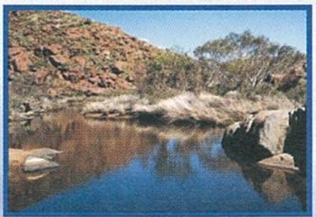
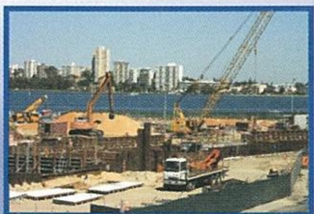
aquaterra

working with you to develop practical water resources and environmental solutions

ASHTON UNDERGROUND MINE BOWMANS CREEK ALLUVIUM INVESTIGATION



Prepared for: Ashton Coal



Ref: S03/R06/22HG

October 2008

[REPORT TITLE HERE]

Document Status

Revision	Date	Revision Description
A	08/07/2008	Draft for Client
B	17/07/2008	Second Draft for Client Review
F	27/08/2008	Third Draft for Client Review
H	13/10/2008	Final

	Name	Position	Signature	Date
Originator:	Andrew Fulton	Senior Hydrogeologist		13/10/2008
Reviewer:	Peter Dundon	Senior Principal Hydrogeologist		13/10/2008

aquaterra
Aquaterra Consulting Pty Ltd
ABN 49 082 286 708
Suite 9, 1051 Pacific Highway
Pymble NSW 2073
Tel: (02) 9440 2666
Fax: (02) 9449 3193

EXECUTIVE SUMMARY

A comprehensive understanding of the nature of the Bowmans Creek alluvium and its hydraulic interaction with Bowmans Creek and the underlying Permian coal measures is necessary for Ashton Coal to satisfy Consent Conditions 3.9 and 4.13.

Investigation of the Bowmans Creek alluvium was initially undertaken during the EIS studies in 2001-2. A series of shallow auger holes and test pits were excavated, several piezometers were constructed, and two test bores were installed to enable hydraulic testing of the alluvium. Periodic monitoring of groundwater quality and bore water levels has been maintained since that time.

Additional piezometers were installed as part of the underground mining assessment carried out in 2006-7. A more comprehensive investigation was undertaken in 2007-8 to delineate the extent of saturated alluvium within the Bowmans Creek floodplain, and to determine the hydraulic properties of the alluvial aquifer system. Forty-two bores were drilled, where possible to the top of fresh Permian, to establish accurate depths to the base of alluvium or colluvium. Twenty-one of the bores were cased and completed as piezometers.

Wherever possible, the piezometers have been subjected to hydraulic testing by either test pumping or falling head permeability testing. Water samples were collected for detailed laboratory analysis. All piezometers have been included in the routine ongoing monitoring program, with water levels measured monthly, and selected bores sampled quarterly for laboratory analysis.

The investigations completed to date and reported in this document have allowed the development of a comprehensive understanding of the extent and nature of the alluvial aquifer system present within the Bowmans Creek floodplain.

Key conclusions in relation to the Bowmans Creek alluvium are as follows:

- The Bowmans Creek alluvium forms a shallow aquifer unit that is clearly distinct from both the underlying Permian coal measures and the Hunter River alluvium. The boundary between Bowmans Creek alluvium and Hunter River alluvium is well-defined, and has been determined by mapping, drilling and reference to aeromagnetic data. The lateral extent of the Bowmans Creek alluvium is quite limited, and is much less extensive than the of the 1955 flood limit. The alluvium merges with colluvium on the flanks of the floodplain, and with residual soils in the highly weathered upper part of the Permian sediments.
- There is highly variable hydraulic conductivity in the Bowmans Creek alluvium, with determined values in the range 0.0002 to 15 m/d. Generally the alluvium comprises silts, sands and gravels tightly bound within a clayey matrix, with occasional stringers or lenses of cleaner gravels.
- Groundwater quality in the Bowmans Creek alluvium is moderately saline to saline, with measured salinity values ranging from 1190 to 6420 μS/cm EC. Salinity in the upper weathered Permian coal measures is similarly variable, with measured values in the range 1100 to 9390 μS/cm EC. Salinities at the lower ends of these ranges are as a result of recharge from infiltration of rainfall to

the alluvium and directly to the Permian in areas of outcrop or subcrop. Salinity in the deeper Permian coal measures is generally higher, typically in the range 6000 to 11000 µS/cm EC. The salinities of groundwater in the alluvium and the near-surface Permian are both higher than typical salinities of surface flow in Bowmans Creek (generally in the range 800 to 1800 µS/cm EC).

- The Bowmans Creek alluvium contributes some baseflow to Bowmans Creek, although the contribution within the Ashton mining area is very small. Likewise, some baseflow is derived locally from the Permian as well, leading to ECs as high as 14000 µS/cm in the surface water at one Bowmans Creek monitoring station during the 2003-2008 drought.
- There is only limited hydraulic connection between the Bowmans Creek alluvium and shallow weathered Permian sediments, and virtually no connection with the Pikes Gully coal seam or the deeper seams planned for future mining. This is supported by distinctly different groundwater levels, differences in groundwater quality, and differing responses to recharge and from mining activity.

Potential impacts of longwall/miniwall mining of Pikes Gully Seam on the Bowmans Creek alluvium have been addressed in detail in a separate report (Aquaterra, 2008). However, a general assessment has been made in this report based on the prevailing hydraulic conductivities, assuming there is no change to the hydraulic properties of the intervening strata between the mine and the base of the alluvium.

Despite the limited or negligible hydraulic connection between the Bowmans Creek alluvium and the Pikes Gully seam, there is potential for some leakage from the alluvium to the underground mine workings through the overburden strata. Even in the case of mining of first workings only, where no continuous subsidence-induced fracturing develops between the goaf and the base of the alluvium, it has been calculated that the prevailing natural vertical permeability of the coal measures overburden would potentially allow leakage in the order of 125 m^3/d (46 ML/year) from the alluvium to the mine.

The impact of subsidence on leakage from the Bowmans Creek alluvium will be controlled by the height of interconnected fracturing and the residual vertical permeability of the Permian above the subsidence affected zone. Providing that a zone of unfractured rock remains between the base of the alluvium and the top of the zone of continuous interconnected fracturing, vertical leakage from the alluvium will be limited by the low vertical permeability within the unfractured barrier zone (or “aquaclude” as described in Consent Condition 3.9).

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

SECTION 1 INTRODUCTION

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

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

The underground mine is located south of New England Highway, and is accessed from the northern side of the highway via 3 portal entries in the Arties pit.

The initial mine plan comprised eight longwall panels (LWs 1 to 8), four of which have been approved for mining of the Pikes Gully seam (LWs 1 to 4) under an SMP Application lodged and approved in 2006. Underground mine development commenced in December 2005, and mining of the first longwall panel (LW1) in the Pikes Gully seam began in March 2007. LW1 was completed in October 2007, and LW2 in July 2008. Mining has commenced in LW3, and it is proposed to continue mining the Pikes Gully seam across the rest of the underground mine area, and then subsequently mine the underlying Upper Liddell, Upper Lower Liddell and Lower Barrett seams in a multi-seam longwall operation.

The first four longwall panels, LW1 to LW4, were designed to mine final voids 215m wide, separated by chain pillars of 25m width rib to rib, with cut-throughs at 100m centres. The layout of LWs 1 to 4, together with the progress of mining to date, is shown on **Figure 2**. The original 8-panel mine plan has been amended, and it is now proposed to mine the remainder of the Pikes Gully Seam from a further five longwall and miniwall panels (LW/MW 5-9), as shown on **Figure 2**.

The main aquifers in the Ashton Project area are the coal seams (with permeability developed in cleat fractures), and unconsolidated aquifers within the alluvium associated with the Hunter River and its tributaries Bowmans Creek and Glennies Creek. Glennies Creek and its alluvial floodplain are located to the east of the underground mine, and do not overlap the mining area. Likewise, the Hunter River and its alluvium do not overlap the mining area.

However, parts of LW/MW 5-9 in the western half of the underground mining area are overlain by Bowmans Creek and its associated alluvial sediments (**Figure 2**).

The mining operation was approved by a Development Consent granted on 11 October 2002. The consent conditions accompanying the project approval (Minister for Planning, 2002) include measures to protect Bowmans Creek and the alluvium. The relevant consent conditions are:

3.9 The Applicant shall design underground mining operations to ensure no direct hydraulic connection between the Bowmans Creek alluvium and the underground workings can occur through subsidence cracking. In order to achieve this criteria the Applicant shall assess levels of uncertainty in all subsidence predictions, and provide adequate contingency in underground mine *design to ensure sufficient sound rock is maintained to provide an aquaclude between the Bowmans Creek alluvium, and the underground mine goaf.*

4.13 All surface and underground operations including long wall mining shall be conducted to minimise potential impacts on groundwater flow and quality of the alluvial groundwater resource, integrity of the alluvial aquifer and to minimise off-site effects.

A comprehensive investigation of the Bowmans Creek alluvial groundwater resource has been undertaken, to characterise the groundwater resource and to provide a basis for prediction of potential impacts, and monitoring / management of any impacts that may occur through the project life. This report presents the findings of that investigation, which were principally definition of the nature and extent of saturated alluvium, and the relationship of the alluvial aquifer to Bowmans Creek and the underlying Permian coal measures.

SECTION 2 BOWMANS CREEK ALLUVIUM AQUIFER

The lateral extent of Bowmans Creek alluvium is shown on **Figure 2**. This extent has been defined as the edge of saturated alluvium, as determined from a combination of aerial photography, aeromagnetic survey, ground mapping, the results of exploration drilling, and monitoring of groundwater levels over a range of above and below average climatic conditions. The alluvium merges with colluvium along the flanks of the floodplain, and has an abrupt boundary with Hunter River alluvium at the southern end of the valley.

The bed of Bowmans Creek is incised directly into bedrock (Permian coal measures) in some locations, and is underlain by a limited thickness of alluvium in other places. The locations of prominent rock-bars, representing outcrops of Permian coal measures in the creek-bed, are shown on **Figure 2**.

Groundwater is present in the alluvium, and is in varying degrees of hydraulic connection with the underlying coal measures. Extensive areas of alluvium are dry to full depth, where the upper surface of the underlying coal measures rises above the water table level. The extent of saturated alluvium (at times of high water table) is much less than the extent of historical flood levels. The limits of the 1995 flood are shown on **Figure 2**.

The Bowmans Creek alluvium is characterised by fine silts, sometimes containing large cobbles, and silty sands. The groundwater quality of the alluvium typically ranges from >1000 µS/cm near the creek to >4,000 µS/cm at the margins.

The nature and extent of the alluvial aquifer are described in more detail in the following sections of the report. The extensive network of piezometers which are monitored routinely is also shown on **Figure 2**.

SECTION 3 INVESTIGATIONS

3.1 PREVIOUS INVESTIGATIONS

HLA (2001) recognised two distinct aquifer systems in the Ashton project area, *"…fractured rock aquifer systems in the coal measures and shallow porous media aquifers in the unconsolidated sediment of the alluvium"*. HLA stated that the alluvium was considered by the DLWC (now DWE) to have regional significance for sustenance of baseflows and ecosystems of the Hunter River. HLA therefore carried out a study of the Bowmans Creek alluvium within the Ashton project area (HLA, 2000).

HLA's study consisted of the following:

- Soil augering and test pits at 36 locations to map the extent of the alluvium and differentiate the Bowmans Creek alluvium from that of the Hunter River.
- Drilling of 13 bores (RM01 to RM10 and RA01 to RA03) to determine stratigraphy and install standpipe piezometers for measuring water levels and water quality.
- Installation of two test bores (PB1 and PB2) to determine hydraulic parameters of the alluvial aquifer.
- Sampling and analysis of water samples from the monitoring bores, the pumping test bores, an old water supply well and from Bowmans Creek on two occasions.

The locations of the HLA soil test pits and bores are shown on **Figure 3**. Piezometers installed during the HLA investigations are detailed in **Table 3.1**.

HLA (2000) reported that the Bowmans Creek floodplain *"… consists of higher terraces underlain by …shallow colluvium overlying coal measures and a narrow strip of alluvium between 300m and 600m wide immediately beside Bowmans Creek itself"*. HLA concluded that the alluvium occupies an estimated area of about 86 ha, significantly less than the area (180 ha) between the 1955 flood levels that were previously considered to define the extent of the alluvium.

Further test drilling was undertaken in the southern part of the Bowmans Creek floodplain in early 2002. Three holes were drilled – RA04, RA05 and RA11 – between the southern end of LW6 and Hunter River (located as shown on **Figure 3**). This drilling revealed that the boundary between the Hunter River alluvium (coarse channel and bar deposits) and the Bowmans Creek alluvium (polymictic gravels in clayey silts and sands) was approximately 100m from the bank of Hunter River (HLA, 2002).

HLA carried out pumping tests on test bores PB1 and PB2, and determined hydraulic conductivity values in the order of 1-2 m/d. Groundwater sampling by HLA indicated relatively high salinity for the alluvium groundwater, ranging from 900-1000 µS/cm EC near Bowmans Creek increasing to 2000-6000 µS/cm EC on the margins, due to upward leakage of saline groundwater from the underlying coal measures strata.

Table 3.1: EIS Investigation Drilling and Piezometer Construction Details

Bore	Ground Level (m AHD)	Drilled Depth (m bgl)	Screened Interval (m bgl)	Aquifer(s) screened	Current Status	EC (µS/cm) (2006 unless stated)	SWL (24 January 2008)	
							(m bgl)	(m AHD)
RM01	**69.15**	10.8	6.8 – 8.8	Alluvium	Abandoned	3170 (2000)	Dry	-
RM02	**60.60**	12.4	9.4 – 11.4	Alluvium + CM		7340 (2000)	10.21	50.84
RM03	**61.75**	11.0	7.0 – 9.0	Alluvium	Abandoned	-	Dry	-
RM04	**61.95**	9.6	6.6 – 8.6	Alluvium	Piezometer	1560	7.27	54.98
RM05	**65.90**	13.5	10.0 – 12.0	CM	Piezometer	2270	Dry	-
RM06	**63.95**	10.2	7.3 – 9.3	Alluvium + CM	Piezometer	1320	5.46	58.49
RM07	**63.7**	9.8	6.4 – 8.4	Alluvium + CM	Piezometer	1510	5.09	58.61
RM08	**65.50**	8.2	6.2 – 8.2	Alluvium + CM	Piezometer	1300 (2000)	4.86	60.94
RM09	**65.45**	8.75	5.7 – 7.7	Alluvium	Piezometer	1360	4.39	61.01
RM10	**61.40**	10.8	7.8 – 9.8	Alluvium + CM	Piezometer	1460	5.49	56.06
RA01	**68.35**	11.5	?	CM (Bayswater Seam)	Lost	-	-	-
RA02	**63.60**	11.25	?	Alluvium + CM	Piezometer	-	8.07	55.73
RA03	**60.85**	6.0	Not cased	Alluvium	Abandoned	-	-	-
RA05	**?**	?	Not cased	Alluvium	Abandoned	-	-	-
RA11	**?**	?	Not cased	Alluvium (HR)	Abandoned	-	-	-
PB1	**61.10**	7.8	5.6 – 7.6	Alluvium + CM	Test bore	1540	5.29	55.81
PB2	**65.30**	9.5	4.7 – 7.0	Alluvium	Lost	1420 (2000)	-	-
WML21	**65.03**	117.0	106 - 112	Pikes Gully Seam	Piezometer	7190	42.27	22.76
WML22	**63.70**	193.0	183 - 189	Pikes Gully Seam	Abandoned	-	-	-

Note:

All screened interval and constructed depths given to nearest 0.1m.
CM coal measures
(m bgl) metres below ground level
(m AHD) metres above Australian Height Datum
\- Indicates where data not available

HLA's main conclusions (HLA, 2001) were:

- *The alluvial groundwater resource contains about 750 ML of water and has an underflow or sustainable yield of 0.003 to 0.1 ML/d.*
- *The alluvial groundwater is medium to high salinity.*
- *The alluvial groundwater baseflow is about 0.2% to 5% of low flows in Bowmans Creek between 1993 and 2000.*
- *The underflow and groundwater storage in the alluvium is negligible in sustaining low flows in the Hunter River.*
- *The environmental value of the alluvial groundwater resource was difficult to assess, given its poor quality and limited contribution to creek baseflow.*

3.2. DRILLING PROGRAMS (2006-2007)

A series of multi-level vibrating wire piezometer bores were completed over the underground mining area during the period April to September 2006 to provide a monitoring network for detecting the impacts of subsidence fracturing on the Permian groundwater system. A piezometer bore was located above the southern end of each longwall panel in the mine plan at that time, and others were installed above the middle and north-western parts of the underground mining area. A number of these bore sites (WML110, WML111, WML112, WML113, WML114 and WML115) were located within or close to the area occupied by the Bowmans Creek alluvium (**Figure 4**).

Each of these sites commonly comprises several monitoring points at different depths. All sites have a 50mm standpipe monitoring bore completed into the uppermost water-bearing zone in the Permian (typically between 18 and 36m deep), a multi-level vibrating wire piezometer completed into each main coal seam (typically to depths of greater than 120m), and at some sites an additional 50mm standpipe monitoring bore into the alluvium (typically 12 to 14m deep). Bores WML112C, WML113C and WML115C were completed as alluvium piezometers. WML110C was completed in colluvium flanking the Bowmans Creek alluvium.

During September and October 2007, a focussed drilling program was undertaken in the area associated with Bowmans creek alluvium, with drilling undertaken by Intertech Drilling under the direction and supervision of Peter Dundon and Associates Pty Ltd (now part of the Aquaterra group). The objective of the program was to delineate the extent of the saturated alluvium and determine the nature and properties of the alluvial aquifer system.

Forty-two bores were drilled into the Bowmans Creek alluvium and/or the flanking colluvium (**Figure 4**). All were drilled to basement where possible.

Air drilling was undertaken in preference to mud drilling, as it allows the identification of groundwater intersections during drilling. The air core method was initially chosen, as it permits precise sampling and allowed the top of the Permian to be identified immediately during drilling. However, the method proved unsuitable due to the presence of occasional boulders within the alluvium. The air rotary method was then used, with greater success, except that the holes were prone to partial fall-back before they were able to be cased. For the final stages of the program, the drilling method employed was the Tubex method, in which an outer casing is advanced during the drilling process, which keeps the hole open and allows the production casing and screens to be placed inside before removal of the drill string and placement of the annular gravel pack. Seven of the bores were drilled using air core drilling methods, twenty-one (21) using rotary air drilling methods, and fourteen using the Tubex (casing advancement) drilling method.

Of the bores drilled, twenty one were constructed as piezometers (**Figure 4**). The remainder were backfilled and abandoned, but the drilling information obtained from all bores was used to provide detail on the depth to the base of the alluvium.

All holes were generally drilled until intersection of the Permian coal measures was identified in the drill cuttings, so the holes penetrated 0.2 to 0.5m into the Permian at most. The exact contact depth with the Permian was occasionally difficult to determine due to limited sample return. The holes selected for completion as piezometers were cased with 50mm PVC casing including a 3m section of factory-slotted screen. The screens were designed to be placed in the lowermost section of the alluvium, although in some cases the casing could not be seated at the bottom of the hole due to partial hole caving. **Table 3.2** provides a summary list of the bores drilled along with relevant completion details. Borelogs for each site are included in **Appendix A**.

Locations are shown on **Figure 4**. Details of the piezometers installed within the Bowmans Creek valley during the 2006 and 2007 drilling are presented in **Table 3.2**.

Table 3.2: Bowmans Creek Alluvium Investigation Drilling and Piezometer Construction Details

Bore	Ground Level (m AHD)	Drilled Depth (m bgl)	Screened Interval* (m bgl)	Aquifer(s) screened	Current Status	EC (µS/cm) (2006 unless stated)	SWL (24 January 2008)	
							(m bgl)	(m AHD)
WML110B	**63.74**	24.0	18 - 24	CM	Piezometer **	9590	13.43	50.35
WML110C	**63.73**	17.0	11 - 14	Alluvium	Piezometer **	9340	13.24	50.39
WML111B	**58.33**	18.0	12 - 18	CM	Piezometer **	2580	7.63	50.74
WML112B	**59.42**	36.0	16 - 19, 22 - 25	Bayswater Seam	Piezometer **	1720	8.63	50.84
WML112C	**59.58**	12.0	9 - 12	Alluvium	Piezometer **	1360	7.91	51.67
WML113B	**60.20**	20.0	15 - 18	Bayswater Seam	Piezometer **	875	9.94	50.31
WML113C	**60.43**	11.5	8.5 – 11.5	Alluvium	Piezometer **	1450	9.61	51.05
WML115B	**66.35**	12.6	9.6 – 12.6	CM	Piezometer **	3970	4.48	61.57
WML115C	**66.22**	6.2	3.2 – 6.2	Alluvium	Piezometer **	4100	4.58	61.64
AC1	-	9	-	-	Uncased, abandoned	-	-	-
AC2	60.68	15	-	-	Uncased, abandoned	-	-	-
AC3	61.43	10.8	-	-	Uncased, abandoned	-	-	-
AC4	58.43	9	-	-	Uncased, abandoned	-	-	-
AC5	59.85	9	-	-	Uncased, abandoned	-	-	-
AC6	61.10	9	-	-	Uncased, abandoned	-	-	-
AC7	61.94	9	-	-	Uncased, abandoned	-	-	-
RA8	63.21	15	11.8 – 14.8	Colluvium	Piezometer	8370	12.88	50.33
RA9	61.84	10	7 – 10	Alluvium	Piezometer	-	Dry	-
RA10	59.13	13	7.9 – 10.9	Alluvium	Piezometer	1780	8.71	50.42
RA11	60.54	13	-	-	Uncased, abandoned	-	-	-
RA12	62.15	13	8.2 – 11.2	Colluvium	Piezometer	-	11.62	50.53
RA13	61.35	12	-		Uncased, abandoned	-	-	-
RA14	59.74	11	6.9 – 9.9	Alluvium	Piezometer	2050	8.38	51.36
RA15	60.30	10.5	6.0 – 9.0	Alluvium	Piezometer	-	9.05	51.55
RA16	70.33	6	2.3 – 5.3	Colluvium	Piezometer	13400	3.85	66.48
RA17	62.33	10.5	7.1 – 10.1	Alluvium	Piezometer	1190	9.19	53.14
RA18	62.56	8.5	5.3 – 8.3	Alluvium	Piezometer	2100	5.78	56.78
RA19	64.47	9	-		Uncased, abandoned	-	-	-
RA20	62.69	8	2.2 – 5.2	Alluvium	Piezometer	-	Dry	-
RA21A	-	1.5	-	-	Uncased, abandoned	-	-	-
RA21B	-	3	-	-	Uncased, abandoned	-	-	-
RA22	66.98	11	-	-	Uncased, abandoned	-	-	-
RA23	63.16	10.5	-	-	Uncased, abandoned	-	-	-
RA24	64.05	6	-	-	Uncased, abandoned	-	-	-
RA25	-	3	-	-	Uncased, abandoned	-	-	-
RA26	60.83	15.5	-	-	Uncased, abandoned	-	-	-
RA27	59.05	15.5	7.2 – 10.2	Alluvium	Piezometer	2550	9.23	49.82
RA28	66.19	11	-	-	Uncased, abandoned	-	-	-
RA30	66.30	9	3.7 – 6.7	Alluvium	Piezometer	1560	5.18	61.12
T1-P	64.74	12.6	9.0 – 12.0	CM	Piezometer	9220	3.63	61.07
T1-A	64.96	7.9	4.2 – 7.2	Alluvium	Piezometer	2040	3.89	61.11
T2-P	60.66	14.9	11.9 – 14.9	CM	Piezometer	1070	5.33	55.74
T2-A	60.80	8.9	5.9 – 8.9	Alluvium	Piezometer	1680	5.06	55.33
T3-P	59.81	30.5	27.5 – 30.5	CM	Piezometer	2050	8.48	51.39
T3-A	59.85	9.9	6.9 – 9.9	Alluvium	Piezometer	2150	8.46	50.83
T4-P	58.52	31.0	28.0 – 31.0	CM	Piezometer	2000	7.73	50.47

Bore	Ground Level (m AHD)	Drilled Depth (m bgl)	Screened Interval* (m bgl)	Aquifer(s) screened	Current Status	EC (µS/cm) (2006 unless stated)	SWL (24 January 2008)	
							(m bgl)	(m AHD)
T4-A	58.58	10.0	6.9 – 9.9	Alluvium	Piezometer	2270	8.11	50.79
T5	65.33	8.0	5.0 – 8.0	Alluvium	Piezometer	1330	3.82	61.51
T6	65.96	7.0	4.0 – 7.0	Alluvium	Piezometer	1280	4.07	61.89
T7	64.42	7.0	3.9 – 6.9	Alluvium	Piezometer	6420	3.70	60.92
T8	59.44	8.9	5.2 – 8.2	Alluvium	Piezometer	-	Dry	-
T9	59.85	10.0	6.7 – 9.7	Alluvium	Piezometer	2490	Dry	-
T10	58.69	10.0	7.0 – 10.0	Alluvium	Piezometer	2050	8.01	50.68

Note:

* All screened intervals given to nearest 0.1m.
** Table includes only standpipe bores relevant to Bowmans Creek alluvium area. Deeper multi-level vibrating wire piezometers in the Permian are also present at these sites.
CM coal measures
(m bgl) metres below ground level
(m AHD) metres above Australian Height Datum
- Indicates where data not available

3.3 HYDRAULIC TESTING

All standpipe piezometers located in the Bowmans Creek floodplain have been subjected to hydraulic testing. Tests were carried out between October 2007 and February 2008 on all alluvium piezometers, as well as piezometers monitoring the uppermost part of the Permian coal measures.

Where there was sufficient depth of water in the bore, a constant rate pumping test was attempted. Due to the limited available drawdowns, the tests were undertaken using low capacity Waterra sampling pumps. Eight piezometers underwent successful short-term constant rate pumping tests. Dataloggers were used to measure the water level drawdown and recovery.

In bores with insufficient water depth and/or insufficient permeability to sustain pumping, falling head slug permeability tests were carried out. Again, dataloggers were used to record water levels during the tests. Successful slug tests were completed on nineteen (19) bores.

The constant rate test data were analysed using the Cooper-Jacob method (Cooper and Jacob, 1946) to determine hydraulic conductivity (permeability) values for both the alluvial and Permian lithologies.

Slug test data were analysed using the Bouwer-Rice method (Bouwer and Rice, 1976) for the tests on unconsolidated sediments (alluvium and colluvium), and the Hvorslev Method (Hvorslev, 1951) for tests on the hard rock units (Permian coal measures). These methods of analysis assume that the entire length of the screened interval in the test well is saturated; however, in many cases this condition was not met. In such cases, an adaptation of the Bouwer and Rice Method was applied, which accounts for conditions in which the bore is screened across the water table (ie the test interval includes saturated and unsaturated components).

A summary of the testing programme along with derived hydraulic conductivity (K) and transmissivity (T) values is presented in **Table 3.3**. Data plots for each test are included for reference in **Appendix B**.

Table 3.3: Summary of Results from Hydraulic Testing Programme

Bore	Aquifer Screened	Screened Interval (m bgl)	Test Date	Type of Test	Duration (min)	Pumping rate (kL/day)	Transmissivity, T (m^2/day)	Hydraulic Conductivity, K (m/day)	Hydraulic Conductivity, K (m/s)	Comments
RA8	Colluvium	11.8 – 14.8	15/11/07	CRT	8	-	-	-	-	Water level reached pump inlet in 2 min. **Uninterpretable.**
			18/12/07	Slug	36	-	-	0.035	4.1×10^{-7}	
RA10	Alluvium	7.9 – 10.9	15/11/07	CRT	10	12.7	5.4	2.5	3×10^{-5}	Based on analysis of data from 1min onwards.
			15/11/07	Recovery	-	-	8.0	3.6	4×10^{-5}	
			18/12/07	Slug	46	-	-	1.5	1.7×10^{-5}	
RA14	Alluvium	6.9 – 9.9	27/11/07	CRT	10	14.6	*11*	*7.1*	*8.2×10^{-5}*	Water level reached pump inlet in 2 min. [1]**Analysis undertaken but low confidence in data. Note: Low b value (1.5m).**
			05/12/07	Slug	47	-	-	0.0002	2.5×10^{-9}	
RA15	Alluvium	6.0 – 9.0	28/03/08	Slug	41	-	-	0.10	1.2×10^{-6}	
RA16	Colluvium	2.5 – 5.5	08/11/07	CRT	10	8.6	*0.5*	*0.4*	*5×10^{-6}*	Water level reached pump inlet in 2 min. **Analysis undertaken but low confidence in data. Note: Low b value (1.25m).**
			19/12/07	Slug	48	-	-	0.0006	7.0×10^{-9}	
RA17	Colluvium	7.1 – 10.1	15/11/07	CRT	-	-	-	-	-	**Insufficient water to test.**
			19/12/07	Slug	31	-	-	0.0054	6.2×10^{-8}	
RA18	Alluvium	5.3 – 8.3	14/11/07	CRT	-	-	-	-		**Uninterpretable.**
			19/12/07	Slug	33	-	-	4.1	4.8×10^{-5}	
RA27	Hunter River Alluvium	7.2 – 10.2	15/11/07	CRT	10	14.4	61	50	6.0×10^{-4}	Based on analysis of data from 0.5 mins onwards. Note: low b value (1.2m).
RA30	Alluvium	3.7 – 6.7	07/11/07	CRT	10	13.5	*0.3*	*0.27*	*3×10^{-6}*	Based on analysis of data from 1.6 mins onwards. Water level reached pump inlet in 2 min. **Low confidence in data. Note: low b value (1.1m)**
			19/12/07	Slug	35	-	-	1.0	1.1×10^{-5}	
T1-A	Alluvium	4.2 – 7.2	08/11/07	CRT	-	-	-	-	-	**Uninterpretable.**
			20/12/07	Slug	32	-	-	6.1	7.1×10^{-5}	

[1] Hydraulic conductivity and transmissivity values in *italics* are of uncertain reliability.

Bore	Aquifer Screened	Screened Interval (m bgl)	Test Date	Type of Test	Duration (min)	Pumping rate (kL/day)	Transmissivity, T (m^2/day)	Hydraulic Conductivity, K		Comments
								(m/day)	(m/s)	
T1-P	Permian	9.0 – 12.0	08/11/07	CRT	38	16	2.3	0.75	9.0×10^{-6}	**Test terminated prior to steady-state equilibrium conditions being reached.**
				Recovery	-	-	5.8	1.9	2.0×10^{-4}	
T2-A	Alluvium	5.9 – 8.9	28/11/07	CRT	40	12.7	-	-	-	**Spurious data. Not valid for interpretation.**
T2-P	Permian	11.9 – 14.9	14/11/07	CRT	60	16	9.9	3.3	4.0×10^{-5}	Two barrier boundaries.
T3-A	Alluvium	6.9 – 9.9	07/11/07	CRT	4	-	-	-	-	**Water level reached pump inlet in 1 min. Uninterpretable**
			19/12/07	Slug	40	-	-	0.36	4.2×10^{-6}	
T3-P	Permian	27.5 – 30.5	13/11/07	CRT	5	-	-	-	-	**Water level reached pump inlet in 3 min. Uninterpretable**
			05/12/07	Slug	33	-	-	0.11	1.2×10^{-6}	Early time data
							-	0.09	1.02×10^{-6}	Late time data
T4-A	Alluvium	6.9 – 9.9	14/11/07	CRT	12	-	-	-	-	**Water level reached pump inlet in 4 min. Uninterpretable**
T4-P	Permian	28.0 – 31.0	15/11/07	CRT	10	12.5	0.2	0.07	8×10^{-7}	Early time data
								0.05	6×10^{-7}	Late time data
T5	Alluvium	5.0 – 8.0	07/11/07	CRT	25	15.1	45	15	1×10^{-4}	
			07/11/07	Recovery	-	-	45	15	1×10^{-4}	
T6	Alluvium	4.0 – 7.0	07/11/07	CRT	-	-	-	-	-	**Uninterpretable**
			19/12/07	Slug	32	-	-	0.24	2.7×10^{-6}	
T7	Alluvium	3.9 – 6.9	07/11/07	CRT	25	14.4	*3*	*0.9*	4×10^{-5}	**Dewatered bore once drawdown reached 1m**
			20/12/07	Slug	35	-	-	0.15	1.7×10^{-6}	
T10	Alluvium	7.0 – 10.0	18/12/07	Slug	31	-	-	6.0	7.0×10^{-5}	
WML110B	Permian	18.0 – 24.0	04/7/07	CRT	100	-	-	-	-	**Water level reached pump inlet in 3 min. Uninterpretable**
WML110C	Colluvium	11.0 – 14.0	04/7/07	Slug	75	-	-	0.05	1.5×10^{-6}	Early time data
							-	0.13	6.3×10^{-7}	Late time data
WML111B	Permian	12.0 – 18.0	14/11/07	CRT	20	11.7	0.37	0.12	1.4×10^{-6}	Early time data
							0.44	0.15	1.7×10^{-6}	Late time data

Bore	**Aquifer Screened**	**Screened Interval (m bgl)**	**Test Date**	**Type of Test**	**Duration (min)**	**Pumping rate (kL/day)**	**Transmissivity, T (m^2/day)**	**Hydraulic Conductivity, K**		**Comments**
								(m/day)	**(m/s)**	
WML112B	Permian	16.0 – 19.0 22.0 – 25.0	05/12/07	Slug	-	-	-	0.011	1.3×10^{-7}	Early time data
							-	0.015	1.7×10^{-7}	Late time data
			13/11/07	CRT	100+	-	-	-		**Uninterpretable.**
WML112C	Alluvium	9.7 – 12.7	19/12/07	Slug	46	-	-	0.0006	7.0×10^{-9}	
WML113B	Permian	15.0 – 18.0	13/11/07	CRT	25	9.4	*0.5*	*0.13*	1.5×10^{-6}	**Water level reached pump inlet in 2 min. Analysis undertaken but more confidence in recovery data.**
				Recovery	-	-	0.66	0.22	2.5×10^{-6}	
WML113C	Alluvium	8.5 – 11.5	05/12/07	Slug	12	-	-	0.16	1.9×10^{-6}	
WML114B	Permian	13.0 – 16.0 27.0 – 30.0	19/12/07	Slug	32	-	-	0.035	4.0×10^{-7}	
WML115B	Permian	9.6 – 12.6	28/02/08	CRT	60	6.7	9.3	3.1	3.6×10^{-5}	
				Recovery	100	-	2.5	0.83	9.6×10^{-6}	
WML115C	Alluvium	3.2 – 6.2	07/11/07	CRT	5	13.3	-	-	-	**Water level reached pump inlet in 2 min. Low confidence in interpretation.**
			07/11/07	Recovery	5	13.3	3.5	4.4	5.1×10^{-5}	
							3.9	4.9	5.7×10^{-5}	

All screened intervals given to nearest 0.1m.
CRT Constant rate pumping test
(m bgl) metres below ground level
(m AHD) metres above Australian Height Datum

Hydraulic conductivity values determined from the testing program for the Bowmans Creek alluvium ranged from 0.0002 to 15 m/d (**Table 3.3**). Values determined from testing of the Permian coal measures also varied across a wide range, from 0.01 to 3.3 m/d. The hydraulic conductivity values determined at each bore are plotted on **Figure 5**.

Recent packer testing carried out on 17 intervals in bore WMLC213, located near the southern end of the underground mining area (**Figure 2**), has shown permeabilities ranging from less than 1×10^{-11} m/s (effectively zero) to a maximum of 9×10^{-8} m/s, or from 1×10^{-6} to 8×10^{-3} m/d (SCT, 2008).

3.4 WATER QUALITY MONITORING

3.4.1 Groundwater Sampling

In conjunction with the hydraulic testing programme during November 2007, each piezometers was purged in accordance with AS/NZS 5667 (Standards Australia, 1998) and water samples were collected for field analysis of pH, electrical conductivity (EC) and temperature, and for laboratory testing of a comprehensive suite of analytes, viz

- pH, electrical conductivity (EC) and total dissolved solids (TDS),
- major cations and anions, and
- dissolved metals (As, B, Cd, Cr, Cu, Fe, Ni, Pb, Mn, Se, Zn, Hg).

The laboratory analysis was undertaken by ALS Environmental, a NATA-accredited laboratory based in Sydney. Field and laboratory analysis results are presented in **Table 3.4**.

Samples from the Bowmans Creek alluvium showed varying salinity, with ECs ranging from 1190 to 6420 µS/cm (**Table 3.4**). Measured ECs of Permian coal measures groundwater ranged from 1070 to 9590 µS/cm. Samples from three bores in colluvium or highly weathered coal measures revealed salinities in the range 8370 to 13400 µS/cm EC. EC values are shown plotted on **Figure 6**.

pH in all samples was neutral to slightly alkaline, generally in the range 6.5 to 8.5 (**Table 3.4**). The very high pH at bore TP3-P (11.9) is believed to be influenced by contamination from the cement grout during construction.

Comparison of the analysis results for dissolved metals against the ANZECC guideline values for Freshwater Ecosystem Protection (ANZECC, 2000) shows a number of exceedences of the guideline values (**Table 3.4**) as follows:

- The guideline value for **cadmium** (0.0002 mg/L) is exceeded at alluvium bores RA18, RA27, T1-A, T2-A, T3-A and T10, at colluvium bores RA8 and RA16, and in Permian bores T4-P and WML111B.
- The **copper** guideline value (0.0014 mg/L) is exceeded at alluvium bore RA10, T7 and T10, at colluvium bore RA16, and Permian bore WML110B.
- The **lead** guideline value (0.0034 mg/L) was exceeded in alluvium bore T10 and Permian bore WML110B.

Table 3.4: Groundwater Quality – Laboratory Analysis Data

Parameter	Units	LOR	ANZECC (2000) Guideline*	RA10	RA14	RA17	RA18	RA27	RA30	T1-A	T2-A	T3-A	T4-A	T5	T6
Aquifer				Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium
pH Value (Field)		0.01	-	7.39	7.08	7.38	7.31	6.94	6.63	7.82	7.11	6.97	7.14	7.04	6.96
pH Value (Laboratory)		-	-	7.38	7.06	7.13	7.06	7.05	6.66	7.26	7.12	6.76	6.99	6.88	6.99
Temperature (Field)	° C	0.1		23.5	20.9	23.3	23.6	23.9	19.7	19.4	22.6	22.1	21.5	19.3	18.9
Conductivity (Field)	µS/cm	0	-	1576	2080	1364	2060	2540	1633	2230	1597	2110	2270	1420	1420
Lab Conductivity @ 25°C	µS/cm	1	-	1780	2050	1190	2100	2550	1560	2040	1680	2150	2270	1330	1280
Total Dissolved Solids (TDS)	mg/L	1	-	1360	1370	702	1310	2030	1140	1390	2580	3200	1490	910	834
Calcium (Ca)	mg/L	1	-	68	68	47	78	132	68	68	78	62	80	66	57
Magnesium (Mg)	mg/L	1	-	40	58	32	54	90	39	49	40	59	58	29	24
Sodium (Na)	mg/L	1	-	266	329	150	328	368	245	377	242	354	383	202	193
Potassium (K)	mg/L	1	-	0	0	4	2	2	1	4	2	0	0	2	2
Chloride (Cl)	mg/L	1	-	373	632	198	618	867	440	608	393	669	694	293	288
Carbonate as $CaCO_3$	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate as $CaCO_3$	mg/L	1	-	191	182	211	220	243	133	216	154	211	209	145	161
Sulphate (SO_4)	mg/L	1	-	<0.01	163	58	138	170	140	176	141	92	189	158	122
Aluminium (Al)	Mg/L	0.01	-	0.06	0.18	0.03	<0.01	0.02			<0.01	0.02	<0.01		
Arsenic (As)	mg/L	0.001	0.013	<0.0001	0.002	0.005	<0.001	0.005	<0.001	0.001	<0.001	<0.001	0.002	0.002	0.002
Boron (B)	mg/L	0.05	-	<0.001	<0.05	0.05	<0.05	<0.05	<0.05	0.05	0.05	<0.05	0.06	0.06	0.06
Cadmium (Cd)	mg/L	0.00005	0.0002	<0.001	<0.0001	<0.0001	0.0008	0.0003	<0.0001	0.0003	0.0003	0.0004	0.0001	<0.0001	<0.0001
Chromium (Cr)	mg/L	0.002	ID	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	mg/L	0.0005	0.0014	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	mg/L	0.05	-	<0.001	0.17	1.58	<0.05	<0.05	<0.05	<0.05	0.06	13.3	0.58	<0.05	<0.05
Lead (Pb)	mg/L	0.00005	0.0034	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Manganese (Mn)	mg/L	0.001	-	<0.001	0.044	1.4	0.03	2.88	0.794	0.008	0.103	3.2	0.788	0.04	0.024
Nickel (Ni)	mg/L	0.001	0.011	0.182	<0.001	0.004	<0.001	0.013	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Selenium (Se)	mg/L	0.01	-	<0.005	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.010	<0.010
Silver (Ag)	Mg/L	0.001	-	<0.0001	<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001		
Zinc (Zn)	mg/L	0.005	0.008		0.01	0.015	0.011	0.01	0.005	<0.005	0.015	<0.005	0.008	<0.005	<0.005
Mercury (Hg)	mg/L	0.0001	0.00006		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: LOR – Limit of Reporting.
* ANZECC (2000) guideline values for Freshwater Ecosystem Protection. ID = Insufficient data to determine guideline value.
- Indicates where data are not available.

Table 3.4: Groundwater Quality – Laboratory Analysis Data (Continued)

Parameter	Units	LOR	ANZECC (2000) Guideline*	T7	T9	T10	WML112C	WML113C	WML115C	RA8	RA16	WML110C	T1-P	T2-P	T3-P
Aquifer				Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Colluvium	Colluvium	Colluvium	Permian	Permian	Permian
pH Value (Field)		0.01	-	7.09	7.7	7.04	8.61	7.13	7.39	7.35	7.00		7.12	6.77	11.97
pH Value (Laboratory)		-	-	6.96	7.36	6.88	8.26	7.06	7.28	7.24	6.79	7.13	7.24	6.76	11.80
Temperature (Field)	° C	0.1	-	18.2	23.3	26.5	22.3	22.6	18.5	22.3	20.0	-	20.9	22.0	23.8
Conductivity (Field)	µS/cm	0	-	6410	2460	2160	1420	1368	3860	7310	13860		9390	1308	1647
Lab Conductivity @ 25°C	µS/cm	1	-	6420	2490	1060	1360	1450	4100	8370	13400	9340	9220	1070	2050
Total Dissolved Solids (TDS)	mg/L	1	-	4180	3800	1240	720	1220	2610	4680	9,240	5900	5990	854	694
Calcium (Ca)	mg/L	1	-	150	59	82	17	93	86	102	20	126	117	75	4
Magnesium (Mg)	mg/L	1	-	149	42	57	22	37	47	180	430	250	247	36	0
Sodium (Na)	mg/L	1	-	1180	479	313	229	151	783	1460	2,450	1570	1690	74	211
Potassium (K)	mg/L	1	-	1	2	0	6	2	1	8	62	13	11	2	80
Chloride (Cl)	mg/L	1	-	2010	711	478	230	319	1210	2540	4,750	2680	2650	237	200
Carbonate as $CaCO_3$	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	128
Bicarbonate as $CaCO_3$	mg/L	1	-	568	341	245	264	107	237	574	126	763	855	102	0
Sulphate (SO_4^{2-})	mg/L	1	-	416	126	183	42	146	325	358	358	356	495	56	33
Aluminium (Al)	Mg/L	0.01	-		<0.01	0.23	<0.01	<0.01		<0.01				0.15	0.06
Arsenic (As)	mg/L	0.001	0.013	0.005	0.004	0.004	<0.001	0.002	0.002	0.001	<0.001	0.002	<0.001	0.01	<0.001
Boron (B)	mg/L	0.05	-	<0.05	0.07	0.08	0.06	0.06	<0.05	<0.05	<0.05	0.11	0.13	0.05	<0.05
Cadmium (Cd)	mg/L	0.00005	0.0002	<0.0001	<0.0001	0.0003	0.0002	0.0002	<0.0001	0.0004	0.0004	0.0001	0.0001	<0.0001	<0.0001
Chromium (Cr)	mg/L	0.002	ID	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	<0.001	0.002
Copper (Cu)	mg/L	0.0005	0.0014	0.002	<0.001	0.002	<0.001	<0.001	0.001	<0.001	0.002	0.001	<0.001	<0.001	0.001
Iron (Fe)	mg/L	0.05	-	0.08	<0.05	1.54	1.75	<0.05	<0.05	0.43	<0.05	2.34	<0.05	5.08	<0.05
Lead (Pb)	mg/L	0.00005	0.0034	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (Mn)	mg/L	0.001	-	1.87	0.554	0.818	0.063	0.015	0.004	0.04	0.146	0.364	0.105	0.372	<0.001
Nickel (Ni)	mg/L	0.001	0.011	0.005	0.002	0.006	<0.001	<0.001	<0.001	<0.001	0.005	0.001	<0.001	0.002	<0.001
Selenium (Se)	mg/L	0.01	-	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	Mg/L	0.001	-		<0.001	<0.001	<0.001	<0.001		<0.001				<0.001	<0.001
Zinc (Zn)	mg/L	0.005	0.008	<0.005	0.006	0.06	0.006	<0.005	<0.005	<0.005	0.034	0.008	<0.005	0.031	0.01
Mercury (Hg)	mg/L	0.0001	0.00006	<0.0001	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0004

Note: LOR – Limit of Reporting.
* ANZECC (2000) guideline values for Freshwater Ecosystem Protection. ID = Insufficient data to determine guideline value.
\- Indicates where data are not available.

Table 3.4: Groundwater Quality – Laboratory Analysis Data (Continued)

Parameter	Units	LOR	ANZECC (2000) Guideline*	T4-P	WML110B	WML111B	WML112B	WML113B	WML115B	WML20	WML21				
Aquifer				Permian	Permian	Permian	Permian	Permian	Permian	Pikes Gully	Pikes Gully				
pH Value (Field)		0.01	-	7.69	7.4	7.48	8.89	7.72		8.05	8.03				
pH Value (Laboratory)		-	-	8.01	7.04	7.28	8.66	7.36	7.57	8.09	7.96				
Temperature (Field)	° C	0.1	-	24.7	18.7	21.5	22.4	21.4	20.5						
Conductivity (Field)	µS/cm	0	-	1751	9240	2640	1903	1100		4940	7190				
Lab Conductivity @ 25°C	µS/cm	1	-	2000	9590	2580	1720	875	3970	6030	8530				
Total Dissolved Solids (TDS)	mg/L	1	-	1100	5590	1660	980	490	2300	3260	4640				
Calcium (Ca)	mg/L	1	-	37	174	68	37	43	43	6	10				
Magnesium (Mg)	mg/L	1	-	35	298	61	13	26	34	2	4				
Sodium (Na)	mg/L	1	-	378	1490	494	316	89	775	1340	1790				
Potassium (K)	mg/L	1	-	4	14	6	21	2	4	4	6				
Chloride (Cl)	mg/L	1	-	367	3060	824	385	120	1150	1300	2240				
Carbonate as $CaCO_3$	mg/L	1	-	>1	<1	<1	<1	<1	<1	<1	<1				
Bicarbonate as $CaCO_3$	mg/L	1	-	468	545	318	92	213	378	1050	882				
Sulphate (SO_4^{2-})	mg/L	1	-	10	446	138	143	24	86	1	1				
Aluminium (Al)	Mg/L	0.01	-	0.01		<0.01	0.13	0.01	<0.01						
Arsenic (As)	mg/L	0.001	0.013	<0.001	0.003	0.003	0.002	0.003	<0.001	<0.001	<0.001				
Boron (B)	mg/L	0.05	-	0.08	0.11	0.08	<0.05	<0.05	0.13	0.18	0.14				
Cadmium (Cd)	mg/L	0.00005	0.0002	0.001	0.0002	0.0027	<0.0001	0.0002	<0.0001	0.0001	0.0001				
Chromium (Cr)	mg/L	0.002	ID	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005				
Copper (Cu)	mg/L	0.0005	0.0014	<0.001	0.009	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Iron (Fe)	mg/L	0.05	-	0.38	2.56	0.58	<0.05	1.41	0.57	0.08	0.10				
Lead (Pb)	mg/L	0.00005	0.0034	<0.001	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Manganese (Mn)	mg/L	0.001	-	0.015	2.12	0.054	0.004	0.406	0.144	0.038	0.006				
Nickel (Ni)	mg/L	0.001	0.011	<0.001	0.01	<0.001	0.001	<0.001	<0.001	<0.001	<0.001				
Selenium (Se)	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01				
Silver (Ag)	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005						
Zinc (Zn)	mg/L	0.005	0.008	<0.005	0.047	0.008	<0.005	<0.005	0.006	<0.005	<0.005				
Mercury (Hg)	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				

Note: LOR – Limit of Reporting.
* ANZECC (2000) guideline values for Freshwater Ecosystem Protection. ID = Insufficient data to determine guideline value.
- Indicates where data are not available.

- The **nickel** guideline value (0.001 mg/L) was exceeded at alluvium bore RA10.
- Many bores reported **zinc** concentrations above the guideline value (0.008 mg/L), viz alluvium bores RA14, RA17, RA18, RA27, T2-A and T10, colluvium bore RA16, and Permian bores T2-P, T3-P and WML110B.

3.4.2 Surface Water Quality Monitoring

Water quality of surface flows in Bowmans Creek and Hunter River is monitored monthly for EC, pH, TDS, TSS, CaCO3 and oil/grease. Five monitoring stations are located on Bowmans Creek (shown as SM3, SM4, SM4A, SM5 and SM6 on **Figure 2**). SM4A was established in March 2007 to supplement the existing station SM4, which is located in a pool affected by localised seepages of saline groundwater.

There are also two DWE stream gauging stations on Bowmans Creek, one located within the Ashton underground mining area (Foy Brook 210130), and the other approximately 2 km upstream of the New England Highway (Ravensworth 210042). Locations are shown on **Figure 2**. Both stations record streamflow and stage height, and EC data are also recorded at Foy Brook 210130.

The range of reported values for each of the measured parameters at Ashton's Bowmans Creek stations and the DWE station Foy Brook 210130 are summarised in **Table 3.5**. Plots of monthly EC readings from the five Ashton stations, and daily readings from the DWE station, are shown on **Figure 7**. The monthly data spans the period from September 2003 to April 2008. Daily ECs at the DWE gauging station cover the period January 2003 to April 2008.

Table 3.5: Summary of Surface Water Quality Monitoring Data

Bowmans Creek Surface Water Monitoring Station	Location (see Figure 2)	EC (µS/cm)		Comments
		Range	Mean	
SM3	1.3 km upstream of NEH *	421 – 1750	1323	
SM4	80 m downstream of NEH	428 – 14400	3952	Rock-pool, saline seepage from Permian
SM4A	80 m downstream of NEH	434 – 1980	1212	
SM5	Mid-way between NEH and Hunter River	432 – 2040	1448	
SM6	200 m above confluence with Hunter River	453 – 1850	981	
Foybrook 210130	Mid-way between NEH and Hunter River	10 – 5654	1680	

* New England Highway

Surface flow in the Hunter River is less saline, with EC between 500 and 1000 µS/cm in this vicinity, but the water quality of surface flow in Bowmans Creek is highly variable, ranging from less than 500 to more than 4000 µS/cm, presumably due to baseflow contributions from the catchment upstream of the Ashton area.

3.5 BOWMANS CREEK FLOW MONITORING

Streamflow data are available from the DWE gauging stations on Bowmans Creek, viz:

- Foy Brook 210130, and
- Ravensworth 210042.

The flow duration curve for Foy Brook 210130 is plotted on **Figure 8**. It shows a 50 percentile mean daily flow rate of 2.5 ML, or 2500 m^3/d. The 95 percentile mean daily flow rate is 0.32 ML/d, or 320 m^3/d. Zero flows occurred on 2.3 % of all days during the period of record.

The Ravensworth 210042 flow duration curve is also plotted on **Figure 8**, and shows a 50 percentile mean daily flow rate of 2 ML, or 2050 m^3/d. The 95 percentile mean daily flow rate is zero. Zero flows have been recorded on 35 % of all days during the period of record, excluding days of missing data (7 % of the total days are missing data).

3.6 GROUNDWATER LEVELS

Water levels are recorded at least monthly in all piezometers. Groundwater level hydrographs for bores within the Bowmans Creek floodplain area are shown on **Figures 9** to **15**, as follows:

- Bowmans Creek alluvium – **Figures 9** to **10**;
- Hunter River alluvium – **Figure 10**;
- Colluvium – **Figure 11**; and
- Permian coal measures – **Figure 12**.

Groundwater level contours for the Bowmans Creek alluvium in January 2008 are shown in **Figure 13**. The contours show a gradient from north to south (ie upstream to downstream), and also with a component gradient towards Bowmans Creek. Groundwater elevations range from around 62 mAHD at the upstream end near New England Highway to around 50 mAHD at the downstream end near the confluence with Hunter River.

Groundwater levels within the Bowmans Creek alluvium measured on 3 January 2008 are detailed in **Table 3.2** (page 7). Water levels in the Permian bores within the floodplain area are also listed in **Table 3.2**.

The alluvium groundwater levels are generally slightly higher than those in the immediately underlying Permian, as illustrated on **Figures 14** and **15**. These are composite plots of the paired alluvium/coal measures piezometers T1-A and -P, T2-A and -P, T3-A and -P, and T4-A and –P, together with other piezometers close to these sites. At the T1 site, the alluvium and Permian groundwater levels are virtually equal, but at the other three sites, the alluvium water level is 0.4 to 0.5m higher than the Permian water level.

Note that this differential applies only to the near surface groundwater within the Permian. Under unstressed (ie pre-mining) conditions, groundwater levels in the Permian are generally higher than those in the alluvium, and there is a tendency to higher heads with depth, as illustrated on **Figure 16**. This figure shows composite hydrograph plots for the WML111 and WML112 sites, where vibrating wire piezometers are installed in various Lemington seams, and standpipe piezometers monitor water levels in the alluvium and near-surface coal measures. These bores are located well away from both the open cut and underground operations, and have not yet experienced major impact from mining. The alluvium groundwater level is seen to be higher than the Bayswater Seam and upper Lemington seams, but the deeper Lemington seams have increasingly higher heads. At WML111, the Lemington 15 Seam head is virtually at ground level, while prior to piezometer installation, the open hole at WML112 was flowing (ie the composite head for the Permian sequence was above ground level). At both sites, the Lemington 15 Seam head is about 6-7m higher than the alluvium groundwater level.

4.1. EXTENT OF BOWMANS CREEK ALLUVIUM

4.1.1 Lateral Extent of Saturated Alluvium

The lateral extent of Bowmans Creek alluvium has been defined as the edge of saturated alluvium. This has been determined from a combination of aerial photography, aeromagnetic survey, ground mapping, the results of exploration drilling, and monitoring of groundwater levels over a range of above and below average climatic conditions.

The limits of saturated alluvium are shown on **Figure 2**, and are based on groundwater levels in July 2007, which represents the high point in groundwater levels over the period during which monitoring records have been maintained on the Ashton Project (2001 to 2008).

The alluvium merges with colluvium along the flanks of the floodplain. The demarcation between alluvium and colluvium has been determined generally on the basis of lithology, groundwater level and salinity.

4.1.2 Interface Between Bowmans Creek and Hunter River Alluvium

Previous investigations sought to delineate the interface between alluvial sediments deposited by Bowmans Creek and the Hunter River respectively. In a 2002 response to EIS submissions, HLA (2002) provided a justification for selection of the boundary between the alluvial sediments of Bowmans Creek and the Hunter River.

Three holes were drilled between the southern end of the Ashton underground mine area and Hunter River (RA4, RA5 and RA11, located as shown on **Figure 3**). RA4 was located on the southern end of the proposed LW panels, and a second borehole (RA 11) was drilled about halfway between the end of the panel and the Hunter River. Both intersected polymictic (poorly-sorted) gravels that are typical of the Bowmans Creek alluvium found in the other boreholes drilled further upstream to the north. The third borehole (RA5) was located about 100 m from the banks of the Hunter River and this intersected cleaner and better-sorted quartz sands, which are similar to those found in the bed of the Hunter River, and markedly different from the basal sands and gravels of the Bowmans Creek alluvium (HLA, 2002).

Further evidence of separation between Hunter River and Bowmans Creek alluvial sediments has been provided by the results of an aeromagnetic survey (**Figure 17)** which shows a distinctly different signature of thicker alluvial sediments associated with the Hunter River, compared with the Bowmans Creek floodplain. The thicker alluvium is confined to a narrow strip (100m or less in width) along the river bank. The signature for sediments within the Bowmans Creek floodplain is much weaker, suggesting a shallower depth of alluvium. The interpreted boundary between sediments associated with Bowmans Creek and Hunter River is indicated by a dashed line on **Figure 17**. The Hunter River sediments are interpreted to extend up to 100 m from the banks of the Hunter River.

The sharp line of demarcation from the Bowmans Creek alluvium extends across the confluence, with no evidence for an embayment of Hunter River alluvium into the Bowmans Creek valley. Survey levelling of the bed of Bowmans Creek carried out for the Ashton Project EIS (Patterson Britton, 2001) also revealed a steep gradient in bed level down to the Hunter River over the final 200-300m of Bowmans Creek.

4.1.3 Saturated Thickness of Bowmans Creek Alluvium

Contours of the base of alluvium beneath the Bowmans Creek floodplain are plotted on **Figure 18**. These are based on the results of drilling. The contours show a clear incised valley profile, with the course of the incised valley not coincident with the present drainage line in all locations.

Contours of saturated alluvium thickness are shown on **Figure 19**. These are based on the groundwater level highs of July 2007 and the base of alluvium as depicted on **Figure 18**. The saturated thickness reaches a maximum of around 4 – 4.5m.

4.2 HYDRAULIC PROPERTIES

The hydraulic conductivity values determined form the hydraulic testing program are summarised in **Table 4.1** below. The detailed results were discussed in **Section 3.3**.

Table 4.1: Summary of Hydraulic Conductivity Values from Hydraulic Testing Program

Aquifer	Number. of Valid Tests	Hydraulic Conductivity (m/d)		Hydraulic Conductivity (m/s)	
		Range	Median	Range	Median
Bowmans Creek Alluvium	14	0.0002 – 15	0.7	2.5×10^{-9} – 1×10^{-4}	8×10^{-6}
Hunter River Alluvium	1	50	50	6×10^{-4}	6×10^{-4}
Colluvium	4	0.0006 – 0.13	0.02	7.0×10^{-9} – 1.5×10^{-6}	2×10^{-7}
Weathered Permian Coal Measures	9	0.01 – 3.3	0.1	1.5×10^{-7} – 4.0×10^{-5}	1×10^{-6}

Bowmans Creek Alluvium:

The hydraulic conductivity of the poorly-sorted silty gravels and weathered conglomerates of the Bowmans Creek alluvium is highly variable, with values determined ranging from 0.0002 to 15 m/d (ie 10^{-9} to 10^{-4} m/s) with a median value of 0.7 m/d. This is consistent with the results of two pumping tests conducted by HLA during the EIS studies, which indicated hydraulic conductivity values of around 0.5 m/d (HLA, 2001). The values at the higher end of the range shown above are believed to be reflecting the presence of localised lenses of cleaner coarse gravels, while the very low values are typical of the clay-silt matrix which encloses the gravels over most of the floodplain area.

Hunter River Alluvium:

The one test conducted on Hunter River alluvium (bore RA27 – see **Figure 2**) indicated a hydraulic conductivity of 50 m/d. This is consistent with the results of extensive testing at the nearby Hunter Valley No 1 mine in 1992, reported by HLA (2001) to have given an average hydraulic conductivity of 45 m/d.

Colluvium:

Four tests conducted on colluvium flanking the Bowmans Creek floodplain also indicated highly variable hydraulic conductivity values, similar to the less permeable parts of the Bowmans Creek alluvium.

Permian Coal Measures:

Testing of the near-surface Permian coal measures underlying the Bowmans Creek floodplain revealed a slightly more consistent permeability, with hydraulic conductivity values ranging from 0.01 to 3.3, and a median value of 0.1 m/d.

The hydraulic conductivities establish the Bowmans Creek alluvium as distinctly different in character from the Hunter River alluvium. Although there are some more permeable zones within the Bowmans Creek alluvium, these are believed to be localised lenses or stringers of cleaner gravels within the generally poorly permeable floodplain alluvium. There appears to be no clear relationship between hydraulic conductivity and groundwater salinity, with both high and low ECs represented among the more and less permeable sites.

4.3 GROUNDWATER QUALITY

Salinity:

Typically, the Bowmans Creek alluvium groundwater is moderately saline, with EC in the range 1190 to 6420 µS/cm (TDS from 702 to 4180 mg/L) – see **Table 3.4**. High salinities were recorded at T7 (6420 µS/cm) and WML115C (3860 µS/cm), both of which are located in the north of the alluvial study area, on the western side of Bowmans Creek. This area is close to the edge of the backfilled former Ravensworth open cut, which may be a potential source of the higher salinity. Alternatively, it could be due to upward seepage of saline groundwater from the underlying Permian.

Groundwater in the coal measures is generally saline, with EC in the range 6000 to 11000 µS/cm, typified by the Pikes Gully samples WML20 and WML21 (**Table 3.4**). The Pikes Gully seam is well below the ground surface at those two bores. Some of the shallow Permian piezometers report similar quality groundwater, eg TP1-P (9220 µS/cm) and WML110B (9590 µS/cm), both of which are screened in sandstones. The salinities tend to be slightly lower in the relatively more permeable coal seams (eg ECs of 6530 and 8350 µS/cm at WML20 and WML21 respectively). The high salinities in the coal measures are believed to be the result of residual salinity from the time of deposition, which was in a predominantly marine environment, combined with very low rates of natural recharge from rainfall.

The upper part of the Permian coal measures at some locations is much less saline, eg TP2-P, TP3-P, TP4-P, WML111B, WML112B, WML113B and WML115B (ECs in the range 875 to 3970 µS/cm – see **Table 3.4**). The lower salinities in these bores have arisen because the near-surface weathered zone is more readily recharged by direct infiltration of rainfall, allowing the residual salinity to be partly flushed out over time.

The Bowmans Creek alluvial groundwater is generally less saline than groundwater from the coal measures, as at site T1, where the alluvium bore T1-A has an EC of 2040 µS/cm, compared with 5990 µS/cm in the Permian bore T1-P. However, at several sites, the upper Permian groundwater was found to be less saline than that in the alluvium at the same location, for example:

- Site T2 – alluvium has an EC of 2150 µS/cm (T2-A); shallow Permian EC is 1070 µS/cm (T2-P);
- Site WML113 – alluvium EC is 1450 µS/cm (WML113C); shallow Permian EC is 875 µS/cm (WML113B);

At several other sites, the alluvium and shallow Permian ECs are similar (eg at the T3, T4 and WML115 sites).

The groundwater salinity is believed to reflect the proximity to rainfall recharge areas, so at sites where the Permian is less saline than the overlying alluvium, it is interpreted that the Permian is being more readily recharged than the alluvium. In these instances, the recharge to the Permian would be occurring updip to the east/north-east outside of the Bowmans Creek floodplain, where the Permian outcrops and is therefore able be recharged by direct infiltration of rainfall.

Accordingly, the pattern of recharge to the alluvium and the underlying Permian is not uniform. Rainfall is the source of recharge, but infiltration potential is variable, and in some places infiltration appears to occur more readily into Permian outcrops, than into the alluvial floodplain.

pH:

The pH of the Bowmans Creek alluvium is close to neutral or slightly alkaline, with measured pH values in the range 6.5 to 8.5 (**Table 3.4**). A similar pH range is observed in the Bowmans Creek surface flow.

Dissolved Metals:

Elevated concentrations above ANZECC (2000) freshwater ecosystem protection guideline values are common in the alluvium groundwater. Cadmium, copper, lead, nickel and zinc exceedences have been reported (**Section 3.4.1**).

Major Ion Chemistry:

The dominant ions in solution are sodium and chloride. This suggests relatively low rates of rainfall recharge.

The major ion chemistry can assist with comparing natural waters to identify whether they are derived from the same or different sources, or mixtures of sources. The Piper Trilinear Diagram is useful for this purpose, as it enables each groundwater sample to be graphically plotted at a unique point on the basis of the relative concentrations of the major ions typically found in solution – ie the cations calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K); and the anions chloride (Cl), carbonate (CO_3), bicarbonate (HCO_3) and sulphate (SO_4). A piper trilinear plot of the groundwater samples from the Bowmans Creek floodplain, together with two samples from Bowmans Creek surface flow (one a low flow sample and one from normal flow conditions) is shown in **Figure 20**. The Piper trilinear plot shows of all groundwater samples from bores located within the general vicinity of the Bowmans Creek floodplain. They include samples of groundwater from the alluvium, colluvium, shallow coal measures (Bayswater Seam and near-surface weathered interburden sediments) and deeper coal measures (Pikes Gully Seam), with each source identified by a different colour. For all samples, the size of plotted point on **Figure 20** is a function of the salinity.

Also included on the plot are two samples of surface water from Bowmans Creek – one collected from Ashton's monitoring site SM4 on 7June 2007 (EC 12,100 µS/cm), just prior to the flood event on 8-9 June 2007, and the other collected from upstream of the New England Highway on 1 February 2008 (EC 756 µS/cm).

In general, natural waters that are close to recharge sources (or intake areas) have calcium and bicarbonate as the dominant ions in solution, and these waters plot in the left or central parts of the diamond field on the Piper Trilinear Diagram. Waters that are not readily recharged or are remote from a recharge source tend to have sodium and chloride as the dominant ions, and these waters plot on the right side of the diamond field.

Hence the higher salinity samples tend to plot near the right hand side of the diamond field on **Figure 20**. The February 2008 low salinity Bowmans Creek sample plots near the centre of the diamond field, along with a number of low salinity groundwater samples, from both alluvium (RA10 and WML112C) and near-surface coal measures (T2-P, T4-P and WML113B). The low salinity in these samples is interpreted to be the result of the weathered Permian being more readily recharged from infiltration of rainfall than at other sites. The June 2007 Bowmans Creek surface water sample plots on the right side of the diamond field, along with the more saline groundwater samples. Note that in most samples, there is a dominance of sodium among the cations, but there is also a relatively high concentration of calcium and to a lesser extent magnesium. This suggests a possible mixing of both older (or remote from recharge) and recently recharged waters. All samples have less than about 20% bicarbonate (among the anions).

However, four coal measures samples have virtually no calcium or magnesium, and have quite high salinity – T3-P and WML115B (shallow coal measures), and WML20 and WML21 (deeper Pikes Gully Seam). The chemistry of these samples indicates very low rates of rainfall recharge and/or remoteness from recharge.

The cluster of most of the alluvium and shallow coal measures groundwaters near the right hand side of the diamond filed on **Figure 20** is suggestive of a similar recharge source (infiltration of local rainfall) and low rate of recharge to both hydrogeological units across most of the alluvial floodplain.

4.4 GROUNDWATER BASEFLOW CONTRIBUTIONS TO BOWMANS CREEK

The Bowmans Creek alluvium groundwater salinity range overlaps with the salinity range typically seen in the Bowmans Creek surface flows. The highest alluvium ECs are much higher than typical streamflow ECs.

Bowmans Creek surface flow ECs are illustrated on **Figure 7**, which shows plots of EC vs time for Ashton's surface water gauging stations SM3, SM4/4A, SM5 and SM6, as well as the DWE gauge (Foybrook 210130). Locations of the Ashton monitoring stations and DWE gauges are shown on **Figure 2.** The SM5 site is located close to the DWE gauge.

Site SM6 at the downstream end of Bowmans Creek, just above the confluence with the Hunter River (**Figure 2**), normally records an EC in the range 800-1200 µS/cm. Ashton sites SM3, SM4, SM4A and SM5 (**Figure 2**) have ECs higher than SM6, generally around 1300-1800 µS/cm, but up to 14000 µS/cm in the case of SM4 (**Figure 7**). SM3 is located upstream of New England Highway, and has a salinity essentially the same as that at SM5, which is located half way between the Highway and Hunter River (locations shown on **Figure 2**). This suggests that there is minimal baseflow contribution from either the alluvium or the Permian between SM3 and SM5.

The much higher salinity reported from the SM4 site, ranging up to 14000 µS/cm under the low flow conditions prevailing during the 2003-2007 drought (**Figure 7**) is believed to have been influenced by a small local baseflow seepage from the Permian coal measures into a pool in Bowmans Creek at the SM4 site. However, the magnitude of this seepage was only sufficient to cause a localised rise in EC, and by the time SM5 was reached, the stream EC remained very similar to what it was upstream of SM4.

The pattern in EC fluctuations reflects the climatic conditions quite strongly, with higher ECs during periods of no or reduced rainfall runoff, and lower ECs at times of high runoff. The higher ECs during times of low runoff are due to the dominant influence of groundwater baseflow discharges, either locally or from higher up the catchment. This pattern is most dramatically illustrated by SM4. During the first half of 2007, continuous flow along most of Bowmans Creek ceased, but the pool sampled at SM4 was apparently sustained by local seepage from the Permian rock outcropping beside and/or beneath the pool. No flow was visible at SM3 and the DWE Ravensworth gauge between February and June 2007, while at other monitoring locations, water was still present in small disconnected pools, supported by local baseflow discharges from either Permian and/or alluvium aquifers.

The cessation of flow between February and June 2007 indicates that the baseflow contribution is very small in volume, both from the local mine area and from the upper catchment.

Large rainfall runoff events in June and August 2007 restored streamflow, and resulted in marked reductions in the EC values at all sites. Since that time, the measured ECs have fluctuated widely, between a low of around 400 µS/cm in February 2008, to a high around 1500-1700 µS/cm in October 2007.

SECTION 5 POTENTIAL IMPACTS OF LONGWALL MINING ON BOWMANS CREEK ALLUVIUM

5.1 GENERAL

Although in physical proximity, there is only limited hydraulic interconnection between the Bowmans Creek alluvium and the underlying coal measures, based on clear differences in observed water quality and groundwater levels. The near-surface weathered zone of the Permian coal measures locally may have similar heads and water quality to the overlying alluvium, but in other locations within the Bowmans Creek floodplain, there are very distinct head differences and differences in water quality. These differences reflect proximity (or lack of proximity) to recharge from local infiltration of rainfall, which in some cases occurs more readily to the alluvium and in others more readily to the Permian.

However, groundwater in deeper zones within the Permian is quite separate and hydraulically unconnected with the alluvium. Groundwater in the Permian has higher salinity and higher groundwater heads than the Bowmans Creek alluvium, except where the heads have been lowered in the Permian by mine dewatering. There is no evidence that groundwater levels in the Bowmans Creek alluvium have been adversely impacted by Ashton's mine dewatering, even though there is clear evidence of significant drawdown in the Pikes Gully seam and some of the Lemington seams beneath the Bowmans Creek floodplain (refer Pikes Gully seam piezometers WML115-144m and WML21 and Lemington 19 seam piezometer WML115-120m on **Figure 21**). Even more significant is the lack of drawdown in the alluvium and Bayswater 1 Seam at the WML113 site, even though there has been several metres drawdown in the Bayswater 2 Seam just 20m below at the same site (**Figure 21**). It is likely that the Bayswater 2 Seam is responding to mining activity at the Narama mine immediately west of Ashton (**Figure 2**).

There is also no evidence that previous open cut mining of the Ravensworth open cut has had any long-term adverse impact on groundwater levels in the Bowmans Creek floodplain. The Bayswater seams that were mined in the Ravensworth open cut subcrop beneath the Bowmans Creek floodplain, and would have left a lasting impact if there was direct hydraulic connection between the alluvium and the underlying Permian.

Accordingly, the underground mining of the Pikes Gully seam will not in itself lead to direct hydraulic connection with the alluvium, and cause a lowering of groundwater levels. Groundwater levels could only be affected if the mining were to cause interconnection by way of subsidence induced fracturing. Providing a mine plan is adopted that minimises subsidence, the Bowmans Creek alluvium will be protected.

5.2 POTENTIAL SEEPAGE FROM ALLUVIUM

Theoretically, some seepage loss from the alluvium might be expected to occur, albeit at very low rates, purely due to the natural prevailing permeability of the overburden strata, due to the head difference that will be induced between the mine workings and the base of the alluvium.

The potential outflow rate from the Bowmans Creek alluvium, under conditions where no change occurs to the prevailing natural permeability of the coal measures overburden between the base of the alluvium and the LW5-LW9 goaf, can be estimated by using the Darcy equation:

$$Q = K\ i\ A,$$

where:

Q	=	flow rate (m^3/d)
K	=	hydraulic conductivity (m/d)
i	=	hydraulic gradient (m/m)
A	=	cross-sectional area of flow region (m^2).

For this application, in which flow would be vertical, the vertical hydraulic conductivity should be used, and the hydraulic gradient would be 1. In cases of vertical flow, the flow rate limiting factor will be the vertical permeability of the least permeable horizon in the sequence.

Hydraulic testing has provided values for horizontal flow, however, in sedimentary sequences comprising alternating siltstones, sandstones, shales, conglomerates and coal seams, it is generally accepted that the vertical permeability is one or more orders of magnitude lower than horizontal permeability. Average horizontal hydraulic conductivity of the coal measures derived from packer testing of hole WMLC213, located in the southwest corner of the Ashton underground mine area (**Figure 2**) was 8×10^{-4} m/d, or 9×10^{-9} m/s (SCT, 2008). Accordingly, it is considered appropriate to adopt an effective vertical conductivity of 5×10^{-5} m/d for this calculation.

The area occupied by the Bowmans Creek alluvium above LW5-9 is approximately 2.5 km^2, so the potential vertical flow to the mine, if mining were conducted to the completion of LW9 without altering the hydraulic conductivity of the intervening coal measures, would be in the order of 46 ML/year, calculated as follows:

$$Q = (5 \times 10^{-5}) \times 1 \times (2.5 \times 10^{6})\ m^3/d$$
$$= 125\ m^3/d$$
$$= 1.5\ L/s$$
$$= 46\ ML/year.$$

The above potential outflow rate assumes no change in the hydraulic conductivity of the coal measures strata between the alluvium and the goaf as a result of the longwall extraction. The development of subsidence fracturing above the longwalls will result in an increase in permeability in the horizons affected by fracturing. However, provided fracturing does not break through to the overlying alluvium, the seepage rate will be limited by the remaining intact low permeability strata above the fractured zone.

Any potential impact predicted by groundwater modelling of various mine plan scenarios will need to be assessed against this potential outflow rate.

SECTION 6 CONCLUSIONS

A comprehensive understanding of the nature of the Bowmans Creek alluvium and its hydraulic interaction with Bowmans Creek and the underlying Permian coal measures is necessary for Ashton Coal to satisfy Consent Conditions 3.9 and 4.13. The investigations completed to date and reported in this document have allowed the development of such understanding.

Key conclusions in relation to the Bowmans Creek alluvium, and the potential impact of the proposed mining from the Pikes Gully seam beneath the alluvium in longwall panels LW5 to LW9, are as follows:

- The Bowmans Creek alluvium forms a shallow aquifer unit that is clearly distinct from both the underlying Permian coal measures and the Hunter River alluvium.
- The Bowmans Creek alluvium merges in places with colluvium on the flanks of the floodplain, and with residual soils in the highly weathered upper part of the Permian sediments.
- There is highly variable hydraulic conductivity in the Bowmans Creek alluvium, with determined values in the range 0.0002 to 15 m/d.
- Groundwater quality in the Bowmans Creek alluvium is moderately saline to saline, with salinity (as EC) ranging from 1190 to 6420 µS/cm. Salinity in the upper weathered Permian coal measures is similar, in the range 1100 to 9390 µS/cm EC. Salinities at the lower ends of these ranges are as a result of recharge from infiltration of rainfall to the alluvium and, in places, directly to the Permian in areas of outcrop or subcrop.
- Salinity in the deeper Permian coal measures is generally higher, typically in the range 6000 to 11000 µS/cm EC.
- The salinities of groundwater in the alluvium and the near-surface Permian are both higher than typical salinities of surface flow in Bowmans Creek (generally in the range 800 to 1800 µS/cm EC).
- The Bowmans Creek alluvium contributes some baseflow to Bowmans Creek, although the contribution from the planned mining area is very small. Likewise, some baseflow is derived locally from the Permian as well, leading to ECs as high as 14000 µS/cm at one Bowmans Creek monitoring station during the 2003-2008 drought.
- There is only limited hydraulic connection between the Bowmans Creek alluvium and shallow weathered Permian sediments, and virtually no connection with the Pikes Gully coal seam or the deeper seams planned for future mining. This is supported by distinctly different groundwater levels, differences in groundwater quality, and differing responses to recharge and from mining activity.
- Despite the limited or negligible hydraulic connection between the Bowmans Creek alluvium and the Pikes Gully seam, there is potential for some leakage from the alluvium to the underground mine workings. Even in the case where no continuous subsidence-induced fracturing develops between the goaf and the base of the alluvium, the prevailing natural vertical permeability of the coal measures overburden would potentially allow leakage in the order of 125 m^3/d (46 ML/year) from the alluvium to the mine.
- The impact of subsidence on leakage from the Bowmans Creek alluvium will be controlled by the height of interconnected fracturing and the residual vertical permeability of the Permian above the affected zone. Provided that a zone of unfractured rock remains between the base of the alluvium

and the top of the zone of continuous interconnected fracturing, vertical leakage from the alluvium will be limited by the low vertical permeability within the unfractured barrier zone (or “aquaclude” as described in Consent Condition 3.9).

SECTION 7 REFERENCES

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

Bouwer, H and Rice R C, 1976. *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partly penetrating wells.* Water Resour Res, 12(3), p 423.

Cooper, H H and C E Jacob, 1946. *A generalized graphical method for evaluating formation constants and summarizing well field history.* Am Geophys Union Trans, Vol 27, pp 526-534.

HLA-Envirosciences Pty Ltd, 2000. *Preliminary Evaluation of Groundwater Resource in Bowmans Creek.* Rpt dated 5 December 2000.

HLA-Envirosciences Pty Ltd, 2001. *Ashton Coal Project – Groundwater Hydrology and Impact Assessment.* Rpt dated 31 October 2001. [Appendix H of the Ashton Project EIS].

HLA-Envirosciences Pty Ltd, 2002. Letter addressed to White Mining Limited, dated 28 February 2002.

Hvorslev, M J, 1951. *Time lag and soil permeability in ground-water observations.* US Army Corps of Engrs. Waterways Exper. Sta. Bull no 36.

Minister for Planning, 2002. Determination of a Development Application for State Significant and Integrated Development Under Section 80 of the Environmental Planning and Assessment Act, 1979 DA No 309-11-2001-I, dated 11 October 2002.

Patterson Britton and Partners Pty Ltd, 2001. *Ashton Coal Project, Camberwell – Proposed Diversion of Bowmans Creek.* Rpt dated October 2001.

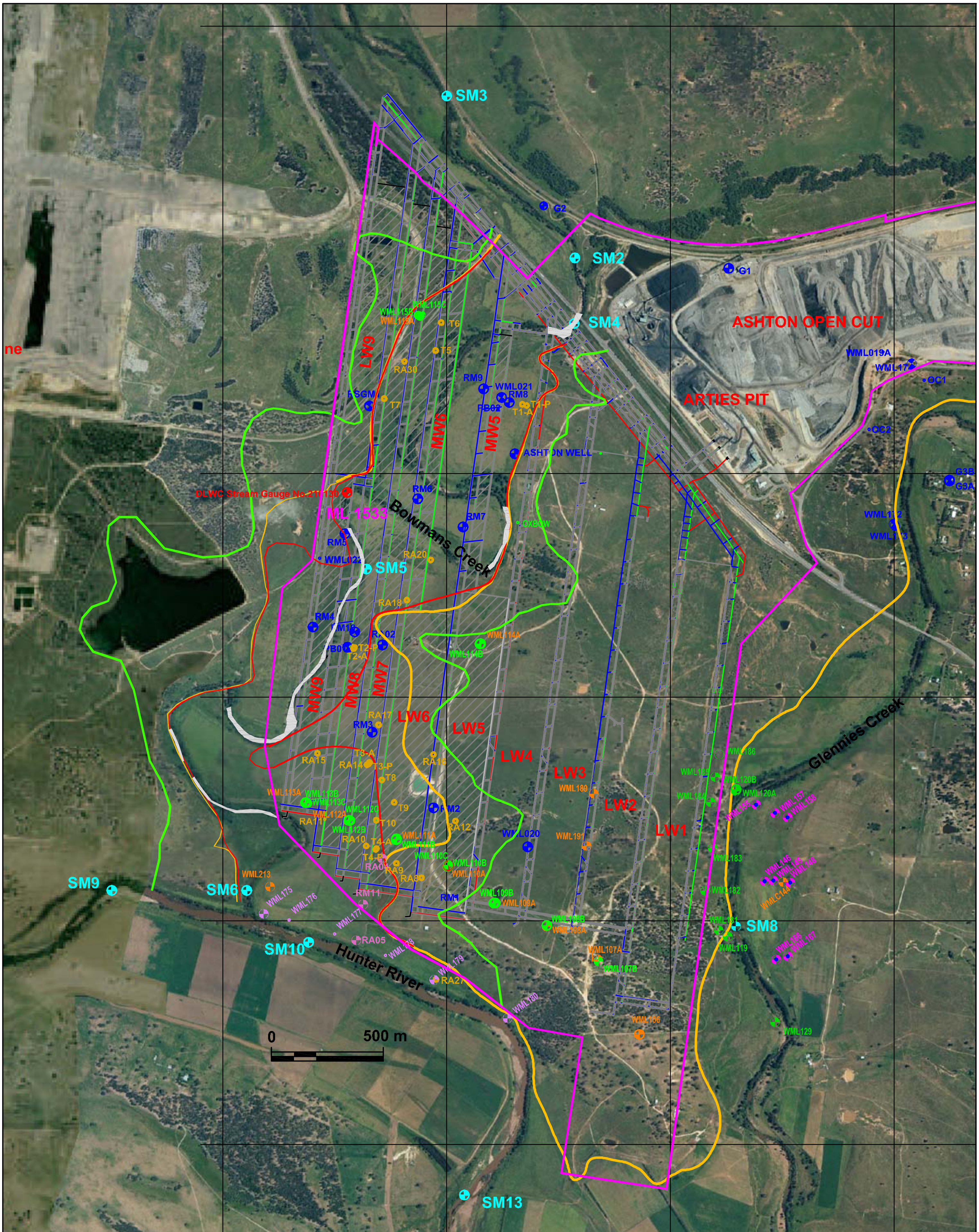
Standards Australia, 1998. *Australian/New Zealand Standard – Water quality – Sampling. Part 11: Guidance on sampling of groundwaters.* AS/NZS 5667.11:1998.

Strata Control Technology (SCT), 2008. *Packer Test Summary, Hole WMLC213.* Rpt dated 16 July 2008.

FIGURES

Basemap sourced from NSW National Parks and Wildlife Service

Ashton Project Location
Figure 1



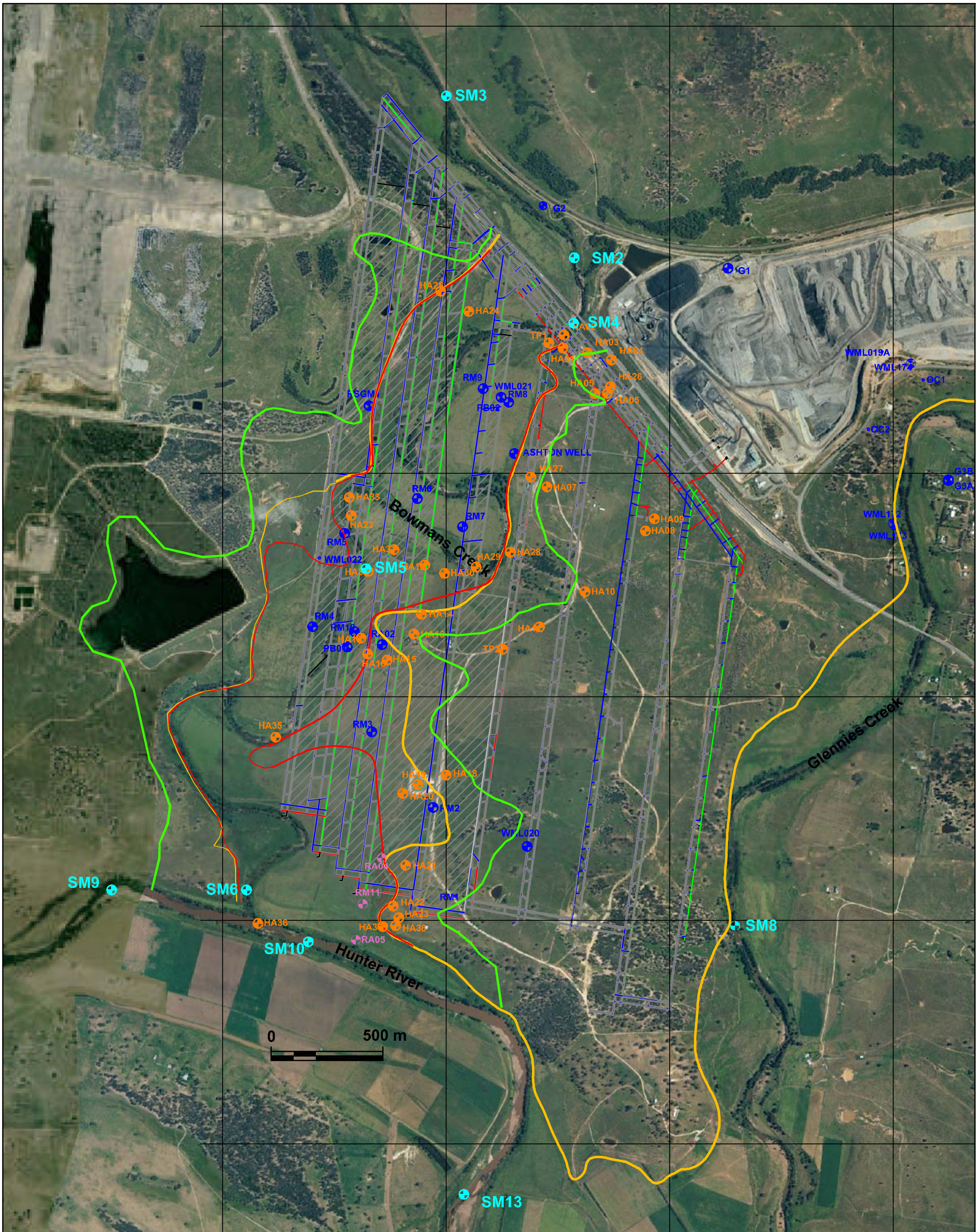
Legend

- EIS Investigation Bores
- Subsidence Monitoring - Vibrating Wire Piezo
- Subsidence Monitoring - Standpipe Piezo
- SEOC Investigation Piezometers
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometer
- LW1 - Glennies Ck Barrier Piezometers
- DWE Stream Gauges
- Surface Water Monitoring Stations
- Extent Of 1955 Flood
- Extent Of Alluvium
- Extent Of Saturated Bowmans Creek Alluvium
- Rock Bars
- Abandoned / Lost Bore

Date:	13 October 2008	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	SRD	Job No:	S03	ASHTON COAL MINE SITE LOCATION PLAN
Drawing No:	S03 -229a	Revision:	A	

aquaterra

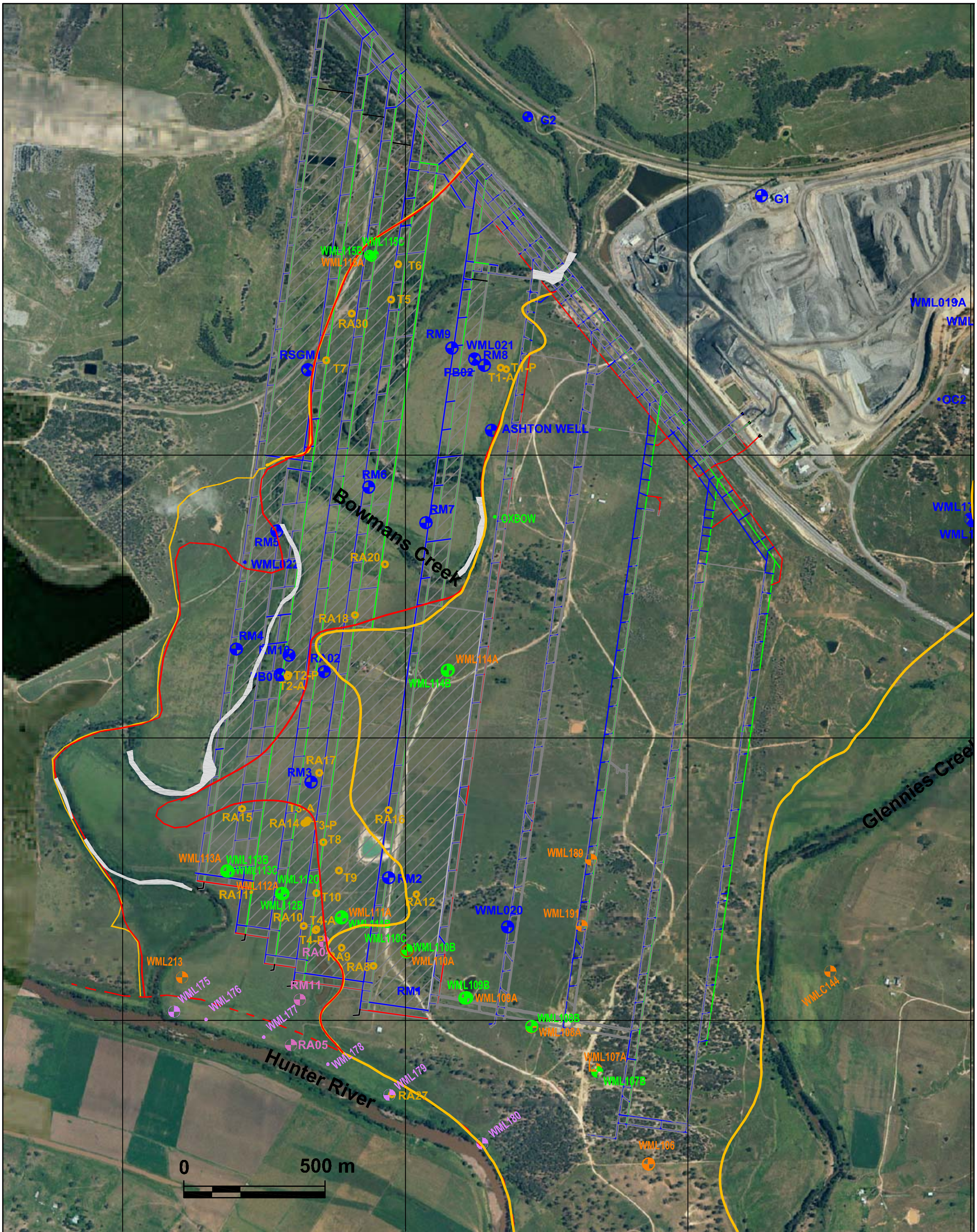
Figure 2



Legend

- HLA Test Pits And Hand Auger Holes
- EIS Investigation Bores
- Bowmans Ck-Hunter River Alluvium Investigation Bores
- Abandoned / Lost Bore
- Extent Of Alluvium
- Extent Of Saturated Alluvium
- Extent Of 1955 Flood Limit

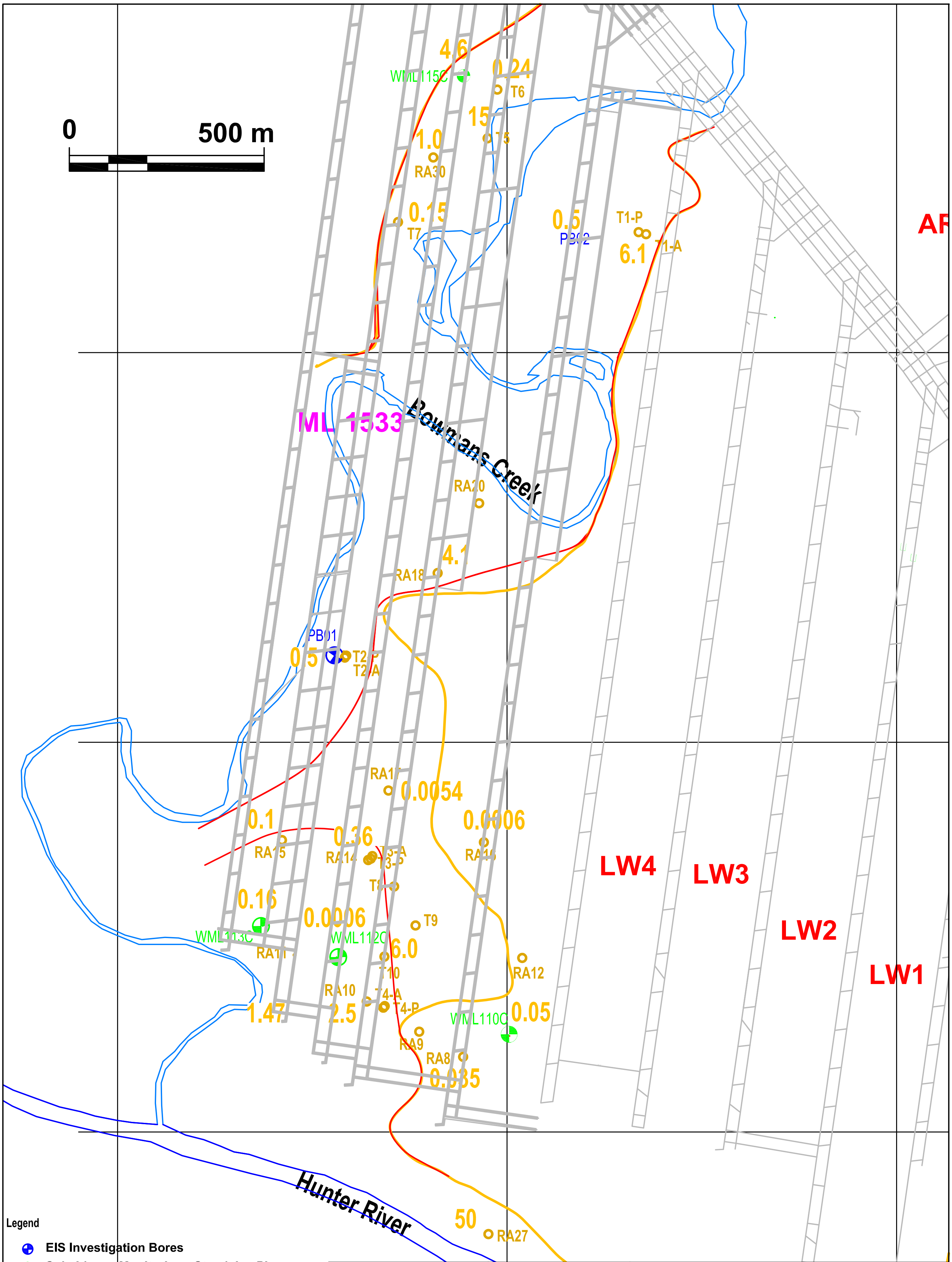
Date: 12 October 2008	Scale: as shown	Ashton Coal Operations Ltd
Initials: SRD	Job No: S03	EIS GROUNDWATER INVESTIGATIONS
Drawing No: S03 -229a	Revision: A	
aquaterra		Figure 3



Legend

- EIS Investigation Bores
- Subsidence Monitoring - Vibrating Wire Piezo
- Subsidence Monitoring - Standpipe Piezo
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometer
- Abandoned / Lost Bore
- Extent Of Alluvium
- Extent Of Saturated Bowmans Creek Alluvium
- Boundary Between Bowmans Ck and Hunter R Alluvium
- Rock Bars

Date: 13 October 2008	Scale: as shown	Ashton Coal Operations Ltd
Initials: SRD	Job No: S03	BOWMANS CREEK INVESTIGATIONS LOCATION PLAN
Drawing No: S03 -229a	Revision: A	
aquaterra		Figure 4



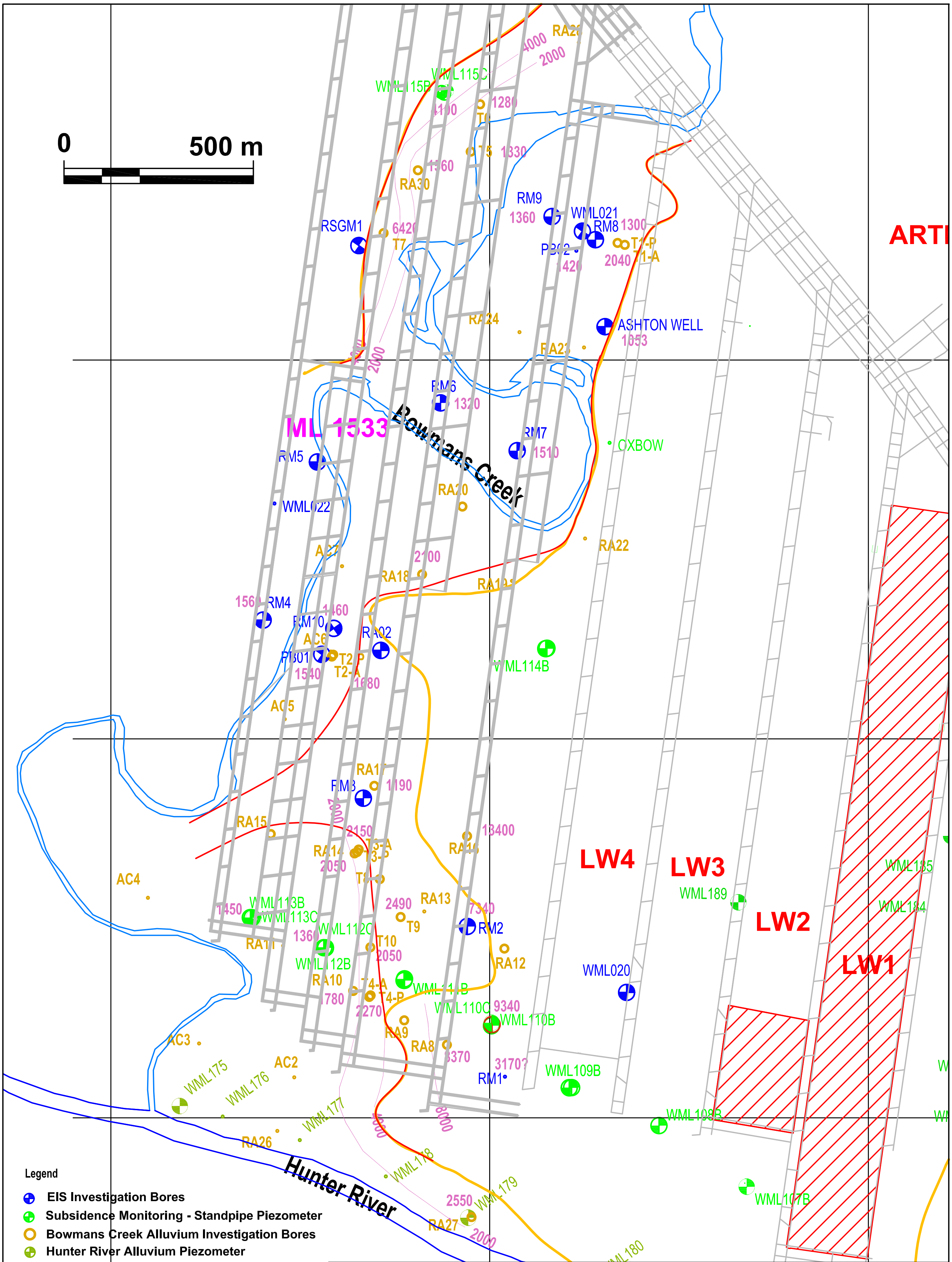
Legend

- EIS Investigation Bores
- Subsidence Monitoring - Standpipe Piezo
- Bowmans Creek Alluvium Investigation Bores
- Abandoned / Uncased Bore
- Alluvium Boundary
- Boundary of Saturated Alluvium
- 0.01 Alluvium Hydraulic Conductivity (m/d)

Date:	14 October 2008	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	PJD	Job No:	S03	BOWMANS CREEK ALLUVIUM and COLLUVIUM HYDRAULIC CONDUCTIVITY (m/d)
Drawing No:	S03-227	Revision:	0	

aquaterra

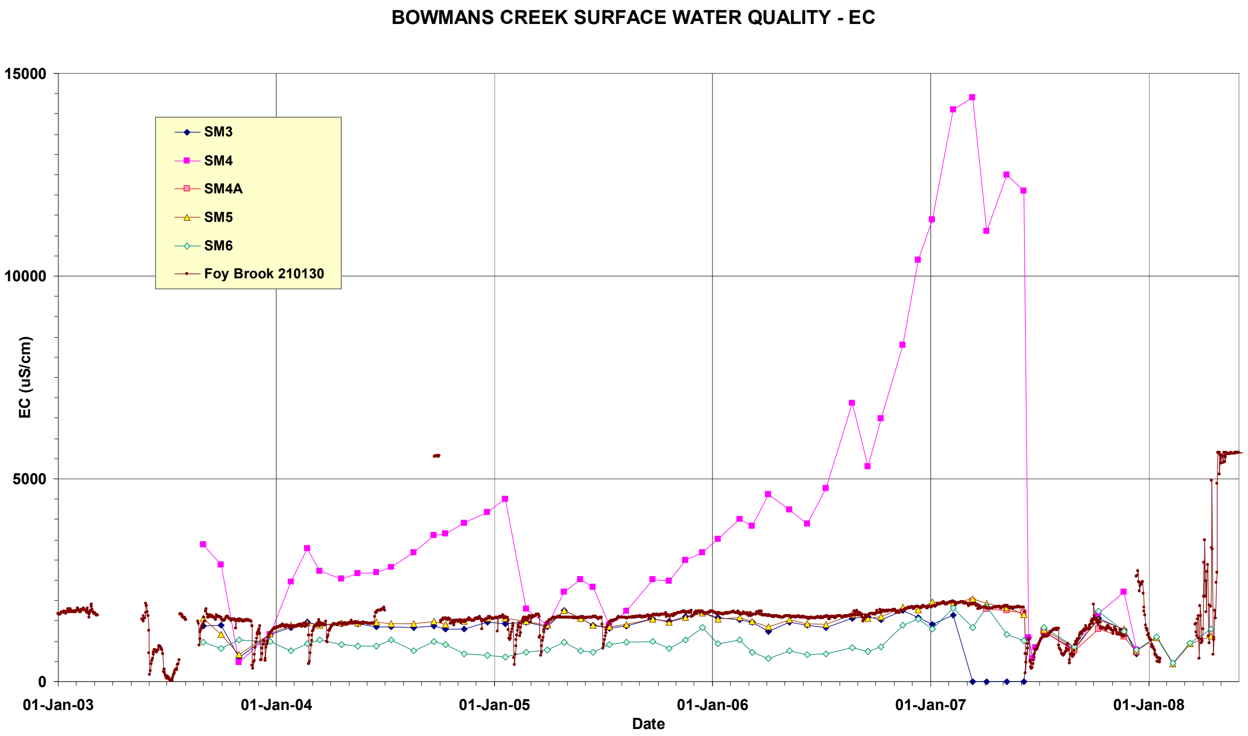
Figure 5

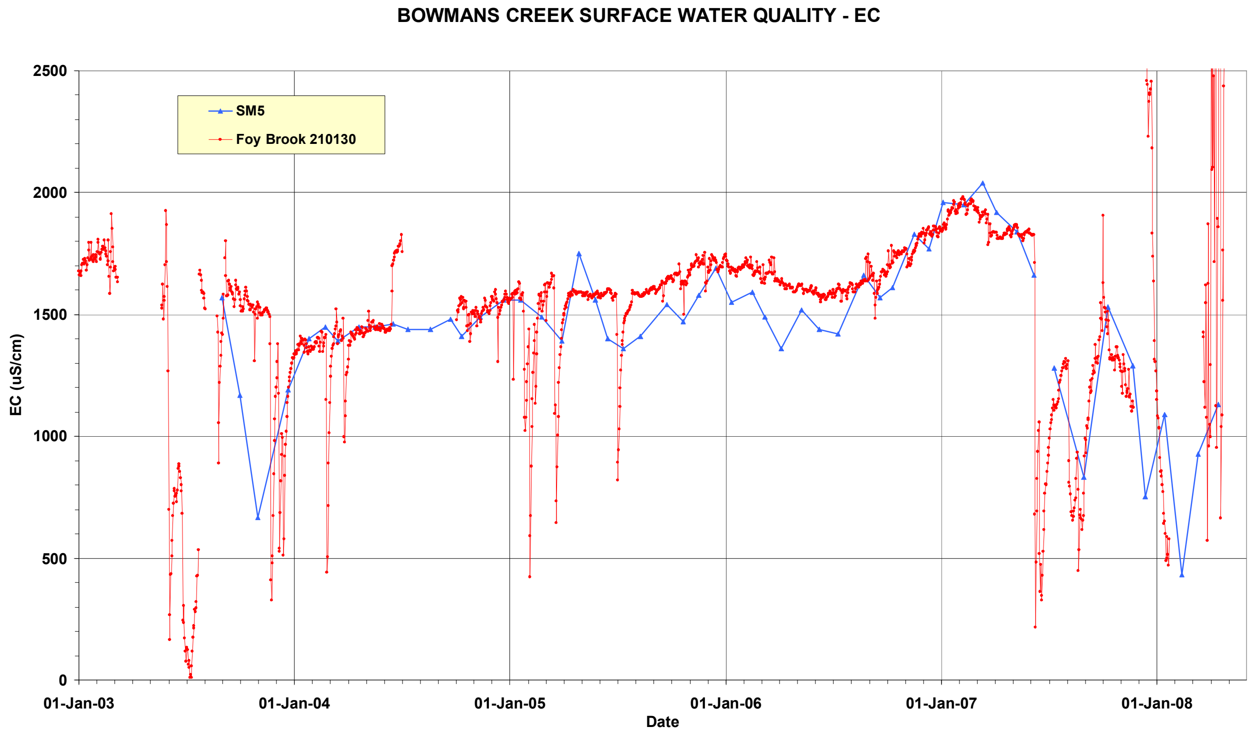


Legend

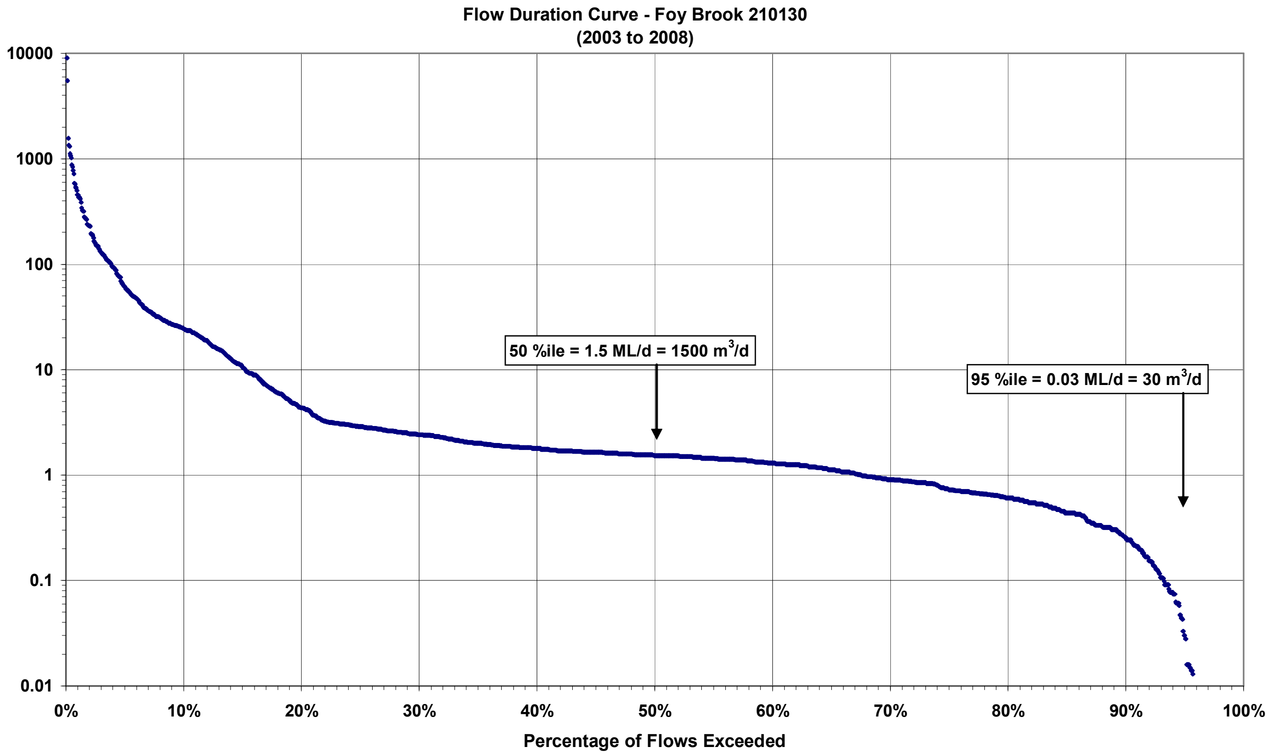
- EIS Investigation Bores
- Subsidence Monitoring - Standpipe Piezometer
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometer
- Abandoned / Uncased Bore
- Alluvium Boundary
- Boundary of Saturated Alluvium
- 1500 Alluvium EC values (uS/cm)
- Alluvium EC contours

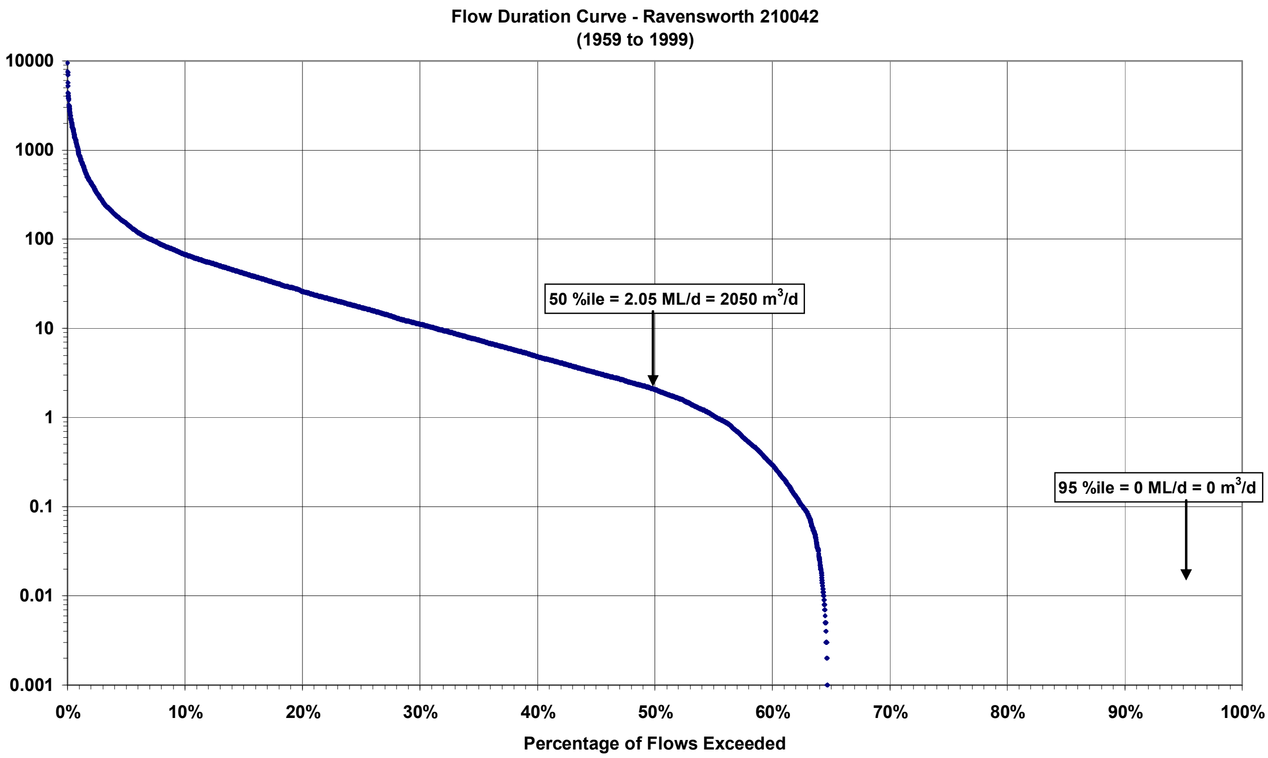
Date: 14 October 2008	Scale: as shown	Ashton Coal Operations Ltd	
Initials: PJD	Job No: S03	BOWMANS CREEK ALLUVIUM GROUNDWATER SALINITY Electrical Conductivity (EC) (uS/cm)	
Drawing No: S03-226	Revision: 0		Figure 6
aquaterra			



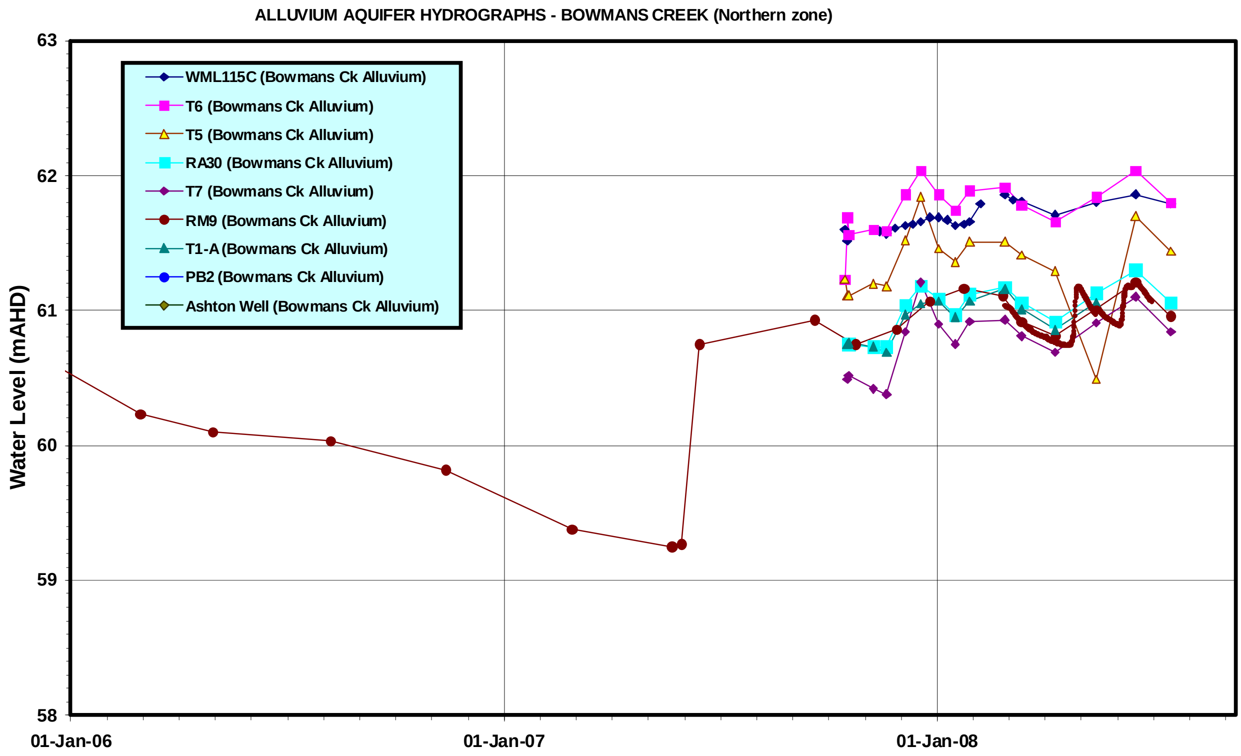


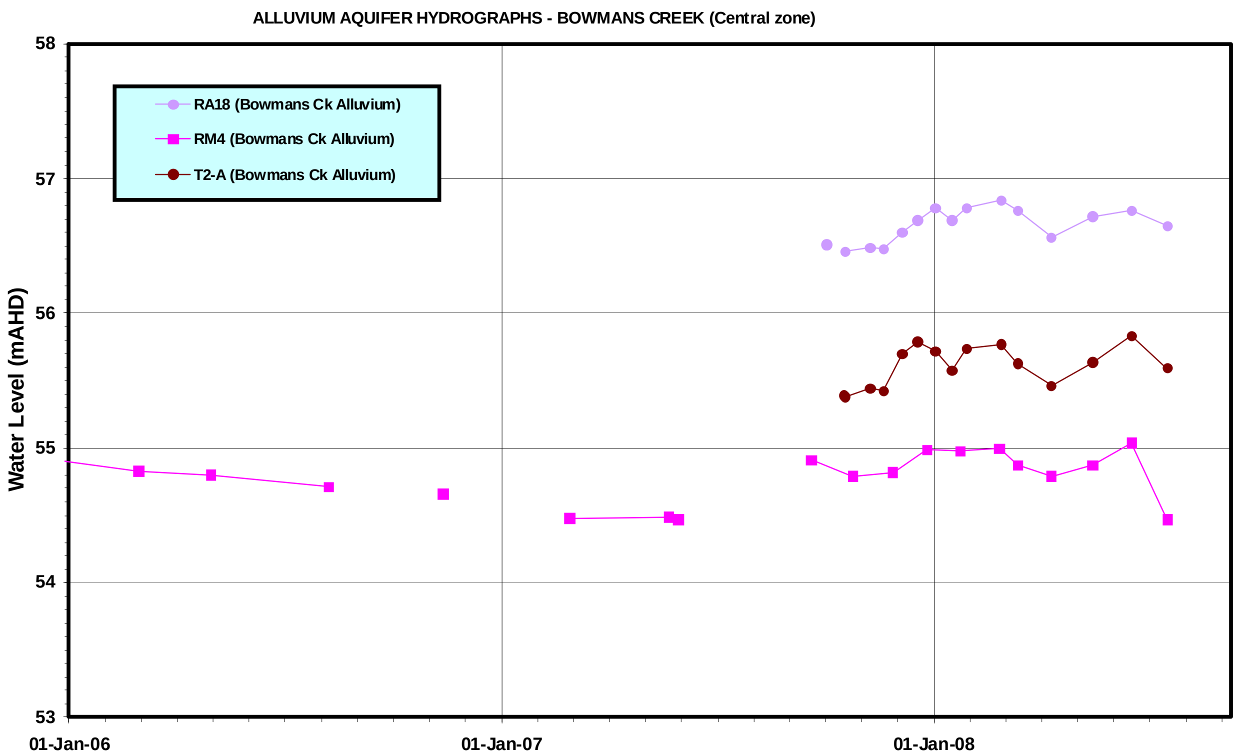
Date: 22 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK SURFACE WATER MONITORING EC Profiles v Time**
Drawing No: S03-214	Rev: 0	
aquaterra		**Figure 7**



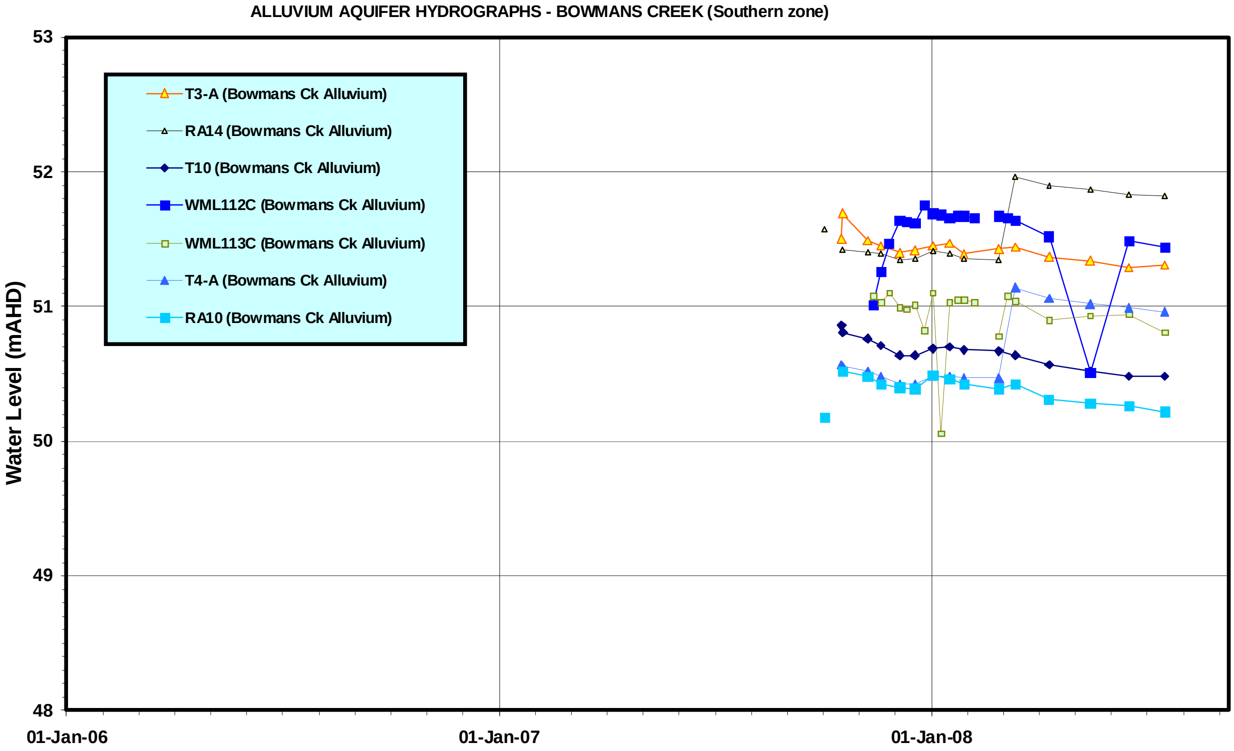


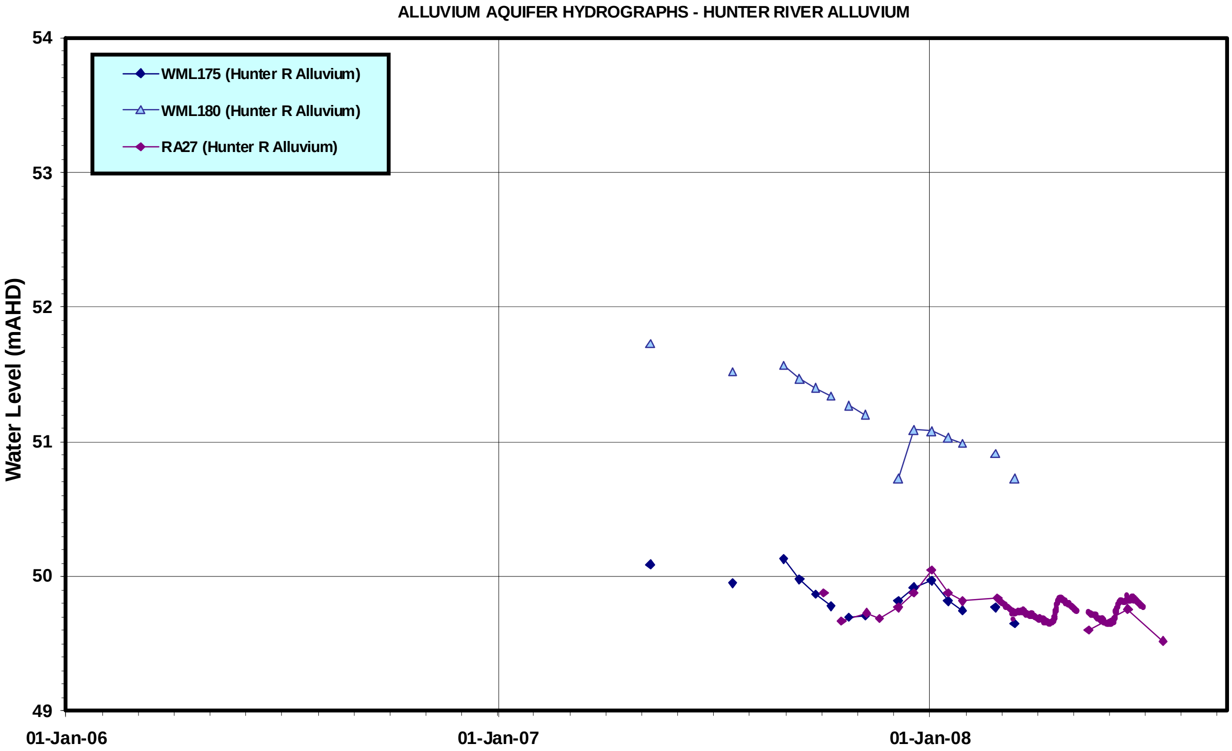
Date: 22 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK - FLOW DURATION CURVES DWE GAUGING STATIONS Foybrook 210130 and Ravensworth 210042**
Drawing No: S03-215	Rev: 0	**Figure 8**
aquaterra		



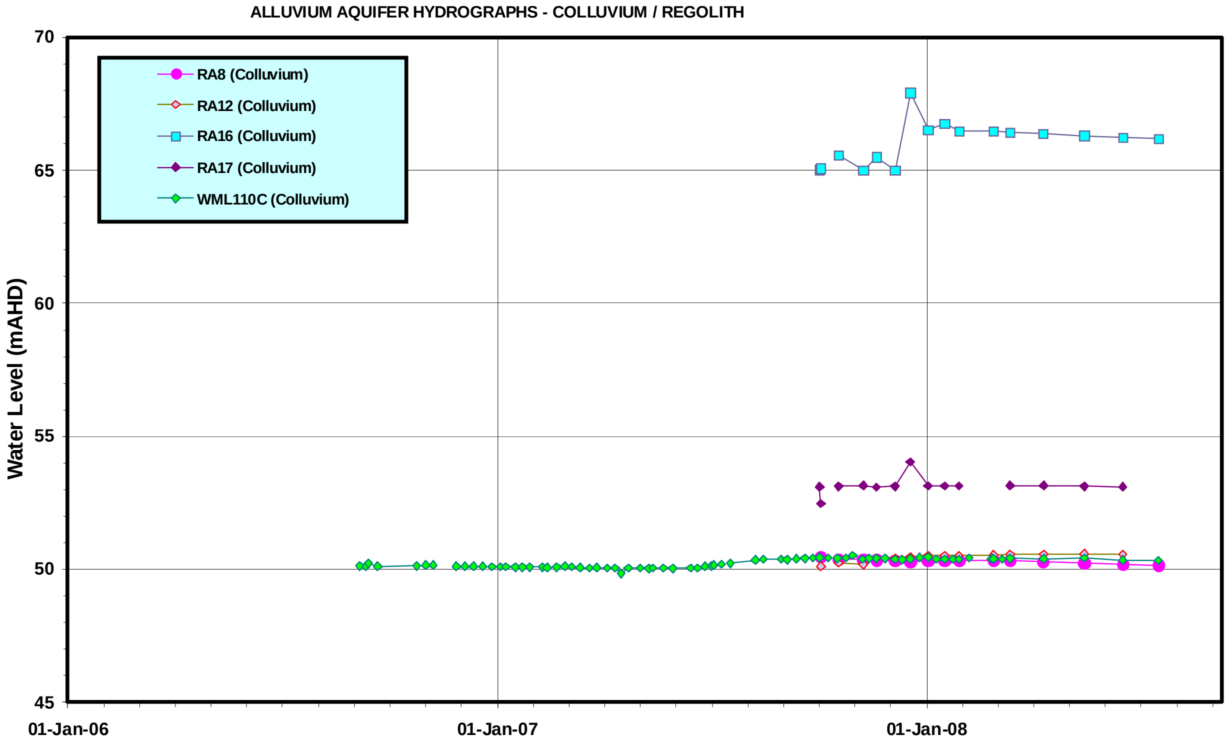


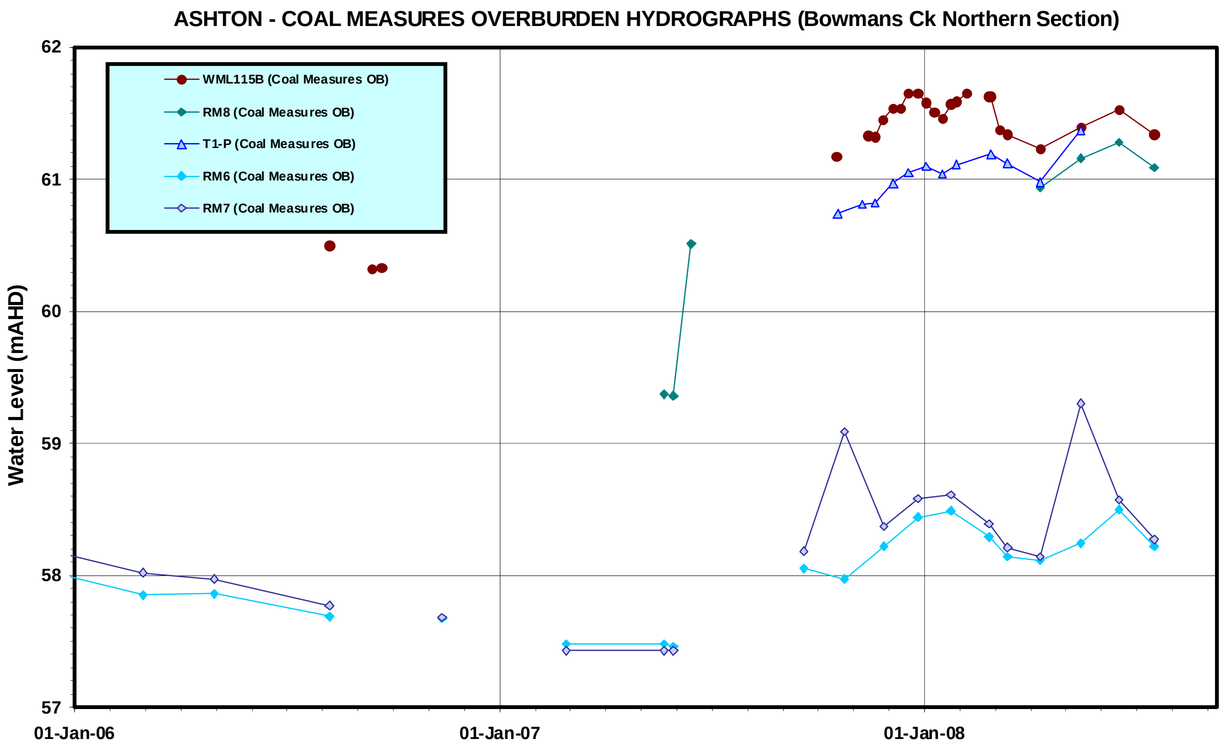
Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**GROUNDWATER LEVEL HYDROGRAPHS BOWMANS CREEK ALLUVIUM Northern and Central Zones**
Drawing No: S03-220	Rev: 0	
aquaterra		**Figure 9**





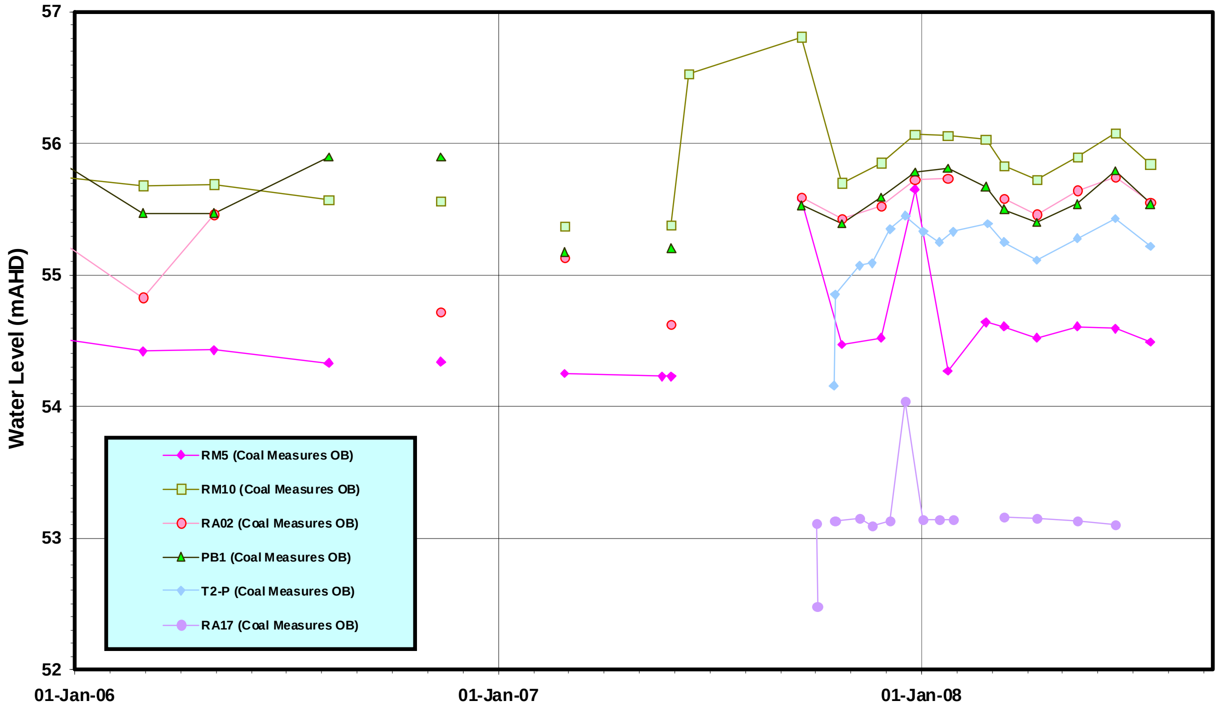
Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**GROUNDWATER LEVEL HYDROGRAPHS BOWMANS CREEK ALLUVIUM - Southern Zone and HUNTER RIVER ALLUVIUM**
Drawing No: S03-221	Rev: 0	
aquaterra		**Figure 10**



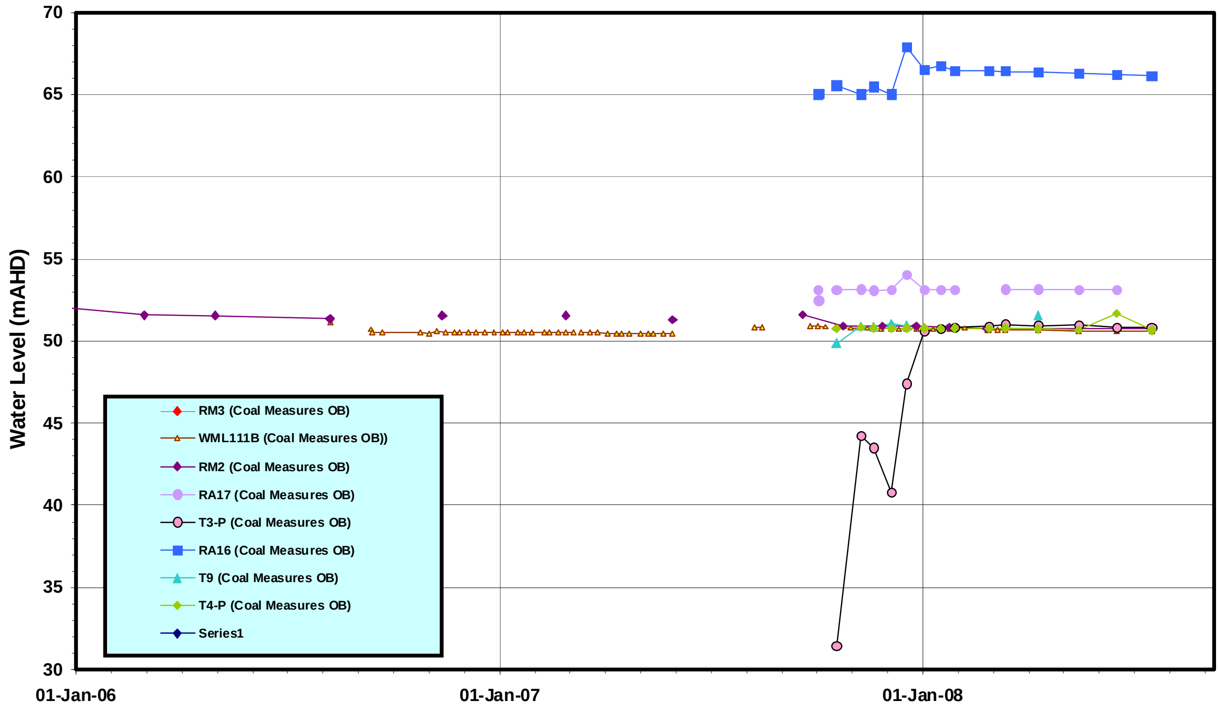


Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**GROUNDWATER LEVEL HYDROGRAPHS BOWMANS CREEK COLLUVIUM and COAL MEASURES**
Drawing No: S03-222	Rev: 0	
aquaterra		**Figure 11**

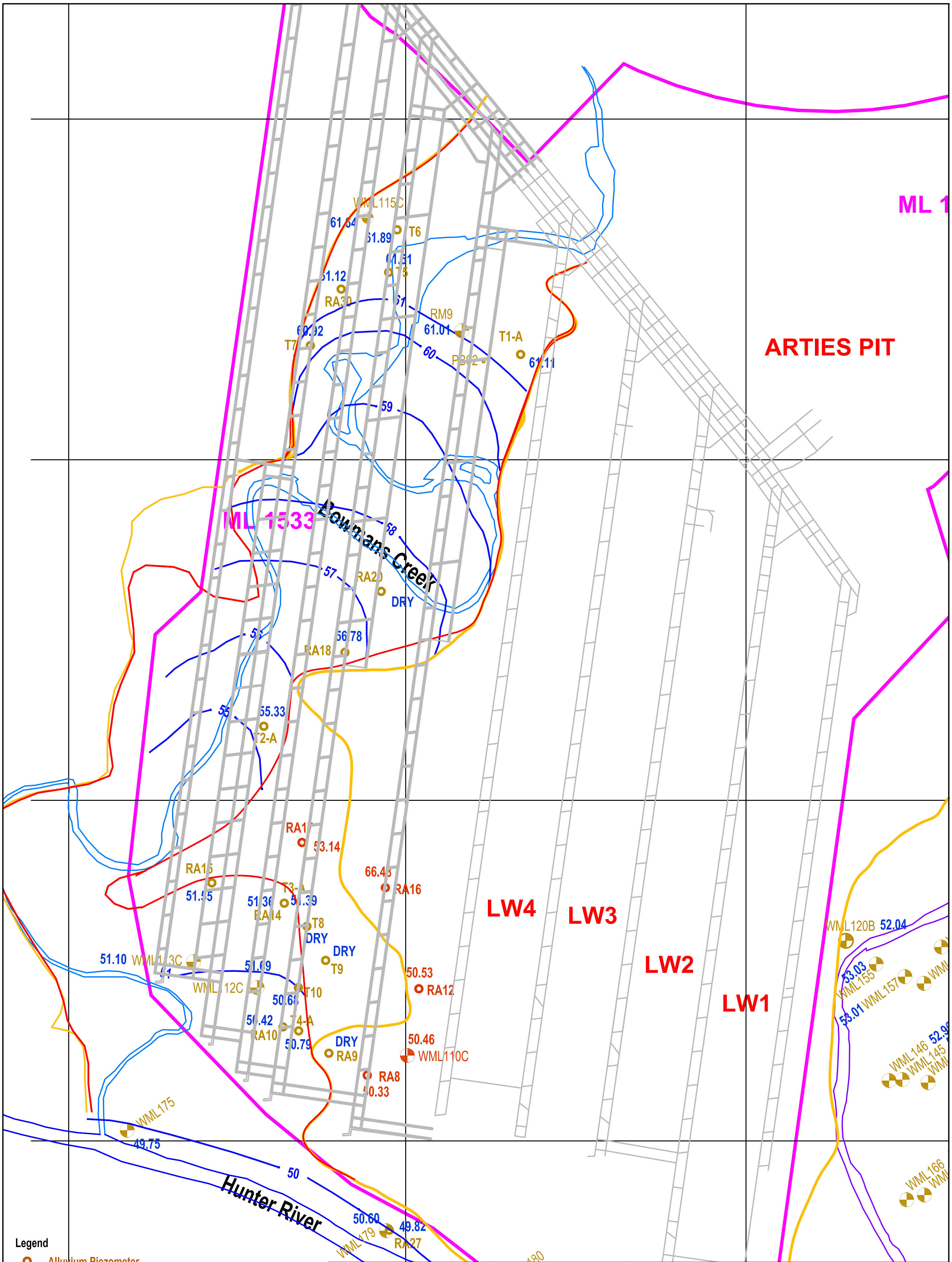
ASHTON - COAL MEASURES OVERBURDEN HYDROGRAPHS (Bowmans Ck Central Section)



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



Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**GROUNDWATER LEVEL HYDROGRAPHS COAL MEASURES OVERBURDEN (Central / Southern Zones)**
Drawing No: S03-223	Rev: 0	
aquaterra		**Figure 12**



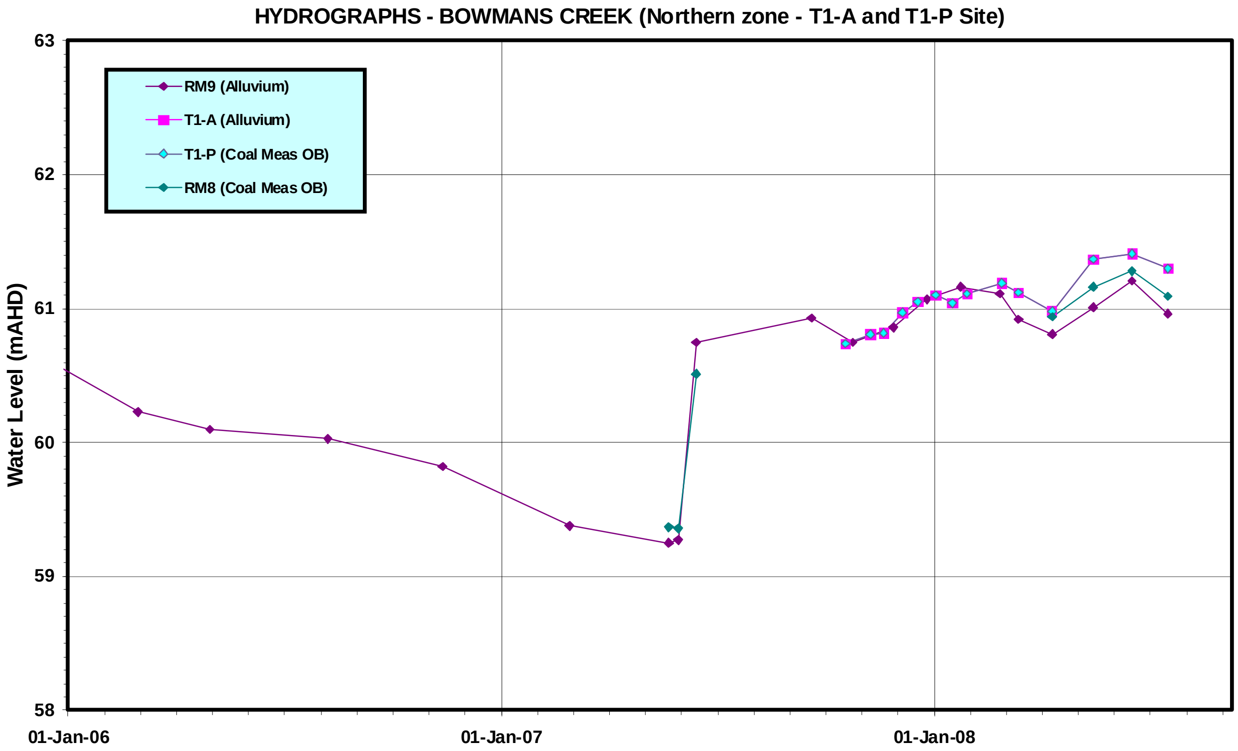
Legend

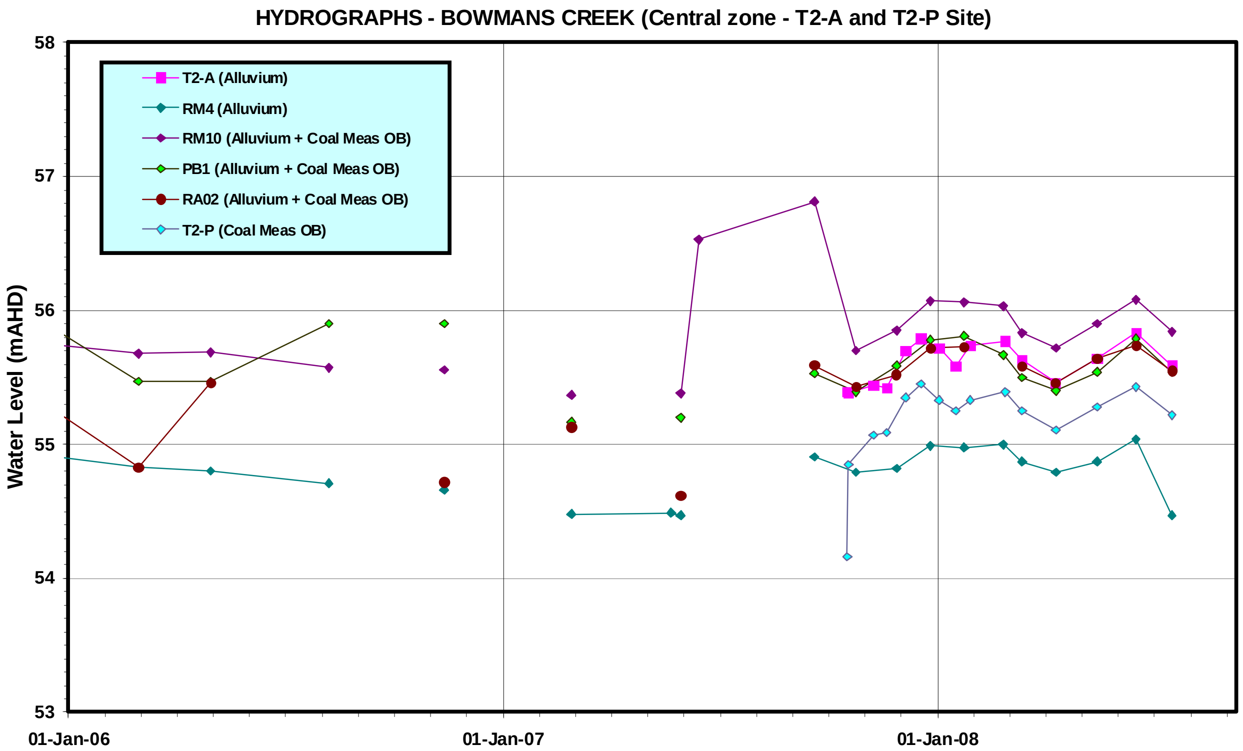
- Alluvium Piezometer
- Alluvium Piezometer
- Colluvium Piezometer
- Alluvium Groundwater Level (mAHD)
- Boundary of Alluvium
- Boundary of Saturated Alluvium

Date:	9 October 2008	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	TL	Job No:	S03	ALLUVIUM GROUNDWATER CONTOURS (mAHD)
Drawing No:	S03-163	Revision:	0	

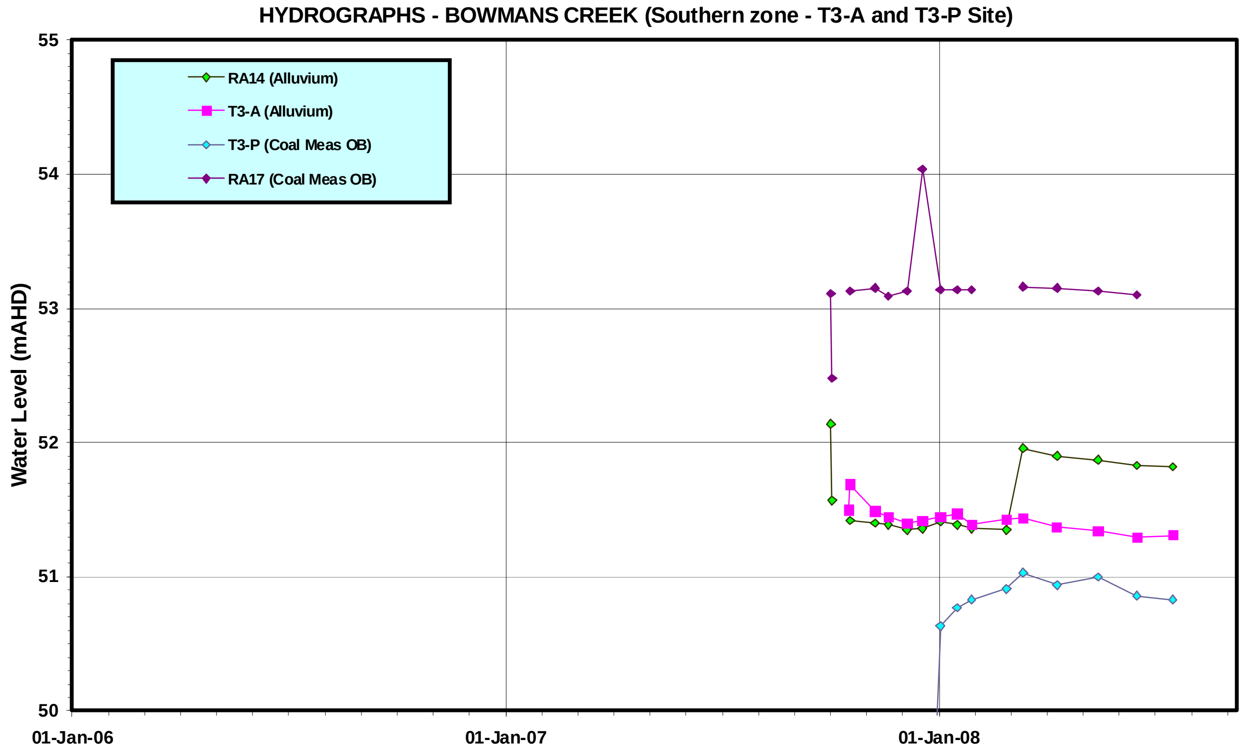
aquaterra

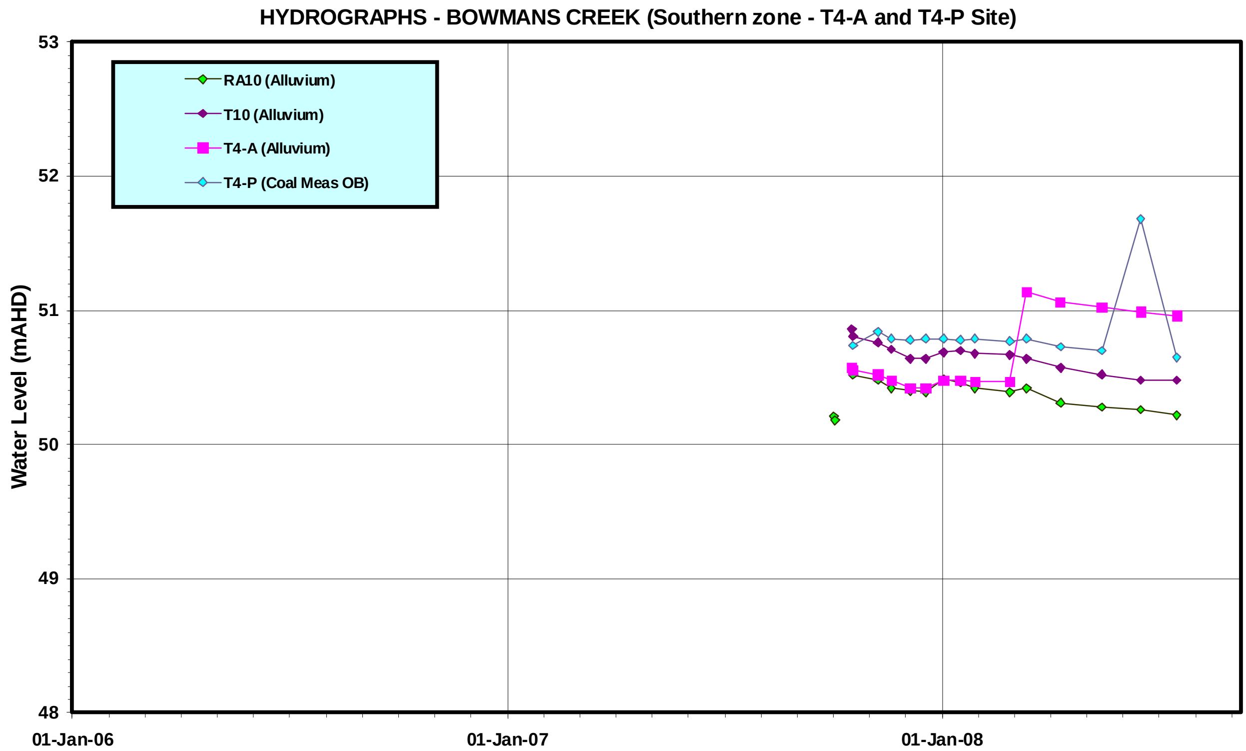
Figure 13



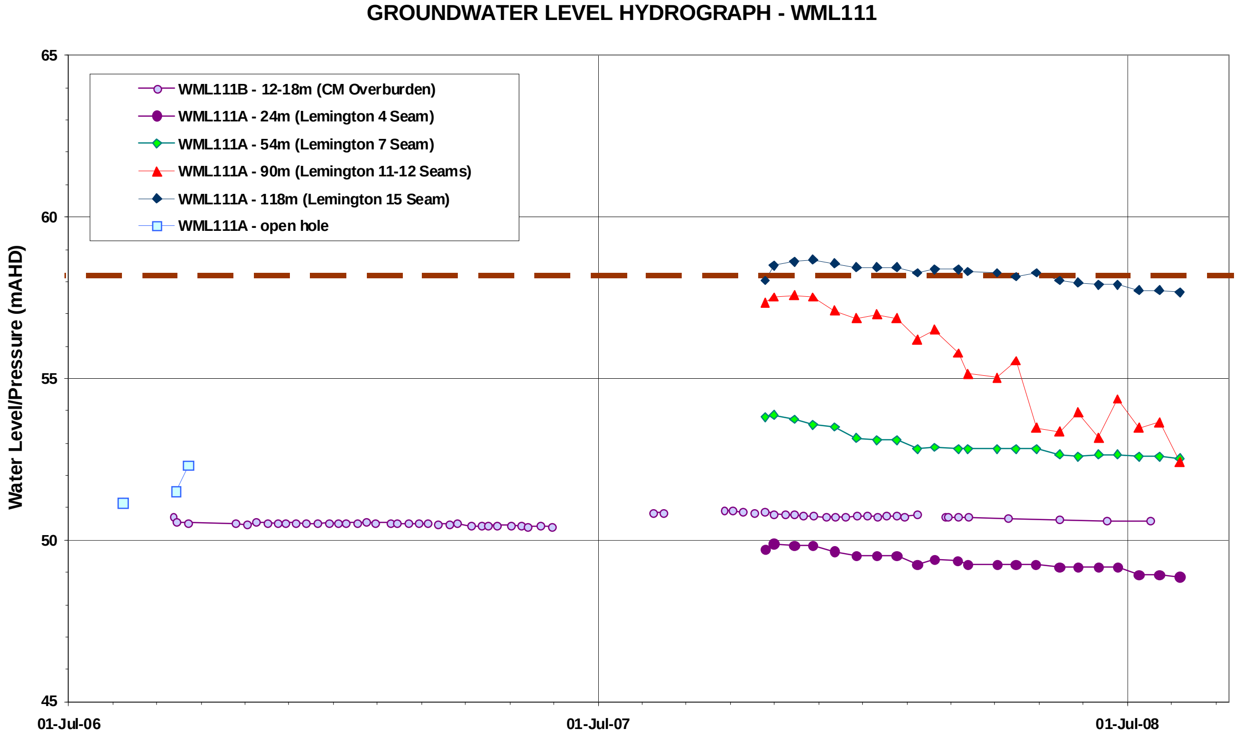


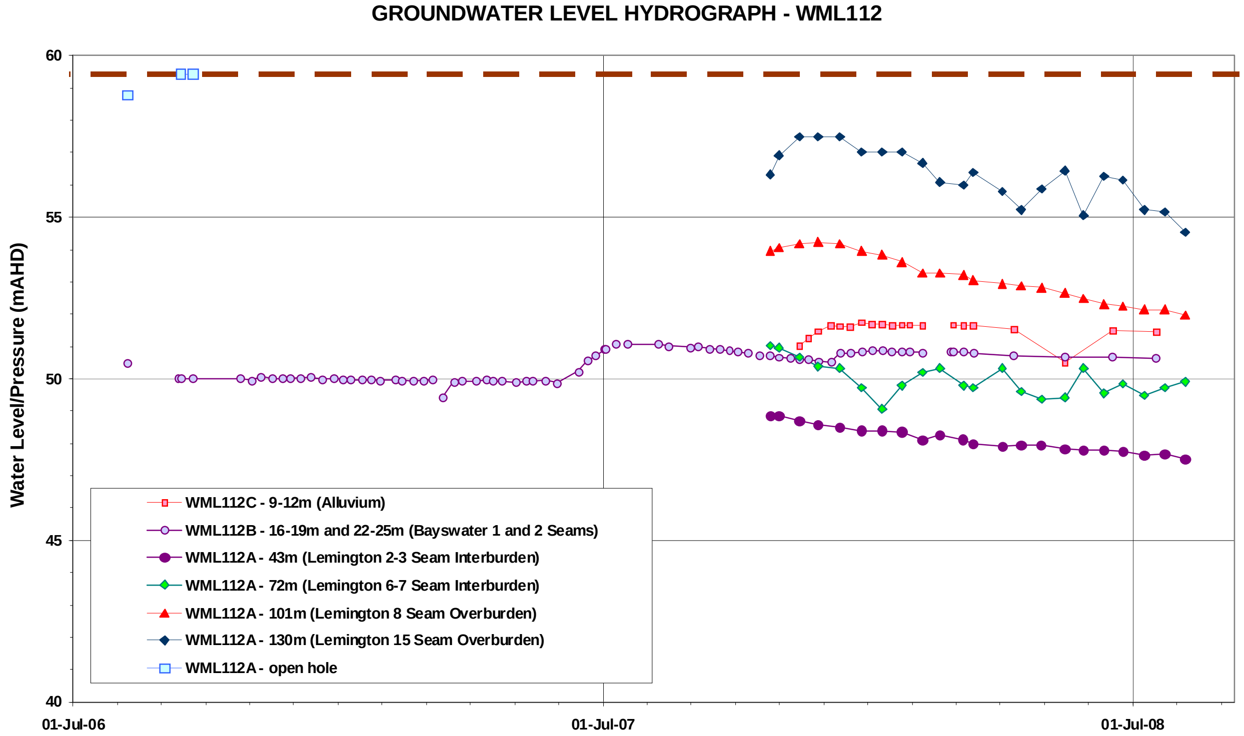
Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDROGRAPHS T1-A and P; T2-A and P**
Drawing No: S03-216	Rev: 0	
aquaterra		**Figure 14**



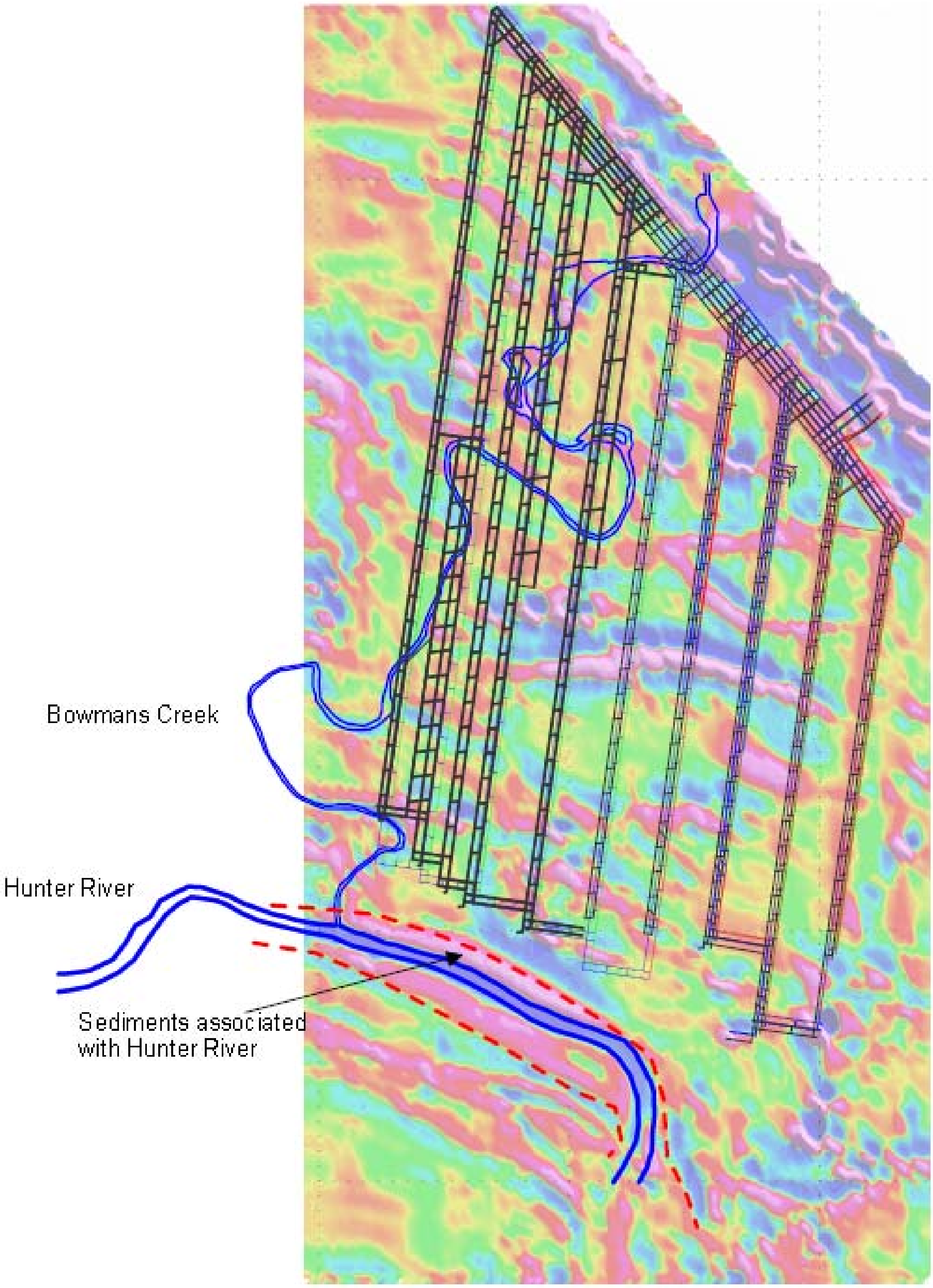


Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDROGRAPHS T3-A and P; T4-A and P**
Drawing No: S03-217	Rev: 0	
aquaterra		**Figure 15**

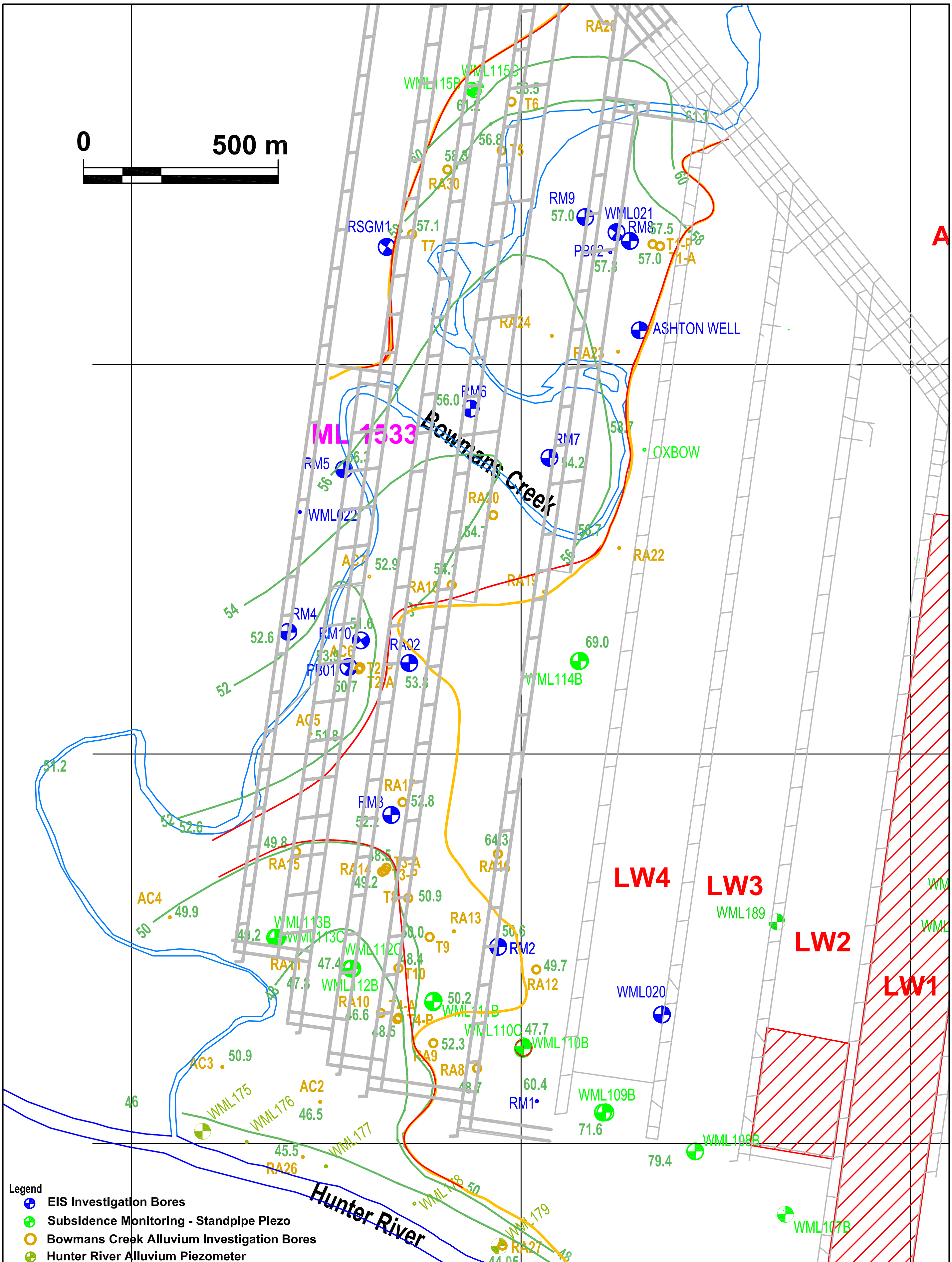




Date: 25 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM MULTI-LEVEL VIBRATING WIRE HYDROGRAPHS WML111 and WML112**
Drawing No: S03-218	Rev: 0	
aquaterra		**Figure 16**



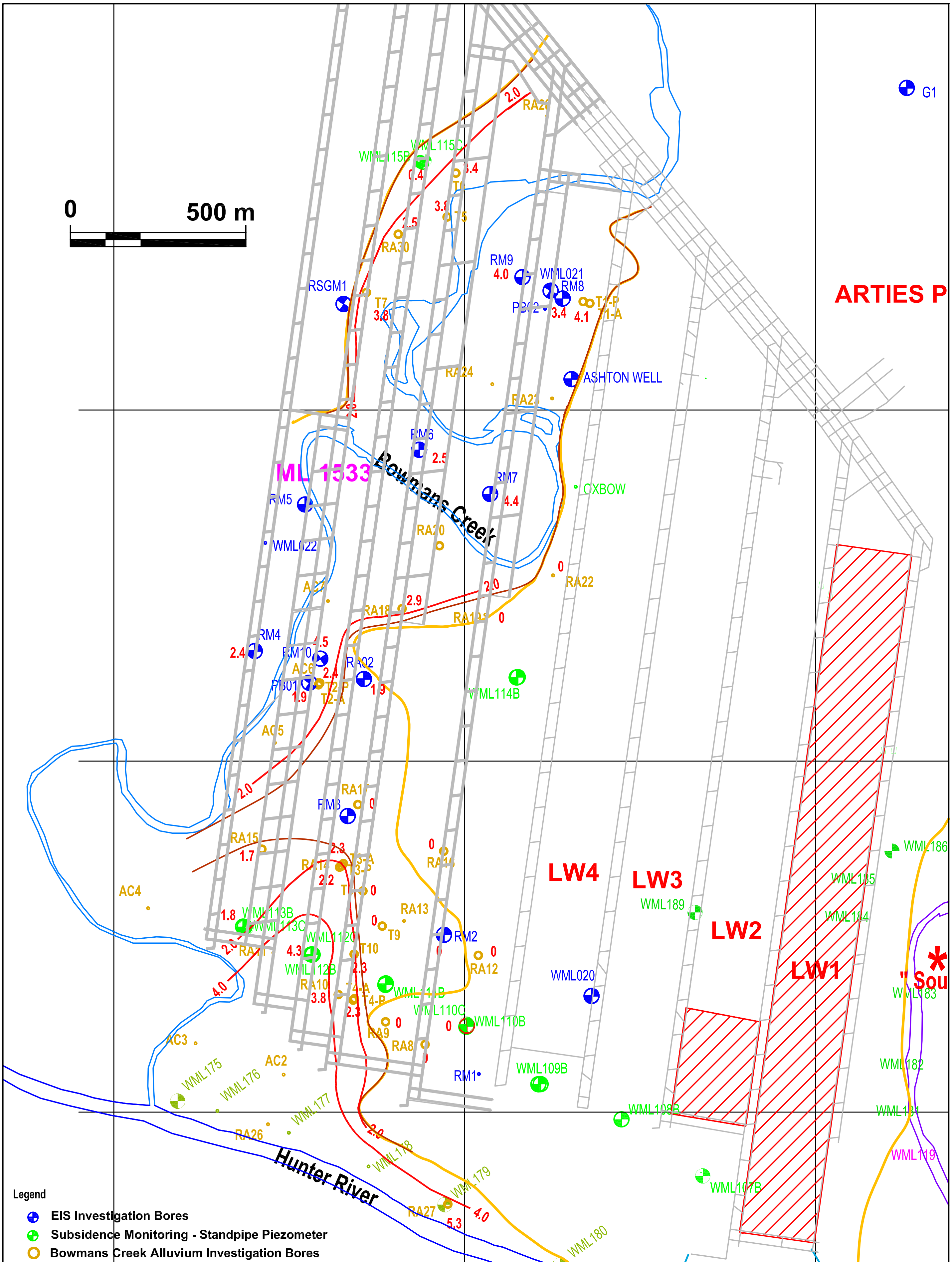
Aeromagnetic Survey
Figure 17



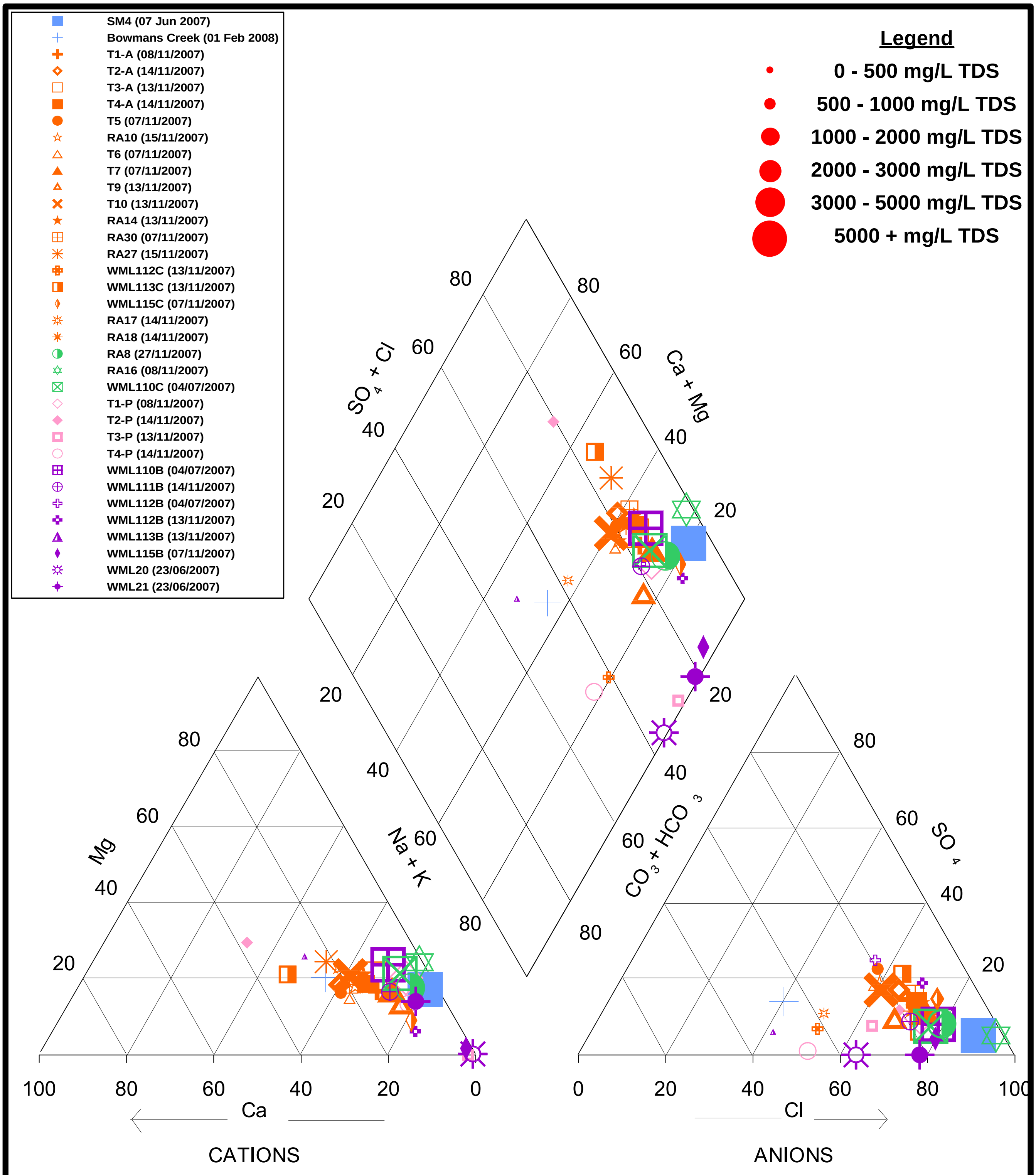
Legend
- EIS Investigation Bores
- Subsidence Monitoring - Standpipe Piezo
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometer
- Abandoned / Lost Bore
- Alluvium Boundary
- Boundary of Saturated Alluvium
- 49.2 Base of Bowmans Ck Alluvium (mAHD)
- Contours of Base of Bowmans Ck Alluvium

Date: 14 October 2008	Scale: as shown	Ashton Coal Operations Ltd	
Initials: PJD	Job No: S03	BOWMANS CREEK ALLUVIUM CONTOURS OF BASE OF ALLUVIUM (m AHD)	
Drawing No: S03-224	Revision: 0		Figure 18

aquaterra



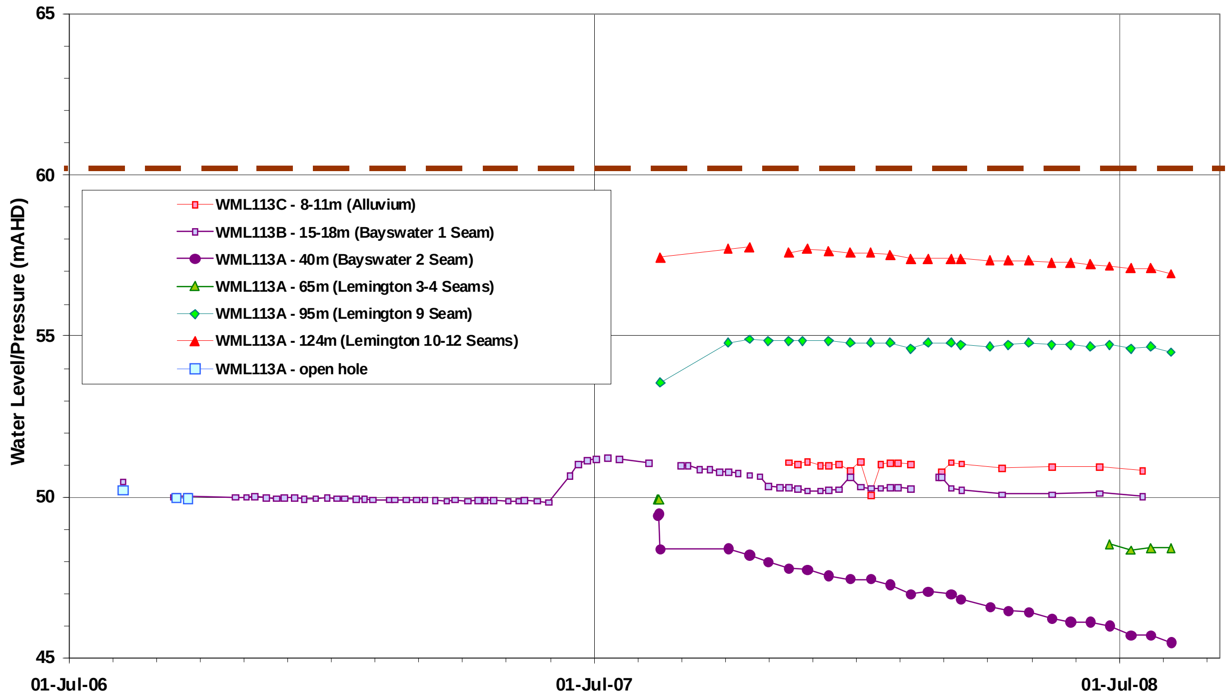
Date: 14 October 2008	Scale: as shown	Ashton Coal Operations Ltd
Initials: PJD	Job No: S03	BOWMANS CREEK ALLUVIUM ISOPACHS OF SATUARATED THICKNESS
Drawing No: S03-225	Revision: 0	
aquaterra		Figure 19



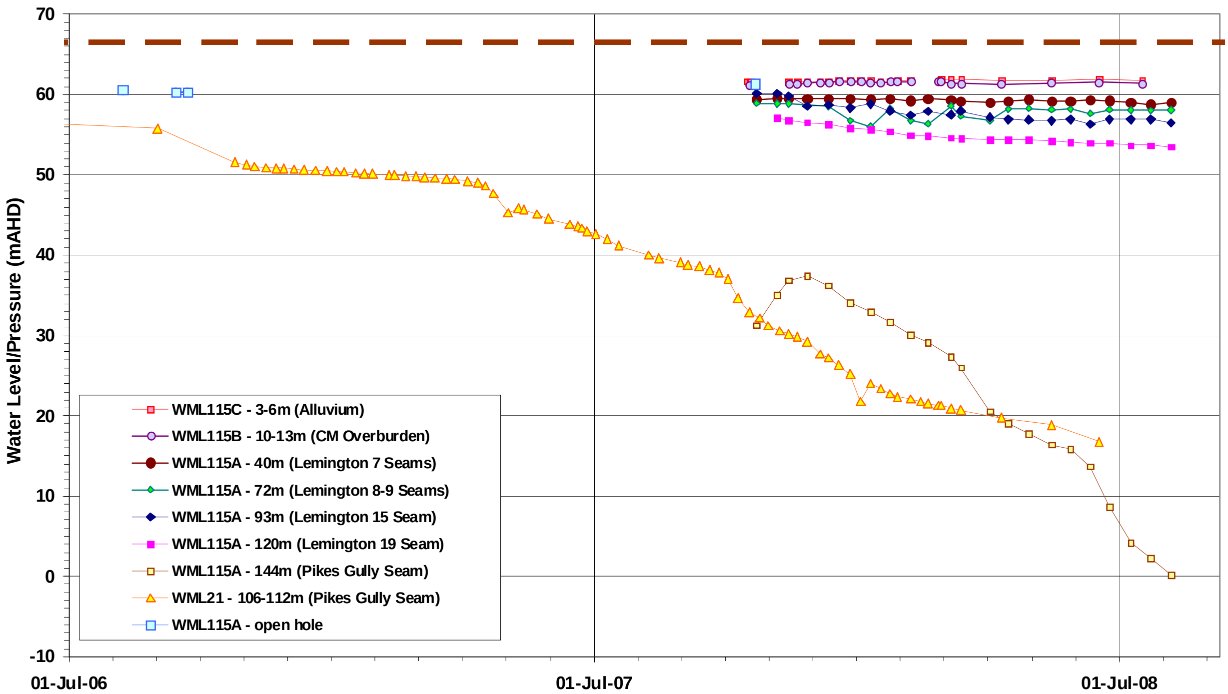
aquaterra	CLIENT Ashton Coal Operations Ltd	PROJECT ASHTON COAL PROJECT
	DRAWN PJD / DATE August 2008	TITLE PIPER TRILINEAR DIAGRAM BOWMANS CREEK BORES
	CHECKED / DATE	
	SCALE As Shown / Dwg S03-301 / A4	PROJECT No S03 / Figure 20

c:\...\S03-301\Bowmans Ck bores\piper.grt

GROUNDWATER LEVEL HYDROGRAPH - WML113A



GROUNDWATER LEVEL HYDROGRAPH - WML115



Date:	25 August 2008	Scale:	as indicated	**Ashton Coal Operations Ltd**
Initials:	PJD	Job No:	S03	**BOWMANS CREEK ALLUVIUM MULTI-LEVEL VIBRATING WIRE HYDROGRAPHS WML113 and WML115**
Drawing No:	S03-219	Rev:	0	
aquaterra				**Figure 21**

APPENDIX A

BORE LOGS

Aquaterra Consulting Pty Ltd

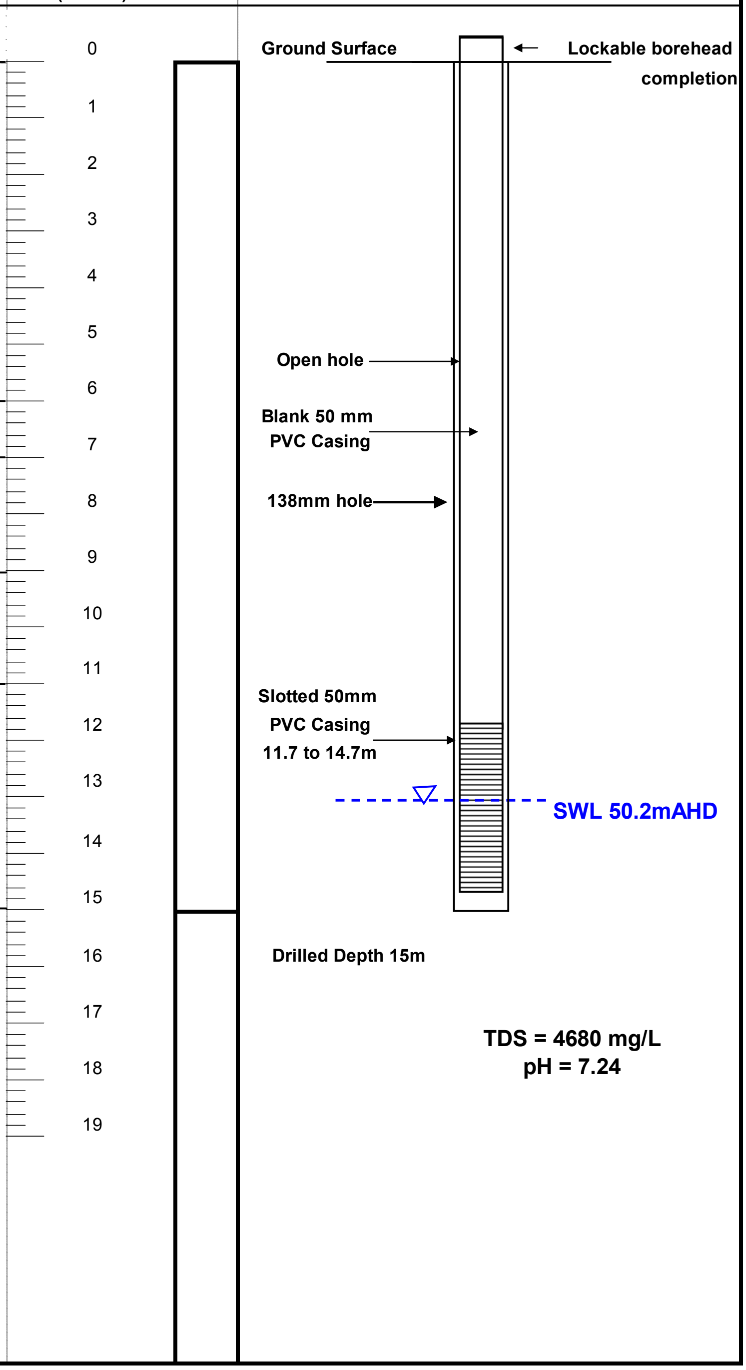
Logging Sheet

BORE: RA8

		Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (GL):	63 21 mAHD	
	Elevation (TOC):	63.98 mAHD	
Location: **Ashton Coal**	Stickup:	0.77m	
	Hole Depth:	15.0 m	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		Rod McCallum

Description	Depth (metres)
CLAY - grey brown, low strength	0 – 6
CLAY - brown, slightly stoney, low strength	6 – 7
GRAVEL - multicoloured, clayey, low strength	7 – 9
CLAY - brown, stoney, low strength	9 – 11
GRAVEL - brown, clayey, low strength *RL = 48.71 mAHD*	11 – 15
PERMIAN COAL MEASURES	15 –

Well Construction Details:



TDS = 4680 mg/L
pH = 7.24

Figure A1: Log RA8

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: RA9

		Project No:	**S03 (05-0166)**
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	**61.84 mAHD**	
	Elevation (TOC):	**62.42 mAHD**	
Location: **Ashton Coal**	Stickup:	**0.58 m**	
	Hole Depth:	**10.0 m**	
Drilling Contractor: **Intertech**	Date Started:		Supervised By: **Rod McCallum**
	Date Completed:		

Description	Depth (metres)
	0
CLAY - brown, slightly stoney, low strength	0 – 2
CLAY - buff brown, low strength	2 – 4
GRAVEL - multicoloured, slightly clayey, low strength	4 – 9
CLAY - yellow cream, slightly stoney, low strength *RL = 52.34 mAHD*	9 – 10
PERMIAN COAL MEASURES - Sandstone	10

Well Construction Details:

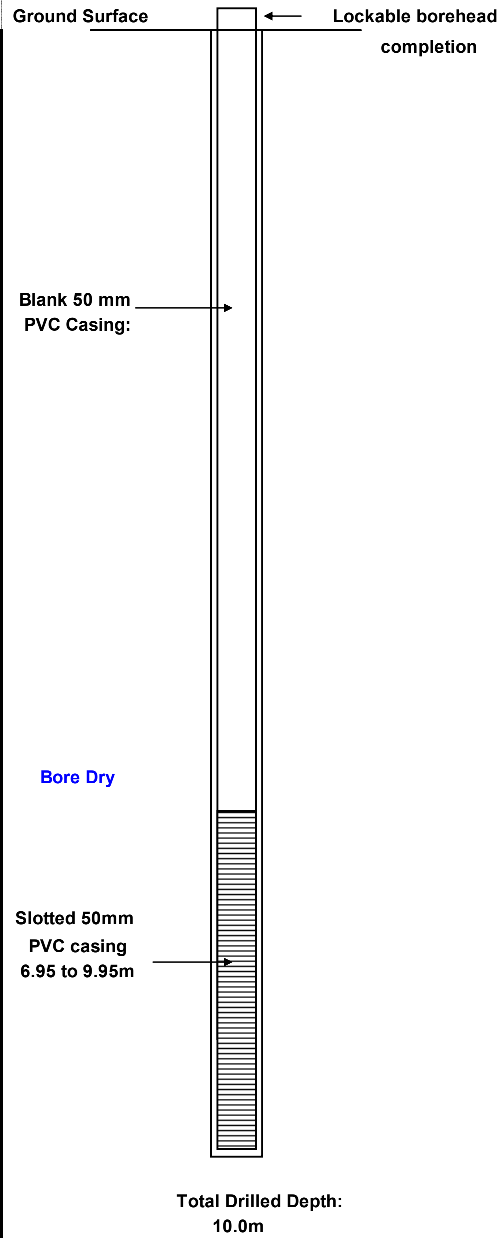


Figure A2: Log RA9

Aquaterra Consulting Pty Ltd

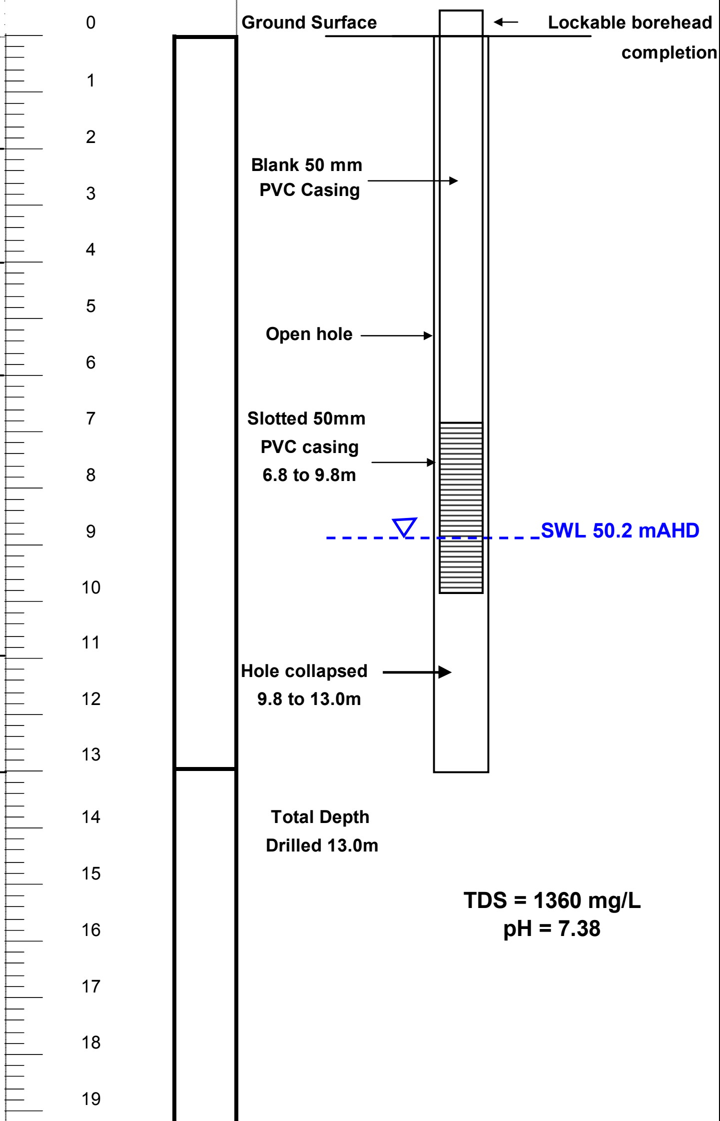
Logging Sheet

BORE: RA10

		Project No:	S03 (05 - 0166)
Client: Ashton Coal Operations Ltd	Elevation (GL):	59.13 mAHD	
	Elevation (TOC):	60.16 mAHD	
Location: Ashton Coal	Stickup:	1.03m	
	Hole Depth:	13.0 m	
Drilling Contractor: Intertech	Date Started:		Supervised By: Rod McCallum
	Date Completed:		

Description	Depth (metres)
SOIL - brown, clayey, very low strength	0–2
CLAY - brown, low strength	2–4
CLAY - orange brown, low strength	4–6
SANDY CLAY - buff brown, low strength	6–11
GRAVEL - multicoloured, low strength *RL = 46.63 mAHD*	11–13
PERMIAN COAL MEASURES	13–

Well Construction Details:



TDS = 1360 mg/L
pH = 7.38

Figure A3: Log RA10

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: RA12

		Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (GL):	62.15 mAHD	
	Elevation (TOC):	62.92 mAHD	
Location: **Ashton Coal**	Stickup:	0.77 m	
	Hole Depth:	13.0 m	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		**Rod McCallum**

Description	Depth (metres)
CLAY - brown, slightly stoney, low strength	0 – 1
CLAY - orange brown, sl sandy, low strength	1 – 5
GRAVEL - multicoloured, clayey, low strength	5 – 12
CLAY - orange brown, low strength	12 – 13
RL = 49.65 mAHD	
PERMIAN COAL MEASURES	13

Well Construction Details:

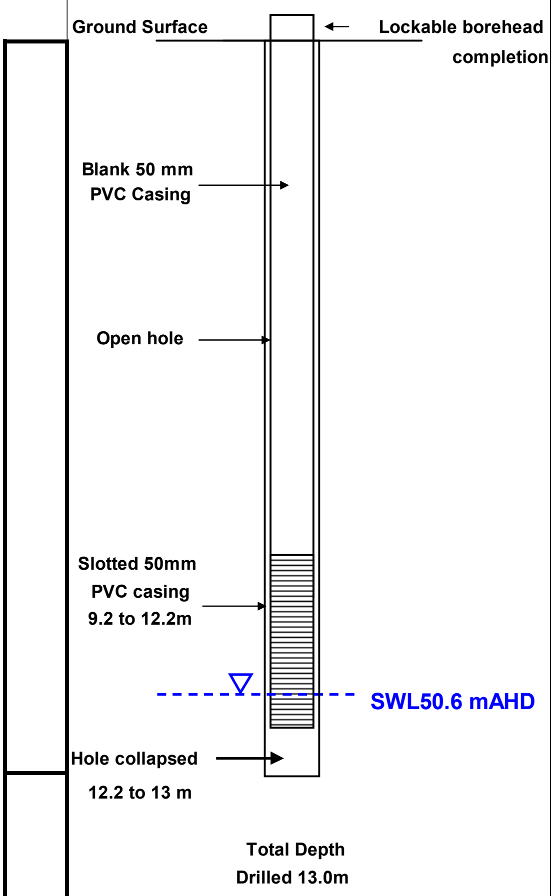


Figure A4: Log RA12

Aquaterra Consulting Pty Ltd

Logging Sheet

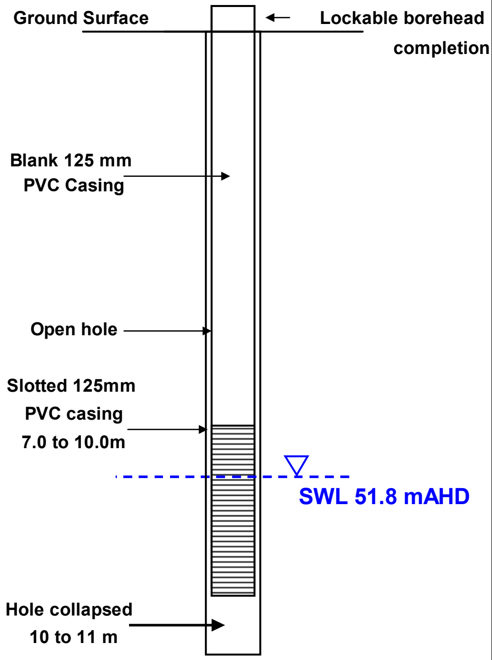
BORE: RA14

			Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (GL):	59.74 mAHD		
	Elevation (TOC):	60.81 mAHD		
Location: **Ashton Coal**	Stickup:	1.07m		
	Hole Depth:	11.0 m		
Drilling Contractor: **Intertech**	Date Started:		Supervised By:	
	Date Completed:			Rod McCallum

Description	Depth (metres)
CLAY - brown, low strength	0 – 2
CLAY - orange brown, slightly sandy, low strength	2 – 5
GRAVEL - brown, clayey, medium strength	5 – 10
CLAY - brown, low strength	10 – 11
RL = 49.24 mAHD SANDY CLAY (?Permian) - brown, low strength	11 –

Depth scale (metres): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

Well Construction Details:



Total Depth Drilled 11.0 m

TDS = 1370 mg/L
pH = 7.06

Figure A5: Log RA14

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: RA15

		Project No:	S03 (05 - 0166)
Client: Ashton Coal Operations Ltd	Elevation (GL):	60.30 mAHD	
	Elevation (TOC):	61.00 mAHD	
Location: Ashton Coal	Stickup:	0.7m	
	Hole Depth:	10.5 m	
Drilling Contractor: Intertech	Date Started:		Supervised By:
	Date Completed:		Rod McCallum

Description	Depth (metres)
CLAY - brown, low strength	0 – 4
SANDY CLAY - brown, slightly stoney, low strength	4 – 6
GRAVEL - multicoloured, medium strength	6 – 10
CLAY - grey, medium strength	10 – 10.5
RL = 49.80 mAHD	
PERMIAN COAL MEASURES	

Depth (metres): 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Well Construction Details:

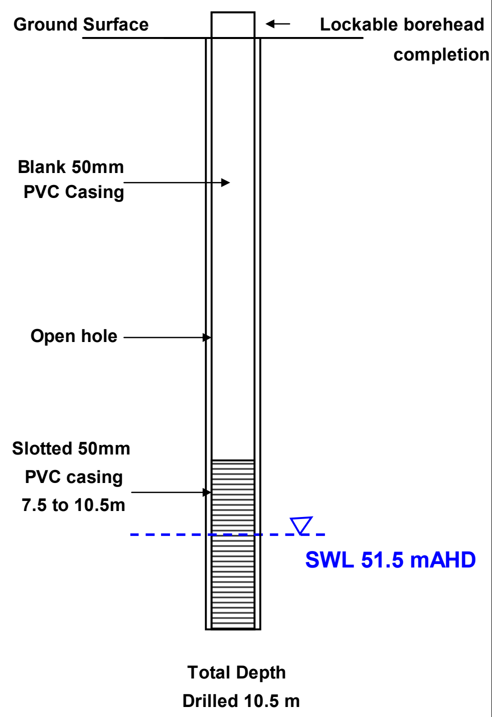


Figure A6: Log RA15

Aquaterra Consulting Pty Ltd

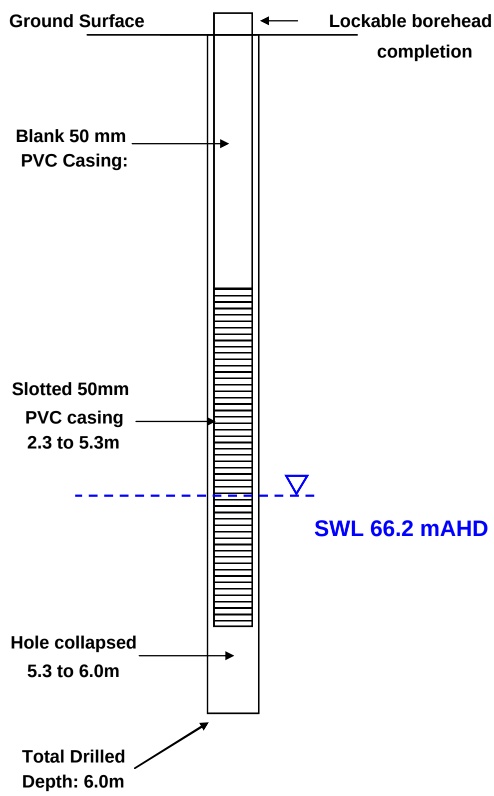
Logging Sheet

BORE: RA16

		Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	70.33 mAHD	
	Elevation (TOC):	70.91 mAHD	
Location: **Ashton Coal**	Stickup:	0.58m	
	Hole Depth:	6.00 m	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		**Rod McCallum**

Description	Depth (metres)
	0
SANDY CLAY - yellow brown, slightly stoney	
	1
SAND - buff brown, clayey	
	2
GRAVEL - orange brown, clayey, low strength	
	3
CLAY - orange brown, slightly sandy, low strength	
	4
CLAY - buff grey, low strength	5
Alluvium *RL = 64.33 mAHD*	
	6
PERMIAN COAL MEASURES	
	7
	8
	9
	10

Well Construction Details:



TDS = 9240 mg/L
pH = 6.79

Figure A7: Log RA16

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: RA17

			Project No:	**S03 (05 - 0166)**
Client: **Ashton Coal Operations Ltd**	Elevation (GL):	**62.33 mAHD**		
	Elevation (TOC):	**63.06 mAHD**		
Location: **Ashton Coal**	Stickup:	**0.73 m**		
	Hole Depth:	**10.7 m**		
Drilling Contractor: **Intertech**	Date Started:		Supervised By:	**Rod McCallum**
	Date Completed:			

Description	Depth (metres)
CLAY - brown, low strength	0 – 7
SANDY CLAY - brown, low strength	7 – 8
GRAVEL - multicoloured, slightly clayey, med strength	8 – 9.5
RL = 52.83 mAHD	
PERMIAN COAL MEASURES	9.5 –

Well Construction Details:

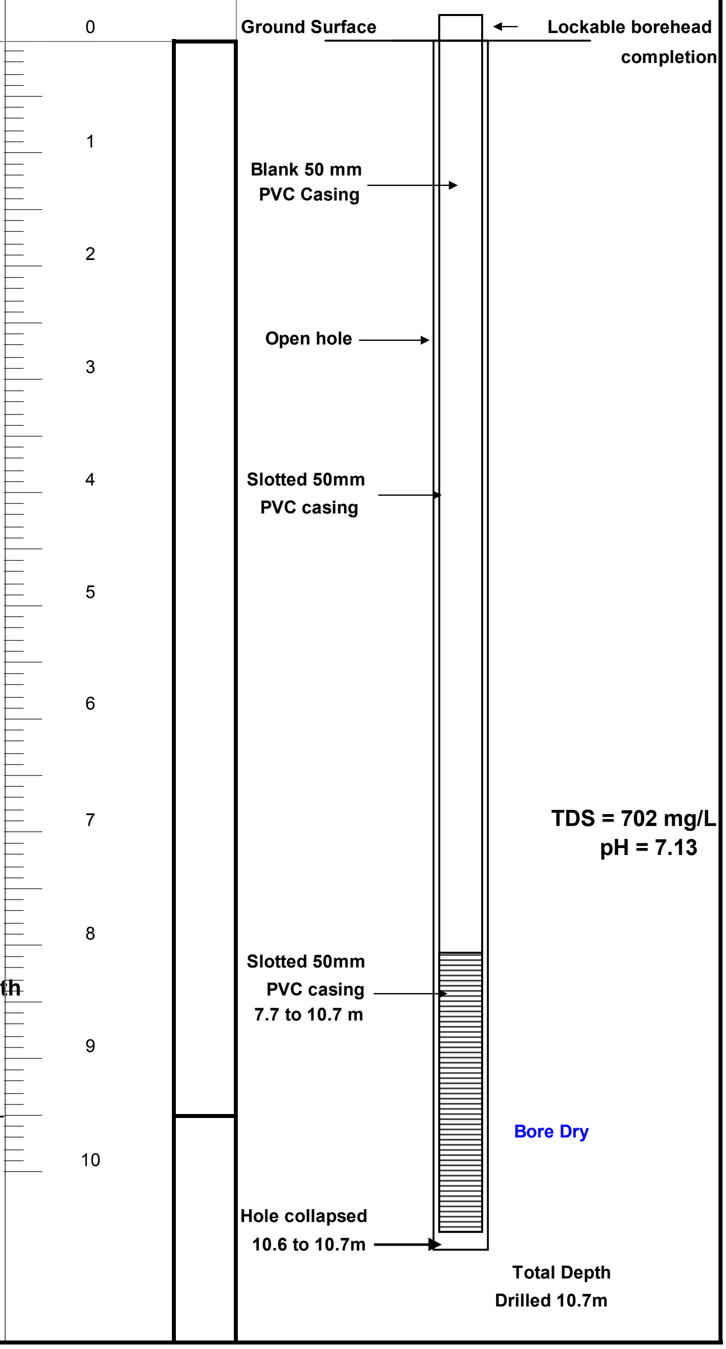


Figure A8: Log RA17

Aquaterra Consulting Pty Ltd

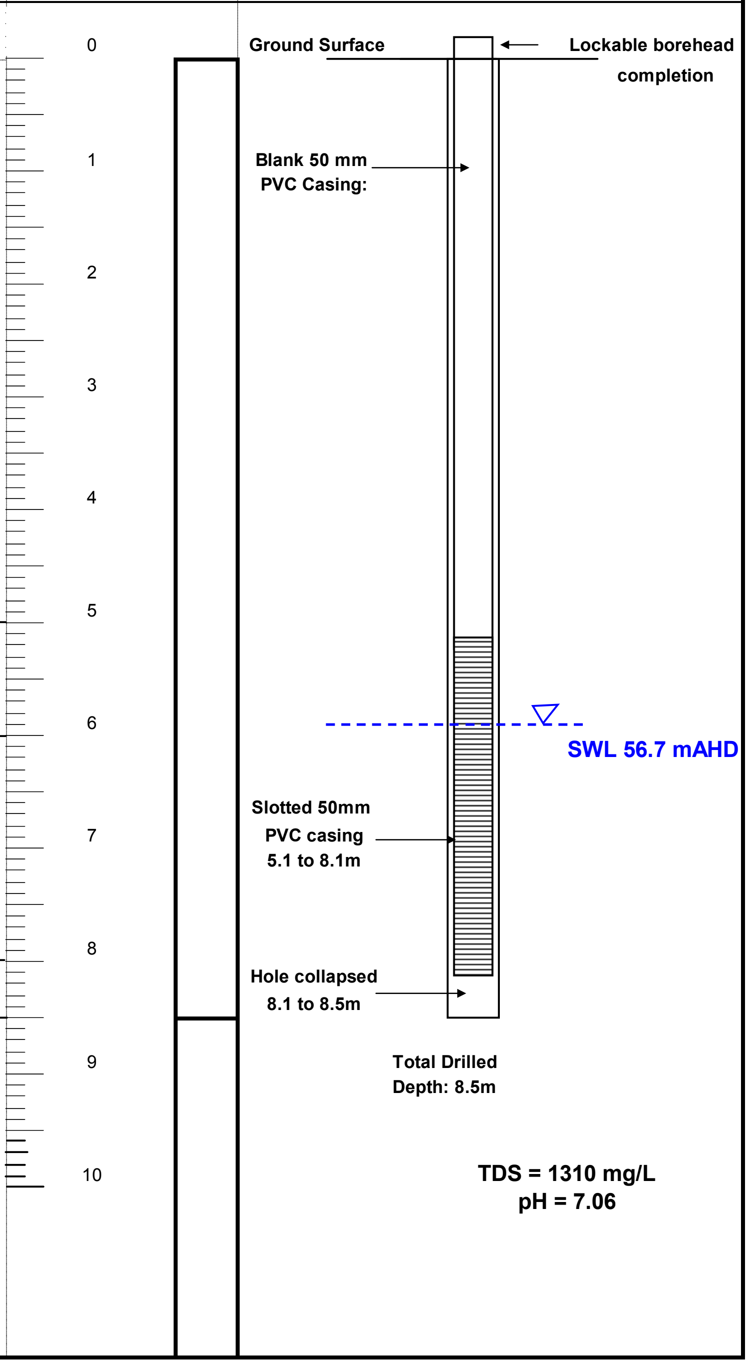
Logging Sheet

BORE: RA18

		Project No:	**S03 (05 - 0166)**
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	**62.56 mAHD**	
	Elevation (TOC):	**63.16 mAHD**	
Location: **Ashton Coal**	Stickup:	**0.60m**	
	Hole Depth:	**8.50 m**	
Drilling Contractor: **Intertech**	Date Started:		Supervised By: **Rod McCallum**
	Date Completed:		

Description	Depth (metres)
CLAY - brown, slightly sandy, low strength.	0 – 5
SANDY CLAY - brown, low strength.	5 – 6
GRAVEL - brown, clayey, medium strength.	6 – 8
SANDY CLAY - brown, lightly stony, med strength ***RL = 54.06 mAHD***	8 – 8.5
PERMIAN COAL MEASURES	8.5 –

Well Construction Details:



TDS = 1310 mg/L
pH = 7.06

Figure A9: Log RA18

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: RA20

		Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	62.60 mAHD	
	Elevation (TOC):	63.30 mAHD	
Location: **Ashton Coal**	Stickup:	0.70m	
	Hole Depth:	8.00 m	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		**Rod McCallum**

Description	Depth (metres)
SOIL - brown, very low strength.	0 – 1
CLAY - brown, slightly stony, low strength.	1 – 2
GRAVEL - brown, sandy, medium strength	2 – 6
GRAVEL - brown, medium strength. *RL = 54.69 mAHD*	6 – 8
PERMIAN COAL MEASURES	8 –

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Well Construction Details:

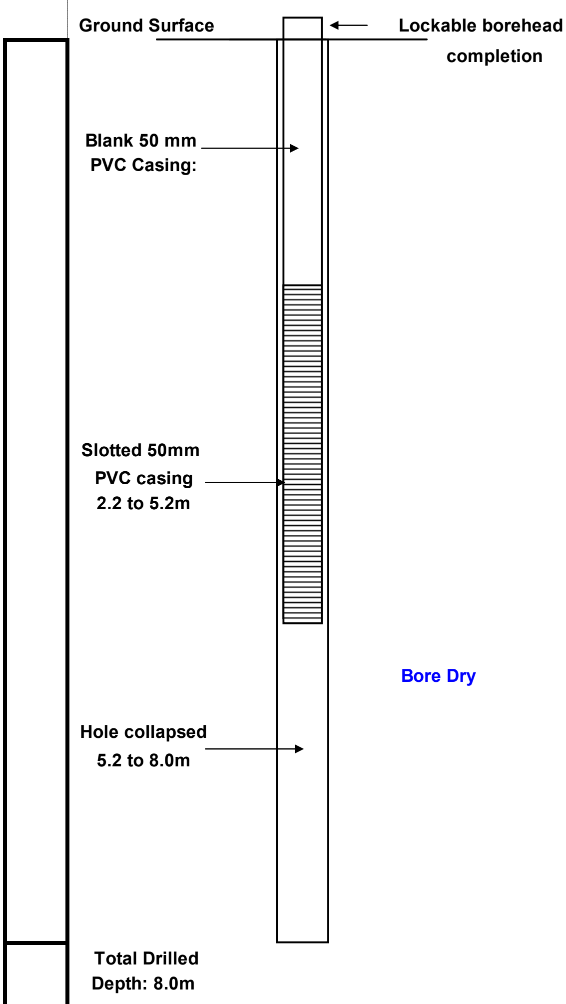


Figure A10: Log RA20

Aquaterra Consulting Pty Ltd

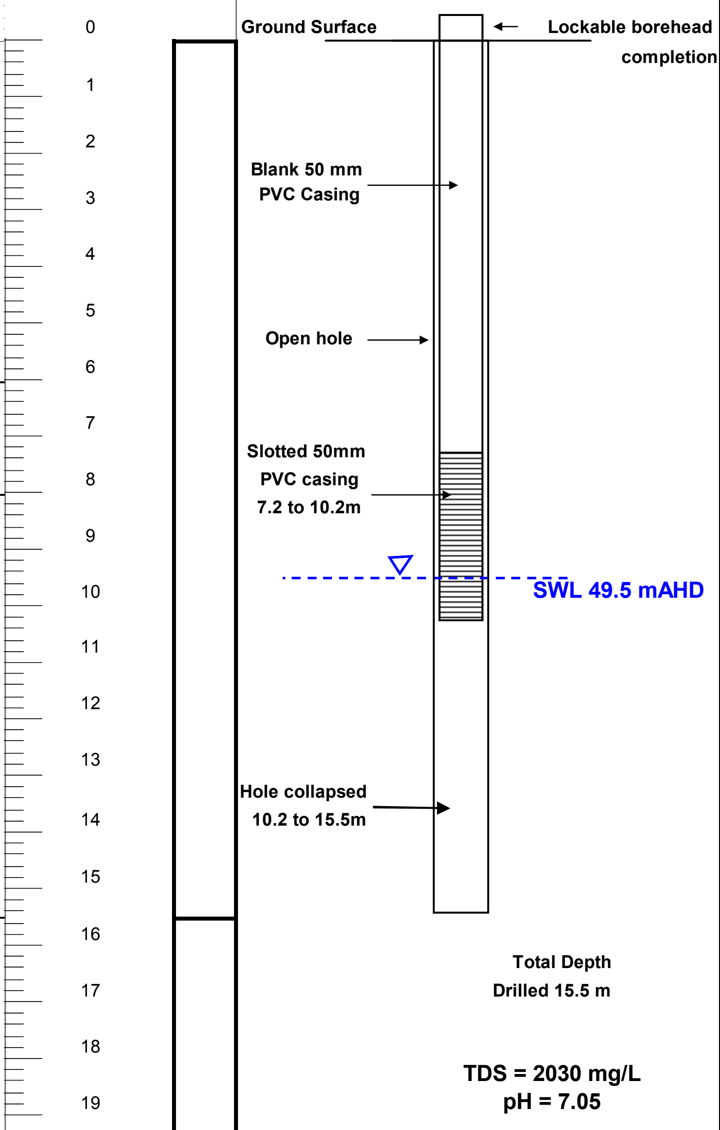
Logging Sheet

BORE: RA27

		Project No:	S03 (05 - 0166)
Client: Ashton Coal Operations Ltd	Elevation (GL):	59.04 mAHD	
	Elevation (TOC):	59.79 mAHD	
Location: Ashton Coal	Stickup:	0.75 m	
	Hole Depth:	15.5 m	
Drilling Contractor: Intertech	Date Started:		Supervised By:
	Date Completed:		Rod McCallum

Description	Depth (metres)
CLAY - dark brown, low strength.	0 – 6.0
CLAY - brown, slightly stony, medium strength.	6.0 – 8.0
GRAVEL - multicolored, medium strength. RL = 44.05 mAHD	8.0 – 15.5
PERMIAN COAL MEASURES	15.5 –

Well Construction Details:



Total Depth Drilled 15.5 m

TDS = 2030 mg/L
pH = 7.05

Figure A11: Log RA27

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: RA30

		Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	66.30 mAHD	
	Elevation (TOC):	67.03 mAHD	
Location: **Ashton Coal**	Stickup:	0.73 m	
	Hole Depth:	9.00 m	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		**Rod McCallum**

Description	Depth (metres)	Well Construction Details:
	0	
CLAY - orange brown,	1	
	2	
	3	
	4	
	5	
SAND - brown, medium grained, v slightly clayey	6	
	7	
GRAVEL - brown, slightly clayey, medium strength		
RL = 58.3 mAHD	8	
PERMIAN COAL MEASURES	9	
	10	

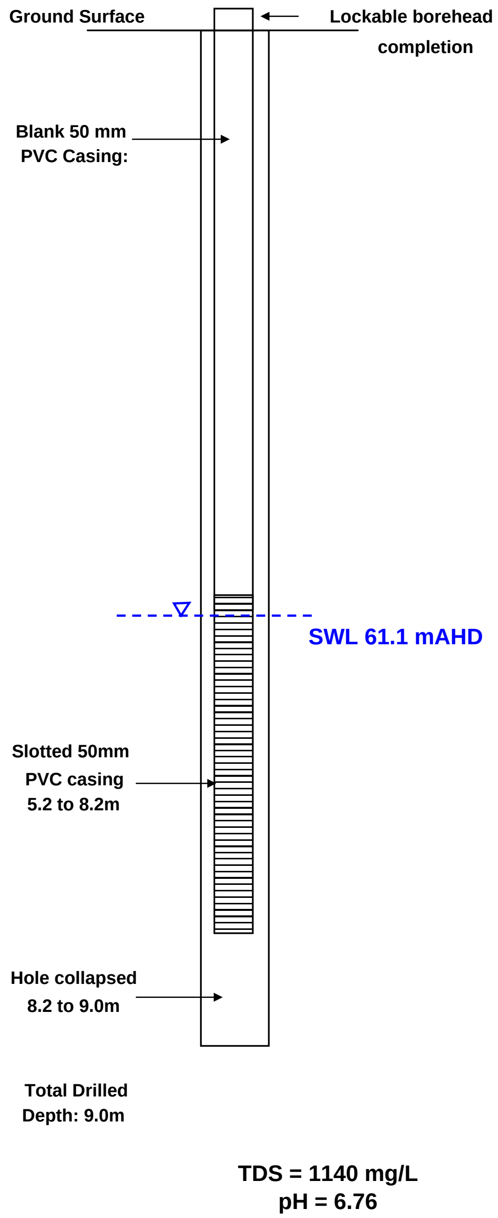


Figure A12: Log RA30

Aquaterra Consulting Pty Ltd

Logging Sheet

BORES: T1-A and T1-P

Project No:	S03 (05 - 0166)

Client:	Bore:	TD (m):	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contra	Date Started:	Date Finished:
Ashton Coal Operations Ltd	T1-A	7.9 m	64.96 mAHD	65.65 mAHD	0.69 m	Intertech		
Location:	T1-P	12.6 m	64.60 mAHD	65.33 mAHD	0.73 m	Intertech		
Ashton Coal					Supervised By:	Rod McCallum		

Description	Depth (metres)	Well Construction Details:
SOIL - brown, slightly sandy, very low strength	0 – 4	
GRAVEL - multicoloured, slightly clayey, low strength *RL = 57.0 mAHD*	4 – 8	
SANDSTONE - grey, med-grained, sl clayey, med strength (PERMIAN COAL MEASURES)	8 –	

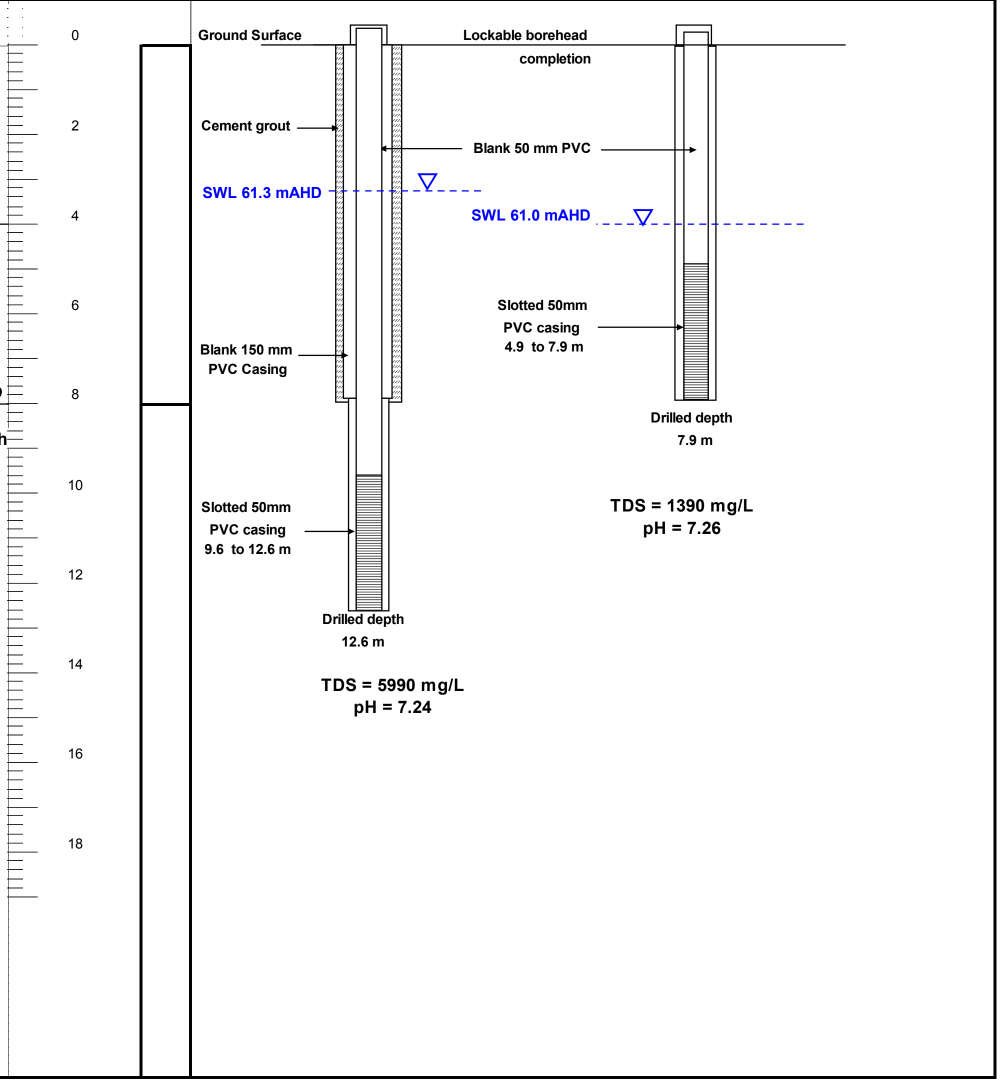


Figure A13: Logs T1-A and T1-P

Aquaterra Consulting Pty Ltd

Logging Sheet

BORES: T2-A and T2-P

Project No: **S03 (05 - 0166)**

Client:	Bore:	TD (m):	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contra	Date Started:	Date Finished:
Ashton Coal Operations Ltd	**T2-A**	**8.9 m**	**60.80 mAHD**	**61.85 mAHD**	**1.05 m**	**Intertech**		
Location:	**T2-P**	**14.9 m**	**60.66 mAHD**	**61.52 mAHD**	**0.86 m**	**Intertech**		
Ashton Coal					Supervised By:	**Rod McCallum**		

Description	Depth (metres)
	0
SOIL - brown, clayey.	
	2
SANDY CLAY - orange brown, low strength	
	4
	6
GRAVEL - multicoloured, slightly clayey, low strength	
	8
CLAY - grey, sandy, low strength.	
RL = 50.7 mAHD	10
SILTSTONE - grey	
SANDSTONE - grey, fine to medium grained, stoney	12
	14
	16
	18

Well Construction Details:

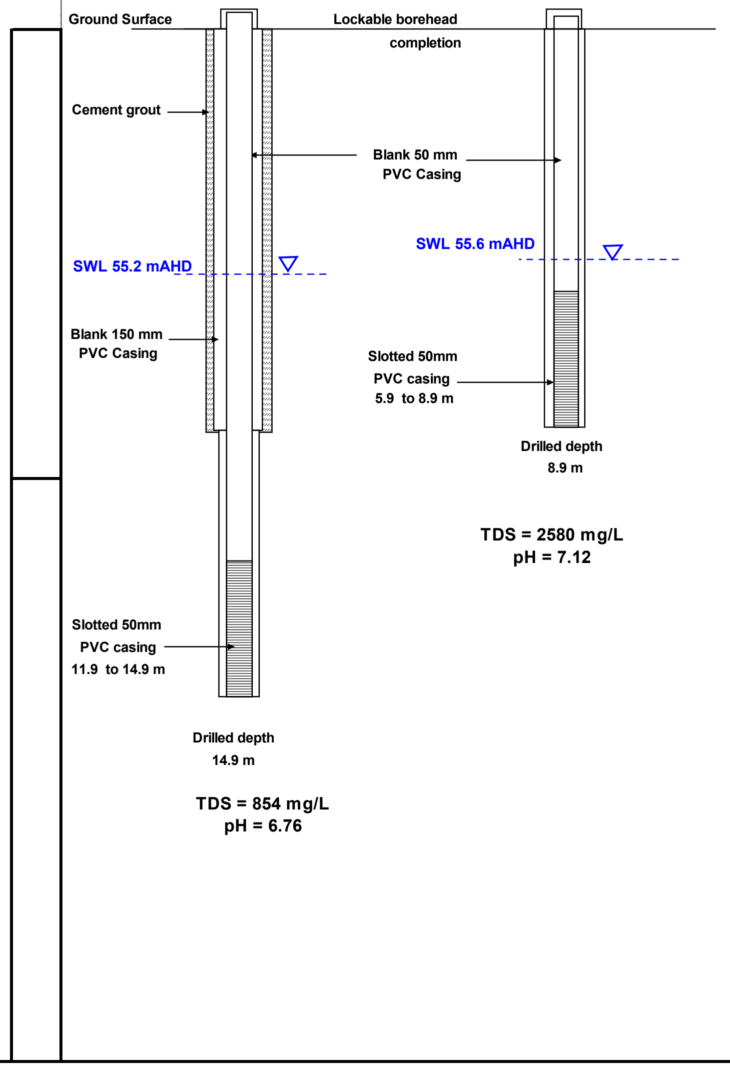


Figure A14: Logs T2-A and T2-P

Aquaterra Consulting Pty Ltd

Logging Sheet

BORES: T3-A and T3-P

Project No: **S03 (05 - 0166)**

Client:	Bore:	TD (m):	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contra	Date Started:	Date Finished:
Ashton Coal Operations Ltd	T3-A	10.8 m	59.85 mAHD	60.75 mAHD	0.9 m	Intertech		
Location:	T3-P	30.5 m	59.81 mAHD	?? mAHD	?? m	Intertech		
Ashton Coal					Supervised By:	Rod McCallum		

Description | **Depth (metres)** | **Well Construction Details:**

- SOIL - brown, slightly clayey, very low strength
- CLAY - brown, low strength
- GRAVEL - brown, clayey, medium strength
- GRAVEL - orange brown, clayey, medium strength
- GRAVEL - buff, medium strength
- GRAVEL - grey, clayey, medium strength
- GRAVEL - grey, sandy

RL = 48.5 mAHD

- SANDSTONE - grey, slightly stony, medium strength
- SANDSTONE - grey, fine to medium grained, medium strength
- COAL - undifferentiated
- SANDSTONE - brown, medium grained, medium strength
- GRAVEL - grey, slightly sandy, medium strength
- SANDSTONE - grey, medium grained, medium strength
- SANDSTONE - grey, fine to medium grained, medium strength
- SANDSTONE - brown to grey, medium grained, medium strength

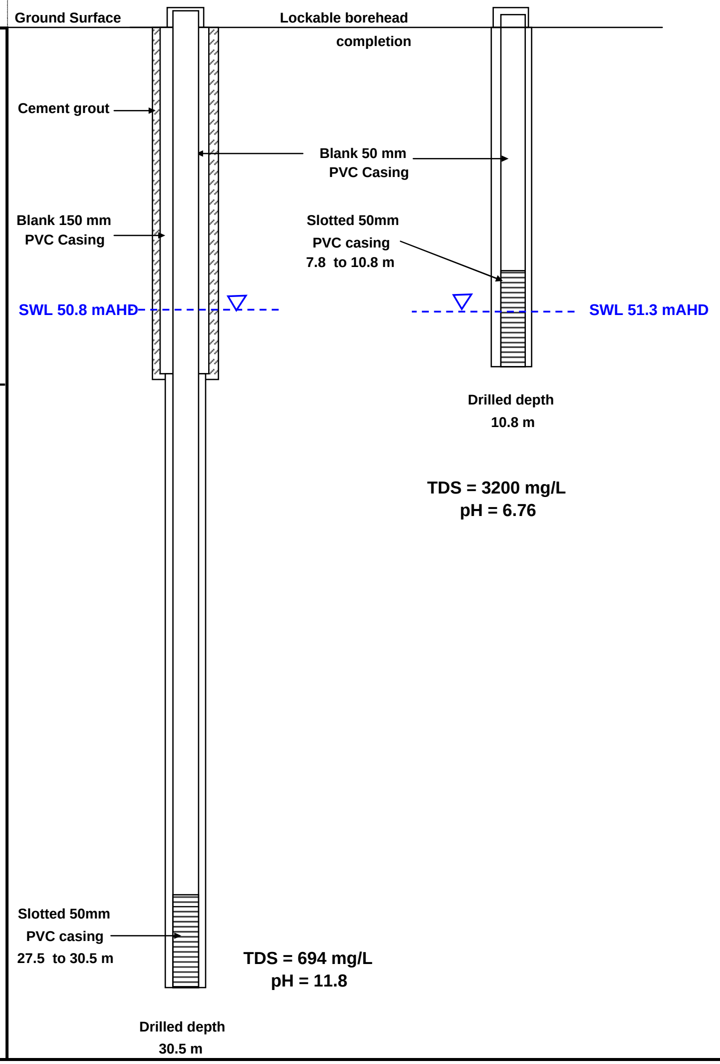


Figure A15: Logs T3-A and T3-P

Aquaterra Consulting Pty Ltd

Logging Sheet

BORES: T4-A and T4-P

Client:	Bore:	TD (m):	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contra	Date Started:	Date Finished:
						Project No:	S03 (05 - 0166)	
Ashton Coal Operations Ltd	T4-A	10.7 m	58.58 mAHD	59.46 mAHD	0.88 m	Intertech		
Location:	T4-P	31.9 m	58.52 mAHD	59.49 mAHD	0.97 m	Intertech		
Ashton Coal					Supervised By:	Rod McCallum		

Description
CLAY - brown, medium strength
GRAVEL - orange brown, clayey, medium strength
GRAVEL - multicoloured, medium strength *RL = 48.5 mAHD*
COAL - Bayswater Seam
SANDSTONE - brown, medium grained, medium strength

Depth (metres) — Well Construction Details:

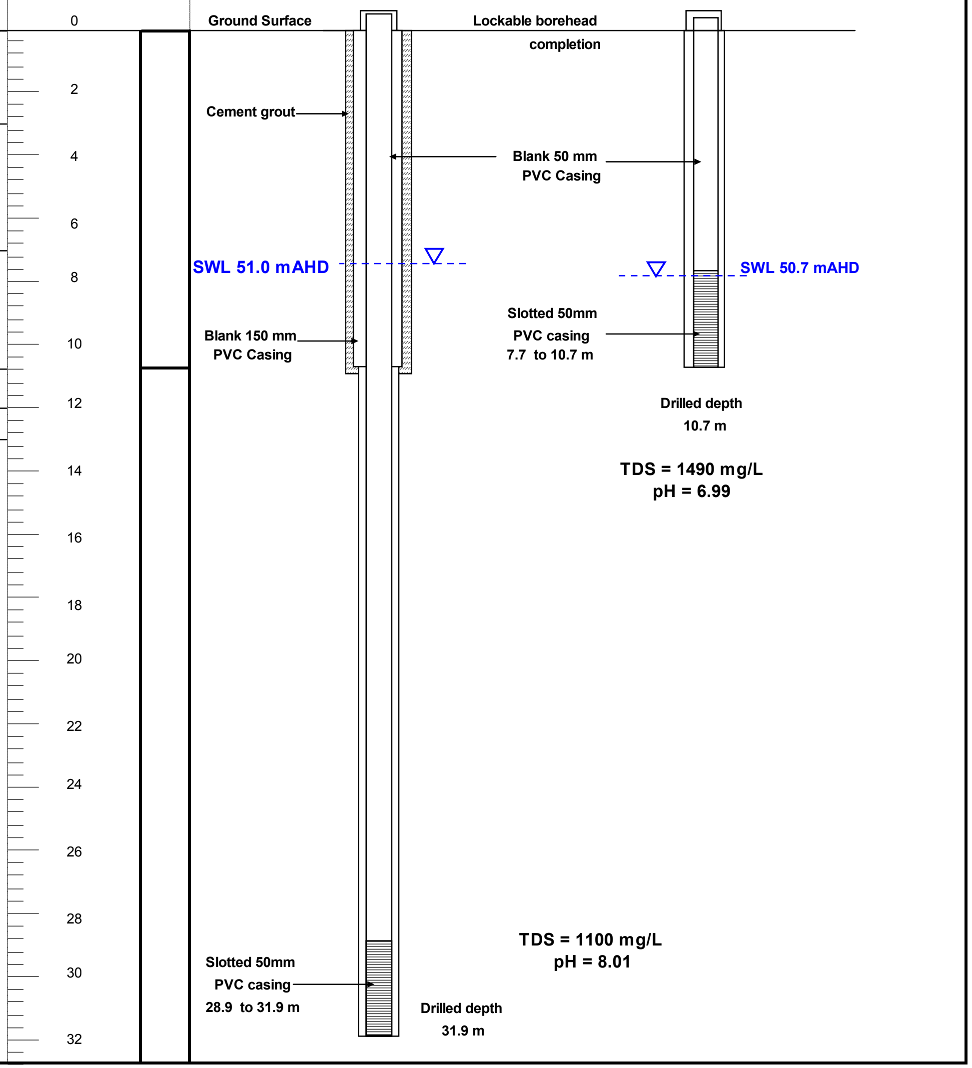


Figure A16: Logs T4-A and T4-P

Aquaterra Consulting Pty Ltd

BORE: T5

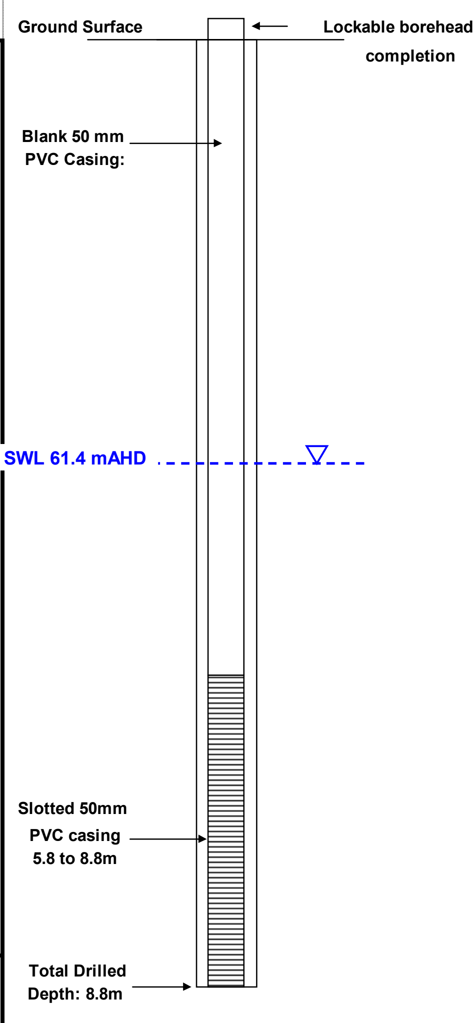
Logging Sheet

		Project No:	S03 (05 - 0166)
Client: Ashton Coal Operations Ltd	Elevation (Concr):	65.33 mAHD	
	Elevation (TOC):	66.11 mAHD	
Location: Ashton Coal	Stickup:	0.78m	
	Hole Depth:	8.80 m	
Drilling Contractor: Intertech	Date Started:		Supervised By: Rod McCallum
	Date Completed:		

Description	Depth (metres)
CLAY - brown, slightly sandy, medium strength	0 – 4
GRAVEL - brown, clayey, medium strength	4 – 6
GRAVEL - grey brown, slightly clayey, medium strength *RL = 56.8 mAHD*	6 – 8.8
PERMIAN COAL MEASURES	8.8 –

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Well Construction Details:



TDS = 910 mg/L
pH = 6.88

Figure A17: Log T5

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: T6

		Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	65.96 mAHD	
	Elevation (TOC):	66.88 mAHD	
Location: **Ashton Coal**	Stickup:	0.92m	
	Hole Depth:	8.00 m	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		Rod McCallum

Description	Depth (metres)	Well Construction Details:

CLAY - brown, low strength,

GRAVEL - orange brown, medium strength

GRAVEL - orange brown, clayey, medium strength

GRAVEL - brown, medium strength

GRAVEL - yellow brown, clayey, medium strength

RL = 58.5 mAHD

PERMIAN COAL MEASURES

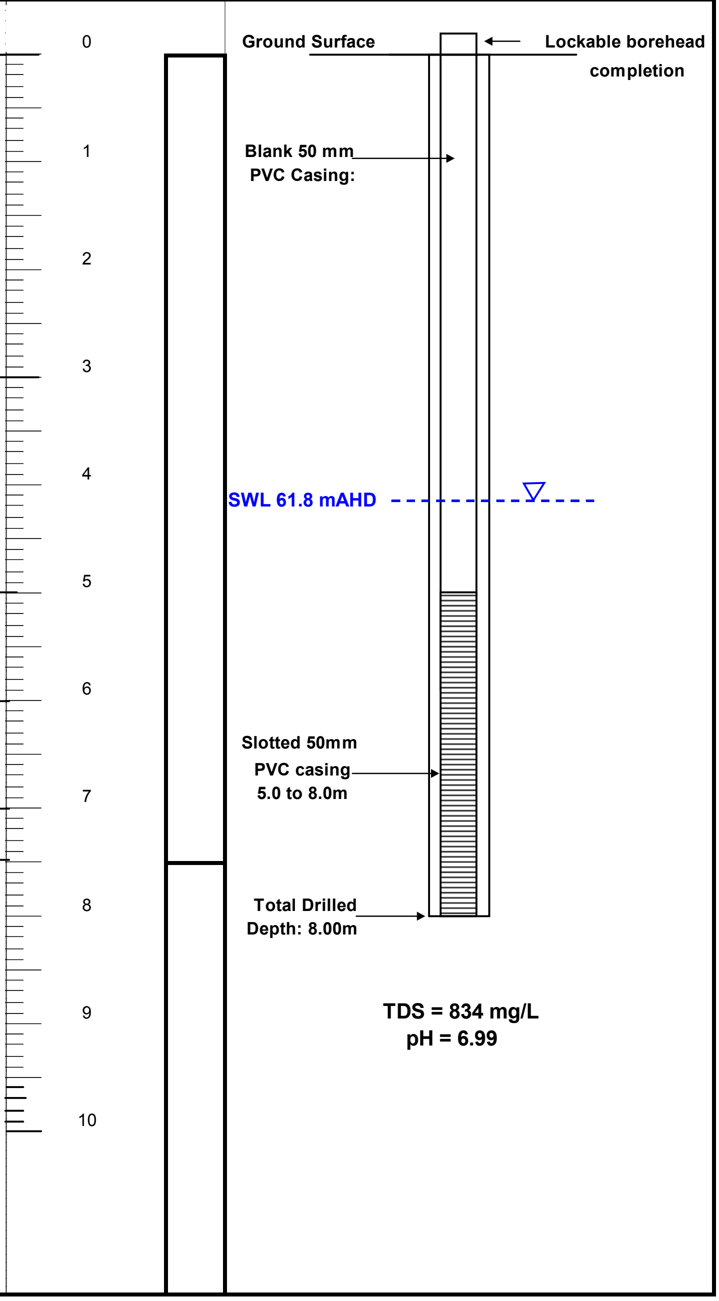


Figure A18: Log T6

Aquaterra Consulting Pty Ltd

Logging Sheet

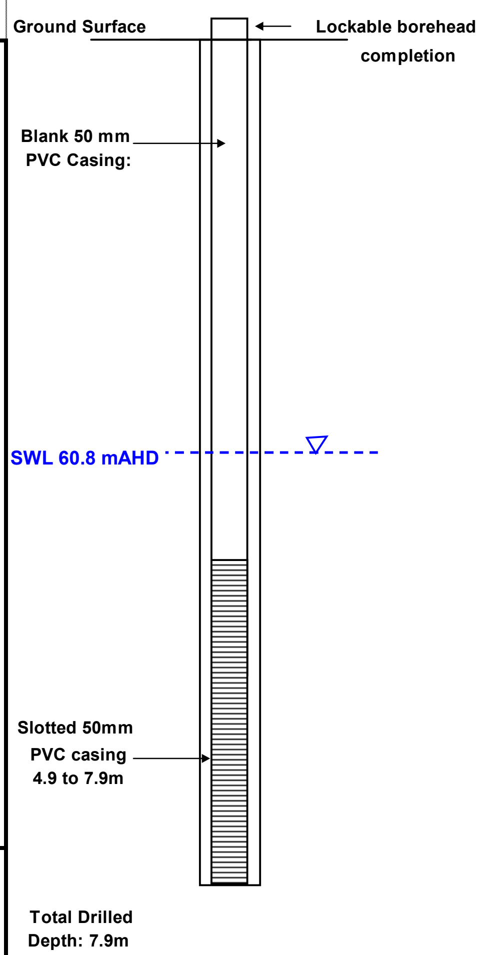
BORE: T7

			Project No:	**S03 (05 - 0166)**
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	**64.62 mAHD**		
	Elevation (TOC):	**65.61 mAHD**		
Location: **Ashton Coal**	Stickup:	**0.99m**		
	Hole Depth:	**7.9 m**		
Drilling Contractor: **Intertech**	Date Started:		Supervised By:	
	Date Completed:			**Rod McCallum**

Description	Depth (metres)
	0
CLAY - orange brown, low strength	0 – 3
GRAVEL - brown, clayey, low strength	3 – 6
GRAVEL - multicoloured, weathered, low strength *RL = 57.1 mAHD*	6 – 7.5
PERMIAN COAL MEASURES	7.5 –

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Well Construction Details:



TDS = 4180 mg/L
pH = 6.96

Figure A19: Log T7

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: T8

		Project No:	**S03 (05 - 0166)**
Client: **Ashton Coal Operations Ltd**	Elevation (Concr):	**59.44 mAHD**	
	Elevation (TOC):	**60.10 mAHD**	
Location: **Ashton Coal**	Stickup:	**0.66m**	
	Hole Depth:	**8.90m**	
Drilling Contractor: **Intertech**	Date Started:		Supervised By:
	Date Completed:		**Rod McCallum**

Description	Depth (metres)
CLAY - brown, low strength	0 – 1
CLAY - orange brown, slightly stony, medium strength	1 – 3
GRAVEL - brown, clayey, low to medium strength	3 – 6
GRAVEL - multicoloured, medium strength *RL = 50.9 mAHD*	6 – 8.9
PERMIAN COAL MEASURES	8.9 – 10

Well Construction Details:

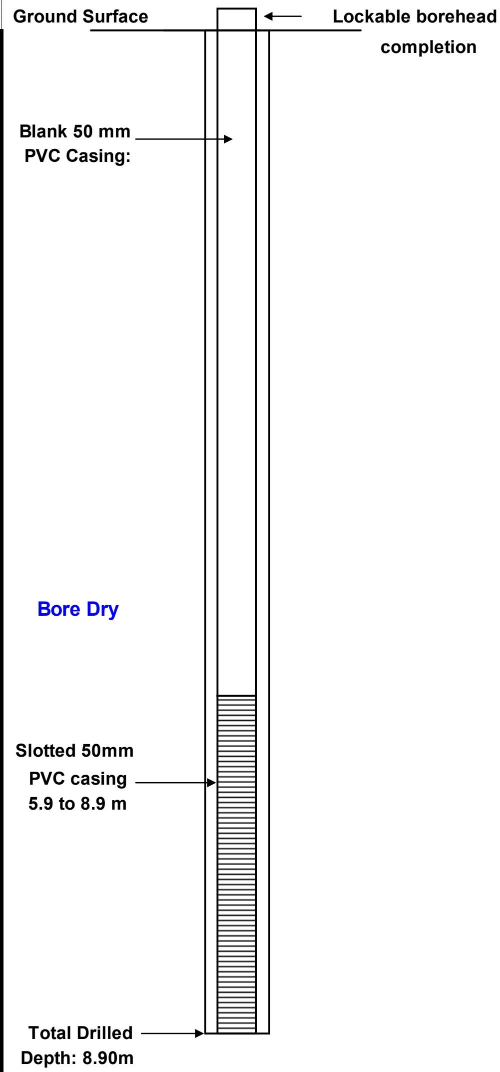


Figure A20: Log T8

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: T9

			Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (GL):	59.85 mAHD		
	Elevation (TOC):	60.59 mAHD		
Location: **Ashton Coal**	Stickup:	0.74m		
	Hole Depth:	10.40m		
Drilling Contractor: **Intertech**	Date Started:		Supervised By:	
	Date Completed:			Rod McCallum

Description	Depth (metres)	Well Construction Details:
CLAY - brown, low strength	0	
CLAY - orange brown, low strength	2	
GRAVEL - brown, slightly sandy, medium strength	4	
SANDY CLAY - brown, slightly stony, medium strength	6	
GRAVEL - multicoloured, medium strength *RL = 50.0 mAHD*	8	
PERMIAN COAL MEASURES	10	
	12	
	14	
	16	
	18	

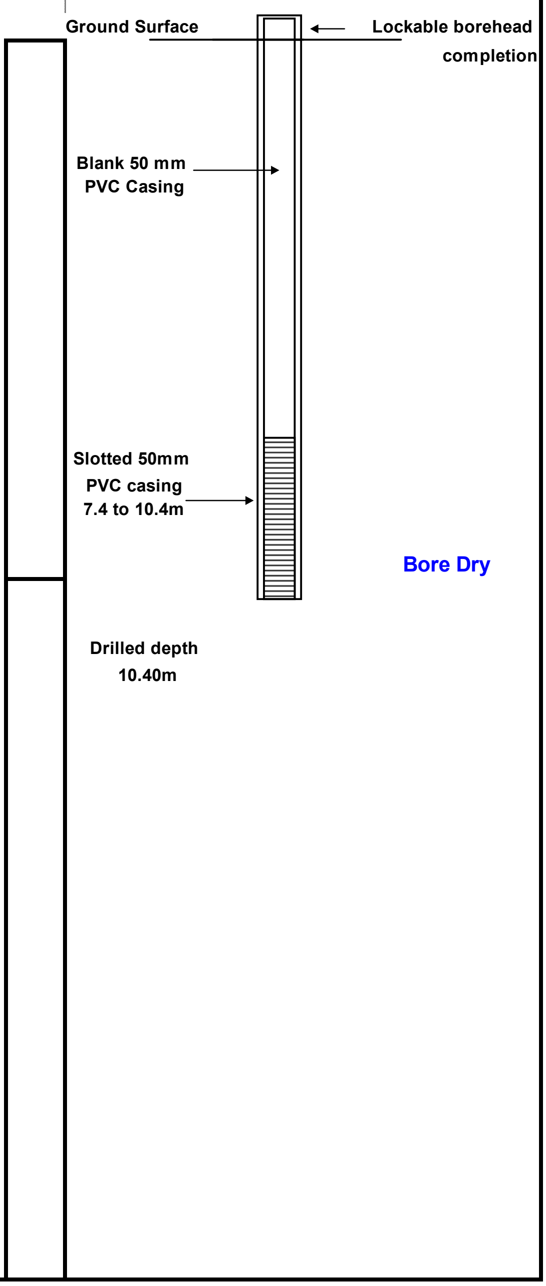


Figure A21: Log T9

Aquaterra Consulting Pty Ltd

Logging Sheet

BORE: T10

			Project No:	S03 (05 - 0166)
Client: **Ashton Coal Operations Ltd**	Elevation (GL):	58.69 mAHD		
	Elevation (TOC):	59.61 mAHD		
Location: **Ashton Coal**	Stickup:	0.92 m		
	Hole Depth:	10.9 m		
Drilling Contractor: **Intertech**	Date Started:		Supervised By:	
	Date Completed:			Rod McCallum

Description	Depth (metres)
	0
SOIL - brown, very low strength	2
SANDY CLAY - brown, slightly stony, low strength	4
CONGLOMERATE - multicoloured, medium strength	6
CONGLOMERATE - buff, clayey, stony, med strength	8, 10
RL = 48.4 mAHD	12
	14
	16
	18

Well Construction Details:

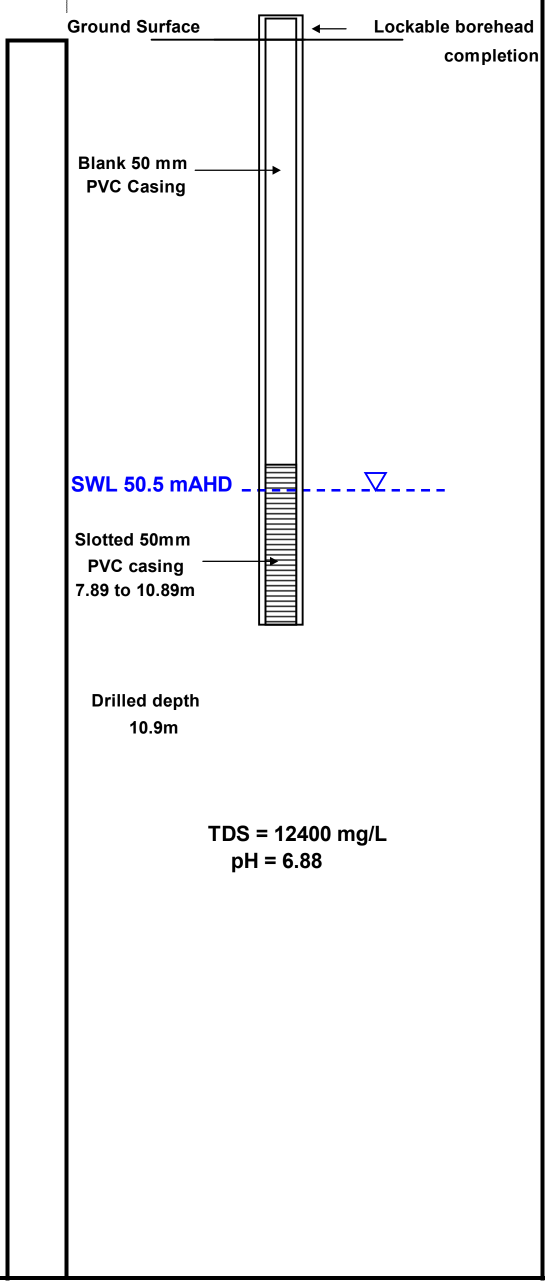


Figure A22: Log T10

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: WML110A, B and C

					Project No:	S03 (05 - 0166)	
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Ashton Coal Operations Pty Ltd	**WML110A**	**63.71 mAHD**			**Hunter Drilling Services**	**03-May-06**	
Locationt:	**WML110B**	**63.74 mAHD**	**63.99 mAHD**	**0.25 m**	**Hunter Drilling Services**	**05-May-06**	
Ashton Coal Project	**WML110C**	**63.73 mAHD**	**63.73 mAHD**	**0.00 m**	**Hunter Drilling Services**	**04-May-06**	
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description	Depth (metres)
Brown alluvium *RL = 47.73 mAHD*	0 – 10
Brown grey sandstone	20
Grey to multicolored conglomerate	
Sandstone	30
Grey to multicolored conglomerate	
Coal (Lemington 6)	
Siltstone, sandstone	40
Conglomerate, sandstone	
Coal (Lemington 7)	50
Sandstone	
Siltstone	
Sandstone, minor siltstone	60 – 70
Coal, carbonaceous mudstone	
Siltstone, mudstone, minor coal	80
Sandstone, minor siltstone	90
Coal	100
Sandstone	
Siltstone, coal, mudstone	110

Well Construction Details:

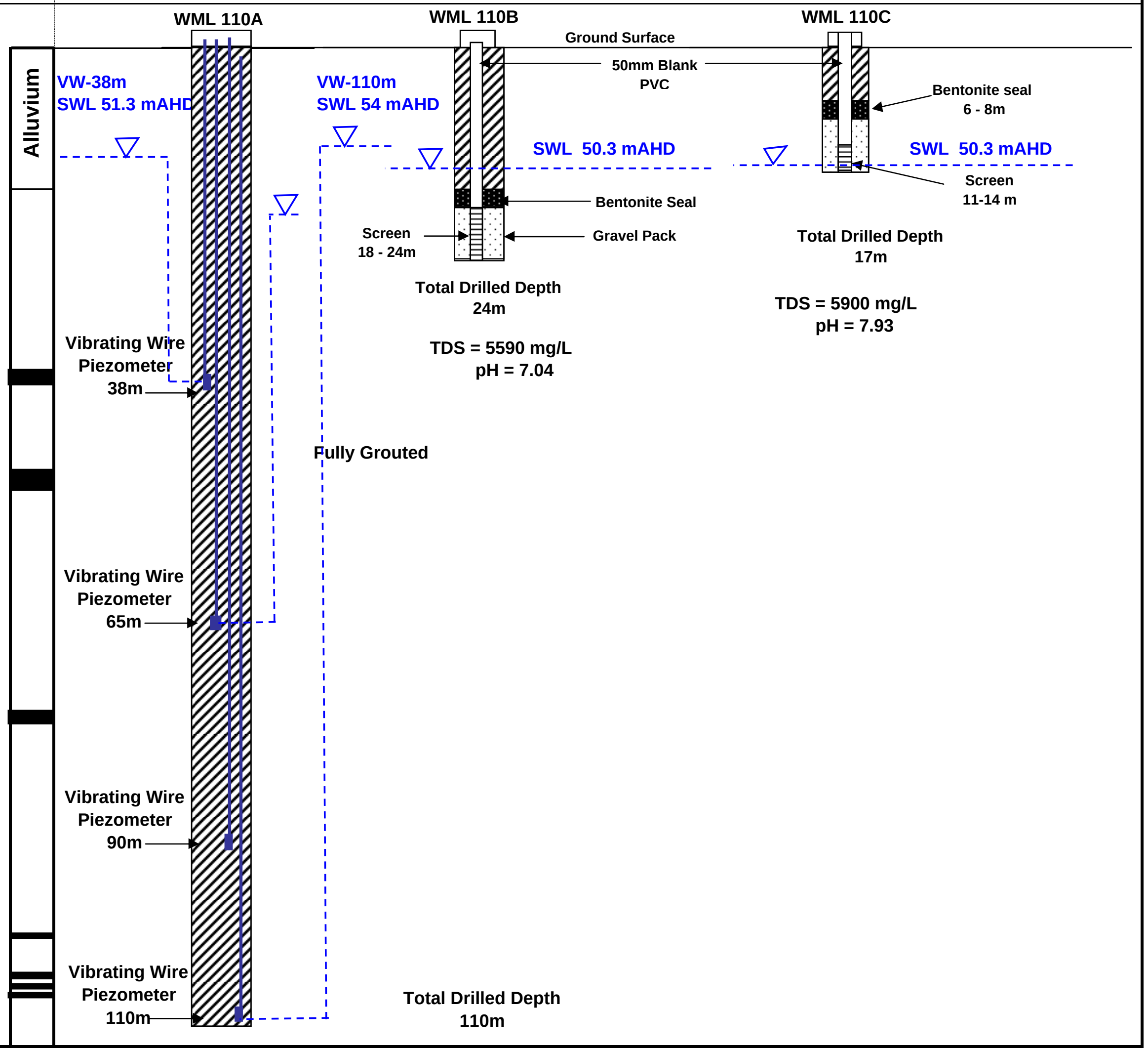


Figure A23: Logs WML110A, WML110B and WML110C

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: WML111A and WML111B

					Project No:	S03 (05 - 0166)	
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Ashton Coal Operations Pty Ltd	**WML111A**	**58.20 mAHD**			**Hunter Drilling Services**	**05-May-06**	
Locationt:	**WML111B**	**58.33 mAHD**	**58.77 mAHD**	**0.44 m**	**Hunter Drilling Services**	**10-May-06**	
Ashton Coal Project							
			Hole depths:			Supervised By:	
			As shown			**R McCallum**	

Description	Depth (metres)	Well Construction Details:

Brown alluvium
Pebble sized conglomerate with sandstone
Coal
Grey mudstone with grey sandstone
Coal (Lemington 4 Seam)
Grey mudstone with grey sand- and siltstone
Pebble sized conglomerate
Grey siltstone with grey sandstone and very thin
Pebble sized conglomerate
Coal (Lemington 7 Seam)
Grey siltstone with grey sandstone
Coal
Light grey sandstone
Grey siltstone
Coal (Lemington 11 and 12 Seams)
Grey sandstone and siltstone
Coal
Grey sand- and siltstone
Coal (Lemington 15 Seam)
Grey mud-, sand- and siltstone

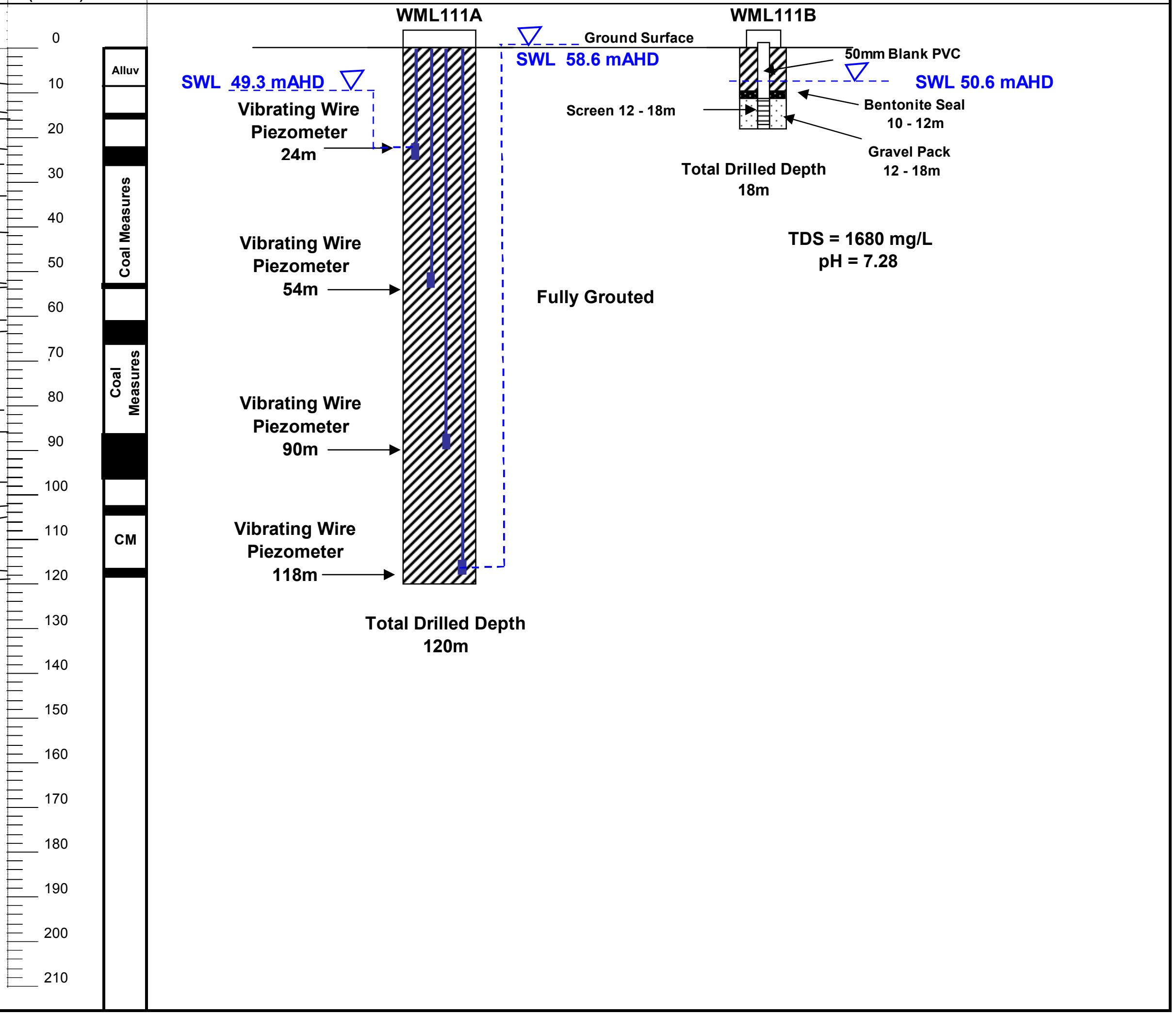


Figure A24: Logs WML111A and WML111B

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: WML112A, WML112B and WML112C

					Project No:	**S03 (05 - 0166)**	
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Ashton Coal Operations Pty Ltd	**WML112A**	**59.44 mAHD**			**Hunter Drilling Services**	**?**	
Locationt:	**WML112B**	**59.42 mAHD**	**59.74 mAHD**	**0.32 m**	**Hunter Drilling Services**	**06-Jul-06**	
Ashton Coal Project	**WML112C**	**59.58 mAHD**	**60.42 mAHD**	**0.84m**	**Hunter Drilling Services**	**?**	
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description	Depth (metres)	Well Construction Details:

Description

- Weathered and low strength alluvium
- Coal
- Grey pebbly conglomerate
- Bayswater 2 Coal Seam
- Conglomerate
- Light grey sandstone with grey siltstone, coal bands
- Lemington 3-4 Coal Seams
- Sandstone, siltstone
- Conglomerate, minor sandstone
- Lemington 5-6 Coal Seams
- Sandstone
- Lemington 7 Coal Seam
- Siltstone, sandstone
- Sandstone, minor siltstone
- Interbedded siltstone, sandstone, mudstone, coal
- Lemington 8-11 Coal Seams
- Siltstone, sandstone
- Lemington 12 Coal Seam
- Sandstone, minor siltstone, carb mudstone
- Mudstone
- Lemington 15-17 Coal Seams
- Sandstone, interbedded mudstone, siltstone
- Lemington 19 Coal Seam
- Sandstone, minor siltstone, mudstone
- Pikes Gully Coal Seam
- Sandstone
- Arties Coal Seam
- Sandstone
- Conglomerate, minor sandstone
- Sandstone
- Upper Liddell Coal Seam

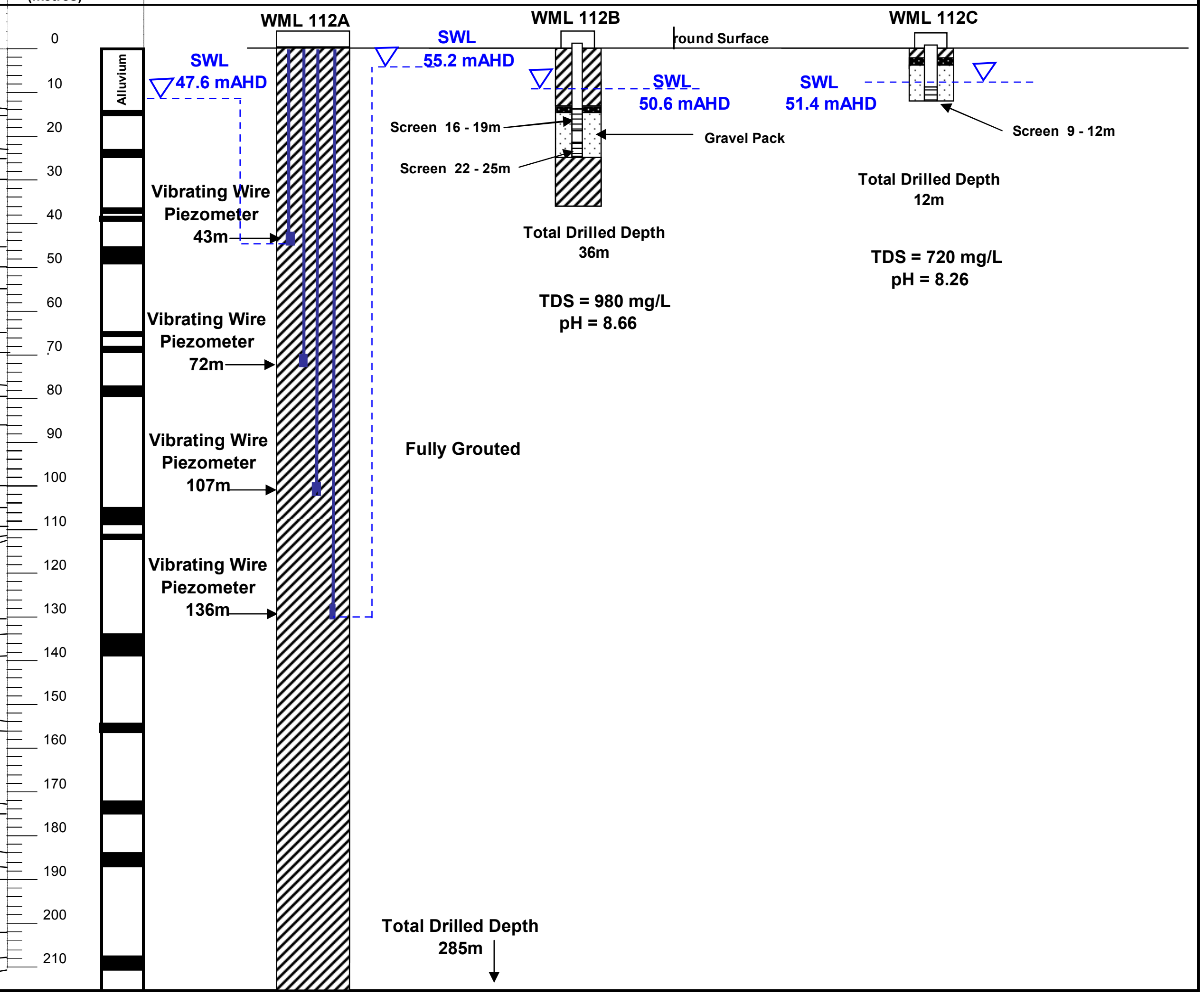


Figure A25: Logs WML112A, WML112B and WML112C

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: WML113A, WML113B and WML113C

					Project No:	S03 (05 - 0166)	
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Ashton Coal Operations Pty Ltd	WML113A	60.20 mAHD			Hunter Drilling Services	10-May-06	
Locationt:	WML113B	60.20 mAHD	60.48 mAHD	0.28 m	Hunter Drilling Services	11-May-06	
Ashton Coal Project	WML113C	60.43 mAHD	60.96 m	0.53 m	Hunter Drilling Services	?	
			Hole depths: As shown			Supervised By: R McCallum	

Description	Depth (metres)	Well Construction Details:

- Brown and dark brown alluvium
- Grey sand- and siltstone with dark grey mudstone
- Coal (Bayswater 1 Seam)
- Grey sand- and siltstone with mudstone
- Multicolored conglomerate
- Coal (Bayswater 2 Seam)
- Grey sand- and siltstone with pebbly conglomerate
- Coal (Lemington 1/2 Seams)
- Grey silt- and sandstone
- Coal (Lemington 3/4 Seams)
- Grey siltstone with grey sandstone
- Pebbly conglomerate with little sand- and siltstone
- Coal
- Grey siltstone with grey sandstone
- Coal
- Grey siltstone and sandstone, with mudstone
- Multicolored pebbly conglomerate
- Coal (Lemington 10, 11 and 12 Seams)
- Grey sand and siltstone

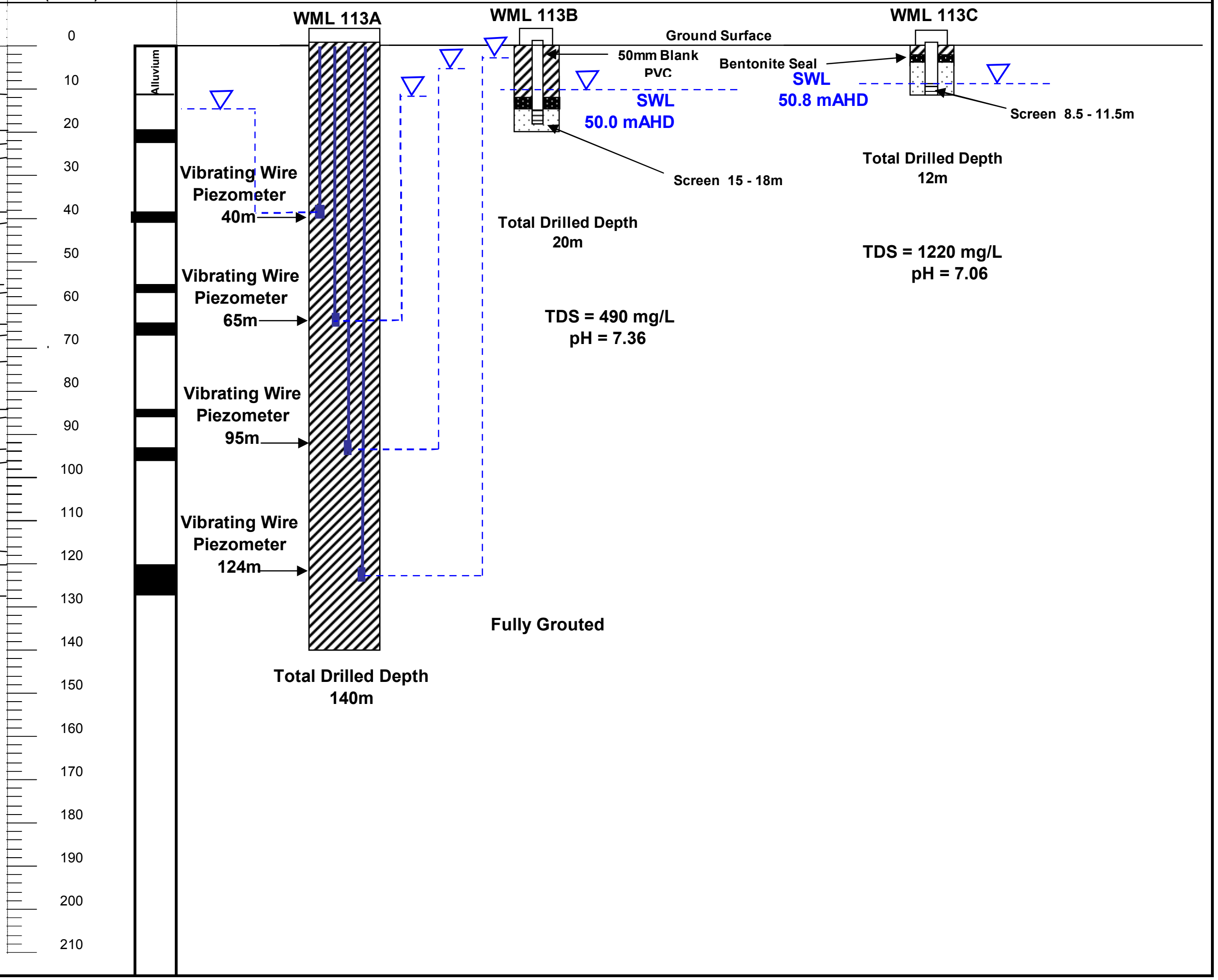


Figure A26: Logs WML113A, WML113B and WML113C

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: WML114A and WML114B

						Project No:	S03 (05 - 0166)
Client: Ashton Coal Operations Pty Ltd	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
	WML114A	71.53 mAHD			Hunter Drilling Services	15-May-06	
Locationt: Ashton Coal Project	WML114B	71.47 mAHD	71.71 mAHD	0.24 m	Hunter Drilling Services	17-May-06	
			Hole depths: As shown			Supervised By: R McCallum	

Description	Depth (metres)
	0
Brown clayey alluvium	
Highly weathered silt-, sand- and mudstone	
Coal	
Grey mudstone and siltstone	10
Coal (Lemington 6/7 Seams)	
Sandstone, minor siltstone	
Siltstone	20
Sandstone	
Coal (Lemington 8/9 Seams)	30
Siltstone, sandstone	
Sandstone, minorsiderite, siltstone	40
Conglomerate, minor siltstone	50
Coal (Lemington 10, 11 and 12 Seams)	60
Sandstone, siltstone, mudstone, coal interbeds	
Siltstone	70
Sandstone, minor siltstone	80
Coal (Lemington 15 Seam)	90
Siltstone, sandstone	
Coal	
Siltstone, sandstone	100
Sandstone, siltstone, coal bands	
Coal (Lemington 19 Seam)	
Sandstone	110

Well Construction Details:

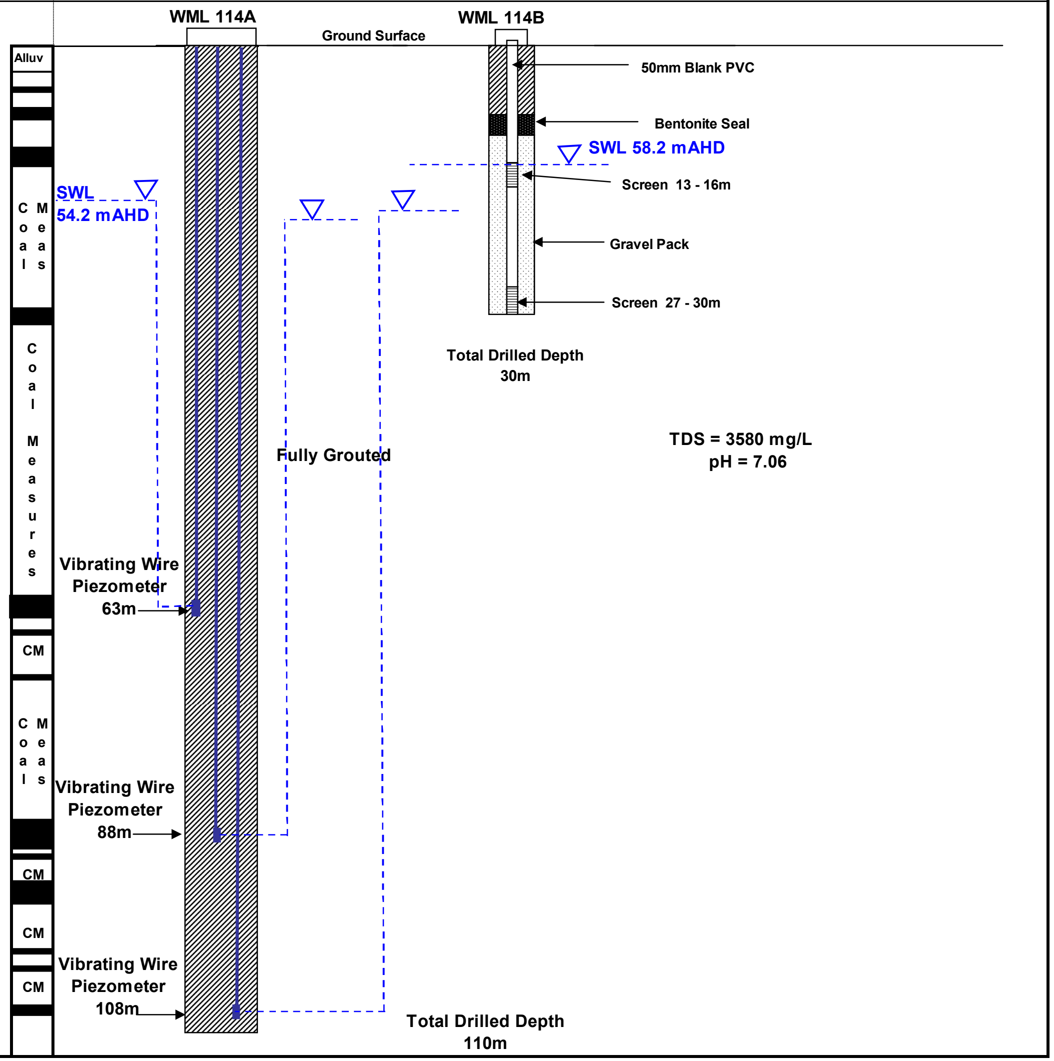


Figure A27: Logs WML114A and WML114B

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: WML115A, WML115B and WML115C

					Project No:	S03 (05 - 0166)	
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Ashton Coal Operations Pty Ltd	WML115A	66.59 mAHD			Hunter Drilling Services		
Locationt:	WML115B	66.35 mAHD	? mAHD	? m	Hunter Drilling Services		
Ashton Coal Project	WML115C	66.22 mAHD	67.04 m	0.82 m	Hunter Drilling Services		
			Hole depths:			Supervised By:	
			As shown			R McCallum	

Description	Depth (metres)	Well Construction Details:

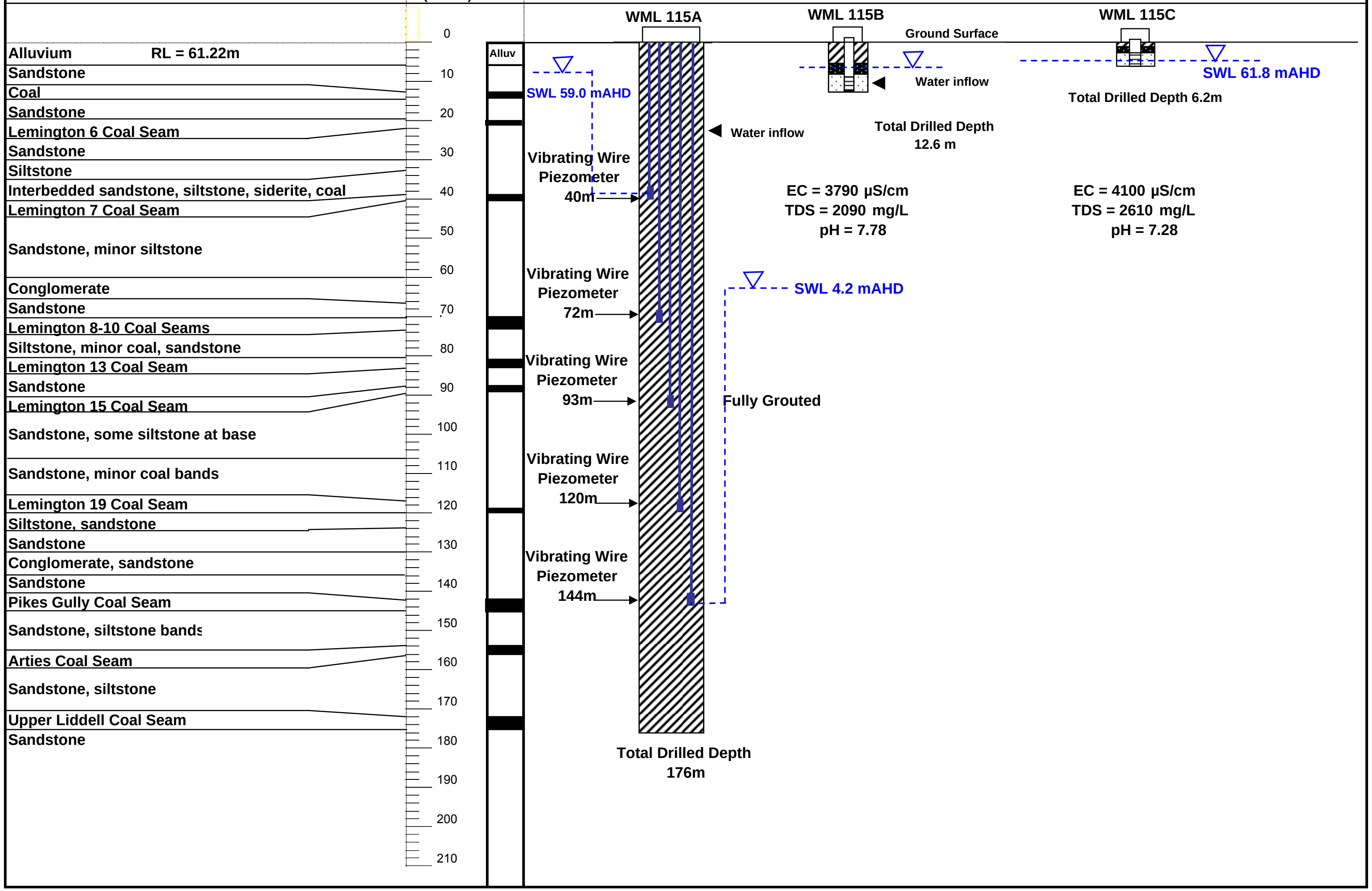
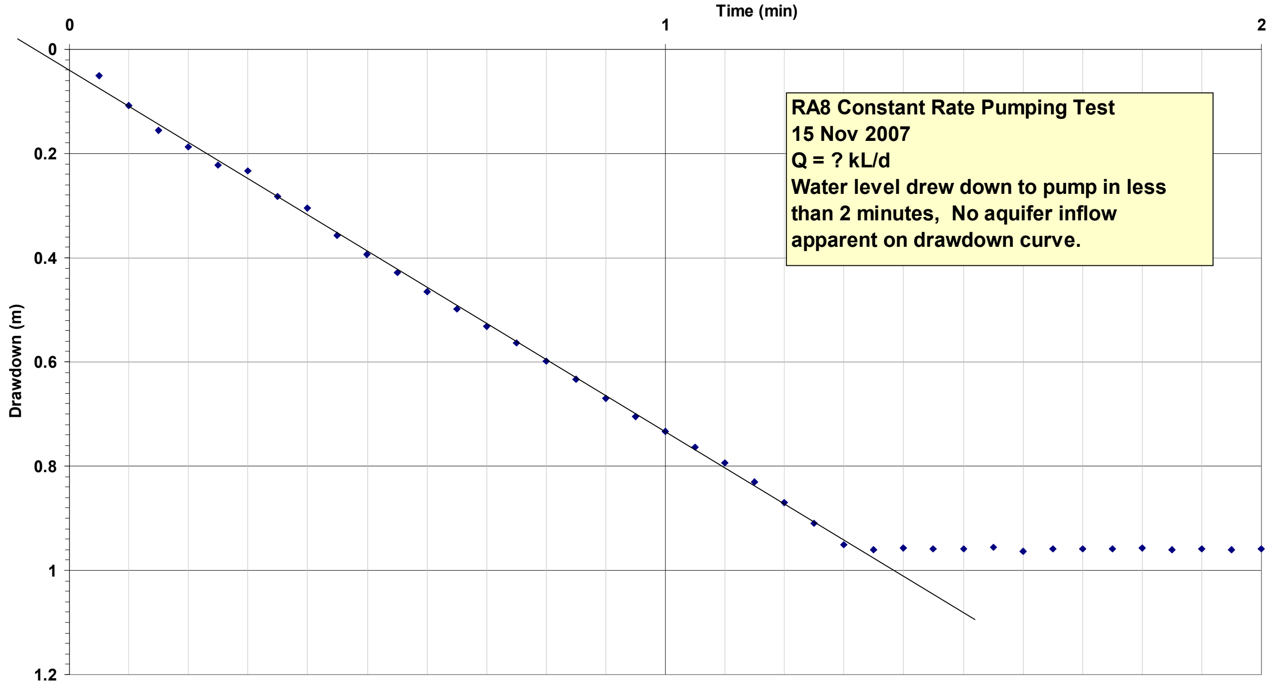


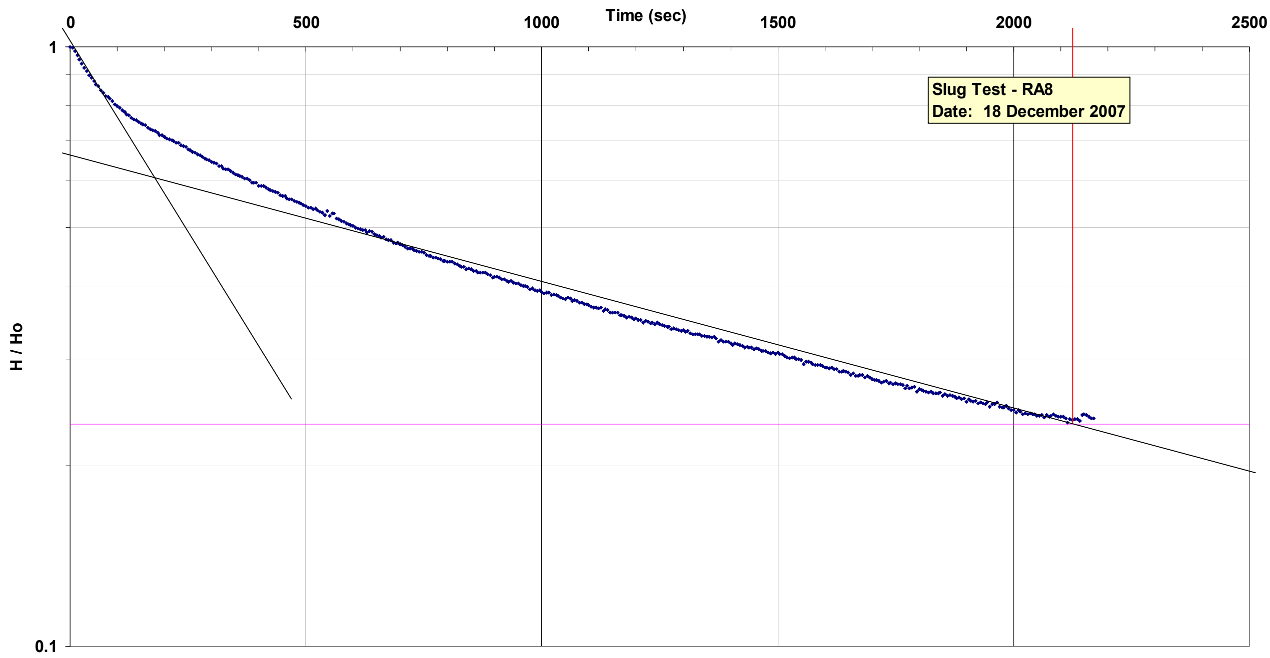
Figure A28: Logs WML115A, WML115B and WML115C

APPENDIX B
HYDRAULIC TESTING DATA

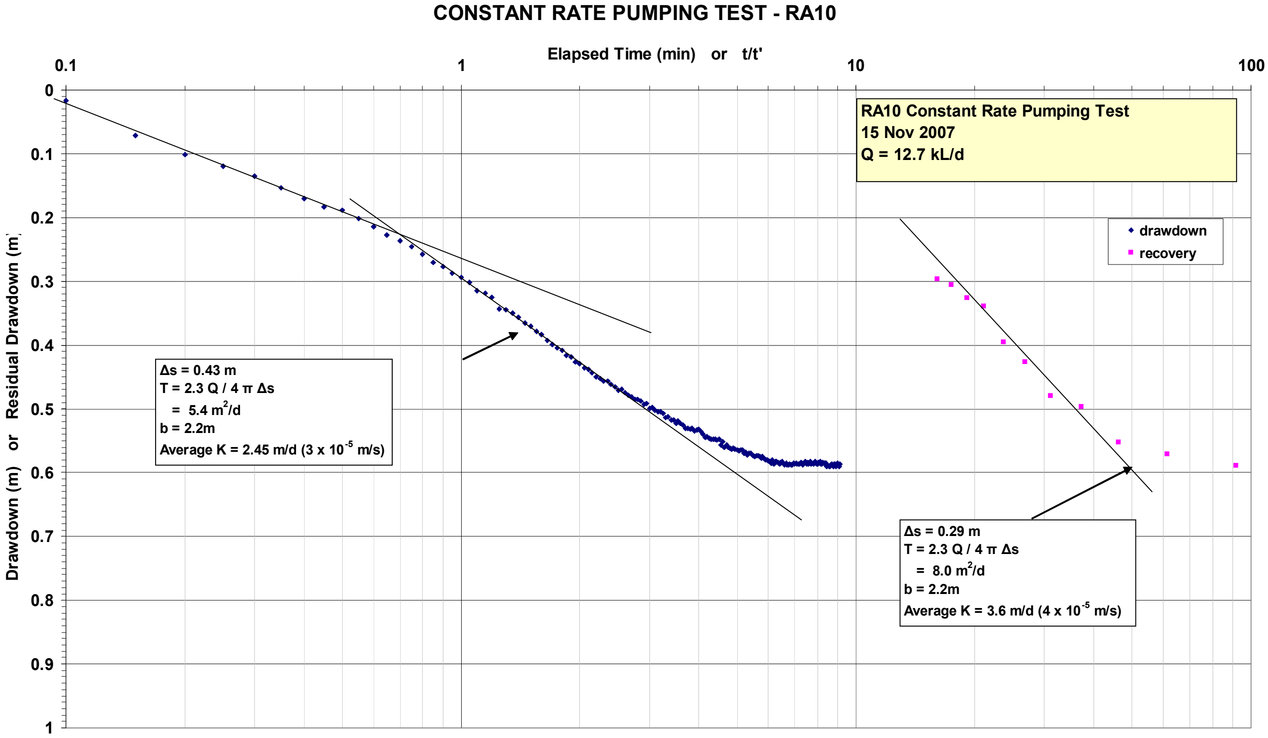
CONSTANT RATE TEST - RA8

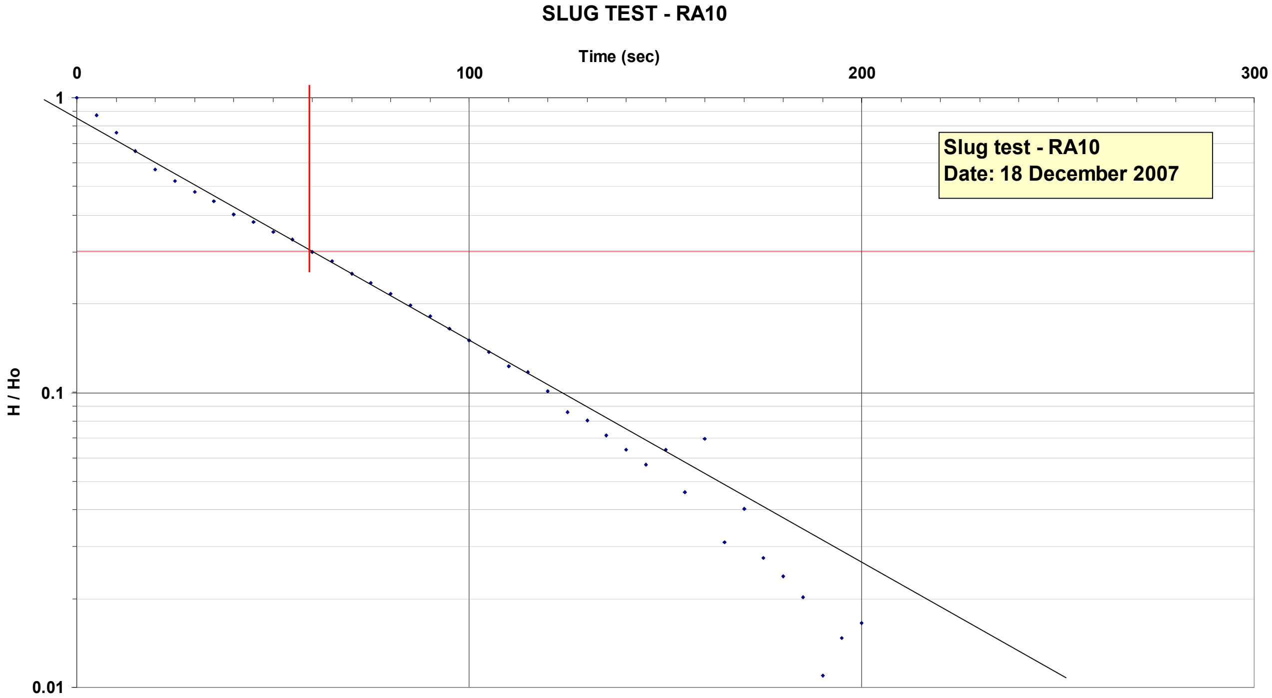


SLUG TEST - RA8

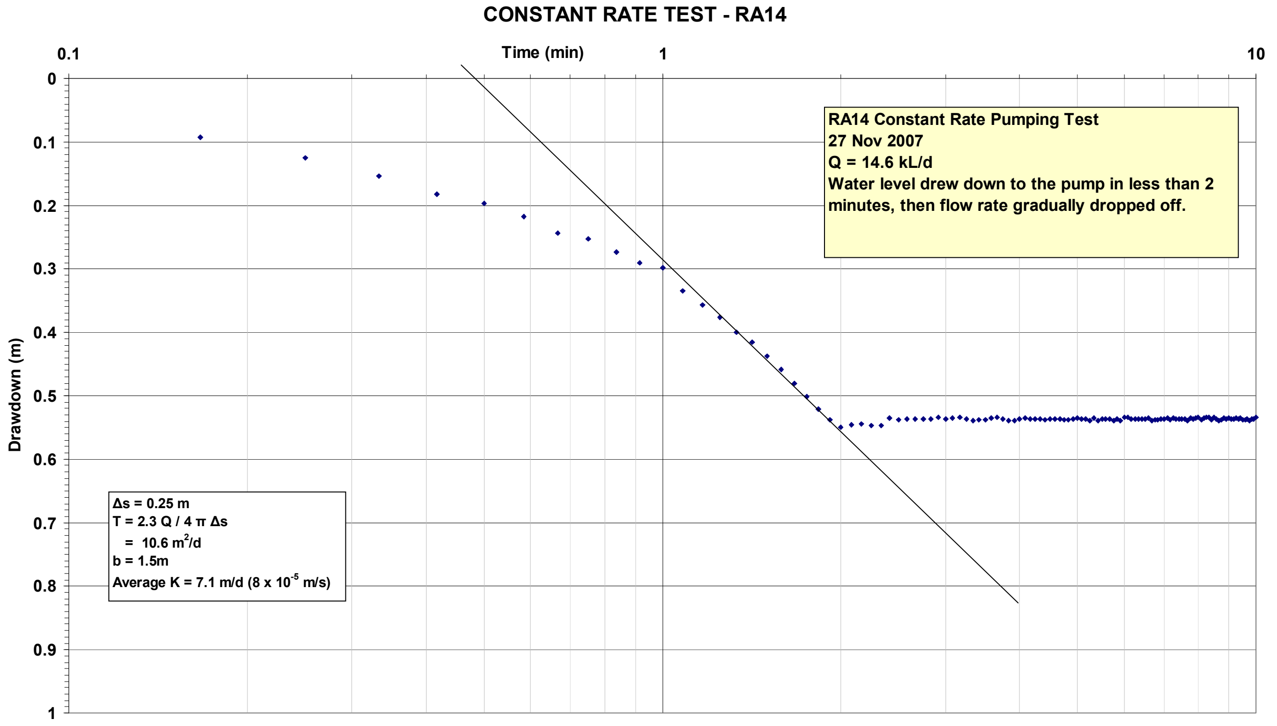


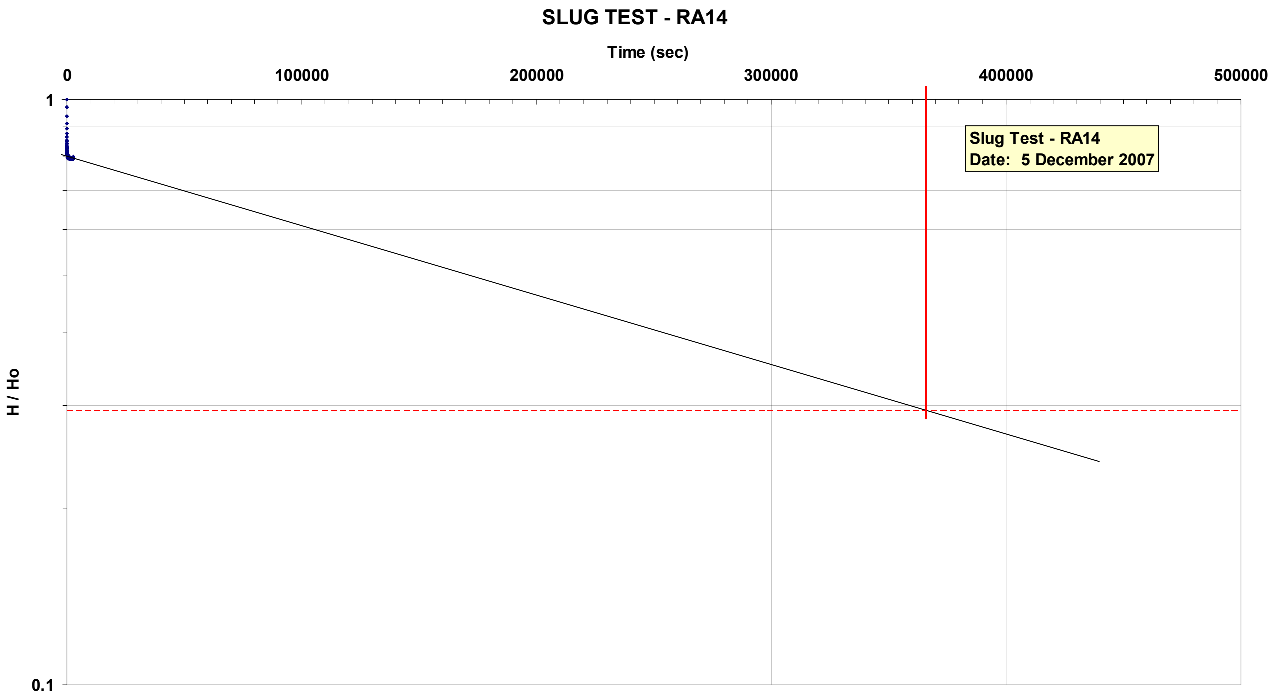
Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA8**
Drawing No: S03-192	Rev: 0	
aquaterra		**Figure B1**



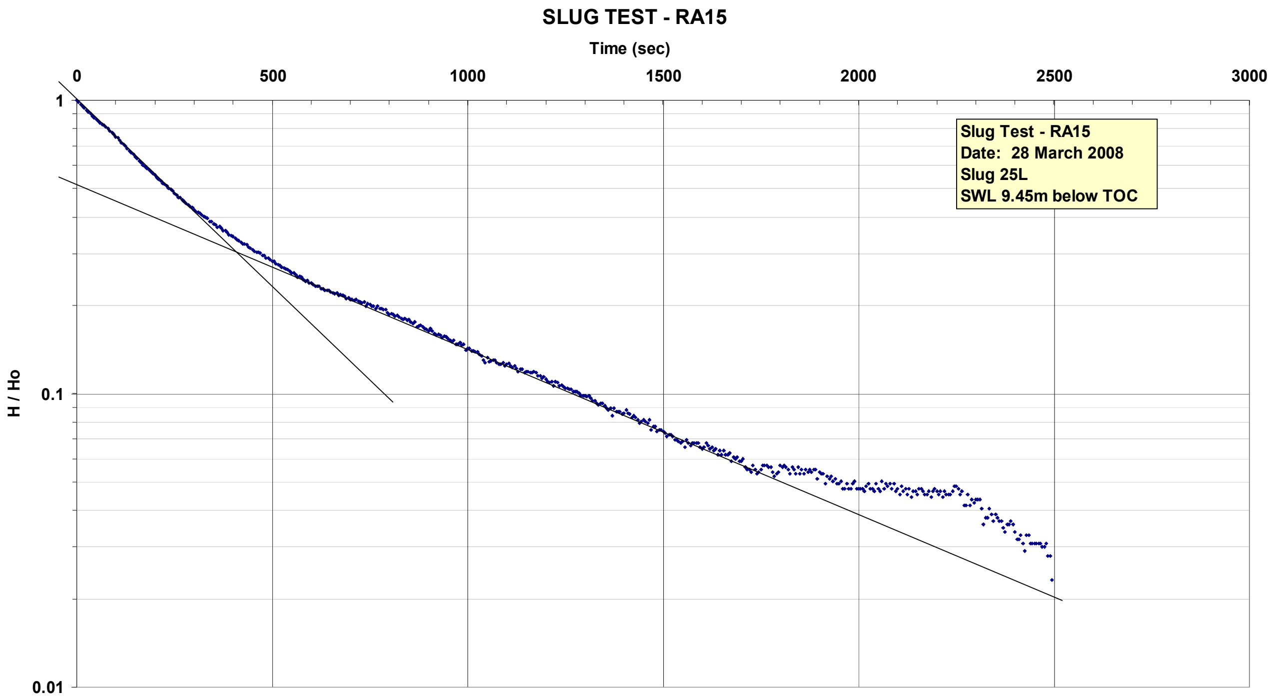


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**	
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA10**	
Drawing No: S03-193	Rev: 0		
aquaterra			**Figure B2**



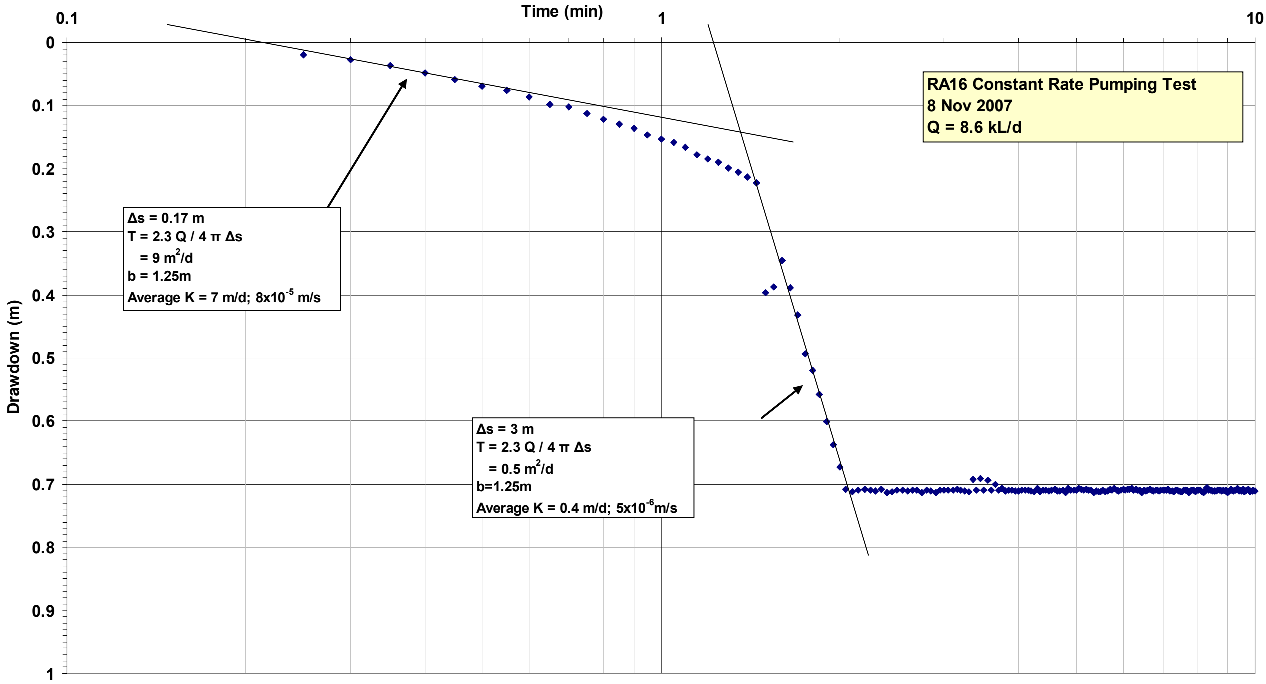


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA14**
Drawing No: S03-194	Rev: 0	**Figure B3**
aquaterra		

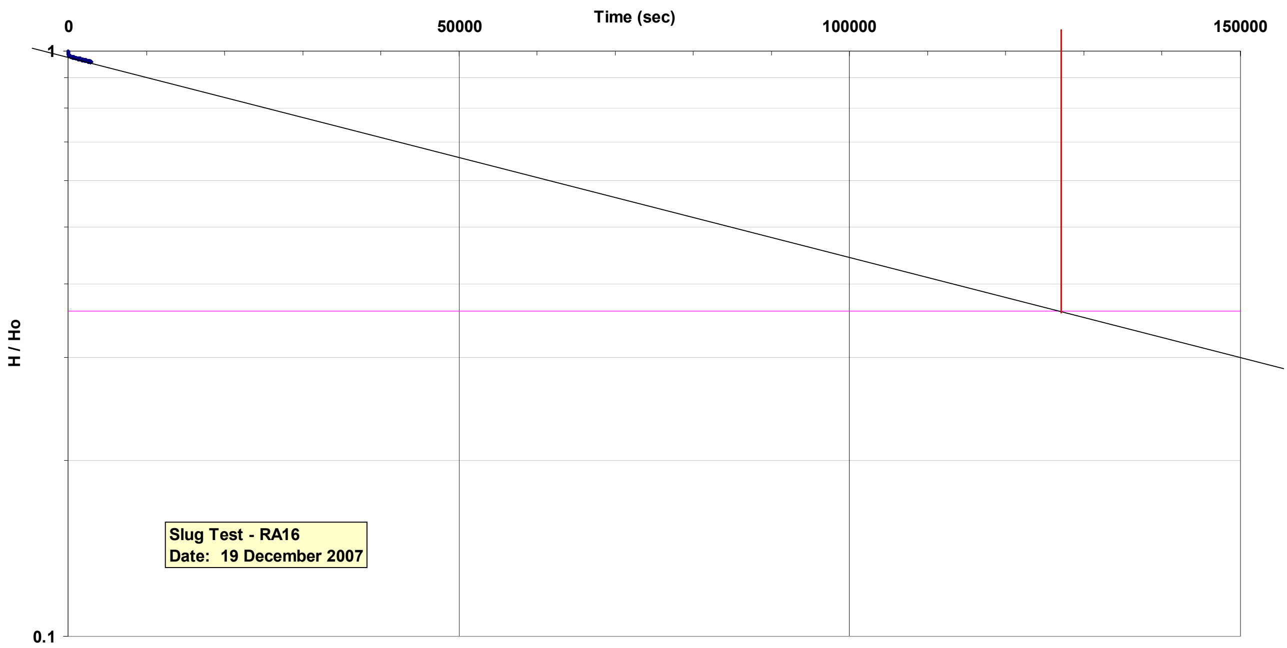


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA15**
Drawing No: S03-195	Rev: 0	
aquaterra		**Figure B4**

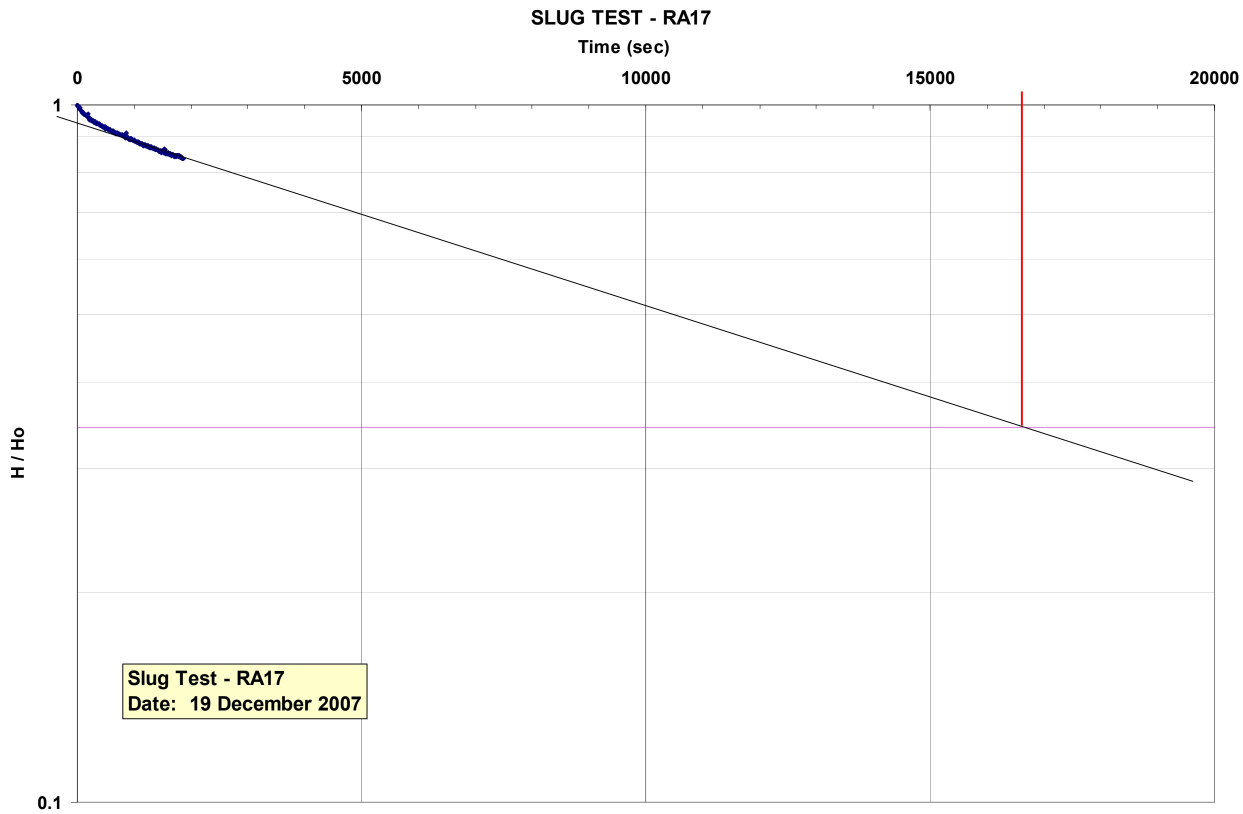
CONSTANT RATE PUMPING TEST - RA16

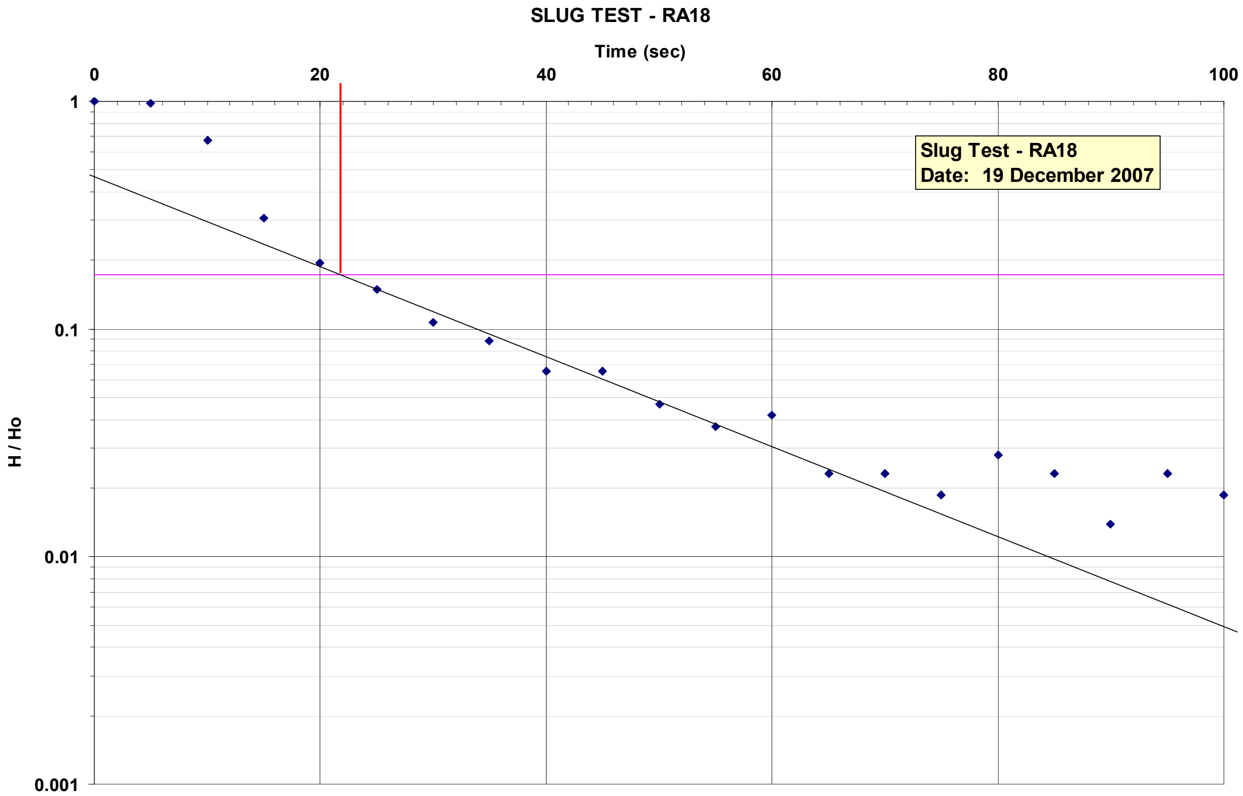


SLUG TEST - RA16

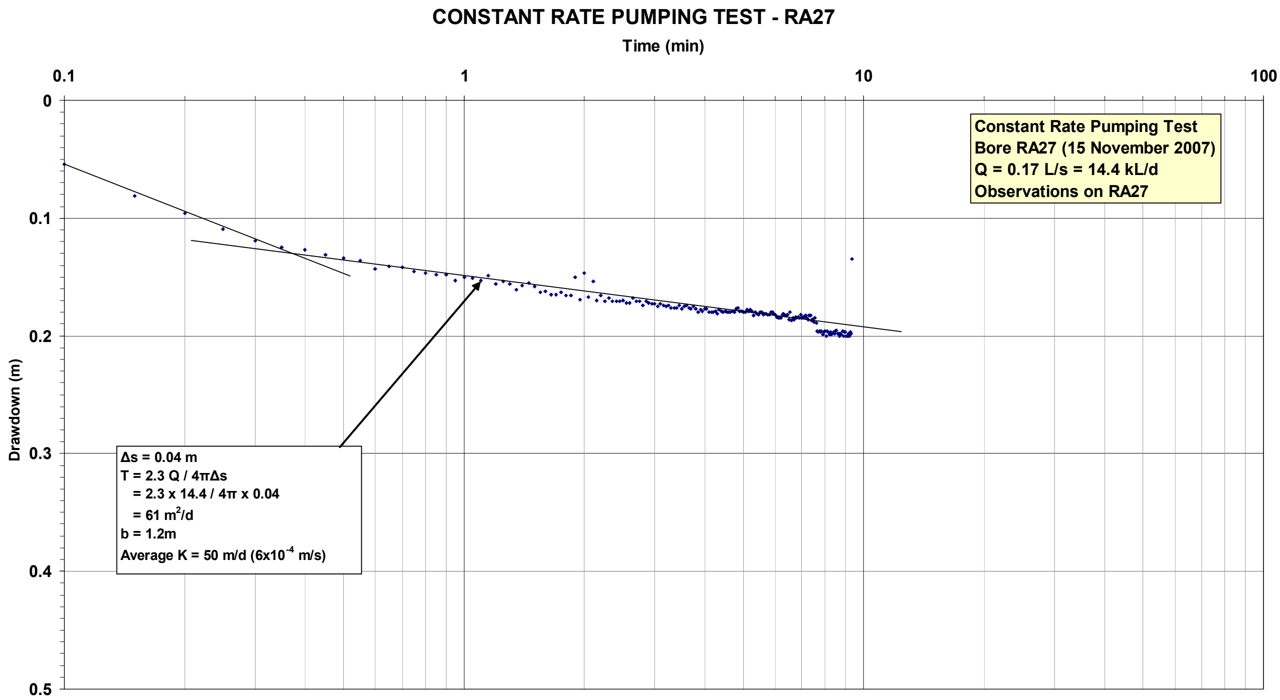


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA16**
Drawing No: S03-196	Rev: 0	
aquaterra		**Figure B5**

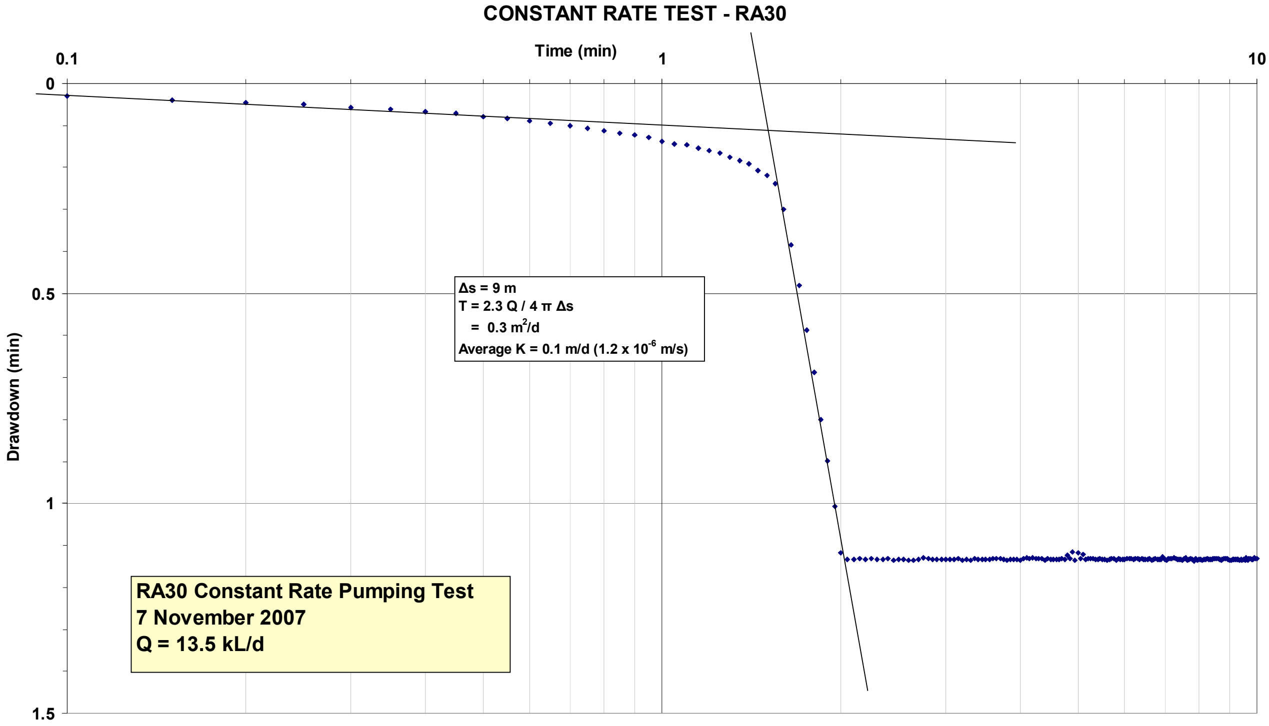


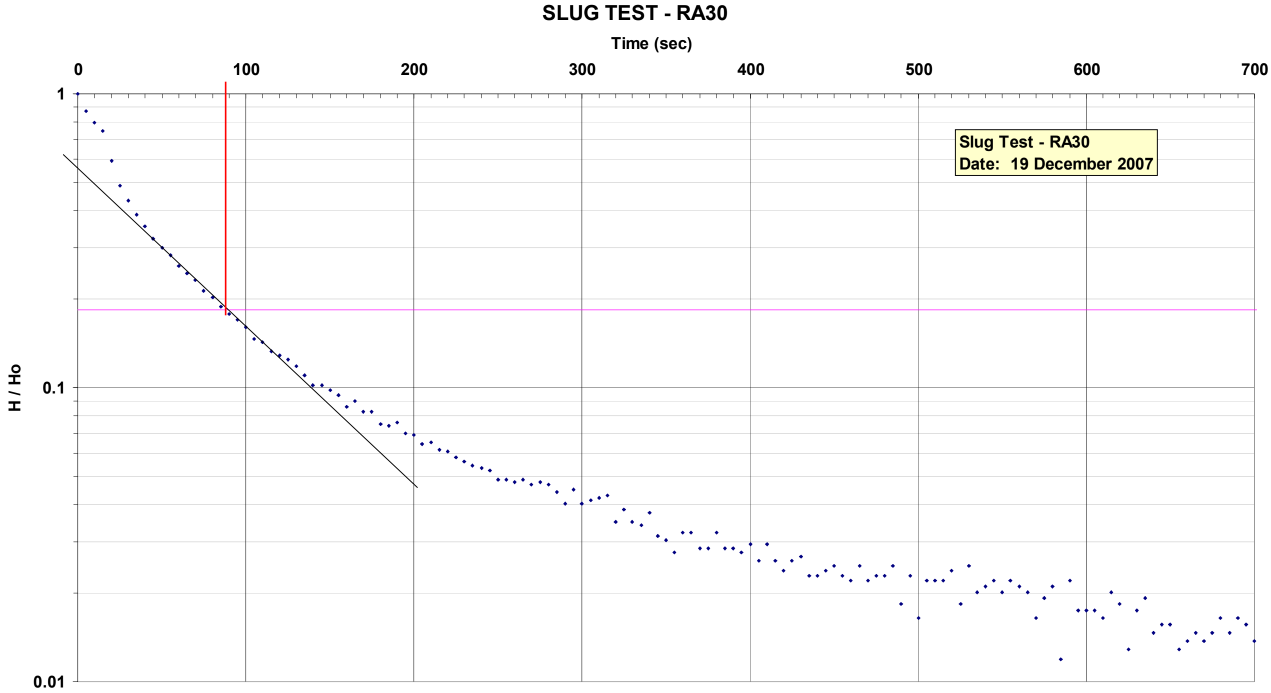


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA17 and RA18**
Drawing No: S03-197	Rev: 0	
aquaterra		**Figure B6**



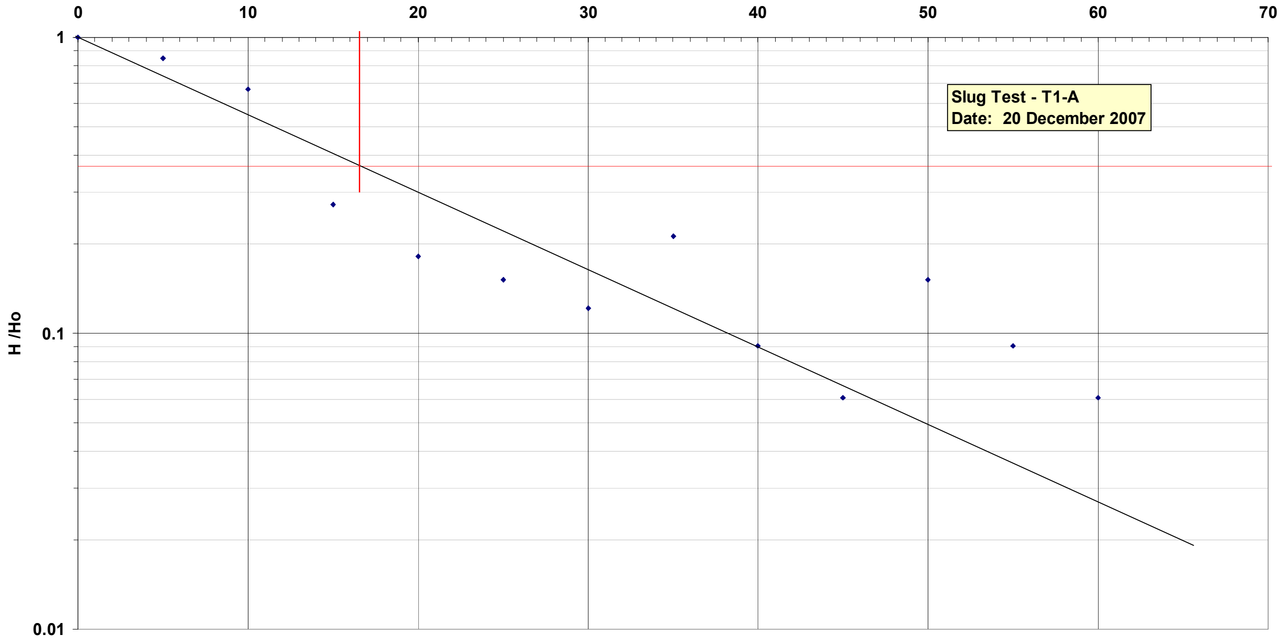
Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA27**
Drawing No: S03-198	Rev: 0	
aquaterra		**Figure B7**



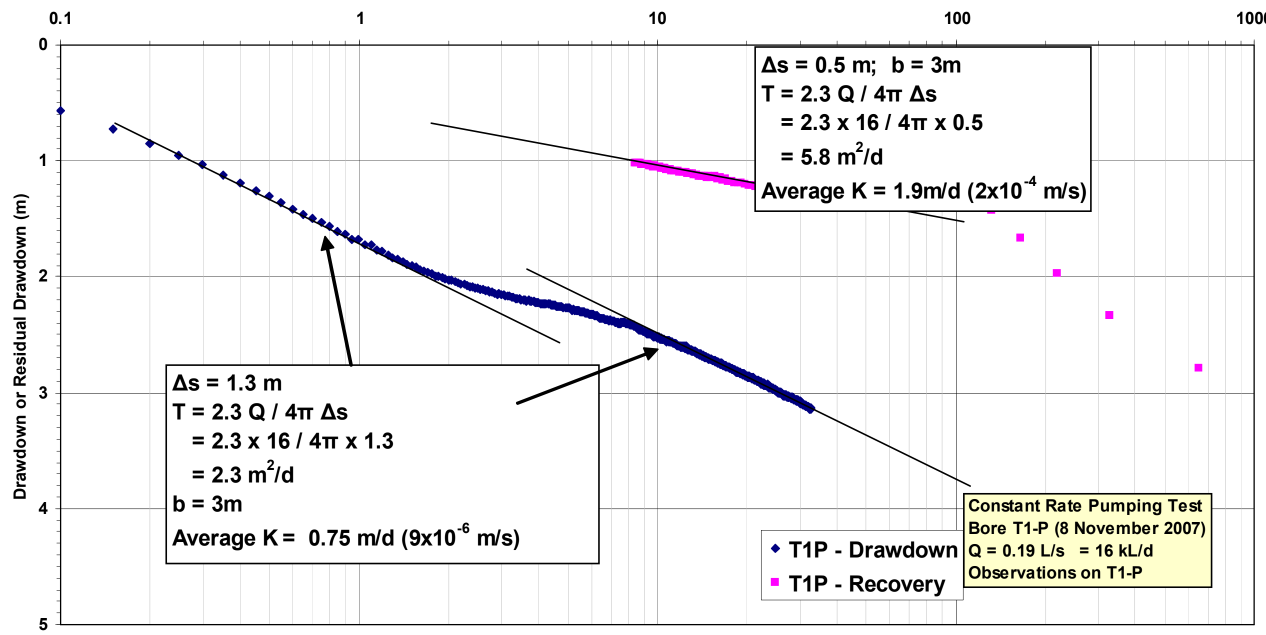


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING RA30**
Drawing No: S03-199	Rev: 0	
aquaterra		**Figure B8**

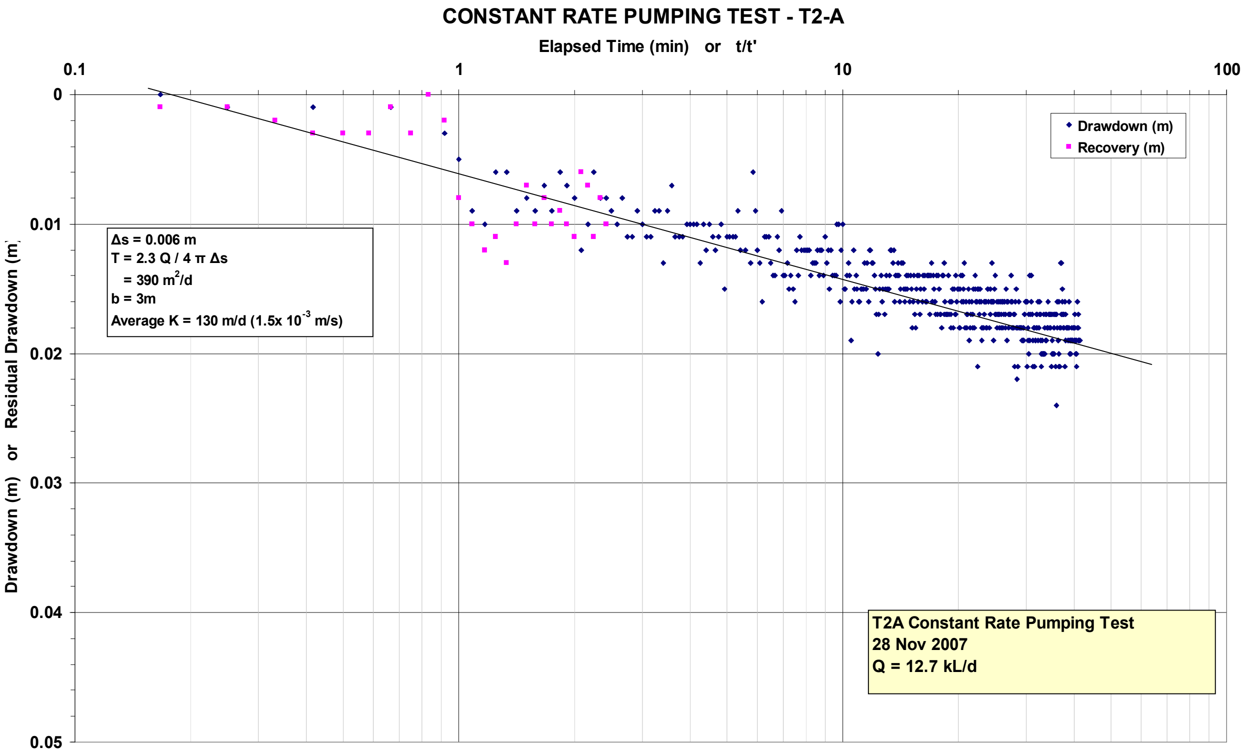
SLUG TEST - T1-A

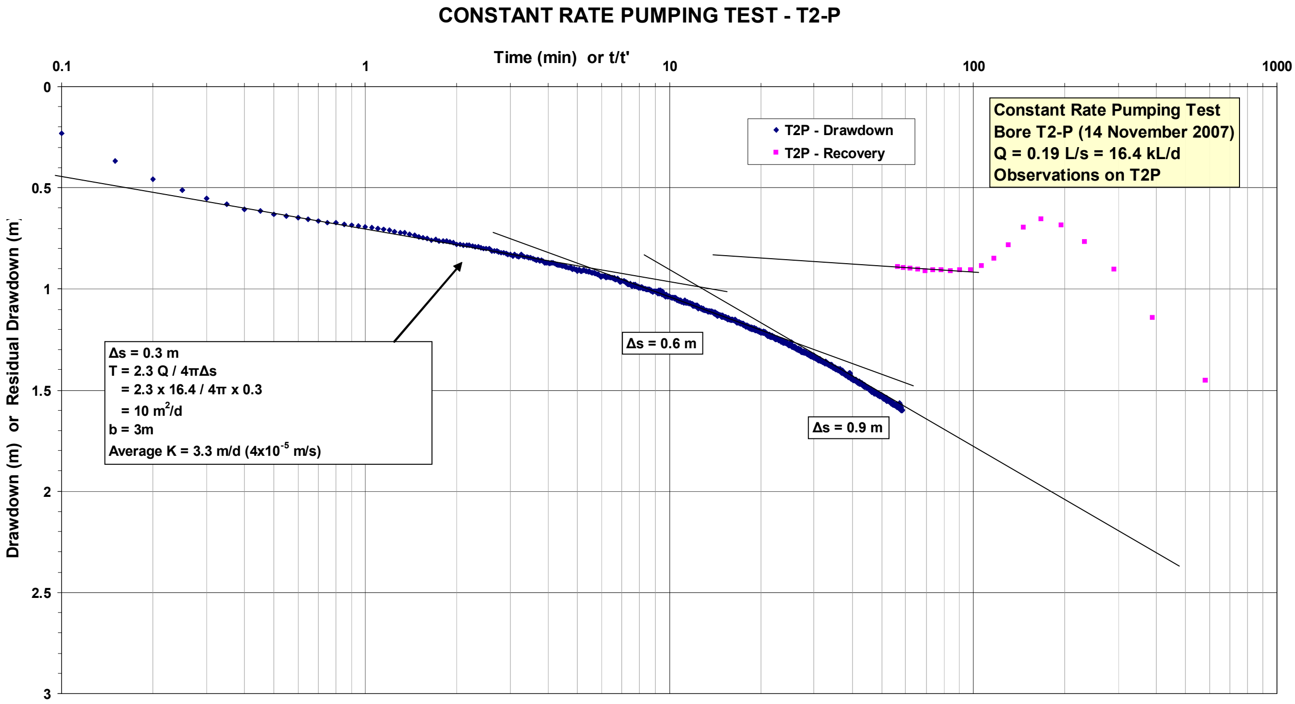


CONSTANT RATE PUMPING TEST - T1-P

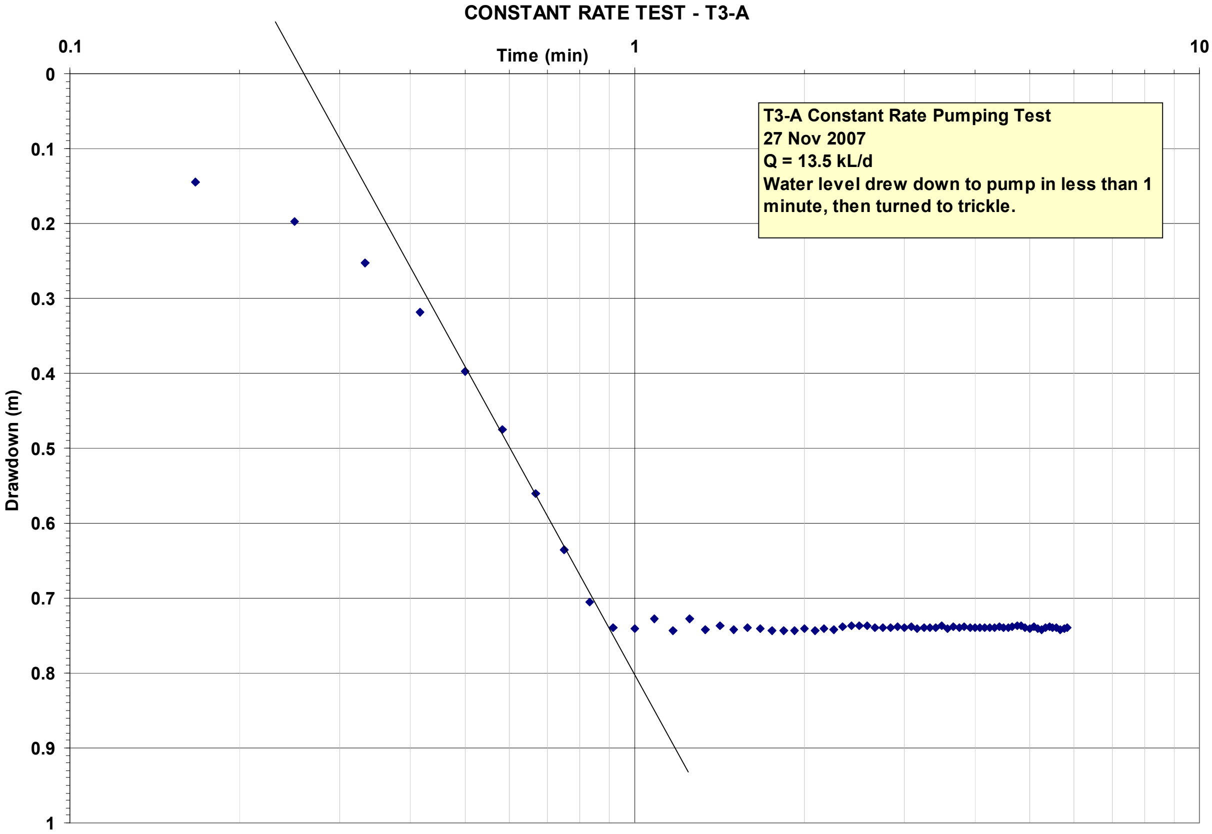


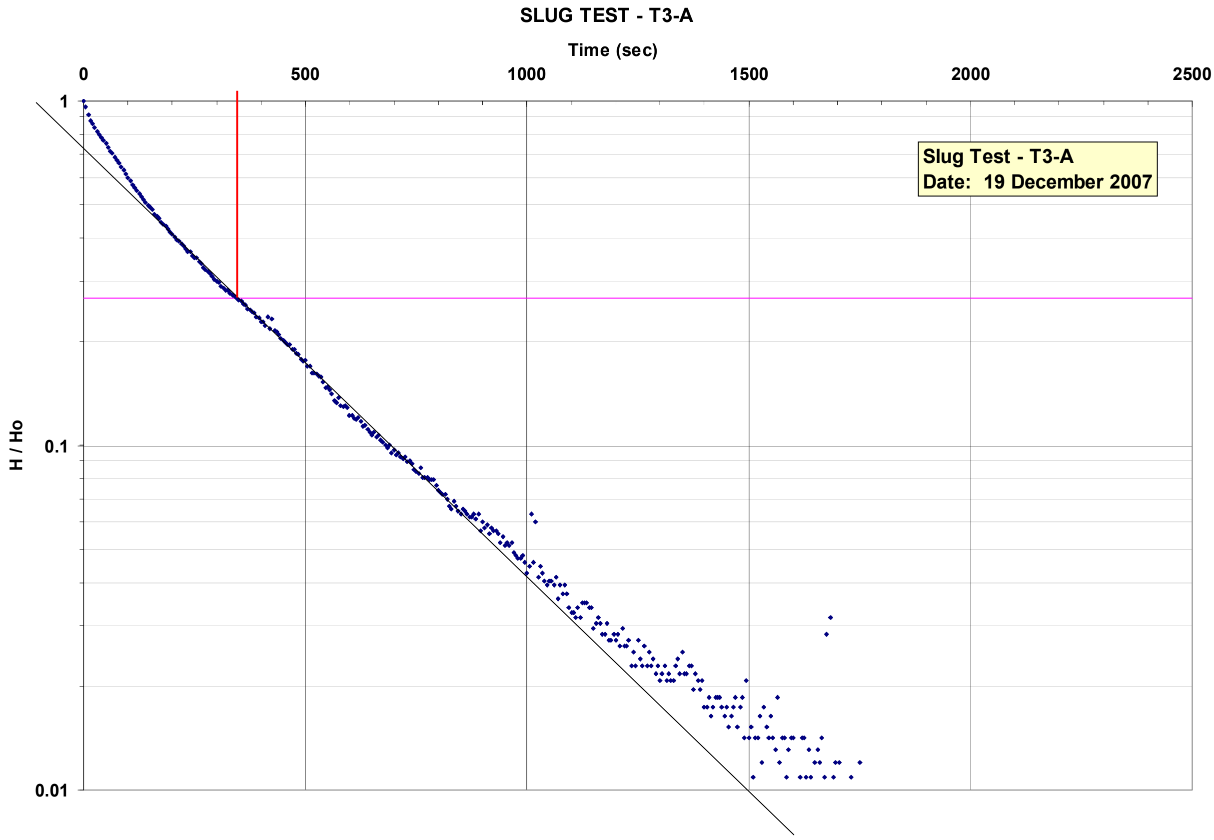
Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T1-A and T1-P**
Drawing No: S03-200	Rev: 0	
aquaterra		**Figure B9**



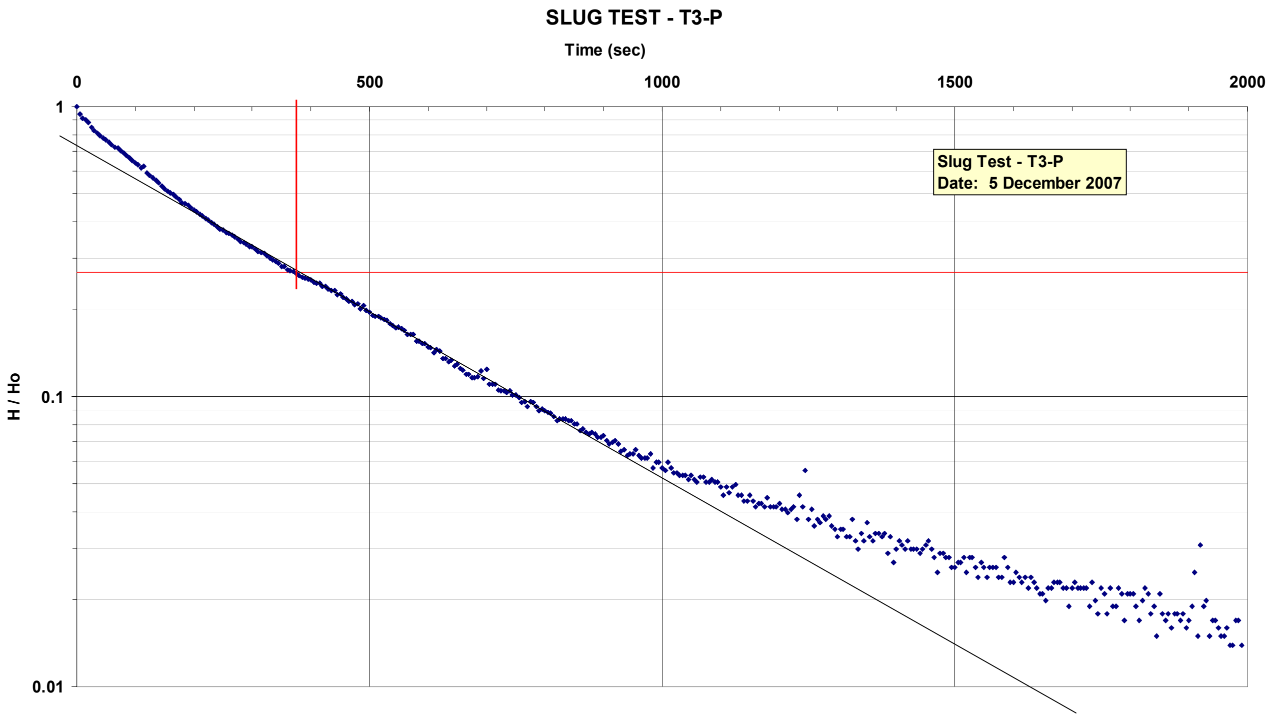


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T2-A and T2-P**
Drawing No: S03-201	Rev: 0	
aquaterra		**Figure B10**



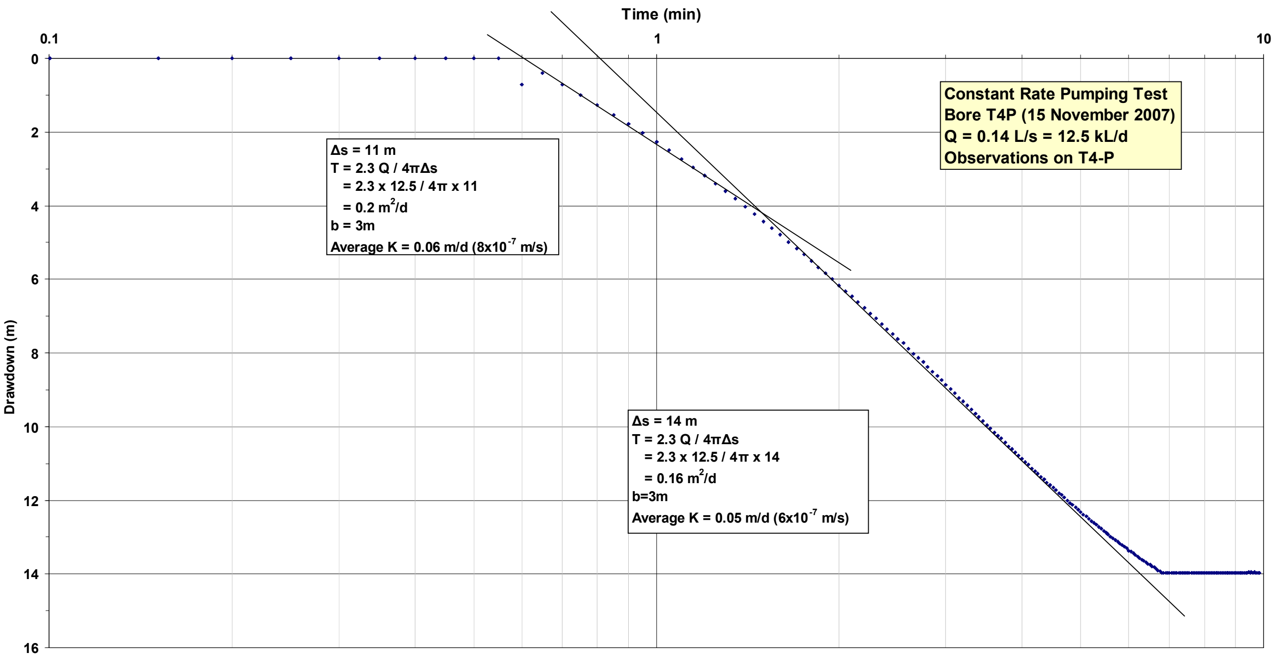


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**	
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T3-A**	
Drawing No: S03-202	Rev: 0		
aquaterra			**Figure B11**



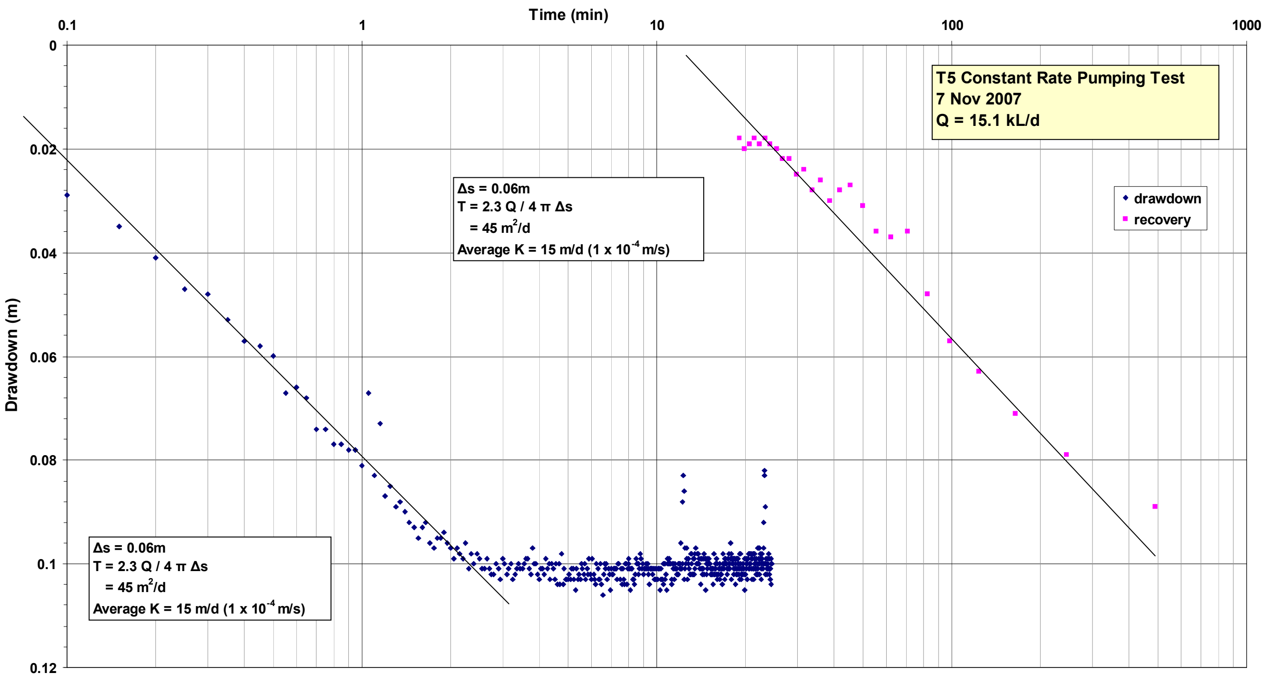
Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T3-P**
Drawing No: S03-203	Rev: 0	
aquaterra		**Figure B12**

CONSTANT RATE PUMPING TEST - T4-P

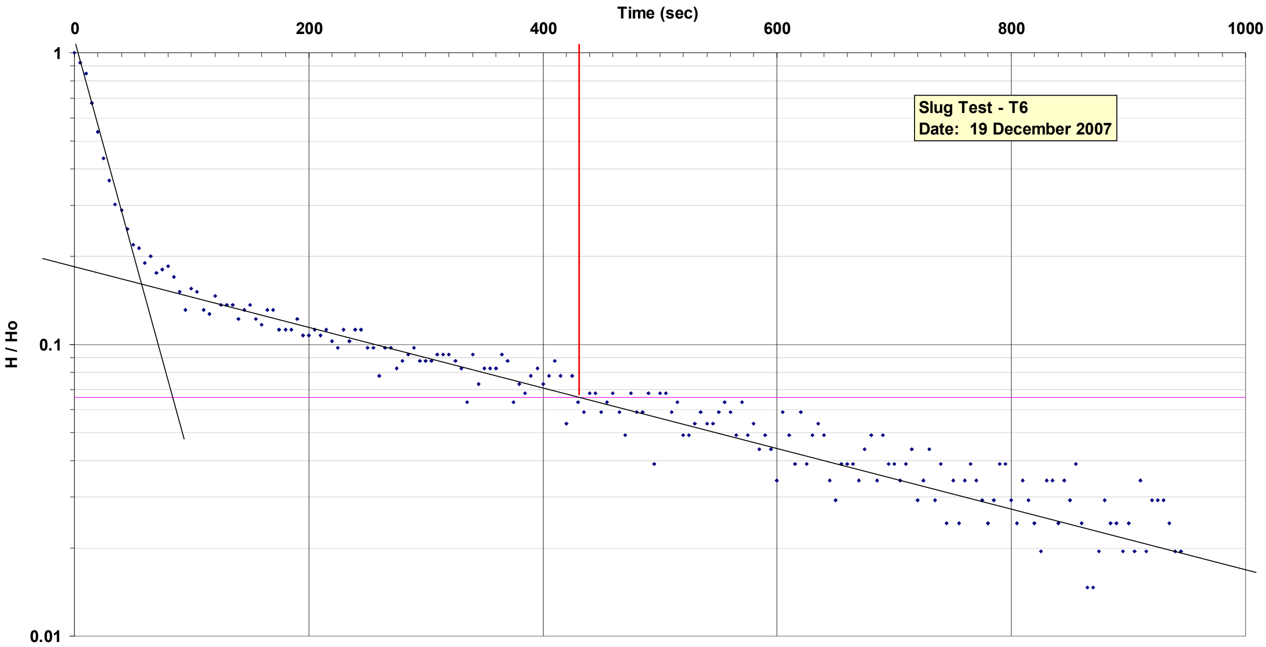


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T4-P**
Drawing No: S03-204	Rev: 0	
aquaterra		**Figure B13**

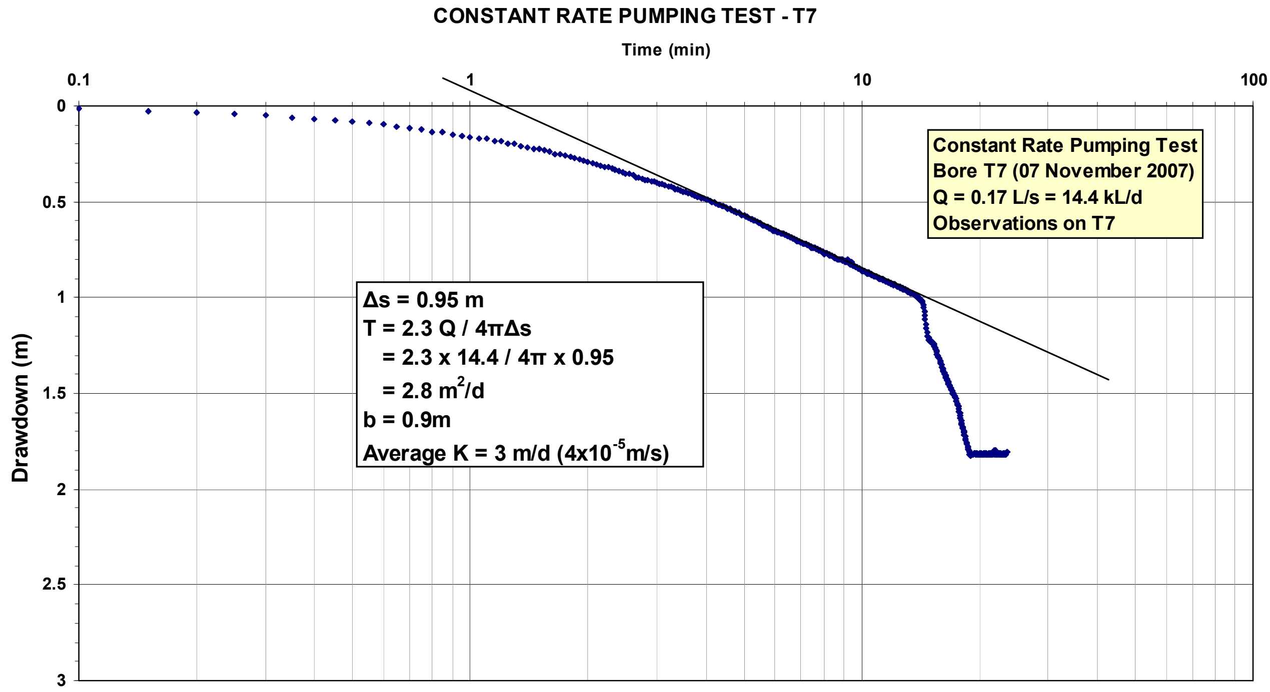
CONSTANT RATE PUMPING TEST - T5

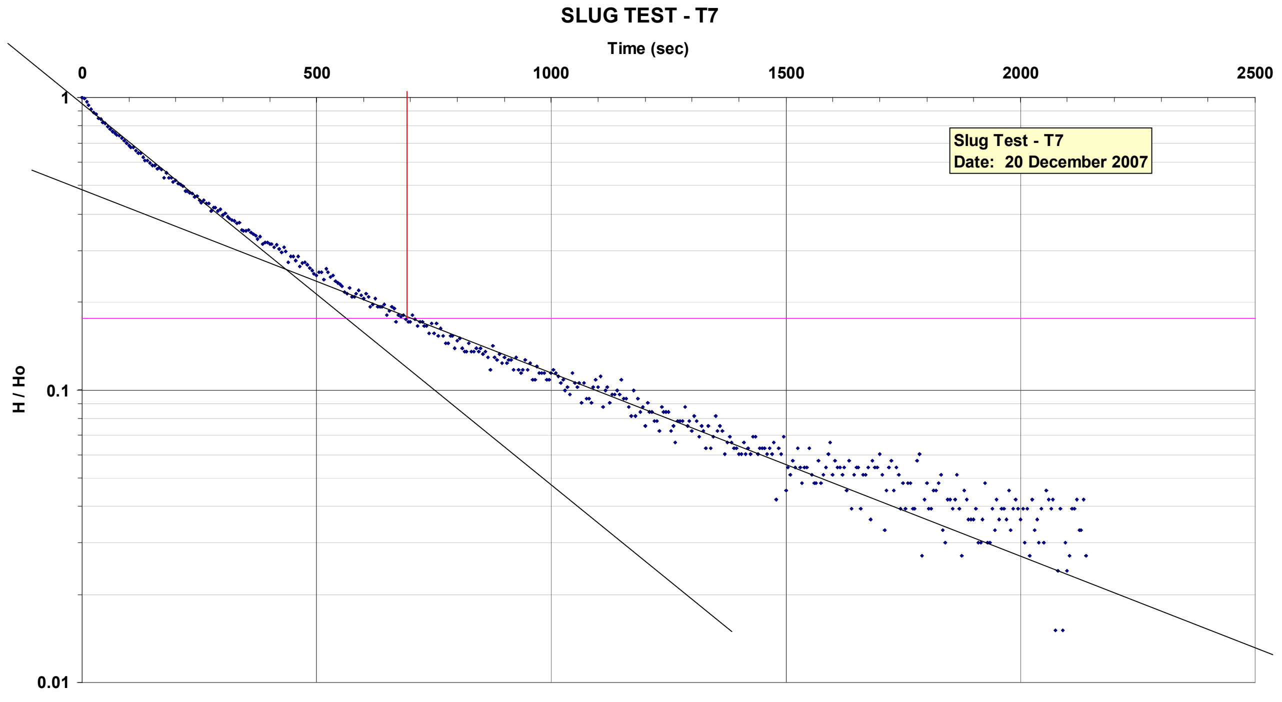


SLUG TEST - T6

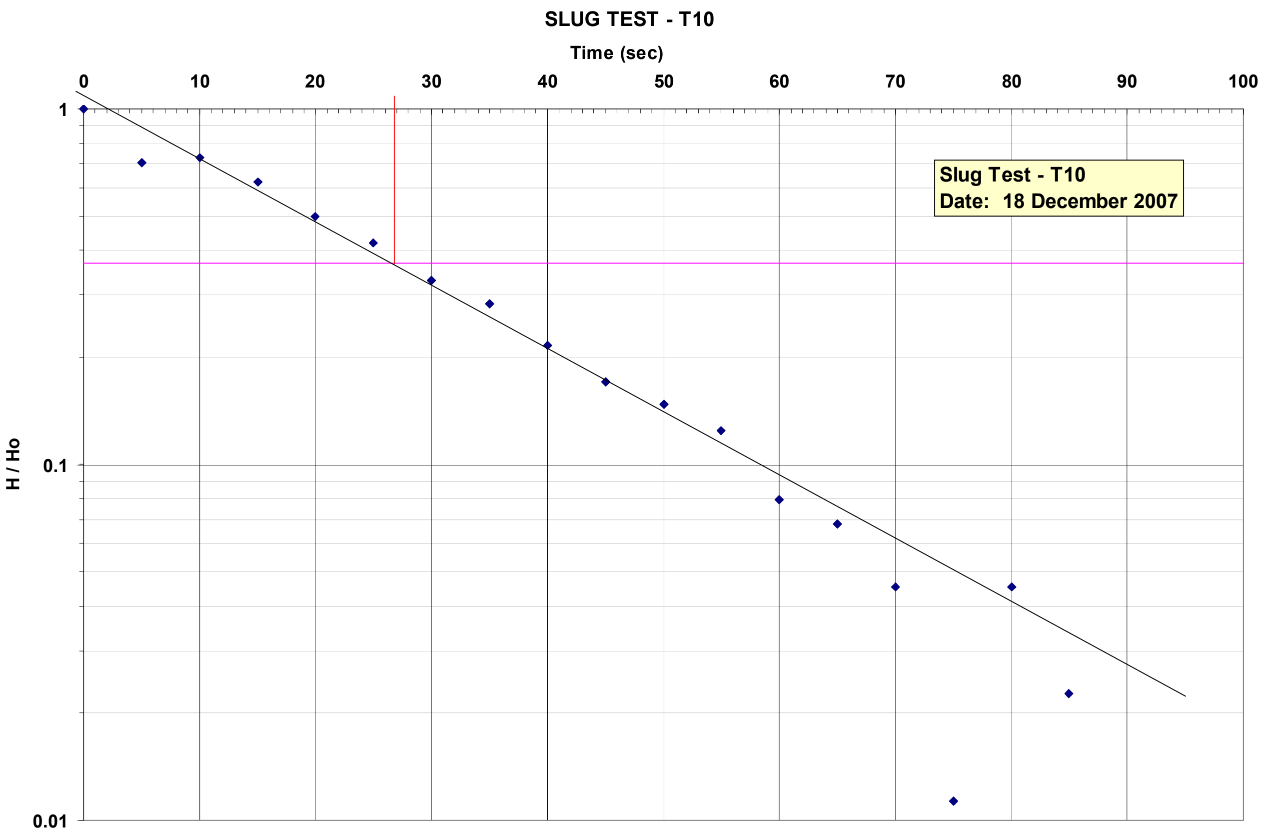


Date:	14 August 2008	Scale:	as indicated	**Ashton Coal Operations Ltd**
Initials:	PJD	Job No:	S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T5 and T6**
Drawing No:	S03-205	Rev:	0	
aquaterra				**Figure B14**



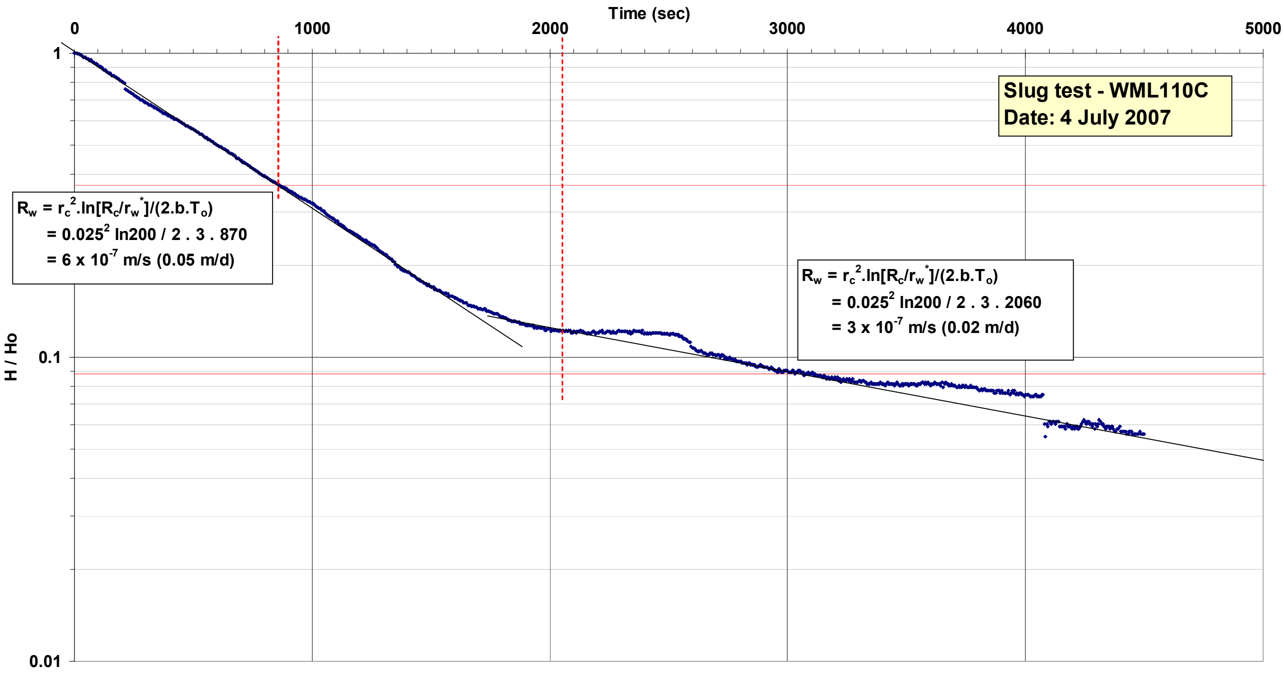


Date: 14 August 2008	Scale: as indicated	Ashton Coal Operations Ltd
Initials: PJD	Job No: S03	BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T7
Drawing No: S03-206	Rev: 0	
aquaterra		Figure B15

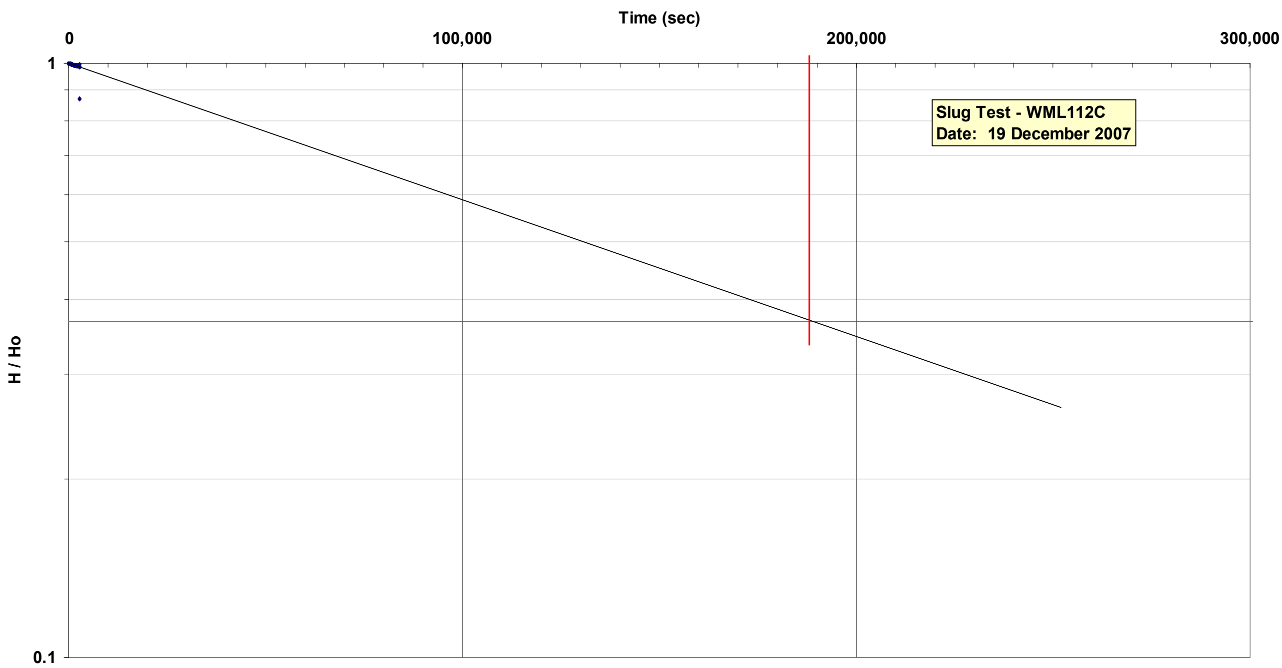


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**		
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING T10**		
Drawing No: S03-207	Rev: 0			
aquaterra			**Figure B16**	

SLUG TEST - WML110C

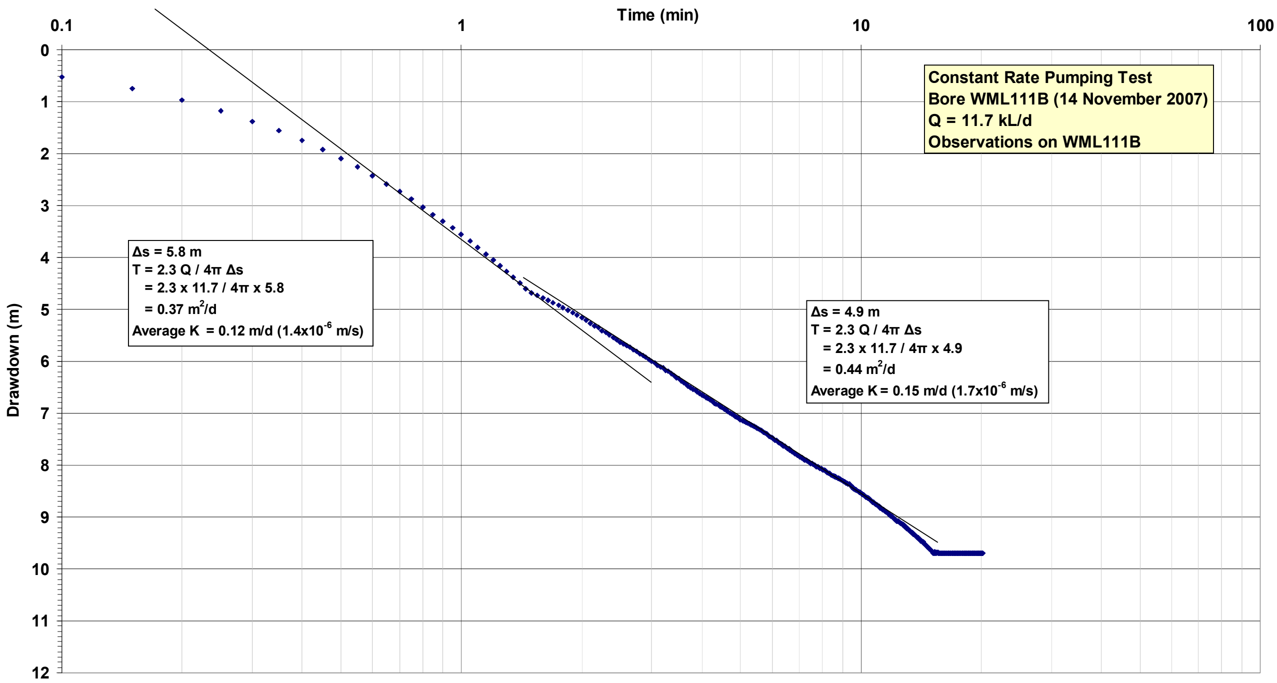


SLUG TEST - WML112C



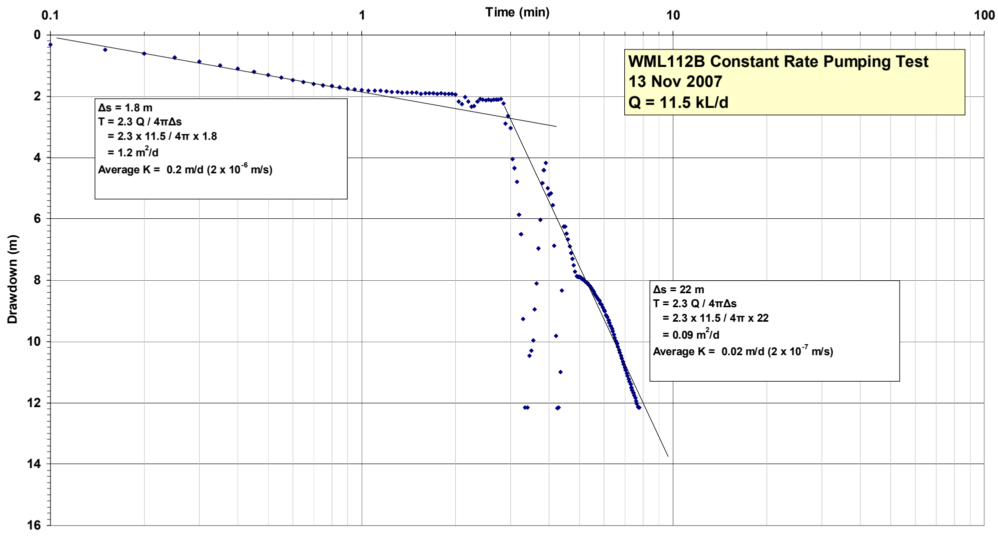
Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING WML110C and WML112C**
Drawing No: S03-208	Rev: 0	
aquaterra		**Figure B17**

CONSTANT RATE PUMPING TEST - WML111B

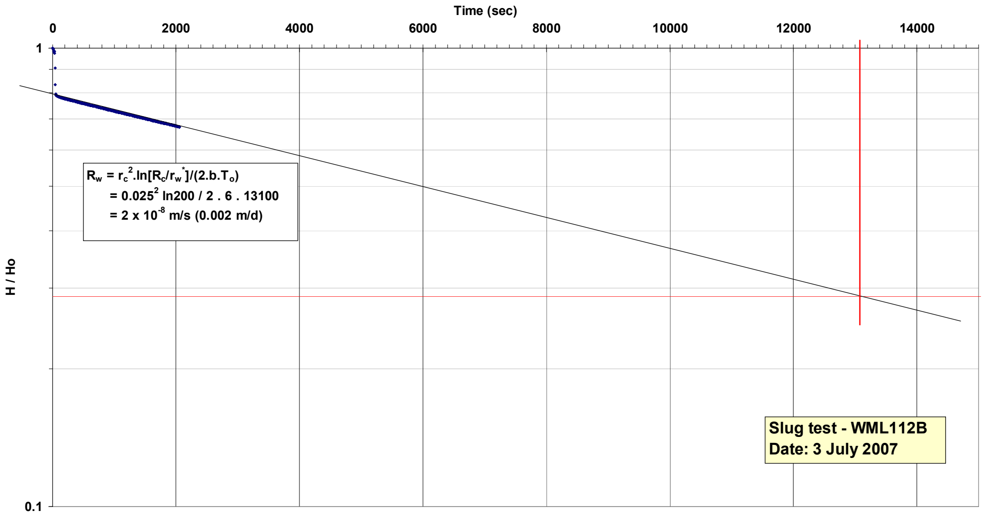


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING WML11B**
Drawing No: S03-209	Rev: 0	
aquaterra		**Figure B18**

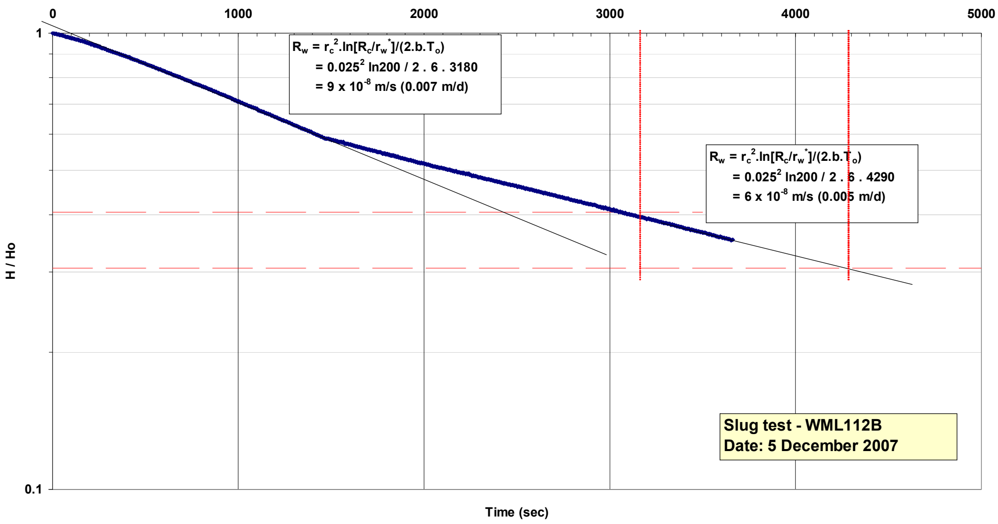
CONSTANT RATE TEST - WML112B



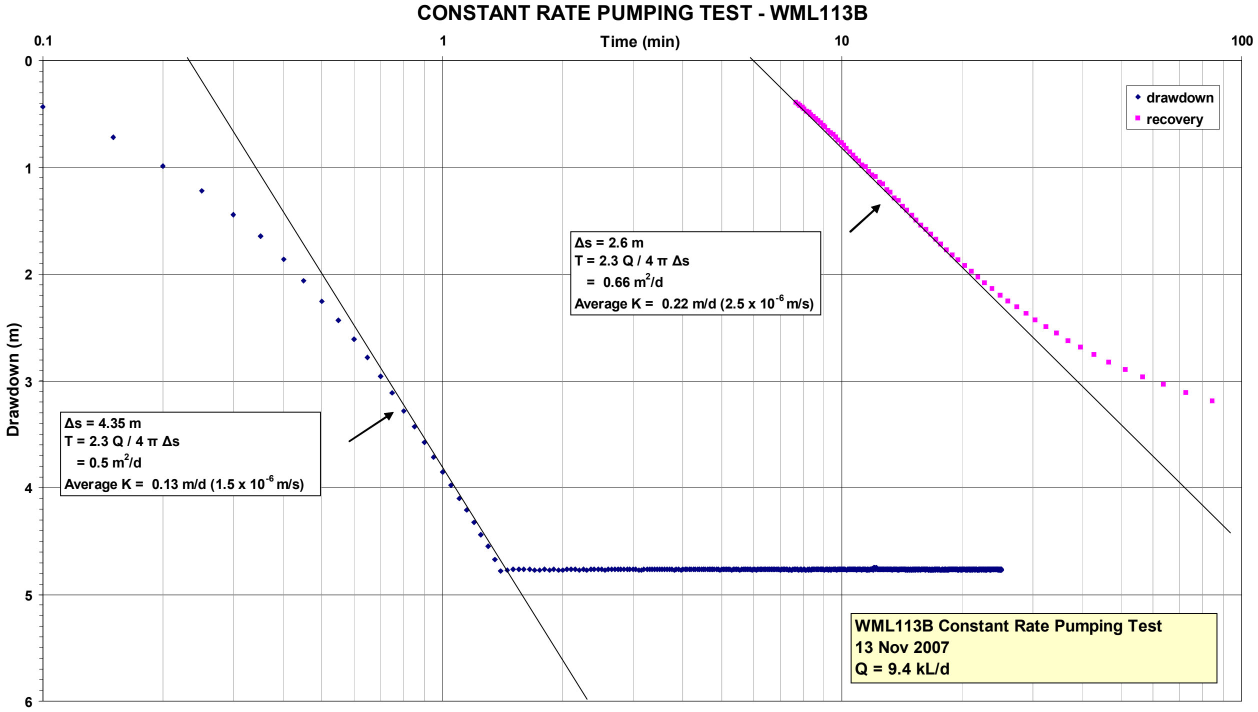
SLUG TEST - WML112B

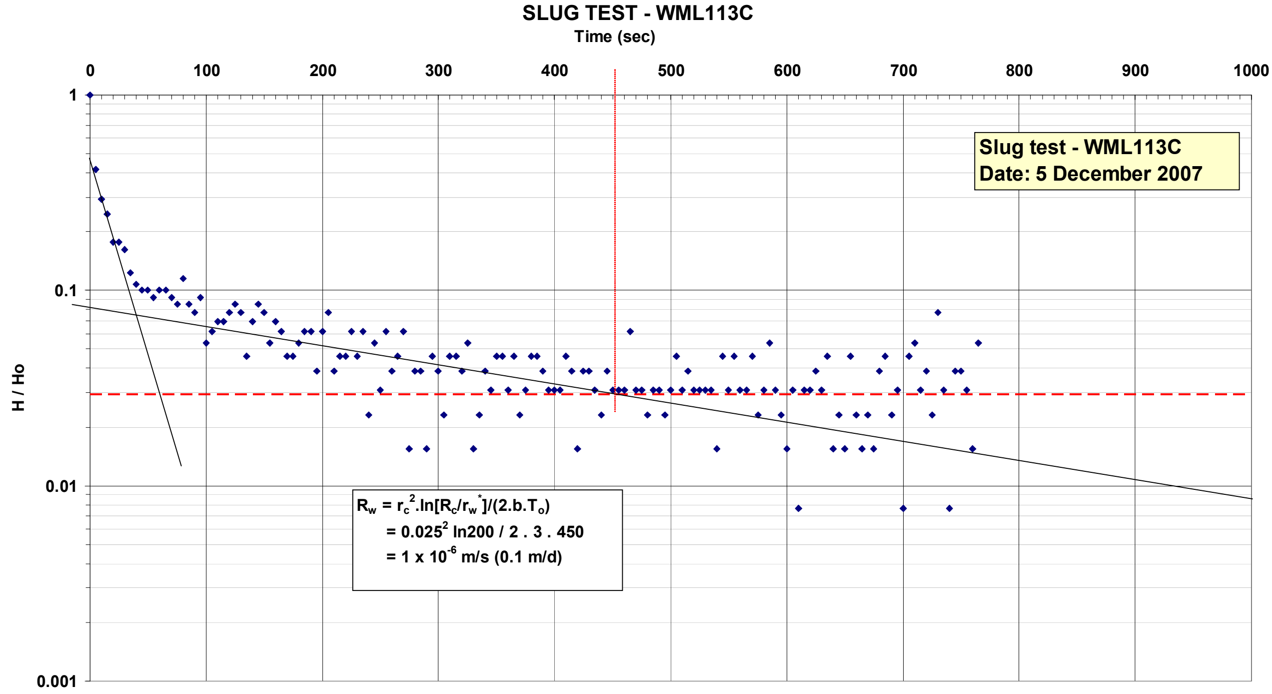


SLUG TEST - WML112B

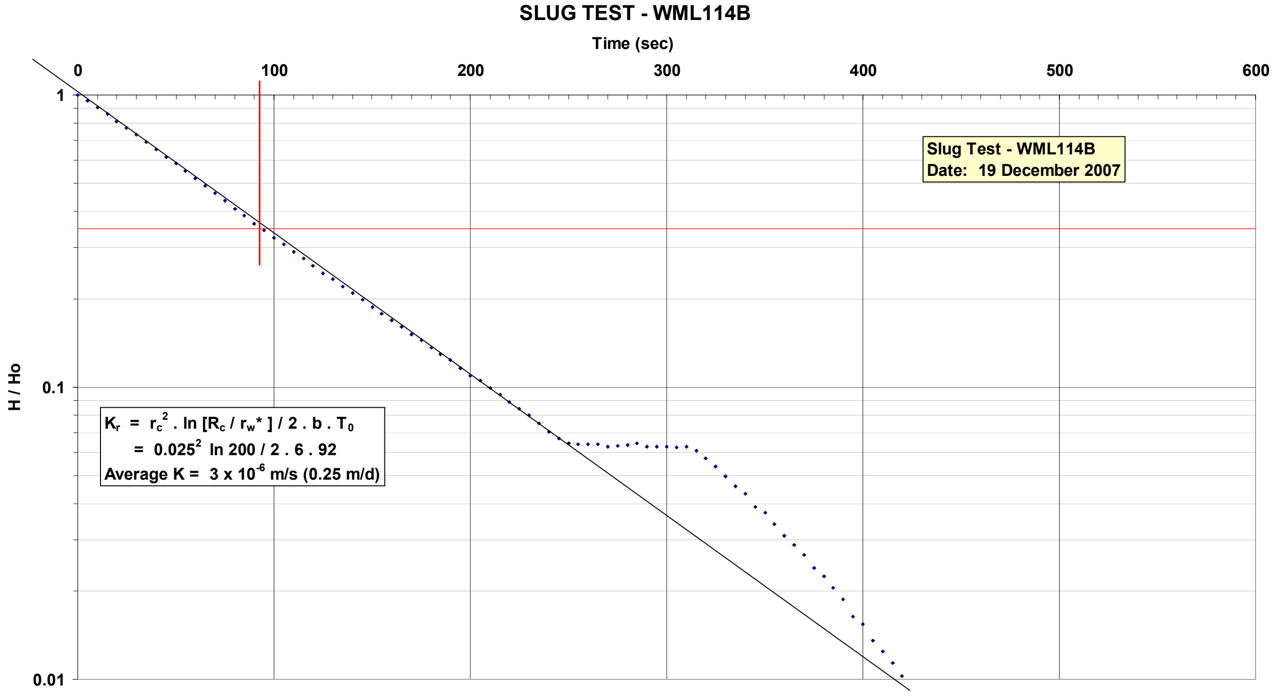


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING WML112B**
Drawing No: S03-210	Rev: 0	
aquaterra		**Figure B19**

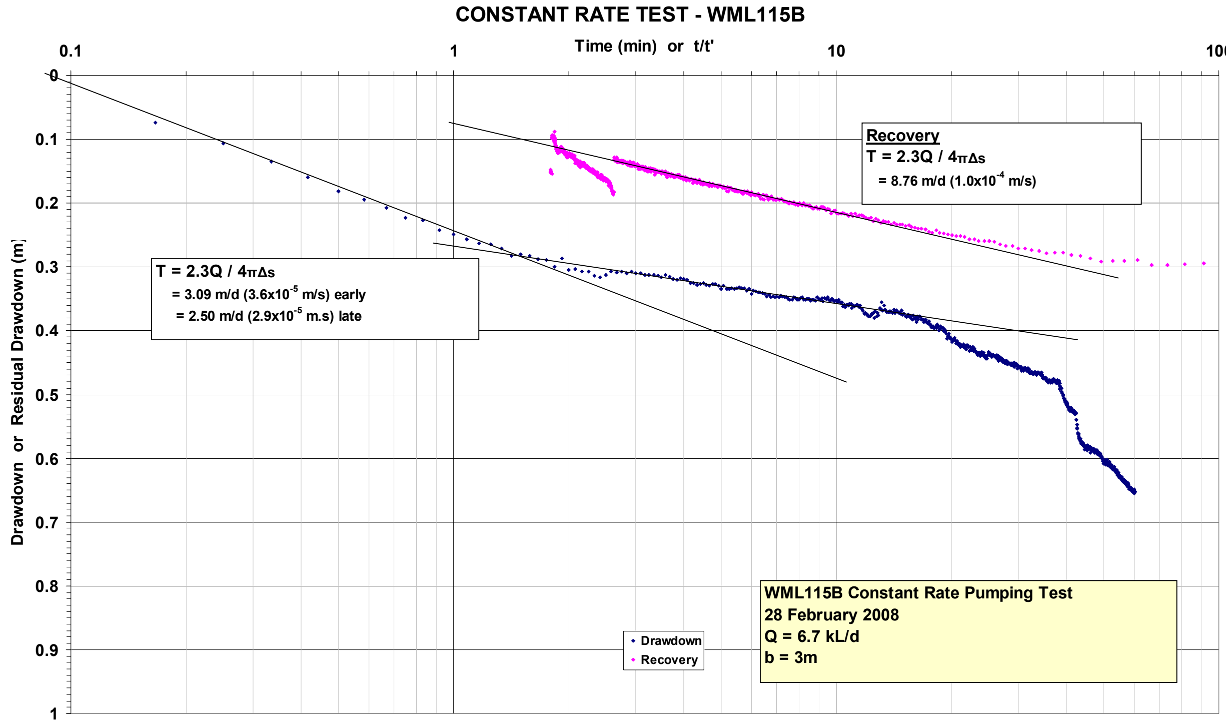


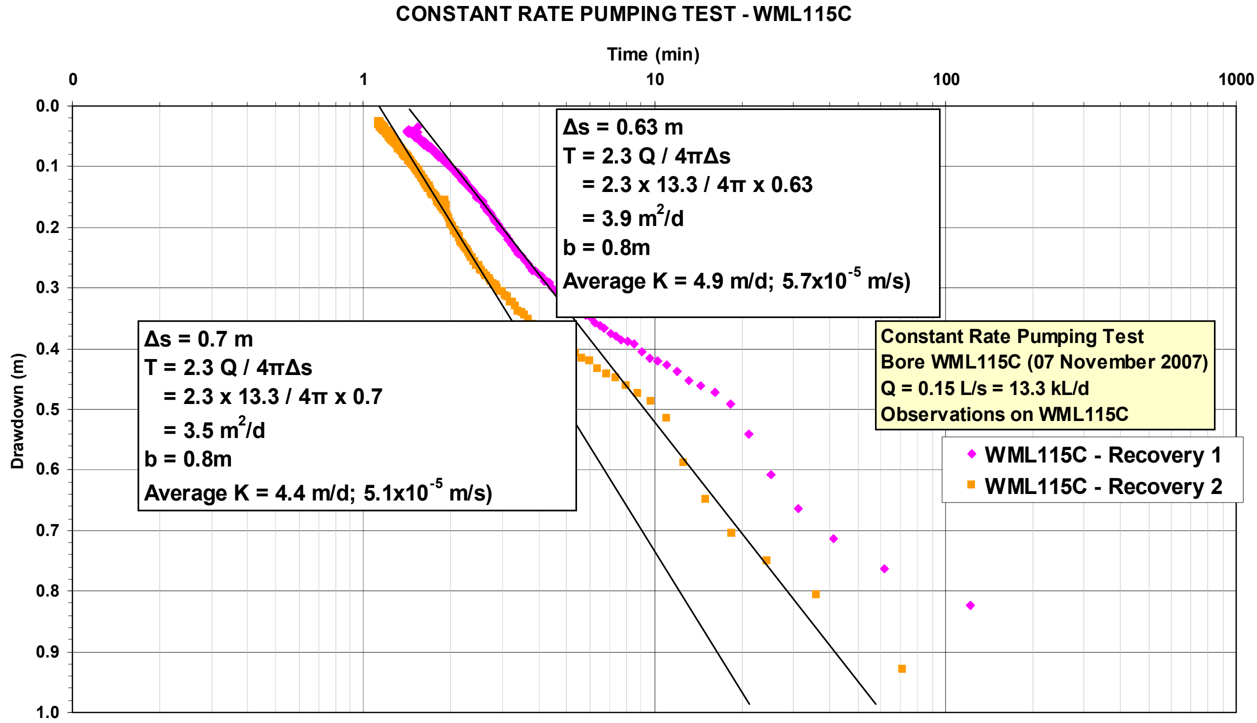


Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING WML113B and WML113C**
Drawing No: S03-211	Rev: 0	
aquaterra		**Figure B20**



Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING WML114B**
Drawing No: S03-212	Rev: 0	
aquaterra		**Figure B21**





Date: 14 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PJD	Job No: S03	**BOWMANS CREEK ALLUVIUM HYDRAULIC TESTING WML115B and WML115C**
Drawing No: S03-213	Rev: 0	
aquaterra		**Figure B22**