HERITAGE COMPUTING REPORT

GALILEE COAL PROJECT GROUNDWATER ASSESSMENT

FOR

WARATAH COAL PTY LIMITED

By

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Heritage Computing Pty Ltd

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ACKNOWLEDGMENTS

Person	Company	Activity
Andrew Fulton	Groundwater Exploration Services Pty Ltd	Report sections and figures

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1 INTRODUCTION

1.1 BACKGROUND

The proposed Galilee Coal Project (the Project), also known as the China First Project, is located about 35 km north-west of Alpha in the Galilee Basin and about 20 km north-east of the township of Jericho (**Figure 1.1**). The Project consists of both open cut and underground mining operations to access a series of coal seams within the Permian Coal Measures.

The Project comprises a new coal mine with a new rail line connecting the mine to coal terminal facilities in the Abbot Point State Development Area and port loading facilities at the Port of Abbot Point (**Figure 1.2**).

Waratah Coal Pty Ltd (WCPL) holds Mining Lease Application (MLA) 70454 and has been granted a Mineral Development Licence. WCPL proposes to mine 1.4 billion tonnes of raw coal from its existing tenements, Exploration Permit for Coal (EPC) 1040 and EPC 1079 (**Figure 1.3**). The annual Run-of-Mine (ROM) coal production will be 56 Mtpa to produce 40 Mtpa of saleable export highly volatile, low sulphur, steaming coal to international markets. The mine will comprise a combination of two surface mines and four underground mines.

There is currently no mining activity surrounding the Project. However, a number of companies are undertaking feasibility studies for development of coal projects across several coal seams within the Galilee Basin with coal to be extracted by means of both underground and open cut mining methods. Proposed projects adjacent to the Project include the approved Alpha Coal Project to the north and the South Galilee Coal Project to south.

Further detail regarding the proposed mining operation description is provided in Part A of the Supplementary Environmental Impact Statement (SEIS).

1.2 SEIS FOCUS

This report has been prepared for WCPL to provide a groundwater assessment of the proposed Open Cut and Underground mining operations (**Figure 1.3**) to support an updated SEIS application. The original groundwater assessment for the EIS was undertaken by E3 Consulting Australia Pty Ltd (2010). The supplementary assessment has been undertaken by Heritage Computing Pty Ltd, primarily to develop a new numerical groundwater model as a basis for a revised assessment of environmental impacts.

The supplementary assessment also focuses on specific issues raised by the Office of the Coordinator General (OCG) on behalf of numerous stakeholders.

Specific responses to these issues are contained in Part C of the SEIS (Submissions Responses) and in the associated Environmental Management Plan for the Project. It is not the intention of this supplementary groundwater assessment to cover ground that has already been addressed satisfactorily in the EIS. For that reason, this report places emphasis on the groundwater modelling component of the assessment but prefaces that with a summary of existing hydrogeological conditions and reporting on activities undertaken since the EIS.

The shortcomings identified by the OCG can be grouped into the following categories:

- ☐ Monitoring Network;
- ☐ Aquifer Testing;
- ☐ Aquifer Connectivity;
- ☐ Groundwater Quality;
- ☐ Great Artesian Basin;
- ☐ Cumulative Impacts; and
- ☐ Groundwater Modelling.

1.2.1 Monitoring Network and Groundwater Quality

The EIS was criticised for an absence of groundwater level hydrographs and for not identifying sufficient long-term monitoring bores or the associated target aquifers. The monitoring network was limited to three sites where nested piezometers monitored shallow Permian aquifers and were restricted to an area in the vicinity of initial intended open cut workings with no monitoring providing groundwater level at greater depths. Measurements and aquifer tests at the monitoring bores were supplemented by measurements at widely spaced private bores during the bore census. Data loggers were hired for the aquifer tests but were not left in place for longer term monitoring.

At that time there were three multi-level standpipe monitoring nests, two in the open cut area and one in the underground mining area. Each site was screened at three depths over a narrow range (minimum 34 m, maximum 85 m). Since the EIS, these holes have been equipped with permanent sensors and data loggers (since 1 May 2012).

Most of the test intervals for the three monitoring nests were in the coal seams close to subcrop. As there was a lack of permeability data from coal seams or interburden with any significant cover depth, a new monitoring plan was put in place for the SEIS.

Seven new sites have been added to the monitoring network. All sites are equipped with continuously datalogged vibrating wire piezometers (VWPs). In all, there are 25 piezometers at the seven sites, designed to monitor the full stratigraphic section down to the deepest coal seam to be mined. Four of the new sites are situated close to the mining footprint, with two upgradient of the open cut pits in the vicinity of Lagoon Creek, and two downgradient of the open cut pits overlying and adjacent to the underground mines.

There are three far-field monitoring sites. The first is a single-piezometer at Alpha airport to monitor groundwater responses close to the Alpha township. The second is a 5-piezometer hole close to Jericho township. The third has two piezometers in the Clematis Sandstone and Rewan Formation strata of the Great Artesian Basin (GAB), as a check on whether mining effects might reach the GAB.

The EIS included a substantial assessment of groundwater quality across the region. For the SEIS, the earlier work has been supplemented with sampling and analysis of two of the new monitoring sites, and a regional analysis of data extracted from the database of the Department of Natural Resources and Mines (DNRM).

1.2.2 Aquifer Testing

The EIS contained details of aquifer testing conducted on the installed nested piezometers. The quality of the analysis from the aquifer testing was not questioned although with the limited number of test locations, it was difficult to gain a representative impression of the existing conditions with respect to aquifer characteristics. A further deficiency of the testing conducted during the EIS studies was the limited depth range in which tests were conducted. No hydraulic conductivity data were obtained from depths greater than 60 m.

Additional testing of aquifer characteristics was required to provide a robust basis on which to base the property parameters within the groundwater model.

Although further pumping tests were requested, Waratah Coal is of the view that it is more effective to obtain formation permeabilities by means of core laboratory measurements and packer testing than long term pumping tests, as the latter are limited to single depths in high-yielding aquifers. This methodology gives permeability values through the entire stratigraphic column for aquifers and aquitards.

For the SEIS, 21 core samples were collected from four holes for laboratory measurement of permeability, and packer testing has been done on two holes from depths of about 140 m to depths of 265 m and 238 m.

1.2.3 Aquifer Connectivity

With respect to aquifer connectivity matters, the EIS was criticised in the following ways:

- ☐ limited spatial extent of the groundwater monitoring network;
- ☐ limited vertical extent of the groundwater monitoring network;
- ☐ limited nested piezometers (three sites);
- ☐ no hydrographs were presented;
- ☐ limited aquifer testing; and
- ☐ assumptions as to the permeability in the fractured zone above mined longwall panels.

For the SEIS, the monitoring network has been expanded spatially by adding bores distant from the mine footprint as described in Section 1.2.1. Better vertical monitoring has been achieved by installation of up to five VWPs in an individual hole. All seven new holes are being datalogged continuously, and dataloggers were installed also in the three EIS holes. Further aquifer testing throughout the whole stratigraphic column has been done as described in Section 1.2.1.

When underground mining is undertaken, a fractured zone is developed above the mined panels which manifests as subsidence of the land surface. Above the underground mined seams it is likely that the fractured zone will extend to the land surface in places. The formation of the fractured zone will be accompanied by increases in the permeability and porosity of overburden materials. This will promote higher mine inflows and lower groundwater heads.

The new groundwater model (reported herein) tracks the dynamic development of the fractured zone as underground mining progresses. There is unavoidable uncertainty in the permeabilities to be applied to the fractured zone as they cannot be measured directly, and at the greenfield mine project sites in the Galilee Basin there is no history of mine inflows to constrain the permeability estimates. For that reason, a sensitivity analysis is required in the modelling to investigate a range of reasonable permeability options. Normally a ramp function formula is applied. This assumes a log-linear reduction in permeability from the goaf to the estimated top of the fractured zone.

1.2.4 Great Artesian Basin

With respect to GAB matters, the EIS was criticised in the following ways:

- wrong position of the GAB boundary (out by 40 km); and
- inadequate assessment of potential impact on the ecological community listed as *'The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin (GAB)*'.

It is true that the EIS did not have the correct position for the GAB boundary. It appears to have been positioned at the western boundary of the recharge zone, rather than at its eastern boundary. As the GAB was thought, at the time, to be far away, an inadequate ecological assessment was a natural consequence.

The base of the GAB is defined by the Lower Triassic Dunda Beds and Rewan Formation, a thick aquitard unit that lies beneath the Clematis Sandstone, the most easterly outcropping aquifer in the GAB (**Figure 1.1**). The Clematis Sandstone is part of the GAB recharge beds known as the Eastern Recharge Zone. This zone is 60-70 km wide between Barcaldine and the GAB boundary which lies about 20 km east of Jericho.

For the SEIS, a thorough examination of published geological maps and re-interpretation of Waratah Coal boreholes drilled in this area has helped to clarify the position of the geological GAB boundary (as distinct from the administrative boundary) and the proximity of the proposed mine footprint to the boundary (See Issue Response 17038 / 8016 in Part C of the SEIS, Submissions Responses). The western edge of the proposed mine plan is close to the boundary of the Clematis Sandstone and the Dunda Beds, but the GAB boundary is obscured by Quaternary (and Tertiary) cover sediments (**Figure 1.4**). This means that the mine's footprint is designed to pass beneath the GAB's basal aquitard but it is not certain whether or not it will lie beneath the GAB's basal aquifer. The modelling in this report assumes a conservative condition by drawing a straight line between the most easterly Clematis Sandstone outcrops to the north and south of the gap (see Layer 2 hydraulic conductivity zonation in **Attachment B**). This assumption puts the model boundary generally to the east of where the boundary is likely to be (Part C of the SEIS, Submissions Responses), so that a conservative estimate of impacts can be made.

For the SEIS, Waratah Coal drilled two holes through GAB strata for inclusion in the expanded monitoring network. One of the holes, which was 530 m deep and located to the north-east of Jericho, penetrated Quaternary colluvium and several GAB formations (Triassic Moolayember Formation, Triassic Clematis Sandstone, Triassic Dunda Beds and Triassic Rewan Formation). The other hole, due west of planned underground mining, has VWPs installed at 100 m and 130 m in the Clematis Sandstone and the Rewan Formation respectively.

There are mapped recharge springs 30-40 km to the west of the GAB boundary within the recharge zone and also to the west of the recharge zone, in the Barcaldine Spring Complex (**Figure 1.5**). However, these are not the discharge springs that are protected under the EPBC Act which lists the "*community of native species dependent on natural discharge of groundwater from the Great Artesian Basin*" as an endangered ecological community. The coordinates of the nearest recharge springs have been obtained and the spring sites are included in the new groundwater model as sites of specific interest for drawdown assessment. The nearest discharge springs are expected to occur at the western and south-western edges of the GAB many hundreds of kilometres away.

The extent of the new numerical groundwater model has been designed to extend to the west to easting 360000, about 50 km west of Jericho and 65 km west of the nearest planned mining (**Figure 1.5**). The locations of mapped springs between Barcaldine and the mine are included in the model extent.

Groundwater models completed for proposed mines to the north and south of the proposed Galilee Coal Mine (**Figure 1.4**) found maximum westerly drawdown extents of 10 km and 15 km, respectively, within the mined coal seam. Both studies found no predicted impact on the GAB aquifers. This is due primarily to the protection offered by the thick Dunda/Rewan aquitard that separates the basal GAB aquifer from the Permian coal measures. More recent modelling of the South Galilee Project (RPS Aquaterra, 2012) has predicted drawdowns in the Clematis Sandstone but this model does not have a specific model layer for the Dunda/Rewan aquitard.

Drawdown in the deepest mined coal seam is predicted to extend to the west of Jericho and will pass beneath the Clematis Sandstone outcrop, but it is unlikely that there will be any impact on the overlying aquifer and highly unlikely that there will be any impact on the recharge springs. There certainly will be no effect on discharge springs hundreds of kilometres away.

1.2.5 Cumulative Impacts

With respect to cumulative impact assessment, the EIS was criticised in the following ways:

- no quantitative assessment of cumulative impacts on the groundwater resource and groundwater-dependent systems due to planned neighbouring mines; and
- only qualitative comment that there would be "significant overlap between the cones of groundwater drawdown".

For the SEIS, a new numerical groundwater model has been developed to extend between eastings 360,000 and 490,000, and between northings 7,360,000 and 7,480,000. This includes two neighbouring mines and also the regional townships of Alpha, Jericho and Alice where groundwater forms an important component of reticulated water supply. It is noted that the Alpha Coal Project EIS did not include any quantitative assessment of cumulative impacts, but the South Galilee Coal Project groundwater assessment has conducted a quantitative assessment.

With the endorsement of OCG and DNRM, the quantitative cumulative impact assessment was to be based on the *Principle of Superposition,* as an approximation of the combined effects, which permits the algebraic summation of drawdowns reported separately by the other mining proponents (subject to limitations). As the model extent is sufficiently broad to include the two nearest proposed mines, explicit simulation of these mines can be done if necessary, but there will be incomplete knowledge of geological detail and mining sequence for the other projects.

Groundwater models completed for proposed mines to the north and south found maximum westerly drawdown extents of 10-15 km, and easterly extents of about 5 km.

1.2.6 Groundwater Modelling

With respect to groundwater modelling, the EIS was criticised in the following ways:

- ☐ model calibration was limited to steady-state;
- ☐ the geometry of the coal seams in the model was incorrect;
- ☐ contours of predicted drawdowns were not provided progressively for different time periods;
- ☐ predictions of impacts many years after mining ceases were not made, and there was no recognition that the maximum impact might occur after mining ceases;
- ☐ no estimate of the timeframe for equilibration of groundwater levels post-mining was made; and
- ☐ no quantitative assessment was made of cumulative impacts on the groundwater resource and groundwater-dependent systems due to planned neighbouring mines.

For the SEIS, Waratah Coal has instigated development of a new and more extensive groundwater model. The additional exploration drilling that has occurred since the EIS has led to a higher-resolution geological model that has provided an updated structure for the new groundwater model. The target coal seams are included in the model as distinct layers that are separated by interburden layers.

With the endorsement of the OCG, the model development proceeded in two stages. **Stage 1** (presented as an interim report to the OCG in December, 2012) simulated steady-state conditions for worst-case impact prediction at the end of mining (Heritage Computing, 2012). **Stage 2** includes transient calibration and simulation of the transient progression of mining. The results of both Stage 1 and Stage 2 are reported upon herein.

To obtain a hydrographic record for transient calibration, dataloggers were installed in the EIS monitoring bores in May 2012 and the VWP monitoring commenced at various sites from September to November 2012. Stage 2 of the modelling was necessarily delayed until sufficient temporal field measurements were acquired. For this reason, the Stage 1 model was limited to steady-state calibration and steady-state simulation. However, it has been calibrated on a much broader off-site set of groundwater levels than was used in the EIS model.

The issues raised above are addressed by the Stage 2 model. In conformity with standard practice, drawdown maps are displayed at a number of times for a number of layers during the project life. The Stage 2 model includes a recovery simulation (for 200 years) to assess the timeframe for equilibration of groundwater levels, and whether they return to pre-mining levels. Delayed effects on groundwater levels are assessed.

Modelling considered a worst case scenario in the Stage 1 model and more likely scenarios in the Stage 2 model. The Stage 2 report presents the completed results of transient calibration, predictive modelling addressing the issues of uncertainty and model sensitivity, and also provides the updated project impact assessment.

For cumulative impact assessment, the original plan was to apply the Principle of Superposition. This would involve overlaying the drawdown contours reported in the neighbouring Alpha and South Galilee groundwater assessments. In the event, the South Galilee assessment did not present the individual impact of that mine, and the Alpha assessment did not include the effects of a fractured zone. For these reasons, the Principle of Superposition could not be applied. Instead, the Galilee Project model simulated the effects of both neighbouring mines at their maximum extents.

1.3 SCOPE OF WORK

The key tasks for the **Stage 1** assessment were:

- preparation of an interim Groundwater Assessment report for inclusion in the SEIS;
- supplemental characterisation of the existing groundwater environment;
- collation and review of baseline groundwater data including:
  - review of existing groundwater monitoring and assessment reports;
  - review of existing WCPL groundwater monitoring data; and
  - collation of additional data as needed;
- updated groundwater modelling tasks:
  - an updated hydrogeological conceptual model in the light of new data;.
  - design of a new numerical groundwater model that extends sufficiently far to the north and south to include the neighbouring Alpha and South Galilee mines;
  - extension of the model sufficiently far to include the GAB springs (to the west) and water bodies and Alpha township (to the east);
  - gathering of mine plan information on the neighbouring mines from public information or data agreements; and

  - re-building of the groundwater model geometry using the latest geological model based on recent exploration drilling.

The key tasks for the **Stage 2** assessment include:

- preparation of a final groundwater assessment report for inclusion in the SEIS that includes the following:
  - assessment of potential underground mine groundwater impacts and cumulative impacts with other existing and approved mines in the area associated with the proposed mine operation;
  - assessment of post-mining groundwater impacts associated with the proposed mine operation; and
  - assessment of groundwater impacts on the surface water features associated with the proposed mine operation;
- updated groundwater modelling tasks:
  - transient model calibration;
  - transient model prediction, tracking the dynamic mine plan;
  - interrogation of model prediction outputs for key information on potential environmental impacts and possible effects on bore water access for third parties; and
  - a recovery simulation for at least 100 years;
- quantitative cumulative impact assessment for the mines immediately to the north and south of the Project;
- recommended mitigation procedures and "make good" commitments when and where necessary;
- development of measures to avoid, mitigate and/or offset (if necessary) potential impacts on groundwater resources; and
- provision of recommendations for future groundwater monitoring to measure actual impacts on groundwater resources associated with the Project.

The results of both Stage 1 and Stage 2 are presented in this report.

2 LEGISLATIVE BACKGROUND

2.1 LEGISLATIVE FRAMEWORK

The Office of the Coordinator General (OCG) within the department of State Development, Infrastructure and Planning administers the *State Development and Public Works Organisation Act 1971* (SDPWO Act). On 28 November 2008, the OCG declared the Project to be a "significant project for which an EIS is required" under Section 26 of the SDPWO Act. On 20 March 2009 the Australian Government Minister for the Environment, Heritage and the Arts determined that the Project constitutes a "controlled action" under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in view of significant potential impacts on matters of national significance (MNES). The OCG subsequently issued Terms of Reference for the preparation of an EIS in accordance with Part 4 of the SDPWO Act and Part 8 of the EPBC Act.

After submission of the EIS by WCPL, the OCG required a supplementary EIS (SEIS) to be prepared to address comments on the EIS by government agencies and the general public.

The *Water Act 2000* (Water Act) is the primary legislation that regulates the interference with, and extraction of, groundwater in Queensland. Section 19 of the Water Act states that "all rights to the use, flow and control of all water in Queensland are vested in the State," and Section 808 makes it an offence to take, supply, or interfere with water without an authority.

Section 20 of the Water Act lists a number of cases where, despite section 19, taking of water without water entitlement is authorised. Artesian water is not mentioned in Section 20 and therefore authority is always required to take or interfere with artesian water. Although there is no known artesian water within the area of the Project, particular attention is paid to this due to the proximity of the Project to the GAB and the consequent risk of mining having an effect on artesian waters in the GAB.

Groundwater management areas have been established to protect underground water resources. These groundwater areas are referred to in various ways under legislation which includes artesian and subartesian areas, groundwater management areas, management areas, management units and subartesian management areas (*Queensland Water Resources Act, 2009*).

Groundwater areas are also identified in the *Water Resources (Areas and Boards) Regulation 2000* (Water Regulation), and this contains water resource plans which specify management requirements for groundwater. An authorisation is required to access groundwater and/or construct works to take groundwater for certain purposes.

The Project lies mostly within the Highlands Subartesian Area and the area covered by the Water Resource (Burdekin Basin) Plan 2007. The south-western part of the Project is within the Great Artesian Basin Subartesian Area and the area covered by the *Water Resource (Great Artesian Basin) Plan 2006*. The administrative boundary between the two Subartesian Areas is shown in **Figure 1.4**. In places it can differ by as much as 20 km from the GAB geological boundary, identified as the eastern boundary of outcropping Dunda Beds.

2.2 ARTESIAN WATER

Artesian water is water that occurs in an aquifer which, if tapped by a bore, would flow naturally to the surface. The majority of artesian water in Queensland resides within the GAB. Under the Water Act 2000 and Sustainable Planning Act 2009, both a water licence and a development permit are required to take or interfere with artesian water anywhere in the state.

2.2.1 Great Artesian Basin

Under the *Water Act 2000* and *Sustainable Planning Act 2009*, both a water licence and a development permit are required to take or interfere with artesian water anywhere in the state. In the GAB, artesian water and subartesian water connected to artesian water are managed under the *Water Resource (Great Artesian Basin) Plan 2006* and the *Great Artesian Basin Resource Operations Plan* (ROP)

The *Water Resources (Great Artesian Basin) Plan 2006* is the primary legislation for groundwater management of the Great Artesian Basin (GAB) in Queensland. In the ROP, there are 25 'groundwater management areas' and associated 'groundwater management units' in this plan.

2.3 SUBARTESIAN WATER

Subartesian water is water that occurs naturally in an aquifer which, if tapped by a bore, would not flow naturally to the surface.

An authorisation to take subartesian water is only required in:

- a subartesian area declared under Schedule 11 of the Water Regulation, or
- a groundwater management area established under Schedule 4, Schedule 10, Schedule 14 or Schedule 15A of the Water Regulation, or
- a groundwater management area or subartesian management area established under a water resource plan, or
- a subartesian management area under a wild river declaration.

2.4 OTHER POLICIES AND GUIDELINES

The following additional technical policies and guidelines have been considered during the undertaking of this study:

- ☐ National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Agriculture and Resource Management Council of Australia and Australian and New Zealand Environment and Conservation Council [ARMCANZ/ANZECC]);
- ☐ Queensland Water Quality Guidelines (QWQG);
- ☐ Murray-Darling Basin Groundwater Quality. Sampling Guidelines. Technical Report No 3 (Murray-Darling Basin Commission [MDBC]);

- ☐ MDBC Groundwater Flow Modelling Guideline (2001); and
- ☐ Australian Groundwater Modelling Guidelines (2012).

The *Environmental Protection Policy (Water) 2009* states that sampling and analysis must comply with the Queensland Water Quality Guidelines (QWQG) as these take precedence over other recognised guidelines. The QWQG indicate that the Project falls within the Central Coast Queensland region and the relevant water types are upland streams for which ANZECC 2000 guidelines are to be adopted. Although the QWQG and ANZECC guidelines are predominantly focused on the protection of surface waters, in the absence of specific guidelines for groundwater quality these have been adopted as a way to assess groundwater quality.

2.5 IMPLICATIONS FOR THE PROJECT

The Project is located mainly within the Highlands Subartesian Area and partly within the GAB Subartesian Area. An authority is required to take or interfere with groundwater for purposes including mine water supply bores and mine dewatering. The Project will require a licence for dewatering of the proposed mine. An authority is currently not required for bore construction or water take from subartesian stock or domestic bores.

The assessment of environmental impacts on the groundwater environment is the key focus of this study with approvals sought via the EIS process. Approval would result in an Environmental Authority (EA) for the Project. Provisional to an EA would be various management conditions which would include monitoring of potential impacts, assessing effects of the Project operations against predicted impacts, and the reporting of any impacts to appropriate agencies. The EA would also include conditions that would ensure that any environmental impacts from mine dewatering will be mitigated, as the rights of existing groundwater users are protected under the provisions of the Water Act.

The eastern boundary of the geological GAB, designated by the subcrop line of the Rewan Formation and overlying Dunda Beds, occurs in the western portion of the Project area (**Figure 1.4**). The geological boundary is obscured by Quaternary colluvial cover in the south-western quadrant of the Project area.

The northern half of the Project is entirely within the Highlands Subartesian Area but a portion lies within the geological GAB (**Figure 1.4**). The southern half of the Project is within both Subartesian Areas in almost equal share but only a small part lies within the geological GAB.

3 HYDROGEOLOGICAL SETTING AND CONCEPTUALISATION

3.1 RAINFALL AND EVAPORATION

The nearest long term meteorological stations are located at Barcaldine and Alpha Post Offices. Barcaldine Post Office (36007) and Alpha Post Office (35000) have rainfall data collected from 1886 to present. Barcaldine Post Office is located approximately 40 km to the south-west of the Project and Alpha Post Office is located approximately 35 km to the south-east of the Project. Long-term rainfall data for these stations are provided in **Table 3.1**.

The annual rainfall at the Barcaldine and Alpha sites exhibits a moderate seasonal pattern with the highest mean rainfall occurring during the summer months and lower rainfall in winter months. Rainfall trends over recent years have been analysed by means of residual mass analysis (cumulative deviation from the mean) (**Figure 3.1**).

The closest pan evaporation data (at Emerald) are given in **Table 3.1**. There is a clear annual rainfall deficit and potential evaporation exceeds rainfall for all months of the year. Occasional recharge could occur at any time of year following prolonged, heavy rains.

Table 3.1 Monthly Average Rainfall and Evaporation

Month	Monthly Average Rainfall (mm)		Monthly Average Pan Evaporation (mm)
	Barcaldine Post Office (36007) (1886 to present)	Alpha Post Office (35000) (1886 to present)	Emerald
January	86.9	96.2	177.5
February	78.2	88.3	151.9
March	60	61.3	150.3
April	36.5	34.6	148.3
May	31	29.5	116.4
June	24.5	30.7	100.7
July	22.8	24.2	110.1
August	15.8	19.4	159.6
September	16	21.3	194.6
October	29	35.5	239.7
November	40.4	49.8	138.2
December	64.2	76.5	243.6
Annual Average	**505.3**	**558.3**	**1930.9**

Source: Bureau of Meteorology (BoM) (2012).

The actual evapotranspiration (ET) in the district is about 520 mm per annum according to BoM (2009). This is commensurate with average annual rainfall. The definition for actual ET is: *"... the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average. For example, this represents the evapotranspiration which would occur over a large area of land under existing (mean) rainfall conditions*."

Natural fluctuations in the groundwater table result from temporal changes in rainfall recharge to groundwater systems. Typically, changes in groundwater elevation reflect the deviation between the long-term monthly (or yearly) average rainfall, and the actual rainfall, often illustrated by the rainfall Residual Mass Curve (RMC).

If rainfall recharge is a significant source of water, the groundwater levels recorded during periods of rising RMC are expected to rise while those recorded during periods of declining RMC are expected to decline. RMC plots using rainfall data from Barcaldine and Alpha weather stations are shown in **Figure 3.1** for the past decade. These plots suggest that the district has experienced a long dry period from 2002 to 2008, with fairly normal weather until 2010, at which time conditions became much wetter.

3.2 TOPOGRAPHY

The Project is located in the Galilee Basin in the central Queensland region where landforms in the project area are characterised by gently undulating plains. To the west of the Project area, undulating foothills form the most prominent topographic feature in the vicinity of Spring Creek, with ridges and escarpments of the Mount Royal Range and Great Dividing Range farther to the west.

Elevations in the vicinity of the Project range from approximately 350 m Australian Height Datum (AHD) at Tallarenha Creek to approximately 400 m AHD at the western margins of the proposed mining operation. The topographical high west of Spring Creek is approximately 500 m AHD. An overview map of the regional topography is shown in **Figure 3.2**.

Land use in the vicinity of the Project is characterised by a number of forms including agricultural land uses with cleared grazing land and remnant open woodland and associated vegetation. The main local land use is beef cattle production, which can tolerate salinity up to 4,000 mg/L (ANZECC & ARMCANZ, 2000). There is little prospect for groundwater-based irrigation due to salinities in excess of limits for all but very tolerant crops.

3.3 HYDROLOGY

The Project is situated within the Belyando Catchment, one of the largest sub- catchments of the Burdekin River Basin. The western edge of EPC 1079 drains to the Cooper Creek Basin. The many braided, generally ephemeral, watercourses in the district are indicated on **Figure 3.3**.

The primary drainage paths through the Project area are Beta and Tallarenha Creeks which originate to the south of the MLA and flow northwards through the southern parts of the MLA; and Lagoon Creek which commences at the junction of Beta and Tallarenha Creeks and flows northwards through the northern parts of the MLA. Lagoon Creek joins with Sandy Creek about 22 km north of the Project, which then discharges into the Belyando River a further 32 km downstream. Lagoon Creek will be diverted into Saltbush Creek as part of the Project. Malcolm Creek, which crosses the site in a west to east direction, will also be diverted.

The south-western corner of the MLA drains to a tributary which flows westwards into Jordan Creek approximately 10 km to the west of the MLA. Jordan Creek flows to the north-west and discharges into Alice River.

There are no stream flow gauging stations within the Project site. Stream gauges are installed and monitored on Native Companion Creek about 30 km east of the Project and on Mistake Creek about 60 km to the west. The mean annual flows at the two creeks are about 58,000 ML/a and 800 ML/a respectively, while the 10th percentile flows are about 1,700 ML/a (4.7 ML/day) and 22 ML/a (0.06 ML/day) respectively.

According to the Waratah Coal Environmental Management Plan, the receiving waterways of the Galilee Coal Mine are considered to be:

- ☐ Lagoon Creek downstream of the Project to the east;
- ☐ Sandy Creek downstream of the Lagoon Creek confluence to the north-east;
- ☐ Belyando River downstream of Sandy Creek confluence to the north;
- ☐ An un-named tributary of Jordan Creek downstream of the Project to the south-west; and
- ☐ Jordan Creek downstream of Project to the west.

According to the Waratah Coal Environmental Management Plan: "*The receiving waterways of the Galilee Coal Mine are ephemeral in nature and provide seasonal habitat for aquatic fauna and flora. Wetlands mapping for the receiving waterways ... indicates the presence of wetlands or remnant ecosystems that may contain wetlands along sections of all receiving waterways. The receiving waterways are considered to be slightly to moderately disturbed from current grazing activities and do not contain any High Ecological Value waters*".

3.4 STRATIGRAPHY AND LITHOLOGY

The Project is situated within the Galilee Basin, a Permian geological basin in central Queensland located west of the Surat Basin and immediately east of part of the GAB drainage basin.

The Galilee Basin is a large intra-cratonic basin filled with mostly fluviatile sediment. It covers about 250,000 km^2 of central Queensland and is connected to the Bowen Basin over the Springsure Shelf (south-east of Alpha).

The surficial geology in the vicinity of the Project, shown in **Figure 3.4**, is dominated by unconsolidated Cainozoic (Quaternary and Tertiary) sediments. Unconsolidated sands, silts and clay, partly lateritised in the Tertiary, form an extensive blanket over the Project area, with thickness of up to 90 m in the eastern and central sections. Recent (Quaternary) alluvial deposits are associated with major drainage pathways.

Beneath the Cainozoic sediments are weathered remnant Tertiary volcanogenic material, Triassic sedimentary sequences and Permian coal measures. **Table 3.2** shows the stratigraphic units relevant to the Project area and **Figure 3.5** shows the stratigraphic sequence in a regional context.

Table 3.2 Stratigraphy of the Project Area

Age	**Formation**	**Lithology**	**Code (Figure 1.1)**
Quaternary		Alluvium, some gravel	Qa
Quaternary		Colluvium: sand, gravel, rubble	Qs
Tertiary		Argillaceous sandstone, sandy mudstone, limestone; partly lateritised	T, Tb
Middle to Upper Triassic	Moolayember Formation	Mudstone, sandstone, siltstone, shale	Rm
Lower to Middle Triassic	Clematis Sandstone	Quartz sandstone, shale layers, minor siltstone and mudstone	Re
Lower Triassic	Dunda Beds	Labile sandstone, siltstone, mudstone	Rld
Lower Triassic	Rewan Formation	Mudstone, siltstone, sandstone	Rlr
Upper Permian	Bandanna Formation	Siltstone, sandstone, coal	Puw, Pup
Lower Permian	Colinlea Sandstone	Labile and quartz sandstone, minor siltstone, coal	Plo
Upper Carboniferous to lower Permian	Joe Joe Group	Mudstone, sandstone, siltstone, shale	CPj

The Quaternary alluvial and colluvial deposits overlie unconformably Triassic and Permian erosional surfaces. Over the eastern part of the Project area, these deposits rest directly on Permian rocks. This contact is erosional in part and represents an extensive unconformity.

To the west of the Project area, alluvial and colluvial deposits cover Triassic GAB formations.

The Tertiary sedimentary sequence is limited to a narrow band adjoining the GAB boundary. The Tertiary flood basalts that feature in the cover sequence in parts of the Bowen Basin are absent from this part of the Galilee Basin.

3.4.1 Great Artesian Basin

The intake beds of the GAB in Queensland form a continuous arc, 50-100 km wide, stretching from east of Goondiwindi through to the top of Cape York, and are located on the western slopes of the Great Dividing Range. In the Jericho region, only the basal GAB formations are present, namely the Hutton Sandstone, Moolayember Formation, Clematis Sandstone, Dunda Beds and Rewan Formation.

The Dunda Beds and Rewan Formation overlie Permian coal measures with an unconformable contact and consist of greenish sandstones and siltstones with some shale layers. It is recognised as a regional aquitard and to a large degree hydrogeologically separates the GAB sediments from the underlying coal measures.

Overlying the Dunda Beds is the Clematis Sandstone, a medium to coarse-grained quartzose to sub-labile, micaceous sandstone, siltstone, mudstone and granule to pebble conglomerate. This is the key formation that accepts rainfall recharge into the GAB. Farther west are outcrops of the Middle to Upper Triassic Moolayember Formation and the Lower Jurassic Hutton Sandstone.

3.4.2 Permian Coal Measures

The coal measures are Permian aged sediments which contain numerous coal seams and associated splits. These are separated by interburden comprising interbedded sandstones and laminated mudstones and siltstones.

In the Project area, the target coal seams are located within the Bandanna Formation and Colinlea Sandstone. This stratigraphy correlates with some of the Bowen Basin's Group IV Permian Rangal Coal Measures.

The coal resource is found in five principal seams with other subordinate coal horizons present. The identified coal seams from shallowest to deepest are allocated the alphabetical sequence used by previous explorers of the area (A, B, C, D and E). Further sub-division of the seams has occurred during WCPL's exploration phase:

- ☐ the top ply of the C seam is recognised but not considered economic due to high ash (C Upper 'CU');
- ☐ the D seam is typically found in two splits - D Upper ('DU') and D Lower ('DL'); and
- ☐ the DL seam is further divided into two splits, DL1 and DL2.

The A seam is typically about 1 m thick, with the thickest intersection recognised so far being around 2 m in the weathered zone in the southern part of the Project area. Due to dip and subcrop geometry, the A Seam occurs only in the far west of the Project area. The A seam tends to be poorly developed and contains considerable carbonaceous shale/mudstone partings.

The B seam is the thickest of the seams in the Project area, typically reaching about 6 m thickness. The B Seam is banded with tuffaceous carbonaceous mudstones. The B8 ply, the target seam for one of the underground mines (UG4), has an average thickness of 2.7 m.

The C Seam thickness ranges from 1 to 3 m in the Project area.

The D Upper (DU) seam lies approximately 10 to 15 m below the C seam. It has fairly uniform thickness with an average of 2.5 m. The DU seam carries some thin stone bands in the mid-section but is generally clean. The DU seam has very sharp roof and floor definition. The DU seam is the target seam for underground mine UG1.

The D Lower (DL) seam exists as the DL1 and DL2 splits, residing within 0.2 to 0.4 m of each other. The separation between these splits is occupied by a carbonaceous mudstone. The DL1 seam is around 0.7 to 0.9 m thick and the DL2 seam is 1.6 to 2.1 m thick. At underground mine UG2, the DL2 seam has an average thickness of 2.0 m. At underground mine UG3, the combined DL1-DL2 seam also has an average thickness of 2.0 m.

The A to D seams are included within the Bandanna Formation (Upper Permian) and the E and F seams reside in the Colinlea Sandstone (Lower Permian) (**Figure 3.6**).

The combination of a very gentle westerly dip (1-2 degrees) and subdued topography creates relatively broad subcrop zones for each seam. Additionally, the B and C intervals are separated by a 90 m sandstone (vertical thickness); this separation and the dip surface geometry causes two north-south orientated bands of seam subcrop; the A and B in the west and the C to DL in the east. The E and F Seams subcrop farther east, the seam limits often influenced by deeply incised alluvial channels associated with drainage along Lagoon Creek and Sandy Creek. The full C-F sequence continues unbroken under the A and B subcrop zone and all seams continue down-dip. Previous drilling has identified a recognised continuum of the seams down-dip for at least 30 km to the west and to over 1,000 m cover at their deepest locations.

The Joe Joe Group which is Late Carboniferous to early Permian in age lies stratigraphically below the Colinlea Sandstone. It includes conglomerates, lithic sandstone, siltstone and minor mudstone and coal. The Joe Joe Group includes the Aramac Coal Measures Formation, Jericho Formation, Oakleigh Siltstone, Jochmus Formation, Edie Tuff and the Lake Galilee Sandstone. The Joe Joe Group is the lowest stratigraphic unit considered in this assessment. It is flanked to the east by the Lower Carboniferous Drummond Group.

3.4.3 Structural Geology

The Permian coal measures generally dip at approximately 1-2 degrees to the west with no recognised structural complexity. Regional geological mapping has detected no major structural features in the area.

3.5 HYDROGEOLOGY

The hydrogeological regime of the Project area and surrounds comprises two main groundwater systems:

- a Quaternary alluvial groundwater system of channel fill deposits associated with various drainages; and
- underlying Permian strata of low yielding sandstone, low permeability siltstone and moderately permeable coal seams.

3.5.1 Alluvial Aquifers

Groundwater flow patterns within the shallow alluvial aquifer reflect topographic levels and the containment of alluvium within the principal drainage pathways. These are to a large degree independent of the underlying Permian hard rock fractured aquifers although contribution from these deeper aquifers may occur where and if upward leakage occurs. In most cases a perched water table is expected in the alluvium. It is likely that the alluvium has a role in supplying recharge to the underlying Permian strata as well as contributing to baseflow of surface water features after high flows by releasing water from bank storage.

3.5.2 Permian Aquifers

The piezometric surface within Permian aquifers in the Project area most probably also reflects topography, as does the water table, with elevated water levels/pressures in areas distant from the major drainages and reduced levels in areas adjacent to the alluvial lands.

The Permian aquifer system within the Project area is continuous through the major geological formations. The various sedimentary rocks have low permeability due to their fine-grained nature, the predominance of cemented lithic sandstones and the common occurrence of a clayey matrix in the sandstones and conglomerates. The permeability of the aquifer system is controlled by joint spacing and aperture width and in some units by primary porosity. Permeability of the rock units generally decreases with depth of burial as the joints tighten and become less frequent, with higher permeabilities expected in the coal seams due to cleating. The coal seams are generally more brittle and therefore more densely fractured than the overburden and interburden strata, with groundwater flow predominantly through cleat fractures. Due to the laminar nature of the coal measures, groundwater flow generally occurs within, or along the boundaries between, stratigraphic layers.

The laminated fabric of the interbedded sandstone/siltstone/mudstone strata suggests that vertical hydraulic conductivities are significantly lower than horizontal hydraulic conductivities.

3.6 GROUNDWATER MONITORING

Groundwater monitoring for the Project is undertaken from an installed monitoring network with the objective of establishing baseline groundwater level and quality data that provides evidence for the response of the groundwater systems to natural and induced stresses. The groundwater monitoring network currently consists of 10 monitoring sites shown in **Figure 3.7** and summarised in **Table 3.3.** Bore logs are included in **Attachment D**.

Groundwater quality sampling has been undertaken by WCPL in accordance with AS/NZS 5667.11:1998 – Guidance on Sampling of Ground Waters. Samples are measured in the field for acidity (pH), electrical conductivity (EC) and temperature.

The groundwater monitoring network consists of three multi-level standpipe monitoring nests, two in the open cut area and one in the underground mining area, and seven sites equipped with continuously datalogged multi-level vibrating wire piezometers (VWPs). There are 25 piezometers at the seven sites, designed to monitor the full stratigraphic section down to the deepest coal seam to be mined.

Sensors have been installed in Triassic and Permian formations, and two holes monitor GAB formations, as listed in **Table 3.3**. Standpipe water levels have been monitored continuously from May to September 2012, and are supplemented by manual measurements in 2010 for the EIS. The VWP continuous measurements date from September 2012 (for 2 holes), October 2012 (for 3 holes) and November 2012 (for 2 holes).

Table 3.3 Groundwater Monitoring Sites

Monitoring Site	Parameters Monitored	Lithology Monitored	Monitoring Frequency
WA3815	• Groundwater level • Groundwater quality	Weathered Permian B-C Interburden B Seam	May 2010; continuous from 1 May to 19 September 2012
WA4213	• Groundwater level • Groundwater quality	Weathered Permian DU Seam DL Seam	May 2010; continuous from 1 May to 19 September 2012
WA4415	• Groundwater level • Groundwater quality	Weathered Permian DL Seam	May 2010; continuous from 1 May to 19 September 2012
WBR1	• Groundwater pressure	Joe Joe Formation	Continuous [from 27 October 2012]
WBR2	• Groundwater pressure	Bandanna Formation Colinlea Sandstone C-D Interburden	Continuous [from 2 November 2012]
WBR3	• Groundwater pressure	Joe Joe Group	Continuous [from 28 September 2012]
WBR4	• Groundwater pressure	Colinlea Sandstone Joe Joe Group	Continuous [from 27 October 2012]
WBR5	• Groundwater pressure	Rewan Formation Bandanna Formation C and DL Seams	Continuous [from 27 October 2012]
WBR6	• Groundwater pressure	Clematis Sandstone Rewan Formation	Continuous [from 2 November 2012]
LP01	• Groundwater pressure	Clematis Sandstone Rewan Formation Bandanna Formation B Seam	Continuous [from 24 September 2012]

Seven multi-level vibrating wire piezometers were installed in 2012. The vibrating wire piezometers were installed into exploration holes located within the project area and at Lagoon Park just to the north-east of Jericho. Each piezometer was installed with transducers targeting coal seams and interburden units to monitor groundwater pressures in coal measures within the Bandanna Formation and Colinlea Sandstone and also in the overlying Clematis

Sandstone and Rewan Formation. The piezometers were located in the B, C and D coal seams and also within selected interburden units.

VWP details are provided in **Table 3.4**.

Table 3.4 Vibrating Wire Piezometers

Bore	Coordinates		Date Completed	Piezometer Depth	Formation	Water Level – December 2012 (m AHD)
	Easting	Northing		(m)		
WBR1	457938	7385076	13/9/2012	60	Joe Joe Group	334.4
WBR2	433124	7412161	14/9/2012	84	Bandanna Formation	323.9
				103	Bandanna Formation	345.4
				162	Colinlea Sandstone	326.7
				178	Colinlea Sandstone	318.7
				215	C-D Interburden	318.1
WBR3	446326	7415146	16/02/2012	47	Joe Joe Group	316.1
				70	Joe Joe Group	328.4
				110	Joe Joe Group	323.7
WBR4	442422	7404026	18/9/2012	30	Colinlea Sandstone	316.2
				47	Colinlea Sandstone	297.2
				70	Joe Joe Group	329.2
				115	Joe Joe Group	314.9
WBR5	431807	7405329	20/9/12	72	Rewan Formation	328.5
				123	Bandanna Formation	345.4
				142	Bandanna Formation	325.8
				205	C Seam	327.7
				227	DL Seam	322.8
WBR6	423309	7408167	1/11/2012	100	Clematis Sandstone	344.1
				130	Rewan Formation	345.8
LP01	413851	7389779	6/5/2012	150	Clematis Sandstone	319.2
				225	Rewan Formation	318.7
				330	Bandanna Formation	313.0
				400	Bandanna Formation	307.6
				470	B Seam	313.8

In 2009-2010, multi-level VWPs were installed at 26 sites within the Alpha Coal Project area monitoring 72 horizons with the number of VWP transducers installed in each hole ranging from one to four (URS, 2012).

3.7 BASELINE GROUNDWATER LEVEL DATA

3.7.1 Spatial Groundwater Levels

A regional contour map of representative shallow groundwater levels has been prepared from recent measurements, supplemented by estimates along drainage lines (**Figure 3.8**). Where multiple measurements were available, only the shallowest head has been used to give a better approximation to the water table. The measurements differ in the time of acquisition, but measurements to date suggest that natural water levels do not vary much with time.

The sources of data for **Figure 3.8** are:

- 21 Galilee Coal Project water levels (average 320.6 mAHD);
- 31 Alpha Coal Project water levels (average 293.7 mAHD);
- 15 South Galilee Coal Project water levels (average 342.1 mAHD);
- 79 DNRM registered bore water levels (average 336.7 mAHD);
- 42 GAB recharge springs (average 357.7 mAHD); and
- groundwater table levels beneath drainage lines (average 333.8 mAHD) based on an empirical relation between depth to water and creek stage:
    - Depth = 0.635 * exp (0.01 Stage)

The regional groundwater system is dominated by two parallel groundwater divides, one associated with the recharge springs and the other corresponding with the GAB Clematis Sandstone recharge zone along the western edge of the Project.

Shallow groundwater flow is generally to the east across the Project site, but the flow direction rotates to the north along the Lagoon Creek and Sandy Creek drainages at the eastern edge of the Project site. Groundwater flow across the South Galilee Coal Project is north-easterly to northerly, while for the Alpha Coal Project it is easterly to north-easterly.

The depth to the regional (not perched) water table is generally a minimum of about 10 m along the drainages, increasing to the order of 100 m beneath the Clematis Sandstone ridge. Across the project site the range is generally 20-60 m.

Although the spatial information for groundwater flow in the Permian formations is more limited, an indication of flow directions is presented in **Figure 3.9** for the B Seam and overburden, and in **Figure 3.10** for the DU and DL Seams and interburden. Measurements to date suggest a pattern sympathetic with the shallower groundwater system but with much less pronounced mounding beneath the ridges. Flow across the three Coal Project sites appears to be north-easterly, tending more northerly with distance to the north. There is a groundwater divide associated with the Great Dividing Range. Heads tend to decrease with depth but the head gradient from the B Seam to the DU/DL Seams is not pronounced.

The pressure head depth profiles at the VWP Project sites are shown in **Figure 3.11**. As all lines are roughly parallel with the hydrostatic pressure line, there is no significant upwards or downwards flow occurring at the monitored sites under natural pre-mining conditions. The offset of each profile from the dashed hydrostatic line is an indication of water table depth at each site. The water table depth can be inferred by extrapolation of each profile to the point of zero pressure head. This reveals the shallowest water tables (about 10 m) at WBR3 and WBR4, which both lie upgradient of the open cut pits to the east of the Project. The deepest site water tables (50-60 m) occur at WBR2 and WBR5, the two downgradient sites in the middle of the proposed mine footprint. Site LP01 near Jericho has an intermediate depth (35 m), WBR1 at Alpha airport is expected to have a watertable depth of about 45 m, and the VWP data at WBR6 in GAB sediments suggest a depth to water of about 80 m.

3.7.2 Temporal Groundwater Levels

Groundwater hydrographs at three standpipe monitoring bores are shown in **Figure 3.12**, compared with rainfall trends indicated by the residual mass curve since 2010. Readings taken from May to September 2012 have been very stable and display no apparent response to varying rainfall. Current water levels are similar but a little lower than those measured in 2010.

The hydrographs at the seven VWP holes are displayed in **Figure 3.13** to **Figure 3.19**. In most cases the VWP readings have not stabilised. As there is no correlation with rainfall trends, and there is no other hydraulic stress on the groundwater system, the temporal variations of several metres at many sites must be due to slow stabilisation of the piezometers in the grouted holes.

There is not always a consistent variation of head with depth. A monotonic change would be expected, with heads declining with depth near recharge areas and heads rising with depth near discharge areas. For example, **Figure 3.15** shows the responses at three depths for hole WBR3 upgradient of the proposed open cut pits. As the depth to the regional water table near this hole was determined to be about 10 m from pressure head analysis in Section 3.7.1 (**Figure 3.11**), the elevation of the water table would be about 331 mAHD. This is consistent with the heads measured with the 70 m piezometer, but the shallowest and deepest piezometers have heads that are 7-11 m lower and 6 m lower, respectively, than would be expected if no vertical flow were occurring. At the shallowest piezometer (47 m depth), the groundwater head has varied from 18 m to 22 m below ground over four months.

The less reliable hydrographs are drawn with a dashed line in **Figure 3.13** to **Figure 3.19**. This assessment of data quality is implemented during model calibration by imposing corresponding weights (from 0 to 1) to each measurement as a control on its contribution to information about the groundwater system.

The groundwater hydrographs reported by URS (2012) for the Alpha Coal Project show similar heads across most formations in an individual hole, usually with no more than 1-2 m head difference vertically. As there is no obvious rainfall signature in any of the hydrographs, the natural rainfall recharge (at the monitored sites) must be very low and/or the accretion of rainfall at the water table is significantly delayed due to substantial depths to water. Two holes (AVP-11 and AVP-13) located in the western part of the mine lease reveal head differences of about 10 m; however, one site suggests upwards flow while the other indicates downwards flow. Overall, water pressures in the hydrographs are static.

3.8 GROUNDWATER CHEMISTRY

Groundwater quality was assessed during the original EIS conducted by E3 Consulting in 2010.

3.8.1 EIS Groundwater Quality Summary

Tertiary groundwater within the study area is dominated by sodium cations and chloride anions. The Tertiary aquifers within the study area are generally slightly brackish, pH neutral, contain low concentrations of trace metals, and in a few instances show elevated nutrient concentrations. The likely cause of the increased nutrient loading may be due to farming practices or general nitrogen movement in shallow systems.

Water of the Permian aquifers is dominated by chloride anions, sodium and potassium cations and is classified as sodium - chloride waters. The pH of Permian aquifers is near neutral ranging from slightly acidic to slightly alkaline. Trace metals occur in low concentrations. The water quality within the Permian aquifers is likely to reflect the age of the water and the characteristics of the aquifer material. The Permian aquifers are most permeable in and around the various coal seams.

The GAB and associated aquifers reported water quality dominated by sodium and potassium cations and chloride and bicarbonate anions. These are classified as sodium – calcium and chloride–sulfate–bicarbonate waters and are characterised by neutral to slightly acidic pH, with slightly elevated levels of trace metals. The cation-anion results reflect reports by GABCC (2009), which state that the GAB aquifers are generally sodium bicarbonates with chloride and minor carbonate.

3.8.2 SEIS Groundwater Quality Assessment

Further assessment of groundwater quality which builds on the earlier work for the Project includes data gathered during the original EIS study. The SEIS study has collated information recorded in the DNRM groundwater database and recent groundwater investigations where groundwater samples were gathered at the time of drilling and installation of vibrating wire piezometers.

Assessments of groundwater quality can be useful in understanding conceptual hydrogeology, particularly by use of electrical conductivity (EC) and major ions using Piper and Schoeller diagram plots. Groundwater salinity (indicated by EC) tends to be low in areas of high recharge or connectivity with surface waters.

Table A1 in **Attachment A** shows major ion concentrations for DNRM data from registered bores within 10 km of the Project area, airlift samples gathered during the drilling program to install VWPs and the previous EIS data. Piper and Schoeller diagrams are shown as a method of graphically presenting this data.

Major ion chemistry can assist with comparing natural waters to identify whether they are derived from the same or different sources, or mixtures of sources. Piper Trilinear and Schoeller Diagrams are useful for this purpose, as they enable groundwater samples to be plotted as a unique point or a profile on the basis of the relative concentrations of the major ions typically found in solution.

The Piper diagram plots the major ions as percentages of milli-equivalents (meq) in two base triangles. The total cations and the total anions are set equal to 100% and the data points in the two triangles are projected onto an adjacent grid. This plot reveals useful properties and relationships for large sample groups. The main purpose of the Piper diagram is to show clustering of data points to indicate samples that have similar compositions.

Figure 3.20 shows that groundwater in the wider Project area is generally of a Sodium - Chloride type. However, a linear trend can be seen in the cations migrating from a Sodium dominance towards a Calcium – Magnesium signature and in the anions, migrating towards a Bicarbonate signature. A higher Calcium – Magnesium - Bicarbonate signature tends to indicate a recharge component to groundwater while Sodium - Chloride type tends to reflect an end product, older groundwater type. While no samples show dominant Bicarbonate water type, a mixing trend can be inferred. The DNRM data illustrates this trend due to broad coverage across different water types.

A Schoeller Diagram is a semi-logarithmic plot of the concentrations of the major ionic constituents in groundwater, expressed in milliequivalents per litre (meq/L). These diagrams have the advantage of showing absolute concentrations at the same time as comparing ionic ratios. If the lines joining adjacent points are parallel from one bore to another, their ionic ratios are the same. The particular shape of connected lines between each ionic concentration can show similarity or dissimilarity of the water's origin or mixing of waters of different origin.

These diagrams in **Figure 3.21** show a general progression from sodium-chloride groundwater within the Permian strata and colluvium through to a calcium-bicarbonate type within the more actively recharged alluvium. This reflects a progression from old, mineralised groundwater with low rainfall recharge in the Permian and colluvium, to more recent rainfall influenced groundwater within the alluvium that is hydraulically connected to the creeks. Most plots show an almost identical signature with ionic ratios uniform across most sites. The absolute magnitudes cover two orders of magnitude.

Groundwater quality database records in the vicinity of the Project have the following characteristics:

- 143 DNRM records within the model domain have records of EC;
- the EC for this data set ranges from 135 µS/cm to 62,000 µS/cm;
- the mean EC is 4372 µS/cm but the data set is heavily skewed to higher values as the median is 945 µS/cm; and
- of the 143 bores within the DNRM sample set with groundwater quality data, only 27 have recorded pH values; most values are near neutral and range from 5.6 to 8.6 with an average of 7.3.

Figure 3.22 illustrates the distribution of recorded DNRM EC data and this shows that the higher salinity groundwater tends to occur at or east of the Colinlea Sandstone subcrop and most probably indicates the influence of the Joe Joe Group.

3.9 HYDRAULIC PROPERTIES

Previous studies and investigations within the region and additional aquifer testing for the Project have provided an appreciation of the order of magnitude of hydraulic properties of geological formations in the vicinity of the Project.

For the SEIS, core samples were collected from four holes for laboratory measurement of permeability, and packer testing has been done on two holes. Additional information is available from the EIS groundwater investigation (E3 Consulting, 2011) and the Alpha Coal Project groundwater investigation (URS, 2012).

3.9.1 Core Testing for Hydraulic Conductivity

Core samples from interburden horizons were selected from core maintained by WCPL for laboratory testing of vertical (Kz) and horizontal (Kx) hydraulic conductivity. Drill holes sampled included SK04, SK05, SK06 and SK07 (**Figure 3.7**)[1]. The locations of the holes and the intervals sampled are listed in **Table 3.5**. The formations sampled were:

- ☐ Rewan Formation;
- ☐ Bandanna Formation;
- ☐ Colinlea Sandstone; and
- ☐ Lower Jochmus Formation (Joe Joe Group)

A total of 21 horizons were sampled and tested for vertical (Kz) and horizontal (Kx) hydraulic conductivity. Of the 42 hydraulic conductivity tests, there were two test failures caused by parting of laminated surfaces. Porosity measurements were also included on a subset of four of these samples.

Compiled results are listed in **Table 3.6**. Laboratory core testing provides a means of assessing the hydraulic conductivity of materials at an inter-granular scale where porous media flow is the primary mechanism of groundwater flow. It does not account for secondary mechanisms of flow (fracturing) which tend to dominate the movement of groundwater within the rock mass, and therefore this estimate is typically the lowest tenable hydraulic conductivity and is most representative of strata where fracturing and jointing are absent or disconnected. For Kx the appropriate average is the arithmetic mean; for Kz it is the harmonic mean.

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[1] Holes SK06 and SK07 are off the southern edge of the map at 35 km and 27 km south of the Alpha-Jericho road, due south of the Project

Table 3.5 Core Samples for Laboratory Tests

Hole	Easting	Northing	From (m)	To (m)	Formation
SK04	435285	7418932	35.90	36.00	Rewan
			65.40	65.50	Bandanna
			66.30	66.40	Bandanna^
			122.50	122.60	Bandanna
			139.70	139.80	Bandanna
			170.00	170.10	Bandanna^
			197.15	197.25	Colinlea^
SK05	426723	7438819	49.60	49.70	Rewan
			101.55	101.65	Bandanna
			182.50	182.60	Bandanna^
			238.70	238.80	Bandanna
			315.40	315.50	Colinlea
SK06	447681	7350725	185.70	185.80	Lower Jochmus
			203.70	203.83	Lower Jochmus
			260.90	261.03	Lower Jochmus
			298.20	298.30	Lower Jochmus
SK07	443850	7359379	29.60	29.70	Rewan
			31.60	31.70	Rewan
			112.55	112.65	Bandanna
			143.50	143.60	Bandanna
			203.60	203.70	Bandanna

^ Total porosity measurement

Table 3.6 Hydraulic Conductivity Core Test Results

Formation	Hydraulic Conductivity (m/day) Arithmetic Mean	Hydraulic Conductivity (m/day) Harmonic Mean	No. of Samples	Maximum Hydraulic Conductivity (m/day)	Minimum Hydraulic Conductivity (m/day)
Horizontal Hydraulic Conductivity					
Rewan	2.3 x10^{-03}	1.3 x10^{-04}	3	4.3 x10^{-03}	4.5 x 10^{-05}
Bandanna	3.9 x10^{-04}	2.9 x10^{-06}	10	2.2 x10^{-03}	5.1 x 10^{-07}
Colinlea	1.3 x10^{-01}	5.1 x10^{-04}	2	2.5 x10^{-01}	2.6 x10^{-04}
Lower Jochmus	1.5 x10^{-01}	1.3 x 10^{-05}	4	5.8 x10^{-01}	3.3 x 10^{-06}
Vertical Hydraulic Conductivity					
Rewan	2.8 x10^{-03}	2.3 x 10^{-05}	4	1.1 x10^{-02}	7.5 x10^{-06}
Bandanna	6.3 x10^{-05}	2.1 x 10^{-06}	11	5.9 x10^{-04}	8.2 x10^{-07}
Colinlea	6.8 x10^{-03}	1.9 x10^{-04}	2	1.3 x10^{-02}	9.4 x 10^{-05}
Lower Jochmus	4.9 x10^{-02}	7.4 x 10^{-06}	4	0.2 x10^{-03}	2.5 x 10^{-06}

The results also show that laboratory tests for interburden materials demonstrate lower permeabilities in comparison to the results of other methods, and vertical permeability is also typically much less than horizontal permeability. Differences between laboratory tests and field scale tests are expected, as the laboratory scale samples do not contain fractures or fissures.

The results of core permeability testing did not show a noticeable decrease in permeability with depth for the coal measure interburden units with horizontal conductivity ranging from 5.1 x 10^{-7} m/day within the Bandanna Formation to 2.5 x 10^{-1} m/day in the Colinlea Sandstone. Vertical hydraulic conductivity ranges from 8.2 x 10^{-7} m/day within the Bandanna Formation to 1.1 x 10^{-2} m/day within the Rewan Formation. The higher result in the Rewan is probably the result of testing in near-surface areas. However, although decreasing permeability with depth is expected with greater cover depth and/or remoteness from outcrop and the near-surface effects of weathering, the results show that the Colinlea Sandstone at depth has a high relative hydraulic conductivity.

Differences between vertical and horizontal permeability are also well documented, with vertical permeabilities typically several orders of magnitude less than horizontal permeability. This is because fractures and fissures are generally aligned parallel with bedding, and because layers of claystones, mudstones or other low permeability strata tend to cause coherent barriers to flow perpendicular to the bedding. Vertical permeabilities of layers in a numerical model must be even lower because vertical aggregation is necessary and anisotropy is enhanced.

Total porosity measurements ranged from 13 to 25 percent in the Bandanna Formation and the single measurement in the Colinlea sandstone was 14 percent.

3.9.2 Packer Testing

Packer tests consist of isolating specific sections of stratigraphy with inflatable packers so that aquifer tests can be conducted by stressing the formations across a range of intervals.

Packer tests were carried out to assess the variability of a borehole as it intersects various hydrogeological units and to correlate data retrieved from groundwater reports from hydrogeological studies in adjacent projects. Open drill hole water levels and pumping tests can give misleading results in such environments as they only provide bulk measurements and the resulting estimates of hydraulic conductivity can often be dominated by single specific intervals. Therefore, packer testing is often utilised to help understand the detailed hydrogeological properties of the various horizons.

Packer tests were conducted at two locations for the Project in exploration drill holes WBR2 and WBR5 (**Figure 3.7**). The intervals tested and hydraulic conductivity results are shown in **Table 3.7**. The tests provide measurements of Kx (not Kz). The coal seam Kx values are consistent and range from 0.045 to 0.09 m/day. The Bandanna Formation values range from 0.0002 to 0.001 m/day (median 0.0008 m/day). The Colinlea Sandstone values range from 0.0025 to 0.2 m/day (median 0.03 m/day). For both the Bandanna Formation and the Colinlea Sandstone, the packer ranges include the values measured in the core tests.

Table 3.7 Packer Test Intervals and Results

Hole	Interval (m bgl*)	Formation	Hydraulic Conductivity (m/day)
WBR2	144 - 149	Bandanna	1.1 x10^{-03}
	171 - 176	Bandanna	7.9 x10^{-04}
	203.5 – 208.5	Colinlea	2.5 x10^{-02}
	223 - 228	C Seam	5.6 x10^{-02}
	232 - 237	Colinlea	1.9 x10^{-01}
	237 - 242	D Seam	7.9 x10^{-02}
	255 - 265	Colinlea	3.9 x10^{-02}
WBR5	142 - 147	Bandanna	8.9 x10^{-04}
	172 - 177	Bandanna	2.0 x10^{-04}
	202 - 207	C Seam	4.5 x10^{-02}
	208 - 213	Colinlea	2.5 x10^{-03}
	227 - 232	D Seam	9.0 x10^{-02}
	233 - 238	Colinlea	2.8 x10^{-02}

*m bgl – metres below ground level

3.9.3 Pumping Tests

Hydraulic properties have been obtained for the Project area from a number of aquifer tests undertaken during the previous EIS groundwater investigation by E3 Consulting (2011). This included slug tests on farm bores and short term constant rate discharge tests which were carried out on small diameter monitoring bores constructed for the purpose of groundwater monitoring. The tests were conducted at WAR38-15, WAR42-13 and WAR44-15 with water levels monitored at adjacent bores. The results are presented in **Table 3.8**.

Aquifer testing has also been undertaken at the nearby Alpha Coal Project by AGC (1983) and by Longworth & McKenzie (1984). A review of this data was undertaken by JBT Consulting (2010) as part of the Alpha Coal Project hydrogeological study. The hydraulic properties obtained from each test are shown in **Table 3.9**.

Table 3.8 Aquifer Test Results for the Galilee Coal Project

Bore Name	Location	Easting	Northing	Lithology	Method	Hydraulic Conductivity (m/day)	Storativity
WAR38-15 (New)	Mine Lease	438041	7415054	B Seam	Slug	1.25	
WAR38-15 (60)	Mine Lease	438017	7415027	B Seam	Slug	0.25	
WAR44-15 (Monitor)	Mine Lease	444095	7415165	Weathered Permian	Slug	0.0029	
WAR44-15(Retro)	Mine Lease	444093	7415172	DL Seam	CRT^	(4.5)	9.1×10^{-5}
WAR42-13 (50)	Mine Lease	442090	7413147	Weathered Permian	Slug	0.001	
WAR42-13(65)	Mine Lease	442087	7413142	DU Seam	CRT	(4.5)	3.4×10^{-4}
WAR42-13(80)	Mine Lease	442090	7413147	DL Seam	CRT	(17)	5.5×10^{-5}
Reids "the new bore"	Mine Lease	448391	7407627	Tertiary	Slug	0.73	
Reids the old bore	Mine Lease	444564	7405706	Tertiary	Slug	0.1	
Monklands 1	Mine Lease	449572	7415474	Tertiary	Slug	0.016	
Hyde Park	GAB				Slug	2.9	
Aldele	GAB				Slug	9	
Locharnoch	GAB				Slug	>10	
Coleraine	GAB				Slug	12	

^ CRT: Constant Rate Test

Table 3.9 Aquifer Test Results for the Alpha Coal Project

Test Bore	Hydraulic Conductivity (m/day)	Unit
TBB1	1.4	D-E Interburden (Colinlea Sandstone)
TPB2	0.26	D-E Interburden (Colinlea Sandstone)
TB3	0.3	C-D Interburden (Bandanna Formation)
TB4	0.5	D-E Interburden (Colinlea Sandstone)
W1	0.14	C-D Interburden (Bandanna Formation)
W2	0.26	D-E Interburden (Colinlea Sandstone)

3.9.4 Summary of Hydraulic Properties

Based on the results of the field testing, and the analysis provided above, a summary of the likely characteristics of the strata within the study area are summarised in **Table 3.10**.

Table 3.10 Summary of Measured Hydraulic Conductivity Values

Unit	**SEIS Core Tests**		**SEIS Packer Tests**[3]	**EIS Pumping/Slug Tests**[4]	**Alpha Coal Pumping Tests**[5]
	Kx (m/day)[1]	**Kz (m/day)**[2]	**K (m/day)**	**K (m/day)**	**K (m/day)**
GAB				3 - 12	
Rewan Formation	2 x10^{-03}	2 x 10^{-05}			1 x 10^{-4} - 1 x 10^{-3}
Tertiary				0.02 - 7	
Weathered Permian				2 x 10^{-03}	
Bandanna Formation	4 x10^{-04}	2 x 10^{-06}	7 x10^{-04}		
B Coal Seam				0.3 - 1.3	
C Coal Seam			5 x10^{-02}		
C-D Interburden					0.2
D Coal Seam			8x10^{-02}	4 - 17	
D-E Interburden					0.6
Colinlea Sandstone	0.1	2 x10^{-04}	5 x10^{-02}		
Basement (Joe Joe Formation)	0.1	7 x 10^{-06}			

[1] Results of core testing undertaken for this study (Arithmetic Mean).

[2] Results of core testing undertaken for this study (Harmonic Mean).

[3] Results of packer testing undertaken for this study

[4] Source: E3 Consulting (2010)

[5] Source: JBT (2010)

3.9.5 Specific Yield/Specific Storage

Direct testing data are not generally available for specific storage (Ss) of coal seams or interburden. However, good estimates can be made based on Young's Modulus and porosity. For coal, Ss generally lies in the range 5×10^{-6} m^{-1} to 5×10^{-5} m^{-1}, and interburden is generally slightly higher than this due to the greater porosity (Mackie, 2009).

For the EIS, E3 Consulting (2011) derived storativity (specific storage times thickness) values of 5×10^{-5} to 3×10^{-4} for the DU and DL coal seams.

3.10 CONCEPTUAL MODEL

A conceptual model of the primary recharge and discharge processes under natural conditions and during proposed mining is illustrated in **Figure 3.6** for a typical west-east cross-section.

Recharge to the groundwater systems occurs from rainfall and runoff infiltration, lateral groundwater flow, and some leakage from surface water sources. Groundwater levels are sustained by rainfall infiltration; however, they are controlled by topography, geology and surface water levels in local and distant drainages. Local groundwater tends to mound beneath hills, with ultimate discharge to distant drainages (via subsurface throughflow) and loss by evapotranspiration through geological outcrops and vegetation where the watertable is near the ground surface (generally 2 to 3 m below ground level). However, given the typical depth to water is 10 to 40 m in the vicinity of the Project, evapotranspiration is an unlikely occurrence except along riverine corridors.

3.10.1 Natural Recharge and Discharge Mechanisms

The main recharge mechanisms at the Project site are lateral groundwater flow from the west and the south (sourced from rainfall over the Great Dividing Range), and direct infiltration of rainfall through the weathered regolith layer, particularly where favourable permeability is exposed in subcrop areas.

As there is an annual rainfall deficit and the permeability of underlying rock is low, recharge rates to the coal measures are low. Significant groundwater recharge from rainfall will tend to occur only following major, prolonged rainfall events, or during the late autumn/early winter period when some longer term ground saturation and recharge is feasible.

The high clay content, and hence long storage/residence times, in the weathered soils that occur above the Permian subcrop areas cause recharge to be particularly low in those areas. Actual vertical percolation of recharge through rock layers is very limited and most recharge is likely to occur at subcrop after which the recharge water will move along relatively more permeable strata, parallel to bedding. The higher permeability of the alluvial areas and runoff concentration within drainage channels means that recharge will also tend to be higher in those areas.

Surface water associated with the principal drainage features will tend to be connected with the associated alluvium in the form of perched water tables, and groundwater within the alluvium will discharge to the stream channels in some areas. Mostly, however, the streams will be losing systems in the sense of leaking water to the underlying sediments. However, connectivity with the regional geological environment is thought to be very limited due to the low vertical permeability of the underlying strata.

Connectivity with the regional hard rock aquifers will be dependent on the nature of the hard rock hydraulic characteristics. As these are generally lower than those of the overlying unconsolidated shallow alluvium and weathered soils, it is the conductivity of the hard rock lithologies which govern the recharge potential when groundwater is available in the shallow aquifers.

Groundwater may at times discharge to streams and much of this discharge would occur through shallow ‘interflow’ (i.e. movement of perched groundwater through regolith layers or alluvium after rainfall recharge has occurred). The discharge rates from deeper, hard rock aquifers to surface water features is limited due to the very low vertical permeability of the Permian strata. In the same manner, groundwater recharge can also be rejected and discharged at the surface as springs.

3.10.2 Springs

Springs form when groundwater emerges at the land surface, usually at a clearly defined point and it may flow strongly or just seep out forming a distinct vegetative area. They often form at low points in the topography where the water table in an unconfined aquifer intersects the ground surface, or they may be the result of subsurface joints, faults or differences in permeability that direct water towards the ground surface under pressure. They can also be the result of changing hydraulic characteristics at lithological boundaries and emanate where the contact subcrops, or they can mound on the surface of regional aquitards.

There are no identified springs within the immediate Project area. However, recharge springs have been identified 30-40 km to the west of the GAB boundary within the recharge zone and also to the west of the recharge zone, in the Barcaldine Spring Complex. The Great Artesian Basin Resource Operations Plan includes a register of vent springs and watercourse springs (at 2009) that support significant cultural and environmental values. Those to the west of the Project area are shown in **Figure 1.5**.

The springs are aligned with a north-south trend passing through the township of Alice on the western side of the Great Dividing Range and appear to be expressed at elevations of 300-400 mAHD. The alignment of registered springs correlates with the Hutton Sandstone and underlying Moolayember Formation subcrop line. It is likely that the interaction of recharge and interflow in these units may form recharge springs within the Hutton Sandstone outcrop.

Fensham et al. (2010) note the distinction between recharge and discharge springs:
"In general the recharge springs show greater fluctuations in flow rates, have lower pH and dissolved solids, and generally distinct plant composition relative to the discharge springs ... Recharge springs are generally associated with outcropping sandstone, which can form rugged landscapes with springs often situated in gullies and providing the source for streams. The discharge springs typically occur through fault structures where there is abutment with bedrock or where the confining beds are sufficiently thin to allow discharge."

It is noted in the Alpha Coal Project groundwater assessment (URS, 2012) that a review of hydrology and satellite imagery indicated that the springs are ephemeral and seasonal. Spring flow results from limited effective storage within the colluvial cover.

3.10.3 Mining Induced Recharge and Discharge Mechanisms

During open cut mining, the watertable will be depressed adjacent to the open cut pits. When the pits are infilled with waste, the watertable would tend to rise beneath the waste rock emplacements. Groundwater inflows from the excavated formations and the emplacements would report to the open cut (**Figure 3.6**).

During underground mining, potentiometric heads will be depressed in the deeper groundwater system in the vicinity of the mine. The formation of a fractured zone above the mined seams will enhance downwards flow from the overlying formations to the mine void (**Figure 3.6**). If the fractured zone reaches land surface, enhanced rainfall recharge will occur at least initially. It is probable that the initially higher infiltration rates will be short-lived as the cracks should infill with sediment after one or more rainfall events.

4 GROUNDWATER SIMULATION MODEL

4.1 PREVIOUS MODELS

A number of previous groundwater models has been constructed to simulate the stresses on the groundwater environment from mining activities within this area. A summary of the extent and use of the previous models is provided below.

4.1.1 Galilee Coal Project

A numerical groundwater model was prepared by E3Consulting (2010) for the EIS. However, as outlined in Section 1.2.6, the model was regarded as being inadequate for a number of reasons related to model construction, model calibration and reporting of model outputs. For this reason, WCPL instigated development of a new and more extensive groundwater model.

With the endorsement of the OCG, the model development proceeded in two stages. **Stage 1** (reported upon as an interim report in December, 2012) simulated steady-state conditions for worst-case impact prediction at the end of mining (Heritage Computing, 2012). **Stage 2** includes transient calibration and simulation of the transient progression of mining. The results of both Stage 1 and Stage 2 are reported upon herein.

The additional exploration drilling that has occurred since the EIS has led to a higher-resolution geological model that has provided an updated structure for the new groundwater model.

4.1.2 Alpha Coal Project

URS Australia Pty Ltd (URS, 2012) undertook a hydrogeological study to assess the potential impacts of the proposed mining activities of the Alpha Coal Project. The hydrogeological studies included drilling, aquifer testing and construction of several numerical groundwater models. The various "built-for-purpose" models included:

- An initial EIS regional numerical mode, which allowed for a preliminary assessment of potential impacts of mine dewatering on the regional groundwater regime. This was compiled by NTEC Environmental Technology (NTEC), and provided an initial assessment of groundwater ingress, drawdown impacts, and final void / long term groundwater levels. These results, presented in the various EIS submissions to date, have been superseded through ongoing model refinement based on the compilation of additional site-specific hydrogeological data;

- A refined predictive groundwater model which allowed for a more accurate estimate of mine inflows over the life of mine with results being used for the site management plan. The aim of the refined model was to provide estimates of groundwater inflows and dewatering volumes over the life of the Alpha and Kevin's Corner coal projects. This was compiled by MTNA; and

- An integrated surface water - groundwater model which was used to assess the potential long term groundwater impacts associated with the Alpha final void. This was compiled also by MTNA.

The calibration of this model included an evaluation of recharge using available groundwater hydrographs from long-term monitoring points across the site, drilling results and hydrochemistry. The assessment of groundwater flow patterns indicated that the dominant recharge mechanism was recharge along the Great Dividing Range, with recharge to the confined Permian aquifers being negligible.

Aquifer hydraulic properties were estimated from historical aquifer test studies as well as aquifer tests conducted across Kevin's Corner, variable head (slug) tests, laboratory permeability testing, and literature data.

The MODHMS groundwater modelling package was used to construct the final groundwater assessment model. MODHMS is similar to MODFLOW-SURFACT (see Section 4.2) in that it is able to simulate variably saturated flow and can handle desaturation and re-saturation of multiple aquifers, but has the added capability of including surface water - groundwater interaction using integrated overland and channel flow algorithms.

4.1.3 Other Coal Projects

Groundwater models have been prepared for the South Galilee Coal Project (SGCP) (RPS Aquaterra, 2012) to the south and the Adani project to the far north, but details are not in the public domain at this time for the Adani project.

The SGCP model was developed with MODFLOW-SURFACT software across an area of 65 km east-west and 73 km north-south. The model consists of seven layers but does not include a separate layer for the Rewan Formation / Dunda Beds. This limits the potential of the model for exploring potential impacts on the GAB. In all likelihood, impacts on the GAB will be overestimated.

4.2 MODEL SOFTWARE AND COMPLEXITY

Groundwater modelling has been conducted in accordance with both the MDBC Groundwater Flow Modelling Guideline (MDBC, 2001) and the more recently published Australian Groundwater Modelling Guidelines. The MDBC Groundwater Flow Modelling Guideline is mostly a generic guide, with no specific guidelines on special applications such as coal mine modelling. The new National Guidelines were announced in June 2012, sponsored by the National Water Commission (Barnett *et al*., 2012). These guidelines build on the 2001 MDBC guide, with substantial consistency in the model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details. In the new guide, there are no specific guidelines on coal mine modelling.

The 2012 guide has replaced the model complexity classification by a "model confidence level". The Galilee model may be classified as Class 2 (effectively “medium confidence”), which is an appropriate level for this project context. Under the 2001 modelling guideline, the model is best categorised as an Impact Assessment Model of medium complexity. The guide (MDBC, 2001) describes this model type as follows:

"*Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies*."

Numerical modelling has been undertaken using the Groundwater Vistas (Version 6) software interface marketed by Environmental Simulations Inc. [ESI] in conjunction with MODFLOW-SURFACT (Version 4) distributed commercially by Hydrogeologic, Inc. (Virginia, USA). MODFLOW-SURFACT is an advanced version of the popular MODFLOW code developed by the United States Geological Survey (McDonald and Harbaugh, 1988). MODFLOW is the most widely used code for groundwater modelling and is accepted as an industry standard.

MODFLOW-SURFACT is a three-dimensional modelling code that is able to simulate variably saturated flow and can handle desaturation and resaturation of multiple aquifers without the "dry cell" problems of Standard-MODFLOW. This is pertinent to the dewatering of layers within underground coal mines. Standard-MODFLOW can handle this to some extent, but model cells that are dewatered (reduced below atmospheric pressure) are replaced by "dry cells".

The most recent derivation of MODFLOW-SURFACT also allows the changing of model properties through time using the TMP package, allowing mine scheduling to be run within a single model. Model properties change with time in open cut waste emplacements and in fractured zones developed above longwall panels.

4.3 MODEL LAYERS AND GEOMETRY

The model domain covers an area designed to be large enough to prevent boundary effects on model outcomes associated with mining-related stress on the groundwater environment. It extends far beyond the subcrop trace of the deepest coal seam to be mined in the future, and extends to the boundary of the Galilee Basin in the east. To the west it extends about 50 km west of Jericho and 65 km west of the nearest planned mining in order to take account of registered springs in the GAB.

The model domain (**Figure 1.4** and **Figure 1.5**) is discretised into 2.2 million cells comprising 519 rows, 379 columns and 11 layers. The dimensions of the model cells range from a minimum of 100 m at the mine sites to a maximum of 1000 m at model edges. The model extent is 130 km from west to east (MGA eastings 360000 - 490000) and 120 km from south to north (MGA northings 7360000 - 7480000), covering an area of approximately 15,600 km^2.

Eleven model layers represent the stratigraphic section for the Southern Region of the Galilee Basin indicated in **Figure 3.5**. The numerical model layers are illustrated in **Figure 4.1**:

- **Layer 1**: Alluvium and regolith. The alluvium was set at 10 m thickness.
- **Layer 2**: Alluvium and regolith in the east, set at 20 m thickness. Clematis Sandstone in the west.
- **Layer 3**: Weathered Permian in the west, set at drilled base of weathering or 25 m thickness away from the Project site. Dunda Beds and Rewan Formation in the west have a thickness of

about 300 m near the mine site but thin to the west until pinching out about 40 km from the mine site.

- **Layer 4**: Bandanna Formation. Including A Seam.
- **Layer 5**: B Coal Seam.
- **Layer 6**: Bandanna Formation. Including C Seam.
- **Layer 7**: DU Coal Seam.
- **Layer 8**: Bandanna Formation.
- **Layer 9**: DL Coal Seam.
- **Layer 10**: Colinlea Sandstone.
- **Layer 11**: Basal Layer (Joe Joe Group). This was set with a typical thickness of 500 m at the base of the model.

It should be noted that all layers are fully present across the active model area. Where a layer becomes inactive, such as up-dip from its subcrop, the layer has been extended across the rest of the model domain as a 0.1 m thick 'dummy' layer, which has the same properties as the first 'active' underlying layer that exists in that area. For example, in the east of the model, all layers except Layers 1-3 (alluvium / regolith / weathered zone) and basement (Layer 11) have subcropped. The model therefore contains 'dummy' layers for Layers 4 to 10, which have the same hydraulic properties as the underlying Permian basal layer, Layer 11.

Surface elevations in the model have been derived from the 250 m grid data released by Geoscience Australia.

Subsurface elevations for formation interfaces were derived from:

- a geological model provided by WCPL for the mine lease as covered by exploration drilling;
- exploration drilling intersections at holes outside the mine lease;
- the Galilee 1:250,000 geological map and representative west-east cross-section passing to the south of Jericho and Alpha townships;
- structural information in the Alpha Coal Project EIS (URS, 2012); and
- structural information on the Galilee Basin gathered by RPS Aquaterra for the Galilee Basin Operators' Forum <http://www.gbof.com.au/ >.

Representative west-east model cross-sections are displayed in **Figure 4.2** for northing 7399120 (along the southern limit of the proposed mine plan, through the GAB gap) and northing 7419400 (along the northern limit of the mine plan and mine lease). South-north cross-sections are shown in **Figure 4.3** for easting 431920 (through the centre of the underground mine, aligned with the western limit of the Alpha mine lease) and easting 444600 (through the eastern edge of the proposed open cut mine, on the western edge of alluvium. Representative groundwater head contours[2] indicate the directions of lateral and vertical groundwater flow.

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[2] The groundwater head contours are those produced by the calibrated transient model at December 2012

4.4 HYDRAULIC PROPERTIES

The coal measures are split into multiple layers in recognition of the potential for vertical hydraulic gradients to occur during mining, although there is no strong evidence for persistent gradients under natural conditions. Several coal seams (B, DU, DL) are represented in the model as separate layers as they are targets for underground mining.

Previous studies and investigations within the region and additional aquifer testing for the Project have provided the basis for chosen hydraulic property parameters used within the modelling component of this project for the coal seams and interburden units. **Table 3.10** is a summary of all work to date.

Also available are the results of calibration for the Alpha Coal Project model (URS, 2012), as summarised in **Table 4.1**.

Table 4.1 Hydraulic Properties Calibrated by URS (2012)

		STEADY STATE		TRANSIENT	
Layer		Kx (m/day)	Kz (m/day)	Kx (m/day)	Kz (m/day)
1	GAB	5.6	0.8	2.9	0.28
2-3	Rewan Formation	6E-5	8E-4	9E-4	9E-5
4	Bandanna Formation	2E-4	1E-3	2E-4	1E-6
5	C Seam	1E-2	2E-3	1.5E-2	1E-5
6	C-D Sandstone	0.12	1E-4	0.15	5E-5
7	D Seam	1E-2	2E-3	1.5E-2	1E-5
8	D-E Sandstone	5E-2	2E-6	0.17	6E-5
9	E Seam	1E-2	2E-3	1.5E-2	1E-5
10	Colinlea Sandstone	5E-2	2E-6	0.17	6E-5
11	Joe Joe Group	2E-4	1E-3	2E-4	1E-6

These values have been adopted as initial estimates for the modelling reported herein. The final distributions of hydraulic properties in each model layer are shown in **Attachment B**.

4.5 MODEL STRESSES AND BOUNDARY CONDITIONS

General heads are applied to the northern, western and southern boundaries to allow lateral inflow/outflow to/from the model area. The heads in model layers 1-4 have been set at those shown in **Figure 3.8** as the best estimate for regional shallow groundwater levels. For deeper layers, heads reduced by 30 m provided the best match to the regional deep groundwater level measurements.

The model domain covers all of the potentially sensitive receptors, including springs to the west represented as drain (DRN) features (**Figure 4.4**). All significant creeks and rivers that could be affected by mining activities are fully contained within the model domain and have been represented in the model, as shown in **Figure 4.4**.

All water bodies are represented as river cells using the MODFLOW RIV package. River beds are given a vertical hydraulic conductivity of 7.5E-4 to 1E-3 m/d and a thickness of 0.5 m. Water depths range from 0 to 2 m to represent ephemeral to permanent streams. Stream stage is taken as an offset from adjacent ground level.

The various streams in the model area (**Figure 3.3**) have been given different "reach" numbers to allow separate water balance reporting (if necessary):

- Reach 101: Native Companion Creek;
- Reach 102: Belyando River;
- Reach 103: Beta Creek;
- Reach 104: Tallarenha Creek;
- Reach 105: Saltbush Creek;
- Reach 106: Lagoon Creek;
- Reach 107: Alice River;
- Reach 108: Jordan Creek;
- Reach 109: Alpha Creek; and
- Reach 110: Remaining small creeks.

The open cut and underground mining activity is defined in the model using drain (DRN) cells within the mined coal seams, with drain invert elevations set at the base of the target seams.

The initial distribution of recharge zones used within the model is provided in **Figure 4.5**. Rainfall infiltration has been imposed initially (for steady-state simulation) as a percentage of long-term average rainfall across eight zones:

Zone 1: Colluvium	0.2 %
Zone 2: GAB (Clematis Sandstone)	5.7 %
Zone 3: GAB (Dunda Beds)	1.3 %
Zone 10: Colinlea Sandstone	1.9 %
Zone 11: Joe Joe Group	0.02 %
Zone 12: Tertiary	0.2 %
Zone 13: GAB (Moolayember Fm.)	5.7 %
Zone 15: Alluvium	0.2 %

The adopted values for rainfall recharge have been guided by the work of Kellett *et al*. (2003) who estimated recharge in the GAB area to be:

- Alluvium: 1.1 mm/yr, 0.21% annual precipitation;
- Clematis Sandstone: 30 mm/yr, 5.40% annual precipitation;
- Rewan Formation and Dunda Beds: 6.7 mm/yr, 1.2% annual precipitation; and
- Bandanna Formation: 1.0 mm/yr, 1.8% annual precipitation.

There is insufficient natural variation in groundwater levels to allow better definition of these rates during model calibration.

The ET package was used in the Galilee model with an extinction depth of 3.0 m and an initial maximum 150 mm per annum ET rate (for steady-state simulation).

4.6 MODEL VARIANTS

With the endorsement of the OCG, the model development proceeded in two stages. **Stage 1** (reported in December, 2012) simulated steady-state conditions for worst-case impact prediction at the end of mining (Heritage Computing, 2012). **Stage 2** (reported herein) includes transient calibration and simulation of the transient progression of mining. Stage 2 also covers sensitivity analysis, uncertainty analysis, recovery simulation and cumulative impact assessment.

The modelling approach is based on six model variants:

A. *Steady state calibration model.*
Initial calibration of aquifer system properties against the best-estimate local groundwater level contour map and measured vertical hydraulic gradients.

B. *Transient calibration model.*
More thorough calibration of aquifer system properties against hydrographic responses for dynamic rainfall recharge.

C. *Steady state prediction models.*
Separate simulations of equilibrium conditions at the end of open cut mining and at the end of underground mining. This provides long-term near-worst case assessments of potential environmental impacts and final mine inflow rates. Most of the open-cut area should be rehabilitated by the end of underground mining.

D. *Transient prediction model.*
Simulation of dynamic open cut and underground mining for one agreed mine plan for the full period of mining. The open-cut mining simulation allows for time-varying properties for spoil (hydraulic conductivity, specific yield and infiltration). The underground mining allows for changes in permeability in the fractured zones above the two mined coal seams. Prediction is made of potential impacts of mine development on the groundwater regime (particularly stream-aquifer interaction and groundwater dependent ecosystems) and prediction of mine inflow rates.

E. *Steady state prediction model for neighbouring mines.*
Quantification of cumulative impacts due to simultaneous mining at the two neighbouring mines and the China First Project. This can be done either through steady state simulation or by adopting the Principle of Superposition, making use of prior modelling undertaken for the neighbouring coal projects.

F. *Transient recovery model.*
Simulation of equilibrium groundwater levels after mine closure for the China First Project alone, for 200 years.

The **Stage 1** modelling of model variants A and C was reported in Heritage Computing (2012). Model variants B, D, E and F are reported herein.

4.7 FRACTURED ZONE IMPLEMENTATION

4.7.1 Background

When underground mining is undertaken, a fractured zone is developed above the mined panels which manifests as subsidence of the land surface. A sequence of deformational zones is established:

- ☐ the caved zone;
- ☐ the fractured zone, consisting of
  - a lower zone of connective-cracking; and
  - an upper zone of disconnected-cracking;
- ☐ the constrained zone; and
- ☐ the surface zone.

The rocks in the connective-cracking part of the fractured zone will have a substantially higher vertical permeability than the undisturbed host rocks. This will encourage groundwater to move out of rock storage downwards towards the goaf. In the upper part of the fractured zone, where disconnected-cracking occurs, the vertical movement of groundwater should not be significantly greater than under natural conditions.

Depending on the width of the longwall panels and the depth of mining, and the presence of low permeability lithologies, there will be a constrained zone in the overburden that acts as a bridge. Rock layers are likely to sag without breaking in this zone, and bedding planes are likely to open. As a result, some increase in horizontal permeability can be expected.

In the surface zone, near-surface fracturing can occur due to horizontal tension at the edges of a subsidence trough. Fracturing will be shallow (<20 m), often transitory, and any loss of water into the cracks will not continue downwards towards the goaf.

The strata movements and deformation that accompany subsidence will alter the hydraulic and storage characteristics of aquifers and aquitards. As there will be an overall increase in rock permeability, groundwater levels will be reduced either due to actual drainage of water into the goaf or by a flattening of the hydraulic gradient without drainage of water (in accordance with Darcy's Law).

At the base of the fractured zone, groundwater pressures will reduce towards atmospheric pressure.

4.7.2 Galilee Coal Project

For the Galilee Coal Project it is likely that the fractured zone will extend to the land surface in places, given that the longwall panel widths are to be 470 m wide. The *Longwall Mining*

Subsidence Report states that this is likely to occur as longitudinal cracking of between 2.5 – 20 mm adjacent to the chain pillars where the distance between the surface and the underground mining operations is less than 180 m.

The **Stage 2** groundwater model tracks the dynamic development of the fractured zone as underground mining progresses. There is unavoidable uncertainty in the permeabilities to be applied to the fractured zone as they cannot be measured directly, and at the greenfield mine project sites in the Galilee Basin there is no history of mine inflows to constrain the permeability estimates. For that reason, a sensitivity analysis is often undertaken in the modelling to investigate a range of reasonable permeability options. Normally a ramp function formula is applied. This assumes a log-linear reduction in permeability from the goaf to the estimated top of the fractured zone.

For the **Stage 1** model, however, a simpler approach was followed because the simulations were steady-state. The fractured zone established across the entire mine footprint was activated simultaneously. As the objective of Stage 1 was to determine order of magnitude environmental impacts, a vertical cylinder of uniformly permeable material was used to represent the fractured zone, with very high vertical hydraulic conductivity of 1 m/day or 10 m/day as conservative estimates. These values are generally 10-100 times the highest Permian horizontal hydraulic conductivities.

The height of the fractured zone has been taken as 180 m, as advised in the SEIS *Longwall Mining Subsidence Report*. This means that full fracturing is applied to model layer 4 and below. Fracturing of model layers 1-3 occurs over the eastern portion of the mine plan.

For Stage 2 modelling of the fractured zone during transient simulation, the properties are changed using hydrostratigraphic unit (HSU) zonation and the TMP package of SURFACT 4 which allows varying property values with time. Fracturing is instigated by altering host properties in accordance with mine progression using a ratio multiplier within the HSU zoning feature.

4.8 STEADY-STATE CALIBRATION

Steady-state calibration was carried out as the first stage of the calibration process. Normally, the primary purposes of steady-state calibration are to check assumptions on the conceptual hydrogeological processes and to generate initial head distributions for all model layers for subsequent transient simulation. In this case, however, steady-state calibration was a precursor for steady-state simulation of worst-case environmental effects to provide an early indication of which, if any, environmental values might be compromised by the proposed mining.

4.8.1 Steady-State Calibration Performance

The steady-state model was calibrated to the groundwater level contours of **Figure 3.8** and the recorded initial VWP heads in **Figure 3.9**. Calibration was carried out against 190 target water levels, using manual modification of zones and model parameters. Steady-state calibration performance was good at 7.1% Scaled Root Mean Square (SRMS), which is below the target 10% SRMS suggested in the MDBC flow model guideline (MDBC, 2001). The 2012 Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012) warn against prescriptive performance targets but note that "*Targets such as SRMS < 5% or SRMS < 10% ... may provide useful guides*". The absolute residual is 13 mRMS.

The scattergram showing a cross-plot of simulated and observed water levels is presented in **Figure 4.6**. The residuals plotted in **Figure 4.7** show some bias to overestimation of heads (negative residuals).

The simulated watertable contours for steady-state conditions are displayed in **Figure 4.8** for comparison with the representative field contours in **Figure 3.8**. The groundwater flow patterns are very similar, although the simulated contours are smoother and do not replicate the fine detail in the field-based contours.

Of interest is the model output for Layer 9, which represents the DL coal seam (until it is eroded to the east of the Project area). The groundwater head contours, displayed in **Figure 4.9**, show the expected flow directions in the Project area emanating from a groundwater divide along part of the Great Dividing Range.

4.8.2 Steady-State Water Balance

The steady-state water balance is given in **Table 4.2**. This shows that lateral boundary flows are dominating the groundwater regime. Most of this net inflow is discharged from the groundwater system through evapotranspiration, most of which occurs in the western third of the model in the GAB. Of the rainfall recharge applied to the land surface, much is rejected across the colluvial areas.

Most stream-aquifer interaction is in the form of leakage from occasionally flowing creeks, with only minor occurrences of baseflow to gaining systems. The creeks near the Project are all simulated to be losing systems, with long-term average leakage rates of 2.6 ML/day for Beta Creek, 3.5 ML/day for Tallarenha Creek, 1.2 ML/day for Lagoon Creek and 0.5 ML/day for Saltbush Creek.

Table 4.2 Simulated Steady-State Water Balance (Pre-Mining)

Component	**Groundwater Inflow (Recharge) (ML/day)**	**Groundwater Outflow (Discharge) (ML/day)**
Rainfall Recharge	125	323
Evapotranspiration	-	399
Rivers/Creeks	30	8
Mines	-	-
Boundary Flow	774	198
TOTAL	**929**	**928**

4.9 TRANSIENT CALIBRATION

Transient calibration was carried out as the second stage of the calibration process. This was conducted on model variant B for the time period January 2010 to December 2012 for 36 monthly stress periods. The starting date was chosen to align with the earliest groundwater level measurements in the district for the Alpha Project (December 2009), the Galilee Coal Project (April 2010) and the South Galilee Project (November 2010).

The dataset for transient calibration consists of 1096 measurements (sampled monthly) at 99 sites. **Table 4.3** lists the number of monitoring sites and the number of head targets in the various project areas. Calibration was conducted manually but was guided by automated sensitivity analysis, a feature of the Groundwater Vistas software that was employed to run the simulations. A separate verification process was not conducted as the full length of monitoring records was required for calibration of hydrographs.

Table 4.3 Transient Calibration Head Targets

Site	No. of Monitoring Sites	No. of Transient Points
Galilee	27	70
Alpha	45	656
Kevins Corner	12	207
South Galilee	15	163
Total	**99**	**1096**

As the measured data are of variable quality, they were not weighted equally in assessing calibration performance. In addition, higher weights were given to Galilee Project measurements than measurements taken at the neighbouring projects. The assigned weights are listed in **Table 4.4**.

Table 4.4 Assigned Target Weights and Distribution of Measurements between Model Layers

Weight	No. of Observations	Model Layer	No. of Observations
0	41	1	0
0.1	21	2	9
0.2	1	3	25
0.3	42	4	98
0.4	0	5	47
0.5	308	6	489
0.6	0	7	62
0.7	532	8	2
0.8	3	9	7
0.9	75	10	358
1	74	11	0

There is a good distribution of measurements throughout the stratigraphic section, as indicated by the number of measurements applicable to different model layers in **Table 4.4**. Most measurements are associated with the Bandanna Formation (layer 6) between the B and DL seams, the Colinlea Sandstone (layer 10) and the Bandanna Formation (layer 4) overlying the B seam. The three coal seams (layers 5, 7 and 9) have a total of 116 measurements (sampled monthly).

4.9.1 Transient Calibration Performance

Transient calibration performance is good at 7.3 %RMS, which is below the target 10% SRMS suggested in the MDBC flow model guideline (MDBC, 2001). The absolute residual is 7.6 mRMS.

The scattergram showing a cross-plot of simulated and observed water levels is presented in **Figure 4.10**. The residuals plotted in **Figure 4.11** show some bias to overestimation of heads (negative residuals).

The simulated hydrographs for the Project sites are displayed in **Attachment E** for comparison with the field hydrographs. The simulated levels are generally higher than observed, as indicated by the residuals plotted in **Figure 4.11.** As noted in Section 3.7.2, the field readings at the standpipes have been very stable and display no apparent response to varying rainfall. However, the VWP readings have not stabilised and there is not always a consistent variation of head with depth. It is for this reason that variable weights (**Table 4.4**) were applied to the field observations to guide the calibration towards what are considered the most reliable data.

There was difficulty in achieving a good calibration. The auto-sensitivity analysis did not reveal a sensitivity to any particular property. Although many different parameter combinations were trialled, the simulation using the steady-state calibrated parameters was as good as any other. For this reason, the steady-state hydraulic conductivities were retained. The rainfall recharge rates applied to the various spatial zones was reduced for some zones, from the steady-state calibration, to reduce the general overestimation of heads. Storage properties were applied but the lack of natural fluctuations in the observations means that these parameters are not well resolved.

While absolute levels are not replicated well, the Australian Modelling Guidelines (Barnett et al., 2012) note that simulation of *drawdowns* as an indicator of environmental impacts can be expected to be more accurate than simulation of *absolute* water levels:

> **Guiding Principle 7.4**: *Analysis of uncertainty should recognise that there is more uncertainty when reporting confidence intervals around an absolute model output, and less uncertainty when a prediction can be formulated as a subtraction of two model results.*

4.9.2 Calibrated Model Properties

Initial hydraulic property values were guided by steady-state model calibration, which in turn was guided by field measurements and calibrated properties in the Alpha Project model (URS, 2012).

Table 4.5 summarises the hydraulic and storage properties for the stratigraphic section at the end of transient calibration. The adopted hydraulic property, recharge and ET distributions are displayed in **Attachment B**. The values for horizontal hydraulic conductivity (K_X) are consistent with field estimates listed in **Table 3.10** and with estimates from other models. The final values are very similar to those adopted in the Alpha Project model, as these were calibrated against a short-term box cut stress. There has been no other significant stress on the groundwater system in this district.

Table 4.5 Calibrated Model Properties

		HYDRAULIC CONDUCTIVITY		**STORAGE PROPERTIES**	
Layer		**Kx (m/day)**	**Kz (m/day)**	**S (-)**	**Sy (-)**
1	Regolith	5	0.1	-	0.05
1	Alluvium	20	2	-	0.2
2	Clematis Sandstone (west)	3	0.1	1E-4	0.05
2-3	Weathered Permian (east)	2.3E-3	9.3E-5	1E-4	0.05
3	Dunda Beds/Rewan Formation (west)	2.3E-3	9.3E-5	1E-4	0.01
4	Bandanna Formation Overburden	1.7E-4	1.3E-6	1E-5	5E-3
5	B Seam	1.5E-2	1.0E-5	1E-4	8E-3
6	Bandanna Formation	1.5E-1	5.0E-5	1E-5	5E-3
7	DU Seam	1.5E-2	1.0E-5	1E-4	8E-3
8	Bandanna Formation	1.5E-1	5.0E-5	1E-5	5E-3
9	DL Seam	1.5E-2	1.0E-5	1E-4	8E-3
10	Colinlea Sandstone	1.3E-1	1.9E-4	1E-5	5E-3
11	Joe Joe Group	1.7E-4	1.3E-6	1E-5	5E-3

The final distribution of recharge zones used within the model is provided in **Attachment B**. Rainfall infiltration has been imposed as a percentage of actual monthly rainfall across eight zones:

Zone 1: Colluvium	0.2 %
Zone 2: GAB (Clematis Sandstone)	1.3 %
Zone 3: GAB (Dunda Beds)	1.2 %
Zone 10: Colinlea Sandstone	1.8 %
Zone 11: Joe Joe Group	0.1 %
Zone 12: Tertiary	0.2 %
Zone 13: GAB (Moolayember Fm.)	1.3 %
Zone 15: Alluvium	0.8 %

There is insufficient natural variation in groundwater levels to allow better definition of these rates during model calibration.

The final distribution of ET zones used within the model is provided in **Attachment B**. ET was applied universally with an extinction depth of 3.0 m and a maximum 300 mm per annum ET rate, except in stream cells where no ET was applied (due to boundary condition conflict).

4.9.3 Transient Water Balance

The average transient water balance over the years 2010-2012 is given in **Table 4.6**. This shows that lateral boundary flows are dominating the groundwater regime. Evapotranspiration is a significant discharge, most of which occurs in the western third of the model in the GAB.

Most stream-aquifer interaction is in the form of leakage from occasionally flowing creeks, with only minor occurrences of baseflow to gaining systems. Overall, the streams in the model area provide about 29 ML/day recharge to the groundwater system, while groundwater discharge to the streams in the form of baseflow is about one-third (10 ML/day) (**Table 4.6**).

Table 4.6 Simulated Average Transient Water Balance (Pre-Mining)

Component	Groundwater Inflow (Recharge) (ML/day)	Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	157	-
Evapotranspiration	-	226
Rivers/Creeks	29	10
Mines	-	-
Boundary Flow	376	844
TOTAL	**562**	**1080**
Storage	**518 Loss**	
Discrepancy	**0.01%**	

The creeks near the Project are all simulated to be losing systems, with long-term average leakage rates of about 2.6 ML/day for Beta Creek, 3.5 ML/day for Tallarenha Creek, 1.2 ML/day for Lagoon Creek and 0.5 ML/day for Saltbush Creek (**Table 4.7**).

Table 4.7 Simulated Steady-State and Transient Stream-Aquifer Water Exchanges

			Steady-State	**Transient**
Reach	**Stream**	**Status**	[ML/day]	[ML/day]
101	Native Companion Creek	Losing	7.7	7.0
102	Belyando River	Losing	7.5	6.8
103	Beta Creek	Losing	2.6	2.6
104	Tallarenha Creek	Losing	3.5	3.5
105	Saltbush Creek	Losing	0.5	0.5
106	Lagoon Creek	Losing	1.2	1.2
107	Alice River	Gaining	-4.3	-3.0
108	Jordan Creek	Losing	0.6	0.5
109	Alpha Creek	Losing	0.2	0.2
110	Other Creeks	Losing	2.1	1.5

5 PREDICTIVE MODELLING

5.1 MINING SCHEDULE

The proposed mine plan consists of two open cut mines and four underground mines (**Figure 1.3**):

- ☐ OC1 North and OC1 South (down to the DL coal seam);
- ☐ OC2 North and OC2 South (down to the B coal seam);
- ☐ UG1 (DU coal seam);
- ☐ UG2 (DL coal seam);
- ☐ UG3 (DL coal seam); and
- ☐ UG4 (B coal seam).

Using the hydraulic and storage properties found during transient calibration and a pit activation period of one year, the model was run in transient mode from January 2013 (after the end of the calibration period) to December 2047 (model period 35) in annual steps. The Project is taken to commence in January 2017 (stress period 5) and finish in December 2046 (stress period 34)[3], a total of 30 years mining.

Rainfall recharge was deactivated in cells where open cut mining was currently active, for a period of five years, as mine waste rock would require roughly this length of time to wet up through the unsaturated zone. After five years, 5% recharge is applied to mine waste rock in the open cut pits. As waste rock is emplaced, its hydraulic conductivity is increased dynamically from the *in situ* pre-mining value to 1 m/day, and specific yield is increased to 0.1, using the TMP facility in SURFACT.

5.2 MODELLING APPROACH

As explained in Section 4.7.2, the groundwater model tracks the dynamic development of the fractured zone as underground mining progresses. The height of the fractured zone has been taken as 180 m, as advised in the SEIS *Longwall Mining Subsidence Report*.

The sensitivity to the choice of fractured zone permeabilities was investigated in the **Stage 1** model (Heritage Computing, 2012), by establishing a fractured zone across the entire mine footprint in the form of a vertical cylinder of uniformly permeable material with very high vertical hydraulic conductivity of 1 m/day or 10 m/day as conservative estimates. The results were compared with a baseline scenario that had no fractured zone in order to provide a lower limit on mine inflow estimates.

Modelling for the Alpha Project (URS, 2012) assumed no fractured zone. Modelling for the South Galilee Project (RPS Aquaterra, 2012) assumed no fractured zone in the base model and a uniform 1 m/day cylinder, active for all time, as a worst case.

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[3] A stress period is the timeframe in the model when all hydrological stresses (e.g. rain recharge, river stage, etc.) remain constant.

This model simulates the fractured zone more realistically than the three prior models. The fractured zone is allowed to develop year by year, as mining proceeds, and the permeabilities are varied dynamically using the TMP package of SURFACT. A ramp function formula is applied. This assumes a log-linear reduction in permeability from the goaf to the estimated top of the fractured zone. The following rules are applied for the four underground mines:

- ☐ UG1 (DU coal seam in Layer 7): 10 m/day for Kx and Kz in Layer 7; ramp variation in Kz from $5x10^{-3}$ m/day to $5x10^{-4}$ m/day across Layers 3 to 6; 0.5 m/day for Kz in Layers 1-2; doubled host Kx in Layers 1-6; 0.15 for Sy in Layer 7; 0.1 for Sy in Layer 6.
- ☐ UG2 and UG3 (DL coal seam in Layer 9): 10 m/day for Kx and Kz in Layer 9; ramp variation in Kz from $5x10^{-3}$ m/day to $5x10^{-4}$ m/day across Layers 3 to 8; 0.5 m/day for Kz in Layers 1-2; doubled host Kx in Layers 1-8; 0.15 for Sy in Layer 9; 0.05 for Sy in Layer 8.
- ☐ UG4 (B coal seam in Layer 5): 10 m/day for Kx and Kz in Layer 5; ramp variation in Kz from $5x10^{-3}$ m/day to $5x10^{-4}$ m/day across Layers 3 to 4; 0.5 m/day for Kz in Layers 1-2; doubled host Kx in Layers 1-4; 0.15 for Sy in Layer 5.

5.3 WATER BALANCE

Simulated water balances for the entire model extent have been averaged over the 35 years of simulation. **Table 5.1** compares the simulated water balances for the natural system over the three years of calibration (with varying rainfall) and the prediction period (with constant rainfall). Mine inflow of about 70 ML/d is expected, on average. This inflow would be supplied primarily from groundwater storage. Variations in the average flows of other components of the water balance are due largely to the difference in rainfall conditions for the two periods of simulation. It is not possible to discern mining effects on these figures. That is addressed in subsequent sections.

Table 5.1 shows that lateral boundary flows still dominate the groundwater regime. Most of this net inflow is discharged from the groundwater system through evapotranspiration, most of which occurs in the western third of the model in the GAB.

Table 5.1 Simulated Average Water Balances for Calibration and Prediction Periods

Component	CALIBRATION PERIOD Groundwater Inflow (Recharge) (ML/day)	PREDICTION PERIOD Groundwater Inflow (Recharge) (ML/day)	CALIBRATION PERIOD Groundwater Outflow (Discharge) (ML/day)	PREDICTION PERIOD Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	157	95	-	-
Evapotranspiration	-	-	226	150
Rivers/Creeks	29	28	10	4
Mines	-	-	-	67
Boundary Flow	376	440	844	451
TOTAL	**562**	**563**	**1080**	**672**
Storage	**518 Loss**	**108 Loss**		
Discrepancy	**0.01%**	**0.06%**		

Recharge during the prediction period is dominated by lateral boundary flow (78%) and rainfall infiltration (17%). Stream leakage accounts for only 5%. Apart from boundary outflow (67%), groundwater discharge is dominated by evapotranspiration (22%) across the entire model area. Predicted mine inflows account for 10% of the groundwater discharge.

5.4 PREDICTED MINE INFLOWS

The predicted mine inflows for each mine for each year of mining are illustrated in **Figure 5.1** (in ML/day units). The deepest mines targeting the DL seam, the UG2 and UG3 mines, have the highest inflows. The shallowest underground mine, UG4 in the B seam, and the open cut mines, generally have less than 5 ML/day inflows. The maximum in any one mine is predicted to be about 42 ML/day in UG3.

The predicted aggregate inflows to the open cut and underground mines for each year of mining are illustrated in **Figure 5.1** (in GL/a units). The four open cut mines average 2.6 GL/a inflow, while the four underground mines average 23.1 GL/a as a group.

The predicted rates are higher than those predicted by other models at adjacent projects. URS (2012) predicted about 6 GL/a for the combined Alpha and Kevin's Corner projects. However, no fractured zone was included. RPS Aquaterra (2012) predicted about 4.5 GL/a without a fractured zone, and about double that rate with a fractured zone. Neither of the adjacent models allowed for higher recharge through mine waste emplacements in the open cut pits.

To estimate the lower bound on predicted mine inflow, the base model was run with the fractured zone deactivated. This led to an average of about 9 GL/a for the combined open cut and underground mines, about one-third of the rate when the fractured zone is included..

Pit OC2 has negligible inflow because it overlies an underground mine which will dewater the formations adjacent to the pit. Similarly, UG4 has low inflow due to depressurisation caused by deeper mines.

5.5 PREDICTED BASEFLOW/LEAKAGE CHANGES

When the model is run in predictive mode for 35 years, starting with groundwater heads established at the end of the calibration period, all streams have a losing status on average. The predicted stream-aquifer exchanges for each stream are listed in **Table 5.2** for natural conditions (no mining) and for simulation with and without a fractured zone.

Mining is predicted to cause some enhanced leakage from some of the losing streams. The largest predicted change is about 1 ML/day at Beta Creek which runs along the eastern edge of the mine lease. Smaller losses are anticipated for Tallarenha Creek (about 0.2 ML/day) and Saltbush Creek (about 0.1 ML/day).

The only gauged stream in the list is Native Companion Creek. This has a 10th percentile flow of 4.6 ML/day, a median flow of about 45 ML/day, and a predicted leakage rate of about 6 ML/day.

Table 5.2 Simulated Average Stream-Aquifer Water Exchanges during the Prediction Period

Reach	Stream	No Mining	Mining (Fractured Zone)	Mining (No Fractured Zone)	Maximum Effect
		[ML/day]	[ML/day]	[ML/day]	[ML/day]
101	Native Companion Creek	5.92	5.92	5.92	0.0
102	Belyando River	5.91	5.91	5.91	0.0
103	Beta Creek	2.53	3.61	3.09	1.1
104	Tallarenha Creek	3.03	3.19	3.14	0.16
105	Saltbush Creek	0.49	0.56	0.55	0.07
106	Lagoon Creek	1.15	1.17	1.16	0.0
107	Alice River	0.86	0.86	0.86	0.0
108	Jordan Creek	0.61	0.61	0.61	0.0
109	Alpha Creek	0.18	0.18	0.18	0.0
110	Other Creeks	1.90	1.97	1.94	0.07

5.6 PREDICTED WATER LEVELS

Figures 5.3 to **5.6** show the groundwater levels predicted at the end of mining for the water table (Layer 1), the Clematis Sandstone and Tertiary (Layer 2), the B seam (Layer 5) and the DL seam (Layer 9).

For Layer 1 (**Figure 5.3**) there is a depression over OC2 and the eastern part of the underground mines, indicated by the 340 mAHD contour compared to pre-mining conditions in **Figure 4.8**. This effect is more pronounced in **Figure 5.4** for Layer 2. The minimum water elevation is about 240 mAHD, compared to land surface of about 380 mAHD. Elsewhere, natural conditions prevail.

For Layer 5 (**Figure 5.5**), the lowest water level of about 120 mAHD would occur at the south-western corner of mine UG2. This is the focus for a strong cone of depression, with groundwater diverted towards this point from the east and the west.

The water levels are lower locally in Layer 9 (**Figure 5.6**), with a minimum of 40 mAHD along the western edge of mine UG3. The contours resume their normal pre-mining appearance beyond the seam outcrops to the east of the Project site.

5.7 PREDICTED DRAWDOWNS

Figures 5.7 to **5.10** show the groundwater drawdowns predicted at the end of mining for the water table (Layer 1), the Clematis Sandstone and Tertiary (Layer 2), the B seam (Layer 5) and the DL seam (Layer 9). Corresponding drawdown contour maps at 10-year intervals are in **Attachment F**.

The water table response (**Figure 5.7**) shows a broad drawdown extent that extends about 20 km from active mining to the north (for 1 m drawdown), 10 km to the south, and 15 km to the east. The western extent (towards the GAB) does not leave the mine lease. The 1 m drawdown contour aligns with the GAB geological boundary.

The 1m drawdown limit remains within the Highlands Subartesian Area except for parts of the UG2, UG3 and UG4 mines where mining is to the west of the administrative boundary. Maximum drawdowns of 5 m and 1 m are expected to occur at the neighbouring Alpha Coal Project and South Galilee Coal Project, respectively, due to Project mining. There is negligible (<1 m) drawdown beneath the Clematis Sandstone, near the recharge springs, at Alpha township, and at Jericho township.

The Layer 2 drawdown (**Figure 5.8**) extends about 50 km to the north, but no farther in the other three directions.

The responses in the B seam (**Figure 5.9**) and the DL seam (**Figure 5.10**) are similar except for greater local drawdown in the deeper seam. The underground mine voids act as large sinks with drawdowns of about 200 m and 250 m, respectively. The drawdown contours radiate from this point to large distances, with about 10 m drawdown beneath the GAB recharge springs. However, as the recharge springs have a shallow source, drawdown at deeper levels will not affect their reliability. The drawdown contours are truncated to the east of the Project site due to outcropping of the coal seams and associated interburden formations.

5.8 SENSITIVITY ANALYSIS

A recognised concern of the proposed mining is potential impact on the GAB water resource. The Rewan Formation / Dunda Beds provide a low permeability barrier between the productive Clematis Sandstone of the GAB and the Bandanna Formation coal measures. To assess the uncertainty in the transmissivity (hydraulic conductivity x thickness) of this unit, scenarios were run for vertical hydraulic conductivity (Kz) increased by a factor of 10 (Scenario 1) and 100 (Scenario 2). The applied Kz values are 9.3 x 10^{-5} m/day (base case), 1 x 10^{-3} m/day (Scenario 1) and 1 x 10^{-2} m/day (Scenario 2)[4].

The water table drawdown for Scenario 2 (**Figure 5.11**) shows no significant change, and certainly no propagation of effects to the GAB.

Only a marginal effect on mine inflows is discernible from increased vertical permeability in Layer 2, as indicated in **Table 5.3**.

Similarly, **Table 5.4** shows that the increased stream losses caused by mining are not sensitive to the vertical permeability of this layer.

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[4] The QWC Surat-Basin cumulative area model uses a typical Kz = 5.4 x 10^{-5} m/d

Table 5.3 Uncertainty in Predicted Average Mine Inflows

Scenario	Open Cut Mines (GL/a)	Underground Mines (GL/a)	All Mines (GL/a)
No Fractured Zone	2.6	23.1	25.7
Base Case	1.1	7.6	8.7
Scenario 1: Layer 2 Kz x 10	2.7	23.9	26.6
Scenario 2: Layer 2 Kz x 100	2.7	24.0	26.7

Table 5.4 Uncertainty in Predicted Average Stream Losses

		No Fractured Zone	Base Case (Fractured Zone)	Scenario 1: Layer 2 Kz x 10	Scenario 2: Layer 2 Kz x 100
Reach	**Stream**	[ML/day]	[ML/day]	[ML/day]	[ML/day]
101	Native Companion Creek	0.0	0.0	0.0	0.0
102	Belyando River	0.0	0.0	0.0	0.0
103	Beta Creek	0.6	1.1	1.1	1.1
104	Tallarenha Creek	0.1	0.2	0.2	0.2
105	Saltbush Creek	0.1	0.1	0.1	0.1
106	Lagoon Creek	0.0	0.0	0.0	0.0
107	Alice River	0.0	0.0	0.0	0.0
108	Jordan Creek	0.0	0.0	0.0	0.0
109	Alpha Creek	0.0	0.0	0.0	0.0
110	Other Creeks	0.0	0.1	0.1	0.1

5.9 POST-MINING EQUILIBRIUM

The recovery of groundwater levels after cessation of mining has been investigated by running a simulation for 200 years without any mining stresses. The final voids at OC1 and OC2 are represented in the model as highly permeable space (1000 m/day) with unit specific yield and free-water evaporation.

The final water table levels, shown in **Figure 5.12**, demonstrate a permanent lowering of the water table over the mine footprint, with a typical elevation of 340 mAHD through the centre of the mining area. Mild groundwater sinks are maintained at each final void.

Representative recovery hydrographs for four piezometer depths at the centrally-located monitoring bore WBR2 are shown in **Figure 5.13**. The deeper hydrographs show rapid recovery over 50 years, with slower incomplete recovery out to 200 years. The shallowest hydrograph behaves differently, and is indicative of what will happen at shallow depths. The water level declines for about 60 years, then stabilises, then starts to climb in concert with the deeper water levels. The early-time response is due to vertical drainage of water through the fractured zone over the mine voids, replenishing the deeper water-bearing formations.

6 POTENTIAL GROUNDWATER IMPACTS

6.1 CHANGES IN HYDRAULIC PROPERTIES

There would be a change in hydraulic properties over the mine footprint where mine waste rock infills the excavation down to the floor of the open cut. As mine waste rock would have a higher permeability than any natural material in this area, with the possible exception of alluvium, there would be associated reductions in hydraulic gradients in accordance with Darcy's Law. As one increases, the other must decrease to maintain the same flow.

There would also be a permanent increase in permeability and porosity of the rocks in the fractured zone above the mine voids.

Rainfall recharge is expected to be higher in the mine waste rock than in any natural local material.

6.2 CHANGES IN GROUNDWATER FLOW AND QUALITY

As mining progresses, the surface and underground voids would act as groundwater sinks. This would cause a temporary change in groundwater flow direction, generally reversal of direction due to the direction and extent of excavation, until mining is completed and the groundwater system recovers to a new equilibrium (**Figure 5.12**).

The post-mining groundwater level pattern in **Figure 5.12** shows that the two final voids would act as mild groundwater sinks. The final equilibrium groundwater levels are expected to be about 10 m lower than current groundwater levels near the western edge of the OC2 final void. As the salinity in the void waters will increase with time due to evaporative concentration, there is a risk of the void lakes becoming flow-through systems and allowing conveyance of water downgradient by means of lateral groundwater flow.

The quality of the inflow water would be a mixture of the qualities of the waters in source lithologies, primarily coal and coal measures of the Bandanna Formation, and leachate from rainfall infiltration through the waste emplacements. As there is a wide range in source waters from very fresh to very saline, the likely salinity of pumped water is not well known.

6.3 THE GREAT ARTESIAN BASIN

The western edge of the proposed mine plan is close to the boundary of the Clematis Sandstone and the Dunda Beds, but the GAB boundary is obscured by Quaternary cover sediments (**Figure 1.4**). This means that the mine's footprint is designed to pass beneath the GAB's basal aquitard but it is not clear whether or not it will lie beneath the GAB's basal aquifer. The modelling in this report assumes a conservative condition by drawing a straight line between the most easterly Clematis Sandstone outcrops to the north and south of the gap. It is more likely that the boundary will be farther to the west, as inferred in Issue Response 17038 / 8016 in Part C of the SEIS (Submissions Responses).

The predictive simulations show negligible drawdown (less than 1 m) in the Clematis Sandstone for the base case model and for sensitivity tests in which the vertical permeability of the Rewan Formation / Dunda Beds aquitard is increased by two orders of magnitude. In the underlying Permian formations, there will be significant drawdowns in the west of the model area caused by Project mining, but it is probable that this depressurisation will not propagate to the GAB aquifer.

6.4 ECOSYSTEMS AND SPRINGS

According to the Waratah Coal Environmental Management Plan: "*The receiving waterways of the Galilee Coal Mine are ephemeral in nature and provide seasonal habitat for aquatic fauna and flora. Wetlands mapping for the receiving waterways ... indicates the presence of wetlands or remnant ecosystems that may contain wetlands along sections of all receiving waterways. The receiving waterways are considered to be slightly to moderately disturbed from current grazing activities and do not contain any High Ecological Value waters*".

It is probable that riparian wetlands are associated with perched groundwater conditions, as the depth to the regional (not perched) water table is generally a minimum of about 10 m along the drainages, increasing to the order of 100 m beneath the Clematis Sandstone ridge. Across the project site the range is generally 20-60 m. The deeper regional water table is too deep for evapotranspiration and vegetation dependence to be active.

Streams are likely to be losing systems as they are disconnected from the regional water table. Connectivity with the regional geological environment is likely to be very limited due to the low vertical permeability of the underlying strata.

There are no identified springs within the immediate Project area. However, recharge springs have been identified 30-40 km to the west of the GAB boundary within the recharge zone and also to the west of the recharge zone, in the Barcaldine Spring Complex. The Great Artesian Basin Resource Operations Plan includes a register of vent springs and watercourse springs (at 2009) that support significant cultural and environmental values.

The springs are aligned with a north-south trend passing through the township of Alice on the western side of the Great Dividing Range and appear to be expressed at elevations of 300-400 mAHD. The alignment of registered springs correlates with the Hutton Sandstone and underlying Moolayember Formation subcrop line. It is likely that the interaction of recharge and interflow in these units may form recharge springs within the Hutton Sandstone outcrop.

It is noted in the Alpha Coal Project groundwater assessment (URS, 2012) that a review of hydrology and satellite imagery indicated that the springs are ephemeral and seasonal.

The predictive simulations show negligible drawdown (much less than 1 m) at the locations of the springs. Deep groundwater system drawdowns of about 10 m would occur beneath the springs as a result of the proposed mining, but it is highly unlikely that this depressurisation would propagate vertically and impact on the springs.

The rate of natural leakage of water from some ephemeral streams is predicted to increase during mining. The affected streams are Beta Creek (about 1 ML/day incremental loss), Tallarenha Creek (about 0.2 ML/day incremental loss), and Saltbush Creek (about 0.1 ML/day incremental loss).

6.5 CUMULATIVE IMPACTS

With the endorsement of OCG and DNRM, the quantitative cumulative impact assessment was to be based on the *Principle of Superposition,* as an approximation of the combined effects, which permits the algebraic summation of drawdowns reported separately by the other mining proponents (subject to limitations). However, the drawdowns estimated for the Alpha Project were based on modelling that did not include a fractured zone. This will give underestimated local drawdowns but it is likely that the far-field drawdowns will be valid. In general, the modelling found maximum westerly drawdown extents of 10-15 km, and easterly extents of about 5 km. For the South Galilee Project, drawdowns are published only for the combined effects of three mines. As the individual impact of the South Galilee Mine was not divulged, the Principle of Superposition for this mine is not applicable.

As the Project model extent is sufficiently broad to include the two nearest proposed mines, explicit simulation of these mines has been undertaken, but there is incomplete knowledge of geological detail and mining sequence for the other projects. Model simulations of all three mines active at the same time have proved difficult, as the level of stress on the overall groundwater system is of such a magnitude as to cause numerical convergence problems.

The cumulative impact modelling has been done as a pseudo-state simulation, that is by running the model for 100 years with no variable stresses. Each Project is represented by the end-of-mining active underground and open cut voids. The Galilee Project retains the detailed fractured zone spatial and vertical distribution. The fractured zones for the other two mines are represented by uniform vertical cylinders of 1 m/day vertical hydraulic conductivity.

Figure 5.14 shows the groundwater table pattern. The hydraulic gradients are more pronounced at the Alpha and South Galilee projects because of the fractured zone assumptions. Overall, the effects on the natural flow pattern seem localised to the three mines.

The predicted drawdowns in **Figure 5.15** show a broad elongated cone of depression that is about 30 km wide and over 100 km in length along a north-south axis, as defined by the 2 m drawdown outline[5]. The eastern limit of drawdown is well defined, as it is controlled by outcropping geology and the erosion of coal measures. There is some expansion of the drawdown limit to the west, including a small tongue crossing the GAB geological boundary in the area where the GAB rocks are hidden by Quaternary cover. The expansion to the west is not substantial and does not compromise conclusions reached as to the lack of likely impact on the GAB aquifer or the GAB springs.

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[5] The 1 m contour exhibits numerical noise and is an unreliable indicator of far-field effects. There is also some numerical noise in the 2 m contour at large distances (north-east and south-east corners of the model area).

6.6 REGISTERED PRODUCTION BORES

The bore census conducted for the EIS identified 18 active bores in the vicinity of the Project site, within about 20 km west and about 4 km east. Water level and water quality were measured at these sites. For the SEIS, a search of the DNRM database was undertaken. A total of 63 bores was identified within 10 km of the mine site boundaries. A broader search was undertaken after the worst-case drawdown impact zone was determined by steady-state modelling (Heritage Computing, 2012). Bores within the original 1 m drawdown impact zone are marked on **Figure 6.1**.

As expected, the transient prediction has found a narrower drawdown impact zone than was found in earlier worst-case steady-state modelling. As a precautionary measure, the list of potentially-affected existing groundwater users has been retained. In **Figure 6.1**, the locations of the bores are compared with the updated 1 m and 5 m predicted drawdown limits for the Layer 2 groundwater level.

There are 236 registered bores within the original 1 m outline, including 123 bores within the original 5 m outline. The screened lithologies of these bores are known for about half the bores (113 within the 1 m outline, including 61 bores within the 5 m outline).

The distribution of screened lithologies at bores that might be affected by dewatering are shown in **Table 6.1**. If bores are screened well below the water table in deeper formations, then they will experience more depressurisation than would occur in the regolith. This means they will be affected severely.

Details of the registered bores within the drawdown impact zone are given in **Attachment C**.

Table 6.1 Lithologies of Potentially Affected Production Bores

Formation	Number of Bores within 5m Drawdown Impact Zone	Number of Bores within 1m Drawdown Impact Zone
Alluvium	4	21
Tertiary	12	23
Dunda Beds	8	8
Bandanna Formation	2	6
Colinlea Sandstone	27	46
Joe Joe Group	8	9
Unknown	62	123
Total	**123**	**236**

The drawdowns at the Jericho and Alpha town supply bores are predicted to be less than 1 m for a worst-case scenario.

6.7 MITIGATION OF IMPACTS

As there is no predicted impact on groundwater-dependent ecosystems or GAB springs or the GAB aquifer, and minimal effect on stream leakage, no mitigation plans are required for these issues.

However, there are predicted impacts on water levels in private bores up to 10 km to the east and south of the mine lease. Should a detrimental impact on landholder groundwater supplies be detected, and shown to be related to the Project, an agreement would be sought with the affected neighbouring groundwater users for the provision of alternative supplies throughout the mine life and after mine closure. In turn, alternate water supplies can be put in place before supplies from relevant existing landholder bores are adversely affected. Due to the progressive nature of drawdown within aquifers, the provision of alternate supplies is likely to be staged. Options for alternate supplies include:

- installation of new pumps capable of extracting groundwater from greater depth than existing bores;
- deepening of existing bores (to target the Colinlea Sandstone water source);
- installation of a new bore at another location on the property; and
- provision of piped water sourced from the mine or nearby water pipelines.

The specific arrangements for affected properties would be discussed with each relevant landholder with a view to reaching a mutually acceptable arrangement.

As the drawdowns at the Jericho and Alpha town supply bores are predicted to be less than 1 m for a worst-case scenario, no mitigation plans are necessary.

Regular groundwater monitoring within the predicted zone of impact should be undertaken to enable groundwater level drawdown to be identified prior to any impacts being experienced in surrounding landholder bores. The existing groundwater monitoring network is sufficient for tracking on-site and near-site effects from mining. An additional five monitoring bores are recommended for far-field effects, generally about 5 km from the mine lease to the east, south-east, south-west and west.

6.8 MONITORING NETWORK

The current groundwater monitoring network as shown in **Figure 3.7** should be supplemented with five new bores to allow comprehensive monitoring within the entire worst-case predicted drawdown impact zone, at sites shown in **Figure 6.2**. The extra monitoring bores will provide hydraulic responses to mining that will enable improved calibration of the groundwater model and a check on whether the predicted drawdowns are realised.

Approximate coordinates for the proposed new monitoring sites are given in **Table 6.2** along with a rationale for selection of the sites.

Sites P1, P2 and P3 should be installed with vibrating wire piezometers and dataloggers measuring hourly. Sites P4 and P5 (in the Joe Joe Group) can be installed as standpipes but dedicated dataloggers (measuring hourly) are recommended. Sites P4 and P5 should also be sampled quarterly for water quality (major ions).

Table 6.2 Proposed New Groundwater Monitoring Sites

Bore ID	Easting	Northing	Rationale
P1	418830	7400340	Outside worst-case 5 m drawdown zone. About 5 km west of mine lease in GAB gap. Close to the south-western corner of mining footprint. Piezos: Clematis, Dunda, Bandanna, DU seam, Colinlea.
P2	423630	7388109	Outside worst-case 1 m drawdown zone. At south-western corner of mine lease. About 12 km south of the south-western corner of mining footprint. Piezos: Clematis, Dunda, Bandanna, DU seam, Colinlea.
P3	445930	7386310	Inside worst-case 5 m drawdown zone. About 10 km to south-east of mine lease, on Tallarenha Creek road crossing. Piezos: Bandanna, DU seam, Colinlea.
P4	456840	7396260	Inside worst-case 5 m drawdown zone. About 7 km to east of mine lease, about 20 km from mining footprint. Piezos: Joe Joe (shallow & deep)
P5	457560	7404900	Inside worst-case 5 m drawdown zone. About 5 km to east of mine lease, about 15 km from mining footprint. Piezos: Joe Joe (shallow & deep)

7 LIMITATIONS

There is uncertainty in formation elevations and thicknesses away from the Project site. The Project geological model has been extrapolated to the west (below the GAB) and to the east, on the basis of seam dip, a representative cross-section on the published Geological Map and on surface contours presented by RPS Aquaterra for the Galilee Basin Operators' Forum (GBOF).

DNRM water level records, used to infer groundwater flow directions, are low quality. In general, they provide snapshot information at the time of construction of a bore and the data span many decades. In particular, the vertical head distribution away from the Project site is not known.

Although substantial hydraulic property measurements have been made via slug tests, pumping tests, packer tests and core lab analysis at the coal projects, there is substantial range in every property. Actual mine inflows will tighten these estimates in time, but all sites are greenfield in the Galilee Basin (apart from a box cut at Alpha). As there is no historical control on mine inflow estimates, there is uncertainty as to the inflow estimates and the associated drawdowns.

The lack of a rainfall recharge signature in groundwater hydrographs means that recharge rates are poorly resolved. This affects the underground water balance. Deep measurements of groundwater pressures (using vibrating wire piezometers) are not always stable or consistent, and the direction of the vertical head gradient has not been established definitively.

The degree of enhancement of permeabilities (mostly vertical) in the underground fractured zone, as a result of mining, cannot be known *a priori*. Assumptions must be made and likely bounds assessed through sensitivity analysis.

In summary, the predicted impacts associated with groundwater are contingent on a number of factors that have inherent uncertainty:

(1) lack of knowledge on mine inflow magnitude due to greenfield conditions;

(2) degree of enhanced permeability in underground fractured zone;

(3) no information content in monitored hydrographs on storage properties due to minimal climatic stress; and

(4) incomplete historical matching of groundwater levels due to inconsistencies and instability in deep groundwater pressures..

9 CONCLUSION

This report provides a groundwater assessment of the proposed Open Cut and Underground mining operations to support an updated SEIS application. In the original EIS groundwater assessment, shortcomings were identified with respect to the monitoring network, aquifer testing, aquifer connectivity, groundwater quality, GAB potential impacts, cumulative impacts and groundwater modelling. The supplementary assessment has been undertaken by Heritage Computing Pty Ltd, primarily to develop a new numerical groundwater model as a basis for a revised assessment of environmental impacts.

Seven new sites have been added to the monitoring network. All sites are equipped with continuously datalogged vibrating wire piezometers. In all, there are 25 piezometers at the seven sites, designed to monitor the full stratigraphic section down to the deepest coal seam to be mined. Four of the new sites are situated close to the mining footprint, with two upgradient of the open cut pits in the vicinity of Lagoon Creek, and two downgradient of the open cut pits overlying and adjacent to the underground mines.

For the SEIS, 21 core samples were collected from four holes for laboratory measurement of permeability, packer testing has been done on two holes from depths of about 140 m to depths of 265 m and 238 m, and additional water quality analysis has been done.

Waratah Coal has instigated development of a new and more extensive groundwater model. The additional exploration drilling that has occurred since the EIS has led to a higher-resolution geological model that has provided an updated structure for the new groundwater model.

With the endorsement of the Coordinator-General, the model development proceeded in two stages. **Stage 1** (presented as an interim report in December 2012) simulated steady-state conditions for worst-case impact prediction at the end of mining. **Stage 2** undertook transient calibration and simulation of the transient progression of mining. Stage 2 also covered sensitivity analysis, uncertainty analysis, recovery simulation and cumulative impact assessment. The results of both Stage 1 and Stage 2 are reported upon herein.

The total mine inflow for all mines is expected to average about 26 GL/annum over the 30 years of proposed mining. This consists of about 2.6 GL/annum reporting to the open cut pits and about 23 GL/a for the underground mines. The deepest mines (UG2 and UG3) would have the highest inflows.

Over the prediction period, all streams are naturally losing systems. Mining is expected to have a mild impact in the form of enhanced leakage on Beta Creek, Tallarenha Creek and Saltbush Creek. The largest predicted change is about 1 ML/day at Beta Creek which runs along the eastern edge of the mine lease.

The modelling predicts a broad drawdown extent that extends about 20 km from the area of active mining to the north (for 1 m drawdown), 10 km to the south, and 15 km to the east. The western extent (towards the GAB) does not leave the mine lease and the 1 m drawdown contour aligns with the GAB geological boundary.

The 1m drawdown limit remains within the Highlands Subartesian Area except for parts of the UG2, UG3 and UG4 mines where mining is to the west of the administrative boundary. Maximum drawdowns of 5 m and 1 m are expected to occur at the neighbouring Alpha Coal Project and South Galilee Coal Project, respectively, due to Project mining.

There is negligible (less than 1 m) drawdown beneath the Clematis Sandstone, near the recharge springs, at Alpha township, and at Jericho township.

Maximum drawdowns of 5 m and 1 m are expected to occur at the neighbouring Alpha Coal Project and South Galilee Coal Project, respectively, due to Project mining.

The cumulative impact assessment for three operating mines reveals a broad elongated cone of depression that is about 30 km wide and over 100 km in length along a north-south axis. The eastern limit of drawdown is well defined, as it is controlled by outcropping geology and the erosion of coal measures. There is some expansion of the drawdown limit to the west, including a small tongue crossing the GAB geological boundary in the area where the GAB rocks are hidden by Quaternary cover. The expansion to the west is not substantial and does not compromise conclusions reached as to the lack of likely impact on the GAB aquifer or the GAB springs.

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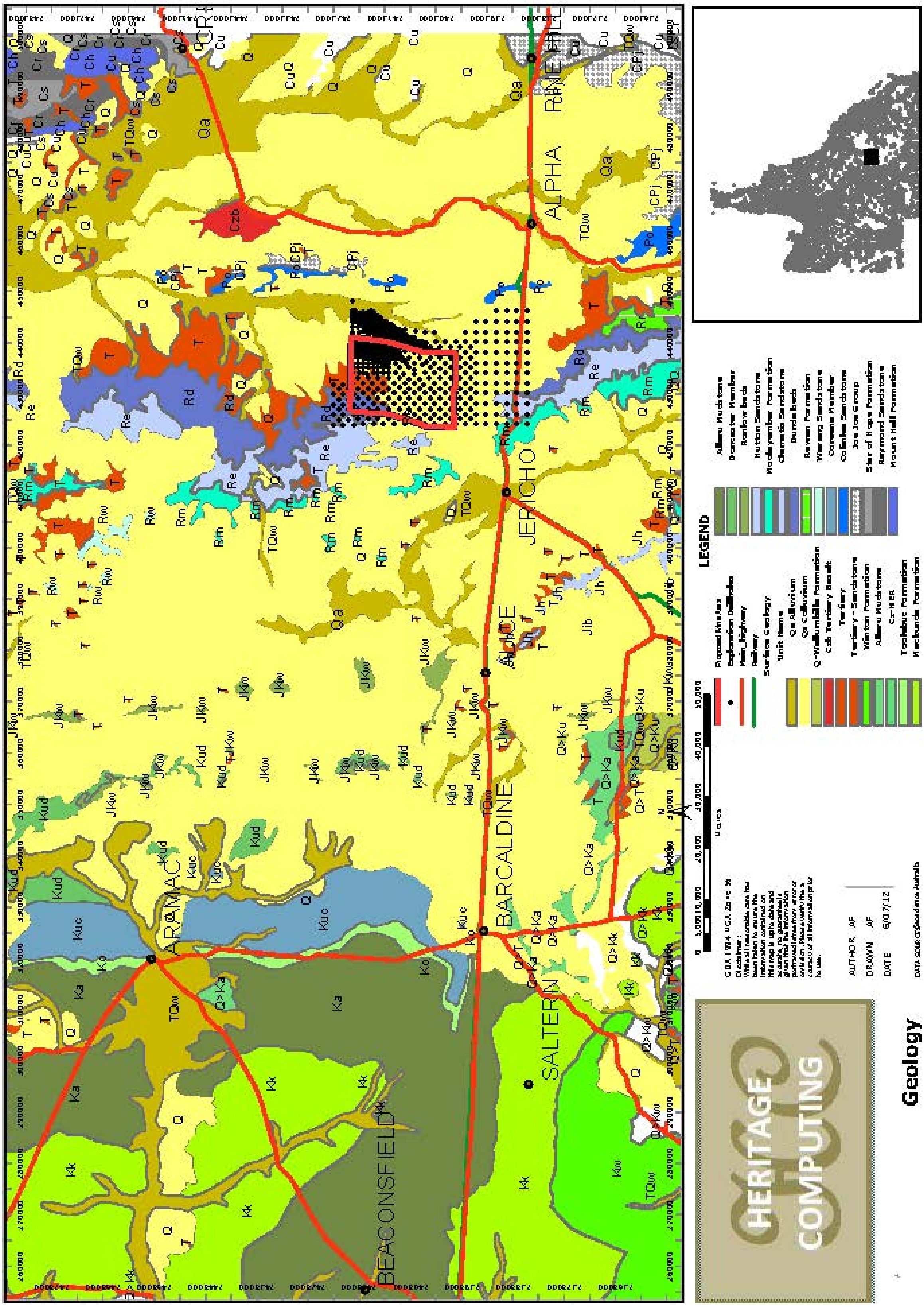


Figure 1.1 Location Plan and Surface Geology

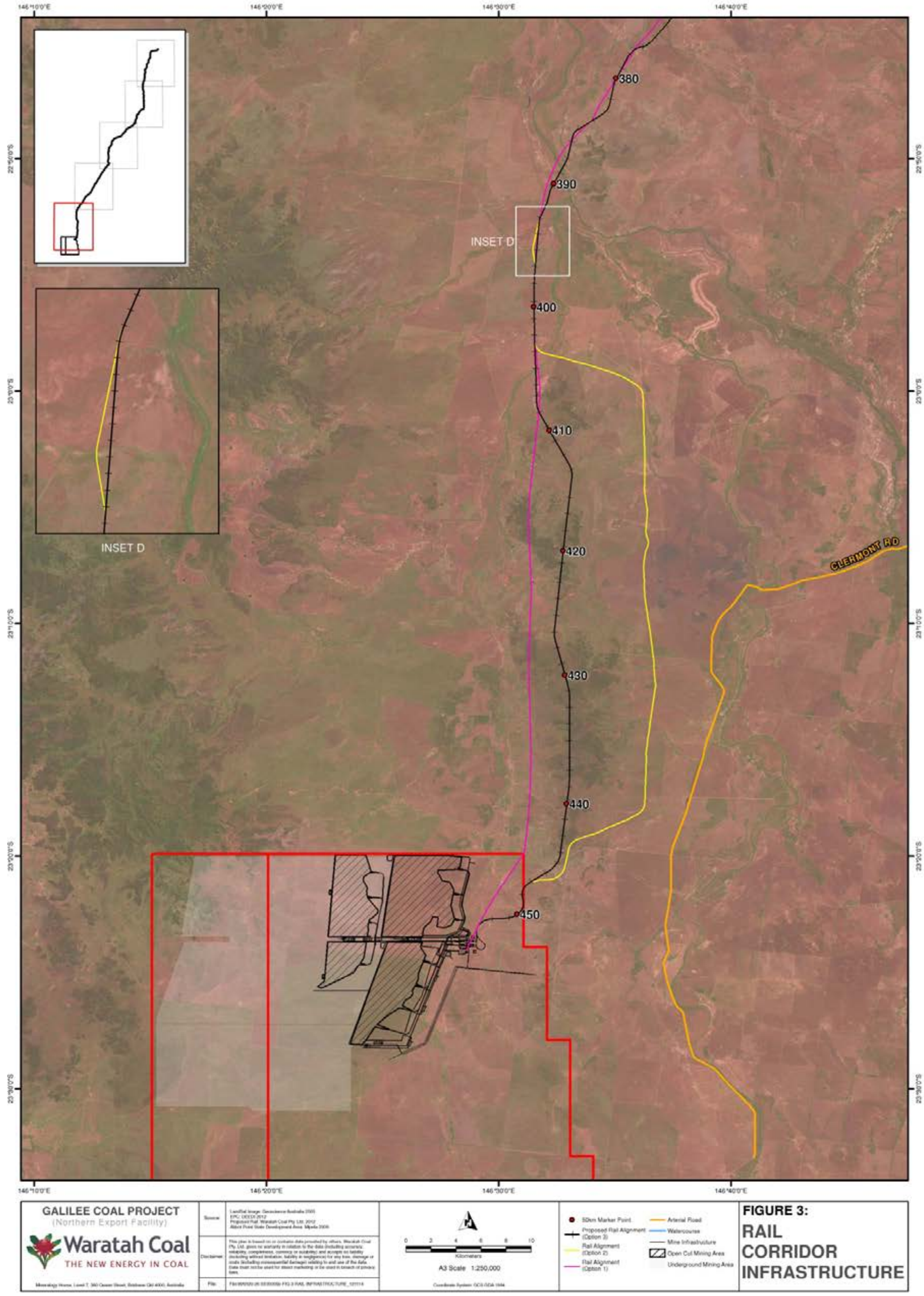


Figure 1.2 Rail Corridor Infrastructure

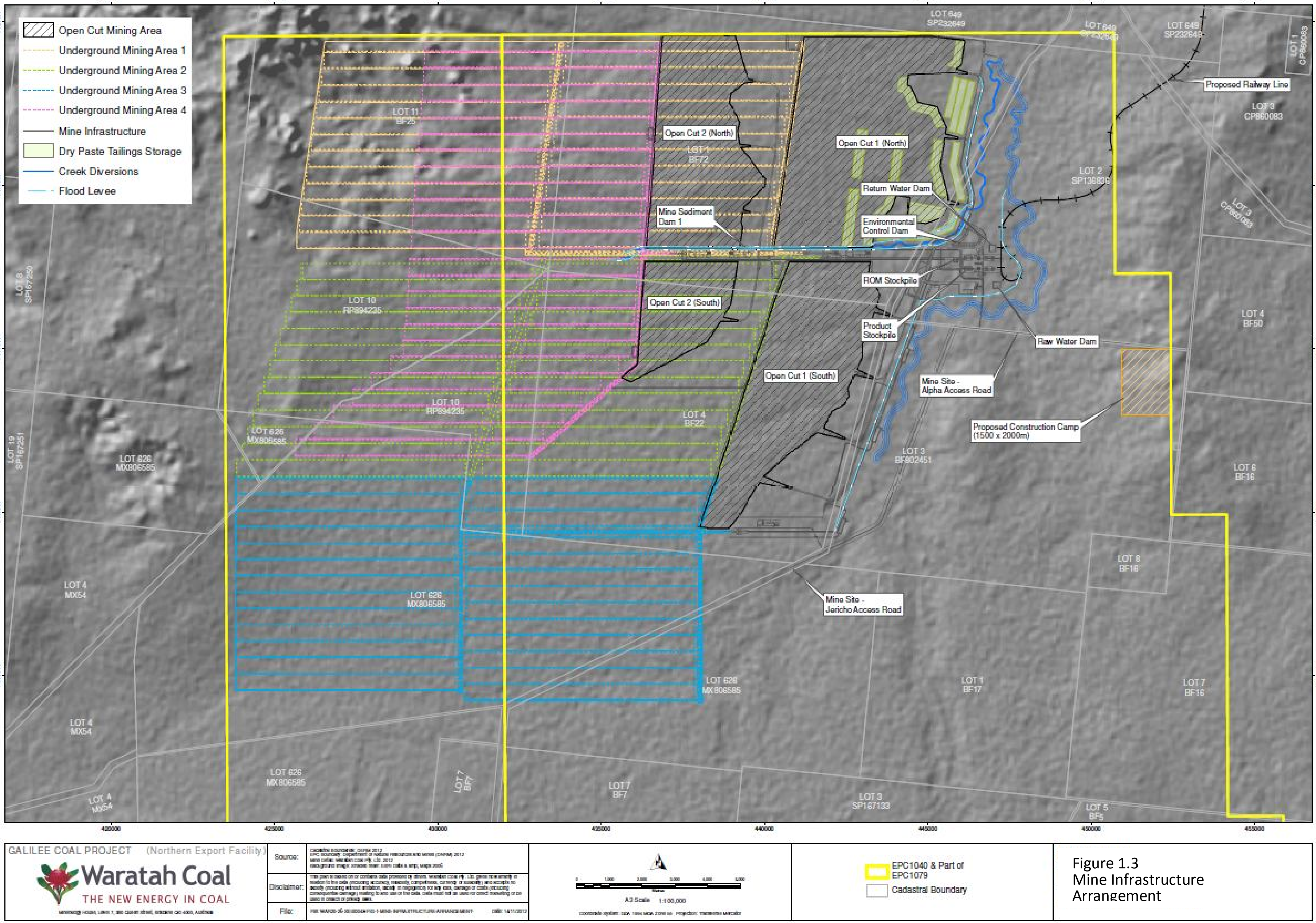


Figure 1.3 Mine Infrastructure

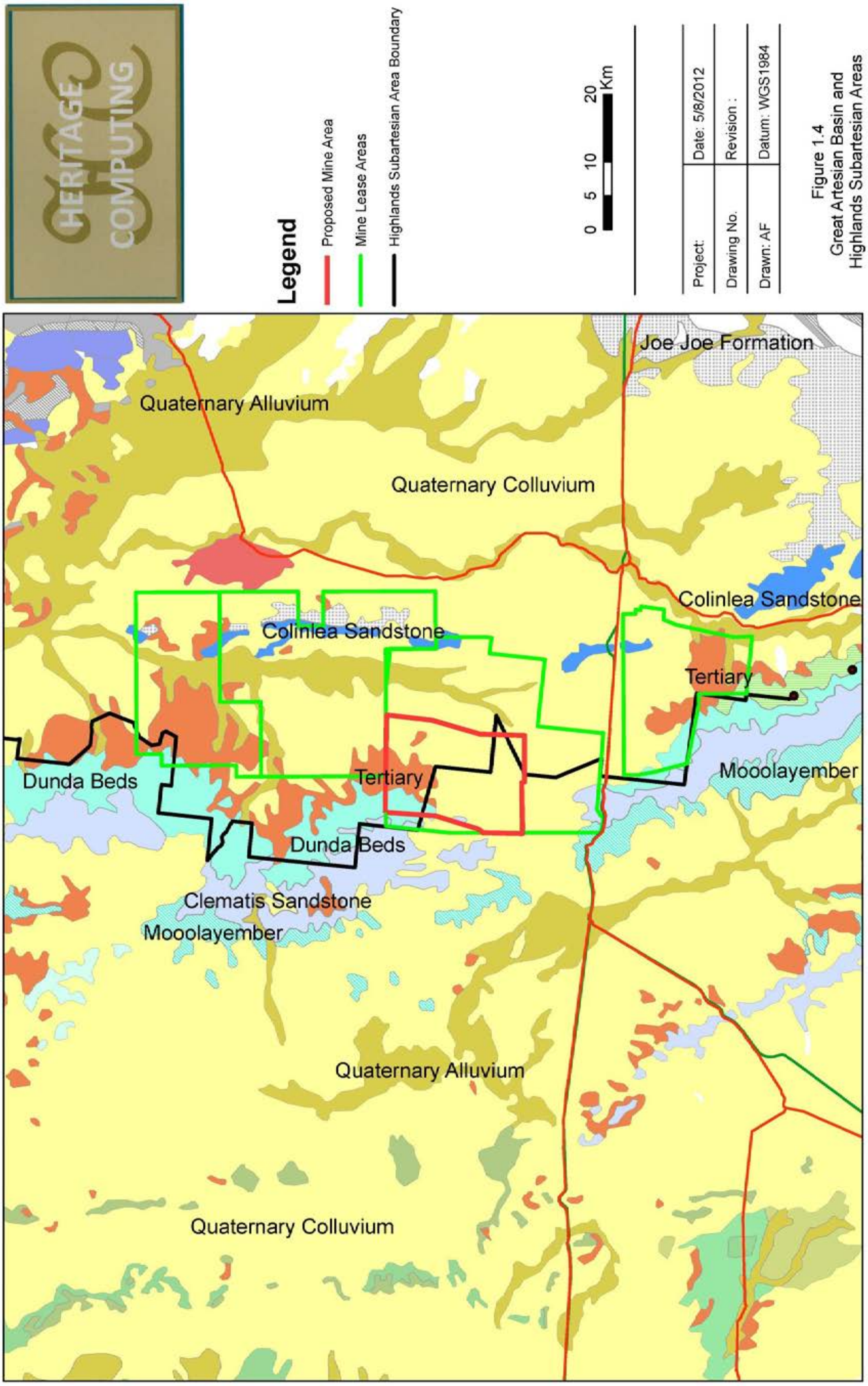


Figure 1.4 Great Artesian Basin and Highlands Subartesian Areas

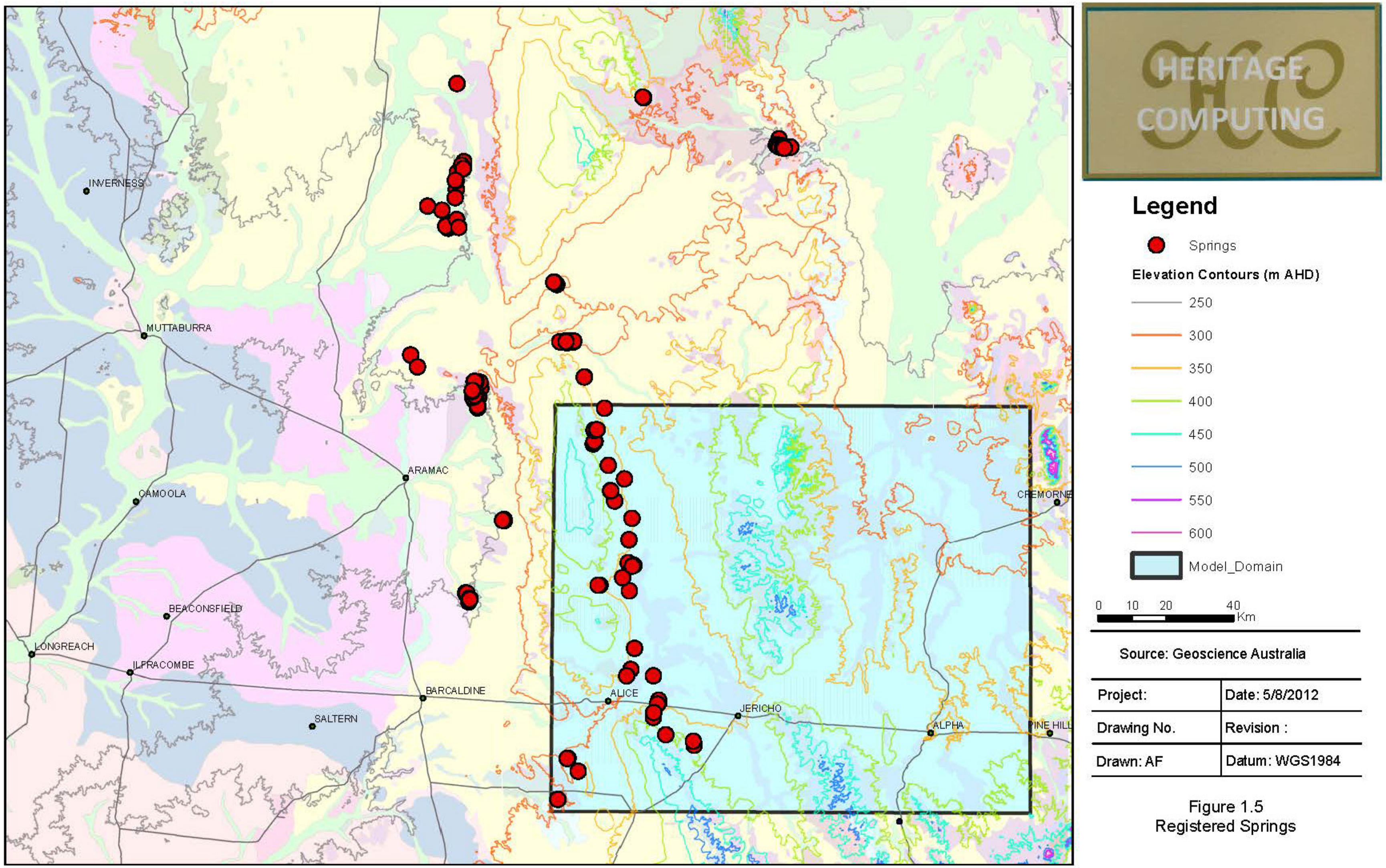
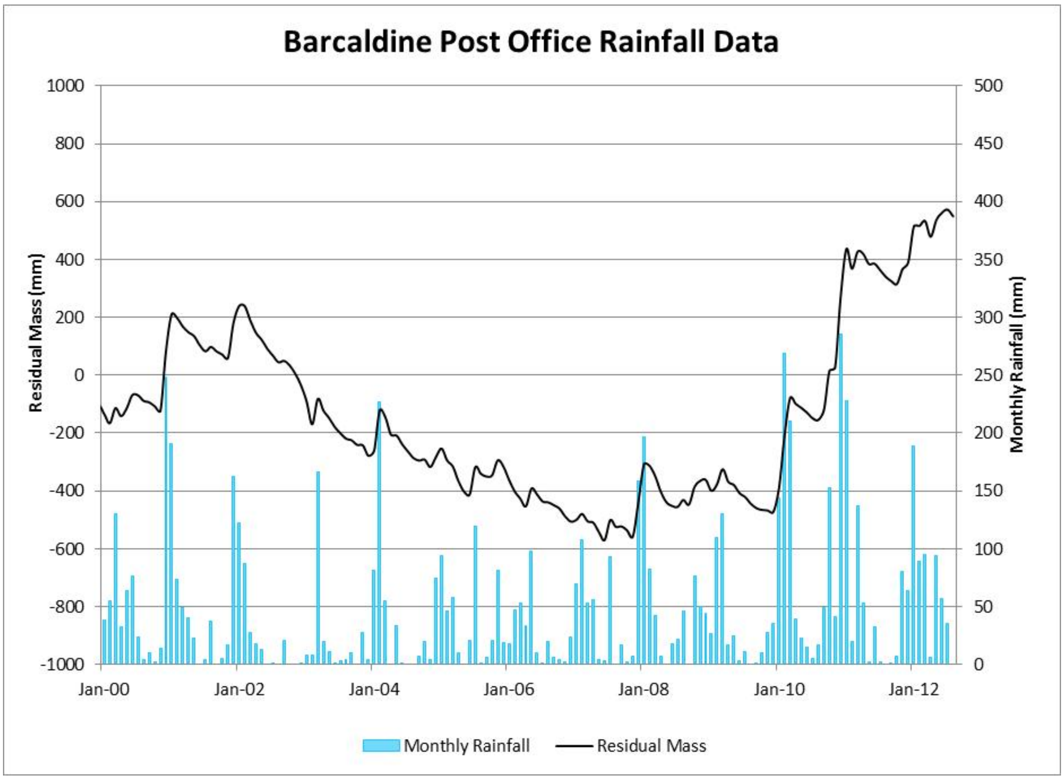


Figure 1.5 Registered Springs



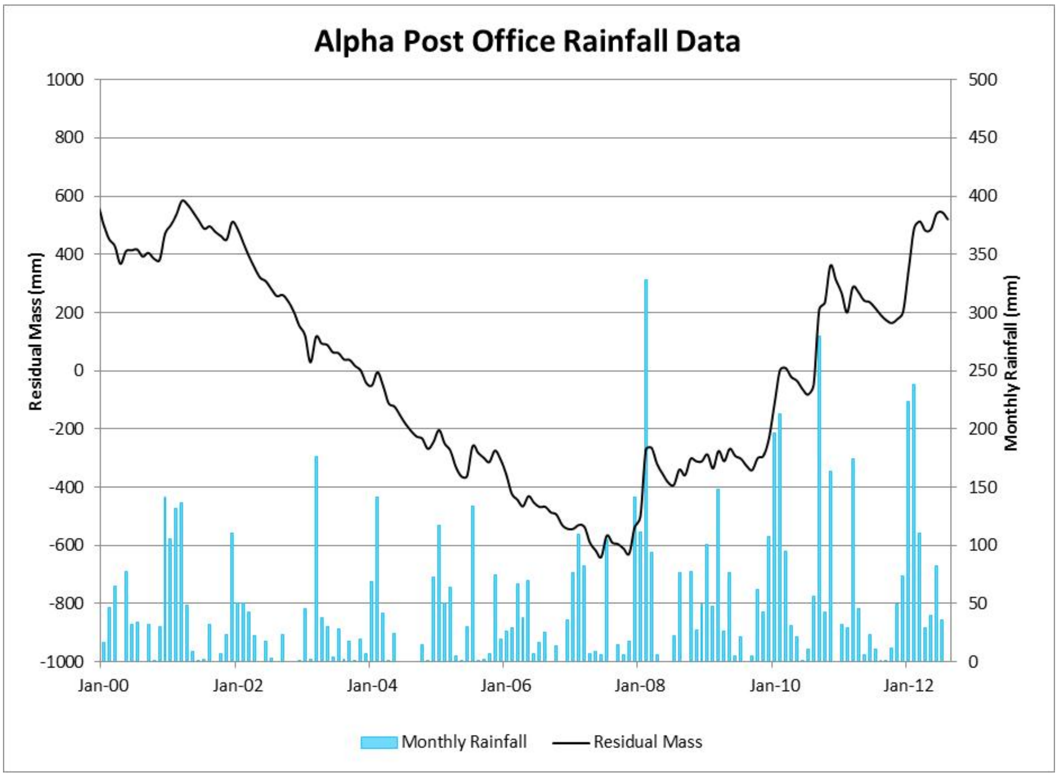


Figure 3.1 **Rainfall Residual Mass Curves for Barcaldine and Alpha**

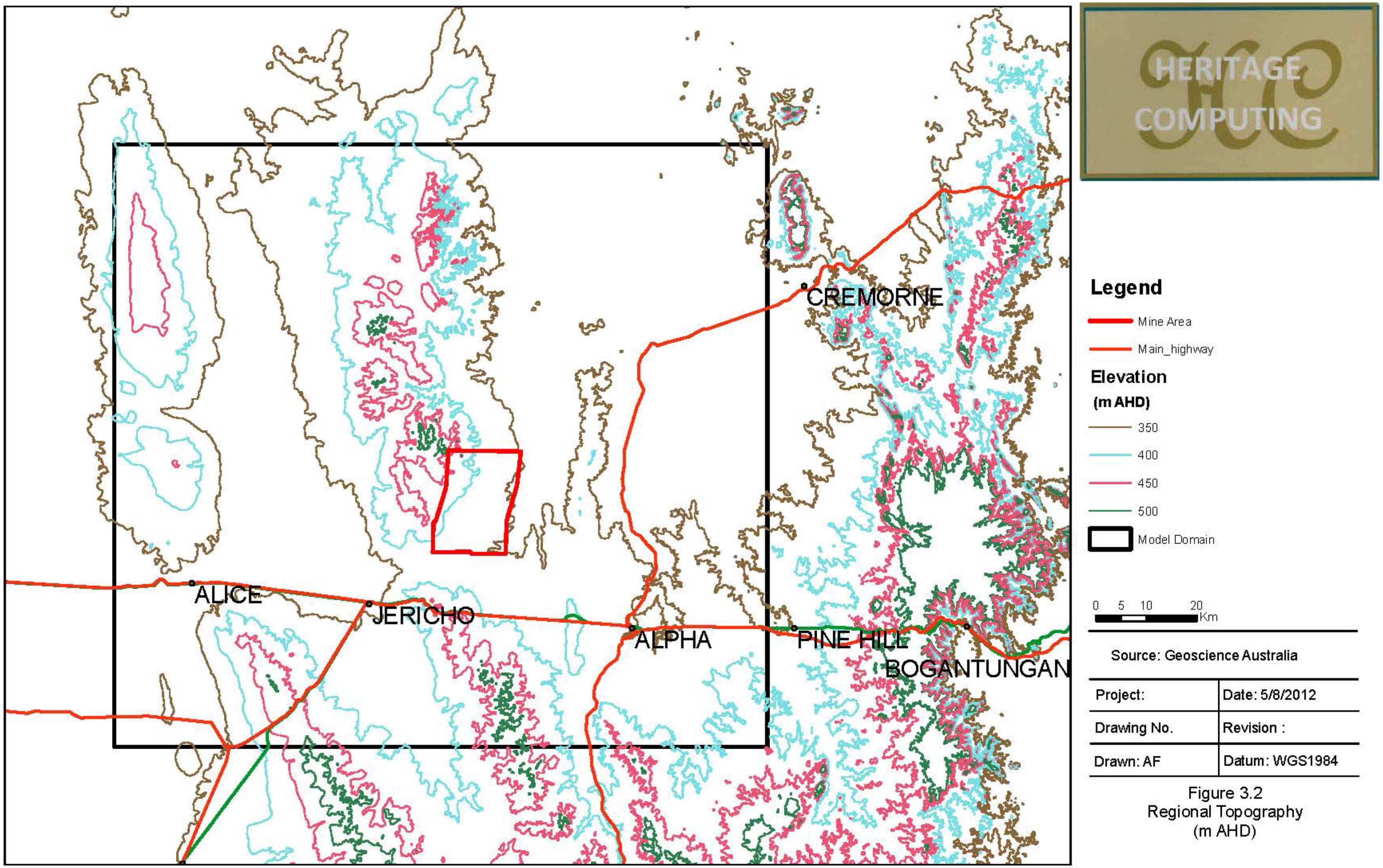


Figure 3.2 Regional Topography

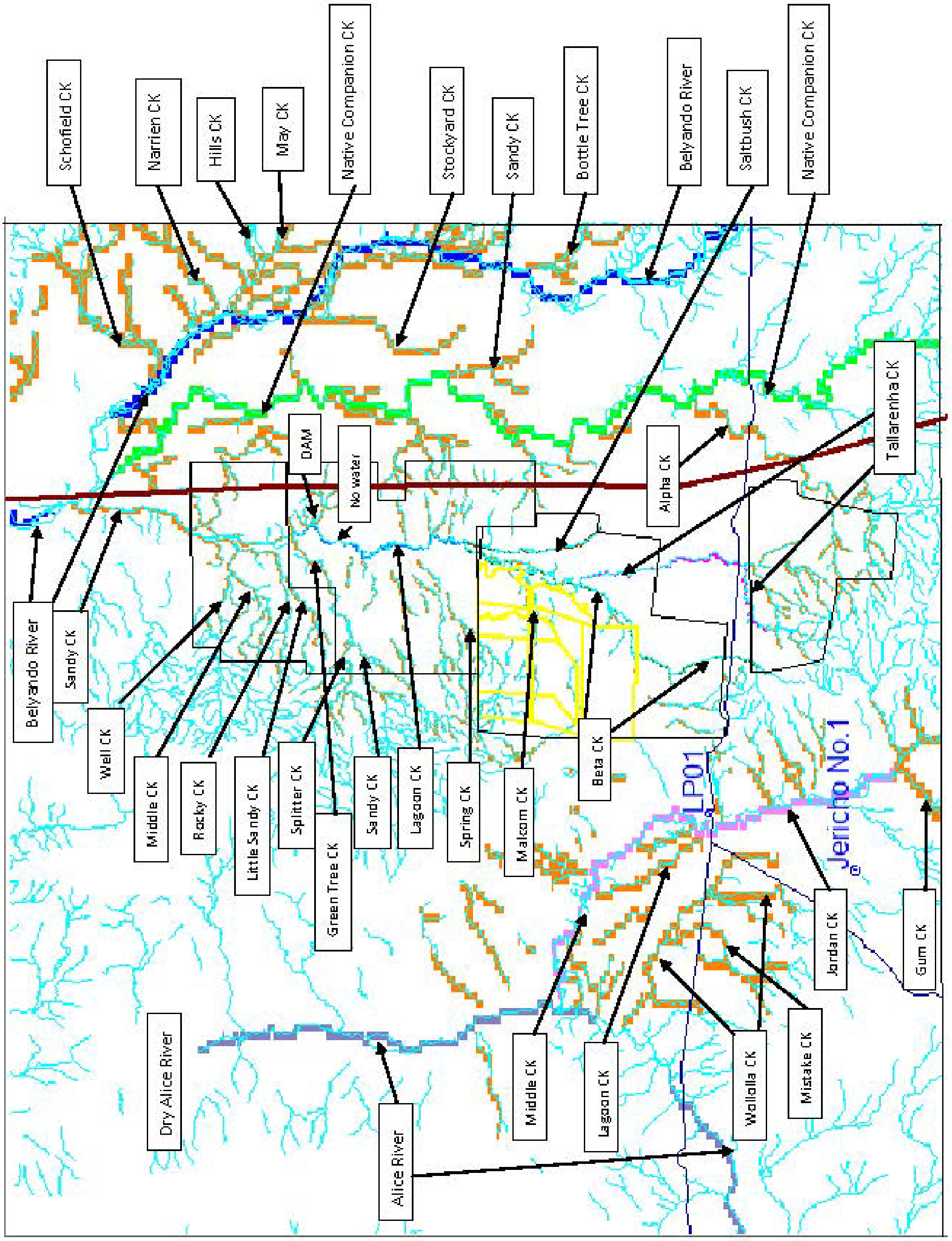


Figure 3.3 District Watercourses

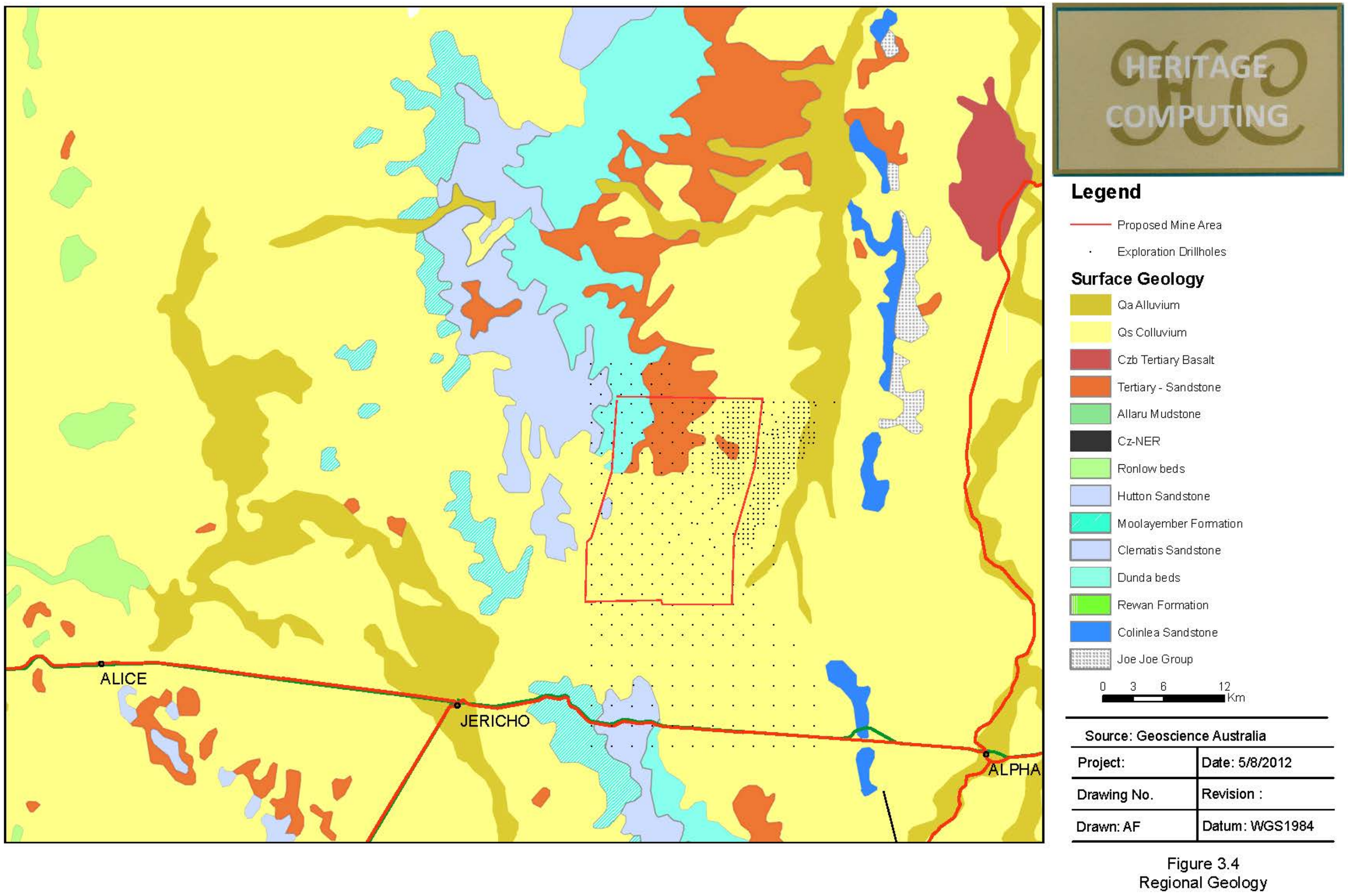


Figure 3.4 Regional Geology

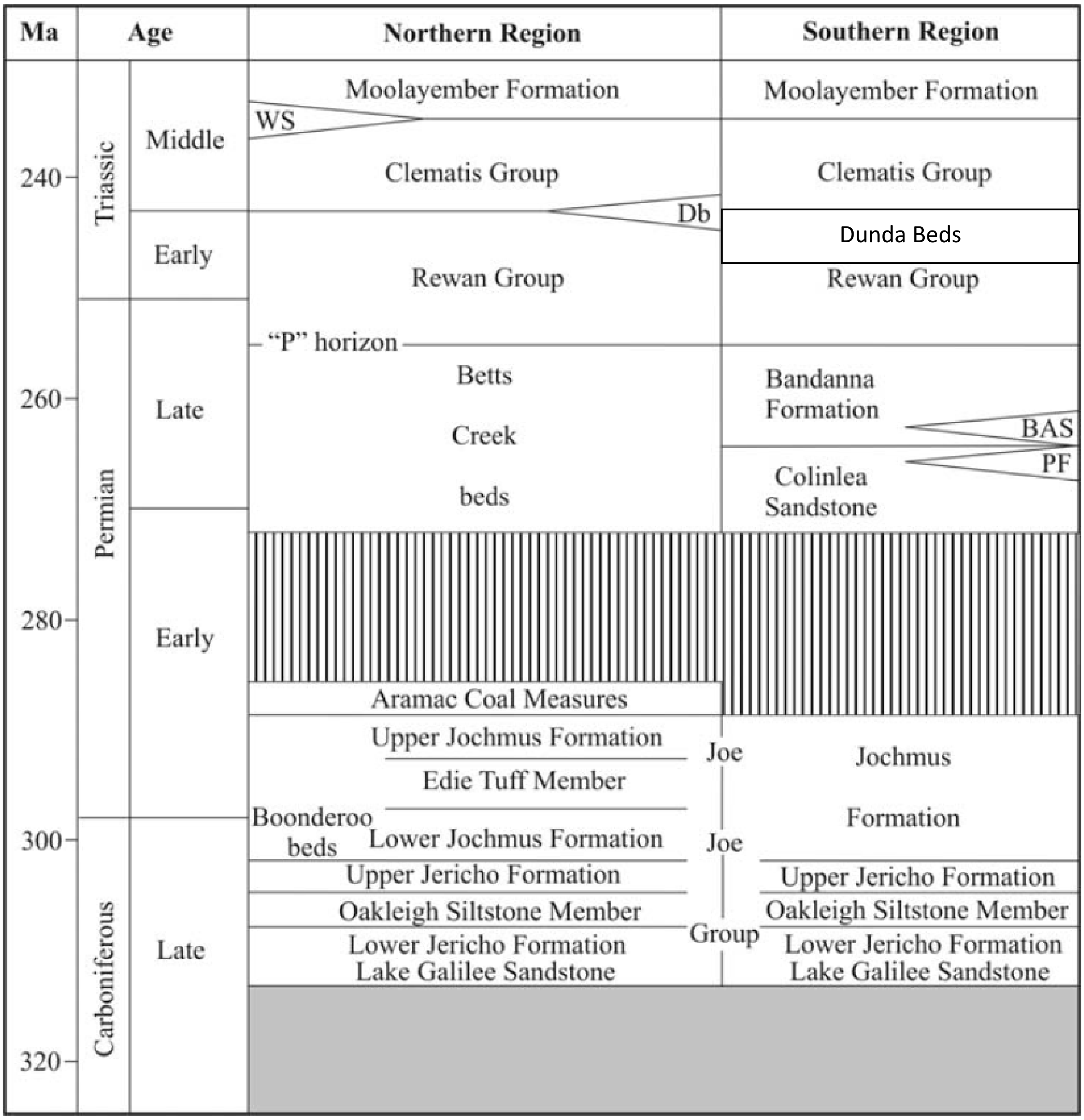


Figure 3.5 **Stratigraphic Subdivision of the Galilee Basin**

(after Van Heeswijck, 2006)

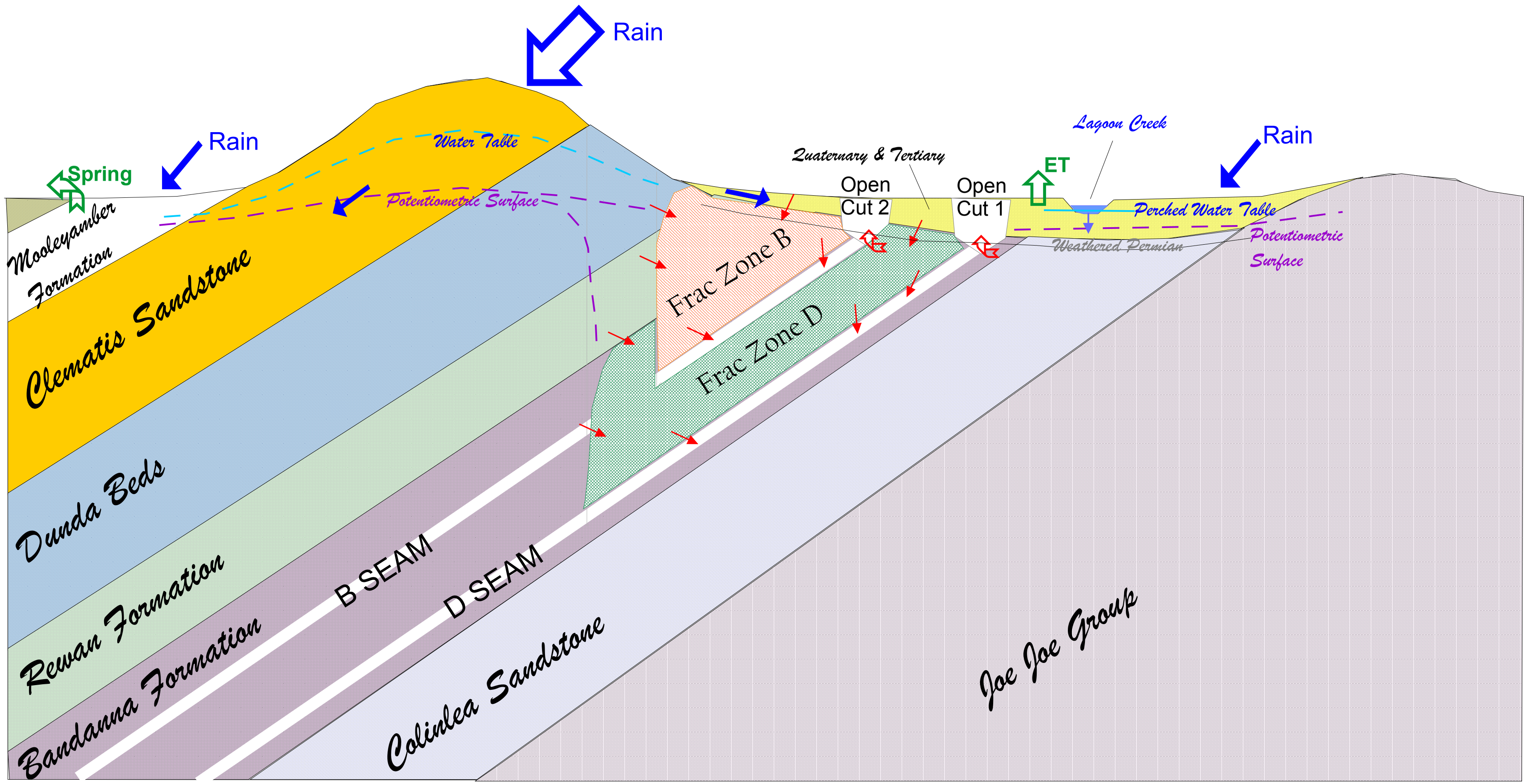


Figure 3.6 Conceptual Hydrogeological Model

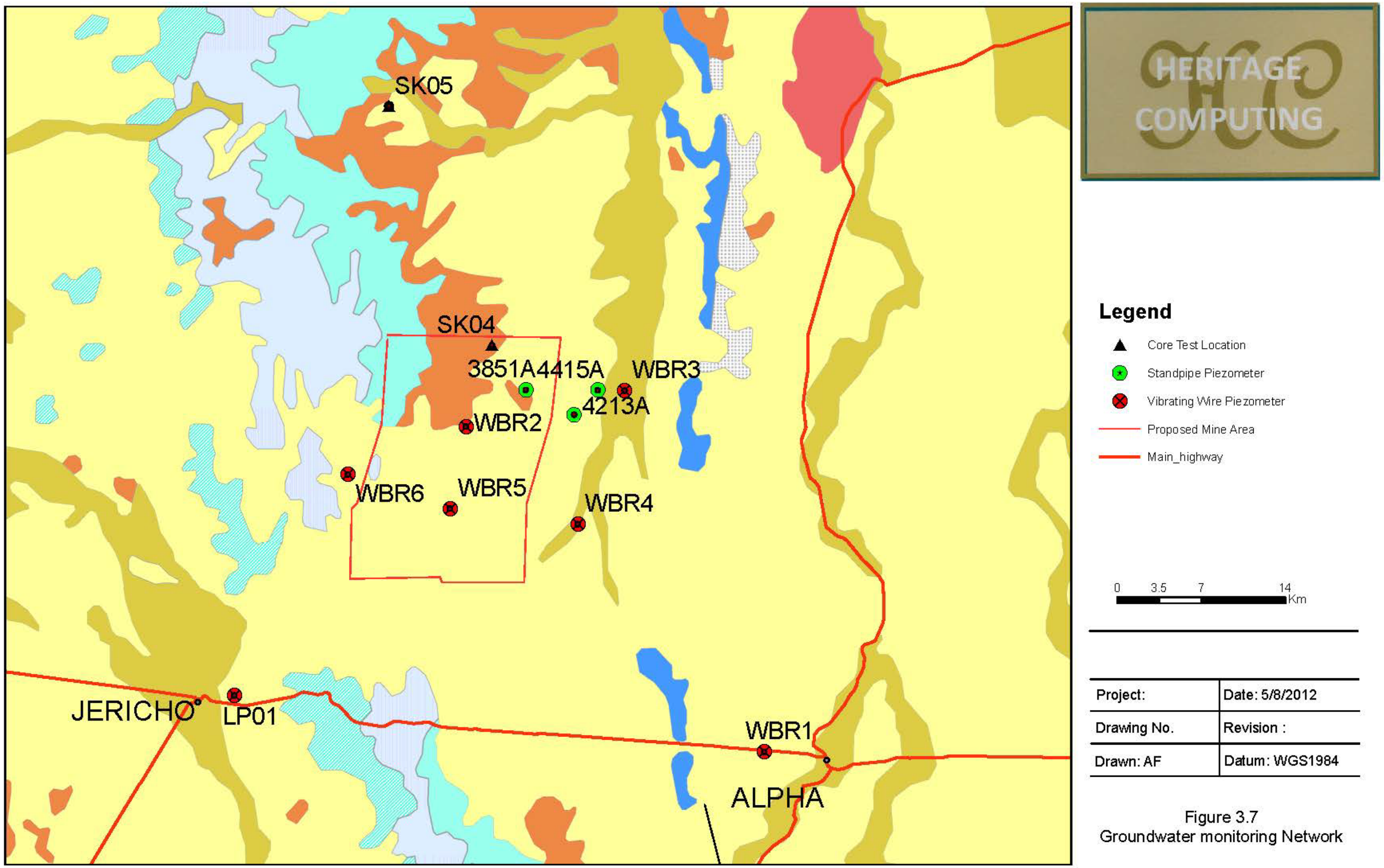


Figure 3.7 Groundwater Monitoring Network

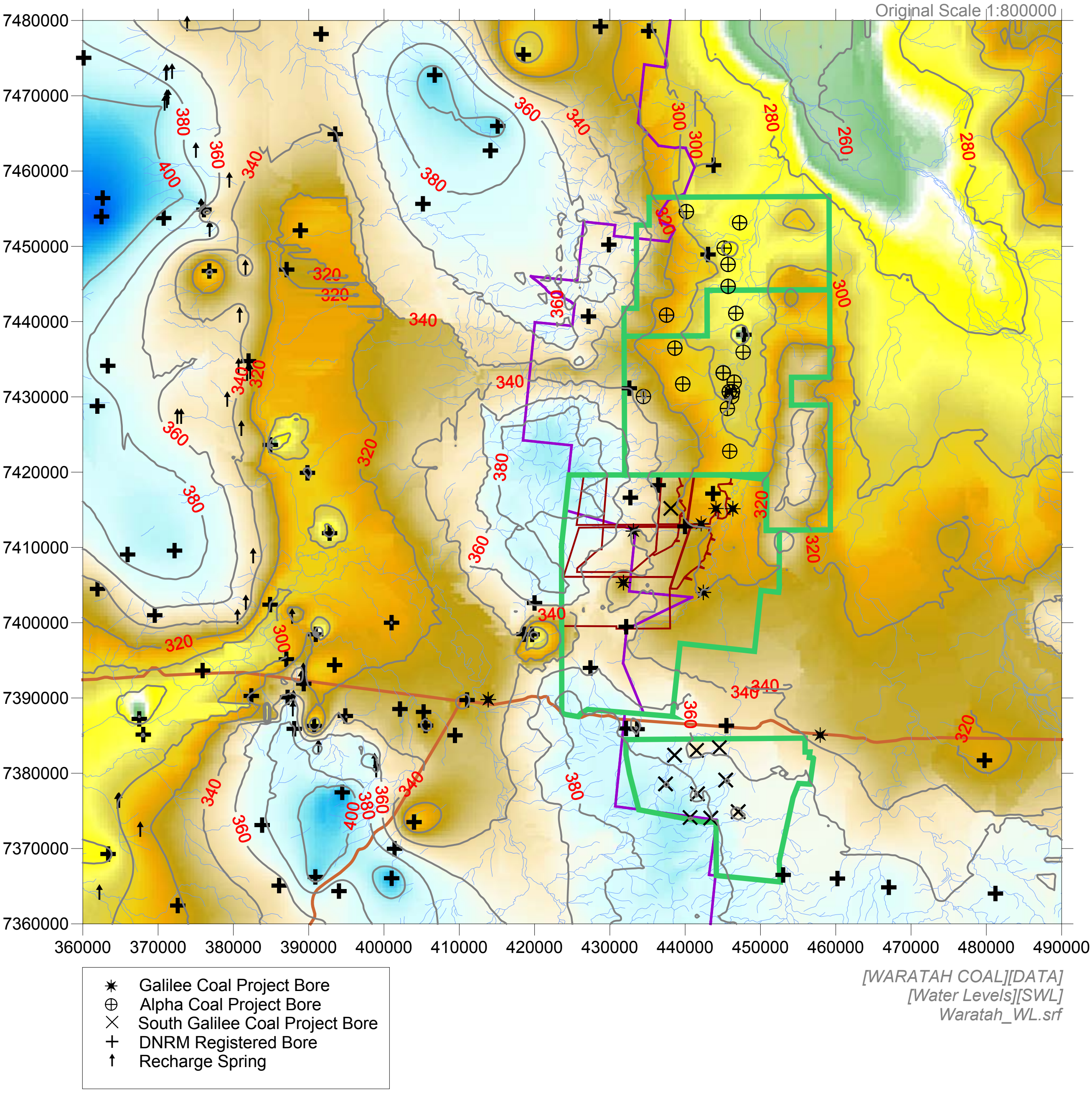


Figure 3.8 Observed and Inferred Regional Groundwater Level Contours [mAHD]

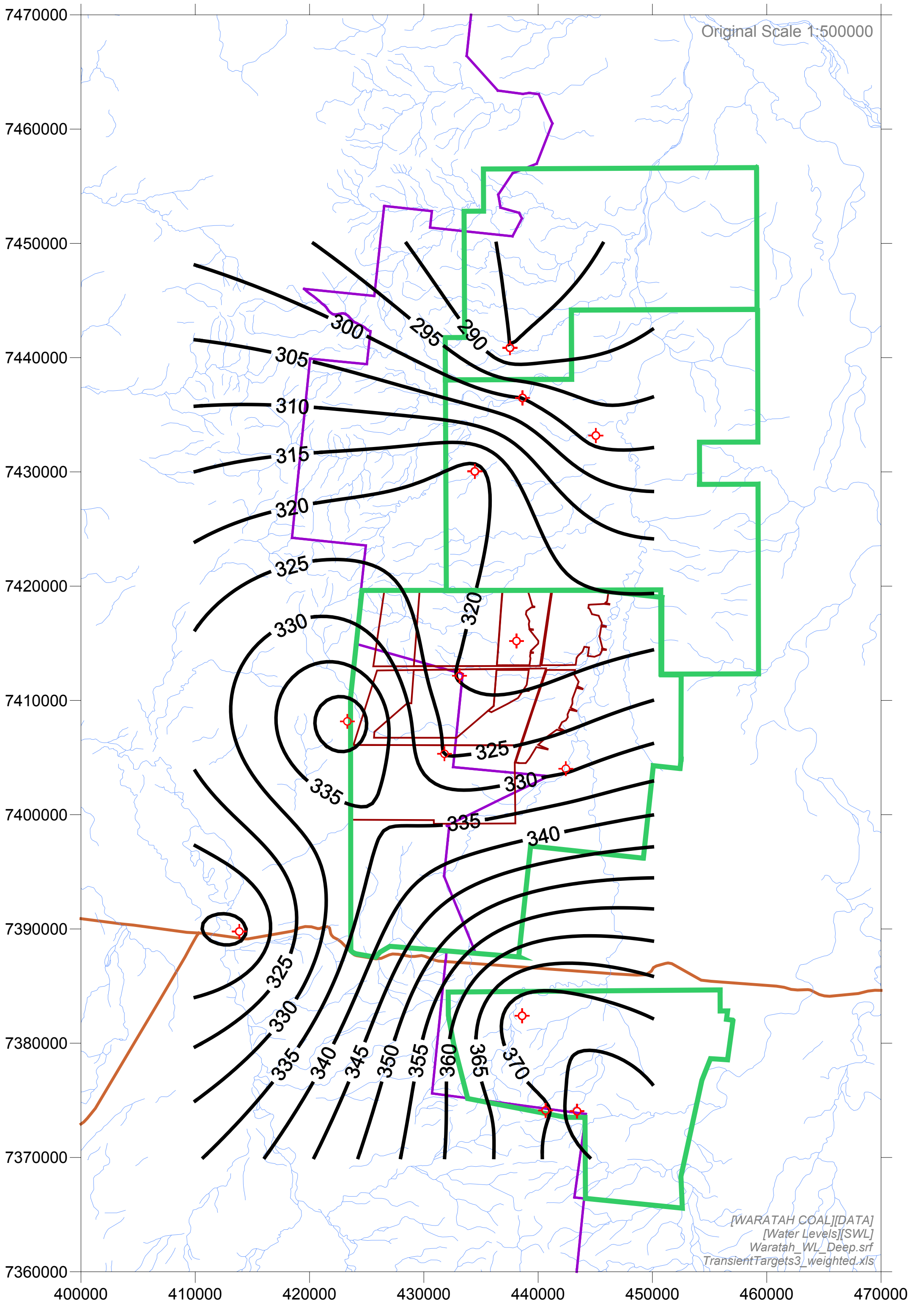


Figure 3.9 Observed Groundwater Level Contours for the B Seam and Overburden [mAHD]

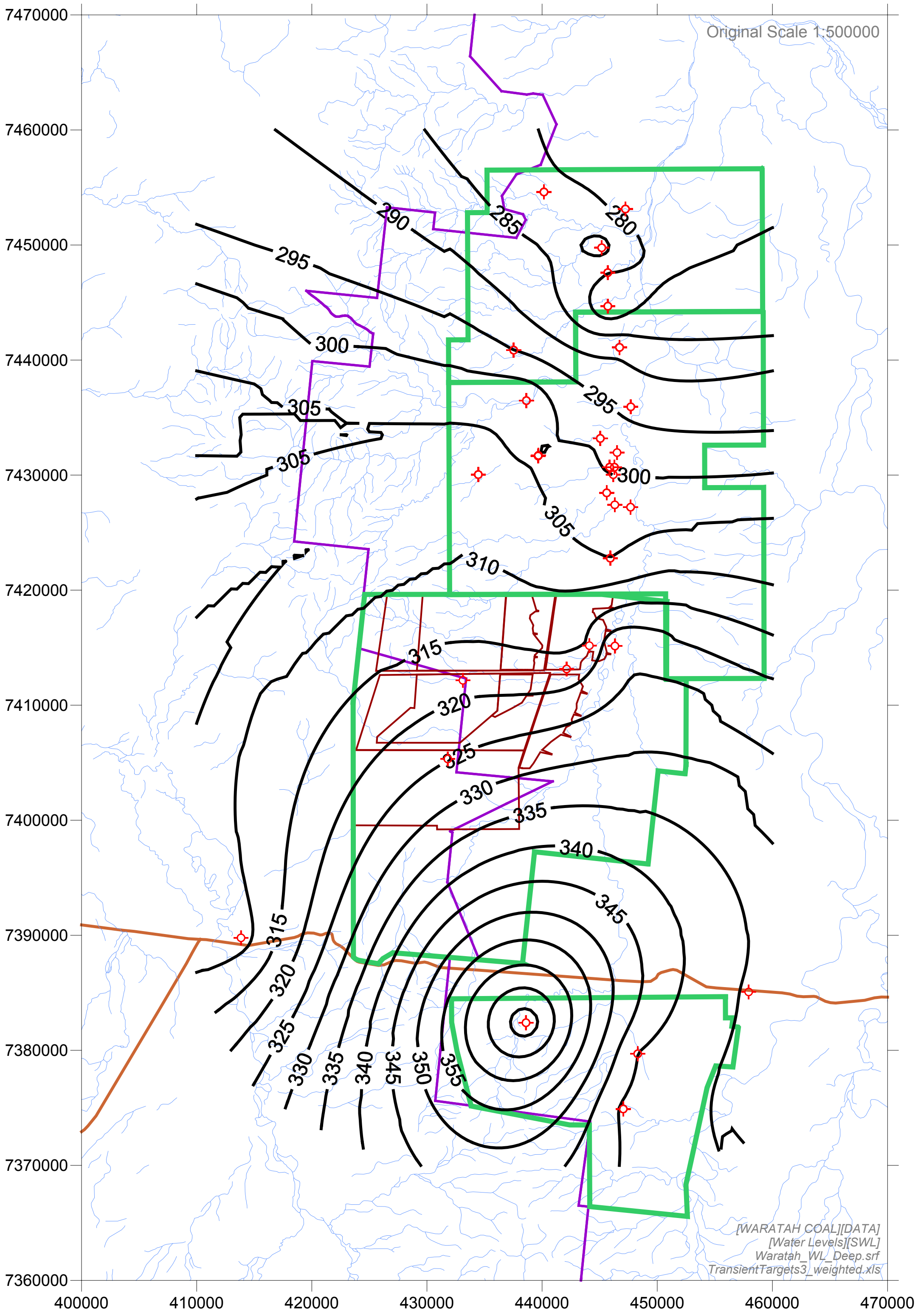


Figure 3.10 Observed Groundwater Level Contours for the DU and DL Seams and Interburden [mAHD]

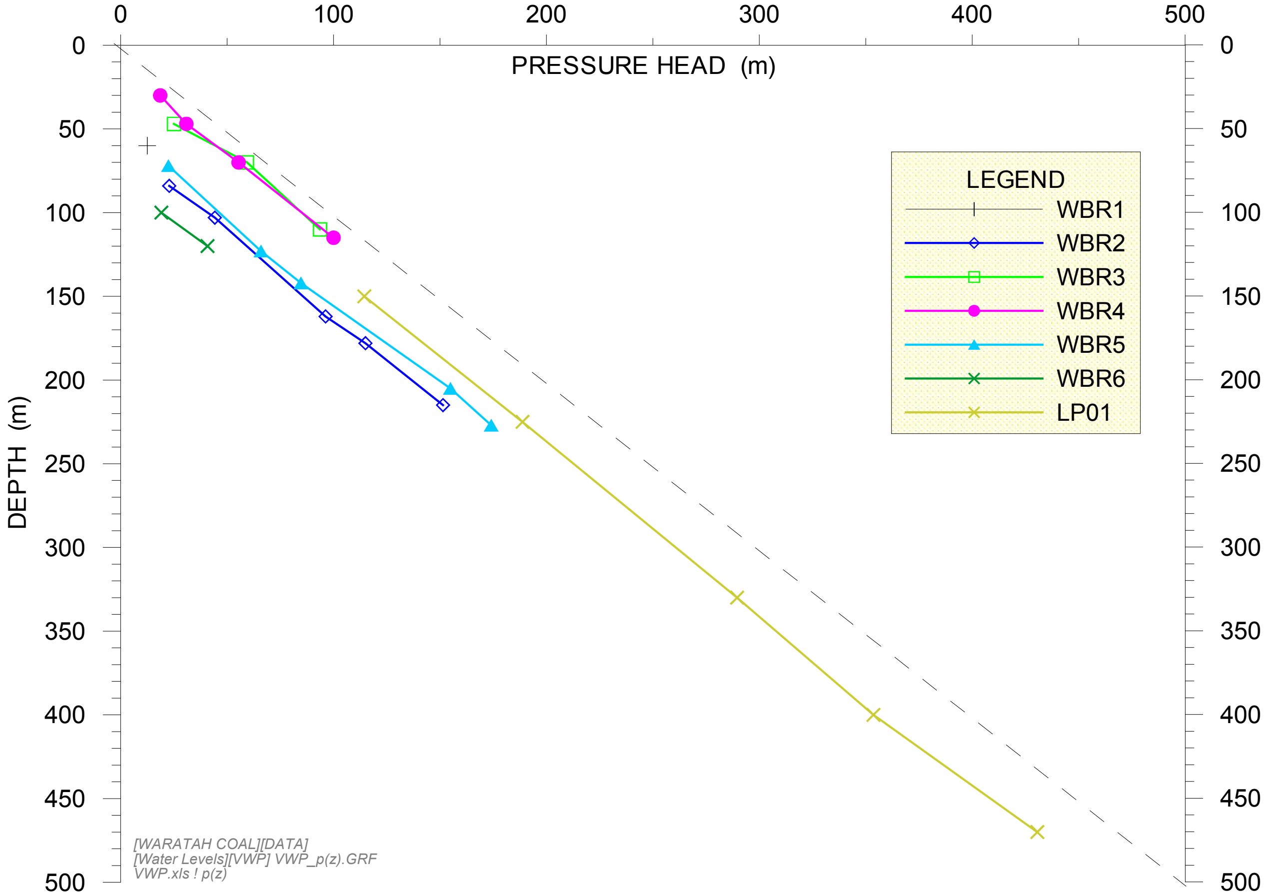


Figure 3.11 Initial Pressure Head Depth Profiles

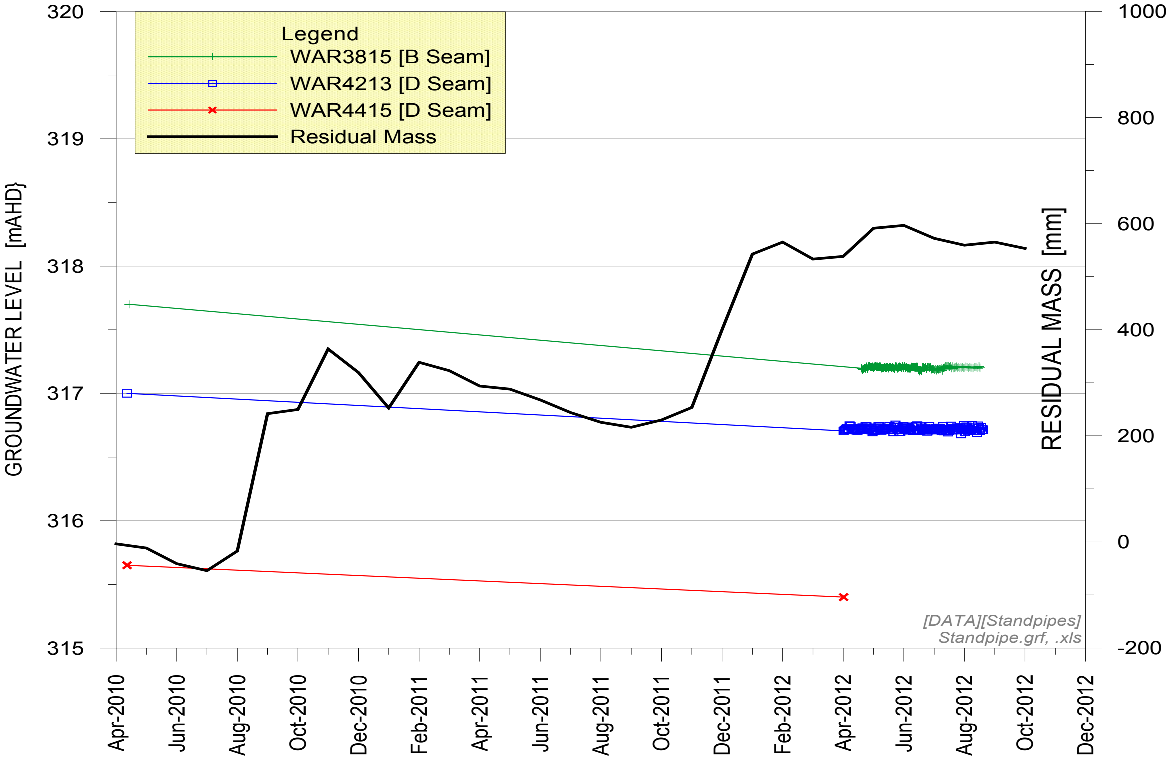


Figure 3.12 Standpipe Groundwater Hydrographs

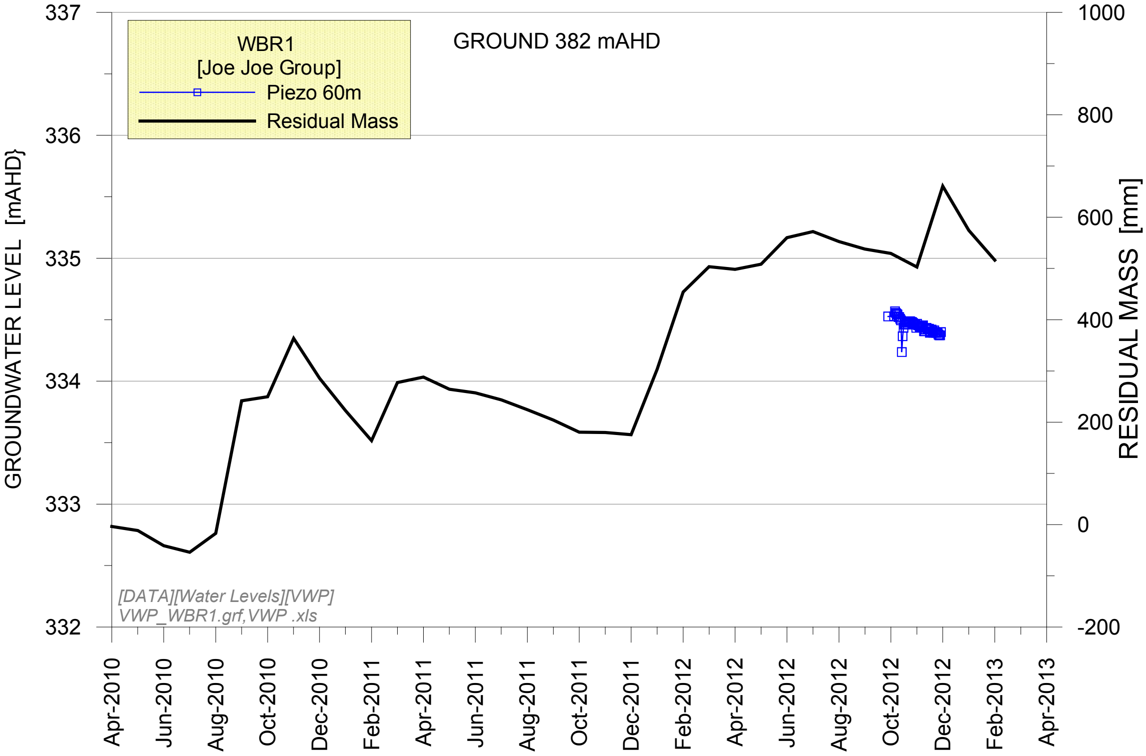


Figure 3.13 Vibrating Wire Piezometer Groundwater Hydrographs [Bore WBR1]

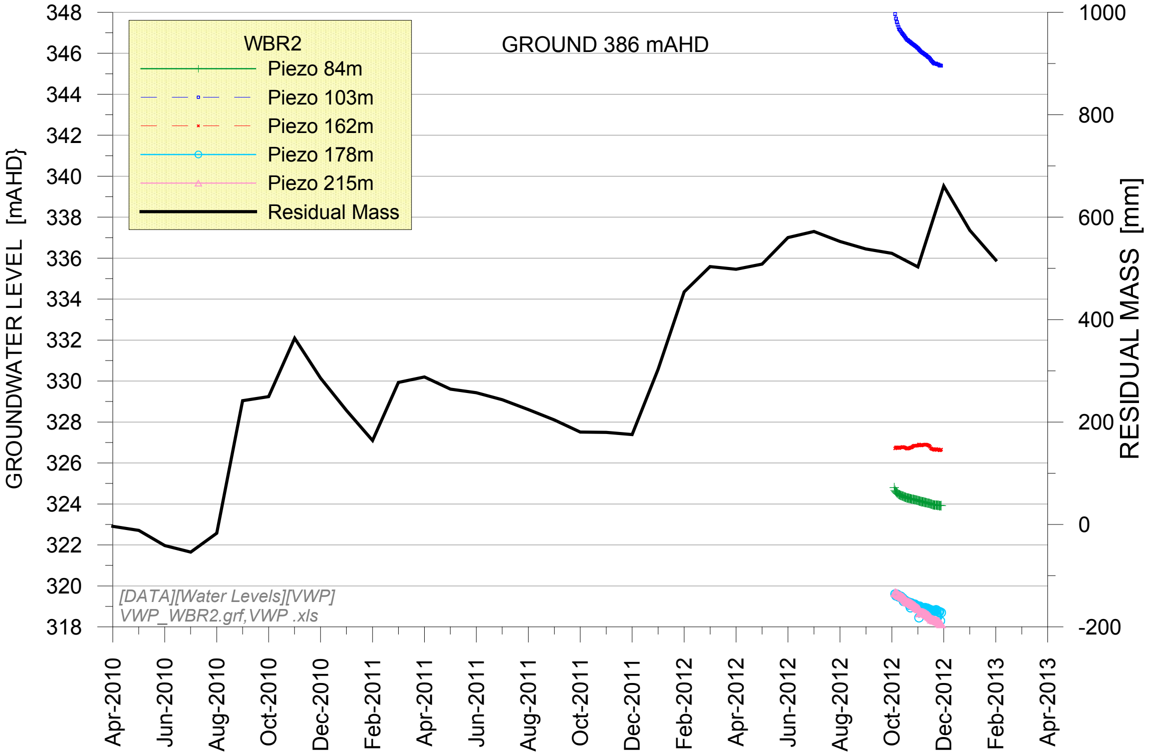


Figure 3.14 Vibrating Wire Piezometer Groundwater Hydrographs [Bore WBR2]

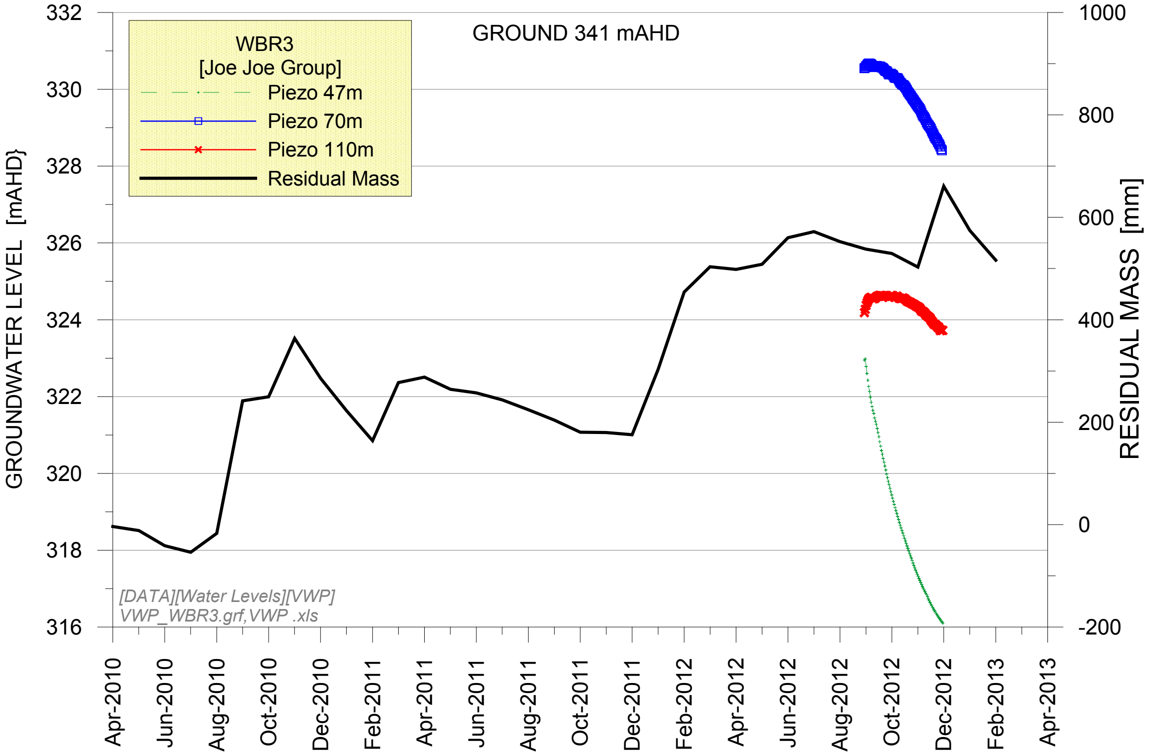


Figure 3.15 Vibrating Wire Piezometer Groundwater Hydrographs [Bore WBR3]

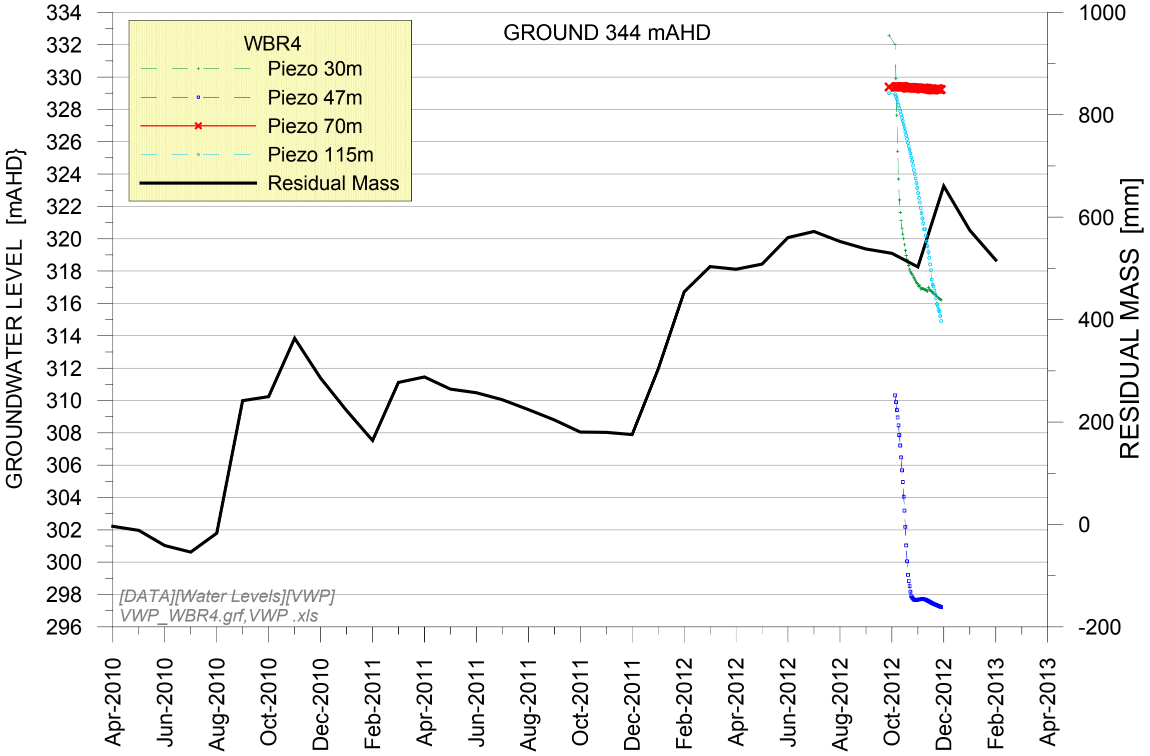


Figure 3.16 Vibrating Wire Piezometer Groundwater Hydrographs [Bore WBR4]

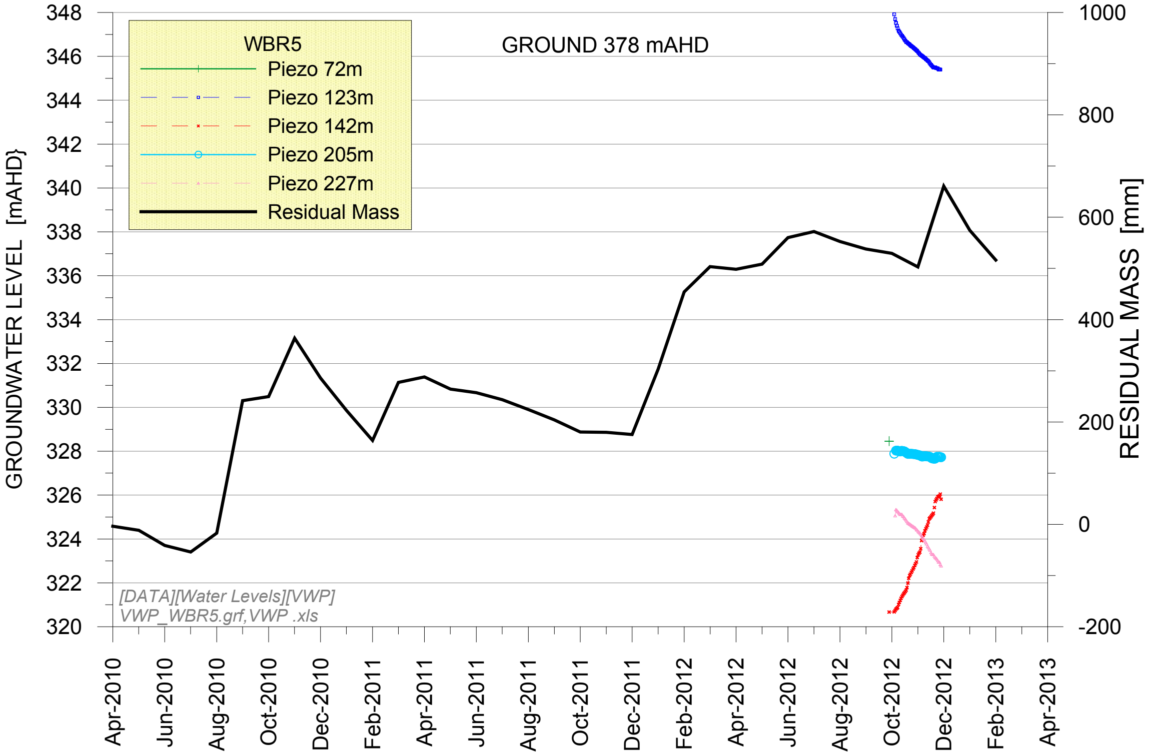


Figure 3.17 Vibrating Wire Piezometer Groundwater Hydrographs [Bore WBR5]

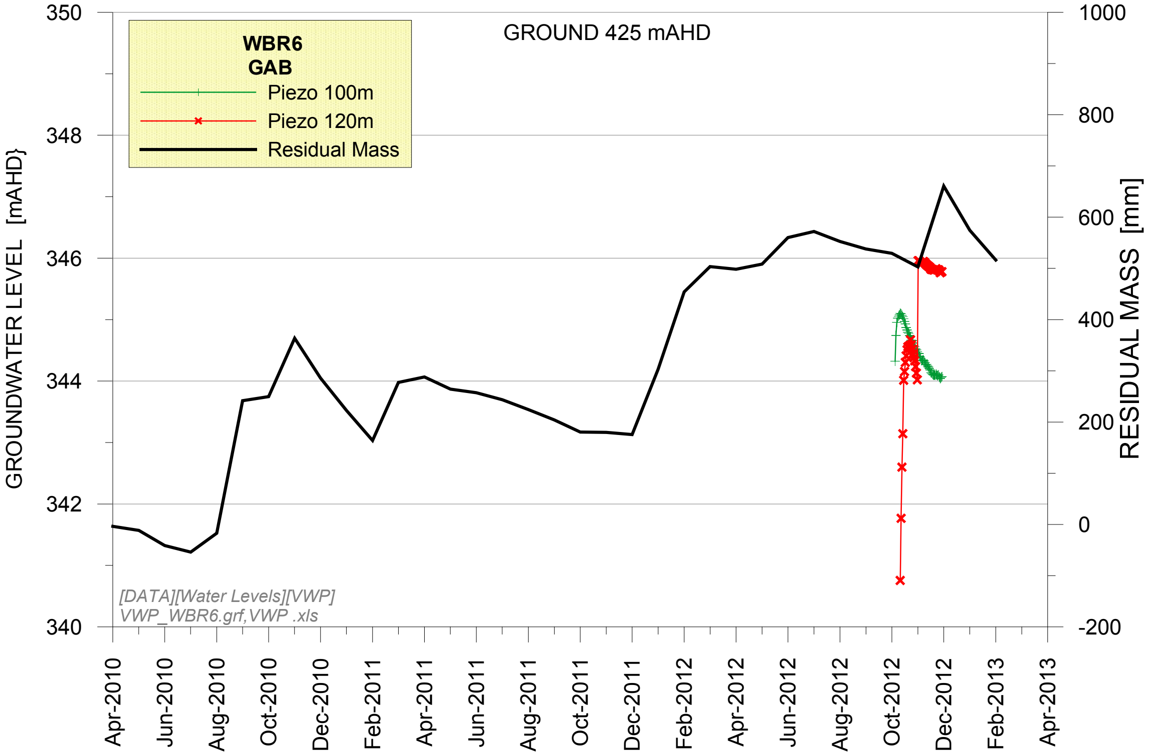


Figure 3.18 Vibrating Wire Piezometer Groundwater Hydrographs [Bore WBR6]

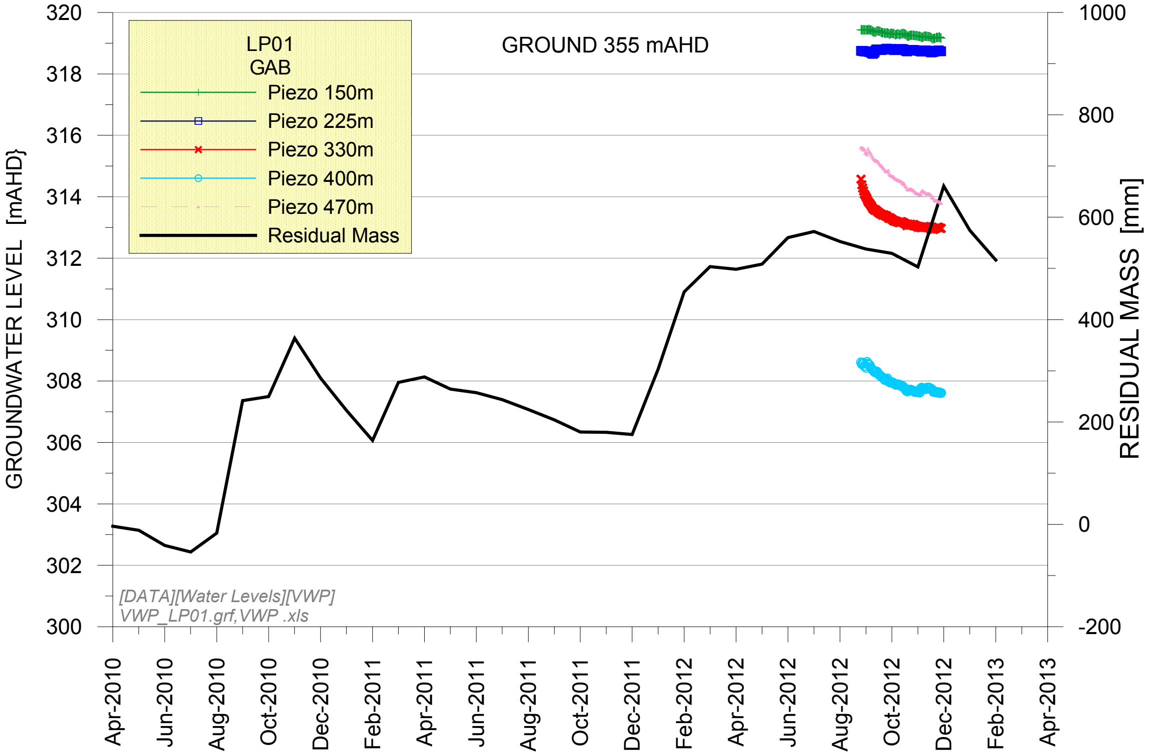


Figure 3.19 Vibrating Wire Piezometer Groundwater Hydrographs [Bore LP01]

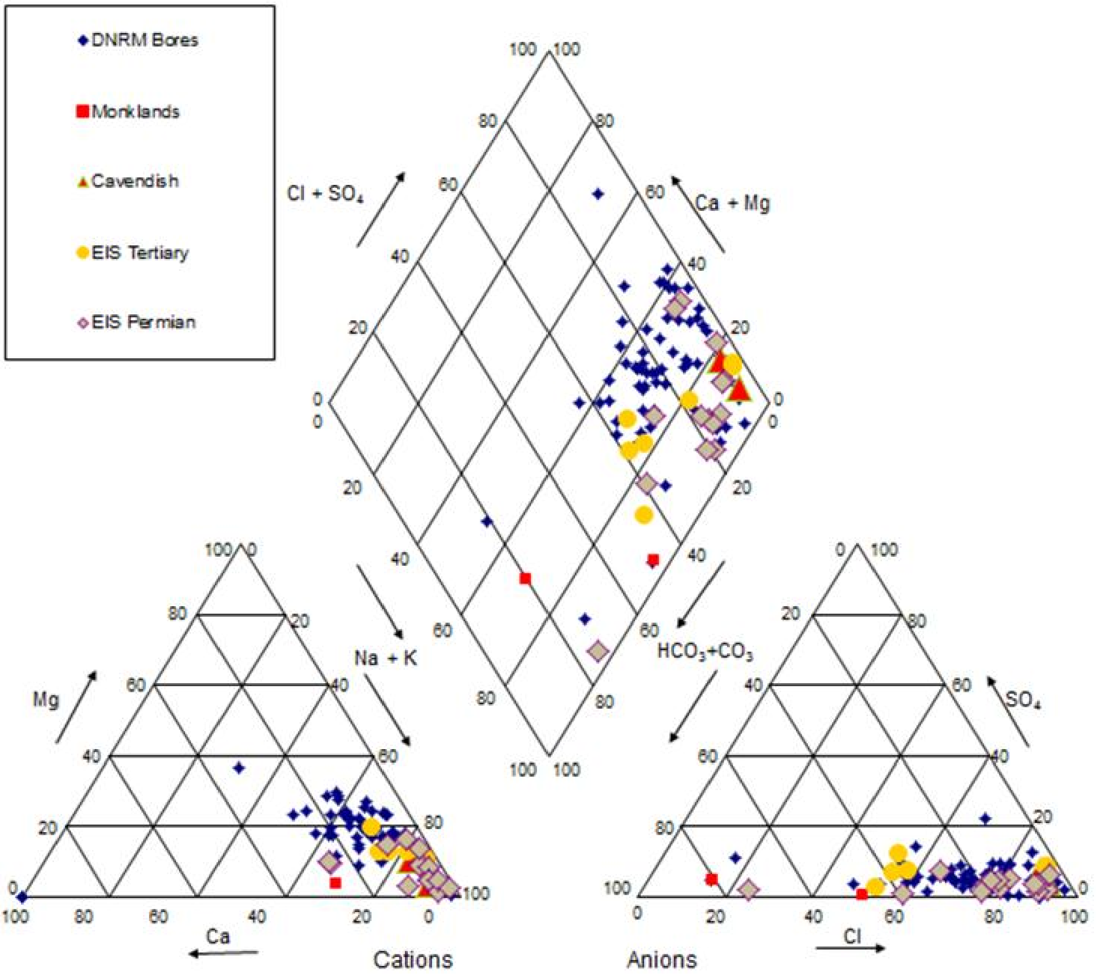


Figure 3.20 Piper Trilinear Diagram

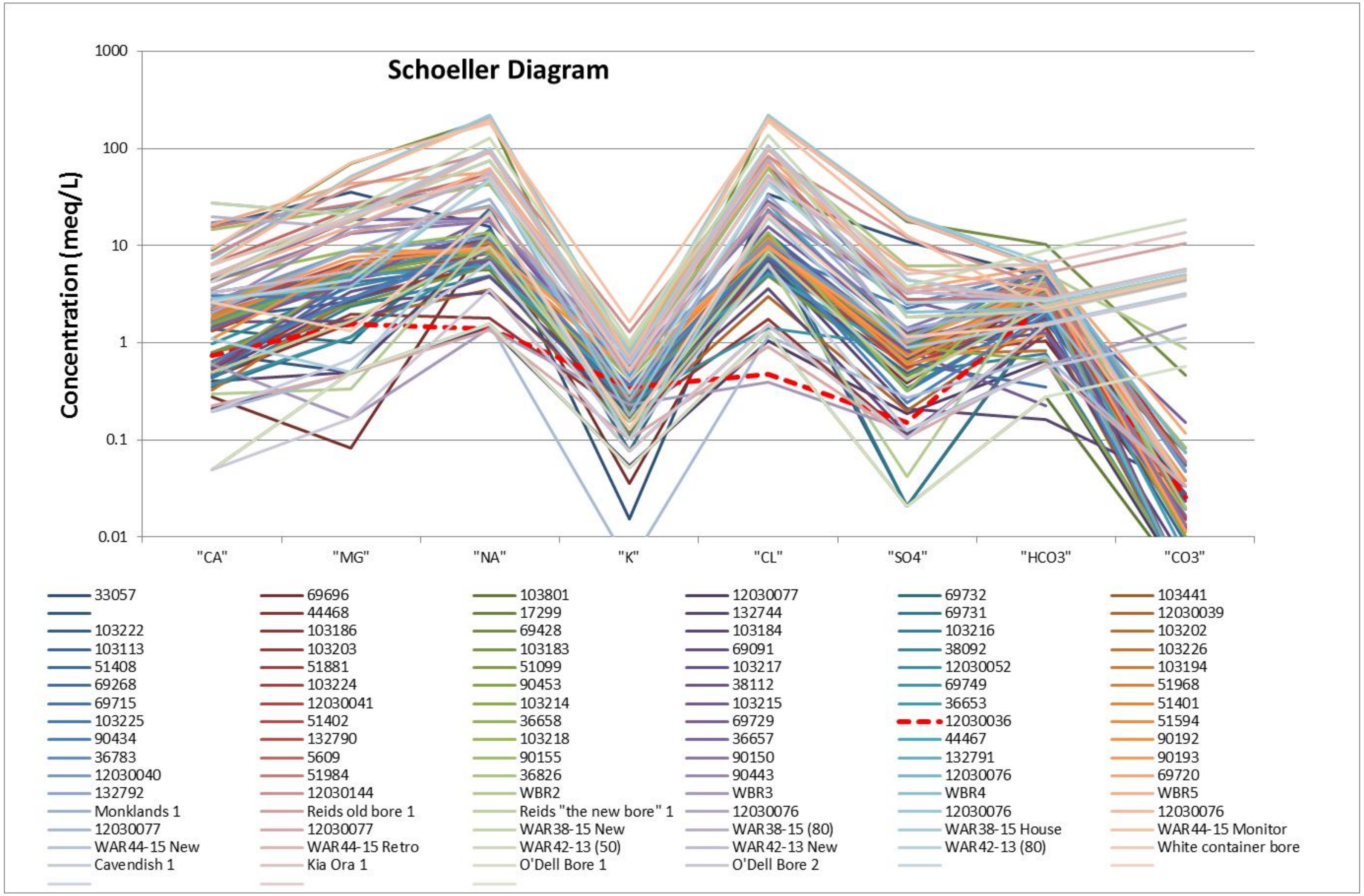


Figure 3.21 Schoeller Diagrams

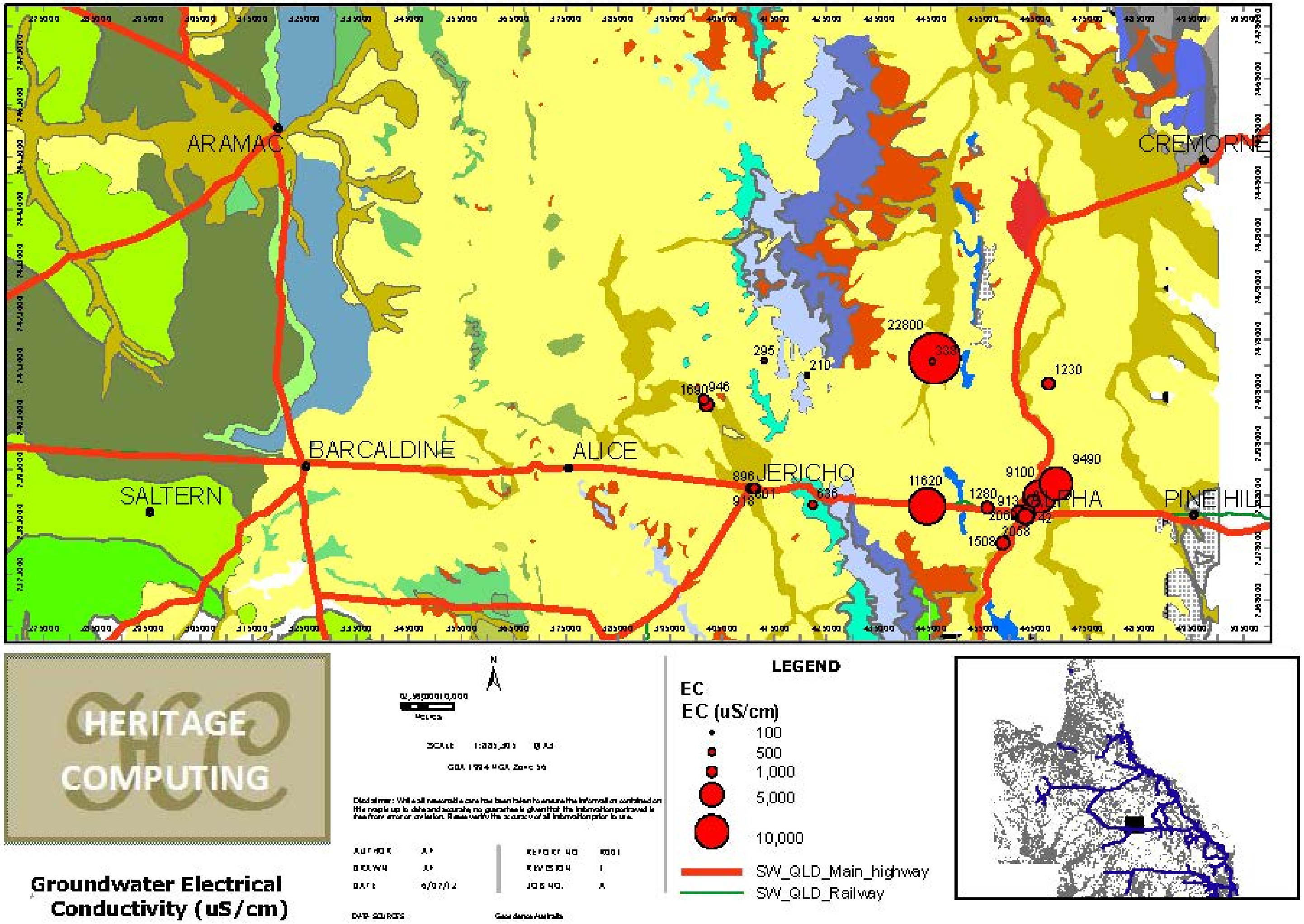
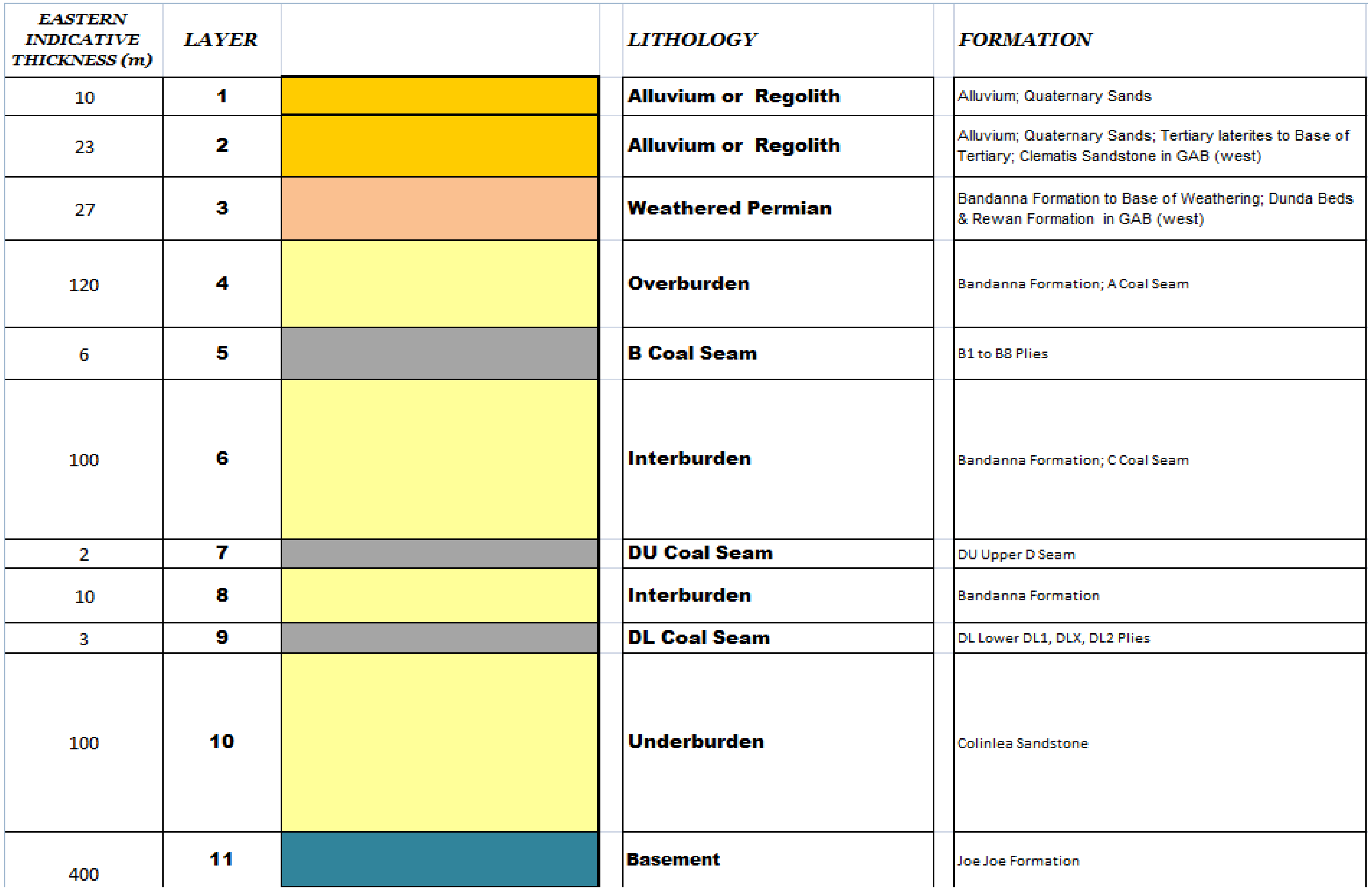


Figure 3.22 Electrical Conductivity Distribution



EASTERN INDICATIVE THICKNESS (m)	LAYER		LITHOLOGY	FORMATION
10	**1**	🟨	**Alluvium or Regolith**	Alluvium; Quaternary Sands
23	**2**	🟨	**Alluvium or Regolith**	Alluvium; Quaternary Sands; Tertiary laterites to Base of Tertiary; Clematis Sandstone in GAB (west)
27	**3**	🟧	**Weathered Permian**	Bandanna Formation to Base of Weathering; Dunda Beds & Rewan Formation in GAB (west)
120	**4**	🟨	**Overburden**	Bandanna Formation; A Coal Seam
6	**5**	⬜	**B Coal Seam**	B1 to B8 Plies
100	**6**	🟨	**Interburden**	Bandanna Formation; C Coal Seam
2	**7**	⬜	**DU Coal Seam**	DU Upper D Seam
10	**8**	🟨	**Interburden**	Bandanna Formation
3	**9**	⬜	**DL Coal Seam**	DL Lower DL1, DLX, DL2 Plies
100	**10**	🟨	**Underburden**	Colinlea Sandstone
400	**11**	🟦	**Basement**	Joe Joe Formation

Figure 4.1 Numerical Model Layers

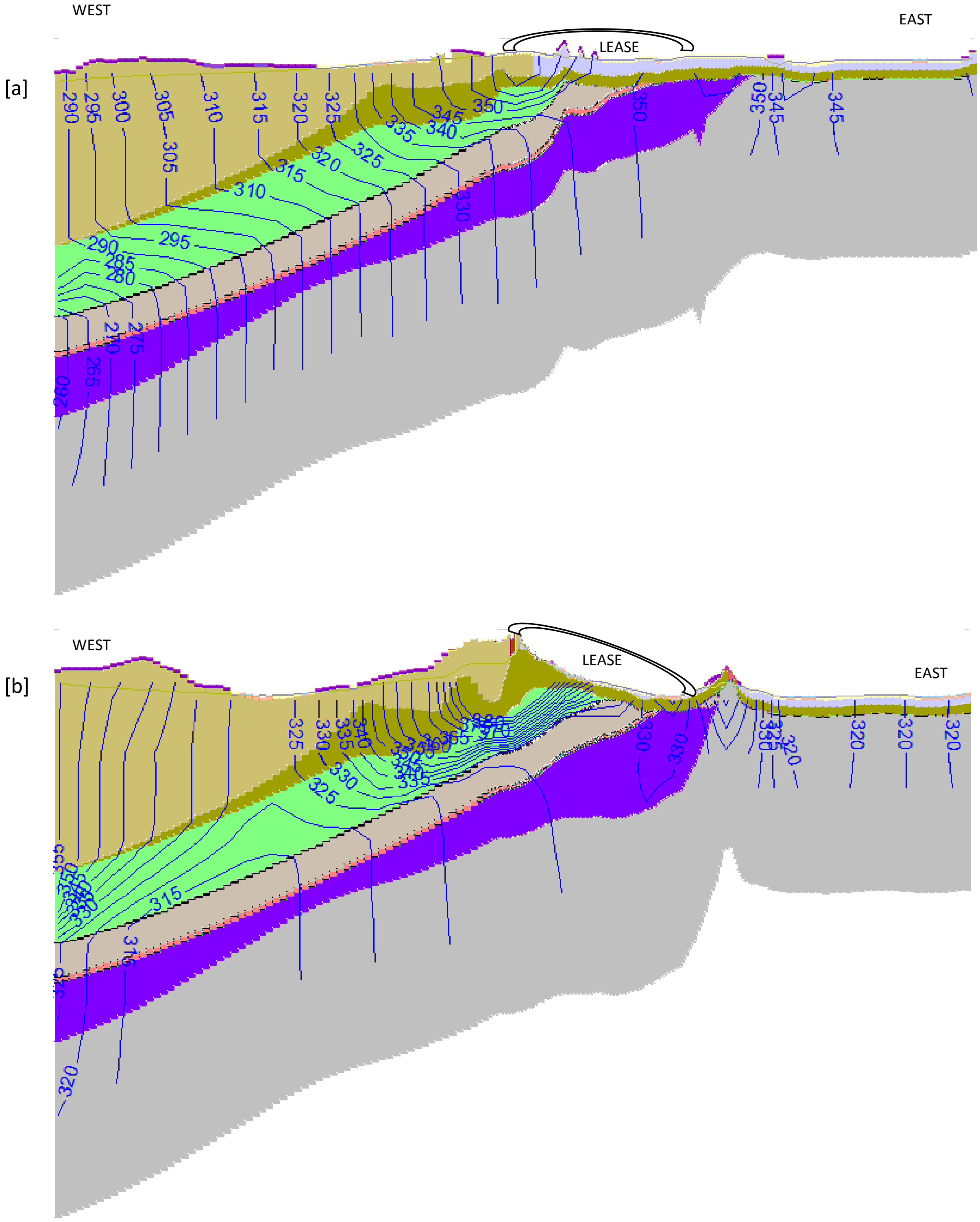


Figure 4.2 Representative West-East Cross Sections through the Project Area: [a] Northing 7399120 (Model Row 380); [b] Northing 7419400 (Model Row 178)

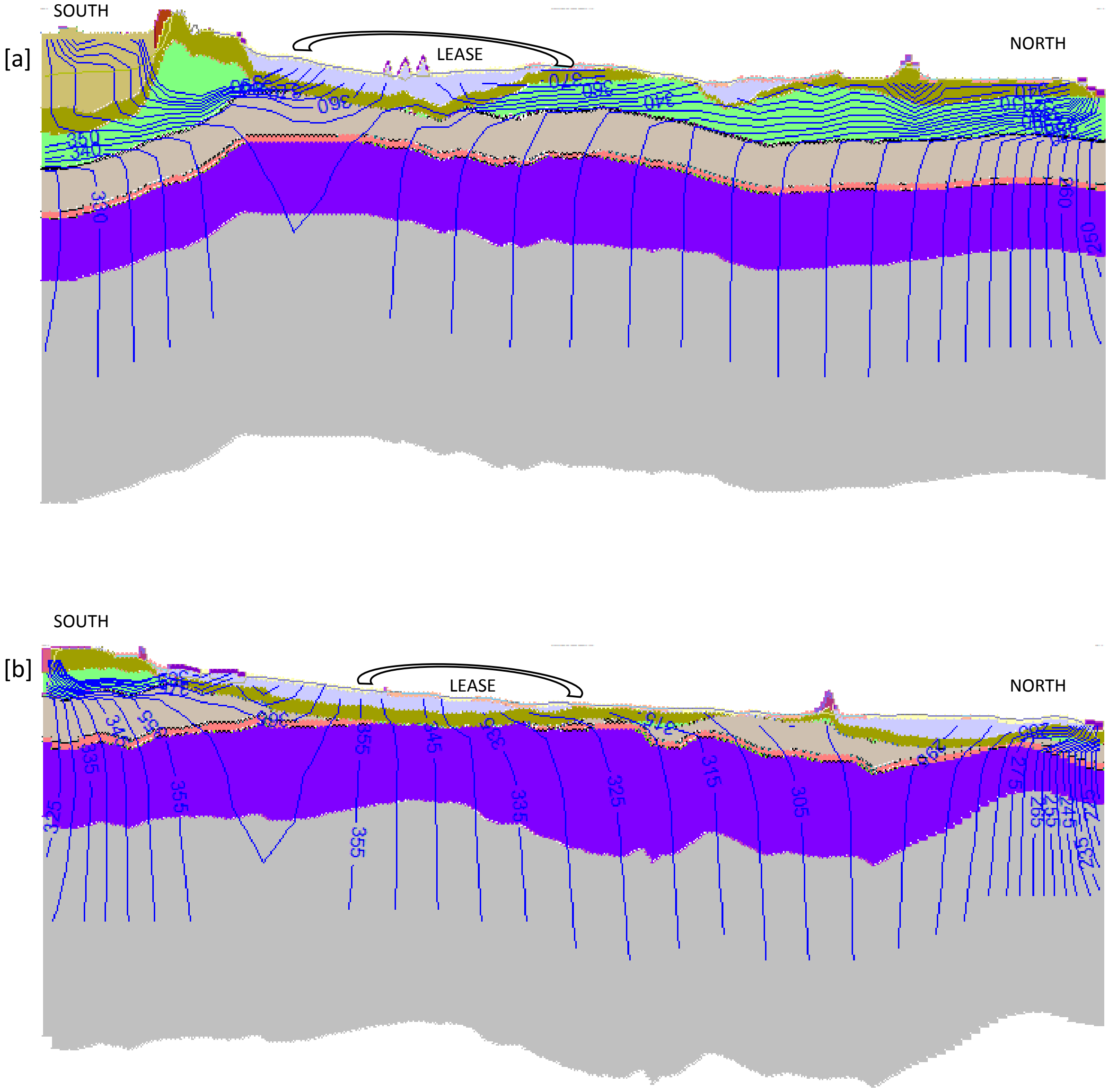


Figure 4.3 Representative South-North Cross Sections through the Project Area [a] Easting 431920 (Model Column 176); [b] Easting 444600 (Model Column 280)

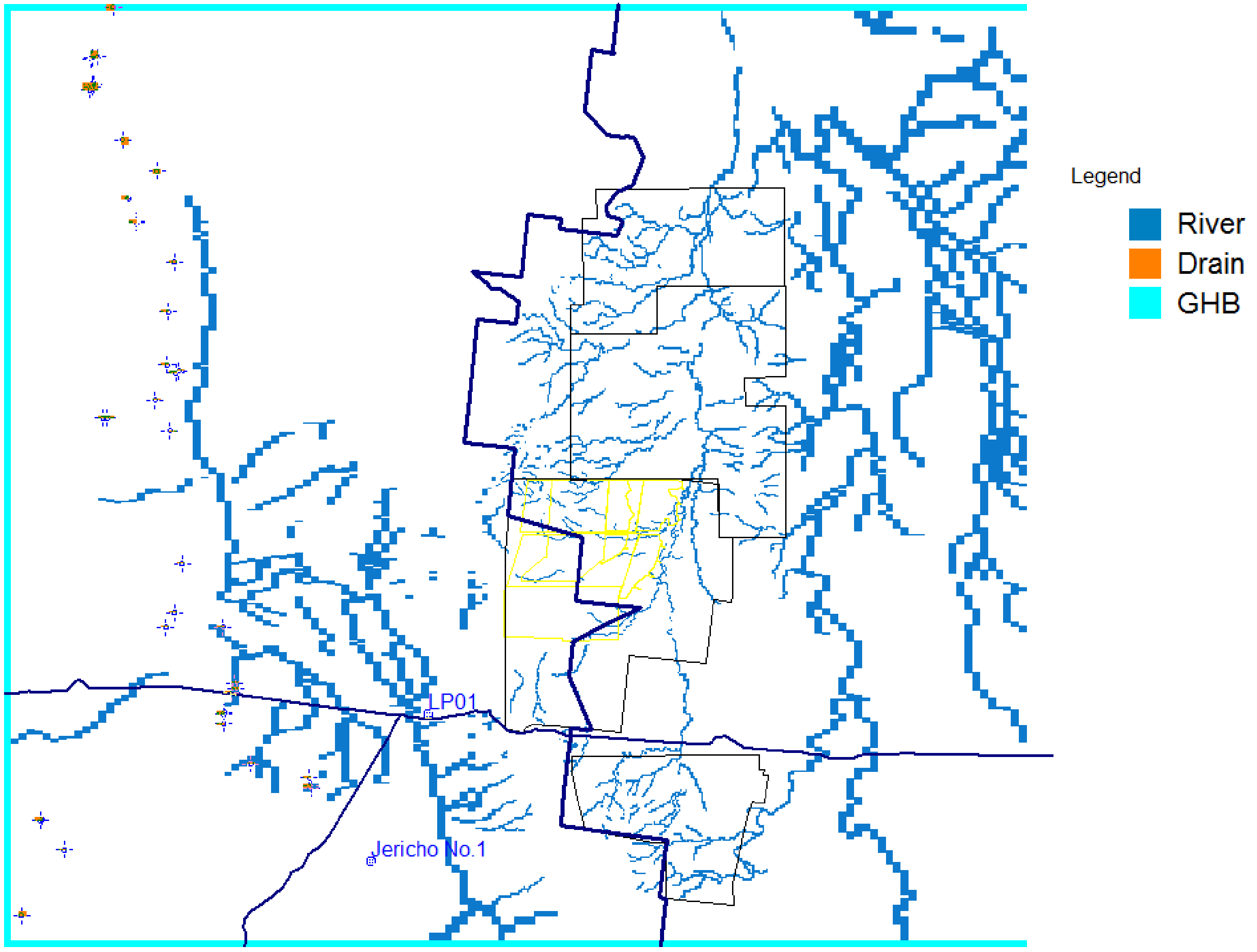


Figure 4.4 Model Boundary Conditions [Layer 1]

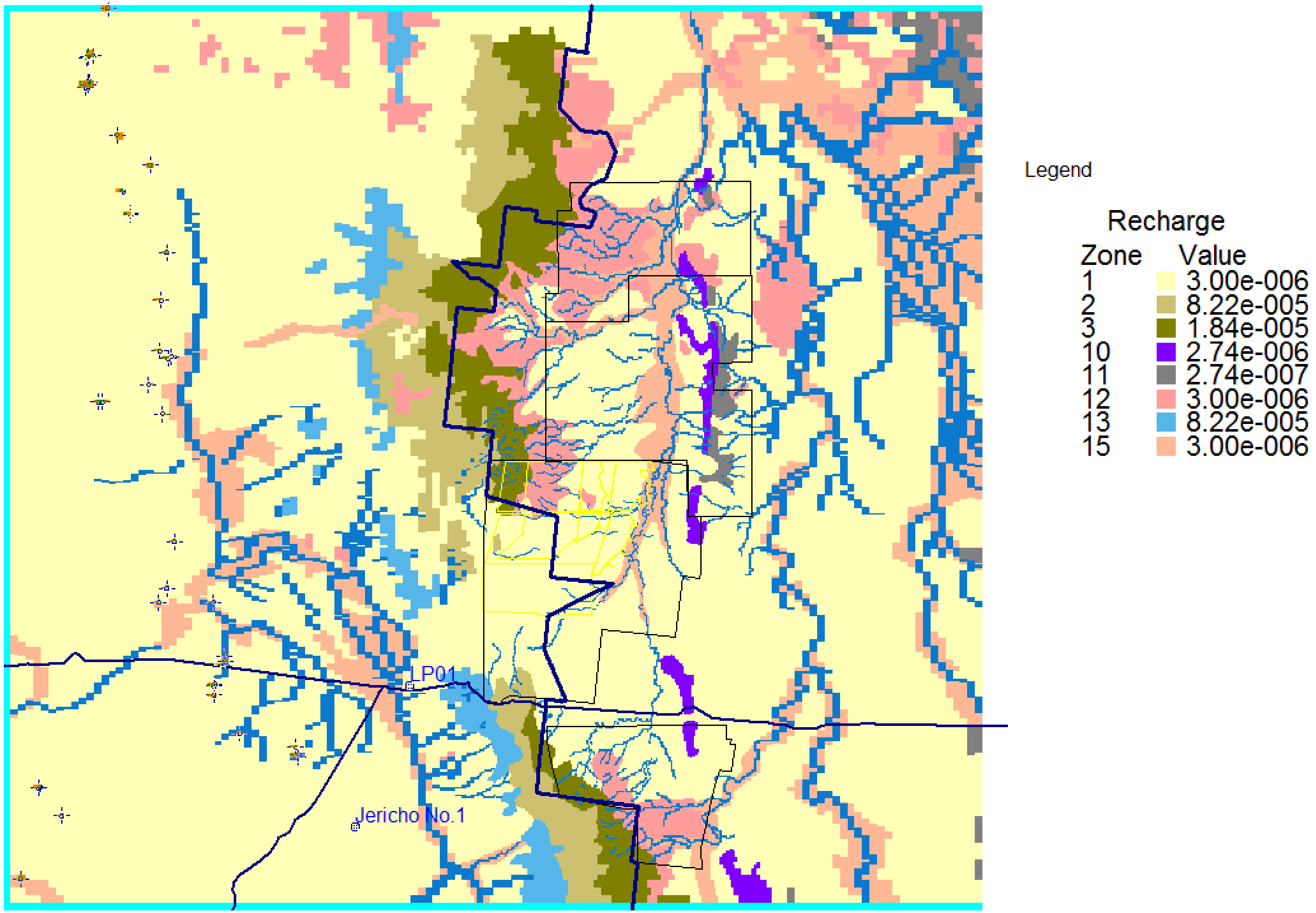


Figure 4.5 Rainfall Recharge Distribution and Initial Applied Rates [m/day]

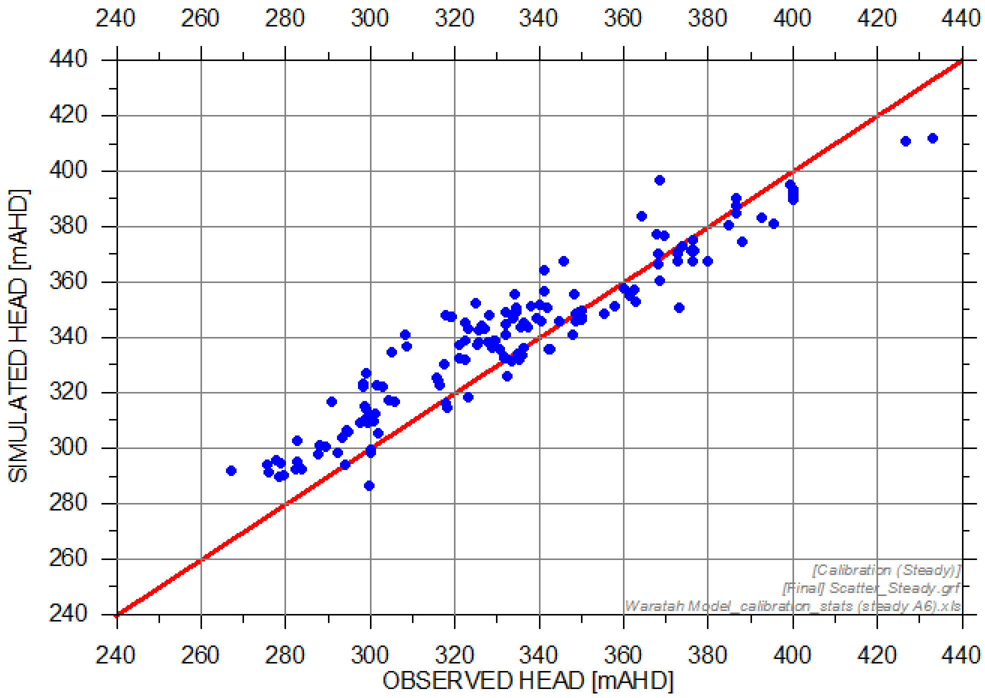


Figure 4.6 Scattergram of Simulated and Measured Heads for Steady-State Calibration

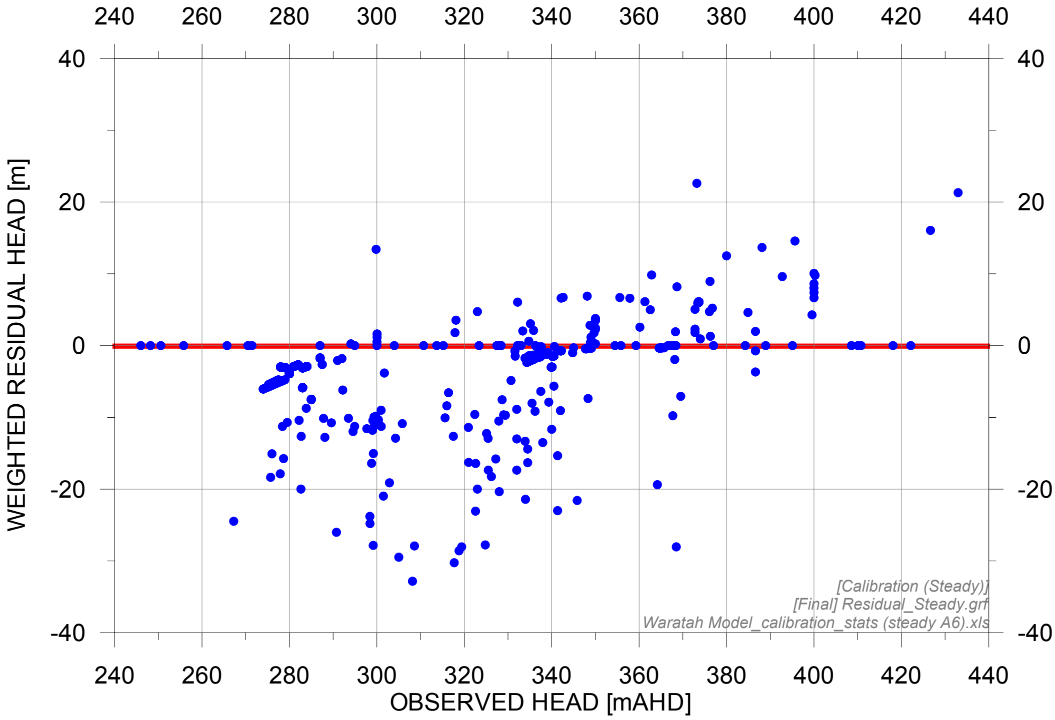


Figure 4.7 Residual between Simulated and Observed Heads for Steady-State Calibration

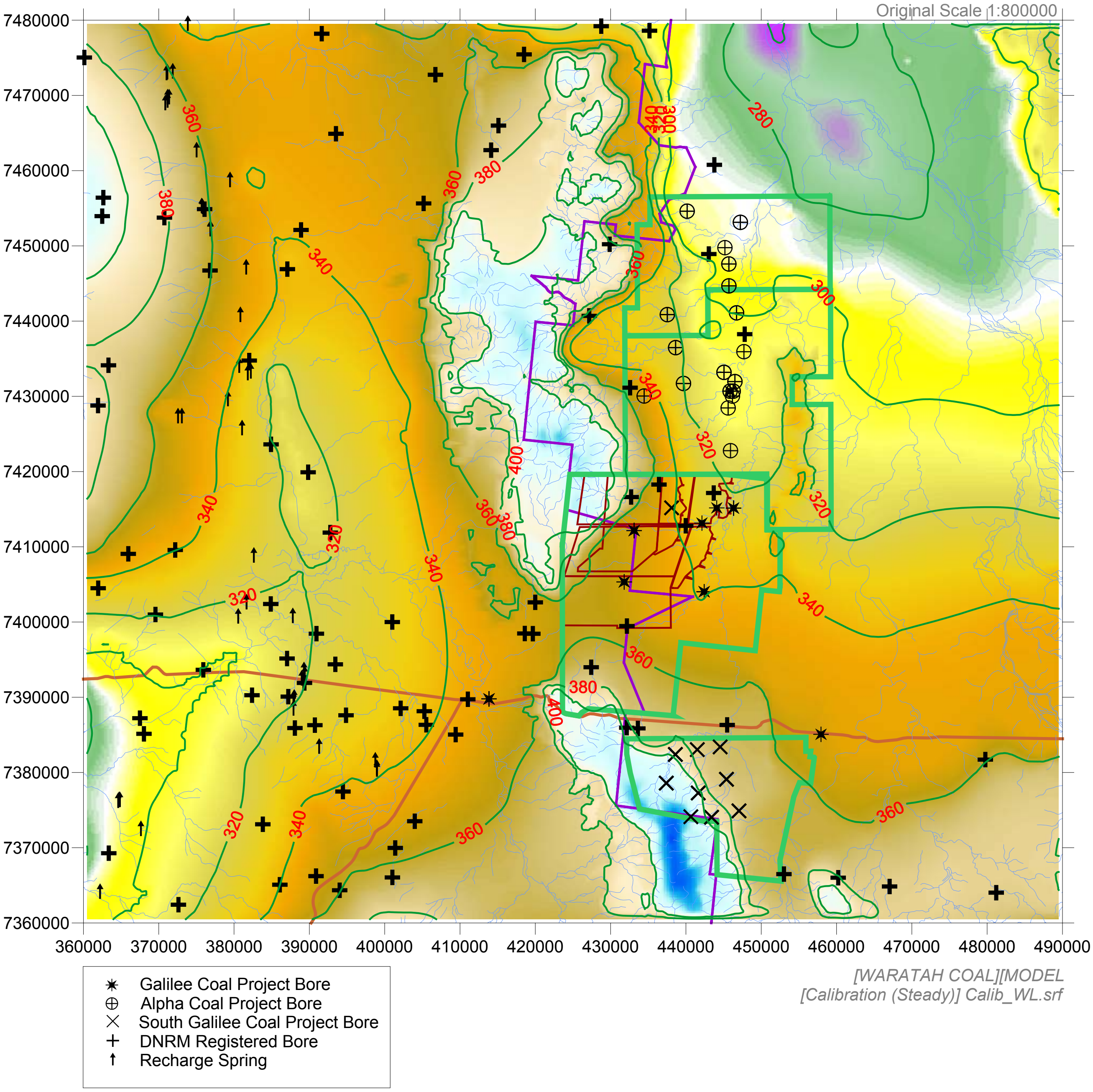


Figure 4.8 Simulated Regional Groundwater Table Contours, Model Layer 1 [mAHD]

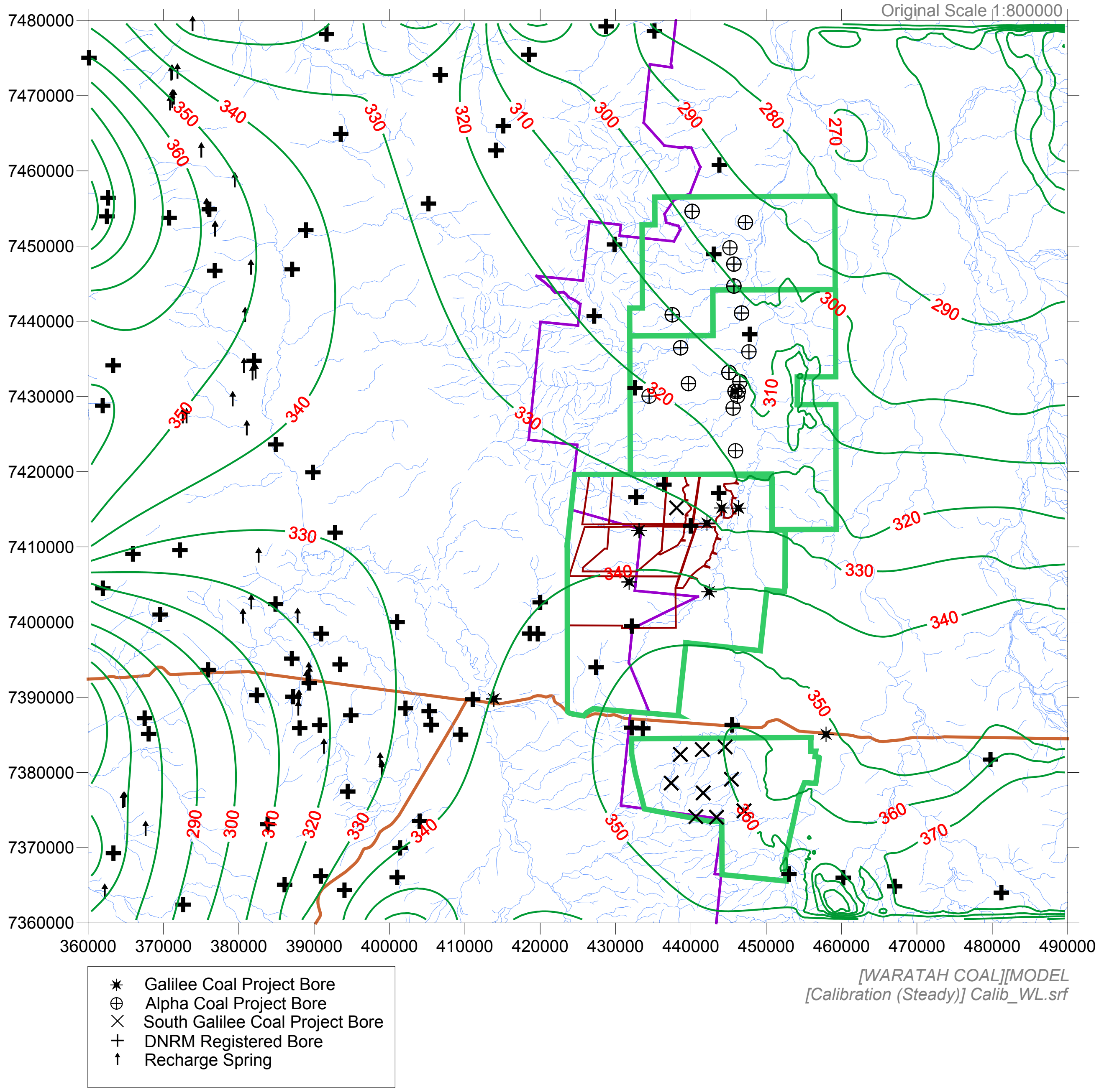


Figure 4.9 Simulated Regional Groundwater Level Contours for the DL Coal Seam and Adjacent Joe Joe Group to the East, Model Layer 9 [mAHD]

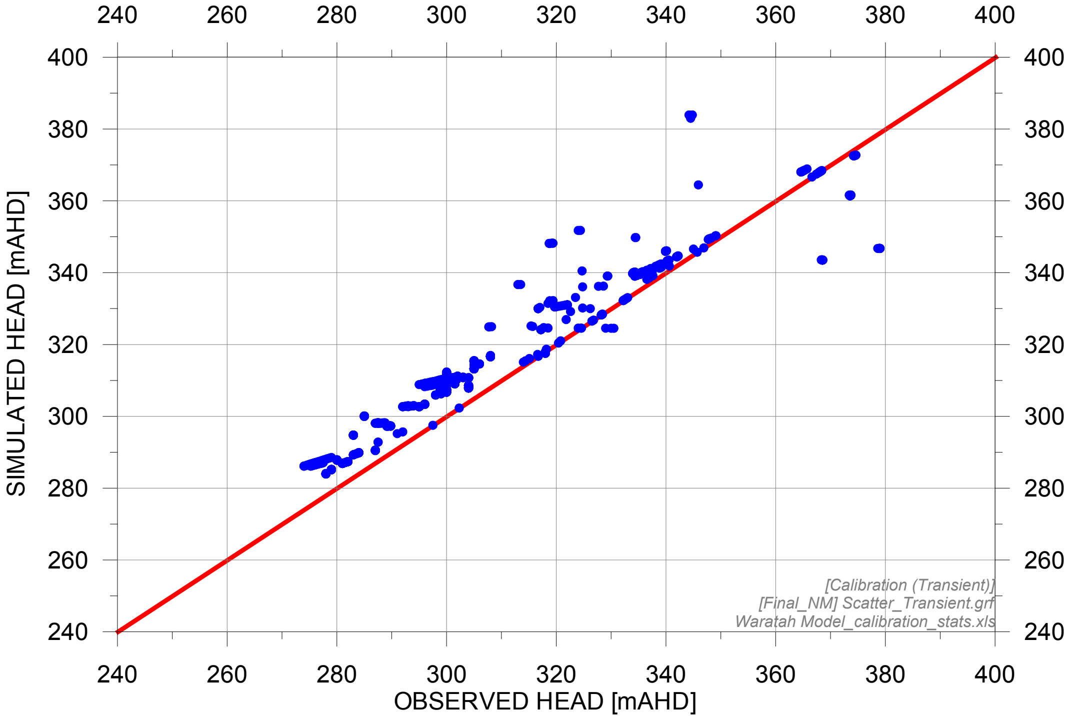


Figure 4.10 Scattergram of Simulated and Observed Heads for Transient Calibration

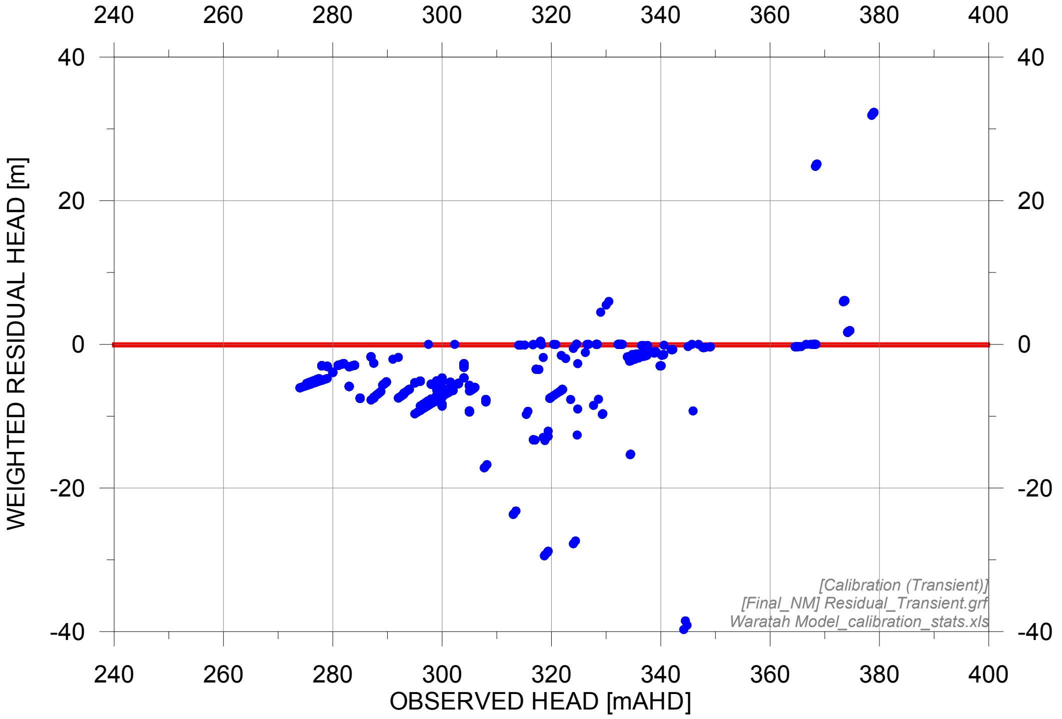


Figure 4.11 Residual between Simulated and Observed Heads for Transient Calibration

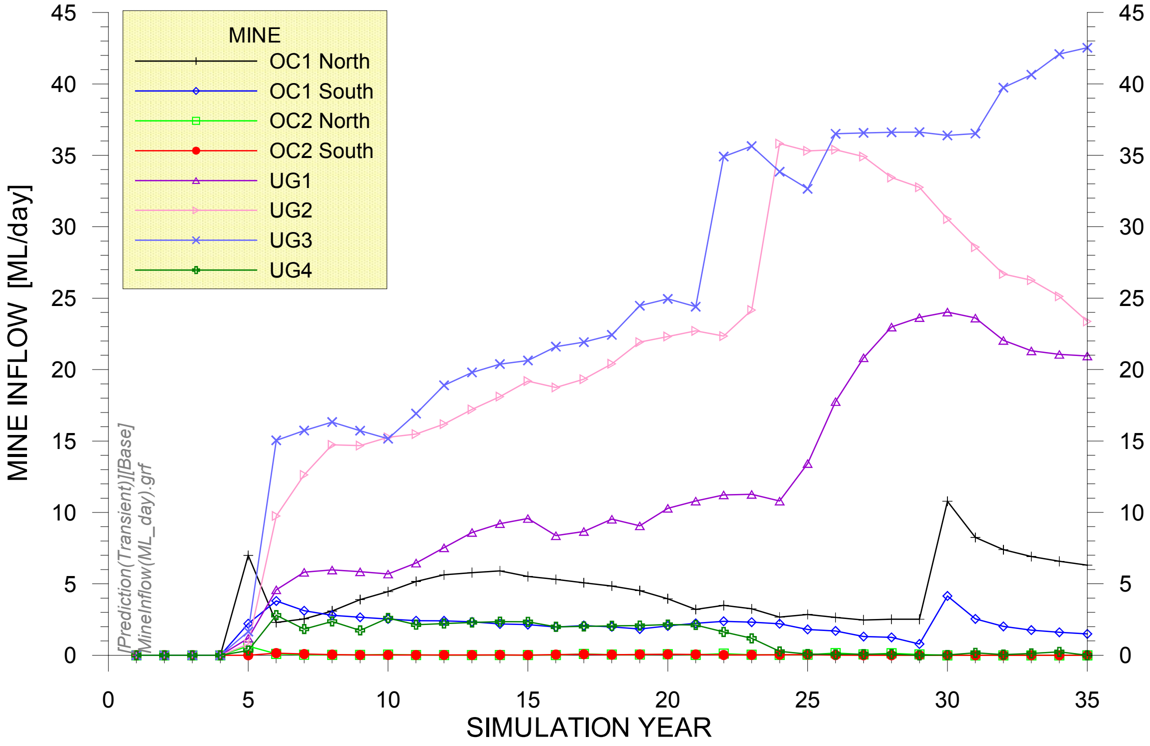


Figure 5.1 Predicted Individual Mine Inflows [ML/day]

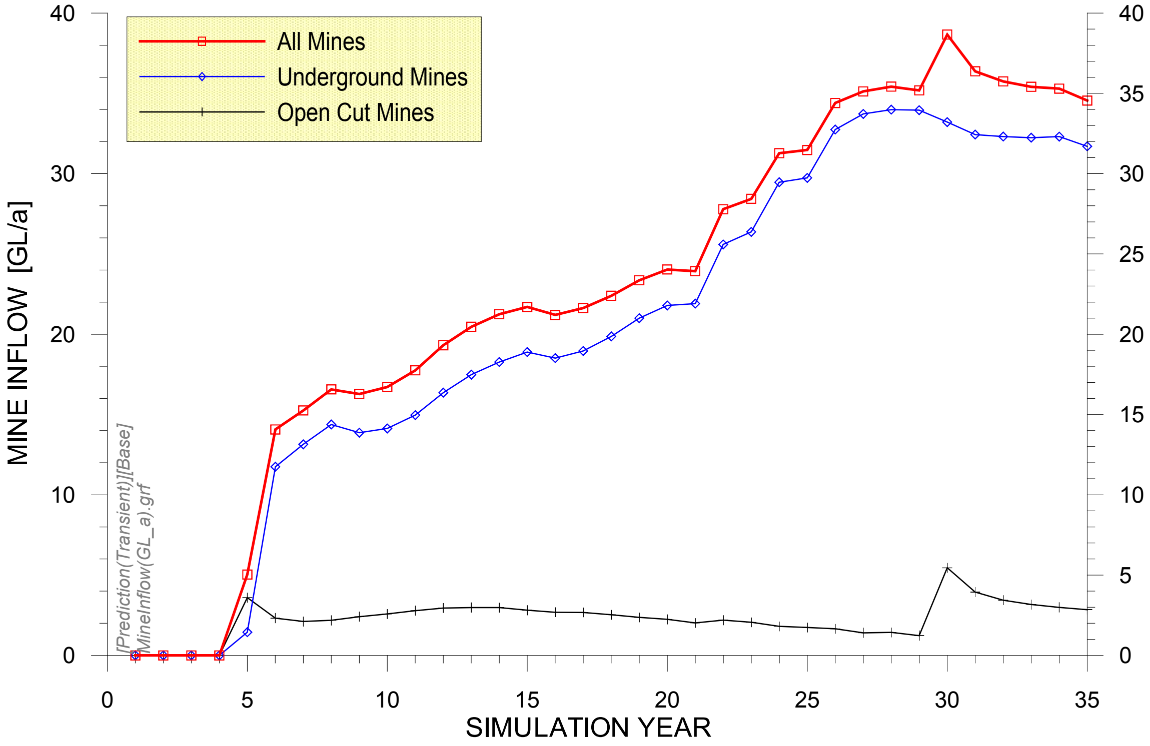


Figure 5.2 Predicted Aggregate Mine Inflows [GL/a]

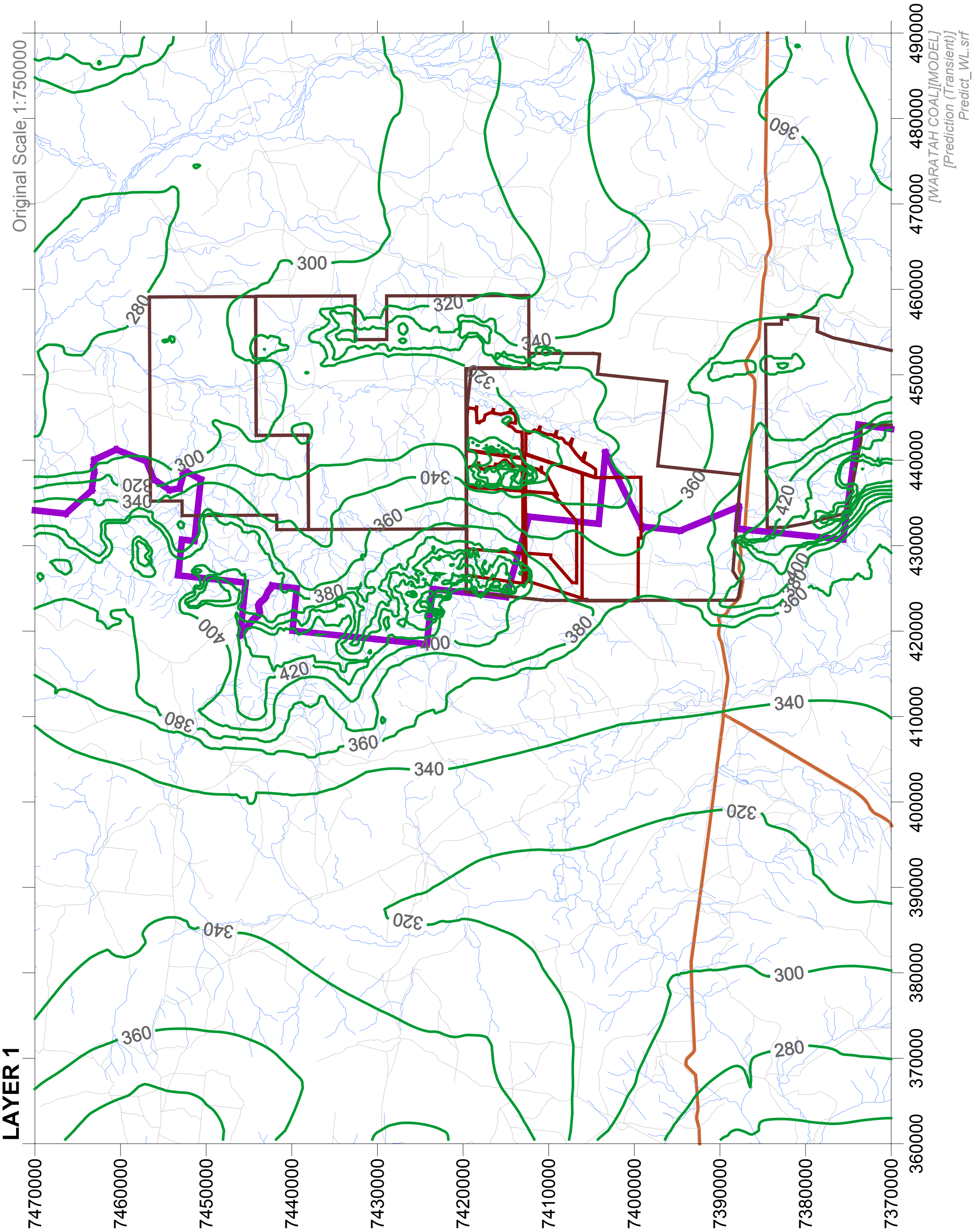


Figure 5.3 Simulated Groundwater Table Contours at the End of Mining, Model Layer 1 [mAHD]

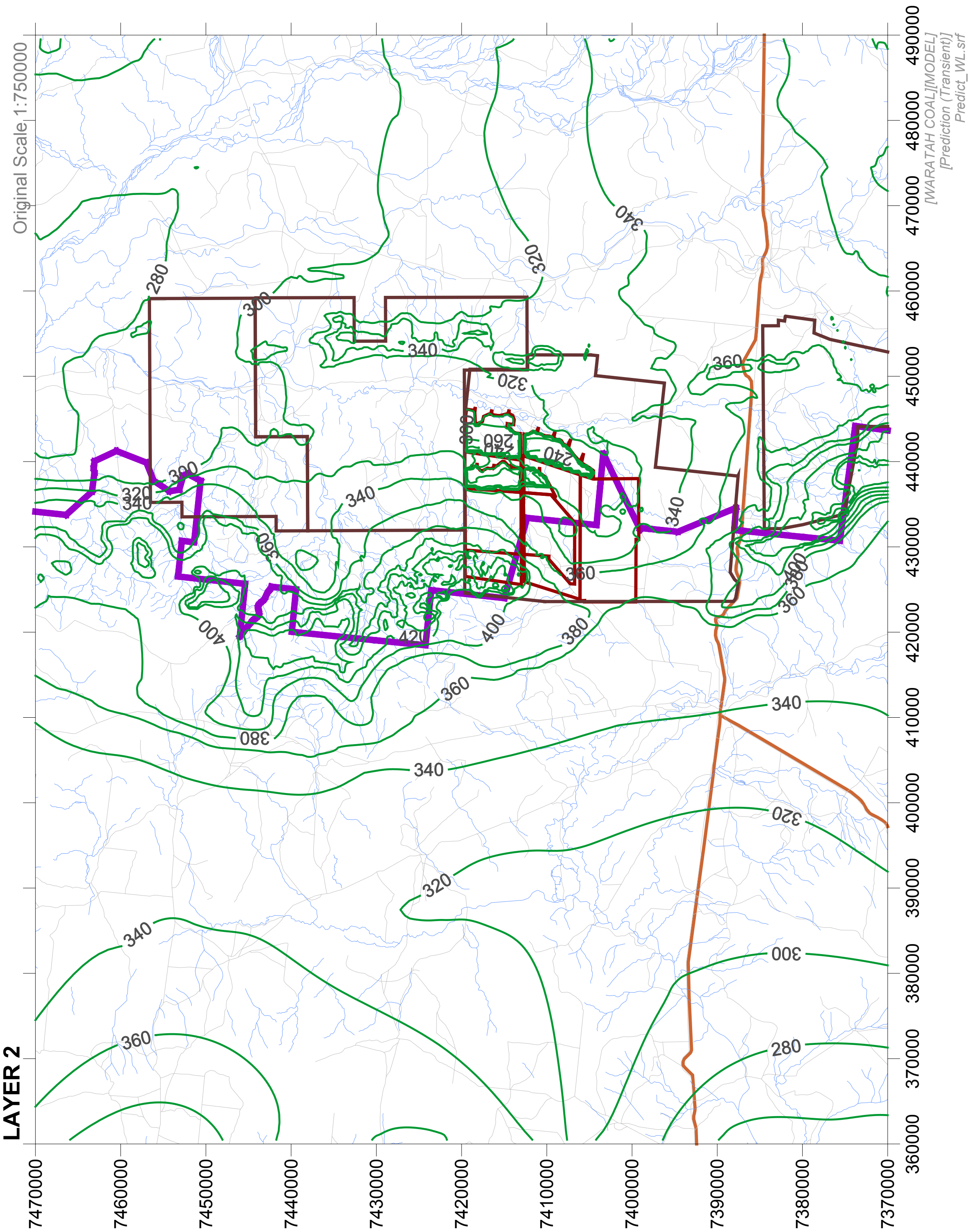


Figure 5.4 Simulated Groundwater Level Contours at the End of Mining, Model Layer 2 [mAHD]

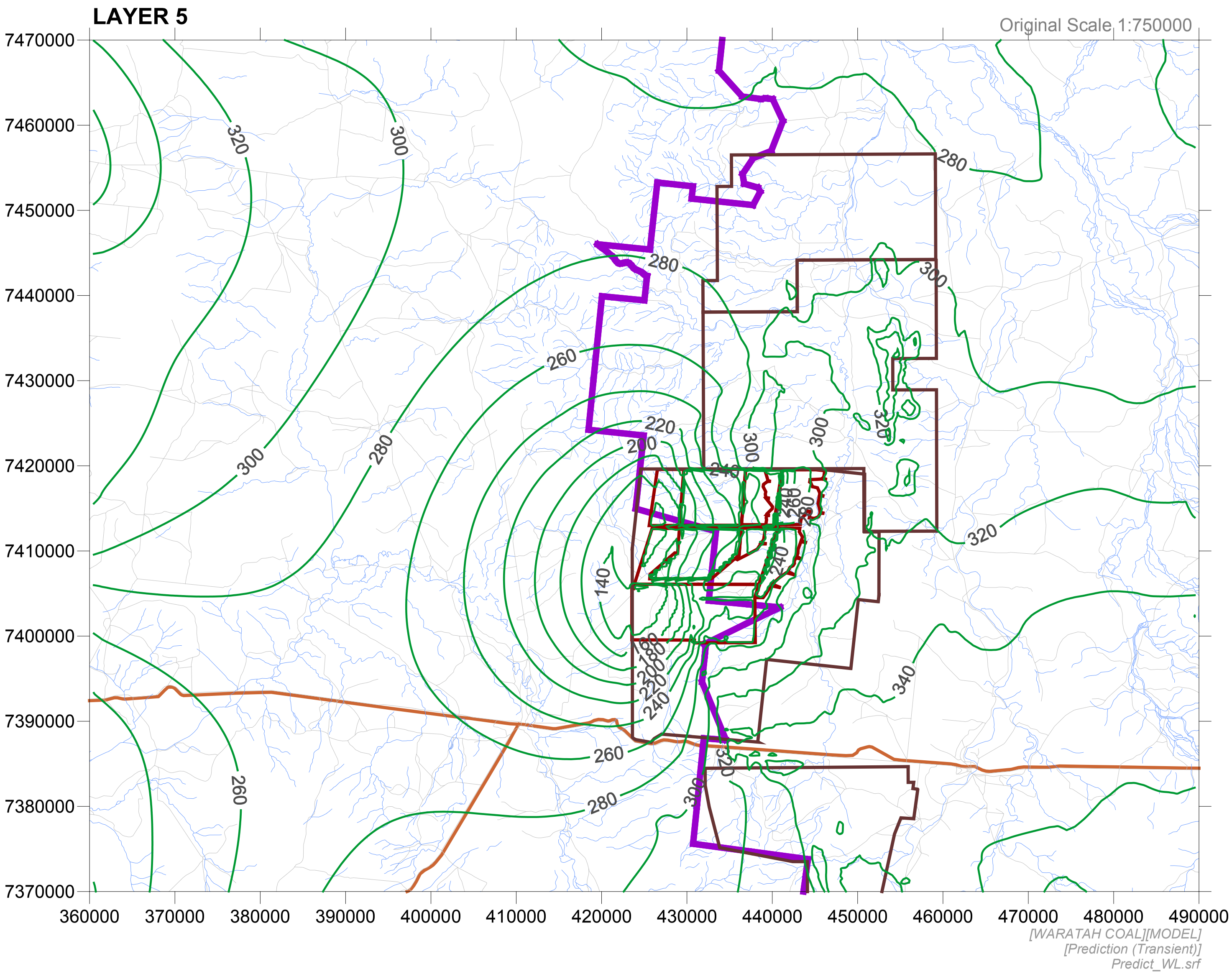


Figure 5.5 Simulated Groundwater Level Contours in the B Seam at the End of Mining, Model Layer 5 [mAHD]

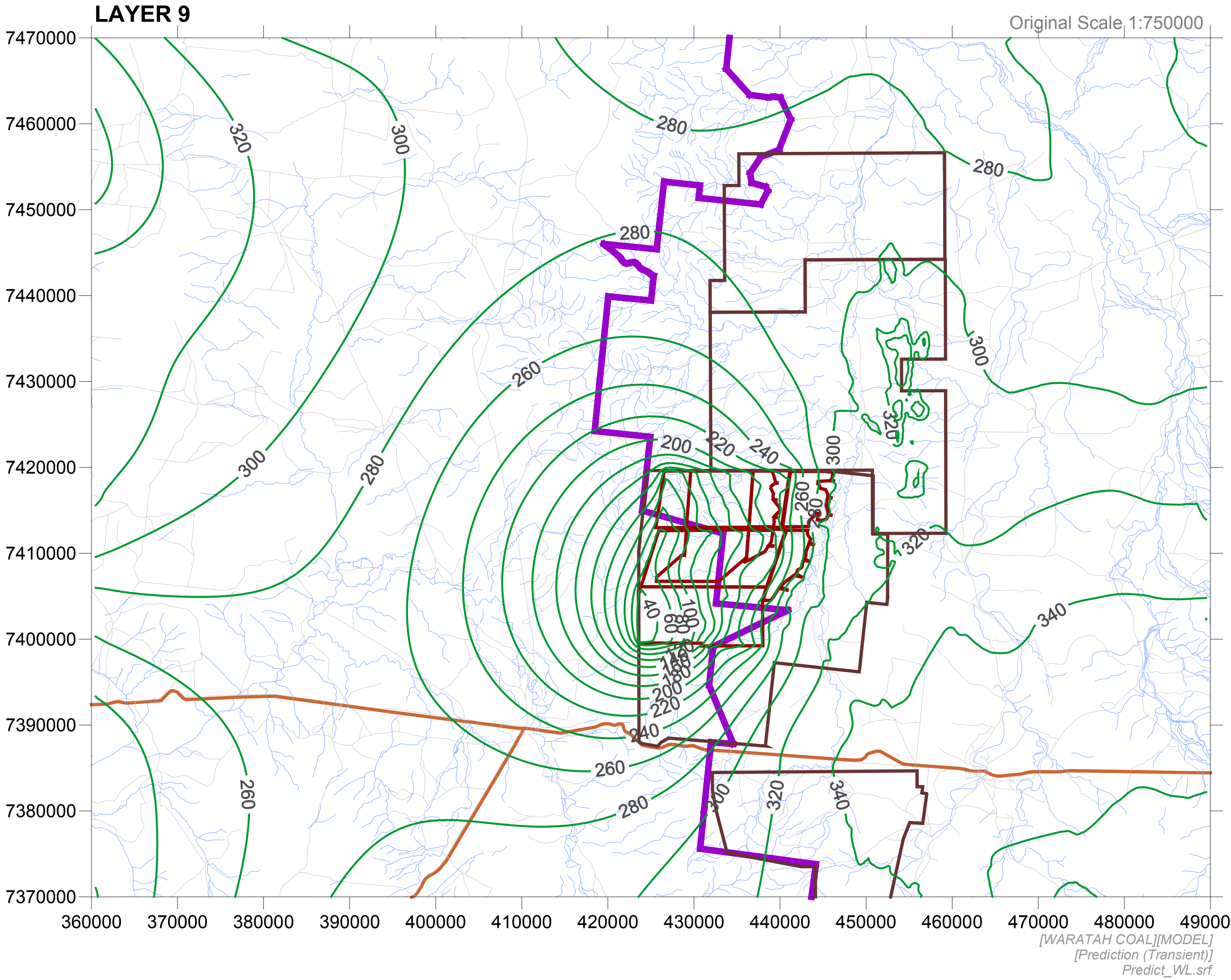


Figure 5.6 Simulated Groundwater Level Contours in the DL Seam at the End of Mining, Model Layer 9 [mAHD]

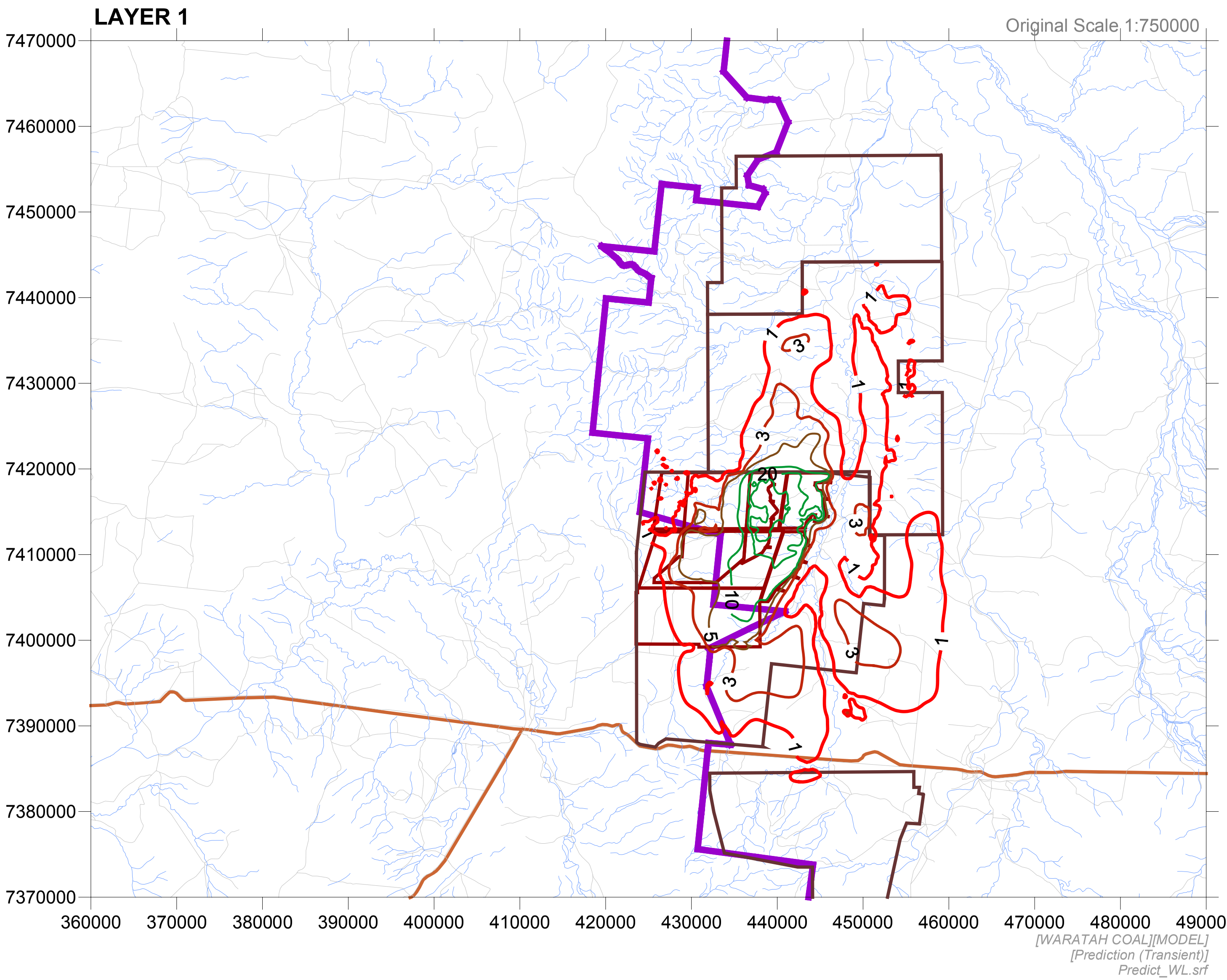


Figure 5.7 Simulated Groundwater Table Drawdown Contours at the End of Mining, Model Layer 1 [m]

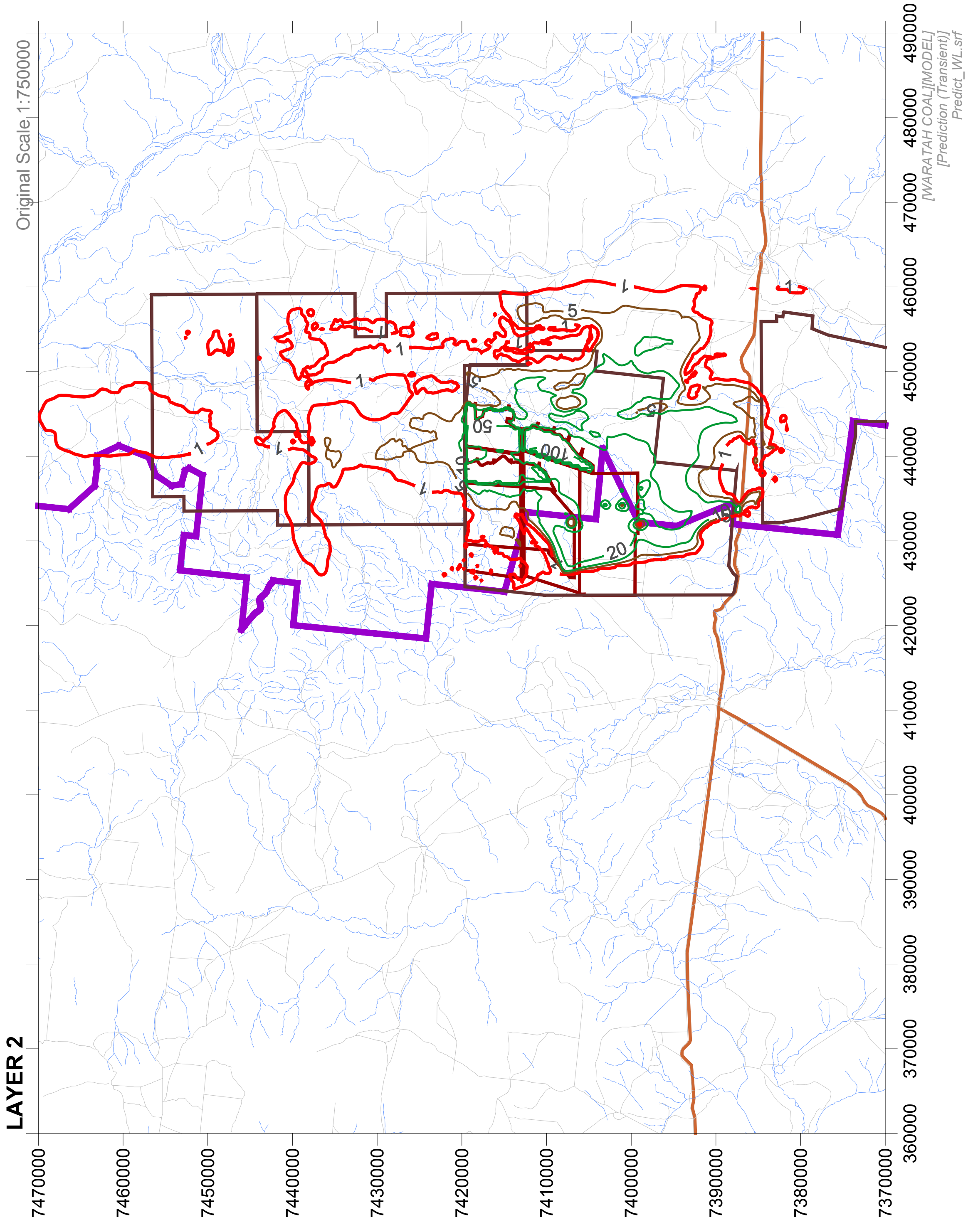


Figure 5.8 Simulated Groundwater Drawdown Contours at the End of Mining, Model Layer 2 [m]

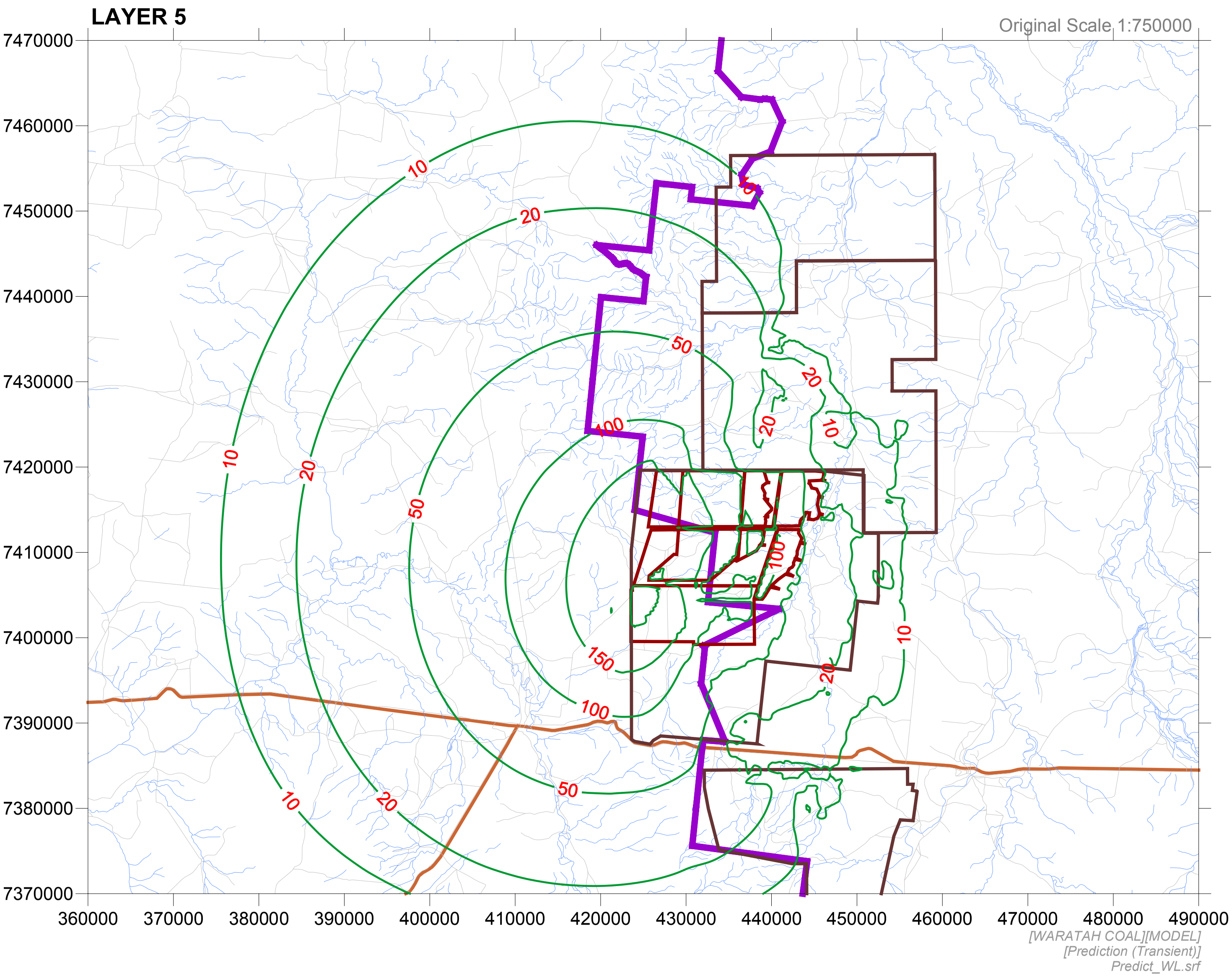


Figure 5.9 Simulated Groundwater Drawdown Contours in the B Seam at the End of Mining, Model Layer 5 [m]

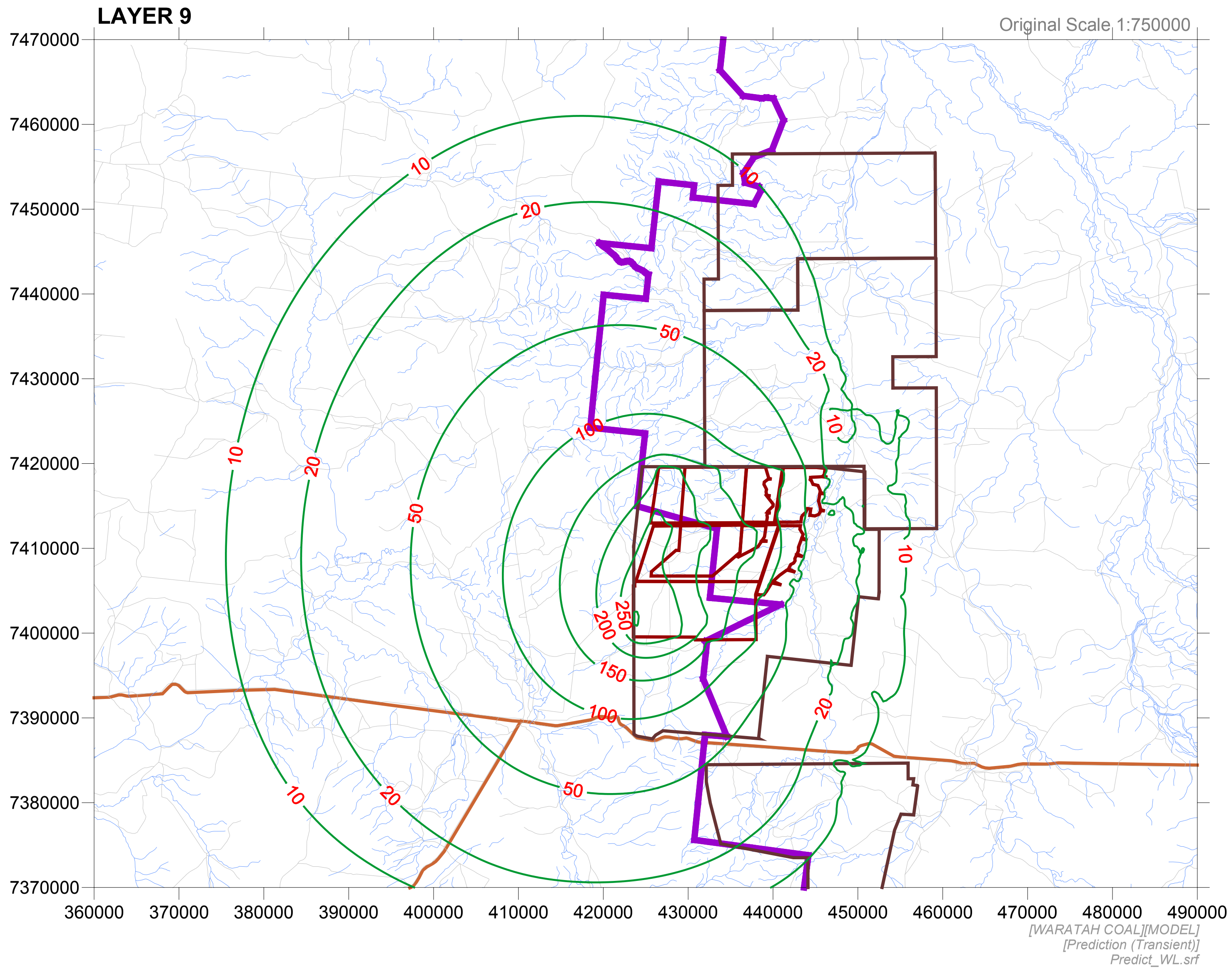


Figure 5.10 Simulated Groundwater Drawdown Contours in the DL Seam at the End of Mining, Model Layer 9 [m]

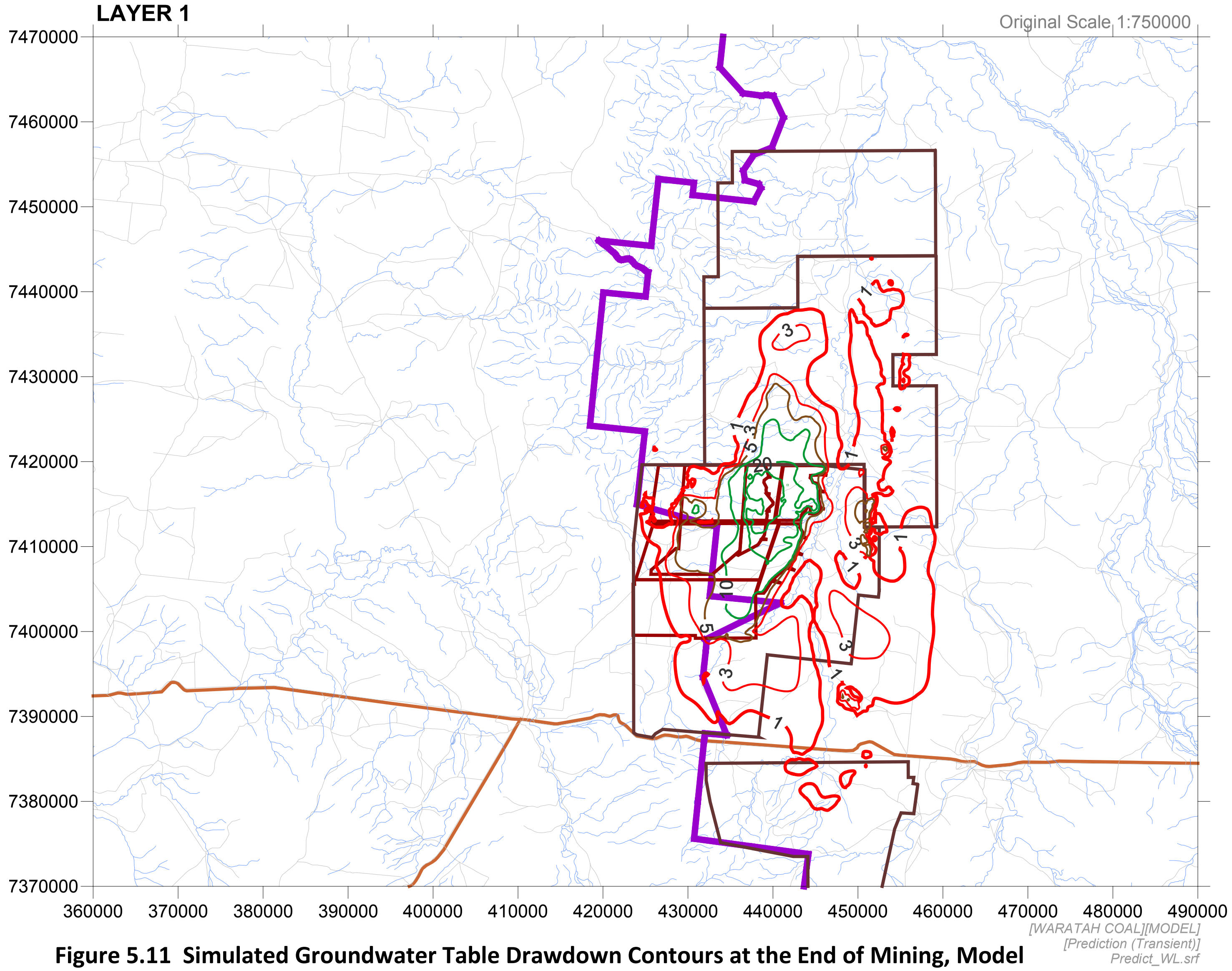


Figure 5.11 Simulated Groundwater Table Drawdown Contours at the End of Mining, Model Layer 1 [m], for Layer 2 Vertical Permeability Increased by a Factor of 100

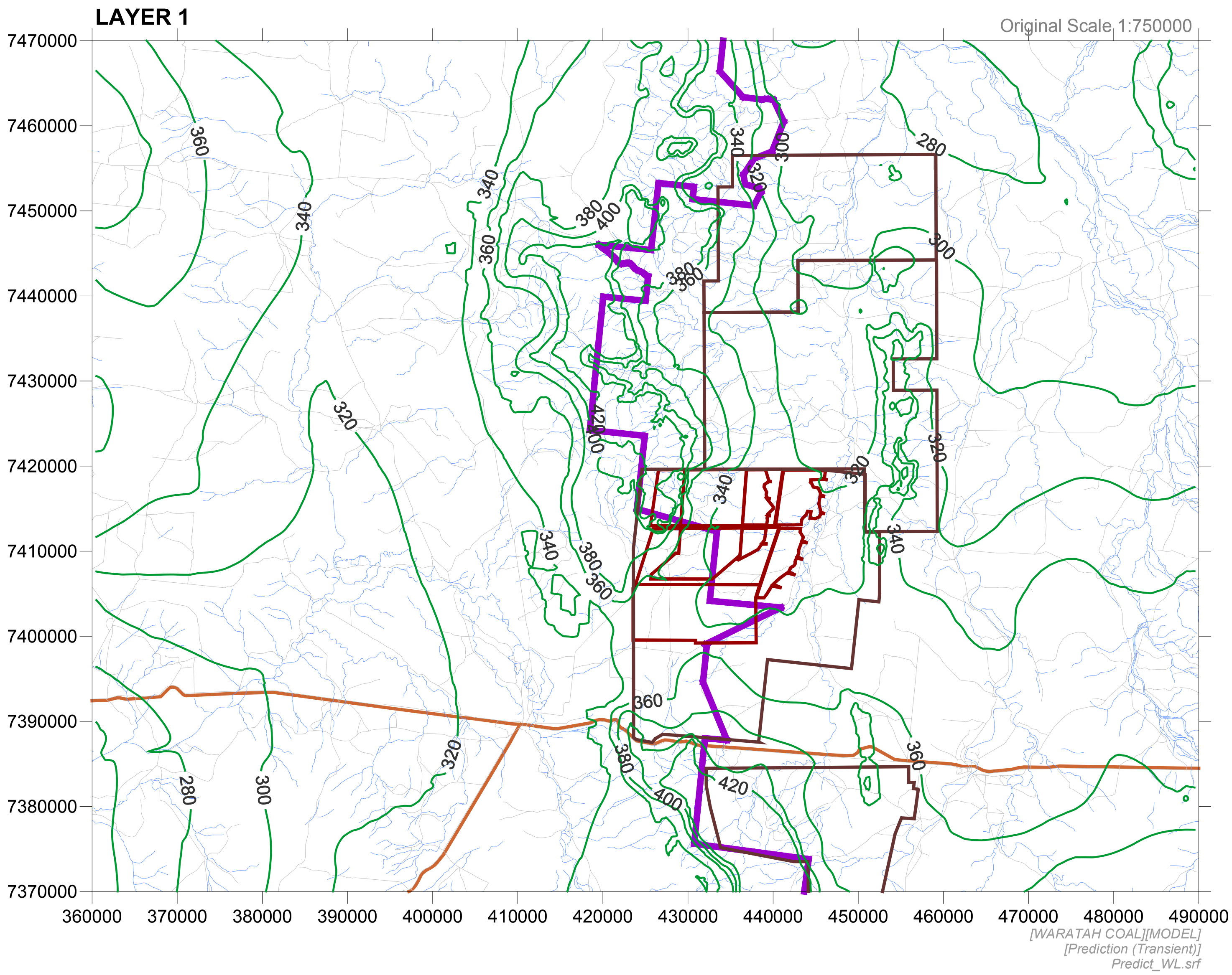


Figure 5.12 Simulated Groundwater Table Contours 200 Years after the End of Mining, Model Layer 1 [mAHD]

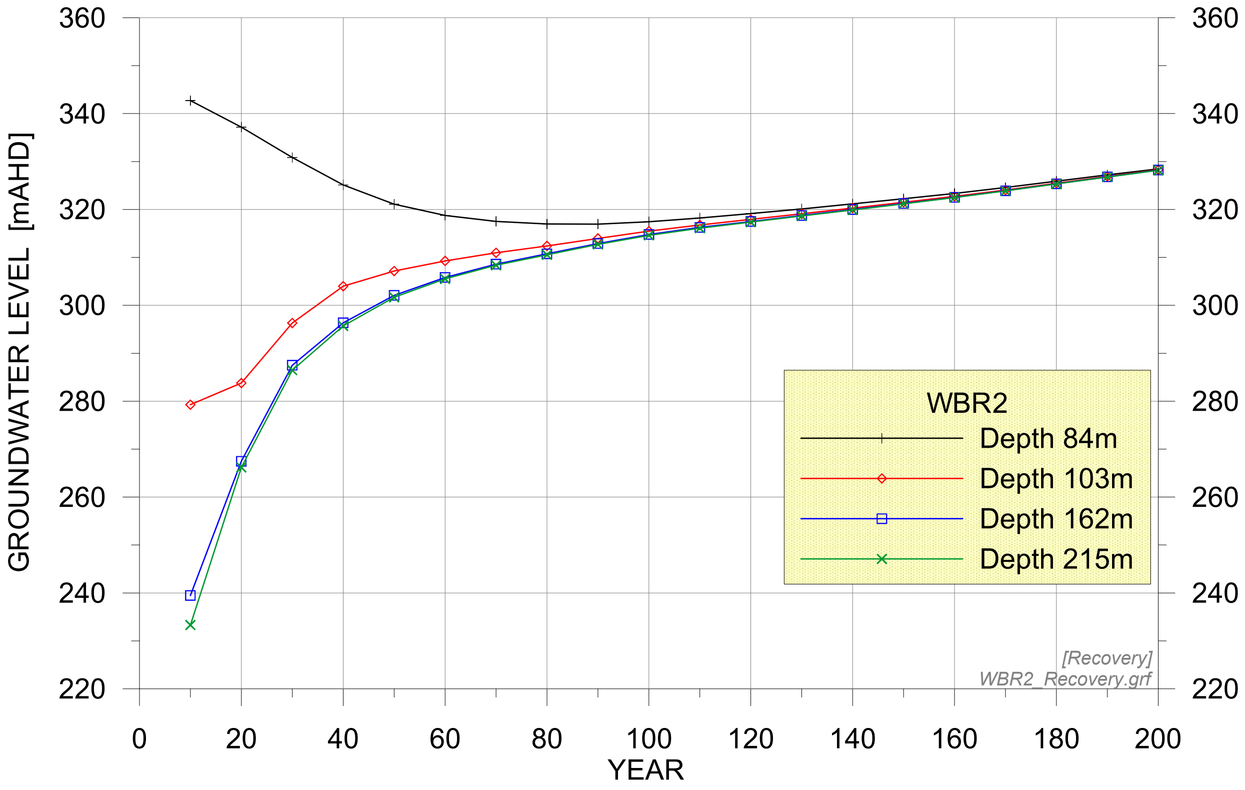


Figure 5.13 Simulated Groundwater Recovery Hydrographs at Site WBR2 [mAHD]

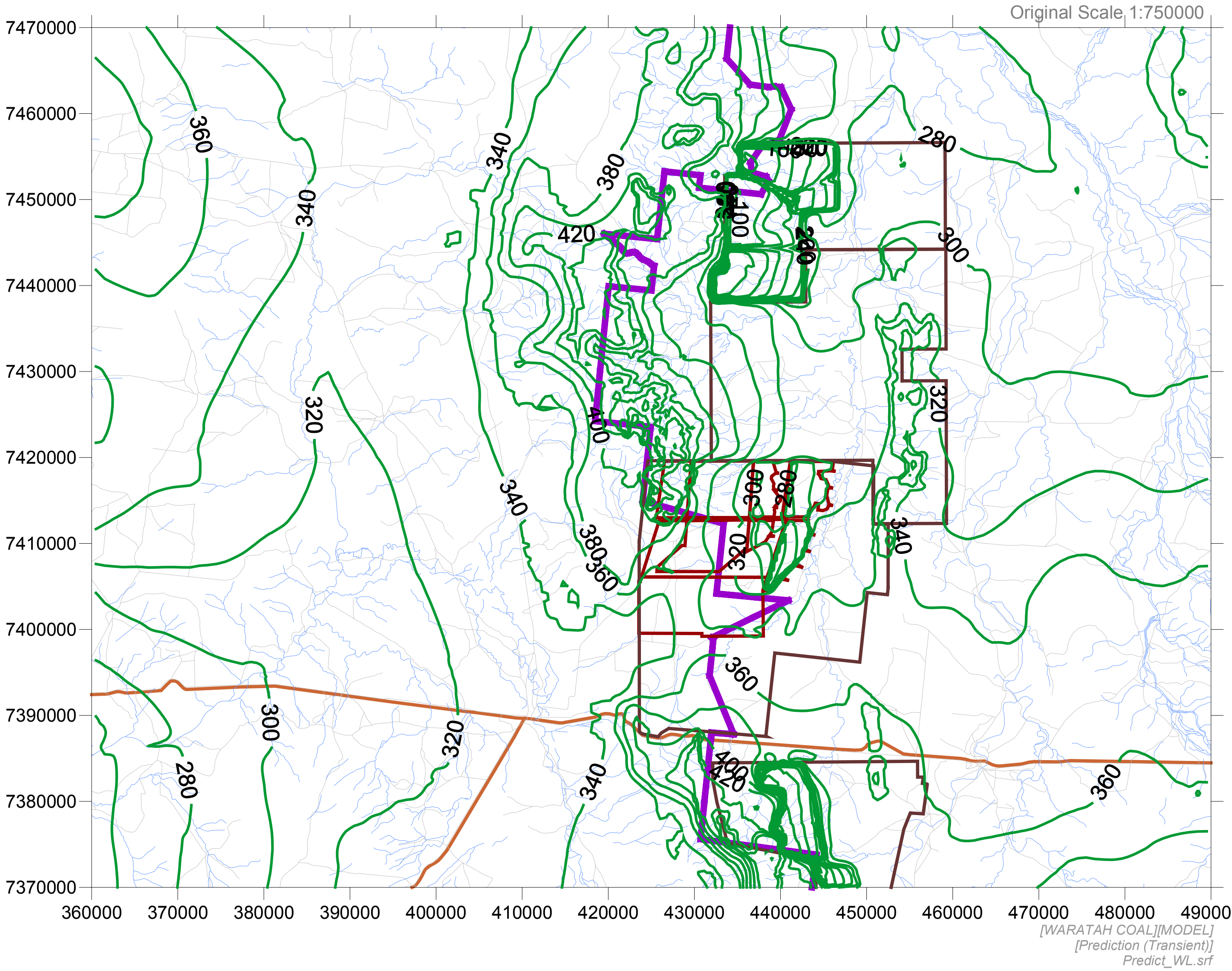


Figure 5.14 Groundwater Table Contours at the End of Mining, Model Layer 1 [m], for Three Operating Mines

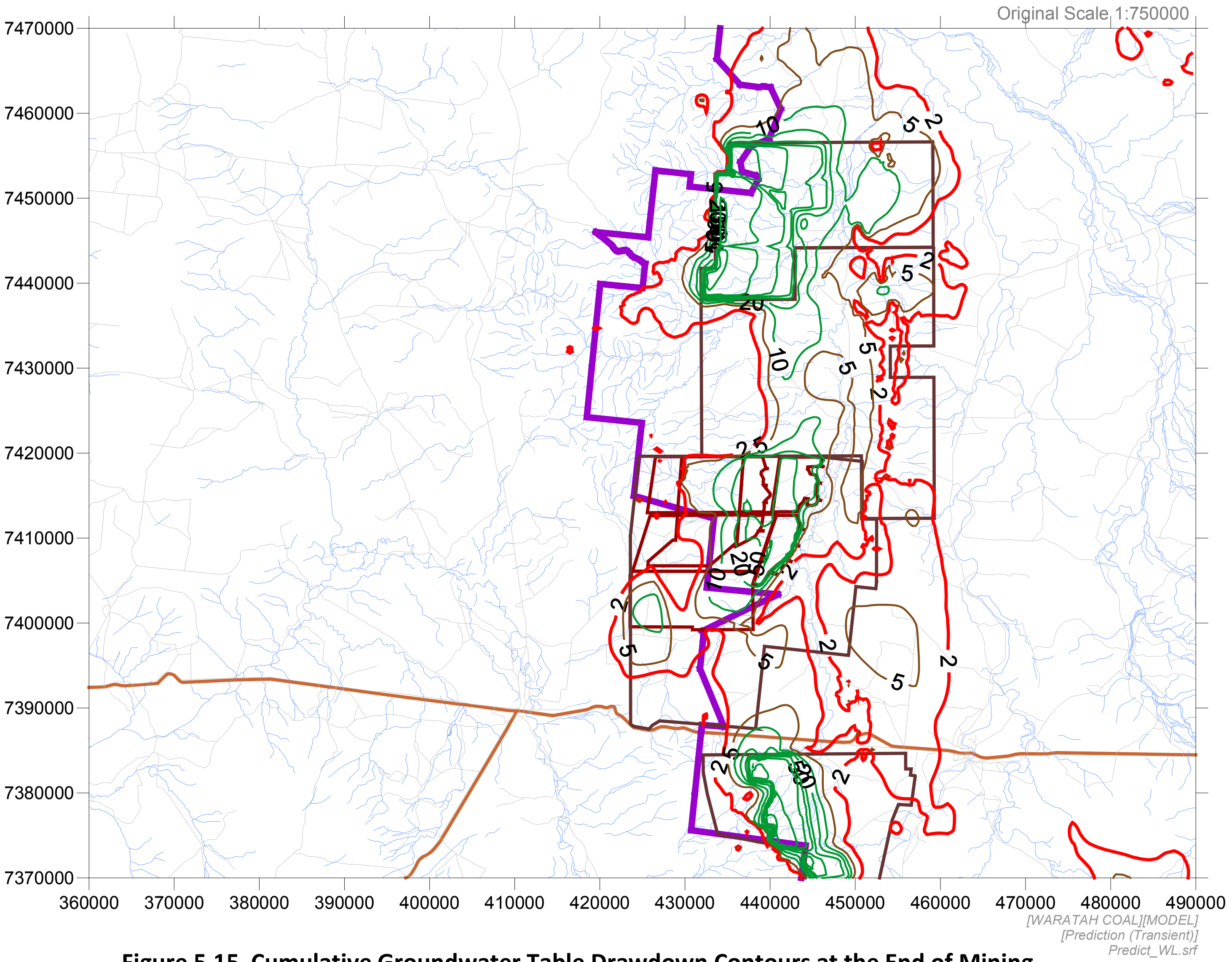


Figure 5.15 Cumulative Groundwater Table Drawdown Contours at the End of Mining, Model Layer 1 [m], for Three Operating Mines

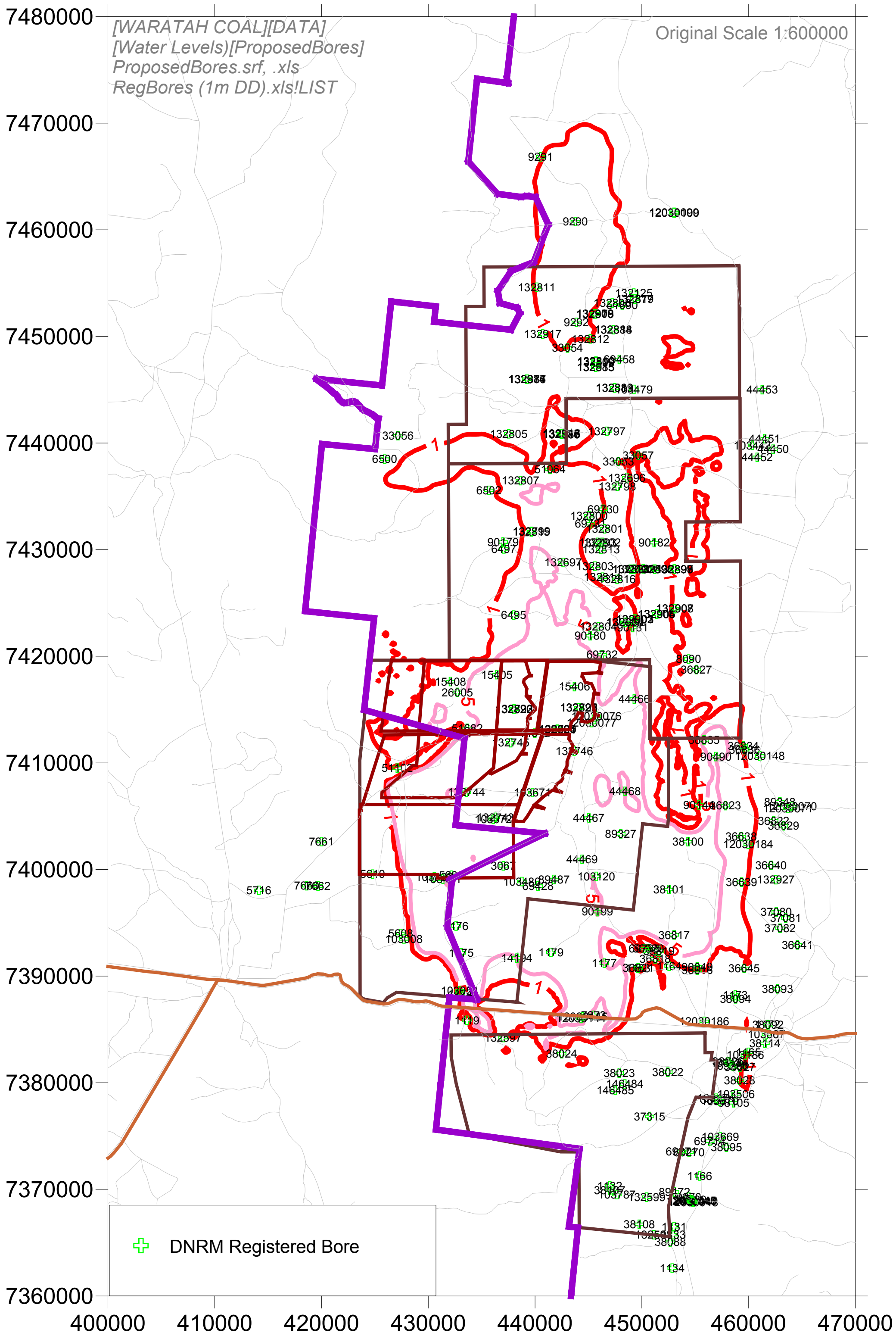


Figure 6.1 Registered DNRM Bores in the Proximity of the Drawdown Impact Zone, Compared with 1 m and 5 m Layer 2 Drawdown Limits at the End of Mining

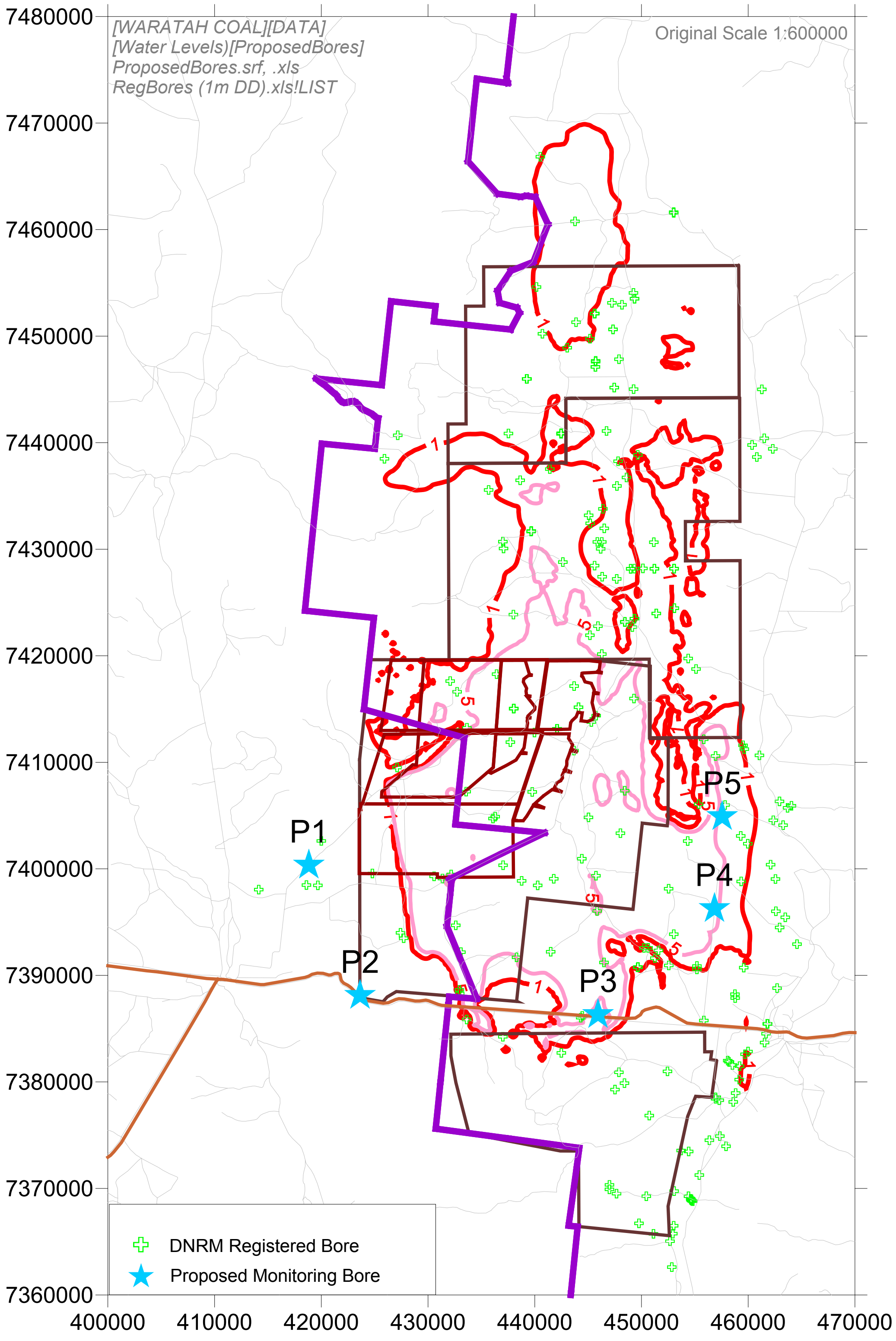


Figure 6.2 Proposed Additional Groundwater Monitoring Bores

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ATTACHMENT A

Water Quality

Table A1. Major Ion Chemistry

		CATIONS				ANIONS			
Sample ID	**Source**	**Na**	**K**	**Ca**	**Mg**	**CO_3**	**HCO_3**	**SO_4**	**Cl**
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	DNRM Databases	266.0	4.0	15.5	3.0	1.0	114.0	1.0	370.0
5609	DNRM Databases	1200.0	21.0	130.0	145.0	0.6	170.0	135.0	2350.0
17299	DNRM Databases	123.6	4.6	57.8	30.6	2.3	107.2	34.3	302.9
33057	DNRM Databases	350.0	0.6	315.0	215.0	0.6	285.0	530.0	1200.0
36653	DNRM Databases	135.0	12.0	28.5	29.5	0.2	220.0	34.5	180.0
36657	DNRM Databases	422.1	17.6	89.6	111.8	0.5	77.1	130.8	1015.0
36658	DNRM Databases	185.0	13.5	50.0	53.0	0.1	180.0	58.0	330.0
36783	DNRM Databases	940.0	20.5	345.0	155.0	1.4	340.0	120.0	2250.0
36826	DNRM Databases	2200.0	28.5	130.0	105.0	0.6	385.0	300.0	3450.0
38092	DNRM Databases	156.7	8.6	19.4	22.6	0.4	132.8	16.4	254.6
38112	DNRM Databases	286.0	11.0	43.0	36.0		250.0	50.0	424.0
44467	DNRM Databases	564.0	17.8	70.0	83.0	0.0	415.0	50.0	960.0
44468	DNRM Databases	210.0	4.4	8.8	9.6	0.8	215.0	18.5	220.0
51099	DNRM Databases	217.2	9.4	31.7	32.3	0.3	185.5	42.2	350.7
51401	DNRM Databases	212.3	12.0	35.5	38.9	0.3	191.1	30.2	347.9
51402	DNRM Databases	217.6	12.8	44.2	40.4	0.4	188.8	34.5	377.5
51408	DNRM Databases	261.4	9.0	34.7	36.4	0.8	145.7	46.3	471.0
51594	DNRM Databases	205.0	14.5	22.0	40.0	0.0	73.0	29.0	435.0
51881	DNRM Databases	232.0	9.0	26.8	28.4	0.4	169.7	46.6	348.1
51968	DNRM Databases	240.5	11.1	37.8	34.7	0.5	232.1	38.0	341.0
51984	DNRM Databases	1090.0	27.5	317.8	161.9	1.8	231.4	122.5	2519.0
69091	DNRM Databases	105.0	8.5	33.0	10.0	0.7	110.0	28.0	180.0
69268	DNRM Databases	140.0	10.5	9.3	25.0	0.0	21.5	30.0	270.0

69428	DNRM Databases	4550.0	7.0	180.0	420.0	14.0	630.0	850.0	7700.0
69696	DNRM Databases	279.0	1.4	5.6	0.5	0.4	63.7	0.0	406.0
69715	DNRM Databases	212.3	11.2	35.0	38.0	1.2	130.7	15.4	411.6
69720	DNRM Databases	1243.0	33.9	332.0	264.0	3.5	376.0	169.0	2968.0
69729	DNRM Databases	431.8	13.5	29.2	25.0	4.5	214.5	60.1	558.3
69731	DNRM Databases	322.0	6.0	7.0	7.0	1.0	120.0	1.0	470.0
69732	DNRM Databases	529.0	3.0	28.0	6.0	1.0	101.0	58.0	828.0
69749	DNRM Databases	210.4	11.0	34.5	32.9	0.6	190.2	30.3	339.0
90150	DNRM Databases	389.9	23.1	85.6	79.3	0.4	281.6	69.0	748.9
90155	DNRM Databases	944.0	22.0	292.9	144.4	2.5	261.0	53.5	2210.0
90192	DNRM Databases	197.7	19.9	44.9	52.3	1.2	226.1	34.6	356.7
90193	DNRM Databases	211.9	24.3	45.1	46.3	0.4	238.0	47.8	343.8
90434	DNRM Databases	197.5	14.5	12.9	17.0	0.1	119.3	11.5	308.7
90443	DNRM Databases	405.0	29.0	46.0	92.0	0.0	188.0	121.0	811.0
90453	DNRM Databases	192.7	10.7	30.3	30.6	0.3	203.1	37.5	295.8
103113	DNRM Databases	143.3	8.1	15.9	16.3	0.3	136.7	23.4	198.5
103183	DNRM Databases	135.0	8.4	16.0	14.8	0.5	163.3	21.8	175.0
103184	DNRM Databases	72.0	7.4	9.7	15.5	0.2	75.0	5.5	128.7
103186	DNRM Databases	39.1	6.6	8.9	11.8	0.4	86.2	5.2	62.6
103194	DNRM Databases	188.4	9.8	40.4	31.9	0.6	195.7	25.7	318.0
103202	DNRM Databases	138.4	8.0	6.6	17.2	0.0	51.0	36.4	227.9
103203	DNRM Databases	140.4	8.3	10.7	17.4	0.0	64.2	36.6	229.3
103214	DNRM Databases	160.7	11.7	12.1	30.0	0.1	40.3	43.8	312.0
103215	DNRM Databases	155.8	11.9	11.3	28.4	0.0	13.8	40.1	312.7
103216	DNRM Databases	107.5	7.8	8.8	14.3	0.1	47.4	23.4	179.7
103217	DNRM Databases	151.8	9.4	11.1	20.2	0.9	77.2	41.5	247.2
103218	DNRM Databases	303.1	16.6	89.6	53.6	0.5	421.0	15.3	484.7
103222	DNRM Databases	229.0	6.4	35.2	15.9	2.5	249.9	32.7	318.1

103224	DNRM Databases	263.4	10.5	55.1	27.9	1.8	398.9	48.7	330.5
103225	DNRM Databases	259.1	12.0	60.9	17.2	1.7	289.5	109.6	321.8
103226	DNRM Databases	246.0	8.8	50.3	27.7	1.6	241.3	36.3	386.6
103441	DNRM Databases	77.0	3.0	1.0	1.0	1.0	93.0	5.0	54.0
103801	DNRM Databases	34.0	2.0	1.0	3.0		17.0	1.0	46.0
132744	DNRM Databases	261.0	5.0	8.0	3.0	2.3	107.2	34.3	302.9
132790	DNRM Databases	1280.0	16.0	66.0	33.0	0.1	165.0	161.0	1890.0
132791	DNRM Databases	2180.0	24.0	97.0	122.0	0.1	164.0	214.0	3790.0
132792	DNRM Databases	1640.0	36.0	555.0	126.0	1.0	130.0	89.0	3740.0
12030036	DNRM Databases	30.6	13.7	15.0	9.4	0.8	160.8	7.2	16.9
12030039	DNRM Databases	77.7	6.1	16.0	10.5	0.5	113.4	9.6	106.5
12030040	DNRM Databases	266.7	24.3	54.0	52.6	1.4	418.7	50.5	397.1
12030041	DNRM Databases	185.5	11.3	27.2	26.8	0.5	150.0	26.6	304.4
12030052	DNRM Databases	170.0	9.5	7.5	7.0	0.6	371.0	44.0	50.0
12030076	DNRM Databases	4713.3	29.0	150.0	295.0	2.2	363.0	930.0	7400.0
12030077	DNRM Databases	32.0	2.1	4.2	2.9	0.1	40.3	9.1	37.0
12030144	DNRM Databases	1980.0	51.0	160.0	240.0	1.0	232.0	590.0	2900.0
WBR2	VWP Installation Drilling	291.0	5.0	6.0	2.0	26.0	324.0	2.0	231.0
WBR3	VWP Installation Drilling	31.0	9.0	12.0	1.0	46.0	36.0	6.0	14.0
WBR4	VWP Installation Drilling	1080.0	7.0	57.0	23.0	1.0	140.0	99.0	1650.0
WBR5	VWP Installation Drilling	1370.0	27.0	95.0	94.0	1.0	217.0	274.0	2410.0
Monklands 1	Original EIS Investigation	661.0	10.0	41.0	54.0	151.0	151.0	67.0	1170.0
Reids old bore 1	Original EIS Investigation	554.0	20.0	72.0	83.0	318.0	318.0	156.0	946.0
Reids "the new bore" 1	Original EIS Investigation	219.0	6.0	10.0	10.0	147.0	147.0	20.0	313.0
12030076	Original EIS Investigation	4860.0	30.0	190.0	280.0	1.0	341.0	890.0	7200.0
12030076	Original EIS Investigation	4830.0	30.0	130.0	310.0	1.0	408.0	980.0	7700.0
12030076	Original EIS Investigation	4450.0	27.0	130.0	295.0	1.0	340.0	920.0	7300.0
12030077	Original EIS Investigation	34.0	0.2	3.9	2.9	1.0	44.0	13.0	42.0

12030077	Original EIS Investigation	30.0	4.0	4.5	2.9	1.0	36.5	5.1	32.0
WAR38-15 New	Original EIS Investigation	1640.0	36.0	555.0	126.0	130.0	130.0	89.0	3740.0
WAR38-15 (80)	Original EIS Investigation	1160.0	25.0	393.0	92.0	135.0	135.0	50.0	2700.0
WAR38-15 House	Original EIS Investigation	489.0	4.0	22.0	3.0	97.0	97.0	43.0	694.0
WAR44-15 Monitor	Original EIS Investigation	3970.0	64.0	190.0	434.0	139.0	139.0	612.0	6810.0
WAR44-15 New	Original EIS Investigation	2180.0	24.0	97.0	122.0	164.0	164.0	214.0	3790.0
WAR44-15 Retro	Original EIS Investigation	2020.0	20.0	100.0	111.0	173.0	173.0	184.0	3500.0
WAR42-13 (50)	Original EIS Investigation	2840.0	40.0	86.0	142.0	553.0	553.0	183.0	4870.0
WAR42-13 New	Original EIS Investigation	1280.0	16.0	66.0	33.0	165.0	165.0	161.0	1890.0
WAR42-13 (80)	Original EIS Investigation	1040.0	12.0	54.0	27.0	167.0	167.0	124.0	1520.0
White container bore	Original EIS Investigation	473.0	5.0	52.0	8.0	93.0	93.0	56.0	738.0
Cavendish 1	Original EIS Investigation	149.0	4.0	4.0	4.0	34.0	34.0	6.0	225.0
Kia Ora 1	Original EIS Investigation	1140.0	21.0	126.0	118.0	406.0	406.0	246.0	1690.0
O'Dell Bore 1	Original EIS Investigation	34.0	2.0	1.0	3.0	17.0	17.0	1.0	46.0
O'Dell Bore 2	Original EIS Investigation	77.0	3.0	1.0	1.0	93.0	93.0	5.0	54.0

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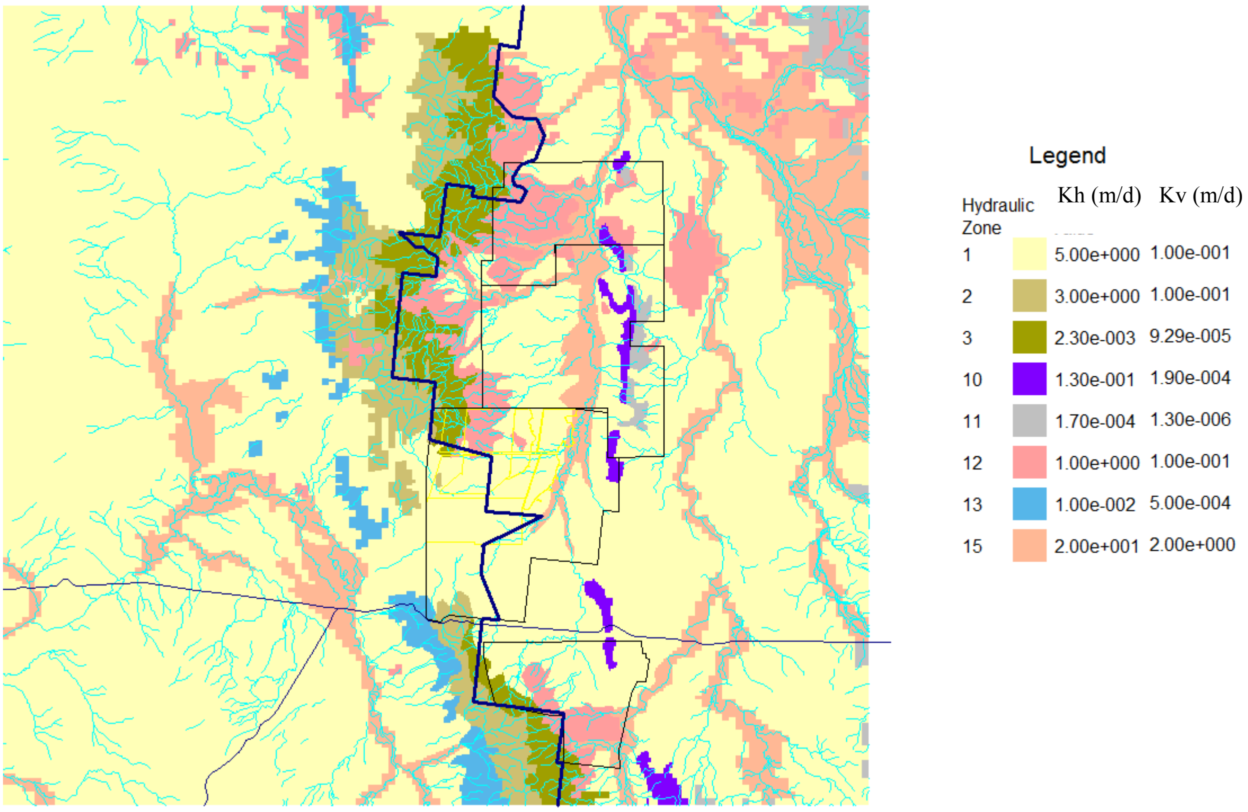
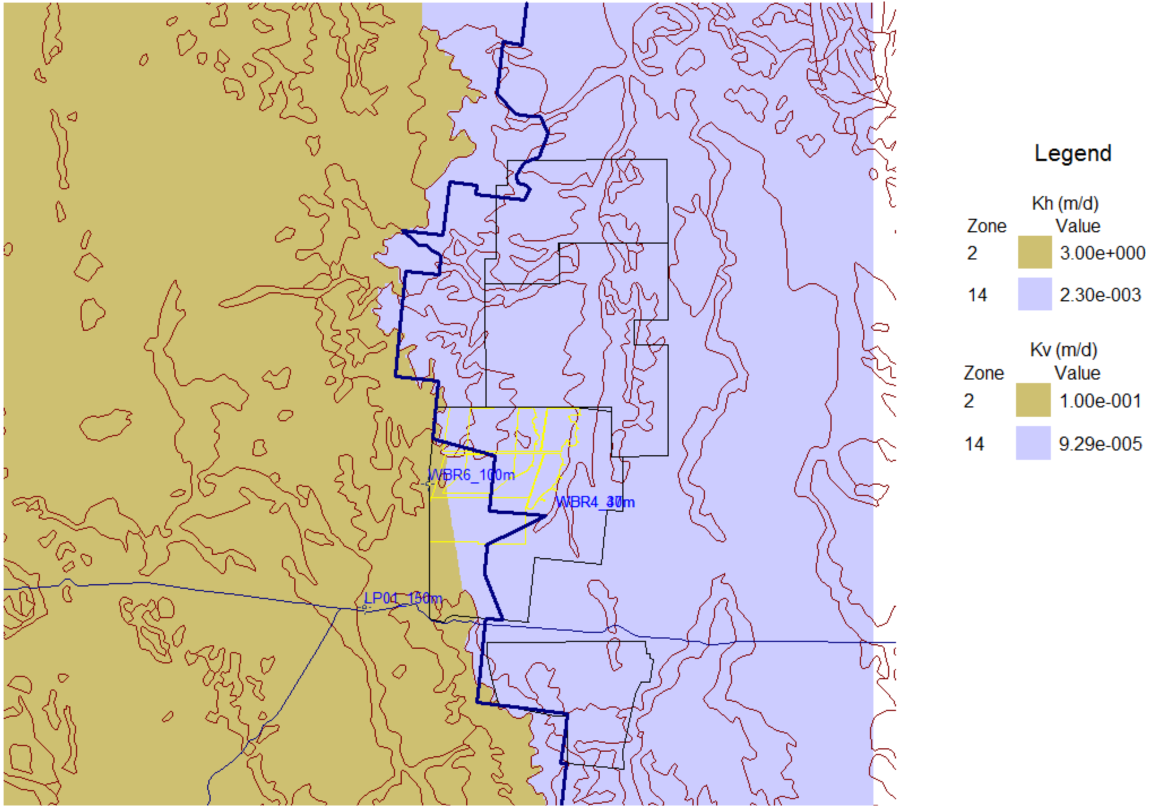
ATTACHMENT B

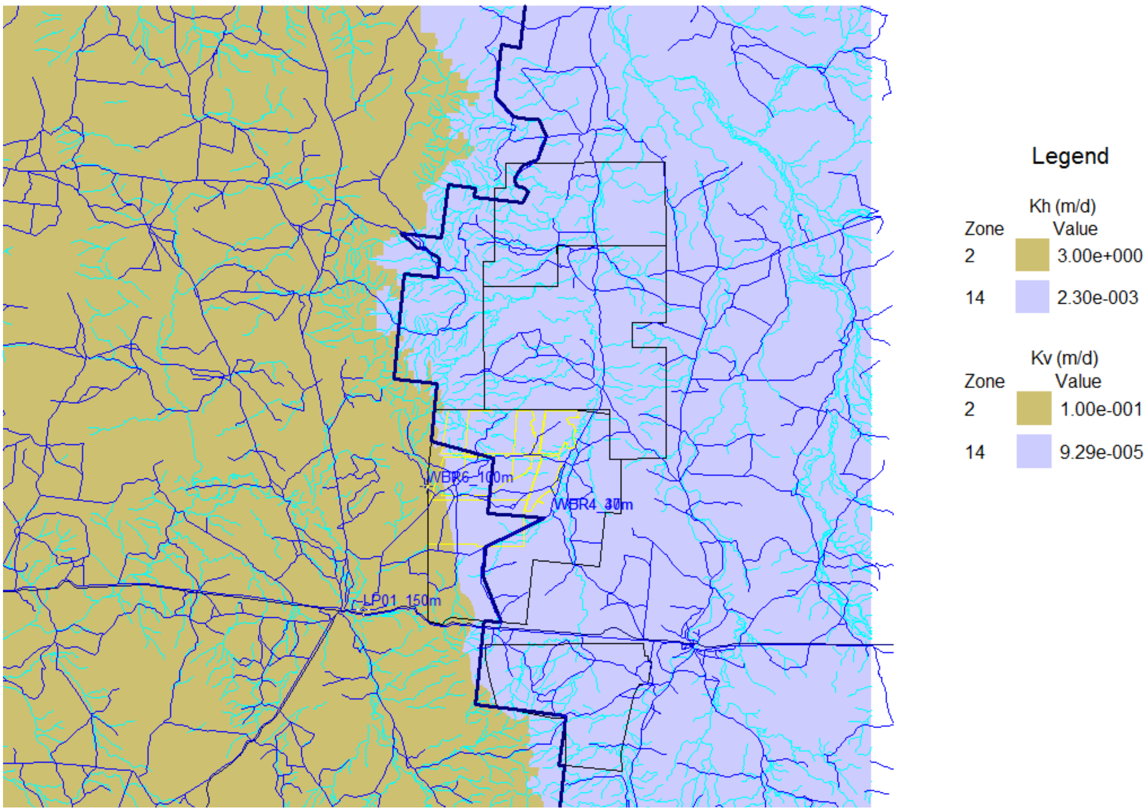
Hydraulic Conductivity, Recharge and Evapotranspiration Distributions



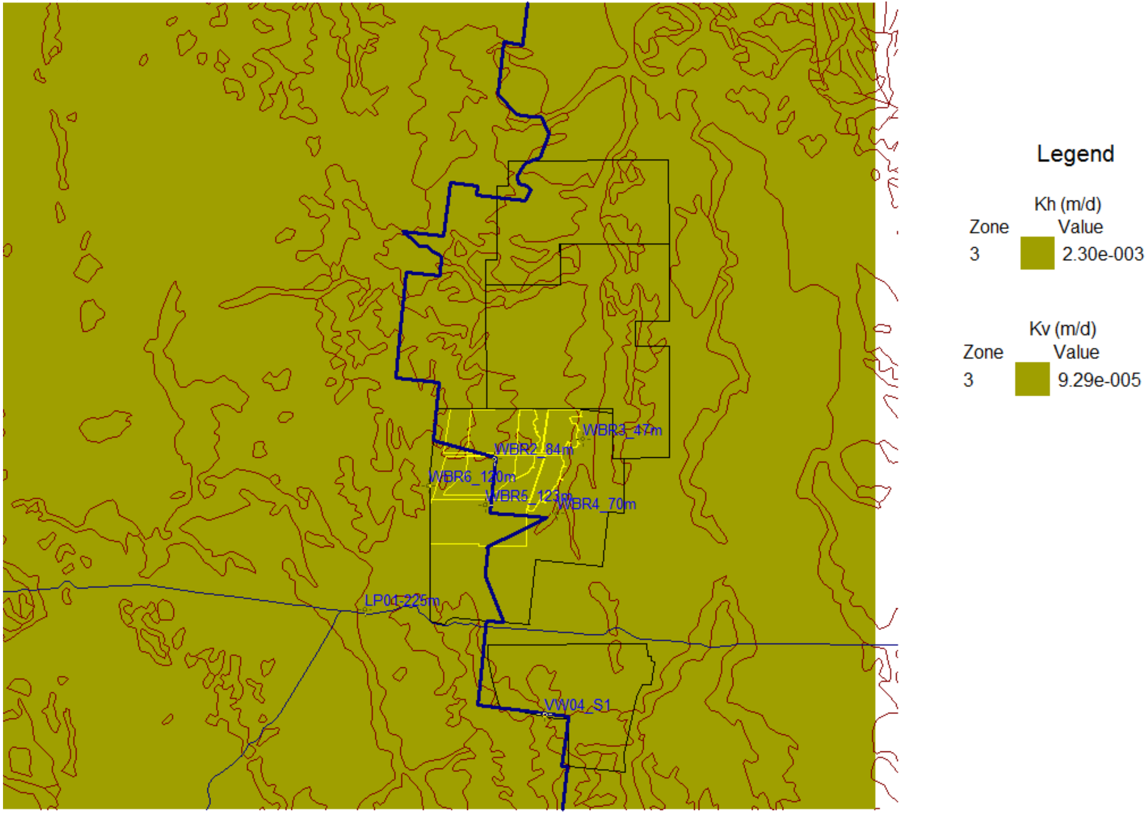
Layer 1: Alluvium and Regolith



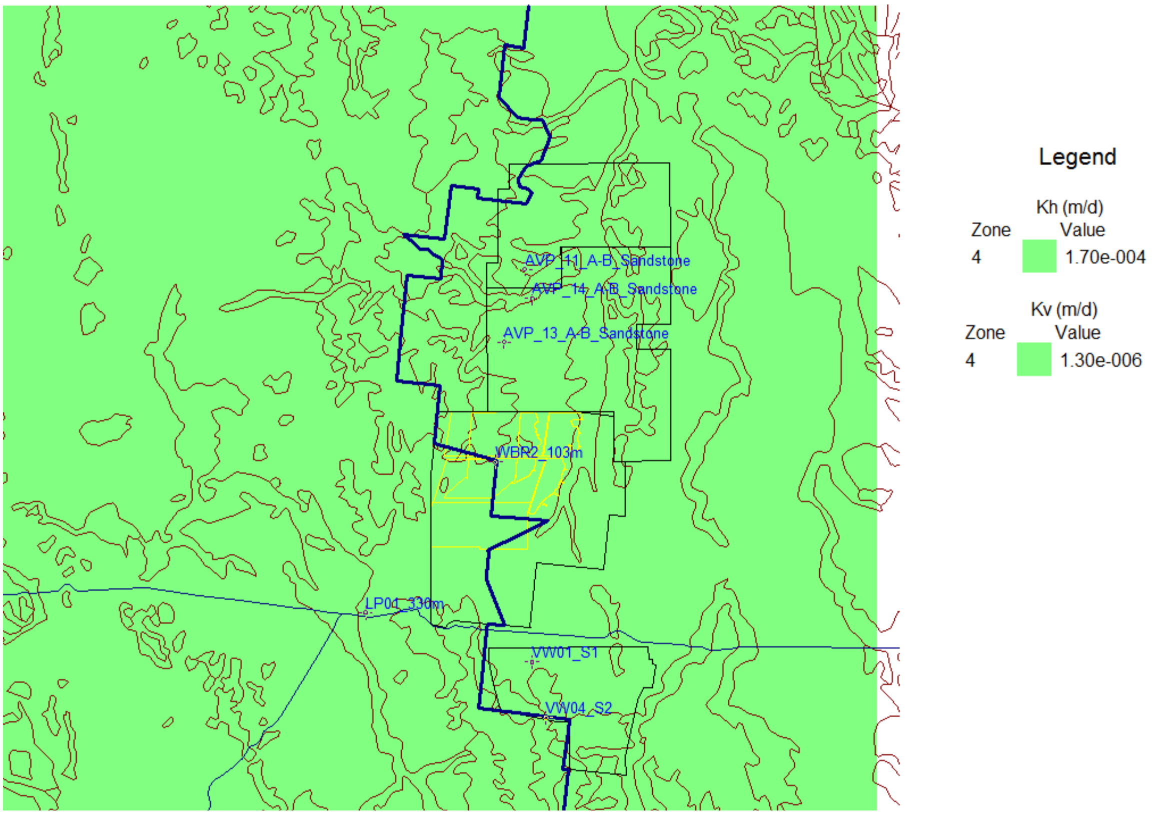
Layer 2: Moolayember Formation and Clematis Sandstone and Weathered Zone (geology outline)



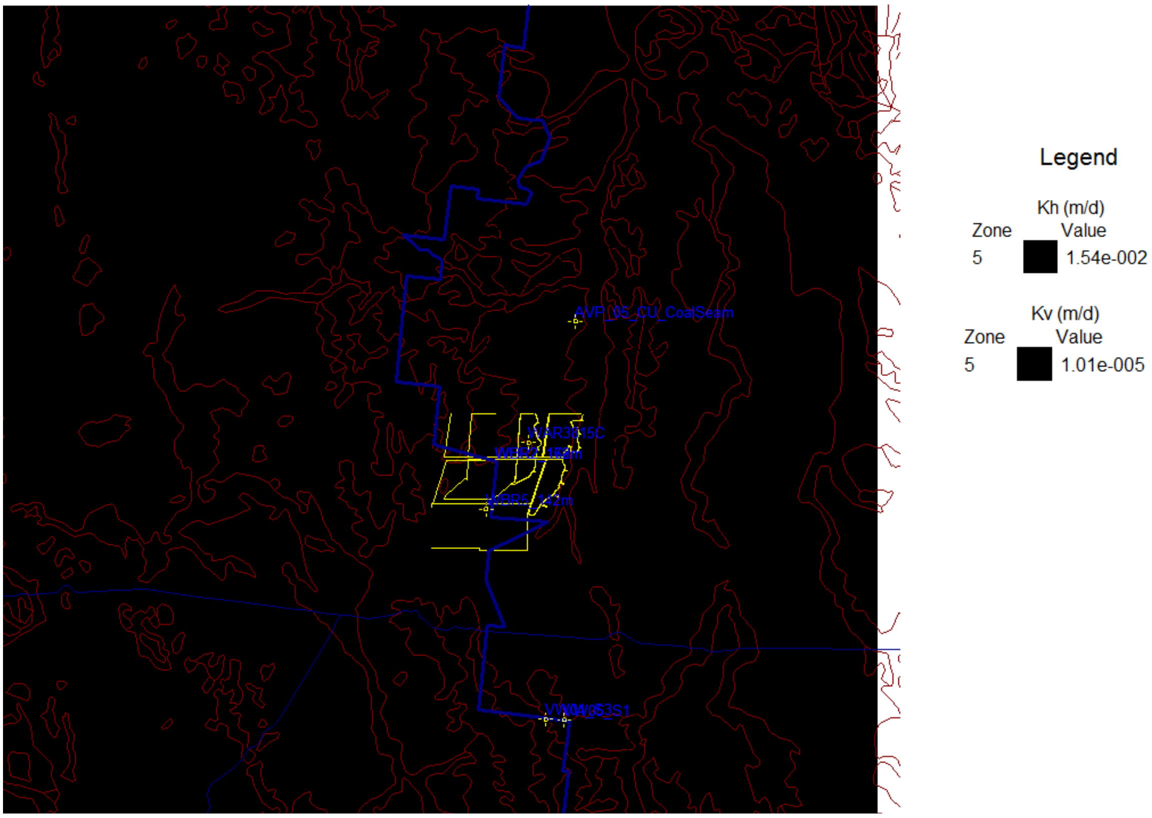
Layer 2: Moolayember Formation and Clematis Sandstone and Weathered Zone (roads & creeks)



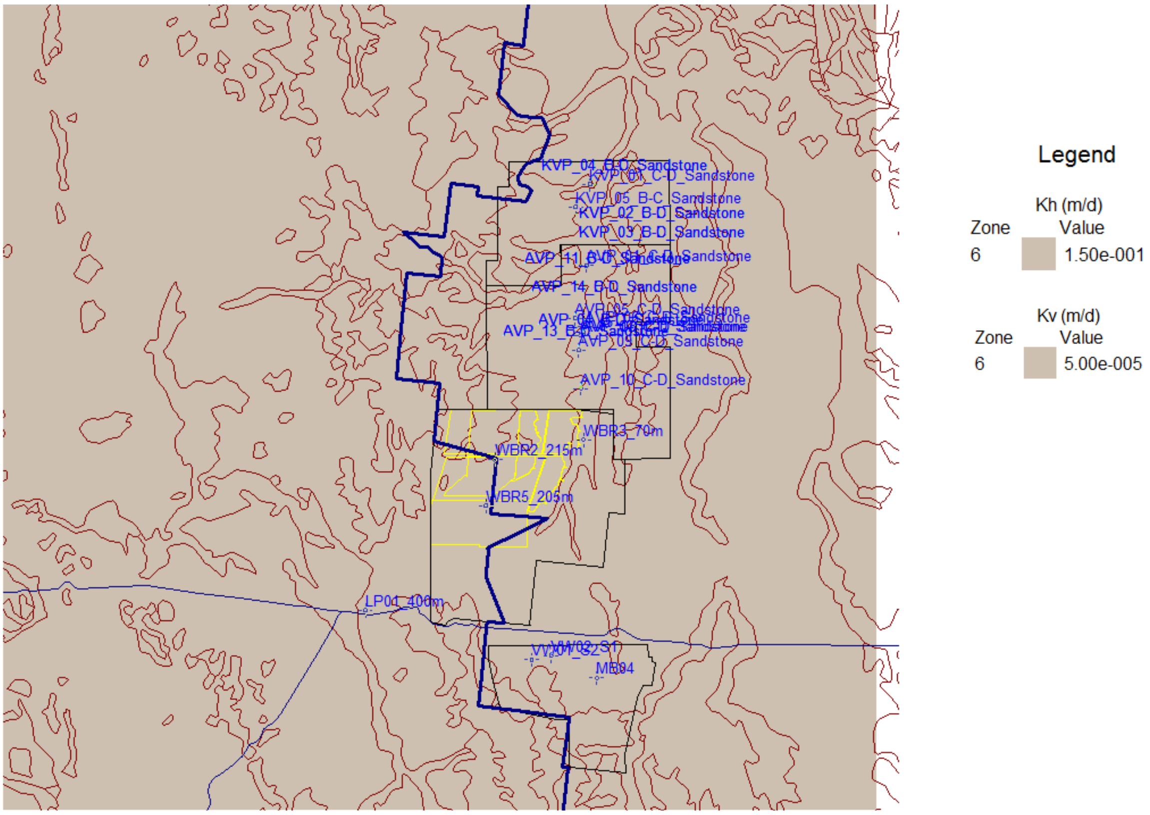
Layer 3: Dunda Beds and Rewan Formation and Weathered Permian



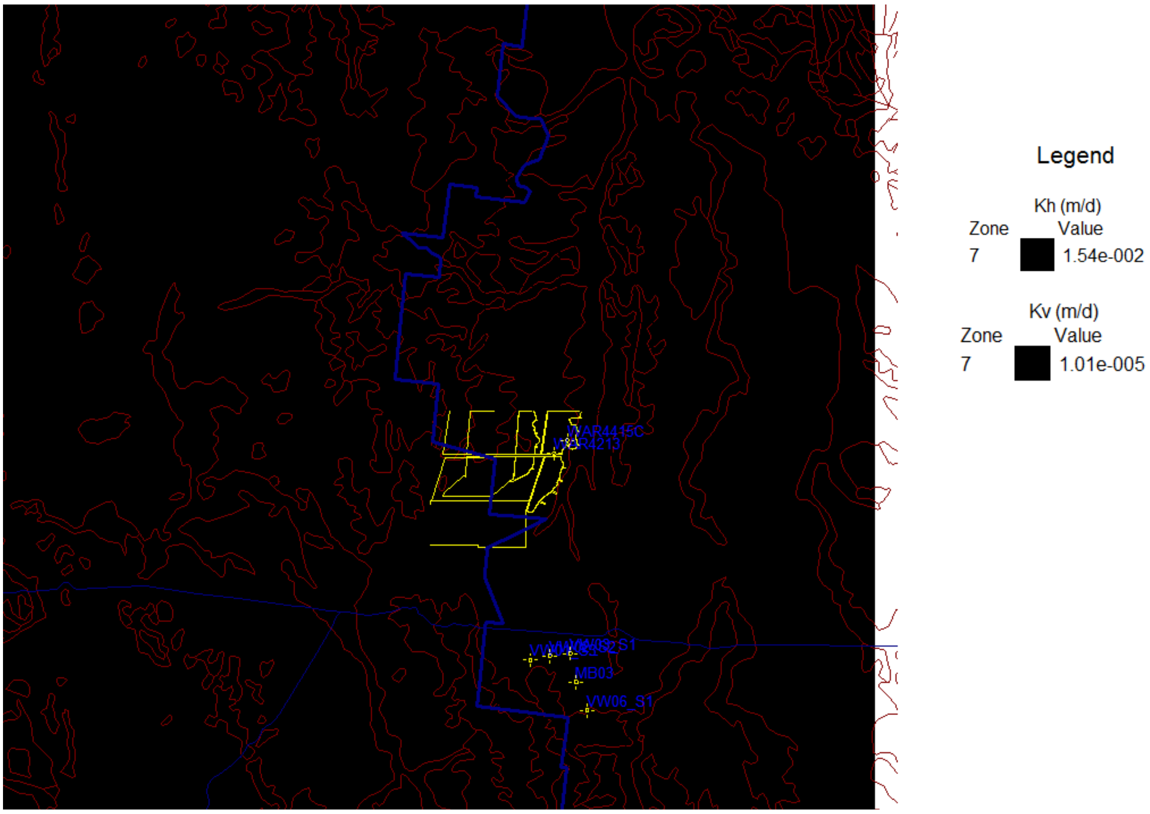
Layer 4: Bandanna Formation (Overburden)



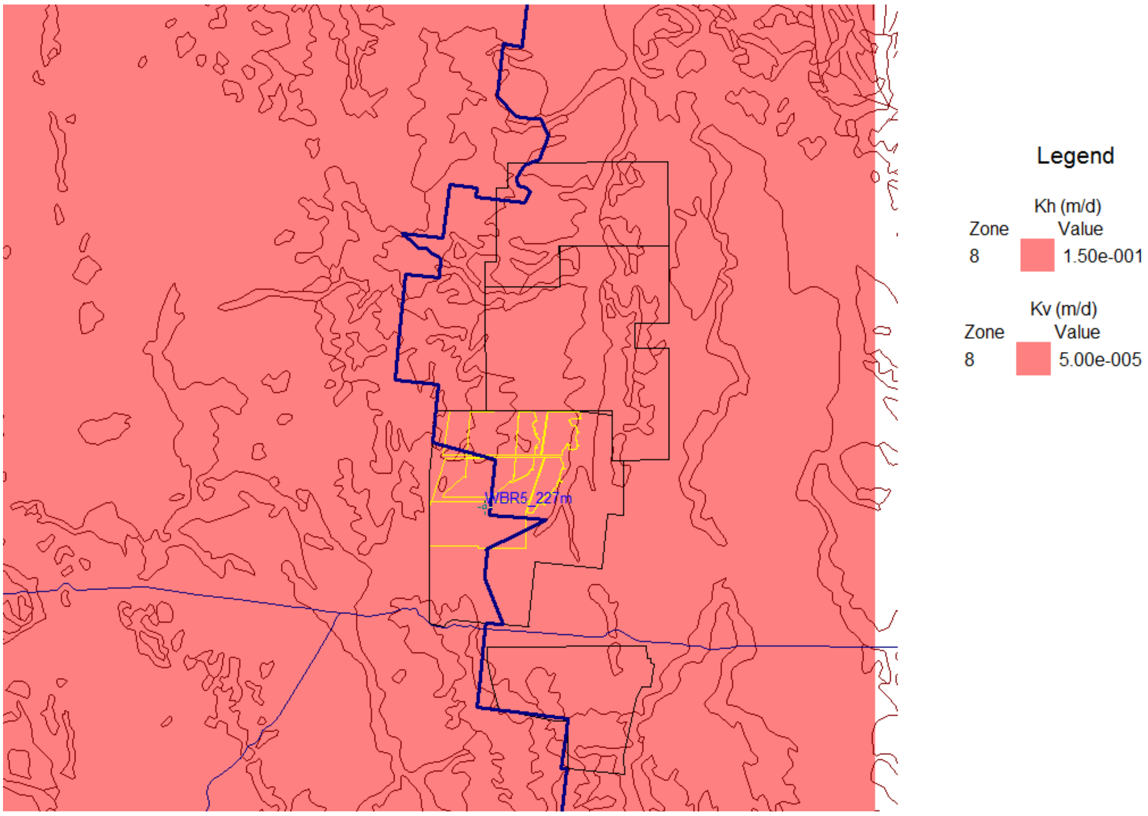
Layer 5: B Coal Seam (B1 to B8 Plies)



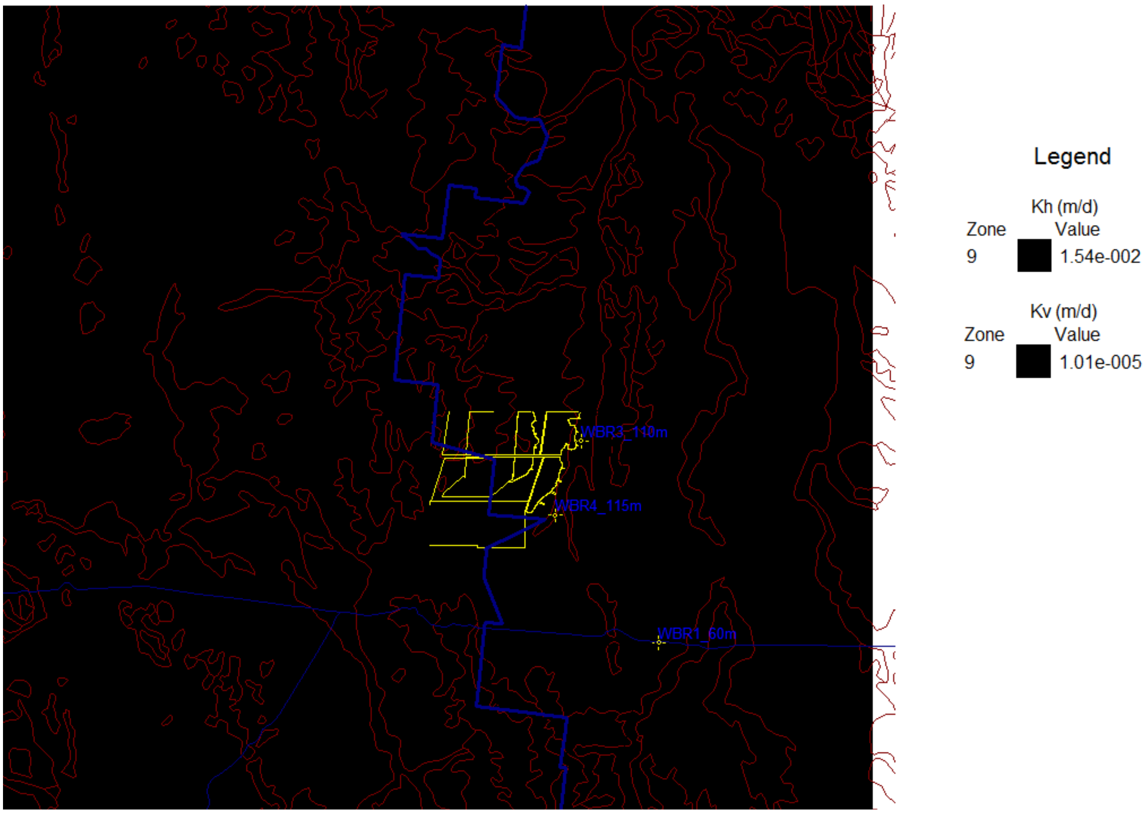
Layer 6: Bandanna Formation (Interburden)



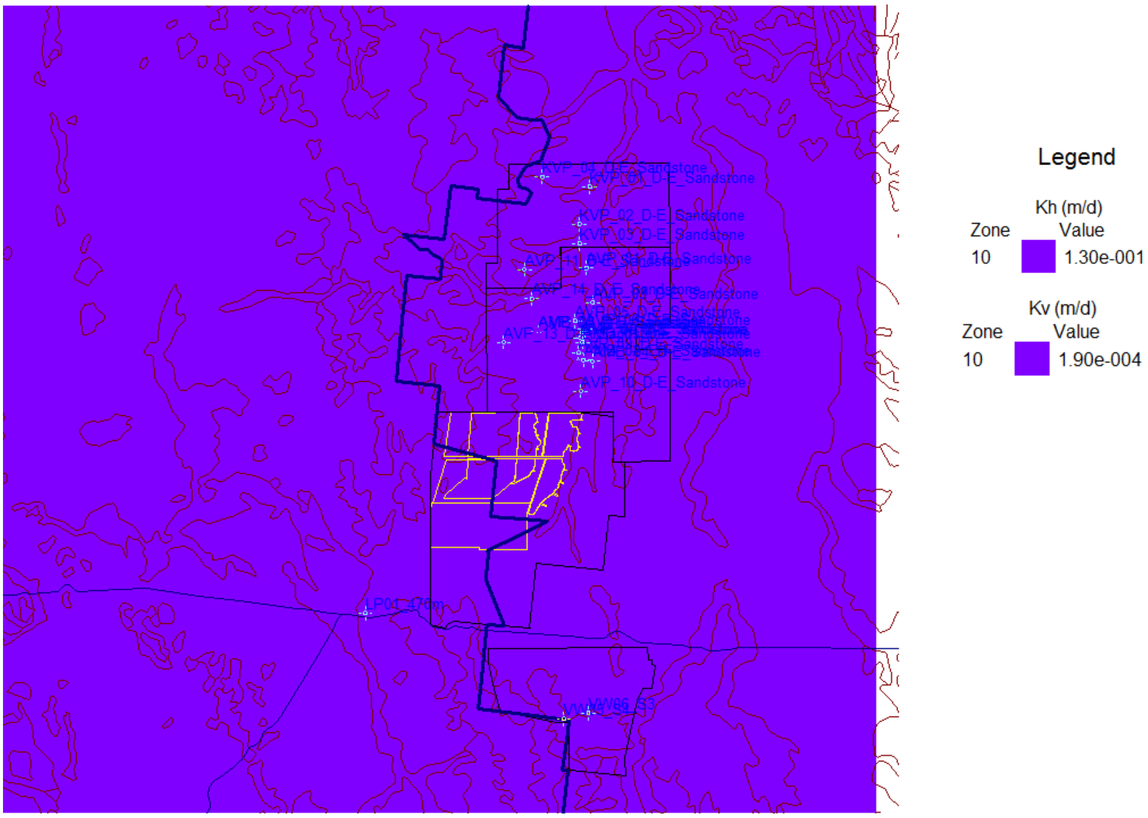
Layer 7: Upper D Seam (DU Coal Seam)



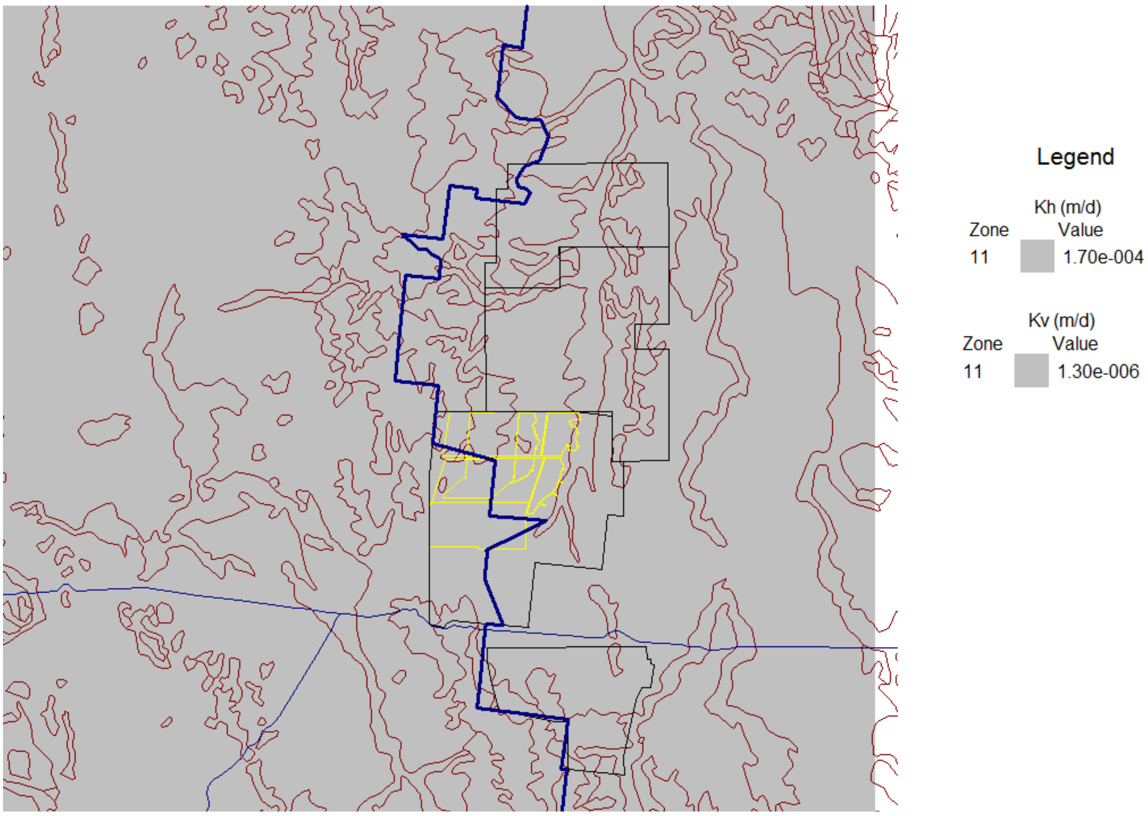
Layer 8: Bandanna Formation (Interburden)



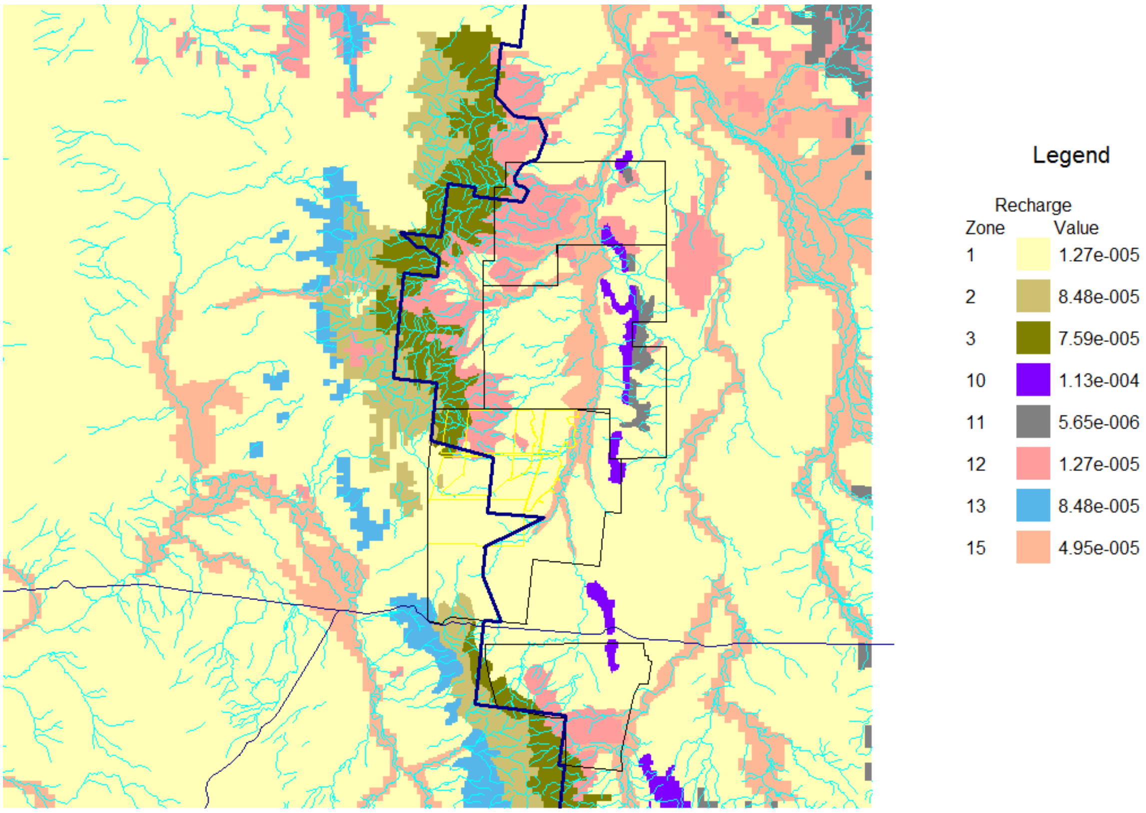
Layer 9: Lower D Seam (DL1, DLX, DL2, DLY and DL3 Plies)



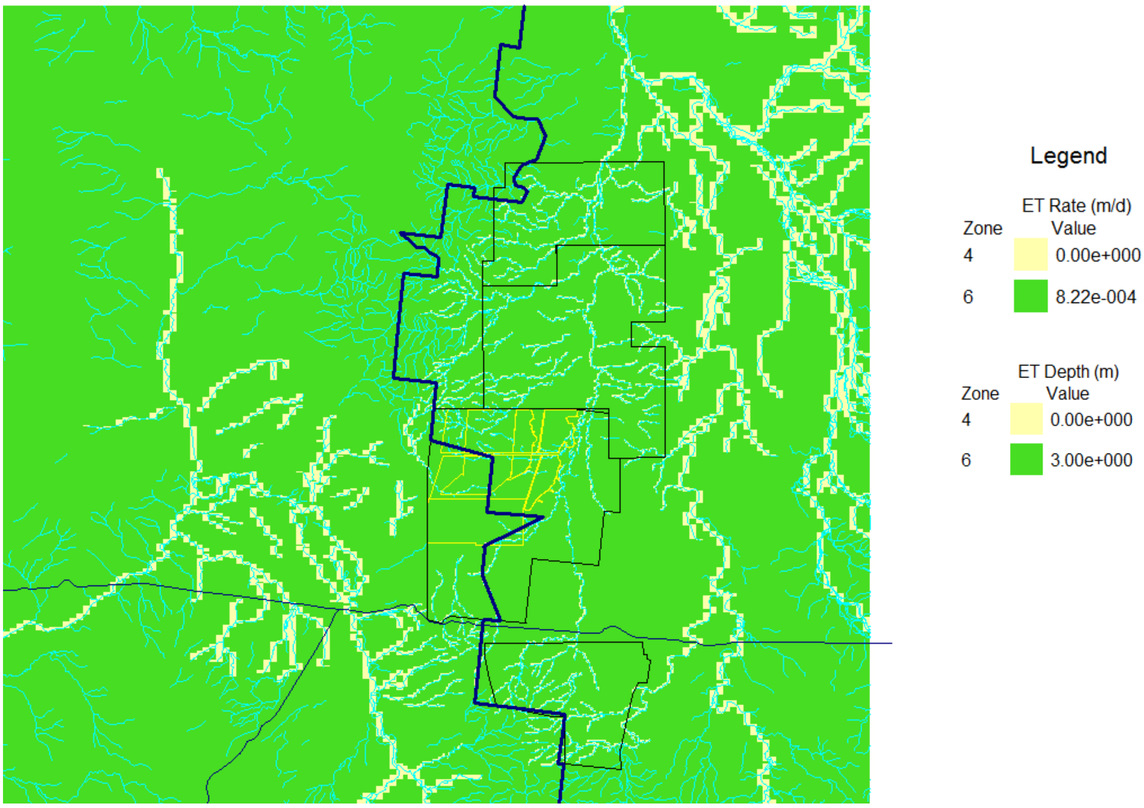
Layer 10: Colinlea Sandstone (Underburden)



Layer 11: Joe Joe Group (Basement)



Rainfall Recharge Distribution (m/day)



Evapotranspiration Discharge Distribution

ATTACHMENT C

Registered Bores

RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m	RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m
1119	433620.0	7385860.0				90199	445841.0	7396048.0			y
1131	453018.0	7366495.0				90490	456944.0	7410590.0	COLINLEA SANDSTONE	70.1	y
1132	446998.0	7370335.0	COLINLEA SANDSTONE	91.4		103008	427720.0	7393488.0	DUNDA BEDS	90.8	y
1133	452939.0	7365756.0	WINTON FORMATION	147.0		103054	432939.0	7388639.0		54.9	y
1134	452844.0	7362616.0				103120	445734.0	7399351.0	COLINLEA SANDSTONE	54.9	y
1163	449641.0	7390752.0			y	103174	456944.0	7378548.0	TERTIARY - UNDEFINED	64.0	
1164	452560.0	7390934.0			y	103184	458197.0	7381893.0	TERTIARY - UNDEFINED	47.2	
1165	459983.0	7382853.0				103186	459702.0	7382595.0	SAND	50.0	
1166	455419.0	7371256.0				103362	430568.0	7399295.0	CLEMATIS GROUP	121.9	y
1172	461782.0	7385457.0				103443	460361.0	7439781.0	TERTIARY - UNDEFINED	61.0	
1173	458758.0	7388232.0			y	103479	449262.0	7445025.0	COLINLEA SANDSTONE	29.0	
1174	432972.0	7388298.0	DUNDA BEDS		y	103480	438771.0	7398870.0	COLINLEA SANDSTONE	121.9	y
1175	433080.0	7392181.0			y	103481	431353.0	7399087.0	DUNDA BEDS	120.4	y
1176	432598.0	7394699.0	DUNDA BEDS		y	103506	458823.0	7378948.0	SEDIMENTARY - UNDIFF.	35.4	
1177	446486.0	7391215.0			y	103667	461675.0	7384526.0	TERTIARY - UNDEFINED	68.2	
1179	441492.0	7392217.0			y	103669	457345.0	7374913.0	SAND	33.0	
3067	437031.0	7400338.0			y	103670	457286.0	7378284.0	SEDIMENTARY - UNDIFF.	70.6	
5608	427421.0	7393993.0			y	103671	439763.0	7407217.0	TERTIARY - UNDEFINED	35.0	y
5609	432167.0	7399465.0			y	103672	436089.0	7404723.0	TERTIARY - UNDEFINED	46.0	y
5610	424787.0	7399565.0			y	103787	447664.0	7369512.0	BLACKWATER GROUP	120.0	
5716	414136.0	7398047.0				132125	449251.0	7454057.0	TERTIARY - UNDEFINED	63.0	
6495	437998.0	7423863.0			y	132597	437007.0	7384238.0	COLINLEA SANDSTONE	90.0	y
6497	437076.0	7430068.0				132598	451122.0	7365741.0	BANDANNA FORMATION	66.0	

RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m	RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m
6500	425917.0	7438490.0				132599	450455.0	7369269.0	BANDANNA FORMATION	47.0	
6502	435677.0	7435560.0				132696	448597.0	7436733.0	COLINLEA SANDSTONE	78.0	
7660	418607.0	7398476.0				132697	442630.0	7428792.0	COLINLEA SANDSTONE	99.0	y
7661	419997.0	7402619.0				132743	436290.0	7404895.0			y
7662	419675.0	7398448.0			y	132744	433574.0	7407244.0			
7673	445478.0	7386327.0	SAND	80.8	y	132745	437714.0	7411893.0			y
8090	454378.0	7419739.0	TERTIARY - UNDEFINED	60.4	y	132746	443677.0	7411097.0			y
9290	443775.0	7460772.0				132790	442104.0	7413143.0	COLINLEA SANDSTONE	80.0	y
9291	440519.0	7466840.0				132791	444105.0	7415170.0	COLINLEA SANDSTONE	62.0	y
9292	443870.0	7451311.0				132792	438040.0	7415054.0	BANDANNA FORMATION	50.4	y
9970	454403.0	7369266.0	SAND	56.1		132793	445862.0	7430685.0	COLINLEA SANDSTONE	76.9	y
14194	438293.0	7391693.0	COLINLEA SANDSTONE	35.1	y	132797	446725.0	7441097.0			
14512	439974.0	7412792.0	COLINLEA SANDSTONE	42.7	y	132798	447701.0	7435936.0			y
15405	436422.0	7418274.0	COLINLEA SANDSTONE	39.6	y	132799	439677.0	7431710.0			
15406	443690.0	7417151.0	COLINLEA SANDSTONE	66.8	y	132800	445052.0	7433186.0			y
15407	432801.0	7412761.0	COLINLEA SANDSTONE	86.6	y	132801	446510.0	7431957.0			y
15408	432078.0	7417623.0			y	132802	446281.0	7430685.0			y
26005	432725.0	7416615.0			y	132803	445607.0	7428457.0			y
33053	447806.0	7438260.0			y	132804	445921.0	7422777.0	COLINLEA SANDSTONE	61.0	y
33054	443041.0	7448915.0				132805	437531.0	7440861.0	COLINLEA SANDSTONE	218.0	
33056	427162.0	7440696.0				132807	438634.0	7436473.0	COLINLEA SANDSTONE	149.5	

RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m	RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m
33057	449658.0	7438848.0				132808	447232.0	7453128.0			
36638	459301.0	7403087.0			y	132809	445701.0	7447597.0			
36639	459339.0	7398815.0			y	132810	445706.0	7447681.0			
36640	462099.0	7400391.0				132811	440160.0	7454610.0			
36641	464574.0	7392929.0				132812	445179.0	7449764.0			
36645	459581.0	7390728.0			y	132813	446180.0	7430035.0	COLINLEA SANDSTONE	72.9	y
36816	455196.0	7390564.0			y	132814	446314.0	7427417.0			y
36817	453027.0	7393864.0			y	132815	439653.0	7431658.0			
36818	451256.0	7391619.0			y	132816	447682.0	7427212.0			y
36819	451603.0	7392343.0			y	132817	449349.0	7453508.0			
36820	450618.0	7392581.0			y	132818	447333.0	7450631.0			
36821	449672.0	7390787.0			y	132819	447448.0	7445168.0			
36822	462351.0	7404558.0				132820	438017.0	7415027.0			y
36823	457834.0	7405989.0			y	132821	442074.0	7413136.0			y
36827	455114.0	7418756.0			y	132822	444093.0	7415172.0			y
36829	463271.0	7404094.0				132823	438037.0	7415043.0			y
36834	459514.0	7411591.0				132824	442087.0	7413142.0			y
36835	455829.0	7412158.0			y	132825	444095.0	7415165.0			y
36836	459631.0	7411240.0				132826	442090.0	7413147.0			y
37080	462592.0	7396016.0	SAND	51.1		132876	442456.0	7440833.0	COLINLEA SANDSTONE	132.0	
37081	463471.0	7395448.0		43.0		132877	439272.0	7445984.0	COLINLEA SANDSTONE	226.0	
37082	462947.0	7394495.0				132878	445630.0	7452131.0	TERTIARY - UNDEFINED		
37315	450728.0	7376837.0	COLINLEA SANDSTONE	160.0	y	132879	449349.0	7453513.0	BANDANNA FORMATION	10.0	
38021	456949.0	7378415.0				132883	447448.0	7445173.0	SANDY CREEK ALLUVIUM	10.0	
38022	452439.0	7380992.0			y	132884	447333.0	7450636.0	SANDY CREEK	10.0	

RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m	RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m
									ALLUVIUM		
38023	447885.0	7380903.0			y	132885	445675.0	7447119.0	COLINLEA SANDSTONE	102.0	
38024	442490.0	7382721.0				132886	439261.0	7445984.0	COLINLEA SANDSTONE	212.0	
38026	458078.0	7381996.0				132887	442467.0	7440833.0	COLINLEA SANDSTONE	156.0	
38027	459189.0	7381479.0				132888	442478.0	7440833.0	COLINLEA SANDSTONE	133.0	
38028	459159.0	7380215.0				132891	448989.0	7428167.0	COLINLEA SANDSTONE	89.0	y
38088	452670.0	7365046.0				132892	448988.0	7428157.0	COLINLEA SANDSTONE	30.0	y
38092	461826.0	7385433.0				132893	449334.0	7428175.0	COLINLEA SANDSTONE	34.9	y
38093	462709.0	7388801.0				132894	450136.0	7428201.0	COLINLEA SANDSTONE	34.0	y
38094	458777.0	7387870.0			y	132895	451213.0	7428165.0	JOE JOE FORMATION	44.0	y
38095	457923.0	7373956.0				132896	451205.0	7428168.0	COLINLEA SANDSTONE	15.0	y
38100	454330.0	7402610.0			y	132897	453056.0	7428172.0	JOE JOE FORMATION	67.0	y
38101	452542.0	7398128.0			y	132898	453054.0	7428178.0	JOE JOE FORMATION	36.0	y
38105	458600.0	7378120.0				132899	453049.0	7428172.0	COLINLEA SANDSTONE	18.0	y
38107	446996.0	7369915.0				132900	448437.0	7423177.0	JOE JOE FORMATION	72.0	y
38108	449764.0	7366726.0				132901	449345.0	7423481.0	JOE JOE FORMATION	60.0	y
38109	454607.0	7369030.0				132902	449336.0	7423481.0	TERTIARY - UNDEFINED	30.0	y
38114	461533.0	7383692.0				132903	449353.0	7423485.0	QUATERNARY - UNDEFINED	12.0	y
44450	462303.0	7439420.0				132904	451387.0	7423969.0	JOE JOE FORMATION	76.0	y
44451	461505.0	7440410.0				132905	451378.0	7423966.0	JOE JOE FORMATION	36.0	y
44452	460807.0	7438656.0				132906	451393.0	7423971.0	TERTIARY - UNDEFINED	10.0	y
44453	461280.0	7445004.0				132907	453085.0	7424462.0	TERTIARY - UNDEFINED	36.0	y
44466	449295.0	7415986.0			y	132908	453086.0	7424471.0	QUATERNARY - UNDEFINED	18.0	y
44467	445036.0	7404829.0			y	132909	445612.0	7452119.0	COLINLEA SANDSTONE	74.0	
44468	448435.0	7407327.0			y	132910	445611.0	7452101.0	COLINLEA SANDSTONE	99.5	

RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m	RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m
44469	444409.0	7400947.0			y	132911	448429.0	7423176.0	COLINLEA SANDSTONE	44.0	y
51064	441410.0	7437525.0				132912	448444.0	7423178.0	COLINLEA SANDSTONE	18.0	y
51102	427101.0	7409511.0		179.8	y	132913	445691.0	7447110.0	COLINLEA SANDSTONE	112.0	
51682	433644.0	7413239.0		76.2	y	132914	439232.0	7445989.0	COLINLEA SANDSTONE	212.0	
51690	448174.0	7452944.0				132915	442478.0	7440873.0	COLINLEA SANDSTONE	132.0	
69270	454424.0	7373470.0	ALPHA CREEK ALLUVIUM	36.0		132916	442479.0	7440891.0	COLINLEA SANDSTONE	157.0	
69271	453714.0	7373560.0	ALPHA CREEK ALLUVIUM	35.0		132917	440717.0	7450223.0	BANDANNA FORMATION	74.5	
69286	458523.0	7381585.0	ALPHA CREEK ALLUVIUM	43.0		132927	462555.0	7399045.0		72.0	
69428	440274.0	7398445.0	TERTIARY - UNDEFINED	51.0	y	146484	448405.0	7379881.0			y
69458	447892.0	7447833.0				146485	447518.0	7379280.0			y
69714	456364.0	7374523.0	ALPHA CREEK ALLUVIUM	31.0		12030045	454630.0	7368942.0	ALPHA CREEK ALLUVIUM	7.9	
69730	446387.0	7433792.0	DUNDA BEDS	57.0	y	12030046	454686.0	7368888.0	ALPHA CREEK ALLUVIUM	7.9	
69731	445196.0	7432429.0	DUNDA BEDS	59.0	y	12030047	454721.0	7368846.0	ALPHA CREEK ALLUVIUM	10.7	
69732	446285.0	7420153.0	DUNDA BEDS	20.0	y	12030048	454804.0	7368802.0	UNDIFF TERT	19.8	
69735	450237.0	7392580.0	COLINLEA SANDSTONE	45.8	y	12030070	464054.0	7405913.0	NATIVE COMPANION ALLUVIUM	16.8	
89327	448027.0	7403346.0	COLINLEA SANDSTONE	59.0	y	12030071	463686.0	7405727.0	COMPANION CREEK ALLUVIUM		
89348	462932.0	7406330.0	SAND	77.0		12030076	445752.0	7414375.0	COLINLEA SANDSTONE	28.3	y
89472	453059.0	7369748.0	UNDIFF	46.0		12030077	445299.0	7413783.0	TERTIARY - UNDEFINED	8.2	y
89487	441779.0	7399064.0	TERTIARY - UNDEFINED	88.4	y	12030099	453018.0	7461641.0	COLINLEA SANDSTONE	56.8	
90049	455195.0	7390874.0	TERTIARY - UNDEFINED	51.9	y	12030100	453023.0	7461570.0	SANDY CREEK ALLUVIUM	15.3	

RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m	RN	EASTING	NORTHING	Formation	Depth(m)	Drawdown^ > 5 m
90144	455357.0	7406058.0	ALLUVIUM ?????	77.0	y	12030144	444309.0	7386028.0	BANDANNA FORMATION	70.0	y
90179	437013.0	7430715.0				12030145	444449.0	7386195.0	TERTIARY - UNDEFINED		y
90180	445169.0	7421926.0			y	12030148	461051.0	7410650.0	TERTIARY - UNDEFINED	27.0	
90181	449142.0	7422691.0			y	12030184	459961.0	7402356.0	TERTIARY - UNDEFINED	61.0	y
90182	451157.0	7430657.0			y	12030186	455844.0	7385759.0	JOE JOE GROUP	65.0	y

* NR – Not Recorded. RN: DNRM registered bore within 1m steady-state drawdown impact zone

^ y: within 5m steady-state drawdown impact zone

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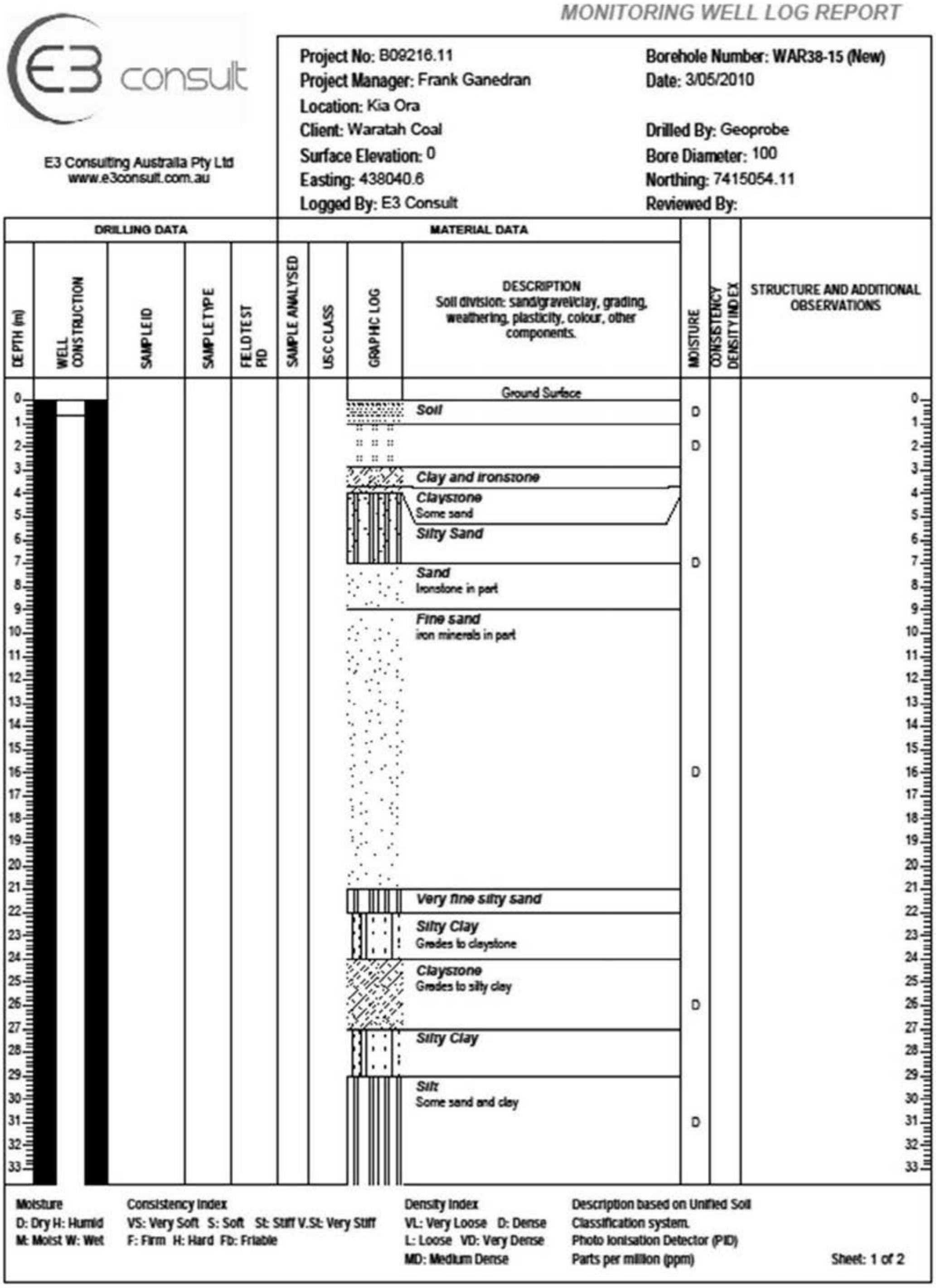
ATTACHMENT D

Bore Logs



MONITORING WELL LOG REPORT

E3 consult

E3 Consulting Australia Pty Ltd
www.e3consult.com.au

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 438040.6
Logged By: E3 Consult

Borehole Number: WAR38-15 (New)
Date: 3/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7415054.11
Reviewed By:

DRILLING DATA: DEPTH (m) | WELL CONSTRUCTION | SAMPLE ID | SAMPLE TYPE | FIELD TEST PID

MATERIAL DATA: SAMPLE ANALYSED | USC CLASS | GRAPHIC LOG | DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components. | MOISTURE | CONSISTENCY DENSITY INDEX | STRUCTURE AND ADDITIONAL OBSERVATIONS

DESCRIPTION	MOISTURE
Ground Surface	
Soil	D D
Clay and ironstone	
Claystone Some sand	
Silty Sand	
Sand Ironstone in part	D
Fine sand iron minerals in part	D
Very fine silty sand	
Silty Clay Grades to claystone	
Claystone Grades to silty clay	D
Silty Clay	
Silt Some sand and clay	D

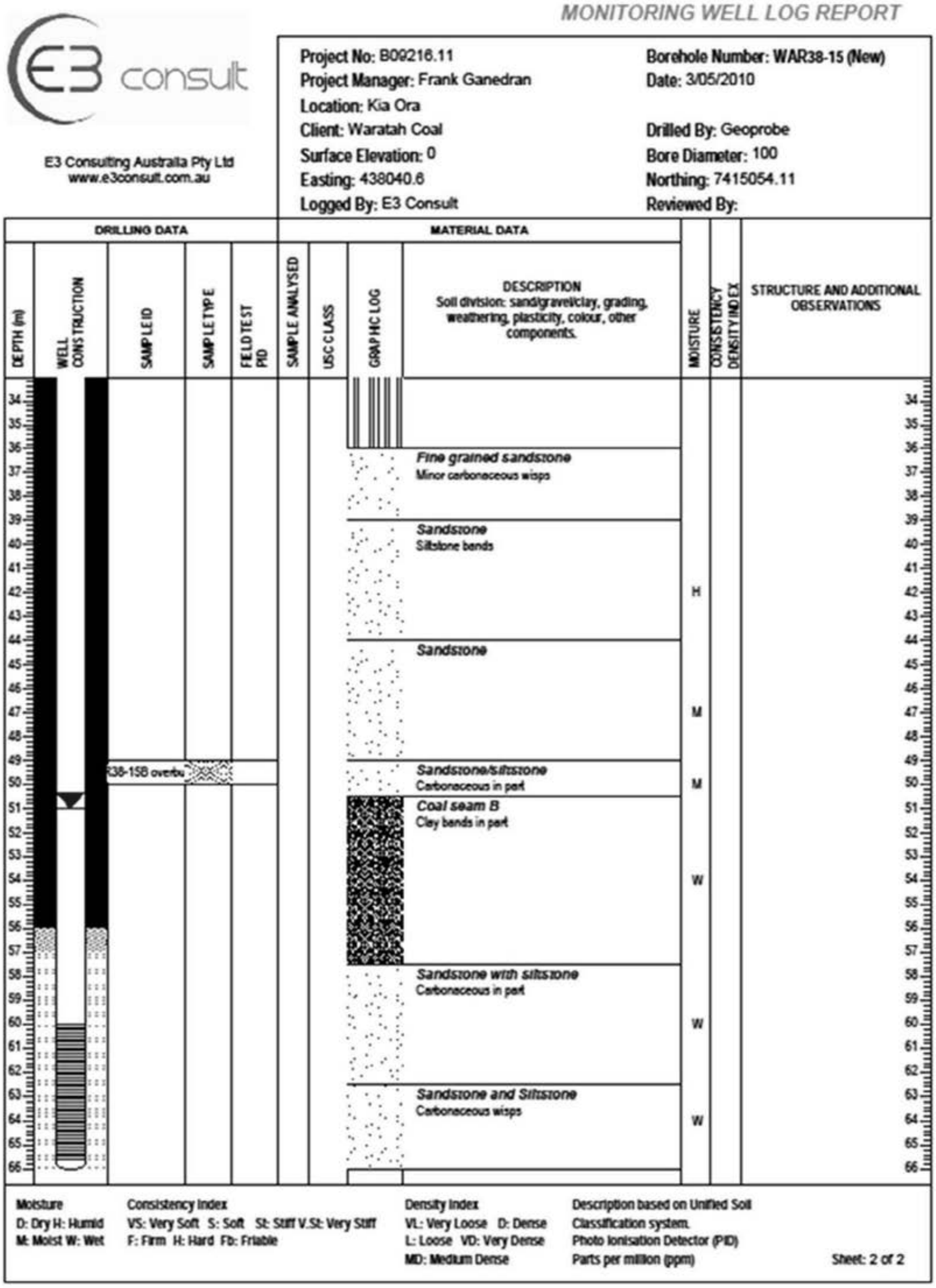
Moisture
D: Dry H: Humid
M: Moist W: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet: 1 of 2



MONITORING WELL LOG REPORT

E3 Consulting Australia Pty Ltd
www.e3consult.com.au

Project No: B09216.11	**Borehole Number: WAR38-15 (New)**
Project Manager: Frank Ganedran	**Date:** 3/05/2010
Location: Kia Ora	
Client: Waratah Coal	**Drilled By:** Geoprobe
Surface Elevation: 0	**Bore Diameter:** 100
Easting: 438040.6	**Northing:** 7415054.11
Logged By: E3 Consult	**Reviewed By:**

DRILLING DATA				MATERIAL DATA							
DEPTH (m)	WELL CONSTRUCTION	SAMPLE ID	SAMPLE TYPE	FIELD TEST PID	SAMPLE ANALYSED	USC CLASS	GRAPHIC LOG	DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.	MOISTURE	CONSISTENCY DENSITY INDEX	STRUCTURE AND ADDITIONAL OBSERVATIONS
								Fine grained sandstone Minor carbonaceous wisps			
								Sandstone Siltstone bands	H		
								Sandstone	M		
		R38-15B overbu						***Sandstone/siltstone*** Carbonaceous in part	M		
								Coal seam B Clay bands in part	W		
								Sandstone with siltstone Carbonaceous in part	W		
								Sandstone and Siltstone Carbonaceous wisps	W		

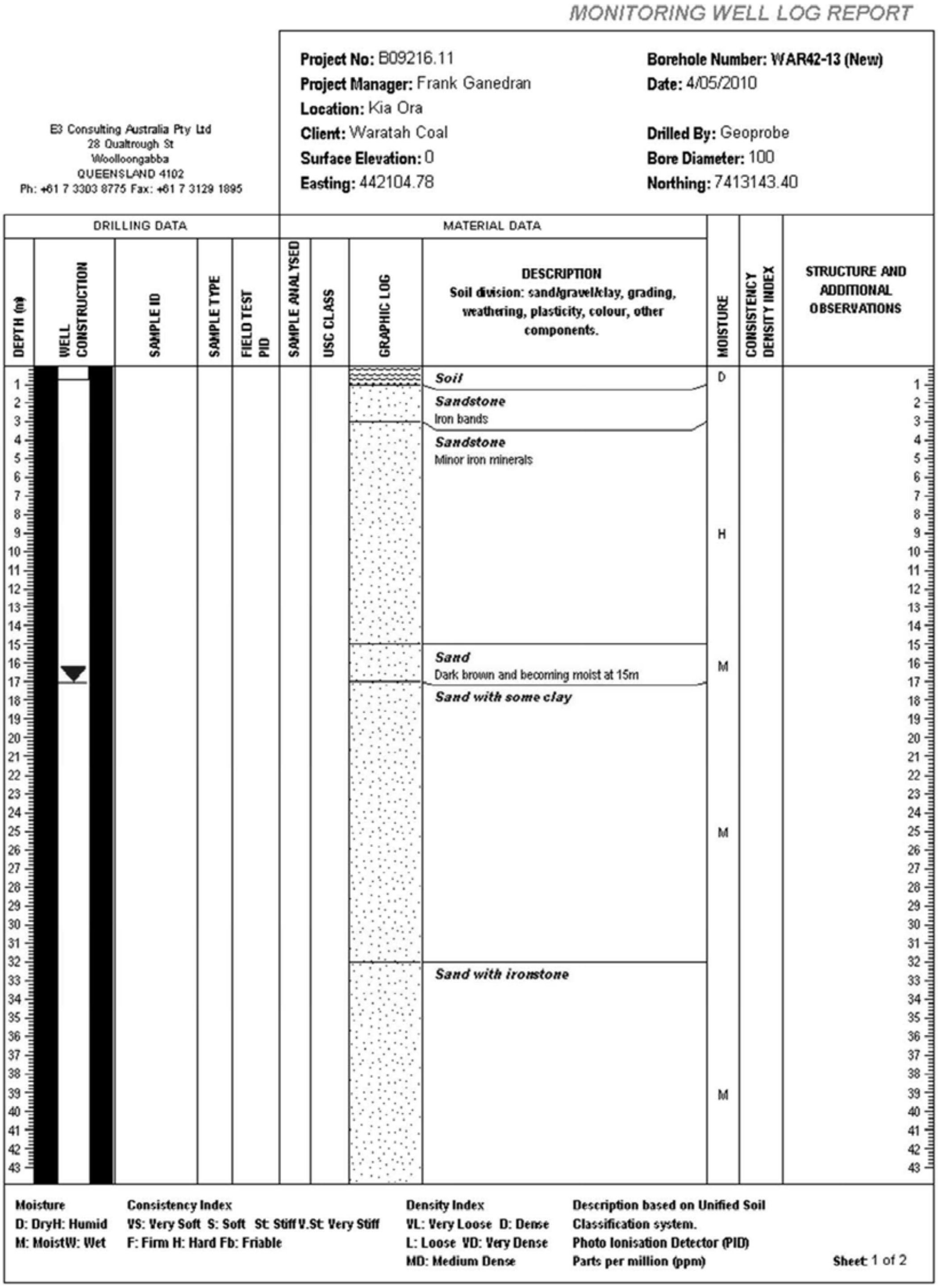
Moisture
D: Dry H: Humid
M: Moist W: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet: 2 of 2



MONITORING WELL LOG REPORT

E3 Consulting Australia Pty Ltd
28 Qualtrough St
Woolloongabba
QUEENSLAND 4102
Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 442104.78

Borehole Number: WAR42-13 (New)
Date: 4/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7413143.40

DRILLING DATA					MATERIAL DATA						
DEPTH (m)	WELL CONSTRUCTION	SAMPLE ID	SAMPLE TYPE	FIELD TEST PID	SAMPLE ANALYSED	USC CLASS	GRAPHIC LOG	DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.	MOISTURE	CONSISTENCY DENSITY INDEX	STRUCTURE AND ADDITIONAL OBSERVATIONS
1								***Soil***	D		
2								***Sandstone*** Iron bands			
4								***Sandstone*** Minor iron minerals			
9									H		
16								***Sand*** Dark brown and becoming moist at 15m	M		
18								***Sand with some clay***			
25									M		
33								***Sand with ironstone***			
39									M		

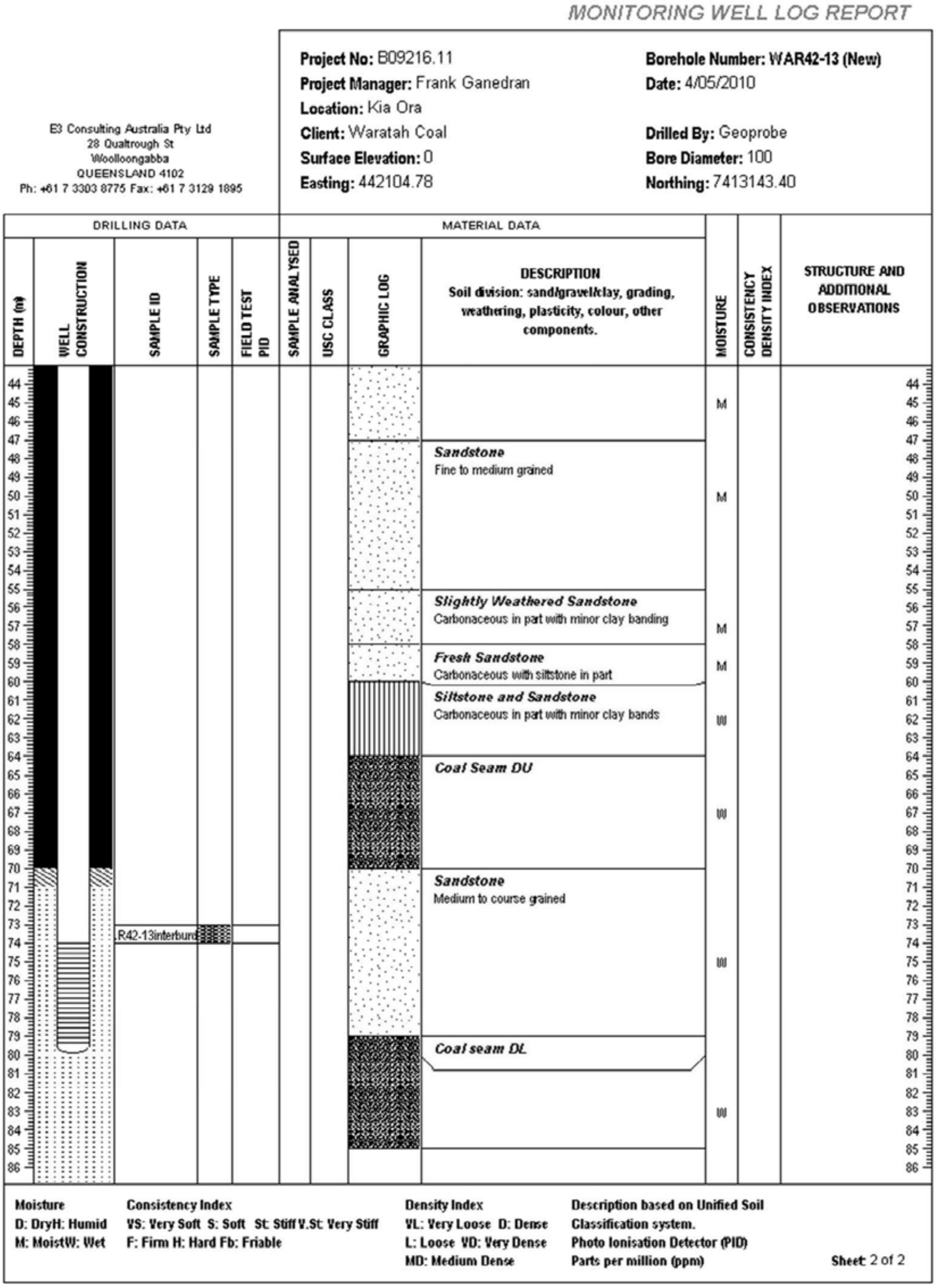
Moisture
D: DryH: Humid
M: MoistW: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet: 1 of 2



MONITORING WELL LOG REPORT

E3 Consulting Australia Pty Ltd
28 Qualtrough St
Woolloongabba
QUEENSLAND 4102
Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 442104.78

Borehole Number: WAR42-13 (New)
Date: 4/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7413143.40

DRILLING DATA					MATERIAL DATA						
DEPTH (m)	WELL CONSTRUCTION	SAMPLE ID	SAMPLE TYPE	FIELD TEST PID	SAMPLE ANALYSED	USC CLASS	GRAPHIC LOG	DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.	MOISTURE	CONSISTENCY DENSITY INDEX	STRUCTURE AND ADDITIONAL OBSERVATIONS
									M		
								Sandstone Fine to medium grained	M		
								Slightly Weathered Sandstone Carbonaceous in part with minor clay banding	M		
								Fresh Sandstone Carbonaceous with siltstone in part	M		
								Siltstone and Sandstone Carbonaceous in part with minor clay bands	W		
								Coal Seam DU	W		
		R42-13interburd						***Sandstone*** Medium to course grained	W		
								Coal seam DL	W		

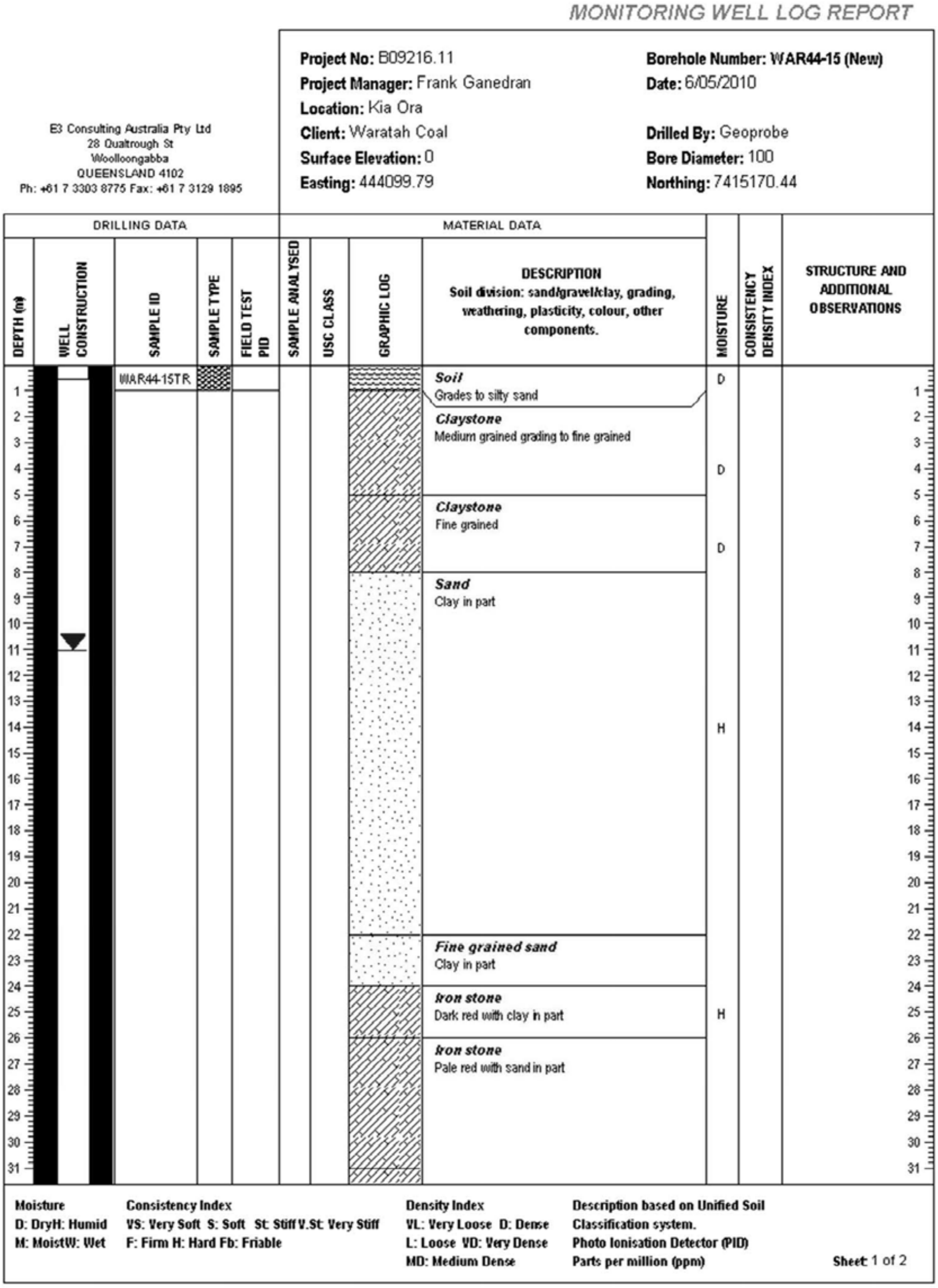
Moisture
D: DryH: Humid
M: MoistW: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet: 2 of 2



MONITORING WELL LOG REPORT

E3 Consulting Australia Pty Ltd
28 Qualtrough St
Woolloongabba
QUEENSLAND 4102
Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 444099.79

Borehole Number: WAR44-15 (New)
Date: 6/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7415170.44

DRILLING DATA					MATERIAL DATA						
DEPTH (m)	WELL CONSTRUCTION	SAMPLE ID	SAMPLE TYPE	FIELD TEST PID	SAMPLE ANALYSED	USC CLASS	GRAPHIC LOG	DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.	MOISTURE	CONSISTENCY DENSITY INDEX	STRUCTURE AND ADDITIONAL OBSERVATIONS
		WAR44-15TR						***Soil*** Grades to silty sand	D		
								Claystone Medium grained grading to fine grained	D		
								Claystone Fine grained	D		
								Sand Clay in part	H		
								Fine grained sand Clay in part			
								Iron stone Dark red with clay in part	H		
								Iron stone Pale red with sand in part			

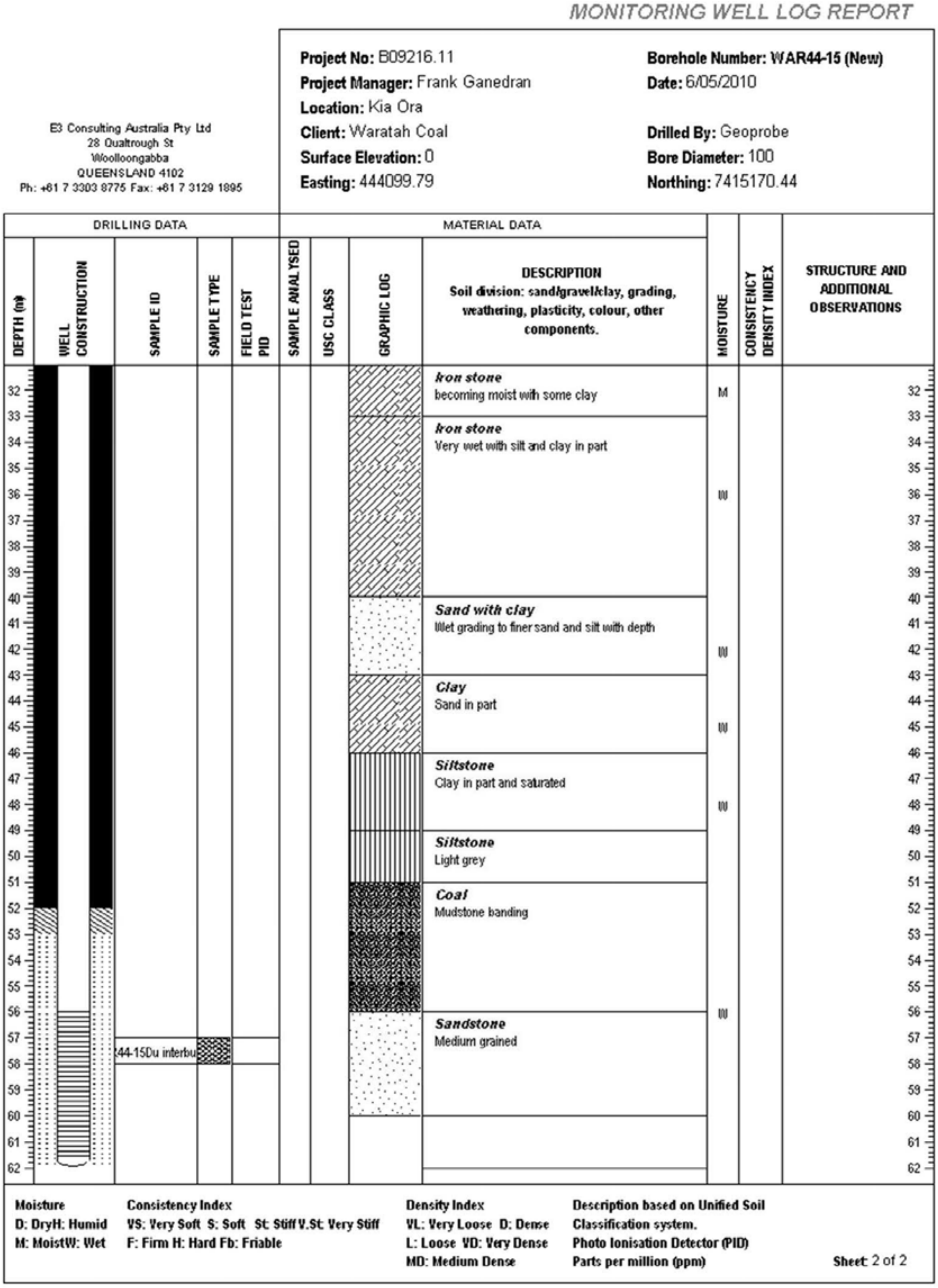
Moisture
D: DryH: Humid
M: MoistW: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet: 1 of 2



MONITORING WELL LOG REPORT

E3 Consulting Australia Pty Ltd
28 Qualtrough St
Woolloongabba
QUEENSLAND 4102
Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 444099.79

Borehole Number: WAR44-15 (New)
Date: 6/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7415170.44

DRILLING DATA					MATERIAL DATA						
DEPTH (m)	WELL CONSTRUCTION	SAMPLE ID	SAMPLE TYPE	FIELD TEST PID	SAMPLE ANALYSED	USC CLASS	GRAPHIC LOG	DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.	MOISTURE	CONSISTENCY DENSITY INDEX	STRUCTURE AND ADDITIONAL OBSERVATIONS
								Iron stone becoming moist with some clay	M		
								Iron stone Very wet with silt and clay in part	W		
								Sand with clay Wet grading to finer sand and silt with depth	W		
								Clay Sand in part	W		
								Siltstone Clay in part and saturated	W		
								Siltstone Light grey			
								Coal Mudstone banding			
		44-15Du interbu						***Sandstone*** Medium grained	W		

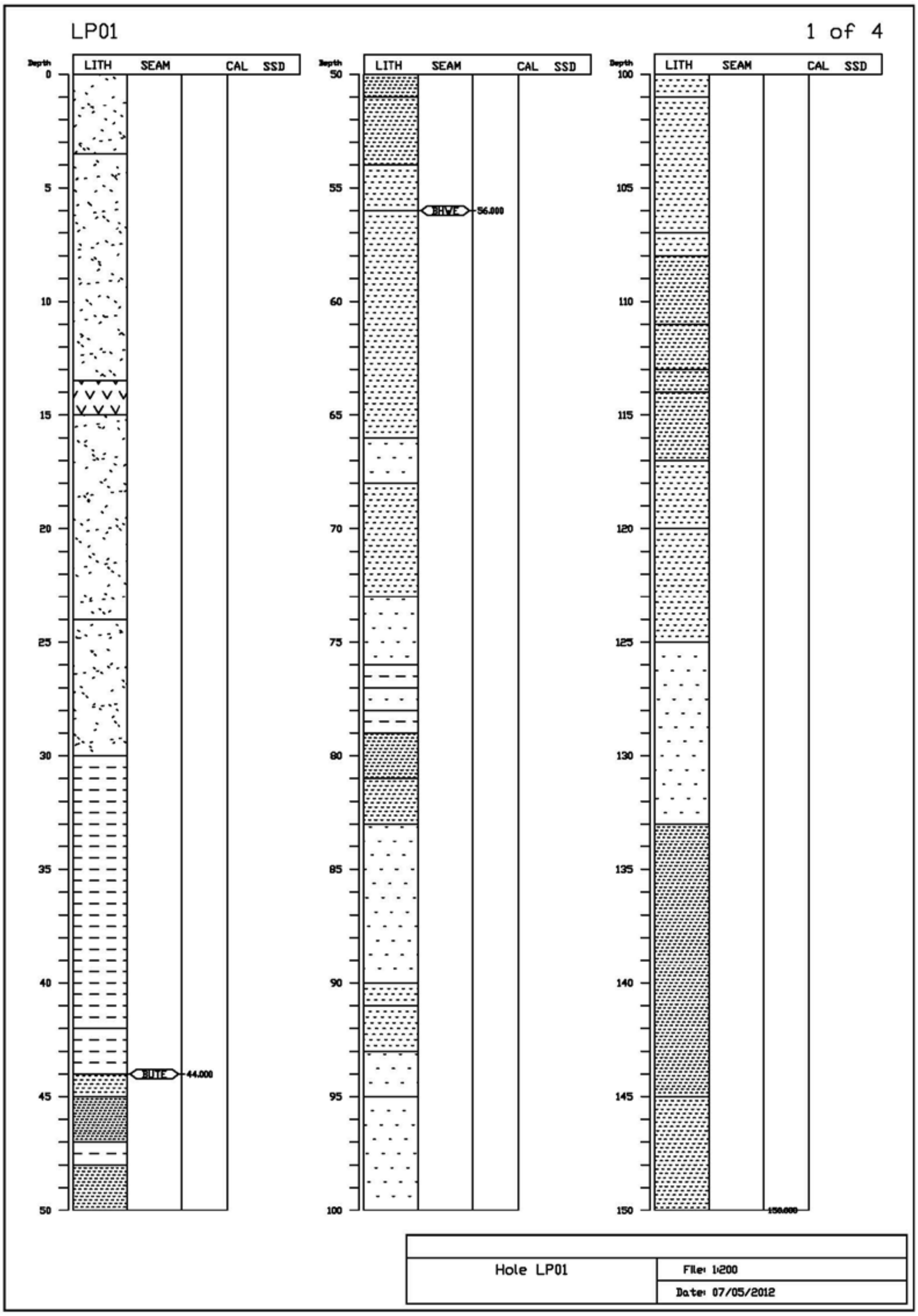
Moisture
D: DryH: Humid
M: MoistW: Wet

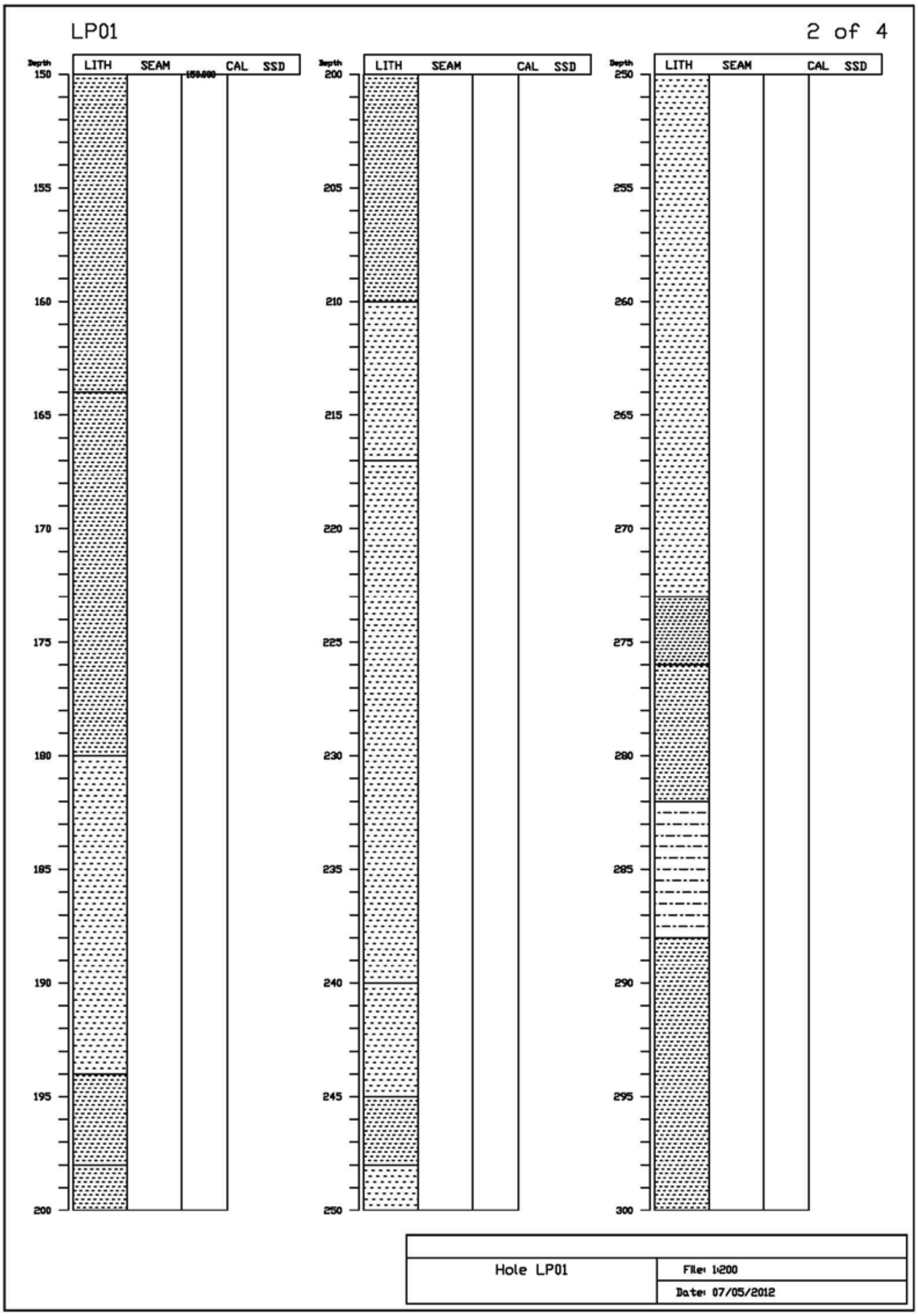
Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

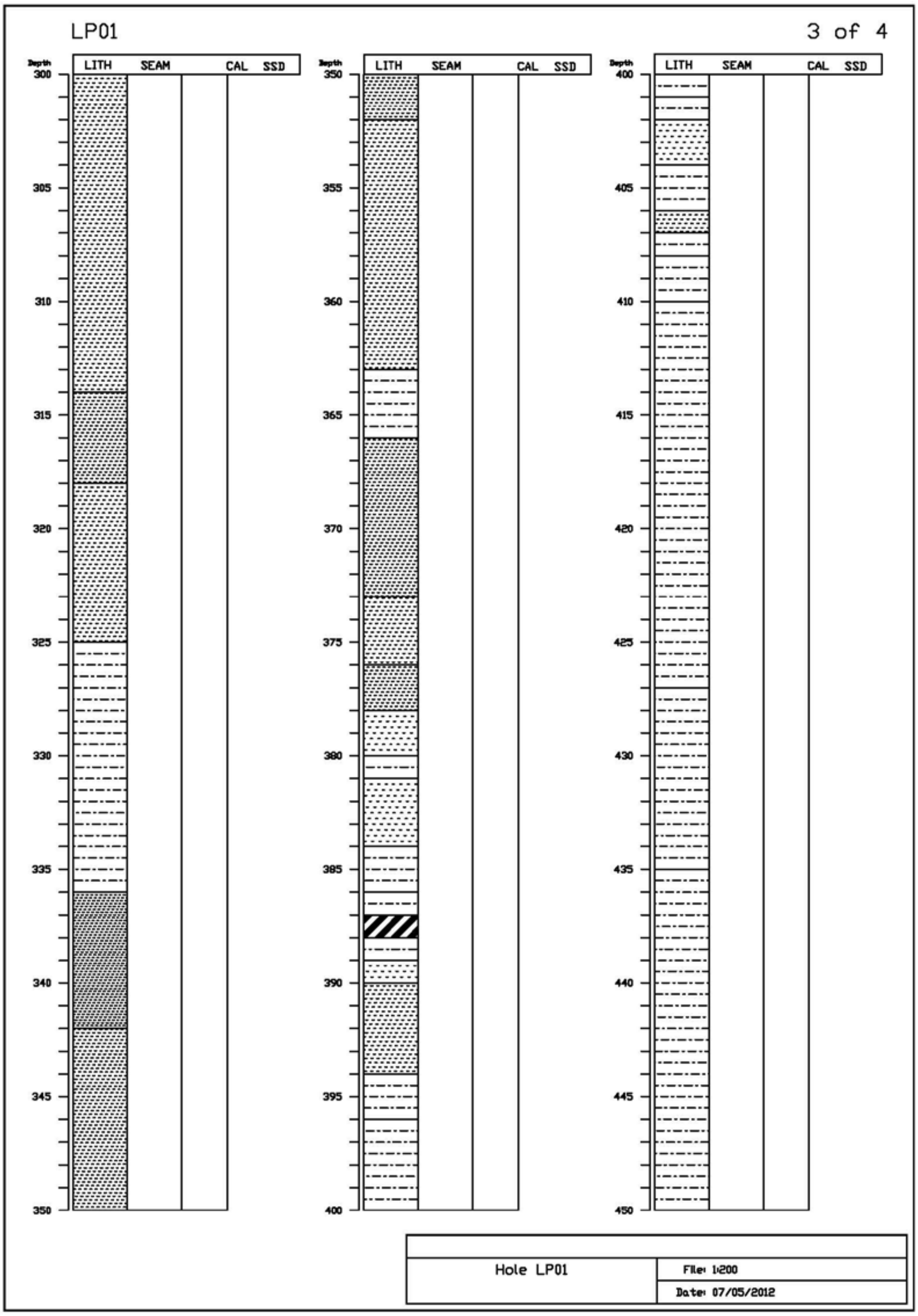
Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

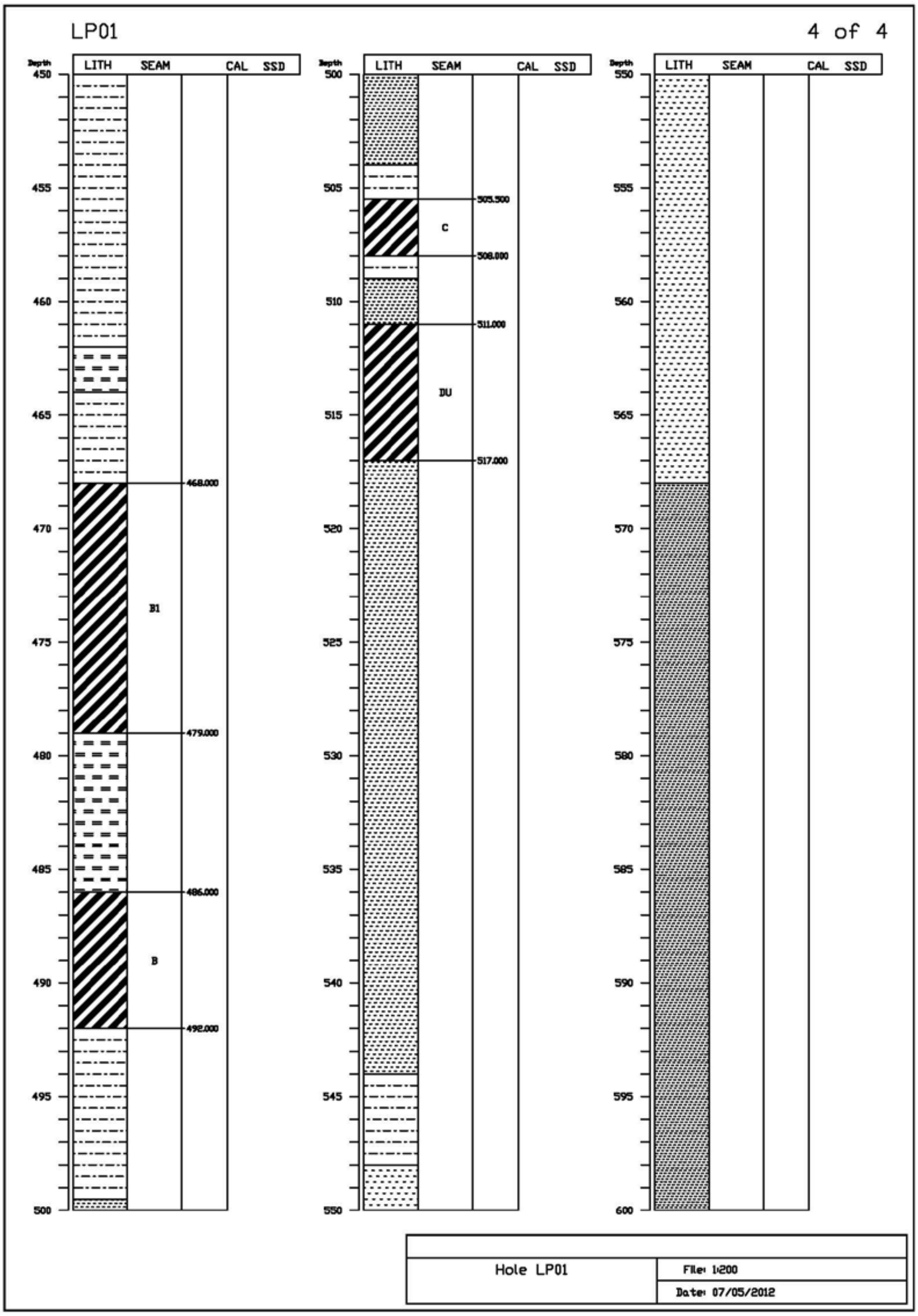
Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

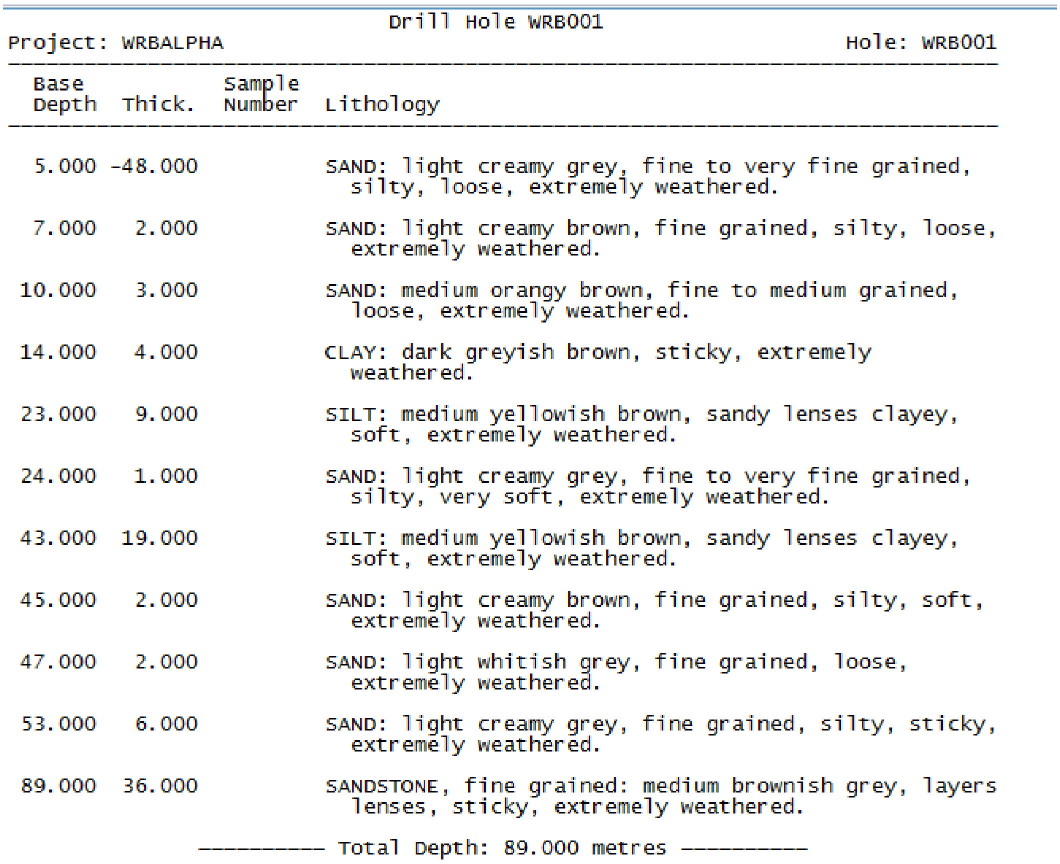
Sheet: 2 of 2


LP01
1 of 4
Depth
LITH
SEAM
CAL
SSD
0
5
10
15
20
25
30
35
40
45
50
BUTE
44.000
55
60
65
70
75
80
85
90
95
100
BHWE
56.000
105
110
115
120
125
130
135
140
145
150
150.000
Hole LP01
File: 1:200
Date: 07/05/2012

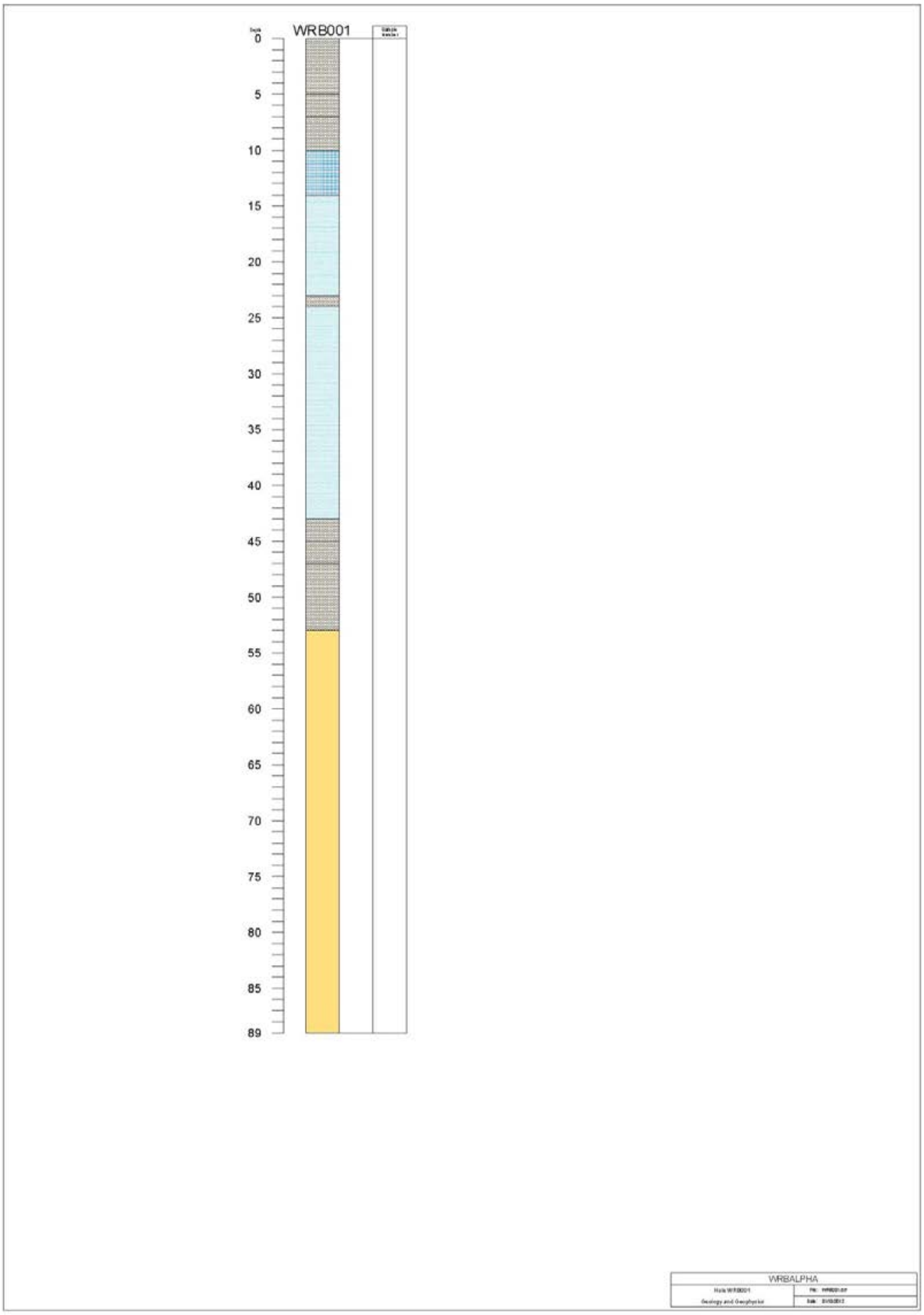

LP01
2 of 4
Depth
LITH
SEAM
CAL
SSD
150.000
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
265
270
275
280
285
290
295
300
Hole LP01
File: 1:200
Date: 07/05/2012

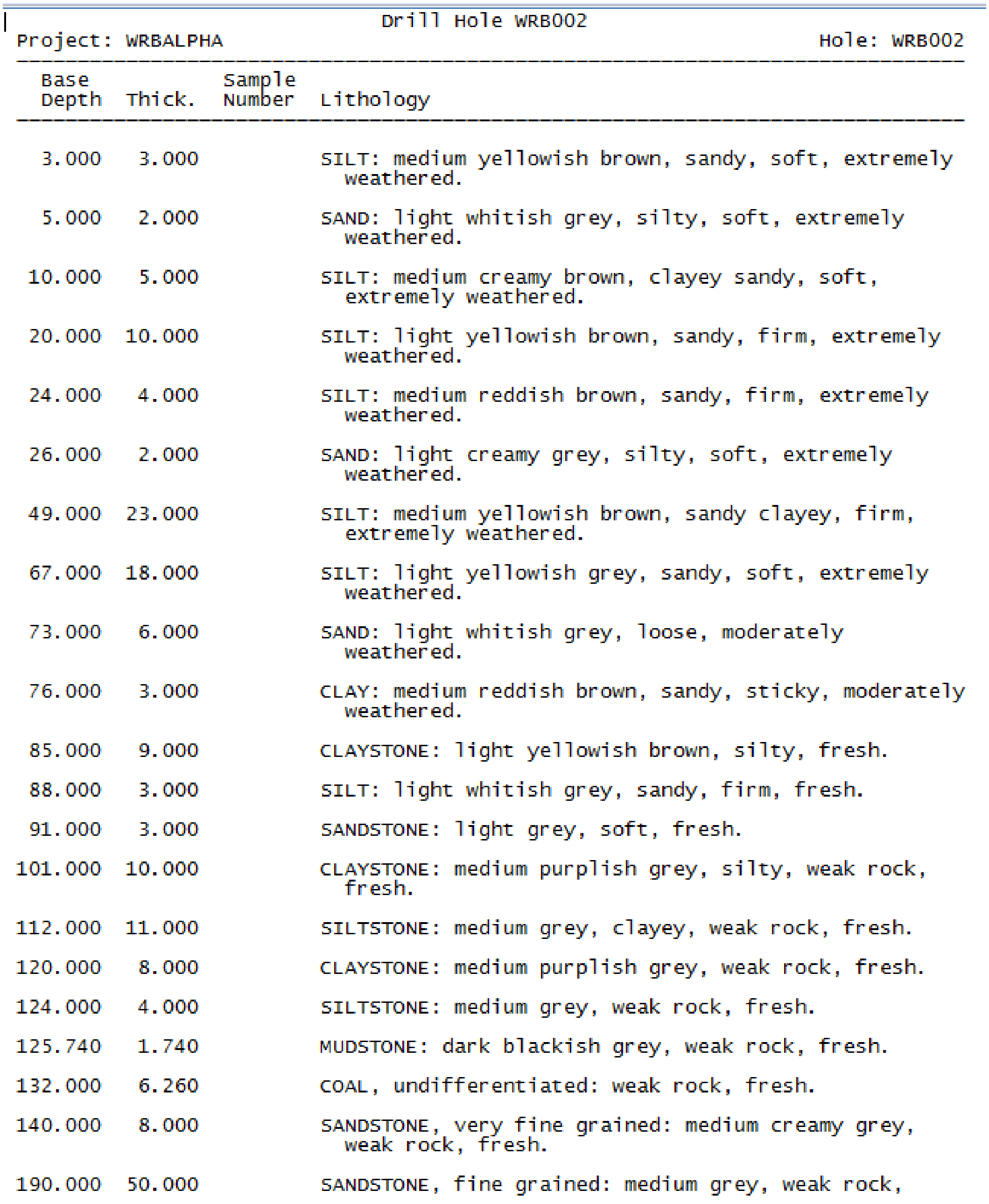

LP01
3 of 4
Depth
LITH
SEAM
CAL
SSD
300
305
310
315
320
325
330
335
340
345
350
355
360
365
370
375
380
385
390
395
400
405
410
415
420
425
430
435
440
445
450
Hole LP01
File: 1:200
Date: 07/05/2012


LP01
4 of 4
Depth
LITH
SEAM
CAL
SSD
450
455
460
465
470
475
480
485
490
495
500
468.000
B1
479.000
486.000
B
492.000
505
510
515
520
525
530
535
540
545
550
505.500
C
508.000
511.000
DU
517.000
555
560
565
570
575
580
585
590
595
600
Hole LP01
File: 1:200
Date: 07/05/2012

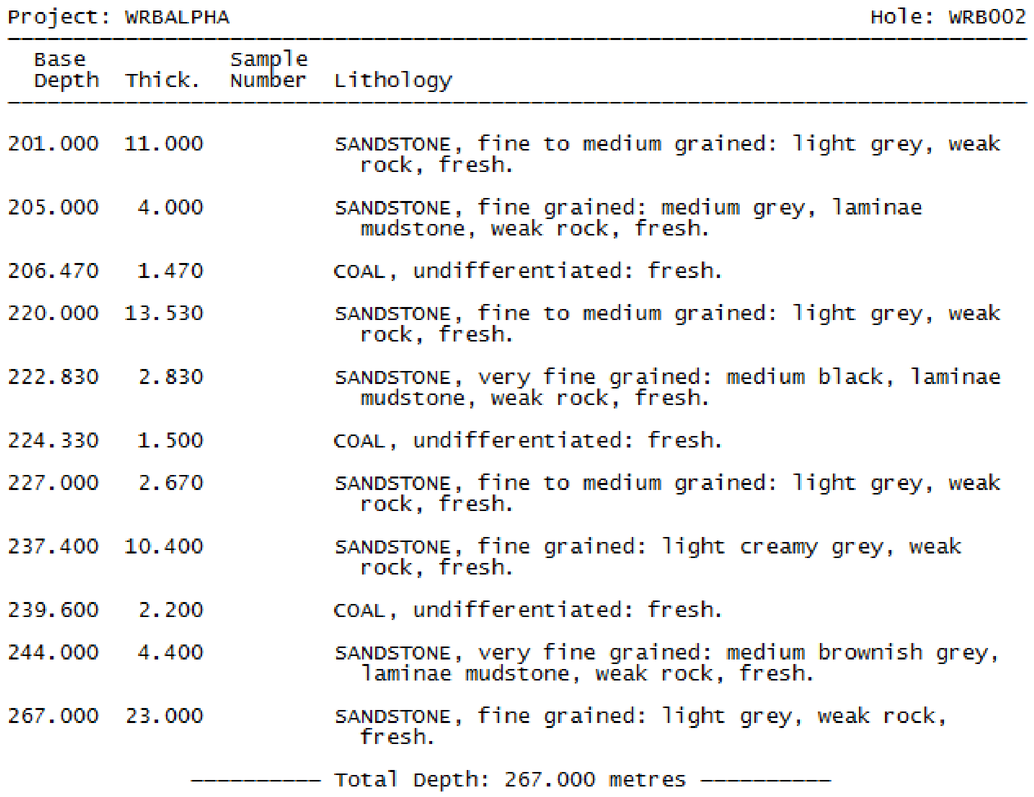


```
                              Drill Hole WRB001
Project: WRBALPHA                                                 Hole: WRB001
------------------------------------------------------------------------------
  Base             Sample
  Depth   Thick.   Number   Lithology
------------------------------------------------------------------------------

  5.000 -48.000             SAND: light creamy grey, fine to very fine grained,
                              silty, loose, extremely weathered.

  7.000   2.000             SAND: light creamy brown, fine grained, silty, loose,
                              extremely weathered.

 10.000   3.000             SAND: medium orangy brown, fine to medium grained,
                              loose, extremely weathered.

 14.000   4.000             CLAY: dark greyish brown, sticky, extremely
                              weathered.

 23.000   9.000             SILT: medium yellowish brown, sandy lenses clayey,
                              soft, extremely weathered.

 24.000   1.000             SAND: light creamy grey, fine to very fine grained,
                              silty, very soft, extremely weathered.

 43.000  19.000             SILT: medium yellowish brown, sandy lenses clayey,
                              soft, extremely weathered.

 45.000   2.000             SAND: light creamy brown, fine grained, silty, soft,
                              extremely weathered.

 47.000   2.000             SAND: light whitish grey, fine grained, loose,
                              extremely weathered.

 53.000   6.000             SAND: light creamy grey, fine grained, silty, sticky,
                              extremely weathered.

 89.000  36.000             SANDSTONE, fine grained: medium brownish grey, layers
                              lenses, sticky, extremely weathered.
               ---------- Total Depth: 89.000 metres ----------
```

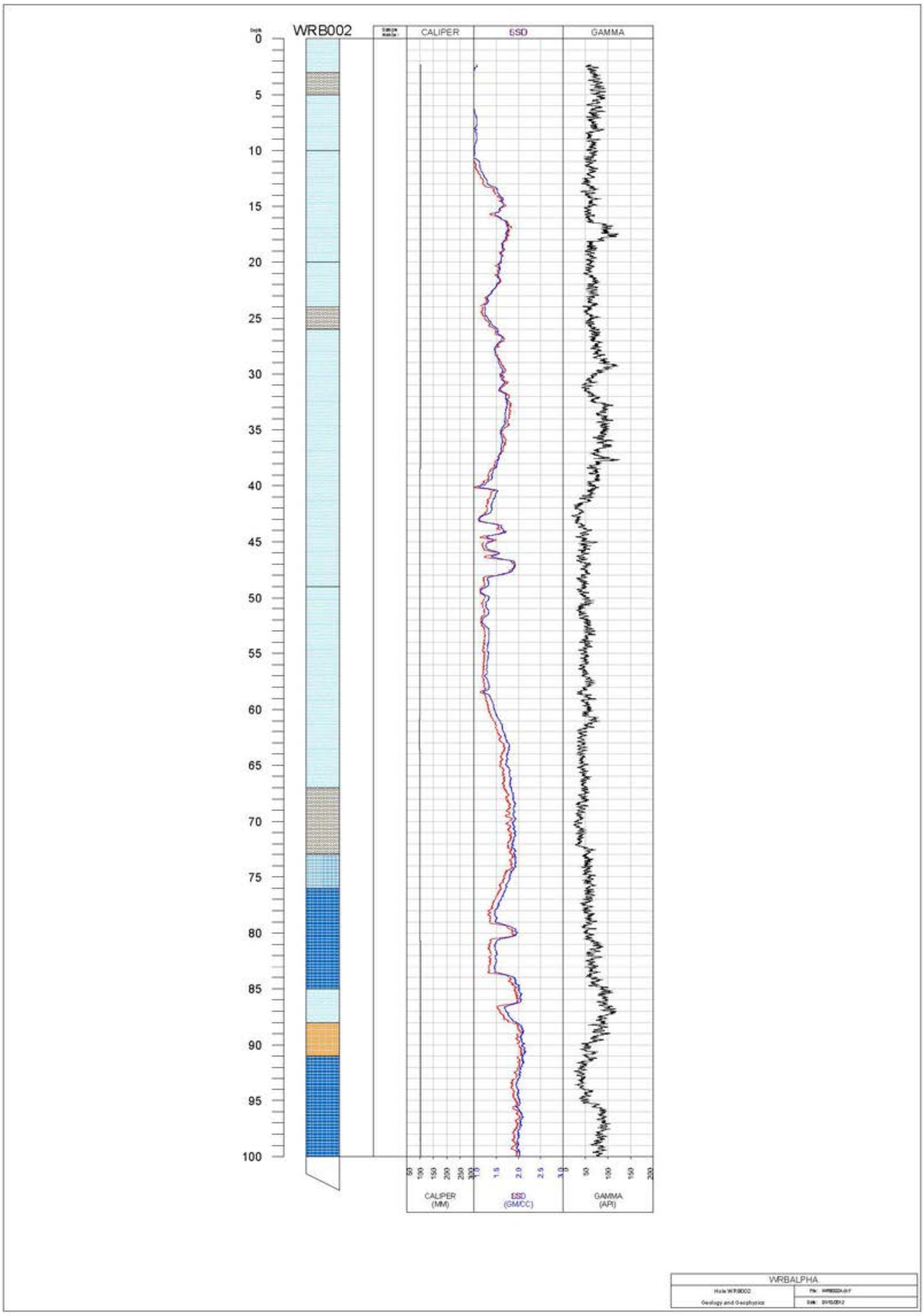

WRB001
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
89
WRBALPHA
Hole WRB001
Geology and Geophysics

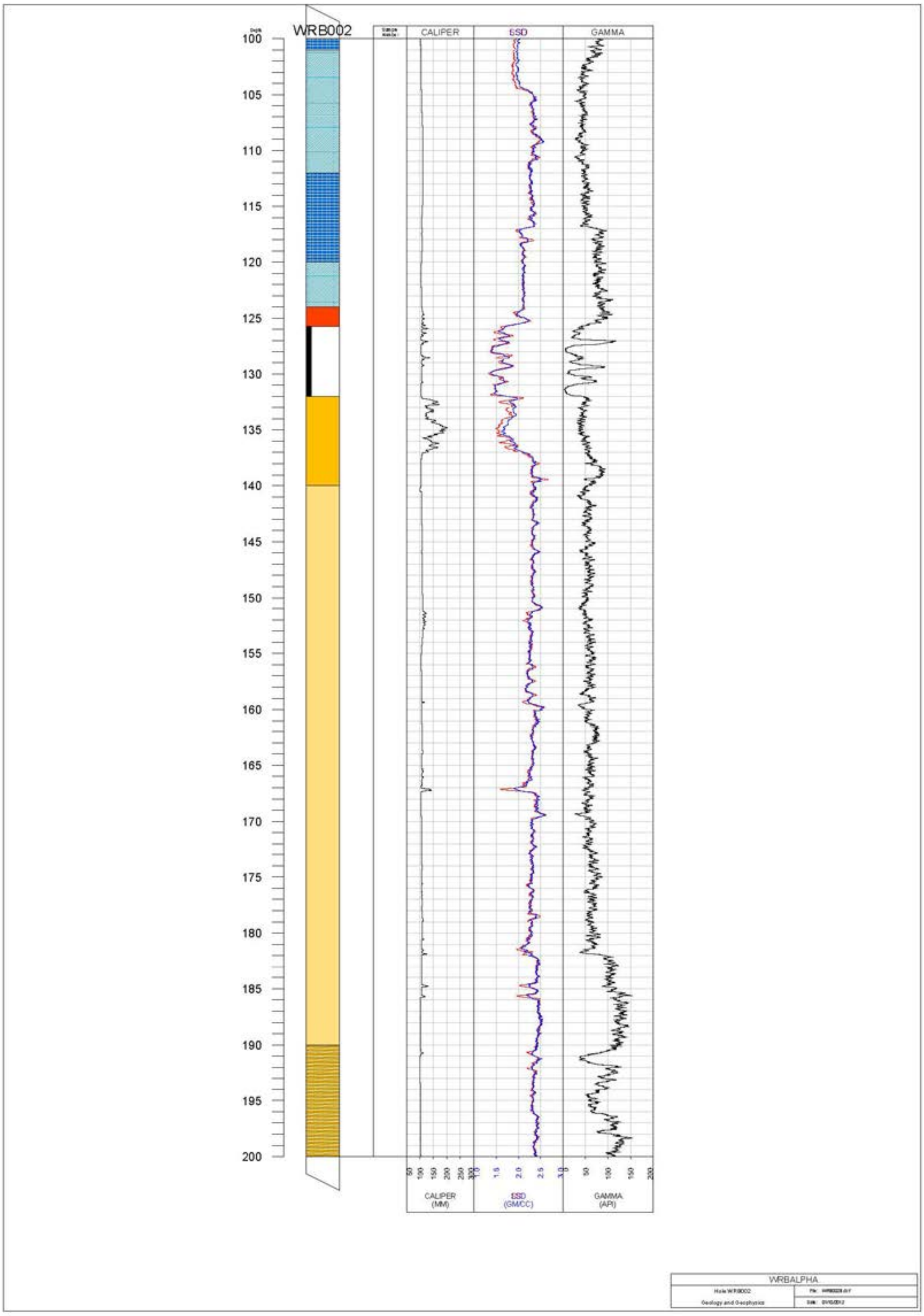


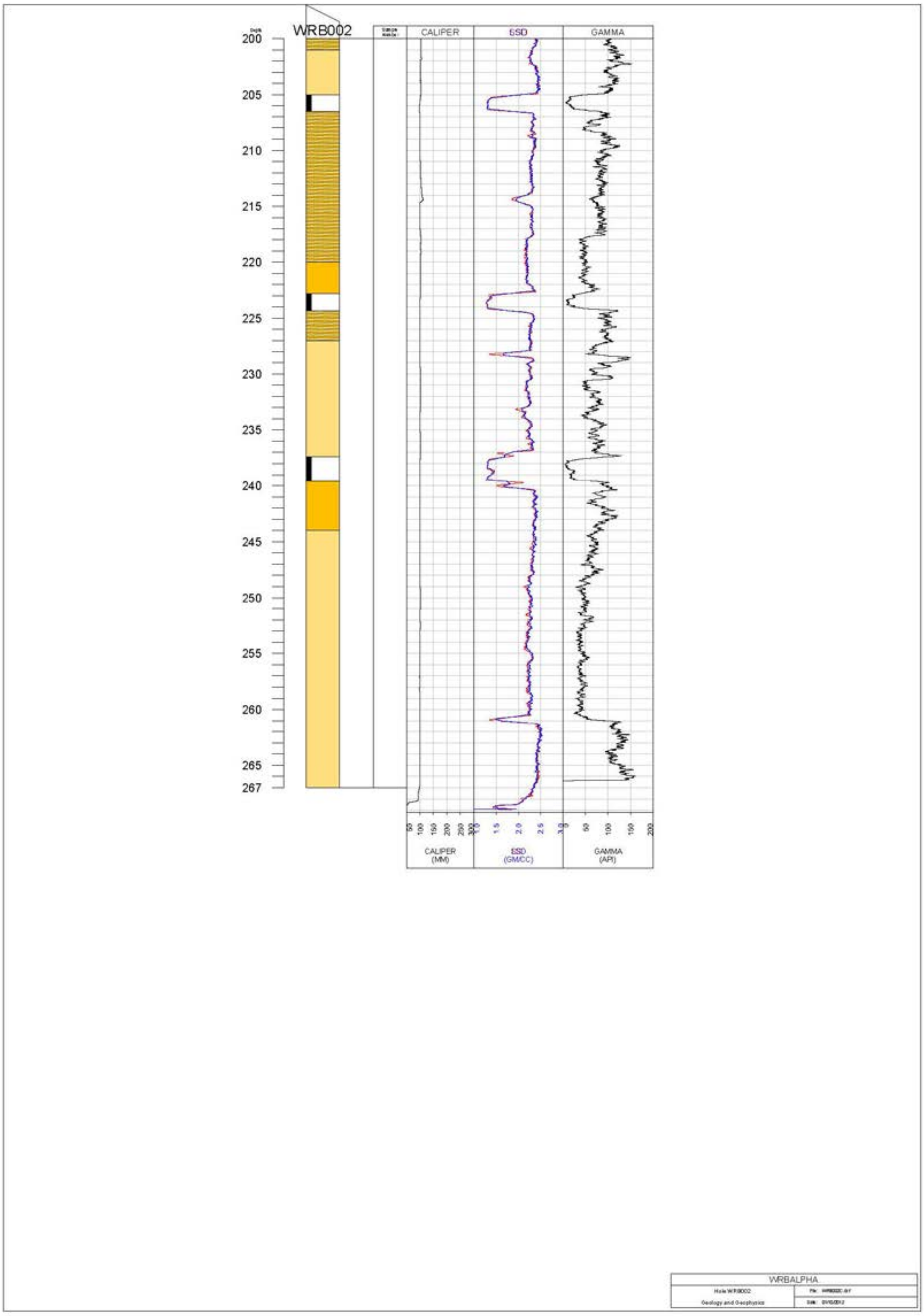
```
                                Drill Hole WRB002
 Project: WRBALPHA                                                   Hole: WRB002
 ------------------------------------------------------------------------------
   Base             Sample
   Depth   Thick.   Number   Lithology
 ------------------------------------------------------------------------------

   3.000    3.000            SILT: medium yellowish brown, sandy, soft, extremely
                               weathered.

   5.000    2.000            SAND: light whitish grey, silty, soft, extremely
                               weathered.

  10.000    5.000            SILT: medium creamy brown, clayey sandy, soft,
                               extremely weathered.

  20.000   10.000            SILT: light yellowish brown, sandy, firm, extremely
                               weathered.

  24.000    4.000            SILT: medium reddish brown, sandy, firm, extremely
                               weathered.

  26.000    2.000            SAND: light creamy grey, silty, soft, extremely
                               weathered.

  49.000   23.000            SILT: medium yellowish brown, sandy clayey, firm,
                               extremely weathered.

  67.000   18.000            SILT: light yellowish grey, sandy, soft, extremely
                               weathered.

  73.000    6.000            SAND: light whitish grey, loose, moderately
                               weathered.

  76.000    3.000            CLAY: medium reddish brown, sandy, sticky, moderately
                               weathered.

  85.000    9.000            CLAYSTONE: light yellowish brown, silty, fresh.

  88.000    3.000            SILT: light whitish grey, sandy, firm, fresh.

  91.000    3.000            SANDSTONE: light grey, soft, fresh.

 101.000   10.000            CLAYSTONE: medium purplish grey, silty, weak rock,
                               fresh.

 112.000   11.000            SILTSTONE: medium grey, clayey, weak rock, fresh.

 120.000    8.000            CLAYSTONE: medium purplish grey, weak rock, fresh.

 124.000    4.000            SILTSTONE: medium grey, weak rock, fresh.

 125.740    1.740            MUDSTONE: dark blackish grey, weak rock, fresh.

 132.000    6.260            COAL, undifferentiated: weak rock, fresh.

 140.000    8.000            SANDSTONE, very fine grained: medium creamy grey,
                               weak rock, fresh.

 190.000   50.000            SANDSTONE, fine grained: medium grey, weak rock,
```

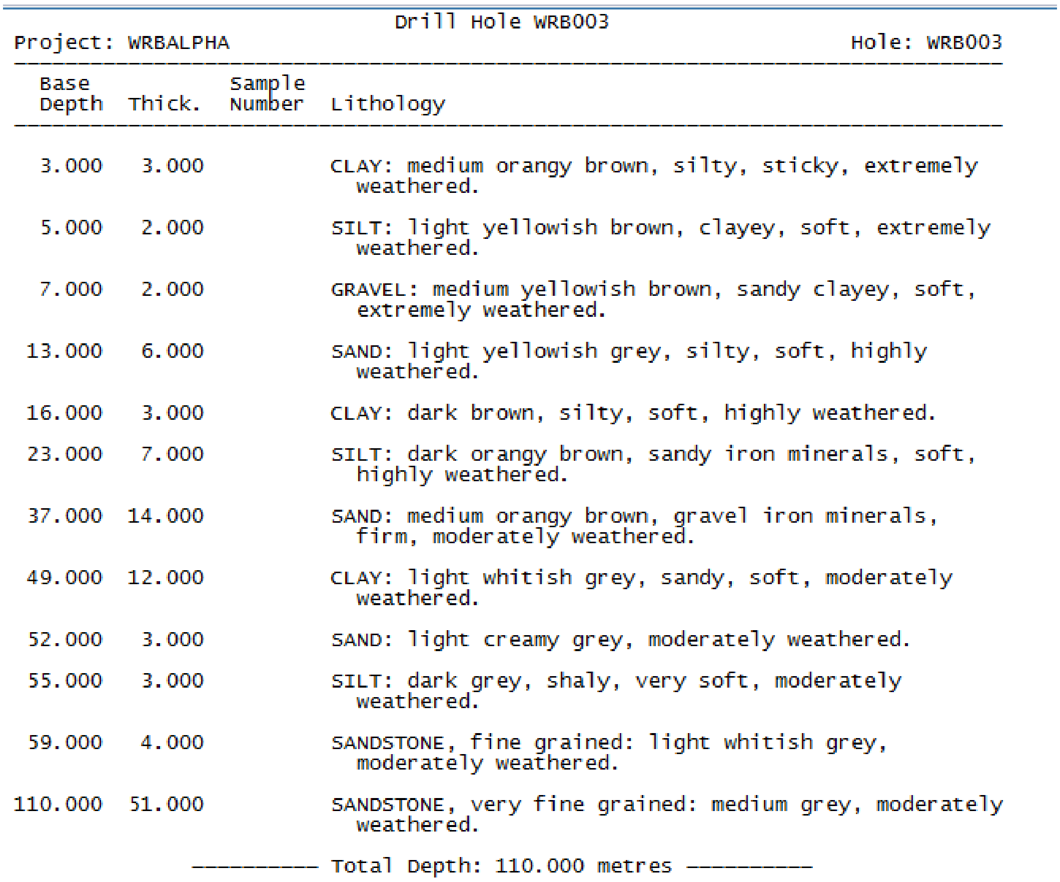


```
Project: WRBALPHA                                                  Hole: WRB002
-------------------------------------------------------------------------------
  Base             Sample
  Depth   Thick.   Number  Lithology
-------------------------------------------------------------------------------

201.000  11.000            SANDSTONE, fine to medium grained: light grey, weak
                             rock, fresh.

205.000   4.000            SANDSTONE, fine grained: medium grey, laminae
                             mudstone, weak rock, fresh.

206.470   1.470            COAL, undifferentiated: fresh.

220.000  13.530            SANDSTONE, fine to medium grained: light grey, weak
                             rock, fresh.

222.830   2.830            SANDSTONE, very fine grained: medium black, laminae
                             mudstone, weak rock, fresh.

224.330   1.500            COAL, undifferentiated: fresh.

227.000   2.670            SANDSTONE, fine to medium grained: light grey, weak
                             rock, fresh.

237.400  10.400            SANDSTONE, fine grained: light creamy grey, weak
                             rock, fresh.

239.600   2.200            COAL, undifferentiated: fresh.

244.000   4.400            SANDSTONE, very fine grained: medium brownish grey,
                             laminae mudstone, weak rock, fresh.

267.000  23.000            SANDSTONE, fine grained: light grey, weak rock,
                             fresh.

              ---------- Total Depth: 267.000 metres ----------
```

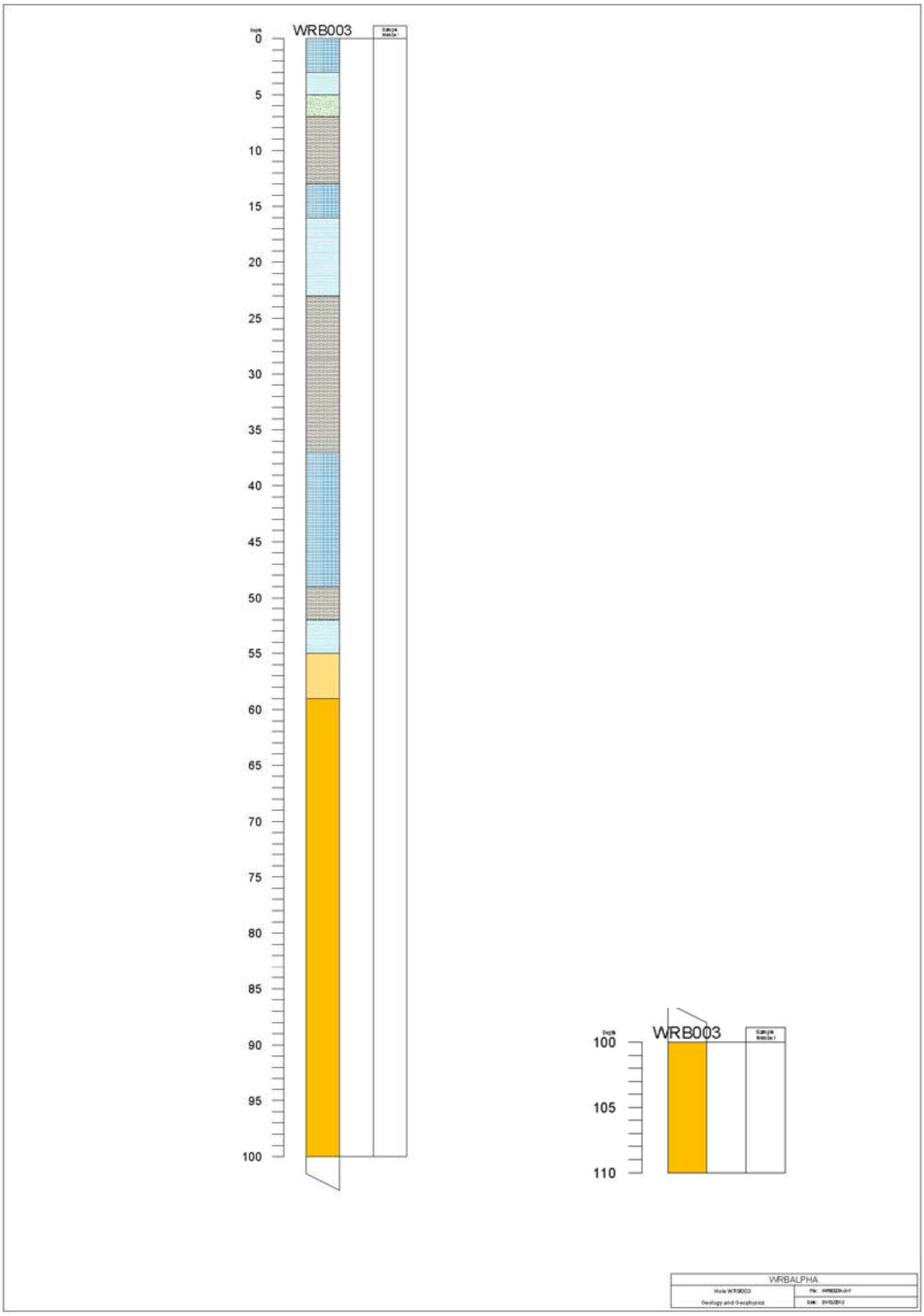

WRB002
Depth
CALIPER
SSD
GAMMA
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
50
100
150
200
250
300
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200
CALIPER (MM)
SSD (GM/CC)
GAMMA (API)
WRBALPHA
Hole WRB002
Geology and Geophysics

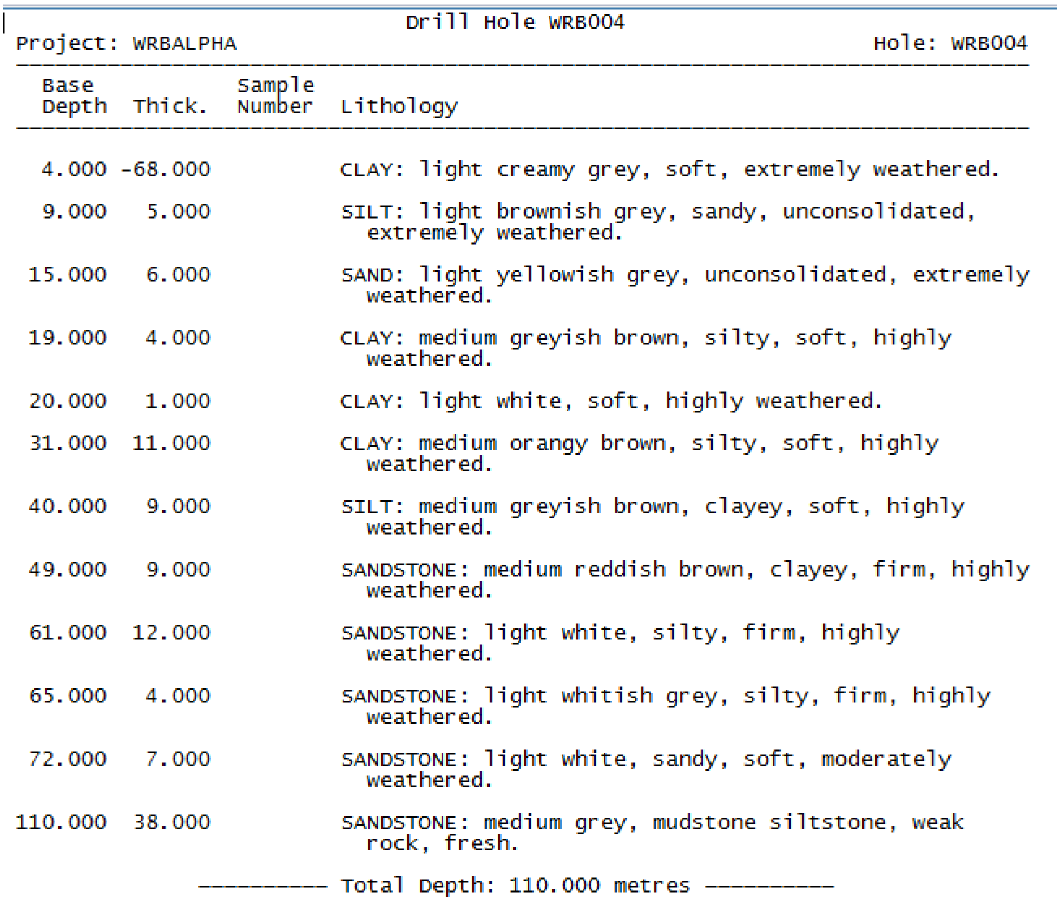

WRB002
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
CALIPER
SSD
GAMMA
50
100
150
200
250
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200
CALIPER (MM)
SSD (GM/CC)
GAMMA (API)
WRBALPHA
Hole WRB002
Geology and Geophysics


WRB002
Depth
200
205
210
215
220
225
230
235
240
245
250
255
260
265
267
CALIPER
SSD
GAMMA
50 100 150 200 250 300
1.0 1.5 2.0 2.5 3.0
0 50 100 150 200
CALIPER (MM)
SSD (GM/CC)
GAMMA (API)
WRBALPHA
Hole WRB002
Geology and Geophysics

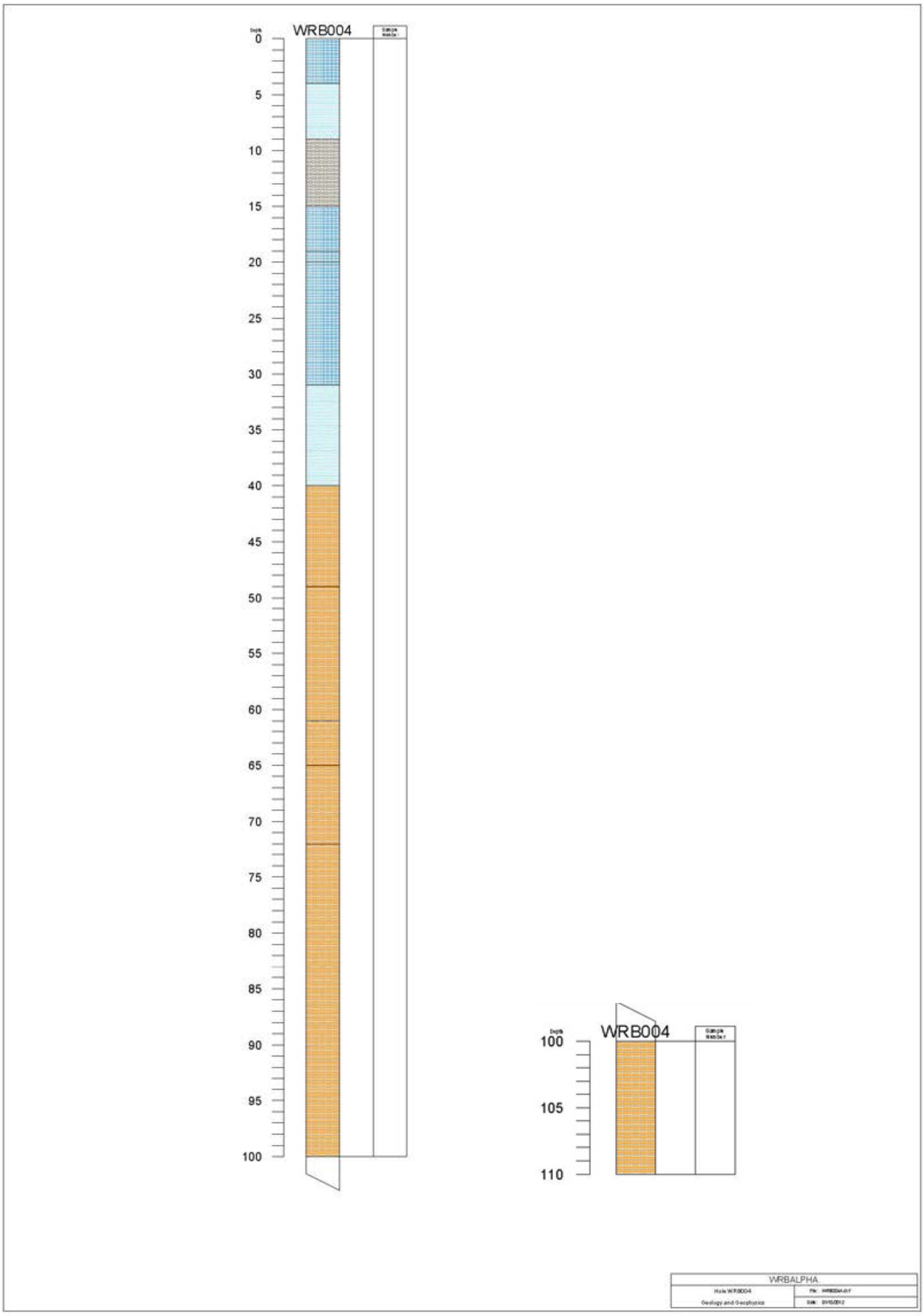


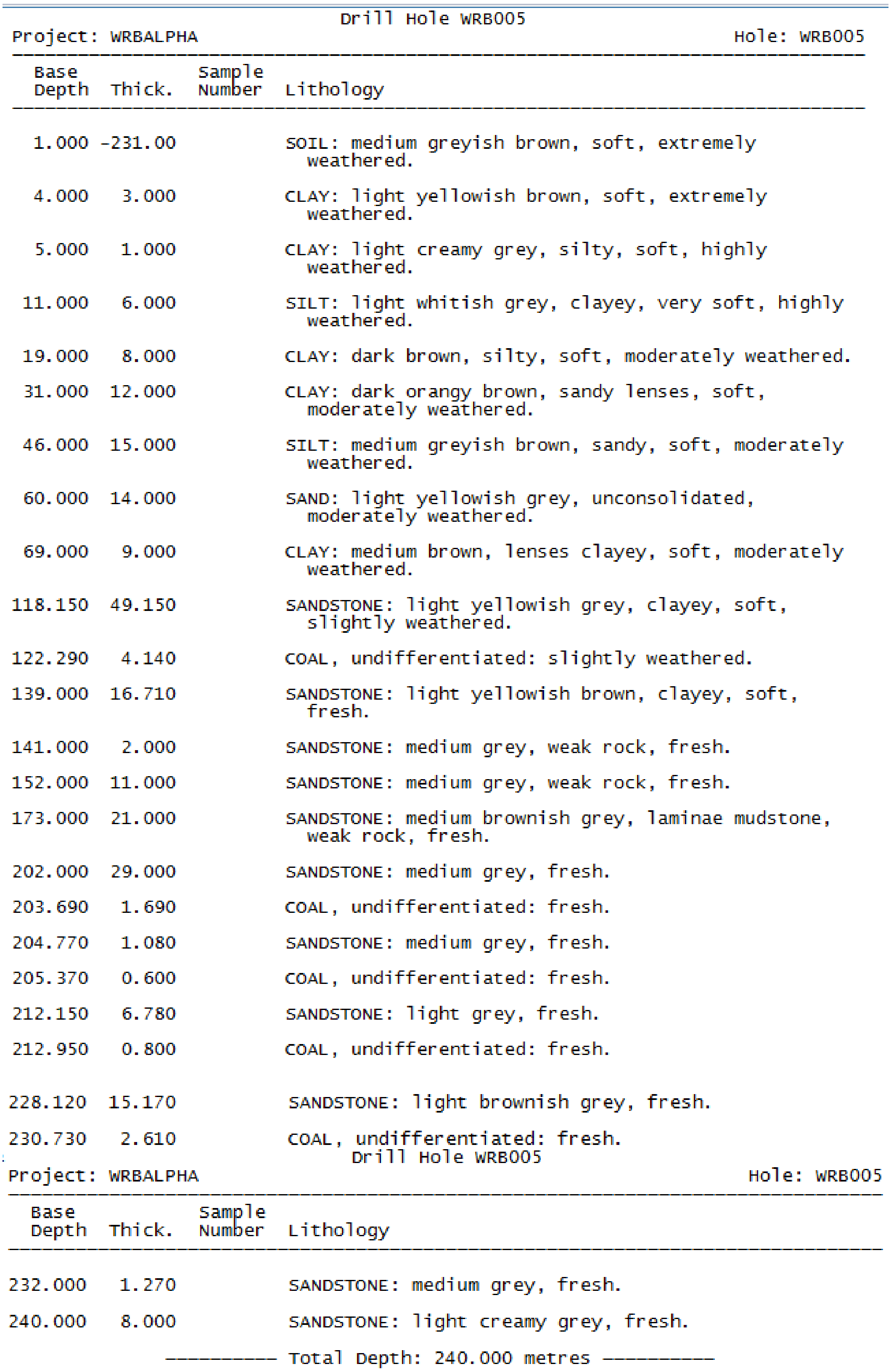
```
                              Drill Hole WRB003
Project: WRBALPHA                                              Hole: WRB003
------------------------------------------------------------------------------
  Base             Sample
  Depth   Thick.   Number   Lithology
------------------------------------------------------------------------------

  3.000    3.000            CLAY: medium orangy brown, silty, sticky, extremely
                              weathered.

  5.000    2.000            SILT: light yellowish brown, clayey, soft, extremely
                              weathered.

  7.000    2.000            GRAVEL: medium yellowish brown, sandy clayey, soft,
                              extremely weathered.

 13.000    6.000            SAND: light yellowish grey, silty, soft, highly
                              weathered.

 16.000    3.000            CLAY: dark brown, silty, soft, highly weathered.

 23.000    7.000            SILT: dark orangy brown, sandy iron minerals, soft,
                              highly weathered.

 37.000   14.000            SAND: medium orangy brown, gravel iron minerals,
                              firm, moderately weathered.

 49.000   12.000            CLAY: light whitish grey, sandy, soft, moderately
                              weathered.

 52.000    3.000            SAND: light creamy grey, moderately weathered.

 55.000    3.000            SILT: dark grey, shaly, very soft, moderately
                              weathered.

 59.000    4.000            SANDSTONE, fine grained: light whitish grey,
                              moderately weathered.

110.000   51.000            SANDSTONE, very fine grained: medium grey, moderately
                              weathered.

              ---------- Total Depth: 110.000 metres ----------
```


WRB003
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
WRB003
100
105
110
WRBALPHA
Hole WRB003
Geology and Geophysics

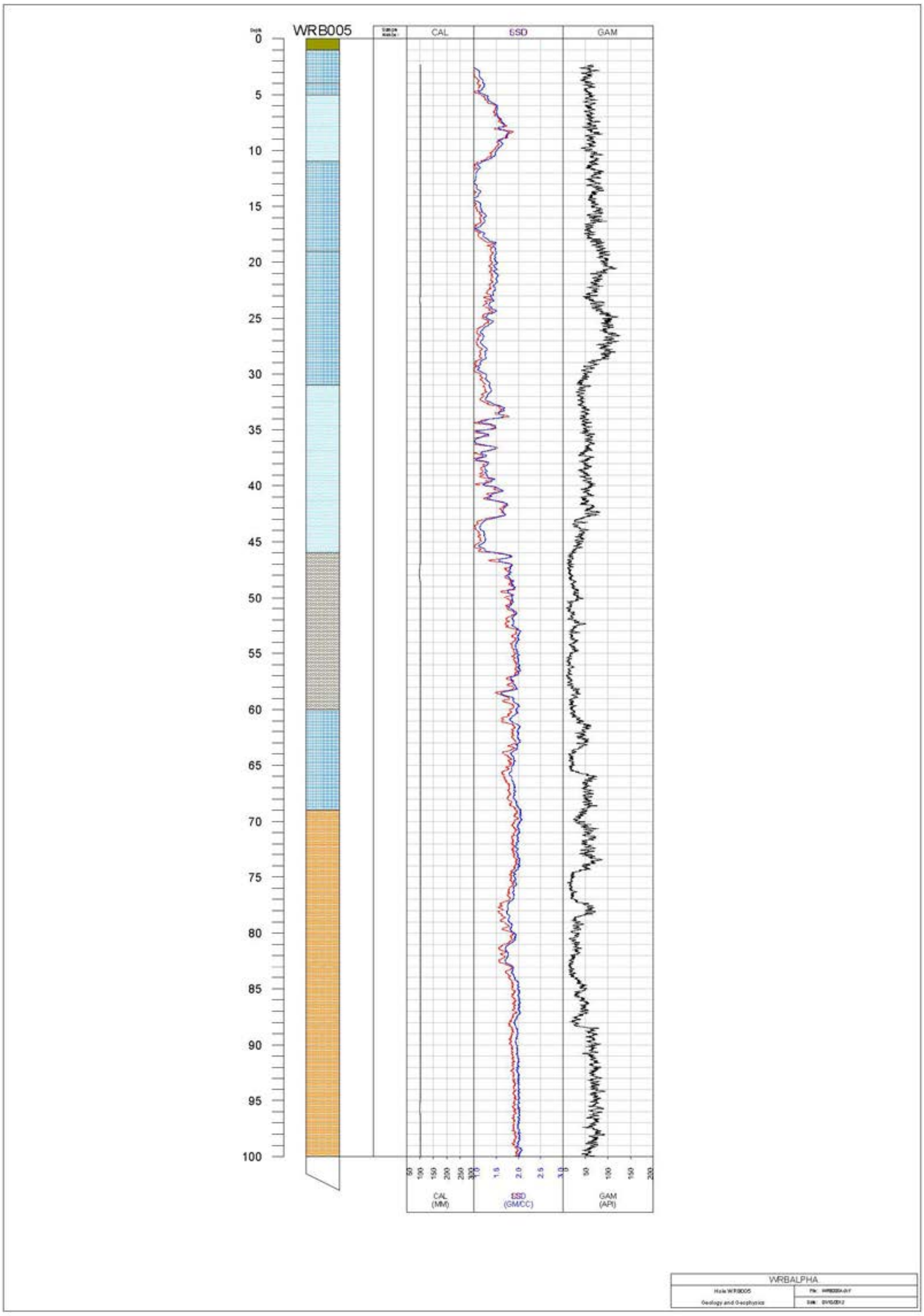


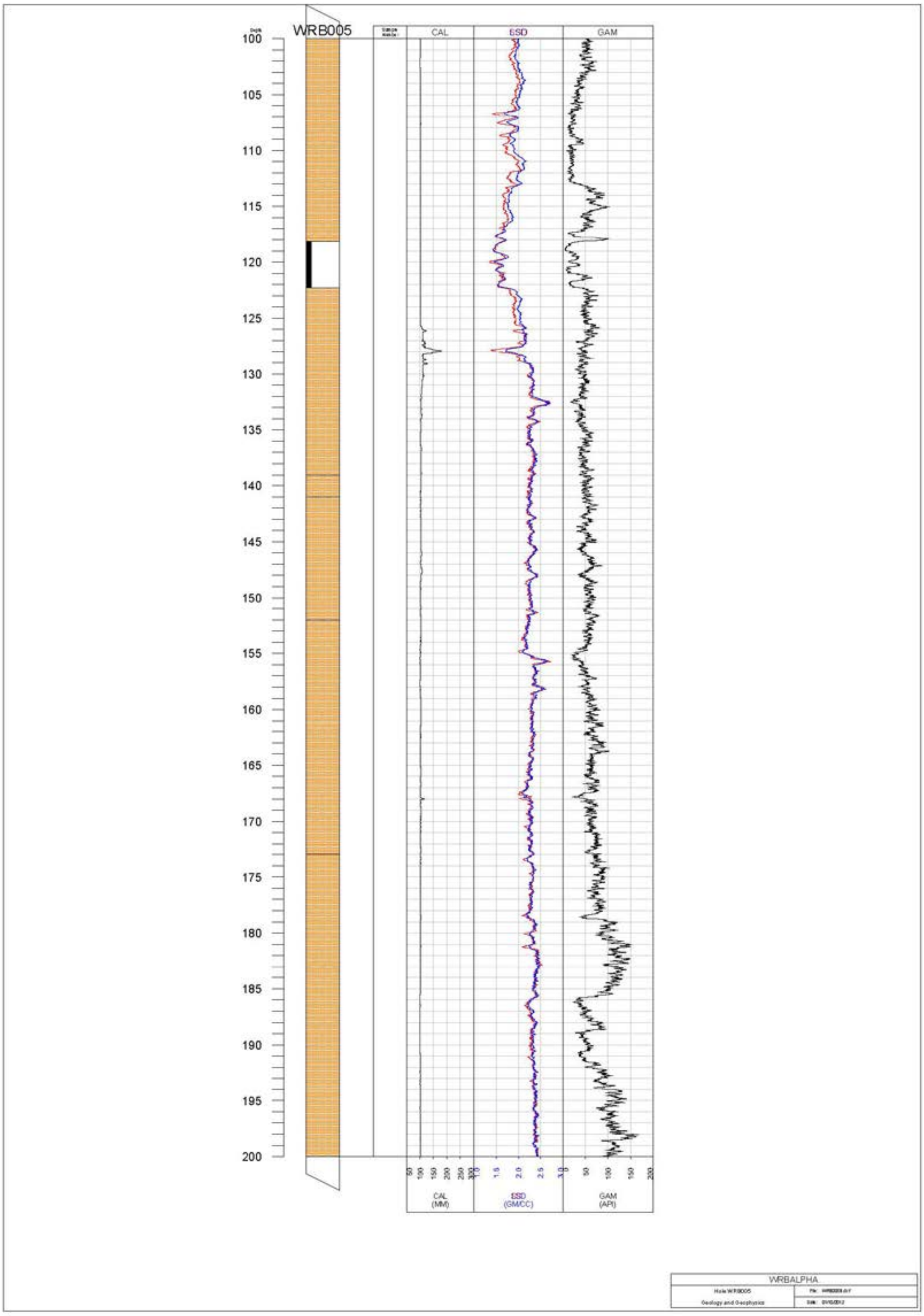
```
                                Drill Hole WRB004
Project: WRBALPHA                                                   Hole: WRB004
------------------------------------------------------------------------------
  Base              Sample
  Depth   Thick.    Number   Lithology
------------------------------------------------------------------------------

  4.000 -68.000              CLAY: light creamy grey, soft, extremely weathered.

  9.000   5.000              SILT: light brownish grey, sandy, unconsolidated,
                               extremely weathered.

 15.000   6.000              SAND: light yellowish grey, unconsolidated, extremely
                               weathered.

 19.000   4.000              CLAY: medium greyish brown, silty, soft, highly
                               weathered.

 20.000   1.000              CLAY: light white, soft, highly weathered.

 31.000  11.000              CLAY: medium orangy brown, silty, soft, highly
                               weathered.

 40.000   9.000              SILT: medium greyish brown, clayey, soft, highly
                               weathered.

 49.000   9.000              SANDSTONE: medium reddish brown, clayey, firm, highly
                               weathered.

 61.000  12.000              SANDSTONE: light white, silty, firm, highly
                               weathered.

 65.000   4.000              SANDSTONE: light whitish grey, silty, firm, highly
                               weathered.

 72.000   7.000              SANDSTONE: light white, sandy, soft, moderately
                               weathered.

110.000  38.000              SANDSTONE: medium grey, mudstone siltstone, weak
                               rock, fresh.
              ---------- Total Depth: 110.000 metres ----------
```

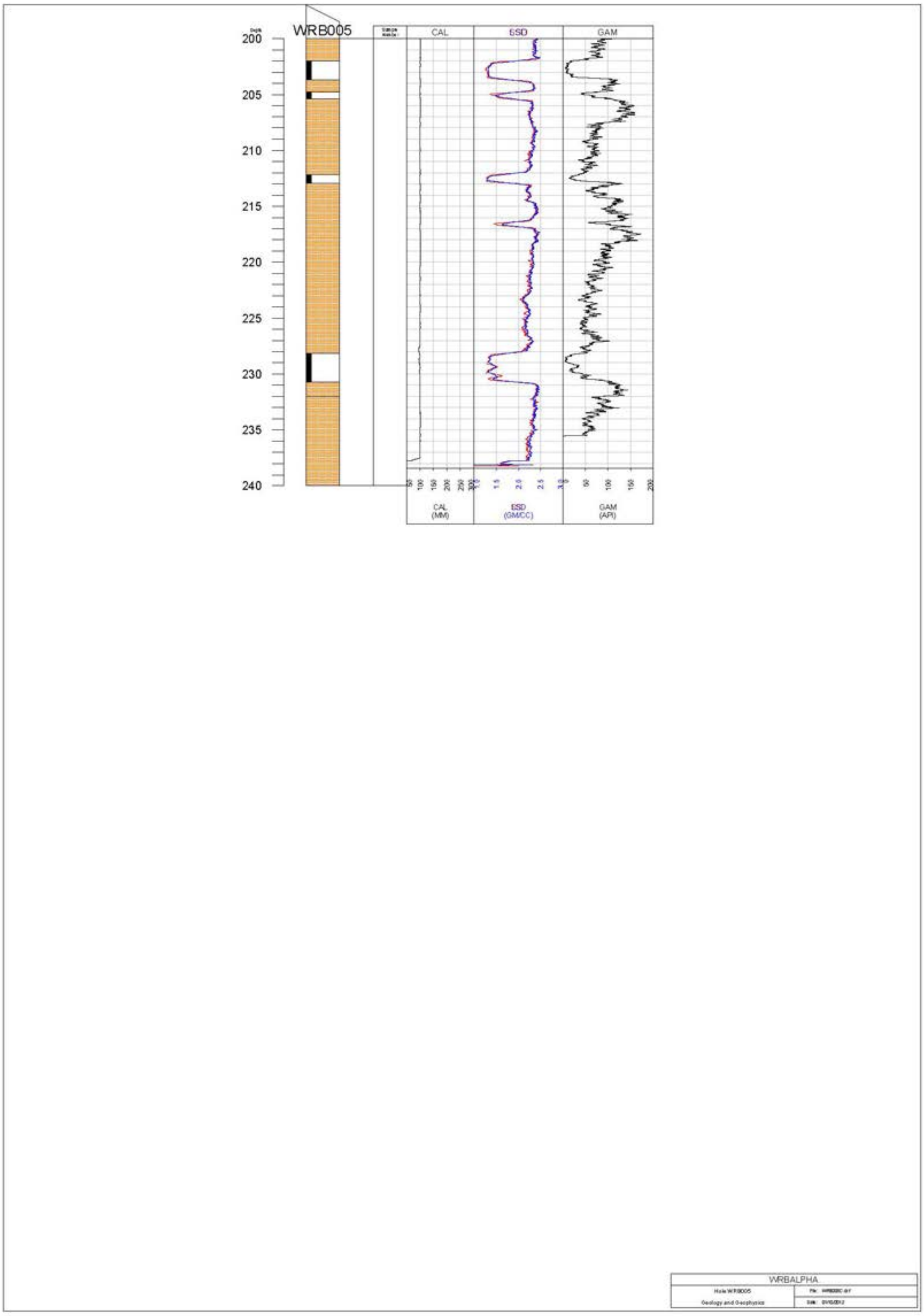

Depth
WRB004
Sample Number
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Depth
WRB004
Sample Number
100
105
110
WRBALPHA
Hole WRB004
Geology and Geophysics
File:
Date:



```
                                Drill Hole WRB005
Project: WRBALPHA                                                    Hole: WRB005
---------------------------------------------------------------------------------
  Base            Sample
  Depth   Thick.  Number   Lithology
---------------------------------------------------------------------------------

  1.000 -231.00            SOIL: medium greyish brown, soft, extremely
                             weathered.

  4.000   3.000            CLAY: light yellowish brown, soft, extremely
                             weathered.

  5.000   1.000            CLAY: light creamy grey, silty, soft, highly
                             weathered.

 11.000   6.000            SILT: light whitish grey, clayey, very soft, highly
                             weathered.

 19.000   8.000            CLAY: dark brown, silty, soft, moderately weathered.

 31.000  12.000            CLAY: dark orangy brown, sandy lenses, soft,
                             moderately weathered.

 46.000  15.000            SILT: medium greyish brown, sandy, soft, moderately
                             weathered.

 60.000  14.000            SAND: light yellowish grey, unconsolidated,
                             moderately weathered.

 69.000   9.000            CLAY: medium brown, lenses clayey, soft, moderately
                             weathered.

118.150  49.150            SANDSTONE: light yellowish grey, clayey, soft,
                             slightly weathered.

122.290   4.140            COAL, undifferentiated: slightly weathered.

139.000  16.710            SANDSTONE: light yellowish brown, clayey, soft,
                             fresh.

141.000   2.000            SANDSTONE: medium grey, weak rock, fresh.

152.000  11.000            SANDSTONE: medium grey, weak rock, fresh.

173.000  21.000            SANDSTONE: medium brownish grey, laminae mudstone,
                             weak rock, fresh.

202.000  29.000            SANDSTONE: medium grey, fresh.

203.690   1.690            COAL, undifferentiated: fresh.

204.770   1.080            SANDSTONE: medium grey, fresh.

205.370   0.600            COAL, undifferentiated: fresh.

212.150   6.780            SANDSTONE: light grey, fresh.

212.950   0.800            COAL, undifferentiated: fresh.


228.120  15.170            SANDSTONE: light brownish grey, fresh.

230.730   2.610            COAL, undifferentiated: fresh.
                                Drill Hole WRB005
Project: WRBALPHA                                                    Hole: WRB005
---------------------------------------------------------------------------------
  Base            Sample
  Depth   Thick.  Number   Lithology
---------------------------------------------------------------------------------

232.000   1.270            SANDSTONE: medium grey, fresh.

240.000   8.000            SANDSTONE: light creamy grey, fresh.

               ---------- Total Depth: 240.000 metres ----------
```

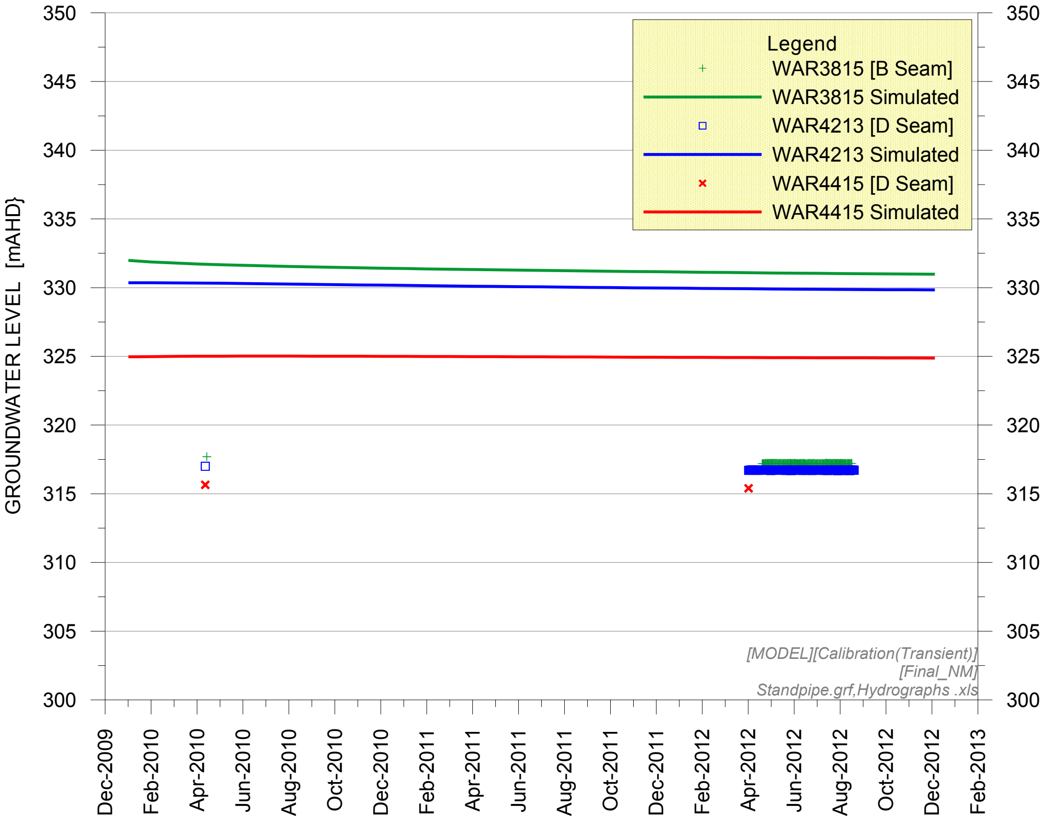

WRB005
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
CAL
SSD
GAM
50 100 150 200 250 300
1.0 1.5 2.0 2.5 3.0
0 50 100 150 200
CAL (MM)
SSD (GM/CC)
GAM (API)
WRBALPHA
Hole WRB005
Geology and Geophysics

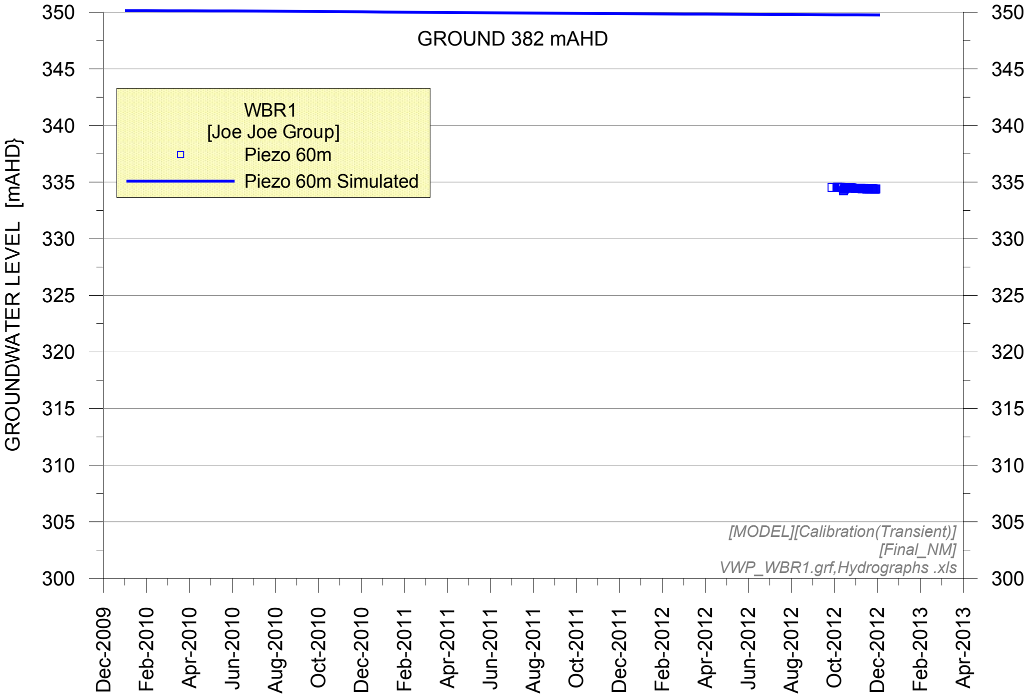

WRB005
Depth
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
CAL
ESD
GAM
50 100 150 200 250 300
1.0 1.5 2.0 2.5 3.0
0 50 100 150 200
CAL
(MM)
ESD
(GM/CC)
GAM
(API)
WRBALPHA
Hole WRB005
Geology and Geophysics
File:
Date:

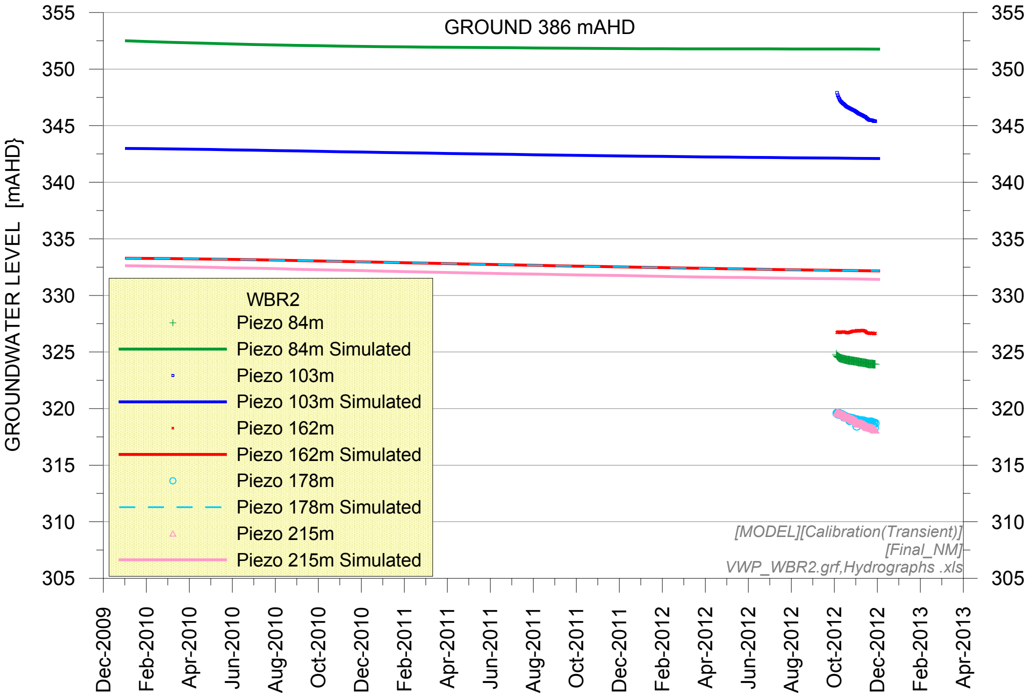

WRB005
Depth
200
205
210
215
220
225
230
235
240
CAL
SSD
GAM
50
100
150
200
250
300
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200
CAL
(MM)
SSD
(GM/CC)
GAM
(API)
WRBALPHA
Hole WRB005
Geology and Geophysics
File:
Date:

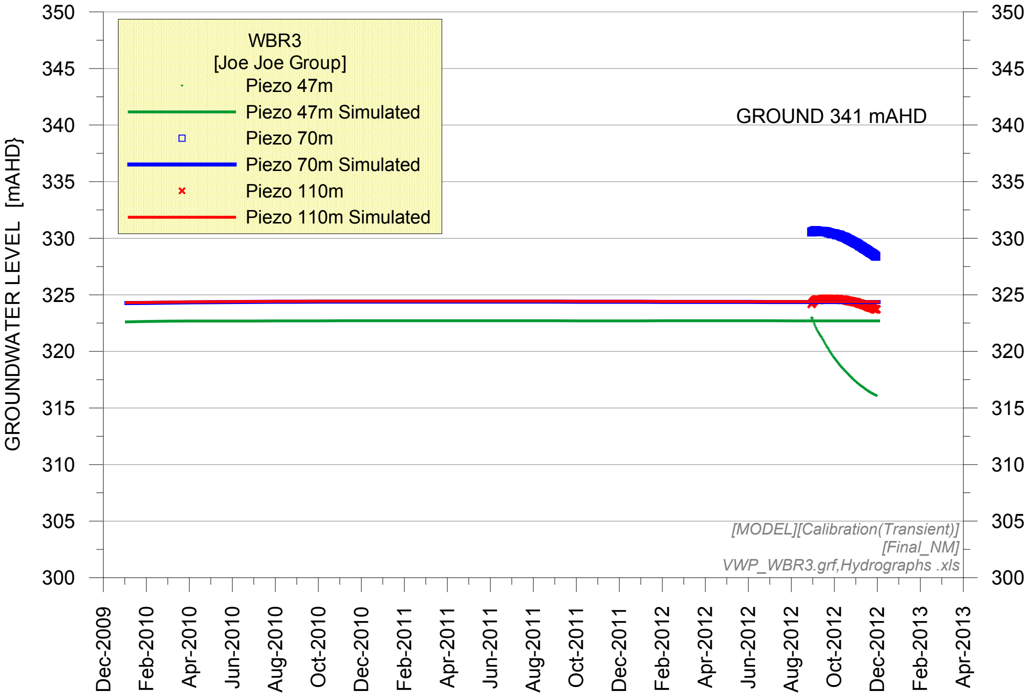
ATTACHMENT E

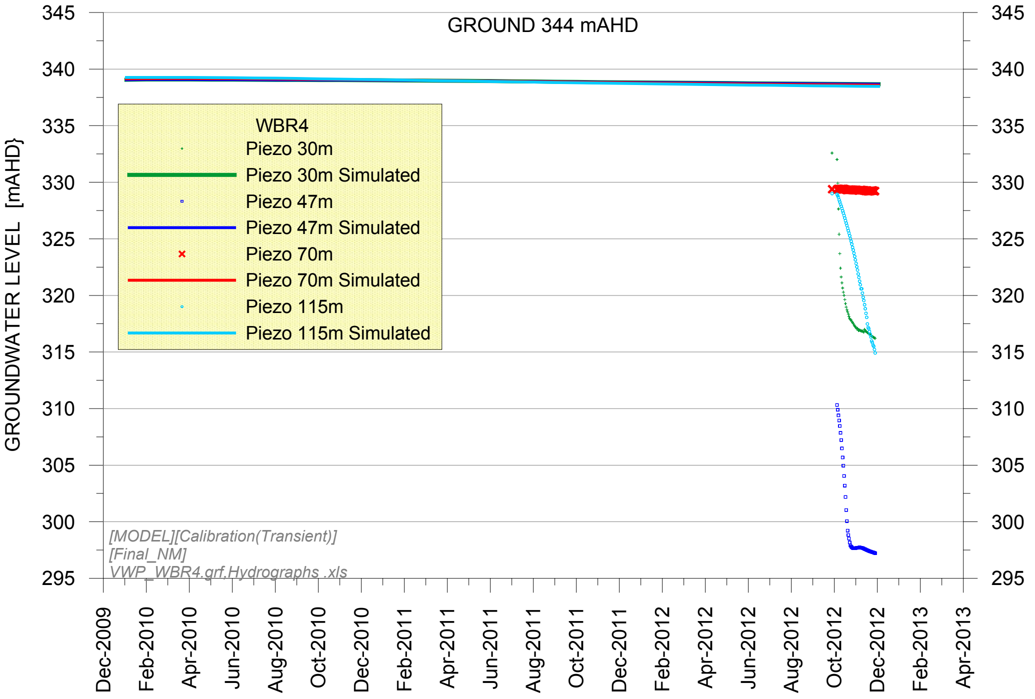
Calibration Hydrographs

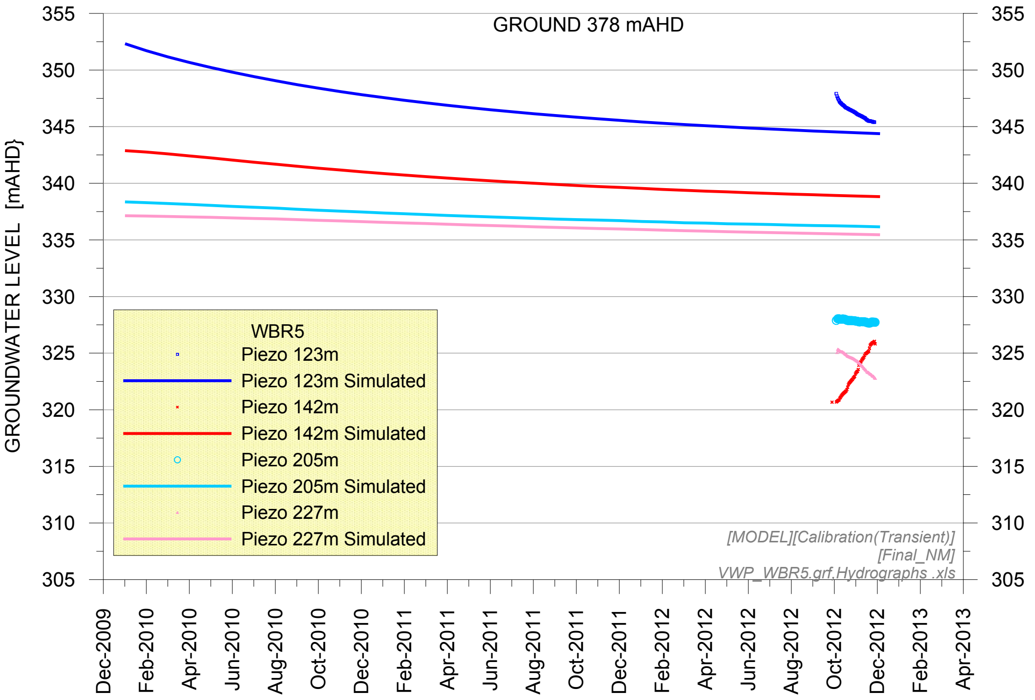

GROUNDWATER LEVEL [mAHD}
350
345
340
335
330
325
320
315
310
305
300
Legend
WAR3815 [B Seam]
WAR3815 Simulated
WAR4213 [D Seam]
WAR4213 Simulated
WAR4415 [D Seam]
WAR4415 Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
Standpipe.grf,Hydrographs .xls
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013

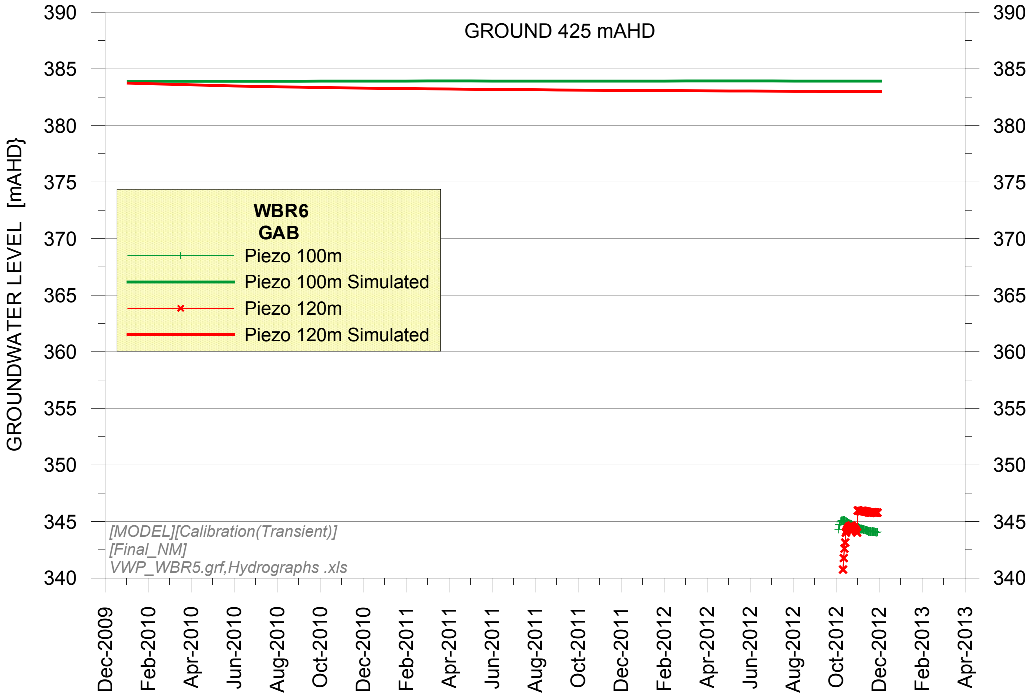

GROUNDWATER LEVEL [mAHD}
350
345
340
335
330
325
320
315
310
305
300
GROUND 382 mAHD
WBR1
[Joe Joe Group]
Piezo 60m
Piezo 60m Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_WBR1.grf,Hydrographs .xls
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013

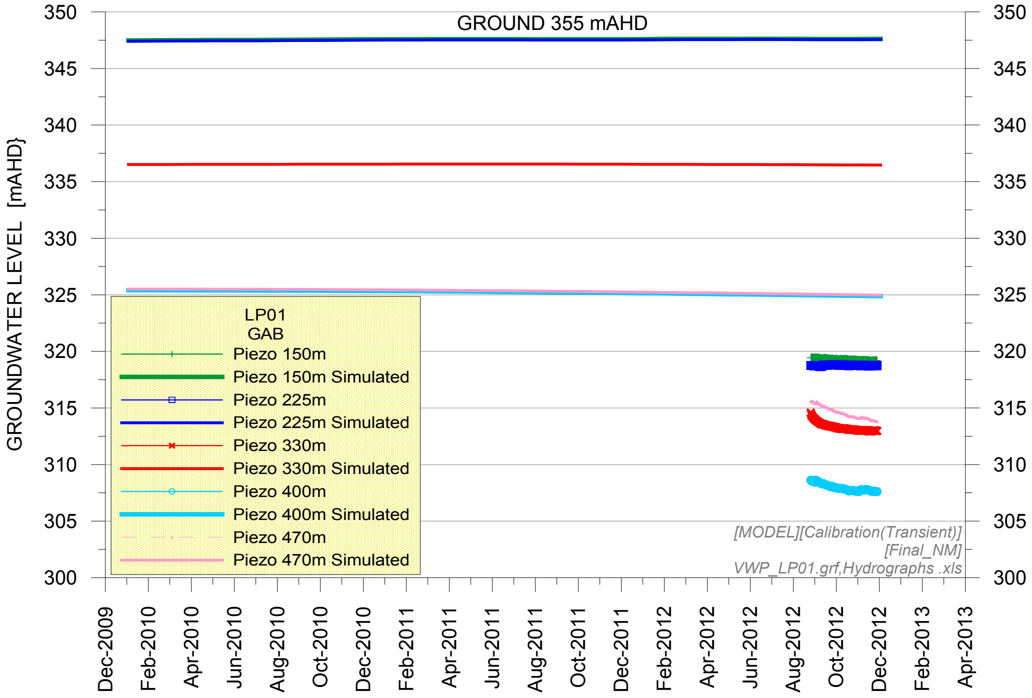

GROUND 386 mAHD
GROUNDWATER LEVEL [mAHD]
355
350
345
340
335
330
325
320
315
310
305
WBR2
Piezo 84m
Piezo 84m Simulated
Piezo 103m
Piezo 103m Simulated
Piezo 162m
Piezo 162m Simulated
Piezo 178m
Piezo 178m Simulated
Piezo 215m
Piezo 215m Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_WBR2.grf,Hydrographs .xls
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013


GROUNDWATER LEVEL [mAHD]
350
345
340
335
330
325
320
315
310
305
300
WBR3
[Joe Joe Group]
Piezo 47m
Piezo 47m Simulated
Piezo 70m
Piezo 70m Simulated
Piezo 110m
Piezo 110m Simulated
GROUND 341 mAHD
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_WBR3.grf,Hydrographs .xls
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013


GROUND 344 mAHD
GROUNDWATER LEVEL [mAHD}
WBR4
Piezo 30m
Piezo 30m Simulated
Piezo 47m
Piezo 47m Simulated
Piezo 70m
Piezo 70m Simulated
Piezo 115m
Piezo 115m Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_WBR4.grf,Hydrographs .xls
345
340
335
330
325
320
315
310
305
300
295
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013


GROUND 378 mAHD
GROUNDWATER LEVEL [mAHD}
WBR5
Piezo 123m
Piezo 123m Simulated
Piezo 142m
Piezo 142m Simulated
Piezo 205m
Piezo 205m Simulated
Piezo 227m
Piezo 227m Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_WBR5.grf,Hydrographs .xls
355
350
345
340
335
330
325
320
315
310
305
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013


GROUND 425 mAHD
GROUNDWATER LEVEL [mAHD]
WBR6
GAB
Piezo 100m
Piezo 100m Simulated
Piezo 120m
Piezo 120m Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_WBR5.grf,Hydrographs .xls
390
385
380
375
370
365
360
355
350
345
340
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013


GROUND 355 mAHD
GROUNDWATER LEVEL [mAHD]
LP01
GAB
Piezo 150m
Piezo 150m Simulated
Piezo 225m
Piezo 225m Simulated
Piezo 330m
Piezo 330m Simulated
Piezo 400m
Piezo 400m Simulated
Piezo 470m
Piezo 470m Simulated
[MODEL][Calibration(Transient)]
[Final_NM]
VWP_LP01.grf,Hydrographs .xls
350
345
340
335
330
325
320
315
310
305
300
Dec-2009
Feb-2010
Apr-2010
Jun-2010
Aug-2010
Oct-2010
Dec-2010
Feb-2011
Apr-2011
Jun-2011
Aug-2011
Oct-2011
Dec-2011
Feb-2012
Apr-2012
Jun-2012
Aug-2012
Oct-2012
Dec-2012
Feb-2013
Apr-2013

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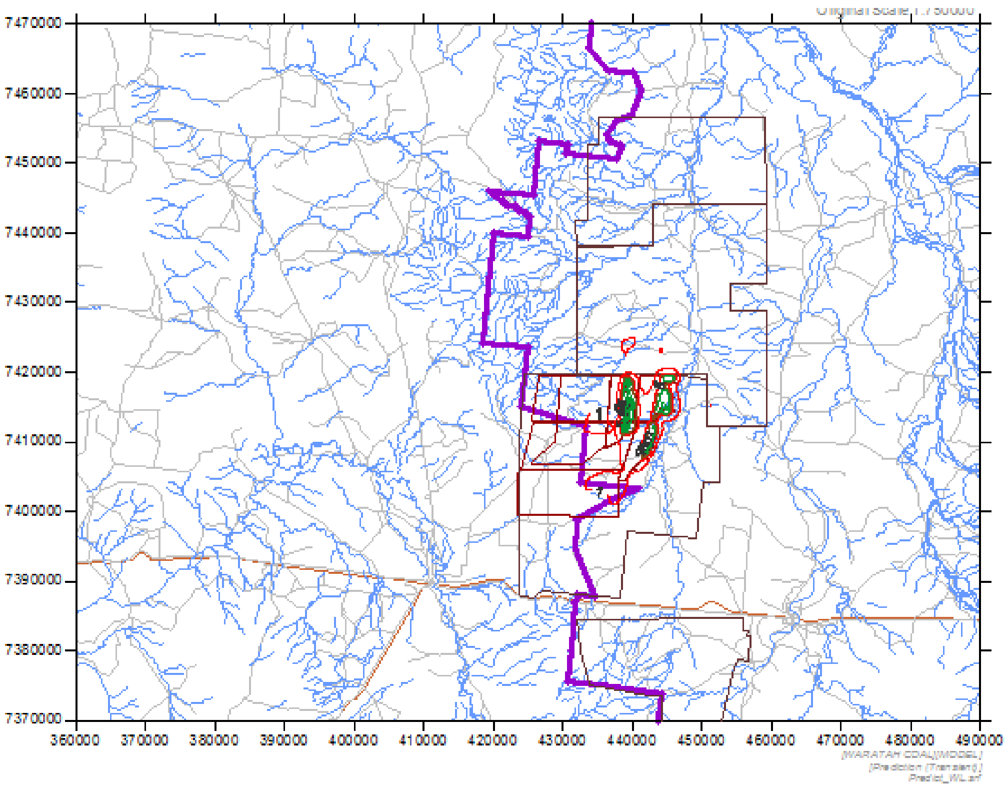
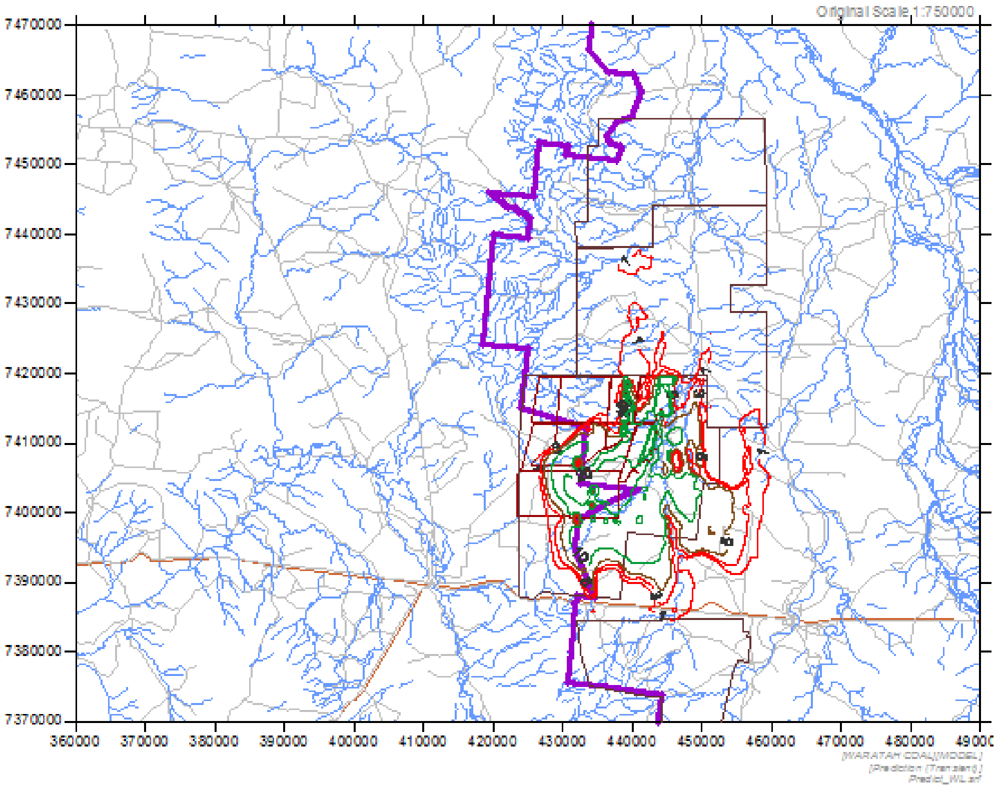
ATTACHMENT F

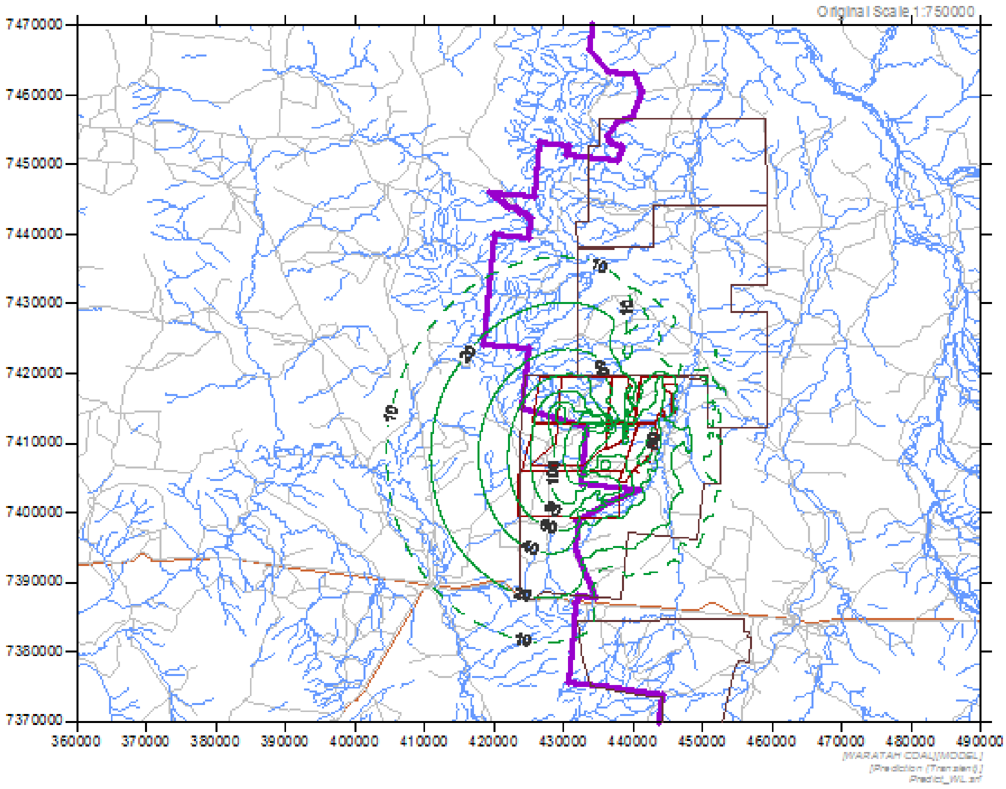
Drawdown Contour Maps



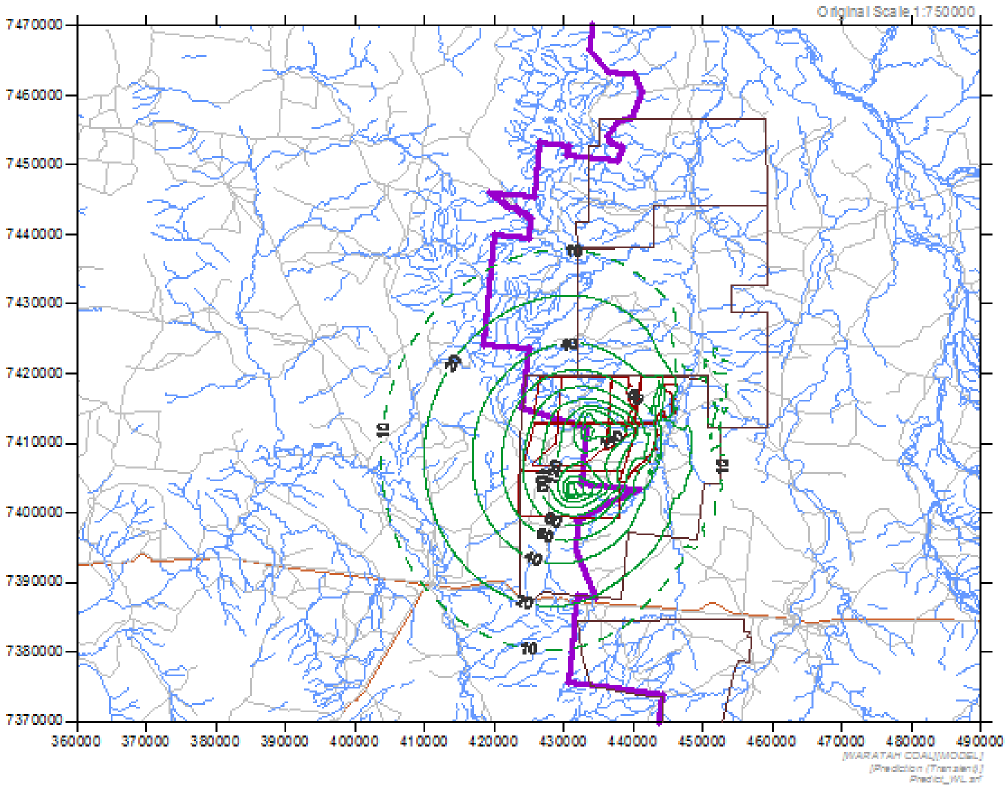
Drawdown in Layer 1 - simulation year 10



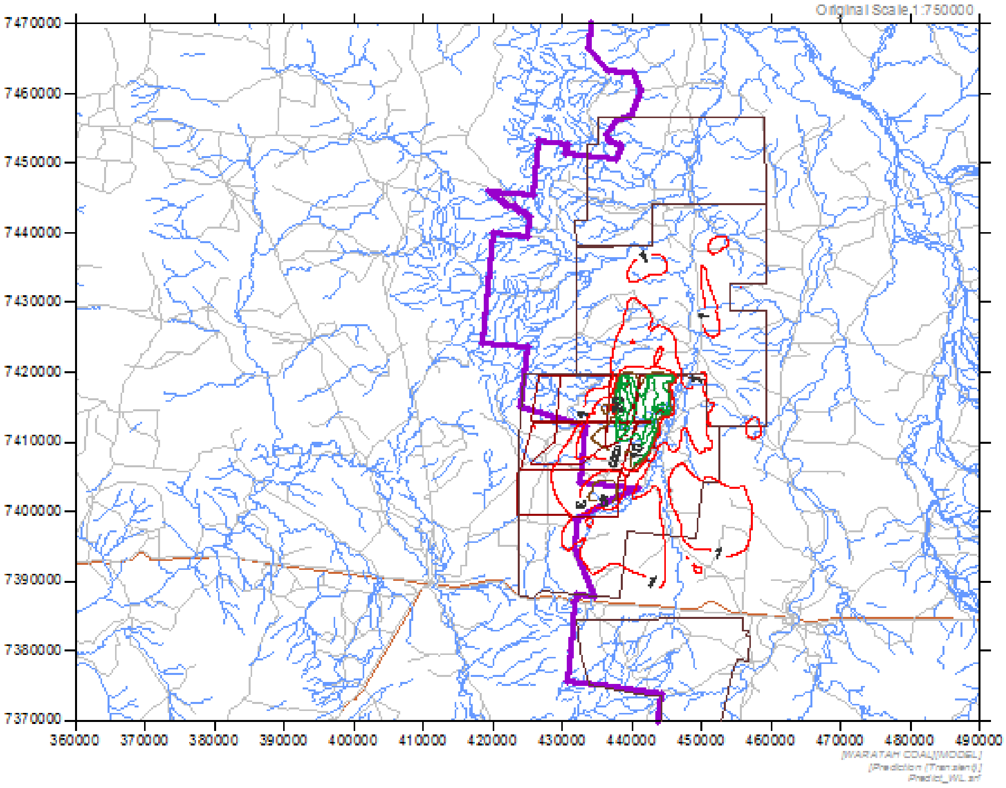
Drawdown in Layer 2 - simulation year 10



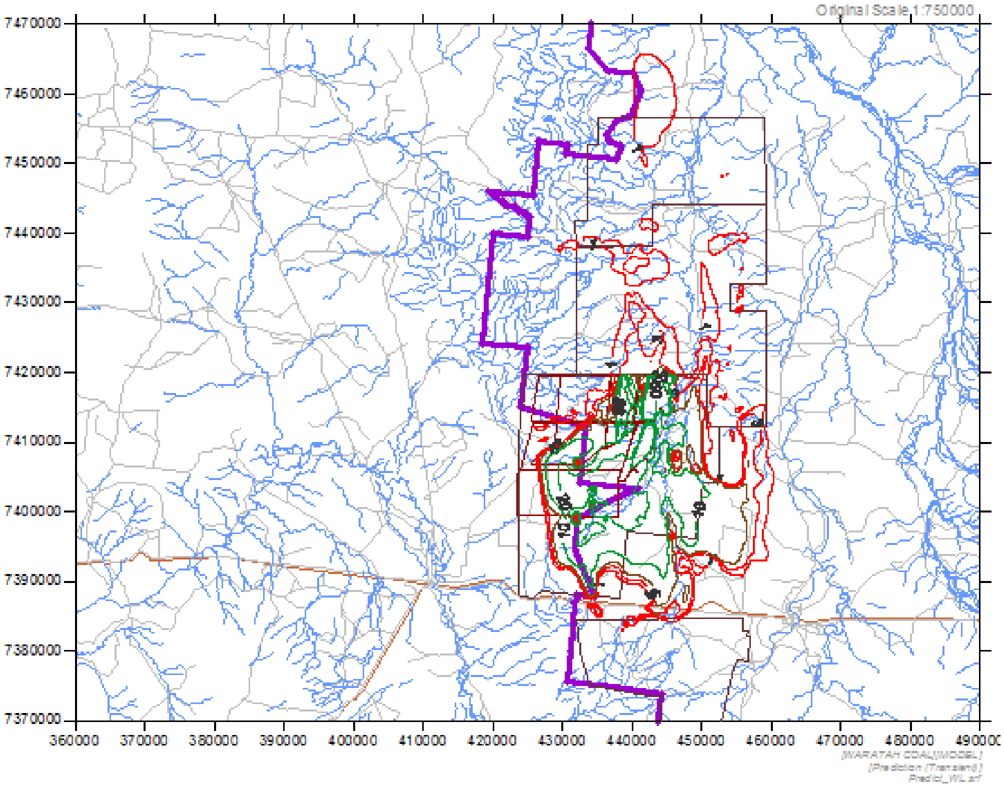
Drawdown in Layer 5 - simulation year 10



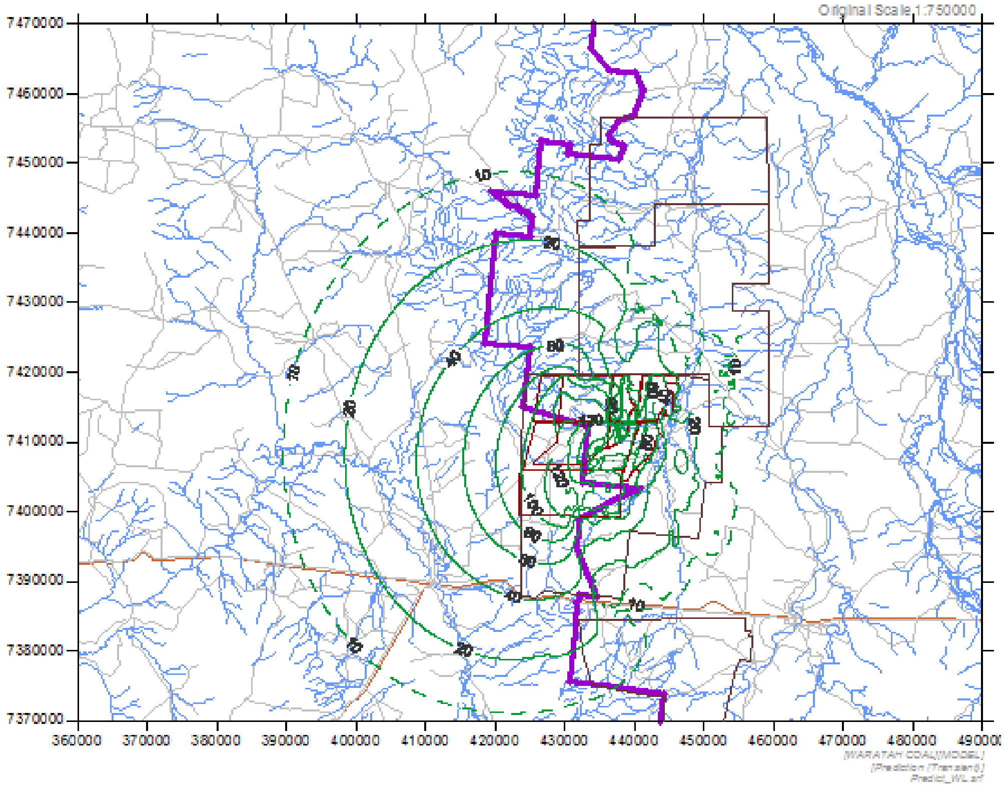
Drawdown in Layer 9 - simulation year 10



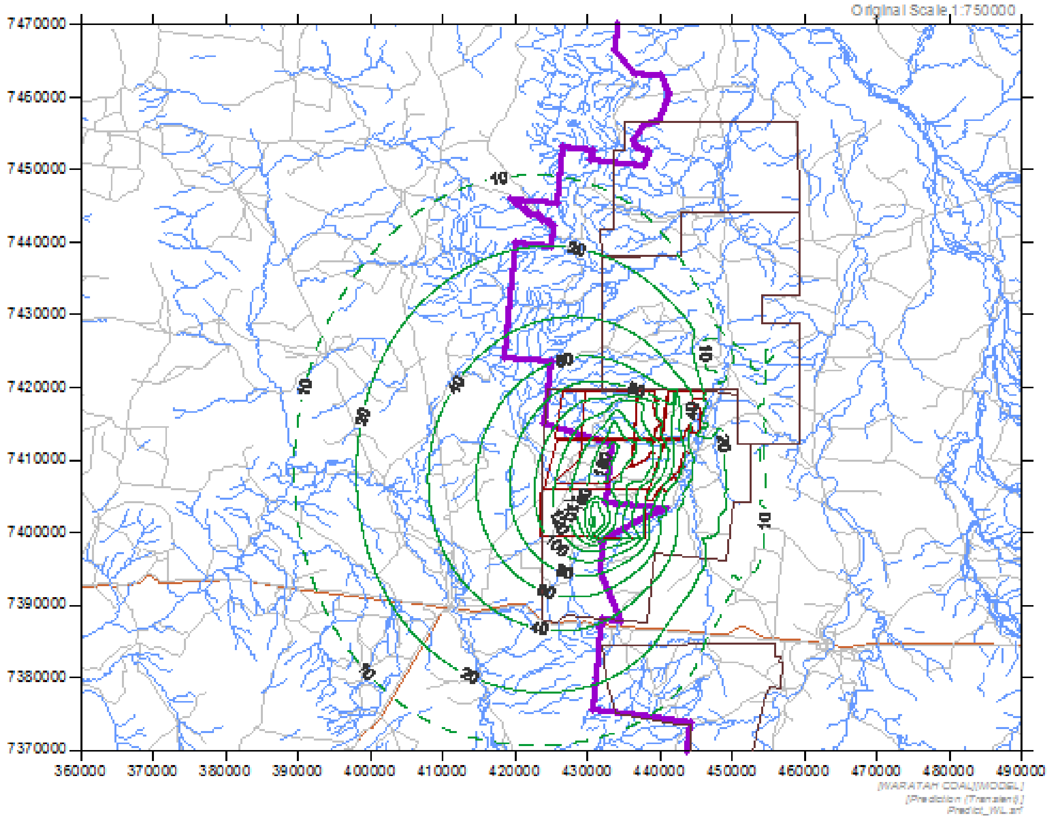
Drawdown in Layer 1 - simulation year 20



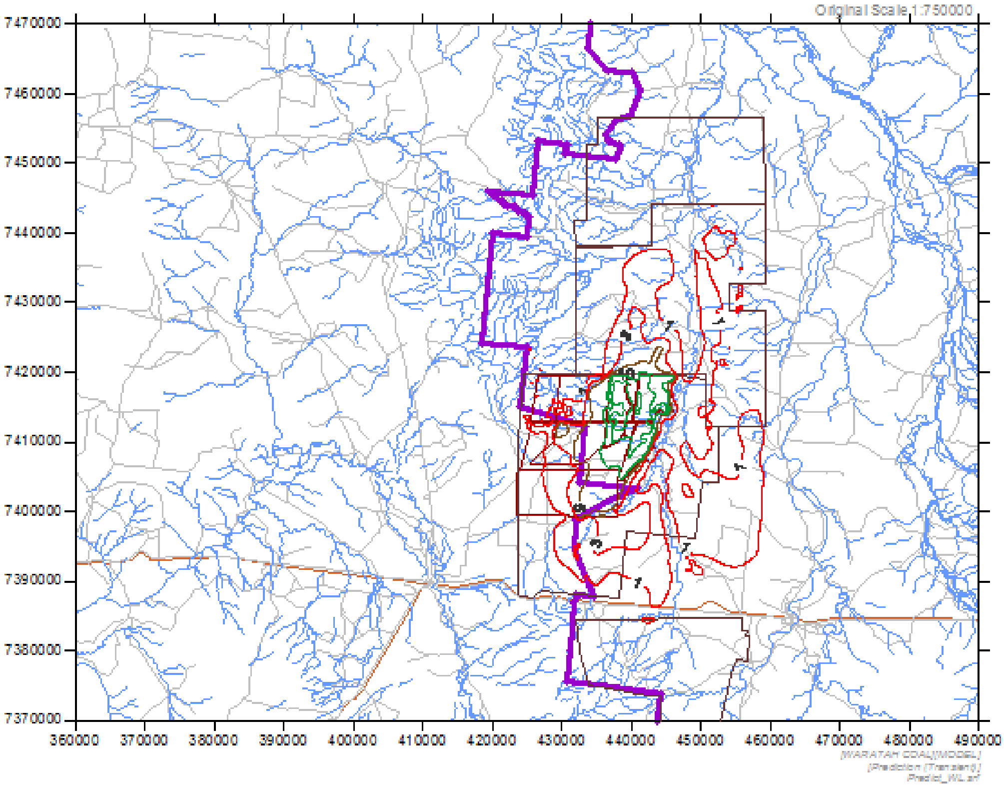
Drawdown in Layer 2 - simulation year 20



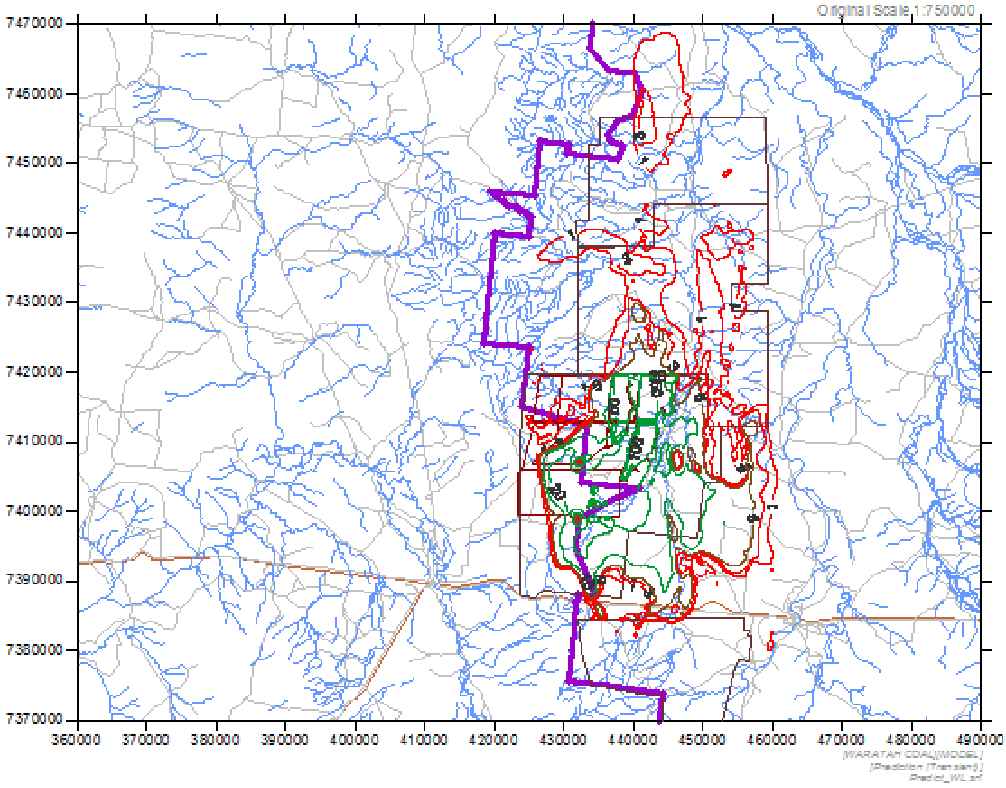
Drawdown in Layer 5 - simulation year 20



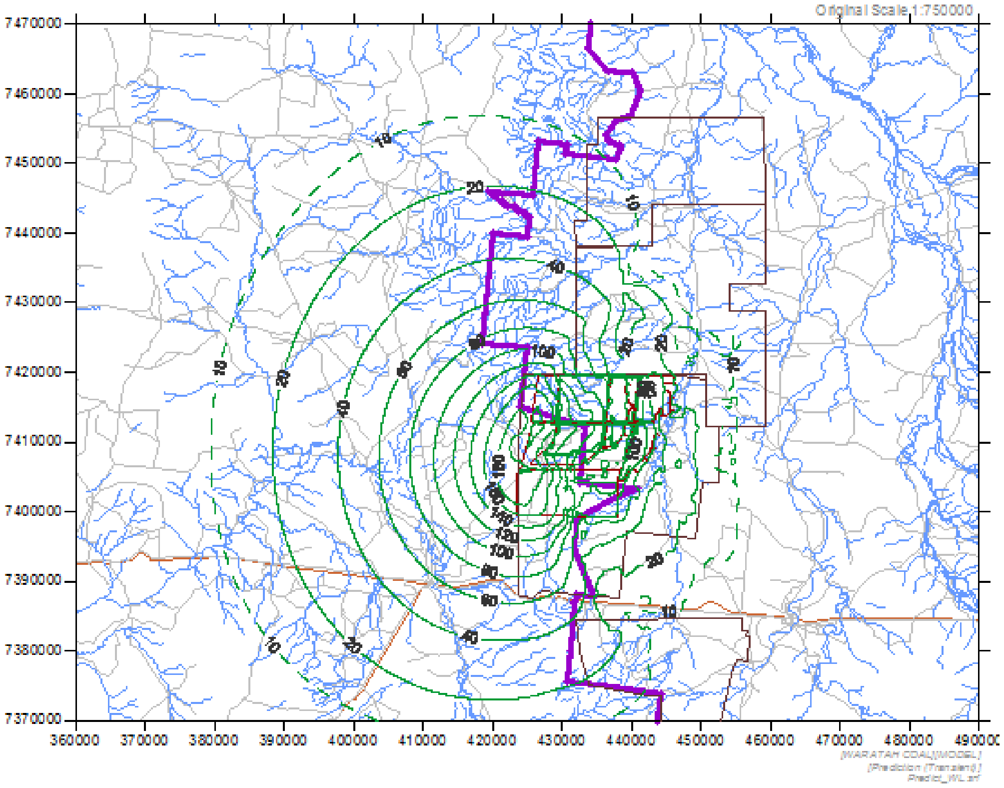
Drawdown in Layer 9 - simulation year 20



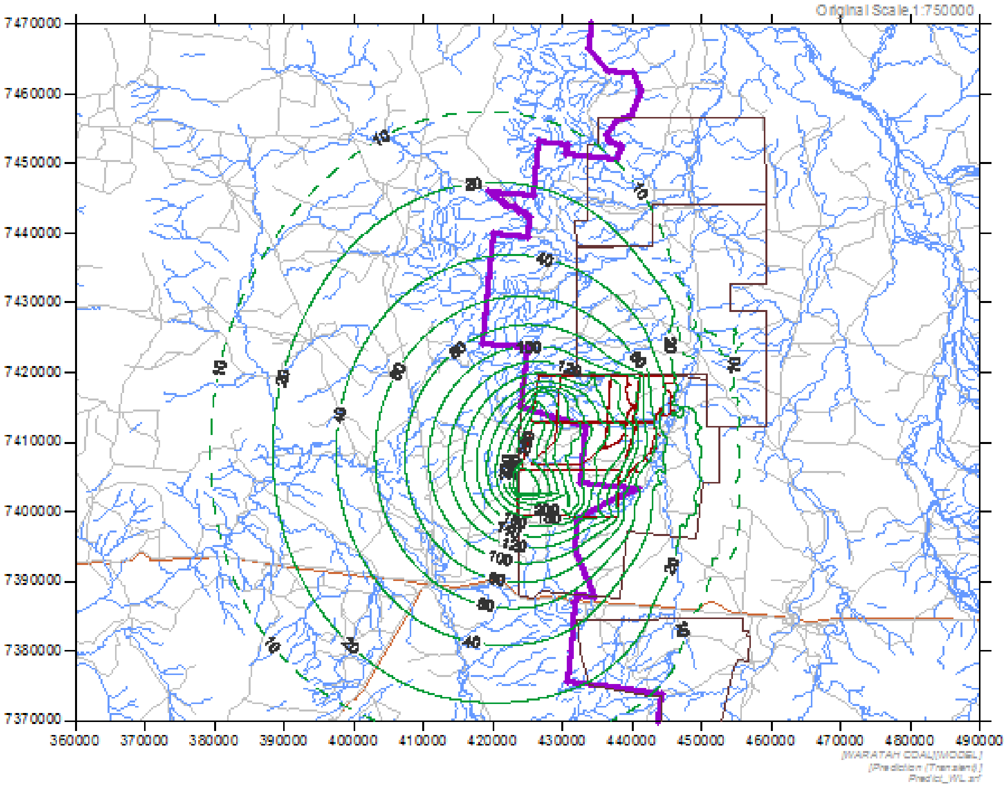
Drawdown in Layer 1 - simulation year 30



Drawdown in Layer 2 - simulation year 30



Drawdown in Layer 5 - simulation year 30



Drawdown in Layer 9 - simulation year 30

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