Water and Environment

END OF PANEL REPORT - LONGWALL 5	
Prepared for	Ashton Coal Operations Limited
Date of Issue	9 August 2011
Our Reference	S55D4 24c

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	Date	Revision Description
Revision A	13-09-10	First Draft
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EXECUTIVE SUMMARY

BACKGROUND

The Ashton Coal Project, located 14 km 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 for the first longwall panel in the Pikes Gully Seam (LW1) commenced in July 2006. Mining of Longwall Panel 5 (LW5) was completed on 4 June 2010 (Mining year 7). Mining is currently proceeding in LW6 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 5 (LW5) 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 Enviroscience, 2001) and studies conducted in support of the LW5-6/MW7-8 Subsidence Management Plan (SMP) Application (Aquaterra, 2008b).

All groundwater related impacts from underground mining up to the completion of LW5 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 accessing 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 current mine plan comprised nine longwall/miniwall panels (LW/MW 1-9), which have been approved for mining the Pikes Gully seam under three SMP applications, viz:

- Longwall panels LW1 to LW4 – SMP approved in April 2007.
- Longwall/miniwall panels LW5-6 MW7-8 – SMP approved in July 2009.
- Longwall panel LW9 – Development Consent modification approved in March 2010.

Longwalls 1 to 6 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 LW/MW 1-9, together with the progress of mining to date, is shown on **Figure 2**.

Underground mine development commenced in July 2006. Four End of Panel Review reports assessing impacts from LW1, LW2, LW3 and LW4 were issued in October 2008 (Aquaterra, 2008a), May 2009 (Aquaterra, 2009a), July 2009 (Aquaterra, 2009b) and April 2010 (Aquaterra, 2010a) respectively. Mining of the fifth longwall panel (LW5) began on 4 January 2010 and was completed on 4 June 2010. This report presents a review of groundwater impacts at the completion of LW5.

Mining is now proceeding in LW6 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, based on those piezometers, 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 EIS groundwater 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 (Peter Dundon and Associates, 2006) and LW/MW 5-9 (Aquaterra, 2008b). These studies included the installation of piezometers, hydraulic testing, and groundwater quality sampling. The new piezometers were added to the baseline monitoring network. Monitoring frequency was increased to weekly in selected bores, as soon as the LW1 headings first passed below the water table, and then again at the start of each longwall panel from LW4 to LW6. At other times, monthly monitoring has continued as an ongoing routine monitoring program.

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 a transect across the LW3-5 goafs (XL5).

Groundwater seepage into the eastern rib of tailgate heading TG1A of LW1 started as soon as the heading first passed below the water table, and has continued since that time. Analysis confirmed that some of this seepage was derived from the alluvium of the Glennies Creek floodplain, east of LW1. These inflows were monitored closely, initially by means of weirs installed along tailgate TG1A, which is the easternmost heading of the underground mine. Access to TG1A was lost during extraction of LW1. Water inflow to TG1A is now 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 Borehole No 2 Sump, which is located to the south of LW6, close to the lowest point in the mine (**Figure 2**), and another in the North West Mains. The discharge from the LW1 Backroad Pipe also flows to the Borehole No 2 Sump. All discharges are monitored by flow meters. 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 SMP applications for LW1-4 (Peter Dundon and Associates, 2006) and LW/MW 5-9 (Aquaterra, 2008b).

2 SITE DESCRIPTION

2.1 LONGWALL 5

Mining of LW5 was carried out between 4 January 2010 and 7 June 2010. Coal was recovered from the Pikes Gully Seam, which varies in thickness between 2.3m and 2.8m along LW5. The overburden thickness above the Pikes Gully Seam along LW5 ranges from 153m at the southern end to around 110m at the northern end, as a consequence of the west-south-westerly dip on the coal measures strata.

Mining of LW5 stopped about 80m to the south of the oxbow bend of Bowman's Creek and associated alluvium (**Figure 2**). The Pikes Gully Seam subcrops beneath the Glennies Creek floodplain alluvium, but is more than 125m below the Bowmans Creek alluvium where it is closest to LW5.

The surface topography above LW5 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 in 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.

Salinity within the Bowmans Creek alluvium ranges from 772 to 9,920 µS/cm EC, with an average of 2,284 µS/cm EC. Groundwater in the colluvium that exists above LW5 is more saline (4,500 to 13,800 µS/cm EC), indicating that it is not strongly connected hydraulically with less saline groundwater in the alluvium associated with Bowmans Creek.

Groundwater in both the Permian and the alluvium is more saline than the typical surface flows 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 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**.

North-south survey lines CL1 and CL2 were established spanning the inbye and outbye ends of LW5. CL2 spans from the LW5 goaf to the oxbow bend of Bowmans Creek (where Bowmans Creek is closest to LW5). During the extraction of LW5, an east-west survey line XL5 was also resurveyed over the LW4 to LW6 panel areas, prior to and shortly after the longwall 5 face passed the survey line.

The plots of horizontal movement versus time are shown on **Figure 3.** A comparison of survey results from XL5 indicates lateral movement above LW5 was generally less than 10mm.

Ground movement outside the LW5 goaf footprint, in the area of Bowmans Creek alluvium, was horizontally less than 3mm and vertically less than 10mm. The small displacements detected are too small to indicate any vertical or horizontal fracturing beneath the alluvium caused by the LW5 extraction.

In the absence of any fracturing beneath the alluvium, either horizontal or vertical, the permeability of the overburden beneath Bowmans Creek cannot have undergone any significant change, and therefore no increase in seepage losses from Bowmans Creek alluvium is anticipated as a result of LW5 mining.

Note that no part of LW5 is overlain by saturated or partly saturated Bowmans Creek or Hunter River alluvium.

There is also no evidence that mining of LW1 to LW5 has caused any significant subsidence or lateral movement to the east of LW1, in the barrier between LW1 and Glennies Creek.

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** and a summary of piezometer information presented in **Table 4.1**.

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); two in the Upper Liddell Seam (WML261 and WML262); two in the Arties Seam (WMLP301 and WMLP302); and 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, (installed east of LW1); and
  - WML269 (installed in the main gate chain pillar at the southern end of LW5).
- 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-P to T4-P, T9, RA16-17 and RA2, screened in the top of the coal measures overburden and regolith above the proposed LW/MW 5-9 area;
- Shallow piezometers WML110C, 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-A to T4-A, T5-10, RA10, RA14, RA11, RA15, RM4, RM9, PB2, WML275, WML276 WML299 and WML300) and colluvium (RA8, RA9, RA12, RA16-17); and
- Shallow standpipe piezometers, RA27 and WML277-280 (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 and/or colluvium.

Table 4.1: Groundwater Monitoring Piezometers

PIEZOMETER	LOCATION	AQUIFER
WML189-49	Located in the chain pillar between LW1 and LW2	Lem15
WML189-93		Arties
WML189-101		Pikes Gully
WML191-52		Lem15
WML191-100		Pikes Gully
WML191-132		Upper Liddell
WML191-155		Upper Lower Lower Liddell
WML191-200		Lower Barrett
WML106-32	Located outside southern end of LW1	Lem15
WML106-68		Lem19
WML106-84		PG
WML107A -38	Located outside southern end of LW2	Lem11
WML107A -69		Lem15
WML107A -98		Lem19
WML107B		Lem8-9
WML108A-53	Located outside southern end of LW3	Lem11-12
WML108A-80		Lem15
WML108B		Lem8-9
WML109A-36	Located inside southern end of LW4	Lem8-9
WML109A-65		Lem11-12
WML109A-84		Lem15
WML109B		Lem7
WML110A-36	Located inside southern end of LW5	Lem6
WML110A-64		Lem8-9
WML110A-90		Lem10-12
WML110A-110		Lem15
WML110B		Lem6 OB
WML110C		BC Colluvium/Alluvium
WML111B	Located inside southern end of LW6	CM Overburden
WML111A-24*		Lem4
WML111A-54*		Lem7
WML111A-90*		Lem11-12
WML111A-118*		Lem15
WML269-24*	Located in maingate chain pillars close to LW5 start end	Lem5
WML269-56*		Lem7
WML269-64*		Lem8-9

PIEZOMETER	LOCATION	AQUIFER
WML269-92*		Lem11-12
WML269-122*		Lem15
WML269-142*		Lem19
WML112C	Located within maingate chain pillars of MW7	BC Alluvium
WML112B		Bayswater 1-2
WML112A-43*		Lem2-3
WML112A-72*		Lem6-7
WML112A-101*		Lem8
▼ WML112A-130*		Lem15
WML113C	Located inside southern end of MW9	BC Alluvium
WML113B-18*		Bayswater 1
WML113A-40*		Bayswater 2
WML113A-65*		Lem9
WML113A-95*		Lem10-12
WML113A-124*		Lem15
WML114A-68	Located south of the Bowmans Creek oxbow inside LW5	Lem10-12
WML114A-88		Lem15
WML114A-108		Lem19
WML114B		Lem6-9
WML115A-40	Located inside northern part of LW7B	Lem7
WML115A-72		Lem8-9
WML115A-93		Lem15
WML115A-120		Lem19
WML115A-144		Pikes Gully
WML115B		CMOB & Lem3-4
WML115C		BCA
WML213-48	Located south west of LW7 and LW8	Bayswater
WML213-110.5		Lem8-9
WML213-169.5		Lem15
WML213-185.5		Lem19
WML213-205		PG
WML213-247		Upper Liddell
WML213-276		Upper Lower Lower Liddell
WML213-300		Lower Barrett
RA8	Located within maingate chain pillars of LW5	Colluvium
RA9	Located in the southern part of LW6	Colluvium

PIEZOMETER	LOCATION	AQUIFER
RA10	Located within/close to MW7	BC Alluvium
RA11	Located in chain pillars between MW8 and MW9	BC Alluvium
RA14	Located close/within MW7	BC Alluvium
RA15	Located in chain pillars between MW8 and MW9	BC Alluvium
RA16	Located within maingate chain pillars of LW5	Colluvium
RM2	Located within maingate chain pillars of LW5	Colluvium/CM
RM9	Located in the northern section of Bowmans Creek	BC Alluvium
T5		BC Alluvium
T6		BC Alluvium
T7		BC Alluvium
RA30		BC Alluvium
RA18	Located in the central section of Bowmans Creek	BC Alluvium
RM4		BC Alluvium
T8	Located within / near main gate pillars between LW6 and MW7	BC Alluvium
T9		BC Alluvium
T10		BC Alluvium
WML275	Located within/close to southern end of LW6	BC Alluvium
WML276		BC Alluvium
RA27	Located to the south of LW5-MW9, along the bank of Hunter River.	HR Alluvium
WML277		HR Alluvium
WML278		HR Alluvium
WML279		HR Alluvium
WML280		HR Alluvium
T1-A	located near the northern end of LW5, 90 m from the LW4 goaf edge	BC Alluvium
T1-P		CM Overburden
T2-A	located within MW8, 440m from LW5 goaf edge and 690m from LW4 goaf edge	BC Alluvium
T2-P		CM Overburden
T3-A	located within MW7, 310m from LW5 goaf edge and 550m from LW4 goaf edge	BC Alluvium
T3-P		CM Overburden
T4-A	located within the southern part of LW6, about 220m from the LW5 goaf edge	BC Alluvium
T4-P		CM Overburden
RA12	Located in mid-panel within LW5	Colluvium
WML110C	Located inside southern end of LW5	Colluvium
WML181	Located in the barrier east of LW1	Pikes Gully
WML182		Pikes Gully
WML183		Pikes Gully
WML184		Pikes Gully

PIEZOMETER	LOCATION	AQUIFER
WML185		Pikes Gully
WML186		Pikes Gully
WML187		Pikes Gully
WML119		Pikes Gully
WML120A		Pikes Gully
WML120B		GC Alluvium
WML129		GC Alluvium

The bores have been monitored routinely since underground mining commenced, or earlier in some cases.

A number of the piezometers were equipped with dataloggers set to record water levels/pressures at hourly or 6-hourly intervals in order that any impacts related to subsidence effects can be detected and related precisely to the position of longwall 5 or other specific site activities occurring at the time. These were:

- WML110A, WML110B and WML110C
- WML111A and WML111B
- WML114A and WML114B
- WML269A
- RA16 and RA27
- T1A.

Water levels/pressures were manually measured weekly in all other piezometers close to LW5, from January to March 2010, during the initial stages of LW5 extraction.

Groundwater quality is monitored less frequently. Selected bores are sampled for field and laboratory analysis in accordance with the monitoring frequencies specified in the GWMP (Groundwater Management Plan).

A brief explanation for all figures is summarised in **Table 4.2**. Water level hydrographs relevant to the LW1 to LW5 extraction are shown on **Figures 4, 5, 6, 9, 10, 11, 13 14, 15** and **16**.

Table 4.2: Figure Explanations

Figure Reference	Explanation
Figure 2: Ashton Coal Groundwater Monitoring Network	Monitoring piezometer location plan
Figure 3: Survey Cross Lines XL5 and CL5- Lateral and Vertical Movement v time	Survey cross lines, showing horizontal movement (CL2) and vertical (subsidence) movement (XL5) versus time above the LW5 goaf.
Figure 4: Groundwater Level Hydrographs – Pikes Gully Seam WML119 and WML120A	Hydrographs of Pikes Gully piezometers WML119 and WML120A located east of LW1, showing the continuation of trends established following mining of LW1 development headings.
Figure 5: Groundwater Level Hydrographs – Pikes Gully Seam East of LW1	Hydrographs of Pikes Gully Piezometers WML181-186 located east of LW1 showing the continuation of trends established following the mining of LW1 development headings.
Figure 6: Groundwater Level Hydrographs – Pikes Gully Seam in Mining Area	Hydrographs of Pikes Gully Piezometers. WML106, WML189, WML191, WML20 and WML21 responded to the mining of LW1-4 development headings. No significant responses were observed during LW5 extractions as these piezometers were dry or exhibited only small residual pressures prior to LW5 headings. WML115 and WML213 showed continuation of trends established prior to LW5 development headings.
Figure 7: Hydrostatic Head Profiles – Pikes Gully Seam (WML189, WML191, WML115 and WML213)	Hydrostatic head profiles of vibrating wire piezometers inside the area of current mining (WML189 and WML191) and outside the area of current mining (WML115 and WML213). WML189 and WML191 show depressurisation in the Pikes Gully and overlying Lemington 15 seam, due to LW2 development headings and LW3 extraction. WML115 and WML213 show steady deviations in the Pikes gully Seam, with no significant depressurisation response in the overlying Lemington seams.
Figure 8: Groundwater Elevations – Pikes Gully Seam, June 2010	Potentiometric contours for the Pikes Gully Seam, produced from groundwater levels measured post LW4 extractions (October 2009) and post LW5 extractions (June 2010), which includes influence of the LW6 development headings.
Figure 9: Groundwater Level Hydrographs – Bayswater Seam and Lemington 1-7 seams	Hydrographs of the Bayswater Seam, showing receding groundwater level trends in WML113-40m and WML213-48m due probably to the adjacent Narama mine, and hydrographs of the Lemington 1-7 seams, showing recent depressurisation as a result of increased storage (bed separation) effects in WML110-WML114, WML213 and WML269, during the mining of LW5.
Figure 10: Groundwater Level Hydrographs – Lemington 8-9 Seams and Lemington 10-12 Seams	Hydrographs of the Lemington 8-9 and 10-12 Seams, showing stress induced responses (bed separation) to the mining of LW4 and LW5
Figure 11: Groundwater Level Hydrographs – Lemington 15 and 19 Seams	Hydrographs of the Lemington 15 and 19 seams, showing temporary stress induced responses in WML110, WML112 and WML111, and slow dewatering response in WML269 during mining of LW5
Figure 12: Hydrostatic Head Profiles – Lemington Seams (WML112, WML113, WML114 and WML269)	Hydrostatic head profiles of vibrating wire piezometers WML112 and WML113 (outside the area of current mining), and WML114 and WML269 (inside the area of current mining) showing depressurisation effects in the Lemington seams.
Figure 13: Groundwater Level Hydrographs – Coal Measures Overburden	Hydrographs of coal measures overburden, showing head declines in T4-P (coinciding with the advancement of LW5) and T1-P (coinciding with the advancement of LW4), and temporary pressure responses in T2-P, T3-P and WML111B. Stable groundwater pressures in all other piezometers.

Figure Reference	Explanation
Figure 14: Groundwater Level Hydrographs – Bowmans Creek Alluvium	Hydrographs of Bowmans Creek paired piezometers. Permian groundwater levels have declined in response to longwall extraction, while alluvium responses have shown no response to mining. T2-P and T3-P showed temporary pressure responses to subsidence impacts above LW4 and LW5. T4-P responded sharply to LW5 and LW6. T1-P revealed a groundwater drop coinciding with the passage of LW4, but no response to LW5.
Figure 15: Groundwater Level Hydrographs – Bowmans Creek and Hunter River Alluvium	Hydrographs of Bowmans Creek Alluvium and Hunter River Alluvium, showing receding groundwater trends as a result of below average rainfall, and a recent rainfall recharge response. No response to mining.
Figure 16: Groundwater Level Hydrographs – Glennies Creek Alluvium	Hydrographs of Glennies Creek alluvium, showing rainfall controlled natural recharge and discharge responses.
Figure 17: Groundwater EC – Glennies Creek Alluvium and Bowmans Creek Alluvium	Groundwater EC trends for the Glennies Creek alluvium and Bowmans Creek alluvium.
Figure 18: Groundwater EC of Tailgate 1A seepages and Pikes Gully	Groundwater EC trends of the Tailgate 1A seepage and Pikes Gully, showing EC decline in LW1 backroad, WML119 and WML120A, following the development headings of LW1, and stable EC's during the extractions of LW2-6.
Figure 19: Groundwater Inflows Versus EIS Predictions	Total underground inflows and seepage inflows from Glennies Creek alluvium, which plot below EIS predictions.

4.2 OBSERVED EFFECTS

4.2.1 PIKES GULLY SEAM

Composite plots of all Pikes Gully Seam piezometers are presented in **Figure 4** and **Figure 5**. 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 LW5 (**Figure 4**). The trends observed in the piezometers are continuations of trends established during the mining of LW1. Consequently, all the seepage impact occurred during LW1 development, and the actual extraction of LW1 to LW5 has not caused any further drawdown impact.

Groundwater levels in WML120A, and WML184 to WML186 have continued to show steady recovery of approximately 0.7m/y, so that about 80% of the initial 3.0m drawdown has now been recovered (**Figure 5**). The partial recovery in water levels suggests a steady reduction in the hydraulic conductivity of the Pikes Gully Seam, possibly due to delayed response to the in-seam grouting carried out in 2007. 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 a number of isolated rainfall recharge events, water levels in WML119, WML181 and WML182 were showing a steady drawdown trend of approximately 0.2m/y since the mining of LW1 began (**Figures 5**), which was consistent with below average rainfall occurring during that period. Since mid 2009, these bores have all showed a reversal of trend, and water levels were rising throughout the mining of LW5, consistent with the increased rainfall recharge during that time.

Piezometers remote from the Pikes Gully Seam outcrop have not shown any response to the recharge events.

Groundwater level responses in the underground SMP area

Piezometers which monitor the Pikes Gully Seam in the underground SMP area have all shown responses to underground mining (**Figure 6**).

Piezometers located inside the LW1-5 area responded during the mining of LW1 to 4. No significant responses were observed during the subsequent LW5 extractions, as these were dry or exhibit small residual pressures, prior to LW5 development headings. The groundwater responses observed to date are summarised as follows:

- WML106-84m and WML20 responded to LW1 development headings, with WML20 responding further to LW2 headings. WML20 became dry during the nearby mining of LW3 maingate headings.
- Vibrating wire piezometer WML191-100m located in the chain pillar between LW2 and LW3 showed dramatic depressurisation in response to the mining of LW3, but showed no response to the earlier passage of the LW2 development headings. 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. The water level had fallen more than 100m below surface and could no longer be monitored before LW5 started. The Pikes Gully seam is 105m below surface at WML20.

Whilst most responses were observed during the mining of LW1 to LW4, continuing depressurisation responses have been observed during the mining of LW5 in piezometers outside of the area of current mining, viz:

- WML115-144m is located closer to the North West Mains than the LW1-4 area. The continued drawdown response observed during the mining of LW5 is believed to be due primarily to drainage into the nearby North West Mains and development headings for LW4, LW5 and LW6, where the lowest point in the headings near WML115 is at an elevation of around -45mAHD.
- WML213 is remote from both LW1-5 and the North West Mains. The steady drawdown observed in WML213 during LW3 to LW5 is believed to be due to the combined effect of Ashton's underground operations and mining activities on neighbouring mine sites.

The drawdown responses discussed above are also shown on hydrostatic head profiles, developed 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 longwall mining (**Figure 7).**

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, post LW4 extraction and post LW5 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 7)**. 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 and WML115 for the reasons outlined above, however unlike the piezometers inside the area of current mining (WML189 and WML191), no significant depressurisation or stress induced effects have occurred in the overlying Lemington Seams (**Figure 7**).

Potentiometric contours for the Pikes Gully Seam have been produced from groundwater levels measured in October 2009 and June 2010 (**Figure 8**). A comparison of potentiometric surfaces for these periods enables an assessment to be made of the depressurisation impacts before and after LW5 extraction. The potentiometric contours show:

- A tight "cone" of depression around the LW1-5 longwall panels, showing the recent expansion of the cone from the influence of the LW5 extraction, including influence from the heading development for LW6 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 WML115-144m are believed to be due to the nearby North West Mains and development headings for LW4, LW5 and LW6.
- A drawdown effect at WML213, in the south western part of the Ashton underground mining area (see both **Figure 7** and **Figure 8**), which is almost certainly responding to the combined effects of LW1-5 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 9, 10** and **11**. The drawdown effects are also apparent on the hydrostatic head profiles (**Figures 7** and **12**).

Two Bayswater seam piezometers show definite drawdown, shown in WML113-40m and WML213-48m (**Figure 9**). 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.

Aside from WML115B, WML115-40m and WML112-43m which monitor the shallow Lemington 1 to 7 seams outside the area of current mining, all piezometers have now shown recognisable drawdowns in response to mining of LW1 to LW5. The magnitude of each response has varied according to the proximity of the piezometer to the nearest active longwall.

Whilst most piezometers had already responded during mining of LW1-4, further drawdowns were detected during the mining of LW5 (**Figures 9 to 12**). The horizons that show recognisable drawdowns in response to LW5 were:

- WML269 – Lem7, Lem8-9, Lem10-12, Lem15 and Lem19 (within main gate pillars, south of LW5)
- WML110 – Lem6OB, Lem6, Lem8-9IB, Lem10-12 and Lem15 (southern end of LW5);
- WML114 – Lem15 and Lem19 (above middle section of LW5);
- WML111 – Lem4 and 7, Lem11-12, Lem15 (southern end of LW6);
- WML112 – Lem6-7, Lem 8 and Lem15 (above chain pillar between MW7 and MW8);
- WML113 – Lem9 (southern end of MW9), and
- WML213 – Lem8-9, Lem15 and Lem19.

VW Piezometer responses in WML110 and WML269 indicate that there was significant disturbance of the strata around the period of 1-4 February 2010. All WML110 vibrating wire piezometers were lost during that period, presumably due to ground movements, although all were still pressurised at the time they ceased recording. The standpipe bore WML110B was also affected by direct or indirect connection with subsidence fracturing, as it was rapidly drained of water between 19 January and 12 February 2010. However, WML269, although it is located immediately adjacent to the LW5 goaf area, has shown only partial depressurisation at all piezometers, indicating that the subsidence fracturing has not caused dewatering of the Permian strata even a few metres from the edge of the LW5 goaf footprint (**Figure 2**). Piezometers at the Lemington 15 and Lemington 19 seams maintain pressures of close to 100m after completion of LW5.

The Lemington 6 (WML110-38m) and Lemington 5-9 responses (WML269-24m, WML269-56m and WML269-64m) are interpreted to be indicative of an increase in storage due to bed separation effects (**Figure 9**).

The deeper Lemington 11-15 seams in WML110 and WML269 responded differently. The head declines observed in WML269 represent slow dewatering from these intervals, whilst the temporary decline and recovery pressure responses at WML110 are considered to be temporary stress induced responses (**Figures 10** and **11**).

Shallow Lemington seams (Lemington 6-12) in the south west corner of the underground mining area (WML112, WML113, and WML213) showed marked drawdown responses to the mining of both LW4 and LW5 (**Figure 9** and **Figure 10**). It is thought that this drawdown represents the lateral expression of bed separation effects above the extracted panels, not dewatering. Similar effects associated with longwall mining elsewhere in the world have been reported in literature (Booth, 2006; Karaman et al, 2001), and are 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 the previous End of Longwall 4 report (Aquaterra, 2010a).

Top of the Coal Measures

The 24m deep coal measures standpipe WML110B had been showing gradual decline in head since 24 January 2010, but on 8 February 2010 the water fell quickly to the base of the bore and the bore became dewatered (**Figure 13**). The bore was cemented up when it became apparent that there was a potential air connection to the goaf or the upper coal measures. The appearance of coal seam gas from this bore at this time suggested that there was probably connective cracking from the goaf to at least 24m below the surface. WML110C which is 14m deep and monitors the alluvium, was dry when LW5 started and has remained dry since, but it has shown no air connection to the goaf, indicating no direct connection from the goaf to 14m below the surface. It is interpreted that connected cracking potentially extends up from the goaf to between 14 and 24m below the ground surface above LW5, and acts as an effective aquaclude.

Hydrographs of paired standpipe piezometers which monitor the uppermost water-bearing horizon in the Permian (T1-P, T2-P, T3-P and T4-P) and overlying Bowmans Creek Alluvium (T1-A, T2-A, T3-A and T4-A) are presented on **Figure 14** and **Figure 15**.

At each of the four sites, differences in water level were found to exist between the alluvium and Permian. At Sites T1 and T4, the Permian groundwater level was initially higher than the alluvium groundwater level, while at sites T2 and T3 the alluvium groundwater level was higher.

However since March 2010, the Permian groundwater levels have declined in response to longwall extraction, while the alluvium responses have shown no response to mining (**Figure 14**). The pattern of responses observed to date is summarised as follows:

- Piezometer T1-P, located 80m west of the northern part of LW4, revealed a groundwater drop of about 2m in August 2009, which coincided 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. The goaf edge of LW4 is approximately 90m east of T1-A and T1-P. T1-P showed no response to the mining of LW5.
- Piezometer T4-P, which is located 220m from the LW5 goaf edge, responded sharply to the passage of LW5, with a permanent water level drop of around 1m between 20 and 28 January 2010, and then further steady decline throughout the mining of LW5. T4-P had earlier shown a temporary decline of around 0.5m with the passage of LW4 in September-

October 2009, but this was followed by almost complete recovery of the water level over the following months until the LW5 response.

- Piezometric responses observed in T2-P and T3-P were interpreted to be temporary pressure responses to subsidence impacts above LW4 or LW5, both of which are a considerable distance away (440m and 690m respectively from T2-P, and 310m and 550m respectively from T3-P).

4.2.3 ALLUVIUM

Bowmans Creek and Hunter River Alluvium

Piezometers which monitor the Bowmans Creek and Hunter River Alluvium have not responded to mining. Instead the water table reflects the rainfall controlled natural recharge and discharge patterns (**Figure 15**).

All piezometers have shown a recent upward trend in response to rainfall recharge (**Figure 15**). Prior to this a gradual recession following a small recharge event in April 2009 was evident across all piezometers. The recession of the water table was associated with a reduction in rainfall recharge over the period, rather than underground mining, and there has been no discernable response to mining.

As discussed above, the absence of any mining related response in the alluvium at any of the paired sites (T1-T4), while all sites show some impact in the Permian from longwall extraction, indicates a clear lack of hydraulic connection between the alluvium and the underlying Permian coal measures.

Glennies Creek 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 16**). No further drawdown occurred in the alluvium bores during subsequent extractions of LW1 to LW5. All drawdown impacts occurred during the development heading stage of LW1.

Water table responses in Glennies Creek alluvium to the east of Glennies Creek are consistent with the rainfall controlled natural recharge and discharge responses also observed in the Hunter River and Bowmans Creek alluvium (**Figure 16**).

4.2.4 RECHARGE

A number of rainfall recharge events are evident in the hydrographs of piezometers which monitor the Glennies Creek, Bowmans Creek and Hunter River alluvium (**Figures 14** to **16**). Aside from the most recent upward trend in response to a rainfall recharge event in July 2010, after completion of LW5, groundwater levels have been mostly on a natural recession trend since early 2009. This was a period of below average rainfall, and the recession trend is due to the natural discharge process, and is not a function of mining, as piezometers distant from current mining activities also exhibited the same trends.

It was reported in Aquaterra (2009b) that recharge events were also evident in piezometers which monitor the Pikes Gully Seam close to the outcrop (WML119 and WML120A – **Figure 4**). Bores distant from outcrop showed no response to these recharge events (e.g. Pikes Gully Bores WML181-186 – see **Figure 5**; and the deeper Lemington Seam bores – see **Figure 11**).

Similar responses to rainfall were apparent in the paired alluvium and Permian bores T1-T4. T1 and T2 piezometers (both alluvium and the top of the Permian) show a strong and large response to rainfall recharge, whereas the T3 and T4 piezometers were less responsive to rainfall, and showed an attenuated and smaller magnitude recharge response to rainfall events (**Figure 14**). The two southern sites (T3 and T4) are considered to be in an area where the alluvium is more clayey/silty, and therefore is characterised by slower infiltration of rainfall, than the alluvium in the northern part of the Bowmans Creek floodplain, where the T1 and T2 sites are located, and where the alluvium is less clayey/silty and permits more rapid infiltration of rainfall.

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 11**), 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 and LW5 at nearby piezometers WML110-65m, WML110-90m, WML110-110m, WML111-118m and WML269-112m (**Figure 11**).

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 directly above the goaf and the same seams outside of the goaf area. These effects are described in detail in Aquaterra (2010a). It should be noted that the sudden depressurisation noted in piezometers close to LW5 (WML110, WML111 and WML269) was not accompanied by an increase in underground inflow, 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**). These responses are significant, as the water levels in these bores are 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 within the barrier between the ine and the Glennies Creek floodplain, and not the storage/pressure response discussed above.

5 GROUNDWATER AND SURFACE WATER QUALITY

5.1 MONITORING PROGRAMME

Monitoring of groundwater quality in the Glennies Creek alluvium, Bowmans Creek alluvium, Coal Measures Overburden and Pikes Gully Seam was undertaken prior to the commencement of mining to establish baseline conditions.

Key monitoring piezometers are listed in **Table 5.1**. Further water quality sampling of the bores has taken place periodically 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, not just seepage through the eastern rib.

EC monitoring of the LW1 Backroad Pipe discharge from TG1A has continued through the extraction of LW5.

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 and Bowmans Creek.

Graphs of measured EC values from the TG1A seepages and monitoring bores are indicated on **Figures 17** and **18**.

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

- Pikes Gully Seam:
    - 6,000 to 6,500 µS/cm (north of LW1 CT13)
    - 8,000 to 9,000 µS/cm (south of LW1 CT14)
- Glennies Creek alluvium - 500 to 2,200 µS/cm,
- Bowmans Creek alluvium – 1,000 to 2,000+ µS/cm; and colluvium – 4,000 to 13,500 µS/cm
- Coal Measures Overburden above LW5 to LW6 - 320 to 2,000 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 1,000 µS/cm (increases to 2,000+ 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 yielded progressively less saline water 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 showed smaller reduction in salinity 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) showed steady decline in salinity, and then stabilised at a moderately low salinity level intermediate between alluvium and Permian groundwater salinity levels, 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 LW5 panel extractions.

Salinities in the Bowmans Creek alluvium fluctuate from a minimum of 1,000 to a maximum of 2,000 µS/cm EC, although at other sites, salinities up to 6,000 µS/cm EC have been recorded at other sites. The steady decrease in EC over the LW1 to LW5 mining period is attributed to dilution from rainfall recharge.

The alluvium and colluvium that exists above LW5 (RA8, RM2 and RM16) contains saline groundwater (4,500 to 13,800 µS/cm EC), indicating that it is not strongly connected hydraulically with less saline groundwater in the rest of the alluvium aquifer.

A dramatic decrease in reported groundwater salinity from 1,820 µS/cm to 86 µS/cm EC was observed in WML119 during the mining of LW3. This bore was found to have been damaged apparently after being hit by a vehicle and has since been repaired. 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	Location	Aquifer	Pre- Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction	During LW5 Extraction
			Jun - Sep 2006	**Jan-07**	**May - Jun 2007**	**Nov 2007 - Feb 2008**	**Mar - Jun 2008**	**Aug 2008 - Mar 2009**	**May - Nov 2009**	**Jan - Jun 2010**
Monitoring Piezometers										
WML 20	Chain Pillar LW3-LW4	Pikes Gully	6240	-	6030	-	-	-	-	-
WML 21	North of LW5	Pikes Gully	8140	-	8530	-	-	-	7550	-
WML 119	East of LW1	Pikes Gully	6470	4940	3090	2320	-	86-1820	87-126	139
WML 120A	East of LW1	Pikes Gully	6350	1470	742	828	-	810-1140	919 - 935	1050
WML 181	East of LW1	Pikes Gully	-	-	4920	-	-	2460-2680	2600-2640	2670
WML 182	East of LW1	Pikes Gully	-	-	4220	8680	-	6510-6950	6390-6760	7900
WML 183	East of LW1	Pikes Gully	-	-	8570	8180	-	5310-5950	5310-5950	5570
WML 184	East of LW1	Pikes Gully	-	-	-	4560	-	4400-5140	4940-5270	5440
WML 185	East of LW1	Pikes Gully	-	-	-	4430	-	2900-2940	2310-2710	2650
WML 186	East of LW1	Pikes Gully	-	-	-	463	-	-	933-1300	1550
WML 120B	East of LW1	Glennies Creek Alluvium	1930	1260	1020	1220	-	915-992	903	639
WML 129	East of LW1	Glennies Creek Alluvium	571	522	396	577	-	458-571	490	433
RA8	Maingate chain pillars of LW5	Bowmans Creek Alluvium							6800-7660	7490
RA10	Located within/ close to MW7	Bowmans Creek Alluvium		1780						1950
T1A	Located within	Bowmans		2040						2230

Source	Location	Aquifer	Pre- Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction	During LW5 Extraction
			Jun - Sep 2006	Jan-07	May - Jun 2007	Nov 2007 - Feb 2008	Mar - Jun 2008	Aug 2008 - Mar 2009	May - Nov 2009	Jan - Jun 2010
	northern end of LW5	Creek Alluvium								
WML110C	Located inside southern end of LW5	Colluvium		9340						
Glennies Creek Surface Flow										
SM7	Glennies Creek		235-518	268	319-325	347-643	402-652	235-727	270-774	366-393
SM8			235-527	267	318-328	339-699	400-644	239-754	264-764	287-408
SM11			238-542	268	320-329	335-686	410-650	476-768	277-769	293-436
Bowmans Creek Surface Flow										
SM3	Bowmans Creek		598-1750	1420	dry	420-1270	531-976	730-917	930-160	916-992
SM4			478-4510	11400	12100-12500	428-2220	531-1170	470-1980	954-1790	2240-2680
Underground Seepages – TG1A										
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	-	-	-	-	-

Source	Location	Aquifer	Pre- Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction	During LW5 Extraction
			Jun - Sep 2006	**Jan-07**	**May - Jun 2007**	**Nov 2007 - Feb 2008**	**Mar - Jun 2008**	**Aug 2008 - Mar 2009**	**May - Nov 2009**	**Jan - Jun 2010**
CT17-18			-	7450	5960	-	-	-	-	-
LW1 BR Pipe	Southern end of LW1		-	-	2830	1726-1950	1620-1760	1554-1772	1579-1666	1580-1718

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6 GROUNDWATER INFLOWS

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. 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 is exported from the mine either via a borehole pump direct to the mine water supply circuit, or via pipelines along the gate-roads to the sump in Arties Pit near the mine portal. Prior to May 2010, a sump borehole situated at the south west corner of LW1 (shown on **Figure 2** as the Backroad Sump Borehole) was used, but since that date, a new sump borehole (Sump Bore No 2) located to the South of LW6, has been used.

The main contributions to groundwater inflow are seepage into TG1A (the eastern gate road of LW1), small inflows to the North West Mains, and broadly distributed goaf seepage into the LW1 to LW5 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 LW5 it varied between about 0.08 and 0.4 ML/d, i.e. between 0.4 and 10 L/s with an average of around 5 L/s (**Figure 19**).

The total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1 to LW5, seepages into maingate roads of LW5, 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 storage dam 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 LW5 extraction (January 2010 to June 2010). 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 0.9 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 18**). 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 LW5.

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 basis 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 actually 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 LW5 occurred during Mining Year 7 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 19**, 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 7 as reported in the EIS are plotted on **Figure 19** in this report.

Figure 19 shows that the actual inflow rate during the extraction of LW5 was in the range 0.4 to 10 L/s (0.03 to 0.86 ML/d), well below the rate predicted for this stage of mining in the EIS (i.e. 17 L/s or 1.64 ML/d).

The total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1 to LW5, seepages into maingate roads of LW5, 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 ALLUVIUM

Seepage 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, and possibly small flows from the roof and floor sediments. 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 19** together with the alluvium seepage inflow rates predicted in the EIS. Furthermore, the actual seepage inflow rates during LW5 extraction (approximately 1.1 – 1.5 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 LW5. 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**.

Seepage from Bowmans Creek Alluvium / Regolith

Although it was reported in the EIS that seepage from the Bowmans Creek alluvium was predicted to occur during this stage of mining (1.7 L/s), LW5 did not undermine any saturated alluvium associated with Bowmans Creek (**Figure 2**), and there have been no observed seepage losses from the alluvium by other indirect flow paths as a result of mining.

The actual seepage from the overlaying unconsolidated material comprising alluvium, colluvium and weathered rock (regolith) during the mining of LW5 is difficult to determine. However, the absence of connected cracking to the surface (**Section 4.2.2** and Aquaterra (2010c)), the lack of water table response in the regolith (**Section 4.2.3**) and the reduction of groundwater mine inflows (**Section 7.1.1**), suggests there was minimal losses from the regolith during the mining of LW5.

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 LW5 extraction, the groundwater level at WML120B had recovered slightly to be only 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 7, coinciding with the present state of underground mining. Hence actual drawdown is very much less than predicted in the EIS.

The hydrographs of bores on the eastern side of Glennies Creek (**Figure 16**) indicate no suggestion that any significant drawdown has occurred at all in the alluvium east of Glennies Creek.

Likewise, hydrographs of bores in Bowmans Creek alluvium and Hunter River alluvium (**Figures 14 and 15**) reveal no evidence of any drawdown impact as a result of underground mining.

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

7.2 SMP PREDICTIONS

The Groundwater Assessment Report (Aquaterra, 2008b) prepared in support of the SMP Application for LW/MW5-9 stated that inflow rates and seepage rates would be 40% lower than those predicted in the EIS until January 2011 during the Mining of MW8-9 when the predicted mine inflow rates are similar to the EIS predictions, 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 (0.4 – 10 L/s, average 5 L/s) during the extraction of LW5 have been well below the EIS prediction (17 L/s), as well as the SMP predictions (11 – 14 L/s) for this stage of mining.

The LW1-4 SMP 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 major and minor rainfall events occurred during the extraction of LW1 to LW5, 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 AND BOWMANS CREEK ALLUVIUM COMPARED WITH SMP PREDICTIONS

It is evident that the actual seepage inflow rates during LW5 extraction (approximately 1.1 – 1.5 L/s) are well below the EIS predictions of 3.0 L/s from the Glennies Creek alluvium and 1.7 L/s from the Bowmans Creek Alluvium for this stage of the mining operation.

Both the observed and modelled impacts (Aquaterra, 2008b) on Glennies Creek alluvium and Bowmans Creek alluvium are substantially smaller than those predicted in the EIS assessment over the entire period of mining of LW/MW5-9.

No increase in measured seepage rate was observed during the extraction of LW5. 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 LW5 extraction were in the range 1.1 to 1.5 L/s, with an average of approximately 1.3 L/s (**Figure 18**) and there were no seepage losses from Bowmans Creek alluvium. The actual seepage rates have therefore continued to be less than the maximum rates contained in the both LW1-4 and LW/MW 5-9 SMP predictions (Peter Dundon and Associates, 2006; Aquaterra, 2008b).

Although it was reported in Peter Dundon and Associates (2006) that 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 2 L/s, with no increase during extraction of LW2 to LW5 or subsequent longwall panels.

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 LW5. Subsidence impacts have been limited to areas immediately above the extraction panels, within the 20 mm 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, while lowered groundwater levels in the barrier have been steadily recovering. This suggests a likely reduction in the permeability of the Pikes Gully seam within the barrier, possibly due to clogging by suspended fines, or a delayed benefit from the TG1-A rib grout injection program implemented during 2007.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Mining of Pikes Gully Seam LW5 was carried out between 4 January 2010 and 4 June 2010. 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 and Bowmans Creek alluvium varies, but it is generally less saline than the coal measures. Alluvium salinity is generally less than 1,000 µS/cm EC, but can be as high as 6,000+ µS/cm EC.

There is abundant evidence that prior to commencement of mining at Ashton, groundwater levels in the Permian coal measures were higher than both groundwater levels in 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 survey monitoring is now being concentrated directly above the longwall goafs, rather than above the barrier between Glennies Creek and the mine workings. 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 LW5). Lateral movement below Bowmans Creek was less than 20mm. The displacements detected are too small to indicate any horizontal shearing caused by the LW4 or LW5 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 5 mining.

There has been no significant increase in total mine inflows following goafing of LW5. Calculated total groundwater inflow rate during LW5 was around 0.4 - 10 L/s (i.e. 0.03 to 0.86 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 not related to dewatering by means of 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, generally 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 (0.4 - 10 L/s) during the extraction of LW5, compared with the EIS and LW/MW5-9 SMP predicted inflow rate for this stage of mining of around 1.64 ML/d (17 L/s) and 1 – 1.2ML/d (11-14 L/s), respectively.
- 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 LW5 extraction were approximately 1.1 – 1.5 L/s. Well below the EIS predictions (3 L/s) and consistent with the LW/MW5-9 SMP prediction.
- 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 LW5 - 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.

- Hydrographs of bores in Bowmans Creek alluvium and Hunter River alluvium reveal no evidence of any drawdown impact as a result of underground mining.
- 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 LW5.

In summary, all groundwater-related impacts from underground mining up to the completion of LW5 (June 2010) were at, or below the levels predicted in the EIS (HLA Envirosciences, 2001), and in the LW1-4 SMP and LW/MW5-9 SMP Groundwater Assessments (Peter Dundon and Associates, 2006; Aquaterra, 2008b).

Most of the impacts relating to Glennies Creek alluvium had stabilised prior to the end of LW1, and no significant incremental impact or influence from mining of LW2 to LW5 has been observed. Impacts on inflows and groundwater levels in alluvium 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.

8.2 RECOMMENDATIONS

There are no recommendations.

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, 2010a, Ashton Coal: End of Panel 4 Groundwater Report

Aquaterra Consulting Pty Ltd, 2010b, Ashton Coal: Longwalls 5-6 and Miniwalls 7-8 SMP Approval – Start and Finish Positions of LW6.

Booth C J 2002. The Effects of Longwall Coal Mining on Overlying Aquifers. In: Younger P L, Robins N S (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__

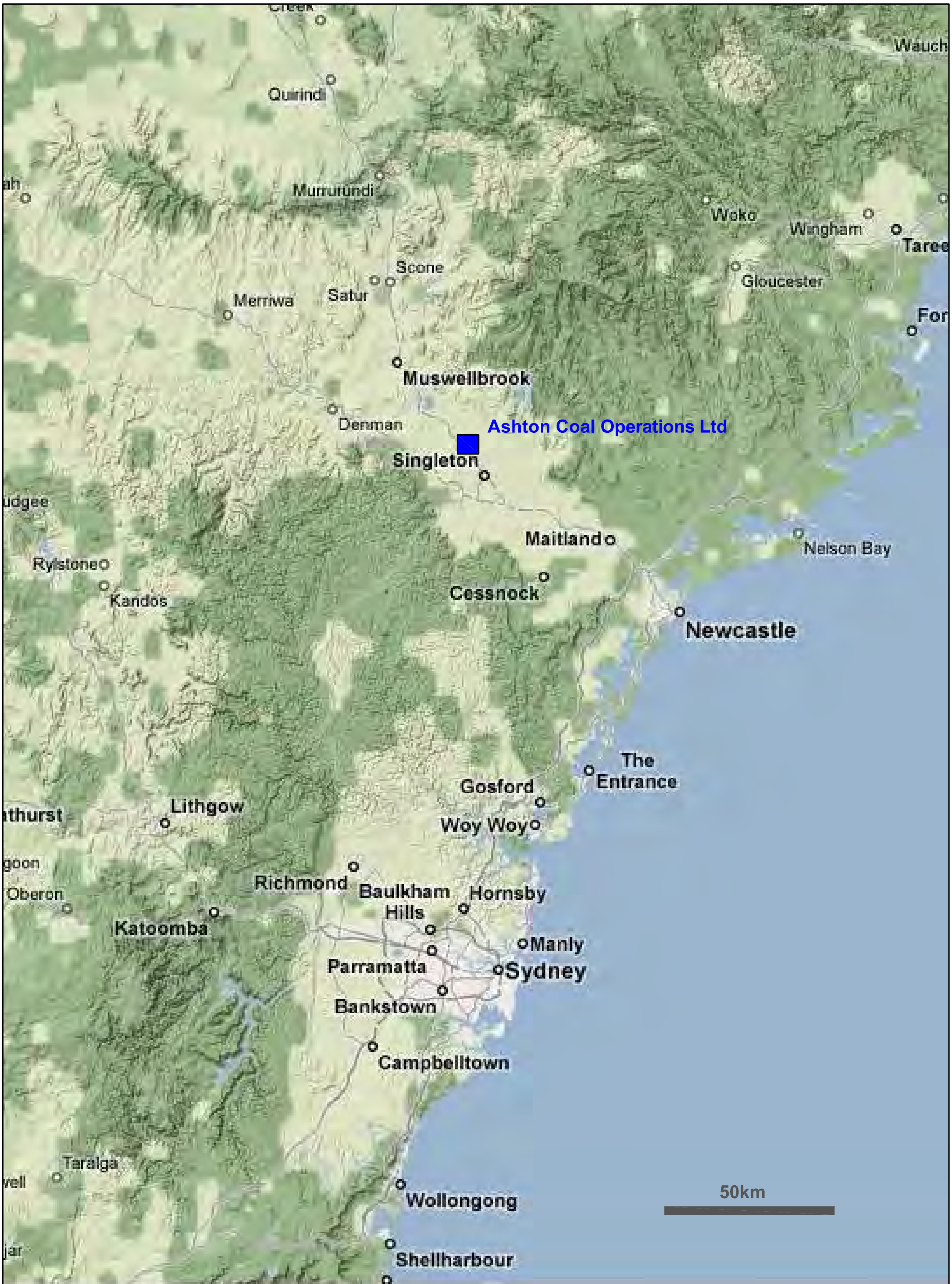
Peter Dundon and Associates Pty Ltd, 2006. Ashton Coal Mine Longwall Panels 1-4, Subsidence Management Plan – Groundwater Assessment.

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 P L, Banwart S A, Hedin R S (2002) Mine Water: Hydrology, Pollution, Remediation. *Environmental Pollution*, vol 5. Kluwer, Dordrecht, 442 pp.

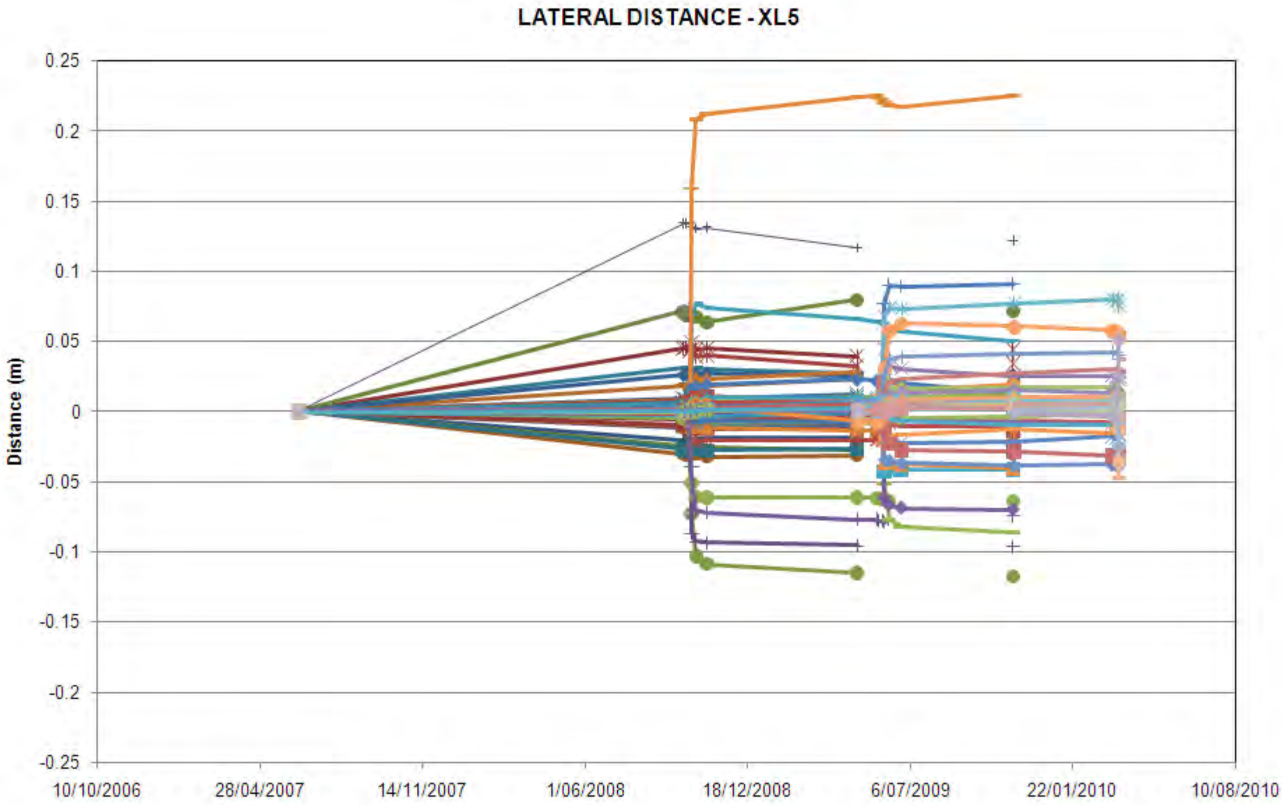


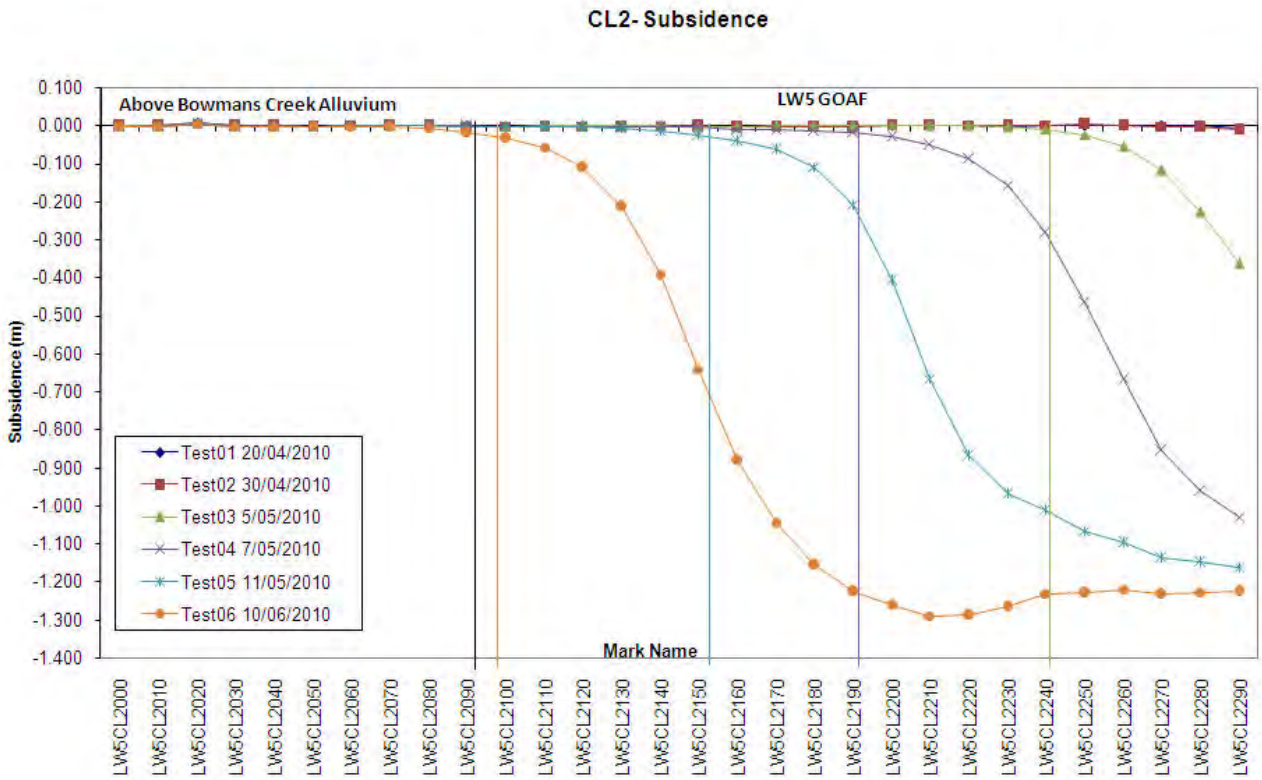
Date:	10 July 2009	Scale:	as indicated	**Ashton Coal Operations Ltd**
Initials:	JVDA	Job No:	S03	**LOCALITY PLAN ASHTON COAL OPERATIONS**
Drawing No:	S03-237a	Rev:	A	
aquaterra				**Figure 1**

Legend

- Arties Seam Bores
- EIS Investigation Bores
- Subsidence Monitoring - Vibrating Wire Piezo
- Subsidence Monitoring - Standpipe Piezo
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometer
- Glennies Creek Piezometers
- Upper Liddell Seam Monitoring Bores
- LW1 Barrier Piezometers
- Dry / Abandoned / Lost Bore
- Extent Of Alluvium
- Extent Of Saturated Bowmans Creek Alluvium
- Longwall Mining Completed - Pikes Gully Seam

Date:	09 August 2011	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	JVDA/SRD	Job No:	S55 D4	ASHTON COAL MINE PIEZOMETER LOCATION PLAN FOR END OF LW5
Drawing No:	S55-232h	Revision:	H	
aquaterra				Figure 2





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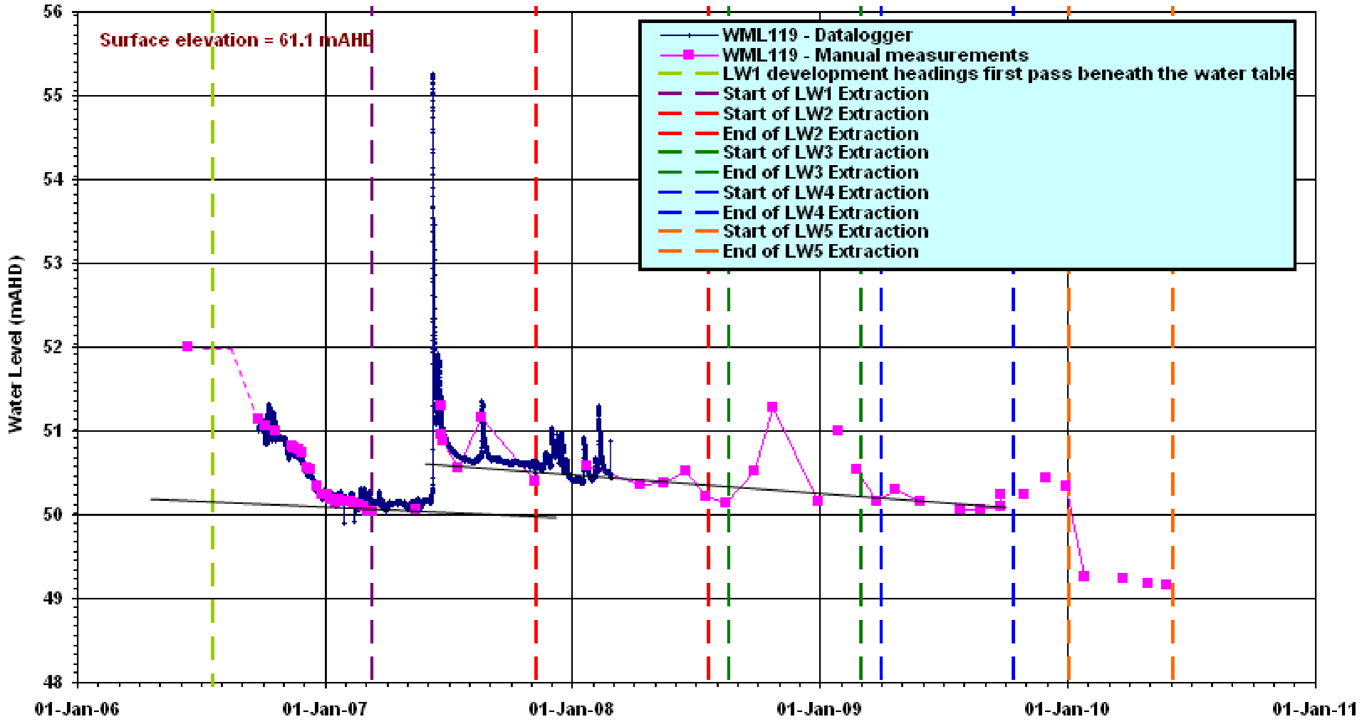
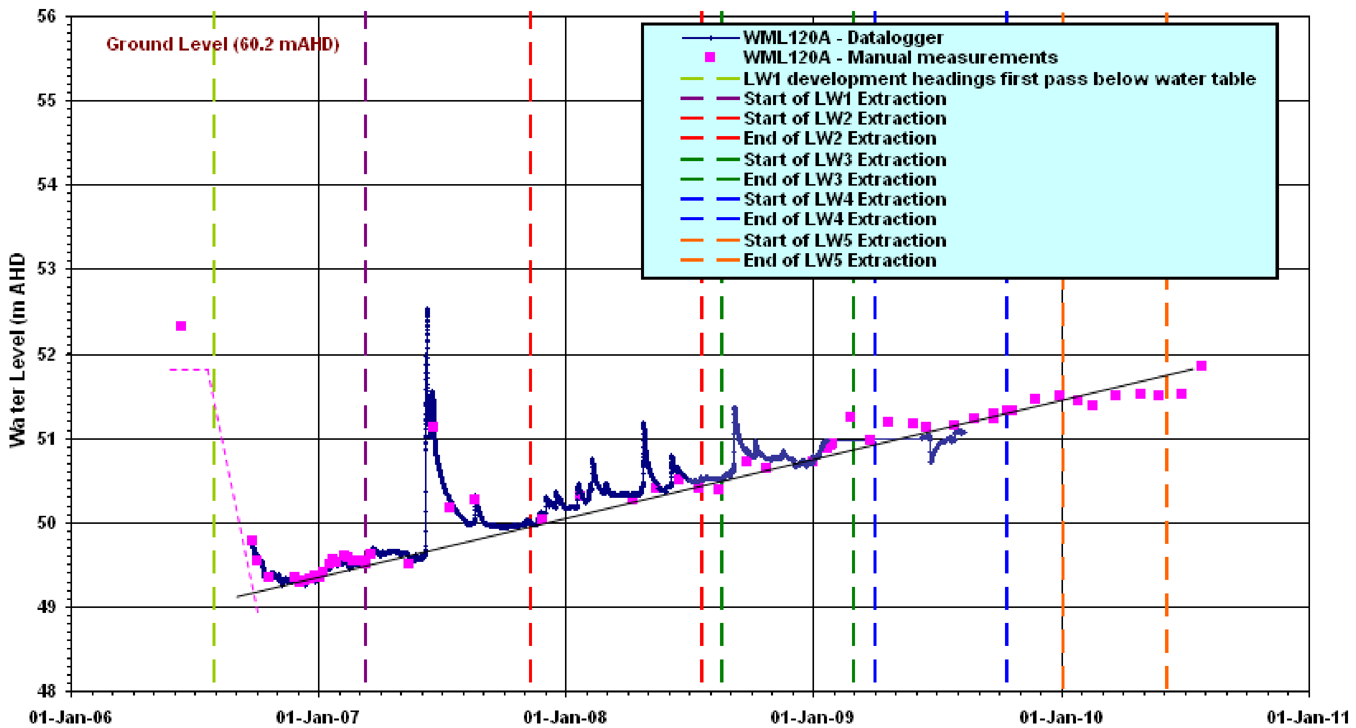
Initials **TL**	Project **S55 D4**	**SURVEY CROSS LINES XL5 AND CL5 LATERAL AND VERTICAL MOVEMENT V TIME**
Drawing Number **srf-016a**	Revision **A**	
aquaterra		**Figure 3**

GROUNDWATER LEVEL HYDROGRAPH - WML119 (Pikes Gully Seam)



GROUNDWATER LEVEL HYDROGRAPH - WML120A (Pikes Gully Seam)



Date	19 August 2010	Scale		**Ashton Coal Operations Ltd**
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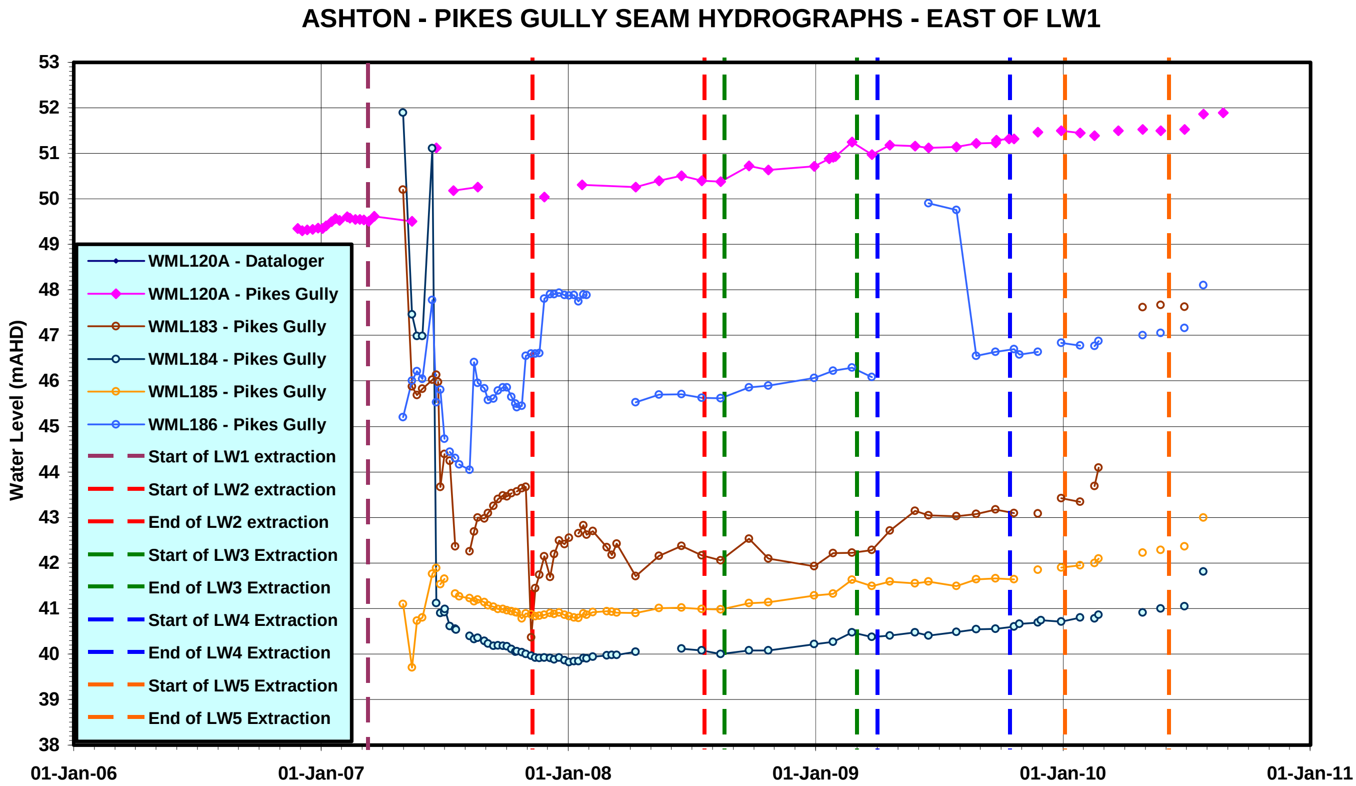
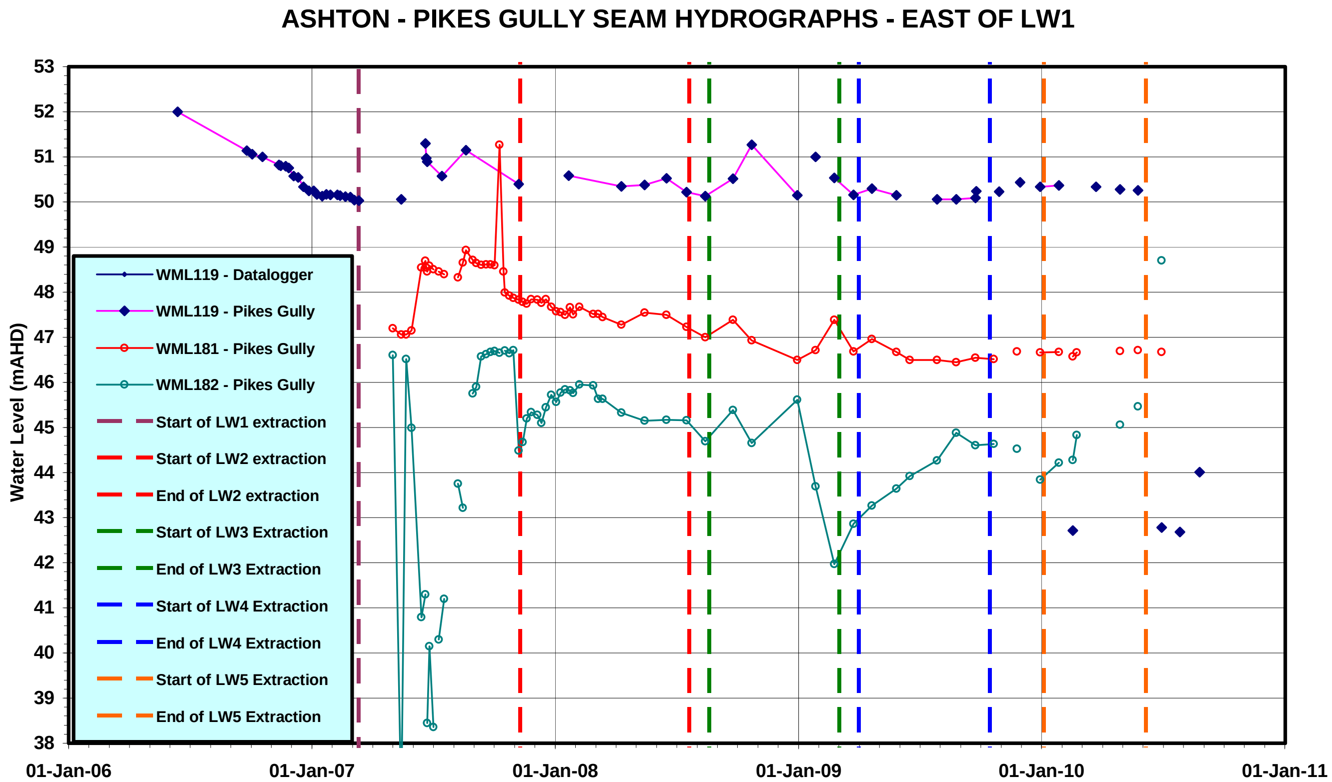
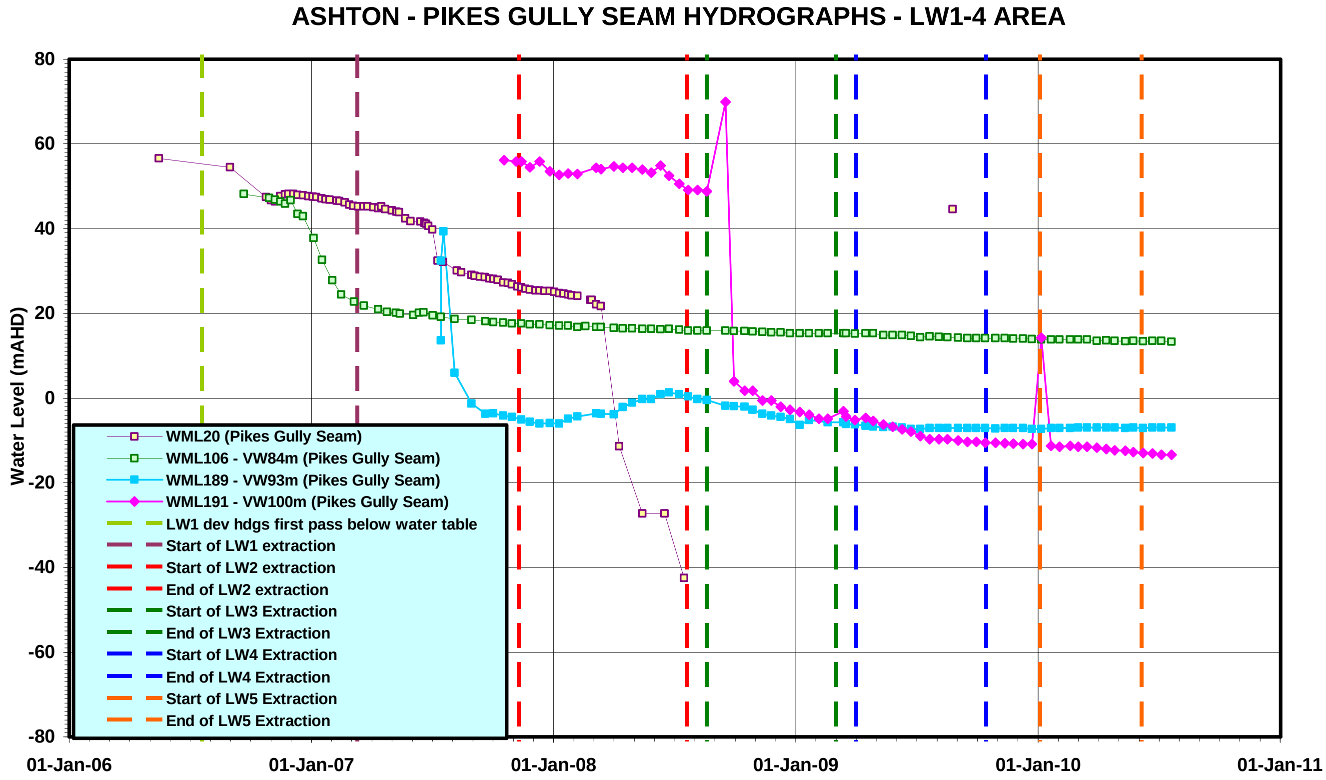
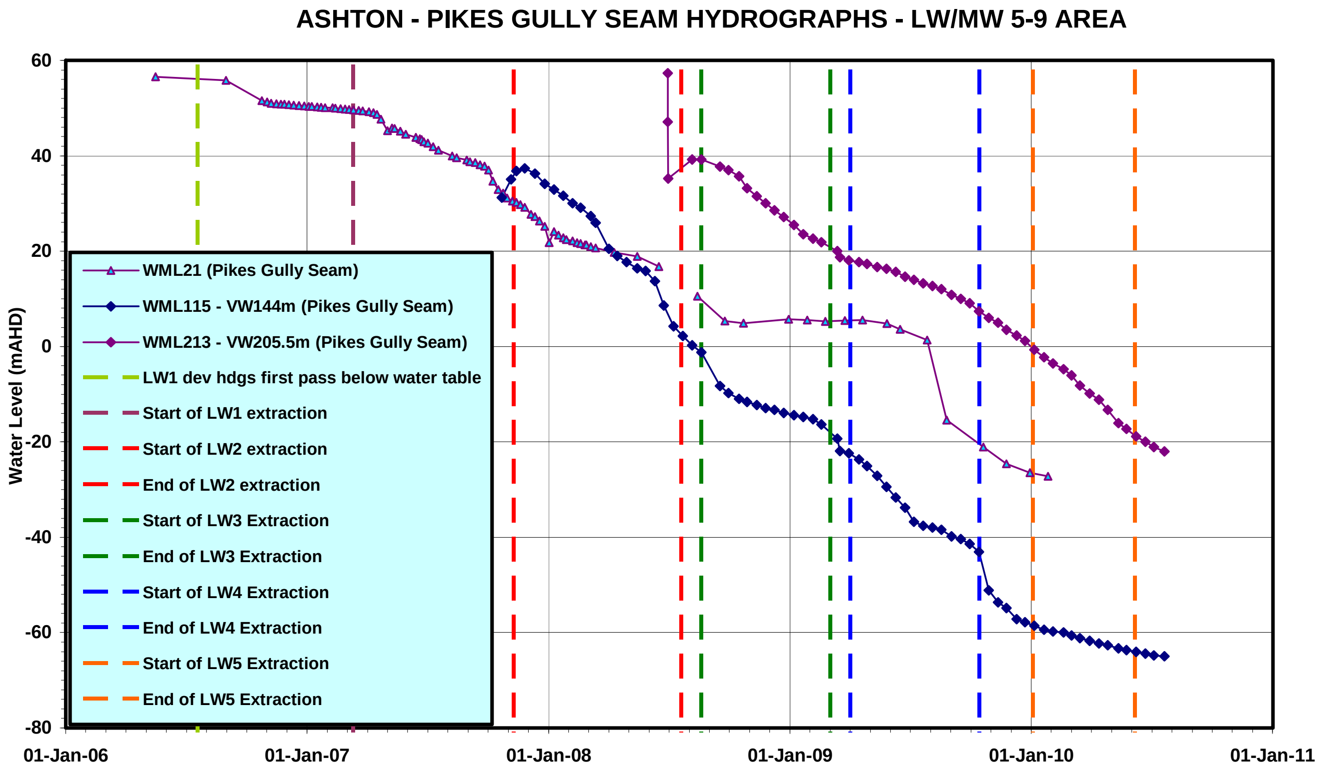
Drawing Number	srf-006c	Revision	C	
aquaterra				**Figure 4**



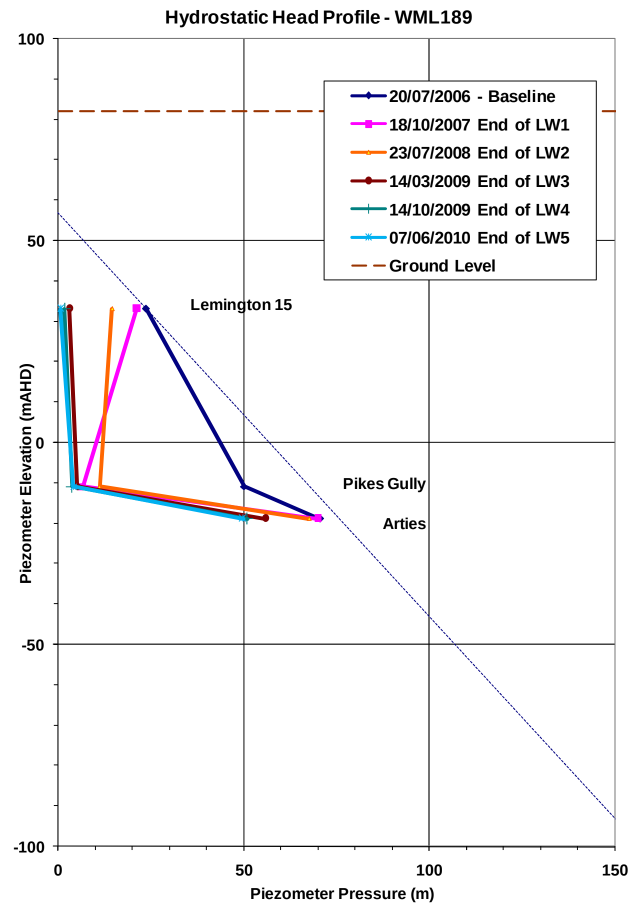


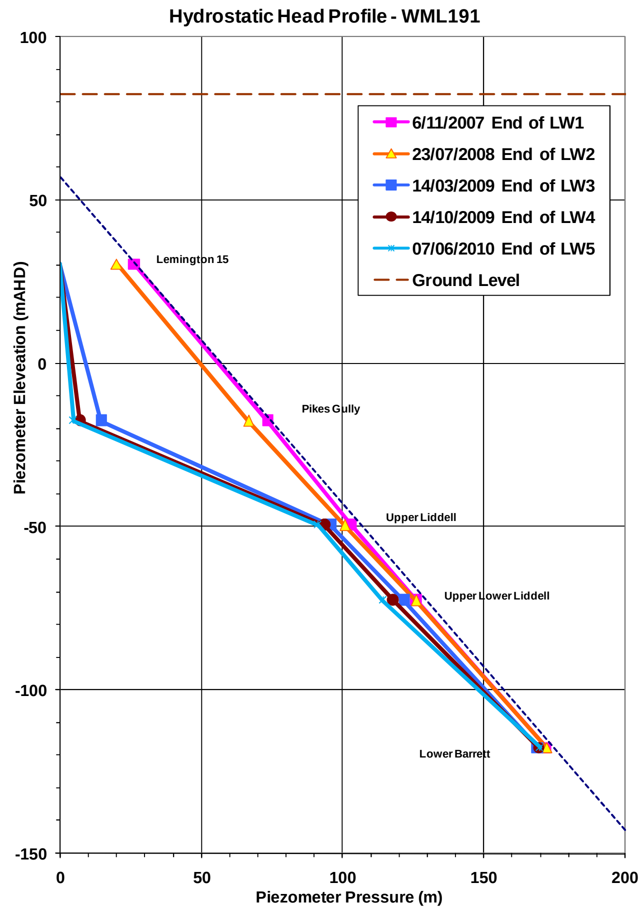
Date 09 September 2010	Scale	**Ashton Coal Operations Ltd**
Initials SM	Project S55 D4	GROUNDWATER LEVEL HYDROGRAPHS PIKES GULLY SEAM EAST OF LW1
Drawing Number srf-007f	Revision F	
aquaterra		**Figure 5**

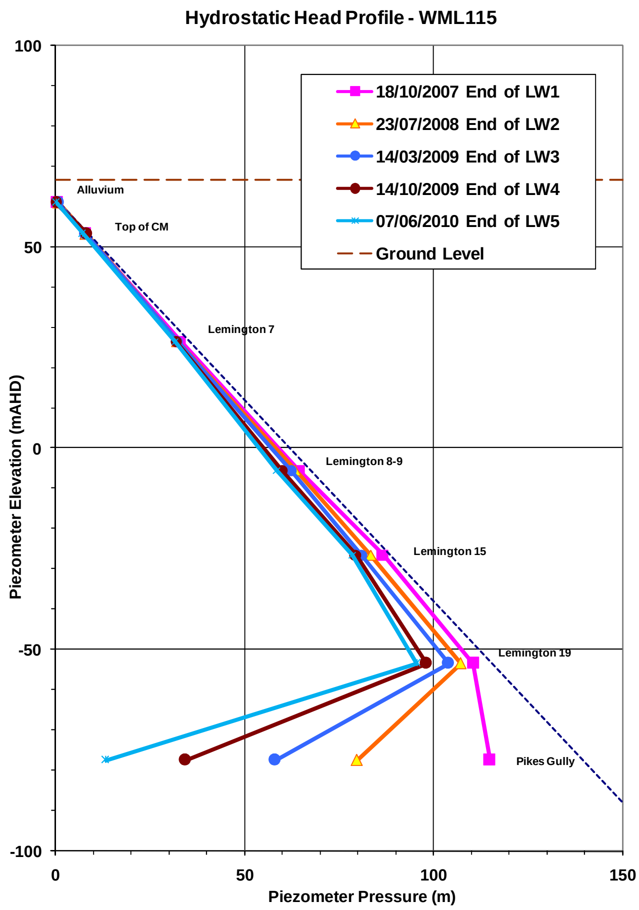


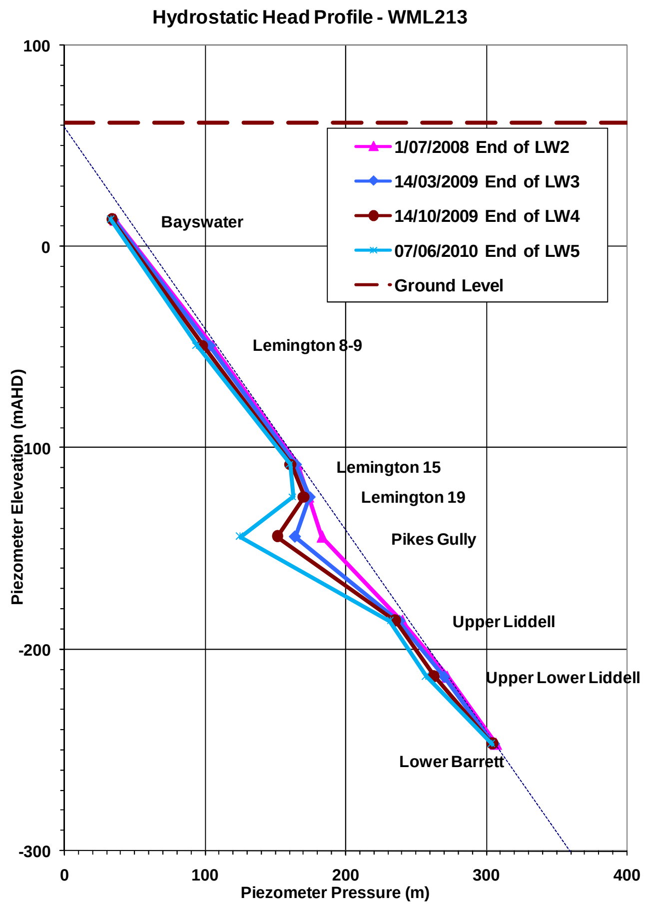


Date **09 September 2010**	Scale	**Ashton Coal Operations Ltd**
Initials **SM**	Project **S55 D4**	**GROUNDWATER LEVEL HYDROGRAPHS PIKES GULLY SEAM - MINGING AREA**
Drawing Number **srf-007g**	Revision **G**	
aquaterra		**Figure 6**









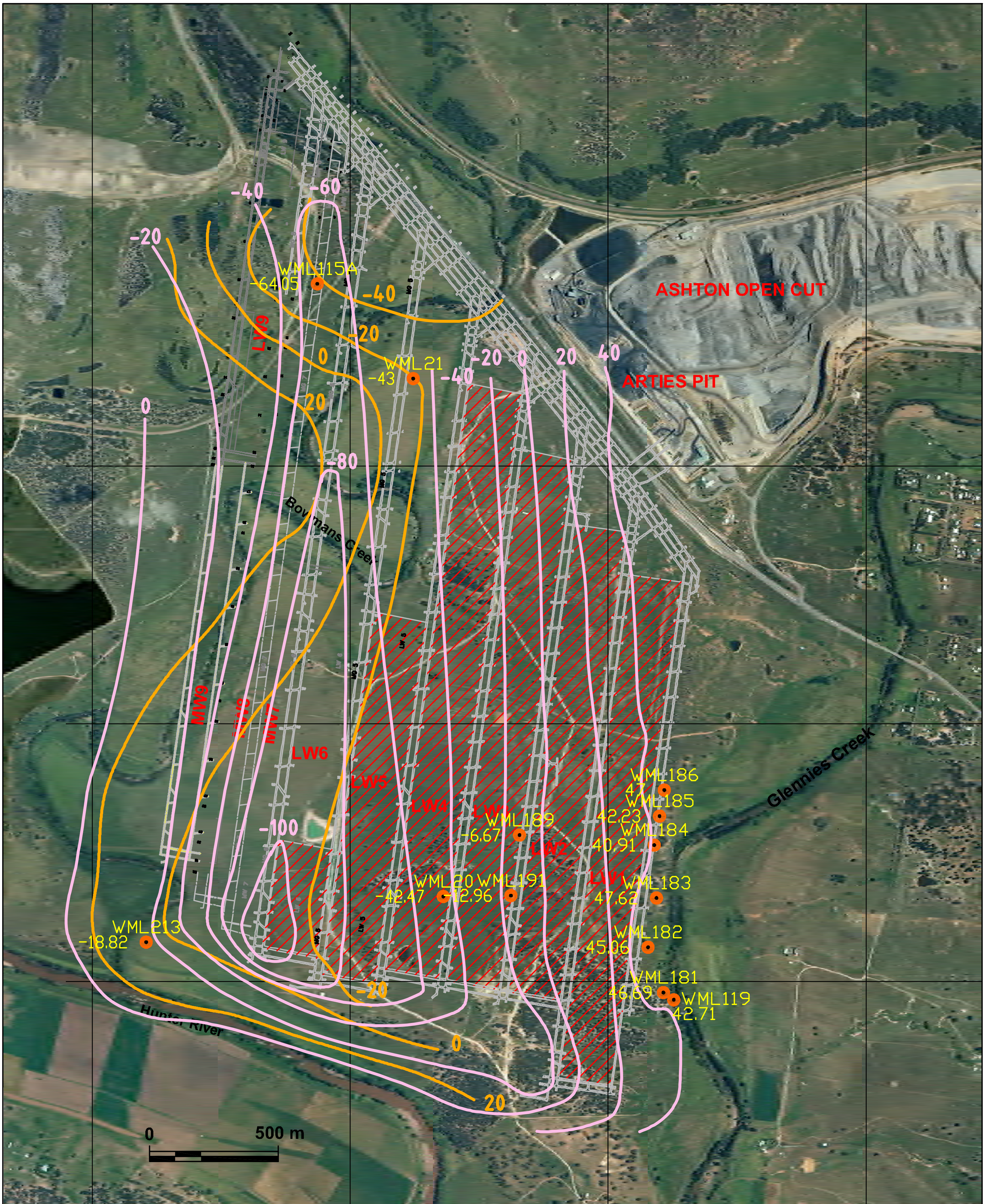
Date	19 August 2010	Scale	
Initials	TL	Project	S55 D4
Drawing Number	srf-003c	Revision	C

aquaterra

Ashton Coal Operations Ltd

HYDROSTATIC HEAD PROFILES
PIKES GULLY SEAM
(WML189, WML191, WML115 and WML213)

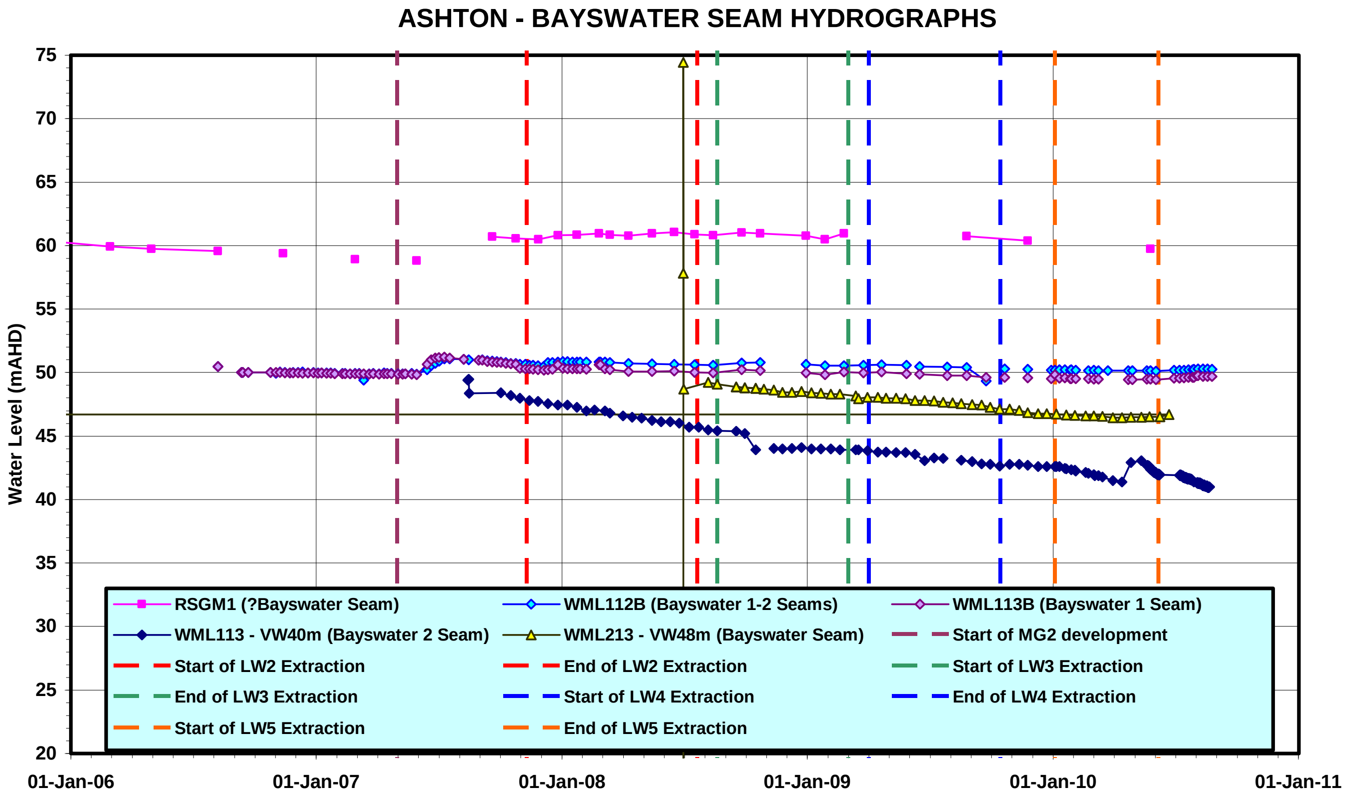
Figure 7

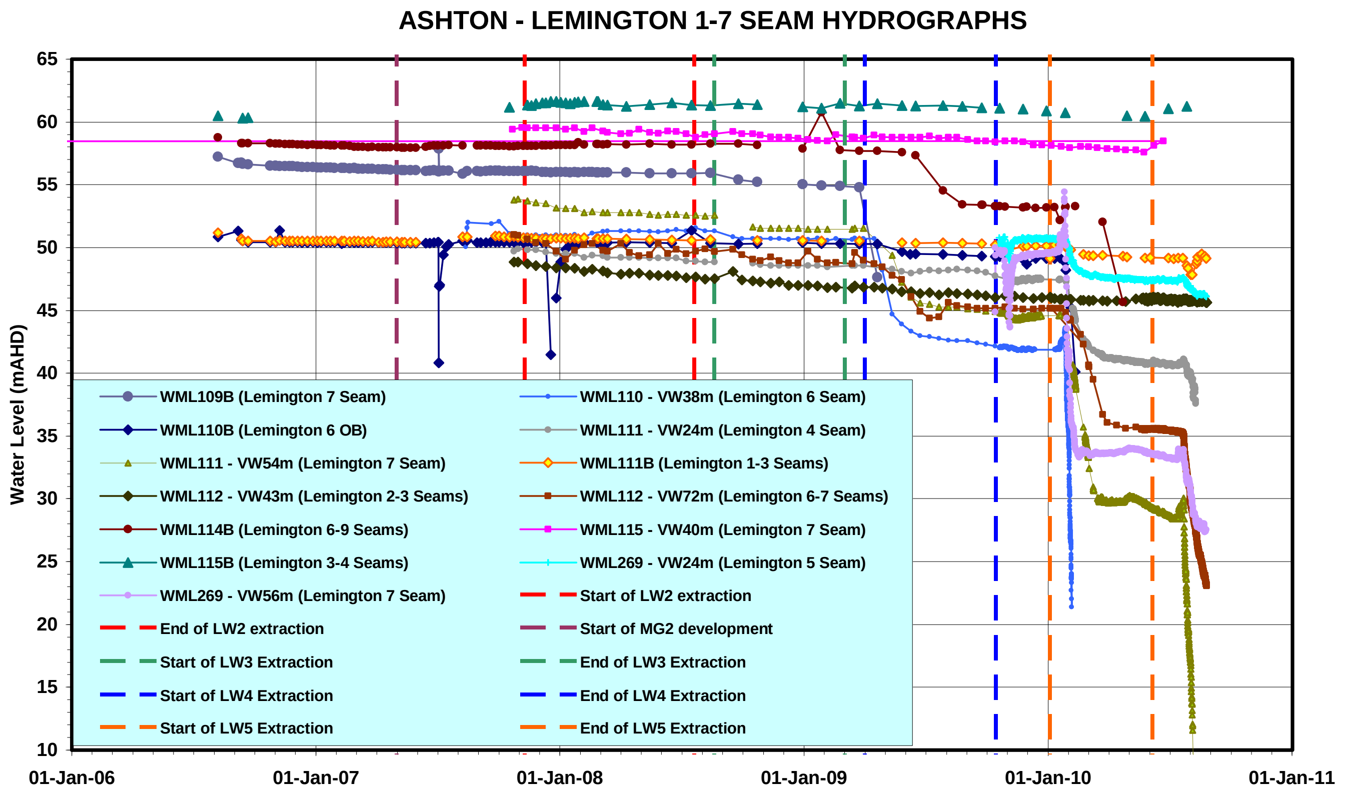


Legend

- Groundwater level contour June 2010
- Groundwater level contour September 2009
- Pikes Gully Mine Plan
- Pikes Gully Piezometers and GWL (mAHD)
- Longwall Mining Completed - Pikes Gully Seam

Date: 10 August 2011	Scale: as shown	Ashton Coal Operations Ltd
Initials: JVDA	Job No: S55 D4	ASHTON COAL MINE PIEZOMETER LOCATION PLAN FOR END OF LW5
Drawing No: S55-232h	Revision: H	
aquaterra		Figure8





Date 09 September 2010	Scale	**Ashton Coal Operations Ltd**
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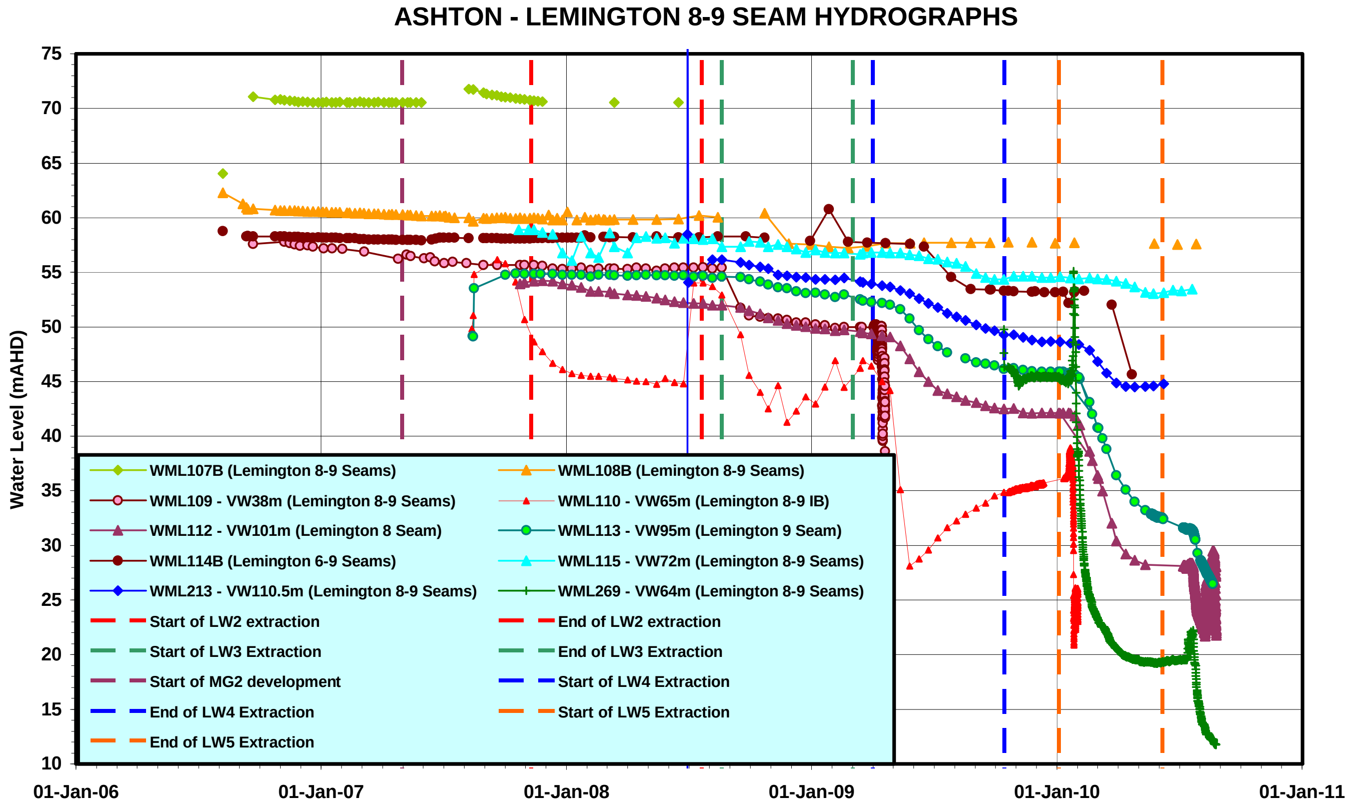
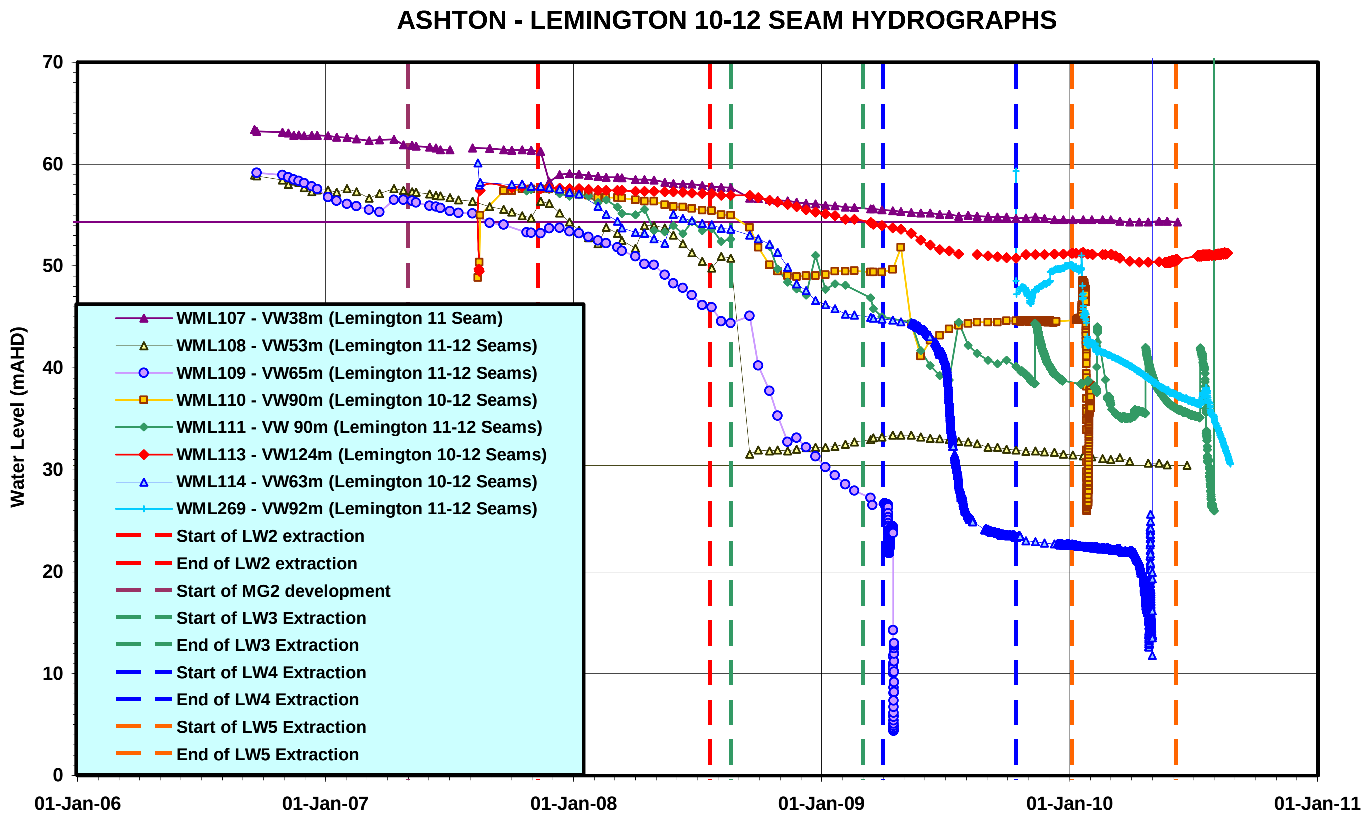
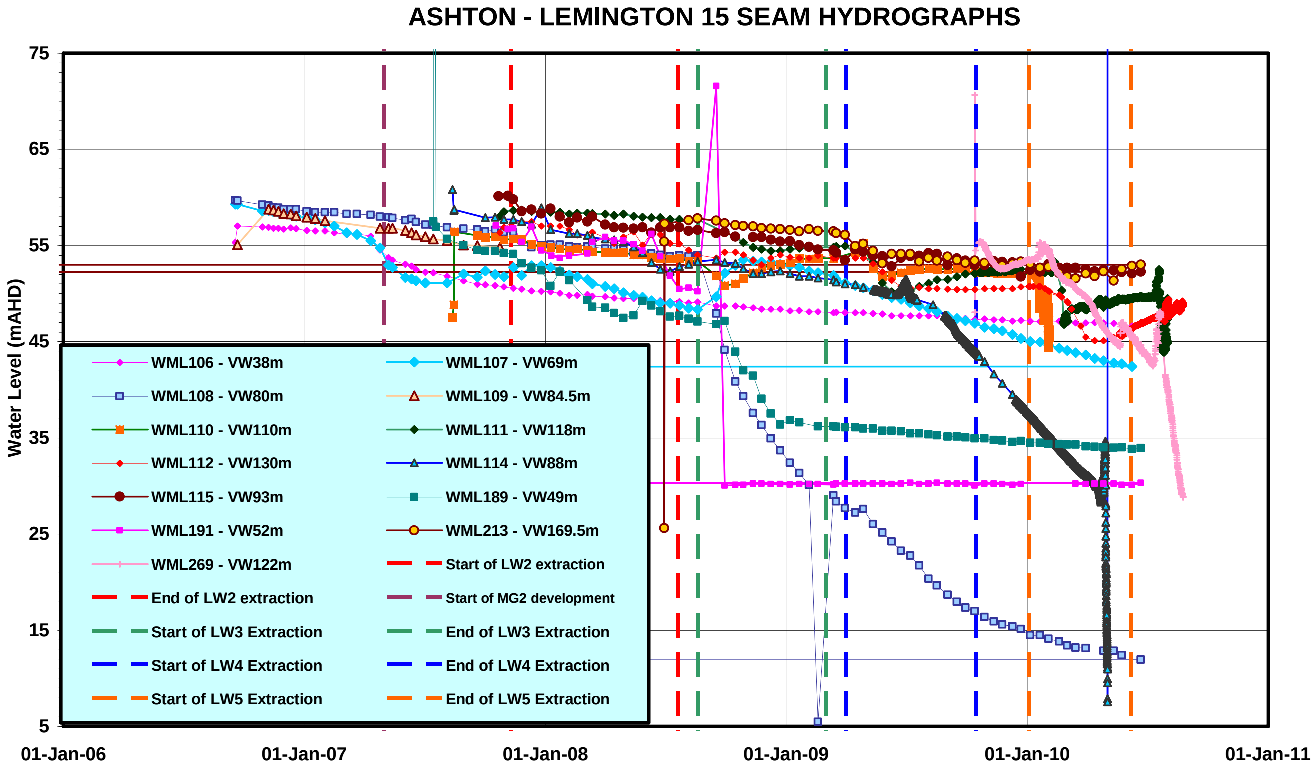
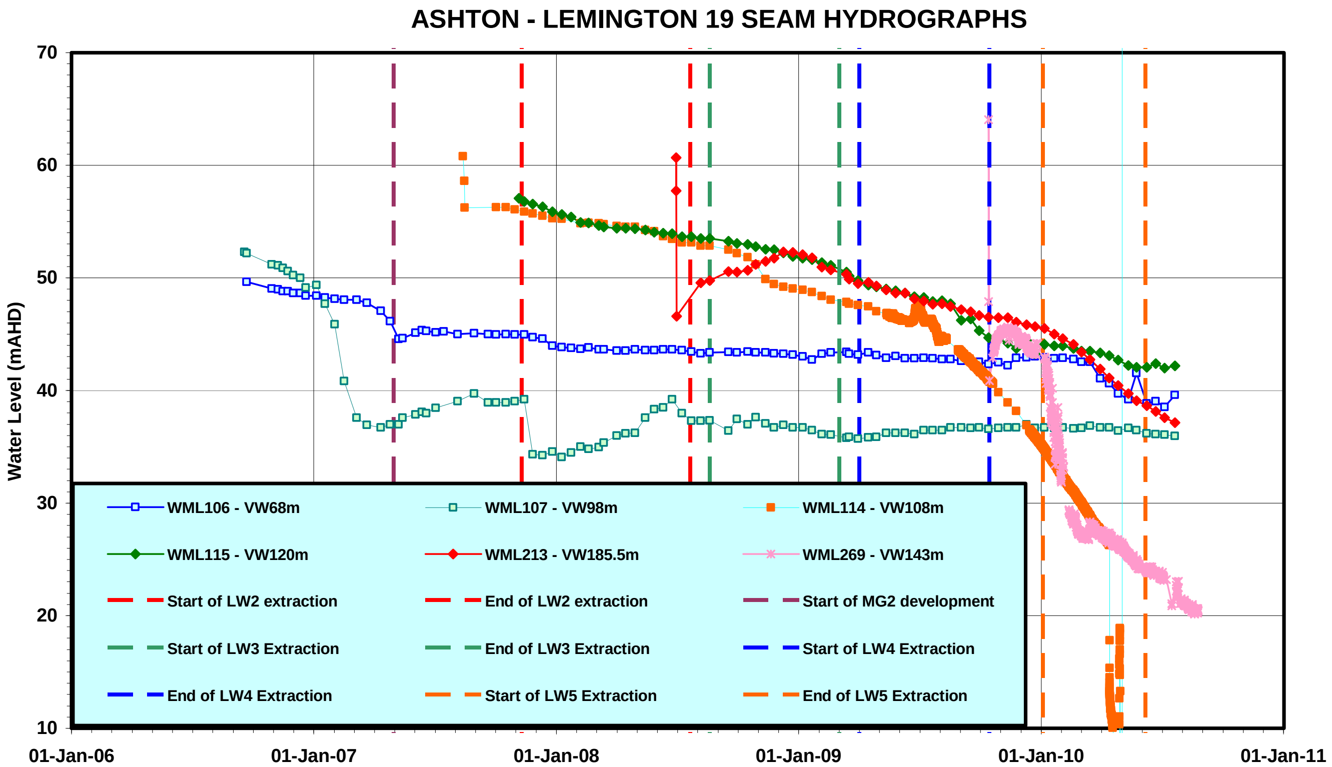
Drawing Number srf-009j	Revision J	
aquaterra		**Figure 9**



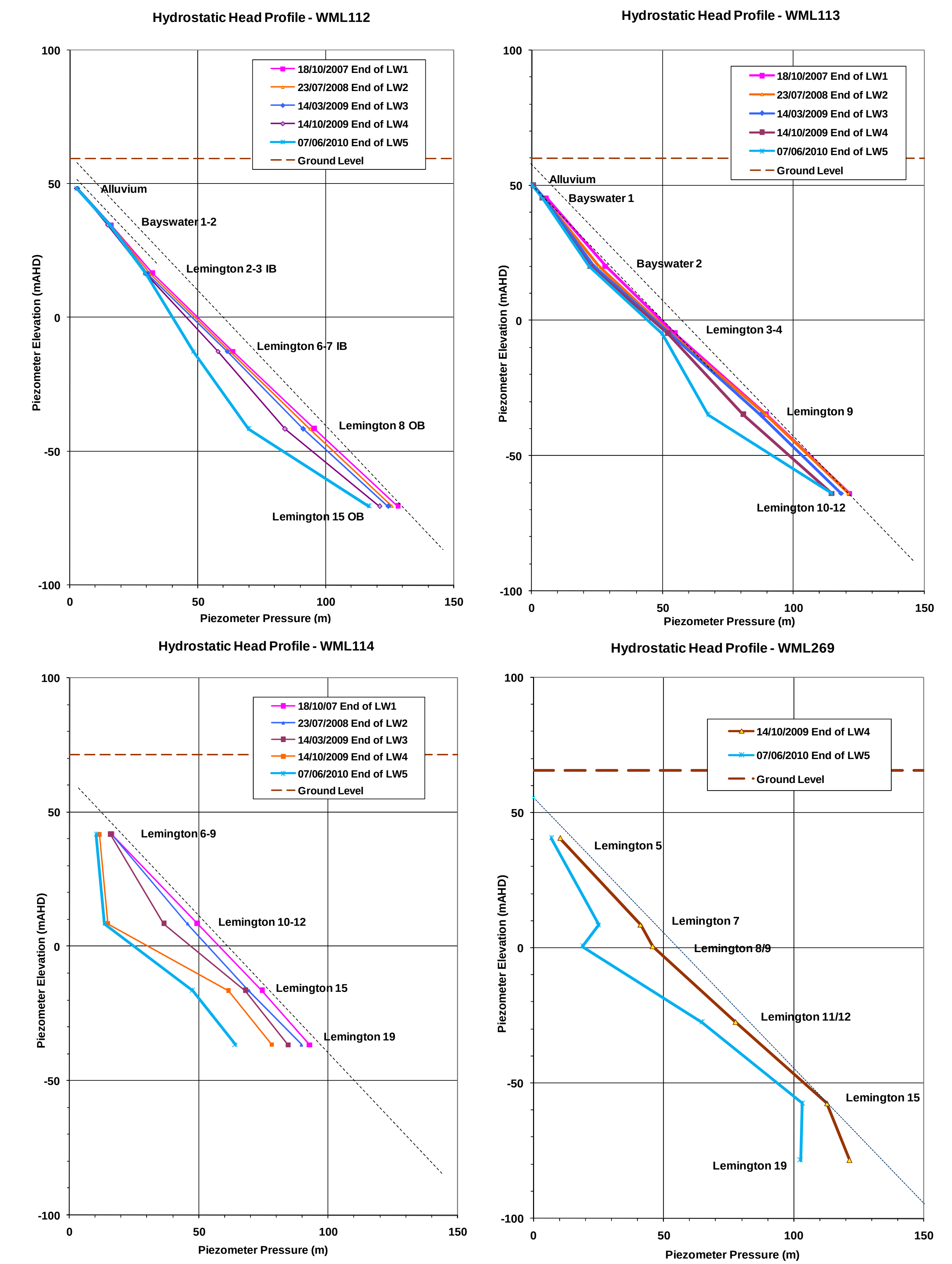


Date 09 September 2010	Scale	**Ashton Coal Operations Ltd**
Initials SM	Project S55 D4	GROUNDWATER LEVEL HYDROGRAPHS LEMINGTON 8-9 SEAMS LEMINGTON 10-12 SEAMS
Drawing Number srf-009i	Revision I	
aquaterra		**Figure 10**



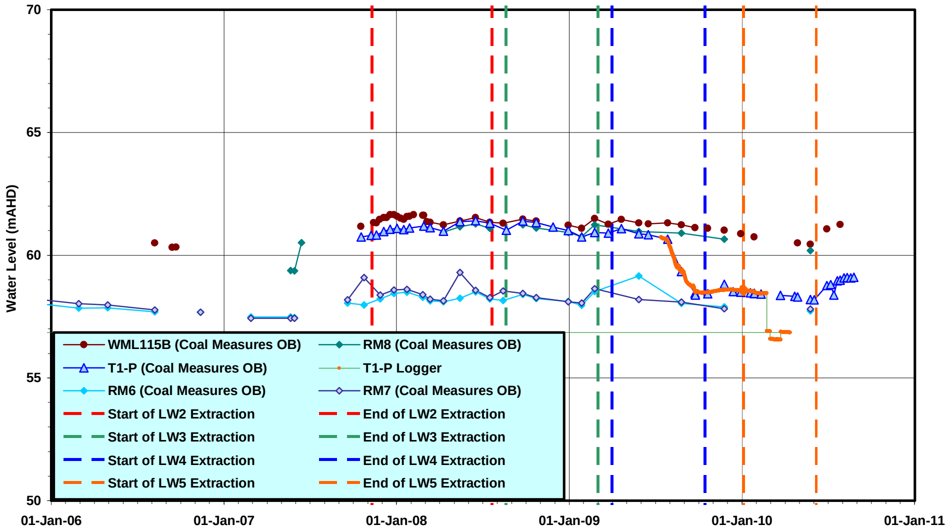


Date 09 September 2010	Scale	**Ashton Coal Operations Ltd**
Initials SM	Project S55 D4	GROUNDWATER LEVEL HYDROGRAPHS LEMINGTON 15 and 19 SEAMS
Drawing Number srf-009h	Revision H	
aquaterra		**Figure 11**

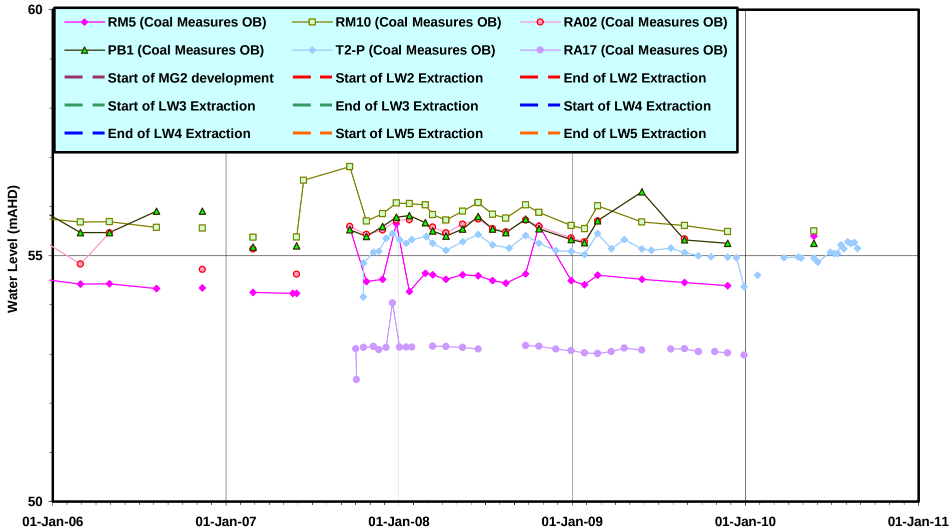


Date 19 August 2010	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D4	HYDROSTATIC HEAD PROFILES LEMINGTON SEAMS (WML112, WML113, WML114 and WML269)
Drawing Number 004c	Revision C	
aquaterra		**Figure 12**

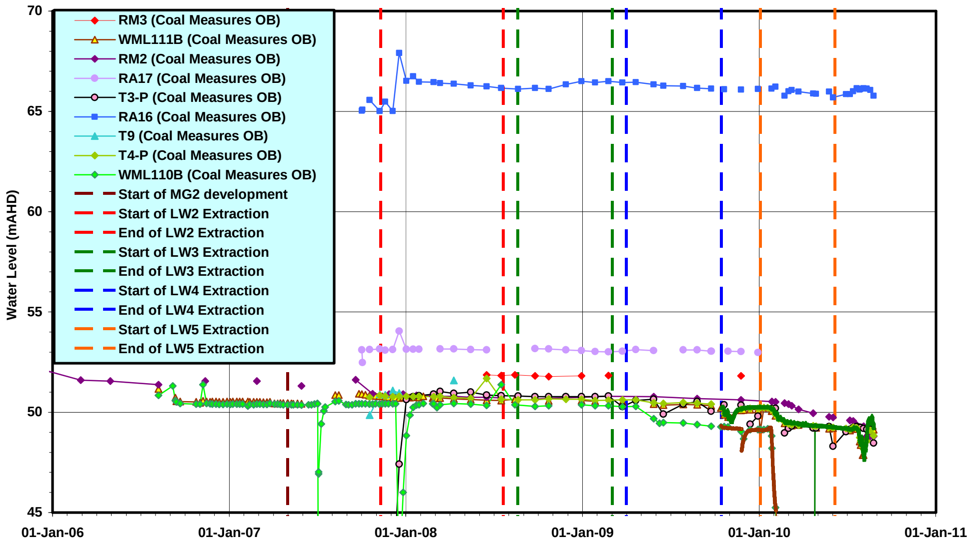
ASHTON - COAL MEASURES OVERBURDEN HYDROGRAPHS (Bowmans Ck Northern Section)



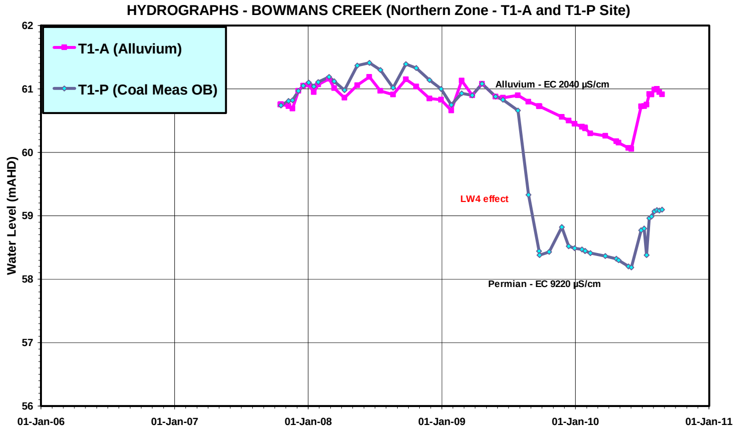
ASHTON - COAL MEASURES OVERBURDEN HYDROGRAPHS (Bowmans Ck Central Section)

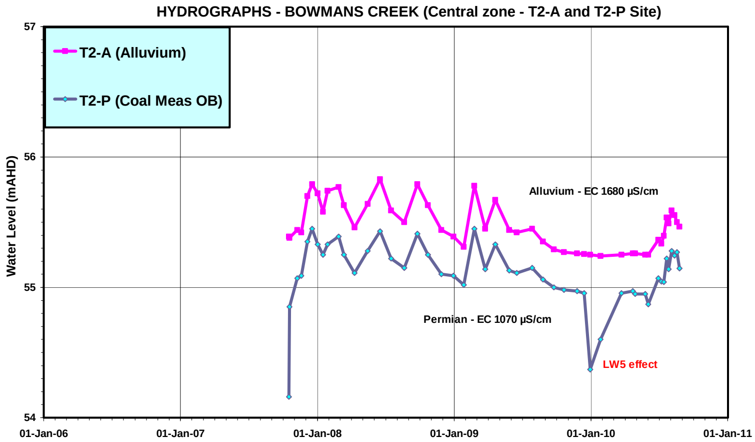


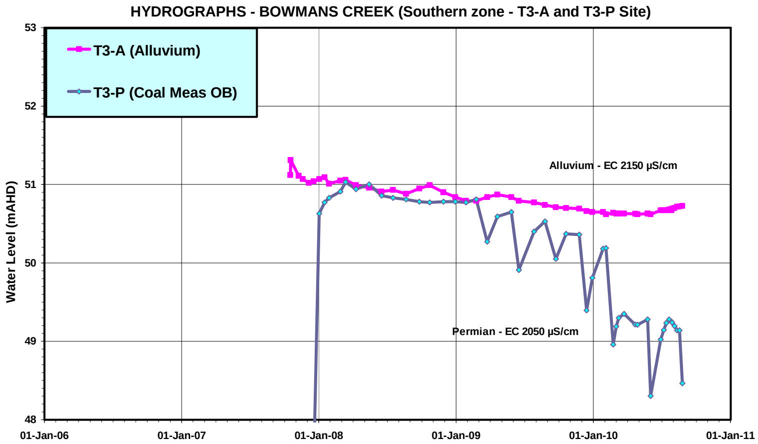
ASHTON - COAL MEASURES OVERBURDEN HYDROGRAPHS (Bowmans Creek Southern Section)

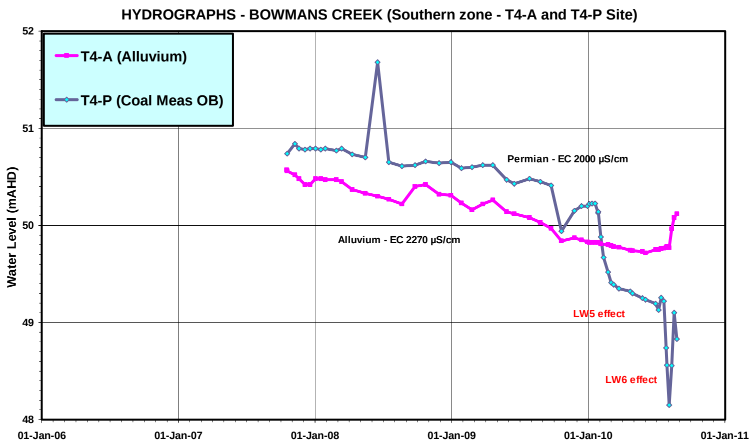


Date **09 September 2010**	Scale		**Ashton Coal Operations Ltd**
Initials **SM**	Project **S55 D4**		**GROUNDWATER LEVEL HYDROGRAPHS** Coal Measures Overburden
Drawing Number **srf-008d**	Revision **D**		
aquaterra			**Figure 13**



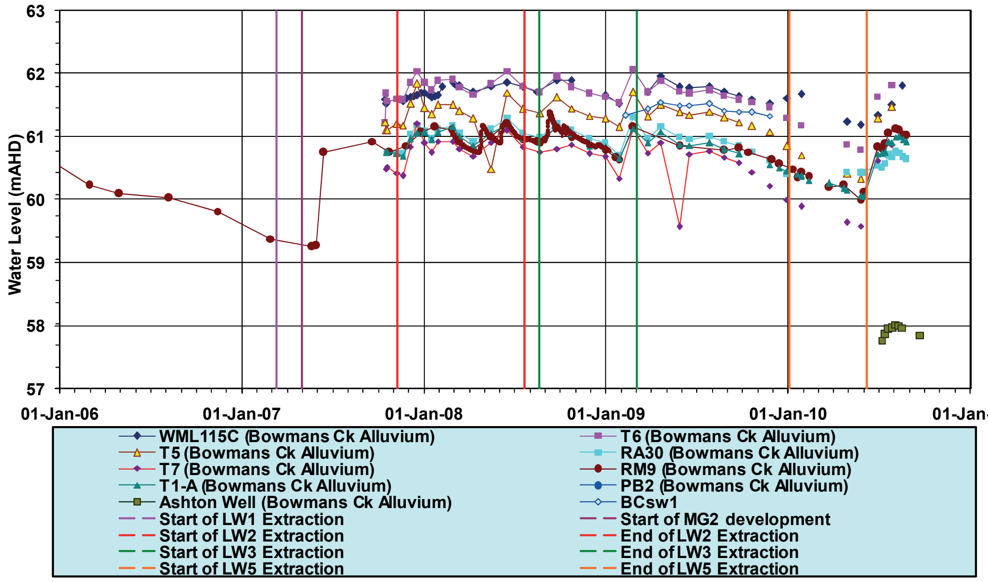




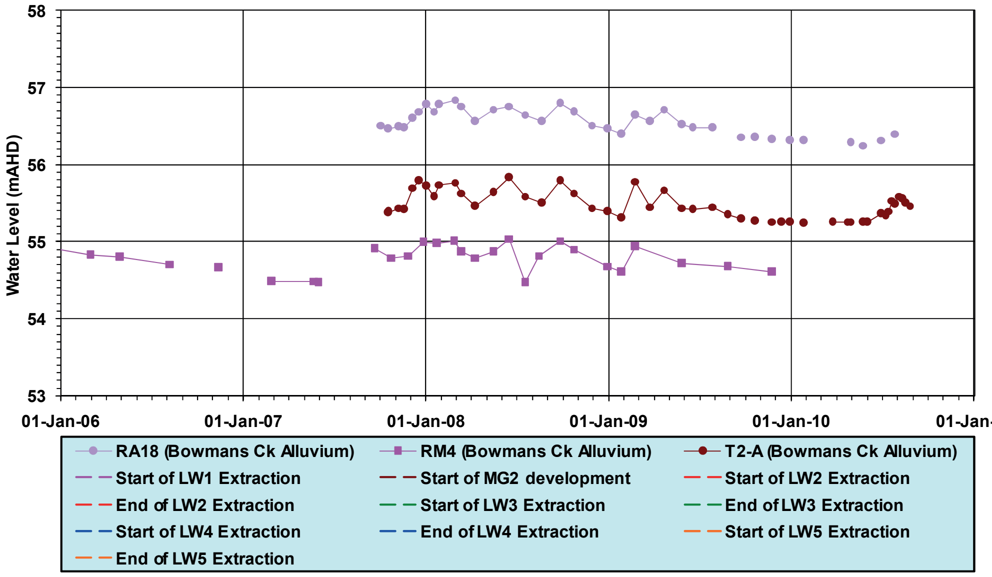


Date **09 September 2010**	Scale	**Ashton Coal Operations Ltd**
Initials **SM**	Project **S55 D4**	**GROUNDWATER LEVEL HYDROGRAPHS BOWMANS CREEK ALLUVIUM**
Drawing Number **srf-011g**	Revision **G**	
aquaterra		**Figure 14**

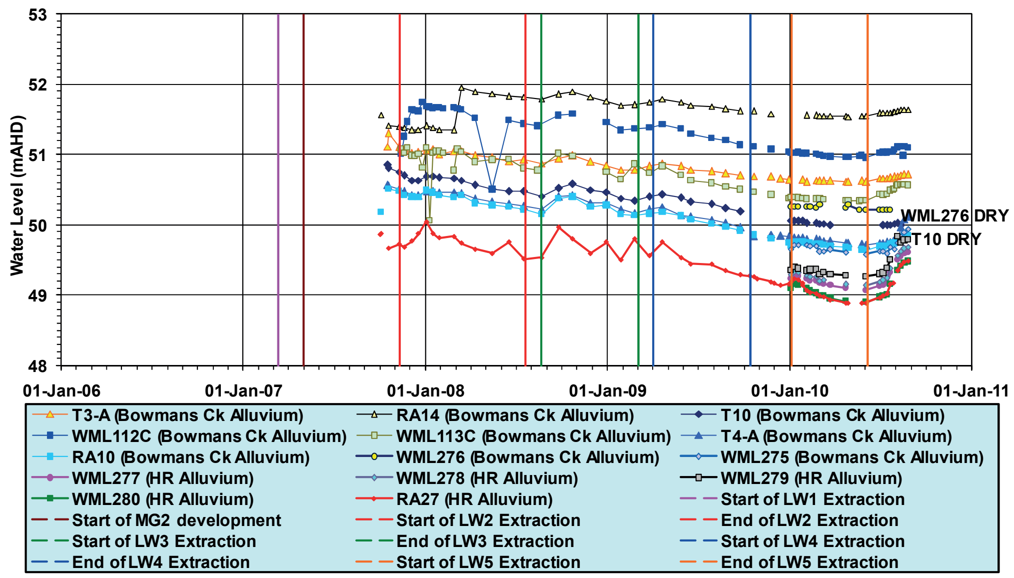
ALLUVIUM AQUIFER HYDROGRAPHS - BOWMANS CREEK (Northern Zone)



ALLUVIUM AQUIFER HYDROGRAPHS - BOWMANS CREEK (Central Zone)

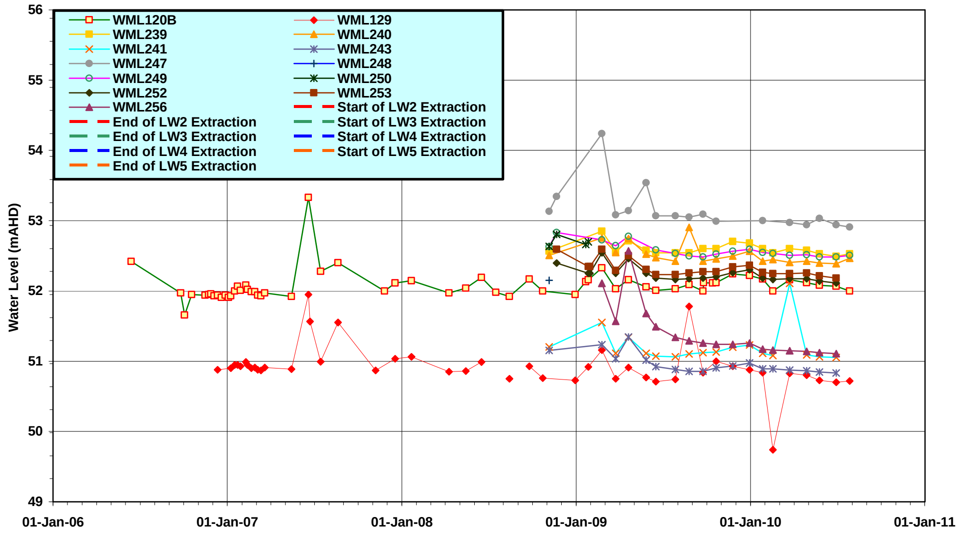


ALLUVIUM AQUIFER HYDROGRAPHS-BOWMANS CREEK (Southern Zone) AND HUNTER RIVER ALLUVIUM

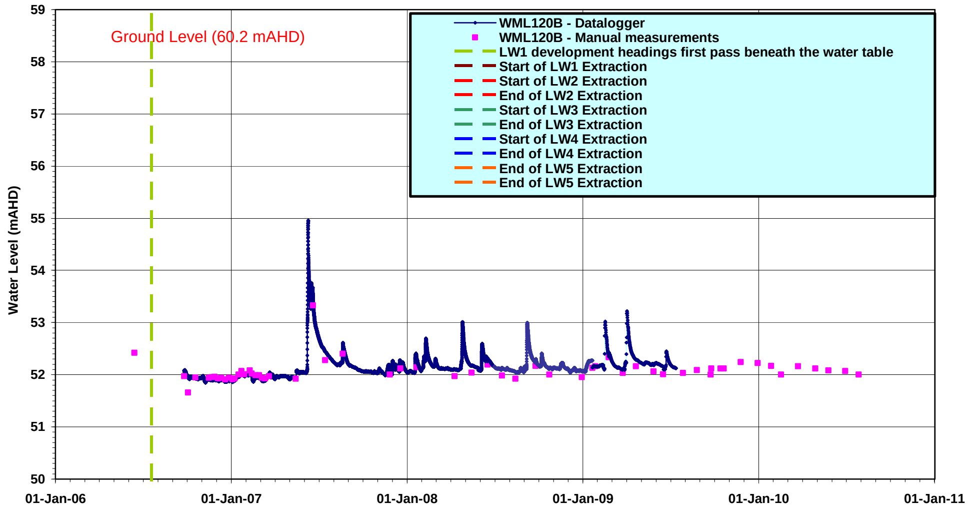


Date **30 September 2010**	Scale	**Ashton Coal Operations Ltd**
Initials **TL**	Project **S55 D4**	**GROUNDWATER LEVEL HYDROGRAPHS BOWMANS CREEK & HUNTER RIVER ALLUVIUM**
Drawing Number **srf-011f**	Revision **F**	
aquaterra		**Figure 15**

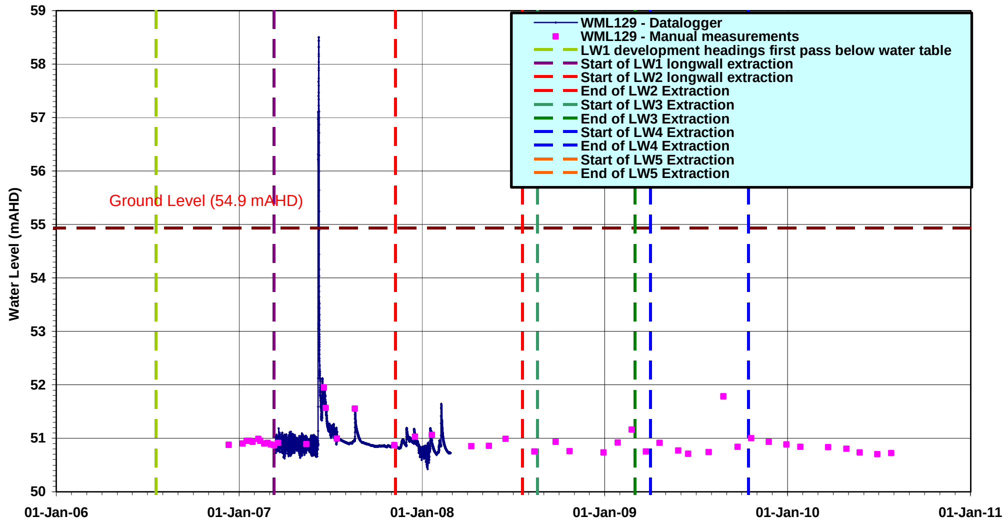
ALLUVIUM AQUIFER HYDROGRAPHS - GLENNIES CREEK ALLUVIUM



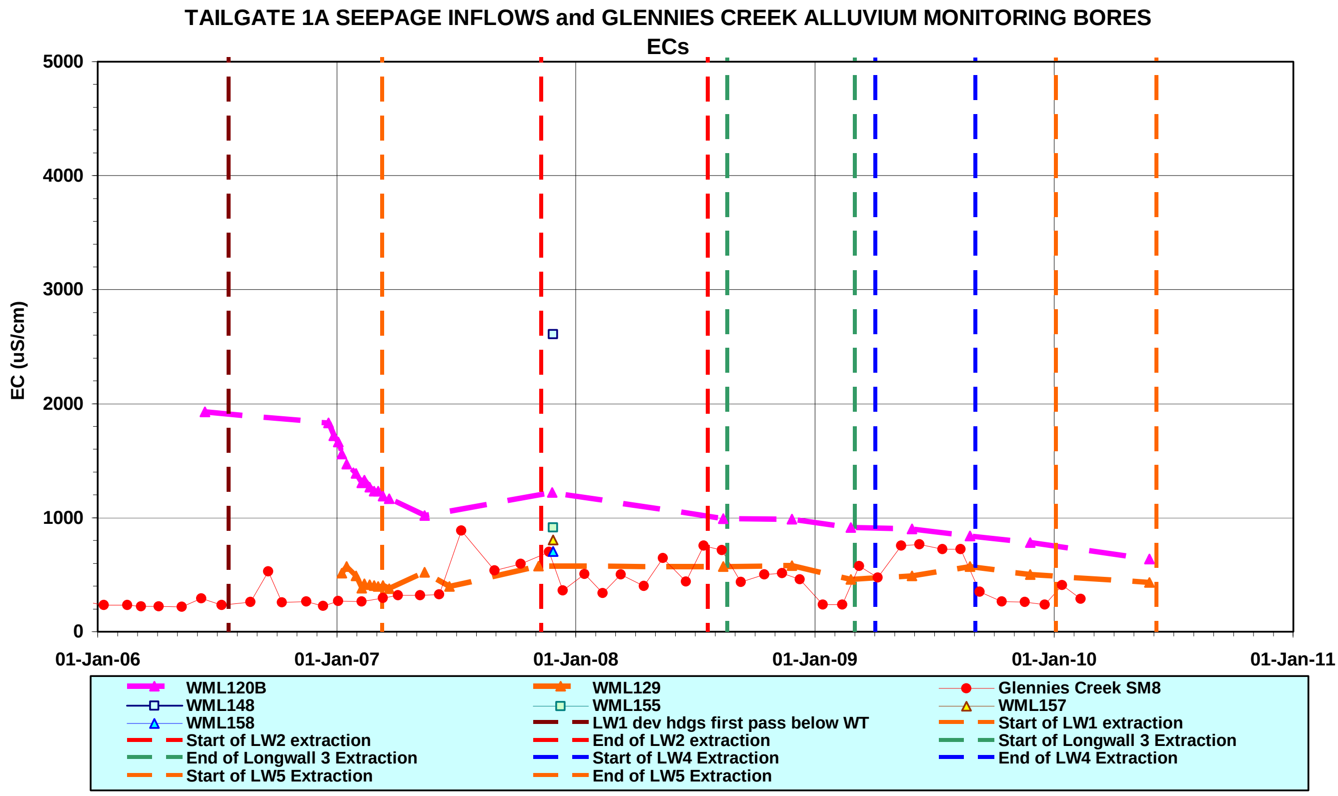
GROUNDWATER LEVEL HYDROGRAPH - WML120B (Glennies Creek Alluvium)

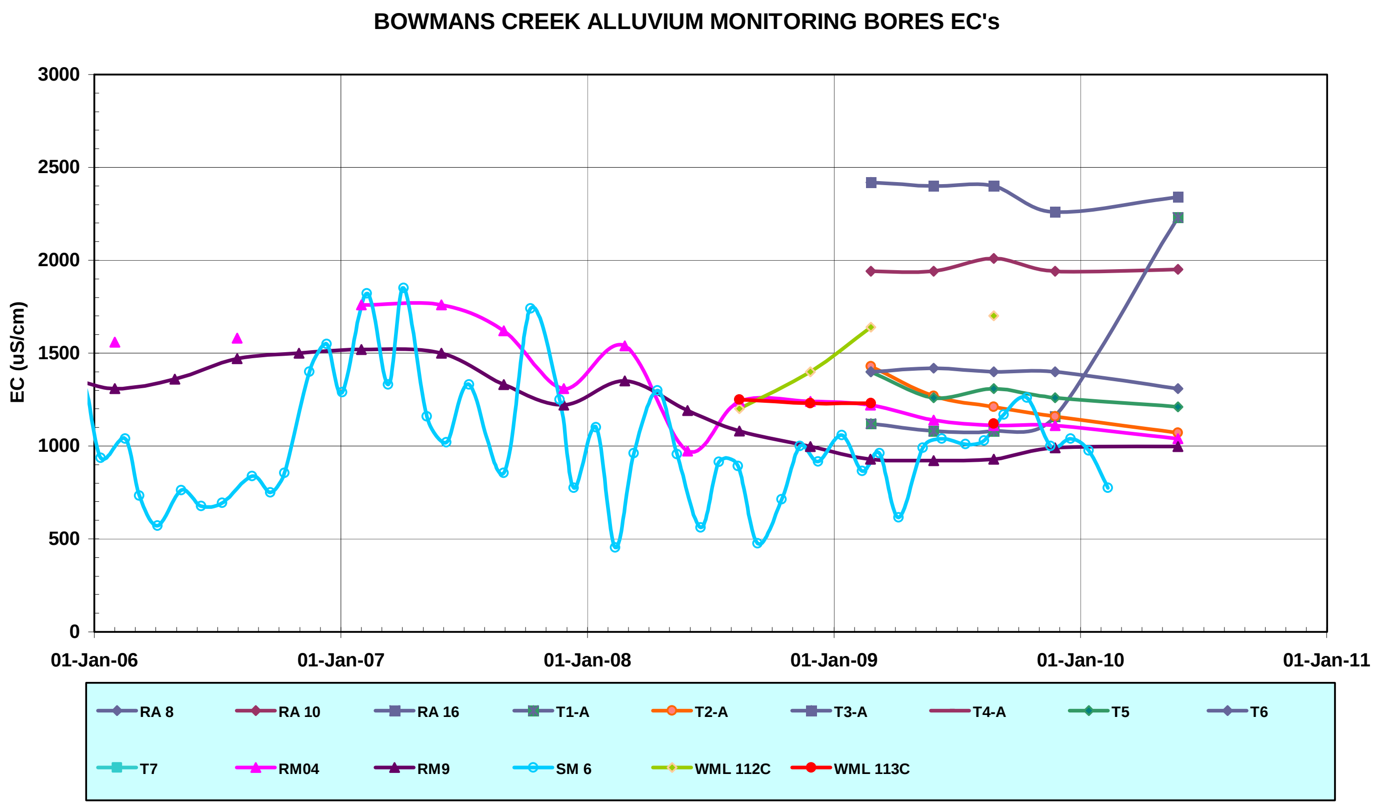


GROUNDWATER LEVEL HYDROGRAPH - WML129 (Glennies Creek Alluvium)

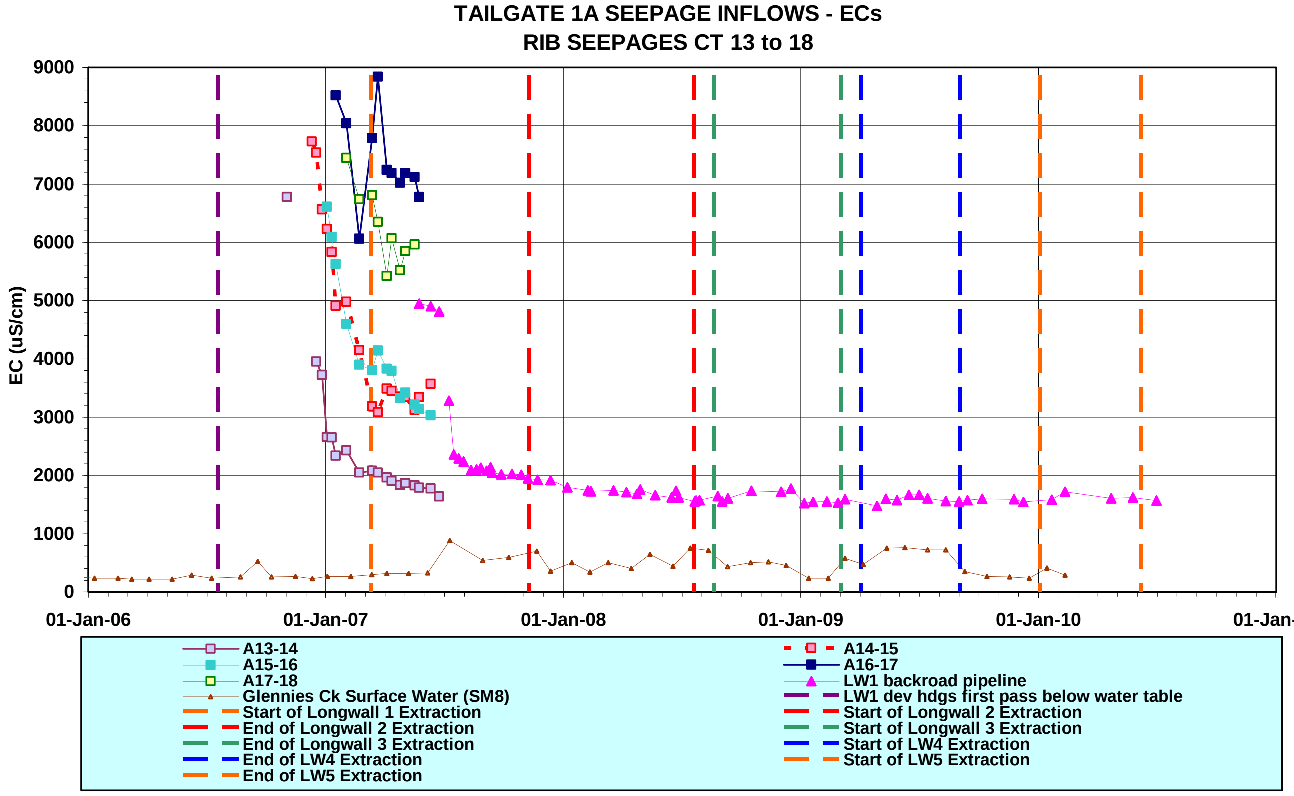


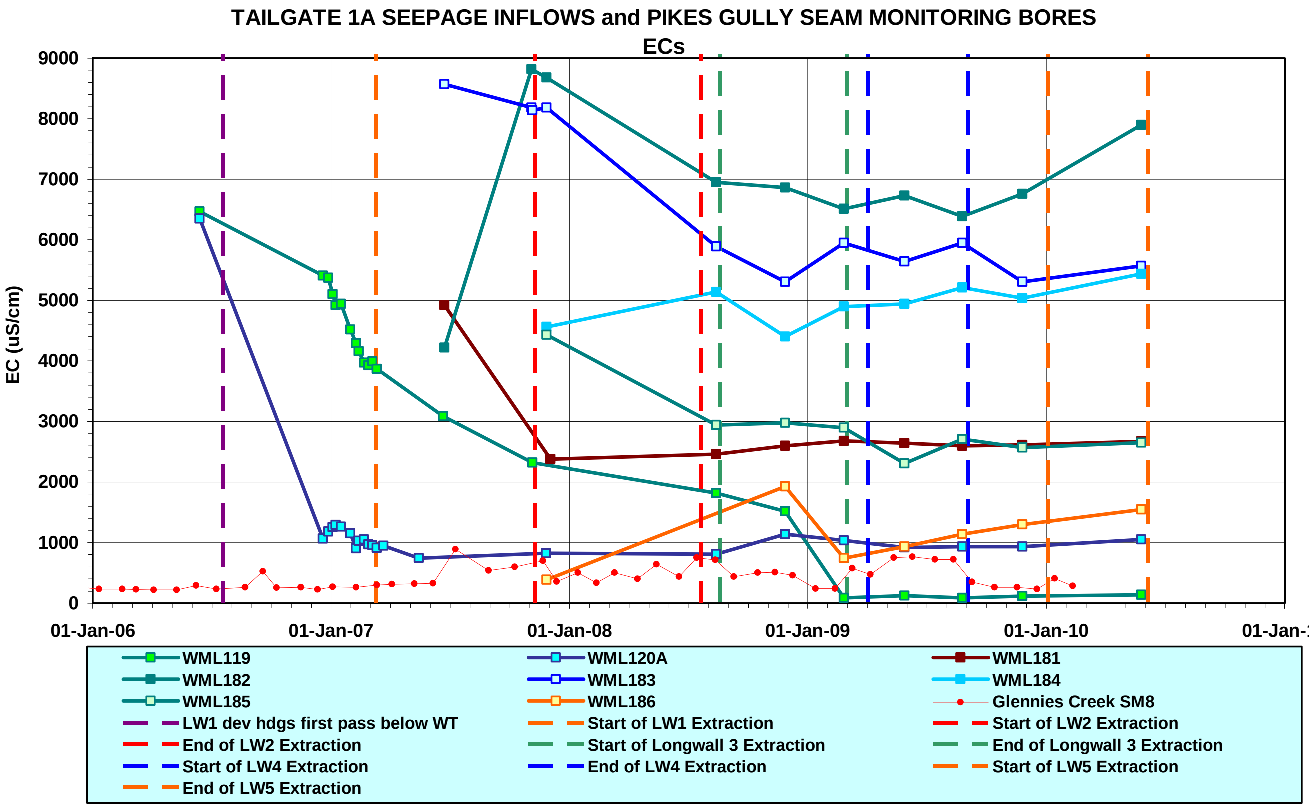
Date 09 September 2010	Scale	**Ashton Coal Operations Ltd**
Initials SM	Project S55 D4	GROUNDWATER LEVEL HYDROGRAPHS GLENNIES CREEK ALLUVIUM
Drawing Number srf-012d	Revision D	
aquaterra		**Figure 16**



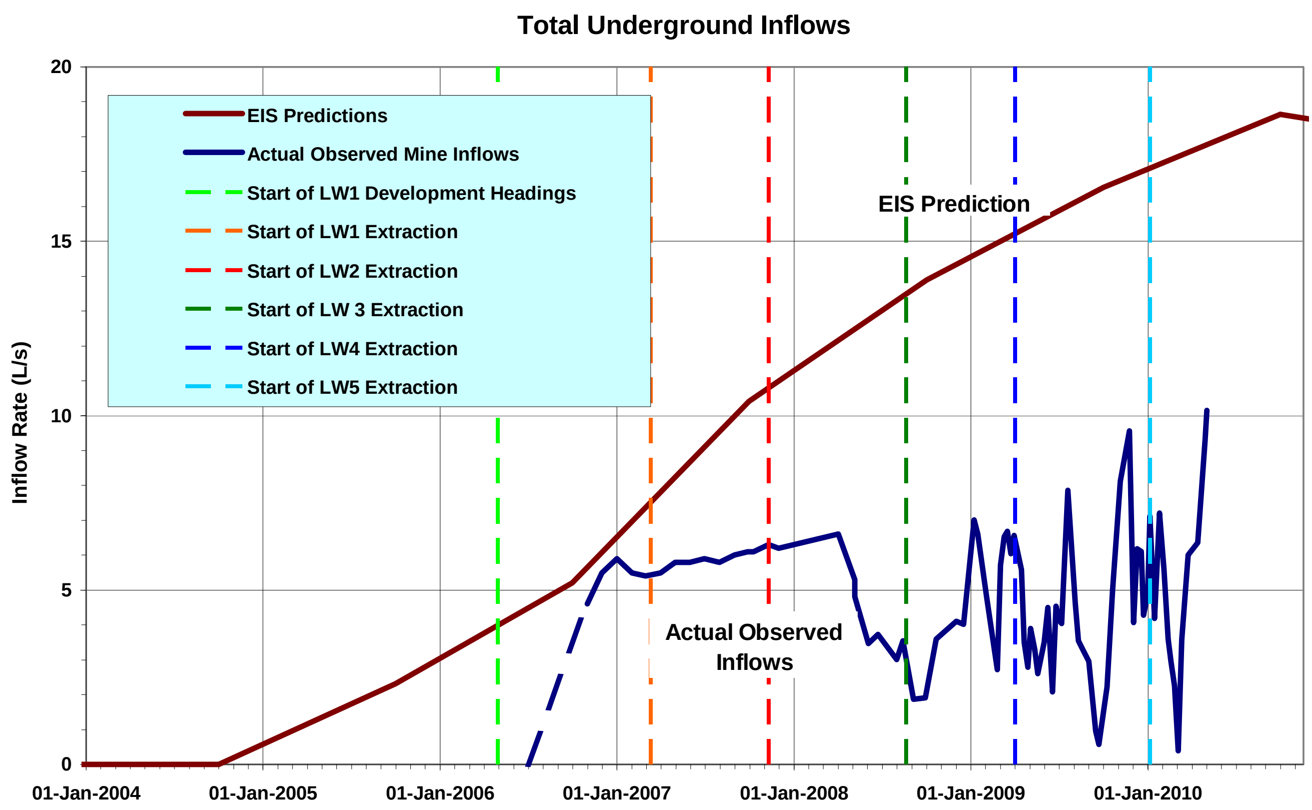


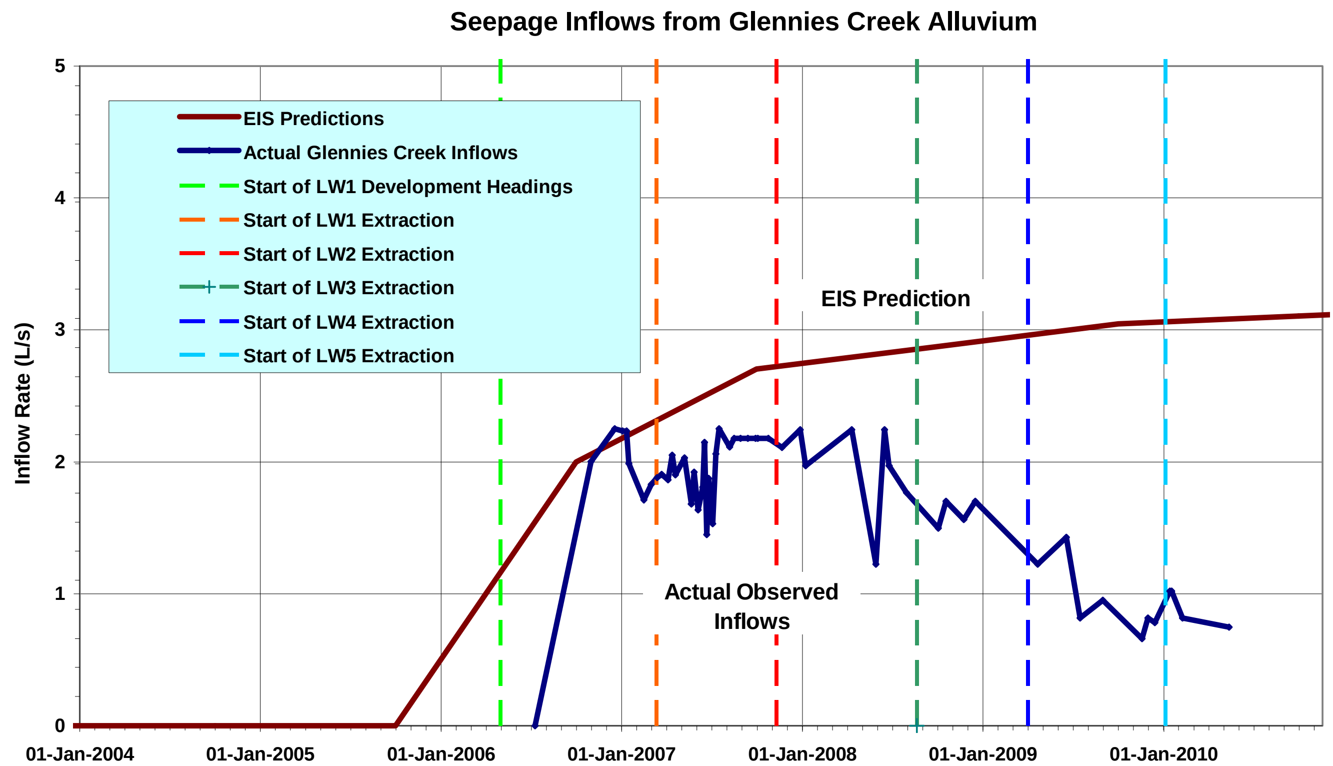
Date 09 September 2010	Scale	**Ashton Coal Operations Ltd**
Initials **SM**	Project **S55 D4**	**GROUNDWATER EC GLENNIES CREEK ALLUVIUM BOWMANS CREEK ALLUVIUM**
Drawing Number **srf-013b**	Revision **B**	
aquaterra		**Figure 17**





Date **09 September 2010**	Scale	**Ashton Coal Operations Ltd**
Initials **SM**	Project **S55 D4**	**GROUNDWATER EC TAILGATE 1A SEEPAGES PIKES GULLY**
Drawing Number **srf-014b**	Revision **B**	
aquaterra		**Figure 18**





Date 19 August 2010	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D4	GROUNDWATER INFLOW vs EIS PREDICTIONS
Drawing Number srf-015a	Revision A	
aquaterra		**Figure 19**

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