Water and Environment

ASHTON UNDERGROUND MINE EXTENSION OF DEVELOPMENT CONSENT AREA – GROUNDWATER IMPACT ASSESSMENT

Prepared for	Ashton Coal Operations Pty Ltd
Date of Issue	23 July 2009
Our Reference	S55B/600/032b

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EXECUTIVE SUMMARY

BACKGROUND

Ashton Coal Operations Pty Limited (Ashton) is seeking to modify the development consent issued by the Minister for Planning on 11 October 2002 in respect to Development Application No 309-11-2001-i. The modification being sought is to allow for an additional Longwall/Miniwall (LW/MW) area outside of the original footprint approved in the 2002 Consent. The additional LW/MW area will allow extraction of coal to the limits of the current Mining Lease and provide replacement coal for the coal lost within the originally approved mining footprint following the finalisation of the LW/MW panel design. The LW/MW design was undertaken to protect Bowmans Creek by providing an aquaclude barrier between the underground mine and Bowmans Creek and its associated alluvium.

This report presents an impact assessment for the additional LW/MW area, comprising LW/MW9.

The Ashton groundwater flow model has been used to simulate mining of the LW/MW 5-9 mine plan, which includes the LW/MW9 panels which form the subject of this report. The groundwater modelling was carried out to investigate the potential impacts of the proposed mining on the groundwater flow system, including in particular, the potential impacts on baseflows to Bowmans Creek, Glennies Creek and Hunter River. The development of the Ashton groundwater model, its calibration against observed impacts during open cut and underground mining up to April 2008, and the predicted impacts of the proposed mining up to the completion of LW/MW9, have been reported in Aquaterra (2008c).

This report focuses on the incremental impacts of mining of LW/MW9, compared with prior mining up to the completion of extraction of MW8, the last panel in the current LW/MW plan which lies within the currently approved mine footprint .

The impacts predicted from this assessment can be summarised as follows:

- Groundwater inflow rates during mining of LW/MW9 (1.45-1.55 ML/d) are not noticeably different from those predicted for the prior extraction of MW8 in the already approved mining area (1.43-1.53 ML/d). It is also noted that the predicted inflow rates from the current modelling are lower than those predicted in the original EIS for the final stage of mining of the Pikes Gully Seam in the currently approved mining area.
- Current modelling predicts a 1.1-1.2 L/s reduction in Bowmans Creek baseflow during the mining of LW/MW9, compared with the predicted reduction of 0.7-1.1 L/s during the prior extraction of MW8. It is noted that these baseflow reductions are both substantially smaller than the EIS prediction of 4.3 L/s (0.37 ML/d) for the same stage of underground mining.
- Negligible additional groundwater level drawdowns are predicted during mining of LW/MW9 compared with the prior mining of MW8. The Pikes Gully Seam is predicted to have already been substantially dewatered across the mine area prior to the commencement of extraction from LW/MW9.

[1] The original development consent was based on a mine plan of seven longwall panels, LW1-LW7. The current mine plan involves 9 panels, which are a combination of full-width longwall (LW) panels and reduced-width miniwall (MW) panels. The first four panels LW1-LW4 are currently being extracted under an SMP approved in 2006.

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FIGURES

1 INTRODUCTION

The Ashton Coal Project is located 14km west of Singleton in the Hunter Valley region (Figure 1) between the villages of Camberwell and Ravensworth on the New England Highway (Figure 2). The project 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 mining operations are located within mining lease ML1533.

The open cut mine 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 a portal in the Arties pit.

The initial mine plan comprised seven longwall panels (LWs 1 to 7), with an unmined area along the western edge of the ML to allow for a diversion of Bowmans Creek. During the Development Consent application process, the Bowmans Creek diversion option was removed, however, the Underground Mine plan was not altered to show the mining footprint extending to that area.

The first four longwall panels the Pikes Gully Seam (LWs 1 to 4) in gained SMP 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 of LW3 has commenced, 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, LWs1 to 4, 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 1.3. The original mine plan described in the EIS has been amended, and it is now proposed to mine the remainder of the Pikes Gully Seam from a further five panels referred to as Longwalls and Miniwalls 5 to 9 (LW/MW 5-9), also shown on Figure 3.

The changes to the mine layout have been made firstly with miniwalls to ensure that no direct hydraulic connection between the Bowmans Creek alluvium and the underground workings can occur through subsidence cracking, and secondly an extension of the mining footprint (LW/MW9) to include the old creek diversion area closer to the western boundary of ML1533 to optimise coal recovery. The LW/MW 5-9 mine plan has been assessed, and predicted impacts on the groundwater and surface water have been reported in Aquaterra (2008c), which was prepared in support of an SMP Application for LW/MW 5-9 lodged in October 2008.

This present report has been prepared to support a development application (DA) amendment to allow an extension of the currently approved mining footprint as detailed above. The additional footprint area includes LW/MW9 from the current proposed mine plan, in the Pikes Gully Seam. The mining footprint area approved by the 2002 development consent (as defined by Consent Condition 1.2 (v)) is shown on Figure 3. It is seen that LW/MW9 extends outside the original mining footprint approved in the consent, but lies fully within the application project area and within ML1533.

2 DEVELOPMENT OF LW/MW 5-9 MINE PLAN

The western half of the underground mining area is overlain by Bowmans Creek and its associated alluvial sediments (Figure 4). The Development Consent granted on 11 October 2002 for the project (Minister for Planning, 2002) included conditions 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.*
>
> *4.13All 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.*

To meet the above consent conditions, the Ashton Coal Project assessed a number of longwall design options and has developed a mine plan for the Pikes Gully Seam which comprises panels of various widths and lengths for the western half of the underground mine. This mine plan is referred to as Longwalls and Miniwalls 5 to 9 (LW/MW 5-9). The basis for this mine plan design is described in detail in the LW/MW5-9 SMP Application and supporting documents, including Aquaterra (2008c) and SCT (2008a).

The LW/MW 5-9 mine layout incorporates the following elements:

▼ Full width (216m) panels beneath areas lacking alluvium or beneath alluvium/colluvium containing saline groundwater; and

▼ Miniwalls of varying width (60m to 93m) to ensure a panel width to cover depth ratio of 0.6 or less beneath Bowmans Creek and areas of good quality saturated alluvium.

MW9 is a miniwall situated largely beneath Bowmans Creek and floodplain alluvium, and has a panel width of 93m to ensure a maximum width to cover depth ratio of 0.6. LW9 is situated substantially outside the floodplain, and its width does not have to be constrained for alluvium protection reasons, but is limited to a 141m width by the proximity of the western boundary of the mining lease ML1533.

Table 2.1: Panel Widths for LW/MW9

Longwall / Miniwall	Panel Width (m)	Overburden Depth (m)	W/D Ratio (Maximum)	W/D Ratio (Minimum)
MW9	93	160 - 190	0.6	0.5
LW9	141	140 – 180	1.0	0.8

MW9 is located more than 500m from Hunter River at its closet point, and at least 400m from the interpreted edge of Hunter River alluvium (Figure 4).

3 PREVIOUS STUDIES

The results of previous work on review of performance of the LW1 and LW2 panels and the Bowmans Creek alluvium have been detailed in separate reports (Aquaterra, 2008a-c; 2009) and will not be repeated verbatim here. However, the key outcomes/findings of these studies were as follows:

- The Bowmans Creek alluvium forms a shallow aquifer unit within the Bowmans Creek floodplain that is hydraulically distinct from both the underlying Permian coal measures and the Hunter River alluvium. It merges laterally with colluvium on the flanks of the floodplain, and with residual soils in the highly weathered upper part of the Permian sediments.
- The Bowmans Creek alluvium contributes some baseflow to Bowmans Creek, although the contribution from the planned mining area is very small. Baseflow is also derived locally from the Permian.
- 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 evidenced by distinctly different groundwater levels, differences in groundwater quality, and differing responses to recharge and mining activity.
- Despite the absence of direct hydraulic connection and the presence of an aquaclude between the Bowmans Creek alluvium and the Pikes Gully seam, there is potential for some leakage from the alluvium to the underground mine workings due to the intrinsic (albeit very low) permeability of the coal measures. Even if coal were extracted by first workings only, with no enhancement of permeability by subsidence-induced fracturing between the goaf and the base of the alluvium, simple analytical flow modelling has shown that the prevailing natural vertical permeability of the coal measures overburden would potentially allow leakage of 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. 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 required by Consent Condition 3.9).
- Monitoring during mining of LW1 and LW2 has shown groundwater level impacts in the Pikes Gully Seam and in the deeper sections of the overlying coal measures. Reduced drawdowns occur at higher levels in the coal measures, but no impacts have been observed in the near-surface weathered Permian or in alluvium above the mine area. Cover depths in LW1 ranged from 35m to 90m, and in LW2 from 50m to 105m.
- Piezometers in the lower sections of the Pikes Gully seam overburden which initially showed drawdown response to subsidence above LW1 or LW2 have shown partial recovery after the initial mining impact. This suggests that some degree of self-healing of subsidence fractures is occurring.
- No drawdown impacts have been observed in the coal measures below the Pikes Gully Seam, even in the Arties Seam which is located just 5-10m below the Pikes Gully (e.g. WML189 – see Figure 5).

4 HYDROGEOLOGY

4.1 GEOLOGY

The study area is located within the Hunter Coalfield of the Sydney Basin. Regional surface geology is shown on Figure 6.

The major mineable coal seams identified in the A area are (in descending stratigraphic order) the Pikes Gully, Upper Liddell, Upper Lower Liddell, and Lower Barrett Seams. Within the overburden above the Pikes Gully seam, other seams are present, including the Bayswater Seam (previously mined at the Ravensworth open cut to the west) and Lemington Seams 1-19 of varying thickness.

The target coal seams are separated by interburden sediments, which comprise sandstone, siltstone, conglomerate, mudstone, and shale, and occasional minor coal seams. The interburden between the Pikes Gully and Bayswater Seams, including the Lemington Seams, is essentially the overburden to the Pikes Gully Seam. A representative geological cross section through the area is presented in Figure 7.

The Pikes Gully coal seam thickness in the study area varies between 2m and 3m, though it is generally in the range of 2.3 to 2.8m. The Pikes Gully seam outcrops/subcrops in the eastern part of the Ashton Coal Project area and is up to about 200m deep (around -140m AHD) in the south west. The Lower Barrett seam, which is the deepest seam considered for potential mining in the Ashton underground mine, occurs within the underground mining area at depths ranging from around 120m to more than 300m below ground (-160 to -240m AHD). The interburdens between the seams vary in thickness between 7m and 63m (refer **Table 4.1**).

Within the project area, alluvium occurs in association with the Hunter River and its tributaries Bowmans Creek and Glennies Creek. Investigation drilling of the Bowmans Creek alluvium (Aquaterra, 2008b) indicates up to about 15 metres of sandy silts, silts and silty clays, with horizons of silty sands and gravels. Maximum recorded saturated thickness is 4.5m.

The Hunter River alluvium comprises clay and silty clay, with gravel horizons. A basal gravel horizon 8.5m thick was drilled in RA27 (Figure 4). The saturated thickness in this bore was 6m, but greater saturated thicknesses are expected.

Table 4.1: Thicknesses of Coal Seams and Interburden Layers in the Ashton Project Area

Geological Unit	Average	Minimum	Maximum
Pikes Gully overburden (Pikes Gully to base of alluvium)	Variable from 0m to 200m, due to dip on strata		
Pikes Gully Seam	2.2 m	1.8 m	3.0 m
Interburden – Upper Liddell to Pikes Gully	36 m	13 m	63 m
Upper Liddell Seam		2.2 m	3.2 m
Interburden – Upper Lower Liddell to Upper Liddell	28 m	7 m	47 m
Upper Lower Liddell Seam		2.1 m	6.1 m
Interburden – Lower Barrett to Upper Lower Liddell	40 m	24 m	62 m
Lower Barrett Seam		2.2 m	5.9 m

4.2 AQUIFERS

Two distinct aquifer systems occur in the study area:

- A fractured rock aquifer system in the Permian coal measures, with flow occurring predominantly in the coal seams.

- A shallow porous media regolith/alluvium aquifer system in the unconsolidated sediments of the alluvium associated with Bowmans Creek, Glennies Creek and Hunter River, merging into colluvium and residual soil (extremely weathered coal measures).

4.2.1 HYDRAULIC PARAMETERS

The coal measures strata have little primary or intergranular permeability, but secondary or fracture permeability exists in joints and fractures.

Generally, the coal seams are more brittle and more densely fractured than the interburden strata and therefore have a relatively higher hydraulic conductivity, typically one to two orders of magnitude higher than the interburden material. Within the coal seams, groundwater flows predominantly through cleat fractures, with very little evidence of structure-related fracturing. Vertical permeability is significantly lower than horizontal (typically three or more orders of magnitude lower).

A summary of representative aquifer properties of the hydrogeological units in the study area, based on hydraulic testing described in Aquaterra (2008a, 2008c) is given in **Table 4.2**.

Table 4.2: Representative Aquifer Parameters for Main Hydrogeological Units

Units	Horizontal Hydraulic Conductivity (m/d)		Confined Storativity	Unconfined Specific Yield
	Tested Range	Median		
Bowmans Creek Alluvium	0.0002 to 15	0.7	0.0001	0.05
Glennies Creek alluvium	0.07 to 0.75	0.3	0.0001	0.05
Floodplain alluvium of the Hunter River	50	50	0.0001	0.1
Coal Seams	0.01 to 10	0.04	0.0001	0.005
Interburden/overburden	<0.000001 to 0.008	0.0003	0.00001	0.005

Vertical hydraulic conductivities are considered to be 2-3 or more orders of magnitude lower than the horizontal hydraulic conductivity in all units, based on the very strongly bedded nature of the strata and the role of bedding plane features in controlling groundwater flow. This applies especially to the interburden sediments which comprise interbedded siltstones, sandstones, claystones and shale, but also to the coal seams themselves (which frequently contain interbeds of siltstone/sandstone/ claystone).

4.2.2 GROUNDWATER LEVELS

Groundwater levels in the upper part of the Permian coal measures tend to reflect the local topography, with higher groundwater levels in elevated areas and lower groundwater levels in topographic lows. However, groundwater levels at depth in the coal measures are more regionally-controlled, and are independent of the local topography.

Early monitoring data from Ashton indicates that prior to commencement of mining at Ashton, groundwater levels in the Pikes Gully seam were above the surface water levels in Bowmans Creek and Glennies Creek. Near the downstream end of the Bowmans Creek floodplain, bores drilled for piezometer installations (Figure 4) were freely flowing until the piezometers were installed and the holes grouted up (e.g. WML112). Groundwater pressures in some of the deeper coal seams are still at or above the ground surface in this area (e.g. WML111 and WML213).

Potentiometric contours for the Pikes Gully Seam have been prepared from recent monitoring data (Figure 7). The potentiometric heads in the coal measures at this time have been influenced by the effects of underground mining (LW1, LW2 and part of LW3 longwall panels, LW3 development headings and the NW Mains) and possibly some effect from longer-term mining at nearby mine sites.

The potentiometric contours for other seams are expected to have quite different patterns – some of the lower Lemington seams would be similar to the Pikes Gully seam, but with a less pronounced response to the underground mining. Seams beneath the Pikes Gully would display negligible impacts from the underground mine, but may show some response to open cut mining. Shallower Lemington seams and the Bayswater seam would show some response to current mining at the Narama pit and former Ravensworth open cut mining to the west, but no response to underground mining.

Groundwater levels in the weathered coal measures, as measured in piezometers installed in the shallowest water-bearing interval in the Permian, tend to reflect the local topography.

Contours of the water table in the Bowmans Creek alluvium are shown on Figure 8, based on measured water levels in standpipe piezometers from the Bowmans Creek alluvium investigation program (Aquaterra, 2008a). Figure 8 also shows the lateral extent of saturated Bowmans Creek alluvium, determined from a combination of drilling results, aerial photography, aeromagnetic survey, ground mapping and groundwater level monitoring. In the Bowmans Creek alluvium, groundwater levels show a gradient from north to south (i.e. upstream to downstream) but also converge about Bowmans Creek.

The shallow groundwater levels are generally similar to or slightly higher than in the immediately underlying weathered Permian coal measures. However, in unstressed (pre-mining) conditions, the potentiometric surface in the deeper Permian coal measures is higher than the water table, and there is a tendency for increasing heads with depth (Aquaterra, 2008a).

4.2.3 RECHARGE

Table 5.3 summarises rainfall data from the Jerry's Plains weather station, situated approximately 14 km to the southwest of the Ashton Project. The table lists the mean monthly rainfall and mean annual rainfall, based on more than 100 years of rainfall data since 1884.

Table 4.3: Average Monthly and Yearly Rainfall and Evaporation Data (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall*	80	70	58	44	41	48	44	37	42	52	57	67	639
Evaporation#	220	169	154	118	89	56	69	81	112	164	195	204	1630
Balance	-140	-99	-96	-74	-48	-8	-25	-44	-70	-112	-138	-137	-991

* BOM Jerry's Plains Meteorological Station
# BOM Scone SCS Meteorological Station

The alluvium and regolith aquifer systems are recharged by direct infiltration of rainfall and local runoff. The primary mode of recharge to the Permian coal seam aquifers is by direct infiltration where the various seams outcrop or subcrop beneath the alluvium or regolith layer. It is considered that recharge via downward leakage through overburden and interburden layers subject to head differences is a very minor or negligible component of recharge. However, where the overburden/interburden has been altered through subsidence fracturing, vertical leakage between seams is more significant.

The nearest station for which average monthly and yearly A Class pan evaporation data are available is Scone SCS Meteorological Station, where the evaporation records date back to 1950 (see **Table 5.3**). The data indicate that evaporation generally exceeds rainfall, indicating that a soil water balance deficit occurs most of the time and only a small percentage of the rainfall is available for runoff and/or recharge of groundwater. Regional studies suggest approximately 0.5% to 1.0 % of the annual rainfall percolates to the coal measures groundwater system (HLA, 2001). Based on observation of responses to rainfall in the Ashton project area, we consider that recharge rates are likely to be highest in areas where the coal seams either outcrop or subcrop beneath alluvium or colluvium, and a recharge rate of 1.7% has been assigned to these areas in the modelling studies. Conversely, recharge rates into weathered coal measures is generally quite low, probably in the order of 0.2% of rainfall. This would result in overall coal measures recharge rates similar to those suggested by HLA (2001).

Recharge rates to the alluvium are expected to be similarly quite low, based on observations of persistent ponded water following the June 2007 rainfall and flood event. Recharge rates of 0.8% have been assigned to the Hunter River alluvium and 0.6% to the Glennies Creek and Bowmans Creek alluvium.

4.2.4 DISCHARGE

Groundwater discharge from the Permian coal measures occurs through evapotranspiration and baseflow contributions to the creeks and rivers, including some discharge to the alluvium, and by groundwater abstraction/pumping.

Analysis of groundwater quality data (Aquaterra, 2008a) indicates that, while some baseflow to Bowmans Creek does occur within the Ashton Coal Project area, the contribution is very small and intermittent.

There is no existing groundwater abstraction from the coal measures in the study area, apart from the coal mine dewatering. Ashton Coal Project is currently extracting around 6 to 7 L/s of groundwater inflows from the underground operations (LW1 to LW3 longwall panels and the development headings).

Alluvial groundwater is only sparingly used for stock and domestic purposes, and a small number of registered bores and wells have been identified from a search of the DWE groundwater database. No registered water supply bores are located within the Ashton mining lease area. The two nearest registered water supply bores are located in Camberwell Village (north-east of the underground mine), and on the south bank of the Hunter River, south-west of Ashton.

Alluvial groundwater in the Bowmans Creek valley discharges via evapotranspiration or baseflow discharge to Bowmans Creek, with a small component from the southern end of the valley possibly discharging directly to Hunter River.

4.3 SURFACE DRAINAGE

The Ashton Coal Project is located in an area of rolling hills typical of the central part of the Hunter Valley, with elevations ranging from approximately 60 mAHD in the valleys to approximately 100 mAHD on the ridge line running north-south adjacent to Glennies Creek. The area is drained by Bowmans Creek to the west and Glennies Creek to the east. Both creeks discharge into the Hunter River, which flows from west to east along the southern boundary of the Ashton project area.

The flow in Bowmans Creek is perennial for most years but it has been known to go dry for short periods. The DWE gauging station (Foy Brook 210130) located on Bowmans Creek midway between New England Highway and the Hunter River (Figure 4) reported a 50 percentile flow rate of 1.5 ML/d in the period 2003 to 2008, with zero flows on 4.3% of days. DWE gauging station Ravensworth 210042, located on Bowmans Creek 2km upstream from New England Highway, reported a 50 percentile flow rate of 2 ML/d from the period 1959 to 1999, with zero flows on 35% of days.

Glennies Creek flows are about 100 ML/day or more for 50% of the time, with a minimum sustained flow of approximately 10 ML/day. Flows are regulated by the Glennies Creek Dam which is located upstream of Ashton.

4.4 IMPACTS OF MINING ON AQUIFER PROPERTIES

The impacts of longwall mining on aquifer properties are three-fold:

- Coal extraction in development headings creates a void which will have essentially infinite permeability and 100% storativity/specific yield when filled with water.

- The goaf and immediate roof collapse zone above an extracted longwall panel will comprise a zone of very high permeability and storativity.

The subsidence zone above the goaf will comprise a region of intense to moderate fracturing extending to heights that will be dependent on the longwall geometry (seam extraction thickness, panel width and chain pillar width), overburden cover depth, and the geological nature of the overburden, particularly rock strength properties and rock stress behaviour. This fractured zone will have moderately to highly altered vertical and/or horizontal permeability, and possibly minor increase in storativity.

- Shallow surface fracturing may occur within the subsidence zone above the goaf, which can result in temporary increase in near-surface vertical permeability, extending down to depths of 10-20m.

Subsidence predictions have been made by SCT for the LW/MW 5-9 area (SCT, 2008c). SCT predicted maximum subsidence of 200mm over miniwall MW9, and 1200mm over LW9.

SCT (2008b) have also undertaken computer modelling of caving and resultant overburden hydraulic conductivity due to mining, leading to the selection of appropriate panel widths for mining beneath the Bowmans Creek floodplain. This work, in conjunction with experience from other mines and the experience gained from mining of Ashton longwalls LW1 and LW2, has indicated that the hydraulic conductivity of the overburden beneath the alluvium could be maintained at similar to in situ values by controlling the amount of subsidence and cracking in the overburden.

SCT found that this control can be accomplished by reducing the panel width/overburden depth ratio to a value less than 0.7. When considering the additional effects of subsequent mining from the next seam (Upper Liddell), SCT recommended that a maximum width/depth ratio of 0.6 be applied to the mine layout for the critical sections of LW/MW 5-9, to maintain a barrier of overburden below the alluvial aquifer which has hydraulic conductivity similar to the in situ conductivity (i.e. to satisfy the aquaclude requirement of Consent Condition 3.9).

5 GROUNDWATER MODELLING

5.1 ASSESSMENT OF GROUNDWATER IMPACTS – LW/MW9

This section details an assessment of the potential impacts of the proposed mining of LW/MW9 on the groundwater resources, in particular the Bowmans Creek alluvium.

Numerical groundwater modelling was undertaken to provide predictions of the impacts of underground mining on local groundwater and surface water to support the SMP application for LW/MW 5-9. This modelling included the LW/MW9 panels which are the subject of this report.

This report focuses on the specific incremental impacts associated with the westernmost panels (LW/MW9), within the Pikes Gully Seam.

5.2 MODEL SELECTION

The MODFLOW numerical groundwater flow modelling package (McDonald and Harbaugh, 1988) has been used for this study with Version 3 of the SURFACT module (HydroGeoLogic Inc, 2006), operating under Version 5 of the Groundwater Vistas graphic interface software package (ESI, 2005).

The predictive simulations were run as a series of successive time slices, allowing aquifer properties to be changed from one time slice to the next to reflect progressive changes in ground conditions within and above longwall panels as the underground mining proceeds. Also, using MODFLOW in conjunction with SURFACT has enabled the simulation of saturated/unsaturated flow conditions and provided for more stable drying and re-wetting of cells in thin model layers (such as coal seams), which cannot be achieved with standard MODFLOW.

The hydrogeological investigations (including modelling) were undertaken with reference to the DWE guideline for mining near stream/aquifer systems in the Hunter Valley (DNR, 2005), and the model was developed in accordance with the best practice guideline for groundwater flow modelling (MDBC, 2001).

The model simulations were undertaken to assess the impacts of mining the full width of the underground mine, i.e. LW1 to LW/MW9. For the purposes of this report, only the incremental impacts associated with the mining of LW/MW9 are considered.

5.3 MODEL DOMAIN, LAYERS AND GRID

The model domain covers an area of around 132 km^2, and is shown in Figure 9. It includes both underground and open cut mining areas at Ashton, and extends to the west to include the former Ravensworth open cut and the Narama Pit. Other nearby mining areas have been included as well. Figure 10 shows a typical section through the model – at model row 158 (equivalent to 6404460m S).

5.3.1 MODEL GRID

The model has cell sizes of 100m by 100m on the outer edges of the model, reducing to 25m by 25m in the area of the Ashton underground mining operation. Smaller cells were implemented in the underground mine area to more accurately represent the geometry of the coal seams and the mining operation, and to simulate the steep groundwater level gradients expected to occur from underground mining. A total of 253 rows and 188 columns were used.

5.3.2 MODEL LAYERS

The hydrogeology has been represented in the model by 9 model layers, where coal seams and interburden are represented independently:

- Layer 1: Bowmans Creek alluvium, Glennies Creek alluvium, Hunter River alluvium, colluvium, weathered Permian overburden (regolith) and Ravensworth spoil (backfill in the old Ravensworth open cut).

- Layers 2, 3, 4, 5, 6 and 7: Pikes Gully Seam overburden – split into a number of layers to allow the simulation of fracturing to different heights above the coal seam during mining impact assessment. These layers include the full range of coal measures lithologies, including the Lemington coal seams (1 to 19), and in the very western part of the area the Bayswater 1 and 2 seams.
- Layer 8: Pikes Gully Seam.
- Layer 9: Pikes Gully – Upper Liddell interburden.

5.3.3 MODEL BOUNDARIES

Model boundaries have been set to coincide with the locations of nearby current or former mines, including Ravensworth No. 2 pit, Ravensworth South mine, Narama mine, Lemington North open cut mine, Camberwell South pit, Camberwell North pit, Glennies Creek Underground mine, and Ravensworth East pit, generally using specified head cells. The specific boundary conditions assumed in the model are described in detail in Aquaterra (2008c).

5.4 MODEL FEATURES

5.4.1 RIVERS AND CREEKS

Glennies Creek, Bowmans Creek and the Hunter River are represented in the model using river cells, to allow for stream-aquifer interaction due to leakage from the creek/river to the shallow aquifers and/or baseflow from the alluvial or Permian aquifers to the creeks. River heights have been based on topography in the absence of any recorded field data. The stage elevation is assumed to be 1m above the creek bed, and the streambed conductance (a term which reflects the degree of hydraulic connection between the surface water and the shallow aquifer) ranges between 6.25 m2/d for the smaller river cells to 1000 m2/d for the larger river cells.

5.4.2 RECHARGE AND EVAPORATION

For areas where the Hunter River alluvium is present, recharge to the water table has been set in the model at 0.8% of the average annual rainfall, while a recharge rate of 0.6% is applied to areas where Bowmans Creek alluvium, Glennies Creek alluvium and the Ravensworth Spoil mound are present. A recharge rate of 1.7% was applied to areas where the shallower coal seams are believed to outcrop. Everywhere else, the recharge rate was set to 0.2 % of average annual precipitation. Recharge has been applied to the highest active model layer.

Evaporation has been simulated using the Evapotranspiration (EVT) package of MODFLOW. The EVT parameter values adopted were a constant rate of 250 mm/yr with an extinction depth of 1.5 m, which allows evapotranspiration to be active in areas of low topography and shallow water table, generally along surface watercourses such as Bowmans Creek, Glennies Creek and the Hunter River floodplain.

5.4.3 UNDERGROUND MINE WORKINGS

Underground mining and dewatering activity have been represented in the model using drain cells within the mined areas of the Pikes Gully coal seam (Model Layer 8). The drain cells allow free drainage of groundwater into both the development headings and the goaf, both from the adjacent undisturbed rock and from the overlying subsidence zone. The drain cells were set up wherever workings occur, and progressed in accordance with the mining schedule, requiring a transient model set-up for both the calibration period and the prediction scenarios.

The drain conductance was set to 1000 m2/d which is sufficiently high to completely drain all the water from the Pikes Gully seam and allow for free drainage from overlying fractured zones. The drain levels are set 0.5 m below the base of the Pikes Gully to ensure no residual groundwater remains in the seam layer.

Nearby mines have been represented in the model as static features, and no allowance has been made for future mining progress in those mines which are still active, as the mine plans and schedules are not known.

This includes the Ravensworth Underground Mine (RUM), immediately west of Ashton, where mining is taking place by longwall extraction in the Pikes Gully Seam. Based on the latest publicly available RUM mine plans, it is possible that Pikes Gully extraction could be occurring within the RUM panels immediately west of LW/MW9, at a similar time to the LW/MW9 panel extraction.

As the actual RUM mining schedule is not known, the RUM extraction has not been simulated in the modelling. The barrier between the proposed RUM and Ashton Pikes Gully headings in this area would be approximately 40m, and there will almost certainly be mutual hydraulic interference between the two mines. Each mine will have a beneficial advance dewatering impact on the other, as there will be a regional dewatering or depressurisation effect extending laterally out from each area of workings, within the Pikes Gully Seam, and to a lesser extent in the overlying strata.

As the RUM mining has not been simulated, the predicted impacts of the Ashton underground mining are likely to be overstated, although the degree would be dependent on the relative times at which the two projects reach the area of closest proximity.

5.4.4 LAYER CONFIGURATION AND GOAF/SUBSIDENCE ZONE REGIME

The Pikes Gully Seam overburden was subdivided into 6 layers to allow subsidence caving and fracturing effects to be simulated to various heights above the seam, so that mine plans involving different panel widths could be assessed. The adopted layer thicknesses and initial estimated parameter values are listed in **Table 5.1**.

Based on modelling by SCT (2008a), two distinct zones of altered hydraulic conductivity have been assumed above excavated longwall panels, a lower zone of highly connected fractures, in which the hydraulic conductivity would be expected to increase by 4 to 5 orders of magnitude above in-situ conductivities, and an upper tortuous zone, in which the fractures would be less interconnected and conductivity may increase to values at some intermediate point between in-situ values and those in the lower highly connected zone. The thickness of this upper zone and magnitude of the conductivity increase would be dependent on the magnitude of subsidence, which in turn would be a function of the panel width to cover height ratio. For panel widths of 0.7 or less, the conductivity of the upper (tortuous) zone would be expected to be similar to in-situ values.

Table 5.1: Model Layer Configuration (LW/MW9)

Layer	Geological Unit	Thickness	In Situ Kh (m/d)	In Situ Kv (m/d)	Subsidence Altered Kh (m/d)	Subsidence Altered Kv (m/d)
1	Bowmans Ck Alluvium	Variable, based on drilling results	0.5	5×10^{-6}	0.5	5×10^{-6}
	Regolith (weathered Permian overburden)	10m (nominal thickness)	0.1	5×10^{-6}	0.1	5×10^{-6}
	Ravensworth spoil	Based on Bayswater Seam floor levels	0.02	5×10^{-6}	0.02	5×10^{-6}
2	PG overburden	Residual thickness between L1 and L3 (thickness variable due to dip on strata)	0.005	5×10^{-5}	0.005	5×10^{-5}
3	PG overburden	20m	0.005	5×10^{-5}	0.005	5×10^{-5}
4	PG overburden	30m	0.005	5×10^{-5}	8	0.0003
5	PG overburden	30m	0.005	5×10^{-5}	8	0.0003
6	PG overburden	40m	0.005	5×10^{-5}	5	0.0005
7	PG overburden	30m	0.005	5×10^{-5}	5	0.0005
8	PG Seam	2m	0.08	0.0008	50	50
9	Basal layer (coal measures)	35 – 40m (as per Ashton Geological Model)	0.001	1×10^{-5}	0.005	1×10^{-5}

The reasoning behind the layer thicknesses in **Table 5.1** is to accommodate the subsidence zone regime which develops above an extracted longwall or miniwall panel. The goaf (Layer 8) and subsidence regime (Layers 7 to 4) are modelled by increasing the vertical and horizontal hydraulic conductivities within the mine footprint for both the Pikes Gully Seam (Layer 8) and various heights into the overburden layers.

The aquifer parameters adopted for the goaf and the overlying subsidence regime as listed in **Table 5.1** were based on the results of subsidence fracture modelling by SCT (2008a), and refined during the groundwater model calibration process.

The predictive modelling was carried out as a series of consecutive "time-slice" models, with hydraulic properties changed from one time slice to the next. Six-month time-slices were used, matched to the quarterly mine schedule shown on Figure 11. The output heads from each time-slice model were used as starting heads for the next successive time-slice, and hydraulic conductivities changed to reflect subsided strata above the extraction area for that time slice. This process was repeated until the entire mine plan had been simulated.

Mined areas in each time slice included both development headings and longwall or miniwall panels. Both areas were represented in the model by drain cells using the MODFLOW drain (DRN) function. The development headings were represented only by drains, whereas the panels were represented by drains as well as by changed hydraulic parameters in both the seam (Layer 8) and one or more of the overlying layers (Layers 3 to 7) in accordance with the panel width, as discussed above. Drains were activated in both development headings and extraction panels in advance (i.e. at the start of the simulation for all cells to be mined in that period), whereas changes to hydraulic properties above the panels were made in arrears (i.e. for the panel area mined in the previous period).

The vertical extent of the subsidence-affected zone above the mined Pikes Gully seam was determined in accordance with the panel width to cover depth ratio (W/D). For the narrower miniwalls, it has been assumed in the model that the hydraulic properties may change up to heights of approximately 1-1.2 times the panel width, above which the rock would remain substantially unimpacted, as suggested by SCT (2008a). Changes to hydraulic conductivity were assumed to extend up to Layer 4 for both LW9 (width 141m) and, MW9 (width 93m). The residual overburden above these layers was assumed to retain its in-situ hydraulic properties.

In addition to goaf and subsidence zone parameter changes, it became necessary in the calibration process to invoke a reduction in horizontal hydraulic conductivity (Kh) in the overburden layers immediately outside extracted panels and above chain pillars between panels in order to achieve a satisfactory calibration between observed and predicted impacts on groundwater levels. The calibration process and the rationale for the reduction in Kh is detailed in Aquaterra (2008c).

5.5 INDEPENDENT MODEL REVIEW

Ashton Coal Operations retained the services of Associate Professor Noel Merrick, a leading groundwater modelling expert, to provide independent review of all stages of modelling and to provide input/advice to the modelling team. Associate Professor Merrick's review report was presented in Appendix A of Aquaterra (2008c).

5.6 MODEL LIMITATIONS

All numerical models have limitations, due mainly to uncertainties in model input parameters, and also due to the computational methods. Due to the complexity of the Ashton model, model limitations exist, which need to be taken into consideration as summarised below:

- The model layer set-up is based on available seam contours supplied by Ashton Coal within the Ashton lease, extrapolated out to the model boundaries based on the regional geology. Some regional inaccuracies in layer elevations may have been introduced.
- Available data on surface water flows in Bowmans Creek and Glennies Creek and stream baseflows are limited. Measured rates of leakage from Glennies Creek alluvium to LW1 have been used to assist the calibration performance of the model. However, similar calibration data are not available for either Bowmans Creek or Hunter River.

- Recharge and evapotranspiration are assumed to be constant at average rates, and seasonal or climatic variability has not been included in the model. Measured values of recharge rate are not available, and recharge rates have been assigned within plausible ranges to obtain a calibrated model, but values cannot be verified. The maximum possible rate of evaporation assumed in the model is 250mm/yr, acting in areas of shallow water levels (<1.5m below surface). The recharge and evapotranspiration rates adopted are considered best estimates based on available data and experienced judgement.
- There is a level of uncertainty with respect to both vertical and horizontal distribution of hydraulic conductivity. The assumed values are consistent with the SCT modelling results (SCT, 2008a) and with the results of hydraulic testing at Ashton, and are generally consistent with values adopted and verified at other mine sites in the Hunter Valley coalfields.
- The model is discretised into 9 layers. Apart from the Pikes Gully Seam (Layer 8), the other model layers represent a mixture of lithologies with a range of individual hydraulic properties and differing hydrostatic heads. The model generates a single head value for each cell in each layer, and the resolution of heads with depth in the model cannot therefore be as detailed as field observations.
- The current data available which is used to calibrate the transient model covers a relatively short hydrogeological time period. Ongoing monitoring will improve knowledge about how the aquifer system responds to mining. The model is consistent with best practice modelling guidelines, however, as with most modelling, the predictions have a degree of uncertainty.
- Uncertainties exist on the "resistance to flow" between the overburden and the underground mine voids, and between the alluvium/regolith and the underlying coal measures, which were simulated in the model using specified drain conductance values. The match to hydrographs and mine inflows during the calibration process has helped minimise these uncertainties.
- The combination of very low hydraulic conductivities and extremely steep pressure gradients associated with underground mining results in long model run times. This makes running multiple predictive uncertainty runs infeasible, and only selected parameters were checked in the uncertainty analysis.
- Due to the potential for "perching" to occur during the underground mining period, as has been predicted also by SCT (2008a), a fully unsaturated flow model may be more suited due to the potential for unsaturated flow to occur. A fully unsaturated flow model would be expected to result in smaller drawdown effects from mining, and water retained in the unsaturated zone would act to mitigate water level declines in the alluvial aquifers, and would allow recharge to continue to occur in cells that have become dry during the model simulation. (The model used in this case can only allow recharge to occur to the highest active layer.) Hence the model predictions are considered conservative. A fully unsaturated flow model would require an order of magnitude increase in the understanding of the unsaturated zone system, and is also beyond currently available computer processing capability.

In conclusion, the model prediction of mine inflows and drawdown effects discussed in the following sections of the report can be regarded as an appropriately conservative prediction based on the available data, determined by adoption of a best practice modelling approach. The sensitivity and uncertainty scenario analysis carried out indicates that the model calibration is robust, and the model results are not highly sensitive to potential errors or uncertainties in the assumed aquifer parameters.

6 MODEL PREDICTION OF IMPACTS

6.1 CALIBRATION

Calibration of the Ashton groundwater model was carried out using a transient approach, matching predicted mine inflow rates and groundwater level impacts to observed inflows and drawdowns through the open cut mining and early stages of underground mining up to April 2008 (LW1 and part of LW2). The calibration was conducted in accordance with best practice (MDBC, 2001).

The following calibration objectives have been achieved, which provide confidence that the dynamic flow processes are adequately represented during the transient model calibration runs:

- A good match (calibration) has been obtained between modelled and observed bore water levels during the periods of open cut mining and the underground mining of LW1 and commencement of LW2. The transient model is calibrated to hydrographs close to the mining operations that have long term monitoring data (examples are shown in Figures 12 to 16.
- Predicted dewatering rates from LW1 and LW2 are consistent with measured dewatering rates, currently around 0.5 ML/day (refer to Figure 17).
- Predicted impacts on Glennies Creek baseflows are consistent with the current estimated inflows from Glennies Creek alluvium of approximately 2L/s (refer to Figures 18 and 19).

6.2 CALIBRATED MODEL PARAMETERS

The calibrated hydraulic conductivity and storage parameters are summarised in **Table 6.1**.

Table 6.1: Hydraulic Conductivity and Storage Parameters for the Calibrated Model

Layer	Geological Unit	Kh (m/d)	Kv (m/d)	Confined S*	Unconfined Sy*
In Situ Parameters:					
1	Bowmans Creek alluvium	0.5	5×10^{-6}	0.0005	0.05
1	Glennies Creek alluvium	1	5×10^{-6}	0.0005	0.05
1	Hunter River alluvium	45	5×10^{-6}	0.0005	0.05
1	Regolith – weathered Permian overburden	0.1	5×10^{-6}	0.0005	0.001
1 to 4	Ravensworth spoil	0.02	0.002	0.0005	0.001
2 to 7	Permian overburden	0.005	5×10^{-5}	0.0003	0.001
2 to 7	Permian overburden west of Bowmans Creek	0.05	0.005	0.0003	0.001
8	Pikes Gully Coal Seam	0.08	8×10^{-4}	0.0003	0.001
9	Interburden between Pikes Gully Seam and the Upper Liddell Seam	0.001	1×10^{-5}	0.0005	0.001
Subsidence Altered Parameters:					
4-5	Subsidence zone area	8	3×10^{-4}	0.0003	0.001
6-7	Subsidence zone area	5	5	0.0003	0.001
3-7	Permian overburden above chain pillars	5×10^{-4}	5×10^{-5}	0.0003	0.001
8	Goaf	50	50	0.0003	0.001

*only applicable for transient model runs.

6.3 SENSITIVITY MODELLING

Sensitivity analysis was undertaken on the steady state model. During the calibration process, the model was found to be most sensitive to recharge and vertical hydraulic conductivity values. As agreed with the independent model reviewer, the sensitivity analysis focused on the alluvium aquifer (Layer 1) since the drawdown in the alluvium aquifers and baseflow impacts on the creek systems (Hunter River, Bowmans Creek and Glennies Creek) are the key groundwater issues in relation to consent conditions for the project.

On the basis of the sensitivity modelling, the model was found to be more sensitive to recharge rate than to the vertical hydraulic conductivity of Layer 1.

6.4 PREDICTIVE MODELLING

The calibrated Ashton Groundwater Model has been used for predictive transient modelling to assess the potential impact of progressive underground mining of the Pikes Gully seam on the groundwater and surface water resources. The modelling allowed assessment of potential changes to flow to/from surface water courses (Bowmans Creek and Hunter River), regional changes in groundwater levels during mining, and on the potential water ingress into the mine workings through vertical leakage from the overlying Bowmans Creek alluvium, during the mining of LW1 to LW/MW9, in accordance with the proposed mine plan.

The overall prediction run included 12 consecutive time-slice models (Time Slices 4 to 15) to simulate progressive mining and changing of goaf and subsidence zone parameters with time (**Table 6.2**). Time Slices 1 to 3 were equivalent to the transient calibration period. The development headings for LW/MW9 are scheduled to commence during Time Slice 13, and panel extraction during Time Slice 14 (**Table 6.2**).

Table 6.2: Stress Period Set-up for Life of Mine Simulation

Period	Time Slice	Stress Period	length (days)	From	To	Development Headings	Longwall/ Miniwall Panels
LW2 to LW 4 PREDICTION	Time Slice 4	35	46	31/03/2008	16/05/2008	LW3	LW2
		36	46	16/05/2008	01/07/2008		
	Time Slice 5	37	31	01/07/2008	01/08/2008		LW3
		38	61	01/08/2008	01/10/2008	LW4	
	Time Slice 6	39	46	01/10/2008	16/11/2008		
		40	46	16/11/2008	01/01/2009		
	Time Slice 7	41	46	01/01/2009	16/02/2009		
		42	44	16/02/2009	01/04/2009		LW4
	Time Slice 8	43	45	01/04/2009	16/05/2009		
		44	46	16/05/2009	01/07/2009	LW/MW5	
	Time Slice 9	45	45	01/07/2009	15/08/2009		
		46	47	15/08/2009	01/10/2009		
LW/MW 5 to 9 PREDICTION	Time Slice 10	47	45	01/10/2009	15/11/2009		LW5
		48	47	15/11/2009	01/01/2010	LW/MW6	
	Time Slice 11	49	90	01/01/2010	01/04/2010	MW7	MW5
		50	91	01/04/2010	01/07/2010		LW6
	Time Slice 12	51	92	01/07/2010	01/10/2010		
		52	92	01/10/2010	01/01/2011	MW8	MW6 and MW7
	Time Slice 13	53	90	01/01/2011	01/04/2011	LW/MW9	
		54	91	01/04/2011	01/07/2011		MW8
	Time Slice 14	55	92	01/07/2011	01/10/2011		
		56	92	01/10/2011	01/01/2012		MW9 and LW9
	Time Slice 15	57	91	01/01/2012	01/04/2012		
		58	91	01/04/2012	01/07/2012		

6.5 PREDICTION RESULTS

The following is a summary of the prediction results of the life of Pikes Gully Seam mining.

6.5.1 MINE INFLOW RATES

Figure 20 shows the model-predicted mine inflow rates over the calibration and prediction periods as compared to both the EIS prediction and the measured underground mine inflow rates to date. The extraction of LW/MW9 are scheduled for the period October 2011 to April 2012 as shown on Figure 6.9. Development headings for LW/MW9 are scheduled for development during the period January to September 2011, concurrently with the extraction of miniwall panel MW8 (**Table 6.2**).

The following observations are made:

- The inflow rates predicted by the model during the extraction of LW/MW9 (1.45-1.55 ML/d) are not noticeably different from those predicted for the prior extraction of MW8 (1.43-1.53 ML/d).
- During mining of LW/MW9, the predicted mine inflow rates are marginally below the EIS predicted inflow rates for the final stage of mining of the Pikes Gully Seam.

6.5.2 CREEK BASEFLOW IMPACTS

Figure 21 shows the model predicted net baseflows during the mining period. Figures 22 to 24 show the predicted baseflow changes for Bowmans Creek, Glennies Creek and Hunter River respectively. Figures 22 to 24 also compare the modelled baseflow changes with the impacts predicted in the EIS, and the observed baseflow impacts for Glennies Creek to date. The relevant periods during which mining is scheduled for the LW/MW9 headings and extraction panels are shown on each figure.

The following observations can be made:

- Baseflow reductions in Glennies Creek and Hunter River during extraction of LW/MW9 as predicted by the model are not noticeably different from those predicted during prior mining of MW8.
- Slightly greater baseflow reduction is predicted for Bowmans Creek during the mining of LW/MW9 (1.1-1.2 L/s) compared with the prediction for the prior extraction of MW8 (0.7-1.1 L/s).
- However, this baseflow reduction is substantially smaller than the EIS prediction of 4.3 L/s (0.37 ML/d) during longwall extraction of the westernmost panel of the currently approved mining area in the Pikes Gully Seam.

6.5.3 GROUNDWATER LEVEL IMPACTS

The modelled versus observed hydrographs over the prediction period are shown in Figures 25 to 33.

The hydrographs show the following:

- Substantial water level declines are predicted in the Pikes Gully Seam (model Layer 8), with the greatest declines at piezometers from the western parts of the mine area (WML213, WML115-144m and WML21), consistent with the dip to the south-west. By the time mining commences in LW/MW9, the Pikes Gully Seam will have already been substantially dewatered across the underground mine area (see Figures 25 to 28).
- Water levels are also predicted to have already declined significantly in model Layers 6 and 7, with no further significant decline during mining of LW/MW9 (Figure 29).
- It is predicted that Layers 4 and 5 will be substantially dewatered within the longwall footprint, but only partially depressurized outside the mine footprint. No additional drawdown in the overburden layers is predicted to occur during the mining of LW/MW9.
- Minimal drawdown response is predicted to occur in Layers 2 and 3 above the restricted width panels LW/MW9 (93m and 141m respectively).
- Drawdowns are predicted to be limited in Layer 1 where it represents the Bowmans Creek alluvium. In the areas above LW/MW9, drawdowns of less that 0.1m are predicted.
- Drawdown in the Hunter River alluvium which is 400m south of the inbye end of MW9 is predicted to be less than 0.1 m.

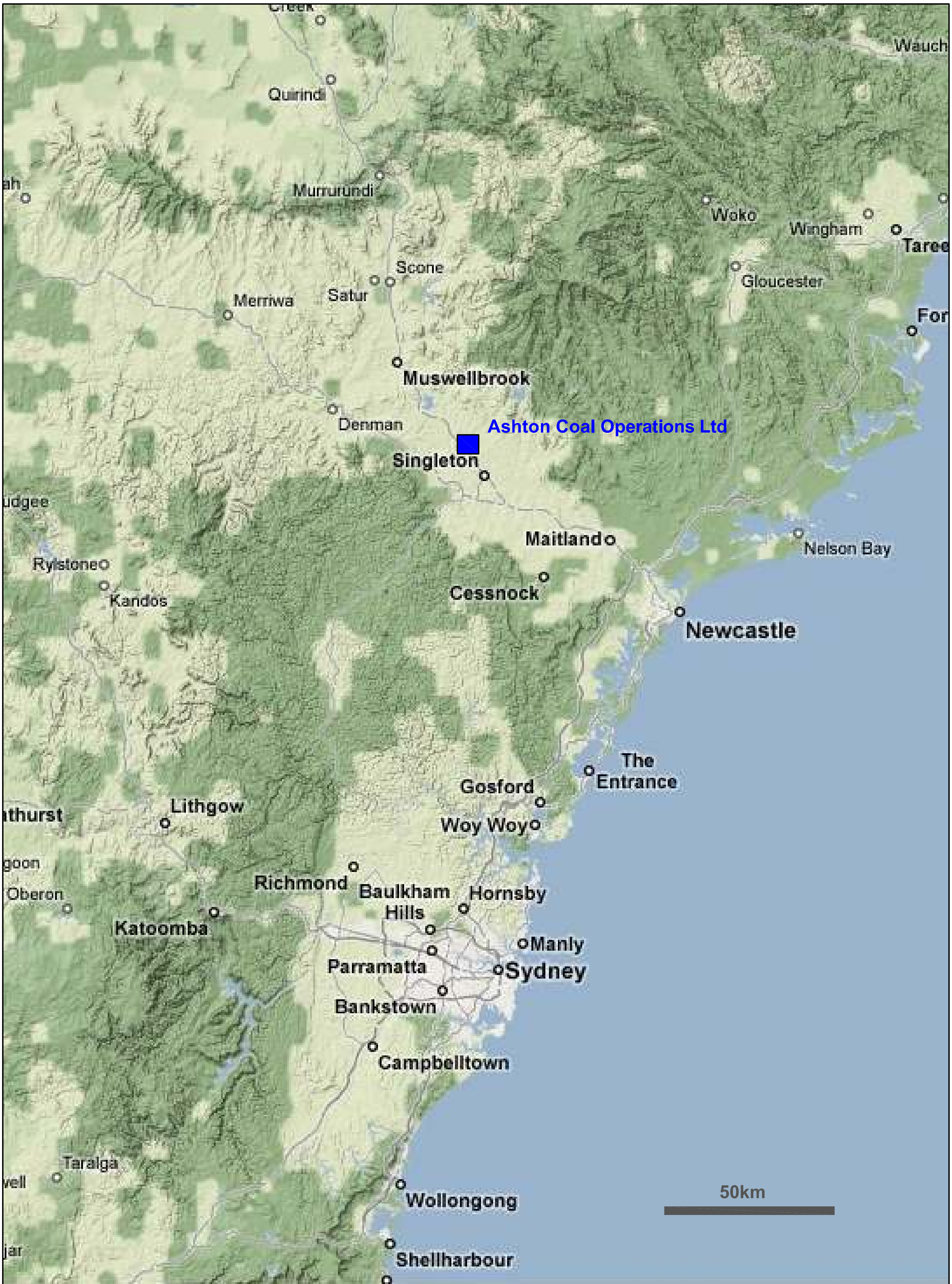
6.5.4 IMPACTS ON BOWMANS CREEK ALLUVIUM AQUIFER STORAGE

The predicted incremental reduction in alluvium saturation during the mining of LW/MW9 is minimal.

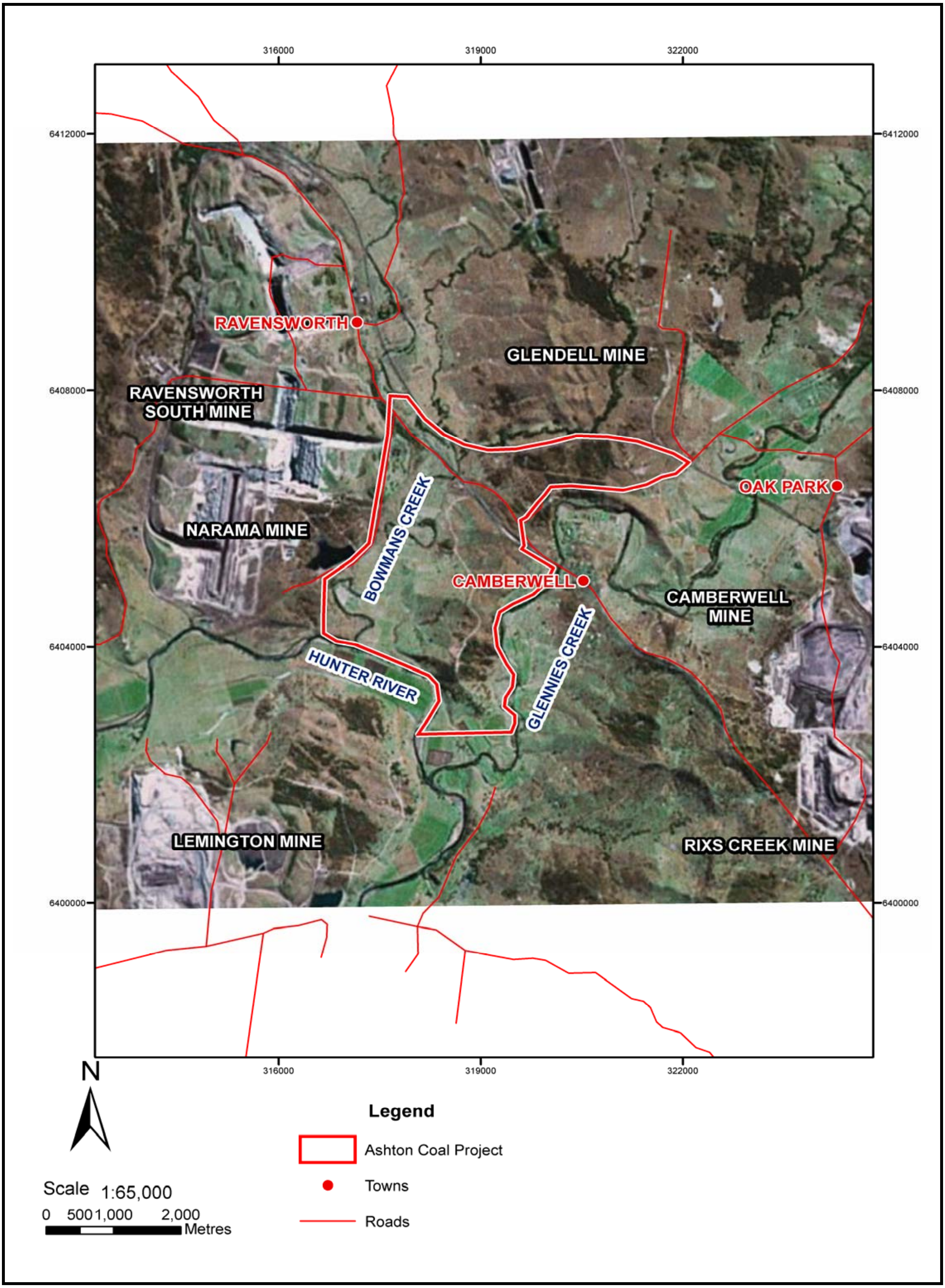
6.5.5 IMPACTS ON ALLUVIUM AND SURFACE WATER QUALITY

Because the extension has a minimal incremental reduction in Permian water levels, any slight impacts on surface water or alluvial water quality will tend to be positive, as flows from the more saline Permian to the alluvium will tend to reduce. This will be the case both during operations, and post mining, when the additional mining will result in slower rebound within the Permian.

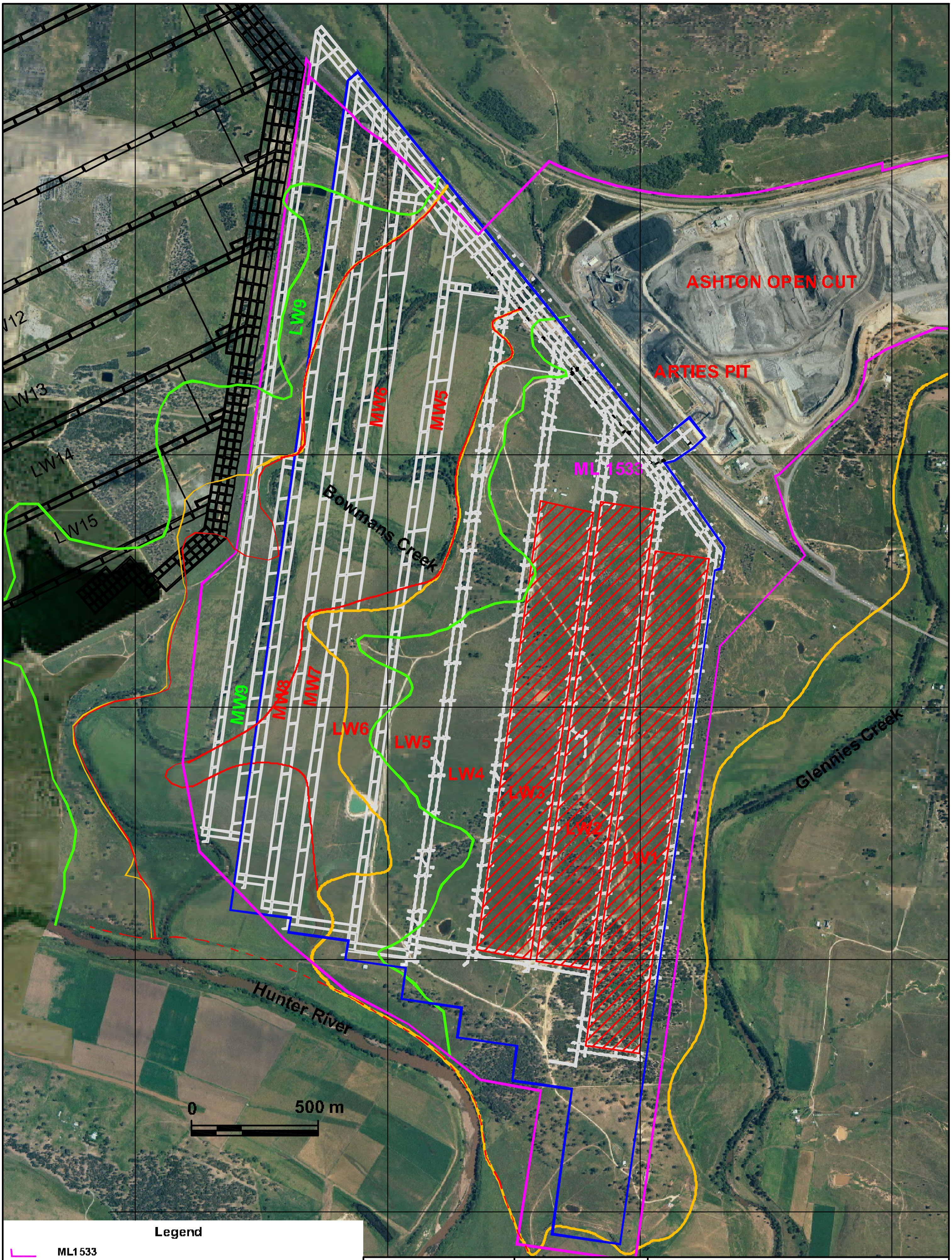
FIGURES



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



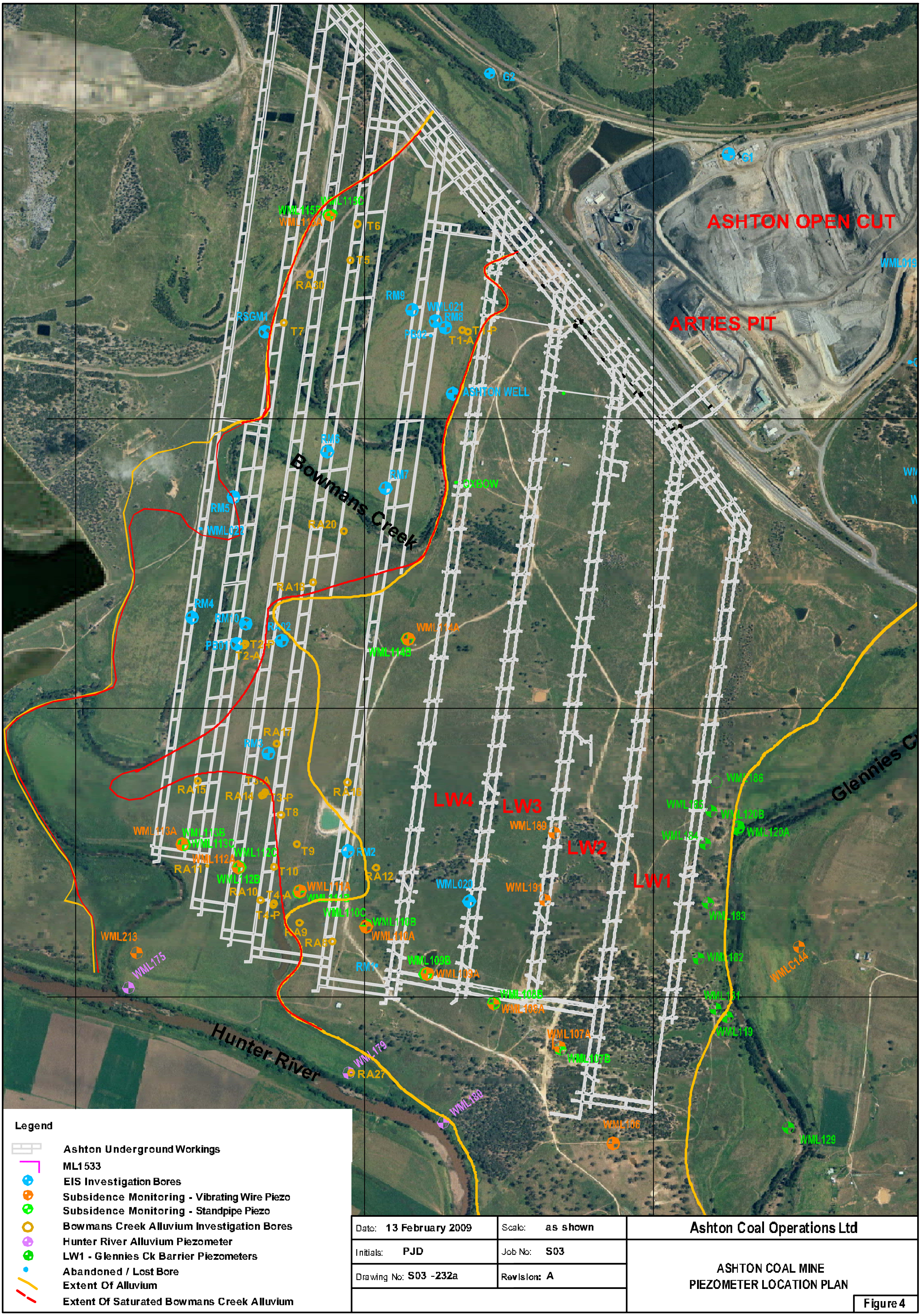
Ashton Project Area
Figure 2



Legend

- ML1533
- Development Consent Approved Area
- Ashton Underground Workings
- Goaf - Extracted Panels
- 1955 Flood Limit
- Extent of Alluvium
- Extent of Saturated Alluvium
- Ravensworth Underground Mine Proposed Workings

Date: 13 February 2009	Scale: as shown	Ashton Coal Operations Ltd
Initials: SRD	Job No: S03	ASHTON COAL MINE MW9 and LW9 PANEL LAYOUT
Drawing No: S03-231b	Revision: B	
aquaterra		Figure 3



Date:	13 February 2009	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	PJD	Job No:	S03	ASHTON COAL MINE PIEZOMETER LOCATION PLAN
Drawing No:	S03 -232a	Revision:	A	
				Figure 4

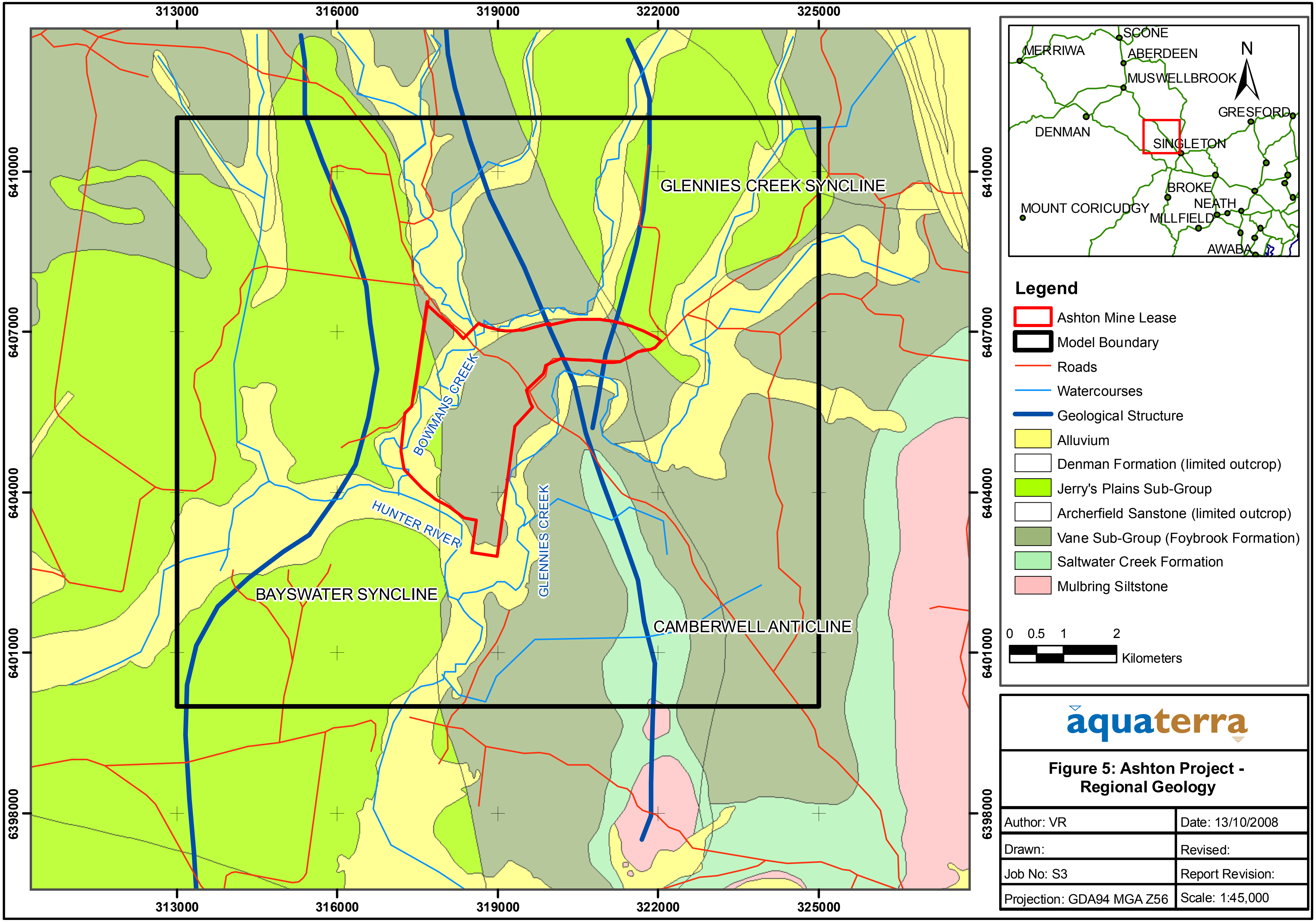


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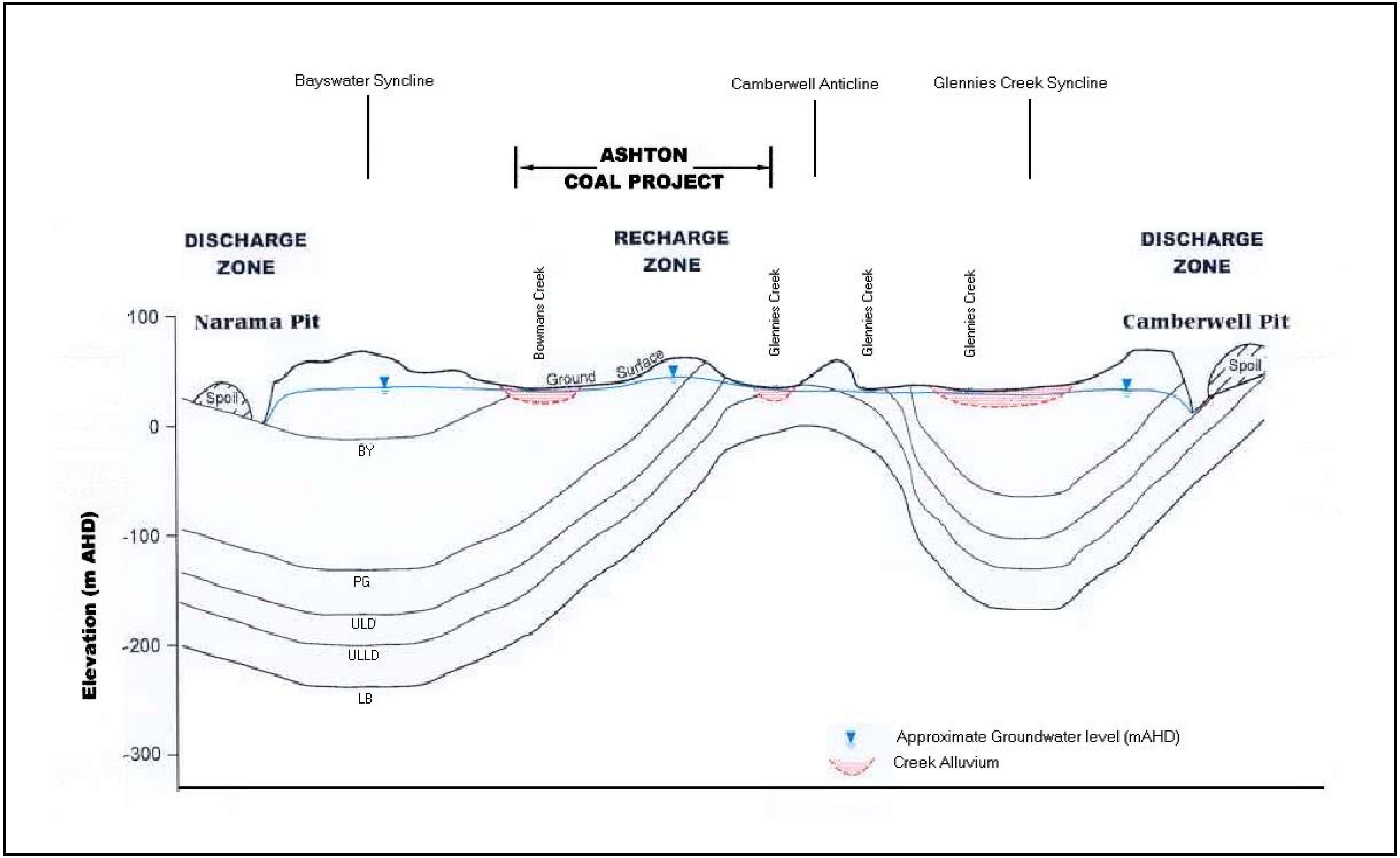
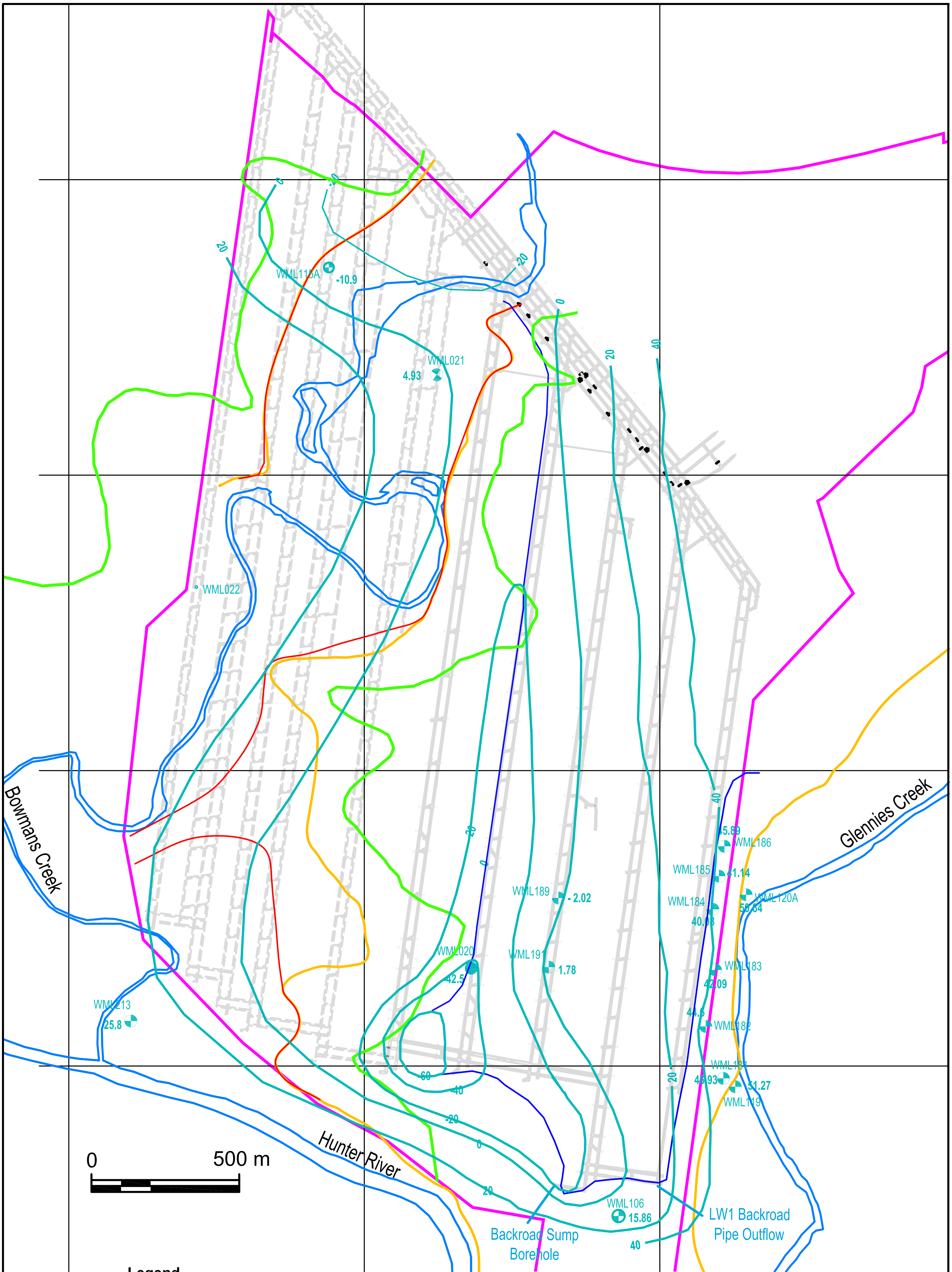
Figure 5: Ashton Project - Regional Geology

Author: VR	Date: 13/10/2008
Drawn:	Revised:
Job No: S3	Report Revision:
Projection: GDA94 MGA Z56	Scale: 1:45,000



Source – HLA (2001)

Representative Geological Cross-Section – Ashton Project
Figure 6



Legend

- Ashton Underground Workings
- -26.3 Pikes Gully Piezometer (GW Level - mAHD)
- GW LevelContour (mAHD)
- Extent of Dewatered Pikes Gully Seam
- Boundary of Alluvium
- Extent of Saturated Bowmans Ck Alluvium
- Extent of 1955 Flood
- ML1533

Date:	13 February 2009	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	PJD	Job No:	S03	GROUNDWATER LEVELS - PIKES GULLY DECEMBER 2008 (mAHD)
Drawing No:	S03-171g	Revision:	G	

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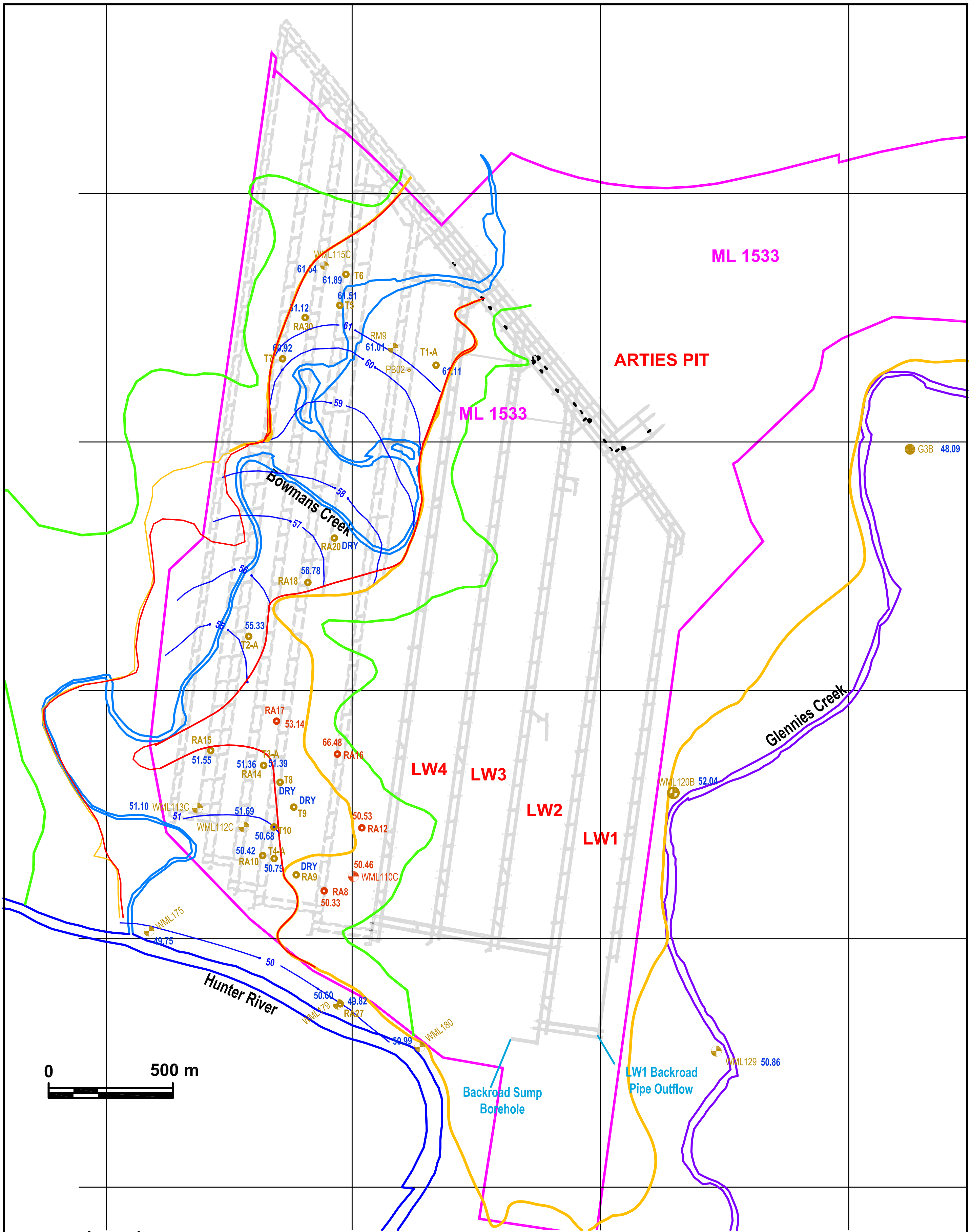
Figure 7



Legend

58.7 Alluvium Piezometer (GW Level - mAHD)
56.8 Colluvium Piezometer
GW Level Contour (mAHD)
Boundary of Alluvium
Extent of Saturated Bowmans Ck Alluvium
1955 Flood Level
Ashton Underground Workings
ML1533

Date:	13 February 2009	Scale:	as shown	Ashton Coal Operations Ltd
Initials:	PJD	Job No:	S03	GROUNDWATER LEVEL CONTOURS BOWMANS CREEK ALLUVIUM (mAHD)
Drawing No:	S03-234a	Revision:	A	

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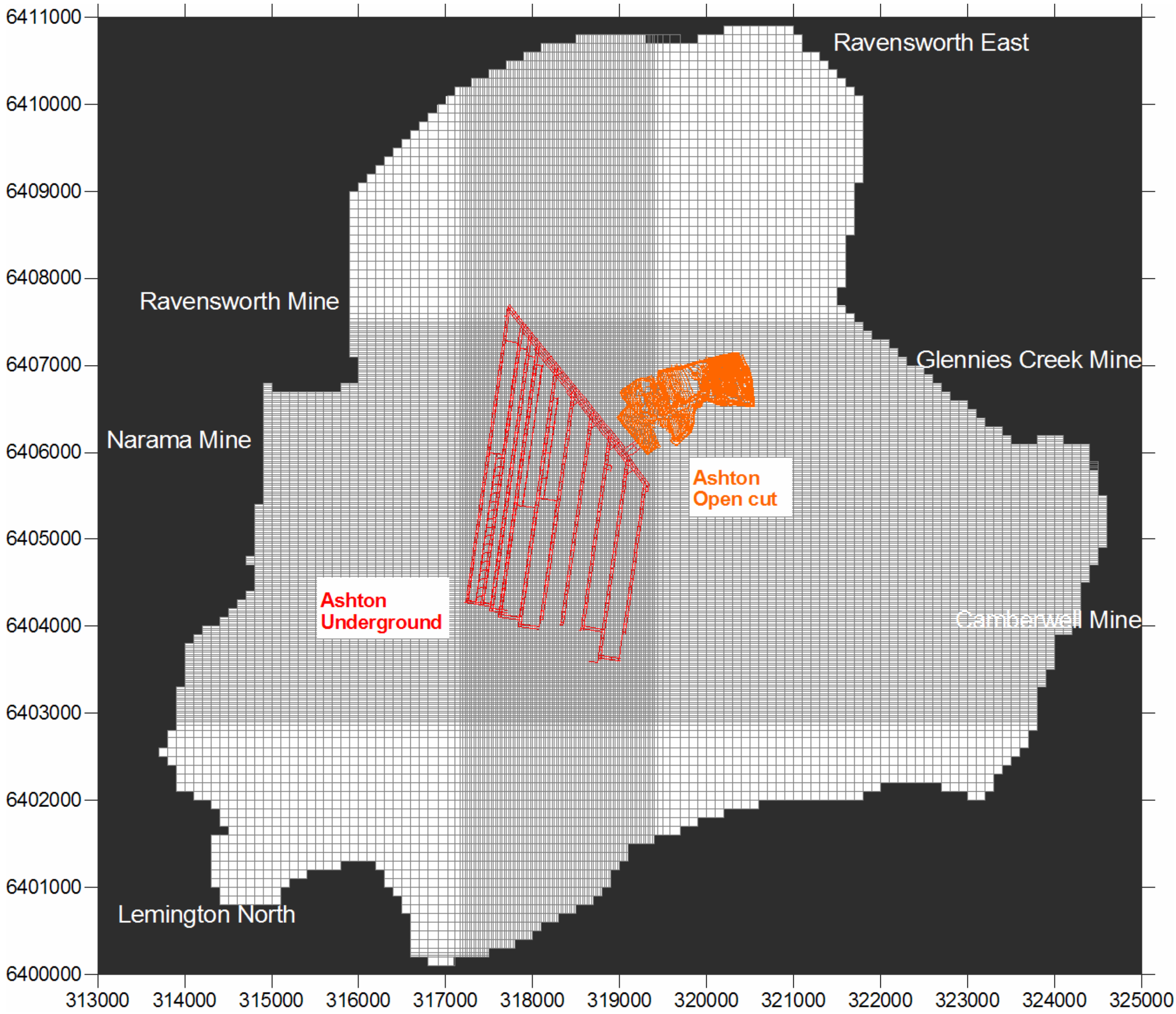
Figure 8



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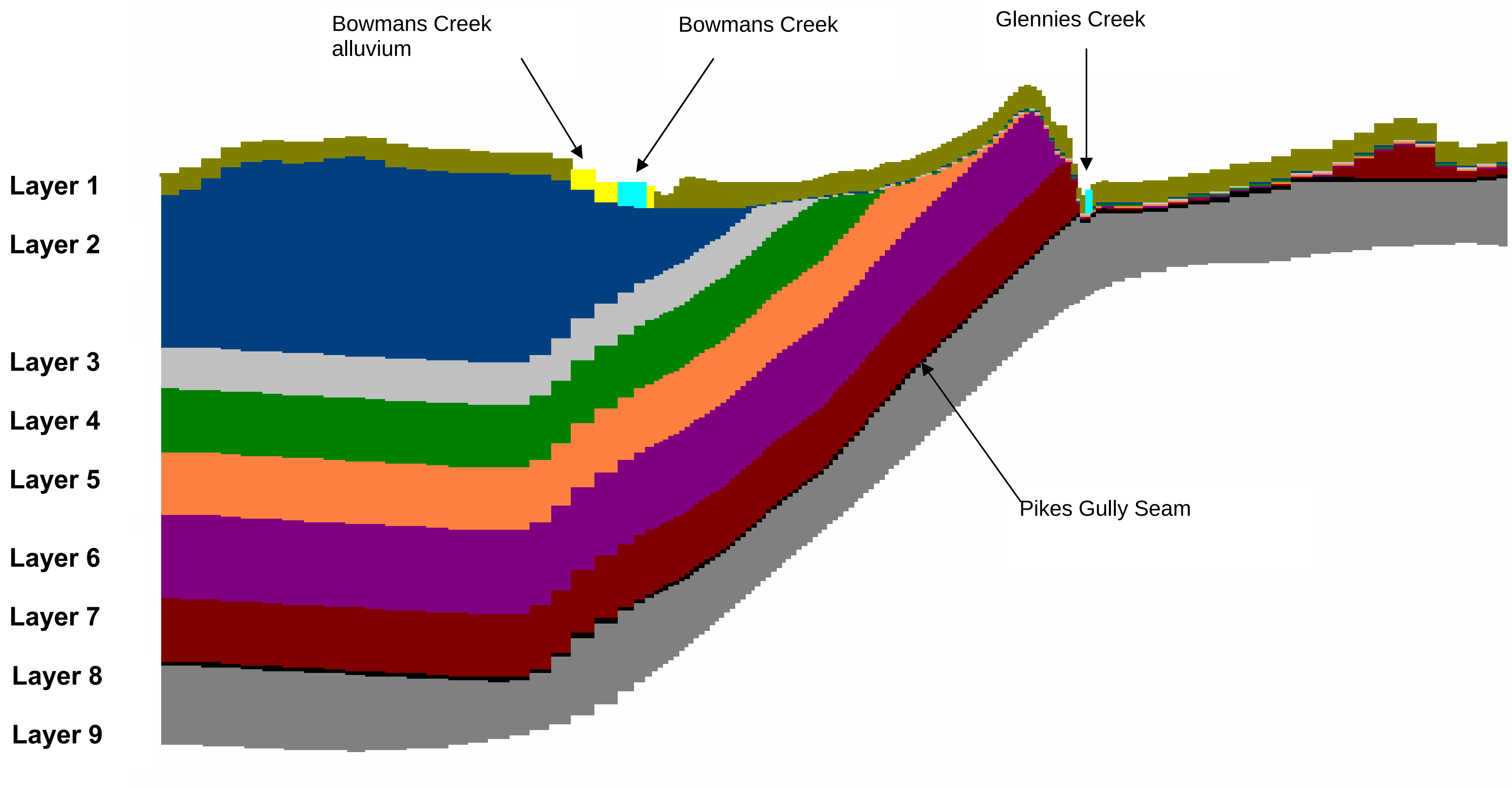
Model Domain, Model Grid and Ashton Mine Layouts
Figure 9



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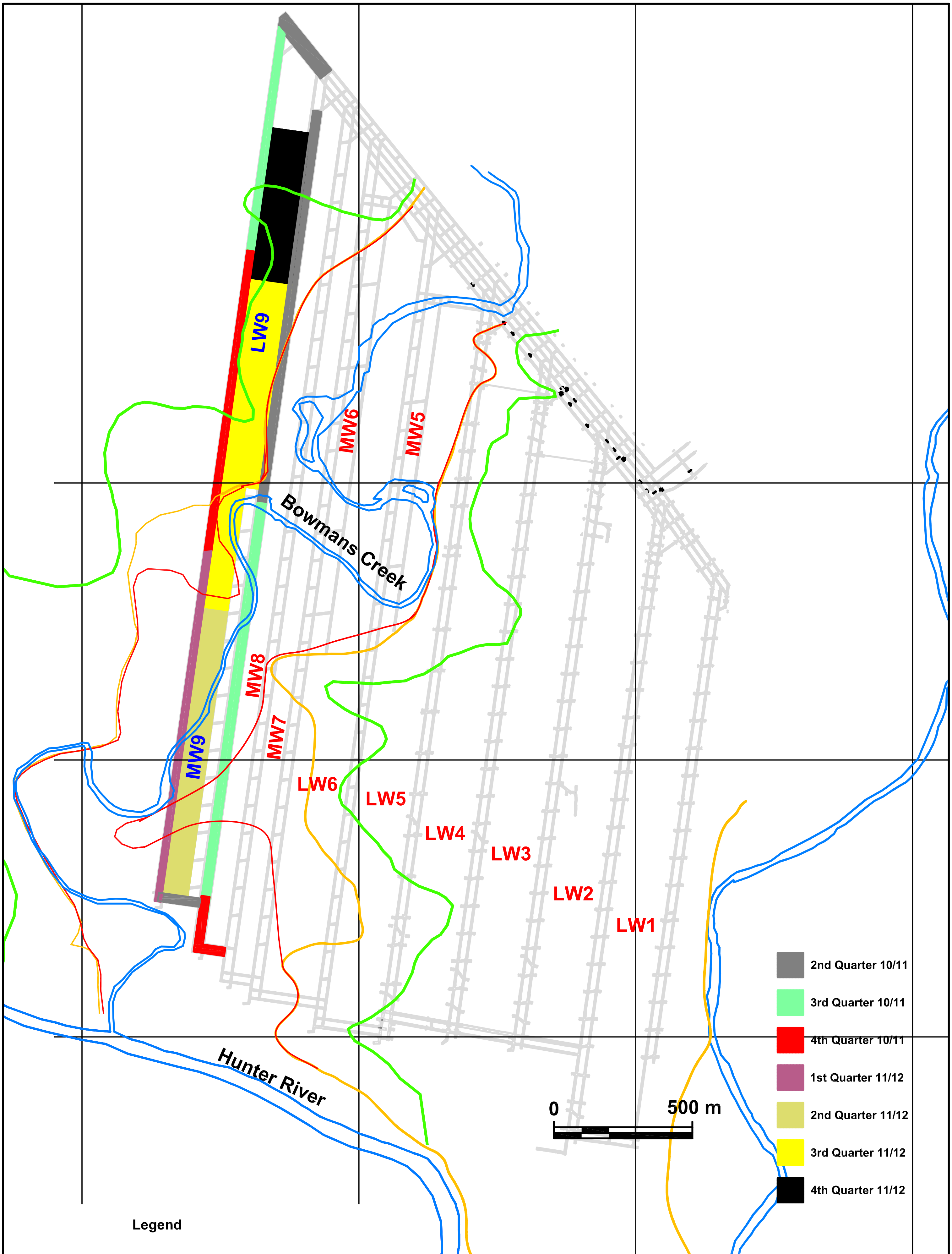
Modelled East-West Cross Section through Northing 6404460

Figure 10

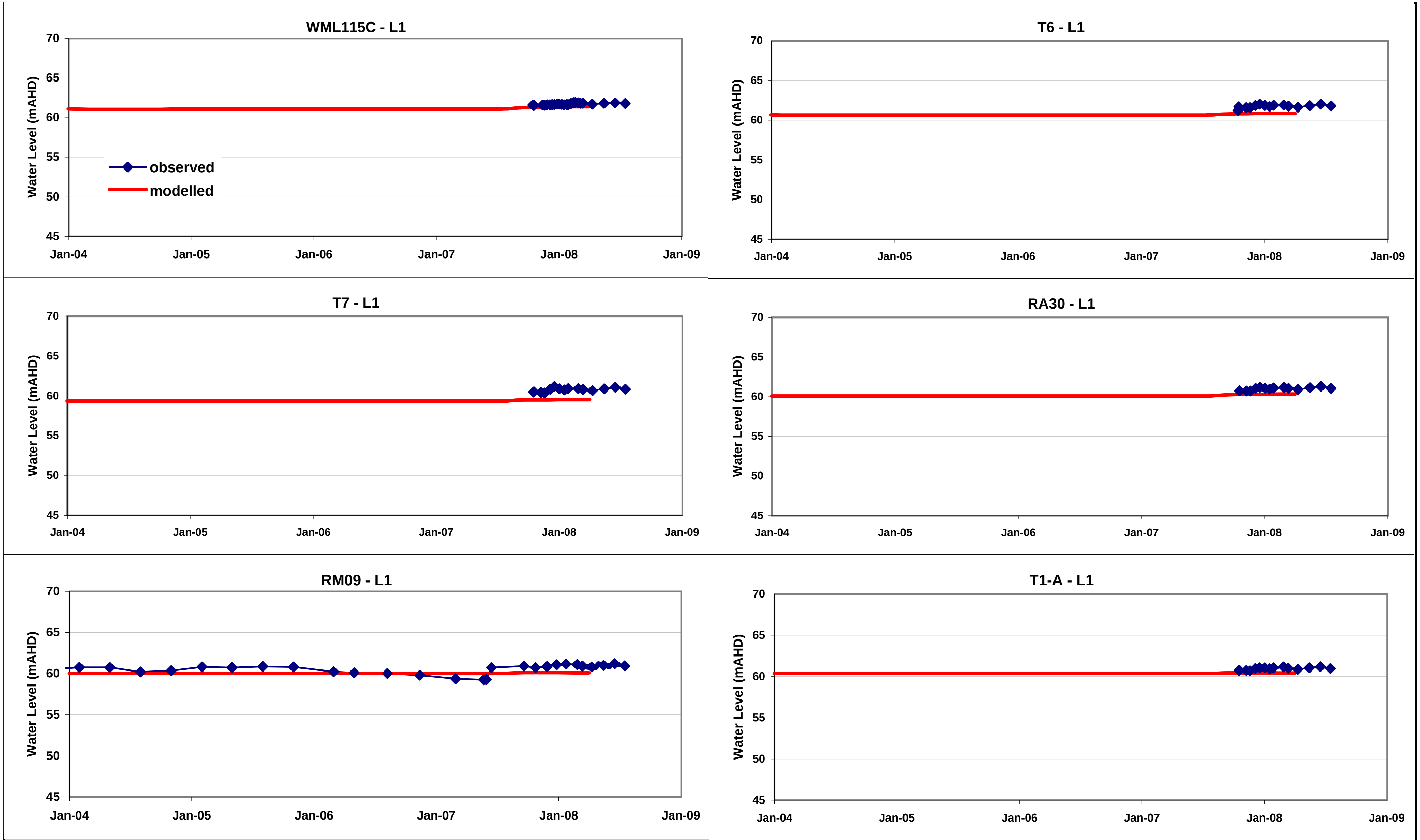


Date: 13 February 2009	Scale: as shown
Initials: PJD	Job No: S03
Drawing No: S03-233a	Revision: A

Ashton Coal Operations Ltd

MW9 and LW9 Mining Schedule
Headings and Panel Extraction

Figure 11



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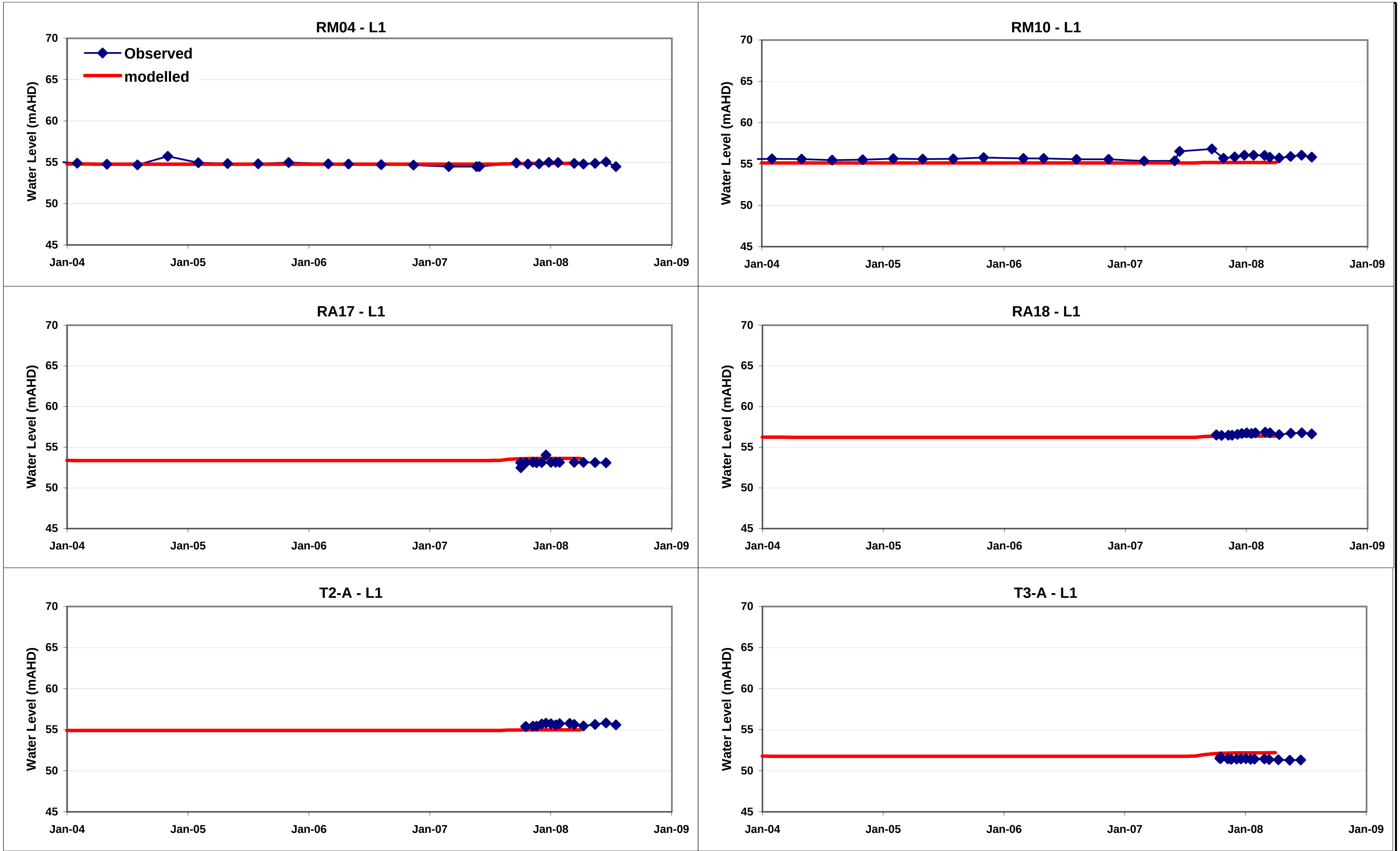
aquaterra

Layer 1 Modelled vs Observed - Bowmans Creek Alluvium Water Levels

Figure 12



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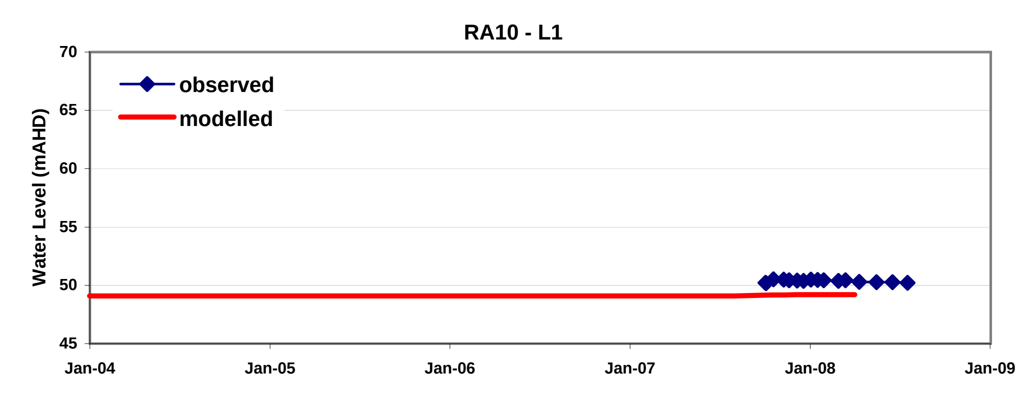
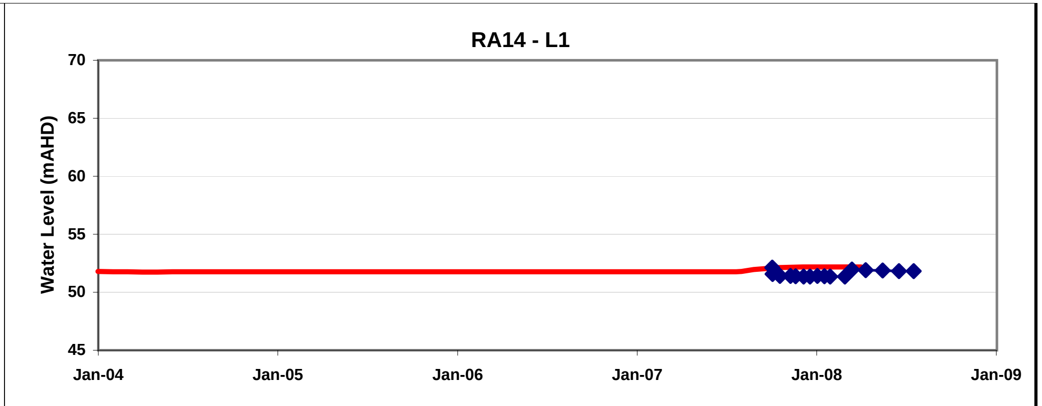
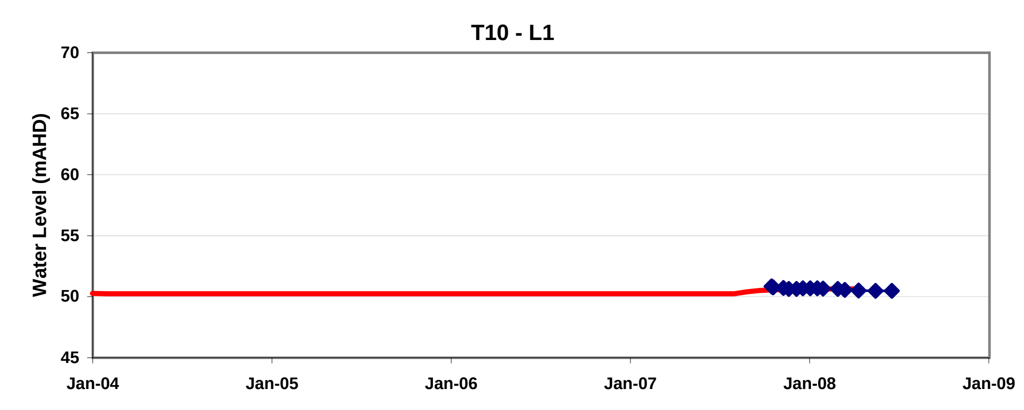
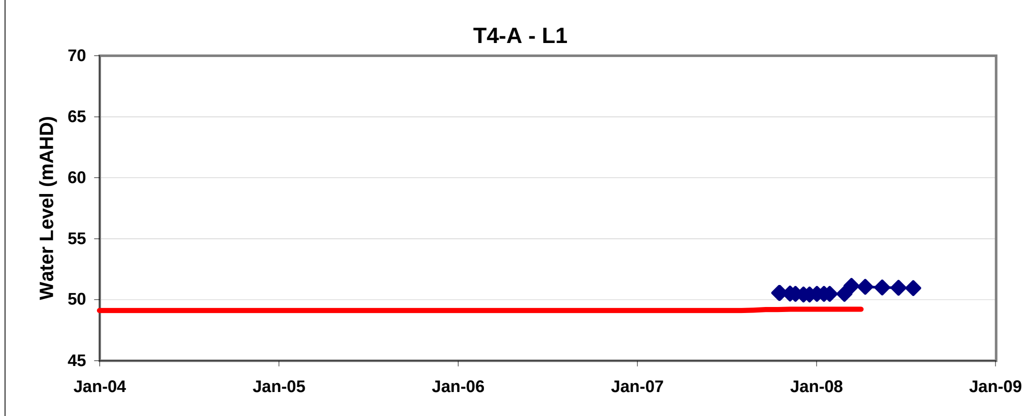
Layer 1 Modelled vs Observed - Bowmans Creek Alluvium Water Levels

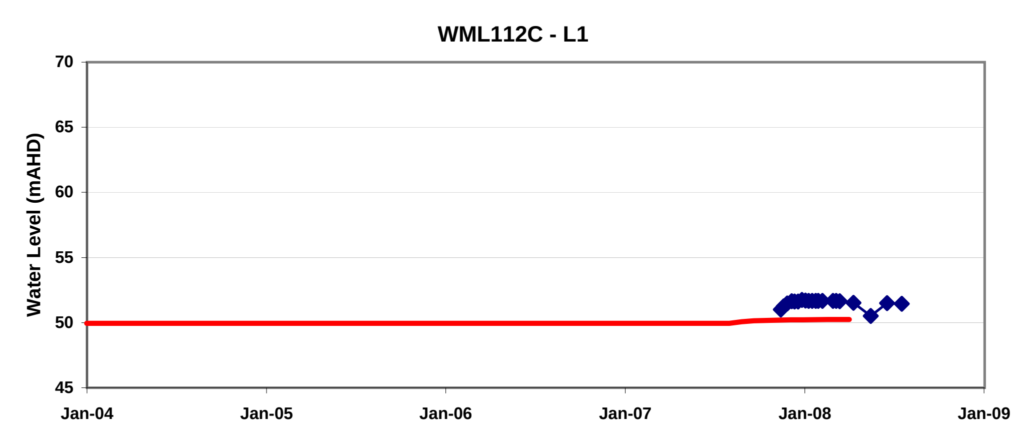
Figure 13

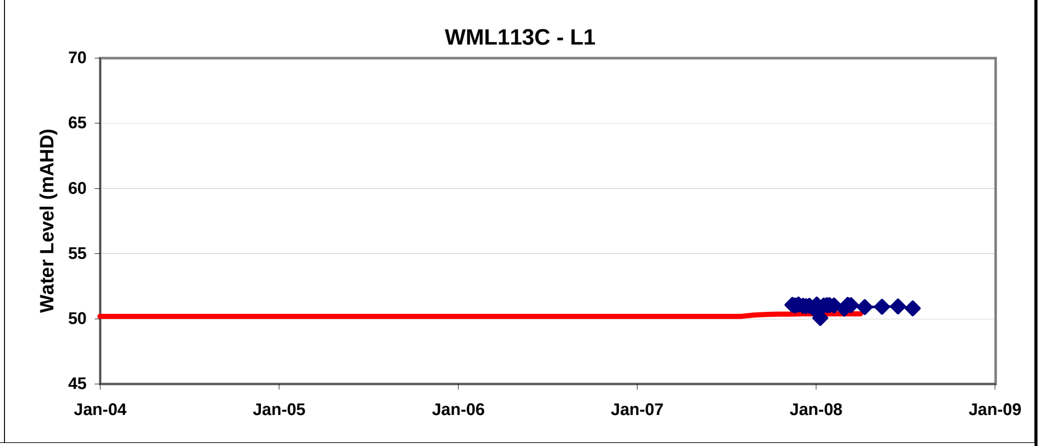












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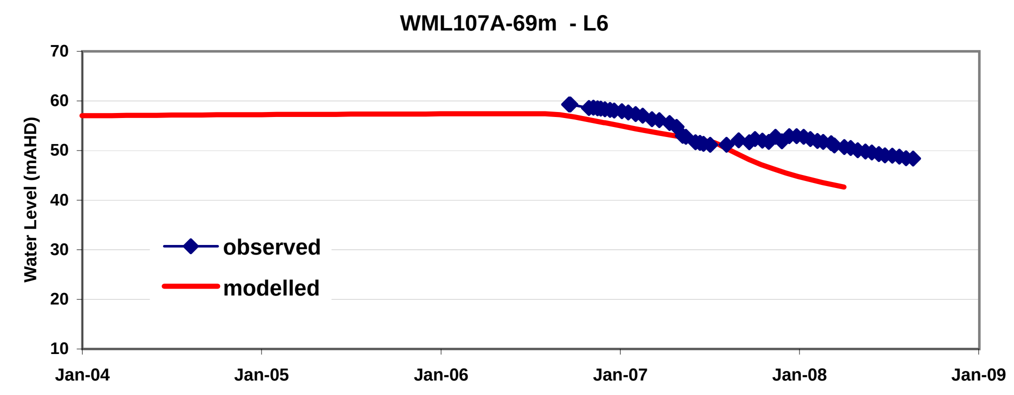
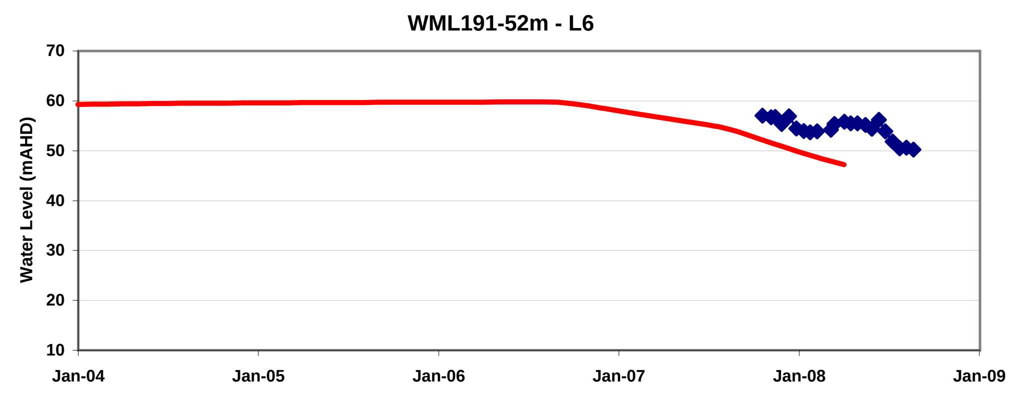
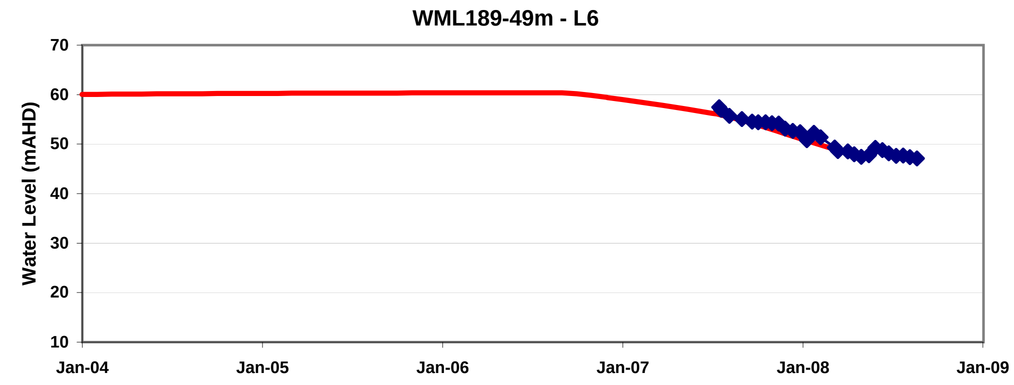
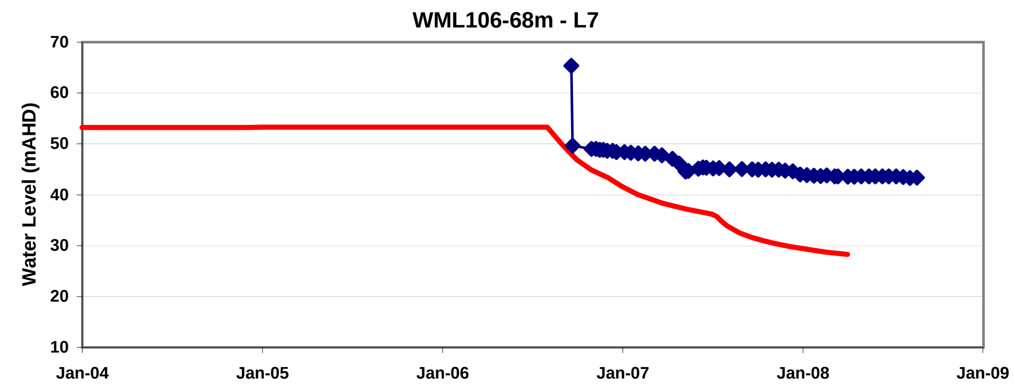
Layer 1 Modelled vs Observed - Bowmans Creek Alluvium Water Levels

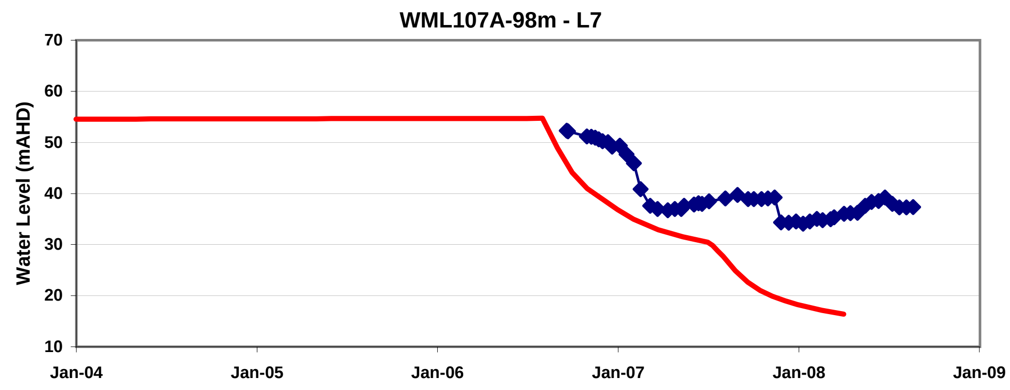
Figure 14











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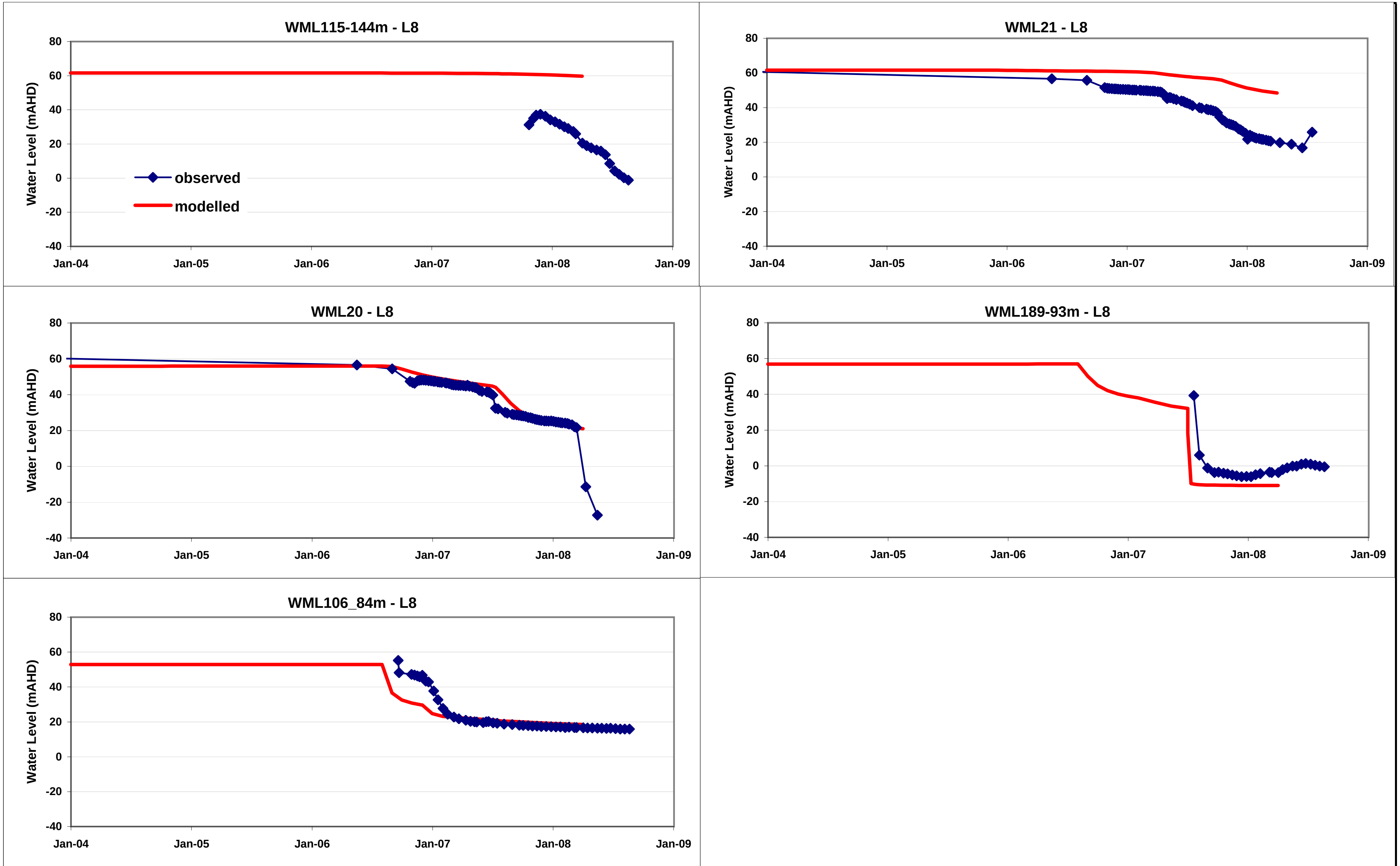
Layers 6 to 7 Modelled vs Observed - Lemington 15 (L6), Lemington 19 (L7) Water Levels

Figure 15



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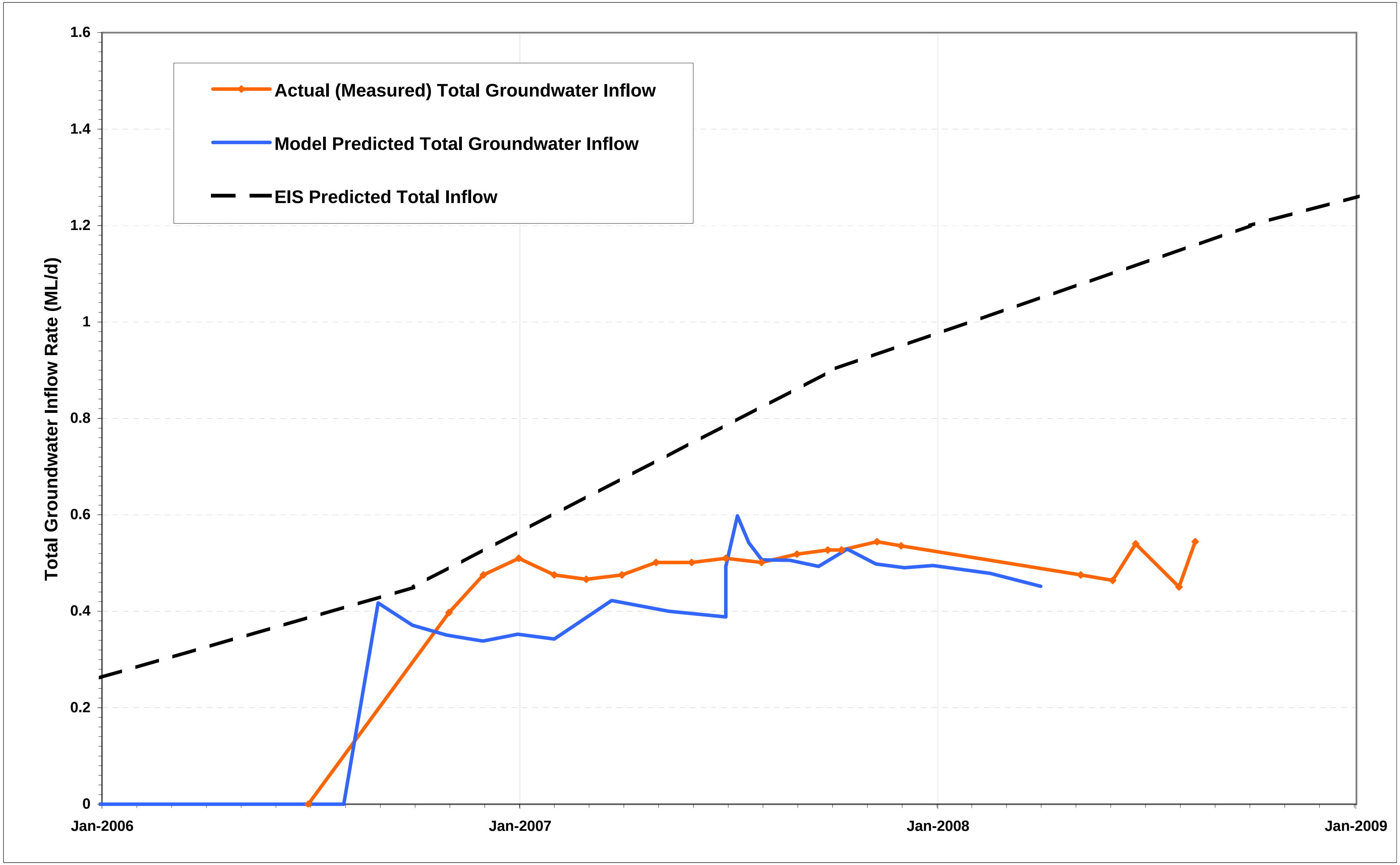
Layer 8 Modelled vs Observed - Pikes Gully Seam Water Levels

Figure 16



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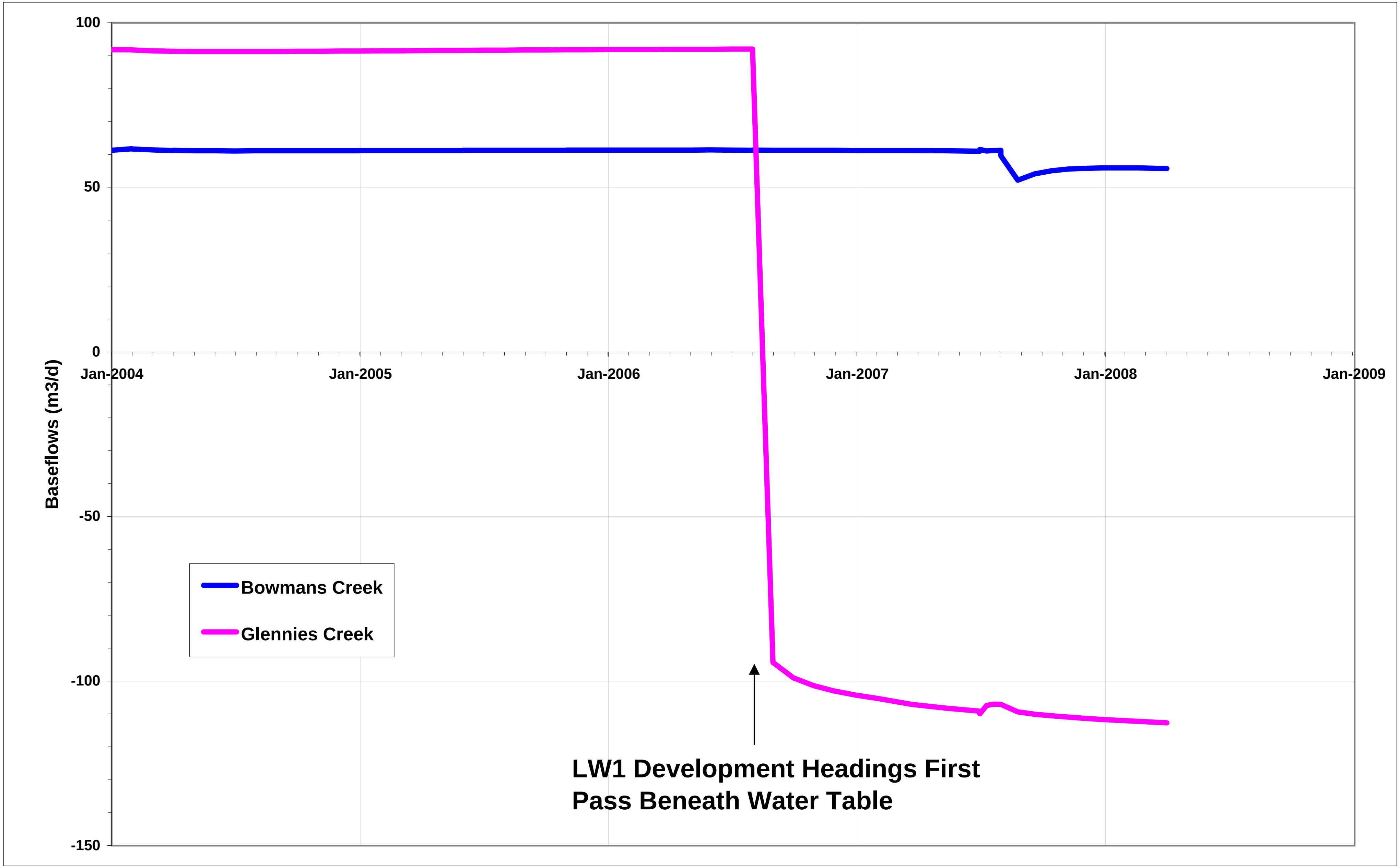
Predicted Total Groundwater Inflow Rates v Measured Inlfows and EIS Predictions
Figure 17



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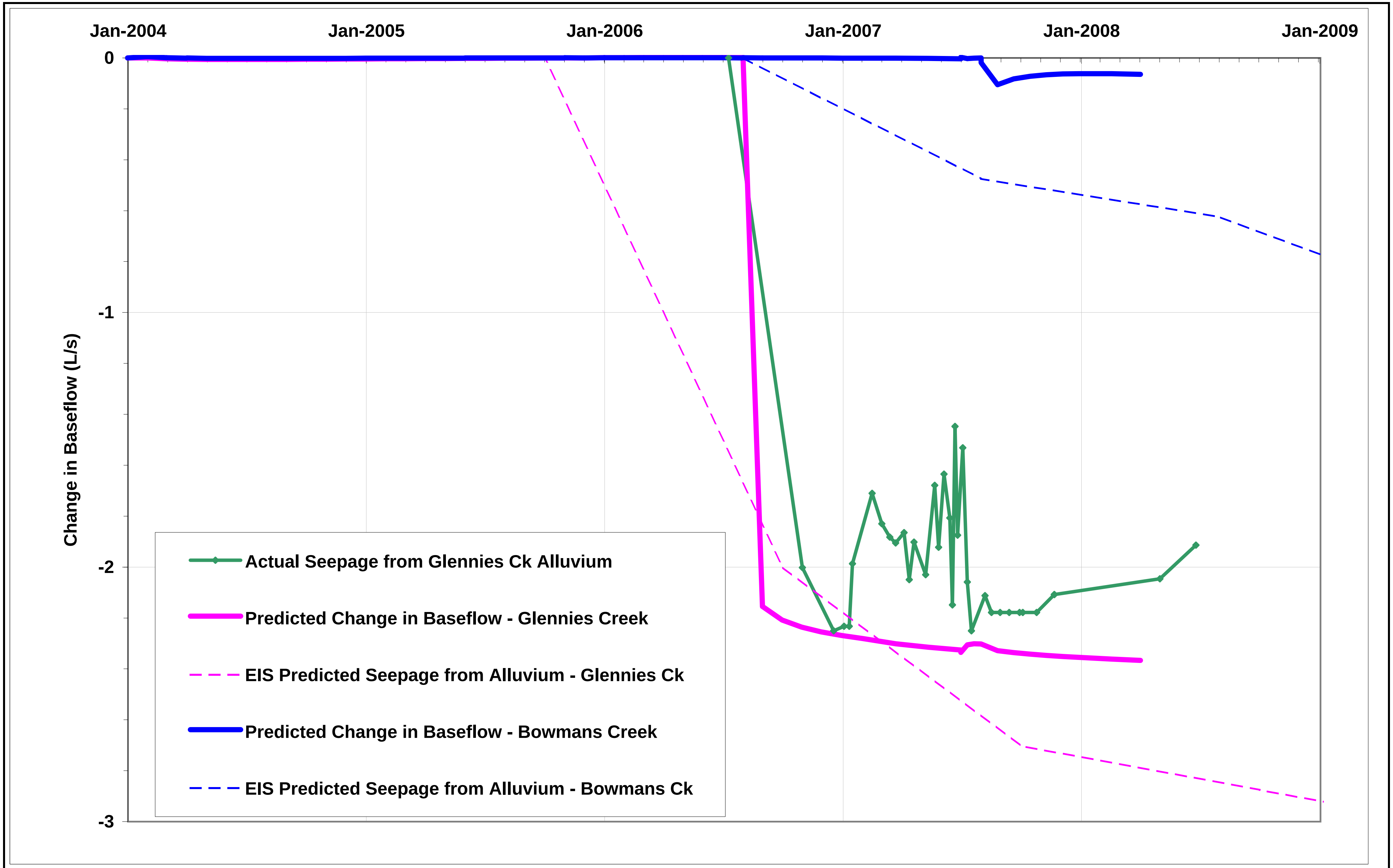
Creek Baseflows Over the Transient Calibration Period
Figure 18



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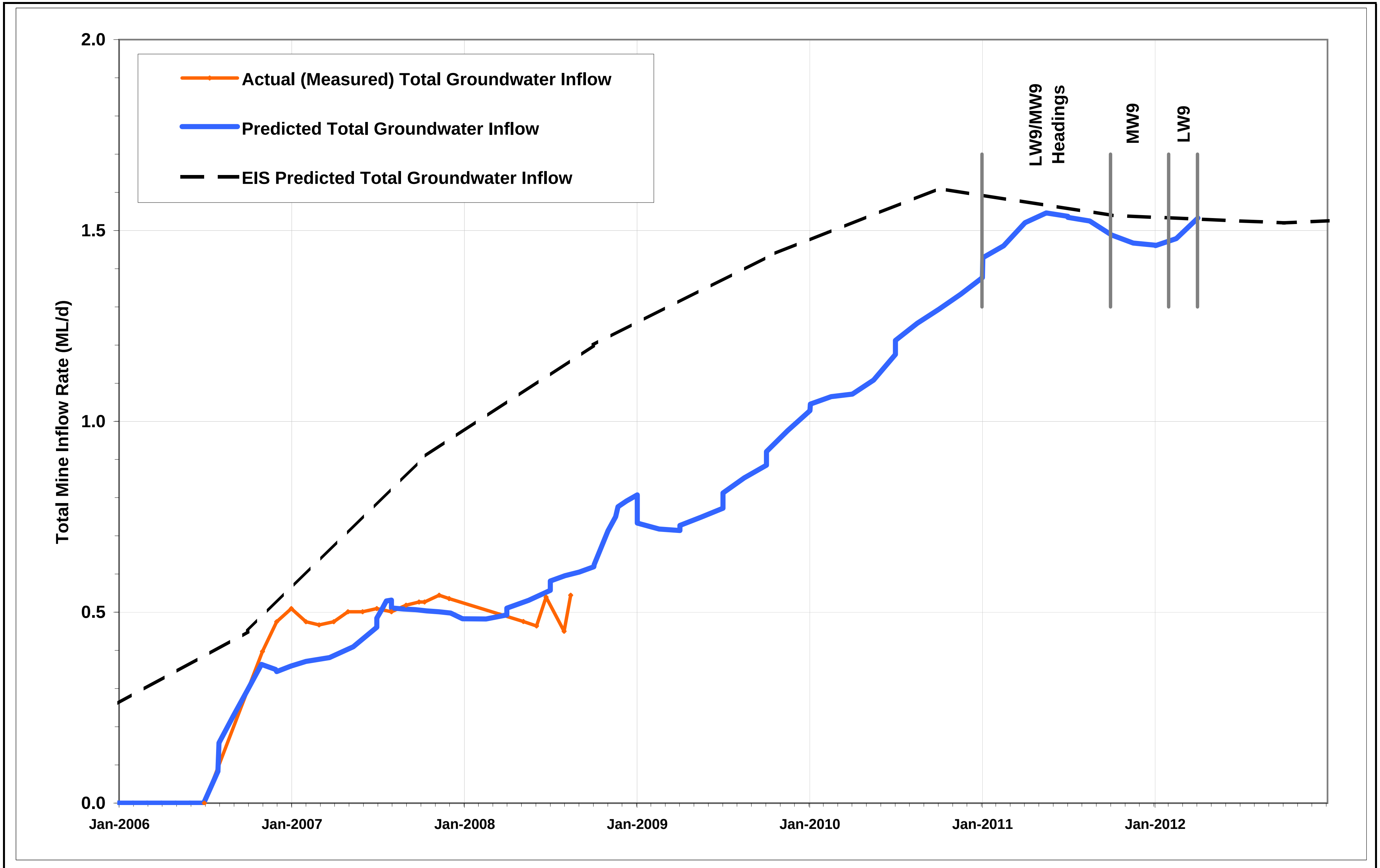
Predicted Baseflow Changes Over the Transient Calibration Period
Figure 19



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Predicted Total Groundwater Inflow Rates

Figure 20

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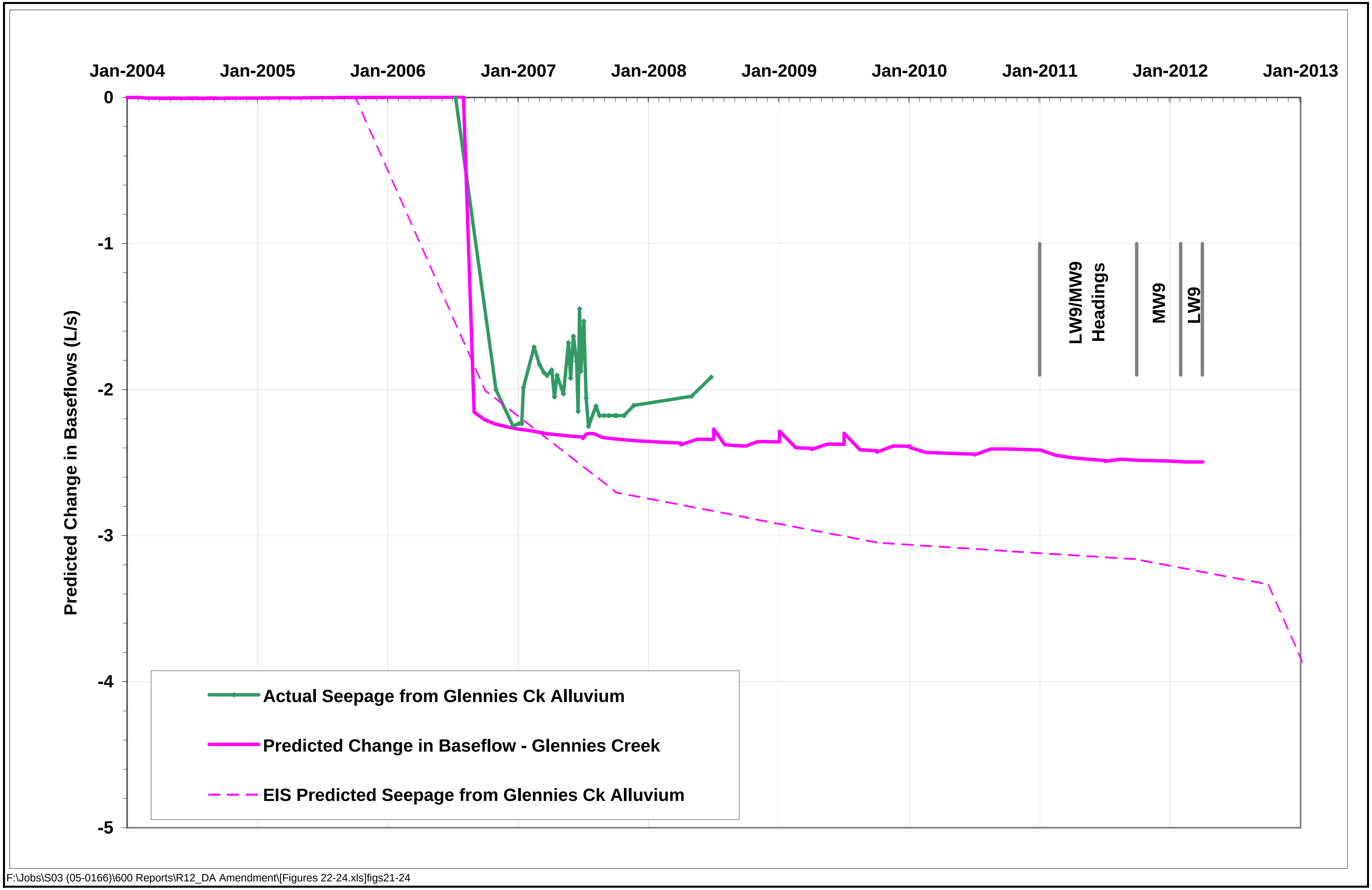
Predicted Creek Baseflows for LW/MW 5-9 Mine Plan

Figure 21



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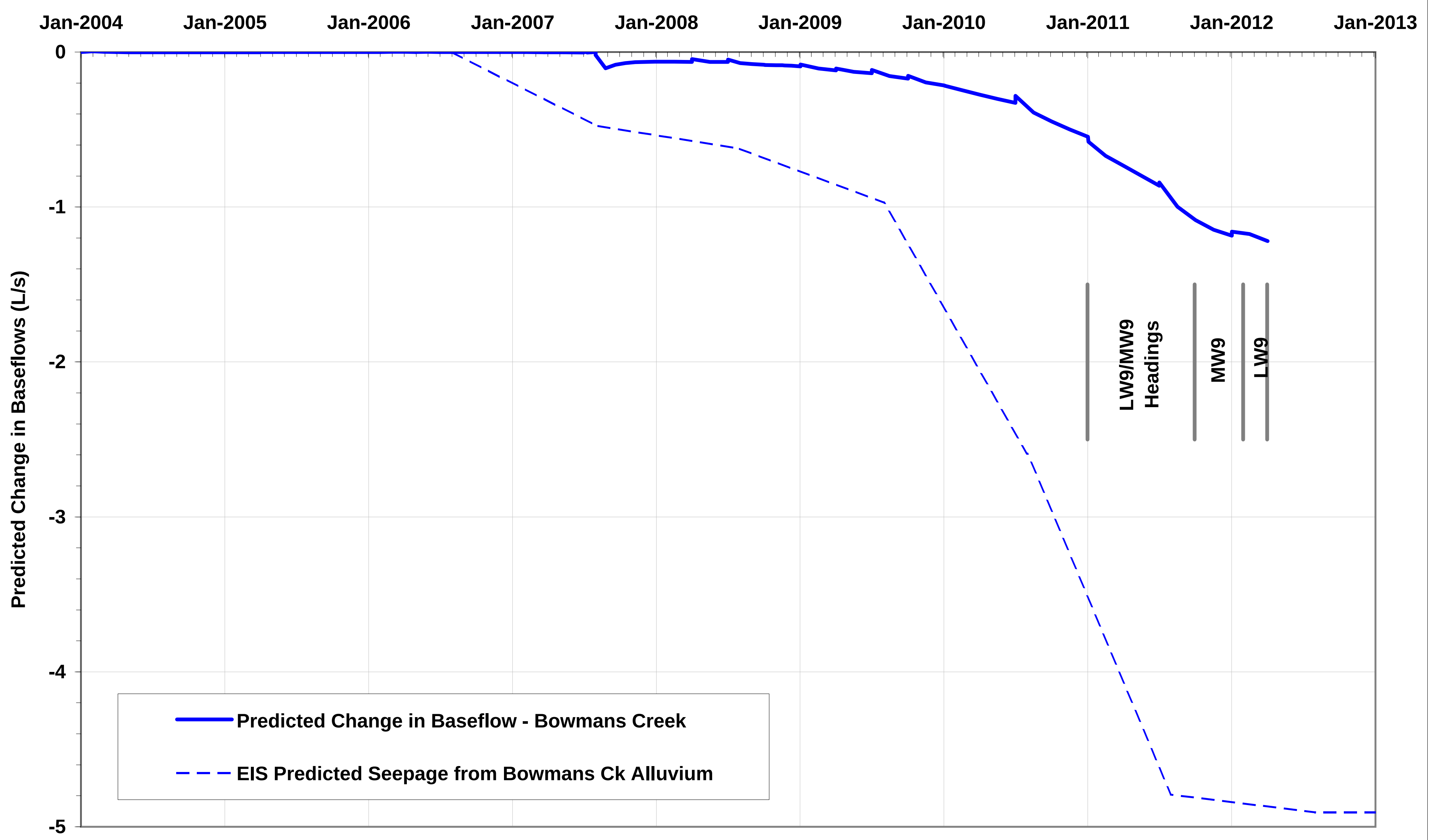
aquaterra

Predicted Baseflow Impacts on Glennies Creek for Option LW/MW 5-9
Figure 22



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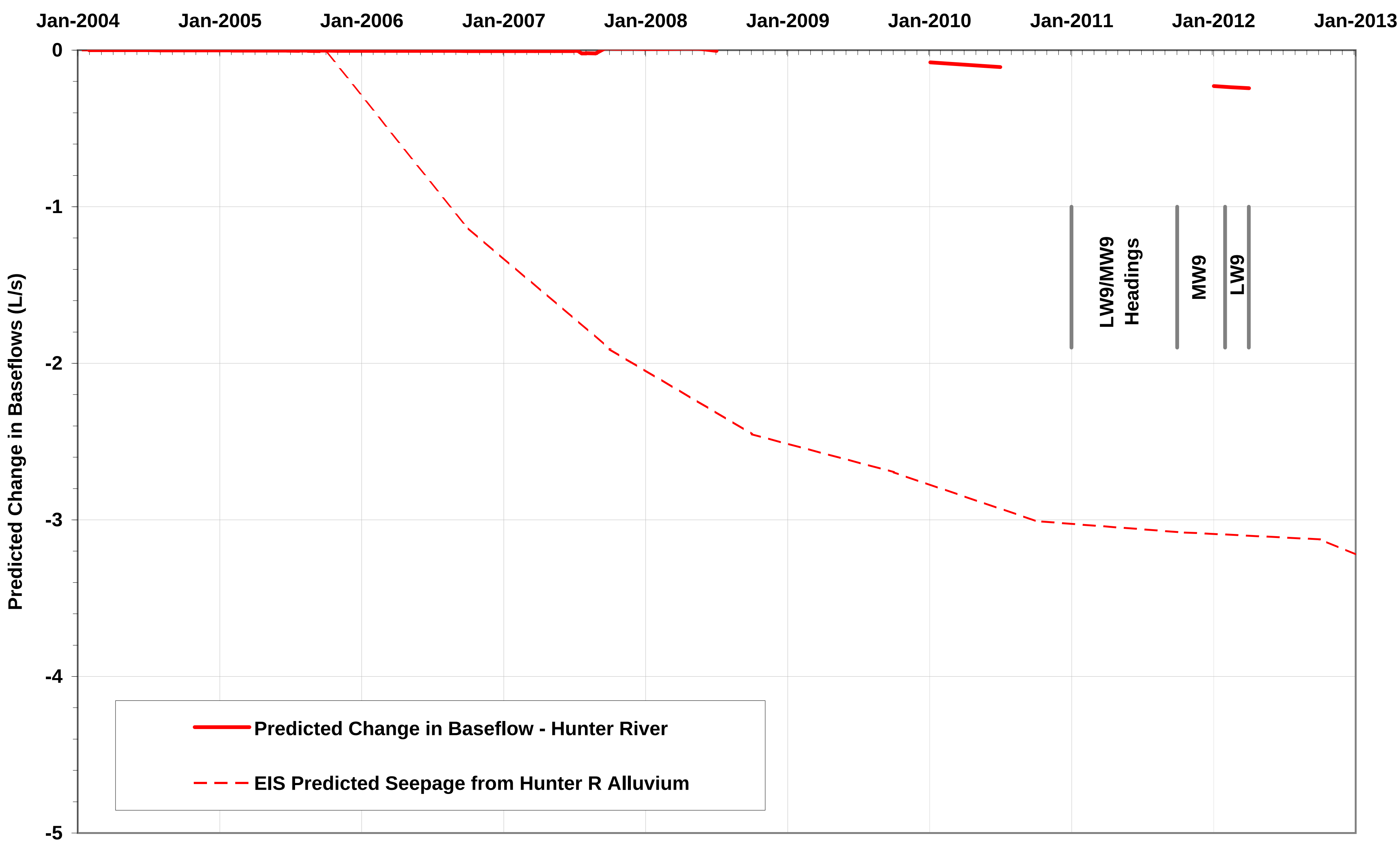
Predicted Baseflow Impacts on Bowmans Creek for Option LW/MW 5-9
Figure 23



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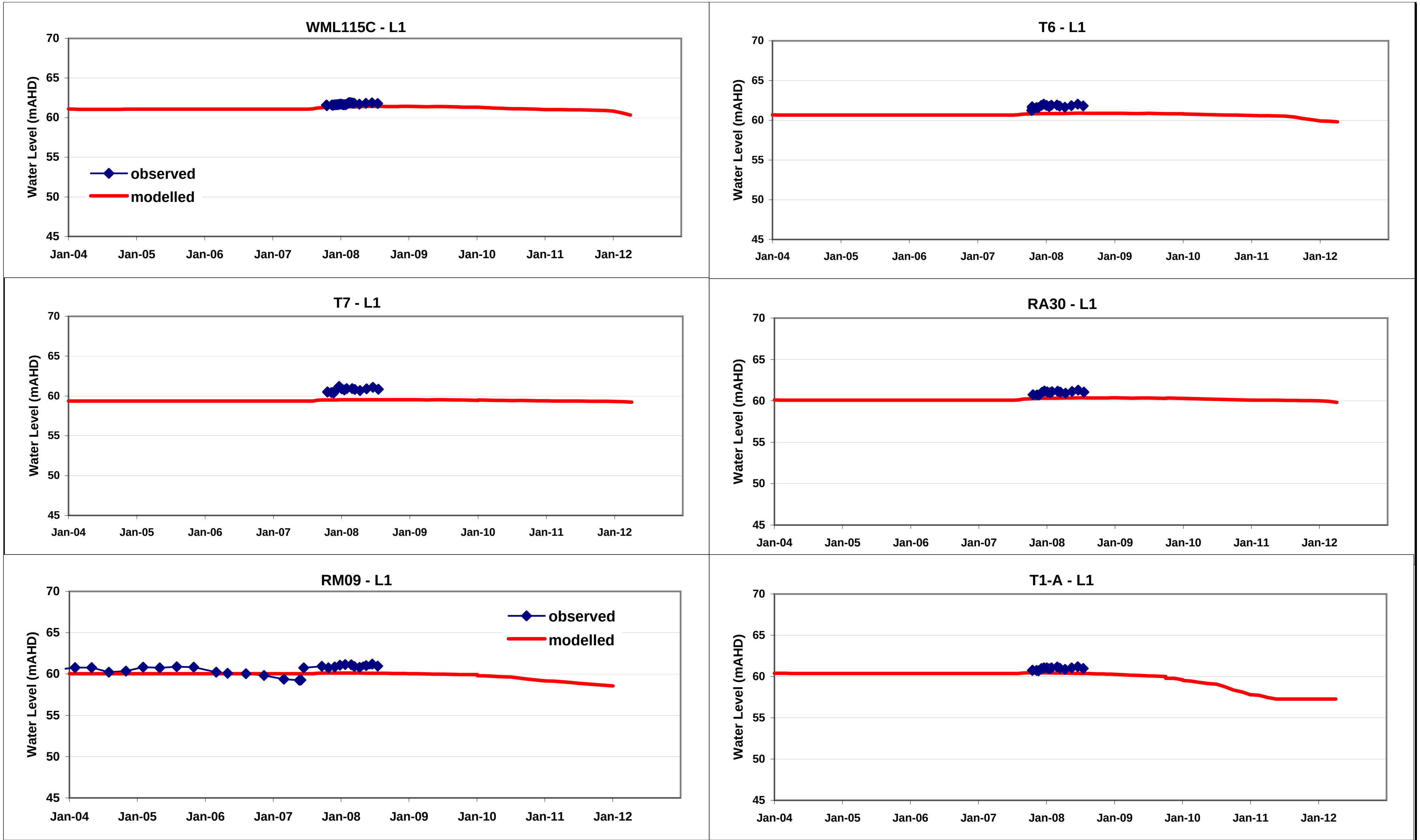
Predicted Baseflow Impacts on Hunter River for Option LW/MW 5-9
Figure 24



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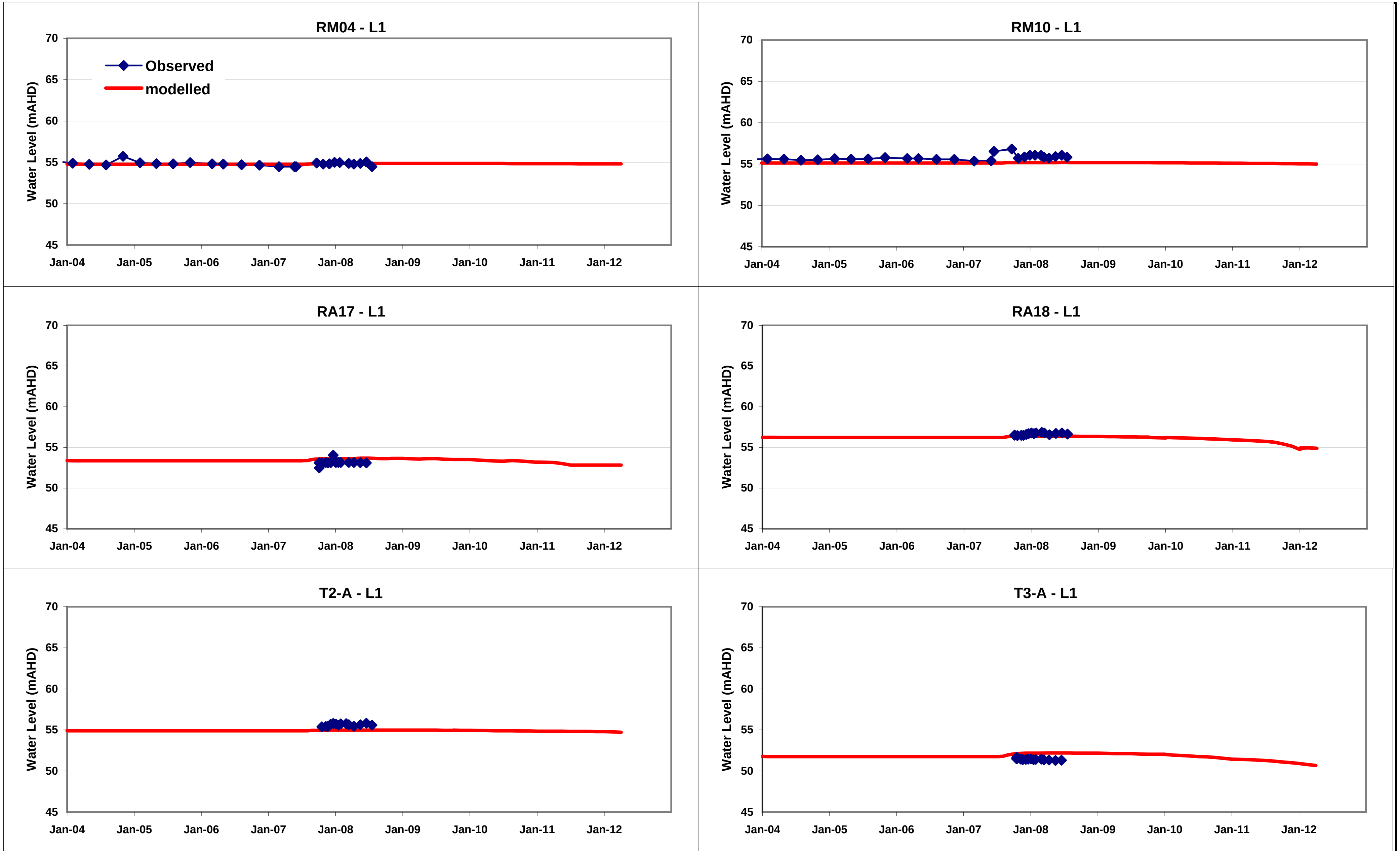
Layer 1 Modelled vs Observed - Bowmans Creek Alluvium Water Levels

Figure 25



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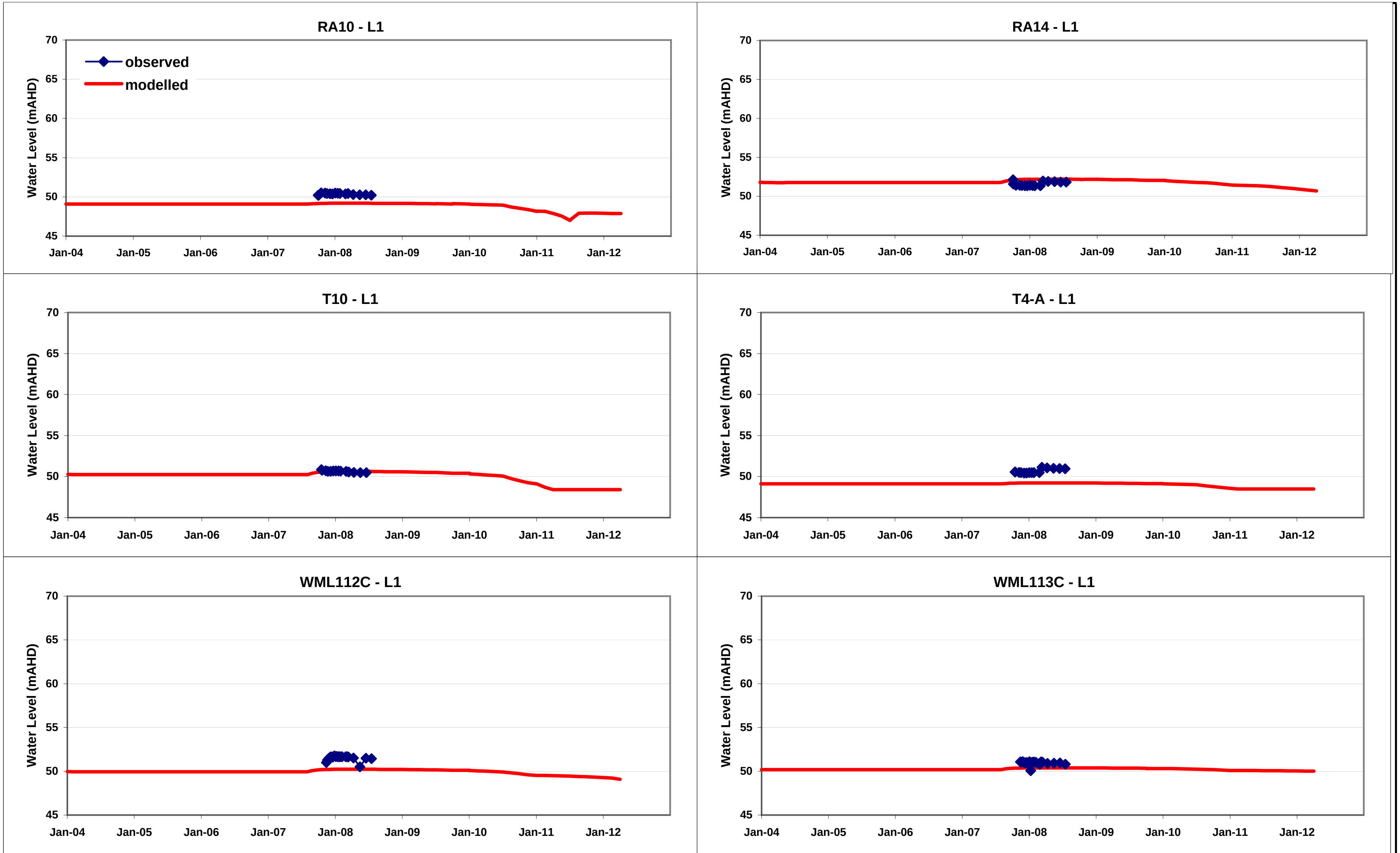
Layer 1 Modelled vs Observed - Bowmans Creek Alluvium Water Levels

Figure 26



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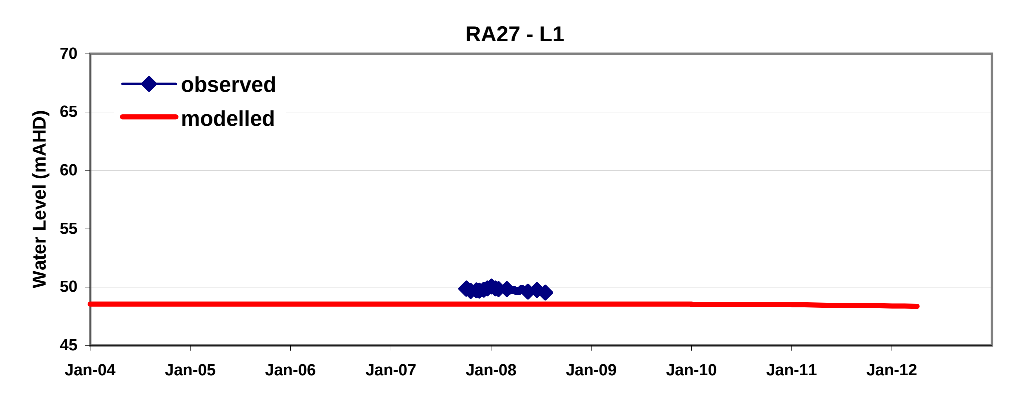
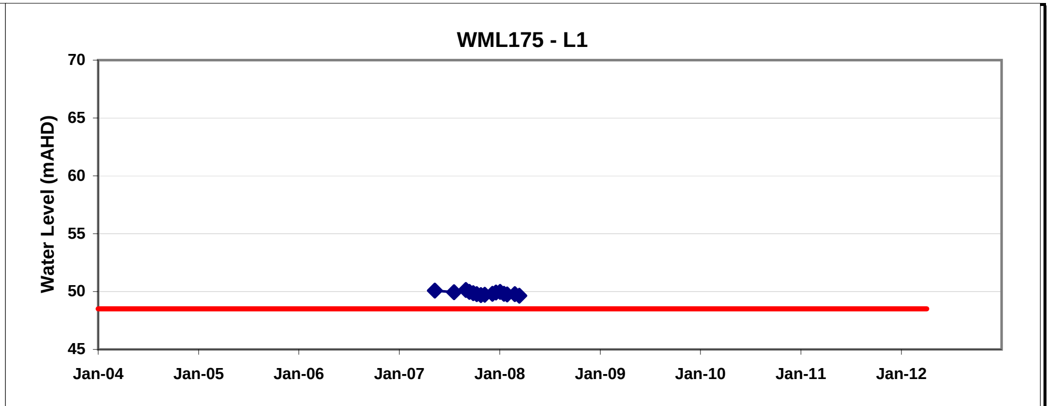
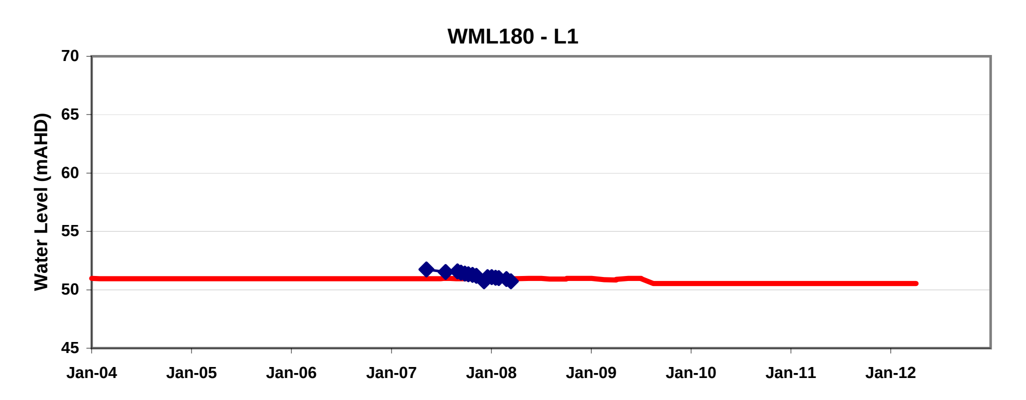
Layer 1 Modelled vs Observed - Bowmans Creek Alluvium Water Levels

Figure 27







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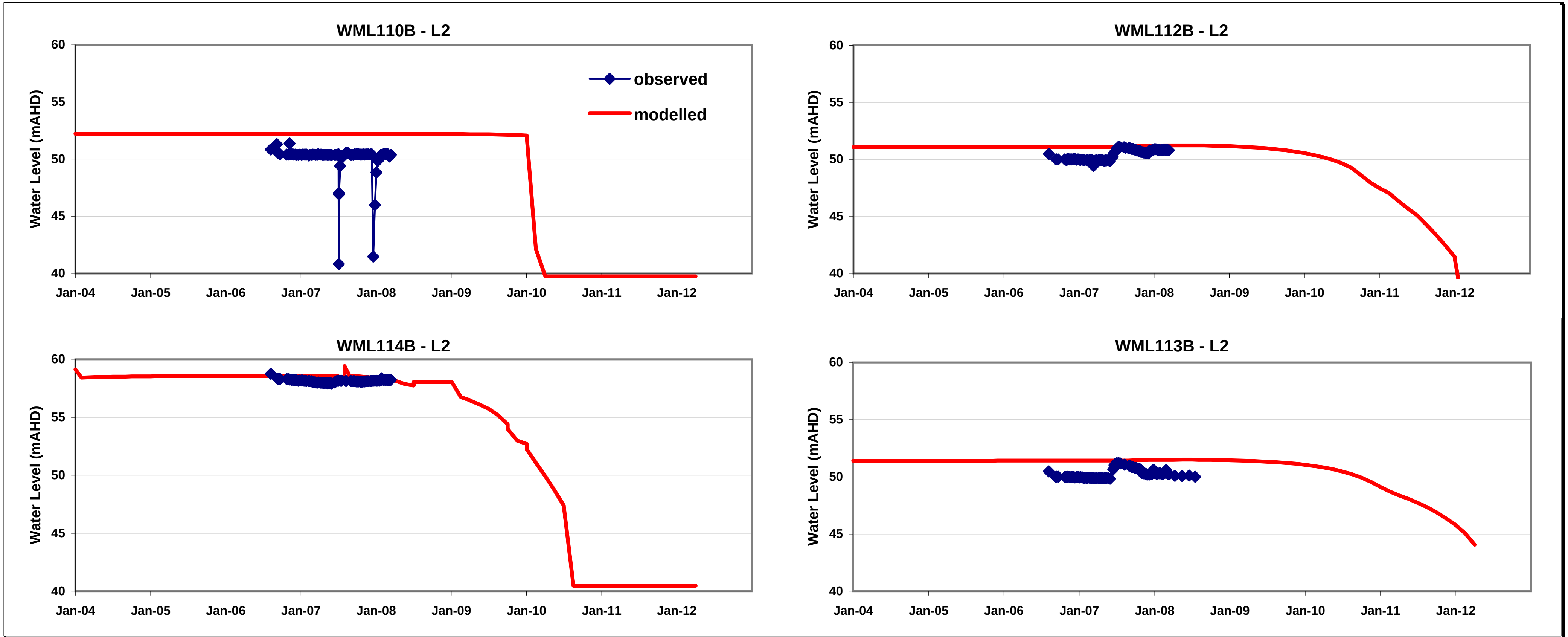
Layer 1 Modelled vs Observed - Hunter River Alluvium Water Levels

Figure 28



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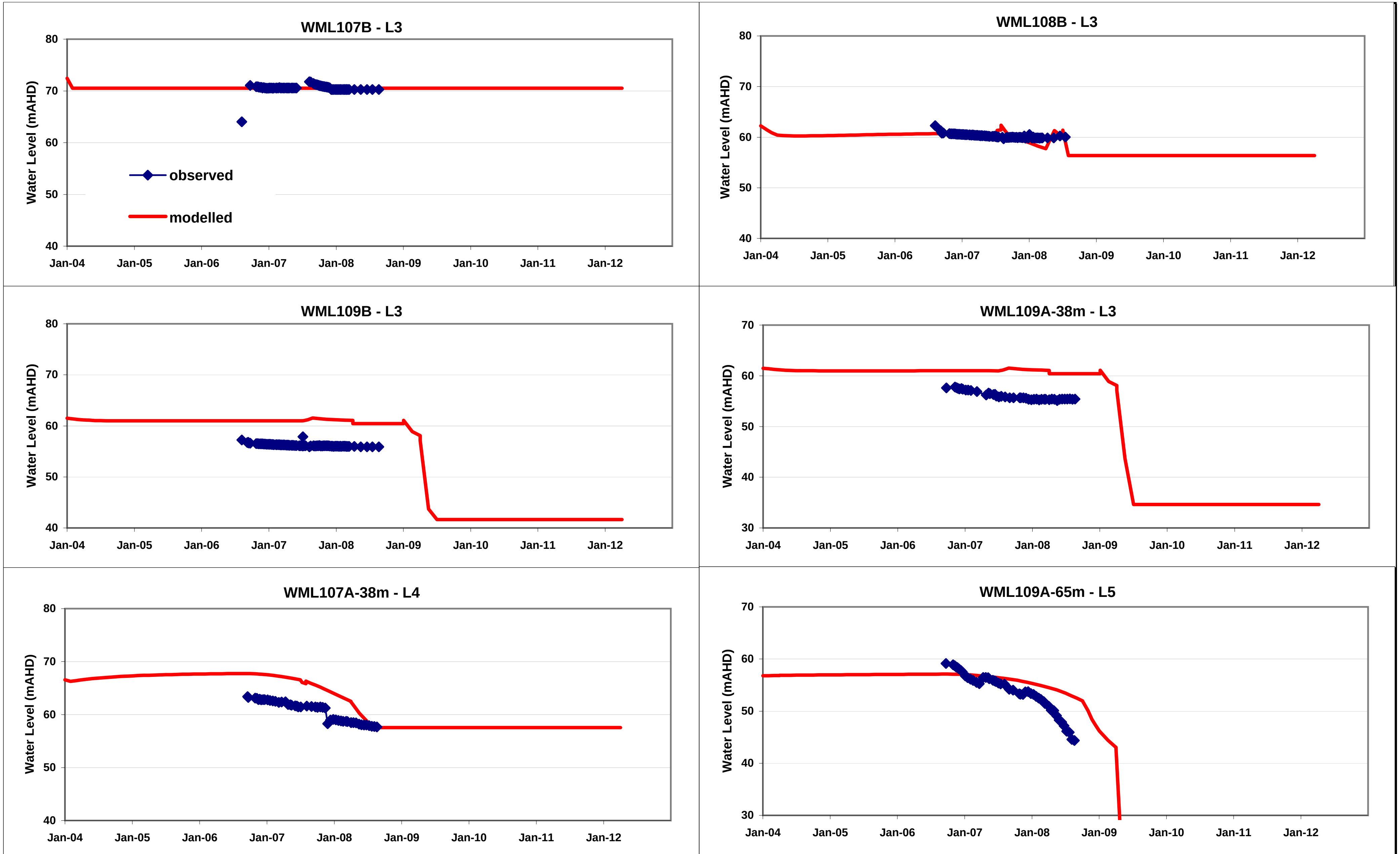
Layers 2 Modelled vs Observed - Permian Coal Measures Overburden Water Levels

Figure 29



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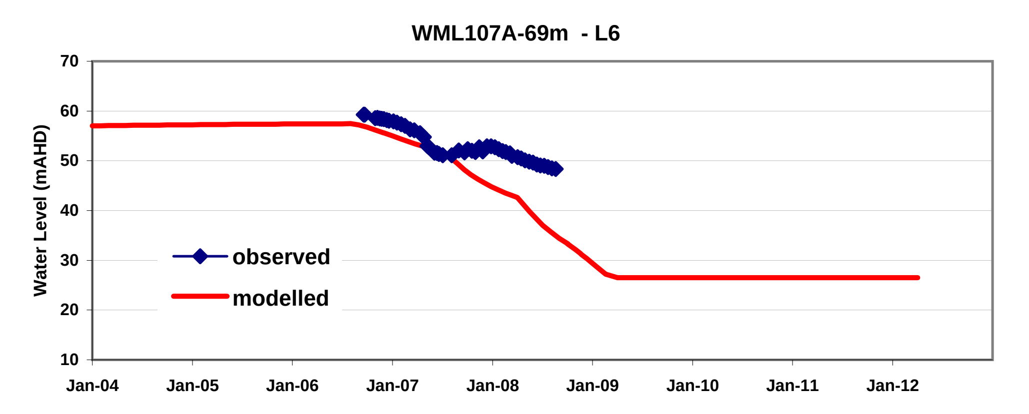
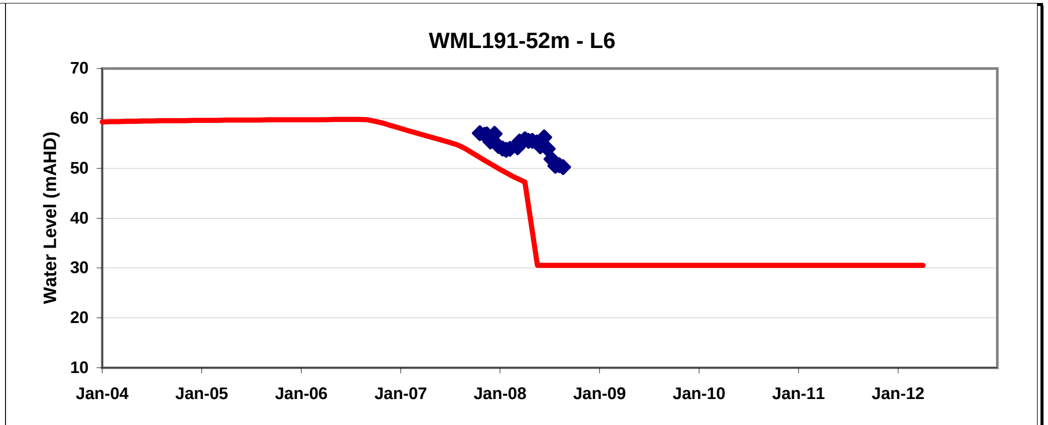
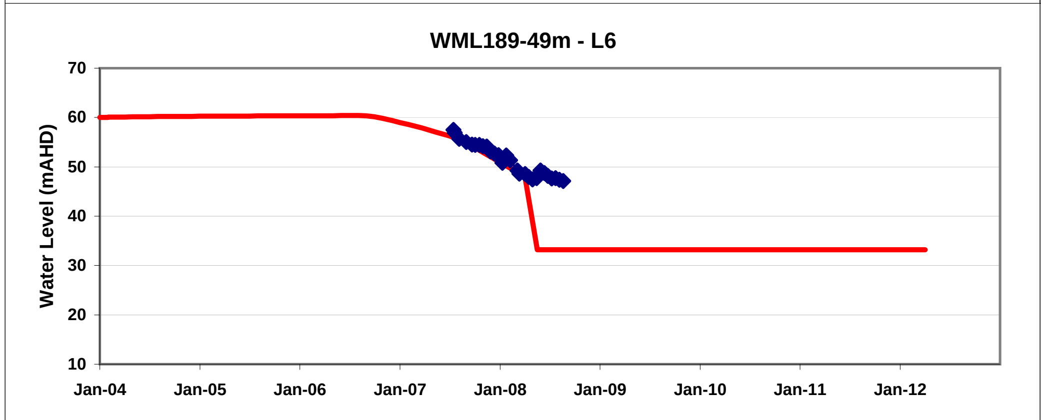
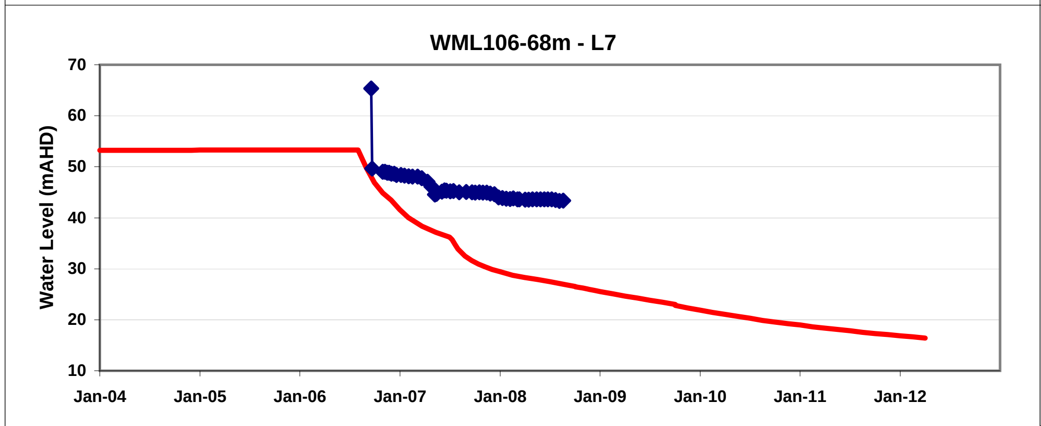
Layers 3 to 4 Modelled vs Observed - Lemington 7-9 Seams (L3), Lemington 11 (L4), Lemington 12 (L5) Water Levels

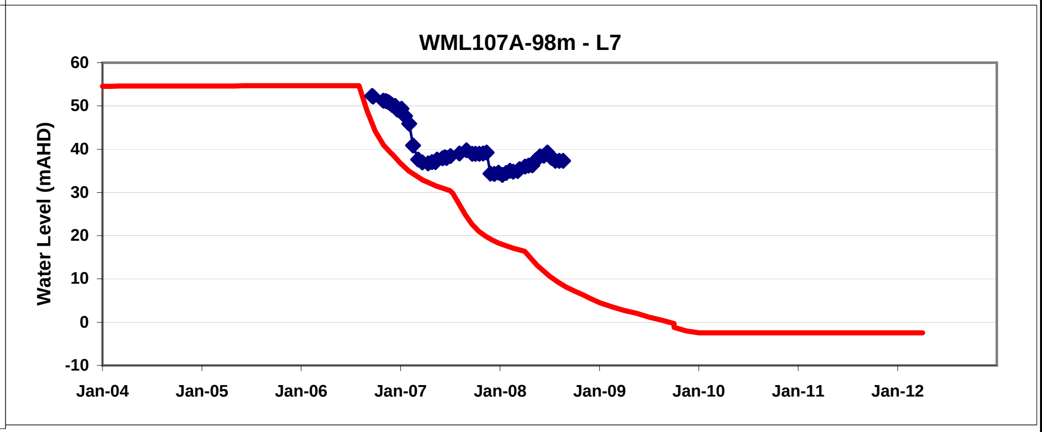
Figure 30











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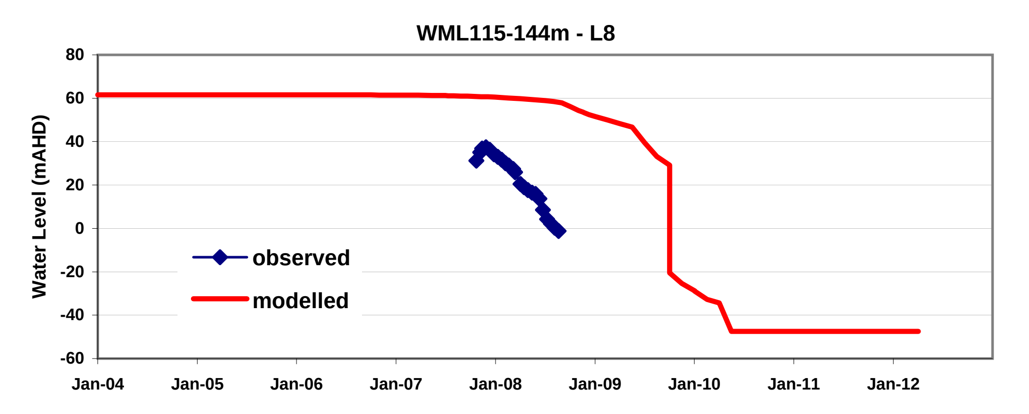
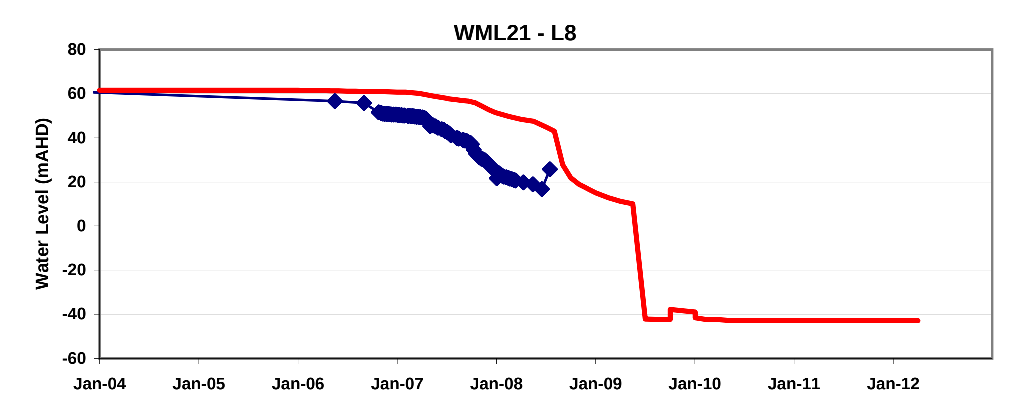
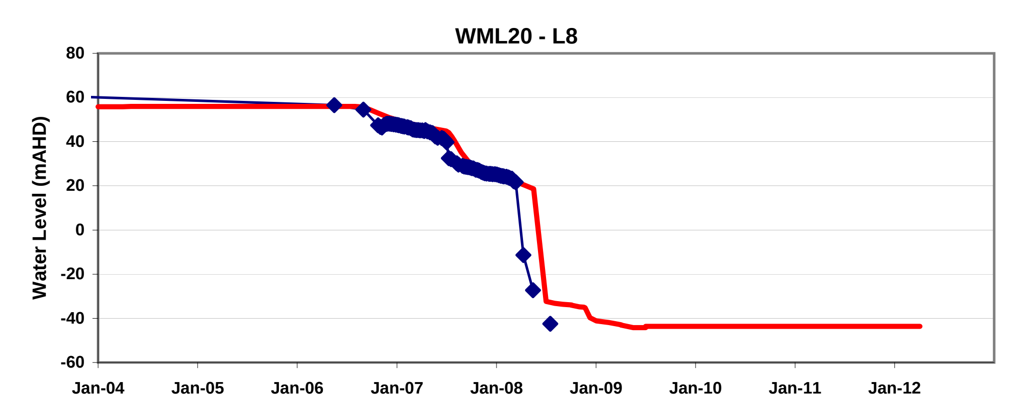
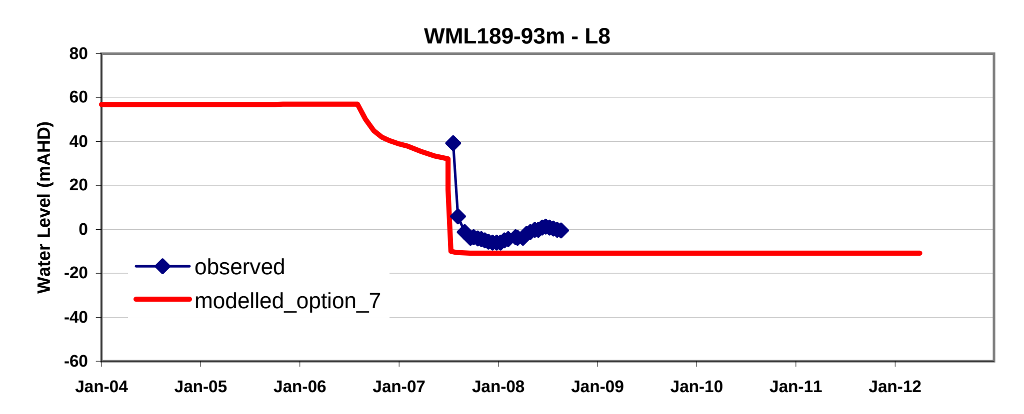
Layers 6 to 7 Modelled vs Observed - Lemington 15 (L6), Lemington 19 (L7) Water Levels

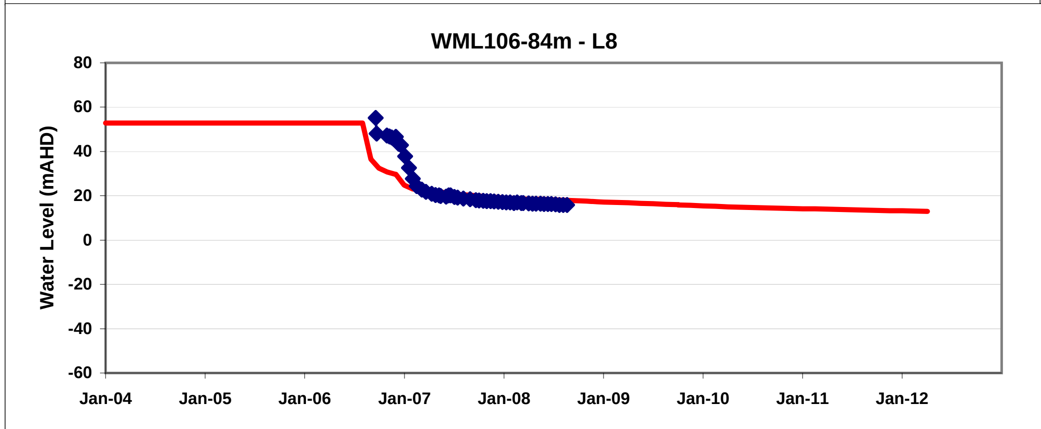
Figure 31











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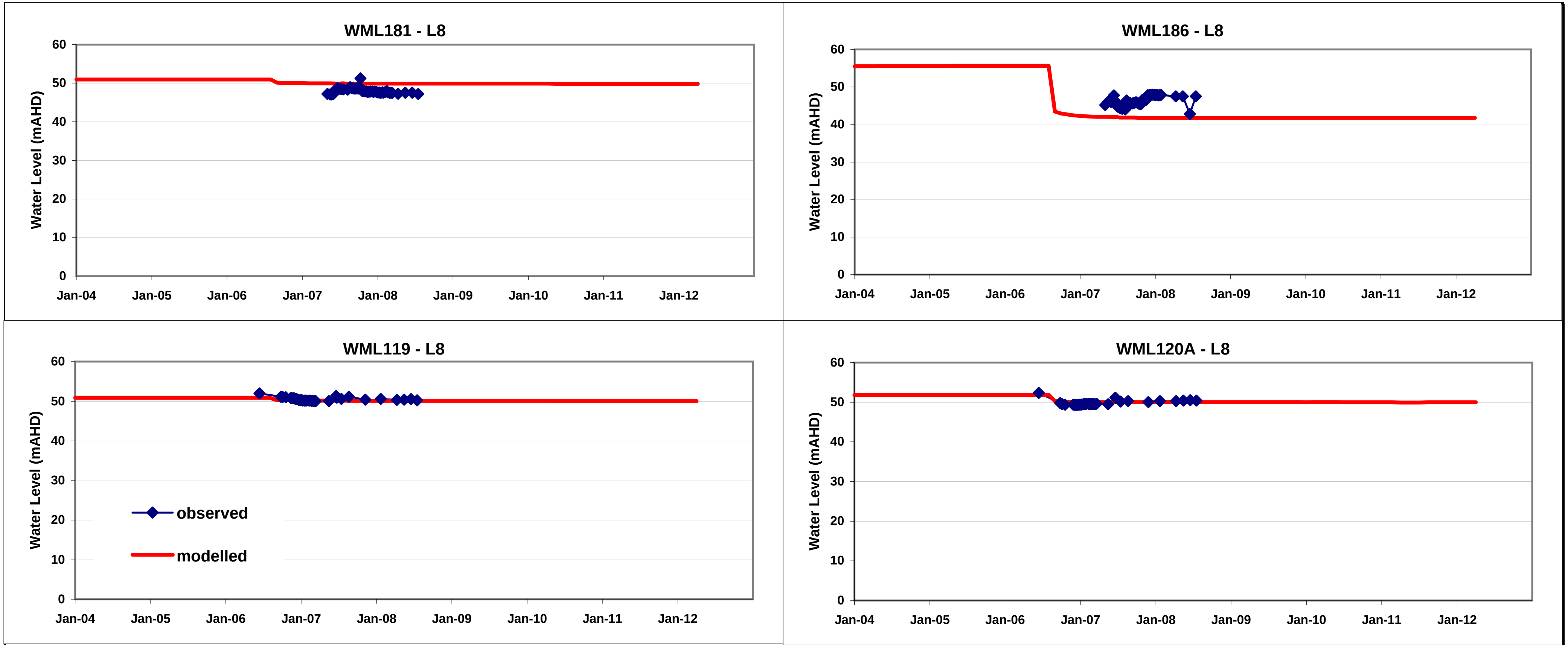
Layer 8 Modelled vs Observed - Pikes Gully Seam Water Levels

Figure 32



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Layer 8 Modelled vs Observed - Pikes Gully Seam Water Levels

Figure 33

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