Water and Environment

ASHTON COAL: END OF PANEL 4 GROUNDWATER REPORT

Prepared for	Ashton Coal Operations Limited
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EXECUTIVE SUMMARY

The Ashton Coal Project, located 14km west of Singleton in the Hunter Valley region of NSW, incorporates both open cut and underground mining operations in order to access a series of coal seams within the Permian Foybrook Formation.

The longwall underground mine is located south of the New England Highway. Development mining for the first longwall panel in the Pikes Gully Seam (LW1). commenced in July 2006. Mining of Longwall Panel 4 (LW4) was completed on 15 October 2009 (Mining year 6). Mining is currently proceeding in LW5 in the Pikes Gully Seam.

Prior to commencement of mining, baseline studies were initiated as part of the Environmental Impact Statement (EIS) process. These were used to inform the impact assessment in that EIS, and were also used to provide a pre-mining baseline against which actual mining impacts can be compared. The monitoring network has been significantly expanded since that original EIS baseline, and has been used to provide additional information on the impacts of the underground mine development. Both standpipe piezometers and multi-level vibrating wire piezometers have been installed and monitored.

Groundwater levels and salinity, have been routinely monitored throughout the life of the mine. This has been supported by subsidence surveys and the monitoring of both total inflows to the underground workings, and inflows to the longwall panel nearest Glennies Creek.

This End of Panel Review Report for Longwall 4 (LW4) has been prepared following consideration of all available monitoring data. Actual impacts derived from data analysis have been compared to the impacts predicted in both the EIS (HLA Envirosciences, 2001) and studies conducted in support of the LW1-4 Subsidence Management Plan (SMP) Application.

All groundwater related impacts from underground mining up to the completion of LW4 were at, or below, the levels predicted in both the EIS and the SMP groundwater assessments for this stage of mining.

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FIGURES

1 INTRODUCTION

The Ashton Coal Project, located 14km west of Singleton in the Hunter Valley region of NSW (**Figure 1**), incorporates both open cut and underground mining operations in order to access a series of coal seams within the Permian Foybrook Formation.

In 2003, the open cut mine, located north of the New England Highway, commenced operations. The coal is recovered from several seams of varying thickness from two open cuts: the smaller Arties Pit and the larger Barrett Pit.

The underground mine is located south of the New England Highway with the mine accessed from the northern side of the highway via a portal in the Arties pit. The original mine plan comprised eight longwall panels (LWs 1-8), four of which have been approved for mining of the Pikes Gully seam (LWs 1-4) under an SMP Application lodged and approved in 2006. The first four longwall panels, including LW4, were designed to mine final voids 216m wide, separated by chain pillars of 25m width rib to rib, with cut-throughs at 100m centres. The layout of LWs 1-4, together with the progress of mining to date, is shown on **Figure 2**.

Underground mine development commenced in July 2006. Three End of Panel Review reports assessing impacts from LW1, LW2 and LW3 were issued in October 2008 (Aquaterra, 2008a), May 2009 (Aquaterra, 2009a) and July 2009 (Aquaterra, 2009b) respectively. Mining of the fourth longwall panel (LW4) began on 2 April 2009 and was completed on 15 October 2009. This report presents a review of groundwater impacts at the completion of LW4.

Mining is now proceeding in LW5 in the Pikes Gully Seam. It is proposed to continue mining the Pikes Gully Seam across the rest of the underground mine area, and then to subsequently mine the underlying Upper Liddell, Upper Lower Liddell and Lower Barrett Seams in a multi-seam longwall operation.

Prior to the commencement of mining, baseline studies were commenced as part of the EIS process. These studies were carried out to allow predictions for the EIS, and to provide a baseline against which actual mining impacts could be compared. A number of monitoring piezometers were installed in July 2000 as part of the baseline assessment. The initial baseline monitoring programme was based on those piezometers. The baseline monitoring program included quarterly monitoring of groundwater levels in piezometers and quarterly water quality sampling from piezometers and from the surface flows in the Hunter River, Glennies Creek and Bowmans Creek. The preliminary EIS investigations were reported in Appendix H of the EIS (HLA Envirosciences, 2001).

Further studies were initiated as part of the SMP Application process for LWs 1-4. These studies included the installation of piezometers, hydraulic testing, and groundwater quality sampling. The new piezometers were added to the baseline monitoring network, and monitoring frequency was increased to monthly, or fortnightly in some bores, in anticipation of the start of underground mining.

Once mining had advanced below the regional groundwater level in the underground mine, monitoring of groundwater inflows into the mine was established as part of the ongoing groundwater monitoring program.

This End of Panel Review Report has been prepared following consideration of all available monitoring data, including:

- Groundwater inflows to the underground mine;
- Groundwater level records from **78** piezometers at **65** sites;

- Field data on water quality from underground seepages, surface water samples and selected bore water samples; and
- Survey data from transects across the LW3-4 goafs (XL5 and XL10).

Access to tailgate TG1A was lost during extraction of LW1. Water inflows to TG1A has now been contained and conveyed along TG1A to a collection point at 18CT, where the water is piped through the goaf to the Longwall 1 backroad, which continues to be accessible (**Figure 2**). The discharge from this pipe is monitored separately from other underground inflows to assess seepage losses from Glennies Creek alluvium into the mine.

All other groundwater inflows are collected at a number of sumps, the main sump being at the LW1 Backroad Sump Borehole (**Figure 2**), and another in the North West Mains. The discharge from the LW1 Backroad Pipe also flows to the LW1 Borehole Sump. Water pumped into the mine is monitored as well, to enable net groundwater inflows to be determined by water balance calculations.

This report includes a comparison between the actual impacts derived from analysis of the monitoring data, and the impacts predicted in both the EIS studies (HLA, 2001) and the LW1-4 SMP Application (Peter Dundon and Associates, 2006).

2 SITE DESCRIPTION

2.1 LONGWALL 4

Mining of LW4 was carried out between 2 April 2009 and 15 October 2009. Coal was recovered from the Pikes Gully Seam, which varies in thickness between 2.3m and 2.8m along LW4. The overburden thickness above the Pikes Gully Seam along LW4 ranges from **130m** at the southern end to around **60m** at the northern end, as a consequence of the west-south-westerly dip on the coal measures strata.

At its closest point, Glennies Creek passes approximately 895 m east of the LW4 goaf, while Bowmans Creek is about 65m west of the LW4 goaf (**Figure 2**). The Pikes Gully Seam subcrops beneath the Glennies Creek floodplain alluvium, but is more than **90m** below the Bowmans Creek alluvium where it is closest to LW4.

The surface topography above LW4 slopes gently to the west-south-west.

2.2 HYDROGEOLOGY

Two main aquifer systems occur within the Ashton underground mining area:

- A hard rock aquifer system in the Permian coal measures, in which groundwater flows predominantly along cleat fractures in the coal seams; and
- A porous-medium aquifer in unconsolidated alluvial sediments associated with Bowmans Creek, Glennies Creek or the Hunter River.

Groundwater flow in the Permian rocks is dominated by fracture flow, particularly in the coal seams. The hydraulic conductivity (permeability) of the coal seams is generally low, usually two or more orders of magnitude lower than the alluvial sediments, but higher seam permeabilities are found in some areas close to outcrop. The hydraulic conductivity of the coal seams declines gradually with greater depth of cover. Because groundwater flow and storage are dominated by relatively tight, sparse fracturing, storage capacity and storativity within the Permian rocks is very low.

Hydraulic testing indicated that hydraulic conductivities in the order of 1 to 10 m/d may apply to parts of the Pikes Gully Seam within the weathered zone close to outcrop, whereas typical values for the seam in the unweathered zone are in the order of 0.001 to 0.05 m/d. The results of hydraulic testing of bores in the zone between Glennies Creek and LW1 have confirmed that the higher permeabilities of the outcrop zone persist to less than 100m from outcrop (Aquaterra, 2008a).

The unconsolidated alluvial sediments comprise clay and silt-bound sands and gravel, with occasional coarser lenses or horizons where sands and gravel have been concentrated. The alluvial aquifer associated with Glennies Creek has generally been found to be moderately or poorly permeable, with hydraulic conductivity values less than 1 m/d, but with occasional coarser horizons with conductivity up to greater than 10 m/d. The alluvial aquifer associated with Bowmans Creek is generally characterised by high silt and clay content, and is less permeable than Glennies Creek, with a mean hydraulic conductivity of around 0.5m/d.

2.3 GROUNDWATER QUALITY

The groundwater in the coal measures aquifer system is saline. Typical salinities range up to more than 8,000 µS/cm EC (electrical conductivity), or more than 6,000 mg/L TDS (total dissolved solids).

Salinity within the Glennies Creek alluvium is generally moderate to low, particularly in the more permeable alluvium that contains a higher rate of through flow from surface recharge. In these areas, the salinity is generally below 2,000 µS/cm EC, although areas of higher EC, more 'stagnant' groundwater does exist in the poorly connected alluvial materials that mix with colluvium and fine sediments in the areas away from the creek.

The lower hydraulic conductivity of the Bowmans Creek alluvium moderately saline conditions (up to 6,400 µS/cm EC) are encountered within much of the groundwater that was tested during previous investigation programs.

Groundwater in both the Permian and the alluvium is more saline than the typical surface flow in Glennies Creek and Bowmans Creek.

2.4 GROUNDWATER LEVELS

Groundwater levels in the Permian Coal Measures may have been influenced to an extent by historical mining in the area, but it is considered that prior to commencement of mining at Ashton, the groundwater levels in the Permian were higher than in both the alluvium and in the streams. The higher groundwater heads in the Permian mean that under natural conditions, groundwater discharged from the Permian to the alluvium and to the surface streams. This is reflected in relatively higher salinities in the alluvium in some places, and also in the stream flow during periods of low rainfall and runoff.

At multi-level piezometer sites, groundwater levels are commonly higher in the deeper piezometers in the Permian than in the shallow alluvium and the near-surface parts of the Permian sequence, unless affected by mining activity. In some cases, Permian groundwater heads have been historically recorded at above the ground surface (i.e. artesian). Typically, there is an upward hydraulic gradient with depth below surface under natural conditions.

In areas where drawdown impacts from mining have lowered groundwater levels in the Permian, the hydraulic gradients may have been reversed, so that there is potential for water to flow from the alluvium directly into the underlying Permian. However, groundwater studies and the ongoing monitoring have indicated there is generally very poor hydraulic connection between the alluvium and the underlying Permian coal measures.

3 SURVEY MONITORING

3.1 GLENNIES CREEK BARRIER SUBSIDENCE MONITORING

Survey lines established across the LW1 tailgates and the slope between LW1 and Glennies Creek (XL1 - XL7) were surveyed at 2 - 4 day intervals while LW1 was advancing past the zone where Glennies Creek is closest to the mine. Monitoring then continued weekly after the longwall face passed each survey line.

As mining progressed further away from Glennies Creek, the number and frequency of subsequent surveys undertaken during the mining of LW2, LW3 and LW4 was reduced. Survey lines XL1 - XL4, XL6 and XL7 were not re-surveyed during LW3 or LW4 extractions, and prior survey results for these four lines were presented in Aquaterra (2008a) and Aquaterra (2009b).

The results from the surveys indicated that the permeability of the barrier between LW1 and Glennies Creek has not undergone any significant change, hence no increase in seepage losses from Glennies Creek alluvium is anticipated to occur as a result of ongoing longwall mining in the Pikes Gully Seam (Aquaterra, 2009b).

3.2 BOWMANS CREEK SUBSIDENCE MONITORING

As underground mining has continued closer to Bowmans Creek, subsidence monitoring has now been concentrated directly above the longwall goafs, as shown on **Figure 2**. As a result, a new survey line XL10 was established spanning an area from the LW4 goaf to the oxbow bend of Bowmans Creek (where Bowmans Creek is closest to LW4). During the extraction of LW4, survey line XL5 was also surveyed over the LW3, LW4 and LW5 goafs, prior to and shortly after the longwall face passed the survey line.

The plots of horizontal movement versus time are shown on **Figures 3a and 3b**. A comparison of survey results from XL5 and XL10 indicates lateral movement above LW4 was slightly greater in the south (100mm) than in the north (50mm).

Lateral movement outside the LW footprint in the area of the Bowmans Creek oxbow was less than 20mm. The small displacements detected are too small to indicate any horizontal shearing caused by the LW4 extraction. In the absence of any shearing, the permeability of the overburden beneath Bowmans Creek can not have undergone any significant change, and therefore no increase in seepage losses from Bowmans Creek alluvium is anticipated as a result of LW4 mining.

4 GROUNDWATER LEVELS

4.1 MONITORING NETWORK

An extensive network of monitoring bores was installed to monitor the effects of underground mining. Locations are shown on **Figure 2**.

The monitoring network includes bores into all the main hydrogeological units (alluvium, Permian overburden, Pikes Gully Seam and deeper seams), and geographically distributed across the underground mining area. They include:

- Standpipe piezometers between LW1 and Glennies Creek, some screened in the Pikes Gully seam (WML119, WML120A, and WML181 to WML186), others in the Glennies Creek alluvium (WML120B and WML129);
- Multi-level vibrating wire piezometer bores:
  - WML106 (south of start of LW1);
  - WML107 (south of start of LW2);
  - WML108 (south of start of LW3);
  - WML109 (6m inside start of LW4);
  - WML110 to WML113 (above southern ends of LW5 to MW9);
  - WML114 (above central part of LW5);
  - WML115 (above northern end of LW9);
  - WML144 (east of Glennies Creek);
  - WML189 and WML191 (above chain pillars between LW2 and LW3);
  - WML213 (south-west corner of UG area, near confluence of Bowmans Ck and Hunter River);
  - WMLC248, (recently installed east of LW1); and
  - WML269 (recently installed at the southern end of LW6).
- Deep standpipe piezometers WML20 and WML21 (screened in the Pikes Gully Seam);
- Shallow standpipe piezometers WML107B to WML115B (located adjacent to vibrating wire piezometers WML107 to WML115, and screened in the uppermost part of the Permian coal measures);
- Shallow standpipe piezometers RM2-3, RM5-6, RM8, T1-4, T9, RA16-17 and RA2, screened in the top of the coal measures overburden and regolith above the proposed LW/MW5-9 area;
- Shallow piezometers WML110C, WML111C, WML112C, WML113C and WML115C (adjacent to vibrating wire piezometers WML110 to WML115, and screened in alluvium);
- A network of shallow standpipe piezometers above the proposed LW/MW 5-9 mining area, screened in the Bowmans Creek alluvium (T1-7, T10, RA10, RA13, RA18, RM4, RM9 and PB2) and colluvium (RA8, RA12 and RA16-17); and
- Shallow standpipe piezometers WML180, RA27 and WML180 (south of LW4, LW5 and MW9 respectively, adjacent to Hunter River, and screened in Hunter River alluvium).

The majority of bores have been installed to monitor regional impacts, and to monitor any impacts on the Glennies Creek or Bowmans Creek alluvium. The monitoring bores located along the bank of the Hunter River, south of the underground mining area, are intended to monitor any impacts on the Hunter River alluvium. Various shallow exploration bores have been installed within the alluvial flat on the eastern side of Glennies Creek. These bores monitor groundwater levels in the Glennies Creek alluvium.

The bores have been monitored routinely since underground mining commenced, or earlier in some cases. A number of piezometers are equipped with automatic water level recorders, set to record at regular intervals (30min to 6 hourly) in order that any impacts related to subsidence effects can be detected and related precisely to the position of the longwall or other specific site activities occurring at the time. These are:

- RA27, located in the Hunter River alluvium south of LW5;
- WML120B, located in the Glennies Creek alluvium west of LW1;
- RM09, located in the Bowmans Creek alluvium, in the north of LW5;
- T1-P, located in the coal measures overburden, in the north of LW5; and
- WML184, WML186 and WML120A, located in the barrier between LW1 and Glennies Creek.

Automatic water level recorders were installed for a period in bores WML119 and WML129 set to record water levels at 6-hourly intervals. The remaining barrier bores WML181 to 183 and WML185 were monitored manually on a weekly basis from May 2007 - January 2008, and subsequently at least once per month.

Water level hydrographs relevant to the LW1 to LW4 extraction are shown on **Figures 4**, **5a&b**, **8**, **9**, **10, 12, 13** and **14**.

4.2 OBSERVED EFFECTS

4.2.1 PIKES GULLY SEAM

Composite plots of all Pikes Gully Seam piezometers are presented in **Figure 4** and **Figures 5a and 5b**. They include the following piezometers (see **Figure 2** for locations):

- Standpipe piezometers to the east of LW1 – WML119, WML120A, WML181, WML182, WML183, WML184 and WML186;
- Multi-level vibrating wire piezometers WML106-84m, WML189-93m, WML191-100m, WML115-144m and WML213-205m; and
- Standpipe piezometers WML20 and WML21, located within the underground mining area.

Groundwater level responses east of LW1

Piezometers east of LW1 (between LW1 and Glennies Creek) have not indicated any response attributable to the mining of LW4 (**Figure 4**). The trends observed in the piezometers are continuations of trends established during the mining of LW1.

Aside from the effects of several rainfall recharge events (discussed further on), the head difference between TG1A and the alluvium has remained essentially unaltered since its initial establishment between July 2006 - April 2007 (the period of LW1 heading development). Consequently, all the seepage impact occurred during LW1 development, and the actual extraction of LW1, LW2, LW3 and LW4 has not caused any further drawdown impact.

Groundwater levels in WML120A have continued to show steady recovery of approximately 0.7m/y, so that more than half of the initial drawdown has now been recovered. This steady recovery is also observed in neighbouring piezometers WML184 to WML186 (**Figure 4**). The partial recovery in water levels suggests a steady reduction in the hydraulic conductivity of the Pikes Gully Seam, possibly due to recompression of the cleat fracture flow pathways. As discussed below in **Section 6**, the gradual recovery in water levels has been accompanied by a gradual reduction in the rate of underground seepage inflows.

Aside from rainfall recharge events, water levels in WML119, WML181 and WML182 have revealed a steady drawdown trend of approximately 1m/y since the mining of LW1 began (**Figures 5a and 5b**). Piezometers remote from the Pikes Gully Seam outcrop have not shown any response to the recharge events.

Groundwater level responses in the SMP mining area

Piezometers which monitor the Pikes Gully Seam in the underground SMP area have all shown responses to underground mining (**Figures 5a and 5b**). Whilst most responses were observed during the mining of LW1, LW2 and LW3, continuing drawdown responses have been observed in WML21 and WML115 during the mining of LW4. The pattern of responses observed to date can be summarised as follows:

▼ WML106-84m and WML20 responded strongly to LW1 development headings, with WML20 responding further to LW2 headings. No significant responses were observed during the subsequent LW2 extractions. WML20 became dry during the nearby mining of LW3 maingate headings and is no longer monitored.

▼ Vibrating wire piezometer WML191-VW100 located in the chain pillar between LW2 and LW3 showed dramatic depressurisation in response to the mining of LW3. WML189-93m, which is also located in the chain pillar to the north of WML191 showed marked drawdown as the LW2 development heading passed and no further responses during the extraction of LW3.

▼ WML21, located in the northern part of LW5, responded strongly to the advance of the North West Mains and LW4 development headings past this point.

▼ WML115-144m is located closer to the North West Mains than the LW1-4 area. The continued drawdown response observed during the mining of LW4 is believed to be due primarily to drainage into the nearby North West Mains and development headings for LW4 and LW5, where the lowest point in the headings near WML115 is at an elevation of around -45mAHD.

▼ WML213 is remote from both LW1-4 and the North West Mains. The steady drawdown observed in WML213 during LW3 and LW4 is believed to be due to the combined effect of Ashton's underground and open cut operations, as well as mining activities on neighbouring mine sites.

Figure 6 shows the hydrostatic head profiles for multi-level vibrating wire piezometers WML189 and WML191 (which are located above chain pillars between LW2 and LW3) and WML115A and WML213, which are located outside the area of current mining.

The plots represent a snapshot of groundwater pressures in relation to the elevation for each piezometer, at the following times: prior to LW1 development (baseline levels), post LW1 extraction, post LW2 extraction, post LW3 extraction and post LW4 extraction.

Generally, under pre-mining conditions, in the Ashton area, pressures plot close to the 45° "hydrostatic line", although there is a slight shift from the line due to the upward head gradient.

Marked deviations from the hydrostatic line were first noted at WML189 and WML191 due to the depressurisation effects of LW2 development headings and LW3 extractions **(Figure 6)**. A small residual pressure remained in the Pikes Gully Seam within the chain pillar at both WML189 and WML191, even after the passage of LW3. Note that a significant depressurisation effect in both WML189 and WML191 is observed to have occurred at the Lemington 15 Seam level, approximately 45m above the Pikes Gully Seam, during the mining from LW3.

Steady deviations from the hydrostatic line have continued in WML213 as a result of neighbouring mining activities, and in WML115 due to drainage into the nearby North West Mains and development headings for LW4 and LW5 (**Figure 6**).

Potentiometric contours for the Pikes Gully Seam have been produced from groundwater levels measured in April 2009 and October 2009 (**Figure 7**). A comparison of potentiometric surfaces for these periods enables an assessment to be made of the depressurisation impacts during LW4 extraction. The potentiometric contours show:

- A tight "cone" of depression around the LW1-4 longwall panels, showing the recent expansion of the cone from the influence of the LW4 extraction, including influence from the heading development for LW5 which was occurring simultaneously. Note that water levels in the Pikes Gully Seam usually respond to mining of the development headings, with only limited additional drawdown occurring in response to subsequent longwall extraction.
- A secondary depression in the north-western part of the underground mining area. The water level impacts in WML21 and WML115-VW144m are believed to be due to the nearby North West Mains and development headings for LW4 and LW5.
- A drawdown effect at WML213, in the south western part of the Ashton underground mining area (see both **Figure 7** and **Figure 6**), which is almost certainly responding to the combined effects of LW1-4 and the North West Mains, and activity on neighbouring mines to the west and/or south.

4.2.2 PERMIAN OVERBURDEN UNITS

Bayswater and Lemington Seams

Varying drawdown impacts have been observed in piezometers that monitor the overlying Bayswater and Lemington seams. Hydrographs for these are presented in **Figures 8, 9 and 10**. The drawdown effects are also apparent on the hydrostatic head profiles (**Figures 6 and 11**).

Two Bayswater seam piezometers show definite drawdown, shown in WML113-40m and WML213-48m (**Figure 8**). These are believed to be responding to mining at the adjacent Narama mine, not the Ashton operation, as they have been on a consistent downward trend throughout the period of monitoring.

Three multi-level piezometers in the LW1-5 mining area and five others to the west of LW5 have shown recognisable drawdowns in the Lemington seams in response to the mining of LW4 (**Figures 8-10**). The horizons that show recognisable drawdowns are:

- WML109 – Lem7 and Lem11-12 (south of LW4);
- WML110 – Lem6OB, Lem 6, Lem8-9IB, Lem11-12 and Lem15 (southern end of LW5);
- WML114 – Lem6-9, Lem10-12, Lem15 and Lem19 (above middle section of LW5);
- WML111 – Lem7, Lem11-12, Lem15 (southern end of LW6);
- WML112 – Lem6-7, Lem 8 and Lem15 (above chain pillar between MW7 and MW8);
- WML113 – Lem9 and Lem10-12 (southern end of MW9), and

- WML213 – Lem8-9, Lem15 and Lem19.

Until recently, the steady drawdown trends noted across most shallow Lemington seams (Lem6-12) in the south west corner of the underground mining area (WML112, WML113, and WML213) were attributed to neighbouring mining activities. However, the recent and sudden drawdown observed in this area appears to have been exacerbated by the mining of LW4 (**Figure 8**). It is thought that this drawdown is related to mining effects, but not by actual mine dewatering. Similar effects have been observed within literature associated with longwall mining elsewhere in the world (Booth, 2006; Karaman et al, 2001), and is related to subsidence/storage response in the unconnected (tortuous and surface) fracture zones above the longwall panel. This effect does not lead to increased mine inflows, and is a transient level response that occurs in upper layers in advance of the impacts that occur due to mine dewatering. This effect and its implications to impact predictions are explained in **Section 4.3**.

With exception of WML189-48m, WML191-52m, WML107-38m, WML08-25m and WML109-65m, the Lemington seams remain partially saturated in piezometers near LW1-4 (**Figures 9 and 10**).

Top of the Coal Measures

WML110B, which is completed at the top of the coal measures above LW5, responded to mining of LW4 (**Figure 12**). A drawdown of about 1m was noted during May 2009, coinciding with passage of the LW4 past this location. At the same time, a small groundwater level impact of 0.5m was observed in the neighbouring colluvium bore WML110C.

Further to the north, standpipe piezometers completed into the upper weathered zone of the Permian coal measures in the Bowmans Creek floodplain area mostly show no impact on groundwater levels from the mining of LW4 (**Figure 12**). The exception is bore T1-P, which is completed into the uppermost water-bearing horizon in the Permian at a location within the Bowmans Creek floodplain, 80m west of the northern part of LW4. During August 2009, the groundwater level fell by about 2m in T1-P, coinciding with the passage of LW4 past this location. At the same time, no water level impact was observed in the alluvium bore T1-A at the same location.

4.2.3 ALLUVIUM

As reported in the LW1 End of Panel Report (Aquaterra, 2008a), a small drawdown of 0.4m was observed in alluvium monitoring bore WML120B, between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location (**Figure 13**). No further drawdown occurred in the alluvium bores during subsequent extractions of LW1, LW2, LW3 and LW4. All drawdown impacts occurred during the development heading stage of LW1.

A gradual recession of groundwater levels following a small recharge event in April 2009 is evident across some piezometers monitoring the Bowmans Creek and Hunter River alluvium (**Figure 14**). The recession of water appears to be associated with a reduction in rainfall recharge (experienced during the months of June - October 2009), rather than underground mining, as there is no discernable response to mining advance.

Piezometers situated in close proximity to LW4, which monitor the Bowmans Creek alluvium (RM09 and T1-A, above LW5) and the Hunter River alluvium (RA27, south of LW5) did not indicate any groundwater level impacts during the mining of LW4 panel (**Figure 14**).

4.2.4 RECHARGE

A number of small rainfall recharge events in April 2009, June 2009 and August 2009 during the LW4 extraction caused water levels in the alluvium to rise by up to 1 m in all bores monitored close to Glennies Creek (e.g. WML120B and WML129 west of Glennies Creek and WML240, WML247, WML 252, WML253 and WML256 east of Glennies Creek - see **Figure 13)**. As transducers were not present during the monitoring period, recharge responses were not detected in coal measures in bores close to the outcrop (Pikes Gully bores WML119 and WML120A - **Figure 4**). Bores distant from the outcrop showed no response to these recharge events (e.g. Pikes Gully Bores WML181-186 – see **Figure 5a**; and the deeper Lemington Seam bores – see **Figure 10**).

4.2.5 POST EXTRACTION RECOVERY IN WATER LEVELS

Several piezometers have shown partial recovery of groundwater levels after initial drawdown impacts from mining. The best example of this is WML107-98m set at the Lemington 19 Seam (**Figure 10**), which showed drawdowns during LW1 development headings, and again at the start of LW2 and LW3 extraction. Following each initial drawdown, the groundwater level has risen by several metres, although each rise represents only partial recovery.

Similar effects were noted during the mining of LW4 at nearby piezometers WML110-65m, WML110-90m, WML110m, WML111-118m and WML114-88m and WML114-108m (**Figure 9**).

As previously discussed, recent and greater understanding of rock stress impacts from long wall mining suggests that the drawdown and partial recovery seen in the Lemington seams at distance from the longwall panels is a pressure response associated with changes in storage in the rock mass above the longwall panels, rather than a drainage response related to mine dewatering and inflows. The physical movement of coal seams within caved areas can also cause a hydraulic disconnection between coal seams within the goaf and the seams outside of the goaf area. These effects are described in detail in **Section 4.3**. It should be noted that the sudden depressurisation noted in piezometers close to LW4 (WML110, WML111 and WML114) was not accompanied by an increase in underground flow, which supports the evidence of a storage/pressure response, rather than a dewatering response.

Standpipe piezometers WML120A and WML183 to WML186, located within the Pikes Gully Seam between LW1 and Glennies Creek have shown steady recovery post LW1 extraction (**Figure 5**). The WML120A response is particularly significant, as the water level in this bore is controlled by the head difference between Glennies Creek alluvium to the east and TG1A to the west, and the hydraulic conductivity of the Pikes Gully Seam between the two. As the head difference between Glennies Creek alluvium and TG1A has remained essentially unchanged during the period of ongoing mining, the water level recovery can only have occurred as a result of a progressive reduction in the hydraulic conductivity of the Pikes Gully Seam between the creek alluvium and the mine. This may be due to progressive silting up of the cleat fractures by fines deposited from the through-flowing water, or a delayed benefit from the TG1A rib-grouting measures that were implemented to reduce inflows during LW1 extraction. The reduction in observed inflow rates to TG1A (see **Section 6**), and the fact that this occurs at the same horizon as the mining indicates that this is definitely due to changes in permeability, and not the storage/pressure response discussed above.

4.3 ANALYSIS OF MINING RELATED IMPACTS

As discussed in previous sections, there are a number of boreholes within the Permian overburden to the south and west of the underground mine that have shown marked responses to the longwall mining, even at distances of 500m or more from the edge of the longwall panel. It is important to note that the majority of these 'distant' impacts are <u>not</u> related to dewatering and inflow to the mine, but are actually associated with transient **pressure-storage responses** that have been well observed and documented in international research (Booth, 2006; Karaman et al, 2001).

All underground mines potentially drain groundwater from aquifers with which they are in contact, but the subsidence and strata movement due to longwall mining also affect the groundwater system independently from mine drainage. Above a mined panel, the overburden strata form three major zones of deformational and hydrologic response (Booth, 2002; Younger et al. 2002; SCT, 2008), as shown in **Figure 15** and discussed below:

- **Zone 1**: A fully caved zone that occurs just above the coal seam.
- **Zone 2:** A 'fracture zone' where there is large scale cracking and associated connectivity between the fissures and bedding planes that are created. This leads to varying degrees of increases in the horizontal and vertical permeability of the rock strata.
- **Zone 3:** A 'constrained zone' or 'aquiclude zone' which may include some vertical cracking, but where disturbance is more dominated by bed separation and there is limited vertical connectivity. This leads to either small increases in vertical bulk rock mass permeability, or no effective change, depending on the mining stresses and geotechnical characteristics of these upper strata layers.
- **Zone 4:** A surface cracking zone, where tensile stresses and subsidence cause shallow surface cracks in unconsolidated or weathered near surface materials.

The proportion of the overburden that falls within each of these zones varies according to the width and depth of mining. For shallower parts of the mine (e.g. most of LW 1-3), Zones 1 and 2 may extend almost to surface, and Zone 3 will effectively not exist. Zone 4 will still be different, as it contains large, unconfined storage, but it may be in hydraulic connection to Zone 2.

The nature of the impact that longwall mining has on piezometric heads above the panel, and on strata outside of the panel area, is very different for each of these zones, as shown in **Figure 15.**

Zone 1 displays a 'conventional' dewatering impact. Pressures drop rapidly in response to the depressurisation of the longwall panel and water continues to move through into the mine. Boreholes located outside of the longwall in these strata layers will exhibit a sustained, ongoing loss in piezometric head as water moves towards the mine workings and creates a widening cone of depression. This impact is fully contained within the Ashton groundwater modelling and reflected in the EIS predictions.

In **Zone 2,** the very lowest seams (e.g. Lemington 19) exhibit a dewatering response in the boreholes outside of the goaf area, as expected. However, in some of the higher coal seams within this horizon (e.g. Lemington 15), the physical movement of strata within the goaf area actually leads to a hydraulic separation between the coal seams within the goaf area and the same seams outside of the goaf area. These seams move vertically within the goaf, but the strata layers around them remain largely in-tact. This causes low permeability roof materials within the goaf to become inter-layered against the coal seams outside of the goaf, which hydraulically separates the coal seams from the goaf and mineworkings. This completely prevents any dewatering, and can lead to rapid recovery of pressures within the coal seam outside of the goaf area if there is any recharge or recompression of the coal seam.

In **Zone 3**, fractures and bedding planes above the longwall panel 'dilate' in response to the rock mass stresses. This causes a rapid increase in the effective storage of those layers. Because these layers are highly confined in-situ, and have a very low natural storage coefficient, this increase in storage causes a rapid, and often very large, reduction in piezometric pressure in the strata above the panel, which is not accompanied by any loss of water from storage. This drop in pressure causes a head gradient, which causes strata around the longwall panel to lose pressure in response.

Although these strata layers are generally low permeability, they also have a very low storage coefficient. Karaman et al (2001) show that the rate of depressurisation at a given distance from the longwall panel is entirely related to the ratio of transmissivity to storativity. Piezometric responses in distant observation wells can therefore be relatively large and rapid if storativity is very low, even if horizontal permeability is also low. These transient pressure-storage responses will usually be set against a much slower, longer term trend of groundwater head loss that is related to mine dewatering and movement of water into the mine workings. The rate of the longer term dewatering trend depends on the degree of hydraulic inter connection that occurs in the 'tortuous cracking' region of Zone 3 above the longwall panel.

It is important to note that the transient, rapid piezometric responses in the strata layers within **Zone 3 are not related to mine dewatering.** Pressure is 'lost' simply because localised storage space is created above the longwall panel, and water moves into that space. The volumes of water involved are very small, and can often be recharged relatively quickly if there is any recharge to that strata layer. For a single longwall panel, this pressure-storage effect would lead to a rapid drawdown followed by a recovery response in an observation piezometer.

For multiple panels such as the Ashton underground, the pressure-storage response in **Zone 3,** and the hydraulic separation of the higher seams in **Zone 2,** leads to the cyclical drawdown pattern seen in the upper/mid Lemington seams (seams 6 – 15) in piezometers such as WML 106 – 108 (to the south of LW 1-3), and WML 110 – 115 (west of LW 4), as shown in **Figures 8, 9 and 10.** These show a drawdown response as each longwall panel passes, followed by a 'flattening' of the curve before the next longwall panel passes near the piezometer. In some cases, recovery starts to occur before the next longwall passes. This can be very rapid if it is caused by localised compression of strata after the longwall has passed (which significantly reduces storage and hence increases pressure).

These contrast with the constant drawdowns seen in most Lemington 19 piezometers, and all Pikes Gully Seam piezometers **(Figures 5, 9 and 10)**. These monitor strata layers that intersect the fully caved zone (**Zone 1**), and those seams in **Zone 2** where the rock mass is fully broken up and there is no hydraulic separation between the goaf and the coal seams outside of the panel. These seams are therefore fully connected to the mineworkings and hence are constantly losing water to the mine itself.

Because groundwater in **Zone 4** is unconfined and generally contained in unconsolidated sediments or highly weathered rock (which have relatively high storage properties), the increase in storage that is caused by surface tension cracking is small in comparison to the unconfined storage capacity. The drop in the water table is therefore also small. Any significant drops in water level within unconsolidated sediments will therefore be associated with either continuous cracking and direct connectivity to the underground workings, or with physical movement of the aquifer material in the subsidence zone directly above the panel.

The difference that the larger, unconfined storage capacity associated with unconsolidated sediments has on the observed pressure-storage response in Zone 3 can be seen in **Figure 12.** Borehole T1-P, which is screened at the top of the coal measures and has very low storage, showed a large pressure-storage response to the passage of LW4 next to it. Borehole T1-A, which is screened in the alluvium, showed no response. Both are located close to the area of surface cracking that will have occurred in the tensile zone around the rib line of LW4. However, the much greater storage capacity and unconfined nature of the alluvium in T1-A means that it did not demonstrate any pressure-storage response to the surface cracking in Zone 3. This difference in responses clearly proves that the observed effect at T1-P is not related to dewatering and inflows to the mine workings.

Because this pressure-storage response only has a significant effect on low-storativity, heavily-confined strata layers, and represents a transient impact when set against the longer term, slower drawdowns caused by mine dewatering, the effect is not significant in terms of impacts to water resources. As discussed in **Section 6**, observed inflows to the mine workings are actually significantly lower than the EIS predictions, which supports the conclusion from the international research that pressure-storage responses do not affect mine inflows. The pressure-storage response is not therefore usually modelled as part of a longwall mine impact assessment, unless there are abstraction bores located in the confined layers that are affected. There are no such bores around the Ashton site, so the effect was not considered in the EIS or SMP. The influence that this effect has on some of the monitoring bores will need to be considered during the end of panel report for LW5, when comparisons will need to be made between piezometer observations and groundwater level predictions contained in the LW/MW 5-9 SMP.

5 GROUNDWATER AND SURFACE WATER QUALITY

5.1 MONITORING PROGRAMME

Monitoring of groundwater quality in the Glennies Creek alluvium, Bowmans Creek alluvium and Pikes Gully Seam was undertaken prior to the commencement of mining to establish baseline conditions. Bores WML119 and WML120A monitor the Pikes Gully Seam groundwater. Bores WML120B and WML129 monitor the Glennies Creek alluvium groundwater and Bores RM4 RM6-7 and RM9-10 monitor the Bowmans Creek alluvium. Other bores monitoring the Pikes Gully Seam or the alluvium are listed in **Table 5.1**. Further water quality sampling of the bores has taken place intermittently since underground mining commenced.

Data from an extensive underground water quality monitoring program was collected throughout the mining of LW1 and has been previously reported by Aquaterra (2008a). Initially, while access was available to the TG1A development heading, samples were collected separately from several locations along the eastern rib of TG1A, and from various other underground locations. As access to TG1A was progressively lost due to the longwall advance, water quality monitoring of seepages from the eastern rib of TG1A was maintained by monitoring the discharge from the LW1 Backroad Pipe (**Figure 2**), as explained earlier in **Section 1**. This discharge comprises the total of all seepage into TG1A.

EC monitoring of the LW1 Backroad Pipe discharge from TG1A has continued through the extraction of LW4.

5.2 MONITORING RESULTS

A summary of all available EC measurements from the monitoring bores is detailed in **Table 5.1**, together with selected readings from underground seepages and surface water sampled from Glennies Creek.

Graphs of measured EC values from the TG1A seepages and monitoring bores are indicated on **Figures 16** and **17**.

On the basis of the water quality monitoring data, the typical pre mining salinity (EC) of the water sources were as follows:

- Pikes Gully Seam:
  - 6000 to 6500 μS/cm (north of LW1 CT13)
  - 8000 to 9000 μS/cm (south of LW1 CT14)
- Glennies Creek alluvium - 500 to 2200 μS/cm,
- Bowmans Creek alluvium – 1000 to 1700 μS/cm,
- Glennies Creek surface water - 250 to 350 μS/cm (increases to 800 to 900 μS/cm during high runoff), and
- Bowmans Creek surface water - 600 to 1000 μS/cm (increases to 2000 μS/cm during low flow).

Groundwater EC from piezometers that monitor the Pikes Gully Seam and the Glennies Creek alluvium have shown responses to mining, most of which occurred during the development headings and subsequent mining of LW1. Piezometers that monitor the Bowmans Creek alluvium have only responded to climatic variability. The pattern of responses observed to date can be summarised as follows:

- Significant decrease in EC was observed during the development headings stage and mining of LW1, viz:

  - Pikes Gully piezometers WML120A and WML119 as a result of induced water flow from the Glennies Creek alluvium towards the mine through the Pikes Gully Seam,
  - Glennies Creek piezometers WML120B and WML129 due to elimination of some of the upward leakage of saline groundwater from the underlying Permian coal measures, as the groundwater levels in the Pikes Gully Seam are now lower than in the alluvium in this area as a result of the dewatering associated with the underground mine, and
  - LW1 Backroad Pipe (total TG1A seepage) as a result of induced water flow from the Glennies Creek alluvium towards the mine through the Pikes Gully Seam.
- After some EC decline during the development headings stage of LW1 and mining of LW2, the EC of monitored alluvium bores, Pikes Gully bores and LW1 Backroad Pipe have generally remained steady during LW3 to LW4 panel extractions.
- Salinities in the Bowmans Creek alluvium fluctuate from a minimum of 1000 to a maximum of 2000 µS/cm EC. The steady decrease in EC over the LW1-4 mining period is attributed to dilution from rainfall recharge.
- A dramatic decrease in reported groundwater salinity from 1820 µS/cm to 86 µS/cm was observed in WML119 during the mining of LW3. This bore was damaged apparently after being hit by a vehicle. The very low EC has been caused by ingress of local rainfall runoff into the bore hole (the measured EC is now much lower than the EC measured in Glennies Creek).

Table 5.1: Groundwater and surface water EC values (µS/cm)

Source	Pre-Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction
	June - Sep 2006	Jan-07	May - June 2007	Nov 2007 – Feb 2008	Mar – June 2008	August 08 - March 2009	May - November 2009
Pikes Gully Seam							
WML 20	6240	-	6030	-	-	-	-
WML 21	8140	-	8530	-	-	-	7550
WML 119	6470	4940	3090	2320	-	86 - 1820	87 - 126
WML 120A	6350	1470	742	828	-	810 - 1140	919 - 935
WML 181	-	-	4920	-	-	2460 - 2680	2600 - 2640
WML 182	-	-	4220	8680	-	6510 - 6950	6390 - 6760
WML 183	-	-	8570	8180	-	5310 - 5950	5310 - 5950
WML 184	-	-	-	4560	-	4400 - 5140	4940 - 5270
WML 185	-	-	-	4430	-	2900 - 2940	2310 - 2710
WML 186	-	-	-	463	-	-	933 - 1300
Glennies Creek Alluvium							
WML 120B	1930	1260	1020	1220	-	915 - 992	903
WML 129	571	522	396	577	-	458 - 571	490
WML 148*	-	-	-	2170	-	-	-
WML 155*	-	-	-	978	-	-	-
WML 157*	-	-	-	842	-	-	-
WML 158*	-	-	-	745	-	-	-
Glennies Creek (Surface Water)							
SM7	235-518	268	319-325	347-643	402-652	235-727	270-774
SM8	235-527	267	318-328	339-699	400-644	239-754	264-764
SM11	238-542	268	320-329	335-686	410-650	476-768	277-769
Underground Seepages – TG-1A							
CT9-10	-	3770	3010	-	-	-	-
CT10-11	2820	1680	1390	-	-	-	-
CT11-12	2100	1060	1200	-	-	-	-
CT12-13	-	1740	1500	-	-	-	-
CT13-14	5600	2340	1470	-	-	-	-
CT14-15	-	4910	3050	-	-	-	-
CT15-16	-	5630	2950	-	-	-	-
CT16-17	-	8520	7190	-	-	-	-
CT17-18	-	7450	5960	-	-	-	-
LW1 BR Pipe	-	-	2830	1726-1950	1620-1760	1554-1772	1579-1666

* Exploration hole (now cemented up).

6 GROUNDWATER INFLOWS

Total groundwater inflow rate is determined by a water balance approach, using flow volumes recorded at water meters on the discharge pipelines and the imported water pipeline. Water exported from the mine is monitored by flow meters on the discharge pipelines, as is the water pumped into the mine to meet operational needs of the longwall operation.

Water is exported from the mine either via a borehole pump situated at the south west corner of LW1 (shown on **Figure 2** as the Backroad Sump Borehole) direct to the mine water supply circuit, or via pipelines along the gate-roads to the sump in Arties Pit near the mine portal.

The main contributions to groundwater inflow are seepage into TG1A (the eastern gateroad of LW1), small inflows to the north west mains, and broadly distributed goaf seepage into LW1, to LW4 goafs. Typically, no other persistent areas of seepage are seen.

The recorded total groundwater inflow rate to the underground mine at the completion of LW1 was 0.48 ML/d (5.5 L/s), and during extraction of LW4 varied between about 0.08 and 0.4 ML/d, i.e. between 1 and 4.5 L/s with an average of around 3.5 L/s (**Figure 18**).

The total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1 to LW4, seepages into maingate roads of LW4, all inflows to the North West Mains, and other miscellaneous seepages. The figures are conservative, as they may also include a component of recycled water derived from seepage losses back into the North West Mains from the sump in Arties Pit beside the mine portal.

The flow rate of total seepage into TG1A (easternmost heading of LW1) is monitored separately from other inflows, to allow determination of the relative percentages of groundwater from Glennies Creek alluvium and the coal measures aquifers. The TG1A seepage inflow rate as measured from the LW1 Backroad Pipe (**Figure 2**) reached a peak rate of 3.4 L/s in July 2007, but has since declined to an average rate of 1.5 L/s over the period of LW4 extraction (April 2009 to October 2009). Based on EC comparisons with both the Pikes Gully Seam and Glennies Creek alluvium in-situ salinities, it has been estimated that approximately 70% of the total seepage is derived from the Glennies Creek alluvium, i.e. an average of 1 L/s (equivalent to 0.08 ML/d). Since completion of LW1, the EC of the discharge from the Backroad Pipe has stabilised at around 1500 to 1700 µS/cm (**Figure 17**). The seepage rate from the Glennies Creek alluvium continues to decline gradually. No change in seepage rate or seepage water quality was observed to occur during the extraction of LW4.

7 COMPARISON WITH EIS AND SMP PREDICTIONS

7.1 EIS PREDICTIONS

The predicted groundwater impacts as a result of the Ashton underground mine included in the EIS were outlined in the report *Groundwater Hydrology and Impact Report* (HLA Envirosciences, 2001). This was included in full in Appendix H of the EIS. The main parameters of predicted impacts were:

- Total rates of groundwater inflow to the underground mine – Section 5.2 (page 17) and Figure 11 of the EIS Appendix H,
- Total rates of seepage losses from the Glennies Creek, Bowmans Creek and Hunter River alluvial aquifer systems – Section 5.3 (pages 17-18) and Figure 13 of the EIS Appendix H, and
- Groundwater level drawdowns – Section 5.4 (page 18) and Figures 14-16 of the EIS Appendix H.

Each of the above parameters is addressed in turn in the following sections.

The predicted impacts were derived from HLA Envirosciences's groundwater flow model set up for the Ashton project investigations. The model description and modelling results are presented in Appendix F of the EIS (HLA Envirosciences, 2001).

The mine plan utilised as the base for the groundwater simulation modelling in the EIS involved the commencement of underground development in Year 2, and the commencement of longwall extraction in Year 4. In the HLA model, drain cells were enabled across the full extent of LW1 and the North West Mains from the start of Mining Year 4.

Underground development commenced in December 2005 and first intersected the water table in July 2006. LW1 commenced on 19 March 2007. Based on these dates, it is considered that the year July 2007 - June 2008 is equivalent to Mining Year 5 in the EIS simulation modelling. This has been assumed for comparative purposes. On this basis, the extraction of LW4 occurred during Mining Year 6 as modelled in the EIS.

7.1.1 GROUNDWATER INFLOW TO UNDERGROUND MINE

The measured/calculated total groundwater inflow rates to the underground mine since the commencement of monitoring are plotted on **Figure 18**, for comparison with the inflow rates predicted in the EIS for the equivalent stage of the mining operation.

The EIS predicted a progressively increasing total inflow rate, from zero in Years 1 and 2, increasing to 0.20 ML/d in Year 3, 0.45 ML/d in Year 4, 0.91 ML/d in Year 5 and 1.2 ML/d (14 L/s) in Year 6. Thereafter inflow rates to the underground mine were predicted to increase to a maximum of 1.7 ML/d (20 L/s) in Year 12. The predicted inflow rates for Years 1 to 6 as reported in the EIS are plotted on **Figure 18** in this report.

The recorded actual total groundwater inflow rate to the underground mine at the completion of LW1 was 0.48 ML/d (5.5 L/s), which was similar to the predicted rate at Mining Year 4. **Figure 18** shows that the actual inflow rate during the extraction of LW4 was in the range 1 to 6 L/s (i.e. 0.08 to 0.5 ML/d), well below the rate predicted for this stage of mining in the EIS (i.e. 16 L/s or 1.4 ML/d).

The total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1 to LW4, seepages into maingate roads of LW4, all inflows to the North West Mains, and other miscellaneous seepages. The figures are conservative, as they may also include some recycled water, derived from seepage losses back into the North West Mains from the sump in Arties Pit beside the mine portal.

7.1.2 SEEPAGE LOSSES FROM GLENNIES CREEK ALLUVIUM

The total seepage inflows to the Eastern Gate Road of LW1 have been closely monitored separately from other mine inflows since the first appearance of seepage as the LW1 development headings passed below the water table. Monitoring has continued to the present time through the installation of the collection system and LW1 Backroad Pipeline described in **Section 1**. In addition to flow rates, the EC and pH are monitored.

The seepage into TG1-A includes groundwater from storage within the Pikes Gully Seam, as well as water seeping through the barrier from the Glennies Creek alluvium. Through an assessment of the water quality of TG1-A seepages in comparison to the in-situ groundwater quality of the Pikes Gully Seam and the Glennies Creek alluvium respectively, it was calculated that approximately 70% of the total TG1-A seepage is derived from Glennies Creek alluvium. The balance comes from storage in the Pikes Gully Seam and other Permian strata. The derivation of this proportion was detailed in Peter Dundon and Associates (2007).

The actual seepage from Glennies Creek alluvium into the underground workings, calculated using the above analysis, is plotted on **Figure 18** together with the alluvium seepage inflow rates predicted in the EIS. Furthermore, the actual seepage inflow rates during LW4 extraction (approximately 0.66 – 1.2 L/s) are well below the EIS predictions (3.0 L/s) for this stage of the mining operation.

No increase in measured seepage rate was observed during the extraction of LW4. Rather, the plot of seepage inflows is showing a downward trend with time, which is consistent with the gradual recovery in water levels at WML120A and other bores described in **Section 4.2.5**.

7.1.3 GROUNDWATER LEVEL DRAWDOWNS

Predicted drawdown impacts on the Permian coal measures were only presented in the EIS for the completion of mining, not for intermediate stages of mine life. Hence it's not possible to compare actual impacts with the predicted impacts for the present stage of mining.

However, hydrographs of predicted drawdown in the Glennies Creek alluvium were presented as Figure 16 in the EIS (HLA Envirosciences, 2001). Two prediction hydrographs are shown, one denoted "North Bore" coinciding with registered bore GW064515 in Camberwell village (**Figure 2**), and another denoted "South Bore" at a location "within the alluvium overlying the sub-crop of the Upper Liddell Seam adjacent to the underground mine". Locations of the North Bore and South Bore are shown on Figure E1 of the Groundwater Assessment Report for the EIS (HLA Envirosciences, 2001).

Ashton has a network of monitoring bores located in the general vicinity of these two notional sites:

- G3B in Camberwell village (i.e. near "North Bore"), and
- WML120B and WML129 (alluvium bores on western side of Glennies Creek) and exploration bores AP242, WML249, WML239 and WML240 (on the eastern side of Glennies Creek) adjacent to the underground mine (i.e. near "South Bore"). The location of HLA's "South Bore" shown on their Figure E1 (HLA Envirosciences, 2001) it is situated very close to bores WML120B, AP242 and WML249 (see **Figure 2**).

Bore G3B has been dry through most of the period of underground mining, and has not been able to identify any impact. Monitoring of bore WML120B commenced before underground seepage started. It initially showed a drawdown of approximately 0.6m, and by the completion of LW4 extraction, the groundwater level at WML120B had recovered slightly to be around 0.4m below the pre-LW1 level. The EIS had predicted a 1.3m drawdown in Year 3, increasing to 2.2 m drawdown by Year 6, coinciding with the present state of underground mining. The hydrographs (**Figure 13**) indicate no suggestion that any significant drawdown has occurred at all in the alluvium east of Glennies Creek.

The total impact has continued to be well below the EIS prediction.

Likewise, hydrographs of bores in Bowmans Creek alluvium and Hunter River alluvium (**Figure 14**) reveal no evidence of any drawdown impact as a result of underground mining.

7.2 SMP PREDICTIONS

The Groundwater Assessment Report (Peter Dundon and Associates, 2006) prepared in support of the SMP Application for LW1-4 stated that inflow rates and seepage rates would be consistent with those predicted in the EIS, as described in **Section 7.1**.

7.2.1 TOTAL GROUNDWATER INFLOWS COMPARED WITH SMP PREDICTIONS

As indicated in **Section 7.1.1**, actual inflows during the extraction of LW4 have been well below the EIS prediction, which were adopted as predicted inflows in the SMP.

The LW1-4 Groundwater Assessment report (Peter Dundon and Associates, 2006) also calculated possible increased inflows to the underground workings due to increased recharge from rainfall following surface cracking over the longwall goaf areas. Several minor rainfall events occurred during the extraction of LW1 to LW4, but these were not accompanied by a measurable increase in goaf inflow rates. Hence, the subsidence cracking has not led to an increase in recharge rate.

7.2.2 ACTUAL SEEPAGE FROM GLENNIES CREEK ALLUVIUM COMPARED WITH SMP PREDICTIONS

It is evident that the actual seepage inflow rates during LW4 extraction (approximately 0.66 – 1.2 L/s) are well below the EIS predictions (3.0 L/s) for this stage of the mining operation.

No increase in measured seepage rate was observed during the extraction of LW4. Rather, the plot of seepage inflows is indicating a downward trend, consistent with the gradual recovery in water levels at WML120A and other bores described in **Section 4.2.5**.

Actual seepage inflow rates from the Glennies Creek alluvium during LW4 extraction were in the range 0.66 to 1.2 L/s, with an average of approximately 1 L/s (**Figure 18**). No specific seepage rate was predicted for LW4 in the LW1-4 Groundwater Assessment report. Although seepage was expected to occur during the development of LW1, the rate of seepage was not expected to increase during the mining of subsequent panels. Simple calculations based on Darcy's Law predicted that the seepage rate during LW1 extraction would be around 2L/s, with no increase during extraction of LW2 to LW4 or subsequent longwall panels. The actual seepage rates have therefore continued to be less than the maximum rates contained in the SMP predictions.

The End of Longwall 1 Report (Aquaterra, 2008a) concluded that there was no evidence of any increase in permeability in the barrier between LW1 and Glennies Creek as a result of subsidence impacts.

This situation has not altered with the extraction of LW2 to LW4. Subsidence impacts have been limited to areas immediately above the extraction panels, within the 20mm subsidence line defined by the 26.5° angle of draw from the goaf edge (SCT, 2006). As no change in barrier hydraulic conductivities has occurred, seepage rates from the Glennies Creek alluvium through the Pikes Gully Seam into the alluvium are related to the natural prevailing hydraulic conductivities in the barrier.

As indicated in **Section 7.1.2**, the seepage inflow rate has been declining. This suggests a possible reduction in the permeability of the barrier, possibly due to clogging by suspended fines, or a delayed benefit from the grout injection program implemented during 2007.

8 CONCLUSIONS

Mining of Pikes Gully Seam LW4 was carried out between April 2009 - October 2009. Monitoring data from this period continues to show that the groundwater in the coal measures aquifer system is saline, with salinities ranging to more than 8,000 µS/cm EC. Salinity of the groundwater in the Glennies Creek alluvium varies, but it is generally less saline than the coal measures. Alluvium salinity is typically less than 1000 µS/cm EC, or less than 800 mg/L TDS, but can be as high as 2500 µS/cm (2000mg/L TDS).

Prior to commencement of mining at Ashton, groundwater levels in the Permian coal measures were considered to be higher than both the alluvium and the stage level of the streams. Under natural conditions, groundwater discharged from the Permian to the alluvium and to the surface streams. This is still occurring in some places. Mixing of saline coal measures water with lower salinity water derived from local rainfall recharge is responsible for the salinity variability seen in both the alluvium groundwater and occasionally in the stream flow.

As underground mining is progressing closer to Bowmans Creek, subsidence monitoring is now being concentrated directly above the longwall goafs, rather than above the barrier between Glennies Creek and the mineworkings. A new survey line, XL10, has been established, which spans from the LW4 goaf to the oxbow bend of Bowmans Creek (where Bowmans Creek is closest to LW4). During extraction of LW4, XL5 was also surveyed over the LW3, LW4 and LW5 goafs both before and shortly after the longwall face passed the survey line. Lateral movement below Bowmans Creek was less than 20mm. The displacements detected are too small to indicate any horizontal shearing caused by the LW4 extraction. Without any shearing, the permeability of Bowmans Creek would not have undergone any significant change. Hence no increase in seepage losses from Bowmans Creek alluvium is expected to occur as a result of Longwall 4 mining.

There has been no significant increase in total mine inflows following goafing of LW4. Calculated total groundwater inflow rate during LW4 was around 1 - 6 L/s (i.e. 0.08 to 0.5 ML/d). The majority of mine water inflow is apparently coming from (or through) the Pikes Gully Seam.

Some of the highly confined, low storativity strata layers within the Permian to the south and west of the longwall panels have shown clear pressure-storage responses, consistent with that described in international research into longwall mining. This effect results from the subsidence and strata movement above the longwall panel. It is related to the creation of additional storage caused by fracture and bedding plane dilation. It is <u>not</u> related to dewatering that is caused by continuous cracking and hydraulic connection to the underground workings. The pressure-storage response can result in large piezometric responses at some distance from the mine workings, but these impacts are always transient, only occur in horizons with low storativity, and do not affect the longer term dewatering trends caused by the longwall mining. They are not therefore significant in terms of impacts to water resources around the Ashton Mine area.

A comparison of observed impacts with the EIS and SMP predictions has led to the following conclusions:

- ***Actual groundwater inflows have been below the EIS and SMP predictions at all stages of mining to date.*** Total groundwater inflows into the underground mine averaged approximately 0.08-0.5 ML/d (1 - 6 L/s) during the extraction of LW4, compared with the EIS and LW1-4 SMP predicted inflow rate for this stage of mining of around 1.4 ML/d (16 L/s).

- ***Actual seepage rates from the Glennies Creek alluvium have been at, or below, the EIS and SMP predictions at all stages of mining to date***. Calculated rates of actual Glennies Creek alluvium seepage into the underground mine during the LW4 extraction were approximately 0.6 – 1.2 L/s. Well below the EIS predictions (3L/s) and consistent with the LW1-4 SMP prediction (2.0 L/s).
- ***Groundwater level drawdown in the Glennies Creek alluvium has been significantly less than predicted in the EIS.*** Groundwater levels in bore WML120B indicated a residual net drawdown of about 0.4m by the completion of LW3 - well below the EIS prediction of 2.2m for this locality by this stage of mining. There is no evidence of any drawdown in the alluvium east of Glennies Creek.
- ***Monitoring suggests that the possibility of increased mine inflow from higher rates of rainfall recharge due to the subsidence fracturing is likely to be significantly less than that considered in the LW1-4 SMP groundwater report.*** No measurable increase in mine inflows occurred following significant rainfall events during mining of LW1, and smaller rainfalls during subsequent mining of LW2 to LW4.

In summary, all groundwater-related impacts from underground mining up to the completion of LW4 (October 2009) were at, or below the levels predicted in the EIS (HLA Envirosciences, 2001), and in the LW1-4 SMP Groundwater Assessment conducted in 2006 (Peter Dundon and Associates, 2006).

Most of the impacts relating to Glennies Creek had stabilised prior to the end of LW1, and no significant incremental impact or influence from mining LW2 - LW4 has been observed. Impacts on inflows and levels associated with Glennies Creek have generally continued to decline over time. There have been no observed impacts to date in relation to Bowmans Creek or its alluvium, either in terms of drawdown or mine inflow rates.

9 REFERENCES

Aquaterra Consulting Pty Ltd, 2008a. *Ashton Coal: End of Panel 1 Groundwater Report*

Aquaterra Consulting Pty Ltd, 2008b. *Ashton Underground Mine – LW/MW 5-9 Pikes Gully Seam Groundwater Impact Assessment Report.*

Aquaterra Consulting Pty Ltd, 2009a, *Ashton Coal: End of Panel 2 Groundwater Report*

Aquaterra Consulting Pty Ltd, 2009b, *Ashton Coal: End of Panel 3 Groundwater Report*

Aquaterra Consulting Pty Ltd, 2009c, *Ashton Coal: End of Panel 4 Groundwater Report*

Booth CJ (2002) *The effects of longwall coal mining on overlying aquifers.* In: Younger PL, Robins NS (eds) Mine water hydrogeology and geochemistry. Geological Society, London, Special Publications 198, pp 17–45

Booth, C. J. 2006. *Groundwater as an Environmental Constraint of Longwall Mining.* Environmental Geology 2006; No. 49, *pp 796 – 803.*

Department of Natural Resources (DNR), 2005. *Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region.*

HLA Envirosciences, 2001. *Environmental Impact Statement, Ashton Coal Project:* Appendix H – Groundwater Hydrology and Impact Report.

Karaman A, Carpenter P. J., Booth C, J. 2001 *Type Curve Analysis of Water Level Changes Induced by a Longwall Mine* Environmental Geology 2001; No. 40, *pp 897-901*__

Peter Dundon and Associates Pty Ltd, 2006. *Ashton Coal Mine Longwall Panels 1-4, Subsidence Management Plan – Groundwater Assessment.*

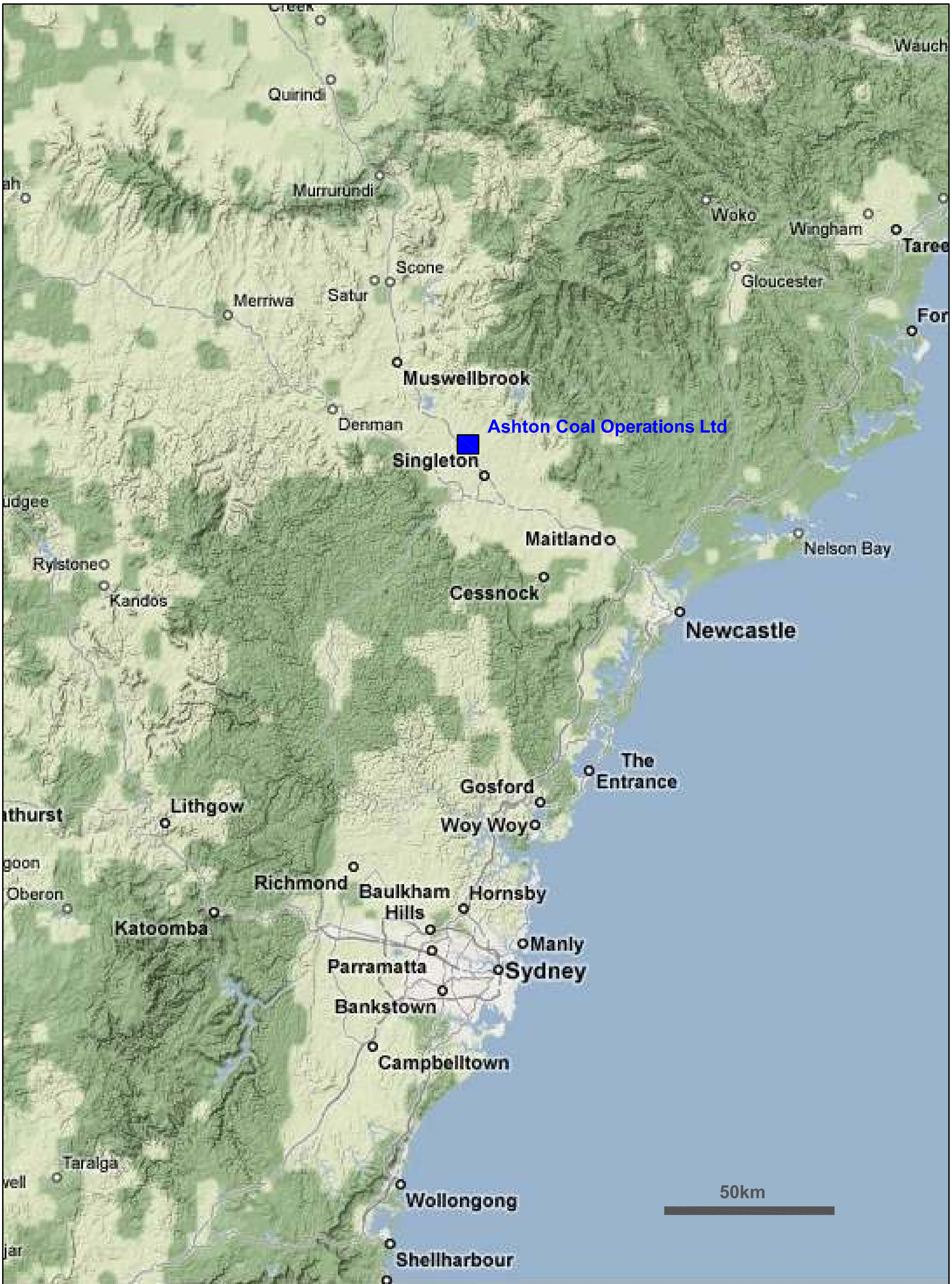
Peter Dundon and Associates Pty Ltd, 2007. *Ashton Underground Mine, Groundwater Impacts of Longwall 1, Comparison with EIS and SMP Predictions.*

Strata Control Technology (SCT), 2006. *Subsidence Assessment for Ashton Coal Mine Longwalls 1-4.*

Strata Control Technology (SCT), 2008. *Aquifer Inflow Predictions Above Longwall Panels.* Australian Coal Association Research Program (ACARP) project C13013

Younger PL, Banwart SA, Hedin RS (2002) *Mine Water: Hydrology, Pollution, Remediation*. Environmental Pollution, vol 5. Kluwer, Dordrecht, *442 pp*

FIGURES



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Initials:	JVDA	Job No:	S03	**LOCALITY PLAN** **ASHTON COAL OPERATIONS**
Drawing No:	S03-237a	Rev:	A	
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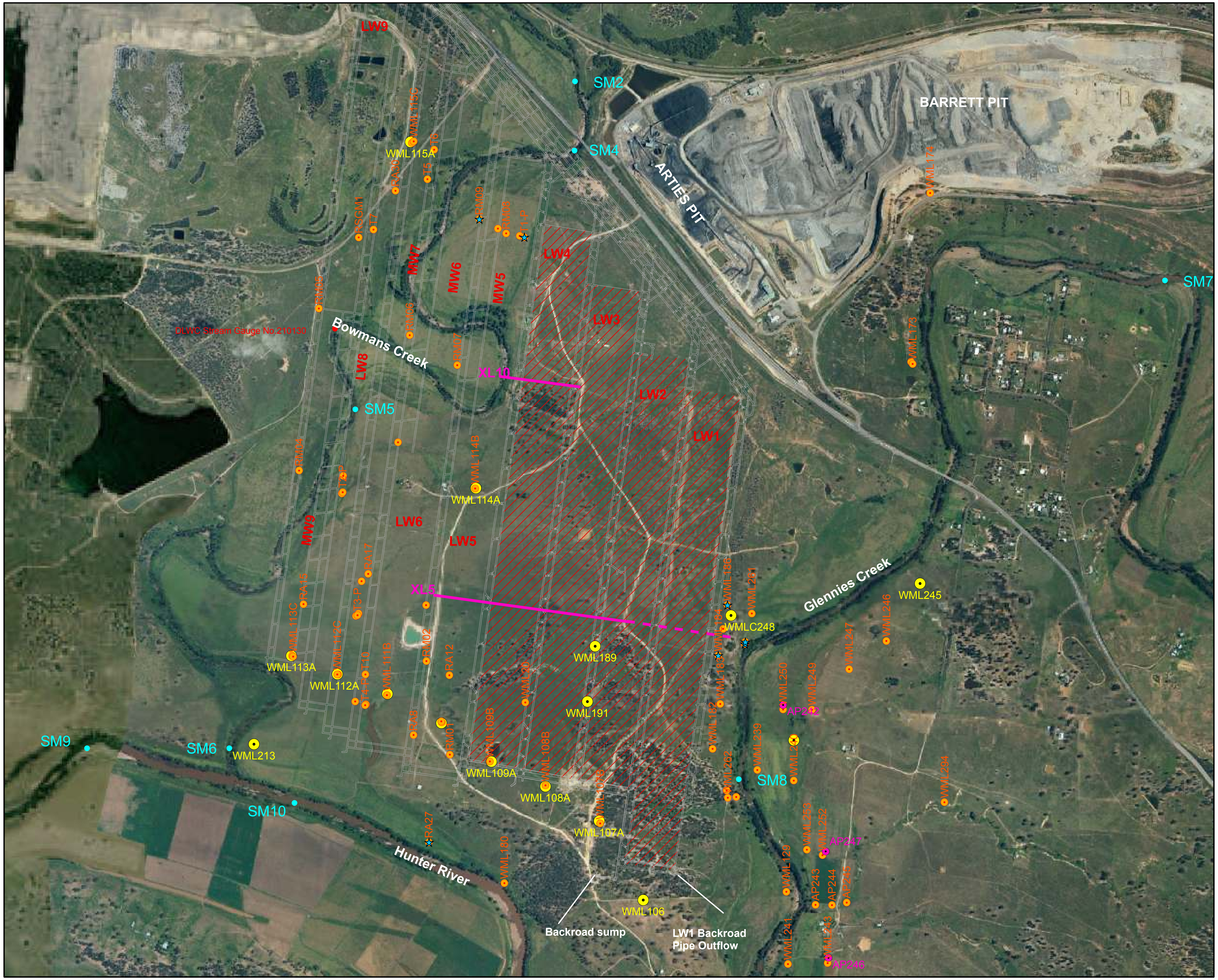


0 250 500 1,000 Meters

Legend

- Historic survey line (Pre LW4)
- Current survey line

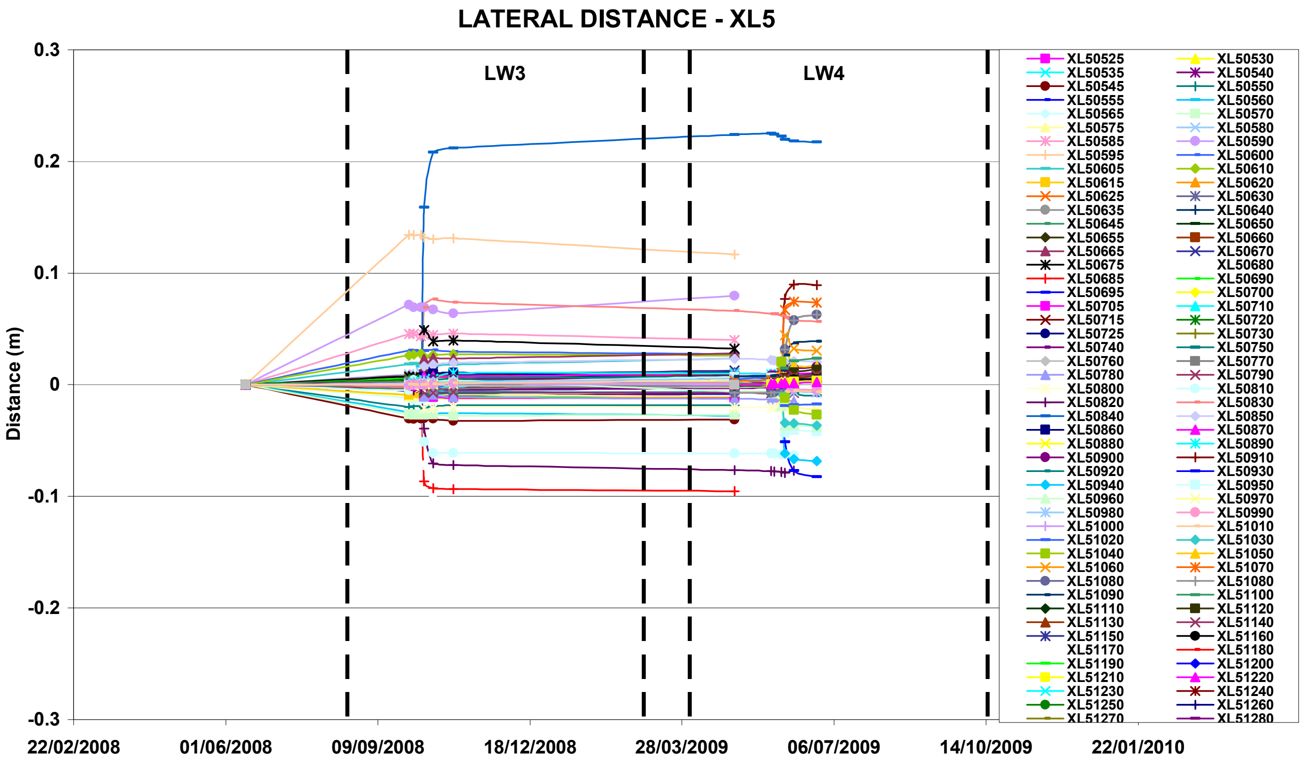
Monitoring Bores

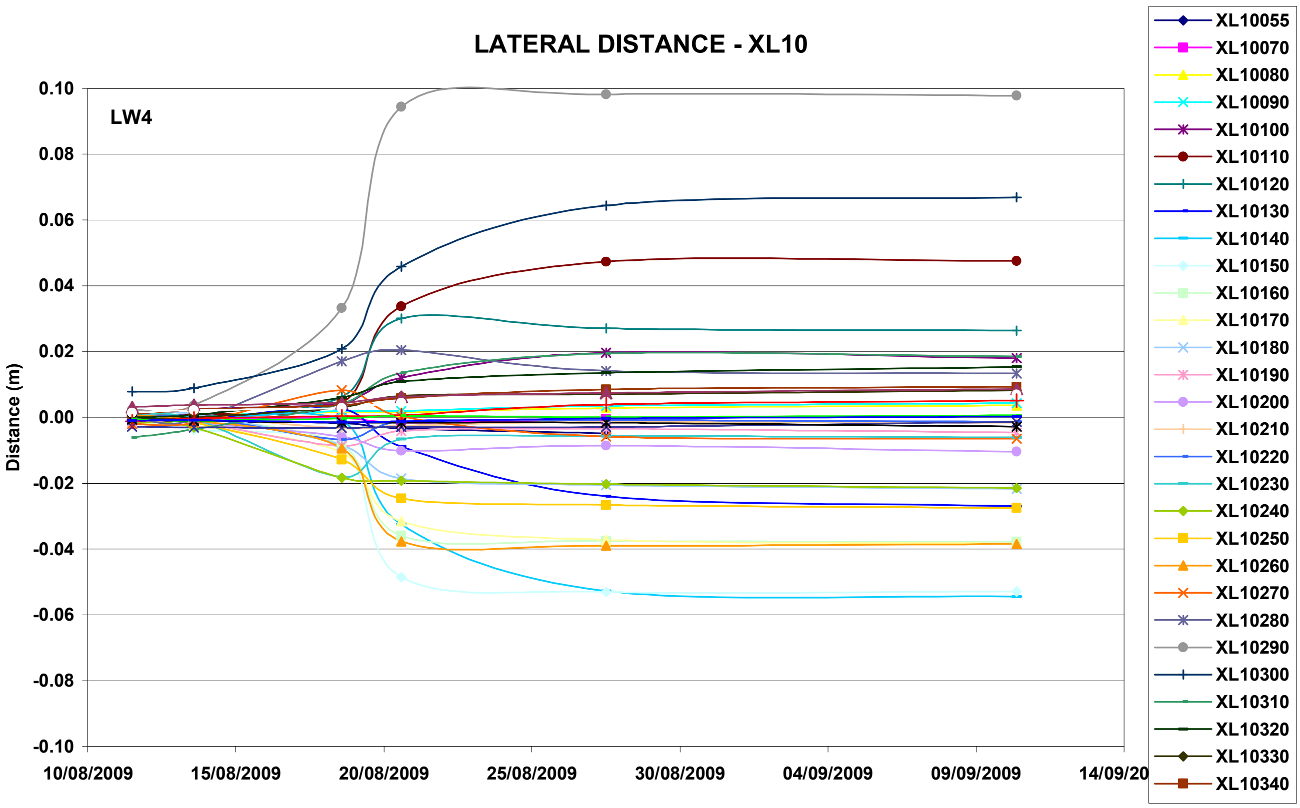
- Piezometer (Stand Pipe)
- Test Bore
- VW Piezometer
- Water level transducer installed
- Pikes Gully Mine Plan
- LW Mining Completed

aquaterra

Project: S55 D2	Date: 26/02/2010
Drawing No. 002	Revision : A
Drawn: JVDA	Datum: WGS1984

Figure 2
Ashton Underground Mine
Monitoring Bore Location Plan





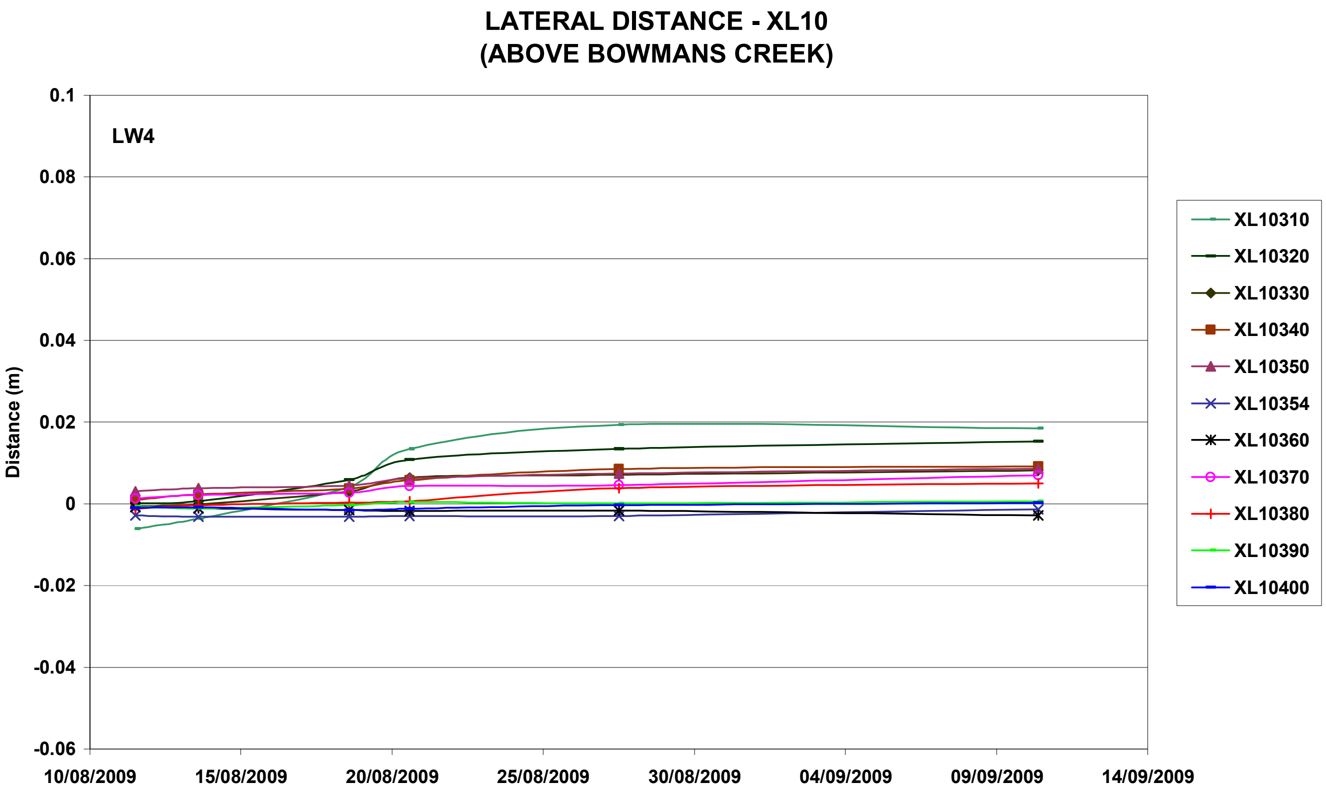
Date	17 November 2009	Scale	
Initials	JVDA	Project	S55 D2
Drawing Number	005	Revision	0

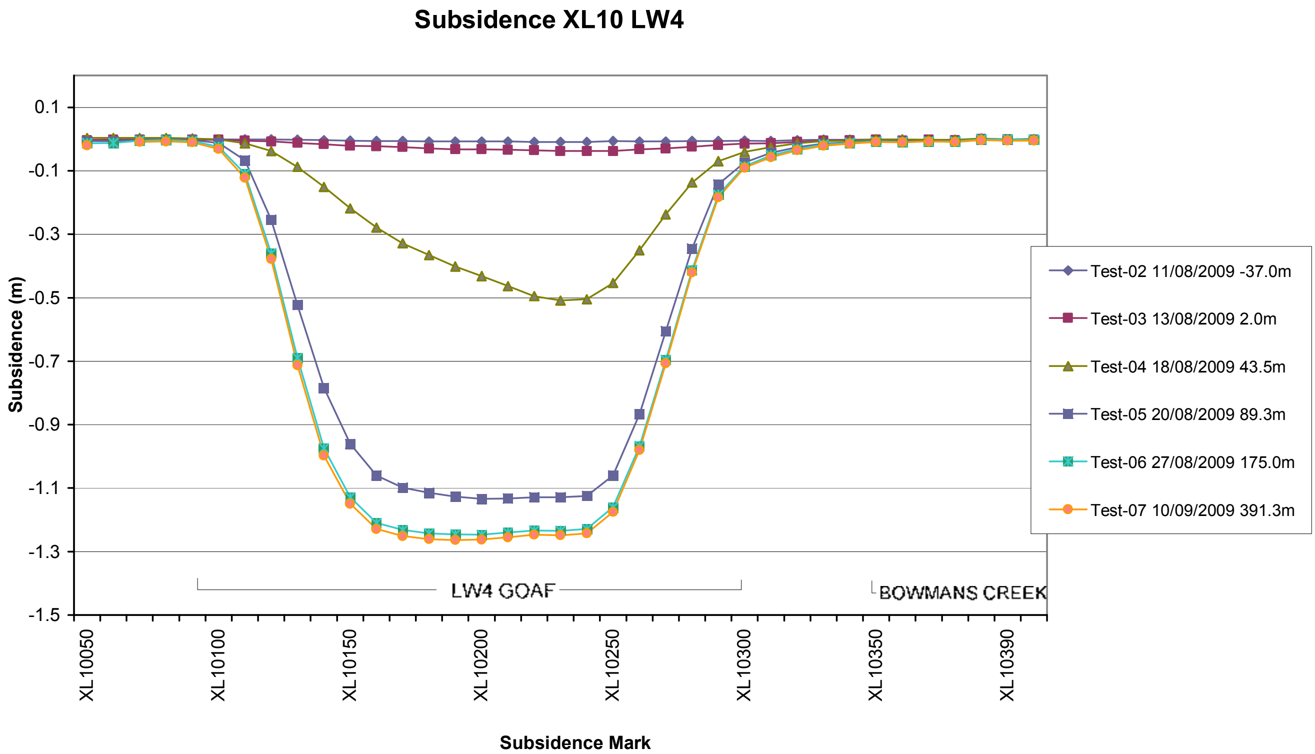
aquaterra

Ashton Coal Operations Ltd

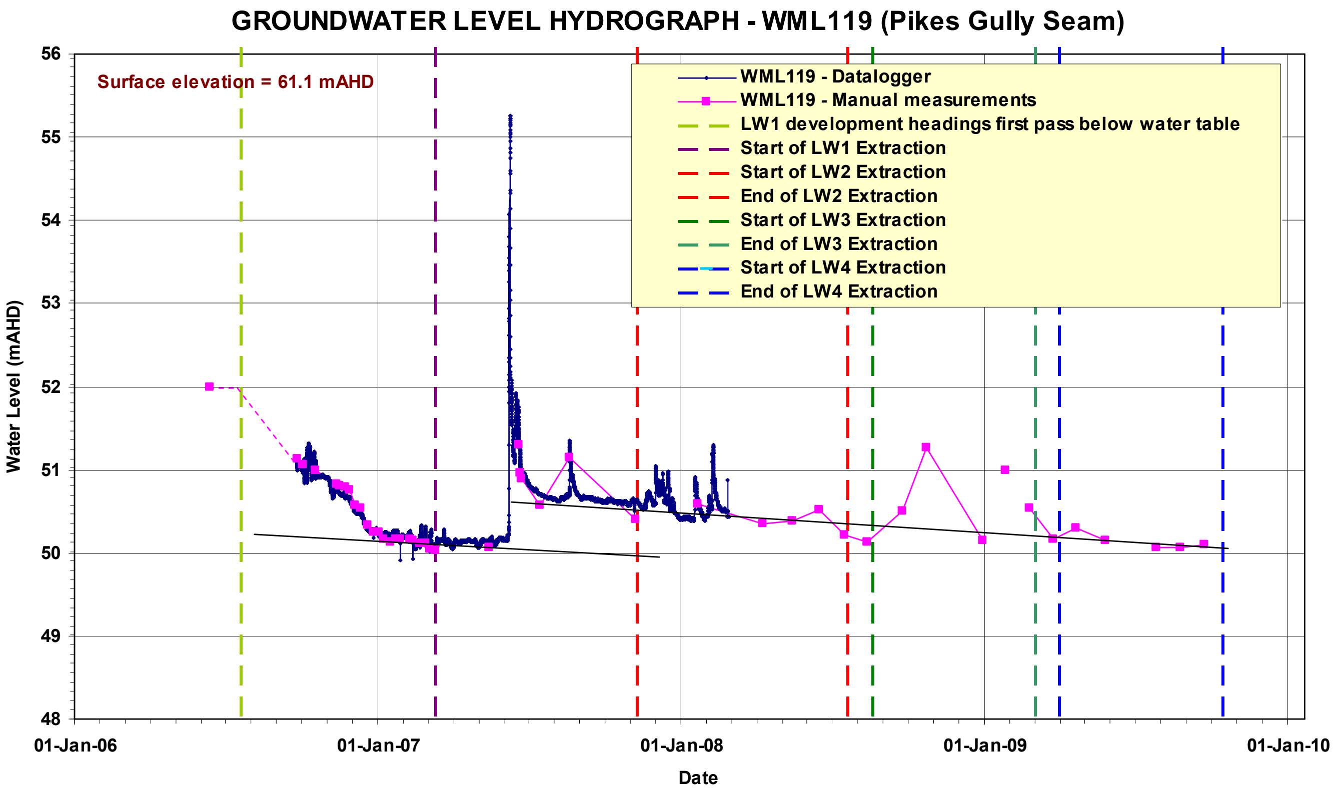
SURVEY CROSS LINES XL5 and XL10
HORIZONTAL MOVEMENT v TIME

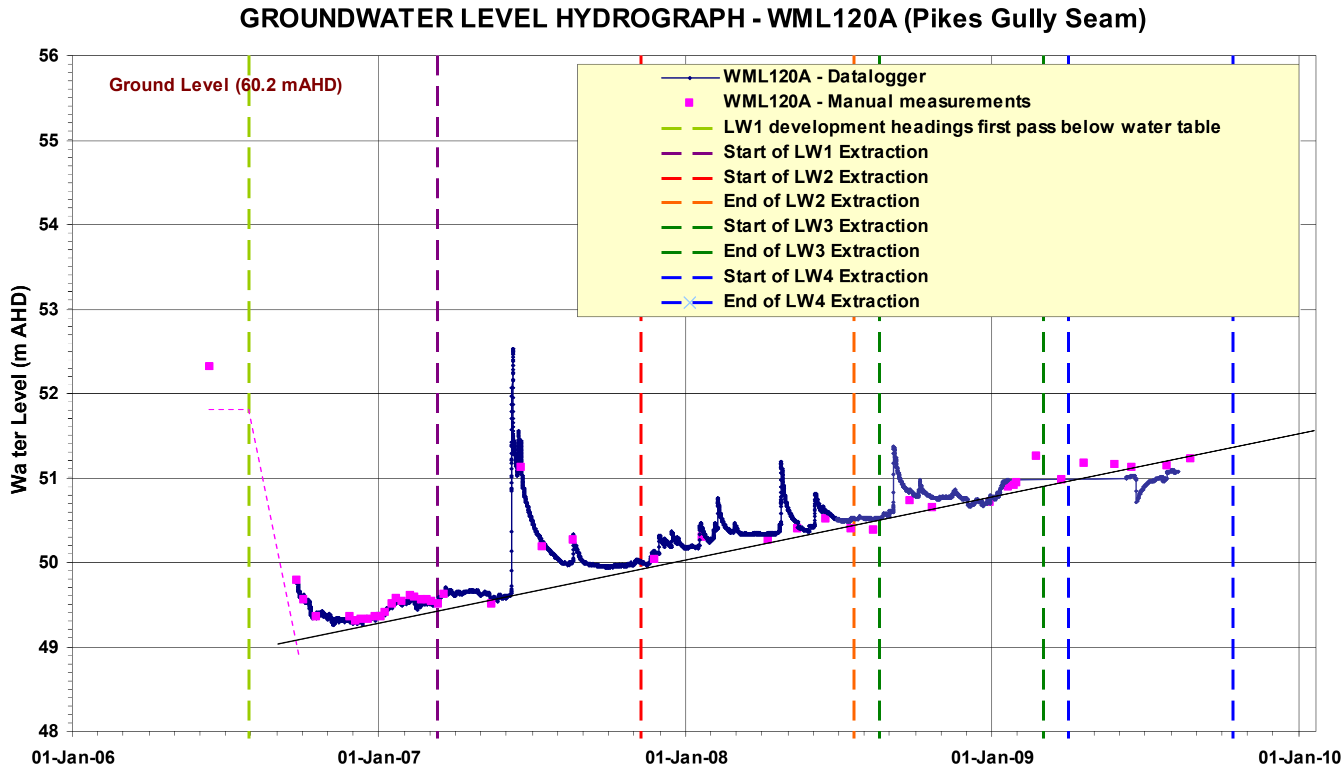
Figure 3a





Date	17 November 2009	Scale	**Ashton Coal Operations Ltd**
Initials	JVDA	Project S55 D2	SURVEY CROSS LINES XL5 and XL10 HORIZONTAL MOVEMENT v TIME
Drawing Number 005		Revision 0	
aquaterra			**Figure 3b**





Date **17 November 2009**	Scale	**Ashton Coal Operations Ltd**
Initials **JVDA**	Project **S55 D2**	GROUNDWATER LEVEL HYDROGRAPHS Pikes Gully Seam WML119 and WML120A
Drawing Number **006**	Revision **0**	
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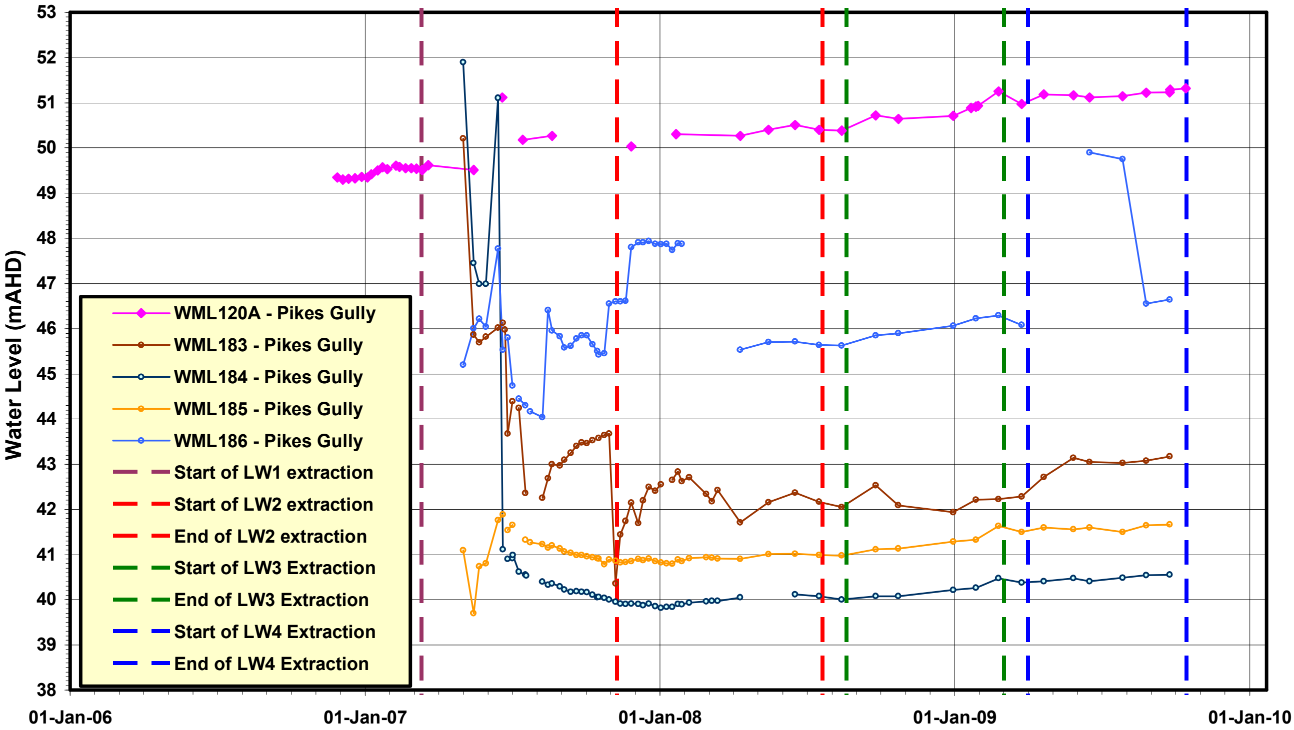
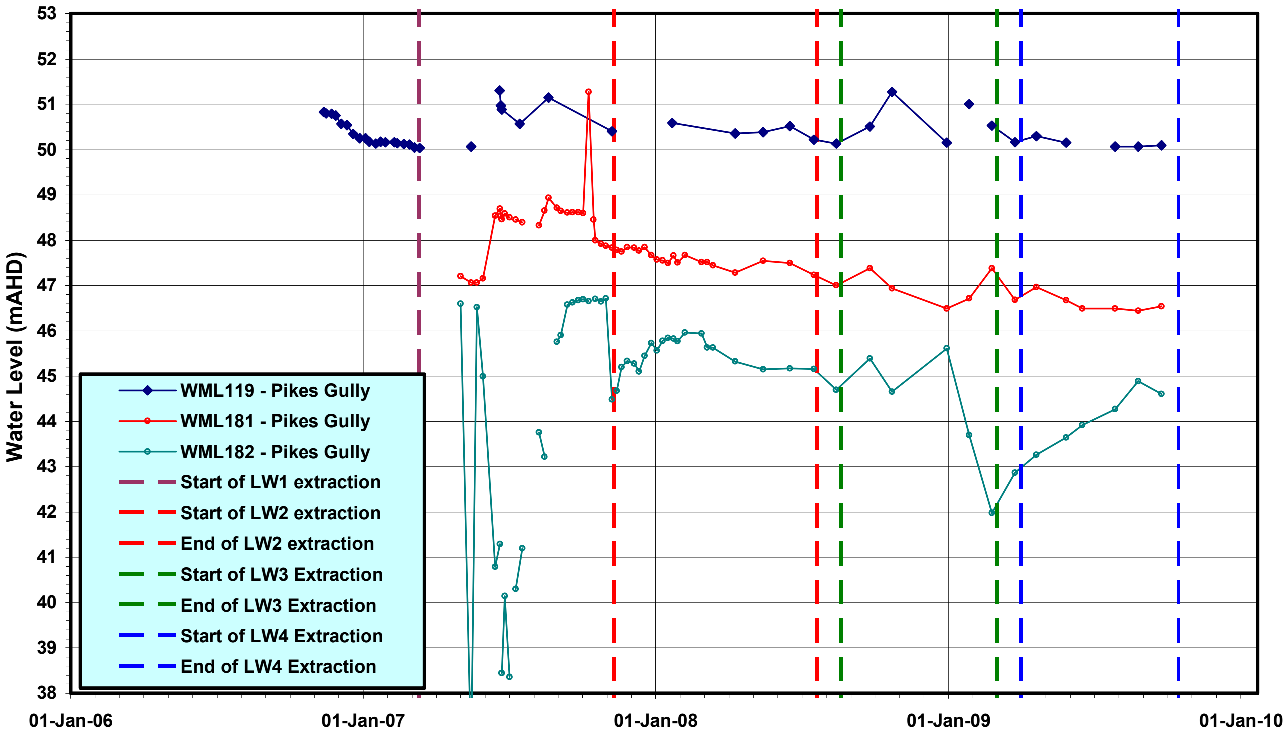
ASHTON - PIKES GULLY SEAM HYDROGRAPHS - EAST OF LW1



ASHTON - PIKES GULLY SEAM HYDROGRAPHS - EAST OF LW1



Date 17 November 2009	Scale		**Ashton Coal Operations Ltd**
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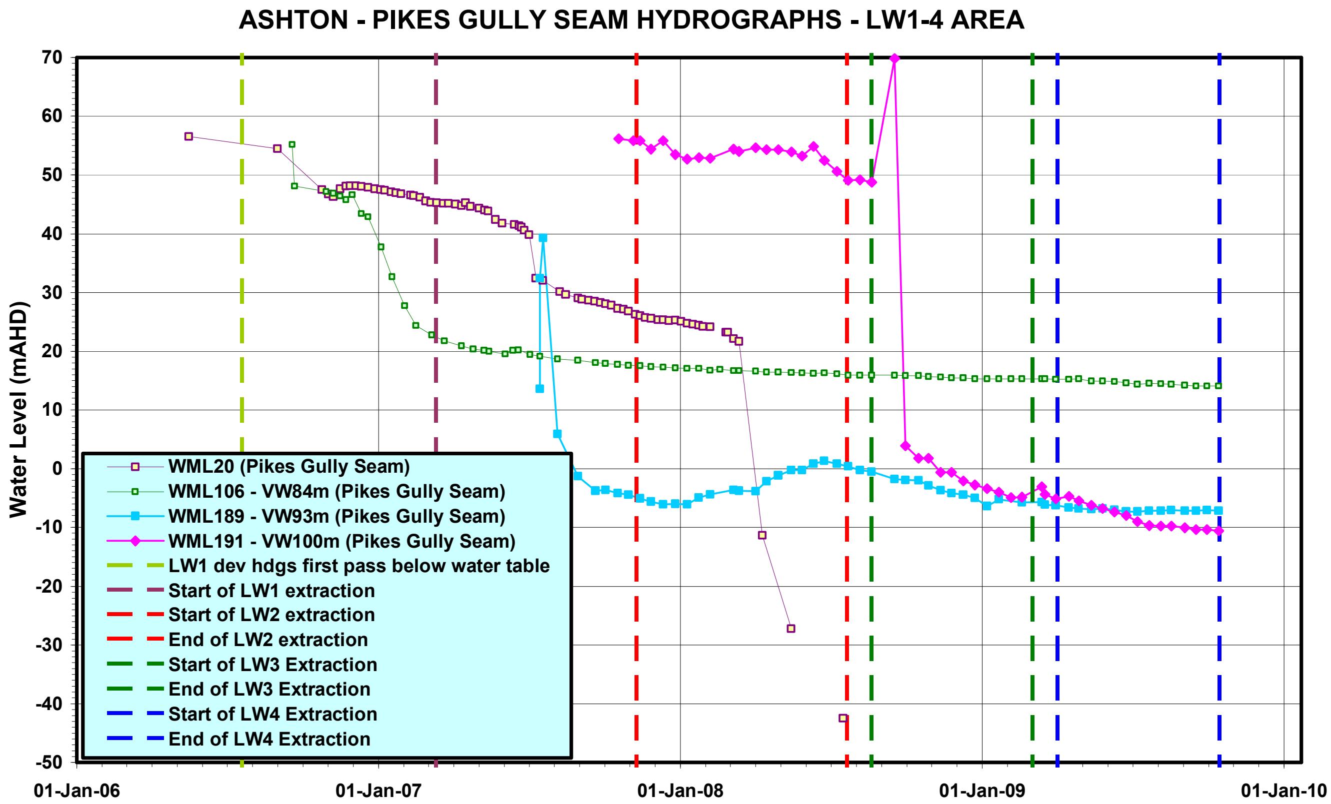
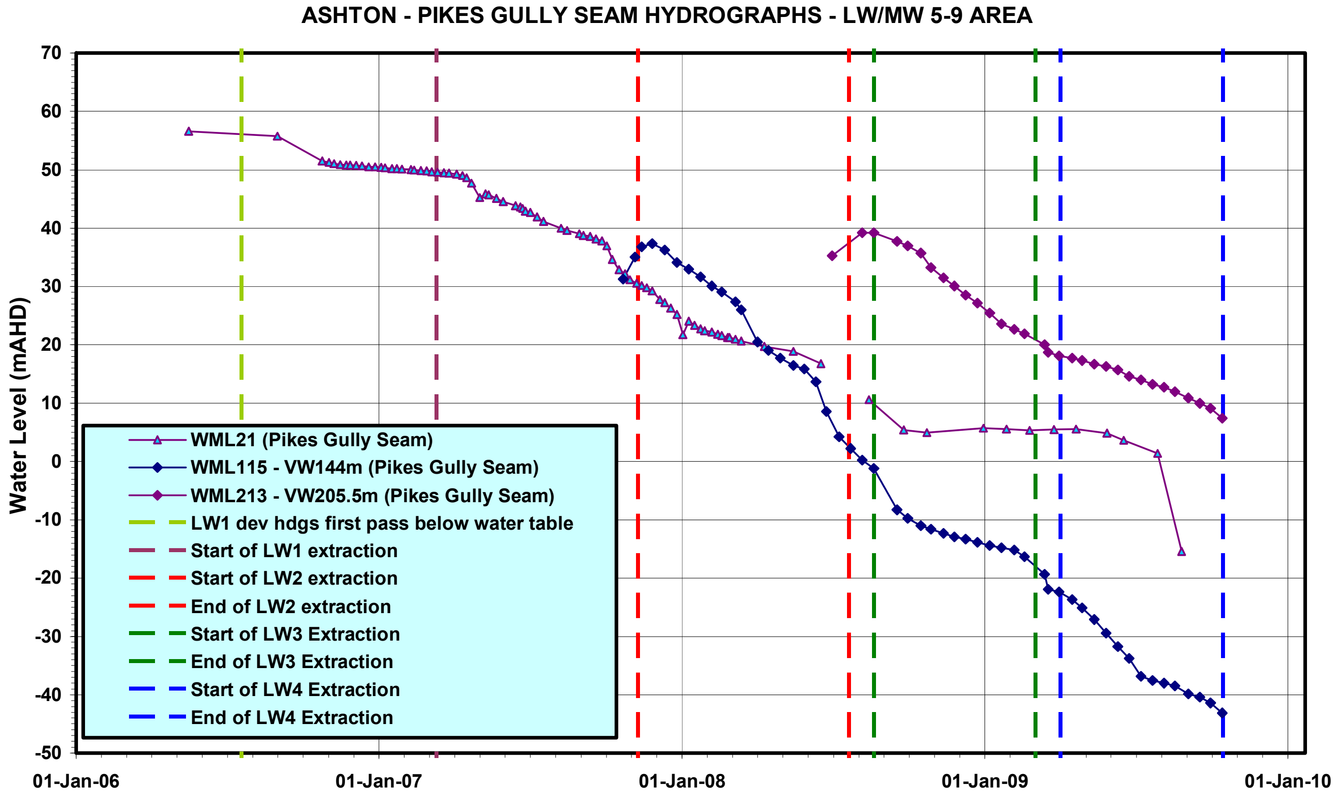
Drawing Number 007	Revision 0		
aquaterra			**Figure 5a**





Date **17 November 2009**	Scale	**Ashton Coal Operations Ltd**
Initials **JVDA**	Project **S55 D2**	**GROUNDWATER LEVEL HYDROGRAPHS** Pikes Gully Seam - Mining Area
Drawing Number **007**	Revision **0**	
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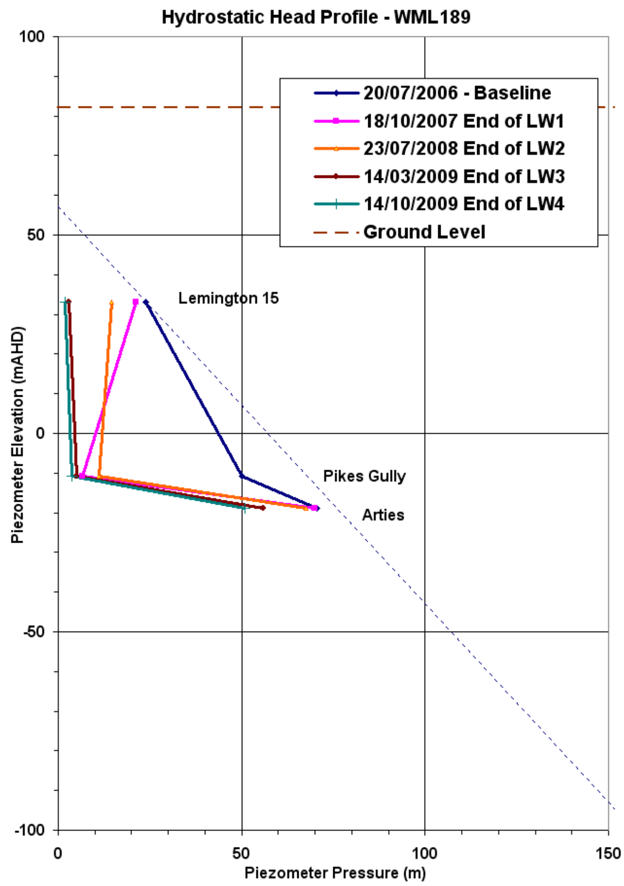

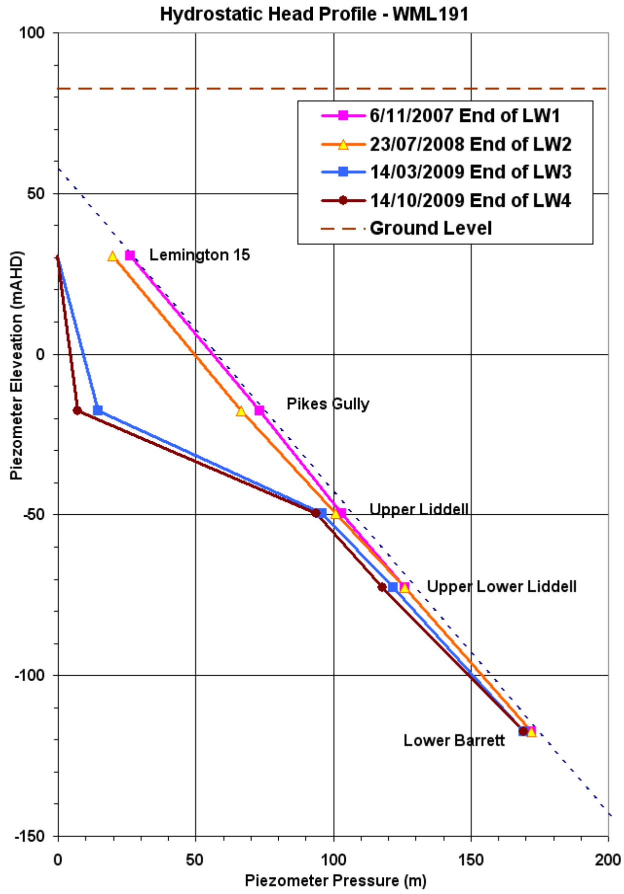

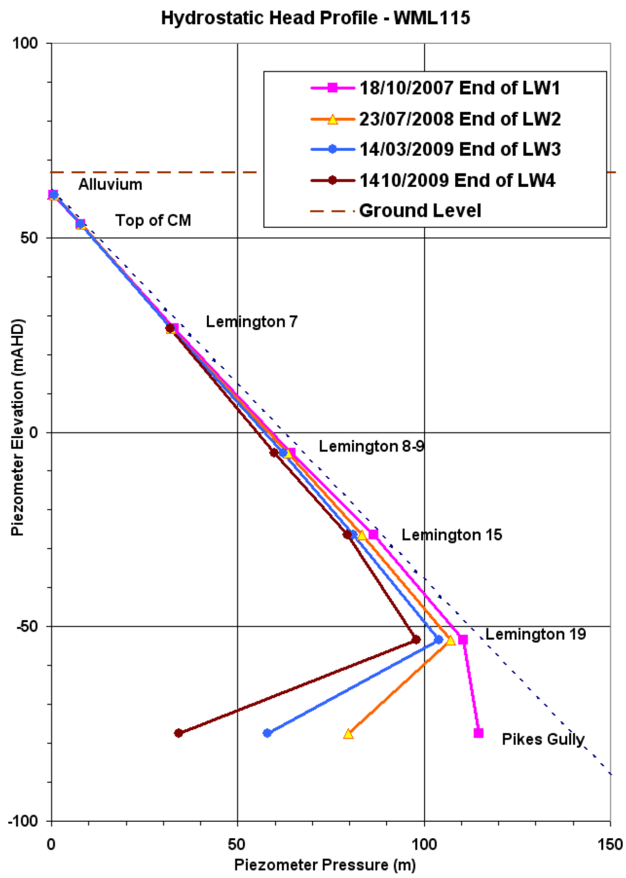

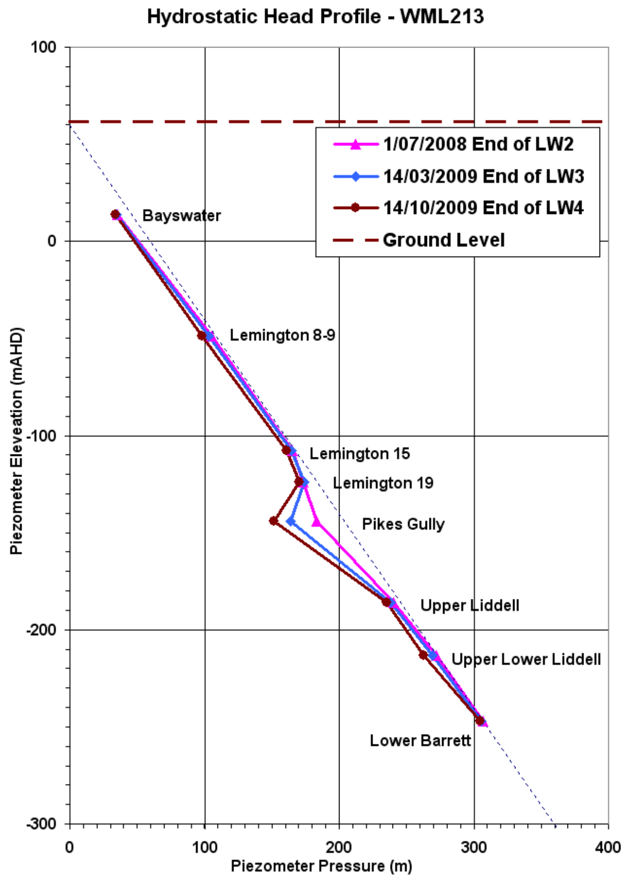

Date 17 November 2009	Scale	**Ashton Coal Operations Ltd**
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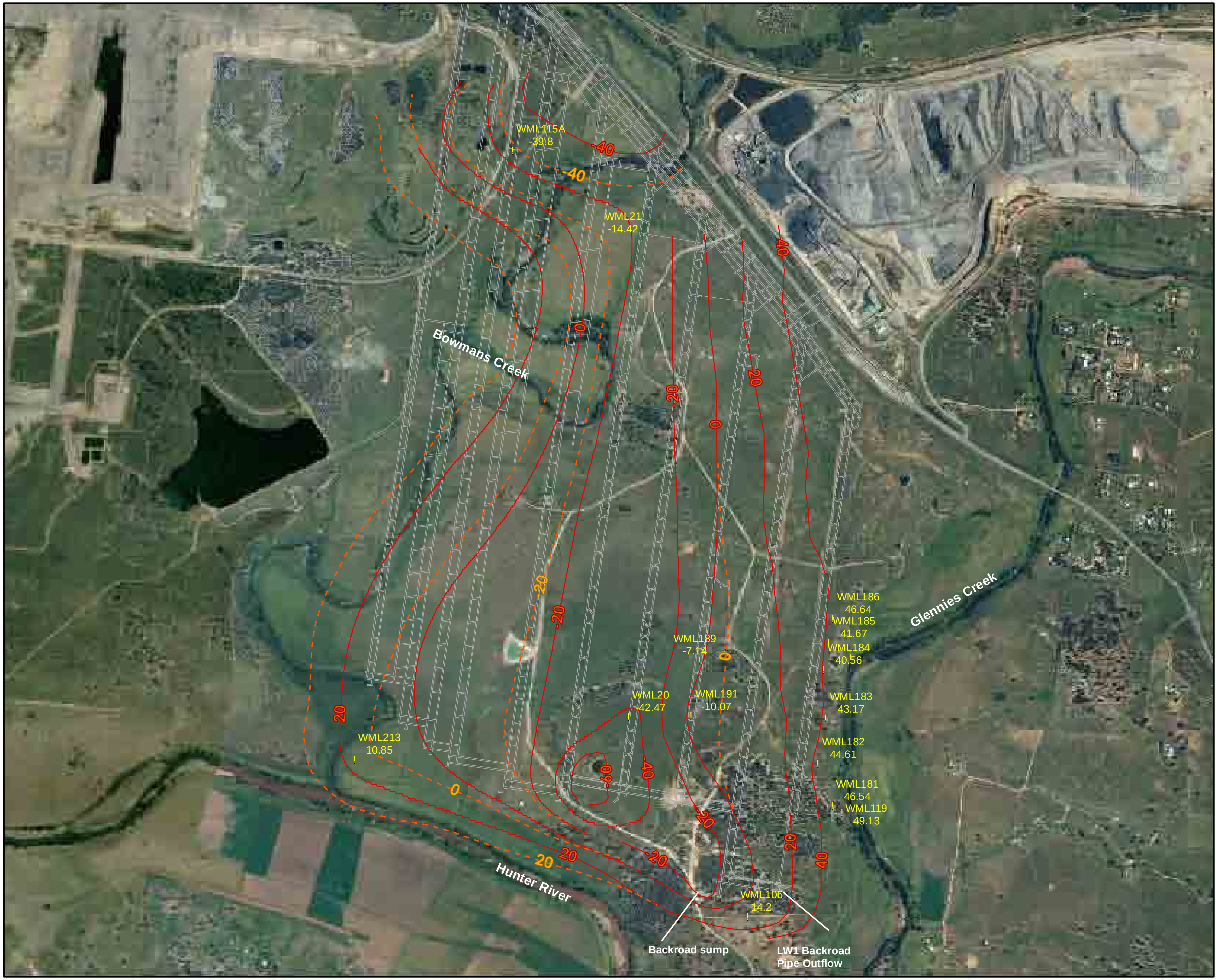
Drawing Number 003	Revision 0	
aquaterra		**Figure 6**



0 255 510 1,020
Meters

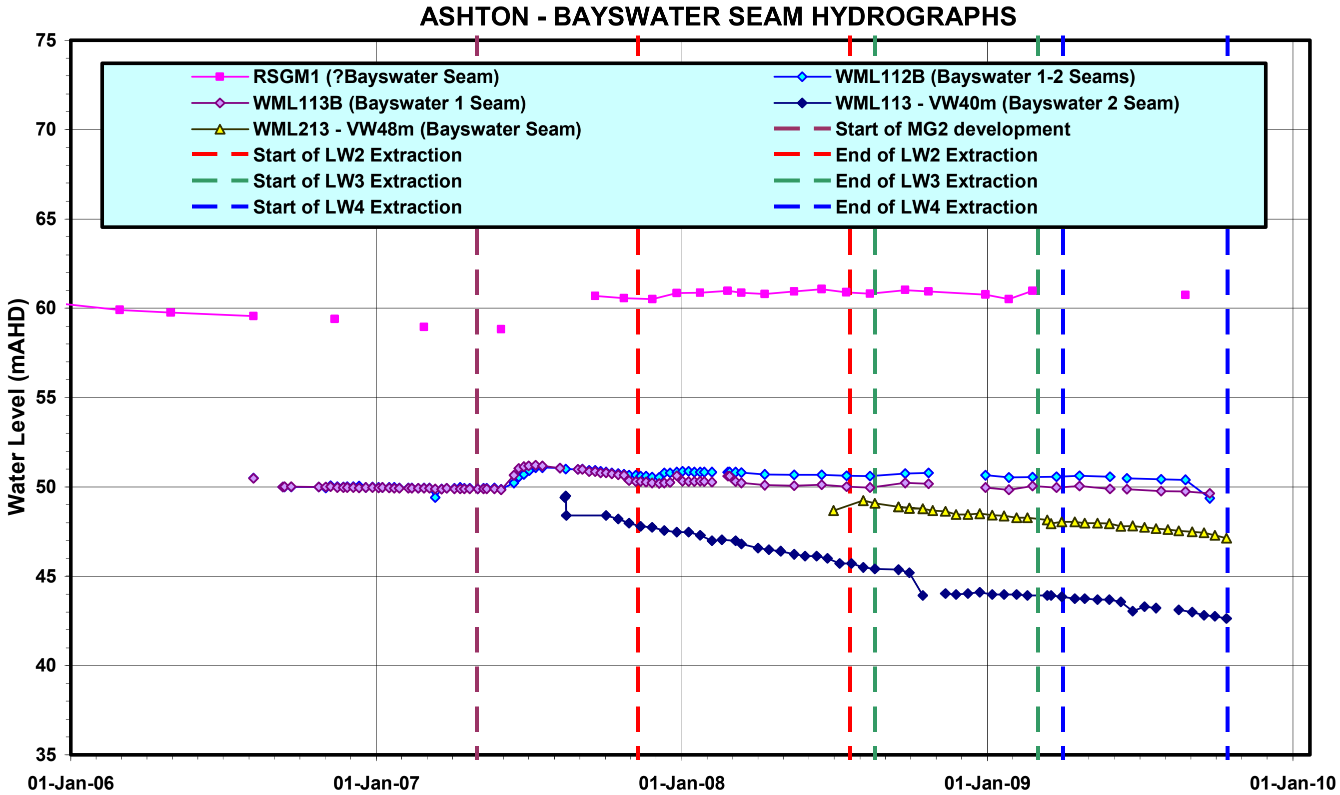
Legend

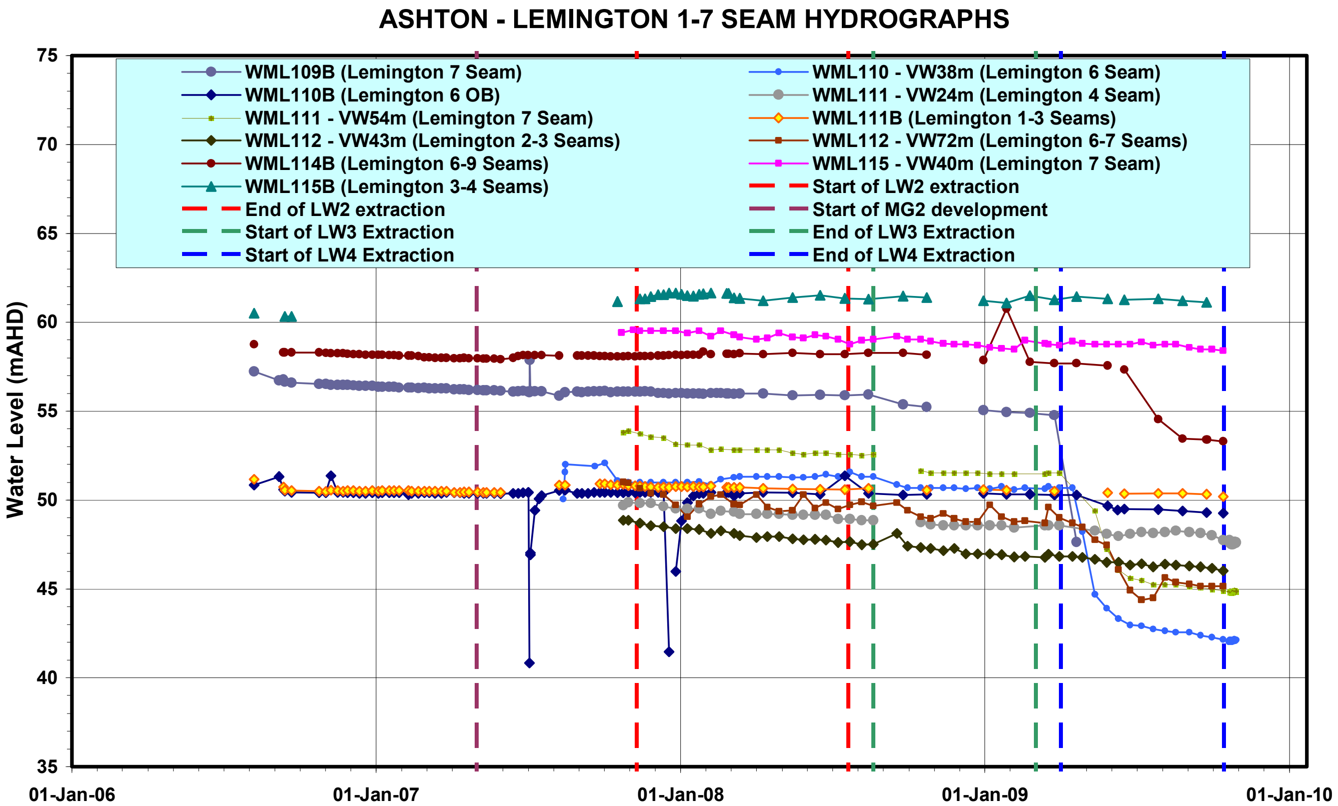
- Pike Gully Piezometers and GWL (mAHD)
- Groundwater level contour September 2009
- Groundwater level contour April 2009
- Pikes Gully Mine Plan

aquaterra

Project: S55 D2	Date: 18/11/2009
Drawing No. 001	Revision : A
Drawn: JVDA	Datum: WGS1984

Figure 7
Groundwater Elevation (mAHD)
Pikes Gully
September 2009





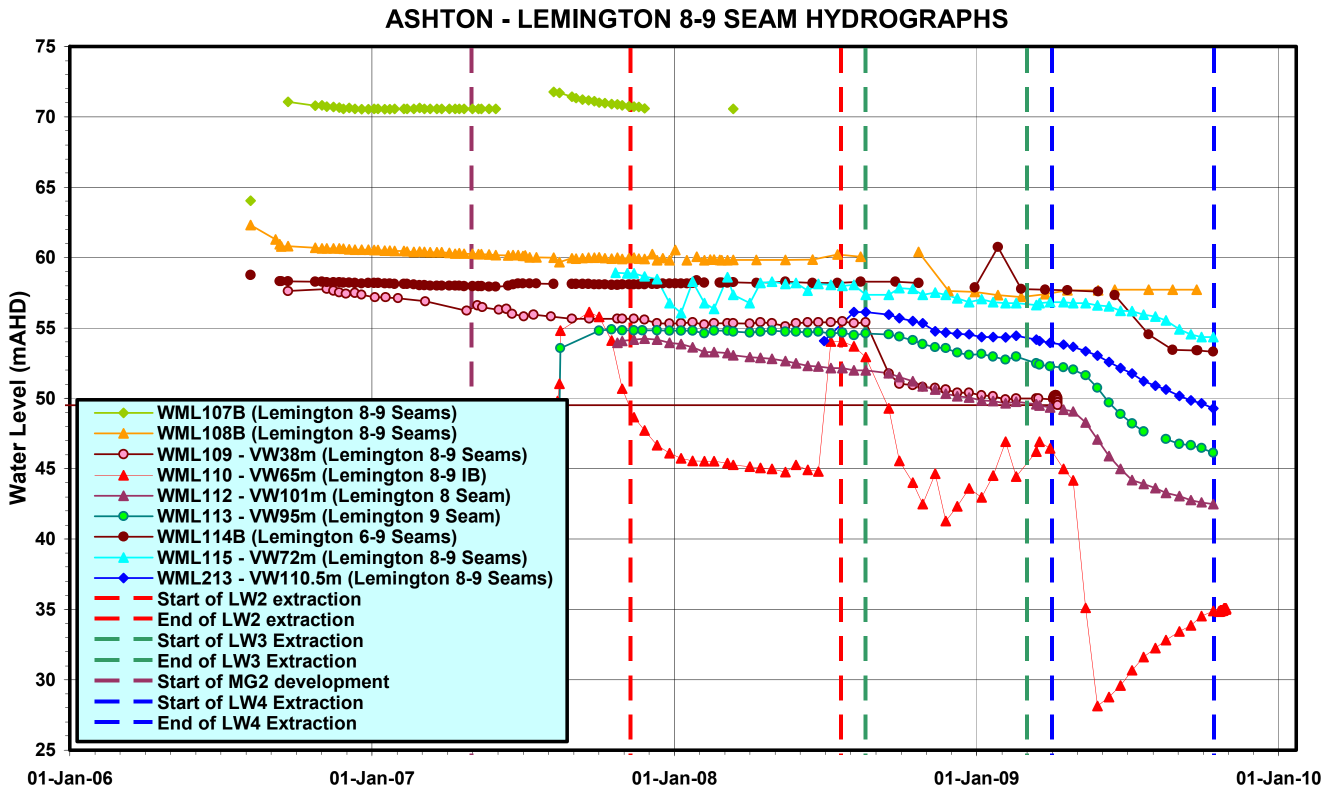
Date	17 November 2009	Scale	
Initials	JVDA	Project	S55 D2
Drawing Number	009	Revision	0

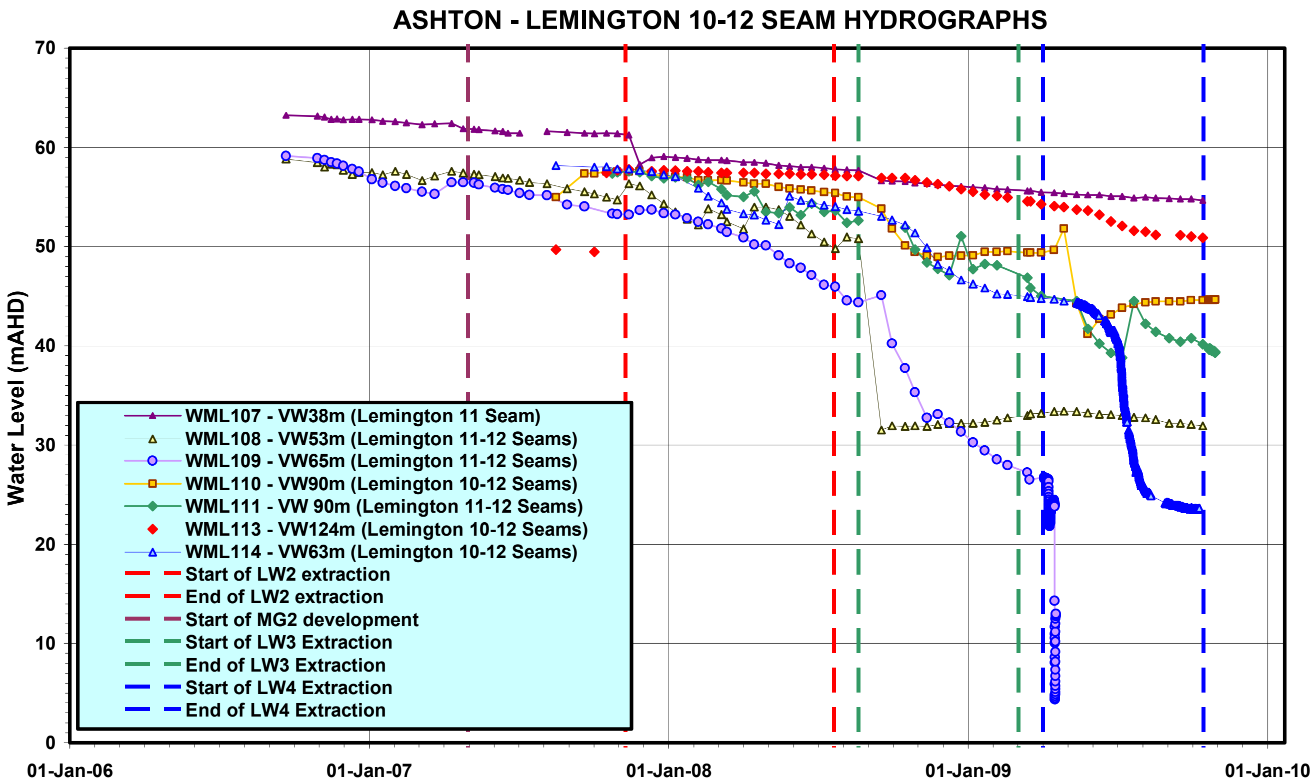
aquaterra

Ashton Coal Operations Ltd

GROUNDWATER LEVEL HYDROGRAPHS
Bayswater Seam
Lemington 1-7 Seams

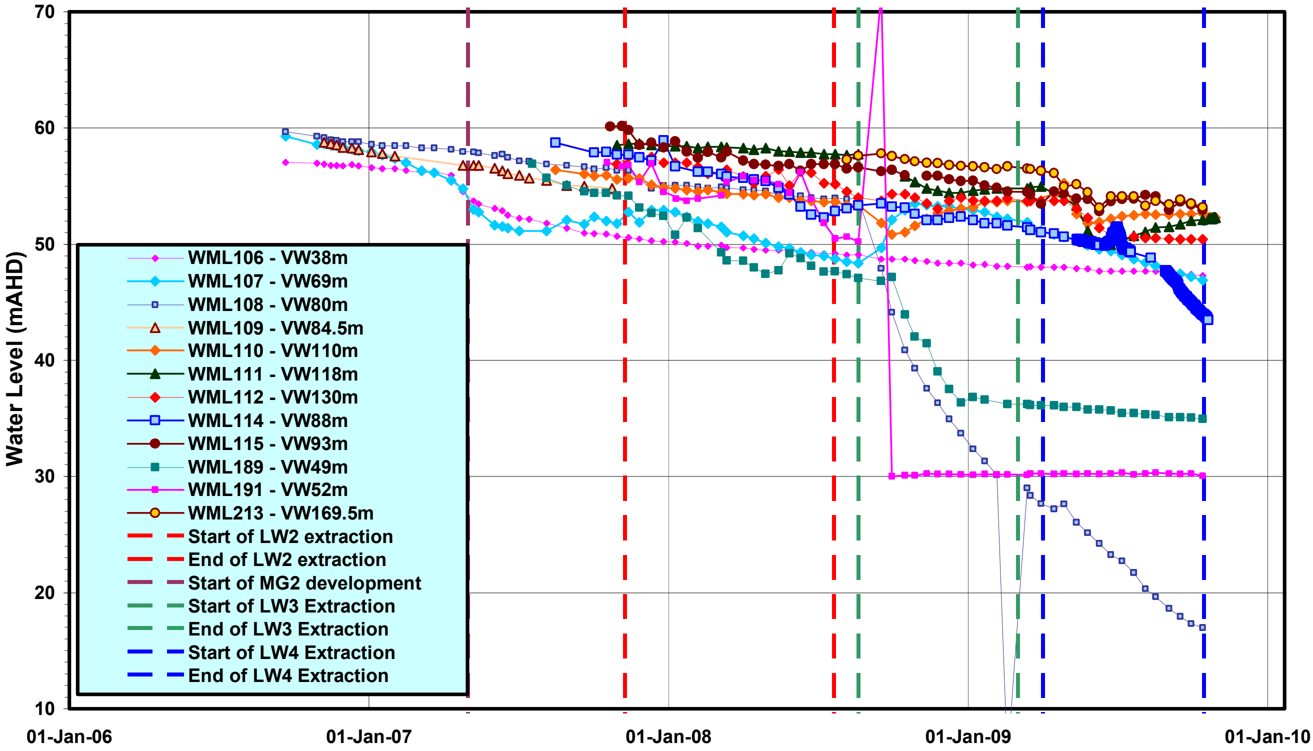
Figure 8



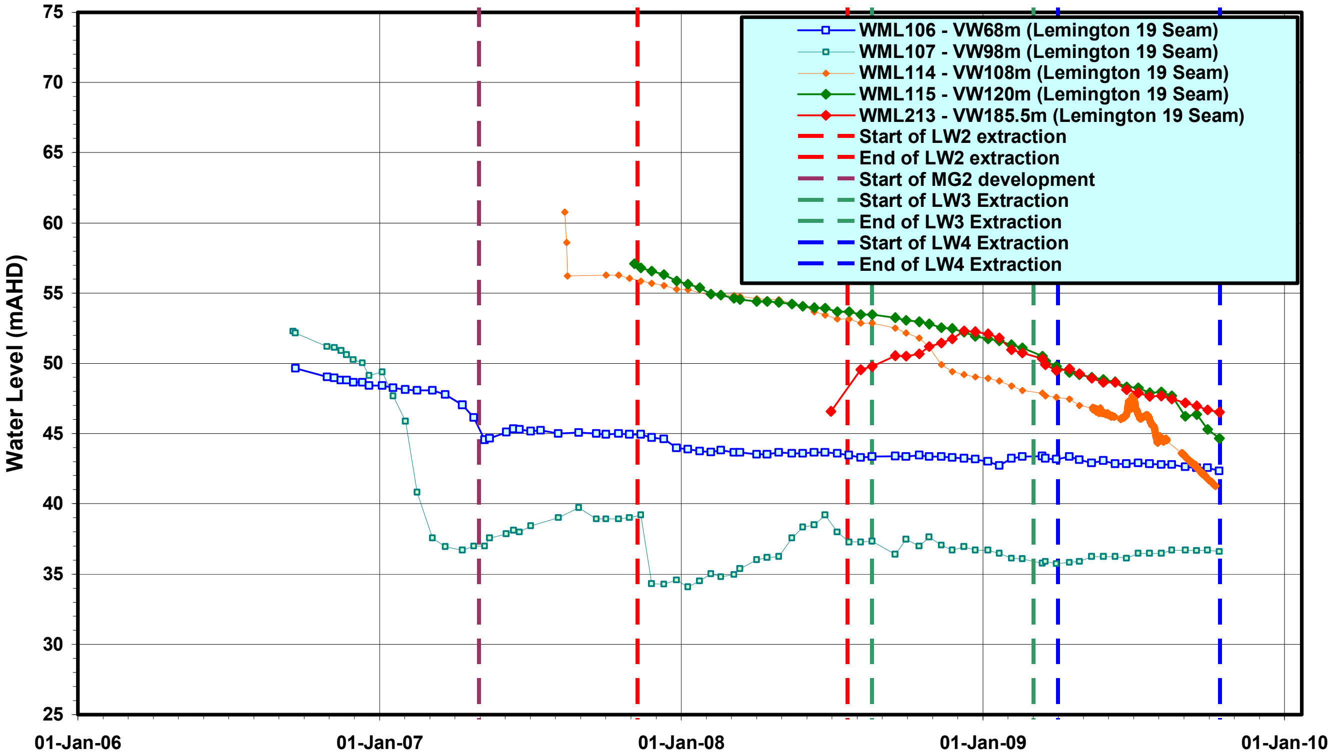


Date	17 November 2009	Scale		**Ashton Coal Operations Ltd**
Initials	JVDA	Project	S55 D2	GROUNDWATER LEVEL HYDROGRAPHS Lemington 8 - 9 Seams Lemington 10 - 12 Seams
Drawing Number	009	Revision	0	
aquaterra				**Figure 9**

ASHTON - LEMINGTON 15 SEAM HYDROGRAPHS



ASHTON - LEMINGTON 19 SEAM HYDROGRAPHS



Date 17 November 2009	Scale	**Ashton Coal Operations Ltd**
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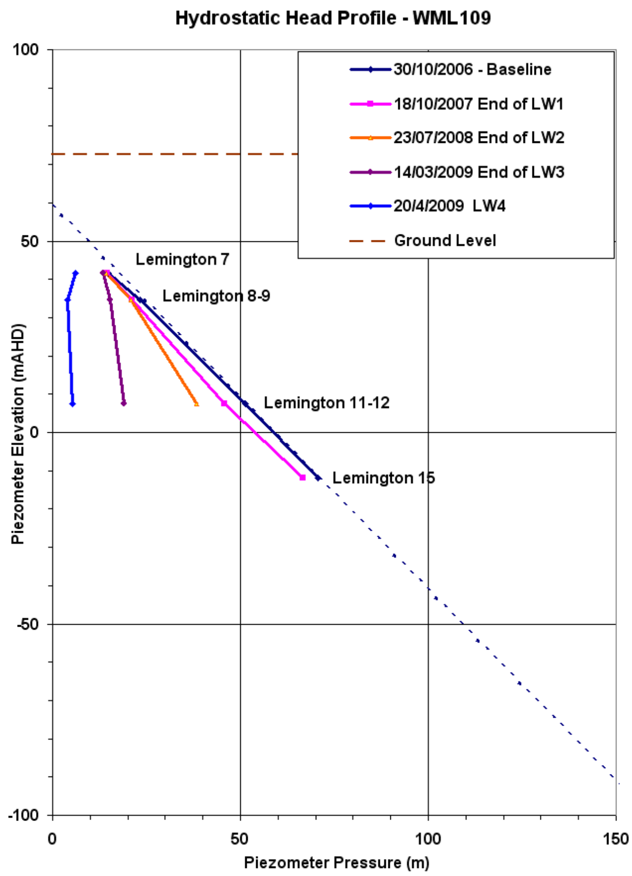

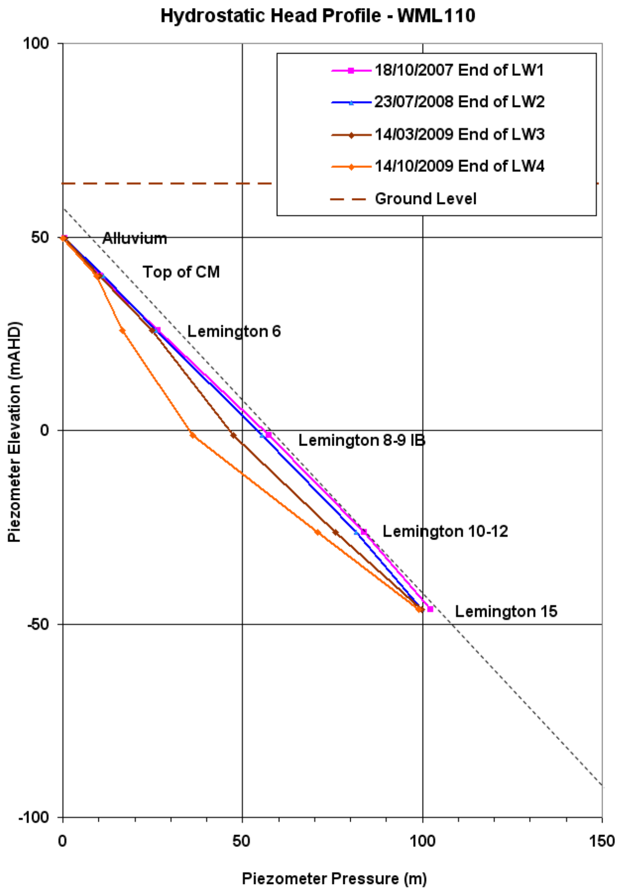

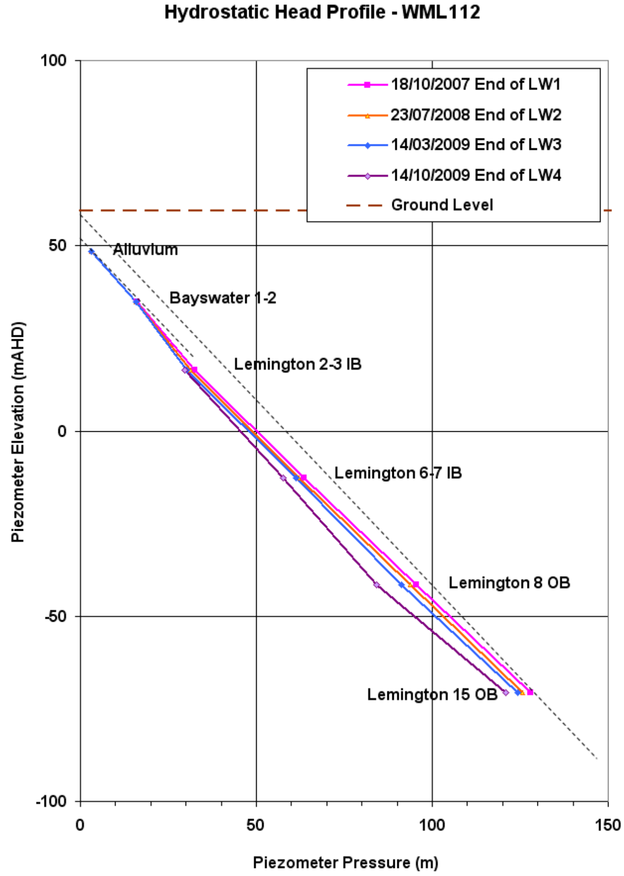

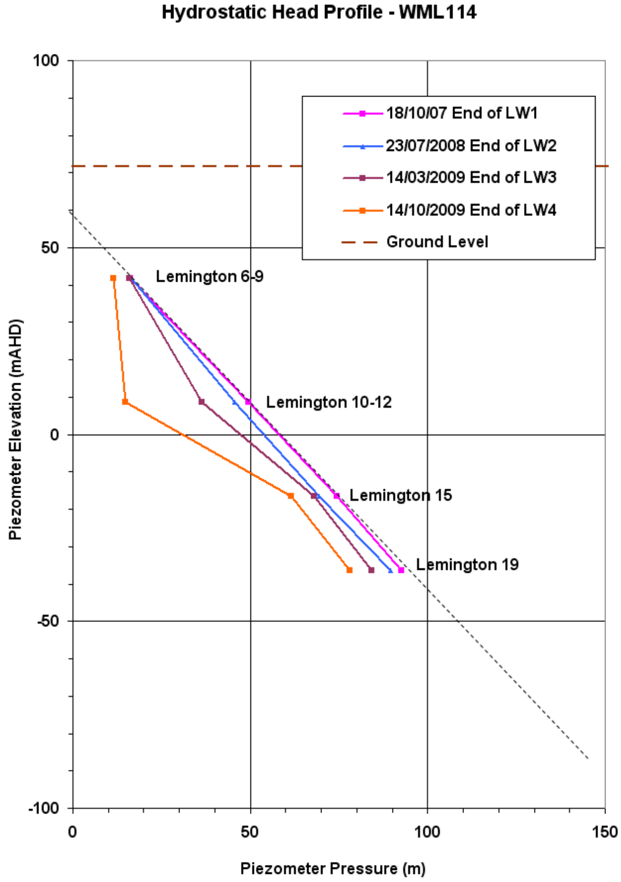

Date 17 November 2009	Scale	**Ashton Coal Operations Ltd**
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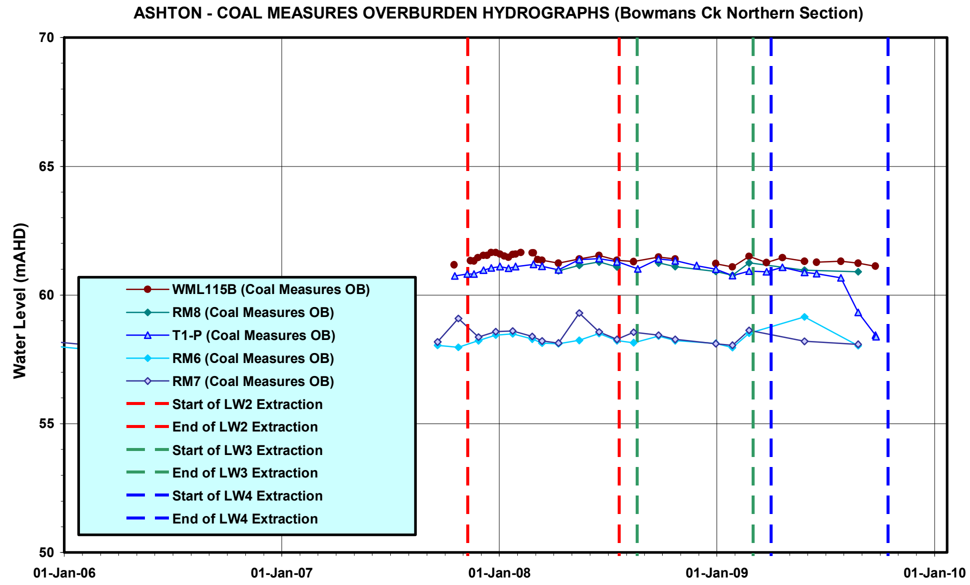

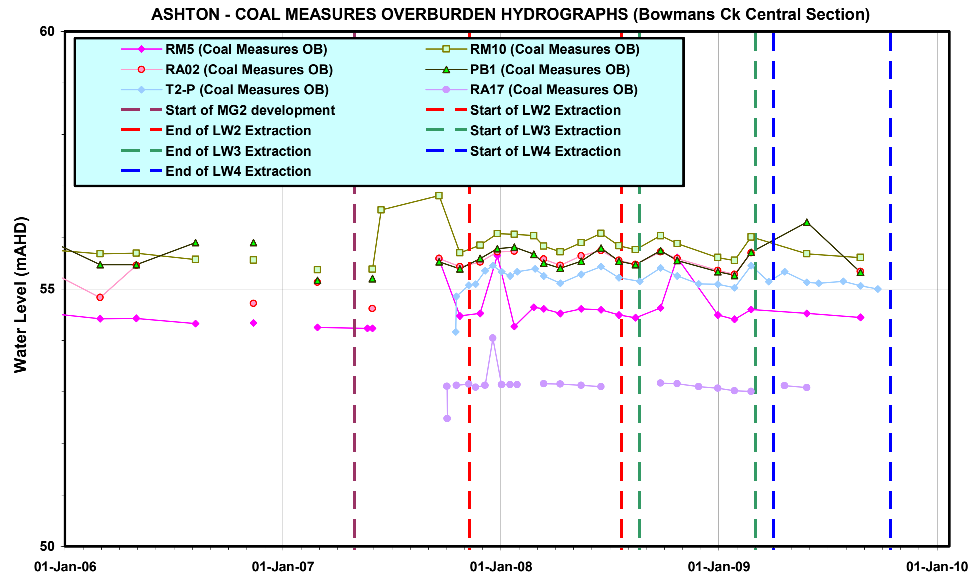

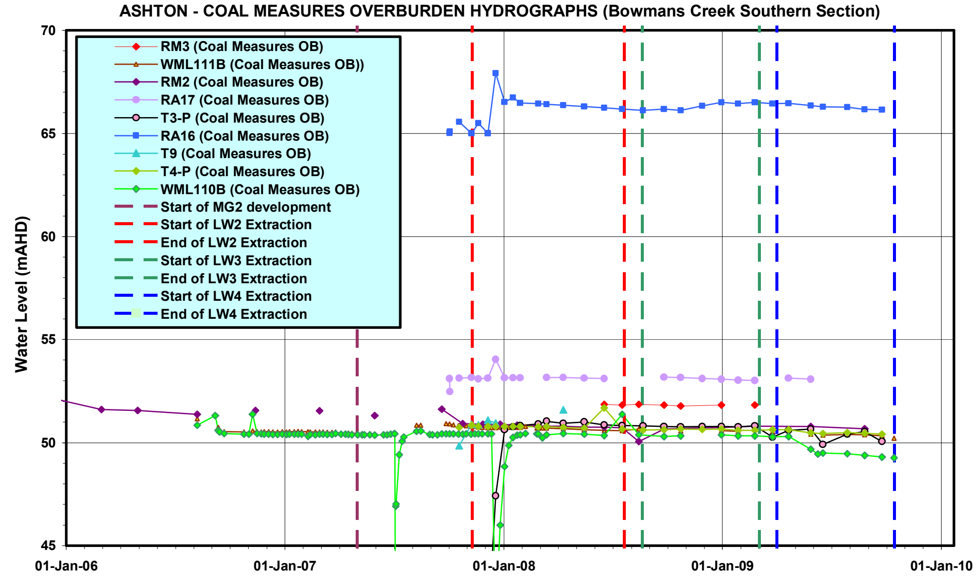

Date 17 November 2009	Scale	**Ashton Coal Operations Ltd**
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Drawing Number 007	Revision 0	
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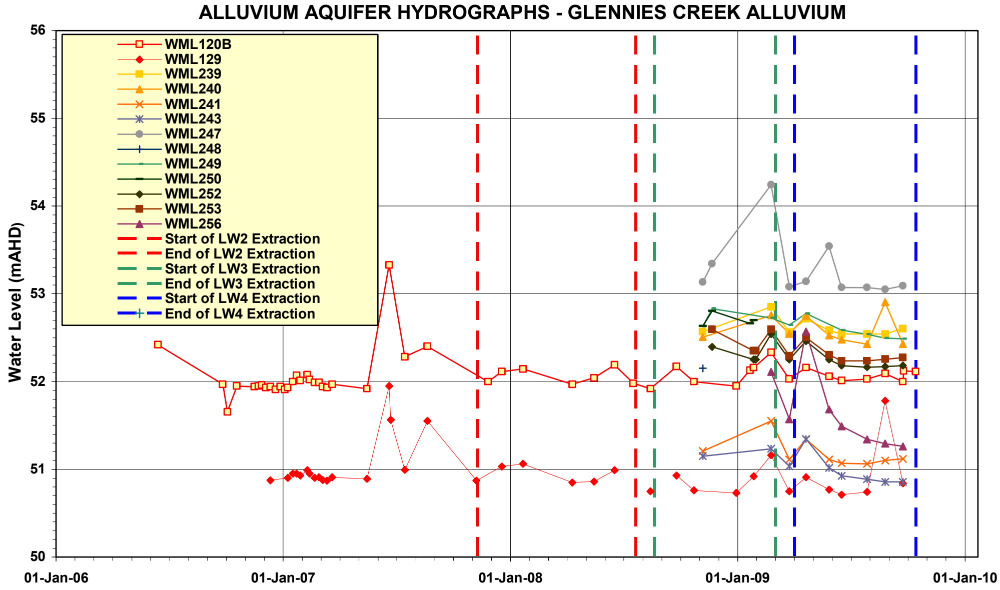

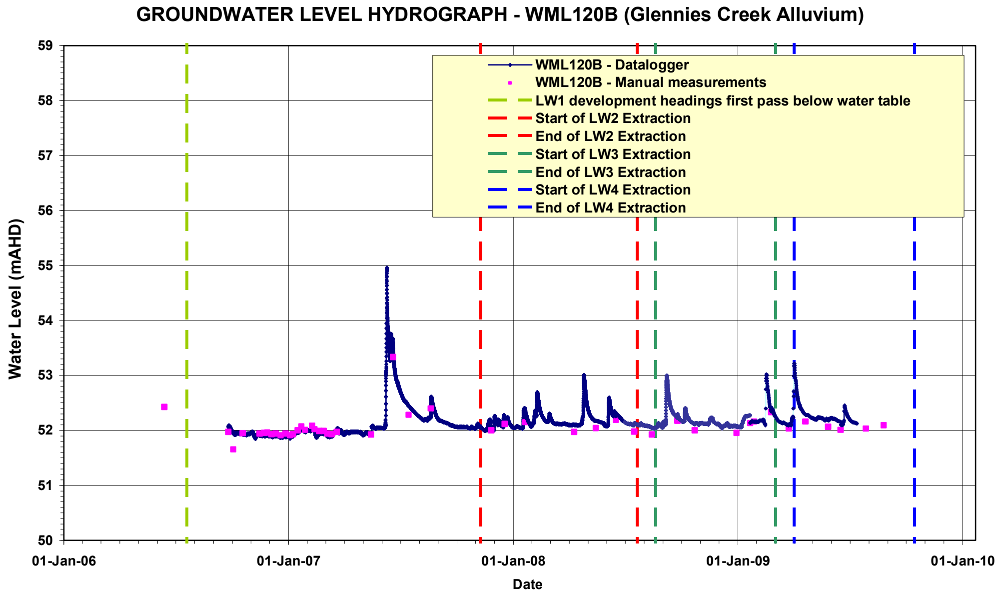

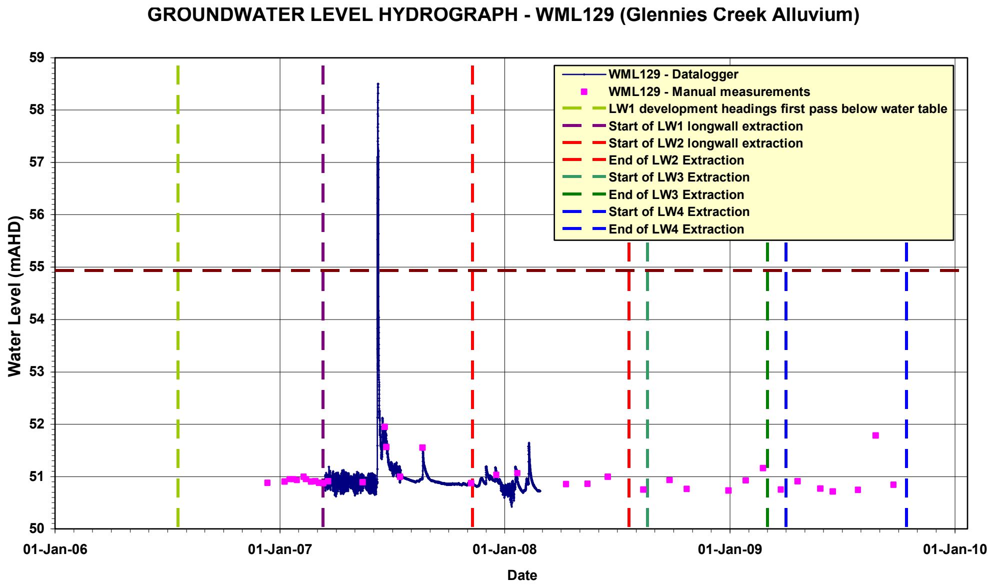

Date **17 November 2009**	Scale	**Ashton Coal Operations Ltd**
Initials **JVDA**	Project **S55 D2**	GROUNDWATER LEVEL HYDROGRAPHS Glennies Creek Alluvium
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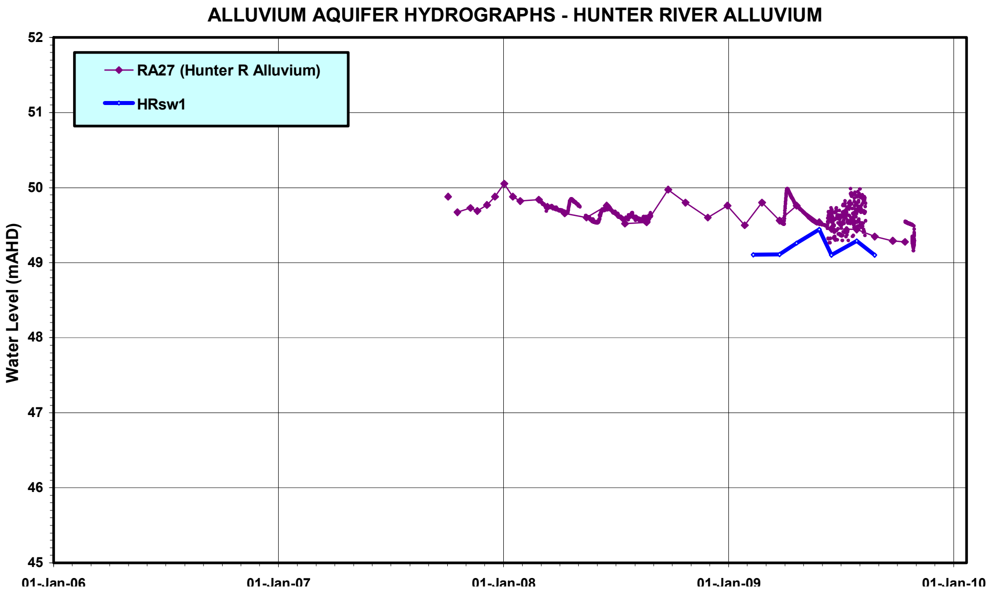
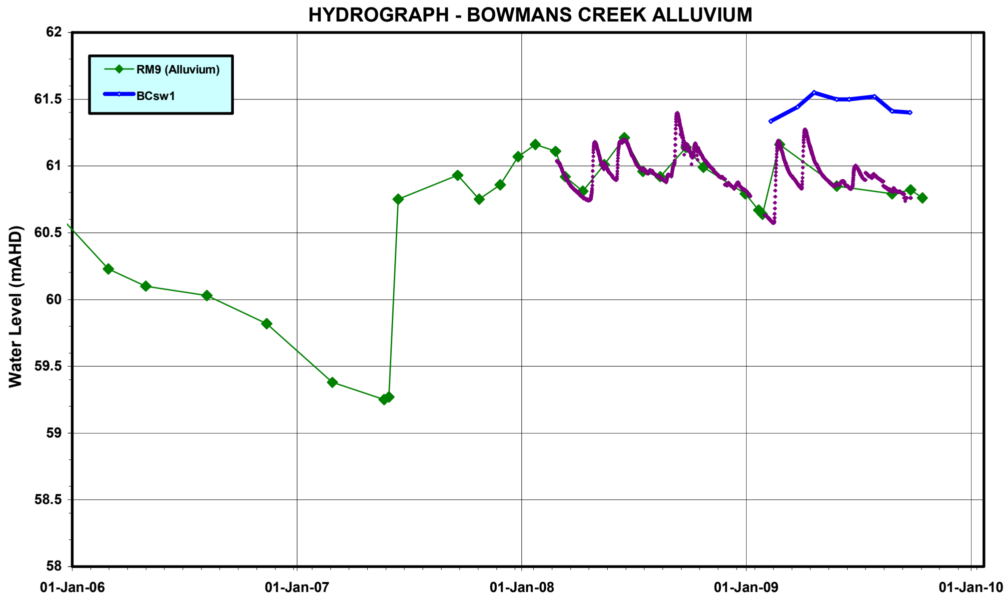
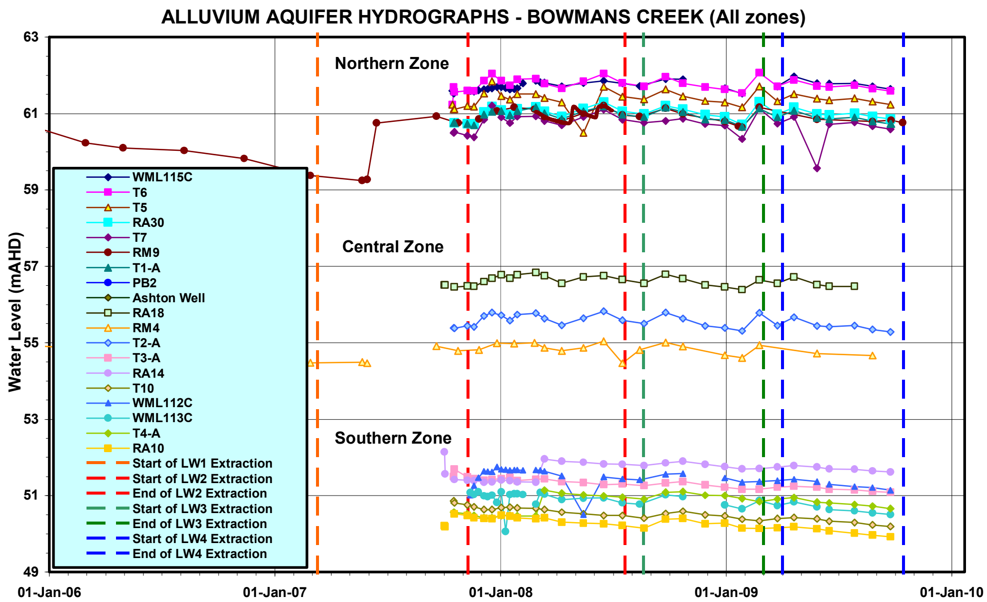






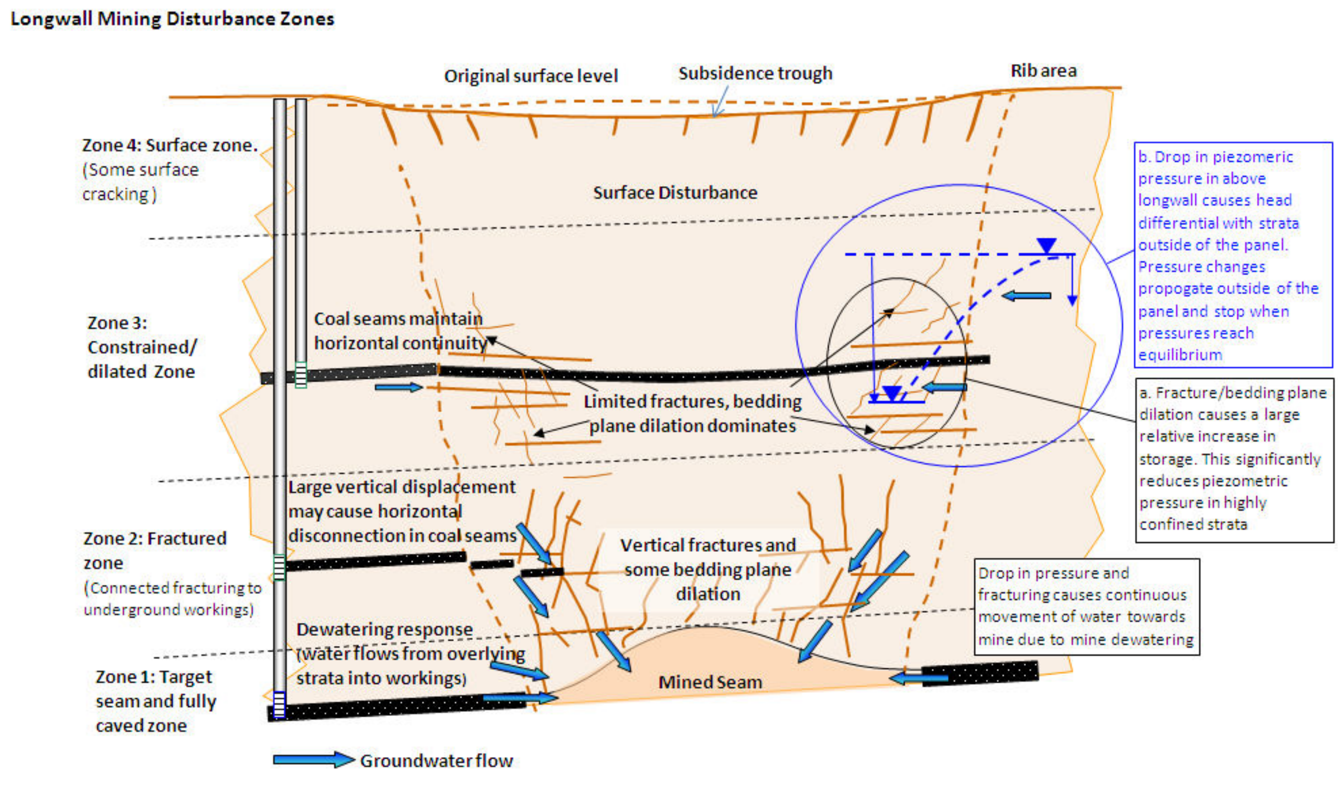
Date	17 November 2009	Scale	
Initials	JVDA	Project	S55 D2
Drawing Number	011	Revision	0

aquaterra

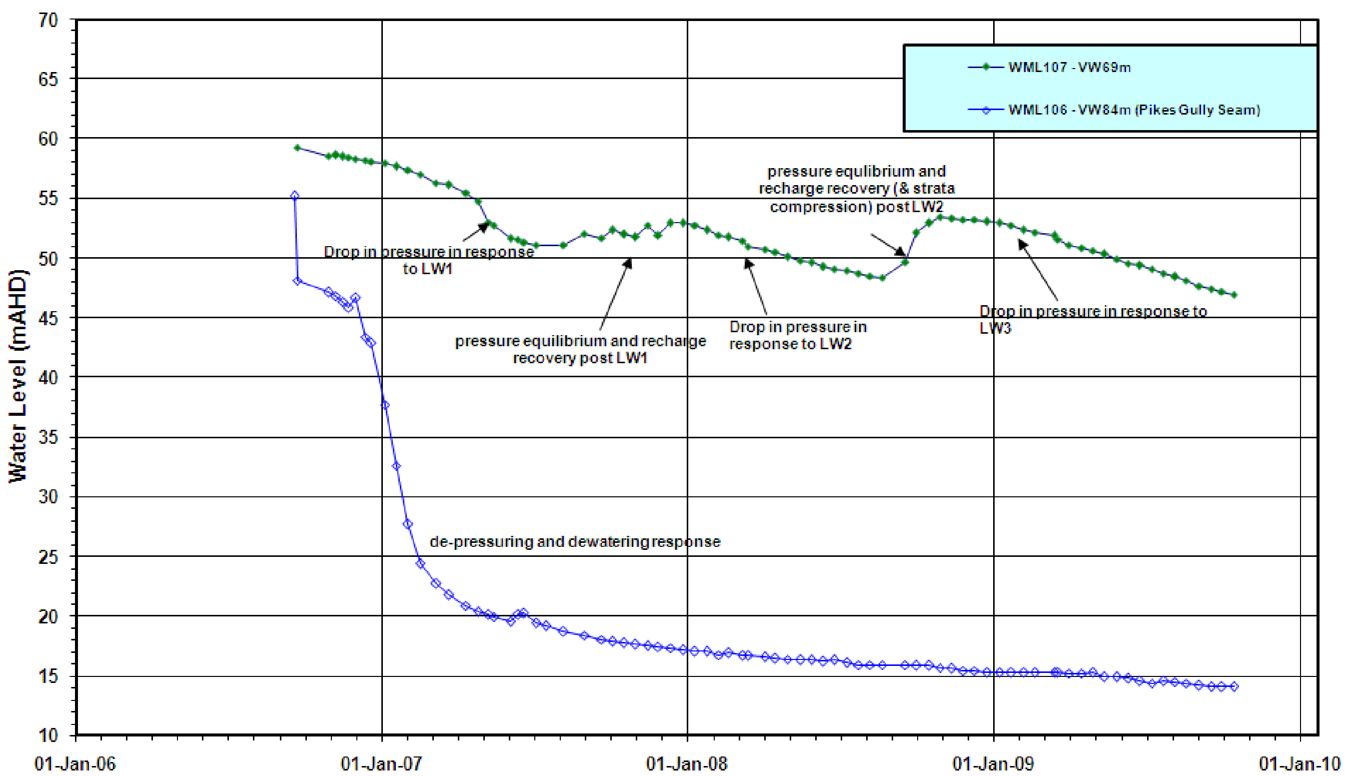
Ashton Coal Operations Ltd

GROUNDWATER LEVEL HYDROGRAPHS
Hunter River Alluvium
Bowmans Creek Alluvium

Figure 14



Schematic diagram showing mining induced disturbance zones



Date 22 April 2010	Scale	**Ashton Coal Operations Ltd**	
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Drawing Number **016**	Revision **1**		
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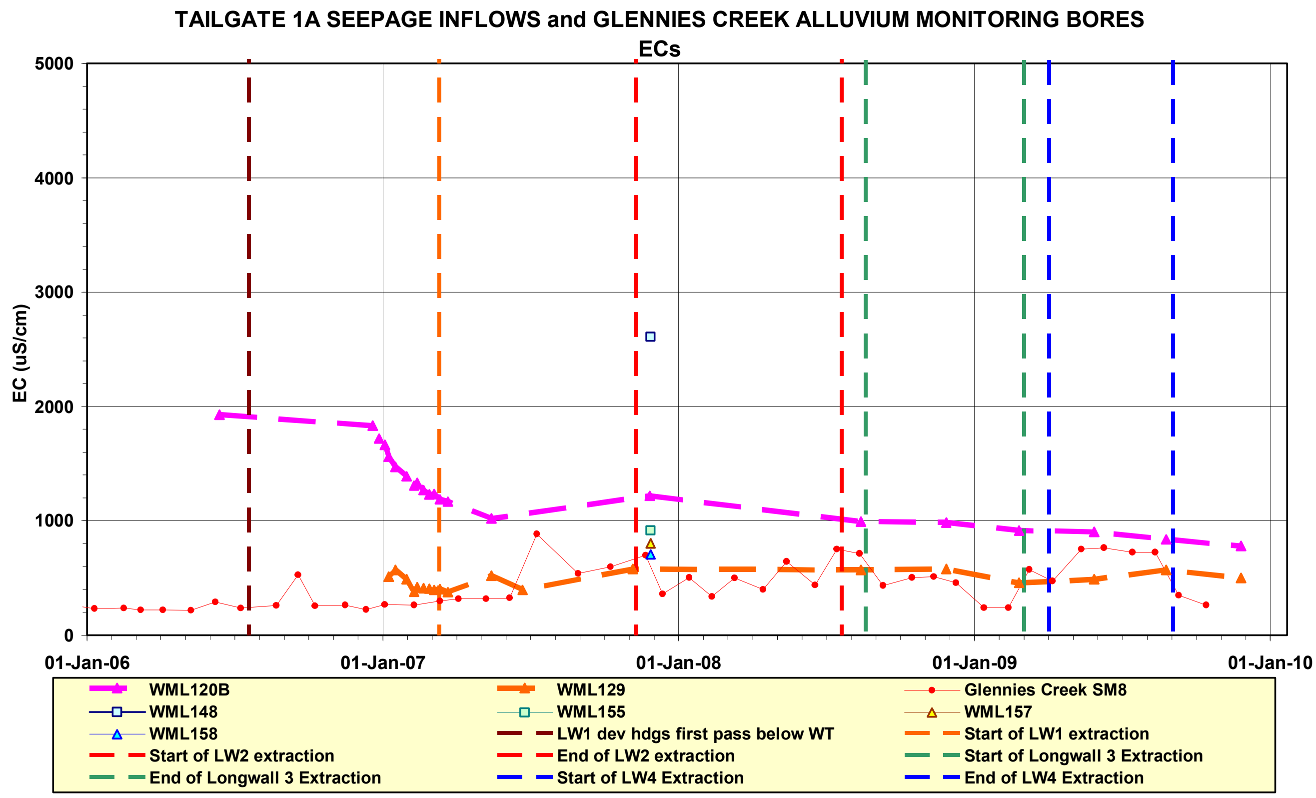

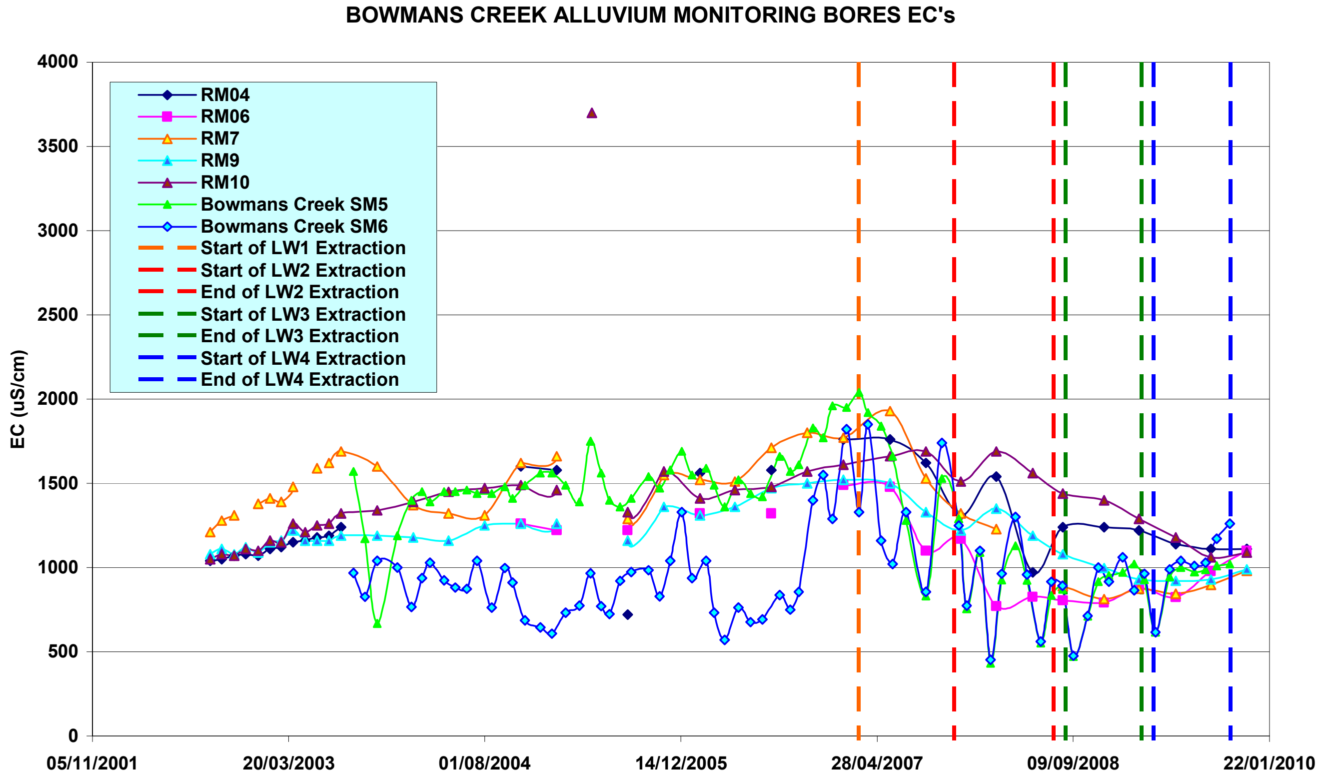

Date	17 November 2009	Scale		**Ashton Coal Operations Ltd**
Initials	JVDA	Project	S55 D2	GROUNDWATER EC Glennies Creek Alluvium Bowmans Creek Alluvium
Drawing Number	013	Revision	0	
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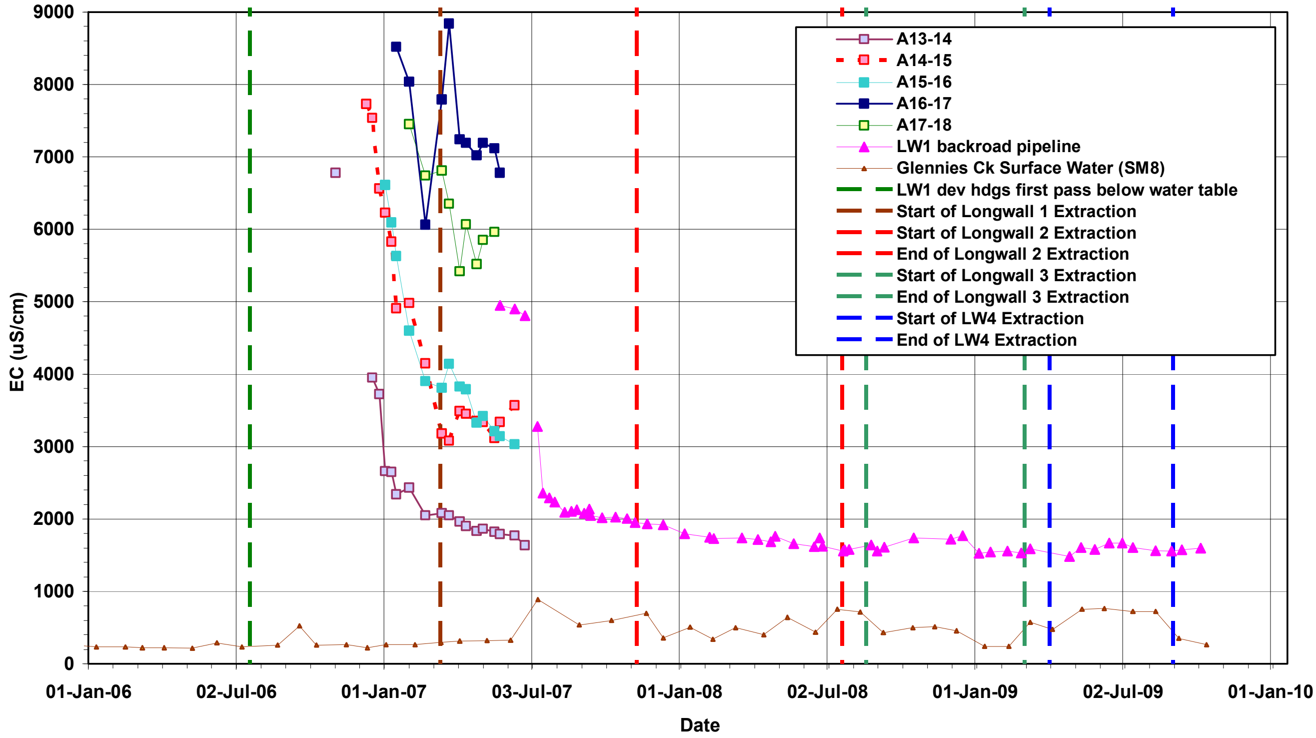
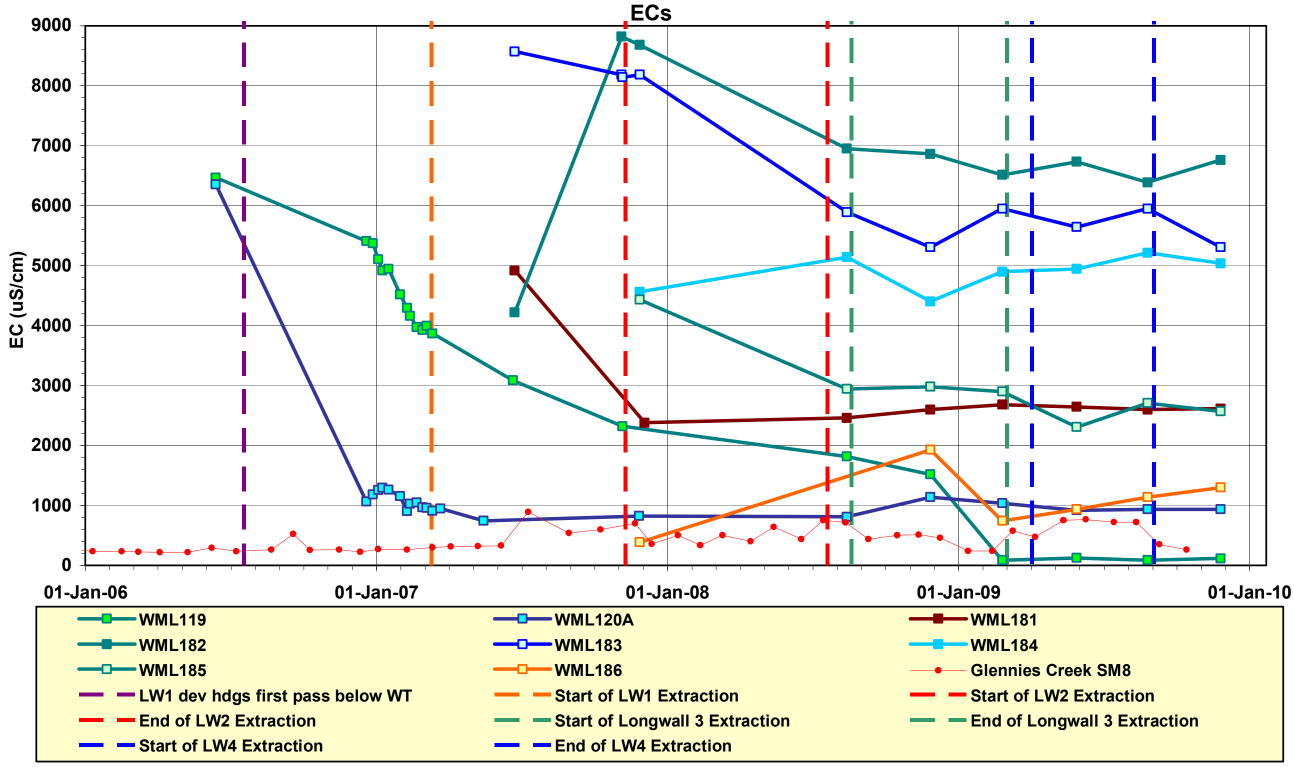
TAILGATE 1A SEEPAGE INFLOWS - ECs
RIB SEEPAGES CT 13 to 18



TAILGATE 1A SEEPAGE INFLOWS and PIKES GULLY SEAM MONITORING BORES
ECs



Date 17 November 2009	Scale	**Ashton Coal Operations Ltd**
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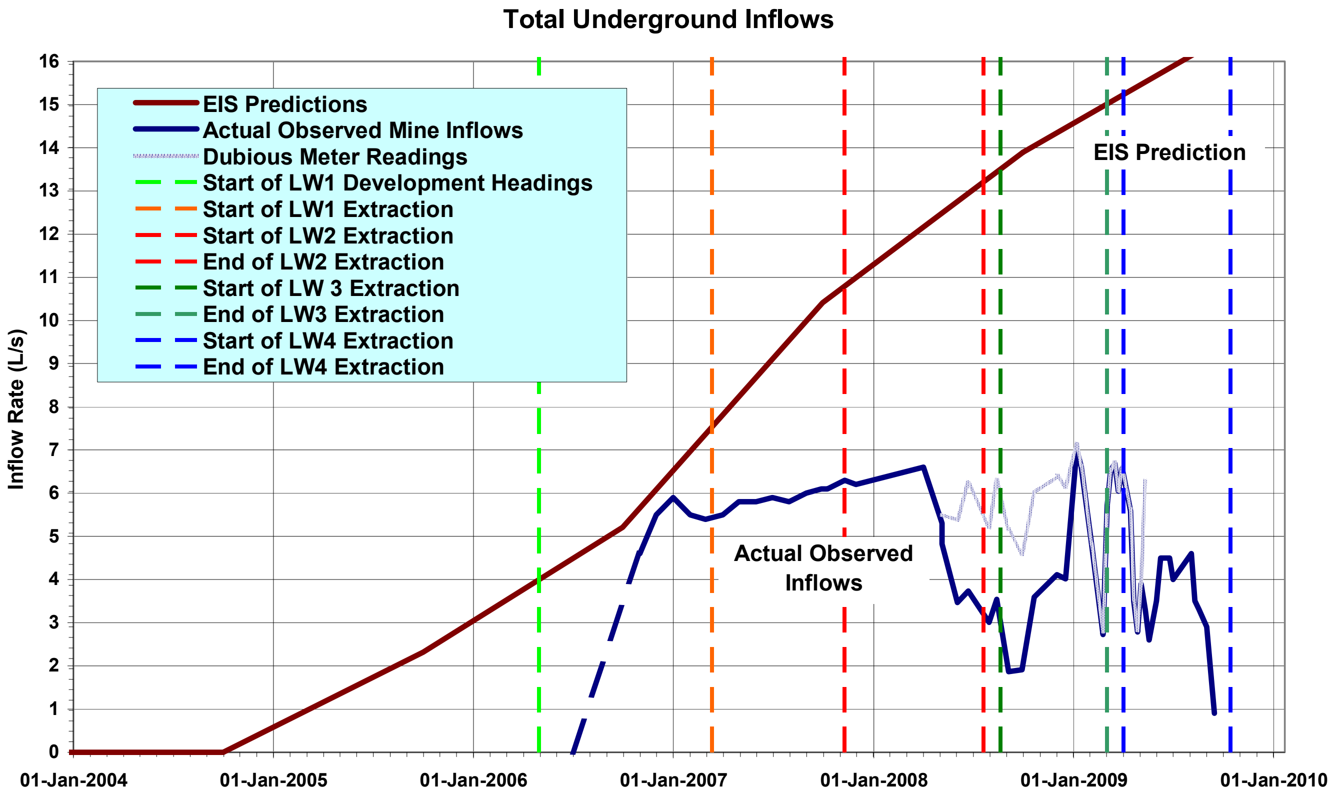

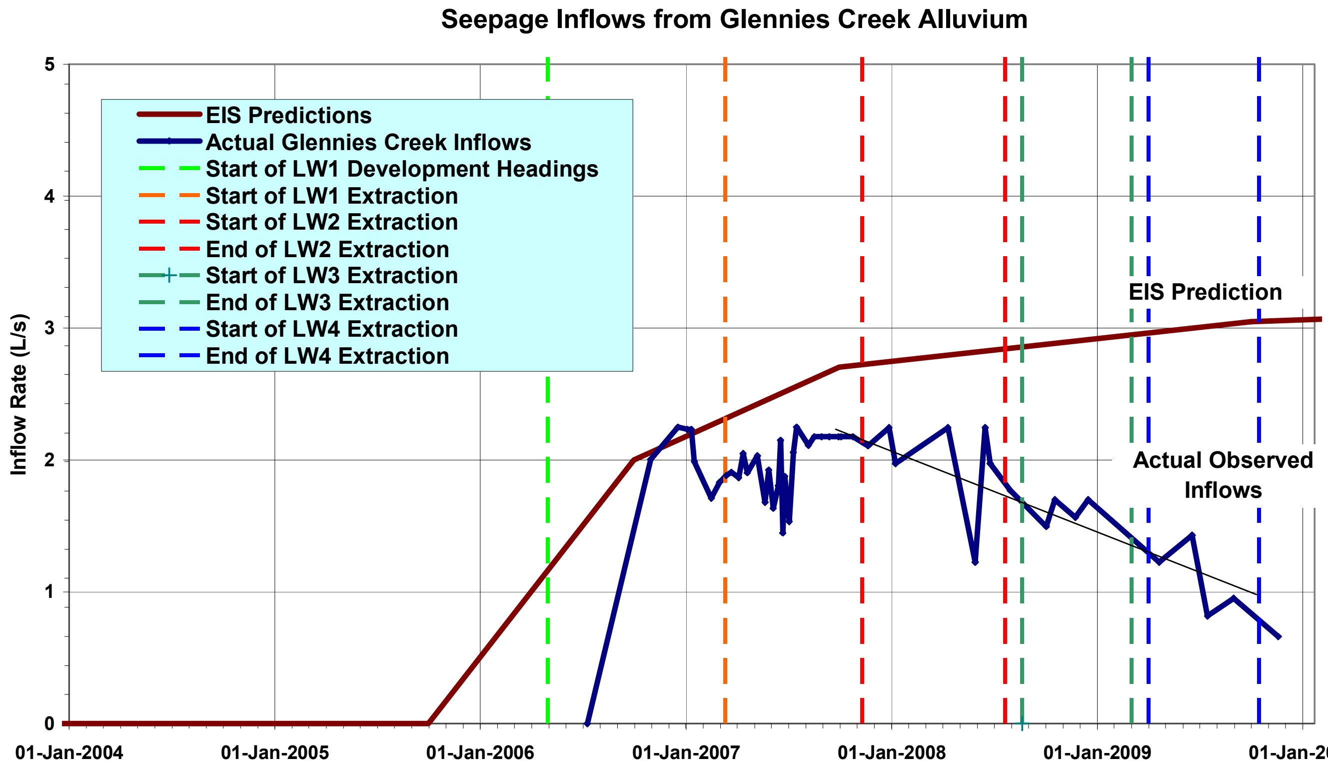

Date 17 November 2009	Scale	**Ashton Coal Operations Ltd**
Initials JVDA	Project S55 D2	Groundwater Inflows vs EIS Predictions
Drawing Number 015	Revision 0	
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