WIVENHOE DAM

ANNUAL DAM SAFETY INSPECTION 2009

Date of Inspection:	22 October 2009	
Inspected by:	John Tibaldi – Seqwater	
Others present:	Doug Grigg - Seqwater	
Report Prepared by:	John Tibaldi (RPEQ 2525)	
Field Conditions:	Clear	☒
	Cloudy	☐
	Overcast	☐
	Rain	☐
	Rainfall	Nil

EXECUTIVE SUMMARY

Wivenhoe Dam has been owned by Seqwater since 1 July 2008. In accordance with the Dam safety Conditions for Wivenhoe Dam issued in accordance with the Water Supply Act 2008, Seqwater must undertake an Annual Inspection of the dam each year in accordance with the *Queensland Dam Safety Management Guidelines.* This report contains the results of the inspection undertaken in September 2009. The previous inspection was undertaken in November 2008.

The dam is generally in good condition and no significant dam safety issues were identified during the inspection. The main concerns from the inspection relate to the discontinuation of the infrastructure condition monitoring programs at the dam and outstanding corrective maintenance works.

It is also recommended that the presentation of the instrumentation data is reviewed and updated to provide graphs that are better able to identify dam safety issues, in accordance with the Wivenhoe Dam Design Report.

The next inspection is scheduled for October 2010.

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1.0 DESCRIPTION

POPULATION AT RISK	- Sunny Day Failure ..... 244000 - Flood.....> 1000 (Not fully assessed)
Failure Impact Rating	2
Hazard Category	Extreme
Name of Reservoir	Lake Wivenhoe
Year Complete	1984
Location	Approximately 5 km upstream of Fernvale
Dam Owner	Seqwater
Water Course	Brisbane River
Purpose	Town water and flood mitigation
Type of Construction	Zoned earth and rockfill embankment
Outlet Works	Radial gated spillway with supplementary fuse plug spillway
Catchment Area	7,020 km^2
FSL	67.0 m AHD
Nominal Full Supply Capacity	1,165,000 ML
Surface Area at FSL	10,750 ha
Main Dam Crest	79.00 m AHD
Main Dam Embankment Length	2,300 m
Maximum Height of Main Dam Embankment	50.0 m
Width at Top of Main Dam Embankment	10.0 m
Spillway Crest	57.0 m AHD

Spillway Length	60.0 m
Gates	5 radial gates – 12m wide x 16.6 m high
Top of Closed Radial Gate	EL 73.0 m
Saddle Dam Crest	80.0 m AHD
Saddle Dam Length	3 x total length of 518 m
Maximum Height of Saddle Dam Embankment	10.0 m
Peak water level as a result of PMF	Dam overtopped
Spillway Capacity (Including fuse plugs)	28,100 m^3/s (EL 79.0 m)
Maximum discharge as a result of PMF	37,400 m^3/s
AEP of Spillway Capacity (Including fuse plugs)	In 100, 000 (EL 79.0 m)
Regulator valves	1 x 1.5 m cone dispersion valve
Mean annual pan evaporation	1600 mm estimated from BoM maps
Mean annual rainfall	986 mm
Hydroelectric Facilities	4.3 mw mini-hydro
Notable events	1986, 1999
Maximum Historic Storage Level	70.45 m (1999)
COMMENT	Besides being a major source of urban water supply, Wivenhoe Dam provides a significant flood mitigation capacity to protect the urban areas downstream of the dam. During periods of heavy rainfall, flood water is temporarily stored in Wivenhoe Dam and released at a controlled rate to minimise the impact of downstream flooding. The dam was built in conjunction with Splityard Creek Dam and water from Wivenhoe is pumped into Splityard Creek Dam where it is used to generate electricity during periods of high demand.

2.0 DAM STATUS

Date	22 October 2009
Reservoir Water Surface Elevation	62.6 m
Percentage Full	66 %
Reservoir Water Level Relative to FSL	-4.4 m
Spillway Releases:	Nil

3.0 DAM OPERATION AND DOCUMENTATION

The following Dam Safety Documentation is held by Seqwater for Wivenhoe Dam:

- Emergency Action Plan.
- Standing Operating Procedures.
- Operation and Maintenance Manual.
- Data Book.
- Dam safety Review.

As part of the Annual Inspection process, the above documents were reviewed and found to be in accordance with the Queensland Dam Safety Management Guidelines. The Emergency Action Plan and Standing Operating Procedures are in a standard Seqwater format. The contact details contained in the Emergency Action Plan were updated in July 2009. The Operation and Maintenance Manual is currently being reviewed and updated and the Data Book remains in the format of the previous owner of Wivenhoe Dam and are scheduled for conversion to a standard Seqwater format in 2009/10**.**

4.0 ROUTINE INSPECTION AND LOGBOOK

Routine Inspections at Wivenhoe Dam are undertaken on a daily basis in accordance with the Queensland Dam Safety Management Guidelines. Complete records of all inspections are kept on site and at Seqwater's Karalee Office. No significant dam safety issues were identified from a review of the inspection records over the last 12 months.

A traditional logbook is currently in place at Wivenhoe Dam. A logbook is maintained generally to record the date of inspections and instrument monitoring, to note maintenance undertaken, and to note unusual events (e.g. seismic activity, floods, change in seepage patterns, etc.) to assist in maintaining the safety management of the dam. Notes in the logbook may assist in identifying the time and cause of incidents which may provide early warning for potential failure mechanisms.

5.0 DAM EMBANKMENT

Wivenhoe Dam is a 56 m high, zoned earth and rock embankment separated into two parts by a concrete gravity spillway, controlled by five radial gates. Two saddle dam embankments are located on the left side of the reservoir. A secondary spillway consisting of three fuse plug embankments was constructed on the right abutment in 2005.

Left Bank Embankment – Trees to be removed

The Left Bank embankment is approximately 1.1 kilometres long and 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 is in place on both the upstream and downstream shoulders of the embankment.

The Right Bank embankment is 1.2 kilometres long and 56 metres high with a central clay core. The embankment contains 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 is in place on both the upstream and downstream shoulders of the embankment.

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. The Saddle Dams have a crest level at EL 80 and have a maximum height of 10 m. The Saddle Dams only retain water during flood operation.

The crest and upstream and downstream faces of the earth embankments and saddle dams were inspected and generally found to be in a satisfactory condition. Many of the recommendations from the 2008 inspection had been acted upon and the overall condition of the embankment and saddle dams was improved from the 2008 inspection. However, some deficiencies were identified and these are listed below, along with recommendations for remedial actions.

Inspection Recommendations:

<u>Left Bank Embankment (Downstream Area)</u>

- ***As noted in the previous year's Annual Inspection, there is some breakdown of rip rap on the downstream side of the embankment, with some areas of rip rap are close to requiring replenishment. These areas should continue to be closely monitored for signs of any erosion damage. Presently the areas generally appear sound and stable.***
- ***Significant erosion repairs have been undertaken along the downstream toe of the embankment. These repairs look to have been quite successful; however some minor areas still require attention.***
- ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***
- ***There is a series of pipelines that gather runoff from the toe drains for outflow into suitable natural drainage points. Some repairs to these pipelines have been undertaken over the last 12 months; however a study is required to examine the relationship between flow in this drainage system and internal drainage within the embankment. It is possible that this drainage system relates only to surface water runoff, in which case maintenance of the system is not critical from a dam safety perspective.***

Minor erosion areas to be repaired along toe

Repaired Area

Downstream Embankment (Left Bank)

Downstream Embankment (Left Bank)

Repaired V Notch Weir

Repaired Pit and new Marker Post

Left Bank Embankment (Upstream Area)

- ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***
- ***The flap gate drains near the left bank end of embankment are to be modified to reduce the risk of the flap gates jamming open. The EAP is to include instructions for checking of these gates in major flood events.***
- ***All trees within five metres of the toe of the embankment are to be removed.***
- ***The hinges on the park flood gate are to be greased and missing bolts reinstated.***

Flap Gates

Park Flood Gate

Dam Crest

- ***The drains under the wave wall are to be modified to prevent blocking and a store of suitable plugs is to be kept at the dam to enable these drains to be closed off in the event of a flood that impacts on the wave wall (in these circumstances the road would be closed due to flooding and would not be used by the public). This issue is outstanding from the 2008 inspection.***

Broken/Blocked Road Drain

Broken/Blocked Road Drain

Spillway Channel

- ***Vegetation growing in the rip rap is to be sprayed with a suitable herbicide.***

Right Bank Embankment

- ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***
- ***All trees within five metres of the toe of the embankment are to be removed.***
- ***All termite mounds within five metres are to be sprayed and destroyed.***
- ***Vegetation growing in the area of the old river diversion is to be burned off each year just prior to the annual inspection to allow proper inspection of this area.***
- ***The erosion hole near the V notch weir is to be filled.***

Erosion Hole

Termite Mound

Fuse Plug Embankments and Auxiliary Spillway

- ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***
- ***All trees within five metres of the toe of the embankment are to be removed.***
- ***All trees within three metres of the spillway retaining walls are to be removed.***

Vegetation to be sprayed

Trees to be removed

Saddle Dams

- ***The condition of the saddle dams is greatly improved from the 2008 Annual Inspection. However, some undesirable vegetation (mainly small tree regrowth) is still evident on the embankments and the current weed spraying and mowing program should continue.***

Saddle Dam

6.0 SPILLWAY

The spillway is located in a low saddle between the two dam earth and rockfill embankments and is controlled by five radial gates supported on a mass concrete ogee crest. The radial gates are 12 metres wide by 16 metres high and discharge via a flip bucket spillway to an unlined rock discharge channel. The five radial gates are operated by hydraulic motor driven wire rope winches, one on each side of each gate. The power units 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.

The spillway and associated gates, hoisting gear and cranes looked to be in good condition. The gauge boards that serve as the radial gate position indicators have recently been replaced and are in excellent condition. Undertaking regular routine maintenance in accordance with the dam Operation and Maintenance Manuals appears to be producing good results and it is important that this program is continued. However, it was noted that the electrical condition monitoring program seems to have been discontinued and this is of concern. Trees on the benched areas of the spillway channel, downstream of the radial gates, that were identified as a problem in the 2008 Annual Inspection and have been removed.

The main issues found during the inspection relate to ensuring the on-going reliability of the spillway gates. The mechanical and electrical infrastructure is now over 25 years old and assessments are needed to determine the remaining useful life of this infrastructure and commence planning renewal and refurbishment works.

Inspection Recommendations

- ***Undertake a risk assessment of the age and condition of the electrical and hydraulic equipment at the dam to determine remaining useful like of this equipment and develop a plan for renewal and replacement. In particular, the following components require examination***
    - ***Radial Gate Electric/Hydraulic System.***
    - ***Radial gate Hydraulic Winch motors.***
    - ***Standby Diesel generator.***
    - ***High Voltage Transformer.***
    - ***Radial Gate Fixed Diesel/Hydraulic System.***
    - ***79 Tonne Gantry Crane Electric/Hydraulic System.***
- ***Recommence the electrical condition monitoring program associated with the radial gate infrastructure.***
- ***Install a suitable hydraulic oil overflow collection and oil transfer system to manage hydraulic balancing between the electric hydraulic and fixed diesel hydraulic systems.***
- ***Engage a suitable hydraulic specialist to investigate the recent low hydraulic oil pressure alarms that have occurred during radial gate operations and repair the creeping anchor pin on the 79 tonne Gantry Crane.***
- ***Repair the leak in the Standby Diesel generator oil cooler system. It is considered that this leak requires urgent attention.***
- ***Repair the concrete damage to the spillway floor and replace the missing flap gate on one of the spillway underdrain outlets.***
- ***Initiate a painting program for the downstream sides of the radial gates. It may be sensible to paint one gate per year over the next five years.***

Standby Diesel Generator

7.0 RESERVOIR RIM AND DOWNSTREAM WATERWAY

The reservoir rim slopes appear generally stable and above the Full Supply Level are relatively well vegetated with no signs of slips or movement that would be of concern from a dam safety perspective.

There were also no slips or restrictions that would prevent spillway outflow or raise tail water levels to an unacceptable level during a dam outflow event.

8.0 OUTLET WORKS

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 is a 3.6 metre diameter penstock, located below a 1.9 metre diameter river outlet. A single fixed wheel bulkhead gate is provided to command either outlet (but not both outlets at the same time) to provide for emergency closure or dewatering.

The 3.6m diameter penstock is sealed off with a semi-ellipsoidal dome. A 1.5 metre diameter offtake from this penstock provides an outlet into the river that diverts water through a mini hydro Power Station constructed in 2002. Control of this conduit is provided through mini-hydro facility. The second outlet into the river is a 1.5 metre diameter stainless steel Fixed Cone Dispersion Valve located at the downstream end of the 1.9 metre diameter river outlet.

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.

The mechanical equipment in the outlet works was inspected and found to be in generally good condition. Internal inspection of the conduits and valves had occurred within the last five years and will occur again at or before the next five year comprehensive inspection.

Issues relating to water leaking into the outlet works area through the service penetrations to the mini-hydro facility remain outstanding from the 2008 Inspection as to issues relating to the stability of the sandstone cliffs adjacent to the outlet works. There is an issue with chains disengaging on the chain hoists associated with the selective baulks and a new and accurate float well recorder is to be installed at the dam. It was also noted that sump pump flows from the mini hydro are not monitored and a suitable flow recording device should be installed to allow this to occur.

Inspection Recommendations

- ***Seal the service penetrations to the mini-hydro facility as these are causing water leaks into the outlet works.***
- ***Suitable engineering works are to be constructed to eliminate the hazard to persons and dam infrastructure caused by the erosion of the sandstone cliffs adjacent to the outlet works.***
- ***Repair the mechanical problems causing the hoist chains to disengage for the drive wheels on the selective baulks.***
- ***Install a new float well water level recorder in the intake works.***
- ***Install a flow meter to allow measurement of the sump pump outflows from the mini hydro and record these outflows on the weekly inspection sheets.***

Cone Valve

9.0 INSTRUMENTATION

Surveillance instrumentation at the dam monitors movement of the dam embankment, seepage and pressure within the embankment. The instrumentation consists of:

- 10 foundation drains.
- 65 hydraulic piezometers
- 24 surface settlement points
- 2 V-notch weirs
- 1 automatic water level recorder

Most of the post tensioning anchors were load tested since the previous annual inspection in accordance with ANCOLD guidelines and the results of this testing are shown in the following table.

Wivenhoe Testing Results - 2009

Cable No	Location	Position	Load Cell Gauge Reading No 1	Load Cell Gauge Reading No 2	Average Reading	Calculated Load	MBL for Cable	Design Load for Cable	Measured vs Design Difference	OK?	Test Date
1	Bay 1	LHS	38.2	38.2	38.20	10.16	16.51	10.73	-0.57	NO	24/11/2008
2	Bay 1	Centre	42.0	42.0	42.00	11.18	16.51	10.73	0.45	YES	12/02/2009
3	Bay 1	RHS	39.5	39.5	39.50	10.51	16.51	10.73	-0.22	NO	24/02/2009
4	Bay 2	LHS	42.6	42.7	42.65	11.35	16.51	10.73	0.62	YES	9/04/2009
5	Bay 2	Centre	41.8	41.8	41.80	11.13	16.51	10.73	0.40	YES	15/04/2009
6	Bay 2	Centre	41.9	41.9	41.90	11.15	16.51	10.73	0.42	YES	16/04/2009
7	Bay 2	RHS	41.8	41.8	41.80	11.13	16.51	10.73	0.40	YES	20/04/2009
8	Bay 3	LHS	40.8	40.9	40.85	10.87	16.51	10.73	0.14	YES	17/06/2009
9	Bay 3	Centre	40.6	40.5	40.55	10.79	16.51	10.73	0.06	YES	18/06/2009
10	Bay 3	Centre	40.9	40.9	40.90	10.88	16.51	10.73	0.16	YES	23/06/2009
11	Bay 3	RHS	41.2	41.3	41.25	10.98	16.51	10.73	0.25	YES	24/06/2009
12	Bay 4	LHS	41.3	41.3	41.30	10.99	16.51	10.73	0.26	YES	29/06/2009
13	Bay 4	Centre	42.0	42.0	42.00	11.18	16.51	10.73	0.45	YES	30/06/2009
14	Bay 4	Centre	41.2	41.2	41.20	10.96	16.51	10.73	0.24	YES	1/07/2009
15	Bay 4	RHS	41.8	41.8	41.80	11.13	16.51	10.73	0.40	YES	2/07/2009
16	Bay 5	LHS					16.51	10.73			
17	Bay 5	Centre					16.51	10.73			
18	Bay 5	Centre					16.51	10.73			
19	Bay 5	RHS					16.51	10.73			

The table above shows that Cable No. 1 is 5% outside the required test load and that Cable No. 3 is 2% outside the required test load. In the first instance both cables will be retested to verify these results. Cables 16 to 19 still require testing.

The instrumentation results are contained in Appendix A. Although no trends of concern were noted, the presentation of this data is to be reviewed and updated to provide graphs that are better able to allow review of the data to identify issues, in accordance with the Wivenhoe Dam Design Report.

The instrumentation was also inspected, and the following works recommendations were made:

Inspection Recommendations:

- ***All seepage measuring points, survey points and foundation drains are to be suitably labelled and numbered on site and a suitable engineering plan prepared to show instrumentation point locations and corresponding numbering.***
- ***Post tensioning anchor Cables No. 1 and No. 3 are to be retested in 2010 to determine if the anchor strength remains outside desirable values.***
- ***Post tensioning anchor Cables No. 16, No. 17, No. 18 and No. 19 are to be tested by 2010.***
- ***The presentation of the instrumentation data is to be reviewed and updated to provide graphs that are better able to identify dam safety issues, in accordance with the Wivenhoe Dam Design Report.***

10.0 RECOMMENDATIONS

Section Reference	Recommendation	Rating (See Below)
5.0	***<u>Left Bank Embankment (Downstream Area)</u>***	
	• ***As noted in the previous year's Annual Inspection, there is some breakdown of rip rap on the downstream side of the embankment, with some areas of rip rap are close to requiring replenishment. These areas should continue to be closely monitored for signs of any erosion damage. Presently the areas generally appear sound and stable.***	**4**
	• ***Significant erosion repairs have been undertaken along the downstream toe of the embankment. These repairs look to have been quite successful; however some minor areas still require attention.***	**3**
	• ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***	**3**
	• ***There is a series of pipelines that gather runoff from the toe drains for outflow into suitable natural drainage points. Some repairs to these pipelines have been undertaken over the last 12 months; however a study is required to examine the relationship between flow in this drainage system and internal drainage within the embankment. It is possible that this drainage system relates only to surface water runoff, in which case maintenance of the system is not critical from a dam safety perspective.***	**2**
	<u>Left Bank Embankment (Upstream Area)</u>	
	• ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***	**3**

	• ***The flap gate drains near the left bank end of embankment are to be modified to reduce the risk of the flap gates jamming open. The EAP is to include instructions for checking of these gates in major flood events.***	**3**
	• ***All trees within five metres of the toe of the embankment are to be removed.***	**3**
	• ***The hinges on the park flood gate are to be greased and missing bolts reinstated.***	**3**
	<u>Dam Crest</u>	
	• ***The drains under the wave wall are to be modified to prevent blocking and a store of suitable plugs is to be kept at the dam to enable these drains to be closed off in the event of a flood that impacts on the wave wall (in these circumstances the road would be closed due to flooding and would not be used by the public). This issue is outstanding from the 2008 inspection.***	**3**
	<u>Spillway Channel</u>	
	• ***Vegetation growing in the rip rap is to be sprayed with a suitable herbicide.***	**3**
	<u>Right Bank Embankment</u>	
	• ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***	**3**
	• ***All trees within five metres of the toe of the embankment are to be removed.***	**3**
	• ***All termite mounds within five metres are to be sprayed and destroyed.***	**3**
	• ***Vegetation growing in the area of the old river diversion is to be burned off each year just prior to the annual inspection to allow proper inspection of this area.***	**3**
	• ***The erosion hole near the V notch weir is to be filled.***	**3**

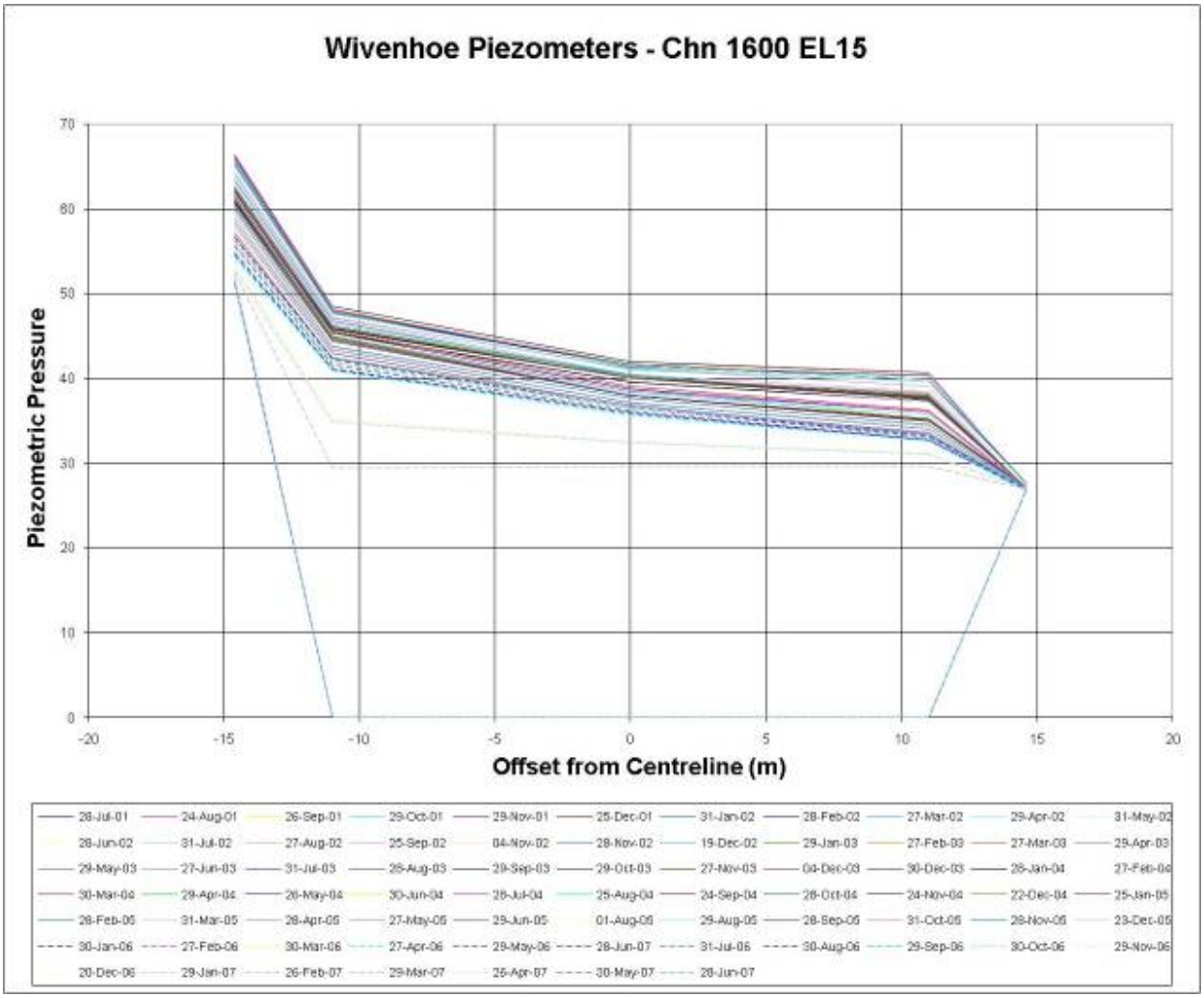
	Fuse Plug Embankments and Auxiliary Spillway	
	• ***Some minor vegetation is evident on the embankment face and the current weed spraying program should continue.***	**3**
	• ***All trees within five metres of the toe of the embankment are to be removed.***	**3**
	• ***All trees within three metres of the spillway retaining walls are to be removed.***	**3**
	Saddle Dams	
	• ***The condition of the saddle dams is greatly improved from the 2008 Annual Inspection. However, some undesirable vegetation (mainly small tree regrowth) is still evident on the embankments and the current weed spraying and mowing program should continue.***	**3**
6.0	• ***Undertake a risk assessment of the age and condition of the electrical and hydraulic equipment at the dam to determine remaining useful like of this equipment and develop a plan for renewal and replacement. In particular, the following components require examination*** o ***Radial Gate Electric/Hydraulic System.*** o ***Radial gate Hydraulic Winch motors.*** o ***Standby Diesel generator.*** o ***High Voltage Transformer.*** o ***Radial Gate Fixed Diesel/Hydraulic System.*** o ***79 Tonne Gantry Crane Electric/Hydraulic System.***	**3**
	• ***Recommence the electrical condition monitoring program associated with the radial gate infrastructure.***	**1**
	• ***Install a suitable hydraulic oil overflow collection and oil transfer system to manage hydraulic balancing between the electric hydraulic and fixed diesel hydraulic systems.***	**3**
	• ***Engage a suitable hydraulic specialist to investigate the recent low hydraulic oil pressure alarms that have occurred during radial gate operations and repair the creeping anchor pin on the 79 tonne Gantry Crane.***	**1**
	• ***Repair the leak in the Standby Diesel generator oil cooler system. It is considered that this leak requires urgent***	**2**

	attention.	
	• ***Repair the concrete damage to the spillway floor and replace the missing flap gate on one of the spillway underdrain outlets.***	**3**
	• ***Initiate a painting program for the downstream sides of the radial gates. It may be sensible to paint one gate per year over the next five years.***	**3**
8.0	• ***Seal the service penetrations to the mini-hydro facility as these are causing water leaks into the outlet works.***	**3**
	• ***Suitable engineering works are to be constructed to eliminate the hazard to persons and dam infrastructure caused by the erosion of the sandstone cliffs adjacent to the outlet works.***	**3**
	• ***Repair the mechanical problems causing the hoist chains to disengage for the drive wheels on the selective baulks.***	**3**
	• ***Install a new float well water level recorder in the intake works.***	**3**
	• ***Install a flow meter to allow measurement of the sump pump outflows from the mini hydro and record these outflows on the weekly inspection sheets.***	**3**
9.0	• ***All seepage measuring points, survey points and foundation drains are to be suitably labelled and numbered on site and a suitable engineering plan prepared to show instrumentation point locations and corresponding numbering.***	**3**
	• ***Post tensioning anchor Cables No. 1 and No. 3 are to be retested in 2010 to determine if the anchor strength remains outside desirable values.***	**3**
	• ***Post tensioning anchor Cables No. 16, No. 17, No. 18 and No. 19 are to be tested by 2010.***	**3**
	• ***The presentation of the instrumentation data is to be reviewed and updated to provide graphs that are better able to identify dam safety issues, in accordance with the Wivenhoe Dam Design Report.***	**3**

Legend of Criticality Rating

Rating 1	Rectification required immediately, i.e. within 1 month
Rating 2	Rectification required within 3 months
Rating 3	Rectification required within 12 months
Rating 4	Ongoing

APPENDIX A
INSTRUMENTATION DATA


Wivenhoe Piezometers - Chn 1600 EL15
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50
40
30
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10
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-20
-15
-10
-5
0
5
10
15
20
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
31-Jul-02
27-Aug-02
25-Sep-02
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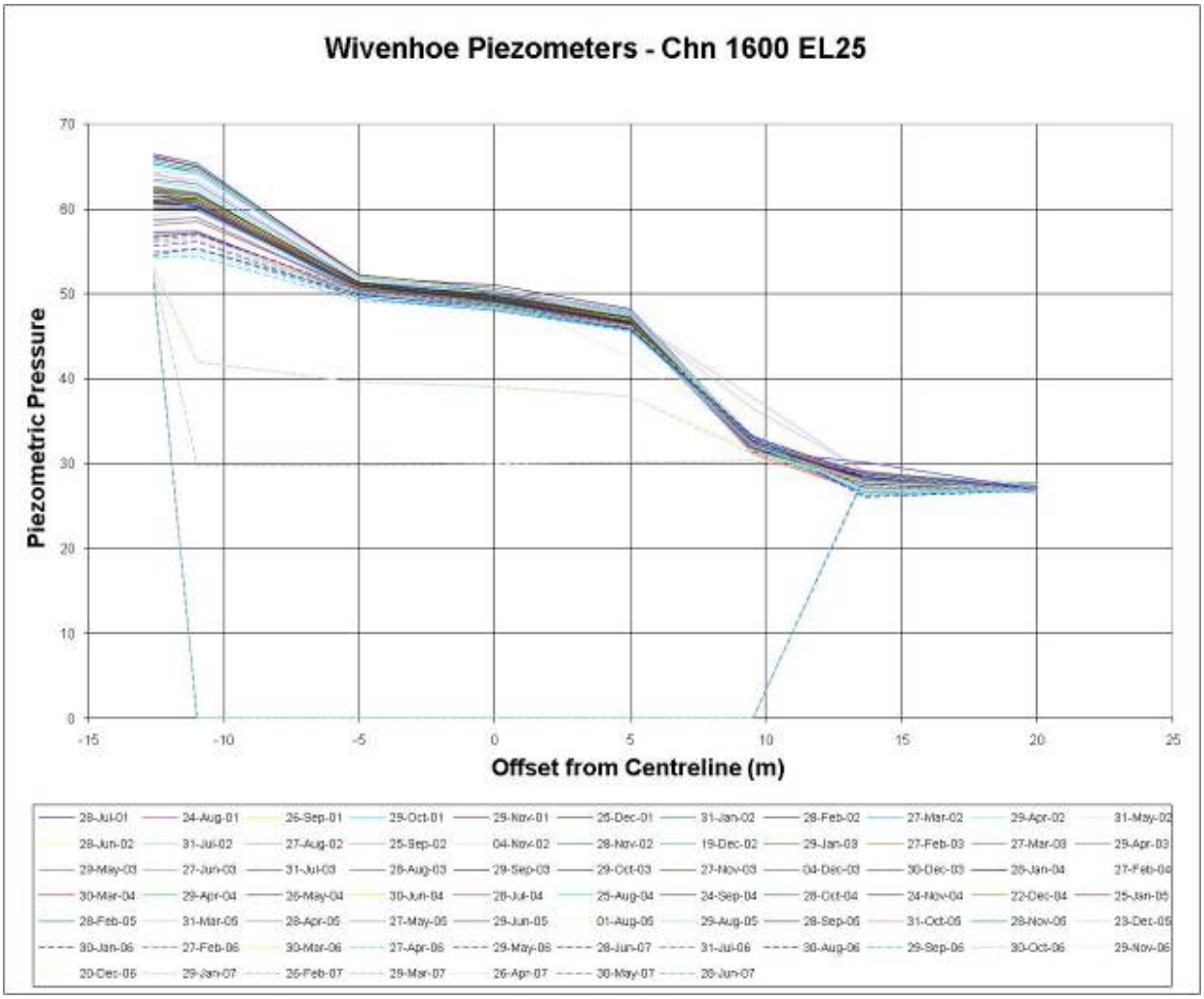
28-Jun-07


Wivenhoe Piezometers - Chn 1600 EL25
Piezometric Pressure
70
60
50
40
30
20
10
0
-15
-10
-5
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10
15
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24-Aug-01
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27-Mar-02
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31-May-02
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31-Jul-02
27-Aug-02
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04-Nov-02
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27-Jun-03
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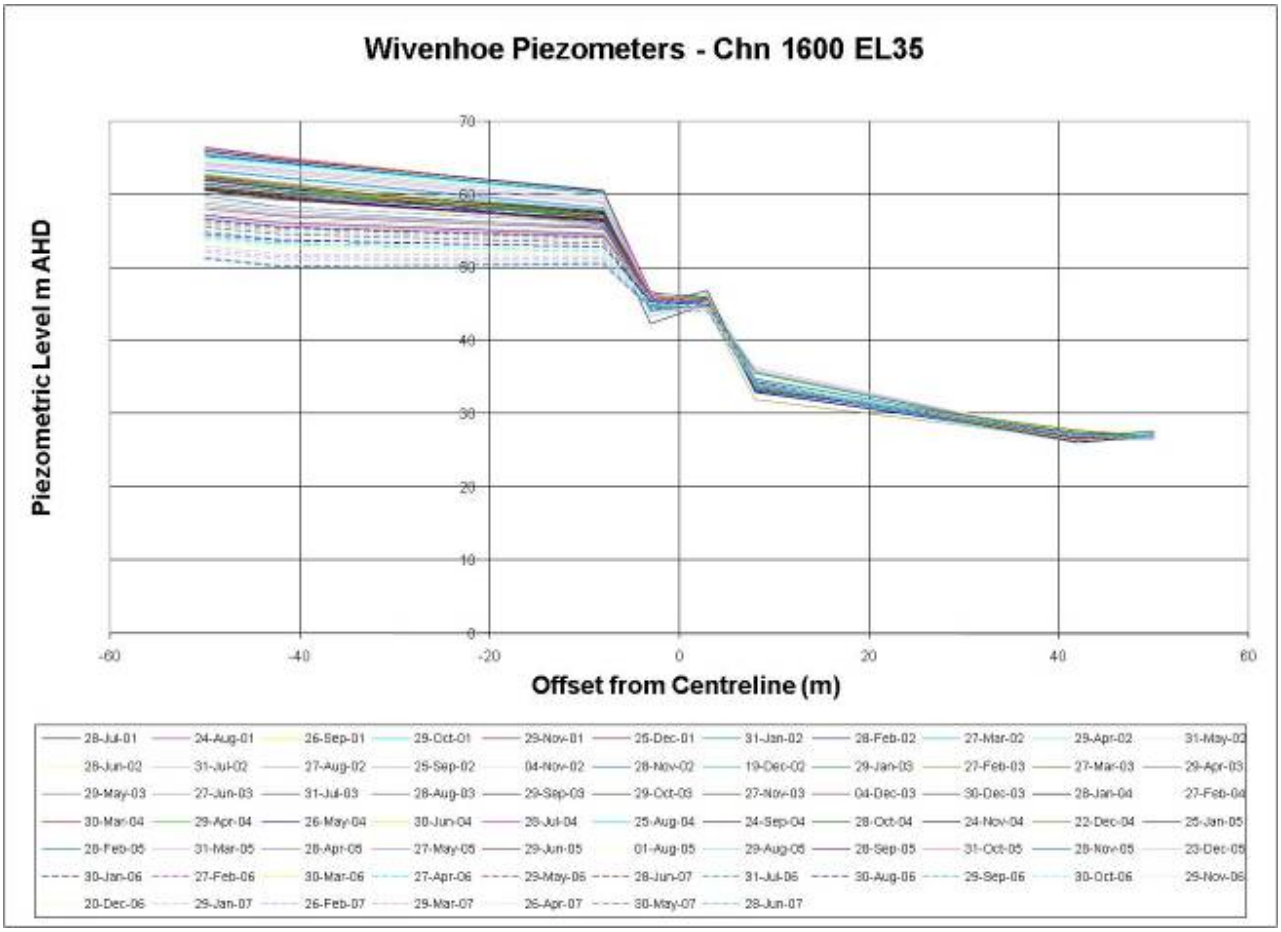
26-Jun-07


Wivenhoe Piezometers - Chn 1600 EL35
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-60
-40
-20
0
20
40
60
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
25-Apr-02
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27-Aug-02
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04-Nov-02
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27-Feb-03
27-Mar-03
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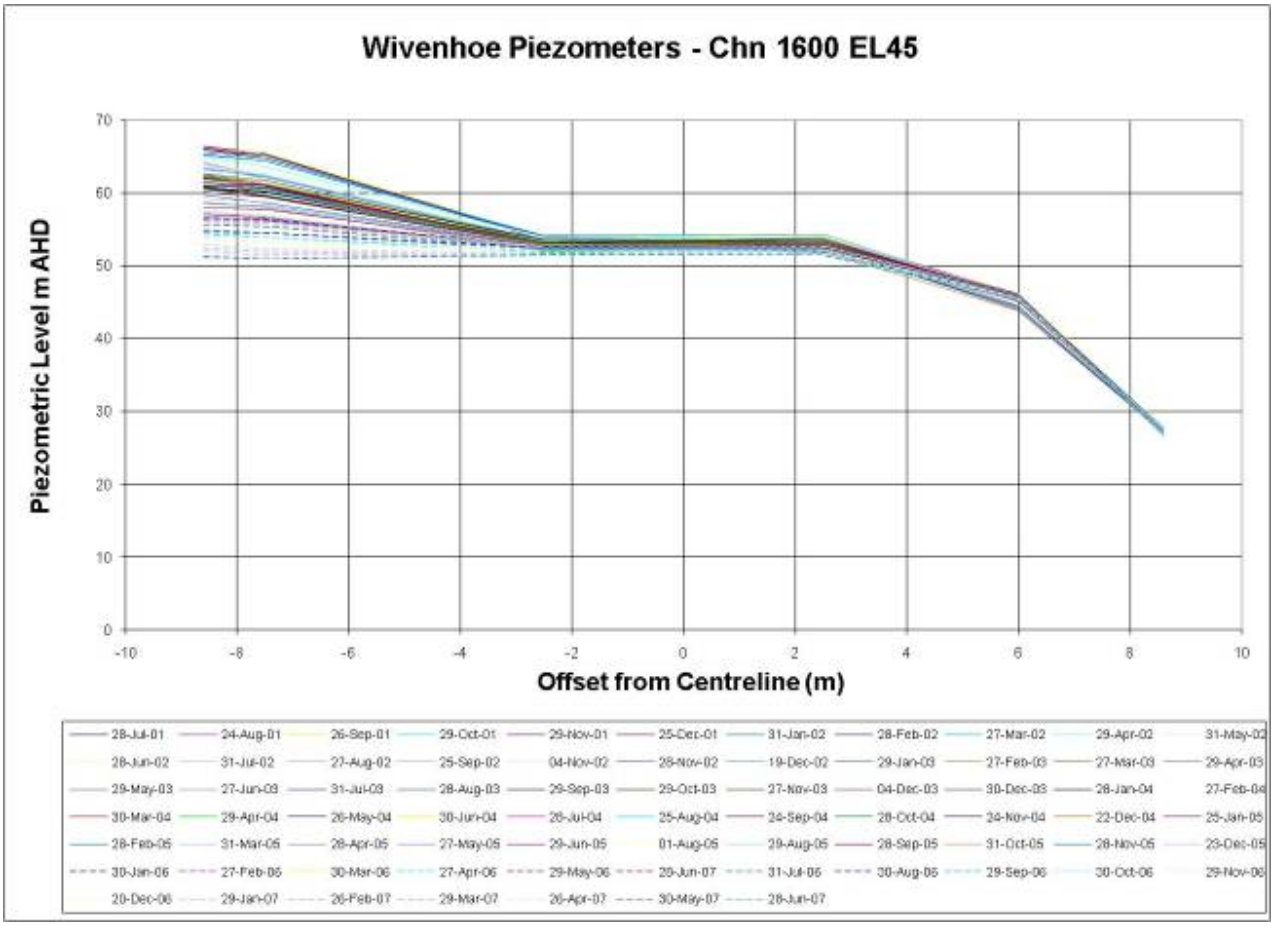
28-Jun-07


Wivenhoe Piezometers - Chn 1600 EL45
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
31-Jul-02
27-Aug-02
25-Sep-02
04-Nov-02
28-Nov-02
19-Dec-02
29-Jan-03
27-Feb-03
27-Mar-03
29-Apr-03
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27-Nov-03
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29-Sep-06
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20-Dec-06
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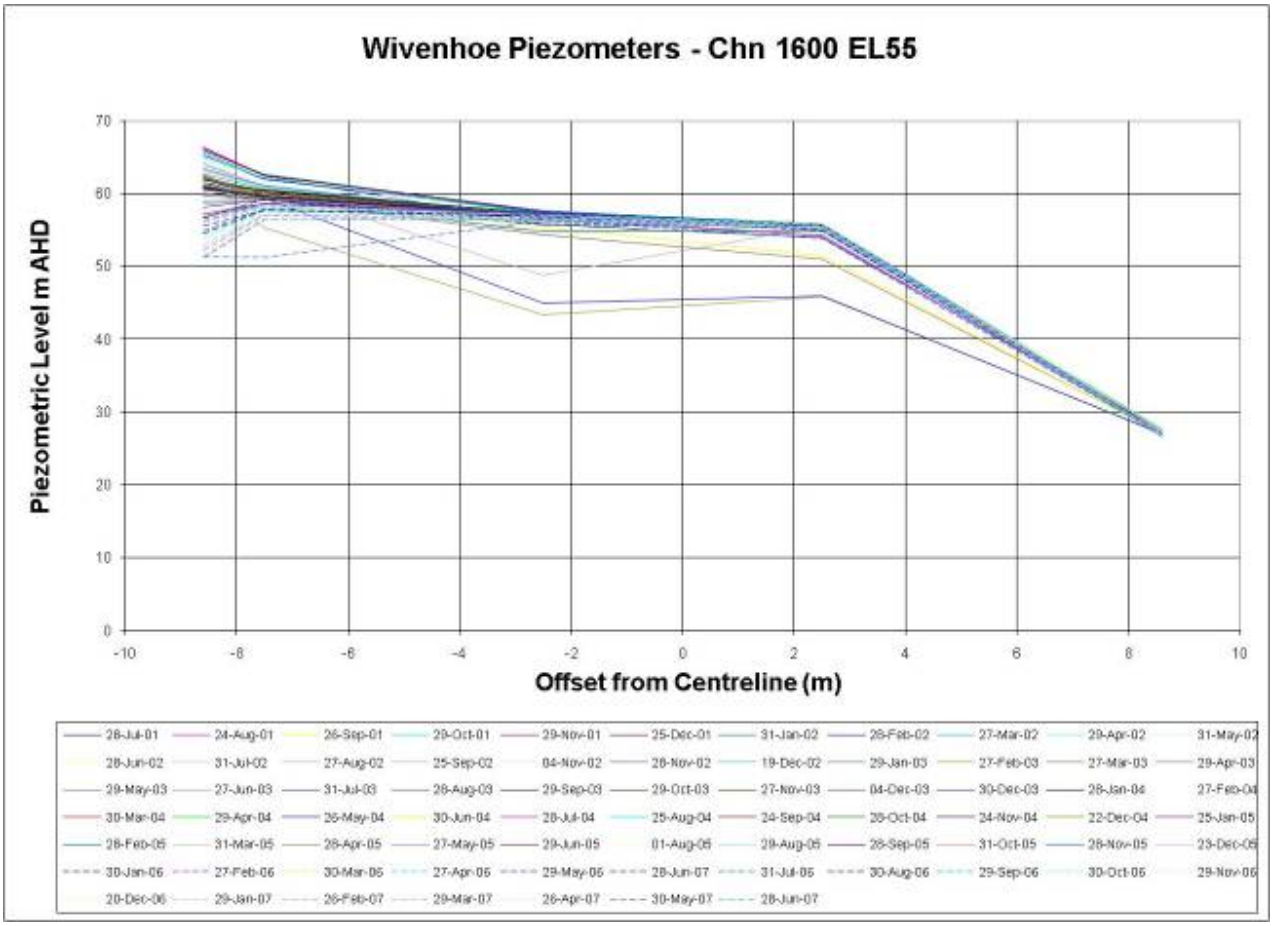
26-Feb-07
29-Mar-07
26-Apr-07
30-May-07
28-Jun-07


Wivenhoe Piezometers - Chn 1600 EL55
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
31-Jul-02
27-Aug-02
25-Sep-02
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28-Nov-02
19-Dec-02
29-Jan-03
27-Feb-03
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29-Sep-06
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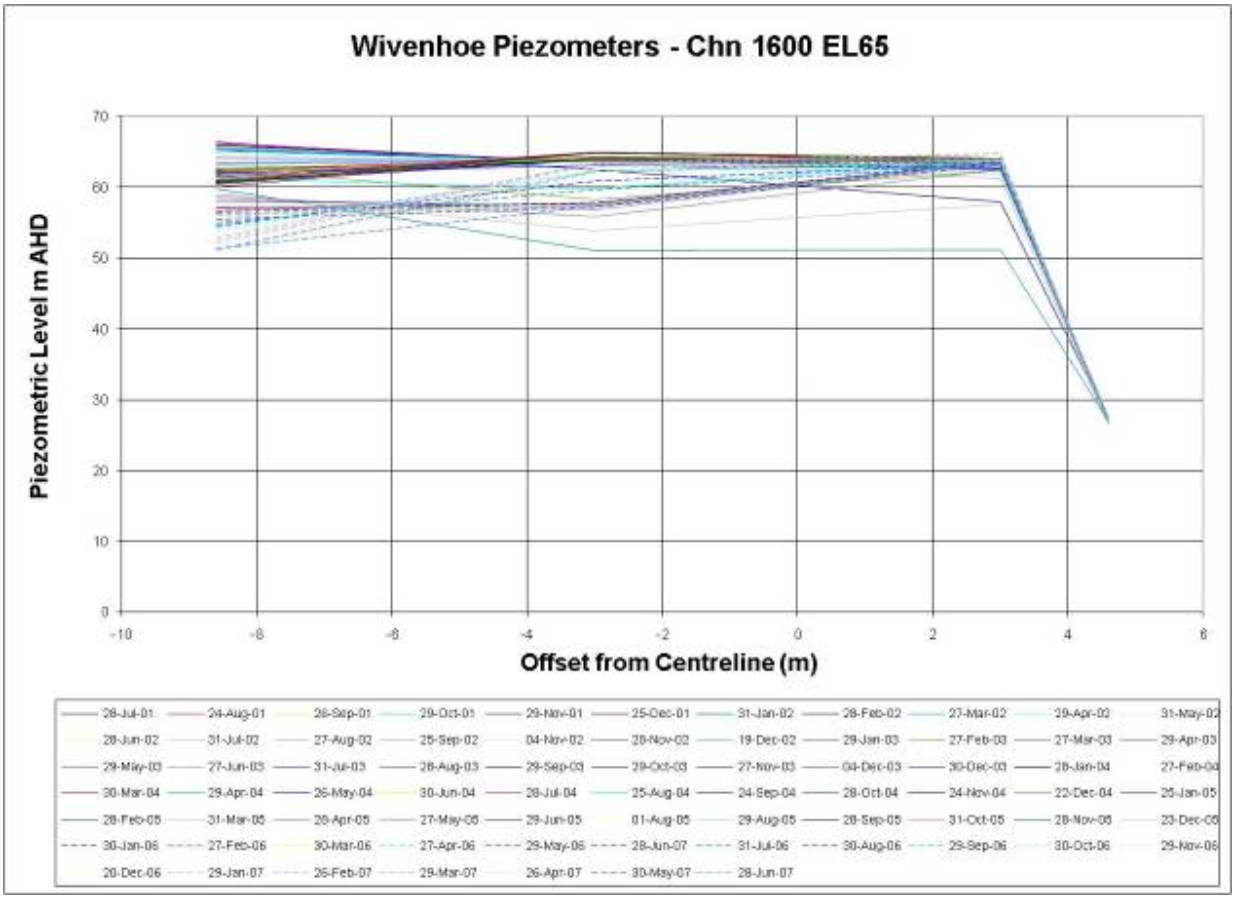
30-May-07
28-Jun-07


Wivenhoe Piezometers - Chn 1600 EL65
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
31-Jul-02
27-Aug-02
25-Sep-02
04-Nov-02
29-Nov-02
19-Dec-02
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29-May-03
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01-Aug-05
29-Aug-05
28-Sep-05
31-Oct-05
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23-Dec-05
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27-Apr-06
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30-Aug-06
29-Sep-06
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26-Apr-07
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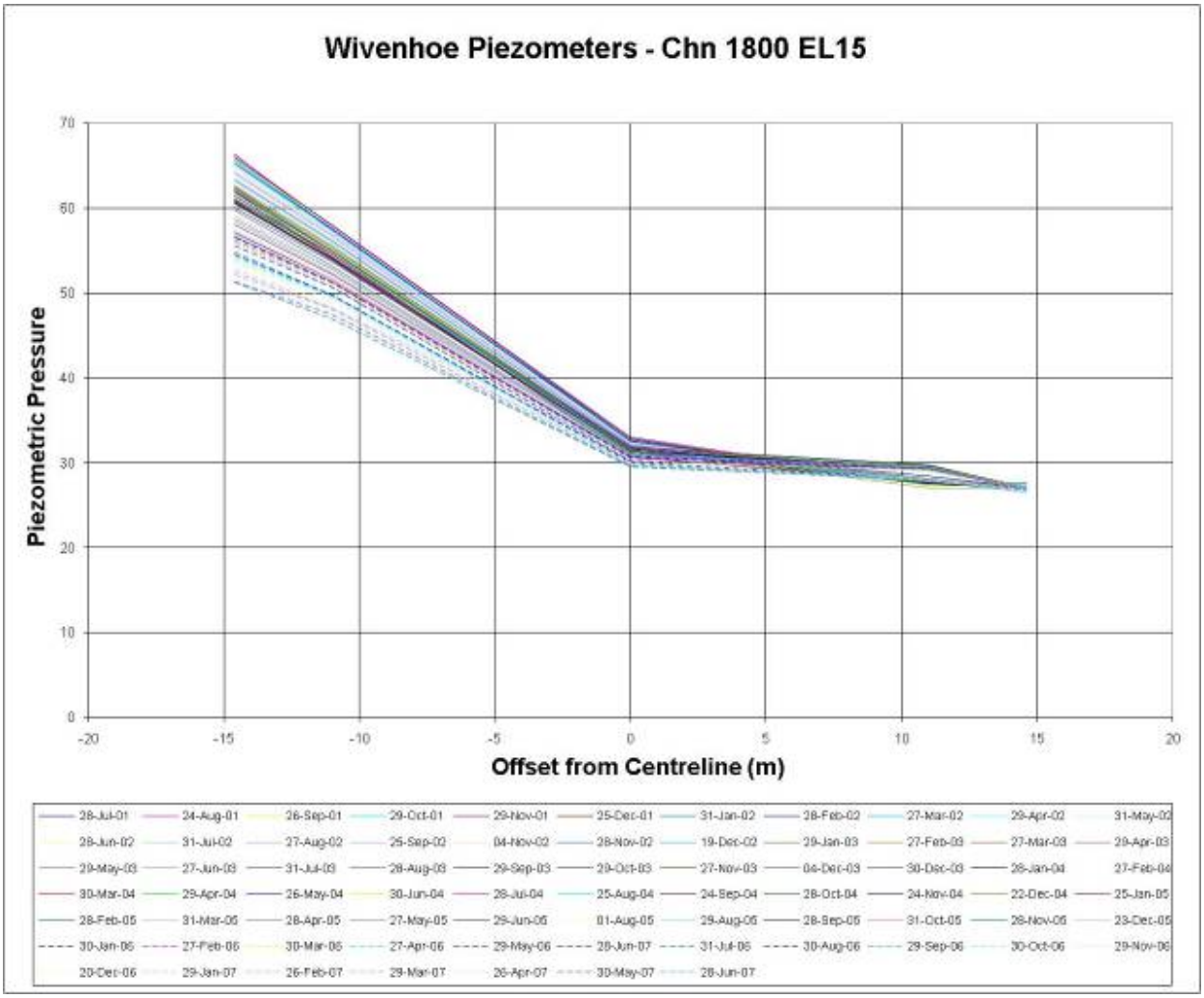
28-Jun-07


Wivenhoe Piezometers - Chn 1800 EL15
Piezometric Pressure
70
60
50
40
30
20
10
0
-20
-15
-10
-5
0
5
10
15
20
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
31-Jul-02
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25-Sep-02
04-Nov-02
28-Nov-02
19-Dec-02
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27-Feb-03
27-Mar-03
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29-May-03
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28-Apr-05
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29-Aug-05
28-Sep-05
31-Oct-05
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29-Sep-06
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26-Apr-07
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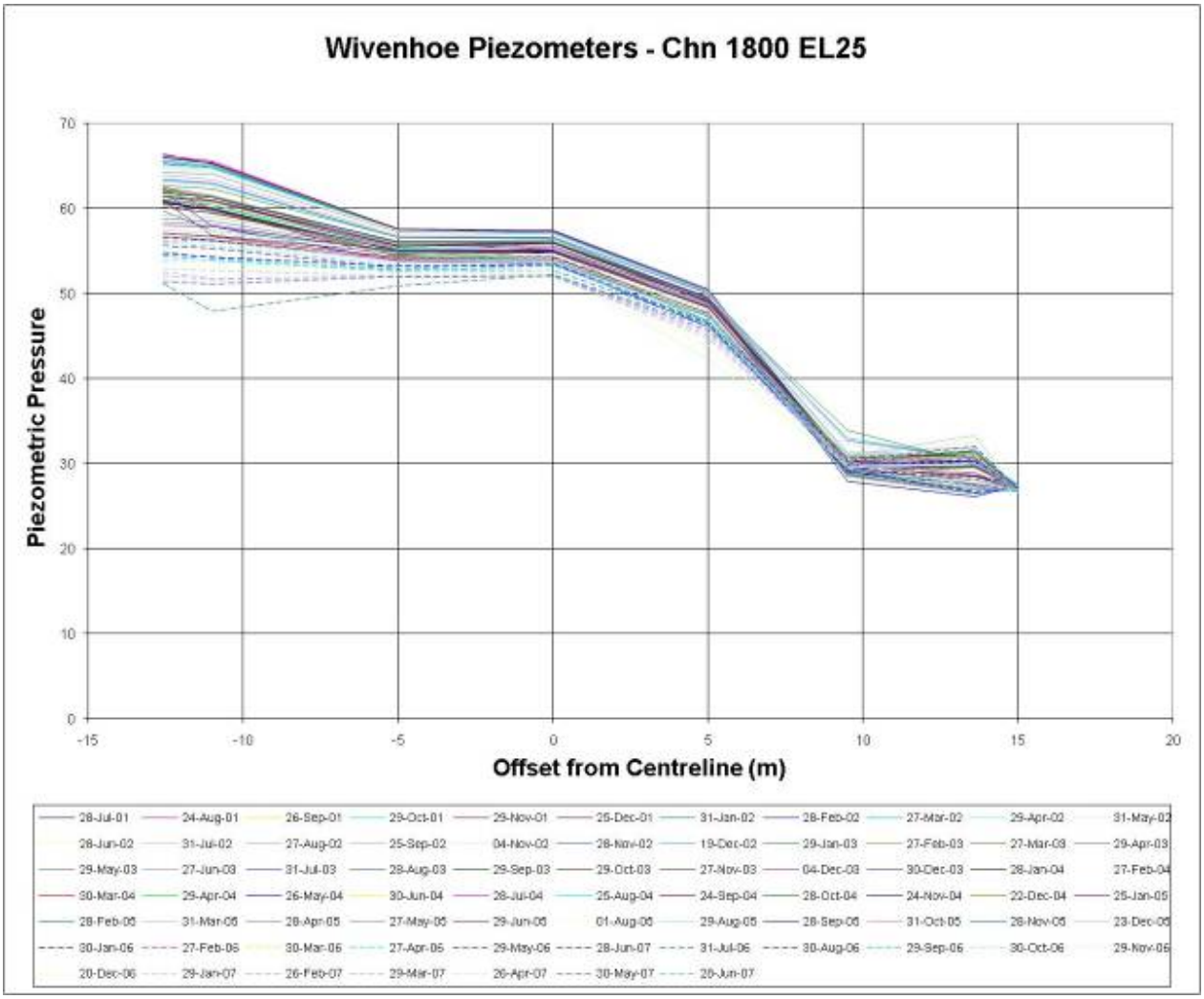
Wivenhoe Piezometers - Chn 1800 EL25
Piezometric Pressure
70
60
50
40
30
20
10
0
-15
-10
-5
0
5
10
15
20
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
31-Jul-02
27-Aug-02
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28-Nov-02
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23-Dec-05
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27-Feb-06
30-Mar-06
27-Apr-06
29-May-06
28-Jun-07
31-Jul-06
30-Aug-06
29-Sep-06
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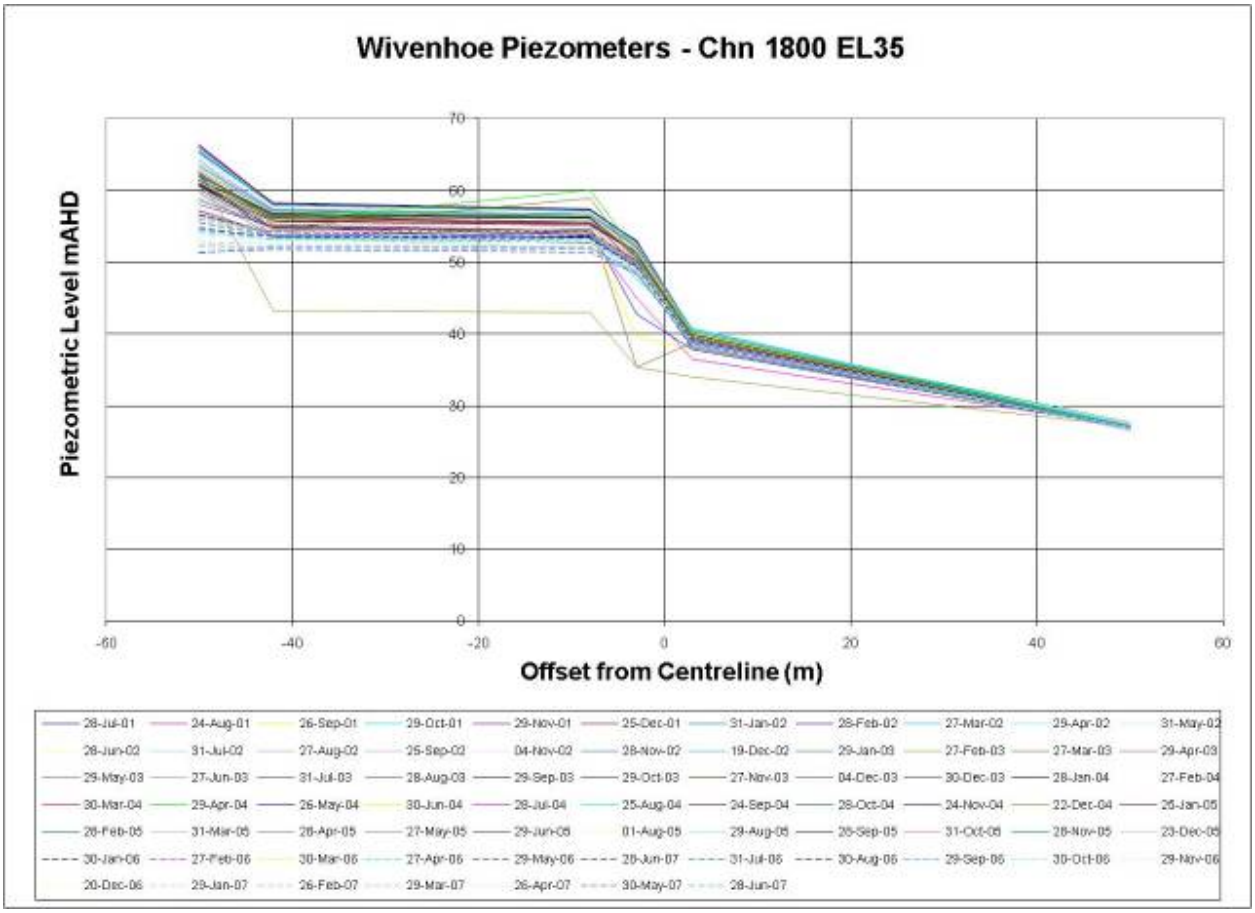
26-Apr-07
30-May-07
25-Jun-07


Wivenhoe Piezometers - Chn 1800 EL35
Piezometric Level mAHD
70
60
50
40
30
20
10
0
-60
-40
-20
0
20
40
60
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
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28-Apr-05
27-May-05
29-Jun-05
01-Aug-05
29-Aug-05
26-Sep-05
31-Oct-05
28-Nov-05
23-Dec-05
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27-Feb-06
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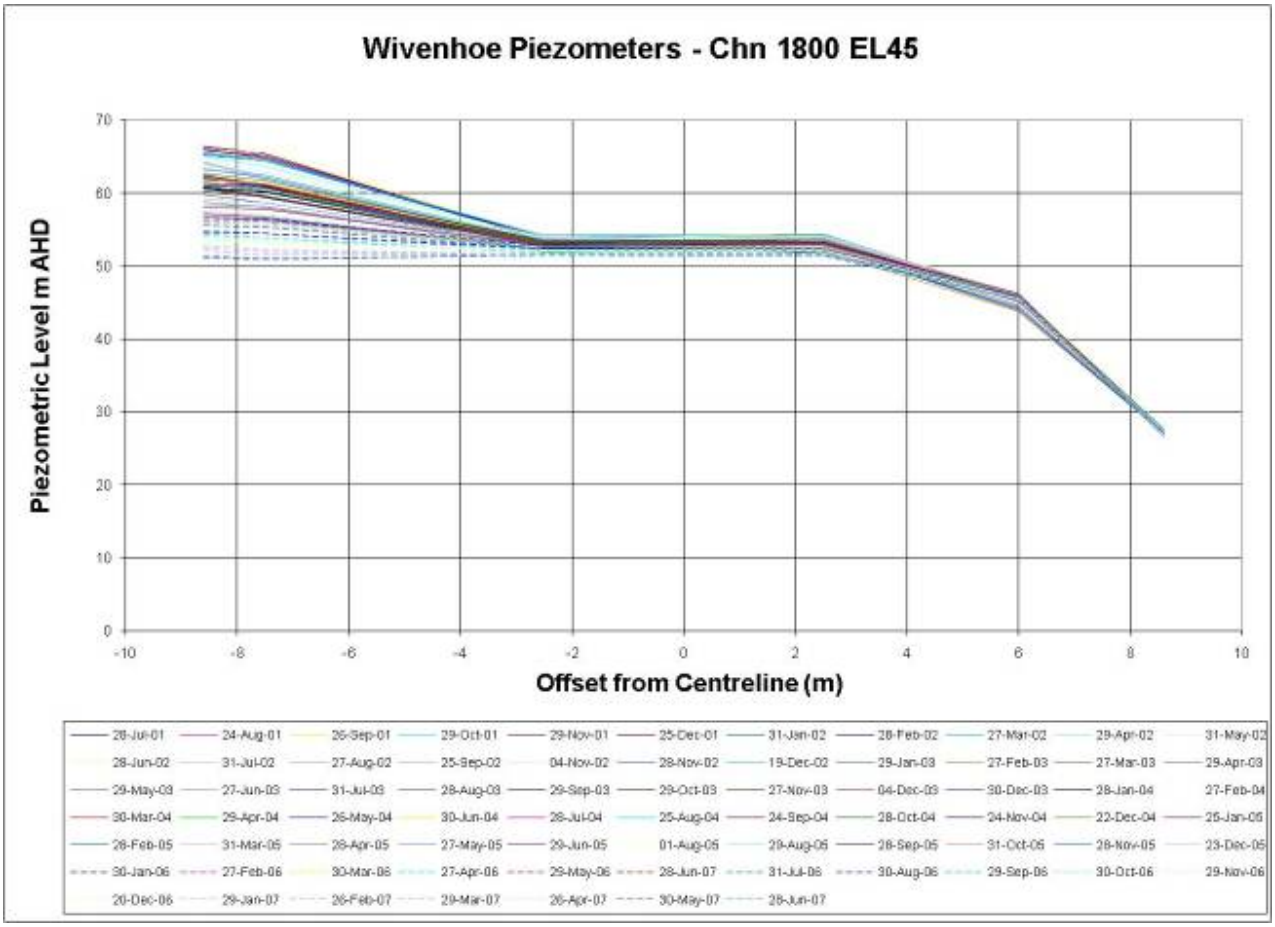
28-Jun-07


Wivenhoe Piezometers - Chn 1800 EL45
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
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27-Aug-02
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28-Jul-04
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24-Sep-04
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28-Apr-05
27-May-05
29-Jun-05
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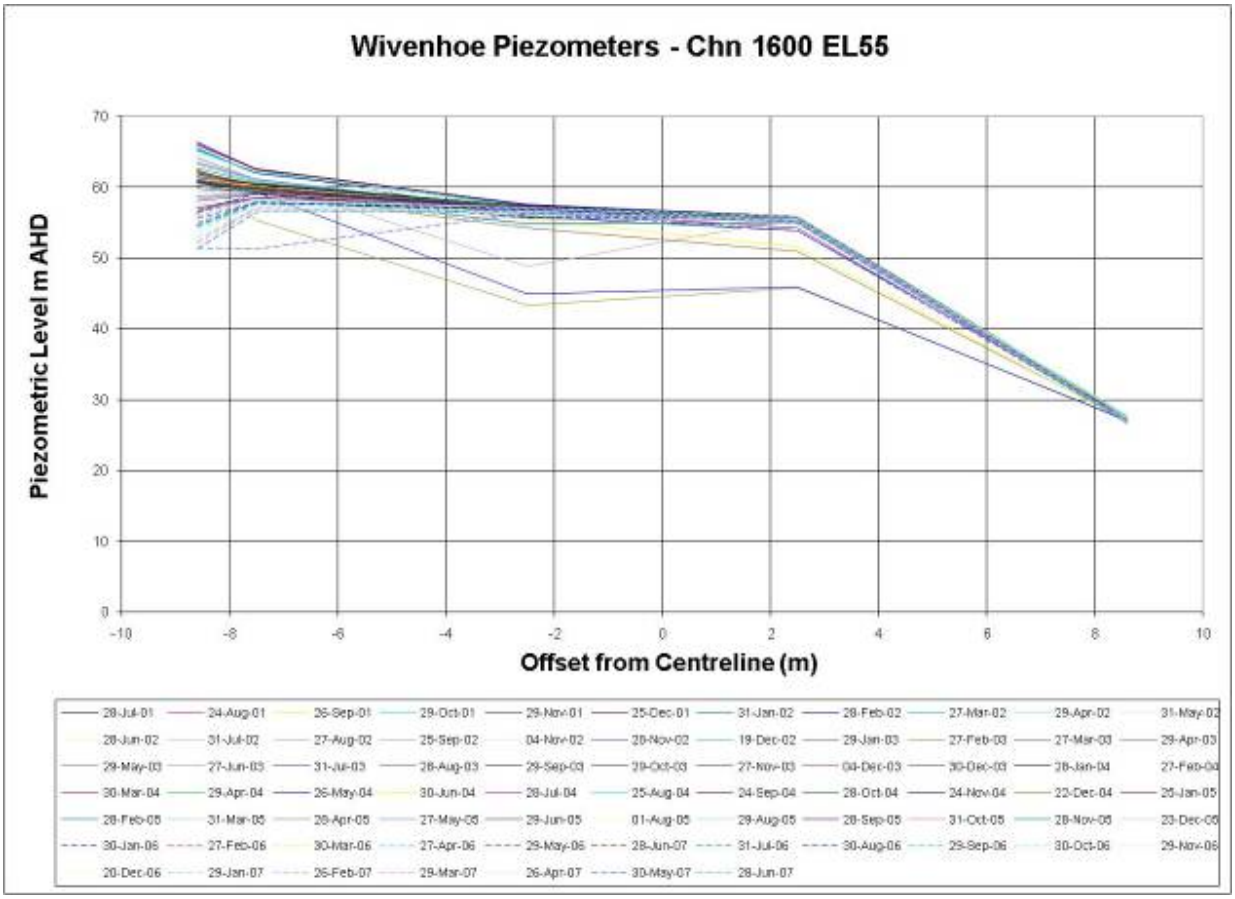
30-May-07
28-Jun-07


Wivenhoe Piezometers - Chn 1600 EL55
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
31-May-02
28-Jun-02
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27-Aug-02
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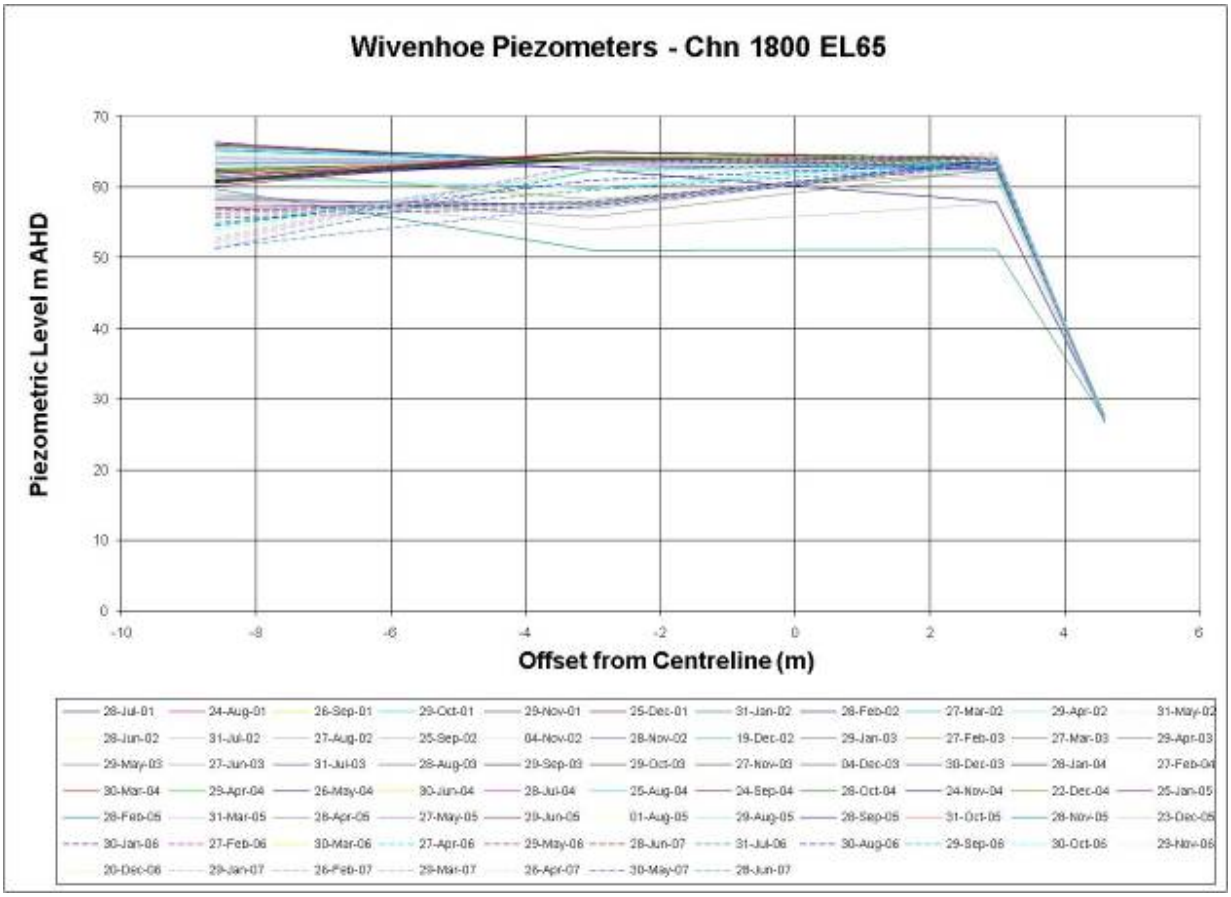
28-Jun-07


Wivenhoe Piezometers - Chn 1800 EL65
Piezometric Level m AHD
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
6
Offset from Centreline (m)
28-Jul-01
24-Aug-01
26-Sep-01
29-Oct-01
29-Nov-01
25-Dec-01
31-Jan-02
28-Feb-02
27-Mar-02
29-Apr-02
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28-Jun-02
31-Jul-02
27-Aug-02
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28-Feb-05
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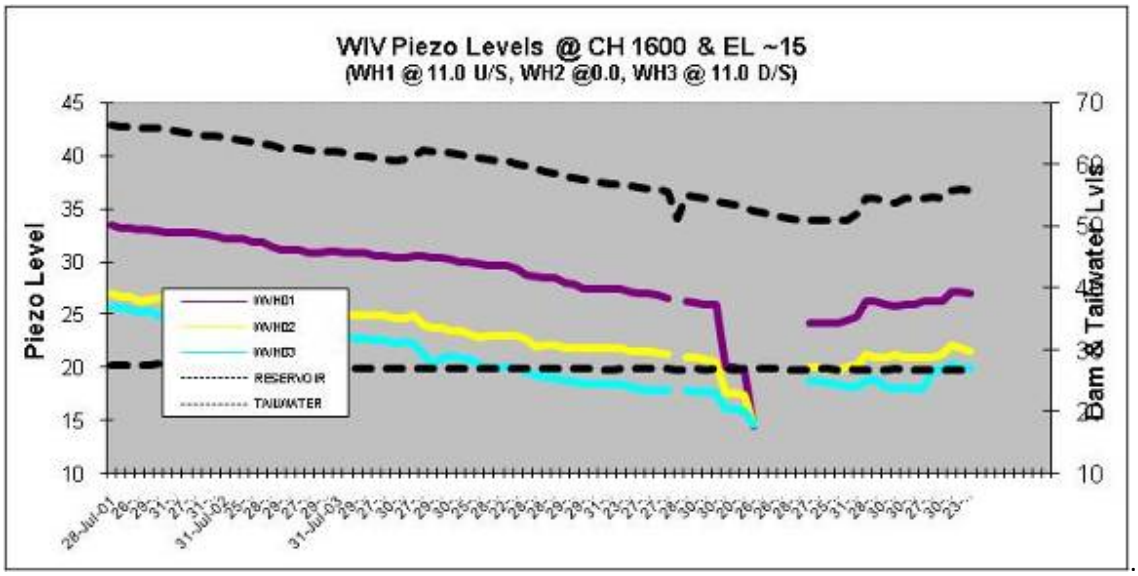
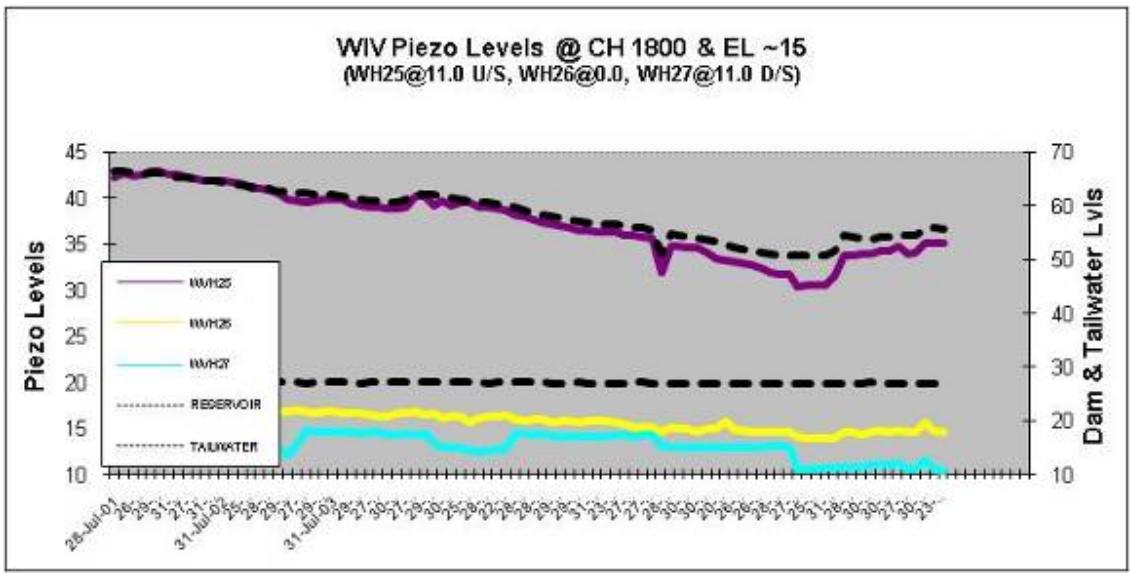
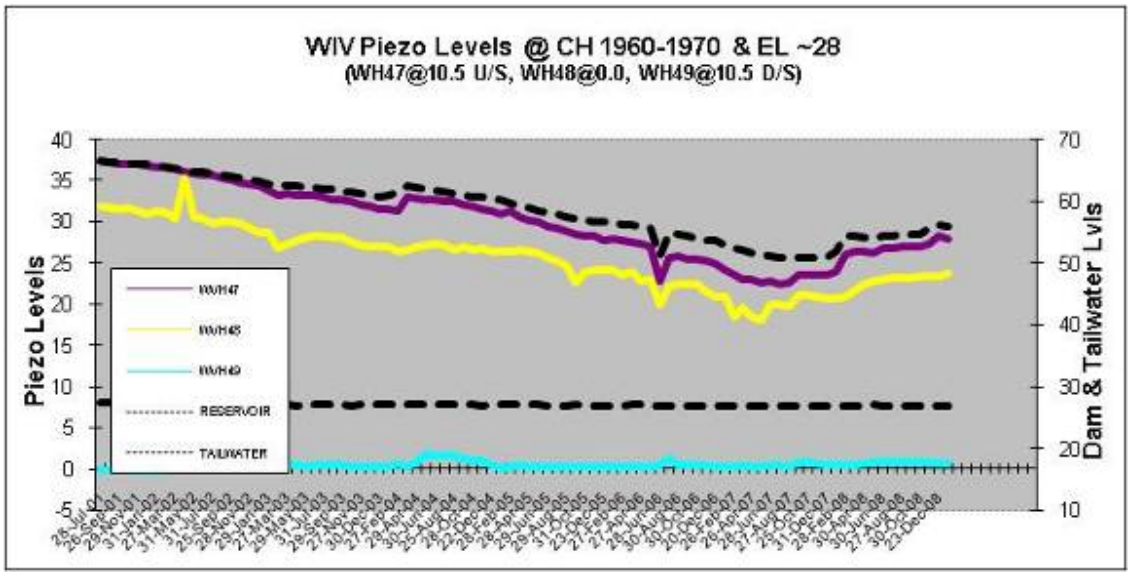
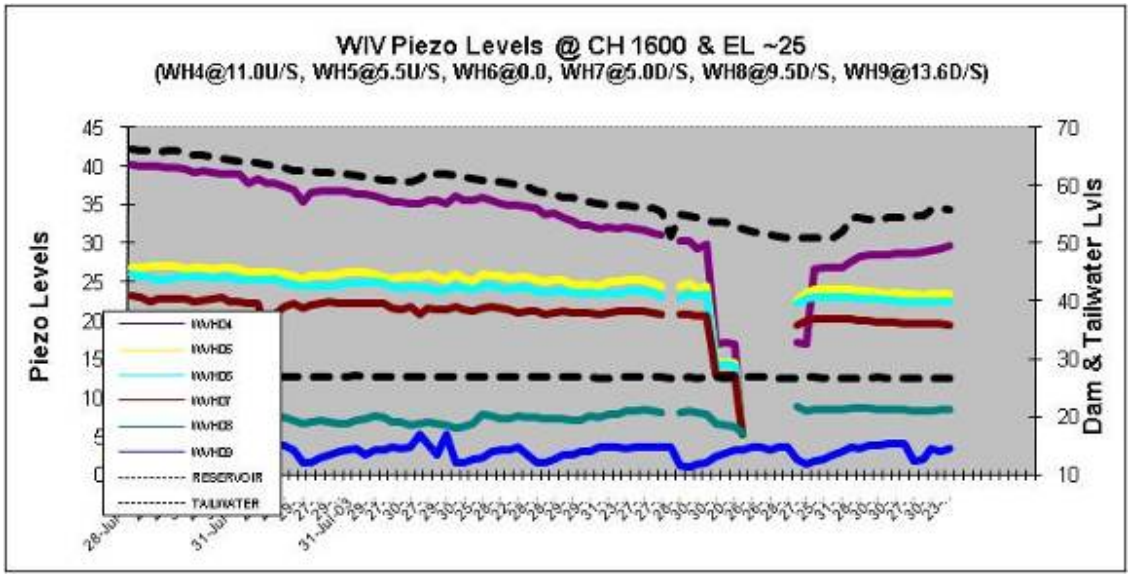
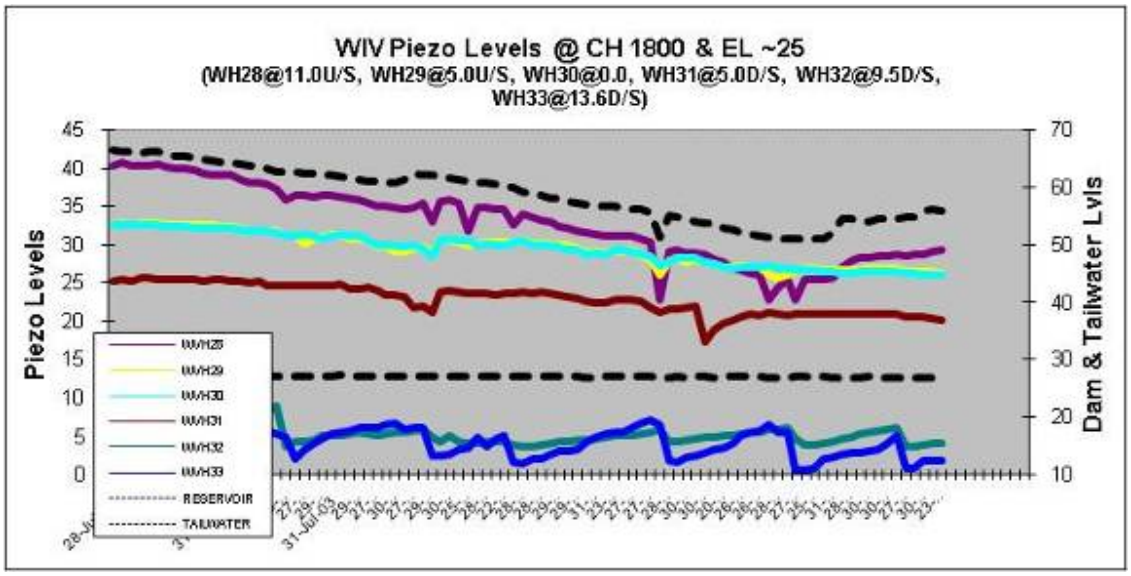
28-Jun-07

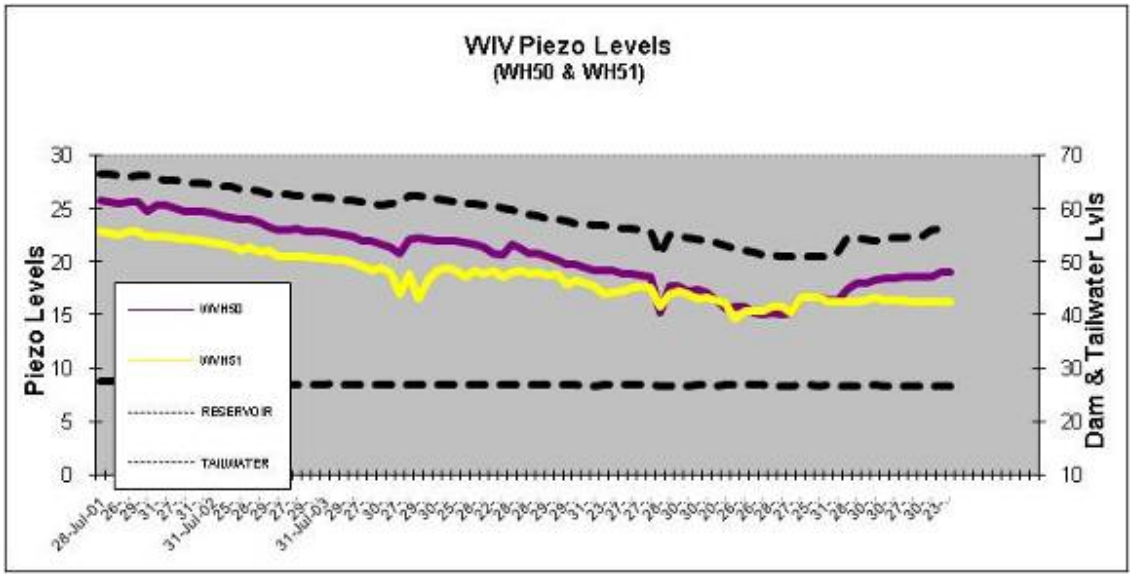

WIV Piezo Levels @ CH 1600 & EL ~15
(WH1 @ 11.0 U/S, WH2 @0.0, WH3 @ 11.0 D/S)
Piezo Level
Dam & Tailwater Lvls
WH01
WH02
WH03
RESERVOIR
TAILWATER

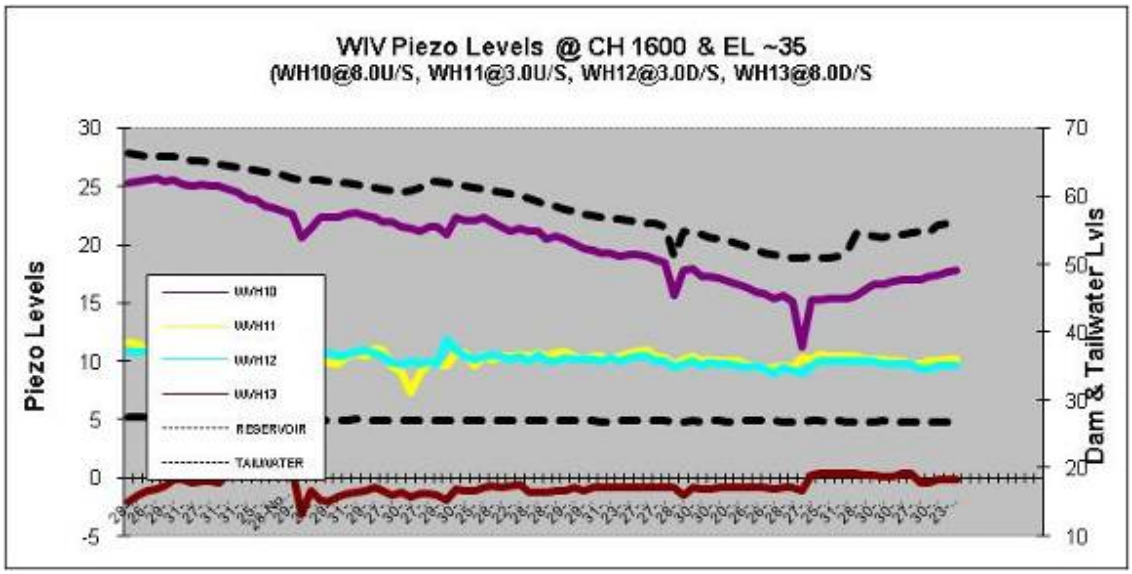

WIV Piezo Levels @ CH 1800 & EL ~15
(WH25@11.0 U/S, WH26@0.0, WH27@11.0 D/S)
Piezo Levels
Dam & Tailwater Lvls
WH25
WH26
WH27
RESERVOIR
TAILWATER

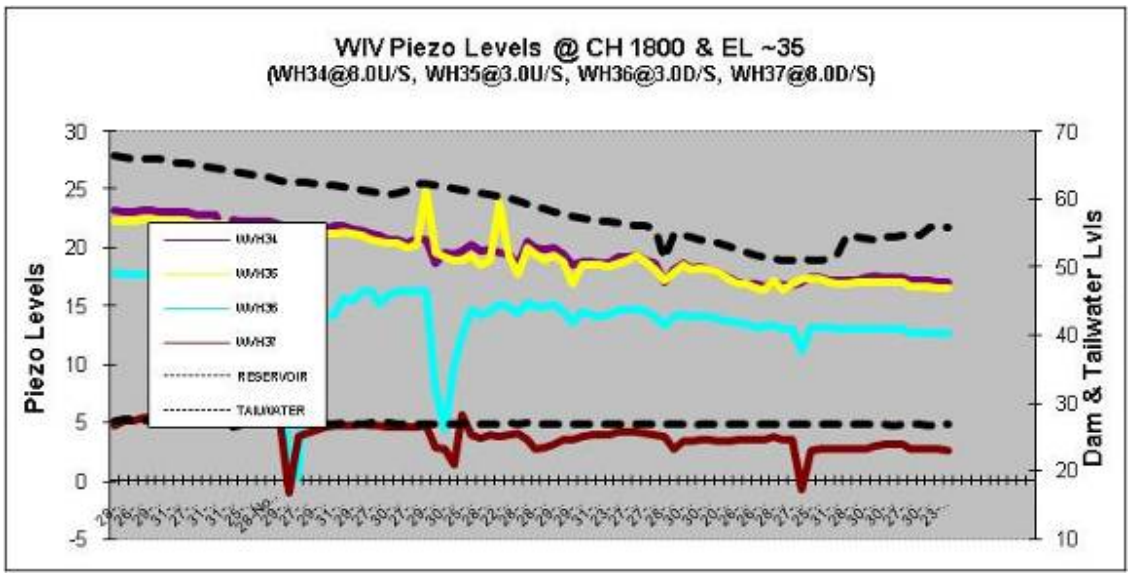

WIV Piezo Levels @ CH 1960-1970 & EL ~28
(WH47@10.5 U/S, WH48@0.0, WH49@10.5 D/S)
Piezo Levels
Dam & Tailwater Lvls
WH47
WH48
WH49
RESERVOIR
TAILWATER

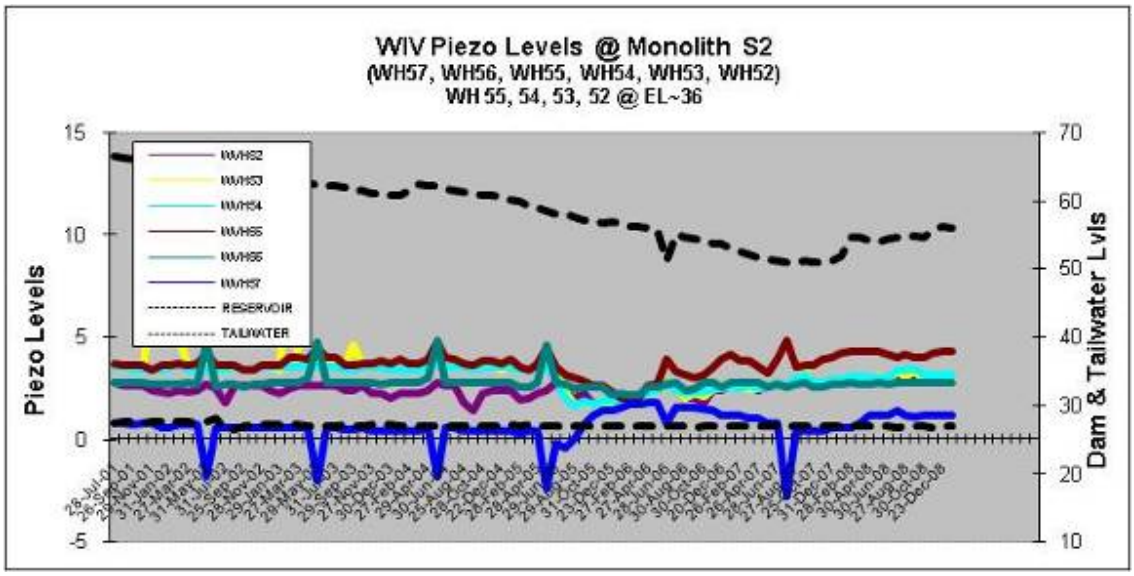

WIV Piezo Levels @ CH 1600 & EL ~25
(WH4@11.0U/S, WH5@5.5U/S, WH6@0.0, WH7@5.0D/S, WH8@9.5D/S, WH9@13.6D/S)
Piezo Levels
Dam & Tailwater Lvls
WH4
WH5
WH6
WH7
WH8
WH9
RESERVOIR
TAILWATER

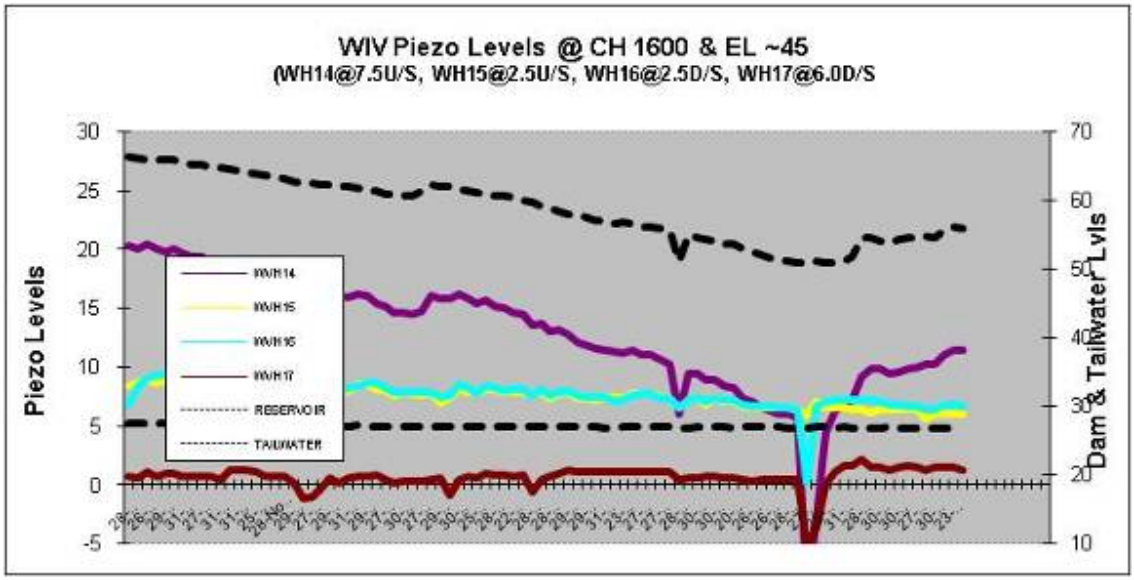

WIV Piezo Levels @ CH 1800 & EL ~25
(WH28@11.0U/S, WH29@5.0U/S, WH30@0.0, WH31@5.0D/S, WH32@9.5D/S,
WH33@13.6D/S)
Piezo Levels
Dam & Tailwater Lvls
WH28
WH29
WH30
WH31
WH32
WH33
RESERVOIR
TAILWATER

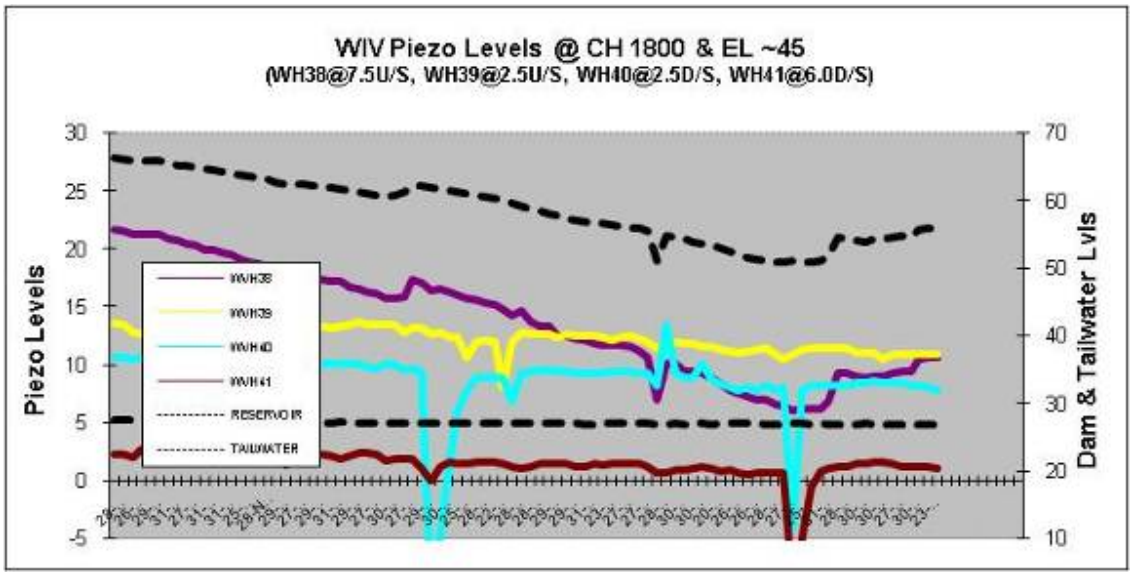

WIV Piezo Levels
(WH50 & WH51)
Piezo Levels
Dam & Tailwater Lvls
WH50
WH51
RESERVOIR
TAILWATER

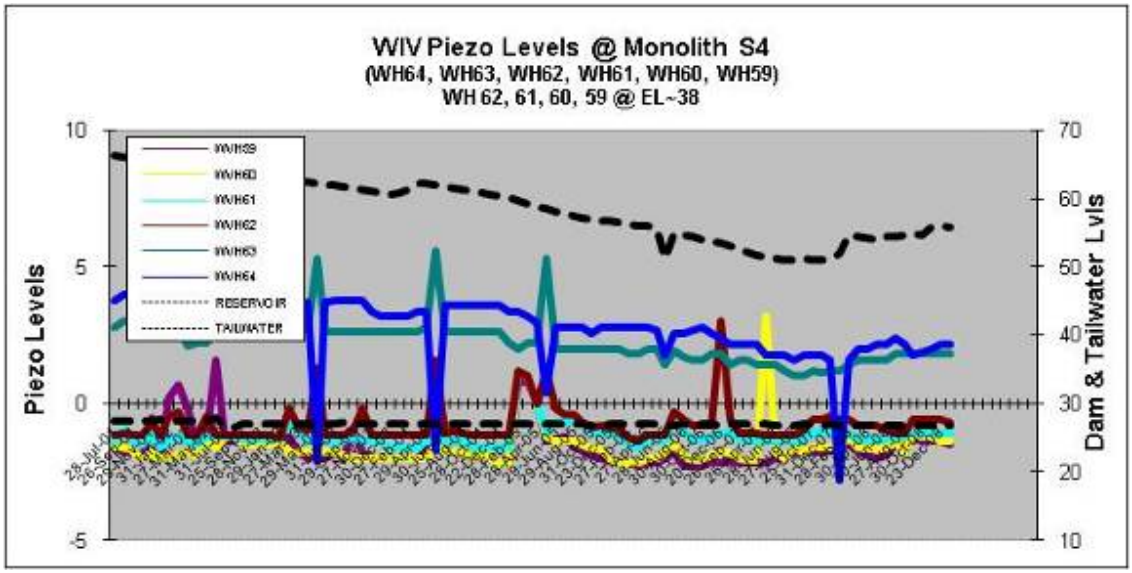

WIV Piezo Levels @ CH 1600 & EL ~35
(WH10@8.0U/S, WH11@3.0U/S, WH12@3.0D/S, WH13@8.0D/S
Piezo Levels
Dam & Tailwater Lvls
WH10
WH11
WH12
WH13
RESERVOIR
TAILWATER

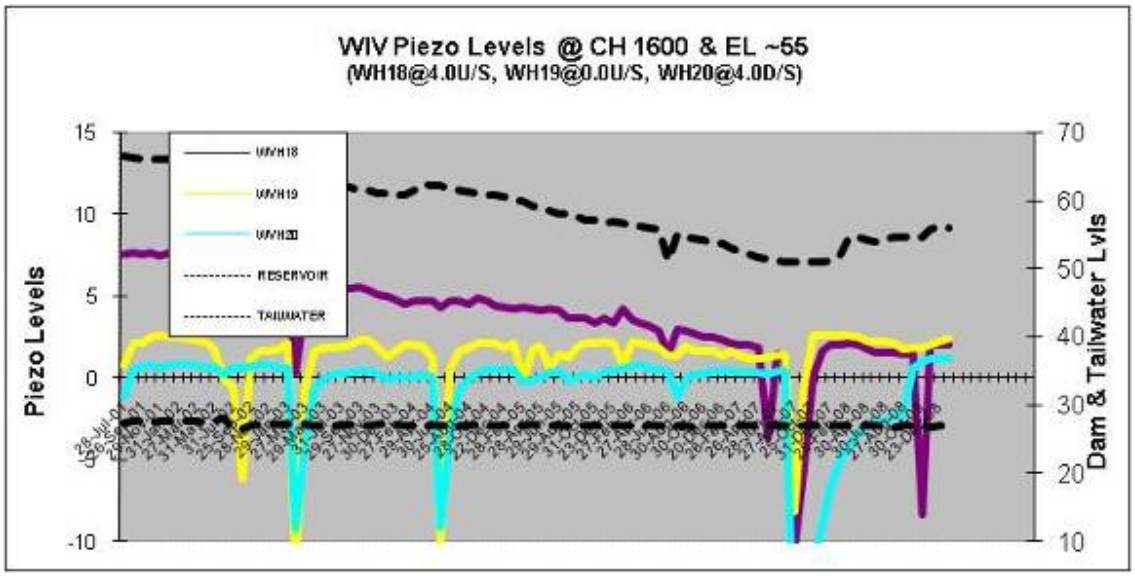

WIV Piezo Levels @ CH 1800 & EL ~35
(WH34@8.0U/S, WH35@3.0U/S, WH36@3.0D/S, WH37@8.0D/S)
Piezo Levels
Dam & Tailwater Lvls
WH34
WH35
WH36
WH37
RESERVOIR
TAILWATER

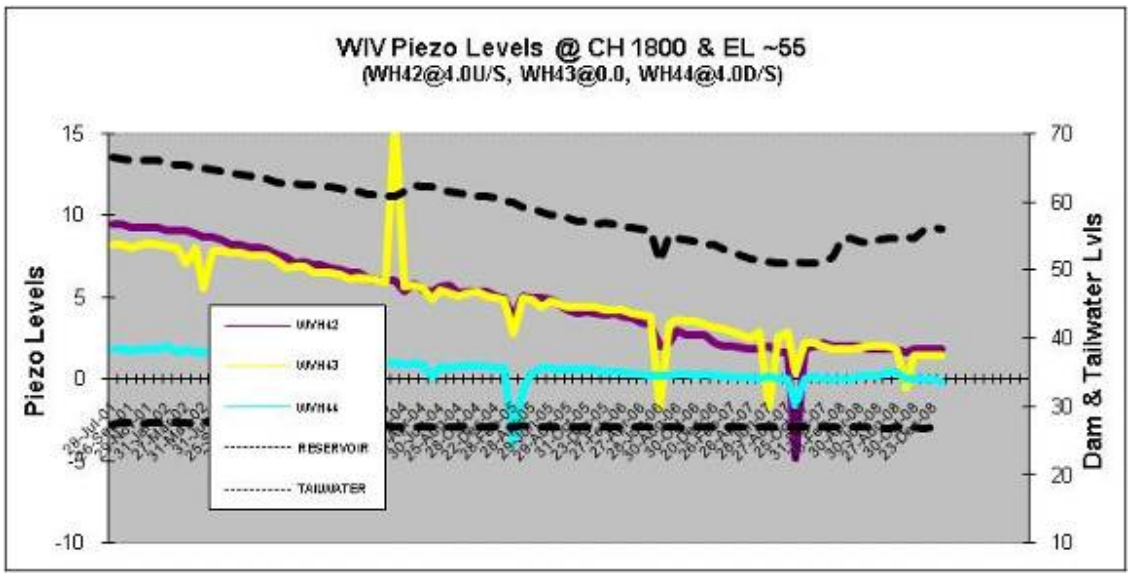

WIV Piezo Levels @ Monolith S2
(WH57, WH56, WH55, WH54, WH53, WH52)
WH 55, 54, 53, 52 @ EL~36
Piezo Levels
Dam & Tailwater Lvls
WH52
WH53
WH54
WH55
WH56
WH57
RESERVOIR
TAILWATER

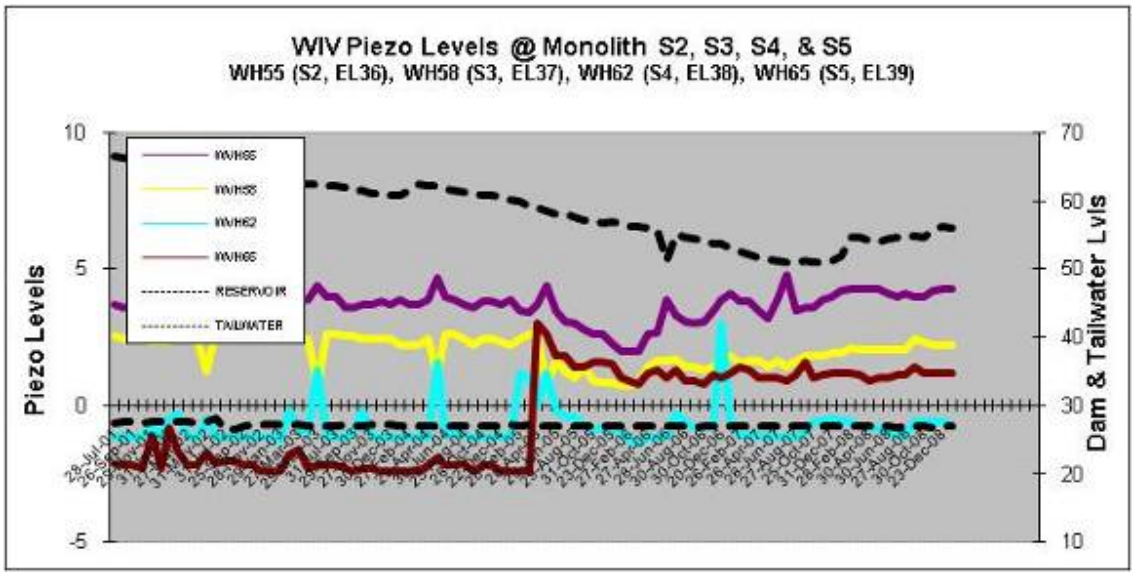

WIV Piezo Levels @ CH 1600 & EL ~45
(WH14@7.5U/S, WH15@2.5U/S, WH16@2.5D/S, WH17@6.0D/S
Piezo Levels
Dam & Tailwater Lvls
WH14
WH15
WH16
WH17
RESERVOIR
TAILWATER

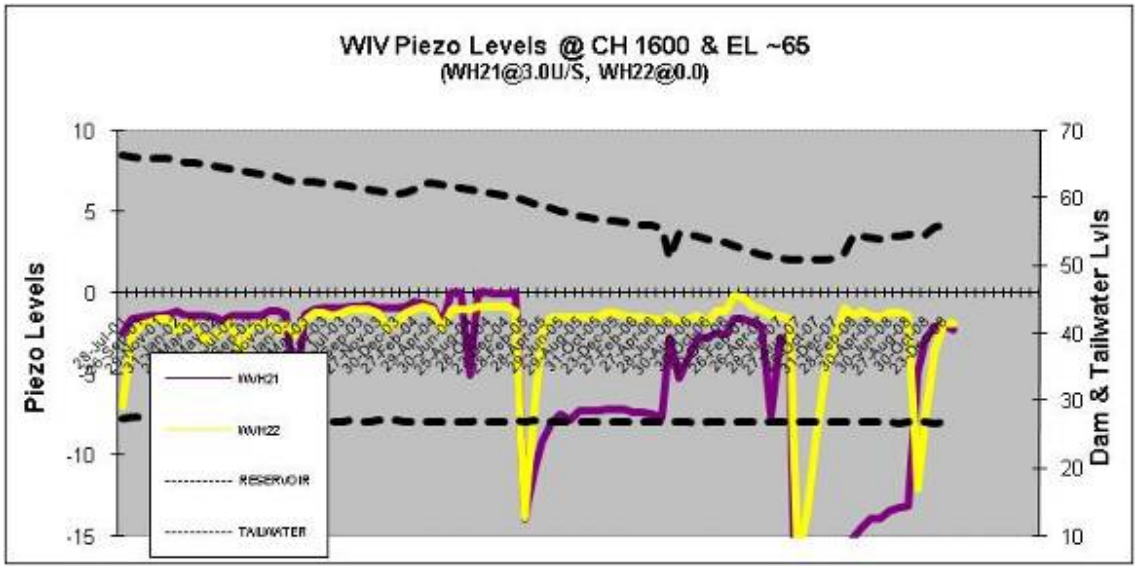

WIV Piezo Levels @ CH 1800 & EL ~45
(WH38@7.5U/S, WH39@2.5U/S, WH40@2.5D/S, WH41@6.0D/S)
Piezo Levels
Dam & Tailwater Lvls
WH38
WH39
WH40
WH41
RESERVOIR
TAILWATER

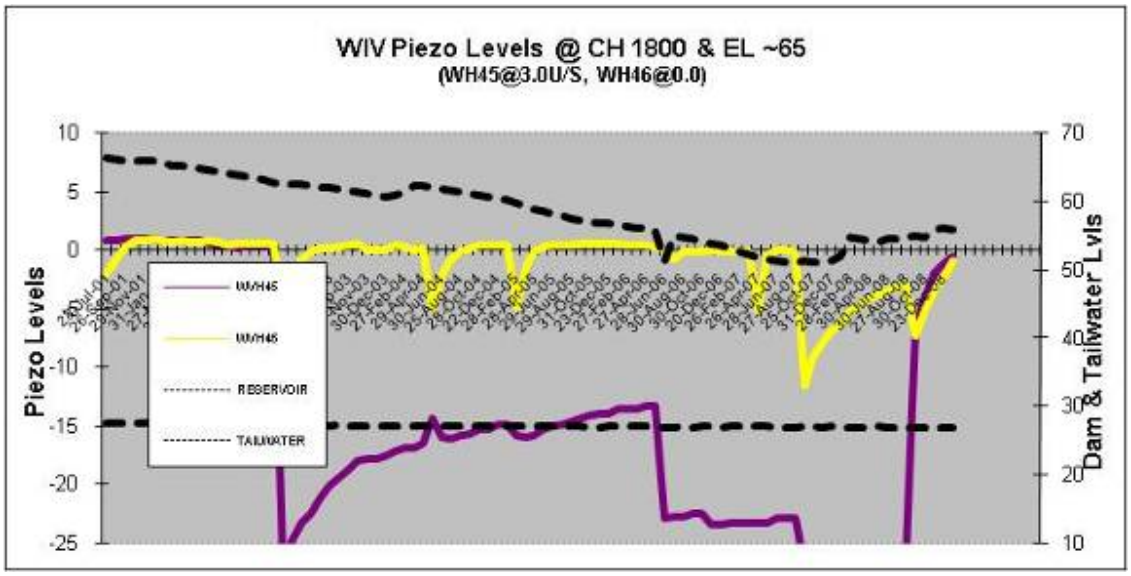

WIV Piezo Levels @ Monolith S4
(WH64, WH63, WH62, WH61, WH60, WH59)
WH 62, 61, 60, 59 @ EL~38
Piezo Levels
Dam & Tailwater Lvls
WH59
WH60
WH61
WH62
WH63
WH64
RESERVOIR
TAILWATER

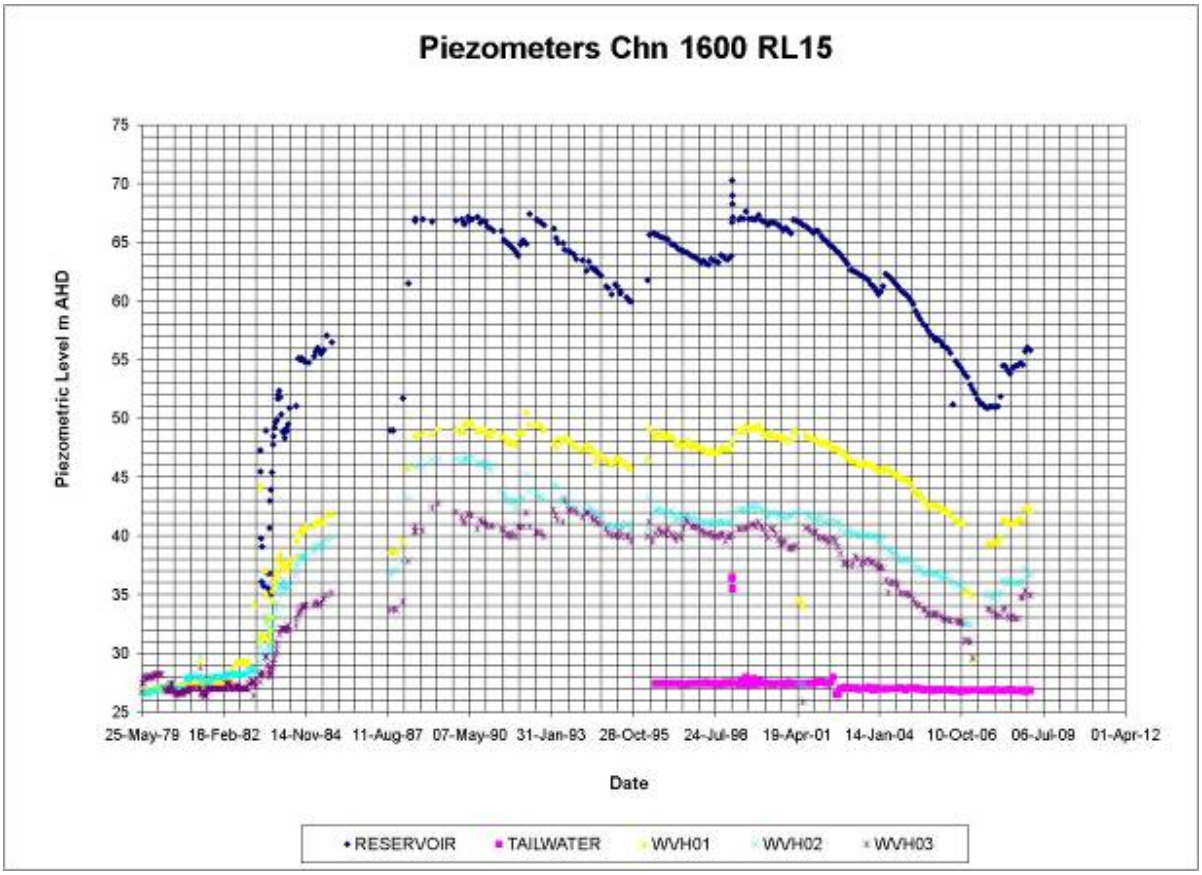

WIV Piezo Levels @ CH 1600 & EL ~55
(WH18@4.0U/S, WH19@0.0U/S, WH20@4.0D/S)
Piezo Levels
Dam & Tailwater Lvls
WH18
WH19
WH20
RESERVOIR
TAILWATER
15
10
5
0
-5
-10
70
60
50
40
30
20
10

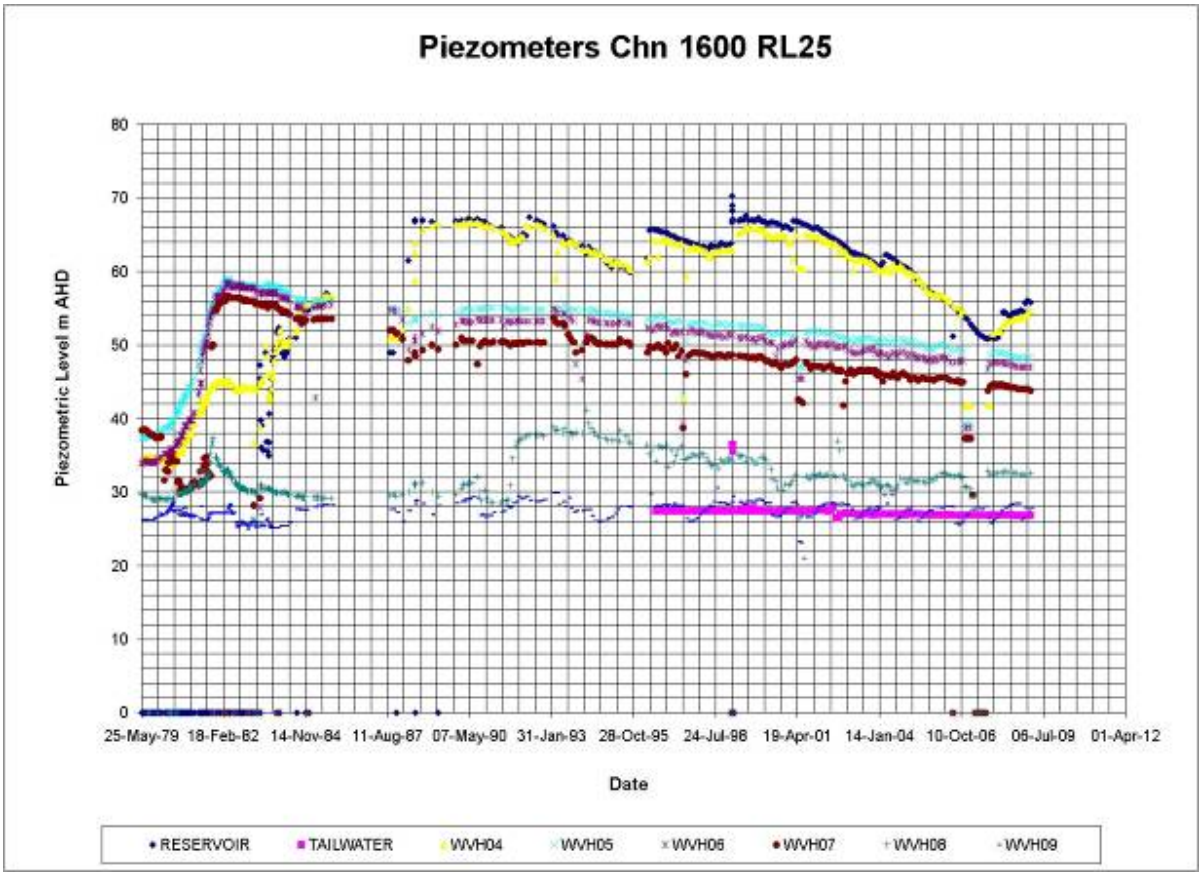

WIV Piezo Levels @ CH 1800 & EL ~55
(WH42@4.0U/S, WH43@0.0, WH44@4.0D/S)
Piezo Levels
Dam & Tailwater Lvls
WH42
WH43
WH44
RESERVOIR
TAILWATER
15
10
5
0
-5
-10
70
60
50
40
30
20
10

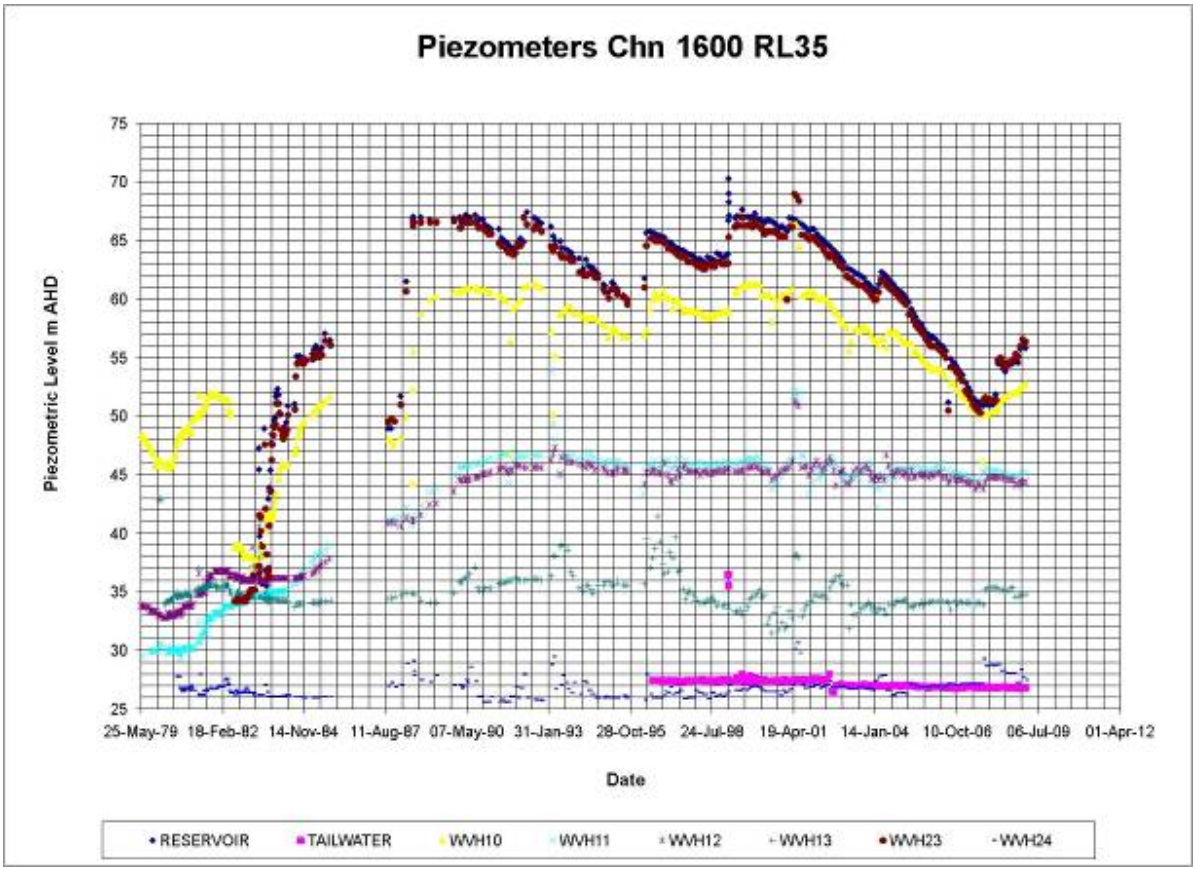

WIV Piezo Levels @ Monolith S2, S3, S4, & S5
WH55 (S2, EL36), WH58 (S3, EL37), WH62 (S4, EL38), WH65 (S5, EL39)
Piezo Levels
Dam & Tailwater Lvls
WH65
WH58
WH62
WH65
RESERVOIR
TAILWATER
10
5
0
-5
70
60
50
40
30
20
10

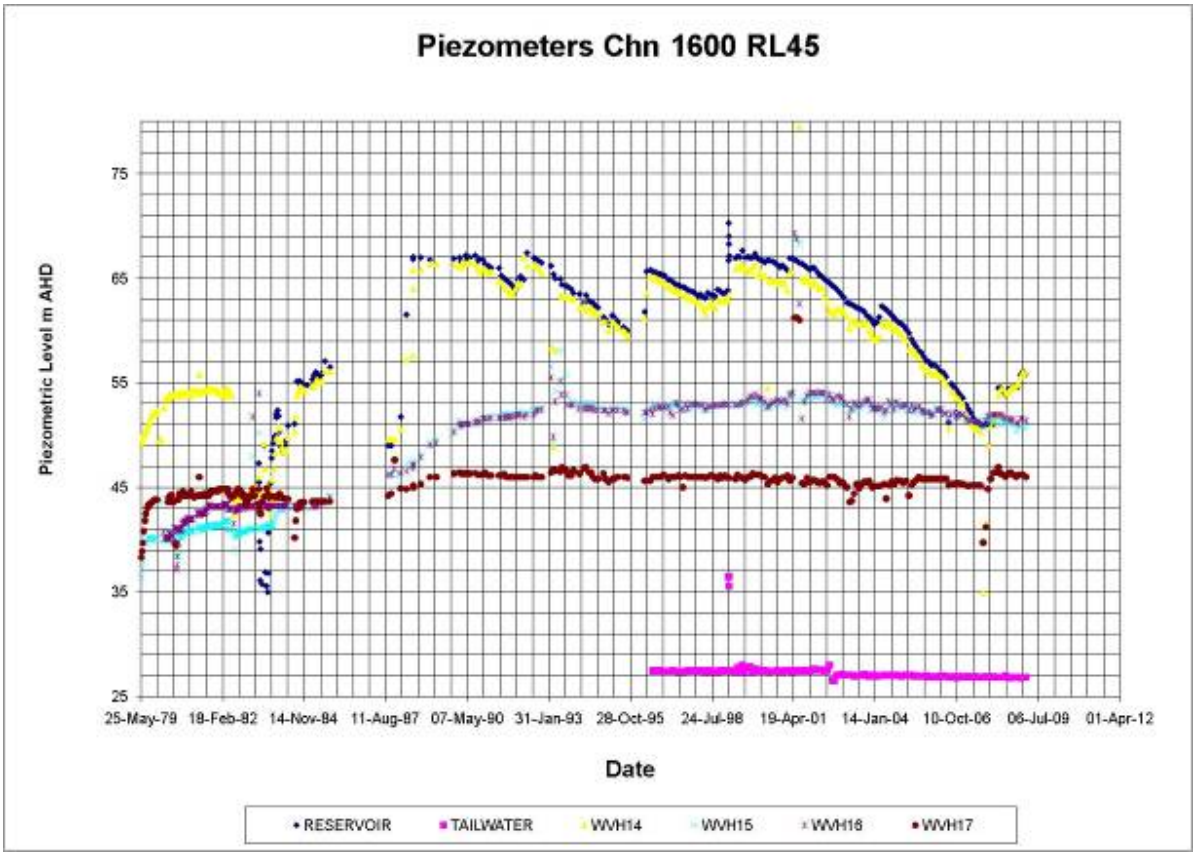

WIV Piezo Levels @ CH 1600 & EL ~65
(WH21@3.0U/S, WH22@0.0)
Piezo Levels
Dam & Tailwater Lvls
WH21
WH22
RESERVOIR
TAILWATER
10
5
0
-10
-15
70
60
50
40
30
20
10

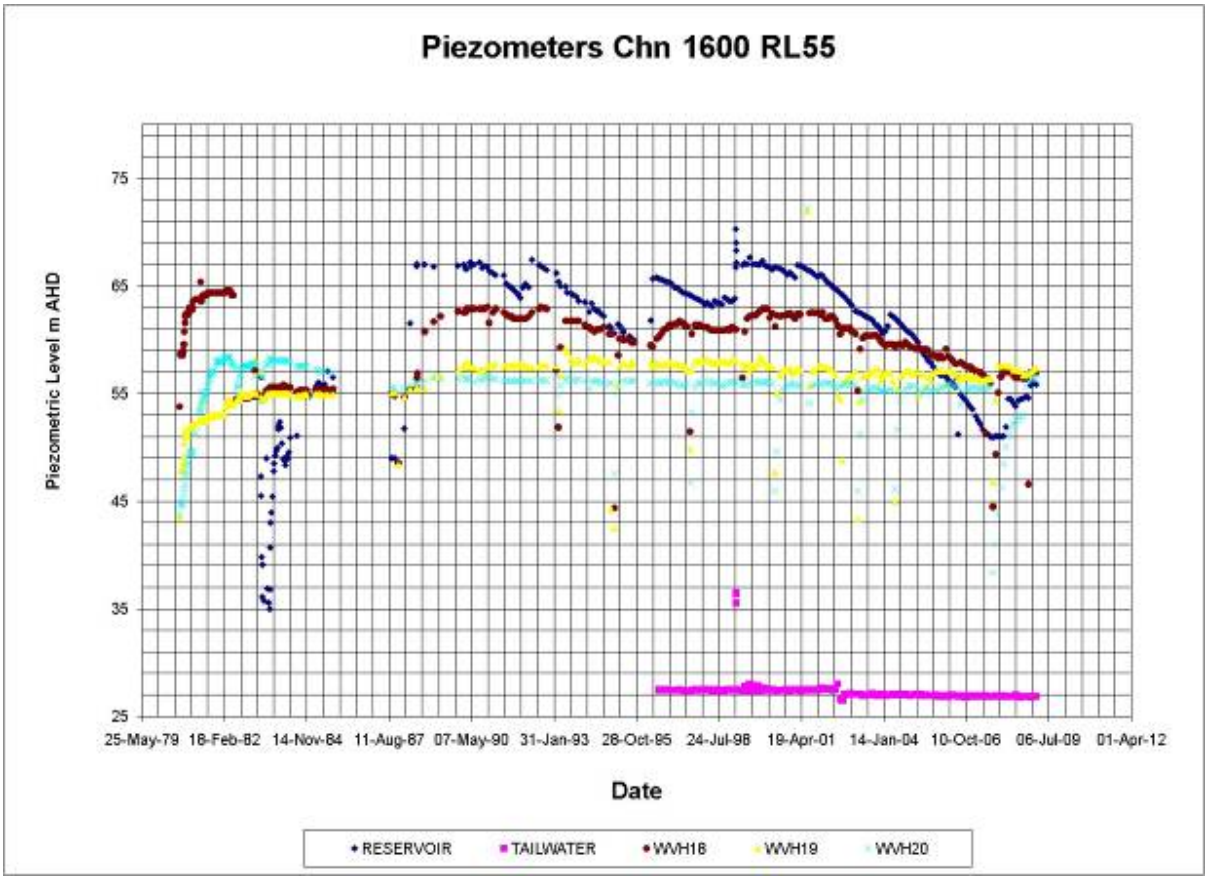

W/V Piezo Levels @ CH 1800 & EL ~65
(WH45@3.0U/S, WH46@0.0)
Piezo Levels
Dam & Tailwater Lvls
W/H45
W/H46
RESERVOIR
TAILWATER
10
5
0
-10
-15
-20
-25
70
60
50
40
30
20
10

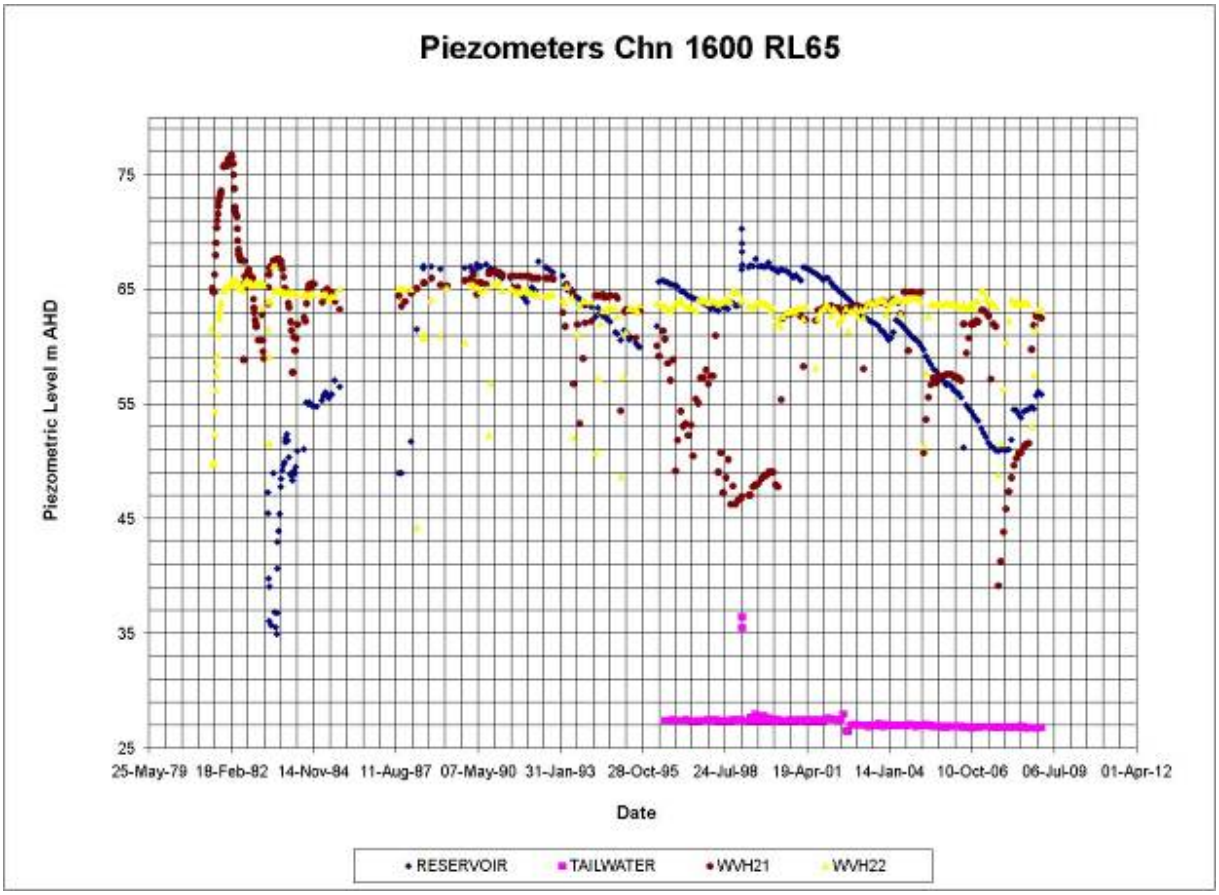

Piezometers Chn 1600 RL15
Piezometric Level m AHD
75
70
65
60
55
50
45
40
35
30
25
25-May-79
16-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH01
WVH02
WVH03

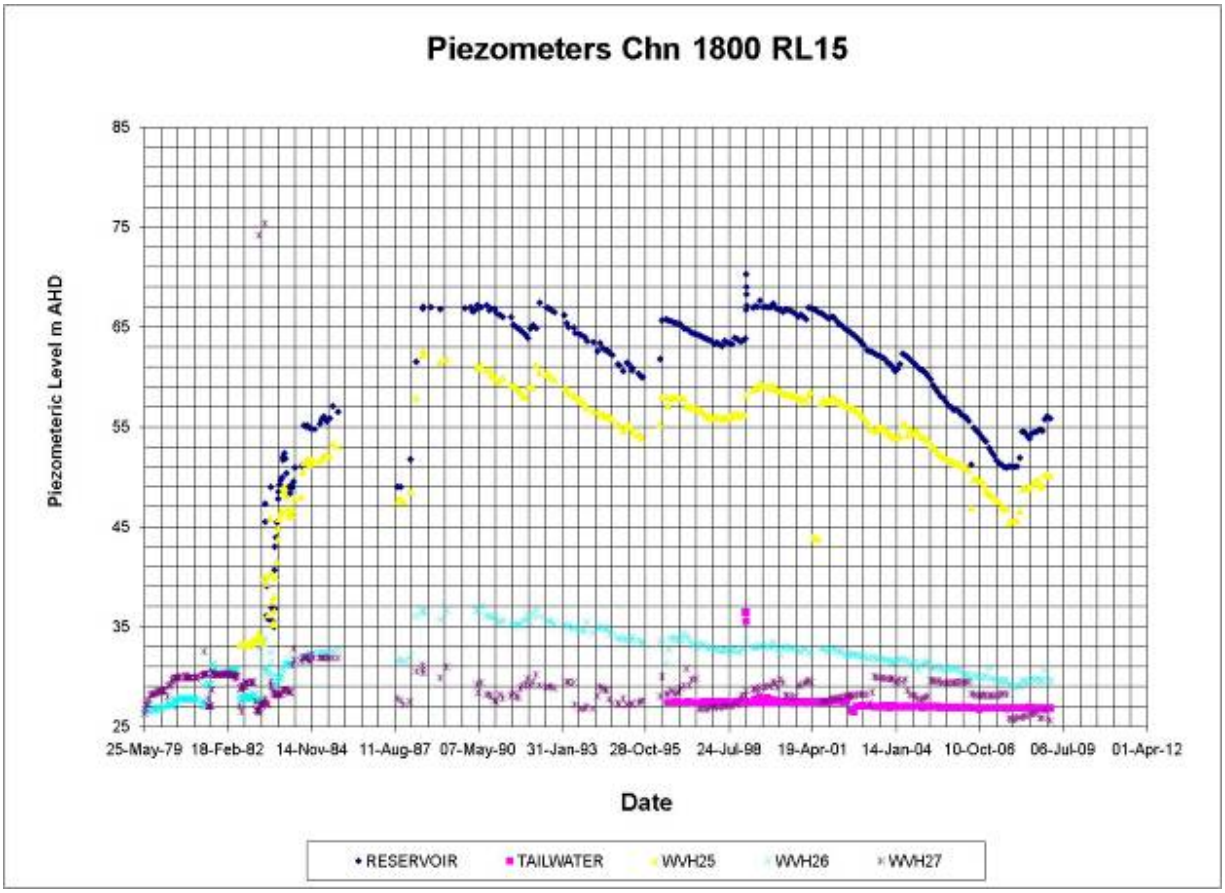

Piezometers Chn 1600 RL25
Piezometric Level m AHD
80
70
60
50
40
30
20
10
0
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH04
WVH05
WVH06
WVH07
WVH08
WVH09

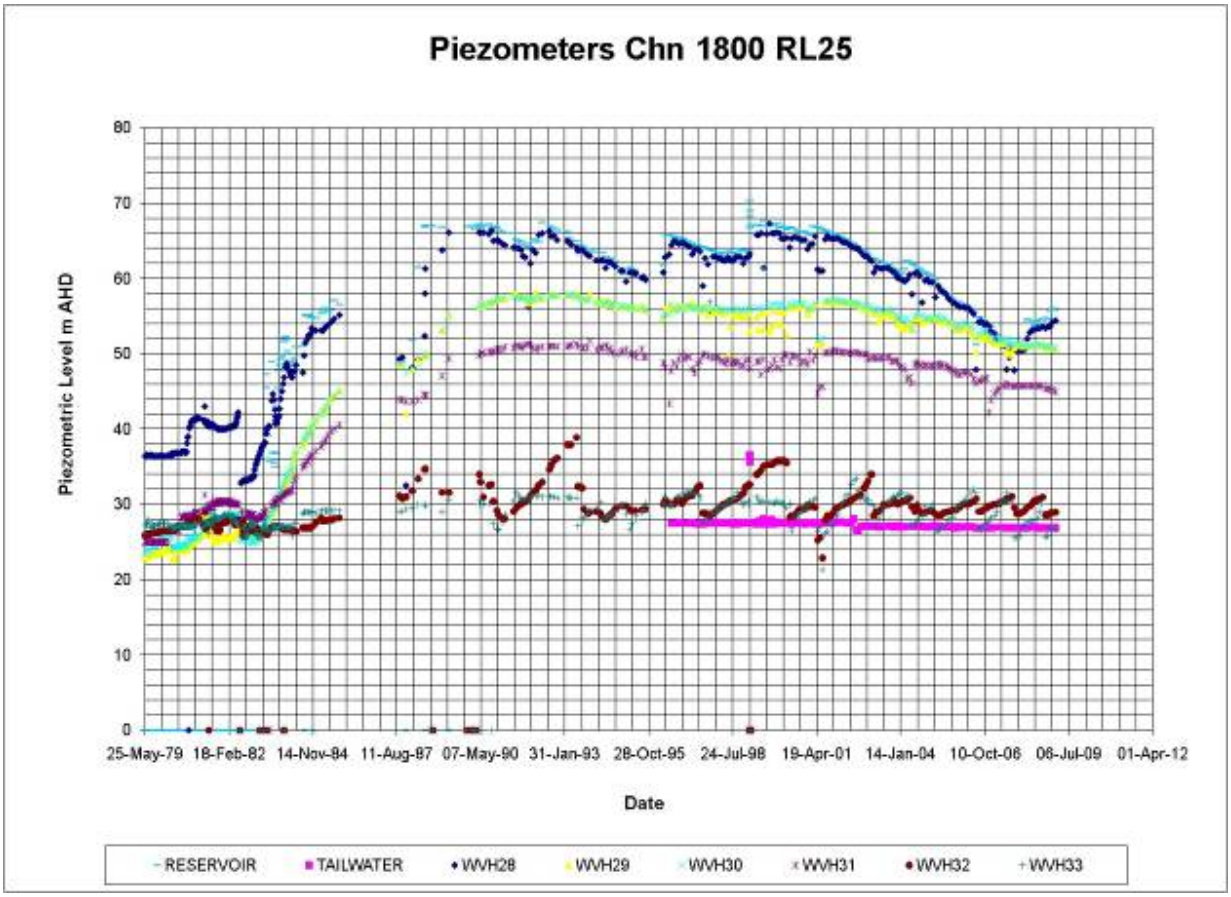

Piezometers Chn 1600 RL35
Piezometric Level m AHD
75
70
65
60
55
50
45
40
35
30
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH10
WVH11
WVH12
WVH13
WVH23
WVH24

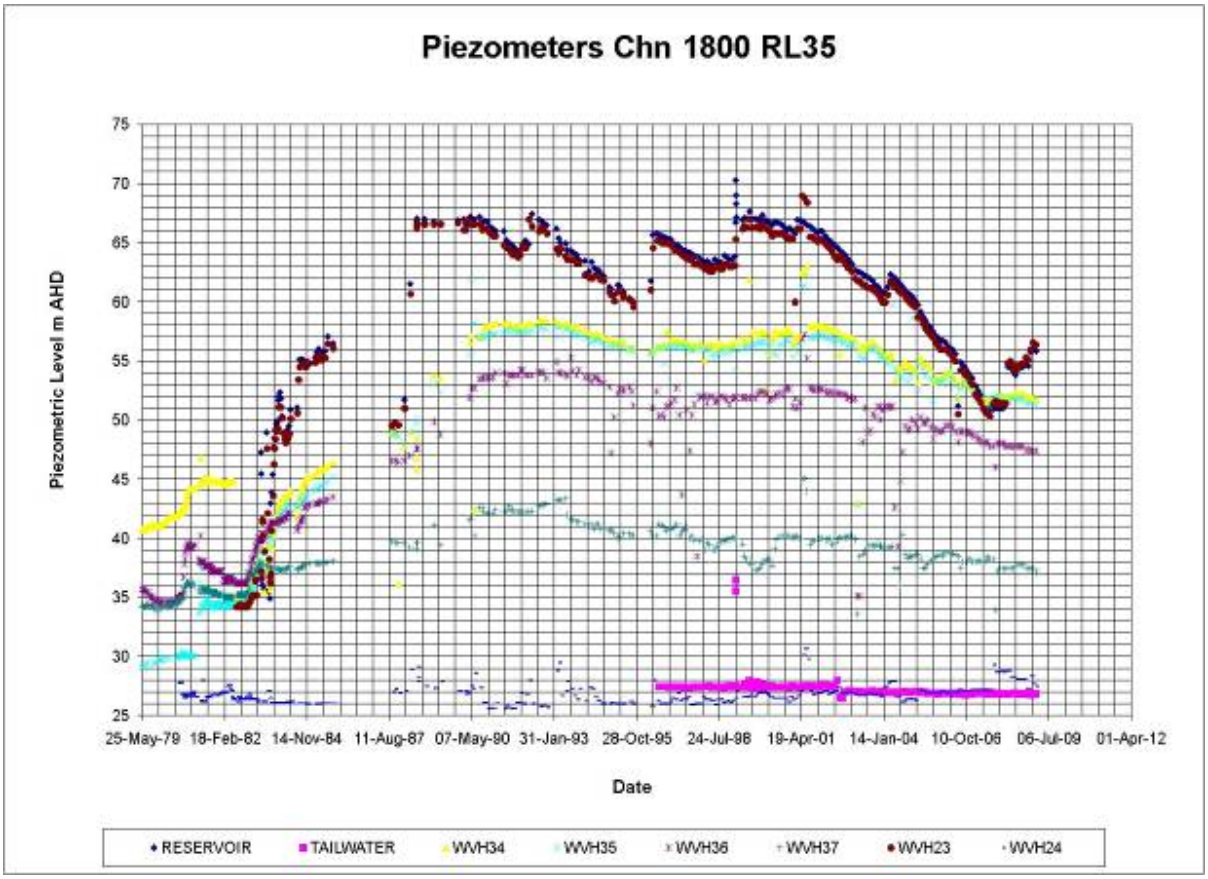

Piezometers Chn 1600 RL45
Piezometric Level m AHD
75
65
55
45
35
25
25-May-79
19-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH14
WVH15
WVH16
WVH17

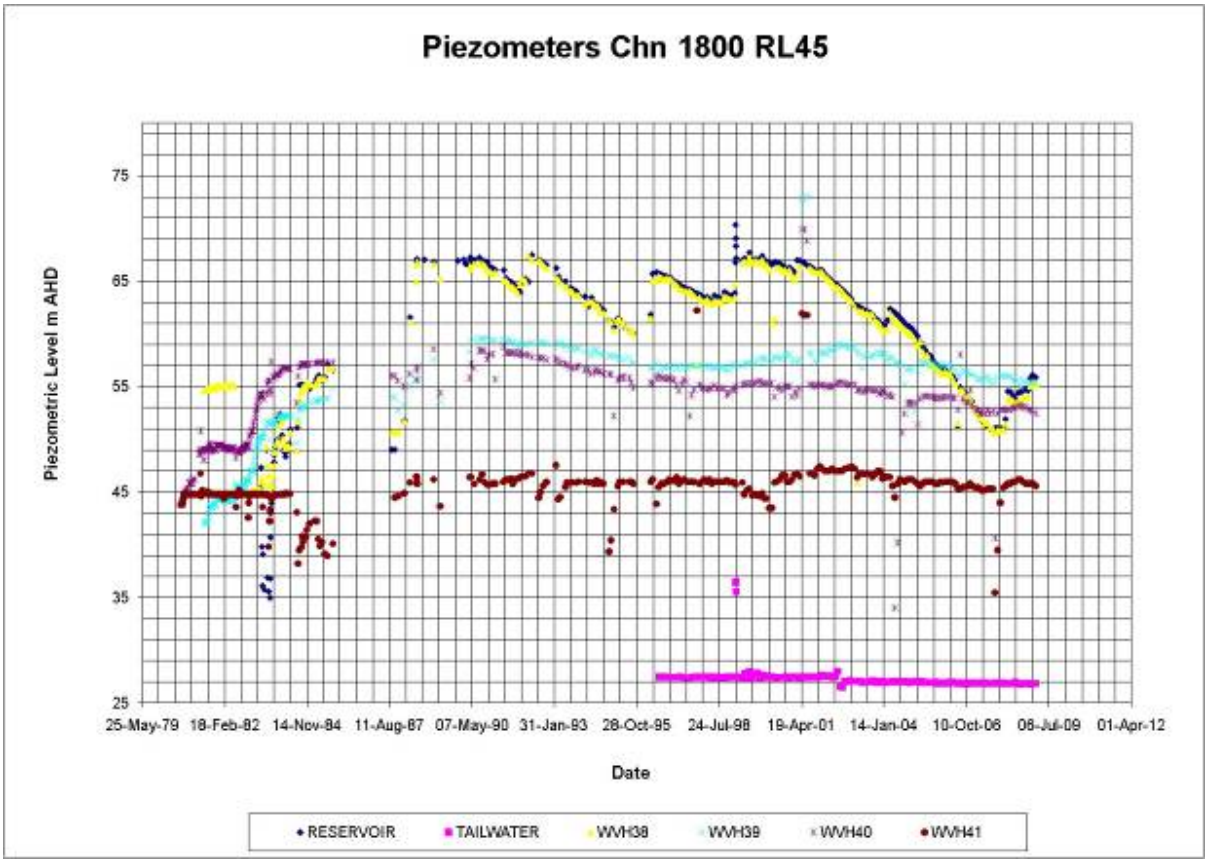

Piezometers Chn 1600 RL55
Piezometric Level m AHD
75
65
55
45
35
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH18
WVH19
WVH20

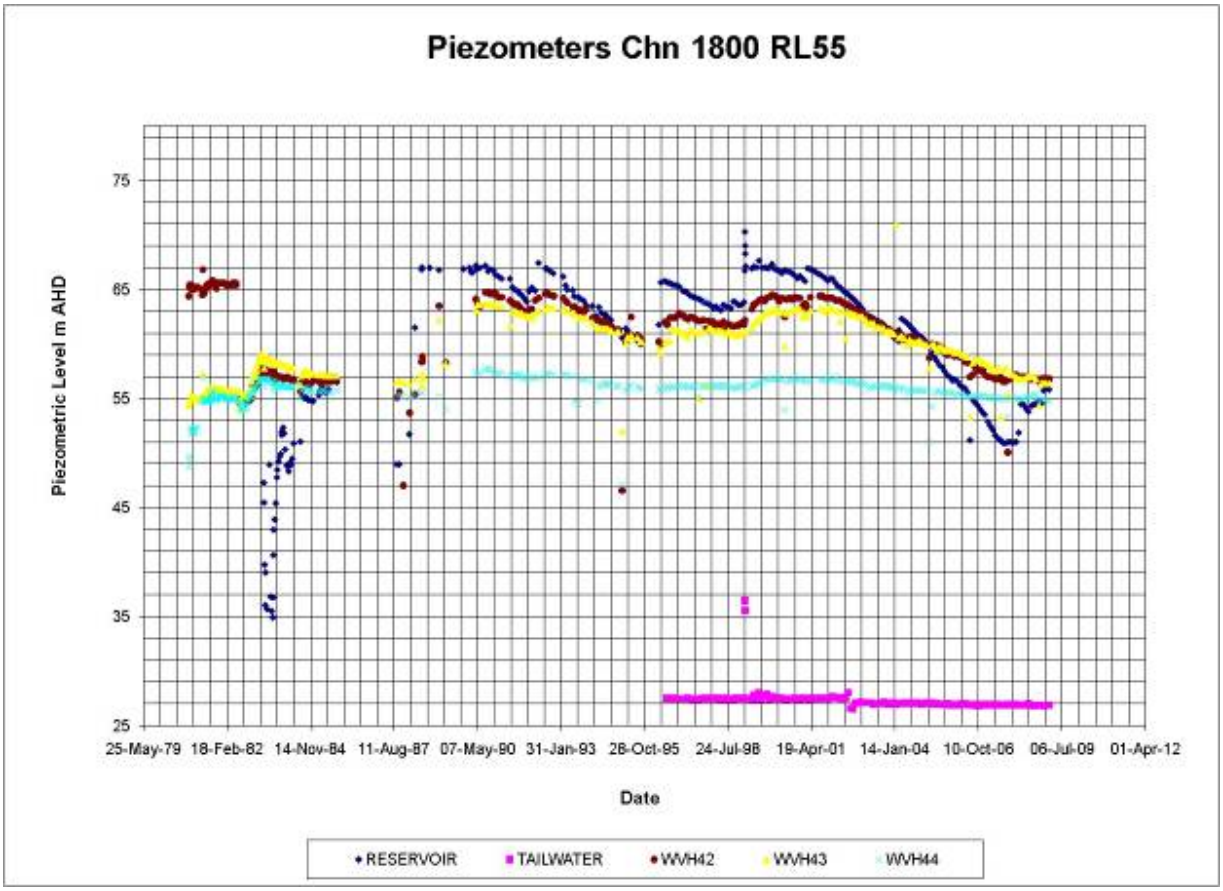

Piezometers Chn 1600 RL65
Piezometric Level m AHD
75
65
55
45
35
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH21
WVH22

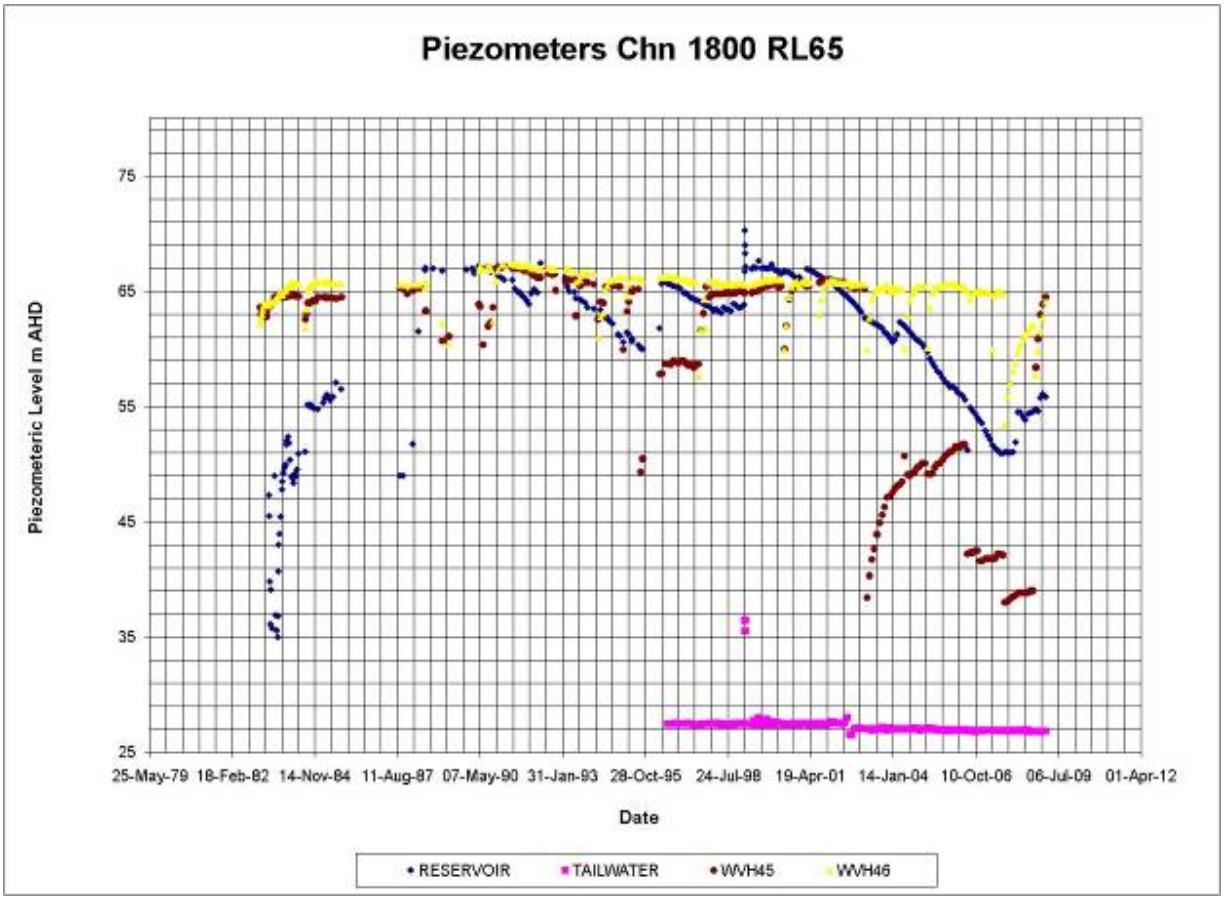

Piezometers Chn 1800 RL15
Piezometeric Level m AHD
85
75
65
55
45
35
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH25
WVH26
WVH27

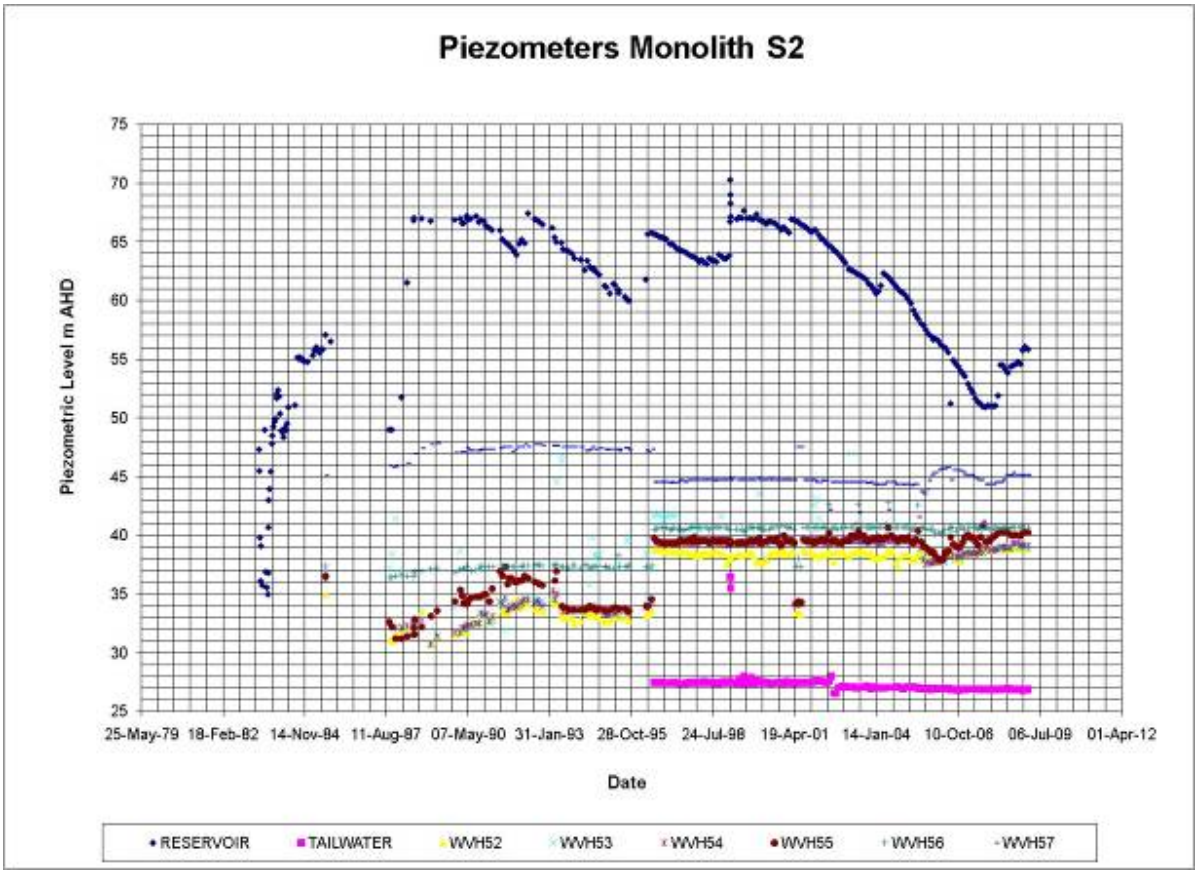

Piezometers Chn 1800 RL25
Piezometric Level m AHD
80
70
60
50
40
30
20
10
0
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH28
WVH29
WVH30
WVH31
WVH32
WVH33

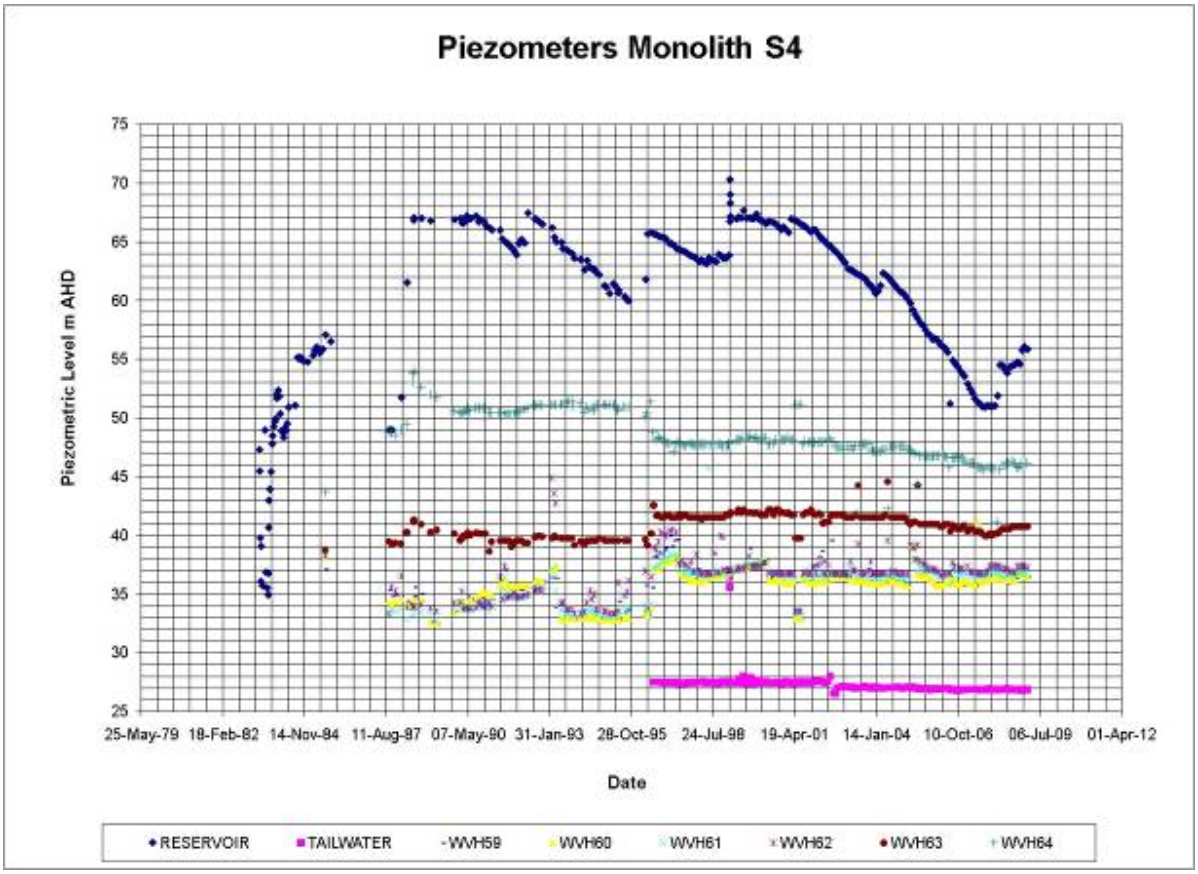

Piezometers Chn 1800 RL35
Piezometric Level m AHD
75
70
65
60
55
50
45
40
35
30
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH34
WVH35
WVH36
WVH37
WVH23
WVH24

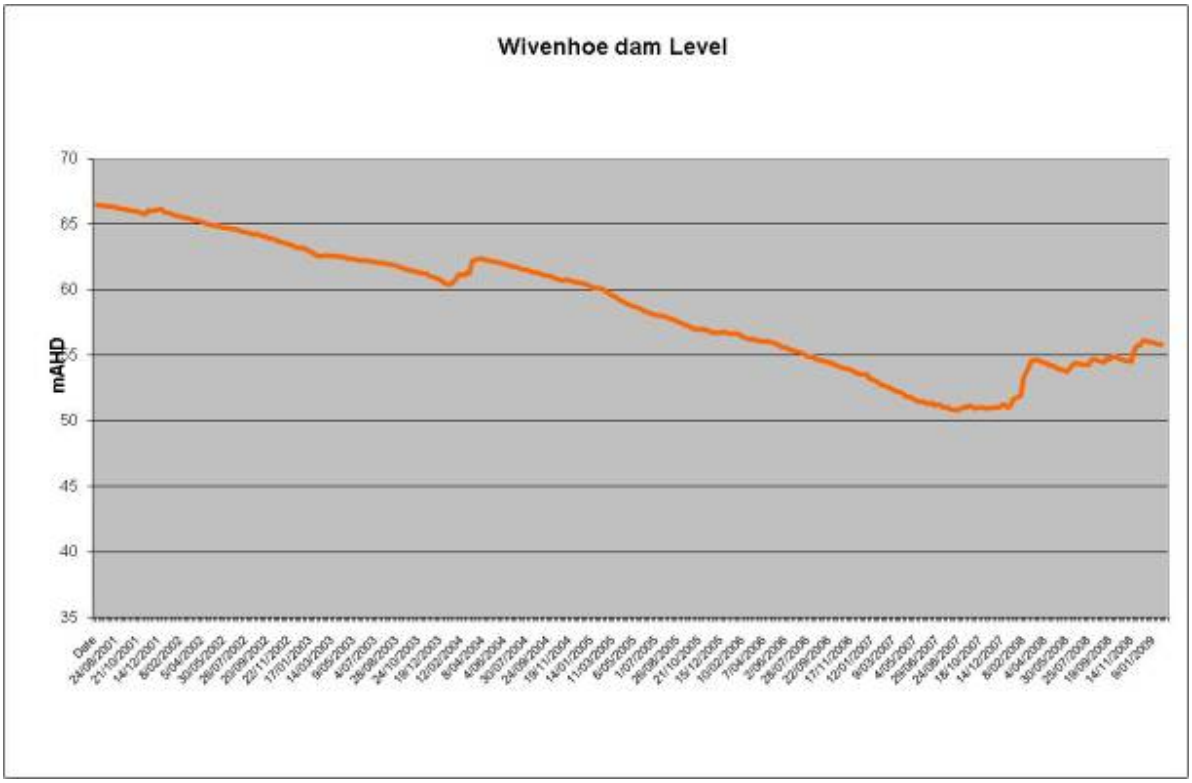

Piezometers Chn 1800 RL45
Piezometric Level m AHD
75
65
55
45
35
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
08-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH38
WVH39
WVH40
WVH41

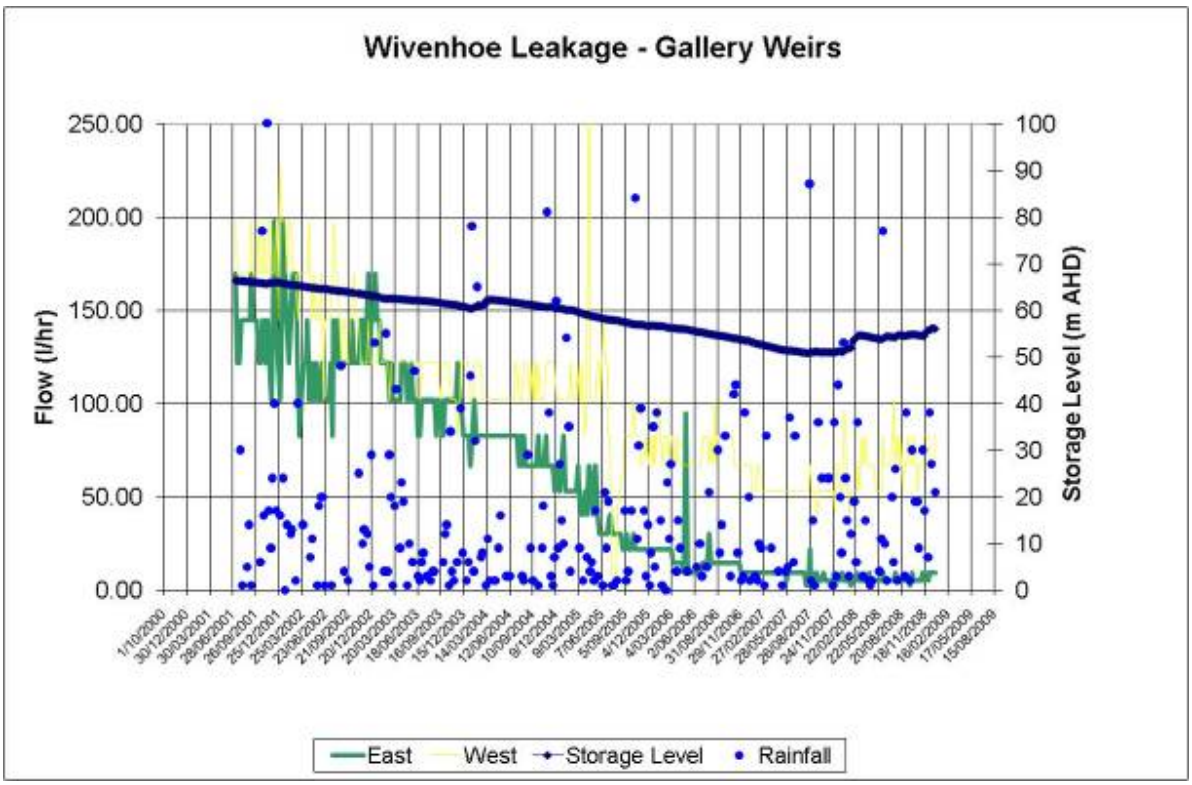

Piezometers Chn 1800 RL55
Piezometric Level m AHD
75
65
55
45
35
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH42
WVH43
WVH44

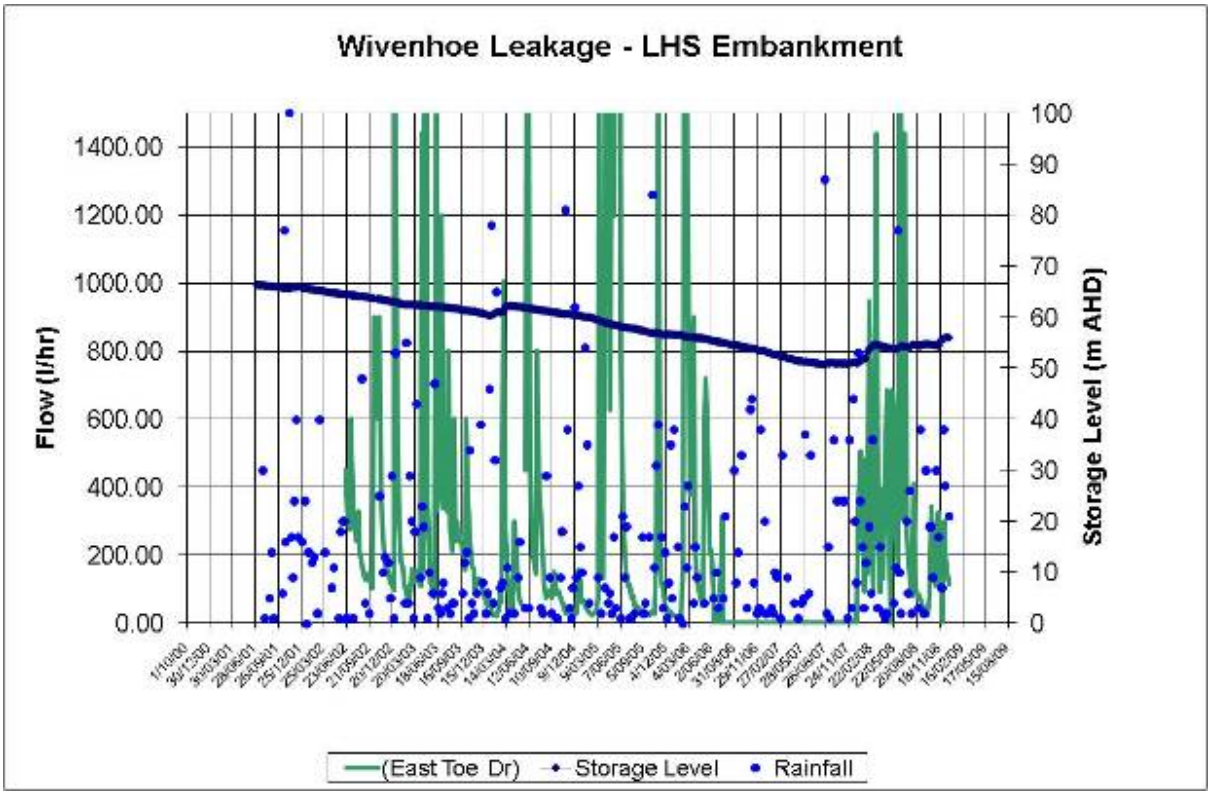

Piezometers Chn 1800 RL65
Piezometeric Level m AHD
75
65
55
45
35
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH45
WVH46

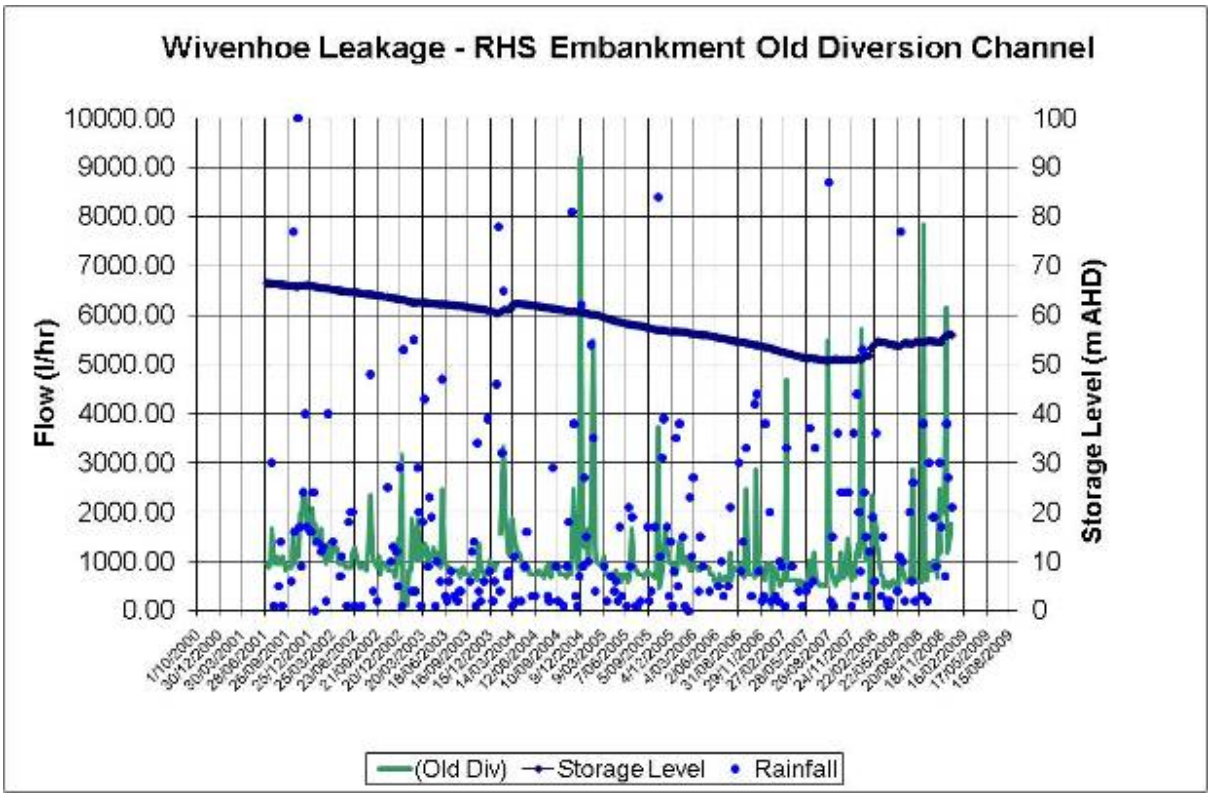

Piezometers Monolith S2
Piezometric Level m AHD
75
70
65
60
55
50
45
40
35
30
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH52
WVH53
WVH54
WVH55
WVH56
WVH57


Piezometers Monolith S4
Piezometric Level m AHD
75
70
65
60
55
50
45
40
35
30
25
25-May-79
18-Feb-82
14-Nov-84
11-Aug-87
07-May-90
31-Jan-93
28-Oct-95
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
Date
RESERVOIR
TAILWATER
WVH59
WVH60
WVH61
WVH62
WVH63
WVH64


Wivenhoe dam Level
mAHD
70
65
60
55
50
45
40
35
Date


Wivenhoe Leakage - Gallery Weirs
Flow (l/hr)
250.00
200.00
150.00
100.00
50.00
0.00
Storage Level (m AHD)
100
90
80
70
60
50
40
30
20
10
0
East
West
Storage Level
Rainfall


Wivenhoe Leakage - LHS Embankment
Flow (l/hr)
Storage Level (m AHD)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
100
90
80
70
60
50
40
30
20
10
0
(East Toe Dr)
Storage Level
Rainfall


Wivenhoe Leakage - RHS Embankment Old Diversion Channel
Flow (l/hr)
Storage Level (m AHD)
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
100
90
80
70
60
50
40
30
20
10
0
(Old Div)
Storage Level
Rainfall