INSTALLATIONS SEE DRG A1-53375

Revision

Date		Remarks	Ckd	Psd
15-11-79	W	Tender drg. to working drg.	R.D.	[illegible]
8-5-79	B	Contract No. amended	M.J.C.	[illegible]
27-7-78	A	Piezometres 47-50 TP's 23-25 added	R.D.	[illegible]

Drawing Schedule

A1-53377	Hydraulic & Electric Piezometer Tips Installation Details.
A1-50780	Right bank embankment details Sh 3 of 3
A2-43361	Measurement of Crest & Surface movement points
A1-56232	Access Pipe Arrangement.
A1-43535	Inclinometer Installations
~~A1-49876~~	~~Piezometer Tip Installation Details~~
A1-53375	Left Bank-Embankment Instrumentation Sh 2 of 2

Scale 0 50 100 150 200m (1:2000 Scale Before Reduction)

CONTRACT Nº 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting	
Prep [illegible]	Dr [illegible]	Recommended [signature] Senior Engineer Designs
Ckd	Ckd [illegible]	
Supv [illegible]	Supv [illegible]	Approved [signature] Act Chief Designing Engineer
Submitted Executive Engineer		

CO-ORDINATOR GENERAL'S DEPARTMENT

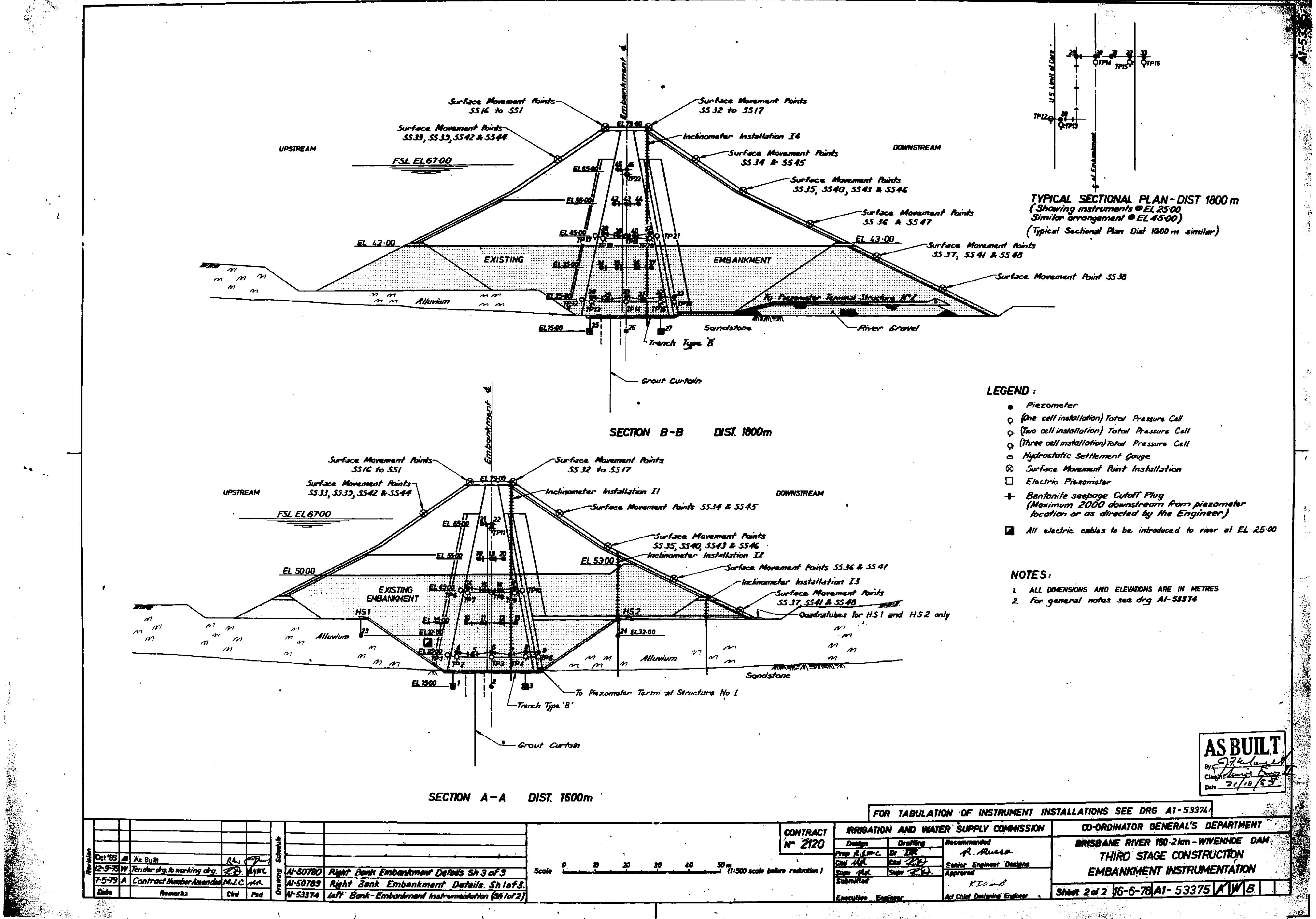
BRISBANE RIVER 150·2 km – WIVENHOE DAM

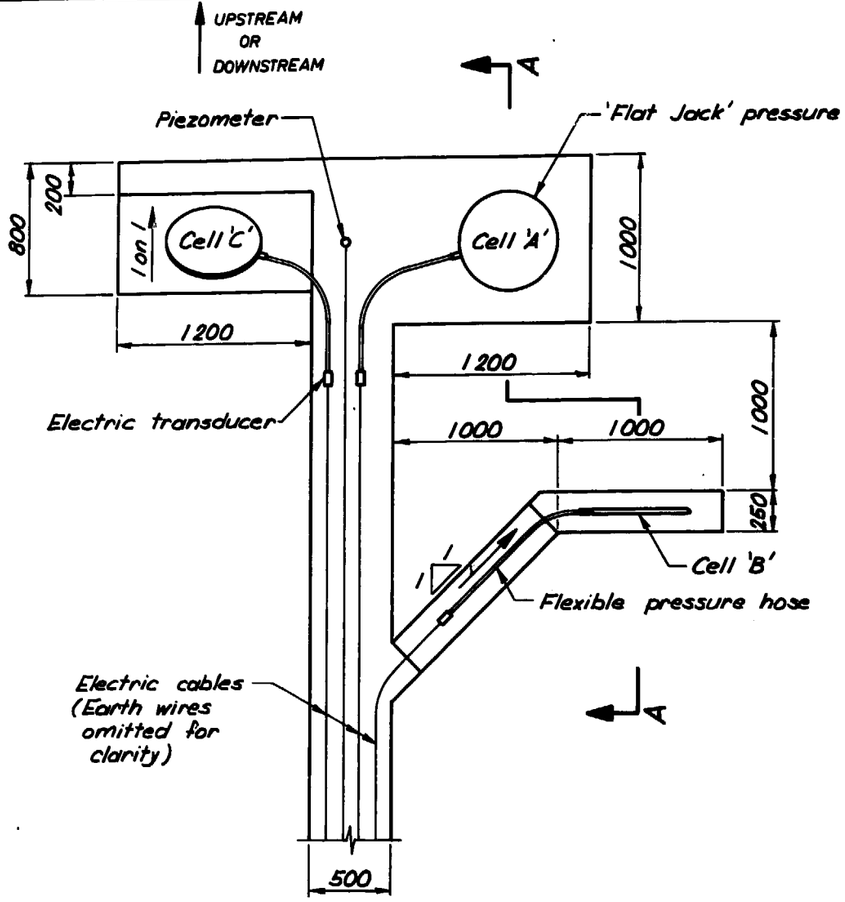
THIRD STAGE CONSTRUCTION

EMBANKMENT INSTRUMENTATION

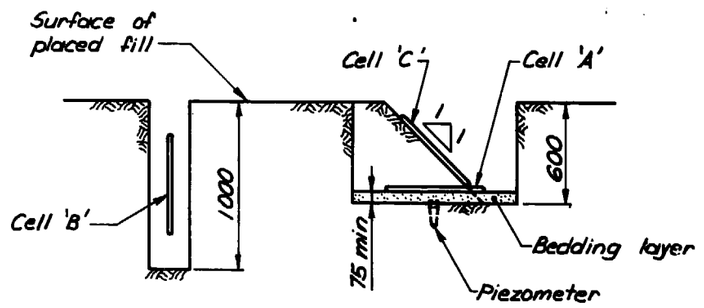
Sheet 1 of 2 | 16-6-78 | A1 - 53374 | A | B | W

Figure C1.3 - Main Embankment Instrumentation Dwg 2 of 2





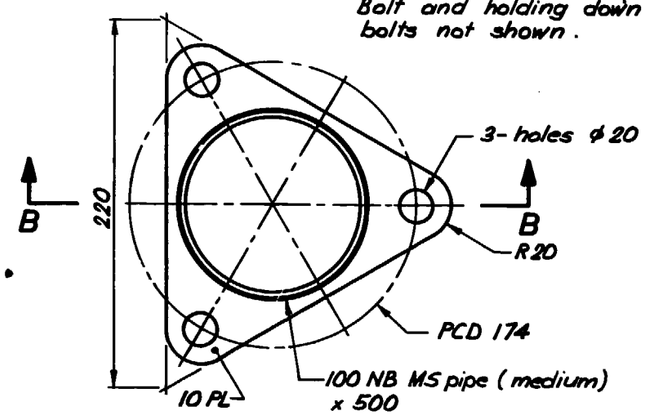
PLAN



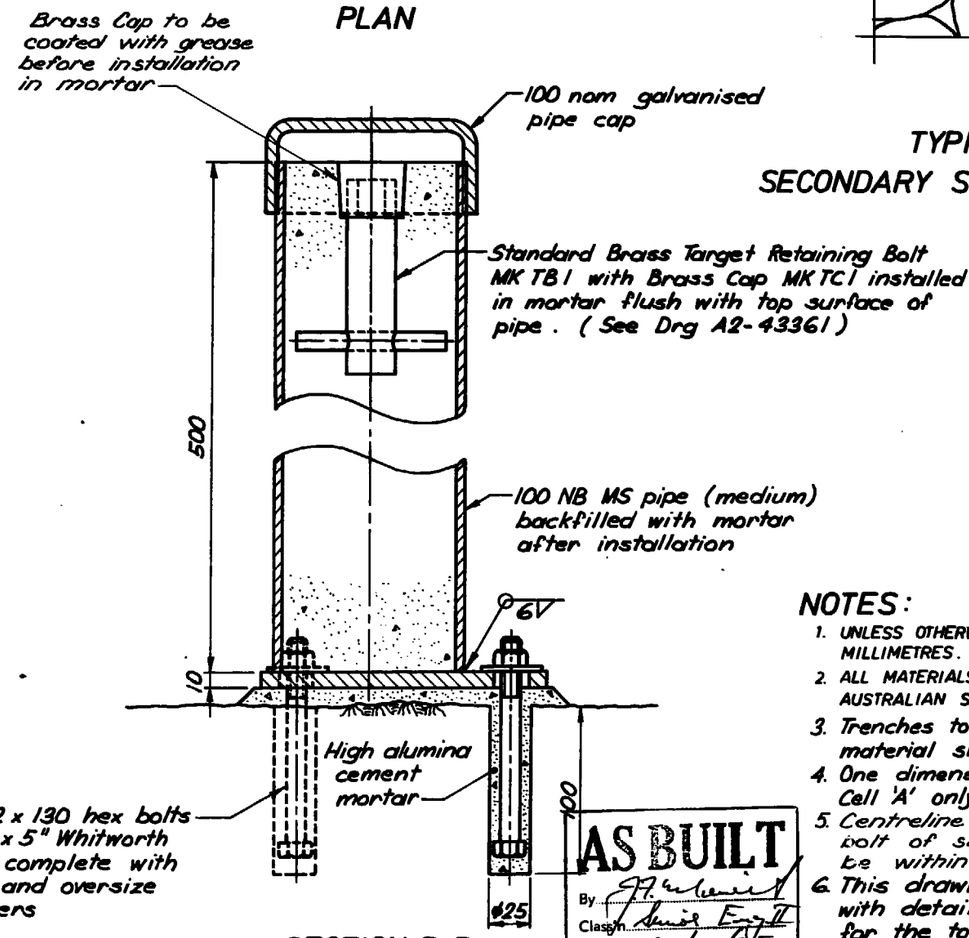
SECTION A-A

TOTAL PRESSURE CELLS
(Scale 'a')

Note : Pipe cap, Target Retaining Bolt and holding down bolts not shown.

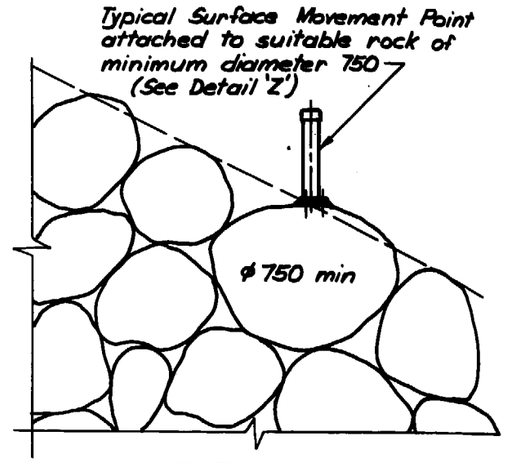


PLAN



SECTION B-B

DETAIL 'Z' (Scale 'b')



ELEVATION

TYPICAL INSTALLATION
SECONDARY SURFACE MOVEMENT POINTS
(Scale 'a')

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 bolt 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.

ALL MS ITEMS TO BE GALVANISED

AS BUILT
By
Class
Date 31/10/85

Revision					Drawing Schedule
Oct '85	B	As Built	RL		A2-43361
13-11-79	W	Tender to Working drwg.			
9-5-79	A	Contract N° amend	M.J.C.		
Date		Remarks	Ckd	Psd	

Scale 'a' 0 0·5 1·0 1·5 2·0 m (1:25 before reduction)

Scale 'b' 0 50 100 150 200 mm (1:2·5 before reduction)

CONTRACT N° 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting
Prep M.R.B	Dr KFP
Ckd R.J.M.C.	Ckd GJG
Supv	Supv M.J.C.
Submitted	
Executive Engineer	

Recommended
Senior Engineer Designs
Approved
Act Chief Designing Engineer

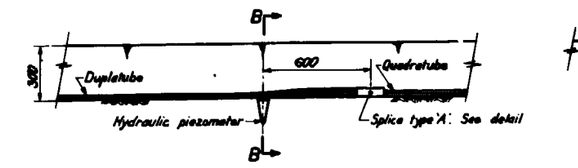
CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km – WIVENHOE DAM
INSTRUMENTATION-TOTAL PRESSURE CELL
& SECONDARY SURFACE MOVEMENT POINT
INSTALLATION DETAILS

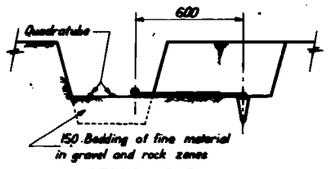
16-6-78 | A2-53376 | A W B

Figure C1.5 - Instrumentation Details Dwg 2 of 4

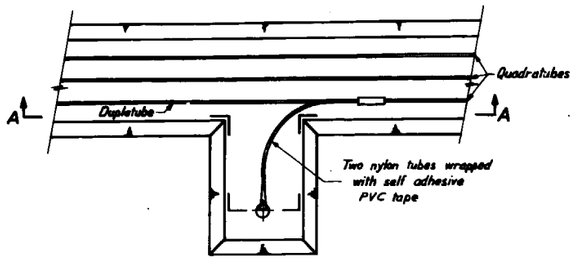
A1-53377



SECTION A-A

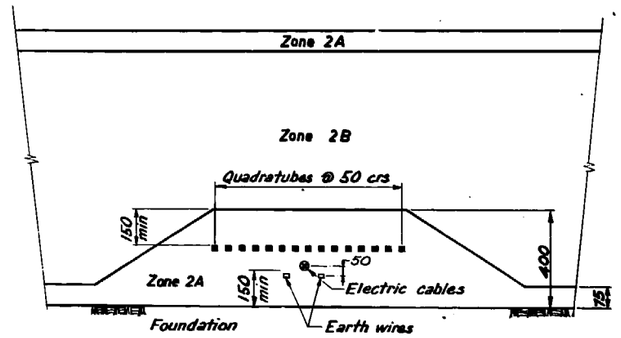


SECTION B-B

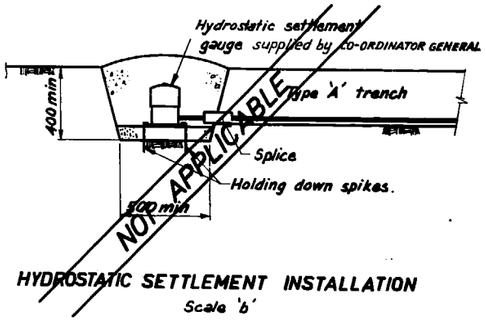


PLAN

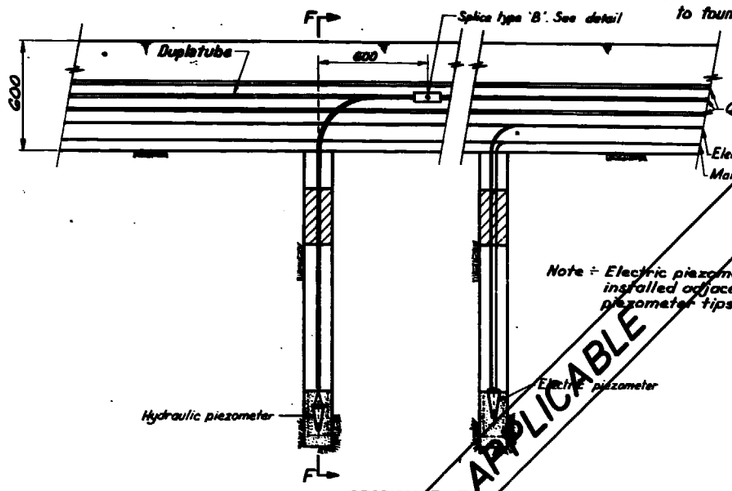
TYPE A
TYPICAL TRENCH INSTALLATION
(Scale 'b')



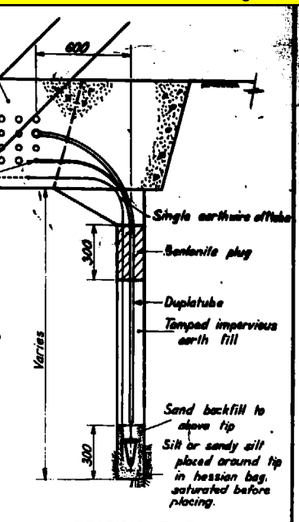
BEDDING DETAIL IN ZONE 2B DRAIN
Scale 'b'



HYDROSTATIC SETTLEMENT INSTALLATION
Scale 'b'



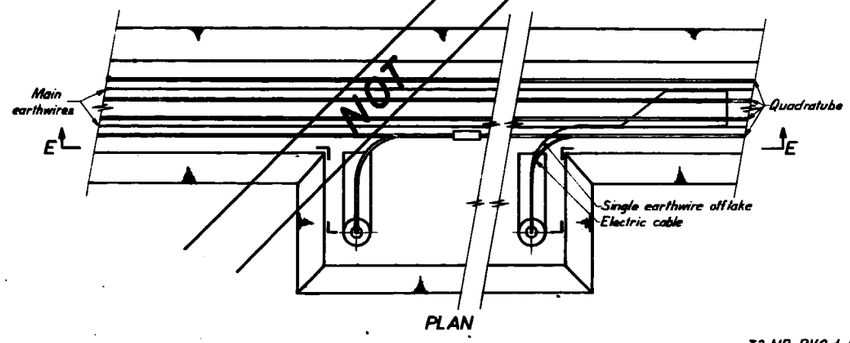
SECTION E-E



SECTION F-F

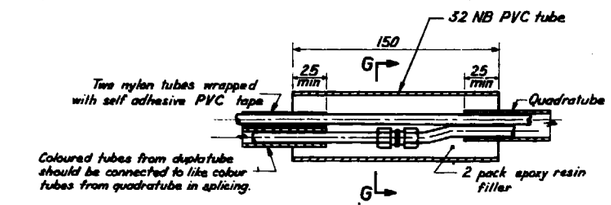
Note :- Electric piezometer tips may be installed adjacent to hydraulic piezometer tips in the same hole

NOT APPLICABLE



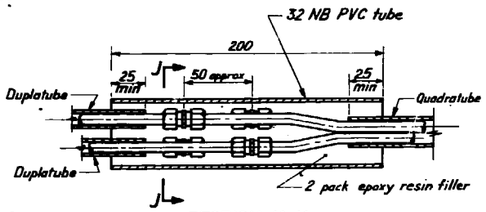
PLAN

TYPE B
TYPICAL BORE HOLE INSTALLATION
(Scale 'b')



SECTION H-H

SECTION G-G

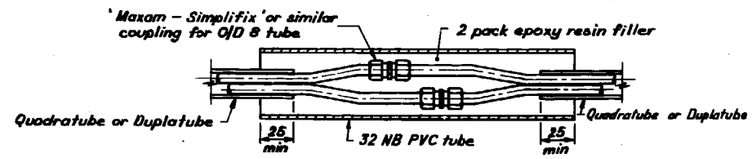


SECTION K-K

SECTION J-J

SPLICE TYPE 'A'

SPLICE TYPE 'B'



FIELD SPLICE
(Duplatube illustrated)

DETAILS OF SPLICES
(Scale 'a')

AS BUILT
By
Class
Date 31/10/84

NOTE :-
1. ALL DIMENSIONS ARE IN MILLIMETRES
2. White (or yellow) tube should be connected to even numbered tips and red tube to odd numbered tips.

Revision					Schedule	
Oct '85	B	As Built			Drawing	
19-7-79	W	Tender tolerancing drwg.			A2-48458	Standard Earthwire Connections
5-6-78	A	Contract N° amend.	M.J.C.	Ma.		
Date		Remarks	Chd	Pad		

Scale 'a' 0 50 100 150 200mm 1:2
Scale 'b' 0 500 1000 1500mm 1:15
(Scales Before Reduction)

CONTRACT N° 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting
Prep'd	Dr P.S.
Ckd	Ckd R.D.
Supv	Supv R.D.
Submitted	

Executive Engineer

Recommended A. Russo Senior Engineer Designs

Approved K Bell Acting Chief Designing Engineer

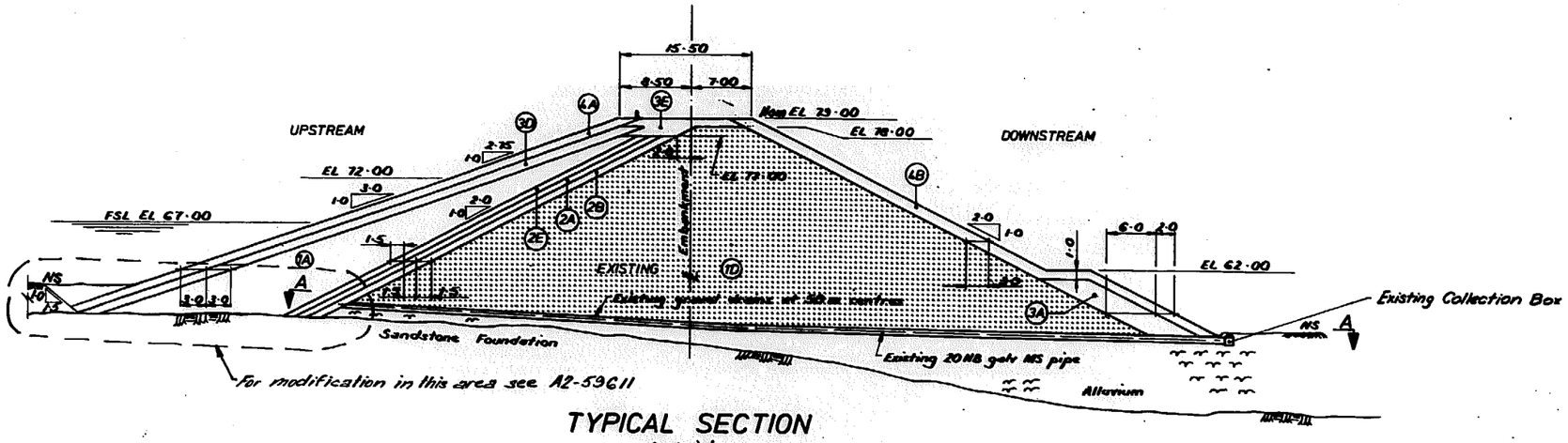
CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2km – WIVENHOE DAM
HYDRAULIC AND ELECTRIC PIEZOMETER TIPS AND HYDROSTATIC SETTLEMENT GAUGE INSTALLATION DETAILS

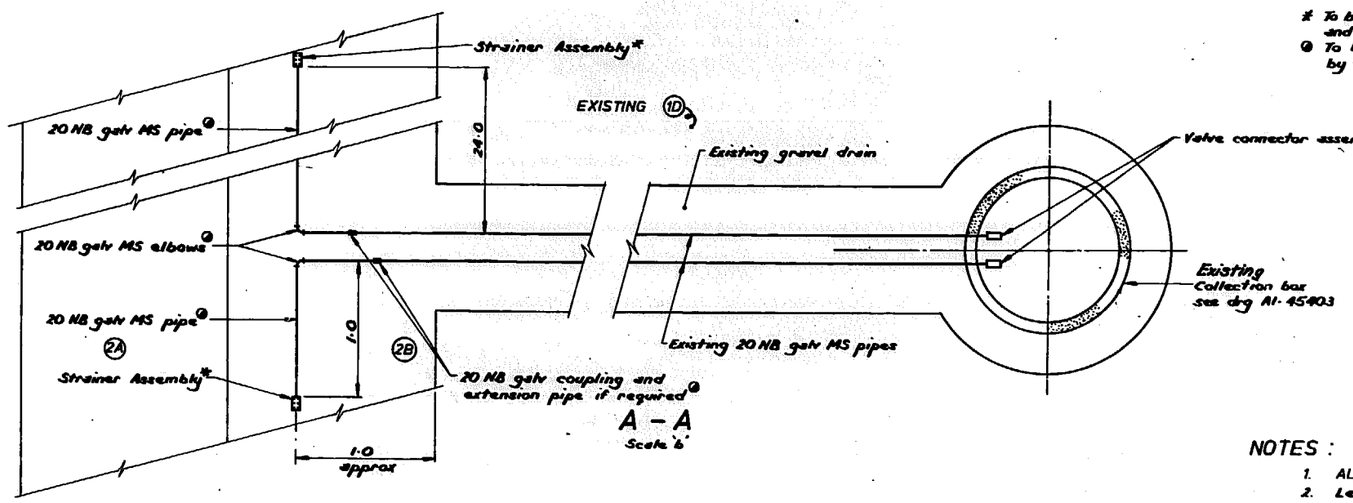
16-6-78 | A1-53377 | A | W | B

Figure C1.6 - Instrumentation Details Dwg 3 of 4

A1-53362



TYPICAL SECTION
Scale '6'



A – A
Scale '6'

* To be supplied by the Principal and installed by the Contractor
② To be supplied and installed by the Contractor

NOTES :

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES
2. Levels Datum : All levels are to AHD (PSM N° 34242 = EL 74·784)
3. For zone legend and existing downstream drainage see drg A1-45403

AS BUILT
By EJ Jakubiec
Class Design Engr II
Date 6/11/85

Revision					Schedule
Oct '85	C	As Built	RLW		
15-4-82	B	Typical Section amended	M.J.C.	AM.	
12-9-79	W	Tender drg. to working drg.	RD.	R.J.B.C.	
9-5-79	A	Centreline Number Amended	M.J.C.	M.A.	
Date		Remarks	Chd	Psd	Drawing
					A1-50813 Left Bank - Axis Distance 100 - 1143 Argyt & Seat
					A1-45403 Found Earthworks Axis Distance 00-1100 Outside

Scale '6' 0 15 30m (1:300 Scale Before Reduction)
Scale '6' 0 0·5 1·0 1·5 2·0m (1:20 Scale Before Reduction)

CONTRACT N° 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting
Prep'd	Dr T.S.
Chd	Chd R.D.
Supv	Supv R.D.
Submitted	
Executive Engineer	

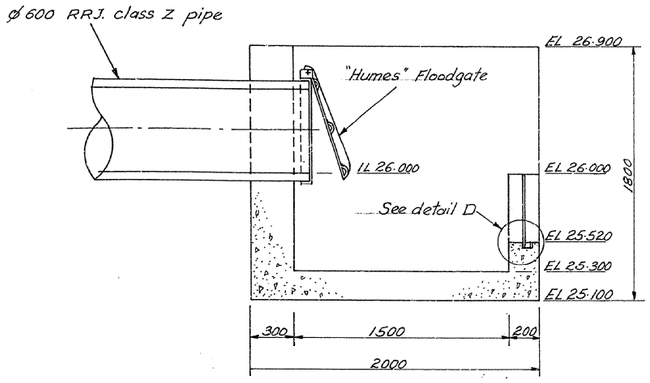
Recommended R. Russo Senior Engineer Designs
Approved K.D.W. Acting Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

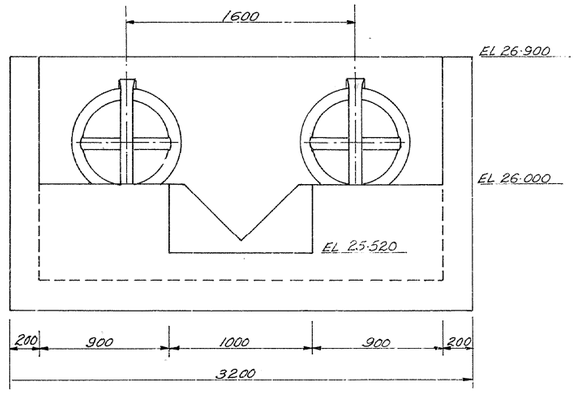
BRISBANE RIVER 150·2 km - WIVENHOE DAM
THIRD STAGE CONSTRUCTION
LEFT BANK - AXIS DISTANCE 00 - 1100
INSTRUMENTATION DETAILS

16-6-78 | A1-53362 | A | B | C

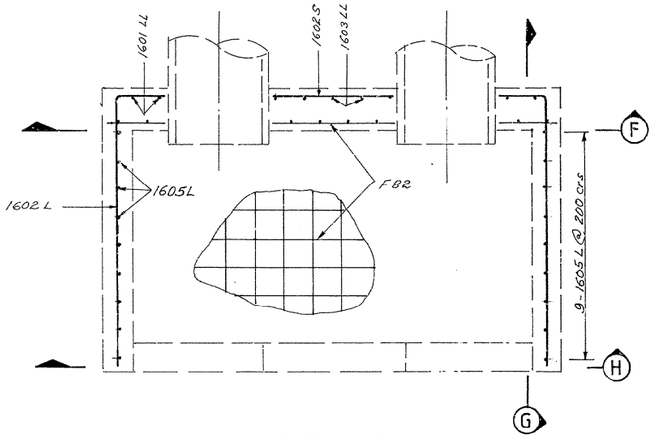
Figure C1.7 - Instrumentation Details Dwg 4 of 4



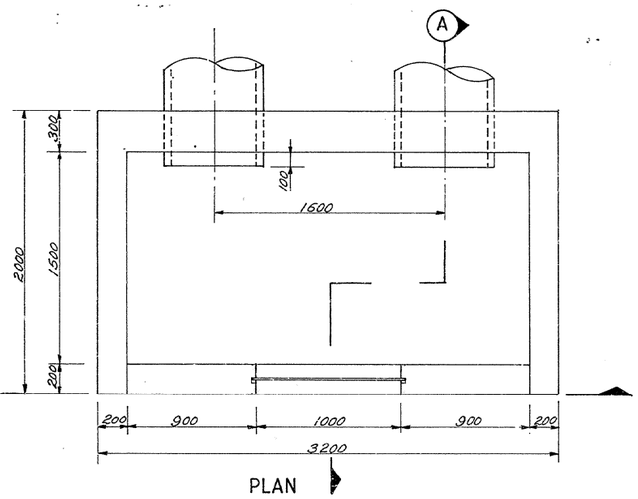
SECTION A



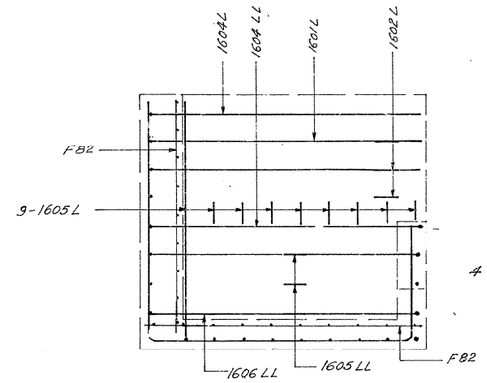
VIEW B



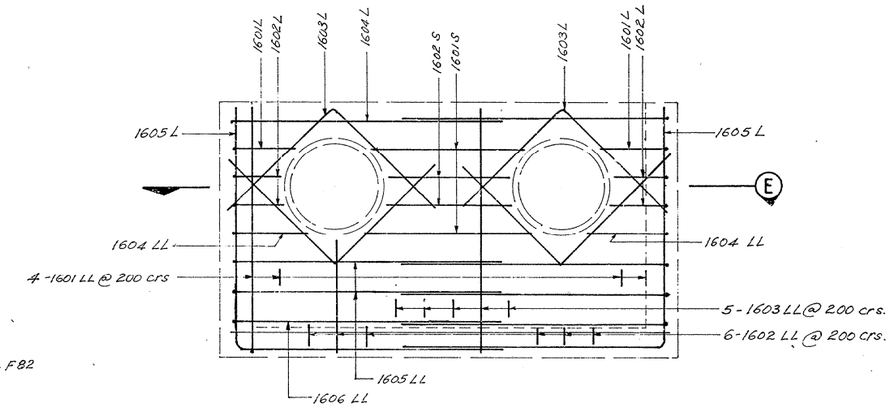
SECTION E



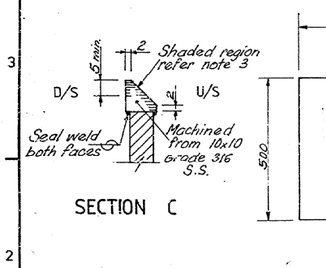
PLAN



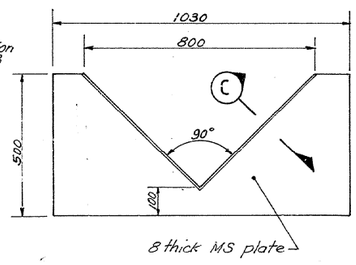
SECTION G

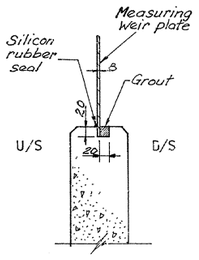


SECTION F



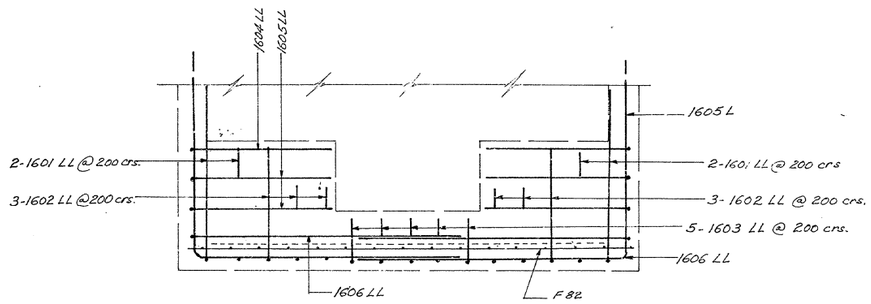
SECTION C





DETAIL D

MEASURING WEIR DETAILS
(not to scale)



SECTION H

NOTE

1. All fillets to be 25 x 25
2. All bars to be spaced @ 200 crs. min. cover 50
3. All material and workmanship to be in accordance with Australian Standard
4. Concrete shall develop a minimum compressive strength of 20 MPa at 28 days
5. Galvanizing to be removed in region shown shaded on section ©. Crest faces to be left smooth and edges sharp.

AS BUILT
By
Class'n
Date

REVISION					DRAWING SCHEDULE		SURVEY BOOKS
DATE	REMARKS	ZONE	CKD	PSD	A3-749 ~~Steel schedule (Destroyed)~~		

SCALES 1: 20

DESIGN	DRAFTING
PREP	DR C.P.P.
CKD	CKD
SUPV	SUPV
SUBMITTED	

Queensland Water Resources Commission

RECOMMENDED P.G. Richardson

APPROVED/DATE I.A. Chalmers 5.8.84

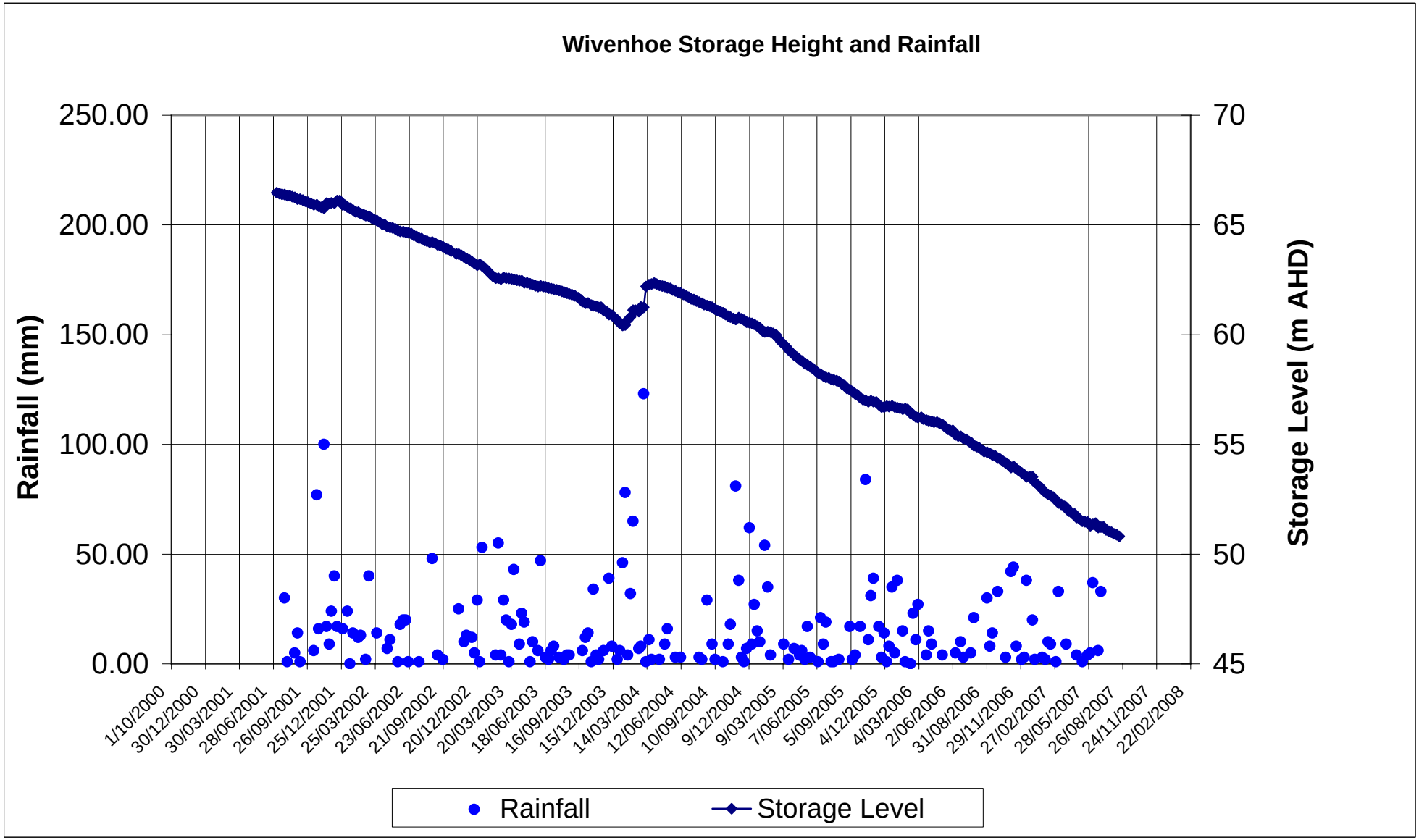
BRISBANE RIVER 150·2km-WIVENHOE DAM
MAIN EMBANKMENT
DIVERSION CHANNEL - FILTER DRAIN
MEASURING WEIR DETAILS

CONTRACT NUMBER
DRAWING NUMBER A1-72011
1-3-84

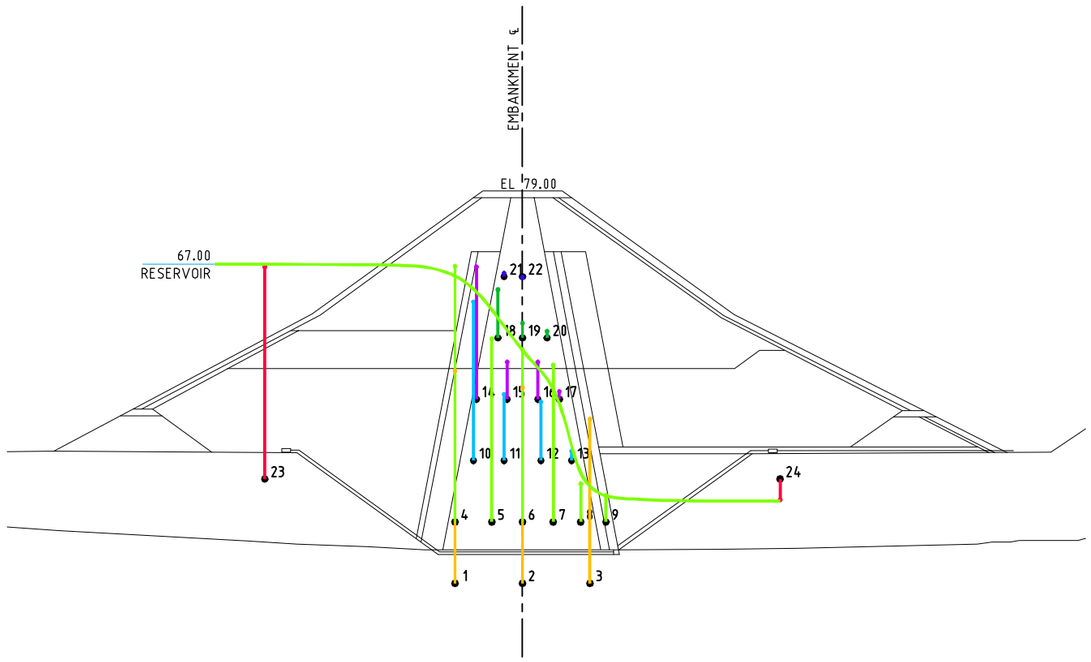
WD-A1-748

DWG 72011.TIF

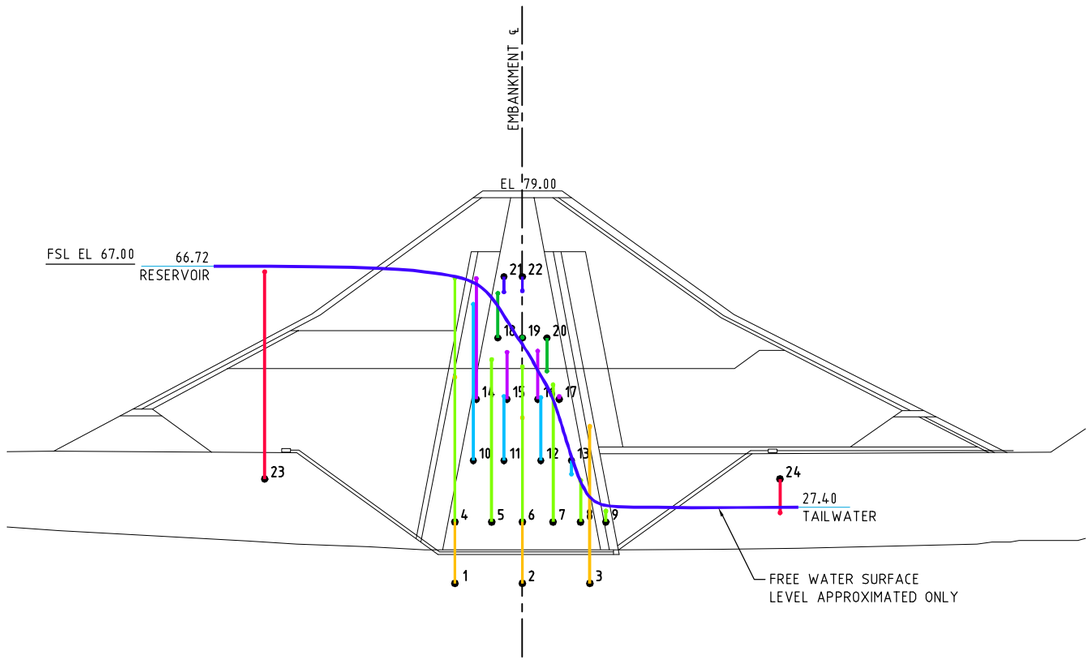
Appendix C2 – Storage Level Behaviour and Rainfall


Wivenhoe Storage Height and Rainfall
Rainfall (mm)
250.00
200.00
150.00
100.00
50.00
0.00
Storage Level (m AHD)
70
65
60
55
50
45
1/10/2000
30/12/2000
30/03/2001
28/06/2001
26/09/2001
25/12/2001
25/03/2002
23/06/2002
21/09/2002
20/12/2002
20/03/2003
18/06/2003
16/09/2003
15/12/2003
14/03/2004
12/06/2004
10/09/2004
9/12/2004
9/03/2005
7/06/2005
5/09/2005
4/12/2005
4/03/2006
2/06/2006
31/08/2006
29/11/2006
27/02/2007
28/05/2007
26/08/2007
24/11/2007
22/02/2008
Rainfall
Storage Level

Appendix C3 – Piezometric Data

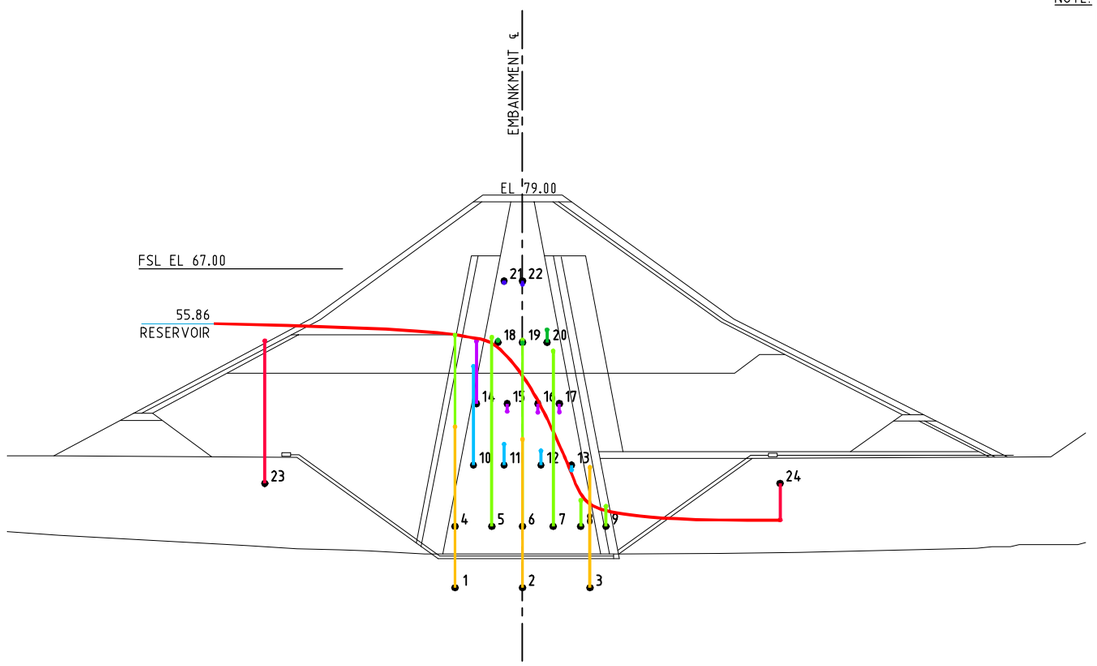


5th JUNE 1990

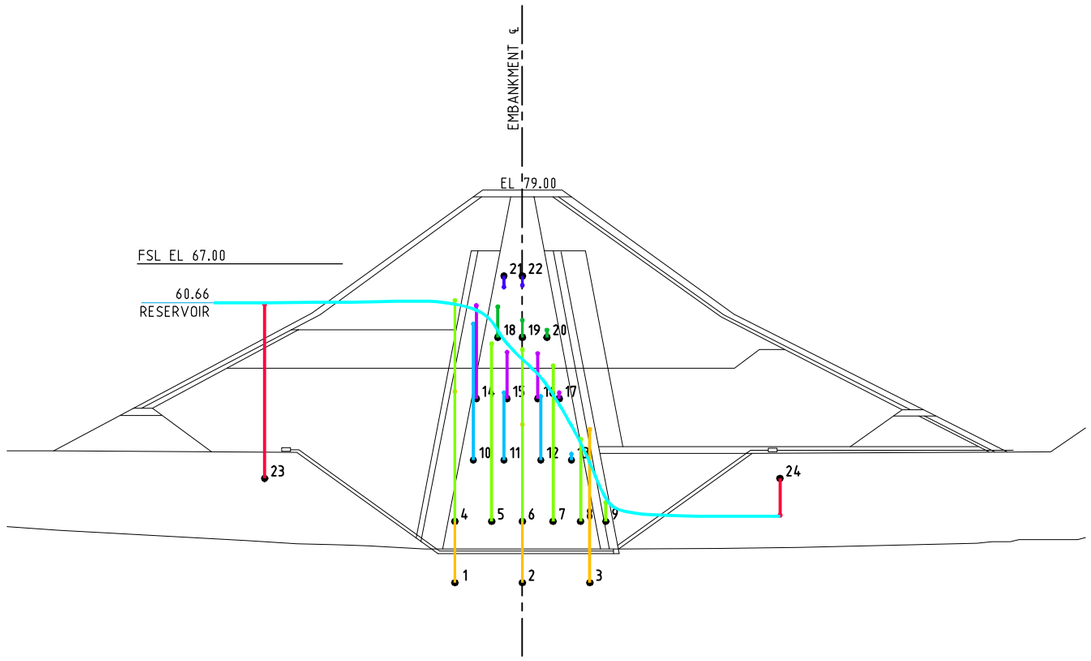


21st JUNE 2000

NOTE: DATA SUPPLIED
BY SEQ WATER



19th JUNE 1985



19th MAY 1995

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

SCALE A 0 10 20 25m
1 : 1000 (A3) 1 : 500 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DETAIL\60020162-121.dwg
Last modified: 23 Nov 06 - 13:21

MAUNSELL | AECOM

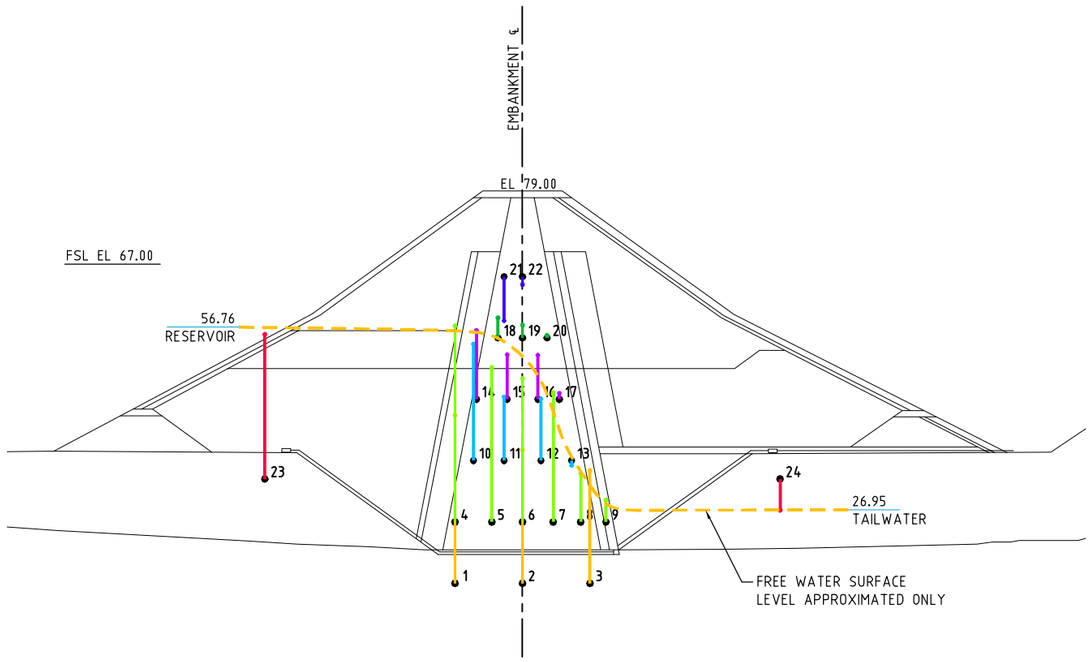
Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

WIVENHOE DAM
MAIN EMBANKMENT SECTIONS
PIEZOMETER INSTALLATIONS - CHAINAGE 1600

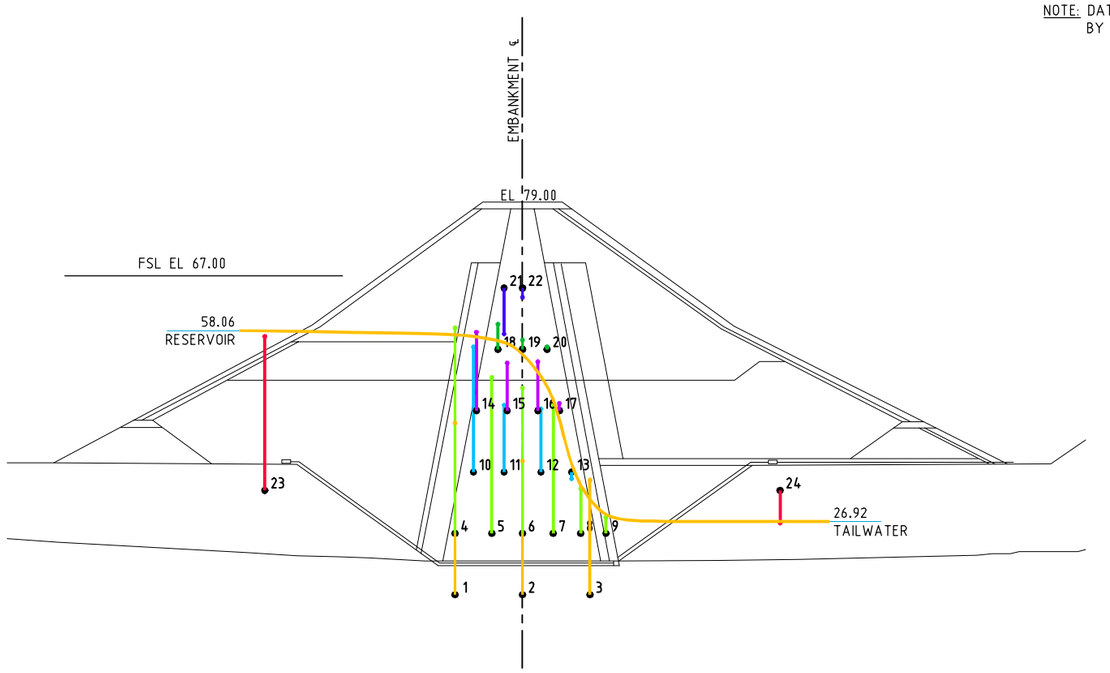
Status	Drg No.	Rev.
	60020162-121	

Xref's Maunsell-A1

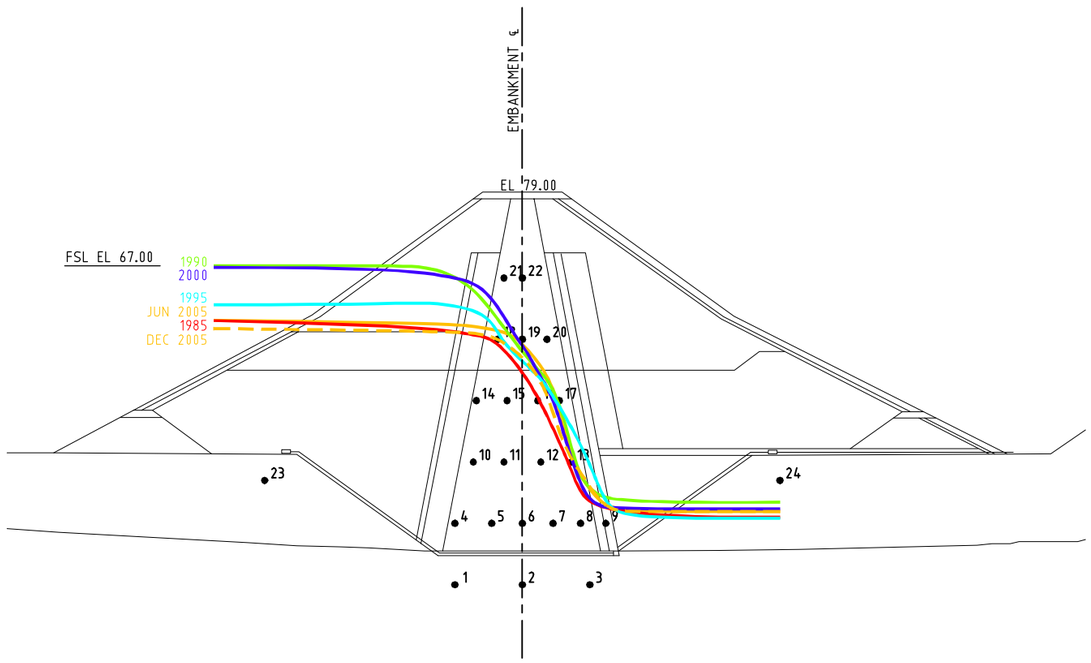


23rd DECEMBER 2005

NOTE: DATA SUPPLIED
BY SEQ WATER



29th JUNE 2005



MID-YEAR COLLECTIVE

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

SCALE A 0 10 20 25m
1 : 1000 (A3) 1 : 500 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DETAIL\60020162-122.dwg
Last modified: 23 Nov 06 - 13:21

MAUNSELL AECOM

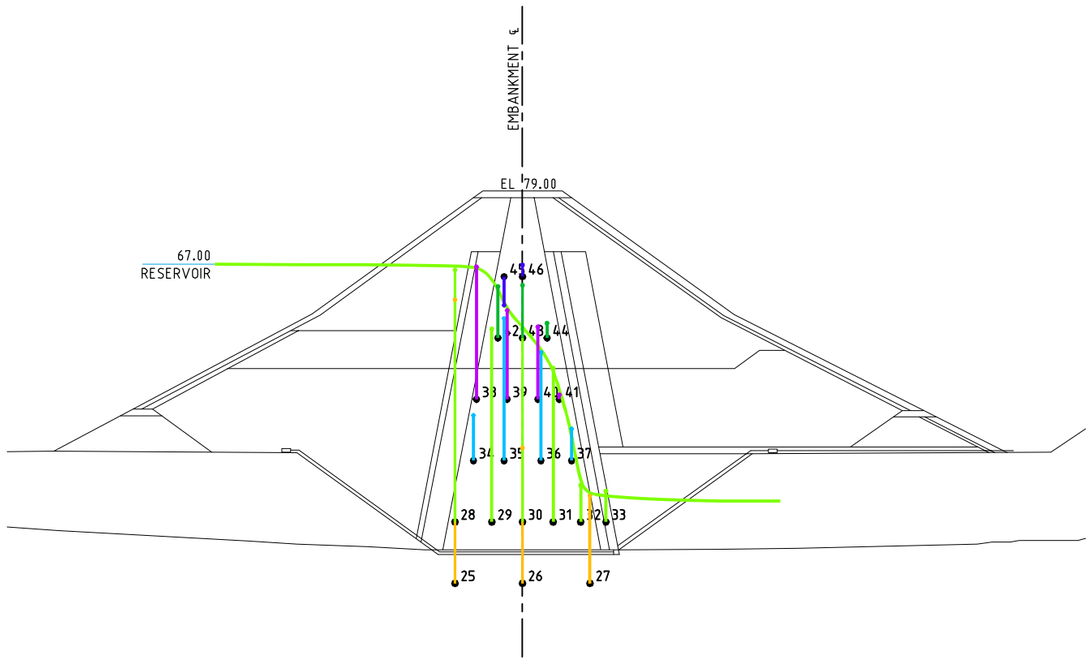
Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

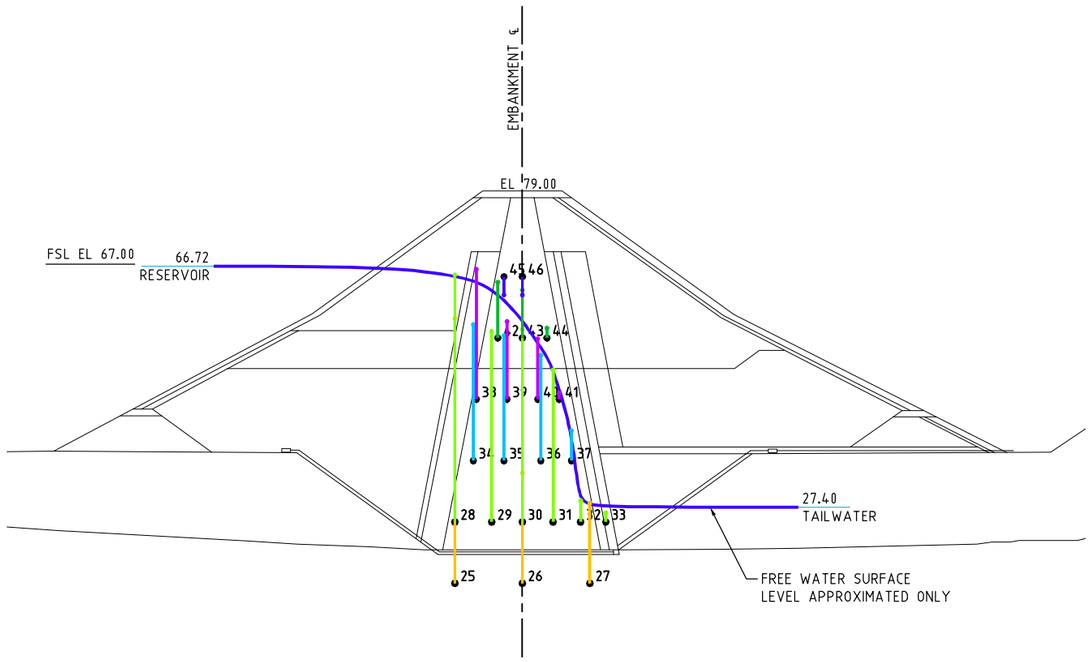
WIVENHOE DAM
MAIN EMBANKMENT SECTIONS
PIEZOMETER INSTALLATIONS - CHAINAGE 1600

Status	Drg No.	Rev.
	60020162-122	

Xref's Maunsell-A1

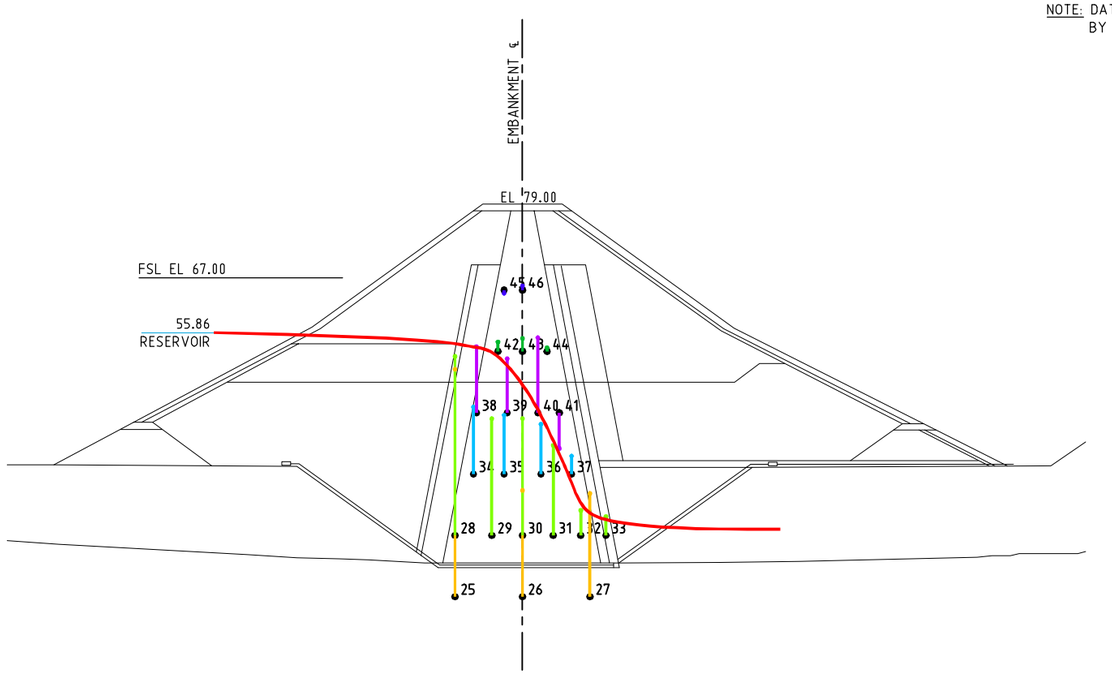


5th JUNE 1990

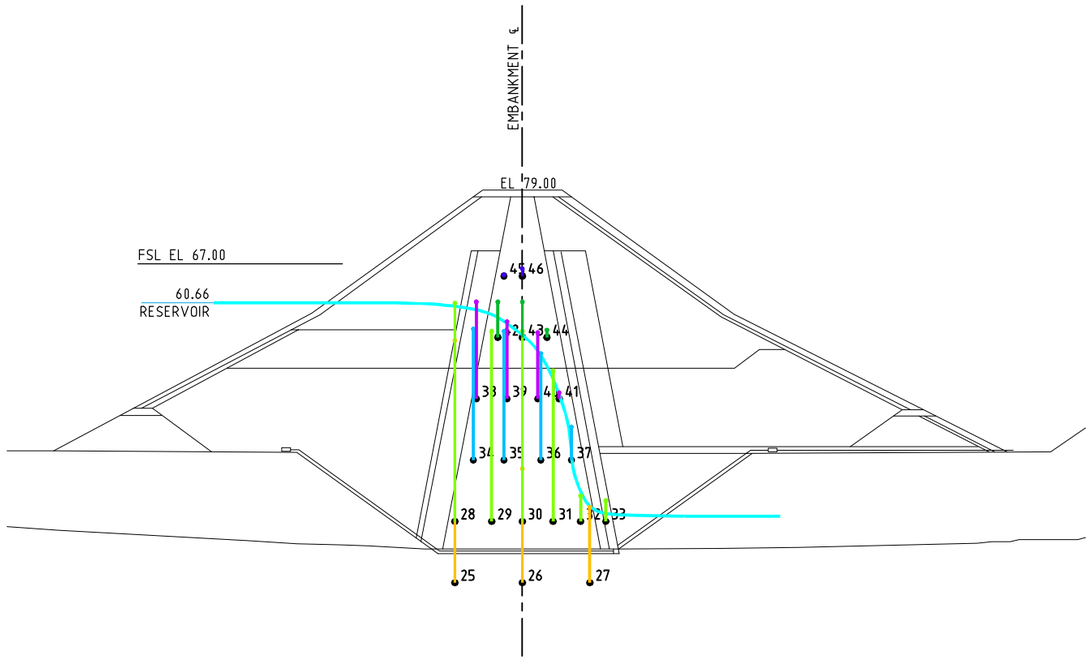


21st JUNE 2000

NOTE: DATA SUPPLIED
BY SEQ WATER



19th JUNE 1985



19th MAY 1995

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

SCALE A 0 10 20 25m

1 : 1000 (A3) 1 : 500 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DETAIL\60020162-123.dwg
Last modified: 23 Nov 06 - 13:21

MAUNSELL | AECOM

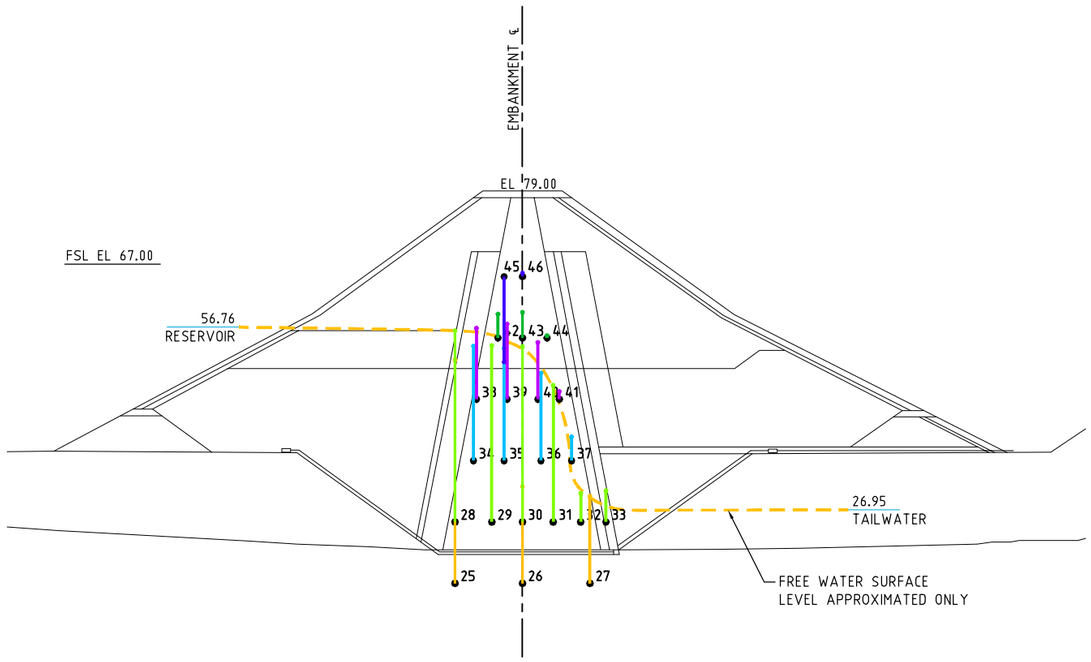
Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

WIVENHOE DAM
MAIN EMBANKMENT SECTIONS
PIEZOMETER INSTALLATIONS - CHAINAGE 1800

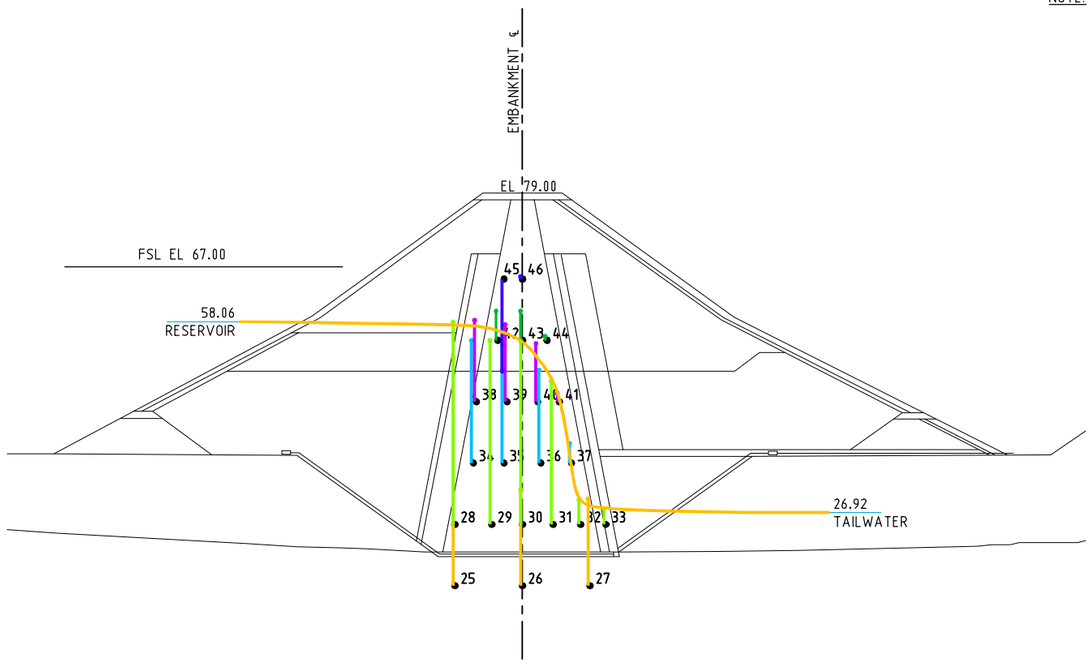
Status	Drg No.	Rev.
	60020162-123	

Xref's Maunsell A1

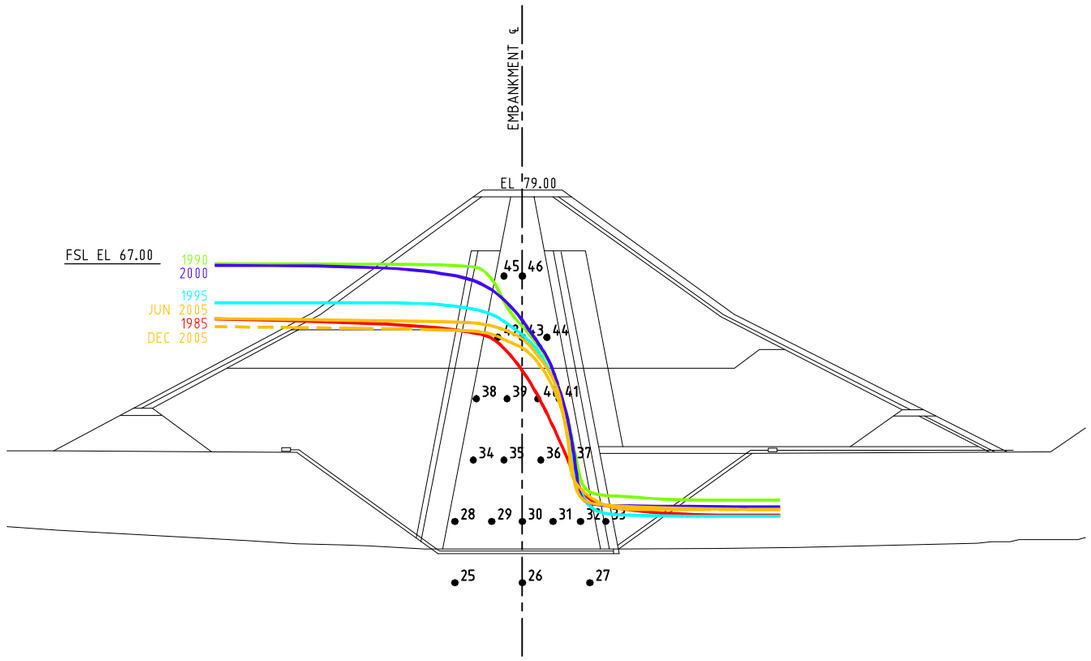


23rd DECEMBER 2005

NOTE: DATA SUPPLIED BY SEQ WATER



29th JUNE 2005



MID-YEAR COLLECTIVE

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

SCALE A 0 10 20 25m

1 : 1000 (A3) 1 : 500 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DETAIL\60020162-124.dwg
Last modified: 23 Nov 06 - 13:21

MAUNSELL AECOM

Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

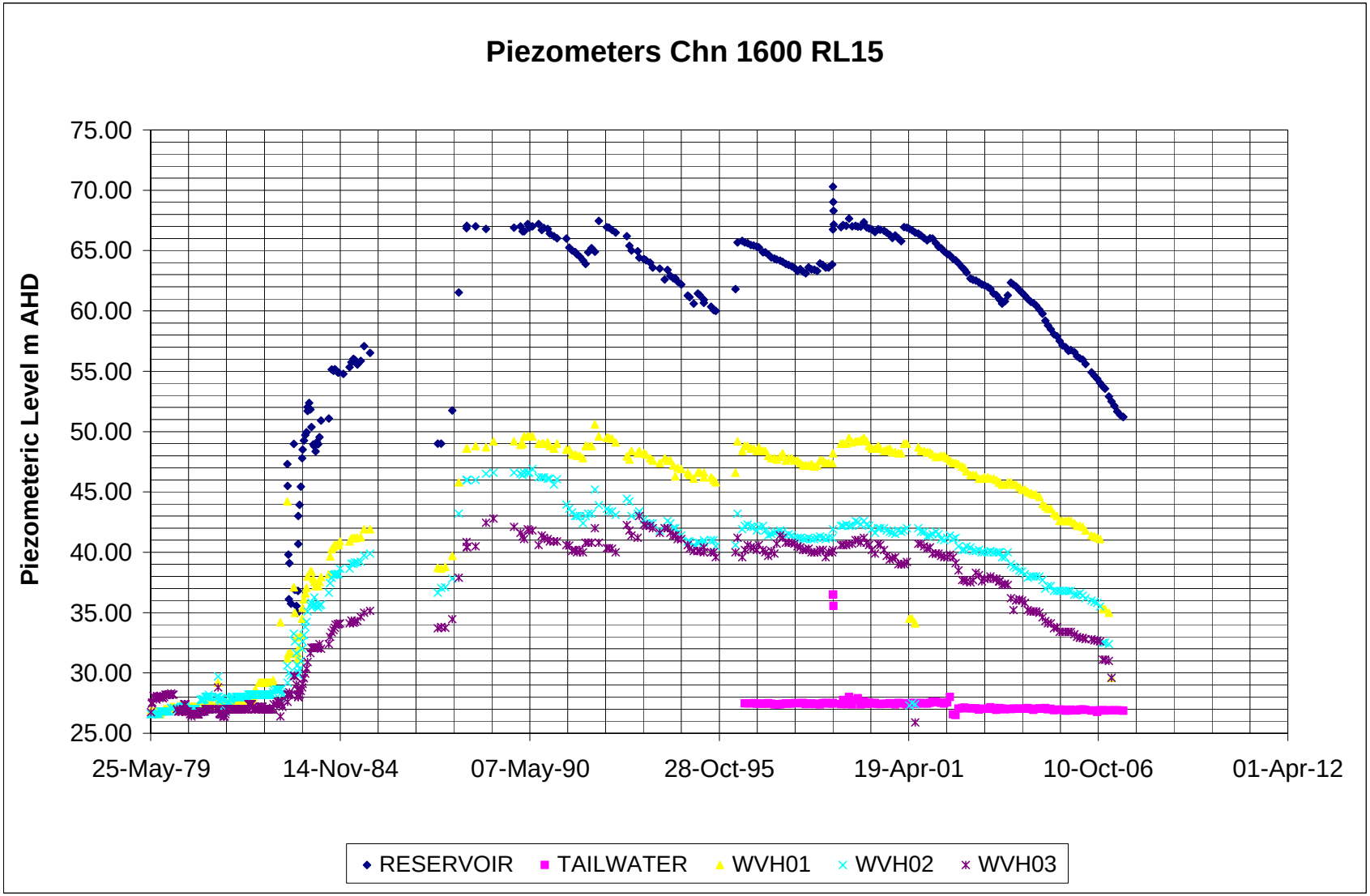
WIVENHOE DAM
MAIN EMBANKMENT SECTIONS
PIEZOMETER INSTALLATIONS - CHAINAGE 1800

Status

Drg No. 60020162-124

Rev.

Xref's Maunsell-A1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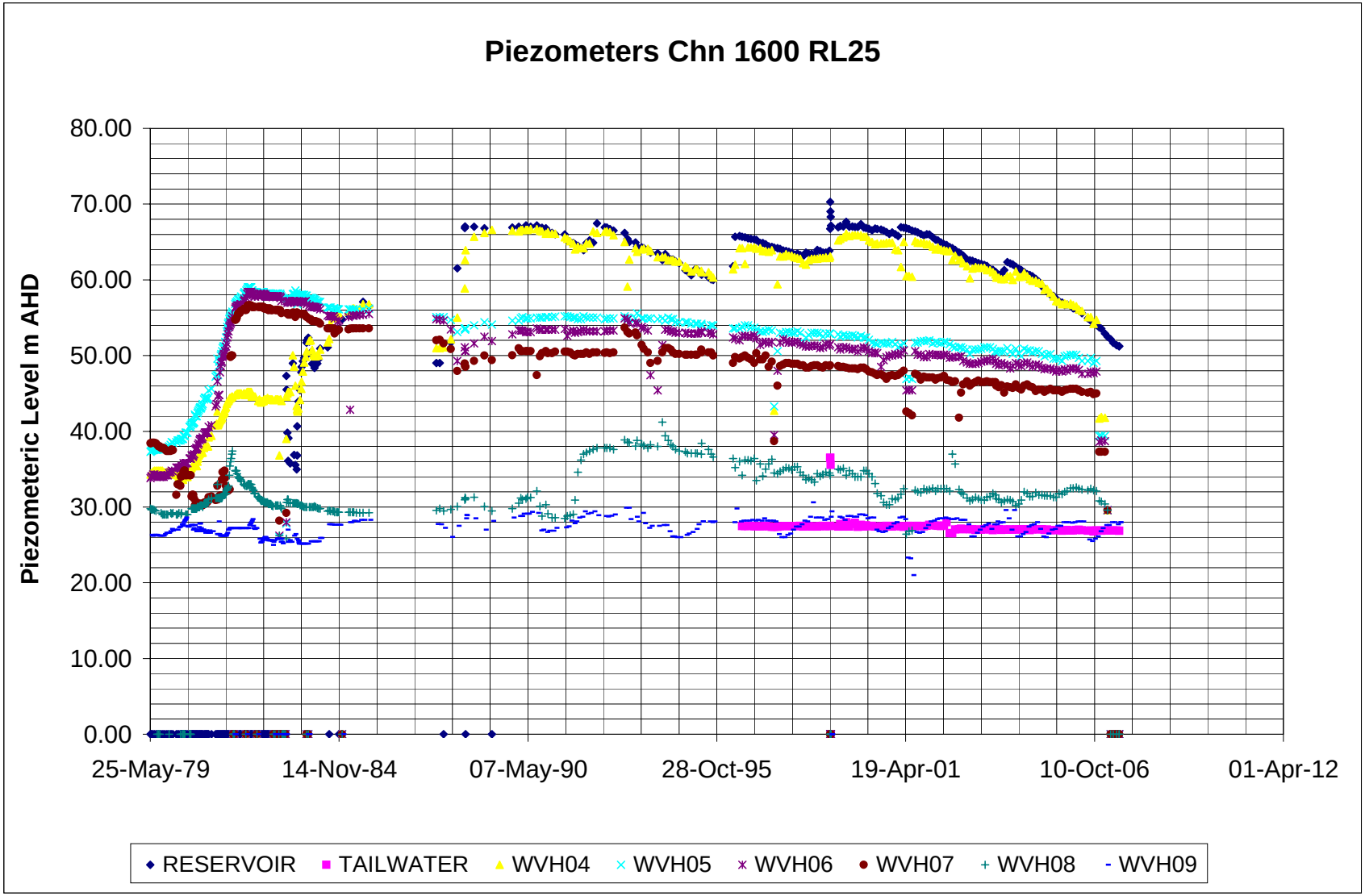
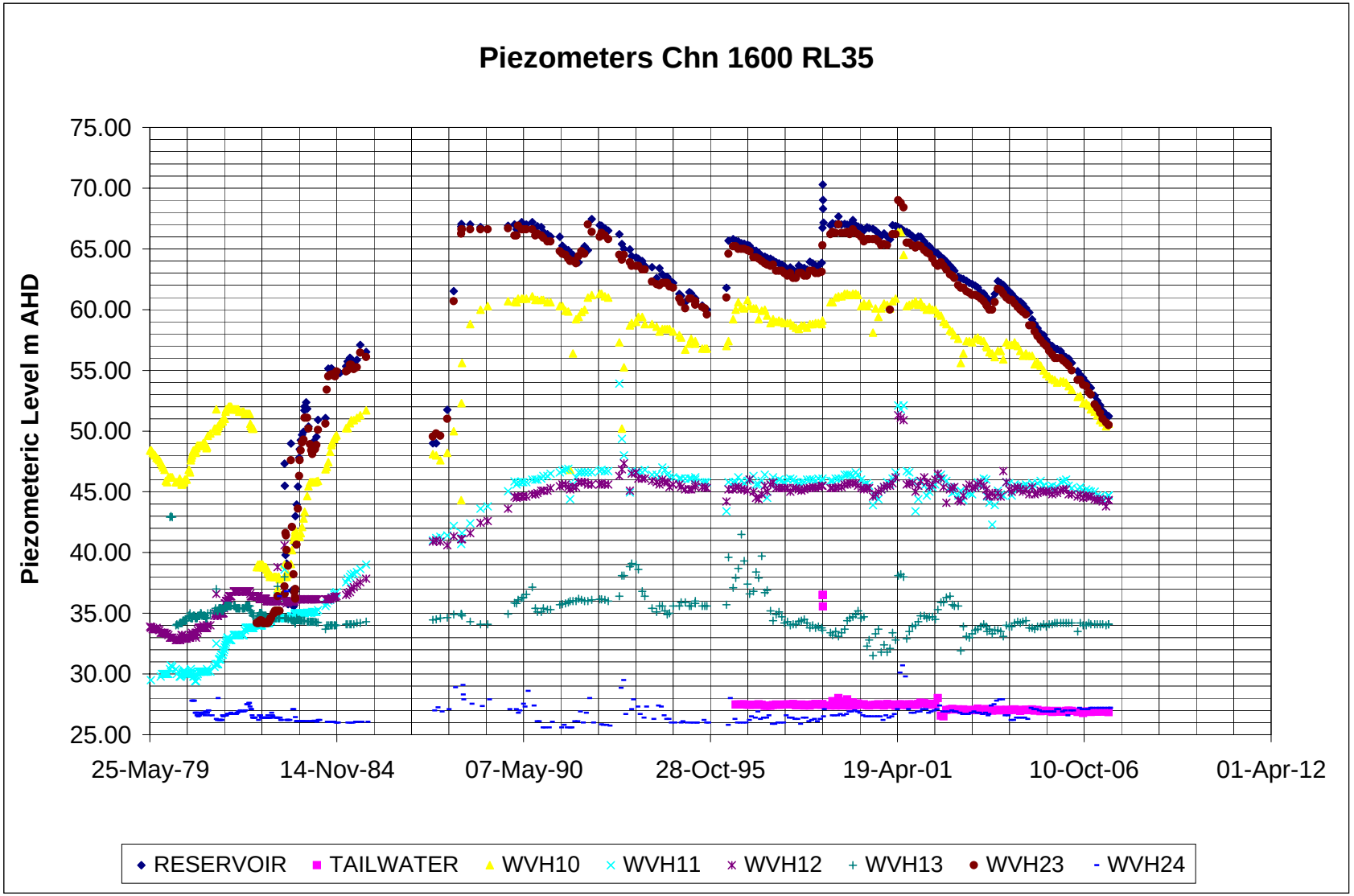
Piezometeric Level m AHD
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH01
WVH02
WVH03


Piezometers Chn 1600 RL25
Piezometeric Level m AHD
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH04
WVH05
WVH06
WVH07
WVH08
WVH09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Piezometeric Level m AHD
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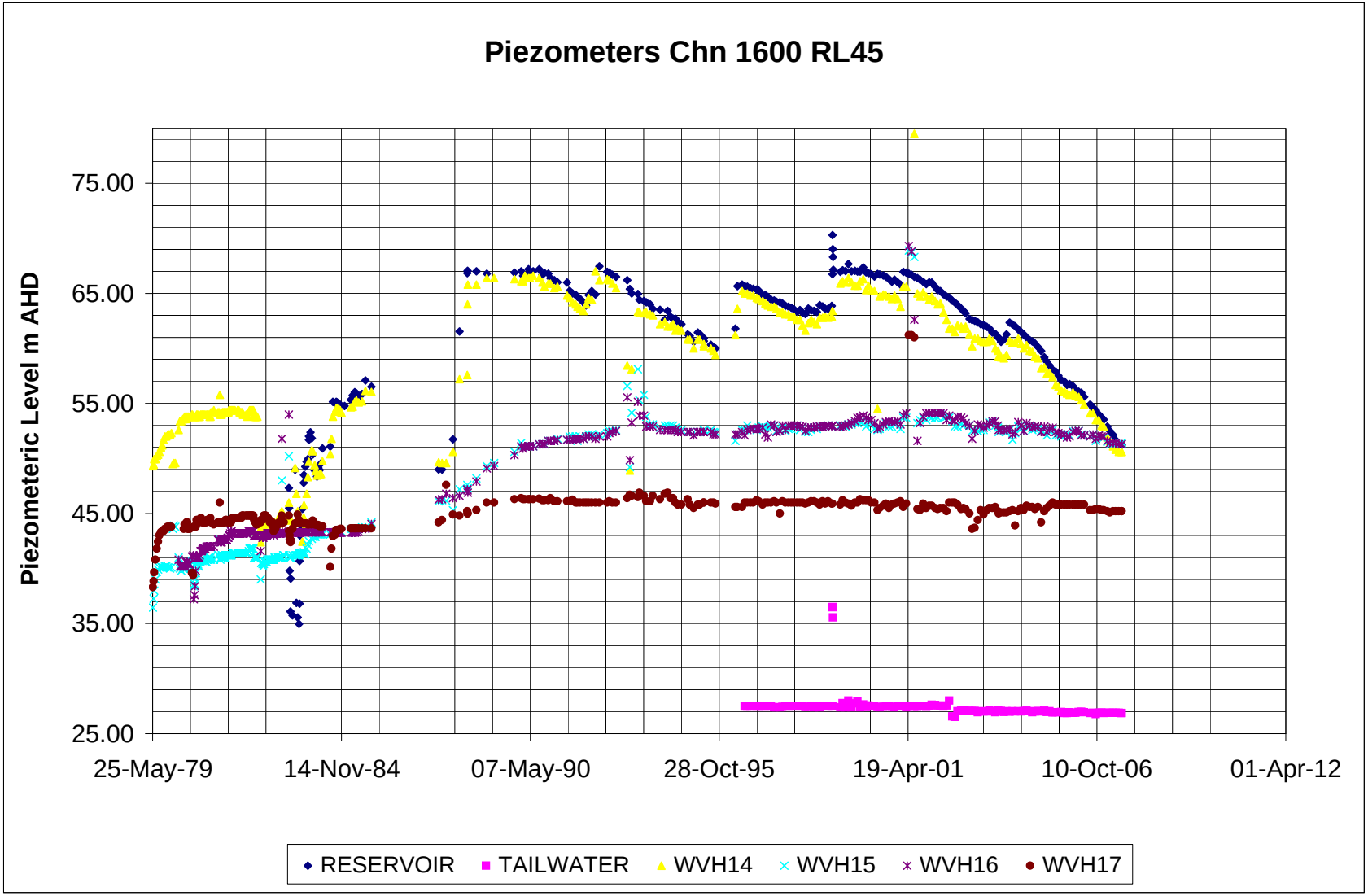
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH10
WVH11
WVH12
WVH13
WVH23
WVH24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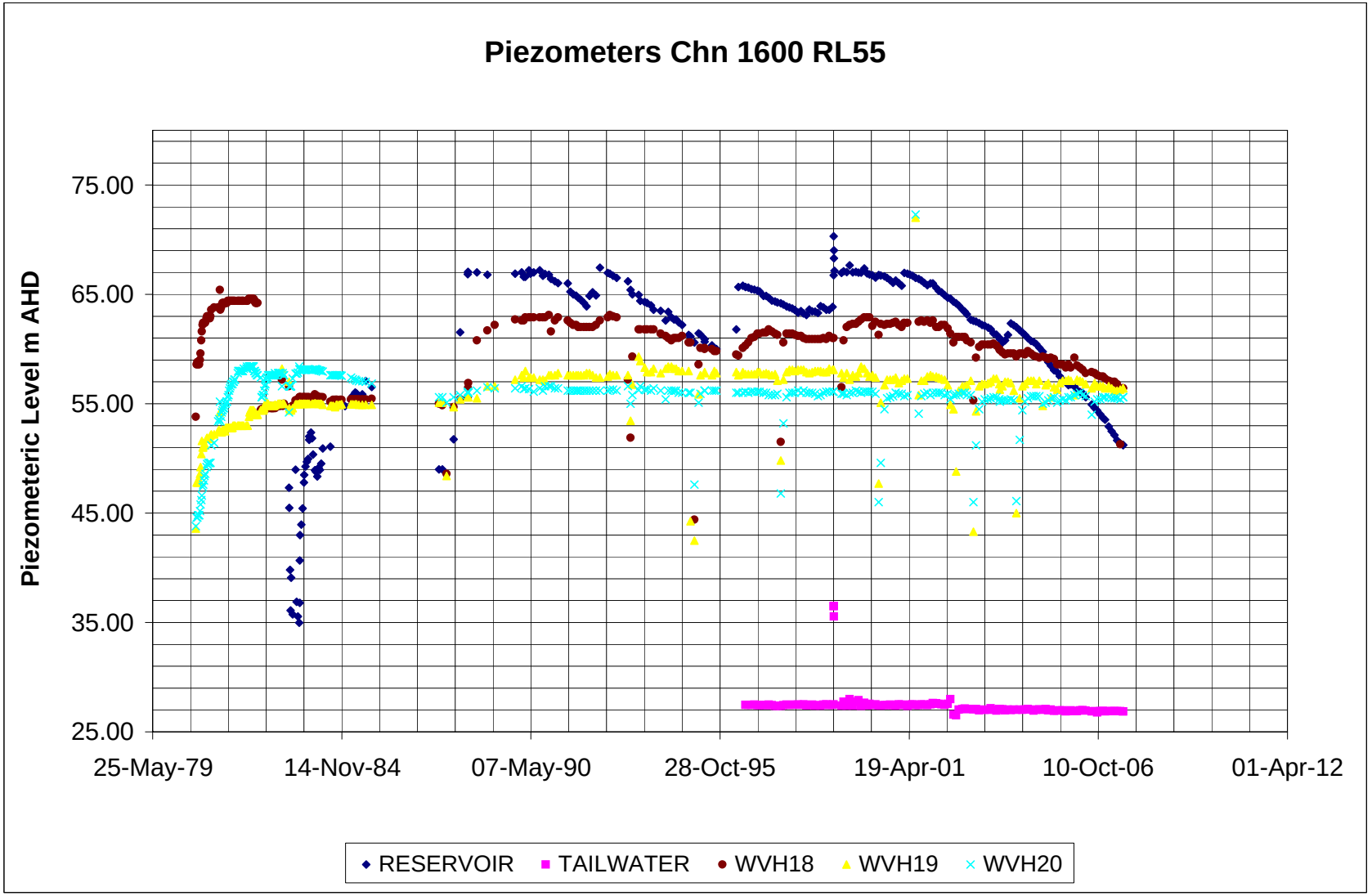
Piezometeric Level m AHD
75.00
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH14
WVH15
WVH16
WVH17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Piezometeric Level m AHD
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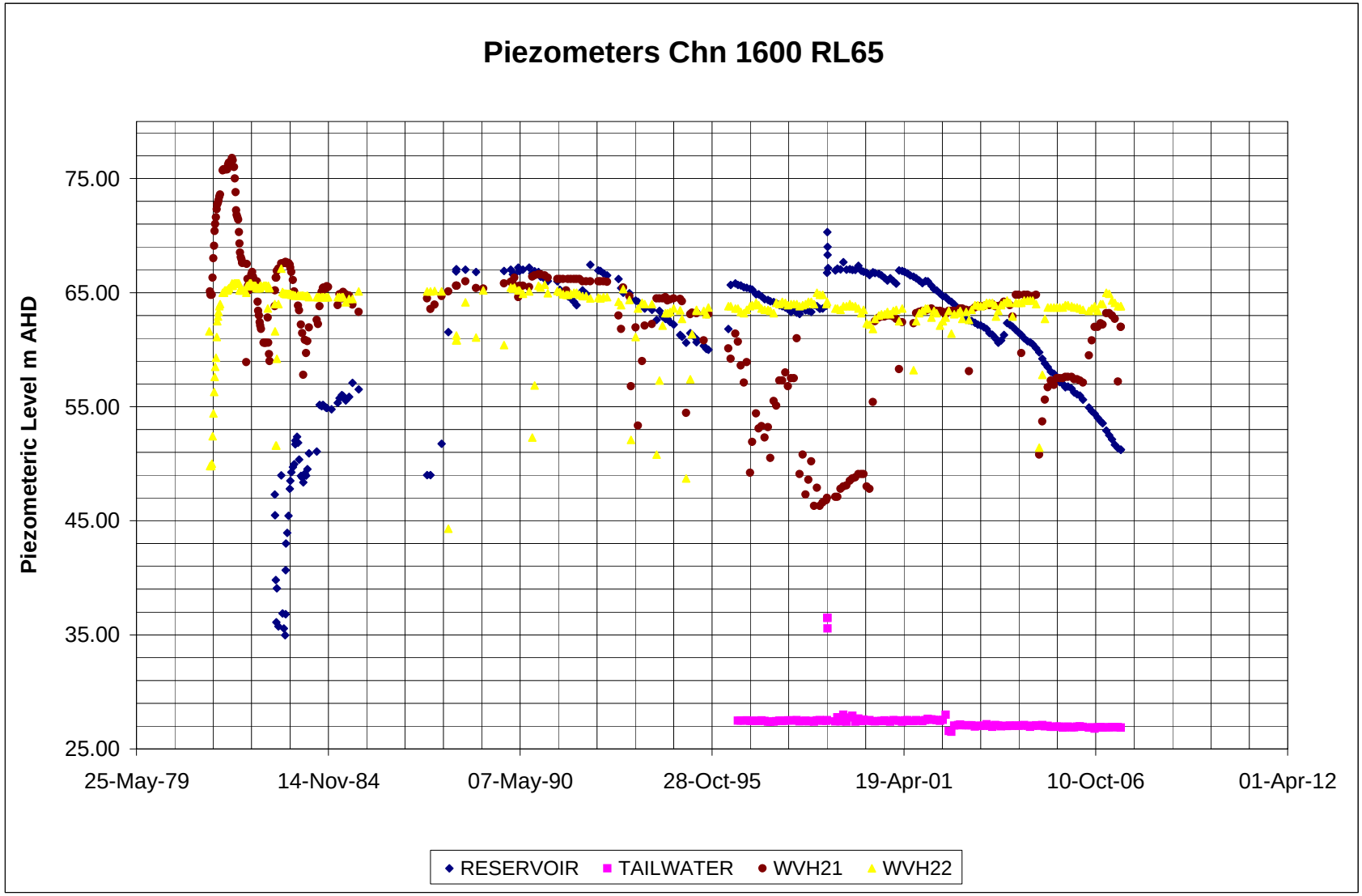
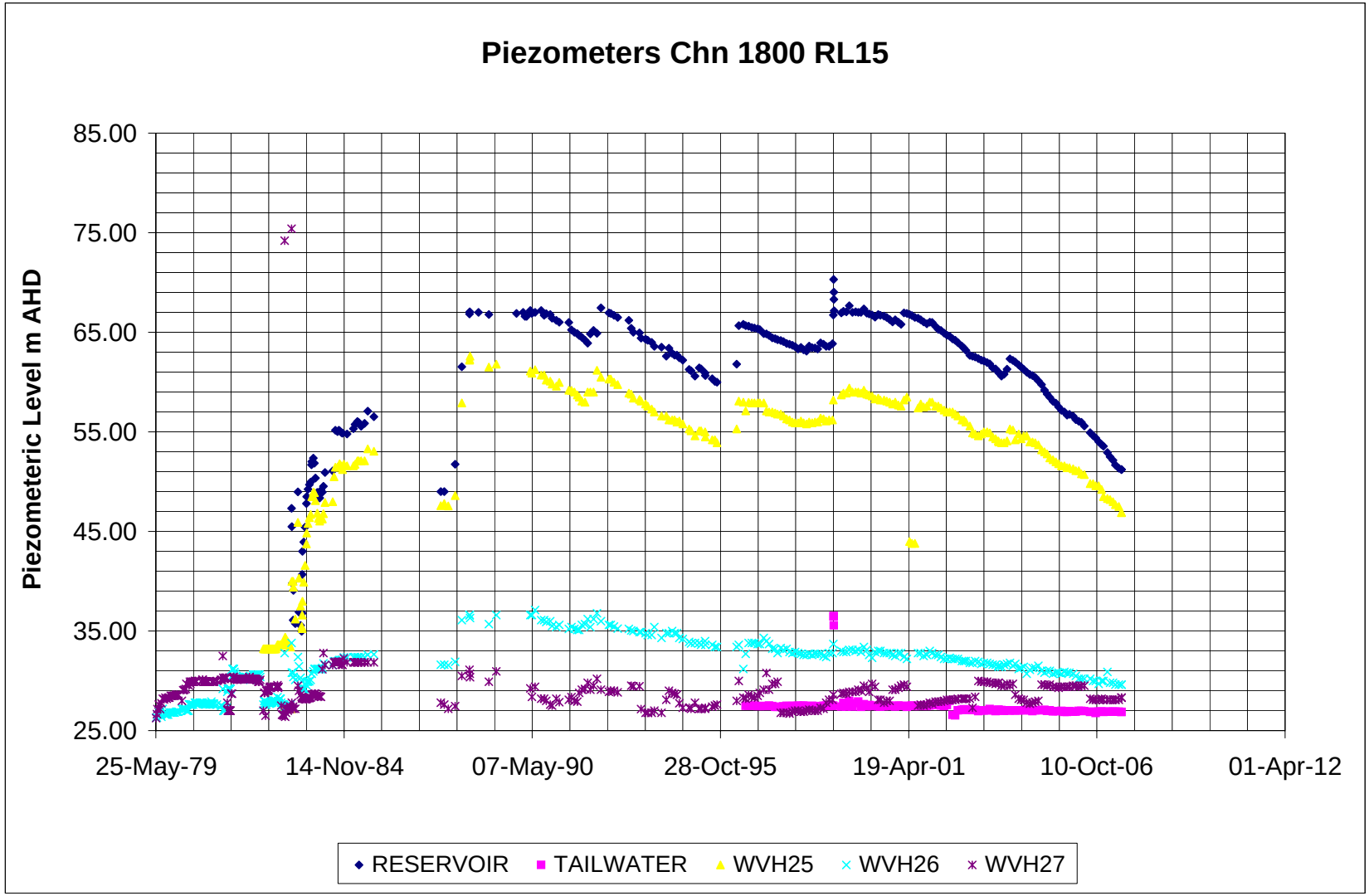
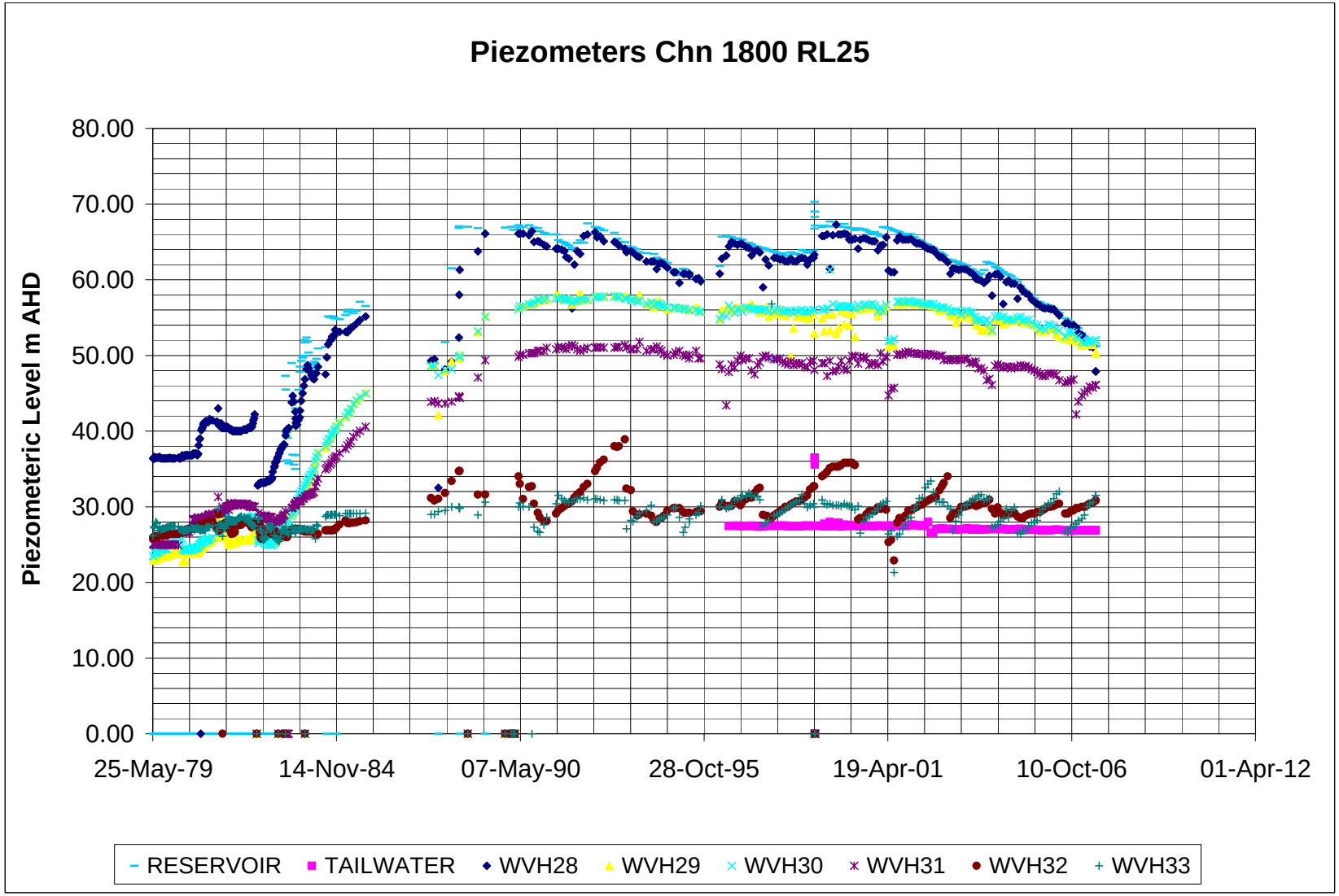
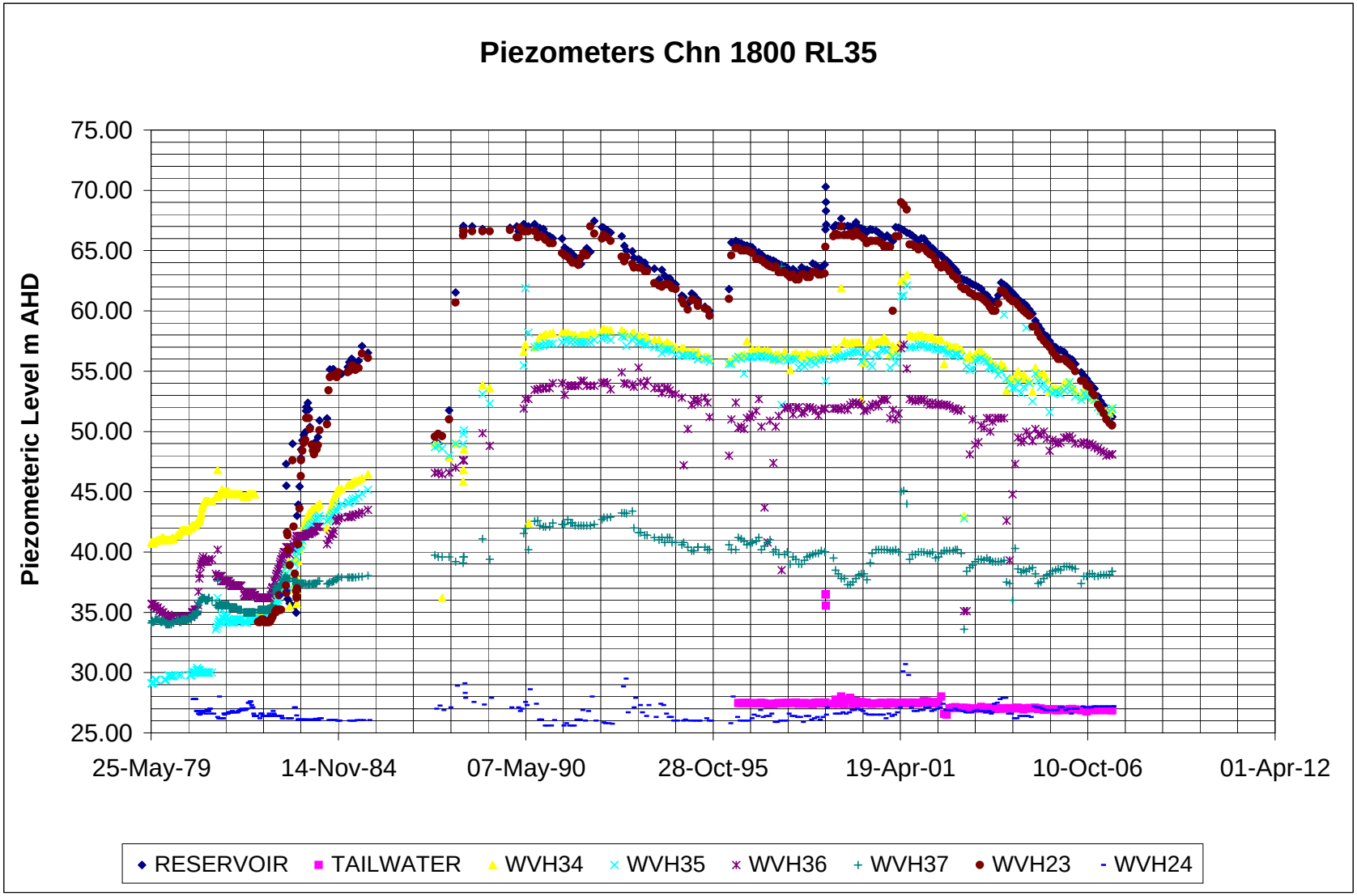
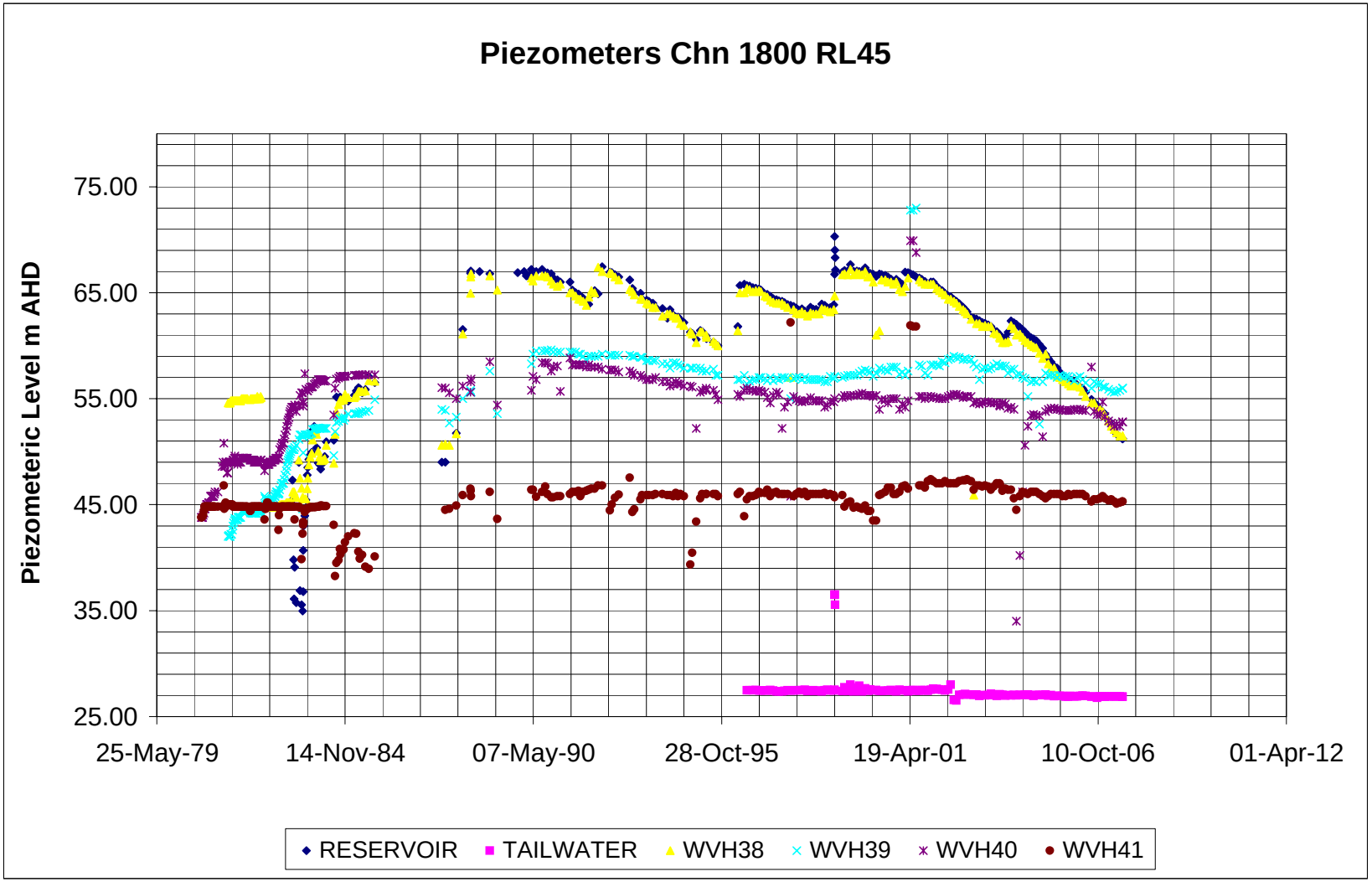
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH18
WVH19
WVH20

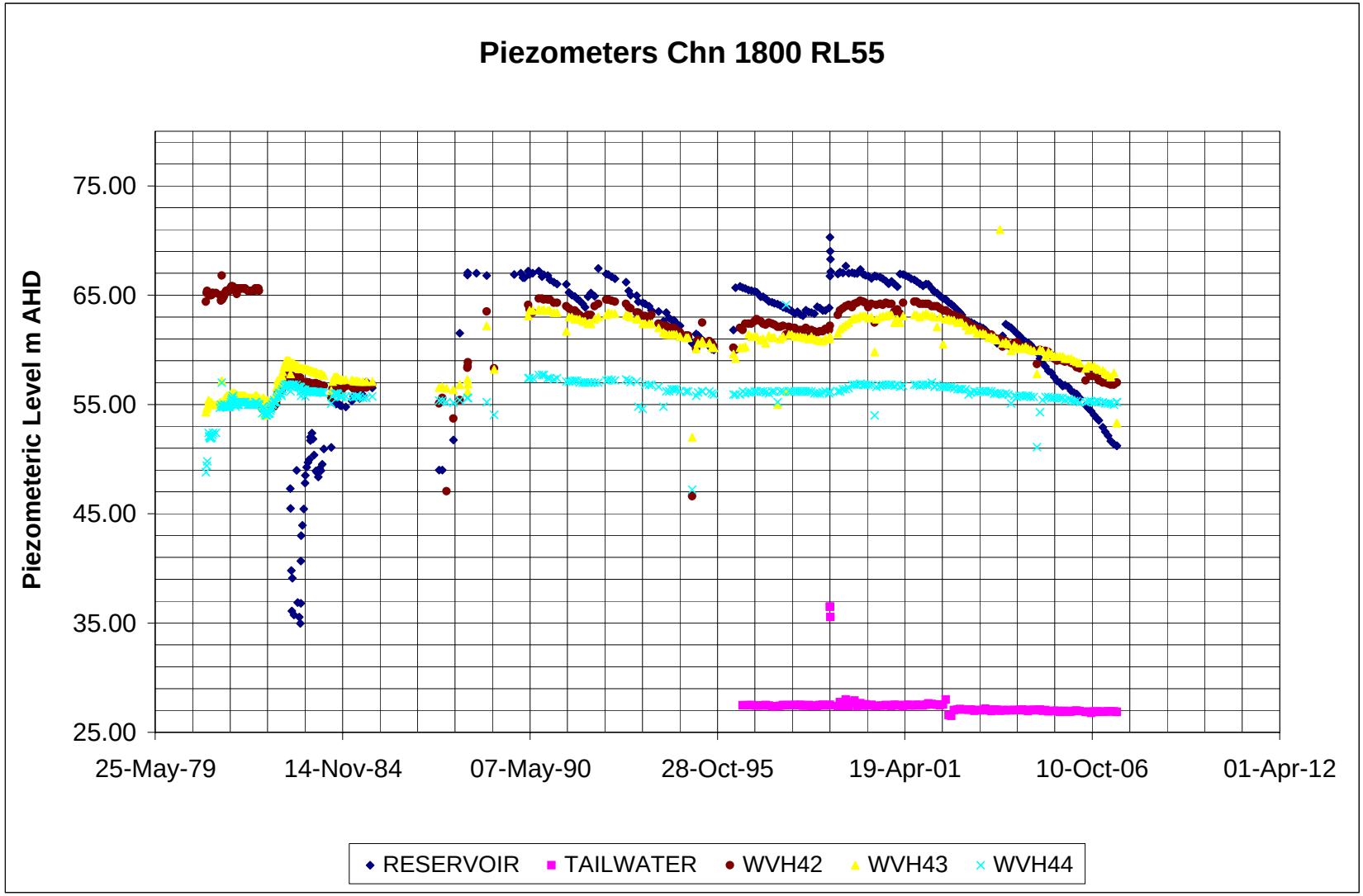

Piezometers Chn 1600 RL65
Piezometeric Level m AHD
75.00
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH21
WVH22

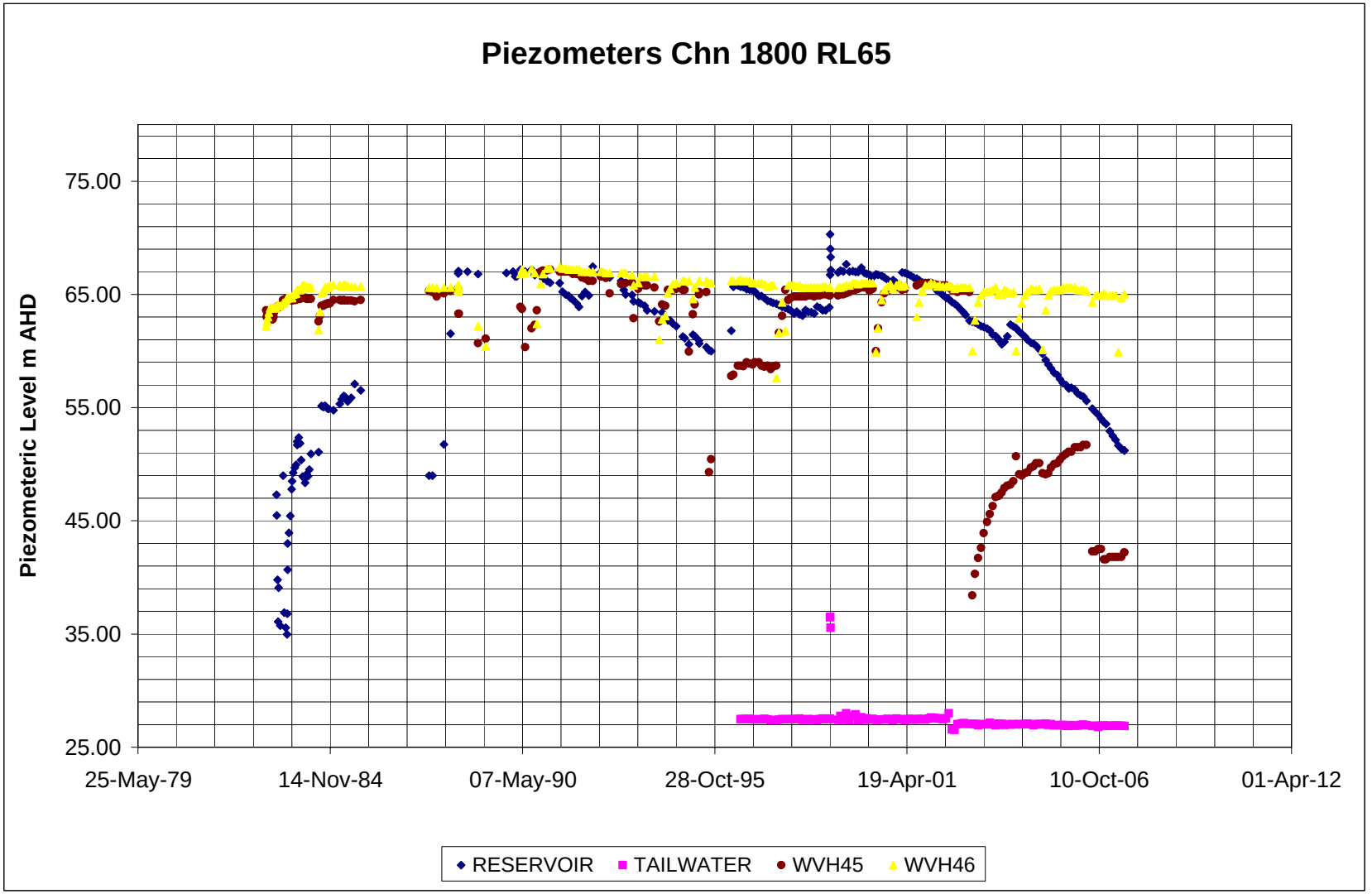

Piezometers Chn 1800 RL15
Piezometeric Level m AHD
85.00
75.00
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH25
WVH26
WVH27

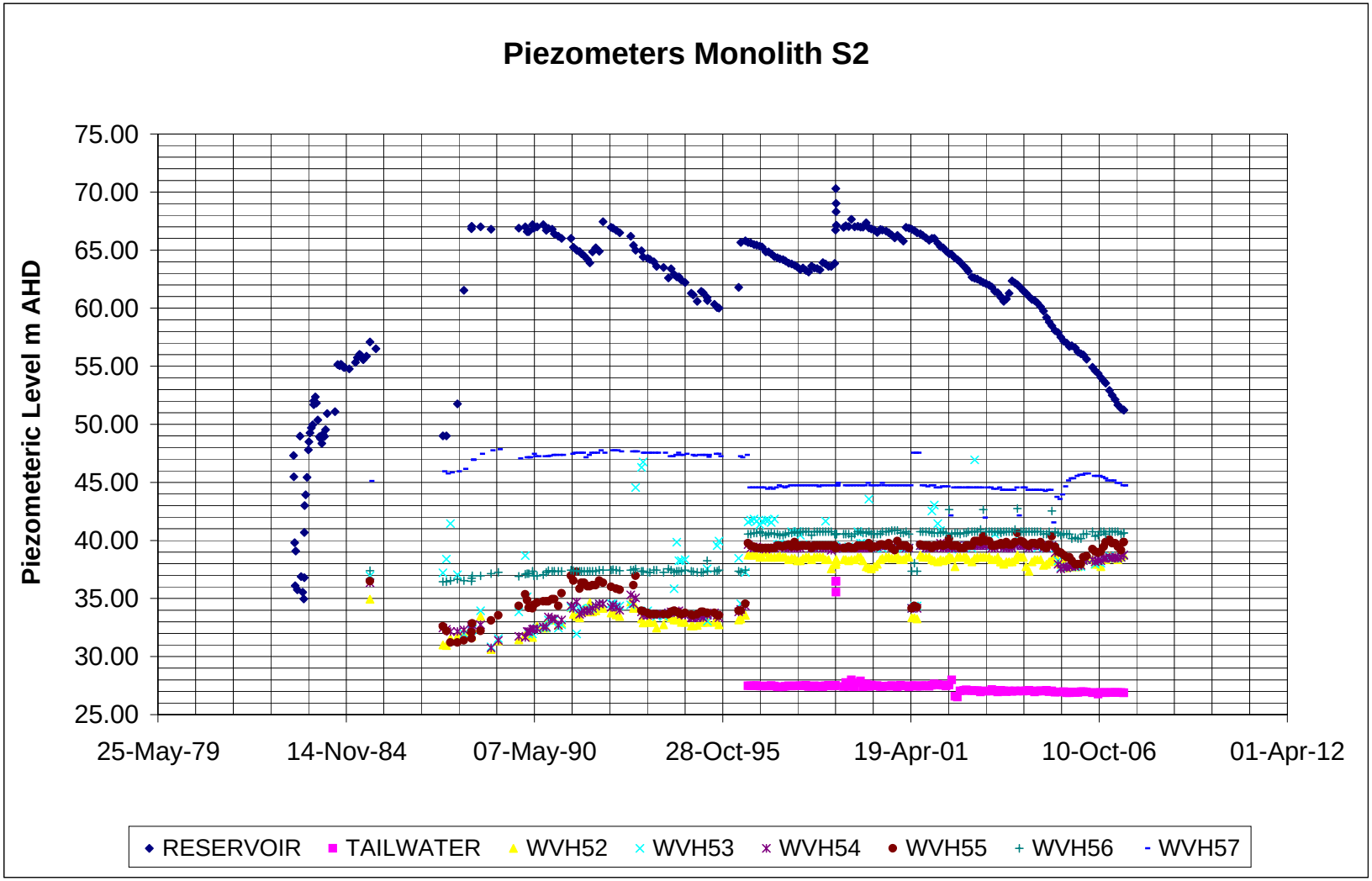

Piezometers Chn 1800 RL25
Piezometeric Level m AHD
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH28
WVH29
WVH30
WVH31
WVH32
WVH33

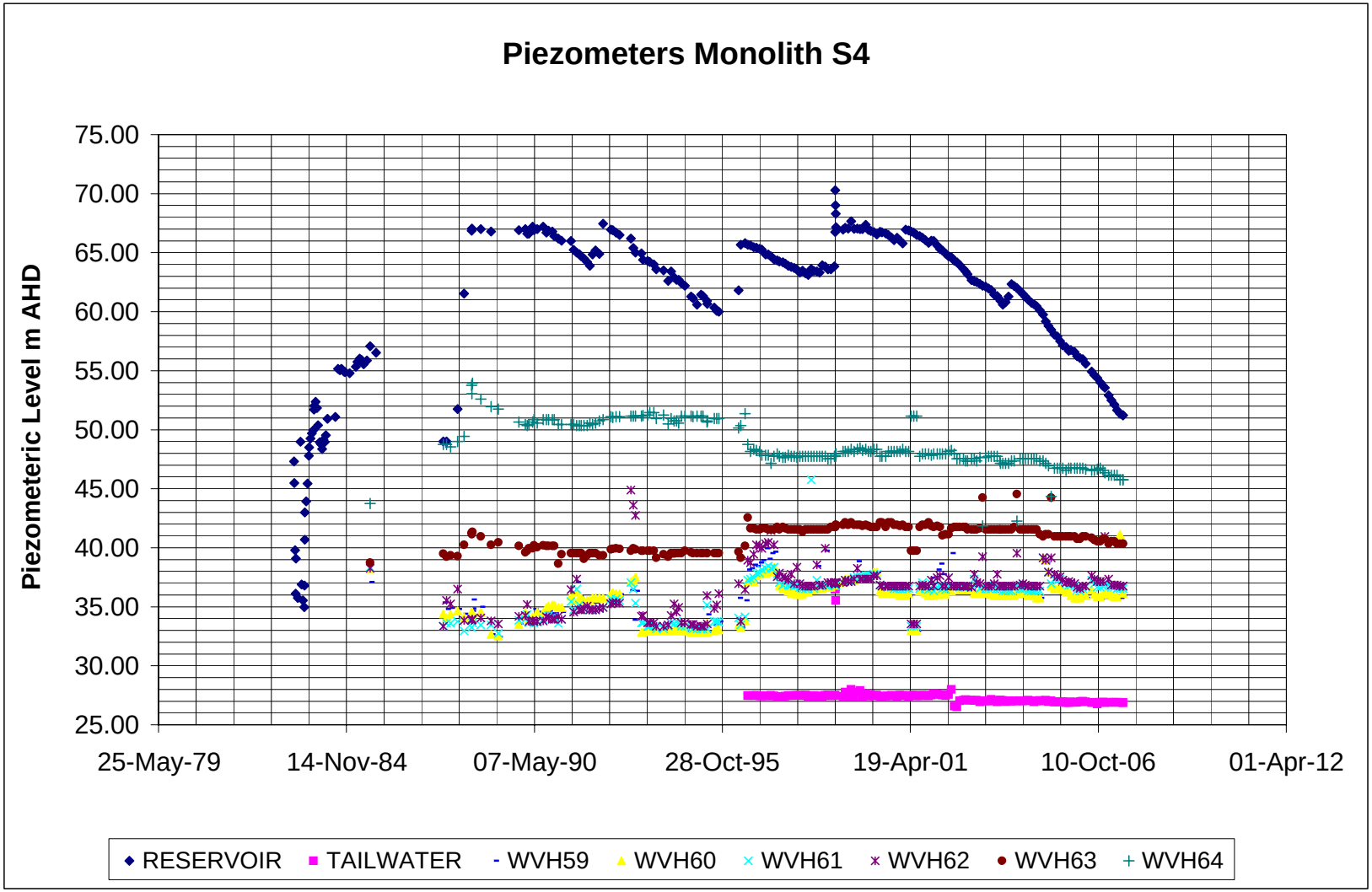

Piezometers Chn 1800 RL35
Piezometeric Level m AHD
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH34
WVH35
WVH36
WVH37
WVH23
WVH24


Piezometers Chn 1800 RL45
Piezometeric Level m AHD
75.00
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH38
WVH39
WVH40
WVH41


Piezometers Chn 1800 RL55
Piezometeric Level m AHD
75.00
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH42
WVH43
WVH44


Piezometers Chn 1800 RL65
Piezometeric Level m AHD
75.00
65.00
55.00
45.00
35.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH45
WVH46


Piezometers Monolith S2
Piezometeric Level m AHD
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH52
WVH53
WVH54
WVH55
WVH56
WVH57


Piezometers Monolith S4
Piezometeric Level m AHD
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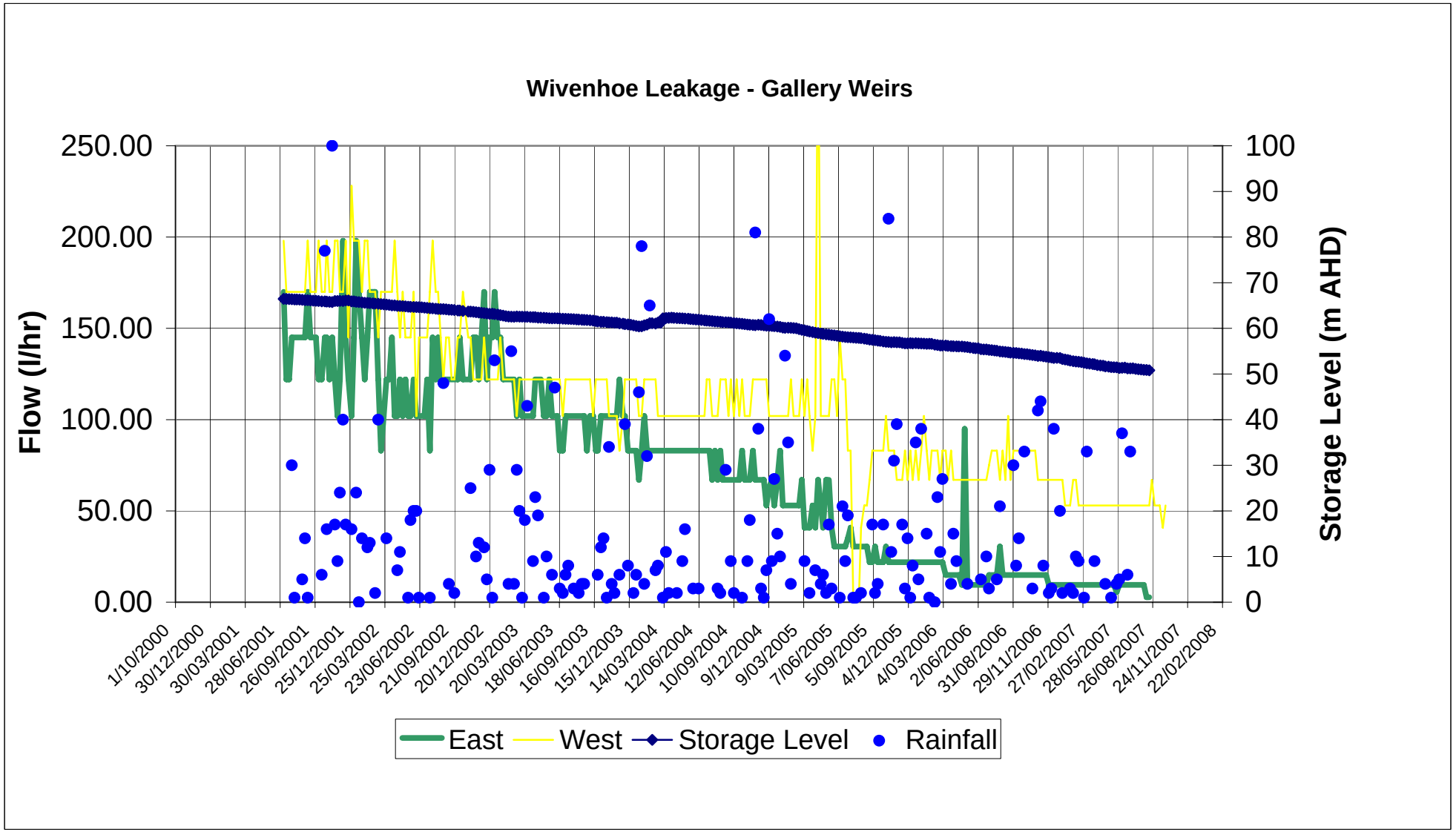
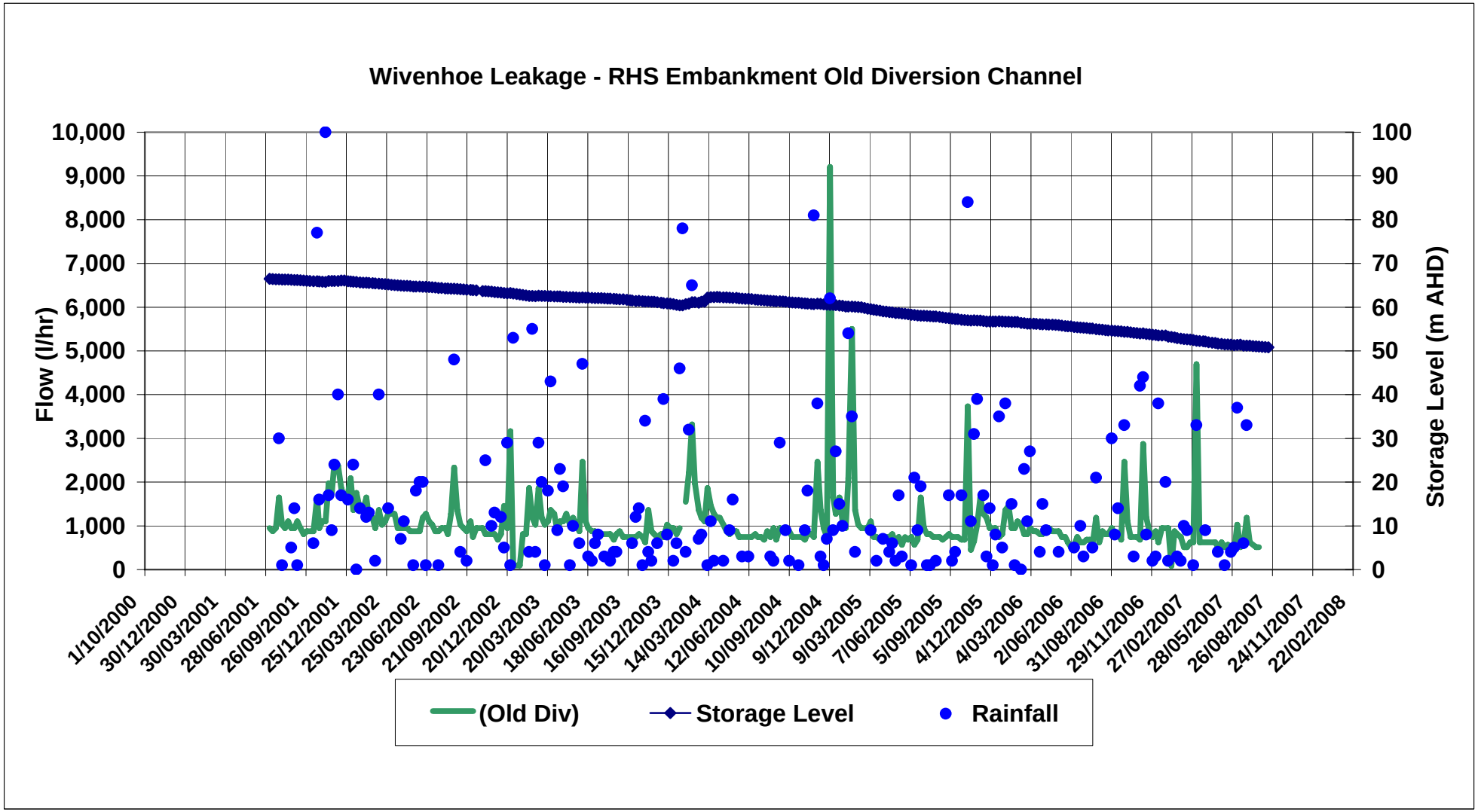
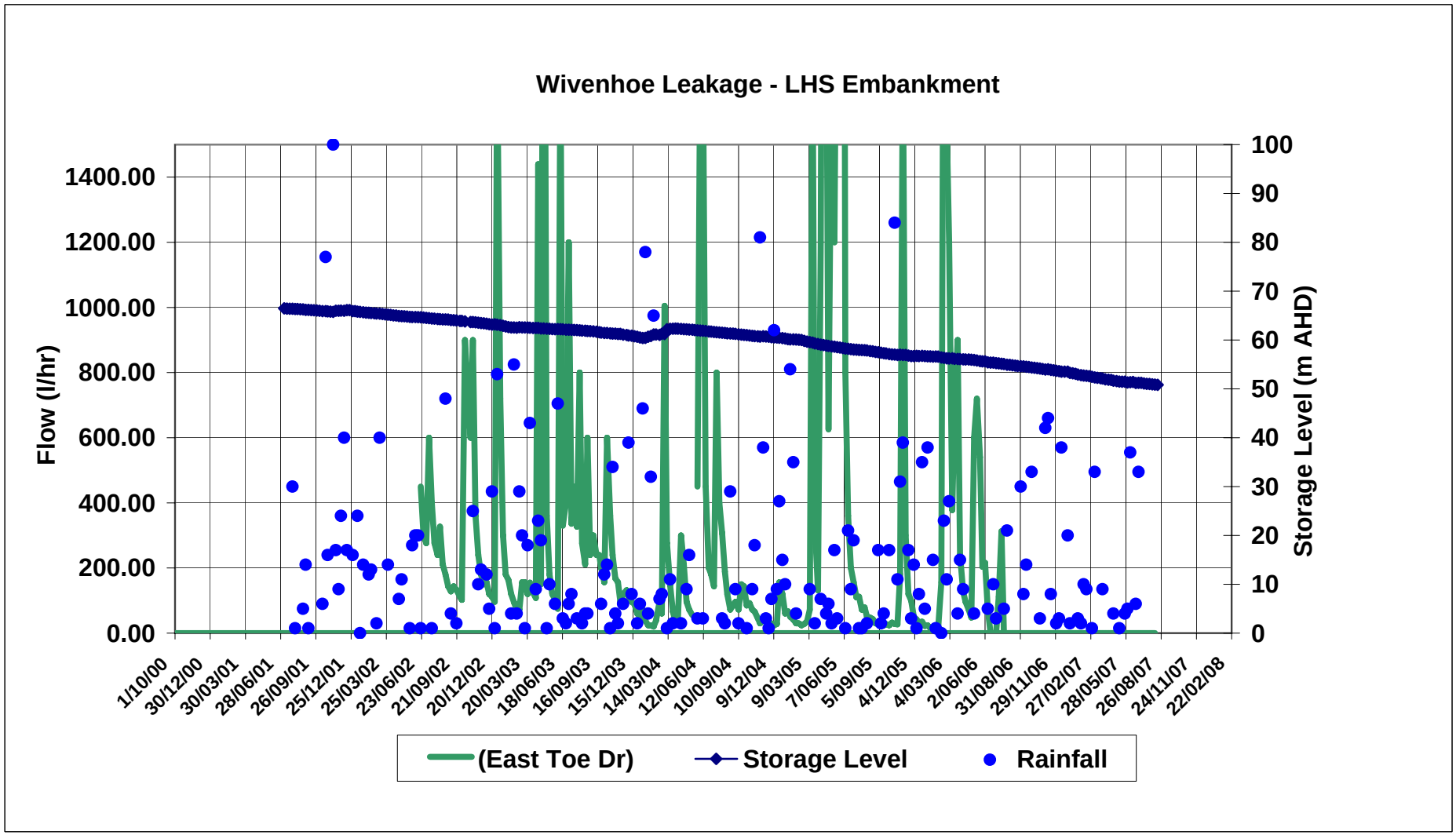
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
25-May-79
14-Nov-84
07-May-90
28-Oct-95
19-Apr-01
10-Oct-06
01-Apr-12
RESERVOIR
TAILWATER
WVH59
WVH60
WVH61
WVH62
WVH63
WVH64

Appendix C4 – Leakage Data

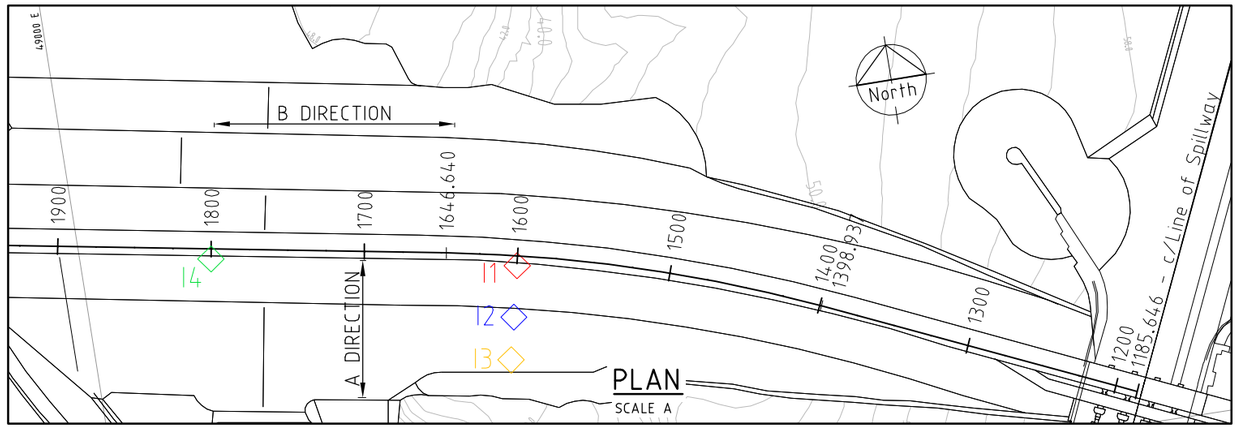


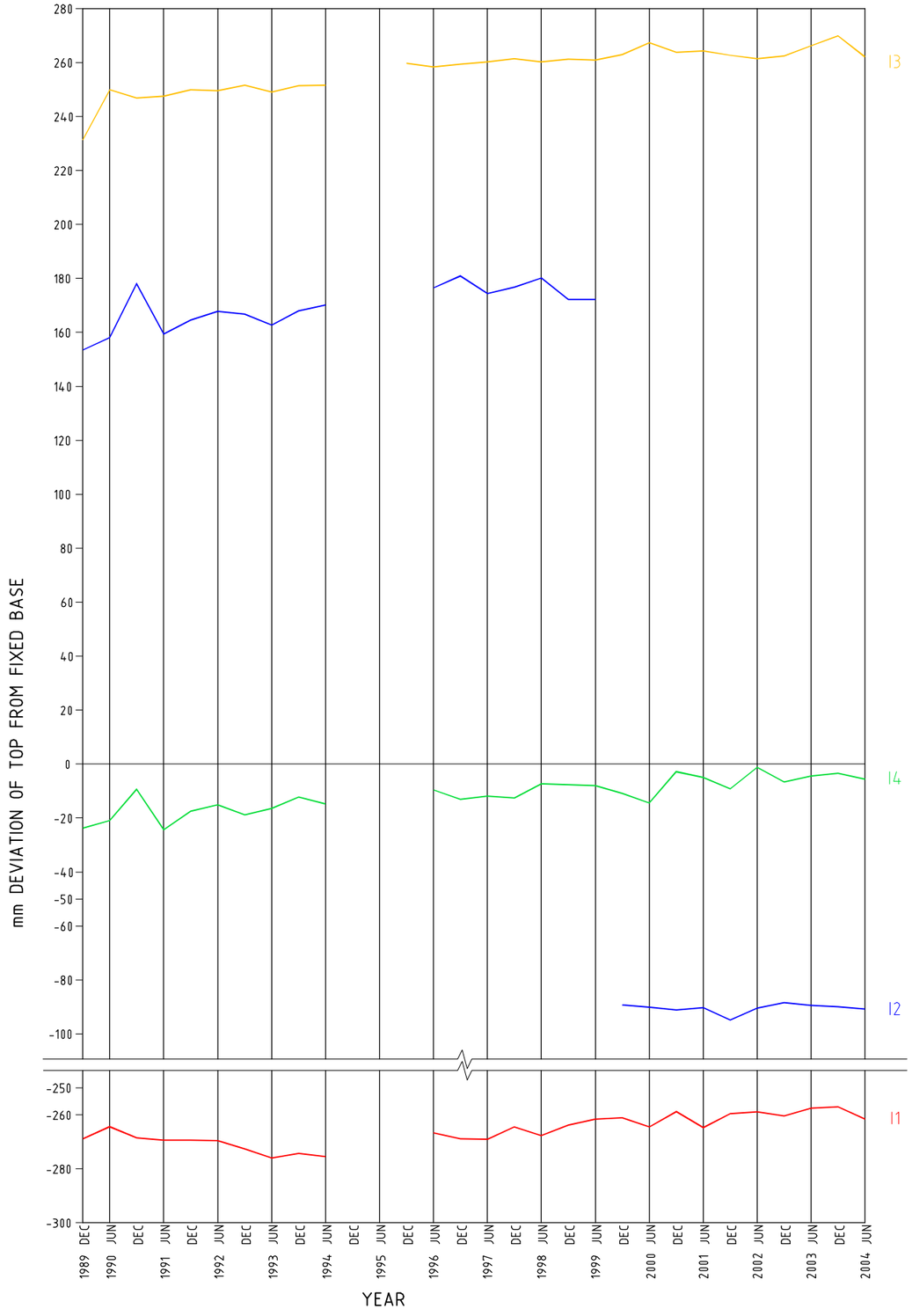
Gallery Leakage Plot


Wivenhoe Leakage - RHS Embankment Old Diversion Channel
Flow (l/hr)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Storage Level (m AHD)
100
90
80
70
60
50
40
30
20
10
0
1/10/2000
30/12/2000
30/03/2001
28/06/2001
26/09/2001
25/12/2001
25/03/2002
23/06/2002
21/09/2002
20/12/2002
20/03/2003
18/06/2003
16/09/2003
15/12/2003
14/03/2004
12/06/2004
10/09/2004
9/12/2004
9/03/2005
7/06/2005
5/09/2005
4/12/2005
4/03/2006
2/06/2006
31/08/2006
29/11/2006
27/02/2007
28/05/2007
26/08/2007
24/11/2007
22/02/2008
(Old Div)
Storage Level
Rainfall

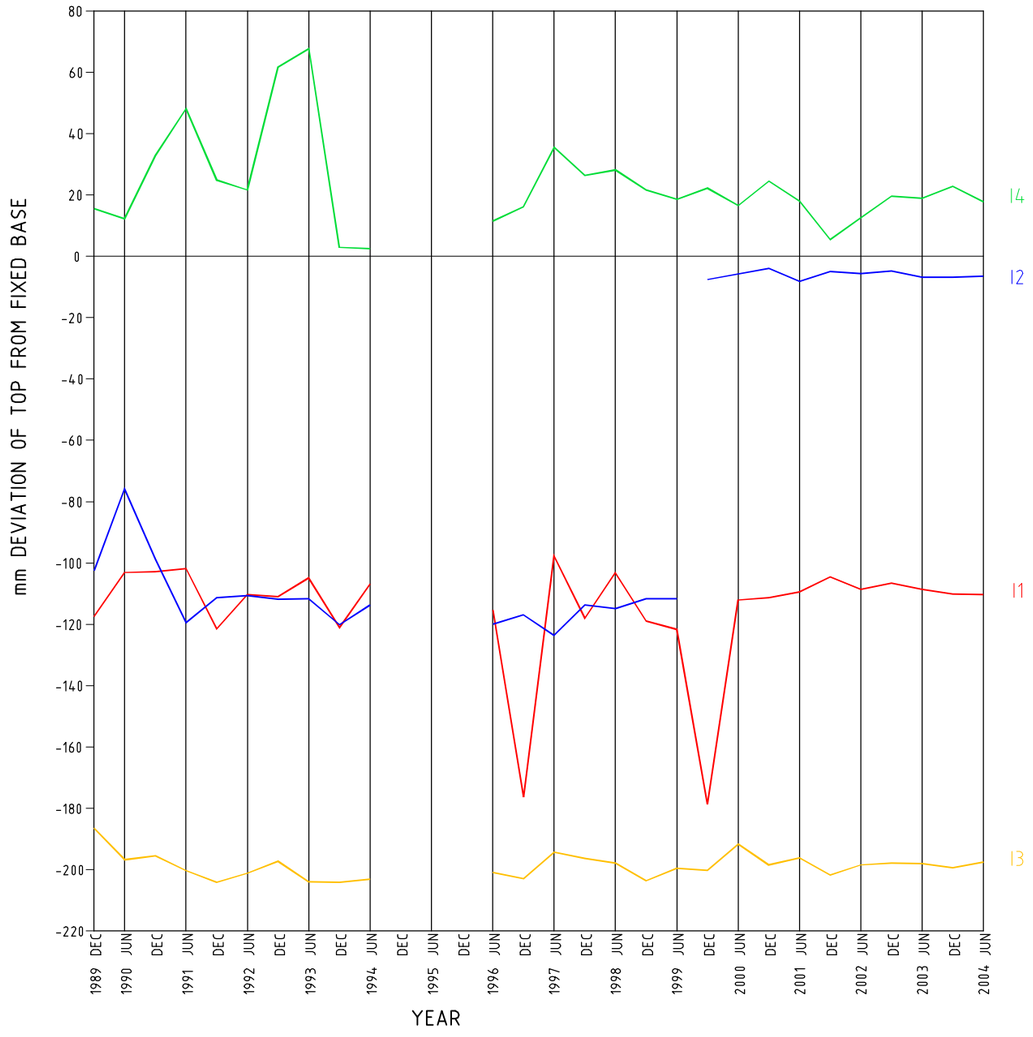

Wivenhoe Leakage - LHS Embankment
Flow (l/hr)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
Storage Level (m AHD)
100
90
80
70
60
50
40
30
20
10
0
1/10/00
30/12/00
30/03/01
28/06/01
26/09/01
25/12/01
25/03/02
23/06/02
21/09/02
20/12/02
20/03/03
18/06/03
16/09/03
15/12/03
14/03/04
12/06/04
10/09/04
9/12/04
9/03/05
7/06/05
5/09/05
4/12/05
4/03/06
2/06/06
31/08/06
29/11/06
27/02/07
28/05/07
26/08/07
24/11/07
22/02/08
(East Toe Dr)
Storage Level
Rainfall

Appendix C5 – Inclinometer Data





mm DEVIATION IN 'A' DIRECTION



mm DEVIATION IN 'B' DIRECTION

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

OVERALL MAP 0 20 40 60 80 100m
1 : 4000 (A3) 1 : 2000 (A1)

DEVIATION 0 10 20 30 40 50mm
1 : 2 (A3) 1 : 1 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DETAIL\60020162-131.dwg
Last modified: 23 Nov 06 - 13:21

MAUNSELL AECOM

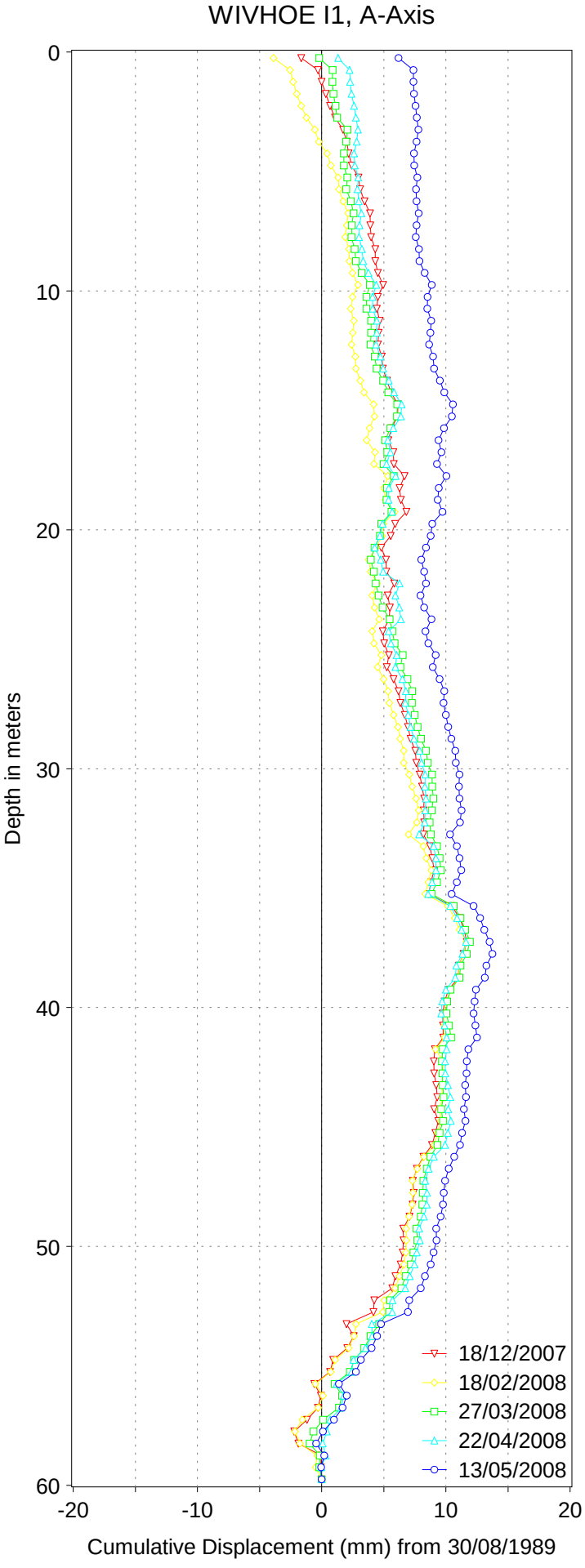
Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

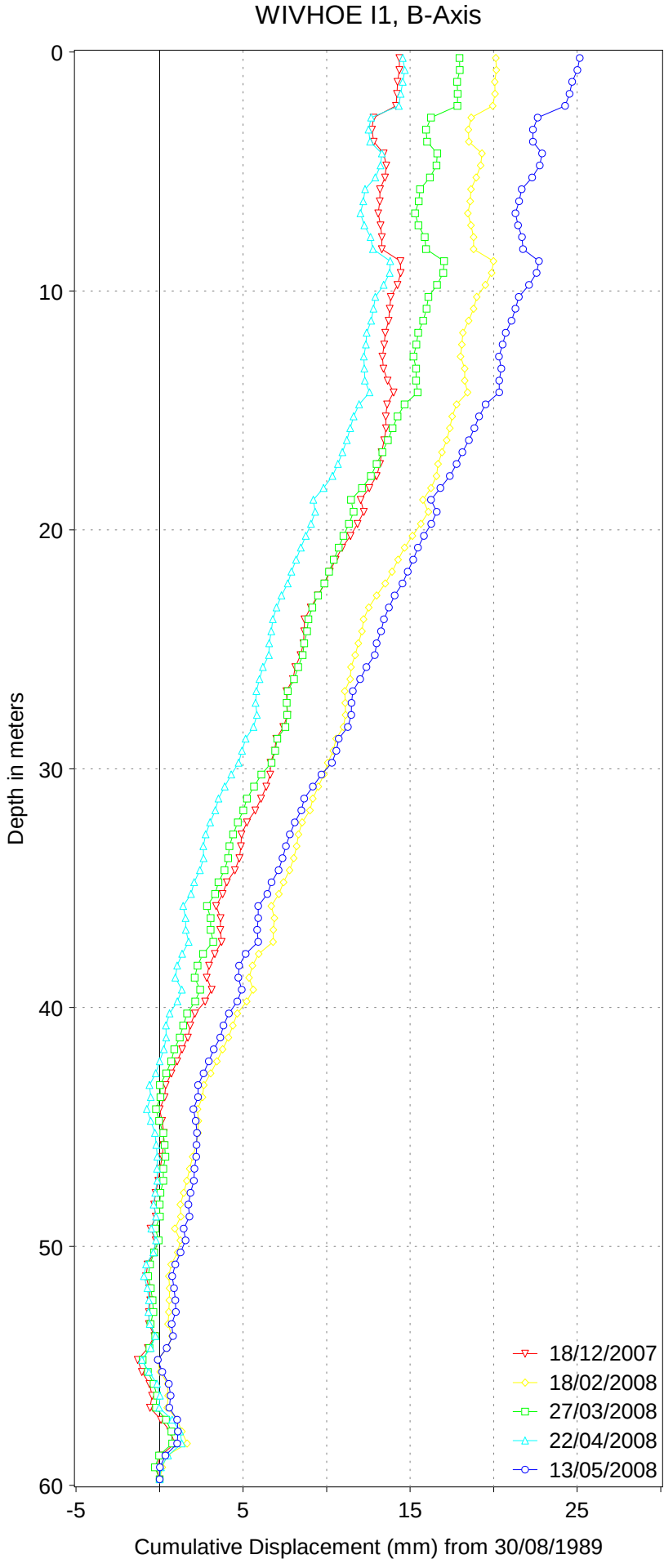
DAM SURVEILLANCE

WIVENHOE DAM
MAIN EMBANKMENT SECTIONS
INCLINOMETER INSTALLATIONS

Status	Drg No.	Rev.
	60020162-131	

Xref's contours,DAM_CADASTRAL,EX_BLDGS,ex_dam survey_base,SPILLWAY_RHS,Maunsell-A1.MRG, CHAINAGE





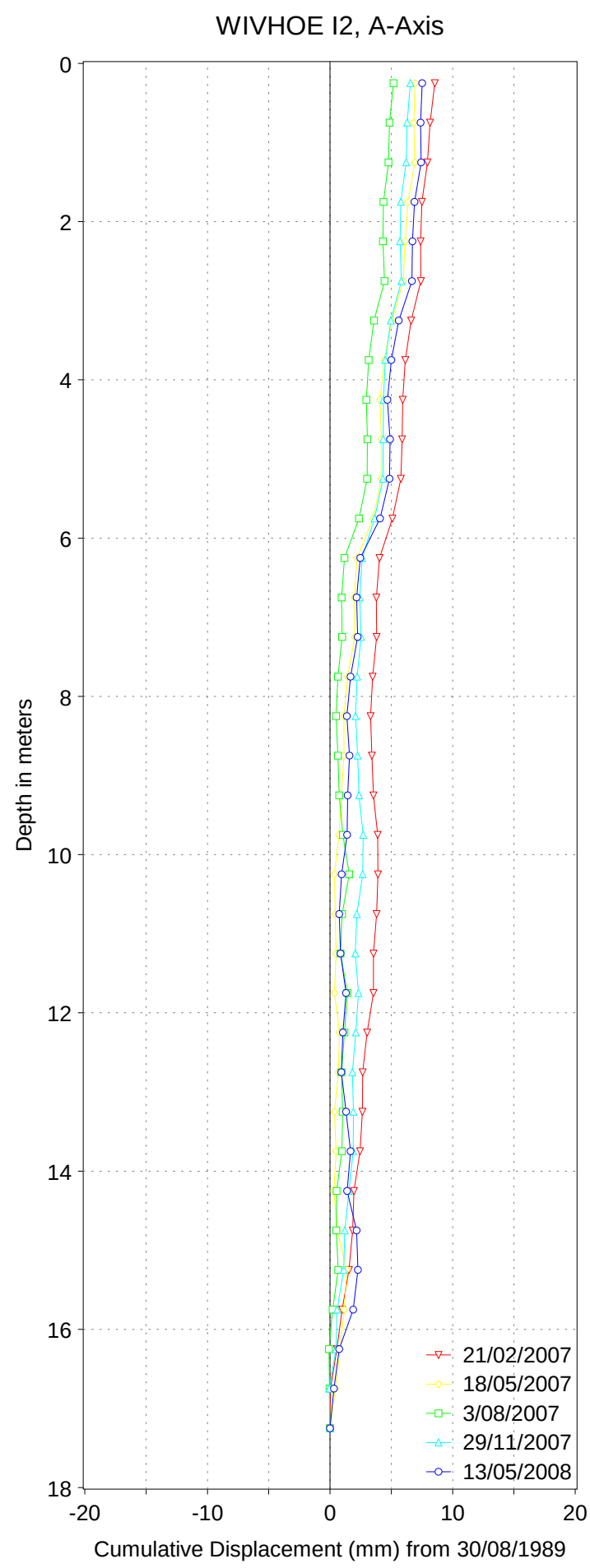
WIVENHOE DAM

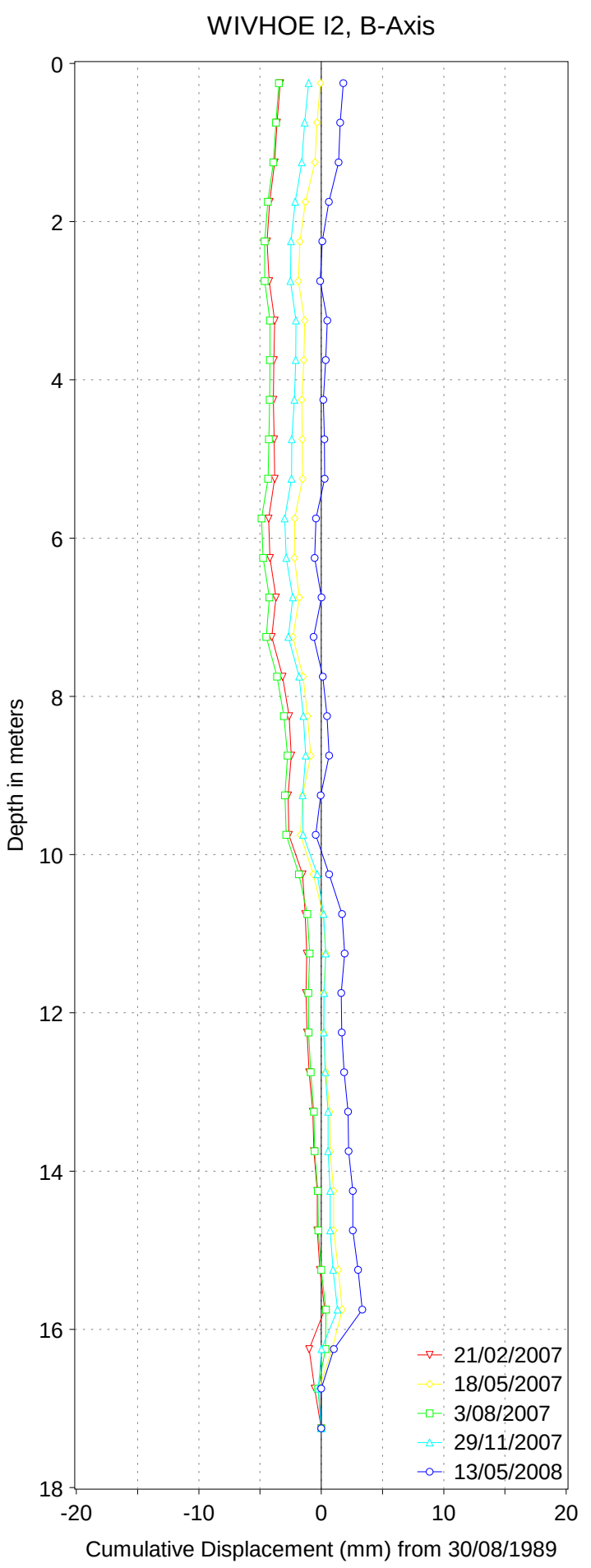
Inclinometer I1- Cumulative Displacement Report

Comparing the latest 5 readings with 30/08/1989

A axis faces Downstream

B axis is to the right





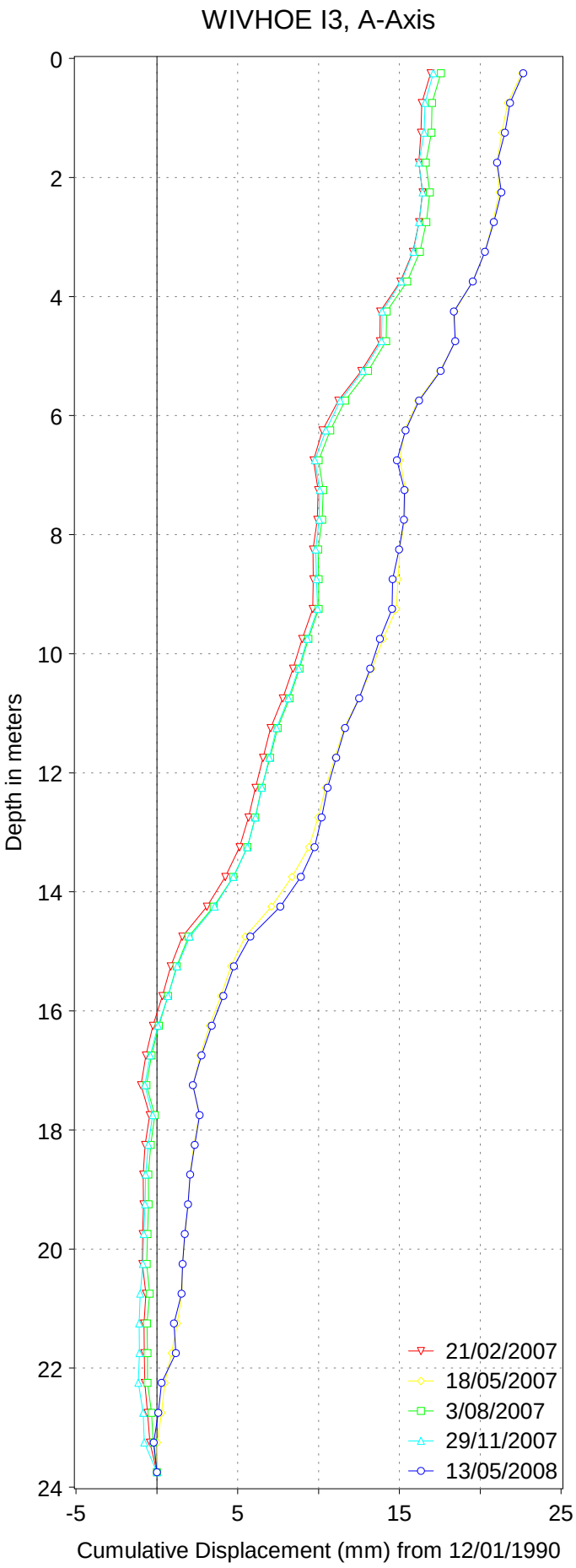
WIVENHOE DAM

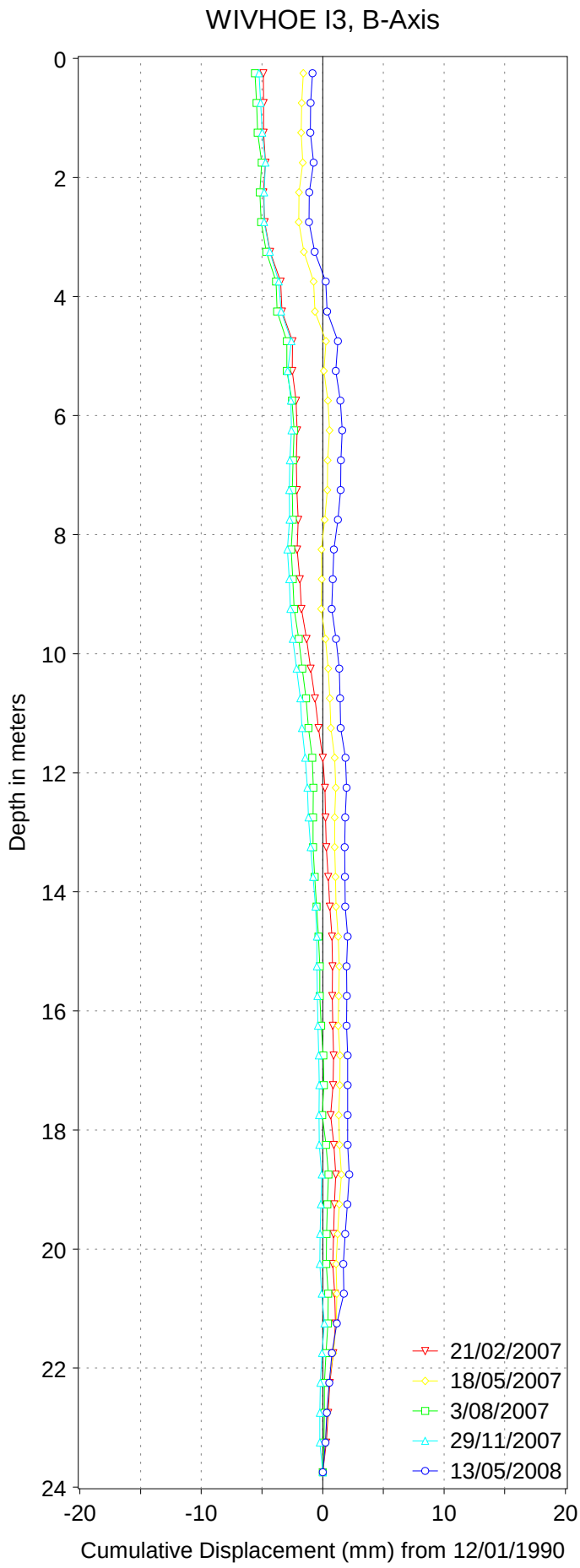
Inclinometer I2

Comparing the latest 5 readings with 30/08/1989

A axis faces Downstream

B axis is to the right





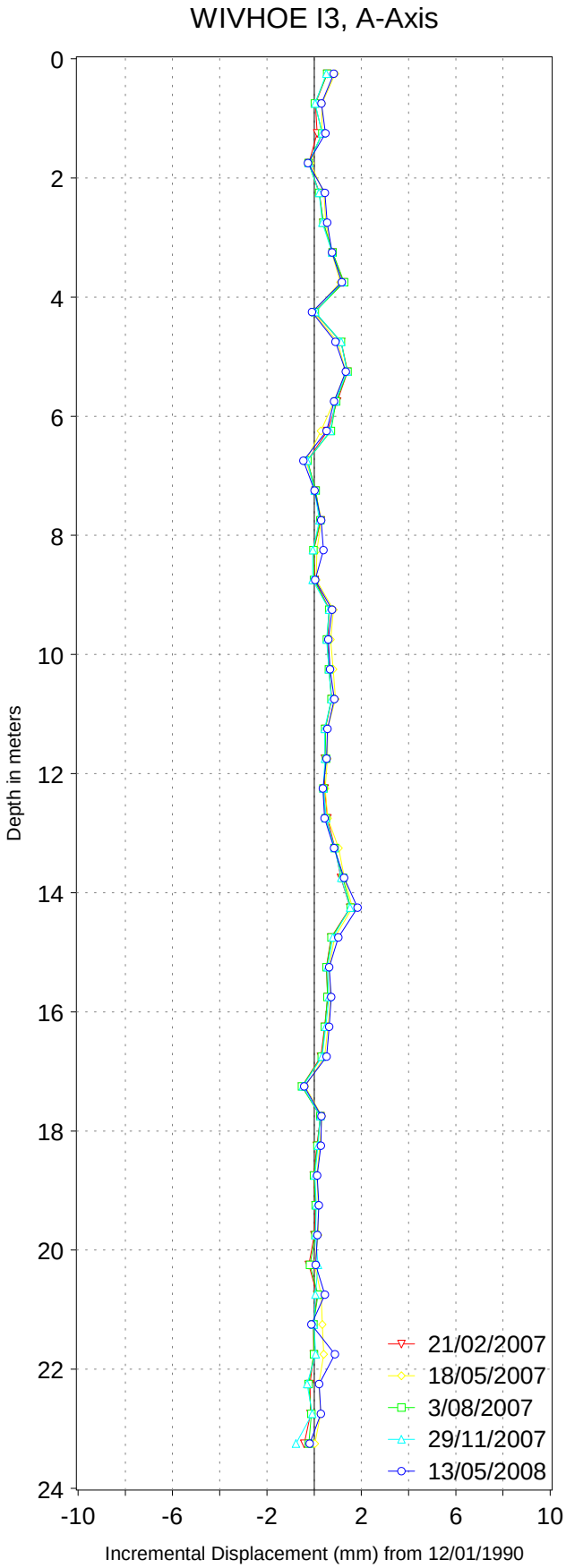
WIVENHOE DAM

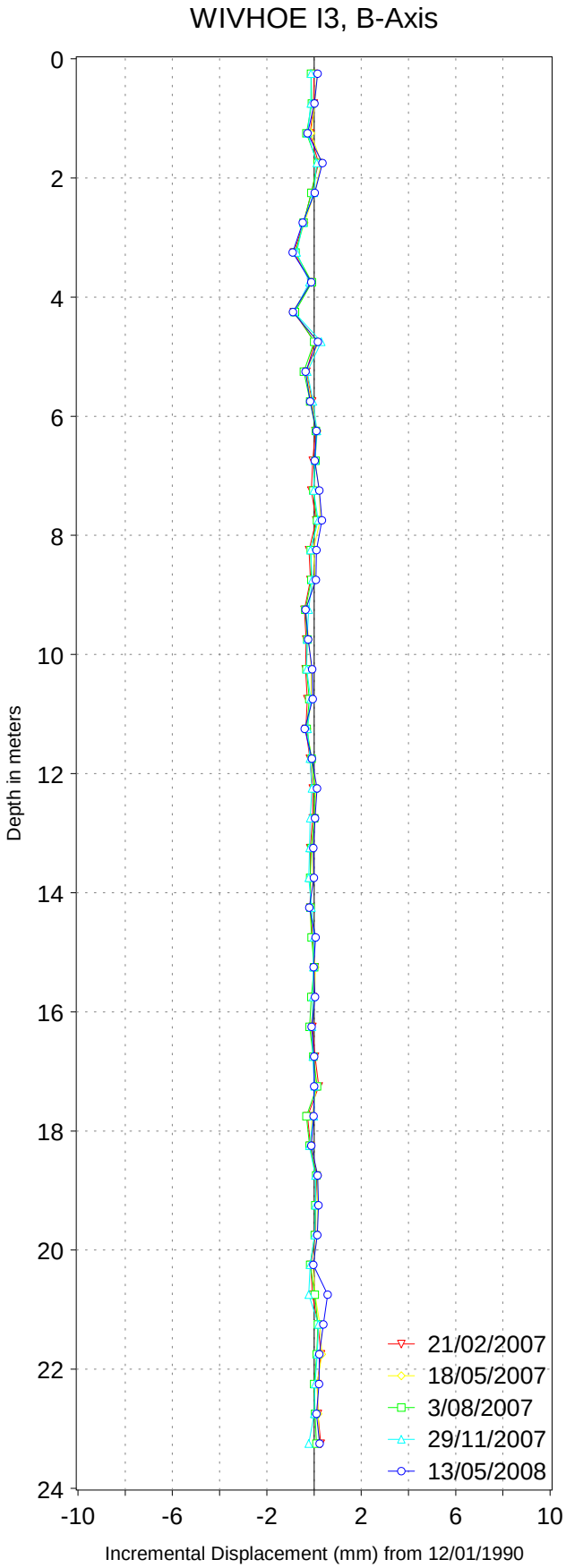
Inclinometer I3

Comparing the latest 5 readings with 12/01/1990

A axis faces Downstream

B axis is to the right





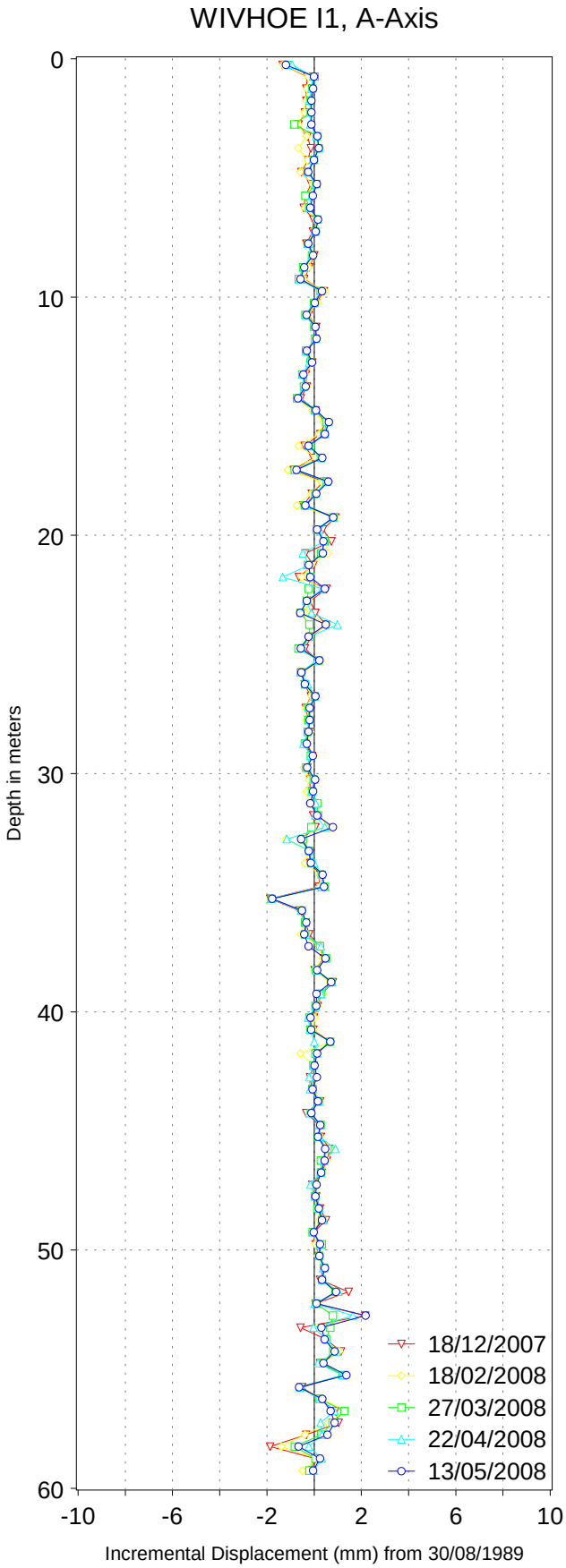
WIVENHOE DAM

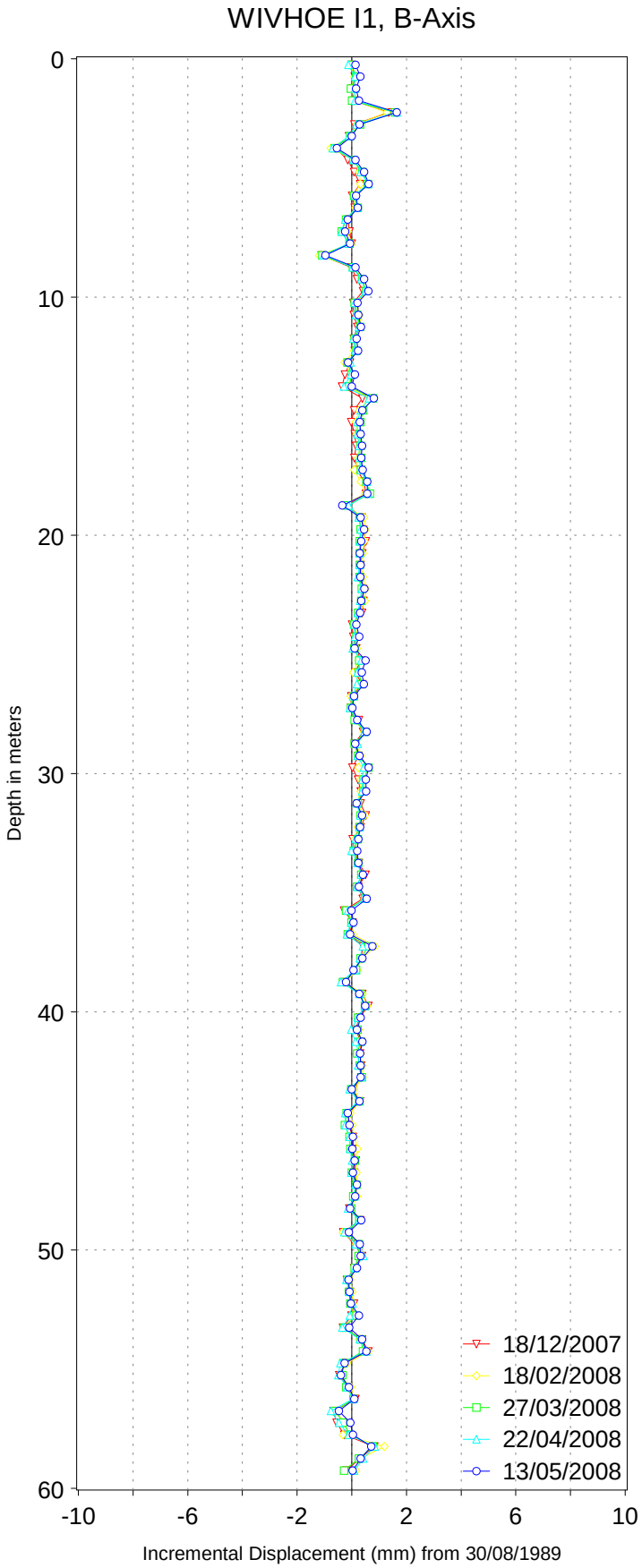
Inclinometer I3

Comparing the latest 5 readings with 12/01/1990

A axis faces downstream

B axis is to the right





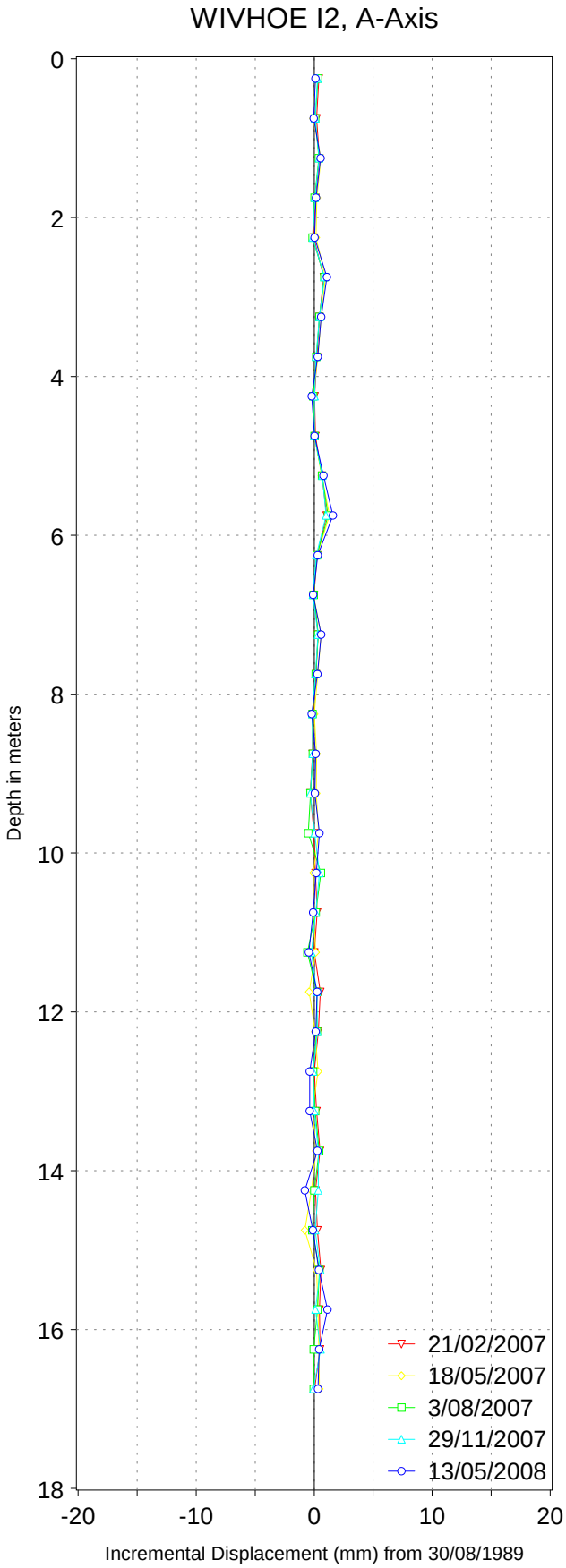
WIVENHOE DAM

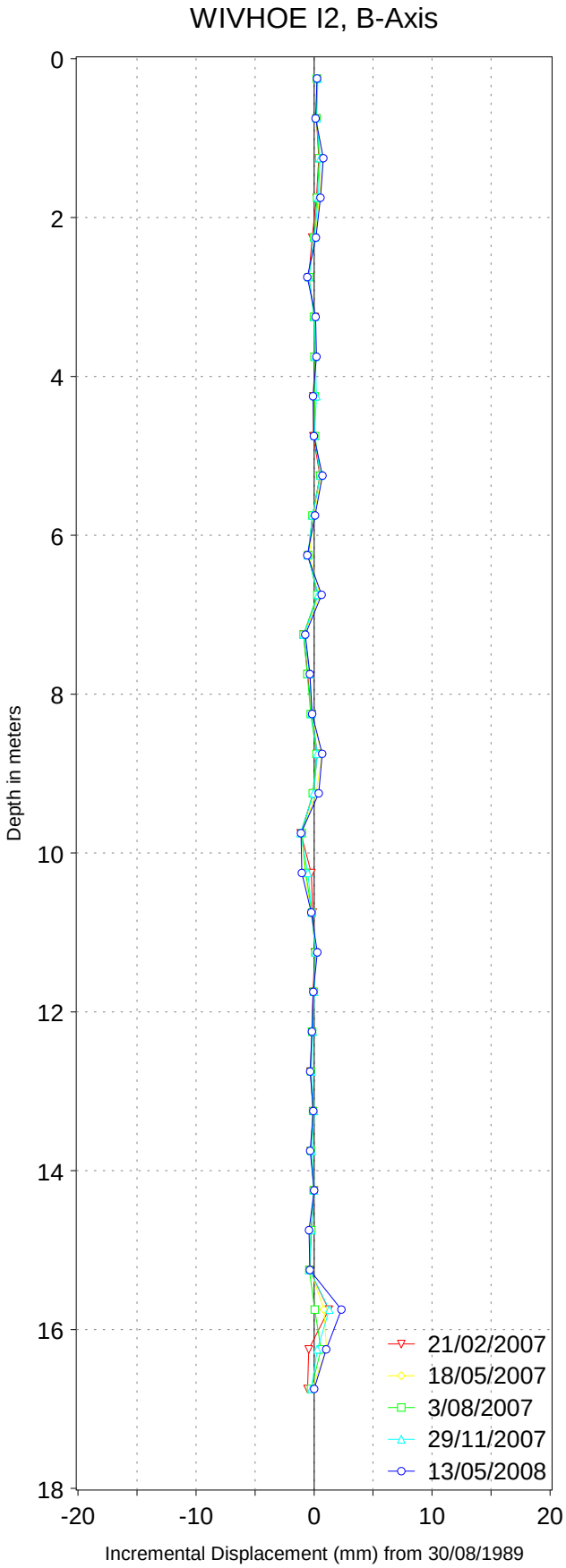
Inclinometer I1- Incremental Displacement Report

Comparing the last 5 readings with 30/08/1989

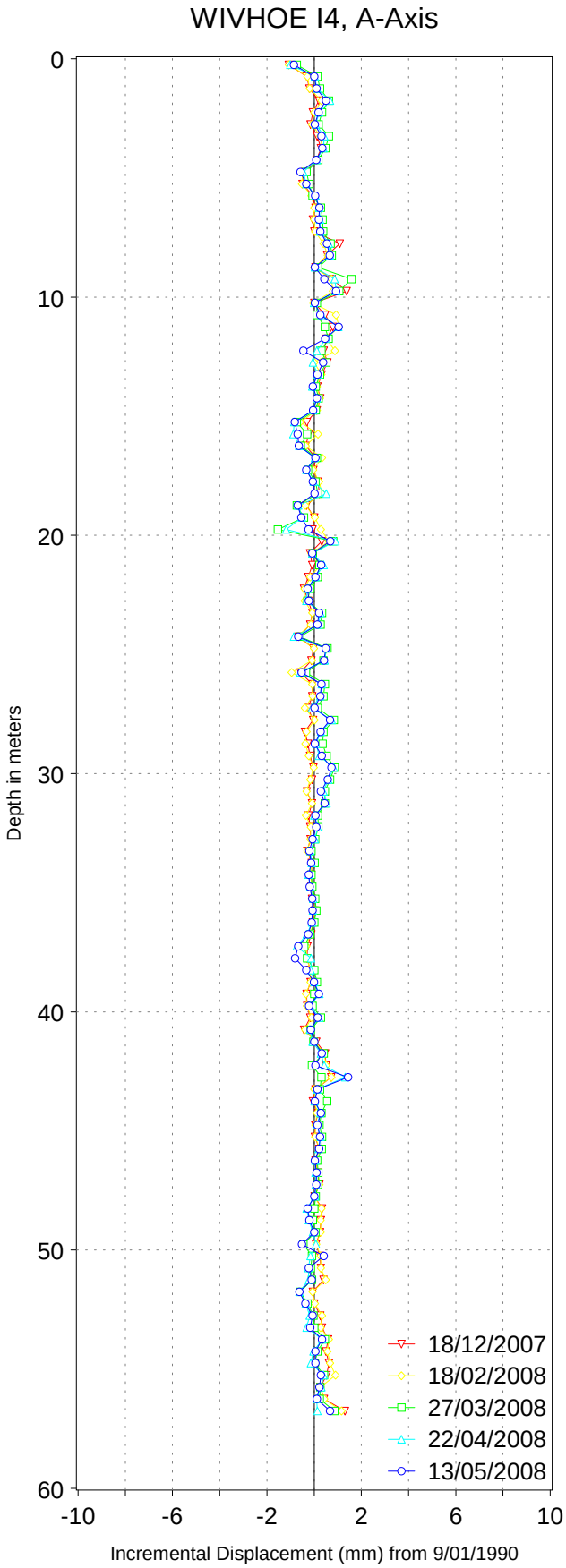
A axis faces downstream

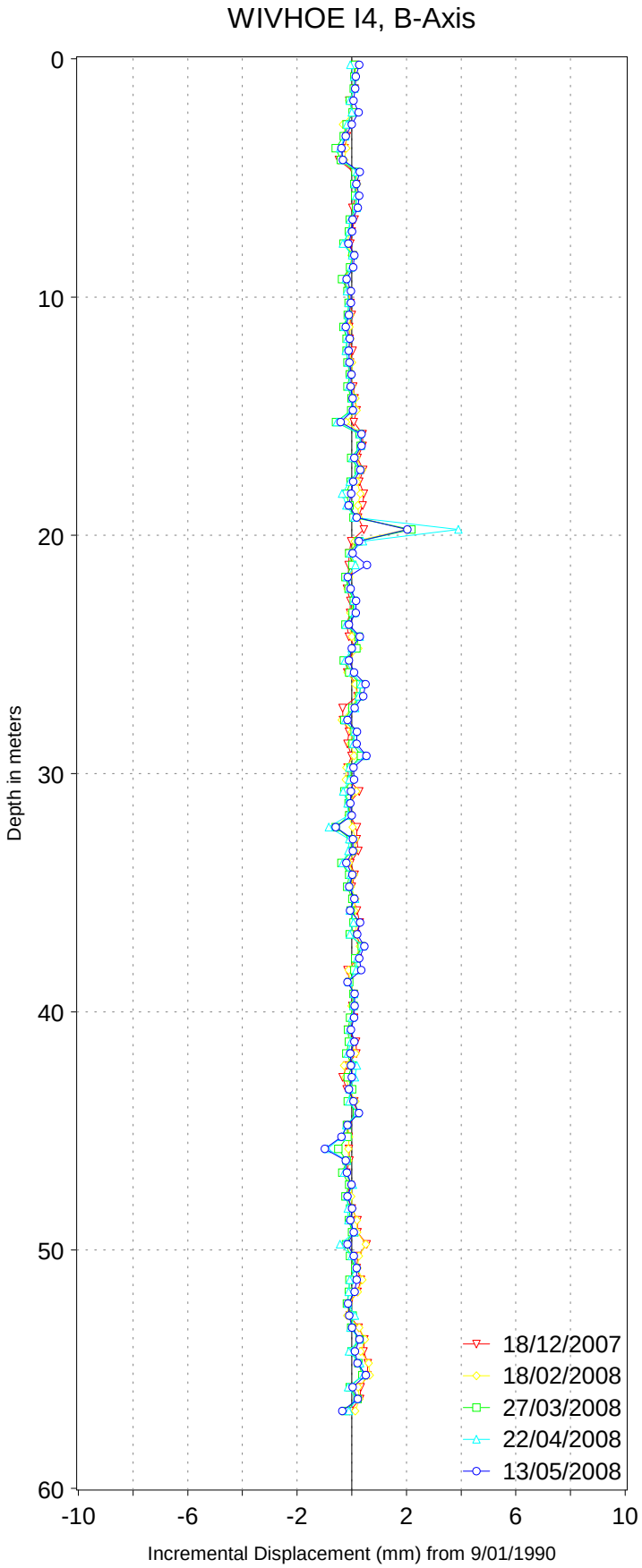
B axis faces to the right





Wivenhoe Dam
Inclinometer I2
Comparing latest 5 readings with 30/08/1989
A axis faces downstream B axis is to the right





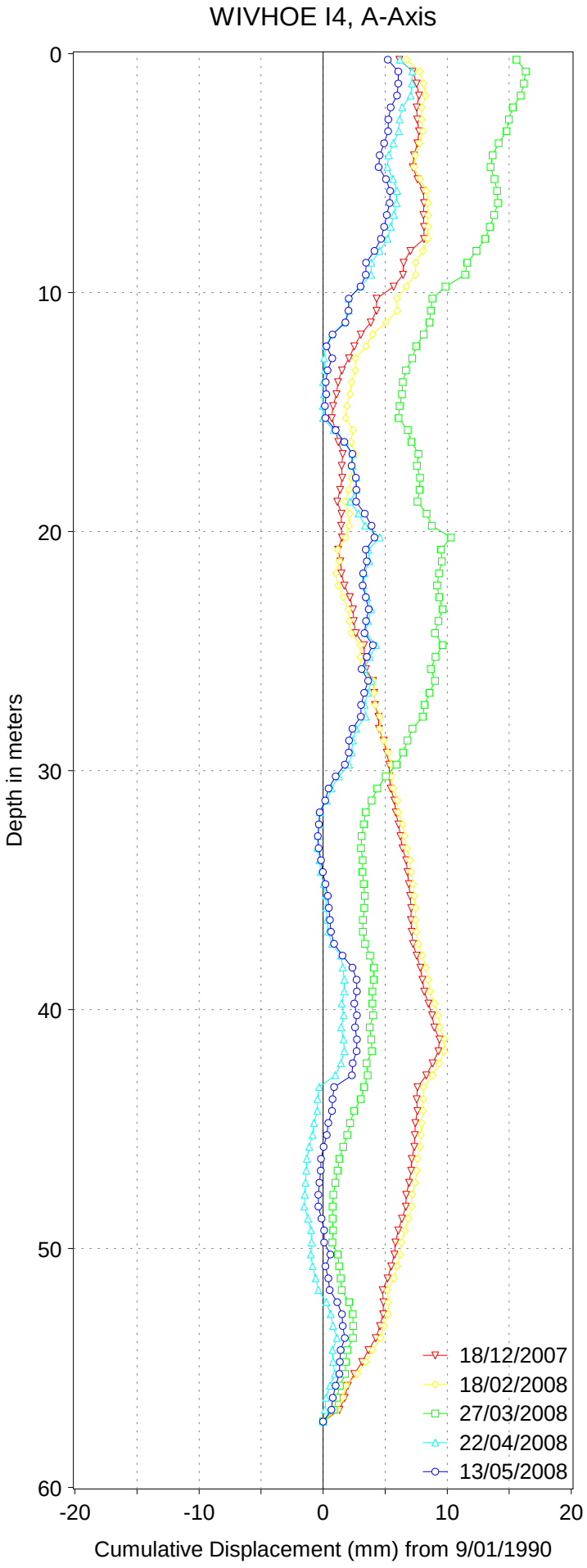
WIVENHOE DAM

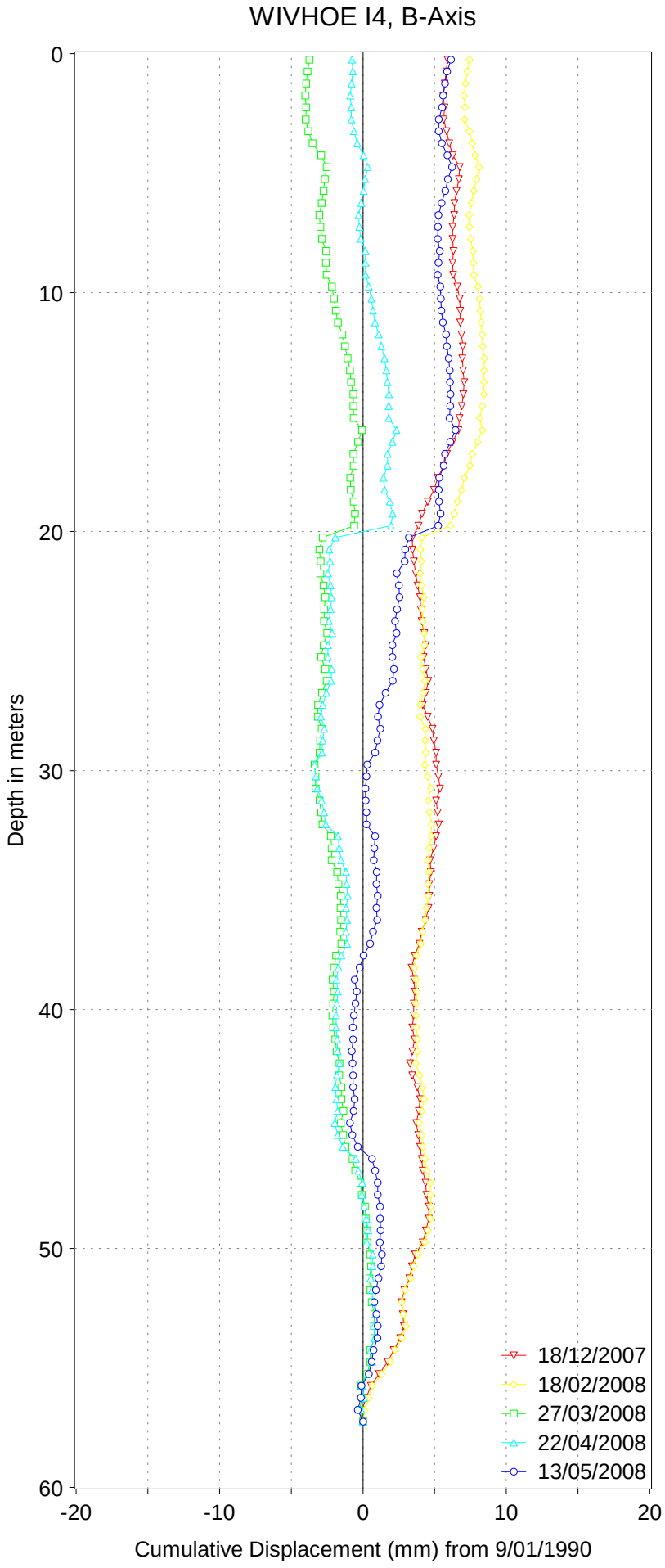
Inclinometer I4- Incremental Displacement Report

Comparing the last 5 readings with 09/01/1990

A axis faces downstream

B axis is to the right





WIVENHOE DAM

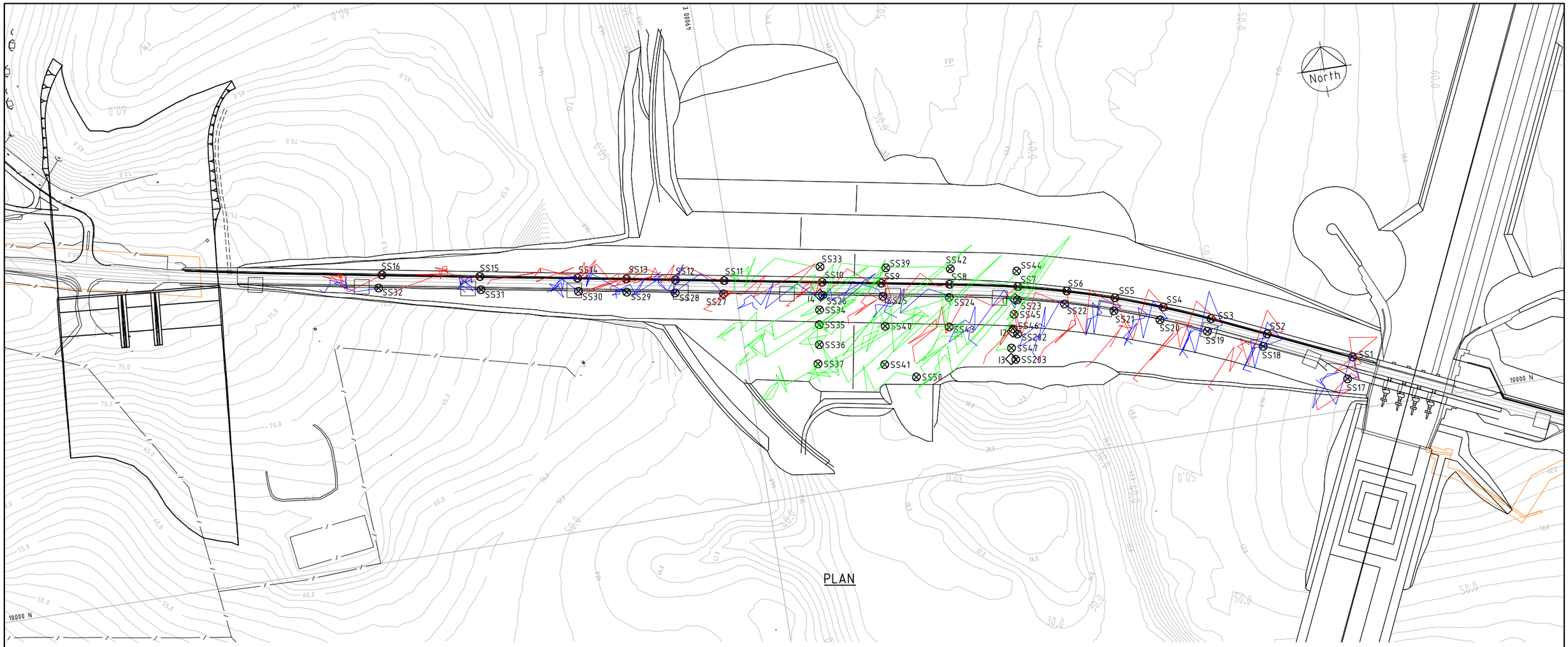
Inclinometer I4- Cumulative Displacement Report

Comparing the latest 5 readings with 9/01/1990

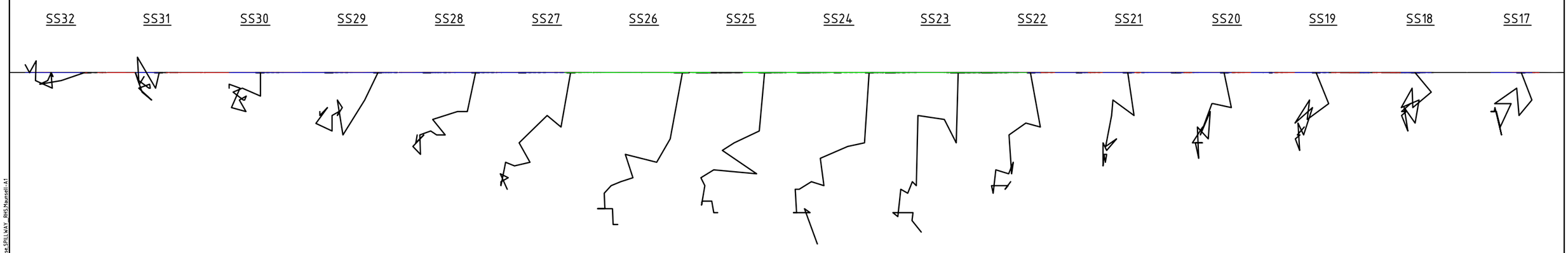
A axis faces Downstream

B axis is to the right

Appendix C6 - Surface Movement Survey



PLAN



ELEVATION VIEW
PERPENDICULAR TO DAM WALL AT EACH INSTALLATION

No.	BY	DATE	DESCRIPTION	APPD

REVISIONS

Scale

OVERALL MAP 0 20 40 60 80 100m
1 : 4000 (A3) 1 : 2000 (A1)

MOVEMENTS 0 10 20 25mm
1 : 1 (A3) 1 : 0.5 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DRAWINGS\60020162-111.dwg
Last modified: 02 Mar 07 - 16:22

MAUNSELL AECOM

Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

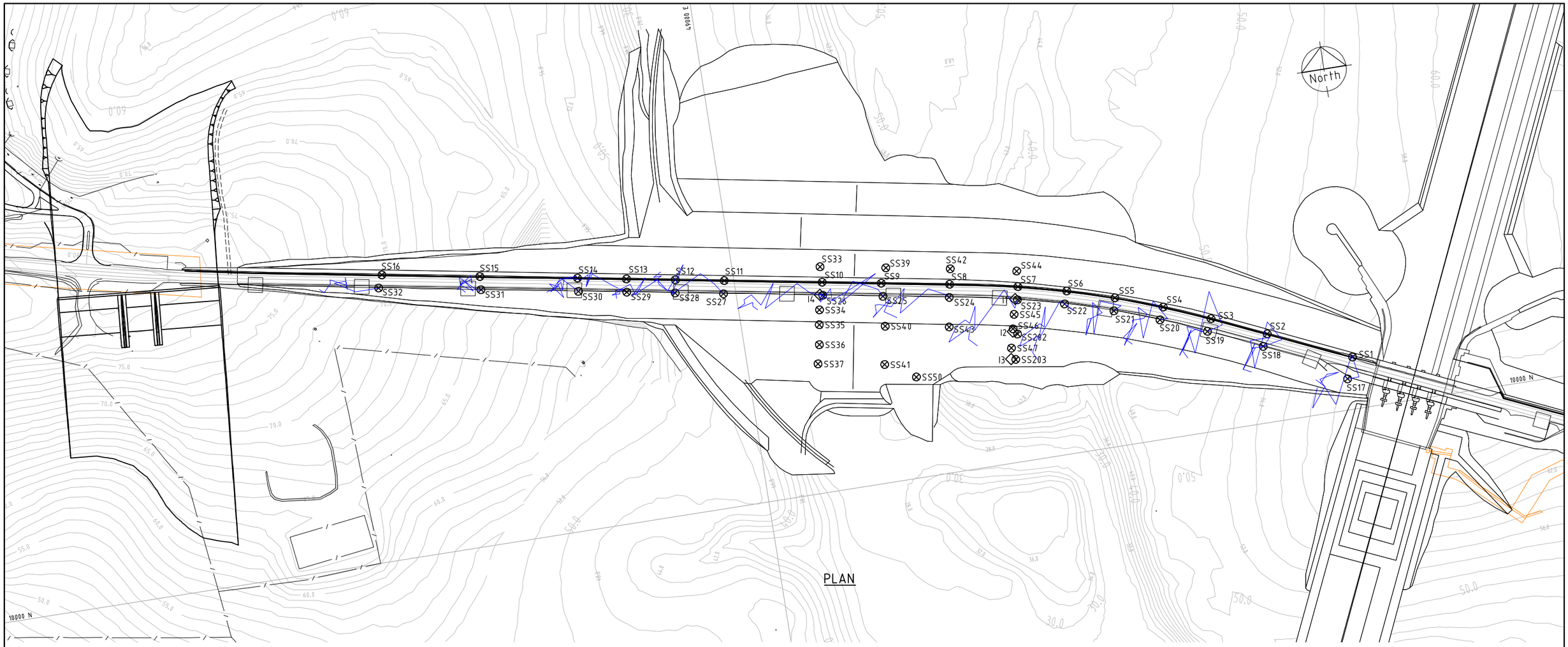
WIVENHOE DAM
MAIN EMBANKMENT PLAN
SURFACE MOVEMENT INSTALLATIONS

Status

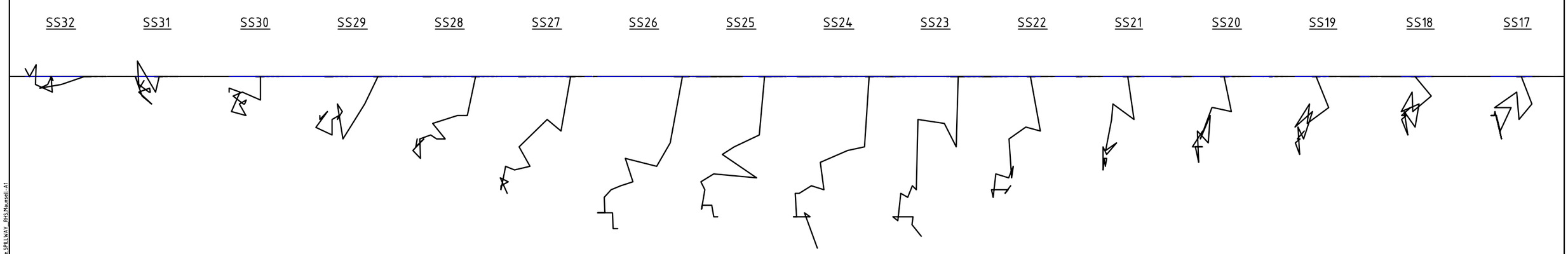
Drg No. 60020162-111

Rev.

Xref's contour;DAM_CADASTRAL;EX_BLDGS;ex_dam;survey_base;SPILLWAY_RNS;Maunsell_A1



PLAN



ELEVATION VIEW
PERPENDICULAR TO DAM WALL AT EACH INSTALLATION

No.	BY	DATE	DESCRIPTION	APPD

REVISIONS

Scale

OVERALL MAP 0 20 40 60 80 100m
1 : 4000 (A3) 1 : 2000 (A1)

MOVEMENTS 0 10 20 25mm
1 : 1 (A3) 1 : 0.5 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED		CHECKED	
DRAWN		CHECKED	
APPROVED		DATE	

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MAUNSELL AECOM

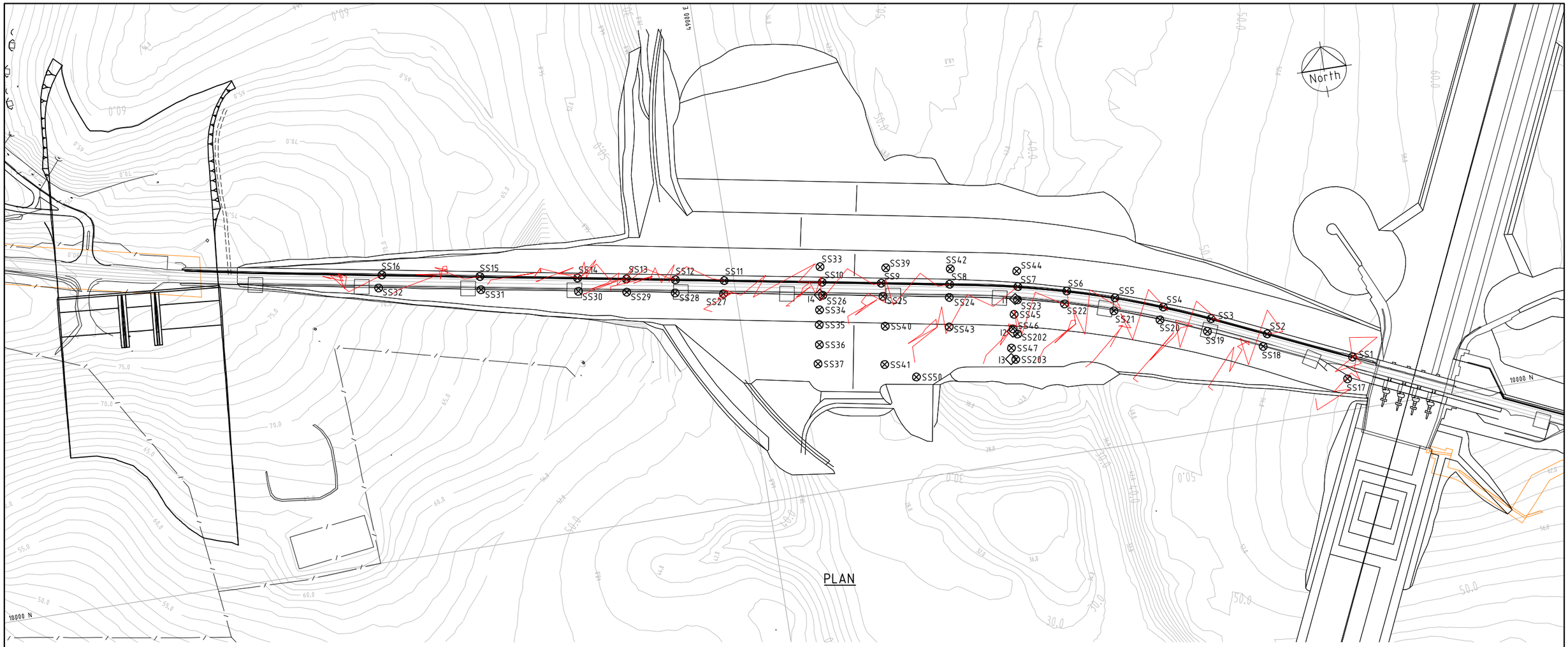
Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

WIVENHOE DAM
MAIN EMBANKMENT PLAN
SURFACE MOVEMENT INSTALLATIONS - D/S FACE ONLY

Status	Drg No.	Rev.
	60020162-111a	

Xref's: contour;DAM_CADASTRAL;EX_BLDGS;ex_dam;survey_base;SPILLWAY_RNS;Maunsell_A1



PLAN

This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

OVERALL MAP 0 20 40 60 80 100m
1 : 4000 (A3) 1 : 2000 (A1)

MOVEMENTS 0 10 20 25mm
1 : 1 (A3) 1 : 0.5 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED		CHECKED	
DRAWN		CHECKED	
APPROVED		DATE	

Cad ref: J:\mmpl\60020162\Cad\DRAWINGS\60020162-111b.dwg
Last modified: 02 Mar 07 - 16:18

MAUNSELL | AECOM

Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

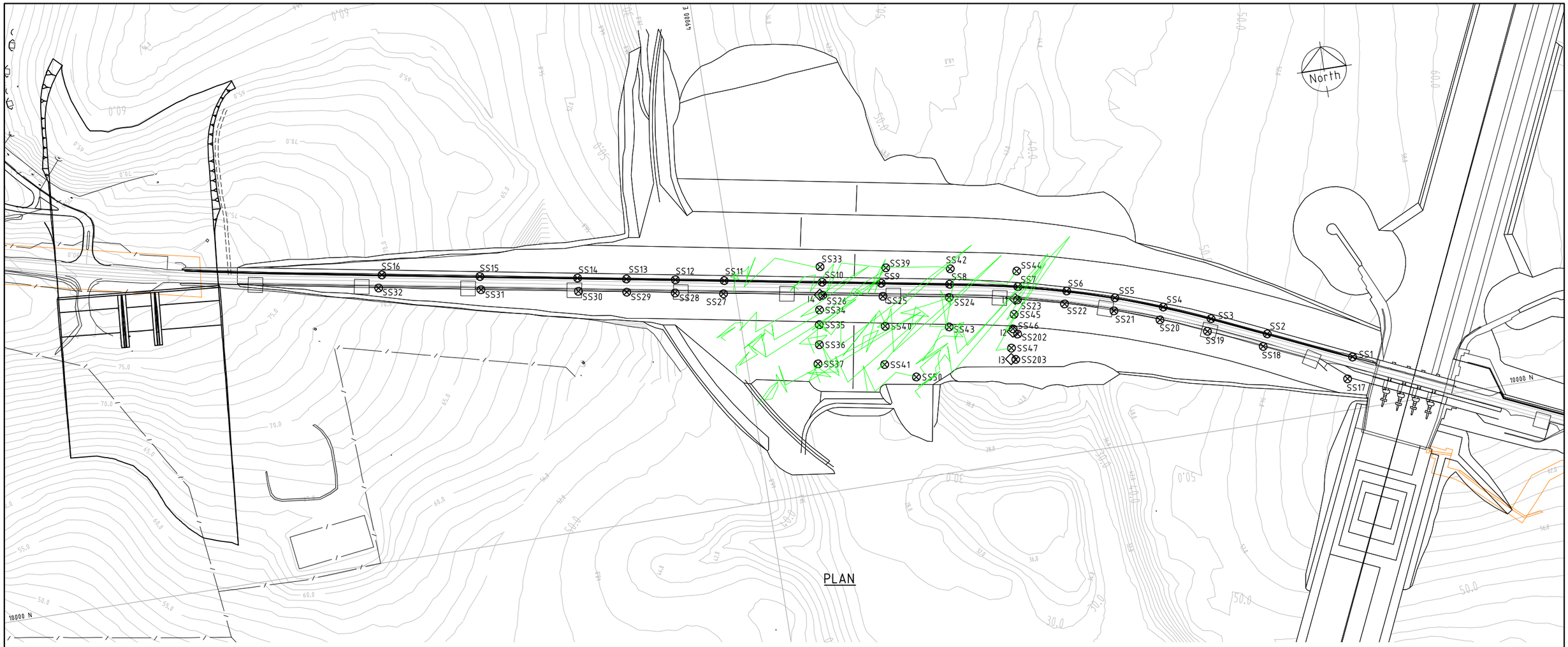
WIVENHOE DAM
MAIN EMBANKMENT PLAN
SURFACE MOVEMENT INSTALLATIONS - U/S FACE ONLY

Status

Drg No. 60020162-111b

Rev.

Xref's contour;DAM_CADASTRAL;EX_BLDGS;ex dam survey;Aqua;SPILLWAY_RNS;Maunsell_A1



PLAN

No.	BY	DATE	DESCRIPTION	APPD

REVISIONS

Scale

OVERALL MAP 0 20 40 60 80 100m
1 : 4000 (A3) 1 : 2000 (A1)

MOVEMENTS 0 10 20 25mm
1 : 1 (A3) 1 : 0.5 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED		CHECKED	
DRAWN		CHECKED	
APPROVED		DATE	

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Last modified: 02 Mar 07 - 16:18

MAUNSELL | AECOM

Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

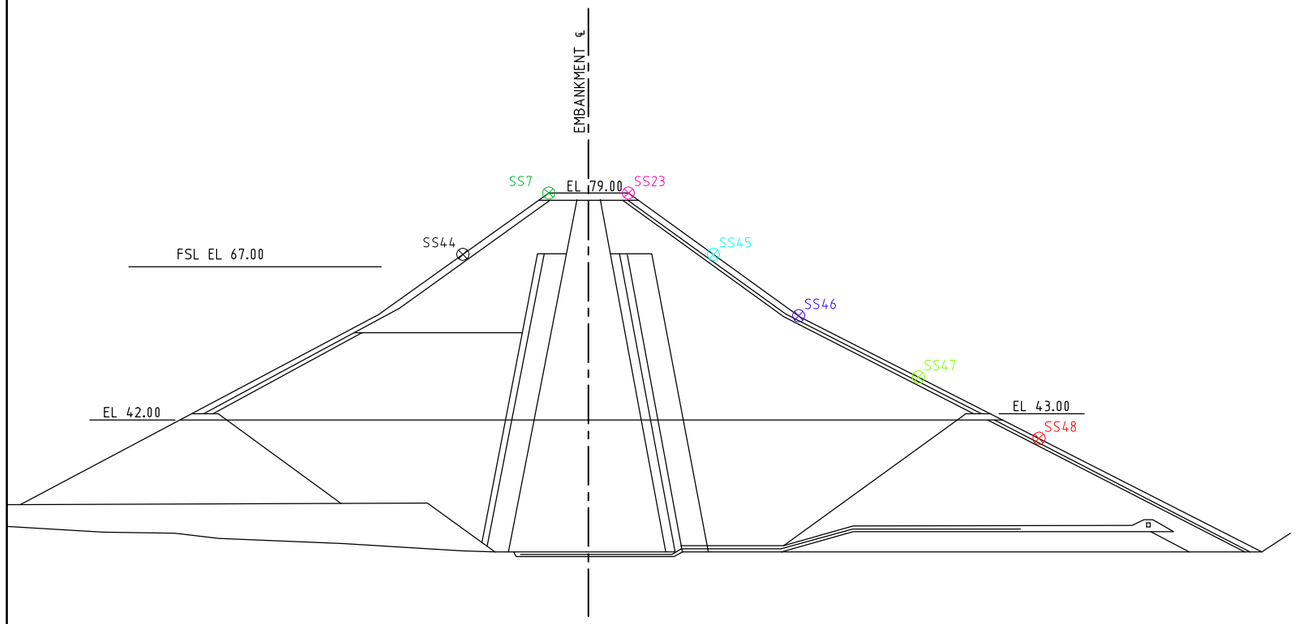
WIVENHOE DAM
MAIN EMBANKMENT PLAN
SURFACE MOVEMENT INSTALLATIONS - EMBANK. ONLY

Status

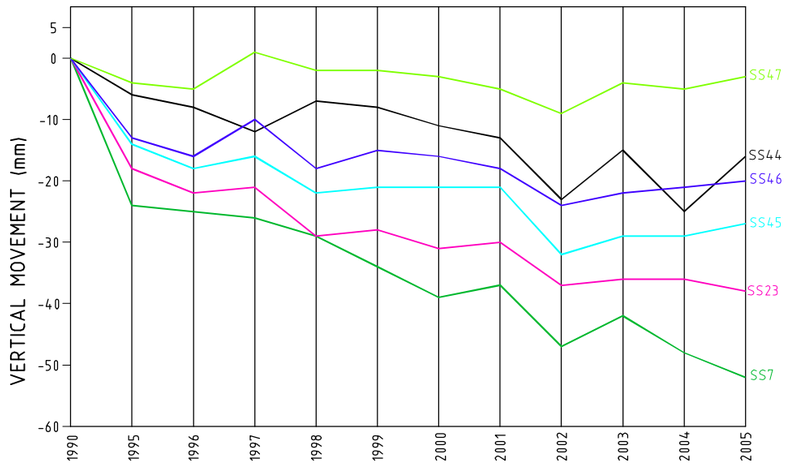
Drg No. 60020162-111c

Rev.

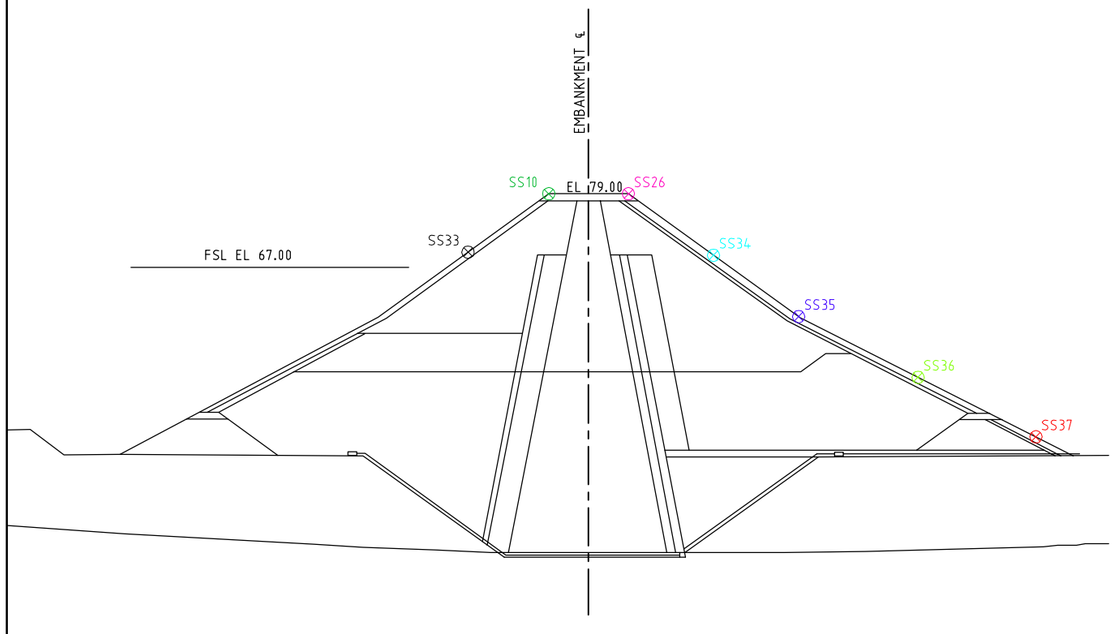
Xref's contour;DAM_CADASTRAL;EX_BLDGS;ex dam survey_base;SPILLWAY_RNS;Maunsell_A1



SECTION A CH. 1800
NTS 001



YEAR
SCALE A



SECTION B CH. 1600
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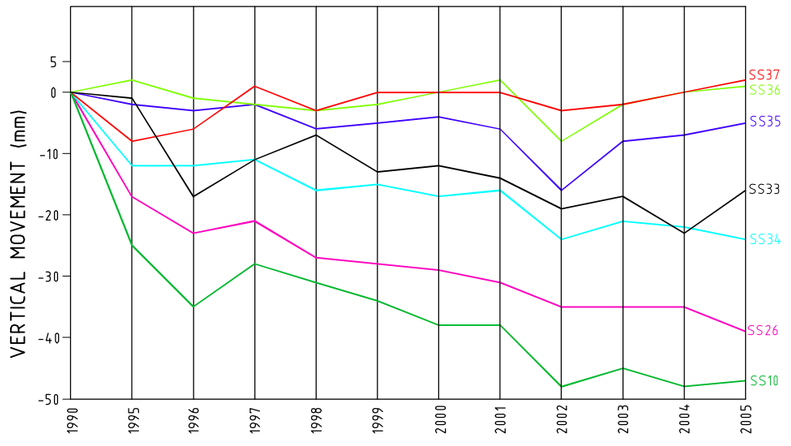

YEAR
SCALE A

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD

Scale

SCALE A 0 10 20 25mm
1 : 1 (A3) 1 : 0.5 (A1)

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE MAUNSELL QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	SG	CHECKED	
DRAWN	SG	CHECKED	
APPROVED		DATE	

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Last modified: 23 Nov 06 - 13:21

MAUNSELL AECOM

Maunsell Australia Pty Ltd A.B.N. 20 093 846 925
RPEQ No.

DAM SURVEILLANCE

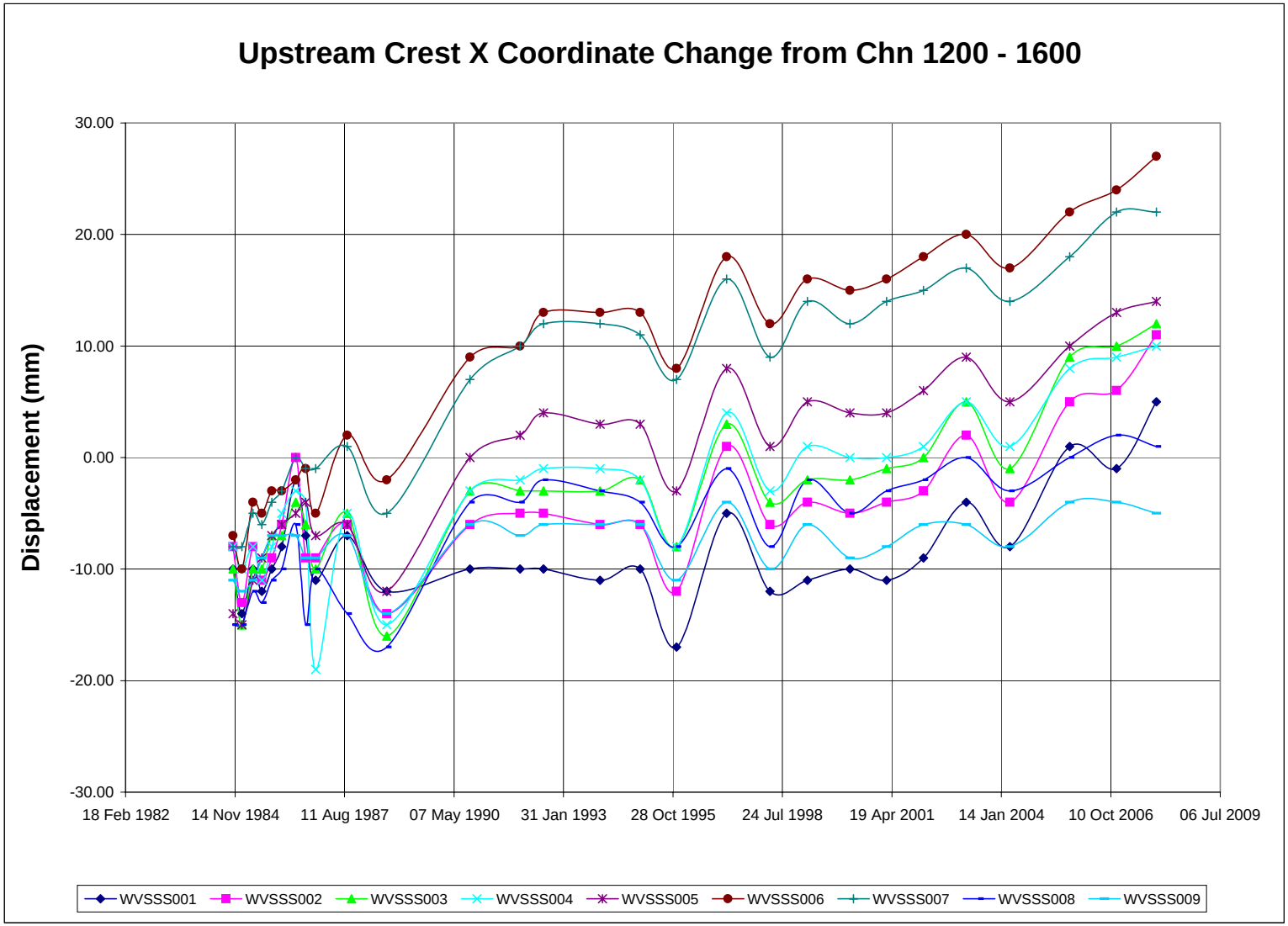
WIVENHOE DAM
MAIN EMBANKMENT SECTIONS
SURFACE MOVEMENT INSTALLATIONS

Status

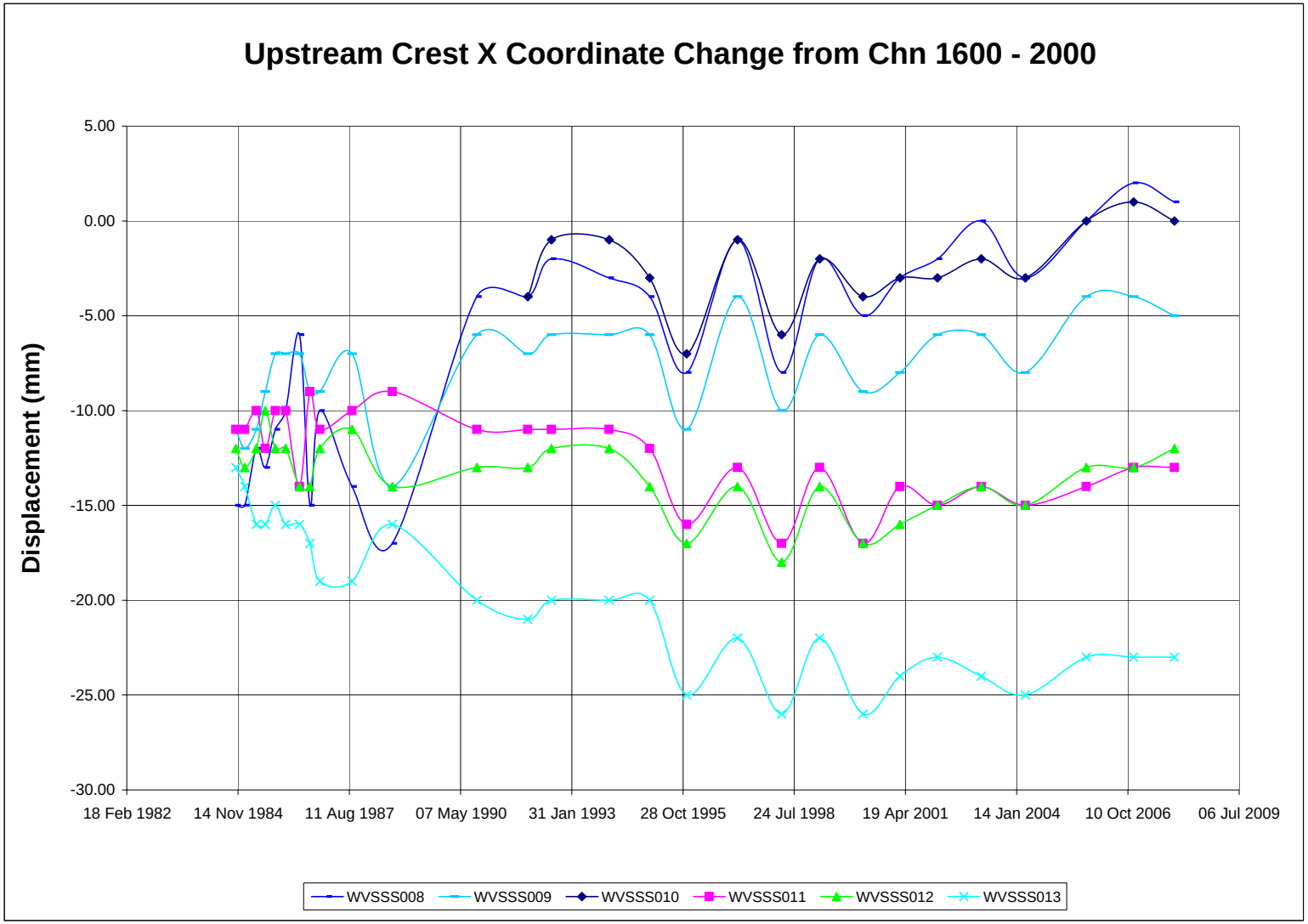
Drg No. 60020162-112

Rev.

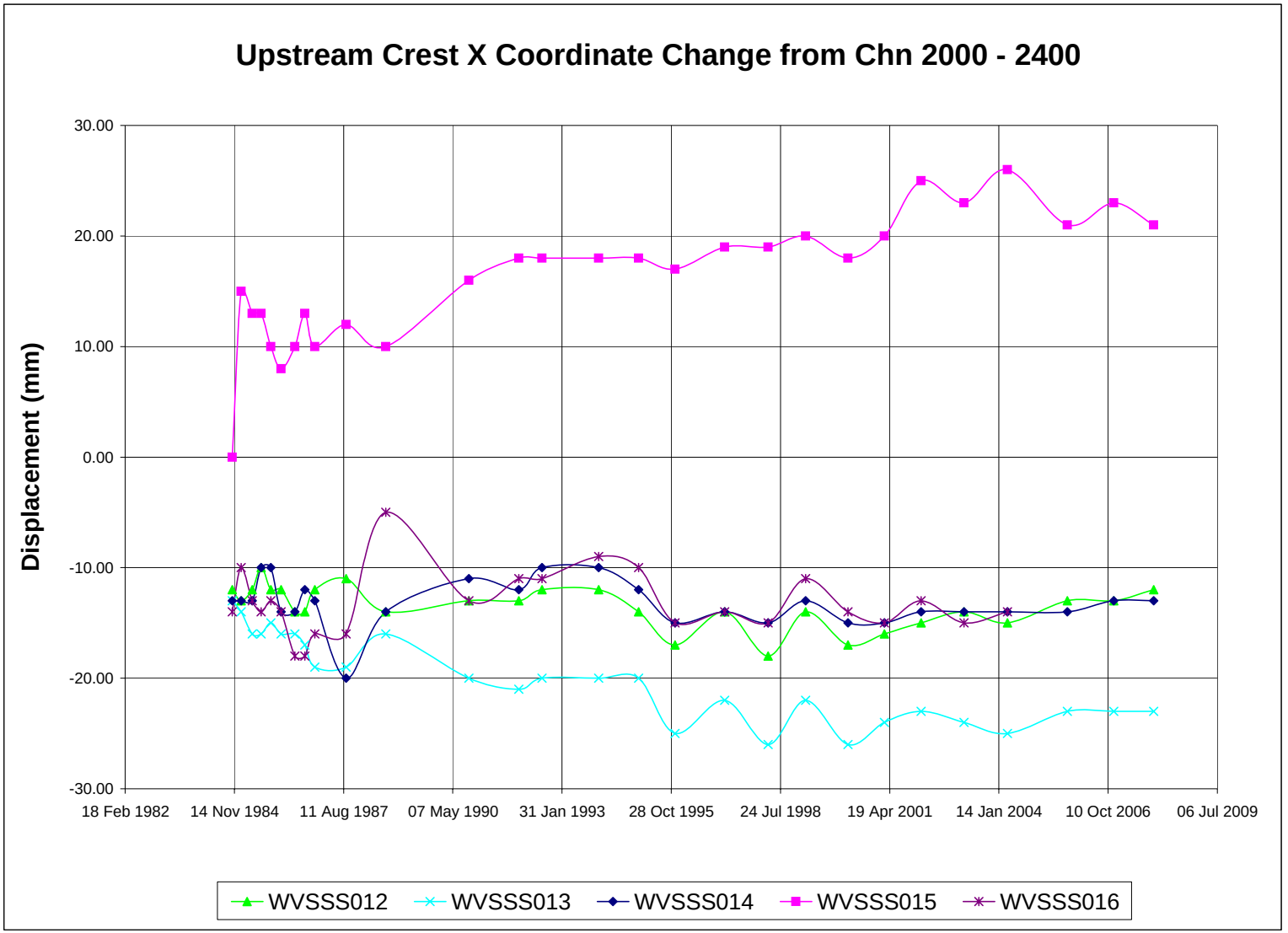
Xref's Maunsell A1



Movement Plots



Movement Plots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Displacement (mm)
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10.00
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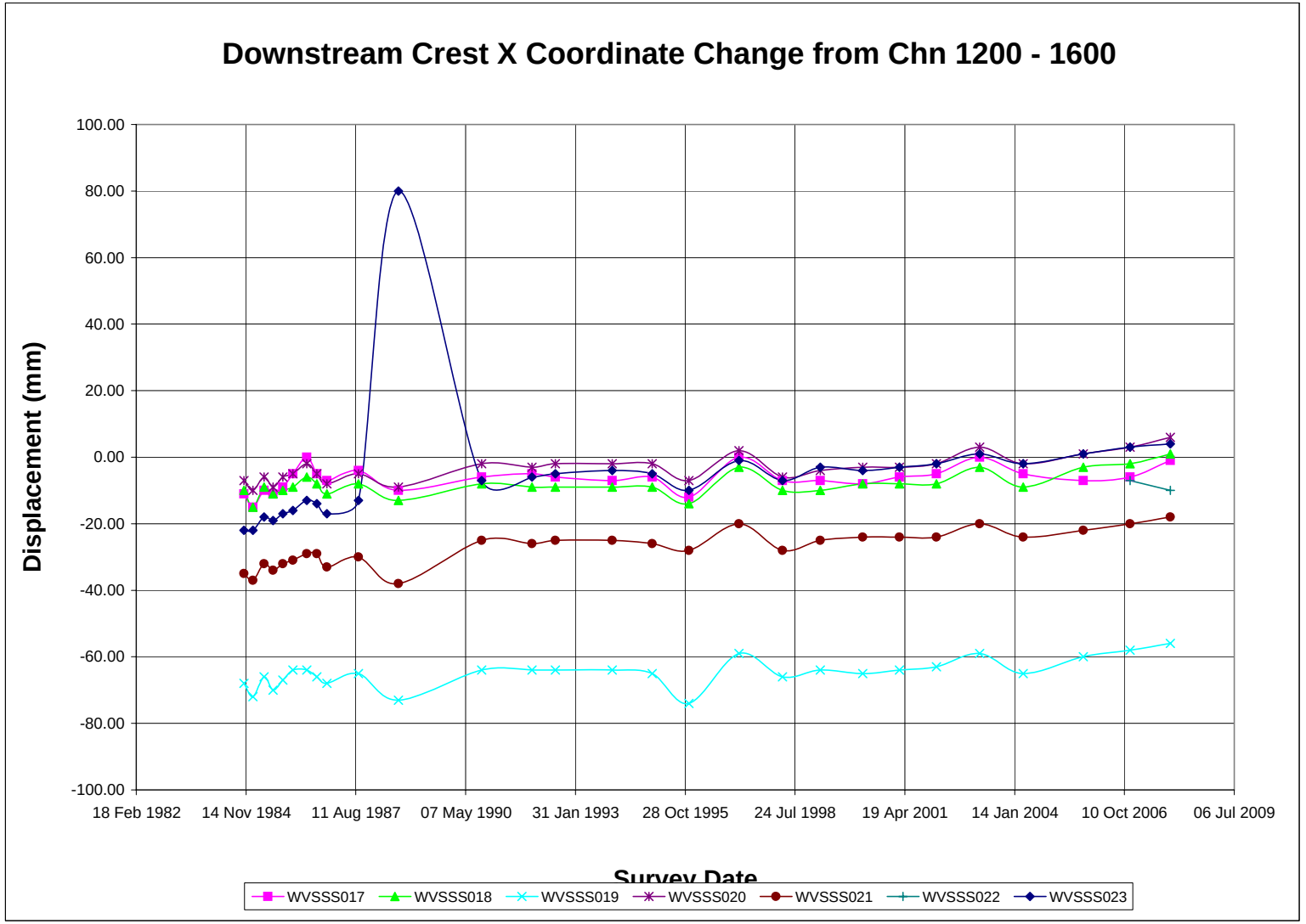
-10.00
-20.00
-30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS012
WVSSS013
WVSSS014
WVSSS015
WVSSS016


Downstream Crest X Coordinate Change from Chn 1200 - 1600
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0.00
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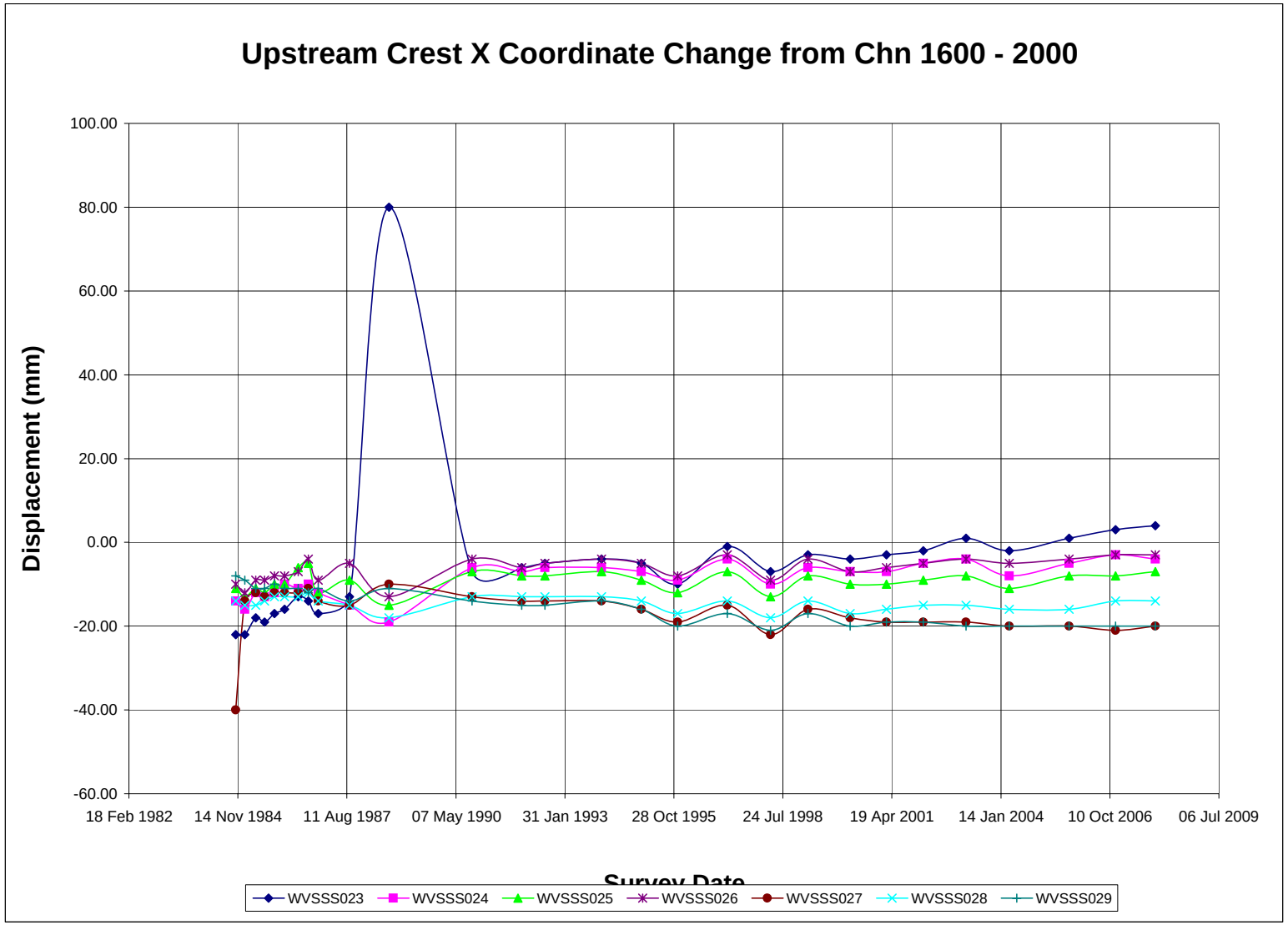
-60.00
-80.00
-100.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
Survey Date
WVSSS017
WVSSS018
WVSSS019
WVSSS020
WVSSS021
WVSSS022
WVSSS023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-60.00
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11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
Survey Date
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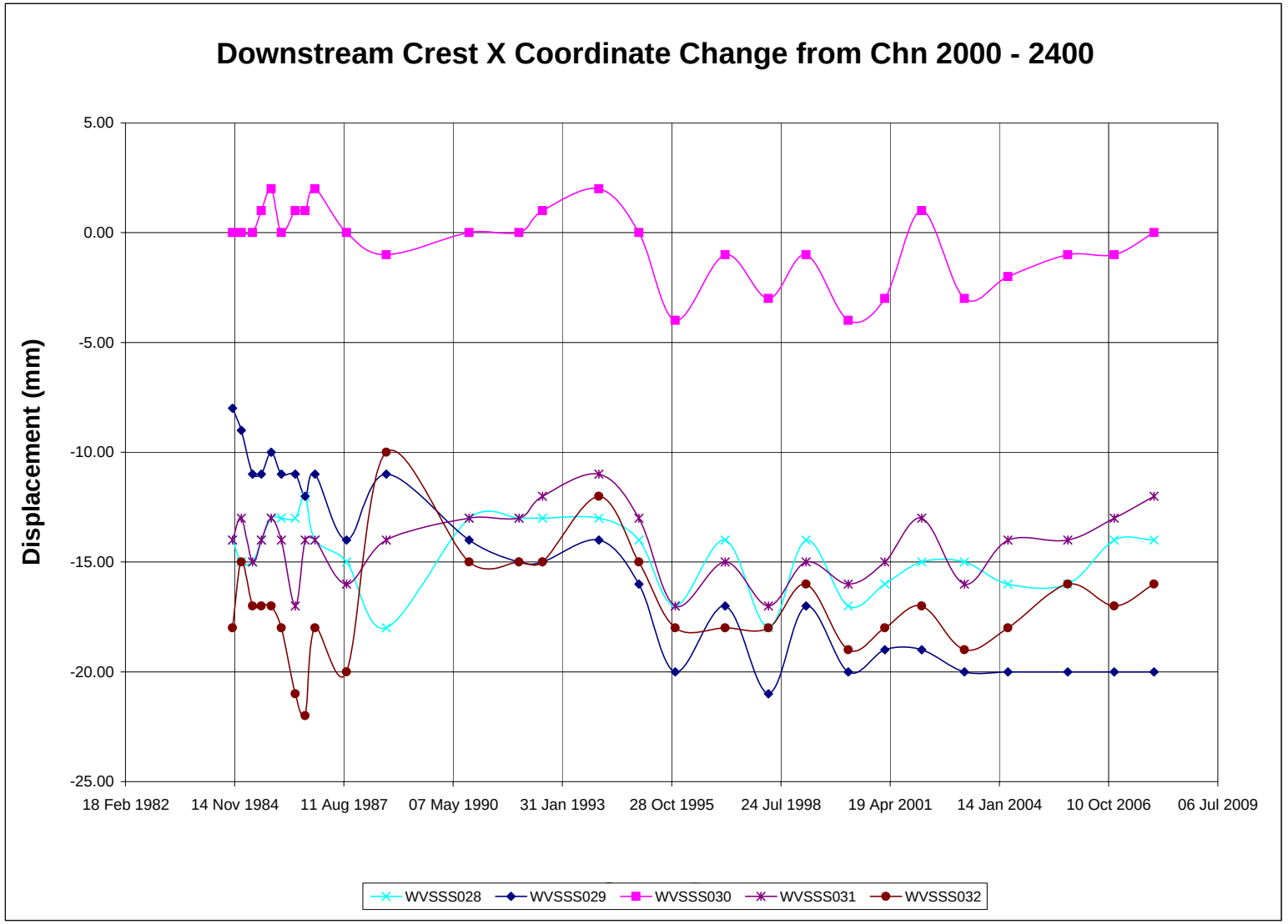
WVSSS024
WVSSS025
WVSSS026
WVSSS027
WVSSS028
WVSSS029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14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
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14 Jan 2004
10 Oct 2006
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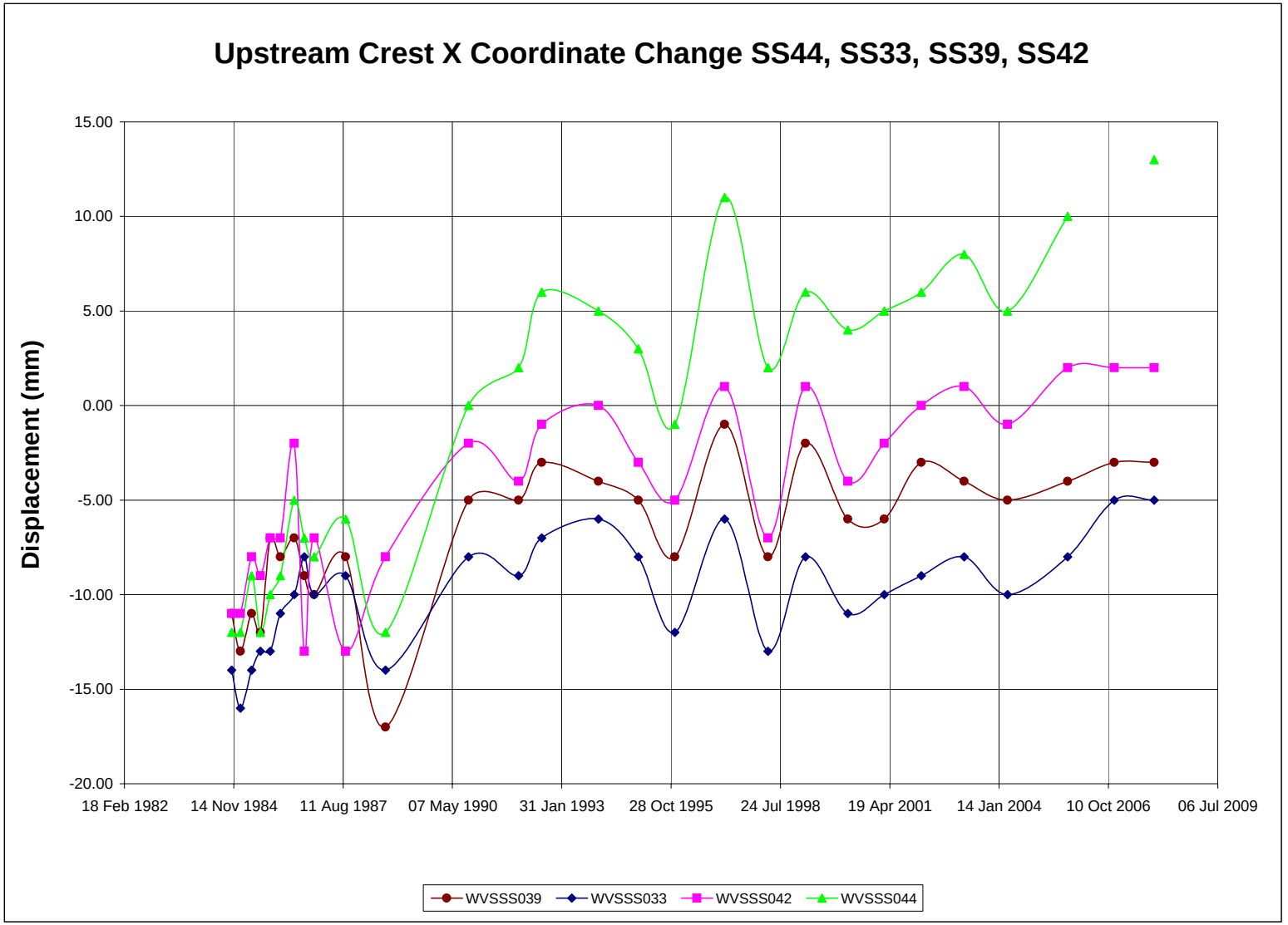
WVSSS029
WVSSS030
WVSSS031
WVSSS032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-20.00
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14 Nov 1984
11 Aug 1987
07 May 1990
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14 Jan 2004
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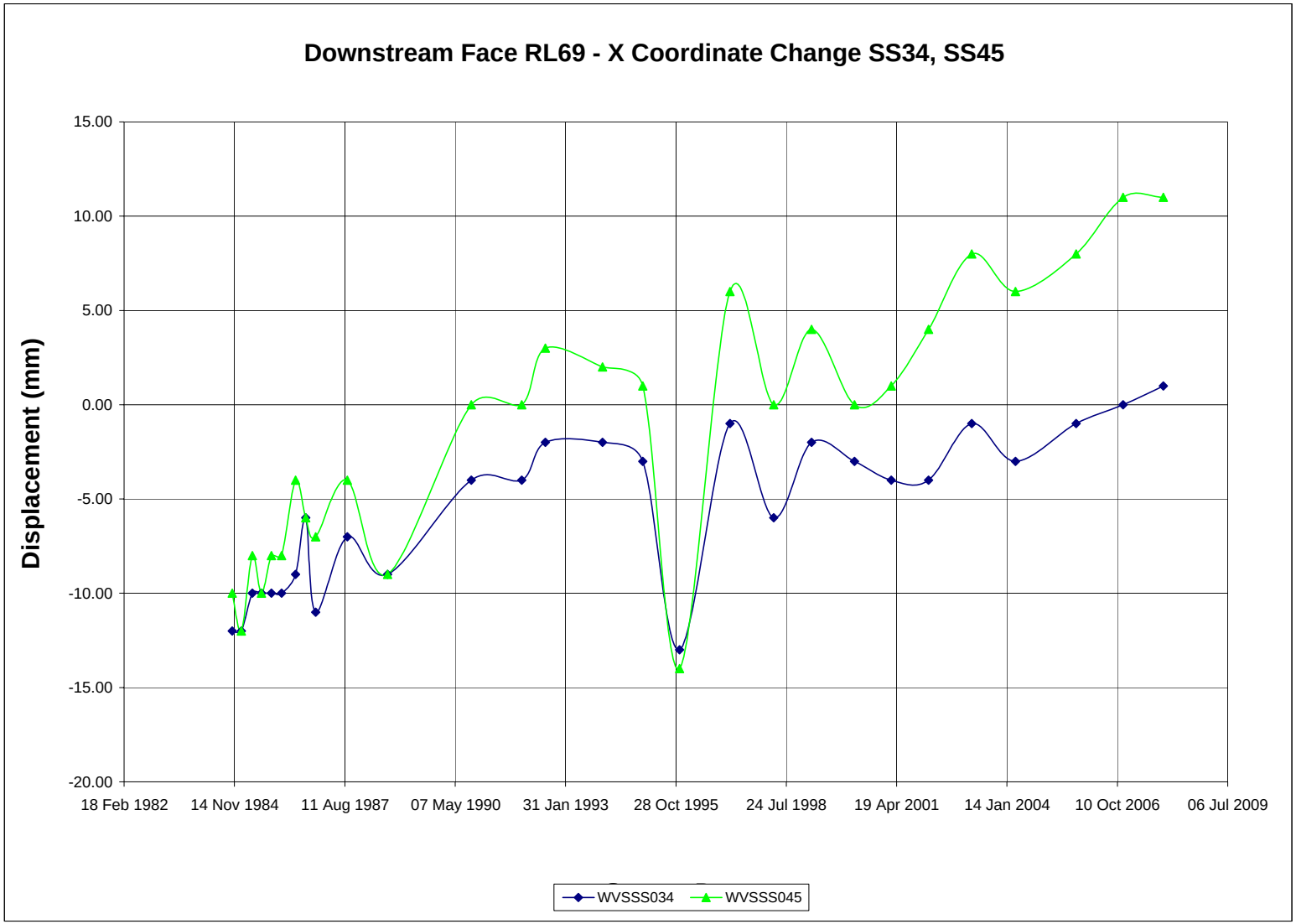
WVSSS033
WVSSS042
WVSSS044


Downstream Face RL69 - X Coordinate Change SS34, SS45
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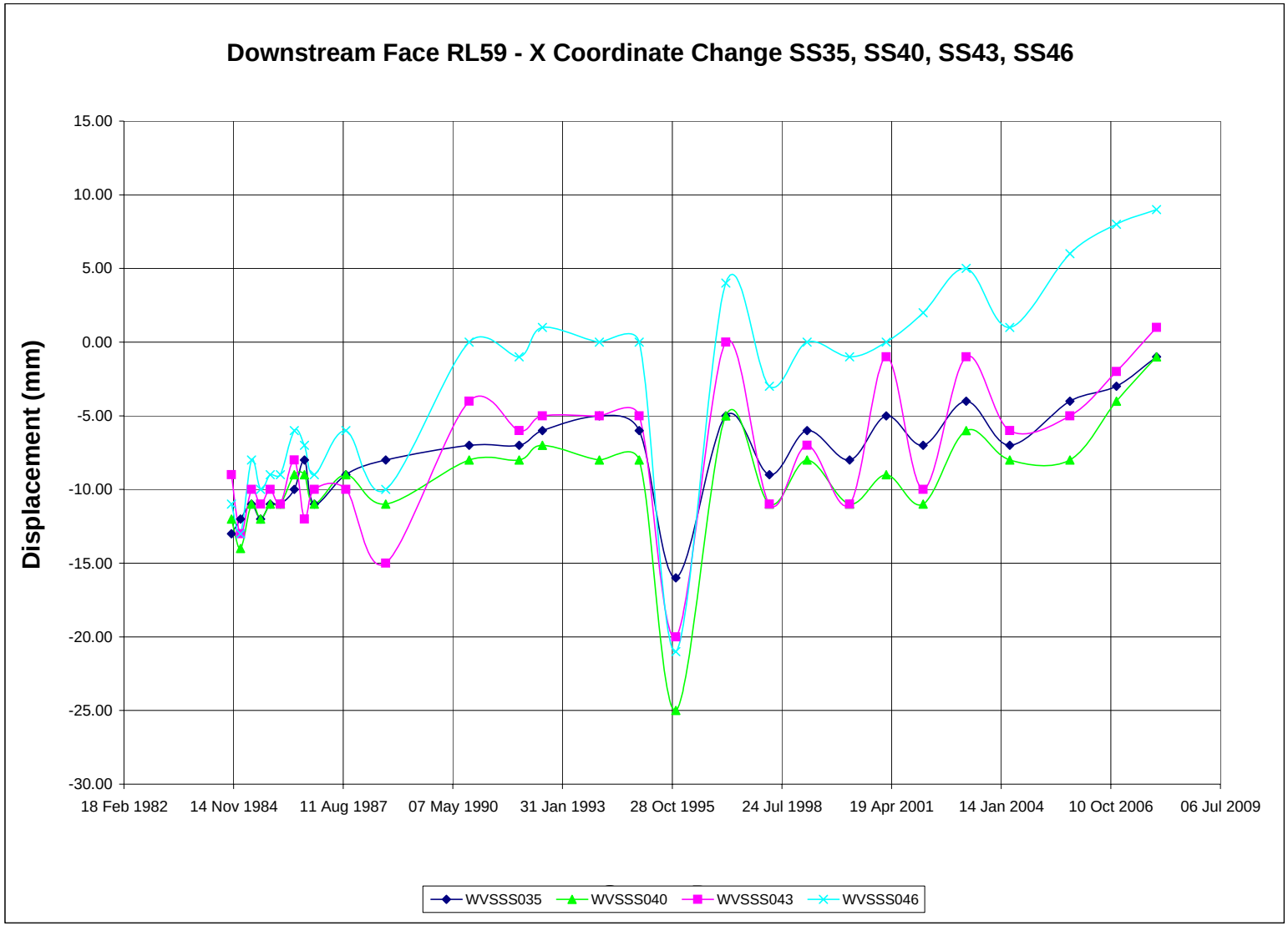
WVSSS045


Downstream Face RL59 - X Coordinate Change SS35, SS40, SS43, SS46
Displacement (mm)
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5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
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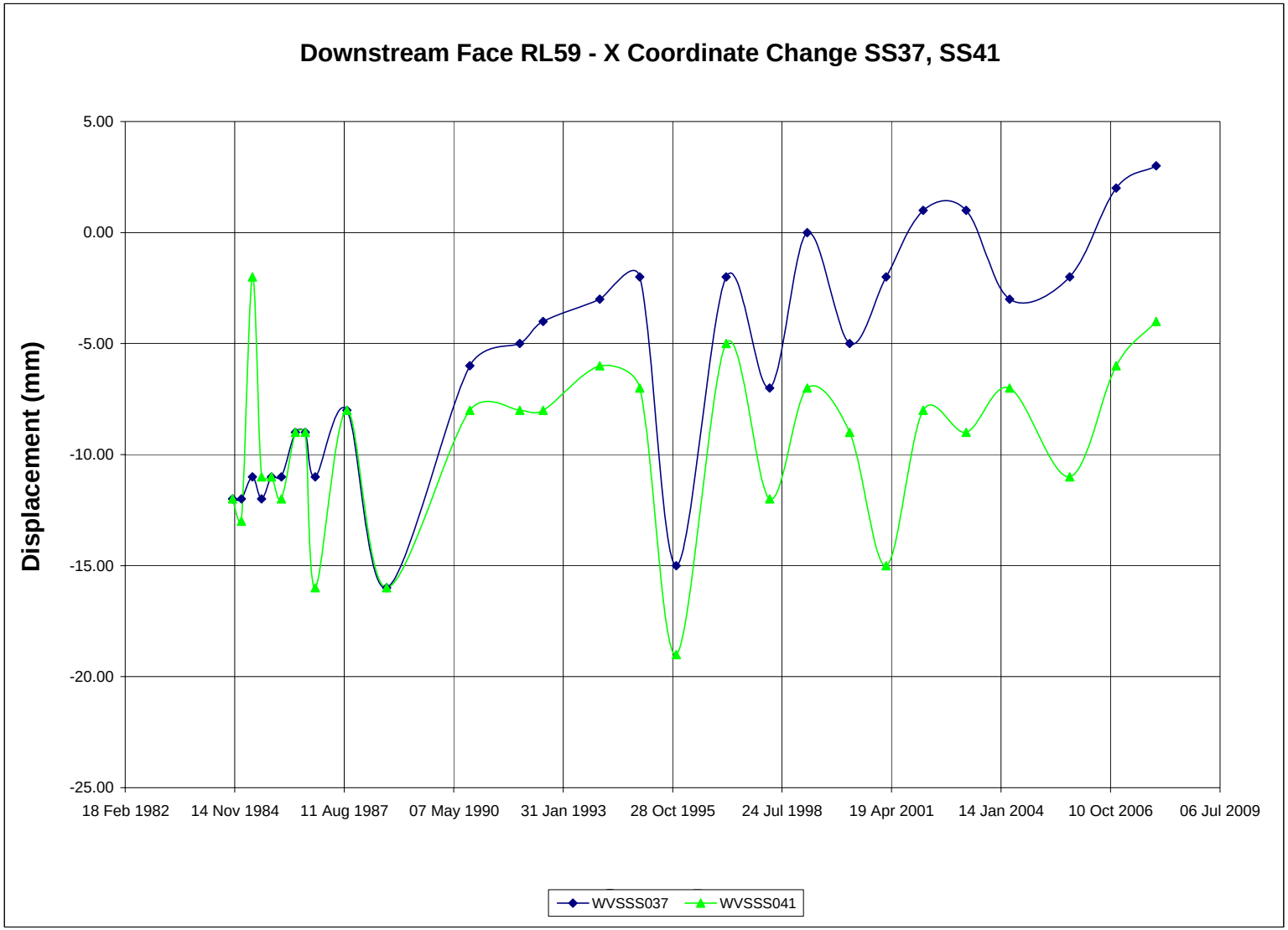
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS035
WVSSS040
WVSSS043
WVSSS046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Displacement (mm)
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-20.00
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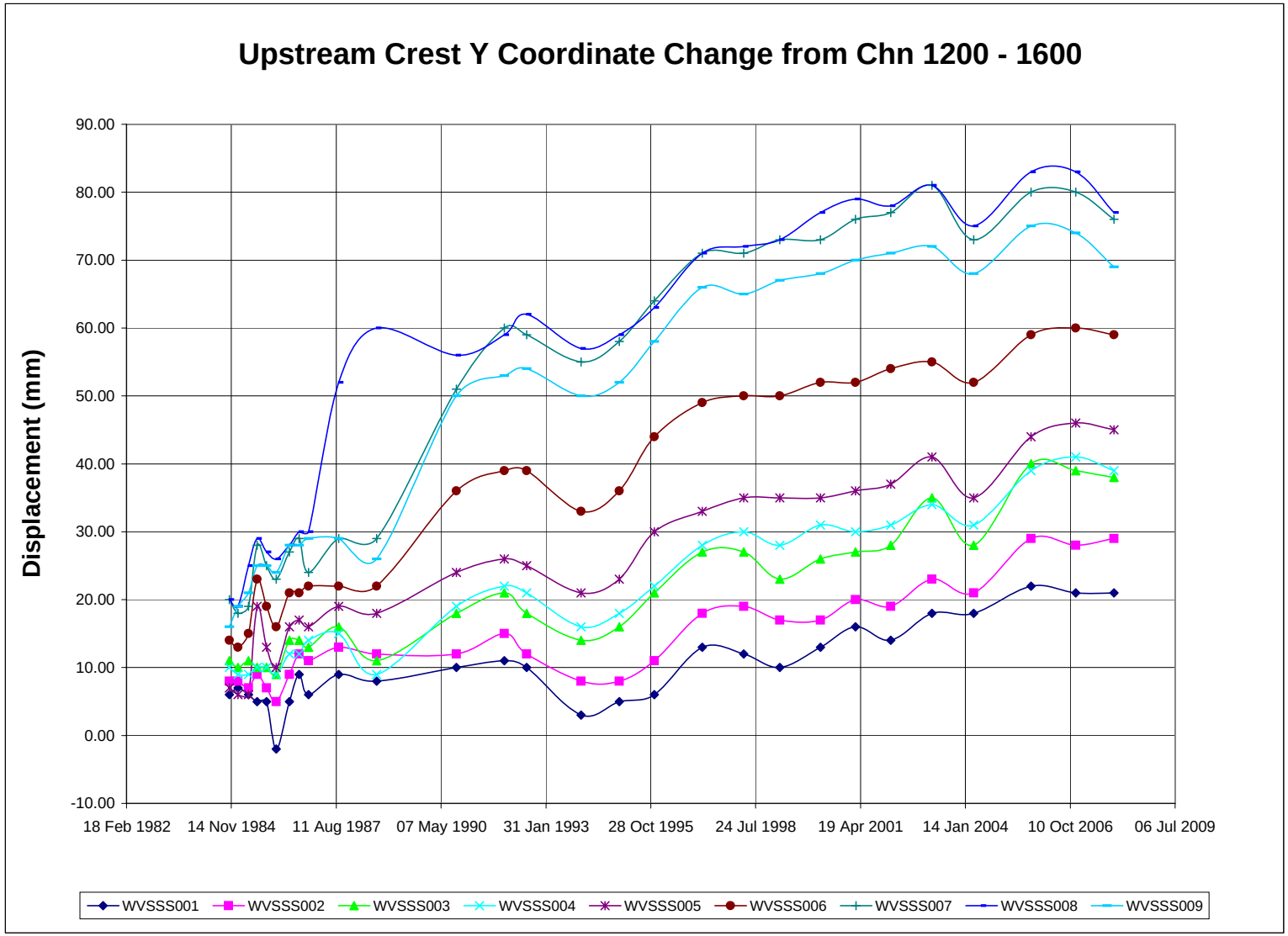
WVSSS037
WVSSS041


Upstream Crest Y Coordinate Change from Chn 1200 - 1600
Displacement (mm)
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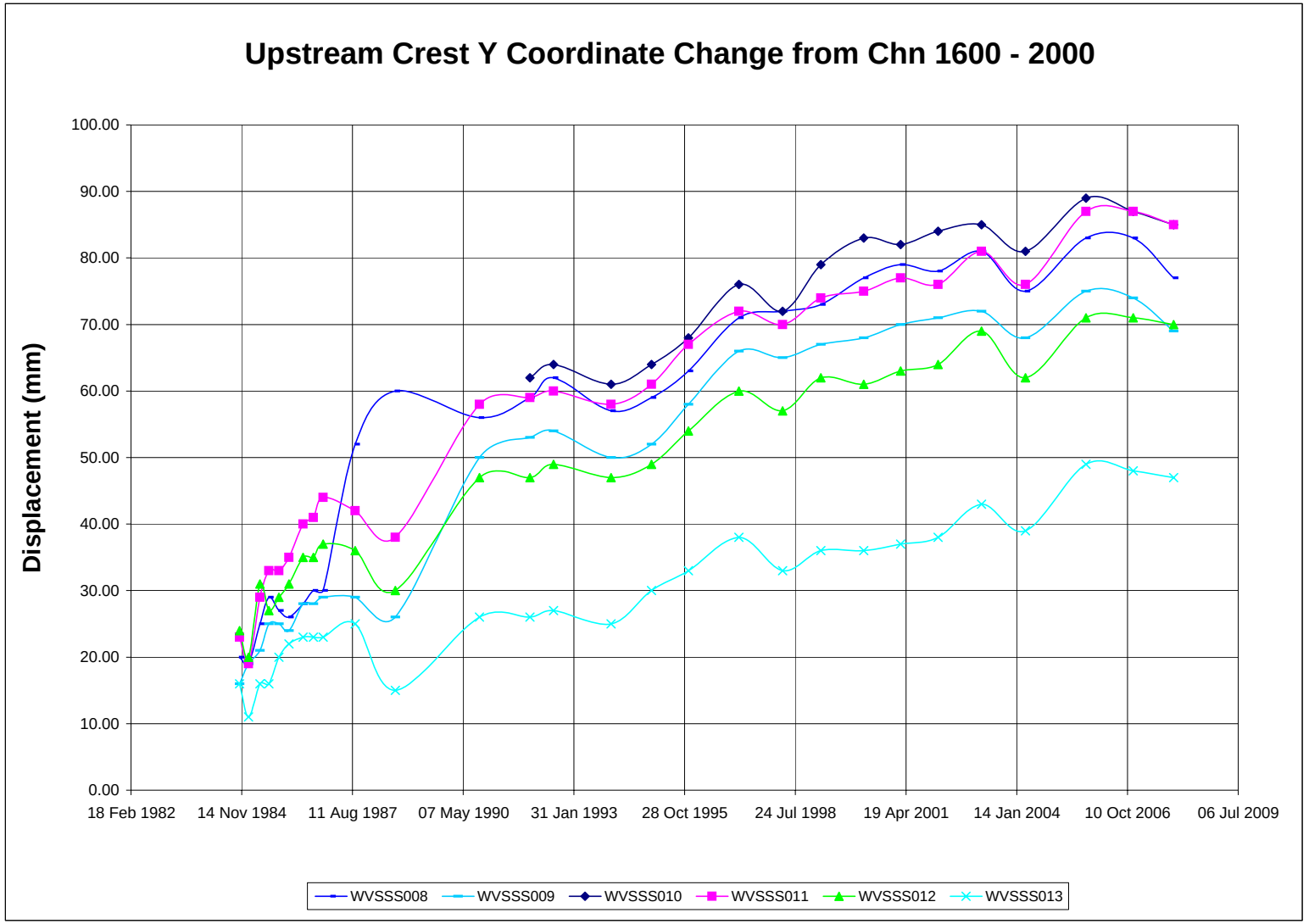
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS001
WVSSS002
WVSSS003
WVSSS004
WVSSS005
WVSSS006
WVSSS007
WVSSS008
WVSSS009


Upstream Crest Y Coordinate Change from Chn 1600 - 2000
Displacement (mm)
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90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
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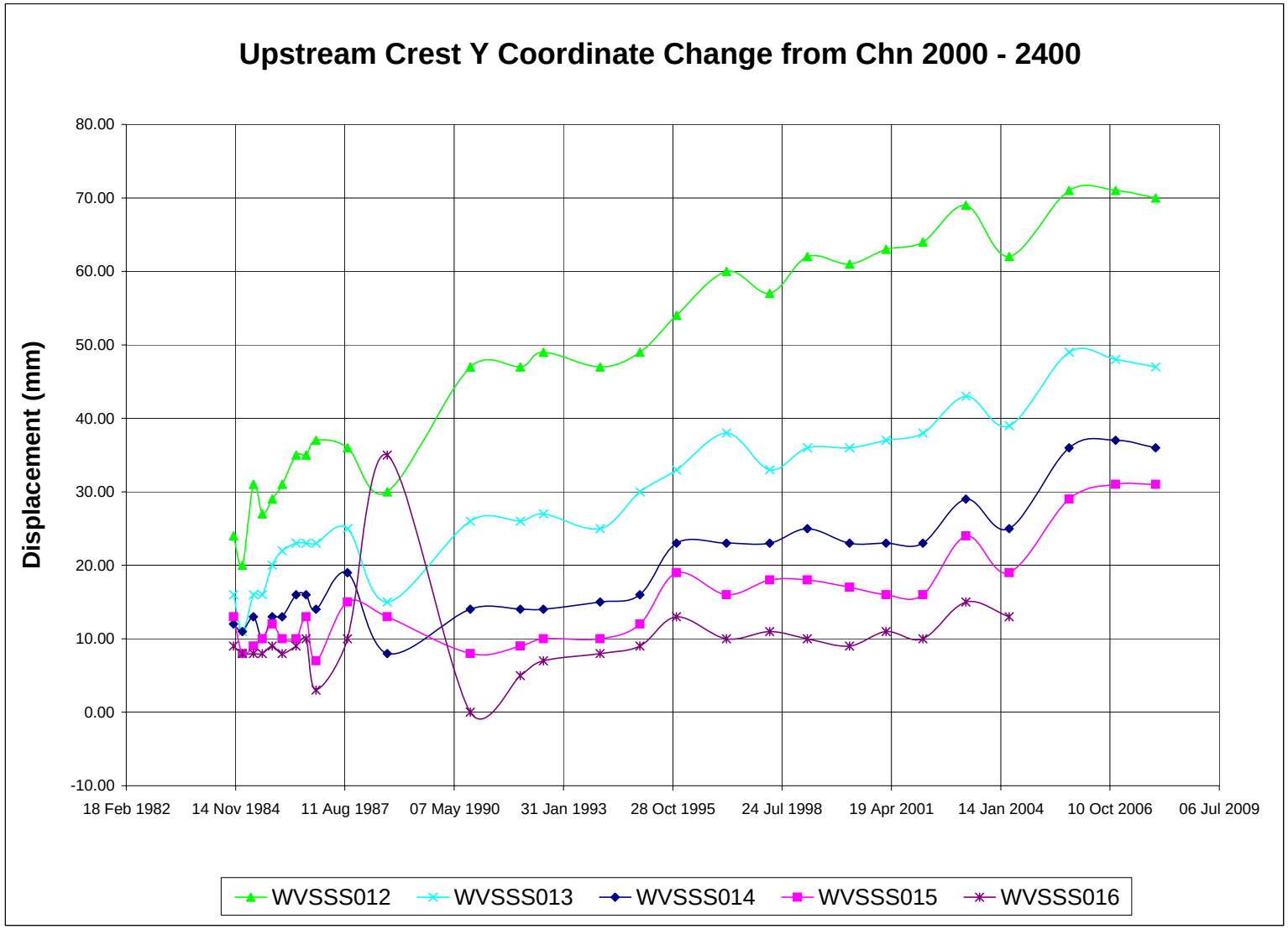
10 Oct 2006
06 Jul 2009
WVSSS008
WVSSS009
WVSSS010
WVSSS011
WVSSS012
WVSSS013


Upstream Crest Y Coordinate Change from Chn 2000 - 2400
Displacement (mm)
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60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
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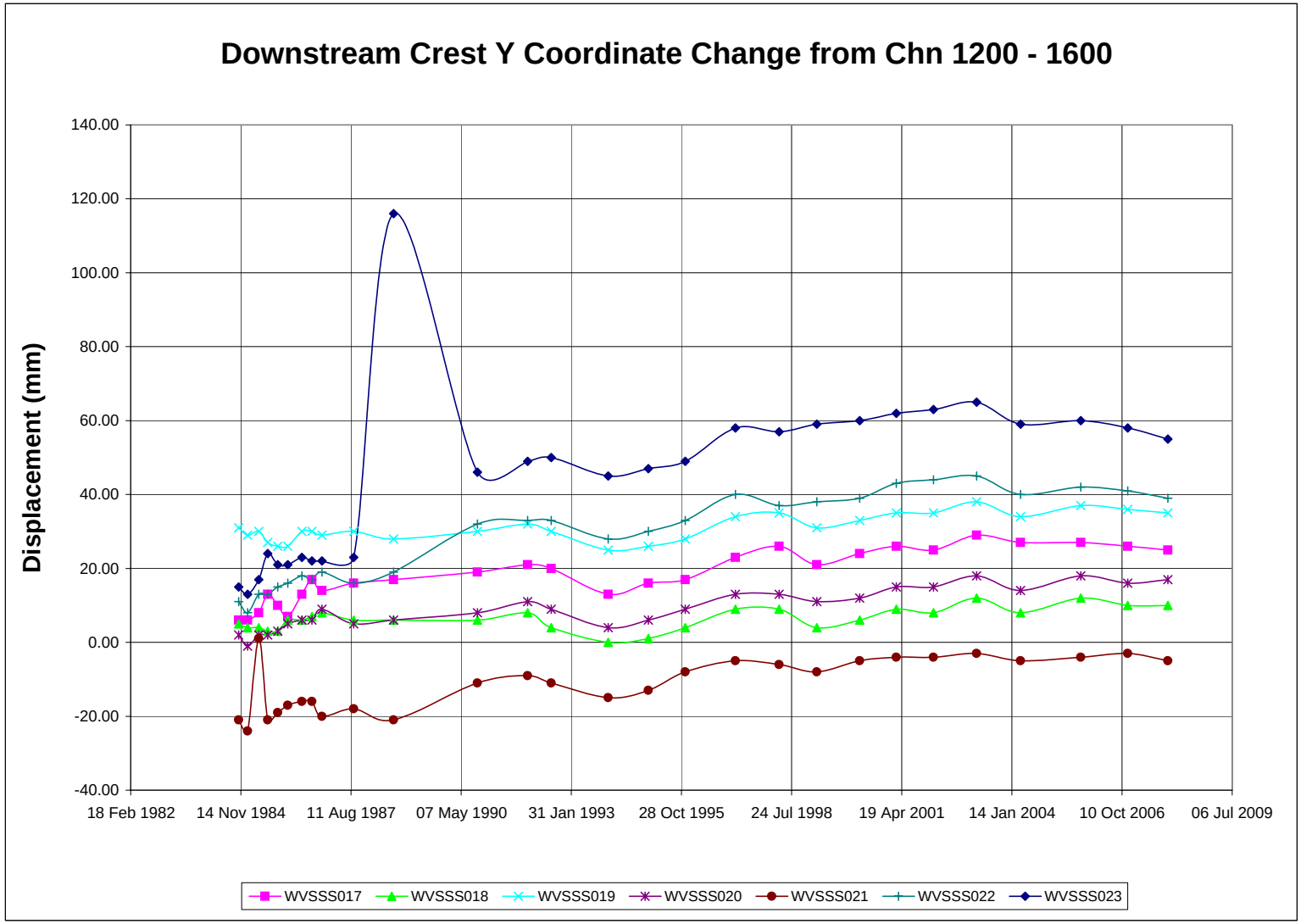
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS012
WVSSS013
WVSSS014
WVSSS015
WVSSS016


Downstream Crest Y Coordinate Change from Chn 1200 - 1600
Displacement (mm)
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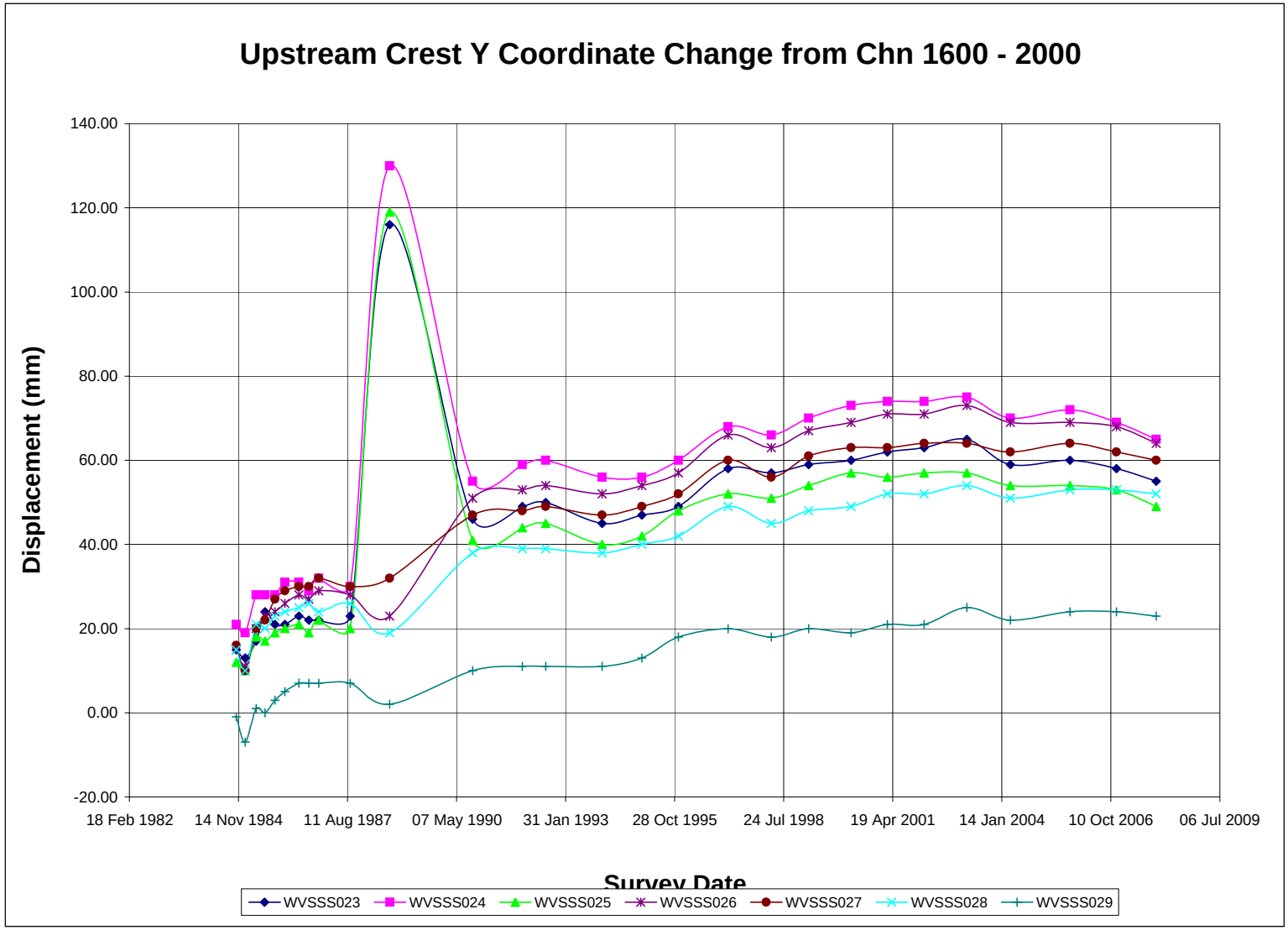
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS017
WVSSS018
WVSSS019
WVSSS020
WVSSS021
WVSSS022
WVSSS023


Upstream Crest Y Coordinate Change from Chn 1600 - 2000
Displacement (mm)
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120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
Survey Date
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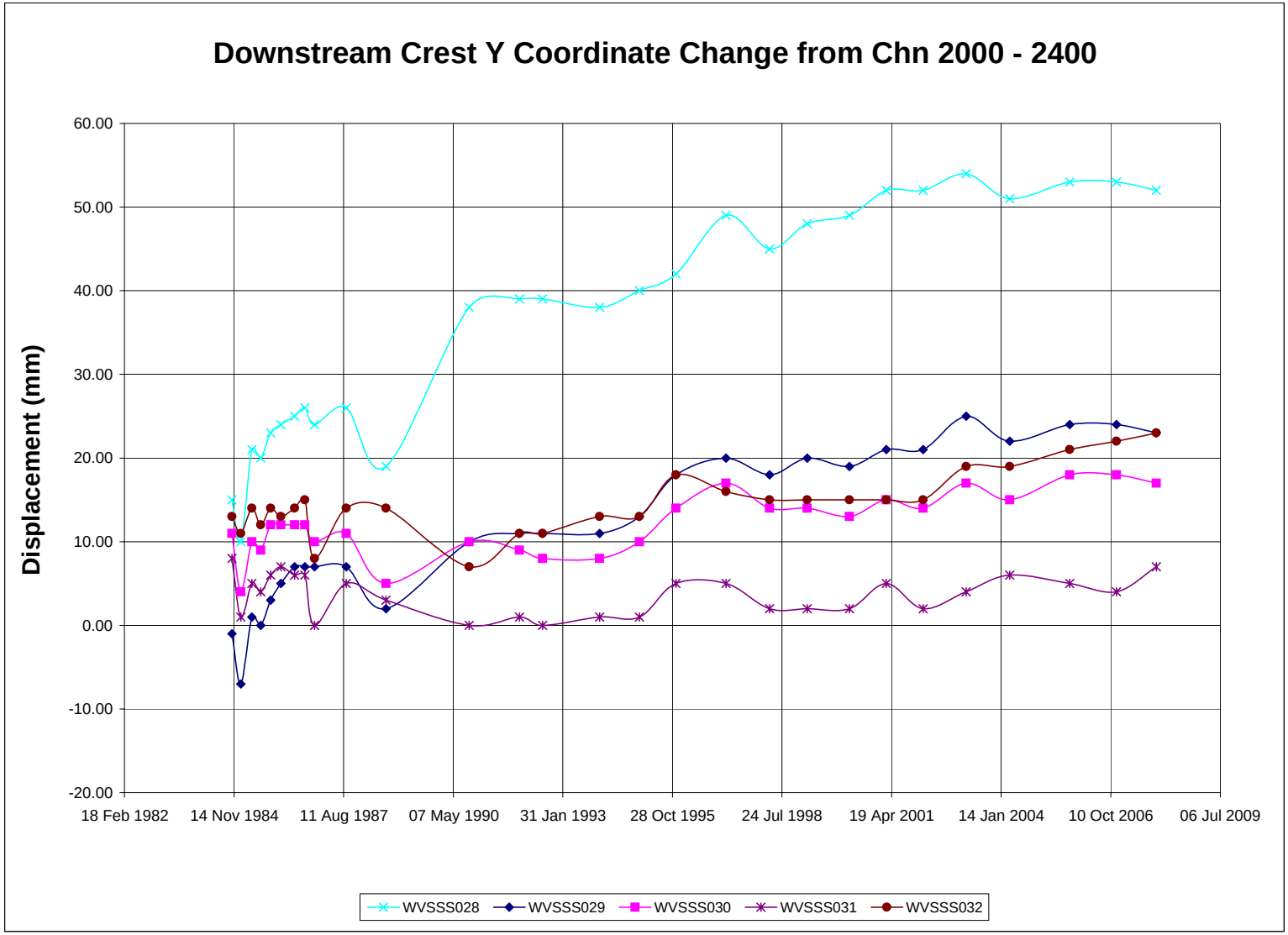
WVSSS024
WVSSS025
WVSSS026
WVSSS027
WVSSS028
WVSSS029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Displacement (mm)
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20.00
10.00
0.00
-10.00
-20.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
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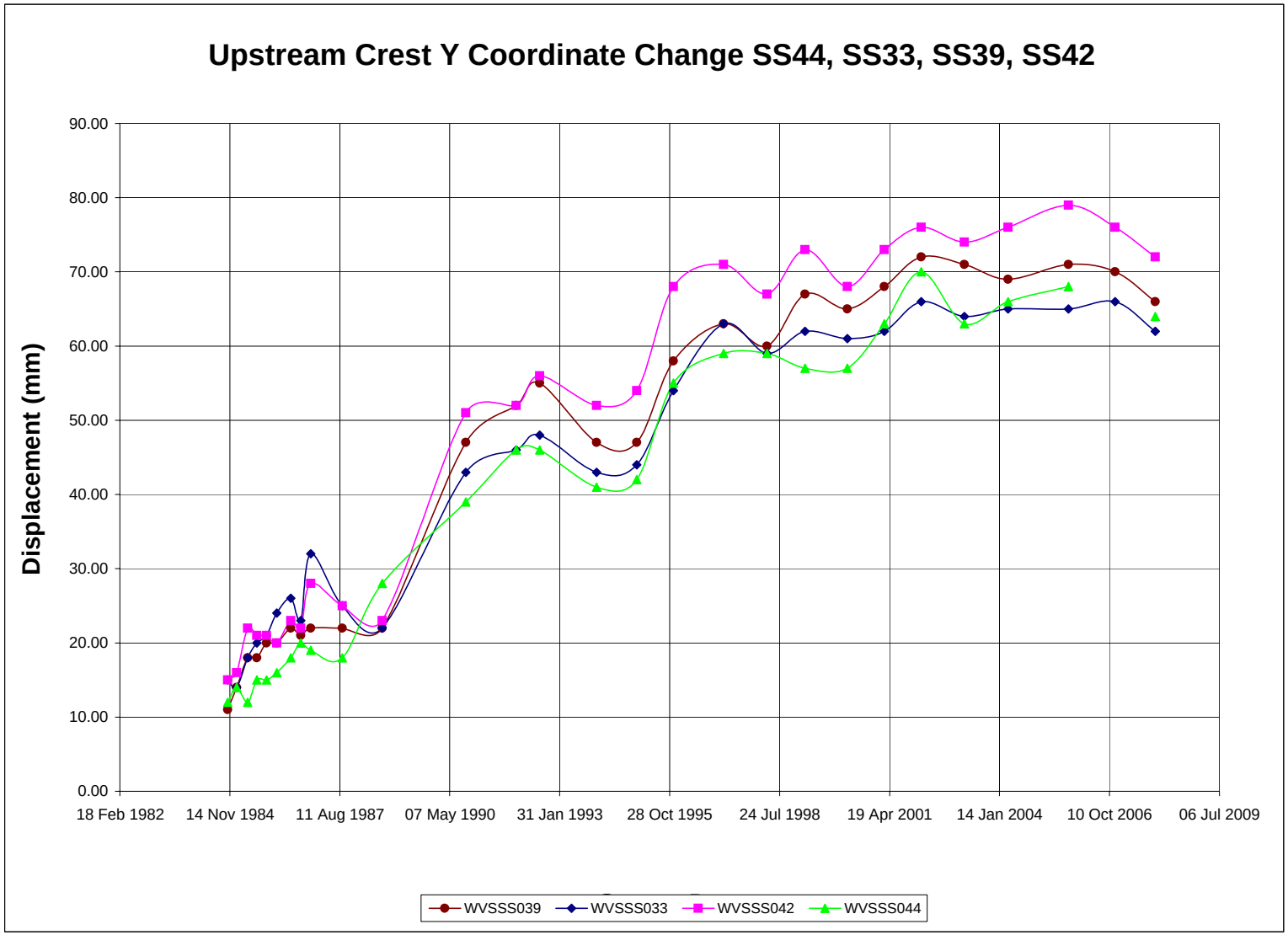
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS028
WVSSS029
WVSSS030
WVSSS031
WVSSS032


Upstream Crest Y Coordinate Change SS44, SS33, SS39, SS42
Displacement (mm)
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50.00
40.00
30.00
20.00
10.00
0.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
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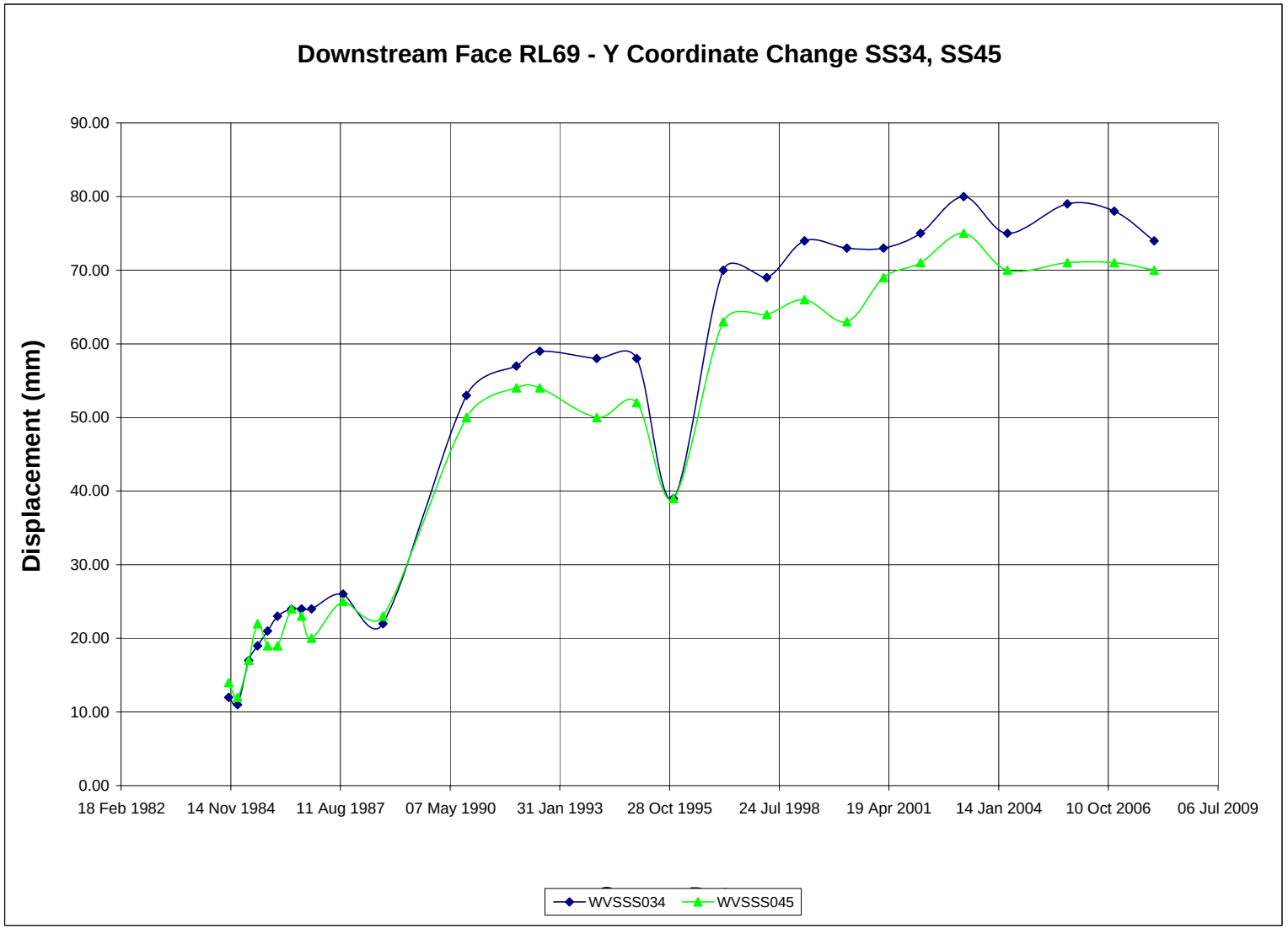
WVSSS033
WVSSS042
WVSSS044


Downstream Face RL69 - Y Coordinate Change SS34, SS45
Displacement (mm)
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70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
18 Feb 1982
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11 Aug 1987
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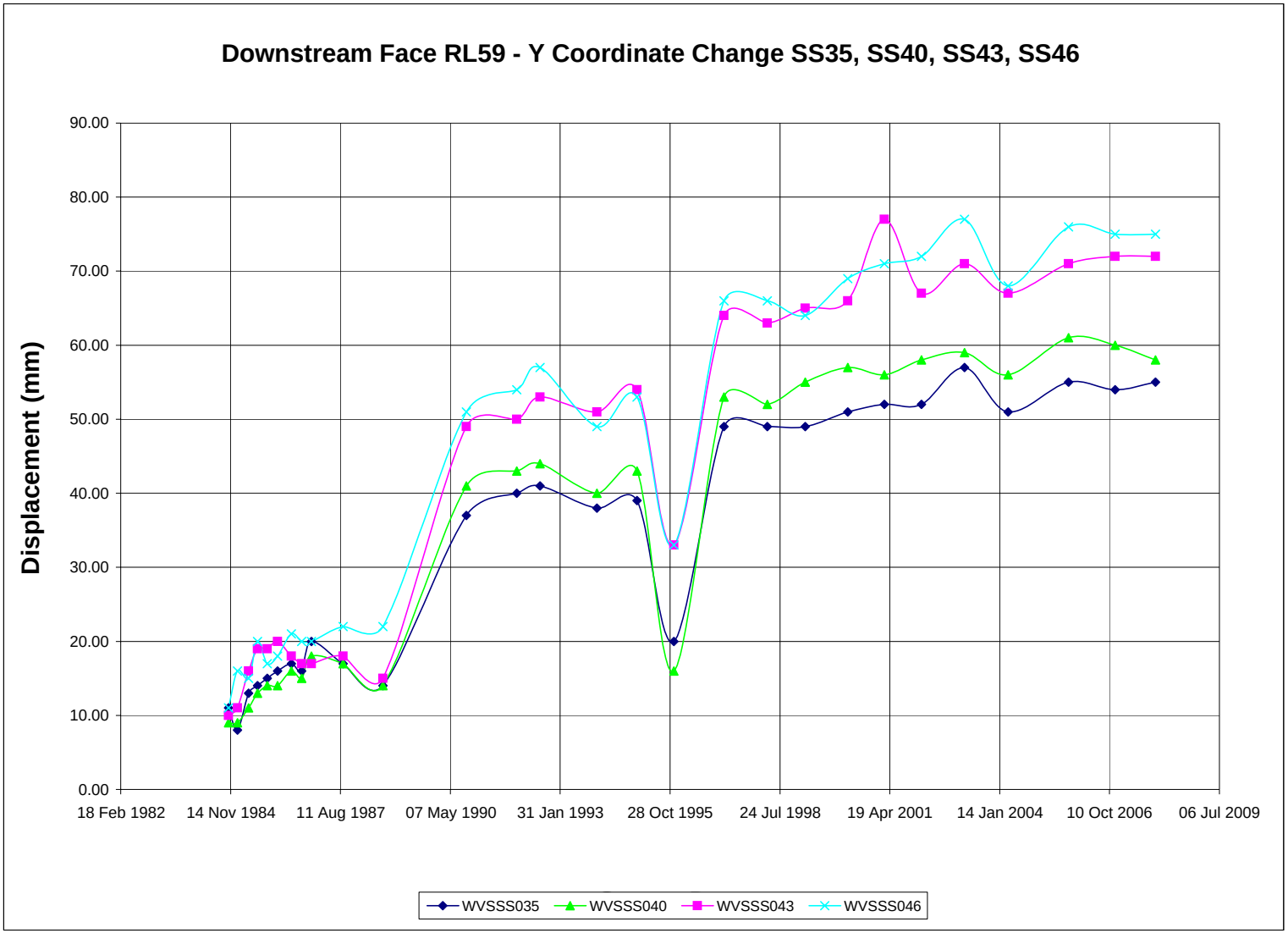
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS034
WVSSS045


Downstream Face RL59 - Y Coordinate Change SS35, SS40, SS43, SS46
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70.00
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50.00
40.00
30.00
20.00
10.00
0.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
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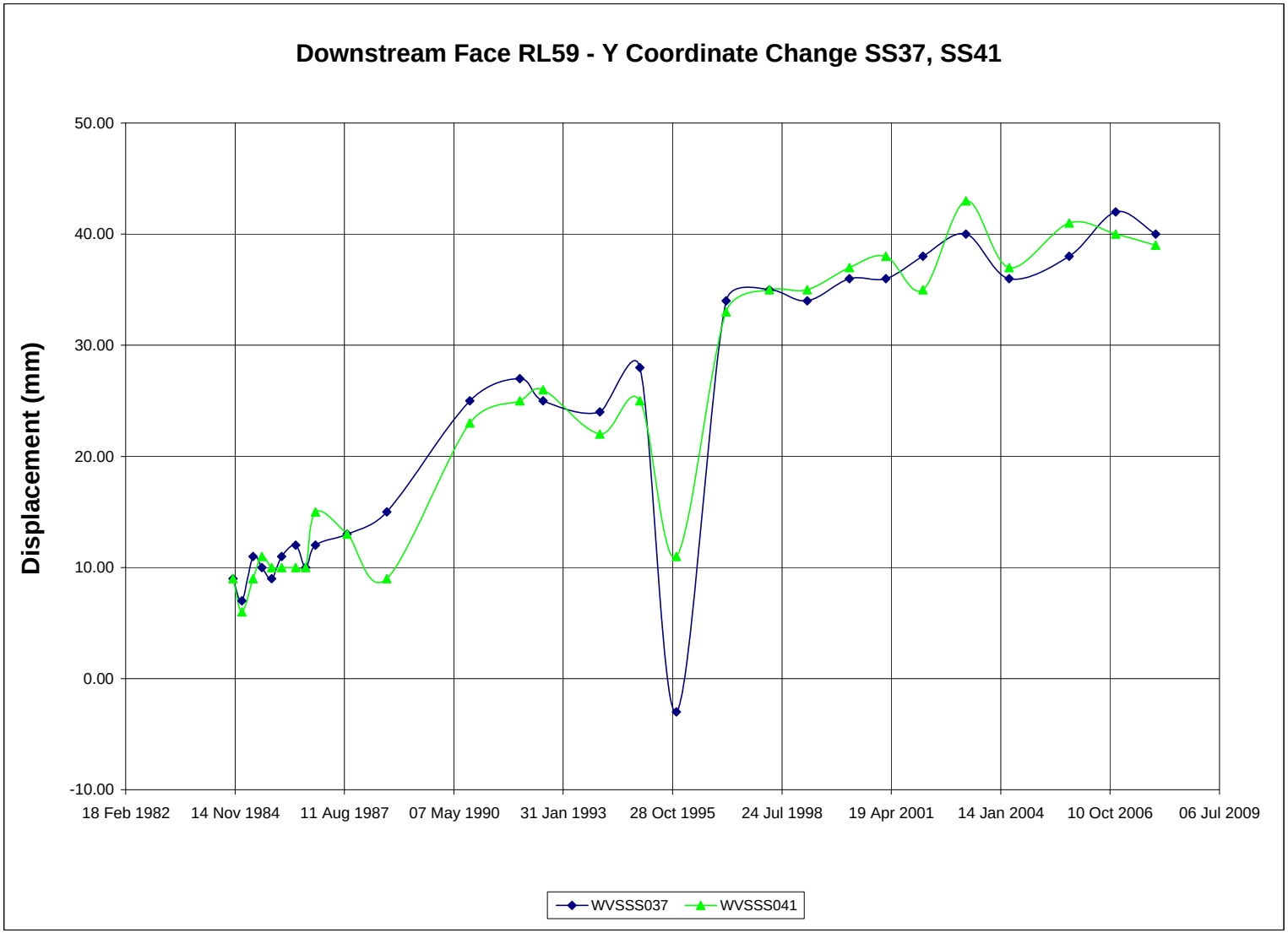
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS035
WVSSS040
WVSSS043
WVSSS046


Downstream Face RL59 - Y Coordinate Change SS37, SS41
Displacement (mm)
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40.00
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10.00
0.00
-10.00
18 Feb 1982
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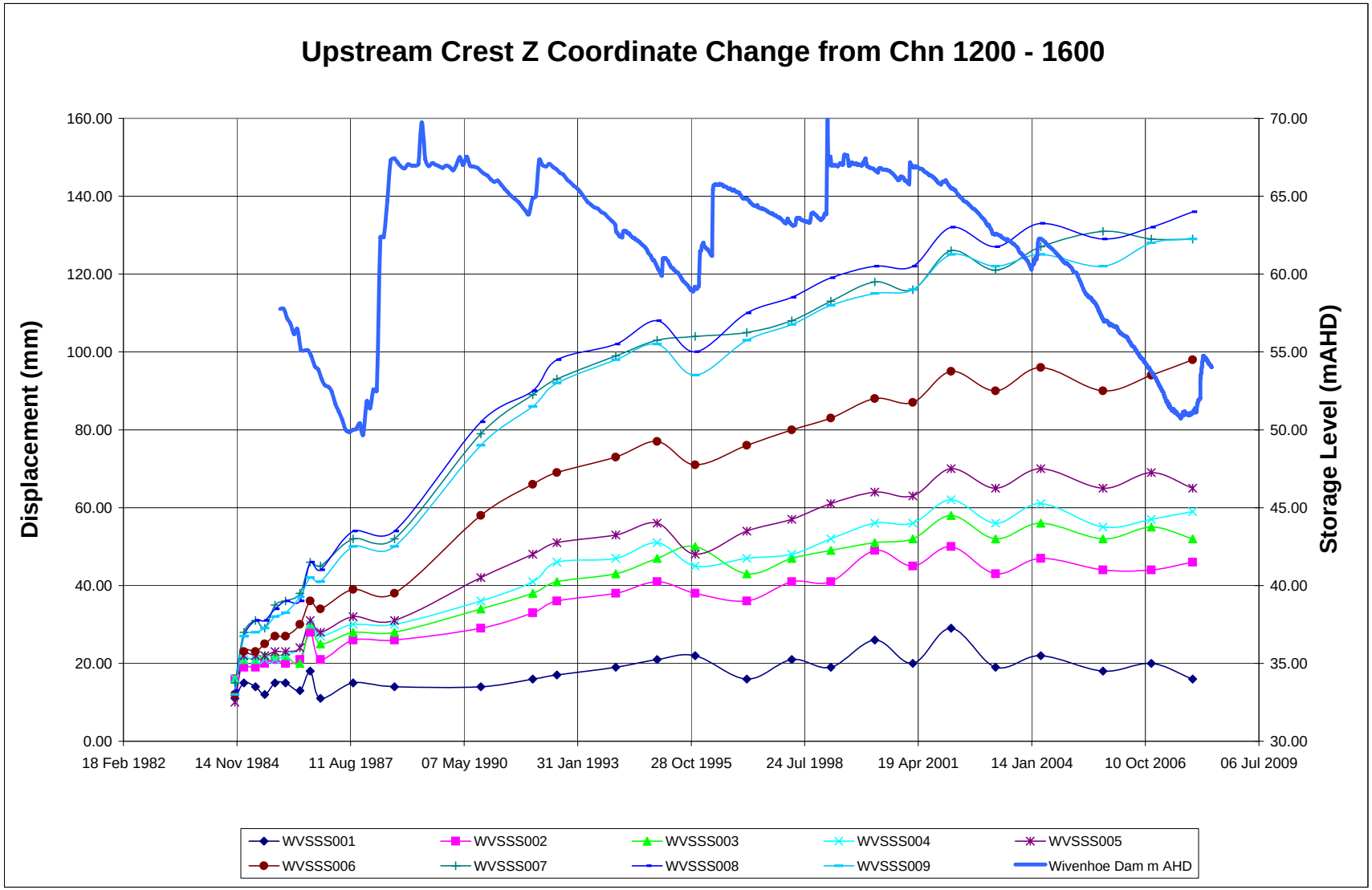
06 Jul 2009
WVSSS037
WVSSS041


Upstream Crest Z Coordinate Change from Chn 1200 - 1600
Displacement (mm)
Storage Level (mAHD)
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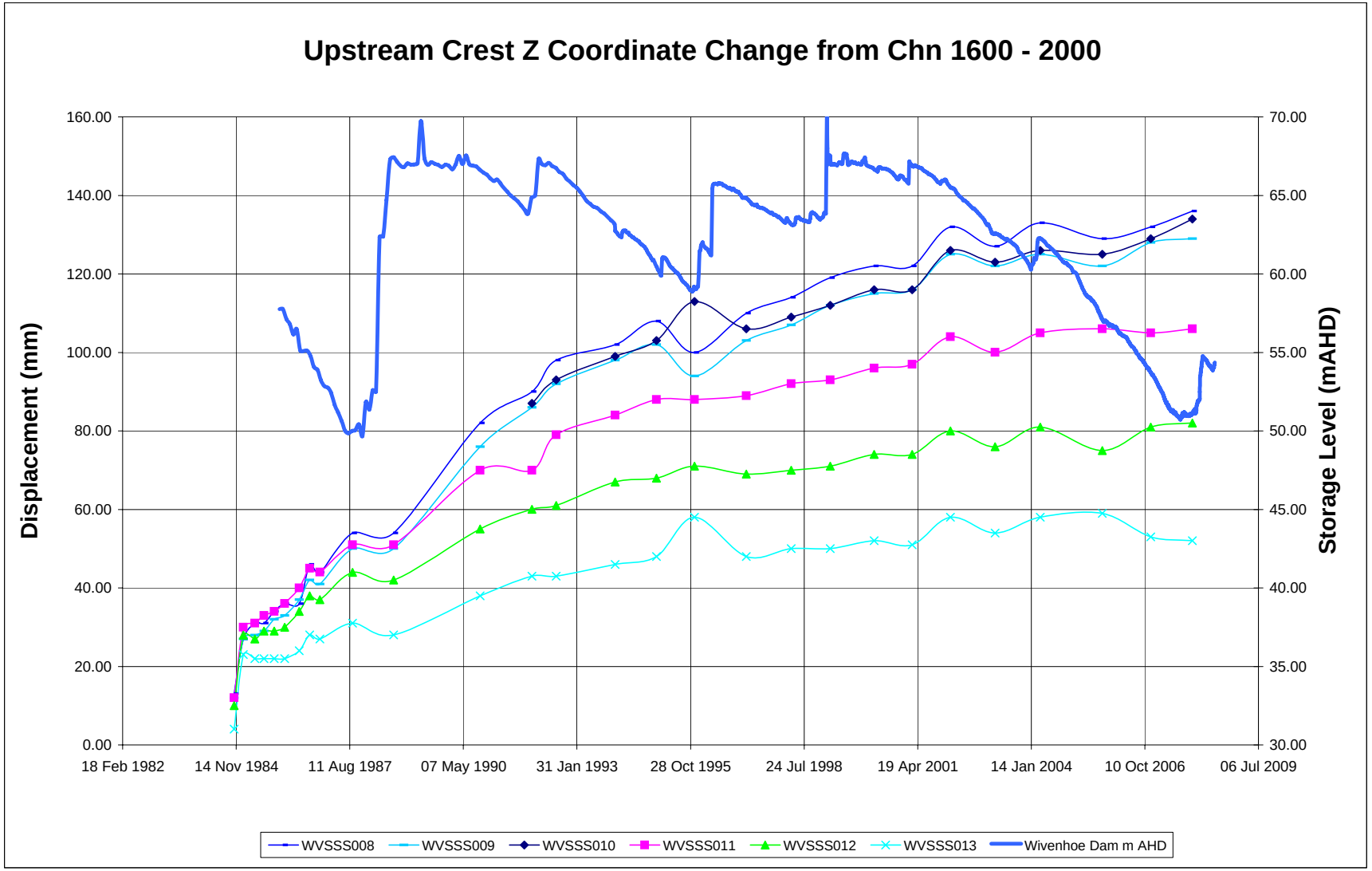
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS001
WVSSS002
WVSSS003
WVSSS004
WVSSS005
WVSSS006
WVSSS007
WVSSS008
WVSSS009
Wivenhoe Dam m AHD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Displacement (mm)
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120.00
100.00
80.00
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45.00
40.00
35.00
30.00
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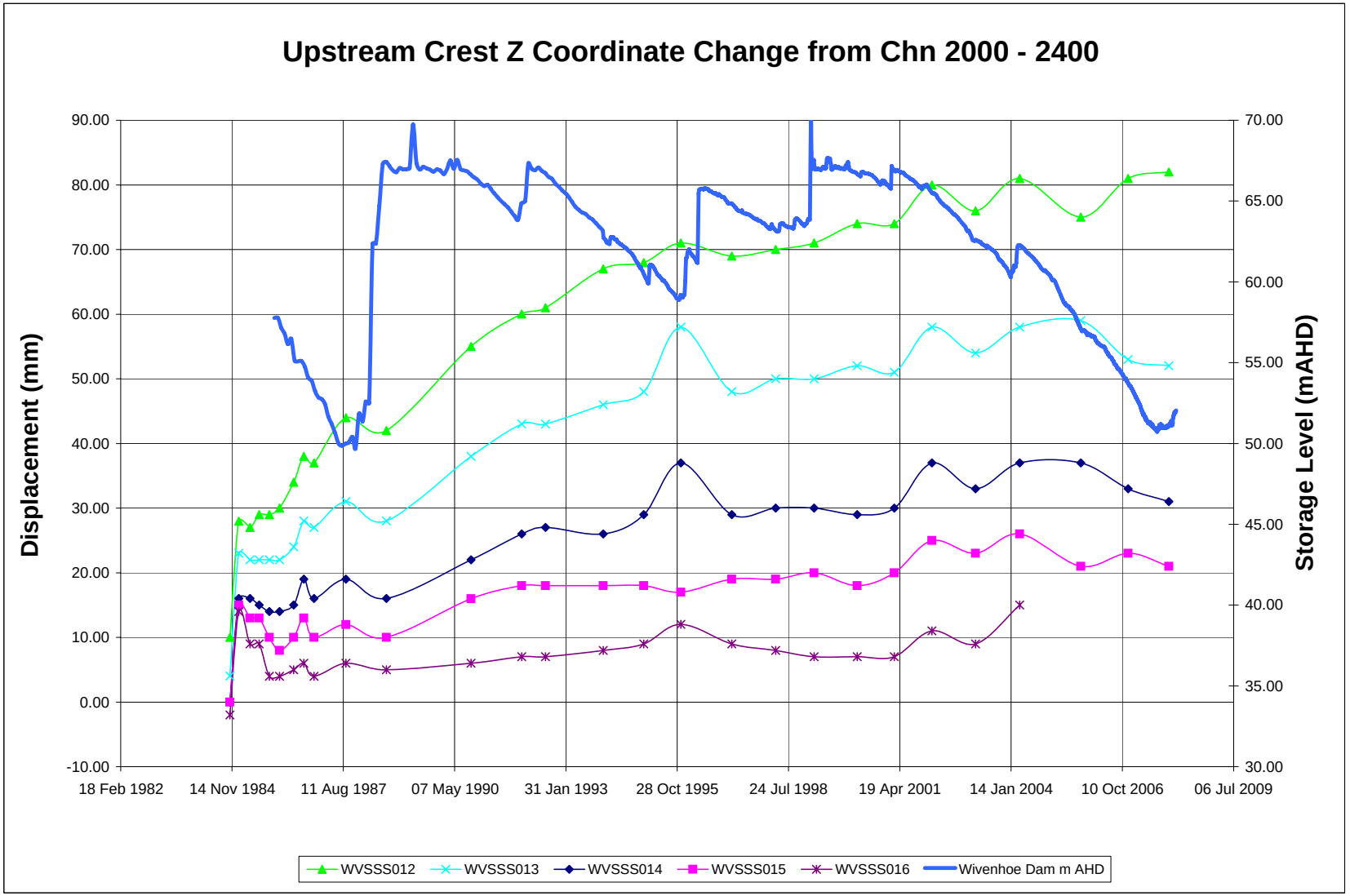
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS008
WVSSS009
WVSSS010
WVSSS011
WVSSS012
WVSSS013
Wivenhoe Dam m AHD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Displacement (mm)
Storage Level (mAHD)
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80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
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10 Oct 2006
06 Jul 2009
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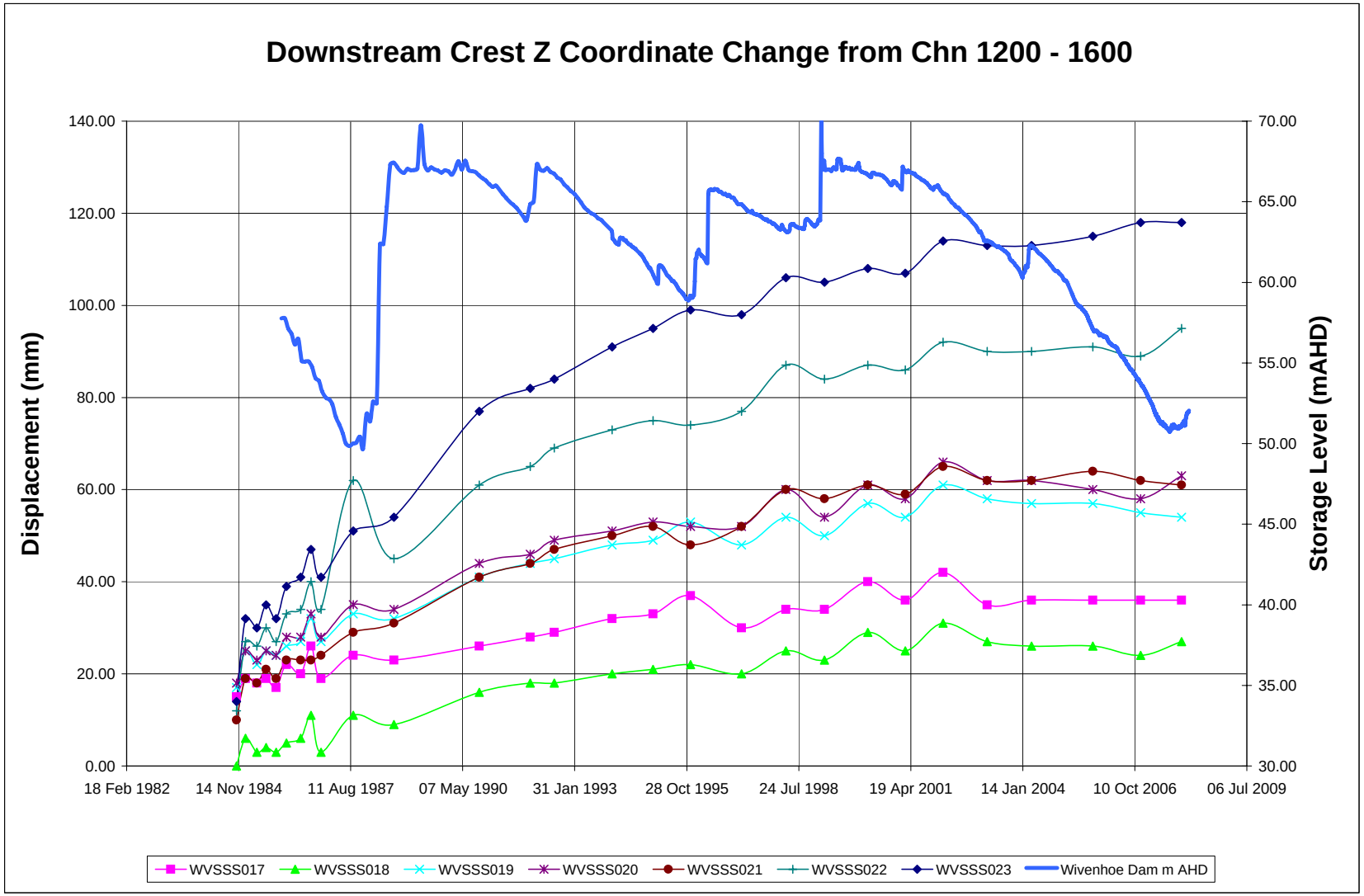
WVSSS013
WVSSS014
WVSSS015
WVSSS016
Wivenhoe Dam m AHD


Downstream Crest Z Coordinate Change from Chn 1200 - 1600
Displacement (mm)
Storage Level (mAHD)
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120.00
100.00
80.00
60.00
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60.00
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50.00
45.00
40.00
35.00
30.00
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31 Jan 1993
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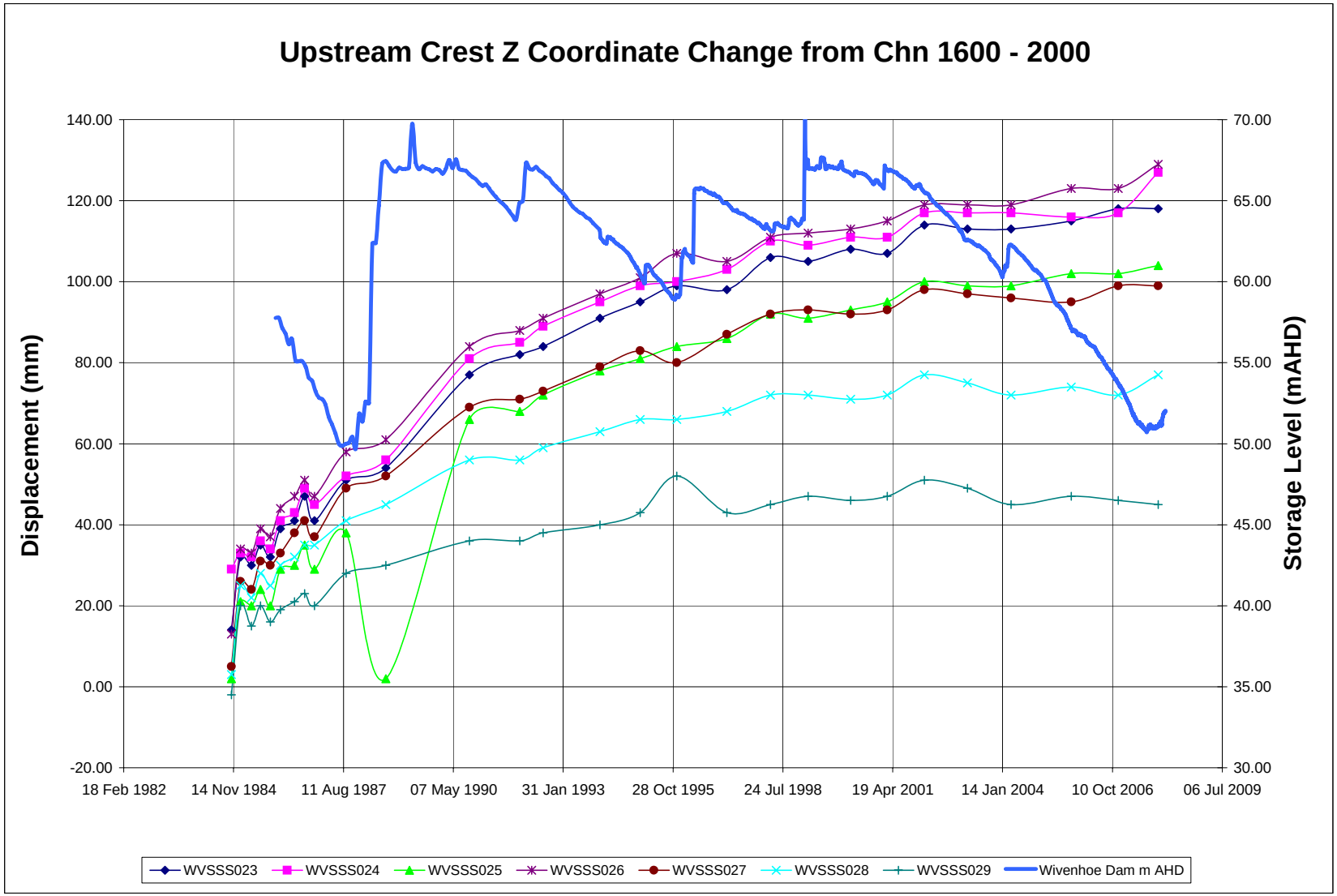
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS017
WVSSS018
WVSSS019
WVSSS020
WVSSS021
WVSSS022
WVSSS023
Wivenhoe Dam m AHD


Upstream Crest Z Coordinate Change from Chn 1600 - 2000
Displacement (mm)
Storage Level (mAHD)
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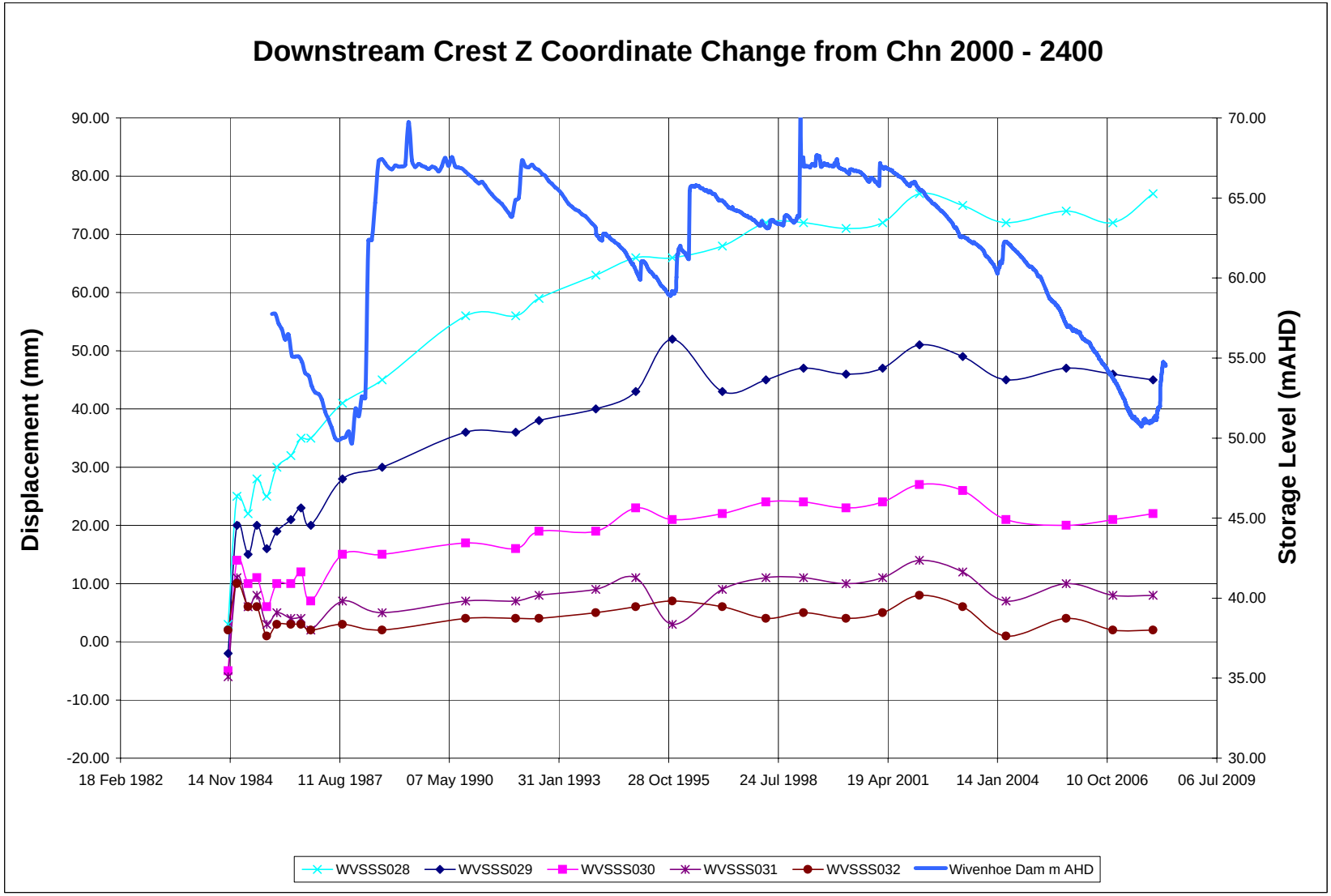
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS023
WVSSS024
WVSSS025
WVSSS026
WVSSS027
WVSSS028
WVSSS029
Wivenhoe Dam m AHD


Downstream Crest Z Coordinate Change from Chn 2000 - 2400
Displacement (mm)
Storage Level (mAHD)
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60.00
55.00
50.00
45.00
40.00
35.00
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18 Feb 1982
14 Nov 1984
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28 Oct 1995
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WVSSS028
WVSSS029
WVSSS030
WVSSS031
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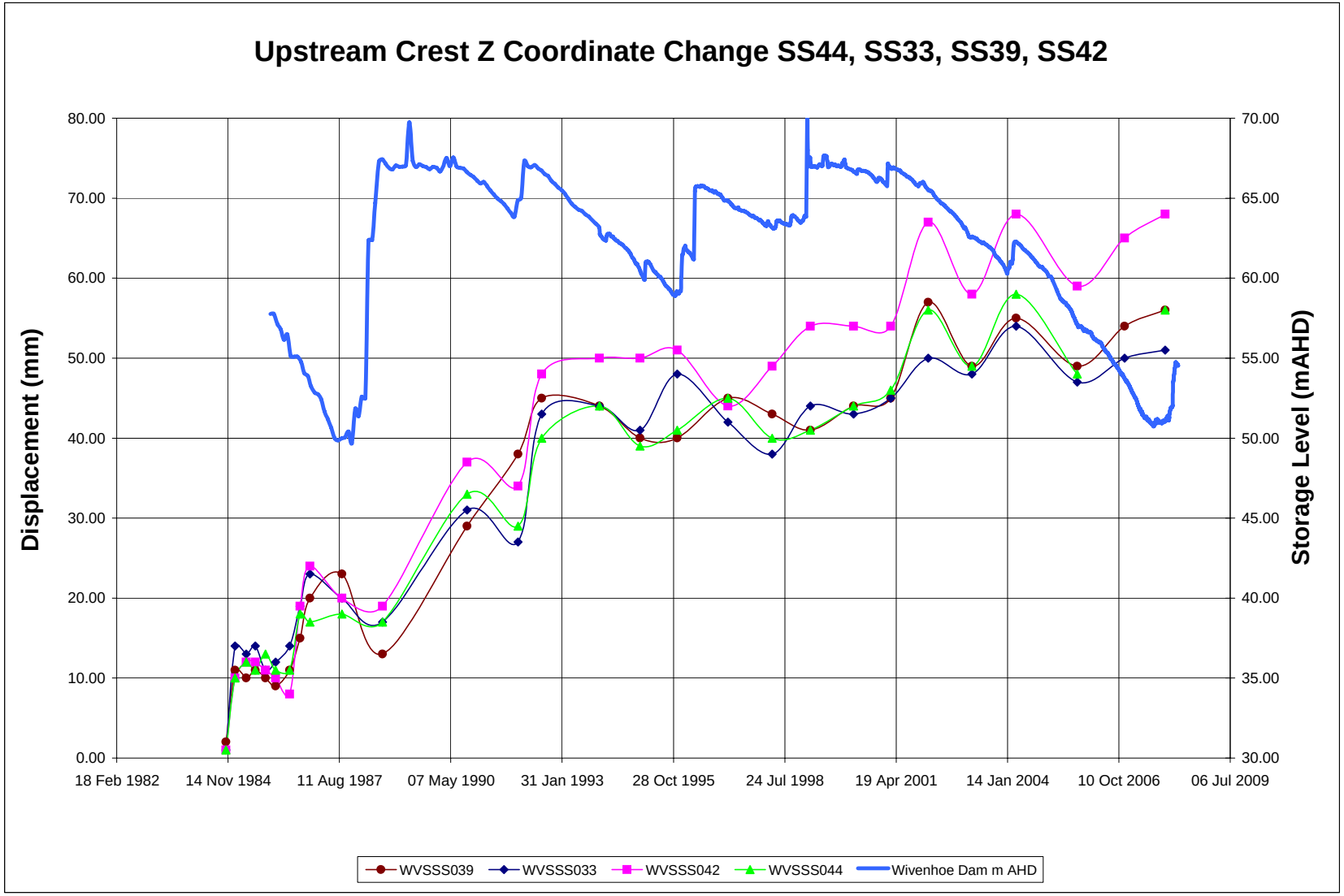
Wivenhoe Dam m AHD


Upstream Crest Z Coordinate Change SS44, SS33, SS39, SS42
Displacement (mm)
Storage Level (mAHD)
80.00
70.00
60.00
50.00
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55.00
50.00
45.00
40.00
35.00
30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
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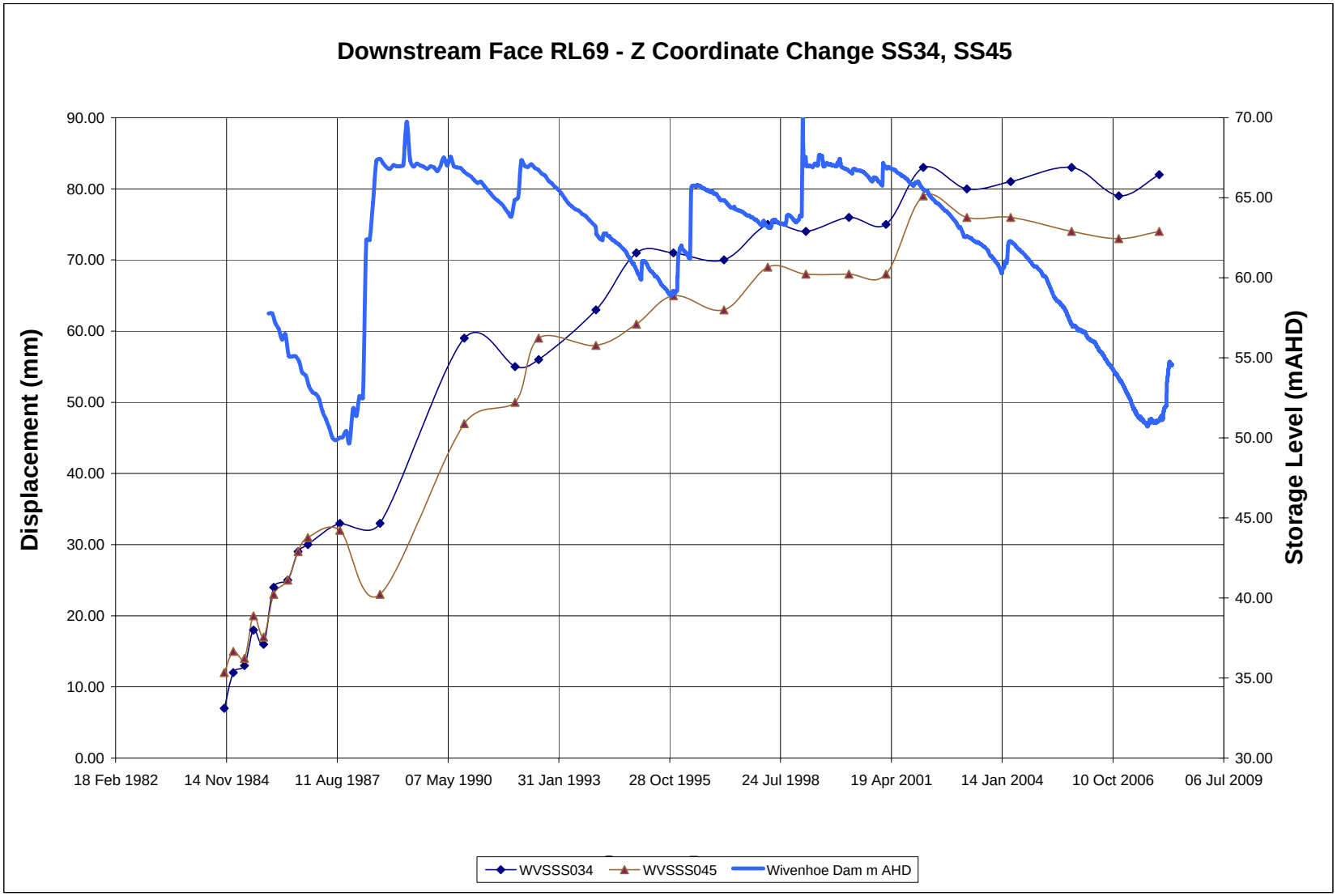
10 Oct 2006
06 Jul 2009
WVSSS039
WVSSS033
WVSSS042
WVSSS044
Wivenhoe Dam m AHD


Downstream Face RL69 - Z Coordinate Change SS34, SS45
Displacement (mm)
Storage Level (mAHD)
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60.00
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30.00
20.00
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0.00
70.00
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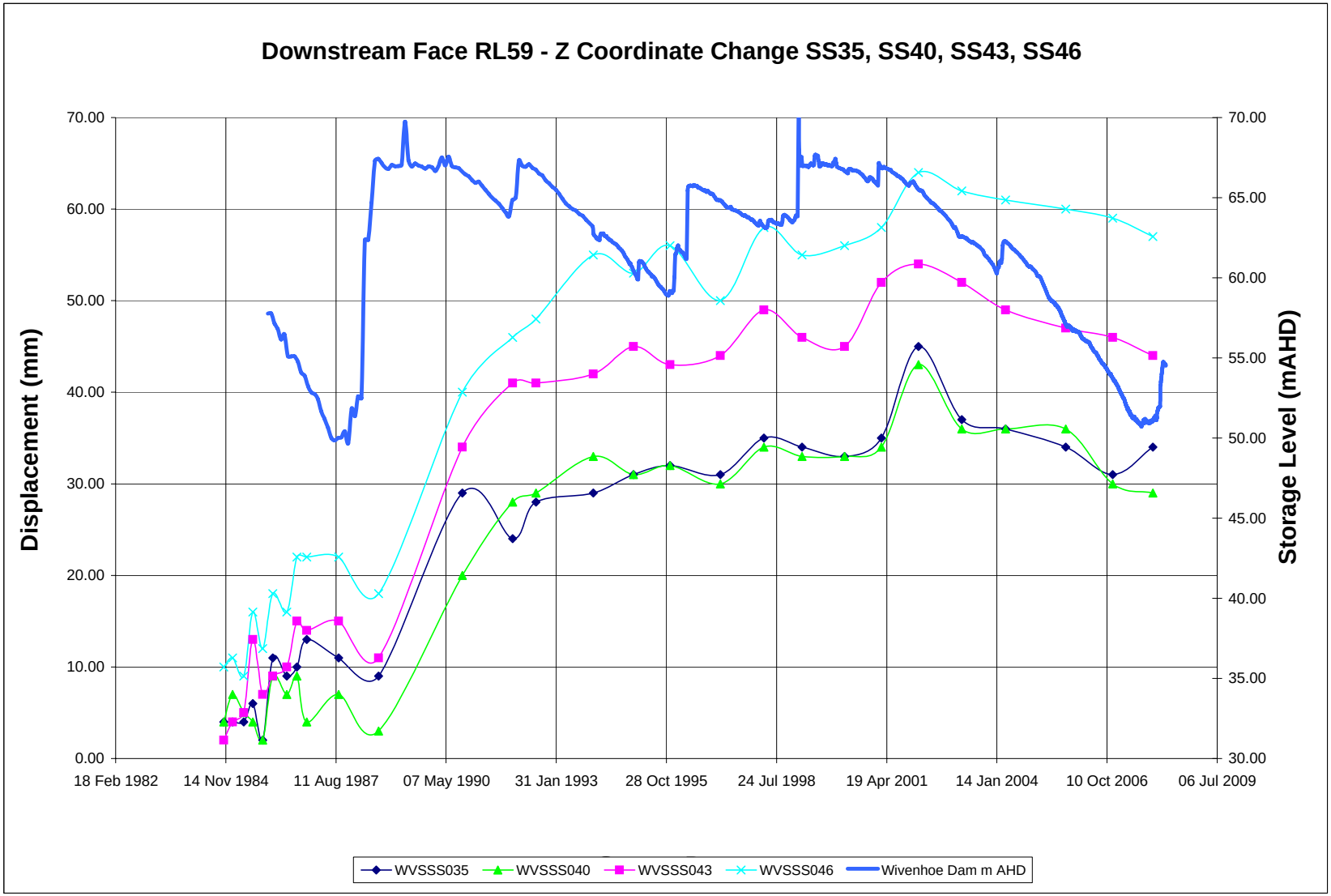
50.00
45.00
40.00
35.00
30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS034
WVSSS045
Wivenhoe Dam m AHD


Downstream Face RL59 - Z Coordinate Change SS35, SS40, SS43, SS46
Displacement (mm)
Storage Level (mAHD)
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50.00
40.00
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10.00
0.00
65.00
55.00
45.00
35.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
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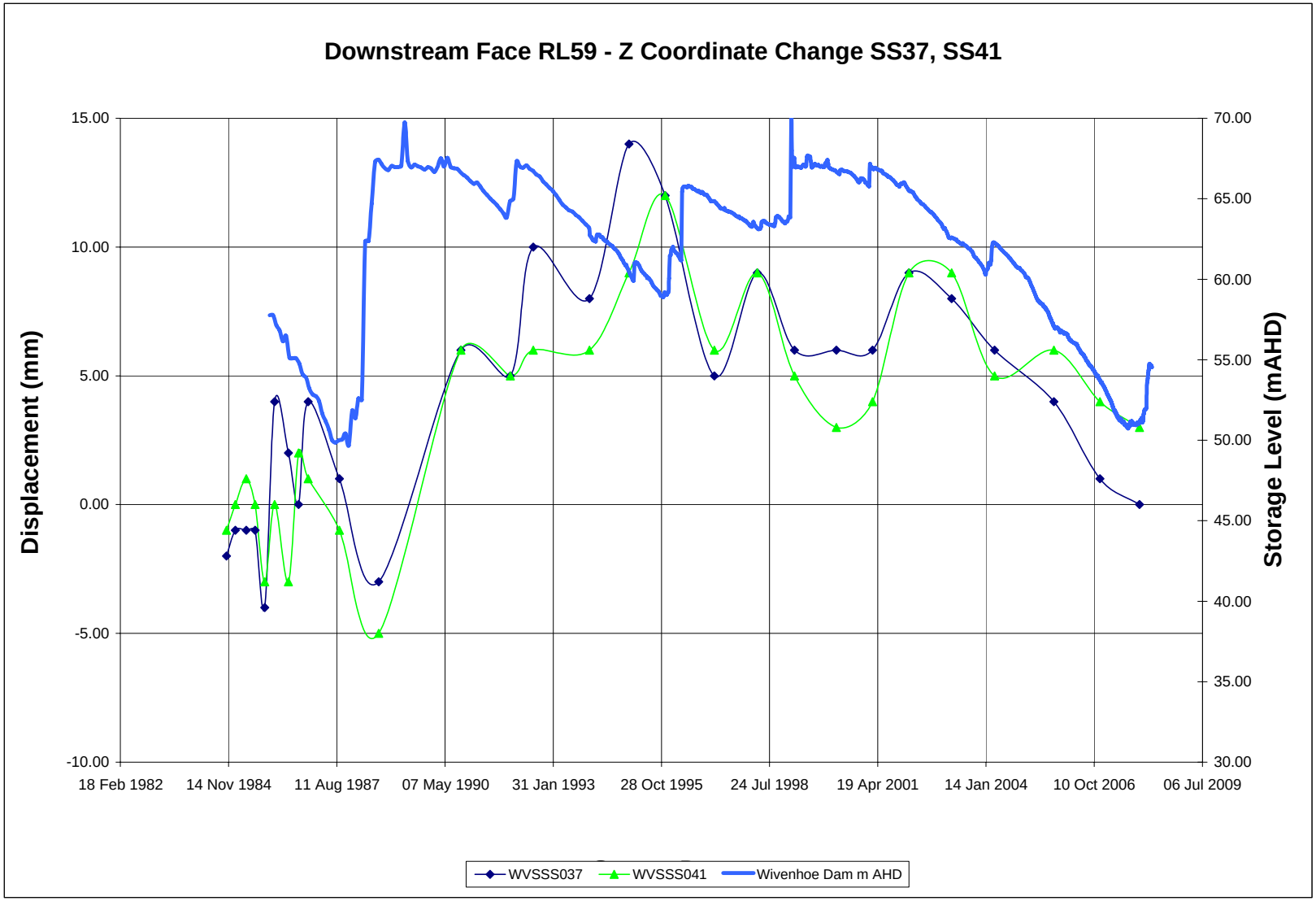
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS035
WVSSS040
WVSSS043
WVSSS046
Wivenhoe Dam m AHD


Downstream Face RL59 - Z Coordinate Change SS37, SS41
Displacement (mm)
Storage Level (mAHD)
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10.00
5.00
0.00
-5.00
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70.00
65.00
60.00
55.00
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45.00
40.00
35.00
30.00
18 Feb 1982
14 Nov 1984
11 Aug 1987
07 May 1990
31 Jan 1993
28 Oct 1995
24 Jul 1998
19 Apr 2001
14 Jan 2004
10 Oct 2006
06 Jul 2009
WVSSS037
WVSSS041
Wivenhoe Dam m AHD

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)

A1-53344

BRISBANE RIVER

BRISBANE VALLEY HIGHWAY

Spillway

Creek

Sheep Station Creek

Spring Creek

Access fence

Camp

Caravan Park

Store and Amenities

IWS Commission Office and Works Area

Playground

Sewerage Pump Sta.

Water Treat Plant

Single Staff Quarters

Single Mens Quarters

Saddle Dam N° 1

Saddle Dam N° 2

Approach

Sewerage Treatment Works

PSM N° 34242

Power available here

For location of Saddle Dam N° 2 see drg A2-47529

LIMIT OF RESUMPTION

LIMIT OF RESUMPTION (Not in BRISBANE VALLEY HIGHWAY contract)

460 000 X

6 970 900 Y

6 970 000 Y

6 969 000 Y

6 968 500 Y

461 000 X

462 500 X

NOTES:

1. ALL DIMENSIONS AND ALL ELEVATIONS ARE IN METRES
2. Levels Datum : All levels to AHD (PSM N° 34242 = EL 74·784)
3. Azimuth Datum ; AMG

FOR AS BUILT RECORD SEE AMENDED DRG. SAME NUMBER

Revision					
14·9·79	W	Tender drg. to working drg.	R.D.	A.J.W.C.	
9·5·79	A	Camp Layout and Contract N° amend.	M.J.C.	A.J.W.C.	
Date		Remarks	Ckd	Psd	

Drawing Schedule	
A1-50771	Spillway-General Arrangement
A1-50781	Right Bank-Embankment Arrangement. Sh 2 of 2
A1-50779	Right Bank-Embankment Arrangement Sh 1 of 2.
A1-50819	Left Bank-Embankment Arrangement & Section
K1-47502	Centre Line Survey of Axis and Spillway
A2-47523	Locality Plan
A1-50820	Embankment Area Plan.

0 100 200 300 400 500m

(1:5000 Scale Before Reduction)

CONTRACT N° 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting	Recommended
Prep'd	Dr T.S.	
Ckd	Ckd R.D.	Act Chief Designing Engineer
Supv	Supv R.D.	Approved
Submitted		
Senior Engineer Designs		Commissioner 14.6.78

CO-ORDINATOR GENERAL'S DEPARTMENT

S. Scholes 16.6.78
Co-ordinator General

BRISBANE RIVER 150·2 km — WIVENHOE DAM
THIRD STAGE CONSTRUCTION

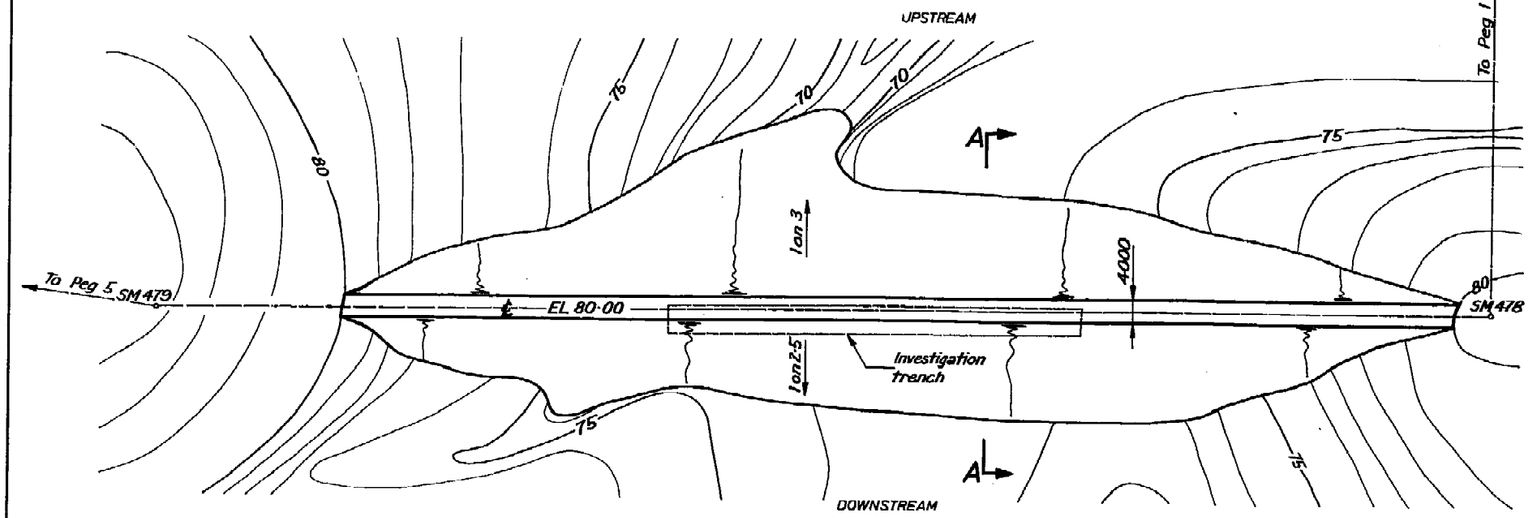
GENERAL ARRANGEMENT

16·6·78 | A1-53344 | A | W

INS. 0 2 4 6 8 10

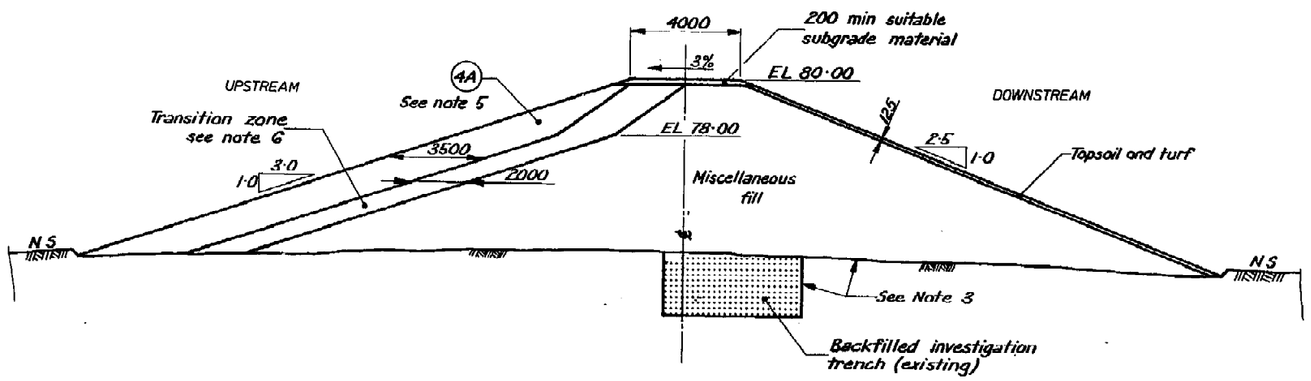
CM. 0 2 4 6 8 10 20 30

A1-53346



PLAN
Scale 'a'

AMG N



A-A
Scale 'b'

NOTES:-

1. ALL DIMENSIONS ARE IN MILLIMETRES AND ALL ELEVATIONS ARE IN METRES.
2. Levels Datum :- AHD (PSM 34242 - EL 74·784.)
3. Foundation has been stripped to below root zone.
4. Miscellaneous fill may consist of relatively impermeable low shrinkage material such as CL clays, well graded sandy clays and gravelly clays.
5. (4A) will be the same as rip rap of the main embankment.
6. Transition material shall be selected to be intermediate in grading between the miscellaneous fill and the rip rap.
7. A camber allowance of 1% of the height above foundation level shall be added to the crest EL of 80·00.
8. The downstream face is to be topsoiled and grassed.
9. The crest is to be sloped to aid in drainage.
10. For location of Saddle Dam see drg A2 - 47523

FOR 'AS BUILT' CROSS SECTIONS SEE A3-79166 – A3-79177

AS BUILT
By
Class
Date 31/10/85

Revision					Schedule		
Oct '85	B	As Built					
14-11-79	W	Tender to working drg.					
9-5-79	A	Contract Number Amended	M.J.C.	A.R.			
Date		Remarks	Ckd	Psd			
					Drawing	A2-47523	Location & Detail Locality Maps
						A1-45989	Saddle Dam Site N°1. Contour Plan.

Scale 'a' 0 10 20 30 40 50 m (Scale 1:500 before reduction)

Scale 'b' 0 5000 10000 mm (Scale 1:100 before reduction)

CONTRACT N° 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting
Prep K.J.M.C	Dr P.G.
Ckd	Ckd A.P.
Supv A.A.	Supv
Submitted	
Executive Engineer	

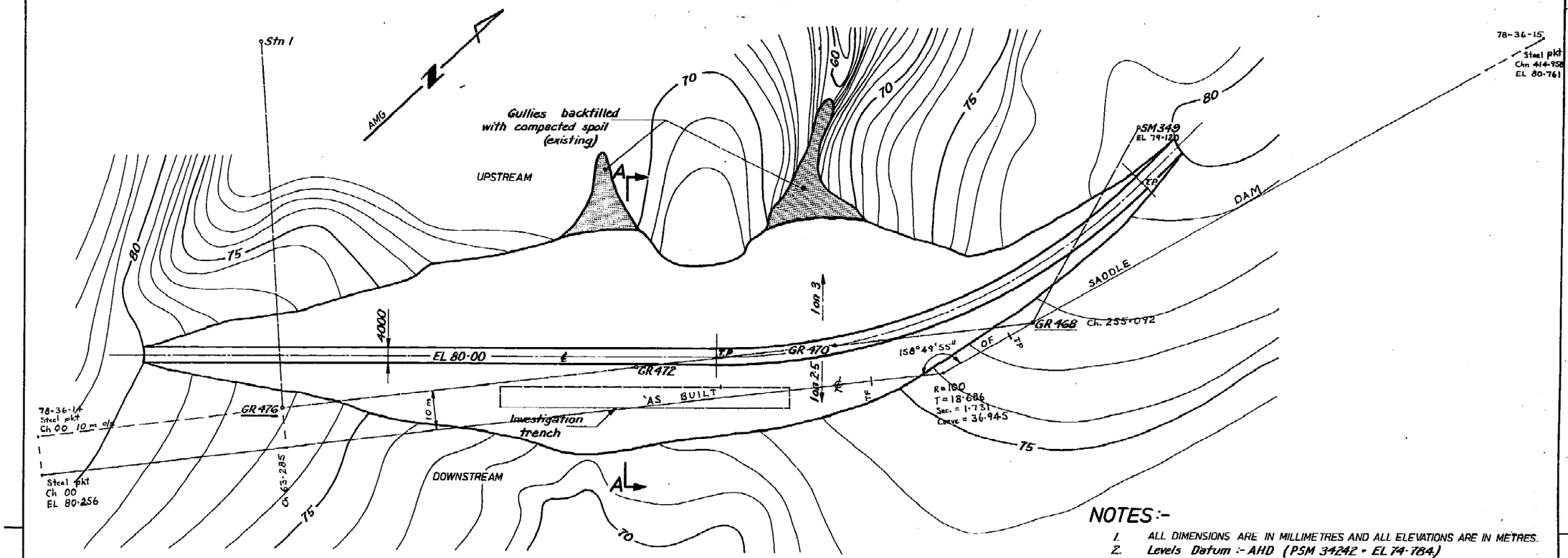
Recommended A. Russo. Senior Engineer Designs
Approved K.D.M. A/ Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

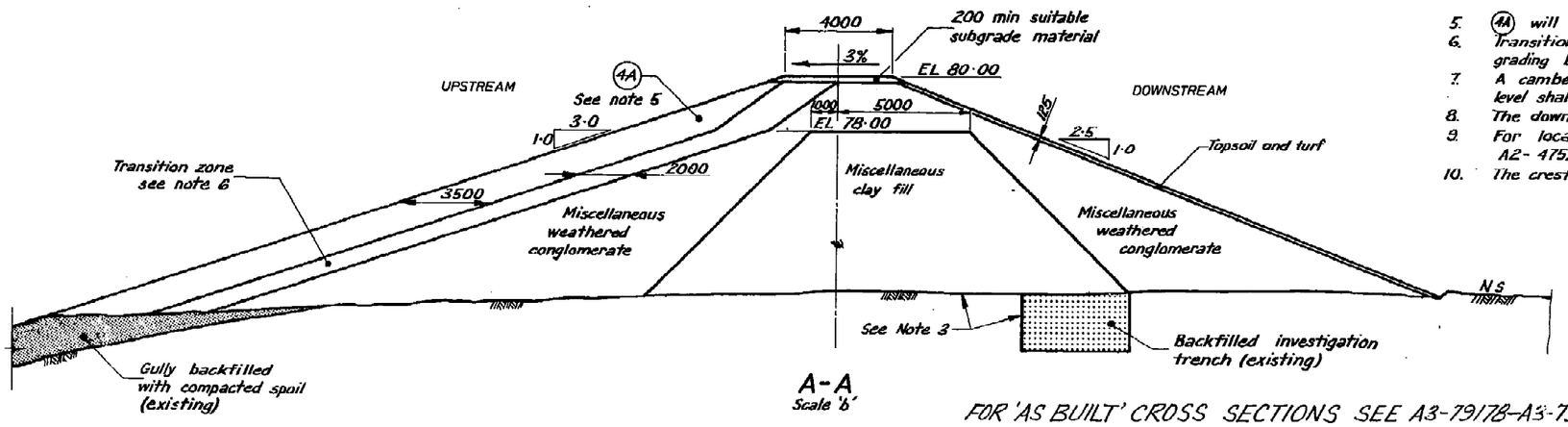
BRISBANE RIVER 150·2km – WIVENHOE DAM
LEFT BANK
SADDLE DAM N° 1

16-6-78 | A1-53346 | A | W | B

A1-53347



PLAN
Scale 'a'



A-A
Scale 'b'

FOR 'AS BUILT' CROSS SECTIONS SEE A3-79178-A3-79193

NOTES:-

1. ALL DIMENSIONS ARE IN MILLIMETRES AND ALL ELEVATIONS ARE IN METRES.
2. Levels Datum :- AHD (PSM 34242 - EL 74·784)
3. Foundation has been stripped to below root zone.
4. Miscellaneous fill may consist of relatively impermeable clays and sandy clays and low shrinkage weathered conglomerates.
5. (4A) will be the same as rip rap of the main embankment.
6. Transition material shall be selected to be intermediate in grading between the miscellaneous fill and the rip rap.
7. A camber allowance of 1% of the height above foundation level shall be added to the crest EL of 80·00.
8. The downstream face is to be topsoiled and grassed.
9. For location of Saddle Dam see drawing A2-47529.
10. The crest is to be sloped to aid in drainage.

AS BUILT
By
Ch'k'n
Date 31/10/85

Revision				
Oct '85	B	As Built		
14-11-79	W	Tender to working drg.		
9-5-79	A	Contract Number Amended	M.J.C.	
Date		Remarks	Ckd	Psd

Drawing Schedule	
A2-47523	Location & Detail Locality Maps
A1-45979	Saddle Dam Site Nº 2. Contour Plan.

Scale 'a' 0 10 20 30 40 50 m (1:500 scale before reduction)

Scale 'b' 0 5000 10 000 mm (1:100 scale before reduction)

CONTRACT Nº 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting
Prep'd M'C.	Dr
Ckd	Ckd
Supv	Supv
Submitted	
Executive Engineer	

Recommended
Senior Engineer Designs
Approved
Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km - WIVENHOE DAM
LEFT BANK
SADDLE DAM Nº 2

16-6-78 | A1-53347 | A | W | B

A1-54653

CIRCULAR PROFILE

$(x - 40{\cdot}331)^2 + (EL - 82{\cdot}891)^2 = 41{\cdot}808^2$

Bulkhead Gate Slot Refer A1-56215

Radial Gate Slot Refer A1-56215

7940 2580 1400 T.P. 5500 EL 57·000 EL 56·000 600 600 R3000 R7500 1550 EL 55·116 EL 53·808 2700

$EL = 57 - 0{\cdot}05004x^{1{\cdot}85}$

500 Typical

100 min

T.P. EL 50·899 1:333

Pier nib Refer A1-54551 & A1-56213

8000

17·416 to axis of spillway

6000

31·000 to axis of spillway

EL 43·265 EL 42·850

Ø150 formed drains see A1-56216

600 600 4000 x 140 PVC Waterstop EL 49·500 240 PVC waterstops 150 Upper Gallery

EL 48·000 Grout Cap Refer A1-56249 750 750 Grout & Drain Holes Refer A1-56216

EL 44·000 140 PVC Waterstop 600 600 160 Typical Lower Gallery 025 Axis of Spillway

Drain Holes Refer A1-56216

* PFL 36·000 500 1500 1000 lg concrete cutoff to suit waterstops.

5000 8 @ 3000 = 24000

35 @ 500 = 17500

A 3000 B 800

EL 36·750

TYPICAL SECTION THROUGH C/J

Scale a

150 NB DSI concrete lined pipe Refer A1-54717

EL 43·265 240 PVC waterstops EL 41·400 EL 42·850

450 NB DSI concrete lined pipe Refer A1-54717

EL 45·000 EL 44·600 EL 43·000 EL 41·700 EL 41·000 140 PVC waterstop EL 40·750

C/J * PFL 40·000

2000 25° 500 1500 1000

36 500 5500 5750 5750 4500 4000

To axis of spillway

64 000 to axis of spillway

Drain Hole Refer A1-54547

CIRCULAR PROFILE

$(x - 40{\cdot}331)^2 + (EL - 82{\cdot}891)^2 = 41{\cdot}808^2$

SECTION (B)

Scale 'b'

3000. 2 1 2 1

SECTION (A)

Scale 'c'

200 2 1 2 1 100 100 100 200 100

PFL 40·000

NOTES :-

1. All dimensions are in millimetres and all elevations are in metres.
2. All materials and workmanship to the relevant Australian Standards.
3. The ℄s of each shear key shown thus +

* For foundation levels see. A1-59623 & A1-59624

AS BUILT By [signature] Civil Senior Engr II Date 31/10/85

TYPICAL SECTION THROUGH C/J

Scale 'b'

Revision				Drawing Schedule	
Oct '85	A	As Built	[signature]	A1-56250	Key To Working Drawings Numbers
Date		Remarks	Ckd / Prd		

Scale 'a' 0 5000 10 000 mm (1:100)

Scale 'b' 0 1000 2000 3000 4000 5000 mm (1:50)

Scale 'c' 0 500 1000 mm (1:10)

Scales before reduction.

CONTRACT Nº 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting
Prep BJS	Dr [signature]
Ckd	Ckd [signature]
Supv	Supv M.J.C.

Submitted [signature] Executive Engineer

Recommended Senior Engineer Designs

Approved [signature] Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km - WIVENHOE DAM

SPILLWAY

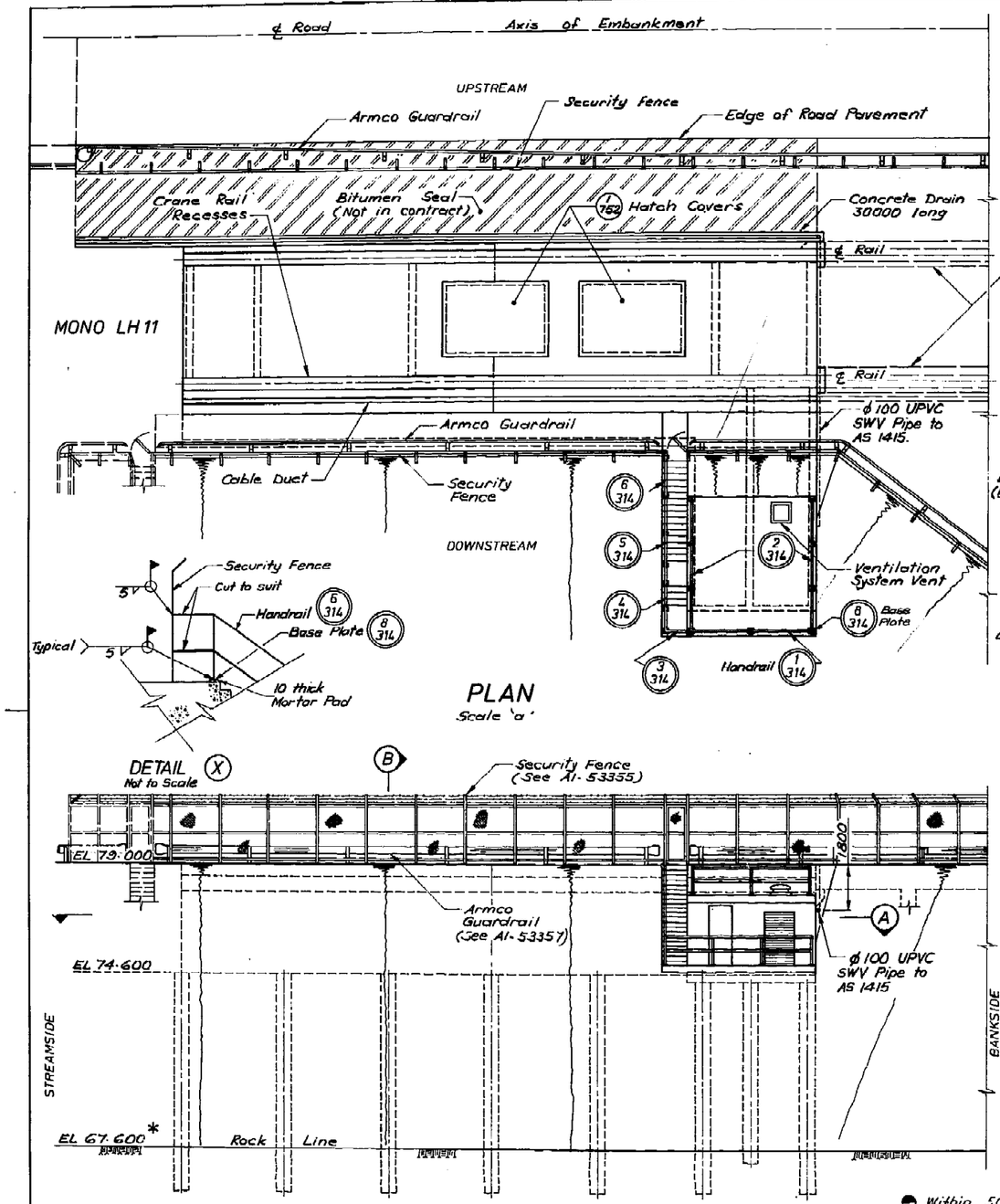
CONCRETE PROFILE

12·5·80 A1-54653 A

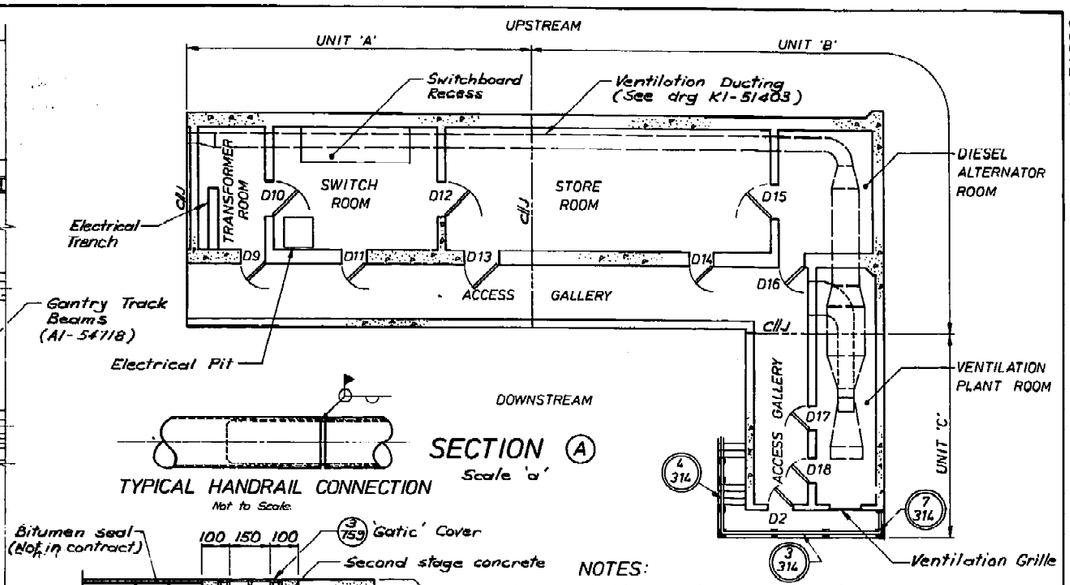
INS. 0 2 4 6 8 10

CM. 0 2 4 6 8 10 20 30

A1-54663



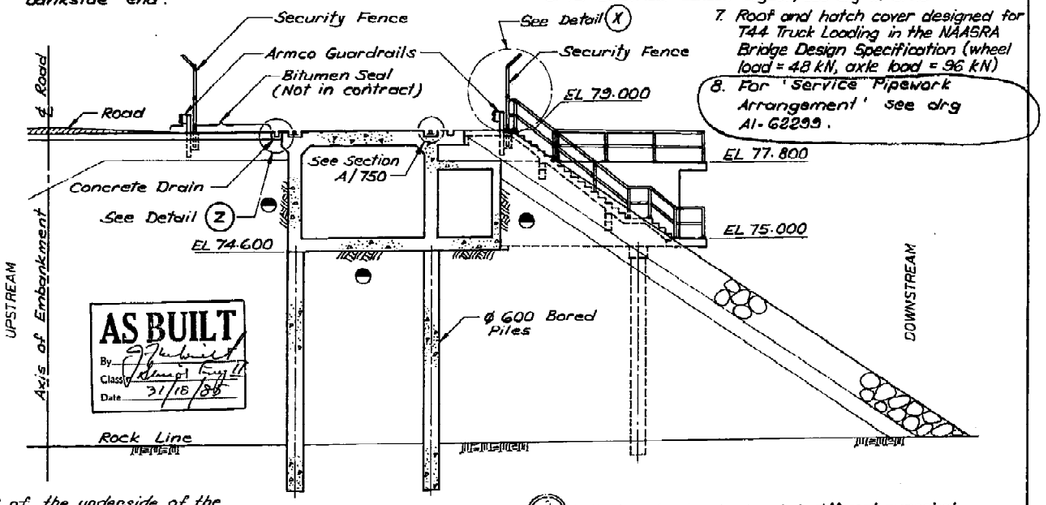
* Rock level shown is an approximate level only. Actual level to be determined by Engineer.



Note: Depth of drain 'd' varies from 100 at streamside end to 200 at bankside end.

NOTES:

1. All dimensions are in millimetres and all elevations are in metres.
2. All materials and workmanship to the relevant Australian Standards.
3. Levels Datum : AHD (PSM 34242 = EL 74.784)
4. 'D9' indicates door number as per Appendix 4 of the Specification.
5. After fabrication all galvanised surfaces damaged by cutting, welding or otherwise shall be cleaned and painted in accordance with procedure 2, clause 122.22 of the Specification.
6. For Electrical Conduit Layout, see drg KI-51418
7. Roof and hatch cover designed for T44 Truck Loading in the NAASRA Bridge Design Specification (wheel load = 48 kN, axle load = 96 kN)
8. For 'Service Pipework Arrangement' see drg A1-62299.



● Within 500 of the underside of the floor and the sidewalls of the control structure, the embankment backfill should not contain hard rock particles greater than 150 in size

SECTION (B)
Scale 'a'

(3/314) indicates drawing number is in different numerical series to this drawing, refer drawing schedule.

Revision					
Date		Remarks	Ckd	Psd	
Oct '85	B	As Built			
12.1.82	A	Note 8 added			

Drawing Schedule	
A1-62299	Left Bank Monos - Service Pipework Arrgt.
A1-56314	Left Bk Uground Control Struct. Handrail Details
A1-54750	Spillway Gantry Crane Rails - Installation & Arrgt
A1-54759	Metal Items
A1-54752	Precast RC Hatch Covers - Conc. & Paint.
KI-51403	Ventilation System
KI-51402	Mechanical & Electrical Plant Layout
A1-54558	Concrete (Sheet 1 of 3)

Scale 'a' 0 5 10 m (1:100)

Scale 'b' 0 500 1000 mm (1:10)

(Scales before reduction)

CONTRACT Nº 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting	Recommended
Prep	Dr KEP	
Ckd	Ckd	Senior Engineer Designs
Supv	Supv M.J.C.	Approved
Submitted		
Executive Engineer		Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

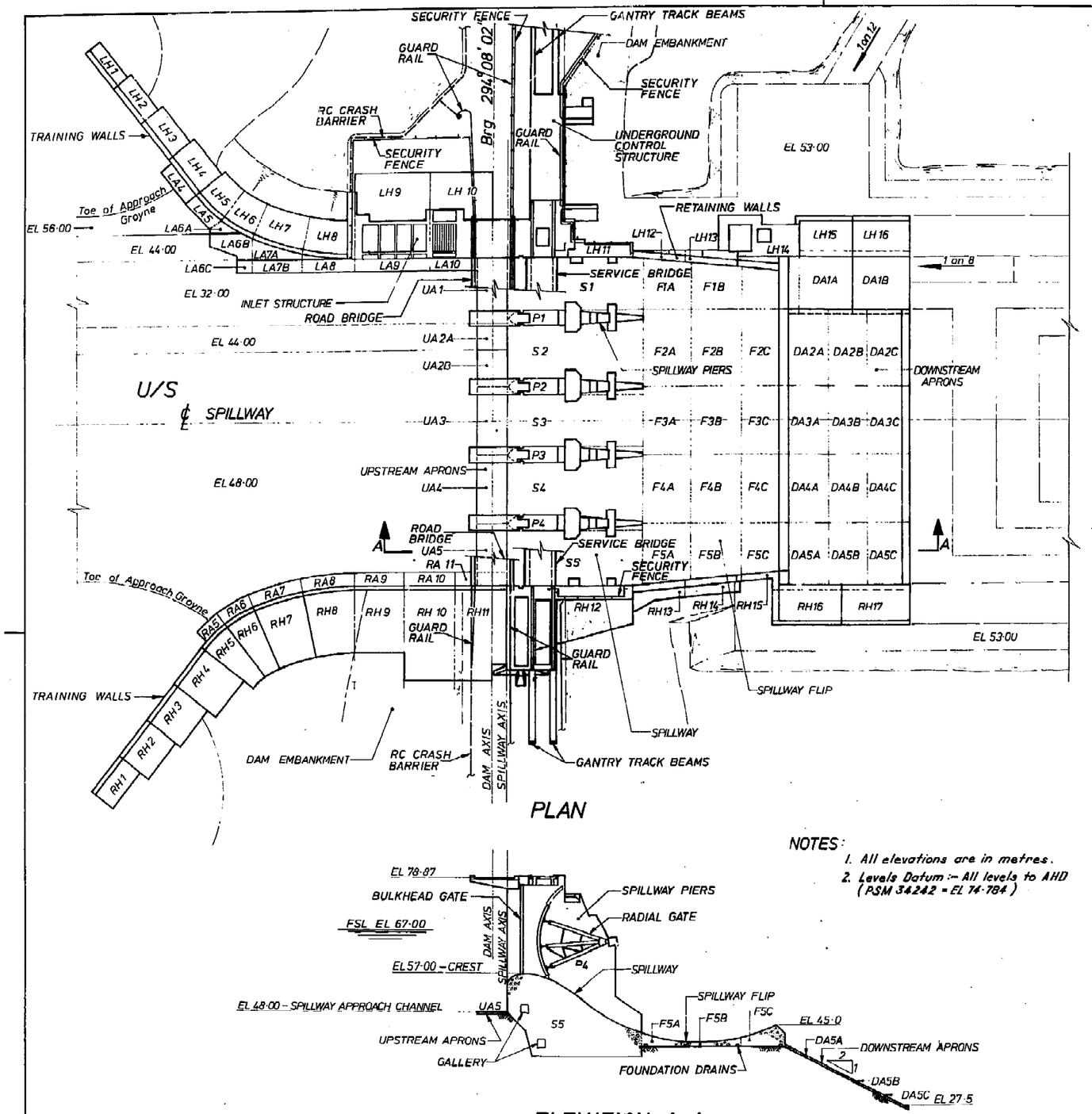
BRISBANE RIVER 150.2 km - WIVENHOE DAM

LEFT BANK - UNDERGROUND CONTROL STRUCTURE

ARRANGEMENT

9.12.80 A1-54663 A B

INS. CM.



NOTES:

1. All elevations are in metres.
2. Levels Datum :– All levels to AHD (PSM 34242 = EL 74·784)

INDEX TO SPILLWAY WORKING DRAWING NUMBERS

MONOLITH N°	ARRANGEMENT	CONCRETE DETAILS	REINFORCEMENT DETAILS	MS/FABRICATED ITEMS
LH1 – LH3	A1-54836	A1-54771	A1-54771	—
LH4 – LH5	A1-54836	A1-54829	A1-54829	—
LH6 – LH7	A1-54836	A1-54833	A1-54833	—
LH8	A1-54836	A1-54826	A1-54827-8	
LH9	A1-60888	A1-54612-3(< EL 62) A1-59941-3(> EL 62)	A1-54764-5 A1-60924 A1-60894-901	A1-56276, A1-54590 A1-60886, A1-60891
LH10	A1-60903-5	A1-56120-2(> EL 62) A1-54614-5(< EL 62)	A1-56149-56(> EL 62) A1-56097-103(< EL 62)	A1-56276 A1-56322-5
LH11	A1-61550-2	A1-54842-8(> EL 60) A1-54730-1(< EL 60) A1-54664-5 A2-56239	A1-56105-6 A1-54849-54(EL 60-71) A1-54740-4(EL 43-60) A1-54732-8(< EL 43) A1-62241-60(> EL 71)	A2-56225, A3-54729 A1-54543-5 A1-54767, A1-54769 A1-54814, A1-54841 A1-56096, A1-56123 A1-56138-43
LH12	A1-54542	A1-54542	A1-54552-4	A1-54748-9
LH 13		A1-54550	A1-54597-601	A1-54748-9 A3-56204
LH14 (Diversion Stage)	A1-56234-8	A1-56181, A2-54761 A1-54700-4	A1-56163-79	A1-56148, A1-54856 A1-54756-7, A1-54710 A1-54705, A1-54654-6 A1-54824-5, A1-54837 A1-54693-4, A1-54760
LH14 (Final Stage)	A1-56234-8	A1-54706-8	A1-56163-79	A1-54837-8 A1-54824-5 A1-54748-9
LH15 – LH16	A1-54529	A1-54529	A1-54530-1	A1-54748-9
LA4	A1-54836	A1-54836	A1-56262	—
LA5, LA6A-6B, LA7A	A1-54836	A1-54836	A1-54688	—
LA6C – LA7B	A1-54836	A1-54836	A1-54682	—
LA8 – LA10	A1-54836	A1-54836	A1-54685	—
LA11		A1-56161	A1-56161	—
RH1 – RH3	A1-54836	A1-56114	A1-56114	—
RH4 – RH5	A1-54836	A1-56127	A1-56127	—
RH6 – RH9	A1-54836	A1-56187	A1-56187	—
RH10 – RH11	A1-54836	A1-56192	A1-56192	—
RH12	A1-56331-2	A1-54815-22	A1-56089-94 A1-59953-72	A1-54695-6, A2-56303-4 A1-56306-8, A1-56312-3 A1-56291-2
RH13	—	A1-54557	A1-54591-3	A1-54747
RH14	—	A1-54562	A1-54604	A1-54561, A1-54747
RH15	—	A1-54563	A1-54564	A1-54747
RH16	—	A1-54605	A1-54606	A1-54747
RH17	—	A1-54608	A1-54609	A1-54747
RA5 – RA11	A1-54836	A1-54836	A1-54667	—
UA1	—	A1-54674	A1-54674	—
UA2A – UA5	—	A1-54676	A1-54676	—
S1 – S5	—	A1-54556, A1-54551 A1-56208, A1-56210-14	A1-56252-3, A1-56300-1 A1-56199-202	A1-54840
F1A	—	A1-54566-7	A1-54568	—
F2A	—	A1-54566-7	A1-54572	—
F3A, F4A	—	A1-54566-7	A1-54578	—
F5A	—	A1-54566-7	A1-54584	—
F1B	—	A1-54566-7	A1-54570	—
F2B	—	A1-54566-7	A1-54574	—
F3B, F4B	—	A1-54566-7	A1-54580	—
F5B	—	A1-54566-7	A1-54586	—
F2C	—	A1-54566-7	A1-54576	A1-54717
F3C, F4C	—	A1-54566-7	A1-54582	A1-54717
F5C	—	A1-54566-7	A1-54588	A1-54717
DA1A, DA1B	—	A1-54533	A1-54548-9	A2-54768
DA2A	—	A1-54628	A1-54629	—
DA2B	—	A1-54628	A1-54637	—
DA2C	—	A1-54628	A1-54644	—
DA3A, DA4A	—	A1-54628	A1-54633	—
DA3B, DA4B	—	A1-54628	A1-54639	—
DA3C, DA4C	—	A1-54628	A1-54646	—
DA5A	—	A1-54628	A1-54635	—
DA5B	—	A1-54628	A1-54642	—
DA5C	—	A1-54628	A1-54649	—
P1 – P4	A1-62279-80	A1-56289 A1-56309 A1-56311	A1-56315-20 A1-59981	A1-62290-1

Revision					Drawing Schedule	
9-3-83	A	Index Amended	M.J.C.	M.J.C.	A1-62306	5 Way Key to Working Drawing Numbers (Sh 2 of 2)
Date		Remarks	Ckd	Psd	A1-50771	Spillway General Arrangement

0 10 20 30 40 50 m
(Scale 1:500 Before Reduction)

CONTRACT N° 2120

IRRIGATION AND WATER SUPPLY COMMISSION

Design	Drafting	Recomended
Prep	Dr MK	
Ckd	Ckd P.G.	Senior Engineer Designs
Supv	Supv M.J.C.	Approved
Submitted		
Executive Engineer		Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km – WIVENHOE DAM

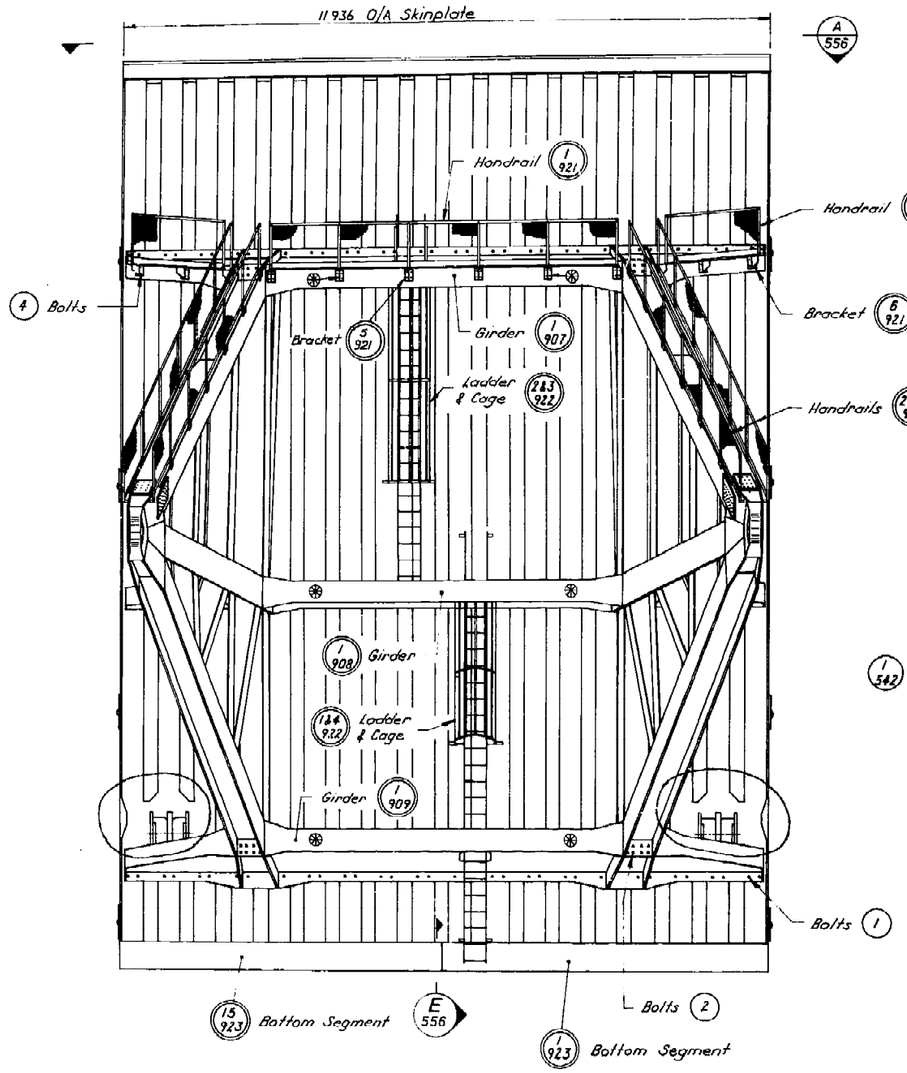
SPILLWAY

KEY TO WORKING DRAWING NUMBERS

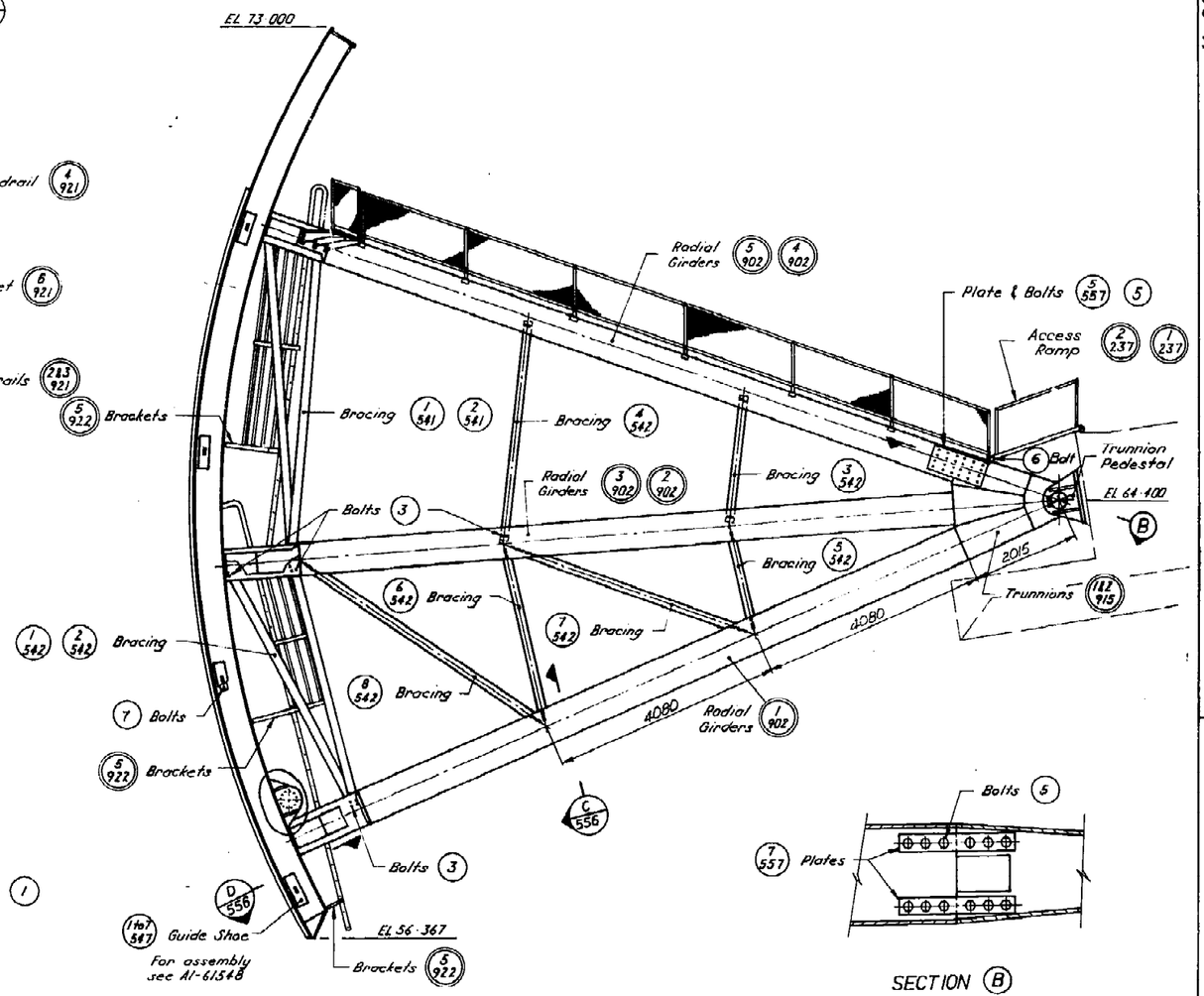
Sh 1 of 2 | 14.12.81 | A1-56250 | A

A1-56250

A1-61555



ELEVATION



END ELEVATION

SECTION (B)

Not to Scale

⊛ With approval of the Engineer. Temporary bracing may be bolted to the outer girder flanges at the positions marked ⊛. After field erections holes to be filled and ground flush.

NOTES:

1. All dimensions are in millimetres and elevations in metres.
2. All materials and workmanship shall be in accordance with the specification.
3. (5/922) Indicates drawing number is in a different numerical series to this drawing. See drawing schedule.

BOLT SCHEDULE - QUANTITY FOR 5 GATES

ITEM No	GRADE	LOCATION	DIA	LENGTH	TYPE	THREAD LENGTH	No REQD	NUTS REQD	WASHERS REQD
7	4.6	Guide Shoe	20	65	Galv Hex	46	80	80	80
6		Lug to Walkway	20	55	Galv Hex	22	20	20	20
5		Girder to Trunnion	30		HSFG				
4	4.6	Brackets to Girder	12	50	Galv Hex	30	240	240	240
3	4.6	Bracing	24	65	Galv Hex	54	560	540	540
2	8.8	Radial Girders	20	75	Galv Hex	46	480	480	480
1	4.6	Bot, Top & Mid Girders	16	55	Galv Hex	38	1080	1080	1080

Revision					
	16.9.83	D	Sheave block shifted	M.J.C	
	15.8.83	C	Section 'E' added	M.J.C	
	20.10.82	B	Bracket item number amended.	M.J.C.	
	26.8.82	A	Guide Shoe & O/A Skinplate Dim. added	M.J.C.	
	Date		Remarks	Ckd	Psd

Drawing Schedule	
A1-62237	Radial Gates - Access Ramp
A1-61557	Radial Gates - Grid Floor & Splice Plates
A1-61556	Radial Gates - Arrangement Sh 2 of 2
A1-61547	Radial Gates - Guide Shoe Fabrication
A1-61548	Radial Gates - Guide Shoe Assembly
A1-61541	Radial Gates - Girder Bracing
A1-61542	Radial Gates - Girder Bracing
A1-60902	Radial Gates - Radial Girders
A1-60921	Radial Gates - Handrails
A1-60907	Radial Gates - Top Horiz Girder
A1-60908	Radial Gates - Middle Horiz Girder
A1-60909	Radial Gates - Bottom Horiz Girder
A1-60923	Radial Gates - Bottom Segment & Seal Clamps
A1-60922	Radial Gates - Ladders

Scale Before Reduction

0 1000 2000 3000 4000 5000 mm (1:50)

CONTRACT Nº 2123

QUEENSLAND WATER RESOURCES COMMISSION

Design	Drafting	Recommended
Prep	Dr AR	M. Russo
Ckd	Ckd M.J.C.	Senior Engineer Designs
Supv	Supv M.J.C.	Approved
Submitted		
Executive Engineer		Chief Designing Engineer

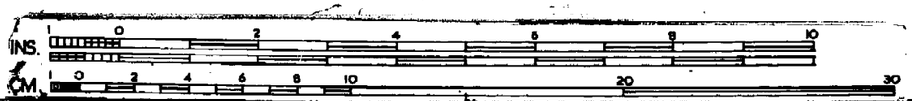
CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km - WIVENHOE DAM

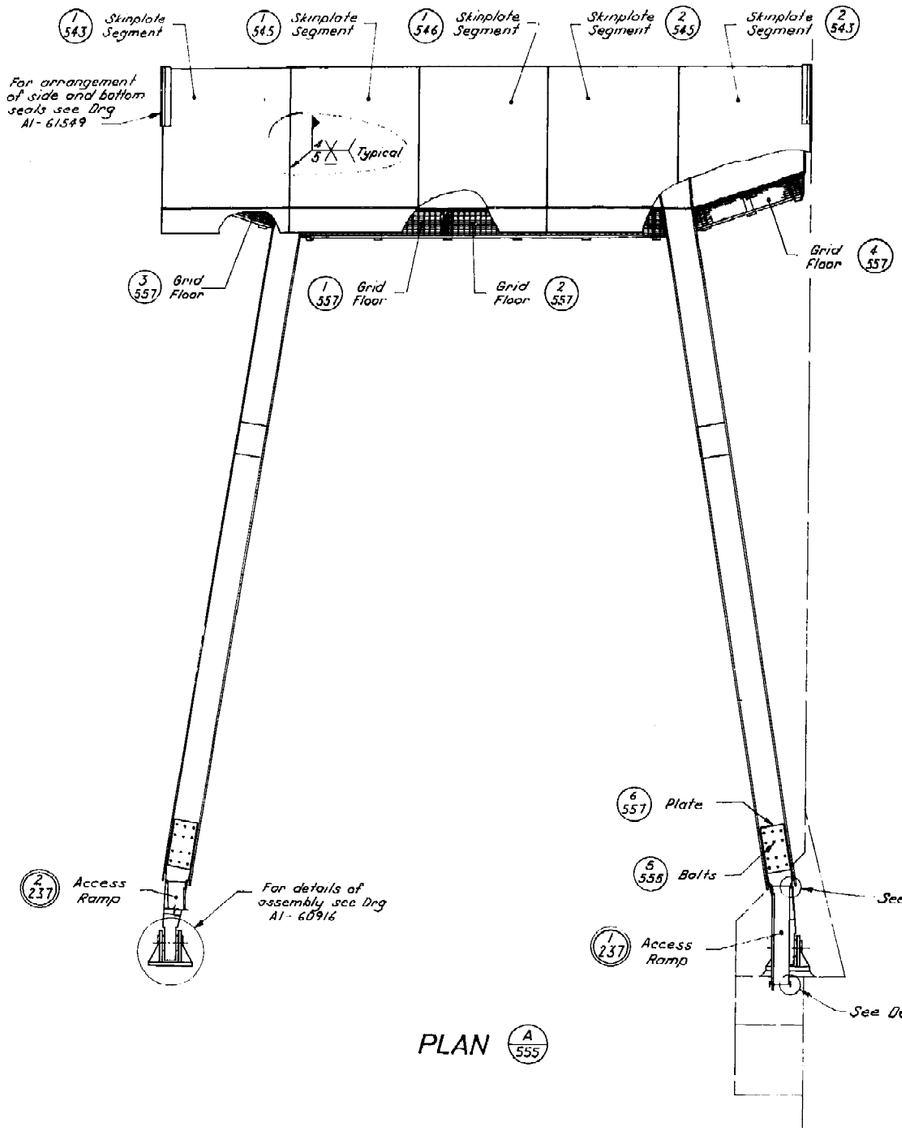
RADIAL GATES

ARRANGEMENT

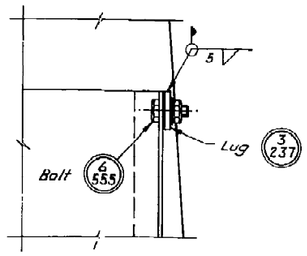
Sh 1 of 2 | A1-61555 | A | B | C | D



A1-61556

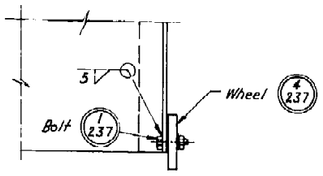


PLAN (A/555)



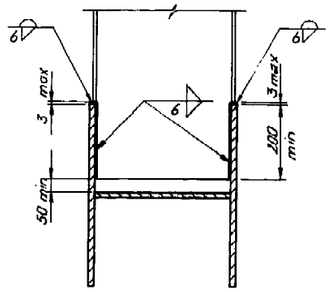
DETAIL (X)

(Not to scale)



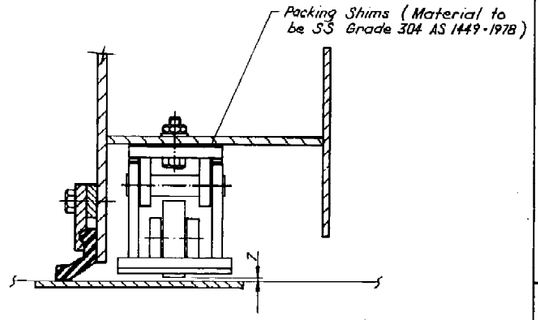
DETAIL (Y)

(Not to scale)



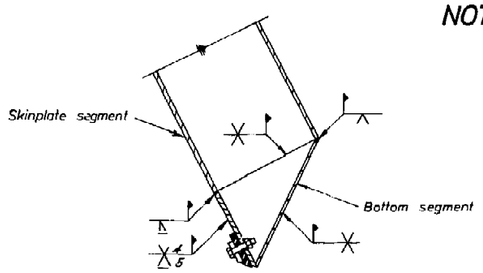
SECTION (C/555)

(Not to Scale)



SECTION (D/555)

(Not to Scale)



SECTION (E)

NOTES:

1. All dimensions are in millimetres.
2. All materials and workmanship shall be in accordance with the specification.

Drawing Schedule	
A1-61559	Bulkhead & Radial Gate - Arrangement
A1-61557	Radial Gates - Grid Floor & Splice Plates
A1-61549	Radial Gates - Seal Arrangement
A1-60916	Radial Gates - Trunnion Details
A1-61555	Radial Gates - Arrangement (Sh 1 of 2)
A1-61546	Radial Gates - Skinplate Segments
A1-61545	Radial Gates - Skinplate Segments
A1-61543	Radial Gates - Skinplate Segments

Revision				
Date		Remarks	Ckd	Psd
15-12-82	B	Skinplate weld amend. Section 'E' added	M.J.C.	
22-6-82	A	Details 'X' & 'Y' amended Section C/555	M.J.C.	

Scale Before Reduction

0 1000 2000 3000 4000 5000 mm (1:50)

CONTRACT Nº 2123

QUEENSLAND WATER RESOURCES COMMISSION

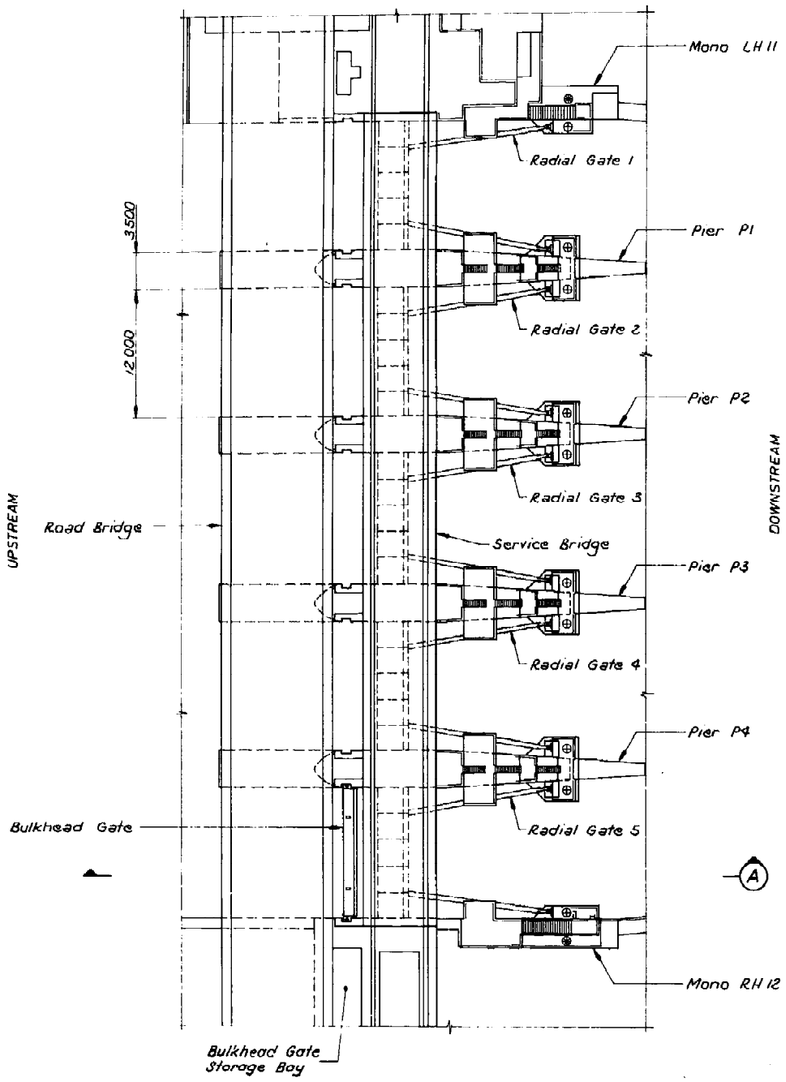
Design	Drafting	Recommended
Prep	Dr ABR	R. Russo
Ckd	Ckd M.J.C.	Senior Engineer Designs
Supv	Supv M.J.C.	Approved
Submitted		
Executive Engineer		Chief Designing Engineer

CO-ORDINATOR GENERAL'S DEPARTMENT

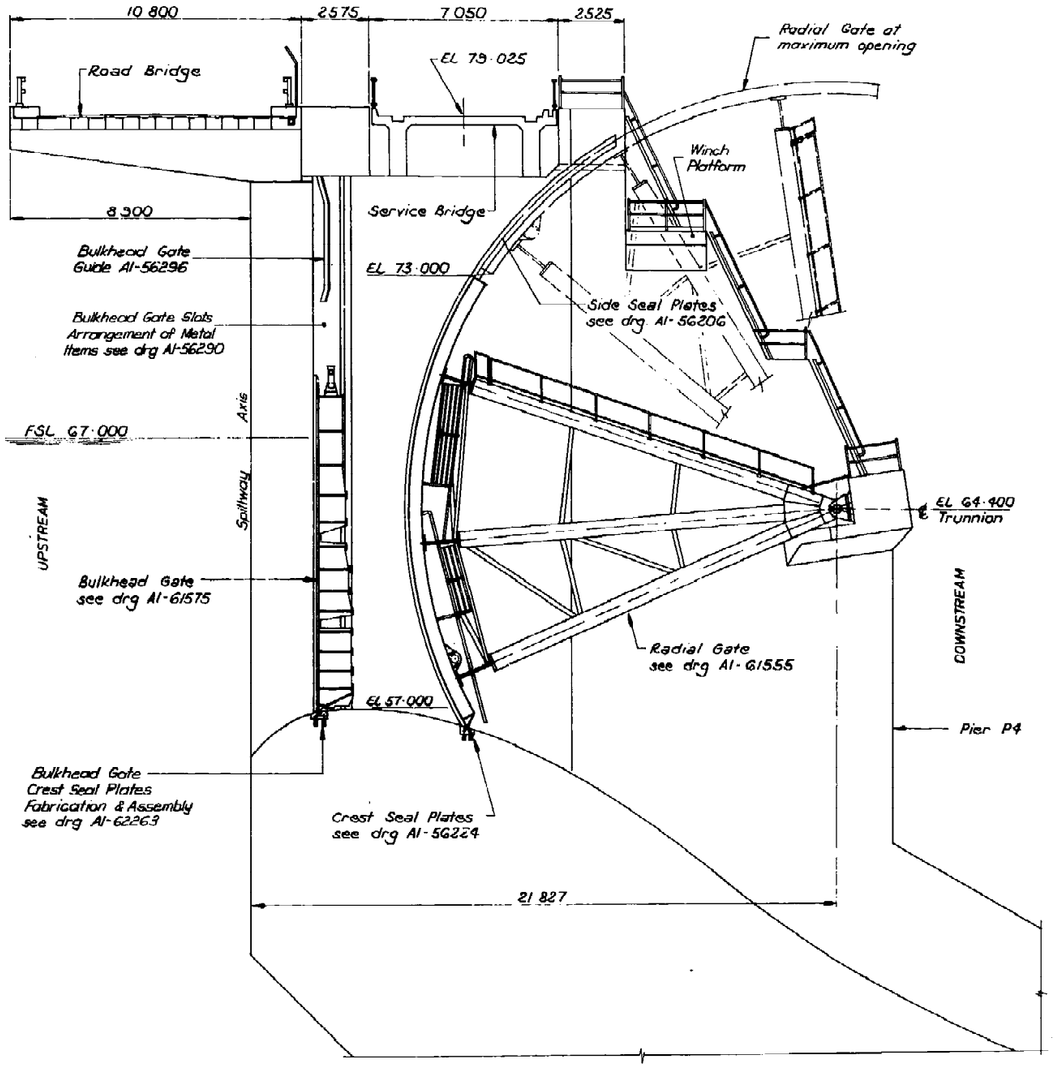
BRISBANE RIVER 150·2 km — WIVENHOE DAM
RADIAL GATES

ARRANGEMENT

Sh 2 of 2 | A1-61556 | A | B



PLAN
Scale 'a'



SECTION (A)
Scale 'b'

⊕ Means Secondary Benchmark ⊘

⊗ Means Primary Benchmark ⊘

⊘ The exact positions of these benchmarks shall be supplied to the Contractor prior to the field erection of the gates.

NOTES :
1. All dimensions are in millimetres and elevations are in metres.
2. Levels Datum : All levels to AHD PSM 39242 = EL 79·784
3. The system of numbering to be used throughout Contract 2123 for identification of and reference to gates, bays, piers and abutments is as shown on the plan.

Revision					Drawing Schedule	
					A1-56296	Bulkhead Gate Guide Fabrication.
					A1-56207	Side Seal Plates Fabrication.
Date		Remarks	Ckd	Psd	A1-56209	Crest Seal Plate Fabrication.

Scales Before Reduction
Scale 'a' 0 5 10 15 20 25 m 1:250
Scale 'b' 0 5 10 m 1:100

CONTRACT Nº 2123

QUEENSLAND WATER RESOURCES COMMISSION

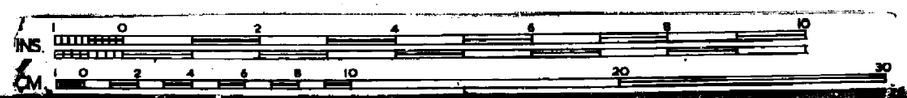
Design	Drafting	Recommended
Prep	Dr T.S.	
Ckd	Ukd M.J.C.	Chief Designing Engineer
Supv	Supv M.J.C.	Approved
Submitted		
Senior Engineer Designs		Commissioner

CO-ORDINATOR GENERAL'S DEPARTMENT

BRISBANE RIVER 150·2 km – WIVENHOE DAM

BULKHEAD AND RADIAL GATE ARRANGEMENT

30.7.81 A1-61559



Appendix D2 - 2005 "As Built" Drawings (Flood Security Upgrade)

SEQ WATER INFORMATION CENTRE

RELOCATE SEQ WATER ENTRANCE (STAGE 1 WORKS)

UPSTREAM SPOIL DISPOSAL AREA

EXISTING DAM EMBANKMENT

UPGRADE EXISTING CRASH BARRIER NEW HEIGHT AT A MINIMUM OF RL 80.1 (STAGE 1 WORKS)

CONSTRUCT RIGHT ABUTMENT SPILLWAY (STAGE 1 WORKS)

TRANSPIRATION BEDS

STRENGTHEN EXISTING SPILLWAY (STAGE 1 WORKS)

DOWNSTREAM SPOIL DISPOSAL AREA

HOLDING POND

BATCHING PLANT PLATFORM

LEFT HAND SIDE EMBANKMENT

HOLDING PONDS

HOLDING POND

CORMORANT BAY PICNIC AREA

RAISE SADDLE DAMS TO RL 81.0 (STAGE 2 WORKS)

EXISTING SADDLE DAM 1

CONSTRUCT CLAY CUT-OFF WALL (STAGE 1 WORKS)

EXISTING SADDLE DAM 2

CONSTRUCT SADDLE DAM 2 SPILLWAY (STAGE 2 WORKS)

LEFT BANK (QUARRY) DISPOSAL AREA

HOLDING POND

BRISBANE VALLEY HIGHWAY

N

3	AS CONSTRUCTED	B.MAHER	30.11.05
2	SITE LAYOUT AMENDED	B.MAHER	01.03.05
1	ISSUED FOR CONSTRUCTION	B.MAHER	05.03.04

50 0 100 200m

ORGANISATIONS IN THE ALLIANCE:
SEQWater
LEIGHTON CONTRACTORS Pty. Ltd.
NSW DEPARTMENT OF COMMERCE Water Technologies.
Coffey Geosciences Pty. Ltd.
MWH Global Inc.

WIVENHOE ALLIANCE

DESIGNED B. MAHER	DESIGN MANAGER ORIGINAL SIGNED BY: B.J. MAHER (RPEQ 6833)
DRAFTED A. CRAWFORD	DESIGN DIRECTOR
CHECKED G. SAMIOS	PROJECT MANAGER ORIGINAL SIGNED BY: S. McDOWALL

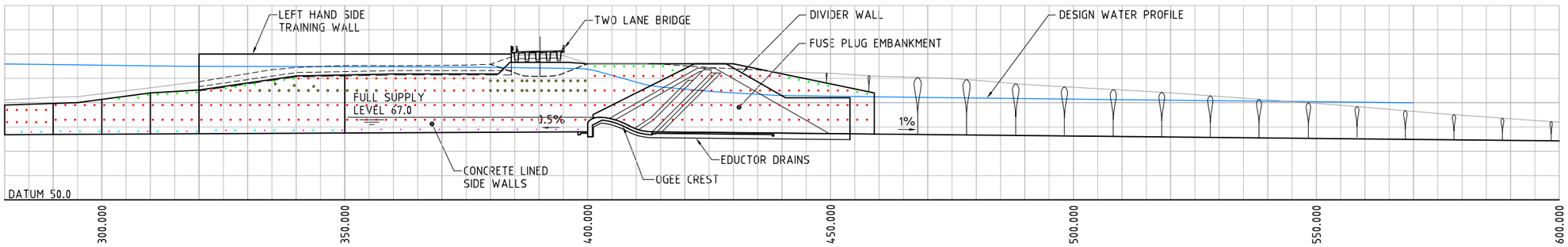
WIVENHOE DAM UPGRADE

GENERAL
SPILLWAY AND DAM WORKS LAYOUT

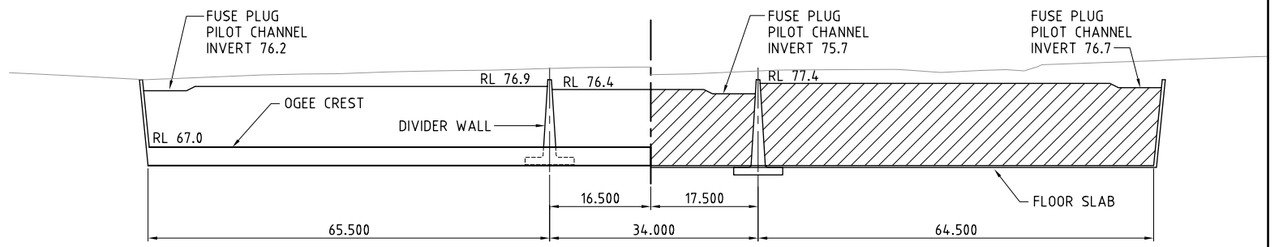
DRAWING NO. WIV/DWG/CG/1000

1 2 3 A1

PLAN
SCALE A



SECTION A
SCALE B



SECTION B
SCALE B

2	AS CONSTRUCTED	B.MAHER	27.10.05
1	ISSUED FOR CONSTRUCTION	B.MAHER	28.04.04

SCALE A 20 0 20 40 60 80 100m

SCALE B 5 0 10 20m

ORGANISATIONS IN THE ALLIANCE:
SEQWater
LEIGHTON CONTRACTORS Pty. Ltd.
NSW DEPARTMENT OF COMMERCE Water Technologies.
Coffey Geosciences Pty. Ltd.
MWH Global Inc.

WIVENHOE ALLIANCE

DESIGNED B. MAHER	DESIGN MANAGER ORIGINAL SIGNED BY: B.J. MAHER (RPEQ 6833)
DRAFTED A. CRAWFORD	DESIGN DIRECTOR
CHECKED G. SAMIOS	PROJECT MANAGER ORIGINAL SIGNED BY: S. McDOWALL

WIVENHOE DAM UPGRADE

STAGE 1 WORKS
RIGHT ABUTMENT SPILLWAY
GENERAL ARRANGEMENT

DRAWING NO. WIV/DWG/CG/1025

1 2 A1

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Last modified: 28 Oct 05 - 17:07

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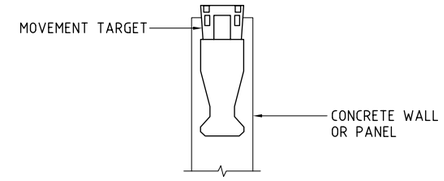
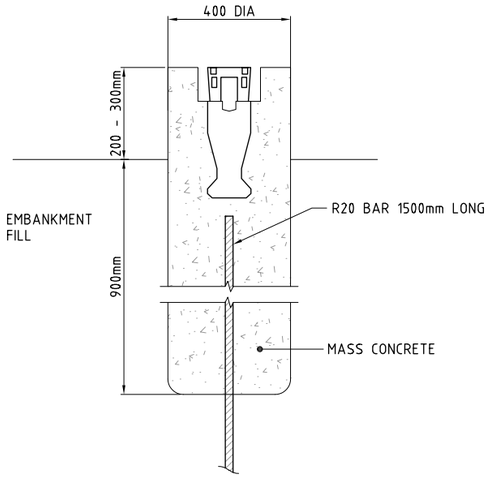


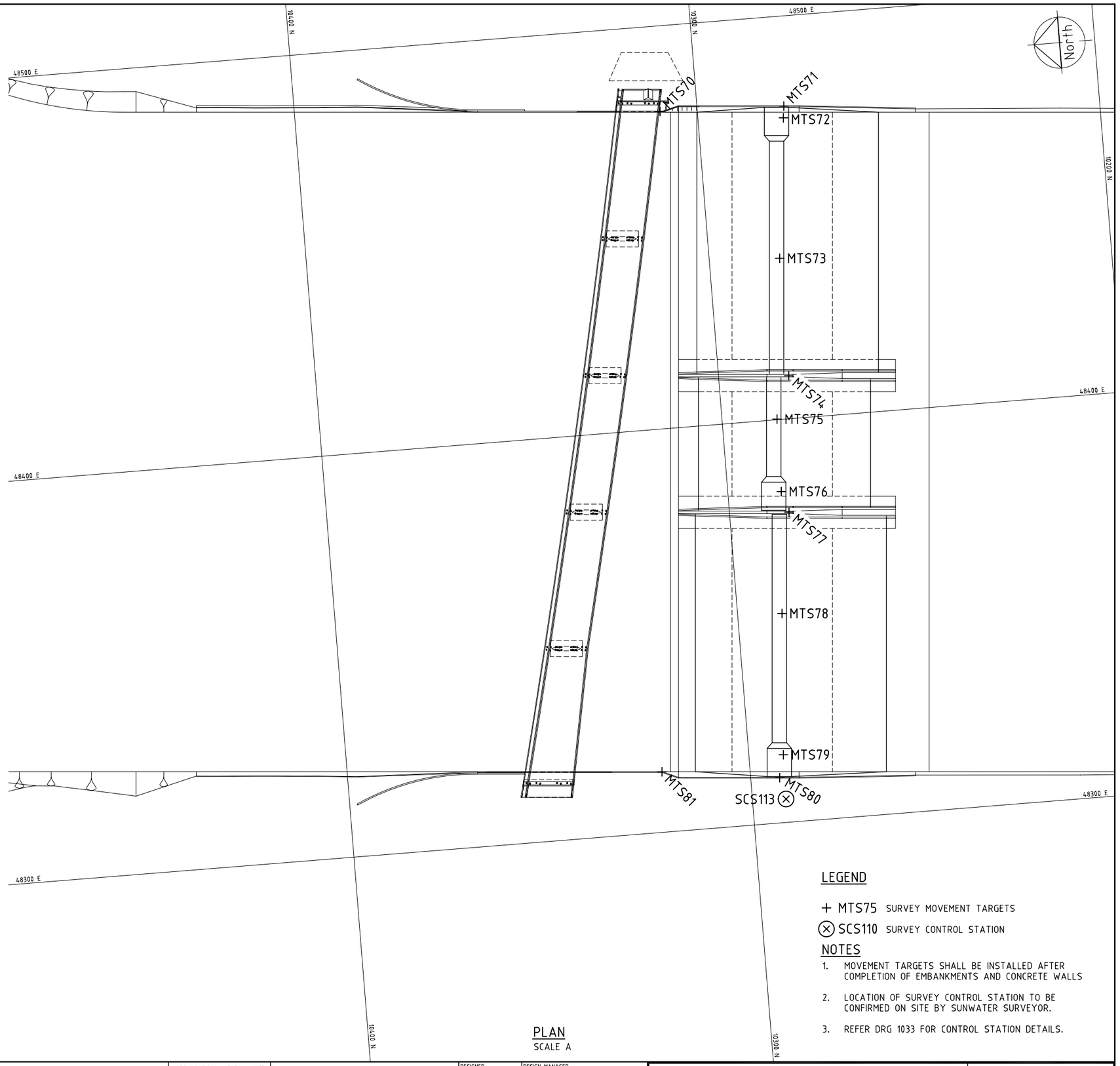
MOVEMENT TARGET ON CONCRETE WALL
TYPICAL DETAIL
SCALE B



MOVEMENT TARGET ON EMBANKMENT CREST
TYPICAL DETAIL
SCALE B

TARGET LOCATION TABLE

MOVEMENT TARGET	LOCATION
MTS81	TOP OF CONCRETE PANEL WALL
MTS80	TOP OF CONCRETE PANEL WALL
MTS79	PLACED IN TRIGGER SECTION
MTS78	PLACED IN FUSE PLUG EMBANKMENT
MTS77	TOP OF CONCRETE DIVIDER WALL
MTS76	PLACED IN TRIGGER SECTION
MTS75	PLACED IN FUSE PLUG EMBANKMENT
MTS74	TOP OF CONCRETE DIVIDER WALL
MTS73	PLACED IN FUSE PLUG EMBANKMENT
MTS72	PLACED IN TRIGGER SECTION
MTS71	TOP OF CONCRETE PANEL WALL
MTS70	TOP OF CONCRETE PANEL WALL



PLAN
SCALE A

LEGEND

+ MTS75 SURVEY MOVEMENT TARGETS

⊗ SCS110 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 CONFIRMED ON SITE BY SUNWATER SURVEYOR.
3. REFER DRG 1033 FOR CONTROL STATION DETAILS.

3	AS CONSTRUCTED - UPDATED FROM SUNWATER SURVEY DATA	B.MAHER	27.10.05
2	SURVEY CONTROL STATIONS ADDED	B.MAHER	05.04.05
1	ISSUED FOR CONSTRUCTION	B.MAHER	05.03.04

SCALE A 5 0 10 20m

SCALE B 100 0 100 200 300 400 500mm

ORGANISATIONS IN THE ALLIANCE:
SEQWater
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WIVENHOE ALLIANCE

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WIVENHOE DAM UPGRADE

RIGHT ABUTMENT SPILLWAY
MOVEMENT TARGETS AND SURVEY CONTROL POINTS

DRAWING NO. WIV/DWG/CG/1032

1 2 3 A1

Cad ref: K:\01091 Wivenhoe Dam\CAD\Detail\1032-WIV-DWG-CG-1032.dwg Last modified: 28 Oct 05 - 17:19

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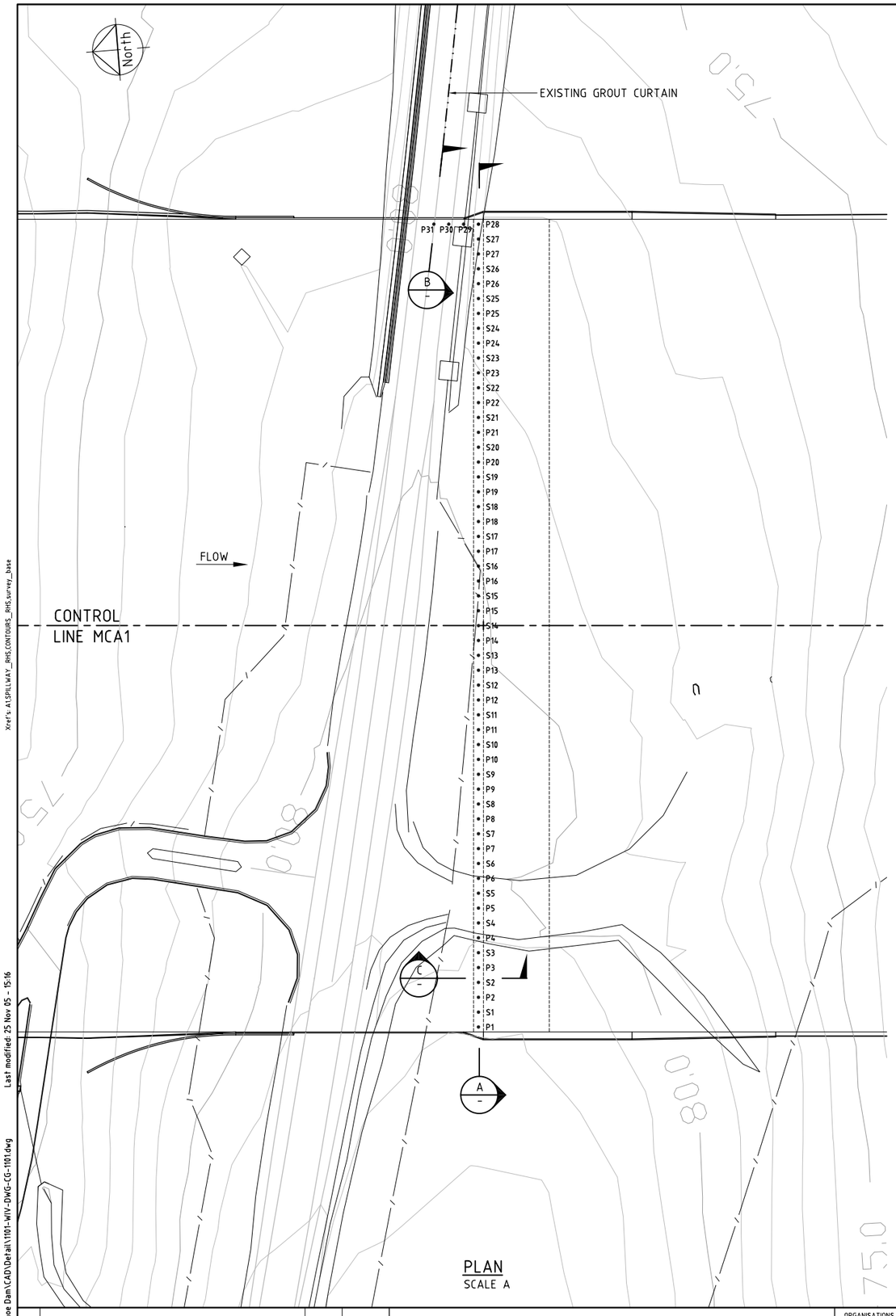
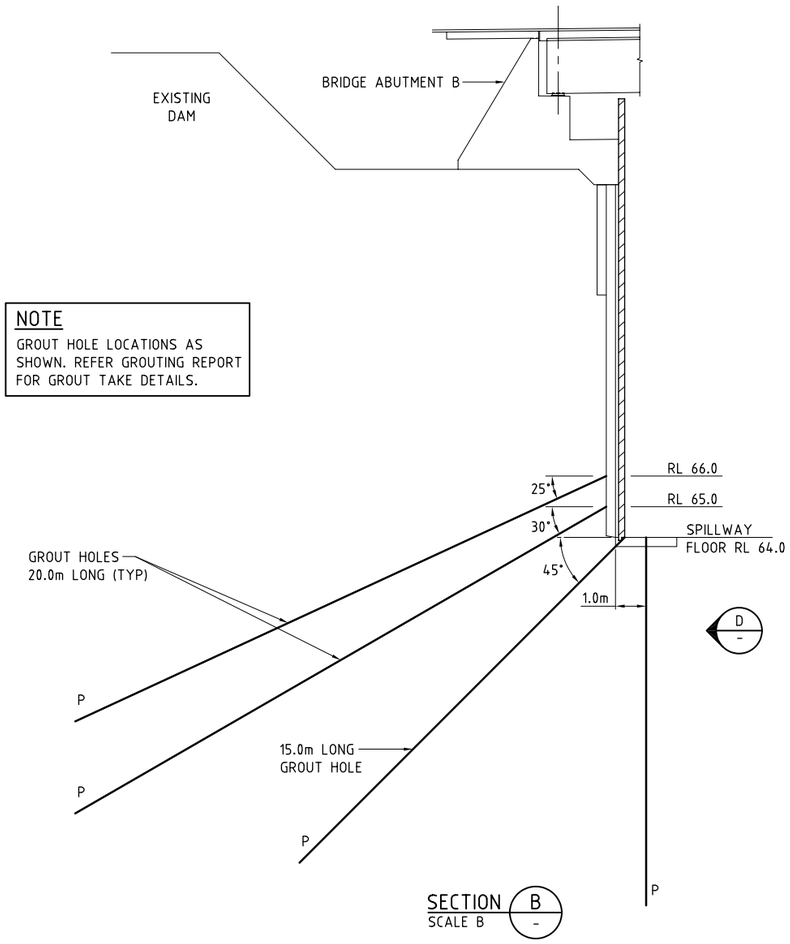


PLAN
SCALE A

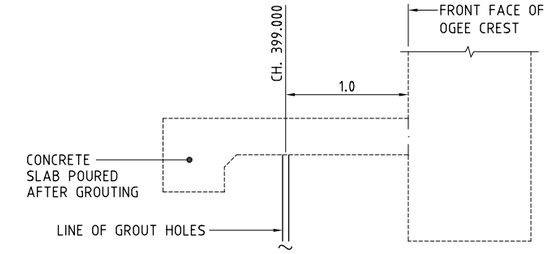


SECTION B
SCALE B

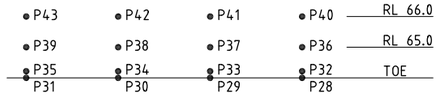
NOTE
GROUT HOLE LOCATIONS AS SHOWN. REFER GROUTING REPORT FOR GROUT TAKE DETAILS.

GROUT NOTES

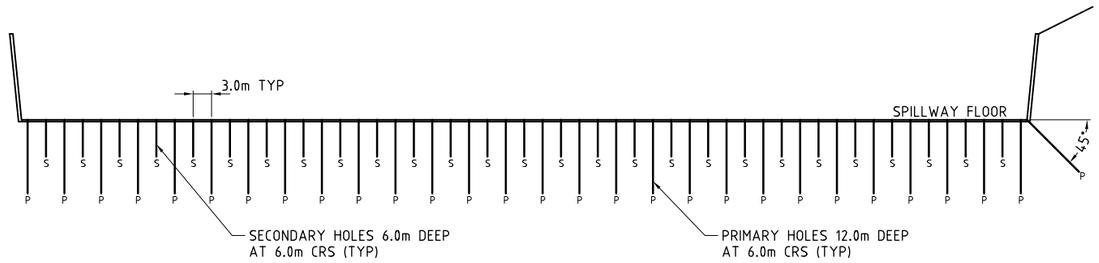
1. REMOVE UNSUITABLE MATERIAL AND REPLACE WITH CEMENT STABILISED FILL PRIOR TO COMMENCEMENT OF GROUT CURTAIN WORKS.
2. PRIMARY GROUT HOLES TO HAVE 50mm MINIMUM DIAMETER AND NOMINAL DEPTH OF 12m BELOW APRON SLAB. RAKED PRIMARY GROUT HOLES TO HAVE 50mm MINIMUM DIAMETER AND NOMINAL DEPTH OF 20.0m. SECONDARY GROUT HOLES TO HAVE 50mm MIN DIAMETER AND NOMINAL DEPTH OF 6.0m.
3. STARTING GROUT MIX FOR PRIMARY HOLES TO BE 3:1 (WATER:CEMENT BY VOLUME). GROUT MIX TO VARY DEPENDING ON ROCK CONDITIONS ENCOUNTERED.
4. GUIDELINES FOR EFFECTIVE GROUTING LIMITS. NO FURTHER GROUTING IS REQUIRED WHEN:
   - WATER TEST VALUE PRIOR TO GROUTING LESS THAN 5 LUGEONS
   OR
   - LESS THAN 20% REDUCTION IN LUGEON VALUE OR GROUT TAKE OCCURS FROM PREVIOUS STAGE WHERE LUGEON VALUE FOR THE PREVIOUS STAGE IS LESS THAN 10 LUGEONS.
   OR
   - ALL GROUT TAKES (LITRES GROUT/m) ARE LESS THAN 25
   OR
   - GROUT HOLE SPACING LESS THAN 0.75m
5. REQUIREMENTS FOR SECONDARY AND TERTIARY GROUTING OTHER THAN RAKED GROUTING HOLES TO BE DETERMINED BY THE ENGINEER.
6. IF SHOTCRETING IS CARRIED OUT PRIOR TO GROUTING, A BLANK AREA 2m x 2m SHALL BE LEFT AROUND THE GROUT HOLES.



SECTION C
SCALE C



ELEVATION D
SCALE B



SECTION A
SCALE A

LEGEND
P = PRIMARY HOLE
S = SECONDARY HOLE

4	AS CONSTRUCTED	B.MAHER	30.11.05
3	GROUT HOLE ELEVATION D ADDED	B.MAHER	16.05.05
2	REVISED LAYOUT FOR ABUTMENT B	B.MAHER	28.2.05
1	ISSUED FOR CONSTRUCTION	B.MAHER	05.03.04

SCALE A 5 0 10 20m
SCALE B 1 0 1 2 3 4 5m
SCALE C 0.25 0 0.50 1.00m

ORGANISATIONS IN THE ALLIANCE:
SEQWater
LEIGHTON CONTRACTORS Pty. Ltd.
NSW DEPARTMENT OF COMMERCE Water Technologies.
Coffey Geosciences Pty. Ltd.
MWH Global Inc.

WIVENHOE ALLIANCE

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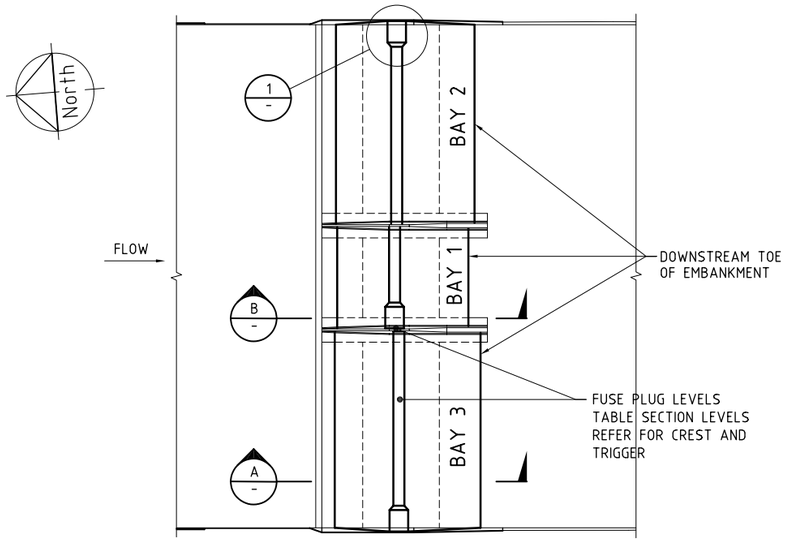
DRAFTED P. COOK	DESIGN DIRECTOR
CHECKED G. SAMIOS	PROJECT MANAGER ORIGINAL SIGNED BY: S. McDOWALL

WIVENHOE DAM UPGRADE

RIGHT ABUT SPILLWAY - FLOOR & OGEE STRUCTURE
GROUT CURTAIN
ARRANGEMENT

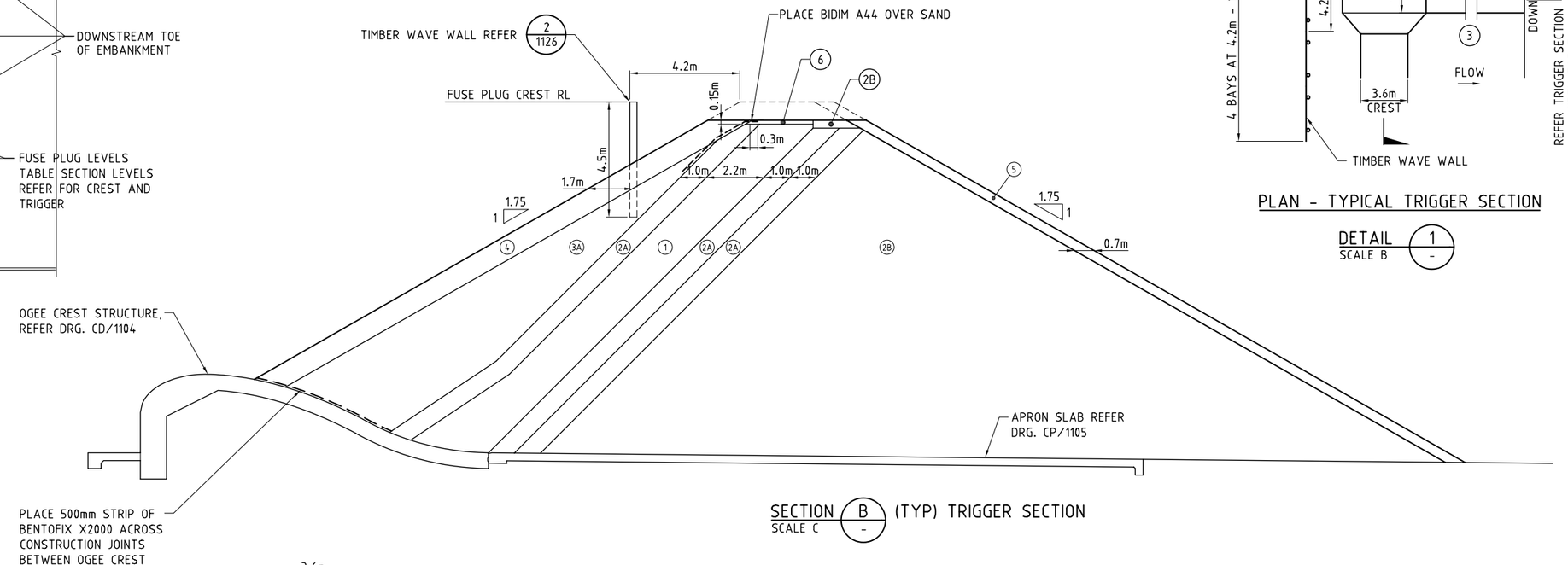
DRAWING NO. WIV/DWG/CG/1101
1 2 3 4 A1

Xref's A1SPILLWAY_RHS,CONTOURS_RHS,survey_base
Last modified: 25 Nov 05 - 15:16
Cad ref: K:\01891 Wivenhoe Dam\CAD\Detail\1101-WIV-DWG-CG-1101.dwg



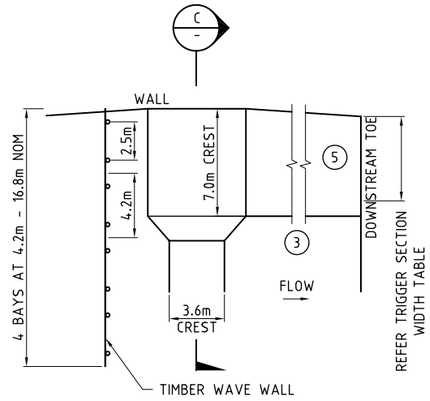
PLAN OF FUSE PLUG

SCALE A



SECTION B (TYP) TRIGGER SECTION

SCALE C

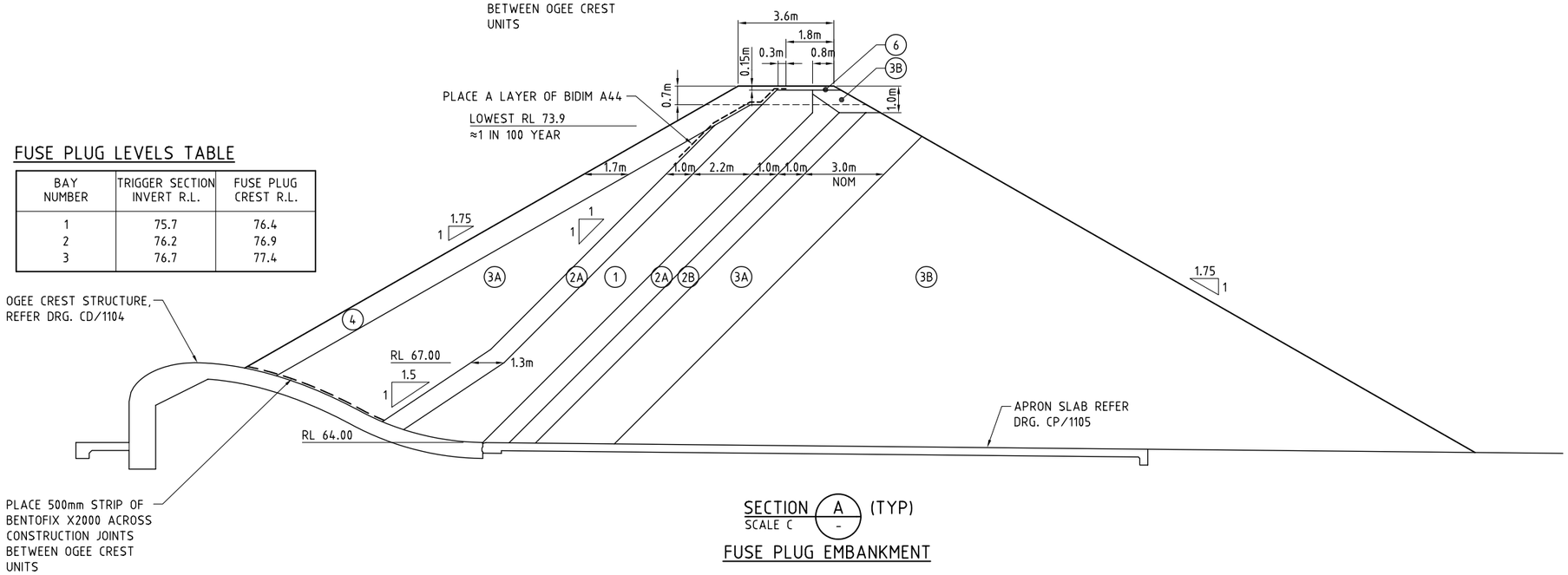


PLAN - TYPICAL TRIGGER SECTION

DETAIL 1 - SCALE B

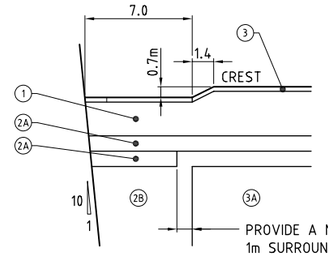
FUSE PLUG LEVELS TABLE

BAY NUMBER	TRIGGER SECTION INVERT R.L.	FUSE PLUG CREST R.L.
1	75.7	76.4
2	76.2	76.9
3	76.7	77.4



SECTION A (TYP) - SCALE C

FUSE PLUG EMBANKMENT



SECTION C - SCALE B

TRIGGER SECTION WIDTH

BAY NUMBER	CREST WIDTH (m)	BASE WIDTH (m)
1	7	5.83
2	7	5.78
3	7	5.73

5	AS CONSTRUCTED	B.MAHER	30.11.05
4	RL AMENDED	B.MAHER	19.04.05
3	UPDATED AS PER DSN'S 487 & 491	B.MAHER	15.03.05
2	ZONES AND CLAY CORE FLARE AMENDED	B.MAHER	23.12.04
1	ISSUED FOR CONSTRUCTION	B.MAHER	05.03.04

SCALE A 10 0 10 20 30 40 50m

SCALE B 2 0 2 4 6 8 10m

SCALE C 1 0 1 2 3 4 5m

ORGANISATIONS IN THE ALLIANCE:
SEQWater
LEIGHTON CONTRACTORS Pty. Ltd.
NSW DEPARTMENT OF COMMERCE Water Technologies.
Coffey Geosciences Pty. Ltd.
MWH Global Inc.

WIVENHOE ALLIANCE

DESIGNED	S. PERRETT	DESIGN MANAGER	ORIGINAL SIGNED BY: B.J. MAHER (RPEQ 6833)
DRAFTED	P. COOK	DESIGN DIRECTOR	
CHECKED	G. SAMIOS	PROJECT MANAGER	ORIGINAL SIGNED BY: S. McDOWALL

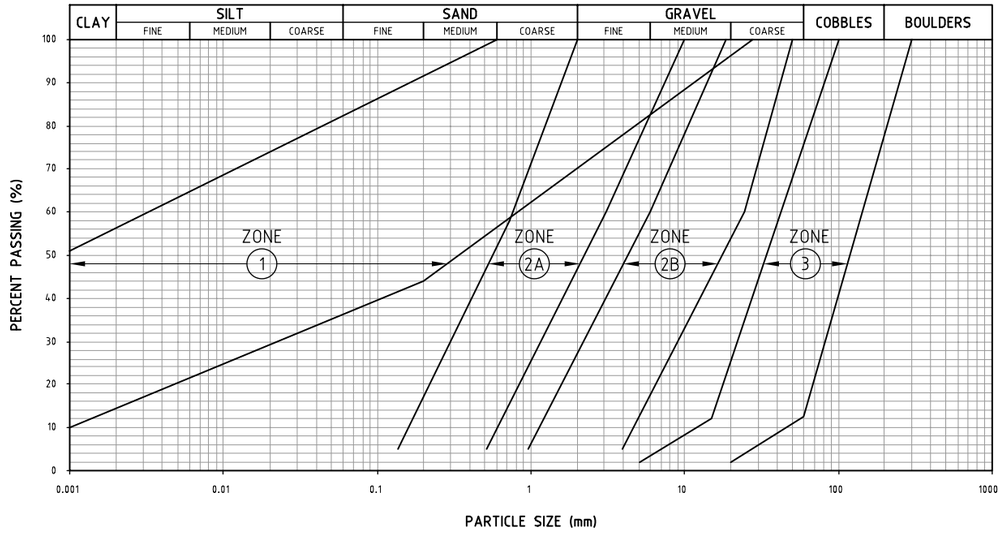
WIVENHOE DAM UPGRADE

RIGHT ABUT SPILLWAY - FUSE PLUG EMBANKMENTS ARRANGEMENT & DETAILS

DRAWING NO. WIV/DWG/CS/1125

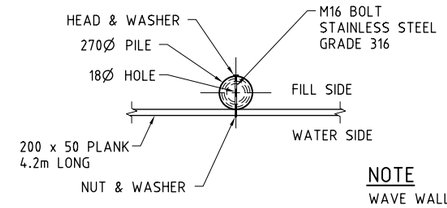
1 2 3 4 5 A1

Cad ref: K:\01091 Wivenhoe Dam\CAD\Detail\1125-WIV-DWG-CS-1125.dwg Last modified: 30 Nov 05 - 09:52 Xref's: A1SPILLWAY_RHS



GRADING LIMITS
(AFTER PLACEMENT / COMPACTION)

ZONE		MATERIAL	PLACEMENT SPECIFICATION
(1)	CORE	IMPERVIOUS SC OR CL MATERIAL, GRADING LIMITS AS SHOWN EMERSON CLASS NUMBER 3 TO 5 TESTED IN WIVENHOE STORAGE WATER PLASTIC LIMIT < 25%, LIQUID LIMIT < 60%	COMPACTED IN 250mm LAYERS TO NOT LESS THAN 98% STANDARD MAX DRY DENSITY MOISTURE LIMITS FROM OMC-1% TO OMC+2%
(2A)	FINE FILTER	WELL GRADED CLEAN NON-COHESIVE SAND-GRAVEL, GRADING LIMITS AS SHOWN	COMPACTED IN 250mm LAYERS TO MIN 70% DENSITY INDEX
(2B)	COARSE FILTER	WELL GRADED CLEAN, ROUNDED, NATURAL GRAVEL, GRADING LIMITS AS SHOWN	AS PER ZONE (2A)
(3)	ROCK FILL	FRESH, HARD, DURABLE ROCKFILL, GRADING LIMITS AS SHOWN	PLACED IN 400mm LAYERS WITH COMPACTION FROM TRACKED CONSTRUCTION EQUIPMENT (30T EXCAVATOR OR EQUIVALENT)
(4)	RIPRAP	FRESH, HARD, DURABLE ROCK, 200 TO 500mm WITH 60% >300mm	SPREAD TO PRODUCE A UNIFORM DENSE AND STABLE LAYER
(5)	SLOPE PROTECTION	FRESH, HARD, DURABLE ROCK, 75 TO 150mm	SPREAD TO PRODUCE A UNIFORM DENSE AND STABLE LAYER ON D/S FACE OF PILOT CHANNEL
(6)	ROAD BASE	2.3 ROAD PAVEMENT MATERIAL	COMPACTED IN A SINGLE LAYER TO NOT LESS THAN 95% STANDARD MAX DRY DENSITY MOISTURE LIMITS FROM OMC-2% TO OMC+2%



NOTE
WAVE WALL TO BE CONSTRUCTED FROM TREATED HARDWOOD AS PER SPECIFICATION

WAVE WALL
TYPICAL BOLTED CONNECTION DETAILS

DETAIL (2) 1125

4	AS CONSTRUCTED	B.MAHER	30.11.05
3	ZONE 6 MATERIAL ADDED	B.MAHER	19.04.05
2	ROCK FILL PLACEMENT SPECIFICATION AMENDED	B.MAHER	12.10.04
1	ISSUED FOR CONSTRUCTION	B.MAHER	05.03.04

0.25 0 0.50 1.00m

ORGANISATIONS IN THE ALLIANCE:
SEQWater
LEIGHTON CONTRACTORS Pty. Ltd.
NSW DEPARTMENT OF COMMERCE Water Technologies.
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MWH Global Inc.

WIVENHOE ALLIANCE

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DRAFTED	P. COOK	DESIGN DIRECTOR	
CHECKED	G. SAMIOS	PROJECT MANAGER	ORIGINAL SIGNED BY: S. McDOWALL

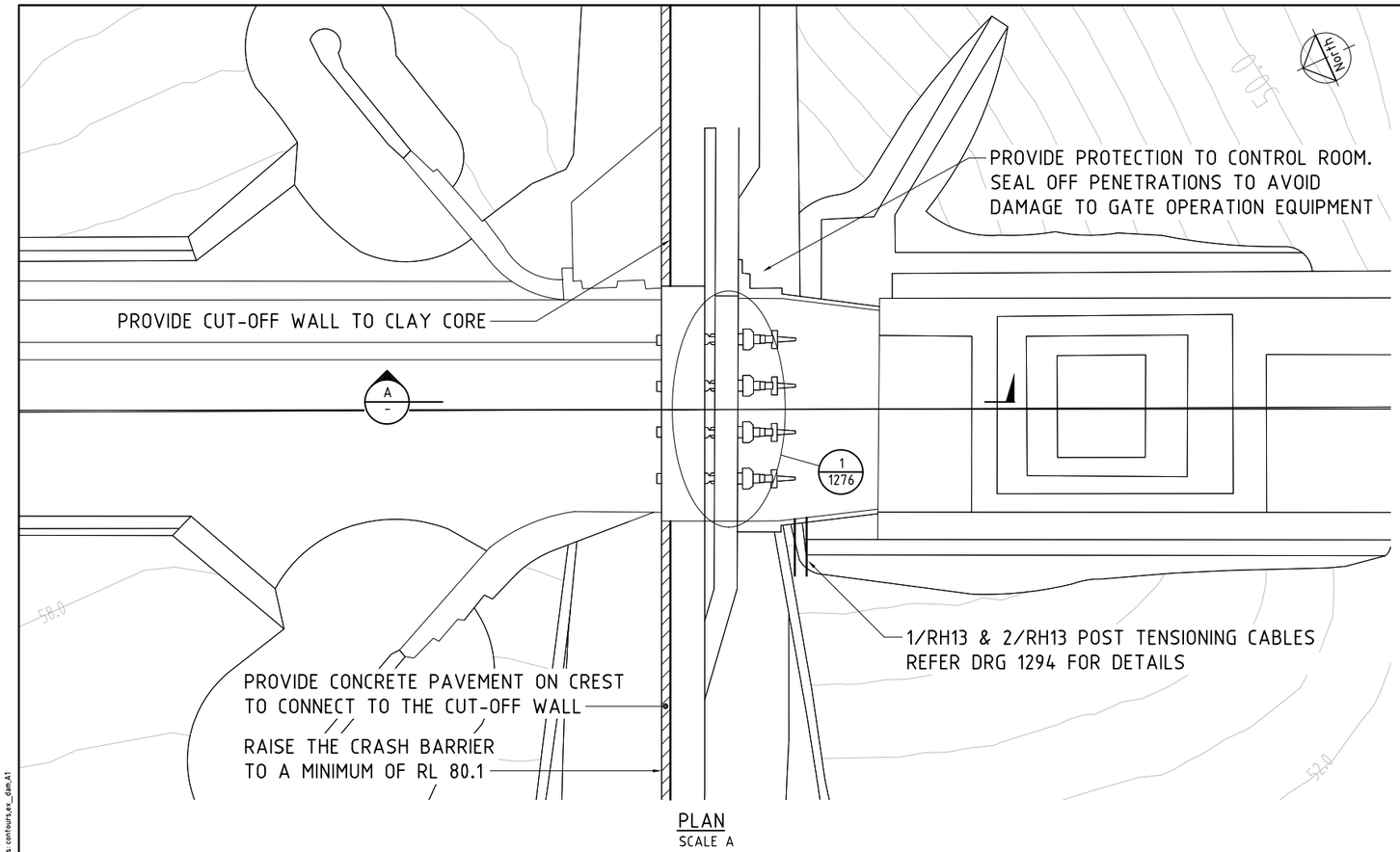
WIVENHOE DAM UPGRADE

RIGHT ABUT SPILLWAY - FUSE PLUG EMBANKMENTS
MATERIAL SPECIFICATION

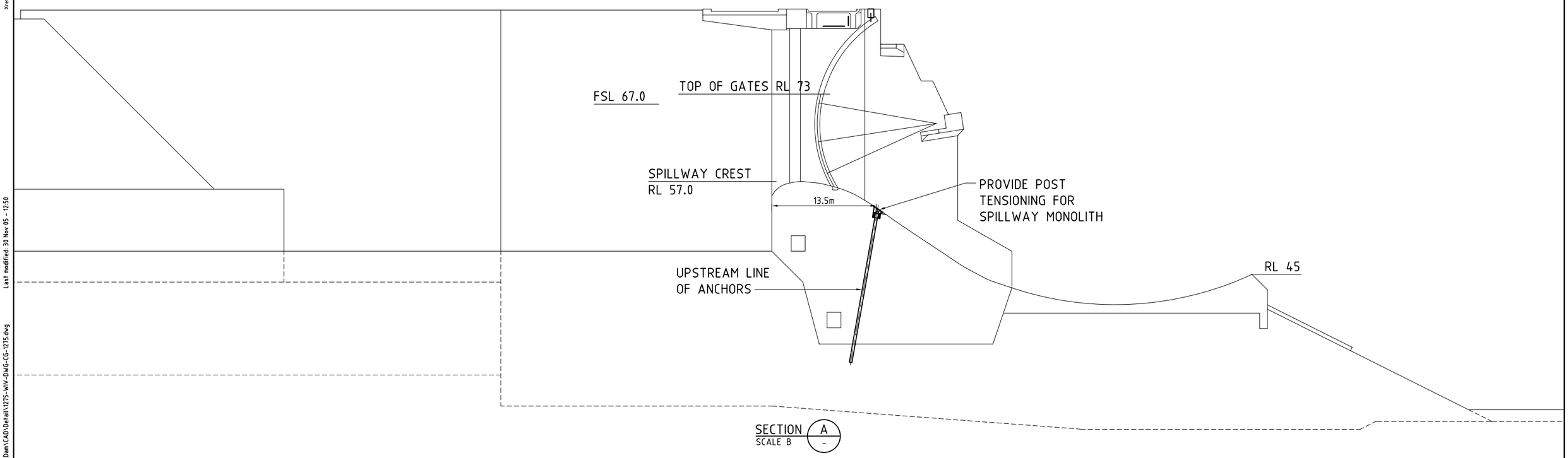
DRAWING NO. WIV/DWG/CD/1126

1 2 3 4 A1

Cad ref: K:\Q1691 Wivenhoe Dam\CAD\Detail\1126-WIV-DWG-CD-1126.dwg Last modified: 25 Nov 05 - 15:38 Xref's A1



PLAN
SCALE A



SECTION A–
SCALE B

3	AS CONSTRUCTED	B.MAHER	30.11.05
2	TENSIONING LOCATION AMENDED	B.MAHER	01.12.04
1	ISSUED FOR CONSTRUCTION	B.MAHER	30.06.04

SCALE A 10 0 10 20 30 40 50m

SCALE B 2.5 0 5 10m

ORGANISATIONS IN THE ALLIANCE:
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Coffey Geosciences Pty. Ltd.
MWH Global Inc.

WIVENHOE ALLIANCE

DESIGNED R. RODD	DESIGN MANAGER ORIGINAL SIGNED BY: B.J. MAHER (RPEQ 6833)
DRAFTED A. CRAWFORD	DESIGN DIRECTOR ORIGINAL SIGNED BY: B.W. COOPER
CHECKED G. SAMIOS	PROJECT MANAGER ORIGINAL SIGNED BY: S. McDOWALL

WIVENHOE DAM UPGRADE

EXISTING DAM WORKS
GENERAL ARRANGEMENT

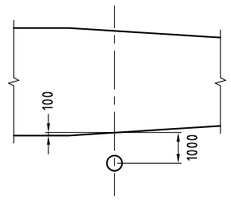
DRAWING NO. WIV/DWG/CG/1275

1 2 3 A1

Cad ref: K:\01091 Wivenhoe Dam\CAD\Detail\1275-WIV-DWG-CG-1275.dwg
Last modified: 30 Nov 05 – 12:50
Xref's contours_ex_dam.A1

NOTES

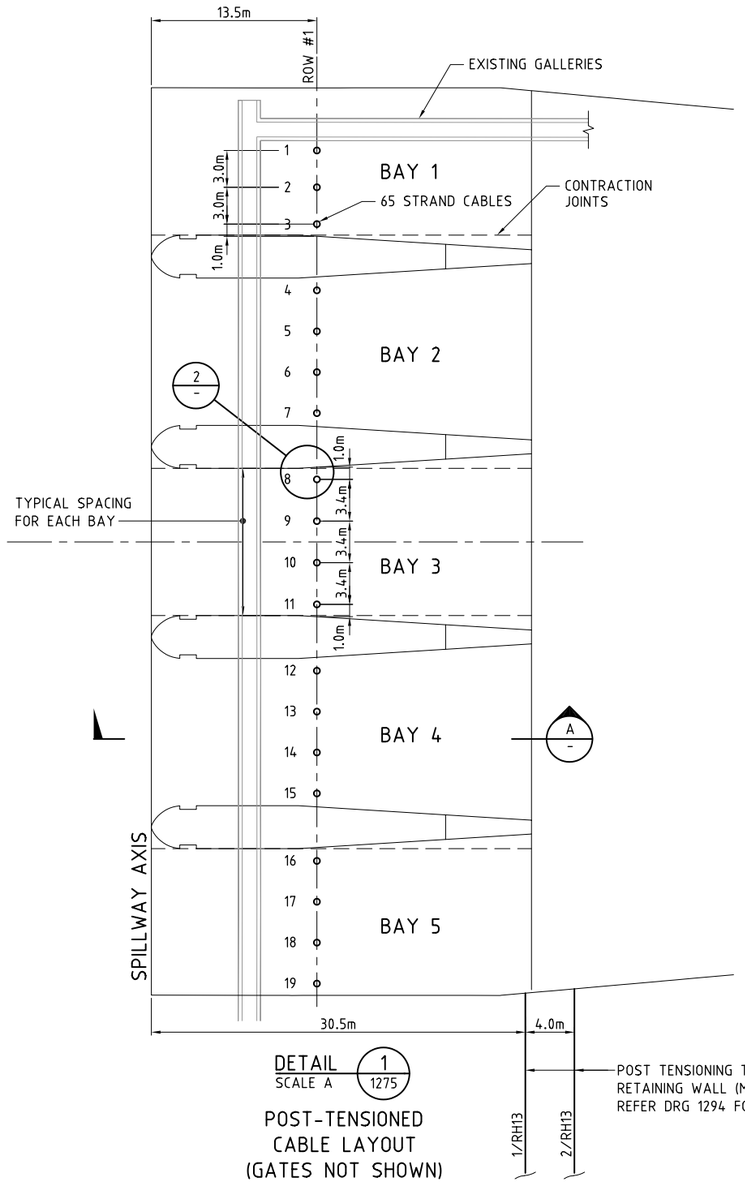
1. 19 POST-TENSIONING CABLES REQUIRED IN SERVICE SPILLWAY AREA, WITH LOCATION, SIZE AND LOADS BEING :-
   CABLE LOCATIONS 1 TO 19 EACH CONSISTING OF 65 - 15.2mm DIA SUPERGRADE STRANDS, HAVING AN M.B.L. OF 16250 kN.
   DESIGN WORKING LOAD IS 9750 kN (65% M.B.L.)
2. THE BOND LENGTHS SHALL BE 16.0m FOR THE 63 - 15.2mm DIA CABLES
3. ALL CABLES SHALL BE IDENTIFIED BY THE CABLE CODING ASSIGNED
4. DATA IN TABLE 1 SHALL BE MODIFIED WHERE NECESSARY (AND NOTED ACCORDINGLY) TO SHOW ACTUAL FINAL VALUES AT WORK-AS-EXECUTED STAGE
5. CONCRETE CHARACTERISTIC COMPRESSIVE STRENGTH FOR THE POST TENSIONED CABLES HEAD BLOCKS SHALL BE 40 MPa AT 28 DAYS
6. MINIMUM CLEAR COVER TO REINFORCEMENT SHALL BE 30mm UNLESS OTHERWISE SHOWN
7. PENSTOCKS AND FOUNDATION DRAINS NOT SHOWN



TYPICAL DETAIL 2 / - SCALE B

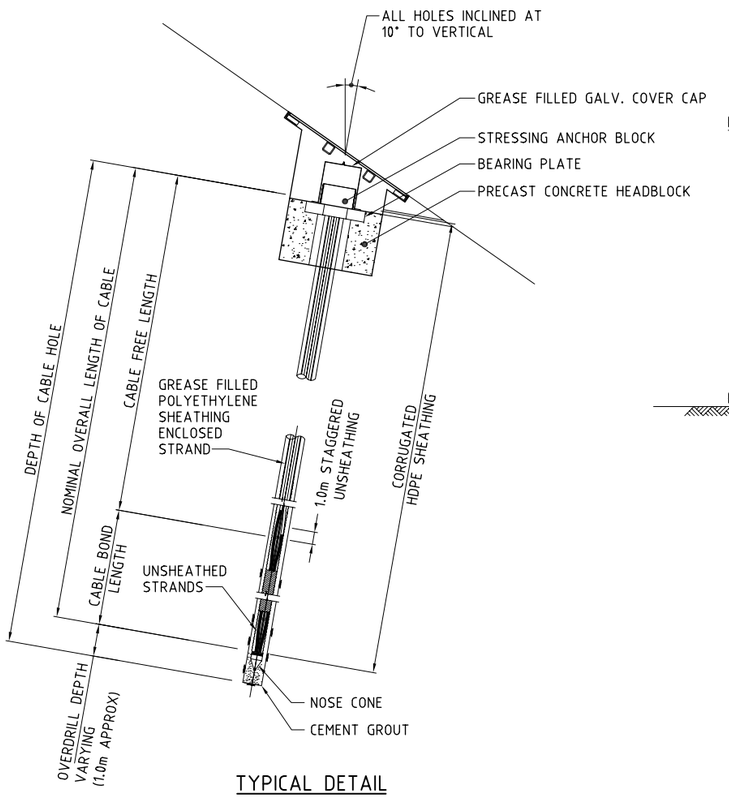
TABLE 1 - POST-TENSIONING CABLES IN SPILLWAY (SEE ALSO NOTES 1 - 4)

CABLE LOCATION No.	HOLE ANGLE	TOP OF CABLE HOLE (RL) m	ESTIMATED HOLE LENGTH (m)				CABLE NOMINAL LENGTH (m)			STRESSING ORDER
			ESTIMATED HOLE LENGTH	STEEL FORMER LENGTH	APPROX DRILLING LENGTH IN CONCRETE	APPROX DRILLING LENGTH IN ROCK	BOND LENGTH	FREE LENGTH	OVERALL LENGTH	
1	80	52.480	72	1.065	26	45	16	55	71	6
2	80	52.480	64	1.065	24	39	16	47	63	5
3	80	52.480	72	1.065	20	51	16	55	71	7
4	80	52.480	64	1.065	17	46	16	47	63	14
5	80	52.480	72	1.065	17	54	16	55	71	12
6	80	52.480	64	1.065	17	46	16	47	63	15
7	80	52.480	72	1.065	17	54	16	55	71	13
8	80	52.480	64	1.065	17	46	16	47	63	3
9	80	52.480	72	1.065	17	54	16	55	71	1
10	80	52.480	64	1.065	17	46	16	47	63	4
11	80	52.480	72	1.065	17	54	16	55	71	2
12	80	52.480	64	1.065	17	46	16	47	63	18
13	80	52.480	72	1.065	17	54	16	55	71	16
14	80	52.480	64	1.065	17	46	16	47	63	19
15	80	52.480	72	1.065	17	54	16	55	71	17
16	80	52.480	64	1.065	17	46	16	47	63	10
17	80	52.480	72	1.065	17	54	16	55	71	8
18	80	52.480	64	1.065	17	46	16	47	63	11
19	80	52.480	72	1.065	17	54	16	55	71	9



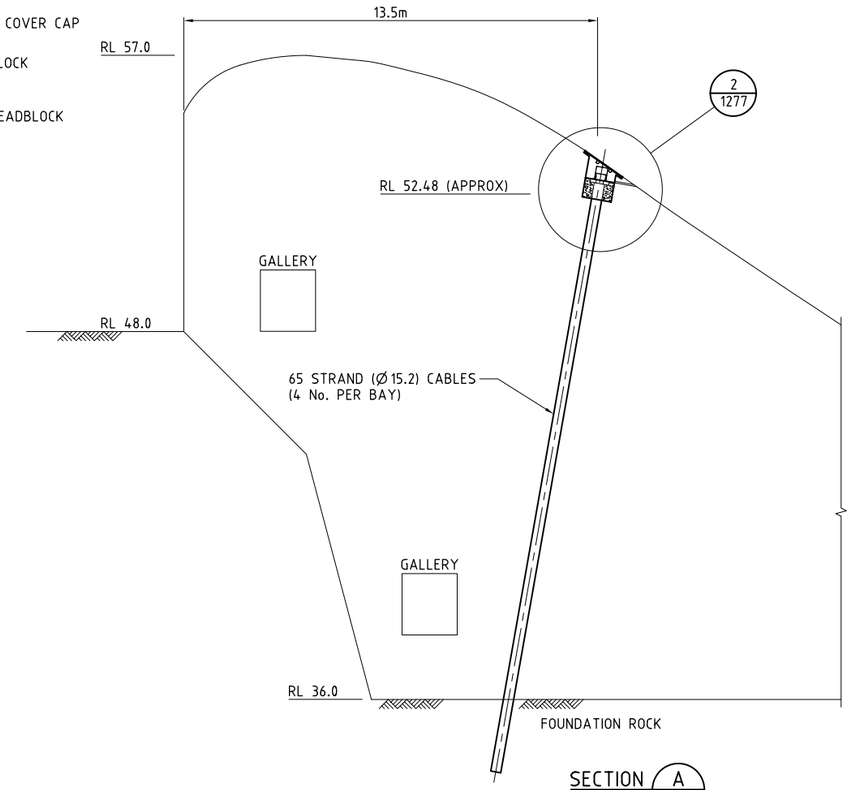
DETAIL 1 / 1275 SCALE A

POST-TENSIONED CABLE LAYOUT (GATES NOT SHOWN)



TYPICAL DETAIL

SHOWING CABLE COMPONENTS
(NOTE : CABLE COMPONENTS ARE TYPICAL FOR ALL CABLES)
N.T.S.



SECTION A / - SCALE B

4	AS CONSTRUCTED	B.MAHER	30.11.05
3	ANCHOR HEAD AND CABLE NUMBERING AMENDED	B.MAHER	06.12.04
2	REVISED FOR CONSTRUCTION	B.MAHER	24.09.04
1	ISSUED FOR CONSTRUCTION	B.MAHER	30.06.04

SCALE A 2.5 0 5 10m

SCALE B 1 0 1 2 3 4 5m

ORGANISATIONS IN THE ALLIANCE:
SEQWater
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NSW DEPARTMENT OF COMMERCE Water Technologies.
Coffey Geosciences Pty. Ltd.
MWH Global Inc.

WIVENHOE ALLIANCE

DESIGNED	R. RODD	DESIGN MANAGER ORIGINAL SIGNED BY:	B.J. MAHER (RPEQ 6833)
DRAFTED	A. CRAWFORD	DESIGN DIRECTOR ORIGINAL SIGNED BY:	B.W. COOPER
CHECKED	G. SAMIOS	PROJECT MANAGER ORIGINAL SIGNED BY:	S. McDOWALL

WIVENHOE DAM UPGRADE

EXISTING DAM WORKS
SPILLWAY POST-TENSIONING
GENERAL ARRANGEMENT - SHEET 1 OF 2

DRAWING NO. WIV/DWG/CG/1276

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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

CONTENTS

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

No.	Recommendation	Priority	Date Complete	Comments
1.	**Mechanical/Electrical**			
a.	The feasibility of converting the gates to automatic operation be investigated.			Automatic operation not considered economical
b.	That consideration be given to refurbishing the control system to provide condition monitoring.	H	1996	Completed 1996
c.	That means of improving the security of the hydraulic pipework be investigated.	M	2000	Completed 2000
d.	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.	M	2000	Completed 2000
e.	That the diesel hydraulic unit be re-located to the surface/or be converted to a mobile unit.	M	2000	Completed 2000
f.	That consideration be given to re-locating the main hydraulic unit and control panels to a higher level in the building.	M	July 1999	The room containing this equipment has been waterproofed – no further action.
g.	That consideration be given to providing a sheltered control station or control room near the present control complex.			Not considered necessary
h.	That consideration be given to providing on-line alternative oil supplies, and improved drainage system including an oil separator.	M		Included with 1b, c, d.
k.	That the fuel system be upgraded to be more accessible, and to reduce the fire risk from leaks.	H	July 1999	Completed
l.	That the adequacy of the system be reviewed by a fire detection and control expert.	H	July 1999	Completed
m.	That consideration be given to upgrading the ventilation provisions of the underground control complex and running the system continuously.	M		Fire safety equipment upgraded in 2000.
n.	That consideration be given to improving the system for delivering fuel to the diesel operated oil pump.	M	1996	Completed 1996

No.	Recommendation	Priority	Date Complete	Comments
o.	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.	M		Security system with dial out completed in 2001
p.	That operators be equipped with hand held radios for used while operating the spillway gates.	H	1997	Completed 1997
q.	That gate position indicators be investigated.	L		Installed 2000
r.	That tests be conducted to determine whether a single hoist would be capable of moving a gate safely under emergency conditions.	H	July 1999	Discussions held with DNR design staff – one winch will hold gate – no further action.
s.	Consideration be given to ensuring the duplicate hydraulic pumps be made flood proof.	H	August 1999	Included with 1b, c, d.
t.	That consideration be given to improving the fail safe nature of the Main Switchboard.	M		Inspections done during annual condition monitoring
u.	A review of the load bank size be undertaken.	L		Planned Mntce in plan to 2010.
v.	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.	L		Regular inspection and operation is done on dewatering pumps
w.	A review of the UPS power supply standby time be undertaken to see if it is adequate.	H		Overhauled 2000
x.	The position sensors be installed on each side of each gate.	H		Position indicators connected to flood alert in 2001
2.	**Civil**			
a.	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.	L	July 2003	
c.	The effectiveness of the spillway flip bucket drainage system be investigated further (section 11.1.1)	M		Review in comprehensive inspection 2005
d.	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)	M	Dec 1999	Structurally ok refer Report WS222-C1
e.	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	Nil	1999	Observed in Feb 99 flood

No.	Recommendation	Priority	Date Complete	Comments
	may be of used such as video or photographs of spill (section 12.9.4).			
f.	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).	M	1999	Observed in Feb 99 flood. Not considered necessary.
g.	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).	M	Dec 1999	Will be resurveyed after each significant flood event.
h.	The flood immunity of the spillway gate control equipment is checked for extreme flood events (section 12.9.6).			As per 1f
i.	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).	L		Design check complete in 2001
3.	**Embankment General:**			
a.	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).	L		Not considered necessary.
b.	The alluvium properties are obtained (section 12.8.3.2).	L		Report by GHD Review by Sunwater
c.	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).	L		Report by GHD Review by Sunwater Strength is adequate.
e.	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).	L		Report by GHD Review by Sunwater
f.	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	L	yes	Investigation done Monitor during annual inspections

No.	Recommendation	Priority	Date Complete	Comments
	12.8.3.6).			
g.	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).	L		Piezometric levels read on monthly basis
4.	**Right Bank Section.**			
a.	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).	M	1996	Complete. Material was from access ramp on top of the riprap
d.	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).	H	Yes	Review during annual inspection in October each year
f.	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).	H	1996	Complete. Material was from access ramp on top of the riprap.
g.	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).	H	Yes	Review during annual inspection in October each year
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	M	1998	Complete

No.	Recommendation	Priority	Date Complete	Comments
	recompacted and sowed with grass (section 13.8.4).			
e.	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).	M		Complete refer Sunwater Reports
f.	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).	M	1998	Complete
7.	**Saddle Dam 2**			
a.	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).	M	1998	Complete and on-going
b.	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).	M	1998	Complete
c.	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).	M	1998	Complete
8.	**Outlet Works** It is recommended that a detailed inspection of the corrosion protection of the inside of the penstock be undertaken	M	May 1999	Complete

WIVENHOE DAM SAFETY REVIEW STATUS AS AT DECEMBER 2003- GENERAL MAINTENANCE

No.	Recommendation	Priority	Date Complete	Comments
1.	**Mechanical/Electrical**			
i.	Replacement oil be purchased in advance and stored on site as reserve oil for the system.	H	1997	Review during annual inspection in October each year
j.	Consideration be given to providing oil containment and oil clean up materials.	L		As above
2.	**Civil**			
b.	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)	L		As above
j.	Appropriate water safety buoys and booms be placed across the entrance to the spillway.	L		As above
3.	**Spillway Section.**			
d.	The rip rap condition be monitored following significant wind storm events. (section 12.8.1)	M	Yes	As above
4.	**Right Bank Section.**			
b.	One or two trees are removed on the downstream shoulder of the right abutment section (section 13.8.2).	M	Yes	As above
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).	M	July 1999	Review during annual inspection in October each year
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).	M	Yes	Review during annual inspection in October each year
5.	**Left Bank Section**			
a.	Removal of a few trees in a zone 10 meters from the toe of the left embankment section is undertaken (section 13.8.3)	M	1997	As above
b.	The creeper on the upstream face near the left abutment be poisoned so that	M	1997	As Above

No.	Recommendation	Priority	Date Complete	Comments
	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).			
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).	M	July 1999	Completed and review during annual inspection in October each year. Seepage is monitored by timed pipe discharge.
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).	M	July 1999	Completed and review during annual inspection in October each year. This drain needs cleaning out again.
6.	**Saddle Dam 1**			
a.	The long grass on saddle dam 1 (close to the main dam) be slashed or mowed to allow easy detection of seepage or erosion.	H	1997	As above
b.	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).	H	1997	As above
7.	**Saddle Dam 2**			
d.	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).	M	1997	As above
e.	The minor runoff erosion on the downstream shoulder of saddle dam 2 be monitored (section 13.8.5).	H	Yes	Completed and review during annual inspection in October each year

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

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

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 handrailing 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 :

Clear	X
Cloudy	
Overcast	
Rain	Nil
Temperature	Max 32°C
Wind	Calm

Contents

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)	14,000m^3/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

Name	Application
Richard Evans	GHD
Doug Grigg	Sunwater

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

2. Warning Systems

Alarms

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 _____ Appear 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 _____ Appear 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 GHD (1997)

APPENDIX F

Recommended Actions from 1997 Safety Review by GHD

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

No.	Recommendation	Priority	Date Complete	Comments
1.	**Mechanical/Electrical**			
a.	The feasibility of converting the gates to automatic operation be investigated.			Automatic operation not considered economical
b.	That consideration be given to refurbishing the control system to provide condition monitoring.	H	1996	Completed 1996
c.	That means of improving the security of the hydraulic pipework be investigated.	M	2000	Completed 2000
d.	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.	M	2000	Completed 2000
e.	That the diesel hydraulic unit be re-located to the surface/or be converted to a mobile unit.	M	2000	Completed 2000
f.	That consideration be given to re-locating the main hydraulic unit and control panels to a higher level in the building.	M	July 1999	The room containing this equipment has been waterproofed – no further action.
g.	That consideration be given to providing a sheltered control station or control room near the present control complex.			Not considered necessary
h.	That consideration be given to providing on-line alternative oil supplies, and improved drainage system including an oil separator.	M		Included with 1b, c, d.
k.	That the fuel system be upgraded to be more accessible, and to reduce the fire risk from leaks.	H	July 1999	Completed

APPENDIX F

Recommended Actions from GHD (1997)

No.	Recommendation	Priority	Date Complete	Comments
l.	That the adequacy of the system be reviewed by a fire detection and control expert.	H	July 1999	Completed
m.	That consideration be given to upgrading the ventilation provisions of the underground control complex and running the system continuously.	M		Fire safety equipment upgraded in 2000.
n.	That consideration be given to improving the system for delivering fuel to the diesel operated oil pump.	M	1996	Completed 1996
o.	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.	M		Security system with dial out completed in 2001
p.	That operators be equipped with hand held radios for used while operating the spillway gates.	H	1997	Completed 1997
q.	That gate position indicators be investigated.	L		Installed 2000
r.	That tests be conducted to determine whether a single hoist would be capable of moving a gate safely under emergency conditions.	H	July 1999	Discussions held with DNR design staff – one winch will hold gate – no further action.
s.	Consideration be given to ensuring the duplicate hydraulic pumps be made flood proof.	H	August 1999	Included with 1b, c, d.
t.	That consideration be given to improving the fail safe nature of the Main Switchboard.	M		Inspections done during annual condition monitoring
u.	A review of the load bank size be undertaken.	L		Planned Mntce in plan to 2010.
v.	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.	L		Regular inspection and operation is done on dewatering pumps
w.	A review of the UPS power supply standby time be undertaken to see if it is adequate.	H		Overhauled 2000
x.	The position sensors be installed on	H		Position indicators

No.	Recommendation	Priority	Date Complete	Comments
	each side of each gate.			connected to flood alert in 2001
2.	**Civil**			
a.	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.	L	July 2003	
c.	The effectiveness of the spillway flip bucket drainage system be investigated further (section 11.1.1)	M		Review in comprehensive inspection 2005
d.	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)	M	Dec 1999	Structurally ok refer Report WS222-C1
e.	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).	Nil	1999	Observed in Feb 99 flood
f.	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).	M	1999	Observed in Feb 99 flood. Not considered necessary.
g.	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).	M	Dec 1999	Will be resurveyed after each significant flood event.
h.	The flood immunity of the spillway gate control equipment is checked for extreme flood events (section 12.9.6).			As per 1f
i.	The spillway retaining wall monoliths are checked for stability, particularly in light of current earthquake and “at rest” pressure design methods (section	L		Design check complete in 2001

No.	Recommendation	Priority	Date Complete	Comments
	12.9.7).			
3.	**Embankment General:**			
a.	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).	L		Not considered necessary.
b.	The alluvium properties are obtained (section 12.8.3.2).	L		Report by GHD Review by Sunwater
c.	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).	L		Report by GHD Review by Sunwater Strength is adequate.
e.	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).	L		Report by GHD Review by Sunwater
f.	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).	L	yes	Investigation done Monitor during annual inspections
g.	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).	L		Piezometric levels read on monthly basis
4.	**Right Bank Section.**			
a.	The reason for the presence of the fine zone in the rip rap on the upstream	M	1996	Complete. Material was from access ramp on top of

No.	Recommendation	Priority	Date Complete	Comments
	face approximately halfway between the spillway and the right abutment is investigated further (section 13.8.2).			the riprap
d.	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).	H	Yes	Review during annual inspection in October each year
f.	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).	H	1996	Complete. Material was from access ramp on top of the riprap.
g.	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).	H	Yes	Review during annual inspection in October each year
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

No.	Recommendation	Priority	Date Complete	Comments
	construction testing is investigated to determine whether the soil used for saddle dam 1 is dispersive (section 13.8.4).			Reports
f.	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).	M	1998	Complete
7.	**Saddle Dam 2**			
a.	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).	M	1998	Complete and on-going
b.	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).	M	1998	Complete
c.	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).	M	1998	Complete
8.	**Outlet Works**			
.	It is recommended that a detailed inspection of the corrosion protection of the inside of the penstock be undertaken	M	May 1999	Complete