Report

Hancock Coal Pty Ltd

Groundwater Modelling Report - Alpha Coal Project

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Prepared for

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Abbreviations

Abbreviation	Description
AGC	Australian Groundwater Consultants
ATP	Alpha Test Pit
BOM	Bureau of Meteorology
BFS	bankable feasibility study
CRD	Cumulative rainfall departure
DERM	Department of Environment and Resource Management
EIS	Environmental Impact Statement
EPC	Exploration Permit Coal
ET	evapotranspiration
GAB	Great Artesian Basin
GL	Gigalitre
Hancock	Hancock Coal Pty Ltd
HPPL	Hancock Prospecting Pty Ltd
K	Hydraulic conductivity (m/day)
K_{xy}	Horizontal hydraulic conductivity
K_z	Vertical hydraulic conductivity
KC_OC_S	Kevin's Corner open cut south
KC_OC_N	Kevin's Corner open cut north
KC_UG	Kevin's Corner underground
LOM	Life of mine
L/s	litres per second
m AHD	metres Australian Height Datum
MDL	Mineral Development Licence
mbtoc	metres below top of casing
mbgl	metres below ground level
m/day	metres per day
ME	Mean error
MLA	Mine lease application
ML/a	Megalitres per annum
mm	millimetres
m/s	metres per second
Mtpa	Million tonnes per annum
NTEC	NTEC Environmental Technology
QPED	Queensland Petroleum Exploration Database
RCS	Relative composite sensitivity
RMSE	Root-mean-square error
ROM	Run of mine
RRM	Rainfall Residual Mass
Sc	Storage coefficient
SWL	static water level
SST	sandstone
Sy	Specific yield

Abbreviations

Abbreviation	Description
T	Transmissivity (m^2/day)
URS	URS Australia Pty Ltd
VWP	Vibrating wire piezometers
4T	4T Consultants Pty Ltd

Executive Summary

URS Australia Pty Ltd were commissioned to undertake hydrogeological studies necessary to allow for the assessment of potential impacts of the proposed mining activities on the groundwater regime. These hydrogeological studies, including drilling, aquifer testing, and compilation of aquifer hydraulic parameters, allowed for the construction and calibration of several numerical groundwater models. The various "built-for-purpose" models included:

- An initial Environmental Impact Statement (EIS) regional numerical model, which allowed for a preliminary assessment of potential impacts of mine dewatering on the regional groundwater regime;
- A refined predictive groundwater model, which allowed for an accurate estimate of groundwater ingress over the life of mine (LOM) and facilitated mine water management and mine water budget studies; and
- An integrated surface water - groundwater model, which allowed for a more detailed and accurate simulation and assessment of potential long term groundwater impacts associated with the Alpha final void.

The initial EIS model, compiled by NTEC Environmental Technology (NTEC), provided an initial assessment of groundwater ingress, drawdown impacts, and final void / long term groundwater levels. These results, presented in the various EIS submissions to date, have been superseded through ongoing model refinement based on the compilation of additional site-specific hydrogeological data.

The predictive modelling aimed at providing estimates of groundwater inflows and dewatering volumes, over the life of the Alpha and Kevin's Corner coal projects. URS had originally proposed to utilise the existing regional groundwater model, constructed to assess impacts of mining on the local and regional groundwater regime, through refinement based on additional hydrogeological data. Through a review process, assessment of model limitations, and limitations of modelling resources, a MODHMS model was constructed and calibrated (utilising a specialist groundwater modelling company MTNA) to undertake the predictive groundwater assessment.

The predictive groundwater model was constructed and calibrated to provide bankable feasibility study (BFS) level estimates of groundwater inflows and dewatering volumes available to the Alpha and Kevin's Corner coal projects.

An evaluation of possible recharge mechanisms was undertaken. A review of available groundwater hydrographs, from long term monitoring points across the Hancock properties, drilling results, hydrochemistry, and groundwater flow patterns indicated that the dominant recharge mechanism is diffuse recharge along the Great Dividing Range; however, the effective recharge to the confined Permian aquifers is negligible.

Aquifer hydraulic properties were estimated based on historic aquifer test studies as well as 2011 pump-out tests conducted across Kevin's Corner, variable (slug) head tests, laboratory permeability testing, and literature data. These data plus the transient pumping, water level, and extraction volume information compiled during the Alpha Test Pit (ATP) dewatering were used to validate model parameters and allow for model calibration within site specific representative constraints.

The MODHMS groundwater modelling package was used to construct the required groundwater assessment model. This software package also allowed for the development of the integrated (surface water – groundwater) model, which was used to assess potential long term impacts and groundwater conditions. For the purpose of predictive inflow simulation, steady-state and transient flow calibration was conducted in order to verify model conceptualisation and attain reasonable parameter ranges

aligned with field measurements. The calibrated hydraulic conductivity (K) values from the steady-state model and calibrated storativity values from the transient model were adopted for the predictive dewatering simulations.

The root-mean-square error (RMSE), used to evaluate the performance of steady-state model calibration based on groundwater levels, was 3.7% (good agreement between calibrated results and field measurements is to have RMSE < 10 %). The mean error (ME) of -0.22, very close to zero, indicated no significant bias in the data. For the transient calibration the RMSE was 3.9%. The simulated dewatering volume totalled 44.9 ML, which comprised out-of-pit dewatering of 38.8 ML and losses (seepage plus evaporation) of 6.1 ML. This simulation was close to the estimated volumes calculated using field measurements of 45.3 ML. The transient calibration not only had good comparison to volumes of water removed during the Alpha Test Pit dewatering but also matched groundwater level drawdown in 5 observation bores, screened across different units.

Sensitivity analysis was conducted to evaluate the effects of changes in individual model parameters on model results and provides an indication of the uncertainty within which the model parameters have been estimated. The sensitivity of simulated heads to parameters was used to aid model calibration and was assessed through relative composite sensitivity.

Predictive simulation was conducted for both open-cut and underground mining (Alpha and Kevin's Corner coal projects) during the active period till end of 2043. Predictive inflows for Alpha and Kevin's Corner were estimated through zone budget in the model simulation, which allowed for an assessment of cumulative impacts.

Parameter uncertainty was explored through additional model scenario runs using different parameters values, which were potentially sensitive and have impacts on predictive inflow values. The uncertainty analysis was conducted, along with calibration statistics, for both steady-state and transient models to examine whether the additional predictive runs were still within the calibration constraints (based on site specific data).

Scenario Case 7 (doubling of specific yield in various model layers) provided the highest estimates of groundwater volumes LOM (although the probability of this scenario is very low due to transient calibration results) and the lowest groundwater volume estimate resulted from scenario Case 21. Case 21 reduces vertical hydraulic conductivity by a factor of 10^{-3} in Bandana Formation and Joe Joe Formation. The reduction results in the marked reduction in groundwater ingress volumes estimates as it reduces the potential impact longwall mining (goaf) interconnectivity to the upper units within the underground mining operations. Based on documented goaf impacts (resulting fracturing) it is considered that Case 21 has a low probability. A range of high, low, and expected groundwater ingress estimates were compiled using the three matching scenarios (Case 7, Base Case, and Case 21). The total volumes of groundwater ingress for the two Hancock projects at LOM were 241 GL (Case 7), 176 GL (Base Case), and 104 GL (Case 21).

An estimate of groundwater ingress volumes into Alpha Coal Project alone was undertaken. Three scenarios (high (Case 7), base, and low (Case 8)) were modelled using only the Alpha mine schedule and plan. Case 8 (reducing the Sy) for open cut mining provides the lowest estimate as this limits the drainable volumes of groundwater that could enter the open pits from the over- and interburden. The total volumes of groundwater ingress for Alpha Project only at LOM were 100 GL (Case 7), 60 GL (Base Case), and 41 GL (Case 8).

Executive Summary

The predictive model was utilised to assess drawdown within the different aquifers and geological model layers, over time and spatially across the model domain. Projected groundwater levels below the Great Artesian Basin Rewan Formation and Clematis Sandstone do not indicate any drawdown effects as a result of mine dewatering over the life of mine (30 years). Thus no impacts of potential induced flow are considered.

The direct and indirect impacts of mine dewatering on the vegetation communities were evaluated based on the (largest) predicted drawdown associated with the D coal seam. There is limited potential for induced flow from the isolated (non-continuous) perched water down into the depressurised deeper aquifers. These perched water tables are regular recharged through rain and flood events and not reliant on upward groundwater movement. However, it is anticipated that there will be some direct impacts to the perched water table(s) due to direct drainage into the open mine voids. It has been predicted that there will be a 10 to 100 m zone of influence directly around the mine voids.

An assessment of neighbouring bores, which may be at risk from Alpha mine dewatering, was conducted. An assessment of bores within the projected 1 and 5 m drawdown contours for the target D seam, at the end of mining, was conducted. 18 neighbouring bores, recorded during the study, have been identified and will be field checked as part of the Proponent's make-good commitment.

Drawdown cones in the D coal seam were contoured, up to 0.5 m, to assess groundwater level change during mining for Alpha alone and also for (cumulative contours) Alpha and Kevin's Corner. The projected contours indicate that there will be minimal drawdown to the east of the mine footprint because of the aquitard nature of the Joe Joe Formation metasediments. This low permeability unit restricts groundwater drawdown, resulting from mining, to the east. Drawdown cones elongate north and south, within the more permeable Colinlea Sandstone. The cumulative impact of adding the Kevin's Corner dewatering results is deeper drawdown where drawdown cones overlap and further elongation along strike. The low permeable Bandana Formation and Rewan Formations constrain drawdown to the west. These constraints apply across the entire portion of the Galilee Basin containing Alpha. This means that the potential for induced flow from the GAB or drawdown in the older units to the east of the Joe Joe Formation does not increase based on additional mining.

An integrated model was constructed to allow for an assessment of potential long term impacts based on predicted final void water levels and long term groundwater levels. The final void modelling predicts that the final void water level reaches a pseudo steady-state after ~ 50 years, at around 37 m above pit floor (around 250 m AHD depending on location within the final void). An uncertainty assessment, allowing for varying climate conditions (long term climate change) indicates that the variation in in / out flux components in the integrated model do not markedly alter predictions, ~ 1 m. The lowest elevation point where decant could potentially occur is along the northern most portion of the final void, at an elevation of 305 m AHD. The projected final void water level in the northern portion of the final void is 249 m AHD, some 56 m below the lowest pit surface elevation. The risk of decant is, therefore, considered negligible.

Final void quality is recognised to deteriorate over time due to the concentration of salts as a result of evaporation. The final void water could be utilised for ~ 150 years before the salinity reached 5,000 mg/L TDS, the ANZECC 2000 guidelines for cattle livestock drinking water.

Based on requests for data compiled post EIS submission, additional predictive groundwater

modelling was undertaken to allow for an assessment of possible risks with regards to:

- The closest Great Artesian Basin (GAB) major aquifer, the Clematis Sandstone;
- The basal unit of the GAB, the Rewan Formation, which overlies the target Permian sediments;
- Registered springs to the north of Alpha and Kevin's Corner coal projects;
- Sub-E coal seam sandstone, which has been identified as a source of make-good water; and
- Cumulative impacts through assessing the model predictions for Alpha alone and then comparing the results of simulating Alpha and Kevin's Corner.

Observation points within the model allowed for the assessment of groundwater level changes in different model layers, over time (during mining and for 300 years post mining), within and adjacent to the Alpha Open Cut mine and final void. The predictions of the changes in groundwater resources as a result of mining and final void indicate a permanent alteration to groundwater flow patterns and levels around the final void.

The predicted changes in groundwater levels in the units below the Clematis Sandstone, after 300 years, are sufficiently small (within natural fluctuations) that the risk of induced flow from the Clematis Sandstone to the mine depressurised units is negligible. Larger drawdown is projected for the Bandana Formation below the Rewan Formation, which indicates limited potential (to the west of Alpha) to induce flow from this unit. The resultant change in groundwater levels would, however, not result in marked reductions in groundwater resources within this aquitard.

No projected impacts, in any of the model layers, below the northern registered springs have been predicted during or post mining.

The potentiometric pressure in the sub-E sandstone is predicted to decrease to ~ 275 m AHD adjacent to the final void, where the bottom of pit is ~ 220 m AHD. Thus the sub-E sandstone is still fully saturated (no dewatering) but has been depressurised (10 to 20 m depressurisation). It was, therefore, considered that the sub-E sandstone can be utilised, away from the immediate mining area, as a source of make-good water.

Cumulative impacts of multiple mines, along strike, within the Permian Galilee Basin units were considered. Based on the cumulative impact modelling of both Alpha and Kevin's Corner, the dewatering impacts (drawdown cones) are predicted to elongate north and south, within the more permeable sandstone units of the Colinlea Sandstone. The cumulative impact of adding the additional mine dewatering will result in deeper drawdown where drawdown cones overlap and further elongation along strike. Drawdown cones created for Alpha alone and for mining both Alpha and Kevin's Corner do not result in any additional or cumulative impact to the west. This indicates that the risk to the units to the west (i.e. the GAB units) is not increased by additional mine projects along strike of one another.

Limited risk of long term TSF impacts on Lagoon Creek were considered using concentration propagation simulations in the integrated model. Little or no risk to Lagoon Creek is predicted if the base of the TSF ensures vertical leakance of 1E-06 (vertical permeability ~ 1E-05) or less.

1

Introduction

A regional numerical groundwater model was prepared as part of the EIS studies to allow prediction of the impact of mining of the proposed Alpha and Kevin's Corner Projects on regional groundwater levels. The EIS regional groundwater model also made predictions of post-mining impacts, including studies of the final void.

URS Australia Pty Ltd (URS) were appointed by Hancock Coal Pty Ltd (HCPL) to undertake additional hydrogeological assessments, which aimed at the refinement of the existing Environmental Impact Statement (EIS) regional numerical groundwater model.

The objective of the modified model was initially to provide estimates of groundwater inflows and dewatering volumes, over the life of mine (LOM), to a higher degree of confidence. These estimates were required for input into the mine water balance (both Alpha and Kevin's Corner).

Based on requests for data compiled post EIS submission, additional predictive groundwater modelling was undertaken to allow for an assessment of possible risks with regards to:

- The closest Great Artesian Basin (GAB) major aquifer, the Clematis Sandstone;
- The basal unit of the GAB, the Rewan Formation, which overlies the target Permian sediments;
- Registered springs to the north of Alpha and Kevin's Corner coal projects;
- Direct and indirect impacts of mining on vegetation communities;
- Sub-E coal seam sandstone, which has been identified as a source of make-good water; and
- Cumulative impacts through assessing the model predictions for Alpha alone and then comparing the results of simulating Alpha and Kevin's Corner.

2

Project Details

2.1 Proposed Mining

The Alpha Coal and Kevin's Corner Coal Projects (Alpha Project and Kevin's Corner) are located in the Galilee Basin, Queensland, Australia, approximately 130 km south-west of Clermont and 360 km south-west of Mackay.

Coal is to be mined at the Alpha Project using draglines, shovels and trucks, while at Kevin's Corner two relatively small open cuts will be developed, with the bulk of mining to occur via underground longwall mining techniques.

The Alpha Project is a 30 million tonnes per annum (Mtpa) open cut thermal coal mine targeting the C and D Seams in the Upper Permian coal measures of the Galilee Basin, while the Kevin's Corner Project targets the C and D seams where they occur at greater depth, to the north of the Alpha Project.

3

Modelling

3.1 Model Objectives

The objectives and work conducted regarding predictive groundwater modelling included:

- Review of available geological, hydrogeological, and climatic data and preparation of a conceptual groundwater model for the area of the model including the most up to date geological and groundwater knowledge and data;
- Construction and calibration of numerical groundwater models (both steady state and transient) based on the conceptual groundwater model;
- Incorporation of the year-on-year mine plan and mine development schedule for the Alpha Coal Project and Kevin's Corner Project;
- Assessment of the possible groundwater impacts of the Alpha Coal Project, as well as the cumulative impact of the Alpha Coal Project and Kevin's Corner Coal Project. This assessment included the risk of impact on existing groundwater users, water resources of the GAB, matters of national environmental significance (MNEs), and registered springs;
- Assess groundwater inflow rates to each operation, for planning of mine dewatering requirements, water infrastructure requirements, and water supply potential; and
- Long term impact predictions, using integrated modelling to estimate final void water level.

3.2 Model Complexity

Based on the requirements of the scope of work and model objectives (with the principal objective of being able to predict the groundwater volumes available to the Alpha Coal Project over the life of mine), the appropriate level of complexity for the predictive groundwater assessment model was judged to be a moderate complexity Impact Assessment Model (Aquaterra, 2010).

According to the Murray Darling Basin Commission modelling guidelines (Aquaterra, 2000) and the relatively limited data available across the entire model domain, the model(s) produced for the predictions are considered impact assessment models.

4

Hydrogeological Setting and Data

4.1 Climate Data

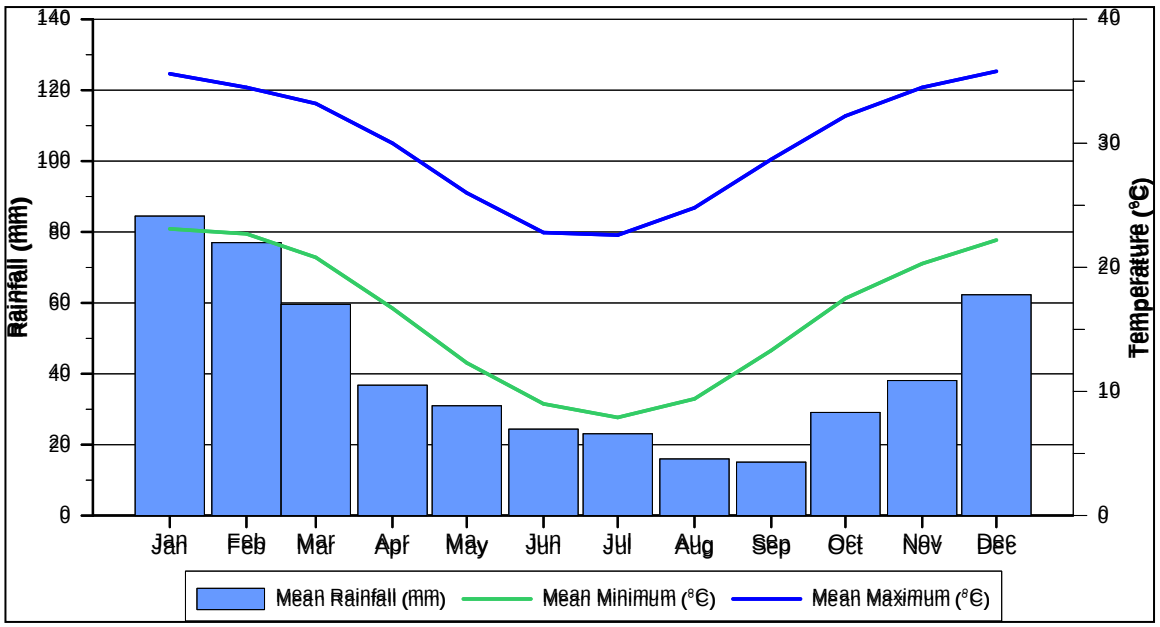
4.1.1 Barcaldine Data

This climatic description of the region in which the Project site is located has been compiled using regional data collected by Australian Bureau of Meteorology (BOM) (www.bom.gov.au). Rainfall and temperature data is sourced from the BOM station at Barcaldine Post Office (Station 036007), located approximately 138 km west of the project site. Recording of data at Barcaldine Post Office has been occurring from 1886 to present.

Data trends indicate that mean annual rainfall for the region is approximately 497 millimetres (mm). Figure 4-1 shows that rainfall is highly seasonal, with the dry season peaking between August and September, and the wet season peaking from December through to February.

The coldest mean daily temperatures occur in July (8ºC), with November to January having a mean maximum temperature of 35.3ºC (Figure 4-1).

Figure 4-1 Climograph for Barcaldine Post Office (1886-2010)



4.1.2 Rainfall and Evaporation – SILO Data

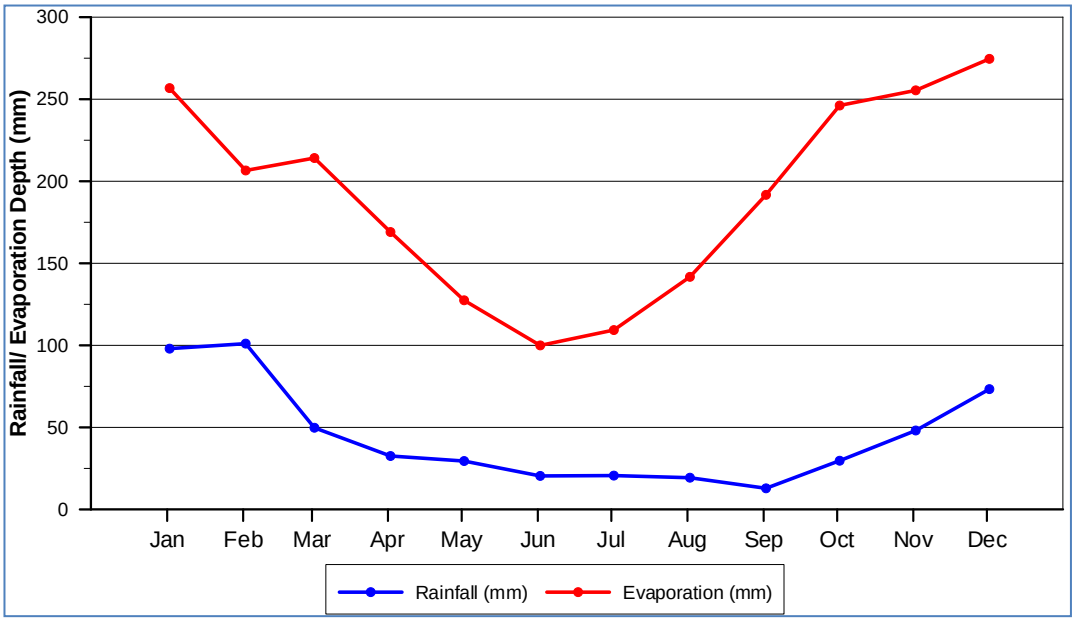
As long-term climate data is only available from a weather station some 138 km from site, DERM Silo Data Drill facility data was used to obtain synthetic climatic data for the centre of the Alpha MLA. The Data Drill accesses grids of data interpolated from surrounding BOM point observations and in the case of the Project site, this will include data from existing stations at Barcaldine, Clermont and, to a lesser extent, Emerald. The interpolations are calculated by splining and kriging techniques. The data in the Data Drill are therefore all synthetic, although they have been derived from surrounding observed values. The key advantage of using the Data Drill is that rainfall and other climate data can

be derived for any location throughout Australia, the data is continuous and can be provided for an extended period generally in excess of 100 years.

Averaged monthly SILO data for the period 1950 to 2009 is shown below in Figure 4-2. The data indicates that:

- Average annual site rainfall is approximately 535 mm and is highest in the wet summer season months between November and February and lowest during the dry months of winter;
- Average annual site evaporation (class A pan) is approximately 2,290 mm and is highest in summer and lowest in winter; and
- Average evaporation is in excess of average rainfall during every month of the year, resulting in a significant rainfall deficit at site for every month of the year, under average conditions.

Figure 4-2 Monthly Rainfall and Evaporation Data from SILO Datadrill



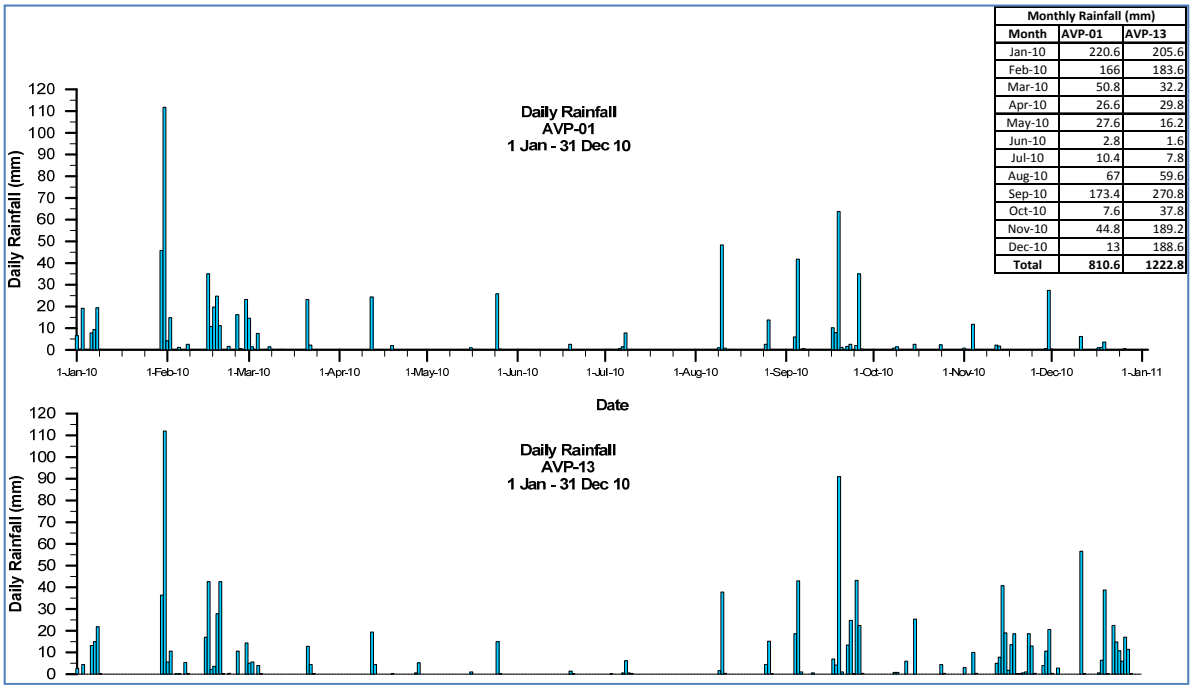
4.1.3 Site Rainfall

Rainfall data is being collected across the Alpha MLA, using two tipping-bucket rain gauges that have been in operation since mid-December 2009. Figure 4-3 shows the daily data and monthly summary data from each site between 1 January and 31 December 2010. It is apparent from the data that rainfall across the site is highly variable, as noted from rainfall results for each site for September, November and December 2010, where recorded rainfall varied between sites by more than 100 mm for each month.

The use of SILO data is supported for current design purposes on site due to the length of available record. However the variable nature of rainfall in the region, and even at site level, indicates that a number of rain gauges will be required at site to provide accurate rainfall data for ongoing use.

4 Hydrogeological Setting and Data

Figure 4-3 Site Rainfall Data



The rain gauge at AVP-01 has since October 2010 been providing inaccurate data and requires replacement. A new rain gauge has recently (December 2011) been installed within the proposed out-of-pit tailings storage facility (TSF), at monitoring bore ATSF-04. The most recent available data from site is included in Table 4-1.

Table 4-1 Monthly rainfall data (mm)

Month	AVP-01	AVP-13	TSF-04
Jan-10	220.6	205.6	
Feb-10	166	183.6	
Mar-10	50.8	32.2	
Apr-10	26.6	29.8	
May-10	27.6	16.2	
Jun-10	2.8	1.6	
Jul-10	10.4	7.8	
Aug-10	67	59.6	
Sep-10	173.4	270.8	
Oct-10	*7.6*	37.8	
Nov-10	*44.8*	189.2	
Dec-10	*13*	188.6	

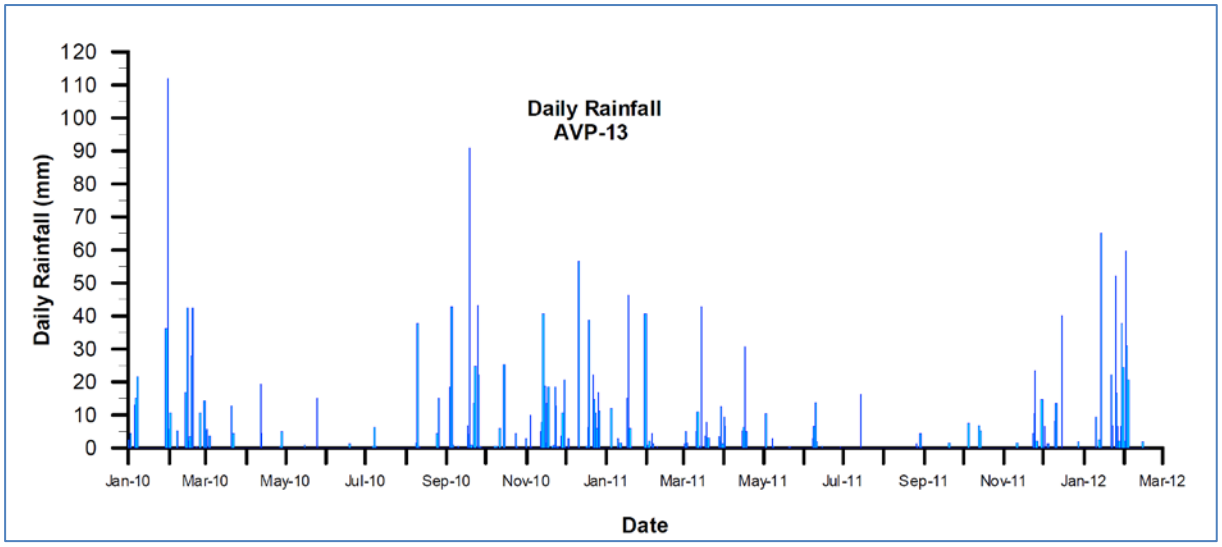
4 Hydrogeological Setting and Data

Total 2010	***810.6***	**1222.8**	
Jan-11	*18.6*	125.8	
Feb-11	*8*	10.8	
Mar-11	*8.2*	104	
Apr-11	*2.6*	63.8	
May-11	*1.2*	15	
Jun-11	*2*	27	
Jul-11	*0.4*	16.4	
Aug-11	*1.2*	6.8	
Sep-11	*1.6*	1.6	
Oct-11	*5.6*	21	
Nov-11	*2.8*	57.2	
Dec-11	*0*	74.2	39.2
Total 2011	***52.2***	**523.6**	
Jan-12	-	253.6	276
Feb-12			
Total 2012	**0**	**253.6**	**276**

Numbers in italic for AVP-01 are considered incorrect, when compared to AVP-13

The latest daily rainfall data set for AVP-13 is presented in Figure 4-4. Refer to Figure 4-14, showing monitoring points, for rain gauge locations.

Figure 4-4 Site rainfall data at AVP-13



4.2 Topography

The broad topographical setting of the catchment at the Project site consists of flat to undulating topography, with a range of 305 – 330 m above Australian Height Datum (m AHD). Hills and tertiary sand plains create higher relief on the western and eastern margins (formed by bordering mountains/hills of the Great Dividing Range to the west and Drummond Range to the east). These rises ascend approximately 70 m above the plains. Lagoon Creek is the central topographical feature, comprising of incised drainage profiles, formed within a broad floodplain. Within the Kevin's Corner lease Lagoon Creek becomes Sandy Creek.

4.3 Existing Surface Water Environment

The major surface water drainage feature through the Alpha MLA is Lagoon Creek, which drains from south to north. In the Kevin's Corner MLA Lagoon Creek joins Sandy Creek, this is the major drainage feature for the Kevin's Corner MLA.

The catchment area for Lagoon Creek is approximately 1,470 km^2. Major systems which drain the site from west to east toward Lagoon Creek and Sandy Creek (i.e. from the eastern foothills of the Great Dividing Range) include Well Creek, Rocky Creek, Middle Creek, and Little Sandy Creek. Drainage from the east of the MLA occurs from a low unnamed range that comprises the outcrop of the Joe Joe Formation. Drainage from this range is to the west toward Lagoon Creek, and to the east toward Native Companion Creek.

At the confluence of Lagoon Creek and Sandy Creek the drainage system continues north (as Sandy Creek) until joining the Belyando River, which in turn drains to the Suttor River, and ultimately to the Burdekin River. All surface water systems in the Project area and within the model area are ephemeral. No perennial springs or seeps have been recorded on or adjacent to the MLAs.

4.4 Regional Geology

4.4.1 Introduction

The Project is located within the Galilee Basin, a sequence of Late Carboniferous to Middle Triassic sedimentary rocks overlying Late Devonian to Early Carboniferous sedimentary and volcanic rocks of the Drummond Basin.

The rocks of the Galilee Basin are of similar age to those of the Bowen Basin (Late Permian) which are exposed to the east of the Drummond Basin. The Bowen and Galilee Basins are separated along a north-trending structural ridge between Anakie and Springsure, referred to as the Springsure Shelf. Much of the western portion of the Galilee Basin is interpreted as occurring beneath Mesozoic sediments of the Eromanga Basin. The Anakie Inlier comprises older Palaeozoic rocks.

Late Permian, coal-bearing strata of the Galilee Basin sub-crop are found in a linear, north-trending Belt in the central portion of the exposed section of the Basin and are essentially flat lying (dip generally <1º to the west). No major, regional scale fold and fault structures have been identified in regional mapping of the Project area.

The proposed mining is located to the east of the basal boundary of the geological GAB (Figure 4-5 shows the MLAs relative to the GAB). The proximity to the GAB to the mining is considered as registered springs (along the Hutton outcrop) and the Clematis Sandstone (major GAB aquifer) are

located some 65 to 150 km to the west. Predictive modelling was therefore conducted to assess the potential risk to these groundwater resources of the GAB.

The Alpha and Kevin's Corner target coal deposits occur within the Colinlea Sandstone unit of the Galilee Basin. The geology consists mainly of sediments, dipping 1-2° westward, which are unconformably overlain by Tertiary and Quaternary sediments. The thickness of Tertiary and Quaternary sediments varies from 20 m to 60 m, across the proposed mine area. There are four coal seams in the Colinlea Sandstone designated, from upper to lower, as C, D, E, and F. The interburden is named based on the coal seams it occurs between. For example the C-D sandstone lies between the C and D coal seams.

Figure 4-6 shows a typical east-west cross section across the deposit.

4.4.2 Colinlea Sandstone – Regional Scale

From available literature, in regards to the western extent of the Colinlea Sandstone, it is apparent the Colinlea Sandstone (Late Permian) is present in the centre and eastern portions of the Galilee Basin.

The Galilee Basin is divided into northern and southern parts by the east – west trending Barcaldine Ridge, located near Barcaldine. The northern part of the basin is sub-divided by the Maneroo Platform (metamorphic and basement granite intrusion) and its easterly component, the Beryl Ridge, into the eastern Koburra Trough and the Western Lovell Depression. The southern part of the basin is divided into the western Powell Depression and the Springsure Shelf by the Pleasant Creek Arch, the border between the Galilee and Bowen basins.

4 Hydrogeological Setting and Data

Figure 4-5 Stratigraphy/Hydrostratigraphy of the Project Site

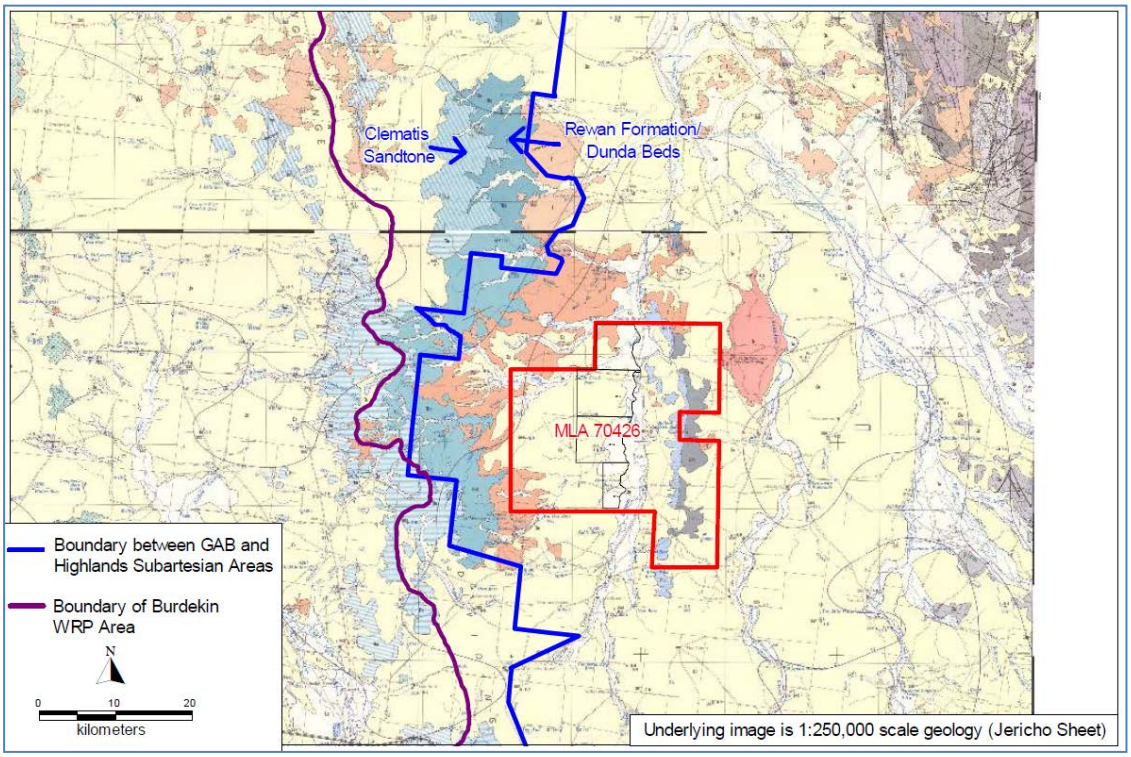
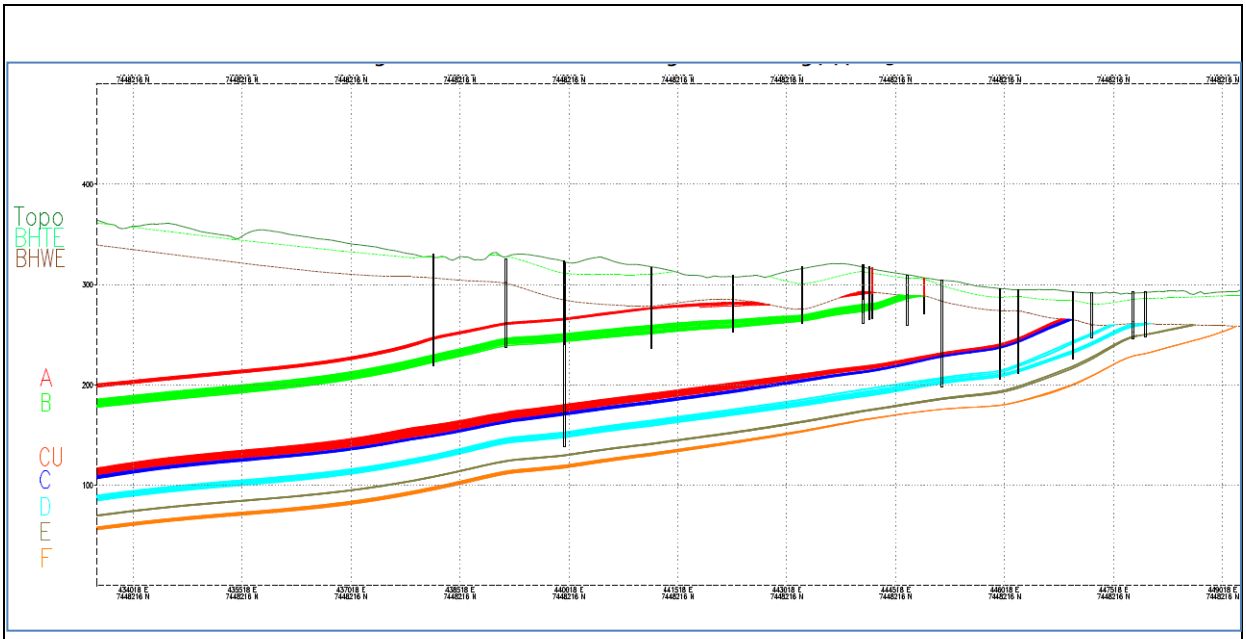


Figure 4-6 Typical east-west cross section across the deposit



Legend:

Topo: topography

BHTE: base of tertiary

BHWE: base of visible weathering

A: coal seam A

B: coal seam B

CU: Upper carbonaceous unit

C: coal seam C

D: coal seam D

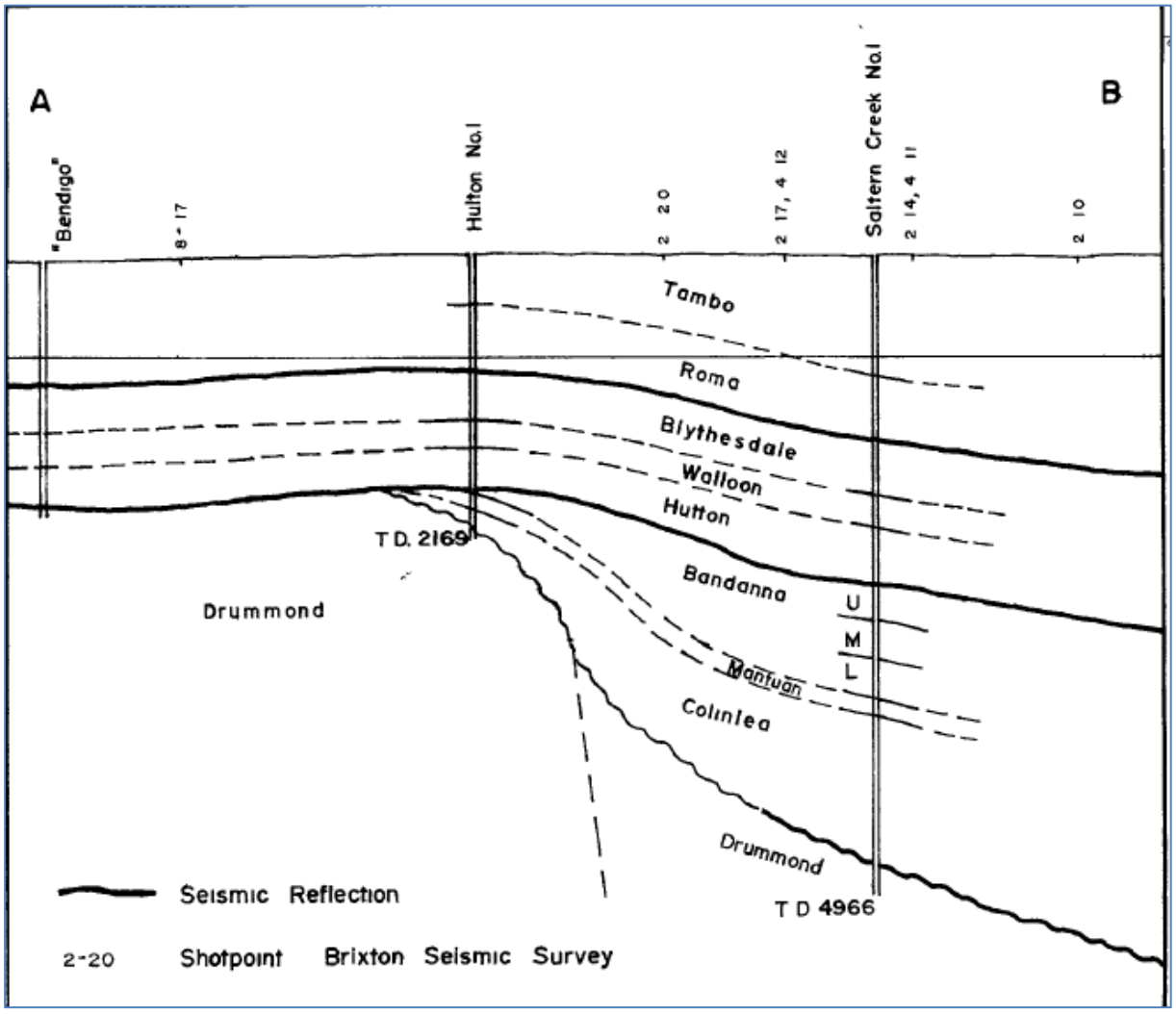
E: coal seam E

F: coal seam F

4 Hydrogeological Setting and Data

The Colinlea Sandstone, in its westernmost extent, ends at the Maneroo Platform (metamorphic basement and granitic intrusions), along the western boundary of the Galilee Basin. Review of stratigraphy and related cross sections, from the Interactive Resource and Tenure Maps (IRTM) database, of petroleum wells located northwest of Barcaldine indicates the Colinlea Sandstone does not outcrop but pinches out into the Drummond Basin, below the Hulton – Rand Monocline (Figure 4-7).

Figure 4-7 Geological Cross-Section showing discontinuation of Colinlea Sandstone unit (Mott & Associates, 1990)



Unlike the GAB units, which facilitate discharge springs within the south western portion of the GAB, the Colinlea Sandstone pinches out below the GAB.

4.4.4 Site Geology

4.4.4.1 Cainozoic

A sequence of sand, fine gravel and minor clay horizons covers the project study area. This cover has an average thickness of 40 m, thickest in the eastern and central regions and thinning towards the high-lying areas to the west (< 5 m thick). Figure 4-8 (Kevin's Corner) and Figure 4-9 (Alpha) provide a cross-section across each of the relevant MLAs, showing the geological units mapped on and adjacent to the proposed mine areas. Lateritic horizons (laterisation process of Permian sediments during the Tertiary period) are recorded along with mottled clay paleosols. Minor localised perched groundwater was recorded on the clay-rich laterite during exploration drilling within the Cainozoic. The Cainozoic unconformably overlies the Triassic Rewan Group (along the Great Dividing Range) and Permian Bandana Formation, Colinlea Sandstone, and Joe Joe Formation units (Figure 4-8).

Tertiary intrusive and extrusive rocks (e.g. Tertiary basalts) have not been encountered on site.

In the Tertiary sediments above the base of weathering, water is encountered only sporadically, and the Tertiary sediments are not regarded as comprising a significant groundwater resource. Quaternary alluvium associated with current surface water drainage systems may contain localised occurrences of groundwater, especially following wet season rainfall, but the alluvium is not extensive or continuous, with limited effective storage. It is therefore not regarded as a significant groundwater resource.

4.4.4.2 Rewan Formation

The Rewan Formation is the basal confining unit of the hydrogeological GAB. The Rewan Formation occurs to the west of the Alpha MLA and within the western portion of Kevin's Corner, where it subcrops under Cainozoic cover (Figure 4-8). The Rewan Formation comprises typical green to brown-purple siltstone and fine grained sandstone. The base of the Rewan Formation is located some 30 to 50 m above the uppermost Bandana Formation A seam coal ply, and is taken to have an average thickness of 175 m (based on Salva geological modelling Section 4.4.5 (Salva, 2010a)).

4.4.4.3 Permian Sediments

Permian sedimentary deposits at site comprise the Bandanna Formation and the underlying Colinlea Sandstone, and these units contain both economic and sub-economic coal seams which dip to the west at an angle of 1-2º. The coal seams are named alphabetically A through F, with the A seam being uppermost. There are two major coal seams that will be the target of mining within the deposit: the C seam and D seam, which vary in thickness from 3 m to 6 m in the area to be mined. The overlying A and B coal seams will not be the target of mining by the proponent.

Geologically the boundary between the Bandanna Formation and the underlying Colinlea Sandstone is taken to be an interval above the C coal seam at which sedimentation style changes from increasingly argillaceous to increasingly arenaceous. Therefore the Bandanna Formation hosts the A and B coal seams, while the Colinlea Sandstone hosts the target C and D coal seams.

4 Hydrogeological Setting and Data

Figure 4-8 Cross-section through MLA70425 at 7454000N (Kevin's Corner)

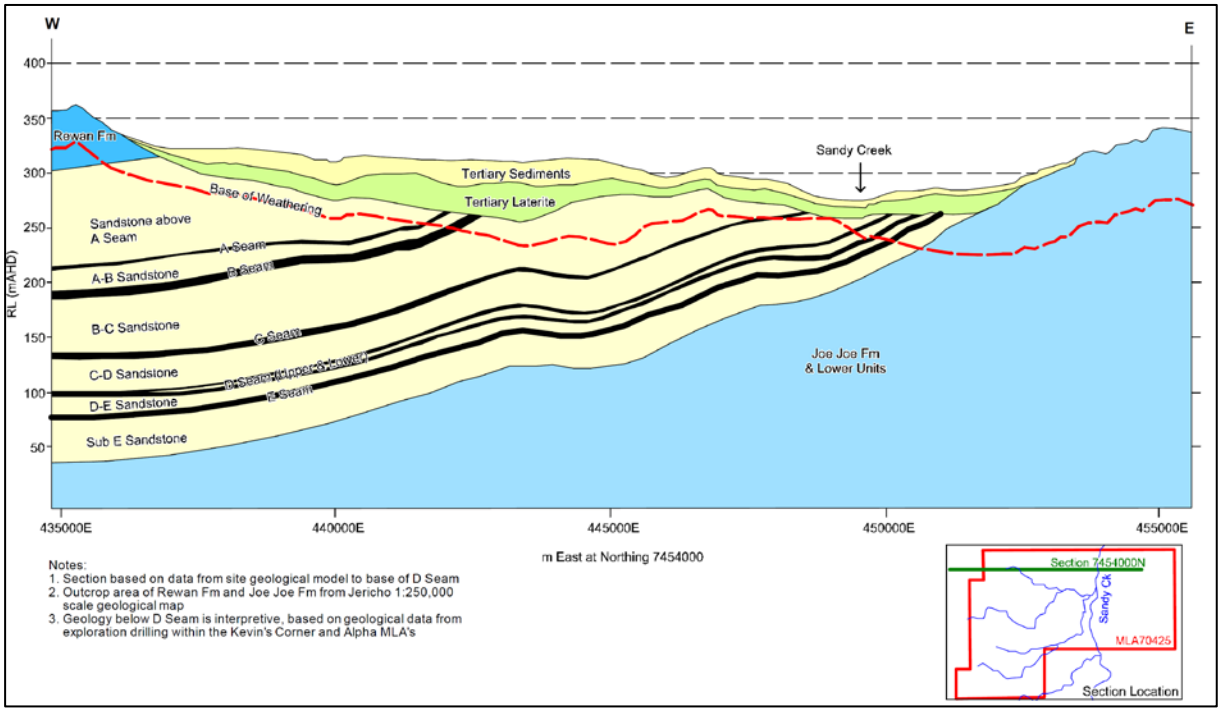
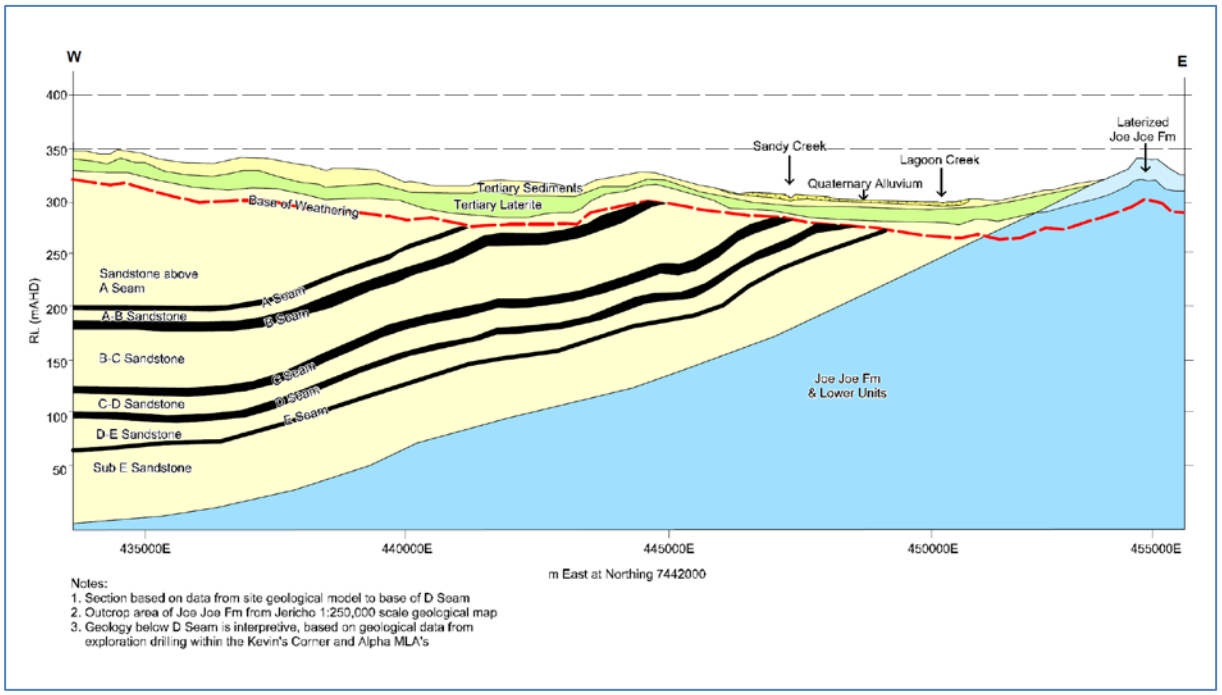


Figure 4-9 Cross-Section through MLA70426 at 7442000N (Alpha)



From a groundwater perspective, major hydrostratigraphic boundaries occur within the MLA at the base of weathering, beyond which groundwater is encountered under confined conditions in the B-C and C-D sandstones and C and D coal seams, and also at the base of the D coal seam.

4 Hydrogeological Setting and Data

It has been observed during exploration drilling that groundwater inflows are relatively low until the D coal seam is drilled through, at which point higher rates of groundwater flow are often encountered. The sandstone unit directly below the D coal seam and above the E coal seam (D-E sandstone) is a target of aquifer depressurisation, and the overlying sandstone (B-C sandstone, C-D sandstone, and C and D coal seams) will need to be locally dewatered in order for mining to occur safely.

Below the D-E sandstone the Colinlea Sandstone coarsens with increasing depth. The sub-E sandstone (between the E and F coal seams) and sub-F sandstone (below the F coal seam and to the Joe Joe Formation aquitard) have the potential to containing usable (quantity and quality) groundwater resources, and these units will not be actively depressurised during mining.

The Colinlea Sandstone is underlain by sediments of the Joe Joe Formation. The Jericho 1:250 000 scale geological map describes the Joe Joe Formation as “mudstone, labile sandstone, siltstone, shale” and on this basis the Joe Joe Formation is interpreted to be a confining unit below the Colinlea Sandstone aquifers.

The regional stratigraphy of the Galilee Basin, which includes the Alpha Coal Project and Kevin’s Corner Project area, is described in Table 4-2.

Table 4-2 Regional Stratigraphy

Age	Stratigraphic unit		Lithology	Thickness	Aquifer Type
Quaternary			Alluvium	15 - 20 m	Unconfined
Tertiary			Argillaceous laterite and clays	~ 40 m	Unconfined
Unconformity					
Triassic	Clematis Sandstone		Quartz sandstone, minor siltstone and mudstone	~ 140 m	Confined aquifer – GAB aquifer, outcrops and dips to west of MLAs
	Rewan Formation / Dunda beds		Green-grey mudstone, siltstone and labile sandstone – Rewan Fm grades into Dunda beds below Clematis Sandstone	~ 175 m	Confining unit – base of hydrogeological GAB
Late Permian	Bandanna Formation		Argillaceous sandstone	10 - 30 m	Unconfined to semi-confined
			Coal – A Seam	1 – 2.5 m	Unconfined to semi-confined
			A-B Sandstone - Labile sandstone, siltstone and mudstone	~ 10 m	Unconfined to semi-confined
			Coal – B Seam	6 - 8 m	Unconfined to semi-confined
			B-C sandstone - Labile sandstone, siltstone and mudstone	70 - 90 m	Semi-confined to confined
Early Permian	Colinlea Sandstone		Coal – C Seam – target coal seam	2 - 3 m	Confined
			C-D sandstone – Labile sandstone, siltstone and mudstone	5 - 20 m	Confined aquifer
			Coal – D Seam – target coal seam	4.5 – 6 m	Confines underlying D-E sandstone
			D-E sandstone	~ 15 m	Confined aquifer
			Coal – E Seam – dirty coal /	0.1 – 0.4 m	Leaky confining layer

4 Hydrogeological Setting and Data

			carbonaceous shale – uneconomic		
			Sub-E sandstone, labile sandstone, siltstone and mudstone	15 - 20 m	Confined aquifer
			Coal Seam F. Localised thick geological section, no working section	0.5 – 5 m	
			Labile sandstone, siltstone and mudstone	Unknown	
Early Permian	Joe Joe Formation		Labile and quartz sandstone	Transition to Joe Joe Formation	
Unconformity					
Early Carbonaceous	Drummond Basin				

4.4.5 Salva Geological Model

Salva Resources (Project geologists) constructed a 3-dimensional geological model, which extends from the Galilee Basin in the area of the mining projects, westward. The purpose of the model was to understand the relationship of the Project geology and the GAB, and to serve as input to the conceptual groundwater model.

The following data, from within and adjacent to the Alpha and Kevin's Corner MLAs, aided in constructing the geological model:

- Hancock exploration holes – 362 holes;
- 'B' series holes (Bridge Oil) – 465 holes;
- 278 'W' series holes (Dampier BHP and Wright & Hancock);
- Waratah Coal – 7 holes from public announced data;
- Shell Degulla 'DE' series – 50 holes;
- Government Regional drilling 'NS Galilee' series – 21 holes; and
- Oil and Gas drilling – 18 holes.

The layer surfaces (elevations) from the Salva geological model were used as input to both the NTEC regional groundwater model and the MNTA predictive groundwater assessment model.

4.4.6 GAB Hydrostratigraphy

Due to the proposed mining activities proximity to the GAB, the regional groundwater model included both the Galilee Basin and GAB hydrostratigraphy. The potential impacts of the proposed mining activities were assessed as part of the EIS process, these assessments were included in the URS EIS submissions (URS, 2011a,b,c,d,e).

The lithostratigraphy and hydrostratigraphy[1] of the GAB, as taken from the GAB Hydrogeology map[2], is shown below in Figure 4-10. The hydrostratigraphy in the area of the mine leases is equivalent to

[1] One or more geological (i.e. lithostratigraphic) units may be regarded as a single hydrostratigraphic unit on the basis of similar hydraulic parameters (e.g. hydraulic conductivity) and therefore constitute a distinct aquifer or confining unit. Conversely, a single geological formation may be subdivided into a number of hydrostratigraphic units (e.g. aquifer, confining bed, etc.). In other words, formation boundaries and aquifer/confining unit boundaries do not necessarily correspond.

[2] Habermehl, M.A. & Lau, J.E. (1997) *Hydrogeology of the Great Artesian Basin, Australia* (map at scale 1:250,000). Australian Geological Survey Organisation, Canberra.

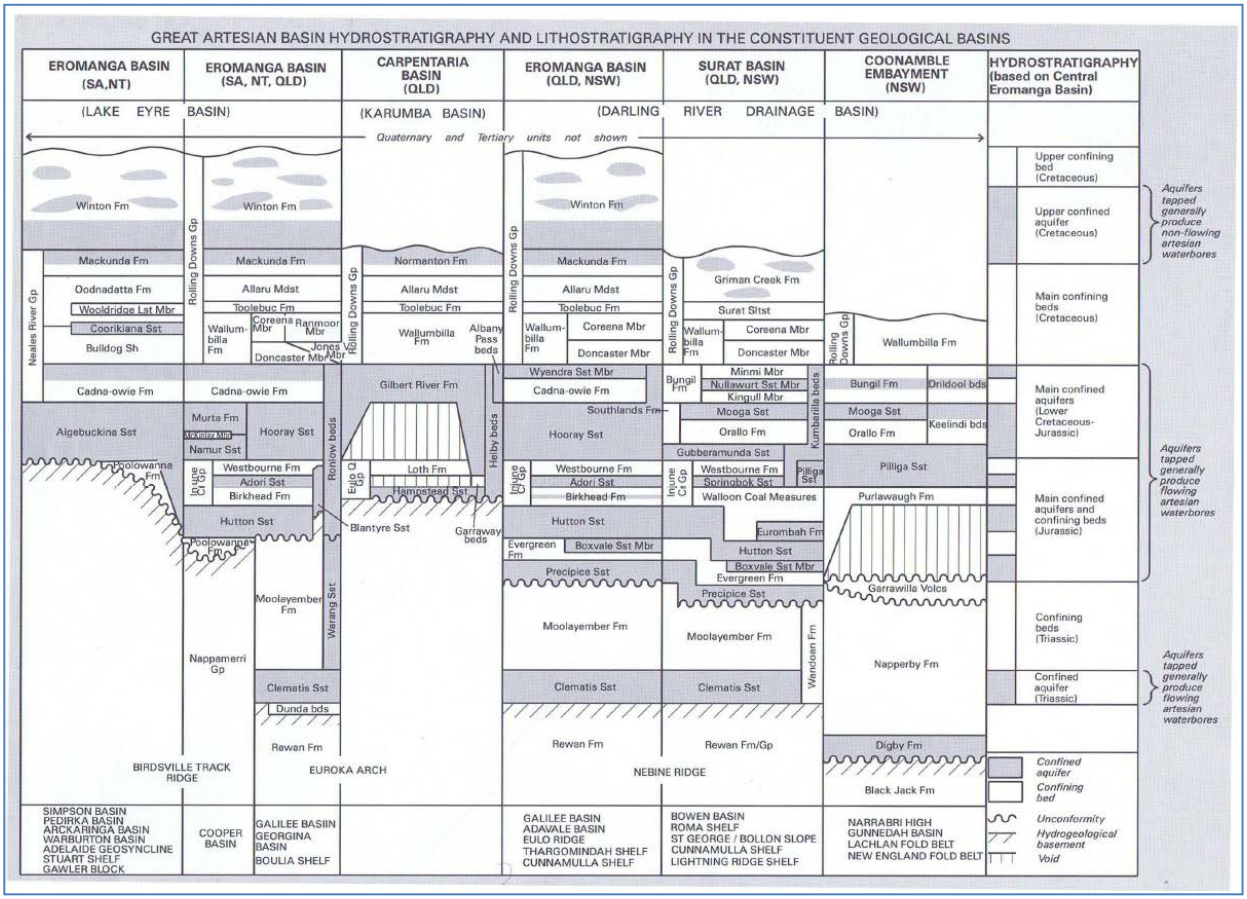
4 Hydrogeological Setting and Data

the hydrostratigraphy shown for the Eromanga Basin (SA, NT, and QLD) to the left of Figure 4-9 (Note: no Precipice Sandstone is mapped within this portion of the GAB, the Clematis Sandstone and Hutton Sandstone are separated by the Moolayember Formation). The figure shows that the Rewan Formation, which occurs to the west of the mining lease boundary (Figure 4-8), is the lowest recognised unit of the GAB.

Figure 4-11 shows a schematic section through the area of the Alpha Coal and Kevin's Corner projects, extending west into the GAB. The section is based on information from the Salva geological model (Section 4.4.5), as well as the corresponding 1:250,000 scale geological map (Jericho). Note: the registered recharge reject springs occur at the Hutton Sandstone outcrop, separated from the proposed mining by significant aquitards (Bandana Formation, Rewan Formation, and Moolayember Formation).

The relationship between GAB aquifers, confining beds, and hydraulic basement, is summarised in Habermehl (1997):

Figure 4-10 GAB Hydrostratigraphy Source: Habermehl, M.A. & Lau, J.E. (1997)



"The confined aquifers of the Great Artesian Basin are bounded by the Rewan Group at the bottom, and the Winton Formation at the top.

Aquifers are present in the Clematis, Precipice, Boxvale, Hutton, Adori and Hooray Sandstones, and the Cadna-owie Formation and their equivalents, and in the Mackunda and Winton Formations.

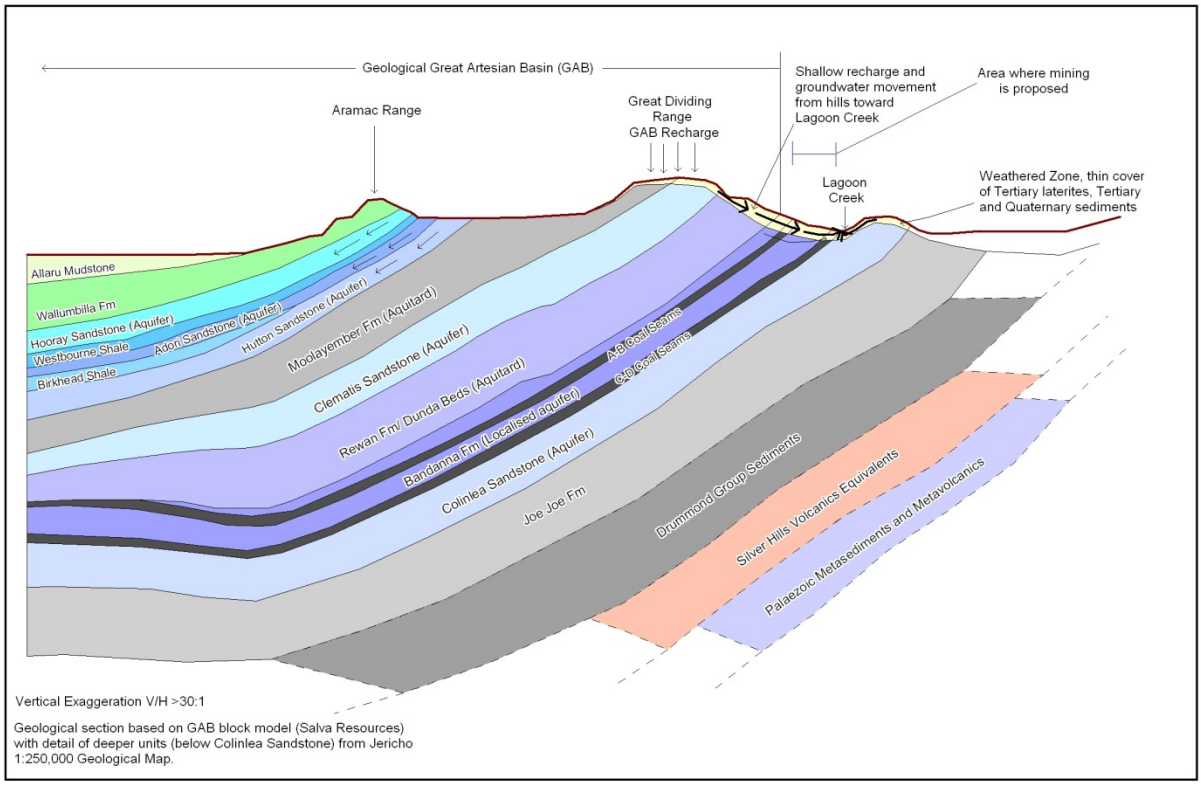
4 Hydrogeological Setting and Data

The major confining beds consist of the Rewan Group, Moolayember, Evergreen, Birkhead, Westbourne, Wallumbilla and Toolebuc Formations, and their equivalents, and the Allaru Mudstone, and parts of the Mackunda and Winton Formations.

The hydrogeological basement comprises impervious Mesozoic, Palaeozoic and Proterozoic sedimentary, metamorphic or igneous rocks, and this basement forms in part an aquiclude or aquifuge."

The descriptions above are consistent with the hydrostratigraphic table shown as Figure 4-10, which is taken from Habermehl (1997).

Figure 4-11 Schematic Section through Galilee Basin and GAB



From Figure 4-11:

- The eastern and lower limit of the GAB is shown as the base of Rewan Formation/ Dunda Beds, which occur to the west of the project site (Figure 4-8);
- The coal deposits that will be the target of mining are located below the Permian-age Bandanna Formation, within the Colinlea Sandstone;
- The boundary between the Bandanna Formation and Colinlea Sandstone is interpreted to be the top of the C coal seam, based on interpretation of lithostratigraphy;
- The Colinlea Sandstone is underlain by the Joe Joe Formation. The Jericho 1:250,000 scale geological map describes the Joe Joe Formation as "mudstone, labile sandstone, siltstone, shale" and on this basis the Joe Joe Formation is interpreted to be a confining unit below the Colinlea Sandstone aquifer;
- GAB sediments overlying the Rewan Formation are shown in Figure 4-11; and

- Figure 4-11 shows generalised concepts of diffuse groundwater recharge within Great Dividing Range and groundwater flow direction.

The boundary of the hydrogeological GAB (outcrop of Rewan Formation) occurs predominantly to the west of MLA70425 and MLA70426 (refer Figure 4-8). The north western corner of MLA70425 is underlain by Rewan Formation, which is the basal confining unit to the hydrogeological GAB.

4.4.7 Geological Structures

Minor and localised faults have been identified in exploration core with presence of calcitic healed faults, small breccia zones, and small scale fault offsets. On a regional scale, drilling within MDL333 does not indicate any major fold and fault structures, though recent seismic studies suggest the presence of faults at a spacing of 2 to 3 km, with throws in the order of 3 times the seam height. There is no evidence available to date to suggest any impact from faulting on the groundwater flow regime.

4.5 Potentiometric Surface and Groundwater Flow Direction

4.5.1 Water Level Data from Exploration Bores

Groundwater level data have been reviewed from over 250 groundwater exploration bores within MLA 70425 and MLA 70426. From these data, a potentiometric surface map has been produced (Figure 4-12) which must be viewed with consideration for the following:

- The groundwater levels were measured in open exploration holes, and therefore represent a composite groundwater level for all water-bearing intervals encountered within each bore; and
- Groundwater levels are taken from recent phases of exploration drilling, but the levels have been collected over a period of approximately 1 year. Therefore the potentiometric surface contours do not represent a surface at a single moment in time.

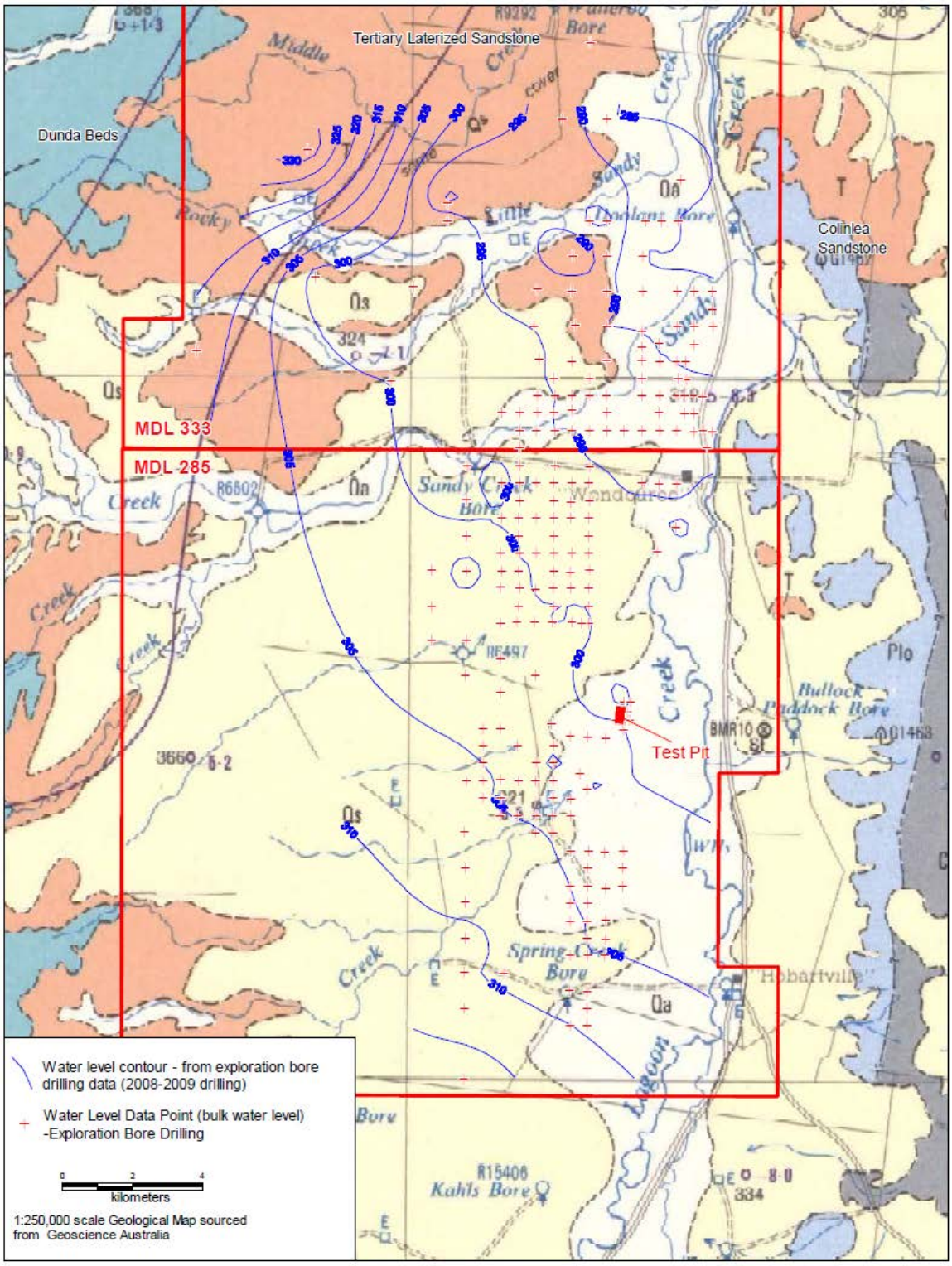
In spite of the above a general trend is evident from the data, i.e. the groundwater level is higher in the southwest and lower in the northeast, suggesting that the composite potentiometric surface is a subdued reflection of topography (i.e. mimics topography), with groundwater flowing towards the northeast.

4.5.2 Water Level Monitoring Bores

A number of VWP bores were installed during the 2009 exploration drilling program, and these bores generally targeted the sandstone aquifer below the D seam (i.e. D-E sandstone interval, within the Colinlea Sandstone) as well as sandstone unit above the D seam (C-D sandstone). Figure 4-13 shows the potentiometric surface of the D-E sandstone for readings taken in December 2009. Piezometeric pressures are higher in the southwest of the MLA70426 and lower in the northeast. This indicates that the potentiometric surface of the D-E sandstone (Colinlea Sandstone) follows the same general trend as shown in Figure 4-12 for the potentiometric surface generated from exploration drilling data.

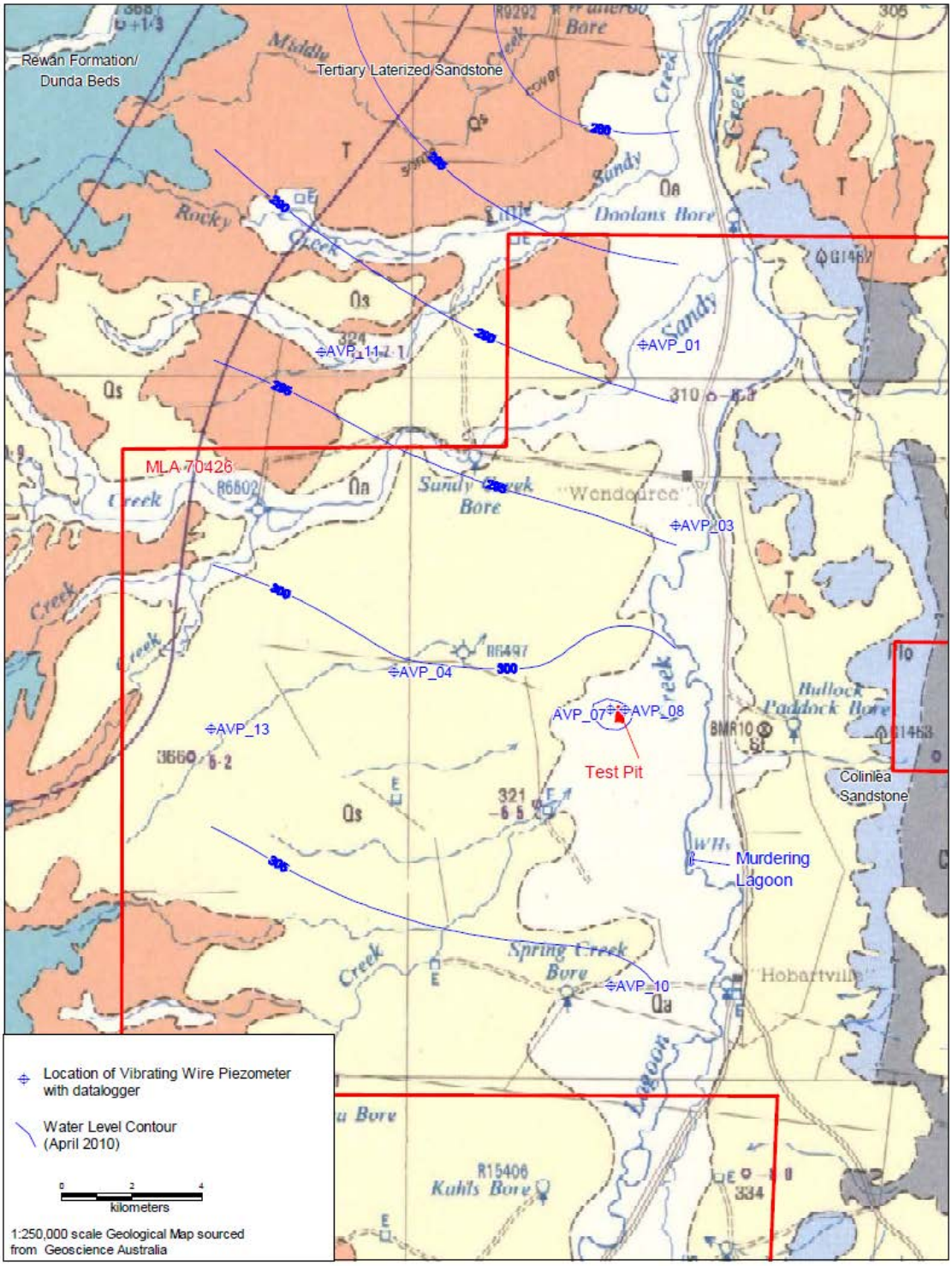
4 Hydrogeological Setting and Data

Figure 4-12 Water Level Data from Exploration Bores



4 Hydrogeological Setting and Data

Figure 4-13 Water Level Monitoring Bores



4.6 Groundwater Monitoring Network

Groundwater monitoring bores have been constructed at a number of sites throughout the Alpha and Kevin's Corner MLA's, as shown on Figure 4-14. Sites have been constructed as either vibrating wire piezometers, which monitor groundwater level fluctuation, or standpipe monitoring bores, which can be used for both groundwater level and groundwater quality monitoring. The existing monitoring bore network is discussed below.

4.6.1 Vibrating Wire Piezometers

Vibrating Wire Piezometer (VWP) monitoring bores have been constructed at 26 sites within the Project Mining Lease Application (MLA 70426 and 70425) area, with 72 separate intervals monitored (the number of VWPs installed in each bore ranges from one to four). The location of these VWP bores is shown on Figure 4-14, and the interval(s) monitored by each bore is shown in **Appendix A**.

The VWP bores were constructed using the grout-in method. Using this method the bores are fully grouted after installation of the piezometers. This method allows the piezometers to record changes in pore pressure adjacent to the piezometer, as the grout is porous and allows transfer of pressure. As the grout does not allow vertical movement of water it is possible to monitor a number of vertical intervals within the one hole without the risk of inter-aquifer transfer of water.

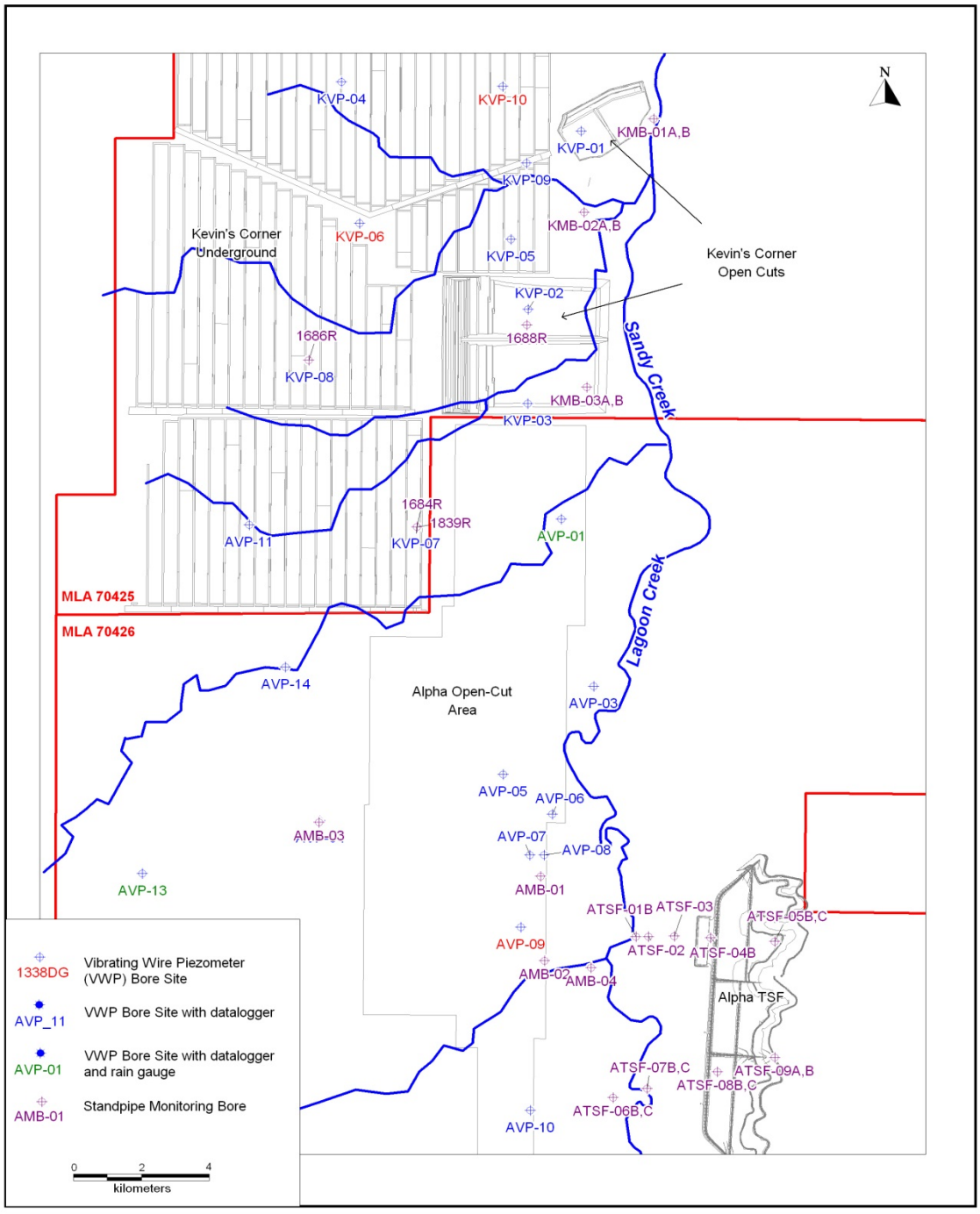
The majority of VWP bores are monitored using automated data loggers, which compile daily groundwater level records (6 hour intervals). In addition, two of these sites are equipped with tipping-bucket rain gauges, with rainfall data also captured by the data loggers.

Hydrographs for all VWP bores with data loggers are shown in Figures 4-15 to 4-20. The following observations are made with respect to VWP readings:

- For the monitoring period shown in Figures 4-15 to 4-20, the data loggers were recording pressure readings at 6-hourly intervals;
- Most of the piezometer readings show diurnal variations in groundwater level. A number of trends are apparent with respect to these diurnal groundwater level variations:
  - Within an individual bore the magnitude of variation increases with depth (i.e. generally the diurnal variation is more distinct in VWPs monitoring the D-E sands interval than for overlying sediments);
  - The magnitude of variation increases to the west, e.g. compare the piezometer response for the D-E sands interval in the east of the lease area (AVP01, AVP03, AVP07, AVP10) with bores in the middle of the lease area (AVP04) and in the western part of the lease (AVP11, AVP13); and
  - For a number of bores a trend is evident (refer AVP04, VW2; AVP11, VW3; AVP13, VW3) that overprints the diurnal variation discussed above. In these cases it appears that pressures rise before significant rainfall events and reduce following rainfall.
- The interpretation at this stage is that these diurnal variations are due in part to earth tides (caused by deformation of the solid earth as it rotates within the gravitational field of the sun and moon) and barometric effects (i.e. from passing high and low pressure systems).

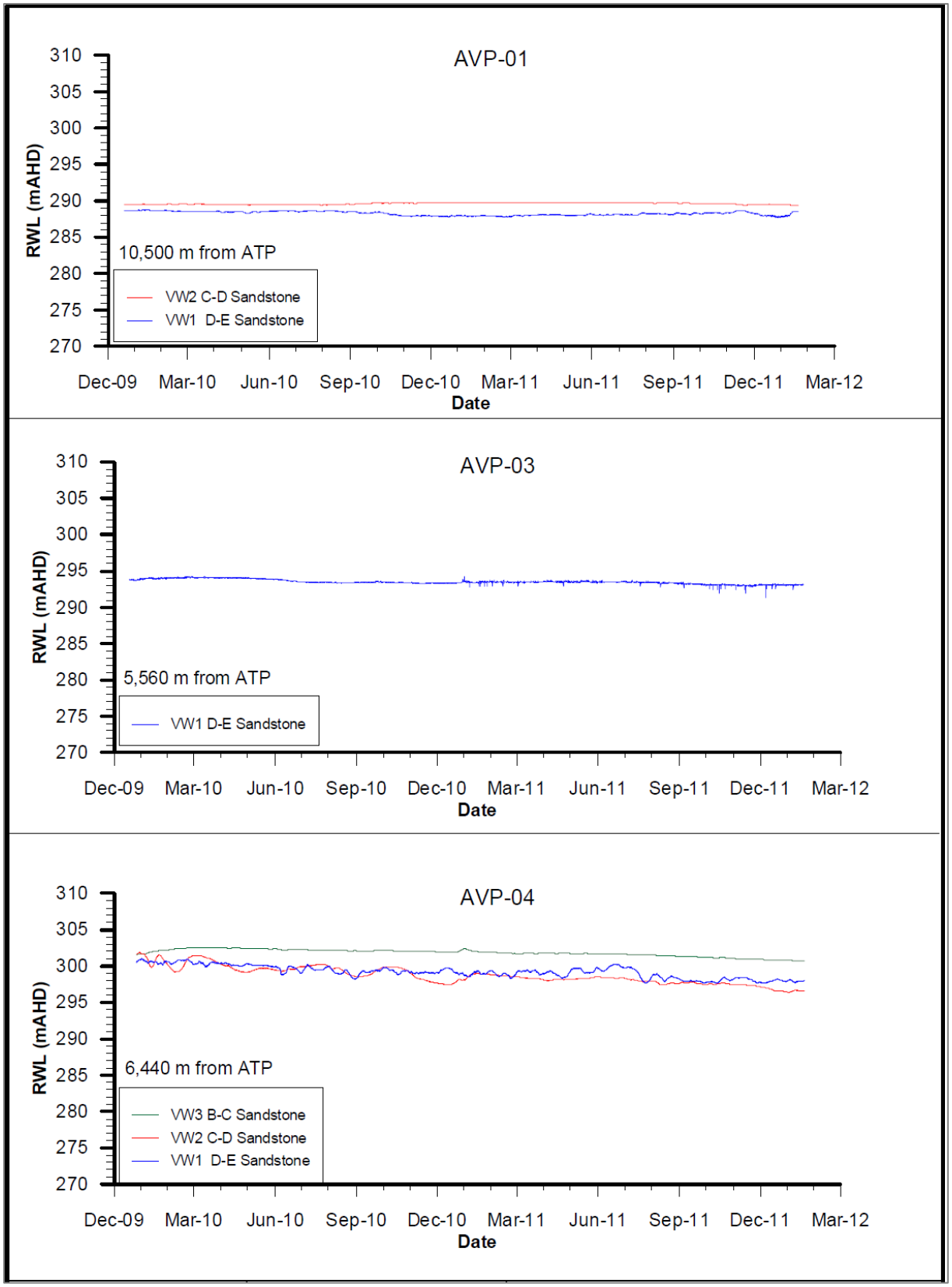
4 Hydrogeological Setting and Data

Figure 4-14 Monitoring Points



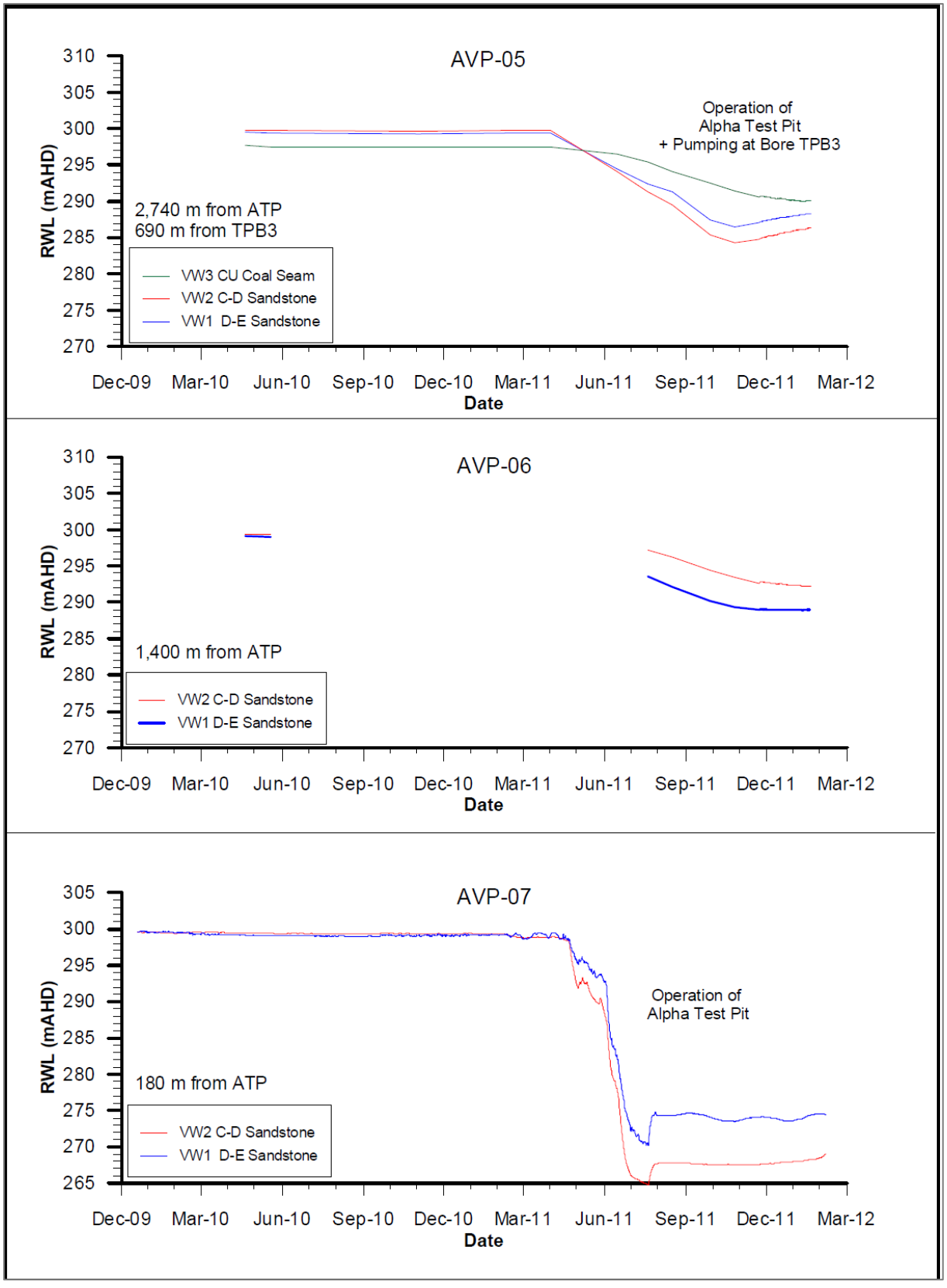
4 Hydrogeological Setting and Data

Figure 4-15 Bore Hydrographs - AVP-01, AVP-03, AVP-04



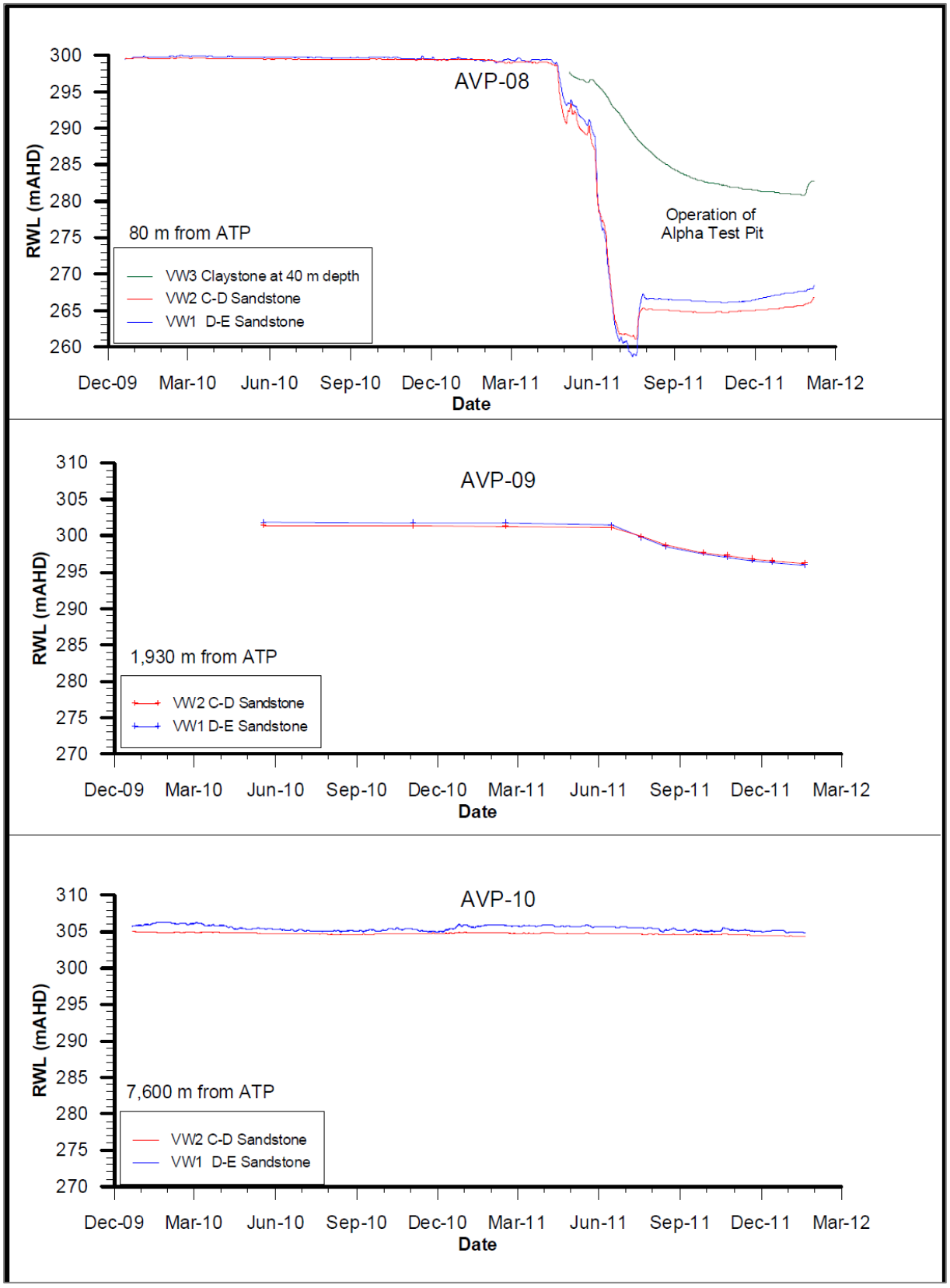
4 Hydrogeological Setting and Data

Figure 4-16 Bore Hydrographs – AVP-05, AVP-06, AVP-07



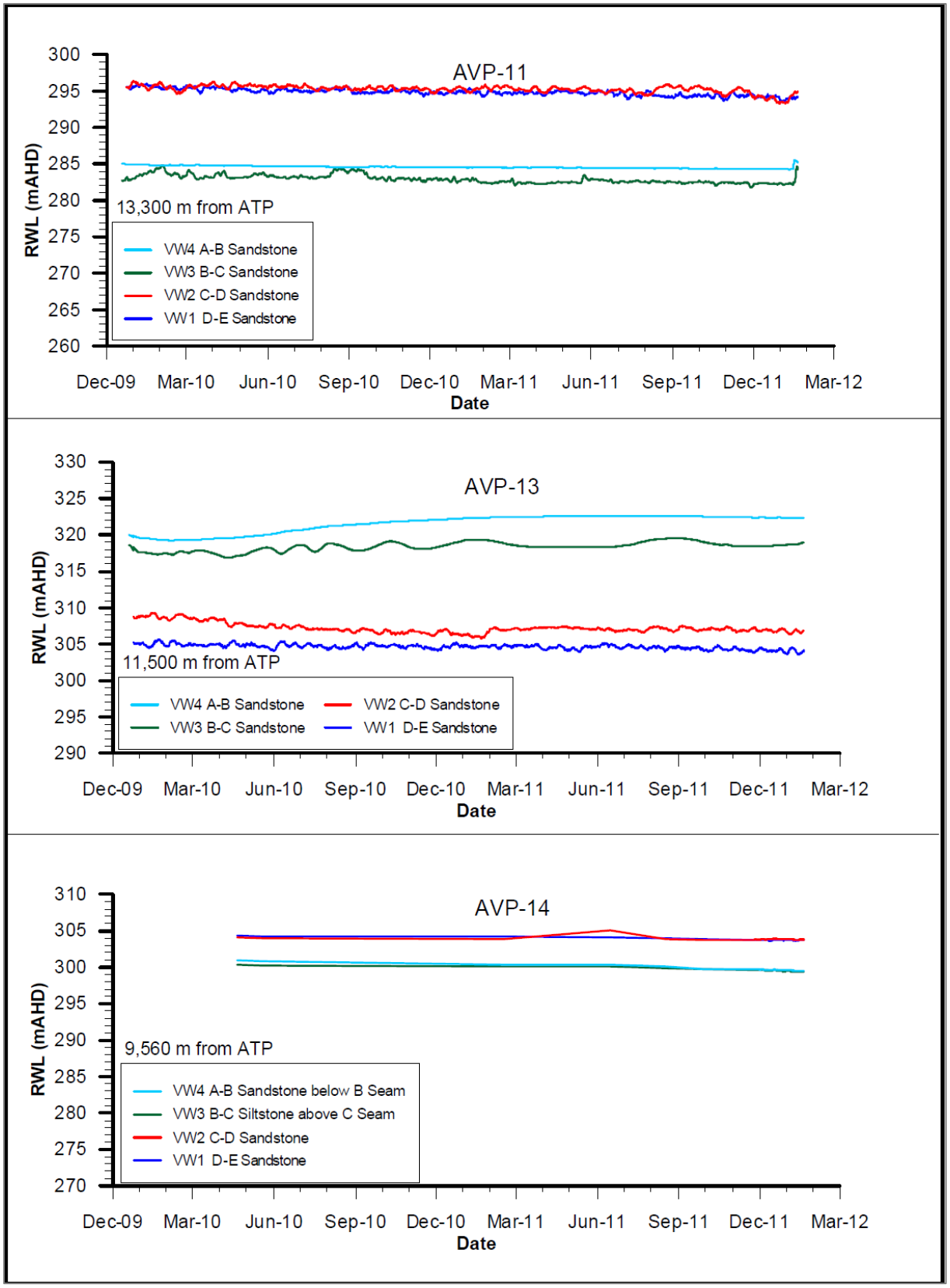
4 Hydrogeological Setting and Data

Figure 4-17 Bore Hydrographs – AVP-08, AVP-09, AVP-10



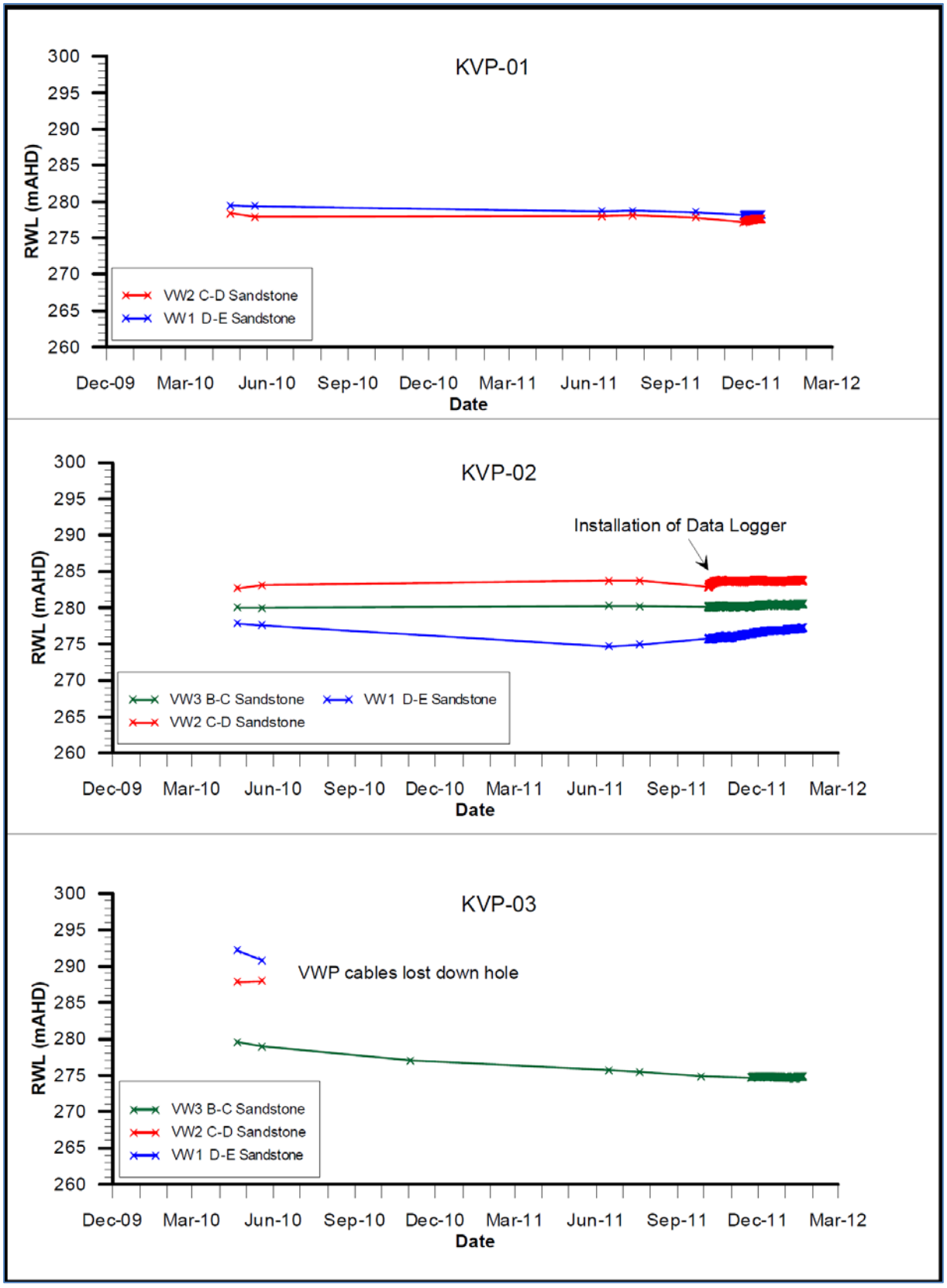
4 Hydrogeological Setting and Data

Figure 4-18 Bore Hydrographs – AVP-11, AVP-13, AVP-14



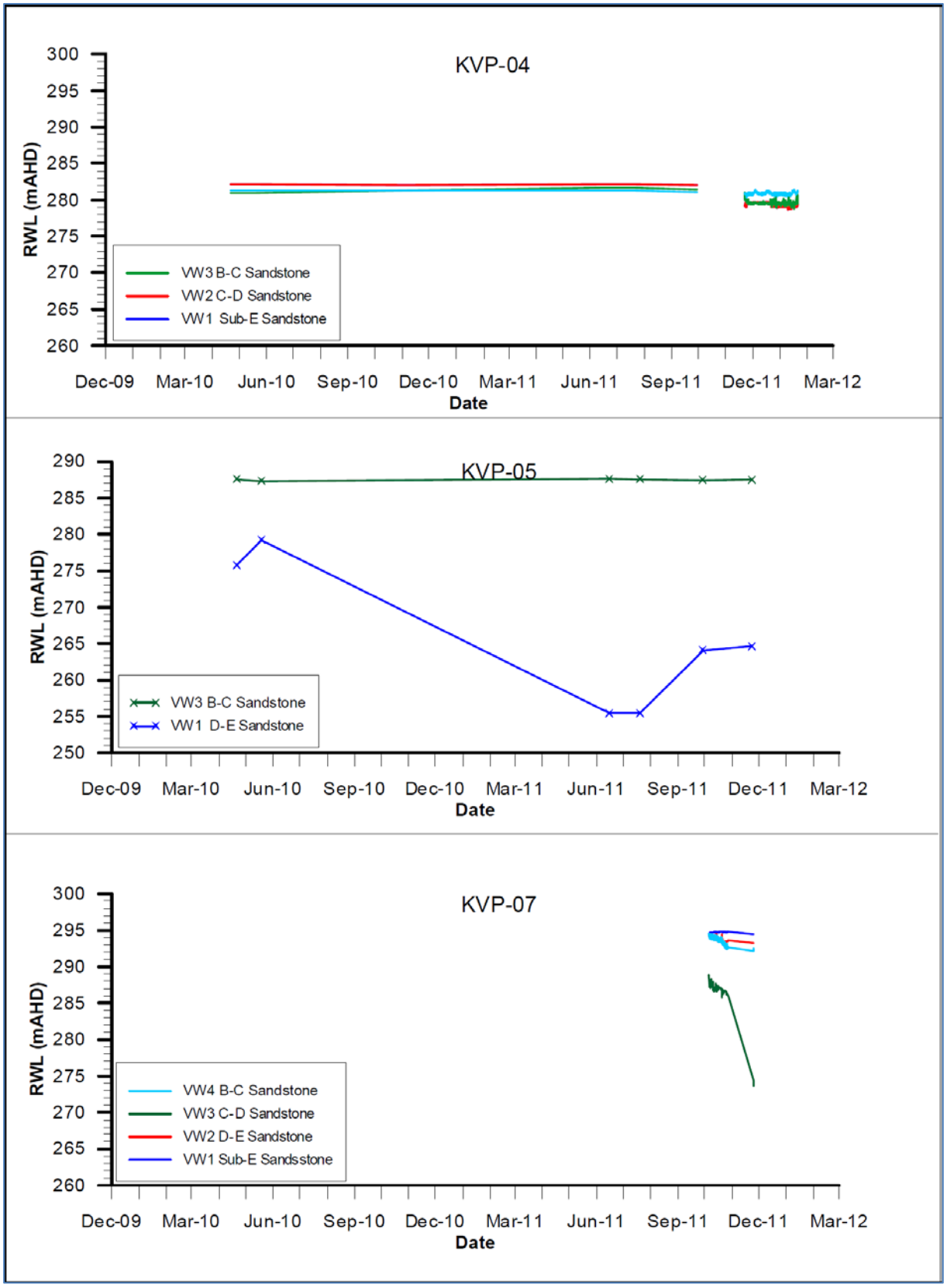
4 Hydrogeological Setting and Data

Figure 4-19 Bore Hydrographs – KVP-01, KVP-02, KVP-03



4 Hydrogeological Setting and Data

Figure 4-20 Bore Hydrographs – KVP-04, KVP-05, KVP-07



4.6.2 Standpipe Monitoring Bores

Standpipe monitoring bores have been constructed at sites shown on Figure 4-14. These bores will be utilised for groundwater level as well as groundwater quality monitoring. The interval screened by each standpipe monitoring bore is shown in **Appendix A**.

The groundwater level data for the four long term monitoring bores, AMB-01 to AMB-04 (Figure 4-14) is presented in Figure 4-21 and Figure 4-22.

Data from VWP and standpipe monitoring bores were considered when assessing recharge response to rainfall within the area of the proposed mine sites.

4.7 Groundwater Recharge

4.7.1 Background on Groundwater Recharge

The potential for groundwater recharge in the area of the proposed mines was estimated using data from VWP and standpipe monitoring bores within the Alpha and Kevin's Corner MLA areas. It is noted that significant rainfall (above average of SILO-generated rainfall) was recorded in site rain gauges for both the 2009-2010 and especially the 2010-2011 wet seasons. This data has proved valuable in assessing the potential for groundwater recharge to the groundwater system from significant rainfall events.

The aim of the analysis provided an indication of the intensity of rainfall required for recharge to occur, as it was recognised that not all rainfall events result in recharge. For rainfall events below a particular intensity groundwater recharge is restricted due to:

- Rainfall runoff via the surface drainage system;
- Water lost through evapotranspiration (resulting in no deep drainage); or
- Infiltration to shallow depth until encountering low permeability layers, at which point the water is directed down topographic gradient as interflow until being removed via plant roots, evaporation, or discharge to surface water drainage features.

Potential recharge processes assessed at the Project site are discussed below.

4.7.2 Groundwater Recharge – Project Area

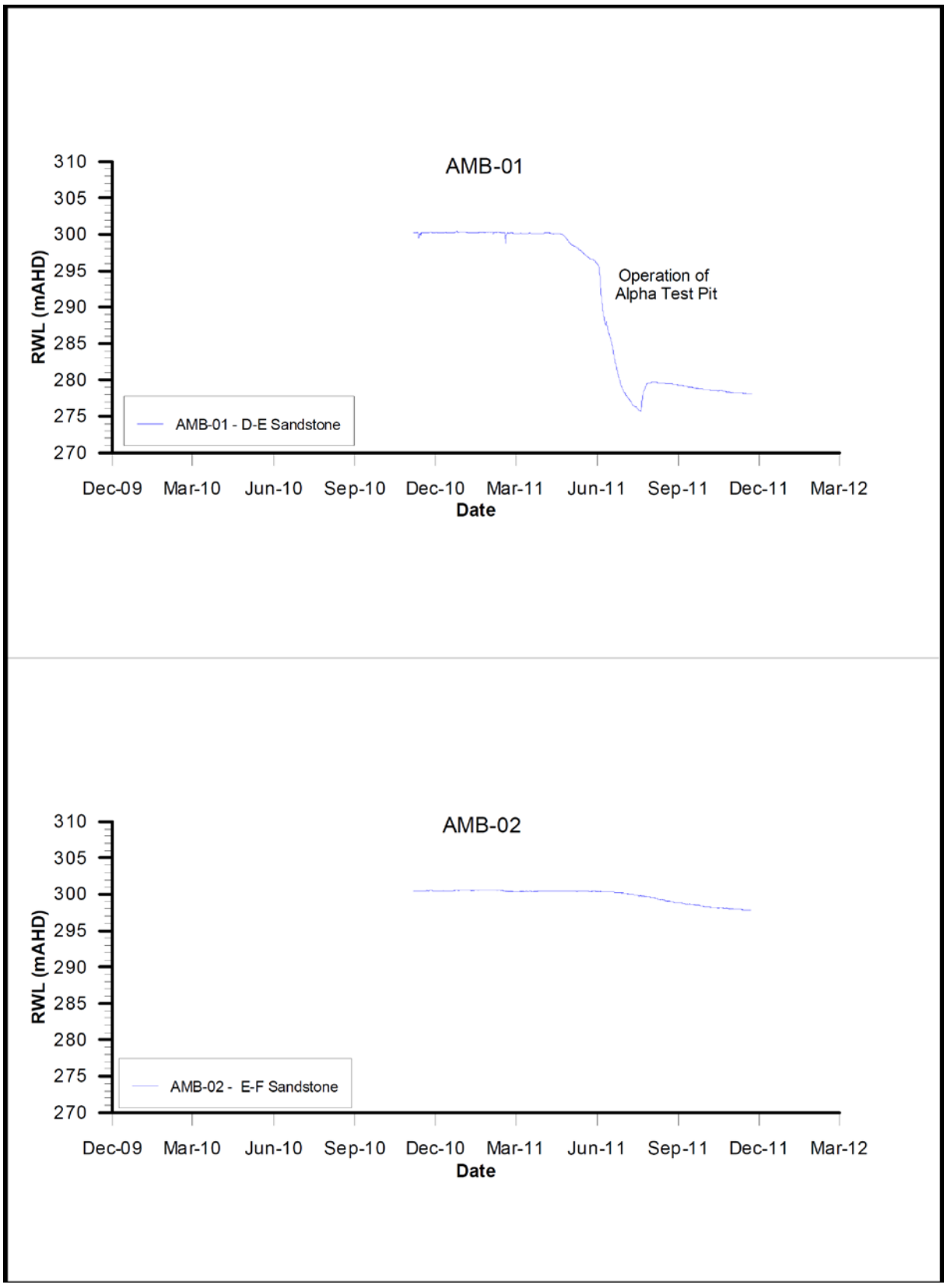
4.7.2.1 Observations from Site

Eight vibrating wire piezometer sites on MLA 70425 and the adjacent Alpha site MLA 70426 have had data loggers fitted since December 2009, and two automated rain gauges are installed at two of these sites. Recorded site rainfall during the wet season months of 2010 included:

- January 2010 – 220.6 mm at AVP-01 and 205.6 mm at AVP13;
- February 2010 – 166 mm at AVP-01 and 183.6 mm at AVP13;
- September 2010 – 173.4 mm at AVP-01 and 270.8 mm at AVP13;
- November 2010 – 44.8 mm at AVP-01 and 189.2 mm at AVP13;
- December 2010 – 13 mm at AVP-01 and 188.6 mm at AVP13; and
- January 2011 – 18.6 mm at AVP-01 and 125.8 mm at AVP-13.

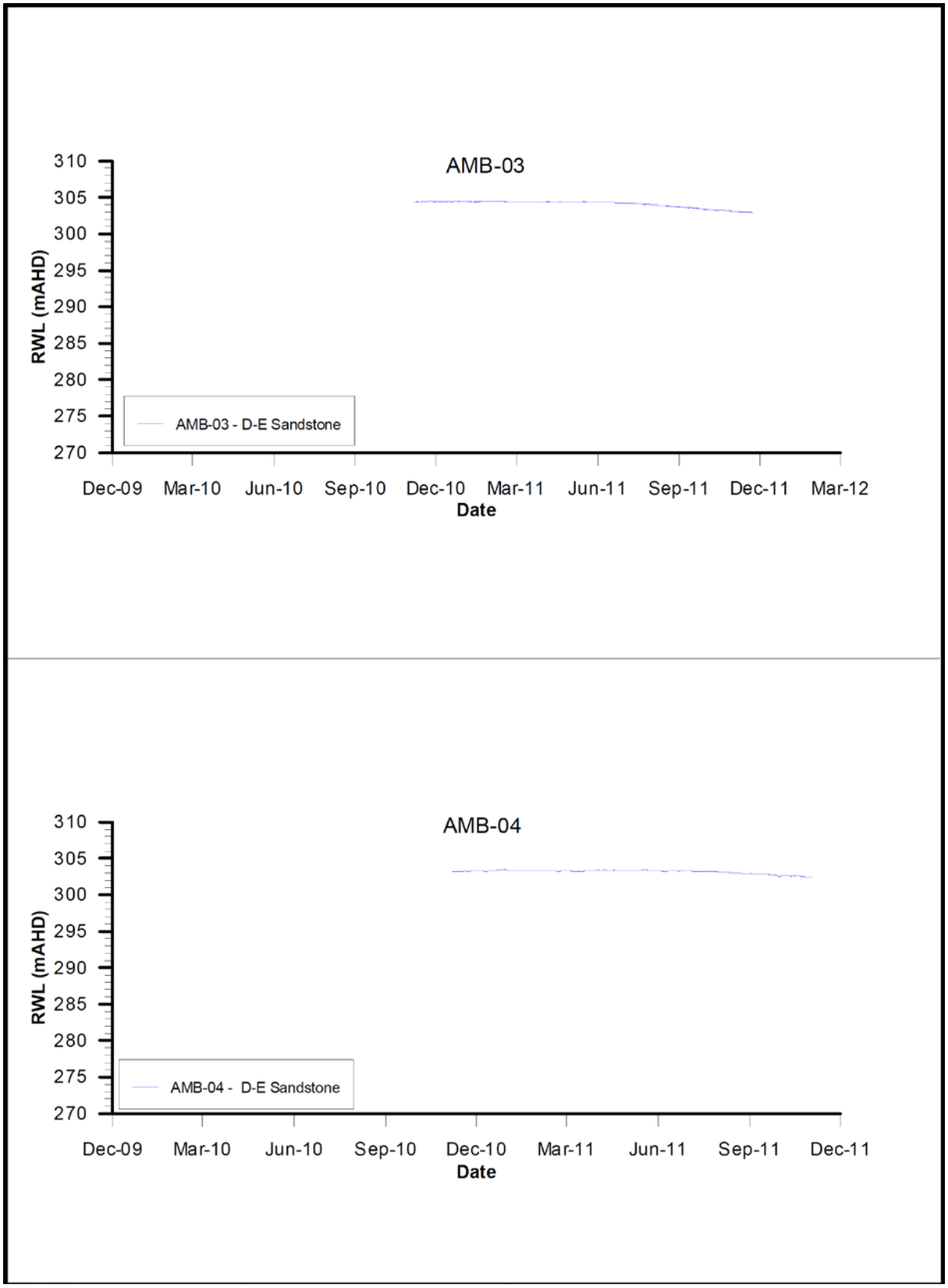
4 Hydrogeological Setting and Data

Figure 4-21 Bore Hydrographs – AMB-01, AMB-02



4 Hydrogeological Setting and Data

Figure 4-22 Bore Hydrographs – AMB-03, AMB-04



(It should be noted that the rain gauge at AVP-01 is under review (refer to Section 4.1.2) to assess whether the apparent low rainfall recorded from November 2010 to January 2011 is real, or whether the gauge is faulty). Therefore, the 2009/2010 and 2010/2011 wet seasons represented potentially significant groundwater recharge events.

A review of bore hydrographs (Figures 4-15 to 4-22) does not indicate an obvious increase in groundwater levels that could be interpreted as aquifer recharge in response to wet season rainfall, in spite of significant rainfall recorded at site over the 2009/2010 or 2010/2011 wet seasons.

The exception is bore AVP-13 (Figure 4-18) where piezometers in the shallow sandstone (sandstone above the A coal seam) as well as the underlying A-B sandstone, both recorded groundwater level increasing trends over the 2010 year. The relationship to water levels in underlying piezometers in this bore suggests a recharge potential at this site (i.e. potential for downward movement of groundwater).

Bore AVP-11 (Figure 4-18) also has a piezometer monitoring the A-B sandstone but pressures at this location have remained stable throughout 2010. The pressures in the underlying C-D and D-E sandstones are higher in this (AVP-11) area, indicating an upward potential for groundwater flow from deeper units to shallower units.

Therefore it is interpreted that groundwater occurs under confined conditions in the western area of the MLA, as well as in the area immediately west of Sandy Creek, potentially becoming unconfined to the east of Sandy Creek in the subcrop area of the Colinlea Sandstone.

Geotechnical drilling undertaken in the area to the east of Sandy Creek (URS, 2011h) within the proposed Alpha TSF encountered weathered parent rock (both Colinlea Sandstone and Joe Joe Formation) at shallow depths. Hydraulic conductivity testing of the unsaturated weathered rock indicated very low hydraulic conductivity values (in the range of 10^{-7} to 10^{-8} m/s), and also found a single occurrence of (perched) groundwater in shallow unconsolidated sands lenses above weathered rock (six bores were drilled to depths ranging from 2.5 to 5.5 m and did not strike water. Fourteen test pits were dug to depths ranging from 1.2 to 2.4 m, and only one intersected water at a depth below surface of 1.6 m). These results tend to support the conclusion that even under above average rainfall conditions infiltration is limited in this area of Colinlea Sandstone outcrop, at least not until enough rainfall had occurred that the rock profile becomes saturated, which will then allow infiltration to occur more readily via the higher saturated hydraulic conductivity of the rock.

Analysis of site geology and available groundwater data, therefore, suggests two potential recharge mechanisms (albeit very low recharge based on hydrographs) at site, as summarised below.

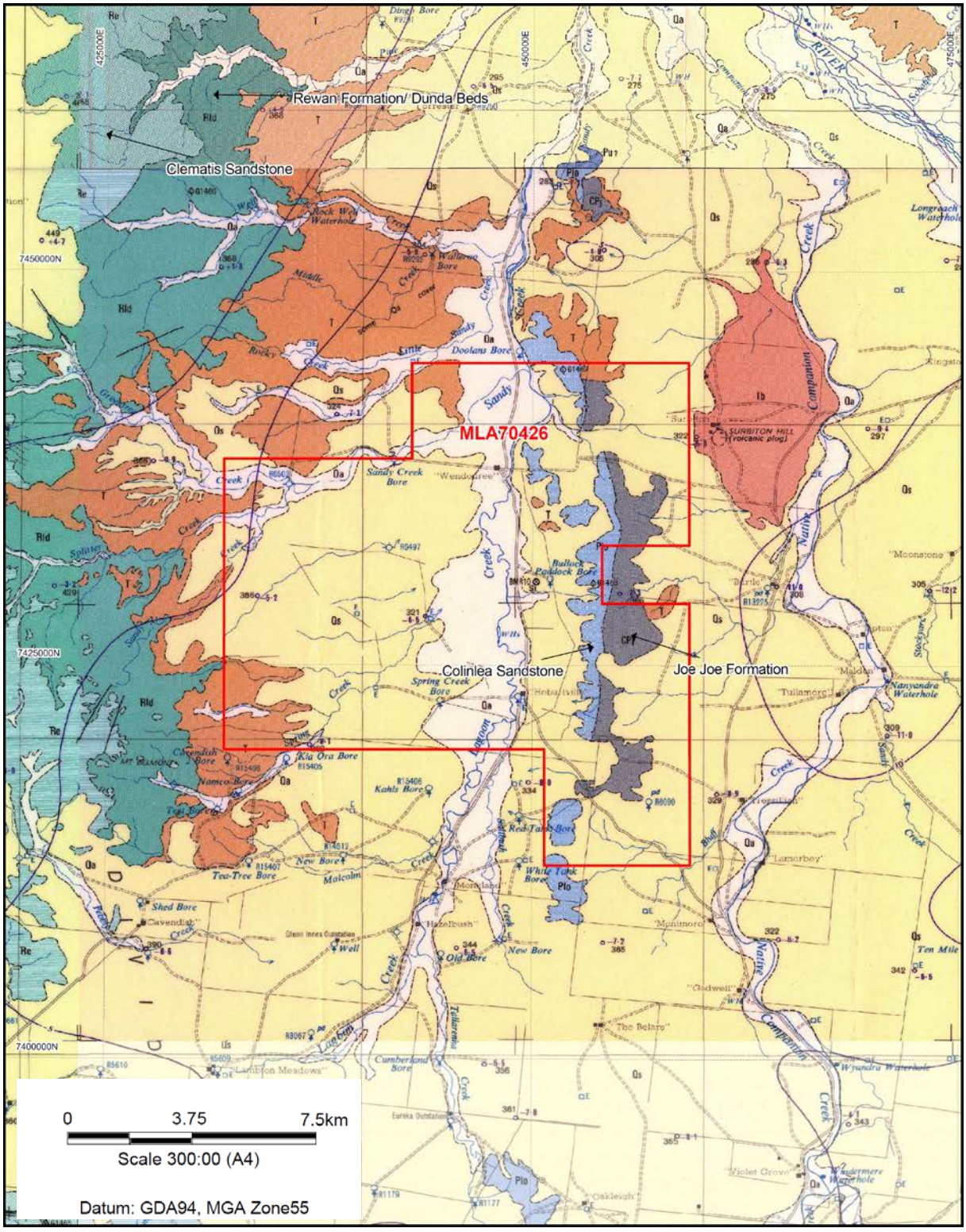
4.7.2.2 Recharge Mechanism 1 – Direct Recharge to Outcrop Areas

Figure 4-23 shows the outcrop geology within the proposed mine area. The Colinlea Sandstone is mapped on the Jericho 1:250 000 scale geological map to outcrop to the east of Lagoon Creek and Sandy Creek. Site investigations (hydrogeology and geotechnical) indicate that weathered Colinlea Sandstone subcrops between the area of mapped Joe Joe Formation (Figure 4-23) outcrop and Lagoon Creek / Sandy Creek.

It was therefore considered that one possible recharge mechanism could be via direct rainfall recharge to the Colinlea Sandstone units in the subcrop areas (once sufficient rainfall has occurred to facilitate infiltration, a threshold rainfall intensity of ~ 200 mm/month is considered, similar to that of the GAB).

4 Hydrogeological Setting and Data

Figure 4-23 Site geology



This is the same mechanism by which effective recharge is assumed to occur within groundwater intake (outcrop) beds of the GAB. The base of the Colinlea Sandstone is, for the purpose of considering recharge, the eastern-most extent of Colinlea Sandstone outcrop (Figure 4-23).

4.7.2.3 Recharge Mechanism 2 – Diffuse recharge along the Great Dividing Range

The Great Dividing Range is located directly west of the Hancock MLAs. The second recharge mechanism that has been considered is that recharge occurs in topographically elevated areas and flows down gradient (i.e. as a subdued reflection of topography) toward the lower-lying areas to the northeast. Existing potentiometric surface data (Figures 4-12 and 4-13) indicate that groundwater flow is to the northeast and that depth to groundwater gets shallower to the north. There are, however, no perennial discharge springs mapped to the northeast, thus discharge of confined aquifers has not been recognised within the study area.

4.7.3 Alpha Tailings Storage Facility Assessment – Recharge Considerations

A geological and hydrogeological assessment of the proposed Alpha Coal Mine 30 year life of mine out-of-pit tailings storage facility (TSF) has been undertaken to describe the underlying geology including the nature of the boundary between the Colinlea Sandstone and the Joe Joe Formation. The assessment included an evaluation of groundwater occurrence and the nature of the groundwater resources within and adjacent to the TSF footprint (URS, 2011g).

The study allowed for the construction of groundwater monitoring bores to obtain groundwater data from multiple vertical zones. These field data allowed for an evaluation of the suitability of the proposed TSF site from a groundwater perspective. The assessment also allowed for the consideration of recharge mechanisms and alteration within the proposed TSF area.

Based on the site specific geological, geotechnical, and hydrogeological data compiled during the TSF study, an assessment of the recharge within the Colinlea Sandstone / Joe Joe Formation contact area indicated:

- Restricted recharge potential to the underlying Colinlea Sandstone units due to the thick clay-rich Tertiary laterite, thin discontinuous Colinlea Sandstone aquifers (cross-sections indicate thin sub-E and sub-F sands) pinching out against the Joe Joe Formation, thick unsaturated zone (even though the site was subject to prolonged high rainfall events during 2010/2011), and no Colinlea Sandstone rock outcrop or shallow subcrop was recorded in any of the 14 bores drilled during the study;
- Drilling results and blow-out yields recorded during rotary-air-percussion within the proposed TSF footprint indicate aquitards and units of limited groundwater potential; and
- The majority of the shallow perched groundwater within the proposed TSF footprint comprises poor quality groundwater. This indicates little or no recharge with fresh rain water to reduce salinity concentrations.

The information compiled and assessed during the TSF assessment indicates that little or no recharge occurs within the Colinlea Sandstone / Joe Joe Formation contact area, indicating that any potential recharge to the confined aquifers within the proposed mine sites occurs as a result of diffuse recharge along the Great Dividing Range.

4.7.4 Conceptualised Recharge Mechanisms

The potentiometric surface contours presented as Figures 4-12 and 4-13 lend support to the second type of recharge mechanism.

If this is the case, a groundwater divide (i.e. representing a point at which some groundwater flow is to the west, and some flow is to the east) may exist for the Colinlea Sandstone to the west of the proposed mining sites. If this recharge mechanism is dominant, recharge from the area of Colinlea Sandstone subcrop may not be as regionally significant as recharge that occurs to the west of the site, as the area to the west of the site represents a much greater surface area in which recharge could occur.

The following observations support the second type of recharge mechanism:

- Groundwater flow direction in the western part of the MLAs is from south-south-west to north-north-east. This is consistent with existing data from site groundwater level monitoring; and
- In the area of mapped Colinlea Sandstone subcrop an extensive drilling program encountered clayey material below the proposed Alpha TSF, relatively little water in spite of recent heavy rainfall, and relatively saline water compared to regional trends. This data suggests that the area below the TSF site, an area of supposed Colinlea Sandstone outcrop, does not receive significant groundwater recharge.

It must also be noted that based on the transient groundwater level data, compiled from the long term VWPs installed across the site, indicates little or no change as a result of rainfall events. This in turn is interpreted as limited recharge potential resulting from rainfall (regardless of recharge mechanism) .

It is proposed that recharge to deeper Permian groundwater units occurs to the south-west of the site (along the Great Dividing Range) and that shallow groundwater units (above the low-permeability Tertiary laterite) are recharged directly via diffuse rainfall recharge; this shallow groundwater then discharges relatively quickly to topographic lows (alluvium of Lagoon Creek and Sandy Creek) leaving isolated pockets of perched groundwater in the longer-term.

Therefore, for the purpose of groundwater modelling, recharge is applied to topographically elevated areas of the Great Dividing Range.

4.8 Groundwater Discharge

4.8.1 General

Groundwater flow contours (Figure 4-12 and Figure 4-13) indicate a groundwater flow direction from topographically elevated areas to the west of site, to the north-north east. These groundwater flow patterns and the lower elevations to the northeast of the mine sites, indicate a potential for groundwater discharge to the northeast, into Sandy Creek.

However, groundwater in the Permian Bandanna Formation and Colinlea Sandstone (the units in which groundwater is usually first intersected) is encountered under confined conditions, even adjacent to Sandy Creek (nested monitoring discussed in Section 4-10 and **Appendix A**).

The latest groundwater level data for the shallow (10 m) bores constructed within the Sandy Creek alluvium from January (February too wet to access bores along Sandy Creek) range from 3.48 to 8.9 m below surface. Bores constructed below the alluvium, within the confined D-E sandstone indicate

groundwater levels for January ranging from 12.53 (1681R) to 22.34 (KMB-04) m below surface. These water level data indicate a 3 to 19 m separation between the perched alluvium water levels and the D-E sandstone potentiometric levels. Please note this is only relevant where shallow unconfined groundwater overlies confined aquifers, however, data shows distinct separation thus no hydraulic linkage between the two groundwater systems. These data, plus the lack of recorded perennial springs and seeps in or adjacent to the MLAs, indicate limited potential for groundwater discharge from the Colinlea Sandstone units.

4.8.2 Groundwater springs

A number of springs have been identified on the Forrester property, with the closest spring being approximately 30 km north of the MLA70425 boundary Figure (4-24). The springs line up in a north-south direction, and occur on the western side of Sandy Creek, adjacent to a change in slope. The springs appear to emanate at the topographic break of slope, where shallow groundwater is moving west to east from recharge areas on the Great Dividing Range, and discharging at the break of slope at points that also correspond with surface drainage lines. A review of hydrology and satellite imagery indicates that these springs are ephemeral (i.e. no perennial surface water flows from these registered springs). It is therefore considered that these springs are seasonal and flow due to limited effective storage within the colluvium cover at the slope break.

However, it is also possible that this coincides with the area to the north of the project where groundwater levels (in a regional sense) are at or approaching surface, so there is an upward discharge potential from the deeper confined (semi-confined) groundwater units. Therefore, the springs occur because shallow groundwater can't leak downwards due to the upward (discharge) potential of regional groundwater. This means that there may be a potential to impact these springs if groundwater levels in deeper aquifers are impacted by mining, as it would mean that the discharge potential for deep (Permian) aquifers is removed at this location, which would also mean that shallow groundwater could leak downwards, and this could in turn impact on the discharge potential of the springs. As no detailed spring assessment (site reconnaissance) has yet been undertaken, an assessment of the potential for the proposed mining activities to impact on groundwater resources at and below these registered springs to the north has been undertaken. Sections 10, 12, and 13 discuss the model predictions regarding these springs.

4.8.2.1 GAB springs

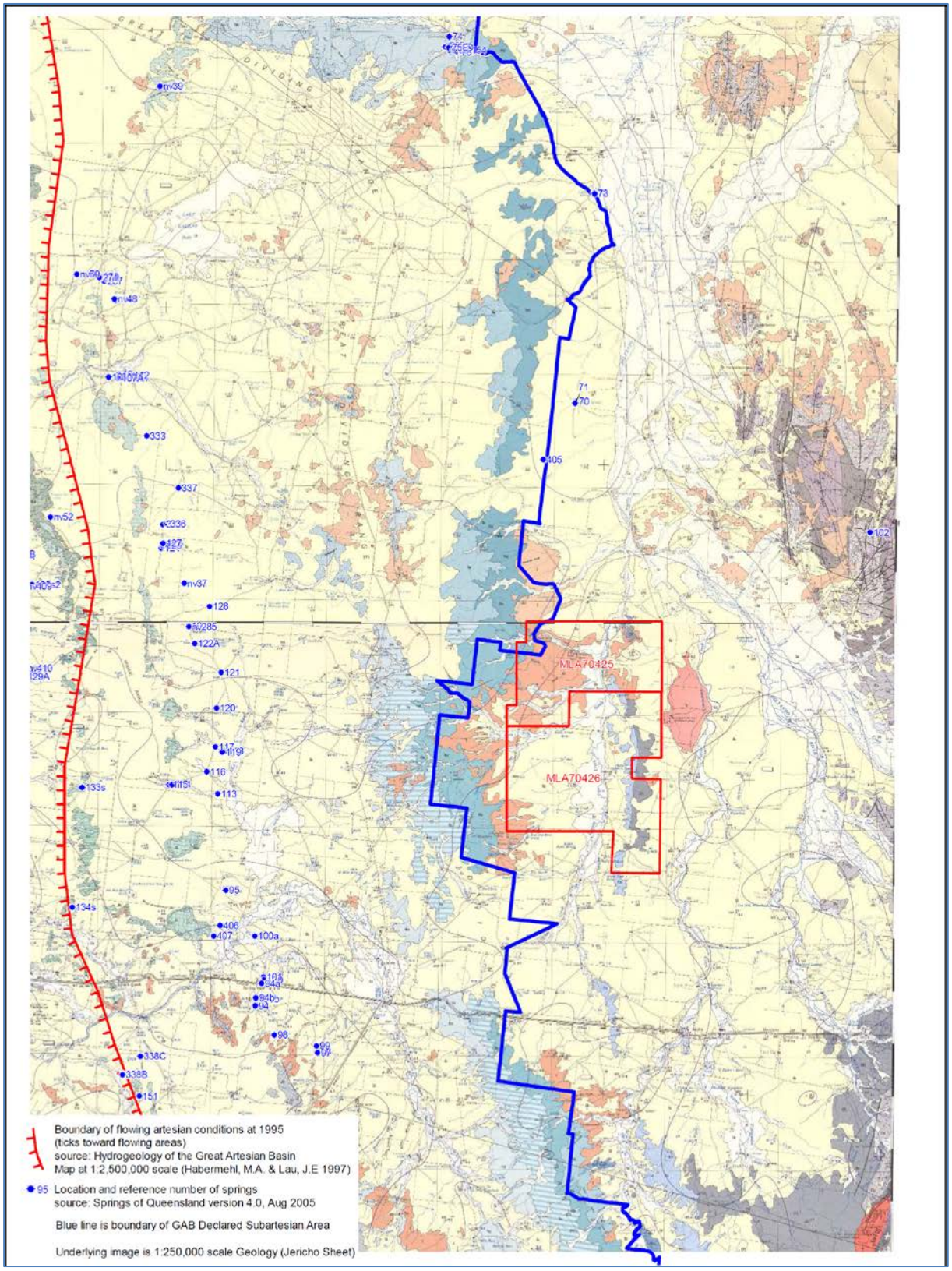
Registered springs within the GAB, to the west of the proposed mining (Figure 4-24), form are as a result of a recharge mechanism known as "rejected recharge". The report "Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland" uses the concept of "rejected recharge" as the origin for many of the springs, and defines the mechanism as "*occurrences of springs and bogomosses in many areas of the intake beds indicate that the underlying aquifers are not sufficiently permeable to accept all deep drainage through the soil as recharge*"

The registered springs within the GAB, Figure 4-24, form a line of springs on the Hutton Sandstone, which may then form as recharge springs within the Hutton Sandstone outcrop. In addition, rainfall recharge onto the Moolayember Formation confining beds may result, due to limited effective storage, in springs related to shallow subcrop of the Moolayember Fm.

The proposed mining impacts will not impact on any recharge to any recharged springs identified on Figure 4-24, thus no change in spring flows or seasonal flow is predicted.

4 Hydrogeological Setting and Data

Figure 4-24 Registered springs



4.9 Groundwater Yield

4.9.1 Review of Air Lift Yield Data

Information on groundwater yield was available from the DERM groundwater database as well as site exploration drilling, where air lift yields are routinely measured at the end of the hole using a 90° v-notch weir. Most exploration bores extend below the D coal seam into the D-E sandstone. Thus the air-lift yield figures presented are assumed to be based on cumulative inflows from the entire Permian sequence down to the top 5 – 10 m of the D-E sandstone (where drilling is generally discontinued). The weathered overburden material, comprising the Tertiary sediments and weathered Permian sediments, is generally cased off at the start of drilling, so it assumed that no water is reporting to the bore from the weathered Permian and overlying Tertiary sediments.

Figure 4-25 shows bore yield classes for data obtained from the DERM groundwater database. The data contains 119 bore records for which data was available (in the area covered by Figure 4-25):

- 46 (38%) recorded a yield less than 1 L/s;
- 39 (33%) recorded a yield between 1 and < 2.5 L/s;
- 21 (18%) recorded a yield between 2.5 and < 5 L/s;
- 7 (6%) recorded a yield between 5 and < 10 L/s; and
- 6 (5%) recorded a yield in excess of 10 L/s.

Figure 4-26 shows bore yield classes for data obtained from air-lift testing of site exploration boreholes. The data shows that of the 451 bores for which data was available (in the area covered by Figure 4-26 in 2010):

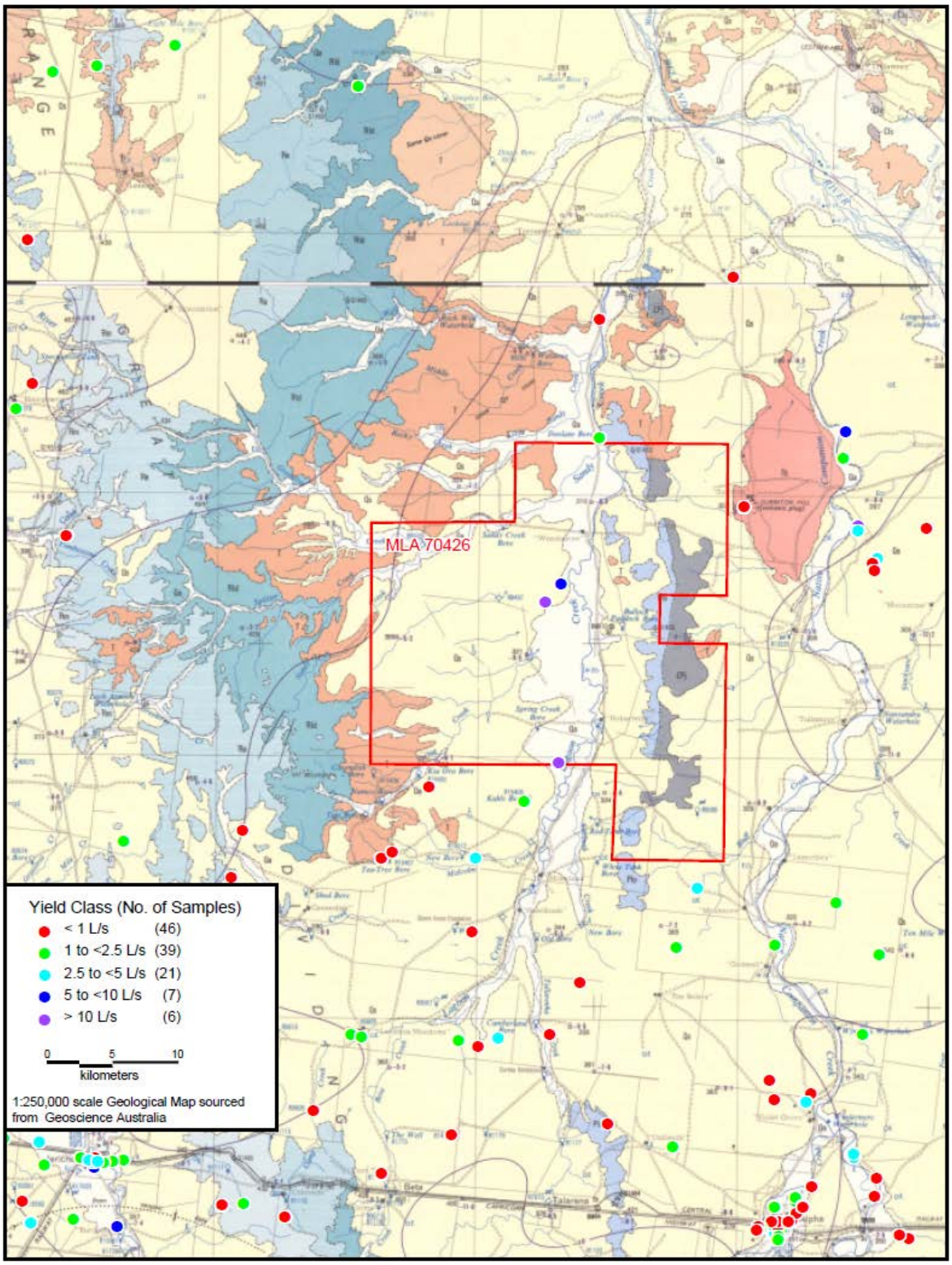
- 142 (31%) recorded a yield less than 0.5 L/s;
- 98 (22%) recorded a yield between 0.5 and < 1 L/s;
- 142 (10%) recorded a yield between 1 and < 2 L/s;
- 55 (12%) recorded a yield between 1 and < 5 L/s;
- 13 (3%) recorded a yield between 5 and <10 L/s; and
- 1 (less than 1%) recorded a yield greater than 10 L/s.

The data from the DERM groundwater database and exploration drilling suggests that the majority of the bores in the area will yield < 2 L/s[3]. However, isolated high yielding bores (10 L/s or more) have been recorded within the groundwater study area. It should be noted that the data set does not include information on holes that were dry, so the data may be skewed towards an assumption of relatively high yields.

[3] The average yields determined during the modelling study was 160 m^3/day (1.85 L/s), which was used in the dewatering modelling assessments (Section 6).

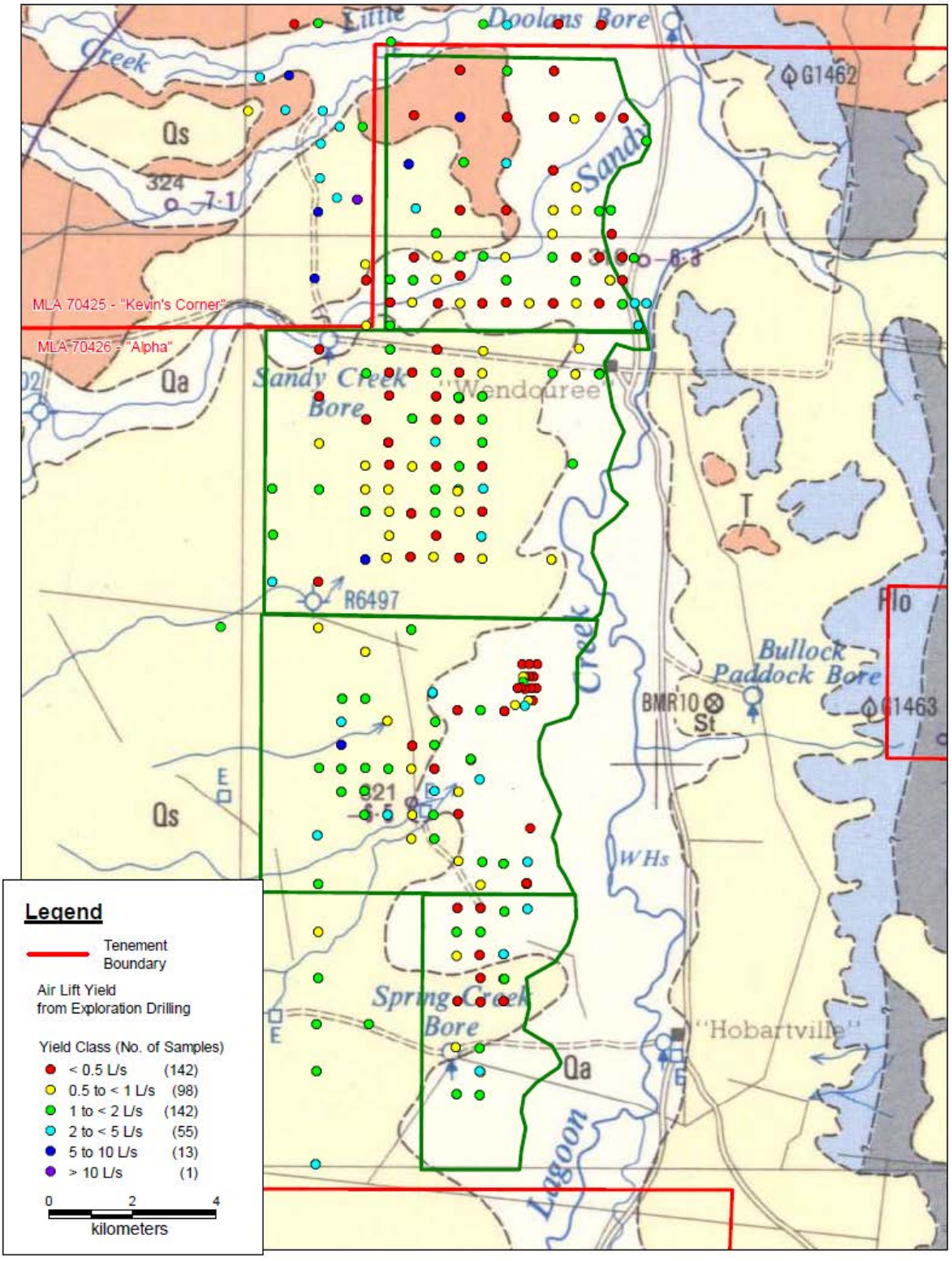
4 Hydrogeological Setting and Data

Figure 4-25 Air-Lift Yield Data - DERM Groundwater Database



4 Hydrogeological Setting and Data

Figure 4-26 Air Lift Yield Data - Site Exploration Drilling



4.10 Aquifer Hydraulic Properties

4.10.1 Site Data

4.10.1.1 Summary of Previous Investigations

There have been three phases of groundwater investigation undertaken previously on MLA70426. These phases of investigation include:

Phase 1 – Surface water, groundwater, and geotechnical investigations by Australian Groundwater Consultants (AGC) for Bridge Oil Limited, during 1982-1983. In summary, these investigations provided:

- Information from the drilling of pumping test wells and monitoring bores at four sites (TPB-1 to TPB-4);
- Information (observations and calculated hydraulic properties) from pumping tests, summarised in Table 4-2;
- Summary of groundwater chemistry (TDS, major and minor ions) from the four pumping test sites;
- Summary of groundwater conditions and observations for the site, including a preliminary conceptual groundwater model;
- Summary of surface water investigations, including description of the surface water system, runoff yield potential, and preliminary flood studies; and
- Preliminary assessment of water supply potential of surface water and groundwater systems at the site.

Phase 2 – Groundwater and geotechnical investigations undertaken by Longworth & McKenzie during 1984 for Bridge Oil Limited. In summary, these investigations provided:

- Information from the drilling of pumping test wells and monitoring bores at one site, with pumping wells developed in vertically separated aquifer systems. Pumping test bores included bore W1 which was constructed within an interval including the C and D coal seams and interburden; and bore W2 which was constructed within the D-E sandstone; and
- Information (observations and calculated hydraulic properties) from pumping tests undertaken on bores W1 and W2.

Pumping tests undertaken by AGC[4] in 1983 and by Longworth & McKenzie[5] in 1984 are included in Table 4-2.

Phase 3 – Prefeasibility Stage Investigations undertaken by Connell Hatch

The Connell Hatch investigations did not present any new work, but provided a summary of previous investigations, and re-iterated the volume of groundwater likely to be held in storage, as calculated by the AGC investigation.

A summary of pumping tests from previous investigations is provided in Table 4-2.

[4] AGC (1983) Alpha Coal Project (A to P 245C), Surface Water and Groundwater Aspects – Preliminary Evaluations. Report for Bridge Oil Limited

[5] Longworth & McKenzie (1984) Report on Geotechnical and Groundwater Investigation (1984) Area 2, ATP245C, Alpha Queensland for Bridge Oil Limited. Report Reference UGT0115/KDS/ejw

Table 4-3 Summary of pumping test from previous investigations

Bore	Test Duration	Interval Tested	Pumping Rate (L/s)	Comments
Testing undertaken by AGC 1983				
TPB-1	100 hr	D-E Sands	10	37 m of drawdown in pumping bore. Water level drawn down to base of top screens.
TPB-2	24 hr	D-E Sands	3.6	At a pumping rate of 10 L/s the water level dropped to the pump intake. Testing continued at 3.6 L/s. Drawdown during test was 55 m in the pumping bore.
TPB-3	100 hr	C-D Sands	10	19 m of drawdown in pumped bore. Water level almost down to top of aquifer.
TPB-4	100 hr	D-E Sands	6	44 m of drawdown in pumped bore. Water level drawn down within the aquifer.
Testing undertaken by Longworth & McKenzie 1984				
W-1	2 days	C-D Sands	0.1	Bores W-1 and W-2 were constructed at the same location, but were screened within separate aquifers. W-1 was constructed within "Aquifer 1" (C-D Aquifer of AGC reports), while W-2 was constructed within "Aquifer 2" (E Aquifer of AGC Reports) 5.5 m of drawdown in pumped bore.
W-2	15.87 days	D-E Sands	1.03	34.27 m of drawdown in pumping bore.

4.10.2 Modelling Field Investigations

The field validation studies conducted during the modelling project included:

- Aquifer (pump-out) tests
- Variable head (slug) tests; and
- Laboratory testing of core samples aimed at obtaining horizontal and vertical hydraulic conductivity data.

4.10.2.1 Pumping tests

Pumping tests have been undertaken at a number of sites across the Alpha and Kevin's Corner MLA's during the 2011 year. Summary reports of field investigations (pumping test reports, permeability testing of core samples) are included in **Appendix B**. The investigations include:

- Alpha MLA – testing of bore 1290L during February 2011 (**Appendix B**); and
- Kevin's Corner MLA – testing of five bores (1680R, 1681R, 1638L, 1637R, 1636R) during October 2011 (**Appendix B**).

4 Hydrogeological Setting and Data

A brief summary of each test is included in this section. Aquifer hydraulic properties derived from testing from all phases of investigation (previous and current) are summarised in Table 4-3. Details are included in **Appendix B**.

Bore 1290L

This site is located adjacent to the Alpha Test Pit, in an area that has already been tested by a pumping test undertaken for bores W1 and W2 (Longworth & McKenzie, 1984) and TPB-2 (AGC, 1983), shown on Figure 4-27. The purpose of running a further test at this location was to provide further aquifer properties for the D-E sands in the area of the test pit, and to provide an indication of the variability of aquifer properties in the area.

Bore 1290L is constructed to a depth of approximately 73 m, and is screened within the D-E sands (aquifer thickness at this location is 6.3 m between base of D and top of E coal seams).

In summary:

- The pump (Mono 820 fitted with variable speed drive) was set at the lowest possible pumping rate (0.4 L/s);
- A constant rate test was initiated at a pumping rate of 0.4 L/s, the water level was reduced to the pump intake (60.9 m drawdown) after 2 ¾ hours. After this time the drawdown in adjacent monitoring bore AMB-01, 30 m distant, was 1.25 m; and
- The results from the pumping test indicated that the cone of depression from pumping was very steep, and that the D-E sandstone in the area of the test bore has a low transmissivity relative to other areas where the D-E sandstone has been tested. Analysis of test results indicates a hydraulic conductivity of approximately 0.16 m/d, or 1.9 x 10^{-6} m/s (Table 4-3) and a storage coefficient (storativity) of 3.8 x 10^{-4}.

Bore 1681R

Bore 1681R is located on the Kevin's Corner MLA (Figure 4-27) and is constructed to test the D-E sandstone. Testing at this site comprised a step drawdown test followed by a constant discharge test. Details for the step drawdown test are as follows:

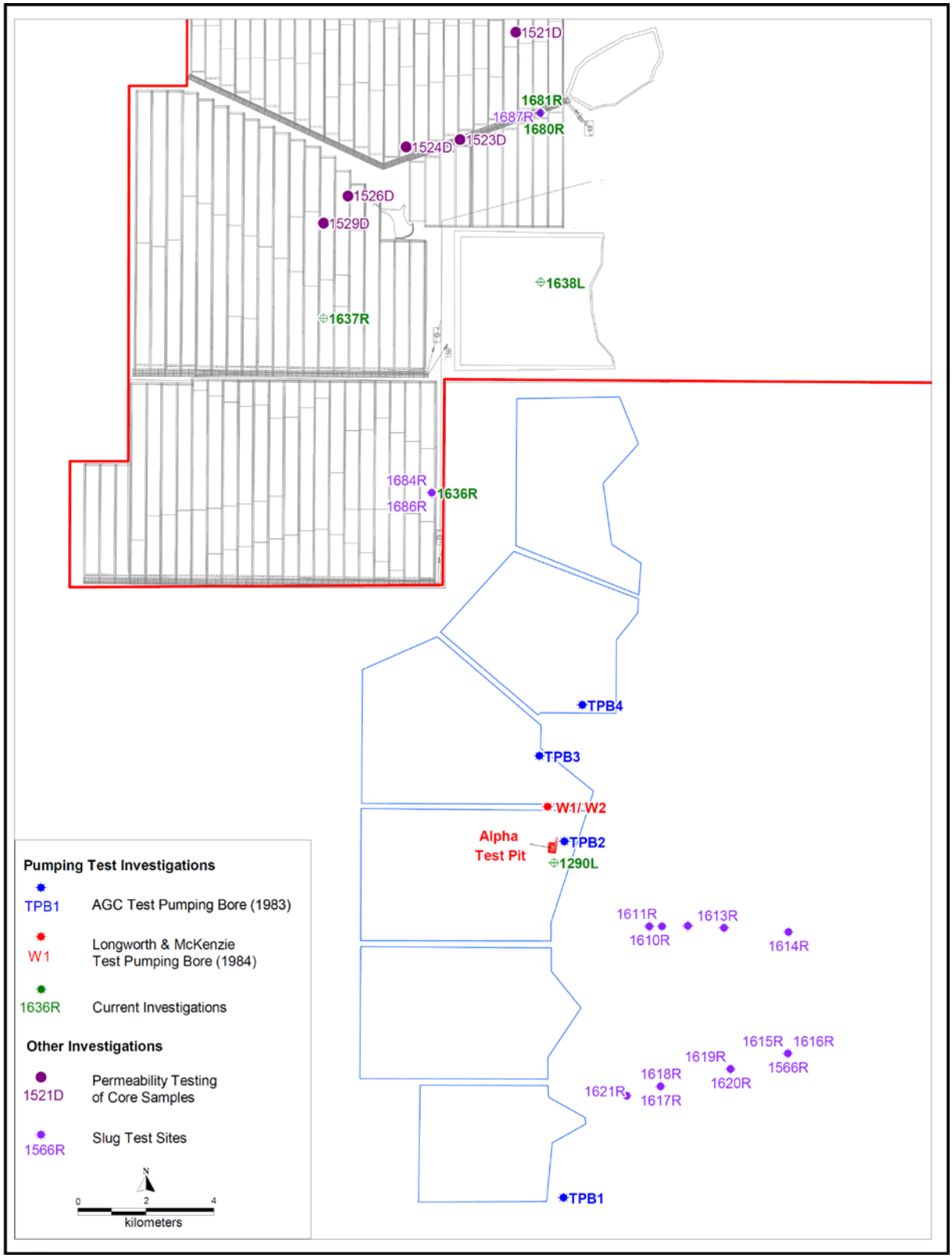
- Step 1 - 0.5 L/s for 70 min – 12.21 m drawdown (specific capacity = 0.04 L/s/m);
- Step 2 - 0.7 L/s for 60 min - 17.04 m drawdown (specific capacity = 0.04 L/s/m);
- Step 3 - 1.11 L/s for 60 min – 25.31 m drawdown (specific capacity = 0.04 L/s/m); and
- Step 4 - 2.11 L/s for 30 min - water level reached pump inlet, test terminated – 48.45 m drawdown

A 24-hour constant discharge pumping test was completed on the bore at a rate of 1.34 L/s, resulting in 51.75 m drawdown in the pumping bore, and 8.96 m drawdown in observation bore KVP-09 (35.9 m from pumped bore).

Calculated aquifer parameters include hydraulic conductivity of 2.05E-06 m/s (0.08 m/day) and storage coefficient of 5.1E-04 (Table 4-3).

4 Hydrogeological Setting and Data

Figure 4-27 Location of Aquifer Hydraulic Data points



4 Hydrogeological Setting and Data

Table 4-4 Aquifer test data

Pumping Test Bore	Bore Monitored	Distance from Pumped Bore (m)	Unit	Analysis Method	Transmissivity (T) (m^2/day)	Aquifer thickness (m)	Hydraulic Conductivity (K)		Storage Coefficient (S)
							(m/day)	**(m/s)**	
AGC (1983)									
TPB1	TPB1	0	D-E Sandstone	Jacob	41.6	24	1.73	2.01E-05	-
				Jacob Late Stage	23.2	24	0.97	1.12E-05	-
				Recovery	29.1	24	1.21	1.40E-05	-
	B597	10.05	D-E Sandstone	Jacob	43.9	30	1.46	1.69E-05	4.80E-05
				Jacob Late Stage	30.4	30	1.01	1.17E-05	4.70E-04
				Recovery	29.8	30	0.99	1.15E-05	-
	B593	260	D-E Sandstone	Jacob	42.7	24	1.78	2.06E-05	3.60E-05
				Jacob Late Stage	28.4	24	1.18	1.37E-05	4.65E-05
				Recovery	28	24	1.17	1.35E-05	-
	B591	572.5	D-E Sandstone	Jacob	42	28	1.50	1.74E-05	1.26E-04
				Recovery	65.3	28	2.33	2.70E-05	-
				Average - Jacob			**1.56**	**1.80E-05**	**7.00E-05**
				Average - Jacob late stage			**1.20**	**1.39E-05**	**2.58E-04**
				Average - Recovery			**1.43**	**1.66E-05**	-
TPB2	TPB2	0	D-E Sandstone	Jacob	2.8	16	0.18	2.03E-06	-
				Recovery	4.7	16	0.29	3.40E-06	-
	B538	20.03	D-E Sandstone	Jacob	5.3	16	0.33	3.83E-06	6.60E-05
				Recovery	4	16	0.25	2.89E-06	-
				Average - Jacob			**0.25**	**2.93E-06**	**6.60E-05**
				Average - Recovery			**0.27**	**3.15E-06**	
TPB3	TPB3	0	C-D Sandstone	Recovery	6.5	20	0.33	3.76E-06	
	B506	21.35	C-D Sandstone	Jacob	5.6	20	0.28	3.24E-06	1.10E-03
				Recovery	5.4	21	0.26	2.98E-06	
				Average			**0.30**	**3.50E-06**	**1.10E-03**

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Pumping Test Bore	Bore Monitored	Distance from Pumped Bore (m)	Unit	Analysis Method	Transmissivity (T) (m^2/day)	Aquifer thickness (m)	Hydraulic Conductivity (K)		Storage Coefficient (S)
							(m/day)	**(m/s)**	
TPB4	TPB4	0	D-E Sandstone	Jacob	10.3	32	0.32	3.73E-06	
				Recovery	9.8	32	0.31	3.54E-06	
	B627	32.9	D-E Sandstone	Jacob	14.8	26	0.57	6.59E-06	1.00E-05
				Recovery	18.3	26	0.70	8.15E-06	
	B191	370	D-E Sandstone	Jacob	16.6	30	0.55	6.40E-06	1.90E-05
				Recovery	15.9	30	0.53	6.13E-06	
				Average - Jacob			**0.48**	**5.57E-06**	**1.45E-05**
				Average - Recovery			**0.51**	**5.94E-06**	
Longworth & McKenzie (1984)									
W1	W1	0	C-D seams/interburden	Jacob early time	2.8	24	0.12	1.35E-06	
	P1/1	30	C-D seams/interburden	Jacob early time	4.3	24	0.18	2.07E-06	1.30E-03
	P3		C-D seams/interburden	Jacob early time	2.8	21	0.13	1.54E-06	8.00E-03
				Average			**0.14**	**1.66E-06**	**4.65E-03**
W2	W2	0	D-E Sandstone	Leaky aquifer analysis	4.6	21	0.22	2.54E-06	
	P1/2	30	D-E Sandstone	Leaky aquifer analysis	4.3	15	0.29	3.32E-06	3.20E-05
	P2/2	50	D-E Sandstone	Leaky aquifer analysis	4.3	15	0.29	3.32E-06	3.70E-05
				Average			**0.26**	**3.06E-06**	**3.45E-05**
JBT Consulting/URS (2011)									
1290L	AMB-01	30	D-E Sandstone	Theis	1.2	6.3	0.16	1.90E-6	3.80E-04
1636R	1684R	41.4	C-D Sandstone	Theis - curve fit to pump bore	0.7	18	0.04	4.50E-07	5.00E-05
				Theis - curve fit to obs bore	1.4	18	0.08	9.00E-07	8.40E-05
				Average	**1.05**	**18**	**0.06**	**6.75E-07**	**6.70E-05**
1637R	1686R	28.5	D-E Sandstone	Theis	1.08	15	0.07	8.33E-07	1.60E-04
1638L	1688R	18.3	D-E Sandstone	Theis - variable rate test	2.2	15	0.15	1.70E-06	3.70E-04
1680R	KVP-09	21.8	C-D Sandstone	Theis - variable rate test	13.3	16	0.83	9.62E-06	2.00E-05
1681R	KVP-09	35.9	D-E Sandstone	Theis - variable rate test	1.95	11	0.18	2.05E-06	5.10E-04

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Bore 1680R

Bore 1681R is located on the Kevin's Corner MLA (Figure 4-27) at the same site as bore 1681R (detailed above) and is constructed to test the C-D sandstone.

Testing at site comprised a step drawdown test with extended final step, as follows:

- Step 1 - 0.5 L/s for 60 min – 3.09 m drawdown (specific capacity = 0.16 L/s/m);
- Step 2 - 0.7 L/s for 60 min - 4.34 m drawdown (specific capacity = 0.16 L/s/m);
- Step 3 - 1.11 L/s for 60 min – 8.06 m drawdown (specific capacity = 0.14 L/s/m); and
- Step 4 - 2.26 L/s for 1,158 minutes (19.3 hours) – 16.75 m drawdown.

Maximum drawdown of 5.67 m was recorded in observation bore KVP-09 (21.8 m from pumped bore). Calculated aquifer parameters include hydraulic conductivity of 9.62E-06 m/s (0.83 m/day) and storage coefficient of 2.0E-05 (Table 4-3).

Bore 1638L

Bore 1638L is located on the Kevin's Corner MLA (Figure 4-27) and is constructed to test the D-E Sandstone. Testing at site comprised a step drawdown test followed by a constant discharge test. Details for the step drawdown test are as follows:

- Step 1 - 0.5 L/s for 71 min – 12.24 m drawdown (specific capacity = 0.04 L/s/m);
- Step 2 - 0.7 L/s for 60 min - 17.35 m drawdown (specific capacity = 0.04 L/s/m);
- Step 3 - 1.11 L/s for 60 min – 25.62 m drawdown (specific capacity = 0.04 L/s/m); and
- Step 4 - 2.11 L/s for 31 min - water level reached pump inlet, test terminated – 48.45 m drawdown

A constant discharge pumping test of 19.6 hours duration was completed on the bore at a rate of 1.34 L/s, resulting in drawdown below initial water level of 39.50 m in the pumping bore, and 9.89 m drawdown in observation bore 1688R (35.9 m distant).

Maximum drawdown of 5.67 m was recorded in observation bore KVP-09 (18.3 m from pumped bore).

Calculated aquifer parameters include hydraulic conductivity of 1.7E-06 m/s (0.15 m/day) and storage coefficient of 1.7E-06 (Table 4-3).

Bore 1637L

Bore 1637L is located on the Kevin's Corner MLA (Figure 4-27) and is constructed to test the D-E Sandstone. Testing at site comprised a step drawdown test with extended final step, as follows:

- Step 1 - 0.5 L/s for 150 min – 25.8 m drawdown (specific capacity = 0.019 L/s/m); and
- Step 2 - 0.7 L/s for 330 min - 36.4 m drawdown (specific capacity = 0.019 L/s/m)

Maximum drawdown of 2.82 m was recorded in observation bore 1686R (28.5 m from pumped bore).

Calculated aquifer parameters include an average hydraulic conductivity of 8.33E-07 m/s (0.07 m/day) and storage coefficient of 1.6E-04 (Table 4-3).

Bore 1636R

Bore 1636R is located on the Kevin's Corner MLA (Figure 4-27) and is constructed to test the C-D Sandstone. Testing at site comprised a constant discharge test and recovery test. A step drawdown test was not attempted at the site as initial testing at a rate of 0.67 L/s resulted in a rapid rate of observed drawdown. The decision was made to continue with the initial test as a constant discharge test until the water level fell to a point at which pumping could not be maintained (52.53 m total

drawdown in pumping bore, after 91 minutes of pumping, with 2.82 m drawdown recorded in observation bore 1684R, which is located 41.4 m from the pumped bore). A recovery test was then performed, with water levels monitored in the pumping bore and observation bore 1684R.

Calculated aquifer parameters include an average hydraulic conductivity of 6.75E-07 m/s (0.06 m/day) and storage coefficient of 6.7E-05 (Table 4-3).

4.10.2.2 Variable head tests

Variable head (slug) tests were undertaken on a number of standpipe piezometers at site, specifically on standpipe piezometers at the site of the proposed Alpha tailings storage facility (TSF), and at standpipe piezometers at the pumping test sites on the Kevin's Corner MLA (Section 4.10.2.1). The location of slug test bores is shown on Figure 4-27.

A report summarising the slug testing results is presented in **Appendix B**. The formations tested, and range of hydraulic conductivity values, include:

- Joe-Joe Formation (below TSF) – range 1-7E-07 to 8.6E-07 m/s (0.01 to 0.07 m/day);
- Tertiary Laterite (below TSF), including high conductivity water-bearing conglomerate – range 2.3E-07 to 1.2E-04 m/s (0.02 to 10 m/day);
- Unconsolidated Tertiary sands in area of TSF – range 4.5E-07 to 1.3E-06 m/s (0.04 to 0.11 m/day);
- C-D Sandstone, Kevin's Corner MLA – 2.0E-06 to 7.1E-06 m/s (0.17 to 0.61 m/day); and
- D-E Sandstone, Kevin's Corner MLA – 3.1E-07 to 1.3E-05 m/s (0.03 to 1.1 m/day).

The range of values obtained from the slug test is within the range obtained from aquifer pumping tests on the same formations (C-D sandstone and D-E sandstone). While the results are instructive, slug tests have the disadvantage of being affected by near-bore conditions (i.e. results can be impacted by drilling conditions), so results from pumping tests generally take precedence.

4.10.2.3 Laboratory permeability testing

Laboratory permeability testing undertaken on a number of core samples obtained from geotechnical boreholes drilled across the Kevin's Corner lease (Figure 4-27). A report summarising the permeability testing results is presented in **Appendix B**.

The collection of samples for testing was biased towards selection of low-permeability (i.e. fine-grained) samples, as little or no site specific data is available for dry bores. A total of 26 samples were selected for testing.

Horizontal permeability results range from a low of 1.0E-11 m/s (8.6E-07 m/day) to a high of 4.0E-07 m/s (0.04 m/day), with a mean of 2.8E-08 m/s (0.002 m/day) and a median of 1.5E-10 m/s (1.3E-05 m/day).

Vertical permeability results range from a low of 4.0E-11 m/s (3.5E-06 m/day) to a high of 2.0E-07 m/s (0.02 m/day), with a mean of 2.4E-08 m/s (2.1E-03) and a median of 3.0E-10 m/s (2.6E-05 m/day).

For samples where both horizontal and vertical permeability results were available (22 out of 26 samples) the vertical permeability was higher than horizontal permeability in 14 samples (64%), and lower than horizontal permeability in 8 samples (36%).

The following observations are made with respect to the results obtained from horizontal and vertical permeability testing of core samples:

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- Results for both vertical and horizontal permeability testing range over at least 4 orders of magnitude;
- The median is approximately 2 orders of magnitude lower than the mean value for both vertical and horizontal permeability samples, indicating that the majority of the selected samples are in the low permeability (10E-10 m/s) range;
- The results obtained from laboratory testing of core samples are generally lower than permeability values obtained from pumping tests at the site. This provides some indication of the degree of heterogeneity at the site as it is known from exploration drilling that some bores do not yield much water (low permeability sites), but it is only bores that yield water (relatively high permeability sites) that can be tested via pumping tests to provide aquifer parameters. In addition, vertical permeability is higher than horizontal permeability in the majority of laboratory test cases. The following theory is offered to explain this phenomenon:
  - Observations from pumping tests undertaken on the Kevin's Corner lease and the adjacent Alpha Lease, as well as observations from dewatering operations at the test pit on the Alpha lease, indicate that the interburden aquifers behave as a continuous porous medium. However, observations from pumping tests also indicate that initially high bore yields (up to 10 L/s) reduce to (more sustainable yields) several L/s relatively quickly (over a matter of days or weeks). This indicates that permeability boundaries are being encountered during long-term pumping and provides further evidence of aquifer heterogeneity at site. In addition, for bores where yields are initially relatively high, the sandstone units intersected are usually medium to coarse and clean (i.e. a matrix of fine material or cement is absent from the pore spaces). However, these bores are usually surrounded by bores with relatively low yields, where the pore spaces contain fine silts and clays or cementing material, so that the zones where clean sandstone occurs are relatively uncommon, isolated and discontinuous indicating limited effective storage and reduced sustainable yields governed by surrounding aquifer permeability ;
  - A number of samples sent for laboratory permeability testing (including 1521D_GT_008, 1523D_GT_005, 1526D_GT_001, **Appendix B**) were logged as medium to coarse sandstone, but the laboratory results indicate these units have low to very low permeability. For these samples the pores are likely to be in-filled with either cement or fine material such as silts and clays. Therefore, the permeability of the lithologies on site are controlled by the permeability of the material that in fills the pore spaces, rather than the permeability of the larger matrix grains, except in cases where the pore spaces of the coarse material are free of silts/clays or cementing material;
  - It is therefore considered that groundwater movement in the study area occurs predominantly through secondary porosity such as fractures or intergranular where infilling is absent. These preferential pathways (fractures) are apparently hydraulically connected, so that at a large scale the aquifers still behave as a continuous porous medium. However, groundwater movement does not necessarily occur through the total body of rock, and while the entire body of rock may be saturated, the entire volume of water does not report to pumping bores as water is obtained preferentially through the secondary porosity of fractures, with the remainder of the water held up in the blocks between the fractures (matrix blocks);
  - In cases where the laboratory permeability is low, even though the core is logged as comprising medium to coarse sandstone, it is the material between fractures that is being tested (i.e., matrix blocks, with poor effective porosity due to infilling of pore spaces with fine material or cement) rather than the secondary fracture porosity; and,

— In cases where the vertical permeability is higher than the horizontal permeability, this may be due to micro-fractures being present, which are continuous in the vertical direction but not in the horizontal direction, and which may be opened up due to removal of weight/stress on the rock.

Laboratory results provide an indication of heterogeneity and allow for constraints regarding aquifer parameter ranges during predictive modelling. Model parameters resulting from steady-state and transient calibration were assessed against laboratory data, allowing for sensitivity analysis within site specific ranges.

4.10.3 Regional Data

Data for units outside the mining lease area (principally, the GAB units) is sparse. The main source of hydraulic properties was a 1976 publication that summarised hydraulic data for GAB aquifers that was available at that time. Despite the age of the report, summarised in Table 4-4, the data set is comprehensive, and includes:

Aquifer Data

- Transmissivity and hydraulic conductivity data for GAB aquifers from 390 government bores;
- Porosity and storage coefficient data from GAB aquifers from 39 petroleum exploration wells. A number of samples were taken from the vertical profile in each well resulting in 122 porosity values and 69 storage coefficient values;

Confining Bed Data

Vertical hydraulic conductivity data for GAB confining beds from 53 petroleum exploration wells is included. A number of samples were taken from the vertical profile in each well resulting in 259 vertical hydraulic conductivity values, and 73 weighted average values for the two confining beds considered in the regional GAB model at that time.

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Table 4-5 Summary of GAB Hydraulic Properties (Audibert, 1976)

Description	Limits	Horizontal Hydraulic Conductivity		Vertical Hydraulic Conductivity		Porosity	Storage coefficient	Comment
		(m/day)	(m/s)	K_v (m/day)	K_v (m/s)			
Confining Bed 1	Lower Limit - Base of Winton Formation			1E-04 to 1E-03	1.16E-09 to 1.16E-08			• Not measured directly - obtained via calibration - average taken to be 1E-03 - relatively high (compared to CB2) owing to presence of sandy layers
Confined Aquifer 1	• Upper Limit - Base of Winton Formation • Lower Limit - Top Alluru Mudstone and equivalents	10	1.16E-04			0.05 to 0.29	6.56E-04	• Kh - Assumed value used in GAB model • S - value provided in report was for specific storage value of 1 x 10-6 per foot of aquifer. For an assumed thickness of 200m, this equates to S of 6.56E-04
Confining Bed 2	• Upper Limit - Top Alluru Mudstone and equivalents • Lower Limit - Base Cadna-Owie Formation			1E-04 to 3E-03	1.16E-09 to 3.5E-08			• Not measured directly - obtained via calibration - average taken to be 1 order of magnitude lower than CB1, owing to more argillaceous nature of sediments • Lower limit not stated in report - interpreted from stratigraphic data
Confined Aquifer 2	All aquifers below Cadna-Owie (mainly Jurassic)	1 to 15	1.16E-05 to 1.74E-04			0.05 to 0.29	5.00E-04	• Formations listed to include all Lower Jurassic formations, the lower part of the Lower Cretaceous, and, in certain areas, older sedimentary rocks of Cambrian, Permian, and Triassic Age

4.11 Transient Calibration Data

4.11.1 Introduction

This section describes groundwater level and pumping data available for transient calibration of the groundwater assessment model. Available data consists of:

- Groundwater level monitoring data; and
- Data from the operation of the Alpha Test Pit (ATP), which includes groundwater level data and pumping data.

These data are described in more detail below.

4.11.2 Groundwater Level Monitoring Data

Groundwater monitoring bore data is available from site from December 2009 to current. During this time there have been two significant wet season rainfall periods (2009/2010 and 2010/2011 wet seasons). In spite of this, groundwater levels have remained relatively stable over the period of monitoring (Figures 4-15 to 4-22). This is interpreted to indicate the following:

- The intervals where the majority of monitoring is undertaken (C-D and D-E sandstone) do not respond to rainfall recharge in the short to medium term. This indicates that the intake areas for these units are located some distance from the site; and
- Direct rainfall recharge could occur in the upper unconfined Quaternary and Tertiary sediments. However, drilling and shallow standpipe bores (Figure 4-27 and **Appendix A**) are often dry indicating limited perched water within these units.

The lack of response to rainfall events means that there is no local data available for calibration of rainfall. However, the data does serve to indicate areas where rainfall recharge does not directly apply, and does suggest that water removed from the model will not be readily replaced by rainfall recharge.

4.11.3 Data from Operation of the Alpha Test Pit

The Alpha Test Pit was developed between November 2010 and July 2011 to enable a bulk sample of coal (150,000 ROM (Run of Mine) tonnes to be extracted for product testing. The ATP was excavated to a depth of 66 m below natural surface, and required advance depressurisation to allow mining to proceed safely to depth (i.e. for prevention of floor heave and to maintain geotechnical stability of the pit walls).

Monitoring of daily pumping volumes from 12 pit perimeter bores (from commencement of pumping on 21 April 2011 to cessation of pumping on 20 July 2011), and 6-hourly groundwater level monitoring of bores adjacent to the pit, provided a data set that was used for calibration of the groundwater assessment telescoped model (Section 8) .

A summary report has been prepared (JBT Consulting, 2011g) and is included in **Appendix C**.

The transient data, groundwater levels and groundwater extraction, was used to calibrate a telescoped model in order to obtain site specific storativity and permeability data for use in the predictive modelling (Section 10).

5

Description of Mining

5.1 Alpha Coal Project

The pit shell for mining at Alpha and Kevin's Corner is shown on Figure 5-1. The Alpha mining schedule is shown on Figure 5-2.

Mining is set to commence in 2013 and ramp up after the first year to a total production of 30 Mtpa of product coal. The operation has a nominal life of 30 years, but it is anticipated that reserves could extend the mine life beyond the 30-year period. At this stage all modelling assessments have been undertaken on the assumption of a 30-year mine life (end of mining in 2043).

During the first few years of the operation coal will be taken from a number of discrete box-cuts extending along the strike length of the operation. By year 5 the mine will be open along the full strike length of approximately 24 km, with mining extending in a westerly direction. Internal dumping behind operations will mean that the open pit floor at any time will have a width in the order of 100 m.

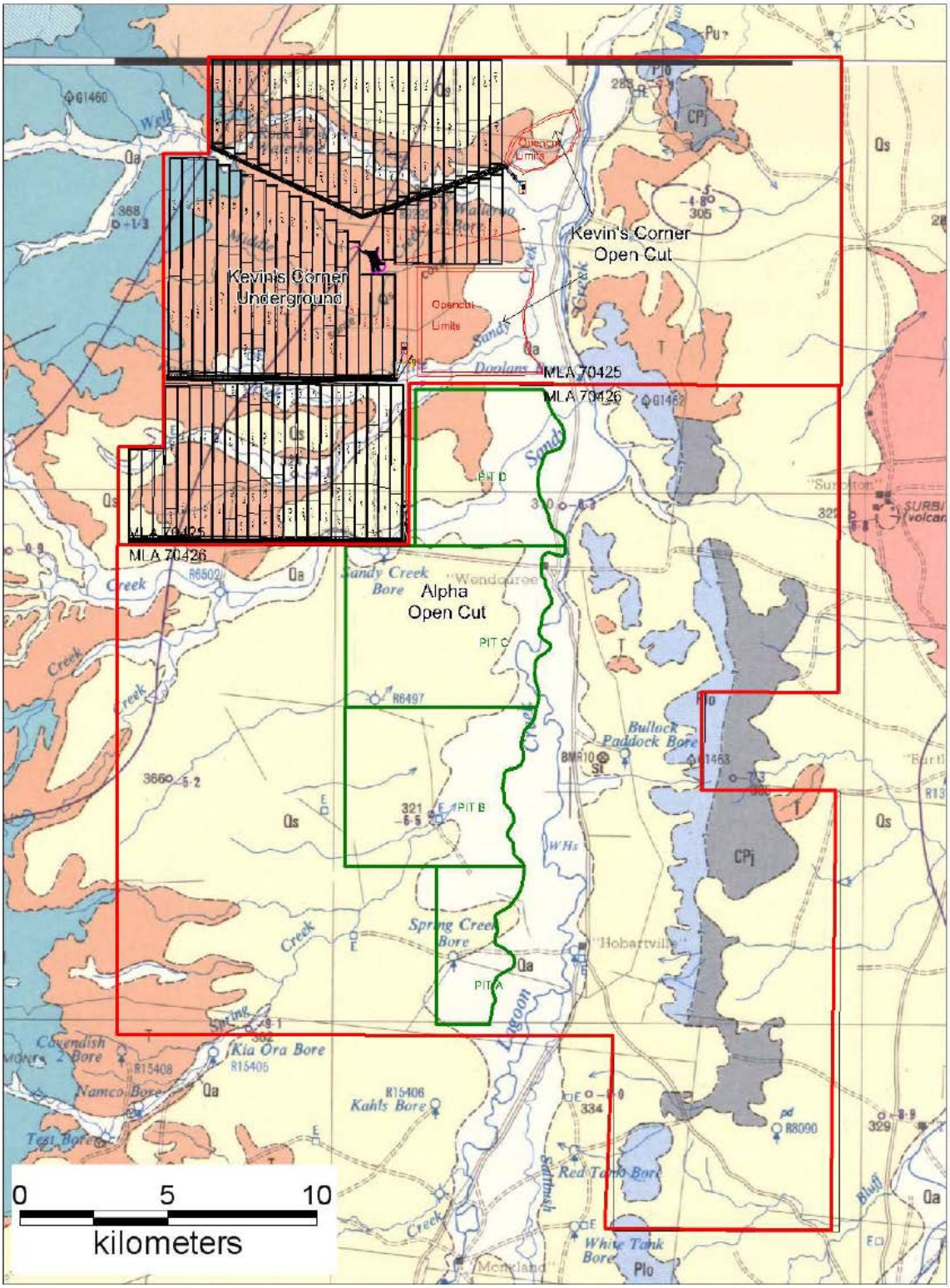
5.2 Kevin's Corner Coal Project

The Kevin's Corner mining schedule is shown on Figure 5-3. Mining is set to commence in late 2014 from two open-cut operations, with underground operations to commence the following year. Production will ramp up after the first year to a total production of 30 Mtpa of product coal. The operation has a nominal life of 30 years, but it is anticipated that reserves will push the mine life beyond the 30-year period. At this stage all assessments have been undertaken (for the purpose of modelling) on the assumption of a 29-year mine life (2014 to 2043, Figure 5-3).

In the first few years of the operation coal will be taken from box-cuts in the east of the project area. The smaller north pit (Figure 5-3) will be mined out after several years, but the larger southern pit will continue operation until 2042. Mining underground will be undertaken through three separate underground mines (northern, central, and southern).

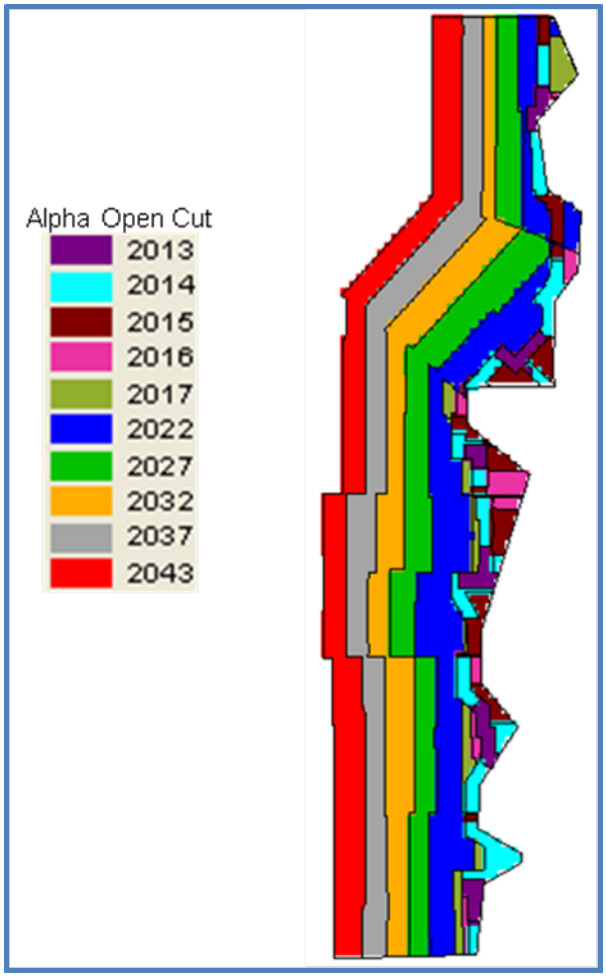
5 Description of Mining

Figure 5-1 Kevin's Corner Project



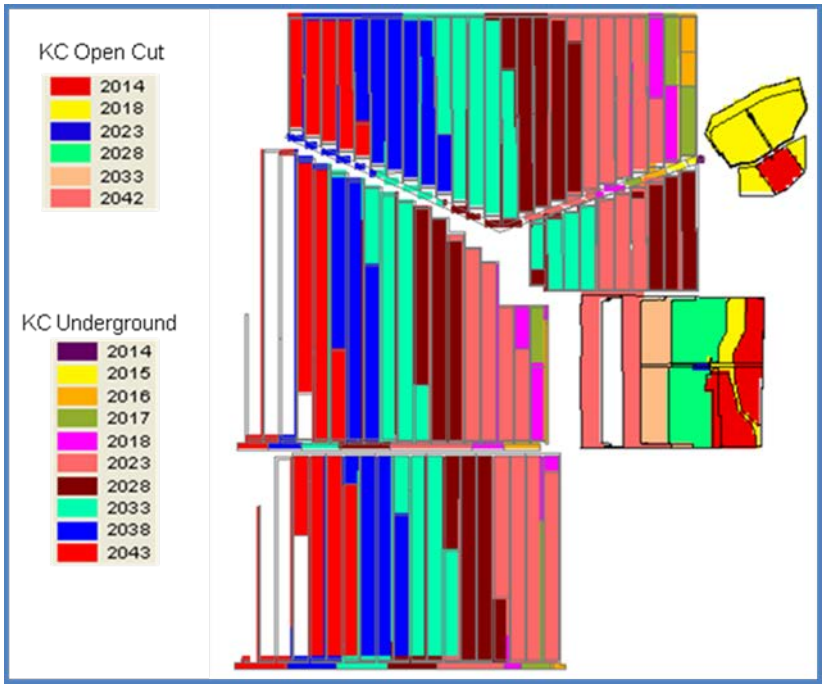
5 Description of Mining

Figure 5-2 Mining Sequence, MLA70425 Alpha



5 Description of Mining

Figure 5-3 Mining Sequence, MLA70426 Kevin's Corner



6

Conceptual Groundwater Model

6.1 Alpha Coal Project

6.1.1 Conceptual Groundwater Model before Mining

A pre-mining conceptual groundwater model is presented as Figure 6-1. The pre-mining conceptual groundwater model is summarised as:

- Groundwater occurs beneath the Alpha MLA in coal seam and sandstone (interburden and floor (D seam)) aquifers. The sandstone aquifers, which occur between and below the coal seams, are the main sources of groundwater in the mine area (bore survey, URS 2011a,c);
- The sandstone aquifers have greater quartz content and are coarser grained with increasing depth;
- The coal seams confine the sandstone aquifers as the coal seams have low vertical permeability relative to horizontal permeability;
- Groundwater occurrence in the units overlying the Permian deposits (Tertiary sediments and Quaternary alluvium) is sporadic, such that the limited volumes of perched groundwater does not constitute useable aquifers;
- Recharge occurs in topographically elevated areas to the west and flows down gradient (i.e. as a subdued reflection of topography) toward the northeast.
- Groundwater flow direction is to the northeast, and the gradient is shallow (approximately 1:1 000); and
- Groundwater in the Permian Bandanna Formation and Colinlea Sandstone is encountered under confined conditions, even adjacent to Lagoon Creek. Hydraulic head differences indicate good confining layers, limiting hydraulic connectivity between confined groundwater resources and surface water systems and perched water tables.

6.1.2 Conceptual Groundwater Model During and Post Mining

Elements of the conceptual groundwater model (post mining) are shown in Figure 6-2. The following post-mining conceptual groundwater model is considered:

- A cone of depression will develop around the final open pit (referred to as the final void), extending preferentially north and south (along strike) and to the west, but will be of limited extent in the east along the Colinlea Sandstone / Joe Joe Formation contact;
- Groundwater will flow into the pit through the pit wall, from the Tertiary sediments (where perched water occurs), the B-C and C-D sands, and C and D coal seams;
- Groundwater will flow up through the pit floor from the underlying D-E sandstone;
- A water table will develop over time in the in-pit backfill, though a drainage layer will be installed at the base to limit pressure build-up (i.e. for geotechnical stability). Sources of water will include direct rainfall infiltration, and inflow from the D-E sandstone that will underlie the in-pit dump; and
- Impacts of groundwater drawdown cone(s) extending to the west will be mitigated through the thick low permeable (clay-rich) Bandana Formation and the Rewan Formation aquitard.

6.2 Kevin's Corner Project

6.2.1 Conceptual Groundwater Model – Pre Mining

A pre-mining conceptual groundwater model is presented as Figure 6-3. Based on available information the pre-mining conceptual groundwater model is summarised as:

6 Conceptual Groundwater Model

- Groundwater occurs beneath the Kevin's Corner MLA in coal seam and sandstone (interburden and floor) aquifers. The sandstone aquifers, which occur between and below the coal seams, are the main groundwater sources;
- The sandstone aquifers become cleaner (greater quartz content) and coarser with increasing depth;
- The coal seams confine the underlying sandstone aquifers;
- Groundwater occurrence in the units overlying the Permian deposits (Tertiary sediments and Quaternary alluvium) is sporadic, and the units are not regarded as significant regional aquifers;
- Limited recharge occurs in topographically elevated areas to the west and flows down gradient (i.e. as a subdued reflection of topography) toward Sandy Creek;
- Groundwater flow direction is to the north-north-east, and the gradient is shallow (approximately 1:1 000); and
- Groundwater in the Permian Bandanna Formation and Colinlea Sandstone is encountered under confined conditions, even adjacent to Sandy Creek (nested bores **Appendix A**).

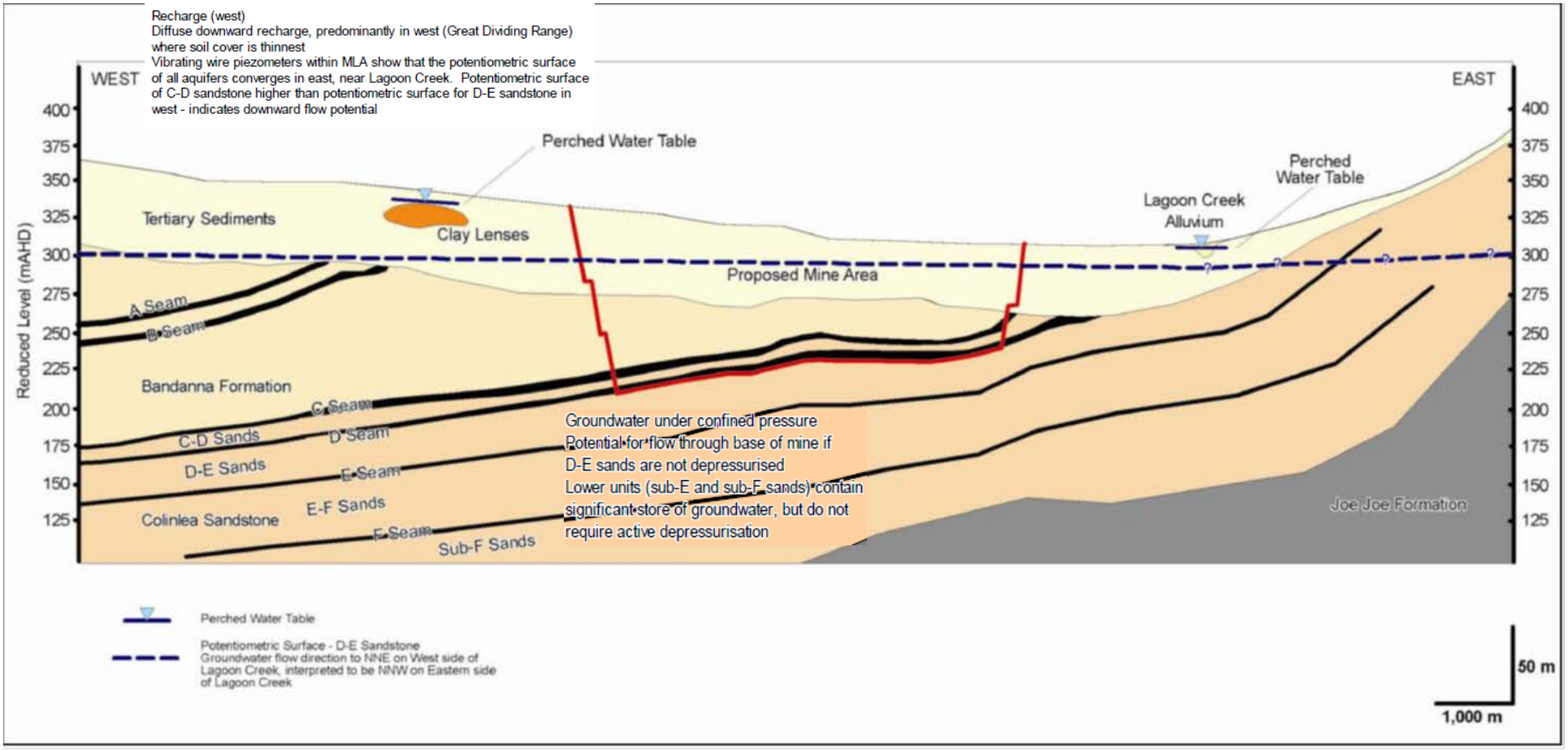
6.2.2 Conceptual Groundwater Model – Post Mining

Elements of the conceptual groundwater model (post mining) are shown in Figure 6-4. The following post-mining conceptual groundwater model is proposed:

- The cone of depression will extend outward around the underground and open cut mining, however propagation of the cone of depression to the east and west will be limited due to the Rewan Formation (in the west) and Joe Joe Formation (in the east). This will have the effect of producing a cone of depression that is elongated in the north-south direction (along geological strike of the coal measures and sandstone);
- Groundwater will flow into the workings through the wall and floor, and from sediments above the underground workings as fracturing (goafing) develops due to collapse of strata into the longwall mining panels. Inflow will come from Tertiary sediments (if and where water occurs), the sediments of the B-C and C-D sands, and C and D coal seams;
- Based on review of the results of laboratory permeability testing of core samples, compared to data derived from pumping tests (**Appendix B**), it is conceptualised that groundwater movement is predominantly through secondary porosity (e.g. through fractures) and that the primary porosity of the rock is relatively low due to effects of cementation and presence of fine material in the pore spaces. It is further conceptualised that goafing will release water from existing secondary porosity, but that groundwater storage in primary porosity is relatively low. This will have the effect of reducing the volume of groundwater inflow to the operation from goafing (relative to the volumes that could be expected if the entire strata overlying the underground operations were fully saturated);
- Groundwater will flow up through the pit and panel floors from the underlying D-E sandstone aquifer and locally from passive depressurisation of sub-E sandstone; and
- Water levels will recover over time as the underground workings are flooded post-mining. The level to which the water levels rise will be governed by the final voids, both on Kevin's Corner and Alpha (Section 5 presents mine plans).

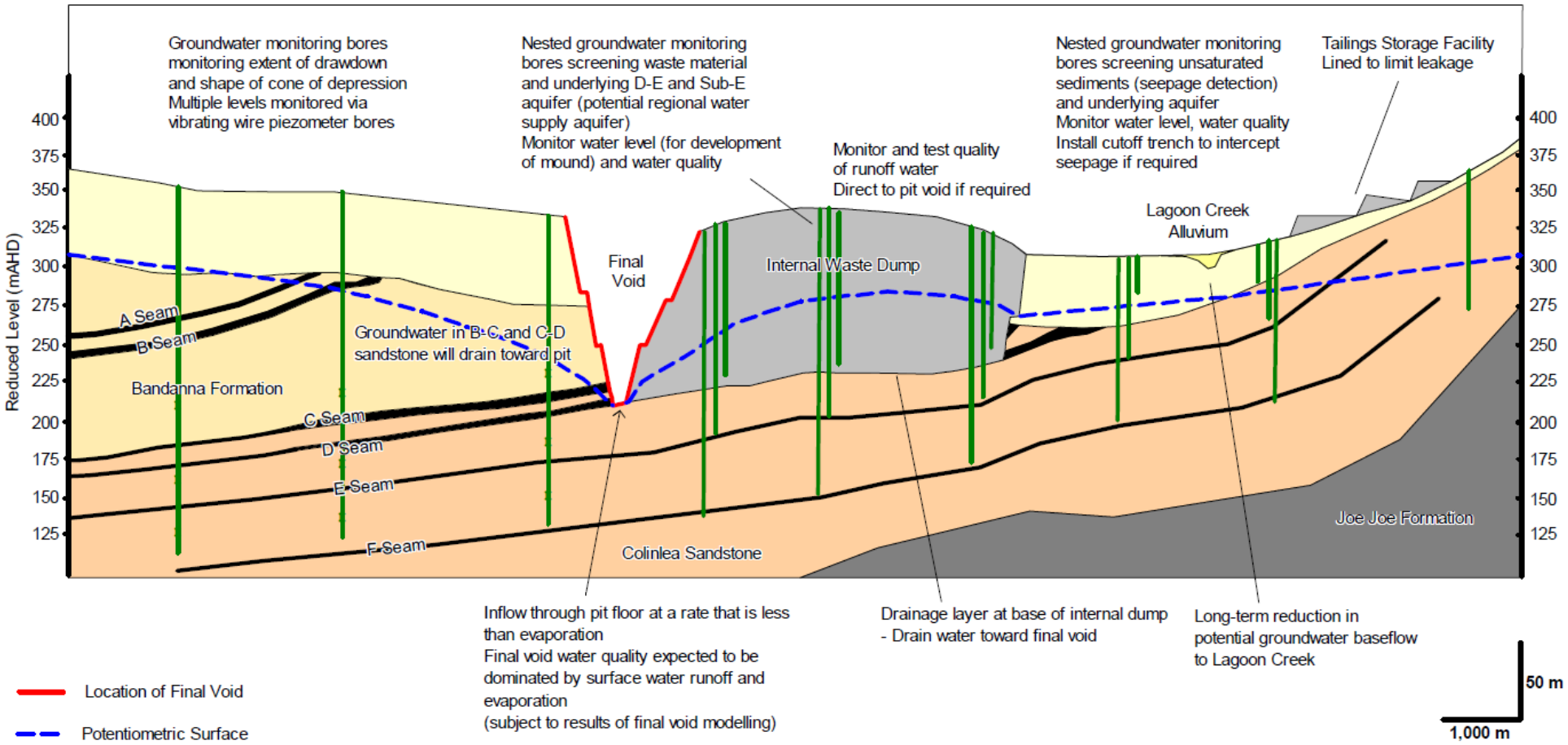
6 Conceptual Groundwater Model

Figure 6-1 Pre-Mining Conceptual Groundwater Model – Alpha



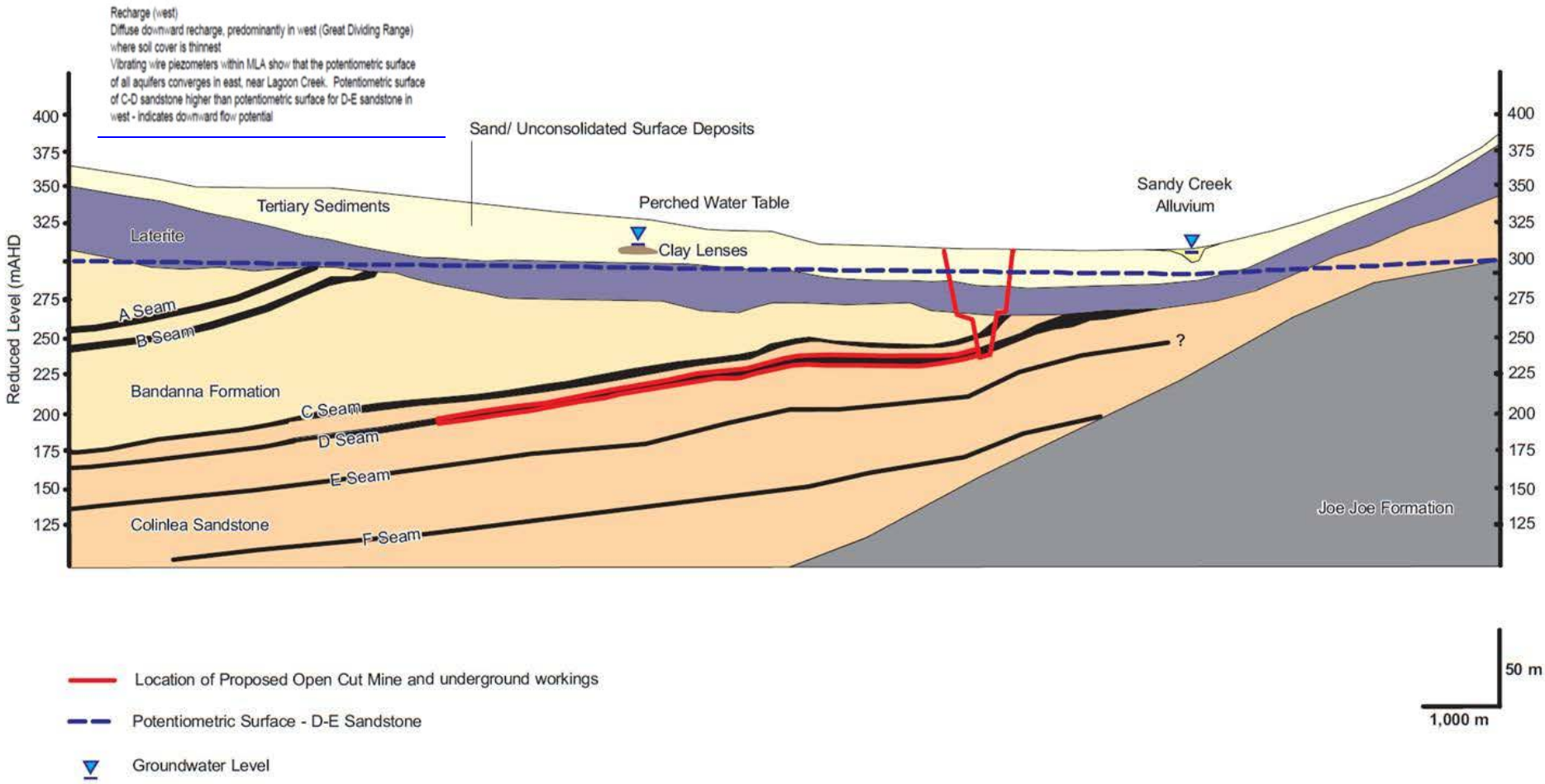
6 Conceptual Groundwater Model

Figure 6-2 Post Mining Conceptual Model – Alpha



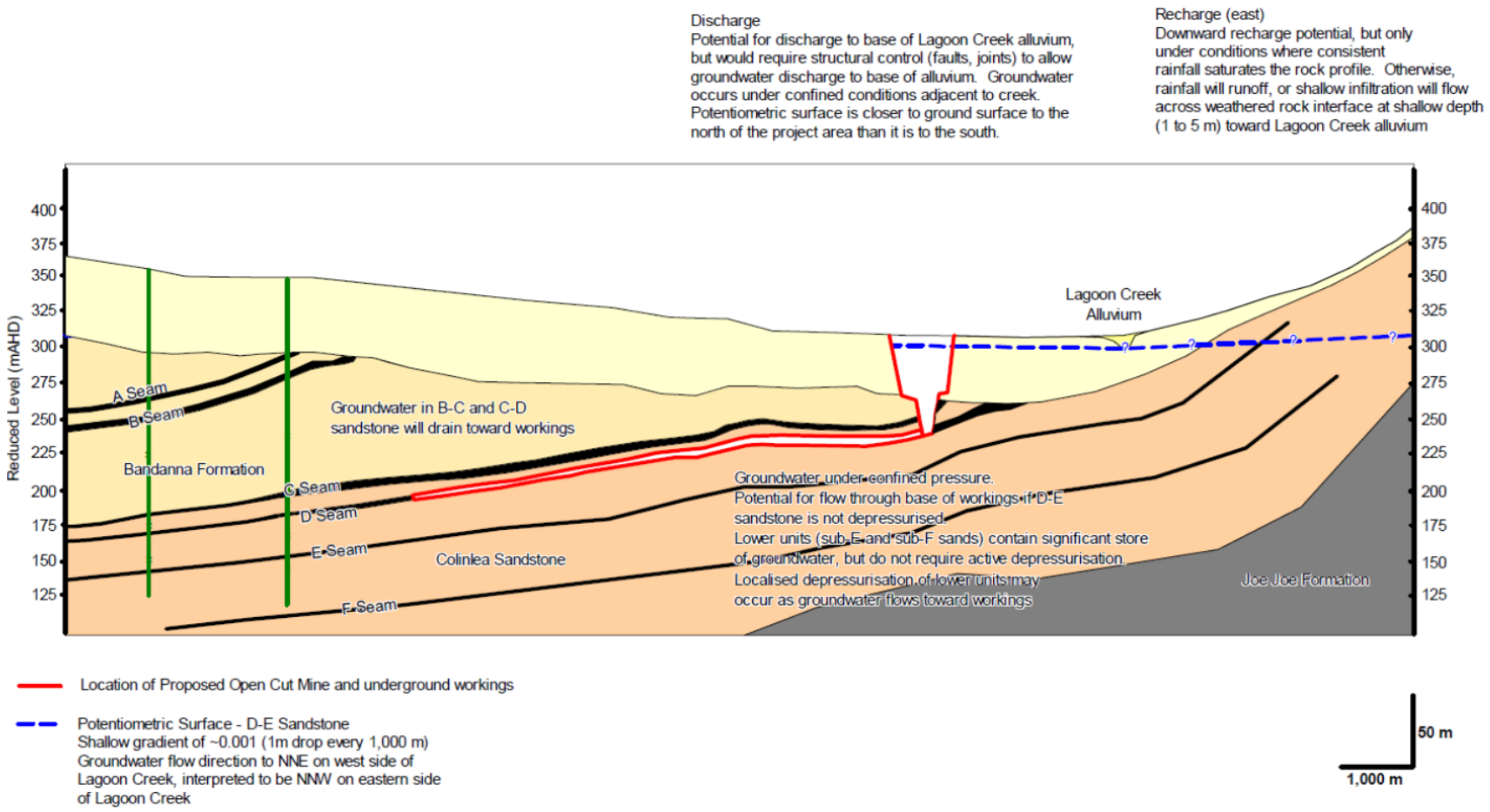
6 Conceptual Groundwater Model

Figure 6-3 Pre-Mining Conceptual Model – Kevin's Corner



6 Conceptual Groundwater Model

Figure 6-4 Post-Mining Conceptual Model – Kevin's Corner



7

Predictive Model Development

The regional models (FEFLOW and MODFLOW-SURFACT) and Alpha Test Pit models, constructed and calibrated by NTEC for the EIS, were used as the basis for the groundwater assessment predictive modelling. A description of the modelling development, changes to the original EIS model (conceptualisation and construction), plus outcomes are discussed in this section. This summary provides a history of model changes and assessments conducted between October and November 2011, which aimed at providing estimates to Hancock and developing the correct model for assessing groundwater resources, discussed in detail in later chapters of this report. The modelling history provides background information for clarity on decisions made during the modelling process.

The models produced for the project to date are summarised below in Table 7-1. The models produced by NTEC for the purpose of the initial EIS studies are discussed in this section. The predictive modelling, undertaken by MTNA, are discussed in Section 8.

Table 7-1 Summary of Model Development

Model Name	Model Code	Description/ Purpose
NTEC Regional Model	Initially Feflow and later Modflow-Surfact	EIS Studies
NTEC ATP Model	Modflow-Surfact	Local-scale model telescoped from regional model. Used for calibration of ATP dewatering
MTNA Groundwater Assessment Model	MODHMS	Mine water supply and dewatering requirement studies
MTNA ATP Model	MODHMS	Local-scale model telescoped from regional model. Used for calibration of ATP dewatering

7.1 NTEC MODFLOW-SURFACT Regional Model

The NTEC regional model compiled for the EIS studies allowed for the assessment of potential impacts associated with envisaged mine dewatering and depressurisation and focussed on alterations to groundwater levels, flow patterns, and potential impacts on existing groundwater users. The model set-up, in order to assess impacts, included:

- A model grid with 274 rows and 312 columns, with a refined cell size of 100 m by 200 m within the mining area;
- Eleven model layers (Table 7-2);
- Boundaries sufficiently far from the mining so as not to influence modelling; and
- An initial uniform groundwater level (head) of 300 m AHD.

7 Predictive Model Development

Table 7-2 Regional EIS MODFLOW-SURFACT Model layers

Unit	Model Layer
Overburden (including GAB to west)	1
Rewan Formation	2 to 3
Bandanna Formation	4 to 5
D seam	6
D-E sandstone	7
E seam	8
Sub E sandstone	9
Joe Joe Formation	10
Basement	11

Aquifer hydraulic parameter data were estimated using the Alpha Test Pit (transient) dewatering information, where NTEC utilised BeoPEST[6], in a local scale MODFLOW-SURFACT model. This allowed for the determination of a combination of model parameters, which best simulated the groundwater drawdown as monitored during the Alpha Test Pit dewatering (**Appendix C**). The NTEC model parameters determined during calibration are included in Table 7-3.

Table 7-3 NTEC model parameters

Unit	K_{xy} (m/day)	K_z (m/day)	S_s (m^{-1})	S_y or n
Overburden	5	0.5	1E-05	0.05
Rewan Formation	4E-04	4E-05	3.5E-07	0.03
Bandanna Formation	4E-03	2E-04	3.5E-07	0.03
D seam	9E-02	1E-05	1.9E-06	0.3
D-E sandstone	0.1	7.6	3.5E-06	0.03
E seam	9E-02	1E-05	1.9E-06	0.3
Sub E sandstone	0.1	7.6	3.5E-06	0.03
Joe Joe Formation	4E-04	4E-05	3.5E-07	0.03
Basement	4E-04	4E-05	3.5E-07	0.03

[6] Model independent parameter estimation and uncertainty analysis software (Schreuder, 2009)

Where:

K_{xy} – Horizontal hydraulic conductivity

K_z – Vertical hydraulic conductivity

S_s – Storativity (Storage can be defined as the volume of water that a saturated confined aquifer releases from storage per unit surface area of the aquifer per unit decline in the water table)

S_y – Specific yield (Ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity from that mass)

7.2 Mine Plan Refinement

Section 5 details the proposed mining at Alpha and Kevin's Corner. Initial mine plans provided annual details for the first 4 to 5 years, after which the mine plan included 5 year blocks (as detailed in the interim model report, URS, 2011i).

For the model modification, mining was assumed to progress on an annual time step as provided in the mine plans. Where the mine plans showed multi-year time steps, the mine plan was subdivided into equal (based on surface area) yearly time steps.

A comparison of model predictions, detailed in the interim model report (URS, 2011i), the 5 year mining plan provides higher predictions than the year-on-year mine plan. The 5 year mining plan predictions were some 22% higher than the year-on-year mine plan.

7.3 Vertical hydraulic conductivity values

Vertical hydraulic conductivity (K_z) values for the D-E sandstone and sub-E sandstone in the NTEC model (Table 7-2) were recognised by JBT Consulting to be unrepresentative of site conditions (too high) and were assessed during the modelling process. The K_z values were reduced as indicated in Table 7-4.

The NTEC model assumed a uniform initial head of 300 m AHD across the entire model domain (NTEC, 2011e). The model was assessed to determine the impacts of changing the initial head, using both 305 m and 295 m, groundwater levels recognised across the proposed mine area.

The change in initial head, 305 m AHD compared to 295 m AHD, results in ~ 5% difference in groundwater inflow estimates using the revised K_z values.

Table 7-4 Revised Kz values

Unit	Kxy (m/d)	Kz (m/d)	Ss (m^{-1})	Sy or n (-)	Model Layer
GAB	5.0E+00	5.0E-01	1.0E-05	5.0E-02	1
Rewan Formation	4.0E-04	4.0E-05	3.5E-07	3.0E-02	2 to 3
Bandanna Formation	4.0E-03	2.0E-04	3.5E-07	3.0E-02	4 to 5
D seam	9.0E-02	1.0E-05	1.9E-06	3.0E-01	6
D-E sandstone	1.0E-01	7.6E-02	3.5E-06	3.0E-02	7
E seam	9.0E-02	1.0E-05	1.9E-06	3.0E-01	8
Sub E sandstone	1.0E-01	7.6E-02	3.5E-06	3.0E-02	9
Joe Joe Formation	4.0E-04	4.0E-05	3.5E-07	3.0E-02	10
Basement	4.0E-04	4.0E-05	3.5E-07	3.0E-02	11

7.4 Boundary changes

The NTEC model had a simple square 100 km x 100 km boundary. Further assessment of available DERM, bore survey, and site groundwater level and elevation data was conducted which allowed for the refinement of the model boundaries.

Groundwater level data from the Department of Environment and Resource Management (DERM), the bore survey (conducted by 4T), and site data were reassessed to refine model boundaries.

7.4.1 No-Flow Boundary

A groundwater divide is recognised within the Great Dividing Range as it acts as a catchment boundary. From the DERM dataset (Figure 7-1), only two data points were available on the western side of study area; a groundwater level at 380 m AHD on the eastern side of range, and a groundwater level of 368.8 m AHD on the western side of range. It is considered that groundwater flow is from southwest to northeast across the mining site. Thus the value of 368.8 m AHD to the northeast, it is interpreted that groundwater divide exists in between these two western points. It was assumed that the highest elevation of the range was the water divide. The water divide was included as a no-flow boundary in the model with recharge occurring in the Great Dividing Range.

7.4.2 Constant head boundary

The eastern, northern, and southern boundaries were set as constant head boundary as no obvious natural boundaries were available, as included in the NTEC model. During the modelling process an evaluation of these boundaries was conducted and discussed in the interim model report (URS, 2011i).

Interpolated pseudo steady-state water levels were generated based on the DERM, bore census data, the site data, and the extrapolated data through relationship of topography and depth to water (Figures 7-2 and 7-3)

Constant head boundary values were extracted from the pseudo steady-state water level.

7 Predictive Model Development

Figure 7-1 Available groundwater level measurement points

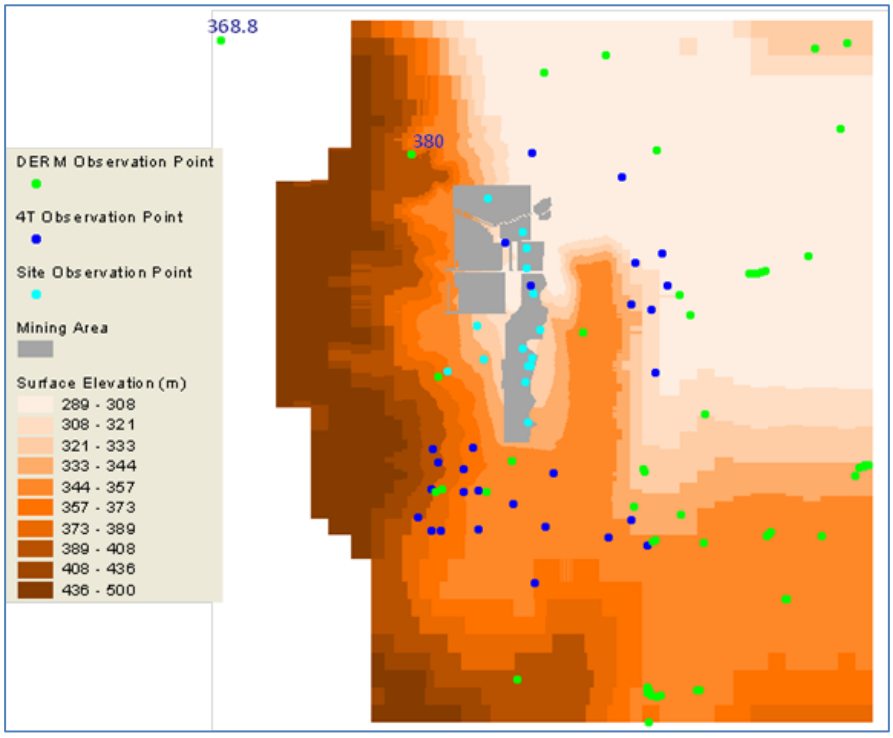
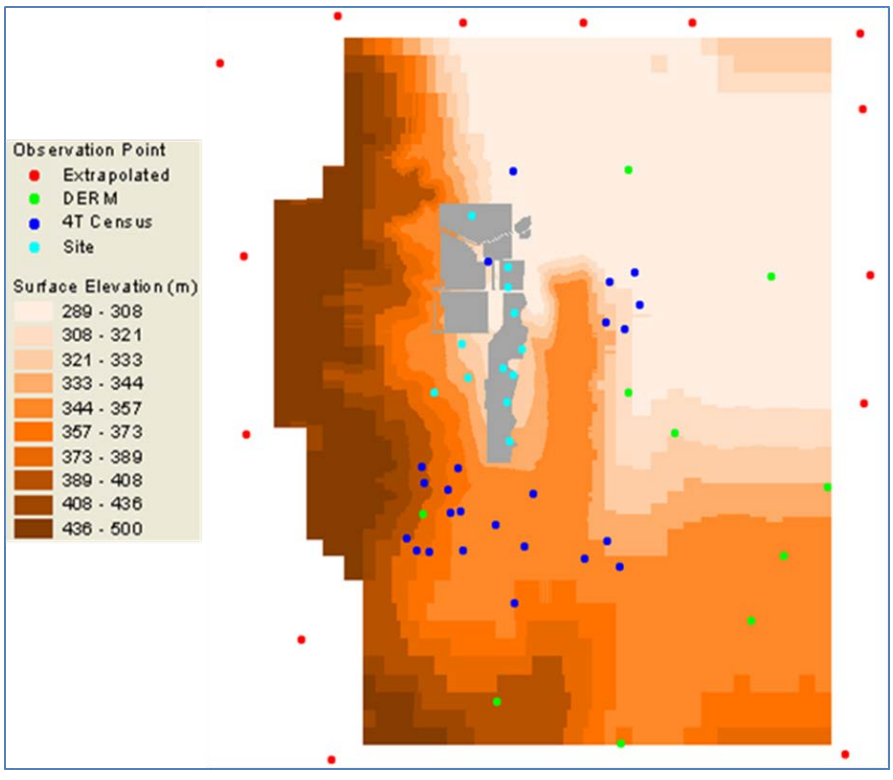
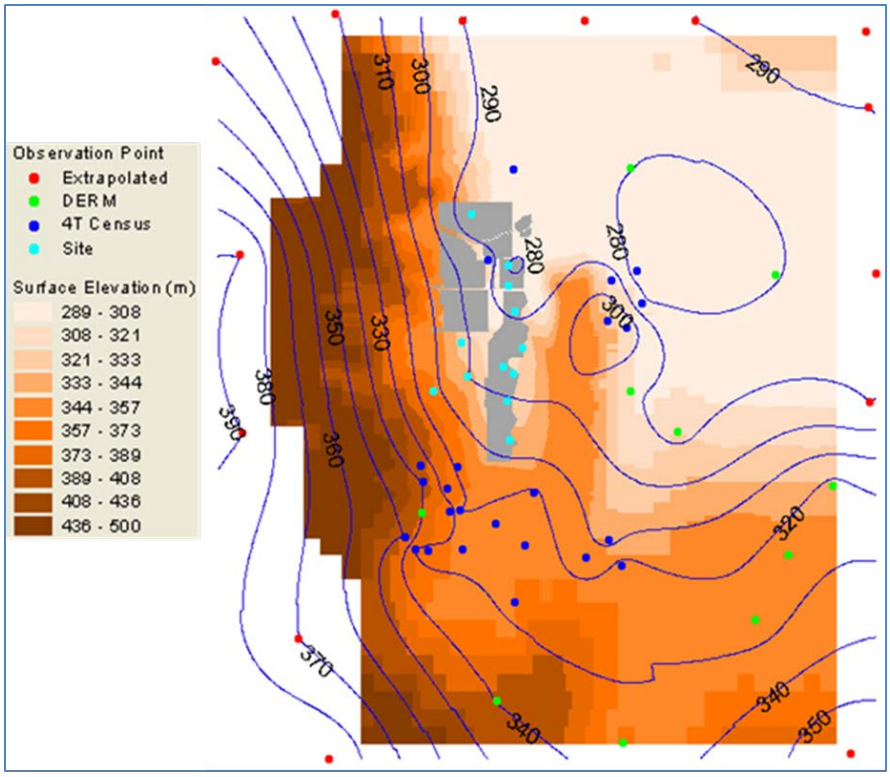


Figure 7-2 Selected and extrapolated points



7 Predictive Model Development

Figure 7-3 Interpolated pseudo steady-state groundwater contours



7.5 Preliminary Model Calibration

The modified predictive model, including revised boundary conditions, was calibrated to capture the regional flow patterns, as indicated in Figure 7-3. This calibration was not aimed at point-to-point matching due to the lack of field measurements across the large model extent.

The model was calibrated to a pseudo steady-state in order to capture a trend of regional flow pattern. This pseudo steady-state condition served as the initial conditions and boundary head conditions for the predictive model.

The calibration process allowed for the delineation of three hydraulic conductivity zones within the modified model (Figure 7-4). The model parameters derived to obtain trend calibration (Figure 7-5) are included in Table 7-5.

7 Predictive Model Development

Figure 7-4 Hydraulic conductivity zones for Layer 1, 7, and 9

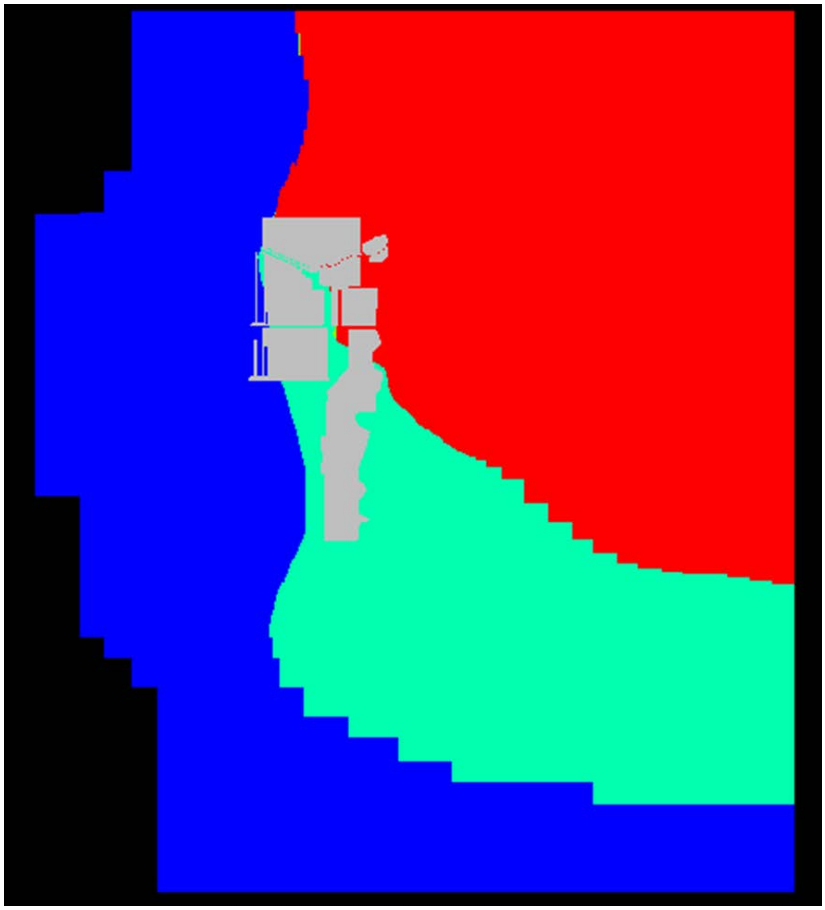
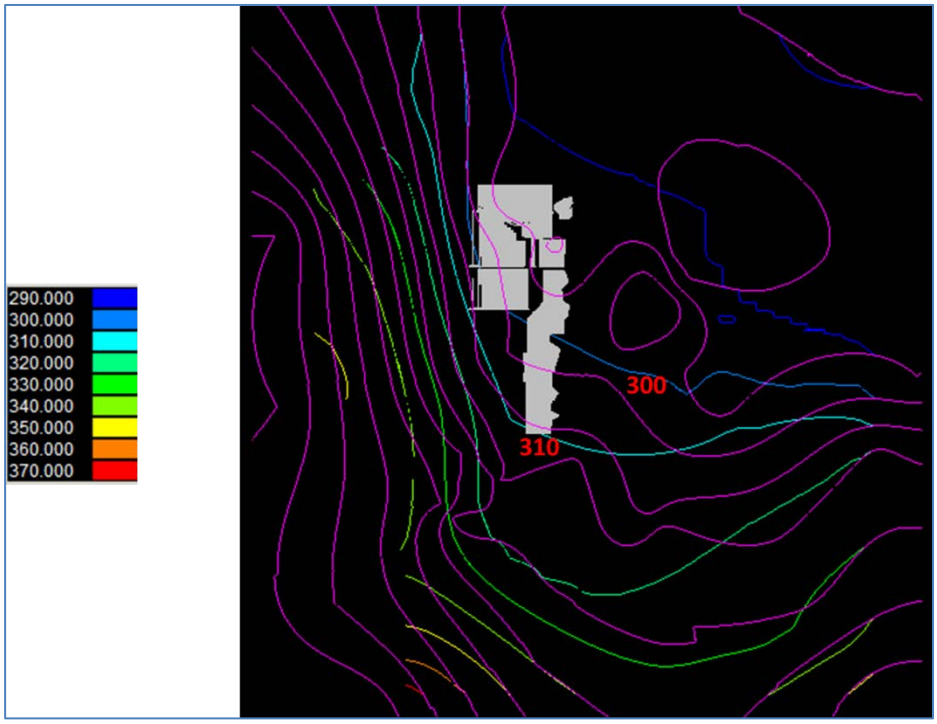


Table 7-5 Calibrated model parameters

Unit	K_{xy} (m/d)	K_z (m/d)	Model Layer
GAB	0.1, 1.7, and 5	5.0E-01	1
Rewan Formation	4.0E-04	4.0E-05	2 to 3
Bandanna Formation	4.0E-03	2.0E-04	4 to 5
D seam	1.00E-02	1E-05	6
D-E sandstone	0.1, 0.78, and 1.5	1.13E-02	7
E seam	1.00E-02	1E-05	8
Sub E sandstone	0.1, 0.78, and 1.5	1.13E-02	9
Joe Joe Formation	4.0E-04	4.0E-05	10
Basement	4.0E-04	4.0E-05	11

7 Predictive Model Development

Figure 7-5 Calibrated water levels in Layer 6 overlain on interpolated water levels



7.6 Sensitivity of vertical hydraulic conductivity values

For quantifying the parameter uncertainty, sensitivity analysis was carried out for investigating impacts to predictive inflow due to parameter changes. The vertical hydraulic conductivity (K_z) of the coal seam units was varied to assess the impacts of interconnection to the layers above and below the seam. For the base case with K_z of 1E-5 m/day, the total predictive inflow was 681 GL during the mine life. In contrast, the predictive inflow increased to 798 GL if K_z value increased 8 times higher to 8E-5 m/day.

The K_z value of 8E-5 m/day hardly changed the groundwater level contours in steady-state calibration, but it increased prediction inflow significantly. This indicated that the available groundwater level measurements did provide enough information to identify the K_z value during calibration.

Note that the calibrated parameters from the steady-state calibration were for horizontal and vertical hydraulic conductivity values only. The storativity values used in the predictive simulations were from the NTEC calibrated values (Table 7-2).

Table 7-6 Groundwater ingress estimates (at LOM) using different Kz values

Parameter set	Alpha	KC_OC_S	KC_OC_N	KC_UG	Total
1 – $K_z = 8 \times 10^{-5}$	341 GL	68.2 GL	20.5 GL	368 GL	798 GL
2 – $K_z = 1 \times 10^{-5}$	327 GL	66 GL	18.7 GL	269 GL	681 GL

7.7 Water budget analysis

The volumes of groundwater ingress predicted using the modified model (Table 7-6) indicated potentially high volumes of groundwater to be managed on site. This was checked using an evaluation of model zone budgets.

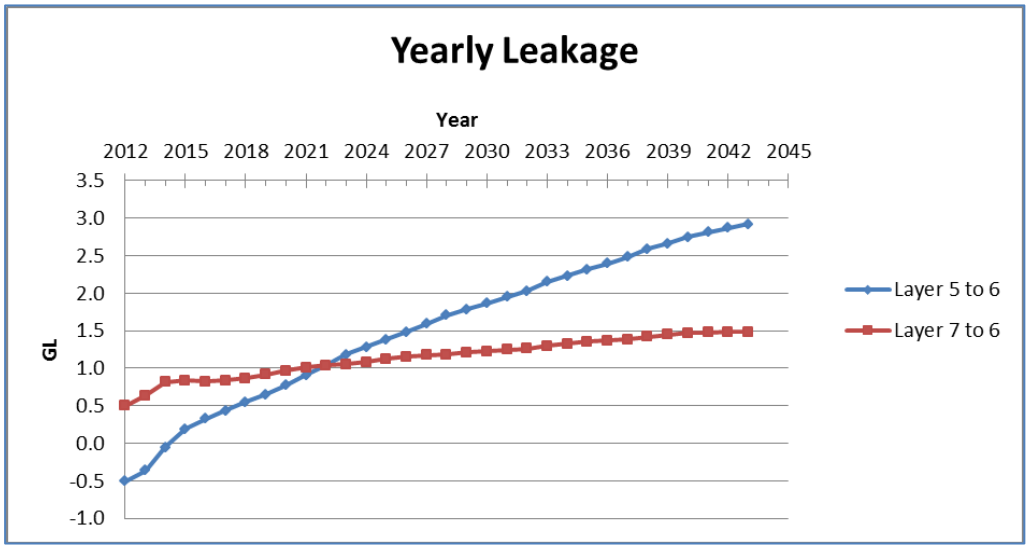
Evaluation of leakage (zone budget analysis) from above and below the D seam was undertaken to determine whether excessive leakage (due to the various K_z values as discussed in Section 7.6) was leading to additional groundwater volumes. Figure 7-6 is a graph indicating groundwater flow from model Layer 5 to Layer 6 (initially negative as groundwater moves from Layer 6 (D seam) to the overlying unit) and groundwater flow from Layer 7 (D-E sands) to Layer 6.

The zone budget assessment, conducted for the proposed mining at Alpha for Year 2013 (320 model cells) indicates that the majority of groundwater predicted relates to the high specific yield assigned to the D seam in the model, 0.3 (Table 7-3), calibrated parameters from the NTEC local-scale model.

Once groundwater levels decline to within the D seam the unit becomes unconfined (specific yield as compared to storativity) and high groundwater volumes (over the large mine area) is recorded.

Consideration of the field data (Section 4), aquifer test programs, and the groundwater volumes recorded during the Alpha Test Pit dewatering, all indicate that the drainable volumes within the D seam are closer to 1 to 3% than the 30% included in the regional NTEC model.

Figure 7-6 Zone budget for Layer 6



7.8 Base case and predictions

It was considered, based on the data evaluated, that predictions regarding groundwater volumes available over the LOM could be estimated using revised conservative parameters within the modified model.

For the conservative estimates, using the modified model, a specific yield (S_y) of 1% (0.01) was adopted along with the lower K_z value of 1 x 10^{-5} m/day. The resultant year-on-year estimates are presented in Table 7-7.

7 Predictive Model Development

Table 7-7 Conservative groundwater estimates (in GL) using modified model

Year	Alpha	KC_OC_S	KC_OC_N	KCUG	Total	Available volumes (in GL) for use in water balance
2013	5.27	0.00	0.00	0.00	5.27	4.75
2014	10.15	4.50	1.34	0.01	16.00	14.40
2015	5.58	0.00	2.78	0.20	8.56	7.70
2016	2.98	0.06	2.48	0.71	6.24	5.62
2017	3.51	0.50	1.88	1.15	7.05	6.34
2018	3.50	0.89	1.74	1.97	8.10	5.67
2019	5.46	0.15	0.00	1.88	7.49	5.24
2020	6.44	0.00	0.00	1.90	8.34	5.84
2021	6.98	0.00	0.00	2.35	9.34	6.54
2022	6.99	0.00	0.00	2.20	9.19	6.43
2023	4.32	0.05	0.00	2.64	7.00	3.50
2024	5.07	1.62	0.00	1.67	8.36	4.18
2025	6.31	1.73	0.00	2.07	10.10	5.05
2026	6.86	2.03	0.00	2.36	11.25	5.63
2027	6.89	2.23	0.00	2.47	11.60	5.80
2028	4.87	2.50	0.00	2.98	10.34	5.17
2029	5.70	1.58	0.00	1.98	9.27	4.63
2030	6.19	1.65	0.00	2.30	10.14	5.07
2031	6.53	1.71	0.00	2.64	10.88	5.44
2032	6.38	1.80	0.00	2.62	10.79	5.40
2033	6.46	1.91	0.00	3.11	11.48	5.74
2034	6.75	1.54	0.00	2.21	10.50	5.25
2035	7.04	1.61	0.00	2.32	10.97	5.48
2036	7.46	1.68	0.00	2.49	11.63	5.82
2037	6.98	1.69	0.00	2.59	11.26	5.63
2038	6.69	1.97	0.00	3.09	11.76	5.88
2039	6.74	2.60	0.00	2.12	11.46	5.73
2040	6.48	1.94	0.00	2.34	10.76	5.38

2041	7.14	1.96	0.00	2.30	11.39	5.70
2042	7.07	2.13	0.00	2.26	11.46	5.73
2043	5.32	0.00	0.00	2.70	8.01	4.01

The estimated groundwater volumes were further decreased. The reductions included 90% of predictions for the first 5 years, 70% of predictions for the next 5 years, reducing to 50% of the modelled predictions after 10 years. This was to provide Hancock with an initial conservative estimate of groundwater available, whilst modelling was ongoing.

The estimates were reduced due to uncertainty regarding the modified model (parameter uncertainty), model construction (uncertainty regarding calibration and boundaries), and the consideration of Hancock only (i.e. no consideration of cumulative impacts from adjacent proposed mining activities).

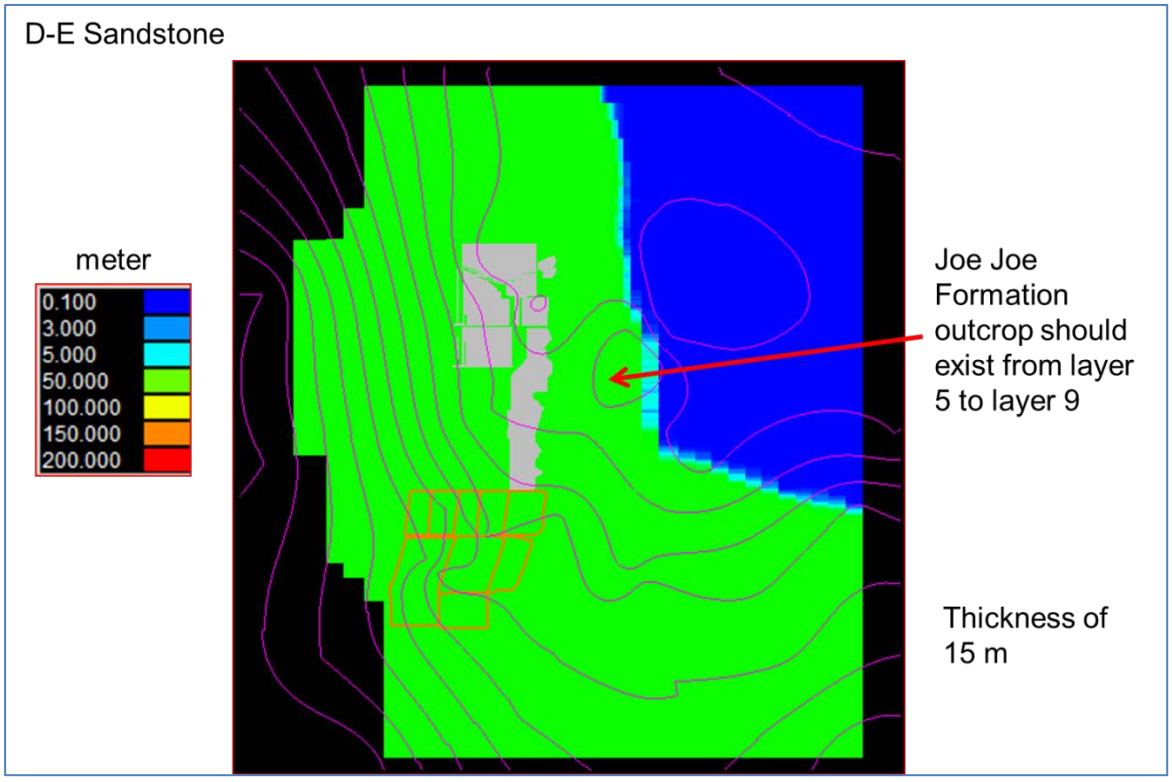
Note: The parameter range was selected based on known field conditions and was considered a probable range to occur. A more systematic uncertainty analysis was performed in Section 10.3 for the predictive model.

7.9 Geological model layer changes

The geological data included in the NTEC model was evaluated. The geological layers were recognised to extent to the southeast of the model domain, an example of this is shown in Figure 7-7, which shows the D-E sandstone layer extending past the Joe Joe Formation outcrop to the east of the proposed mining.

7 Predictive Model Development

Figure 7-7 NTEC model geology layer 7



The outcrop of the Joe Joe Formation, as mapped on the Jericho geological series map, is shown in Figure 7-8. The geological units were thus revised in the modified model.

In addition, during the geological layer assessment additional model layers were included in the modified model to ensure a more accurate representation of the underlying geology and hydrogeology. Table 7-8 presents the modified layers.

7 Predictive Model Development

Figure 7-8 Joe Joe Formation and Colinlea Sandstone contact

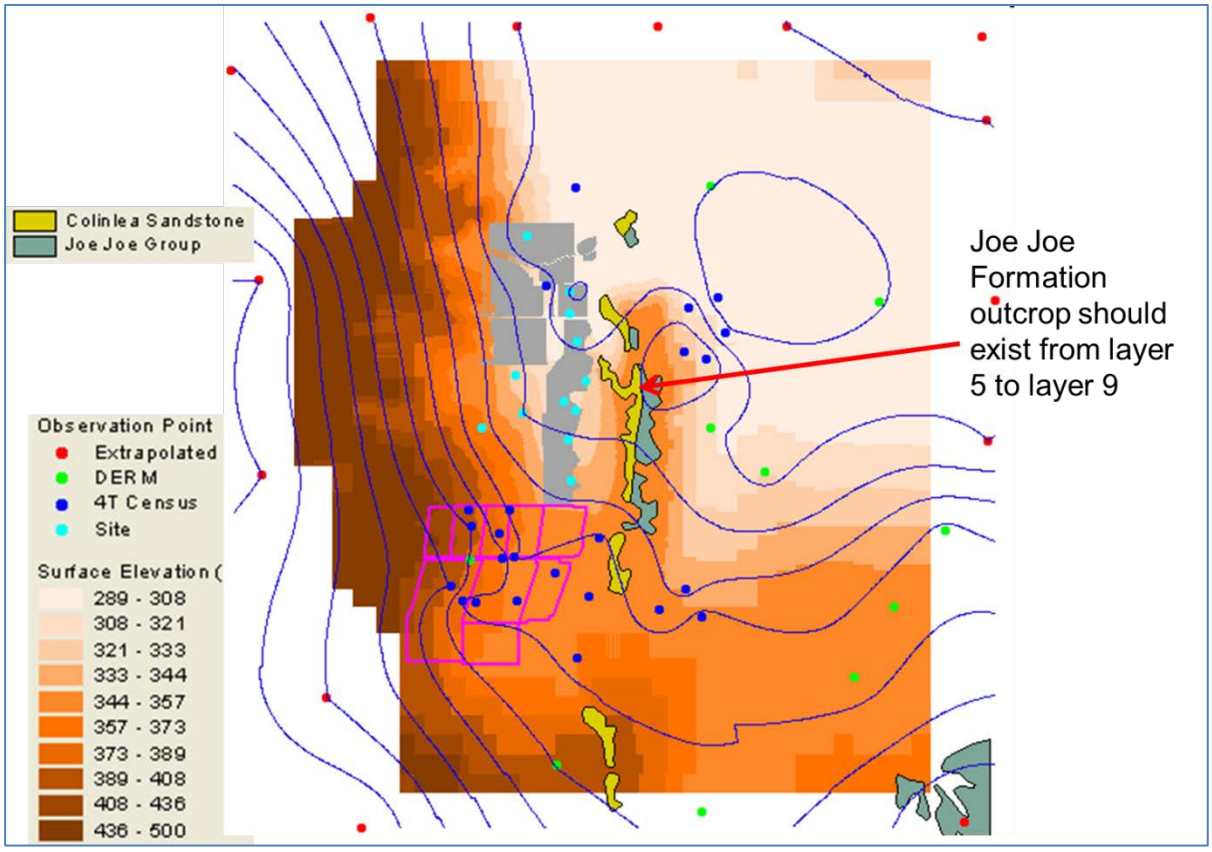


Table 7-8 Modified model layers

Unit	Kxy (m/d)	Kz (m/d)	Ss (m^{-1})	Sy or n (-)	Model Layer
GAB	0.1, 1.7, and 5	5.0E-01	1.0E-05	5.0E-02	1
Rewan Formation	4.0E-04	4.0E-05	3.5E-07	3.0E-02	2 to 3
Bandanna Formation	4.0E-03	2.0E-04	3.5E-07	3.0E-02	4 to 5
C seam	1.00E-02	1.0E-05	1.9E-06	3.0E-02	6
C-D sandstone	0.1, 0.78, and 1.5	1.13E-02	3.5E-06	3.0E-02	7
D seam	1.00E-02	1.0E-05	1.9E-06	3.0E-02	8
D-E sandstone	0.1, 0.78, and 1.5	1.13E-02	3.5E-06	3.0E-02	9
E seam	1.00E-02	1.0E-05	1.9E-06	3.0E-02	10
Sub E sandstone	0.1, 0.78, and 1.5	1.13E-02	3.5E-06	3.0E-02	11
Joe Joe Formation	4.0E-04	4.0E-05	3.5E-07	3.0E-02	12

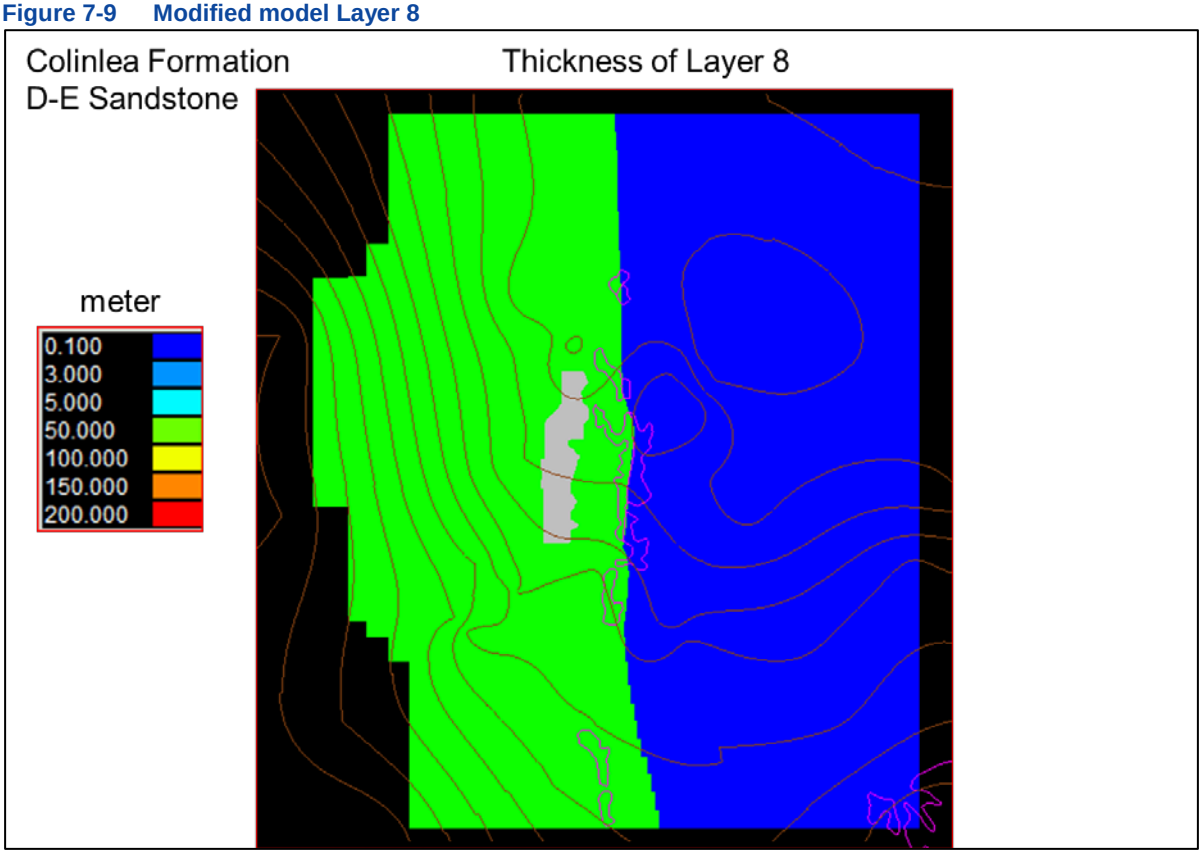
7 Predictive Model Development

7.9.1 Model layer revisions

Drilling results, providing geological cross-sections from west to east across Lagoon Creek and the Colinlea Sandstone / Joe Joe Formation contact (URS, 2011g), allowed for the revision of the geological layers within the modified model.

The Colinlea Sandstone layers were identified to pinch-out against the Joe Joe Formation, in the vicinity of the Colinlea Sandstone / Joe Joe Formation contact mapped on Figure 7-9. The model layers were revised to match site geology. An example, the D-E sandstone (modified model Layer 8), is presented in Figure 7-9 and can be compared to Figure 7-7.

Figure 7-9 Modified model Layer 8



8

Construction of Groundwater Assessment Model

The groundwater assessment model, is a model based on the original NTEC models but which has been modified based on modelling assessments (detailed in Section 7), additional hydrogeological data, and revised conceptualisation.

8.1 Modelling Software

The MODHMS (Hydrogeologic Inc., USA) groundwater modelling package was used to construct the required groundwater assessment model. MODHMS is based on the standard MODFLOW groundwater modelling code. The MODFLOW code was developed by the United States Geological Survey (McDonald and Harbaugh, 1984) for three-dimensional, finite-difference, modular, groundwater flow modelling. The MODFLOW code is the most widely used code for groundwater modelling and is currently considered an industry standard. MODHMS incorporates additional computational modules to enhance the simulation capabilities and robustness. MODHMS was selected because it:

- Allows modelling of variable saturation conditions (allowing for complete desaturation conditions) thus avoiding dry-cell problems;
- Allows fracture porous media simulation with dual porosity;
- Includes adaptive time-stepping schemes, which automatically adjusts time-step size to the non-linearity of the system to optimize the solution stability;
- Prevents water table build-up beyond a specified recharge-ponding elevation;
- Allows time-varying properties of hydraulic conductivity and storativity;
- Allows integrated groundwater and surface water modelling, which can simulate dynamic interactions of surface/subsurface flow and transport in the final voids; and
- Allows better understanding and control of the model water budget (relative to FEFLOW).

8.1.1 Considerations

The main considerations of changing modelling software from FEFLOW (utilised in the initial EIS model) to MODHMS were as follows:

- The simulation of long term groundwater conditions (final void modelling) would need an integrated surface/subsurface flow and transport model to conduct a systematic and coherent analysis. MODHMS is an integrated code whereas FEFLOW is only suitable for groundwater;
- Components of aquifer storage are not reported in FEFLOW, and mass balance errors tend to be high;
- For implementing detailed mining plan such as yearly or even quarterly, it is very difficult to manage in FEFLOW. The mining plan used in the FEFLOW model was based on every five years. The updated MODHMS model allowed for simulation of mining on a year by year basis; and
- Recharge cannot be applied in FEFLOW if the hydrogeological units were simulated as unsaturated flow.

8.2 Modelling Strategy

For the purpose of predictive inflow simulation, steady-state and transient flow calibration was conducted in order to verify model conceptualisation and attain reasonable parameter ranges aligned with field measurements.

The steady-state model had the same model extent of the predictive model based on the one-time groundwater level measurements available. The transient model was a local-scaled model limited to a local area surrounding the Alpha Test Pit. The transient model was calibrated against 91 days of 6-hourly head measurements and the total extraction volumes (bore pumping and in-pit pumping) during this period.

The calibrated hydraulic conductivity (K) values from the steady-state model and calibrated storativity values from the transient model were adopted for the predictive dewatering simulations. Since calibrated K values from a regional scale (steady-state model) and from a local scale (transient model) were not always consistent, a range of K values were further examined in the sensitivity model runs.

8.3 Model Geometry

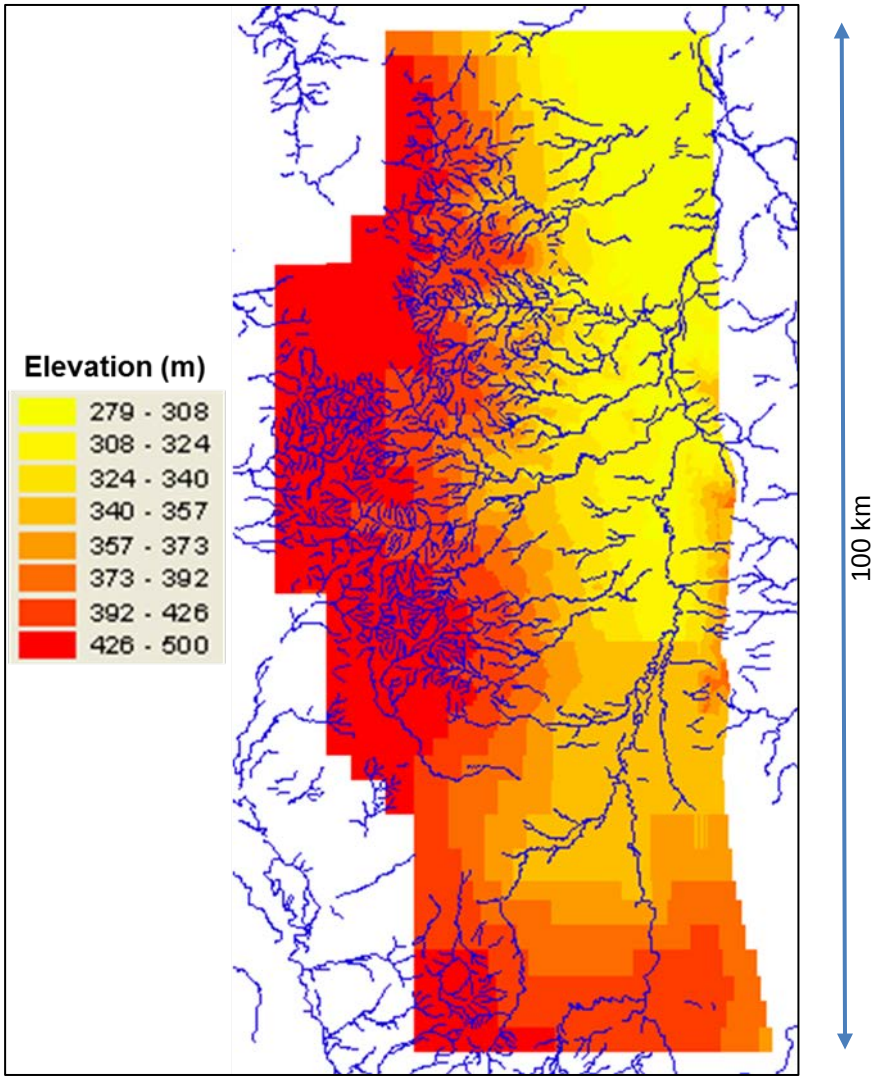
8.3.1 Steady state model

The predictive groundwater assessment model was constructed across an area of 100 km by 45.6 km (Figure 8-1). The model extent was governed by a catchment boundary associated with the Great Dividing Range in the west and the outcrop of Joe Joe Formation (representing the Colinlea Sandstone / Joe Joe Formation contact) in the east.

The model has a refined grid of 100 m by 200 m for the mining area (Figure 8-2) and has coarser grid spacing extending to the boundaries.

8 Construction of Groundwater Assessment Model

Figure 8-1 Groundwater assessment model extent

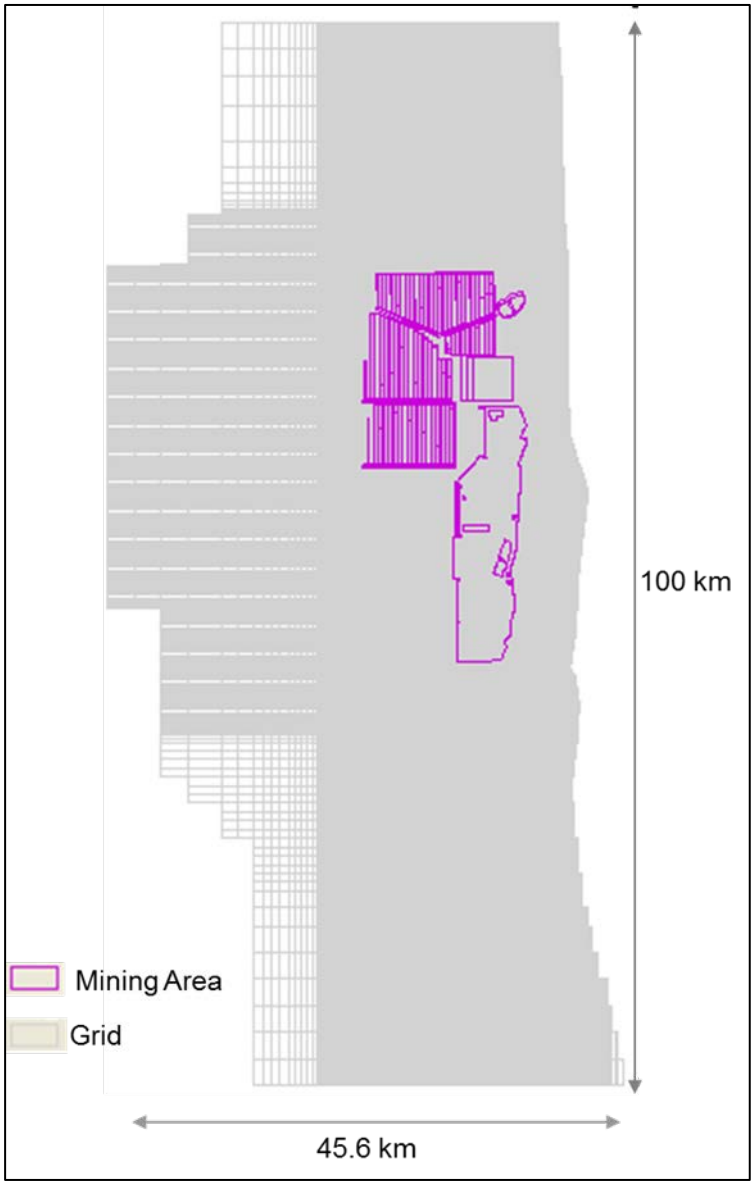


The model comprised:

- A model area of 4,560 km^2;
- 285 rows and 316 columns; and
- 798,633 active cells for an eleven-layer model.

8 Construction of Groundwater Assessment Model

Figure 8-2 Groundwater assessment model grid



The model layer structure was according to the Salva geological model (Salva, 2010b). The conceptual model layers were summarised in Table 8-1.

8 Construction of Groundwater Assessment Model

Table 8-1 Groundwater assessment model layers

Model Layer	Unit
1	Overburden / GAB
2 to 3	Rewan Formation
4	Bandanna Formation
5	C seam
6	C-D sandstone
7	D seam
8	D-E sandstone
9	E seam
10	Sub E sandstone
11	Joe Joe Formation

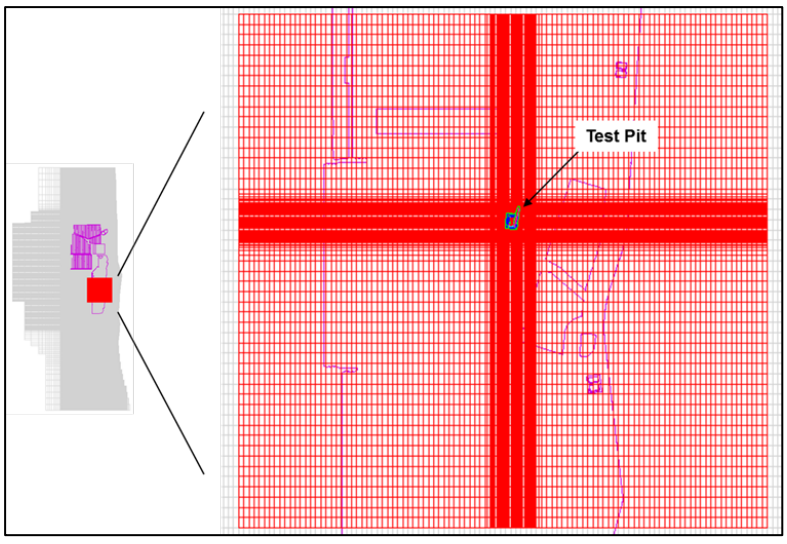
8.3.2 Transient telescoped model

The transient model, constructed to facilitate calibration based on the ATP dewatering data, was a telescoped model from the regional steady-state model with a model area of 10 km by 10.3 km.

The transient model has a refined grid of 20 m by 20 m in the area containing the Alpha Test Pit and a coarser grid of 100 m by 200 m in the model boundary. The zoom-in model has the same 11 model layers as the regional model, and comprises 95 rows and 141 columns, allowing for 147,345 active cells for the 11 layers.

The location of the telescoped model in relation to the larger predictive groundwater assessment model and the grid details are presented in Figure 8-3.

Figure 8-3 Transient (telescoped) model details



8.4 Recharge

Based on review of available groundwater monitoring data, recharge was only applied to the shallow perched aquifer as there was no correlation observed between rainfall events and groundwater level fluctuations in the deeper Permian layers that comprise the major aquifer systems in the MLA areas.

8.5 Boundary and Initial Conditions

The model boundary conditions for the steady state model include:

- **Top flux boundary** comprising recharge and evapotranspiration rates. Recharge was considered insignificant and could be less than 0.1% of mean annual rainfall. All surface water drainages (creeks) are ephemeral and dry through the year except when receiving wet season rainfall runoff. Constant base flow from groundwater is not considered to occur. Any potential groundwater loss to creeks was included through evapotranspiration.
- **No Flow Boundary**: The Great Diving Range forms the model boundary in the west, as it is assumed to comprise a groundwater divide and to act as a groundwater catchment boundary. The water divide was considered as a no-flow boundary for all 11 layers in the model.
  The Joe Joe Formation aquitards to the east, based on drilling and aquifer hydraulic data, acts as another no-flow boundary for the model with partly no-flow boundary for Layer 1 (overburden) and fully no-flow boundary for Layers 2 to 10.
- **Head Boundaries**: Horizontal inflow/outflow into and out of the model was determined based on specified head boundaries. The head boundaries along the model north and south boundaries were assigned based on the extrapolation of available topographical data.
  The eastern boundary for Layer 11 (Joe Joe Formation) was also assigned as prescribed head boundary as the Joe Joe Formation / Colinlea Sandstone contact was conceptualised (based on Galilee Basin geology) to extend to the north as there is no mapped geological outcrop.

The model boundary conditions for the transient zoom-in model included:

- **Top flux boundary:** same as the regional model.
- **Head Boundaries** were assigned to the four sides of the model based on the head values from the calibrated larger groundwater assessment model.

8.6 Hydraulic Parameters

Probable ranges of hydraulic conductivity (K) were derived from hydraulic test results (as described in Section 4-10) and literature values where onsite data was not available.

9

Calibration and Sensitivity Analysis

9.1 Calibration data

9.1.1 Steady-state calibration data

The groundwater level data from the monitoring and VWP bores constructed across Alpha and Kevin's Corner were used as head calibration targets as screen and geological data was readily available. Thus groundwater level data could be correctly assigned to the correct model layers.

Head data used were the first available groundwater levels measured in early 2010. These were used to avoid any impacts of subsequent ATP dewatering and pump test activities on site.

Average values were used if long term VWP data sets were stable and did not indicate any marked seasonal fluctuations, such as AVP-04 and AVP-11 in Section 4.6.

The DERM data set, as discussed in Section 4.10.3, could not be used for calibration purposes as the DERM records did not include elevation reference heights, accurate geology, or construction (screen) details. The bore survey bores (URS, 2011d,e) could also not be used for point-to-point calibration due to the lack of geological and construction data. Both DERM and bore survey data were used; however, to assist in determining head boundaries for the northern and southern model boundaries.

The data set utilised for the steady-state calibration included 31 observations at 18 locations, with several locations having measurements for different lithological units / model layers within the same VWP bores. These locations are shown in Figure 9-1.

9.1.2 Transient calibration data

The transient model was a local scale model for the test pit at Alpha. The Alpha Test Pit is detailed in **Appendix C** and discussed in Section 4.11.

Monitoring data was available for C-D sandstone and D-E sandstone at AVP-07 and AVP-08 and for D-E sandstone at AMB-01 during the 91-day dewatering. A total of 5 data sets were available for the three locations (Figure 9-2).

The 91-day dewatering records were simplified to 16 records by selecting one record every six days. It was verified that the resultant 16 records still kept similar accuracy to the original 91-day records without losing significant resolution in the drawdown curves.

With 16 records for each of the 5 data sets a total of 80 targets were obtained. However, as the last day reading for AMB-01 was unavailable only 79 head targets for transient calibration were used.

In addition to the 79 head targets, pumping volumes and losses from seepage and evaporation (**Appendix C** contains the ATP water balance) were used during transient calibration. An estimated 38.8 ML was extracted from out-of-pit dewatering bores and 6.5 ML was lost from in-pit pumping and evaporation (JBT Consulting, 2011g).

9 Calibration and Sensitivity Analysis

Figure 9-1 Monitoring locations used for the steady-state calibration

9.2 Model Parameterization

Following the principle of parsimony, model parameterization was kept as simple as possible while accounting for the system processes and characteristics that are evident in observations and important to predictions. In this study, hydraulic conductivity (K) and storativity (S) values were assigned as homogeneous values within the hydrogeologic units.

Six horizontal and six vertical K parameters were assigned to the model layers. An additional eight storativity parameters (storage coefficient and specific yield) were assigned to the transient model. The parameters were summarised in Table 9-1. The nomenclature used in Table 9-1 is referred to in subsequent sections (e.g. in discussion of sensitivity analysis).

9 Calibration and Sensitivity Analysis

Figure 9-2 Monitoring locations for transient calibration

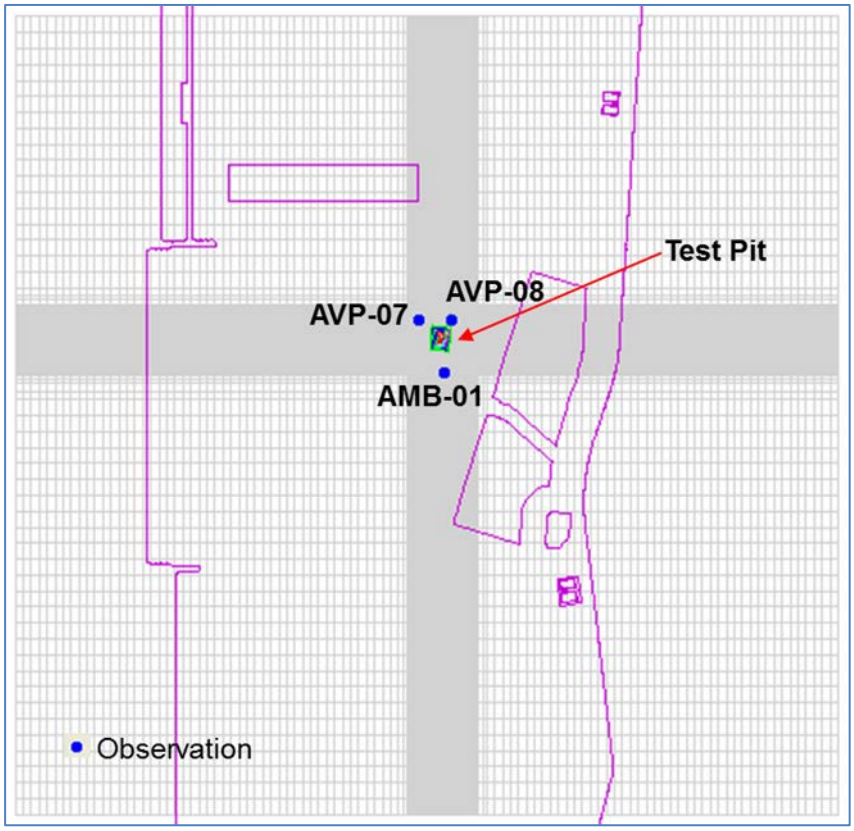


Table 9-1 Model parameters

Unit	Kx	Kz	Sc	Sy	Model
	(m/d)	(m/d)			Layer
GAB / overburden	kx1	kz1	sc1	sy1	1
Rewan Formation	kx2	kz2	sc2	sy2	2 to 3
Bandanna Formation	kx3	kz3	sc2	sy2	4
C seam	kx4	kz4	sc3	sy3	5
C-D sandstone	kx5	kz5	sc4	sy4	6
D seam	kx4	kz4	sc3	sy3	7
D-E sandstone	kx6	kz6	sc2	sy2	8
E seam	kx4	kz4	sc3	sy3	9
Sub E sandstone	kx6	kz6	sc2	sy2	10
Joe Joe Formation	kx3	kz3	sc2	sy2	11

Recharge rate parameter (rch1) and a parameter of extinction depth for evapotranspiration (edp) were included in the transient calibration. A uniform recharge rate was applied to the study area and estimated during the calibration process. Evapotranspiration rate was also uniformly applied to the area with extinction depth of 2 to 3 m, determined through calibration.

9.3 Calibration Approach

Model calibration is a process of refining the model's depiction of the hydrogeological framework, aquifer hydraulic properties, and boundary conditions until an adequate correspondence is achieved between the model simulated and measured field data. The end result of the model calibration process is a potential optimal set of parameter values and boundary conditions that minimise the discrepancy between simulated and observed data.

The major calibration target of the model was groundwater level data with constraints of reasonable ranges of hydraulic conductivity, storage coefficient, and other parameters. The parameter estimation program PEST (Doherty, 2008), along with detailed parameter output verification, was used to calibrate the parameters of the groundwater assessment model. PEST implements a nonlinear least-squares regression method to estimate model parameters by minimising the sum of squared weighted residuals of groundwater levels.

The calibration process was assessed against the Murray-Darling Basin Commission Groundwater Flow Modelling Guidelines, (Aquaterra, 2000). In order to further validate the predictive model, and to allow for a higher level of confidence with regards to the groundwater volume estimates, the Proponent contracted Parson's Brinkerhoff to undertake an independent review of the predictive model, including an evaluation of modelling processes, parameters, calibration, sensitivity, and uncertainty. **Appendix D** contains the third party review report.

Please note: An initial calibration journal was documented during trial-and-error manual calibration. Once the calibrations were conducted through PEST automatic calibration, the process of maintaining a calibration journal was discontinued. Automated PEST records are available; however these have limited merit as the PEST generated parameter suites were assessed based on calibration statistics. The parameter constraints were, based on field data sets, refined until an optimum (base case) set of parameters were determined.

9.3.1 Steady-state calibration

The pseudo steady-state calibration aimed at representing an average state of groundwater levels. A total of 31 groundwater measurements from 18 different monitoring locations were used for this calibration process.

Parameter values of hydraulic conductivities, recharge, and evapotranspiration extinction depth were estimated through PEST calibration process. Recharge rate was a uniform value for the model area.

The relation between the simulated and observed groundwater levels was the preferred indicator of model error. A scatter plot of simulated versus observed groundwater levels is shown in Figure 9-3 for steady-state calibration. The relationship follows a straight line with a R^2 value of 0.86. Detail simulated head values and residuals at the observed locations are listed in **Appendix D**.

Root-mean-square error (RMSE) was selected to evaluate the performance of model calibration based on groundwater levels. Good agreements between calibrated results and field measurements usually

9 Calibration and Sensitivity Analysis

have RMSE less than 10 % of the difference between the maximum and minimum potentiometric heads across the model area. The RMSE for the steady-state calibration was 3.4 m, which was 3.7% of the approximate 90 m range of groundwater levels. A mean error (ME) of -0.22 indicated that no significant bias was evident. Table 9-2 presents calibration statistics for steady-state simulation.

Figure 9-3 Simulated versus observed head values for steady-state calibration

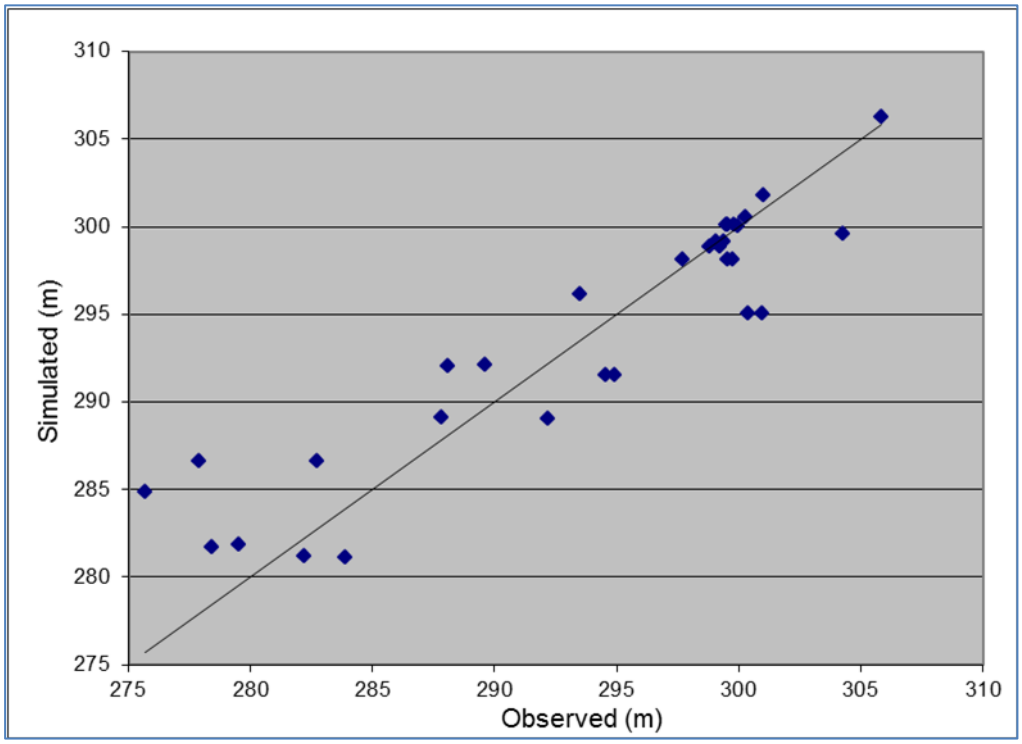


Table 9-2 Calibration statistics for steady-state calibration

Calibration Statistics	Steady-State Calibration (31 observations)
Mean Error (m)	-0.22
RMSE (m)	3.37
Standard Deviation (m)	3.42
Head Range (m)	90.00
Mean Error %	-0.24%
RMSE %	3.7%
Standard Deviation %	3.8%
R^2	0.86

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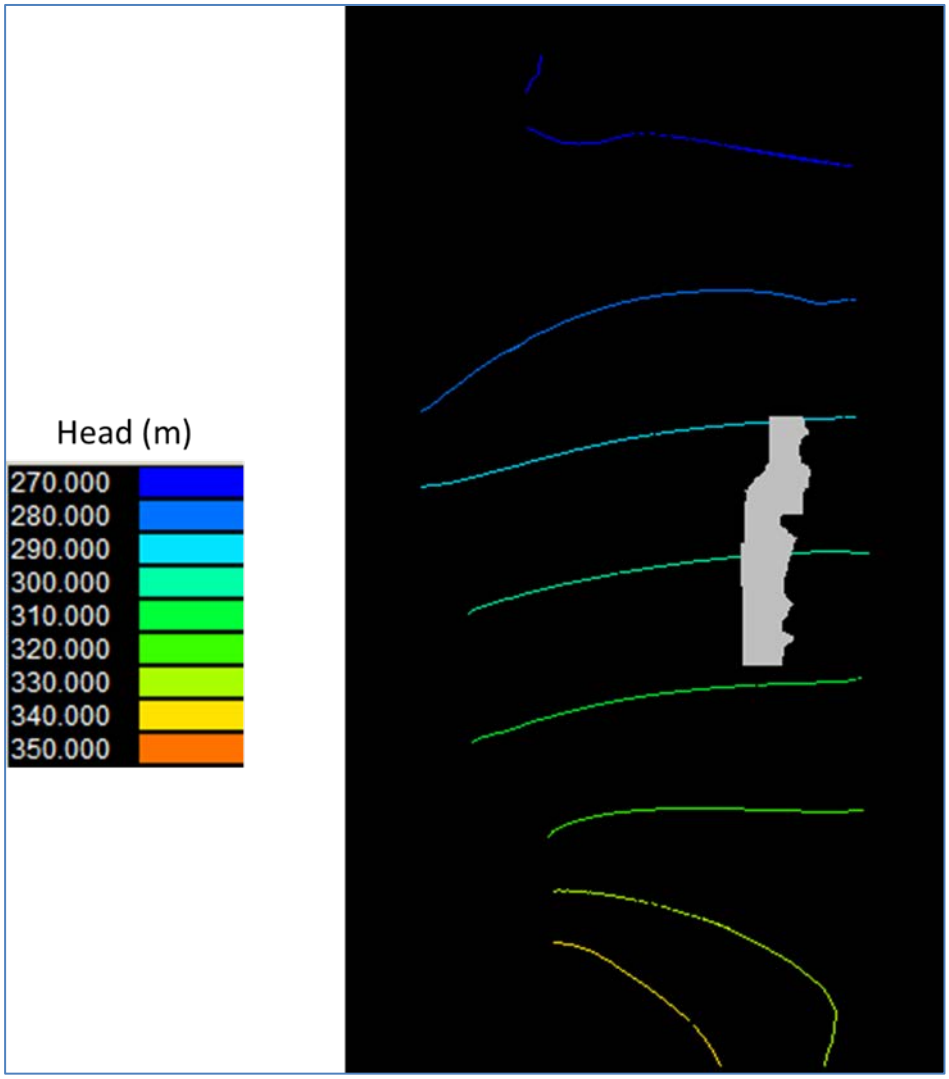
The groundwater levels from steady-state simulation for Layer 8 (D-E sandstone) were contoured to provide an indication of groundwater level variation across the site. Figure 9-4 presents the modelled pseudo steady state groundwater contours. The final calibrated parameters are summarised in Table 9-3.

Figure 9-4 Pseudo steady-state groundwater contours for Layer 8 – D-E Sandstone (showing Alpha mine layout)



9 Calibration and Sensitivity Analysis

Table 9-3 Calibrated parameters for steady-state calibration

Unit	Kx	Kz	Model
	(m/d)	(m/d)	Layer
GAB	5.60	0.8	1
Rewan Formation	6.0E-05	8.3E-04	2 to 3
Bandanna Formation	1.8E-04	1.0E-03	4
C seam	1.0E-02	2.0E-03	5
C-D sandstone	0.12	1.0E-04	6
D seam	1.0E-02	2.0E-03	7
D-E sandstone	5.0E-02	2.3E-06	8
E seam	1.0E-02	2.0E-03	9
Sub E sandstone	5.0E-02	2.3E-06	10
Joe Joe Formation	1.8E-04	1.0E-03	11
rch1= 1E-8 m/day (recharge rate)			
edp = 3 m (extinction depth)			

9.3.1.1 Mass balance for steady-state calibration

The resultant mass balance for the steady-state calibration is included in Table 9-4.

Table 9-4 Simulated mass balance for the steady-state model

Budget Component	Annual Groundwater Inflow (m^3)	Annual Groundwater Outflow (m^3)
Horizontal flow	175629	192369
Recharge	19149	0
Evapotranspiration	0	2613
Total	194778	194982
Discrepancy (%)	-0.1%	

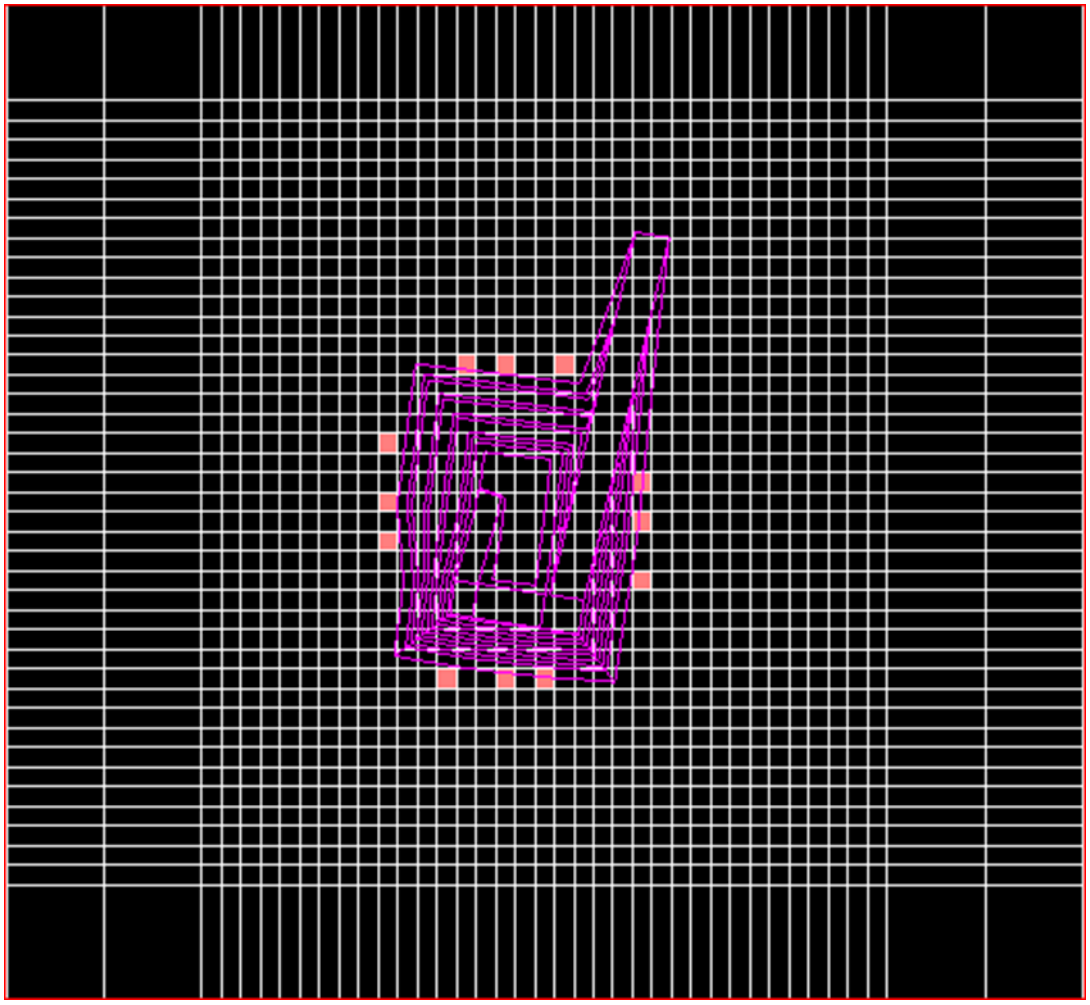
9 Calibration and Sensitivity Analysis

9.3.2 Transient calibration

Due to a lack of hydrograph response to stressors such as rainfall, the only useful data for transient calibration was the data set obtained from dewatering of the ATP.

The transient model included 12 perimeter pumping bores for simulating the dewatering of the Alpha test pit, with bores sited in the location of the 12 actual perimeter bores (Figure 9-5).

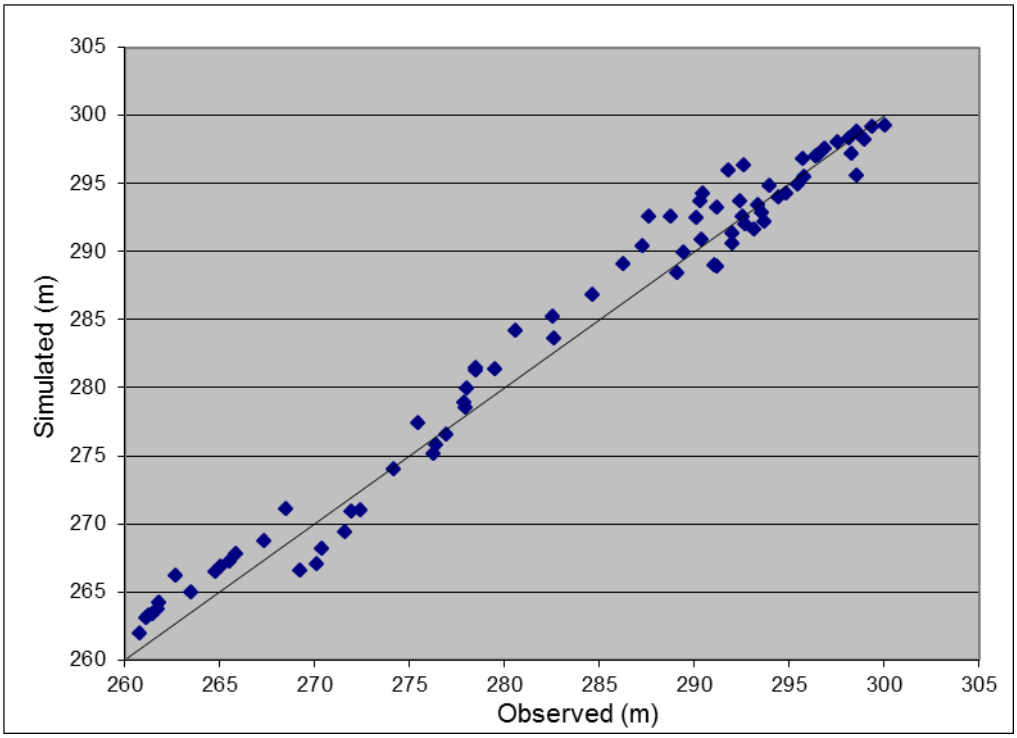
Figure 9-5 Location of the 12 ATP pumping bores



A scatter plot of overall simulated versus observed groundwater levels for the five data sets is shown in Figure 9-6 for transient calibration. The relationship follows a straight line with a R^2 value of 0.98.

9 Calibration and Sensitivity Analysis

Figure 9-6 Simulated versus observed head values for transient calibration



The RMSE for the calibration was 1.9 m, which was 3.9% of the approximate 49 m range of groundwater levels across the model area. The simulated dewatering volume totalled 44.9 ML, which comprised out-of-pit dewatering of 38.8 ML and losses (seepage plus evaporation) of 6.1 ML. This simulation was close to the estimated volumes calculated using the field measurements of 45.3 ML. The summary of calibration statistics was listed in Table 9-5.

Table 9-5 Calibration statistics for transient calibration

Calibration Statistics	Transient Calibration (79 observations)
Mean Error (m)	-0.64
RMSE (m)	1.93
Standard Deviation (m)	1.83
Head Range (m)	49.15
Mean Error %	-1.31%
RMSE %	3.9%
Standard Deviation %	3.7%
R^2	0.98

9 Calibration and Sensitivity Analysis

The five sets of simulated versus observed groundwater levels are presented in Figures 9-7 to 9-11. The simulated results match favourably with the field measurements. Note that the data used in the graphs were based on the original 91-day records rather than the simplified 15 or 16 records in each data set.

Figure 9-7 Simulated versus observed in D-E sandstone at AVP-08

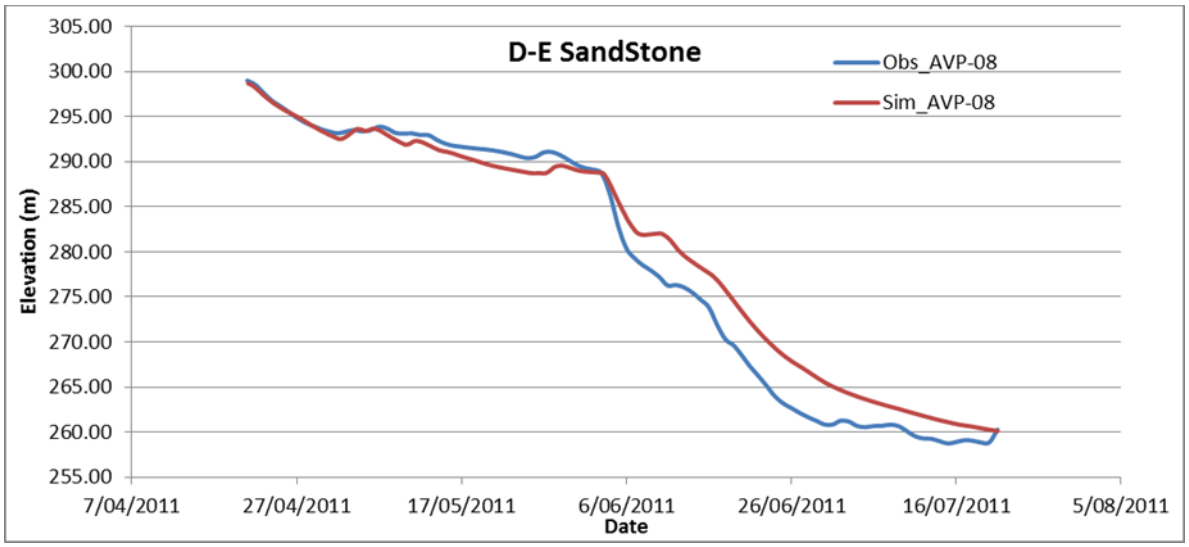
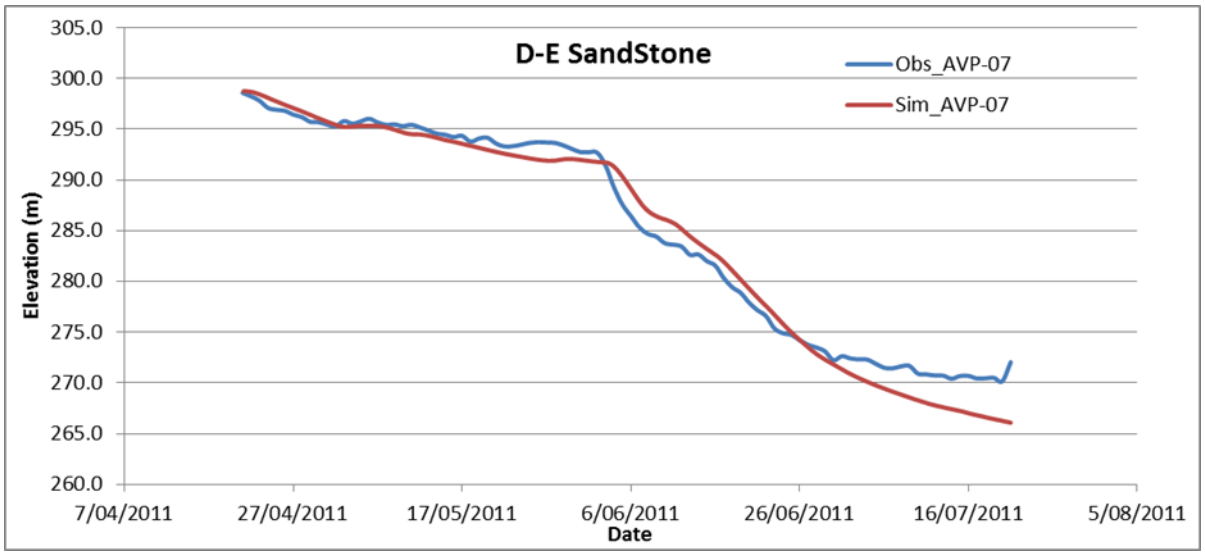


Figure 9-8 Simulated versus observed in D-E sandstone at AVP-07



9 Calibration and Sensitivity Analysis

Figure 9-9 Simulated versus observed in D-E sandstone at AMB-01

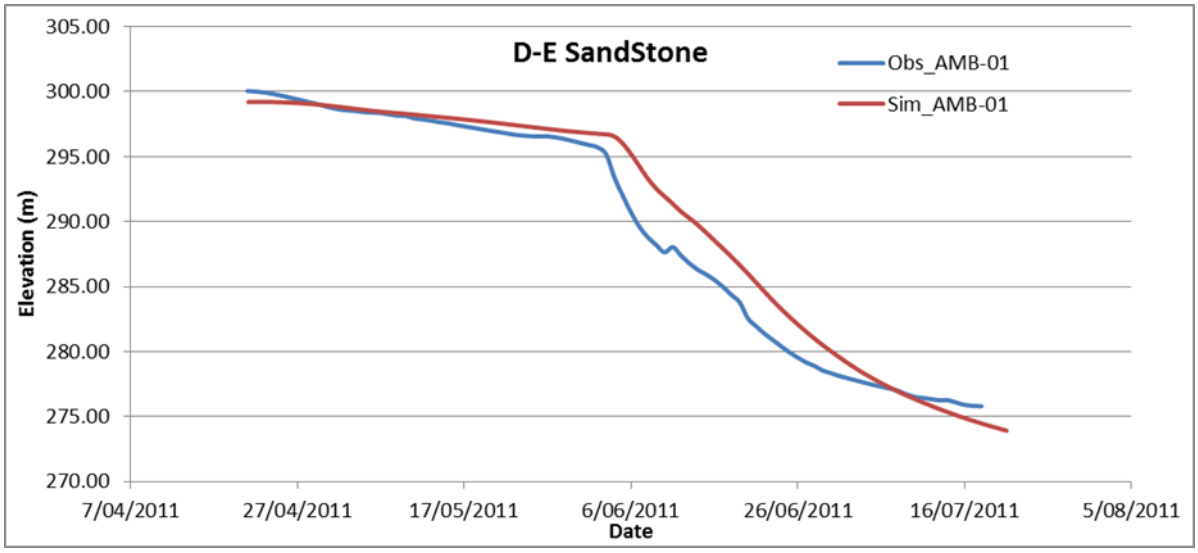
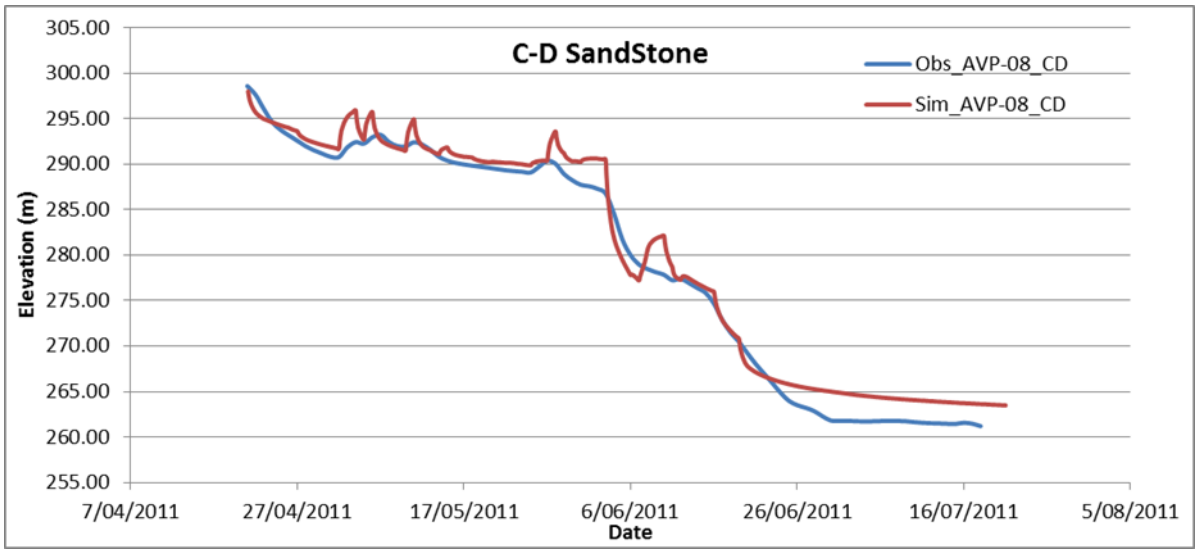
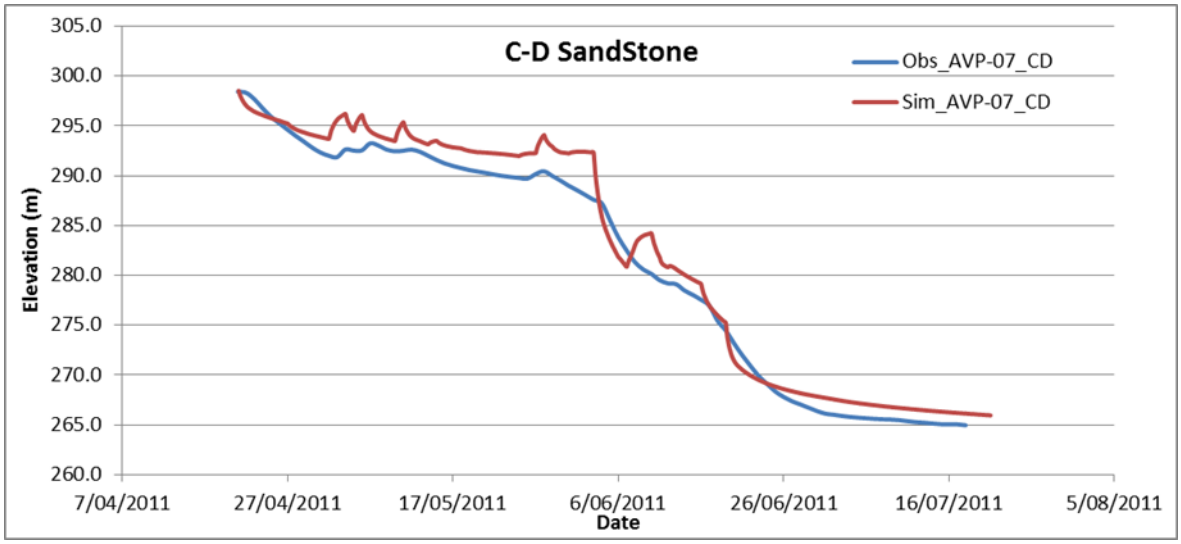


Figure 9-10 Simulated versus observed in C-D sandstone at AVP-08



9 Calibration and Sensitivity Analysis

Figure 9-11 Simulated versus observed in C-D sandstone at AVP-07



The calibrated parameters are listed in Table 9-6.

Table 9-6 Calibrated parameters for transient calibration

Unit	K_x	K_z	S_c	S_y	Model
	(m/d)	(m/d)			Layer
GAB	2.93E+00	2.81E-01	1.00E-04	5.01E-02	1
Rewan Formation	9.39E-04	9.29E-05	4.56E-04	8.41E-03	2 to 3
Bandanna Formation	1.70E-04	1.30E-06	4.56E-04	8.41E-03	4
C seam	1.54E-02	1.01E-05	9.77E-06	8.02E-03	5
C-D sandstone	1.50E-01	5.00E-05	6.23E-06	8.03E-03	6
D seam	1.54E-02	1.01E-05	9.77E-06	8.02E-03	7
D-E sandstone	1.70E-01	5.82E-05	4.56E-04	8.41E-03	8
E seam	1.54E-02	1.01E-05	9.77E-06	8.02E-03	9
Sub E sandstone	1.70E-01	5.82E-05	4.56E-04	8.41E-03	10
Joe Joe Formation	1.70E-04	1.30E-06	4.56E-04	8.41E-03	11
rch1 = 1E-7 m/day (recharge rate)					
edp = 3 m (extinction depth)					

9 Calibration and Sensitivity Analysis

9.3.2.1 Transient Calibration mass balance

The mass balance for the transient calibration is shown in Table 9-7. Note that the outflow from the drains includes in-pit pumping and evaporation from the pit. The component of evapotranspiration accounted for loss in the model area and was zero as groundwater levels were lower than the extinction depth.

Table 9-7 Calibrated parameters for transient calibration

Budget Component	Accumulated Groundwater Inflow (m^3)	Accumulated Groundwater Outflow (m^3)
Storage	59155	17513
Horizontal flow	5704	2610
Pumping	0	38842
Recharge	1378	0
Drains	0	6059
Evapotranspiration	0	0
Total	66236	65024
Discrepancy (%)	1.8%	

9.4 Sensitivity Analysis

Sensitivity analysis involved evaluating the effects of changes in individual model parameters on model results and provides an indication of the uncertainty within which the model parameters have been estimated. The sensitivity of simulated heads to parameters was used to aid model calibration and was assessed through relative composite sensitivity. The relative composite sensitivity (RCS) is defined as follows (PEST, 2008):

$$s_i = (J^tQJ)^{0.5}b_i/m$$

Where, **J** represents the Jacobian matrix, derivatives of simulated heads at observations with respect to the i^{th} parameter in vector **b**; **Q** is the cofactor matrix, a diagonal matrix with the elements being the squared observation weights; b_i is i^{th} parameter value in vector **b**; and **m** is the number of observations that have non-zero weights.

Relative composite sensitivity (a dimensionless statistic) is a measure of the composite changes in model outputs that are incurred by a fractional change in the value of the parameter, so it can be used to assess the relative sensitivity of model parameters given the set of observations used in the model. Parameters with higher RCS values are more important to the model simulated values.

The RCS values were calculated in the PEST calibration process. Figure 9-12 shows RCS of the calibrated parameters for the steady-state model. Kz6 (vertical hydraulic conductivity for D-E sandstone and sub E sandstone) and Kz5 (vertical K for C-D sandstone) were the two parameters with the highest RCS. It was because observations were mainly for C-D sandstone and D-E sandstone, so these two parameters had direct impacts on the simulated heads at the observation points. (Refer to Table 9-1 for parameters associated with model layers).

RCS also reflects the total amount of information provided by the observation points for the estimation of each parameter (Hill and Tiedeman, 2007). Generally, if RCS of a parameter is greater than 1, it means that model observation points provide enough information to estimate the parameter. There were 8 parameters with RCS greater than 1, indicating that more than half of parameters were estimated with sufficient information.

Note that the steady-state model was calibrated with head targets only; while the main target in predictive simulation was inflow. Therefore, sensitive parameters in the steady-state model may not be the same ones leading to the largest uncertainty of inflow prediction. Most parameters would be applied to the predictive simulation for further uncertainty analysis even though some of them might not be sensitive in steady-state.

RCS values for transient parameters were presented in Figure 9-13. The highest RCS value was sc2, storage coefficient for formations of Rewan Formation, Bandana Formation, D-E sandstone, sub E sandstone, and Joe Joe Formation. The head targets were for C-D sandstone and D-E sandstone, so parameters with higher RCS values were mainly associated with the two units. Since the D-E sandstone behaved as a confined aquifer during the dewatering process, storage coefficient had important impacts on observations, resulting in higher RCS.

9 Calibration and Sensitivity Analysis

Figure 9-12 Relative composite sensitivity for parameters in steady-state calibration

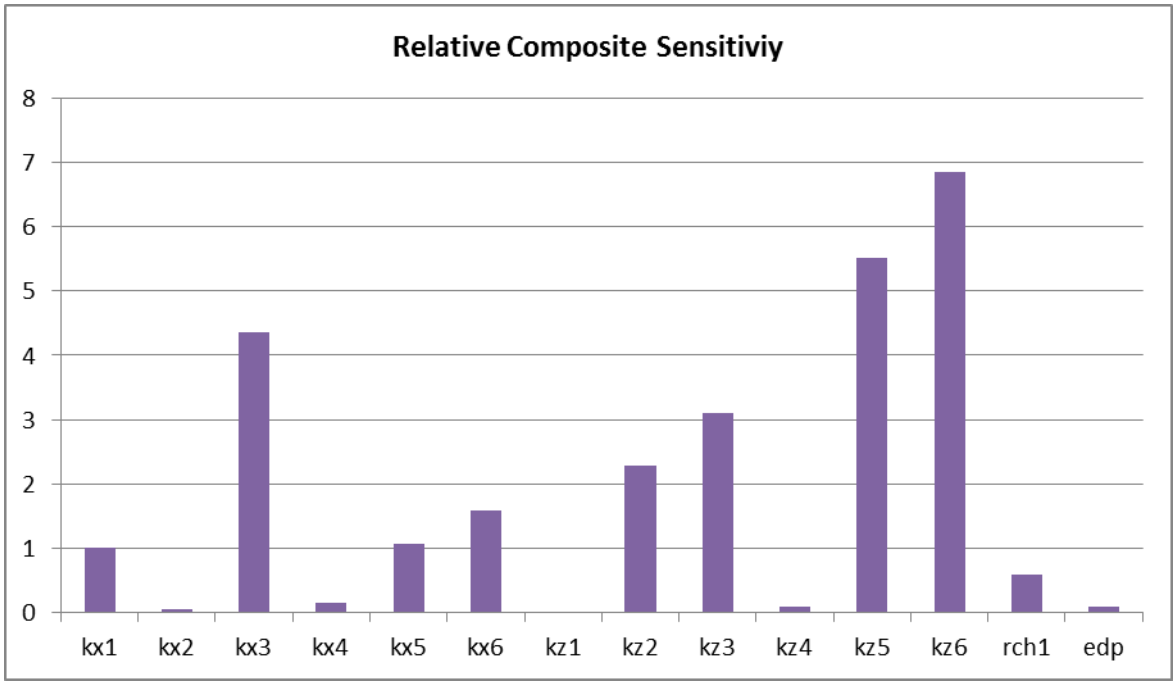
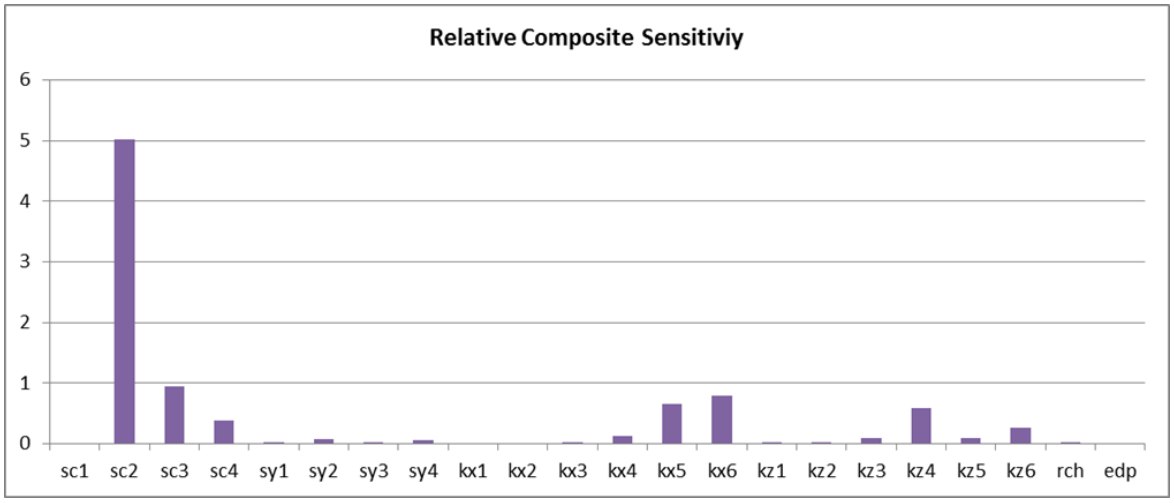


Figure 9-13 Relative composite sensitivity for parameters in transient calibration



There was only one parameter (sc2) with RCS greater than 1, indicating that observations were localised and unable to provide enough information for identifying parameters in other layers.

Similar to the steady-state calibration, the parameter with the highest RCS might not be the one leading to the largest uncertainty in the predictive simulation as inflow was the main focus in the prediction.

9.4.1 Comments

Due to limited field data across the entire model domain, sensitivity of parameters established in steady-state and transient calibrations (Section 9.3) may not be directly applicable when considering

the sensitivity in predictive uncertainty. This is as the result of the predictive target was inflow estimates over time and not (predictions in changes of) head values, which were the calibration targets during parameter calibration.

According to Darcy's law, flux is directly related to head gradient not head value, so parameters with high sensitivity (as shown in Figures 9-12 and 9-13) may not be the same parameters causing uncertainty in inflow predictions. Therefore, it is envisaged that the comparison of parameter sensitivity for the two may not be a good indicator to gauge how well the predictive uncertainty has been assessed.

The approach adopted for uncertainty analysis in Section 10.3 allowed for an assessment of a probable range of parameters and parameter changes with steady-state and transient calibrations. If the parameter change could not be rejected when considering calibration statistics then the parameter change was identified as possible. In this way, sensitive parameters to the predictive targets were identified, while ensuring the parameters were within a realistic (field data) range and the model (either steady-state or transient) remained calibrated (i.e. within calibration statistics).

9.5 Parameter Comparison

Aquifer hydraulic parameters determined during calibration (both steady-state and transient) have been compared to site specific field data compiled during hydrogeological studies across the Hancock projects. The comparison was considered when validating parameters included in the base case for predictive modelling (Chapter 10).

Table 9-8 presents a summary of the aquifer parameters, estimated for different units, based on the pump out tests (**Appendix B**).

Table 9-8 Pump test data summary

Bore	Unit	K_x (m/day)	S_c	Method
TPB1	D-E Sandstone	1.56	7E-05	Pumping test
TPB2	D-E Sandstone	0.25	6.6E-05	Pumping test
TPB3	C-D Sandstone	0.3	1.1E-03	Pumping test
TPB4	D-E Sandstone	0.48	1.45E-05	Pumping test
W1	C-D Sandstone	0.14	4.65E-03	Pumping test
W2	D-E Sandstone	0.26	3.45E-05	Pumping test
1290L	D-E Sandstone	0.16	3.8E-04	Pumping test
1636R	C-D Sandstone	0.06	6.7E-05	Pumping test
1637R	D-E Sandstone	0.07	1.6E-04	Pumping test
1638L	D-E Sandstone	0.15	3.7E-04	Pumping test
1680R	C-D Sandstone	0.83	2.0E-05	Pumping test
1681R	D-E Sandstone	0.18	5.1E-04	Pumping test

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The range of field derived aquifer hydraulic parameters, from pumping tests and variable (slug) head tests is presented in Table 9-9.

Table 9-9 Field derived parameter range (summary of Section 4.10.2)

Unit	K_x_min	K_x_max	Sc_min	Sc_max	Method
C-D Sandstone	0.06	0.83	2.00E-05	1.10E-03	Pumping test
D-E Sandstone	0.07	1.56	1.45E-05	5.10E-04	Pumping test
C-D Sandstone	0.17	0.61	-	-	Slug test
D-E Sandstone	0.03	1.1	-	-	Slug test
Tertiary Laterite	0.02	10	-	-	Slug test
Tertiary Sediment	0.04	0.11	-	-	Slug test
Joe Joe Formation	0.01	0.07	-	-	Slug test

The parameters derived for the base case based on the calibration process is combined in Table 9-10.

Table 9-10 Calibrated parameters (source Tables 9.3 and 9.6)

Unit	Kx_ST	Kz_ST	Kx_TR	Kz_TR	Sc	Sy	Model
	(m/d)	(m/d)	(m/d)	(m/d)			Layer
GAB	5.60	0.8	2.93	0.28	1.00E-04	5.01E-02	1
Rewan Formation	6.0E-05	8.3E-04	9.39E-04	9.29E-05	4.56E-04	8.41E-03	2 to 3
Bandanna Formation	1.8E-04	1.0E-03	1.70E-04	1.30E-06	4.56E-04	8.41E-03	4
C seam	1.0E-02	2.0E-03	1.54E-02	1.01E-05	9.77E-06	8.02E-03	5
C-D sandstone	0.12	1.0E-04	0.15	5.00E-05	6.23E-06	8.03E-03	6
D seam	1.0E-02	2.0E-03	1.54E-02	1.01E-05	9.77E-06	8.02E-03	7
D-E sandstone	5.0E-02	2.3E-06	1.70E-01	5.82E-05	4.56E-04	8.41E-03	8
E seam	1.0E-02	2.0E-03	1.54E-02	1.01E-05	9.77E-06	8.02E-03	9
Sub E sandstone	5.0E-02	2.3E-06	1.70E-01	5.82E-05	4.56E-04	8.41E-03	10
Joe Joe Formation	1.8E-04	1.0E-03	1.70E-04	1.30E-06	4.56E-04	8.41E-03	11

ST – steady-state TR - transient

9.5.1 Comments

The calibrated values are within the field test ranges except for Joe Joe Formation. The drilling results indicate little or no groundwater potential within the Joe Joe Formation; however, the variable head (slug) tests indicate higher permeability within this unit. This is as a result of vertical flow on top of low

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permeable (refusal) layers. These higher permeability estimates are not representative of the deeper Joe Joe Formation.

The minimum value of Sc for C-D sandstone was 2E-5 (Table 9-9), and the calibrated value of 6E-6 (Table 9-10) was lower than the low-end value. In the sensitivity analysis, Case 5 had Sc value of 3E-5 for C-D sandstone, but it was not sensitive to the groundwater inflow (Figure 10-9). Interestingly, Case 5 actually gave the exactly the same pumped out volume (45.3 ML) as the observed value for the test-pit case (Table 10-6); however, it gave a little higher of RMSE (Table 10-5). Thus it is considered that the calibrated value is suitable for predictive ingress modelling.

10

Predictive Modelling

Predictive simulation was conducted for both open-cut and underground mining during the active period till end of 2043. Steady-state calibrated model parameters were used for the predictive model as they were in the same regional scale. Parameter values of storage coefficient and specific yield in the predictive model were from calibrated parameters of the transient local-scale model.

The combination of the two parameter sets served as the base case for predictive simulation. The parameters in the base case were summarised in Table 10-1 and were further examined through uncertainty analysis.

Table 10-1 Parameter values for the base case

Unit	K_x	K_z	S_c	S_y	Model
	(m/day)	(m/day)			Layer
GAB	5.60	0.8	1.00E-04	5.01E-02	1
Rewan Formation	6.0E-05	8.3E-04	4.56E-04	8.41E-03	2 to 3
Bandanna Formation	1.8E-04	1.0E-03	4.56E-04	8.41E-03	4
C seam	1.0E-02	2.0E-03	9.77E-06	8.02E-03	5
C-D sandstone	0.12	1.0E-04	6.23E-06	8.03E-03	6
D seam	1.0E-02	2.0E-03	9.77E-06	8.02E-03	7
D-E sandstone	5.0E-02	2.3E-06	4.56E-04	8.41E-03	8
E seam	1.0E-02	2.0E-03	9.77E-06	8.02E-03	9
Sub E sandstone	5.0E-02	2.3E-06	4.56E-04	8.41E-03	10
Joe Joe Formation	1.8E-04	1.0E-03	4.56E-04	8.41E-03	11
rch1 = 1E-8 m/day (recharge rate)					
edp = 3 m (extinction depth)					

10.1 Mine Development Schedule

10.1.1 Alpha and Kevin's Corner Projects

In order to determine more accurately the groundwater volumes available the latest mine plan (Rev S) for both Alpha and Kevin's Corner projects was utilised. Detailed year-by-year mine planning is available for the first 5 years, after which the mine plan is presented in 5 year blocks (Table 10-2). These blocks were divided into equal areas, allowing for the model simulation of annual mining over the LOM.

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Table 10-2 Mining schedules

Stage	Alpha Open Cut	Kevin's Corner Open Cut	Kevin's Corner underground
1	2013	-	-
2	2014	2014	2014
3	2015	2015 – 2018	2015
4	2016	2019 – 2023	2016
5	2017	2024 – 2028	2017
6	2018 – 2022	2029 – 2033	2018
7	2023 – 2027	2034 – 2033	2019 – 2023
8	2028 – 2032	-	2024 – 2028
9	2033 – 2037	-	2029 – 2033
10	2038 – 2043	-	2034 – 2038
11	-	-	2039 - 2043

Figure 5-3 shows the adopted mine plan for the Kevin's Corner Project and Figure 5-2 shows the Alpha open cut mine plan. Note that the mine plan for Kevin's Corner indicates little or no open cut mining during 2023 to 2027; this is reflected in the predictive mine inflow volumes discussed in this section.

10.2 Predicted Mine Inflow Rates

Predictive inflows for Alpha and Kevin's Corner were estimated through zone budget in the model simulation. The predictive inflows for the base case were presented as annual inflow values in Figure 10-1. The estimates, simulating mining at Alpha and Kevin's Corner using the base case parameters presented in Table 10-1, are presented in Table 10-3.

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Figure 10-1 Annual inflow values for the base case

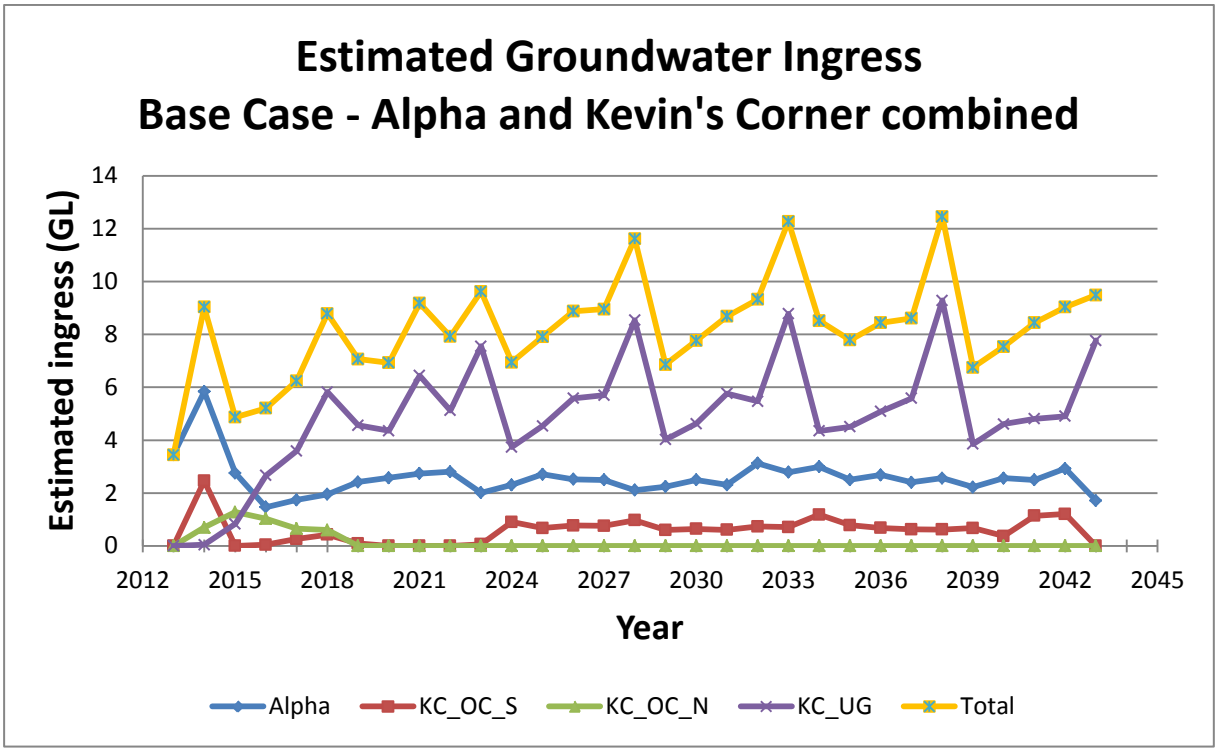

Table 10-3 Base case annual groundwater ingress estimates (in GL)

Year	Alpha	KC_OC_S	KC_OC_N	KC_UG	Hancock Total
2013	2.13	0.00	0.00	0.00	2.13
2014	4.07	1.66	0.44	0.01	6.18
2015	2.09	0.00	0.91	0.37	3.37
2016	1.07	0.04	0.73	1.30	3.13
2017	1.21	0.16	0.50	1.94	3.82
2018	1.37	0.29	0.48	3.37	5.52
2019	1.67	0.06	0.00	2.72	4.45
2020	2.08	0.00	0.00	2.71	4.80
2021	2.09	0.00	0.00	3.75	5.83
2022	2.10	0.00	0.00	3.24	5.34
2023	1.52	0.03	0.00	4.54	6.09
2024	1.41	0.57	0.00	2.21	4.19
2025	2.04	0.54	0.00	2.91	5.49
2026	2.02	0.63	0.00	3.56	6.21
2027	2.15	0.69	0.00	3.75	6.59
2028	1.57	0.78	0.00	5.23	7.57
2029	1.81	0.52	0.00	2.67	5.00
2030	1.80	0.52	0.00	3.18	5.49
2031	1.88	0.53	0.00	3.90	6.31
2032	1.91	0.57	0.00	3.79	6.26
2033	1.97	0.60	0.00	5.52	8.10

2034	2.16	0.99	0.00	3.11	6.26
2035	2.10	0.72	0.00	3.32	6.14
2036	2.18	0.63	0.00	3.65	6.46
2037	1.96	0.58	0.00	3.90	6.44
2038	2.04	0.60	0.00	5.76	8.40
2039	2.00	0.65	0.00	3.07	5.72
2040	1.92	0.40	0.00	3.48	5.79
2041	1.92	0.97	0.00	3.50	6.39
2042	2.07	1.00	0.00	3.50	6.56
2043	1.37	0.00	0.00	5.01	6.38
Totals	59.68	14.73	3.07	98.97	176.44

Where:

- Alpha – Alpha open cut mine
- KC_OC_S – Kevin's Corner open cut south
- KC_OC_N – Kevin's Corner open cut north
- KC_UG – Kevin's Corner underground mine

10.3 Uncertainty Analysis

Parameter uncertainty was explored through additional model scenario runs using different parameters values, which were potentially sensitive and have impacts on predictive inflow values. The uncertainty analysis was conducted, along with calibration statistics, for both steady-state and transient models to examine whether the additional predictive runs were still within the calibration constraints (based on site specific data).

Parameters from Table 10-1 were used in the base case. The base case assumes dewatering at Alpha, Kevin's Corner, and Waratah occurs during the same period. In addition to the base case, twenty-five (25) sensitivity cases were carried out. The parameter variation occurred using the multiplication factors was listed in Table 10-4. The parameters from the steady-state model were adopted as base parameters because the predictive model had the same model scale as the steady-state model and used the steady-state results as initial conditions. However, the storativity values of the base case were derived from the transient model as the steady-state model did not have such parameters.

Table 10-4 Twenty-five scenario runs

Case	Unit	Steady State	Transient	Base Parameters	Multipliers			
					K_x	K_z	S_y	S_c
1	Sc2	-	4.6E-04	4.6E-04	x1	x1	x1	x5
2	Sc2	-	4.6E-04	4.6E-04	x1	x1	x1	x0.2
3	Sc3	-	9.8E-06	9.8E-06	x1	x1	x1	x5
4	Sc3	-	9.8E-06	9.8E-06	x1	x1	x1	x0.2
5	Sc4	-	6.2E-06	6.2E-06	x1	x1	x1	x5

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Case	Unit	Steady State	Transient	Base Parameters	Multipliers			
					K_x	K_z	S_y	S_c
6	Sc4	-	6.2E-06	6.2E-06	x1	x1	x1	x0.2
7	Sy2	-	8.4E-03	8.4E-03	x1	x1	x2	x1
8	Sy2	-	8.4E-03	8.4E-03	x1	x1	x0.5	x1
9	Sy3	-	8.0E-03	8.0E-03	x1	x1	x5	x1
10	Sy3	-	8.0E-03	8.0E-03	x1	x1	x0.2	x1
11	Sy4	-	8.0E-03	8.0E-03	x1	x1	x5	x1
12	Sy4	-	8.0E-03	8.0E-03	x1	x1	x0.2	x1
13	kx1	5.60	2.93	5.60	x0.5	x1	x1	x1
14	kx2	6.0E-05	9.4E-04	6.0E-05	x20	x1	x1	x1
15	kx3	1.8E-04	1.7E-04	1.8E-04	x2	x1	x1	x1
16	kx4	1.0E-02	1.5E-02	1.0E-02	x0.5	x1	x1	x1
17	kx5	0.12	0.15	0.12	x2	x1	x1	x1
18	kx6	5.0E-02	0.17	5.0E-02	x5	x1	x1	x1
19	kz1	0.8	0.28	0.8	x1	x0.2	x1	x1
20	kz2	8.3E-04	9.3E-05	8.3E-04	x1	x0.1	x1	x1
21	kz3	1.0E-03	1.3E-06	1.0E-03	x1	x1.0E-03	x1	x1
22	kz4	2.0E-03	1.0E-05	2.0E-03	x1	x5.0E-03	x1	x1
23	kz5	1.0E-04	5.0E-05	1.0E-04	x1	x0.5	x1	x1
24	kz6	2.3E-06	5.8E-05	2.3E-06	x1	x40	x1	x1
25	rch1	1.0E-08	1.0E-07	1.0E-08	increase one order= 1E-7 (m/day)			

Case 1 to Case 12 allowed for the evaluation of the variation of storage coefficient (S_c) and specific yield (S_y). The multiplying factors were selected within recognised (field data) parameter ranges. While factors for Case 13 to Case 25 were selected based on differences in steady-state and transient calibration parameters as well as recognised (field data) parameter ranges.

Before running the sensitivity cases, the varied parameters of Case 1 to Case 12 were applied to the transient model and Case 13 to Case 25 were applied to the steady-state model to verify whether the selected parameters could still keep the model calibrated. If the calibration statistics were beyond the acceptable range, the selected parameters might not be suitable for the predictive model as the parameters might not reflect the field conditions.

Table 10-5 shows the calibration statistics for Case 1 to Case 12 (transient parameters). Most of cases had RMSE% under 10%, except Case 1 and Case 2. These two cases also had the lowest R^2

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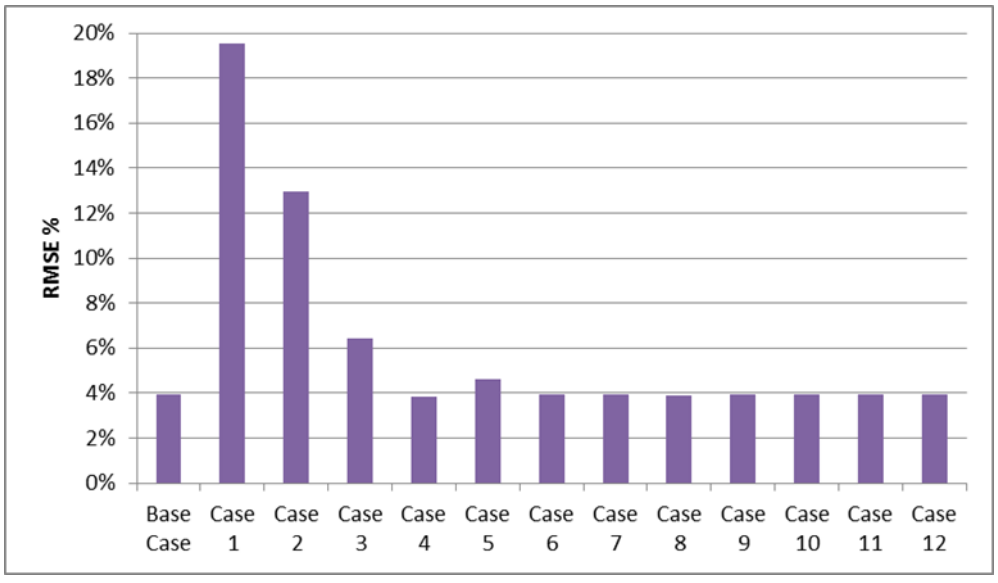
values, 0.71 and 0.91, respectively. This indicates that the selected parameter values for Case 1 and Case 2 are less likely to occur at the test-pit area, so the predictive results using the two parameters were less reliable. Figure 10-2 shows the RMSE% for Case 1 to Case 12.

Table 10-5 Calibration statistics for Case 1 to Case 12

Sensitivity Run	ME (m)	RMSE (m)	ME%	RMSE%	R^2
Base Case (transient)	-0.64	1.93	-1.3%	3.9%	0.98
Case 1	-6.65	9.61	-13.5%	19.5%	0.71
Case 2	4.45	6.39	9.1%	13.0%	0.91
Case 3	-1.92	3.18	-3.9%	6.5%	0.96
Case 4	-0.27	1.88	-0.5%	3.8%	0.98
Case 5	-1.17	2.28	-2.4%	4.6%	0.98
Case 6	-0.54	1.95	-1.1%	4.0%	0.98
Case 7	-0.69	1.94	-1.4%	3.9%	0.98
Case 8	-0.61	1.93	-1.2%	3.9%	0.98
Case 9	-0.66	1.94	-1.3%	3.9%	0.98
Case 10	-0.64	1.93	-1.3%	3.9%	0.98
Case 11	-0.69	1.93	-1.4%	3.9%	0.98
Case 12	-0.63	1.93	-1.3%	3.9%	0.98

Figure 10-2 RMSE% for Case 1 to Case 12



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In addition to considering the calibration statistics for head targets, water volume (pumped during the ATP dewatering simulations) was another measure for these cases. The total estimated volume was 45.3 ML during the 91-day pumping period (JBT Consulting, 2011g). Cases 1 and 2 were significantly higher or lower than the field measured value. Another two pairs similar to this were Cases 7 and 8 and Cases 11 and 12. Even though these two pairs had good RMSE% or R^2, the measure of water volume deviated significantly from the observed value (Table 10-6).

Table 10-6 Simulated extraction for 12 transient cases

Case	Pumped (ML)	Loss (ML)	Total (ML)
Observed	38.8	6.5	45.3
Base	38.8	6.1	44.9
1	39.8	12.1	51.9
2	35.4	5.4	40.7
3	39.6	6.3	45.9
4	38.7	6.1	44.7
5	39.1	6.1	45.3
6	38.8	6.1	44.8
7	39.0	9.3	48.4
8	38.7	4.5	43.2
9	38.8	7.8	46.7
10	38.8	5.6	44.5
11	40.3	8.5	48.8
12	38.4	5.4	43.7

Similar calibration statistics are shown in Table 10-7 for Case 13 to Case 25. All cases were under (RMSE %) 10%, which means the selected parameters were within the acceptable range. Figure 10-3 shows the RMSE% for Case 13 to Case 25.

Note that the base case, Base Case (transient), in Table 10-5 was for the calibrated transient model; while the base case, Base Case (steady), in Table 10-7 was for the calibrated steady-state model. They were not the same and were compared separately.

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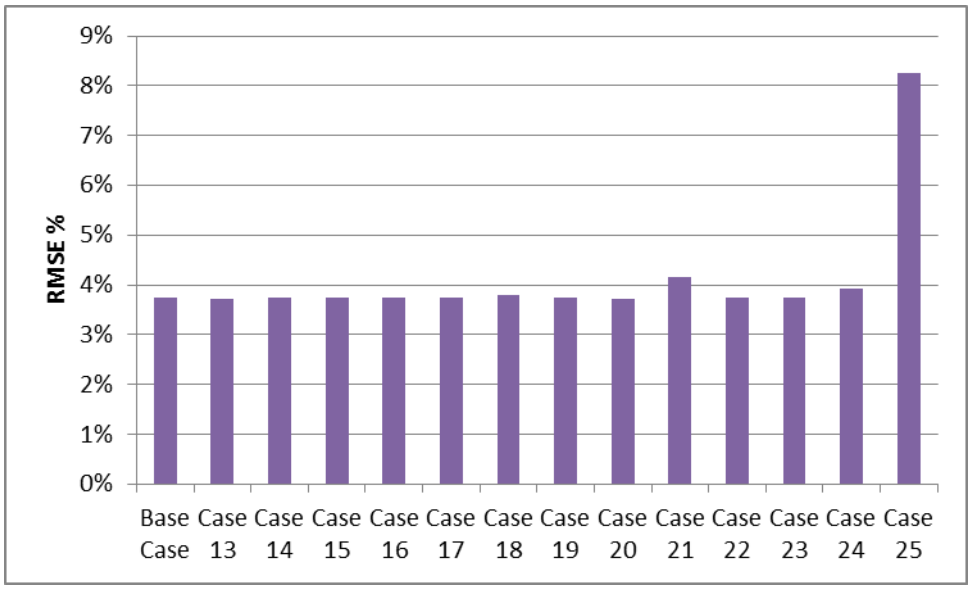
Table 10-7 Calibration statistics for Case 13 to Case 25

Sensitivity Run	ME (m)	RMSE (m)	ME%	RMSE%
Base Case (steady)	-0.22	3.37	-0.2%	3.7%
13	-0.19	3.35	-0.2%	3.7%
14	-0.11	3.38	-0.1%	3.8%
15	-0.19	3.37	-0.2%	3.7%
16	-0.21	3.37	-0.2%	3.7%
17	-0.20	3.37	-0.2%	3.7%
18	-0.24	3.42	-0.3%	3.8%
19	-0.19	3.37	-0.2%	3.7%
20	-0.19	3.36	-0.2%	3.7%
21	-1.48	3.75	-1.6%	4.2%
22	-0.22	3.38	-0.2%	3.8%
23	-0.21	3.37	-0.2%	3.7%
24	0.48	3.53	0.5%	3.9%
25	-6.99	7.44	-7.8%	8.3%

Figure 10-3 RMSE% for Case 13 to Case 25



The predictive inflow values for the 25 scenario cases plus the base case are shown in Figure 10-4. Figure 10-5 shows relative change from the base case total (LOM) estimate for the 25 cases.

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Figure 10-4 Sum of predictive inflows

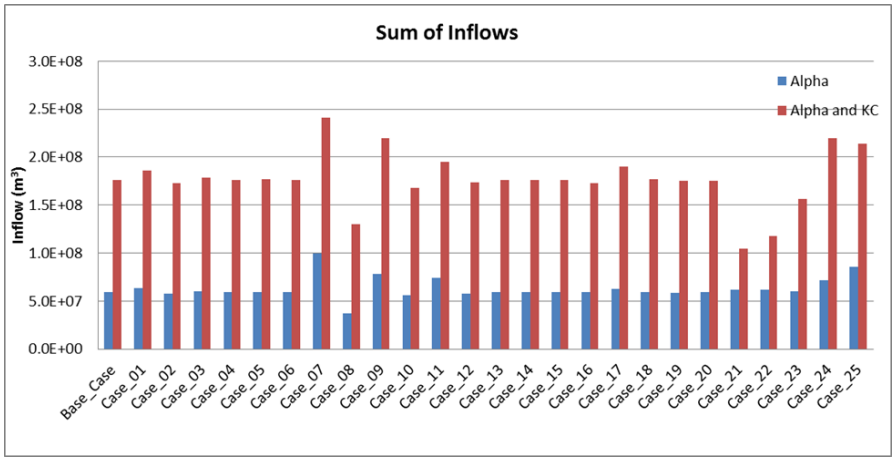
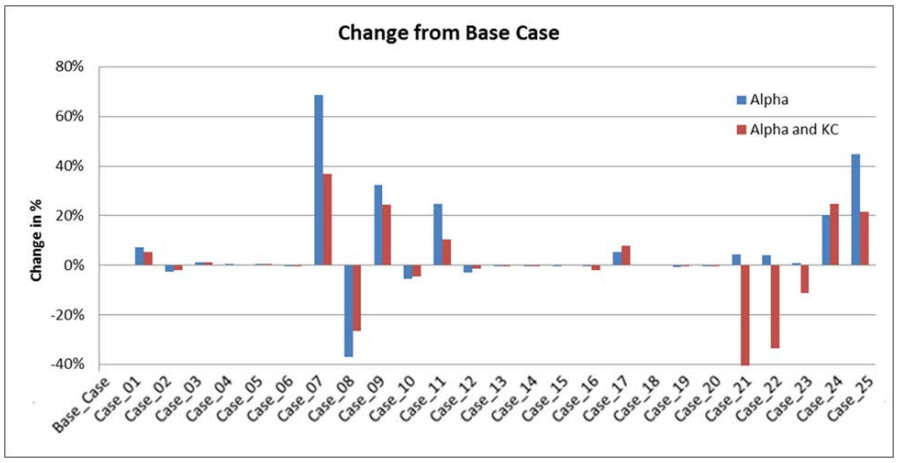


Figure 10-5 Percentage change from the base case



Cases 7, 8, 9, 11, 21, 22, 24, and 25 had significant changes from the base case. The most marked changes were for Cases 7 and 8, which relate to the changes of specific yield (Sy2) assigned to Rewan Formation, Bandana Formation, D-E sandstone, Sub-E sandstone, and Joe Joe Formation (Table 9-1). It was considered that the change of specific yield (higher drainable volumes if units become unconfined) in Rewan Formation and Bandanna Formation resulted in the marked increase in predicted inflows (Case 7). This was because the higher specific yields would yield higher volume of groundwater into the open cuts or through increased interconnection with the underground workings (due to longwall mining goaf). Field evidence (drilling results) indicates, however, that these units have little groundwater potential (except at extremely localised scale) and that the range of Sy used in the base case is more representative than Case 7. Sy could be lower as considered in Case 8.

The estimated minimum, maximum, and average groundwater ingress volumes over the LOM are presented in Figure 10-6.

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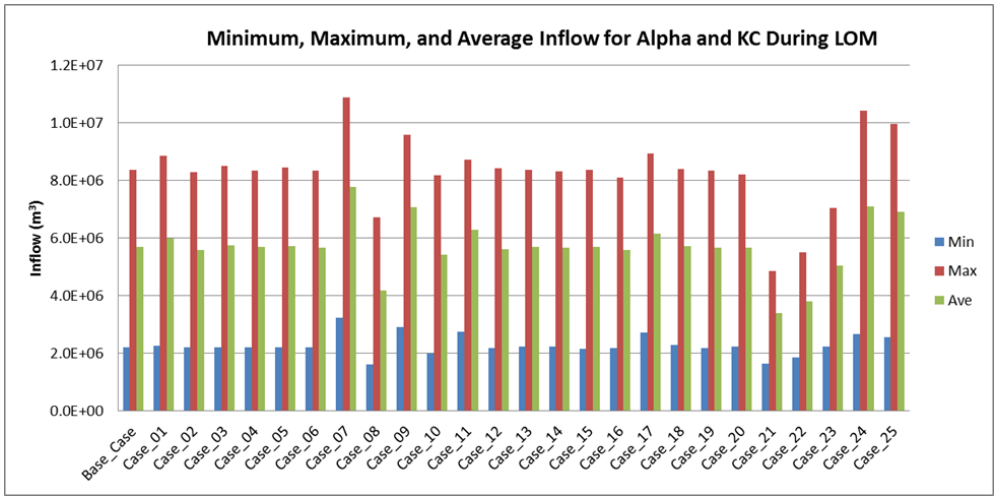
Figure 10-6 Minimum, maximum, and average annual inflow estimates



10.4 Range of Groundwater Volumes

Based on the calibration process and comparison to site specific aquifer characteristics it is considered that the combination of model parameters used in the base case provides the most likely estimate of groundwater volumes available using the groundwater assessment model. The year-on-year volume estimates are presented in Table 10-3 and include consideration of impacts of three mining operations being undertaken at the same time within the same hydrogeological regime.

For the mining operations, Case 7 (doubling of specific yield in various model layers) provides the highest estimates of groundwater volumes LOM (although it is noted that, based on transient calibration results, the probability of this scenario is very low) and the lowest groundwater volume estimate resulted from Case 21. Case 21 reduces vertical hydraulic conductivity (Kz3) by a factor of 10^{-3} (to values calibrated in the transient model the open cut zoom-in model) in Bandana Formation and Joe Joe Formation (Table 9-1). The reduction results in the marked reduction in groundwater ingress volumes to the underground mines. It is considered that Case 21 has a low probability as the process of goafing above longwall mining operations (vertical fracturing due to caving collapse of mined-out strata) will lead to an increase in vertical K above the underground operation.

The range of high, low, and expected groundwater ingress estimates is presented in Table 10-8 and in Figure 10-7.

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Table 10-8 Groundwater total year-on-year estimate range for Hancock (in GL)

Year	Case 7 (high estimate, low probability)	Base Case (best estimate)	Case 21 (low estimate, low probability)
2013	3.10	2.13	2.07
2014	8.57	6.18	4.62
2015	5.04	3.37	2.61
2016	4.28	3.13	2.18
2017	5.08	3.82	2.56
2018	6.89	5.52	2.92
2019	5.89	4.45	2.65
2020	6.33	4.80	2.92
2021	7.56	5.83	3.41
2022	7.18	5.34	3.57
2023	7.06	6.09	2.50
2024	6.16	4.19	2.72
2025	7.48	5.49	3.38
2026	8.60	6.21	3.58
2027	8.94	6.59	3.87
2028	9.34	7.57	3.52
2029	6.86	5.00	2.91
2030	7.82	5.49	3.38
2031	8.74	6.31	3.42
2032	8.56	6.26	3.59
2033	10.37	8.10	3.95
2034	8.82	6.26	3.38
2035	8.70	6.14	3.47
2036	9.17	6.46	3.76
2037	9.04	6.44	3.57
2038	10.69	8.40	4.21
2039	8.25	5.72	3.86
2040	8.58	5.79	3.77
2041	9.62	6.39	4.11
2042	9.96	6.56	4.28
2043	8.10	6.38	2.94
Total LOM	240.78	176.44	103.67

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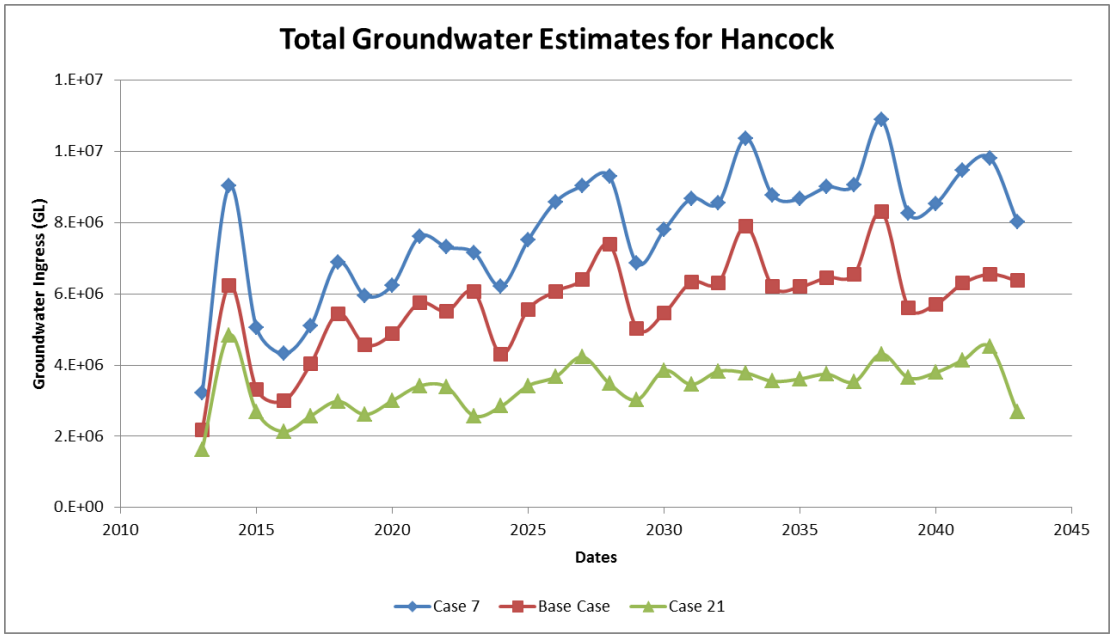
Figure 10-7 Total groundwater estimates at LOM for Alpha and Kevin's Corner



10.5 Alpha Only

The potential groundwater volumes available to Alpha, without the influence of Kevin's Corner and Waratah projects, were estimated.

The three scenarios (high (Case 7), base, and low (Case 8)) were modelled using only the Alpha mine schedule and plan. Case 8 (reducing the Sy) for open cut mining provides the lowest estimate as this limits the drainable volumes of groundwater that could enter the open pits from the over- and interburden. Table 10-9 presents the predictions and Figure 10-8 shows the variation year-on-year.

Table 10-9 Groundwater ingress predictions for Alpha only (in GL)

Year	Case 7 (high estimate, low probability)	Base Case (best estimate)	Case 8 (low estimate, moderate probability)
2013	3.10	2.13	1.58
2014	5.67	4.07	3.33
2015	3.14	2.11	1.40
2016	1.67	1.05	0.69
2017	1.93	1.32	0.92
2018	2.11	1.39	0.89
2019	2.86	1.95	1.49
2020	3.33	1.97	1.50
2021	3.46	2.01	1.43

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2022	3.62	2.00	1.43
2023	2.25	1.37	1.02
2024	2.53	1.63	0.95
2025	3.34	2.02	1.51
2026	3.68	1.99	1.36
2027	3.68	2.15	1.35
2028	2.55	1.57	1.07
2029	2.96	1.77	1.23
2030	3.18	1.88	1.36
2031	3.35	1.87	1.29
2032	3.24	1.92	1.11
2033	3.38	2.00	1.48
2034	3.60	2.14	1.31
2035	3.74	2.07	1.35
2036	3.71	2.29	1.45
2037	3.77	1.96	1.34
2038	3.44	2.07	1.26
2039	3.42	1.86	1.18
2040	3.46	2.01	1.32
2041	3.40	1.94	1.11
2042	3.69	2.13	1.25
2043	2.65	1.43	0.80
Total LOM (GL)	99.9	60.1	40.8

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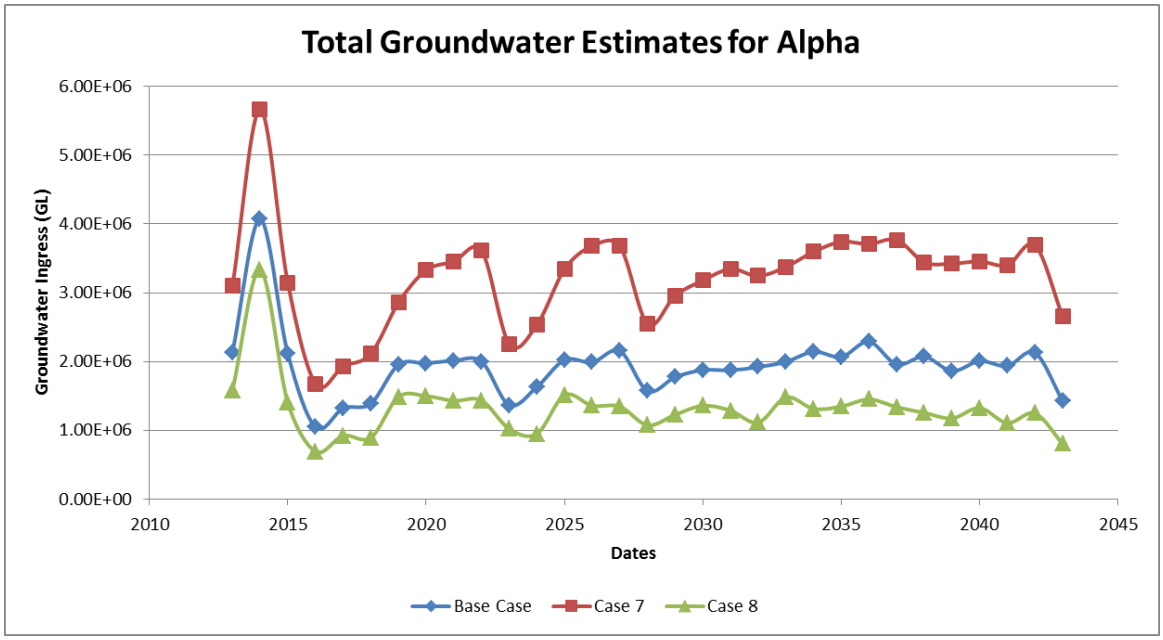
Figure 10-8 Total groundwater estimates at LOM for Alpha only



10.6 Predictive Model Impact Assessments

Based on requests for data compiled post EIS submission, the predictive groundwater model was utilised to predict changes in groundwater levels as a result of mine dewatering and depressurisation. The groundwater level data at the end of mining was used in the integrated surface water runoff – groundwater model constructed to assess final void water levels, quality, and long term impacts, Section 12. The calibrated predictive groundwater model allowed for an assessment of possible risks with regards to:

- The closest Great Artesian Basin (GAB) major aquifer, the Clematis Sandstone;
- The basal unit of the GAB, the Rewan Formation, which overlies the target Permian sediments;
- Cumulative impacts through assessing the model predictions for Alpha alone and then comparing the results of simulating Alpha and Kevin's Corner;
- Vegetation communities[7]; and
- At-risk bores.

10.6.1 Groundwater level projections

Observation points were included in the predictive groundwater model to allow for an assessment of potential for groundwater level changes, through induced flow, within the GAB Clematis Sandstone and Rewan Formation (Figure 10-9).

The groundwater levels at these points, within the saturated layers below the Clematis Sandstone and Rewan Formation, were projected over the 30 years life of mine (Figure 10-10).

[7] No assessment of the registered springs to the north of the MLAs was included as the predictive model domain did not extend sufficiently far north. These springs were included during model refinement, Section 11.

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Figure 10-9 Observation points within the GAB

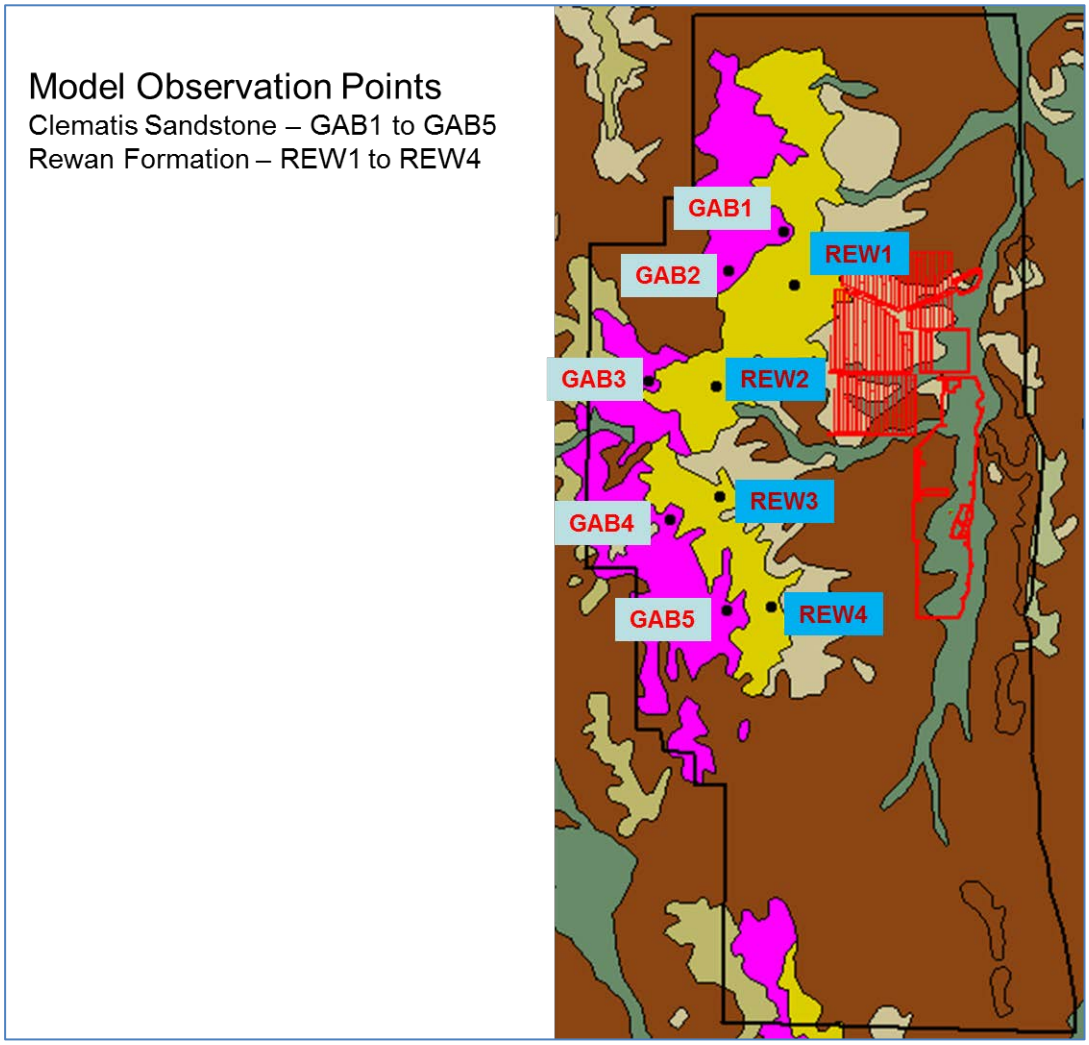

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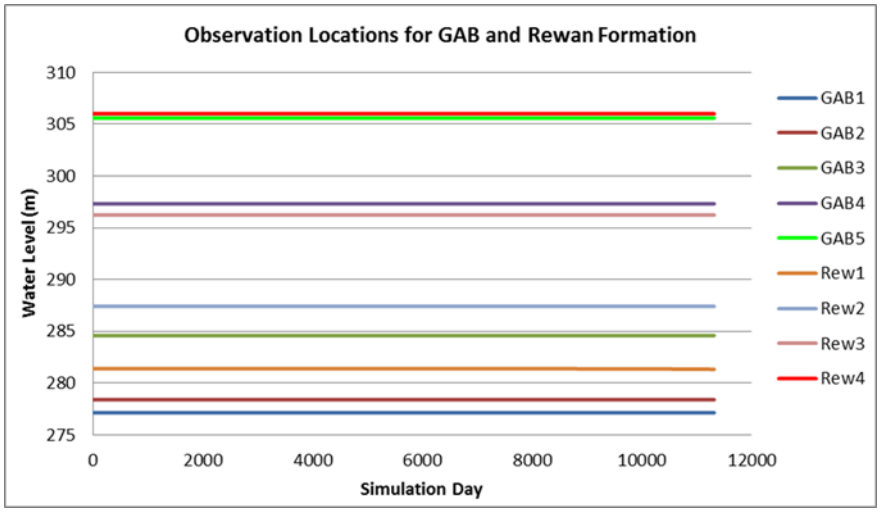
Figure 10-10 Projected GAB groundwater levels



Based on the projected groundwater levels within the observation points, there is no risk of potential induced groundwater movement from the closest GAB Clematis Sandstone aquifer to the west towards the dewatered and depressurised mine site, during the LOM, due to the low permeable nature of the sediments within the Bandana and Rewan formations.

It is predicted that there will be minimal risk of induced drawdown in the Rewan Formation to the west of the mine footprint (resulting from the depressurisation of the D-E sandstone) in the long term (Section 13); however, this risk is limited because of the low permeable (vertical) nature of the clay-rich Bandana Formation and Rewan Formation aquitard. Field measurements (drill stem tests in exploration bores) indicate very low vertical permeability (< 0.0009 m/day in the Rewan Formation), which restrict any potential induced drainage from these western units towards the mine.

10.6.2 Groundwater water level drawdown

Drawdown cones in the D coal seam were contoured to assess the largest predicted zone of influence during mining. The drawdown, up to 0.5 m change from initial groundwater levels, contours were developed for Alpha alone (green contours on Figure 10-11) and also for (cumulative contours) Alpha and Kevin's Corner as modelled using the predictive model (yellow contours on Figure 10-11).

The projected contours indicate that there will be minimal drawdown to the east of the mine footprint because of the aquitard nature of the Joe Joe Formation metasediments. Drilling and aquifer and geotechnical hydraulic testing within this formation indicate little or no groundwater potential. This low permeability unit restricts groundwater drawdown, resulting from mining, to the east.

Dewatering impacts (drawdown cones) are predicted to elongate north and south, within the more permeable sandstone units of the Colinlea Sandstone. The cumulative impact of adding the Kevin's Corner dewatering results in deeper drawdown where drawdown cones overlap and further elongation along strike. The drawdown is also more pronounced to the west as a result of deeper mining further to the west than Alpha. The same geological / hydrogeological constraints, however, which govern drawdown impacts to the east and west (as discussed in Section 10.6.1) apply across the entire portion of the Galilee Basin containing Alpha. This means that the potential for induced flow from the GAB or drawdown in the older units to the east of the Joe Joe Formation does not increase based on additional mining.

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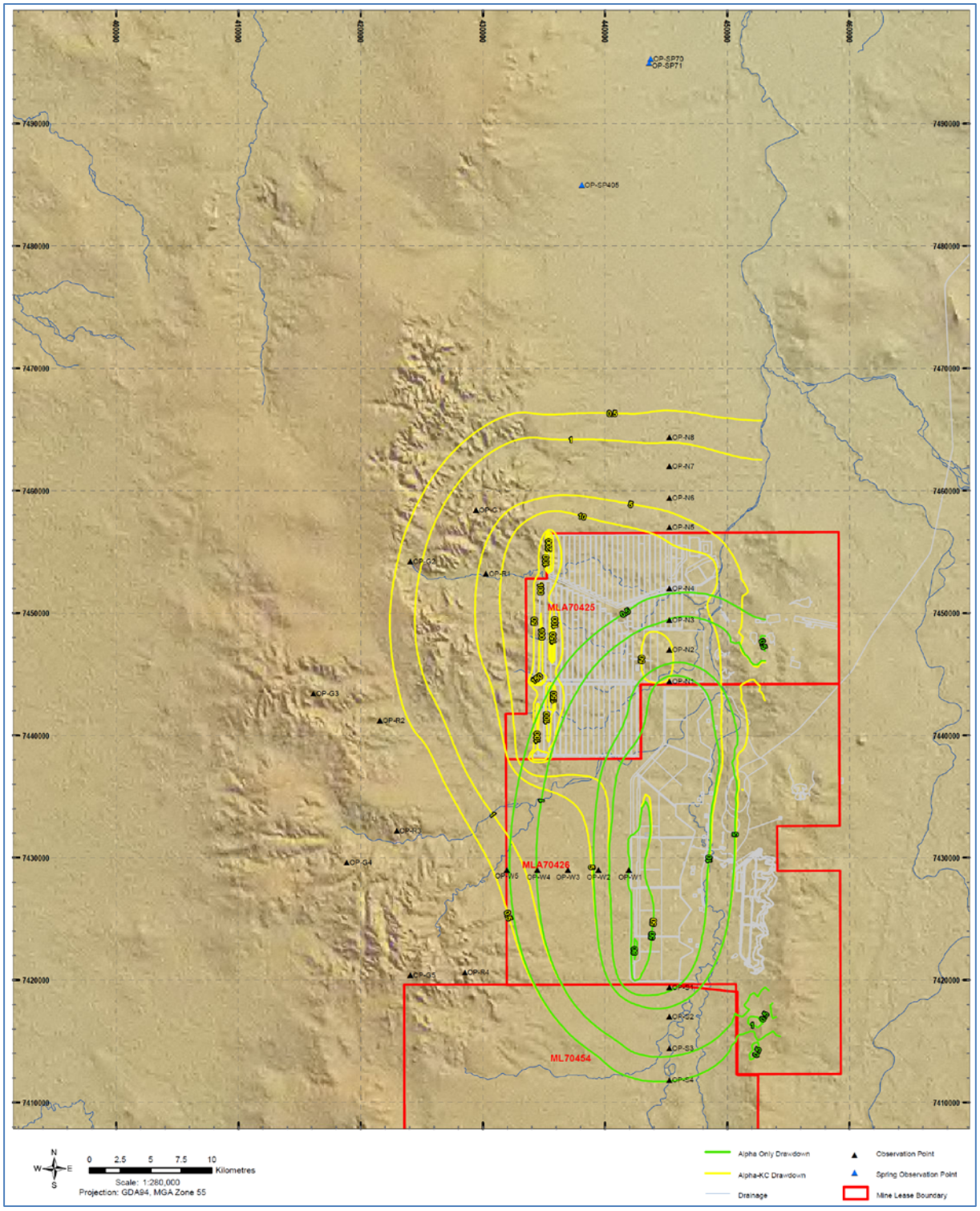
Figure 10-11 Predicted groundwater drawdown contours with D coal seam



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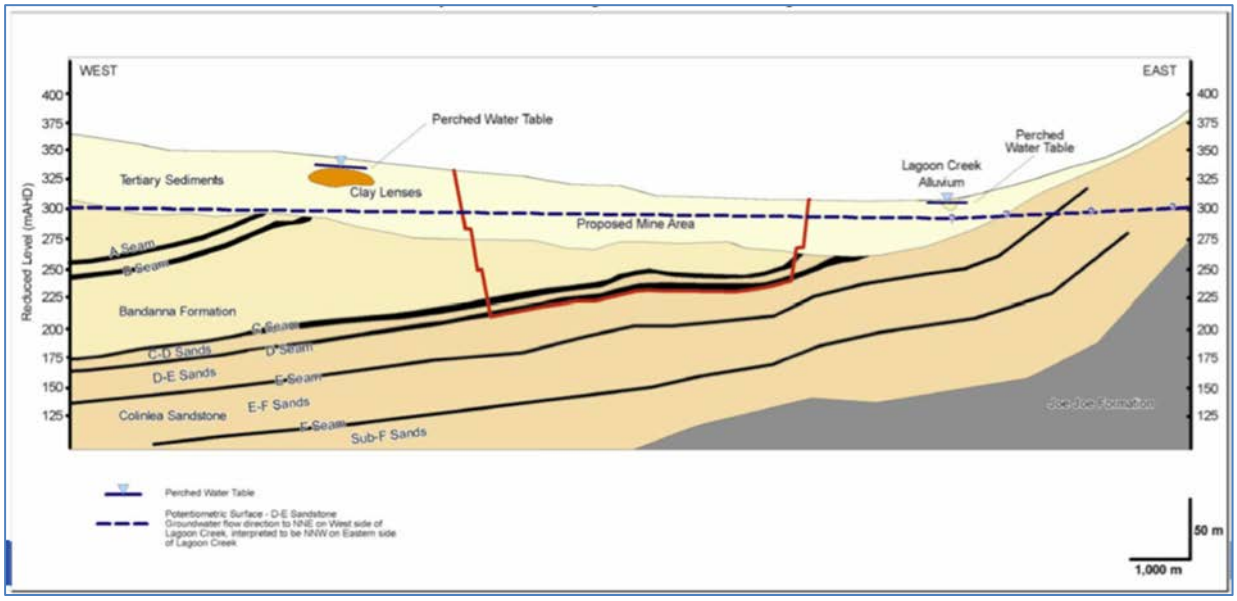
10.6.3 Assessment of potential impacts on vegetation communities

Based on drilling and field measurements presented in this report it was conceptualised that isolated perched water tables occur within the clay-rich Tertiary overburden (Figure 10-12). Groundwater level data for the confined and unconfined monitoring bores across the MLAs (**Appendix A**) indicate no hydraulic connection between the confined potentiometric levels and the perched water tables.

Figure 10-12 Perched water separate from confined potentiometric level



The dewatering groundwater monitoring data compiled during the construction of the test pit at Alpha have shown that there is no hydraulic link between the deeper aquifers and the perched aquifers. This is due to the presence of the laterisation of Permian sediments during the Tertiary period, which resulted in a thick clay confining layer (Figure 10-13). Monitoring data from a 20 m and a 40 m bore adjacent to the ATP (Figure 11-17) show that minor induced flow occurred at the base of the Permian laterite (40 m) over time, however, there was no impact of induced flow on the water level within the 20 m bore.

Vegetation communities (root depth) would occur within the zone not impacted by induced flow, i.e. above 20 m, and thus the isolated perched water tables (which may be used by vegetation communities) are not expected to be impacted by mine dewatering (induced flow) away from the pit.

The implications of this mean is that as groundwater is extracted during mine dewatering and depressurisation occurs, there will be limited potential for induced flow from impacts on the isolated (non-continuous) perched water aquifers because water will not be induced to flow down into the mine pit through the depressurised deeper aquifers. These perched water tables are regular recharged through rain and flood events and not reliant on upward groundwater movement.

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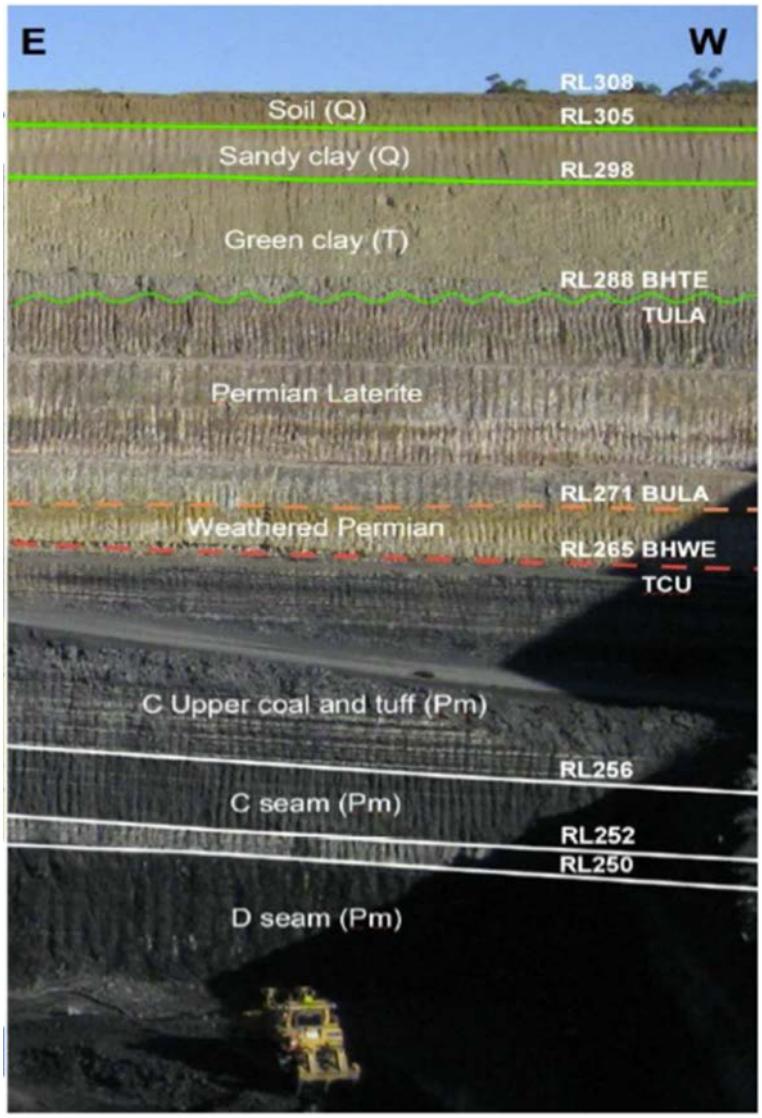
Table 10-10 Alpha test pit lithology



However, it is anticipated that there will be some impacts to the perched aquifers water table(s) due to induced direct drainage flow into the open mine voids the surface. It has been predicted that there will be a 10 to 100 m zone of influence directly around the mine void on the perched aquifers (Figure 10-11). This area will, however, be disturbed for mine infrastructure and services, thus the vegetation is considered to be removed in these area.

Figure 10-10 includes the predicted drawdown contours of the D seam at the end of mining. It is considered that there may be areas of thin laterite below perched water tables within the predicted drawdown cone, where there is a minor risk of induced downward flow. The possible area is located immediately adjacent to the mine disturbed area.

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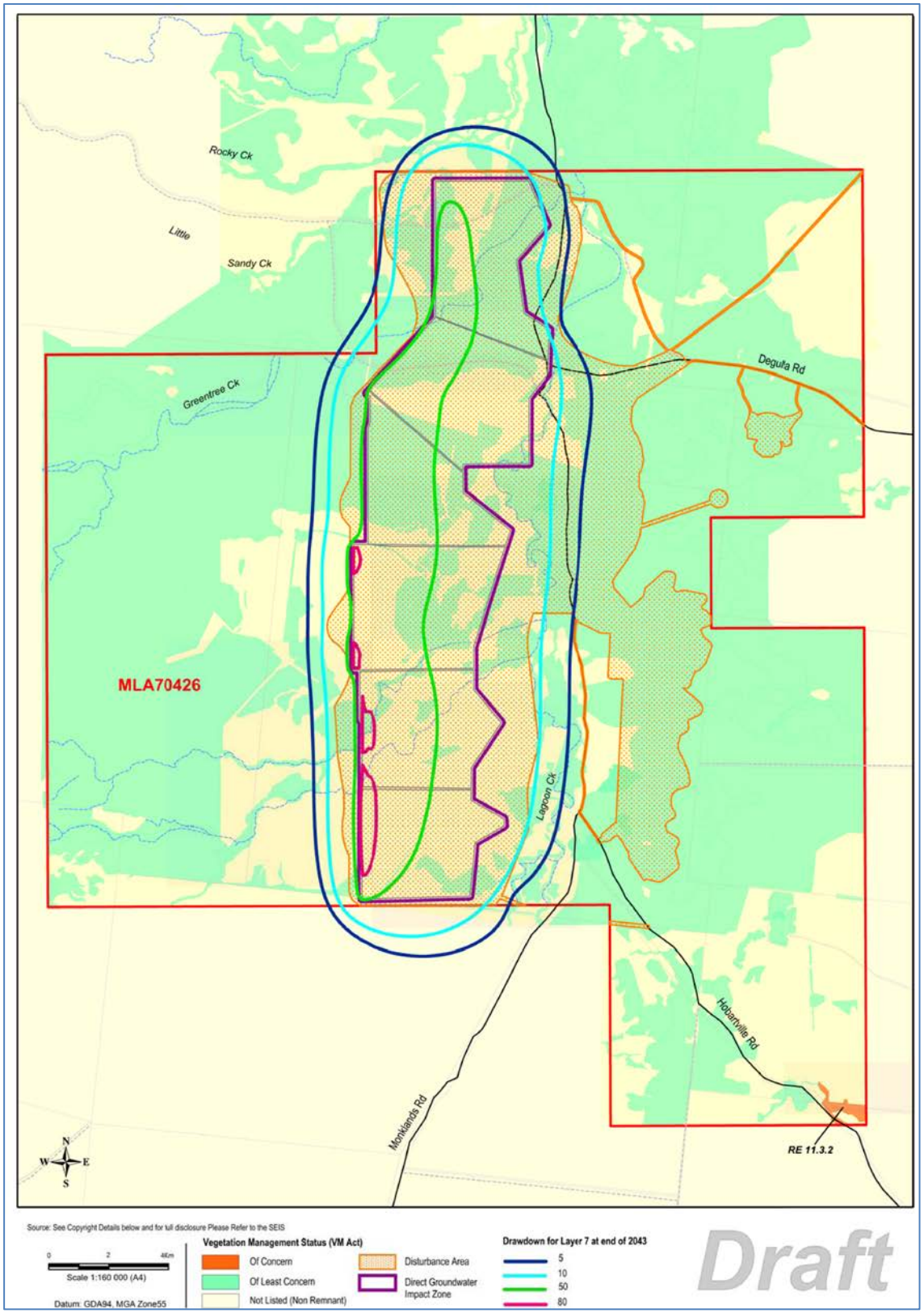
Figure 10-13 Vegetation and predicted groundwater drawdown in the D seam



10.6.4 Assessment of at-risk bores

Drawdown predictions from the predictive model allowed for the assessment of at-risk bores, where it is assumed that any bore (recorded during the study) within the predicted 1 and 5 m drawdown contours could potentially be impacted by mine dewatering.

These bores, as part of the Proponent's make-good commitment, will be field verified and assessed as part of any make good agreements. The bore data sources include:

- Registered bores on the DERM database;
- A bore survey conducted by 4T Consultants during the EIS process, within ~ 10 km of the MLAs; and
- Existing monitoring bore network.

As the majority of the bores have little or no data regarding construction and aquifer, the approach to be taken is to validate and assess all existing bores within these drawdown contours prior to mining. This will allow for the compilation of all available groundwater use and develop the optimum make-good strategies.

Figure 10-14 presents the predicted drawdown and recorded bores. Table 10-11 provides a summary of the at-risk bores related to the predicted Alpha only drawdown cones.

Table 10-11 Alpha at-risk bore summary

Bore ID	Type of Bore	Site Location	Lease	Notes/Comments
33054	DERM Registered	Kevin's Corner	Wendouree	Confirmed during 2010 Private Bore Survey
69458	DERM Registered	Kevin's Corner	Wendouree	Confirmed during 2010 Private Bore Survey
KMB-05	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Standpipe bore, monitoring C-D Sandstone
1637L	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Pump test bore, monitoring D-E Sandstone
1638L	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Pump test bore, monitoring D-E Sandstone
KMB-04	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Standpipe bore, monitoring D-E Sandstone
103479	DERM Registered	Kevin's Corner	Wendouree	Unable to locate during 2010 Private Bore Survey
90179	DERM Registered	Alpha	Hobartville	Unable to locate during 2010 Private Bore

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				Survey
15405	DERM Registered	Waratah	Kia Ora	Confirmed during 2010 Private Bore Survey
15406	DERM Registered	Waratah	Kia Ora	Confirmed during 2010 Private Bore Survey
12030077	DERM Registered	Waratah	Kia Ora	Confirmed during 2010 Private Bore Survey
12030076	DERM Registered	Waratah	Kia Ora	Confirmed during 2010 Private Bore Survey
Not Registered	2010 Private Bore Survey	Waratah	Monklands	Confirmed during 2010 Private Bore Survey - Not Registered with DERM or with Unknown RN
ATSF-08C	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Surficial Sands/Top of Laterite
ATSF-08B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Joe-Joe Formation
ATSF-09A	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Joe-Joe Formation
ATSF-09B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Surficial Sands
ATSF-04B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Laterite
ATSF-05B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Joe-Joe Formation
ATSF-05C	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Laterite
90182	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey
KMB-03A	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Standpipe bore, monitoring Surficial Deposits

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KMB-03B	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Standpipe bore, monitoring Tertiary Deposits
1635R	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Pump test bore, monitoring D-E Sandstone
1636R	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Pump test bore, monitoring C-D Sandstone
KMB-06	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Standpipe bore, monitoring D-E Sandstone
KMB-07	On-site GW Monitoring Bore	Kevin's Corner	Wendouree	Standpipe bore, monitoring C-D Sandstone
33057	DERM Registered	Alpha	Wendouree	Unable to located during 2010 Private Bore Survey
33053	DERM Registered	Alpha	Wendouree	Confirmed during 2010 Private Bore Survey (URS ID 236)
51064	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey
69730	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey
69731	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey
AMB-01	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring D-E Sandstone
AMB-02	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring E-F Sandstone
AMB-03	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring D-E Sandstone
AMB-04	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring C-D Sandstone

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ATSF-01B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Laterite
ATSF-02	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Conglomerate within Laterite
ATSF-03	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Conglomerate within Laterite
ATSF-06B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring D-E Sandstone
ATSF-06C	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Surficial Deposits
ATSF-07B	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Base of Laterite
ATSF-07C	On-site GW Monitoring Bore	Alpha	Hobartville	Standpipe bore, monitoring Base of Surficial Sands
90181	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey
90180	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey
69732	DERM Registered	Alpha	Hobartville	Confirmed during 2010 Private Bore Survey

Alpha Model:

- 21 bores are at a potential risk of a drawdown of 1 meter
  - 9 DERM Bores Confirmed During 2010 Private Bore Survey
  - 11 On-Site Monitoring Bores
  - 1 Bore Located During 2010 Private Bore Survey but Not Registered or with Unknown RN
- 25 bores are at a potential risk of a drawdown of up to 5 meters
  - 8 DERM Bores Confirmed During 2010 Private Bore Survey
  - 17 On-Site Monitoring Bores

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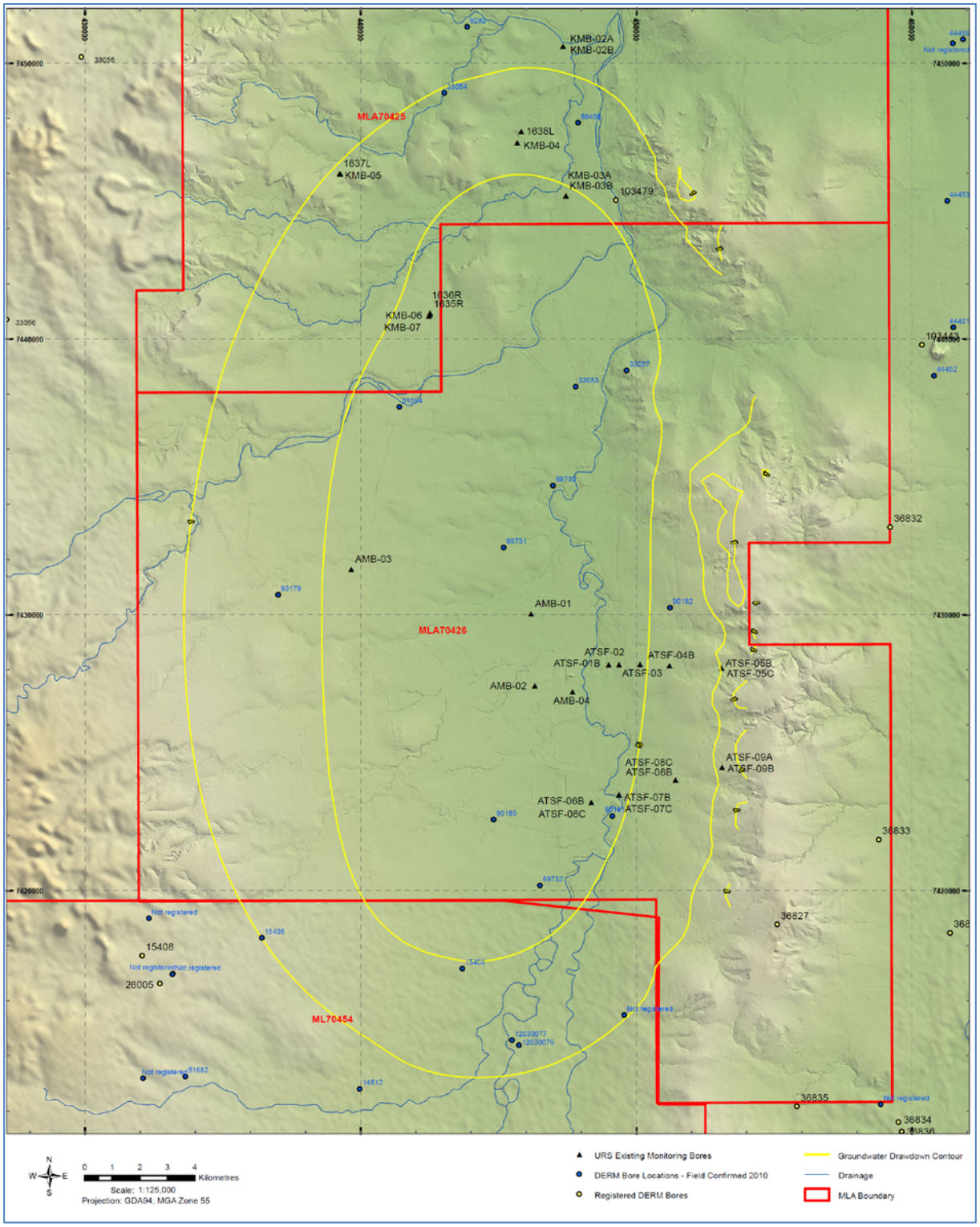
Figure 10-14 Alpha at-risk bores



Predicted cumulative drawdown cones, for Alpha and Kevin's Corner were projected to the end of mining. The resultant 1 and 5 m contours are included on Figure 10-15 along with the bore datasets.

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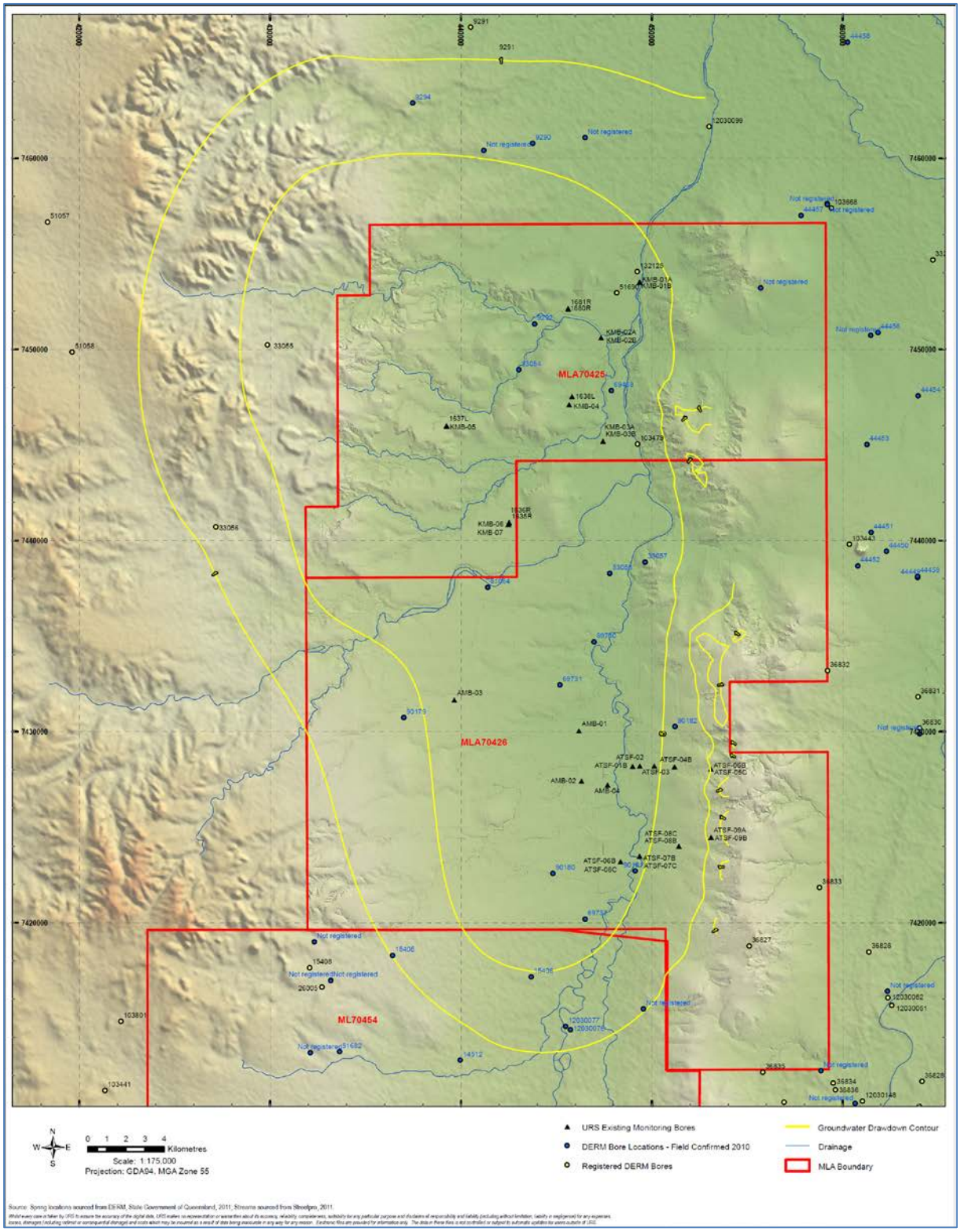
Figure 10-15 Alpha and Kevin's Corner at-risk bores



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Based on the cumulative Alpha and Kevin's Corner predictive modelling, the following bores are considered at-risk:

- 20 bores are at a potential risk of a drawdown of 1 meter
  - 10 DERM Bores Confirmed During 2010 Private Bore Survey
  - 7 On-Site Monitoring Bores
  - 3 Bore Located During 2010 Private Bore Survey but Not Registered or with Unknown RN
- 42 bores at a potential risk of a drawdown of up to 5 meters
  - 15 DERM Bores Confirmed During 2010 Private Bore Survey
  - 27 On-Site Monitoring Bores

It is considered that the additional bores identified will be assessed, for make-good commitments, as proposed for Alpha within the Kevin's Corner EIS commitments.

11

Model Revision for Additional Impact Assessment

Based on requests for data compiled post EIS submission, additional predictive groundwater modelling was undertaken to allow for an assessment of possible risks with regards to:

- The GAB aquifer, the Clematis Sandstone, and the GAB basal unit, the Rewan Formation;
- Registered springs to the north of Alpha and Kevin's Corner coal projects;
- Direct and indirect impacts of mining on vegetation communities;
- Sub-E coal seam sandstone, which has been identified as a source of make-good water; and
- Cumulative impacts through assessing the model predictions for Alpha alone and then comparing the results of simulating Alpha and Kevin's Corner.

In order to best simulate mining activities on the groundwater resources to provide a more detailed assessment of potential risks to the assessment areas listed above, the predictive model was further refined and reconfigured to allow for more accurate simulations of mine dewatering and depressurisation.

The model refinement included:

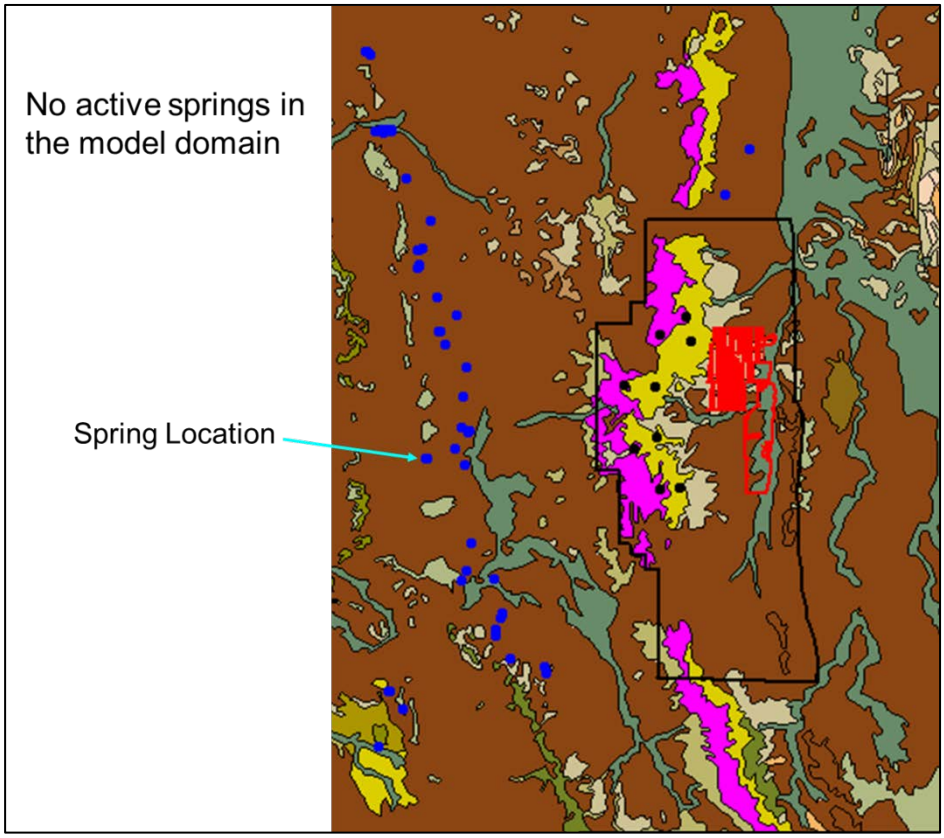
- Increased model domain to include the registered springs north of MLA70425 and MLA70426;
- Revision of the elevation data, outside of the MLAs, using more accurate dataset;
- Model layer parameter change to better represent the upper layers, either GAB or Tertiary units; and
- Revised model layer calibration, using Alpha Test Pit transient data to obtain parameter data for the Tertiary layers.

11.1 Predictive model refinement

The constructed and calibrated predictive groundwater resource (ingress) model, discussed in Sections 8, 9, and 10, did not include any registered springs (Figure 11-1). The model domain was increased northwards to include the three registered springs (Figure 11-2). The western model boundary matches a water divide (as discussed in Section 7.4 and 8.5) and thus was not moved further to the west.

11 Model Revision for Additional Impact Assessment

Figure 11-1 Predictive model domain and registered springs



The model grid size, 200 m x 100 m, over the mining area remains, however, the grid size was increased further away, as shown in Figure 11-2, keeping the aspect ratio under 1: 10.

The revised model domain now covers:

- The model area has increased to 5,404 km^2 (118.5 km x 45.6 km);
- 321 rows and 320 columns; and
- 904,915 active cells for an eleven-layer model.

Topography data, Figure 8-1, in the predictive groundwater model included 9 second (250 m spacing) digital terrain model (DTM) data (available from Geoscience Australia) outside of the MLAs. The MLA DTM is at 1 m contour intervals. Additional elevation data, 3 second (90 m spacing) was subsequently made available from Geoscience Australia[8], which allowed for an update of the land surface (Figure 11-3). This does not change the groundwater ingress predictions but allows for a more representative evaluation of changes in groundwater level.

[8] SRTM 3 second Digital Elevation Model data

11 Model Revision for Additional Impact Assessment

Figure 11-2 Refined model domain and registered springs

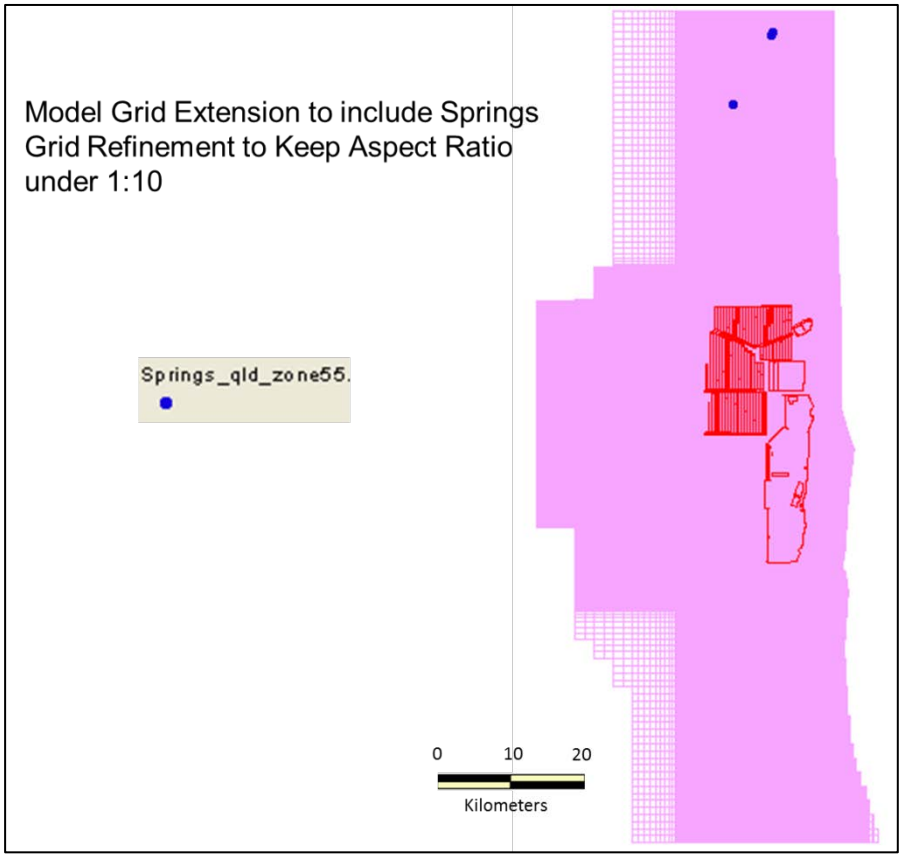
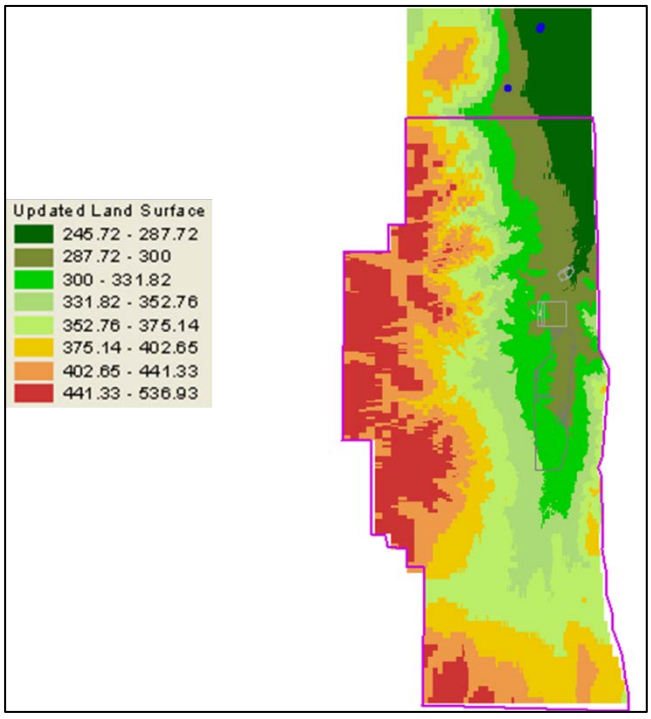


Figure 11-3 Updated land surface data across model domain and registered springs

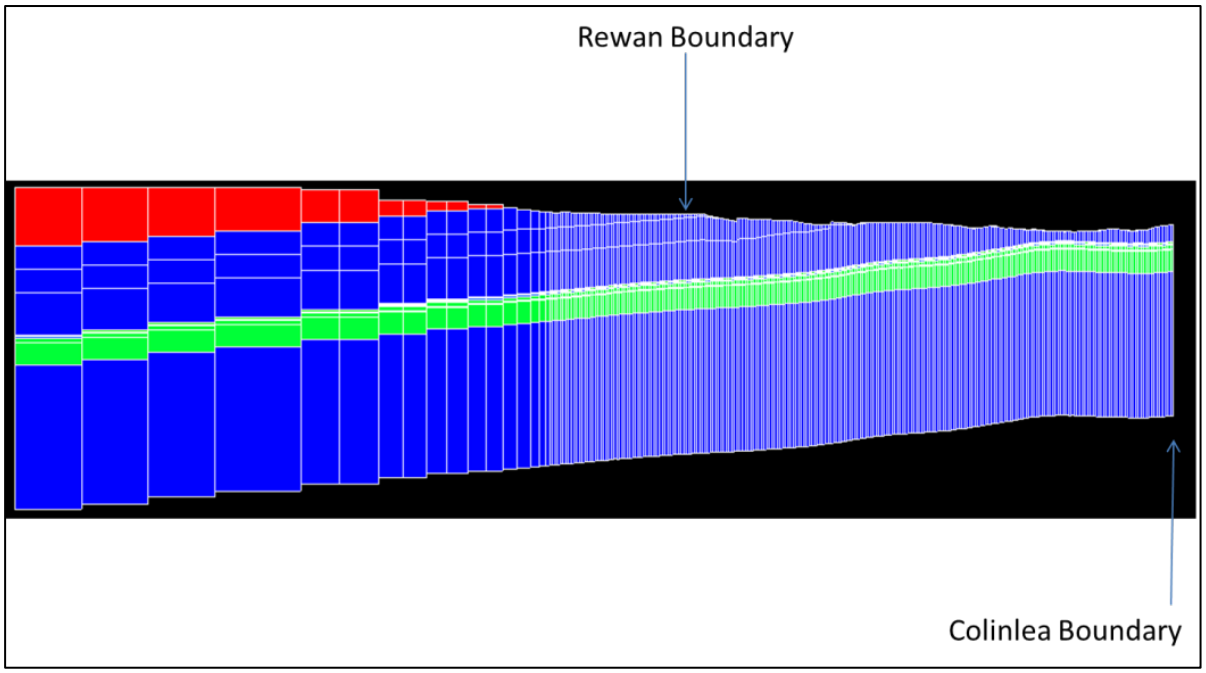


11.2 Model layer refinement

In order to best assess the potential impacts on mine induced dewatering, i.e. possible induced flow from the perched water tables to the depressurised units adjacent to the mine footprint, the upper model layers were refined to allow for the representation of the Tertiary layers. **PLEASE NOTE**: these layers are not saturated based on field drilling and water level monitoring (**Appendix A**); however, for the purposes of assessing possible risk these upper Tertiary layers were assumed to have the same initial groundwater levels as those used in the steady-state calibration (Section 9).

The model layers have been changed across the model domain to better assess the overlying units, as recognised in Figures 4-7 and 4-8. Figure 11-4 shows the model layering within the predictive model, which was revised as shown in Figure 11-5. The changes allow for different units (e.g. GAB Clematis Sandstone and Tertiary overburden) to be represented (thickness and aquifer hydraulic parameters) within the top layers. Table 11-1 presents the revised model layering, which still comprises 11 model layers.

Figure 11-4 Predictive model layering



11 Model Revision for Additional Impact Assessment

Figure 11-5 Revised model layering

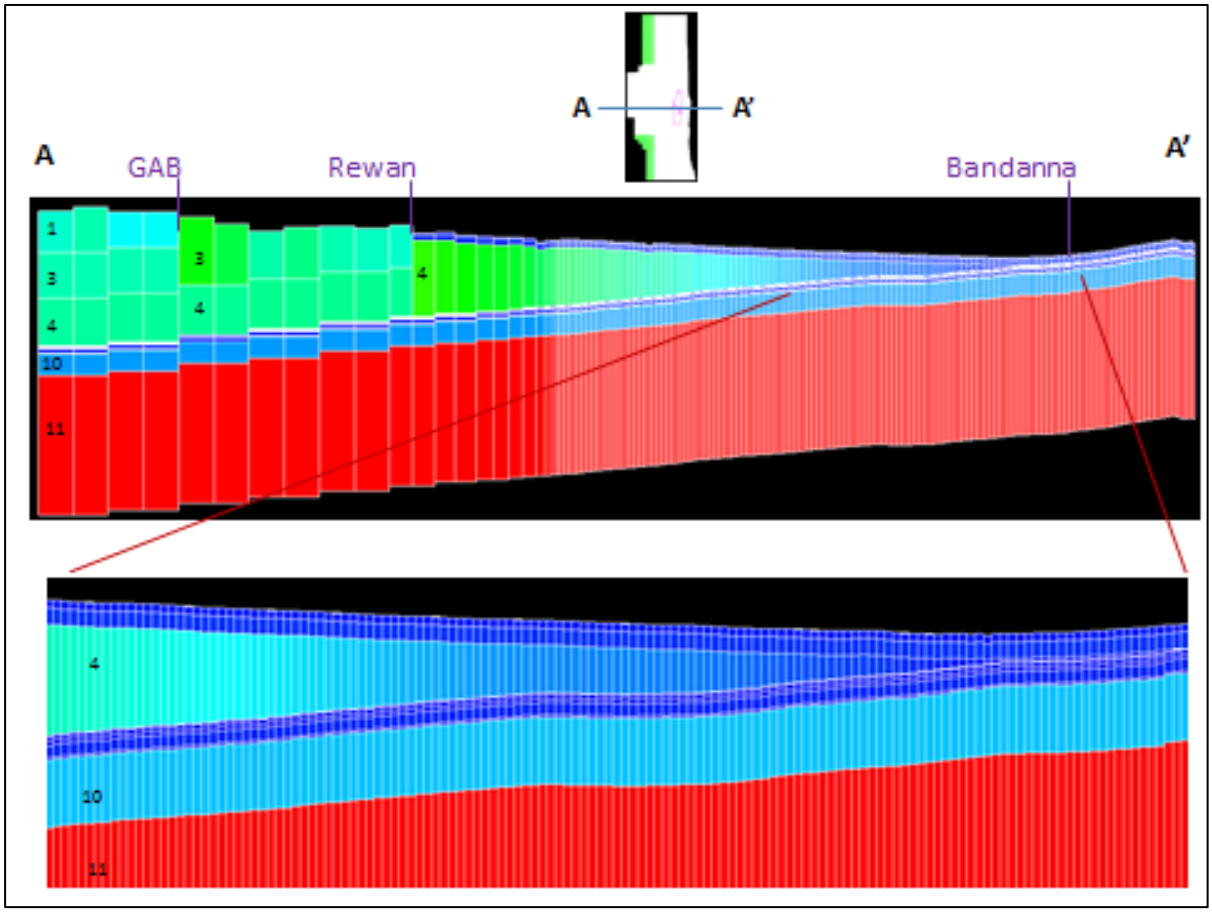


Table 11-1 Refined model layers

Unit	Model Layer	Thickness (m)
GAB	1	0.1 to 266
Tertiary sediment	2	0.1 to 21 (mostly for 10)
Rewan/Tertiary laterite	3	0.1 to 414 for Rewan; 0.1 to 20 for laterite
Bandanna Formation	4	0.1 to 436
C seam	5	2
C-D sandstone	6	5
D seam	7	5
D-E sandstone	8	15
E seam	9	3
Sub E sandstone	10	82
Joe Joe Formation	11	540

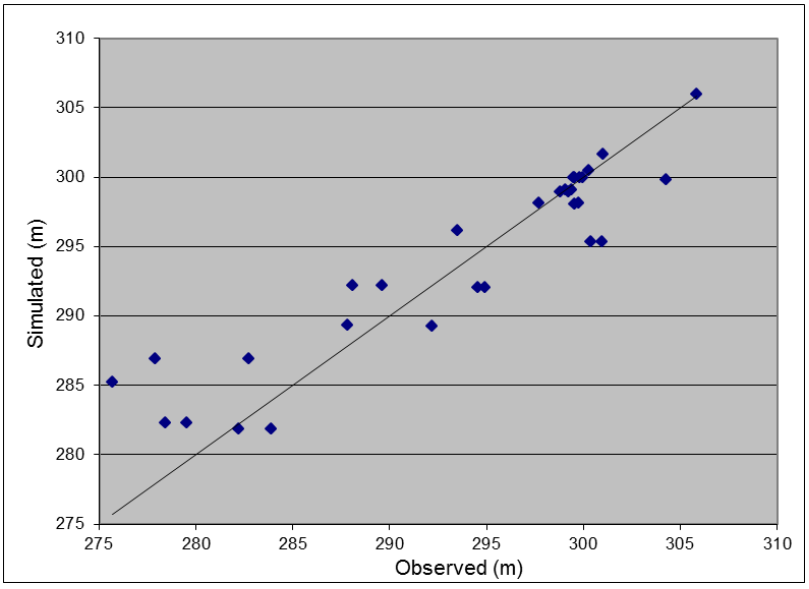
11.3 Refined model layer parameters

The transient data compiled during the ATP dewatering, including monitoring data for the 20 m and 40 m monitoring bores adjacent to the ATP, as described in Section 8 and **Appendix C** was used to calibrate the revised model. The monitoring bores and locations adjacent to the ATP are presented in **Appendix A and Appendix C**. The calibration statistics for the refined model are compiled in Table 11-2 (steady-state) and Table 11-3 (transient). The steady state simulated heads versus field measured data is included in Figure 11-6.

Table 11-2 Steady-state calibration statistics for refined predictive model

Calibration Statistics	Steady-State Calibration (31 observations)
Mean Error (m)	-0.44
RMSE (m)	3.39
Standard Deviation (m)	3.41
Head Range (m)	105.00
Mean Error %	-0.42%
RMSE %	3.2%
Standard Deviation %	3.3%
R^2	0.87

Figure 11-6 Simulated versus observed head values for steady-state calibration



11 Model Revision for Additional Impact Assessment

The resultant simulations versus field measured drawdown curves, ensuring the similar volumes of groundwater were extracted (45.3 ML) are shown in Figure 11- 7 and Figure 11-8.

Figure 11-7 Simulated versus field measured drawdown curves

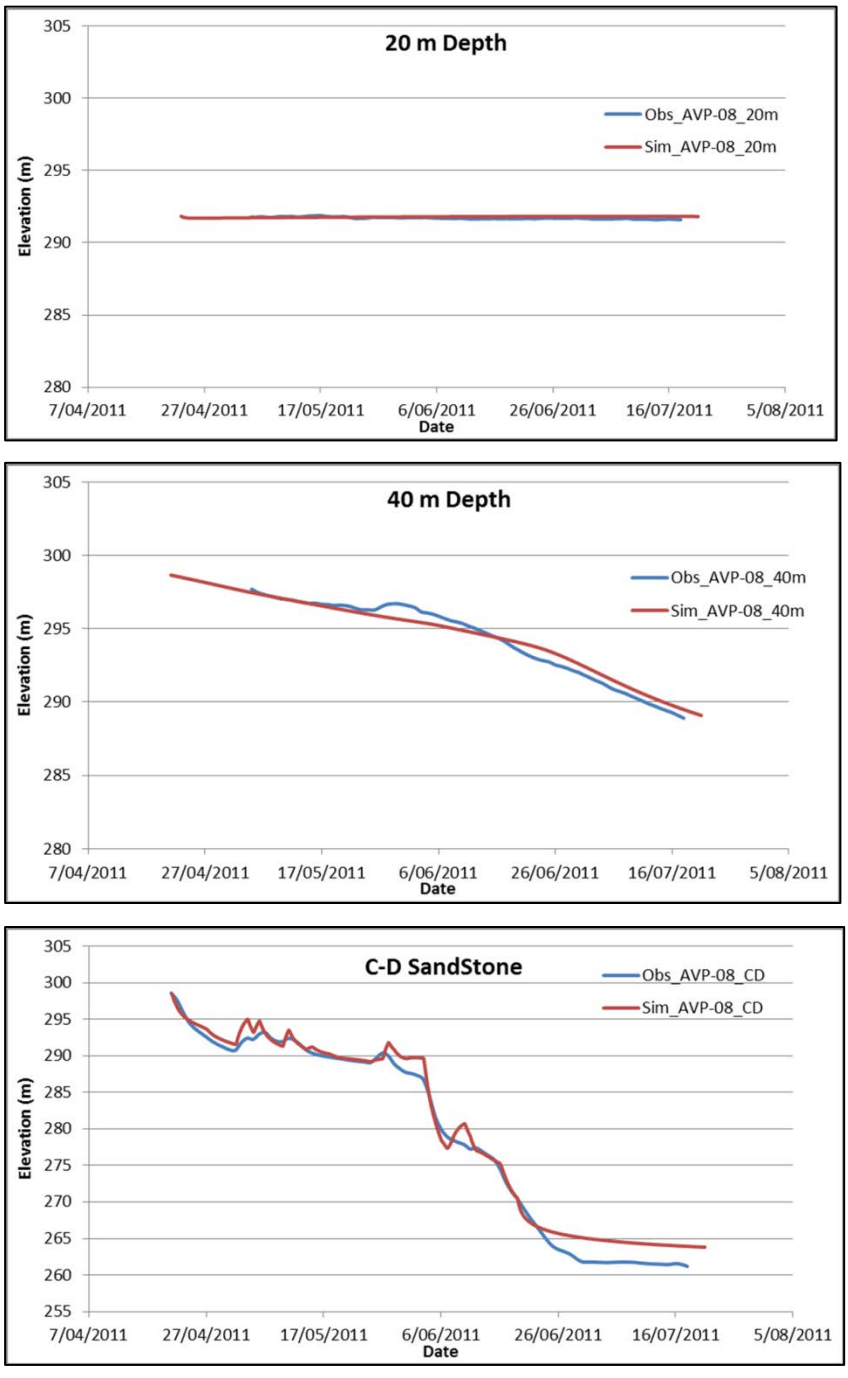


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Figure 11-8 Simulated versus field measured drawdown curves (part 2)

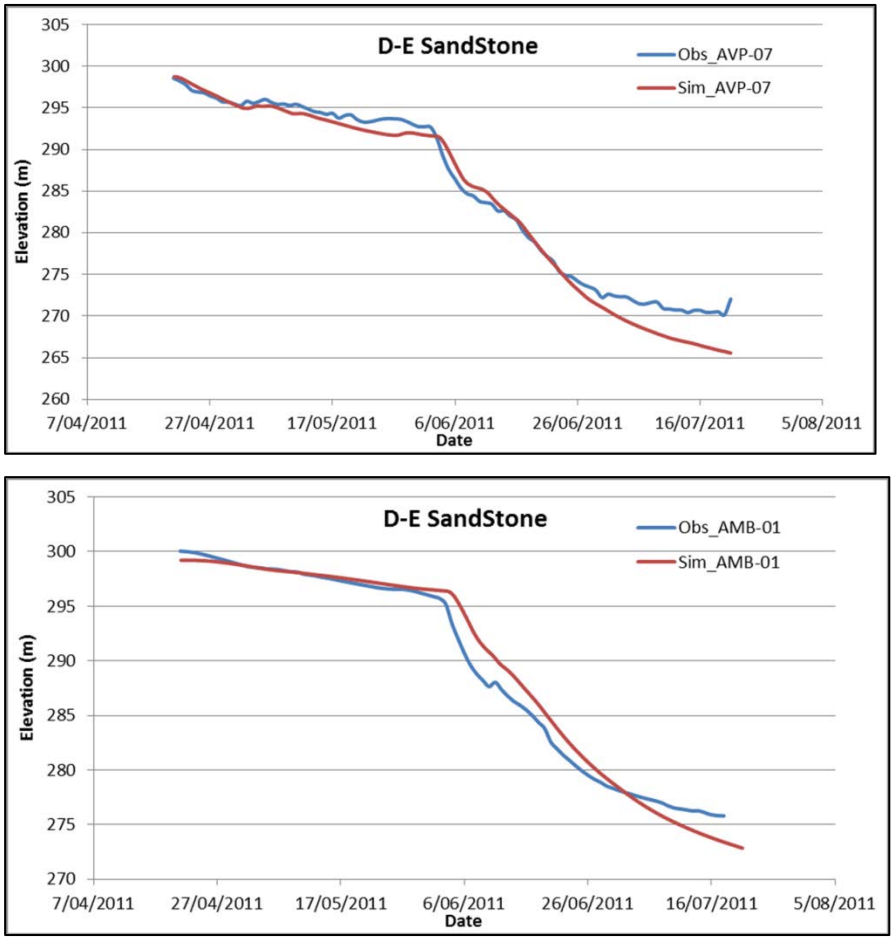


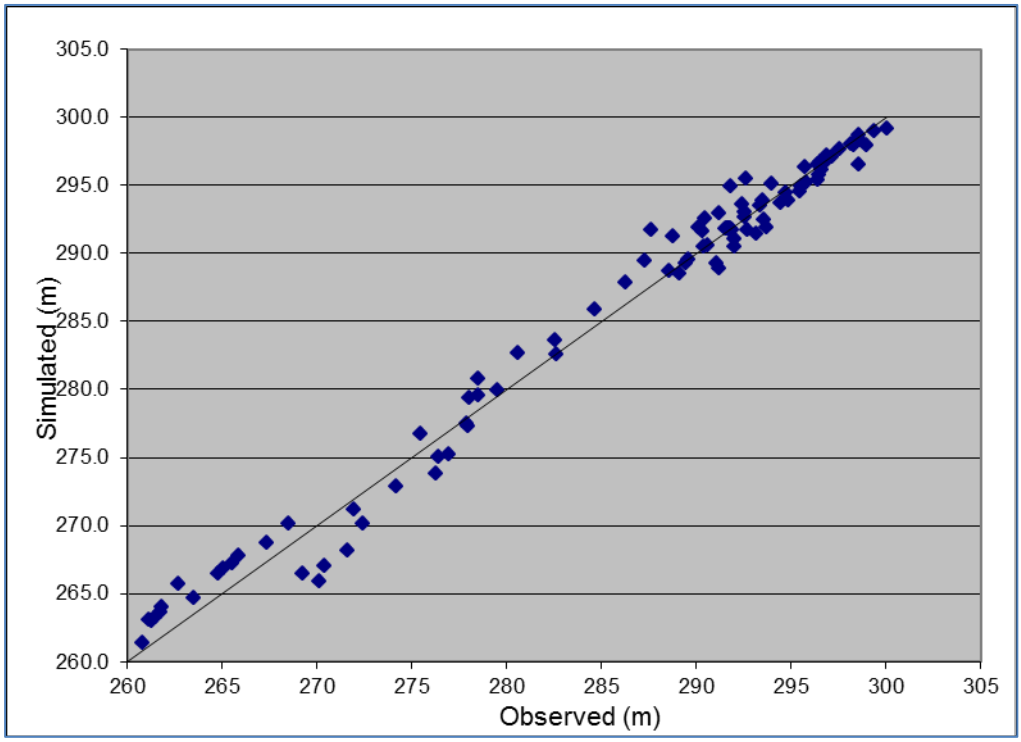
Table 11-3 Steady-state calibration statistics for refined predictive model

Calibration Statistics	Transient Calibration (79 observations)
Mean Error (m)	-0.16
RMSE (m)	1.48
Standard Deviation (m)	1.48
Head Range (m)	49.15
Mean Error %	-0.33%
RMSE %	3.0%
Standard Deviation %	3.0%
R^2	0.98

A scatter plot of overall simulated versus observed groundwater levels is shown in Figure 11-8 for transient calibration. The relationship follows a straight line with a R^2 value of 0.98.

11 Model Revision for Additional Impact Assessment

Figure 11-9 Simulated versus observed head values for transient calibration



11.3.1 Calibration comments

The root-mean-square error (RMSE) was used to evaluate the performance of model calibration based on groundwater levels. Good agreements between calibrated results and field measurements usually have RMSE less than 10 % of the difference between the maximum and minimum potentiometric heads across the model area. The RMSE for the revised steady-state calibration was 3.39 m, which was 3.2% of the approximate 105 m range of groundwater levels. A mean error (ME) of -0.42 indicated that no significant bias was evident.

The RMSE for the transient calibration was 1.48 m, which was 3.0% of the approximate 49 m range of groundwater levels across the model area. The simulated dewatering volume totalled 44.6 ML, which is close to the estimated volumes calculated using the field measurements of 45.3 ML. The summary of calibration statistics was listed in Table 11-3.

11.4 Refined model layer parameters

The updated parameter values for the refined predictive model, allowing for layer and model domain changes, is included in Table 11-4. These values differ to those presented in Section 9.5.

11 Model Revision for Additional Impact Assessment

Table 11-4 Refined model parameters

Model Layer	Unit	Kx (m/d)	Kz (m/d)	Sc	Sy
1	GAB	5.60E+00	5.60E-01	6.00E-04	5.01E-02
2	Tertiary sediment	1.00E-01	1.00E-02	6.00E-04	5.01E-02
3	Rewan	1.00E-04	1.00E-05	4.56E-04	8.41E-03
3	Tertiary laterite	1.00E-03	1.00E-05	4.56E-04	8.41E-03
4	Bandanna Formation	1.76E-03	1.76E-04	4.56E-04	8.41E-03
5	C seam	1.00E-02	1.00E-05	9.77E-06	8.02E-03
6	C-D sandstone	1.00E-01	1.00E-04	6.23E-06	8.03E-03
7	D seam	1.00E-02	1.00E-05	9.77E-06	8.02E-03
8	D-E sandstone	5.00E-02	5.00E-05	4.56E-04	8.41E-03
9	E seam	1.00E-02	1.00E-05	9.77E-06	8.02E-03
10	Sub E sandstone	5.00E-02	5.00E-05	4.56E-04	8.41E-03
11	Joe Joe Formation	1.00E-04	1.00E-05	4.56E-04	8.41E-03

The refined model was then used to reassess potential groundwater level drawdown and impacts (during operations and long term). Observation points were included in the refined predictive model, which allowed for the evaluation of groundwater level changes, over time and distance, within the various model layers as a result of mining. The impact assessment is detailed in Section 13.

12

Integrated Model

Long term groundwater level predictions were evaluated using an integrated (surface water runoff – groundwater) model. This model, utilising the end of mine groundwater heads, was constructed to allow for an assessment of potential long term impacts on groundwater resources, within the modelled layers, over time (~ 300 years post mining) and spatially. The prediction of final void water levels and long term groundwater levels, flow patterns, and gradients allowed for further assessment of risks to the following:

- The Clematis Sandstone;
- The Rewan Formation;
- Registered springs;
- Vegetation communities; and
- Sub-E coal seam sandstone.

12.1 Initial Conditions

On completion of mining it is envisaged that all pumping from the final mine voids (final void) will cease and that groundwater levels will begin to rebound. The groundwater level contours at the end of mining are predicted through the refined predictive groundwater model (detailed in Section 11) and are presented in Section 13 (impact assessment). These contour levels were used as initial conditions for the recovery simulation of the final void.

12.2 Integrated Modelling Approach

An assessment of hydrological and salinity performance of the final void is typically done using separate groundwater models and runoff models, requiring merging of datasets to calculate water and salt balances based on flux contributions from individual modelling components. One major disadvantage of this approach is the lack of consideration of the dynamic interactions between the separate components. Pre-defined conditions or assumptions in separate simulations lack dynamic adjustments in the simulation. This approach can potentially result in misleading interpretations based on the incomplete simulation results.

In contrast, an integrated surface/subsurface flow and transport modelling approach provides a more accurate assessment of final void hydrology based on complete hydrologic simulation. The only in/out- flux components to the integrated hydrologic system are rainfall and evapotranspiration. The remaining flux components are derived within the integrated system based on physical parameters obtained through model calibration and/or field measurements. Since this approach includes flow and transport simulations in an integrated system, it allows for predictions of equilibrated water levels and salinities in the final void.

MODHMS was utilised to construct the integrated surface/subsurface model to simulate groundwater recovery in the final void stage. The predictive water levels and salinities were simulated for 300 years after cease of mining.

12.3 Integrated Model Conceptualisation

The integrated model was constructed based on the refined predictive groundwater model with an additional model layer created to represent the overland flow surface. The groundwater flow domain was the same as the refined groundwater model (Section 11) and the overland flow domain was created for the Alpha site as the disturbed mining area is to be contained (i.e. secondary containment

12 Integrated Model

bunds are to be constructed around the mine footprint) such that it will not have external surface runoff interactions.

Figures 12-1 and 12-2 show the model extents and land surface elevations of groundwater flow and overland flow domains. Based on projected mine activities, resulting in a final void and rehabilitated backfilled areas over the life of mine, the land surface in the integrated model was updated (from the DTM data) to an envisaged final mine layout and surface, compiled by the Proponent (Figure 12-3). A west-east cross section, at a selected location, indicates the final void and out-of-pit spoil dump elevations included in the integrated model (Figure 12-4).

Figure 12-1 Land surface and groundwater flow domain

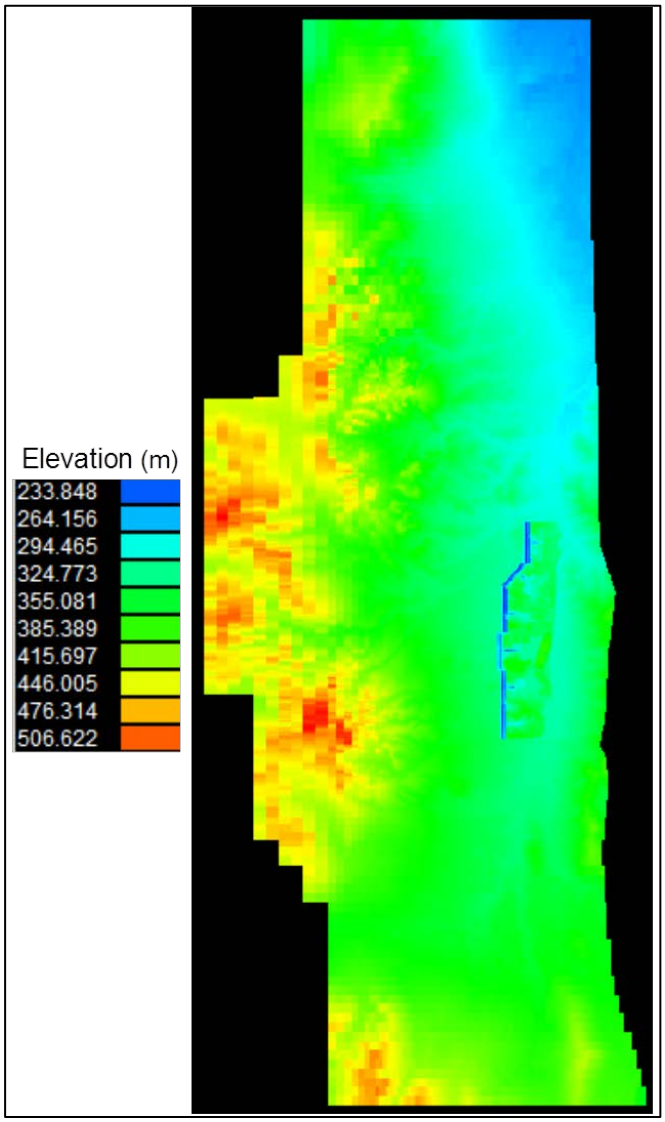


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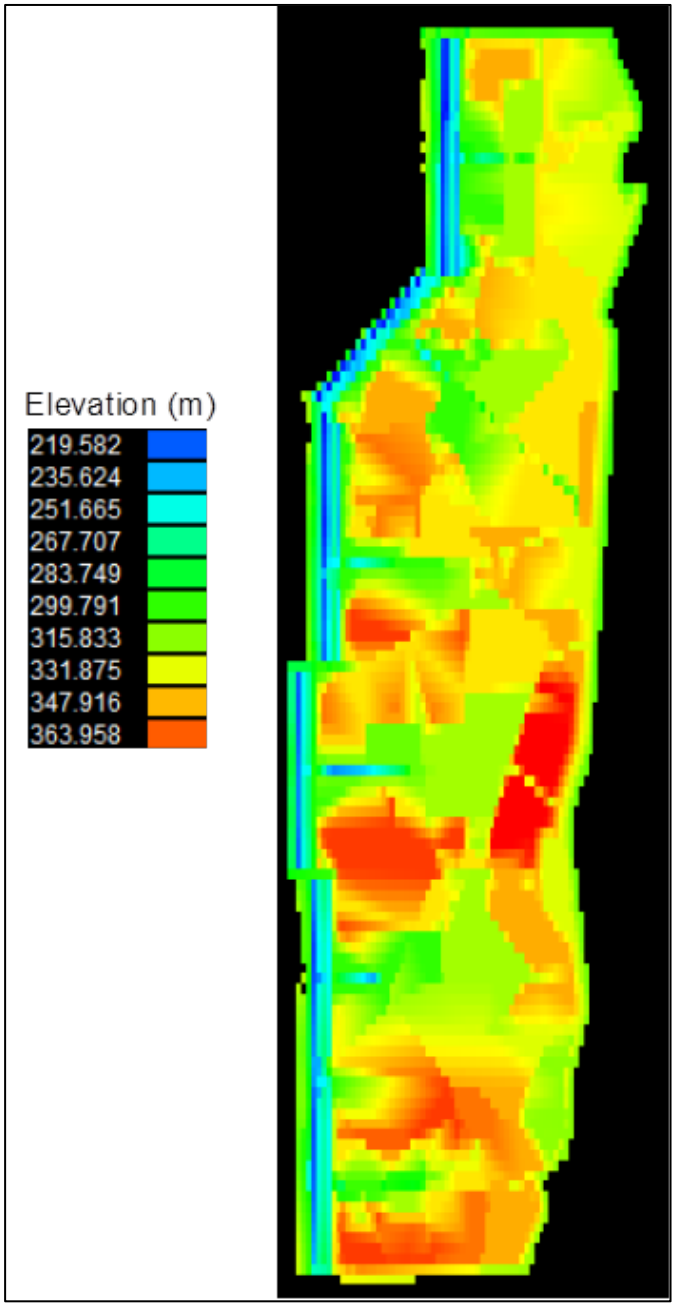
Figure 12-2 Land surface and overland flow domain (Alpha mine footprint)



Boundary conditions and model layer structure for the groundwater flow domain were the same as those included in the predictive groundwater model. Ephemeral creeks adjacent to the mine site were represented as drains within the groundwater flow domain. No flow boundary conditions were assumed for the overland flow domain as the mine footprint (Figure 12-2) will be contained within berms.

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Figure 12-3 Alpha final landform

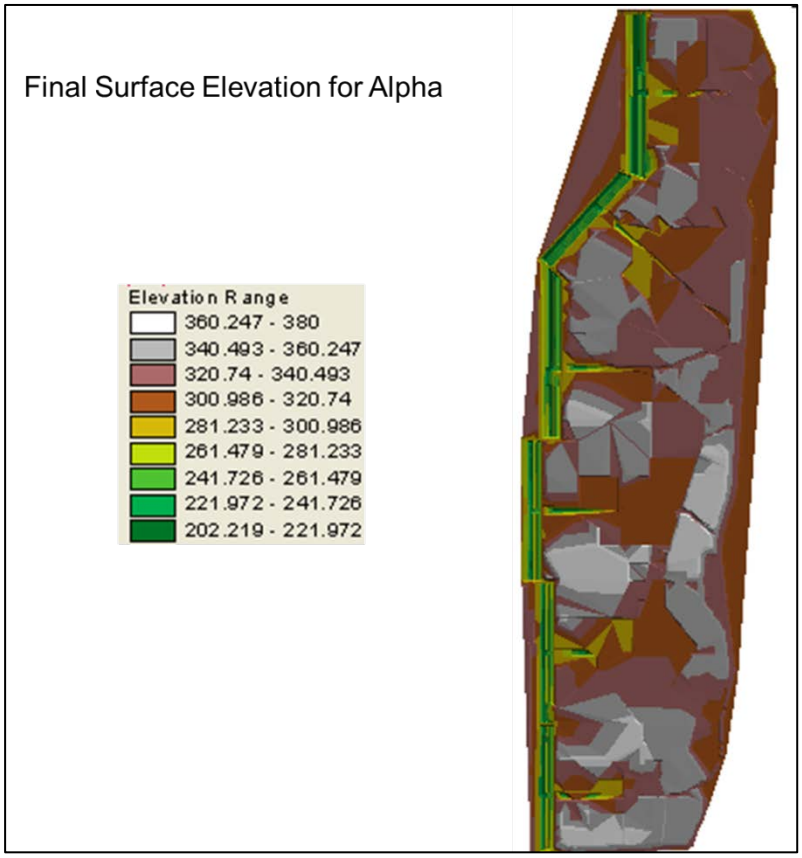
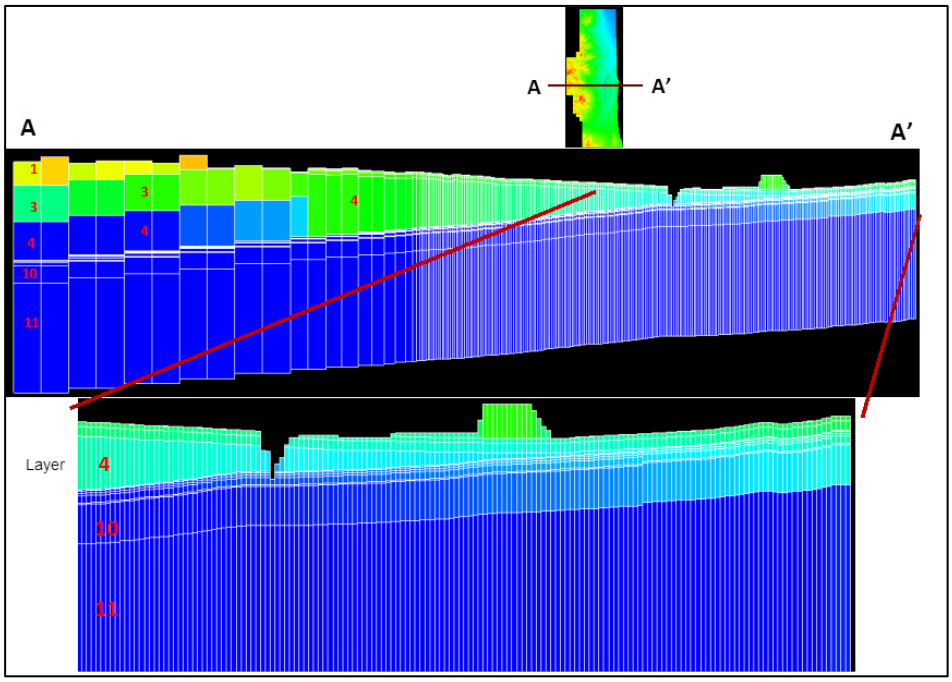


Figure 12-4 Cross-section through the groundwater flow domain (showing final void)



12.4 Integrated Model Assumptions

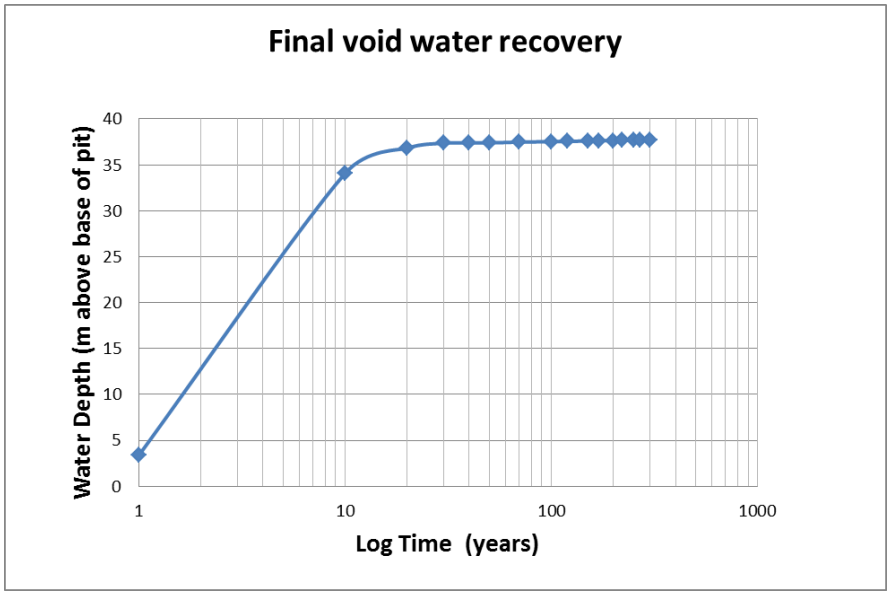
The following assumptions were made when constructing and running the integrated model:

- The physical and chemical properties of the backfill / spoil pile(s) remain constant throughout the modelled period;
- Groundwater levels are relatively deep below surface. Evaporation and transpiration impacts on groundwater are, therefore, considered to be of limited significance. Evaporation and transpiration are, however, included and combined with recharge, as net recharge, for the areas outside the disturbed mining area. Evaporation from land surface is considered only in the mining area, which accounts for the major outflow within the integrated model;
- Annual evaporation value of 1 148 mm was estimated as 50% of the potential evapotranspiration value (Section 4.1.2);
- Rainfall was only applied to the disturbed mine footprint area (as indicated in Figure 12-3) and was obtained based on annual average value (Section 4);
- Groundwater net recharge was applied outside the mining area and was obtained from predictive groundwater model calibration;
- The horizontal and vertical hydraulic conductivity values in the backfilled area were assumed to be 0.1 m/day and 0.01 m/day (well drained and rehabilitated), respectively; and
- Hydraulic conductivity and storativity were assumed to be homogeneous within each model layer.

12.5 Modelling Results

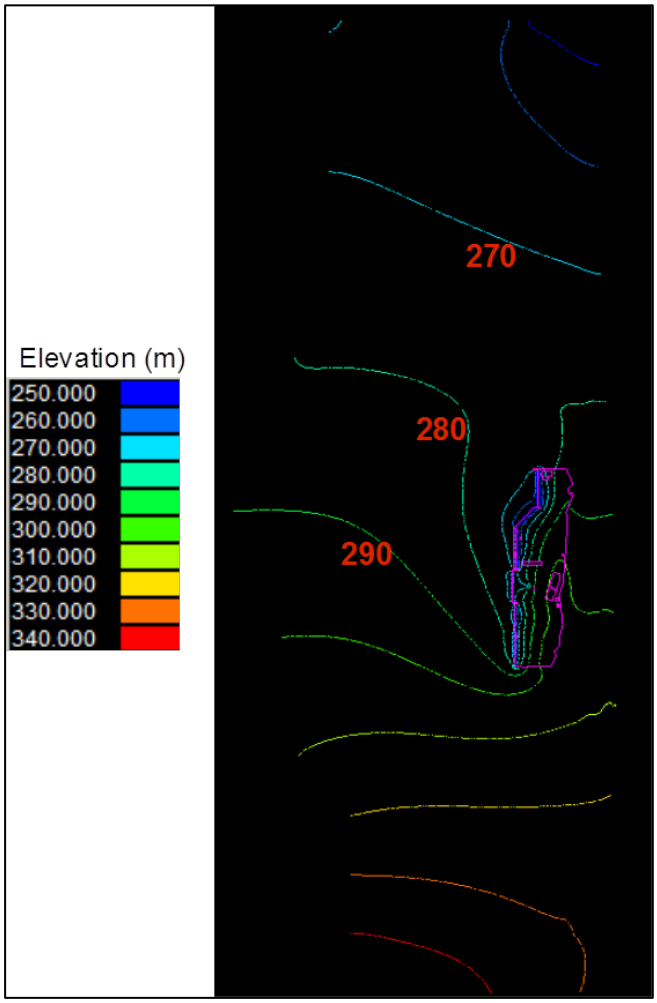
The integrated model, using the in- and output parameters and assumptions compiled in Section 12.4, was used to estimate the pseudo steady-state final void water level (i.e. an estimate of where the water level will rise to and stabilise over time based on in (rainfall recharge and runoff) and out (evaporation) flux components. Figure 12-4 presents a predicted final void water level change with time, based on an observation point in the middle of the final void. The final void water level reaches a pseudo steady-state after ~ 50 years, at around 37 m above pit floor (around 250 m AHD depending on location within the final void).

Figure 12-5 Final void water level recovery



The recovery simulation was conducted for 300 years. The simulated head contours for Layer 7 (D seam) after 300 years is presented in Figure 12-6. The long term changes in groundwater flow patterns, mainly around the northern and western sides of the final void, can be compared to the initial groundwater levels used during steady-state calibration (Figure 9-4).

Figure 12-6 Simulated water levels in D seam after 300 years



12.6 Uncertainty Analysis

Rainfall and evaporation are two major in/out flux components for the integrated model. Higher rainfall value will increase water level and dilute concentration in the pit, and the higher evaporation will work in the opposite way. Therefore, the final equilibrated water level and salinity in the pit are largely hinged on the choice of these two parameters.

The variations of plus/minus 10% of the average rainfall value were selected to perform influx uncertainty analysis. In addition, the increase of 10% and 20% from the base evaporation value (1 148 mm) were selected to conduct out flux uncertainty analysis. The simulated results, for an observation point in the middle of the final void, of the four scenarios are summarised in Table 12-1.

Table 12-1 Integrated model range of results (in m AHD)

Parameter variation	Base case	+10% rainfall	-10% rainfall	+10% evaporation	+20% evaporation
Predicted final void level	253.5	253.8	253.1	253.2	253.0

The predicted final void pseudo steady-state water level results, allowing for climate change, indicate that the variation in in / out flux components in the integrated model do not markedly alter predictions. The final void pseudo steady-state water level, for the northern portion (lowest elevation) of the final void was then used, recognising that the water level may vary by ~ 1 m depending on long term climate change / variation, in assessing potential decant risk.

12.7 Final Void Decant Potential

The lowest elevation point where decant could potentially occur is along the northern most portion of the final void, at an elevation of 305 m AHD. The projected final void water level in the northern portion of the final void is 249 m AHD, some 56 m below the lowest pit surface elevation. The risk of decant, of potentially poor quality water (discussed in Section 12.8), is therefore negligible as the volume of water required to fill the remaining void space would be in excess of 750 GL.

The potential additional rainfall ingress, using 1:100 year rainfall event volumes ~ 400 mm (based on the high rainfall data which resulted in flooding in 2011), over the disturbed mine footprint[9] would result in ~ 52 GL entering the void. This would increase the final void water level to 257 m AHD. This increase does not increase the risk of decant. Figure 12-7 provides a conceptual figure of the long term final void water level and D seam potentiometric level (based on predictions in Section 13).

12.8 Final Void Water Quality Assessment

An assessment of final void water quality over time was conducted using the integrated model. The modelling allowed for the following salinity (in terms of Total Dissolved Solids (TDS)) input:

- Composite groundwater quality with a TDS of 1,200 mg/L[10]; and
- Variable runoff quality based on surface conditions including TDS of 50 mg/L for rehabilitated areas, 100 mg/L for partially rehabilitated areas, and 200 mg/L for disturbed areas.

[9] The final void assessment assumes that disturbed footprint is contained within berms such that all rain water falling within the berms will reach the final void.
[10] The mean groundwater TDS value for composite groundwater samples collected from 313 open exploration bores across the MLAs.

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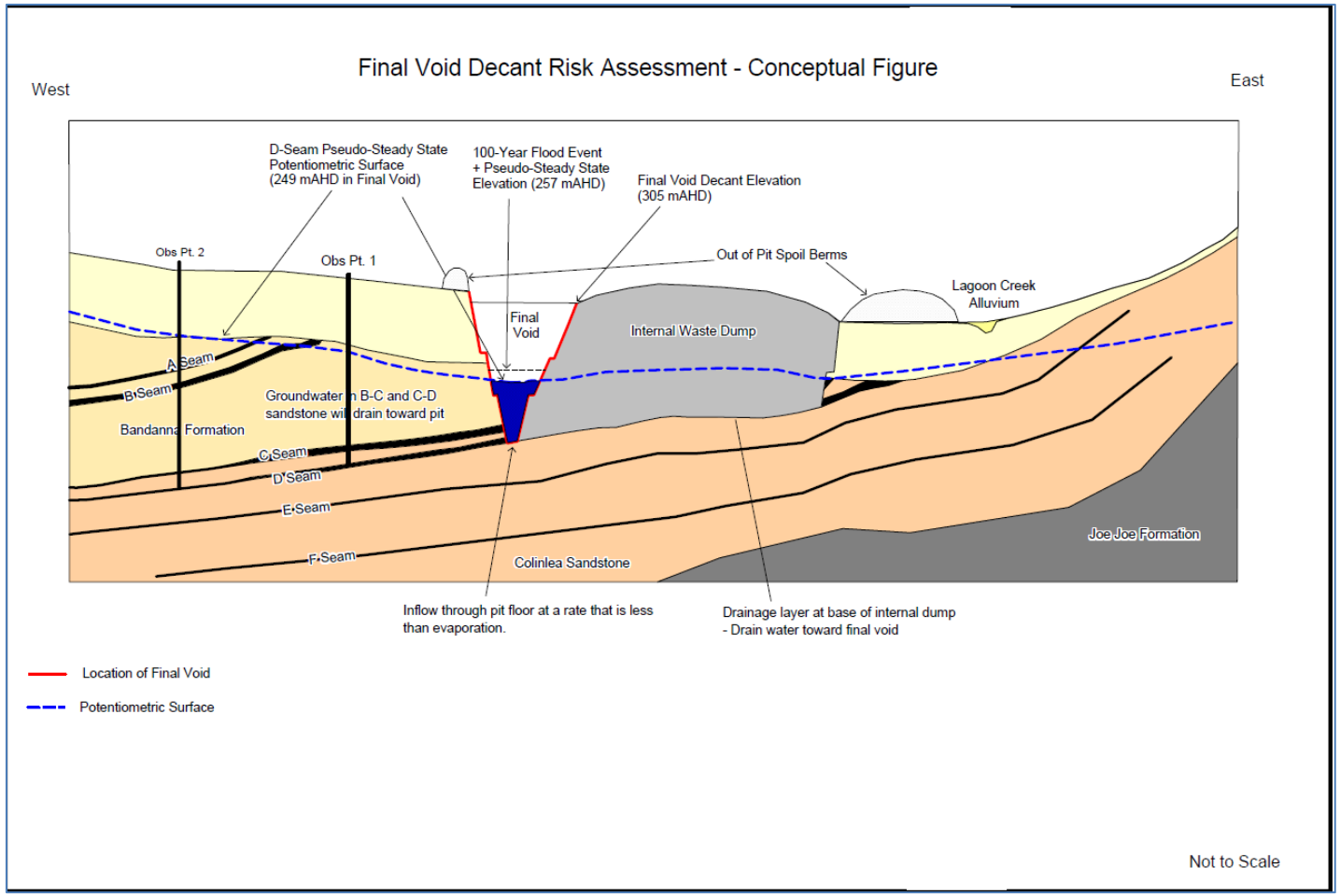
Figure 12-7 Final void decant potential figure



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Figures 12-8 (50 mg/L), 12-9 (100 mg/L), and 12-10 (200 mg/L) indicate the deterioration of final void water quality over time, due to the concentration of salts as a result of evaporation.

Figure 12-8 Final void water quality with time, runoff 50 mg/L TDS

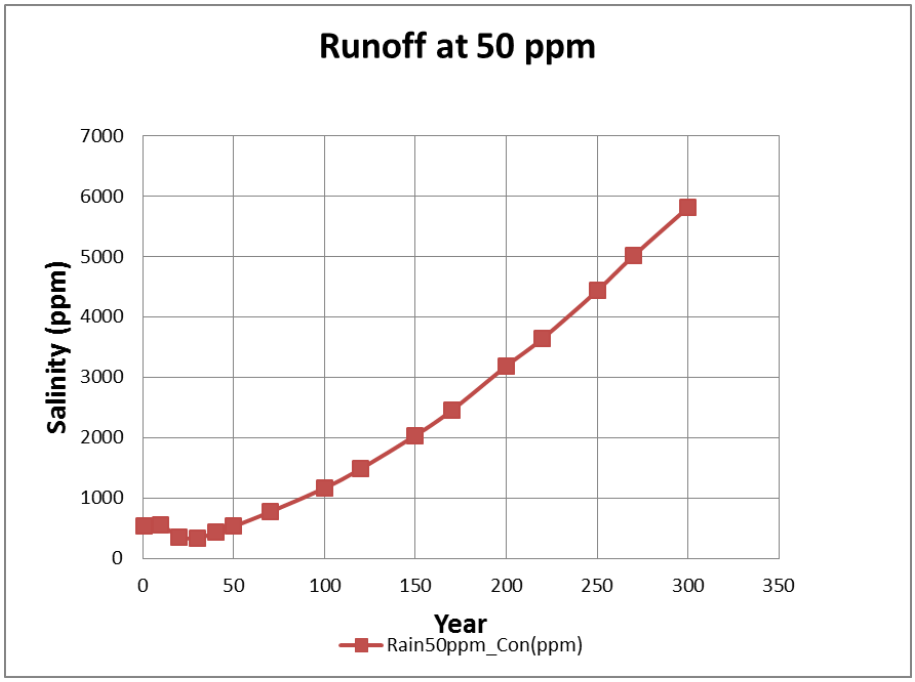

Figure 12-9 Final void water quality with time, runoff 100 mg/L TDS

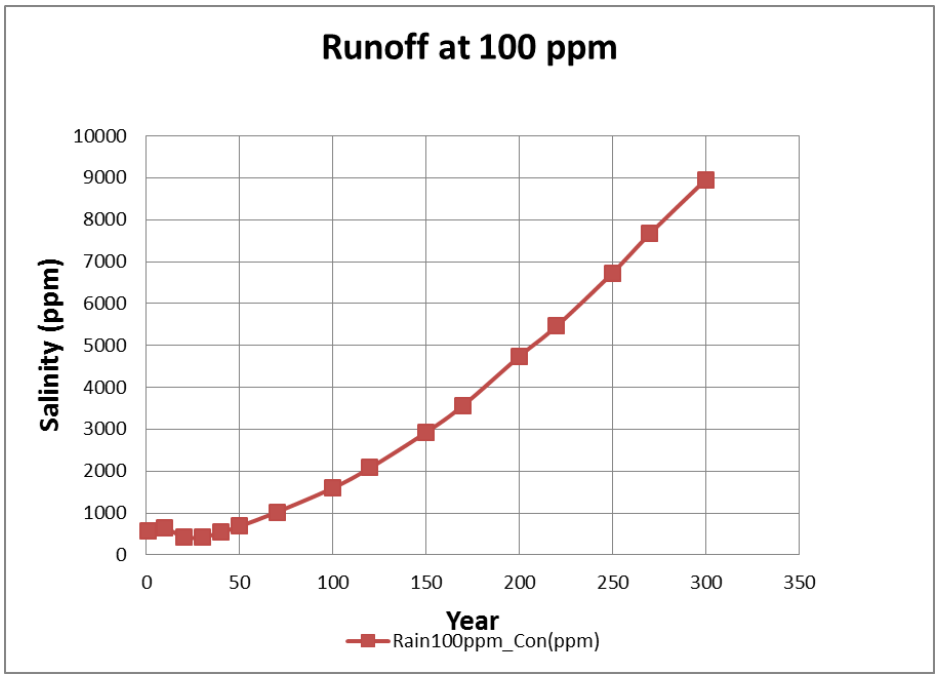

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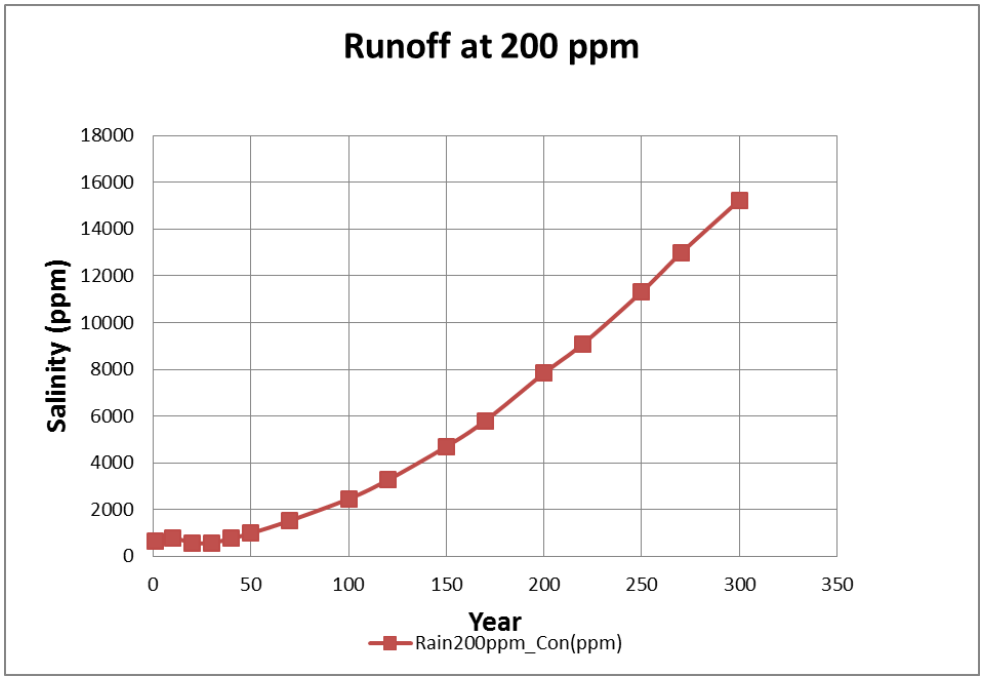
Figure 12-10 Final void water quality with time, runoff 200 mg/L TDS



The projected increase in salinity indicates that the final void water could, when compared to the ANZECC 2000 guidelines for cattle livestock drinking water, be utilised for ~ 150 years (using the worst case 200 mg/L runoff value). The TDS (salinity) guidelines for beef cattle are:

- TDS 0 to 4,000 mg/L – No adverse effects on animals;
- TDS 4,000 to 5,000 mg/L – Stock should adapt without loss of production; and
- TDS 5,000 to 10,000 mg/L – Loss of production and decline in animal condition.

The final void water could, therefore, be utilised for a significantly long time before salinity exceeds the 5,000 mg/L guideline. There is, however, an issue of obtaining this water safely as the water will be some 55 m below surface.

Impact Assessment

Based on requests for data compiled post EIS submission, additional predictive groundwater modelling was undertaken to allow for an assessment of possible risks with regards to:

- The closest Great Artesian Basin (GAB) major aquifer, the Clematis Sandstone;
- The basal unit of the GAB, the Rewan Formation, which overlies the target Permian sediments;
- Registered springs to the north of Alpha and Kevin's Corner coal projects;
- Sub-E coal seam sandstone, which has been identified as a source of make-good water; and
- Cumulative impacts through assessing the model predictions for Alpha alone and then comparing the results of simulating Alpha and Kevin's Corner.

13.1 Observation Points

In order to assess the potential impacts of mining on groundwater level, both during mining (using the results of the refined predictive model) and long-term (using the integrated final void model) several observation points were introduced at key locations. The observation points allowed for the estimation of changes in groundwater level in different model layers / hydrogeological units over time. The observation points are described in Table 13-1 and indicated on Figure 13-1.

Table 13-1 Observation points for groundwater level projections

Observation point	Easting (m MGA55)	Northing (m MGA55)	Model layer(s) observed	Notes
OP-G1	429455	7458409	Layer 1 – Clematis Sandstone	1
OP-G2	424062	7454209	Layer 1 – Clematis Sandstone	1
OP-G3	416129	7443409	Layer 1 – Clematis Sandstone	1
OP-G4	418853	7429609	Layer 1 – Clematis Sandstone	1
OP-G5	424062	7420409	Layer 1 – Clematis Sandstone	1
OP-R1	430249	7453209	Layer 3 – Rewan Formation	1
OP-R2	421577	7441209	Layer 3 – Rewan Formation	1
OP-R3	422939	7432209	Layer 3 – Rewan Formation	1
OP-R4	428511	7420609	Layer 3 – Rewan Formation	1
OP-S1	445249	7419409	Layers 1 to 11 – South transect – Alpha	4
OP-S2	445249	7417009	Layers 1 to 11 – South transect – Alpha	4
OP-S3	445249	7414409	Layers 1 to 11 – South transect – Alpha	4
OP-S4	445249	7411822	Layers 1 to 11 – South transect – Alpha	4
OP-W1	441949	7429009	Layers 1 to 11 – West transect	4

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			– Alpha	
OP-W2	439449	7429009	Layers 1 to 11 – West transect – Alpha	4
OP-W3	436949	7429009	Layers 1 to 11 – West transect – Alpha	4
OP-W4	434449	7429009	Layers 1 to 11 – West transect – Alpha	4
OP-W5	431949	7429009	Layers 1 to 11 – West transect – Alpha	4
OP-N1	445249	7444409	Layers 1 to 11 – North transect – Alpha	4
OP-N2	445249	7447009	Layers 1 to 11 – North transect – Alpha	4
OP-N3	445249	7449409	Layers 1 to 11 – North transect – Alpha	4
OP-N4	445249	7452009	Layers 1 to 11 – North transect – Alpha	4
OP-N5	445249	7457009	Layers 1 to 11 – North transect – Kevin's Corner	4
OP-N6	445249	7459409	Layers 1 to 11 – North transect – Kevin's Corner	4
OP-N7	445249	7462009	Layers 1 to 11 – North transect – Kevin's Corner	4
OP-N8	445249	7464356	Layers 1 to 11 – North transect – Kevin's Corner	4
OP-SP70	443708	7495293	Layer 1 - Spring 70	2, 3
OP-SP71	443607	7494960	Layer 1 - Spring 71	2, 3
OP-SP405	438099	7484976	Layer 1 - Spring 405	2, 3

Notes:

1 - No groundwater level within the GAB Rewan Formation and Clematis Sandstone[11]

2 - DERM Queensland Springs Database (2006)

3 - http://wetlandinfo.derm.qld.gov.au/wetlands/factsfigures/springs.html

4 - Location of a hypothetical observation wellbore (no bore actually exists)

[11] The models were calibrated to groundwater levels derived for the D-E sandstone during model calibration. Based on the elevation differences in the GAB units, the groundwater levels in the D-E sandstone do not reach into these units. The assessment of water level changes below the GAB units was conducted to assess potential for induced flow. Please note that this is an impact assessment model (Section 3.2) and not an aquifer performance / simulation model due the lack of GAB water level data and large model domain.

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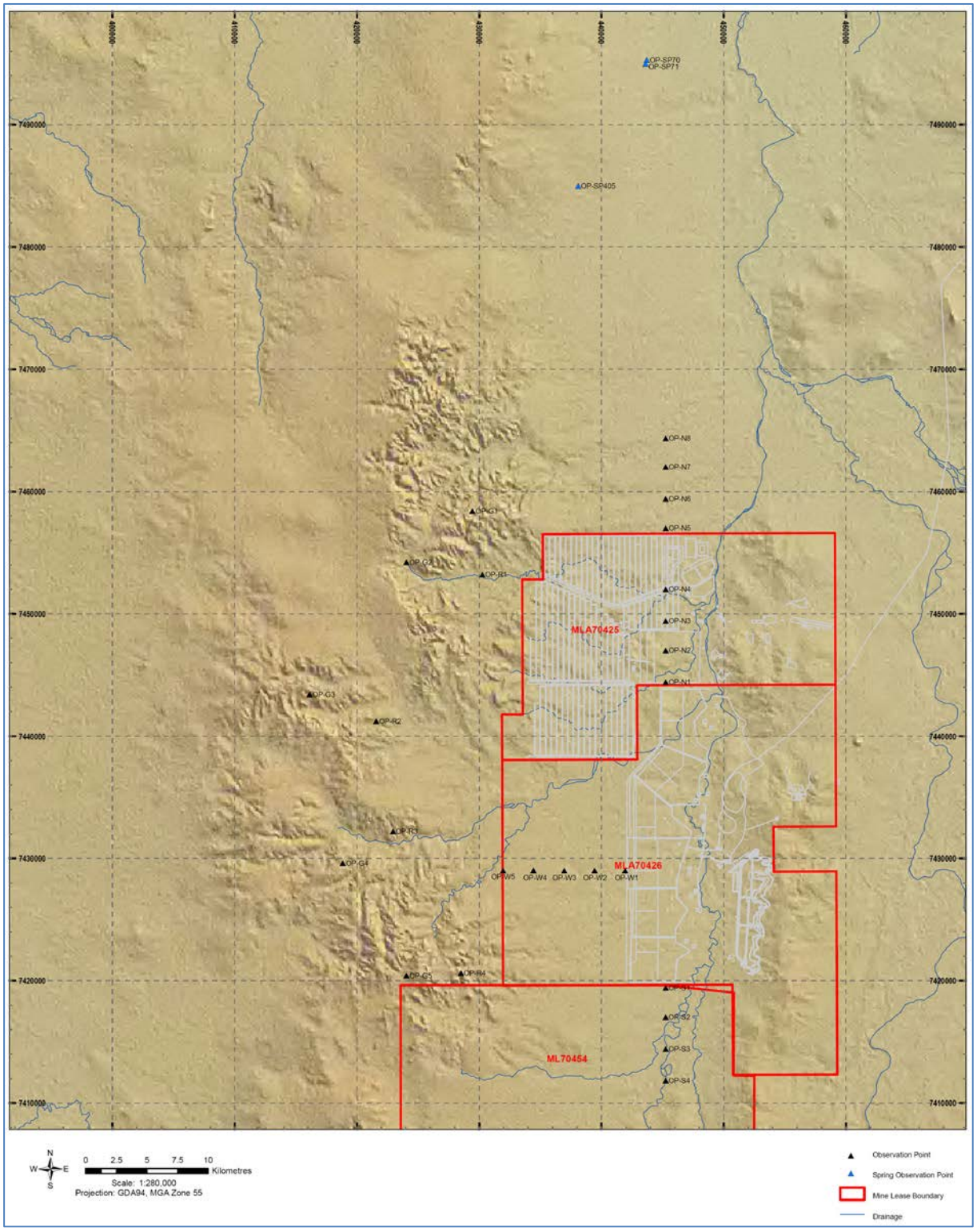
Figure 13-1 Groundwater observation points



13.2 Hydrographs

Groundwater level projections have been made, for the various observation points, based on a combination of predictions from the refined predicted model (30 year life of mine operations) and the integrated model (final void and long term impacts). The hydrographs are included in **Appendix E**.

13.3 Hydrograph projects

Comments regarding the risk of mine operations impacting markedly on the GAB Clematis Sandstone and Rewan Formation, the registered springs, and sub-E sands have been compiled.

13.3.1 Long term trends

The long term projected hydrographs for observation points adjacent to Alpha (**Appendix E** Figures e-4, e-5, e-6, e-7, e-11, and e-12) indicate that groundwater heads do not stabilise once the pseudo steady-state final void water level is reached (after ~ 50 years Section 12-5). This is due to the model layer parameters (low vertical permeability determined from transient calibrations) and the ongoing final void evaporation (which represents a loss from the system). Model projections indicate pseudo steady-state groundwater levels and flow patterns (Figure 12-6) after ~ 300 years.

The long term impacts indicate that groundwater resources will be “mined” from the Galilee Basin sediments and will be permanently lost.

It is noted that the long term projected unconfined groundwater levels (**Appendix E**, Figures e-8 and e-9), assumed within the Tertiary units indicate the potential for induced flow over time. This is due to the same groundwater heads, as Layer 7 D seam, being assigned to the Tertiary units. The projected changes for the D seam have been indicated for the Tertiary units. This will not occur in reality as these units are unsaturated, not directly hydraulically linked to confined aquifers, and are regularly recharged by rain and flood events.

13.3.2 Clematis Sandstone

Observation points within the Clematis Sandstone were included in the predictive groundwater model. Section 10.6 provides the projected groundwater levels within the Clematis Sandstone during the 30 year life of mine. No impact or change in groundwater level was predicted in any of the 5 observation points (GAB1 to GAB5).

In order to further assess these predictions and to look at the potential long term impacts, observations points OP-G1 to OP-G5 (Figure 13-1), at the same locations as GAB1 to GAB5 (Figure 10-9), were included in the integrated model.

In the integrated model the model cells in Layer 1 Clematis Sandstone are dry. Thus the model looked at the long term change in the groundwater levels within the first saturated layer, Layer 4, the Bandana Formation.

Projected groundwater levels within the Bandana Formation (**Appendix E** Figures e-1 and e-2) indicate minor, ~ 1 m changes in groundwater levels, below observation points OP-G1, OP-G2, and OP-G3 after 300 years post mining. Observation points OP-G4 (~ 1.5 m) and OP-G5 (~ 2.5 m) are located closest to Alpha and indicate that modelling predicts ongoing impacts of the final void as evaporation exceeds ingress and recharge.

It is noted that these long term impacts are limited, occur below the GAB aquifers, are within acceptable seasonal groundwater fluctuations, and are within model uncertainty.

Based on the low vertical permeability of the Rewan Formation, between the predicted long term (slightly) depressurised Bandana Formation (after 300 year) and the Clematis Sandstone; it is considered that any induced flow impacts would be immeasurable within the Clematis Sandstone.

13.3.3 Rewan Formation

Observation points within the Rewan Formation were included in the predictive groundwater model. Section 10.6 provides the projected groundwater levels within the Rewan Formation during the 30 year life of mine. No impact or change in groundwater level was predicted in any of the 4 observation points (REW1 to REW4).

In order to further assess these predictions and to look at the potential long term impacts, observations points OP-R1 to OP-R4 (Figure 13-1), at the same locations as REW1 to REW4 (Figure 10-9), were included in the integrated model.

As with the Clematis Sandstone, the model cells for Layer 3 Rewan Formation in the integrated model are dry. Thus the model looked at the long term change in the groundwater levels within the first saturated layer, Layer 4, the Bandana Formation.

Projected groundwater levels within the Bandana Formation (**Appendix E** Figure e-3) indicate a dewatering trend within the Bandana Formation post mining. Projections in groundwater levels, below observation points OP-R1 to OP-R4, after 300 years post mining indicate declines in levels up to ~ 5 m (OP-R4). OP-R4 is located closest to Alpha and predictions indicate that modelling predicts ongoing impacts of the final void as evaporation exceeds ingress and recharge.

It is noted that these long term impacts are < 5 m (a drawdown value which is considered to result in measurable impacts on bore yields within confined aquifers), occur below the GAB aquifers, and include model uncertainty.

Considering the Rewan Formation directly overlies the Bandana Formation and even though the Rewan Formation has recognised low vertical permeability, the depressurising trend within the Bandana Formation over time indicates that there is the potential for induced flow from the Rewan Formation albeit in the long term (> 300 years).

13.3.4 Registered springs

Registered springs SP70, SP405, and SP71, were included in the model predictions. Groundwater level data for the Tertiary overburden (Layer 1), Tertiary sediments (Layer 2), and the target D seam was projected over time (30 years LOM and 300 years post mining). The Tertiary layers were assumed to be saturated and have the same initial heads as the steady-state calibration.

No change in groundwater levels (**Appendix E** Figure e-15 and Figure e-16), in any of the model layers, was predicted.

13.3.5 Sub-E sands

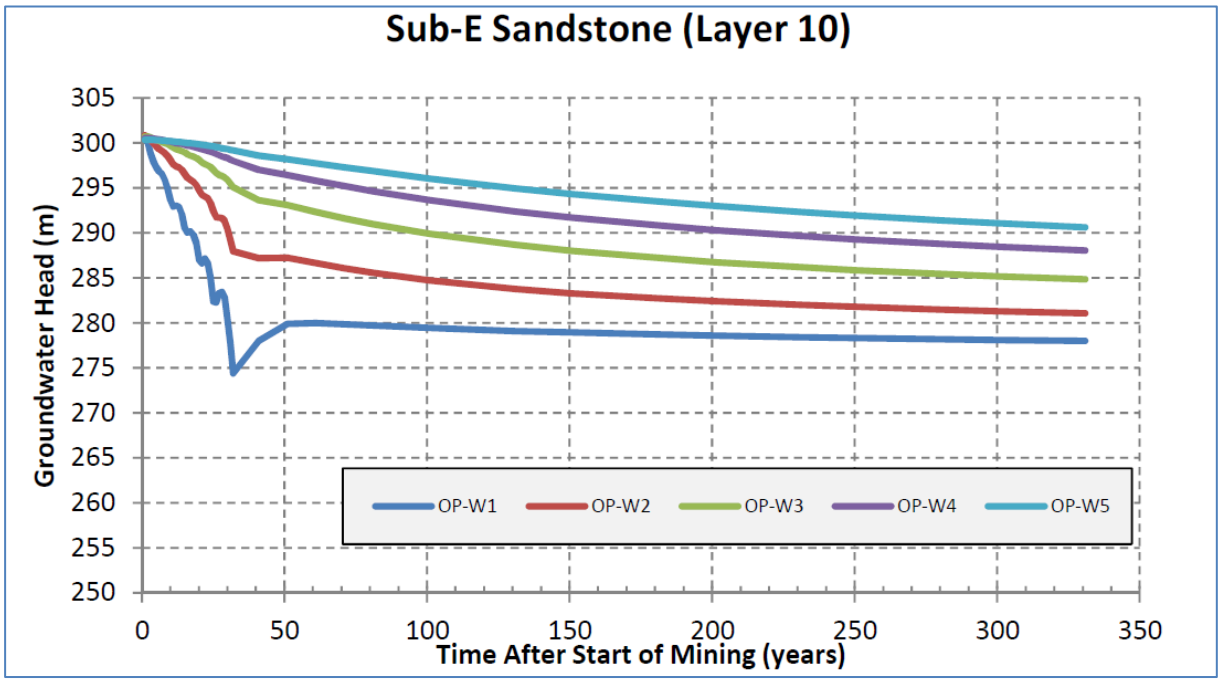
The sub-E sandstone unit within the Colinlea Sandstone is recognised, through drilling and site assessments, to have good groundwater (quality and quantity) potential. Based on the identified at-

risk bores (Section 10.6.4), all of which are located within the Permian sediments, it is recommended that the alternative make-good water supply be obtained from this aquifer. This would require the drilling of new or deeper bores, into the sub-E sandstone, adjacent or within the existing impacted at-risk bore.

In order to establish the viability of utilising this aquifer an assessment of the potential of the proposed mine dewatering to impact on the sub-E sandstone (through induced flow from the sub-E sandstone to the dewatered and depressurised overlying units) was conducted.

Hydrographs of projected water levels in the sub-E sandstone are included in **Appendix E**. The projected decrease in pressure (the sub-E sandstone will remain fully saturated but will have reduced pressure resulting in decreased potentiometric levels) will occur over time and stabilise after ~ 300 years (Figure 13-2). Figure 13-2 shows the extent of depressurisation over time and spatially (to the west) as a result of final void (evaporation) dominated groundwater rebound. Groundwater pressure differences are between 10 and 20 m across the MLA.

Figure 13-2 Projected potentiometric levels within the sub-E sandstone



An assessment of the model zone budget for the sub-E sandstone was undertaken to further quantify the potential impacts of mine dewatering on the sub-E sandstone groundwater supply. The predictive groundwater model, simulating dewatering during mining, provided an indication of groundwater *out* of model layer 10 (sub-E sandstone) to layer 9 (E coal seam) and *in* to layer 10 from the underlying Joe Joe Formation (layer 11). Table 13-2 provides the predicted volumes.

Table 13-2 Predicted net loss from Layer 10

Time	Total loss to Layer 9	Total gain from Layer 11	Net loss from Layer 10
2013 to 2043	4.7 GL	0.7 GL	5.4 GL

The total estimated volume of groundwater to be extracted from Alpha (Section 10.2) is 60 GL (base case), thus an estimated 9% of groundwater removed during mining will be obtained from induced flow from the underlying units. This equates to an extraction rate of 5.7 L/s from the sub-E sandstone.

The potentiometric pressure in the sub-E sandstone decreases to ~ 275 m AHD adjacent to the final void (Figure 13-2), where the bottom of pit is ~ 220 m AHD. Thus the sub-E sandstone is still fully saturated (no dewatering) but has been depressurised.

The mine dewatering and long term alterations to confining pressures in the sub-E sandstone indicates that the unit can supply a (9%) large proportion of the water to be removed during mining without having a marked dewatering impact on the aquifer (10 to 20 m depressurisation), it is therefore considered that the sub-E sandstone can be utilised, away from the immediate mining area, as a source of make-good water. Figure 13-3 presents the projected zone of influence (5 m drawdown contour) associated with the sub-E sandstone (Layer 10) at the end of mining. Section 10.6.4 details the at-risk bores considered within the mine dewatering, also included on Figure 13-3.

Based on the envisaged change in pressure, and to ensure sufficient available drawdown, it is recommended that the make-good bores be drilled and screened across the sub-E sandstone. Pump inlets are then to be placed within the screened section of the bores.

13.4 Cumulative Impacts

The cumulative impact of mine dewatering at Alpha and Kevin's Corner was assessed using the predictive model for Alpha and Kevin's Corner in Section 10.6. The inclusion of other proposed coal projects, namely Waratah and South Galilee, was considered based on post EIS requests received.

Cumulative impacts of all proposed mining operations raises issues regarding use of data, reliance on unchecked / validated data available in the public domain, limited information, and potentially leading to inaccurate impact assessments. This could, in the case of Waratah and South Galilee, result in legal consequences were these proponents do not agree with the regional model approach, resultant impact evaluation, or predictions. Based on the number of assumptions, differences in conceptualisation (geology and hydrogeology), and simplifications that would be required to obtain a very preliminary high level assessment of potential drawdown using a large regional the model. It is, therefore, considered that a cumulative model, at this stage without all the proponents buy-in and data, would not provide a very accurate assessment of potential impacts of mine dewatering associated with all proposed projects within this portion of the Galilee Basin.

The cumulative impact assessment was, therefore, considered quantitatively and discussed in terms of possible additional impacts.

13.4.1 Impacts of multiple mine pits

The impact of mine dewatering around the proposed open cut mine at Alpha is predicted to impact on groundwater levels in each of the model layers / geological units, to varying degrees based on groundwater heads (gradient) and permeability. A simplification of this is presented in Figure 13-4.

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Figure 13-3 Alpha drawdown contours in sub-E sandstone

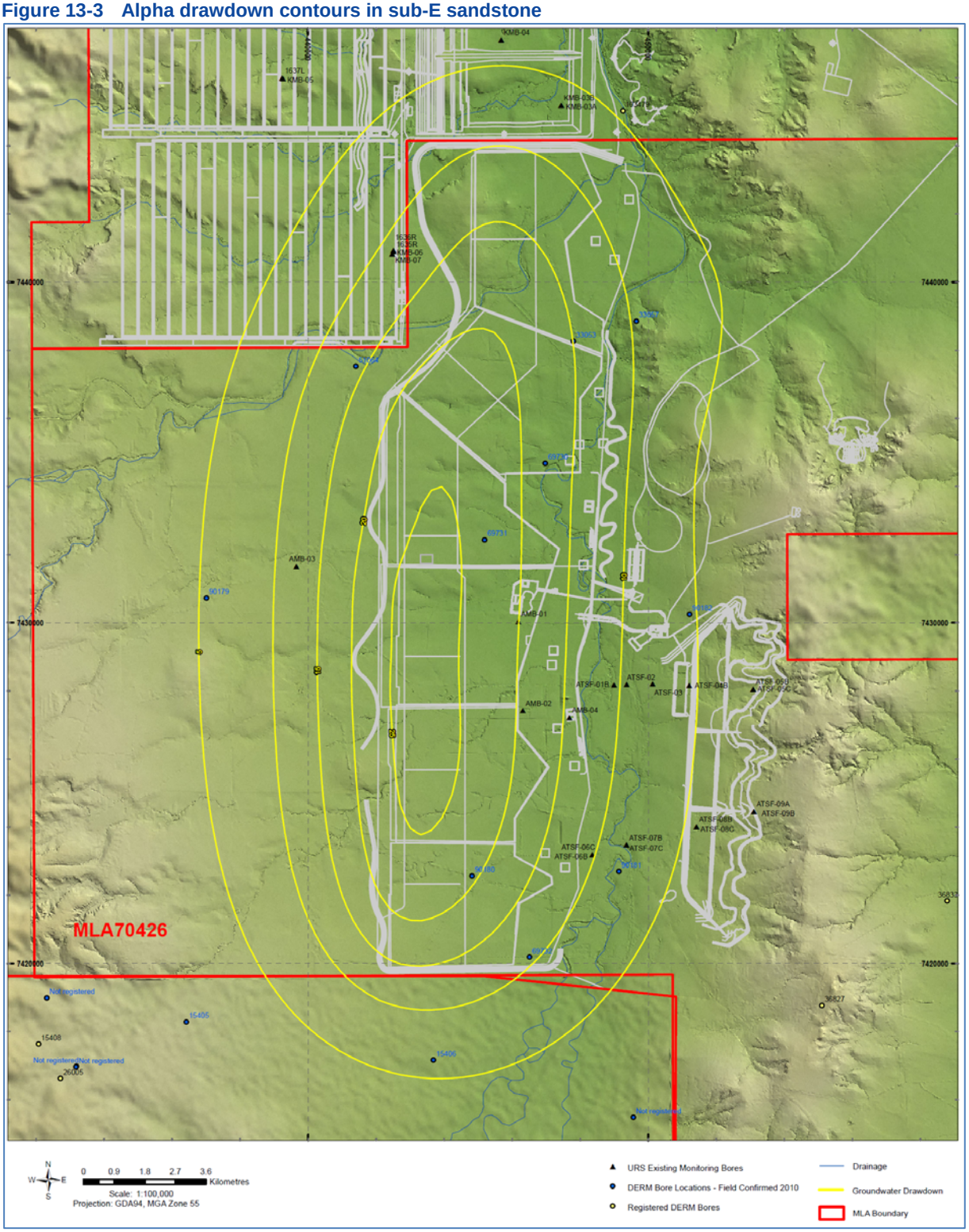

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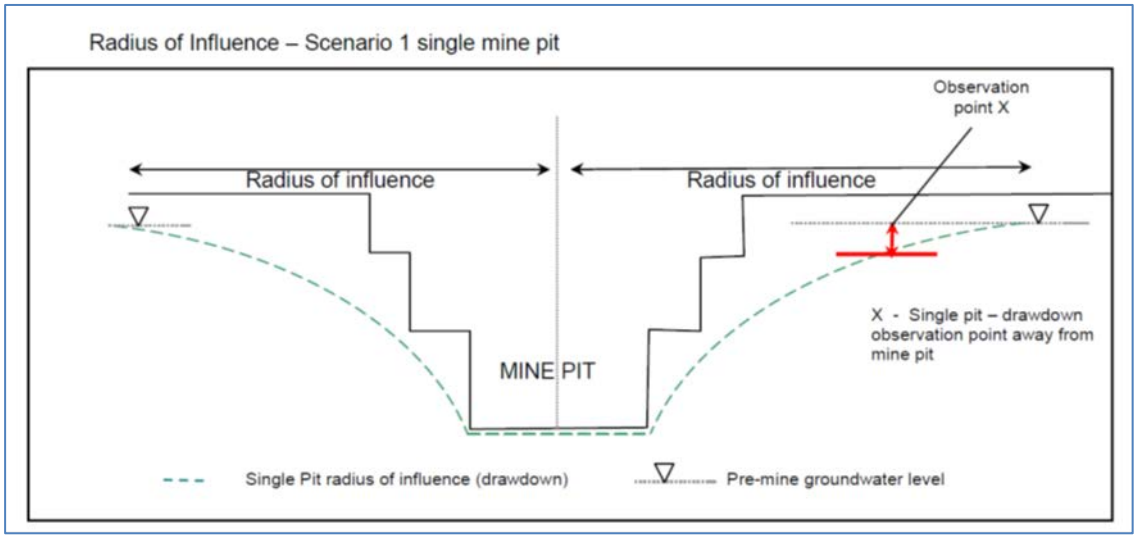
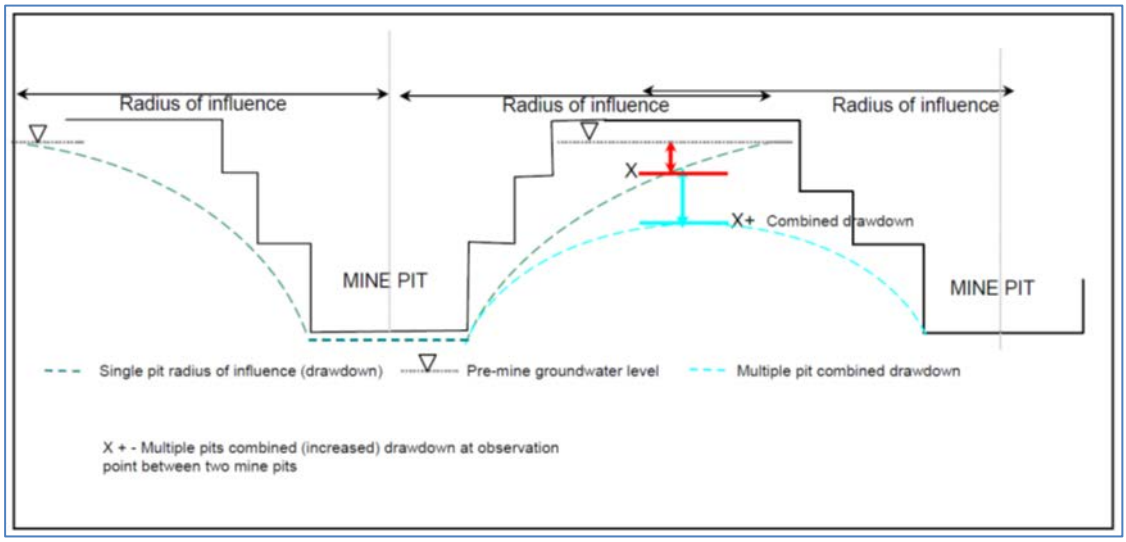
Figure 13-4 Sketch of zone or radius of influence



The predicted change in groundwater level can be estimated at selected observation points, as described in this report (Section 10 and Section 13).

The impact of additional mines, proposed adjacent and along strike, where predicted drawdown cones overlap will result in an increase in the drawdown in groundwater level. These areas are recognised to occur (as simulated in Figure 10-11) outside of the Alpha MLA boundaries and are considered to increase the potential impacts on groundwater resources and users. The extent of the drawdown cones outside any overlap will be governed by the hydraulic conductivity. Figure 13-5 provides an illustration of the conceptualised drawdown around one pit and also the impact of overlapping drawdown cones.

Figure 13-5 Mine pit drawdown conceptualisation



Dewatering impacts (drawdown cones) are, therefore, predicted to elongate north and south, within the more permeable sandstone units of the Colinlea Sandstone. The cumulative impact of adding the

additional mine dewatering will result in deeper drawdown where drawdown cones overlap and further elongation along strike.

Note: Drawdown cones created for Alpha alone and for mining both Alpha and Kevin's Corner (Figure 10-11) and **Appendix E** (Figures e-9 and e-10) do not indicate any additional or cumulative impact to the west, i.e. the cumulative drawdown only increases to the north where the two drawdown cones overlap. This is important as this indicates that the risk to the units to the west (i.e. the GAB units) is not increased by additional mine projects along strike of one another. The Rewan Formation aquitard limits drawdown to the east, regardless of projects or location, based on the drilling (dry) and aquifer assessments.

13.4.2 Dewatering constraints

Consideration of cumulative impacts of multiple projects, all within the same Permian coal bearing sediments, was given with respect to potential impacts on the GAB units to the west and to the older units to the east (below the Joe Joe Formation).

It is noted that the same geological / hydrogeological constraints (Rewan Formation aquitard) that separates the mining operations at Hancock from the GAB are the same for Waratah and South Galilee, thus it is predicted that the dewatering associated with these mining operations will not result in drawdown in the Rewan Formation or Clematis Sandstone.

The Joe Joe Formation aquitard, similarly, reduces the potential for induced drawdown, associated with additional mining projects, in the older units to the east.

The cumulative impact of these mining operations will, however, impact over a larger area within the Colinlea Sandstone and affect long term groundwater flow patterns and resources.

13.4.3 Risk to Rewan Formation

Section 13.3.2 considers that as the Rewan Formation directly overlies the Bandana Formation and even though the Rewan Formation has recognised low vertical permeability, there is a projected depressurising trend within the Bandana Formation over time which increases the potential for induced flow from the Rewan Formation albeit in the long term (> 300 years).

It is, therefore, recognised that should mining activities occur closer to the Rewan Formation then an assessment of potential for marked decrease in the Bandana Formation needs to be conducted, as increased depressurisation directly below the Rewan Formation could result in induced flow from this unit.

Cumulative impacts (Section 10-6 and Section 13.4.1) of multiple mines along strike are not recognised to result in increased cumulative drawdown down dip (i.e. to the west), thus the risk to the Rewan Formation does not alter.

13.5 Alpha Tailings Storage Facility

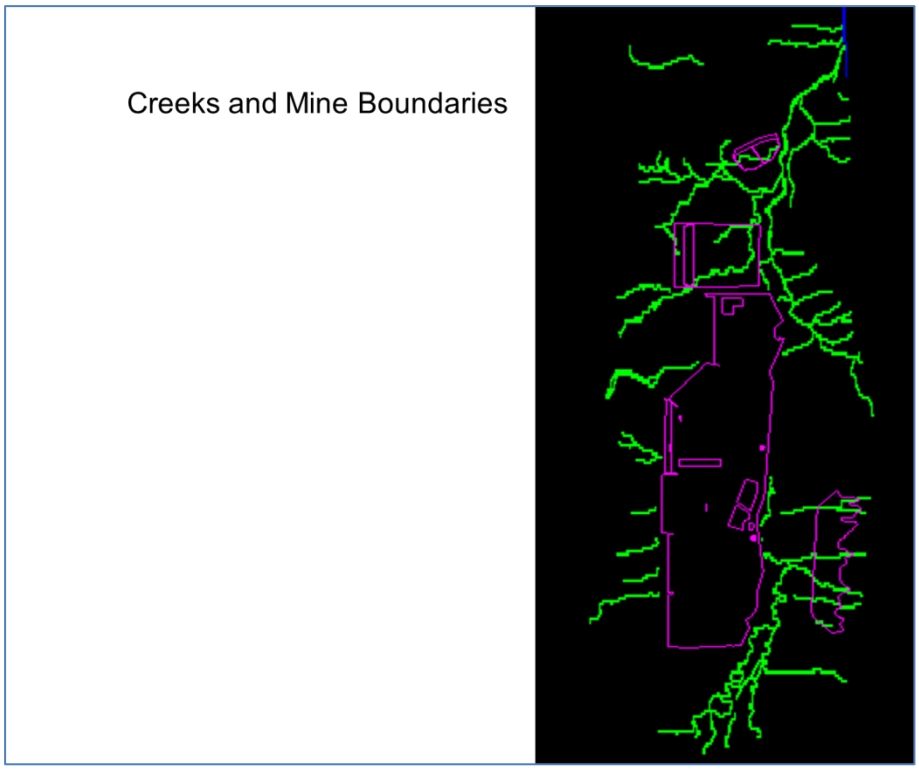
An evaluation of permeability data during both the hydrogeological drilling and testing and geotechnical studies was conducted of the altered (laterite) underlying Colinlea Sandstone and Joe Joe Formation units within the proposed out-of-pit Tailings Storage Facility (TSF). The resultant reports (URS, 2011g and h) studies provided differing recommendations regarding the need for lining than those provided in the SEIS submission. Hancock has committed to designing and constructing the TSF to a standard sufficient to prevent leaching and other impacts on the surrounding environment.

The integrated model was utilised to consider the long term potential impacts of the TSF, providing additional information to facilitate decision making. The TSF was simulated as a constant source of poor quality water (assumed constant source of 1,000 mg/L TDS) at a constant head of 340 m AHD, some 12 to 15 m above surface. The surface leakance[12] was set at (conservative) 1E-06 based on integrated model results and layer thickness (Table 11.4 and Table 11.1, respectively).

The model simulation allowed for the prediction of concentration propagation (similar to particle tracking) over time (300 years) assessing risk to Lagoon Creek and to deeper aquifers.

Figure 13-6 presents the TSF footprint, drainage lines, and transect where the cross-section through the model was assessed. Figure 13-7 indicates the model cross-section, simulated TSF footprint which acts as a constant source (and head), and Lagoon Creek, which was simulated as a drain in the integrated model.

Figure 13-6 TSF footprint and drainage



[12] Vertical leakance is based on the half-thickness of model layers and the vertical permeability of the layers. Note that overland flow, which has an unlimited vertical permeability, is taken into consideration when estimating leakance.

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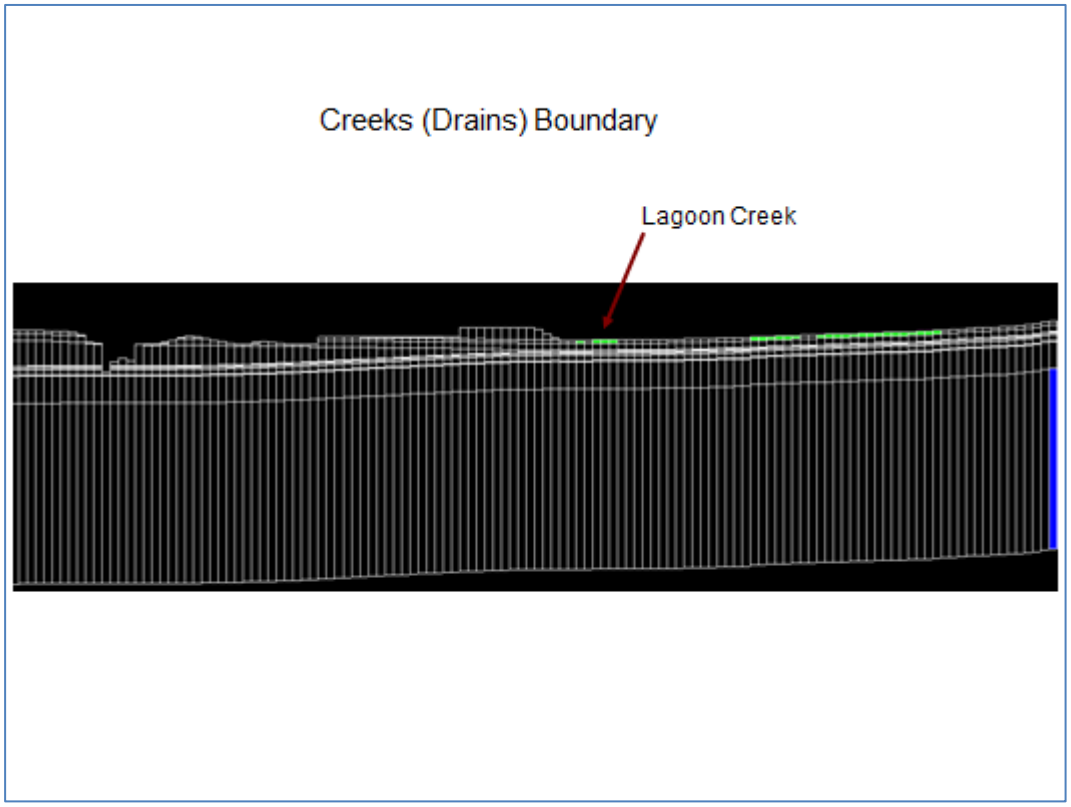
Figure 13-7 Model cross-section



The concentration propagation indicates expanding plume away and with depth over time. The predicted propagation indicates that no impact to Lagoon Creek is predicted during the simulation. Deeper drainage migrates more readily within the lower more depressurised layers at depth. Concentration changes with depth are predicted below the TSF but are limited by the fresh Joe Joe Formation. Figure 13-8 presents the predicted concentration propagation for 300 years post mining assuming a constant head within the TSF.

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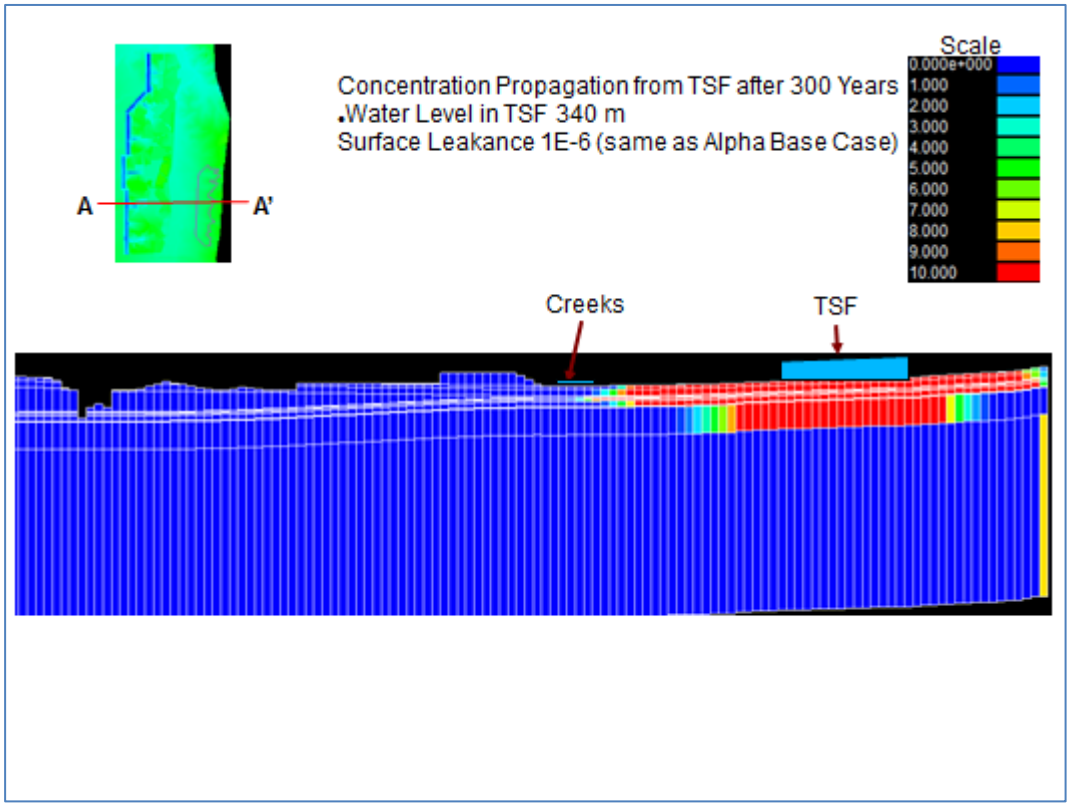
Figure 13-8 Predicted concentration propagation



Limited risk to Lagoon Creek and sub-E sandstone (aquifer) units are predicted assuming the base of the TSF is sufficiently prepared to lower the leakance to 1E-06, which equates to a vertical hydraulic conductivity of 1E-05 m/day , as determined for Tertiary laterite during calibration (Table 11-4).

14

Conclusions and Commitments

14.1 Conclusions

- Several “built-for-purpose” numerical groundwater models were constructed to aid in assessing potential impacts of mining on groundwater resources in the eastern limb of the Galilee Basin, these models included:
  - An initial EIS regional numerical model, which provided a preliminary assessment of potential mine dewatering impacts on the groundwater regime;
  - Predictive groundwater modelling, which allowed for an accurate estimate of groundwater ingress over the life of mine (LOM); and
  - Integrated surface water - groundwater modelling to provide an assessment of potential long term groundwater impacts associated with the Alpha final void.
- Predictive simulation was conducted for both open-cut and underground mining (Alpha and Kevin’s Corner coal projects) during the active period till end of 2043. A range of high, low, and expected groundwater ingress estimates were compiled for the total volumes of groundwater ingress for the two Hancock projects at LOM, which were 241 GL, 104 GL, and 176 GL, respectively. The total estimated range (high, low, and expected) volumes of groundwater ingress for Alpha Project only over the LOM were 100 GL, 41 GL, and 60 GL, respectively.
- Projected groundwater levels below the GAB Rewan Formation and Clematis Sandstone units do not indicate any potential for induced flow (resulting in dewatering of GAB units) over the life of mine (30 years).
- An assessment of the direct and indirect impacts of mine dewatering on the vegetation communities indicates that there is limited potential for induced flow from the isolated (non-continuous) perched water down into the depressurised deeper aquifers. These perched water tables are regular recharged through rain and flood events and not reliant on upward groundwater movement. Direct impacts to the perched water table(s) can occur as a result of direct drainage into the open mine voids, considered to occur within a 10 to 100 m zone around the mine voids based on low gradients and permeability.
- An assessment of at-risk bores, resulting from Alpha mine dewatering, indicated that there are 18 neighbouring bores (recorded during the study) within the projected 1 and 5 m drawdown contours for the target D seam at the end of mining. These bores are to be field checked as part of the Proponent’s make-good commitment.
- Drawdown cones in the D coal seam were contoured, up to 0.5 m, to assess groundwater level change during mining for Alpha alone and also for (cumulative contours) Alpha and Kevin’s Corner. The projected contours indicate that there will be minimal drawdown to the east of the mine footprint because of the aquitard nature of the Joe Joe Formation metasediments. This low permeability unit restricts groundwater drawdown, resulting from mining, to the east. Drawdown cones elongate north and south, within the more permeable Colinlea Sandstone. The cumulative impact of adding the Kevin’s Corner dewatering results is deeper drawdown where drawdown cones overlap and further elongation along strike. The low permeable Bandana Formation and Rewan Formations constrain drawdown to the west. These constraints apply across the entire portion of the Galilee Basin containing Alpha. This means that the potential for induced flow from the GAB or drawdown in the older units to the east of the Joe Joe Formation does not increase based on additional mining.
- The final void modelling predicts that the final void water level reaches a pseudo steady-state after ~ 50 years, at around 37 m above pit floor (around 250 m AHD depending on location within the final void).

14 Conclusions and Commitments

- The lowest elevation point where decant could potentially occur is along the northern most portion of the final void, at an elevation of 305 m AHD. The projected final void water level in the northern portion of the final void is 249 m AHD, some 56 m below the lowest pit surface elevation. The risk of decant is, therefore, considered negligible.
- Final void quality is recognised to deteriorate over time due to the concentration of salts as a result of evaporation. The final void water could be utilised for ~ 150 years before the salinity reached 5,000 mg/L TDS, the ANZECC 2000 guidelines for cattle livestock drinking water.
- Observation points within the model indicate that changes in groundwater levels and pressures, as a result of mining and final void, will permanently alter groundwater flow patterns and levels around the final void.
- The predicted changes in groundwater levels in the units below the Clematis Sandstone, after 300 years, are sufficiently small (within natural fluctuations) that the risk of induced flow from the Clematis Sandstone to the mine depressurised units is negligible.
- Larger drawdown is projected for the Bandana Formation below the Rewan Formation, which indicates limited potential to induce flow from this unit. The resultant change in groundwater levels would, however, not result in marked reductions in groundwater resources within the Rewan Formation.
- No projected impacts, in any of the model layers, below the northern registered springs have been predicted during or post mining.
- The potentiometric pressure in the sub-E sandstone is predicted to decrease to ~ 275 m AHD adjacent to the final void, where the bottom of pit is ~ 220 m AHD. Thus the sub-E sandstone is still fully saturated (no dewatering) but has been depressurised (10 to 20 m depressurisation). It was, therefore, considered that the sub-E sandstone can be utilised, away from the immediate mining area, as a source of make-good water.
- Cumulative impacts of multiple mines, along strike, within the Permian Galilee Basin units were considered. Based on the cumulative impact modelling of both Alpha and Kevin's Corner, the dewatering impacts (drawdown cones) are predicted to elongate north and south, within the more permeable sandstone units of the Colinlea Sandstone. The cumulative impact of adding the additional mine dewatering will result in deeper drawdown where drawdown cones overlap and further elongation along strike. Drawdown cones created for Alpha alone and for mining both Alpha and Kevin's Corner do not result in any additional or cumulative impact to the west. This indicates that the risk to the units to the west (i.e. the GAB units) is not increased by additional mine projects along strike of one another.
- Limited risk of long term TSF impacts on Lagoon Creek are predicted if the base of the TSF ensures leakance of 1E-06 or less.

14.2 Commitments

14.2.1 Model audits

Model post audits test the predictive capabilities of groundwater models and shed light on their practical limitations. Probable model error can be investigated and improved by including the additional field and monitoring data compiled during construction and mining phases. It is recommended that model evaluation be conducted on a regular basis, as additional field data becomes available.

The model predictions can be verified on completion of the pilot dewatering borefields, and regularly (every 3 years) during mining using groundwater monitoring data and water management records. It is now understood that the Proponent has included a commitment to undertake the modelling audits on a regular basis (no longer than ever 3 years) and that these modelling results will be provided to the relevant authority for review.

14.2.2 Groundwater quality

A groundwater monitoring network and program has been instigated on site. This program aims at compiling sufficient (from a statistical perspective) hydrochemical data in order to propose trigger levels and compliance limits for inclusion in the Environmental Authority conditions. These proposed trigger levels and compliance limits will be provided to DERM for consideration.

The groundwater monitoring network (as shown on Figure 4-14, Section 4-6) for Alpha is summarised as follows:

- To date, monthly background groundwater samples have been successfully collected from fifteen (15) of eighteen (18) on site monitoring bores in the Alpha project area. Background groundwater samples have not been collected from three bores drilled dry (ATSF-04B, ATSF-08C, and ATSF-09B);
- Most bores have completed seven (7) monthly sampling events (August 2011 through February 2012). Four bores, AMB-01 through AMB-04, have completed eight (8) monthly sampling events (July 2011 through February 2012). One bore, ATSF-05C, has completed only monthly sampling event (August 2011) and has been lost as it is blocked, preventing the pump from sample collection; and
- The groundwater samples collected represent the various geologic and hydrogeologic units, as outlined in Table 14-1.

Table 14-1 Alpha groundwater monitoring summary

Bore ID	Unit Monitoring	Sample Events Completed	Comments
AMB-01	D-E Sandstone	8	
AMB-02	E-F Sandstone	8	
AMB-03	D-E Sandstone	8	
AMB-04	C-D Sandstone	8	

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ATSF-01B	Laterite	7	
ATSF-02	Conglomerate within Laterite	7	
ATSF-03	Conglomerate within Laterite	7	
ATSF-04B	Laterite	0	Dry
ATSF-05B	Joe-Joe Formation	7	
ATSF-05C	Laterite	1	Dry/Blocked
ATSF-06B	D-E Sandstone	7	
ATSF-06C	Surficial Deposits	7	
ATSF-07B	Base of Laterite	7	
ATSF-07C	Base of Surficial Sands	7	
ATSF-08B	Joe-Joe Formation	7	
ATSF-08C	Surficial Sands/Top of Laterite	0	Dry
ATSF-09A	Joe-Joe Formation	7	
ATSF-09B	Surficial Sands	0	Dry

All groundwater samples are analysed for the following components:

- pH
- EC
- TDS
- Alkalinity as $CaCO_3$
- Fluoride
- Dissolved Metals
- Major Cations
- Major Anions
- Nutrients (Nitrogen components, phosphorous
- Ionic Balance

In addition to the components above, four bores, AMB-01 through AMB-04, are also analysed for:

- Total Metals
- TPH

The draft Environmental Management Plan includes commitments to install additional monitoring bores adjacent to proposed mine infrastructure at least 6 months prior to construction. Thus the Proponent will augment the monitoring network over time.

14.2.3 At-risk bores

Under the Water Act 2000 DERM has authority to direct the licensee to provide and maintain alternative water supplies for other holders of water entitlements who are materially impacted by the granting of a licence.

The project will develop alternate water supply agreements with landholders who will potentially be impacted by mine dewatering and aquifer depressurisation. Landholders who have groundwater supplies that are materially impacted before and during mine operations as a result of Alpha mining, to a degree where groundwater is not able to be used for its pre-mining beneficial use (in terms of quality and/or quantity) will be provided with an alternate water supply of comparable yield and quality. The Proponent has made a commitment to make-good affected groundwater supplies.

The make-good commitment, to be mutually agreeable to the Proponent and the affected groundwater user, is envisaged to include:

- Details regarding the baseline data compiled during the bore survey of groundwater use;
- Details from a groundwater data validation program to be undertaken on all identified at-risk bores (identified in Section 10.6.4);
- Access to groundwater monitoring data, trend analyses, and interpretation;
- Groundwater level data trends and comparison to any agreed Environmental Authority condition trigger values;
- Details regarding the groundwater monitoring network, predictive groundwater modelling validation (3 year intervals) and dewatering scheme(s);
- A commitment that all groundwater monitoring will be conducted and assessed by a suitably qualified independent experts;
- The implementation of make-good agreements as soon as impacts are predicted / observed or recorded (i.e. alternative water supplies to be provided prior to the loss of supply from bores);
- Provision for the repair or replacement of damaged bores or water supply infrastructure, if the Proponent is deemed to have caused the damage;
    - The replacement of diminished groundwater, same quality or better, and volume;
    - A subsidy to cover additional costs associated with:
        - Larger or different pump types;
        - Pumping from deeper depths;
        - Additional water related infrastructure;
        - Additional power costs; and
        - Costs related to maintenance and spare parts for new larger or deeper set pumps.
- Financial provisions are to be made to ensure future costs (post closure) are covered;
- A dispute resolution system; and
- In the absence of agreement the provision for arbitration to settle the terms of agreement.

The make-good strategies to be put in place for groundwater level impacts were considered to include:

- Lowering pumps within an existing borehole, or supplying different pumps with a greater head capacity if required.
- Drilling new bores to a greater depth, e.g. to intersect the sub-E sands, which are not a target of dewatering by the operation and therefore are not predicted to be impacted to the degree predicted for the D-E sandstone and overlying sediments. Based on the envisaged change in pressure, and to ensure sufficient available drawdown, it is recommended that the make-good bores be drilled

and screened across the sub-E sandstone. Pump inlets are then to be placed within the screened section of the bores.

- The provision of replacement bores for affected landholders will be such that the new bores are able to continue to supply water for the maximum predicted impacts of mining on water level.

Glossary

ALLUVIUM - Sediments (days, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.

ALLUVIUM AQUIFER - A deposit of detrital material- mostly sediment- formed by river, stream and floodplain processes that store and transmit water in spaces between sediments grains. Stored water can be extracted and used.

ANALYTICAL MODEL - Equations that represent exact solutions to the hydraulic equation for one- or two-dimensional flow problems under broad simplifying assumptions, usually including aquifer homogeneity.

ANISOTROPY - The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.

AQUICLUDE - A low-permeability unit that forms either the upper or lower boundary of a groundwater flow system.

AQUITARD – These are geologic units that are of low permeability. Aquitards usually form a layer in a geologic sequence. They may contain water, but would not yield reasonable volumes of water to bores or wells. An example of an aquitard would be a saturated clay layer that is overlying a saturated sandy aquifer.

AQUIFER - A geological structure of formation or part thereof, permeated with water or capable of- (a) being permeated permanently or intermittently with water; and (b) transmitting water.

AQUIFER, CONFINED - An aquifer that is overlain and underlain by impervious layers. The water level in bores tapping confined aquifers rises within the bore to a level above the top of the aquifer, and may result in an artesian or sub artesian bore. Confined aquifers tend to occur in the central and deeper parts of the Basin.

AQUIFER, PERCHED - Perched Aquifers occur in the upper catchments. They sit over a thick layer of clayey weathered sediments and have no connection to the fractured rock aquifers beneath the clay. This lack of connection means that their ecosystems are highly dependent on rainfall runoff, lateral subflow, from unconsolidated sediments overlying the clay or upstream flow contributions. These systems are more sensitive to surface water changes. Development of surface water resources or disruptions to subsurface flow will have the greatest impact on flora and fauna in this setting.

AQUIFER, SEMICONFINED - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

AQUIFER TEST - A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

AQUIFER, UNCONFINED - An aquifer which has the water table as its upper surface which may be recharged directly by infiltration from the groundwater surface.

ARTESIAN - Groundwater which rises above the surface of the ground under its own pressure by way of a spring or when accessed by a bore. An artesian well, including all associated works, from which water flows, or has flowed, naturally to the surface.

AUSTRALIAN HEIGHT DATUM (AHD) - The Australian height datum, adopted by the National Mapping Council of Australia, for referencing a level or height back to a standard base level.

BORE (WELL) - Any bore, well or excavation or any artificially constructed or improved underground cavity used or to be used for the purpose of—(a) the interception, collection, storage or extraction of groundwater; or (b) groundwater observation or the collection of data concerning groundwater; or (c) the drainage or desalination of any land; or (d) in the case of a bore that does not form part of a septic tank system, the disposal of any matter below the surface of the ground; or (e) the recharge of an aquifer— but does not include a bore that is used solely for purposes other than those specified in paragraphs (a), (b) and (d).

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BORE WORK - (a) Drilling, constructing, altering, plugging, backfilling or sealing off a bore; (b) removing, replacing, altering, slotting or repairing the casing, lining or screen of a bore; (c) deepening a bore (in the course of construction or otherwise).

BOUNDARY CONDITIONS - Specified Head (or Fixed or Constant Head). Refer to Dirichlet Condition (also known as First Type Boundary). Specified Flow. Refer to Neumann Condition (also known as Second Type Boundary). Head-dependent Flow. Refer to Cauchy Condition (also known as Third Type Boundary).

CAUCHY CONDITION - Also known as Head-dependent Flow or Third Type Boundary Condition. A boundary condition for a groundwater model where the relationship between the head and the flow at a boundary is specified, and the model computes the groundwater flux for the head conditions applying.

CALIBRATION - Calibration of a model is the process where parameters in the model are fine tuned to get the best possible match between actual and modelled data over a defined period.

CALIBRATION, INITIAL CONDITIONS - The initial hydrologic conditions for a flow system that are represented by its aquifer head distribution at some particular time corresponding to the antecedent hydrologic conditions in that system. Initial conditions provide a starting point for transient simulations.

CALIBRATION, STEADY STATE - The calibration of a model to a set of hydrologic conditions that represent (approximately) an equilibrium condition, with no accounting for aquifer storage changes.

CALIBRATION, TRANSIENT - The calibration of a model to hydrologic conditions that vary dynamically with time, including consideration of aquifer storage changes in the mathematical model.

COMPEXITY. - The degree to which a model application resembles, or is designed to resemble, the physical hydrogeological system. A hierarchical classification of three main complexities in order of increasing complexity: Basic, Impact Assessment and Aquifer Simulator. Higher complexity models have a capability to provide for more complex simulations of hydrogeological process and/or address resource management issues more comprehensively. In this guide, the term complexity is used in preference to fidelity.

COMPLEXITY –*Basic Model* - With limited data availability and status of hydrogeological understanding, and possibly limited budgets, a *Basic* model could be suitable for preliminary quantitative assessment (rough calculations), or to guide a field program.

COMPLEXITY –*Impact Assessment Model* - More detailed assessments are possible with an *Impact Assessment* approach, which usually requires more data, better understanding, and greater resources for the study.

COMPLEXITY – *Aquifer Simulator* - An *Aquifer Simulator* is a high complexity representation of the groundwater system, suitable for predicting the response of a system to arbitrary changes in hydrogeological conditions.

CONCEPTUAL MODEL - A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and our hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.

CONE OF DEPRESSION - The radial decline of potentiometric levels or underground water levels around a point of water extraction from an aquifer.

DARCY'S LAW - An empirical equation developed to compute the quantity of water flowing through an aquifer. Usually expressed as Q=kiA, where Q=flow, k=hydraulic conductivity, I=hydraulic gradient, A=aquifer cross-sectional area.

DEWATERING - Removing underground water for construction or other activity. It is often used as a safety measure in mining below the water table or as a preliminary step to development in an area

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DIRICHLET CONDITION - Also known as a Specified, Fixed or Constant Head Boundary, or Third Type Boundary Condition. A boundary condition for a groundwater model where the head is known and specified at the boundary of the flow field, and the model computes the associated groundwater flow.

DRAWDOWN - Refers to a lowering of the surface that represents the level to which water will rise in cased bores. Natural drawdown may occur due to seasonal climatic changes. Groundwater pumping may also result in seasonal and long-term drawdown.

EXTRACTION - In relation to any bore includes withdrawing, taking, using or permitting the withdrawing, taking or using of water from that bore.

EVAPOTRANSPIRATION - The sum of evaporation and transpiration.

FINITE-DIFFERENCE MODEL - A particular kind of numerical model based upon a rectangular grid that sets the boundaries of the model and the nodes where the model will be solved.

FINITE-ELEMENT MODEL - A particular kind of numerical model where the aquifer is divided into a mesh formed of a number of polygonal (usually triangular) cells.

Gigalitre (GL) - A volumetric measure equal to one million kilolitres or one billion litres.

GRAPHICAL USER INTERFACE (GUI) - A software package to facilitate the data input, flow simulation and results output of groundwater modelling codes, usually based on the Microsoft Windows system.

GREAT ARTESIAN BASIN - Is a ‘confined’ groundwater basin comprised of a complex multi-layered system of water bearing strata (porous sandstone aquifers) separated by largely impervious rock units, underlying largely arid and semi-arid landscapes to the west of the Great Dividing Range, and extending from Queensland through New South Wales and the Northern Territory, to South Australia.

GROUNDWATER - (a) Water occurring naturally below ground level (whether in an aquifer or otherwise); or (b) water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there; but does not include water held in underground tanks, pipes or other works.

GROUNDWATER FLOW MODEL - An application of a mathematical model to represent a site-specific groundwater flow system.

GROUNDWATER-DEPENDENT ECOSYSTEMS (GDE) - Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater.

HETEROGENEOUS - A medium which consists of different (non-uniform) characteristics in different locations.

HOMOGENEOUS - A medium with identical (uniform) characteristics regardless of location.

HYDRAULIC CONDUCTANCE - A term which incorporates model geometry and hydraulic conductivity into a single value for simplification purposes. Controls rate of flow to or from a given model cell, river reach, etc.

HYDRAULIC CONDUCTIVITY - A measure of the ease of flow through a pore space or fractures. Hydraulic conductivity has units with dimensions of length per time (e.g. m/s, m/min, or m/d).

HYDRAULIC DIFFUSIVITY - A property of an aquifer or confining bed defined as the ratio of the transmissivity to the storativity.

HYDRAULIC GRADIENT - Spatial variation in the effective elevation of water table and/or potentiometric level, which drives lateral flow of underground water.

HYDRAULICALLY LINKED - In relation to sub artesian water, means there is a direct connection between the sub artesian water and surface water to the extent that— (a) if the aquifer is full and surface water is removed, sub artesian water begins,

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within approximately 1 day, to flow to the surface, replacing the surface water removed; and (b) if the aquifer is not full, surface water begins, within approximately 1 day, to seep into the aquifer causing the water level in the aquifer to rise.

HYDROGRAPH - A graph that shows some property of groundwater or surface water (usually head or flow) as a function of time.

HYDROLOGIC EQUATION - An expression of the law of mass conservation for purposes of water budgets. It may be stated as inflow equals outflow plus or minus changes in storage.

INFILTRATION - The flow of water downward from the land surface into and through the upper soil layers.

ISOTROPY - The condition in which hydraulic properties of the aquifer are equal in all directions.

LEAKANCE - Controls vertical flow in a model between cells in adjacent layers. Equivalent to effective vertical hydraulic conductivity divided by the vertical distance between layer midpoints.

MODEL CALIBRATION - The process by which the independent variables (parameters) of a numerical model are adjusted, within realistic limits, to produce the best match between simulated and observed data (usually water-level values). This process involves refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve the desired degree of correspondence between the model simulations and observations of the groundwater flow system.

MONTE CARLO ANALYSIS - A set of model simulations for alternative model realisations, on the assumption that aspects of the model are stochastic. A *realisation* is one of many possible valid descriptions of a model in terms of its aquifer parameters, boundary conditions or stresses.

NEUMANN CONDITION - Also called a constant flux boundary. The boundary condition for a groundwater flow model where a flux across the boundary of the flow region is known and specified, and the model computes the associated aquifer head.

NON-UNIQUENESS - The principle that many different possible sets of model inputs can produce nearly identical computed aquifer head distributions for any given model.

NUMERICAL MODEL - Refers to a mathematical representation of a physical system intended to mimic the behaviour of a real system, allowing description about empirical data and prediction about untested states of the system.

OBSERVATION WELL - A non-pumping well used to observe the elevation of the water table or the potentiometric surface. An observation well is generally of larger diameter than a piezometer and typically is screened or slotted throughout the thickness of the aquifer.

PIEZOMETER - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

PIEZOMETERIC SURFACE - Is a surface that represents the level to which groundwater will rise in cased bores intersecting confined aquifers.

POROSITY - The ratio of the aggregate volume of the spaces between grains or fractures in a rock, sediment or soil to its total volume, generally expressed as a percentage.

POST-AUDIT - Comparison of model predictions with what actually happened.

RECHARGE - Is the addition of water, usually by infiltration, to an aquifer.

RECHARGE BOUNDARY - An aquifer system boundary that adds water to the aquifer. Streams and lakes are typically recharge boundaries.

RESIDUAL - The difference between the computed and observed value of a variable at a specific time and location.

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SATURATED ZONE - The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined aquifer.

SEDIMENTARY AQUIFERS - These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas *and* may be tens or hundreds of metres thick. In terms of quantity, they contain the largest groundwater resources.

SENSITIVITY ANALYSIS - The measurement of the uncertainty in a calibrated model as a function of uncertainty in estimates of aquifer parameters and boundary conditions.

SIMULATION - One complete execution of a groundwater modelling program, including input and output.

SPECIFIC CAPACITY - The ratio of the rate of discharge of water from the well to the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time the drawdown measurement is made. It will generally decrease with time as the drawdown increases.

SPECIFIC RETENTION - The ratio of the volume of water the rock or sediment will retain against the pull of gravity to the total volume of the rock or sediment.

SPECIFIC STORAGE - The amount of water per unit volume of a saturated formation that is expelled from storage due to compression of the mineral skeleton and the pore water.

SPECIFIC YIELD - The ratio of the volume of water that a given mass of saturated soil or rock will yield by gravity to the volume of that mass.

SPRING - A spring of water naturally rising to and flowing over the surface of land, but does not include the discharge of underground water directly into a watercourse, wetland, reservoir or other body of water.

STOCHASTIC - A description of a parameter or a process with random qualities. A stochastic parameter has a range of possible values, each with a defined probability. The outcome of a stochastic process is not known with certainty.

STORAGE COEFFICIENT (STORATIVITY) Is the volume of water released or taken into storage per unit plan area of aquifer per unit change of head. It is a dimensionless value. In an unconfined aquifer, it is equal to specific yield.

SUB-ARTESIAN - Groundwater that does not rise above the surface of the ground when accessed by a bore and must be pumped to the surface.

TOPOGRAPHIC DIVIDE - The boundary between adjacent surface water boundaries. It is represented by a topographically high area.

TRANSMISSIVITY - Aquifer hydraulic parameter used to indicate the ease of groundwater flow through a metre width of aquifer section.

UNCERTAINTY ANALYSIS - The quantification of uncertainty in model results due to incomplete knowledge of model aquifer parameters, boundary conditions or stresses.

VADOSE ZONE - Also known as the zone of aeration and the unsaturated zone. The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched groundwater, may exist in the unsaturated zone.

VERIFICATION - A test of the integrity of a model by checking if its predictions reasonably match the observations of a reserved data set, deliberately excluded from consideration during calibration.

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WATER BUDGET - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

WATER TABLE - Is the upper surface of an unconfined aquifer.

YIELD, SAFE - The amount of naturally occurring groundwater that can be economically and legally withdrawn from an aquifer on a sustained basis without impairing the native groundwater quality or creating an undesirable effect such as environmental damage. It cannot exceed the increase in recharge or leakage from adjacent strata plus the reduction in discharge that is due to the decline in head caused by pumping.

YIELD, SUSTAINABLE - An accepted working definition of sustainable yield is (Kalaitzis et al, 1999): "*Sustainable yield is that proportion of the long term average annual recharge which can be extracted each year without causing unacceptable impacts on groundwater users or the environment*".

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Limitations

17.1 Geotechnical & Hydro Geological Report

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Hancock Coal Pty Ltd1 and only those third parties who have been authorised in writing by URS to rely on the report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 19 May 2011.

The methodology adopted and sources of information used by URS are outlined in this the Report.

Where this report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information unless required as part of the agreed scope of work. URS assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between May and December 2011.The information in this report is considered to be accurate at the date of issue and is in accordance with conditions at the site at the dates sampled. Opinions and recommendations presented herein apply to the site existing at the time of our investigation and cannot necessarily apply to site changes of which URS is not aware and has not had the opportunity to evaluate. This document and the information contained herein should only be regarded as validly representing the site conditions at the time of the investigation unless otherwise explicitly stated in a preceding section of this report. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

17 Limitations

Except as required by law, no third party may use or rely on, this Report unless otherwise agreed by URS in writing. Where such agreement is provided, URS will provide a letter of reliance to the agreed third party in the form required by URS.

To the extent permitted by law, URS expressly disclaims and excludes liability for any loss, damage, cost or expenses suffered by any third party relating to or resulting from the use of, or reliance on, any information contained in this Report. URS does not admit that any action, liability or claim may exist or be available to any third party.

URS does not represent that this Report is suitable for use by any third party.

Except as specifically stated in this section, URS does not authorise the use of this Report by any third party.

It is the responsibility of third parties to independently make inquiries or seek advice in relation to their particular requirements and proposed use of the relevant property.

Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.

A

Appendix A Groundwater Monitoring Network Details

Appendix A - Groundwater Monitoring Bore Details

Monitoring Bore ID	Alternate ID	Easting_MGA94	Northing_MGA94	Surface RL (mAHD)	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Comment
Vibrating Wire Piezometer Bores								
AVP-01	1252D	446725	7441097	307.89	55	C-D Sandstone	Yes	
AVP-01	1252D	446725	7441097	307.89	77	D-E Sandstone	Yes	
AVP-03	1262D	447701	7435936	303.12	42.5	D-E Sandstone	Yes	
AVP-04	1347DG	439677	7431710	333.08	80	B-C Sandstone	Yes	
AVP-04	1347DG	439677	7431710	333.08	132	C-D Sandstone	Yes	
AVP-04	1347DG	439677	7431710	333.08	143	D-E Sandstone	Yes	
AVP_05	1315D	445052	7433186	312	49	CU Coal Seam	Yes	
AVP_05	1315D	445052	7433186	312	65	C-D Sandstone	Yes	
AVP_05	1315D	445052	7433186	312	80	D-E Sandstone	Yes	
AVP_06	1336D	446510	7431957	313	48.5	C-D Sandstone	Yes	
AVP_06	1336D	446510	7431957	313	70	D-E Sandstone	Yes	
AVP-07	1337DG	445862	7430685	309	63.5	C-D Sandstone	Yes	
AVP-07	1337DG	445862	7430685	309	79	D-E Sandstone	Yes	

Appendix A - Groundwater Monitoring Bore Details

Monitoring Bore ID	Alternate ID	Easting_MGA94	Northing_MGA94	Surface RL (mAHD)	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Comment
AVP-08	1327D	446281	7430685	308	57.5	DU Coal Seam	Yes	
AVP-08	1327D	446281	7430685	308	67	D-E Sandstone	Yes	
AVP_09	1338DG	445607	7428457	316	61	C-D Sandstone		
AVP_09	1338DG	445607	7428457	316	73	D-E Sandstone		
AVP-10	1339DG	445921	7422777	321	61	Base DLM Seam	Yes	
AVP-10	1339DG	445921	7422777	321	84	D-E Sandstone	Yes	
AVP-11	1263DG	437531	7440861	327	122	A-B Sandstone	Yes	
AVP-11	1263DG	437531	7440861	327	165	B-C Sandstone	Yes	
AVP-11	1263DG	437531	7440861	327	205	C-D Sandstone	Yes	
AVP-11	1263DG	437531	7440861	327	218	D-E Sandstone	Yes	
AVP-13	1328DG	434457	7430044	363	70	Sandstone above A1	Yes	
AVP-13	1328DG	434457	7430044	363	112	A-B Sandstone	Yes	
AVP-13	1328DG	434457	7430044	363	182	B-C Sandstone	Yes	
AVP-13	1328DG	434457	7430044	363	229.3	D-E	Yes	

Appendix A - Groundwater Monitoring Bore Details

Monitoring Bore ID	Alternate ID	Easting_MGA94	Northing_MGA94	Surface RL (mAHD)	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Comment
						Sandstone		
AVP-14	1357D	438634	7436473	330.95	58.5	B-C Sandstone	Yes	
AVP-14	1357D	438634	7436473	330.95	108.5	B-C Sandstone	Yes	
AVP-14	1357D	438634	7436473	330.95	134.5	C-D Sandstone	Yes	
AVP-14	1357D	438634	7436473	330.95	149.5	D-E Sandstone	Yes	
KVP-01	1313C	447232	7453128	289.5	45	C-D Sandstone	Yes	
KVP-01	1313C	447232	7453128	289.5	70	D-E Sandstone	Yes	
KVP-02	1234C	445702	7447597	298.6	45	B-C Sandstone	Yes	
KVP-02	1234C	445702	7447597	298.6	67	C-D Sandstone	Yes	
KVP-02	1234C	445702	7447597	298.6	98	D-E Sandstone	Yes	
KVP-03	1228C	445706	7444681	299.25	33	B-C Sandstone	Yes	
KVP-03	1228C	445706	7444681	299.25	64	C-D Sandstone	Yes	
KVP-03	1228C	445706	7444681	299.25	83	D-E Sandstone	Yes	
KVP-04	1356R	440160	7454610	315.05	71	Tertiary above A1	Yes	

Appendix A - Groundwater Monitoring Bore Details

Monitoring Bore ID	Alternate ID	Easting_MGA94	Northing_MGA94	Surface RL (mAHD)	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Comment
KVP-04	1356R	440160	7454610	315.05	150	B-C Sandstone	Yes	
KVP-04	1356R	440160	7454610	315.05	180	C-D Sandstone	Yes	
KVP-04	1356R	440160	7454610	315.05	210	E-F Sandstone	Yes	
KVP-05	1238C	445179	7449764	307.15	40	B-C Sandstone	Yes	
KVP-05	1238C	445179	7449764	307.15	80	C-D Sandstone	Yes	
KVP-05	1238C	445179	7449764	307.15	105.5	D-E Sandstone	Yes	
KVP-06	1516D	440730	7450228	325	70			
KVP-06	1516D	440730	7450228	325	100			
KVP-06	1516D	440730	7450228	325	155			
KVP-06	1516D	440730	7450228	325	175			
KVP-07	1683R	442457	7440833	318.13	105	B-C Sandstone	Yes	
KVP-07	1683R	442457	7440833	318.13	125	C-D Sandstone	Yes	
KVP-07	1683R	442457	7440833	318.13	145	D-E Sandstone	Yes	
KVP-07	1683R	442457	7440833	318.13	157	Sub-E Sandstone	Yes	
KVP-08	1685R	439272	7445984	325.95	127	B-C Sandstone	Yes	
KVP-08	1685R	439272	7445984	325.95	190	C-D Sandstone	Yes	

Appendix A - Groundwater Monitoring Bore Details

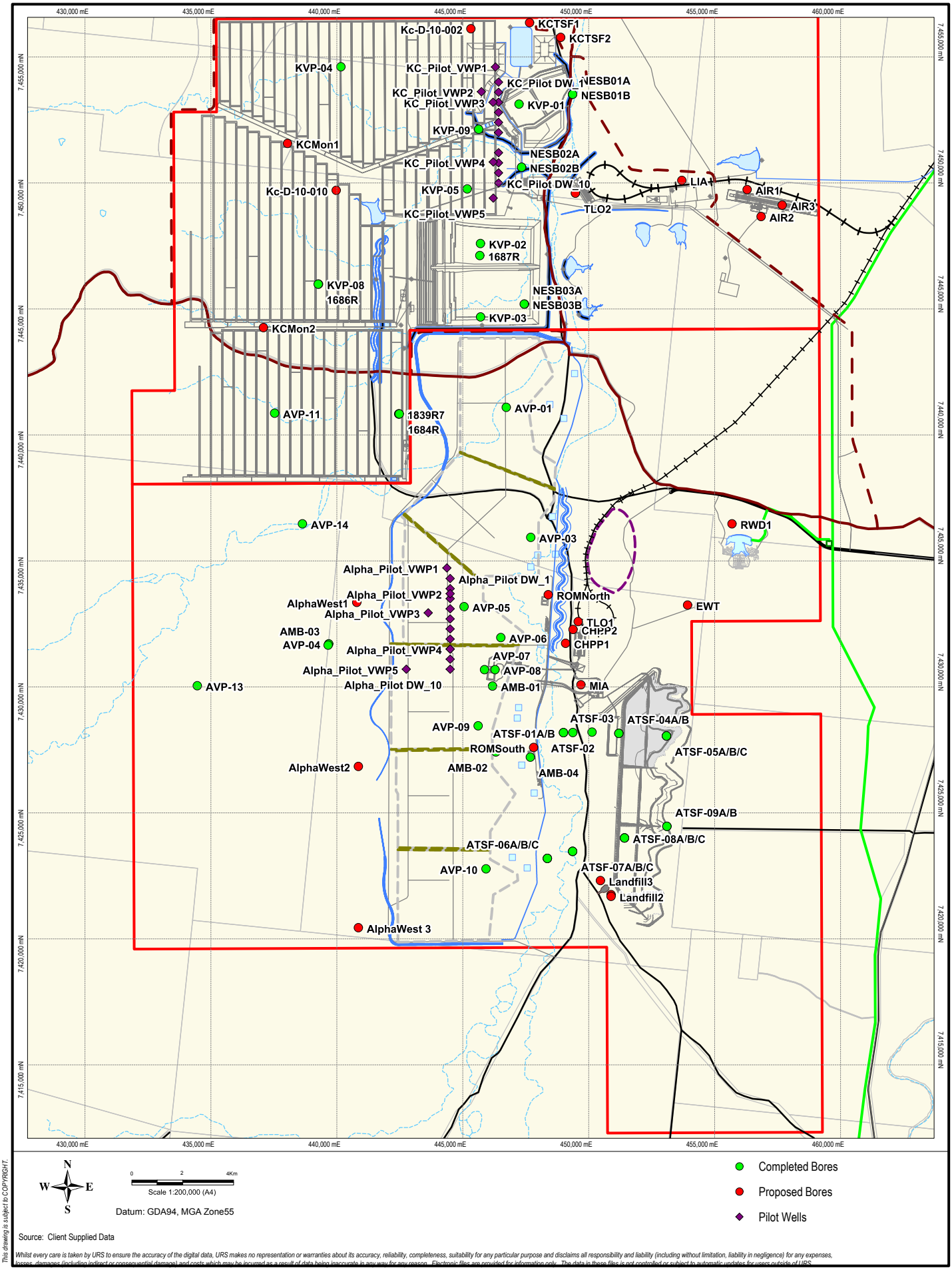
Monitoring Bore ID	Alternate ID	Easting_MGA94	Northing_MGA94	Surface RL (mAHD)	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Comment
KVP-08	1685R	439272	7445984	325.95	212	D-E Sandstone	Yes	
KVP-08	1685R	439272	7445984	325.95	224	Sub-E Sandstone	Yes	
KVP-09	1682R	445631	7452132	294.99	49	B-C Sandstone	Yes	
KVP-09	1682R	445631	7452132	294.99	68	C-D Sandstone	Yes	
KVP-09	1682R	445631	7452132	294.99	93	D-E Sandstone	Yes	
KVP-09	1682R	445631	7452132	294.99	107	Sub-E Sandstone	Yes	
KVP-10	1521D	444908	7454496	305	95			
KVP-10	1521D	444908	7454496	305	125			
KVP-10	1521D	444908	7454496	305	148			

Standpipe Monitoring Bores								
Monitoring Bore ID	**Alternate ID**	**Easting_MGA94**	**Northing_MGA94**	**Surface RL (mAHD)**	**Slotted Interval (mbgl)**	**Unit Monitored**	**Datalogger Installed**	**Comment**
AMB-01	AMB-01	446180	7430035	307.89	67-73	D-E Sandstone	Yes	
AMB-02	AMB-02	446314	7427417	303.12	83-95	E-F Sandstone	Yes	
AMB-03	AMB-03	439653	7431658	333.08	136-148	D-E Sandstone	Yes	
AMB-04	AMB-04	447682	7427212	312	30-36	C-D Sandstone	Yes	
KMB-01A	1623	442474	7438328	285	24-30	Tertiary		
KMB-01B	1624	442743	7438444	285	5-10	Quaternary sand		

Standpipe Monitoring Bores								
Monitoring Bore ID	**Alternate ID**	**Easting_MGA94**	**Northing_MGA94**	**Surface RL (mAHD)**	**Slotted Interval (mbgl)**	**Unit Monitored**	**Datalogger Installed**	**Comment**
KMB-02A	1625	447339	7450618	290	24-30	Tertiary		
KMB-02B	1626	447333	7450625	290	5-10	Quaternary sand		
KMB-03A	1627	447447	7445191	297	24-30	Permian coal		
KMB-03B	1628	447439	7445192	297	5-10	Quaternary cover		
KMB-04	1688R	445676	7447119	301.27	89-101	D-E Sandstone		
KMB-05	1686R	439261	7445984	325.95	200-212	C-D Sandstone		
KMB-06	2031R	442468	7440833	317.76	142-154	D-E Sandstone		
KMB-07	1684R	442478	7440833	317.91	120-132	C-D Sandstone		

Combination Bores								
Monitoring Bore ID	**Alt ID**	**Easting_MGA94**	**Northing_MGA94**	**Surface RL (m AHD)**	**Slotted Interval (mbgl)**	**Unit Monitored**	**Datalogger Installed**	**Comment**
ATSF-01B	1610R	448996	7428186	310	24-30	Laterite	Yes	Standpipe Bore - VWP installed S/N 15795
ATSF-01A	1553R	448996	7428186	310		Sub-E Sandstone	Yes	VWP Bore - S/N 14622
ATSF-01A	1553R	448996	7428186	310		Joe-Joe Formation	Yes	VWP Bore - S/N 15291
ATSF-02	1611R	449368	7428188	312	30-36	Conglomerate within laterite		Standpipe Bore
ATSF-03	1612R	450132	7428204	317	29-36	Conglomerate within laterite		Standpipe Bore
ATSF-04B	1613R	451199	7428156	325	12-18	Laterite	Yes	Standpipe Bore - VWP installed S/N 15793
ATSF-04A	1558R	451199	7428156	325		Joe-Joe Formation	Yes	VWP Bore - S/N 14621

Combination Bores								
Monitoring Bore ID	**Alt ID**	**Easting_MGA94**	**Northing_MGA94**	**Surface RL (m AHD)**	**Slotted Interval (mbgl)**	**Unit Monitored**	**Datalogger Installed**	**Comment**
ATSF-04A	1558R	451199	7428156	325		Joe-Joe Formation	Yes	VWP Bore - S/N 15292
ATSF-05C	1614R	453090	7428053	340	12-18	Laterite	Yes	Standpipe Bore - VWP installed S/N 15794
ATSF-05B	1615R	453090	7428053	340	30-36	Joe-Joe Formation	Yes	Standpipe Bore - VWP installed S/N 15796
ATSF-05A	1565R	453090	7428053	340		Joe-Joe Formation	Yes	VWP Bore - S/N 14623
ATSF-06C	1621R	448357	7423195	314.5	12-18	Surficial Sands		Standpipe Bore
ATSF-06B	1622R	448357	7423195	314.5	38-44	D-E Sandstone		Standpipe Bore
ATSF-06A	1564R	448357	7423195	314.5		Joe-Joe Formation		VWP Bore - S/N 15375
ATSF-07C	1618R	449361	7423473	315	6-12	Base of Surficial Sands		Standpipe Bore
ATSF-07B	1617R	449361	7423473	315	24-30	Base of Laterite		Standpipe Bore
ATSF-07A	1561R	449361	7423473	315	VWP	Joe-Joe Formation		VWP Bore - S/N 15294
ATSF-08C	1619R	451420	7424006	328	6-10	Surfical Sands/ top of Laterite		Standpipe Bore
ATSF-08B	1620R	451420	7424006	328	30-36	Joe-Joe Formation		Standpipe Bore
ATSF-08A	1563R	451420	7424006	328		Joe-Joe Formation		VWP Bore - S/N 15376
ATSF-09B	1616R	453106	7424465	333	12-18	Unconsolidated sands		Standpipe Bore
ATSF-09A	1566R	453106	7424465	333	24-36	Joe-Joe Formation		Standpipe Bore



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HANCOCK COAL PTY LTD

HANCOCK REGIONAL MODEL REFINEMENT

MONITORING BORE NETWORK

Draft

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GROUNDWATER

Figure: 1

File No: 42626660-g-912.wor | Drawn: RG | Approved: MS | Date: 08-11-2011 | Rev.A | A4

Monitoring Bore ID	Alternate ID	Alternate ID	Alternate ID	Alternate ID	Alternate ID	Site ID	Lease	Location	Type	Sample Collection Date	Sample Collection Time	SWL (mBTOC)	Field Temp (°C)	Field pH	Field EC (µS/cm)	VWP SN	VWP Temp	VWP Depth	Field Comments
AVP-01	1252D						Alpha		VWP Bore	20/07/2011	900								
										17/08/2011	1003								
										28/09/2011	1413								
										25/10/2011	1100								Level Loggers Downloaded
										22/11/2011	630								
										14/12/2011	1043								
										20/01/2012	1215								
AVP-03	1262D						Alpha		VWP Bore	20/07/2011	0								
										17/08/2011	940								
										28/09/2011	621								
										25/10/2011	1040								Level Loggers Downloaded
										21/11/2011	1755								
										14/12/2011	1019								
										19/01/2012	632								
AVP-04	1347DG						Alpha		VWP Bore	20/07/2011	0								
										16/08/2011	1615								
										28/09/2011	1105								
										24/10/2011	1610								Level Loggers Downloaded
										22/11/2011	1600								
										14/12/2011	820								
										20/01/2012	720								
AVP-05	1315D						Alpha		VWP Bore	15/12/2011	1722								Data Downloaded.
										20/01/2012	1048								Data Downloaded.
		AVP-05A	AVP-05_11776							20/07/2011	1145					11776	25.4	6056.6	
										18/08/2011	844						20.9	2482.7	
										28/09/2011	745						20.9	6389.5	
										26/10/2011	1200						20.9	6450.7	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		AVP-05B	AVP-05_8970							20/07/2011	1145					8970	17.1	6701	
										17/08/2011	844						17.1	2604	
										28/09/2011	745						17.1	6877.5	
										26/10/2011	1200						17.1	6941.1	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		AVP-05C	AVP-05_11793							20/07/2011	1145					11793	61.7	6983.2	
										17/08/2011	844						61.7	2650.3	
										28/09/2011	745						61.7	7157.4	
										26/10/2011	1200						61.7	7190.4	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
AVP-06	1336D						Alpha		VWP Bore	13/12/2011	1735								Data Downloaded.
										20/01/2012	1110								Data Downloaded.
		AVP-06A	AVP-06_8967							20/07/2011	1125					8967	52	6491.7	
										17/08/2011	914						51.9	2559	
										28/09/2011	715						51.9	6652.1	
										26/10/2011	1221						51.9	6711.6	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		AVP-06B	AVP-06_11794							20/07/2011	1125					11794	22.8	7097.3	
										17/08/2011	914						22.8	2673.3	
										28/09/2011	715						22.8	7215.1	
										26/10/2011	1221						22.8	7243.9	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
AVP-07	1337DG						Alpha		VWP Bore										
AVP-08	1327D						Alpha		VWP Bore										
AVP-09	1338DG	AVP-09A	AVP-09_8619				Alpha		VWP Bore	19/07/2011	1625					8619	-13.2	7166.6	
										16/08/2011	1330						-13.2	2685.1	
										27/09/2011	1740						-13.2	7245.2	
										24/10/2011	1210						-13.2	7259.1	
										21/11/2011	1650						-13.2	7277	
										14/12/2011	644						-13.2	7284.7	
										19/01/2012	1230						-13.2	7298.3	
		AVP-09B	AVP-09_9121							19/07/2011	1625					9121	-11.3	5526.1	
										16/08/2011	1330						-11.3	2365.7	
										27/09/2011	540						-11.3	5650.2	
										24/10/2011	1211						-11.3	5675.6	
										21/11/2011	1651						-11.3	5702.1	
										14/12/2011	654						-11.3	5716.1	
										19/01/2012	1232						-11.3	5736.3	
AVP-10	1339DG						Alpha		VWP Bore	19/07/2011	1400								
										16/08/2011	1054								
										27/09/2011	1412								
										24/10/2011	1028								Level Loggers Downloaded
										21/11/2011	1254								
										13/12/2011	1315								
										19/01/2012	1547								
AVP-11	1263DG						Alpha		VWP Bore	20/07/2011	935								
										24/08/2011	1710								
										28/09/2011	1455								
										25/10/2011	1200								Level Loggers Downloaded
										22/11/2011	707								
										15/12/2011	659								
										20/01/2012	1254								
AVP-13	1328DG						Alpha		VWP Bore	20/07/2011	0								
										17/08/2011	815								
										28/09/2011	1255								
										24/10/2011	1453								Level Loggers Downloaded
										22/11/2011	1732								
										14/12/2011	845								
										20/01/2012	930								
AVP-14	1357D						Alpha		VWP Bore	14/12/2011	752								Data Downloaded.
										20/01/2012	1015								Data Downloaded.
		AVP-14A	AVP-14_11796							19/07/2011	1755					11796	-38.3	6832.8	
										17/08/2011	710						-32.8	2503.9	
										28/09/2011	955						-32.8	6271.3	
										26/10/2011	1300						-32.8	6275.6	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		AVP-14B	AVP-14_11765							19/07/2011	1755					11765	-39.4	6554.6	
										17/08/2011	710						-38.3	2614.4	
										28/09/2011	955						-38.3	6838.3	
										26/10/2011	1300						-38.3	6844	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		AVP-14C	AVP-14_11766							17/08/2011	710					11766	-39.2	2560.6	
										28/09/2011	955						-39.2	6561.9	
										26/10/2011	1300						-39.2	6564.4	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		AVP-14D	AVP-14_11777							17/08/2011	710					11777	15.1	2647.4	
										28/09/2011	955						15.1	7013.7	
										26/10/2011	1300						15.1	7021.5	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
KVP-01	1313C						Kevin's Corner		VWP Bore	12/12/2011	1445								Data Downloaded.
										21/01/2012	800								Too wet to access.
		1313CA								20/07/2011	630					8977	-2.3	5363	KCA-M-005
										24/08/2011	1150						-2.4	2316.1	
										29/09/2011	828						-2.4	5371.4	
										26/10/2011	923						-2.4	5380.2	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		1313CB								20/07/2011	630					8976	-0.4	6873.3	KCA-M-005
										24/08/2011	1150						-0.5	2623.3	
										29/09/2011	828						-0.5	6891.3	
										26/10/2011	923						-0.5	6900.4	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
KVP-02	1234C						Kevin's Corner		VWP Bore	26/10/2011	840								Data Downloaded.
										22/11/2011	1355								Data Downloaded.
										14/12/2011	1218								Data Downloaded.
										21/01/2012	1600								Data Downloaded.
		1234CA								20/07/2011	755					8624	-22.1	6385.8	
										24/08/2011	1521						-22.2	2525.2	
										28/09/2011	1722						-22.2	6361.3	
										26/10/2011	0								
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		1234CB								20/07/2011	755					8621	-16.5	6965.4	
										24/08/2011	1521						-16.4	2639.5	
										28/09/2011	1722						-16.4	6583.2	
										26/10/2011	0								
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		1234CC								20/07/2011	755					8978	-4	7563.2	
										25/08/2011	1521						-4	2750.5	
										28/09/2011	1722						-4	7571.6	
										26/10/2011	0								
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
KVP-03	1228C	1228CA					Kevin's Corner		VWP Bore	20/07/2011	820						61.8	7839.2	
										24/08/2011	1628						61.5	2804.1	
										28/09/2011	1657						61.5	7892.6	
										26/10/2011	712						61.5	7901.2	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
										14/12/2011	1115						--	--	Data Downloaded.
										21/01/2012	1350						--	--	Data Downloaded.
KVP-04	1356R						Kevin's Corner		VWP Bore	12/12/2011	1300								Data Downloaded.
										21/01/2012	1032								Data Downloaded.
		1356RA								20/07/2011	650					N/A	39.2	6591.7	No SN in folder.
										24/08/2011	1120					N/A	37.3	2482.8	No SN in folder.
										29/09/2011	859						37.3	6165.8	
		1356RB								20/07/2011	650					N/A	37.4	6163.1	No SN in folder.
										24/08/2011	1120					N/A	39.1	2568.1	No SN in folder.
										29/09/2011	859						39.1	6596.9	
		1356RC								24/08/2011	1120					N/A	82.4	2608.8	No SN in folder.
										29/09/2011	859						82.4	6813.3	

Monitoring Bore ID	Alternate ID	Alternate ID	Alternate ID	Alternate ID	Alternate ID	Site ID	Lease	Location	Type	Sample Collection Date	Sample Collection Time	SWL (mBTOC)	Field Temp (°C)	Field pH	Field EC (µS/cm)	VWP SN	VWP Temp	VWP Depth	Field Comments
KVP-05	1238C	1238CA					Kevin's Corner		VWP Bore	12/12/2011	1504								Data Downloaded.
										21/01/2012	1114								Too wet to access.
										20/07/2011	725						-29.5	8218.5	
										24/08/2011	1455						-29.7	2866.8	
										29/09/2011	630					11781	-29.7	8219.2	
										26/10/2011	900						-29.7	8220.5	
										21/11/2011							--	--	JBT installing cabinet/downloading data.
		1238CB								20/07/2011	725						24	6943.2	
										24/08/2011	1455						24.1	2636	
										29/09/2011	630					11728	24.1	6958.1	
										26/10/2011	900						24.1	6955.8	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
		1238CC								24/08/2011	1455						-17.2	2578.1	
										29/09/2011	630						-17.2	6652	
										26/10/2011	900						-17.2	6634.6	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
KVP-06	1516D						Kevin's Corner		VWP Bore	21/01/2012	1745								Too wet to access, per Salva.
		KVP06_11770								12/12/2011	1226					11770	-44.7	6131.4	
		KVP06_11757								12/12/2011	1226					11757	24.8	6309.3	
		KVP06_11576								12/12/2011	1226					11576	57.5	6412.3	
		KVP06_11734								12/12/2011	1226					11734	72.7	7158.5	
KVP-07	1683R	1492L VWP				1492	Kevin's Corner		VWP Bore	27/10/2011	704								Data downloaded
										22/11/2011	800								Station failed to connect
										12/12/2011	1536								Data Downloaded.
										20/01/2012	1405								Unable to connect to station - no data downloaded.
KVP-08	1685R	1446L_Monitoring_2	1637L	1446L		1446	Kevin's Corner		VWP Bore	22/11/2011	1115								
										14/12/2011	1300								Data Downloaded.
										22/01/2012	730								Too wet to access.
																			Data Downloaded.
																			Too wet to access.
KVP-09	1682R	1447 VWP				1447	Kevin's Corner		VWP Bore	12/12/2011	1430								Data Downloaded.
										21/01/2012	825								Data Downloaded.
										21/01/2012	1730								Too wet to access.
KVP-10	1521D	KC_D_005	KVP10_A				Kevin's Corner		VWP Bore	13/12/2011	1119						27.5	6478.7	No Serial Number.
			KVP10_B							13/12/2011	1119						-14.9	6522.8	No Serial Number.
			KVP10_C							13/12/2011	1119						28.5	6922.4	No Serial Number.
AMB-01							Alpha		Standpipe Bore	19/07/2011	1645	33.19	23.8	7.43	1534				
										16/08/2011	1434	29.4	28.2	7.49	1499				Clear, no odor.
										28/09/2011	810	30.17	25	7.52	1516				Level logger downloaded, sulphur odor.
										24/10/2011	1328	30.54	29.3	7.59	1531				
										22/11/2011	1440	30.76	32	7.878	1504				Level logger downloaded, clear, dup collected.
										14/12/2011	625	30.8	23.7	7.71	1522				Level logger downloaded, clear, slight sulphur odor, dup.
										19/01/2012	1111	30.76	31.8	7.225	1557				Level logger downloaeded, clear, no odor (dup).
AMB-02							Alpha		Standpipe Bore	19/07/2011	1535	15.19	26.1	7.64	1627				Clear, no odor.
										16/08/2011	1249	15.82	29.5	7.62	1685				Clear, light sulphur odor.
										27/09/2011	1615	16.4	29.7	7.78	1656				Level logger downloaded.
										24/10/2011	1153	16.82	30.4	7.82	1671				
										21/11/2011	1515	17.02	31.3	7.7	1699				Level logger downloaded, slightly turbid, sulphur odor.
										13/12/2011	1603	17.34	30.8	7.71	1720				Level logger downloaded, slight sulphur odor, slightly turbid.
										19/01/2012	1250	17.67	33.4	7.447	1626				Level logger downloaded, clear.
AMB-03							Alpha		Standpipe Bore	20/07/2011	1211	28.43	25.3	7.74	1460				
										16/08/2011	1608	28.62	25.7	8.07	1427				Clear, no odor.
										28/09/2011	1041	29.02	28	8.07	1438				Level logger downloaded, very light sulphur odor, slightly opaque.
										24/10/2011	1546	29.16	29	7.89	1475				
										22/11/2011	1550	29.47	32.6	7.991	1441				Level logger downloaded, clear.
										14/12/2011	732	29.67	27.1	8.03	1465				Clear; bottom of drop tube lost down borehole.
										20/01/2012	709	29.81	28.5	7.801	1537				Clear, slight sulphur odor, level logger downloaded.
AMB-04							Alpha		Standpipe Bore	19/07/2011	1430	11.2	26.1	6.81	4713				Cloudy.
										16/08/2011	1131	11.39	26.5	6.85	4626				Slight sulphur odor.
										27/09/2011	1500	11.64	33.4	7	4346				Level loggers downloaded, blackish in color, strong sulphur odor, visible particles in water.
										24/10/2011	1053	11.88	28.7	6.89	4656				Sulphur odor.
										21/11/2011	1419	12.03	30.9	6.797	5946				Level loggers downloaded, milky in color, turbid, sulphur odor.
										13/12/2011	1459	12.15	29.7	6.91	4953				Level logger downloaded, milky gray color, slightly turbid, slight sulphur odor.
										19/01/2012	1417	12.35	33.3	6.827	4416				Level logger downloaded, turbid, small black particulate, small amount of organic matter, sulphur odor.
KMB-01A	1623R	NESB01A				Nest 1	Kevin's Corner	Sandy Creek	Standpipe Bore	24/08/2011	1233	7.28	26.8	7.925	1547				Bailed, brown, very turbid, salty odor, small chunks in sample.
										29/09/2011	930	7.81	24.8	6.52	797				Bailed, turbid sample, insects and vegetation drawn from well.
										25/10/2011	1540	8.82							Bailed, very turbid, brown, chemical odor.
										23/11/2011	1215	8.95	26	6.874	1126				Bailed, very turbid, slight sulphur odor, about 2.5L water in well.
										12/12/2011	915	8.97	26.5	6.83	1419				Bailed (3L), very turbid, slight sulphur odor.
										21/01/2012	635	8.92	24.6	6.78	5656				Slightly turbid, sulphur odor, small particles.
KMB-01B	1624R	NESB01B				Nest 1	Kevin's Corner	Sandy Creek	Standpipe Bore	24/08/2011	1233	9.06	29	7.02	5900				Strong chlorine odor.
										29/09/2011	930	8.97	23.9	6.51	5566				Slightly turbid, slight to medium chlorine odor.
										25/10/2011	1530	8.94	31	6.64	5717				Pumped at 25 m.
										23/11/2011	1213	8.96	27.4	6.629	5420				Pumped at 25 m, slight sulphur odor, black particles throughout, turbid, orangish yellow color.
										12/12/2011	913	8.9	29.9	6.7	5706				Slight black color, mild sulphur odor, small black particulate.
										21/01/2012	640	8.99	25.3	6.913	2470				Bailed (3L), turbid, slight sulphur odor, lots of settleable matter.
KMB-02A	1625R	NESB02A				Nest 2	Kevin's Corner	Sandy Creek	Standpipe Bore	24/08/2011	1350	3.51	25.8	9.066	211				Bailed, very turbid, high clay content.
										29/09/2011	645	3.62	22.1	6.02	215				Bailed.
										25/10/2011	1645	3.69	24.8	6.51	333				Bailed, brown, very turbid.
										23/11/2011	1500	3.8	24.9	6.091	250				Turbid, yellowish brown, slight sulphur odor.
										12/12/2011	1219	3.66	27.5	6.06	256				Very turbid, slight sulphur odor.
										21/01/2012	1127	3.48	28.3	6.144	327				Bailed (6L), orange/brown color, slight sulphur odor, sediment in sample.
KMB-02B	1626R	NESB02B				Nest 2	Kevin's Corner	Sandy Creek	Standpipe Bore	24/08/2011	1345	10.49	28.9	7.58	2673				Very turbid, high clay content, very difficult to field filter, pump unable to push water; bore only 26m deep.
										29/09/2011	655	10.82	21.8	7.18	1503				Strong sulphur odor, yellow, turbid.
										25/10/2011	1642	10.76	32.2	7.22	1529				Pumped at 25 m.
										23/11/2011	1456	10.74	28.3	7.088	1540				Pumped bottom out at 25 m raised pump to 23 m, very turbid, earthy odor.
										12/12/2011	1216	10.73	33.2	7.22	1478				Pump at 23m, blocked at 25m, slightly turbid/cloudy, slight sulphur odor.
										21/01/2012	1123	10.73	30.6	7.369	1457				Slightly turbid, sulphur odor.
KMB-03A	1627R	NESB03A				Nest 3	Kevin's Corner	Sandy Creek	Standpipe Bore	24/08/2011	345	5.97	24.8	7.25	1558				Bailed, very turbid, high clay content, TD: 10.89.
										28/09/2011	1542	6.11	6.87	1252					Bailed, very turbid.
										26/10/2011	725	6.32	24.3	6.82	1159				Bailed, very turbid.
										23/11/2011	1550	6.2	24.7	6.693	1130				Turbid, yellowish brown, sulphurous odor.
										12/12/2011	1320	6.22	26.7	6.78	1115				Very turbid, slight sulphur odor.
										21/01/2012	1241	6.36	28.4	6.763	1162				Bailed (10L), turbid, orange/brown, sulphur odor, sediment in sample.
KMB-03B	1628R	NESB03B				Nest 3	Kevin's Corner	Sandy Creek	Standpipe Bore	24/08/2011	340	13.42	27.1	7.46	1145				Gray/cloudy, sulphur odor, TD: 31 m.
										28/09/2011	1545	13.4	30.3	7.38	950				Clear.
										26/10/2011	725	13.42	27.3	7.32	998				No odor.
										23/11/2011	1555	13.41	27.4	7.373	974				Turbid, milky gray, slight sulphur odor.
										12/12/2011	1315	13.37	34.8	7.38	983				Cloudy, gray in color, strong sulphur odor.
										21/01/2012	1239	13.37	32.3	7.401	961				Slightly turbid, slight sulphur odor.
KMB-04	1688R	1687R		1493L_Monitoring		1493	Kevin's Corner		Standpipe Bore	10/11/2011	1527								No sample, pump blocked by screws.
										14/12/2011	1141	14.7	31.3	7.79	835				Sample clear, no odor.
										21/01/2012	1610	14.63							SWL only.
KMB-05	1686R	1686A		1446L_Monitoring_1		1446	Kevin's Corner		Standpipe Bore	22/11/2011	1130	31.01							Bore dipped for SWL.
										14/12/2011	1258	30.98	36.3	8.18	971				Clear, no odor.
										22/01/2012	730								Too wet to access.
KMB-06	2031R	1839R	1683R	1492L_D-E_Monitoring		1492	Kevin's Corner		Standpipe Bore	28/10/2011	619	22.3							No sample, pump blocked by screws.
										22/11/2011	823	22.36							No sample, pump blocked by screws.
										15/12/2011	642	22.35							No sample, pump blocked by screws.
										20/01/2012	1457	22.34							Water level only.
KMB-07	1684R			1492L_C-D_Monitoring		1492	Kevin's Corner		Standpipe Bore	27/10/2011	652	22.85	31.3	8.16	1044				Bottom of tubing stopped at approx 120m (casing screws?).
										22/11/2011	820	22.85							
										15/12/2011	639	22.81							Could not be pumped due to screws in casing.
										20/01/2012	1405	22.8							Water level only.
ATSF-01										13/12/2011	1246								Data Downloaded.
ATSF-01A	1553R	A_11_SP_018	1553RA	1553R_14622		1553R	Alpha	TSF - Northern Line	VWP Bore	18/01/2012	1730								Data Downloaded.
										15/08/2011	1520					14622	61.7	2481.9	
										26/09/2011	1145						61.7	6178.7	
										25/10/2011	1425						61.7	6189.1	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
			1553RB	1553R_15291						15/08/2011	1520					15291	20.9	2608.7	
										26/09/2011	1145						20.9	6815	
										25/10/2011	1425						20.9	6820.4	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
ATSF-01B	1610R	A_11_SP_018				1553R	Alpha	TSF - Northern Line	Standpipe Bore	15/08/2011	1518	10.28	27.5	6.17	25633				
										27/09/2011	1140	10.37	30.6	6.99	26700				Slight sulphur smell, clear.
										25/10/2011	1421	10.37	31.4	5.96	26900				Sulphur odor.
										23/11/2011	1001	10.4	27.1	60.71	26000				Clear, slight sulphur odor.
										13/12/2011	1102	10.43	32.6	6.27	26233				Clear, strong sulphur odor. Solid block at 24 m, pump at 20m (new equipment installed down bore recently).
										18/01/2012	1655	10.47	32.6	6.019	25700				Sulphur odor, very small white particles.
ATSF-02	1611R	1554R		TSF4		1554R	Alpha	TSF - Northern Line	Standpipe Bore	15/08/2011	1436	11.28	27.8	5.79	7056				Clear, no odor.
										27/09/2011	1053	11.26	30.6	5.98	7206				Slight sulphur smell, clear.
										25/10/2011	1321	11.32	32.3	5.74	7523				Sulphur odor.
										23/11/2011	917	11.33	26.9	6.142	7133				Slightly turbid, strong sulphur odor.
										13/12/2011	1140	11.31	33.1	5.84	7783				Slightly turbid, strong sulphur odor.
										18/01/2012	1552	11.37	33.5	5.752	7513				Clear, sulphur odor.
ATSF-03	1612R	1556R		TSF5		1556R	Alpha	TSF - Northern Line	Standpipe Bore	15/08/2011	1330	16.56	27.9	5.998	7930				Clear, no odor.
										27/09/2011	945	15.53	29.3	6.22	7166				Slight sulphur smell, slightly turbid.
										25/10/2011	1515	16.48	31.7	5.76	8323				
										23/11/2011	822	16.53	26	5.896	8036				Slightly turbid.
										13/12/2011	1009	16.51	32.3	5.84	8363				Very slight turbidity, slight sulphur odor.
										19/01/2012	957	16.56	31.3	5.927	7490				Clear, sulphur odor.
ATSF-04										15/12/2011	900								Data Downloaded.
ATSF-04A	1558R	A_11_SP_022	1558RA	TSF6	1558R_15292	1558R	Alpha	TSF - Northern Line	VWP Bore	19/01/2012	929								Data Downloaded.
										16/08/2011	636					15292	19.1	2773.9	
										27/09/2011	903						19.1	7735.5	
										25/10/2011	1630						19.1	7706.8	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
			1558RB		1558R_14621					16/08/2011	636					14621	75.8	2862.9	
										27/09/2011	903						75.8	8159.6	
										25/10/2011	1630						75.8	8121.5	
										21/11/2011	900						--	--	JBT installing cabinet/downloading data.
ATSF-04B	1613R			TSF6		1558R	Alpha	TSF - Northern Line	Standpipe Bore	16/08/2011	636								Dry at 18.92 m.
										27/09/2011	9.3								Dry at 18.84 m.
										25/10/2011	1628								Dry at 19.10 m.
										23/11/2011	802								Dry at 18.86 m.
										15/12/2011	907								Dry.
										19/01/2012	930								Dry at 18.94 m.
ATSF-05										15/12/2011	815								Data Downloaded.
ATSF-05A	1565R	A_11_SP_023	1565R_14623	TSF7	VWP 14623	1565R	Alpha	TSF - Northern Line	VWP Bore	16/08/2011	704								
										27/09/2011	710					14623	22.8	7580.8	
										25/10/2011	1707						22.8	7602.1	
										21/11/2011							--	--	JBT installing cabinet/downloading data.
										15/12/2011	815								Data Downloaded.
										19/01/2012	753								Data Downloaded.
ATSF-05B	1615R	A_11_SP_023		TSF7		1565R	Alpha	TSF - Northern Line	Standpipe Bore	16/08/2011	705	30.22	19.3	7.36	566				Clear, no odor.
										27/09/2011	705	30.17	22.5	6.99	684				Sulphur smell.
										25/10/2011	1657	30.14	26.2	7.47	886				Bailed, sulphur odor.

Monitoring Bore ID	Alternate ID	Alternate ID	Alternate ID	Alternate ID	Alternate ID	Site ID	Lease	Location	Type	Sample Collection Date	Sample Collection Time	SWL (mBTOC)	Field Temp (°C)	Field pH	Field EC (µS/cm)	VWP SN	VWP Temp	VWP Depth	Field Comments
										23/11/2011	641	30.17	24.5	6.764	1224				Unable to get bailer past top of water (possible layer of decaying material), pump put to 34.5 m, putrified smell, turbid.
										15/12/2011	741	30.2	25.5	6.82	1005				Turbid, putrid odor.
										19/01/2012	735	30.21	31.8	6.598	1036				Clear, sulphur odor, small white particulat and organic matter.
ATSF-05C	1614R	A_11_SP_023		TSF7		1565R	Alpha	TSF - Northern Line	Standpipe Bore	16/08/2011	700	16.36	21.4	6.874	921				Bailed, very turbid, earthy color, 1.6 m water.
										27/09/2011	710	--	--	--	--				Dry at 18.91 m.
										25/10/2011	1704	--	--	--	--				No sample collected - bees.
										23/11/2011	645	--	--	--	--				Blocked at 16.08 m, possible dead bees or dry.
										15/12/2011	802	--	--	--	--				Blocked at 16.20 m; dry or possible organic matter.
										19/01/2012	738	--	--	--	--				Dry at 18.53 m.
ATSF-06A	1564R	A_11_SP_024	1664RA	TSF8	1564R_15375	1564R	Alpha	TSF - Southern Line	VWP Bore	16/08/2011	953						11.4	2656.2	
										26/09/2011	1520						11.4	7083.4	
										25/10/2011	1147					15375	11.4	7088.5	
										21/11/2011	1320						11.3	7083.4	
										13/12/2011	1327						11.3	7069.5	
										19/01/2012	1654						11.3	7067.8	
ATSF-06B	1622R	A_11_SP_024		TSF8		1564R	Alpha	TSF - Southern Line	Standpipe Bore	16/08/2011	918	10.27	24.9	6.78	33833				Sample very turbid. Lifted pump to 38m (above sediment in bottom of bore); no odor.
										26/09/2011	1518	10.21	30	6.95	28300				
										25/10/2011	1130	10.32	31.4	6.48	43800				
										21/11/2011	1310	10.32	32.8	6.972	27630				Black, sulphur odor.
										13/12/2011	1335	10.33	32.1	6.53	44133				Turbid, stong sulphur odor.
										19/01/2012	1603	10.38	33.9	6.517	42100				
ATSF-06C	1621R	A_11_SP_024		TSF8		1564R	Alpha	TSF - Southern Line	Standpipe Bore	16/08/2011	921	8.23	24.6	6.98	17610				Bailed.
										26/09/2011	1525	13.36	25.4	6.47	33800				Bailed.
										25/10/2011	1130	8.78							Bailed.
										21/11/2011	1315	9.3	28.1	6.27	40500				Very turbid.
										13/12/2011	1340	9.77	27.5	6.69	47300				
										19/01/2012	1608	9.61	27.7	6.304	49200				Bailed (7.5L), turbid, dark gray, black particulate, strong organic/stagnant odor.
ATSF-07A	1561R	A_11_SP_025	1561R_15294			1561R	Alpha	TSF - Southern Line	VWP Bore	15/08/2011	1630						13.3	2733.9	
										26/09/2011	1230						13.3	7484.9	
										25/10/2011	1000					15294	13.3	7491.7	
										21/11/2011	1141						13.3	7494.2	
										13/12/2011	1304						13.3	7497.3	
										18/01/2012	1530						13.3	7499.2	
ATSF-07B	1617R	A_11_SP_025				1561R	Alpha	TSF - Southern Line	Standpipe Bore	15/08/2011	1627	13.77	25.1	5.29	32633				
										26/09/2011	1227	13.87	32.5	6.14	49133				Slight suphur odor, slightly turbid.
										25/10/2011	952	13.97	30.9	4.97	50100				
										21/11/2011	1130	13.97	30.3	5.207	49166				Slight sulphur odor.
										13/12/2011	905	13.86	33.6	5.39	50466				Slight sulphur odor, slightly turbid, black particulate.
										18/01/2012	1442	14.02	31.5	5.202	49333				Slight sulphur odor, slightly turbid.
ATSF-07C	1618R	A_11_SP_025				1561R	Alpha	TSF - Southern Line	Standpipe Bore	15/08/2011	1612	10.29	22.9	5.873	22200				Bailed, highly turbid but sediment settled out.
										26/09/2011	1228	10.54	27.8	5.48	44900				Bailed.
										25/10/2011	951	10.61	26.7	5.3	40700				
										21/11/2011	1136	10.66	27	5.188	50100				Turbid.
										13/12/2011	913	10.71	25.8	5.5	51100				Bailed, turbid, strong sulphur odor.
										18/01/2012	1445	10.75	28.1	5.233	51200				Bailed (9L), light brown, turbid, no odor.
ATSF-08A	1563R	A_11_SP_028	1563R_15376	TSF10		1563R	Alpha	TSF - Southern Line	VWP Bore	15/08/2011	1725						9.1	2743.6	
										26/09/2011	1710						9.1	7615.3	
										25/10/2011	650					15376	9.1	7666.4	
										22/11/2011	1037						9.2	7721.2	
										13/12/2011	1250						9.2	7758.9	
										18/01/2012	1300						9.2	7790.1	
ATSF-08B	1620R			TSF10		1563R	Alpha	TSF - Southern Line	Standpipe Bore	15/08/2011	1718	25.81	23.9	7.15	1957				Opaque, strong sulphur odor.
										26/09/2011	1700	25.59	27.4	6.76	1669				Sample opaque, very slight sulphur odor.
										25/10/2011	650	25.93	25.8	6.16	2000				Malodorous, insect bodies on pumping equipment, possibly decomposing bees.
										21/11/2011	1034	25.74	30.6	6.459	1666				Suphur odor, turbid, decomposing bees, some detritus.
										13/12/2011	626	25.7	25..0	6.85	1643				Very turbid/muddy; putrid odor, organic matter on well cap and in sample, extremely slow to pump.
										18/01/2012	1257	25.75	33.8	6.606	1532				Light brown, turbid, putrid odor, dead organic matter.
ATSF-08C	1619R			TSF10		1563R	Alpha	TSF - Southern Line	Standpipe Bore	15/08/2011	1721	10.84							Not enough water to collect a sample.
										26/09/2011	1705								Dry at 11.93 m.
										11/11/2011	857								Dry at 10.85 m (insect wings on probe tip).
										21/11/2011	1036								Dry at 11.05 m.
										13/12/2011	632								Dry at 11.03 m.
										18/01/2012	1300								Dry at 10.87 m.
ATSF-09A	1566R			TSF11		1566R	Alpha	TSF - Southern Line	Standpipe Bore	15/08/2011	1115	26.31	26.4	4.73	1918				Turbid, red in color, chemical odor.
										26/09/2011	943	26.25	32.3	4.9	2136				Chemical/strong sulphur odor, light brown.
										25/10/2011	917								Blocked at about 28 m.
										21/11/2011	919	26.23	30.3	5.465	2020				Very sulphurous odor, turbid with detritus, highly organic/decomposing odor.
										13/12/2011	753	26.19	32.7	5.68	2270				Turbid, orange/yellow color, strong sulphur odor, small organic matter particles.
										18/01/2012	1033	26.23	32	5.91	1949				Turbid, orange/brown color, putrid odor, organic particulates, TD: 35.45.
ATSF-09B	1616R			TSF11		1566R	Alpha	TSF - Southern Line	Standpipe Bore	15/08/2011	1125								Dry.
										26/09/2011	947								Dry at 19 m.
										25/10/2011	917								Dry at 19 m.
										21/11/2011	919								Dry at 18.80 m.
										13/12/2011	801								Dry at 18.70 m.
										18/01/2012	1045								Dry at 18.67 m.
1492L_C-D	1636R	1365L							Pump Test Bore	26/10/2011	1519	22.12	32.4	11.55	1431				
										22/11/2011									
										12/12/2011	1535	22.08	35	10.69	1180				Turbid/black, slight sulphur odor, black particulat settles out rapidly.
										20/01/2012	1341	22.13	32.7	9.445	982				Clear, no odor, small black particles.
1492L_D-E	1635R	1365R							Pump Test Bore	26/10/2011	1350	21.8	31.7	12.28	2930				
										22/11/2011	915	21.86	29.5	12.036	3807				Clear, faint sulphur odor.
										12/12/2011	1429	21.81	31.3	12.03	3833				Clear, sulphur odor.
										20/01/2012	1427	21.86	29.1	11.087	1225				Clear, slight sulphur odor.
1493L_D-E	1638L								Pump Test Bore	10/11/2011	1346	14.43	36	8.2	857				Clear, few dark particles, no odor
										22/11/2011	1251	14.35	33.3	8.73	853				Clear, slight sulphurous odor, no cap on well casing
										14/12/2011	1027	14.27	31.7	8.83	859				Clear, no odor.
										21/01/2012	1506	14.22	31.6	8.668	849				Clear, no odor.
1446L	1637L	1637R							Pump Test Bore	11/10/2011	1032	30.61	34.6	8.82	782				Clear, no odor.
										22/11/2011	1107	30.59	32	9.518	816				Clear, slight sulphur odor.
										15/12/2011	959	30.54	29	8.92	809				Clear, mild sulphur odor.
										22/01/2012	730								Too wet to access.
1447L_C-D	1687L	1680R							Pump Test Bore	23/11/2011	1120	13.2	27.7	10.331	1152				Clear, no odor
										12/12/2011	1121	12.97	31.5	10.25	1008				Clear, very slight sulphur odor.
										21/01/2012	833	12.96	29.5	10.049	935				Clear, no odor, fine white particles.
1447L_D-E	1681R								Pump Test Bore	10/11/2011	1549	12.86	32.3	8.11	754				Clear, no odor, few particles.
										23/11/2011	1340	12.72	27.8	8.154	830				Clear, slight sulphur odor.
										12/12/2011	1012	12.55	30.9	8.15	874				Clear, slight sulphur odor.
										21/01/2012	813	12.53	29.9	8.273	832				Clear, slight sulphur odor, small amound of suspended particles, cap replaced.
										PROPOSED BORES									
AIR1									Standpipe Bore										
AIR2									Standpipe Bore										
AIR3									Standpipe Bore										
Kc-D-10-002									VWP										
Kc-D-10-010									VWP										
KCMon1									Standpipe Bore										
KCMon2									Standpipe Bore										
KCTSF1									Standpipe Bore										
KCTSF2									Standpipe Bore										
TLO2									Standpipe Bore										
LIA									Standpipe Bore										
AlphaWest1									Standpipe Bore										
AlphaWest2									Standpipe Bore										
AlphaWest3									Standpipe Bore										
Landfill1									Standpipe Bore										
Landfill2									Standpipe Bore										
Landfill3									Standpipe Bore										
MIA									Standpipe Bore										
CHPP1									Standpipe Bore										
CHPP2									Standpipe Bore										
EWT									Standpipe Bore										
TLO1									Standpipe Bore										
RWD1									Standpipe Bore										
ROMSouth									Standpipe Bore										
ROMNorth									Standpipe Bore										

B

Appendix B Summary of Field Data

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Our reference: JBT01-005-028 - Pumping Test Report-1290L.doc

11 April 2011

Hancock Coal Pty Ltd
GPO Box 963 Brisbane QLD 4101

Pumping Test Analysis – Bore 1290L

Introduction

A pumping test of bore 1290L, a bore screened within the D-E sandstone aquifer, was undertaken as part of the BFS study. The purpose of the test was to obtain hydraulic parameters for the D-E sandstone aquifer in an area where the permeability was apparently low relative to other locations, and in an area where mining of the proposed Alpha open cut is planned to commence.

The location of the bores is shown in Figure 1.

Pumping Test

The pumping test was conducted on 17 February 2011. The testing process included:

Test Bore and Monitoring Bore

The pumping test bore (1290L) was constructed as follows:

- The bore was constructed within an existing hole from which large diameter core was previously taken from the D coal seam for testing purposes. The hole was subsequently deepened and drilled to the top of the E coal seam to enable construction of the bore within the D-E sandstone;
- The total depth of the bore is 73 m below ground level (mbgl). The bore construction log is shown in Attachment A.

The monitoring bore (AMB-01) was constructed as follows:

- On completion of the pumping test bore a site was selected for drilling and construction of a monitoring bore, 31 m distant from the pumping bore;
- The bore was drilled to intersect and monitor the D-E sandstone over the same interval as the pumping bore
- The total depth of the bore is 73 mbgl. The bore construction log is shown in Attachment A.

Test Equipment and General Layout

- Testing was conducted using a Mono 820 helical rotor pump, fitted with a Weg CFW-11 Variable Frequency Drive (VFD). The potential flow range of the pump was between approximately 0.5 and 12 L/s at up to 120 m total dynamic head. The pump intake was set at

a depth of 69 m below ground level (mbgl), 4 m above the total depth of the bore (73 mbgl). The general layout of the pumping test is shown in Photo 1 (Attachment B);

- The pump was powered by a Cummins 43 kVa diesel genset;
- Flow was measured using a Krohn Optiflux 1000 electromagnetic flow meter, and manually checked using a bucket and stop watch at the point where the water discharged to the holding dam;
- Water was discharged via ND100 poly pipe to an existing dam located approximately 100 m from the pumping bore. The dam is not known to leak and it is assumed that no leakage occurred to the groundwater system during testing. The dam and discharge pipe is shown in Photo 2 (Attachment B).

Conduct of Pumping Test

- A test pump was conducted on February 16 2011 for the purpose of testing pump performance, and also to select a flow range for step testing. The bore was pumped at a range of flows from 0.7 L/s to 0.4 L/s, and during this process the bore was almost pumped dry (60 m drawdown) over the course of one hour.
- Based on the results of the initial test it was decided that a step test would not be run. Instead, a constant discharge test would be undertaken at a pumping rate of 0.4 L/s, on the understanding that the test would need to be concluded once the bore was pumped dry.
- A constant rate test was run on Thursday 17 Feb. For this test the bore was pumped at 0.4 L/s, and the bore was sucked dry after 2 ¾ hours (pump intake was at 69 m below ground level, and the drawdown in the pumped bore was 60.9 m). After this time the drawdown in adjacent monitoring bore AMB-01, 30 m distant, was 1.25 m.
- A recovery test was undertaken at completion of the constant-discharge test, with water levels measured in the pumping bore and monitoring bore for a period of 19 hours.
- The drawdown and recovery at each bore is shown graphically in Attachment C, and is summarized as follows:
    - 1290L (pumping bore). Water level drawdown was 60.9 m from initial level, and recovered to within 0.08 m of initial level after 19 hours (99.8% recovery); and,
    - AMB-01 (monitoring bore). Water level drawdown was 1.25 m from initial level, and recovered to within 0.04 m of initial level after 19 hours (97% recovery);

Water Quality

An attempt was made to collect field water quality during testing. However, the pH/EC meter was found to have a faulty pH probe and was recording spurious results (negative pH). A backup pH EC meter obtained from the site office was also found to be producing faulty readings. Therefore testing was only conducted on the water quality sample taken near the end of testing, with analysis undertaken at a NATA accredited laboratory for pH/EC as well as major and minor ions and metals (refer Attachment D for laboratory results).

Data Analysis

Pumping test data was analysed by the Theis method using the program AQTESOLV Professional (v4.5). Results of analysis are included in Attachment E.

In summary, hydraulic parameters calculated from the pumping test were:

- Transmissivity (T) – 1.17 m^2/day
- Hydraulic Conductivity (K) - 0.18 m/day, (2.1 x 10^{-6} m/sec)
- Storage Coefficient (S) - 3.94 x 10^{-4}

The pumping test results indicate that in the area of testing the D-E sandstone has a very low transmissivity, resulting in a very steep cone of depression (60.9 m of drawdown in the pumped bore, 1.25 m of drawdown in a monitoring bore 31 m away). Further analysis of results in a spreadsheet program using the Theis method returned similar drawdown results for the pumping and monitoring bore to those obtained from analysis of the data in AQTESOLV. On this basis it is concluded that the large drawdown in the pumping bore relative to the monitoring bore is not related to the efficiency of the pumping bore, but is consistent with the hydraulic properties of the test site.

ATTACHMENT A

BORE CONSTRUCTION LOGS

Project: Alpha Coal Project **Bore ID: 1290L**

Drilled Date: 6/5/2010

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, light grey and mottled orange, clayey matrix		0		
		4		
CLAYSTONE, light grey and mottled orange, highly weathered		8		
		12		
		16		
		20		
		24		
		28		
		32		
		36		
		40		
SILCRETE, light orange-grey		44		
CLAYSTONE, light grey and mottled orange, highly weathered		48		
COAL (C Seam) interbedded coal, claystone, carbonaceous mudstone		52		
SANDSTONE (C-D Sandstone) light grey, coarse to very coarse. Top 1.9 m of unit is medium blackish mudstone, basal 0.5 m of unit is carbonaceous mudstone.		56		
		60		
COAL (D Seam) interbedded with stony coal and claystone bands		64		
SANDSTONE (D-E sandstone) light grey, fine-grained, interbedded with medium grey siltstone		68		
		72		
Coal (E seam)		76		

JBT consulting

Easting: 446159.88

Northing: 7430010.57

Collar RL (mAHD): 307.9

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig:

Hole Diameter (mm): 285

Total Depth (m): 73.15

Project: Alpha Coal Project **Bore ID: AMB-01**

Drilled Date: 6/14/2010

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, light grey and mottled orange, clayey matrix		0		
		4		
CLAYSTONE, light grey and mottled orange, highly weathered		8		
		12		
		16		
		20		
		24		
		28		
		32		
		36		
		40		
SILCRETE, light orange-grey		44		
CLAYSTONE, light grey and mottled orange, highly weathered		48		
COAL (C Seam) interbedded coal, claystone, carbonaceous mudstone		52		
SANDSTONE (C-D Sandstone) light grey, coarse to very coarse. Top 1.9 m of unit is medium blackish mudstone, basal 0.5 m of unit is carbonaceous mudstone.		56		
		60		
COAL (D Seam) interbedded with stony coal and claystone bands		64		
SANDSTONE (D-E sandstone) light grey, fine-grained, interbedded with medium grey siltstone		68		
		72		
Coal (E seam)		76		

JBT consulting

Easting: 446191

Northing: 7430010

Collar RL (mAHD): 307.89

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 73

ATTACHMENT B

PHOTOS

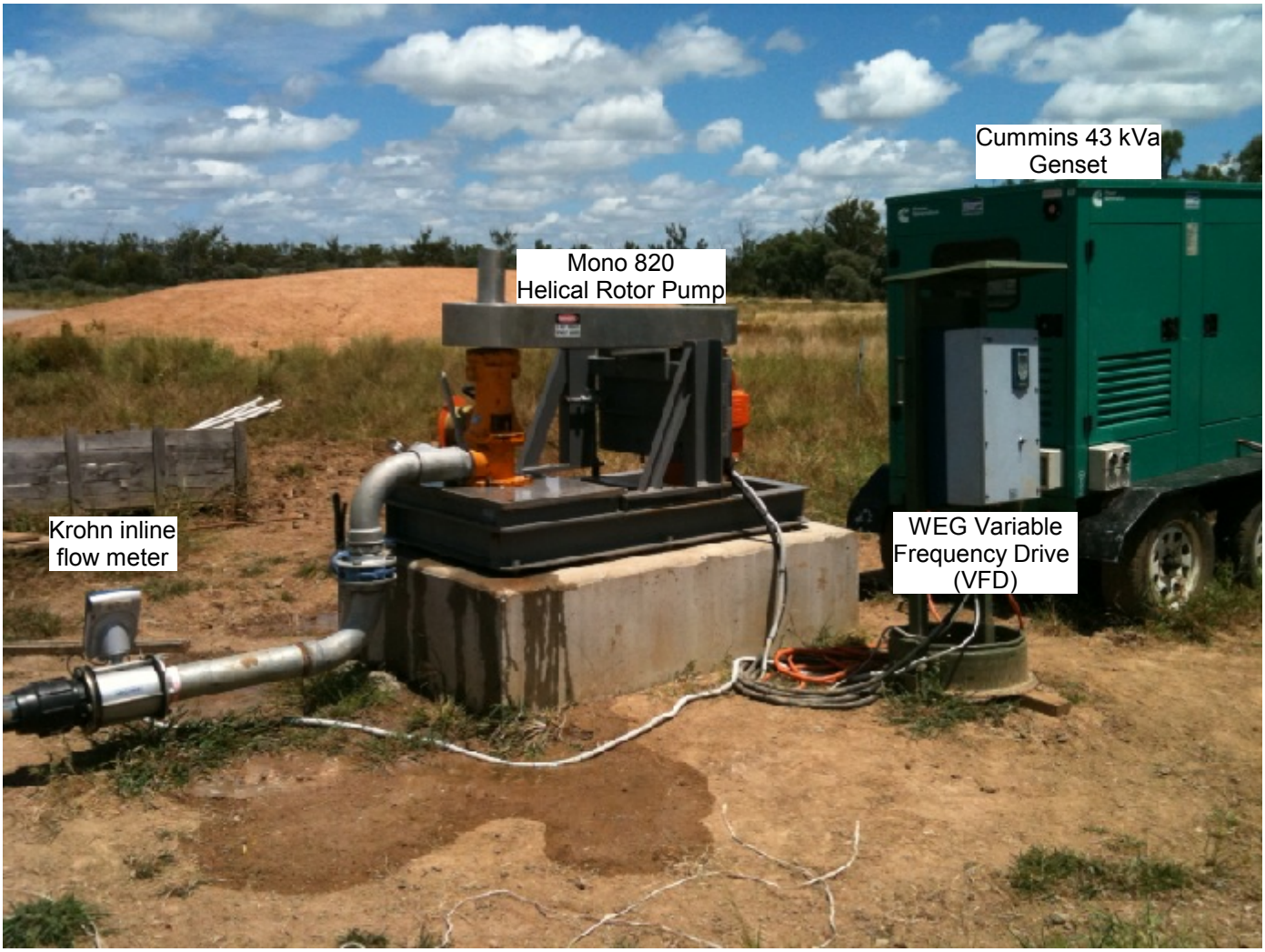
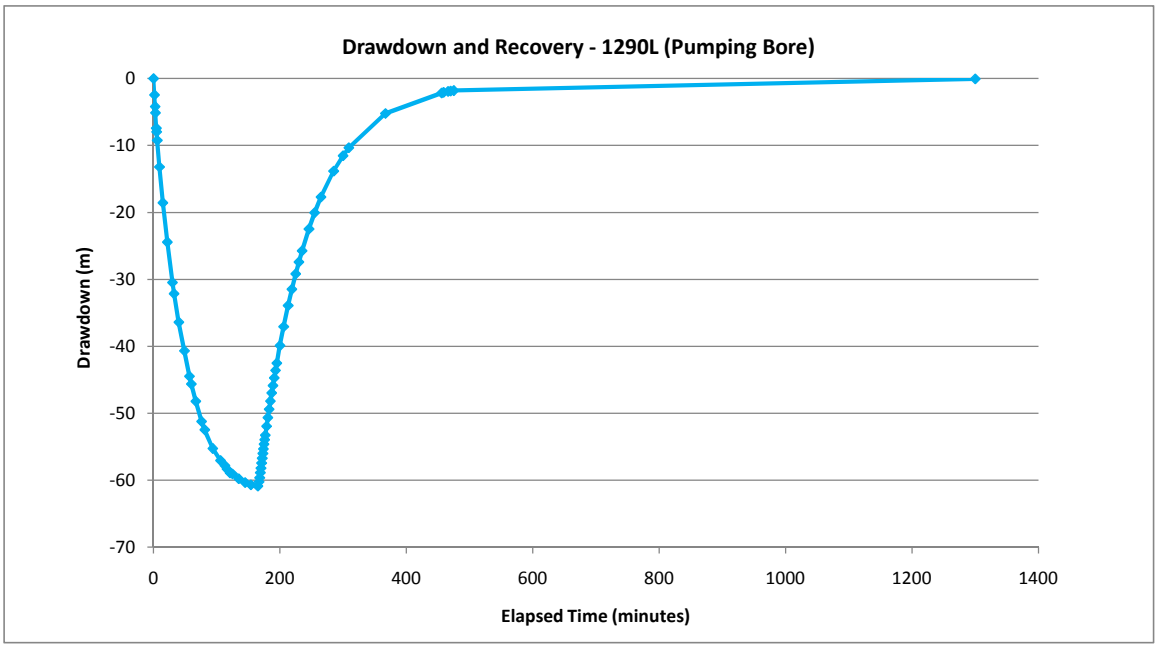


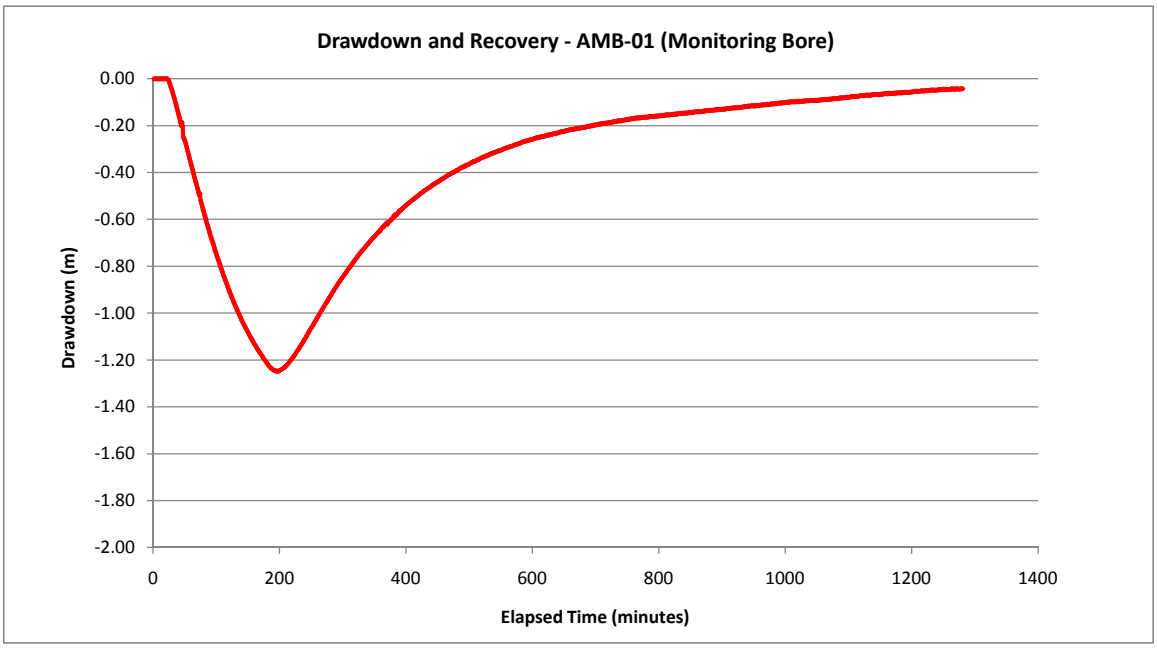
Photo 1: General layout of pumping test

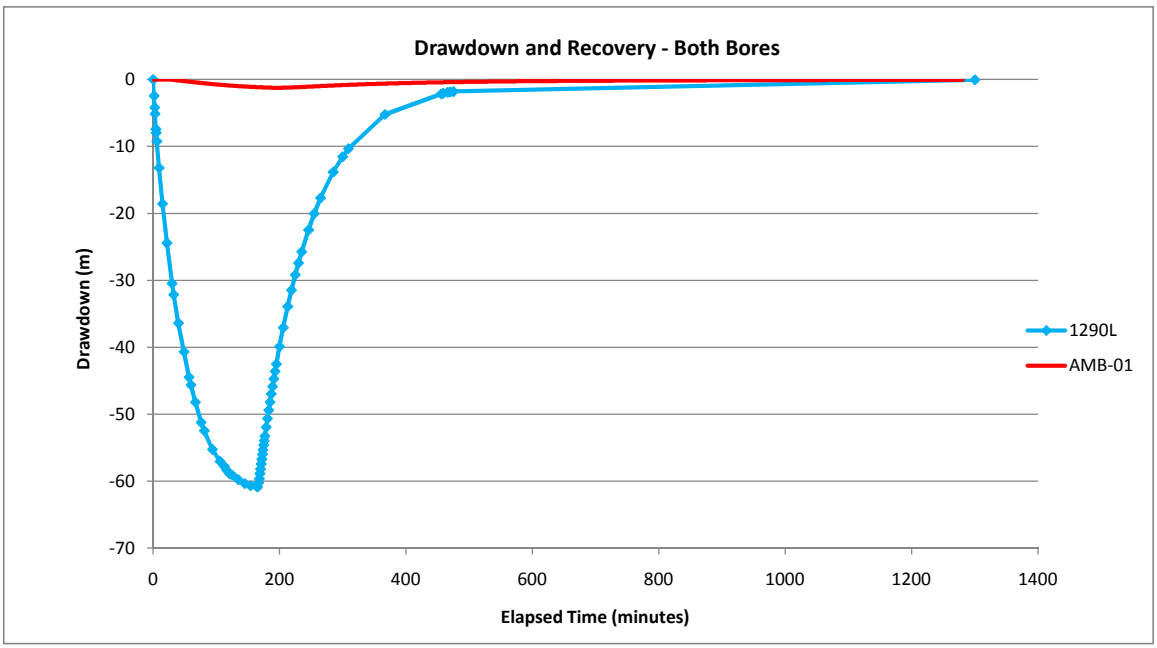
Photo 2: Point of discharge from ND100 pipe to dam

ATTACHMENT C

DRAWDOWN AND RECOVERY GRAPHS


Drawdown and Recovery - 1290L (Pumping Bore)
Drawdown (m)
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1000
1200
1400
Elapsed Time (minutes)


Drawdown and Recovery - AMB-01 (Monitoring Bore)
Drawdown (m)
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-1.20
-1.40
-1.60
-1.80
-2.00
0
200
400
600
800
1000
1200
1400
Elapsed Time (minutes)


Drawdown and Recovery - Both Bores
Drawdown (m)
0
-10
-20
-30
-40
-50
-60
-70
0
200
400
600
800
1000
1200
1400
Elapsed Time (minutes)
1290L
AMB-01

ATTACHMENT D

WATER QUALITY ANALYSES

Simmonds & Bristow
Established 1965 ACN 010 252 418 Pty Ltd

P/O Box 3160 Yeronga 4104
40 Reginald St
Rocklea, Qld 4106

Attention: John Bradley

Client: JBT Consulting Pty Ltd
130 Daisy Hill Road

Daisy Hill, QLD 4127

Client Order No.: Proposal Accep **Ph:** 07 3388 7604

Batch Reference No.: J-1011-413 **Fax:**

Job Description: Monthly Water Analysis

Chemical Analytical Results

		Sample Reference	J-1011-413-01 -AMB 03	J-1011-413-02 -AMB04	J-1011-413-03 -AMB 02	LJ-1011-413-04 -LD 002 (1290L)
		Sample Point	Sample Point 01	Sample Point 02	Sample Point 03	Sample Point 04
		Date Collected	18/02/2011	18/02/2011	18/02/2011	18/02/2011
		Date Received	21/02/2011	21/02/2011	21/02/2011	21/02/2011
		Date Testing Completed	4/03/2011	4/03/2011	4/03/2011	4/03/2011
* CA090.	pHs		9.0	8.2	8.7	8.9
* CA090.1	Langelier Index		-1.6	-1.1	-1.4	-0.20
* CA105.	Residual Alkali		3.9 meq/L	0.88 meq/L	2.2 meq/L	2.8 meq/L
* CA110.	Total Dissolved Salts (calc'd)		800 mg/L	2100 mg/L	850 mg/L	930 mg/L
* CA130.	Sodium Adsorption Ratio		21	21	17	27
* CA205.1	Hydroxide Alkalinity as CaCO3		0.016 mg/L	0.0095 mg/L	0.013 mg/L	0.32 mg/L
* CA205.11	Hydroxide as OH (mg/L)		0.10 mg/L	0.10 mg/L	0.10 mg/L	0.10 mg/L
* CA205.2	Carbonate Alkalinity as CaCO3		0.44 mg/L	0.48 mg/L	0.36 mg/L	7.4 mg/L
* CA205.21	Carbonate as CO3 (mg/L)		0.53 mg/L	0.58 mg/L	0.43 mg/L	8.9 mg/L
* CA205.3	Bicarbonate Alk'y as CaCO3		110 mg/L	170 mg/L	110 mg/L	91 mg/L
* CA205.31	Bicarbonate as HCO3 (mg/L)		130 mg/L	210 mg/L	130 mg/L	110 mg/L
* CA215.1	Free Carbon Dioxide		7.9 mg/L	20 mg/L	9.2 mg/L	0.32 mg/L
* CA215.2	Free Carbon Dioxide at pHs		1.0 mg/L	1.4 mg/L	1.0 mg/L	1.0 mg/L
* CA215.3	Aggressive Carbon Dioxide		6.9 mg/L	19 mg/L	8.2 mg/L	1.0 mg/L
* CA247.1	Total Hardness as CaCO3		28 mg/L	200 mg/L	50 mg/L	35 mg/L
* CA247.2	Calcium Hardness as CaCO3		24 mg/L	100 mg/L	40 mg/L	30 mg/L
* CA247.3	Magnesium Hardness as CaCO3		4.1 mg/L	99 mg/L	9.9 mg/L	5.4 mg/L
* CALC.003	Actual Sum [Anions-Cations]		1.0 meq/L	1.0 meq/L	1.0 meq/L	-3 meq/L

Note: All tests covered by NATA accreditation except where marked *

Authorised for release:

Date: 13/04/2011

NATA
WORLD RECOGNISED ACCREDITATION

NATA Corporate Accreditation Number: 1500
Chemical Laboratory Corporate Site Number: 1493
Microbiological Laboratory Corporate Site Number:1706
NATA ENDORSED TEST REPORT
This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

...Helping you make good clean water.

LORA NEWBY
Water Chemistry Supervisor

Simmonds & Bristow
Established 1965 ACN 010 252 418 Pty Ltd

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Batch Reference No.: J-1011-413 **Fax:**

Job Description: Monthly Water Analysis

Chemical Analytical Results

	Sample Reference	J-1011-413-01 -AMB 03	J-1011-413-02 -AMB04	J-1011-413-03 -AMB 02	LJ-1011-413-04 -LD 002 (1290L)
	Sample Point	Sample Point 01	Sample Point 02	Sample Point 03	Sample Point 04
	Date Collected	18/02/2011	18/02/2011	18/02/2011	18/02/2011
	Date Received	21/02/2011	21/02/2011	21/02/2011	21/02/2011
	Date Testing Completed	4/03/2011	4/03/2011	4/03/2011	4/03/2011
* CALC.019	[H+]s	0.0000000011	0.0000000058	0.0000000019	0.0000000012
CALC.001	Sum Anions	13 meq/L	35 meq/L	14 meq/L	14 meq/L
CALC.002	Sum Cations	12 meq/L	34 meq/L	13 meq/L	17 meq/L
GC030	TPH water C6-C9	< 10 µg/L	20 µg/L	41 µg/L	< 10 µg/L
GC040	TPH water C10-C14	< 50 µg/L	< 50 µg/L	< 50 µg/L	< 50 µg/L
	TPH water C15-C28	< 100 µg/L	< 100 µg/L	< 100 µg/L	< 100 µg/L
	TPH water C29-C36	< 50 µg/L	< 50 µg/L	< 50 µg/L	61 µg/L
WC065	Mercury as Hg - Dissolved	< 0.50 µg/L	< 0.50 µg/L	< 0.50 µg/L	< 0.50 µg/L
	Mercury as Hg - Total	< 0.50 µg/L	< 0.50 µg/L	< 0.50 µg/L	< 0.50 µg/L
WC11	Calcium as Ca - Total	9.7 mg/L	40 mg/L	16 mg/L	12 mg/L
	Magnesium as Mg - Total	1.0 mg/L	24 mg/L	2.4 mg/L	1.3 mg/L
	Potassium as K - Total	2.2 mg/L	9.4 mg/L	3.1 mg/L	3.5 mg/L
	Sodium as Na - Total	260 mg/L	690 mg/L	280 mg/L	370 mg/L
WC205.	Alkalinity - Total as CaCO3	110 mg/L	170 mg/L	110 mg/L	100 mg/L
WC220.4	Chloride as Cl	400 mg/L	1100 mg/L	420 mg/L	420 mg/L
WC245.5	Fluoride as F	0.95 mg/L	1.3 mg/L	0.95 mg/L	0.96 mg/L
WC250.19	Ammonia as N	0.10 mg/L	< 0.006 mg/L	< 0.006 mg/L	0.098 mg/L
WC250.22	Nitrate as N (calc)	< 0.01 mg/L	0.016 mg/L	0.017 mg/L	< 0.01 mg/L

Note: All tests covered by NATA accreditation except where marked *

Authorised for release:

Date: 13/04/2011

NATA
WORLD RECOGNISED ACCREDITATION

NATA Corporate Accreditation Number: 1500
Chemical Laboratory Corporate Site Number: 1493
Microbiological Laboratory Corporate Site Number:1706
NATA ENDORSED TEST REPORT
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Simmonds & Bristow
Established 1965 ACN 010 252 418 Pty Ltd

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Attention: John Bradley

Client: JBT Consulting Pty Ltd
130 Daisy Hill Road

Daisy Hill, QLD 4127

Client Order No.: Proposal Accep **Ph:** 07 3388 7604

Batch Reference No.: J-1011-413 **Fax:**

Job Description: Monthly Water Analysis

Chemical Analytical Results

	Sample Reference	J-1011-413-01 -AMB 03	J-1011-413-02 -AMB04	J-1011-413-03 -AMB 02	LJ-1011-413-04 -LD 002 (1290L)
	Sample Point	Sample Point 01	Sample Point 02	Sample Point 03	Sample Point 04
	Date Collected	18/02/2011	18/02/2011	18/02/2011	18/02/2011
	Date Received	21/02/2011	21/02/2011	21/02/2011	21/02/2011
	Date Testing Completed	4/03/2011	4/03/2011	4/03/2011	4/03/2011
WC250.232	Nitrite + Nitrate as N	< 0.01 mg/L	0.018 mg/L	0.030 mg/L	0.012 mg/L
WC250.312	Nitrite as N	< 0.002 mg/L	< 0.002 mg/L	0.013 mg/L	0.0038 mg/L
WC270.113	Orthophosphate as P	< 0.006 mg/L	0.0087 mg/L	0.013 mg/L	0.014 mg/L
WC280.4	Sulphate as SO4	< 1 mg/L	29 mg/L	< 1 mg/L	2.0 mg/L
WCX.4 41&SCX.4	Aluminium as Al - Dissolved	25 µg/L	19 µg/L	24 µg/L	43 µg/L
	Aluminium as Al - Total	570 µg/L	110 µg/L	1000 µg/L	120 µg/L
	Arsenic as As - Dissolved	< 1 µg/L	< 1 µg/L	19 µg/L	< 1 µg/L
	Arsenic as As - Total	< 1.0 µg/L	< 1.0 µg/L	31 µg/L	< 1.0 µg/L
	Boron as B - Dissolved	170 ug/L	460 ug/L	200 ug/L	190 ug/L
	Boron as B - Total	180 µg/L	500 µg/L	200 µg/L	200 µg/L
	Cadmium as Cd - Dissolved	< 1 µg/L	< 1 µg/L	< 1 µg/L	< 1 µg/L
	Cadmium as Cd - Total	< 1 µg/L	< 1 µg/L	< 1 µg/L	< 1 µg/L
	Chromium as Cr - Dissolved	4.0 µg/L	3.0 µg/L	2.0 µg/L	2.0 µg/L
	Chromium as Cr - Total	10 µg/L	3.0 µg/L	5.0 µg/L	2.0 µg/L
	Cobalt as Co - Dissolved	< 1 µg/L	< 1 µg/L	< 1 µg/L	< 1 µg/L
	Cobalt as Co - Total	< 1.0 µg/L	< 1.0 µg/L	< 1.0 µg/L	< 1.0 µg/L
	Copper as Cu - Dissolved	1.0 µg/L	< 1 µg/L	1.0 µg/L	1.0 µg/L
	Copper as Cu - Total	1.0 µg/L	< 1.0 µg/L	2.0 µg/L	3.0 µg/L

Note: All tests covered by NATA accreditation except where marked *

Authorised for release:

Date: 13/04/2011

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NATA
WORLD RECOGNISED ACCREDITATION

NATA Corporate Accreditation Number: 1500
Chemical Laboratory Corporate Site Number: 1493
Microbiological Laboratory Corporate Site Number:1706
NATA ENDORSED TEST REPORT
This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025.

Simmonds & Bristow
Established 1965 ACN 010 252 418 Pty Ltd

P/O Box 3160 Yeronga 4104
40 Reginald St
Rocklea, Qld 4106

Attention: John Bradley

Client: JBT Consulting Pty Ltd
130 Daisy Hill Road

Daisy Hill, QLD 4127

Client Order No.: Proposal Accep **Ph:** 07 3388 7604

Batch Reference No.: J-1011-413 **Fax:**

Job Description: Monthly Water Analysis

Chemical Analytical Results

	Sample Reference	J-1011-413-01 -AMB 03	J-1011-413-02 -AMB04	J-1011-413-03 -AMB 02	LJ-1011-413-04 -LD 002 (1290L)
	Sample Point	Sample Point 01	Sample Point 02	Sample Point 03	Sample Point 04
	Date Collected	18/02/2011	18/02/2011	18/02/2011	18/02/2011
	Date Received	21/02/2011	21/02/2011	21/02/2011	21/02/2011
	Date Testing Completed	4/03/2011	4/03/2011	4/03/2011	4/03/2011
WCX.4 41&SCX.4	Iron as Fe - Dissolved	57 µg/L	210 µg/L	79 µg/L	52 µg/L
	Iron as Fe - Total	420 µg/L	780 µg/L	800 µg/L	1500 µg/L
	Lead as Pb - Dissolved	< 1 µg/L	< 1 µg/L	< 1 µg/L	< 1 µg/L
	Lead as Pb - Total	< 1.0 µg/L	< 1.0 µg/L	1.0 µg/L	2.0 µg/L
	Manganese as Mn - Dissolved	38 µg/L	28 µg/L	45 µg/L	28 µg/L
	Manganese as Mn - Total	43 µg/L	43 µg/L	73 µg/L	45 µg/L
	Molybdenum as Mo - Dissolved	< 1 µg/L	< 1 µg/L	5.0 µg/L	2.0 µg/L
	Molybdenum as Mo - Total	< 1.0 µg/L	< 1.0 µg/L	8.0 µg/L	2.0 µg/L
	Nickel as Ni - Dissolved	1.0 µg/L	2.0 µg/L	2.0 µg/L	2.0 µg/L
	Nickel as Ni - Total	1.0 µg/L	2.0 µg/L	2.0 µg/L	2.0 µg/L
	Selenium as Se - Dissolved	6.0 µg/L	17 µg/L	7.0 µg/L	6.0 µg/L
	Selenium as Se - Total	10 µg/L	25 µg/L	12 µg/L	10 µg/L
	Silver as Ag - Dissolved	< 1 µg/L	< 1 µg/L	< 1 µg/L	< 1 µg/L
	Silver as Ag - Total	< 1.0 µg/L	< 1.0 µg/L	< 1.0 µg/L	< 1.0 µg/L
	Uranium as U - Dissolved	< 1 µg/L	< 1 µg/L	< 1 µg/L	< 1 µg/L
	Uranium as U - Total	< 1.0 µg/L	< 1.0 µg/L	< 1.0 µg/L	< 1.0 µg/L
	Vanadium as V - Dissolved	4.0 µg/L	10 µg/L	6.0 µg/L	6.0 µg/L
	Vanadium as V - Total	5.0 µg/L	12 µg/L	8.0 µg/L	7.0 µg/L

Note: All tests covered by NATA accreditation except where marked *

Authorised for release:

Date: 13/04/2011

NATA Corporate Accreditation Number: 1500
Chemical Laboratory Corporate Site Number: 1493
Microbiological Laboratory Corporate Site Number:1706
NATA ENDORSED TEST REPORT
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Simmonds & Bristow
Established 1965 ACN 010 252 418 Pty Ltd

P/O Box 3160 Yeronga 4104
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Attention: John Bradley

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130 Daisy Hill Road

Daisy Hill, QLD 4127

Client Order No.: Proposal Accep **Ph:** 07 3388 7604

Batch Reference No.: J-1011-413 **Fax:**

Job Description: Monthly Water Analysis

Chemical Analytical Results

	Sample Reference	J-1011-413-01 -AMB 03	J-1011-413-02 -AMB04	J-1011-413-03 -AMB 02	LJ-1011-413-04 -LD 002 (1290L)
	Sample Point	Sample Point 01	Sample Point 02	Sample Point 03	Sample Point 04
	Date Collected	18/02/2011	18/02/2011	18/02/2011	18/02/2011
	Date Received	21/02/2011	21/02/2011	21/02/2011	21/02/2011
	Date Testing Completed	4/03/2011	4/03/2011	4/03/2011	4/03/2011
WCX.4 41&SCX.4	Zinc as Zn - Dissolved	49 µg/L	15 µg/L	13 µg/L	8.0 µg/L
	Zinc as Zn - Total	85 µg/L	18 µg/L	56 µg/L	260 µg/L
WP040.	Conductivity @ 25øC	1500 µS/cm	3900 µS/cm	1600 µS/cm	1600 µS/cm
WP090.	pH Value @ 25øC	7.4	7.1	7.3	8.7
WP100.X	Total Dissolved Solids @ 180øC	1100 mg/L	2100 mg/L	910 mg/L	790 mg/L

Notes:

Samples are disposed of 14 days after completion of testing.
Results reported on an 'as received' basis

This is a replacement report for the original issued on 08.03.2011.

Note: All tests covered by NATA accreditation except where marked *

Authorised for release:

Date: 13/04/2011

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NATA
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NATA Corporate Accreditation Number: 1500
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NATA ENDORSED TEST REPORT
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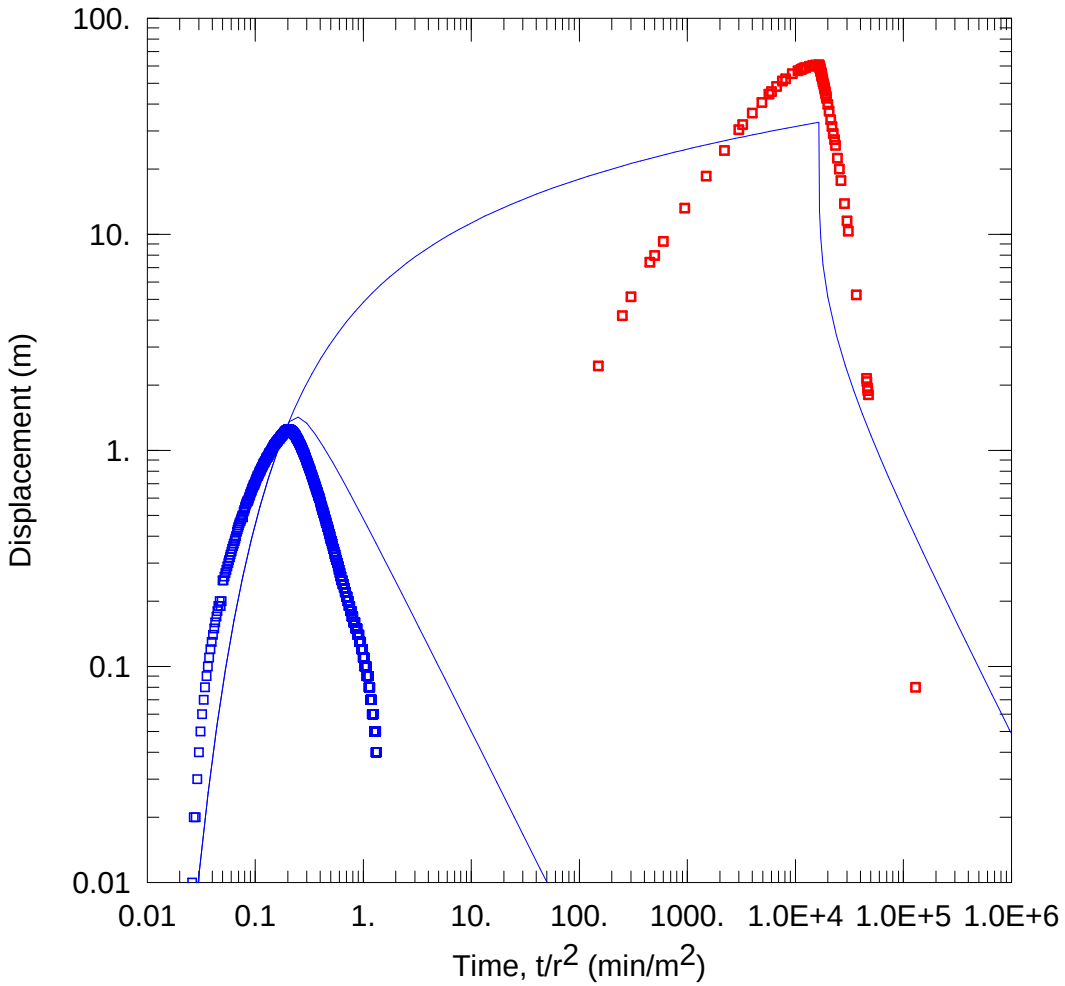
ATTACHMENT E

PUMPING TEST ANALYSIS



1290L PUMPING TEST

Data Set: C:\...\1290L Pumping Test_Theis.aqt
Date: 02/20/11 Time: 20:55:48

PROJECT INFORMATION

Company: JBT Consulting Pty Ltd
Client: Hancock Coal
Project: JBT005
Location: Alpha
Test Well: 1290L
Test Date: 17 February 2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
1290L	446160	7433010

Observation Wells

Well Name	X (m)	Y (m)
1290L	446160	7433010
AMB-01	446191	7433010

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1.173 m^2/day
S = 0.000394
Kz/Kr = 1.
b = 6.3 m

HANCOCK PROSPECTING PTY LTD

KEVIN'S CORNER PROJECT

SUMMARY OF TEST PUMPING PROGRAM KEVIN'S CORNER PROJECT

December 2011

JBT01-005-032

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery
JBT01-005-032(D1)	Draft	URS	21.12.2011	email
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APPENDICES

Appendix A Bore Construction Logs
Appendix B Pumping Test Analyses

1.0 INTRODUCTION

A program of pumping tests was undertaken on MLA 70425 during October 2011. The purpose of testing was to obtain site specific aquifer hydraulic parameters within the Kevin's Corner (KC) lease area. No hydraulic testing had been undertaken on site previously, and hydraulic parameters were required for the KC lease area as input and validation to predictive groundwater modelling studies.

This report summarises the pumping test program, and presents the results of analysis of the resultant pumping test data.

2.0 PUMPING TEST SITES

2.1 Site Locations

Pumping tests were undertaken on the Kevin's Corner lease on five bores, located at four separate sites. The sites are shown on Figure 2-1 and are described in Table 2-1.

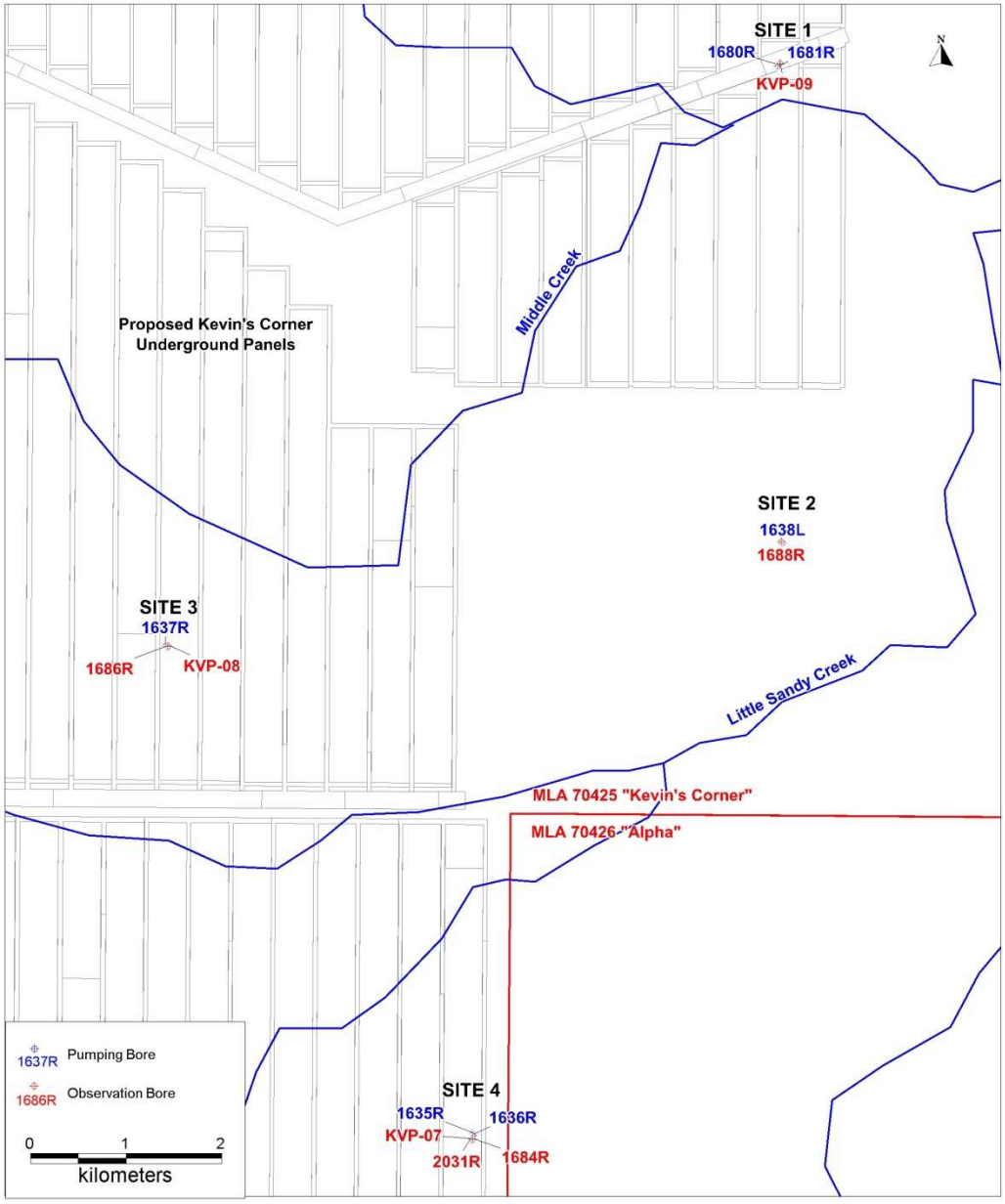


Figure 2-1: Location of Pumping Test Sites

The pumping bores and observation bores were constructed specifically for the pumping test program between 21 August 2011 and 8 October 2011. The drilling was undertaken by Hancock as part of their ongoing exploration drilling. Hancock recognised the importance of obtaining site specific data from Kevin's Corner and altered their drilling program to facilitate the groundwater study. Bore construction logs are provided in Appendix A.

Table 2-1: Description of Pumping Test Sites

Site No	Bore ID	Easting (MGA94)	Northing (MGA94)	Bore Type	Formation Monitored	Distance from pumped Bore (m)	
Site 1	1680R	445613	7452120	Pumping	C-D Sandstone	0	
	1681R	445612	7452101	Pumping	D-E Sandstone	0	
	KVP-09 (1682R)	445631	7452132	Observation (WWP*)	B-C Sandstone C-D Sandstone D-E Sandstone	21.8 m from 1680R	35.9 m from 1681R
Site 2	1638L	445692	7447110	Pumping	D-E Sandstone	0	
	1688R	445676	7447119	Observation (Standpipe)	D-E Sandstone	18.3	
Site 3	1637R	439233	7445989	Pumping	D-E Sandstone	0	
	KVP-08 (1685R)	439272	7445984	Observation (VWP)	B-C Sandstone C-D Sandstone D-E Sandstone Sub-E Sandstone	39.5	
	1686R	439261	7445984	Observation (Standpipe)	D-E Sandstone	28.5	
Site 4	1636R	442478	7440873	Pumping	C-D Sandstone	0	
	1635R	442480	7440891	Pumping	D-E Sandstone	0	
	2031R	442468	7440833	Observation (Standpipe)	D-E Sandstone	59.4 m from 1635R	40.1 m from 1636R
	1684R	442478	7440833	Observation (Standpipe)	C-D Sandstone	58.2 m from 1635R	41.4 m from 1636R
	KVP-07 (1683R)	442457	7440833	Observation (VWP)	B-C Sandstone C-D Sandstone D-E Sandstone Sub-E Sandstone	62.5 m from 1635R	45.4 m from 1636R

*VWP – Vibrating Wire Piezometer

At a number of sites, vibrating wire piezometer (VWP) bores were installed in addition to standpipe monitoring bores. Standpipe monitoring bore were screened over the same interval as the pumping bore, whereas VWP bores had sensors installed within the pumped interval, as well as units above and below. Data from standpipe observation bores was used for analysis of pumping tests (to obtain storage estimates), whereas data from the VWP bores was collected to enable assessment of induced leakage from adjacent units in response to pumping. The exception was at Site 1, where

the only monitoring bore installed was VWP monitoring bore KVP-09. For this site, data from the VWP bore was used for the pumping test analysis.

3.0 PUMPING TEST SUMMARY

3.1 Pumping Test Equipment

A pumping test rig was hired from Ayr Boring Company Pty Ltd. The pumping test rig comprised:

- Trailer-mounted reel containing flexible poly riser pipe and electrical dropper cable;
- Electric motor powered by an on-board generator, to operate reel for raising/lowering pump;
- Submersible bore pump;
- Orifice weir to regulate and monitor bore discharge rate; and,
- Plastic drum and lay-flat hose to collect water and dissipate away from pumping test area.

The general layout of the pumping test setup is shown below in Figure 3-1.

Figure 3-1: Pumping Test Setup

The initial pumping test setup included a submersible pump with duty characteristics (head and yield) based on air-lift yield estimates of bores as they were being drilled. The initial pump proved to be unsuited (too high-yielding) to the completed bores as the yields of constructed bores were significantly lower than the initial reported air-lift yields. A replacement wet end (impeller/ bowl assembly) was freighted to site and the testing completed with the lower yielding replacement pump (Lowara HF15, suited to pumping between 0.5 and 4 L/s at 55 to 85 m total dynamic head).

3.2 Description of Tests

3.2.1 Bore 1681R - Site 1

A pumping test was undertaken on bore 1681L comprising a step drawdown test, recovery test, and constant discharge (CD) test. Following the constant discharge test the water level dipper became tangled in the pump riser and electrical cable, preventing recovery measurements from being taken.

The bores utilised for the test included are described in Table 3-1.

Bore logs for each bore are included in Appendix A.

A description of duration, pumping rate, and drawdown for each test is included in Table 3-2.

Weather conditions during testing were fine.

Table 3-1: Description of Bores Utilised for Testing of Bore 1681R

Bore	Type	Formation Monitored	Comments
1681R	Pumping	D-E Sandstone	Initial water level 12.53 mTOC
KVP-09	Observation	B-C, C-D, D-E Sandstone	VWP Bore – 35.9 m from pumped bore

Table 3-2: Pumping Test Description – Site 1 - Pumping Bore 1681R

Test Type	Date/ Duration	Comments
Step Test	28/10/11, 12:30 PM to 4:10PM (220 min)	• Initial static water level 12.53 mTOC (m from top of casing) • Step 1 - 0.5 L/s for 70 min – 12.21 m drawdown (Specific capacity = 0.04 L/s/m) • Step 2 - 0.7 L/s for 60 min - 17.04 m drawdown (specific capacity = 0.04 L/s/m) • Step 3 - 1.11 L/s for 60 min – 25.31 m drawdown (specific capacity = 0.04 L/s/m) • Step 4 - 2.11 L/s for 30 min - water level reached pump inlet, test terminated – 48.45 m drawdown
Constant Discharge	29/10/2011 8:10 AM to 30/10/2011 8:00 AM (1,430 min, 23.8 hours)	• Water level recovered overnight to 20.39 mTOC (7.86 m from initial static level = 84% recovery), • Pumping rate for CD test was 1.34 L/s • 51.75 m drawdown recorded in pumping bore; • 8.96 m drawdown recorded in observation bore KVP-09 (35.9 m from pumped bore)
Recovery Test		Recovery data not recorded as the water level dipper became tangled in the pump column, and could not be recovered until the pump was removed from the bore.

3.2.2 Bore 1680R - Site 1

Following the pumping test and recovery of the adjacent bore 1681R (D-E Sandstone), a pumping test was conducted on bore 1680R (C-D Sandstone). It was apparent from the testing of bore 1681R that pumping of the D-E Sandstone induced leakage from the C-D sandstone (refer Figure 3-2), and that the water level in the C-D Sandstone was still recovering when the test pumping of 1680R was initiated. From an initial static water level of 13.16 mTOC, the water level in bore 1680R fell to 14.05 mTOC (0.89 m) due to pumping of bore 1681R. By the start of the pumping test on 1680R, the static water level had recovered to 13.95 mTOC (0.79 m below initial static level)

Figure 3-2 shows the relationship between water levels during testing.

The pumping test on bore 1680RL comprised a step drawdown test, with an extended final step.

The bores utilised for the test included are described in Table 3-3.

Bore logs for each bore are included in Appendix A.

A description of duration, pumping rate, and drawdown for each test is included in Table 3-4.

Weather conditions during testing were fine.

Table 3-3: Description of Bores Utilised for Testing of Bore 1680R

Bore	Type	Formation Monitored	Comments
1680R	Pumping	C-D Sandstone	Initial water level 13.9 mTOC
KVP-09	Observation	B-C, C-D, D-E Sandstone	VWP Bore – 21.8 m from pumped bore

Table 3-4: Pumping Test Description – Site 1 - Pumping Bore 1680R

Test Type	Date/ Duration	Comments
Step Drawdown with extended final step	30/10/2011, 9:47AM to 31/10/2011, 8:00AM (1348 min, 22.5 hours)	• Step 1 - 0.5 L/s for 60 min – 3.09 m drawdown (Specific capacity = 0.16 L/s/m) • Step 2 - 0.7 L/s for 60 min - 4.34 m drawdown (specific capacity = 0.16 L/s/m) • Step 3 - 1.11 L/s for 60 min – 8.06 m drawdown (specific capacity = 0.14 L/s/m) • Step 4 - 2.26 L/s for 1,158 minutes (19.3 hours) – 16.75 m drawdown • 5.67 m drawdown recorded in observation bore KVP-09 (21.8 m from pumped bore)
Recovery	31/10/2011, from 8:00AM	• Recovery data was collected via data logger for 343 minutes (5.7 hours) after pump shutdown. • Recovery data recorded until water level in the pumped bore was within 0.94 m of the original static level (94% recovery)

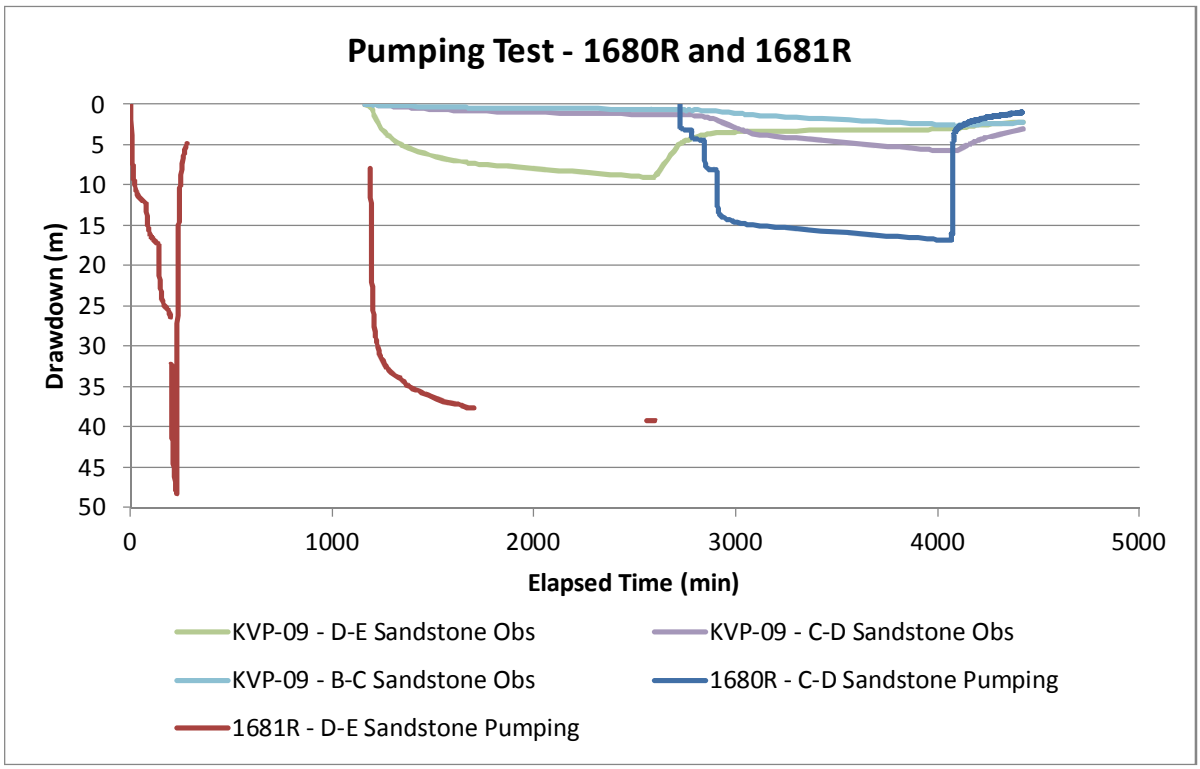


Figure 3-2: Drawdown Data – 1680R and 1681R Pumping Tests

3.2.3 Bore 1638L - Site 2

A pumping test was undertaken on bore 1638L comprising a step drawdown test, step recovery test, constant discharge (CD) test, and CD recovery test.

The bores utilised for the test included are described in Table 3-5.

Bore logs for each bore are included in Appendix A.

A description of duration, pumping rate, and drawdown for each test is included in Table 3-6.

Weather conditions during testing were fine.

Table 3-5: Description of Bores Utilised for Testing of Bore 1638L

Bore	Type	Formation Monitored	Comments
1638L	Pumping	D-E Sandstone	Initial water level 13.84 mTOC
1688R	Observation	D-E Sandstone	Standpipe bore – 18.3 m from pumped bore

Table 3-6: Pumping Test Description – Site 2 - Pumping Bore 1638L

Test Type	Date/ Duration	Comments
Step Drawdown	26/10/2011, 12:30PM to 26/10/2011, 5:15PM (285 minutes)	• Step 1 - 0.5 L/s for 71 min – 12.24 m drawdown (specific capacity = 0.04 L/s/m) • Step 2 - 0.7 L/s for 60 min - 17.35 m drawdown (specific capacity = 0.04 L/s/m) • Step 3 - 1.11 L/s for 60 min – 25.62 m drawdown (specific capacity = 0.04 L/s/m) • Step 4 - 2.11 L/s for 31 min - water level reached pump inlet, test terminated – 48.45 m drawdown
Step Recovery	26/10/2011, 5:15PM to 27/10/2011, 9:20AM	• Recovery to 5.1 m from initial water level (89%) just prior to commencement of constant discharge test
Constant Discharge	27/10/2011, 9:20AM to 28/10/2011, 8:30AM	• Pumping rate for CD test of 1.34 L/s for 1,180 minutes (19.6 hrs) • Maximum drawdown in pumped bore (1638L) 39.50 m below static / initial water • Maximum drawdown in observation bore (1688R, 18.3 m from pumped bore) 9.89 m below initial static water
CD Recovery		• Recovery measured in observation bore (1688R) only. Water level dipper in pumping bore became stuck within pump riser pipe/ electrical cable.

3.2.4 Bore 1637L - Site 3

A pumping test was undertaken on bore 1637L comprising a step drawdown test with an extended final step, and a recovery test.

The bores utilised for the test included are described in Table 3-7.

Bore logs for each bore are included in Appendix A.

A description of duration, pumping rate, and drawdown for each test is included in Table 3-8.

Weather conditions during testing were fine.

Table 3-7: Description of Bores Utilised for Testing of Bore 1637L

Bore	Type	Formation Monitored	Comments
1637L	Pumping	D-E Sandstone	Initial water level 29.3 mTOC
1686R	Observation	D-E Sandstone	Standpipe bore – 28.5 m from pumped bore
KVP-08	Observation	C-D, D-E, Sub-E Sandstone	VWP bore – 39.5 m from pumped bore

Table 3-8: Pumping Test Description – Site 3 - Pumping Bore 1637L

Test Type	Date/ Duration	Comments
Step Drawdown with extended final step	21/10/2011 12:00PM to 21/10/2011 8:00PM	• Step 1 - 0.5 L/s for 150 min – 25.8 m drawdown (specific capacity = 0.019 L/s/m) • Step 2 - 0.7 L/s for 330 min - 38.2 m drawdown (specific capacity = 0.019 L/s/m) • Test duration 480 min (8 hours) • 2.82 m drawdown recorded in observation bore 1686R (28.5 m from pumped bore)
Recovery	Commenced 21/10/2011 at 8:00PM	• Recovery data was recorded in the pumped bore and observation bore (1686R) using data loggers. Recovery data was collected from the pumped bore for 5.7 hours and from the observation bore for 15.7 hours, after pump shutdown • Recovery data was collected from the pumped bore until the water level was within 0.79 m of the pre-test static water level (98% recovery)

3.2.5 Bore 1636R – Site 4

A pumping test was undertaken on bore 1636L comprising a constant discharge test and recovery test. It became apparent from the initial test pump that the water level within the bore dropped rapidly at a low pumping rate of 0.67 L/s. For this reason a step drawdown test was not attempted, and the initial test was continued as a constant discharge test until the water level fell to a point where the pumping rate could no longer be maintained.

Bore 1636R was pumped for a period of 91 minutes at a rate of 0.67 L/s. After 91 minutes the water level in the pumped bore had drawn down to a point where the discharge valve was fully open and the flow rate was starting to diminish (i.e. constant discharge conditions could no longer be maintained). The decision was made to end the pumping at this time.

Recovery data was collected from both the pumping bore and monitoring bore for a duration of 950 minutes (15.8 hours) following pump shutdown. Recovery was to within 0.03 m of initial static water level, which corresponds to effectively 100% recovery.

The bores utilised for the test included are described in Table 3-9.

Bore logs for each bore are included in Appendix A.

A description of duration, pumping rate, and drawdown for each test is included in Table 3-10.

Weather conditions during testing were fine.

Table 3-9: Description of Bores Utilised for Testing of Bore 1636R

Bore	Type	Formation Monitored	Comments
1636R	Pumping	C-D Sandstone	Initial static level 22.45
1684R	Observation	C-D Sandstone	Standpipe bore – 41.4 m from pumped bore

Table 3-10: Pumping Test Description – Site 4 - Pumping Bore 1636R

Test Type	Date/ Duration	Comments
Constant discharge	20/10/2011, 2:15PM to 20/10/2011, 3:46PM 91 minutes duration	• Water level data was collected in the pumping bore and observation bore using both manual measurements as well as automated water level data loggers. • Initial static level was 22.45 m • 52.53 m of drawdown was recorded in the pumping bore • 2.82 m drawdown was recorded in the observation bore 1684R (41.4 m from pumped bore)
Recovery	Commenced 20/10/2011 at 3:46PM	• Recovery data collected in the pumping bore and observation bore using both manual measurements as well as a data loggers. • Recovery data collected via data logger for 950 minutes (15.8 hours) after pump shutdown. • Recovery data was collected from the pumped bore until the water level was within 0.03 m of the pre-test static water level (effectively 100% recovery)

3.2.6 Bore 1635R - Site 4

Bore 1635R (D-E Sandstone) was the first bore where a pumping test was attempted for this phase of field testing. The pump that was used initially had too great a capacity (head versus yield) for the bore and each test attempt resulted in the bore being pumped dry. As the aquifer had been considerably stressed, the decision was made to test the adjacent bore (1636R) when the replacement pump arrived. The pumping test on bore 1636R was of short duration (refer Section 3.2.5) so the decision was made to proceed to testing of bore 1637R once testing of 1636R had been completed.

Due to time constraints bore 1635R was not re-visited for re-testing. The initial results indicated limited groundwater potential, thus the likelihood of a long duration test, producing additional hydraulic data, being conducted was limited

Based on the initial response to pumping, and the recovery time, it is assumed that the D-E sandstone at this location has relatively low permeability, and has similar hydraulic properties to those obtained for testing of the C-D sandstone in adjacent bore 1636R.

3.3 Analysis of Results

Pumping tests were analysed using Aqtesolv version 4.5, using the Theis method for step drawdown tests or constant discharge tests (whichever was more appropriate for the test conditions, as described in the sections above).

Where possible a curve was fitted to the entire data set, including step drawdown test, recovery test, and constant discharge test.

Results for each test are presented below in Table 3-11.

The analysis for each test is presented in Appendix B.

Table 3-11: Summary of Hydraulic Parameters from Pumping Tests

Pumping Test Bore	Unit	Analysis Method	Transmissivity (T) (m^2/day)	Aquifer thickness (m)	Hydraulic Conductivity (K)		Storativity
					(m/d)	(m/s)	
1636R	C-D Sandstone	Theis - curve fit to pump bore (assume 100% efficient well - gives lowest T fitted to dataset)	0.7	18	0.04	4.50E-07	5.00E-05
		Theis - curve fit to obs bore (assumes <100% efficient pumping well, but ignores possibility of heterogeneity - gives highest T fitted to dataset)	1.4	18	0.08	9.00E-07	8.40E-05
		Average	**1.05**	**18**	**0.06**	**6.75E-07**	**6.70E-05**
1637R	D-E Sandstone	Theis	1.08	15	0.07	8.33E-07	1.60E-04
1638L	D-E Sandstone	Theis - variable rate test using measurements from pumping bore and monitoring bore	2.2	15	0.15	1.70E-06	3.70E-04
1680R	C-D Sandstone	Theis - variable rate test using measurements from pumping bore and monitoring bore	13.3	16	0.83	9.62E-06	2.00E-05
1681R	D-E Sandstone	Theis - variable rate test using measurements from pumping bore and monitoring bore	1.95	11	0.18	2.05E-06	5.10E-04

APPENDIX A

BORE CONSTRUCTION LOGS

Project: Kevins Corner Project

Bore ID: 1635R

Drilled Date: 8-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
Silty CLAY, light brown, pebbly bands, weathered		0		
SAND, light brown, fine to coarse, clayey				
CLAYSTONE, light grey, silty bands, ferruginous bands towards base of unit - Base of Tertiary		10		Grout from surface to 138 mbgl
CLAYSTONE, light whitish grey, silty, weathered				
SANDSTONE, light whitish-brown, fine to very-fine grained, occasional coarse bands		20		
		30		
SILTSTONE, brown to orange-brown, ferruginous, interbedded with limonitic claystone				
		40		Steel casing 155 mm ID - Surface to 139 mbgl
CARBONACEOUS MUDSTONE, black with coaly bands, alternating with bands of claystone				
COAL (B Seam), black, fresh		50		
SILTSTONE, dark grey, fresh				
		60		
		70		
SANDSTONE (B-C Sandstone), light grey, fine to medium grained, fresh, abundant silty laminae towards base		80		
		90		
		100		
CARBONACEOUS MUDSTONE (C Seam), black, fresh, alternating with bands of coaly mudstone, claystone, and thin bands of coal		110		
Stony Coal (C Seam), black, fresh, thin coal bands alternating with bands of light brown claystone and black carbonaceous mudstone.		120		
SANDSTONE (C-D Sandstone), light grey, fine to very fine grained, quartzose, abundant silty laminae, medium to coarse 122 to 134.9 m		130		
COAL (D Seam) bright, black, fresh, occasional bands of whitish-grey claystone		140		Bentonite Seal - 138 to 140 mbgl
CARBONACEOUS MUDSTONE, dark grey, alternating with bands of dark grey siltstone				
SANDSTONE (D-E Sandstone) light grey, medium to coarse-grained, occasional cobbles, alternating with bands of fine-grained sandstone and coarse to very coarse-grained sandstone		150		Filter Pack (Yuleba Minerals WP2.5) - 140 to 153 mbgl Screen - stainless steel wire-wound 1.0 mm aperture - 139 to 151 mbgl
COAL (E Seam)		160		
		170		

JBT consulting

Easting: 442479.6

Northing: 7440891

Collar RL (mAHD): 318.18

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig:

Hole Diameter (mm): 285

Total Depth (m): 157

Project: Kevins Corner Project

Bore ID: 1636R

Drilled Date: 15-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
Silty CLAY, light brown, pebbly bands, weathered		0		
SAND, light brown, fine to coarse, clayey		10		Grout from surface to 114 mbgl
CLAYSTONE, light grey, silty bands, ferruginous bands towards base of unit - Base of Tertiary				
CLAYSTONE, light whitish grey, silty, weathered		20		
SANDSTONE, light whitish-brown, fine to very-fine grained, occasional coarse bands				
SILTSTONE, brown to orange-brown, ferruginous, interbedded with limonitic claystone		30		
		40		
CARBONACEOUS MUDSTONE, black with coaly bands, alternating with bands of claystone				
COAL (B Seam), black, fresh		50		Steel casing 155 mm ID - Surface to 120 mbgl
SILTSTONE, dark grey, fresh				
		60		
		70		
SANDSTONE (B-C Sandstone), light grey, fine to medium grained, fresh, abundant silty laminae towards base		80		
		90		
		100		
CARBONACEOUS MUDSTONE (C Seam), black, fresh, alternating with bands of coaly mudstone, claystone, and thin bands of coal		110		
Stony Coal (C Seam), black, fresh, thin coal bands alternating with bands of light brown claystone and black carbonaceous mudstone.		120		Bentonite Seal - 114 to 116 mbgl
SANDSTONE (C-D Sandstone), light grey, fine to very fine grained, quartzose, abundant silty laminae				Filter Pack (Yuleba Minerals WP2.5) - 116 to 133 mbgl
SANDSTONE (C-D Sandstone), light grey, medium to coarse-grained, occasional pebbly bands		130		
SILTSTONE, dark grey, alternating with bands of dark grey mudstone				Screen - stainless steel wire-wound 1.0 mm aperture - 120 to 132 mbgl
COAL (D Seam) bright, black, fresh, occasional bands of whitish-grey claystone		140		
		150		

JBT consulting

Easting: 442478

Northing: 7440873

Collar RL (mAHD): 318.326

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K9

Hole Diameter (mm): 285

Total Depth (m): 134

Project: Kevins Corner Project

Bore ID: 1637R

Drilled Date: 21-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, medium orange-brown, fine to medium grained		0		
SILTSTONE, medium pinkish-grey, moderately weathered		20		Grout from surface to 198 mbgl
CLAYSTONE, medium orange brown to medium greyish brown				
CLAYSTONE, dark greyish-black, carbonaceous throughout, base of weathering at 42 mbgl		40		
SANDSTONE, pale creamy grey, fine to medium-grained, moderately sorted, poorly cemented, loose (drilling chips crumble apart)		60		Steel casing 155 mm ID - Surface to 200 mbgl
COAL (A Seam), bright black coal, interbedded with dark blackish-brown carbonaceous mudstone		80		
CLAYSTONE (A-B Interburden), dark greyish-black mottled with pale creamy grey, interbedded with carbonaceous sandstone		100		
COAL (B Seam), dull, greyish-black, interbedded with stony coal, pale greyish-brown tuff and claystone				
SILTSTONE, pale greyish-black, interbedded with carbonaceous sandstone		120		
SANDSTONE (B-C Sandstone), pale creamy grey, minor siltstone laminae				
SILTSTONE, dark grey, interbedded with pale creamy brown tuff		140		
		160		
COAL (C Seam), dull, dark brownish-black, interbedded with brownish-grey tuff and carbonaceous sandstone		180		
SILTSTONE (C-D Interburden), dark grey, interbedded with mottled greenish-grey sandstone and occasional bands of dark reddish brown conglomerate				
SANDSTONE (C-D Sandstone), pale brownish-grey, medium grained, subrounded, moderately sorted, containing thin (10-30 mm) laminae of carbonaceous siltstone		200		Bentonite Seal - 196 to 198 mbgl Filter Pack (Yuleba Minerals WP2.5) - 198 to 213 mbgl
COAL (D Seam), black, dull, interbedded with brownish-black carbonaceous mudstone		220		Screen - stainless steel wire-wound 1.0 mm aperture - 200 to 212 mbgl
SANDSTONE (D-E Sandstone), pale grey, fine to medium grained, common carbonaceous laminae		240		

JBT consulting

Easting: 439232.9

Northing: 7445989

Collar RL (mAHD): 326.432

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K9

Hole Diameter (mm): 285

Total Depth (m): 214

Project: Kevins Corner Project

Bore ID: 1638L

Drilled Date: 5-Oct-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SILTSTONE, light creamy brown		0		
		5		
Silty SAND, light creamy grey, very fine grained		10		
		15		
LATERITE, brownish-red				
Silty SAND, medium orange brown to light grey, very fine grained. Base Horizon of Tertiary at 19.0 m		20		Grout from surface to 86 mbgl
SANDSTONE, medium grey to light orange brown, very fine grained. Base Horizon of Weathering at 25.0 m.		25		
SANDSTONE, light grey with carbonaceous fragments, 50% sandstone 50% siltstone from 30 - 35 m.		30		
		35		
SILTSTONE, medium grey, carbonaceous laminae		40		
		45		
		50		Steel casing 155 mm ID - Surface to 89 mbgl
COAL (C Seam), bands of coal, stony coal, light brown claystone, brownish-black carbonaceous mudstone		55		
		60		
SANDSTONE (C-D Sandstone), light grey, fine to medium-grained, carbonaceous wisps throughout		65		
		70		
		75		
MUDSTONE, dark grey		80		
COAL (D Seam), black coal interbedded with medium greyish-brown mudstone and light grey fine-grained sandstone		85		Bentonite Seal - 86 to 88 mbgl
		90		Filter Pack (Yuleba Minerals WP2.5) - 88 to 102 mbgl
SANDSTONE (D-E Sandstone), light grey, very fine-grained, interbedded with medium grey siltstone		95		
		100		Screen - stainless steel wire-wound 1.0 mm aperture - 89 to 101 mbgl
		105		

JBT consulting

Easting: 445691.5

Northing: 7447110

Collar RL (mAHD): 301.824

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K9

Hole Diameter (mm): 285

Total Depth (m): 102

Project: Kevins Corner Project

Bore ID: 1680R

Drilled Date: 21-Aug-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, orange-brown, fine to medium-grained. Base of Tertiary at 6.0 m		0, 4		
CLAYSTONE, pale brownish-grey, weathered, lateritic		8, 12		Grout from surface to 53 mbgl
SILCRETE, pale creamy-grey, iron-oxide staining, limonitic in parts.		16, 20		
SANDSTONE, pale creamy-white, medium to coarse-grained		24		
CLAYSTONE, medium pinkish-brown to medium orange-brown. Base of weathering at 39 m.		28, 32, 36, 40, 44, 48		Steel casing 155 mm ID - Surface to 53 mbgl
SANDSTONE, medium greyish-black, fine to medium grained		52		
CARBONACEOUS MUDSTONE, dark greyish black, bands of pale creamy-grey sandstone				Bentonite Seal - 53 to 55 mbgl
COAL (C Seam), black coal interbedded with dark brownish-black stony coal and pale creamy-brown tuff		56		
SILTSTONE, dark grey, carbonaceous laminae		60		Filter Pack (Yuleba Minerals WP2.5) - 55 to 76 mbgl
SANDSTONE, pale to medium grey				
SILTSTONE, dark grey		64		
SANDSTONE (C-D Sandstone), pale to medium grey, very fine to medium-grained, occasional bands of quartz pebbles		68, 72		Screen - stainless steel wire-wound 1.0 mm aperture - 62 to 74 mbgl
CLAYSTONE, dark greyish-black, interbedded with carbonaceous laminae		76		
		80		

JBT consulting

Easting: 445612.773

Northing: 7452119.536

Collar RL (mAHD): 295.191

Co-ord System: GDA94

Drilling Company: Wildcat Drilling

Drill Rig: WDS1

Hole Diameter (mm): 285

Total Depth (m): 76

Project: Kevins Corner Project

Bore ID: 1681R

Drilled Date: 23-Aug-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, orange-brown, fine to medium-grained. Base of Tertiary at 6.0 m		0		
CLAYSTONE, pale brownish-grey, weathered, lateritic		10		
SILCRETE, pale creamy-grey, iron-oxide staining, limonitic in parts.		20		Grout from surface to 86 mbgl
SANDSTONE, pale creamy-white, medium to coarse-grained				
CLAYSTONE, medium pinkish-brown to medium orange-brown. Base of weathering at 39 m.		30		
		40		
SANDSTONE, medium greyish-black, fine to medium grained		50		Steel casing 155 mm ID - Surface to 92 mbgl
CARBONACEOUS MUDSTONE, dark greyish black, bands of pale creamy-grey sandstone				
COAL (C Seam), black coal interbedded with dark brownish-black stony coal and pale creamy-brown tuff		60		
SILTSTONE, dark grey, carbonaceous laminae				
SANDSTONE, pale to medium grey				
SILTSTONE, dark grey				
SANDSTONE (C-D Sandstone), pale to medium grey, very fine to medium-grained, occasional bands of quartz pebbles		70		
CLAYSTONE, dark greyish-black, interbedded with carbonaceous laminae				
COAL (D Seam), black coal interbedded with dark grey claystone, laminated siltstone, carbonaceous mudstone, stony coal		80		
SILTSTONE, medium grey, interbedded with pale grey sandstone		90		Bentonite Seal - 86 to 88 mbgl
SANDSTONE (D-E Sandstone), pale creamy grey to brownish-grey, interbedded with dark greyish-black siltstone				Filter Pack (Yuleba Minerals WP2.5) - 88 to 103 mbgl
STONEY COAL (E Seam)		100		Screen - stainless steel wire-wound 1.0 mm aperture - 92 to 98 mbgl
SILTSTONE, dark greyish-black, interbedded with pale creamy grey sandstone				
		110		

JBT consulting

Easting: 445611.777

Northing: 7452101.124

Collar RL (mAHD): 295.356

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K9

Hole Diameter (mm): 285

Total Depth (m): 102

Project: Kevins Corner Project

Bore ID: 1684R

Drilled Date: 21-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
Silty CLAY, light brown, pebbly bands, weathered		0		
SAND, light brown, fine to coarse, clayey		10		Grout from surface to 114 mbgl
CLAYSTONE, light grey, silty bands, ferruginous bands towards base of unit - Base of Tertiary				
CLAYSTONE, light whitish grey, silty, weathered		20		
SANDSTONE, light whitish-brown, fine to very-fine grained, occasional coarse bands				
SILTSTONE, brown to orange-brown, ferruginous, interbedded with limonitic claystone		30		
		40		
CARBONACEOUS MUDSTONE, black with coaly bands, alternating with bands of claystone				
COAL (B Seam), black, fresh		50		50mm cl18 PVC casing - Surface to 120 mbgl
SILTSTONE, dark grey, fresh				
		60		
SANDSTONE (B-C Sandstone), light grey, fine to medium grained, fresh, abundant silty laminae towards base		70		
		80		
		90		
		100		
CARBONACEOUS MUDSTONE (C Seam), black, fresh, alternating with bands of coaly mudstone, claystone, and thin bands of coal		110		
Stony Coal (C Seam), black, fresh, thin coal bands alternating with bands of light brown claystone and black carbonaceous mudstone.		120		Bentonite Seal - 114 to 116 mbgl
SANDSTONE (C-D Sandstone), light grey, fine to very fine grained, quartzose, abundant silty laminae				Filter Pack (Yuleba Minerals WP2.5) - 116 to 133 mbgl
SANDSTONE (C-D Sandstone), light grey, medium to coarse-grained, occasional pebbly bands		130		
SILTSTONE, dark grey, alternating with bands of dark grey mudstone				Screen - machine-slotted 50 mm cl18 PVC - 120 to 132 mbgl
COAL (D Seam) bright, black, fresh, occasional bands of whitish-grey claystone		140		
		150		

JBT consulting

Easting: 442478.2

Northing: 7440833

Collar RL (mAHD): 317.909

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K10

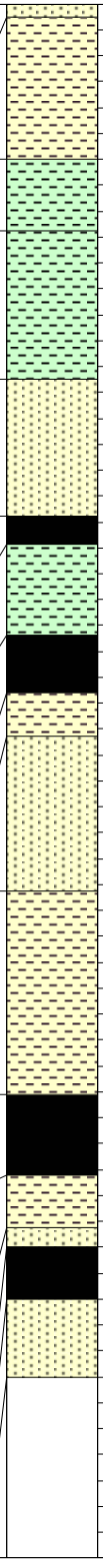
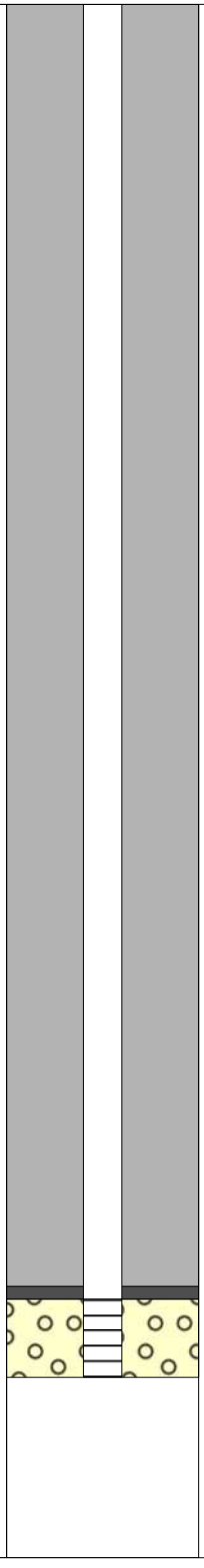
Hole Diameter (mm): 152

Total Depth (m): 134

Project: Kevins Corner Project

Bore ID: 1686R

Drilled Date: 27-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, medium orange-brown, fine to medium grained		0		Grout from surface to 198 mbgl
SILTSTONE, medium pinkish-grey, moderately weathered		20		
CLAYSTONE, medium orange brown to medium greyish brown				
CLAYSTONE, dark greyish-black, carbonaceous throughout, base of weathering at 42 mbgl		40		
SANDSTONE, pale creamy grey, fine to medium-grained, moderately sorted, poorly cemented, loose (drilling chips crumble apart)		60		50mm cl18 PVC - Surface to 200 mbgl
COAL (A Seam), bright black coal, interbedded with dark blackish-brown carbonaceous mudstone		80		
CLAYSTONE (A-B Interburden), dark greyish-black mottled with pale creamy grey, interbedded with carbonaceous sandstone				
COAL (B Seam), dull, greyish-black, interbedded with stony coal, pale greyish-brown tuff and claystone		100		
SILTSTONE, pale greyish-black, interbedded with carbonaceous sandstone				
SANDSTONE (B-C Sandstone), pale creamy grey, minor siltstone laminae		120		
SILTSTONE, dark grey, interbedded with pale creamy brown tuff		140		
		160		
COAL (C Seam), dull, dark brownish-black, interbedded with brownish-grey tuff and carbonaceous sandstone				
SILTSTONE (C-D Interburden), dark grey, interbedded with mottled greenish-grey sandstone and occasional bands of dark reddish brown conglomerate		180		
SANDSTONE (C-D Sandstone), pale brownish-grey, medium grained, subrounded, moderately sorted, containing thin (10-30 mm) laminae of carbonaceous siltstone		200		Bentonite Seal - 196 to 198 mbgl Filter Pack (Yuleba Minerals WP2.5) - 198 to 213 mbgl
COAL (D Seam), black, dull, interbedded with brownish-black carbonaceous mudstone		220		
SANDSTONE (D-E Sandstone), pale grey, fine to medium grained, common carbonaceous laminae		240		Screen - machine-slotted 50 mm cl18 PVC - 200 to 212 mbgl

JBT consulting

Easting: 439261

Northing: 7445984

Collar RL (mAHD): 326.114

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K10

Hole Diameter (mm): 152

Total Depth (m): 214

Project: Kevins Corner Project

Bore ID: 1688R

Drilled Date: 23-Aug-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SILTSTONE, light creamy brown		0		
		5		
Silty SAND, light creamy grey, very fine grained		10		
		15		
LATERITE, brownish-red Silty SAND, medium orange brown to light grey, very fine grained. Base Horizon of Tertiary at 19.0 m		20		Grout from surface to 86 mbgl
SANDSTONE, medium grey to light orange brown, very fine grained. Base Horizon of Weathering at 25.0 m.		25		
SANDSTONE, light grey with carbonaceous fragments, 50% sandstone 50% siltstone from 30 - 35 m.		30		
		35		
SILTSTONE, medium grey, carbonaceous laminae		40		
		45		
		50		50mm cl18 PVC - Surface to 89 mbgl
COAL (C Seam), bands of coal, stony coal, light brown claystone, brownish-black carbonaceous mudstone		55		
		60		
SANDSTONE (C-D Sandstone), light grey, fine to medium-grained, carbonaceous wisps throughout		65		
		70		
		75		
MUDSTONE, dark grey		80		
COAL (D Seam), black coal interbedded with medium greyish-brown mudstone and light grey fine-grained sandstone		85		Bentonite Seal - 86 to 88 mbgl
		90		Filter Pack (Yuleba Minerals WP2.5) - 88 to 102 mbgl
SANDSTONE (D-E Sandstone), light grey, very fine-grained, interbedded with medium grey siltstone		95		
		100		Screen - machine-slotted 50 mm cl18 PVC - 89 to 101 mbgl
		105		

JBT consulting

Easting: 445611.777

Northing: 7452101.124

Collar RL (mAHD): 295.356

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K9

Hole Diameter (mm): 152

Total Depth (m): 102

Project: Kevins Corner Project

Bore ID: 2031R

Drilled Date: 22-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
Silty CLAY, light brown, pebbly bands, weathered		0		
SAND, light brown, fine to coarse, clayey				
CLAYSTONE, light grey, silty bands, ferruginous bands towards base of unit - Base of Tertiary		10		Grout from surface to 138 mbgl
CLAYSTONE, light whitish grey, silty, weathered				
SANDSTONE, light whitish-brown, fine to very-fine grained, occasional coarse bands		20		
		30		
SILTSTONE, brown to orange-brown, ferruginous, interbedded with limonitic claystone				
		40		50mm cl18 PVC - Surface to 139 mbgl
CARBONACEOUS MUDSTONE, black with coaly bands, alternating with bands of claystone				
COAL (B Seam), black, fresh		50		
SILTSTONE, dark grey, fresh				
		60		
		70		
SANDSTONE (B-C Sandstone), light grey, fine to medium grained, fresh, abundant silty laminae towards base		80		
		90		
		100		
CARBONACEOUS MUDSTONE (C Seam), black, fresh, alternating with bands of coaly mudstone, claystone, and thin bands of coal		110		
Stony Coal (C Seam), black, fresh, thin coal bands alternating with bands of light brown claystone and black carbonaceous mudstone.		120		
SANDSTONE (C-D Sandstone), light grey, fine to very fine grained, quartzose, abundant silty laminae, medium to coarse 122 to 134.9 m		130		
COAL (D Seam) bright, black, fresh, occasional bands of whitish-grey claystone		140		Bentonite Seal - 138 to 140 mbgl
CARBONACEOUS MUDSTONE, dark grey, alternating with bands of dark grey siltstone				
SANDSTONE (D-E Sandstone) light grey, medium to coarse-grained, occasional cobbles, alternating with bands of fine-grained sandstone and coarse to very coarse-grained sandstone		150		Filter Pack (Yuleba Minerals WP2.5) - 140 to 153 mbgl Screen - machine-slotted 50 mm cl18 PVC - 139 to 151 mbgl
COAL (E Seam)		160		
		170		

JBT consulting

Easting: 442467.5

Northing: 7440833

Collar RL (mAHD): 317.763

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K10

Hole Diameter (mm): 152

Total Depth (m): 157

Project: Kevins Corner Project

Bore ID: KVP-07

Drilled Date: 18-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
Silty CLAY, light brown, pebbly bands, weathered		0		
SAND, light brown, fine to coarse, clayey				
CLAYSTONE, light grey, silty bands, ferruginous bands towards base of unit - Base of Tertiary		10		
CLAYSTONE, light whitish grey, silty, weathered		20		
SANDSTONE, light whitish-brown, fine to very-fine grained, occasional coarse bands				
SILTSTONE, brown to orange-brown, ferruginous, interbedded with limonitic claystone		30		
CARBONACEOUS MUDSTONE, black with coaly bands, alternating with bands of claystone		40		
COAL (B Seam), black, fresh		50		
SILTSTONE, dark grey, fresh				
SANDSTONE (B-C Sandstone), light grey, fine to medium grained, fresh, abundant silty laminae towards base		60		
		70		
		80		
		90		
		100		
CARBONACEOUS MUDSTONE (C Seam), black, fresh, alternating with bands of coaly mudstone, claystone, and thin bands of coal		110		Vibrating Wire Piezometer @ 105 m - s/n 15377
Stony Coal (C Seam), black, fresh, thin coal bands alternating with bands of light brown claystone and black carbonaceous mudstone.		120		
SANDSTONE (C-D Sandstone), light grey, fine to very fine grained, quartzose, abundant silty laminae		130		Vibrating Wire Piezometer @ 125 m - s/n 15231
SANDSTONE (C-D Sandstone), light grey, medium to coarse-grained, occasional pebbly bands		140		
SILTSTONE, dark grey, alternating with bands of dark grey mudstone				Vibrating Wire Piezometer @ 145 m - s/n 15227
COAL (D Seam) bright, black, fresh, occasional bands of whitish-grey claystone		150		
CARBONACEOUS MUDSTONE, dark grey, alternating with bands of dark grey siltstone		160		Vibrating Wire Piezometer @ 157 m - s/n 11752
SANDSTONE (D-E Sandstone) light grey, medium to coarse-grained, occasional cobbles, alternating with bands of fine-grained sandstone and coarse to very coarse-grained sandstone		170		
COAL (E Seam)		180		
SANDSTONE (Sub-E Sandstone)		190		

JBT consulting

Easting: 442456.6

Northing: 7440833

Collar RL (mAHD): 318.133

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K10

Hole Diameter (mm): 100

Total Depth (m): 168

Project: Kevins Corner Project

Bore ID: KVP-08

Drilled Date: 25-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, medium orange-brown, fine to medium grained		0		
SILTSTONE, medium pinkish-grey, moderately weathered		20		
CLAYSTONE, medium orange brown to medium greyish brown				
CLAYSTONE, dark greyish-black, carbonaceous throughout, base of weathering at 42 mbgl		40		
SANDSTONE, pale creamy grey, fine to medium-grained, moderately sorted, poorly cemented, loose (drilling chips crumble apart)		60		
COAL (A Seam), bright black coal, interbedded with dark blackish-brown carbonaceous mudstone		80		
CLAYSTONE (A-B Interburden), dark greyish-black mottled with pale creamy grey, interbedded with carbonaceous sandstone		100		
COAL (B Seam), dull, greyish-black, interbedded with stony coal, pale greyish-brown tuff and claystone				
SILTSTONE, pale greyish-black, interbedded with carbonaceous sandstone		120		
SANDSTONE (B-C Sandstone), pale creamy grey, minor siltstone laminae				Vibrating Wire Piezometer @ 127 m - s/n 15230
SILTSTONE, dark grey, interbedded with pale creamy brown tuff		140		
COAL (C Seam), dull, dark brownish-black, interbedded with brownish-grey tuff and carbonaceous sandstone		160		
SILTSTONE (C-D Interburden), dark grey, interbedded with mottled greenish-grey sandstone and occasional bands of dark reddish brown conglomerate		180		
SANDSTONE (C-D Sandstone), pale brownish-grey, medium grained, subrounded, moderately sorted, containing thin (10-30 mm) laminae of carbonaceous siltstone		200		Vibrating Wire Piezometer @ 190 m - s/n 11753
COAL (D Seam), black, dull, interbedded with brownish-black carbonaceous mudstone		220		Vibrating Wire Piezometer @ 212 m - s/n 11756
SANDSTONE (D-E Sandstone), pale grey, fine to medium grained, common carbonaceous laminae				Vibrating Wire Piezometer @ 224 m - s/n 15027
E Seam		240		
Sub-E Sandstone		260		

JBT consulting

Easting: 439272

Northing: 7445984

Collar RL (mAHD): 325.95

Co-ord System: GDA94

Drilling Company: S&K Drilling

Drill Rig: S&K10

Hole Diameter (mm): 100

Total Depth (m): 226

Project: Kevins Corner Project

Bore ID: KVP-09

Drilled Date: 16-Sep-2011

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
SAND, orange-brown, fine to medium-grained. Base of Tertiary at 6.0 m		0		
CLAYSTONE, pale brownish-grey, weathered, lateritic		10		
SILCRETE, pale creamy-grey, iron-oxide staining, limonitic in parts.		20		
SANDSTONE, pale creamy-white, medium to coarse-grained				
CLAYSTONE, medium pinkish-brown to medium orange-brown. Base of weathering at 39 m.		30 40		
SANDSTONE, medium greyish-black, fine to medium grained		50		Vibrating Wire Piezometer @ 49 m - s/n 11735
CARBONACEOUS MUDSTONE, dark greyish black, bands of pale creamy-grey sandstone				
COAL (C Seam), black coal interbedded with dark brownish-black stony coal and pale creamy-brown tuff		60		
SILTSTONE, dark grey, carbonaceous laminae				
SANDSTONE, pale to medium grey				
SILTSTONE, dark grey		70		Vibrating Wire Piezometer @ 68 m - s/n 14803
SANDSTONE (C-D Sandstone), pale to medium grey, very fine to medium-grained, occasional bands of quartz pebbles				
CLAYSTONE, dark greyish-black, interbedded with carbonaceous laminae		80		
COAL (D Seam), black coal interbedded with dark grey claystone, laminated siltstone, carbonaceous mudstone, stony coal				
SILTSTONE, medium grey, interbedded with pale grey sandstone		90		
SANDSTONE (D-E Sandstone), pale creamy grey to brownish-grey, interbedded with dark greyish-black siltstone				Vibrating Wire Piezometer @ 93 m - s/n 15383
STONY COAL (E Seam)		100		
SILTSTONE, dark greyish-black, interbedded with pale creamy grey sandstone (Sub-E Sandstone)		110		Vibrating Wire Piezometer @ 107 m - s/n 15316
		120		

JBT consulting

Easting: 445630.847

Northing: 7452131.5

Collar RL (mAHD): 294.986

Co-ord System: GDA94

Drilling Company: S&K Drilling

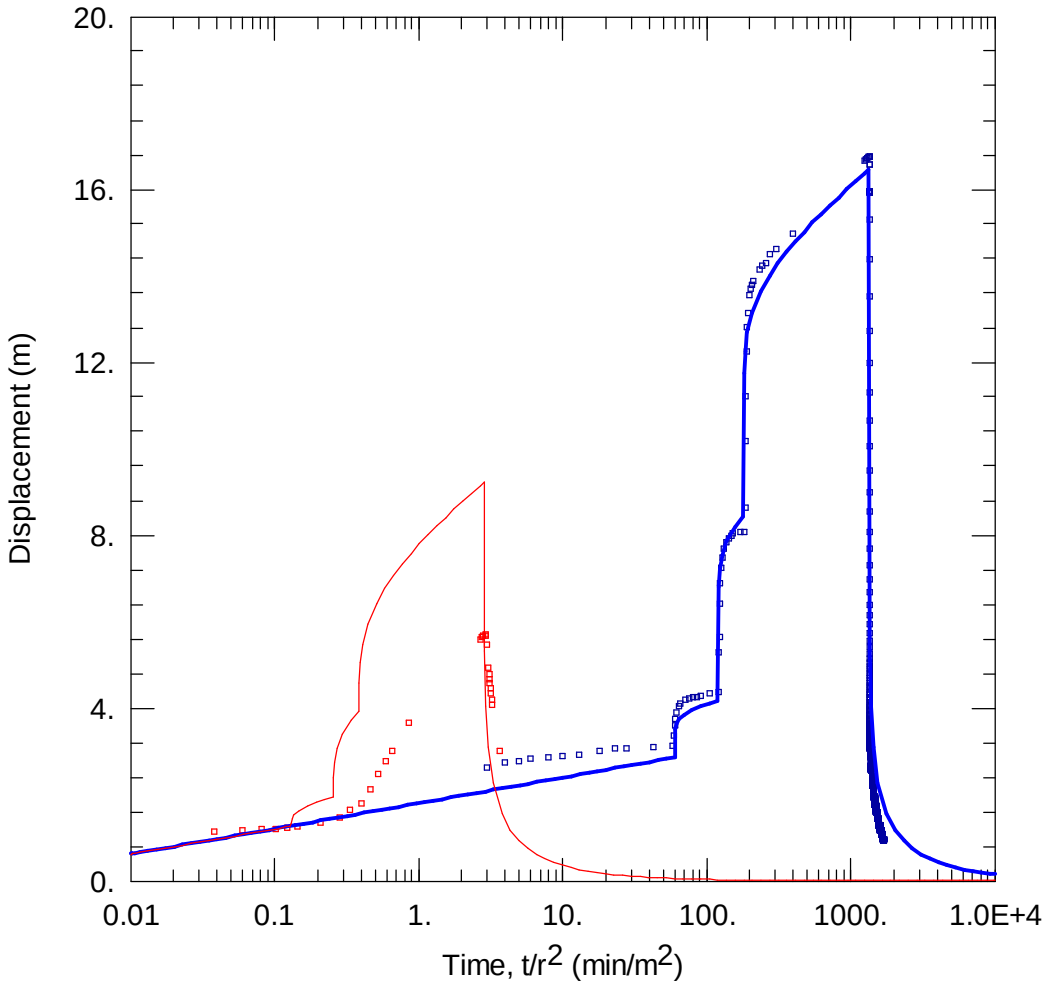
Drill Rig: S&K10

Hole Diameter (mm): 100

Total Depth (m): 120

APPENDIX B

PUMPING TEST ANALYSES



1680R - STEP DRAWDOWN TEST WITH EXTENDED FINAL STEP

Data Set: C:\...\1680R Pumping Test_Pumping Data.aqt
Date: 12/22/11 Time: 20:23:21

PROJECT INFORMATION

Client: Hancock Coal
Location: Kevin's Corner
Test Well: 1680R_Pumping
Test Date: 30 October 2010

AQUIFER DATA

Saturated Thickness: 16. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
1680R_Pumping	445613	7452120

Observation Wells

Well Name	X (m)	Y (m)
▫ 1680R_Pumping	445613	7452120
▫ KVP-09 (1682R)	445631	7452132

SOLUTION

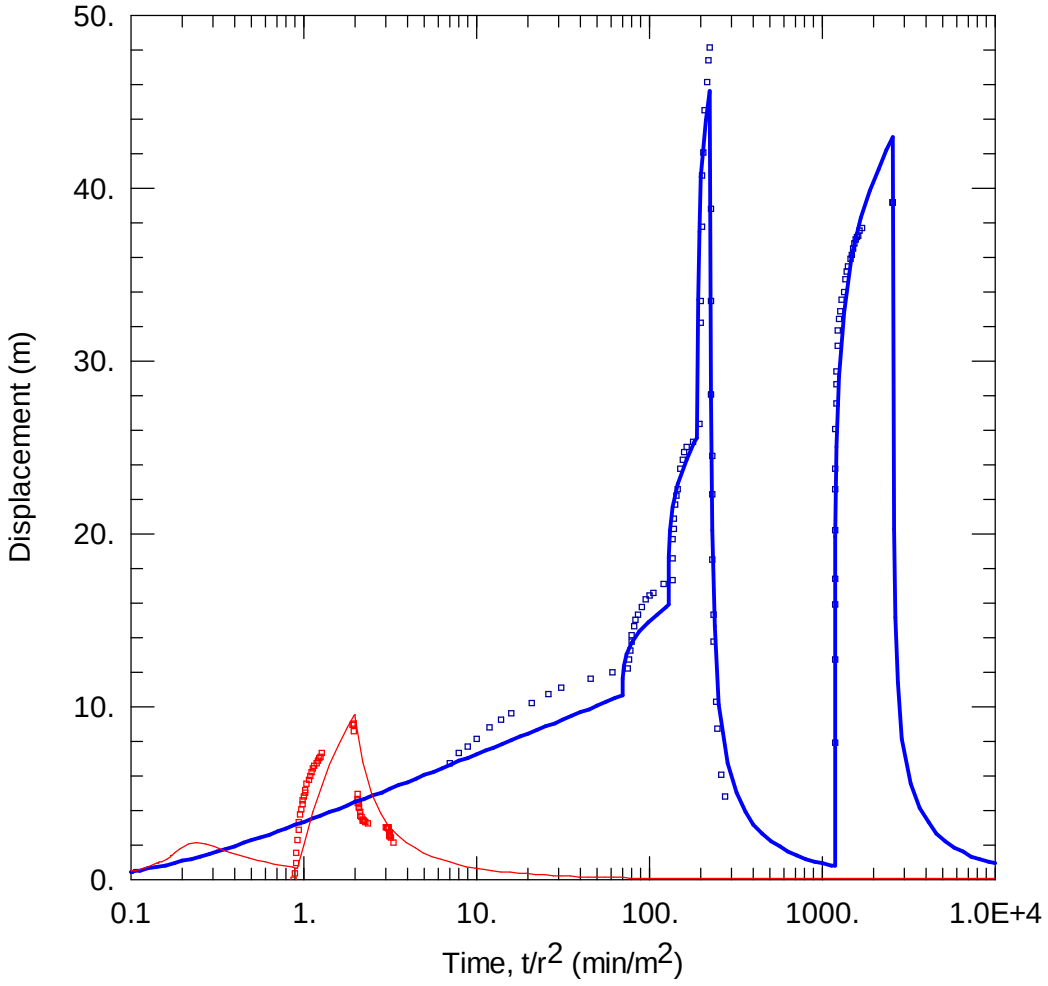
Aquifer Model: Confined
Solution Method: Theis (Step Test)

T = 13.31 m^2/day
Sw = 0.
P = 1.5

S = 2.007E-5
C = 1. min^2/m^5

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. min Rate (Q) in cu. m/min

$s(t) = 59.75Q + 1.Q^{1.5}$
W.E. = 99.39% (Q from last step)



1681R STEP DRAWDOWN TEST & CONSTANT DISCHARGE

Data Set: C:\...\1681R Obs Bore.aqt
Date: 12/22/11 Time: 20:02:58

PROJECT INFORMATION

Client: Hancock Coal
Location: Kevin's Corner
Test Well: 1681R_Pumping
Test Date: 28 October 2010

AQUIFER DATA

Saturated Thickness: 11. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
1681R_Pumping	445612	7452101

Observation Wells

Well Name	X (m)	Y (m)
▫ 1681R_Pumping	445612	7452101
▫ KVP-09 (1682R)	445631	7452132

SOLUTION

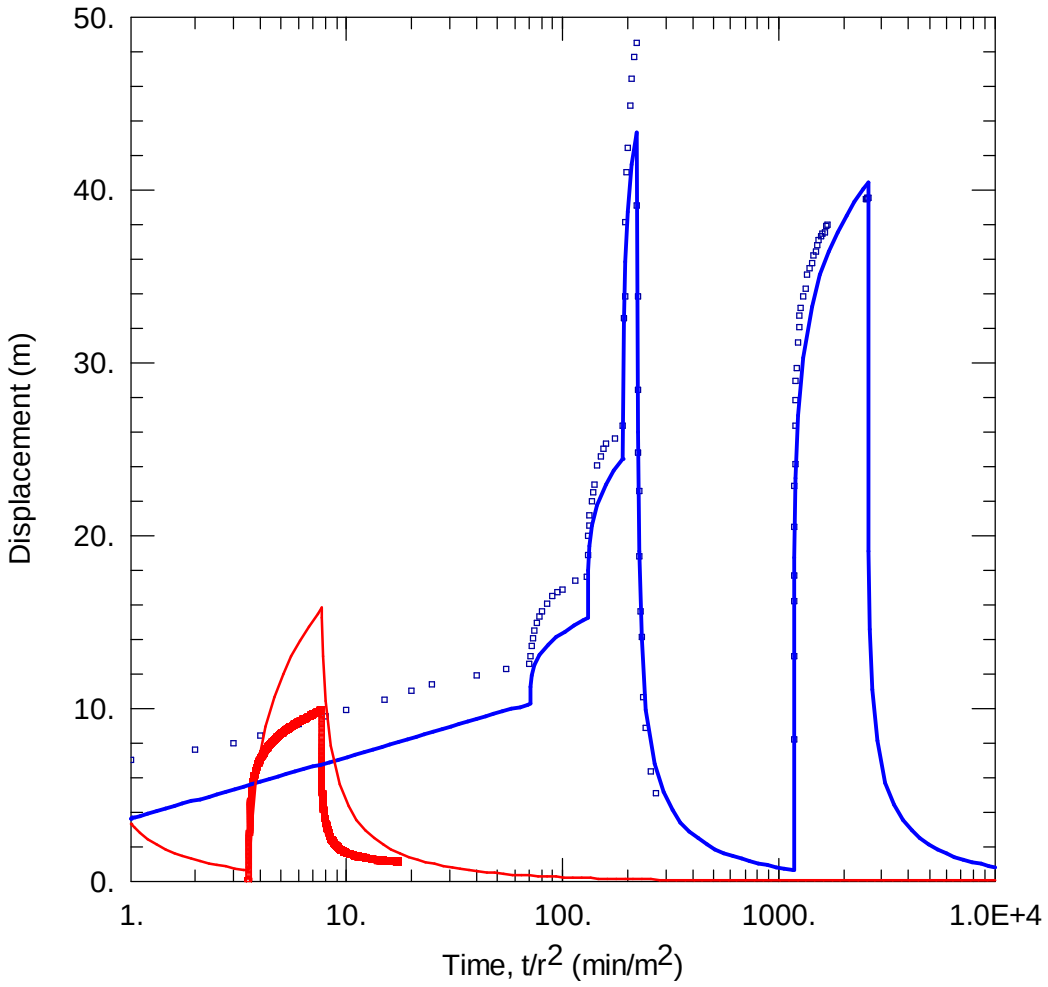
Aquifer Model: Confined
Solution Method: Theis (Step Test)

T = 1.952 m^2/day
Sw = 0.
P = 1.5

S = 0.0005113
C = 0. min^2/m^5

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. min Rate (Q) in cu. m/min

$s(t) = 110.1Q + 0.Q^{1.5}$
W.E. = 100.% (Q from last step)



1638L STEP DRAWDOWN + CONSTANT DISCHARGE TEST

Data Set: C:\...\1638L_Pumping + Obs Bore_All Data.aqt
Date: 12/22/11 Time: 20:05:33

PROJECT INFORMATION

Client: Hancock Coal
Location: Kevin's Corner
Test Well: 1638L_Pumping
Test Date: 26 October 2010

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
1638L_Pumping	445692	7447110

Observation Wells

Well Name	X (m)	Y (m)
▫ 1638L_Pumping	445692	7447110
▫ 1688R_Obs	445676	7447119

SOLUTION

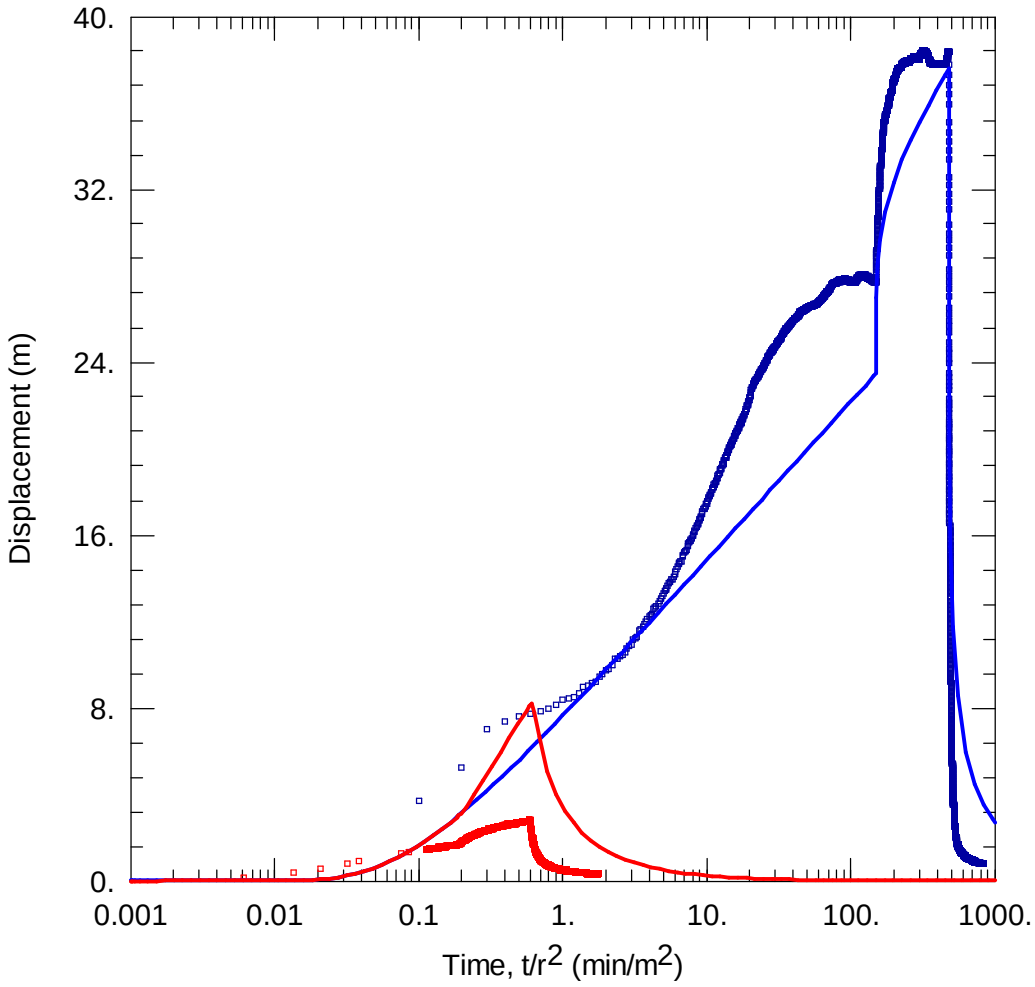
Aquifer Model: Confined
Solution Method: Theis (Step Test)

T = 2.177 m^2/day
Sw = 0.
P = 1.5

S = 0.000366
C = 1. min^2/m^5

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. min Rate (Q) in cu. m/min

$s(t) = 120.4Q + 1.Q^{1.5}$
W.E. = 99.71% (Q from last step)



1637R - STEP DRAWDOWN TEST - EXTENDED FINAL STEP

Data Set: C:\...\1637L Pumping Test_Theis.aqt
Date: 12/22/11 Time: 20:24:33

PROJECT INFORMATION

Client: Hancock Coal
Location: Kevin's Corner
Test Well: 1637R_Pumping
Test Date: 20 October 2010

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
1637L_Pumping	439233	7445989

Observation Wells

Well Name	X (m)	Y (m)
▫ 1637L_Pumping	439233	7445989
▫ 1686R_Obs	439261	7445984

SOLUTION

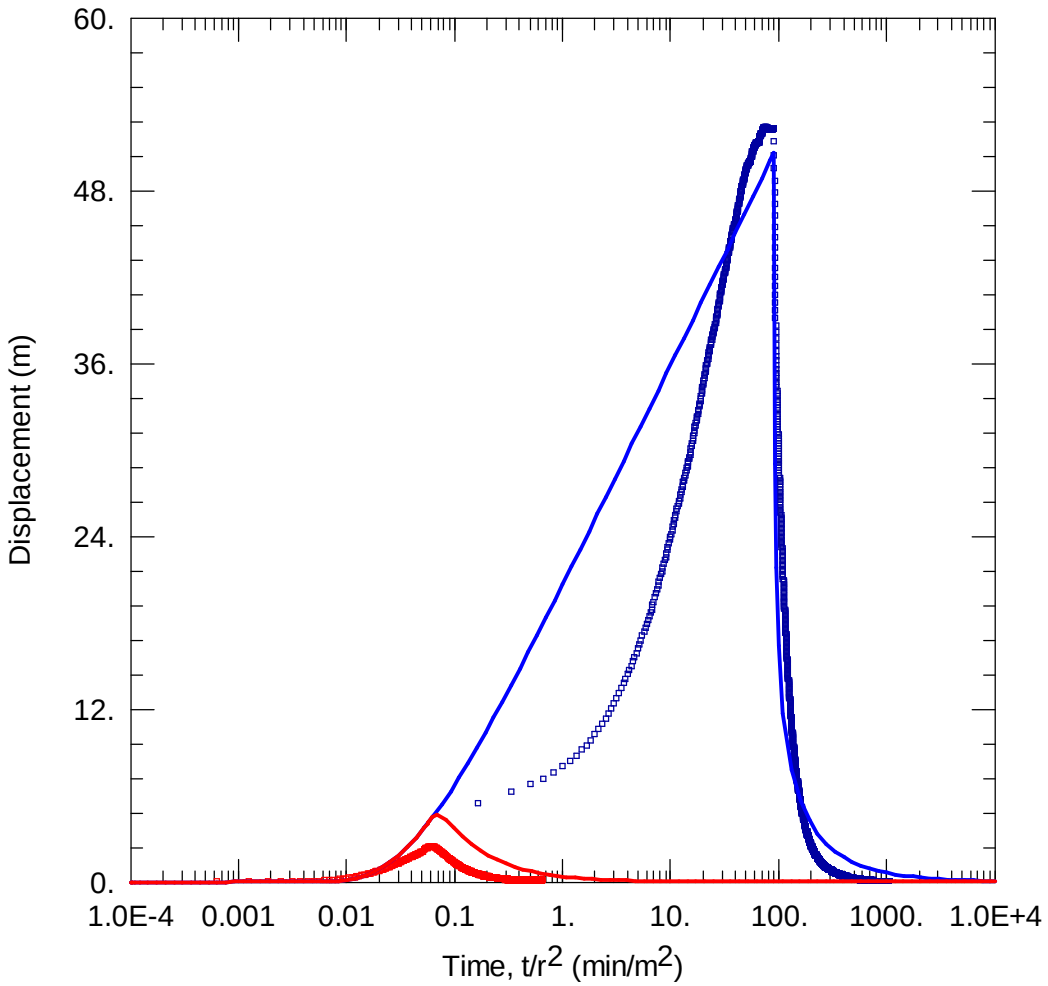
Aquifer Model: Confined
Solution Method: Theis (Step Test)

T = 1.077 m^2/day
Sw = 0.
P = 1.5

S = 0.0001615
C = 1. min^2/m^5

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. min Rate (Q) in cu. m/min

$s(t) = 254.8Q + 1.Q^{1.5}$
W.E. = 99.92% (Q from last step)



1636R CONSTANT RATE PUMPING TEST

Data Set: C:\...\1636R Pumping Test_all.aqt
Date: 12/22/11 Time: 20:08:39

PROJECT INFORMATION

Client: Hancock Coal
Location: Kevin's Corner
Test Well: 1636L_Pumping
Test Date: 20 October 2010

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
1636L_Pumping	442478	7440873

Observation Wells

Well Name	X (m)	Y (m)
▫ 1636L_Pumping	442478	7440873
▫ 1684_Obs	442478	7440833

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 0.6898 m^2/day
S = 5.013E-5
Kz/Kr = 1.
b = 18. m

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Our reference: JBT01-005-034 - Summary of Permeability Testing Data.docx

20 December 2011

Mark Stewart
Principal Hydrogeologist
URS
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Alpha and Kevin's Corner Projects – Summary of Slug Testing Data

1. Introduction

This report presents a summary of laboratory permeability testing undertaken on a number of core samples obtained from geotechnical boreholes drilled across the Kevin's Corner lease.

Samples were selected for testing from available fresh core samples based on the following criteria:

- On advice from the testing laboratory the minimum length of core sample was set at 20 cm, to allow selection of appropriate samples for horizontal and vertical permeability testing;
- Samples were selected from a range of formations and lithology types, with a bias towards selection of low-permeability (i.e. fine-grained) samples for testing, as little or no site specific data is available for dry bores.

A total of 26 samples were selected for testing, as summarised in Table 2-1.

The rock samples were sent to TriLab, a NATA-Accredited geotechnical testing facility in Brisbane. Testing was undertaken in accordance with Australian Standard Test Method AS1289, 6.7.3, 5.1.1 / KH2.

Samples were tested, where possible, to obtain both horizontal and vertical permeability.

The location of bores from which samples were selected is shown in Figure 1-1.

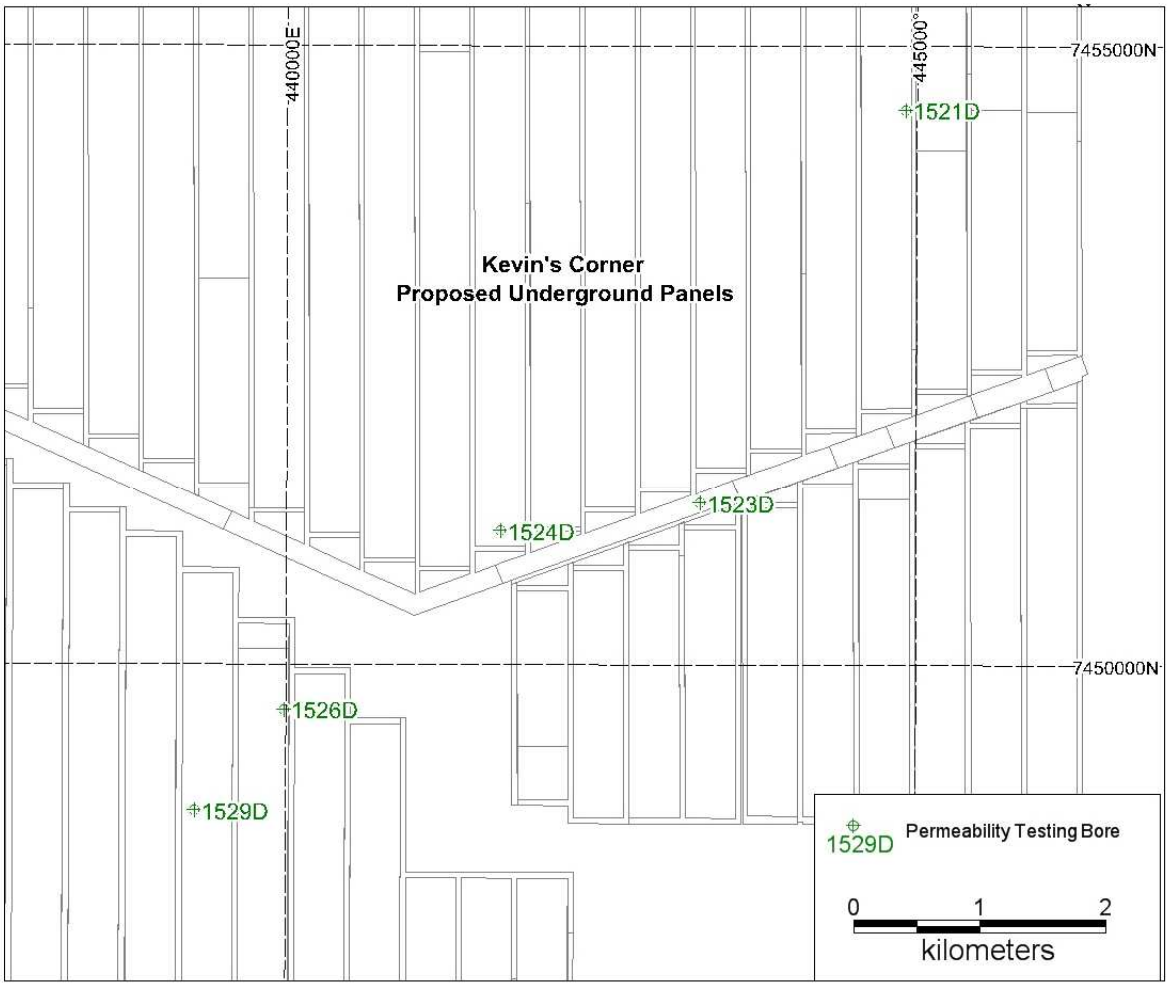

Figure 1-1: Location of Permeability Testing Bores

2. Results

Results of testing are summarised in Table 2-1. Laboratory certificates are provided in Appendix A.

Horizontal permeability results range from a low of 1.0E-11 m/s (8.6E-07 m/day) to a high of 4.0E-07 m/s (0.04 m/day), with a mean of 2.8E-08 m/s (0.002 m/day) and a median of 1.5E-10 m/s (1.3E-05 m/day).

Vertical permeability results range from a low of 4.0E-11 m/s (3.5E-06 m/day) to a high of 2.0E-07 m/s (0.02 m/day), with a mean of 2.4E-08 m/s (2.1E-03) and a median of 3.0E-10 m/s (2.6E-05 m/day).

For samples where both horizontal and vertical permeability results were available (22 out of 26 samples) the vertical permeability was higher than horizontal permeability in 14 samples (64%), and lower than horizontal permeability in 8 samples (36%).

Table 2-1: Summary of Laboratory Permeability Testing Data

Hole ID	Sample ID	Depth (mbgl)		Description	Permeability (m/s)	
		From	To		Horizontal	Vertical
1521D	1521D_GT_002	90.82	91.04	B-C SST - SST medium grained 60%, Siltstone 40%	1.00E-11	5.00E-11
	1521D_GT_005	104.72	105.00	C-D SST - SST 50% carbonaceous throughout	3.00E-09	2.00E-10
	1521D_GT_008	127.88	128.16	C-D SST - coarse grained	3.00E-08	3.00E-08
	1521D_GT_010	134.56	134.83	C-D - Siltstone above DU1 coal seam	3.00E-11	1.00E-10
1523D	1523D_GT_001	68.78	69.00	B-C SST - SST fine grained 50%, Siltstone 50%	9.00E-11	2.00E-10
	1523D_GT_005	101.42	101.68	C-D SST - SST med-coarse grained	3.00E-11	2.00E-07
	1523D_GT_006	114.00	114.20	C-D Carbonaceous siltstone 90%, Siltstone 10%	2.00E-10	1.00E-10
	1523D_GT_007	118.27	118.57	D interburden Sandstone 60%, Siltstone 40%, carbonaceous	1.00E-10	9.00E-11
1524D	1524D_GT_001	48.00	48.30	Above A Seam - Siltstone, clayey throughout	4.00E-11	3.00E-10
	1524D_GT_003	56.35	56.59	B-C Sandstone, fine-grained, silty bands	1.00E-09	2.00E-10
	1524D_GT_008	121.81	122.03	B-C - Carbonaceous mudstone just above top of C coal seam	a.	2.00E-08
	1524D_GT_011	140.92	141.08	C-D siltstone, claystone laminae throughout	a.	a.
	1524D_GT_014	148.62	148.94	D-E Sandstone, fine-grained, claystone bands throughout	6.00E-10	2.00E-10
1526D	1526D_GT_001	45.67	45.86	Above A seam - sandstone med-coarse grained, lithic	2.00E-08	7.00E-09
	1526D_GT_002	72.78	73.04	B-C, just below base B. Sandstone fine-med grained, carbonaceous laminae	2.00E-10	4.00E-10
	1526D_GT_003	132.30	132.48	B-C, just above top C coal seam. Sandstone fine-med grained, fine silty matrix	1.00E-10	4.00E-10
	1526D_GT_004	146.69	146.90	C-D dark grey mudstone 70%, fine-grained sandstone 30%	4.00E-11	4.00E-11
	1526D_GT_010	163.84	164.04	C-D Sandstone med to very coarse grained	4.00E-07	2.00E-07
	1526D_GT_013	176.17	176.49	D-E sandstone fine-med grained, abundant silty and carbonaceous laminae	9.00E-08	1.00E-07
1529D	1529D_GT_001	75.00	75.17	Above A Seam - Carbonaceous siltstone	a.	4.00E-11
	1529D_GT_003	80.22	80.52	A-B sandstone, fine-grained	a.	5.00E-10
	1529D_GT_005	99.98	100.27	C interburden (between C coal seams) Sandstone, fine-med grained, some lithics	5.00E-11	9.00E-11
	1529D_GT_008	167.59	167.80	C-D sandstone, fine-med grained, rare carbonaceous bands throughout	9.00E-09	1.00E-08
	1529D_GT_012	180.00	181.98	C-D siltstone	2.00E-11	4.00E-10
	1529D_GT_013	187.86	188.10	D-E sandstone, rare coal wisps	4.00E-11	1.00E-10
	1529D_GT_015	191.24	191.44	D-E sandstone, medium to coarse, some lithics	7.00E-08	4.00E-08

a. Not possible to test sample (refer Appendix A)

3. Discussion of Results

The following observations are made with respect to the results obtained from horizontal and vertical permeability testing of core samples:

- Results for both vertical and horizontal permeability testing range over at least 4 orders of magnitude;
- The median is approximately 2 orders of magnitude lower than the mean value for both vertical and horizontal permeability samples, indicating that the majority of the selected samples are in the low permeability (10E-10 m/s) range;
- The results obtained from laboratory testing of core samples are generally lower than permeability values obtained from pumping tests at the site. This provides some indication of the degree of heterogeneity at the site as it is known from exploration drilling that some bores do not yield much water (low permeability sites), but it is only bores that yield water (relatively high permeability sites) that can be tested via pumping tests to provide aquifer parameters. In addition, vertical permeability is higher than horizontal permeability in the majority of laboratory test cases. The following theory is offered to explain this phenomenon:
    - Observations from pumping tests undertaken on the Kevin's Corner lease and the adjacent Alpha Lease, as well as observations from dewatering operations at the test pit on the Alpha lease, indicate that the interburden aquifers behave as a continuous porous medium. However, observations from pumping tests also indicates that initially high bore yields (up to 10 L/s) reduce to (more sustainable yields) several L/s relatively quickly (over a matter of days or weeks). This indicates that permeability boundaries are being encountered during long-term pumping and provides further evidence of aquifer heterogeneity at site. In addition, for bores where yields are initially relatively high, the sandstone units intersected are usually medium to coarse and clean (i.e. a matrix of fine material or cement is absent from the pore spaces). However, these bores are usually surrounded by bores with relatively low yields, where the pore spaces contain fine silts and clays or cementing material, so that the zones where clean sandstone occurs are relatively uncommon, isolated and discontinuous indicating limited effective storage and reduced sustainable yields governed by surrounding aquifer permeability ;
    - A number of samples sent for laboratory permeability testing (including 1521D_GT_008, 1523D_GT_005, 1526D_GT_001, refer Table 2-1) were logged as medium to coarse sandstone, but the laboratory results indicate these units have low to very low permeability. For these samples the pores are likely to be in-filled with either cement or fine material such as silts and clays. Therefore, the permeability of the lithologies on site are controlled by the permeability of the material that infills the pore spaces, rather than the permeability of the larger matrix grains, except in cases where the pore spaces of the coarse material are free of silts/clays or cementing material;
    - It is therefore considered that groundwater movement in the study area occurs predominantly through secondary porosity such as fractures or intergranular where infilling is absent. These preferential pathways (fractures) are apparently hydraulically connected, so that at a large scale the aquifers still behave as a continuous porous medium. However, groundwater movement does not necessarily occur through the total body of rock, and while the entire body of rock may be saturated, the entire volume of water does not report to pumping bores as water is obtained preferentially through the secondary porosity of fractures, with the remainder of the water held up in the blocks between the fractures (matrix blocks);
    - In cases where the laboratory permeability is low, even though the core is logged as comprising medium to coarse sandstone, it is the material between fractures that is being tested (i.e., matrix blocks, with poor effective porosity due to infilling of pore spaces with fine material or cement) rather than the secondary fracture porosity; and,

- In cases where the vertical permeability is higher than the horizontal permeability, this may be due to micro-fractures being present, which are continuous in the vertical direction but not in the horizontal direction, and which may be opened up due to removal of weight/stress on the rock.

APPENDIX A

LABORATORY CERTIFICATES

Trilab
www.trilab.com.au

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10/104 Newmarket Rd, Windsor
QLD 4030
Ph: +61 7 3357 5535

Perth
2 Kimmer Place, Queens Park
WA 6107
Ph: +61 8 9258 8323

PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070001-CHP Horizontal
Project	Permeability Testing	**Test Date**	01/09-12/09/2011
		Report Date	13/09/2011

Sample No.	11070001
Client ID	1521D_GT_002
Depth (m)	90.82-91.04
Received Moisture Content (%)	11.1
Received Wet Density (t/m^3)	2.33
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	49.0
Length (mm)	34.7

PERMEABILITY

$K_{20} = 1 \times 10^{-11}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IES 17025. The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Authorised Signatory
James Russell
J. Russell

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070001-CHP Vertical
Project	Permeability Testing	**Test Date**	24/08-31/08/2011
		Report Date	13/09/2011

Sample No.	11070001
Client ID	1521D_GT_002
Depth (m)	90.82-91.04
Received Moisture Content (%)	11.1
Received Wet Density (t/m^3)	2.33
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.2
Length (mm)	68.4

PERMEABILITY

$K_{20} = 5 \times 10^{-11}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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Authorised Signatory
James Russell
J. Russell

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070002-CHP Horizontal
Project	Permeability Testing	**Test Date**	01/09-07/09/2011
		Report Date	13/09/2011

Sample No.	11070002
Client ID	1521D_GT_005
Depth (m)	104.72-105.00
Received Moisture Content (%)	6.9
Received Wet Density (t/m^3)	2.34
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	49.0
Length (mm)	34.3

PERMEABILITY

$K_{20} = 3 \times 10^{-9}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070002-CHP Vertical
Project	Permeability Testing	**Test Date**	22/08-30/08/2011
		Report Date	13/09/2011

Sample No.	11070002
Client ID	1521D_GT_005
Depth (m)	104.72-105.00
Received Moisture Content (%)	6.9
Received Wet Density (t/m^3)	2.34
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	61.2
Length (mm)	60.5

PERMEABILITY

$K_{20} = 2 \times 10^{-10}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070003-CHP Horizontal
Project	Permeability Testing	**Test Date**	04/08-09/08/2011
		Report Date	13/09/2011

Sample No.	11070003
Client ID	1521D_GT_008
Depth (m)	127.88-128.16
Received Moisture Content (%)	6.4
Received Wet Density (t/m^3)	2.25
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	49.7
Length (mm)	43.7

PERMEABILITY

$K_{20} = 3 \times 10^{-8}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070003-CHP Vertical
Project	Permeability Testing	**Test Date**	04/08-09/08/2011
		Report Date	13/09/2011

Sample No.	11070003
Client ID	1521D_GT_008
Depth (m)	127.88-128.16
Received Moisture Content (%)	6.4
Received Wet Density (t/m^3)	2.25
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.4
Length (mm)	59.7

PERMEABILITY

$K_{20} = 3 \times 10^{-8}$ m/s

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070004-CHP Horizontal
Project	Permeability Testing	**Test Date**	11/08-18/08/2011
		Report Date	13/09/2011

Sample No.	11070004
Client ID	1521D_GT_010
Depth (m)	134.56-134.83
Received Moisture Content (%)	8.3
Received Wet Density (t/m^3)	2.22
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	45.0
Length (mm)	36.6

PERMEABILITY

$K_{20} = 3 \times 10^{-11}$ m/s

Notes/Remarks: -

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070004-CHP Vertical
Project	Permeability Testing	**Test Date**	11/08-18/08/2011
		Report Date	13/09/2011

Sample No.	11070004
Client ID	1521D_GT_010
Depth (m)	134.56-134.83
Received Moisture Content (%)	8.3
Received Wet Density (t/m^3)	2.22
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.6
Length (mm)	69.0

PERMEABILITY

K_{20} = 1 X 10^{-10} m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070005-CHP Horizontal
Project	Permeability Testing	**Test Date**	22/08-29/08/2011
		Report Date	13/09/2011

Sample No.	11070005
Client ID	1523D_GT_001
Depth (m)	68.78-69.00
Received Moisture Content (%)	15.5
Received Wet Density (t/m^3)	2.42
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	52.0
Length (mm)	34.0

PERMEABILITY

$K_{20} = 9 \times 10^{-11}$ m/s

Notes/Remarks: -

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070005-CHP Vertical
Project	Permeability Testing	**Test Date**	22/08-29/08/2011
		Report Date	13/09/2011

Sample No.	11070005
Client ID	1523D_GT_001
Depth (m)	68.78-69.00
Received Moisture Content (%)	15.5
Received Wet Density (t/m^3)	2.42
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.3
Length (mm)	67.5

PERMEABILITY

$K_{20} = 2 \times 10^{-10}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070006-CHP Horizontal
Project	Permeability Testing	**Test Date**	07/09-12/09/2011
		Report Date	13/09/2011

Sample No.	11070006
Client ID	1523D_GT_005
Depth (m)	101.42-101.68
Received Moisture Content (%)	8.4
Received Wet Density (t/m^3)	2.35
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	49.0
Length (mm)	39.8

PERMEABILITY

$K_{20} = 3 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070006-CHP Vertical
Project	Permeability Testing	**Test Date**	30/08-01/09/2011
		Report Date	13/09/2011

Sample No.	11070006
Client ID	1523D_GT_005
Depth (m)	101.42-101.68
Received Moisture Content (%)	8.4
Received Wet Density (t/m^3)	2.35
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	58.4
Length (mm)	59.7

PERMEABILITY

$K_{20} = 2 \times 10^{-7}$ m/s

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070007-CHP Horizontal
Project	Permeability Testing	**Test Date**	26/09-30/09/2011
		Report Date	7/10/2011

Sample No.	11070007
Client ID	1523D_GT_006
Depth (m)	114.00-114.20
Received Moisture Content (%)	9.0
Received Wet Density (t/m^3)	2.30
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	50.2
Length (mm)	48.7

PERMEABILITY

$K_{20} = 2 \times 10^{-10}$ m/s

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070007-CHP
			Vertical
Project	Permeability Testing	**Test Date**	26/09-30/09/2011
		Report Date	7/10/2011

Sample No.	11070007
Client ID	1523D_GT_006
Depth (m)	114.00-114.20
Received Moisture Content (%)	9.0
Received Wet Density (t/m^3)	2.30
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.6
Length (mm)	72.6

PERMEABILITY

K_{20} = 1 X 10^{-10} m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070008-CHP Horizontal
Project	Permeability Testing	**Test Date**	12/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070008
Client ID	1523D_GT_007
Depth (m)	118.27-118.57
Received Moisture Content (%)	0.8
Received Wet Density (t/m^3)	2.26
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	49.9
Length (mm)	35.6

PERMEABILITY

$K_{20} = 1 \times 10^{-10}$ m/s

Notes/Remarks: -

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070008-CHP Vertical
Project	Permeability Testing	**Test Date**	06/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070008
Client ID	1523D_GT_007
Depth (m)	118.27-118.57
Received Moisture Content (%)	0.8
Received Wet Density (t/m^3)	2.26
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.6
Length (mm)	58.6

PERMEABILITY

$K_{20} = 9 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070009-CHP Horizontal
Project	Permeability Testing	**Test Date**	24/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070009
Client ID	1524D_GT_001
Depth (m)	48.00-48.30
Received Moisture Content (%)	21.4
Received Wet Density (t/m^3)	1.97
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	47.1
Length (mm)	36.6

PERMEABILITY

$K_{20} = 4 \times 10^{-11}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070009-CHP
			Vertical
Project	Permeability Testing	**Test Date**	17/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070009
Client ID	1524D_GT_001
Depth (m)	48.00-48.30
Received Moisture Content (%)	21.4
Received Wet Density (t/m^3)	1.97
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	61.2
Length (mm)	79.6

PERMEABILITY

$K_{20} = 3 \times 10^{-10}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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Authorised Signatory
James Russell
J. Russell

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070010-CHP Horizontal
Project	Permeability Testing	**Test Date**	1/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070010
Client ID	1524D_GT_003
Depth (m)	56.35-56.59
Received Moisture Content (%)	20.5
Received Wet Density (t/m^3)	1.95
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	46.9
Length (mm)	37.7

PERMEABILITY

$K_{20} = 1 \times 10^{-9}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070010-CHP Vertical
Project	Permeability Testing	**Test Date**	27/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070010
Client ID	1524D_GT_003
Depth (m)	56.35-56.59
Received Moisture Content (%)	20.5
Received Wet Density (t/m^3)	1.95
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.2
Length (mm)	78.2

PERMEABILITY

$K_{20} = 2 \times 10^{-10}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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[redacted] / NOT TESTABLE SHEET

Client:	CRS Australia Pty Ltd		Job No.	permeability testing	Date:	21/10/11
Sample No.	Client ID BH	Depth (m)	Explanation			By:
1107001	1524D-GT_008	121.81-122.03	Sample broke upon cutting Horizontal permeability was only able to test for vertical perm.			MS.
1107001R	1524D-GT_001	140.92-141.08	Sample broke along shear lines- was unable to test for vertical or horizontal perm.			MS

General Comments:

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070011-CHP Vertical
Project	Permeability Testing	**Test Date**	27/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070011
Client ID	1524D_GT_008
Depth (m)	121.81-122.03
Received Moisture Content (%)	24.9
Received Wet Density (t/m^3)	2.04
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.6
Length (mm)	62.2

PERMEABILITY

$K_{20} = 2 \times 10^{-8}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070013-CHP Horizontal
Project	Permeability Testing	**Test Date**	27/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070013
Client ID	1524D_GT_014
Depth (m)	148.62-148.94
Received Moisture Content (%)	6.6
Received Wet Density (t/m^3)	2.33
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	48.6
Length (mm)	42.6

PERMEABILITY

$K_{20} = 6 \times 10^{-10}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070013-CHP Vertical
Project	Permeability Testing	**Test Date**	01/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070013
Client ID	1524D_GT_014
Depth (m)	148.62-148.94
Received Moisture Content (%)	6.6
Received Wet Density (t/m^3)	2.33
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.9
Length (mm)	64.2

PERMEABILITY

$K_{20} = 2 \times 10^{-10}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070014-CHP Horizontal
Project	Permeability Testing	**Test Date**	07/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070014
Client ID	1526D_GT_001
Depth (m)	45.67-45.86
Received Moisture Content (%)	12.4
Received Wet Density (t/m^3)	2.14
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	43.3
Length (mm)	44.0

PERMEABILITY

$K_{20} = 2 \times 10^{-8}$ m/s

Notes/Remarks: -

Sample/s supplied by client Tested as received

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070014-CHP
			Vertical
Project	Permeability Testing	**Test Date**	09/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070014
Client ID	1526D_GT_001
Depth (m)	45.67-45.86
Received Moisture Content (%)	12.4
Received Wet Density (t/m^3)	2.14
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.5
Length (mm)	66.8

PERMEABILITY

$K_{20} = 7 \times 10^{-9}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070015-CHP Horizontal
Project	Permeability Testing	**Test Date**	06/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070015
Client ID	1526D_GT_002
Depth (m)	72.78-73.04
Received Moisture Content (%)	8.7
Received Wet Density (t/m^3)	2.32
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	43.0
Length (mm)	44.0

PERMEABILITY

$K_{20} = 2 \times 10^{-10}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070015-CHP Vertical
Project	Permeability Testing	**Test Date**	06/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070015
Client ID	1526D_GT_002
Depth (m)	72.78-73.04
Received Moisture Content (%)	8.7
Received Wet Density (t/m^3)	2.32
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.7
Length (mm)	68.4

PERMEABILITY

$K_{20} = 4 \times 10^{-10}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070016-CHP Horizontal
Project	Permeability Testing	**Test Date**	12/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070016
Client ID	1526D_GT_003
Depth (m)	132.30-132.48
Received Moisture Content (%)	5.3
Received Wet Density (t/m^3)	2.40
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	50.1
Length (mm)	42.2

PERMEABILITY

$K_{20} = 1 \times 10^{-10}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070016-CHP Vertical
Project	Permeability Testing	**Test Date**	10/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070016
Client ID	1526D_GT_003
Depth (m)	132.30-132.48
Received Moisture Content (%)	5.3
Received Wet Density (t/m^3)	2.40
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.7
Length (mm)	64.9

PERMEABILITY

$K_{20} = 4 \times 10^{-10}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070017-CHP Horizontal
Project	Permeability Testing	**Test Date**	28/10-1/11/2011
		Report Date	11/11/2011

Sample No.	11070017
Client ID	1526D_GT_004
Depth (m)	146.69-146.90
Received Moisture Content (%)	6.2
Received Wet Density (t/m^3)	2.37
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	50.1
Length (mm)	35.8

PERMEABILITY

$K_{20} = 4 \times 10^{-11}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070017-CHP
			Vertical
Project	Permeability Testing	**Test Date**	10/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070017
Client ID	1526D_GT_004
Depth (m)	146.69-146.90
Received Moisture Content (%)	6.2
Received Wet Density (t/m^3)	2.37
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.8
Length (mm)	72.3

PERMEABILITY

$K_{20} = 4 \times 10^{-11}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070018-CHP
			Horizontal
Project	Permeability Testing	**Test Date**	31/10-2/11/2011
		Report Date	11/11/2011

Sample No.	11070018
Client ID	1526D_GT_010
Depth (m)	163.84-164.04
Received Moisture Content (%)	12.0
Received Wet Density (t/m^3)	2.10
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	49.3
Length (mm)	40.7

PERMEABILITY

$K_{20} = 4 \times 10^{-7}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070018-CHP Vertical
Project	Permeability Testing	**Test Date**	17/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070018
Client ID	1526D_GT_010
Depth (m)	163.84-164.04
Received Moisture Content (%)	12.0
Received Wet Density (t/m^3)	2.10
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.0
Length (mm)	61.7

PERMEABILITY

$K_{20} = 2 \times 10^{-7}$ m/s

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070019-CHP Horizontal
Project	Permeability Testing	**Test Date**	31/10-11/11/2011
		Report Date	11/11/2011

Sample No.	11070019
Client ID	1526D_GT_013
Depth (m)	176.17-176.49
Received Moisture Content (%)	10.0
Received Wet Density (t/m^3)	2.16
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	46.6
Length (mm)	36.6

PERMEABILITY

$K_{20} = 9 \times 10^{-8}$ m/s

Notes/Remarks: -

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070019-CHP Vertical
Project	Permeability Testing	**Test Date**	17/10-20/10/2011
		Report Date	21/10/2011

Sample No.	11070019
Client ID	1526D_GT_013
Depth (m)	176.17-176.49
Received Moisture Content (%)	10.0
Received Wet Density (t/m^3)	2.16
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.5
Length (mm)	70.7

PERMEABILITY

$K_{20} = 1 \times 10^{-7}$ m/s

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~~MISSING~~ / NOT TESTABLE SHEET

Client:	CIRS AUSTRALIA pty LTD		Job No.	permeability testing	Date:	31/10/11
Sample No.	Client ID BH	Depth (m)	Explanation			By:
1107002a	15290-GT-001	~~75.200~~ - 75.17	sample broke upon cutting for horizontal permeability- was only able to test for vertical perm.			MS
1107004	15290-GT-003	80.22-80.32				MS

General Comments:

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070020-CHP Vertical
Project	Permeability Testing	**Test Date**	25/10-11/11/2011
		Report Date	11/11/2011

Sample No.	11070020
Client ID	1529D_GT_001
Depth (m)	75.00-75.17
Received Moisture Content (%)	10.2
Received Wet Density (t/m^3)	2.02
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.5
Length (mm)	62.0

PERMEABILITY

$K_{20} = 4 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070021-CHP
			Vertical
Project	Permeability Testing	**Test Date**	1/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070021
Client ID	1529D_GT_003
Depth (m)	80.22-80.52
Received Moisture Content (%)	12.1
Received Wet Density (t/m^3)	2.20
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.1
Length (mm)	60.6

PERMEABILITY

$K_{20} = 5 \times 10^{-10}$ m/s

Notes/Remarks: -

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070022-CHP Horizontal
Project	Permeability Testing	**Test Date**	4/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070022
Client ID	1529D_GT_005
Depth (m)	99.98-100.27
Received Moisture Content (%)	8.0
Received Wet Density (t/m^3)	2.33
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	47.7
Length (mm)	44.6

PERMEABILITY

$K_{20} = 5 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070022-CHP
			Vertical
Project	Permeability Testing	**Test Date**	28/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070022
Client ID	1529D_GT_005
Depth (m)	99.98-100.27
Received Moisture Content (%)	8.0
Received Wet Density (t/m^3)	2.33
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.7
Length (mm)	59.2

PERMEABILITY

$K_{20} = 9 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070023-CHP Horizontal
Project	Permeability Testing	**Test Date**	01/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070023
Client ID	1529D_GT_008
Depth (m)	167.59-167.80
Received Moisture Content (%)	8.1
Received Wet Density (t/m^3)	2.37
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	46.3
Length (mm)	42.8

PERMEABILITY

$K_{20} = 9 \times 10^{-9}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070023-CHP Vertical
Project	Permeability Testing	**Test Date**	1/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070023
Client ID	1529D_GT_008
Depth (m)	167.59-167.80
Received Moisture Content (%)	8.1
Received Wet Density (t/m^3)	2.37
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.9
Length (mm)	59.9

PERMEABILITY

$K_{20} = 1 \times 10^{-8}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070024-CHP
			Horizontal
Project	Permeability Testing	**Test Date**	31/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070024
Client ID	1529D_GT_012
Depth (m)	180.00-181.98
Received Moisture Content (%)	5.3
Received Wet Density (t/m^3)	2.35
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	48.6
Length (mm)	38.1

PERMEABILITY

$K_{20} = 2 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070024-CHP
			Vertical
Project	Permeability Testing	**Test Date**	28/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070024
Client ID	1529D_GT_012
Depth (m)	180.00-181.98
Received Moisture Content (%)	5.3
Received Wet Density (t/m^3)	2.35
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.9
Length (mm)	60.1

PERMEABILITY

$K_{20} = 4 \times 10^{-10}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070025-CHP Horizontal
Project	Permeability Testing	**Test Date**	4/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070025
Client ID	1529D_GT_013
Depth (m)	187.86-188.10
Received Moisture Content (%)	8.0
Received Wet Density (t/m^3)	2.40
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	46.5
Length (mm)	39.7

PERMEABILITY

$K_{20} = 4 \times 10^{-11}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070025-CHP Vertical
Project	Permeability Testing	**Test Date**	3/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070025
Client ID	1529D_GT_013
Depth (m)	187.86-188.10
Received Moisture Content (%)	8.0
Received Wet Density (t/m^3)	2.40
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.9
Length (mm)	60.1

PERMEABILITY

$K_{20} = 1 \times 10^{-10}$ m/s

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PERMEABILITY BY CONSTANT HEAD TEST REPORT

Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070026-CHP Horizontal
Project	Permeability Testing	**Test Date**	2/11-10/11/2011
		Report Date	11/11/2011

Sample No.	11070026
Client ID	1529D_GT_015
Depth (m)	191.24-191.44
Received Moisture Content (%)	10.2
Received Wet Density (t/m^3)	2.16
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	48.0
Length (mm)	36.8

PERMEABILITY

$K_{20} = 7 \times 10^{-8}$ m/s

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Test Method AS 1289 6.7.3, 5.1.1 / KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	URS Australia Pty Ltd	**Report No.**	11070026-CHP Vertical
Project	Permeability Testing	**Test Date**	28/10-10/11/2011
		Report Date	11/11/2011

Sample No.	11070026
Client ID	1529D_GT_015
Depth (m)	191.24-191.44
Received Moisture Content (%)	9.1
Received Wet Density (t/m^3)	2.16
Water Used	Distilled
Pressure Applied (kPa)	50
Specimen Dimensions	
Diameter (mm)	60.3
Length (mm)	61.4

PERMEABILITY

$K_{20} = 4 \times 10^{-8}$ m/s

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

C

Appendix C Alpha Test Pit Summary

HANCOCK PROSPECTING PTY LTD

ALPHA COAL PROJECT

SUMMARY OF PUMPING DATA FROM THE ALPHA TEST PIT

August 2011

JBT01-005-031(D1)

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery

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1.0 INTRODUCTION

Hancock Prospecting Pty Ltd (HPPL) developed the Alpha Test Pit (ATP) project for the purpose of obtaining a bulk sample of coal for product testing. The ATP was to produce 150,000 tonnes of Run of Mine (ROM) coal, and 100,000 tonnes of product coal. The dimensions of the completed test pit from crest level are approximately 300 m long (north-south direction), 250 m wide (east-west direction) and 66 m deep (from surface RL of 308 mAHD to final floor RL of 242 mAHD).

The dimensions and general layout of the ATP are shown in Figure 1.

Overburden removal and development of site infrastructure commenced in November 2010 however initial progress was delayed by significant rainfall and surface water flow encountered during the 2010/2011 wet season. The majority of test pit development occurred during the period May to July 2011, with all equipment removed from the pit on 13 July 2011.

Dewatering of the ATP occurred via 12 perimeter pumping bores, with pit inflows controlled via an in-pit sump pump.

This report presents:

- A description of the ATP dewatering system design and infrastructure;
- A summary of pumping from both pit dewatering bores and in-pit sump pumps;
- Observations relating to groundwater levels adjacent to, and at distance from, the ATP;
- Calculation of hydraulic parameters, based on analytical modelling of the ATP pumping and water level drawdown data; and,
- Conclusions and recommendations.

It should be noted that data is still being collected and analysed from the development of the ATP. The results presented and conclusions drawn in this report should therefore be regarded as preliminary, and will be subject to review and amendment in light of additional data and further interpretation.

2.0 SUMMARY OF PIT DEWATERING

2.1 Requirement for Pit Dewatering

The following section presents a background of ground conditions in the ATP area, as well as a summary of reasoning behind the adoption of the pit dewatering strategy for the ATP.

- A representative view of the stratigraphy and lithology encountered at the ATP is shown in the bore log of adjacent groundwater monitoring bore AVP-07 (Figure 2);
- As a general observation from drilling of exploration bores in the area of the ATP, it has been observed that:
    - the upper part of the holes, where surficial deposits and lateritic claystones are encountered, tend to drill dry;
    - minor groundwater is encountered in the interval representing the C coal seam, C-D sandstone, and D coal seam;
    - The D coal seam acts as a confining layer to the underlying D-E sandstone, so that when the coal seam is breached by drilling water enters the hole and rises to a level above the coal seam; and,
    - The water make from the D-E sandstone is variable, but in general the majority of water entering a bore will derive from the D-E sandstone.

- Seepage modelling undertaken for the ATP site[1] concluded that depressurisation of the D-E sandstone below the floor of the pit would be required for pit wall stability and prevention of floor heave;
- Initial water levels as measured in bores AVP-07 and AVP-08, which both had piezometers in the D-E and C-D sandstone, were approximately RL299 prior to pumping (i.e., approximately 9 m below natural surface of RL308);
- A key question from the perspective of slope stability design was whether the observed groundwater levels at site (approximately RL299) represented a phreatic surface[2] (i.e. high initial water table) or a potentiometric surface[3] . If RL299 represented a phreatic surface, the implications of excavating the ATP without active depressurisation (i.e. pumping) would be significant, as the initial slope stability designs assumed a substantially drained pit slope;
- The construction of existing monitoring bores did not allow for observation of groundwater pore pressures in the upper part of the ATP profile (claystone/ laterite). To enable the above questions to be answered two additional bores were drilled adjacent to AVP-08; one to 20 m depth and the other to 40 m depth. The bores were constructed as open standpipes, and vibrating wire piezometers were lowered into the bores and connected to the datalogger at AVP-08 to enable regular monitoring and remote downloading of groundwater levels in these bores;
- During excavation of the test pit it was noted that the upper strata were dry, but that the clay horizon at approximately 10 m depth were damp to the touch. In addition, initial monitoring results from the 40 m standpipe (constructed within the lower part of the claystone) indicated an initial groundwater level of approximately RL299; and
- Based on observations from monitoring bores and pit excavation, and as a conservative assumption, it was assumed that RL299 represented a phreatic surface, and that active mine dewatering via perimeter production bores was required to maintain geotechnical stability.

Groundwater pumping infrastructure requirements were based on analytical modelling using parameters obtained from aquifer pumping tests undertaken within the Alpha Coal Project lease. Aquifer parameters are discussed further in Section 3.3. The number of perimeter dewatering bores was based on observed hydraulic parameters, but also had to take into account the relatively short time frame available to achieve dewatering targets.

The dewatering strategy can be summarised as:

- Construct perimeter pumping bores that are screened over the entire water bearing interval (claystone, C coal seam, C-D sandstone, D coal seam, and D-E sandstone) to allow dewatering of the pit walls and depressurisation of the D-E sandstone below the floor of the pit.
- Size bore pumps to allow groundwater levels in the pumping bores to be lowered to below pit floor level, and to be held at that level. This would depressurise the floor of the pit and encourage free drainage of pore pressures within the pit walls; and,
- Control drainage to the pit by directing flow to sumps in the pit floor and removing collected water via sump pumps.

The following section describes the infrastructure for undertaking pit dewatering.

[1] JBT01-005-011 - Seepage Modelling, Bulk Sample Pit. Report to Hancock Coal Pty Ltd December 2009

[2] Phreatic Surface – a level below which the ground is continually saturated

[3] Potentiometric Surface – when a bore taps a confined aquifer the water level will rise in the bore to a level that represents the potentiometric surface. The strata overlying the confined aquifer may, however, be completely dry.

2.2 Description of Dewatering Infrastructure

- Twelve (12) pit dewatering bores were constructed adjacent to the test pit, with three (3) bores located on each of the northern, southern, eastern, and western walls (refer Figure 1). The bores were screened from base of claystone (refer Figure 2) to base of D-E sandstone, and were therefore designed to depressurise below the floor of the pit as well as dewatering the pit walls.
- Seepage to the pit was controlled via drainage to sumps, and removal of pit water via a sump pump.
- Water from both sources (out-of-pit and in-pit pumping) was pumped to a water control dam located to the north of the pit. The dam was sized for storage of anticipated groundwater pumping volumes as well as diversion and pit pumping requirements for wet season rainfall.
- Monitoring of dewatering performance was undertaken in monitoring bores AVP-08, as well as water level measurements in perimeter pumping bores and other observation wells.

2.3 Summary of Pumping

2.3.1 Perimeter Dewatering Bores

- Pumping commenced from bore TP-11 on 21 April 2011. The remaining eleven (11) bores were commissioned between 3 June and 16 June (refer pumping history, Appendix A). With all bores operational the groundwater level in the majority of pumping bores quickly fell below the base of the pit floor, and the bores were throttled back to allow pumping to be maintained at the existing water level below the pit floor.
- Individual bore yields ranged from < 1 to ~ 2 L/s.
- The total average pumping rate with all bores operating was approximately 8 L/s, and approximately 38.8 ML was removed via bore pumps during the course of the ATP program (21 April to 20 July 2011). The daily and cumulative pumping rates from perimeter bores is shown in Figure 3.
- The mine achieved full development level (RL 242) on 1 July 2011, and mining of the D coal seam was completed on 12 July 2011.
- Pumping of perimeter dewatering bores continued until 20 July 2011 to allow additional data to be collected, at which point the pumps were switched off and groundwater level and pit lake water level recovery was monitored.

2.3.2 In-Pit Dewatering

In-pit dewatering infrastructure was employed to manage groundwater reporting as drainage to the pit and to allow control of surface water inflow during rainfall events. Rainfall during the middle to latter stages of pit development was minor, so in-pit pumping was utilised primarily for control of groundwater inflow.

The following section presents a history of pit inflows and requirements for sump pumping in the ATP, and presents an estimate of inflows to the pit.

- Prior to 1 July 2011, relatively minor rates of inflow were observed in the pit. Where inflow did occur, it tended to occur as discharge through old boreholes. This flow needed to be captured and diverted to sumps for removal via sump pumps;
- Regular pumping of a drainage sump in the south-west corner of the operation (lowest point in the ATP, and also the area where groundwater levels remained relatively high) occurred from

1 July, when the D coal seam was first excavated (removal of D-E sandstone confining layer). Daily sump pumping continued until end of mining on July 13;

- Based on review of the site pumping history and discussions with site personnel, an average pumping rate of 2.5 to 3.5 L/s is assumed as the requirement for controlling pit inflows (and possible return flow from the water containment dam); and
- The majority of groundwater inflow was encountered in the south-west corner of the pit. This was the deepest area of the pit, but also the area where groundwater pressures remained highest in the perimeter pumping bores. This is discussed further in Section 2.4.2.

2.4 Observations Relating to Groundwater Levels

2.4.1 Groundwater Levels Pre–Mining

Groundwater levels pre-mining are available from a number of groundwater monitoring bores as shown in Table 2-1 and Figure 1.

Groundwater levels have been monitored across the Alpha site since December 2009. Groundwater pressures in the C-D and D-E sandstone units have remained steady for the period monitored, which included prolonged periods of high rainfall during the 2009/2010 and 2010/2011 wet seasons.

In the area of the ATP, groundwater levels in the C-D and D-E sandstone units where approximately RL299 mAHD prior to development of the test pit.

2.4.2 Groundwater Levels during Mining

2.4.2.1 Perimeter Pumping Bores

During pumping the water level in the majority of pumping bores was below the base of mine (Figure 4). Notable exceptions were bores TP-02, TP-03, and TP-04, which were all located in the south-west corner of the test pit. TP-02 and TP-03 repeatedly ran dry when pumping, and eventually produced little water relative to the other bores (refer pumping history, Appendix A). Dynamic groundwater levels in TP-04 remained approximately 15-20 m higher than those measured in the other production bores, and the pumping continued from this bore at a rate of approximately 1.8 L/s, when the rate in other bores (throttled) were reduced to approximately 1 L/s or less. Prism monitoring also showed that maximum rates of movement were encountered in the south-west corner of the pit, in the area where groundwater differentials were highest. It is not known whether the higher yield at AVP-04 is related to lithology or structure (eg fault/fracture) but the results do show the variability (heterogeneity) in groundwater conditions at site, even at small scale.

2.4.2.2 Groundwater Monitoring Bores

The response to pumping in dedicated groundwater monitoring bores is shown in Figure 5 (bores AVP-08 and AVP-07), and Figure 6 (AMB-01 and AVP-05). Bore locatons are shown on Figure 1. Maximum measured drawdown within each bore, in response to development of the ATP, is show in Table 2-1. Groundwater response to pumping is summarised as:

- AVP-08 is a vibrating wire piezometer (VWP) bore located adjacent to the pit ramp, some 130 m from the closest pumping bore. The hydrographs show the rapid development of two phreatic surfaces –one associated with the C-D and D-E sandstones, where pressures had dropped relatively quickly below the base of claystone, and another phreatic surface in the claystone (measured in the 40 m piezometer), where pore pressures were draining at a much slower rate in response to pumping (i.e. induced flow response). The measured groundwater level in the 20 m piezometer remained constant. It is assumed that this represents water remaining in the

base of bore casing, and that the surrounding strata is actually dry (i.e within the thick unsaturated cover logged across the site). Observed drawdown is shown in Figure 5 and Table 2-1;

- AVP-07 is a VWP bore located 200 m west of the ATP and monitors pressures in the C-D and D-E sandstone. Water levels showed a similar (but slightly more subdued) response to those observed in AVP-08. Observed drawdown is shown in Figure 5 and Table 2-1;
- AMP-01 is a standpipe monitoring bore located 270 m south of the ATP, and screened within the D-E sandstone. Observed drawdown is shown in Figure 6 and Table 2-1;
- AVP-05 is a VWP bore located approximately 2.7 km NNW of the ATP, which monitors groundwater pressures in the D-E and C-D sandstone, and C upper coal seam. This monitoring point does not have a datalogger installed so readings are taken manually. If it is assumed that groundwater levels have remained relatively constant at this location since December 2009 (as has been the case in other bores on site that continuously monitor C-D and D-E sandstone water pressures) then the drawdown observed in the bore can be assumed to be in response to development of the ATP. Observed drawdown is shown in Figure 6 and Table 2-1.

Table 2-1: Summary of Groundwater Monitoring Bores Referred to in Report

Bore	Intervals Monitored	Distance from ATP (m)	Maximum Observed Decline in Head (m)
AVP-07	C-D Sandstone (within mined interval)	200	33.6
	D-E Sandstone (below mined interval)		28.4
AVP-08	20 mbgl (lateritic claystone)	130	-
	40 mbgl (lateritic claystone)		10.05
	C-D Sandstone (within mined interval)		37.71
	D-E Sandstone (below mined interval)		39.93
AMB-01	D-E Sandstone	270	24.20
AVP-05	C upper coal seam	2,700	2.1
	C-D Sandstone		8.4
	D-E Sandstone		7.0

2.4.3 Groundwater Levels Post-Mining

Groundwater levels post-mining (dewatering ceased at ATP) have been measured in perimeter pumping bores (Figure 4) as well as VWP bores AVP-07 and aVP-08 (Figure 5).

In the pit perimeter bores groundwater levels recovery in the majority of bores indicates groundwater rebound between 20 and 33 m since 20 July when pumps were switched off, and the last round of water level readings taken on 3 August 2011. These levels correspond to groundwater levels in the pit wall that are between 19 and 22 m above the floor of the pit. The exception is bore TP-04 where water levels remained relatively high during the operation of the ATP (refer Section 2.4.2.1) and where water levels are now almost 30 m above the floor of the ATP.

As can be seen from Figure 4, groundwater levels initially rebounded relatively quickly but are now relatively stable at the levels described above. Based on the flat water level graphs in existing groundwater monitoring bores over the past two wet seasons (indicating low recharge rates to deep groundwater units such as D-E and C-D sandstone), and initial post-mining water level data as

presented above, the data suggests that mining will locally dewater the groundwater resource, and that there will be little or no recharge to replenish the "mined" groundwater. This has implications for long-term sustainable yields for mine use, and for local groundwater users with bores constructed within the D-E sandstone or stratigraphically higher sediments.

Following removal of in-pit pumping facilities (13 July) and the shut-down of perimeter bore pumps (20 July) marked inflow to the ATP has been observed. Review of pit water levels has been aided by the installation of a webcam on the northern pit wall, which provides regular photographs of pit flooding. A series of photographs has been compiled at approximately 12:00 daily (to minimise shadows on the pit walls). A number of photographs showing pit conditions at end of mining, cessation of in-pit pumping, and cessation of perimeter bore pumping, are included in Appendix B.

2.5 ATP Water Balance

2.5.1 Water Balance Components

The following section presents a brief summary of the ATP water balance components for the operational period of the ATP. Rainfall events during the development of ATP provided direct water into the ATP and thus the rainfall components of the water balance can be ignored. Therefore, the water balance components during the operational phase of the test pit include:

- Total water pumped from pit perimeter bores was measured at 38.82 ML (refer pumping summary, Appendix A);
- Total pit water pumped from in-pit pumping was estimated as:
  - 1 L/s from 23 June when ponding water was first encountered in the test pit; and,
  - 2.5 L/s from 1 July when the D coal seam was first excavated to July 13 when mining was completed.
  - This represents an estimated total volume of in-pit dewatering of approximately 3.6 ML.
- Total water lost to evaporation from the period when the coal seams were exposed (say from 15 June to 13 July is estimated at 1.1 L/s. This is based on the following assumptions:
  - Daily evaporation rate (June, based on SILO data) = 3.3 mm/day = 0.0033 m/day
  - Area of the pit floor below claystone (refer Figure 1) is 14,400 m^2 (this includes the lower ramps)
  - Length of pit wall (N-S direction) is 190 m
  - Length of pit wall (E-W direction) is 100 m
  - Height of face over which evaporation is applied (from base of claystone to pit floor) is taken to be 25 m.

  On this basis:
  - Daily evaporation from pit floor = 14,400 m^2 x 0.0033 m = 47 m^3/day
  - Daily evaporation from sides = (190+190+100+100 m) x 25 m x 0.0033 m = 47.8 m^3/day
  - Daily evaporation = 47 + 48 m^3/day = 95 m^3/day
  - Total Evaporative losses (June 15 – July 13 = 30 days) = 95 m^3/day x 30 days = 2,850 m^3 = 2.85 ML (approximately 1.1 L/s)

2.5.2 Water Balance Summary

Total groundwater inflow to the pit over the period of ATP development is summarised below in Table 2-2.

Table 2-2: Summary of Groundwater Inflows and losses to ATP during Operational Phase

Component	Volume (ML)
Groundwater pumping (perimeter bore pumps)	38.82
In-Pit Pumping	3.60
Evaporative Losses	2.85
Total (ML)	**45.27**

3.0 BACK-ANALYSIS OF AQUIFER PARAMETERS USING WINFLOW

3.1 Introduction

The data set obtained from the development of the ATP presents a valuable opportunity for assessment of groundwater pumping (mine dewatering) requirements and potential groundwater impacts, which can be applied to the full-scale mine operation.

An initial assessment of early pumping data has been undertaken using the analytical program Winflow (Version 3.28, Environmental Simulations Inc.). This was undertaken to provide an assessment of hydraulic parameters to be used in the regional groundwater model. The data set obtained from the ATP will also provide a useful set of transient calibration data for the regional groundwater model.

Winflow is Windows-based analytical model that simulates two-dimensional steady-state and transient groundwater flow. The model has a number of advantages over spreadsheet solutions, including:

- The Winflow program is visual, ie the borefield layout can be viewed on the screen, and wells can readily be added, deleted, edited, or dragged to new positions; and,
- When simulating transient operation of a borefield, the model allows wells to be switched on and off and to have different pumping rates at different times during the simulation.

3.2 Model Assumptions

The program uses the same assumptions inherent in the Theis method, which are the same as those used for previous studies that used applied the solution using spreadsheets. The assumptions are:

- The aquifer is of seemingly infinite areal extent;
- The aquifer is confined. When using the Theis solution, the aquifer is always confined, even when the water level falls below the top of the aquifer;
- The wells fully penetrate the aquifer, and groundwater flow is horizontal;
- The aquifer is homogenous and isotropic;
- The base and top of the aquifer are horizontal and fixed at a given elevation; and,
- The volume of water stored in the well is minimal and can be ignored.

3.3 Model Setup

3.3.1 Aquifer Hydraulic Parameters

3.3.1.1 Available Data

Aquifer hydraulic properties are available from a pumping test on bore TPB2, which was constructed approximately 200 m east of the ATP (Figure 1) and tested during an earlier phase of investigation by AGC[4]. The details of test include:

- The bore was screened in D-E sandstone
- The bore was pumped at 3.6 L/s for 24 hours, resulting in 55 m drawdown in the pumping bore. An earlier test at a rate of 10 L/s resulted in the bore being pumped dry.
- Aquifer parameters derived from testing include:
  - Transmissivity of 2.8 to 5.0 m^2/day;
  - Hydraulic conductivity of 0.18 to 0.3 m/day; and,
  - Storage coefficient of 6.6 x 10^{-5}

However, the ATP perimeter pumping bores are also screened over the interval comprising C coal, C-D sandstone and D coal.

A number of pumping tests have also been undertaken at site over the interval described above. These include TPB3 from the AGC phase of testing (located approximately 2.5 km north of the ATP), as well as bore W1 (located approximately 1 km north of the ATP) during a phase of testing undertaken by Longworth & McKenzie[5].

Aquifer parameters derived from testing of these bores are summarised as:

- Bore TPB3:
  - Transmissivity of 5.4 to 6.5 m^2/day;
  - Average hydraulic conductivity of 0.3 m/day; and,
  - Storage coefficient of 1.1 x 10^{-3}.
- Bore W1:
  - Transmissivity of 2.8 to 4.3 m^2/day;
  - Average hydraulic conductivity of 0.14 m/day; and,
  - Average storage coefficient of 4.65 x 10^{-3}.

3.3.1.2 Hydraulic Parameters Applied to Model

The hydraulic properties to be applied to analysis of the ATP site will represent a combination of parameters from the D-E sandstone as well as C coal seam, C-D sandstone and D coal seam.

A range of parameters was tested via trial and error testing, and the final parameter set applied to the Winflow model is summarised as:

- Transmissivity of 8 m^2/day;

[4] AGC (1983) Alpha Coal Project (A to P 245C), Surface Water and Groundwater Aspects – Preliminary Evaluations. Report for Bridge Oil Limited

[5] Longworth & McKenzie (1984) Report on Geotechnical and Groundwater Investigation (1984) Area 2, ATP245C, Alpha Queensland for Bridge Oil Limited. Report Reference UGT0115/KDS/ejw

- Hydraulic conductivity of 0.2 m/day (multiplied over a screened interval in each bore of approximately 40 m, gives a transmissivity of 8 m^2/day); and,
- Storage coefficient of 1.0 x 10^{-3}.

3.3.2 Pumping Data

Pumping data at the ATP from 21 April to 20 July (operational period of perimeter bore pumps) was converted to m^3/day for each of the 12 pumping bores (TP-01 to TP-12) and input to the model as transient pumping data. The data set that was used for modelling is provided in Appendix A.

It should be noted that modelling was undertaken prior to completion of ATP activities, so modelling was undertaken on a data set that only covered the period 21 April to 7 July. However, this period included commencement of pumping to a time approaching steady state water levels and is therefore considered to be an adequate data set to allow model calibration.

3.3.3 Water Level Data

The Winflow model is a single layer model, however the data available in the vicinity of the ATP (AVP-07 and AVP08) contained data for multiple layers (C-D and D-E sandstone) over which perimeter pumping bores were screened.

To enable assessment as a single layer the drawdown responses in the D-E and C-D sandstone piezometers were averaged to provide a single drawdown target. The composite curve for each bore is shown on Figures 7 and 8 as the observed data curve.

3.4 Results

3.4.1 Consideration of Bore Pumping Only

Modelled vs. observed groundwater heads based on the application of bore pumping data are shown in Figure 7.

The modelled parameters provide a good fit to averaged data for AVP-07. For AVP-08 the computed vs. observed curves are reasonable up to approximately day 60 when the modelled drawdown increasingly fails to match the observed water levels. Day 60 represents the period in mine development when mining occurred below the base of claystone, and groundwater inflow was observed in the base of the pit. The additional observed drawdown is therefore taken to represent groundwater losses to pit inflows and evaporation. An attempt was made to quantify the magnitude of this component, as discussed below.

3.4.2 Incorporation of losses to pit seepage and evaporation

In an attempt to quantify losses to evaporation and seepage to the pit, additional pumping was applied to the model (from day 60) in an attempt to better match the observed vs. computed curves in bore AVP-08.

The pumping rate was increased by a total of 2 L/s (0.167 L/s increase for each of 12 pumping bores) from day 60. The results are shown in Figure 8. The fit for the latter part of the observed vs. computed curves are improved for AVP-08, but are made worse for AVP-07.

This may suggest that the additional evaporation / seepage losses to the pit are localised, and occur from unconfined storage immediately adjacent to the pit wall. This could explain why the impacts of localised pit seepage / evaporation are not seen in the confined aquifer response that is observed at AVP-07.

4.0 CONCLUSIONS

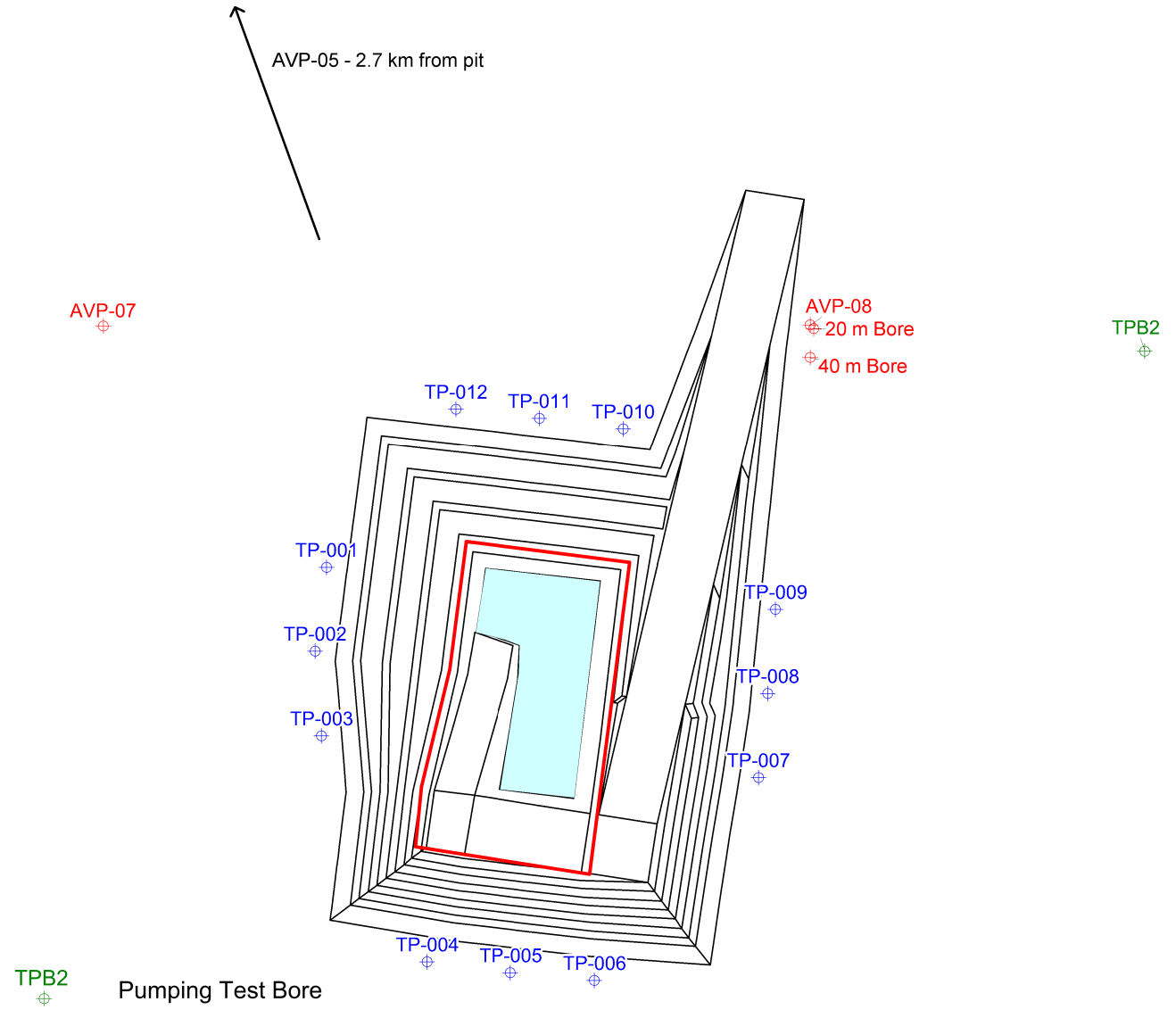
- This report presents a preliminary review of the groundwater conditions encountered during mining of the ATP, and the actual performance of the mine dewatering system compared to initial (design) performance.
- The mine dewatering system (perimeter pumping bores) was designed to intersect the main water-bearing units adjacent to the mine (in the pit walls) and immediately below the mine.
- The relatively good agreement between predicted and observed water levels, using a simple one-layer analytical model, suggests that:
    - The groundwater system in the area where aquifer dewatering / depressurisation takes place can be adequately represented as a single-layer system;
    - The differences between observed and calculated drawdown in the single layer analytical model can be explained by losses to the pit via inflow and evaporation from the modelled layer. This suggests that inflows from above, and from units deeper than the D-E sandstone, were not significant contributors to the ATP water balance.
- The results will be useful as input to the regional-scale numerical groundwater model, both in terms of providing useful aquifer parameters for pit dewatering scenarios, and for providing meaningful calibration targets for a transient model.

5.0 RECOMMENDATIONS

- Use observations and data from the test pit, and initial parameters from the Winflow Model, to assist in refinement and calibration of the regional-scale numerical groundwater model;
- Continue to collate and interpret data from the ATP program, and use for design of the dewatering system for the full-scale project.

Yours Faithfully,

Principal Hydrogeologist
JBT Consulting Pty Ltd



JBT consulting	CLIENT: Hancock Prospecting PL			PROJECT: Alpha Test Pit	
	DRAWN: JWB	DATE: Aug 2011		TITLE: GROUNDWATER BORE LOCATIONS - TEST PIT	
	CHECKED	DATE			
	SCALE: 1:4,000	A4		PROJECT No: JBT01-005-031	FIGURE No: 1

Project: Alpha Coal Project **Bore ID: AVP-07**

Drilled Date: 11/4/2009

Lithological Description	Graphic Log	Depth	Bore Design	Bore Construction/ General Drilling Notes
Silty CLAY medium grey, highly weathered, base Tertiary at 18.5 mbgl		0, 4, 8, 12, 16		
LATERITE mottled creamy red and purple claystone		20, 24, 28		
CLAYSTONE medium creamy grey		32, 36, 40		
Carbonaceous Siltstone		44, 48		
Stony COAL (C Seam), claystone and carbonaceous mudstone - CU Coal Seam		52, 56		
Stony COAL (C Seam), C1, C2, C3 coal seams, interbedded stony coal and claystone		60		
SANDSTONE fine grained, carbonaceous, C-D Sandstone		64		Vibrating Wire Piezometer @ 63.5 m - s/n 8968
Stony COAL (D Seam) - DU and DLM1 Coal Seams				
COAL (D Seam) - DLM2 and DLL Coal Seams, separated by 0.2 m of creamy white claystone		68, 72		
SANDSTONE (D-E Sandstone) fine to medium grained, clayey matrix, carbonaceous partings, D-E Sandstone		76		
Stony COAL (E Seam)		80		Vibrating Wire Piezometer @ 79 m - s/n 11795
MUDSTONE, medium grey with siltstone laminae		84		

JBT consulting

Easting: 445862.01

Northing: 7430684.68

Collar RL (mAHD): 309

Co-ord System: GDA94

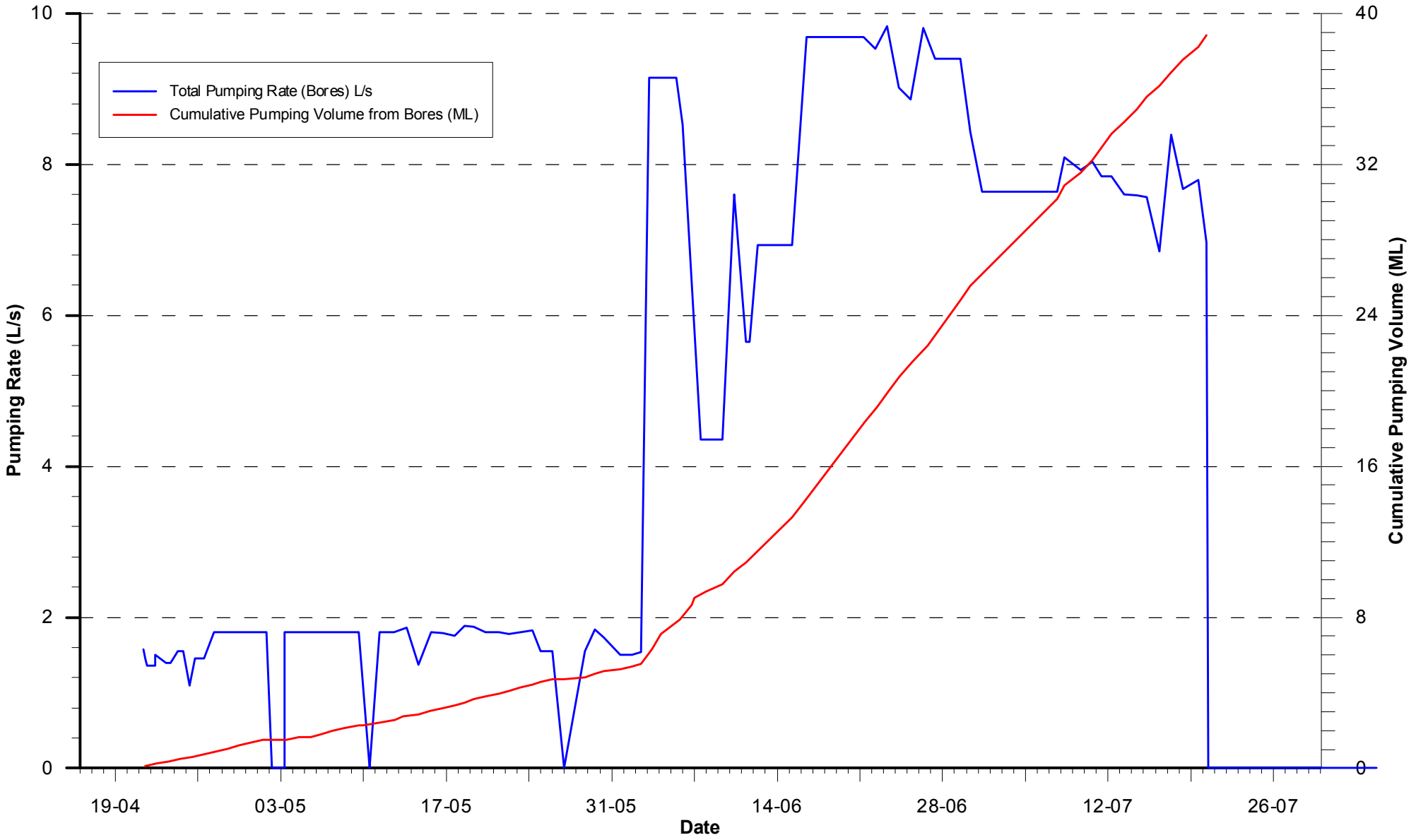
Drilling Company: Mineral Enterprises Aust

Drill Rig: No. 1

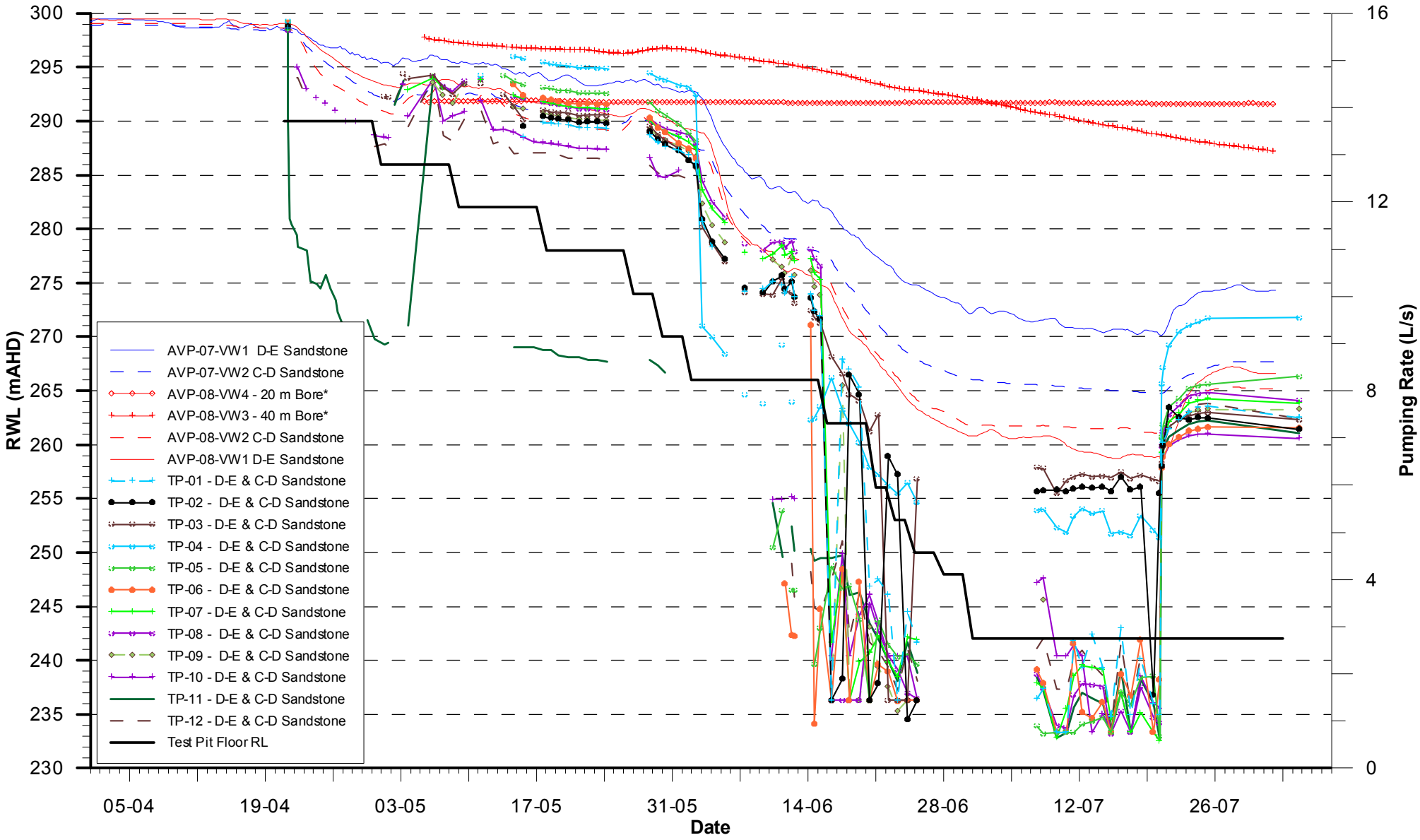
Hole Diameter (mm): 100

Total Depth (m): 81.73

Figure 2



CLIENT: Hancock Coal Pty Limited		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2011	TITLE: **Pumping Rate and Volume Perimeter Pumping Bores**	
CHECKED:	DATE:		
SCALE: As Shown	A4	PROJECT No.: JBT01-005-031	FIGURE No.: 3



* 20 m deep and 40 m deep bores at AVP-08 are standpipe bores constructed with DN125 casing and monitored via vibrating wire piezometers

CLIENT: Hancock Coal Pty Limited		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2011	TITLE: **Reduced Water Level (mAHD) Perimeter Pumping Bores**	
CHECKED	DATE		
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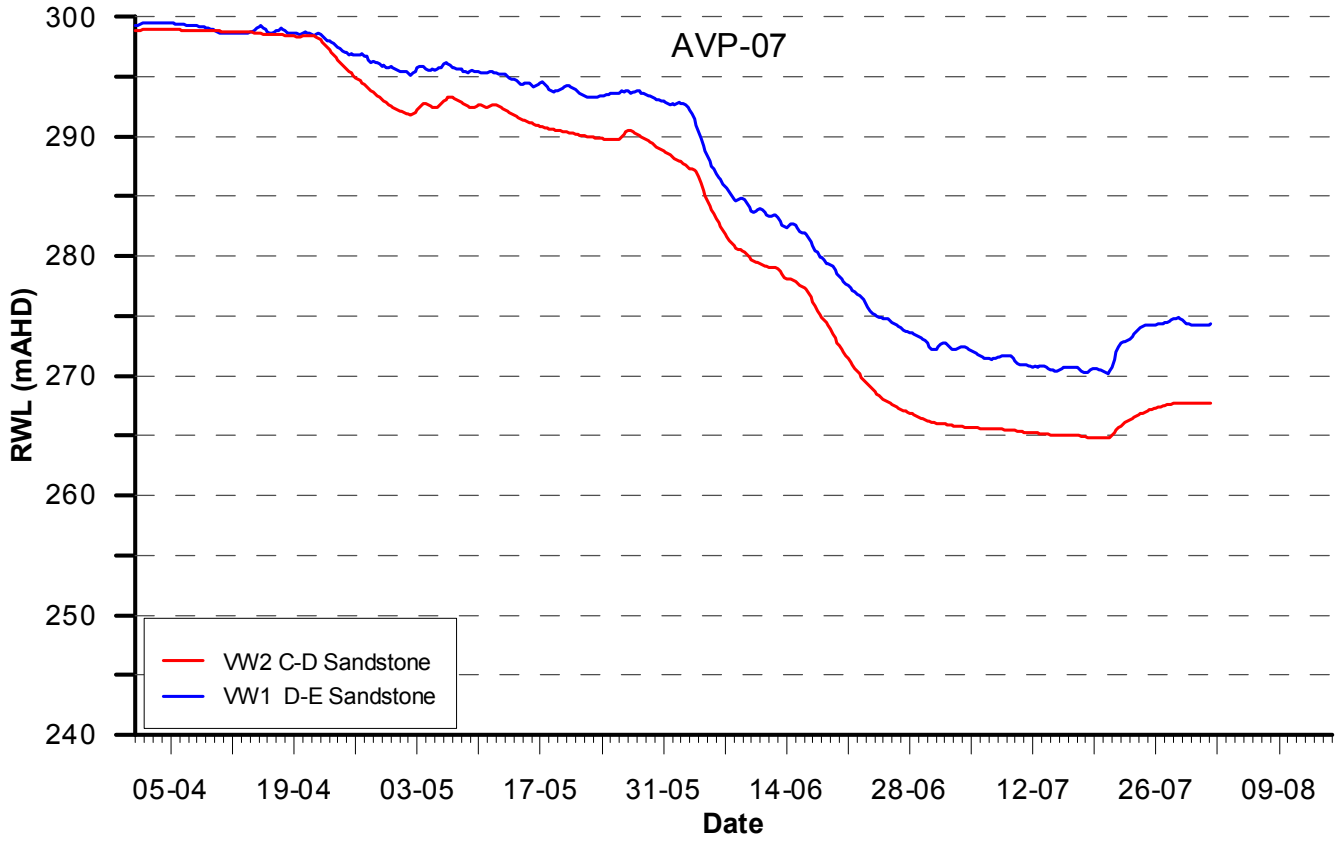

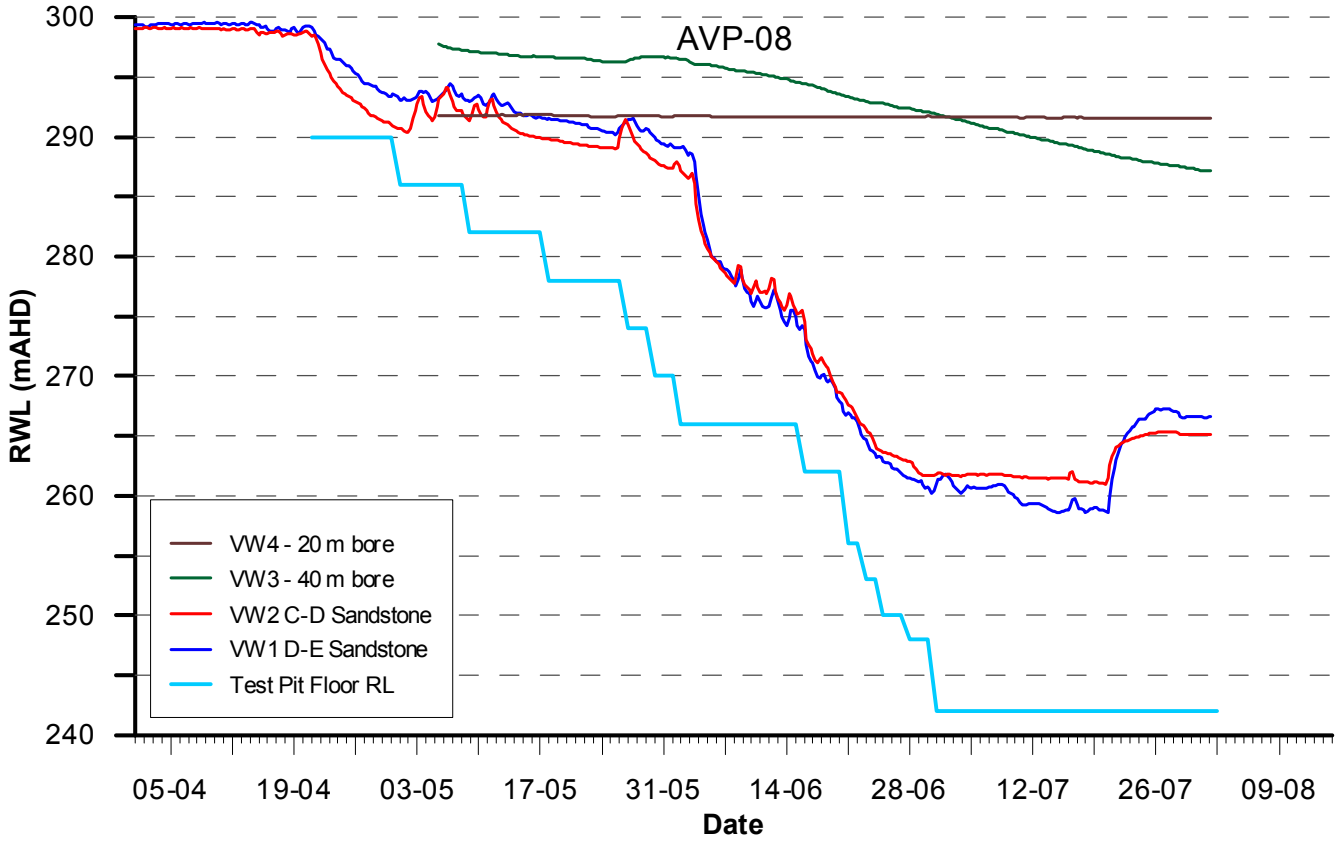

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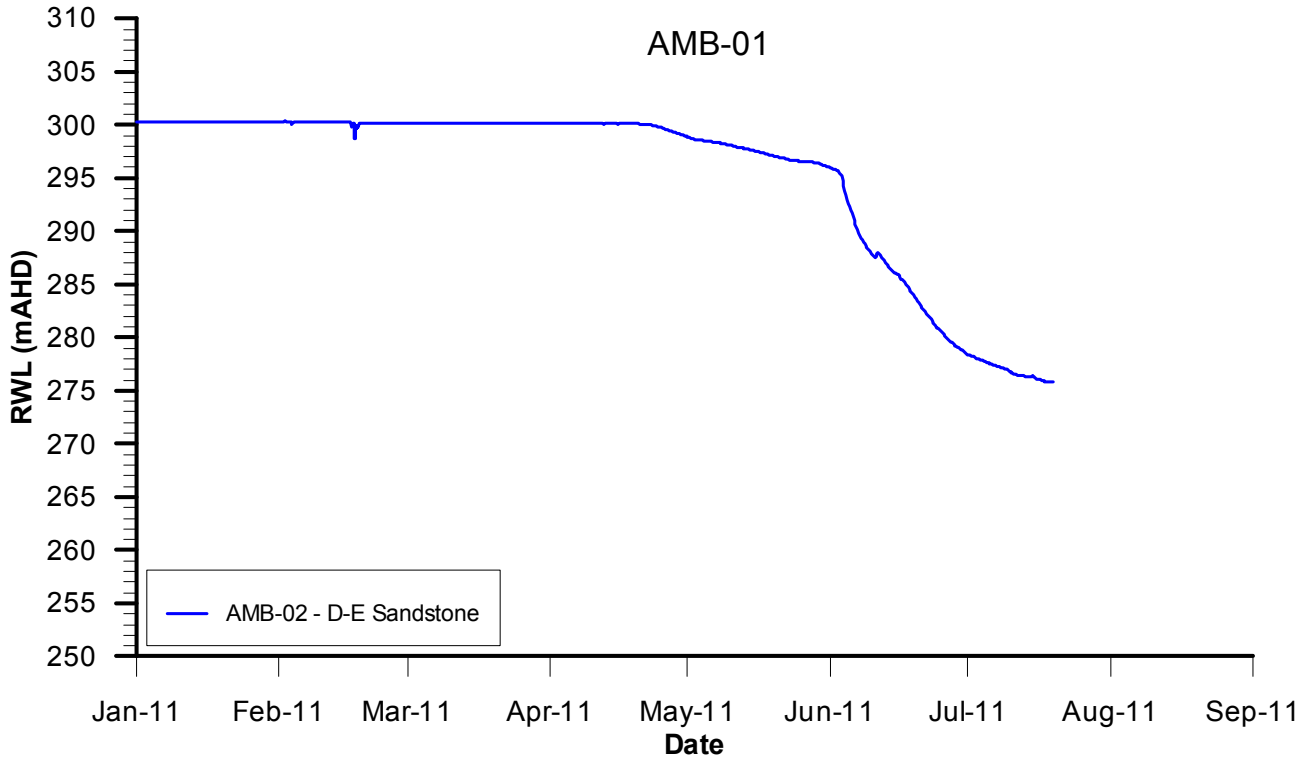

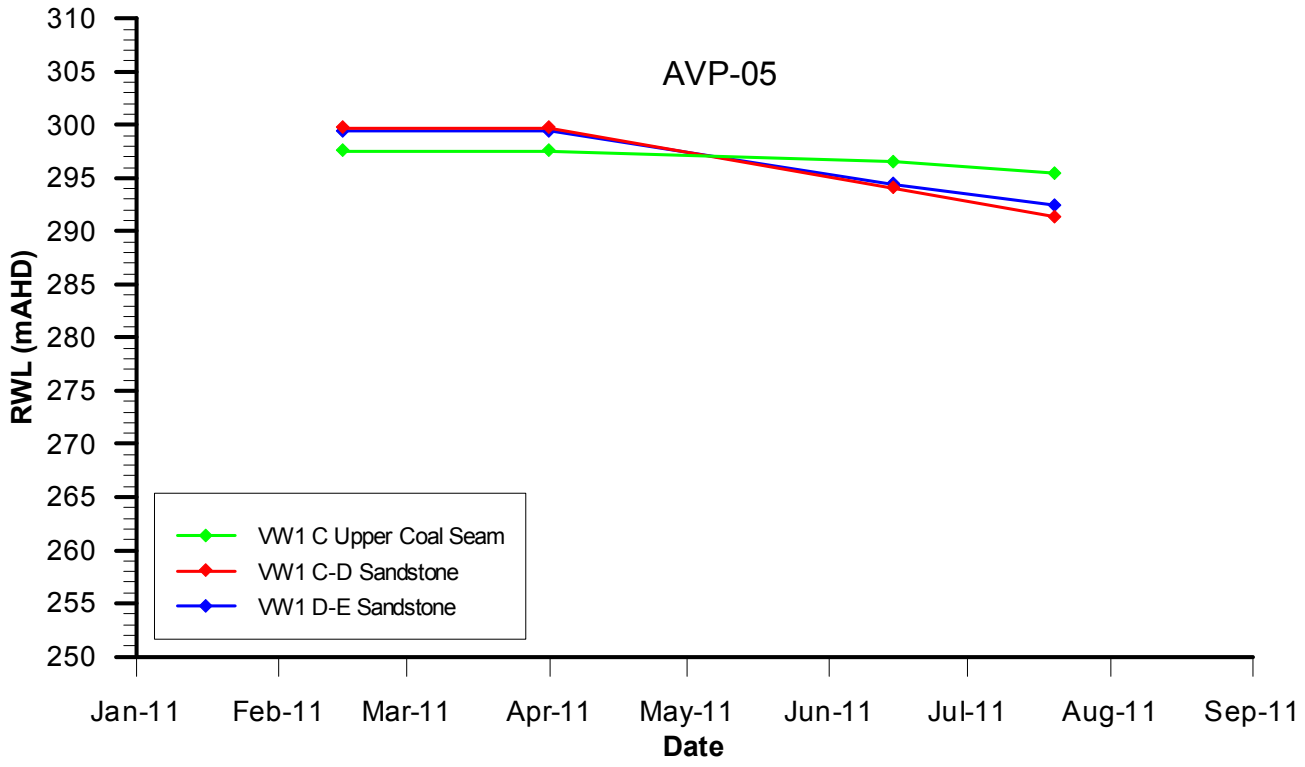

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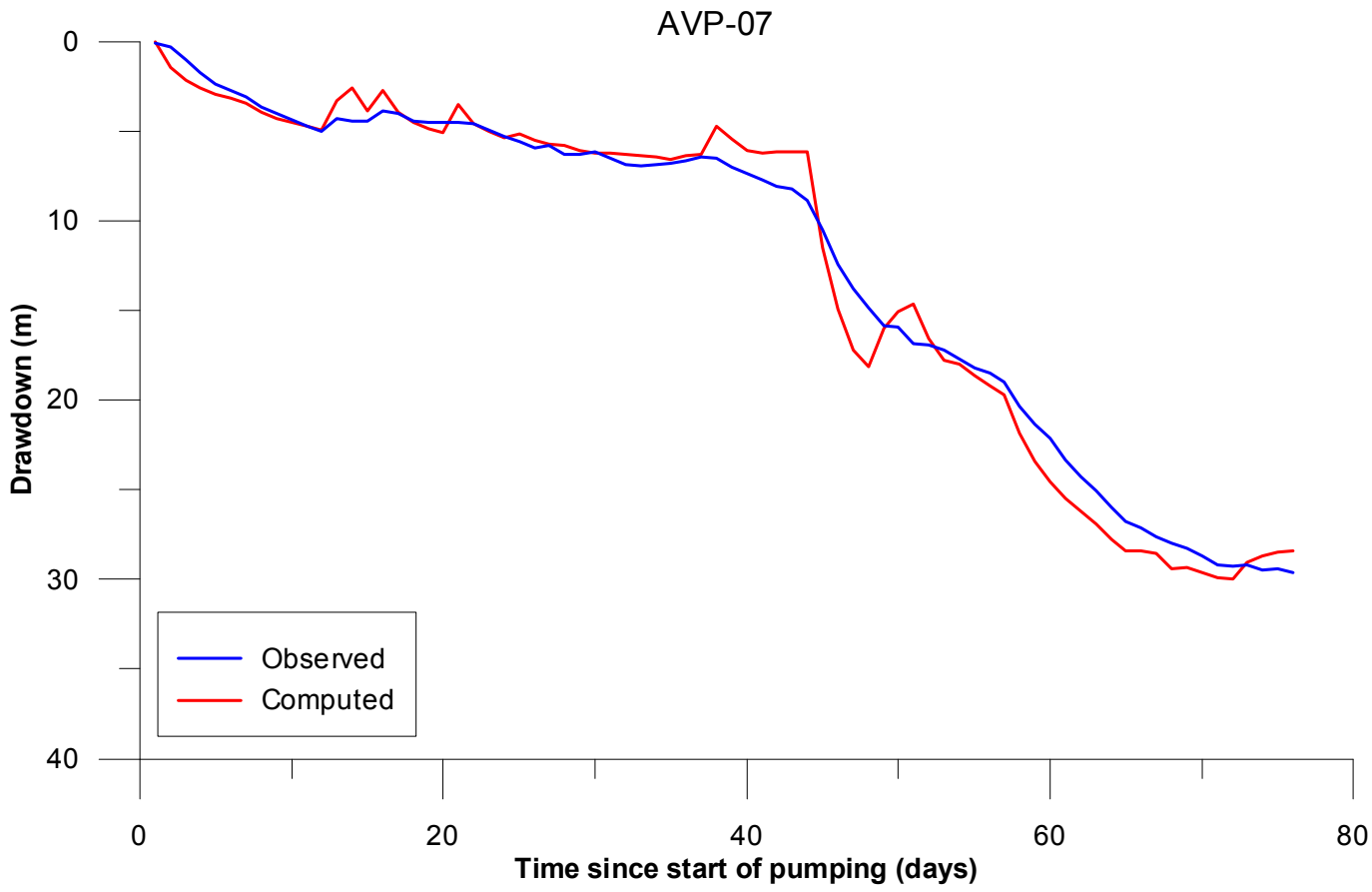

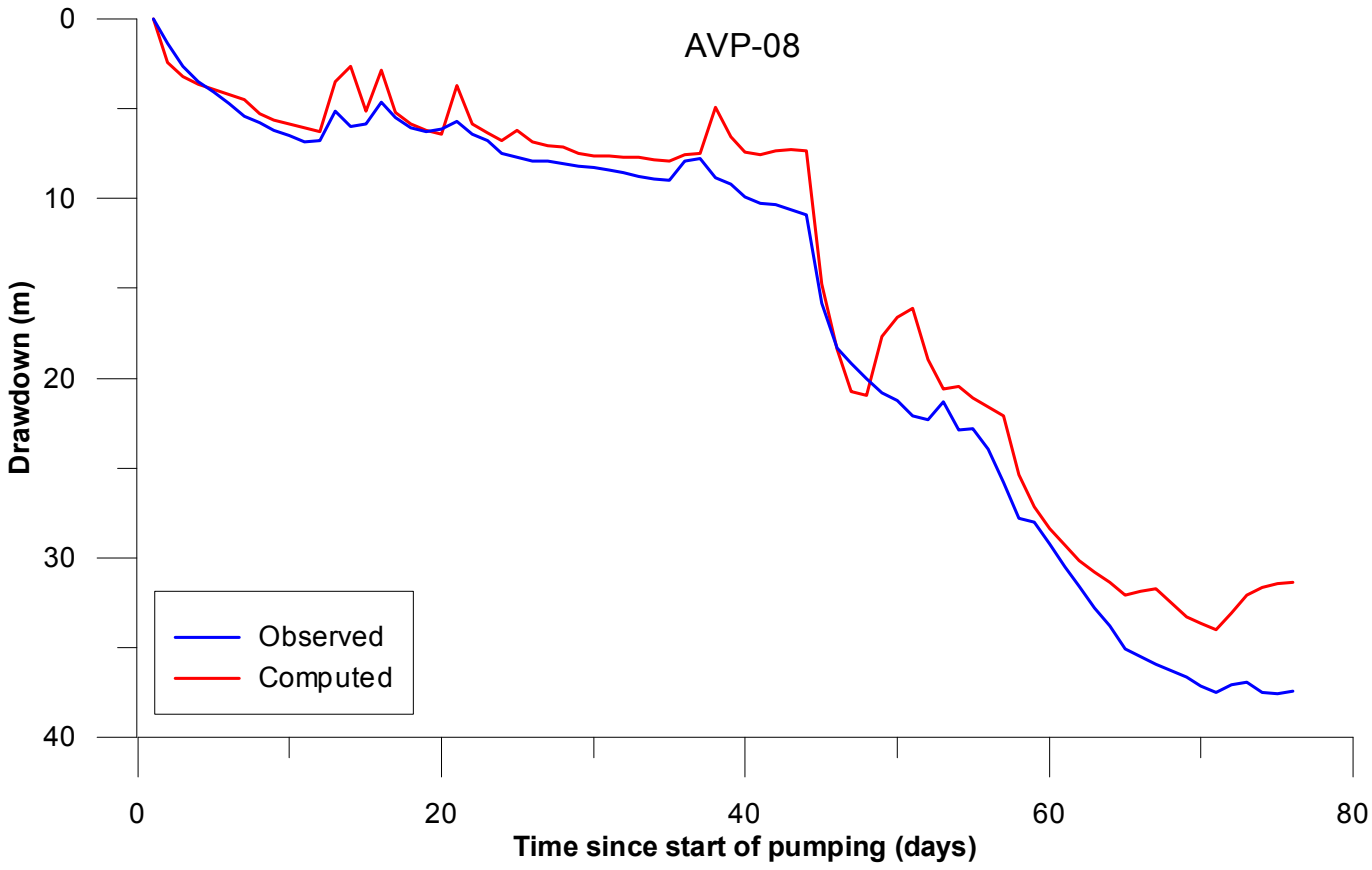

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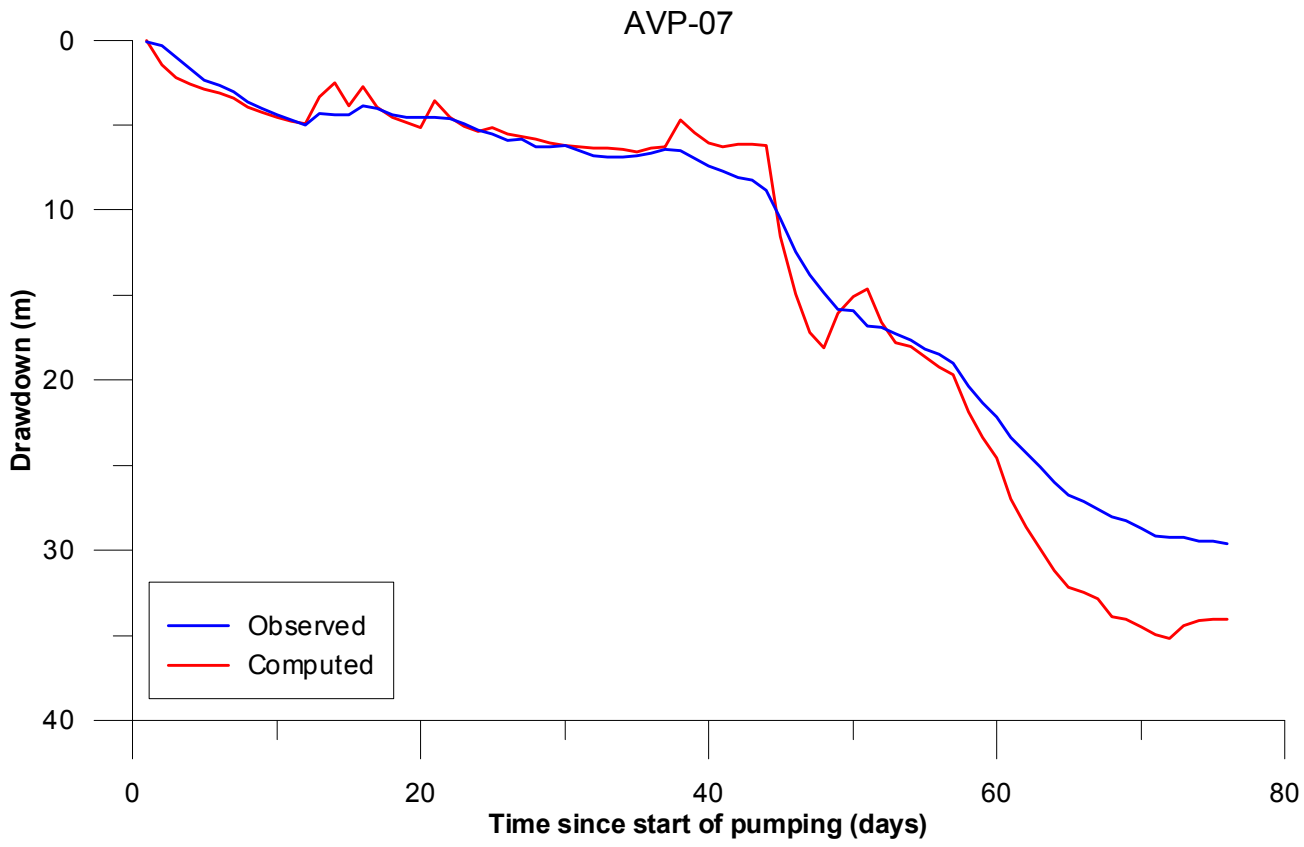

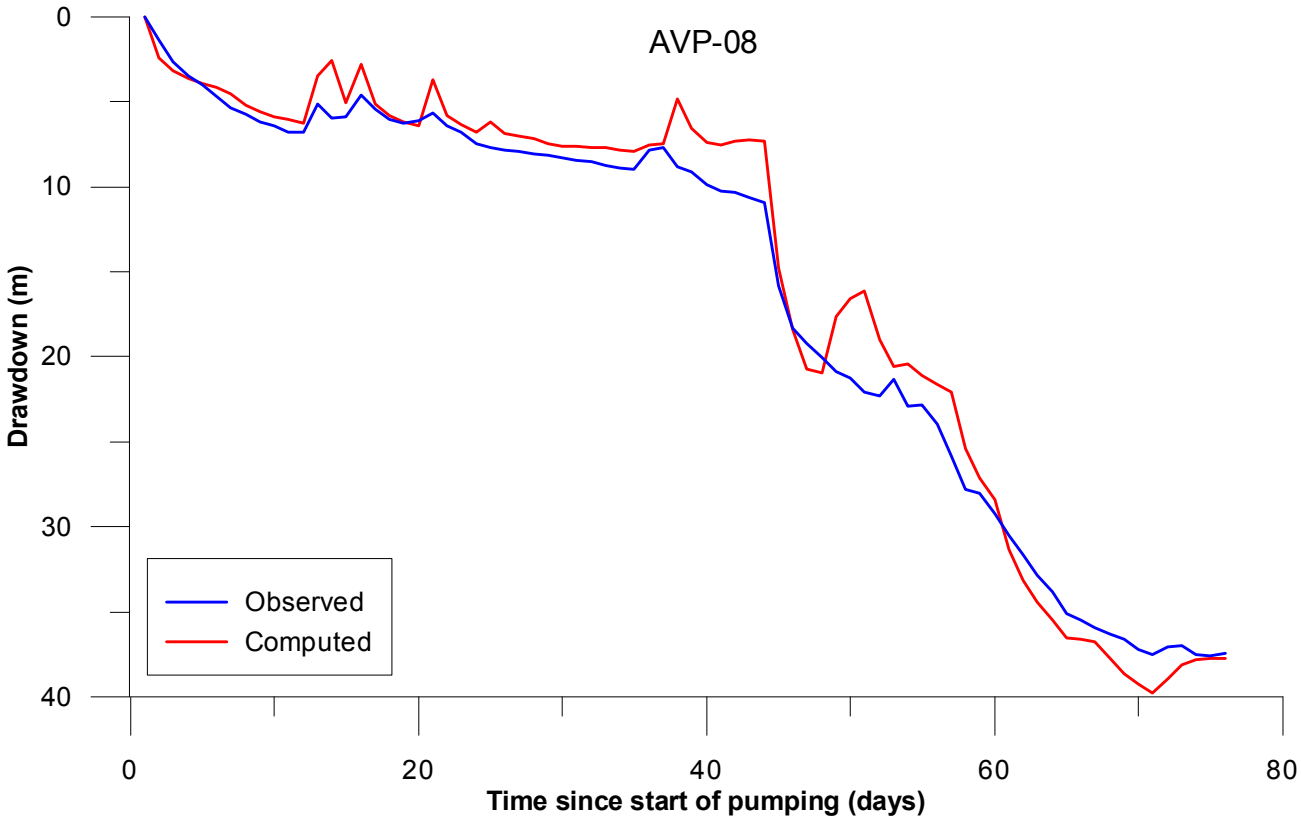

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	DRAWN	JWB	DATE Aug 2011	TITLE	**Modelled vs Observed Drawdown - Consideration of Seepage Losses**
	CHECKED		DATE		
	SCALE	As Shown	**A4**	PROJECT No.	JBT-01-005-031 FIGURE No. **8**

Appendix A: Pumping Rates – Perimeter Dewatering Bores

Date	Day	Pumping Rate (m^3/day)											
		TP-01	TP-02	TP-03	TP-04	TP-05	TP-06	TP-07	TP-08	TP-09	TP-10	TP-11	TP-12
21-Apr	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.3	0.0
22-Apr	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.3	0.0
23-Apr	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.0	0.0
24-Apr	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.0	0.0
25-Apr	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	121.0	0.0
26-Apr	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	126.1	0.0
27-Apr	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
28-Apr	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
29-Apr	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
30-Apr	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
1-May	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
2-May	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3-May	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-May	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
5-May	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-May	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
7-May	17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
8-May	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
9-May	19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
10-May	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-May	21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
12-May	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
13-May	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	160.7	0.0
14-May	24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	118.9	0.0
15-May	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	155.6	0.0
16-May	26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	154.8	0.0
17-May	27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	151.7	0.0
18-May	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.8	0.0
19-May	29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	161.6	0.0
20-May	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	155.5	0.0
21-May	31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	155.3	0.0
22-May	32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	153.8	0.0
23-May	33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	155.6	0.0
24-May	34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	157.9	0.0
25-May	35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.9	0.0
26-May	36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.9	0.0
27-May	37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-May	38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.9	0.0
29-May	39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	158.8	0.0
30-May	40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	149.9	0.0
31-May	41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	129.6	0.0
1-Jun	42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	129.6	0.0
2-Jun	43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.1	0.0
3-Jun	44	0.0	0.0	0.0	174.5	67.4	113.2	0.0	0.0	0.0	105.4	173.7	155.5
4-Jun	45	0.0	0.0	0.0	174.5	67.4	113.2	0.0	0.0	0.0	105.4	173.7	155.5
5-Jun	46	0.0	0.0	0.0	174.5	67.4	113.2	0.0	0.0	0.0	105.4	173.7	155.5
6-Jun	47	0.0	0.0	0.0	166.0	121.0	92.0	0.0	0.0	0.0	78.0	137.0	142.0
7-Jun	48	0.0	0.0	0.0	95.0	60.5	51.8	0.0	0.0	0.0	38.9	69.1	60.5
8-Jun	49	0.0	0.0	0.0	95.0	60.5	51.8	0.0	0.0	0.0	38.9	69.1	60.5
9-Jun	50	0.0	0.0	0.0	95.0	60.5	51.8	0.0	0.0	0.0	38.9	69.1	60.5
10-Jun	51	0.0	0.0	0.0	169.8	109.7	92.8	0.0	0.0	0.0	77.0	105.5	101.3
11-Jun	52	0.0	0.0	0.0	60.1	38.8	28.1	0.0	0.0	0.0	93.1	126.1	141.6

Appendix A: Pumping Rates – Perimeter Dewatering Bores

Date	Day	Pumping Rate (m^3/day)											
		TP-01	TP-02	TP-03	TP-04	TP-05	TP-06	TP-07	TP-08	TP-09	TP-10	TP-11	TP-12
12-Jun	53	0.0	0.0	0.0	145.7	96.8	68.8	0.0	0.0	0.0	70.2	114.4	102.5
13-Jun	54	0.0	0.0	0.0	145.7	96.8	68.8	0.0	0.0	0.0	70.2	114.4	102.5
14-Jun	55	0.0	0.0	0.0	145.7	96.8	68.8	0.0	0.0	0.0	70.2	114.4	102.5
15-Jun	56	0.0	0.0	0.0	145.7	96.8	68.8	0.0	0.0	0.0	70.2	114.4	102.5
16-Jun	57	35.0	24.0	12.8	145.7	96.8	68.8	83.5	47.5	35.3	70.2	114.4	102.5
17-Jun	58	35.0	24.0	12.8	145.7	96.8	68.8	83.5	47.5	35.3	70.2	114.4	102.5
18-Jun	59	35.0	24.0	12.8	145.7	96.8	68.8	83.5	47.5	35.3	70.2	114.4	102.5
19-Jun	60	35.0	24.0	12.8	145.7	96.8	68.8	83.5	47.5	35.3	70.2	114.4	102.5
20-Jun	61	35.0	24.0	12.8	145.7	96.8	68.8	83.5	47.5	35.3	70.2	114.4	102.5
21-Jun	62	35.0	24.0	12.8	145.7	96.8	68.8	83.5	47.5	35.3	70.2	114.4	102.5
22-Jun	63	52.8	26.9	19.2	158.4	54.7	54.7	79.7	56.6	49.9	56.6	100.8	113.3
23-Jun	64	49.0	26.1	18.8	162.8	74.1	56.3	79.3	55.3	49.0	56.3	107.1	114.8
24-Jun	65	51.1	34.4	3.1	143.0	71.0	52.2	73.0	59.5	49.0	48.0	95.0	99.1
25-Jun	66	53.5	33.2	1.8	156.9	64.6	48.9	61.8	54.5	45.2	45.2	96.9	102.5
26-Jun	67	60.8	37.6	13.6	176.8	75.2	54.4	70.4	63.2	40.8	40.0	106.4	108.0
27-Jun	68	52.5	22.1	1.1	154.3	62.7	35.1	141.3	55.1	45.3	52.5	95.3	94.6
28-Jun	69	52.5	22.1	1.1	154.3	62.7	35.1	141.3	55.1	45.3	52.5	95.3	94.6
29-Jun	70	52.5	22.1	1.1	154.3	62.7	35.1	141.3	55.1	45.3	52.5	95.3	94.6
30-Jun	71	60.6	29.7	0.0	154.3	61.7	43.4	57.1	56.0	41.1	40.0	92.6	91.4
1-Jul	72	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
2-Jul	73	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
3-Jul	74	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
4-Jul	75	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
5-Jul	76	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
6-Jul	77	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
7-Jul	78	60.5	0.8	0.4	143.5	65.8	39.7	53.3	45.1	44.0	33.5	90.4	82.8
8-Jul	79	60.8	1.6	1.6	139.2	70.4	38.4	51.2	40.0	41.6	35.2	129.6	89.6
9-Jul	80	58.0	1.4	0.7	145.4	72.4	40.1	58.0	45.9	48.0	38.0	92.4	84.5
10-Jul	81	59.0	2.0	1.0	154.0	70.0	38.0	53.0	48.0	43.0	40.0	96.0	90.0
11-Jul	82	48.4	0.6	1.2	149.0	71.1	38.6	51.7	48.0	45.5	43.0	91.6	88.5
12-Jul	83	48.4	0.6	1.2	149.0	71.1	38.6	51.7	48.0	45.5	43.0	91.6	88.5
13-Jul	84	44.2	1.9	1.0	141.1	70.1	39.4	48.0	42.2	42.2	46.1	88.3	92.2
14-Jul	85	47.5	0.0	0.0	139.9	70.4	40.2	50.3	43.9	46.6	43.0	83.2	90.5
15-Jul	86	53.2	1.2	1.2	119.1	59.0	32.4	52.0	46.3	42.8	46.3	96.0	104.1
16-Jul	87	47.5	1.0	0.0	155.2	65.9	38.8	39.8	28.1	35.9	34.9	72.7	71.8
17-Jul	88	54.1	1.0	1.0	158.3	65.4	39.8	66.4	51.1	48.0	43.9	96.0	100.1
18-Jul	89	49.0	1.0	1.0	145.9	61.4	36.5	59.5	40.3	45.1	42.2	87.4	93.1
19-Jul	90	48.4	1.6	0.8	140.5	59.3	39.8	57.8	61.7	45.3	42.1	84.3	92.1
20-Jul	91	54.0	0.0	1.5	156.0	75.0	34.5	0.0	0.0	43.5	43.5	93.0	100.5

Appendix B: Webcam Photos

Plate 1: Wednesday 13 July – Sump pump switched off, perimeter bore pumps remain operational

Plate 2: Wednesday 20 July – Perimeter bore pumps switched off

Plate 3: Wednesday 27 July – 1 week after perimeter bore pumps switched off

Plate 4: Tuesday 2 August - 2 weeks after perimeter bore pumps switched off

D

Appendix D Steady-state calibration data

Alpha Project groundwater modelling - Independent due diligence assessment

March 2012

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A+ GRI Rating: Sustainability Report 2010

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Revision	Details	Date	Amended By
C	Original	31 January 2012	Stuart Brown
D	Final draft	5 March 2012	Stuart Brown
E	Revision for SEWPaC	27 March 2012	Stuart Brown

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Signed: .....

Date: 27 March 2012 .....

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Appendices

Appendix A
Model review checklist (MDBC, 2000)

List of Abbreviations

Abbreviation	Description
ATP	Alpha Test Pit
BOM	Australian Bureau of Meteorology
CDFM	Cumulative departure from the mean (rainfall)
EIS	Environmental Impact Statement
EVT, ET	Evapotranspiration (specifically the evapotranspiration package in MODFLOW)
GAB	Great Artesian Basin
GDE	Groundwater Dependent Ecosystem
GL	Gigalitre (10^9 litres or 10^6 m^3)
Hancock	Hancock Coal Pty Ltd
K	Hydraulic conductivity
K_h (or K_{xy})	Horizontal hydraulic conductivity (K_{xy} is numerical model notation)
K_v (or K_z)	Vertical hydraulic conductivity (K_z is numerical model notation)
KC	Kevins Corner mine lease
LOM	Life of mine
L/s	Litres per second
m AHD	metres Australian Height Datum
MDL	Mineral Development Lease
mbtoc	metres below top of casing (in a bore)
mbgl	metres below ground level
m/day, m/d	metres per day (velocity or hydraulic conductivity)
ME	Mean error
ML	Megalitre (10^6 litres)
ML/a	Megalitre per annum
mm	millimetre
MNES	Matters of National Environmental Significance
m/s	metres per second (velocity or hydraulic conductivity)
Mtpa	Million tonnes per annum
NTEC	NTEC Environmental Technology
RMSE	Root mean square error
S	Storage coefficient
Ss	Specific storage
Sy	Specific yield (Unconfined storage or drainable porosity)
SOW	Scope of work (specifically, the scope for this review)
T	Transmissivity (m^2/day)
TEC	Threatened Ecological Community
URS	URS Australian Pty Ltd
VWP	Vibrating wire piezometer
WPAJV	Worley Parsons Ausenco Joint Venture

Executive summary

Parsons Brinckerhoff Australia Pty Ltd (Parsons Brinckerhoff) was engaged by Worley Parsons Ausenco Joint Venture (WPAJV) on behalf of Hancock Coal Pty Ltd (Hancock Coal) to undertake an independent due diligence assessment of a groundwater model report issued by URS Australia Pty Ltd on 23 December 2011 (URS 2011c). Parsons Brinckerhoff carried out a review of the final URS report and model in accordance with the Murray Darling Commission Groundwater Modelling Guideline (MDBC, 2001).

A large amount of detailed hydrogeological fieldwork has been carried out at the Alpha Coal Project site leading to a good conceptual understanding of the site. Additional fieldwork carried out by URS has further constrained estimates of key aquifer parameters and enhanced the conceptual understanding of groundwater in the project area. Parsons Brinckerhoff considers that the field investigations carried out to date have been of appropriate scope and were executed and analysed in a competent manner. The available background data and conceptualisation provide an adequate basis for numerical modelling.

The final modelling report by URS (2011c) summarises the findings of the field investigations, model revision and calibration, and model predictions of groundwater inflow. The following conclusions are drawn from a review of that report:

- The report is presented in a way that is broadly consistent with the recommended reporting standards of the MDBC (2000) guidelines.
- Modelling was carried out at two different scales in order to effectively use the available calibration data: 1) A local scale transient model was used to calibrate parameters to the Alpha Test Pit (ATP) dewatering observations, and 2) A regional scale model was used to calibrate against regional measurements of groundwater level. The numerical models were significantly revised and rebuilt using the MODHMS software code. Model construction, calibration and predictions were carried out broadly in line with the guideline and industry best practice.
- The sensitivity analysis showed that a number of parameters that are important in estimating groundwater inflow and drawdown are relatively insensitive and subject to uncertainty. This relates particularly to vertical permeability in coal seams and interburden. It is noted however that the majority of model parameters lie within the broad range of field estimates of hydraulic conductivity. In addition, parameter values are generally consistent with values of hydraulic conductivity observed in coal measures in other regions of Australia.
- An uncertainty analysis was carried out by running 25 scenarios with differing values of key sensitive parameters. The results of the uncertainty analysis were used to define a high and low inflow estimate (241 GL and 105 GL, LOM) in addition to a base case estimate of 176 GL (LOM). Both the inflow estimates and the parameters used in the models appear to be within plausible ranges compared with the field data and experience elsewhere.

While groundwater drawdown impacts were not considered in detail in the URS (2011c) report, the calibrated model parameters themselves are broadly appropriate for assessing potential drawdown impacts in the vicinity of the mine. It is understood that the model is currently being further updated to assess drawdown impacts on potential groundwater dependent ecosystems and Matters of National Environmental Significance (MNES).

1. Introduction

Parsons Brinckerhoff Australia Pty Ltd (Parsons Brinckerhoff) was engaged by Worley Parsons Ausenco Joint Venture (WPAJV) on behalf of Hancock Coal Pty Ltd (Hancock Coal) to undertake an independent due diligence assessment of a groundwater model report issued by URS Australia Pty Ltd (URS, 2011c).

URS was engaged by Hancock Coal to carry out a program of field investigations and revision of the existing regional groundwater model to provide estimates of groundwater inflow and water supply and to assess groundwater drawdown impacts associated with the proposed Alpha Mine (including the Kevin's Corner underground project), located within the Galilee Basin, near the township of Alpha, Queensland.

Parsons Brinckerhoff carried out a review of the final URS report and model in accordance with the Murray Darling Commission Groundwater Modelling Guideline (MDBC, 2001) which has become a default national guideline for modelling in Australia and commonly applied to groundwater models for mining applications. This report summarises our comments and recommendations from the review. In addition, Parsons Brinckerhoff has provided comments on the model report in response to specific items raised by SEWPaC (December 2011) as part of their review process.

2. Objective and scope of service

2.1 Objective

The objective of this report is to provide an independent due diligence review of the numerical groundwater modelling report and model revisions carried out by URS (2011c) relating to potential groundwater impacts from the proposed Alpha Coal and Kevin's Corner Coal Projects. The results of the groundwater modelling are an integral part of the groundwater impact assessment which is currently being considered by the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC). This review is intended to provide SEWPaC with an independent assessment of the numerical modelling used to assess groundwater impacts and mine inflow rates as presented by URS (2011c).

2.2 Scope of service

This review was carried out under the scope or works supplied in Hancock Coal's Scope of work (SOW), dated 27 October 2011, and the proposal submitted by Parsons Brinckerhoff, dated 2 November 2011. The scope of work (pages 24 to 27 of the SOW), is summarised below:

1. Compliance assessment of the main model report and model, focusing on the following main elements:
    a. Data analysis
    b. Conceptualisation
    c. Model design
    d. Model calibration
    e. Verification
    f. Predictions
    g. Sensitivity analysis
    h. Reporting
2. Review of supporting documents and reports, as background information.
3. Workshops and engagement; specifically, the URS final model presentation workshop held on 4 November 2011. Also other meetings and workshops, as required.
4. Provide recommendations that would enhance the final model and report in terms of the level of confidence and accuracy.
5. Provide comments regarding the modelling carried out in response to specific queries raised by SEWPaC (2011) as part of their review process.

3. Response to SEWPaC comments

The Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) has recently reviewed the EIS and supplementary EIS documents for the Alpha Coal Project. As part of the review process, SEWPaC issued a number of comments and requests for clarification to Hancock Coal (SEWPaC, 2011). Specific comments that are related to modelling of groundwater impacts are listed below in Table 1, with responses based on Parsons Brinckerhoff's review of the groundwater modelling and investigations carried out to date.

Table 1 Comments in response to items raised by SEWPaC (2011)

Item	Reference*	Summary of item	Comment
1	**9C; also Bruce Gray (pers. comm.)**	Information that supports and validates the low transmissivity and porosity of groundwater systems.	The model parameters relating to permeability and porosity of relevant hydrogeological units have been assessed in detail as part of this review (Section 5.5). It is noted that the calibrated model parameters lie generally within the broad range of field estimates of hydraulic conductivity. In addition, the parameter values are consistent with values of hydraulic conductivity and storativity observed in coal measures in other regions of Australia (e.g. Hunter Valley; Southern Coalfields, NSW). Drill stem permeability tests for the Rewan Formation are listed in the SEIS. These results confirm that the Rewan Formation is a regional aquitard of very low permeability which will significantly retard the transmission of drawdown to the west of the site. The calibrated model parameters are considered to be appropriate for assessing potential groundwater inflow and drawdown impacts in the vicinity of the mine
2	**9C**	Assessment of cumulative impacts	An estimate of cumulative drawdown related to the multiple planned mining projects would rely on obtaining accurate information regarding the proposed mining operations and hydrogeological conditions at neighbouring sites. In addition, a realistic estimate of cumulative drawdown would require a regional scale groundwater model which is beyond the scope of the current impact assessment model.
3	**9C**	Assessment of MNES and TEC	It is noted that the western boundary of the groundwater model corresponds to the topographic divide of the Great Dividing Range and therefore the model does not include the intake (recharge) beds of the GAB. However, the model will still be capable of providing conservative estimates of drawdown to the west of the tenement boundary and therefore conservative indications as to whether drawdown may occur within the GAB.
4	**9F1**	Contours of drawdown	It is understood that contours of predicted drawdown can be exported easily from the model at any desired interval. However it should be noted that, given the uncertainties in model input parameters and the natural variation in groundwater levels, predictions of drawdown less than 0.5 m are beyond the reasonable precision of the model.
5	**9D**	Impacts on the GAB	Further to item 3 above, it is noted that the mine is located well east of the main GAB recharge beds and therefore is unlikely to impact on recharge to the GAB

Item	Reference*	Summary of item	Comment
6	**9F; also Bruce Gray (pers. comm.)**	Tertiary sediments, including palaeochannels	Groundwater investigations at the site have identified up to 60 m of Tertiary to recent sedimentary deposits overlying the Permian Coal Measures. A number of potentially perched aquifers have been identified, but no significant palaeochannel aquifers. Perched groundwater systems are conceptually (and therefore numerically) modelled as disconnected from the regional groundwater system. Therefore impacts to those perched systems are only possible where they are intersected by mining. It is understood that URS is currently updating the groundwater model to assess the potential drawdown impacts to intersected perched systems.
7	**Bruce Gray (pers. comm)**	A map showing springs within 100 km of the MLA boundary	It is understood that URS is currently preparing this map as part of their response to SEWPaC comments.

*Note: References correspond to those in Hancock Coal's response to SEWPaC comments (28 March 2012). Bruce Grey (pers. comm.) refers to communications between Hancock Coal and Bruce Gray of SEWPaC.

4. Review of background information

In addition to the final URS modelling report (URS 2011c) Parsons Brinckerhoff informally reviewed seventeen (17) previous reports relating to hydrogeological assessment of the site and development of a number of groundwater models for the site. These reports are listed in the References section of this report). This review specifically relates to the numerical model report of URS (2011c) but makes reference to other reports and previous model versions to provide background to the review process where relevant.

A significant amount of hydrogeological and numerical modelling work has been undertaken by JBT, NTEC and URS over the last three years. The initial hydrogeological conceptualisation by JBT (2010a) is comprehensive and draws upon previous and ongoing hydrogeological investigations to constrain the hydrogeology and main hydraulic parameters for the site. The conceptual diagrams in the JBT reports (2010c and 2011c) in particular are comprehensive and provide a good basis for numerical modelling.

The modelling summary report by NTEC (2011b) provides a useful insight into some of the challenges in modelling in an area with relatively little regional scale data for calibration. Some aspects such as the large uncertainty in inflow estimates, the high storage values in some units and the lack of regional calibration have been the focus of the ongoing revision by URS (2011b, 2011c).

Prior to the submission of the final URS modelling report (23 December 2011), modelling reports submitted to Hancock Coal in the last two years included a large number of estimates of groundwater inflow into the proposed mine workings (these are shown in chronological order in Figure 1, below). Note that the individual model labels and abbreviations in Figure 1 were defined by the author to identify the various model versions and have no relevance outside of this review. Many of these estimates are the result of sensitivity analyses that seek to understand the uncertainty in inflow estimates that arise from the inherent uncertainty in physical parameters (principally hydraulic conductivity and storage coefficients).

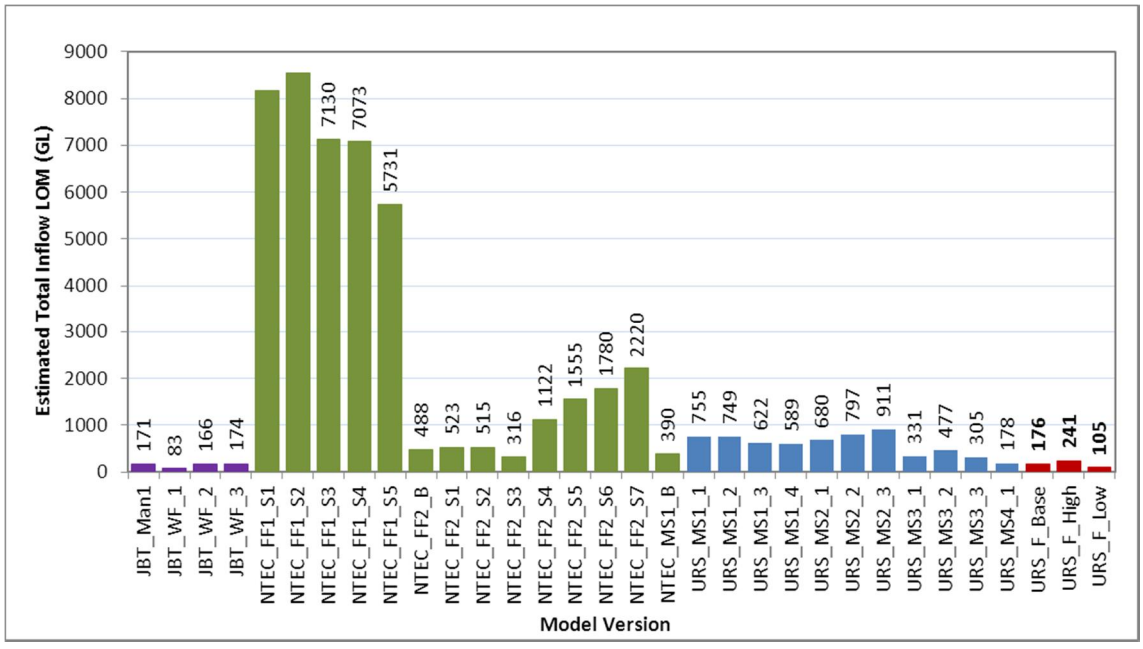

Figure 1 Estimates of total mine inflow by model version (in GL, LOM)

The very highest estimates are from the NTEC Feflow model (presented in JBT, 2011b) in which the parameters are based on average values derived from field tests. The hydraulic conductivity and storage coefficients were subsequently revised downwards based direct observations of drawdown and inflow associated with the Alpha Test Pit (ATP). Subsequent models (NTEC, 2011b) therefore generated significantly lower inflow rates and drawdown estimates and, because they are calibrated to the ATP data, are considered to be more realistic. Inflow rates were revised lower again during the interim and final URS revisions (2011b, 2011c), primarily due to the identification (and correction) of unusually high storage coefficients for the coal seams in previous models (initially with Sy = 30%; in the latest model Sy < 1%). Again, this review concurs with that revision.

The most recent groundwater modelling report by URS (2011c) summarises the conceptual hydrogeolgoical model for the project site and outlines the model revisions undertaken to provide robust estimates of groundwater inflow into the proposed open pit and underground workings. While groundwater drawdown impacts were not considered in detail in the URS (2011c) report, the calibrated model parameters themselves will be broadly appropriate for assessing potential drawdown impacts in the vicinity of the mine.

5. Model compliance assessment

As documented in the scope of works, the final URS model revision report (23 December 2011) and supporting documents have been reviewed in accordance with the Murray Darling Basin Commission Groundwater Modelling Guidelines (MDBC, 2001). It is noted that the compliance criteria outlined in Hancock's scope are derived from the MDBC Guideline.

The following review is divided into categories of assessment as per the SOW. Specific items of assessment in each category are listed in tables under each category (as per the MDBC checklist) and the entire summary checklist is attached to this report. For aspects in which the report and/or model are found to be deficient, comments are offered regarding the potential impact of the deficiency on the model prediction.

5.1 General reporting

In general the report complies with most requirements of the MDBC guideline, covering all of the recommended headings. In particular, the project scope and objectives are clearly stated and the results are in line with the stated objectives. It is noted that most of the recommendations from the review of the interim (draft) modelling report have been incorporated into the final report.

The main elements of general reporting are listed and assessed in Table 2 below.

Table 2 Assessment of reporting requirements

Item	Assessment criterion	Addressed?	Comments	Impact on project?
1.1	Is there a clear statement of project objectives in the modelling report?	Very good	Yes the scope was clearly listed in sections 1.1 and Objectives clearly listed in 3.1; Deliverables are listed in Section 1.2	N/A
1.2	Is the level of model complexity clear or acknowledged?	Yes	Yes, the model is described as "moderate complexity" in Section 3.2, which is appropriate	N/A
1.3	Is a water or mass balance reported?	Deficient	No overall hydraulic water balance is reported although components of the water balance are discussed in 6.8. *The inclusion of a water balance would have assisted in assessing the model output.*	Minimal impact
1.4	Has the modelling study satisfied project objectives?	Adequate	Yes; the results include estimates of drawdown and mine inflow as well as an analysis of uncertainty	N/A
1.5	Are the model results of any practical use?	Yes	Yes; they are of direct use in mine planning. Predictions are discussed further below	N/A

While the report is generally adequate and compliant with guidelines, there are a number of areas in which the report was below a professional standard. While these aspects would not

have a significant impact on the model predictions, they made the report difficult to follow in some sections. Specifically:

- Graphics are poor in many cases and below industry standard. Many of the maps are raw screen dumps with poor resolution and insufficient labelling (e.g. Figure 6-6, 6-12, 9-5…). Many of the plots are raw exports from excel with poor axis and series labelling; in some cases the axes are mislabelled (final prediction Figures 10-10 and 10-11; labelled GL instead of m^3). Similarly tables appear to be unformatted imports from excel.

- Organisation difficult to follow at times, particularly Section 6. It presents details on the calibration and predictive output from older (redundant) models. Under the heading of "*Base case and predictions*", Table 6-9 presents the interim (draft) estimates of inflow with an arbitrary reduction factor applied. This detracts from the report. In the same section, details of the development and calibration of the latest (MODHMS) model are presented. Surely this should have gone in Section 8.

- No hydrological water balance was provided as part of the conceptual model, as is recommended by the MDBC guidelines. This is not a model water balance but a hydrogeologists estimate of the regional and mine scale water balances, against which the model outputs can later be compared. This omission is not likely to impact significantly on the groundwater model predictions.

5.2 Data analysis

As noted in the sections above, a great deal of data has been collected by URS and previous workers. The final URS report provides a summary of the field and laboratory analysis undertaken. Data analysis reports (by JBT consulting) are included as appendices to the main final report. The analysis includes the presentation and discussion of background information, groundwater levels, aquifer testing results (test pumping and rising head tests), and laboratory permeability testing. As discussed above, the proposed isotopic analysis was reassessed by URS and considered not to be necessary based on the results of other field tests at the TSF site. We concur that the omission of the isotopic study would not have any adverse impact on the model predictions.

As discussed elsewhere in this review, it would have been useful to see a diagram that summarised the field results and compared them with previous estimates and calibrated model parameters. This would have better satisfied the scope item related to integration of the field data with the conceptual and numerical models. In this respect seems to be a slight disconnection between the hydrogeological investigations and conceptualisation, and the modelling process.

The main elements of data analysis for model development are listed and assessed in Table 3 below. Assessment of the field data are assessed further in the following sub-sections.

Table 3 Assessment of data analysis

Item	Assessment criterion	Addressed?	Comments	Impact on project?
2.1	Has hydrogeology data been collected and analysed?	Adequate	Yes; Good summary of regional data and results from investigations; could have been more discussion on field K measurements and how they might guide model parameterisation	Minimal impact
2.2	Are groundwater contours or flow directions presented?	Adequate	Yes, contours derived from exploration holes and VWPs are shown; regional data are limited	N/A
2.3	Have all potential recharge data been collected and analysed? (rainfall, stream flow, irrigation, floods etc.)	Adequate	Recharge has been assessed in Section 4.7 in some detail and mechanisms for recharge described.	N/A
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, spring flow, etc.)	Adequate	Section 4.8 discussed discharge; no obvious discharge in project areas; the mechanism for discharge to Sandy Creek beds is a little vague.	Minimal impact to inflow estimates
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?	Adequate	Yes, to the extent possible. Report notes there is negligible response in hydrographs to high rainfall events in 2010/11	N/A
2.6	Are groundwater hydrographs used for calibration?	Yes	Yes, Figures 9-7 to 9-11 show observed and simulated hydrographs for the Alpha Test Pit dewatering	N/A
2.7	Have consistent data units and standard geometrical datums been used?	Yes	Most of the time, but it is noted that Figures 10-10 and 10-11 have incorrect units (should be m^3, not GL).	N/A

5.2.1 Hydrologic data

Section 4 of the URS report provides general hydrological background information for the project area. It describes the climate, surface water features, geology, groundwater flow and a summary of new and existing aquifer characteristics. The section is quite comprehensive and includes good quality graphics.

5.2.2 Aquifer tests ("pumping tests")

Test pumping was carried out at 6 bore locations. The testing typically consisted of a step-rate test to determine the maximum possible drawdown and well characteristics, followed by a constant rate test to determine aquifer characteristics. In some cases the step test was completed with a longer final step instead of a separate constant rate test (which would not affect the validity of the test).

There is no guideline or standard that dictates the exact number of tests that are required to determine the hydrogeological conditions at a site. Rather it is a matter of professional judgement, and would vary from site to site based on the geological complexity, project scope and modelling approach. The number and types of tests carried out at the Alpha Coal Project site are within the range of that typically carried out for characterising a mine site.

Test pumping data were analysed using Aqtesolve software using the solution of Theis (confined aquifer) for step tests and constant rate tests. The analysis approach is considered appropriate for this study and the results and interpretation are reasonable.

5.2.3 Variable head tests ("slug" tests")

Falling head (slug) tests were carried out at 17 locations. Data analysis was carried out using the Bower and Rice (1976) method which is appropriate for fully or partially penetrating wells and can be used in confined and unconfined conditions. The analysis approach is considered appropriate for this study and the results and interpretation are reasonable.

5.2.4 Laboratory permeability testing

Permeability testing was carried out on 26 core samples from five exploration holes in the Kevin's Corner lease. The core samples were sent to Trilab (Perth) for constant head permeability analysis. Trilab is a NATA accredited laboratory and the results are considered reliable. The permeability values span a wide range (several orders of magnitude) and are, on average, significantly lower than slug testing and test pumping results. This is not unusual for coal measures where the permeability of the rock mass is largely controlled by larger-scale rock defects such as joints and bedding plane fractures. This is discussed in the JBT and URS reports.

5.2.5 Field hydraulic parameters

The latest estimates of hydraulic conductivity for the main hydrogeological units from field and laboratory testing are presented in Figure 2. Also shown are the parameters used in the revised groundwater model (discussed in Section 5.5). This graph clearly demonstrates how estimates of permeability can range over six orders of magnitude, even for the same hydrogeological unit. It is also interesting to note that estimates from laboratory core testing are typically several orders of magnitude lower than estimates derived from test pumping and slug testing. This is a well-known phenomenon and reflects the scale dependent nature of permeability testing (especially in fractured or dual porosity aquifers), and also the inherent bias of each particular testing method (test pumping is not possible in formations of very low permeability, for instance). This was discussed in Section 7.2.3 of the URS report. Estimates of storage coefficients are also variable for the same reasons.

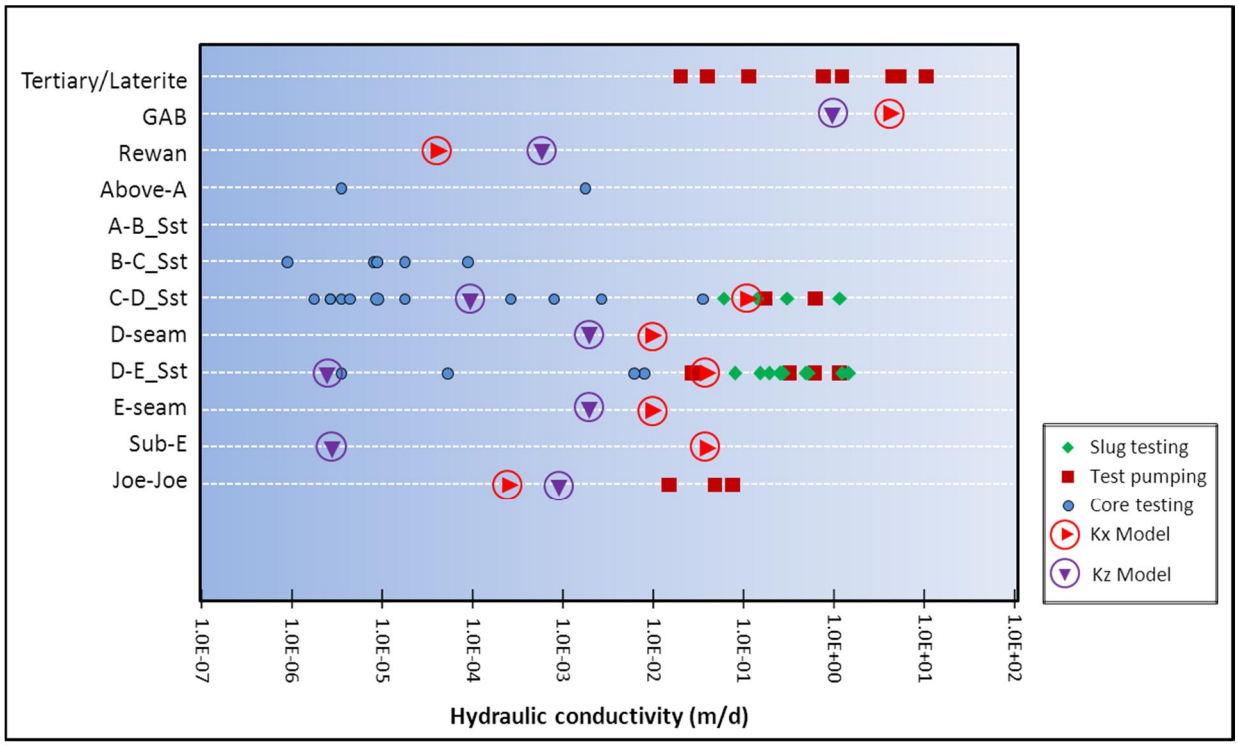

Figure 2 Summary of permeability test data

These results highlight the difficulty in estimating hydraulic parameters at a regional scale in order to provide a reliable estimate of groundwater inflows at the mine scale. In the case of the Alpha project, the dewatering of the Alpha Test Pit provided an opportunity to constrain those parameters in what is essentially a very large pumping test, analogous to the mining operation itself. The approach by NTEC and URS to preferentially use parameters derived calibration of a local model and detailed observations of groundwater levels and fluxes is therefore very sound. It is noted however that the values of Kv for the D-E and Sub-E sandstone interburden units are quite low compared with the test data. Low estimates of Kv would tend to underestimate the groundwater inflow rate and therefore the choice of values should be further justified.

In summary testing appears to have been carried out in a competent manner and the data analysis is sound. As a general comment, the field data could have been better integrated into the conceptual model to determine a set of preferred values and ranges for aquifer characteristics such as permeability and storage. These values could then be used to justify the (insensitive) calibrated parameter values of the model in a more transparent manner.

5.3 Conceptualisation

A sound regional and mine scale conceptual model was developed by JBT (2010a). This has been the basis for the development of the NTEC Feflow/Surfact models on which the revised MODHMS steady state model is based.

The main elements of general reporting are listed and assessed in Table 5 below. Conceptualisation of the hydrogeological system is considered appropriate and adequate for the design of the model.

Table 4 Assessment of groundwater conceptualisation

Item	Assessment criterion	Addressed?	Comments	Impact on Project?
3.1	Is the conceptual model consistent with project objectives and the required model complexity?	Yes	Yes, conceptual framework for both the regional system and mining are presented.	N/A
3.2	Is there a clear description of the conceptual model?	Very Good	Yes; conceptual model is mainly from earlier JBT reports and are clear, reasonable and concise	N/A
3.3	Is there a graphical representation of the modeller's conceptualisation?	Very Good	Yes, Figures 4-9 shows the regional conceptualisation and Figures 7-1 to 7-4 show mining conceptualisation	N/A
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?	Adequate	Adequate	N/A

5.4 Model design

It is noted that the latest revised modes were constructed and run using MODHMS, whereas previous models were constructed by NTEC using Groundwater Vistas and MODFLOW-SURFACT. The URS final report states that MODHMS is preferred because it has many advantages over the previous platform (Section 8.1, page 88). Most of the advantageous features quoted are not utilised in any of the models (i.e. mass transport and surface water features) and the use of MODHMS is simply a matter of preference. MODHMS is an appropriate code and modelling platform for the current impact assessment.

Three separate models were constructed in MODHMS for groundwater influx predictions:

1. **Steady state** regional model, which was based on the NTEC regional Vistas/Surfact model with structural modifications as described in Section 6 and Section 8 of the report. This model was used to calibrate key parameters (horizontal and vertical permeability) using available groundwater head data.

2. **Transient model**, which is a separate, small scale model of the Alpha test pit based on the similar NTEC model developed using Vistas/Surfact. This model was used to calibrate a wide range of parameters (but mainly storage coefficients) using dewatering and inflow data from the Alpha Test Pit.

3. **Predictive model**, which is a transient model based on the steady state model, but with numerical representation of the mining operations. The model uses the parameter values derived from the steady state and transient model calibrations.

The modelling was carried out using three models because each was designed for a different purpose. In particular the smaller transient model was necessary to assess the ATP dewatering data in an efficient manner. This would have been difficult to do using the main model. Section 8 of the Final URS report outlines the construction of the numerical model in MODHMS. The updated steady state and predictive models included the following modifications:

- Layer structure; additional layers were included in the model. These may have assisted in calibration.
- Hydraulic boundaries; Recharge was considered minimal (0.1% rainfall) and discharge via streams limited to evapotranspiration in areas where groundwater is at shallow depths.
- The eastern no-flow/constant head boundary was moved to coincide with the outcrop of the Colinlea Sandstone – Joe Joe Formation contact. This was done on the assumption that the Joe Joe Formation is essentially impermeable (but this contrasts with the parameters selected in Table 10-1 of the URS report). This modification may be restrictive for longer term (post mining) estimates of drawdown and void inflow. Specifically, the use of a constant head boundary would tend to restrict and underestimate drawdown towards that eastern boundary.
- The western model boundary is a no-flow boundary located some 20 – 25 km west of the proposed Alpha mine pit. The location of this boundary coincides with the topographical divide which is appropriate for surface water and shallow groundwater catchments. However it does not allow for rigorous assessment of potential drawdown in GAB aquifers and potential recharge zones of the GAB west of that boundary.
- Parameters were assigned according to zones such that a single parameter zone can correspond to more than one hydrostratigraphic unit (e.g. storage zone ”Sc2” and permeability zone “Kx4”). This may have reduced the sensitivity of those parameters during calibration, but does not seem to have impacted on the calibration itself.

The transient “zoom-in” model was a local scale model of the Alpha Test Pit. The model had the same layer structure but was limited to an area of 10 km by 10.3 km centred on the Alpha Test Pit. Given the objective of the transient most was to calibrate against available monitoring and dewatering data, the model design is considered appropriate.

Although it was not explicitly described in the text, the mine was represented by MODFLOW drain boundaries. This approach is standard amongst groundwater modellers and an appropriate way to represent the mining operation.

One aspect that was notably absent from the model design is the discussion of whether any time-variant materials properties were included. For instance, in some mines it is appropriate to vary the hydraulic properties and recharge in the back-filled waste rock piles (both tend to be higher in the waste rock). For longwall mining there are significant post-mining changes that can occur in response to goaf collapse and resulting unconnected fracturing of the overlying strata.

The main elements of model development are listed and assessed in Table 5 below.

Table 5 Assessment of model design

Item	Assessment criterion	Addressed?	Comments	Impact on project?
4.1	Is the spatial extent of the model appropriate?	Adequate	Spatial extent is based on the conceptual hydrogeology.	N/A
4.2	Are the applied boundary conditions plausible and unrestrictive?	Adequate	Boundaries are reasonable based on conceptualisation; The eastern no-flow boundary may be restrictive and needs greater explanation and justification.	Likely minimal impact

Item	Assessment criterion	Addressed?	Comments	Impact on project?
4.3	Is the software appropriate for the objectives of the study?	Very Good	MODHMS is a comprehensive groundwater modelling platform. However, Justification for changing software was not strong or clear.	No significant impact

In general, the model design is considered appropriate for prediction of groundwater inflows to the mine during mining operations. The restriction of the eastern constant head boundary and the western no-flow boundary may be significant for longer tem estimates of groundwater drawdown, however it is noted that this was not the objective of the URS (2011c) report.

5.5 Calibration

Model calibration is the process of changing key model parameters to achieve an acceptable match between simulated groundwater levels and/or fluxes and observed groundwater levels and flows. Typically this is undertaken using manual ("trial and error") methods, automated parameter estimation software (such as PEST), or some combination of the two. One of the most widely used measures of calibration is the sum of squared residuals (SSR) between simulated and observed data. The objective of the calibration process is to drive an "objective function" (such as the SSR) to a minimum value while ensuring that parameters remain within a geologically reasonable range. The quality of the calibration is typically assessed using the root mean square error (RMSE with units of metres) and the scaled RMS (SRMS) in which the RMSE is expressed as a percentage of the total head differential. Graphically, the quality of calibration is often demonstrated using a bivariate plot of simulated heads versus observed heads.

The URS report uses this approach which is consistent with industry guidelines. It is noted that the SRMS for calibration of both the steady state and transient models is less than 5%, which is considered an excellent fit. It is noted that a calibration journal was not included in the final report, as was included in the proposed URS scope of works.

The concept of calibration as applied to the current model is not straightforward. The quantity and type of regional information is not sufficient to calibrate and constrain the key parameters in the regional model that are most important for estimating groundwater inflow to the mine (this is not unusual because often good quality data on regional water fluxes are lacking). On the other hand, calibration of the Alpha Test Pit does provide some excellent constraints on those relevant parameters. Accordingly, URS has taken the following approach to model calibration:

- The local transient model was used to calibrate storage parameters to the observed groundwater levels and dewatering rates for the Alpha Test Pit. The calibration appears to be very good and those parameters were adopted in the predictive model. The ATP dewatering observations provide superior data for calibration because the test was carried out at a scale similar to the mine scale and includes reliable measurements of drawdown (hydraulic head) and pumping volumes (groundwater flux).

- The steady state model was used to calibrate horizontal permeability (Kx) and vertical permeability (Kz) to the distribution of observed groundwater levels on a regional scale. Again, the calibration statistics indicate a very good calibration was achieved. However it is likely that, given the boundary conditions, correlation amongst parameters and

sparse data, the calibration will be relatively insensitive to many of these parameters (i.e. there is no unique preferred value, but rather a plausible range). This is discussed further below.

The main elements of model calibration are listed and assessed in Table 6 below.

Table 6 Assessment of model calibration and verification

Item	Assessment criterion	Addressed?	Comments	Impact on the project?
5.1	Is there sufficient evidence provided for model calibration?	Adequate	Yes, standard calibration plots and statistics are provided.	N/A
5.2	Is the model sufficiently calibrated against spatial observations?	Adequate	Yes, steady state calibration of the regional model against groundwater heads is shown in Fig. 9-3 and Table 9-2	N/A
5.3	Is the model sufficiently calibrated against temporal observations?	Adequate	Yes, transient calibration of the ATP model against GW head and flux is shown in Fig. 9-6 and Table 9-5	N/A
5.4	Are calibrated parameter distributions and ranges plausible?	Yes	Yes, generally; Could do with more verification against field data and experience given insensitivities.	Likely minimal impact
5.5	Does the calibration statistic satisfy agreed performance criteria?	Very Good	Yes, the quoted scaled RMSE is well below the adopted 5% performance criteria.	N/A
5.6	Are there good reasons for not meeting agreed performance criteria?	Satisfied	Performance criteria are met	N/A

With regard to the above approach, it is noted that the ATP calibration exercise provides well-constrained estimates for hydraulic conductivity as well as storage and it is not clear in the report why the ATP transient model parameters were not given preference over the steady state calibrated parameters. The argument that the steady state model parameters are more representative because of its regional scale (URS, 2011c, page 108) is not strictly valid, given that the regional calibration data are sparse and lack estimates of groundwater flow or discharge.

Figure 2 shows that the calibrated model parameters lie generally within the broad range of field estimates of hydraulic conductivity. Typically the adopted values lie close to a mid-range value which should be considered plausible (vertical permeability in the interburden units are a possible exception and seem anomalously low). It is further noted that the parameter values are generally consistent with values of hydraulic conductivity observed in coal measures in other regions of Australia (e.g. Hunter Valley; Southern Coalfields, NSW), were K_h values in the range of 10^{-1} to 10^{-4} m/d are common.

Similarly, the calibrated storage coefficients seem plausible. Confined storativity (Sc) in the range of 10^{-4} to 10^{-6} is commonly observed in sandstone aquifers, and low specific yields (Sy) of 1 to 2% or less is typical of sparsely fractured rocks. It is noted that the specific yield (to which inflows are sensitive) are set to just under 1% which, although considerably less than the URS interim model, is still considered plausible.

Estimates of potential drawdown within the Rewan Formation and the GAB aquifers will be reliant on reasonable estimates of permeability in the Rewan Formation which acts as a regional aquitard between the Permian mine sequence and the GAB. It is noted that the calibrated values of horizontal (K_h) and vertical (K_v) hydraulic conductivity for the Rewan Formation are 6 x 10^{-5} m/d and 8.3 x 10^{-4} m/d respectively. Results of drill stem permeability tests for the Rewan Formation are summarised in the supplementary EIS (SEIS; Appendix N). These test results show a range in values with a geometric mean K_h of 0.02 m/d and K_v of 0.004 m/d), but also implies that individual units within the Formation will have very low permeability (<10^{-4} m/d) consistent with this formation being a regional aquitard that will impede the transmission of drawdown. It is noted that the model invokes a vertical anisotropy (K_h/K_v) of 0.07, implying vertical permeability is higher than horizontal permeability, whereas the published test data implies a vertical anisotropy (K_h/K_v) of 5.0, which is more typical of stratified sedimentary rocks.

5.6 Verification

The term "verification" has a specific meaning in numerical model calibration procedures. According to the MDBC guidelines, verification typically relates to transient groundwater models where sufficient time-series observation data (e.g. rainfall records, bore and stream hydrographs, groundwater abstraction records) are available. In such a case, the model may be calibrated using only a subset (say 75%) of the observation data, while reserving the remaining portion to "test" the predictive ability of the calibrated model against real data.

It is unusual to have sufficient data to make verification in this sense practical or worthwhile and it is not often carried out. In the case of the URS revised model, there is clearly insufficient time-series data to carry out verification.

The main elements of model verification are listed and assessed in Table 7 below.

Table 7 Assessment of model calibration and verification

Item	Assessment criterion	Addressed?	Comments	Impact to the project?
6.1	Is there sufficient evidence provided for model verification?	N/A	Verification is not possible due to the lack of regional and mine-scale transient data	N/A
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A		N/A
6.3	Are there good reasons for unsatisfactory verification?	N/A		N/A

5.7 Predictions

Predictions of groundwater inflow into the mine pit and underground workings were undertaken using the MODHMS "predictive model" which incorporated the calibrated hydraulic parameters. The mine schedule was represented using MODFLOW drain boundaries, located at the appropriate layer and activated according to the interpolated mine schedule. Estimates of groundwater inflow were obtained from the model output of groundwater flux through the drain boundaries.

Notwithstanding the uncertainties relating to parameters, this approach to modelling mine inflows is appropriate and is standard within the groundwater industry. Multiple scenarios of

the model were run to assess uncertainty in the predicted groundwater inflows. This is discussed further in the following two sections.

The proposal scope of URS included a number of predictive outputs, some of which were not included or seem to be based on earlier versions of the model. These include:

- Groundwater drawdown; Section 6 contains drawdown output from an earlier model but it is noted that the drawdown extends beyond the new model extent.
- Calculation of potential drawdown in the Colinlea Sandstone using SEEP/W; this is not included in this report.
- Use of Mote Carlo type stochastic representations of K fields; no results are presented for this.
- Prediction of the cumulative impacts of the proposed Waratah mine to the south of the Alpha project; this was included in the model, but the results were not clearly presented.

The main elements of model prediction are listed and assessed in Table 8 below.

Table 8 Assessment of model prediction

Item	Assessment criterion	Addressed?	Comments	Impact to project?
7.1	Have multiple scenarios been run for climate variability?	N/A	N/A; Not included, but not amongst the objectives	No impact on the base case estimates
7.2	Have multiple scenarios been run for operational / management alternatives?	Adequate	Multiple scenarios have been run as part of the sensitivity and uncertainty analysis.	N/A
7.3	Is the time horizon for prediction comparable with the length of the calibration + verification period?	Adequate	Not comparable, but the time line for transient calibration is limited to the ATP dewatering program.	No significant impact
7.4	Are the model predictions plausible?	Adequate	Predicted pit inflows are within the expected range. High and low scenarios are also reasonable. See Section 5.9 for further discussion.	N/A

5.8 Sensitivity analysis

Sensitivity analysis is the process of quantifying the impact on an aquifers simulated response to an incremental variation in a model parameter or a model stress (MDBC, 2000). The URS final modelling report details sensitivity analysis carried out in two ways:

1. During the automated calibration process, PEST generates a matrix of relative sensitivity coefficients. These coefficients represent the relative composite sensitivity (RCS) of each parameter with respect to the calibration objective function. These have been plotted on histograms in Figures 9-12 and 9-13 of the URS report.
2. The predictive model was run under twenty five scenarios in order to test the impact of changing key model parameters on groundwater inflow predictions. The results of this analysis are presented in Figures 10-6 to 10-9 of the URS report.

Together these provide a good understanding of parameter sensitivities in the model and their impact on groundwater predictions (i.e. uncertainty). The sensitivity analyses carried out are in accordance with the MDBC guideline and are actually more rigorous than is commonly seen in modelling reports.

The main elements of sensitivity analysis are listed and assessed in Table 9 below. The implications of the sensitivity analysis are discussed further below.

Table 9 Assessment of sensitivity analysis

Item	Assessment criterion	Addressed?	Comments	Impact to project?
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?	Adequate	Yes the sensitivity analysis covers both calibration sensitivity and predictive uncertainty.	N/A
8.2	Are sensitivity results used to qualify the reliability of the model calibration?	Adequate	Yes, some scenarios are shown to push model out of calibration, see Fig. 10-5 and 10-6	N/A
8.3	Are sensitivity results used to qualify the accuracy of the model prediction?	Adequate	Yes, key sensitive parameters are varied to develop a predictive uncertainty estimate. See Figs. 10-7 to 10-10.	N/A

5.8.1 Parameter sensitivity

The sensitivity analyses presented in the final URS report are summarised in two tables (11 and 12), below. Although not presented in the URS report in this manner, the tables allow comparison between the sensitivity of the parameter with respect to calibration versus the sensitivity with respect to the predictive output (inflow). This is turn allows assessment of how well predictive uncertainty has been assessed.

The following conclusions are drawn in this review (Tables 10 and 11) on the basis of model and parameter sensitivity undertaken by URS on both the steady state and transient (ATP) models:

- Model calibration and (inflow) predictions are generally insensitive to estimates of storage and permeability for the GAB (transient ATP model).
- Model calibration and (inflow) predictions are typically insensitive or moderately sensitive to horizontal permeability (Kx) (transient ATP model).
- Model predictions of inflows are most sensitive to vertical permeability (Kz) and specific yield in most coal seam and interburden units (transient ATP model).
- In contrast, model calibration is relatively insensitive to specific yield (Sy) and moderately sensitive to vertical permeability (steady state model).

Parameters for which the calibration sensitivity is low and the prediction sensitivity is high are said to exhibit Type IV sensitivity (Richey & Rumbaugh, 1996). In such cases there potential that influential model parameters are not well constrained by the observation data and those parameters should be further constrained by field data and/or professional judgement (this point forms the main recommendation of this review). This is the case for the parameters Kz and Sy in the coal seams and interburden units.

Table 10 Review of model parameterisation – Permeability and recharge

Hydrogeological Unit	Kx (m/day)	Kz (m/day)	Relative Sensitivity to calibration		Relative Sensitivity to Inflow Prediction		Comments / consequence
			Kx	Kz	Kx	Kz	
Great Artesian Basin	5.6	0.8	Mod	Mod	Low	Low	Relatively insensitive
Rewan Formation	6.0×10^{-5}	8.3×10^{-4}	Low	Low	Low	Low	Insensitive
Bandanna Formation	1.8×10^{-4}	1.0×10^{-3}	High	High	Low	High	Parameter reasonably constrained by calibration
C Seam	1.0×10^{-2}	2.0×10^{-3}	Low	Low	Low	High	***Potential consequence:*** For parameters where the calibration sensitivity is low and the prediction sensitivity is high (known as ***Type IV sensitivity***; Richey & Rumbaugh, 1996), there is potential that influential model parameters are not well constrained. Parameters should be further constrained by field data and professional judgement. **Mainly relates to Kz of coal seams and interburden**
C-D Sandstone	1.2×10^{-1}	1.0×10^{-4}	Mod	Mod	Mod	Mod	
D Seam	1.0×10^{-2}	2.0×10^{-3}	Low	Low	Low	High	
D-E Sandstone	5.0×10^{-2}	**2.3×10^{-6}**	Mod	Mod	Low	High	
E Seam	1.0×10^{-2}	2.0×10^{-3}	Low	Low	Low	High	
Sub-E Sandstone	1.0×10^{-2}	**2.3×10^{-6}**	Mod	Mod	Low	High	
Joe Joe Formation	1.8×10^{-4}	1.0×10^{-3}	High	High	Low	High	
Recharge Rate	N/A	N/A	Low		Mod		Relatively insensitive
EVT Extinction depth	N/A	N/A	Low		N/A		Relatively insensitive

Table 11 Review of model parameterisation – Storage

Hydrogeological Unit	Sc	Sy	Relative Sensitivity to calibration		Relative Sensitivity to Inflow Prediction		Comments / consequence
			Sc	Sy	Sc	Sy	
Great Artesian Basin	1.0×10^{-4}	5.0×10^{-2}	Low	Low	Low	Low	Insensitive
Rewan Formation	4.6×10^{-4}	8.4×10^{-3}	High	Low	Mod	High	***Potential consequence:*** For parameters where the calibration sensitivity is low and the prediction sensitivity is high (known as ***Type IV sensitivity***; Richey & Rumbaugh, 1996), there is potential that influential model parameters are not well constrained. Parameters should be further constrained by field data and professional judgement. **This relates to Specific Yield (Sy) in most units.**
Bandanna Formation	4.6×10^{-4}	8.4×10^{-3}	High	Low	Mod	High	
C Seam	9.8×10^{-6}	8.0×10^{-3}	Mod	Low	Low	High	
C-D Sandstone	6.2×10^{-6}	8.0×10^{-3}	Mod	Low	Low	High	
D Seam	9.8×10^{-6}	8.0×10^{-3}	Mod	Low	Low	High	
D-E Sandstone	4.6×10^{-4}	8.4×10^{-3}	High	Low	Mod	High	
E Seam	9.8×10^{-6}	8.0×10^{-3}	Mod	Low	Low	High	
Sub-E Sandstone	4.6×10^{-4}	8.4×10^{-3}	High	Low	Mod	High	
Joe Joe Formation	4.6×10^{-4}	8.4×10^{-3}	High	Low	Mod	High	

5.9 Uncertainty analysis

The proposal by URS included quantification of uncertainty in model outputs as a result of uncertainty in key parameters (Phase 6 – model predictions). An assessment of prediction uncertainty was carried out and presented in Section 10.3 of the URS final report. The uncertainty analysis was carried out using a good approach as follows:

- Twenty-five scenarios were developed in which key parameters thought to have an impact on inflow predictions were varied systematically. Each scenario was run and the groundwater inflows and calibration statistics were noted for each run.
- Model runs that generated poor calibration statistics were deemed to be invalid.
- Scenarios with the highest and lowest groundwater inflow predictions were identified and used to represent the high (case 7) and low (case 21) groundwater inflow estimates.
- Case 7 (high) includes doubling of the specific yield in several layers, whereas case 21 (low) includes reduction of the Kz6 (Rewan, Bandanna, Joe Joe Formations) by a factor of 10^{-3} to be more consistent with the ATP calibrated values of Kz.

This is considered to be a relatively sound approach to uncertainty analysis. Table 10-8 and Figure 10-10 of the final URS report clearly show the predicted annual groundwater inflow rates for the base case and nominated high and low inflow scenarios.

It should be noted that the uncertainty analysis was not extended to estimates of potential groundwater drawdown due to mining.

The main elements of uncertainty analysis are listed and assessed in Table 12 below.

Table 12 Assessment of uncertainty analysis

Item	Assessment criterion	Addressed?	Comments	Impact to project?
9.1	If required by the project brief, is uncertainty quantified in any way?	Adequate	Yes, an assessment of uncertainty was carried out as part of the sensitivity analysis; see Section 10.3 (URS)	N/A

6. Conclusion

A large amount of detailed hydrogeological fieldwork has been carried out at the Alpha Coal Project site leading to a good conceptual understanding of the site. Additional fieldwork carried out by URS has further constrained estimates of key aquifer parameters and enhanced the conceptual understanding of groundwater in the project area. Parsons Brinckerhoff considers that the field investigations carried out to date have been of appropriate scope and were executed and analysed in a competent manner.

The final modelling report by URS (2011c) summarises the findings of the field investigations, model revision and calibration, and model predictions of groundwater inflow. The report is broadly consistent with the recommended reporting standards of the MDBC (2000) guidelines.

The numerical models were significantly revised and rebuilt using the MODHMS software code. A review of the model design, calibration, sensitivity analysis and prediction against the MDBC guideline indicates that the modelling has been performed broadly in line with the guideline and industry best practice. Several minor issues relating to parameterisation and model design were noted but these are not considered to adversely affect the modelled inflow estimates.

An uncertainty analysis was carried out by running 25 scenarios with differing values of key sensitive parameters. The results of the uncertainty analysis were used to define a high and low inflow estimate (241 GL and 105 GL, LOM) in addition to a base case estimate of 176 GL (LOM). Both the inflow estimates and the parameters used in the models appear to be within plausible ranges compared with the field data and experience elsewhere.

While groundwater drawdown impacts were not considered in detail in the URS (2011c) report, the calibrated model parameters themselves are broadly appropriate for assessing potential drawdown impacts in the vicinity of the mine.

7. Recommendations

We make the following recommendations in relation to the final URS report and ongoing investigations:

- Insensitive aquifer parameters that are important to inflow predictions need to be independently constrained by field data and/or professional judgement (MDBC, 2000; Niccoli, 2009). A revised final report would benefit from the inclusion of a section that clearly discusses field data and how that data constrains insensitive parameters such as Kz and Sy in key aquitard units.

- The eastern no-flow/constant head boundary was significantly altered in the updated model to account for the outcrop limits of the Colinlea Sandstone – Joe Joe Formation contact. This was done on the assumption that the Joe Joe Formation is essentially impermeable. The justification and implications of this change need to be better discussed in the report. In particular, how does this assumption alter the predicted inflow over the long term? And how does it alter the predicted cumulative drawdown related to mining?

- It is recommended that the uncertainty analysis be extended to estimates of drawdown with particular focus on sensitivities to the hydraulic conductivity in the Rewan Formation and model boundary conditions.

- If required by Hancock Coal, DERM or SEWPaC, groundwater drawdown maps based on the updated model should be presented.

- Parsons Brinkerhoff concurs with the URS recommendation of revising the groundwater model after a year or two of operational data has been collected, or if sufficient data are obtained from a pilot dewatering bore field.

8. References

Hancock Prospecting Pty Ltd, 2010a; Alpha Coal Project Environmental Impacts Statement, Volume 2, Section 4 Geology.

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NTEC Environmental Technology, 2011b; *Alpha Coal Project and Kevin's Corner Project: Regional Groundwater Model for URS Australia Pty Ltd*, Report 1045-1-RevC, dated 3 November 2011

Parsons Brinckerhoff, 2011, *Hancock Coal Pty Ltd, Alpha Coal Project, Site water management system and water balance technical report*, dated April 2011

Salva Resources, 2009; *Summary of Galilee Regional Model (GAB)*. Internal Project memorandum from Salva Resources, dated 18 February 2009

SEWPaC, 2011. *SEWPaC comments on the addendum to the SEIS – Alpha Coal Project (2008/4648),* dated 22 December 2011.

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URS Pty Ltd, 2011b; *Interim Modelling Report, Hancock Coal Pty Ltd Groundwater Resource, Water Supply and Dewatering Assessment*, dated 11 November 2011

URS Pty Ltd, 2011c*; Report, Hancock Coal Pty Ltd, Alpha and Kevin's Corner Coal Projects Predictive Groundwater Modelling,* dated 23 December 2011

URS Pty Ltd, 2012*; Presentation to SEWPaC, Alpha Coal Project – Groundwater: Response to SEWPaC comments on the Addendum to the SEIS,* dated March 2012

Appendix A

Model review checklist (MDBC, 2000)

Groundwater Model Appraisal (after Middlemis, 2001, Appx E) **Model Report Ref:** URS (Dec 2011), Final Modelling Report (Alpha Coal Mine), Hancock Co **Date:** 25/01/2012 PARSONS BRINCKERHOFF

Q	Question	N/A or Unknown	Score_0	Score_1	Score_3	Score_5	Score	Max_Score	Comments
1.0	**THE REPORT**								
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good	5	5	Yes the scope was clearly listed in sections 1.1 and Objectives clearly listed in 3.1; Deliverables are listed in section 1.2
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes		3	3	Yes, the model is described as "moderate complexity" in section 3.2, which is appropriate
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good	1	5	No overall hydraulic water balance is reported although components of the water balance are discussed in 6.8.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good	3	5	Yes; the results include estimates of drawdown and mine inflow as well as an analysis of uncertainty
1.5	Are the model results of any practical use?			No	Maybe	Yes	5	5	Yes; they are of direct use in mine planning. Predictions are discussed further below
2.0	**DATA ANALYSIS**								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good	3	5	Yes; Good summary of regional data and results from investigations; could have been more discussion on field K measurements and how they might guide model parameterisation
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good	3	5	Yes, contours derived from exploration holes and VWPs are shown; regional data are limited
2.3	Have all potential recharge data been collected and analysed? (rainfall, stream flow, irrigation, floods etc.)		Missing	Deficient	Adequate	Very Good	3	5	Recharge has been assessed in section 4.7 in some detail and mechanisms for recharge described.
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, spring flow, etc.)		Missing	Deficient	Adequate	Very Good	3	5	Section 4.8 discussed discharge; no obvious discharge in project areas; the mechanism for discharge to Sandy Creek beds is a little vague.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good	3	5	Yes, to the extent possible. Report notes there is negligible response in hydrographs to high rainfall events in 2010/11
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes	5	5	Yes, Figures 9-7 to 9-11 show observed and simulated hydrographs for the Alpha Test Pit dewatering
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes		3	3	Most of the time, but it is noted that Figures 10-10 and 10-11 have incorrect units (M3, not GL).
3.0	**CONCEPTUALISATION**								
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes	5	5	Yes, conceptual framework for both the regional system and mining are presented.
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good	3	5	Yes; conceptual model is mainly from earlier JBT reports and are clear, reasonable and concise
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good	3	5	Yes, Figures 4-9 shows the regional conceptualisation and Figures 7-1 to 7-4 show mining conceptualisation
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No		3	3	Adequate
4.0	**MODEL DESIGN**								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes	3	5	Spatial extent is based on the conceptual hydrogeology and estents of aquifer.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good	3	5	Boundaries are reasonable based on conceptualisation; The eastern no-flow boundary may be restrictive.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes	5	5	Yes, MODHMS is appropriate (as was Vistas/Surfact)
5.0	**CALIBRATION**								
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good	3	5	Yes, standard calibration plots and statistics are provided.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good	3	5	Yes, steady state calibration of the regional model against groundwater heads is shown in Fig. 9-3 and Tbl. 9-2
5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good	3	5	Yes, transient calibration of the ATP model against gw head and flux is shown in Fig. 9-6 and Tbl. 9-5
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes	3	5	Yes, generally; Could do with more verification against field data and experience given insensitivities.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good	5	5	Yes, the quoted scaled RMSE is well below the adopted 5% performance criteria.
5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good	0	0	N/A
6.0	**VERIFICATION**								
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good	0	0	N/A
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes	0	0	N/A
6.3	Are there good reasons for unsatisfactory verification?	N/A	Missing	Deficient	Adequate	Very Good	0	0	N/A

Groundwater Model Appraisal (after Middlemis, 2001, Appx E) **Model Report Ref:** URS (Dec 2011), Final Modelling Report (Alpha Coal Mine), Hancock Co **Date:** 25/01/2012

PARSONS BRINCKERHOFF

Q	Question	N/A or Unknown	Score_0	Score_1	Score_3	Score_5	Score	Max_Score	Comments
1.0	**THE REPORT**								
7.0	**PREDICTION**								
7.1	Have multiple scenarios been run for climate variability?	N/A	Missing	Deficient	Adequate	Very Good	0	0	N/A; Not included, but not amongst the objectives
7.2	Have multiple scenarios been run for operational / management alternatives?		Missing	Deficient	Adequate	Very Good	3	5	Multiple scenarios have been run as part of the sensitivity and uncertainty analysis.
7.3	Is the time horizon for prediction comparable with the length of the calibration + verification period?		Missing	No	Maybe	Yes	3	0	Not comparable, but the time line for transient calibration is limited to the ATP dewatering program.
7.4	Are the model predictions plausible?			No	Maybe	Yes	3	5	Predicted pit inflows are within the expected range. High and low scenarios are also reasonable. See text for discussion.
8.0	**SENSITIVITY ANALYSIS**								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good	3	5	Yes the sensitivity analysis covers both calibration sensitivity and predictive uncertainty.
8.2	Are sensitivity results used to qualify the reliability of the model calibration?		Missing	Deficient	Adequate	Very Good	3	5	Yes, some scenarios are shown to push model out of calibration, see Fig. 10-5 and 10-6
8.3	Are sensitivity results used to qualify the accuracy of the model prediction?		Missing	Deficient	Adequate	Very Good	3	5	Yes, key sensitive parameters are varied to develop a predictive uncertainty estimate. See Figs. 10-7 to 10-10.
9.0	**UNCERTAINTY ANALYSIS**								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes	3	5	Yes, as part of the sensitivity analysis; see Section 10.3

10.0	**TOTAL SCORE**						103	144	**PERFORMANCE: 71.5 %**

Steady-State Data

Well	Easting	Northing	Obs (m)	Cal (m)	Residual (m)	Layer
1228C	445706.3	7444681	287.80	289.03	-1.23	6
1228C	445706.3	7444681	292.20	288.99	3.21	8
1234C	445701.6	7447597	282.70	286.59	-3.89	6
1234C	445701.6	7447597	277.90	286.57	-8.67	8
1238C	445179	7449764	275.70	284.76	-9.06	8
1238C	447231.6	7453128	278.40	281.65	-3.25	6
1313C	447231.6	7453128	279.50	281.76	-2.26	8
1313C	440159.9	7454610	282.21	281.10	1.11	6
1356C	440159.9	7454610	283.86	281.08	2.79	8
1356C	446180	7430035	300.30	300.51	-0.21	8
AMB-01	446725.2	7441097	289.60	292.03	-2.43	6
AVP-01	446725.2	7441097	288.10	291.99	-3.89	8
AVP-01	447700.5	7435936	293.50	296.12	-2.62	8
AVP-03	439677.1	7431710	298.80	298.82	-0.02	6
AVP-04	439677.1	7431710	299.20	298.78	0.42	8
AVP-04	445052.3	7433186	299.74	298.08	1.66	6
AVP-05	445052.3	7433186	299.51	298.04	1.48	8
AVP-05	445052.3	7433186	297.70	298.08	-0.38	5
AVP-05	446510.4	7431957	299.36	299.10	0.26	6
AVP-06	446510.4	7431957	299.09	299.06	0.04	8
AVP-06	445862	7430685	299.49	300.04	-0.56	6
AVP-07	445862	7430685	299.93	300.00	-0.06	8
AVP-07	446280.9	7430685	299.83	300.02	-0.19	8
AVP-08	446280.9	7430685	299.56	300.06	-0.50	7
AVP-08	445607.2	7428457	301.00	301.75	-0.75	6
AVP-09	445920.7	7422777	305.83	306.20	-0.38	8
AVP-10	437531.1	7440861	294.56	291.48	3.08	6
AVP-11	437531.1	7440861	294.93	291.45	3.48	8
AVP-11	434456.9	7430044	304.27	299.55	4.72	8
AVP-13	438634.3	7436473	300.36	295.01	5.35	6
AVP-14	438634.3	7436473	300.97	294.97	6.00	8

Transient Data

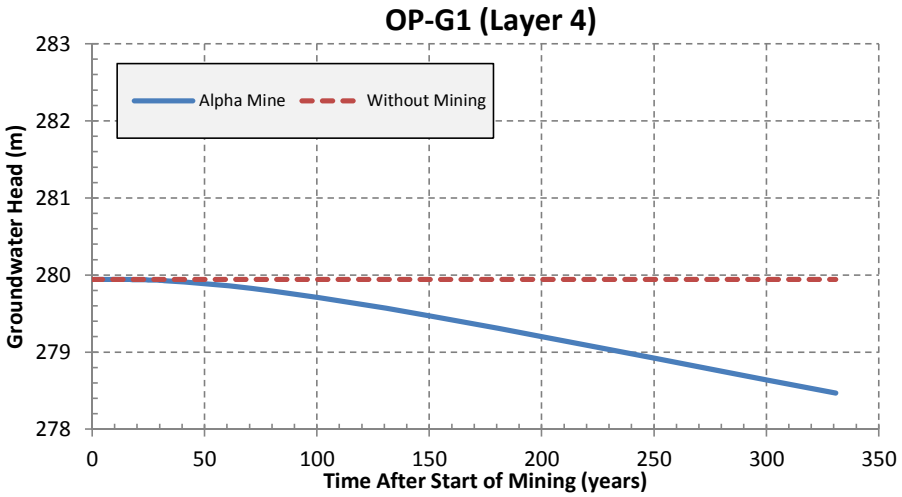
Bore	Easting	Northing	Obs (m)	Cal (m)	Residual (m)	Layer
AVP7_CD-Sand	445862	7430685	298.33	297.13	1.20	6
AVP7_CD-Sand	445862	7430685	294.01	294.77	-0.76	6
AVP7_CD-Sand	445862	7430685	292.64	296.25	-3.61	6
AVP7_CD-Sand	445862	7430685	292.45	293.60	-1.15	6
AVP7_CD-Sand	445862	7430685	291.24	293.16	-1.91	6
AVP7_CD-Sand	445862	7430685	290.12	292.36	-2.25	6
AVP7_CD-Sand	445862	7430685	290.45	294.13	-3.68	6
AVP7_CD-Sand	445862	7430685	287.60	292.45	-4.85	6
AVP7_CD-Sand	445862	7430685	280.60	284.12	-3.51	6
AVP7_CD-Sand	445862	7430685	278.04	279.81	-1.76	6
AVP7_CD-Sand	445862	7430685	271.96	270.83	1.14	6
AVP7_CD-Sand	445862	7430685	267.36	268.65	-1.29	6
AVP7_CD-Sand	445862	7430685	265.89	267.74	-1.84	6
AVP7_CD-Sand	445862	7430685	265.52	267.16	-1.64	6
AVP7_CD-Sand	445862	7430685	265.06	266.73	-1.67	6
AVP7_CD-Sand	445862	7430685	264.78	266.38	-1.60	6
AVP7_DE-Sand	445862	7430685	298.58	298.70	-0.12	8
AVP7_DE-Sand	445862	7430685	296.44	296.87	-0.43	8
AVP7_DE-Sand	445862	7430685	295.81	295.38	0.43	8
AVP7_DE-Sand	445862	7430685	295.48	294.82	0.66	8
AVP7_DE-Sand	445862	7430685	294.45	293.91	0.54	8
AVP7_DE-Sand	445862	7430685	293.60	292.77	0.84	8
AVP7_DE-Sand	445862	7430685	293.70	292.07	1.62	8
AVP7_DE-Sand	445862	7430685	292.69	291.87	0.82	8
AVP7_DE-Sand	445862	7430685	284.69	286.75	-2.07	8
AVP7_DE-Sand	445862	7430685	282.66	283.53	-0.87	8
AVP7_DE-Sand	445862	7430685	277.90	278.78	-0.87	8
AVP7_DE-Sand	445862	7430685	274.20	273.88	0.32	8
AVP7_DE-Sand	445862	7430685	272.41	270.91	1.51	8
AVP7_DE-Sand	445862	7430685	271.63	269.29	2.34	8
AVP7_DE-Sand	445862	7430685	270.41	268.06	2.35	8
AVP7_DE-Sand	445862	7430685	270.16	266.91	3.25	8
AVP8_CD-Sand	446280.9	7430685	298.59	295.51	3.08	6
AVP8_CD-Sand	446280.9	7430685	292.58	292.48	0.10	6

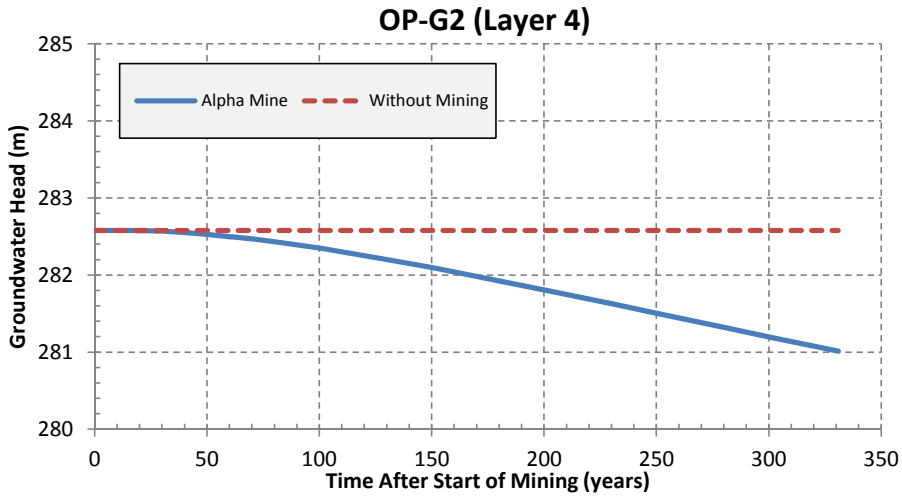
Bore	Easting	Northing	Obs (m)	Cal (m)	Residual (m)	Layer
AVP8_CD-Sand	446280.9	7430685	291.85	295.90	-4.05	6
AVP8_CD-Sand	446280.9	7430685	291.99	291.22	0.77	6
AVP8_CD-Sand	446280.9	7430685	290.39	290.75	-0.36	6
AVP8_CD-Sand	446280.9	7430685	289.46	289.87	-0.41	6
AVP8_CD-Sand	446280.9	7430685	290.36	293.57	-3.21	6
AVP8_CD-Sand	446280.9	7430685	287.30	290.27	-2.97	6
AVP8_CD-Sand	446280.9	7430685	278.48	281.36	-2.88	6
AVP8_CD-Sand	446280.9	7430685	276.39	275.75	0.64	6
AVP8_CD-Sand	446280.9	7430685	269.24	266.51	2.73	6
AVP8_CD-Sand	446280.9	7430685	263.51	264.83	-1.32	6
AVP8_CD-Sand	446280.9	7430685	261.79	264.10	-2.31	6
AVP8_CD-Sand	446280.9	7430685	261.78	263.65	-1.88	6
AVP8_CD-Sand	446280.9	7430685	261.46	263.31	-1.85	6
AVP8_CD-Sand	446280.9	7430685	261.17	263.04	-1.86	6
AVP8_DE-Sand	446280.9	7430685	299.00	298.09	0.91	8
AVP8_DE-Sand	446280.9	7430685	294.87	294.13	0.74	8
AVP8_DE-Sand	446280.9	7430685	293.34	293.29	0.05	8
AVP8_DE-Sand	446280.9	7430685	293.19	291.55	1.65	8
AVP8_DE-Sand	446280.9	7430685	292.01	290.48	1.53	8
AVP8_DE-Sand	446280.9	7430685	291.23	288.84	2.39	8
AVP8_DE-Sand	446280.9	7430685	291.05	288.91	2.14	8
AVP8_DE-Sand	446280.9	7430685	289.11	288.36	0.75	8
AVP8_DE-Sand	446280.9	7430685	278.50	281.16	-2.66	8
AVP8_DE-Sand	446280.9	7430685	275.48	277.26	-1.78	8
AVP8_DE-Sand	446280.9	7430685	268.49	271.02	-2.53	8
AVP8_DE-Sand	446280.9	7430685	262.67	266.12	-3.45	8
AVP8_DE-Sand	446280.9	7430685	261.28	263.22	-1.95	8
AVP8_DE-Sand	446280.9	7430685	260.83	261.86	-1.03	8
AVP8_DE-Sand	446280.9	7430685	258.99	260.46	-1.47	8
AVP8_DE-Sand	446280.9	7430685	258.85	259.52	-0.67	8
AMB-01_DE-Sand	446180	7430035	300.05	299.20	0.85	8
AMB-01_DE-Sand	446180	7430035	299.41	299.07	0.33	8
AMB-01_DE-Sand	446180	7430035	298.56	298.66	-0.10	8
AMB-01_DE-Sand	446180	7430035	298.15	298.27	-0.12	8
AMB-01_DE-Sand	446180	7430035	297.57	297.90	-0.33	8

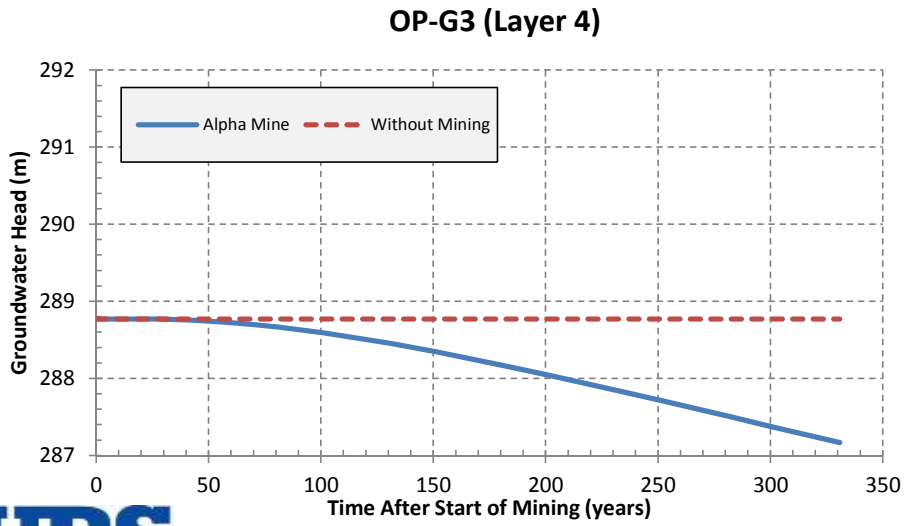
Bore	Easting	Northing	Obs (m)	Cal (m)	Residual (m)	Layer
AMB-01_DE-Sand	446180	7430035	296.90	297.47	-0.57	8
AMB-01_DE-Sand	446180	7430035	296.56	297.02	-0.47	8
AMB-01_DE-Sand	446180	7430035	295.71	296.68	-0.97	8
AMB-01_DE-Sand	446180	7430035	288.80	292.43	-3.64	8
AMB-01_DE-Sand	446180	7430035	286.29	289.01	-2.73	8
AMB-01_DE-Sand	446180	7430035	282.55	285.12	-2.56	8
AMB-01_DE-Sand	446180	7430035	279.52	281.30	-1.78	8
AMB-01_DE-Sand	446180	7430035	277.95	278.46	-0.51	8
AMB-01_DE-Sand	446180	7430035	276.99	276.50	0.49	8
AMB-01_DE-Sand	446180	7430035	276.26	275.06	1.20	8

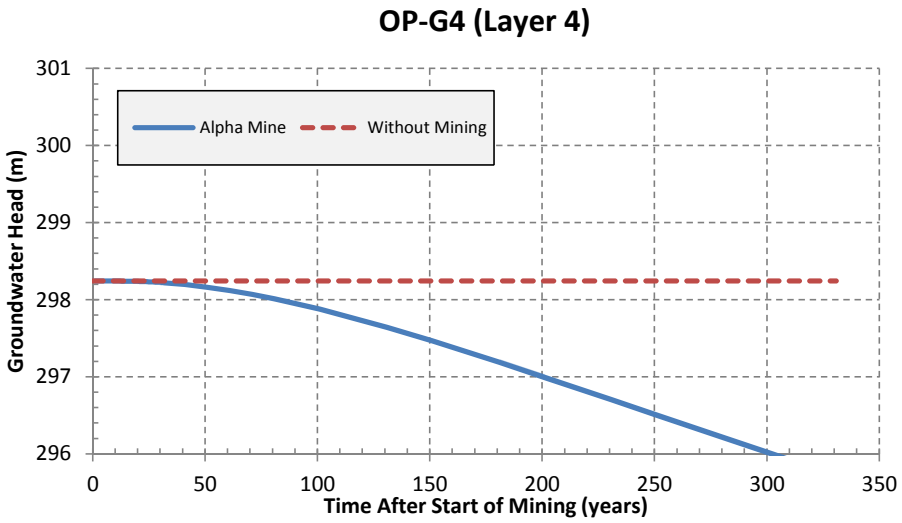
E

Appendix E Observation point hydrographs









URS

Model Projected Groundwater Heads for 30-Year Life-of-Mine and Long-Term Recovery - Bandanna Formation

Figure E1

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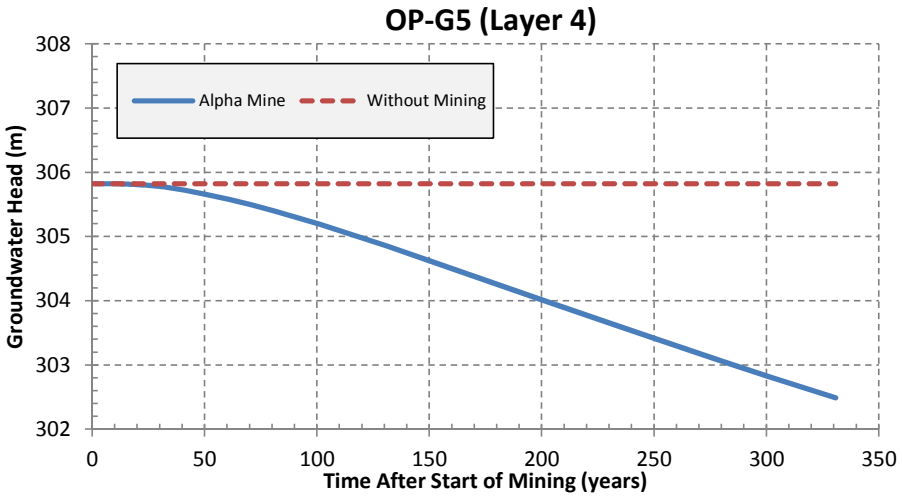

URS

Model Projected Groundwater Heads for 30-Year Life-of-Mine and Long-Term Recovery - Bandanna Formation

Figure E2

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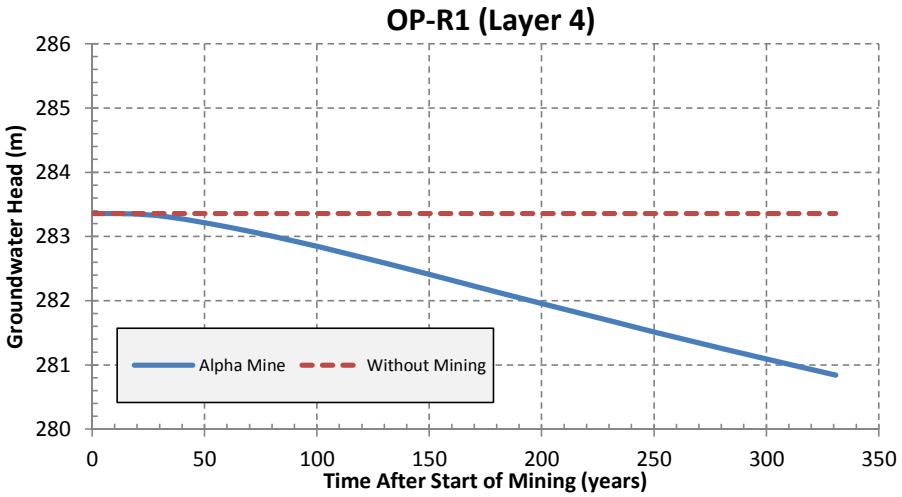

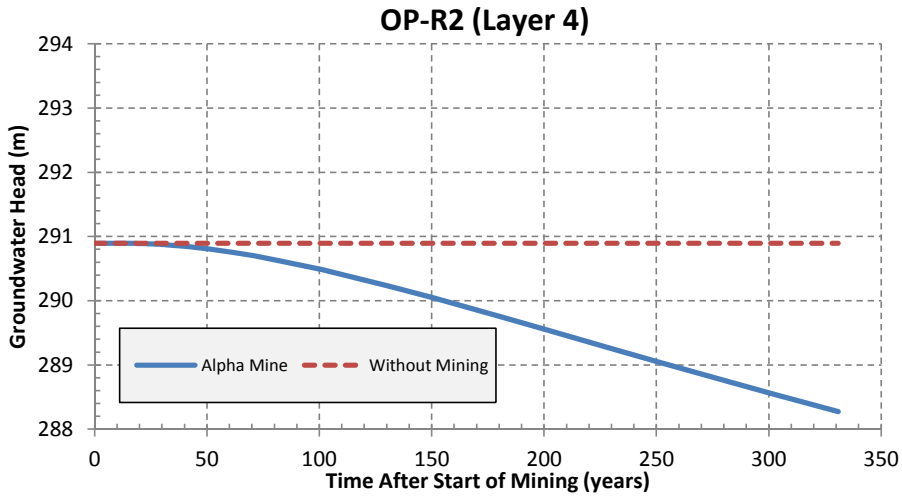

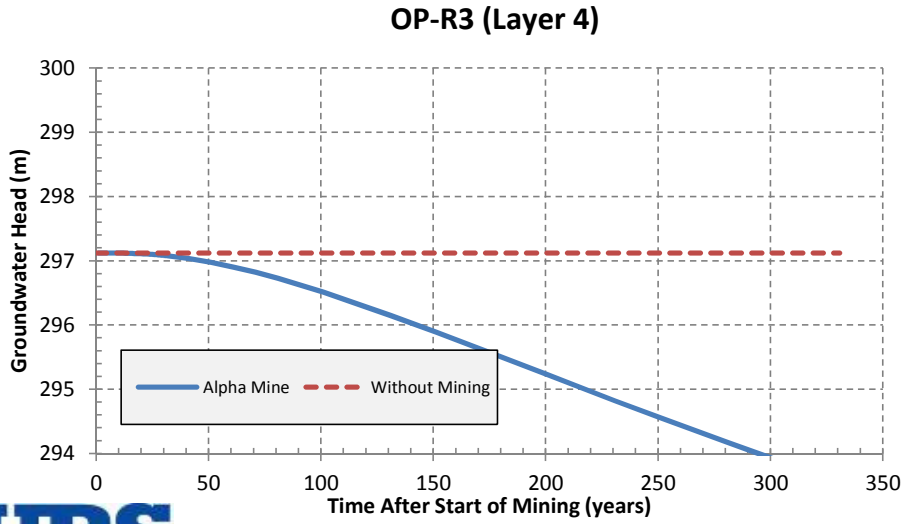

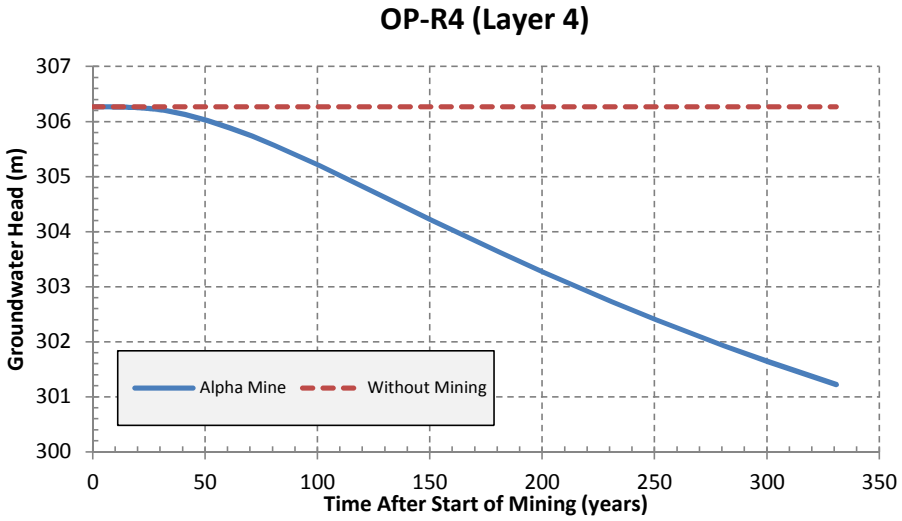

URS

Model Projected Groundwater Heads for 30-Year Life-of-Mine and Long-Term Recovery - Bandanna Formation

Figure E3

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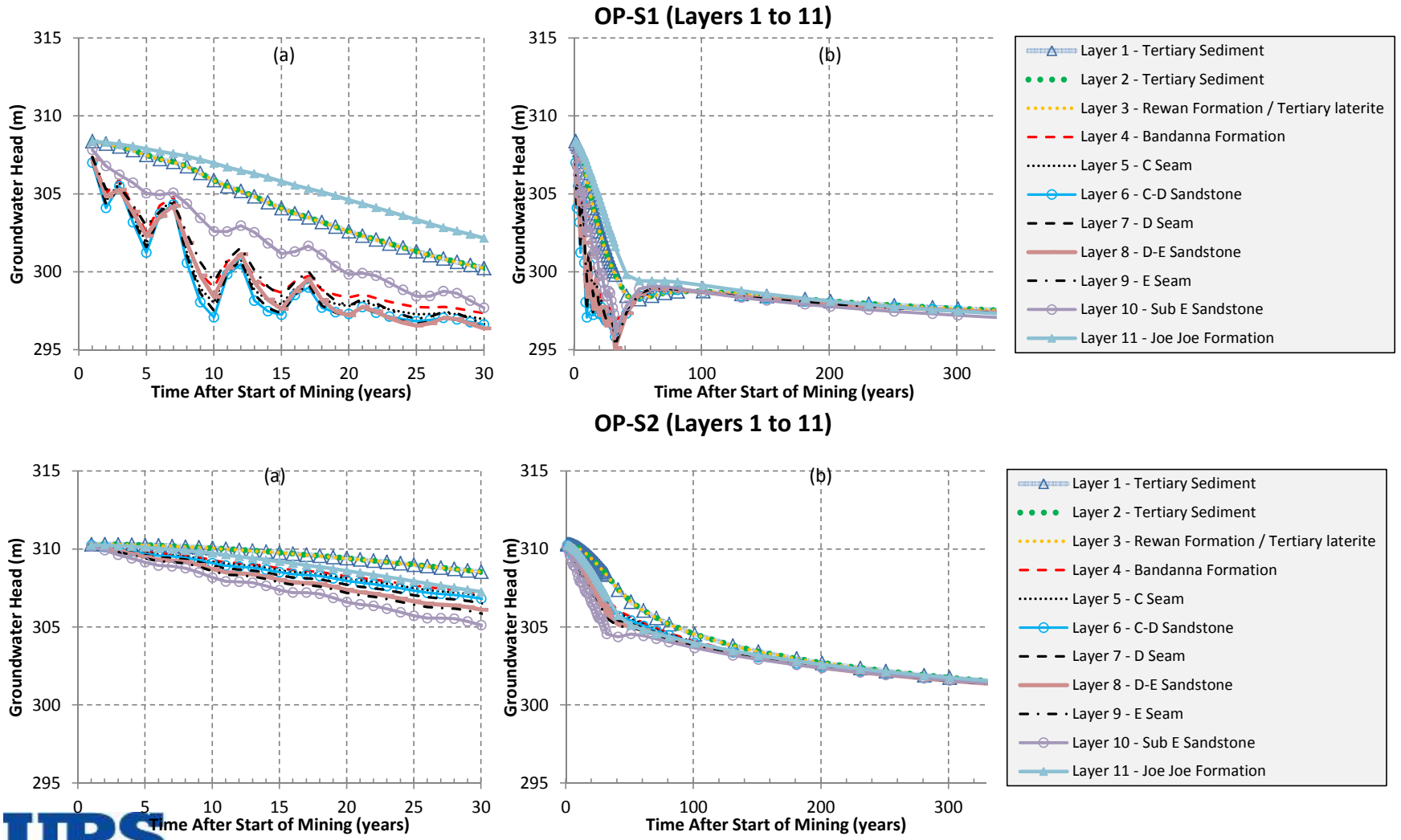
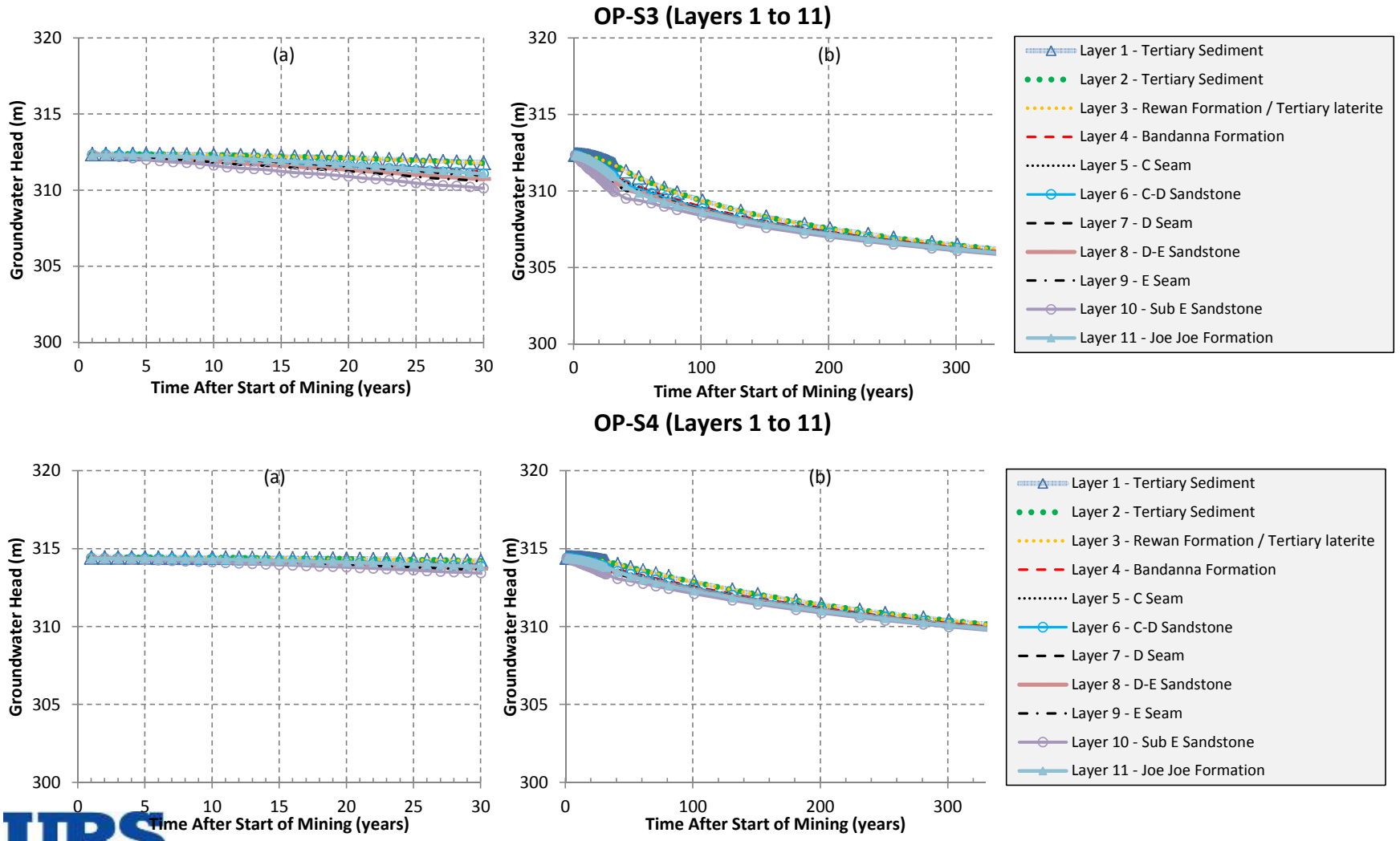


URS

Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - South Transect Near Alpha Mine

C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-S1_to_S4.xlsx]REPORT MULTI-CHART (2)

Figure E4

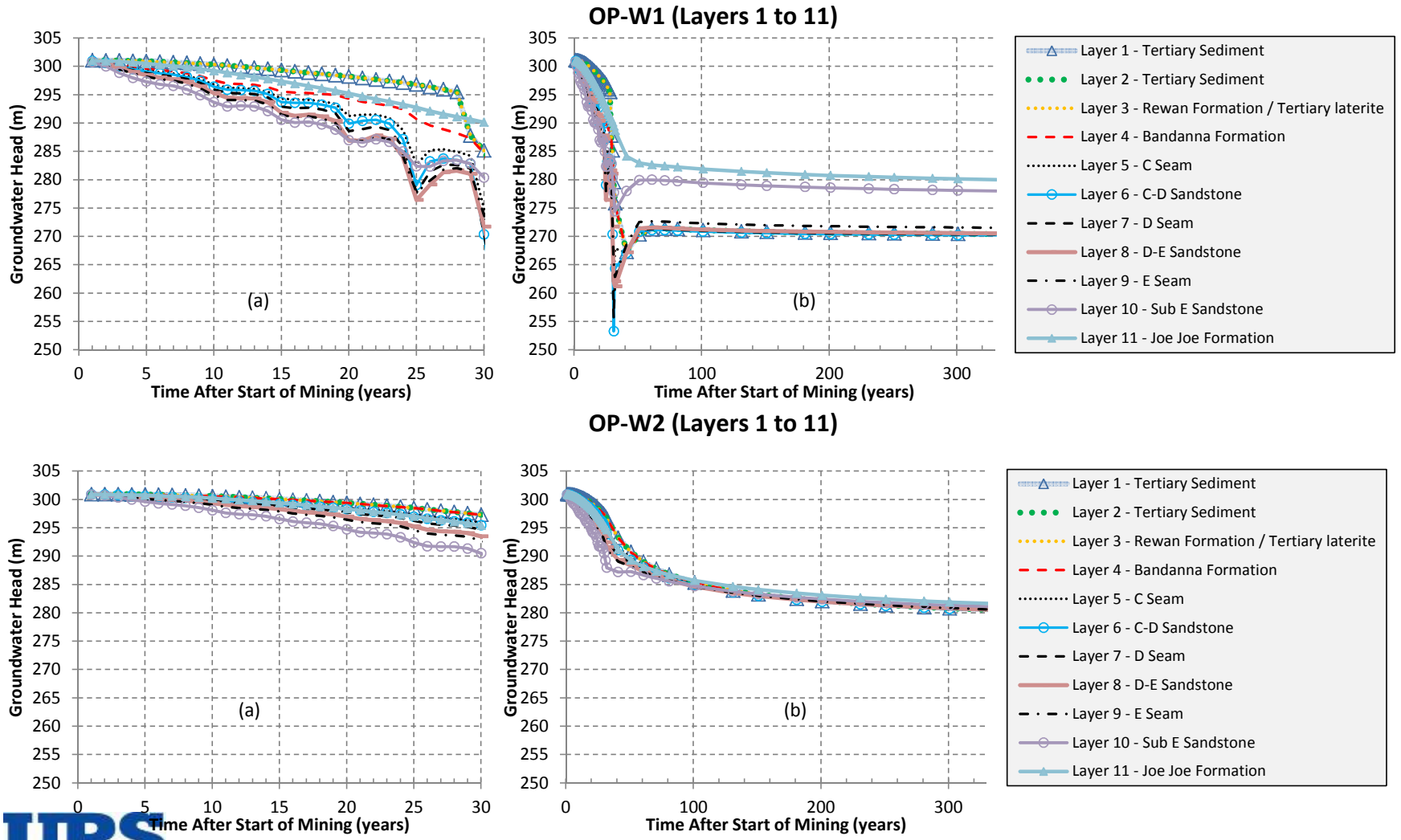


URS

Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - South Transect Near Alpha Mine

C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-S1_to_S4.xlsx]REPORT MULTI-CHART (3)

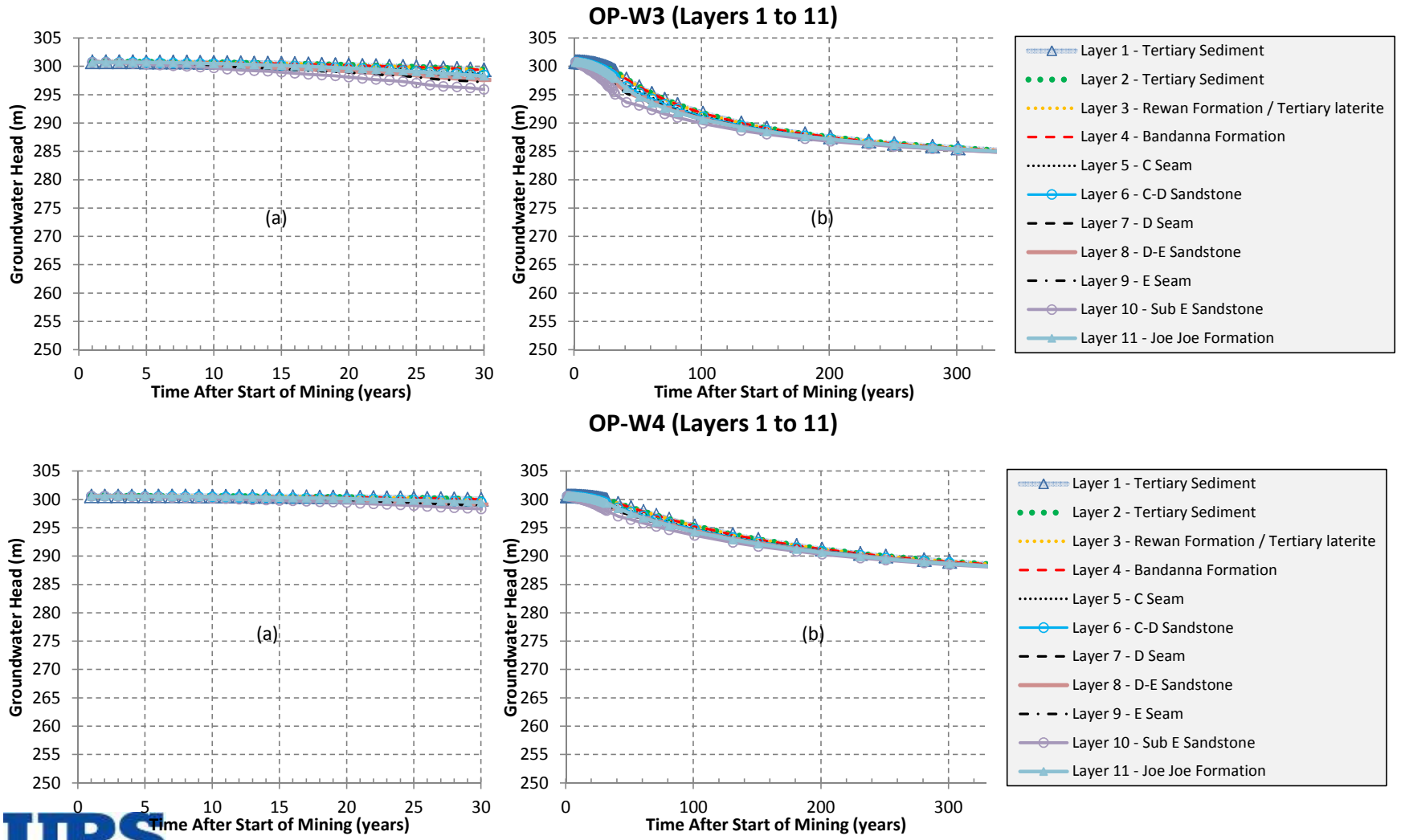
Figure E5



Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - West Transect Near Alpha Mine

C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-W1_to_W4.xlsx]REPORT MULTI-CHART (2)

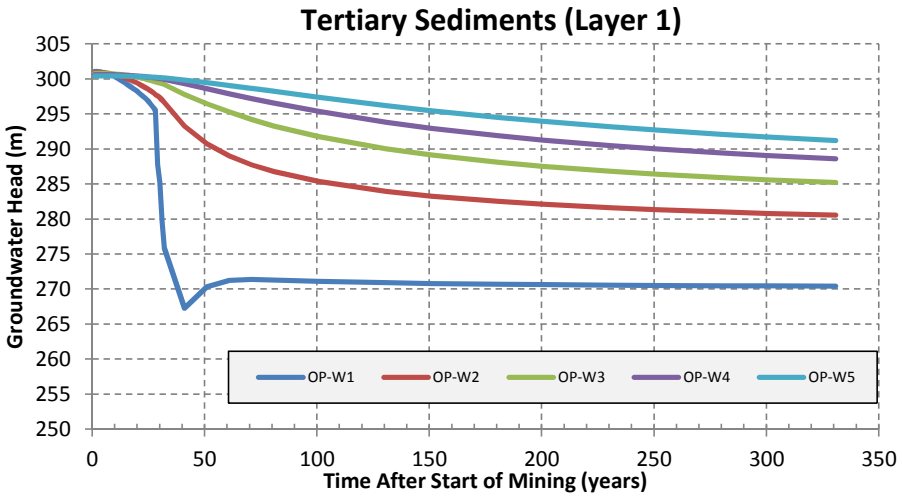
Figure E6

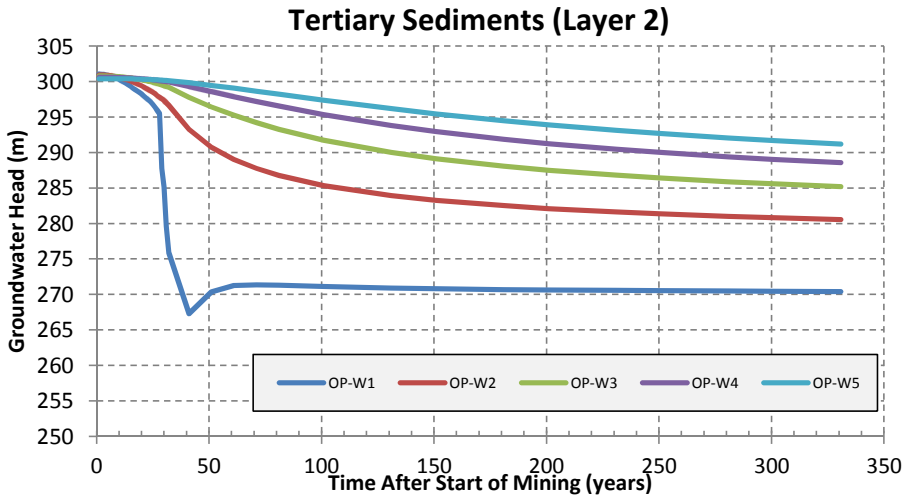


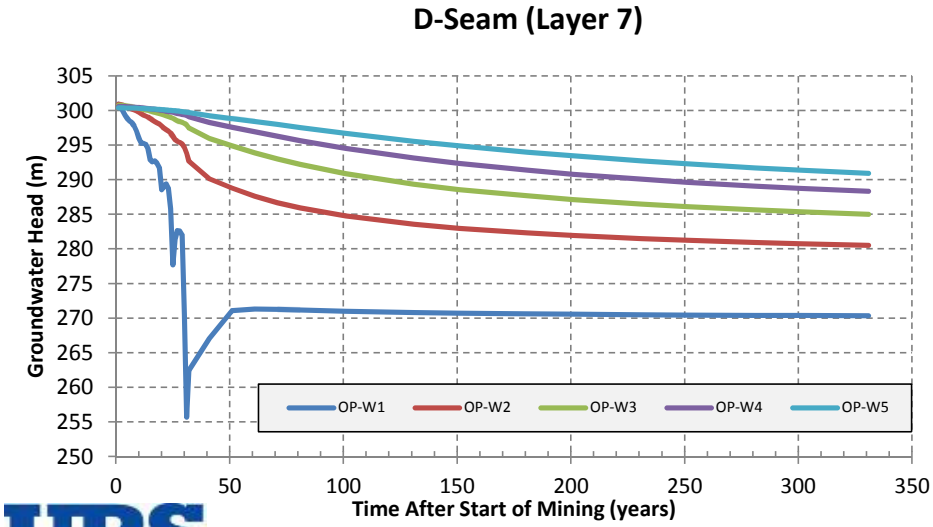
Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - West Transect Near Alpha Mine

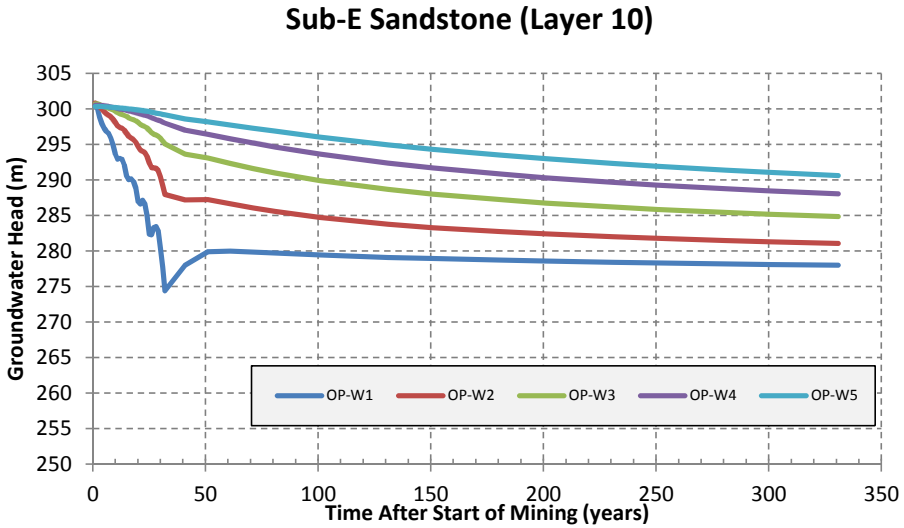
C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-W1_to_W4.xlsx]REPORT MULTI-CHART (3)

Figure E7







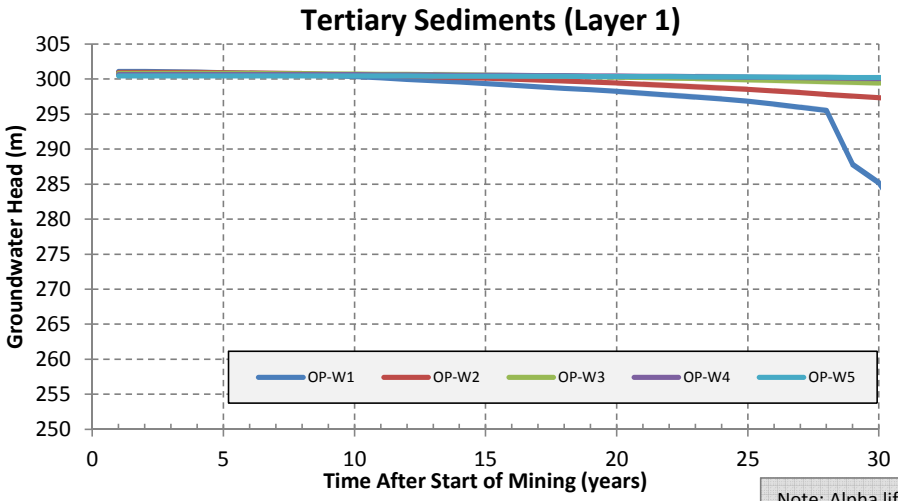


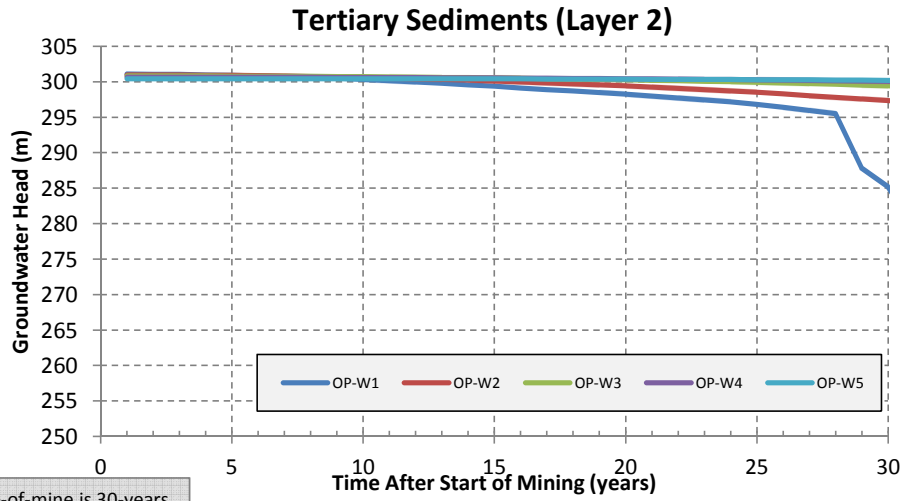
URS

Model Projected Groundwater Heads for 30-Year Life-of-Mine and Long-Term Recovery - West Transect Near Alpha Mine

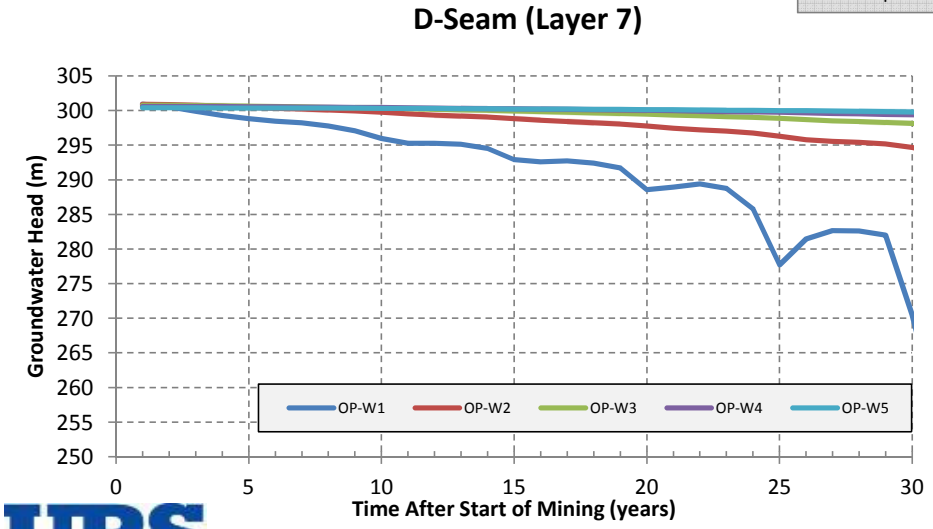
C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-W1_to_W5_Layers_1,2,7,10.xlsx]REPORT MULTI-CHART

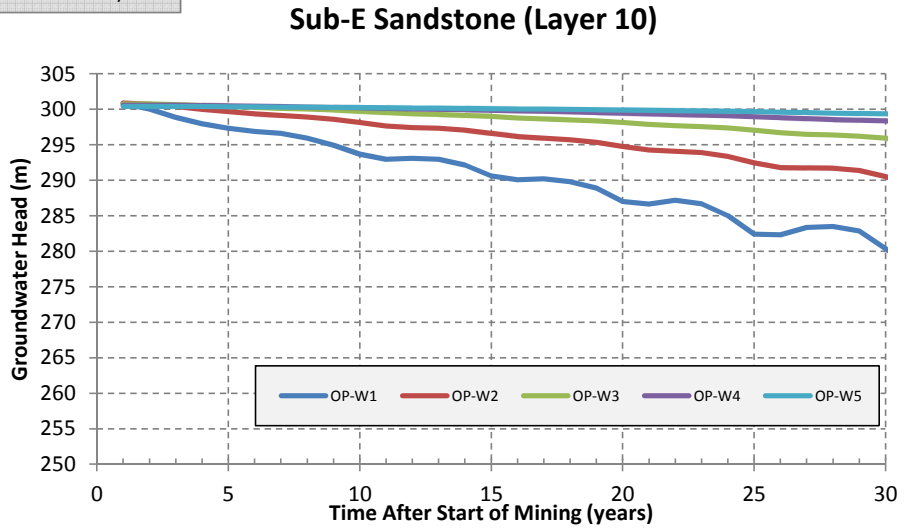
Figure E8





Note: Alpha life-of-mine is 30-years





URS

Model Projected Groundwater Heads for Alpha Mine Only - West Transect Near Alpha Mine

Figure E9

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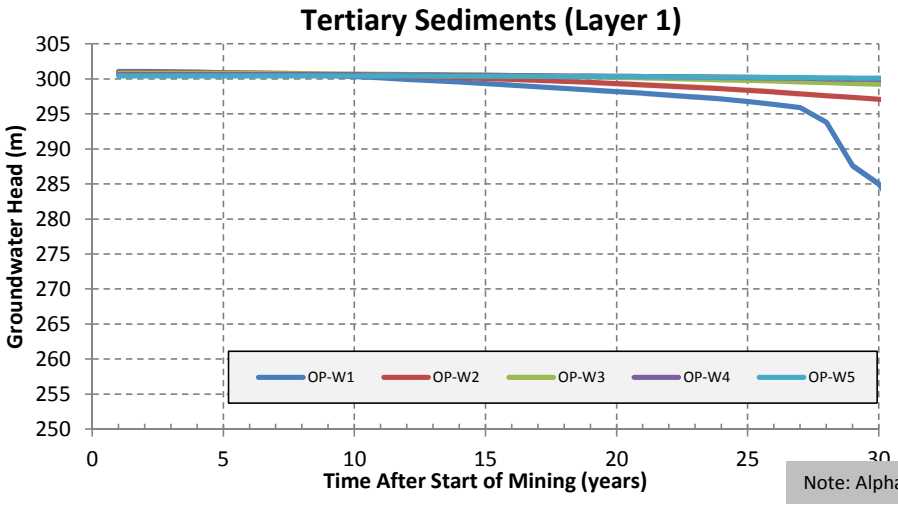
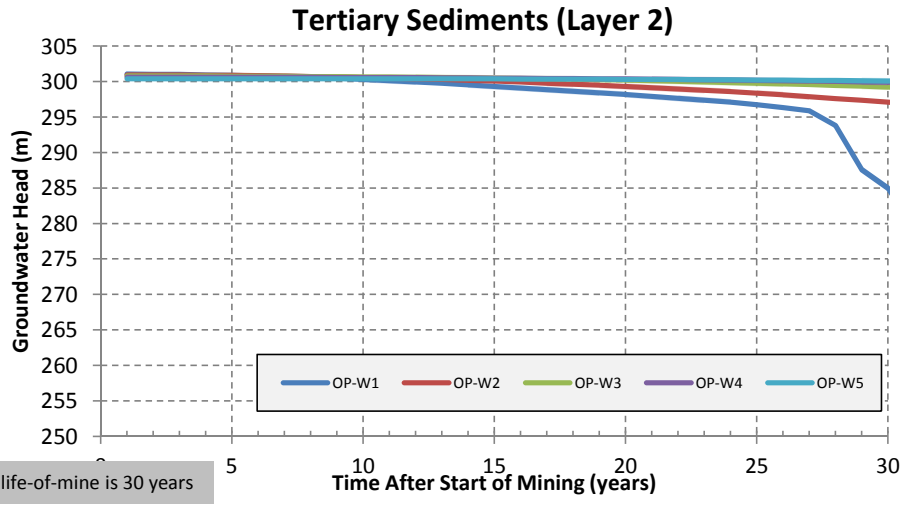
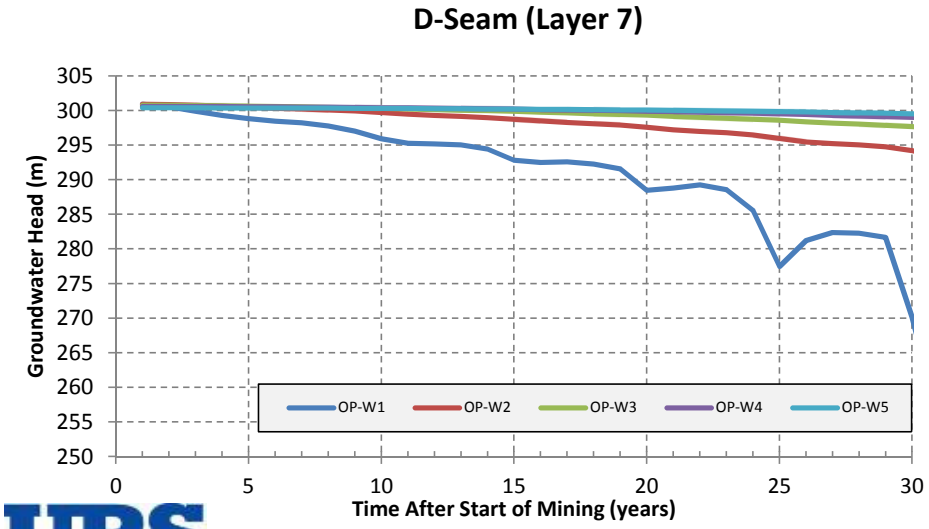
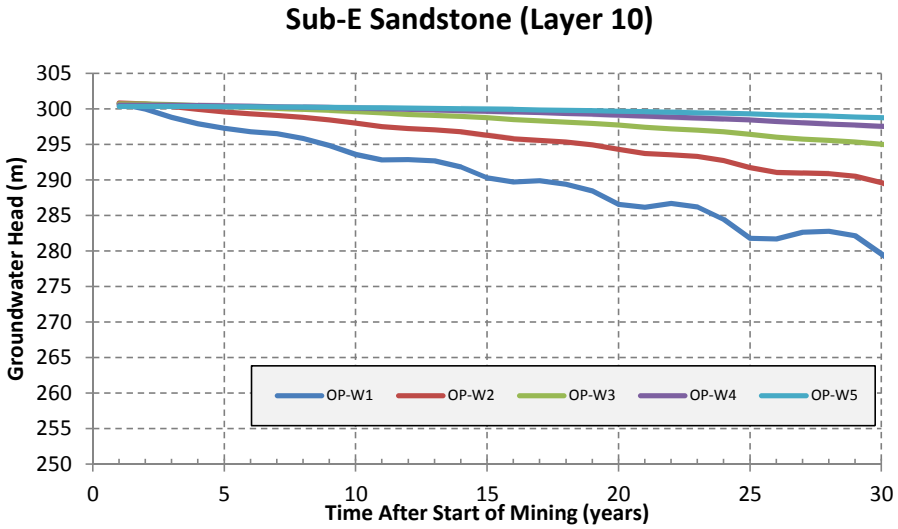




Note: Alpha life-of-mine is 30 years





URS

Model Projected Groundwater Heads for Cumulative Impacts of Alpha Mine and Kevin's Corner - West Transect Near Alpha Mine

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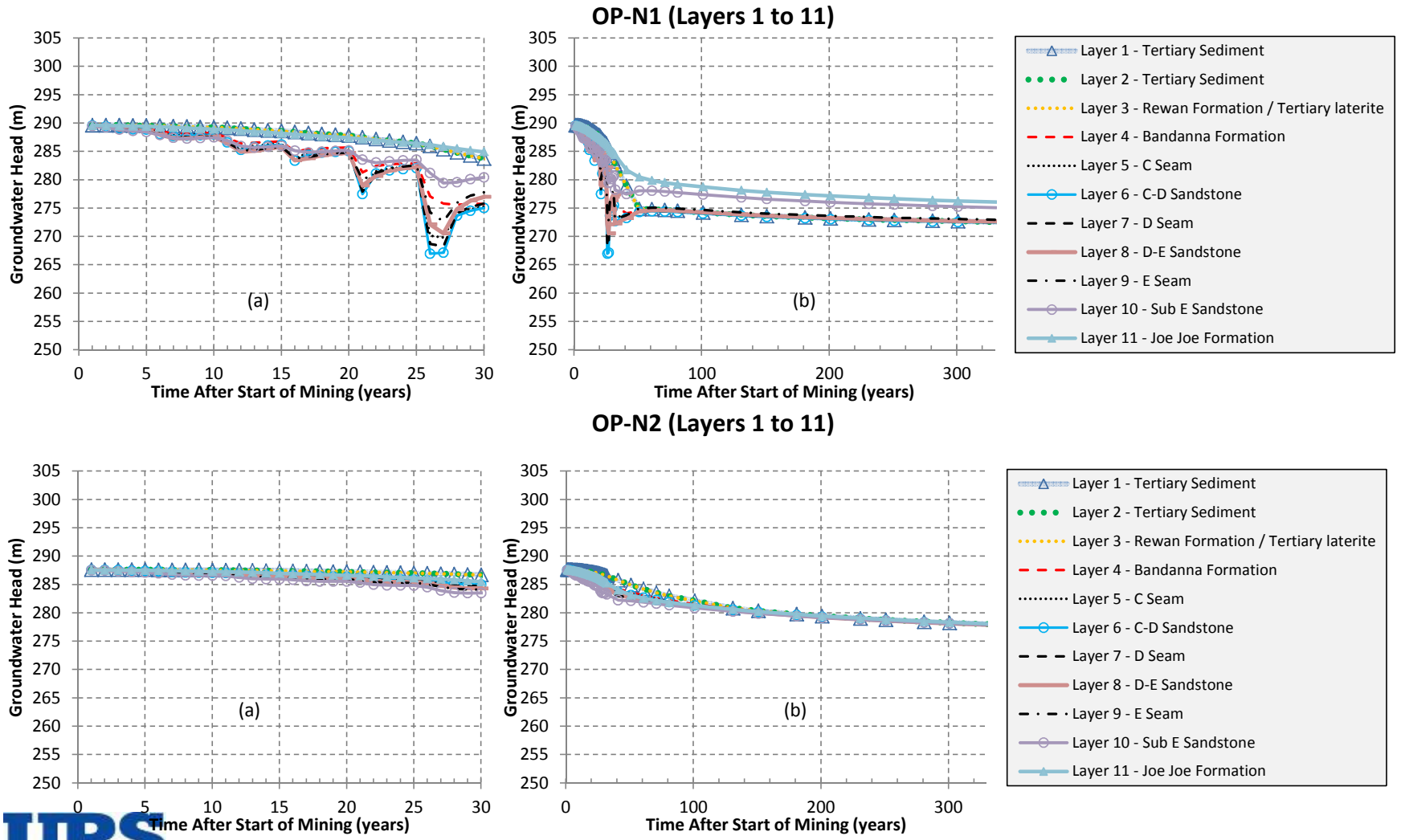
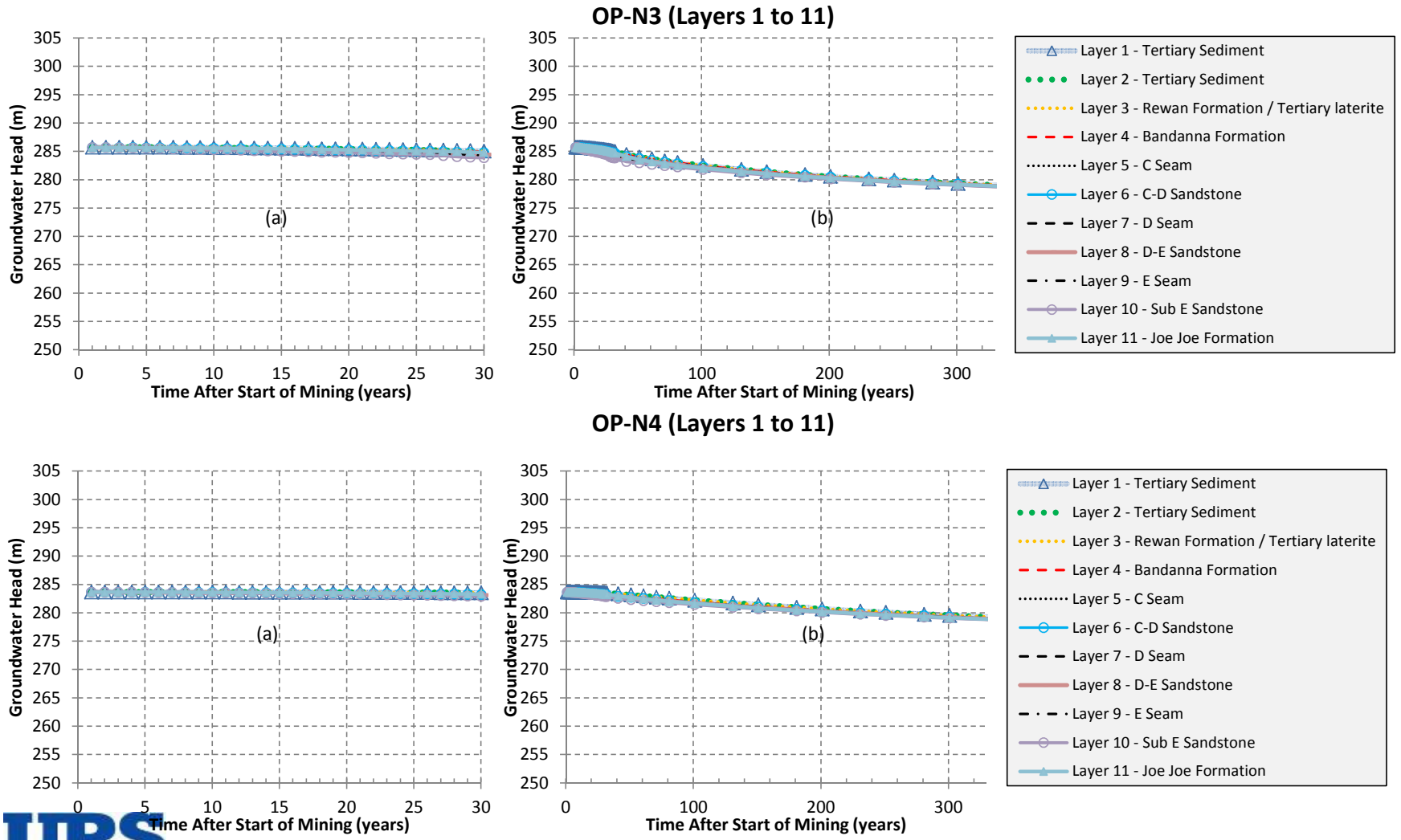
Figure E10



Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - North Transect Near Alpha Mine

C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-N1_to_N4.xlsx]REPORT MULTI-CHART (2)

Figure E11



Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - North Transect Near Alpha Mine

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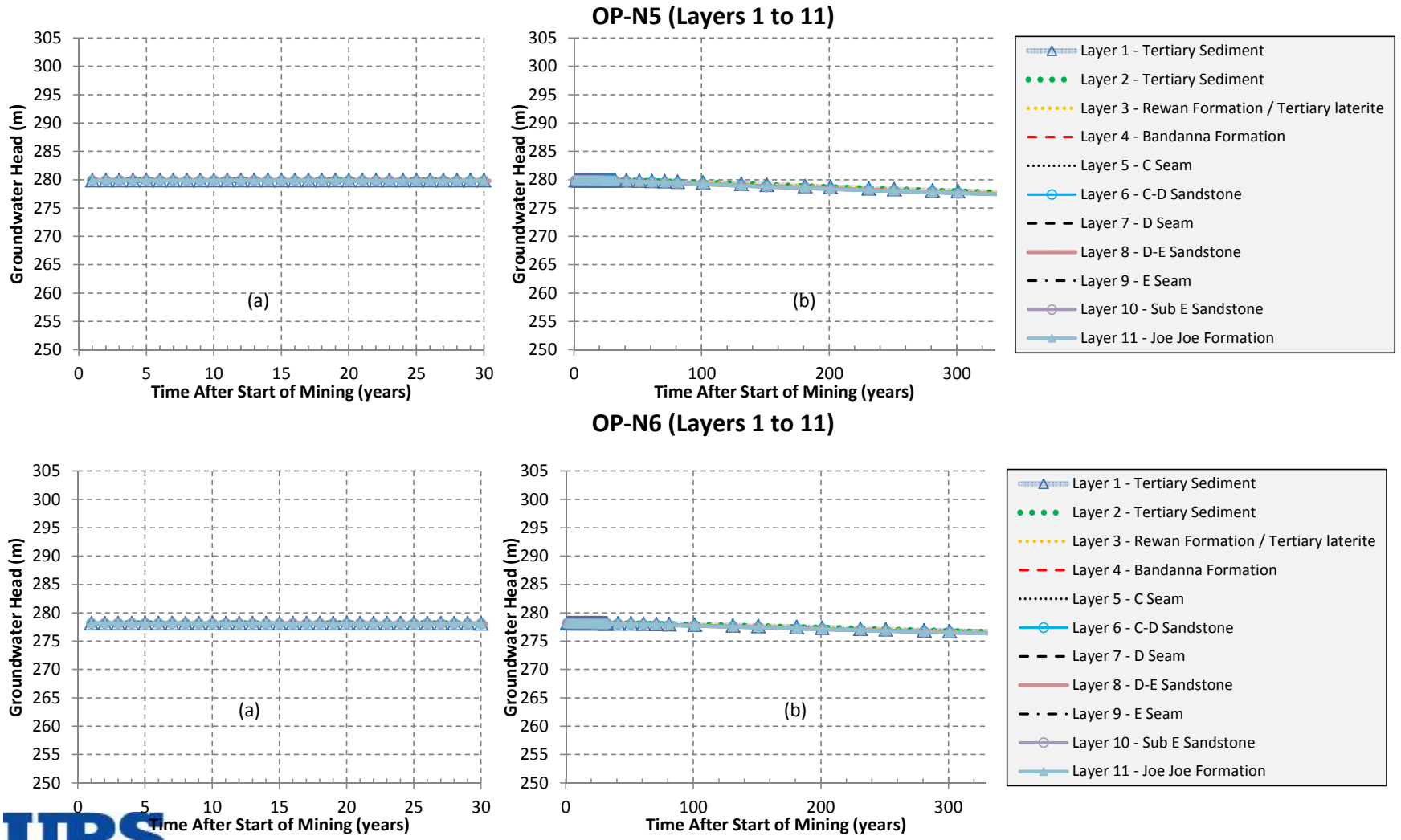
Figure E12



Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - North Transect Near Kevin's Corner

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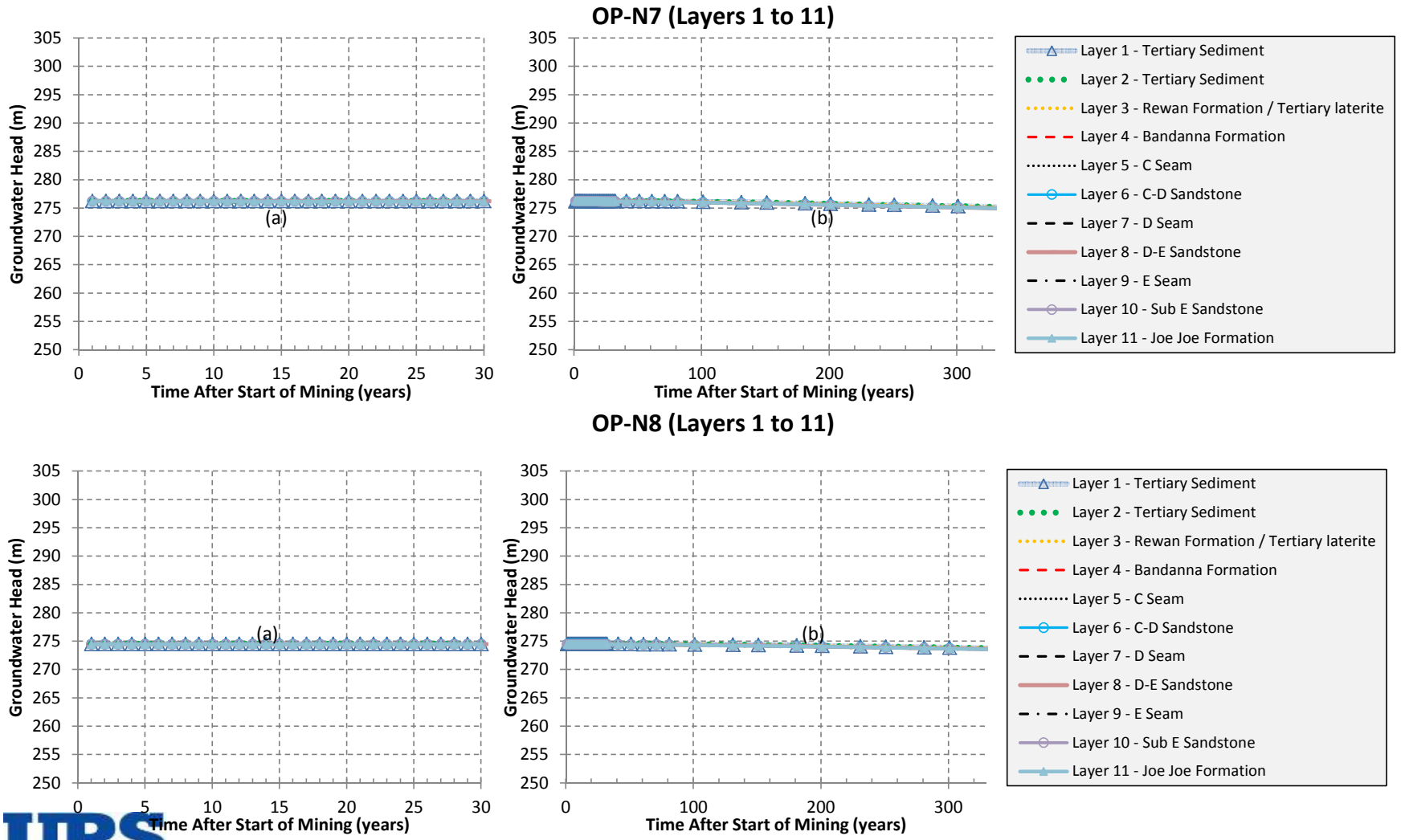
Figure E13



Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - North Transect Near Kevin's Corner

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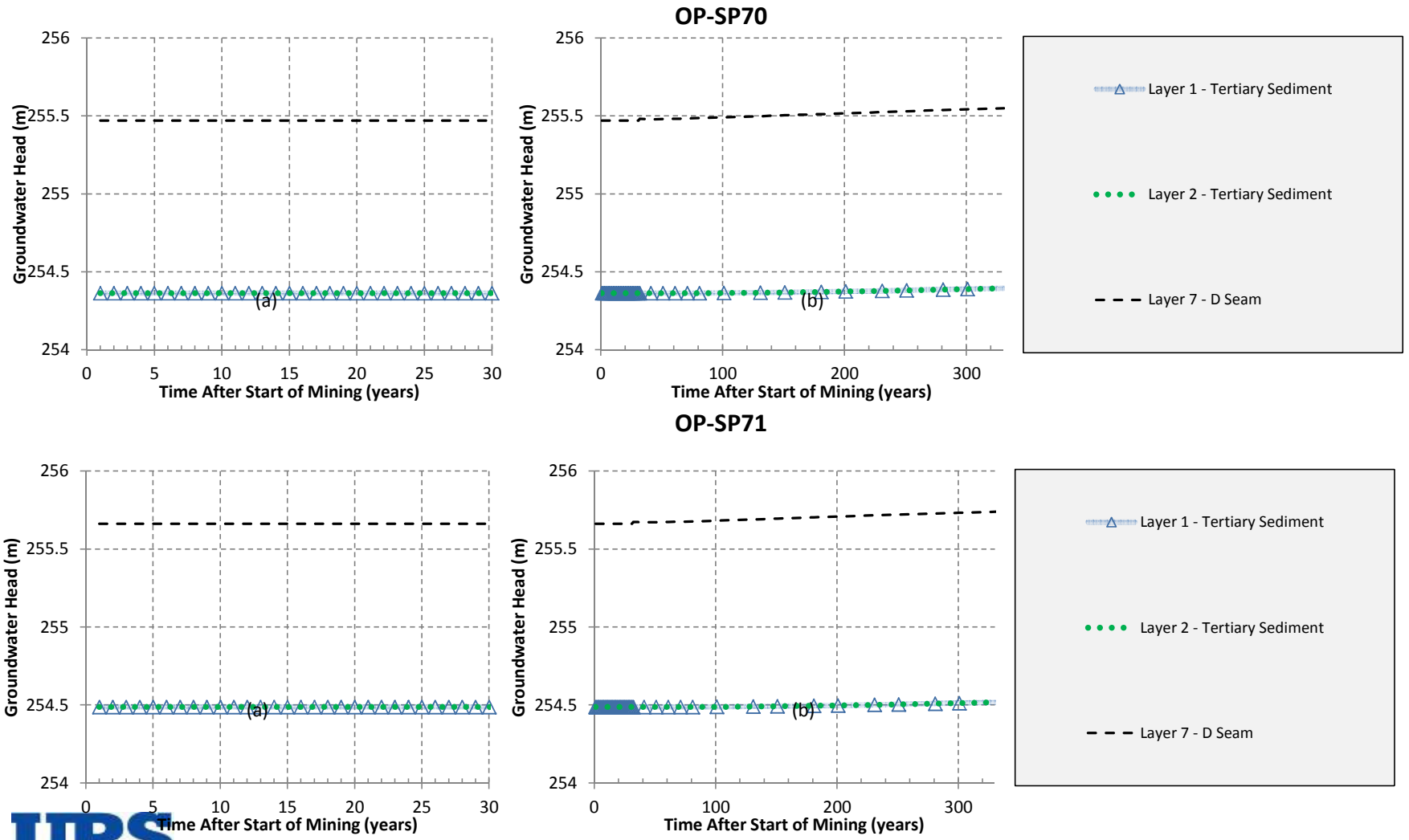
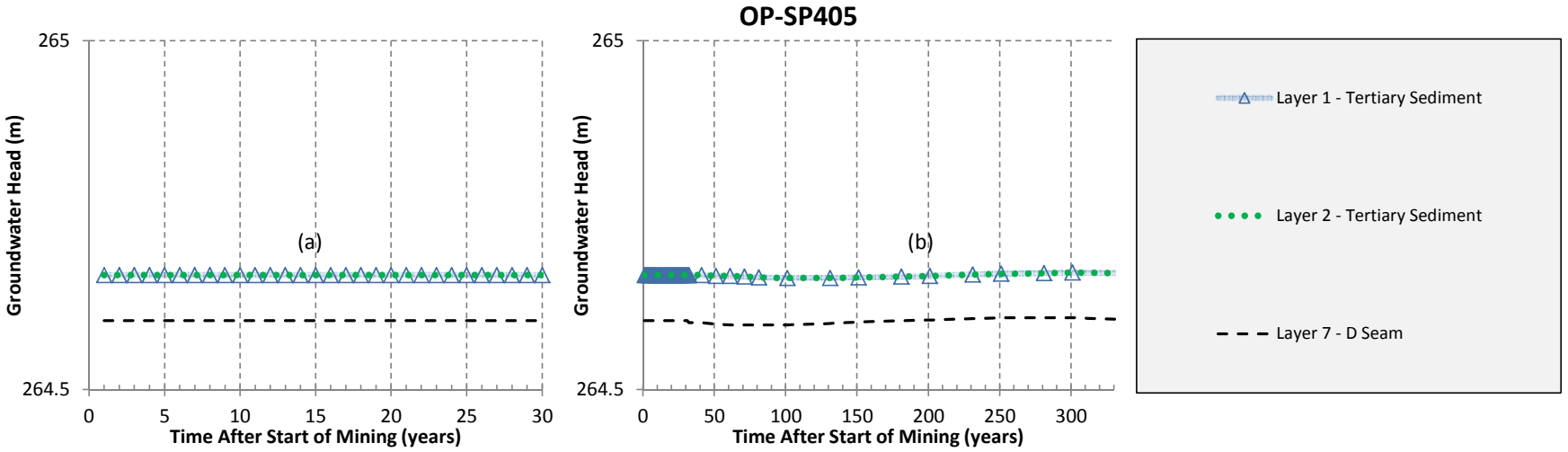
Figure E14



Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - Northerly Springs

Figure E15

C:\3_URS-Projects\42626920 HANCOCK Kevin's Corner SEIS\Hydrographs_E\[AppendE_OP-SP405_to_SP71.xlsx]REPORT MULTI-CHART (2)



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Model Projected Groundwater Heads for (a) 30-Year Life-of-Mine and (b) Long-Term Recovery - Northerly Springs

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Figure E16

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