

# Twenty-Five Years' Experience Operating a HDPE Lined Twin Pond Ashing System

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## ABSTRACT

The Yallourn North Twin Ash Ponds (TAP) are twin high density polyethylene (HDPE) lined ash ponds constructed in 1987 on the ash delta of an existing decommissioned ash pond to manage the ash from Energy Australia's 1500MW Yallourn brown coal power station. The ponds each store approximately 6 months brown coal ash. They are alternately filled with ash, drained then the ash removed by excavator and truck for stacking in a mined out area of the open cut. The decant water from the operating pond is discharged to a return water storage where it is pumped back to the power station for re-use in the ashing system.

One of the more critical issues related to the pond operation is the cuts and tears from the ash excavation leading to elevated ground water levels beneath the liner. Excavation pre-planning, GPS control and routine inspections have been effective in reducing damage to the liner. However existing damage has resulted in elevated ground water pressure against the liner on the batters and floor of the ponds. Interim solutions to maintain batter stability have been implemented but in the long term it is proposed to install a dewatering system behind the liner.

Forecast settlements of the ash foundation material of up to 1500mm, primarily during construction, have generally been accommodated and a settlement monitoring system is in place to monitor ongoing settlement of the embankment and structures.

The HDPE lined TAP have been subject to a harsh environment of continuous deposition and excavation cycles for over 25 years. Although they have been subject to significant settlements and are prone to cuts and tears during ash excavation they have continued to provide uninterrupted ash containment over that period, and the current plans are to continue operation of the TAP system until 2032.

## 1 INTRODUCTION

The Yallourn North TAP receive the ash residue from Energy Australia's 1500MW Yallourn Power Station in the Latrobe Valley, Victoria, Australia. The power station produces approximately 300,000m<sup>3</sup> (260,000 tonnes) of hearth and precipitator ash

(bottom and fly ash) per year at a solids content of approximately 2-3%. The HDPE lined pond system was commissioned in 1987 and is still operating today with plans being prepared to extend the life of the ashing system, including the TAP until 2032. The ponds were constructed on an existing ash delta and have undergone significant settlement as well as wear and tear due to their regular filling and excavation cycle. This paper describes the twin ash pond system, its operation and performance over that time.

## 2 BACKGROUND

The TAP site is located in the Yallourn North Open Cut (YNOC), which was mined for brown coal between 1919 and 1963. Figures 1 and 2 show the site location and key features of the system. Rehabilitation of the open cut, including slope stabilisation and plant removal, commenced in the late 1950's and was largely complete by the cessation of mining. Through the 1960's and 1970's the floor of the northern area of the YNOC (initially the Western and Central Basins and later the larger Eastern Basin) was utilised as a recirculating hydraulic ashing system for the Yallourn E Power Station (240MW, decommissioned 1989) and the Yallourn W Power Station (1500MW).



Figure 1 - Location Plan – Victoria, Australia



**Figure 2 – Locality Plan of Twin Ash Ponds**

A seepage study in 1983 concluded that the operating water level of the existing ash pond in the Eastern Basin of RL 41 m needed to be reduced to RL 34 m to control the impact of seepage into the natural aquifers and the adjacent LaTrobe River. This severely reduced the available capacity of the existing wet ash system. The need to provide for end of mine ash storage led to the development of the TAP ashing system to meet the requirements of the Yallourn group of Power Stations for the remainder of their operating life, and in compliance with their statutory environmental requirements.<sup>5</sup>

The project involved the construction of the TAP system on the ash delta of the existing Eastern Basin pond that allowed the ash from the non-operational pond to be drained, excavated and the dry ash stacked in the Western and Central Basins of the YNOC. Design of the TAP system commenced in 1985 and the ponds were constructed during 1986 and 1987. They were commissioned in 1987 and have operated continuously to date.

### 3 ASH AND LEACHATE PROPERTIES OF BROWN COAL ASH

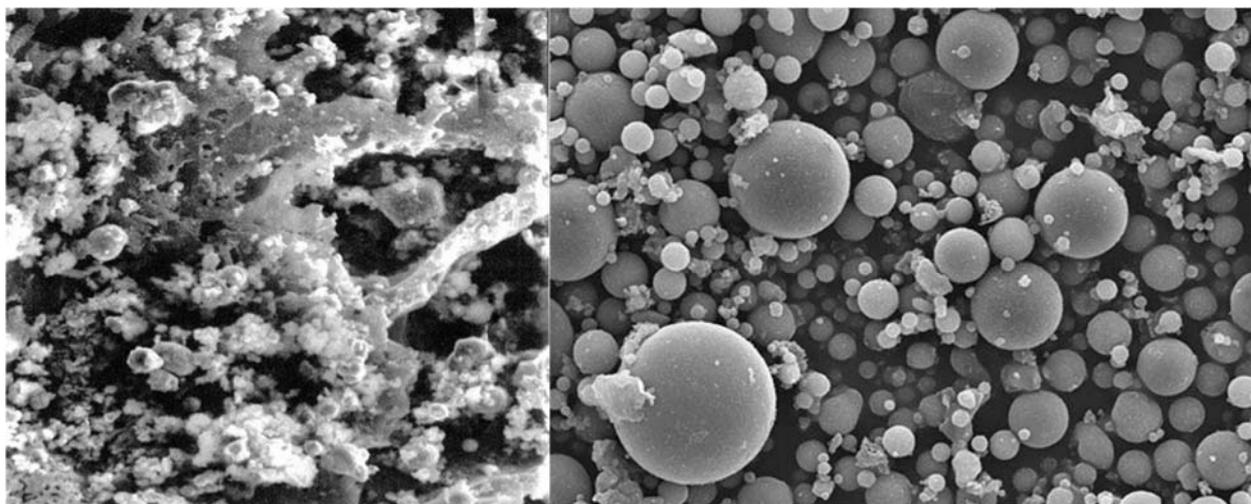
#### 3.1 PHYSICAL

Yallourn W power station burns approximately 17 million tonnes per annum of brown coal (lignite) producing approximately 300,000 m<sup>3</sup> (260,000 tonnes) of fly and hearth ash. Although the ash content of brown coal is low compared to most thermal black coals it has a much higher moisture content (approximately 66%) and hence has lower thermal efficiency. Effectively brown coal and black coal power stations produce a similar quantity of ash per Mw of power generated. However the properties of brown coal ash from the Latrobe Valley power stations are quite different from other brown and black coal ash.

Ash from the Yallourn W Power Station typically consists of the following properties:

- Ash contains 25% to 50% char (unburnt carbon);
- Ash is classified as a sand or sandy silt with less than 15% passing the 75 micron sieve;
- The bulk density of the coal ash (excluding char) is around 1.22 t/m<sup>3</sup>;
- The bulk density of the char is 0.3 t/m<sup>3</sup>;
- The combined bulk density of the ash mixture assuming 30% char is 0.94 t/m<sup>3</sup>;

The particle size distribution of brown coal fly ash is similar to black coal fly ash but the shape of the fly ash particles are markedly different. The fly ash particles from black coal ash are generally spherical whereas the brown ash particles vary considerably in shape as shown in Figure 3.<sup>7,8</sup>



Yallourn Brown Coal Ash

Typical Black Coal Ash

### Figure 3 – Electron microphotography of black and brown coal ash (X2000)

Brown coal ash also contains more reactive components than is generally observed with black coal ash which tends to allow water to bind to the fly ash particles. These factors have a significant effect on the rheological and physical behaviour of the Yallourn Power Station coal ash. Rheologically it is more non-Newtonian than black coal ash in that it demonstrates higher apparent shear strength at rest and in the drained condition which quickly dissipates once mobilized.

The high proportion of char in the Latrobe Valley coal ash significantly improves the permeability of the deposited ash. These properties allow the deposited ash to drain relatively quickly and, in the drained state, allow near vertical excavation faces up to 3m high.

### 3.2 CHEMICAL

The chemical composition and leachability (TCLP) of the ash is given in Tables 1 and 2.<sup>2</sup>

**Table 1 – Chemical Composition of Yallourn Ash**

<b>Analyte</b>	<b>% Composition</b>
SiO <sub>2</sub>	8.18
Al <sub>2</sub> O <sub>3</sub>	5.34
Fe <sub>2</sub> O <sub>3</sub>	33.08
CaO	8.68
MgO	13.76
SO <sub>4</sub>	19.69
TiO <sub>2</sub>	0.26
K <sub>2</sub> O	0.24
Na <sub>2</sub> O	5.92

**Table 2 – TCLP Test Results (mg/L)**

<b>Analyte</b>	<b>Concentration (mg/L)</b>
Barium	0.16
Cadmium	<0.03
Manganese	0.35
Nickel	<0.03
Selenium	<0.1
Zinc	<0.03
Mercury	<0.0005

The Yallourn ash has high concentrations of soluble salts and the leachate is saline and alkaline. A groundwater and surface water monitoring network has been established to monitor water quality and potential leachate migration from the excavated ash landfill in the vicinity of the YNOC. Analysis of groundwater quality indicates that the main ash leachate indicators, sulphate and salinity concentrations, remain relatively stable within the vicinity of the YNOC and that the contaminant plume remains within the Yallourn power station property boundary.

Water sampling of the adjacent Latrobe River upstream and downstream of the YNOC site does not indicate any impact from ash landfill seepage on the beneficial uses of the water environment.

## 4 REGULATORY REQUIREMENTS

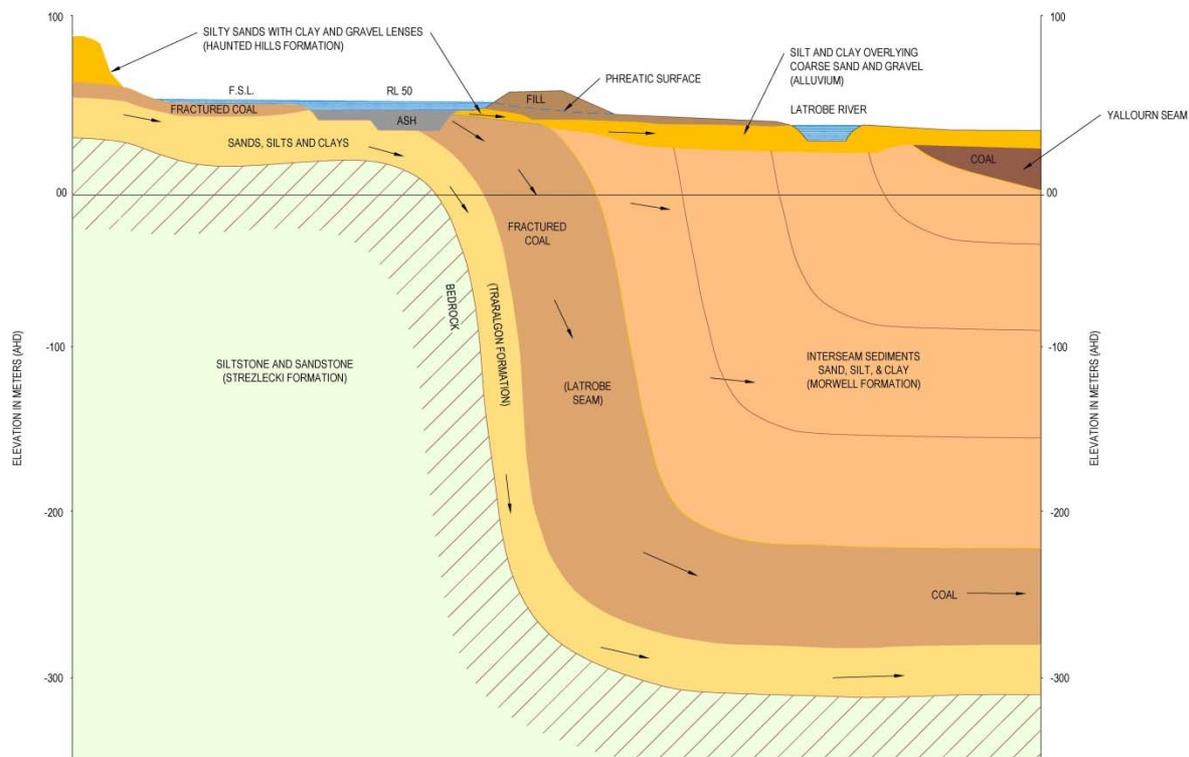
The TAP operates under the State Water Act (Victoria) which in 2010 issued a Works Licence under the category of a “potentially hazardous” dam. The regional water authority, Southern Rural Water, administers the Licence and requires that the TAP be managed to comply with ANCOLD Guidelines. The ANCOLD Guidelines are a set of advisory documents which have been prepared by the Australian National Committee

on Large Dams, an industry body, and are widely recognised as providing accepted industry standards for dam safety management in Australia including design standards, management techniques, surveillance frequencies, safety review procedures and other similar guidelines required to construct and sustain dams in a safe condition.

EnergyAustralia Yallourn have operating procedures which detail the dam safety management requirements of the TAP to meet the requirements of the ANCOLD guidelines. The document formally assigns a consequence category of High C to the Twin Ash Ponds. Alarm levels for the critical piezometers at the ponds have been included in the site Trigger Action Response Plan (TARP).

## 5 SITE GEOLOGY

The TAP are located within the YNOC. The major geological structure in the area is the Yallourn Monocline as shown in Figure 4, Site Geology<sup>2</sup>. This north-east trending structure dips steeply (up to 90°) to the south-east and plunges up to 300 m over a short distance. The open cut was excavated as three shallow basins in the Latrobe Seam Coal along the up thrown side of the monocline.



**Figure 4 – Site Geology**

Underlying the coal seam is a sequence containing clays, silts, sands and minor coal (Traralgon Formation) up to 30 m thick which is, in turn, underlain by weathered group basement rock (Mesozoic).

The TAP were constructed on the ash delta of a former ash pond within the eastern basin of the YNOC. The ash underlying the ponds, which varies from 12 to 30 m thick, constitutes an aquifer providing a potential pathway for groundwater flow. A buried former meander of the Latrobe River underlying the ash delta also represents a potential pathway for groundwater flow.

## 6 SETTLEMENT

Significant settlement of the TAPs and associated structures, both immediate and long term were anticipated, however the settlement parameters of the ash determined from their physical properties were initially not well understood. A trial embankment was constructed and monitored to determine the properties required to estimate settlement during construction and operation.

### 6.1 TRIAL EMBANKMENT

An embankment approximately 50m long and 20m wide was constructed from clay borrow material on the ash delta overlying 29 m of ash deposit. It was constructed approximately 3.5m above the surface with the foundation approximately 1m below the surface. The observed settlement one week after construction was 1000mm, a further 50mm after four weeks and a further 15-20mm during the following four weeks.<sup>6</sup>

The settlement parameters adopted for the Twin Ash Pond design were based on the trial embankment properties for the ash and known parameters for the underlying coal and Traralgon Formation foundation material.

### 6.2 SETTLEMENT ESTIMATE

The results of the trial embankment verified the settlement analysis of the proposed TAP design using a one-dimensional consolidation analyses. Using these consolidation parameters the following settlements were estimated for the TAP:<sup>6</sup>

- Lowering of the water level in the Eastern Basin prior to construction – up to 700mm
- Intermediate foundation settlements during construction - 40mm at the western end up to 1500mm at the eastern end of the embankment,
- Post construction settlements of the embankment (end of construction to 2020) – 200mm to 750mm,
- Outlet towers would be subject to significant settlement and tilt,
- Bypass pipeline would undergo up to 1200mm immediate settlement and 200mm secondary settlement

It was expected that 90% of the foundation settlement would occur during construction and post construction settlement would be relatively small and uniform. While this could be accommodated during embankment construction, provision would have to be made for the bypass pipeline, pipeline outlet and outlet tower structures.



2.5 mm thick HDPE liner. On the access ramps and inlet aprons the thickness of the liner is 4 mm. The inside (upstream) batters are sloped at 2H:1V. The only downstream batter, on the eastern embankment, is sloped at 2H:1V. Stabilising fill was later placed at the toe of the eastern embankment.

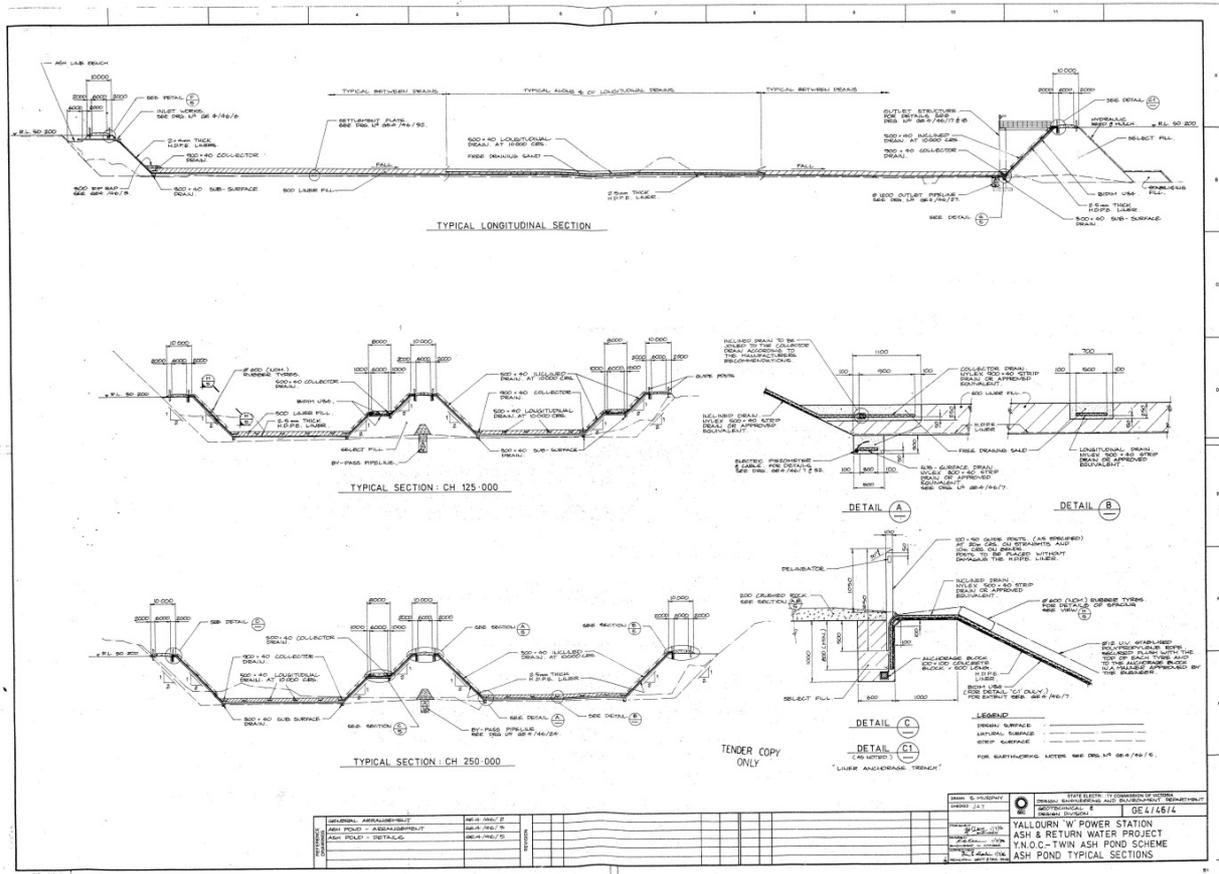


Figure 6 – Details of Twin Ash Ponds

## 7.1 LINER UNDERDRAIN SYSTEM

Underdrains to collect and monitor leakage through the liner were placed under the liner on the pond batters or slopes, under the upstream toe of the ponds and under the floor. These comprised strip drains encased in free draining sand. The underdrains discharge into a collection pit at the upstream embankment toe near the outlet tower in each pond. The collection pit discharges to the headwall at the end of the main outlet pipe.

## 7.2 POND OUTLET WORKS

The decant water is discharged from the ponds to the eastern basin via outlet towers situated at the eastern end of the ponds. Each pond has one controlled outlet tower with a walkway to allow pedestrian access from the crest road to the top of the tower and a spillway tower. The towers in Pond No.1 and 2 vary from 10.8 m to 13.6 m high. The towers consist of a square 2 m x 2 m reinforced concrete shaft founded on an 8 m x 8 m reinforced concrete footing. Stop logs are placed in one side of the control tower to

manage the decant water level in the pond. The second tower in each pond is an uncontrolled spillway. Both spillway towers are 'wet' towers with an open top at RL 49 m. Discharge from the tower flows through a 1200 ND Mild Steel Cement Lined (MSCL) pipe that connects to the bypass pipeline.

#### 7.4 BYPASS PIPELINE

The bypass pipeline passes stormwater from the ash dump west of the ponds beneath the central embankment of the TAP to the eastern basin where it is pumped, with the ash decant water, back to the power station for reuse. The pipe varies from 1200 ND, reinforced concrete (RC) pipe adjacent to the ponds to 1752 OD, MSCL pipe beneath the central embankment. The MSCL pipe beneath the central embankment was placed in a trench in the foundation ash. In an effort to reduce the settlement of the pipe, an uncompacted layer of ash was placed over the pipe which would consolidate with the embankment consolidation and reduce some loading directly on the pipe. The pipe was also placed with a camber to allow for settlement.

#### 8 ASH EXCAVATION

The following ash excavation procedure has been developed.

- Prior to the excavation of the Twin Ash Ponds, a check is made of the current groundwater conditions to determine if there are any special requirements to be considered in the excavation program such as leaving ash material behind to maintain the ongoing stability of the TAP upstream slopes.
- A risk assessment is conducted prior to the commencement of excavation to identify the hazards and, where appropriate, allow implementation of measures to reduce the level of risk to an acceptable level.
- An even 1m layer of ash is left on the batters to prevent liner slips and as a buffer to protect the batter liner from damage. This is maintained by GPS control of the excavator.
- To ensure the integrity of the Twin Ash Pond's floor liner, excavation of Twin Ash Ponds is restricted to 0.5m from the pond liner. A layer of sand approximately 0.5m thick is maintained on the floor of the pond as a buffer and marker for the operator. This has proven to be very effective.
- A final detailed inspection of the excavated pond is conducted to verify the integrity of the liner and any repairs are completed by the contractor. The final inspection is critical to the ash pond operation.

The plant used to excavate the pond and haul the ash to the deposition area are as follows:

- 40T articulated dump trucks (D400 CAT)
- PC 400 Excavator (40T) with wide tracks
- D7 swamp dozer

A large, 50T excavator was initially used but the additional bearing pressure delayed gaining access onto the ash after drainage and placed additional restrictions on movement on ash within the pond.

Figures 7, 8 and 9 show the ash excavation in progress.



**Figure 7 – Ash excavation showing ash berms**



**Figure 8 – Ash excavation**



**Figure 9 – Excavation around outlet structures**

## 9 MONITORING PROGRAM

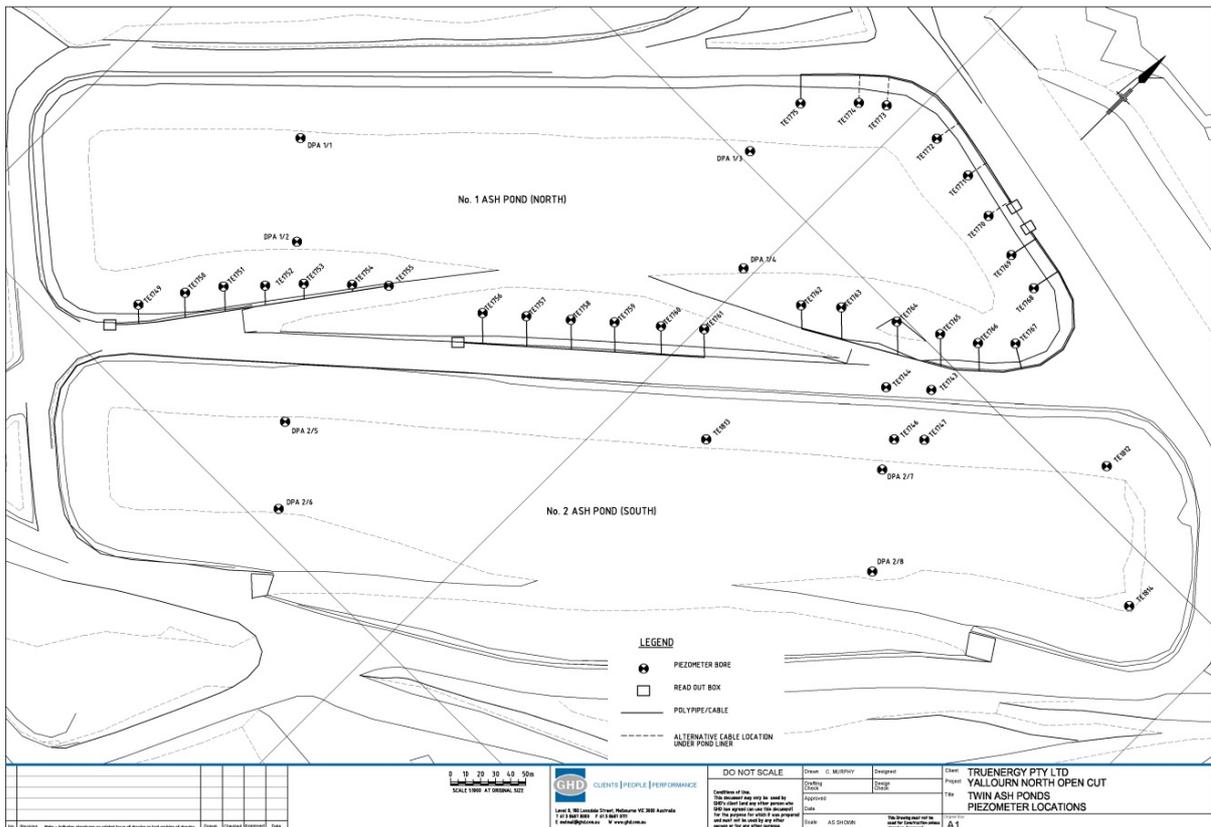
### 9.1 INSTRUMENTATION

An extensive instrumentation and monitoring network has been established to monitor the condition of the TAP and its impact on the adjacent groundwater levels as listed below.

- Groundwater pressures in the sub-surface drainage system are monitored using eight vibrating wire piezometers;
- As part of a trial process to test the effectiveness of piezometers to detect leaks through the liner eight vibrating wire piezometers and two open standpipe piezometers were installed in the crest of the central embankment and four vibrating wire piezometers installed in the upstream batter of Pond No. 2;
- Based on the effectiveness of the liner leak detection trial, an additional twenty seven vibrating wire piezometers were installed in the upstream batter of Pond No. 1;
- To monitor the groundwater pressures in the upstream batter of Pond No. 2, three vibrating wire piezometers were installed in July 2009;
- Seepage flows from the underdrainage systems in both ponds are monitored at the underdrain outlets at the headwall at the downstream toe of the eastern embankment;

- Ground movements around both of the ponds are monitored using 18 survey pins on the embankment and one on each of the outlet towers. Three sets of pairs of pins are used to monitor horizontal separation across known features.

Figure 10 shows the location of the groundwater piezometers around the TAP.



**Figure 10 – Piezometer installation**

## 9.2 INSPECTIONS - ROUTINE

The ANCOLD guidelines specify the appropriate dam safety management program based on the consequence of failure of the structure regarding either population at risk or potential loss of life (separate measures), damage to the environment, social impacts and economic loss. A “low” hazard category rating would be appropriate for the dam based on the direct consequences of a failure of one of the ponds. However, based on the consequences to Energy Australia’s business if both ponds were out of operation for a period of time, a hazard category of “High C” has been assigned by Energy Australia.

Energy Australia Yallourn have adopted the following management program which complies with the ANCOLD guidelines for a High C hazard category dam:

- Routine visual inspections of the dam on a weekly basis;
- Undertake and report on routine seepage and piezometer readings monthly and settlement readings at the completion of each cycle (6-9 monthly);
- Complete an intermediate inspection by an experienced dams engineer annually;
- Complete comprehensive inspections on a 5 yearly basis;
- Maintain a dam specific operations and management plan; and
- Include a dam specific Dam Safety Emergency Plan in the organisation's emergency management plan.

The intermediate inspection report reviews and comments on the adequacy of the dam safety management program's compliance with ANCOLD guidelines.

## 10 OPERATING EXPERIENCE

### 10.1 LINER – CUTS AND TEARS

From the time of the first excavation cycle liner damage on the walls during ash excavation became a significant problem. For example, the liner inspection following the routine excavation of the ash from the northern pond in 1989 revealed 10 cuts to the liner but in 1991 revealed over 120 cuts to the liner walls. These were repaired prior to re-commissioning the pond. The following year after a 1 m layer of ash was left against the wall only three holes were identified and repaired in the southern pond. However the following year there were 21 holes in the northern pond liner after the ash excavation.

Initially tyres were roped together on the walls of the ponds to protect the liner from damage. These were quickly removed as they were not close enough to provide protection, the excavators snagged the cables pulling them from the walls and it inhibited cleaning of the liner walls.

It was considered that the full wall liner clean and inspection was onerous after each excavation cycle and in 1993, after undertaking a stability analysis of the upstream face with the liner subject to theoretical liner breakage, it was decided that full liner cleaning and repairs would be undertaken after every 5 filling and excavation cycles.

In 1997, to further mitigate the cost of continual cleaning of the liner, a trial was undertaken to see if piezometers placed in the embankment could identify the locations of holes in the liner. Therefore, only targeted areas of liner would be cleaned. The bore monitoring system trial was conducted from July 1997 to June 1998 on the eastern end of the central embankment of Pond No. 2. The bore monitoring system trial concluded that it was feasible to use piezometers to locate tears and leakage through the liner.

In 1999 a further 27 piezometers were placed along the upstream batter of the central and eastern embankment of Pond No. 1 as the first stage of placing piezometers around the ponds.

Over the next 10 years the piezometers in the upstream batter found high and continually increasing water levels in the eastern corner of Pond No. 1. A number of liner cleans of the area were completed and holes patched. Patching of the liner on the batters did not seem to have any impact on the groundwater pressures monitored in the embankment.

On the floor of the ponds the 0.5 m sand layer is an effective means for the plant operators to avoid damage to the floor liner. With GPS control and the change in colour between the ash and the sand, reported damage to the floor liner has been limited compared to the batters. The sand is regularly topped up to maintain the depth of cover. It is however suspected that there is some damage to the floor liner but the tight ash pond cycle has not allowed cleaning, inspection and repairs to the floor.

Figures 11 and 12 show some tears and repairs to the liner.



**Figure 11– Damage and repairs to the liner on the crest of the batter.**



**Figure 12 – Damage to liner on the ramp**

The liner leakage and resulting elevated groundwater pressures is having a significant effect on the embankment stability as discussed in the section on embankment stability below, Section 10.5.

## 10.2 LINER PULLED FROM CREST EMBEDMENT TRENCH

Around the perimeter of the pond the liner is anchored in a 1.0 m deep trench 1.0 m back from the edge of the pond. While this has generally been satisfactory, a number of major slippages of the HDPE liner down the face have occurred where the liner has been pulled from the trench. Slippages have occurred at separate times at the eastern end of both ponds. Major slippage has occurred in 1989, 1992 and again in 1997. The initial liner slippage were blamed on the saturation and loss of strength of the liner trench clay backfill. A flap of HDPE liner was added to cover the trench to try and limit infiltration of water into the trench. It has since been established that the cause of the liner failures were that large wedges of ash were left on the batters during excavation which overstressed the liner, combined with poor maintenance of the crest resulting in water pooling over the liner trench.

In October 2010 a liner slippage occurred in Pond No.2 towards the centre of the central embankment. The liner had been pulled out of the anchor trench and slipped approximately 200 mm down the face of the embankment. This is shown in Figure 13. Again the suspected cause of the liner slippage was that large wedges of ash were left on the batter during the excavation process which overstressed the liner. The liner was

lifted to its original position and a new piece of liner welded over the top. The new liner was anchored into a new trench behind existing anchor trench.

The incidence of large wedges of ash being left on the batters putting the liner of risk have been largely eliminated by the adoption of GPS control of the excavator.



**Figure 13 –Liner pulled from trench**

### 10.3 EMBANKMENT CRACKING

Cracking was noted in 1987 along the crest and the ramp at the eastern corner of Pond No. 2. The cracking is believed to be due to differential settlement of the embankment material against the coal batter. Survey pins were placed either side of the cracks and separation of the pins continues to be monitored. After initial movement of up to 200 mm movement, it has been relatively stable since 1996.

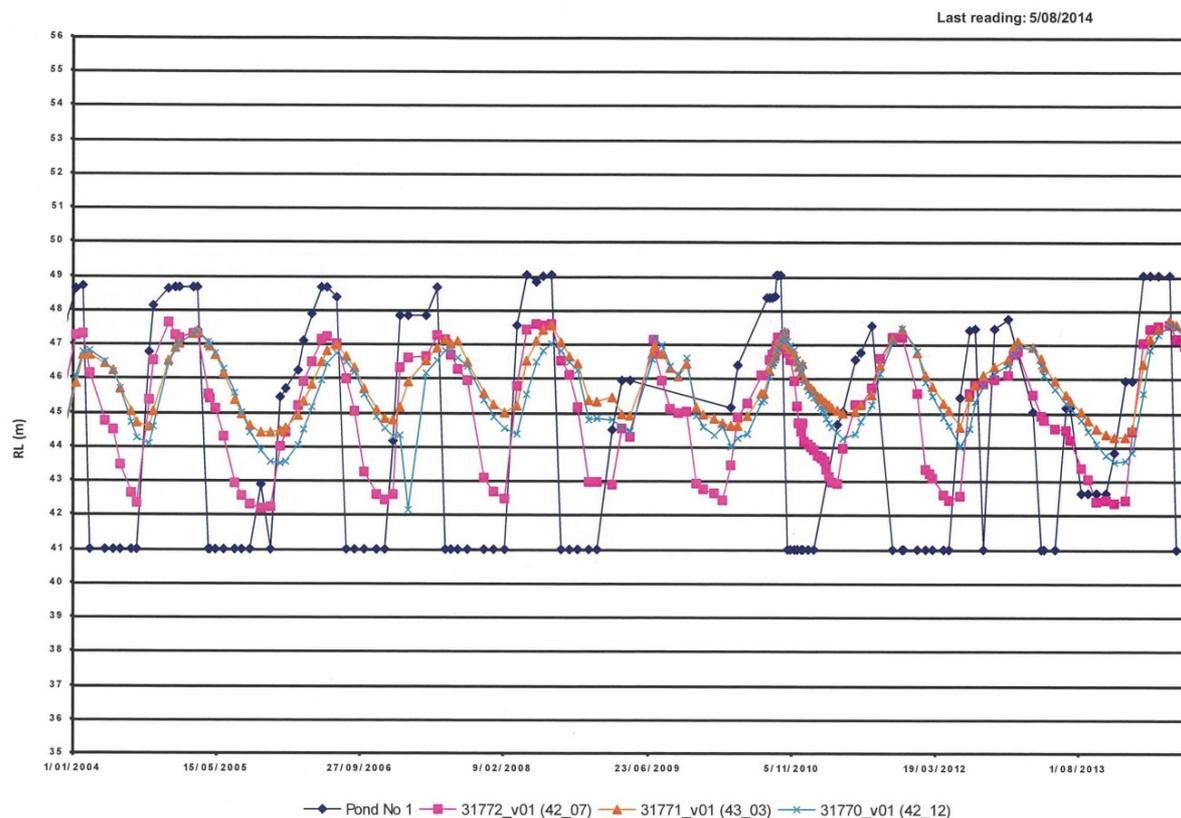
### 10.4 LINER UNDERDRAINAGE

The liner underdrainage system has not been effective for many years and was assumed to be blocked. In December 2008 a clean back of the liner in Pond No. 1 was completed using a smooth bucket on the excavator and hosing the final layer of ash from the liner, and an investigation into the underdrainage system was also to be completed. Excavation of the protective sand from the upstream batter found the liner to be creased and torn in a number of locations. After a minor batter slump occurred it was decided that excavation to remediate the underdrainage had a risk of causing batter slumping and so was abandoned. Monitoring continued and it was decided to replace the underdrains at a later date. In July 2009 the same process was attempted in Pond No.2 and another slump occurred. Tears below the protective sand layer were patched and pooled water behind the liner relieved. Again repair work to the underdrains was postponed.

During those investigations and repairs in 2008 and 2009, the underdrainage seepage collection pits were located and the strip drains into the pit were completely blocked with ash. In Pond No.2 it appeared that the drains were either partially or completely blocked with cemented sand, which may have been due to carbonate leached from the ash. Major repairs and replacement of the toe drains have been considered but a number of recent attempts to clean back to the liner at the toe of the batters has initiated minor slumping of the batter and were abandoned.

### 10.5 EMBANKMENT STABILITY

The piezometer monitoring shows elevated water pressures behind the liner at the eastern end of the ponds that respond directly to the level of ash water in the pond. This is considered to be due to cuts in the liner and the blockage of the sub-surface drains beneath the liner at the toe of the batter. Repairs to the liner have locally provided temporary relief but the overall trend continues. This behaviour is shown in the piezometer plot Figure 14. It can be seen that the measured groundwater level behind the liner peaks when the pond levels starts to drop. The rapid drawdown of the pond water level at the commencement of the drainage cycle has led to excess pressure behind the liner causing batter slumping and subsequent liner damage.



**Figure 14 – Piezometer readings at eastern end of the ponds**

To maintain the stability of the batters during pond drainage it has been necessary to leave an upstream toe weighting berm approximately 9 m wide and 4 m high comprised of ash during excavation around the affected areas of the ponds as shown in Figure 7. These have been designed to maintain an acceptable factor of safety but reduce the storage capacity and cycle times of the ponds.

As a long term solution to reduce the groundwater pressure beneath the liner it is proposed to install dewatering wells in the embankments adjacent to the liner. It is expected that this will reduce the risk of embankment slumping following dewatering and restore the full capacity of the ponds.

## 11 SETTLEMENT

Despite good correlation between the back analysis of the trial embankment settlement and consolidation parameters from laboratory testing of ash delta and the underlying formations, observed settlements were up to 25% higher than predicted.<sup>1</sup> This was thought to be due to the variable ash foundation properties over the ash delta and the effects of first filling.

Survey pins for vertical and lateral movement measurement are located on the embankment, the outlet towers and the by-pass pipe outlet and are routinely monitored and reported.

### 11.1 EMBANKMENT SETTLEMENT

Vertical movements of the crest pins vary around the ponds, generally as follows:<sup>5</sup>

- The crest of the eastern embankment of Pond No. 1 settled initially after construction and then changed to either heaving or remaining steady since 1992. The total movement since construction varies from 30 mm heave at the northern end to 100 mm settlement at the southern end;
- The crest of the eastern embankment of Pond No. 2, had a steadily decreasing rate of settlement to the year 2000, when the settlement rate increased and it continues to settle. The total movement since construction is 200 mm to 300 mm settlement, with the most settlement occurring at the southern end;
- The crest of the central embankment settled rapidly after construction to 1996 and then steadied. The total movement since construction is 450 mm to 75 mm settlement with the greatest settlement occurring at the western end;
- The crest of the northern embankment has continually heaved since the end of construction. A total of 100 mm heave has been recorded since construction; and
- The crest of the southern embankment all initially settled post construction, but have been reasonably steady since 1996. The total movement since construction varies from 60 mm heave at the western end to 200 mm settlement at the eastern end.

In general the horizontal movement of all the crest pins has been towards the centre of the ponds with an average total movement post construction of 100 mm.

These movements are regularly reviewed and have not affected the operation and integrity of the ponds.

## 11.2 BY-PASS PIPELINE SETTLEMENT

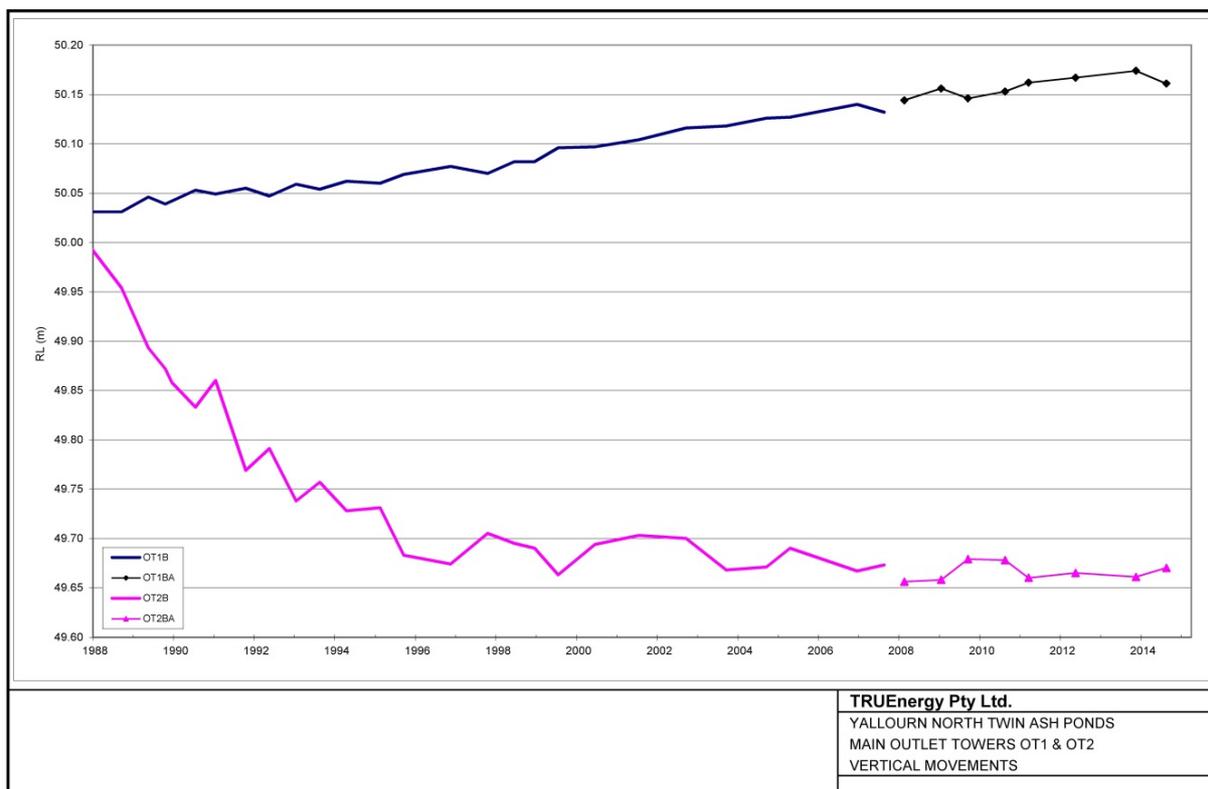
A survey of the bypass pipeline in July 1987 immediately following construction found that at its worst, just west of the centre of the central embankment, it had settled 2.4 m, which, although it was 1.0 m more than expected, had not overstressed the pipe. It had, however, caused the failure of the cement lining in this section of the pipeline. As a precautionary measure cathodic protection had been installed on the mild steel pipeline. At the Junction to Pond No.1 and No.2, the bypass pipeline had settled approximately 0.5 m more than expected. As the settlement of the pipe near the centre of the central embankment is greater than both ends, water pools in the sag in the pipe. It has been observed that the settlement trend of the by-pass pipeline is similar to the embankment and the majority of the long term settlement occurred during construction. As the bypass pipeline is in continuous operation opportunities to dewater the pipeline for inspection have been limited.

In December 2011 the downstream 120 m of the bypass pipeline were cleaned out from the outlet wall to just beyond the confluence with the No.1 Outlet Pipeline. Both outlets to the towers were also cleaned out to reinstate the original design spillway capacity. The remaining bypass pipeline running beneath the central embankment to the inlet pit is nearly half full with silt and ash. In some locations it had previously been reported that the cement lining of the cement lined mild steel pipe had failed but the steel pipe remained intact.<sup>4</sup>

## 11.3 OUTLET STRUCTURE MOVEMENT

Differential settlement and tilting of the outlet towers, which are founded on the ash delta, has been monitored since commissioning. The surveyed outlet tower in Pond No. 1 has recorded negligible horizontal movements since 1987 but has heaved over this period at approximately 5mm per year.

The surveyed outlet tower in Pond No.2 has shown a horizontal movement since 1987 of approximately 280 mm in the southerly direction. It settled approximately 330 mm up until 1997 and has since fluctuated by approximately 30 mm with filling and emptying cycles.<sup>4</sup> The vertical movements for these towers are shown in Figure 15.



**Figure 15 – Graph of Outlet Tower vertical movement**

## 12 HDPE LINER LIFE

The HDPE lined ponds have been in continual use for 28 years and, although portions of liner have been replaced after major cuts and slips, it has never been completely replaced. Uncertainty over the integrity of previous repairs, general wear and tear and material degradation are all factors to be considered in the current development of the long term TAP operating strategy.

## 13 FUTURE OPERATION AND CLOSURE

It is currently proposed to continue ashing to the YNOC until 2032. Options for placement of the excavated ash, operation of the return water system and the impact on the TAP are currently being considered.

The current approved closure strategy includes returning the YNOC to a combination of forest/woodland and grassland with a number of constructed wetlands which include TAP.

## 14 CONCLUSIONS

The HDPE lined TAP have been subject to continuous deposition and excavation cycles for over 25 years. Although they have been subject to significant settlements during and since construction, and are prone to cuts and tears during ash excavation they have continued to provide uninterrupted ash containment over that period, and the current plans are to continue operation of the TAP system until 2032.

The ponds operate under licence conditions which require compliance with the appropriate ANCOLD guidelines. These have provided a framework for a risk based program of monitoring including regular inspections and reporting which has allowed Energy Australia Yallourn to effectively identify and manage potential issues as they have arisen

Nonetheless there have been a number of issues which have in the past which still continue to put at risk the integrity of the TAP. The most critical issues are related to the ash excavation. These are the protection of the liner from cuts and tears from the excavator leading to elevated ground water levels behind the liner, and liner pull out and slumping due to wedges of ash left on the batters during excavation.

Effective control of the ash excavation has therefore been critical and the adoption of GPS control of the excavator, pre-planning prior to each excavation cycle and post excavation inspections, has led to a significant reduction in liner damage. However the existing damage to the liner and the blockage of the underdrain system has resulted in uncontrolled transient elevated ground water pressure against the liner on the batters and underneath the floor of the ponds.

The extensive monitoring system has been essential to monitor the stability of the batters given the elevated groundwater pressures. Based on this data the interim solution to maintain batter stability has been to leave ash berms along the critical sections of the batter toe. It is proposed in the long term to install a dewatering system behind the liner.

Significant settlements were expected during construction and operation. Information gathered from the trial embankment allowed the behavior of the highly compressible ash foundation to generally be accommodated in the design and construction. However the settlements were still underestimated by up to 25% which has seriously affected the by pass pipeline. While it continues to operate as an essential part of the drainage system it is unable to be decommissioned for repair or replacement.

In summary, with the benefit of adequate monitoring, responsive maintenance and appropriate operation, the TAP have operated continuously and effectively for over 25 years in a harsh operating environment.

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