HANCOCK PROSPECTING PTY LTD

Alpha Coal Project Supplementary Environmental Impact Statement

N | Coal Mine – Groundwater and Final Void Report

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Appendix N Groundwater and Final Void Report

N.1 Introduction

Comments and responses received regarding the groundwater resources detailed in the Alpha Coal Project EIS submission have been compiled in Volume 1 Section 4 and Volume 2 Appendix AJ of the SEIS. Discussions held with several regulatory bodies indicated the need to provide additional clarification and information on several issues; namely:

- The status and calibration of the project groundwater model;
- The potential impacts of mine dewatering on the Great Artesian Basin aquifers;
- The potential impacts of mine dewatering on Groundwater Dependent Ecosystems; and
- The geological and hydrogeological conditions underlying the proposed tailings storage facility (TSF).

N.2 Groundwater Modelling

The groundwater model update report (Appendix A) includes details regarding the current groundwater model refinement study, which includes for independent review of the model to ensure predictions made using the model are as accurate as possible. Furthermore commitments have been made by the Proponent to ensure regular updates of the model, based on monitoring data recorded during mine operations. The regular review and updating as required (every 3 years) of the model will allow for predictions to be compared to field measurements, which will allow for refined model calibrations and more accurate ongoing predictions.

N.2.1.1 Model Refinement and Ongoing Calibration

The existing predictive finite element (FEFLOW) groundwater model has been reviewed by external independent reviewers. The review has allowed for the revision of existing groundwater model layers (based on geological units), refined leakage (to simulate induced flow due to mine dewatering), and the refined confining layer parameters to ensure the site hydrogeology is realistically simulated in the model.

The outer boundary of the model have been refined based on hydrogeological information compiled during the bore survey (hydrocensus) completed within and adjacent (10 km radius) of the mine development lease boundaries. This ensured that boundary conditions do not influence model predictions. Layer extrapolation, across the large size of the model, was considered to ensure model layers include all available information.

Model calibration to refine the model's depiction of the hydrogeological framework, aquifer hydraulic properties, and boundary conditions was undertaken using site specific data obtained from the Alpha Test Pit, which allowed for a good correspondence between the model simulated and measured field data. Transient data from the dewatering system (and groundwater level responses in observation wells) recorded during the Alpha Bulk Sample Test Pit dewatering were used to obtain accurate aquifer hydraulic parameters (transmissivity, storage, and permeability) for inclusion in the model. The refined model is continuing to be calibrated using a set of model parameters, which are within the range observed from testing undertaken at site.

Refined boundary conditions and hydraulic stresses (mine dewatering volumes based on the Alpha Test Pit) are aiding in generating simulated potentiometric surfaces, and fluxes that match field measurements to within an acceptable range of error.

The current calibration process employs both automatic calibration (using PEST) and manual trial-and-error and parameter sensitivity analysis. This is to ensure that the optimum calibration (model parameter sets) is reached. Model-derived budget terms are evaluated to prevent masking the effect of parameter changes. A table documenting calibration history and parameter sensitivity is being recorded and frequently reviewed as a roadmap for the calibration practice. The calibration process followed conforms to the guidelines compiled in the Murray-Darling Basin Commission Groundwater Flow Modelling Guideline (Aquaterra, 2000) and the relevant ASTM standards.

The current status of the regional (encompassing Alpha and Kevin's Corner coal projects) groundwater model is presented in Appendix A.

N.2.1.2 Model Monitoring and Mitigation Program

In addition to the commitment to conduct regular updating of the predictive groundwater model a monitoring and mitigation program will be implemented to ensure that any unpredicted changes in groundwater quality and quantity are responded to so as to minimise mine related impacts.

Mitigation and potential responses to mine related impacts include the following aspects.

N.2.1.2.1 Construction of monitoring bores

The current monitoring network at Alpha Coal Project includes:

- Eight (8) vibrating wire piezometer (VWP) bores, equipped with continuous data loggers;
- Eight (8) VWPs without data loggers, allowing for single measurements to be recorded (a program is currently being implemented to equip these bores with data loggers);
- Four (4) standpipe bores are constructed and equipped with automated water level loggers, allowing for daily groundwater level data to be recorded; and
- Fourteen (14) new standpipe bores constructed on and adjacent to the Alpha TSF, to be equipped with automated water level loggers.

An additional fourteen (14) standpipe monitoring bores, for groundwater level and quality monitoring, are to be constructed across the site adjacent to selected mine water and waste storage facilities as these ancillary infrastructure have the potential to impact on shallow groundwater resources. The proposed additional monitoring points are included in Table N-1.

Table N-1 Additional groundwater monitoring points

Bore	Easting (GDA94)	Northing (GDA94)	Depth (m)	Location
AlphaWest1	440 790	7 433 356	100	Western extent of mining
AlphaWest2	440 854	7 426 844	100	Western extent of mining
AlphaWest3	440 854	7 420 445	100	Western extent of mining
Landfill1	450 887	7 421 756	60	Up gradient of landfill
Landfill2	450 887	7 421 689	50	Down gradient of landfill
Landfill3	450 466	7 422 311	50	Down gradient of landfill
MIA	449 692	7 430 083	40	Industrial area
CHPP1	449 081	7 431 729	40	Coal handling and processing area
CHPP2	449 378	7 432 279	40	Coal handling and processing area
EWT	453 924	7 433 249	60	Water storage dam
TLO1	449 583	7 432 593	40	Train loading facility
RWD1	455 689	7 436 471	50	Return water dam
ROMSouth	447 811	7 427 598	30	ROM stockpile area
ROMNorth	448 392	7 433 658	30	ROM stockpile area

The existing and proposed monitoring bores are presented in Figure N-1. The new monitoring bores installed at the TSF are discussed in Section N4.1.1 and indicated on Figure N-7.

Monitoring Parameters

All existing and proposed standpipe monitoring bores are constructed according to the Australian Minimum Construction Requirements for Water Bores. These bores allow for the sampling and monitoring of all the different aquifers identified on site. These include alluvium, coal seam aquifers, and the interbedded sandstone.

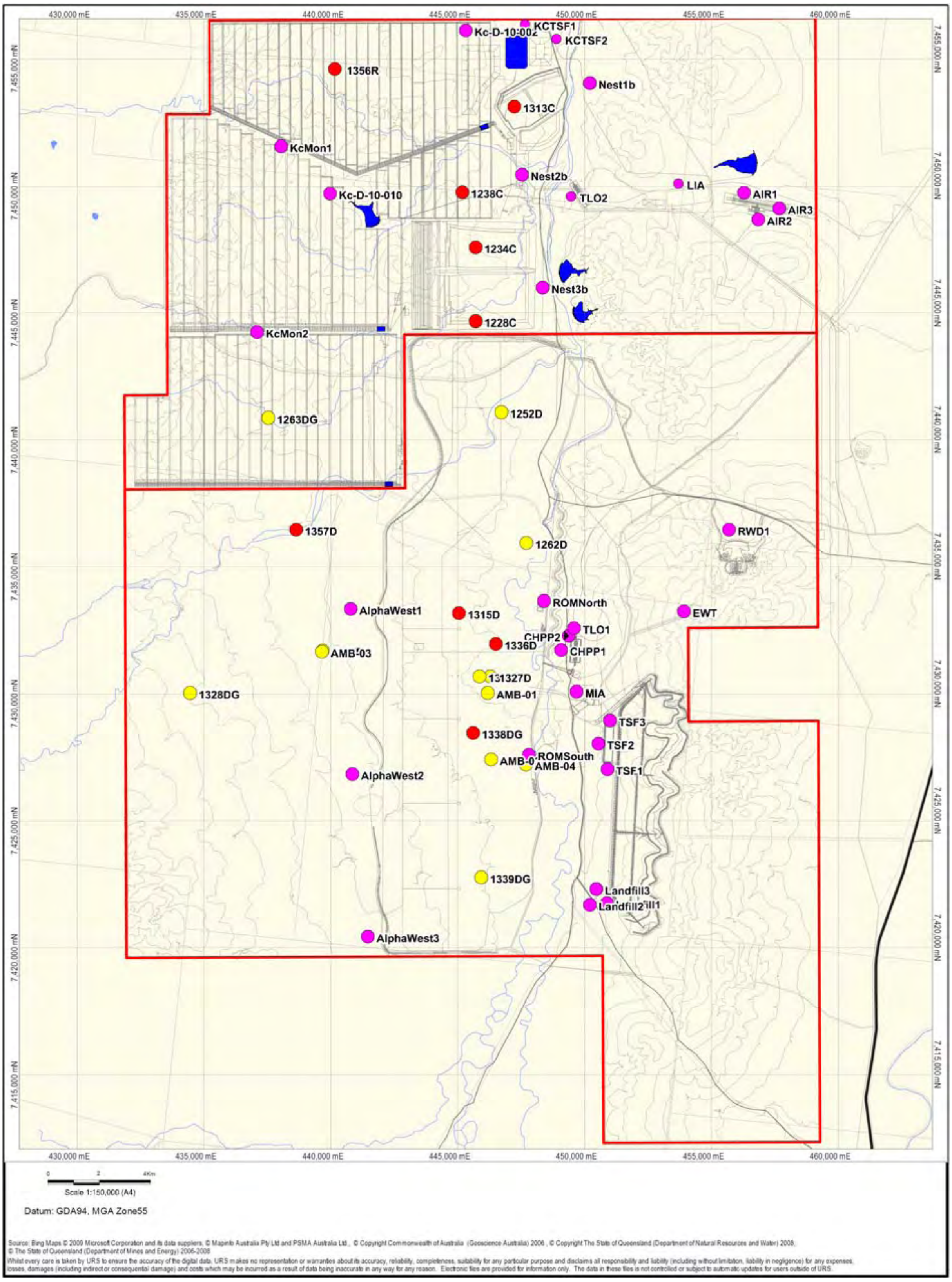
Groundwater samples are to be collected, stabilised / preserved (according to recognised protocols) and analysed for the following:

- Field parameters - pH and EC
- Major anions and cations - TDS, calcium, magnesium, potassium, sodium, chloride, sulfate, Alkalinity, fluoride
- Dissolved metals - aluminium, arsenic, boron, cadmium, copper, iron, lead, mercury, manganese, molybdenum, nickel, selenium, silver, zinc
- Total petroleum hydrocarbons (TPH)
- Nutrients - nitrogen

Monitoring Frequency

Baseline data is required to assess pre-mining conditions and natural fluctuations, based on seasonal changes. A minimum of 12 months of data will be collected prior to any mining activities. Current monitoring will be conducted monthly until construction begins in order to obtain sufficient data. These data can then be used to determine representative groundwater level and quality data, which will be used to determine trigger values for Environmental Authority conditions. Once sufficient information is available then the sampling frequency (and data downloads) will be reduced to every three months. The number of parameters analysed can also be re-assessed.

Figure N-1 Existing (yellow) and proposed monitoring bores



The augmented groundwater monitoring network will:

- Include nested bores (one shallow and one deep adjacent to one another) to allow for the assessment of mine dewatering and depressurisation of the underlying confined aquifers on the overlying alluvium aquifers (determine if and to what extent induced flow is impacting on the alluvium aquifers);
- Allow for the identification of any changes in groundwater quality due to depressurisation (i.e. mixing of groundwater types);
- Provide continuous groundwater level data, to assess trends due to recharge, natural fluctuations, and mine activities; and
- Provide field pH and electrical conductivity (EC) data across the site and different aquifers / units.

N.2.1.2.2 Continuation of existing monitoring program

The Proponent has contracted an independent specialist consulting company, 4T Consultants, from Emerald to undertake monthly baseline monitoring. Currently the groundwater monitoring comprises:

- The monthly collection of piezometeric level data from the monitoring bores equipped with vibrating wire piezometers;
- The monthly collection of groundwater level data from the monitoring bores equipped with automated water level loggers; and
- The sampling and analysis of water quality from four stand pipe monitoring bores, AMB01 to AMB04, on a monthly basis.

Additional information collected during the current groundwater monitoring program includes groundwater level data from bores (used for dewatering and observation) around the Alpha Test Pit.

This program will be ongoing and will include the newly constructed (July 2011) monitoring bores within and adjacent to the TSF.

The existing groundwater monitoring program will be augmented over time to include the proposed monitoring bores detailed in Section N2.1.2.1. These monitoring bores will be constructed a minimum of 6 months prior to any mining.

N.2.1.2.3 Annual assessment

During mining an annual assessment of the monitoring data, both water level and quality will be conducted. The annual assessment will establish any departures from identified monitoring data trends.

If consecutive monthly monitoring results depart from the established or predicted trends then a review and cause identification study will be implemented.

N.2.1.2.4 Responses

A detailed review of possible causes of the departure(s) from identified or predicted (model predictions) trends will be conducted. This will allow for the most suitable groundwater responses to be implemented. These responses, including possible variations to model predictions, could include:

- An independent review / check of the model.
- Intensify monitoring, increased frequency, monitoring points, and parameters to aid in making informed decisions to reduce impacts.

- Obtain an assessment of geotechnical and structural data from a suitably qualified professional.
- Review changes in mine plan and assess whether these would result in changes to model predictions.
- Evaluate suitability for artificial recharge to address mine dewatering impacts.
- Design and implement active systems to assist with possible contaminant plume migration.

Additional commitments to be implemented to allow for the identification and response to departures from predicted trends include:

- A review of coal measure dewatering and depressurisation and the potential impacts of induced flow from surrounding overlying- and underlying units. This will be conducted annually using the groundwater monitoring information by a suitably qualified hydrogeologist.
- Every three (3) years model predictions will be reassessed to determine the suitability of the model and predictions. If monitoring data indicates marked divergence from the predictions then the model will either be updated or a new model will be constructed and calibrated based on site specific data.
- Annual public reporting of groundwater level and quality data. This data will require validation and detailed checking prior to dissemination.

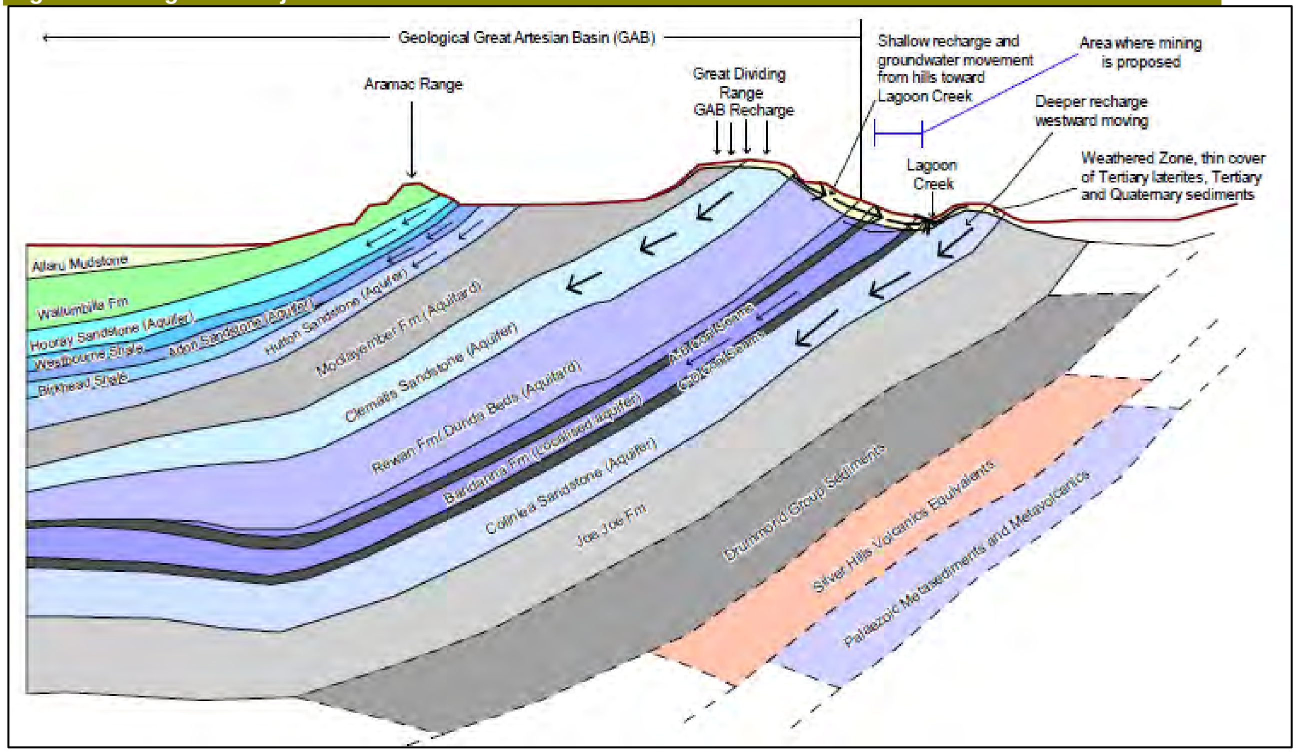
N.3 Great Artesian Basin

The Alpha Coal Project targets the Permian age C and D coal seams of the Colinlea Sandstone. This Permian age unit and the overlying Permian Bandanna Formation occur below the younger Triassic age Great Artesian Basin (GAB). The hydrogeological GAB is located to the west of the proposed mining area and is bounded below by the Rewan Group (Habermehl, 2001). This indicates that the proposed mining activities at Alpha Coal Project will occur in older formations below the GAB and separated from the oldest GAB aquifer, the Clematis Sandstone, by the Rewan Group. Table N-2 presents the lithostratigraphy of the regional geology within and adjacent to the proposed Project. Figure N-2 shows a conceptualisation of the regional geology.

Table N-2 Lithostratigraphy

Age	Lithology	Stratigraphic Unit	Thickness	Comments
Triassic	Green brown-purple mudstone, siltstone and labile sandstone	Rewan Group		Only in west
Late Permian	Sandstone	Bandanna Formation	10–30 m	Increasingly argillaceous
	Coal Seam A. Seam contains thin dirt bands that thicken from south to north.		1–2.5 m	
	Labile sandstone, siltstone and mudstone		10 m	
	Coal Seam B. Seam contains numerous dirt bands that constitute between 15 and 30% of seam. Variable in quality.		6–8 m	
	Labile sandstone, siltstone and mudstone		70–90 m	
	Coal Seam C. Coal seam thins northward and splits apart	Colinlea Sandstone	2–3 m	Increasingly arenaceous
	Labile sandstone, siltstone and mudstone		5–20 m	
	Coal Seam D. Stone bands present with seam thickening westward, upper section splits off main seam to north west		4.5–6 m	
	Labile sandstone, siltstone and mudstone		15 m	
	Coal Seam E. Thin (0.2 m) clean coal bands, usually 2 bands E1 & E2		0.1 – 0.4 m	
	Labile sandstone, siltstone and mudstone		15 – 20 m	
	Coal Seam F. Localised thick geological section, no working section		0.5 – 5 m	
	Labile sandstone, siltstone and mudstone		Unknown	
Early Permian	Labile and quartz sandstone	Undefined	Transition to Joe Joe Formation	

Figure N-2 Regional Project Location



A geological cross-section (Figure N-3), west-east, (covering a distance of 310 km) through the proposed mining area was compiled based on available exploration log data for the area. The cross-section indicates the continuous thick (~ 175 m) Rewan Group separating the Bandana Formation (containing the A-B coal seams) and the Clematis Sandstone GAB aquifer. The target coal seams for the proposed mining operations are the C and D coal seams within the Colinlea Sandstone, which are further separated from the GAB by the groundwater poor (in terms of both quantity and quality) Bandana Formation.

Figure N-4 provides a geological plan view of the area indicating the geological unit outcrops and the Hancock MDL boundaries. The regional geological model shows that the Rewan Group subcrop and outcrop within MDL285 and MDL333 and the Clematis Sandstone subcrops within 8 km of the MDL boundaries. The GAB aquifers do not outcrop at all within the MDLs.

Figure N-3 East-West cross-section across geological model (source, Salva, 2009)

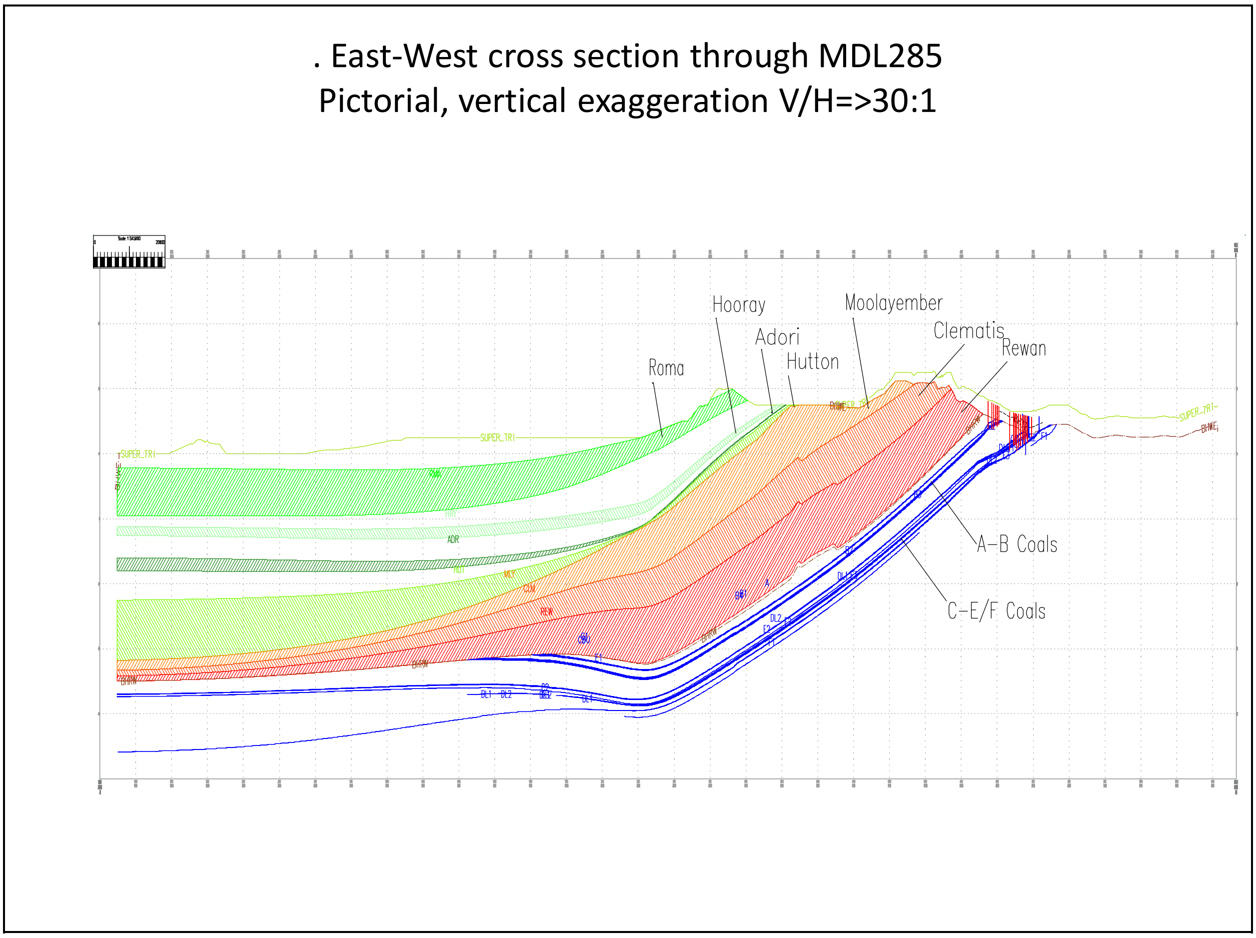
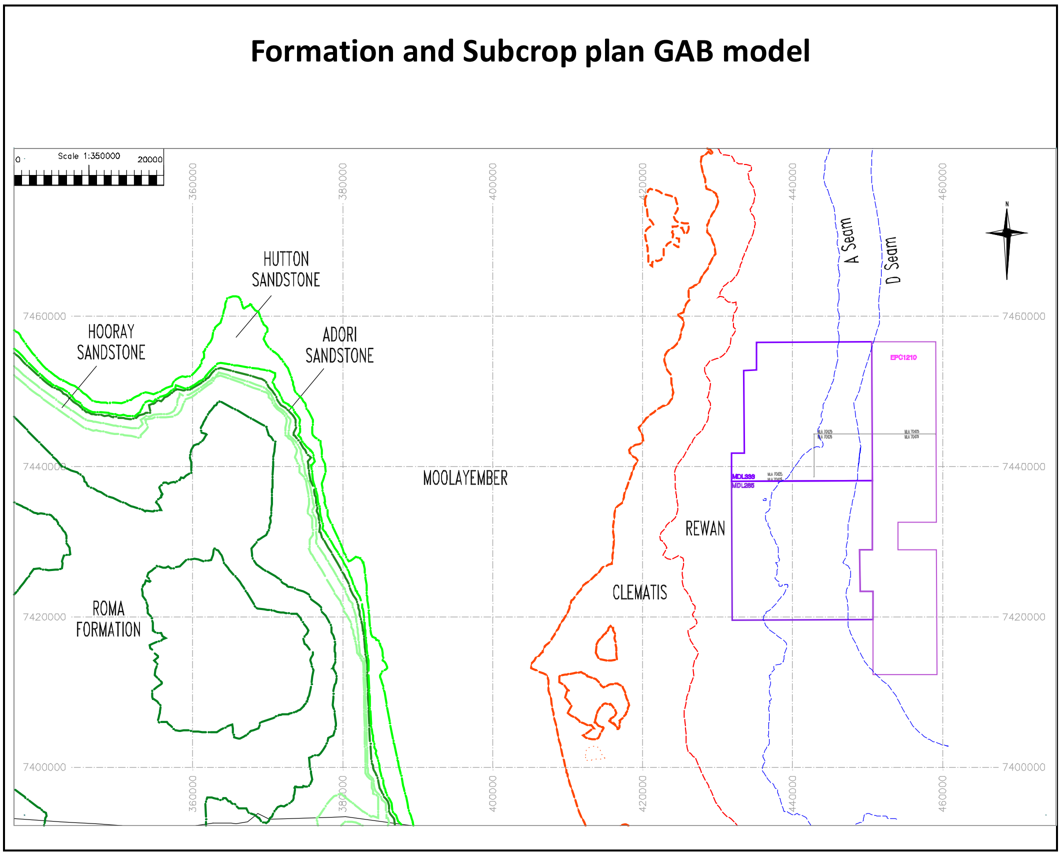


Figure N-4 Formation and subcrop plan from GAB model (source, Salva, 2009)



Dewatering of the hanging wall sediments and depressurising of the sediments (D-E sands) below the proposed open cut mine can potentially induce vertical flow from the overlying (and underlying) units. The induced flow can result in decrease in groundwater levels within the surrounding units; this in turn could result in decreased bore yields. The potential for induced flow from the overlying Rewan Group was considered to determine whether mine dewatering could impact on the closest GAB aquifer, the Clematis Sandstone.

N.3.1Literature review

The Rewan Group comprises mudstone, siltstone, and lithic sandstone of fluvial, lacustrine, and Aeolian origin, and is generally considered to have low porosity and permeability (Butcher, 1984). The upper section mostly comprises shale and is considered to represent a seal to the basal Rewan Group sandstones (Henning et al., 2006) and is considered a barrier to groundwater migration from the deeper coal seams making it an important hydrocarbon exploration feature (Conybeare, 1970). The maximum encountered thickness of 1,363 m in the Bowen Basin (DME, 1997) may increase up to a suspected maximum thickness of 3,500 m. This unit is recognised as the basal unit of the hydrogeological GAB (Habermehl, 2001).

All of the water-bearing units below the Rewan Group exist as confined water-bearing units that contain reservoirs of groundwater, which display different hydraulic characteristics and different hydrochemistry indicating a distinctly different hydrogeological system to the GAB (GABCC, 1998). The deeper water bearing units associated with the Permian coal measures are isolated from the GAB aquifers by the Rewan Group confining unit and are considered to be isolated water-bearing units (WorleyParsons, 2010).

Permeability of the Rewan Group aquitard is in the order of 0.1 millidarcy[1] to 1.0 millidarcy (9.3×10^{-5} to 9.3×10^{-4} m^2/day) (Cadman and Pain, 1998). However, porosity and permeability within this unit is thought to be highly variable. This is in line with Butcher (1984) who considers the Rewan Group as a barrier to vertical migration of groundwater from below to the GAB.

A study by Henning et al. (2006) evaluated inter-aquifer flow between the Clematis Sandstone, Rewan Group, Moolayember Formation and the Precipice Sandstone. The study concluded that the Moolayember Formation and the upper Rewan Group act as effective barriers to vertical groundwater movement between units.

It is generally accepted that the Rewan Group is a regional aquitard that prevents significant inter-aquifer transmission of water within and between basins. There are, however, indications that some preferential flow paths may exist across the aquifer allowing some inter-aquifer flow. There is no evidence, based on the exploration data compiled by Salva (2009) during the generation of the regional geological model (Figure N-3 and Figure N-4), of any large scale geological structures (faults, etc.), within the proposed mine areas that could promote inter-aquifer or inter-basin hydraulic connection.

N.3.2 Potential for Induced Flow

The potential impacts for induced flow were evaluated based on available data, which allowed for the conceptualisation of the hydrogeology within the study area. This conceptualisation was used to construct a numerical groundwater model. The modelling, using the finite element modelling package FEFLOW, is currently being undertaken to assess the potential impacts of mine dewatering on groundwater resources and levels. Initial model predictions indicate that, due to the low permeable nature of the Rewan Group to the west and the Joe Joe Formation to the east, dewatering will elongate north-south within the more permeable Colinlea Sandstone.

Piezometeric pressures will decrease, resulting in declining groundwater levels, to the west of the proposed coal projects. Drawdown would result in a hydraulic gradient from the overlying Rewan Group to the underlying coal measures. In order to evaluate the potential for induced flow the permeability (vertical) of the Rewan Group was considered and included in the numerical groundwater model.

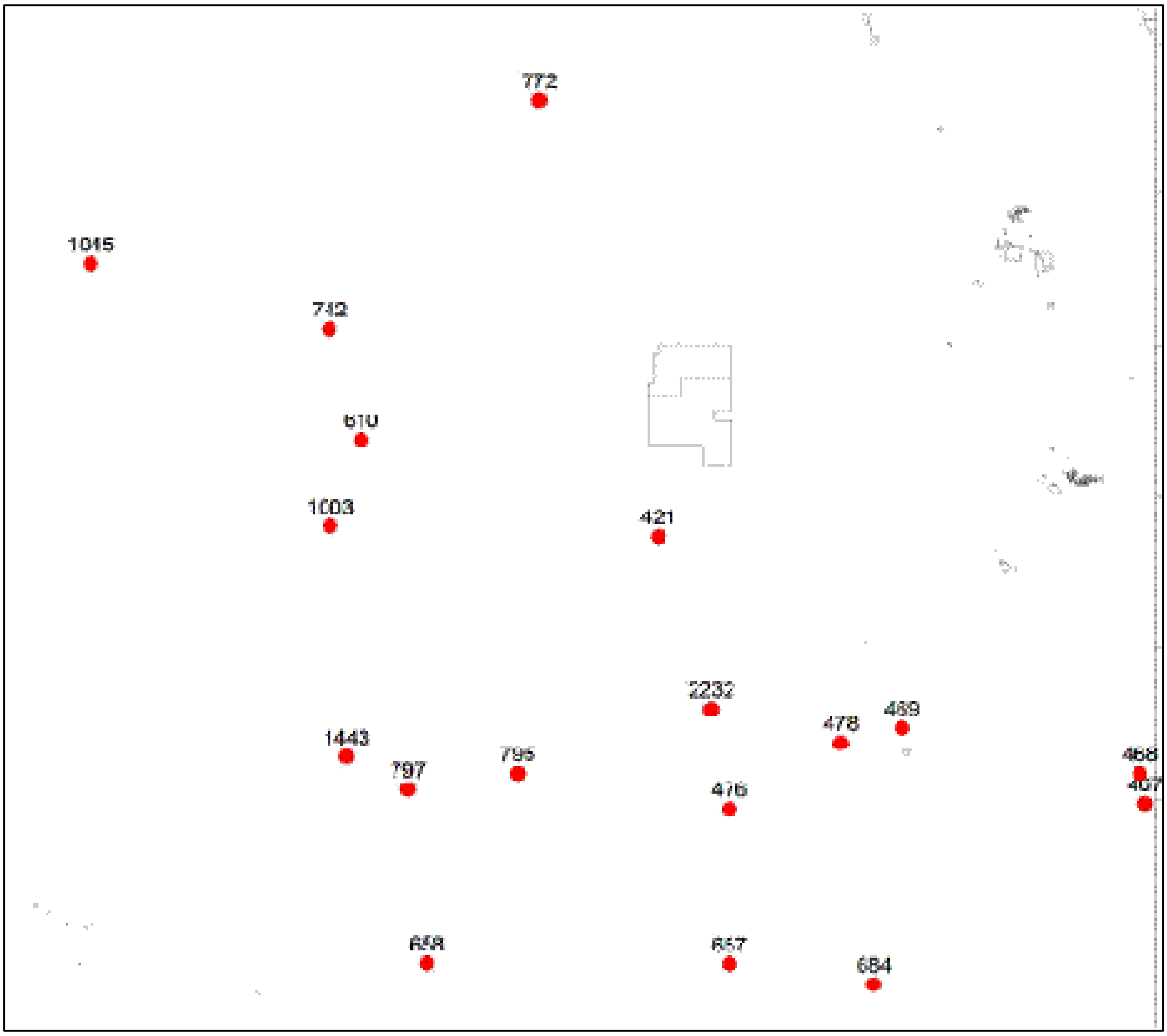
N.3.3 Site specific permeability data

In order to obtain representative permeability data, both horizontal and vertical, for the Rewan Group, an assessment of the Queensland Petroleum Exploration Data (QPED) database was conducted. Eighteen bores were recorded containing permeability data, obtained from drill stem tests during exploration drilling, within the study area (Figure N-5).

The available QPED records are summarised in Table N-3. The permeability (hydraulic conductivity) was determined for different depths within the bores. Several tests did not result in a response during the drill stem tests, indicating very low permeability (lower than the lowest permeability measured in Table N-2, 0.0009 m/day).

[1] The SI unit for permeability is m^2. A traditional unit for permeability is the darcy (D), or more commonly the *millidarcy* (mD) (1 darcy $\approx 10^{-12} m^2$).

Figure N-5 QPED bores relative to HPPL tenures



These results indicate heterogeneity within the Rewan Group, which contains layers of very low permeability. These zones provide the confining pressures required for artesian and sub-artesian conditions recorded in the GAB and reduce the potential for vertical induced flow. The results match the conceptualisation of the Rewan Group acting as a regional aquitard, which prevents inter-aquifer and inter-basin flow.

The impacts of mine dewatering on the Rewan Group and ultimately to the Clematis Sandstone are therefore recognised as negligible. Groundwater model predictions, as discussed in the model refinement report appendix to this report, will be conducted to provide verification of this impact evaluation.

Table N-3 Permeability data

Bore No	Test depth (m)	Porosity (%)	Permeability Horizontal (m/day)	Permeability Vertical (m/day)
476	575.46	23.3	0.014	0.0014
476	578.82	12.2	0[2]	0
476	588.87	17.1	0	0
476	593.14	12	0	0
476	597.41	30	0.79	0.47
476	601.98	25.9	0.86	0.011
476	619.35	28.2	0.13	0.012
476	623.62	26.4	4.44	0.14
476	629.11	23.5	0.016	0.015
476	636.42	23.4	0.055	0.036
476	645.26	28.3	0.43	1.18
476	651.05	27.3	2.07	0.05
476	657.15	27.6	0.83	0.34
478	40.2	23.3	0.28	0.015
772	541.9	23	0	0
772	641.6	13.5	0	0
772	734.3	16	0	0
1045	906.37	18.2	0.07	0.006
1045	919	17.2	0.44	0.07
1045	929.3	20.3	0.28	0.028
1443	1149.43	20	0.02	0.005
1443	1158.28	25	0.099	0.07
1443	1169.02	25	0.099	0.07
1443	1179.57	25	0.13	0.055
1443	1193.63	22	0.029	0.005
1443	1203.21	21	0.029	0.0048
1443	1212.34	18	0.027	0.004
1443	1221.69	18	0.0048	0.003
1443	1234.57	23	0.0039	0.001
1443	1241.97	24	0.055	0.002

[2] No response during drill stem test, very low permeability

Bore No	Test depth (m)	Porosity (%)	Permeability Horizontal (m/day)	Permeability Vertical (m/day)
1443	1251.97	21	0.06	0.004
1443	1266.85	19	0.17	0.002
2232	22.4	27	0.001	0
2232	22.8	26	0.0009	0
2232	64	26	0.014	0

N.4 Groundwater Dependent Ecosystems

A review of available data, compiled during the compilation of the Alpha Coal Project EIS, did not indicate the presence of any Groundwater Dependent Ecosystems (GDEs) within or adjacent to the proposed mine.

Two surface water features, which may be groundwater related, are shown on Figure N-6 and include:

- A modified ox-bow lake, palustrine wetland, which is interpreted to be a perennial water feature, and which will be monitored to establish whether the feature is groundwater dependent; and
- The location of registered springs as defined by Springs of Queensland[3]. The nearest of these springs to the boundary of the MLA 70426 (Alpha Coal Project) is spring reference no. 405, which is located just over 40 km from the boundary of the MLA 70426.

N.4.1 Ox-bow Lake

Groundwater monitoring occurs and will continue at bore AMB04, some 800 m northwest of the palustrine wetland. Piezometeric levels, associated with the underlying C-D sands aquifer and a combined piezometeric level (from open exploration bores), are at 300 to 305 m AHD, respectively. The elevation of the palustrine wetland (modified ox-bow lake) is at 311 m AHD. Figure N-7 presents the location of monitoring bore AMB04 adjacent to the ox-bow lake. The location of AMB04 could not be located closer to the surface water feature due to restrictions on access that were in place at the time of drilling. Table N-4 presents the most recent groundwater level measures collected from AMB04.

Table N-4 AMB04 Groundwater data

Bore No	Elevation (m AHD)	Groundwater depth (mbgl)	Date	Groundwater static water level (m AHD)	Field pH (pH units)	Field EC (µS/cm)
AMB04	312	11.06	20/06/2011	300.94	6.92	4,443
AMB04	312	11.20	19/07/2011	300.80	6.81	4,713

Based on the depth variation (~10 m difference between water levels) the wetland is considered to be perched above the groundwater resources within the weathered Cainozoic sediments.

[3] Springs of Queensland version 4.0, Aug 2005, http://www.epa.qld.gov.au/wetlandinfo/site/factsfigures/springs.html

Figure N-6: Surface water features

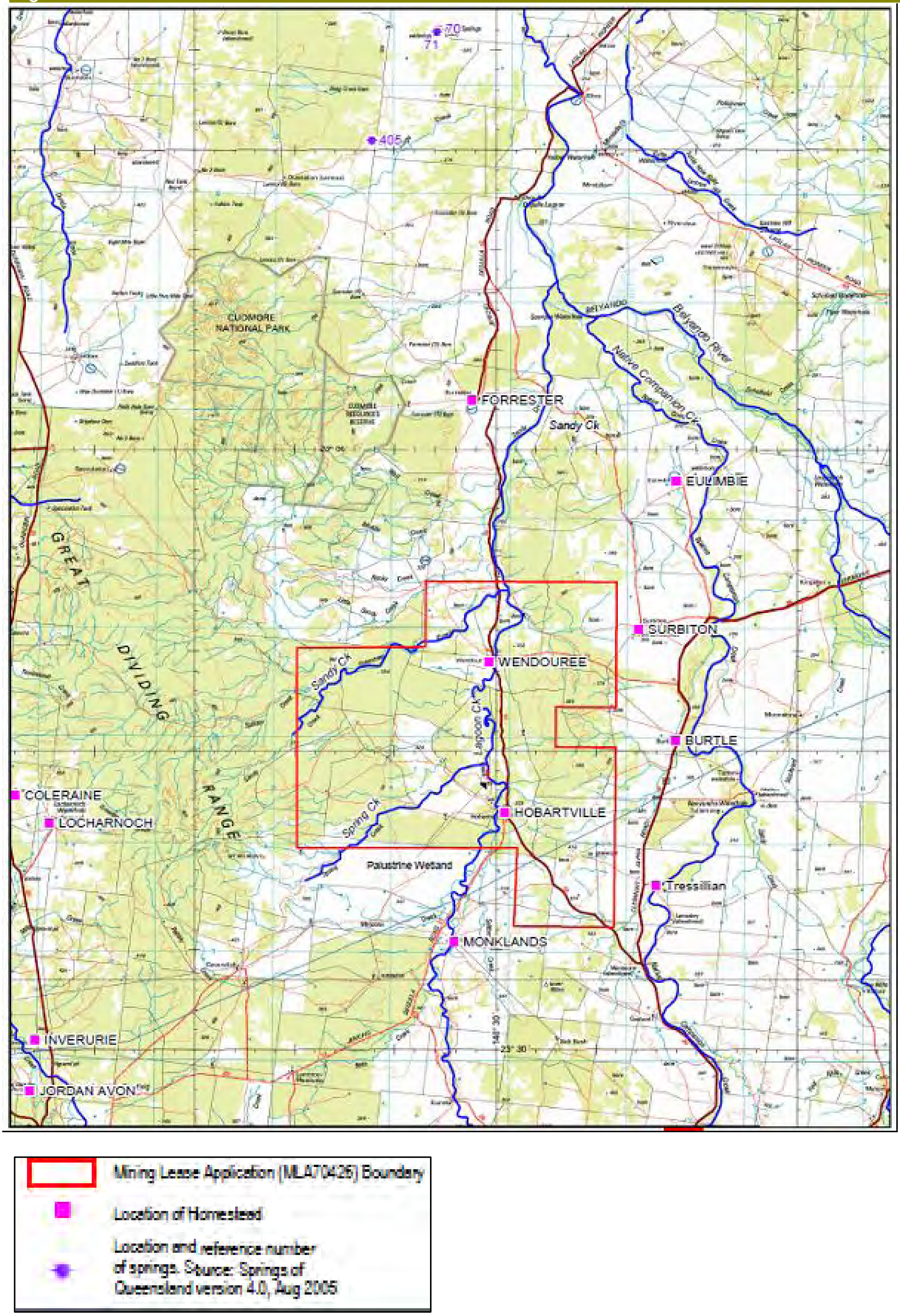
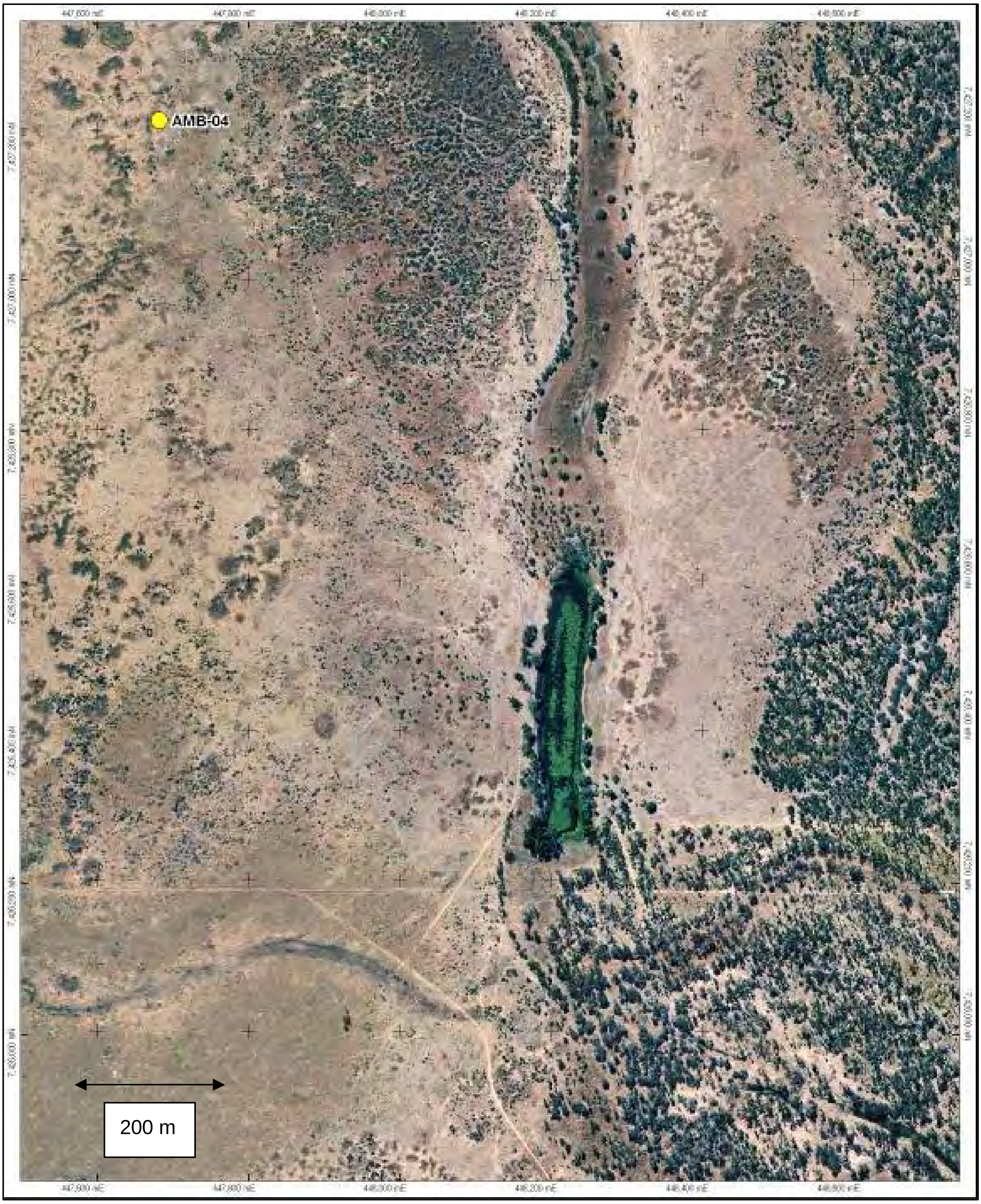


Figure N-7: Ox-bow lake and monitoring bore AMB04



Mine dewatering is, thus, not considered to represent a potential impact on the palustrine wetland. However, bore AMB04 will be monitored to determine impacts on the groundwater within this area.

EIS Volume 2 Section 19 Non Indigenous Cultural Heritage (Table 19-1) indicates that the mapped palustrine wetland is known as Murdering Lagoon, which is a man-made water management feature. This was constructed on Hobartville station in the early 20th century. Section 19.3.3.2.3 indicates that the site represents elements of a rural cultural landscape but has little heritage value (see Table 19-4). The cultural heritage mitigation measures regarding Murdering Lagoon are compiled in Section 19.4.2.4.

N.4.1.2 Additional groundwater level data

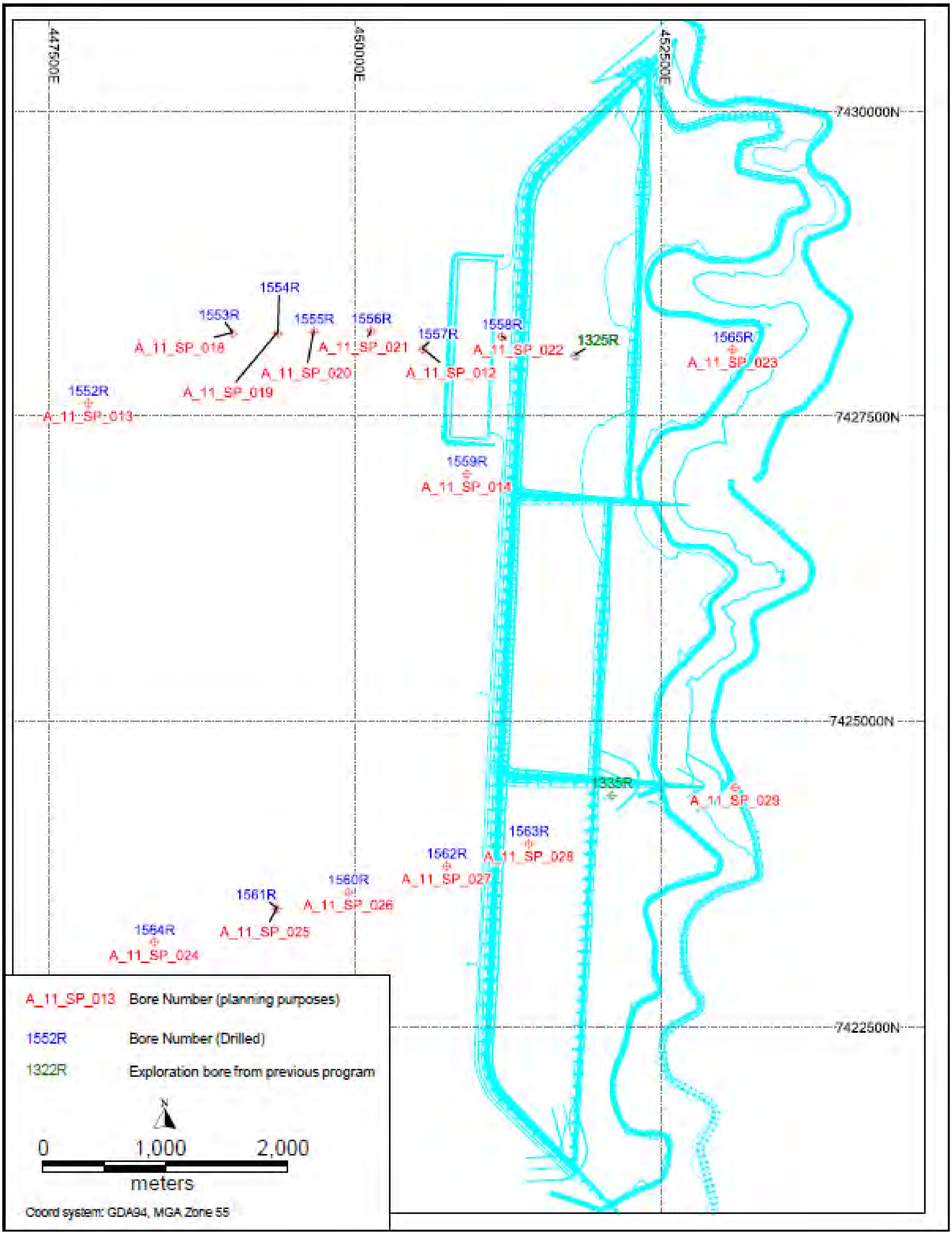
Additional groundwater monitoring bores have been constructed adjacent and within the proposed Alpha Tailings Storage facility (TSF) footprint, to the east of Lagoon Creek. Several of the monitoring points, as indicated on Figure N-8, include shallow stand pipes adjacent to Lagoon Creek. The details of the shallow monitoring points and the groundwater levels (Table N-5) indicate the perched natures of the surface water compared to the shallow groundwater resources.

Table N-5 Shallow groundwater data (28/07/2011)

Bore No	Elevation (m AHD)	Bore depth (m)	Groundwater depth (mbgl)	Groundwater static water level (m AHD)	Screened unit and distance from Lagoon Creek
1553R	310	30	10.27	299.73	Contact between Tertiary sediments and laterite, 850 m east of Lagoon Creek
1554R	312	36	11.30	300.7	Water strike at 33 m within sandstone and laterite, 1 250 m east of Lagoon Creek
1556R	317	36	16.55	300.45	Conglomerate, 2 000 m east of Lagoon Creek
1558R	325	18	Dry	-	Conglomerate, 3 125 m east of Lagoon Creek
1561R	315	12	10.1	304.90	Weathered Tertiary sediments, 100 m east of Lagoon Creek
1561R	315	30	12.86	302.14	Sandstone, 100 m east of Lagoon Creek
1561R	315	57*	13.08	301.92	VWP at base of weathering, 100 m east of Lagoon creek
1564R	314.5	18	10.77	303.73	Base of Tertiary, 700 m west of Lagoon Creek
1564R	314.5	44	10.50	304.00	Base of weathering, 700 m west of Lagoon Creek

* Vibrating wire piezometer

Figure N-8: TSF groundwater monitoring points



All groundwater level data, recorded in the new monitoring bores within different aquifers, adjacent to Lagoon Creek and the TSF are ~ 10 m below surface, significantly deeper than the likely root depth of plants or the depth of surface water bodies.

In addition, groundwater levels for multiple aquifers within one bore (such as 1561R, 100 m from Lagoon Creek) indicate that the piezometeric levels in the shallower aquifers are higher than the deeper aquifers in this area. This suggests a downward potential for groundwater flow in the area of the palustrine wetlands, and supports a view that water levels in the ox-bow lake are recharged by surface water flow rather than groundwater.

N.4.2 Registered springs

Preliminary predictive modelling (Appendix A) allowed for the predicted extent of drawdown after 30 years of mine dewatering at both Alpha and Kevin's Corner coal projects. The drawdown contour (5 m) was determined based on the depressurisation of the saturated units above the D coal seam.

Drawdown extends ~ 10 km beyond the north and south of the Alpha and Kevin's Corner MLA boundaries, some 10 km from the registered springs. The zone of influence created due to (cumulative) mine dewatering is not predicted to impact on the registered springs.

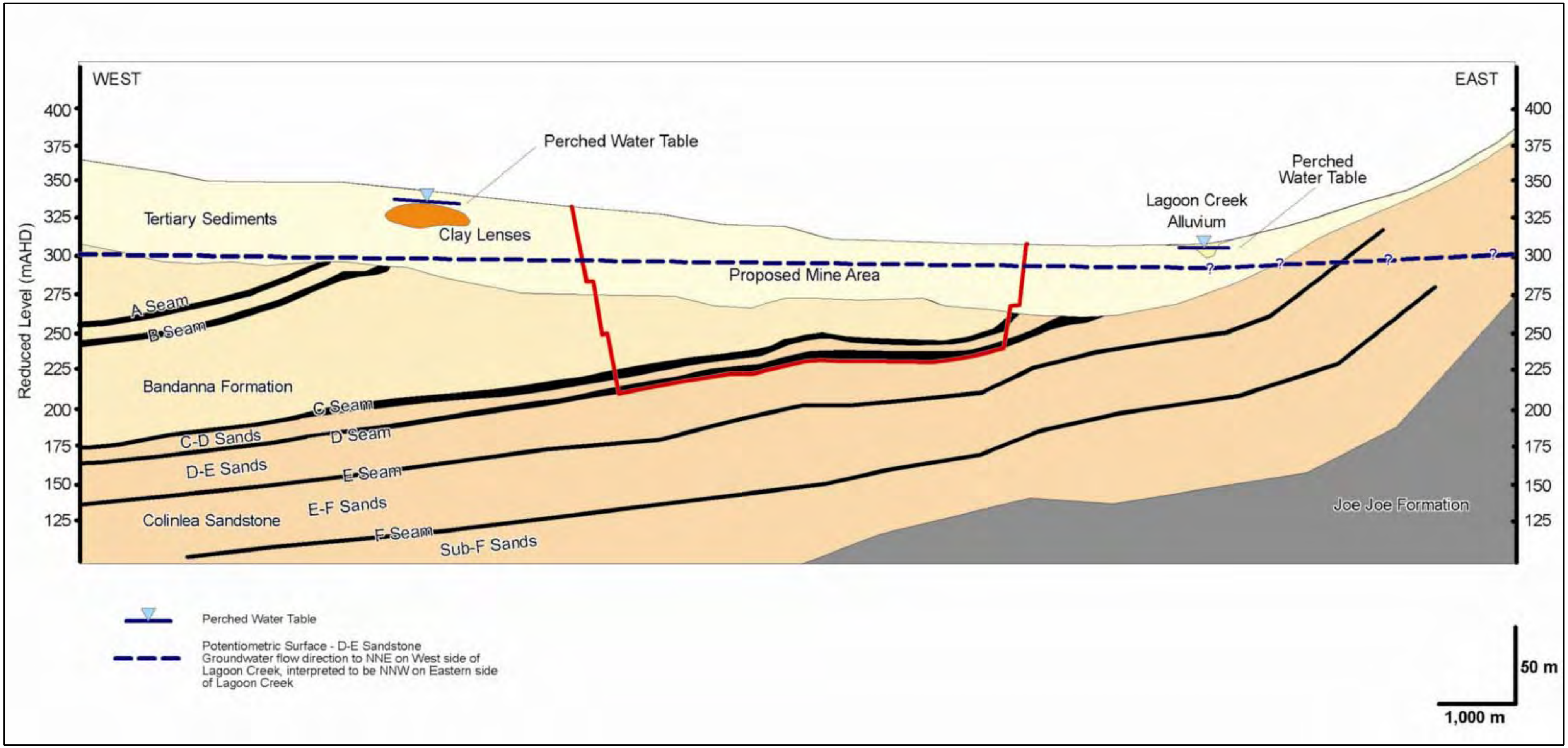
N.4.3 Groundwater level conceptualisation

Groundwater resources in the coal seams and Colinlea Sandstone aquifers are confined below by low permeable claystone layers and the coal seams and above by the thick weathered clay-rich Tertiary saprolite. The groundwater levels associated with the confined aquifers allowed for the identification of a potentiometric surface above the coal seams. The potentiometric surface is conceptualised in Figure N-9.

Quaternary sediments, alluvium and colluvium, are recognised to be deposited on the clay-rich saprolite. Shallow drilling during geotechnical studies across the site indicate occurrence of perched groundwater within the shallow sediments. The perched water is limited in extent and has limited effective storage (i.e. seasonal). This water may, however, be important to flora in the study area.

It is considered that in places where the potentiometric surface intersects the overlying perched groundwater there may be hydraulic connection. Thus should dewatering result in the reduction of groundwater / potentiometric levels, then this could impact on the perched groundwater resources. No hydraulic connectivity between the perched water table and the underlying confined aquifers has been identified on site (as presented in Table N-5). The details of the current drilling and monitoring bore construction program are detailed in Section N.5.

Figure N-9: Conceptual potentiometric surface associated with the confined D-E sandstone



N.4.3.1 Impacts on vegetation communities

The potential for groundwater drawdown due to mining to impact on vegetation communities within the Project site is regarded as low. There are no identified groundwater dependent ecosystems located on the Project site, and the groundwater piezometeric levels associated with usable aquifers are at depths > 10 m and thus not accessible to the existing vegetation.

Current information (groundwater level monitoring on site) indicates no hydraulic connectivity (linkage) between the piezometeric groundwater levels (associated with the underlying confined aquifers) and the ephemeral surface water resources or perched water tables. Thus any reduction in piezometeric pressure, resulting in decrease in groundwater levels, due to mine depressurisation will not impact on the vegetation communities.

Incidents of isolated perched groundwater, during and immediately after the wet season, within the weathered Tertiary laterite and saprolite and clay-rich Quaternary alluvium have been recorded. The perched groundwater table(s) are at depths of 0.5 to 1.5 m below surface. These perched water tables may provide limited water (low sustainable volumes) for local vegetation communities (Figure N-8).

Based on the low permeability of the Tertiary laterite and saprolite and the very low gradients drawdown within the Tertiary units, resulting from open pit mining, would be limited, some 10 to 100 m around the pits. Any perched water within this zone would report to the open pit. The vegetation in the area immediately adjacent to the mine pit will, however, be disturbed / removed due to the envisaged infrastructure (surface water levees, roads, water and power easements, etc.).

Based on the bore baseline monitoring program, trigger and guideline values for assessing impacts of groundwater drawdown related to mining activities will be proposed for all identified aquifers, including the perched water table(s). If mine induced groundwater drawdown is indicated, mitigation through the Proponents "make-good" commitment will be made, which could include artificial recharge of affected areas with water from alternative water sources.

N.5 Tailings Storage Facility Assessment

N.5.1Study objectives

A geological and hydrogeological assessment of the proposed 30 year life of mine TSF footprint has been undertaken to:

- Determine the underlying geology and investigate the nature of the boundary between the Colinlea Sandstone and the underlying Joe Joe Group;
- Investigate groundwater occurrence and yield and determine the nature of the groundwater resources within and adjacent to the TSF footprint;
- Construct groundwater monitoring bores to obtain groundwater data from multiple vertical zones;
- Assess suitability of the proposed TSF site from a groundwater perspective; and
- Assess recharge within the proposed TSF area

The study is ongoing and currently the drilling and monitoring bore construction has been complete, which allows for an initial assessment of the geology and hydrogeology. This initial data is presented to aid in making decisions regarding the potential impacts of the TSF on the groundwater and determining optimum mitigation and management options.

N.5.2Background

The proposed TSF is located in an area that is shown on the Jericho 1:250,000 geological sheet to comprise outcrop of Colinlea Sandstone and Joe Joe Formation.

The Colinlea Sandstone is encountered throughout the project area, and comprises the D coal seam, D-E sandstone, E and F coal seams, and sub-E sandstone.

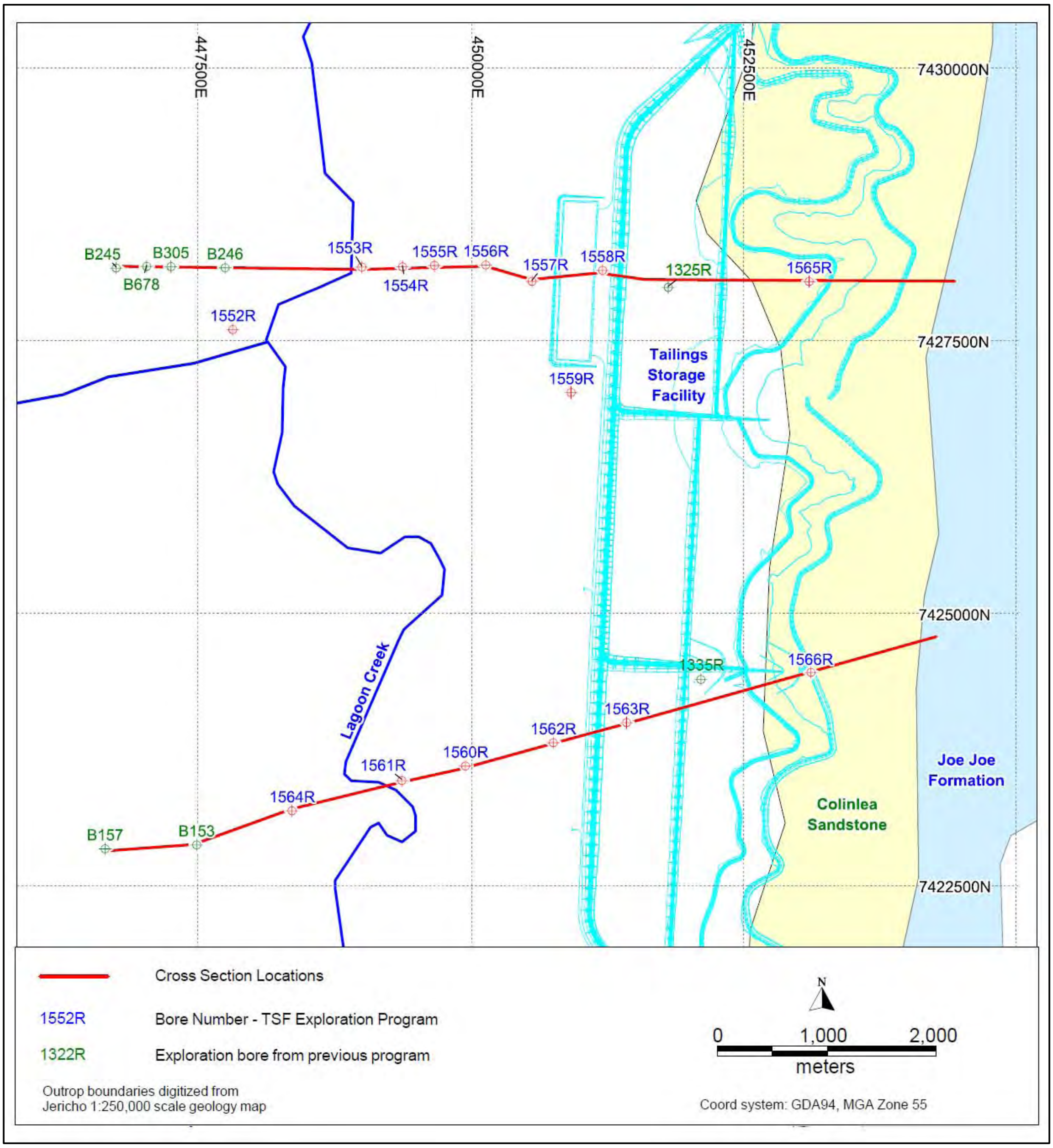
The geology of the Colinlea Sandstone (at least down to the D-E sandstone) and the overlying Bandanna Formation is well known within the project area based on extensive exploration drilling data. However only a limited number of exploration holes have been drilled to specifically target the Joe Joe Formation in the project area, therefore a local description of the Joe Joe Formation has not been compiled.

In addition relatively little data existed on groundwater occurrence and recharge potential of the Colinlea Sandstone outcrop in the area of the proposed TSF.

In order to address the issues outlined above, a field investigation program was undertaken at the site of the proposed TSF (Figure N-10) in order to obtain:

- Data relating to the stratigraphy and lithology underlying the site, particularly the nature of the boundary between the Colinlea Sandstone and the Joe Joe Formation, which both outcrop in the area of the proposed TSF;
- Data relating to groundwater occurrence and aquifer types; and
- Data relating to the potential for the site to be located within a groundwater recharge area.

Figure N-10: Location of TSF investigation bores and cross-sections



N.5.3 Previous work

N.5.3.1 Geology of the Joe Joe Formation

The geology of the Joe Joe Formation within the Galilee Basin has been described in detail in Gray and Swarbrick (1975). The paper notes that the strata described as the Joe Joe Formation, and shown on the Jericho 1:250,000 scale geological map, comprises (in stratigraphically ascending order) the Lake Galilee Sandstone at it's base and the overlying Jericho Formation, Jochmus Formation, and Aramac Coal Measures.

On this basis the paper recommends that the Joe Joe Formation be raised to Group status (Joe Joe Group). The Joe Joe Formation is hereafter referred to as the Joe Joe Group.

Gray and Swarback (1975) define the Joe Joe Group as "that succession of formations which is unconformably overlain by the Colinlea Sandstone and its lateral correlative, and unconformably overlies strata of the Adavale and Drummond Basins…" The Joe Joe Group consists of entirely non-marine sediments and, based on dating of spore assemblages, is assigned a likely age of Late Carboniferous to early Permian (Gray and Swarback, 1975).

Gray and Swarback (1975) indicate that the Colinlea Sandstone is coarser and more quartz-rich than the Joe Joe Group sediments. A description of the units comprising the Joe Joe Group and overlying units is shown in Table N-6.

Table N-6 Summary of lithology of Joe Joe Group

<table>
<tr><th>Age</th><th colspan="2">Rock Unit</th><th>Lithology</th></tr>
<tr><td rowspan="2">Late Permian</td><td colspan="2">Bandanna Formation</td><td>Sandstone, siltstone, mudstone, coal</td></tr>
<tr><td colspan="2">Colinlea Sandstone</td><td>Sandstone, conglomerate, coal</td></tr>
<tr><td colspan="4">Unconformity</td></tr>
<tr><td rowspan="4">Late Carboniferous to early Permian</td><td rowspan="4">Joe Joe Group</td><td>Aramac Coal Measures</td><td>Sandstone – light grey, very fine to medium, quartzose to labile
Siltstone – medium to dark grey, carbonaceous, micaceous
Mudstone – grey and dark grey-brown, carbonaceous, micaceous
Coal – grey to black, dull</td></tr>
<tr><td>Jochmus Formation</td><td>Sandstone – light grey, green, fine to medium grained, labile, locally conglomeratic
Siltstone – light to medium grey and grey-green, argillaceous to sandy, carbonaceous.
Mudstone – grey-green, silty, micaceous, carbonaceous.
Contains Edie Tuff Member (siltstone, tuff, minor sandstone. Tuff contains "Red Tuff Marker")</td></tr>
<tr><td>Jericho Formation</td><td>Mudstone, siltstone, sandstone.
Contains Oakleigh Siltstone Member (siltstone, mudstone, shale)</td></tr>
<tr><td>Lake Galilee Sandstone</td><td>Silicified sandstone, minor mudstone</td></tr>
</table>

N.5.3.2 Previous drilling on site

A limited number of exploration bores have been drilled in the area of the proposed TSF. The purpose of these bores was for investigation of coal potential. Several of these bores were drilled deep enough to intersect sediments of the Joe Joe Group, and a number of bores have been drilled in areas where Joe Joe Group sediments outcrop (based on interpretation of the Jericho 1:250,000 geological sheet).

The interpretation of a number of these bores is discussed further below.

N.5.4 Drilling

As part of the investigation program groundwater monitoring bores were constructed at the site of a number of geological investigation bores. The intent of this phase of the program was to:

- Provide information on groundwater levels spatially and vertically, to establish groundwater flow direction and groundwater recharge potential at the site;
- Enable long-term monitoring of groundwater levels to enable study of the groundwater response to rainfall events (i.e. groundwater recharge);
- Provide a means of obtaining groundwater quality samples; and
- Nested sites were established at a number of locations as a combination of standpipe piezometers, which allow sampling for water level and water quality, and vibrating wire piezometers (VWPs), which allow measurement of groundwater level.

The field investigation program comprised drilling and logging of a number of geological / groundwater exploration bores, as shown on Figure N-8 and Figure N-10. The final drilling program allowed for the drilling of geological (exploration) and / or groundwater monitoring bores at 15 sites and the construction of 22 monitoring points (Table N-7).

Two parallel lines of bores were drilled, from west to east, across the proposed TSF footprint (as indicated in Figure N-8 and Figure N-10). These bores, drilled to intersect fresh Joe Joe Group at depth, allowed for the detailed logging of the geology across the proposed TSF site.

A summary of the bores drilled are presented in Table N-7 and number as indicated on Figure N-8.

Table N-7 Drilling summary and groundwater monitoring bore construction and water levels (01/08/2011)

Bore No	Easting (GDA94)	Northing (GDA94)	Bore depth	Bore type	Surface RL (mAHD)	SWL (mbgl)	RWL (mAHD)
1552R	447 816	7 427 611	132	Exploration	-	-	-
1553R	448 996	7 428 186	30	Standpipe	310	9.44	300.56
1553R			55	VWP	310	9.63	300.37
1553R			78	VWP	310	12.87	297.13
1554R	449 368	7 428 188	36	Standpipe	312	10.53	301.47
1555R	449 662	7 428 201	102	Exploration	-	-	-
1556R	450 132	7 428 204	36	Standpipe	317	15.75	301.25
1557R	450 553	7 428 055	78	Exploration	-	-	-
1558R	451 199	7 428 156	18	Standpipe	325	Dry	Dry
1558R			34	VWP	325	21.88	303.12
1558R			50	VWP	325	16.57	308.43
1559R	450 912	7 427 033	90	Exploration	-	-	-

Bore No	Easting (GDA94)	Northing (GDA94)	Bore depth	Bore type	Surface RL (mAHD)	SWL (mbgl)	RWL (mAHD)
1560R	449 944	7 423 607	102	Exploration	-	-	-
1561R	449 361	7 423 473	12	Standpipe	315	9.26	305.74
1561R			30	Standpipe	315	12.04	302.96
1561R			57	VWP	315	13.08	301.92
1562R	450 748	7 423 820	90	Exploration	-	-	-
1563R	451 420	7 424 006	10	Standpipe	328	Dry	Dry
1563R			36	Standpipe	328	24.94	303.06
1563R			70	VWP	328	26.61	301.39
1564R	448 357	7 423 195	18	Standpipe	314.5	Dry	Dry
1564R			44	Standpipe	314.5	9.77	304.73
1564R			68	VWP	314.5	10.23	304.27
1565R	453 090	7 428 053	18	Standpipe	340	Dry	Dry
1565R			36	Standpipe	340	29.43	310.57
1565R			50	VWP	340	22.87	317.13
1566R	453 106	7 424 465	18	Standpipe	333	Dry	Dry
1566R			36	Standpipe	333	Dry	Dry

Note: Groundwater level data is preliminary as not all groundwater levels have stabilised after construction. Groundwater level data varies between 28/07/2011 (Table N-5) and 01/08/2011 (Table N-7).

N.5.5 TSF geology and groundwater

Information obtained from the field investigation program is summarised in cross sections shown as Figure N- 11 (northern line) and Figure N-12 (southern line). The location of each cross section is shown on Figure N-10.

The results and interpretation of drilling / groundwater data are summarised as:

- In the proposed TSF footprint the fresh (unweathered) Joe Joe Group comprises blue-grey micaceous, chloritic, lithic sandstone and well cemented conglomerate. The sediments are well cemented and, based on low (dry) air-lift yield results, have low primary permeability. Areas of relatively high yield are therefore expected to be related to secondary permeability, such as fracturing, which may offer low sustainable yields due to low storage;
- The weathered / lateritic Joe Joe Group sediments are difficult to distinguish from weathered / lateritic Colinlea Sandstone (Permian parent material of the Tertiary laterite is difficult to discern). However, an abundance of lithic sediments and occurrence of carbonaceous material is considered diagnostic as the Colinlea Sandstone is more quartz-rich;

In terms of potential groundwater impacts from the proposed TSF, the stratigraphy of the proposed TSF area (in terms of whether the TSF footprint is on outcrop of Joe Joe Group or Colinlea Sandstone sediments) is considered to be less important than the lithology underlying the proposed TSF site. This is due to the lack of rock outcrop or shallow subcrop of either unit within the TSF footprint as the Permian sediments are covered by thick clay-rich saprolite and laterite (Figures N-11 and N-12).

Figure N-11: Cross-section through TSF investigation area – Northern Line

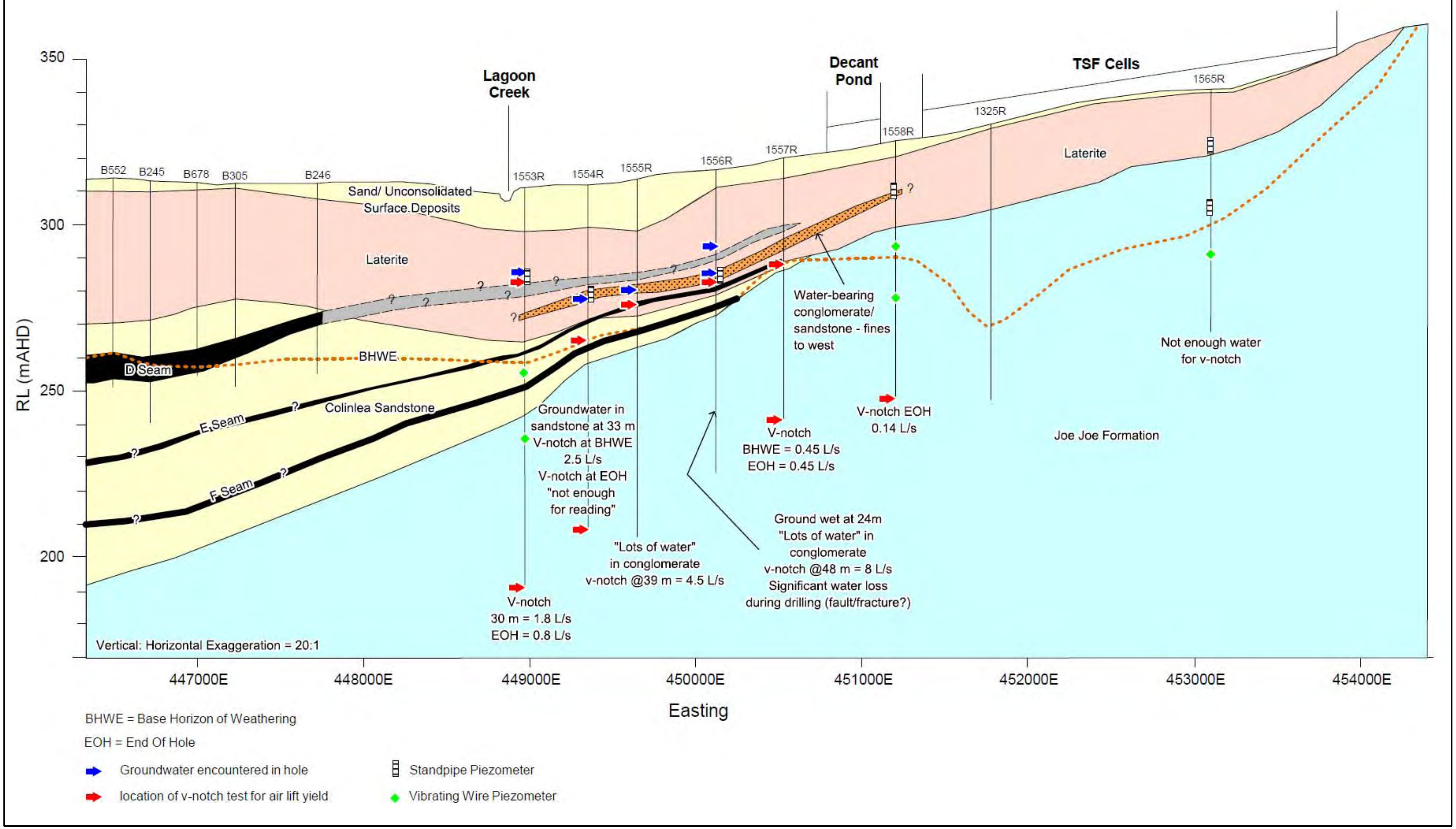
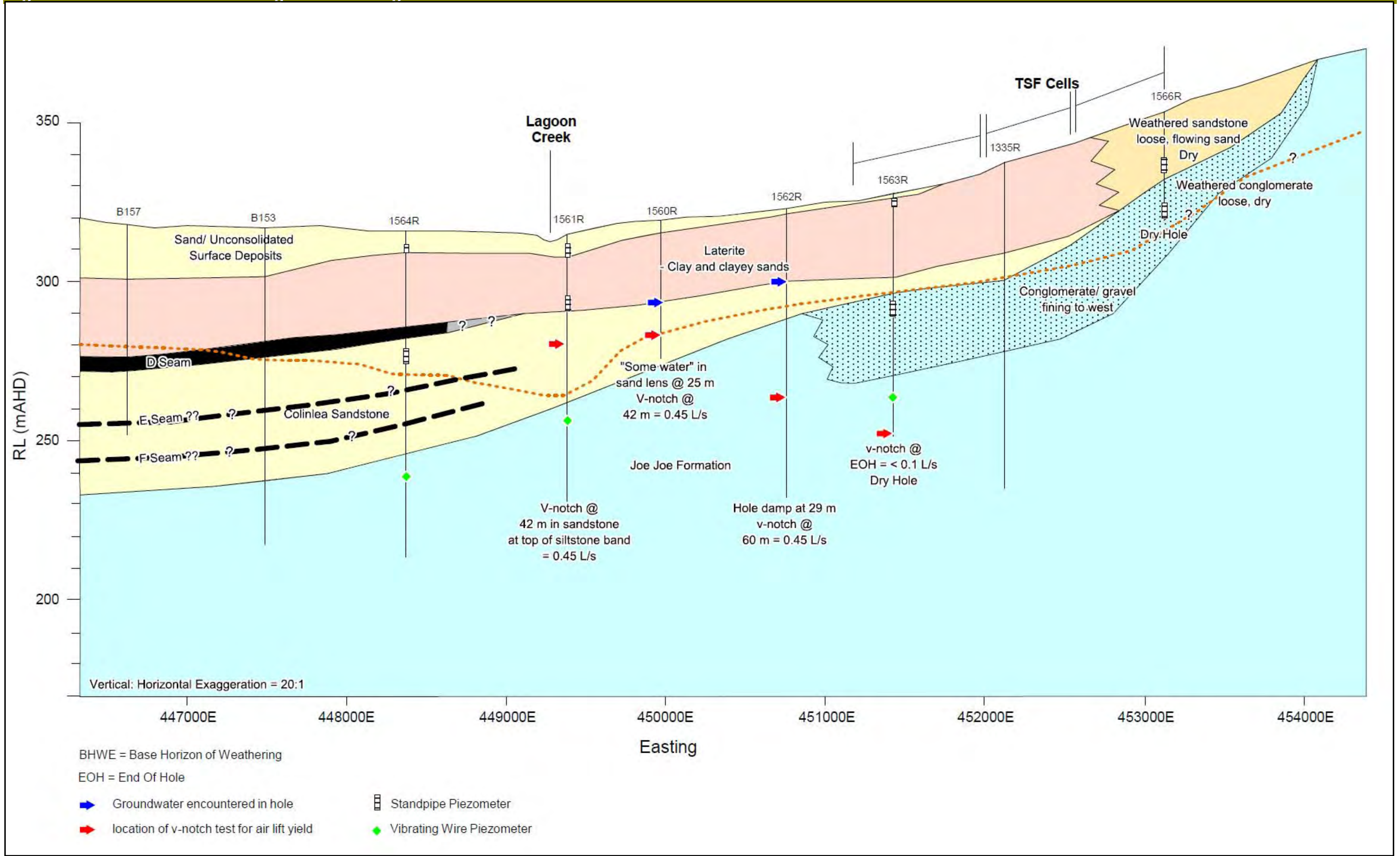


Figure N-12: Cross-section through TSF investigation area – Southern Line



N.5.5.1 Underlying lithology and groundwater resources

Northern Line (Figure N-11)

- The proposed TSF is underlain by laterized clays and clayey sands. The sediments drilled dry (rotary-air-percussion), and the underlying Joe Joe Group sediments contained little water.
- Down-gradient of the proposed TSF a water-bearing conglomerate / sandstone was intersected at a depth ranging between approximately 35 and 40 mbgl within the Tertiary laterite. Little or no groundwater was intersected within the conglomerate / sandstone unit within bores 1557R and 1558R, however, bores 1555R and 1554R intersected an area of enhanced groundwater potential within the conglomerate / sandstone down-gradient of the TSF. The volume of groundwater intersected in 1556R, and the loss of water during drilling, is suggestive of alteration (fault or fracture) at this location. The unit is less distinct in 1553R and the main occurrence of water in this hole is a sandstone layer within weathered coal, between 30 and 36 mbgl.
- In bores down-gradient of the proposed TSF it was observed during drilling that the Joe Joe Group sediments made little water, even when coarse sandstone and conglomerate was encountered. This supports the observation that matrix sediments and cement have resulted in a low primary porosity for Joe Joe Group sediments.

Southern Line (Figure N-12)

- The area of the proposed TSF is underlain by laterized clays and sands, which drilled dry. In the western area of the proposed TSF (bore 1566R) drilling encountered highly weathered, red (iron-stained) sandstone, which occurred as flowing sand. Below this unit a highly-weathered pebble conglomerate was encountered, which also tended to fall into the bore. Bore 1566R was drilled to a depth of 36 mbgl and was dry;
- The gravel / pebble conglomerate extends west and is encountered in bore 1563R. Further west the unit appears to fine to sand, and is generally indistinguishable from the sandstone generally encountered in the Joe Joe Group;
- In general, the bores on the southern line drilled much drier than bores on the northern line, where the main water occurrence was the contact between the laterite and the underlying sandstone.

N.5.5.2 Groundwater levels

Groundwater levels within newly constructed monitoring bores are shown in Table N-7. The results must be taken as preliminary as the bores are newly drilled and constructed. However in general the following observations are made with respect to geology, groundwater occurrence and water levels in the area of the proposed TSF:

- Depth to groundwater in most units in the area of Lagoon Creek is in the order of 10 mbgl. Where multiple piezometers have been constructed at the one site (e.g. 1553R, 1564R, 1561R) there is an apparent downward potential for groundwater movement (i.e. deep drainage potential). The results are preliminary as groundwater levels may still be stabilising in the newly-constructed monitoring bores, and it is also possible that the higher shallow groundwater levels are reflective of recent (2010/11) wet-season rainfall.
- Beneath the proposed TSF footprint most bores were relatively dry during drilling, and current levels suggest groundwater levels between 25 and 30 mbgl (e.g. 1563R). Vibrating wire

piezometer data for bore 1558R (located between the toe of the proposed TSF and the decant pond, refer Figure N-10) suggests water levels between 16 and 22 mbgl and an upward potential for groundwater flow. However, groundwater levels in this bore may not have stabilised post-construction (i.e. the levels may reflect grout pressures) so all groundwater level data will require further review in the lead-up to the next wet season.

N.5.6 Preliminary assessment of proposed TSF site

Based on the initial available site specific geological and hydrogeological data an assessment of the potential impacts of the proposed TSF have been compiled. This assessment will be reassessed once additional information is available, which will include more accurate groundwater levels, aquifer hydraulic parameters from variable head tests to be conducted in the new standpipe bores, hydrochemical assessment, and groundwater flow / contours.

The preliminary assessment indicates:

- Limited recharge potential to the underlying Colinlea Sandstone aquifers due to the thick clay-rich Tertiary cover, thin discontinuous Colinlea Sandstone aquifers (cross-sections indicate thin sub-E and sub-F sands), 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. This coincides with the conceptualisation, borne from the groundwater flow patterns recorded on site, from south west to north east, that groundwater recharge predominantly occurs to south west along the Great Dividing Range.
- Drilling results and blow-out yields recorded during rotary-air-percussion within the proposed TSF footprint indicate aquitards and units of limited groundwater potential.
- Discrete zones of alteration, resulting in enhanced groundwater potential, occur to the west of the northern portion of the proposed TSF footprint. These groundwater resources can be protected through the use of lining and seepage control measures down gradient of the proposed TSF.
- The footprint is underlain by Tertiary age saprolite and laterite (Tertiary weathering of Colinlea Sandstone sediments) and Joe Joe Group sediments that are shown from drilling to be hydraulically tight and to have very low groundwater potential.

N.6 Bore Survey

A bore survey of existing groundwater users and use was conducted within a ~ 10 km radius of the Hancock MLAs, both Alpha Coal Project and Kevin's Corner Coal Project. The survey aimed at obtaining pre-mining ambient groundwater data.

The hydrocensus was completed in July 2011 and the detailed findings are presented in SEIS Volume 2, Appendix O.

The bore survey included the sampling of bores used for domestic purposes and stock watering on each of the farms visited, in order to obtain representative groundwater quality data. These results, compared to the Australian Drinking Water Guidelines and the ANZEEC guidelines for stock watering (beef) indicate that the groundwater is suitable for both domestic and stock watering (SEIS Volume 2, Appendix O).

These results have allowed for a revision of the groundwater environmental values, which have been revised in SEIS Appendix V the Environmental Management Plan.

N.7 References

Butcher. (1984), The Showgrounds Formation, its setting and seal

Cadman and Pain. (1998), Bowen and Surat Basins, Clarence-Moreton Basin, Sydney Basin, Gunnedah basin and other minor onshore basins, QLD, NSW, and NT

Conybeare. (1970), Solubility and mobility of petroleum under hydrodynamic conditions, Surat Basin, Queensland

Gray, A.R.G. and Swarbrick, C.F.J. (1975). Nomenclature of Late Palaeozoic Strata in the Northeastern Galilee Basin. *Queensland Government Mining Journal Vol. LXXVI No. 888*, October 1975

Habermehl. M.A. (2001), Wire-Line Logged Waterbores in the Great Artesian Basin. Digital Data of Logs and Waterbore Data Acquired by AGSO. Bureau of Rural Sciences Australia

Henning et al. (2006), Hydrodynamic Characterisation of the Triassic Showgrounds Aquifer at the Wunger Ridge Site in Queensland: Assessing Suitability for CO_2 Sequestration

Jericho 1:250,000 Geological Map, Sheet SF55-14. Bureau of Mineral Resources, Geology and Geophysics, Canberra, ACT. First Edition 1972

Queensland Department of Mines and Energy. (1997), The Surat and Bowen Basins South-East Queensland

Salva. (2009), Summary of Galilee Regional Model (GAB).

WorleyParsons. (2010), Spatial Analysis of Coal Water Chemistry Task 1: Literature Review

Appendix A Groundwater Modelling Update

HANCOCK COAL PTY LTD

ALPHA COAL PROJECT
and
KEVIN'S CORNER PROJECT

REGIONAL GROUNDWATER MODEL
INTERIM REPORT

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery
JBT01-005-026	Draft 1	URS	23 June 2011	electronic
JBT01-005-026	Final	URS	4 August 2011	electronic

PROJECT TEAM

Project Personnel	Organisation	Role
John Bradley	JBT Consulting	Project management, data gathering, interpretation and review, preparation of data sets, report writing, consultation and liaison with NTEC Environmental Technology
Dr Lloyd Townley	NTEC Environmental Technology	Conceptualisation, representation of mine pit lakes post-mining, automation of FEFLOW runs
Dr Andrew Brooker	NTEC Environmental Technology	Initial processing of hydrostratigraphic data
Dr Attila Kovacs	NTEC Environmental Technology	Development of FEFLOW models with increasing complexity, aligned to mine plans

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Executive Summary

JBT Consulting and NTEC Environmental Technology have developed a numerical groundwater model of the region surrounding the Alpha and Kevin's Corner Coal Projects. The model represents the regional hydrogeological system and has been designed to predict the potential cumulative impacts of the Alpha and Kevin's Corner mines.

Predictions of inflows to mines and regional drawdown during mining have been made, but a number of hydrogeological properties are uncertain, especially relating to the storage and flow properties of sedimentary units above and below the D Seam. Additional tests in the field and laboratory are required before modelling can be completed.

The model results presented in this report are based on an interim stage of modelling. Further refinements will be made to improve the quality of the model and to reduce uncertainty in the results.

According to simulation results, the cumulative inflow volume into the Alpha pit varies between 658 and 1150 GL over the 31 years of mining activity. The cumulative inflow volumes into the Kevin's Corner underground mine and into the Northern and Southern Kevin's Corner open pits are in the ranges 4844-7150 GL, 60-123 GL and 169-348 GL, respectively.

These figures take into account the effect of rock deformation on inflow rates, especially above the Kevin's Corner underground mine, but the predicted inflow rates are believed to be too large. The impacts of deformation will be investigated further during a subsequent stage of the modelling process.

Simulation results indicate that the cumulative cone of depression caused by the two operations will extend approximately 10 km around the mines. In the north-west corner of mining lease MDL333, the outcropping low conductivity Rewan Formation limits the extent of the cone of depression to between 1.5 and 6 km.

Depressurisation is also predicted in the Joe Joe Formation beneath the mines, and this contributes to the inflow of groundwater into the mines.

No significant impact on the GAB can be observed after 31 years of mining operations. The Rewan Formation acts as an effective hydraulic barrier, limiting the propagation of the cone of depression towards the GAB.

Predictions of the recovery of the water table and the evolution of mine pit lakes have been made, based on predictions of drawdown at the end of mining. Given the uncertainty in predictions of drawdown, there is also uncertainty in predictions of recovery.

The water table is predicted to recover over a period of ~250-300 years after the start of mining. Water levels in mine pit lakes will equilibrate at about 280 mAHD, and the regional water table will show a cone of depression with almost radial flow towards the mine pit lakes.

During recovery, groundwater will flow initially towards Kevin's Corner, and there will be a long period during which a number of separate mine pit lakes along the length of the Alpha open cut coal mine with a gradient in levels from south to north.

The final equilibrium predicted is influenced by an assumption that regional recharge to the water table is negligibly small. This assumption is reasonable during mining, when groundwater flows are dominated by dewatering in the mines. The assumption is not appropriate in the long term, and leads to a predicted cone of depression that is larger than would occur if recharge were taken into account.

This assessment is preliminary, and will be revised when the regional model is finalised, taking long-term recharge into account.

The predicted pumping volumes include water in storage that is removed by mining – i.e. the model currently does not distinguish between water removed via pumping and water removed via the mining process. As the area of mining is signficant, this current limitation will also result in an over-estimate of pumping volumes. This situation will be addressed in future versions of the model.

The Alpha Test Pit (ATP) was developed between November 2010 and July 2011 to enable a bulk sample of coal (150,000 ROM 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 (ie for prevention of floor heave and to maintain geotechnical stability of the pit walls). The development of the ATP has provided valuable information on dewatering requirements, and groundwater drawdown impacts from mining. A summary of ATP development is included as Appendix D.

A separate numerical model is being developed in FEFLOW by NTEC to simulate the development of the ATP. It is intended that the calibration data from the small-scale ATP model will be carried over to the large-scale regional model to improve model calibration.

1.0 INTRODUCTION

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. The nearest residential area to the Project is the township of Alpha, located approximately 50 km south of the Project (Refer Figure 1-1). Access to the mining lease is from the Hobartville Road north off the Capricorn Highway at Alpha.

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 coal will be washed on site and then conveyed to a train load-out facility where it will be transported more than 400 km to the east coast of Australia to the port facility at Abbot Point for export.

The Alpha Project is a 30 Mtpa open cut thermal coal mine to target 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.

The mining tenements comprise Mineral Development Licence (MDL) 285 (Alpha), MDL333 (Kevin's Corner) and Exploration Permit Coal (EPC) 1210 (shown on Figure 1-2). Mining Lease Applications (MLA's) have been taken out over the same area, and comprise MLA 70245 (Kevin's Corner) and MLA 70246 (Alpha). For historical reasons all the tenement descriptions above may be used in this report.

The location of the Alpha and Kevin's Corner MLA are shown on Figure 1-2, with the mine layout for each project shown on Figure 1-3. The relationship between the tenements described above can be seen from these figures.

Regional groundwater modelling is being undertaken to support the Environmental Impact Statement (EIS) requirements of each project, in addition to providing a means for assessing the mine dewatering requirements and water supply potential of each project.

This interim report has been prepared to allow assessment and review of the model in its current form, prior to undertaking work to refine the model.

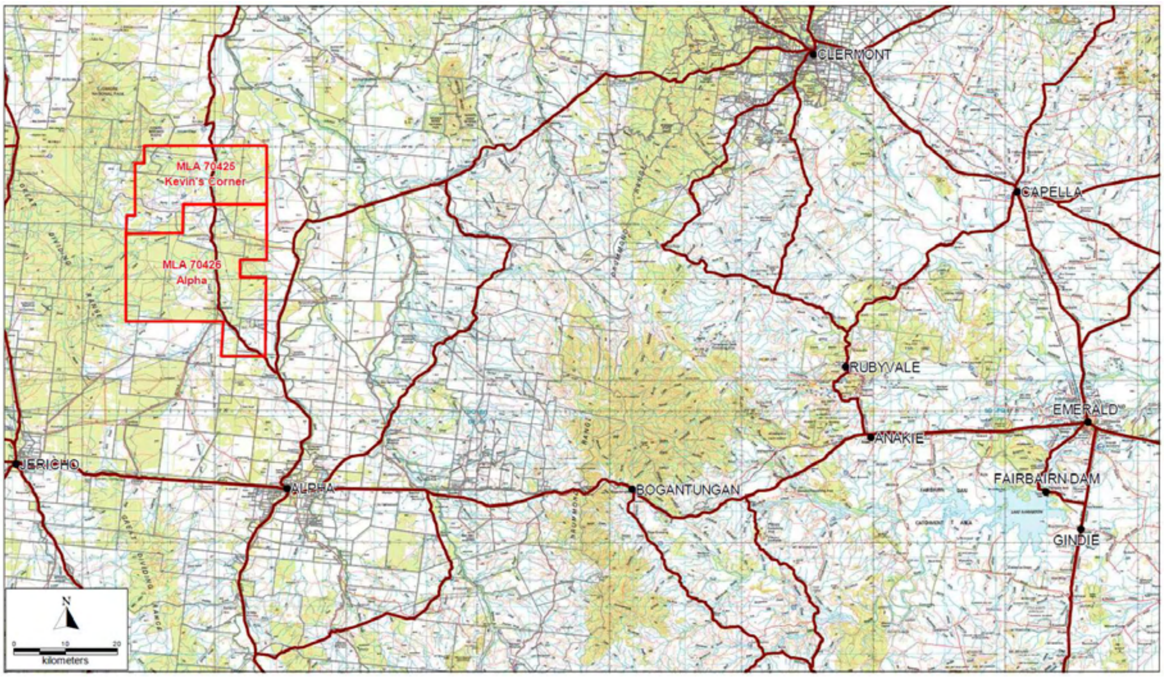

Figure 1-1: Project Location

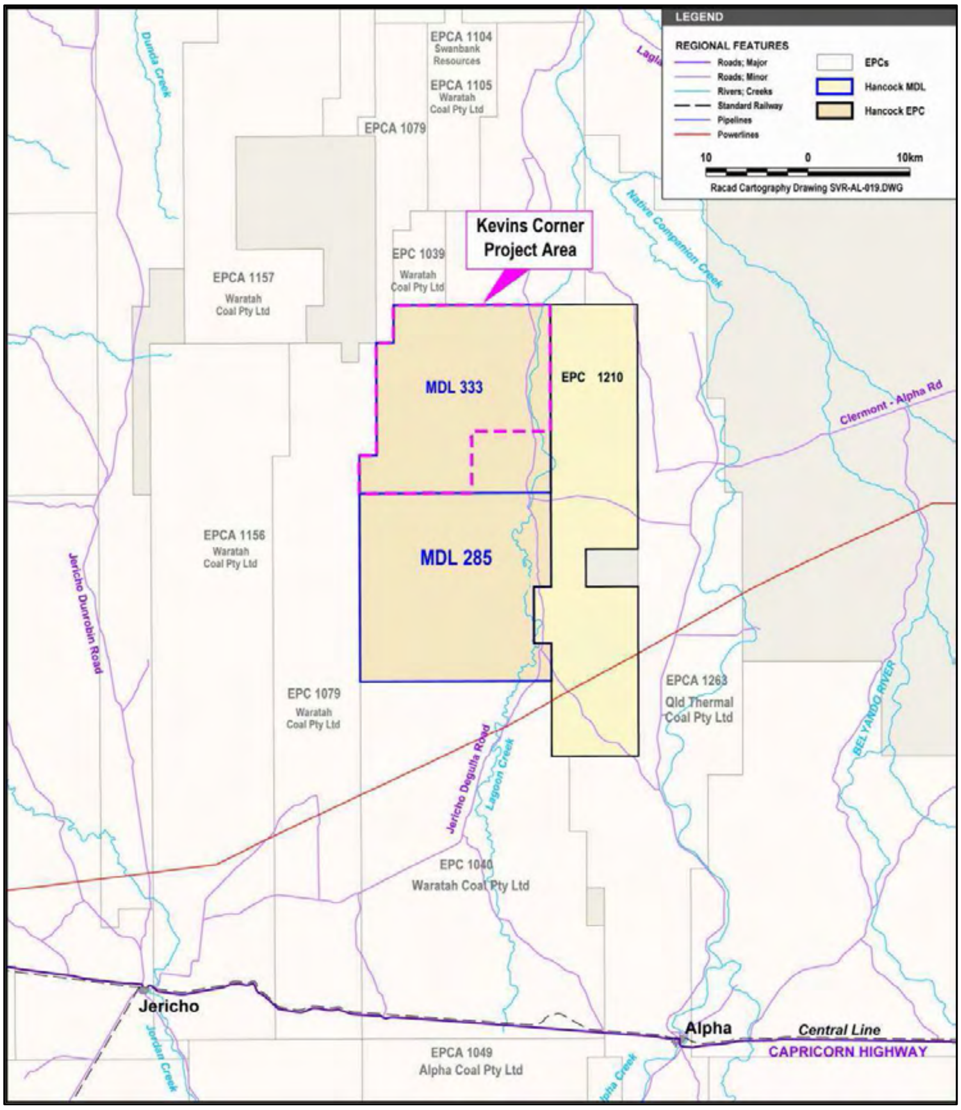

Figure 1-2: Project Mining Location within the Galilee Basin, Central Queensland

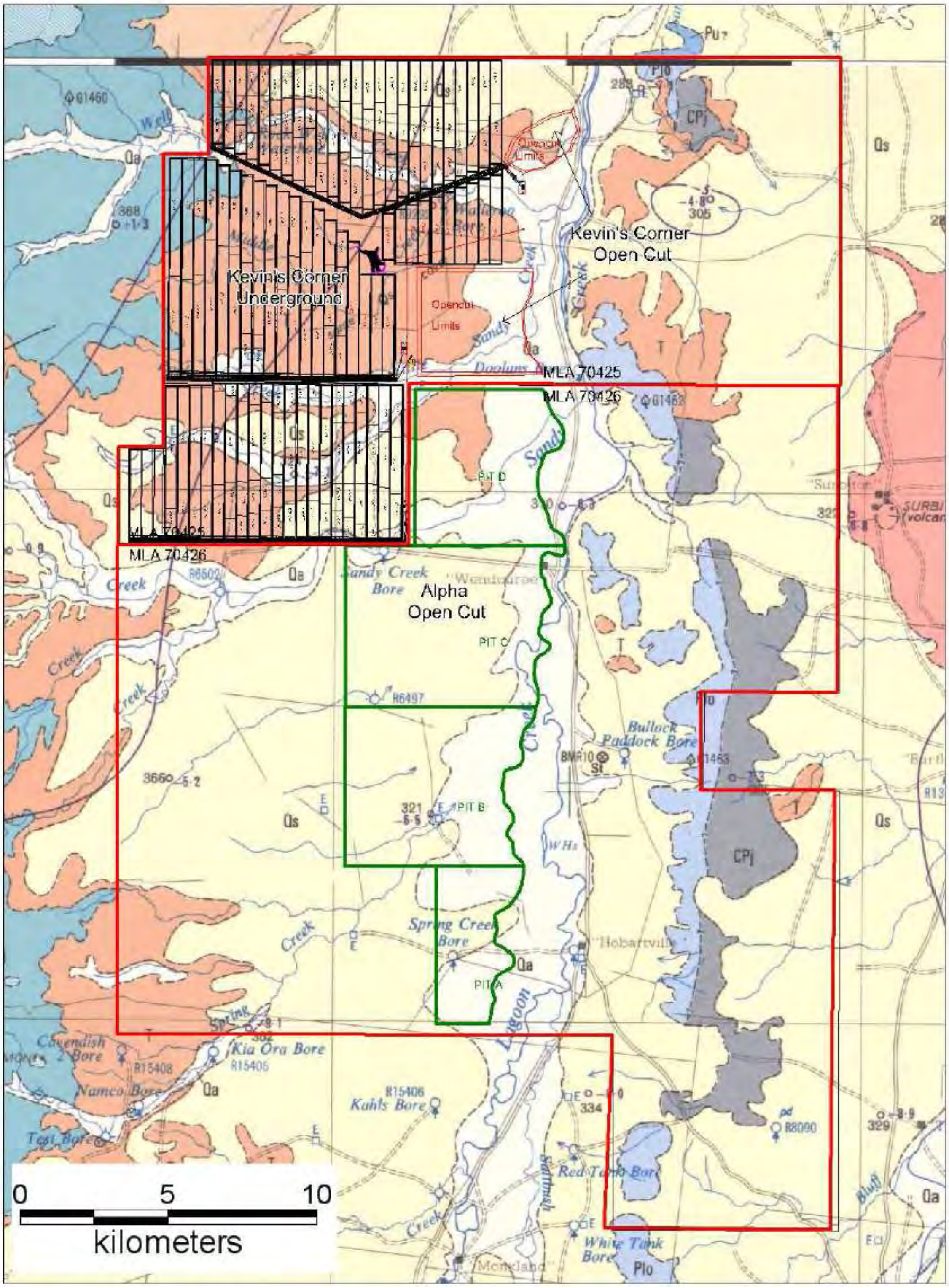

Figure 1-3: Mine Layout – Alpha Coal and Kevin's Corner Projects

2.0 SCOPE OF WORK

2.1 Scope of Work and Model Objectives

The Scope of Work for the current phase of regional groundwater modelling includes:

- Review available geological, hydrogeological, and climatic data and prepare a conceptual groundwater model for the area of the model to include the most up to date geological and groundwater knowledge and data;
- Construct and calibrate (to steady state) a numerical groundwater model based on the conceptual groundwater model;
- Incorporate the mine plan and mine development schedule for the Alpha Coal Project and Kevin's Corner Project;
- Assess the regional groundwater impact of the Alpha Coal Project and Kevin's Corner Project, as well as the cumulative impact of the Alpha Coal Project and Kevin's Corner Coal Project. This assessment is to include potential for impact on existing groundwater users, as well as the water resources of the Great Artesian Basin (GAB) which occurs to the west of the Project area; and,
- Assess groundwater inflow rates to each operation, for planning of mine dewatering requirements, water infrastructure requirements, and water supply potential.

2.2 Model Complexity

Based on the requirements of the scope of work and model objectives (with the principal objective of being able to predict the impact of the Alpha Coal Project on regional groundwater levels), the appropriate level of complexity for the Alpha regional groundwater model is judged to be a moderate complexity Impact Assessment Model[1].

3.0 HYDROGEOLOGICAL SETTING AND DATA

3.1 Climate Data

3.1.1 Barcaldine BOM Station

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) (http://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.

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[1] Refer Middlemis et al. (2000) *Groundwater Flow Modelling Guideline,* Table 2.1.1.

Data trends indicate that mean annual rainfall for the region is approximately 497 millimetres (mm). Figure 3-1 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 (Refer Figure 3-1).

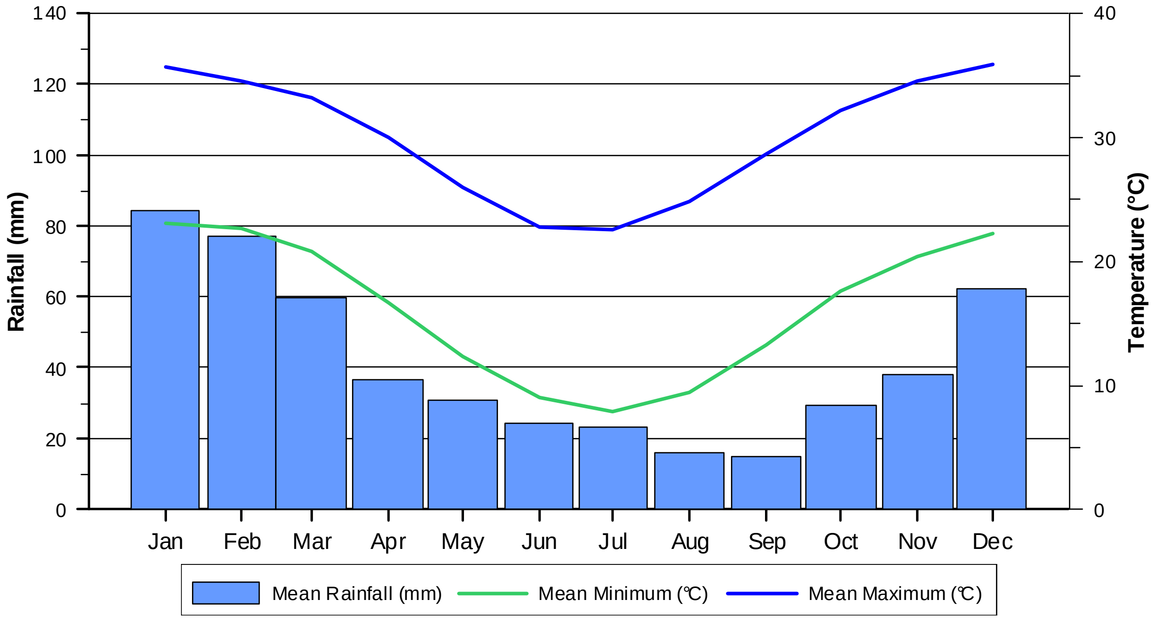


Figure 3-1: Climograph for Barcaldine Post Office (1886 – 2010)

3.1.2 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 MLA. The Data Drill accesses grids of data interpolated from surrounding Bureau of Meteorology (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 3-2. 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.

For the purpose of groundwater analysis the monthly rainfall data was analysed to produce a Rainfall Residual Mass (RRM) curve.

The RRM is calculated by subtracting the long-term average monthly rainfall (535 mm average annual rainfall divided by 12 equals 44.6 mm average monthly rainfall) from the synthetic monthly rainfall, to provide a monthly “departure” from average conditions. If the monthly rainfall is above average the resulting rainfall departure number is positive, whereas if rainfall is below average, the number is negative. The monthly rainfall departures are summed cumulatively to provide the RRM. A number of below-average rainfall months will result in a falling RRM curve, while a number of above average rainfall months will result in a rising RRM curve. The RRM curve is used routinely in groundwater investigations due to the strong correlation in many locations between the RRM and groundwater level trends, especially for shallow aquifers. Analysis of the RRM curve is useful as it allows analysis of rising or falling trends in groundwater levels against long-term climatic data, i.e. it allows for consideration of factors such as long-term drought periods in assessing groundwater level response, allowing impacts from mining to be assessed against underlying groundwater level trends.

Figure 3-3 shows the calculated RRM curve plotted against monthly rainfall from January 1980 to February 2010.

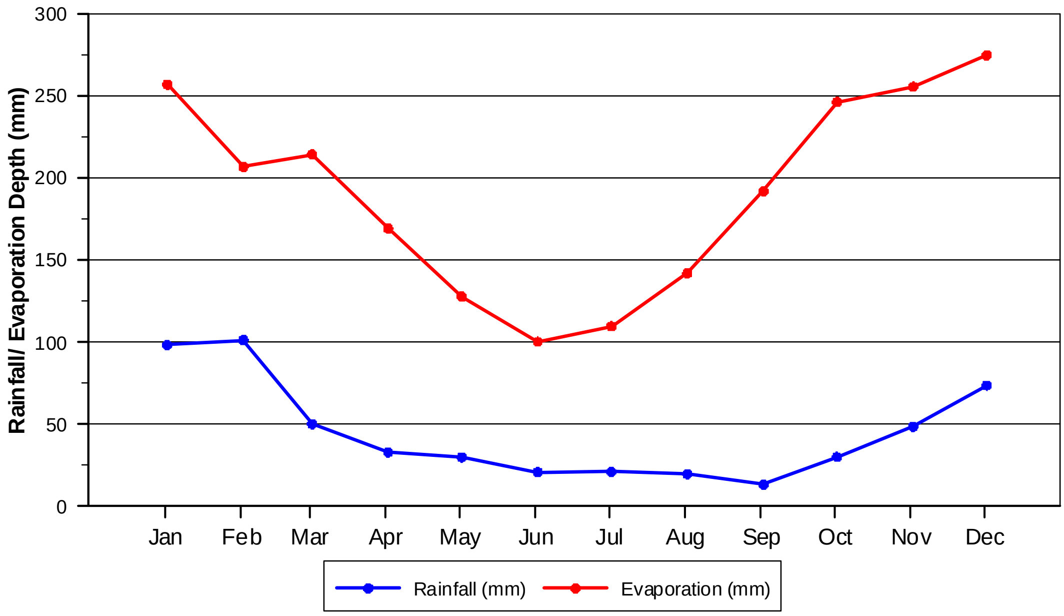


Figure 3-2: Monthly Rainfall and Evaporation Data from SILO Datadrill

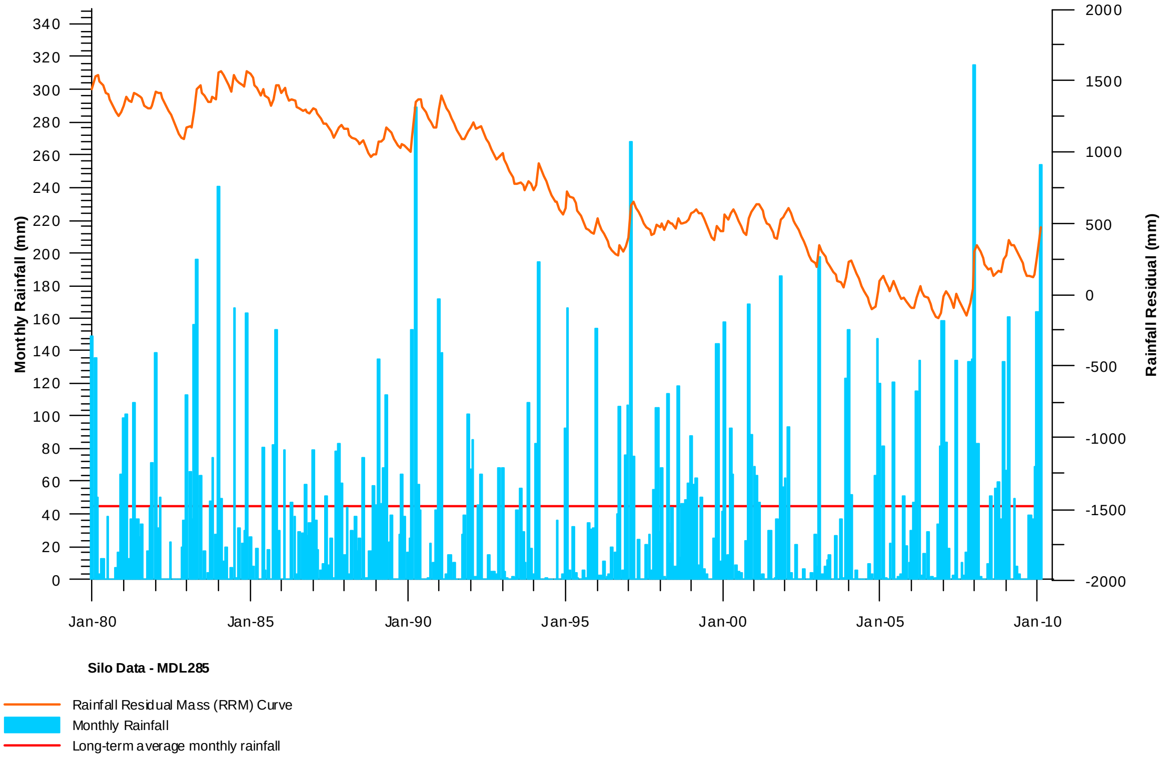
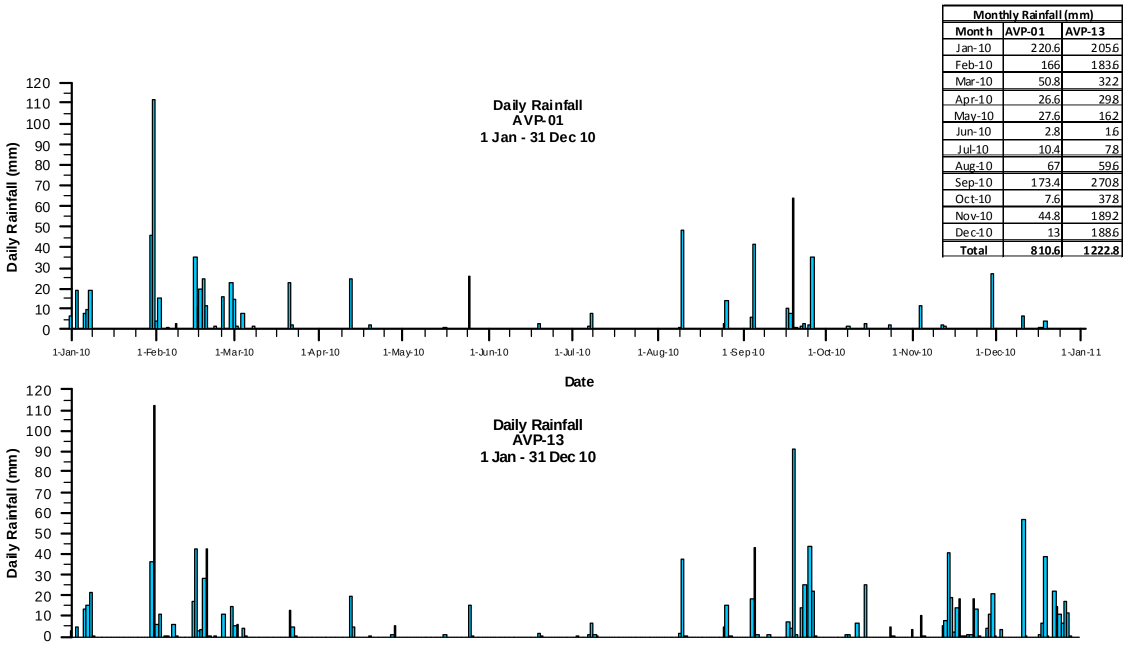


Figure 3-3: Monthly Rainfall and Rainfall Residual Mass Curve

3.1.3 Site Rainfall

Rainfall data is also being collected from the adjacent Alpha site from two tipping-bucket rain gauges that have been in operation since mid-December 2009. Figure 3-4 shows the daily data and monthly summary data from each site between 1 January and 31 December 2010, and Figure 3-12 shows the location of the rain gauge sites. 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.



Monthly Rainfall (mm)		
Month	**AVP-01**	**AVP-13**
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
Total	**810.6**	**1222.8**

Figure 3-4: Site Rainfall Data

3.2 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 sea level. 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.

3.3 Existing Surface Water Environment

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

The catchment area for Lagoon Creek above the Alpha MLA is approximately 1,470 km^2. Major systems which drain the site from west to east toward Lagoon Creek and Sandy Creek (ie 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 Colinlea Sandstone and underlying Joe Joe Formation (refer Figure 3-6 for site geology). Drainage from this range is to the west toward Lagoon Creek, and to the east (at the eastern margin of the MLA) 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.

3.4 Regional Geology

3.4.1 Introduction

The Project is located within the Galilee Basin (Figure 3-5), 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 project is located to the east of the eastern boundary of the geological Great Artesian Basin (GAB) (refer Figure 3-6 for site location relative to the GAB). The proximity of the project to the GAB is significant as the regional model will need to be able to demonstrate the potential for the project to impact the water resources of the GAB.

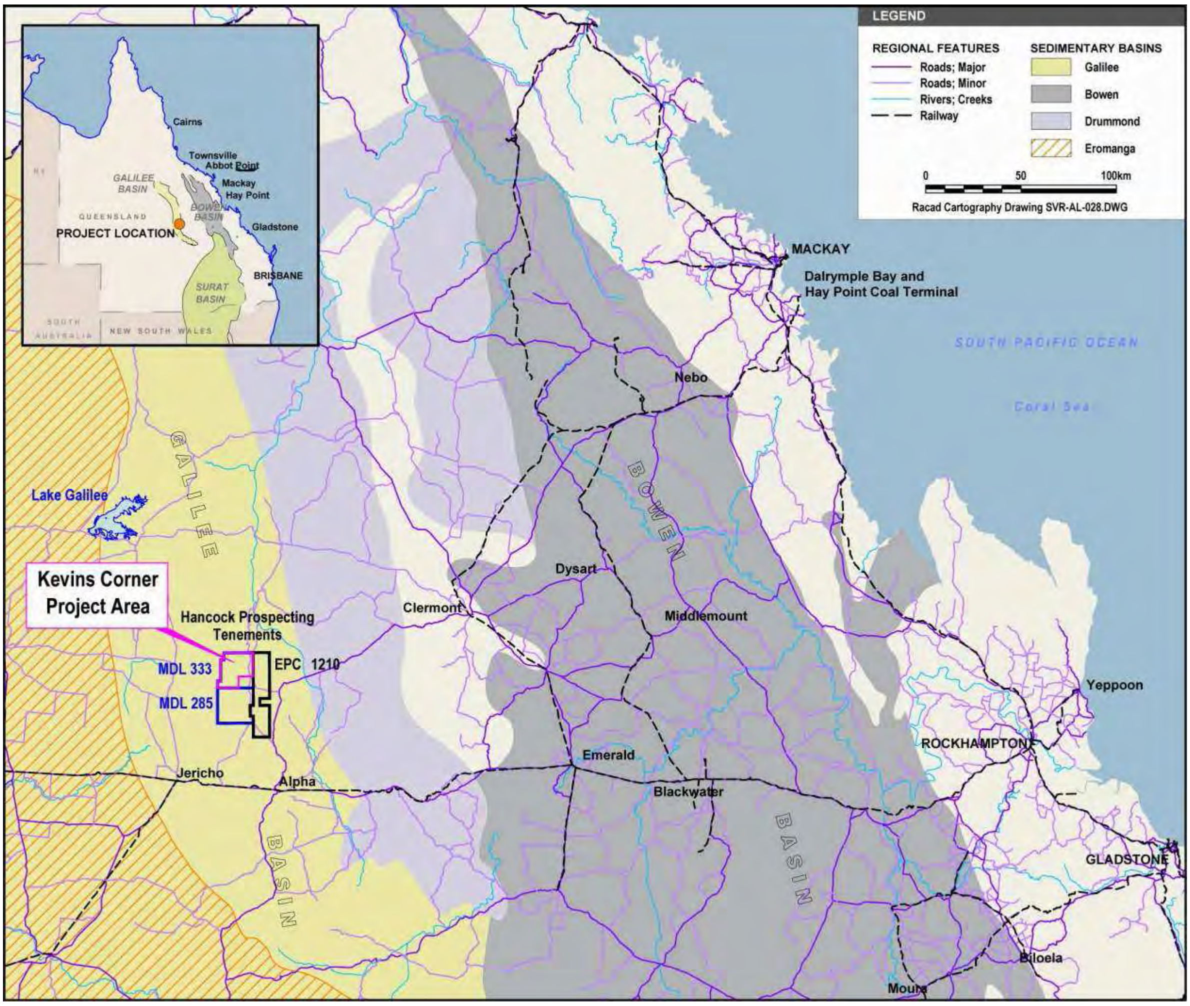


Figure 3-5: Geological Basins

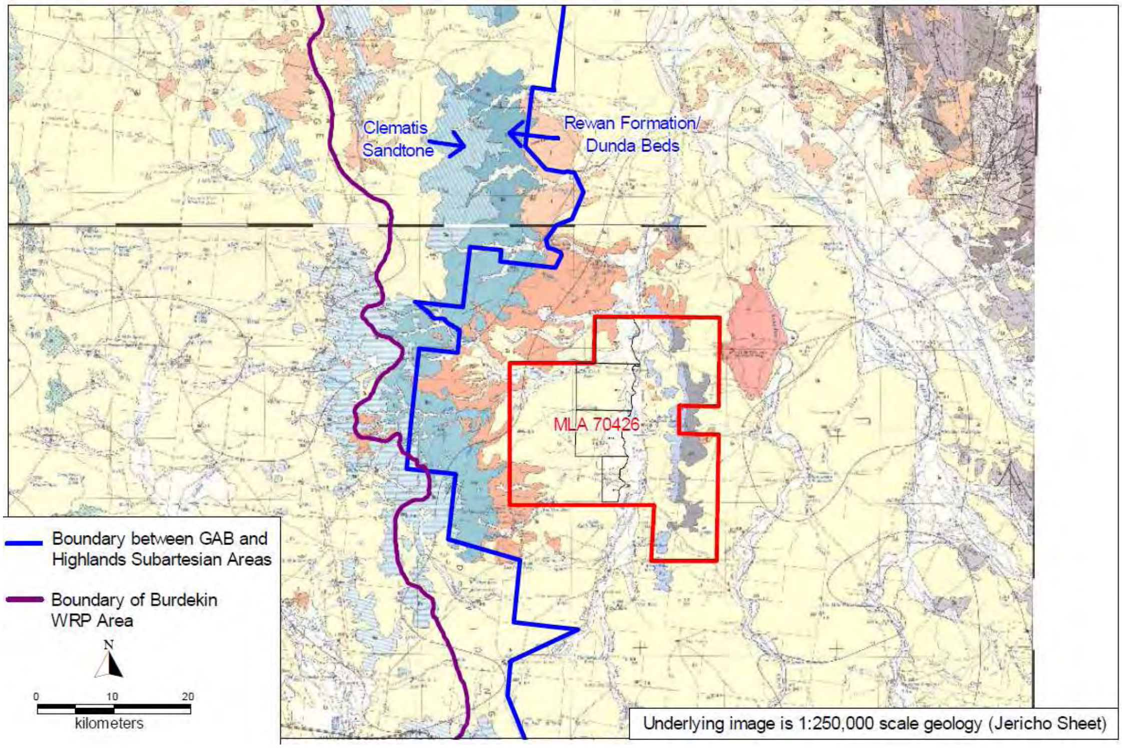
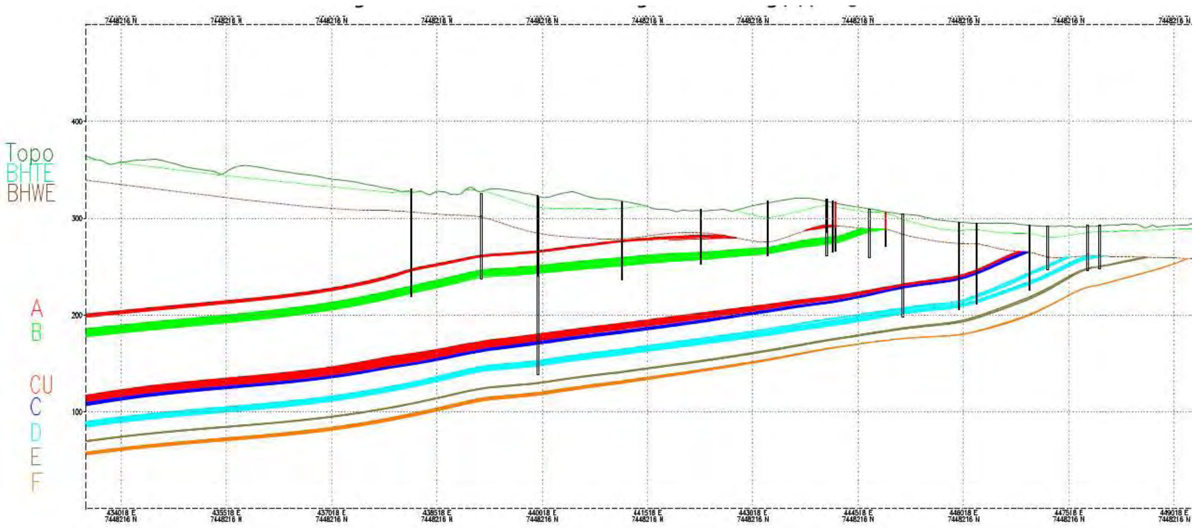


Figure 3-6: Boundary of Hydrogeological GAB (Rewan Fm Outcrop) Compared to GAB Management Boundary

3.4.2 Stratigraphy/Hydrostratigraphy of the Project Site

The Alpha and Kevin's Corner Coal Deposits occur within the Galilee Basin (Figure 3-5), a sequence of Late Permian to Early Triassic age. The geology consists mainly of sediments, dipping 1-2° westward, which are unconformably over lain by Tertiary and Quaternary sediments (Figure 6-2, Table 6-1). The thickness of Tertiary and Quaternary sediments varies from 20 m to 60 m, across MDL's 285 and 333. There are six coal seams in the project (mine) area designated, from upper to lower, as A, B, 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 3-7 (below) shows a 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

Figure 3-7: Geological W-E Cross-Section through Alpha Project Area (Source: Hancock)

3.4.2.1 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). Saprolitic and lateritic horizons are recorded along with mottled clay paleosols. Minor localised perched groundwater was recorded on the clay saprolite during exploration drilling within the Cainozoic.

The Cainozoic unconformably overlies the Triassic Rewan Group and Permian units.

Weathering of the Mesozoic / Palaeozoic occurs at the base of the Cainozoic. The depth to the base of weathering in the Mesozoic is enlarged at Kevin's Corner due to accumulation of a recent Cainozoic layer over the top of the ancient weathered layers.

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.

3.4.2.2 Rewan Formation

The Rewan Formation is the lowest confining unit of the hydrogeological GAB (refer Figure 3-6 for the location of Rewan Formation outcrop relative to the project area). The Rewan Formation occurs only in the far west of MDL333 and MDL285, where it subcrops under Cainozoic cover. 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 A seam coal ply, and is taken to have an average thickness of 175 m (based on Salva geological modelling[2]).

3.4.2.3 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 Project, as the western limit of the proposed open cut does not extend to include these seams.

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 (i.e. becoming more clayey with depth) to increasingly arenaceous (i.e. becoming more sandy with depth). Therefore the Bandanna Formation hosts the A and B coal seams, while the Colinlea Sandstone hosts the target C and D coal seams.

From a groundwater perspective, major hydrostratigraphic boundaries occur within the MLA at the base of weathering, beyond which groundwater is often encountered under confined conditions in the B-C and C-D sands and B and C coal seams, and also at the base of the D coal seam. 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) will be the major 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 base of the Colinlea Sandstone) have the potential to containing significant groundwater resources, but it is not planned that these units will be actively depressurised.

The Colinlea Sandstone is in turn 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 aquifer.

The stratigraphy of the Galilee Basin in the Alpha Coal Project and Kevin’s Corner Project area is described in Table 3-1 below.

[2] Salva Resources (2010) Summary of Galilee Regional Model (GAB). Internal Project Memorandum from Salva Resources to Hancock Coal Pty Ltd, February 2010.

Table 3-1: Site Stratigraphy

Age	Stratigraphic unit		Lithology	Thickness	Aquifer Type
Quaternary			Alluvium	15 - 20 m	Unconfined
Tertiary			Argillaceous sandstones and clays	40 m	Unconfined
Unconformity					
Triassic	Clematis Sandstone		Quartz sandstone, minor siltstone and mudstone	140 m	Confined aquifer – GAB aquifer, occurs to west of MLA
	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 – occurs to the west of the MLA
Late Permian	Bandanna Formation		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
Early Permian	Colinlea Sandstone		B-C Sandstone - Labile sandstone, siltstone and mudstone	70 - 90 m	Semi-confined to confined
			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/ carbonaceous shale – generally considered uneconomic	0.1 – 0.4 m	Leaky confining layer
			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				

3.4.3 Salva Geological Model

At the request of HPPL, Salva Resources (Project geologists) prepared a 3-dimensional geological model which extends from the Galilee Basin in the area of the mining projects, westward into the GAB. The purpose of the model was to further the understanding of the relationship of the project to the GAB, and to serve as input to the regional groundwater model.

The geological model was based on the following data:

Within the boundaries of the Alpha and Kevin's Corner MDL's

- HPPL exploration holes – 362 holes;
- 'B' series holes (Bridge Oil) – 465 holes; and,
- 'W' series holes (Dampier BHP and Wright & Hancock) - 278 holes

Outside the boundaries of the Alpha and Kevin's Corner MDL's

- 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 project memorandum[3] describing the development of the geological model is included in Appendix B.

The layer surfaces from the Salva geological model were used as input to the regional groundwater model.

3.4.4 GAB Hydrostratigraphy

Due to the extent of a regional groundwater model, the model needs to contain a combination of Galilee Basin and GAB hydrostratigraphy.

The lithostratigraphy and hydrostratigraphy[4] of the GAB, as taken from the GAB Hydrogeology map[5], is shown below in Figure 3-8. The hydrostratigraphy in the area of the mine leases is equivalent to the hydrostratigraphy shown for the Eromanga Basin (SA, NT, QLD) to the left of Figure 3-8. The figure shows that the Rewan Formation, which occurs to the west of the mining lease boundary (refer Figure 3-6), is the lowest recognized unit of the GAB;

Figure 3-9 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

3 Salva Resources (2010) Summary of Galilee Regional Model (GAB). Internal Project Memorandum from Salva Resources to Hancock Coal Pty Ltd, February 2010.

4 One or more geological (ie lithostratigraphic) units may be regarded as a single hydrostratigraphic unit on the basis of similar hydraulic parameters (eg 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 (eg aquifer, confining bed, etc.). In other words, formation boundaries and aquifer/confining unit boundaries do not necessarily correspond.

5 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.

geological model (refer Section 3.3.3), as well as the corresponding 1:250,000 scale geological maps (Jericho).

The relationship between GAB aquifers, confining beds, and hydraulic basement, is summarised in Habermehl (2001):

> *"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.*
>
> *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 3-8, which is taken from Habermehl (1997).

From Figure 3-9:

- 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 (refer also Figure 3-6);
- The coal deposits that will be the target of mining are located within the Permian-age Bandanna Formation and underlying Colinlea Sandstone;
- The boundary between the Bandanna Formation and Colinlea Sandstone is interpreted differently by different workers. The project geologists (Salva 2010, Appendix B) interpret the boundary of the Bandanna Formation/Colinlea Sandstone to be the top of the C coal seam, based on interpretation of lithostratigraphy. For the purposes of groundwater interpretation (ie hydrostratigraphy) for this project, the base of the Bandanna Formation is taken to be the base of the "D" coal seam (lowest coal seam targeted by the project) with the top of Colinlea Sandstone set as the sandstone units occurring directly below the D coal seam (including E and F coal seams, which are not targeted by this project). This interpretation is based on the nature of groundwater occurrence above and below the D coal seam, with the D coal seam observed from exploration drilling to be acting as a confining layer to the underlying D-E sands;
- The Colinlea Sandstone is in turn underlain by sediments of the Joe Joe Group. 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 3-9 in terms of whether they are regarded as GAB aquifers or aquitards (confining units), as outlined in the hydrostratigraphic table shown as Figure 3-8; and,

- Figure 3-9 also shows generalised concepts of groundwater recharge and groundwater flow direction. This is discussed further in Sections 3.5 and 3.6.

The boundary of the hydrogeological GAB (outcrop of Rewan Formation) occurs predominantly to the west of MLA70425 and MLA70426 (refer Figure 3-6). The north western corner of MLA70425 is underlain by Rewan Formation, which is the basal confining unit to the hydrogeological GAB.

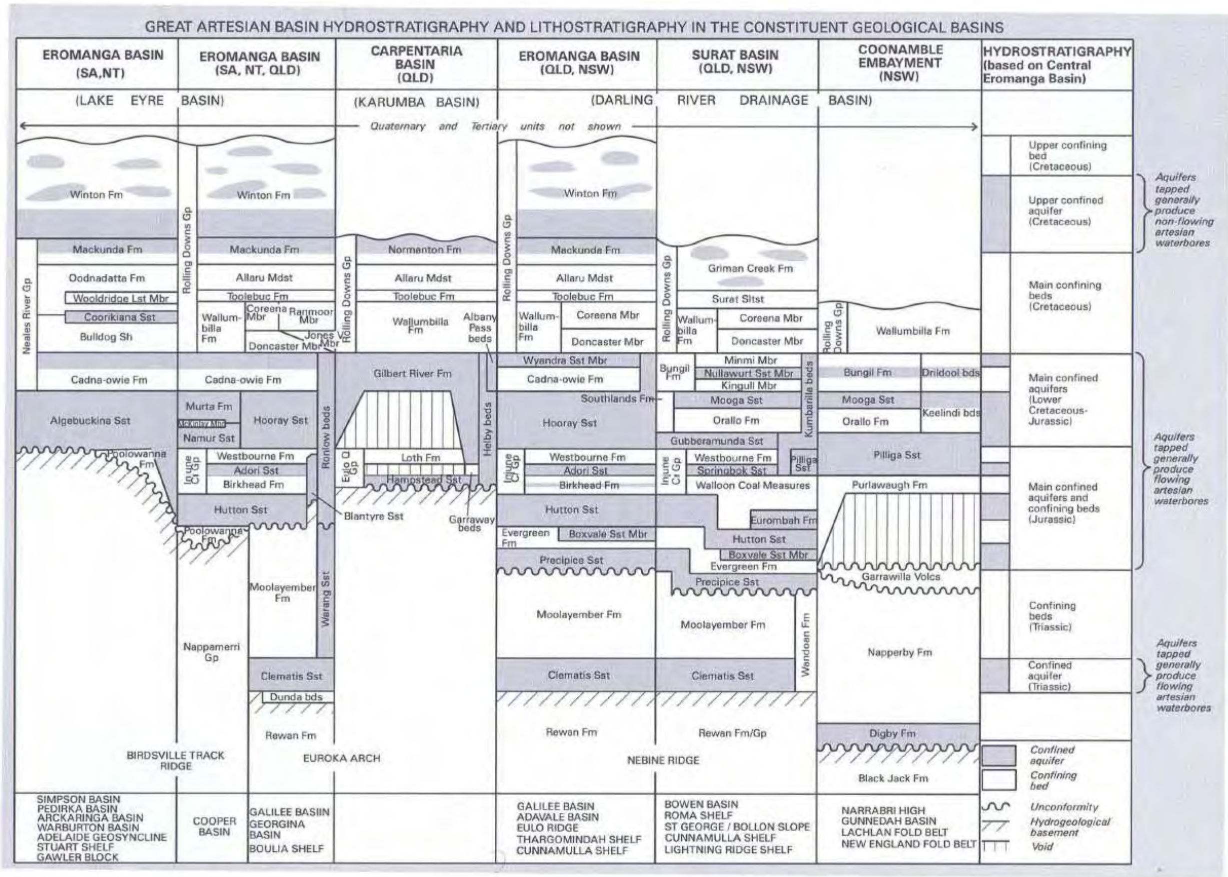
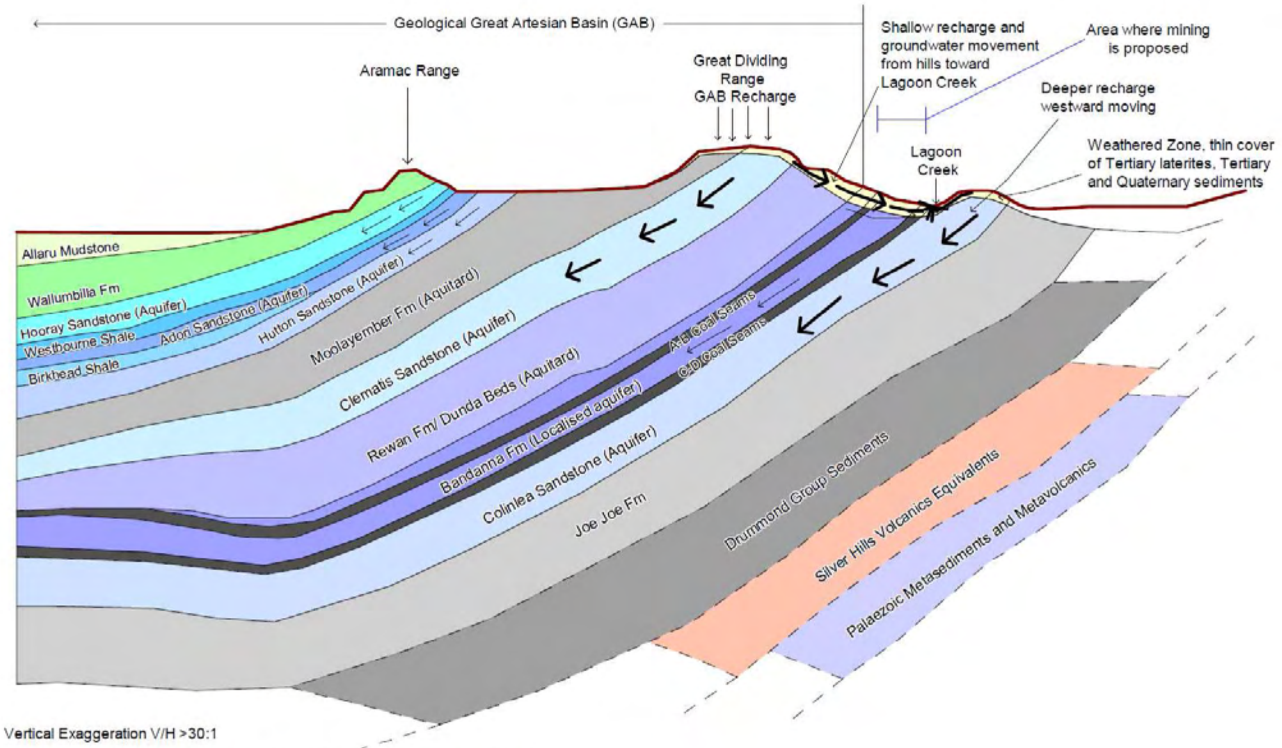


Figure 3-8: GAB Hydrostratigraphy. Source: Habermehl, M.A. & Lau, J.E. (1997)



Vertical Exaggeration V/H >30:1

Geological section based on GAB block model (Salva Resources) with detail of deeper units (below Colinlea Sandstone) from Jericho 1:250,000 Geological Map.

Figure 3-9: Schematic Section through Galilee Basin and GAB

3.4.5 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.

3.5 Potentiometric Surface and Groundwater Flow Direction

3.5.1 Water Level Data from Exploration Bores

Groundwater level data have been reviewed from over 250 groundwater exploration bores within MLA 70425 and the adjacent Alpha lease (MLA 70426). From these data, a potentiometric surface map has been produced (Figure 3-10) which must be viewed with consideration for the following:

- The water levels were measured in open exploration holes, and therefore represent a composite water level for all water-bearing intervals encountered within each borehole; and,
- Water 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 limitations a general trend is evident from the data, i.e. the water level is higher in the west and lower in the east, suggesting that the composite potentiometric surface is a subdued reflection of topography (i.e. mimics topography), with groundwater flowing towards Sandy Creek.

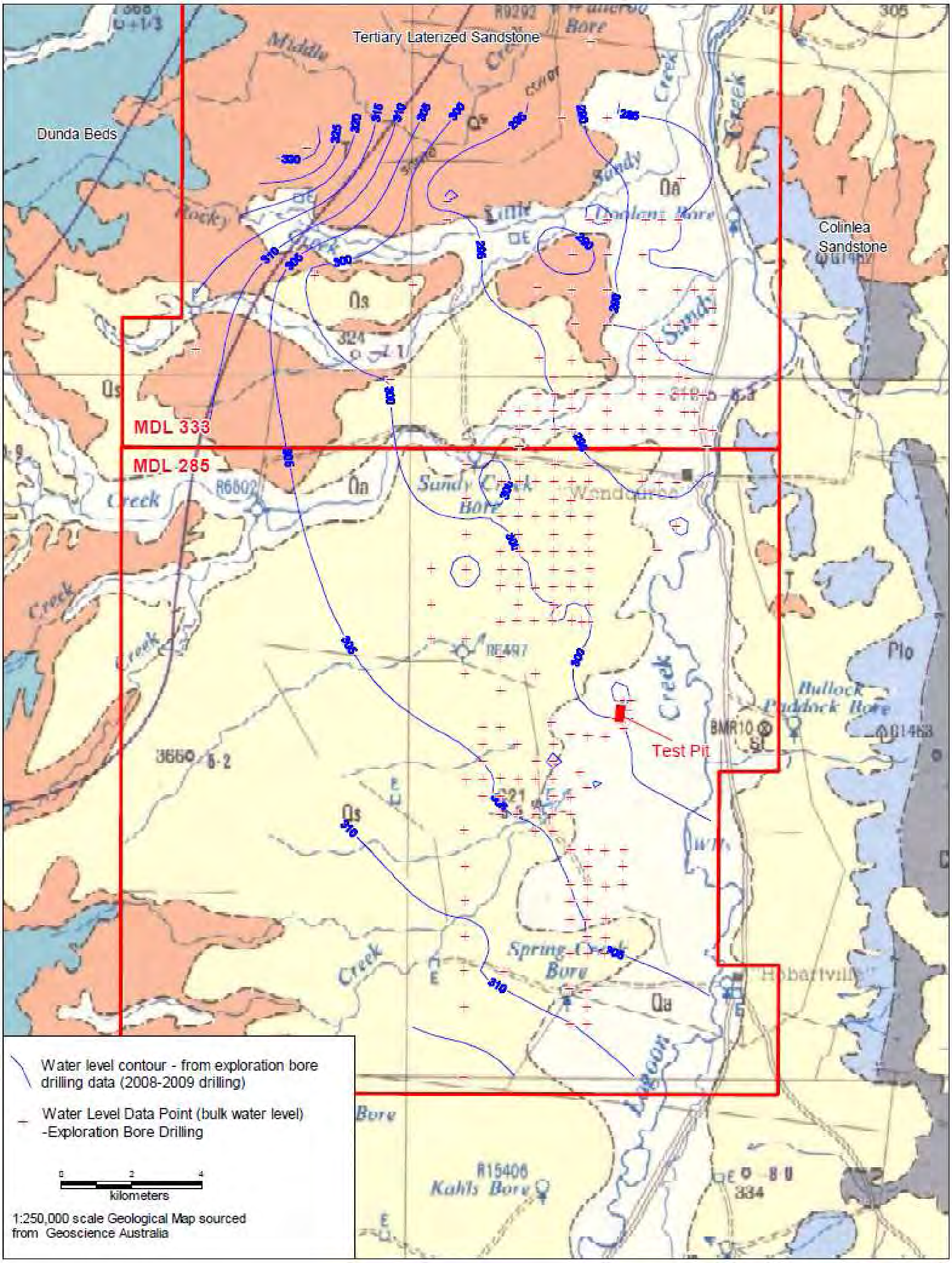


Figure 3-10: Potentiometric Surface Contours – Exploration Bore Drilling

3.5.2 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 (typically C-D sands, within the Bandanna Formation). Figure 3-11 shows the potentiometric surface of the D-E sands aquifer (i.e. upper Colinlea Sandstone aquifer) for readings taken in December 2009. Water pressures are higher in the west and southwest of the lease area and lower in the east toward Sandy Creek. This indicates that the potentiometric surface of the D-E sandstone (Colinlea Sandstone) follows the same general trend as shown in Figure 3-10 for the potentiometric surface generated from exploration drilling data.

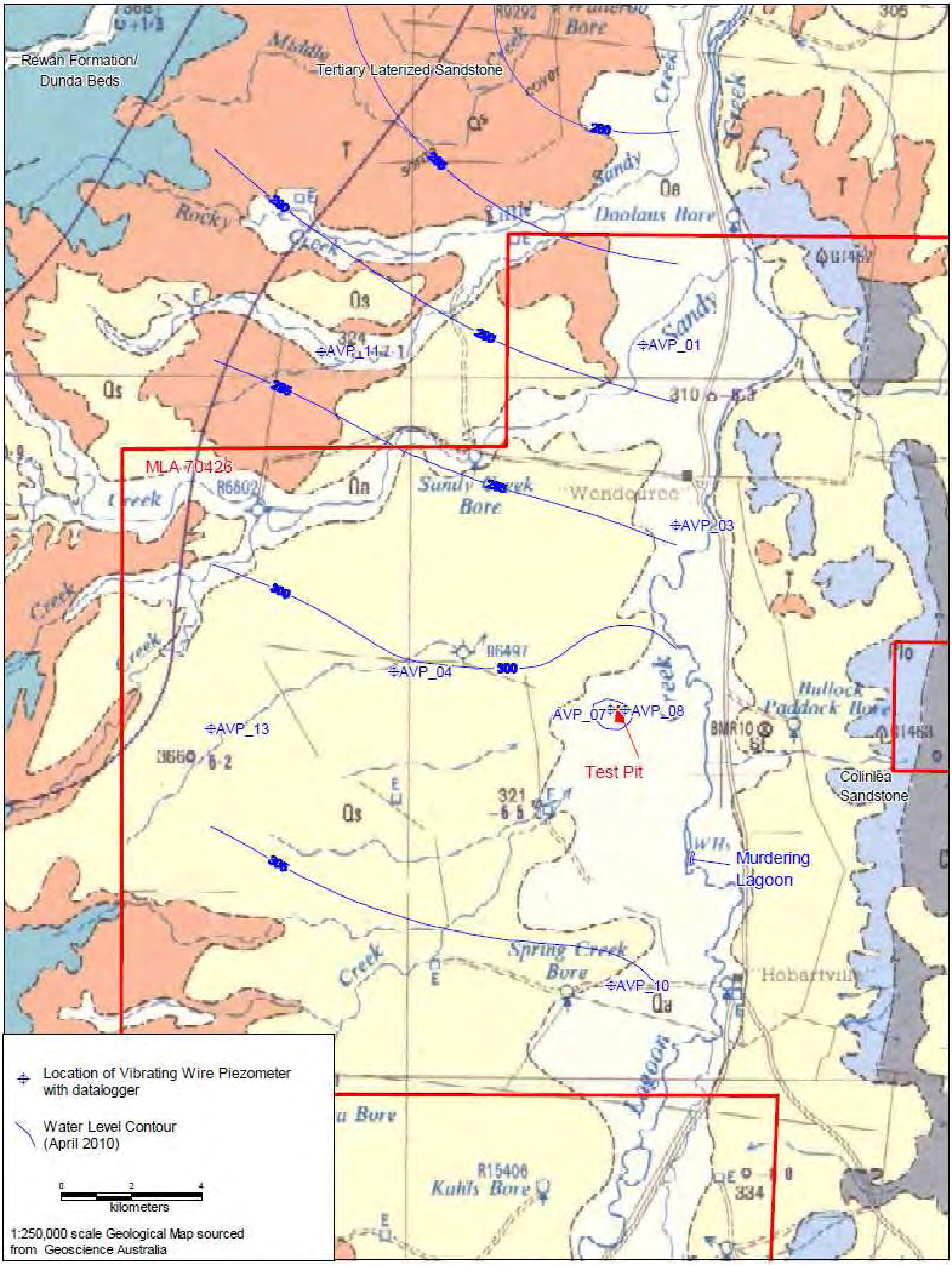


Figure 3-11: Potentiometric Surface Contours – D-E Sandstone (from VWP Data)

3.6 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 3-12. 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.

3.6.1 Vibrating Wire Piezometers

Vibrating Wire Piezometer (VWP) monitoring bores have been constructed at 17 sites within or adjacent to the Project Mining Lease Application (MLA 70426 and 70425) area, with 46 separate intervals monitored (the number of VWPs installed in each bore ranges from one to four). The location of these bores is shown on Figure 8, and the interval monitored by each bore is shown in Appendix C.

The VWP bores were constructed using the grout-in method, where the piezometers are strapped to the outside of poly pipe at locations that correspond to their planned setting depth. The poly pipe then acts as a tremmie tube, as cement-bentonite grout is pumped down the inside of the poly pipe, with the column of grout rising up the borehole and displacing the contained water. 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.

At eight sites within the Project area VWP bores are monitored using data loggers, which compile daily groundwater level records. In addition, two of these sites are equipped with tipping-bucket rain gauges, with rainfall data also captured by the data loggers.

The location of all VWP bores drilled and constructed to date, as well as location of bores with data loggers and rain gauges, is shown on Figure 3-12.

Water level plots for all VWP bores with data loggers are shown in Figures 9 to 11. The following observations are made with respect to VWP readings:

- For the monitoring period shown in Figures 3-13 to 3-15, 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:
  - o 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);
  - o 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

- o 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).

3.6.2 Standpipe Monitoring Bores

Standpipe monitoring bores have been constructed at sites shown on Figure 3-12. 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 C

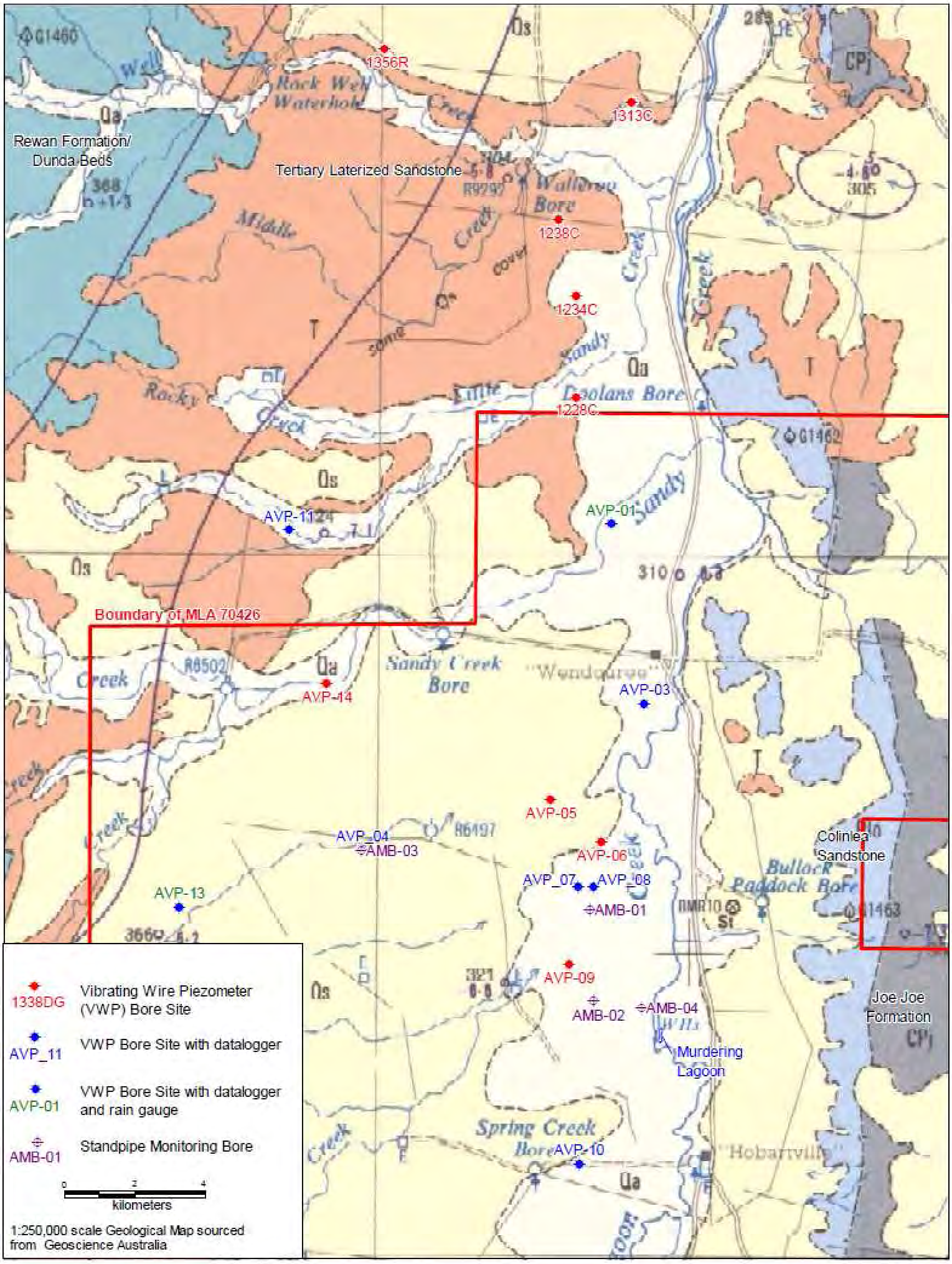
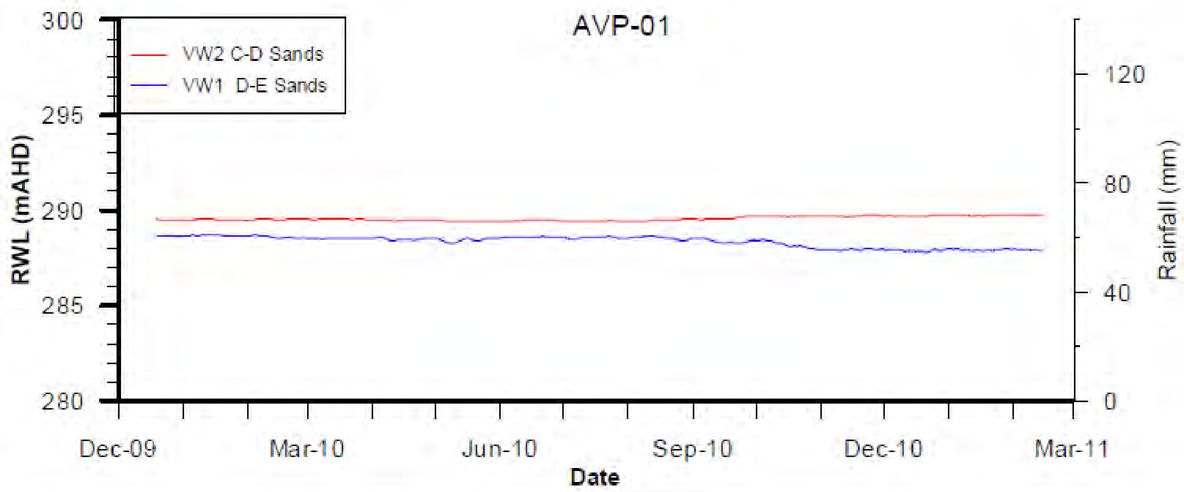
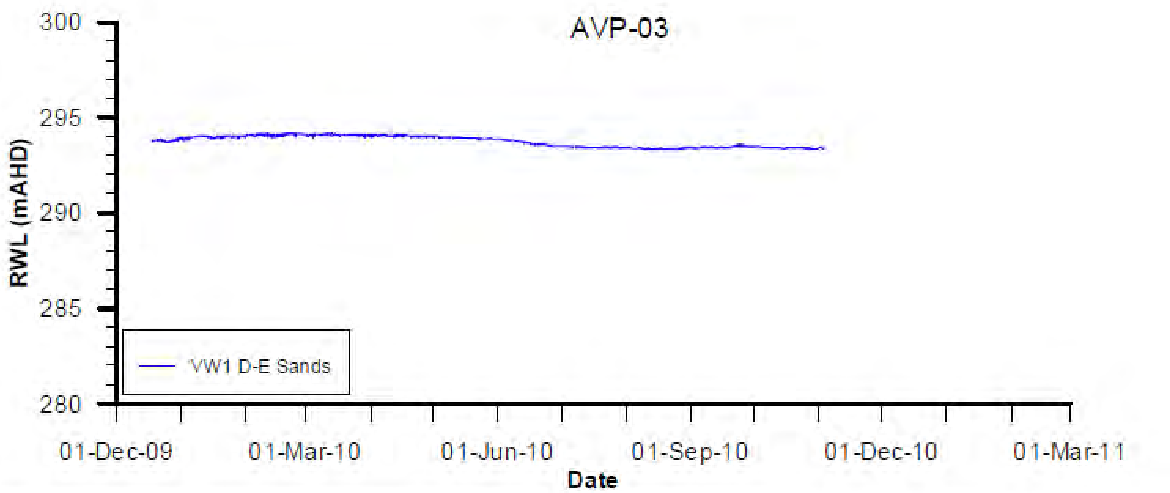


Figure 3-12: Location of Groundwater Monitoring Bores

Figure 3-13: Bore Hydrographs – AVP-01, AVP-03, AVP-04





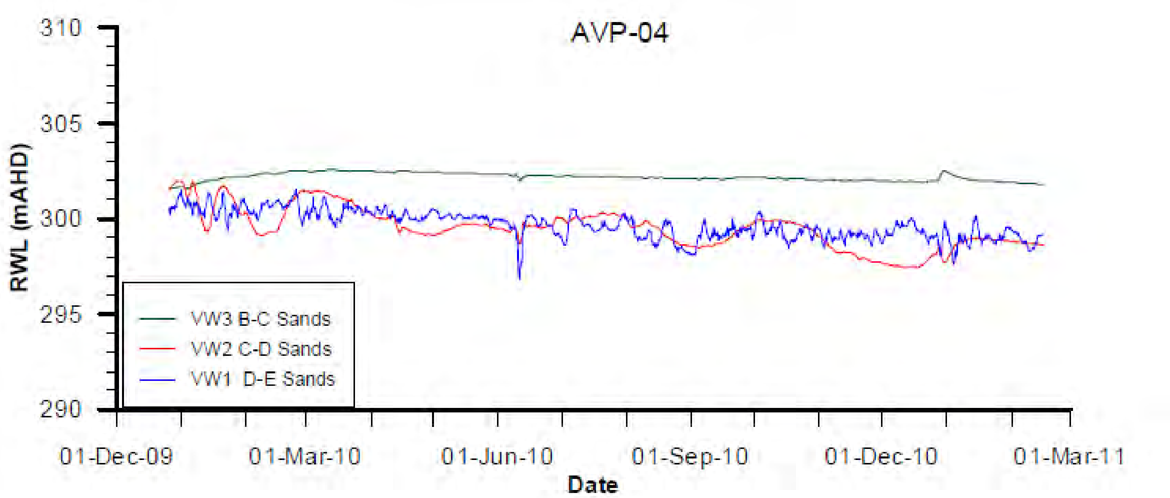
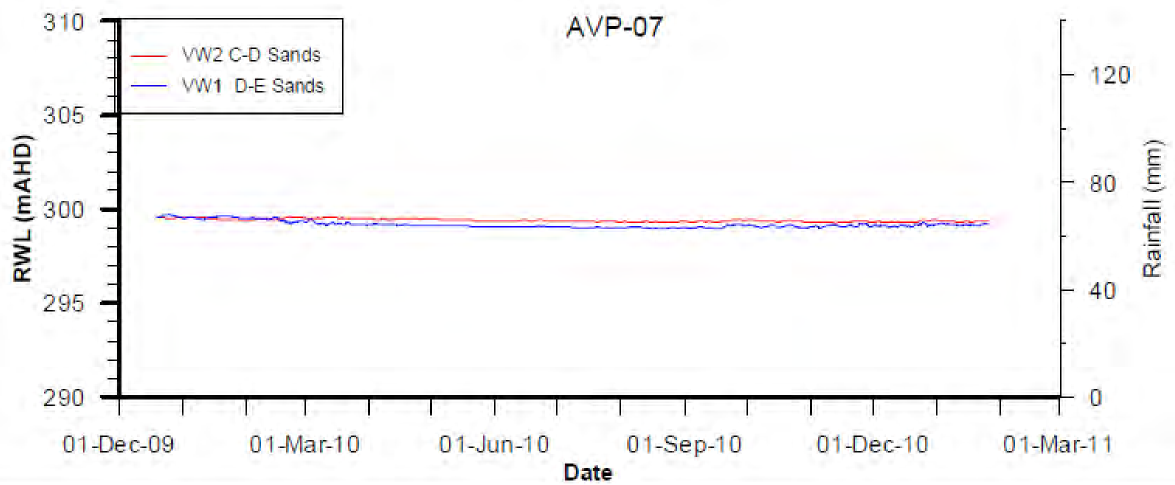
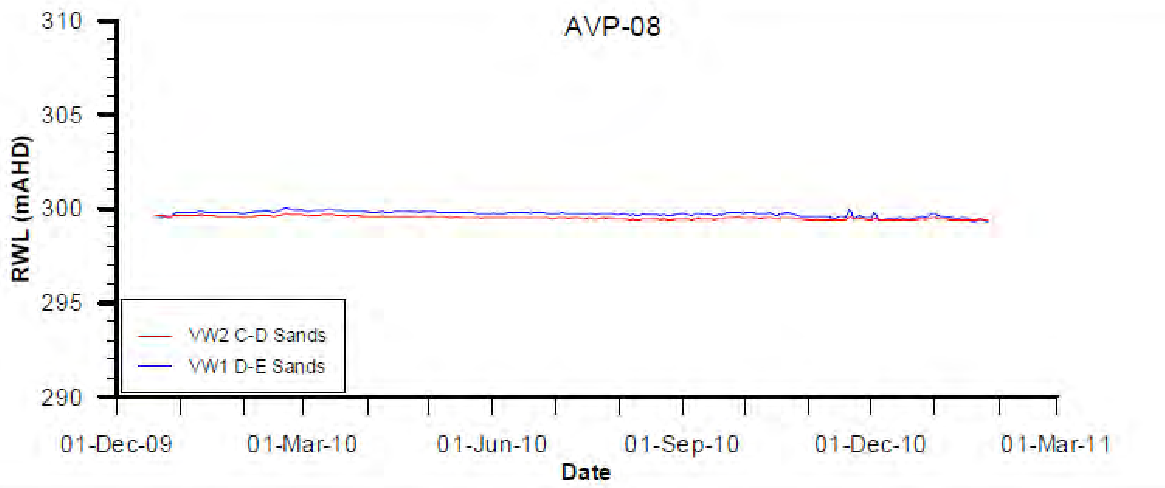


Figure 3-14: Bore Hydrographs – AVP-07, AVP-08, AVP-10





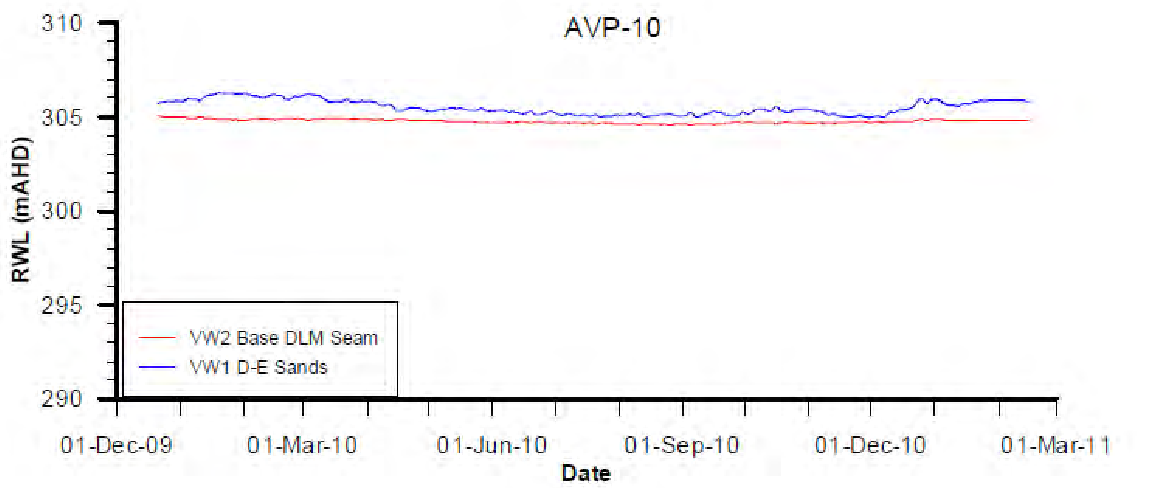
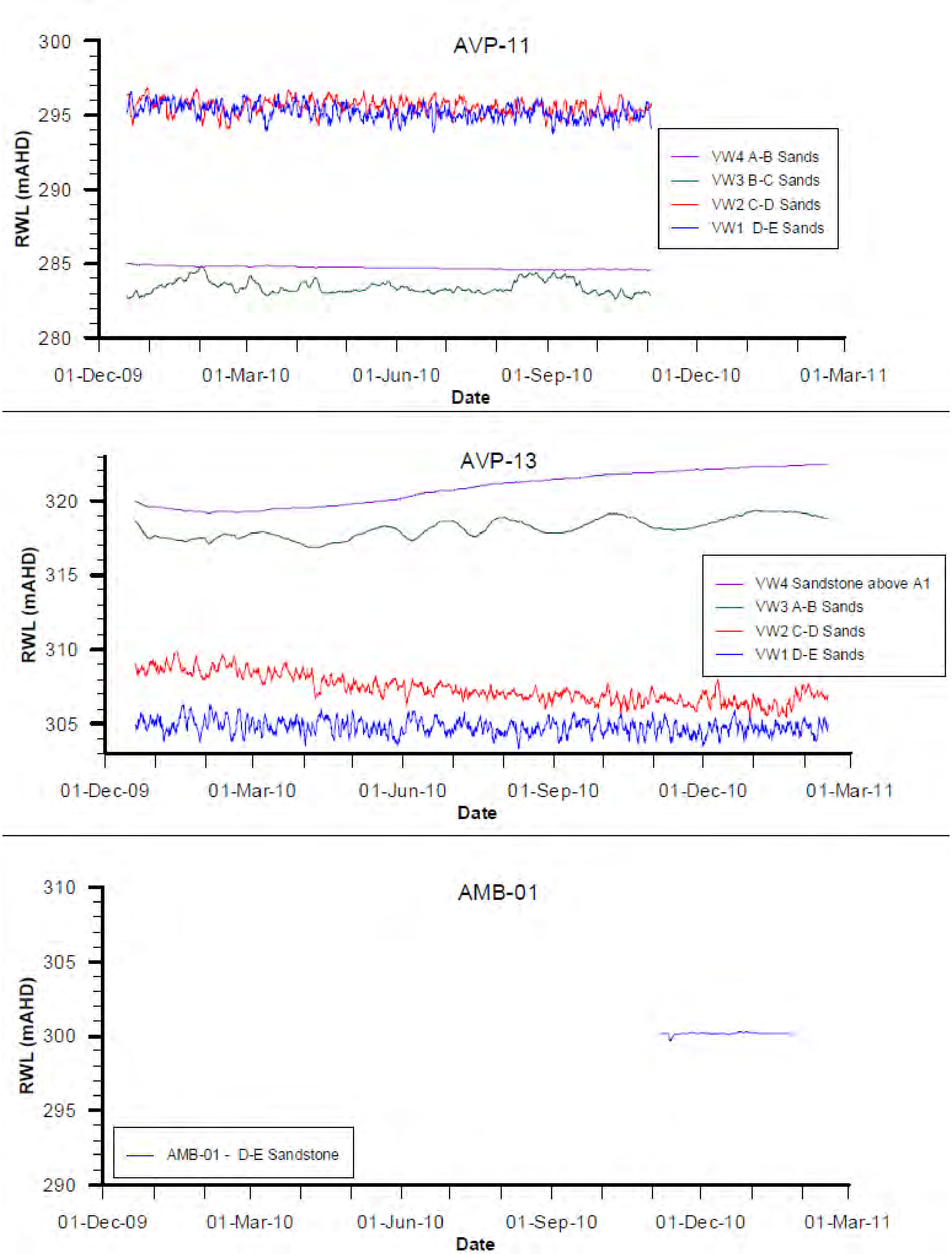


Figure 3-15: Bore Hydrographs – AVP-11, AVP-13, AMB-01



3.7 Groundwater Recharge

3.7.1 Background on Groundwater Recharge

Groundwater recharge is a difficult area of study. One method of estimating recharge is to compare long-term groundwater level trends from bore hydrographs to the rainfall residual mass curve (discussed in Section 3.1.2), and then to undertake an analysis known as cumulative rainfall departure (CRD). The aim of the analysis is to provide an indication of the intensity of rainfall required for recharge to occur, as it is recognised that not all rainfall events result in recharge. One reason for this is that the hydraulic conductivity of unsaturated material is low relative to the hydraulic conductivity of the same material when saturated. For rainfall events below a particular intensity water 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 (below the ground surface but above the regional water table) until being removed via plant roots, evaporation, or discharge to surface water drainage features.

A study of recharge rates to GAB intake beds was undertaken by Kellett et al, (2003). In line with the process described above, it was concluded that rainfall events in excess of 200 mm in a month in the area of the intake beds is required before marked recharge events will occur. The study also concluded that recharge could be described under three distinct recharge processes, as summarised in Table 3-2.

Table 3-2: Recharge Process of the Great Artesian Basin Intake Beds (Kellett et al 2003)

Process	Recharge Rate (mm/year)	Description
Diffuse rainfall	Up to 3 mm	A relatively low rate of recharge that occurs over a wide area of the intake beds in response to average rainfall conditions. Recharge rates for diffuse rainfall range from < 1mm to ~3mm/year, up to 10 mm/year in localised areas.
Preferred pathway flow	0.5 to 28.2	Preferred pathway flow is regarded as the dominant recharge mechanism for GAB intake beds. The study concluded that rainfall events in the order of 200mm per month or more are required for preferred pathway flow to be initiated. An important aspect of this process is that the regolith becomes saturated during periods of high magnitude rainfall, and once this occurs "preferred pathway flow" can occur though fissures, joints, or other more permeable pathways.
River leakage	up to 30	Localised recharge zones where rivers cross subcrops of intake beds. Rivers may alternate between recharge and discharge conditions along different stream reaches, or seasonally.

Recharge processes at the Project site are discussed below, with reference to the recharge processes described above, and observations from site.

3.7.2 Groundwater Recharge – Project Area

3.7.2.1 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 (refer Figure 3-12 for bore locations, and Figures 3-13 to 3-15 for VWP hydrographs). It is noted in Kellett et al. (2003) that marked GAB recharge events are generally associated with monthly rainfall totals in excess of 200 mm. Recorded site rainfall during the wet season months of 2010 (refer Figure 4) 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; and,
- December 2010 – 13 mm at AVP-01 and 188.6 mm at AVP13.

Therefore, the 2009/2010 and 2010/2011 wet seasons represented potentially significant groundwater recharge events.

A review of bore hydrographs (Figures 3-13 to 3-15) 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 3-15) where piezometers in the shallow sandstone (sandstone above A1) as well as the underlying A-B sandstone, both recorded water 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 3-13) also has a piezometer monitoring the A-B sandstone but pressures at this location have remained stable throughout the 2010 year. 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 outcrop area of the Colinlea Sandstone.

Geotechnical drilling undertaken in the area to the east of Sandy Creek within the adjacent Alpha MLA encountered weathered rock (Colinlea Sandstone) at shallow depths of between 1 and 5 m. 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 at site, as summarised below.

3.7.2.2 Recharge Mechanism 1 – Direct Recharge to Outcrop Areas

Figure 3-12 shows the outcrop geology of the project area. From this figure it can be seen that the Colinlea Sandstone outcrops to the east of Sandy Creek within the Project MLA, and as described above weathered Colinlea Sandstone occurs at shallow depth between the area of outcrop and Sandy Creek/Sandy Creek. Therefore, one possible recharge mechanism is via direct rainfall recharge to aquifer units in areas where they outcrop or subcrop (once sufficient rainfall has occurred to facilitate infiltration) – the threshold rainfall intensity after which recharge can occur of 200 mm/month (refer Section 3.6) is acknowledged, however a site-specific value has not been determined as the available data does not yet support the calculation of recharge rates. This is the same mechanism by which recharge is assumed to occur within groundwater intake beds of the GAB. The main aquifer that underlies the project area is the sandstone units of the Colinlea Sandstone. The base of the Colinlea Sandstone is, for the purpose of this groundwater study, the eastern-most extent of Colinlea Sandstone outcrop (Figure 3-12). The top of the Colinlea Sandstone for the purpose of groundwater studies is taken to be the base of the D coal seam, and the D floor subcrop line is also shown on Figure 3-12. Recharge may therefore occur in this zone from either rainfall recharge or from downward leakage from Sandy Creek following flow events in the creek. In this recharge model, groundwater recharge enters the Colinlea Sandstone within this outcrop/subcrop area and flows down-dip (i.e. generally westward).

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

Figure 3-6 shows the location of the Great Dividing Range relative to the MLA. 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 surface water drainage features in lower-lying areas. Existing potentiometric surface data (Figures 3-10 and 3-11) indicate that groundwater flow is toward Sandy Creek, and that depth to groundwater gets shallower to the north.

3.7.3 Conceptualised Recharge Mechanisms

The potentiometric surface contours presented as Figures 3-10 and 3-11 lend support to the second type of recharge mechanism, at least for the shallow aquifer system in the vicinity of the Project site.

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 Project site. If this recharge mechanism is dominant, recharge from the area of Colinlea Sandstone outcrop and 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. However, it is possible that recharge as described by mechanism 1 may be important for deeper units within the Colinlea Sandstone aquifer.

The above interpretation is complicated by the fact that the coal units and interburden aquifers outcrop in the area (beneath and to east) of Sandy Creek, and hydraulic testing data suggests that shallow units to the east are confined to semi-confined. Therefore, depending on surface water levels in Sandy Creek, it is possible that the interburden aquifers are periodically recharged by Sandy Creek (i.e. under flood conditions) and that the groundwater flow potential may be reversed under some conditions. However, under "average" dry conditions, it is considered most likely that groundwater recharge occurs to the west of the site, and that groundwater flow will be from elevated topographic areas toward Sandy Creek. The following observations support the second type of recharge mechanism:

- Groundwater flow direction in the western part of the MLA is from south-south-west to north-north-east, i.e. from a recharge area in the west to a discharge area at Sandy Creek. This is consistent with existing data from site groundwater level monitoring; and,
- Groundwater springs occur to the north of the MLA, but to the west of Sandy Creek, indicating groundwater flow from topographically elevated areas in west toward Sandy Creek.

3.8 Groundwater Discharge

3.8.1 General

Groundwater flow contours indicate a groundwater flow direction from topographically elevated areas to the west of site, to the north-north east and toward Sandy Creek. While groundwater level data is not yet available for the area to the east of Sandy Creek, it is judged as likely that the potentiometric surface observed to the west of Sandy Creek will be mirrored on the eastern side of the creek, i.e. the potentiometric contours will vee up Sandy Creek, indicating a potential for groundwater discharge to the Sandy Creek system.

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. Analysis of groundwater levels (refer Section 3.5, Figures 3-10 and 3-11) indicates that the confined water level (potentiometric surface) is approximately 8 to 10 m from surface in areas adjacent to Sandy Creek, and the Sandy Creek alluvium is interpreted to be in the order of 15 to 20 m deep in central area of the creek (AGC, 1983). Therefore there may be a potential for groundwater to discharge to the bed sands of Sandy Creek, but it may be that actual discharge only occurs if structures are present (e.g. faults, sand lenses, or joints) that allow the upward movement of groundwater to occur.

3.8.2 Areas of Potential Groundwater Discharge

Within the region where the MLA is sited, potential for groundwater discharge exists to the bed sands of Sandy Creek, via the mechanisms described above.

Groundwater springs

A number of springs have been identified on the Forrester property, with the closest spring being approximately 30 km north of MLA 70425 boundary. Discussions with the landholder indicate that, for at least one bore; the groundwater level is close to the surface in the area where other springs occur. The springs appear to line up in a north-south direction, and occur on the western side of Sandy Creek. This is consistent with the interpretation that groundwater flow direction is from south-south-west to north-north-east (i.e. from recharge sources in the west to a discharge area at Sandy Creek and that these are discharge springs).

3.9 Groundwater Yield

3.9.1 Review of Air-Lift Yield Data

Information on groundwater yield is 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. Therefore the air-lift yield figures presented below can be assumed to be based on inflows from the entire Permian sequence down to the top 5 – 10 metres of the D-E sandstone (where drilling is generally discontinued). The weathered overburden material, comprising the Tertiary sediments and weathered Permian sandstones, 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 3-16 shows bore yield classes for data obtained from the DERM groundwater database. The data shows that of the 119 bores for which data was available (in the area covered by Figure 3-16):

- 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
- 6 (5%) recorded a yield in excess of 10 L/s

Figure 3-17 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 3-17):

- 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. However, high yielding bores (10 L/s or more) are known across the area, as discussed below. 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.

Figure 3-16: Air Lift Yield Data – DERM Groundwater Database

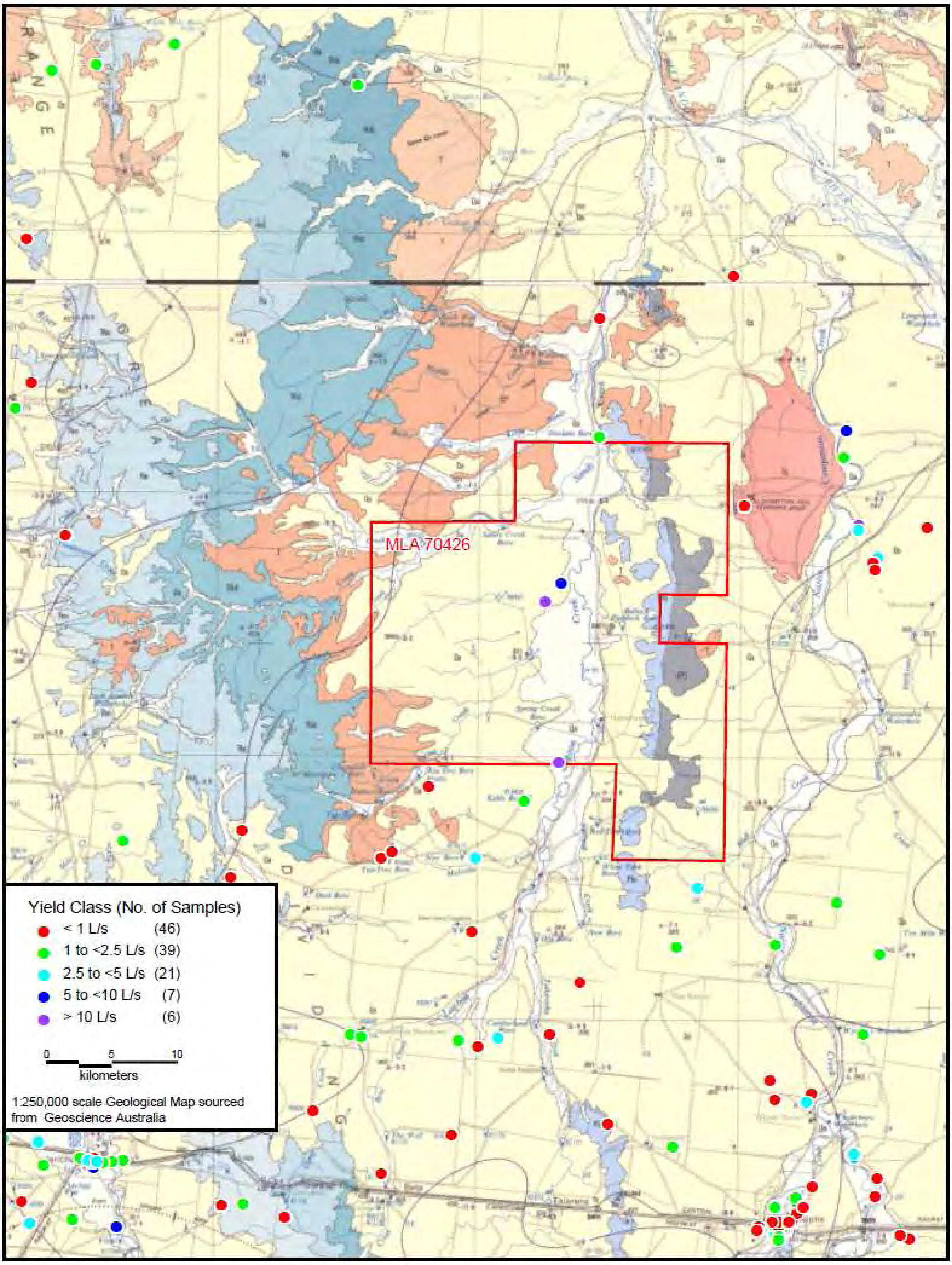
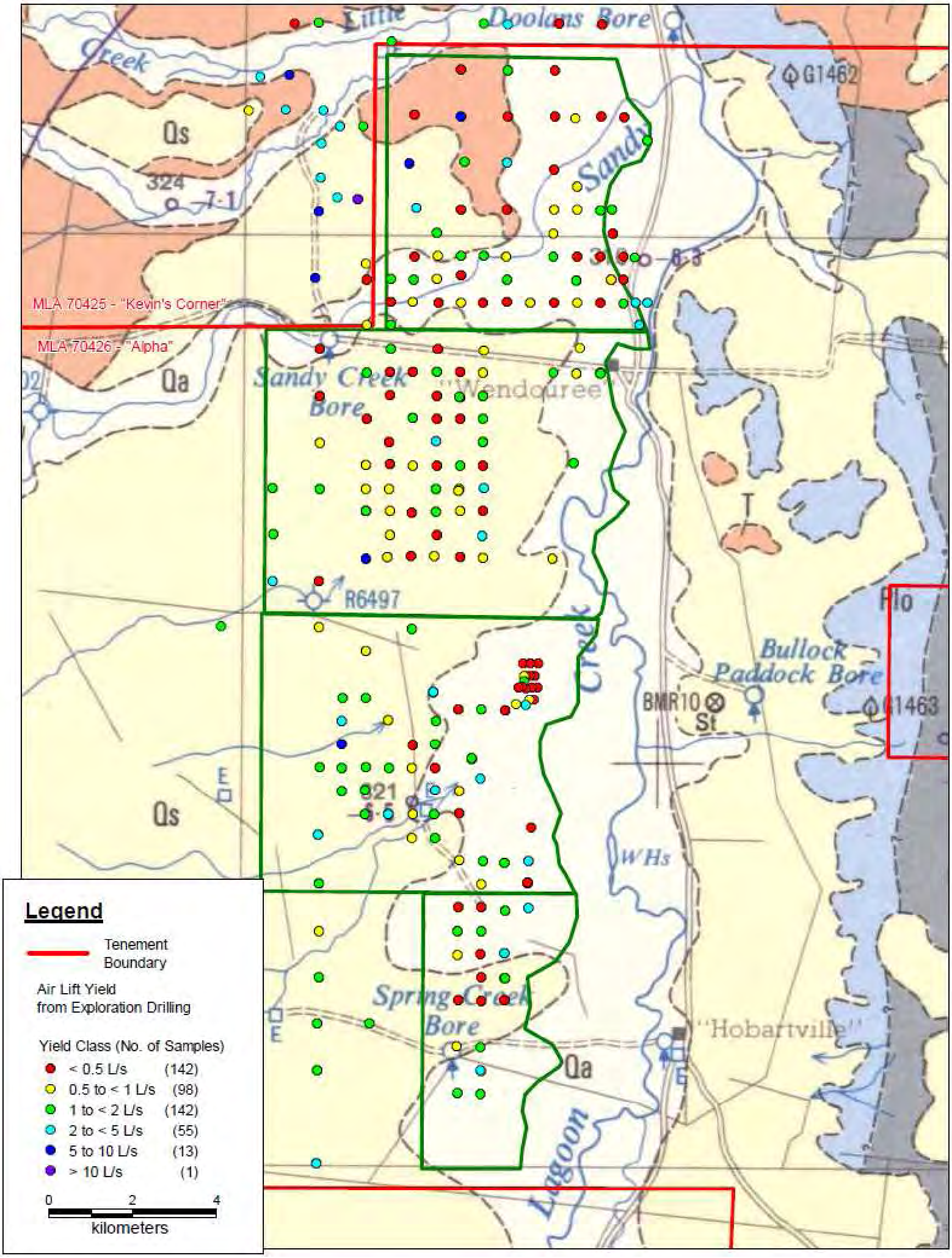


Figure 3-17: Air Lift Yield Data – Site Exploration Drilling



3.10 Aquifer Hydraulic Properties

3.10.1 Site Data

3.10.1.1 Summary of Previous Investigations

Prior to the current phase of groundwater investigations there have been at least three phases of groundwater investigation undertaken on the parcel of land now described as MLA 70426. 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, refer Figure 6 for locations);
- Information (observations and calculated hydraulic properties) from pumping tests undertaken at four sites (TPB-1 to TPB-4). Results from these pumping tests are summarised in Tables 9-1 and 9-2;
- 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,
- 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 “aquifer 1” (this covers an interval including the C and D coal seams and interburden); and bore W2 which was constructed within “aquifer 2” (the sandstone aquifer between the D and E coal seams); and,
- Information (observations and calculated hydraulic properties) from pumping tests undertaken on bores W1 and W2.

Pumping tests undertaken by Australian Groundwater Consultants (AGC)[6] in 1983 and by Longworth & McKenzie[7] in 1984, are summarised below in Tables 9-1 and 9-2.

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

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

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.

3.10.1.2 Current Investigations

A pumping test has recently been completed at one location (bore 1290L) and pumping tests are planned for a further two locations (1244L and 1246L). These locations of these sites are shown on Figure 3-18. The sites include:

Site 1290L

This site is located adjacent to the proposed bulk sample 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). The purpose of running a further test at this location is to provide further aquifer properties for the D-E sands in the area of the test pit, and as an indicator 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 (apparent thickness at this location is 6.3 m between base of D and top of E coal seams).

In summary:

- The pump utilised for the test was a Mono 820 helical rotor pump, which was supplied with a range of gear wheels and belts, as well as being equipped with a variable speed drive (VSD) to allow the pump to be operated at a wide range of pump flows (from less than 1 L/s to approximately 10-12 L/s). Based on observations of bore performance during pump installation, the gearing of the pump was set to allow the lowest possible flow range for the pumping test;
- The pump was initially started on 16 Feb 2011, to test pump performance and also select a pumping rate for the pumping test. During the initial test the pump was run at a range of flows from 0.7 L/s to 0.4 L/s, and during this process the water level in the pumped bore was drawn down by almost 60 m (i.e. to pump intake level) in one hour.
- Due to the observed rate of drawdown during the test pumping process, it was decided that a step-drawdown test would not be run, as it was apparent that water level in the bore would be drawn down to pump intake level at the lowest rate. Instead, the pump was set at the lowest possible pumping rate (0.4 L/s), and water levels allowed to recover over night prior to commencement of the constant rate test;
- A constant rate test was run on Thursday 17 Feb. For this test the bore was pumped at 0.4 L/s, and 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.

- 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 6-2) and a storage coefficient (storativity) of 3.8 x 10^{-4}.

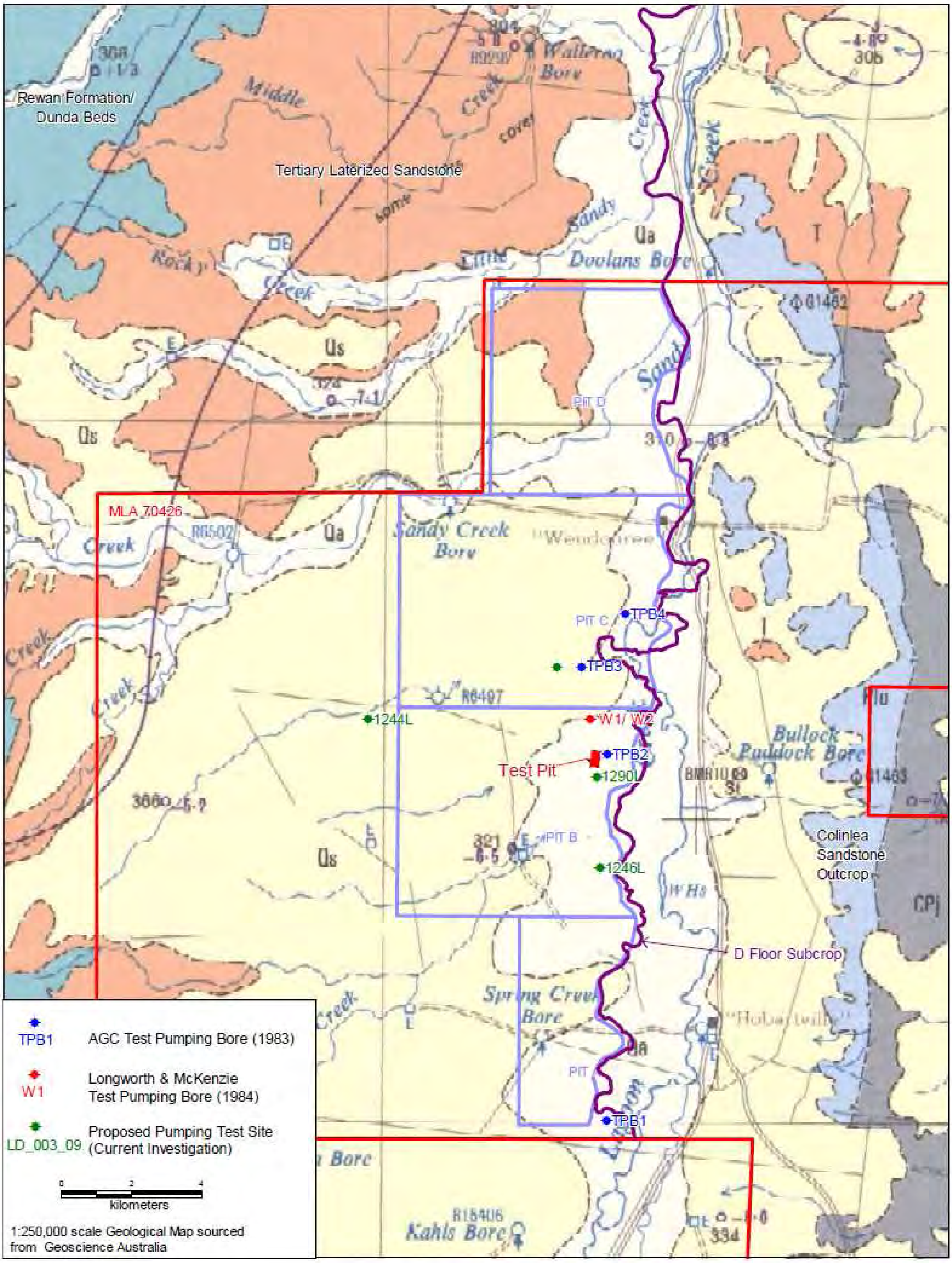


Figure 3-18: Location of Pumping Test Bores

Table 3-3: Recorded Aquifer Hydraulic Properties

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/d)	(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**
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

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/d)	(m/s)	
				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 (2011)									
1290L	AMB-01	30	D-E Sandstone	Theis	1.2	6.3	0.16	1.90E-6	3.80E-04

3.10.2 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 the data set is fairly 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 from GAB confining beds from 53 petroleum exploration wells. 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.

Table 3-4: Summary of GAB Hydraulic Properties, as used in early GAB Model (summarised from Audibert 1976)

Description	Limits	Horizontal Hydraulic Conductivity		Vertical Hydraulic Conductivity		Porosity	Storage coefficient	Comment
		(m/day)	(m/s)	Kv (m/day)	Kv (m/s)			
Confining Bed 1	Lower Limit - Base of Winton Fm			1E-4 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 Fm • 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 Fm			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 Cretceous, and, in certain areas, older sedimentary rocks of Cambrian, Permian, and Triassic Age

3.11 Transient Calibration Data

3.11.1 Introduction

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

1. Groundwater level monitoring data; and,

2. Data from the operation of the Alpha Test Pit (ATP), which includes water level data and pumping data.

These data are described in more detail below.

3.11.2 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 (refer Figures 3-13, 3-14, 3-15). 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 term. This may suggest that the intake areas for these units are located some distance from the site;

- The majority of direct rainfall recharge occurs to upper sediments where groundwater bores have not been constructed. The reason that bores have not been constructed in sediments above the laterite layer is that the majority of bores have been dry in this zone when drilling was undertaken.

The lack of response to rainfall events means that there is no local data available for calibration of rainfall. 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.

3.11.3 Data from Operation of the Alpha Test Pit

The Alpha Test Pit (ATP) was developed between November 2010 and July 2011 to enable a bulk sample of coal (150,000 ROM 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 (ie for prevention of floor heave and to maintain geotechnical stability of the pit walls).

Monitoring of daily pumping volumes from the 12 pit perimeter bores (from commencement of pumping on 21 April 2011 to cessation of pumping on 20 July 2011), and 6-hourly water level monitoring of bores adjacent to the pit, has provided a valuable data set that can be used for calibration of the regional model.

This dataset will be applied to future calibrations of the model. A summary report has been prepared (Appendix D) that:

- Describes the ATP dewatering system design and infrastructure;
- Presents a summary of pumping from both pit dewatering bores and in-pit sump pumps;
- Makes observations relating to groundwater levels adjacent to, and at distance from, the ATP; and,
- Presents a calculation of hydraulic parameters, based on analytical modelling of the ATP pumping and water level drawdown data.

A separate numerical model is being developed in FEFLOW by NTEC to simulate the development of the ATP. It is intended that the calibration data from the small-scale ATP model will be carried over to the large-scale regional model to improve model calibration. Initial information relating to setup and results from the model are shown in Appendix E.

4.0 DESCRIPTION OF MINING

4.1 Alpha Coal Project

The pit shell for mining at Alpha on MLA70426 is shown on Figure 4-1. The mining schedule is shown on Figure 4-2.

Mining is set to commence in 2013 and ramp up after the first year to a total production of 30 million tonnes per annum (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 on the assumption of a 30-year mine life (end of mining in 2042).

In the first few years of the operation coal will be taken from 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.

4.2 Kevin’s Corner Coal Project

The pit shell for mining at Kevin’s Corner on MLA70425 is shown in Figure 4-1. The mining schedule is shown on Figure 4-3.

Mining is set to commence in late 2014 from two open-cut operations, with underground operations to commence the following year. The mine will eventually produce 30 Mtpa of 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 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 31-year mine life.

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 4-3) 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).

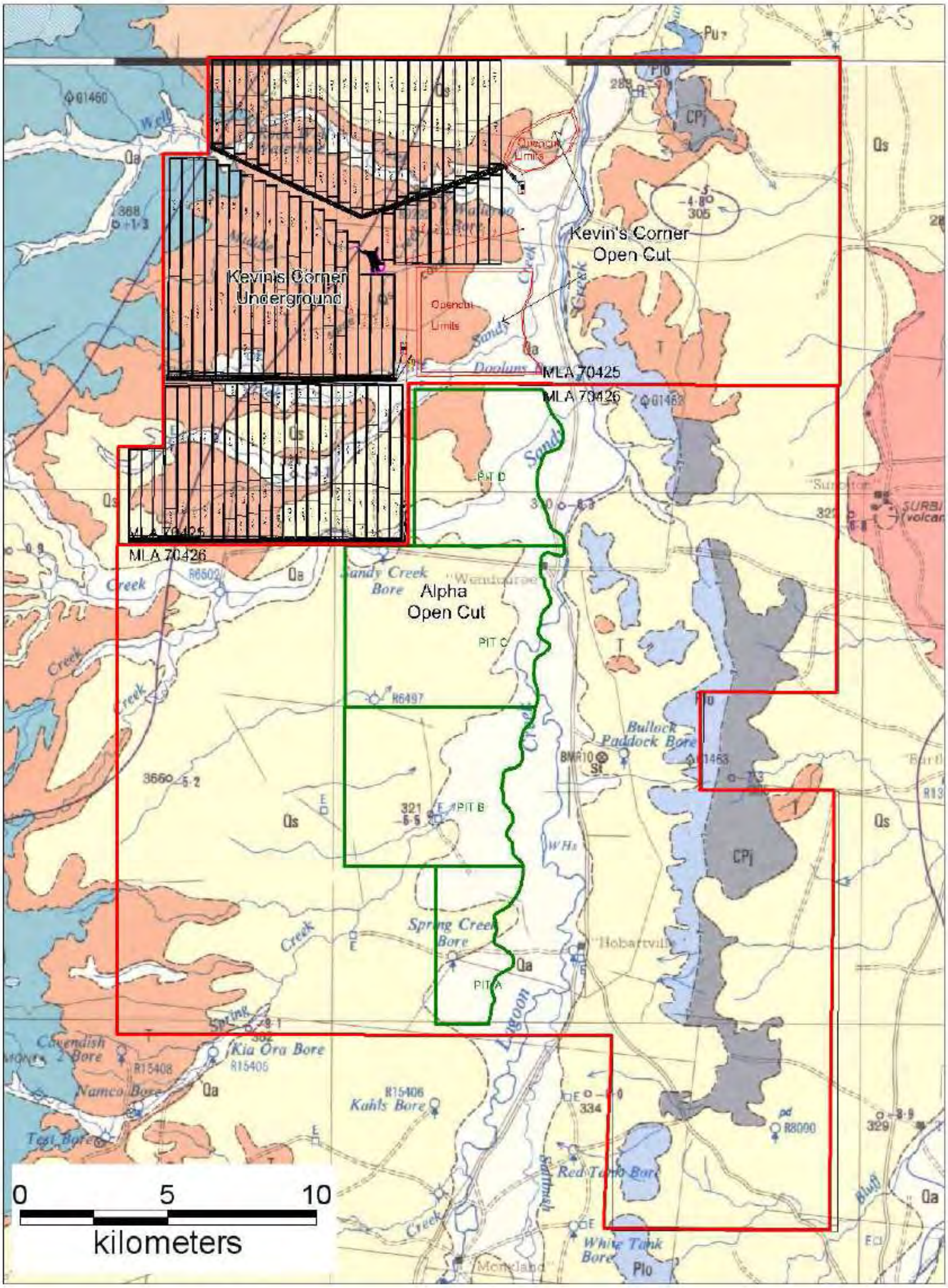


Figure 4-1: Layout of Alpha and Kevin's Corner Mines

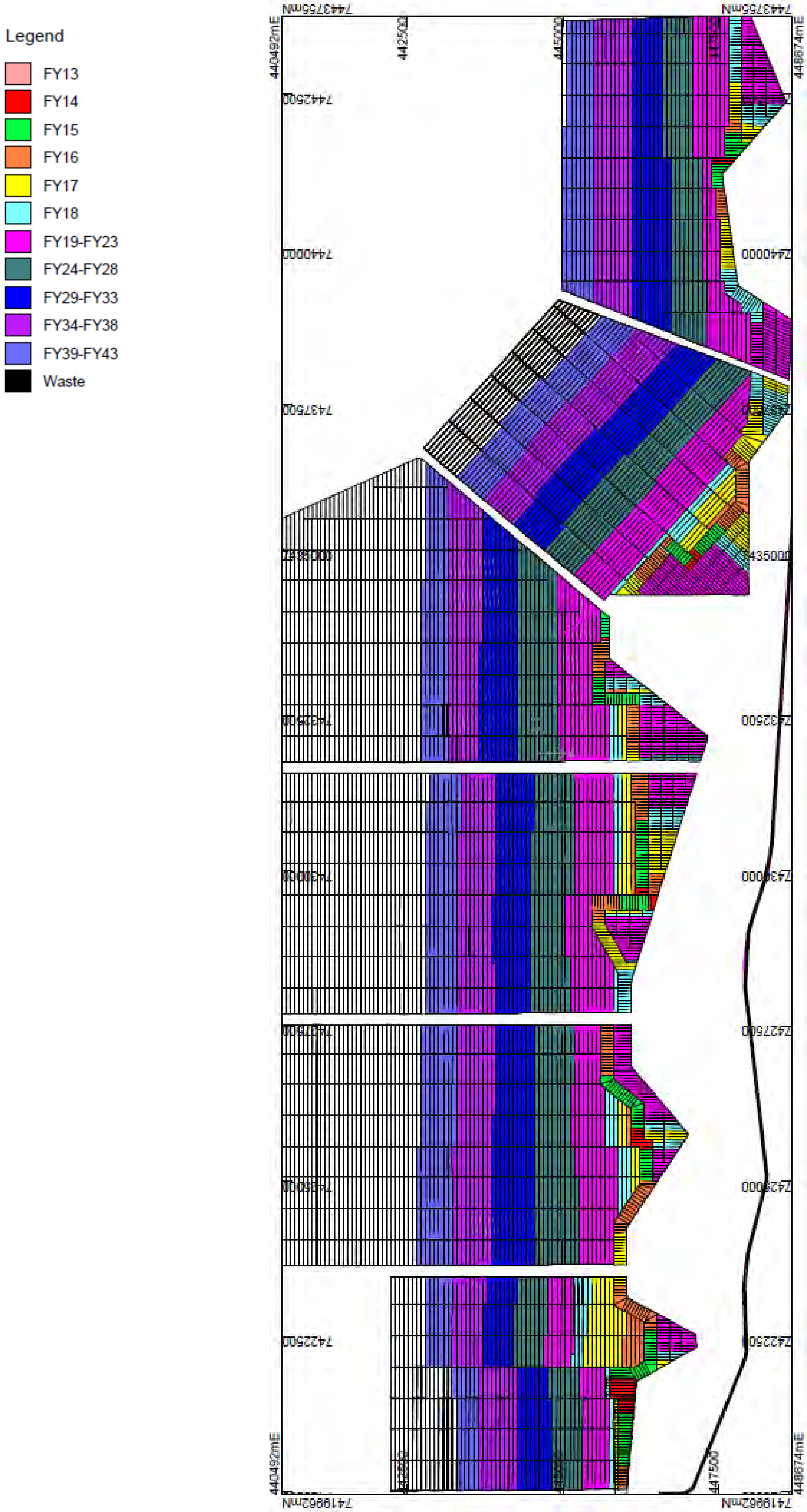


Figure 4-2: Mining Sequence – Alpha Coal Project

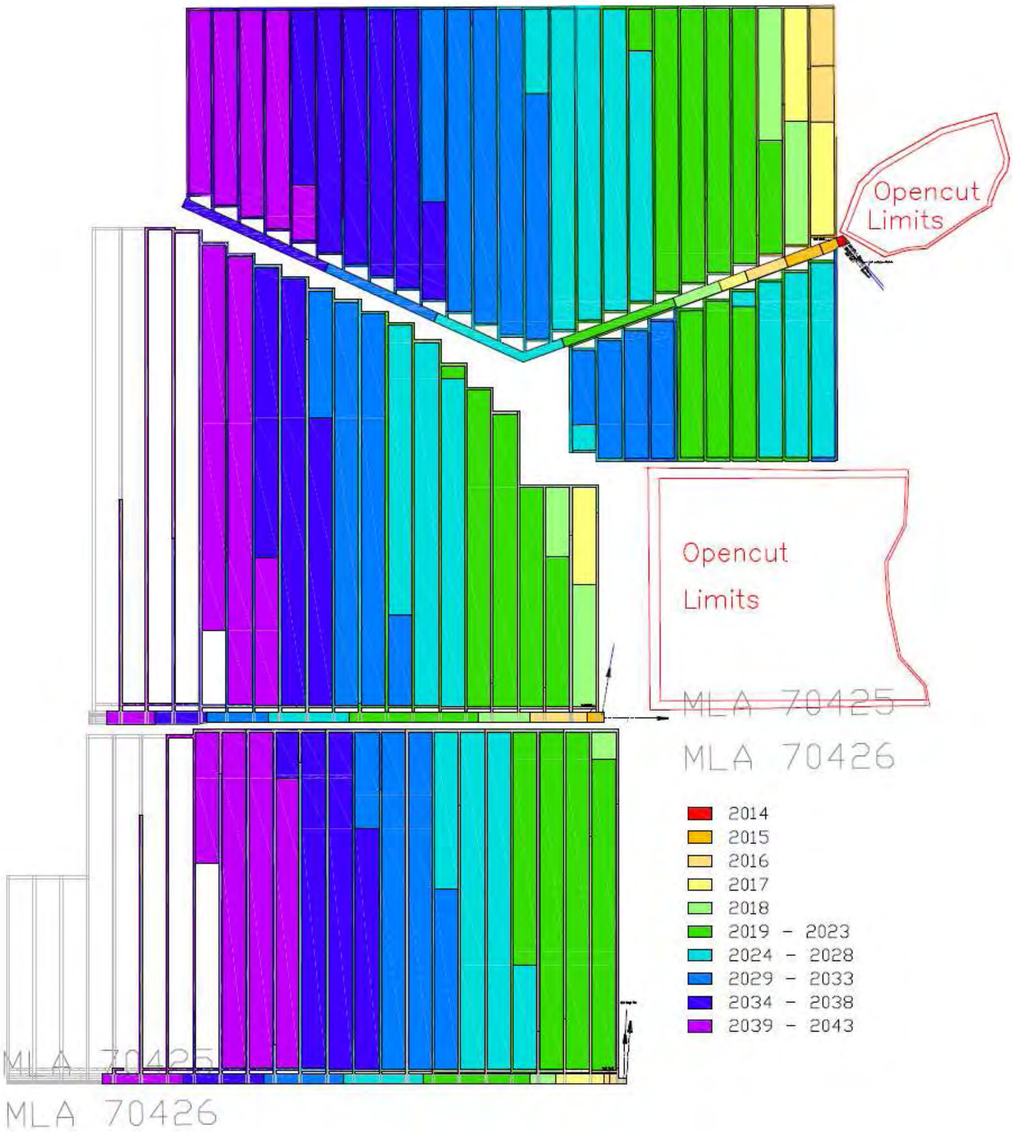


Figure 4-3: Mining Sequence – Kevin's Corner Project

5.0 CONCEPTUAL GROUNDWATER MODEL

5.1 Alpha Coal Project

5.1.1 Conceptual Groundwater Model Before Mining

A pre-mining conceptual groundwater model is presented as Figure 5-1. Based on the information presented in previous sections, the pre-mining conceptual groundwater model is summarised as:

- Groundwater occurs beneath the MLA in coal seam and sandstone (interburden and floor) aquifers. The sandstone aquifers, which occur between and below the coal seams, are the major groundwater sources;
- The sandstone aquifers become cleaner (greater quartz content) and coarser with increasing depth;
- The coal seams confine the underlying sandstone aquifers. This is of greatest significance where the D coal seam confines the underlying D-E sandstone. Seepage modelling predicts that, if the D-E sandstone is not depressurised, the upward pressure from groundwater will exceed the weight of overlying material (i.e. weight balance would be exceeded), causing the floor of the mine to heave (plus groundwater ingress through floor). Therefore, depressurisation of the D-E sands will be required to allow mining to proceed safely to depth;
- 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;
- Recharge occurs in topographically elevated areas and flows down gradient (i.e. as a subdued reflection of topography) toward Lagoon Creek. In the area to be mined the groundwater flow direction (on the western side of Lagoon Creek) 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 Lagoon Creek. This suggests that groundwater does not necessarily discharge to Lagoon Creek under average conditions, but may reach surface e.g. if structures such as joints or faults exist that allow upward movement of water.

5.1.2 Conceptual Groundwater Model During and Post-Mining

Elements of the conceptual groundwater model (post mining) are shown in Figure 5-2.

Predictions relating to the post-mining groundwater regime may need to be revised once regional groundwater modelling has been undertaken (supplemental to this report), but based on modelling undertaken to date, and professional judgement, the following post-mining conceptual groundwater model is proposed:

- A cone of depression will develop around the open pit, extending preferentially north and south (along strike) and to the west, but will be of limited extent in the east as the aquifers outcrop to the east and in this area the aquifers will be locally dewatered;
- Groundwater will flow into the pit through the pit wall, from the Tertiary sediments (where water occurs), the sediments of 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 aquifer. Seepage modelling predicts that the majority of groundwater reporting to the floor of the pit will be derived from the D-E sandstone, and not from underlying sandstone units (sub-E sands, sub-F sands). However, induced flow from underlying aquifers will be considered in the regional groundwater model;
- A water table will develop over time in the in-pit waste dump, though a drainage layer will be installed at the base of the internal dump 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
- Regional groundwater modelling predicts that the cone of depression will extend westward to the Rewan Formation outcrop, but that drawdown in overlying GAB aquifers will not be extensive.

5.2 Kevin’s Corner Project

5.2.1 Conceptual Groundwater Model – Pre-Mining

A pre-mining conceptual groundwater model is presented as Figure 5-3. Based on the information presented in previous sections, the pre-mining conceptual groundwater model is summarised as:

- Groundwater occurs beneath the MLA in coal seam and sandstone (interburden and floor) aquifers. The sandstone aquifers, which occur between and below the coal seams, are the major groundwater sources;
- The sandstone aquifers become cleaner (greater quartz content) and coarser with increasing depth;
- The coal seams confine the underlying sandstone aquifers. This is of greatest significance where the D coal seam confines the underlying D-E sandstone. Seepage modelling undertaken for the adjacent Alpha project predicts that, if the D-E sandstone is not depressurised, the upward pressure from groundwater will exceed the weight of overlying material (i.e. weight balance would be exceeded), causing the floor of the mine to heave (plus groundwater ingress through floor). Therefore, depressurisation of the D-E sands will be required to allow mining to proceed safely to depth;

- 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;
- Recharge occurs in topographically elevated areas and flows down gradient (i.e. as a subdued reflection of topography) toward Sandy Creek. In the area to be mined the groundwater flow direction (on the western side of Sandy Creek) 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. This suggests that groundwater does not necessarily discharge to Sandy Creek under average conditions, but may reach surface e.g. if structures such as joints or faults exist that allow upward movement of water.

5.2.2 Conceptual Groundwater Model – Post Mining

Elements of the conceptual groundwater model (post mining) are shown in Figure 5-4.

Predictions relating to the post-mining groundwater regime may need to be revised once regional groundwater modelling has been undertaken (supplemental to this report), but based on modelling undertaken to date, and professional judgement, the following post-mining conceptual groundwater model is proposed:

- The cone of depression will extend to the east and west of the Project, however propagation of the cone of depression in these directions will be limited due to the presence of outcropping 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 old workings. Inflow will come from Tertiary sediments (where water occurs), the sediments of 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 aquifer and locally from passive depressurisation of sub-E sandstone.
- A water table will be developed over time in the in-pit waste dump. Sources of water will include direct rainfall infiltration, and inflow from the D-E sandstone that will underlie the in-pit dump;

o Rehabilitation (and maintenance to counter settlement) of the surface of the in-pit dump will be required to limit the potential for rainfall infiltration (via capping, revegetation, and/or grading of the surface to encourage runoff and limit surface ponding);

- Water quality monitoring of runoff will be required, should runoff be in the direction of Sandy Creek; and

- Water levels will recover over time as the underground workings are flooded post-mining. Predictions of time taken for water level recovery (full or partial) will be undertaken using the regional groundwater model.

Figure 5-1: Pre-Mining Conceptual Groundwater Model – Alpha

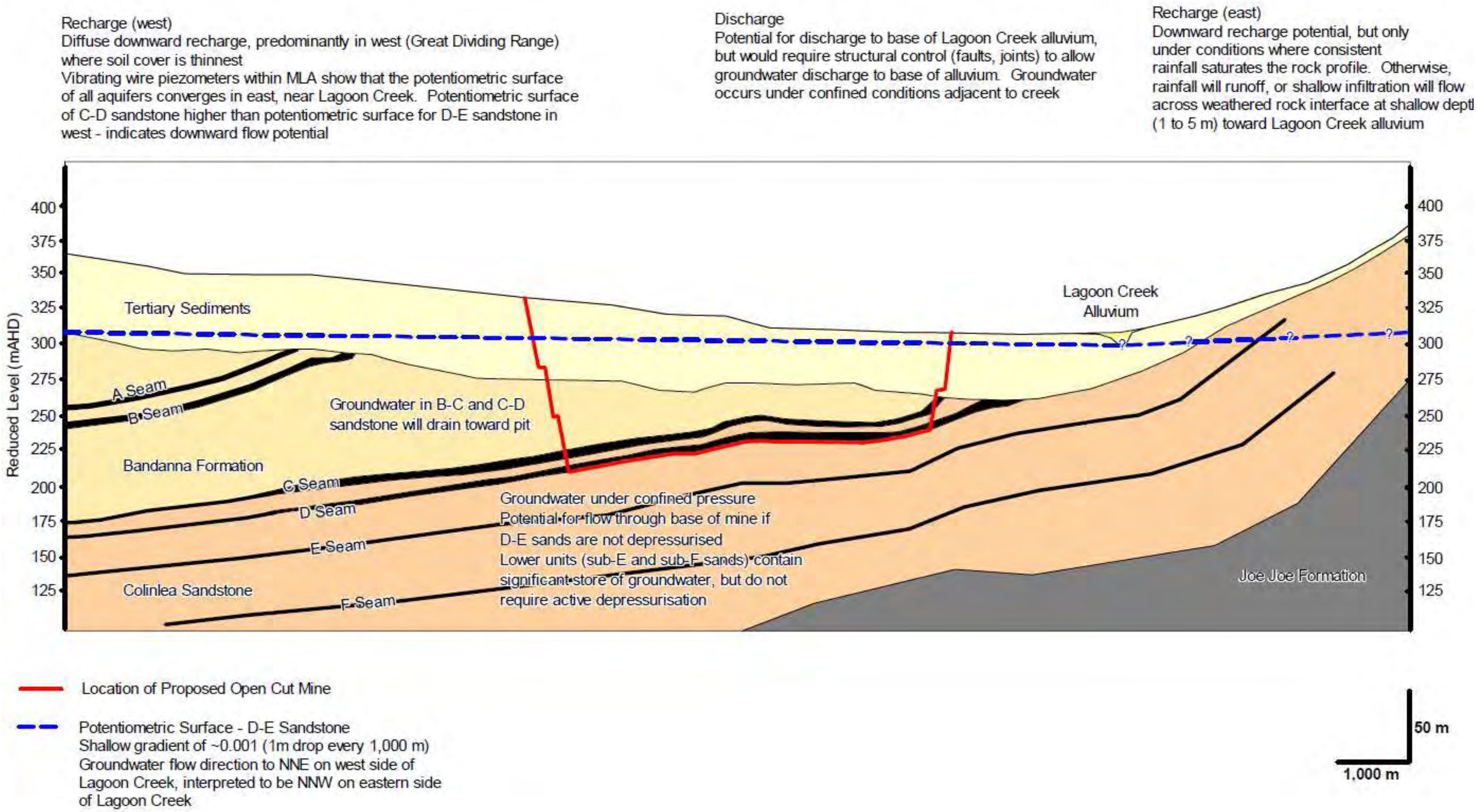


Figure 5-2: Post-Mining Conceptual Model – Alpha

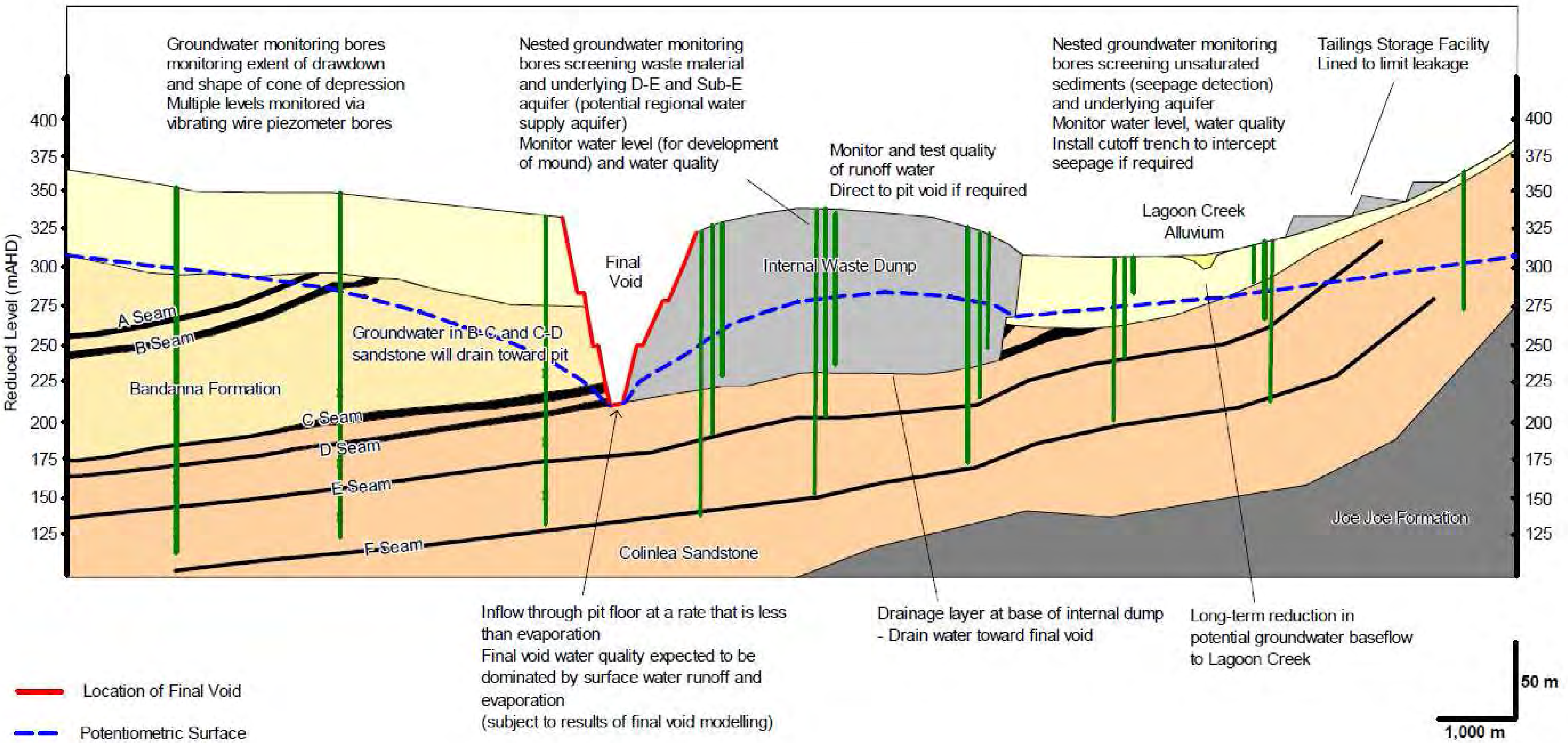


Figure 5-3: Pre-Mining Conceptual Model – Kevin's Corner

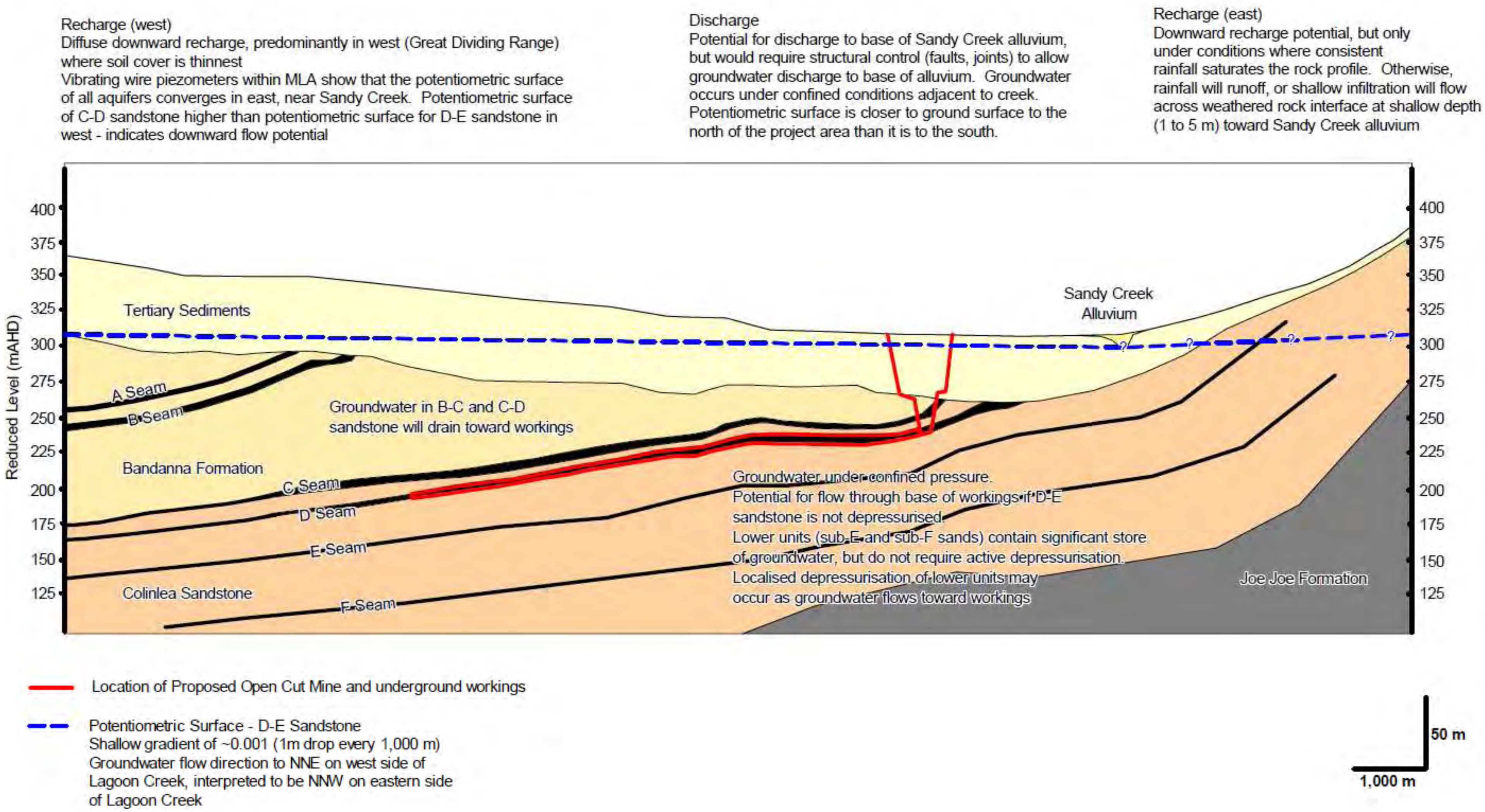
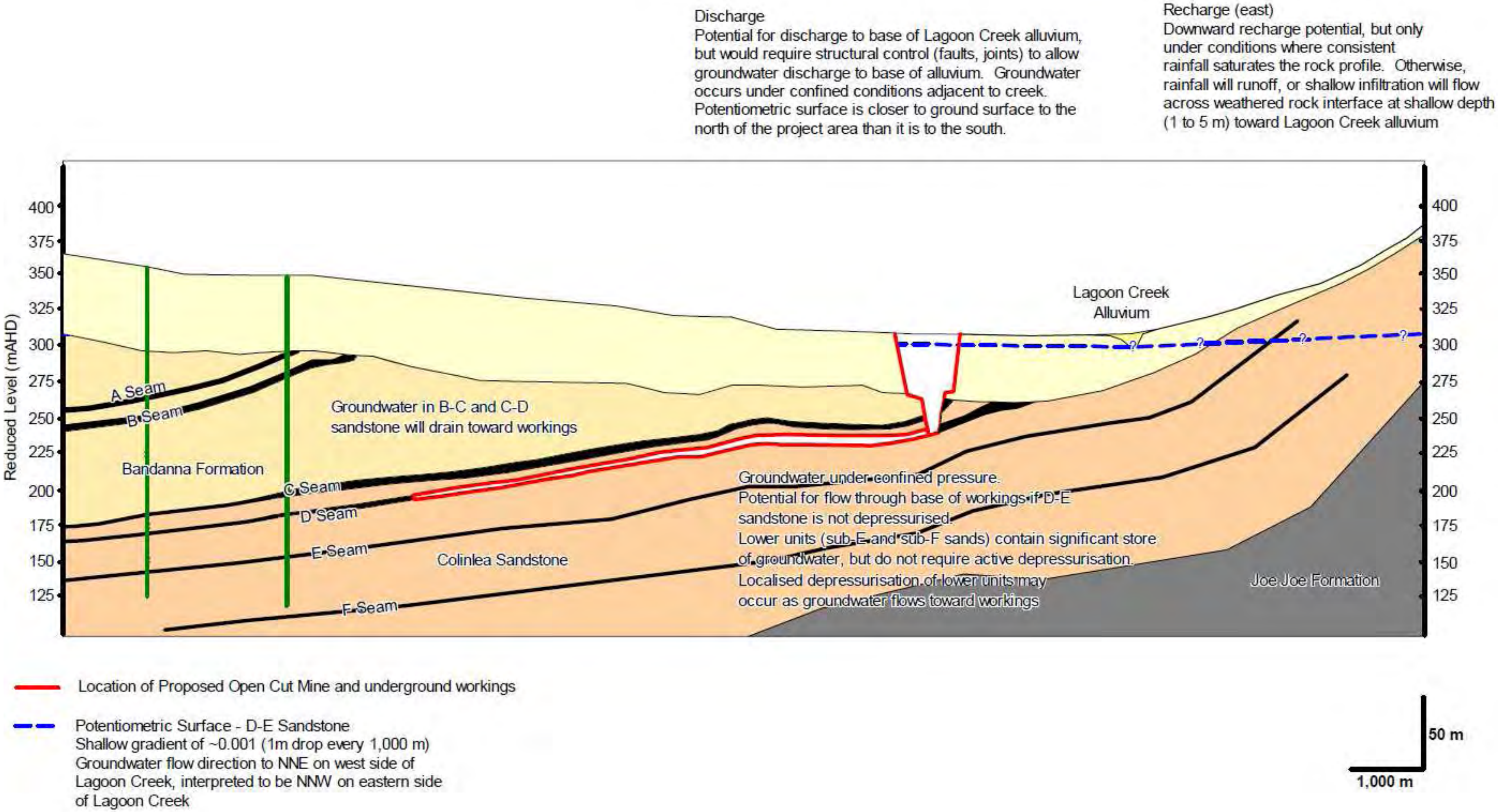


Figure 5-4: Post-Mining Conceptual Model – Kevin's Corner



6.0 NUMERICAL MODEL

6.1 Modelling Software

Modelling was undertaken using FEFLOW (version 6), a finite element groundwater modelling package developed by DHI-WASY, at the Institute for Water Resources Planning and Systems Research in Berlin, Germany.

FEFLOW is well suited to the assessment of open pit mine dewatering where a combination of pumping from perimeter bores and in-pit sumps may be required, as is the case at the proposed Alpha Mine. It also allows simulation of underground mining. FEFLOW allows:

- simulation of groundwater flow in conditions dominated by complex geological structure;
- a refined mesh in areas with complex geometry and/or steep gradients in piezometric head (near mines);
- a coarser mesh in the far field;
- representation of complex time-varying boundary conditions (which is particularly important during simulation of dewatering of a mine and filling of a final void during recovery); and
- time-varying properties in aquifers and aquitards (to represent in pit placement of waste rock as backfill and the influence of deformation above underground mining).

6.2 Modelling Strategy

In order to predict the cumulative impact of the Alpha and Kevin's Corner mining operations, it was necessary to represent the long-term mine plans for all open pit and underground mining within one groundwater model.

Modelling was undertaken separately to simulate:

- mine inflows and regional depressurisation during mining, and
- recovery of groundwater levels and the evolution of mine pit lakes following the end of mining.

FEFLOW provides three methodologies for simulating regional scale groundwater flow in unconfined aquifers.

- The first option requires prior knowledge about which layers are confined and unconfined, but this method works best in regional flow systems where the water table is relatively steady. This is not the case in many mining situations.

- The second option, known as BASD (Best Adaptation to Stratigraphic Data) or the “moving mesh” option, allows layers and slices (the surfaces between layers) to move adaptively, such that the uppermost slice always corresponds to the water table. There is growing evidence that this option is difficult to use in complex mining situations where the water table can fall to elevations far below its initial level.
- The third option is to run the model in an unsaturated or pseudo-unsaturated mode. This appears to be the best way to use FEFLOW for a region that contains both open cut and underground mines.

A decision was made to run FEFLOW in a pseudo unsaturated mode, where the upper layers desaturate (partially drain) as the water table falls during mining. One disadvantage of running FEFLOW in this mode is that recharge cannot be applied to the uppermost slice.

6.3 Model Geometry

There are no natural physical boundaries near the proposed mines that could be used as lateral boundaries for a numerical model. For this reason, the model domain was chosen to be square, 100 km x 100 km in extent (Table 6-1). The domain boundaries are believed to be far enough away from the proposed mines that the impact of mining would not be felt at the boundaries. The proposed Alpha pit was positioned near the centre of the model domain. The domain extends 40 km to the south of the Alpha open pit, and 27 km, 40 km and 45 km to the north, west and east of the Kevin’s Corner underground mine, respectively. The model domain extends 35 km into the Great Artesian Basin (“GAB”).

Table 6-1: Model Extent

	Easting (GDA94, zone 55)	Northing (GDA94, zone 55)
North	-	7480000
East	495000	-
South	-	7380000
West	395000	-

FEFLOW allows a user to develop a finite element mesh based on a network of triangles in plan. The corners of the triangles are called “nodes”. In the vertical direction, the model domain is divided into a number of layers. The layers are bounded above and below by surfaces called “slices”, so all nodes are located within slices. Hydraulic properties are defined for three-dimensional triangular prisms known as finite “elements”. Piezometric heads are computed at the nodes, and boundary conditions and initial conditions are also defined at nodes.

A finite element mesh as designed to align with mine plans and with existing surface drainage, so that hydraulic properties and boundary conditions could be assigned in easily identifiable zones. The mesh was refined along the zone boundaries to ensure sufficient discretisation. Each slice has 23,589 nodes and each layer has 46,012 triangular prismatic finite elements (Figure A 1).

For the purpose of adequately representing hydrostratigraphy, the model domain was divided into 11 layers, representing nine hydrostratigaphic units (Table 6-2). The Rewan Formation (an aquitard) was divided into two layers, and the Bandanna Formation (an aquifer overlying the primary target for mining, the D Seam) was divided initially into two layers, and later into four layers.

Top and bottom elevations were assigned to all model layers based on known and estimated elevations of the tops and bottoms of hydrostratigraphic layers. Where no surface elevations were available, layers were defined using an assumed average layer thickness. The weathered zone was assumed to have the same hydraulic properties as the underlying unweathered rock formations, and hydrostratigraphic layers were assumed to outcrop at the ground surface based on the dip observed below the weathered zone (Figure 6-1).

The base of mining was in slice 7. The model was extended to a depth of 1500 m, i.e. to RL -1200 mAHD. This is somewhat deeper than is often assumed, especially given the level of uncertainty about the nature of the basement, but a decision was made at an early stage of modelling to include and assess the effect of basement, rather than simply assuming that basement would have no effect.

Table 6-2: Model Layering

Hydrostratigraphic unit	Model layers
GAB	1
Rewan Formation	2-3
Bandanna Formation	4-5
D Seam	6
D-E Sands	7
E Seam	8
Sub E Sands	9
Joe Joe Formation	10
Basement	11

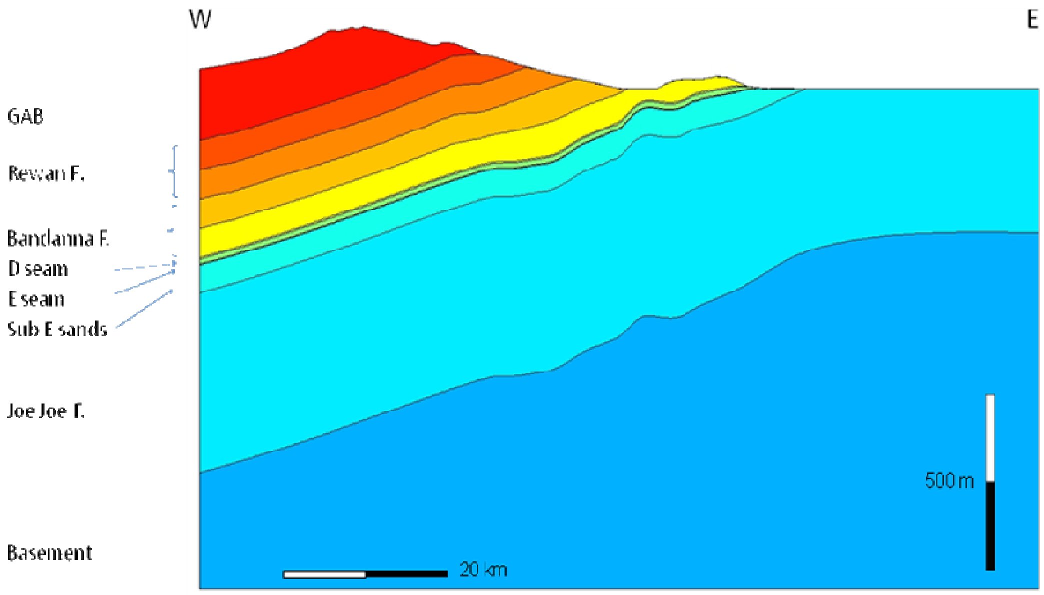


Figure 6-1: Numerical Model Layers and Corresponding Hydrostratigraphic Units

6.4 Hydraulic Properties

Hydraulic properties of the Bandanna and Colinlea formations were obtained from a number of pumping tests undertaken on site during previous groundwater investigations (AGC, 1983; Longworth & McKenzie, 1984). The hydraulic properties used in the numerical model were estimated based on averages of measured values. The hydraulic properties of the GAB were obtained from Audibert (1975). Where no field data are available, parameters were estimated based on lithology. Vertical hydraulic conductivities were assumed to be one order of magnitude (a factor of 10) lower than horizontal hydraulic conductivities, although the anisotropy ration (the ratio of horizontal to vertical hydraulic conductivity) could be much higher than 10, especially in aquitards such as the Rewan Formation.

As no field data were available on the unsaturated properties of any of the rock formations included in the model, capillary parameters were assumed representative of loam sediments. The Van Genuchten capillary function was used to represent saturation ($\alpha = 3.6\ m^{-1}$, n = 1.7), and a linear relationship was assumed for relative hydraulic conductivity, as recommended by DHI-WASY as a way of allowing upper layers to desaturate in a regional model.

Storage in the unsaturated zone depends on porosity, n (not to be confused with the coefficient n in the Van Genuchten capillary function). Porosity takes the place of specific yield, a parameter that would be used in a model that does not allow partial saturation.

Estimating hydraulic properties based on lithology and assuming uniform anisotropy are certainly simplifications. There are many uncertainties with respect to the assumed hydraulic parameters. Baseline properties in the first model simulations are as shown in Table 6-3.

Table 6-3: Baseline Properties Prior to Mining

Unit	Kxy (ms^{-1})	Kz (ms^{-1})	Ss (m^{-1})	n (-)
GAB	5.80E-05	5.80E-06	0.0005	0.05
Rewan Formation	1.00E-07	1.00E-08	0.0001	0.05
Bandanna Formation	1.60E-06	1.60E-07	0.00016	0.05
D seam	1.00E-06	1.00E-07	0.005	0.02
D-E sands	3.00E-06	3.00E-07	3.5E-06	0.05
E seam	1.60E-06	1.60E-07	0.005	0.02
Sub E sands	1.20E-05	1.20E-06	0.0001	0.05
Joe Joe Formation	1.00E-07	1.00E-08	0.0001	0.05
Basement	1.00E-07	1.00E-08	0.0001	0.05

6.5 Recharge

The average annual rainfall in the area is 535 mm. Average annual evaporation (class A pan) is 2,293 mm. Estimates of recharge generally fall between 1 and 3% of average annual rainfall, with localised values up to 5% of rainfall reported.

During the period of mining, no recharge was applied. This is believed to be a reasonable approach, because mine inflows during mining are driven by steep gradients induced by dewatering of the mine, and mine inflows are far greater than any possible contribution of recharge. There is, however, another practical reason for not applying recharge, i.e. the fact that if FEFLOW were run in an unsaturated or pseudo-unsaturated mode, recharge to the uppermost slice would cause heads to rise to unrealistically high levels. This limits the applicability of FEFLOW, but as explained above, the assumption of zero recharge is believed to be reasonable during mining.

Rainfall, runoff and evaporation were taken into account for post mining (final void) simulations, but only locally within the catchment areas that contribute runoff towards mine pit lakes in final voids.

6.6 Boundary and initial conditions

Fixed head boundary conditions were assumed along all sides of the model domain at an elevation of 300 mAHD, prior to and during mining. The lateral boundaries were chosen based on an assumption that they would be far enough away from the mines so that no flow would occur from the boundary to the mine during the period of mining. This assumption can be checked by computing the flow through fixed head boundaries throughout any model run, and by comparing the magnitude of this flow with other flows near the mine.

Initial conditions prior to mining were chosen based on an assumption that the water table is located initially at 300 mAHD throughout the region. In essence, the whole region is assumed to be hydrostatic, with zero regional groundwater flow. This approximation was required because of lack of knowledge of regional water table elevations, but is believed to be sufficient to allow predictions of the impact of mining.

Because mining will progress westwards during the life of the proposed project, numerical modelling requires the mine schedule to be approximated in both space and time. The extraction of coal and overburden at the Alpha open pit and of coal at the Kevin's Corner underground mine has been approximated by an initial six-year mining stage in financial years 2013-2018, followed by five five-year mining stages to mid 2043 (Table 6-4, Figure A 1).

Table 6-4: Mining Stages

Mining stage	Financial years ending 30 June	Years from start
1	2013-2018	0-6
2	2019-2023	6-11
3	2024-2028	11-16
4	2029-2033	16-21
5	2034-2038	21-26
6	2039-2043	26-31

6.7 Model Calibration

The model domain covers an area of 10,000 square kilometres. The available dataset of standing water levels is relatively small, and is generally limited to the vicinity of the two proposed mines. There is little information about water table elevations in many parts of the model domain.

Since the aim of modelling was to predict potential drawdown at a regional scale and to estimate inflow rates into the mine voids, a decision was made not to attempt calibration. A uniform piezometric head of 300 mAHD was assumed as an initial condition for transient simulations, based on an average standing water level of 300 mAHD across the area of the mine leases.

There are also no flow data available in the model domain that could provide information to confirm the relationship between water table elevations, hydraulic properties and flows.

In an ideal situation, model calibration would be based on observed heads and flows over a number of years, during a period where all key hydrostratigraphic units are stressed in a manner similar to the stress that would be applied during mining. Unfortunately, the only way to stress a large regional system in a similar way to mining is by mining.

Without calibration, a groundwater flow model can still be used to indicate the response of the system to mining. The predictions rely on best estimates of hydraulic properties, and can be tested only by sensitivity analysis, i.e. by varying the estimates of hydraulic properties in order to assess the sensitivity of predictions to changes in those properties.

6.8 Representation of Mining

All currently available commercial groundwater modelling software assumes that the ground that contains groundwater is permanently fixed in place. No commercial software has been designed specifically to facilitate the representation of mining projects.

The process of coal mining starts with removal of part of the ground. Coal is removed for washing and shipment to markets. Waste rock remains on site and can influence hydrological and hydrogeological processes, during and after the end of mining.

- In open cut coal mining, waste rock or "spoil" comes from overlying layers ("overburden") and from layers between the coal seams ("interburden"). The spoil is typically placed inside the pits, ultimately leaving a relatively long linear final void, at the location of the high wall. Handling of coal and spoil with draglines allows the release of some water from within the spoil, such water draining to sumps in the floor of the pit. Some moisture is retained within the coal and spoil. The majority of water that reports to the pit does so because the floor of the pit is now a local low point in the hydrogeological system, thus groundwater flow occurs towards this local sink.
- In underground coal mining, longwall mining equipment removes a target seam, and little waste is brought to the surface. Some moisture is retained within the coal that is mined. As longwall panels progress forwards within a seam, the roof of the seam collapses behind the roof supports, ultimately causing subsidence at the land surface. If mining proceeds from shallow depths towards deeper depths, groundwater inflows to the mine are likely to increase as the bottom of the mine becomes lower in the local flow field. If mining starts deep and proceeds up dip, the lowest point in the flow field is established early and mine inflows may decrease throughout the life of the mine.
- Behind a longwall miner, the seam itself is rapidly filled with rubble. Initially the roof of the seam spalls, and slabs of rock fall the height of the seam to the floor. The roof continues to spall until the broken rock fills the space available and provides support to the roof. This region is known as the "goaf". Deformation continues above the goaf, through a combination of downward and horizontal movement (vertical and horizontal "strain"). Depending on the structure and mechanical strength of the geological materials, vertical fractures can open up above the goaf, but at an elevation where "arching" causes horizontal compressive stresses (a so-called "confining" zone), vertical fractures remain closed and the capacity of the rock to transmit groundwater may be no more than before mining. Above the confining zone, horizontal fractures along bedding planes can open up, leading to enhanced horizontal hydraulic conductivity. The net result of longwall mining is "subsidence" at the land surface, which results in an undulating perturbation to the original land surface, with maximum subsidence over the middle of panels and minimum or zero subsidence over the pillars than separate the panels.

In order to use commercial groundwater modelling software to simulate mining, it is necessary to use the capabilities of the software to vary hydraulic properties and boundary conditions as a function of time, to capture the essential features of the mining process.

6.8.1 Boundary Conditions

The most common way to represent the floor of a mine is as a "seepage face" boundary condition. In FEFLOW, a seepage face boundary is a fixed head boundary condition where head at a node is set equal to elevation, on condition that the resulting groundwater flow at that node is a net outward flow, out of the ground and in this case, into a mine. Seepage face boundary conditions are set when an area is being mined, and released after the end of that stage of mining.

In the Alpha and Kevin's Corner open pits, seepage face nodes were defined at all nodes at the bottom of the D Seam (slice 7) within the areas of the pits. Seepage face nodes were also defined at nodes around the walls of open cut mines, in all slices. In slices 5 and 6 (at the middle and base of the Bandanna Formation), seepage face nodes provide an opportunity for slice 6 to desaturate in the high wall, with seepage reporting to the mine wall at the base of the aquifer. In slices 2, 3 and 4 (at the top, middle and bottom of the Rewan Formation), the seepage face will release water to the pit in early time steps, after which groundwater will drain vertically to a water table in the Bandanna Formation, rather than out of the pit wall.

In the Kevin's Corner underground mine, seepage face conditions were defined at the roof and floor of the D Seam (slices 6 and 7) to allow groundwater inflow across these surfaces.

6.8.2 Hydraulic Properties

Within the volume of an open cut mine, hydraulic properties are sometimes changed to emulate what would happen in a mine when rock is removed from a mine. In the case of underground mining, hydraulic properties can be changed in the seam that it mined, and also in the goaf and higher zones above the mine.

In this report, however, hydraulic properties are assumed to be constant in time. Hydraulic properties remain constant before, during and after mining. This is a gross approximation, but given the nature of the results, it is clear that a more detailed representation of the mining process would not significantly change the overall conclusions from this study. Because mining proceeds down dip, and because both backfill and previously mined longwall panels will drain down dip towards the active areas of mining, the hydraulic properties of the mined areas are unlikely to be important until after the end of mining, when water levels recover.

6.8.3 Solution Strategy

With mining assumed to progress in six stages in 31 years (Table 6-4), mining is assumed to occur effectively instantaneously at the start of each stage. This tends to cause a rapid inflow into that part of the mine at the start of a stage, and a gradual decline in inflow rate towards a steady flow more characteristic of what might happen in reality. If a mine plan could be represented at yearly, monthly or weekly time intervals, instead of five-year intervals, the time variation in inflow would be more smooth. Nevertheless, even with a coarse representation of a mine plan, cumulative inflow rates are known to be reasonably accurate.

In this series of simulations, the six stages of mining (a period of 31 years) were simulated in a single model run. Boundary conditions and constraints were set up as time-varying conditions. Inflows to each part of the mine were computed using FEFLOW "observation point groups". Rapid inflows were observed at the start of each stage of mining, so cumulative inflows were calculated.

6.9 Predictions

A number of predictive runs were performed. The first run was based on best estimates of hydraulic properties as defined in Table 6-3. Further runs were based on modified hydraulic properties, as defined in Table 6-5.

This is neither a formal sensitivity analysis nor uncertainty analysis. Rather, the results reported here are a set of deterministic predictions using a number of sets of model parameters, simply to explore the range of possible results.

6.9.1 Base Case

Scenario 1 was based on average values of hydraulic parameters obtained from field measurements. As no information was available on the effective porosity of hydrostratigaphic units, half of the total porosity was assumed to be drainable porosity. A specific yield of 0.05 was used for all formations except for coal seams, where a lower value, 0.02, was used.

6.9.2 Alternatives

The purpose of *scenario 2* was to investigate the influence of the porosity and specific yield on inflow rates. In the case of the Kevin's Corner underground mine, mine inflow originates from the overlying and neighbouring rock formations. Although the porosity and specific yield of all formations were doubled in this scenario, it is only the changes in the D-seam, the Bandanna Formation, the Rewan Formation and to a lesser extent the GAB aquifer, that would affect results.

Scenario 3 was aimed at investigating the influence of hydraulic conductivity in the Bandanna Formation and the D-E Sands on inflow rates. Hydraulic conductivities were doubled compared to original values.

Scenario 4 involved a fivefold increase of the hydraulic conductivity of the Rewan Formation aquitard. The purpose was to investigate the potential for increased impacts on the GAB aquifer.

Scenario 5 involved a tenfold decrease of the specific storativity of every formation which represents a significant thickness. The aim of this simulation was to assess the amount of inflow originating from depressurisation of rock below and around the mine voids.

Table 6-5: Hydraulic Properties

Scenario	Unit / Property	GAB	Rewan	Bandanna	D seam	D-E sands	E seam	Sub E sands	Joe Joe	Basement
		1	2	3	4	5	6	7	8	9
1 (base case)	Kxy (ms^{-1})	5.80E-05	1.00E-07	1.60E-06	1.00E-06	3.00E-06	1.60E-06	1.20E-05	1.00E-07	1.00E-07
	Kz (ms^{-1})	5.80E-06	1.00E-08	1.60E-07	1.00E-07	3.00E-07	1.60E-07	1.20E-06	1.00E-08	1.00E-08
	Ss (m^{-1})	0.0005	0.0001	0.00016	0.005	0.0000035	0.005	0.0001	0.0001	0.0001
	n (-)	0.05	0.05	0.05	0.02	0.05	0.02	0.05	0.05	0.05
2*	Kxy factor									
	Kz factor									
	Ss factor									
	n factor	x2	x2	x2	x2.5	x2	x2.5	x2	x2	x2
3*	Kxy factor			x2		x2				
	Kz factor			x2		x2				
	Ss factor									
	n factor									
4*	Kxy factor		x5							
	Kz factor		x5							
	Ss factor									
	n factor									
5*	Kxy factor									
	Kz factor									
	Ss factor	÷10	÷10	÷10				÷10	÷10	÷10
	n factor									

Note: *For scenarios 2 to 5, this Table shows factors by which base case properties have been multiplied or divided. Empty cells imply x1.

6.9.3 Mine Inflow Rates

Inflow rates were calculated separately into the Alpha and Kevin's Corner open cut mines and into the underground mine. The different mines were not further subdivided for the purpose of inflow calculations.

Cumulative inflow curves for the five investigated scenarios are shown in Figure A 3 to Figure A 7, and summarised in Table 6-6.

Table 6-6: Predicted Cumulative Inflow Volumes

Total inflow (GL)	Alpha pit	KC underground	KC northern pit	KC southern pit
Scenario 1	1,150	6,559	123	339
Scenario 2	954	7,150	89	348
Scenario 3	911	5,910	80	229
Scenario 4	883	5,859	80	251
Scenario 5	658	4,844	60	169

The cumulative inflow volume into the Alpha pit varies between 658 and 1150 GL over a 31-year period. The inflow into the Kevin's Corner underground mine is in the range 4844 to 7150 GL. Inflows to the Northern and Southern Kevin's Corner open pits range from 60 to 123 GL and from 169 to 348 GL, respectively.

Cumulative inflow volumes increase relatively linearly with time throughout the life of the project, hence average annual dewatering volumes are relatively steady.

The predicted cumulative inflow volumes are large, and require some explanation. The total area of longwall mining at Kevin's Corner underground mine is about 180 km^2. The average depth of the mine below surface is about 200 m. If the whole rock mass (overburden) above longwall mining has porosity 0.05, if the porosity is initially full of water (100% saturation), and if mining causes all of this water to drain to the underground mine, then the total volume would be 1800 GL. The fact that the model is predicting an even larger volume suggests that additional inflow is coming from the surrounding area (i.e. not vertically above the underground mine) and also that some inflow is coming from confined storage.

There are always two different sources of groundwater reporting to mines:

- Confined storage: As a response to the extraction of water around the mines, depressurisation will propagate in all directions: laterally, above (in the case of an underground mine) and below. The small but finite compressibility of water and rock results in release of water from storage.
- Unconfined storage: When depressurisation affects the water table, the water table will start to fall, and water will drain from within the porosity. The amount of water removed

from the pore space is less than the total porosity, as capillary forces will keep a small amount of residual water in the pores.

The highest inflow is predicted to be towards the Kevin's Corner underground mine, which is the deepest of the four mines. One of the reasons for a considerably higher inflow rate into the underground operations compared to the open cut operation is vertical drainage of water from the overburden. Another reason is its greater depth which means steeper gradients to cause inflows from the surrounding region.

According to Figure A 8 to Figure A 11, the overburden above the Kevin's Corner underground mine becomes desaturated above all longwall panels by the end of the mining. As the volume of water released from drainable porosity per unit volume of rock is two to four orders of magnitude higher than the volume water released from confined storage, desaturation of the overlying Bandanna and Rewan Formations is the main source of water discharging into the underground mine.

Alternatives sets of hydraulic properties show that both the unconfined storage properties (porosity) and confined storage properties (specific storativity) have a significant influence on inflow rates (scenarios 2 and 5). The hydraulic conductivities of overlying and underlying formations have less influence on groundwater inflow rates (scenarios 3 and 4), however the investigated range of hydraulic conductivities was narrower than that of the storage properties.

6.9.4 Regional Drawdown

Drawdown was calculated as the difference between initial head and simulated hydraulic heads after 31 years. Drawdown plots were produced for important hydrogeological units including the water table, Bandanna Formation, D-E sands and Sub E sands. Drawdown plots for scenario 1 are provided in Figure A 12 to Figure A 18. The simulated water table drawdown plot provides a conservative estimate, as no recharge was applied. Any recharge to the groundwater table would decrease drawdown and thus the extent of the cone of depression surrounding the mines.

Scenario 1 suggests that the cumulative cone of depression extend approximately 10 km around the mines. The only exception is the western side of the Kevin's Corner mine lease (MDL333). In this zone the outcropping low-conductivity Rewan Formation limits the extent of the cone of depression to a distance of 1.5 to 6 km from the mines. The steepest gradient in the post mining water table is predicted to be in the northwestern corner of the Kevin's Corner lease, where the mine is closest to where the Rewan Formation outcrops.

Depressurisation will occur below the level of mining. According to Figure A 8 to Figure A 11, depressurisation occurs in the Joe Joe formation, and groundwater released from confined storage will reports to the mines. For this reason it is important to obtain reliable information about the hydraulic properties of deep hydrogeological units.

Based on scenario 1, no significant impact on the GAB can be observed after 31 years of mining operations. The Rewan Formation appears to act as a partial hydraulic barrier, limiting the propagation of the cone of depression.

Further expansion of the cone of depression after closure of the mining operations may occur depending on recharge and climatic conditions.

According to scenario 4, a fivefold increase in the hydraulic conductivity of the Rewan formation is not sufficient to imply a significant impact on the GAB (Figure A 16).

According to scenario 3, an increased hydraulic conductivity of the Bandanna Formation and D-E sands units does not result in any significant change in the extent of the cone of depression (Figure A 17 and Figure A 18).

7.0 MODEL ASSUMPTIONS AND LIMITATIONS

The model described here was developed for the purpose of making preliminary estimates of mine inflow rates and regional drawdown, and otherwise to provide an indication of issues that may need to be addressed further in further stages of modelling.

The model relies heavily on assumptions leading to estimates of hydraulic properties in a number of key geological formations, and is limited by the current level of uncertainty in these properties. Modelling has shown that estimates of inflow to the Kevin's Corner underground mine are sensitive to estimates of porosity in the layers above the underground mine. The resolution of the regional scale model is such that all water stored initially in this porosity will drain vertically downwards during the life of the project. Other properties such as horizontal and vertical hydraulic conductivities and specific storativity also influence the predictions.

The model assumes a specific model of unsaturated flow in those layers that desaturate above the Kevin's Corner underground mine. The parameters of this unsaturated model are effectively unknown. Nothing is known about the way the Bandanna and Rewan Formations might behave as unsaturated rock layers, before or after the impacts of deformation above longwall mining.

The model depends on the finite element mesh. It is possible that thick deep model layers representing the Joe Joe Formation and basement have led to overestimates of release of water from confined storage. It is also possible that a larger number of thinner layers in the Bandanna and Rewan Formations might lead to more robust calculations of pseudo-unsaturated flow above Kevin's Corner underground mine.

The current model is somewhat limited by FEFLOW's inability to allow recharge to the top of a pseudo unsaturated model.

8.0 REQUIREMENTS FOR ADDITIONAL WORK

Fundamentally, predictive modelling relies on three things:

- a defensible hydrogeological conceptual model;
- defensible estimates of hydraulic properties in all key hydrostratigraphic units, in this case including saturated and unsaturated properties in some units; and

- a defensible implementation of a numerical model, including representation of all important aspects of the conceptual model and ensuring water balance.

8.1 Additional Work and Revised Conceptual Groundwater Model

The conceptual model will be updated in light of ongoing work, which includes:

- Operation of a pilot borefield at Kevin's Corner and Alpha. Planning is underway for construction of pilot dewatering borefields (nominally 10 bores per site) to allow ongoing assessment of advance dewatering requirements, prior to commitment to a larger-scale borefield;
- Test drilling at the tailings storage facility (TSF), which will allow updated assessment of geology, groundwater occurrence, water levels, and recharge mechanisms in the area where the Colinlea Sandstone outcrops;
- Laboratory testing of core samples, where testing of low-permeability material (semi-confining layers) will be undertaken for vertical and hydraulic conductivity;
- Isotope sampling of groundwater samples, to test the age of groundwater in the eastern and western areas of the lease (as input to recharge studies); and,
- Review of ongoing work on mine subsidence and goafing (currently being undertaken by SCT).

8.2 Additional Modelling

The current model needs to be enhanced, before model predictions can be relied upon. A decision to use FEFLOW was made early in the project. It has become clear, however, that the modelling needs to be approached in a slightly different way, to achieve the required results.

The potential inflows to the Alpha and Kevin's Corner open cut mines and to the Kevin's Corner underground mine may be large, but it is also possible that they could be smaller than implied above.

The current FEFLOW model:

- uses time-varying (seepage face) boundary conditions and constraints to represent six stages of mining over the 31-year life of mining;
- uses constant hydraulic properties;
- uses "observation point groups" combining nodes in different spatial zones (polygons in plan) and slices to aggregate flows into four mines during the life of mining;
- does not report changes in storage in any layers or hydrostratigraphic units, or even globally, to allow a precise understanding of the source of groundwater reporting to any mine; and,

- includes water in material removed by mining in the overall water balance (ie the current volumes that are reported as inflow volumes include storage within material that is removed by the mining process). This is a limitation of the FEFLOW software and will need to be accounted for via external processing of results.

During this study, other features of FEFLOW were used, but the results are not reported here because of uncertainty as to whether or not FEFLOW was performing the calculations as implied in the mode setup. These features included:

- the use of so-called “T-Lists”, to change hydraulic properties in time, especially during and after open cut and underground mining; and
- the use of an external database linked to GIS “shape” (.shp) files (that define polygons in plan), as part of the process of changing hydraulic properties in time.

The interaction between time-varying properties, time-varying boundary conditions and reporting of time-varying fluxes is so complex that it is difficult to be confident that FEFLOW’s results are consistent with the conceptual model and ensure water balance.

Based on everything learned during development of this model, NTEC Environmental Technology has developed a number of unique capabilities that extend the capabilities of FEFLOW. FEFLOW allows extensions or “plug-ins” that are developed using a so called “interface manager”. FEFLOW is provided with a software development kit (SDK), giving access to nearly 700 functions that can be called before, during and after a FEFLOW run, allowing direct access to the memory (and data) being used by FEFLOW. NTEC Environmental Technology has been developing plug-ins for many years, and proposes to continue modelling in the following way:

- Rather than simulating 31 years in a single run, it is proposed to run FEFLOW in six separate runs, one for each of the six stages of mining. The final conditions at the end of each stage are exported to a file, ready for import as initial conditions in the following stage. This kind of approach is not unusual. It is familiar to modellers who use FEFLOW, MODFLOW of any other modelling software. The process can be fully automated using plug-ins and “batch” (.bat) files under the Microsoft DOS operating system.
- Boundary conditions and constraints are defined in each run as constant boundary conditions. This is much simpler to set up and check.
- Rather than using T-Lists to define time varying hydraulic properties, a lookup table approach will be used. Although FEFLOW 6 includes a built-in lookup table facility under its new graphical interface, NTEC Environmental Technology has developed a plug-in that reads all necessary hydraulic properties (in this case horizontal and vertical hydraulic conductivities, specific storativity and porosity) from an external text file, based on an integer index stored initially in the Kx field (hydraulic conductivity in the x-direction). The lookup table can include different properties at different time, e.g. within backfill in an open pit, or within and above the goaf.
- Fluxes out of seepage face nodes can be exported from FEFLOW using observation point groups defined in the graphical interface, or alternatively using a plug-in that uses shape files and slices to identify all nodes where fluxes need to be aggregated. Plots of

cumulative inflows to mines can be produced automatically at the end of any set of (six) runs.

- Hydrographs of heads at desired locations can be exported from FEFLOW using observation points defined in the graphical interface, or alternatively using a plug-in that uses observation point locations to identify nodes where heads need to be exported. Plots of heads can be produced automatically at the end of any set of runs.
- The change in storage in any layer and globally can be exported after every time step, both the change in specific storage (due to compressibility) and the change in storage near the water table (due to movement of the water table in a saturated model or due to changes in saturation in an unsaturated or pseudo-unsaturated model). This can be done using a plug-in, and plots of changes in storage can be produced automatically at the end of any set of runs.
- FEFLOW's limitation on the application of recharge to an unsaturated or pseudo-saturated model can be overcome, using the approach taken by MODFLOW-SURFACT. A plug-in can be used to identify in each time step the highest node below the water table (i.e. the highest node with positive pressure) in any column of nodes, and to apply recharge to that node. This will allow the effects of recharge to be assessed, during as well as after mining.

With the degree of automation implied above, it will be relatively easy to assess the impacts of:

- removing or reducing the thickness of the basement layer;
- reducing the thickness of the Joe Joe Formation;
- representing the Joe Joe Formation by a larger number of model layers, to account for delayed yield (very slow upward flow) from the Joe Joe Formation towards the mines, possibly until long after the end of mining; and
- representing the Bandanna and Rewan Formations by a larger number of model layers, to improve the representation of vertical flow in or below the pseudo-unsaturated zone and of delayed yield (slow release) from layers above the goaf in the Kevin's Corner underground mine.

It will also be easy to assess the impact of revised estimates of hydraulic properties.

9.0 CONCLUSIONS

NTEC Environmental Technology has developed a numerical groundwater model designed to predict the potential cumulative impacts of the Alpha and the Kevin's Corner Coal Projects.

Predictions have been made of inflows to mines and of regional drawdown during mining, but a number of hydrogeological properties are uncertain, especially relating to the storage properties and hydraulic conductivities of sedimentary units above and below the D Seam. Additional tests in the field and laboratory are required before modelling can be completed.

The model results presented in this report are preliminary results, and further modelling may improve the quality of the model and decrease uncertainty of the results.

According to the current model, cumulative inflow into the Alpha pit will be between 658 and 1150 GL over the 31 years of mining activity. Cumulative inflow into the Kevin's Corner underground mine is predicted to be in the range of 4844 to 7150 GL, with additional inflows into the Northern and Southern open pits at Kevin's Corner of 60 to 123 GL and 169 to 348 GL, respectively.

These estimates do not explicitly take into account the effect of rock deformation above Kevin's Corner on inflow rates.

The cone of depression caused by the operations will extend to a radius of ~10 km around the mines. In the northwest corner of the mining leases, near Kevin's Corner, the outcropping of the Rewan Formation limits the extent of the cone of depression to between 1.5 and 6 km.

Depressurisation is also predicted in the Joe Joe Formation beneath the mines, and this contributes to the inflow of groundwater into the mines.

No significant impact on the GAB can be observed after 31 years of mining operations. The Rewan Formation acts as an effective hydraulic barrier, limiting the propagation of the cone of depression towards the GAB.

This assessment is preliminary, and will be revised when the regional model is finalised, taking into account long-term recharge to the water table and revised estimates of hydraulic properties.

10.0 REFERENCES

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

Audibert, M. (1976). Progress Report of the Great Artesian Basin Hydrogeological Study 1972 - 1974. Record 1976/5, Bureau of Mineral Resources, Geology and Geophysics, Canberra.

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

Habermehl, M.A. (2001) Wire-line Logged Waterbores in the Great Artesian Basin. Digital Data of Logs and Waterbore Data Acquired by AGSO. Bureau or Rural Sciences Australia.

Jericho 1:250,000 Geological Map, Sheet SF55-14. Bureau of Mineral Resources, Geology and Geophysics, Canberra, ACT. First Edition 1972.

Kellett, J.R., Ransley, T.R., Coram, J., Jaycock, J., Barclay, D.F., McMahon, G.A., Foster, L.M. & Hillier, J.R. (2003). Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland. Water Sciences Program, Bureau of Rural Sciences Canberra, ACT and Water Assessment Group, Natural Resource Sciences, Department of Natural Resources and Mines, Brisbane Qld.

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

MineOp Consulting Pty Ltd (2011), Drawing 1058 Rev A.

Parsons Brinckerhoff (2010), Alpha Coal Project, Site water management system and water balance technical report, prepared for Hancock Coal Pty Ltd, August.

Salva Resources (2010) Summary of Galilee Regional Model (GAB). Internal Project Memorandum from Salva Resources to Hancock Coal Pty Ltd, February 2010.

APPENDIX A

MODEL FIGURES

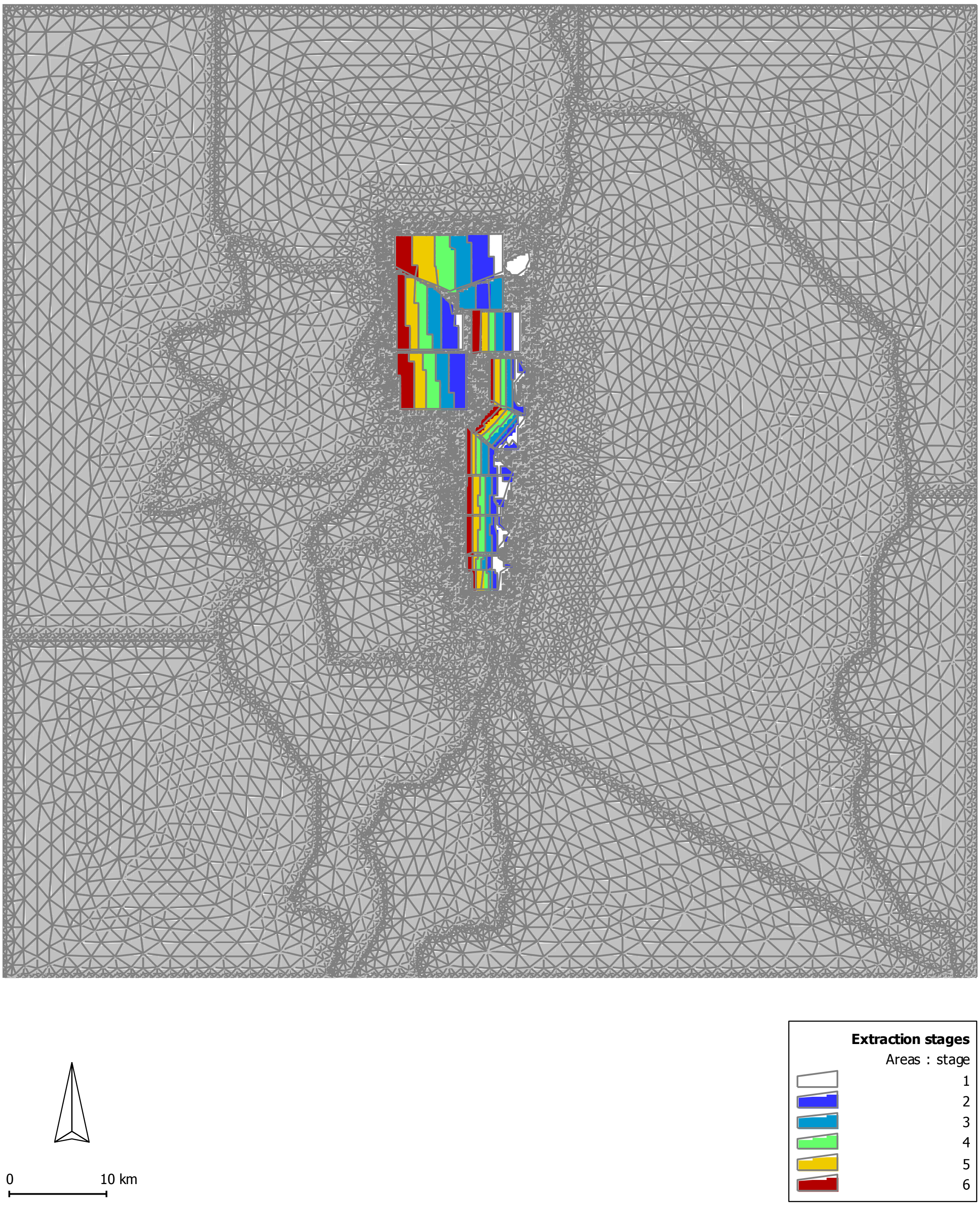


Figure A 1: Finite Element Mesh and Mining Stages

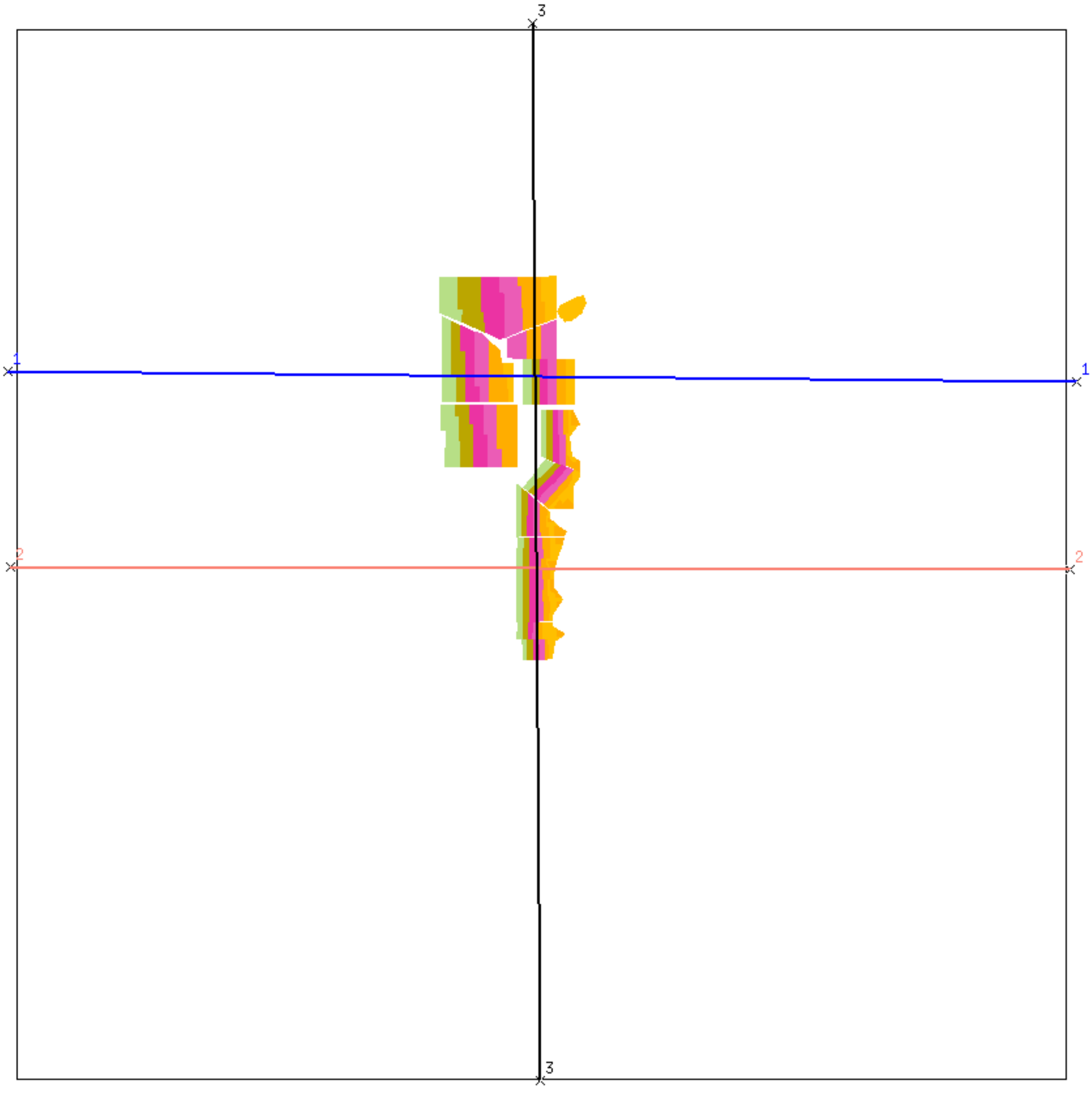


Figure A 2: Cross-Sections

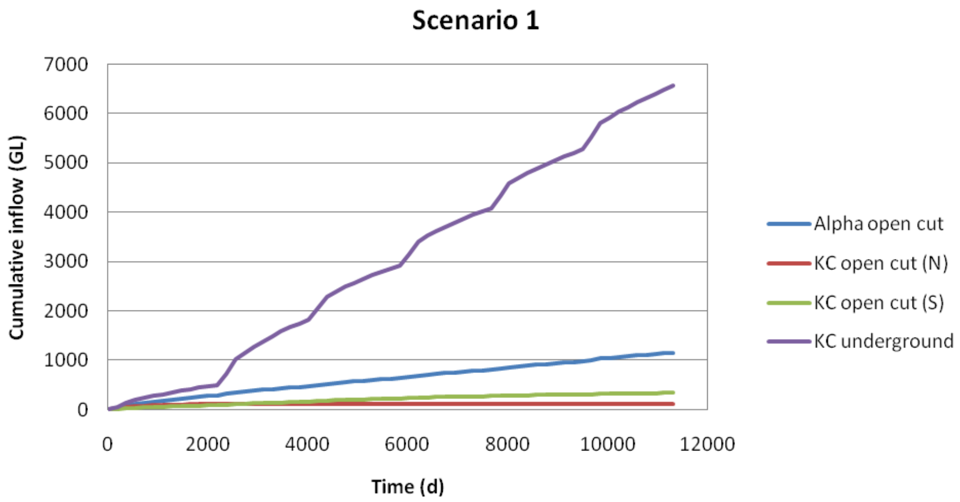


Figure A 3: Cumulative Inflow Volumes – Scenario 1

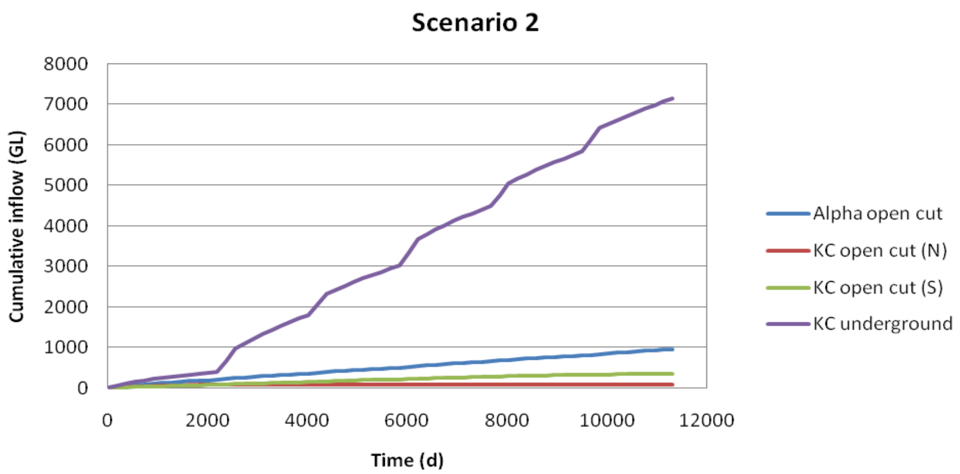


Figure A 4: Cumulative Inflow Volumes – Scenario 2

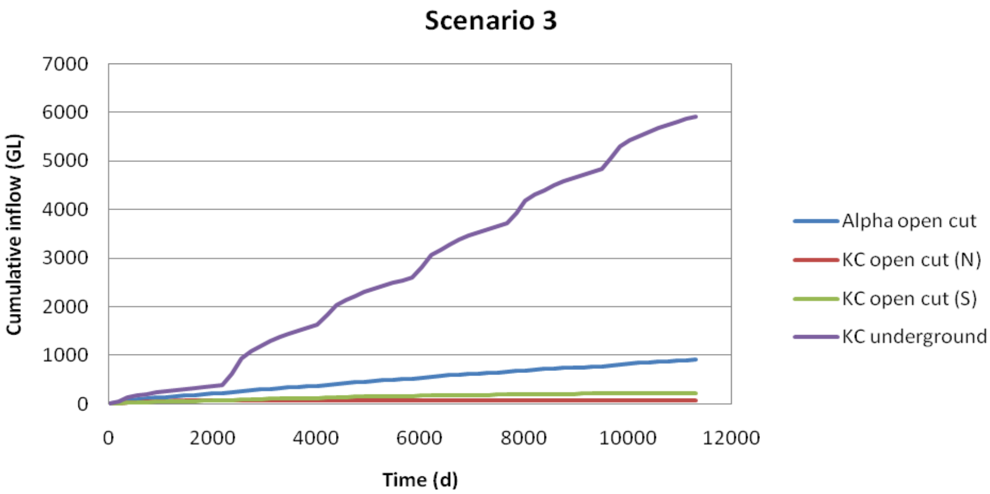


Figure A 5: Cumulative Inflow Volumes – Scenario 3

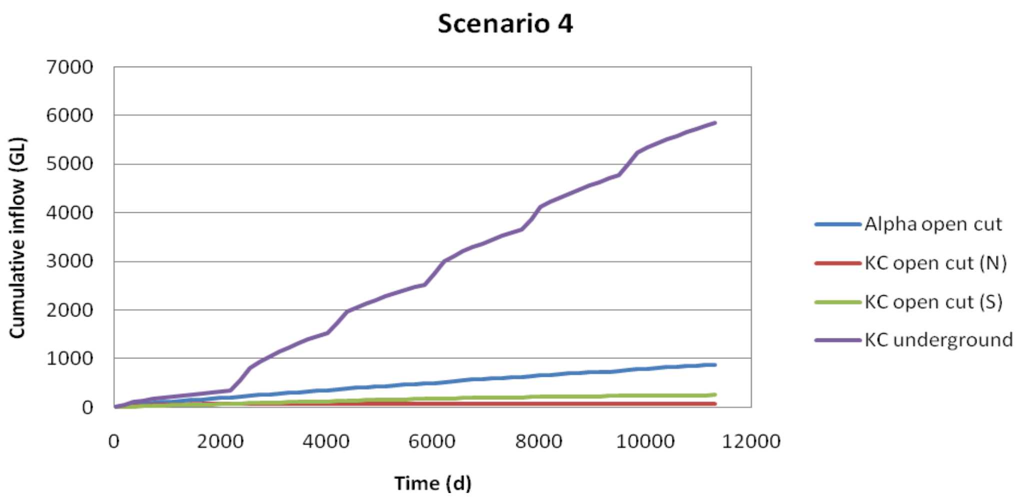


Figure A 6: Cumulative Inflow Volumes – Scenario 4

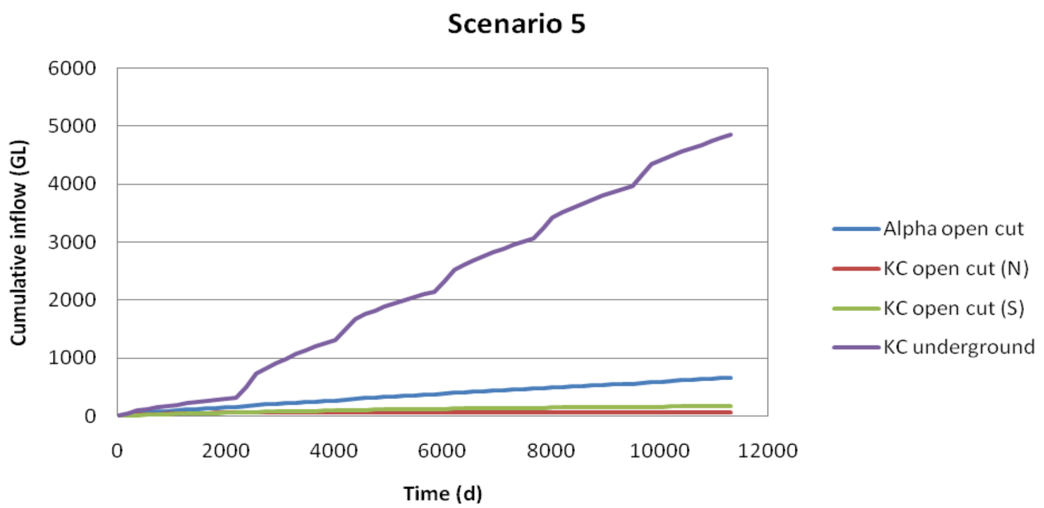


Figure A 7: Cumulative Inflow Volumes – Scenario 5

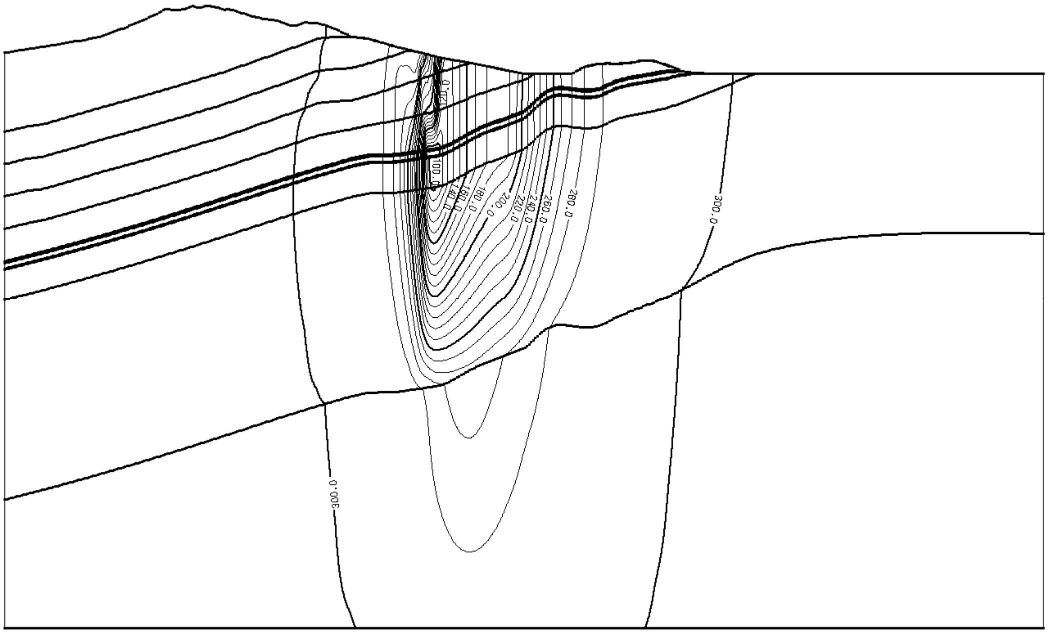


Figure A 8: Cross-Section 1 – Hydraulic Heads at 31 Years – Scenario 1

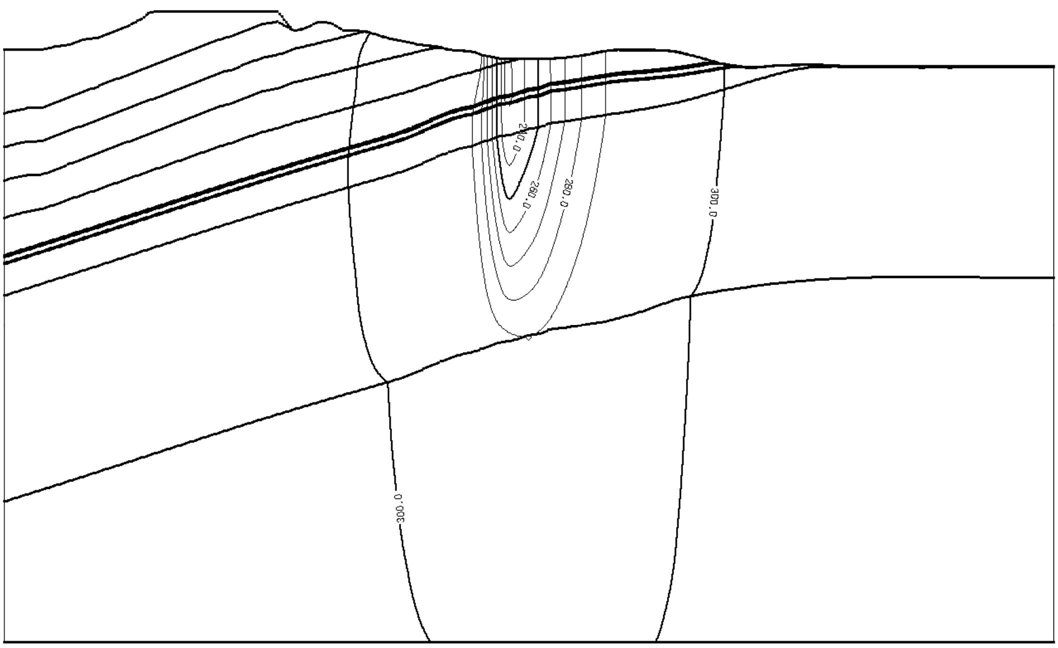


Figure A 9: Cross-Section 2 – Hydraulic Heads at 31 Years – Scenario 1

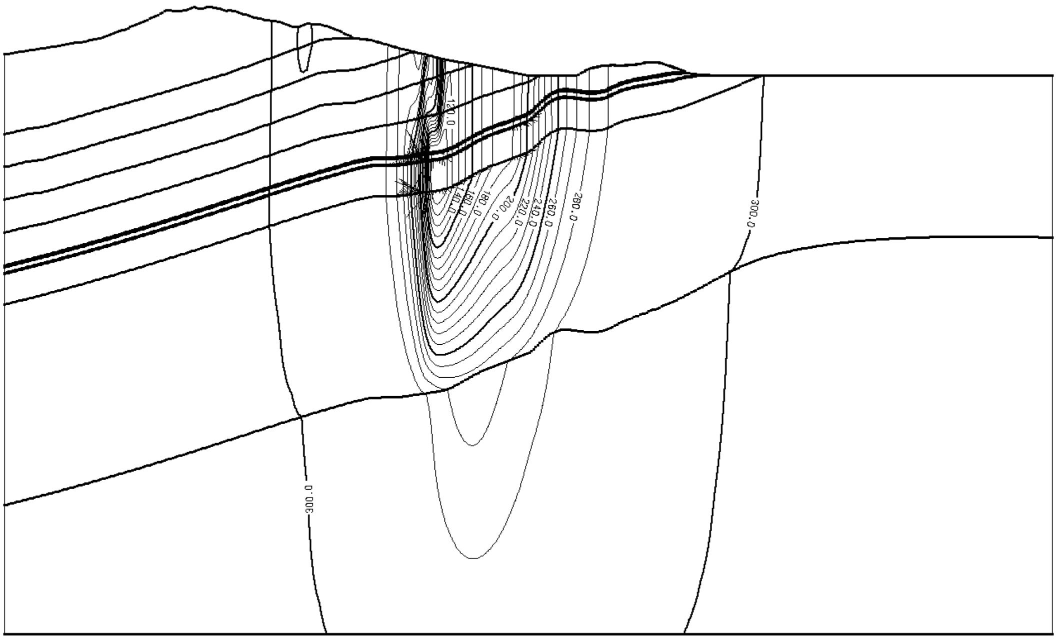


Figure A 10: Cross-Section 3 – Hydraulic Heads at 31 Years – Scenario 1

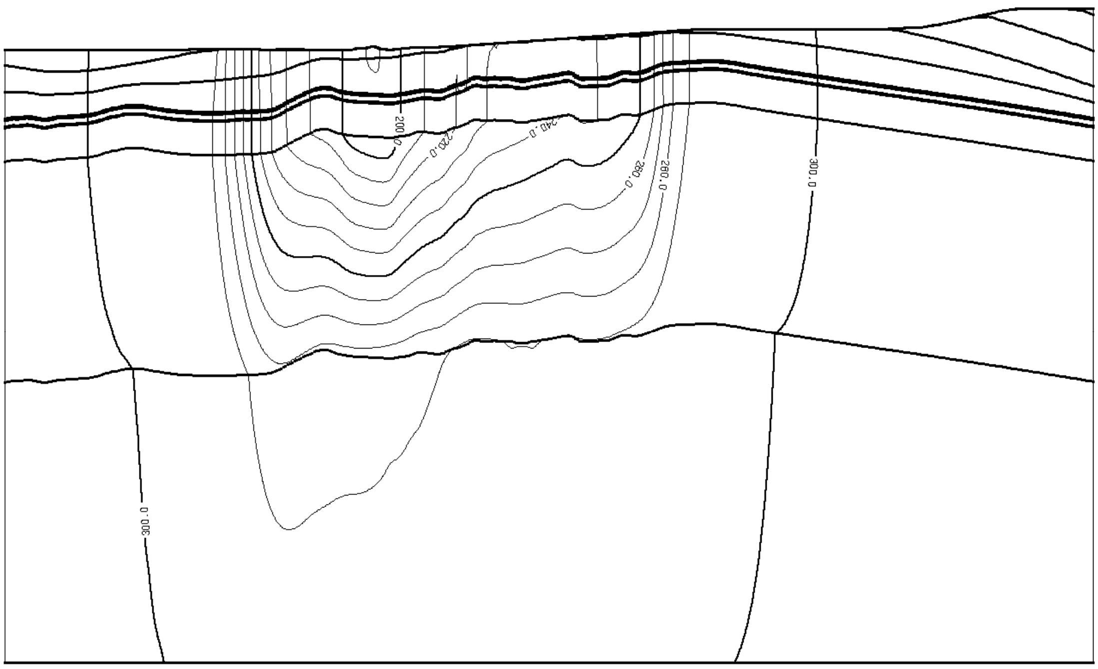


Figure A 11: Cross-Section 1 – Hydraulic Heads at 31 Years – Scenario 4

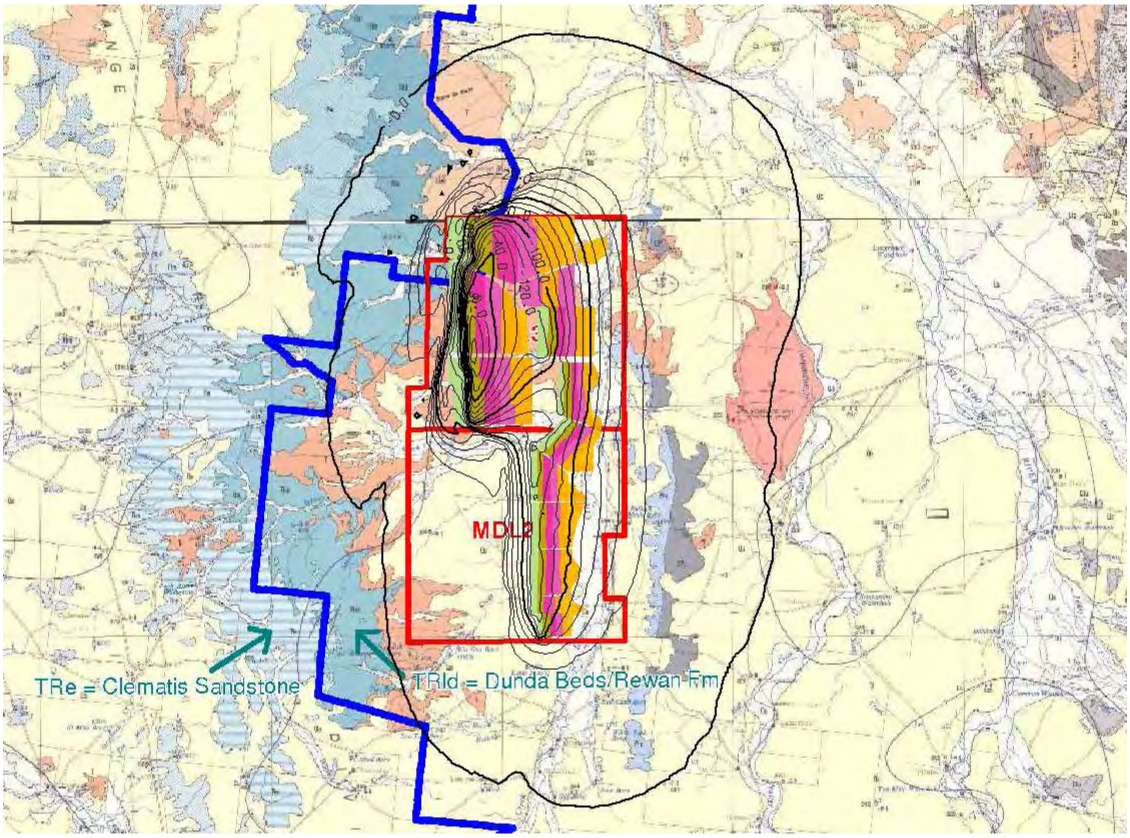


Figure A 12: Simulated Drawdown at the Water Table at 31 Years – Slice 1 – Scenario 1

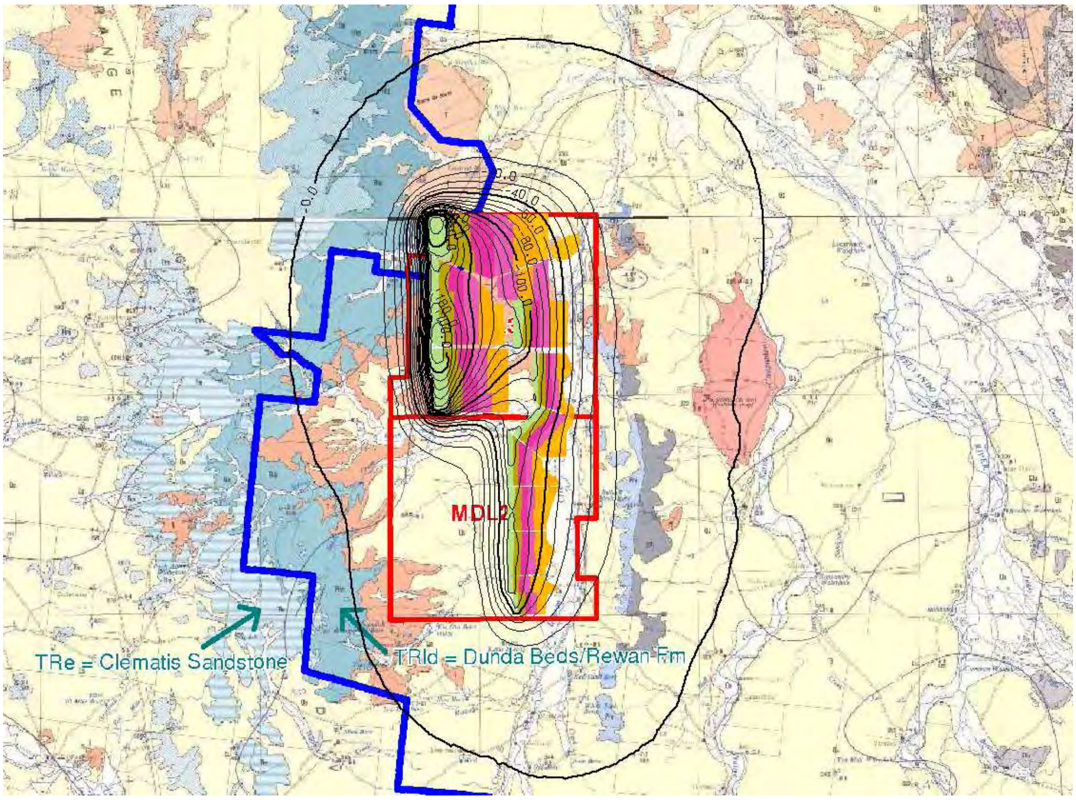


Figure A 13: Simulated Drawdown in Bandanna Formation at 31 Years – Slice 6 – Scenario 1

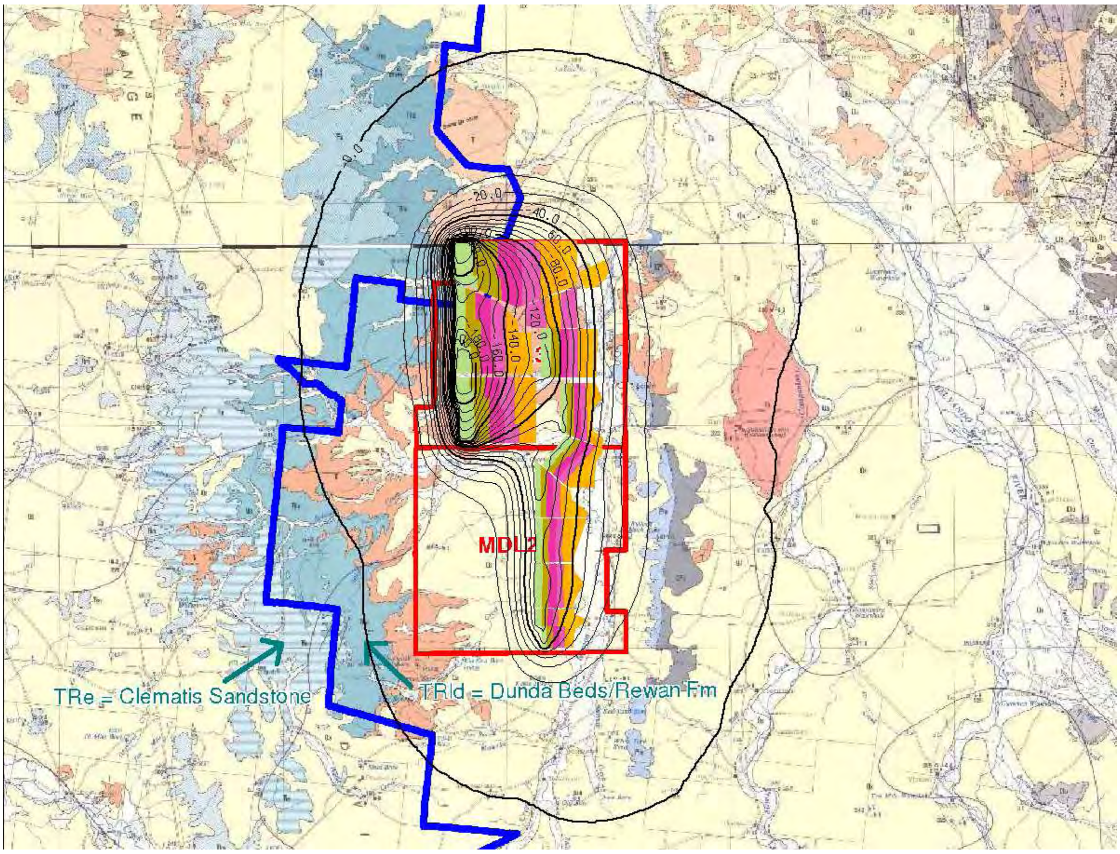


Figure A 14: Simulated Drawdown in D-E Sands at 31 Years – Slice 8 – Scenario 1

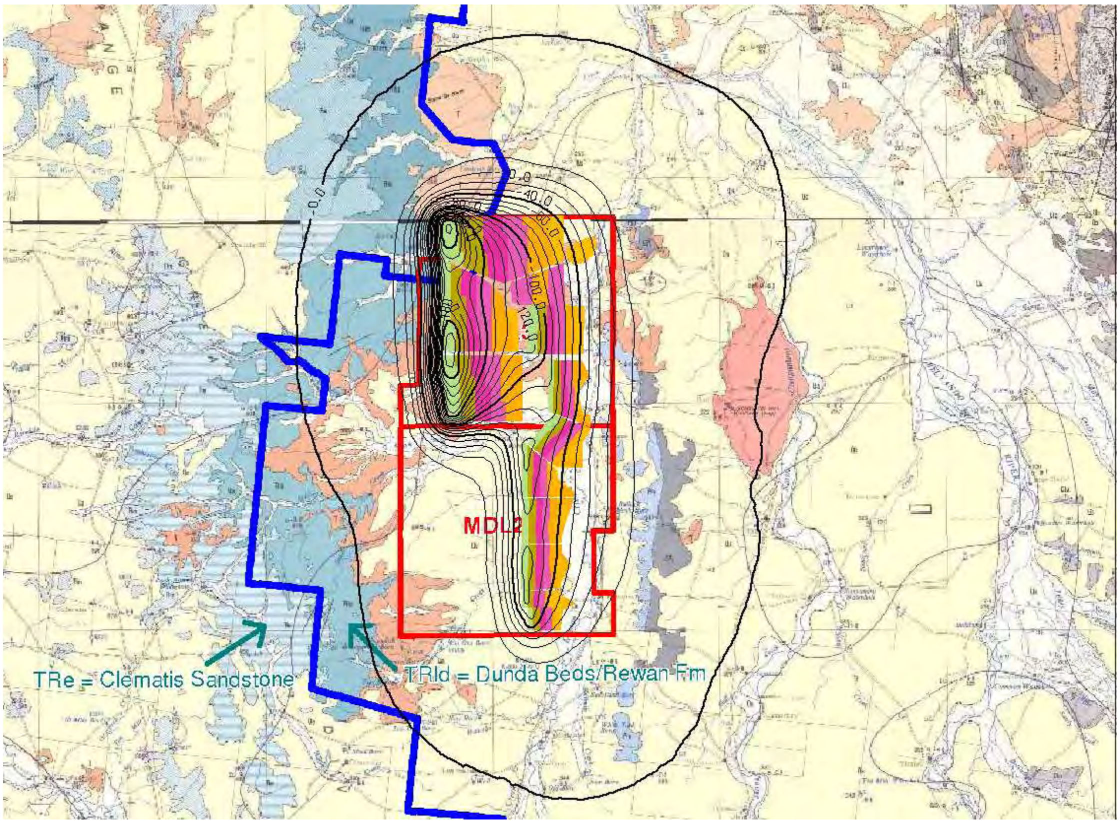


Figure A 15: Simulated Drawdown in Sub E Sands at 31 Years – Slice 10 – Scenario 1

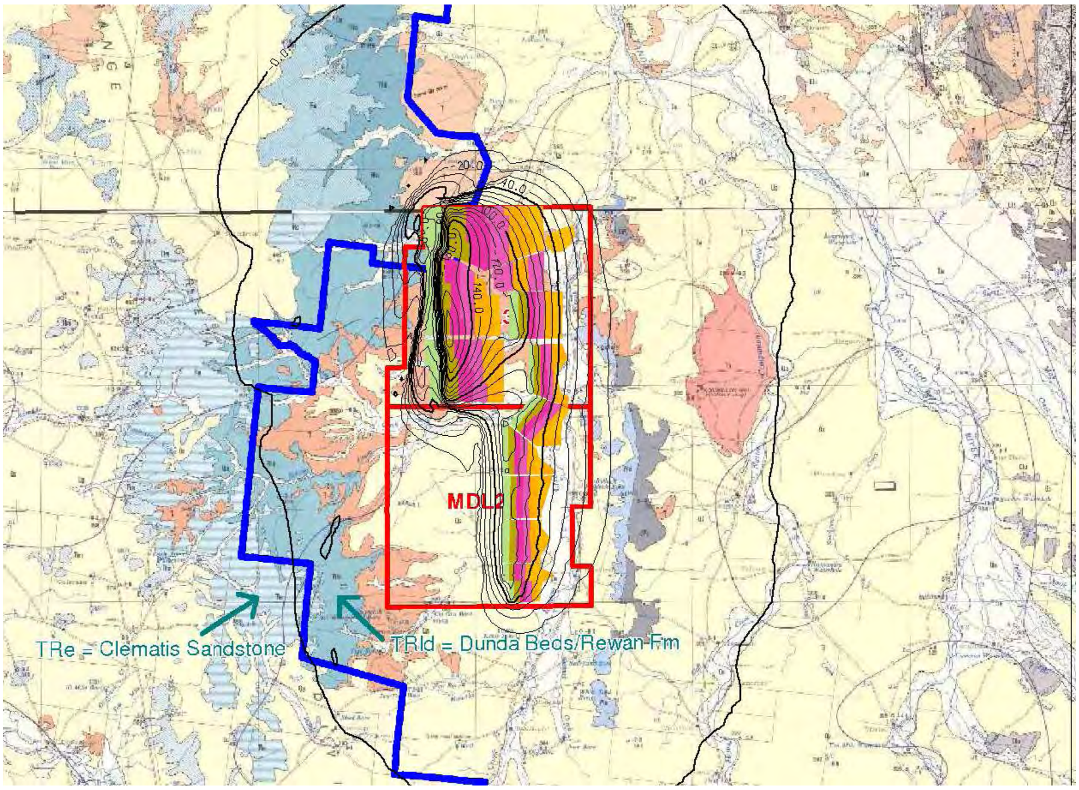


Figure A 16: Simulated Drawdown of Water Table at 31 Years – Slice 1 – Scenario 4

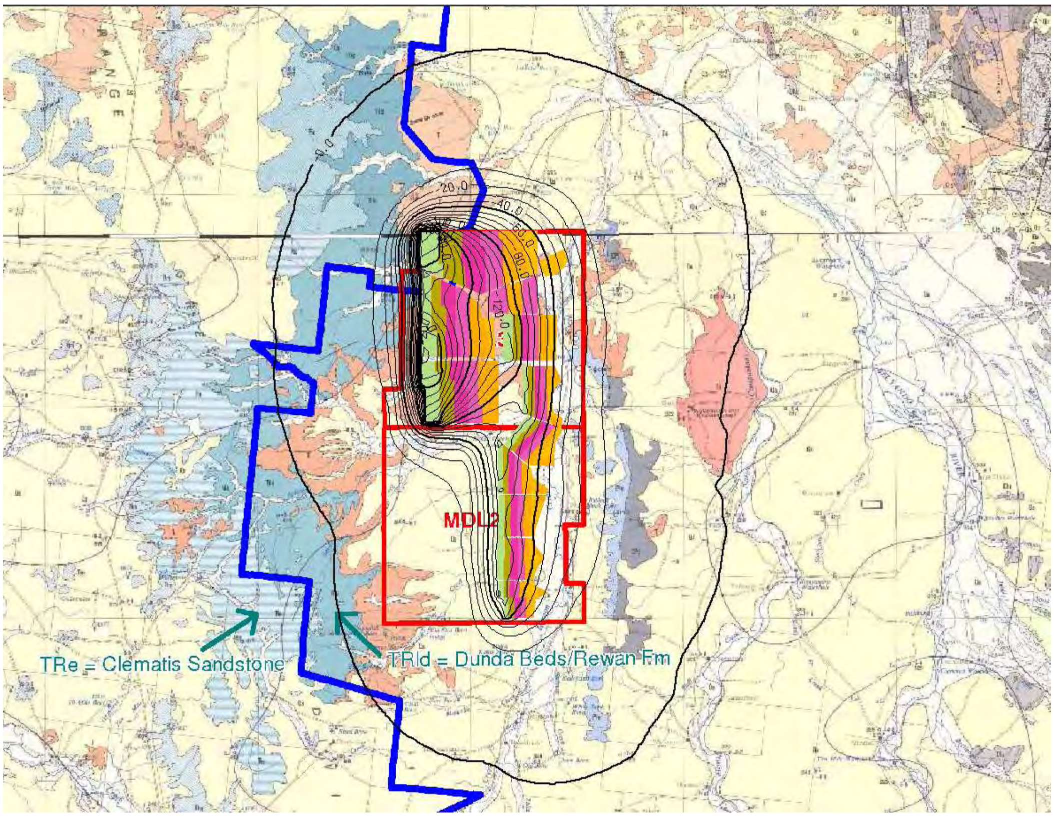


Figure A 17: Simulated Drawdown in Bandanna Formation at 31 Years – Slice 6 – Scenario 3

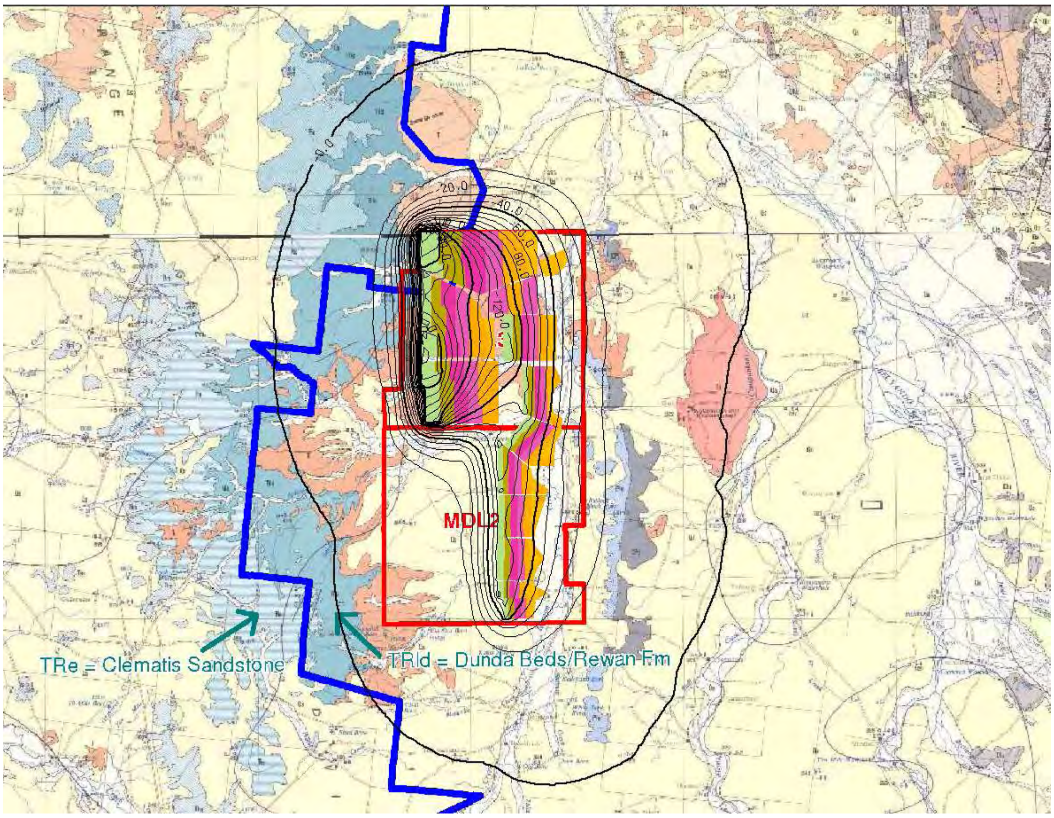


Figure A 18: Simulated Drawdown in Bandanna Formation at 31 Years – Slice 8 – Scenario 3

APPENDIX B

SALVA GEOLOGICAL MODEL REPORT

Memorandum

To: Martti Kankkunen, Ross Marples

From: Andrew McLaughlin

Re: Summary of Galilee Regional Model (GAB)

Date: 18 February 2009

Following is a summary of the construction of a Galilee Basin regional model for the Alpha project. A request was made by HPPL to Salva to generate a regional or basin wide 3D geological model of the eastern Galilee Basin for project assessment purposes. In particular, study of the Great Artesian Basin (GAB) formations and their location with respect the planned Alpha/Kevin's Corner mining areas was of special interest.

Drilling/Exploration Data

Salva used the existing Alpha/KC borehole dataset (HPPL, Hancock and Wright, Bridge Oil and Wendouree Dampier BHP borehole data) starting point for the project. Surrounding information was sourced from public domain data. Sources include Queensland Department of Mines and Energy exploration records (QDEX), public domain company reporting and Stock Exchange announcements. Data sourced included:

- Exploration Drilling (eg Shell Degulla)
- Regional Stratigraphic drilling (eg NS Galilee Government Drilling)
- Oil and gas drilling
- Deep seismic surveys (oil and gas)

A total of 1201 boreholes are present in the GAB model database. It is noted that down-dip and strike spread of data is important to give the broad trend in the GAB formations rather than high density style drilling more commonly practiced in coal resource drilling.

In summary, the GAB database contains:

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

The petroleum/oil and gas holes key summary data is shown in Table 1, below.

Table 1. GAB Model Oil and Gas well summary data

Well	Qdex Report ID	Drilled by	Date	Easting (GDA 94 Zone 55)	Northing (GDA 94 Zone 55)	TD (m)
Allandale 1	CR3373	Beaver-Pexa	06/01/71	388898.9	7299202.183	3004.1
Alice River 1	CR1124	Longreach Oil	01/04/63	328805.7	7387133.21	1631.2
Bellara 1	CR11433	Leighton	10/08/82	322349.5	7438465	1387
Brookwood 1	CR995	Exoil	03/11/62	225670.8	7511554.7	1464.8
Carmichael 1	CR29695A	Maple Oil Ex	23/06/95	400358.6	7571702.89	2855.3
Coreena 1	CR3123	Beaver&Pexa	07/05/70	335345	7420894.87	1587.3
Fairlea 1	CR2576	Aus Sun	23/06/68	330809.2	7297084.321	3147.06
Fleetwood 1	CR28503	Enron	25/07/93	381552.4	7554874.74	1236.8
Foxhall 1	CR12779	Esso	29/01/82	325237.6	7389182.89	1280
Hexham 1	CR5423	Qld Dpt Mines	6/08/1974	392465.2	7477562.267	1830
Jericho 1 (AOD)	CR1831	Alliance	26/06/65	406739.5	7370892.85	2786.4
Koburra 1	CR3275	Flinders	18/07/70	323940.2	7644241.41	3259.2
Lake Galilee 1	CR1537	Exoil & Transoil	27/11/64	394509.4	7545680.26	3406.14
Maranda 1	CR1063	Oil Dev NL	15/01/62	340923.8	7433229.9	1978.4
Mogga 1	CR13721	Canso	04/11/84	384674.2	7651054.98	3620
Muttaburra 1	CR3042	Pursuit	12/12/69	246173.5	7477497.32	1448.71
Splitters Creek 1	CR28226A	Enron Energy	10/10/94	349302	7458186.561	1004
Thunderbolt 1	CR2179	Amerada Petroleum	25/11/67	294350.1	7525331.47	1611.1

SALVA RESOURCES

Topography Data

Detailed satellite Digital Elevation Model (DEM) covering the HPPL, as used in the existing resource models, was copied into the GAB model. Public domain topographic vector data was sourced from Geoscience Australia in Esri GIS data format. The Galilee and Jericho 1:250,000 toposheet vector feature data was also downloaded to provide base cadastral/feature data for the expanded model. Topographic elevation (contours and spot height) data was combined onto common 3D DXF format and transferred to the model. Topography is modelled as a triangulated surface.

Model Stratigraphy

Table 2 shows the stratigraphy used in modelling. Regional reporting and groundwater/GAB formation was queried to determine 1) significant formations that could be recognised in deep oil well data and 2) formations of importance to the GAB and possible recharge formations (eg DERM listings). It is acknowledged that some units have name changes in various regions but a single nomenclature has been deployed for modelling purposes.

Table 2. GAB/Regional Modelled Stratigraphy

Age	Basin	Modelled Formation	Typical Thickness (m)	Comments
Cretaceous	Eromanga	Roma	120	
		Hooray	25	
		Adori Sandstone	10	Westbourne Shale above
Jurassic	Sub Eroganga - Surat equivalent	Hutton Sandstone	105	Birkhead Shale above
		Moolayember	260	
		Clematis Sandstone	140	
Triassic	Galilee	Rewan Formation	175	
Permian		Bandanna Fm Equivalent	75	A & B seams
		Colinlea Sandstone	120	C- F seams

SALVA RESOURCES

Database

The existing Permian data from the resource models was carried over into the GAB model. Reports, logs, geophysical traces, drilling records and core photography were used to identify the Formation and coal seams in the newly acquired data. The upper Formation's extents (Rewan and higher) once identified in the logs were recorded in the database. Formation boundaries were routinely identified in petroleum wells as the varying Formations have significant impact on hydrocarbon generation and storage potential making this process fairly straight forward. It is noted that the Permian Galilee sediments show persistence and consistency across the eastern margin of the basin with seam profiles, thickness and banding being recognised down dip to over 1000m of cover.

Figure 1 shows a typical oil well combination log over the Permian as used to build the database intersection points. Figure 2 shows the Formation intersection summary from Thunderbolt 1, this information is used to generate downhole intersections for the database.

Model

A Minescape 3D geological model was constructed using the newly compiled database. The model has key parameters shown below in Table 3.

Table 3. GAB/Regional Model Summary

Attribute	Value
Schema	Supermodel_1109
Topography model	Super_tri
Topo model method	triangulation
Geology model cell size (m)	500x500
Interpolator - thickness	FEM, power 0, radius freed
Interpolator - surface	FEM, power 1, radius freed
Parting modelled	No
Conformable sequences	OX, TRIA, PERM
Upper limit for seams	TRIA
Control points	Nil
Penetration file	Yes
SE Grid Origin	504185E, 7342201N
Extents ex-Origin	230km North, 320km West
Modelling method	Compound

Figure 1. Oil Well Splitters Creek 1 Combination Log
750m to TD 1004m, Permian interval (Source: Report CR28226)

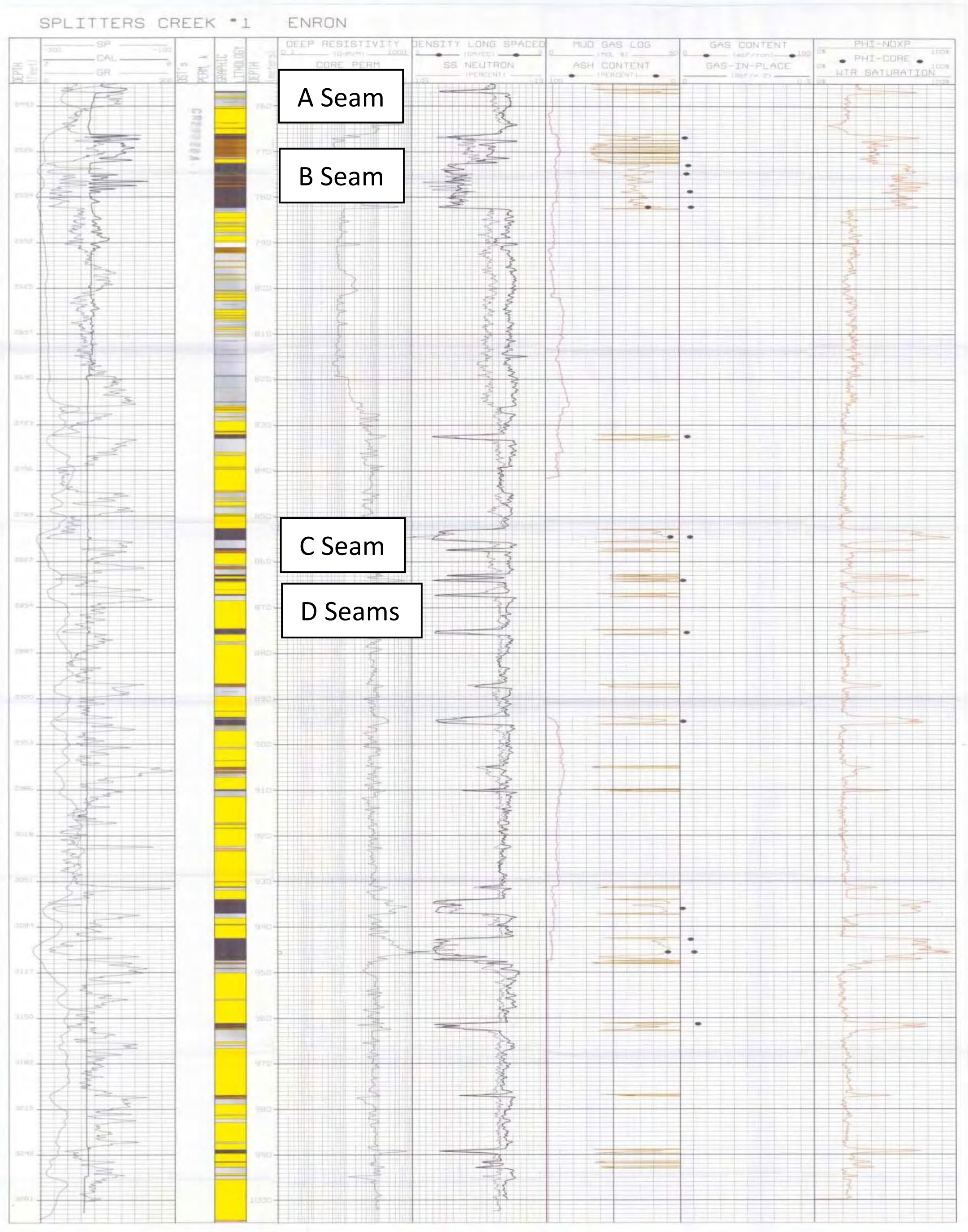


Figure 2. Stratigraphic Summary showing GAB formations from Oil Well Amerada Thunderbolt 1 (Source: report CR2179)

AMERADA THUNDERBOLT No. 1
STRATIGRAPHIC CHART

AGE	FORMATION	DEPTH	THICKNESS	NET POROSITY	RESERVOIR CHARACTERISTICS
LOWER CRETACEOUS	TOOLEBUC	38'	80'	0'	NIL
	ROMA	118'	679'	0'	NIL
LOWER CRETACEOUS UPPER JURASSIC	HOORAY	797'	41'	UNKNOWN	GOOD
MIDDLE JURASSIC	WESTBOURNE SHALE	838'	134'	UNKNOWN	POOR
	ADORI SANDSTONE	972'	51'	51'	GOOD
	BIRKHEAD SHALE	1023'	105'	47'	FAIR
LOWER JURASSIC	HUTTON SANDSTONE	1128'	149'	110'	GOOD
MIDDLE - UPPER TRIASSIC	MOOLAYEMBER	1277'	615'	125'	FAIR
LOWER - MIDDLE TRIASSIC	CLEMATIS	1892'	428'	220'	FAIR - GOOD
LOWER TRIASSIC	REWAN	2320'	572'	187'	FAIR
UPPER PERMIAN	—	2892'	552'	203'	FAIR - GOOD
LOWER PERMIAN UPPER CARBONIFEROUS	—	3444'	1830'	643'	FAIR - GOOD
PRE-UPPER CARBONIFEROUS BASEMENT	UNNAMED	5274'	12'+		NIL

The data was been gridded onto the mesh using the Minescape 4.116 FEM interpolator. Due to the very large geographical coverage and arrangement of data, the system has been allowed to model with a large degree of freedom. This has resulted in a broadly trending 'regional' scale model. The GAB model is intended for use on the regional basis; high precision work must be carried out on the Alpha and KC resource models. Figures following provide examples of output from the model. Grid mesh dumps of topo, formations and seams have been provided to the nominated hydrological consultant.

Specific comment on hydrogeological impact of project operations on the GAB will be left to the relevant experts. The model shows the Rewan Group subcrop and outcrop within MDL285-MDL333 (also current MLA areas) and the Clematis Sandstone subcrops within 8km of the western boundary of the HPPL tenures. The presence of Rewan Group sediments in the west of the HPPL tenure is well recorded in coal exploration data, historic and recent. Shallow westerly dips expose the sedimentary sequence in a continuous succession with the upper Eromanga Basin Formations (Adori Sandstone and higher) occur approximately 52km west of the HPPL tenure (Figure 3).

SALVA RESOURCES

Figure 3. Formation and Subcrop plan GAB model

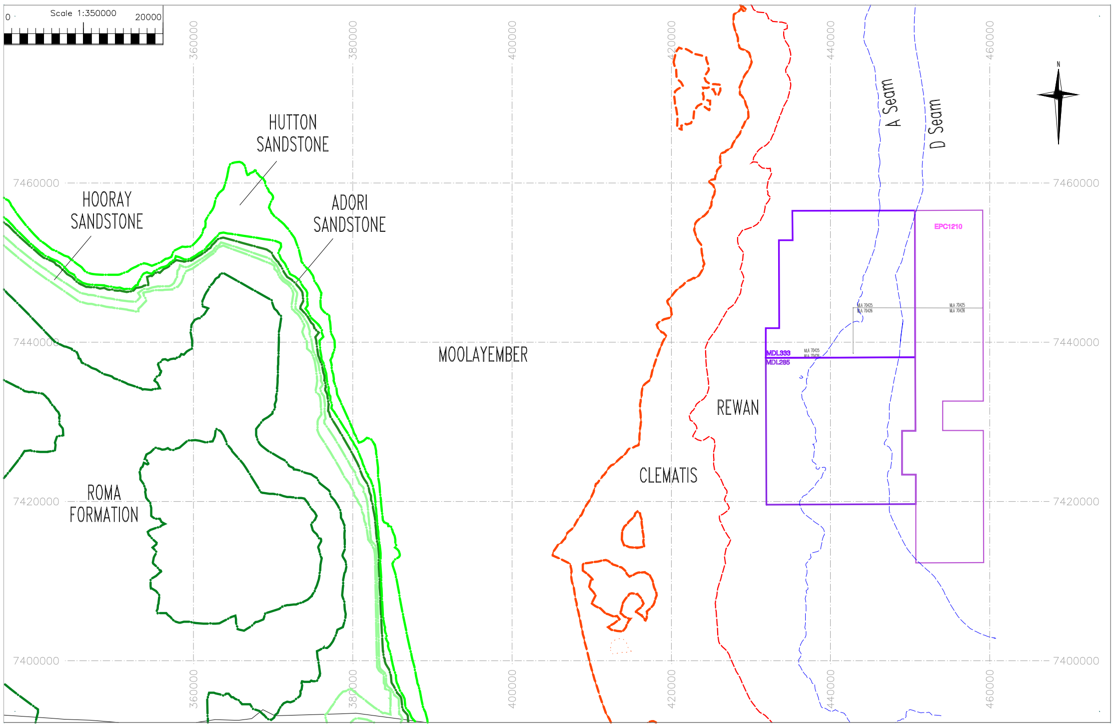
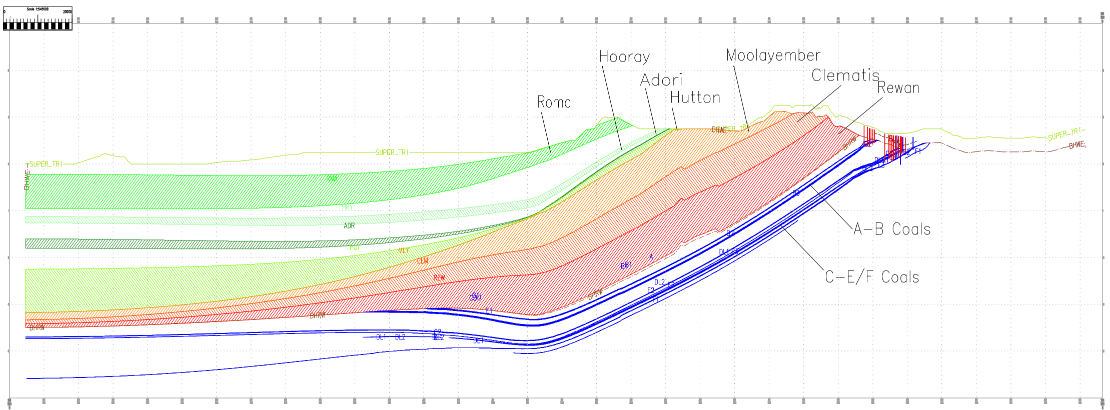


Figure 4. East-West cross section through MDL285



Pictorial, vertical exaggeration V/H=>30:1

APPENDIX C

MONITORING BORE CONSTRUCTION DETAILS

Appendix C - Groundwater Monitoring Bore Details

Hole ID	Monitoring Bore ID	Easting_GDA94	Northing_GDA94	Surface RL (mAHD)	Piezo No.	VWP Serial No.	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Raingauge Installed
Vibrating Wire Piezometer Bores										
1252D	AVP-01	446725.181	7441096.55	307.89	VW2	8972	55	C-D Sandstone	Yes	Yes
1252D	AVP-01	446725.181	7441096.55	307.89	VW1	11791	77	D-E Sandstone	Yes	Yes
1262D	AVP-03	447700.515	7435935.65	303.12	VW1	8974	42.5	D-E Sandstone	Yes	
1347DG	AVP-04	439677.103	7431710.26	333.08	VW3	11792	80	B-C Sandstone	Yes	
1347DG	AVP-04	439677.103	7431710.26	333.08	VW2	11763	132	C-D Sandstone	Yes	
1347DG	AVP-04	439677.103	7431710.26	333.08	VW1	11764	143	D-E Sandstone	Yes	
1315D	AVP_05	445052.296	7433185.69	312	VW3	8970	49	CU Coal Seam		
1315D	AVP_05	445052.296	7433185.69	312	VW2	11776	65	C-D Sandstone		
1315D	AVP_05	445052.296	7433185.69	312	VW1	11793	80	D-E Sandstone		
1336D	AVP_06	446510.39	7431957.19	313	VW2	8967	48.5	C-D Sandstone		
1336D	AVP_06	446510.39	7431957.19	313	VW1	11794	70	D-E Sandstone		
1337DG	AVP-07	445862.01	7430684.68	309	VW2	8968	63.5	C-D Sandstone	Yes	
1337DG	AVP-07	445862.01	7430684.68	309	VW1	11795	79	D-E Sandstone	Yes	
1327D	AVP-08	446280.871	7430685.25	308	VW2	8975	57.5	DU Coal Seam	Yes	
1327D	AVP-08	446280.871	7430685.25	308	VW1	8625	67	D-E Sandstone	Yes	
1338DG	AVP_09	445607.245	7428456.96	316	VW2	8619	61	C-D Sandstone		
1338DG	AVP_09	445607.245	7428456.96	316	VW1	9121	73	D-E Sandstone		
1339DG	AVP-10	445920.65	7422776.91	321	VW2	8980	61	Base DLM Seam	Yes	
1339DG	AVP-10	445920.65	7422776.91	321	VW1	8622	84	D-E Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW4	11798	122	A-B Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW3	11704	165	B-C Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW2	11708	205	C-D Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW1	11771	218	D-E Sandstone	Yes	
1328DG	AVP-13	434456.875	7430044.11	363	VW4	11778	70	Sandstone above A1	Yes	Yes
1328DG	AVP-13	434456.875	7430044.11	363	VW3	11797	112	A-B Sandstone	Yes	Yes
1328DG	AVP-13	434456.875	7430044.11	363	VW2	11768	182	B-C Sandstone	Yes	Yes
1328DG	AVP-13	434456.875	7430044.11	363	VW1	11769	229.3	D-E Sandstone	Yes	Yes
1357D	AVP-14	438634.272	7436473.393	330.95	VW4	11777	58.5	B-C Sandstone		
1357D	AVP-14	438634.272	7436473.393	330.95	VW3	11796	108.5	B-C Sandstone		
1357D	AVP-14	438634.272	7436473.393	330.95	VW2	11765	134.5	C-D Sandstone		
1357D	AVP-14	438634.272	7436473.393	330.95	VW1	11766	149.5	D-E Sandstone		
1313C		447231.603	7453127.691	289.5	VW2	8976	45	C-D Sandstone		
1313C		447231.603	7453127.691	289.5	VW1	8977	70	D-E Sandstone		
1234C		445701.569	7447597.086	298.6	VW3	8978	45	B-C Sandstone		
1234C		445701.569	7447597.086	298.6	VW2	8621	67	C-D Sandstone		
1234C		445701.569	7447597.086	298.6	VW1	8624	98	D-E Sandstone		
1228C		445706.344	7444680.977	299.25	VW3	11727	33	B-C Sandstone		
1228C		445706.344	7444680.977	299.25	VW2	11780	64	C-D Sandstone		
1228C		445706.344	7444680.977	299.25	VW1	11799	83	D-E Sandstone		
1356R		440159.924	7454609.765	315.05	VW4	11733	71	Tertiary above A1		
1356R		440159.924	7454609.765	315.05	VW3	11709	150	B-C Sandstone		
1356R		440159.924	7454609.765	315.05	VW2	11710	180	C-D Sandstone		
1356R		440159.924	7454609.765	315.05	VW1	11711	210	E-F Sandstone		
1238C		445178.959	7449763.639	307.15	VW3	11728	40	B-C Sandstone		
1238C		445178.959	7449763.639	307.15	VW2	11781	80	C-D Sandstone		
1238C		445178.959	7449763.639	307.15	VW1	11800	105.5	D-E Sandstone		
Standpipe Monitoring Bores										
AMB-01	AMB-01	446180	7430035					D-E Sandstone		
AMB-02	AMB-02	446314	7427417					E-F Sandstone		
AMB-03	AMB-03	439653	7431658					D-E Sandstone		
AMB-04	AMB-04	447682	7427212					C-D Sandstone		

APPENDIX D

SUMMARY OF PUMPING DATA FROM THE ALPHA TEST PIT

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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APPENDICES

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:
    - o the upper part of the holes, where surficial deposits and lateritic claystones are encountered, tend to drill dry;
    - o minor groundwater is encountered in the interval representing the C coal seam, C-D sandstone, and D coal seam;
    - o 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,
    - o 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;

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[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

- o 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,
- o 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.

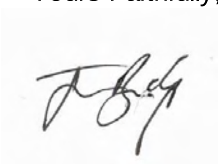
4.0 CONCLUSIONS

- 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.

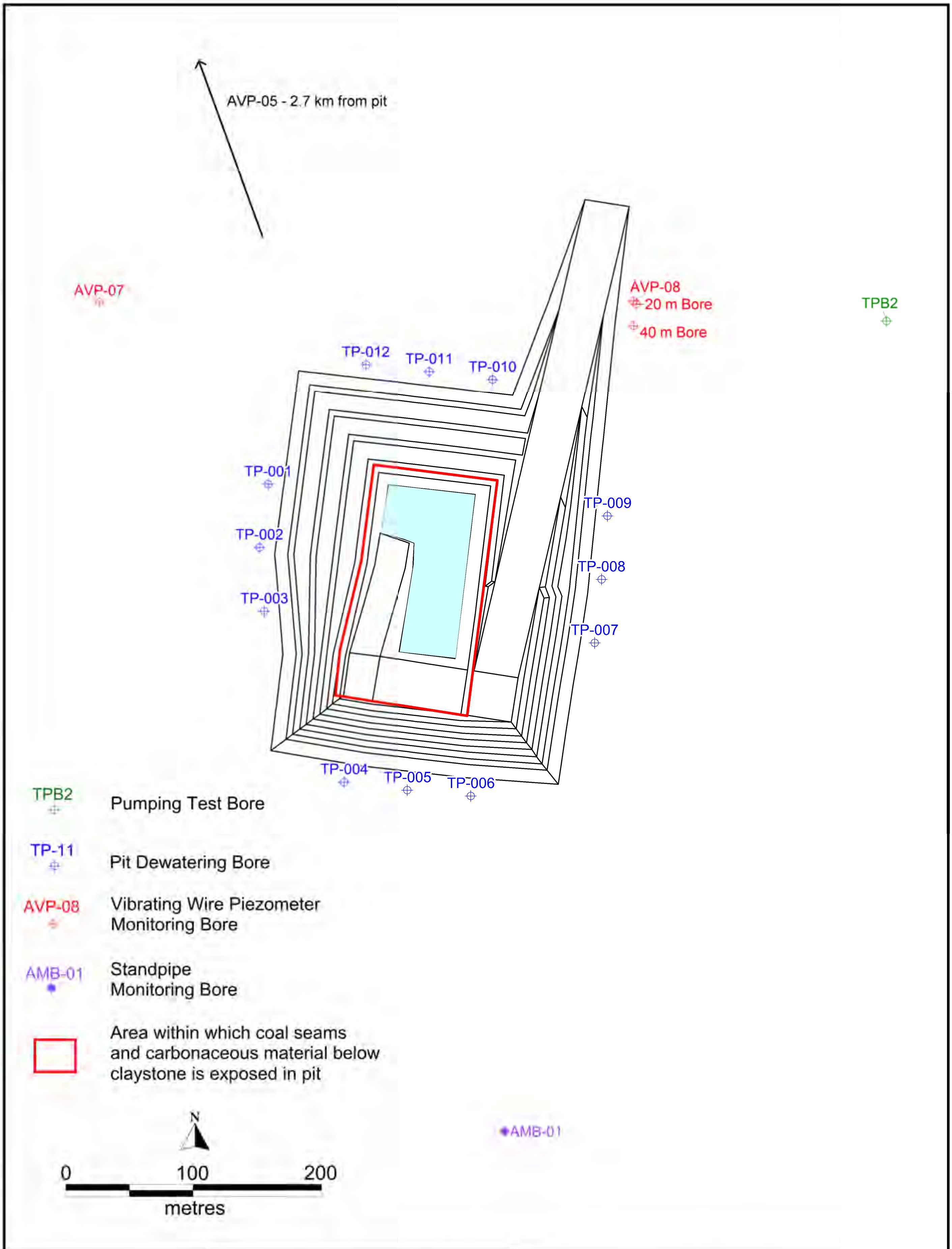
5.0 RECOMMENDATIONS

- 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		

Easting: 445862.01

Northing: 7430684.68

Collar RL (mAHD): 309

Co-ord System: GDA94

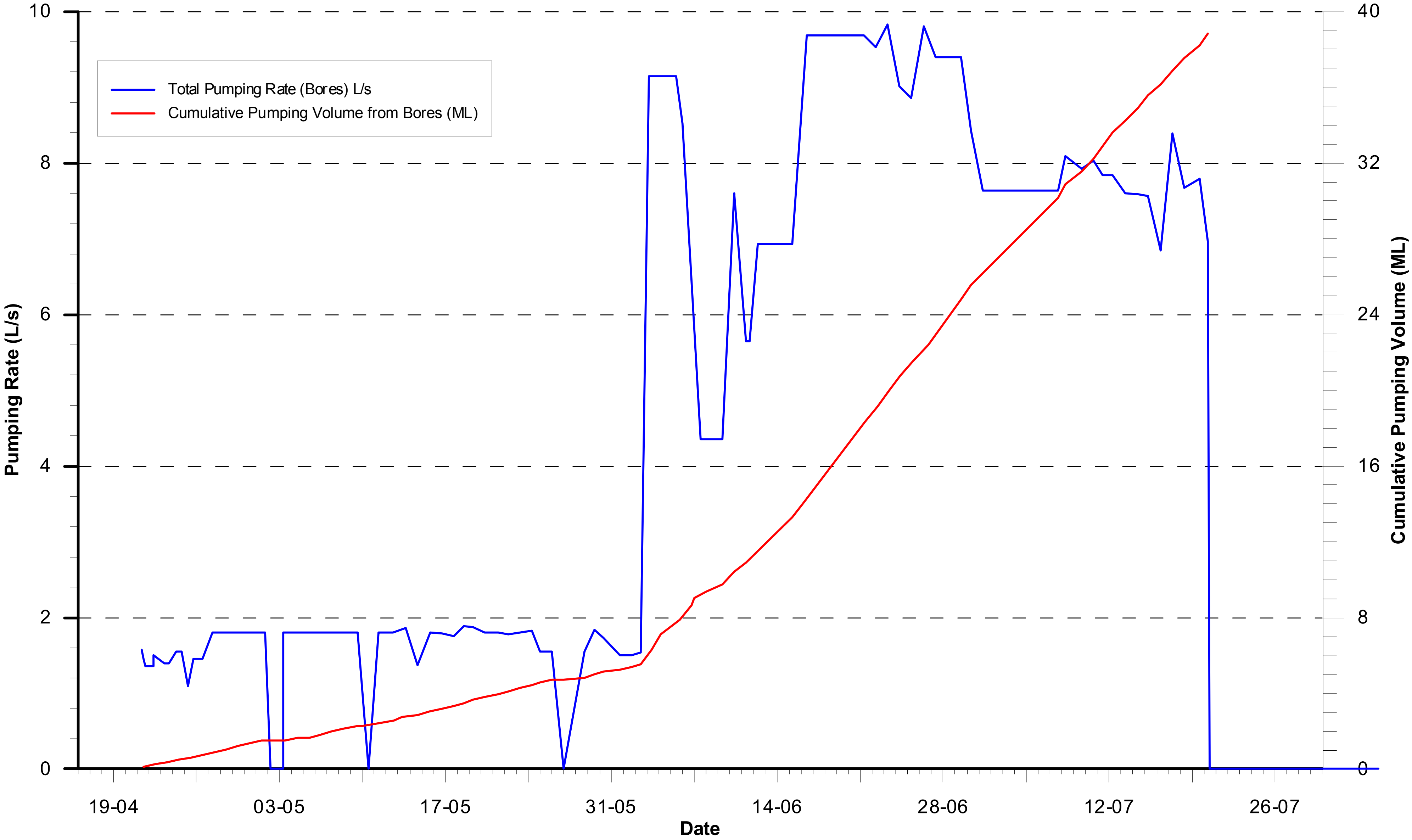
Drilling Company: Mineral Enterprises Aust

Drill Rig: No. 1

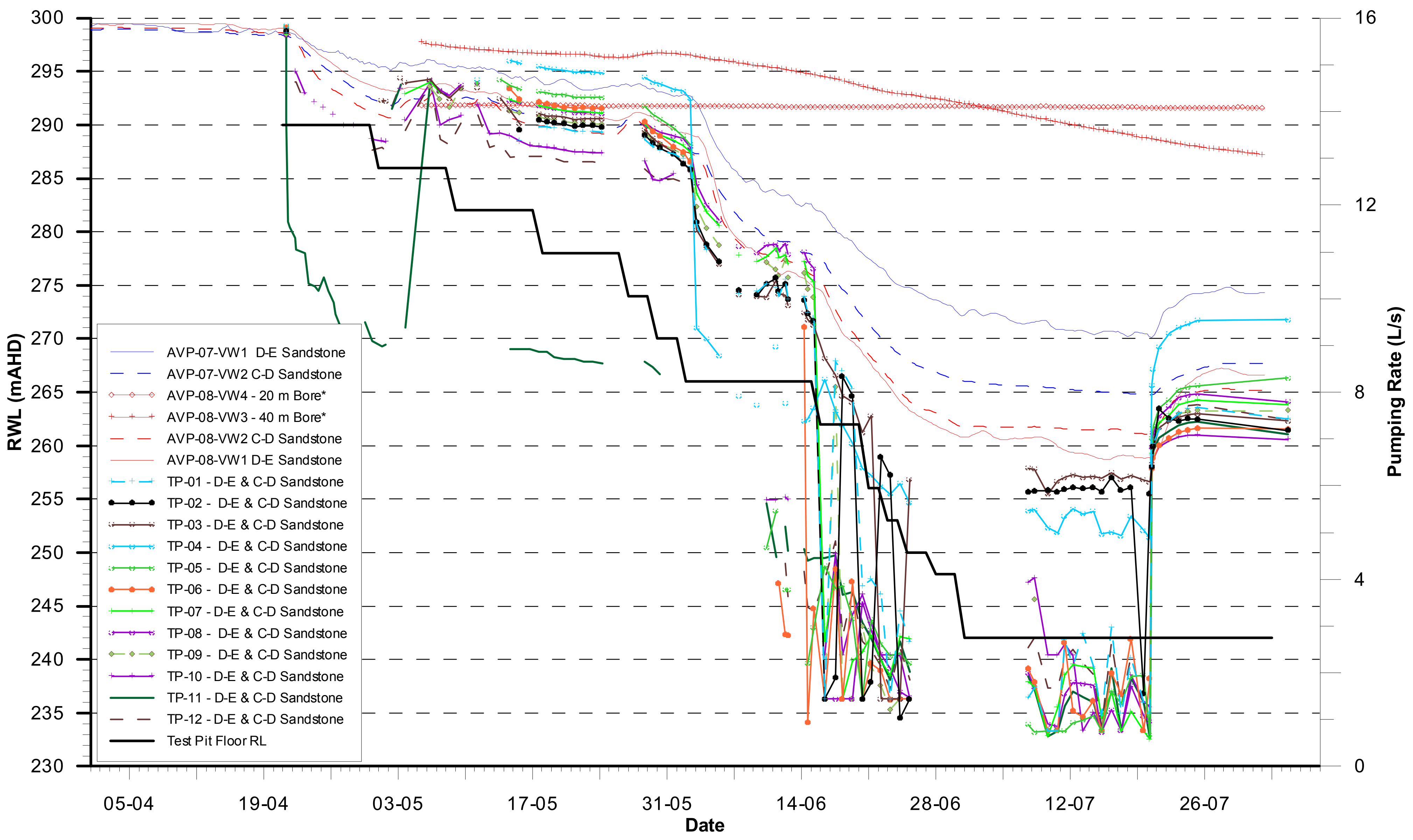
Hole Diameter (mm): 100

Total Depth (m): 81.73

Figure 2



JBT consulting	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

JBT consulting

CLIENT Hancock Coal Pty Limited

PROJECT Alpha Coal Project

DRAWN JWB

DATE Aug 2011

CHECKED

DATE

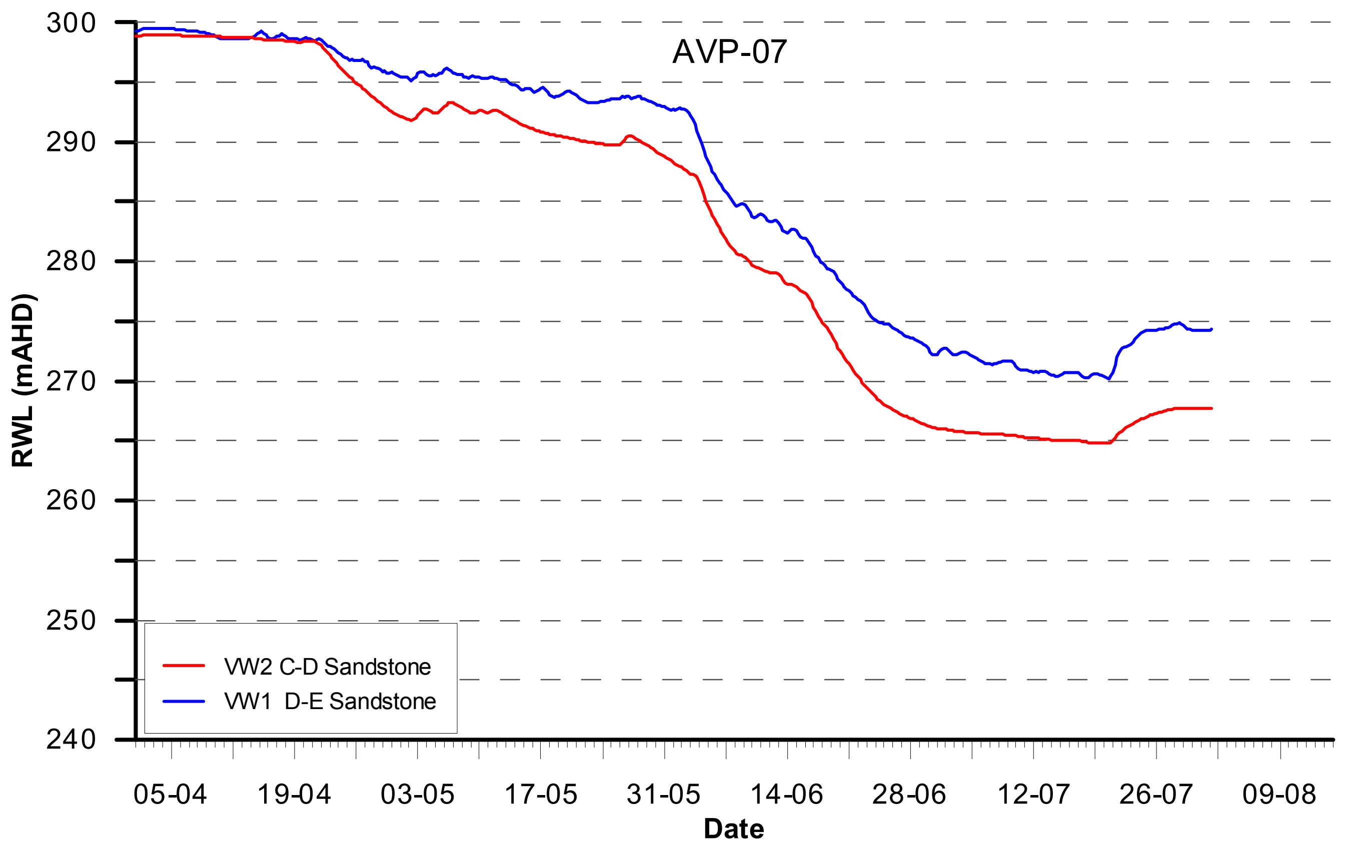
TITLE **Reduced Water Level (mAHD) Perimeter Pumping Bores**

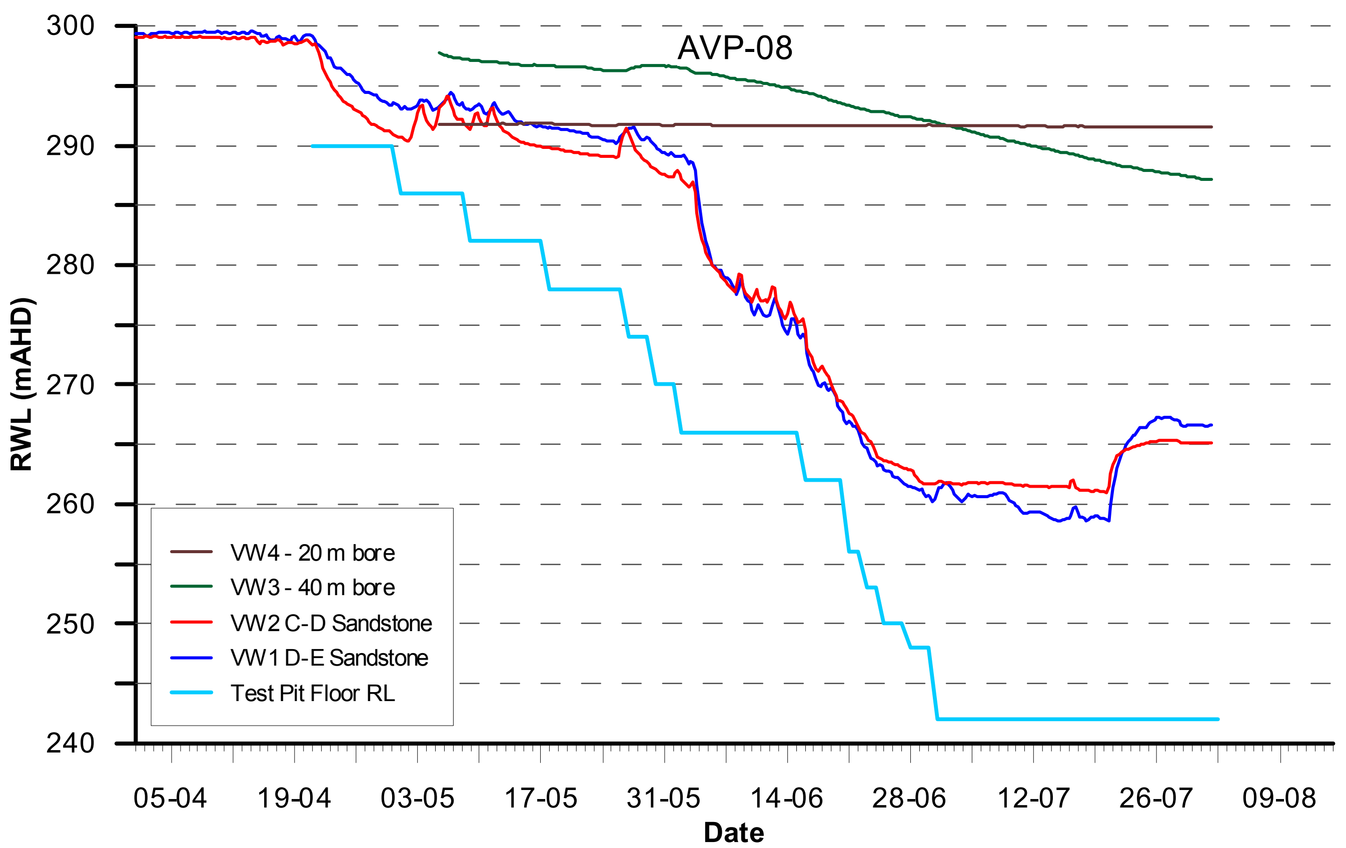
SCALE As Shown

A4

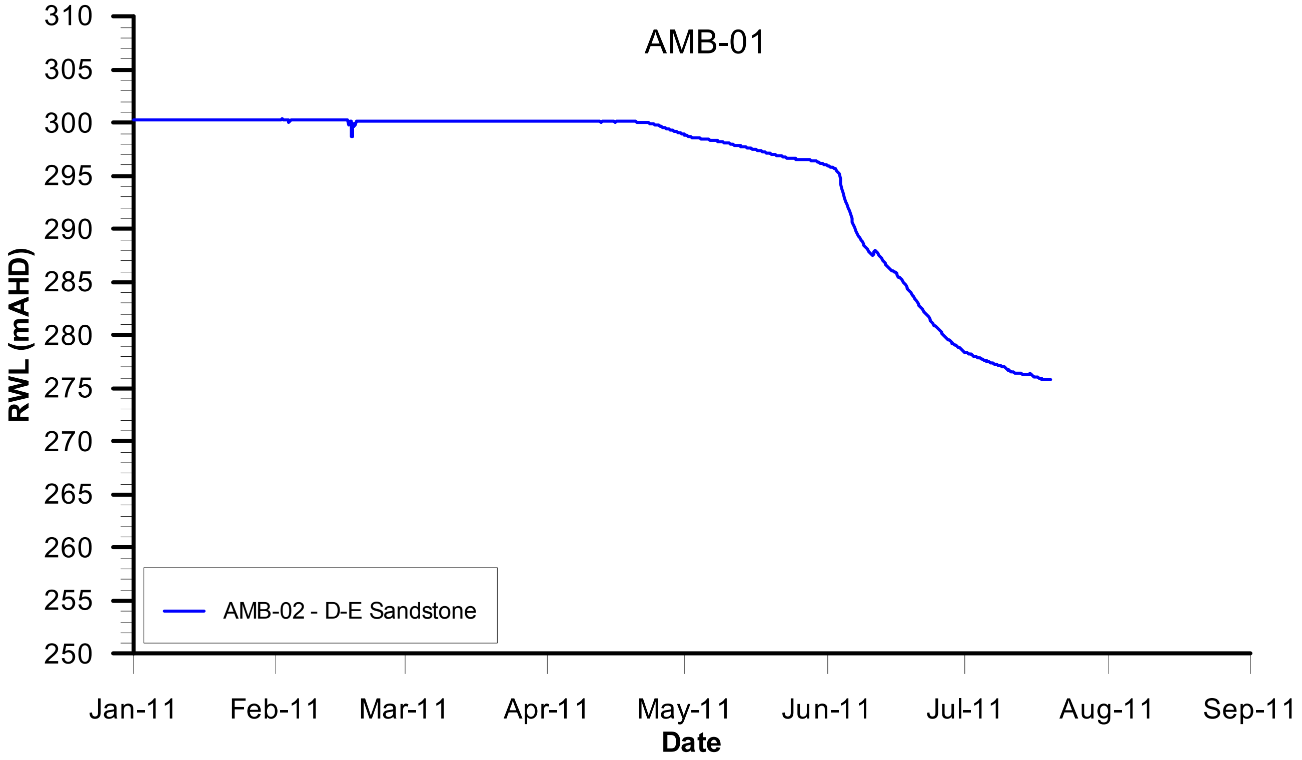
PROJECT No. JBT01-005-031

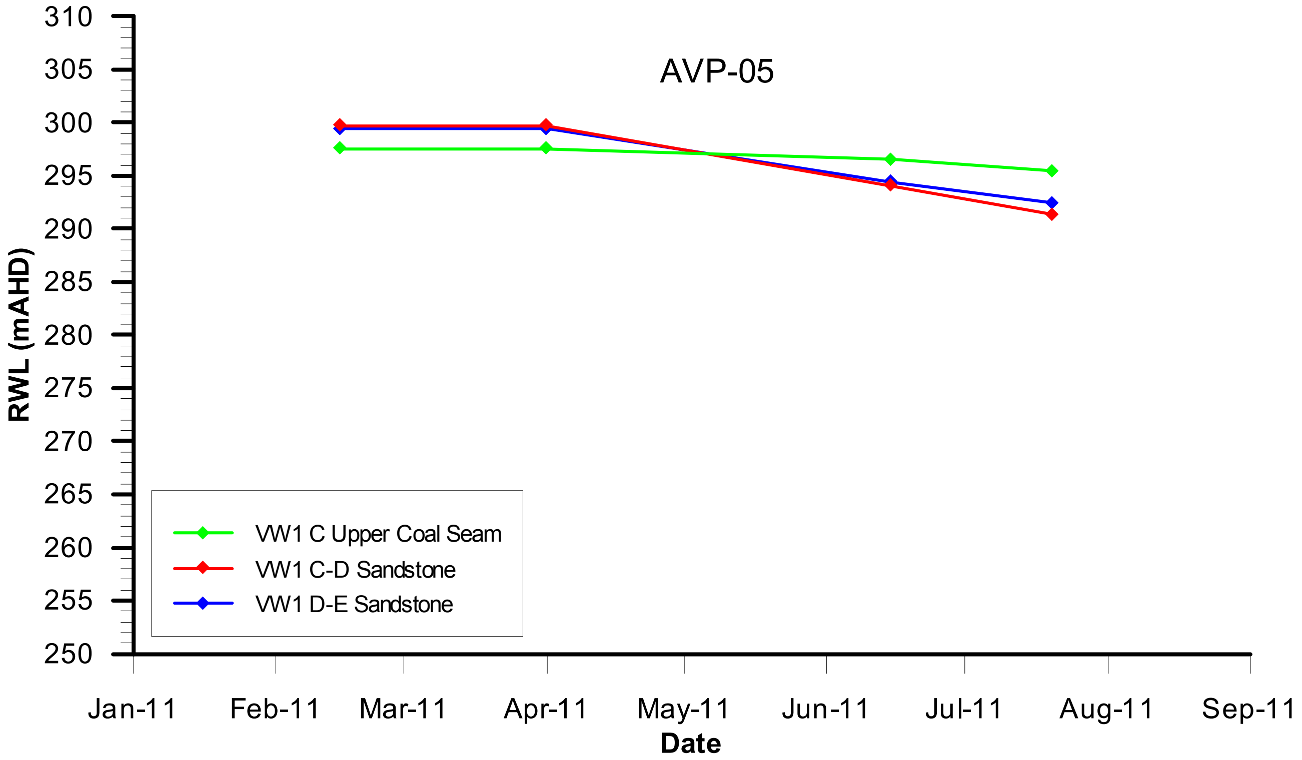
FIGURE No. 4



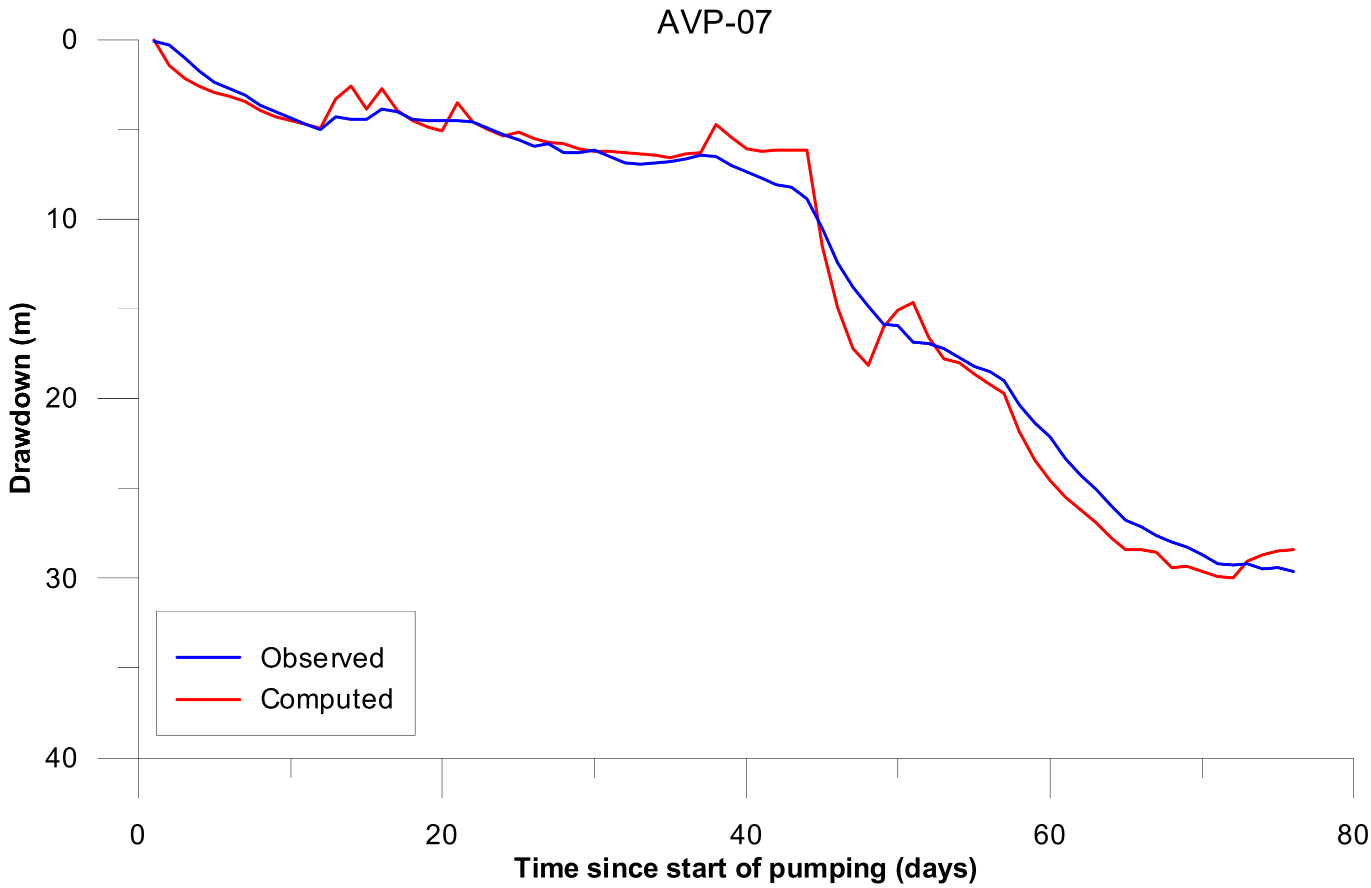


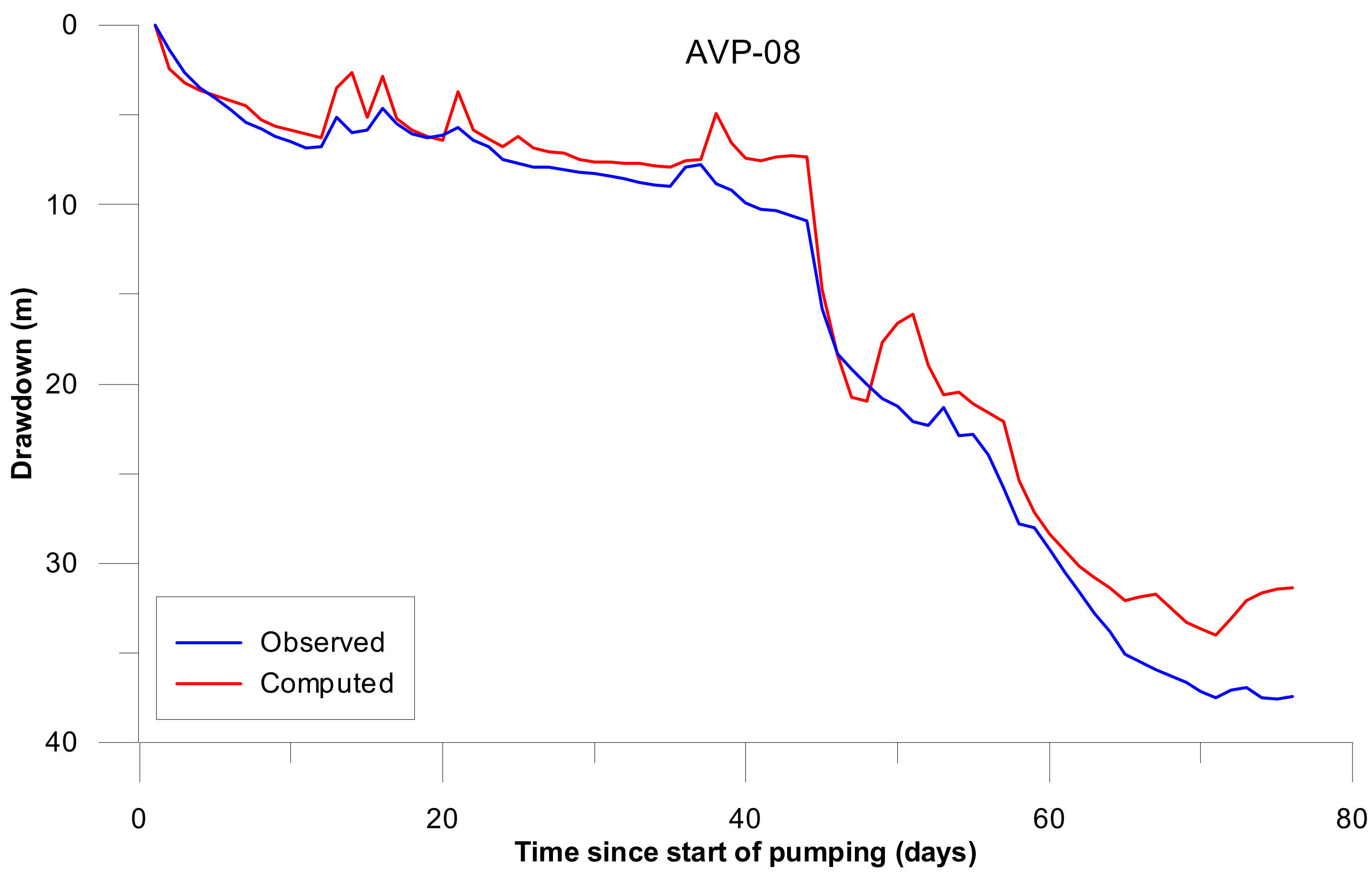
CLIENT Hancock Coal Pty Limited			PROJECT Alpha Coal Project	
DRAWN JWB	DATE Aug 2011		TITLE **Reduced Water Level VWP Bores AVP07, AVP08**	
CHECKED	DATE			
SCALE As Shown		A4	PROJECT No. JBT-01-005-031	FIGURE No. 5



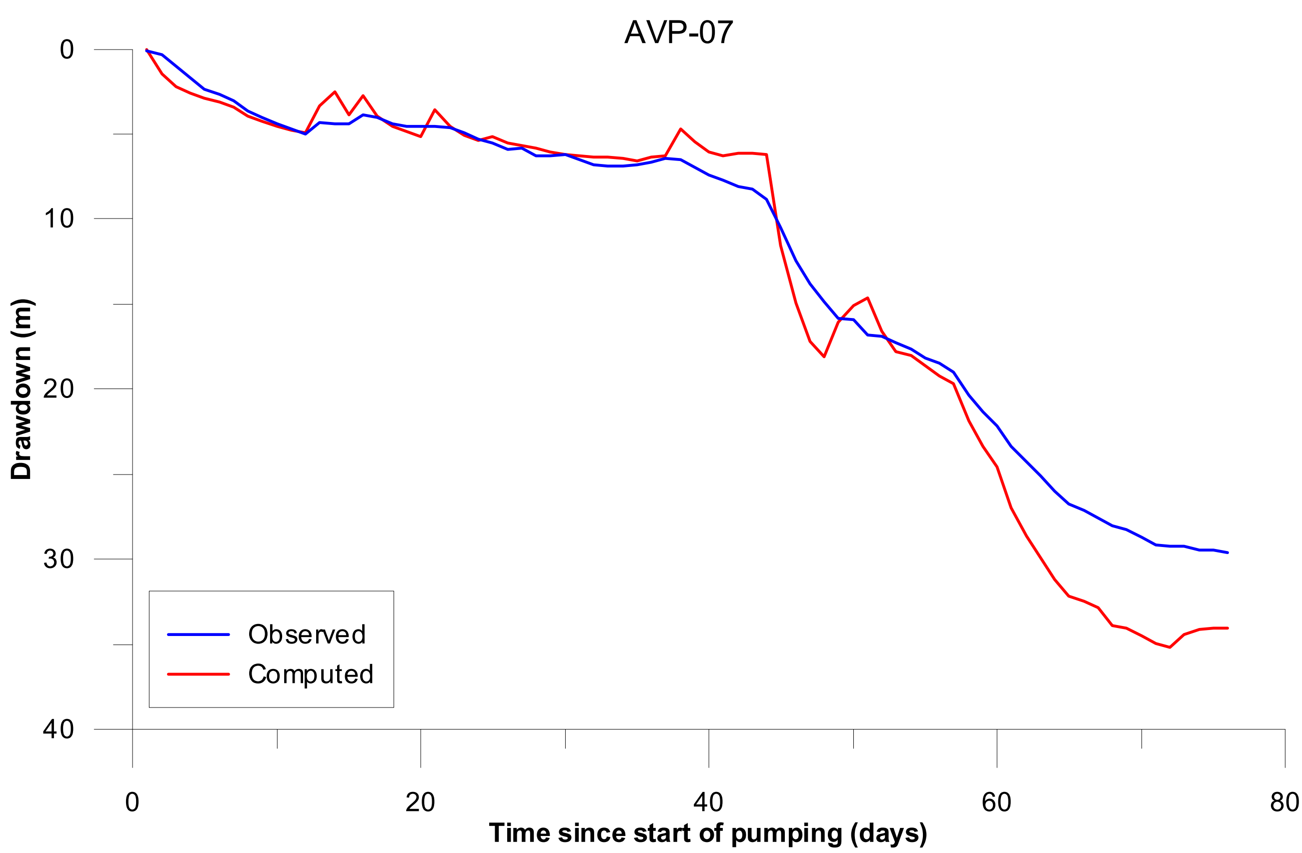


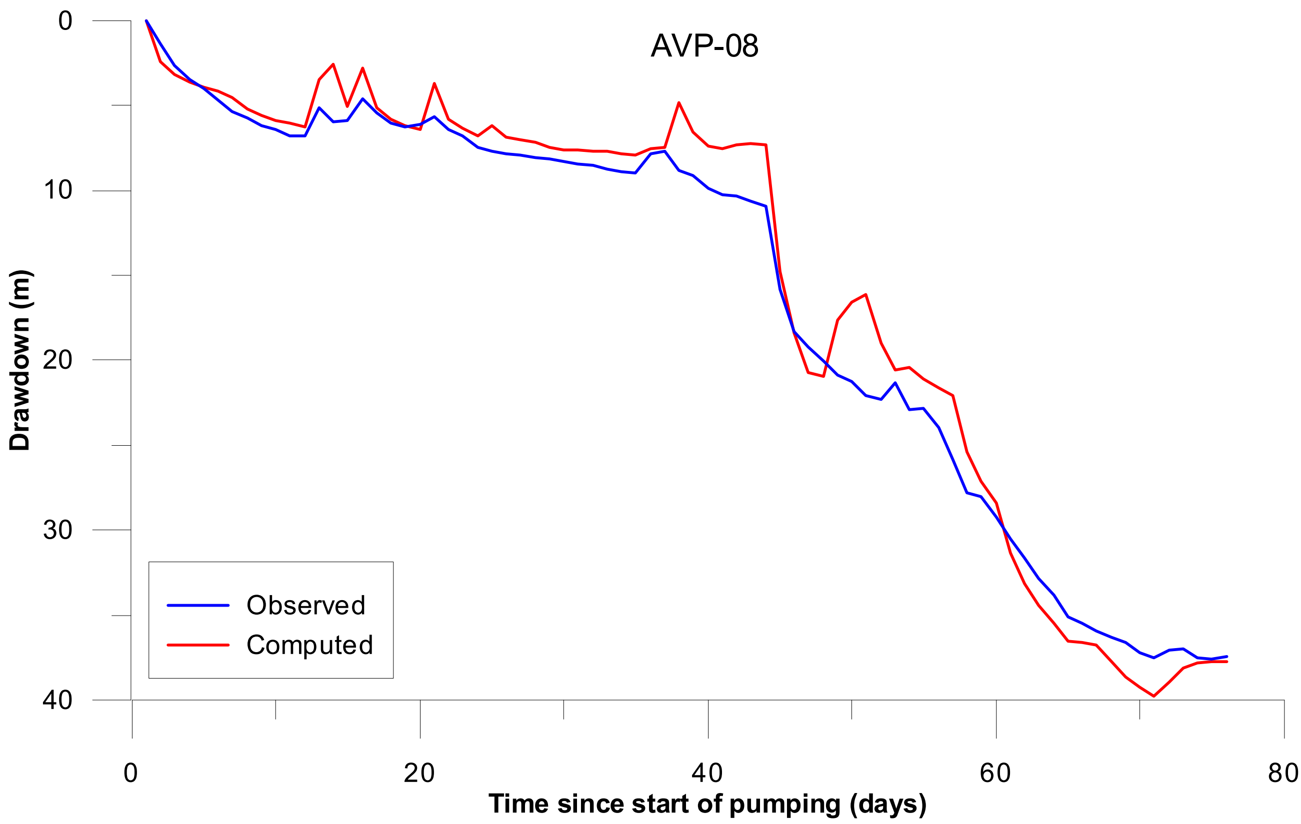
CLIENT Hancock Coal Pty Limited		PROJECT Alpha Coal Project	
DRAWN JWB	DATE Aug 2011	TITLE **Reduced Water Level (mAHD) Bores AMB-01, AVP-05**	
CHECKED	DATE		
SCALE As Shown	A4	PROJECT No. JBT01-005-031	FIGURE No. 6





JBT consulting	CLIENT Hancock Coal Pty Limited		PROJECT Alpha Coal Project	
	DRAWN JWB	DATE Aug 2011	TITLE **Modelled vs Observed Drawdown - Bore Pumping Only**	
	CHECKED	DATE		
	SCALE As Shown	A4	PROJECT No. JBT-01-005-031	FIGURE No. 7





JBT consulting	CLIENT Hancock Coal Pty Limited		PROJECT Alpha Coal Project	
	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

APPENDIX E

SUMMARY OF NUMERICAL MODEL OF ALPHA TEST PIT

Appendix E

Local scale model of Alpha test pit

A separate local scale model has been developed using FEFLOW, to simulate the results of dewatering and subsequent partial flooding of the Alpha test pit.

The model covers a region 2.75 km square, with the test pit roughly in the centre of the region (Figure 1). The mesh is locally refined near the bores used for active dewatering (Figure 2).

An example of water levels in the current model after 91 days (based on starting water level of 299 mAHD) is shown in Figure 3.

Efforts to calibrate the local scale model are continuing, as part of an effort to improve estimates of aquifer properties.

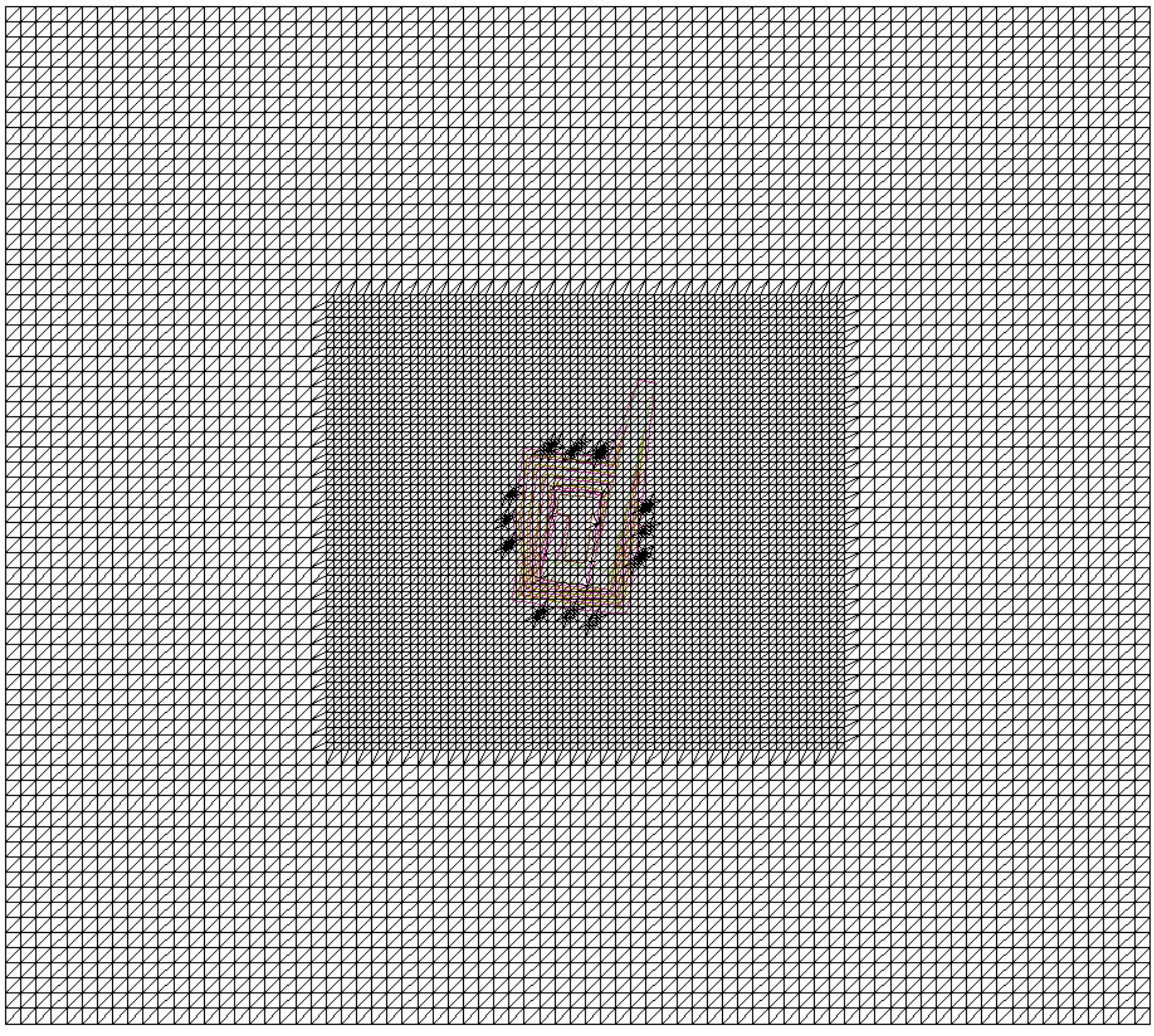


Figure 1 Finite element mesh for local scale model of Alpha test pit

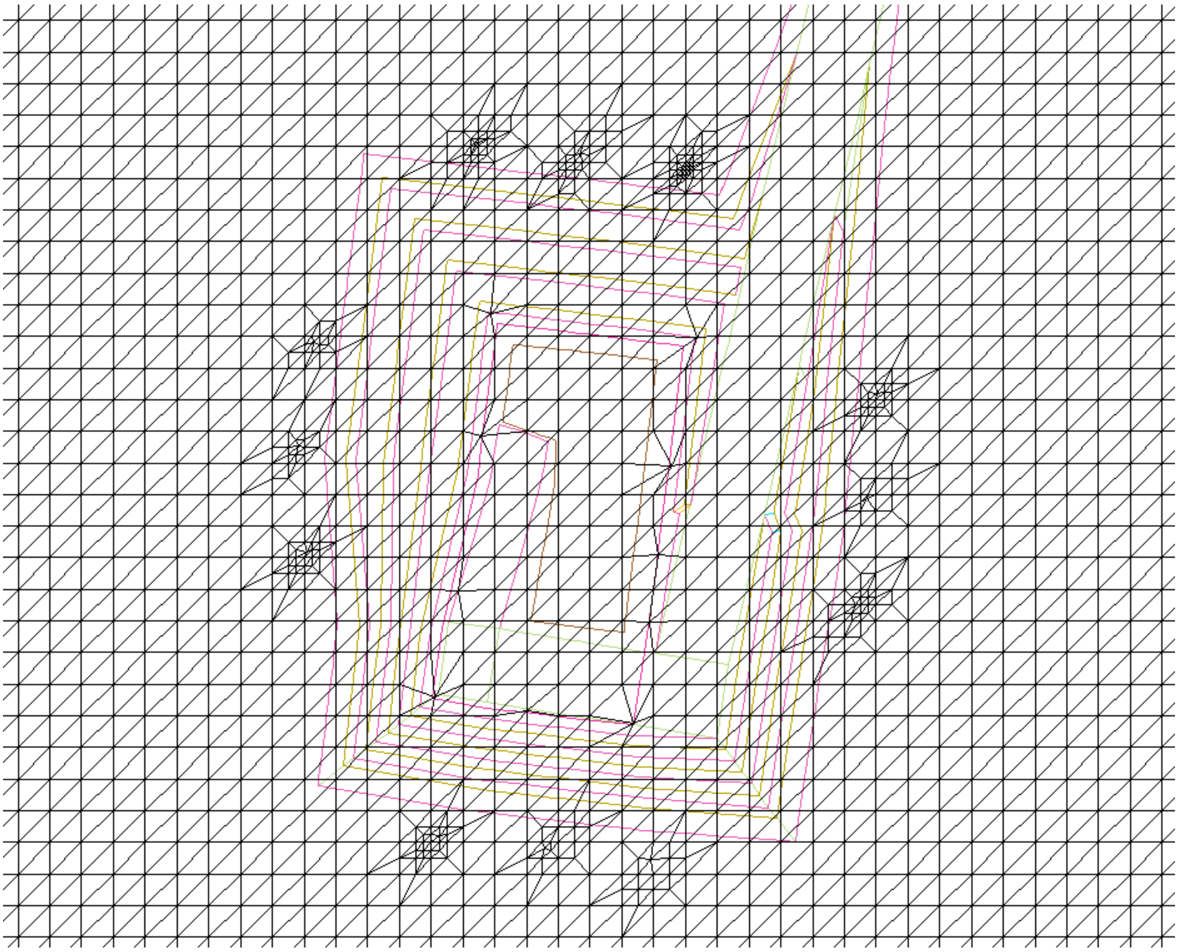


Figure 2 Refined mesh near dewatering bores for local scale model of Alpha test pit

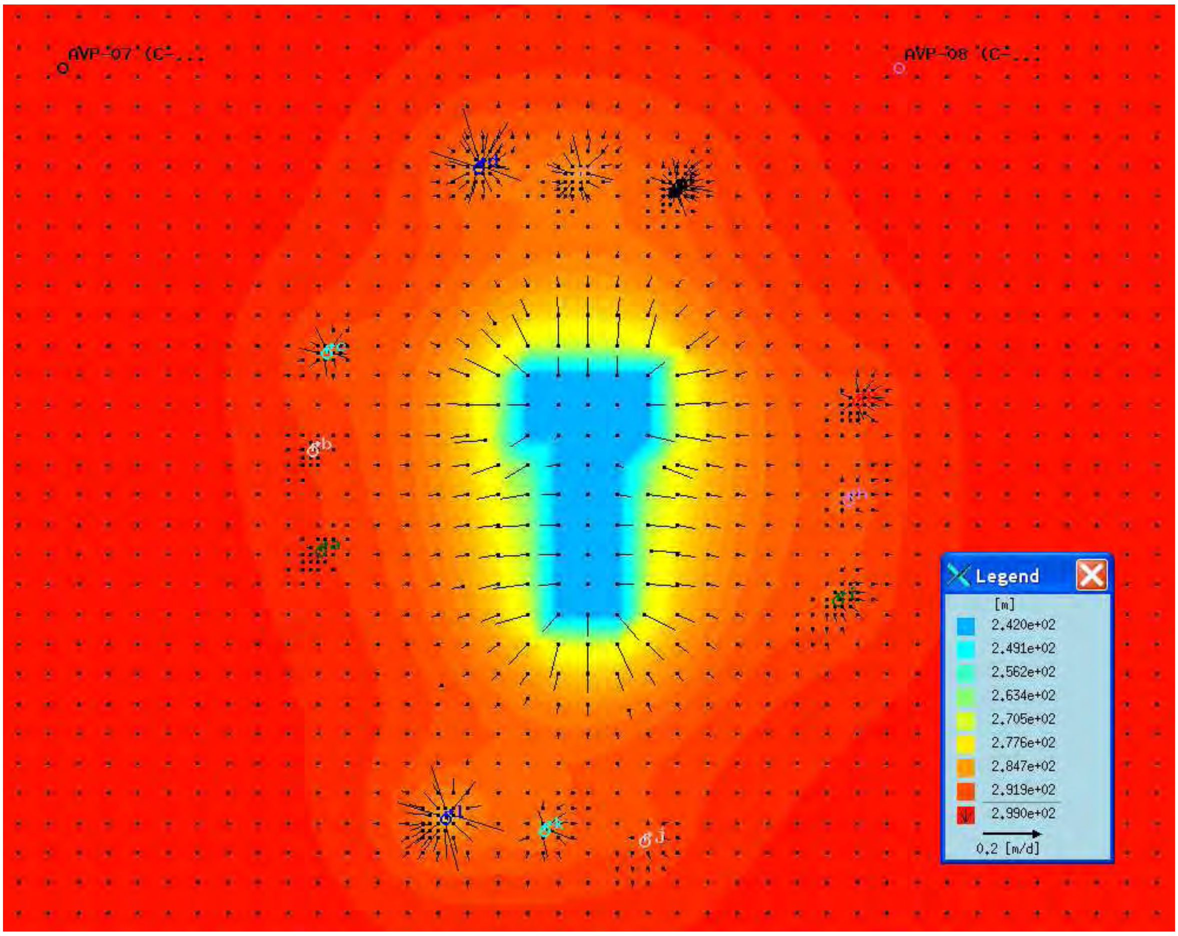


Figure 3 Example of water levels (mAHD) in slice 7 after 91 days

Appendix B Preliminary Assessment of Evolution of Mine Pit Lakes, Alpha Coal Project

NTEC ENVIRONMENTAL TECHNOLOGY

PRELIMINARY ASSESSMENT OF THE EVOLUTION OF MINE PIT LAKES, ALPHA COAL PROJECT

for

JBT Consulting

by

NTEC Environmental Technology

Date: 13 April 2011

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EXECUTIVE SUMMARY

NTEC Environmental Technology has developed a numerical groundwater model of the region surrounding the Alpha Coal Project. The model represents the regional hydrogeological system and has been designed to predict the potential impacts of the Alpha Coal Project, in the context of the potential impacts of the Kevin's Corner Coal Project, immediately to the north.

Predictions of inflows to mines and of regional drawdown during mining have been made, but a number of hydrogeological properties are uncertain, especially relating to the storage properties of sedimentary units above and below the D Seam. Additional tests in the field and laboratory are required before modelling can be completed.

Recovery of the water table and the evolution of mine pit lakes are of interest to stakeholders. Predictions have therefore been made, based on predictions of drawdown during 31 years of mining in the Alpha open cut mines and Kevin's Corner open cut and underground mines. Given the uncertainty in predictions of drawdown, there is also uncertainty in predictions of recovery.

The water table is predicted to recover over a period of ~250-300 years, such that by a time ~300 years after the start of mining, water levels in mine pit lakes will equilibrate at about 280 mAHD, and the regional water table will show a cone of depression with flow occurring radially towards the mine pit lakes.

During recovery, there will be a long period during which a number of separate mine pit lakes along the length of the Alpha open cut coal mine will show a gradient in levels from south to north. Dewatering in the Kevin's Corner underground mine will cause a cone of depression much lower than the floor of the Alpha open cut coal mines, hence groundwater will flow initially towards Kevin's Corner.

The final equilibrium predicted is influenced by an assumption that regional recharge to the water table is negligibly small. This assumption is reasonable during mining, when groundwater flows are dominated by dewatering in the mines. The assumption is not appropriate in the long term, and leads to a predicted cone of depression that is larger than would occur if recharge were taken into account.

This assessment is preliminary, and will be revised when the regional model is finalised, taking long-term recharge into account.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose of this Report

NTEC Environmental Technology has developed a numerical groundwater model of the region surrounding the Alpha Coal Project. The model represents the regional hydrogeological system and has been designed to predict the potential impacts of the Alpha Coal Project, in the context of the potential impacts of the Kevin's Corner Coal Project, immediately to the north.

Potential impacts are of two kinds:

- operational, in the sense that water management infrastructure must be designed to handle groundwater inflows to the mine(s), and
- environmental, in the sense that stakeholders need to understand the potential for lowering of the water table in the region near the mine(s) and the time scale for recovery of the water table post-mining.

The purpose of this report is to present preliminary results on the recovery of the water table post-mining, including predictions of the evolution of mine pit lakes. The model will be documented fully following further assessment of hydrogeological properties.

1.2 Status of Modelling

The model has been developed to allow predictions of the combined or cumulative impacts of two mining projects:

- open cut mining at the Alpha Coal Project, and
- a combination of open cut and underground mining at the Kevin's Corner Coal Project.

The model has the following characteristics:

- The model is a regional scale model, covering a region 100 km square.
- The model has been developed using a three-dimensional finite element modelling package: FEFLOW Version 6.005 (DHI-WASY, 2010).
- The model has 11 layers and 12 "slices", the latter being the surfaces between the layers. In FEFLOW terminology, aquifer properties are defined for all elements (triangular prisms) in all layers, while piezometric heads and boundary conditions are defined at nodes in slices.
- FEFLOW is run in such a way that upper layers are allowed to desaturate (partially drain) as the water table is lowered during mining. This is the only

reliable way that FEFLOW can be run for a region that contains both open cut and underground mines.

- One disadvantage of running FEFLOW in this mode is that recharge to the water table cannot be applied to the uppermost slice. The model is run assuming zero recharge, in the knowledge that groundwater flows induced by mining are much greater than annual recharge.
- Initial conditions prior to mining are based on an assumption that the water table is initially at 300 mAHD at the perimeter of the region. In essence, the whole region is assumed to be hydrostatic, with zero regional groundwater flow. This is an approximation, but such an approximation is sufficient to allow predictions of the impact of mining.
- The water table is assumed not to change at the perimeter of the region, i.e. the boundary conditions are assumed to be “fixed”. As the water table declines in the interior of the domain, there is no change in level at the boundary. The boundary is far enough away so that no flows of groundwater from the boundary towards the mine during the period of mining.

Predictions to date include the following:

- Predictions have been made of the rates of groundwater flow into both mines throughout the 31-year duration of each mine plan. The predictions are sensitive to hydrogeological properties, and field investigations are continuing to allow more confidence in these predictions.
- Predictions have been made of the extent of drawdown in all directions around the mines. The cone of depression does not extend far from the mines during mining. In the northwest of the model domain, where the Rewan Formation overlies the Bandanna Formation, the GAB Aquifer is perched above the Rewan Formation. Lowering of the water table is less than it would be if the Rewan Formation did not act as an aquitard to limit the connection between the GAB Aquifer and the Bandanna Formation below.

1.3 Dependence on Predictions of Drawdown

Clearly it is not possible to predict post-mining recovery, without first predicting drawdown during mining.

Throughout the 31-year mine plan for the two projects, the elevation of the D Seam in which mining is taking place becomes progressively lower. The cone of depression surrounding the mine therefore becomes progressively deeper. In the Alpha Coal Project, mining occurs to 202 mAHD in the northwest of the mine, in an area where the land surface elevation is 302 mAHD, and to 226 mAHD in the southwest, where the land surface elevation is 339 mAHD. In the Kevin’s Corner

Coal Project, mining occurs to 73 mAHD in the northwest of the mine, where the surface elevation is 363 mAHD.

The depth of the cone of the depression is controlled by the depth of mining, and is independent of hydrogeological properties. This aspect of the predicted drawdown is not model-dependent.

At the same time, predictions of the rates of groundwater inflow to the mine(s) and of the lateral extent of the cone of depression depend on hydrogeological properties of the aquifers and aquitards near the mine(s). The important properties are:

- hydraulic conductivity, in horizontal and vertical directions, in every hydrostratigraphic unit,
- specific yield (or drainable porosity) in every unit that at some time has a water table, and
- specific storativity (or compressibility) which allows water to be released from rock when lowering of the water table causes depressurisation at depth.

The predictions also depend on assumptions about natural recharge, prior to mining, and about how recharge may change post-mining when the water table is lower.

Further assessment of hydrogeological properties is currently underway.

2 CONCEPTUAL MODEL OF LONG-TERM RECOVERY

Dewatering during mining operations is necessary to allow safe access to mining surfaces for the purposes of mining. Dewatering in an underground mine removes groundwater. Dewatering in an open cut mine pit also removes water that reports to mine via rainfall-runoff within the catchment area of the pit.

Once mining ceases, pumps are removed and there is a tendency for groundwater to flow into an underground mine, and for both groundwater and surface water to report to an open cut mine.

During the recovery process, the cone of depression that evolved during mining becomes less deep in the middle but continues to deepen further from the location of mining. The centre of the cone of depression is generally the lowest point in the regional water table, so there groundwater flows towards the centre. This flow causes the cone of depression to increase in regional extent.

Water levels throughout the region can only recover towards pre-mining conditions once water is added to the system. How much water is required depends on how much was removed during mining, and whether any of the water removed during mining can be returned post-mining. This in turn depends on operational water management, and on whether excess water can be stored until the end of mining.

Current indications are that more water will be pumped during mining than could possibly be stored.

The primary mechanism by which water is added post-mining is via rainfall-runoff within the catchment of open cut mine pits. This in turn depends on the hydrological characteristics of these catchments. Surface runoff from coal spoil (in pit waste dumps) can flow directly to final voids. At the same time infiltration into coal spoil can percolate to the base of the dumps, and may in some circumstances flow along the level of the seam that has been mined, eventually reporting to mine pit lakes.

The fact that the deepest part of the Kevin's Corner underground mine is 129 m deeper than the deepest part of the Alpha Coal Project's open cut mines ensures that the regional cone of depression in centred far to the north of the Alpha Coal Project. Furthermore, when recovery starts, groundwater will flow almost radially inwards towards the northwest corner of the underground mine, rather than directly towards the Alpha final voids.

Groundwater near the Alpha open cut mines will report to the final voids. Six or seven mine pit lakes will start to form, depending on final details of the mine plan. Whenever a gap or pillar is left between sections of the mine, an opportunity will arise for lakes to exist at different levels in adjacent pits.

Two factors will cause a gradient to develop from south to north. The first is that the deepest part of the floor of the southernmost mine pit in the Alpha mine is ~25 m higher than the deepest part of the floor of the northernmost pit. This would be an influence in early times, before the floors of all lakes are flooded. The second dominant factor is that dewatering in the Kevin's Corner underground mine will create a sink to the north of the Alpha mine that will take many years to fill.

Initial inflows to the Alpha mine pit lakes will therefore tend to flow northwards towards Kevin's Corner. As groundwater levels in the area of Kevin's Corner start to recover, levels in the mine pit lakes will rise, and eventually the gradient between lakes will disappear.

In the absence of groundwater recharge, an equilibrium will be achieved in the long-term between rainfall-runoff to the mine pit lakes, regional groundwater flow from distant boundaries and evaporation from the surface of mine pit lakes. The equilibrium level of mine pit lakes will always be lower than the water table before mining.

Recharge to the water table would lead to a slightly different balance. There may be enhanced recharge in different parts of the domain (i) due to subsidence over the Kevin's Corner underground mine, with possible cracking and enhanced vertical hydraulic conductivity near the land surface, and (ii) due to lowering of the water table which can lead to additional "induced" recharge.

3 MODELLING METHODOLOGY

Long-term recovery is simulated in the following way:

- The initial water table and piezometric heads at the start of recovery are assumed to be equal to the final values at the end of mining.
- The Alpha open cut mines have been divided into seven sections, corresponding to six sections of the Alpha mine (MineOp Consulting Pty Ltd, 2011), with the southernmost section divided into two (based on mine plans available at the time of model setup). These seven sections are considered to become seven potentially separate mine pit lakes.
- Rainfall-recharge within the contributing catchment areas of the mine pit lakes is computed by multiplying the rate of rainfall by the area of the contributing catchments and a runoff coefficient. Rainfall is assumed to be the annual average rainfall. Monthly averages would lead to annual fluctuations in level, but these are perturbations on a long-term trend.
- Evaporation from mine pit lakes is computed by multiplying the rate of evaporation by the surface area of water in each mine pit lake and a pan-to-lake coefficient. The surface area is computed as the length of the high wall in each mine pit lake, multiplied by the width of the lake, with the width defined dynamically using the lake elevation (head) computed by FEFLOW and a generalised depth-width relationship based on four cross sections (MineOp Consulting Pty Ltd, 2011).
- Within FEFLOW, each mine pit lake is represented by a strip approximately 100 m wide, with very high hydraulic conductivity in all directions and specific yield equal to 1. The high hydraulic conductivity ensures that the water surface is horizontal within each lake. Backfill is represented with enhanced hydraulic conductivity (~1 m/d) and specific yield 0.1. Rainfall-runoff and evaporation are applied as sources and sinks in layer 6 (originally the D Seam) on the basis that this layer will always be saturated in the mine pit lakes. Rainfall-runoff and evaporation are lumped and added to two finite elements (one for rainfall-runoff and one for evaporation) using a “formula editor” that allows such relationships to be defined in FEFLOW.
- Forward simulations to the end of mining are for a period of 31 years. Post-mining recovery is computed for another 469 years, to a total of 500 years from the start of mining.

Specific data used for modelling the evolution of lakes in the mine pits are provided in Table 1. Pits are numbered from north to south.

Table 1 Data for mine pit lakes

Characteristic	Mine Pit Lake						
	1	2	3	4	5	6	7
Contributing area (ha)	1593	1824	1305	1714	1565	756	615
Length of highwall (m)	4650	3280	4745	3949	3917	1879	1529
Elevation of floor (mAHD)	204.2	218	220.8	225.6	223.5	220.3	229

The generalised cross-section used for all pits is defined in Table 2.

Table 2 Generalised cross section

Depth (m)	Width (m)
0	67
50	180
52	500
82	570
83	665
100	705

4 PREDICTED EVOLUTION OF MINE PIT LAKES

Given that predictions of the potential impacts of mining are continuing, and that predictions of post-mining recovery are contingent on these earlier predictions, only a small number of predictions of recovery have been made so far. The purpose of these predictions is largely to demonstrate a methodology, and to illustrate the likely results.

Predictions of the evolution of mine pit lakes will depend on hydrogeological properties, and most importantly on the balance between inflows and outflows to the lakes, in the very long-term.

At this stage, two cases have been considered.

Case 1

The runoff coefficient throughout the contributing areas of mine pit lakes is assumed to be 0.035, or 3.5%. The pan-to-lake coefficient is assumed to be 0.83. These values are consistent with those used in surface hydrological studies for the Alpha Coal Project (Parsons Brinckerhoff, 2010).

Other parameters that affect the simulation include:

- all parameters of the regional groundwater flow model, specifically the base case used to date, based on best available estimates of hydrogeological properties,
- the area of contributing catchments,
- the length of the high wall of each mine pit lake,
- an approximate elevation of the base of each mine pit lake, and
- a generalised depth-width relationship for the cross-section of each mine pit lake.

The cone of depression long after mining is shown in Figures 1 and 2, first as elevations, and second, as drawdown relative to an initial elevation of 300 mAHD. The region shown is 100 km square, and the two mines are shown in the background.

The level of mine pit lakes is predicted to rise to 280 mAHD (Figure 1). The cone of depression is slightly elongated, and biased a little towards the north, partly because of enhanced hydraulic conductivity in the Kevin’s Corner underground and the goaf above longwall panels.

The time for equilibrium to be reached is predicted to be most of 300 years (Figure 3). Note that levels in the seven pits (numbered 1 to 7 from north to south) rise at different rates, with a slope generally from south to north. The primary reason for this is that for most of the recovery period, groundwater levels are lower in the Kevin’s Corner area, and the lakes act as flow-through lakes, supplying flow to the north. As equilibrium approaches, groundwater will flow from the north towards the lakes.

These predictions are not “worst case”, but they are very likely to be “worse” than the most likely scenario.

- If hydraulic conductivities are smaller, the contribution of groundwater flow to mine pit lakes at equilibrium will be less. The sum of groundwater inflow and rainfall-runoff will therefore be less, evaporation will be less, and the equilibrium level in mine pit lakes will be lower. Water table gradients far from the lakes will be lower, so drawdown will be less, and the cone of depression will be more localised, with steeper gradients closer to the lakes.
- Recharge to the regional water table can act as a substitute for flow from the boundaries. The higher the rate of recharge, the more localised the cone of depression will be.

- Hydraulic conductivity and recharge are always related. If more were known about either, predictions could be made with more confidence.

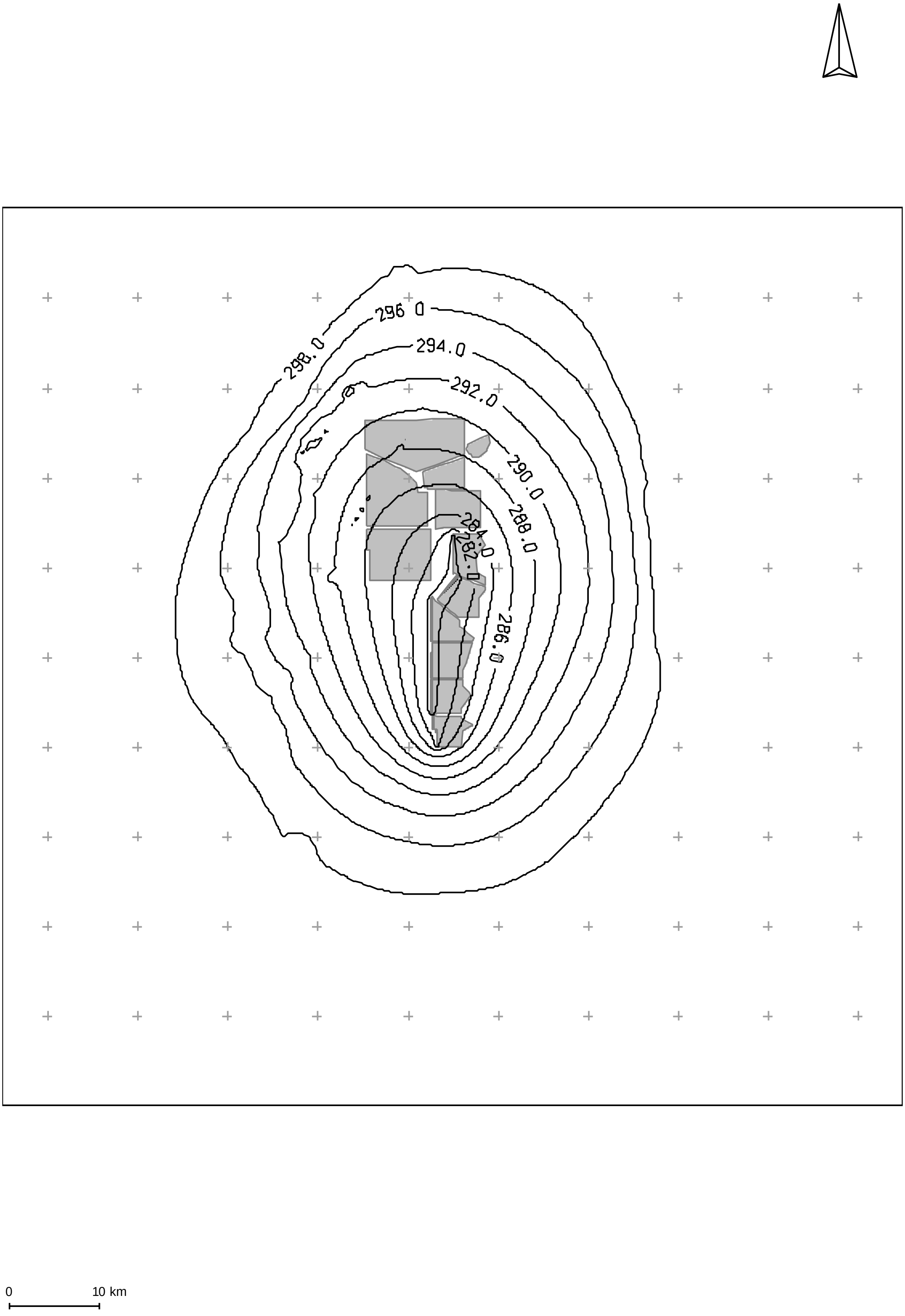

Figure 1 Predicted equilibrium water table elevation (Case 1)

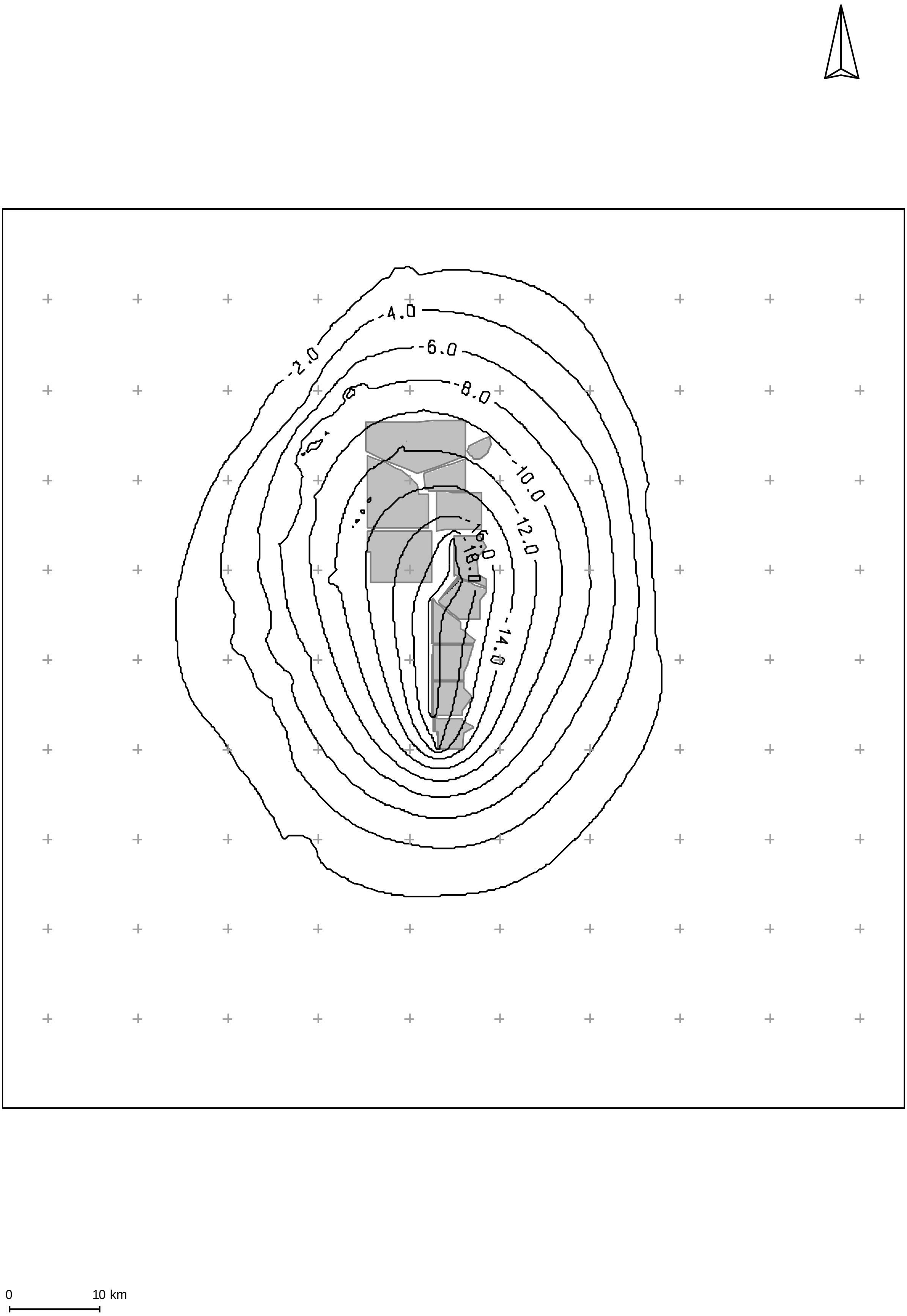

Figure 2 Predicted equilibrium drawdown (Case 1)

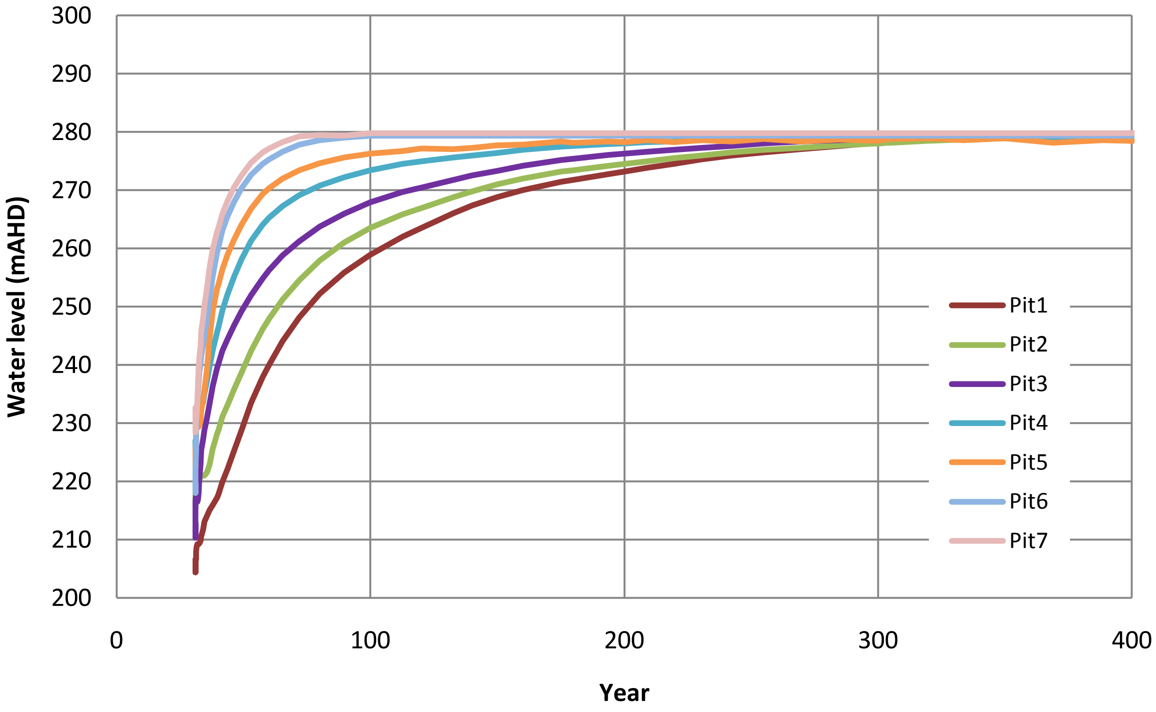

Figure 3 Predicted levels in mine pit lakes (Case 1)

Case 2

The runoff coefficient throughout the contributing areas of mine pit lakes is assumed to be 0.1, or 10%. All other parameters are the same. The reason for increasing the runoff coefficient is partly to take into account the possibility that effective runoff from backfill may have two components: an overland flow component, and also a subsurface percolation or interflow component.

The cone of depression long after mining is shown in Figures 4 and 5. When rainfall-runoff is larger, there is less inflow required from regional boundaries to balance evaporation. Regional drawdown is very slightly less, and the cone of depression is very slightly closer to the mine pit lakes.

The equilibrium level, however, is effectively the same, i.e. about 280 mAHD. This is because the long-term equilibrium level is based on a balance between inflows (regardless of source) and evaporation, and because evaporation depends on lake surface area, hence on water surface elevation.

The time for equilibrium to be reached is predicted to be most of 300 years (Figure 3).

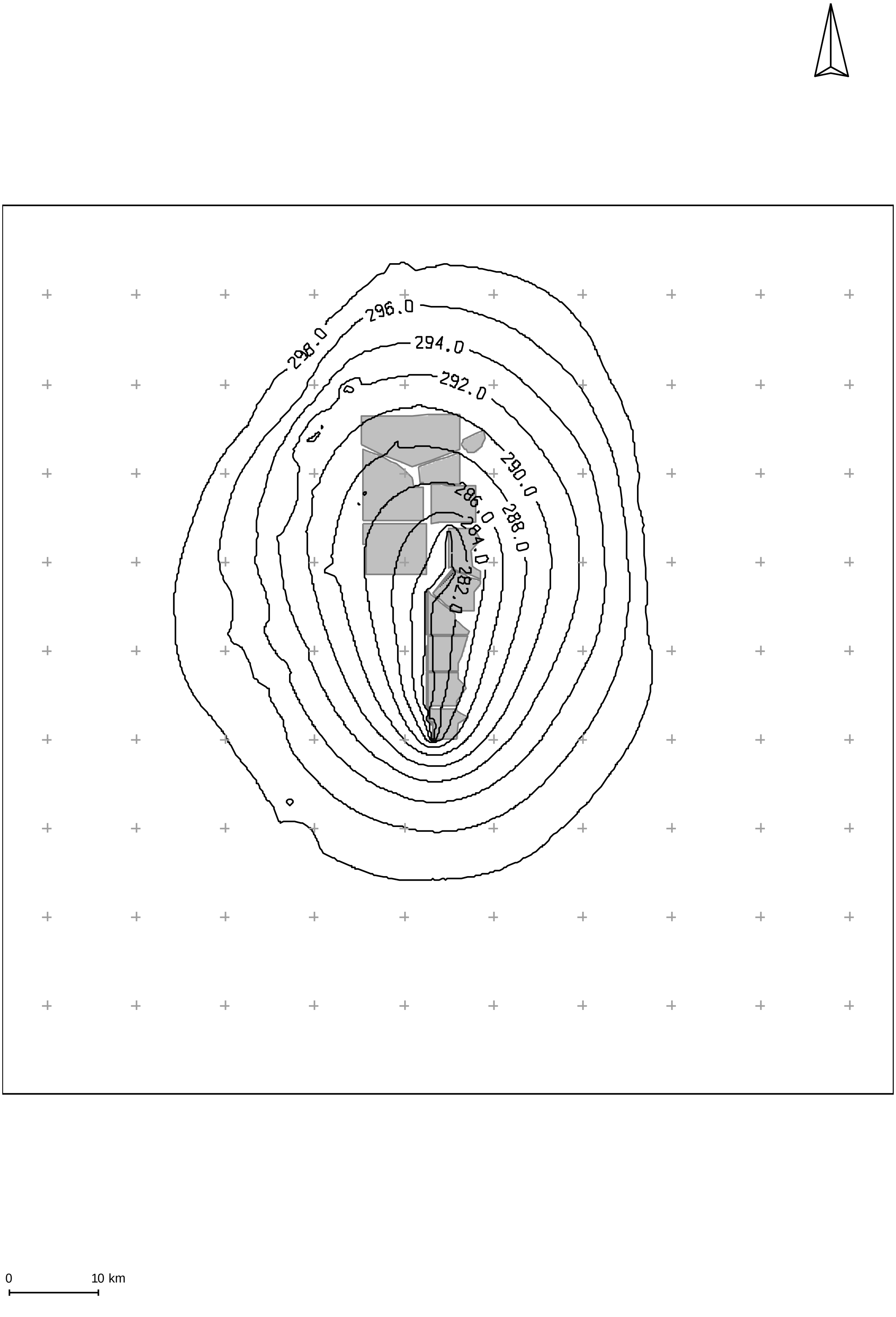

Figure 4 Predicted equilibrium water table elevation (Case 2)

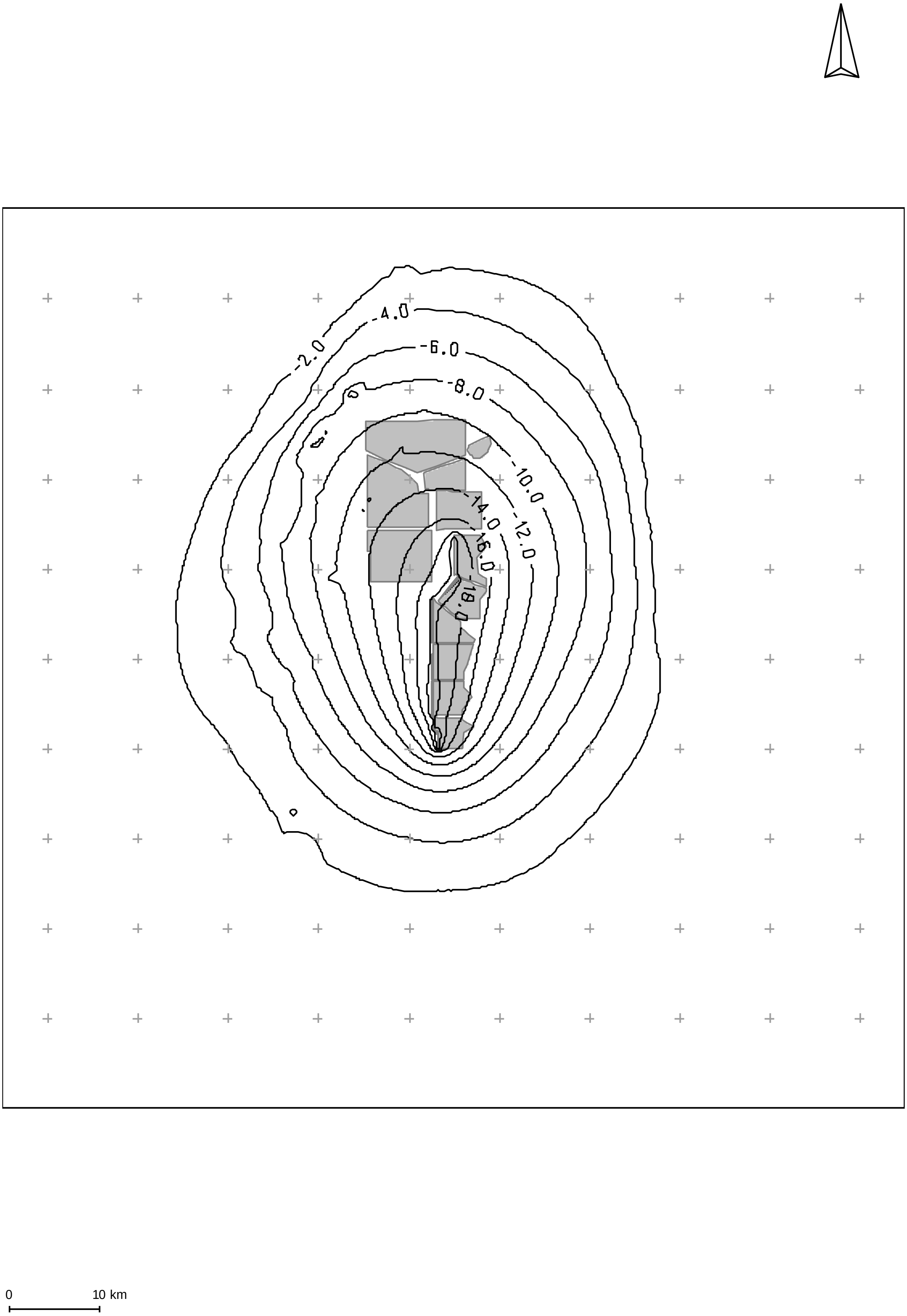

Figure 5 Predicted equilibrium drawdown (Case 2)

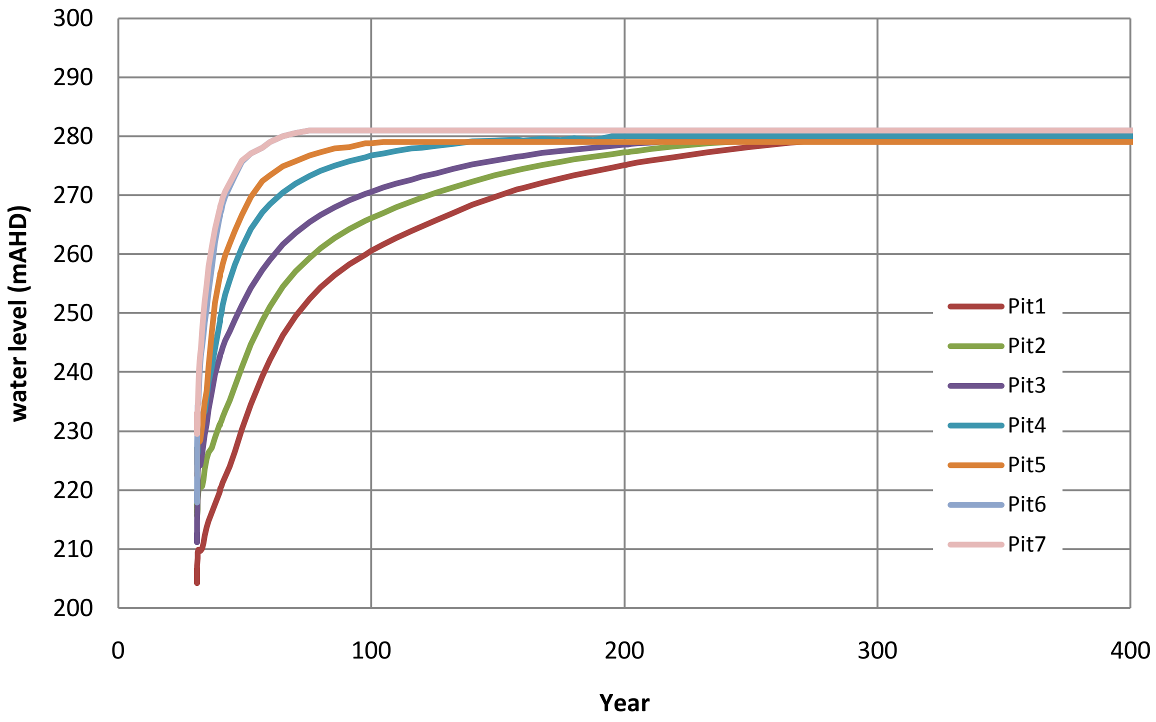

Figure 6 Predicted levels in mine pit lakes (Case 2)

5 EQUILIBRIUM LEVELS IN MINE PIT LAKES

The long-term equilibrium level in a mine pit lake depends on the balance between inflows to and outflows from the lake.

Consider a mine pit lake which receives (i) direct rainfall *P* over the area inside the perimeter of the pit A_p, (ii) surface runoff with a runoff coefficient *R* from a larger contributing catchment area A_c, and (iii) groundwater inflows Q_{gi}. The lake is likely to lose water only by evaporation from the surface area of the lake *A*, and in the early stages of refilling after mining at Kevin's Corner, by groundwater outflow Q_{go}. Surface area is a function of the water level *h* in the lake. Evaporation depends on pan evaporation *E* and a pan-to-lake coefficient *C*.

While the lake is filling, its volume will satisfy the following equation:

$$\frac{\partial V}{\partial t} = A(h)\frac{\partial V}{\partial t} = A_p P + A_c RP + Q_{gi} - A(h)CE - Q_{go}$$

The volume of the lake, and its relationship to depth and surface area, affect the approach to equilibrium. But in the long term, when $\partial/\partial t$ is effectively zero, the balance is controlled by *A(h).* These and other important balances, especially as they apply to equilibrium water quality, are explored by Turner and Townley (2006).

In the analysis presented above, rainfall and evaporation have been assumed to be steady. This explains why the asymptotic approach to equilibrium levels does not show seasonal fluctuations. If seasonal variations in climate are taken into account, the actual water levels will fluctuate, with a range of ~2 m, or perhaps more if several years in a row have little rainfall.

The above equation does not take into account the additional volume that would need to be filled due to dewatering near the mine pits, nor the volume of voids in backfill within the Alpha pits, placed at elevations higher than the floor of the Alpha pits. This is one reason why it becomes essential to simulate the evolution of the lakes using a groundwater flow model.

In order to explore the behaviour of levels in individual mine pit lakes for the Alpha coal project, a very simplistic model was created using GoldSim (GoldSim Technology Group, 2010), largely as a check on results obtained using FEFLOW. In principle it would be possible to call lake models prepared in GoldSim from FEFLOW, or to call FEFLOW from GoldSim. In this case, GoldSim and FEFLOW have been used independently.

When GoldSim is run independently of FEFLOW, with no groundwater inflow to the mine pit lakes, equilibrium lake levels are lower, perhaps as low as 240-260 mAHD. But in reality, if lakes levels are lower than water table elevations pre-mining, groundwater will flow towards the lakes, from a capture zone to some radius of influence defined by long-term recharge rates post-mining, with a lowered water table. In the terminology of Townley and Trefry (2000), the lakes will ultimately become “discharge lakes”. It follows that more water will flow into the lakes, hence more outflow is required for a balance to be achieved, so equilibrium water levels must be higher.

6 REFERENCES

DHI-WASY (2010), FEFLOW 6, Finite Element Subsurface Flow & Transport Simulation System, User Manual.

GoldSim Technology Group LLC (2010), GoldSim Probabilistic Simulation Environment, User’s Guide, Version 10.5.

MineOp Consulting Pty Ltd (2011), Drawing 1058 Rev A.

Parsons Brinckerhoff (2010), Alpha Coal Project, Site water management system and water balance technical report, prepared for Hancock Coal Pty Ltd, August.

Townley, L.R., and Trefry, M.G. (2000), Surface water - groundwater interaction near shallow circular lakes: Flow geometry in three dimensions, Water Resources Research, 36(4), 935-948.

Turner, J.V, and Townley, L.R. (2006), Determination of groundwater flow-through regimes of shallow lakes and wetlands from numerical analysis of stable isotope and chloride tracer distribution patterns, Special issue on groundwater - surface water interactions in wetlands and integrated water resources management, Journal of Hydrology, 320, 451-483.

ABOUT THIS REPORT

NTEC Environmental Technology provides consulting services to the mining and water industries, including assessment of the potential environmental impacts of proposed projects, often using numerical simulation models to provide quantitative predictions of hydrological and other processes.

NTEC Environmental Technology employs highly qualified staff with expertise in impact assessment and simulation methodologies. As members of professional organisations including IEAust, AusIMM, IAH, IAHR, NGWA and AGU, we strive to apply our skills diligently, and to maintain our level of skill through continuing professional development.

Much of our work lies at the interface between the natural and the built environment. While the built environment is designed by engineers, using materials whose properties can be controlled during manufacture, the natural environment is fundamentally different. The geometry and properties of the natural environment can never be fully characterised. Processes that have occurred in the past and may occur in the future can only be inferred from a limited number of uncertain measurements. The history of previous activities at a project site is often poorly documented, adding a further layer of complexity.

Our work combines analysis and prediction: analysis of systems based on available information, and prediction of the response of those systems to man-made changes. We are skilled in selection and application of methods for sensitivity and uncertainty analysis. Uncertainty is inherent in the problems we work on, hence estimating and managing that uncertainty is always part of our work.

This report has been prepared for you, our client:

- to meet specific requirements discussed with you before and during preparation of the report, and
- using information provided by you and otherwise available in the public domain.

Before you rely on analyses and predictions contained in this report, we encourage you to understand the uncertainties identified within the report and the methodologies we have used to address them. If you remain uncertain about the results, it is your responsibility to ask us to clarify. If you or any other party misinterpret the results, NTEC Environmental Technology cannot be held responsible for such misinterpretation.

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