ABN: 69 107 169 102

Werris Creek Coal Pty Limited

GROUNDWATER IMPACT ASSESSMENT

for

Werris Creek Coal Mine Life of Mine Project

Prepared by

Robert Carr & Associates Pty Ltd t/as
RCA Australia

Specialist Consultant Studies Compendium
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Life of Mine Project

Prepared for: R.W. Corkery & Co. Pty Limited
1st Floor, 12 Dangar Road
PO Box 239
BROOKLYN NSW 2083

Tel: (02) 9985 8511
Fax: (02) 9985 8208
Email: brooklyn@rwcorkery.com

On behalf of: Werris Creek Coal Pty Limited
ABN: 69 107 169 103
PO Box 600
GUNNEDAH NSW 2380

Tel: (02) 6768 7071
Fax: (02) 6768 7072
Email: bcullen@whitehavencoal.com.au

Prepared by: Robert Carr & Associates Pty Ltd t/as RCA Australia
92 Hill St
CARRINGTON NSW 2294

Tel: (02) 4902 9200
Fax: (02) 4902 9299
Email: bobc@rca.com.au

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Glossary

AHD	Australian Height Datum.
ANZECC	Australian and New Zealand Environmental Conservation Council.
BOM	Bureau of Meteorology.
DoP	Department of Planning.
DNR	Department of Natural Resources.
DP	Deposited Plan.
DWE	Department of Water and Energy.
GPS	Global Position System.
ha	hectare, 10 000m^2.
km	kilometre, 1000m.
L	Litres.
L/s	Litres per second.
m	metre.
mg/L	milligram per litre.
ML/year	megalitres (1,000,000L) per year.
mm	millimetre, 0.001m.
mm/year	millimetres per year.
MGA	Map Grid Australia.
m^3/day	cubic metres per day.
m/s	metres per second.
NOW	NSW Office of Water
PQL	Practical Quantitation Limit.
RMS	Root Mean Squared.
SWL	Standing Water Level.
WAL	Water Allocation Licence.
WSP	Water Sharing Plan.
˚C	degrees Celsius.
%	percentage.

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EXECUTIVE SUMMARY

Werris Creek Coal Pty Limited ("the Proponent") proposes to extend the open cut operations of the approved Werris Creek Coal Mine to the north (LOM Project). The LOM Project represents mining of the entire Werris Creek outlier of the Greta coal measures, as defined by the sub-crop of the basal G Seam, and would increase the life of the mine by an estimated 15 to 20 years. The LOM Project also consists of modifying the layout of the existing open cut and overburden emplacement areas, removal of the partially inundated underground coal workings of the former Werris Creek Colliery and various changes or upgrades to mine site infrastructure. The LOM Project Site encompasses the existing ML 1563, as well as EL 5993 and EL 7422 and associated infrastructure and facilities.

This report presents a groundwater impact assessment ("the assessment") for the LOM Project. The assessment builds on a previous groundwater impact assessment completed as part of the initial development application for the Werris Creek Coal Mine (prior to the commencement of open cut mining operations) in 2004 and a subsequent application to modify the original development consent (DA 172-7-2004) for the Northern Extension (MOD5) in 2009. The impact of the LOM Project open cut area design on the local and regional groundwater table and creek systems, and inflows to the open cut itself, are considered.

The assessment was based on the collection and review of data from the operation of the existing Werris Creek Coal Mine, a review of data applicable to the LOM Project Site and surrounds, field testing of aquifer parameters, development of a new three dimensional groundwater model, calibration and validation of the model against observed conditions, modelling of the proposed open cut coal mine extension and mining operations and assessment of impact on the LOM Project Site and surrounds.

This groundwater impact assessment has considered the following.

- The impact(s) of the modified open cut coal mining operations on water table levels surrounding the LOM Project Site.
- The impact(s) of the modified open cut coal mining operations on groundwater bores surrounding the LOM Project Site.
- The impact(s) on base flow to the surrounding creek systems of Quipolly and Werris Creeks.
- The predicted groundwater inflow to the modified open cut mining area.
- Appropriate mitigation measures to compensate for any predicted impact(s) on groundwater level or availability arising from the proposed modification.

Groundwater modelling has predicted a drawdown of up to 0.1m within the LOM Project Site boundary with drawdown increasing to approximately 1.0m in the vicinity of LOM Project active pit area. Drawdown outside of the LOM Project Site boundary was predicted to be negligible at less than 0.1m. Reductions in saturated thickness are not predicted to occur above the trigger criteria of 15% at any of groundwater monitoring bores surrounding the LOM Project Site.

Previous modelling of the currently approved Werris Creek Coal Mine open cut mine plan, predicted a 0.5m drawdown to occur up to 2km from the limit of mining (RCA 2009). Monitoring of drawdown resulting from the current operations has determined that actual drawdown is lower than the predicted levels, indicating that the previous modelling provided an overestimation of water level impacts. This information has been used to validate the current model and support the conclusion presented in this assessment.

In the event that groundwater drawdown is in excess of the current predictions, is greater than 15% and is identified as being as a result of mining operations, and this results in a reduction in yield or availability of water to the owners/users of bores on properties that are not Project related, mitigation measures such as the deepening of bores to intercept groundwater lower in the aquifer to re-establish the previous yield would be undertaken by the Proponent. Available geological information for the Project Site and surrounds indicates that a suitable groundwater aquifer is present at depth within fractured rock.

Groundwater inflows into the open cut operations are predicted to reach a maximum of approximately 50ML/year. This assumes that dewatering of the underground workings has been completed prior to the commencement of the LOM Project (as dewatering was predicted to have occurred during mining within the current footprint based on the assessment for MOD5 of DA 172-7-2004. The rate of inflow into the open cut operations is predicted to be below the average evaporative rate for the area and subsequently, the open cut mining area is expected to generally remain dry. Variations in climatic conditions are likely to result in water make within the open cut operations from time to time, with this water either being pumped to one of the void water dams or groundwater storage cell dams which have been approved and constructed on the Project Site. Water from these dams would be preferentially used for dust suppression across the Project Site.

Modelling has predicted that there will be no groundwater related impact to either Quipolly Creek or Werris Creek and therefore no predicted impact to GDE’s. Further information regarding the identification of GDE’s is presented in the Biodiversity Impact Assessment prepared by Eco Logical Australia (Eco Logical, 2010).

In conclusion, the impacts of the proposed Werris Creek Coal Mine LOM Project upon the groundwater resources in the area are predicted to be localised and within seasonal variation. These predictions are consistent with observations of the groundwater table in response to current mining conditions.

1. INTRODUCTION

This report presents the groundwater impact assessment ("the assessment") undertaken for RW Corkery & Co Pty Limited on behalf of Werris Creek Coal Pty Limited ("the Proponent"), to assess the impacts of a proposed Werris Creek Coal Mine Life of Mine Project ("the LOM Project"). Werris Creek Coal Mine is an existing open cut coal mine located within a 679ha Mining Lease (ML 1653) approximately 4km south of the township of Werris Creek and 11km north of Quirindi, NSW (see **Figure 1**). Open cut coal mining at the Werris Creek Coal Mine commenced in 2005.

This report has been prepared to assist in the preparation of, and accompany, an *Environmental Assessment* for the LOM Project.

The objectives of the assessment were to:

- predict the impact(s) of the LOM Project on groundwater levels on the Project Site and surrounds;
- predict the impact(s) of the LOM Project on known groundwater bores surrounding the Project Site;
- assess the impact(s) of the LOM Project on groundwater base flow to the surrounding creek systems of Quipolly and Werris Creek;
- predict the extent of groundwater inflow to the open cut mining area; and
- consider and recommend appropriate mitigation measures as necessary.

The scope of work undertaken to fulfil these objectives included the following.

- Review of a geological model for the LOM Project Site and surrounds on the basis of:
    - a review of previous work undertaken by Robert Carr & Associates Pty Limited, "Groundwater Assessment, Werris Creek Coal Mine, July 2004" and "Groundwater Impact Assessment of the Werris Creek Coal Modification Project, March 2009;
    - pumping test data from two wells installed for the purpose of aquifer testing;
    - exploration bore drilling records; and
    - mapping of the existing underground workings prepared by the Proponent.
- A meeting with the NSW Office of Water (NOW) held on 1 July 2010.
- Discussions with the surface water consultant, GSS Environmental and biodiversity consultant, Eco Logical Australia.
- Assessment of the Director General's Requirements.
- A review of current legislation relating to groundwater management.

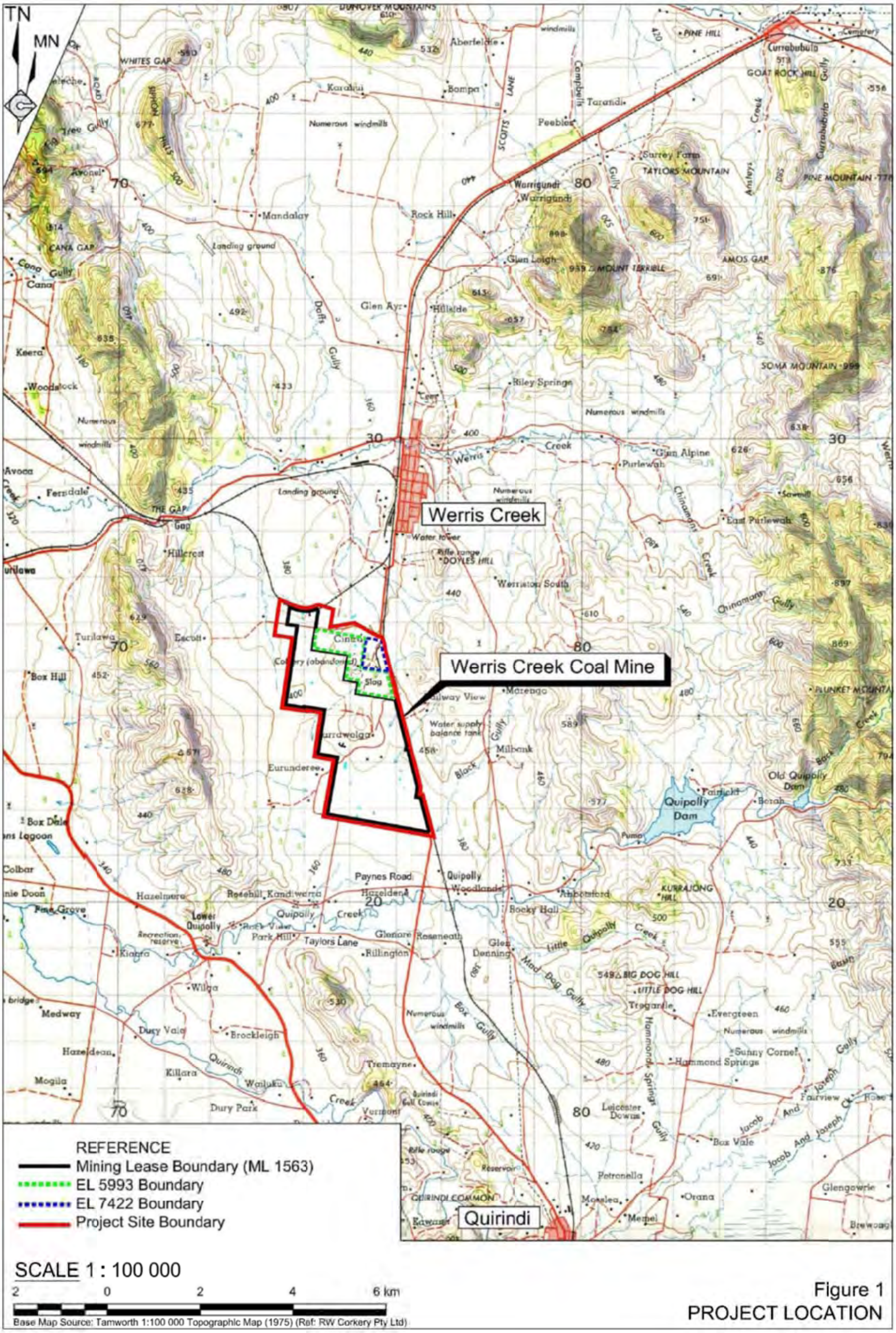


Figure 1
PROJECT LOCATION

- Evaluation of the hydrogeological model for the LOM Project Site and surrounds through the assessment and presentation of data from:
  - routine groundwater monitoring of 15 bores undertaken on a quarterly basis for the last five years for depth to water and water quality parameters, and annual independent review of monitoring results by GeoTerra;
  - evaluation of water level data from site water level measurements in 2004 and 2008;
  - bore records from the NOW database; and
  - water level data within the underground mine void.
- Groundwater modelling of the Project Site and surrounds and an assessment of impact from the LOM Project through:
  - development of a three dimensional hydrogeological model using Modflow;
  - calibration of that model against observed water levels;
  - validation of the model against current mining activities and observed water levels;
  - groundwater modelling to simulate impacts on the groundwater table from proposed mine sequences and at the completion of mining; and
  - prediction of mine inflows during operations and at the completion of mining.

2. SITE IDENTIFICATION AND DESCRIPTION OF THE PROJECT

2.1 SITE DESCRIPTION

The LOM Project Site includes the existing Werris Creek Coal Mine and associated facilities, the proposed open cut mine extension and associated additional facilities. The area encompasses the existing ML 1563 as well as EL 5993 and EL 7422 (see **Figure 1**).

Figure 2 presents the layout of the main features of the approved Werris Creek Coal Mine operations and an overview of the proposed operations associated with the LOM Project.

2.2 DESCRIPTION OF THE LOM PROJECT

The LOM Project, if approved, would provide for a northerly continuation of the Werris Creek Coal Mine, increasing the projected mine life by an estimated 15 to 20 years and involve the following activities (the locations of which are shown on **Figure 2**).

- The northerly extension of the approved open cut. The proposed extent of the open cut represents mining of the entire Werris Creek outlier of the Great Greta coal measures, as defined by the sub-crop of the basal G Seam.

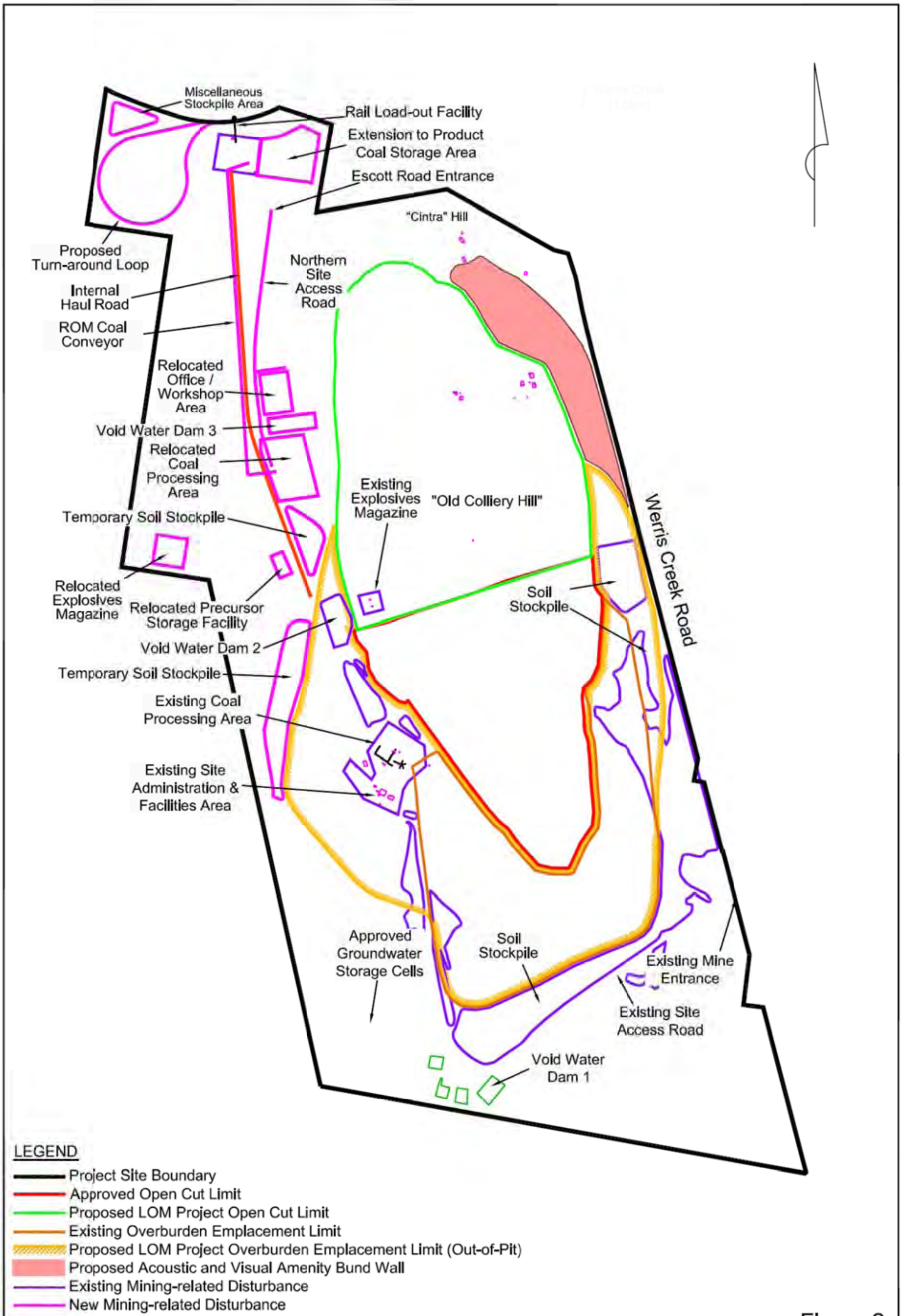


Figure 2
PROJECT SITE LAYOUT

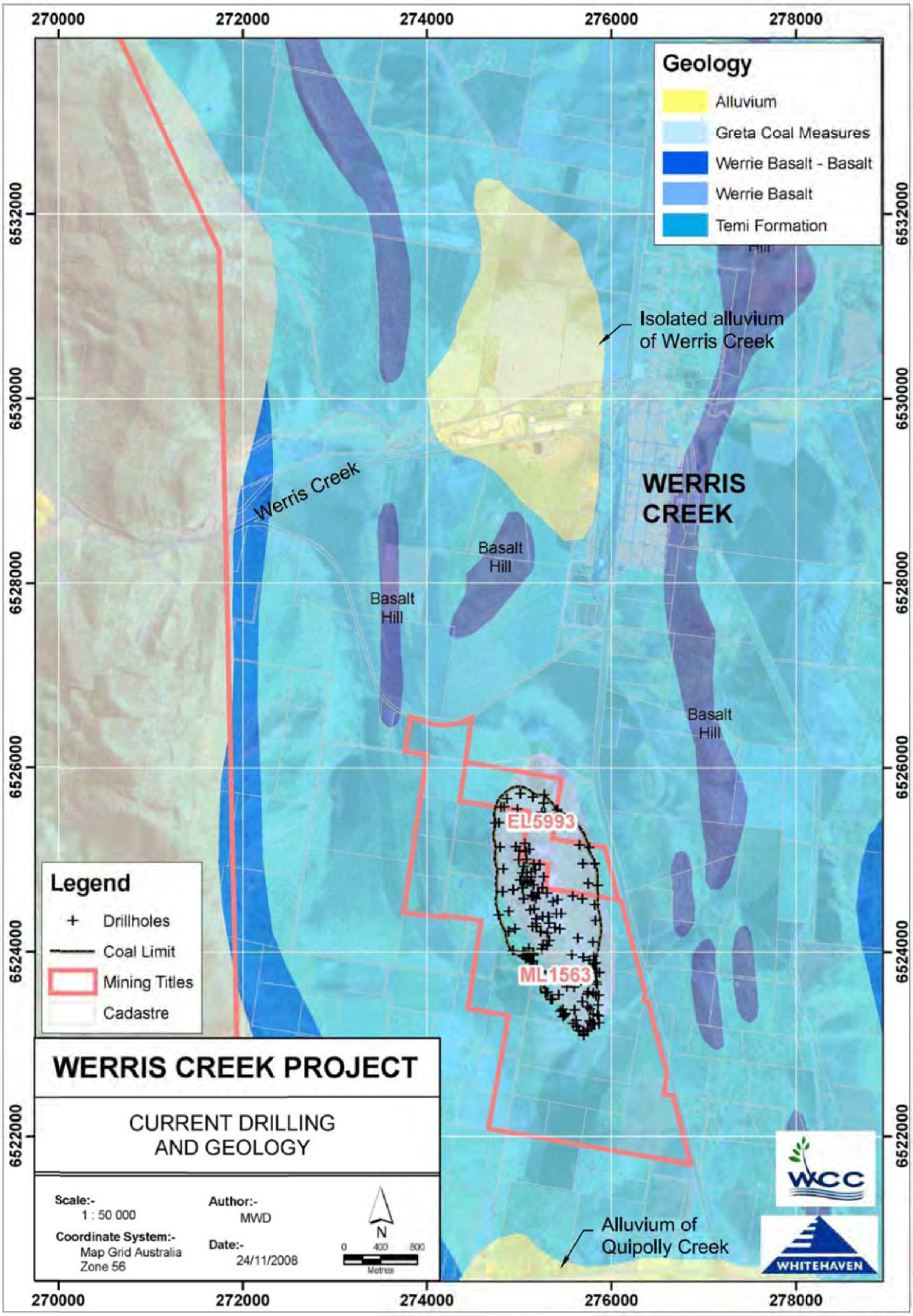
- Extension of the out-of-pit overburden emplacement. The additional volume of overburden removed from the open cut would be placed over the current footprint of the Coal Processing Area and Site Administration and Facilities Area (out-of-pit emplacement) and extend north over the completed sections of the open cut (in-pit emplacement). In order to attenuate noise impacts and screen the operation visually from Werris Creek, the overburden emplacement would also extend around the eastern and north eastern perimeter of the open cut (referred to as the Acoustic and Visual Amenity Bund).
- Relocation of coal processing infrastructure (Coal Processing Area). The primary reason for relocating the Coal Processing Area would be to minimise the haul distance between the open cut and the coal processing infrastructure. A relocation of the Coal Processing Area would also be required to allow for a westerly extension of the out-of-pit overburden emplacement (to increase storage capacity). The relocated coal processing area would have an increased ROM coal stockpile (ROM Coal Pad) capacity of 200 000t.
- Production of up to 2.5Mtpa of thermal and Pulverised Coal Injection (PCI) coal for the domestic and international markets. To improve operational flexibility, an increase in the approved hours of operation to 24 hours, seven days per week is proposed.
- An increase in the road transport of coal to domestic markets to 100 000tpa (from 50 000tpa) to meet the needs of local customers for low ash coal.
- Modification to, or relocation of, mine infrastructure including:
  - an increase to the storage capacity of the Product Coal Stockpile Area;
  - construction of a second feed point to the Rail Load-out Facility to allow for product separation and reduced inter-product contamination;
  - relocation of the coal processing infrastructure and site offices and workshops;
  - construction of a new entrance to the Project Site off Escott Road; and
  - construction of a rail loop which would take off from the Werris Creek Rail Siding to the immediate west of the Rail Load-out Facility.
- Continued dewatering of the underground workings of the former Werris Creek Colliery (approved under DA 172-7-2004) to enable open cut mining through these workings.
- Construction of a new Void Water Dam for the storage of water which accumulates in the open cut.

3. GROUNDWATER LEGISLATION

An evaluation of groundwater legislation that is relevant to the LOM Project has been completed. The legislation (and other regulatory instruments) that have been considered in the preparation of this document are outlined below. A summary of the relevant application of the legislation to the LOMJ Project is also provided.

- *Guidelines for Fresh and Marine Water Quality* (ANZECC 2000). These guidelines were adopted for the evaluation of potential impacts on groundwater quality as a consequence of the LOM Project. The guidelines are endorsed by the Department of Environment, Climate Change and Water (DECCW).
- State Groundwater Policy documents, NOW and the *Water Management Act 2000*. Groundwater extraction or groundwater interference at the Project Site is currently regulated under Part 5 of the *Water Act 1912*. Revisions are currently being made within NOW to incorporate management of groundwater across NSW within the *Water Management Act 2000*. When these changes are enforced, the LOM Project would be regulated under this Act.
- *The Water Sharing Plan (WSP) for the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources 2004*. This WSP identifies and regulates groundwater sources within the alluvium aquifer of each water source. Quipolly Creek is located approximately 2.6km from the LOM Project Site boundary and is situated within the Quirindi Creek water source. The water source was identified to have a highly variable flow with a 50^{th} percentile flow volume of 2ML/day. The identified alluvium aquifer of Quipolly Creek is located 2.6km to the south of the LOM Project Site boundary as shown on **Figure 3**.

  A conceptual hydrogeological regime for the LOM Project Site and surrounds is presented in Section 6.0 of this report. It shows that the impacts related to the LOM Project would be limited to within the hard rock aquifer with minimal connection to the alluvium identified to the south of the site. On this basis, the proposed activities and impacts are not regulated under the WSP.
- Werris Creek is located 3.1 km to the north of the LOM Project Site. Werris Creek is an ephemeral creek with minimal associated alluvium as shown on **Figure 3**. Groundwater of the Werris Creek system is not regulated through a WSP.
- *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DECCW). These guidelines have been utilised in the sampling of groundwater for water quality analysis undertaken for the LOM Project**.**
- *NSW Groundwater Dependent Ecosystem Policy* (formerly the Department of Water and Energy, now the NSW Office of Water (NOW)).



Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

Figure 3
PROJECT SITE AND REGIONAL GEOLOGY

4. BACKGROUND INFORMATION

Prior to the commencement of open cut mining operations at the Werris Creek Coal Mine in 2005, an *Environmental Impact Statement* was completed and included the following *Groundwater Assessment*.

- *Groundwater Assessment, Werris Creek Coal Mine, March 2004*, prepared by Robert Carr & Associates Pty Ltd (RCA 2004).

In 2009, a modification (MOD5) to the subsequently approved Werris Creek Coal Mine (DA 172-7-2004) was approved to allow additional disturbance of approximately 21 hectares within the existing mining lease (ML 1563) including mining through and dewatering of a portion of the underground workings of the former Werris Creek Colliery (known as the Northern Extension). The water removed from the underground workings is stored within a groundwater storage cell that has been constructed in the southwestern corner of the existing mine site with this water being preferentially used for dust suppression. The 2009 modification proposal included the following *Groundwater Assessment*.

- *Groundwater Assessment, Werris Creek Coal Mine, March 2009*, prepared by Robert Carr & Associates Pty Ltd (RCA 2009).

These previous groundwater assessments were reviewed and relevant data included in the preparation of the assessment for the LOM Project.

Also reviewed in the preparation of this assessment were the following documents.

- *Werris Creek Coal Mine, Surface Water and Groundwater Monitoring 2006/2007, May 2007*, prepared by GeoTerra Pty Ltd (GeoTerra 2007).
- *Werris Creek Coal Mine, Surface Water and Groundwater Monitoring 2007/2008, April 2008*, prepared by GeoTerra Pty Ltd (GeoTerra 2008).
- *Werris Creek Coal Mine, Surface Water and Groundwater Monitoring 2008/2009, April 2009*, prepared by GeoTerra Pty Ltd (GeoTerra 2009).
- *Werris Creek Coal Mine, Surface Water and Groundwater Monitoring 2009/2010, May 2010* prepared by GeoTerra Pty Ltd (GeoTerra 2010).

The RCA (2004) report included development of a geological model from which a three dimensional hydrogeological model was developed. This hydrogeological model formed the basis for the modelling undertaken for the Northern Extension (MOD5) presented in RCA (2009). The modelling of RCA (2004) (for the original open cut operations) predicted a groundwater drawdown of up to 11m at the mine site boundary and up to 2m within 5km of the then proposed extent of mining. A reduction in saturated thickness was identified in only three bores (on the “Eurunderee” [4.9%], “Railway View” [0.6%] and “Hillview” [0.9%] properties), with none above the 15% reduction criteria considered to be outside the scope of natural variation. All three of these properties that include these bores have since been acquired by the Proponent and are now considered Project related.

The RCA (2009) report predicted a drawdown of up to 0.5m, up to 2km from the open cut and drawdown of approximately 20m in the vicinity of the underground workings to the north-east of the Northern Extension open cut footprint. A reduction in saturated thickness above the adopted trigger criteria (15% reduction in the saturated thickness) was predicted for bores located on the ‘Old Colliery’, ‘Preston Park‘ and ’Eurunderee‘ properties. Notably, all three properties are now owned by the Proponent and therefore the impact on groundwater availability was considered acceptable. Saturated thickness reductions in bores on all other properties were predicted to be negligible and within the naturally occurring variation.

5. DIRECTOR GENERAL'S REQUIREMENTS

5.1 INTRODUCTION

Table 1 paraphrases the requirements of the Director General and other government agencies relating to the assessment of impacts to groundwater for the LOM Project. **Table 1** also summaries where each requirement is addressed in this document.

Table 1
Director General's Requirements for the Groundwater Assessment for the LOM Project

Page 1 of 4

Government Agency	Paraphrased Requirement	Section(s) Addressed in this Assessment
Department of Planning	The Environmental Assessment of the project must include: • detailed modelling and assessment of potential impacts on : - the quality and quantity of existing surface water and groundwater resources; - affected licensed water users and basic landholder rights; - the riparian, ecological, geomorphological hydrological values of watercourses: and - impacts to agricultural lands, • a detailed description of measures to mitigate surface water and groundwater impacts.	**10.3 to 10.6** **10.3.1** **10.3.3 & 10.3.4** **10.3** **10.5 & 11.1**
NSW Office of Water	NOW supports a full hydro-geological assessment for the mine site. This includes further modelling and work to quantify predictions of impact associated with groundwater levels in the three aquifers, groundwater levels and availability within bores surrounding the Project Site and groundwater in-flow, mine dewatering and surface management of groundwater captured within the open cut.	**10**
	The current monitoring bore network will need to be expanded for the Life of Mine project. Monitoring bores will need to penetrate the full aquifer sequences to the base of the coal measures, At present, there are no monitoring bore sites where there are multiple aquifer installations at each site. They do not have fully penetrating bores both up gradient and down gradient of the aquifer flow direction. It is important the EA outlines all monitoring bores on site and includes all information associated with these monitoring bores, including water quality data and all Form A's are submitted to NOW	**11.2**
	Attention to detail should occur in the EA, in particular to mine cross-sections showing geological layers and hydrogeological layers in the area. It is important from a review perspective that the same colour is utilised for a particular aquifer when representing these on a cross-section or diagram, and the colour does not vary between diagrams and cross-sections.	**8** **Figure 5 to Figure 11**
	•	

Table 1 (cont'd)
Director General's Requirements for the Groundwater Assessment for the LOM Project

Page 2 of 4

Government Agency	Paraphrased Requirement	Section(s) Addressed in this Assessment
NSW Office of Water	The assessment is required to identify groundwater issues and potential degradation to the groundwater source and provide the following:	
	• Details of the predicted highest groundwater table at the development site.	**6**
	• Details of any works likely to intercept, connect with or infiltrate the groundwater sources.	**10**
	• Details of any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes.	**10**
	• Describe the flow directions and rates and the physical and chemical characteristics of the groundwater source.	**6**
	• Details of the predicted impacts of any final landform on the groundwater regime.	**10.3.2**
	• Details of the existing groundwater users within the area (including the environment) and include details of any potential impacts on these users.	**6.6** & **10**
	• Assessment of the quality of the groundwater for the local groundwater catchment.	**6.1.2**
	• Details of how the proposed development will not potentially diminish the current quality of groundwater, both in the short and long term.	**10**
	• Details on preventing groundwater pollution so that remediation is not required.	**11.1**
	• Details on protective measures for any groundwater dependent ecosystems (GDEs).	**10.3.4, 10.5 & 11.1**
	• Details of proposed methods of the disposal of waste water and approval from the relevant authority.	**N/A** (No waste water discharge proposed)
	• Assessment of the need for an Acid Sulfate Management Plan (prepared in accordance with ASSMAC guidelines).	**N/A** (Project Site is not within an ASS area)
	• Assessment of the potential for saline intrusion of the groundwater and measures to prevent such intrusion into the groundwater aquifer.	**N/A** (Project Site is not within a coastal area).
	• Details of the results of any models or predictive tools used.	**7, 8 & 9**

Table 1 (cont'd)
Director General's Requirements for the Groundwater Assessment for the LOM Project

Page 3 of 4

Government Agency	Paraphrased Requirement	Section(s) Addressed in this Assessment
NSW Office of Water (Cont'd)	Where potential impacts are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:	
	• Details of any proposed monitoring programs, including water levels and quality data.	**11.2**
	• Reporting procedures for any monitoring program including mechanism for transfer of information.	**11.1**
	• An assessment of any groundwater source/aquifer that may be sterilised as a consequence of the proposal.	**N/A**
	• Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category).	**10.2**
	• Description of the remedial measures or contingency plans proposed.	**10.5 & 11.1**
	• Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.	**N/A**
	Regulations and Legislative Requirements The assessment is required to take into account the requirements of the following legislation (administered by NOW), as applicable: • Water Act 1912 • Water Management Act 2000 (WMA) In particular, proposals and management plans should be consistent with the Objects (s.3) and Water Management Principles (s.5) of the WMA.	**3**
	If the proposal is within a gazetted WSP area the assessment is required to demonstrate consistency with the rules of the WSP.	**N/A**
	The assessment is required to take into account the following NSW Government policies, as applicable: • NSW Groundwater Policy Framework Document – General • NSW Groundwater Quantity Management Policy • NSW Groundwater Quality Protection Policy • NSW State Groundwater Dependent Ecosystem Policy • NSW Safe Rivers and Estuaries Policy • NSW Sand and Gravel Extraction Policy for Non-Tidal Rivers • NSW Wetlands Management Policy • NSW Farm Dams Policy • NSW Weirs Policy • NSW Coastal Policy In addition assessments should consider the following strategies: • NSW Salinity Strategy • NSW Water Conservation Strategy	**3**

Table 1 (cont'd)
Director General's Requirements for the Groundwater Assessment for the LOM Project
Page 4 of 4

Government Agency	Paraphrased Requirement	Section(s) Addressed in this Assessment
NSW Office of Water (Cont'd)	The mine is located in the Gunnedah Basin in an area administered by the *Water Act 1912*. The area is also embargoed for any further applications for Part 5 water licences under the NSW Inland Groundwater shortage Zones order No. 2 2008 (22 December 2008).	**12**
	A licence under Part 5 of the Water Act 1912 is required to authorise any works which intercept and take groundwater and for any monitoring bores. Licences must be obtained under Part 5 for incidental water (i.e. seepage into underground or open-cut works), dewatering bores, mining extraction works, production and monitoring piezometers prior to their installation.	**12**
	A licence for the extraction, and use for industrial purposes of groundwater, generated through the mining operations will be required for the period of the mining operations, including incidental water and underground void dewatering in addition to the current licence for 50ML/year already owned by the mine. The entitlement of any licence issued will be consistent with the maximum volume of water predicted as inflows as a volumetric entitlement. The company is required to obtain the appropriate licensing for the predicted amount of water inflowing into the pit.	**12**
	All current water licensing issues must be finalised by Werris Creek Coal Pty Ltd in a timely manner including obtaining a water licence for impacts on the Quipolly Creek alluvium aquifer as a result of mining activities.	**12**
	There is currently an embargo on any further applications for Part 5 Water Licences for the 'New South Wales Inland Groundwater Shortage Zones Order No. 2 2008' for areas not covered by a water sharing plan.	**12**

6. SITE CONDITIONS AND SURROUNDING ENVIRONMENT

6.1 TOPOGRAPHY

The LOM Project Site grades from 390m AHD at "Cintra" on the proposed northern boundary of open cut mining to a radial hill feature with maximum elevation of 445m AHD in the midsection of the Project Site ("Old Colliery" Hill) and then down to 355m AHD towards Quipolly Creek. The topography of the LOM Project Site as shown on the 1:25,000 topographic sheet is reproduced in **Figure 4**.

The LOM Project Site is situated in an elevated topographical region within a wide valley formation. The topography to the east of the LOM Project Site comprises a broken ridge line. To the west the topography declines through a valley before rising steeply to a maximum elevation of 638m AHD. Quipolly Creek is located to the south of the LOM Project Site and flows in a westerly direction. Werris Creek is located to the north of the LOM Project Site, and flows in a westerly direction (**Figure 4**).

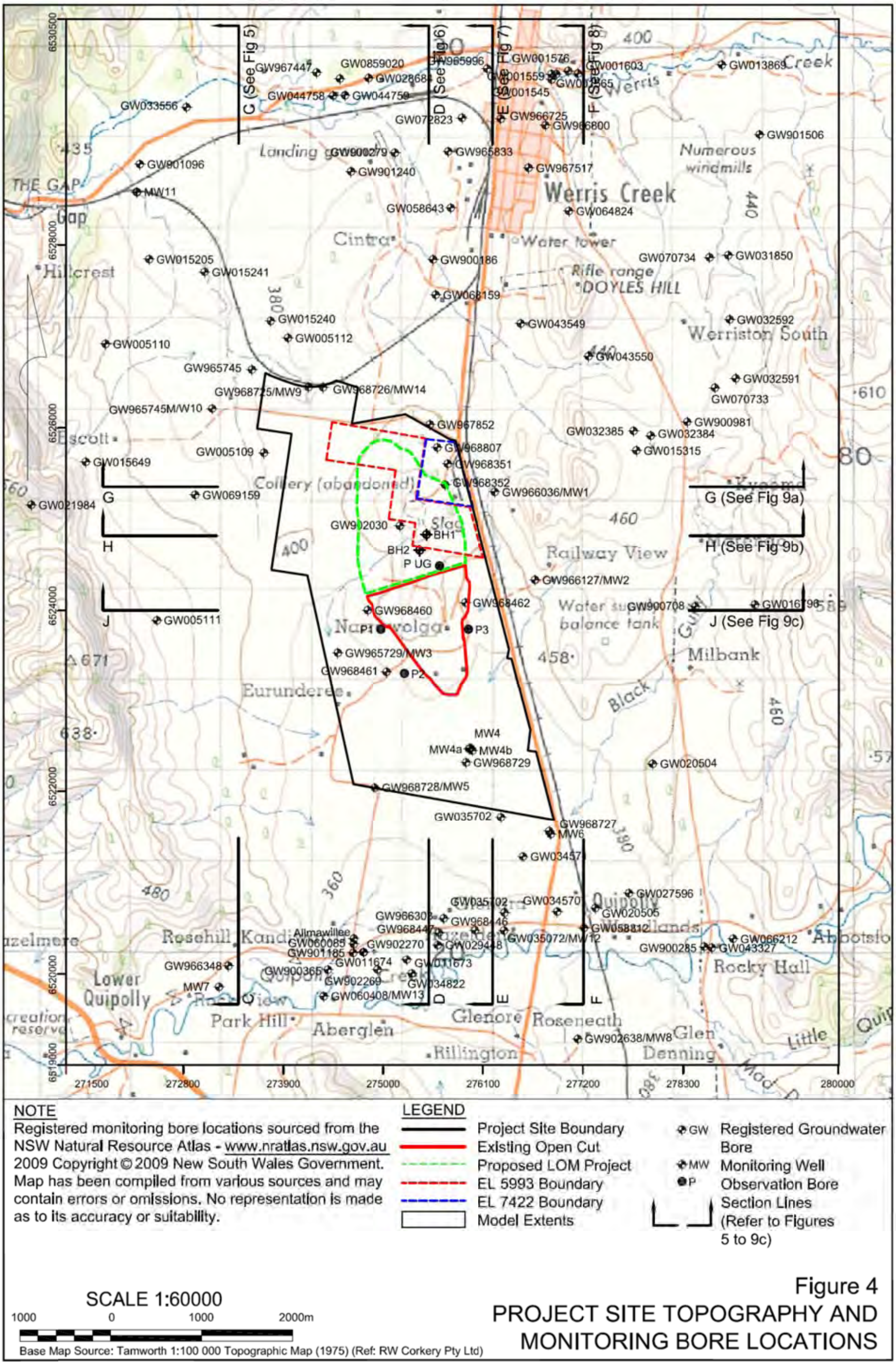


Figure 4
PROJECT SITE TOPOGRAPHY AND MONITORING BORE LOCATIONS

6.3 LOCAL METEOROLOGY

Information on local rainfall was sourced from the Quirindi Bureau of Meteorology Station No. 055049, located approximately 11km to the south-southwest at an elevation of 390m AHD. The total average annual rainfall for the area is 683mm/year.

Information on evaporative rates was sourced from the Tamworth Bureau of Meteorology Station No. 055049, located approximately 40km to the north of the Project Site. The total average evaporation for the area is 1 976mm/year, i.e., almost three times the average annual rainfall.

6.4 STRATIGRAPHY

The geological description and mining history for the area in which the LOM Project Site is situated was provided by Mark Dawson, Whitehaven Coal Limited Group Geologist. An extract of this information is presented below.

The Werrie Basin is a structural basin containing Permian sedimentary and volcanic rocks that unconformably overly Middle Cambrian (Cawood 1980) to earliest Permian (Roberts et al 2006) basement of the Tamworth Belt, Southern New England Orogen (Gilligan and Brownlow 1988). Briefly, the Werrie Basin consists of the basal terrestrial Temi Formation that comprises of up to ~220m of mudstones, sandstones, pebble conglomerates and minor felsic to intermediate volcanics and coal (Roberts et al 2005, Hanlon 1948). Overlying the Temi Formation are a series mafic to intermediate volcanics and associated intrusives (Werrie Basalt and Warrigundi Igneous Complex) up to 2km thick that were deposited in both marine and terrestrial regimes (Carey 1935 Hanlon; Hanlon 1947). The Werrie Basalt is unconformably overlain by late Early Permian coal-bearing sequence of the Willow Tree Formation (Oversby 1971; Pratt 1996) (herein renamed the Greta Coal Measures - Werris Creek outlier). Conformably overlying the Willow Tree Formation is the early Late Permian marine conglomerates and sandstones of the Borambil Creek Formation. This unit consists of basal, poorly-sorted conglomerates and diamictites with sandy and fosilliferous horizons (Hanlon 1948). The youngest unit in the Werrie Basin is the Late Permian Toll Bar Formation. This unit is both terrestrial and marine containing sandstone, siltstone, mudstone and coal with localised pods of limestone (Hanlon 1948).

To the west of the Werrie Basin lies the Rossmore Formation comprising of Carboniferous aged conglomerates and sandstones, siltstones and mudstones. This formation forms a north south trending ridgeline.

The general stratigraphic sequence in the vicinity of the LOM Project Site is presented in **Table 2** with the strata listed from youngest to oldest.

The occurrence of each of the rock or sediment types listed in **Table 2** are shown on **Figure 3**. A summary of the local geology and stratigraphy is as follows.

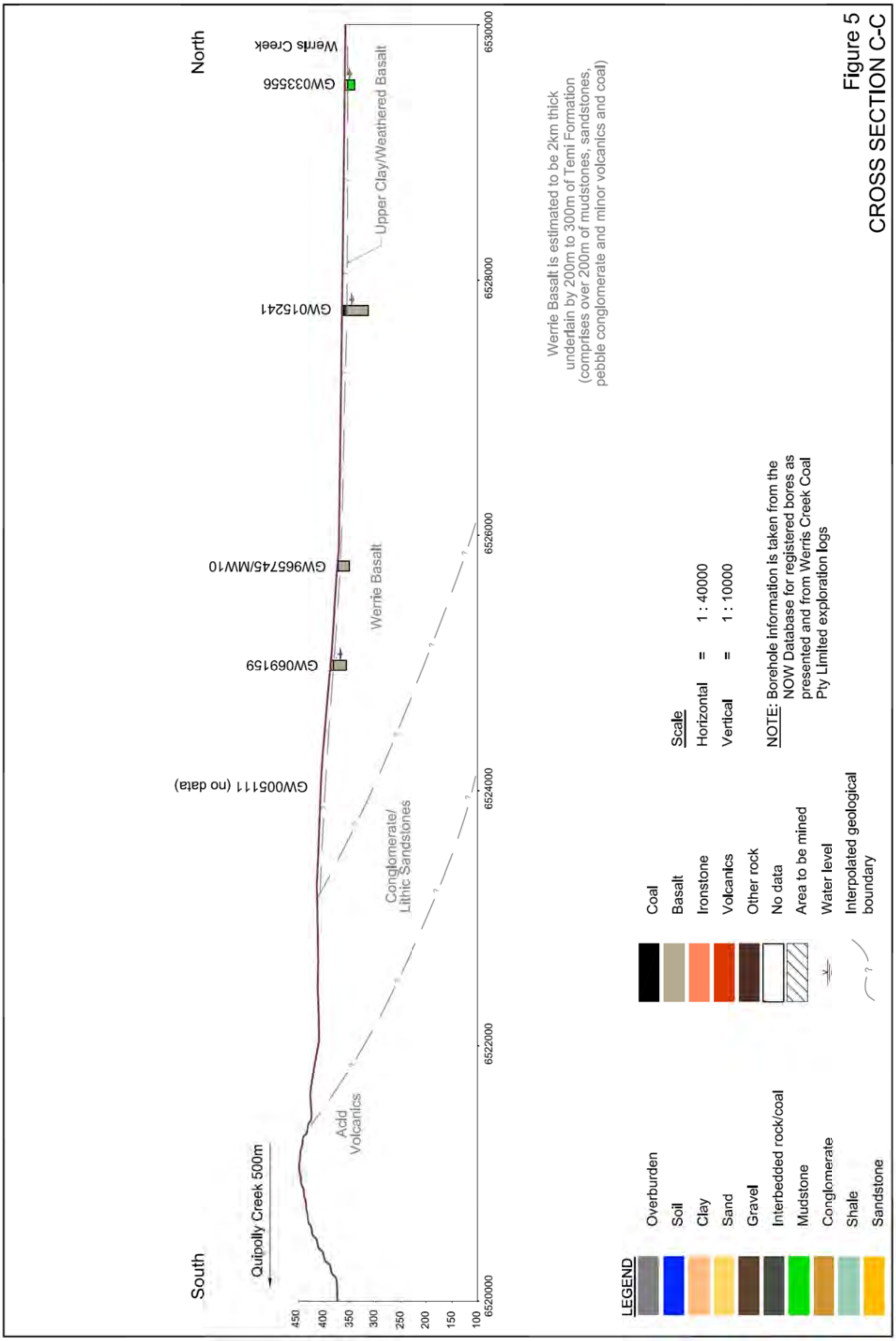
- The coal measures lie approximately 2.5km to the east of the Mooki Thrust Fault. They have been structurally deformed to form an intact closed basin (syncline) that is wholly surrounded by the Werrie Basalt. The upper most weathered section of the basalt has weathered to clay-like consistency.
- The Warrigundi intrusives form a series of north south oriented acid volcanics located to the east and north of the coal measures.

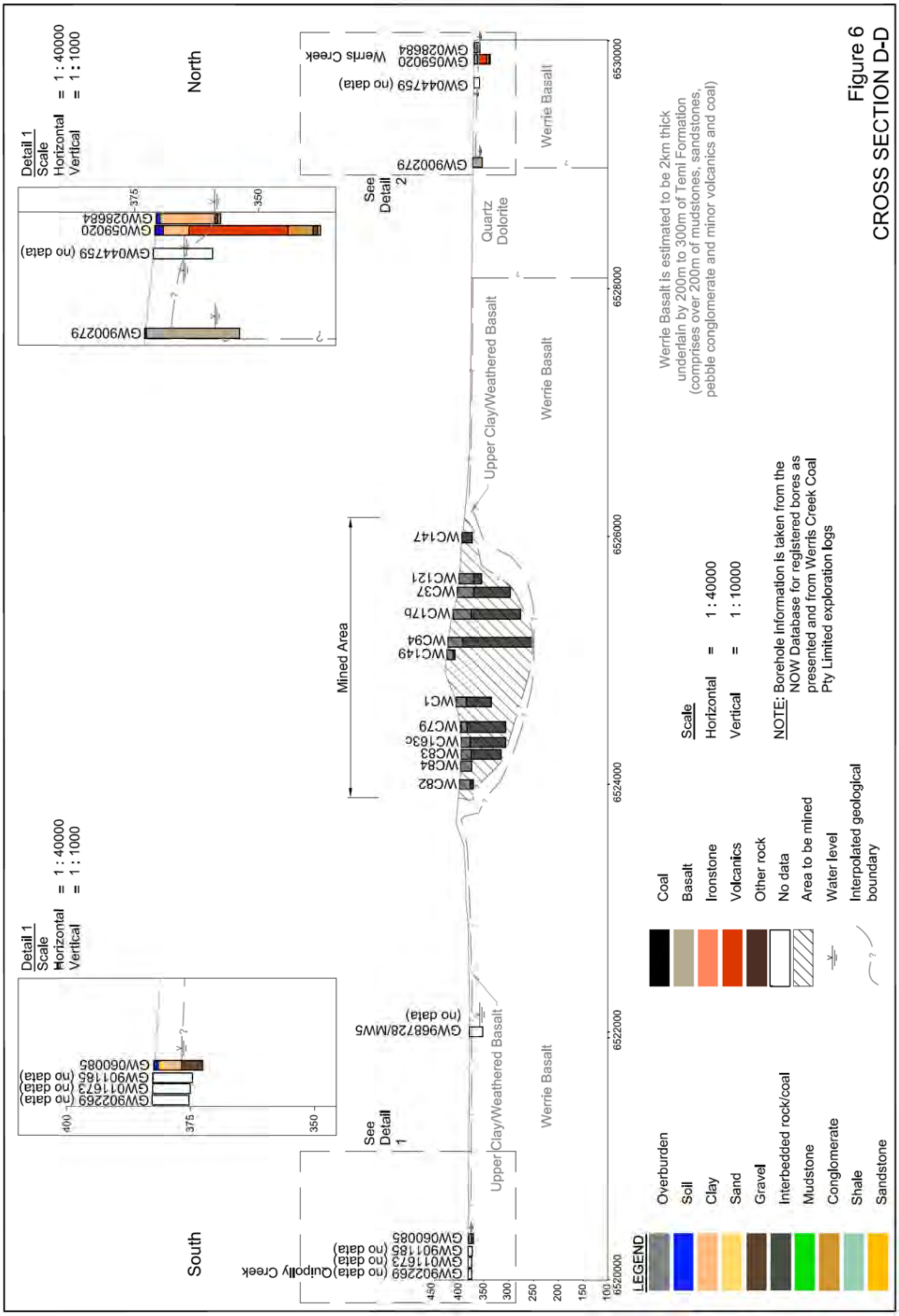
Table 2
General Stratigraphic Sequence

Age	Rock/Sediment Type	Strata Type	Occurrence
Quaternary	Unconsolidated sediments	Sands and gravel	Along Quipolly Creek 2.6km from the site
Permian	Coal Measures	Eight coal seams and interburden strata of sandstones/siltstone and shales	The proposed open cut mine site covers most of this strata
Permian	Werrie Basalt	Basaltic lava flows with a significant weathered profile of clay. Underlying the coal measures, the weathered clays of the upper basalt profile act to form a clay aquitard providing confinement/semi confinement of the basalt aquifer.	Directly underneath the coal measures and completely surrounding them in all directions in most of the valley and lower lying areas
Permian	Warrigundi Igneous Complex	Andesite, dacite and rhyolite	This occurs in a limited zone and forms the ridges immediately to the east of the site and also occurs to the north
Permian	Temi Formation	Conglomerates and lithic sandstones	These strata form the dominant North-south trending ridges to the east
Carboniferous	Rossmore Formation	Conglomerates and sandstones, siltstones and mudstones	These strata form the dominant North-south trending ridges to the west

- Available data shows that north-south oriented faulting occurs in the vicinity and possibly within the coal measures. North-south trending graben and half graben features are identified within the mining area and show normal faulting. Typical displacements of the grabens are in the order of five to ten metres. Igneous dykes have been recorded in the underground workings, however, no intrusions have been intersected during open cut mining to date (Dawson *pers com*, July 2010).
- The type of stratigraphy, combined with structural elements such as faulting and folding (which can disrupt stratigraphy over short distances) and existence of intrusive bodies are reasonable explanations for variances in water levels seen in the current data set.
- The coal measures have in part been previously mined by underground methods in the north of the proposed open cut mine footprint. The base RL of these workings extends from 390m AHD in the northwest to 280m AHD in the southwest.

A series of cross-sections representing the geology at the LOM Project Site and surrounds are presented in **Figures 5** to **10**. The cross-sections have been developed from bore data registered with NOW and from exploratory bore data from the Project Site.


South
North
Quipolly Creek 500m
Werris Creek
GW033556
GW015241
GW965745/MW10
GW069159
GW005111 (no data)
Upper Clay/Weathered Basalt
Werrie Basalt
Conglomerate/ Lithic Sandstones
Acid Volcanics
450
400
350
300
250
200
150
100
6520000
6522000
6524000
6526000
6528000
6530000
Werrie Basalt is estimated to be 2km thick underlain by 200m to 300m of Temi Formation (comprises over 200m of mudstones, sandstones, pebble conglomerate and minor volcanics and coal)
LEGEND
Overburden
Soil
Clay
Sand
Gravel
Interbedded rock/coal
Mudstone
Conglomerate
Shale
Sandstone
Coal
Basalt
Ironstone
Volcanics
Other rock
No data
Area to be mined
Water level
Interpolated geological boundary
Scale
Horizontal = 1 : 40000
Vertical = 1 : 10000
NOTE: Borehole information is taken from the NOW Database for registered bores as presented and from Werris Creek Coal Pty Limited exploration logs
Figure 5
CROSS SECTION C-C


South
North
Detail 1
Scale
Horizontal = 1 : 40000
Vertical = 1 : 1000
See Detail 1
See Detail 2
Quipolly Creek
Werris Creek
GW902269 (no data)
GW011673 (no data)
GW901185 (no data)
GW060085
GW968728/MW5 (no data)
GW900279
GW044759 (no data)
GW059020
GW028684
WC82
WC84
WC83
WC163c
WC79
WC1
WC149
WC94
WC17b
WC37
WC121
WC147
Mined Area
Upper Clay/Weathered Basalt
Werrie Basalt
Quartz Dolorite
Werrie Basalt is estimated to be 2km thick underlain by 200m to 300m of Temi Formation (comprises over 200m of mudstones, sandstones, pebble conglomerate and minor volcanics and coal)
LEGEND
Overburden
Soil
Clay
Sand
Gravel
Interbedded rock/coal
Mudstone
Conglomerate
Shale
Sandstone
Coal
Basalt
Ironstone
Volcanics
Other rock
No data
Area to be mined
Water level
Interpolated geological boundary
Scale
Horizontal = 1 : 40000
Vertical = 1 : 10000
NOTE: Borehole information is taken from the NOW Database for registered bores as presented and from Werris Creek Coal Pty Limited exploration logs
6520000
6522000
6524000
6526000
6528000
6530000
Figure 6
CROSS SECTION D-D

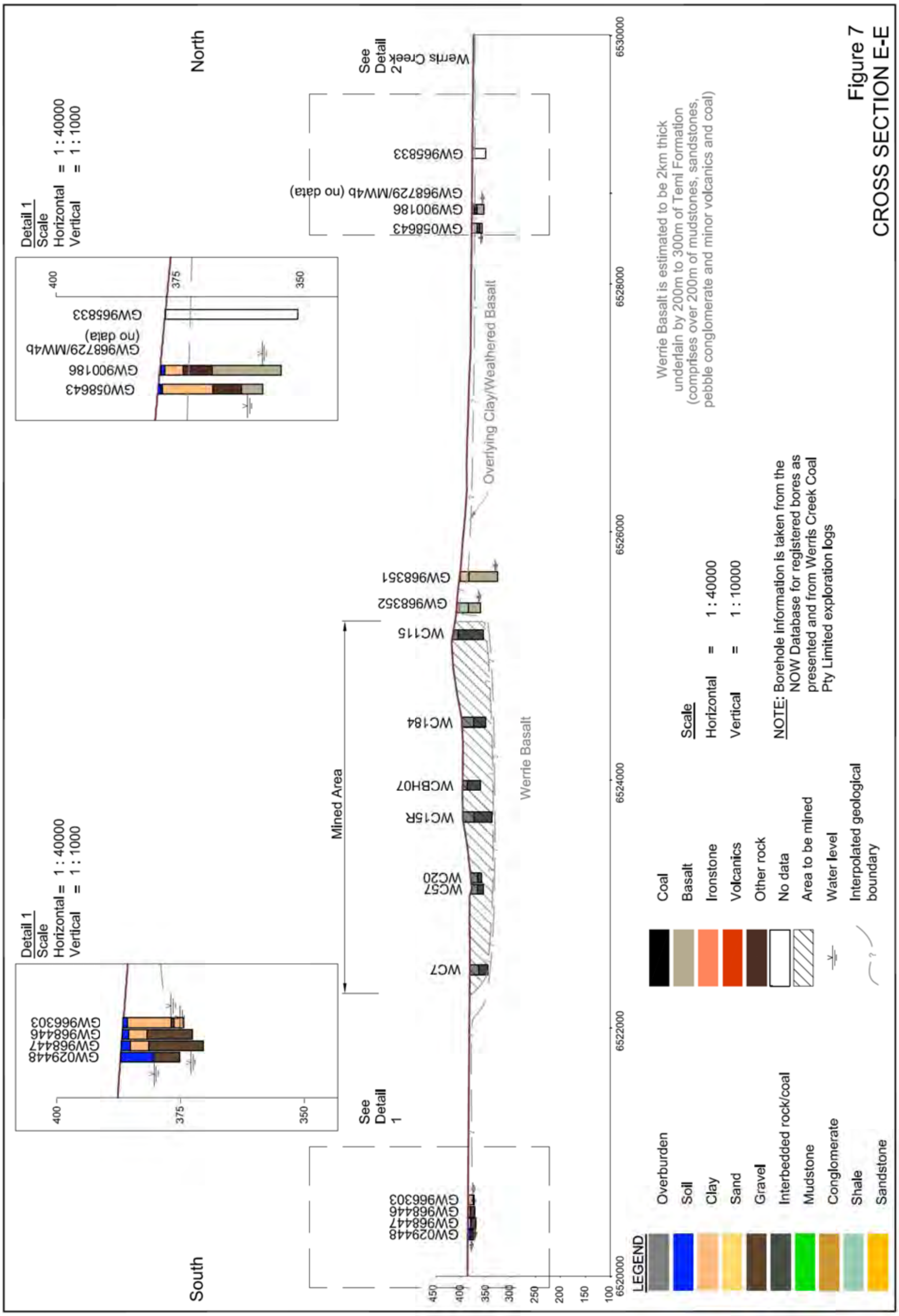


Figure 7
CROSS SECTION E-E
South
North
Mined Area
Werrie Basalt
Overlying Clay/Weathered Basalt
Werris Creek
See Detail 1
See Detail 2
Detail 1
Scale
Horizontal = 1 : 40000
Vertical = 1 : 1000
GW029448
GW968447
GW968446
GW966303
WC7
WC57
WC20
WC15R
WCBH07
WC184
WC115
GW968352
GW968351
GW058643
GW900186
GW968729/MW4b (no data)
GW965833
Werrie Basalt is estimated to be 2km thick underlain by 200m to 300m of Temi Formation (comprises over 200m of mudstones, sandstones, pebble conglomerate and minor volcanics and coal)
Scale
Horizontal = 1 : 40000
Vertical = 1 : 10000
NOTE: Borehole information is taken from the NOW Database for registered bores as presented and from Werris Creek Coal Pty Limited exploration logs
LEGEND
Overburden
Soil
Clay
Sand
Gravel
Interbedded rock/coal
Mudstone
Conglomerate
Shale
Sandstone
Coal
Basalt
Ironstone
Volcanics
Other rock
No data
Area to be mined
Water level
Interpolated geological boundary

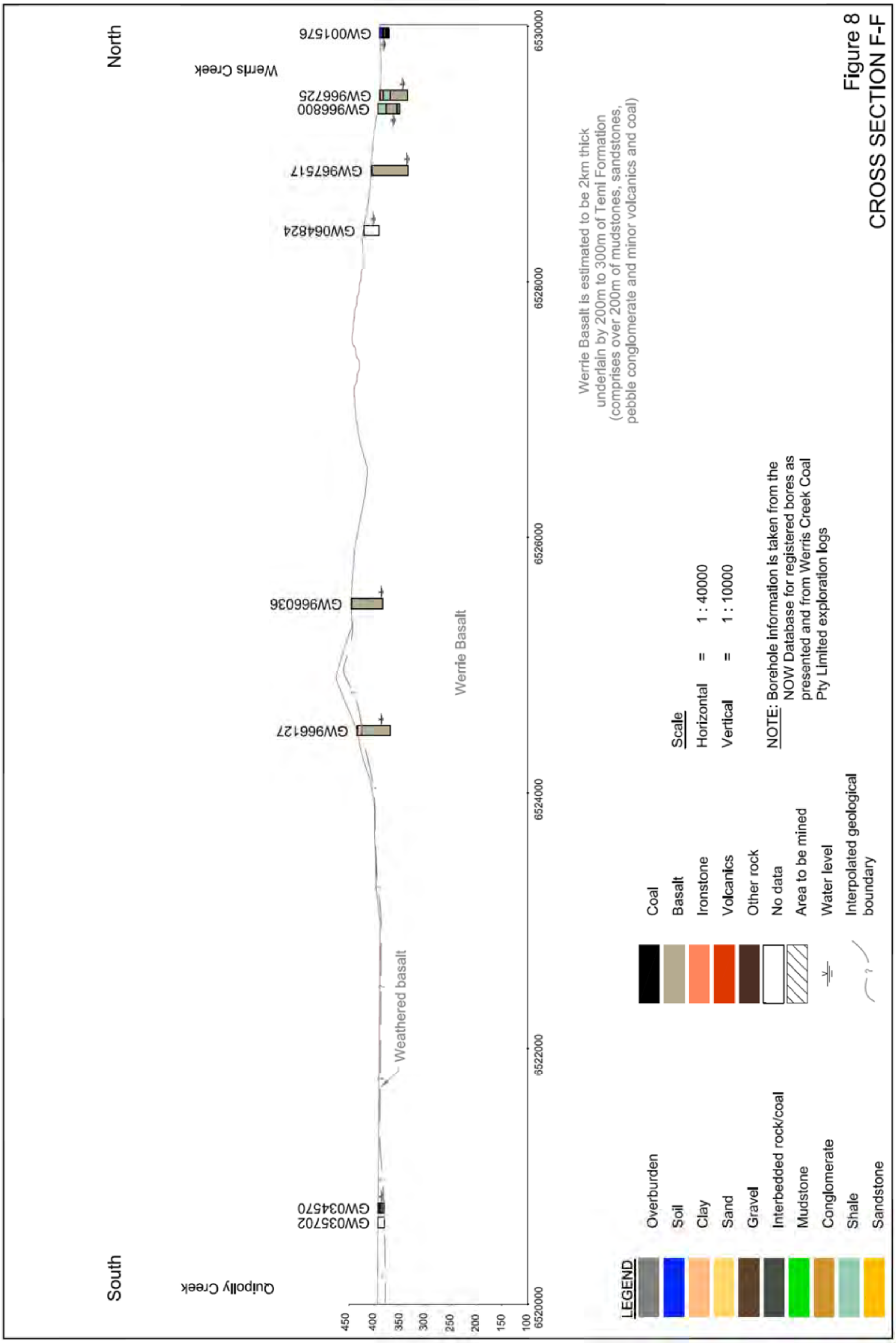
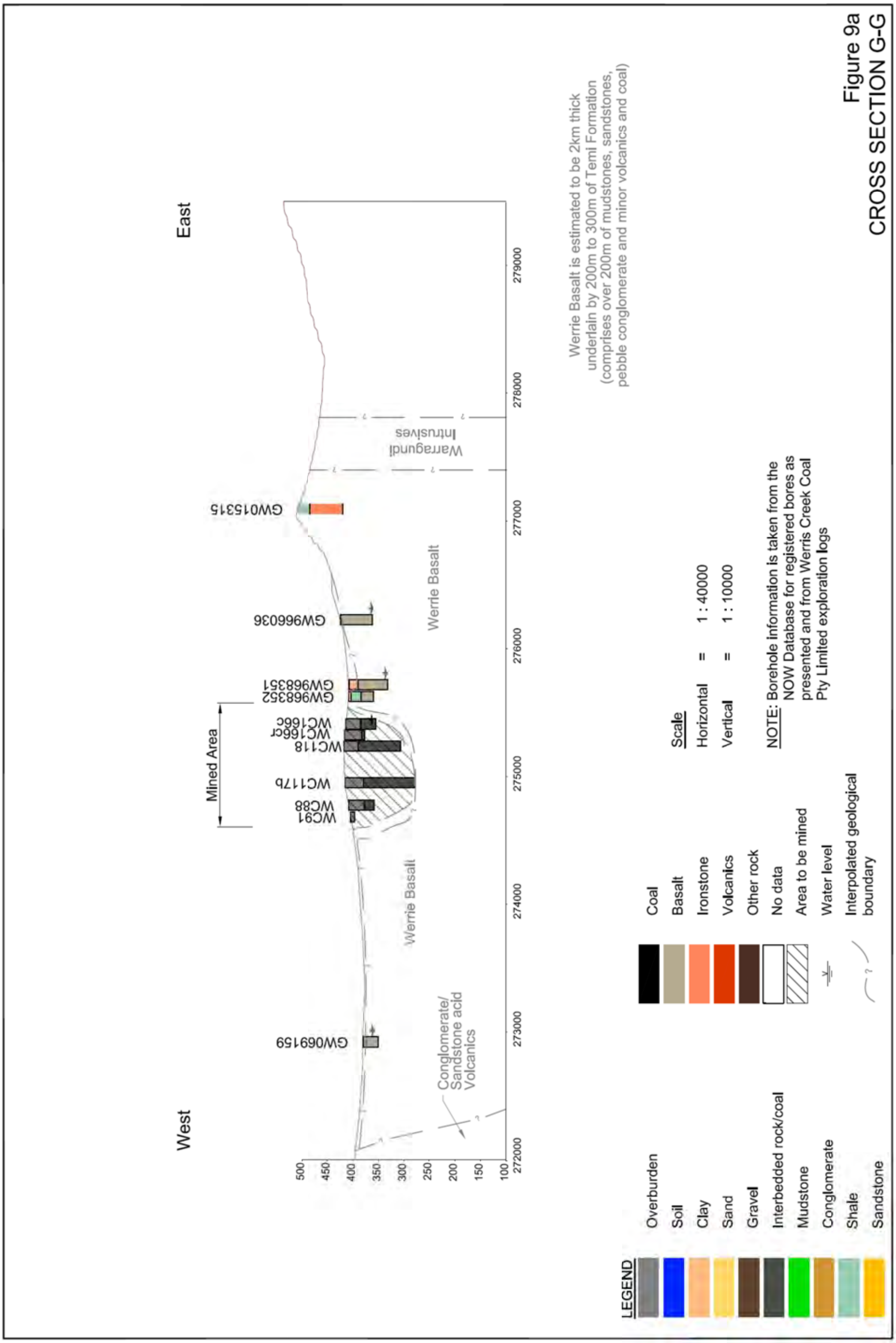
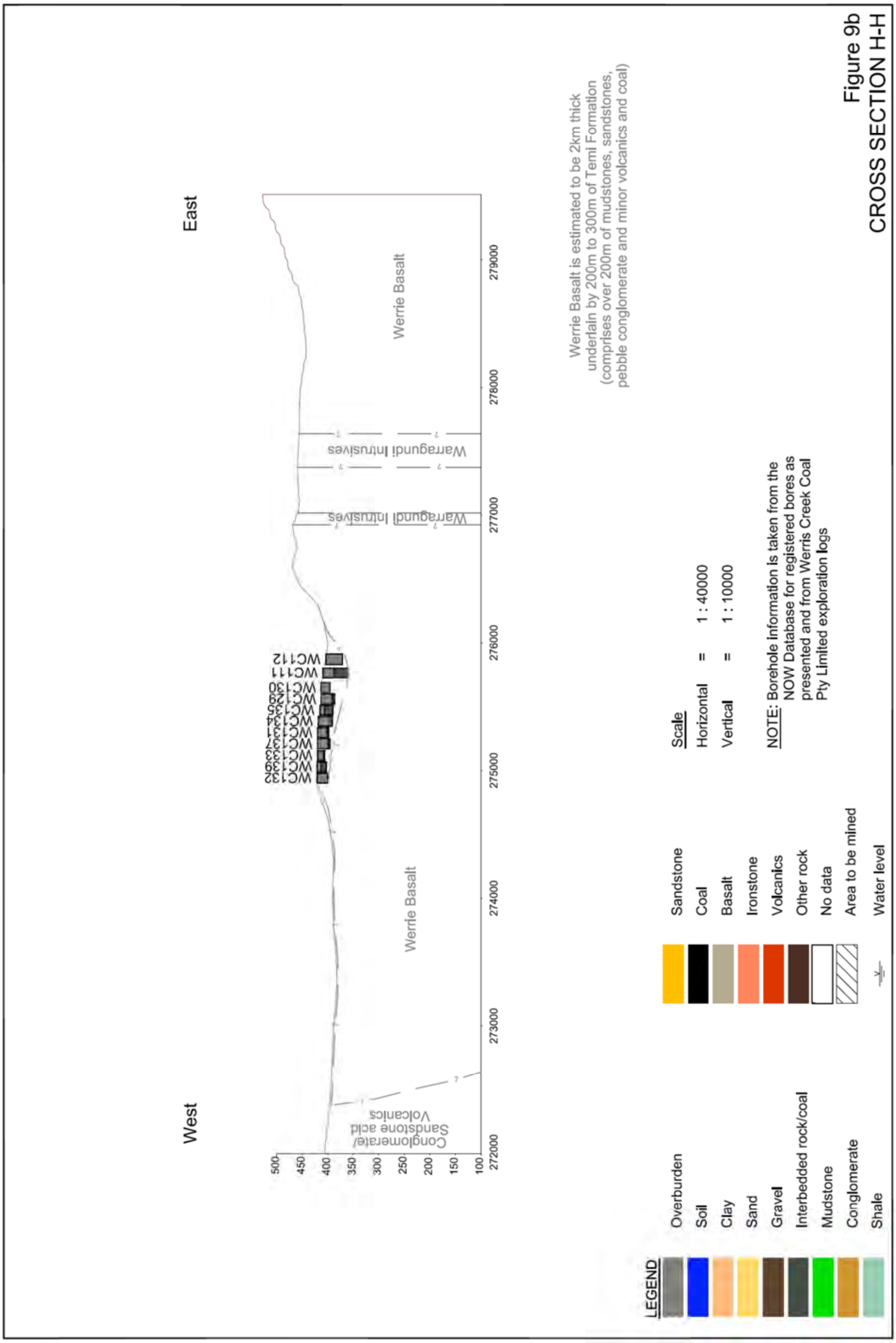


Figure 8
CROSS SECTION F-F


West
East
Mined Area
GW069159
WC91
WC88
WC117b
WC118
WC166cr
WC166C
GW968352
GW968351
GW966036
GW015315
Warragundi Intrusives
Werrie Basalt
Werrie Basalt
Conglomerate/ Sandstone acid Volcanics
500
450
400
350
300
250
200
150
100
272000
273000
274000
275000
276000
277000
278000
279000
Werrie Basalt is estimated to be 2km thick underlain by 200m to 300m of Temi Formation (comprises over 200m of mudstones, sandstones, pebble conglomerate and minor volcanics and coal)
LEGEND
Overburden
Soil
Clay
Sand
Gravel
Interbedded rock/coal
Mudstone
Conglomerate
Shale
Sandstone
Coal
Basalt
Ironstone
Volcanics
Other rock
No data
Area to be mined
Water level
Interpolated geological boundary
Scale
Horizontal = 1 : 40000
Vertical = 1 : 10000
NOTE: Borehole information is taken from the NOW Database for registered bores as presented and from Werris Creek Coal Pty Limited exploration logs
Figure 9a
CROSS SECTION G-G


West
East
Conglomerate/
Sandstone acid
Volcanics
Werrie Basalt
Warragundi Intrusives
Warragundi Intrusives
Werrie Basalt
WC132
WC133
WC137
WC131
WC134
WC135
WC129
WC130
WC111
WC112
500
450
400
350
300
250
200
150
100
272000
273000
274000
275000
276000
277000
278000
279000
Werrie Basalt is estimated to be 2km thick
underlain by 200m to 300m of Temi Formation
(comprises over 200m of mudstones, sandstones,
pebble conglomerate and minor volcanics and coal)
LEGEND
Overburden
Soil
Clay
Sand
Gravel
Interbedded rock/coal
Mudstone
Conglomerate
Shale
Sandstone
Coal
Basalt
Ironstone
Volcanics
Other rock
No data
Area to be mined
Water level
Scale
Horizontal = 1 : 40000
Vertical = 1 : 10000
NOTE: Borehole information is taken from the
NOW Database for registered bores as
presented and from Werris Creek Coal
Pty Limited exploration logs
Figure 9b
CROSS SECTION H-H

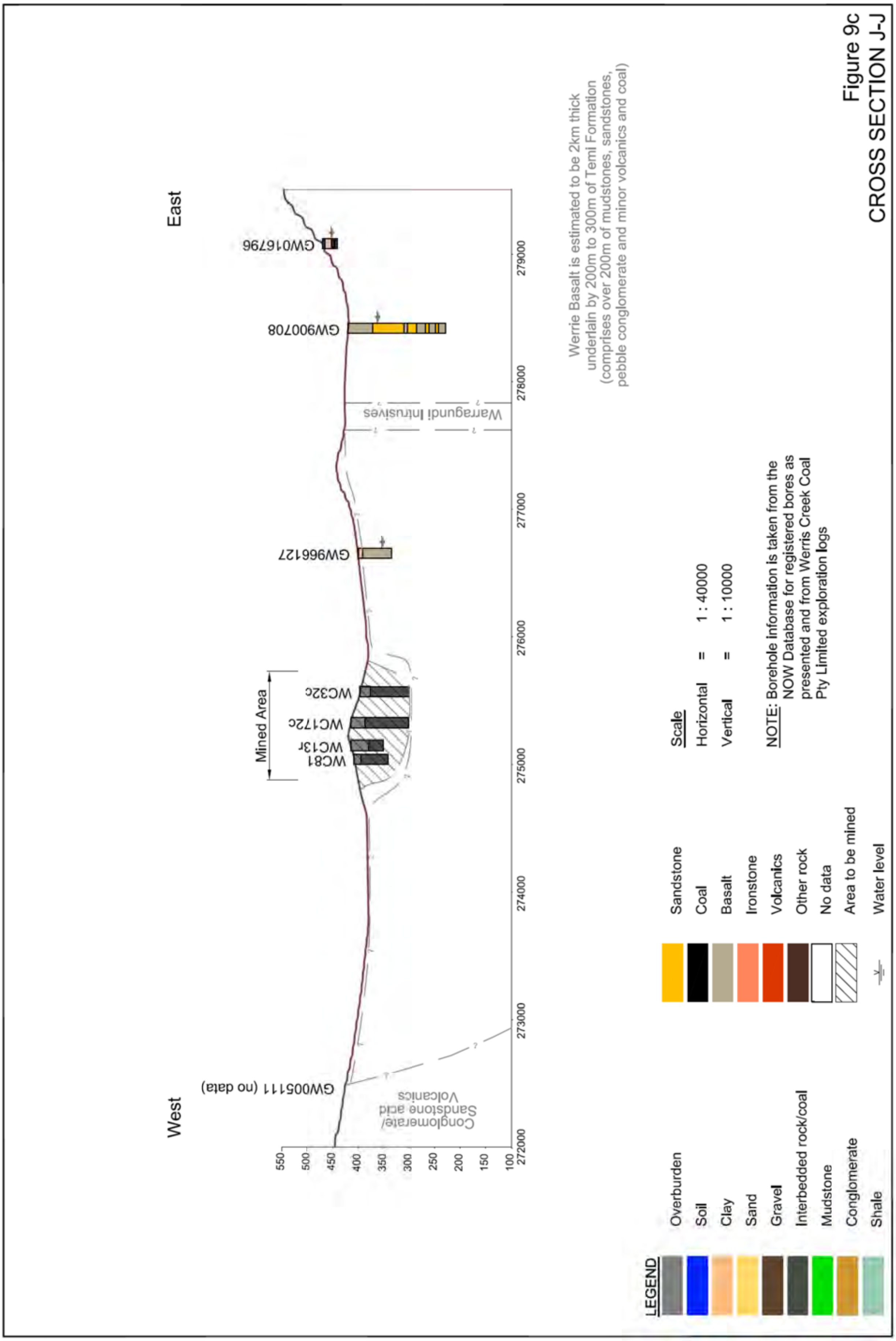


Figure 9c
CROSS SECTION J-J

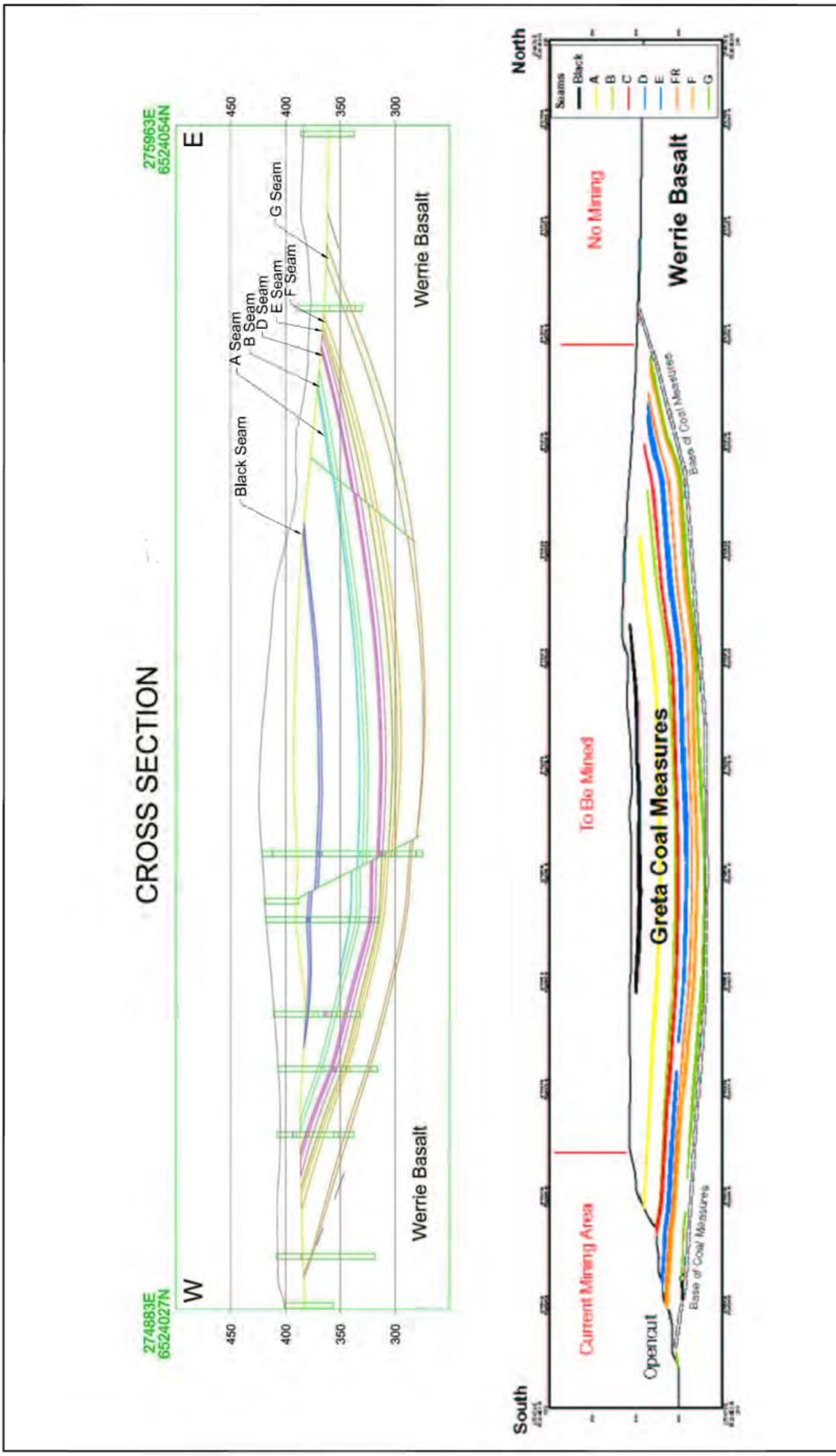


Figure 10
CROSS SECTIONS
THROUGH GRETA COAL MEASURES
SOUTHERN OUTLIER
(Werris Creek Coal Measures)

Source: Werris Creek coal Geology

The cross-sections also depict registered monitoring or pumping bore locations and depths. A review of these cross-sections indicates that registered bores are generally situated within the upper 60m of the strata and well above the maximum depth of proposed open cut mining associated with the LOM Project. The available monitoring points are considered sufficient on the basis that this best represents the impacts to other groundwater users located at similar depths, and groundwater dependent ecosystems (GDEs).

The strata below the depths drilled for monitoring bore installation is not understood in detail. It is understood that the Werrie Basalt is a highly fractured strata, approximately 2km in thickness and is underlain by the Temi Formation. The depth of the Temi Formation is well below the depth of proposed open cut mining associated with the LOM Project. Any barriers to groundwater flow are sufficiently outside the expected impacts of mining and further drilling of the basalt is likely to only provide detail on a micro level and not substantially assist in model parameterisation or calibration.

6.5 HYDROGEOLOGICAL REGIME, PROJECT SITE AND SURROUNDS

Background data, LOM Project Site data and data from the area surrounding the LOM Project Site has been collated to construct a conceptual hydrogeological model for the LOM Project and surrounds. A diagrammatic representation of the following discussion is presented in **Figure 11**.

Groundwater occurs in three main strata in the vicinity of the LOM Project Site, namely the Permian Coal Measures, Werrie Basalt and Quaternary Sediments.

The Permian aged coal measures strata have low permeability and porosity due to their compacted nature. Groundwater in these strata occurs in fractures, joints, cleats and bedding that have resulted from faulting and tensional folding. The main water-bearing zones occur in the coal seams with minor water bearing zones in the interburden rocks. The groundwater is partially confined and under pressure in the coal seams with the interburden rocks acting as semi-confining layers or aquitards. As these aquitards are not completely impermeable, they can also provide water to the coal seams by vertical leakage when there is a pressure drop in the coal seam (such as would occur as a consequence of coal extraction in adjacent areas). Groundwater within the interburden occurs mainly in the fractures with flow rates and storages being small. Vertical leakage is therefore expected to be low.

The rate at which groundwater would flow into the open cut mining void is governed by the permeability of the strata, the hydraulic gradient and the areas of entry. This in turn is related to the degree of fracturing or jointing of the rock strata.

The coal measures strata within the open cut area of the LOM Project Site contains a closed basin of groundwater that is surrounded by a low permeability weathered basalt/clay. Therefore, apart from short-term flow from storage, little long-term inflow to the open cut would be expected when mining occurs below the water table. As the coal measures are a closed basin, flow from the perimeter of the basin, following extraction, would occur through the surrounding and underlying basalt, although the extent is limited by the permeability of the weathered basalt/clay aquitard.

Groundwater within the coal measures occurs between 10m and 30m below the surface (GeoTerra, 2008). Recharge to the aquifer is from infiltration from rainfall. Due to the topographically elevated area relative to the surrounds, recharge from sources other than direct infiltration is not expected.

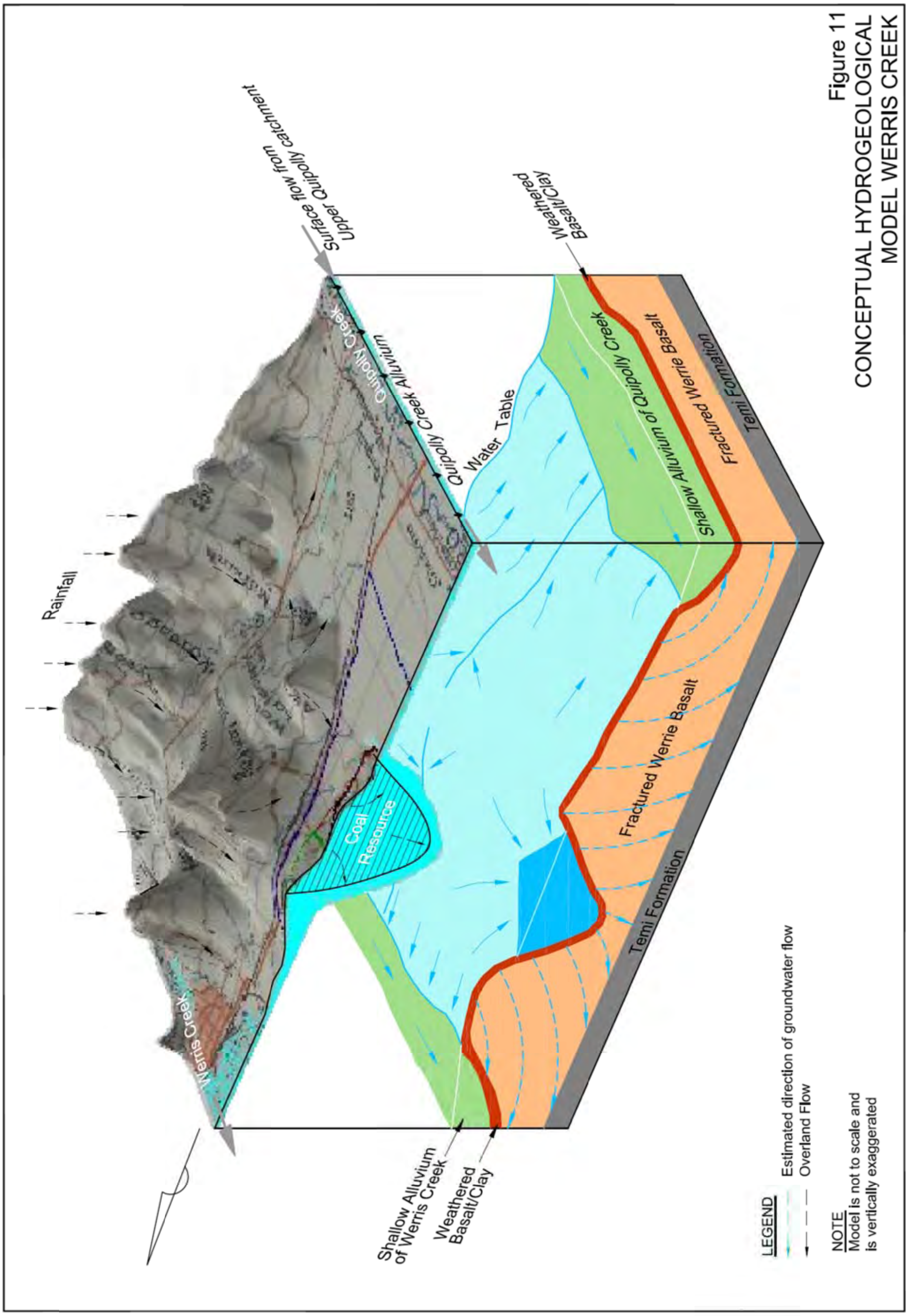


Figure 11
CONCEPTUAL HYDROGEOLOGICAL
MODEL WERRIS CREEK
Surface flow from
Upper Quipolly catchment
Weathered
Basalt/Clay
Rainfall
Quipolly Creek
Quipolly Creek Alluvium
Water Table
Shallow Alluvium of Quipolly Creek
Fractured Werrie Basalt
Temi Formation
Coal
Resource
Fractured Werrie Basalt
Temi Formation
Werris Creek
Shallow Alluvium
of Werris Creek
Weathered
Basalt/Clay
LEGEND
Estimated direction of groundwater flow
Overland Flow
NOTE
Model is not to scale and
is vertically exaggerated

Groundwater in the Werrie Basalt flows to the southwest and northwest from the topographical high point to the east of the Project Site. Flow in the basalt would occur along fractures in the bedrock rather than the interstitial pores. The upper weathered basalt layer acts to confine or semi-confine the aquifer. Recharge to the aquifer is from rainfall and runoff from the surrounding sandstone ridges to the east and west of the LOM Project Site and to a lesser extent from infiltration leakage through the overlying weathered clay aquitard. Only minor interaction between the basalt and coal measures is expected as the claystone/upper weathered basalt in the vicinity of the syncline structure acts as a low permeability barrier, thereby minimising groundwater interaction. Groundwater bore monitoring data indicates that water occurs within this aquifer between 8m and 52m below ground level (GeoTerra 2008).

The Quaternary Sediments alluvial aquifer contains strata of high permeability with flow occurring through the pore spaces between the grains. The alluvium is recharged by the upper reaches of the Quipolly Creek catchment as well as by direct infiltration and discharge from the underlying basalt aquifer. Groundwater flow in the aquifer is in a westerly direction, indicating that recharge is governed by surface water flows within the catchment. Water levels within this aquifer occur approximately 5m to 9m below ground level (GeoTerra 2008). A review of bore logs for bores screened within the alluvium indicate that water bearing zones are generally found between 5m and 15m of the surface, although bore GW058312 (refer to **Figure 4**) found gravel and sands to 26m which indicates that alluvium may be greater in depth in some areas. Water bearing basalt beneath the alluvium has been recorded in only one location (drilling in other locations was not sufficiently deep to assess water bearing basalt). At this location (GW900285 – refer to **Figure 4**) water bearing basalt was identified at 7.3m and in fracture zones to the depth of drilling (30.5m). The presence of weathered clay above the underlying basalt is not known due to the absence of drilling records. It is expected that groundwater within the alluvium is largely governed by rainfall within the catchment. The higher permeability in the alluvium relative to the underlying basalt/weathered basalt would promote horizontal flow through the alluvium. Some connectivity between basalt and alluvium may occur in zones where vertical fracturing intersects the alluvium or where alluvium is sufficiently deep to intersect water bearing basalt layers.

Werris Creek does not appear to be supported by an alluvial aquifer and is an ephemeral creek supported by rainfall within the catchment. Bores situated in the vicinity of Werris Creek are located in the Werrie Basalt.

In addition to the above, sandstone and tight (extremely low permeability) volcanic formations have been identified to the northeast and west of the LOM Project Site. These are not considered to represent sources of groundwater and are considered to be barriers to groundwater flow within the Werrie Basalt.

6.6 GROUNDWATER DATA OF THE LOM PROJECT SITE AND SURROUNDS

A summary of available groundwater data for the LOM Project Site and surrounds has been collated from existing mine site data, NOW records and a field assessment of critical bores undertaken in 2004 and 2008.

A review of the NOW database was undertaken in May 2010 for the area contained within the model boundaries (defined in **Section 7.1**). This review found 88 registered bores within the model boundary (approximately 3km from the LOM Project Site). Of these, 28 are situated in the Werrie Basalt, 22 within the alluvium of Quipolly Creek and the remainder are either unknown or situated within other rock types. A review of the NOW *Groundwater Works Summary* records determined that groundwater bores located within the model domain are generally utilised for rural purposes. The location of all registered bores is presented on **Figure 4** and tabulated in **Table 3**.

6.7 GROUNDWATER LEVEL MONITORING

Water level monitoring data for the LOM Project Site and surrounds was sourced from the NOW database (which includes water levels measured following bore installation), RCA water level gauging carried out in 2004 and 2008 and independent water level monitoring undertaken by ALS/CRIL since December 2005. Data from the 2004 and 2008 RCA monitoring events and from the NOW database have been used to assess the regional hydrogeological regime. The NOW data set was limited to cover the same region that was modelled in 2004 and 2008 to enable a comparison between the data.

Table 3
Summary of Water Bores within the Model Boundary

Registered Number	Property	Aquifer	Usage
GW001545	NK	Gravel Clay	Groundwater explore
GW001559	NK	Sand Interlayer	Groundwater explore
GW001565	NK	Boulders Clay Band	Public/Municipal
GW001576	NK	Shale hard conglomerate	Public/Municipal
GW001603	NK	clay/sand cemented	Public/Municipal
GW005112	NK	NK	NK
GW013869	Werriston	Pebbly sand	Irrigation and Stock
GW015205	Escott	Basalt	Stock
GW015240	Escott	Basalt	Stock
GW015241	Escott	Basalt	Stock
GW028684	NK	Gravel Water Supply	Irrigation and Recreation (Groundwater)
GW031850	NK	NK	Stock
GW032385	Hill View	Basalt Yellow Soak	Stock
GW032591	NK	Coal Water Supply	Stock
GW032592	NK	Basalt Water Supply	Stock
GW033556	Narrawolga	Mudrock Soak/Pink	Stock
GW043549	NK	NK	Stock
GW043550	NK	NK	Stock
GW044758	NK	Clay Gravel Water Supply	Domestic and Stock
GW044759	NK	NK	Domestic and Stock

Table 3
Summary of Water Bores within the Model Boundary (Cont'd)

Page 2 of 3

Registered Number	Property	Aquifer	Usage
GW058643	NK	Basalt Water Supply	Stock
GW059020	GAP Road Complex	Clay Some River Gravel Water Supply/Gravel Some Clay Water Supply	Recreation (Groundwater)
GW064824	NK	NK	Stock
GW068159	NK	Shale	Domestic and Stock
GW070733	Werriston South	Water Bearing Basalt	Stock
GW070734	Werriston South	Water Bearing Basalt/Basalt	Stock
GW072823	LOT 37 38 39	Water Bearing Brown Basalt	Domestic and Stock
GW900186	NK	Water Bearing Basalt/Basalt	Domestic and Stock
GW900279	NK	Water Bearing Basalt	Domestic and Stock
GW900981	Kyooma	NK	Stock
GW901096	Jimbawarra	NK	Domestic/Stock/Irrigation
GW901240	Robynville	Water Bearing Brown Basalt	Domestic and Stock
GW901506	Purlewah	NK	Domestic/Farming/Stock
GW965745	NK	Basalt	Domestic
GW965833	Westfall	NK	Domestic and Stock
GW965996	Lot F DP 27137	Basalt/Water Bearing	Domestic and Stock
GW966725	Lot 16 Section 1 DP 1109	Basalt	Domestic and Stock
GW966800	LOT 7 SEC A DP15137	Basalt/Shale	Domestic and Stock
GW967447	Werris Creek Station	Water Bearing Basalt	Domestic/Farming/Stock
GW967517	Lot 16 Section 8 DP 9878	NK	Domestic and Stock
GW967852	Cintra	Shale	Domestic and Stock
GW968725	Werris Creek Coal	NK	Monitoring Bore
GW968726	Werris Creek Coal	NK	Monitoring Bore
#	Allmawillee	Alluvial	Domestic and Irrigation
GW005111	NK	Basalt	NK
GW011673	Gedhurst	NK	Irrigation
GW011674	Gedhurst	Alluvial	Domestic and Irrigation
GW020504	Woodlands	NK	Stock
GW020505	Woodlands	Alluvial/Basalt	Stock
GW027596	NK	Loam Clay	Domestic and Stock
GW029448	Glenara	Gravel Water Supply	Domestic, Irrigation and Stock
GW034570	Hazeldene	Gravel Water Supply	Irrigation and Stock
GW034571	NK	NK	NK
GW034822	Gedhurst	NK	Groundwater Exploration
GW035072 (MW12)	Hazeldene	Alluvial	Stock

Table 3
Summary of Water Bores within the Model Boundary (Cont'd)

Page 3 of 3

Registered Number	Property	Aquifer	Usage
GW035702	Hazeldene	NK	Stock
GW043327	Rocky Hall	Gravel Water Supply	Domestic and Stock
GW058312	NK	Gravel Water Supply	Domestic
GW060085	NK	Gravel Water Supply	Irrigation and Stock
GW066212	NK	NK	Domestic and Stock
GW069158	not installed		
GW069159	NK	WB Basalt	Domestic and Stock
GW900285	NK	WB Basalt	Domestic and Stock
GW900365	NK	Water Bearing Gravel/Gravel	Domestic and Stock
GW900708	Talavera	Basalt	Domestic and Stock
GW900708	Talavera	Sandstone, siltstone, coaly shale, volcanics, basalt, etc	Domestic and Stock
GW901185	Mountain View	Alluvial	Domestic and Irrigation
GW902030	The Colliery	Water Bearing Coal	Domestic
GW902269	NK	NK	Irrigation
GW902270	Gedhurst	NK	Irrigation
GW965729	Eurunderee	Basalt/Water Bearing	Stock
GW965729 (MW3)	Eurunderee	Basalt	Stock
GW966036	Hillview	Basalt/Water Bearing	Domestic and Stock
GW966036 (MW1)	Hillview	Basalt	Domestic and Stock
GW966127	Railway View	Water Bearing Basalt	Domestic and Stock
GW966127 (MW2)	Railway View	Basalt	Domestic and Stock
GW966303	Blenara	NK	Domestic and Stock
GW966348	Dalriada	NK	Domestic and Stock
GW968351	Preston Park	Basalt	Domestic and Stock
GW968352	Preston Park	Basalt/Water Bearing	Domestic
GW968446	Glenara	Gravel Water Bearing/Gravel	Domestic and Stock
GW968447	Glenara	Gravel Water Bearing	Domestic and Stock
GW968460	WCCM	Basalt	Monitoring
GW968461	WCCM	Basalt	Monitoring
GW968462	WCCM	Basalt	Monitoring
GW968727	NK	NK	Monitoring Bore
GW968728	NK	NK	Monitoring Bore
GW968729	NK	NK	Monitoring Bore
MW11	Turnbulls Gap	Sandstone	NK
MW14	WCCM	Basalt	Monitoring
MW4	WCCM	Basalt	Monitoring
MW5	WCCM	Basalt	Monitoring
MW6	WCCM	Basalt	Monitoring
MW9	WCCM	Basalt	Monitoring

See **Figure 4**.
NA – not available, NT – not tested, NK – not known. # not registered.

The hydrogeological regime generated using the limited NOW data and the 2004 and 2008 data sets is depicted on **Figure 12** and shows a very close relationship between both direction and gradient. In all interpolated regimes, the general direction of flow is from the northeast to the southwest as a result of a small mountain range to the east of the LOM Project Site. The flow direction is radial and steeply graded around the base of this mountain range, reducing in gradient and radial formation as groundwater flows away from the range. Closer to Quipolly Creek, the flow direction demonstrates a slight change back towards the west. In terms of gradient, these interpolations show the same relationship of approximately 10m in height per 700m in length. Water levels were lower in 2004 and 2008 RCA monitoring events in comparison to the limited NOW data set and may reflect long-term stabilisation of the standing water level following well installation. Variations in water level are expected to occur in response to seasonal variation and localised pumping activities.

The limited NOW data set has been collated from standing water levels recorded at the time of installation and spans 15 years. The 2004 and 2008 data sets were collated in one monitoring round occurring within a period of a few days. The close representation of the three regimes in terms of flow directions and gradients indicates a long-standing groundwater regime. The inclusion of the full NOW data set is therefore considered an appropriate representation of the regional groundwater flow regime for the current model domain.

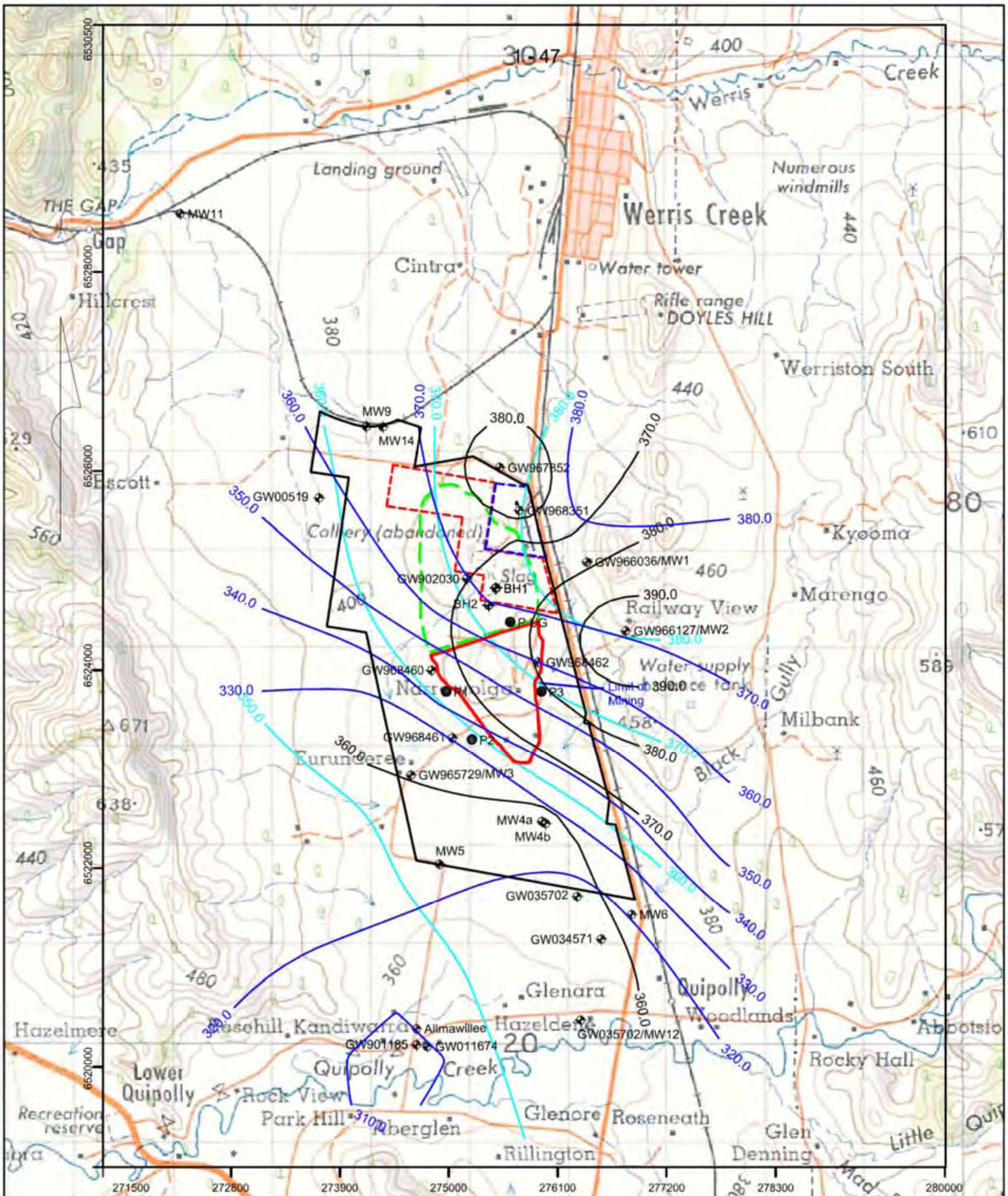
The full NOW data set includes the area from Quipolly Creek in the south to Werris Creek in the north and between the eastern and western bordering ranges as shown in **Figure 13**. Bores situated in the alluvium of Quipolly Creek were not included in the generation of the interpolated regime. The data set shows similarities against the 2004 and 2008 predictions, however the inclusion of data from a larger region including the west and north of the site alters the contours slightly. The hydrogeological regime generated from the expanded data set shows groundwater flows to the east and west from the bordering ranges before dividing to flow to the north or south through the valley and towards the two creek systems. The dominant drivers for the system are the mountain ranges to the east and west of the site suggesting the significance of recharge from these areas to the basalt groundwater system. A groundwater divide is present in the centre of the LOM Project Site.

The consistency between the drawings, particularly between the full NOW data set and the 2008 data set (the two with the most data points), indicates a long-standing water level regime and reasonable representation of the groundwater regime. The full NOW data set was therefore adopted as the groundwater regime for model calibration purposes.

6.8 GROUNDWATER MONITORING UNDERTAKEN DURING MINING OPERATIONS

GeoTerra was engaged by the Proponent to undertake an independent review of groundwater quality and water level monitoring results from a nominated bore field on and surrounding the existing open cut mine site. The bore field is identified as monitoring bores MW1 to MW14 on **Figure 4.** Water level monitoring commenced in December 2005 and is undertaken quarterly. A period of monthly monitoring was undertaken for an initial six month period.

A graph representing this data is presented in **Appendix 1,** including a combined hydrograph presenting recorded water levels in monitoring wells MW1 to MW14, compared to rainfall. Data presented indicates groundwater levels appear to have been stable throughout the monitoring period.



NOTE
Registered monitoring bore locations sourced from the NSW Natural Resource Atlas - www.nratlas.nsw.gov.au 2009 Copyright © 2009 New South Wales Government. Map has been compiled from various sources and may contain errors or omissions. No representation is made as to its accuracy or suitability.

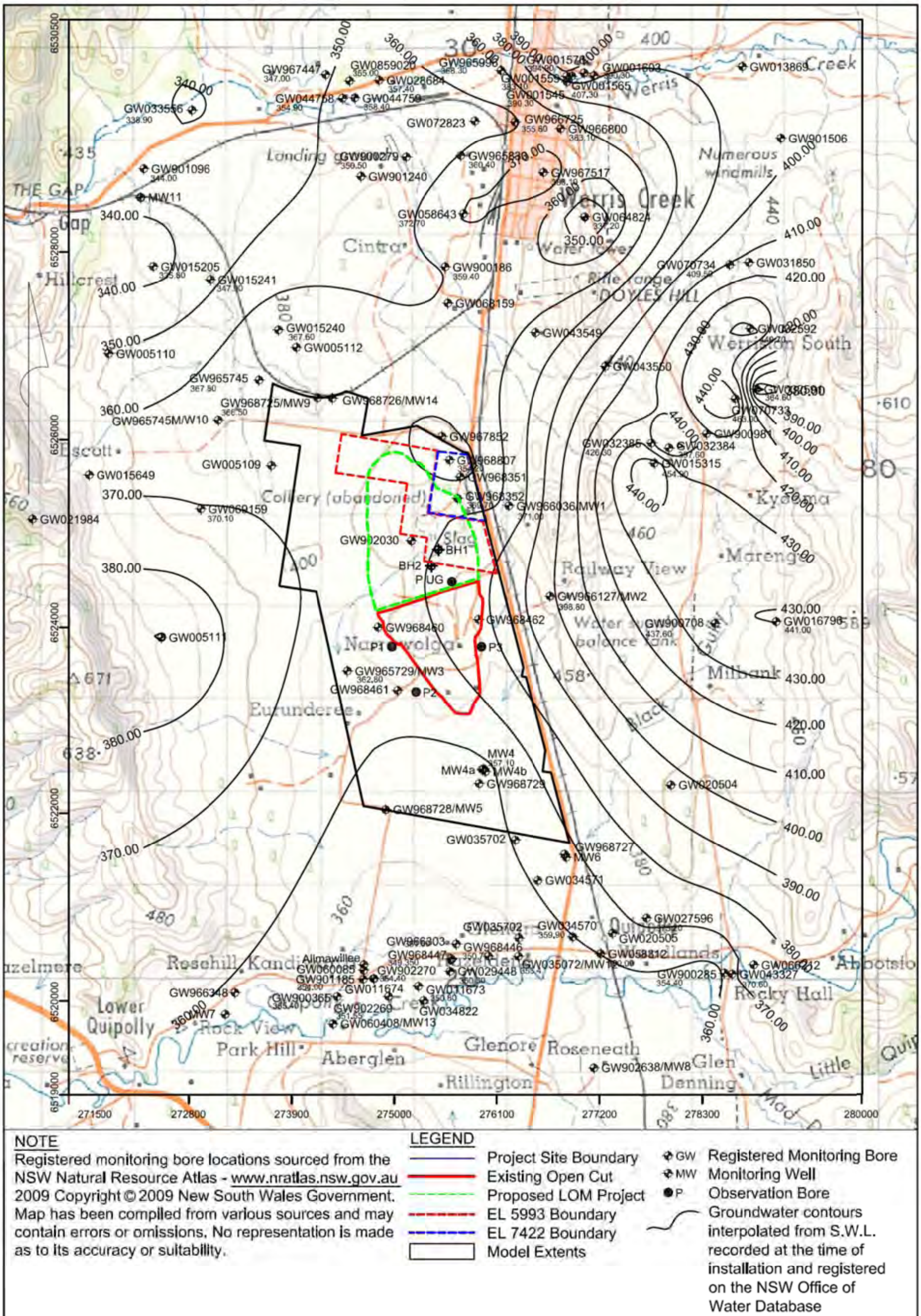
Not all groundwater bores along Quippolly Creek are shown

LEGEND
- Project Site Boundary
- Existing Open Cut
- Proposed LOM Project
- EL 5993 Boundary
- EL 7422 Boundary
- Model Extents
- GW Registered Monitoring Bore
- MW Monitoring Well
- P Observation Bore
- 370.0 Interpolated Head Equipotential (2004 measured bores)
- 370.0 Interpolated Head Equipotential (2008 measured bores)
- 370.0 Interpolated Head Equipotential (Registered bores)

SCALE 1:60000
1000 0 1000 2000m

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

Figure 12
INTERPOLATED HYDROGEOLOGICAL REGIME FROM LIMITED DATASETS



SCALE 1:60000

Figure 13
INTERPOLATED HYDROGEOLOGICAL REGIME FROM NOW DATASET

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

Monitoring bores MW2, MW3, MW4a and MW4b are located in closest proximity to the current open cut operations. **Appendix 1** also presents individual hydrographs of wells, MW1, MW2, MW4 and MW4b, plotted against residual rainfall mass (a cumulative plot of above or below average rainfall for each month allowing comparison of rainfall with groundwater level fluctuation).

A review of this data was not considered to indicate a sustained fall outside of naturally occurring variations.

6.10 GROUNDWATER LEVEL MONITORING IN THE UNDERGROUND MINE WORKINGS

Groundwater is contained with the former Werris Creek Colliery underground mine workings. One groundwater pumping bore is present within these workings and is used to pump water for use within the existing Werris Creek Coal Mine open cut operations. This bore and other bores may be used in the future to assist with dewatering of the underground workings. In December 2008, RCA installed two additional groundwater monitoring bores (BH1 and BH2) in the workings to evaluate water quality and to assess water levels (RCA 2009). The location of the two bores is identified on **Figure 13** and the recorded water level tabulated in **Table 4**.

Table 4
Water Levels in Bores in Old Underground Workings

Well	Bore Depth from Surface (m)	Depth to Water Table below t.o.p (m)	Survey t.o.p (m AHD)	RL of Water Table (m AHD)
BH1	122	76.09	420.64	344.55
BH2	105	78.28	418.41	340.13

t.o.p = top of pipe.

The results indicate a 4m difference in water level between BH1 and BH2 which suggests that the water bodies intercepted by the two bores may not be connected or there is a significant upward gradient.

Dewatering of the underground workings has commenced via collection of seepage from the underground workings into the open cut area to the void water dams. Since May 2010, this water has been pumped to the groundwater storage cell. It is anticipated in the near future that dewatering of the underground workings will be required via dewatering bores. Monitoring has been undertaken to determine the decline in groundwater levels in response to dewatering of the workings. The monitoring bores are situated in the southern section of the Project Site and are located in the basalt underlying the basal G seam of the Greta Coal Measures outlier. Monitoring bores (**Figure 4** and **13**) are numbered P1, P2 and P3, the latter of which was mined through in late November 2009**.** Monitoring was also undertaken within the mine void from piezometer P_UG (**Figure 4** and **13**).

The piezometer P_UG, at the start of monitoring in December 2007, recorded the depth to groundwater to be 45.2m below ground level (mbgl). This was approximately two and a half years after the commencement of mining. Over the following six months this level dropped to 55.8m depth to groundwater due to dewatering of the underground workings (GeoTerra 2009). In early 2009 the depth to groundwater had recovered to 52.2mbgl. This stabilised level remained throughout the proceeding twelve month monitoring period. This represents a decline of approximately seven metres over a three year period which was mainly attributed to depressurisation of the underground workings by open cut mining (Geoterra 2009).

Piezometer P1, to the west of the open cut, commenced monitoring in August 2008, three years after the commencement of mining, with a standing water level (SWL) of 24mbgl. Between August 2008 and July 2010 this level has risen and fallen between 21 and 24mbgl and, as yet , does not seem to have stabilised. In July 2010, five years after the commencement of mining, the level of P1 (20mbgl) was four metres above its installation level.

P2, to the southwest of the open cut, is the only piezometer that has been continually monitored between August 2008 and July 2010. At the start of monitoring the SWL was measured at 21mbgl. This level then rose to 19mbgl between January 2009 and October 2009 before again returning and appearing to re-stabilise at 21mbgl by March 2010.

The P3 piezometer, to the east of the open cut, was monitored between August 2008 and October 2009. Piezometer P3 showed a very similar pattern to P2. The original depth to groundwater was 29mbgl. This level then rose to 28mbgl before again returning to 29mbgl in October 2009. This piezometer was removed in late 2009 when the area was mined through.

Overall, the groundwater levels in P1 and P2 have yet to sustain a fall during the three year monitoring period. In fact, as of July 2010, P1 was well above its installation level. Neither piezometer water levels have fallen as a result the commencement of the Northern Extension in late 2009.

Hydrographs of P1, P2, P3, and P_UG are presented in **Appendix 1**, compared with rainfall. It is considered that there is insufficient data to firmly conclude a relationship with rainfall.

6.11 MINE SITE AQUIFER PARAMETERS

Aquifer data for the LOM Project Site was previously collated in RCA (2004) and comprised of permeability testing within five existing exploration holes, a windmill on the Narrawolga property and five bores/wells on surrounding properties. These results are summarised in **Table 5** and further information is presented in RCA (2004).

Table 5
Results of Permeability Testing, RCA 2004

Bore Number	Permeability (m/s)	Strata Screened
WC28	$2x10^{-6}$	Coal Measures – G Seam
WC31	$2x10^{-6}$	Coal Measures – C Seam
WC32	$3x10^{-7}$	Coal Measures - Interburden above G seam
WC43	$1x10^{-9}$	Clay/weathered basalt underlying the coal measures
WC57	3×10^{-9}	Clay/weathered basalt underlying the coal measures
WM1	$2x10^{-6}$	Werrie Basalt
MW1 – Hillview	$6x10^{-6}$	Werrie Basalt
MW13 – Park Hill	$2x10^{-3}$	Quaternary Sand/Gravel Alluvials
MV1 – Mountain View	$2x10^{-4}$	Quaternary Sand/Gravel Alluvials
GH1 – Gedhurst	$3x10^{-3}$	Quaternary Sand/Gravel Alluvials
A1 – Almawillie	Recovery too fast to measure	Quaternary Sand/Gravel Alluvials
Source: Modified after RCA (2004) – Table 2		

Further aquifer testing was undertaken by RCA in 2010 as part of this assessment. Aquifer testing comprised of pumping tests at locations MW5 and MW14. At each location, a bore suitable for pumping was installed into the basalt aquifer. The basalt aquifer is the primary groundwater source for groundwater extraction bores in the region, as shown on **Table 3**. Previously available data presented in **Table 5** indicates only two locations within the basalt aquifer where permeability had been tested. This testing was undertaken by slug or bail tests which may be misleading in fractured aquifers due to the small area of influence from this type of testing. Locations MW5 and MW14 were therefore selected for pump testing as being representative of the basalt aquifer to the south and north of the LOM Project Site, respectively. Previous modelling by RCA (2004 and 2009) indicated that the basalt aquifer could be represented by two zones of different parameters. Bores MW5 and MW14 are situated within the two zones which therefore allowed evaluation of the different parameters.

Based on the analysis of pumping test results, it is considered that the following range of data provides representative parameters in the basalt aquifer. An aquifer thickness of 60m was assumed for these calculations.

transmissivity 1×10^{-3} to 2×10^{-3} m^2/sec

storage coefficient 0.101 to 0.133 (dimensionless)

permeability 2×10^{-5} m/sec

Further details of this testing program are presented in **Appendix 2**.

6.12 GROUNDWATER QUALITY

6.12.1 Introduction

Groundwater samples taken from the existing open cut and within the underground mine workings prior to the commencement of open cut mining activities by RCA (2004) determined the groundwater to be slightly acidic with low salinity. The low salinity (brackish water) was considered unusual for coal measures and attributed to the close proximity of the recharge point (i.e. the subcrop).

The 2004 monitoring event found that, with three exceptions (WC28, WC33 and WC41), which displayed slightly elevated zinc or nickel concentrations, the metals analysed were all below the accepted limits for irrigation purposes. The slightly elevated zinc or nickel results in the three bores noted above were well under the accepted limits for livestock use.

Analysis of groundwater collected from BH1, BH2 and the existing open cut mine site production bore found similar water quality characteristics (RCA 2009) to those analysed prior to the commencement of open cut mining. Concentrations of other analytes tested indicated the water is suitable for the purpose of irrigation or re-use for operational purposes.

6.12.2 Basalt Aquifer

Water quality sampling in the basalt aquifer was undertaken in 2004 prior to the commencement of open cut mining and routine monitoring is currently ongoing. The basalt aquifer has a slightly acidic to neutral pH and is brackish. Sampling of other analytes indicates that the water body is suitable for irrigation or stock use. **Table 6** presents a summary of water quality results from bores monitoring the basalt aquifer.

Table 6
Summary of Water Quality in the Werrie Basalt

Region Werrie Basalt	No of Bores	No of Samples	Guidelines Agricultural Irrigation and Livestock		Concentration Ranges		
			Irrigation	**Livestock**	**Min**	**Max**	**Mean**
Phosphorous-Reactive (mg/L)	10	202	-	-	0.01	20.50	0.40
Total Phosphorous (mg/L)	10	202	0.8 – 1.2 stv 0.05 ltv	-	0.01	26.30	0.72
Total Nitrogen (mg/L)	10	202	25 - 125 stv 5 ltv		0.33	546.00	15.42
Nitrates (mg/L)	10	194	6.77	6.77	0.01	26.00	6.72
Electrical Conductivity (uS/cm)	10	226	1900 - 4500 stv 2000 - 5000 ltv	5000#	560	4110	1500
pH-field	10	226	6.5 – 8.5	6.5 – 8.5	6.5	8.4	7.20
ltv – long tern value, stv – short-term value, # Poultry – sheep value/long-term trigger value, - No published values							
Source - WCC Groundwater data base June 2010.							

6.12.3 Alluvial Aquifer

Water quality sampling in the alluvial aquifer was undertaken in 2004 prior to the commencement of open cut mining and routine monitoring is currently ongoing. The alluvial aquifer is of neutral pH and is fresh to slightly brackish. Sampling of other analytes determined that the water body is suitable for irrigation or stock use. **Table 7** presents a summary of water quality results from bores monitoring the alluvial aquifer.

Table 7
Summary of Water Quality in the Alluvium

Region Alluvium	No of Bores	No of Samples	Guidelines Agricultural Irrigation and Livestock		Concentration Ranges		
			Irrigation	**Livestock**	**Min**	**Max**	**Mean**
Phosphorous-Reactive (mg/L)	10	202	-	-	0.02	0.80	0.07
Total Phosphorous (mg/L)	10	202	0.8 – 1.2 stv 0.05 ltv	-	0.02	2.50	0.11
Total Nitrogen (mg/L)	10	202	25 - 125 stv 5 ltv		1.10	4.40	1.92
Nitrates (mg/L)	10	194	6.77	6.77	0.96	2.60	1.80
Electrical Conductivity (uS/cm)	10	226	1900 - 4500 stv 2000 - 5000 ltv	5000#	380	1260	800
pH-field	10	226	6.5 – 8.5	6.5 – 8.5	6.00	8.10	5.73
ltv – long-term value, stv – short-term value, # Poultry – sheep value/long-term trigger value, - No published values. .							
Source - WCC Groundwater data base June 2010.							

7. GROUNDWATER MODELLING

7.1 MODEL DESIGN AND BOUNDARY CONDITIONS

Groundwater flow modelling was undertaken using Visual Modflow 2009.1, a three dimensional modular finite difference groundwater flow model. The model is based on Modflow – 83, Modflow – 88, Modflow – 96 and Modflow – 2000 which have been widely used by the profession for over 20 years. The model domain comprised of an area of 8.5km in the east-west direction by 11km in the north-south direction, in which the proposed limit of open cut mining is located towards the centre of the model. The model origin was Easting 271500 and Northing 6530500 (in the MGA co-ordinate system). The cell size adopted was 25m by 25m in the vicinity of the Project Site and increased to 100m by 100m towards the model boundaries. This cell size is considered to give sufficient resolution to model impacts from the proposed coal mining operations associated with the LOM Project.

Boundary conditions adopted for the LOM Project Site are shown on **Figure 14** and can be described as follows.

- A constant head boundary was assigned along a portion of the eastern boundary following the 500m topographical contour and approximately representing the conglomerate ridges to the east of the site. The constant head boundary was set to 450m to represent a groundwater table approximately 50m below ground level. This condition was manipulated during calibration, however, the constant head of 450m was found to provide an optimum calibration.
- A constant head boundary was similarly assigned along a portion of the western boundary to represent the Rossmore Formation along the western model boundary. The boundary was assigned along the 500m surface contour and assigned a value of 430m to represent a groundwater table approximately 70m below ground level. This condition was initially set equal to the eastern boundary condition of 450m, however, model calibration found a lower head provided an optimal calibration.
- Cells to the east of the eastern constant head boundary and to the west of the western constant head boundary were assigned as no-flow cells.
- To the south, a stream function was input along Quipolly Creek. Quipolly Creek flows from an elevation of approximately 370m AHD in the east to 335m AHD in the west of the model domain. Stream heights were approximated from the topographic map.
- To the north a stream function was input along Werris Creek. Werris Creek flows from an elevation of approximately 377m AHD in the east to 349m AHD in the west of the model domain. Stream heights were approximated from the topographic map.
- Stream flow for Quipolly Creek and Werris Creek is not gauged. An estimate of stream flow was taken from Baradine Creek which is gauged and is within an area of similar rainfall. Flows within Baradine Ck are in the order of 46ML/day. The catchment size for Baradine Creek (1000km^2) is larger than Quipolly Creek (70 km^2) and Werris Creek (404km^2) and the streamflow in the later creeks was decreased accordingly. The methodology adopted is not particularly accurate however given the minor interaction between creek flow and the groundwater is considered to be sufficient for the purpose of this model.

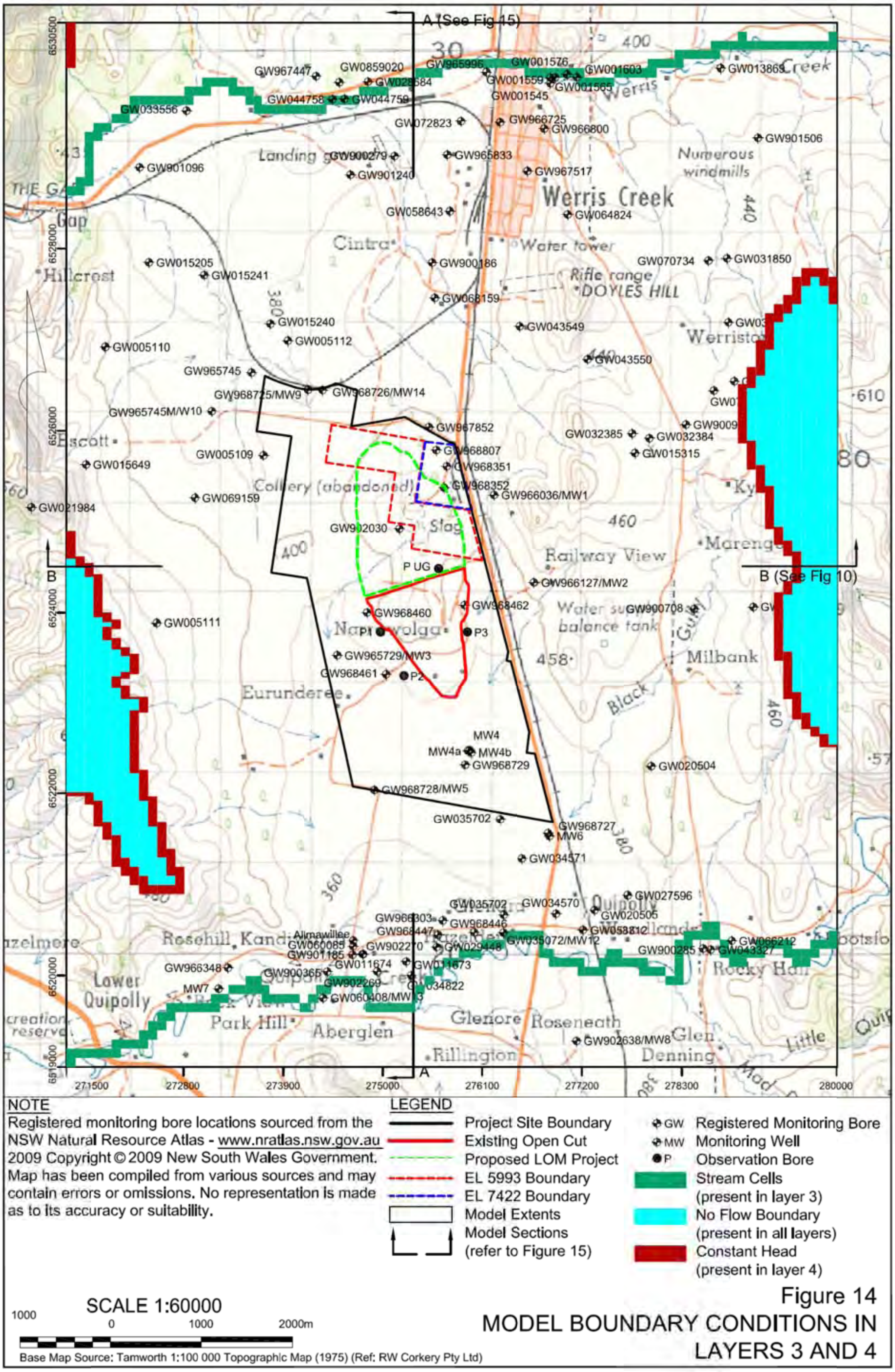


Figure 14
MODEL BOUNDARY CONDITIONS IN LAYERS 3 AND 4

Several small creeks occur within the model domain including Black Gully Creek in the central east of the model domain. Due to the depth of groundwater observed in the aquifers likely to be affected by the LOM Project (approximately 35 mbgl), interaction of surface water with groundwater in these deeper aquifers is unlikely and therefore these creeks have not been incorporated in the model boundary conditions.

7.2 MODEL ASSUMPTIONS

7.2.1 Model Layer

The model comprises seven layers as follows.

- Layer 1 – comprises of a shallow layer approximately 3m in thickness below the topographic surface. This layer represents the upper soil and weathered clay profile and does not contain a water table over the majority of the model domain. In the vicinity of the creek systems the layer comprises of alluvium, although remains dry. Volcanic and conglomerate rock formations are represented in this layer. In the vicinity of the coal formation, the model increases in depth, determined by interpolation of depths to the base of the G seam. Layer parameters have been changed to represent the coal and interburden layers as a composite unit through this area.
- Layer 2 – comprises a thin layer of 2m in thickness off set from the base of Layer 1. This layer contains the same properties as Layer 1 with the exception of the coal measures footprint. In this area the layer comprises a weathered clay profile and represents the upper weathered layer of basalt that underlies the G coal seam.
- Layer 3 – is an interpolated layer with thickness governed by the approximate depth of alluvium in the creek systems. The layer comprises basalt properties across the majority of the model domain with higher permeability properties present in the vicinity of the creek systems. Volcanic and conglomerate formations are represented.
- Layers 4 and 5 – represent the basalt formation with volcanic and conglomerate formations present. This layer could have been modelled as one layer but has been divided to provide greater resolution in the model.
- Layer 6 – represents the basalt formation with volcanic and conglomerate formations. Model calibration found that a good calibration resulted from decreased permeability in this layer possibly representing a less fractured basalt layer.
- Layer 7 – represents the lower Temi Formation at a depth of around 600m from the surface. Records indicate that the Temi Formation lies at depths of approximately 2km beneath the basalt, however at the chosen depth the formation was found to have little influence on the model.

The model surface for the Project Site and surrounds was developed as a contour plot interpolated from the 1:25,000 topographic map for the region. A 100m grid was applied across the model domain and elevations determined. This data was combined with a surface survey across the Project Site and contoured using ‘Surfer’, a commercially available contouring software package. This approach is not as accurate as using the topographic map contour plan but is sufficient for the purposes of this model.

Layer interfaces were determined from geological information collated from exploratory bore holes and bore log information registered on the NOW database. Based on what was the available data, the base of the weathered basalt was assumed to extend to 2m below the base of the coal deposit. The interpolated isopleths were constructed using 'Surfer'.

Each layer was imported to the model and a minimum layer thickness of 1m was assigned. The minimum layer thickness is required to ensure model convergence as model instability can occur where cells become too small relative to the surrounding cells. The 'lensing out' of coal seams away from the Project Site was simulated through permeability assignment and is discussed in **Section 7.3**. North-south and east-west cross-sections (from **Figure 14**) through the model are shown on **Figure 15** (Sections AA' and BB').

7.2.2 Aquifer Parameters

Initial hydraulic conductivity and storage parameters are presented in **Table 8**.

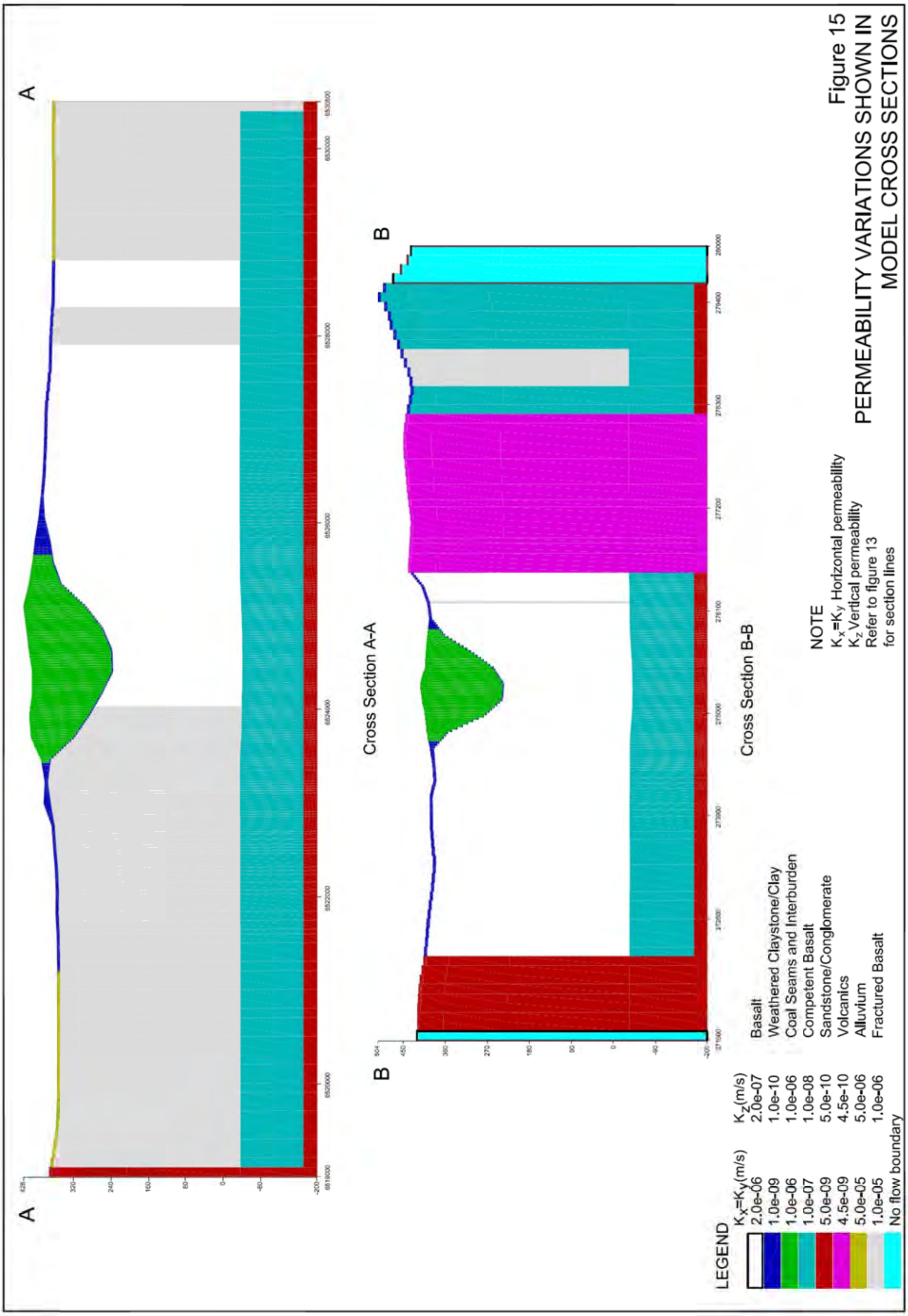
Anecdotal evidence during bore data review determined that secondary porosity was present within the strata, particularly the coal seams, due to fracturing, and that yields in zones of fracturing can be significantly higher. Secondary fracturing was incorporated in the macro permeability through the model calibration process. Localised site specific variations in yields that result from fractures within the strata are beyond the scope of the current modelling. An assessment of the impact on yield from the LOM Project can be undertaken through an evaluation of water level impact.

Storage and porosity values were based on available published data for similar material (Fetter, 1988) with the exception of the basalt strata where estimations were made through field testing. Storage values were used for the transient model analysis, which was conducted to assess impact from the LOM Project. An evaluation of the sensitivity of the model to this parameter is presented in Section 9.2. Initial parameters adopted are presented in **Table 8**.

Table 8
Initial Parameter Assignments

Layer	Permeability (m/s) #	Effective Porosity [1] %	Storativity [2] (1/m)
Coal Seams	1.0E-06	0.15	0.005
Clay/weathered basalt Underlying Lowest Coal Seam (Coal G)	1.0E-10	0.4	0.001
Basalt	2.0E-05 ^	0.1	0.002 ^
Alluvial Strata	5.0E-04	0.25	0.03
Sandstone/conglomerate	1.0E-07	0.03	0.001
Volcanics	5.0E-08	0.03	0.001

Note 1: Freeze and Cherry (1979).
Note 2: Fetter (1988) unless shown.
Refer to **Table 5** unless noted otherwise.
^ Represented as specific storage for a confined aquifer. Estimated from field tests (refer to Appendix 2).


A
A
Cross Section A-A
B
B
Cross Section B-B
LEGEND
Kx=Ky(m/s) Kz(m/s)
2.0e-06 2.0e-07
1.0e-09 1.0e-10 Basalt
1.0e-06 1.0e-06 Weathered Claystone/Clay
1.0e-07 1.0e-08 Coal Seams and Interburden
5.0e-09 5.0e-10 Competent Basalt
4.5e-09 4.5e-10 Sandstone/Conglomerate
5.0e-05 5.0e-06 Volcanics
1.0e-05 1.0e-06 Alluvium
Fractured Basalt
No flow boundary
NOTE
Kx=Ky Horizontal permeability
Kz Vertical permeability
Refer to figure 13
for section lines
Figure 15
PERMEABILITY VARIATIONS SHOWN IN
MODEL CROSS SECTIONS

8. MODEL CALIBRATION AND VALIDATION

8.1 CALIBRATION CRITERIA

The objective of the model calibration was to ensure the model predicted the observed groundwater levels identified in groundwater bores within the model domain. These groundwater levels would be accepted as the steady-state pre-coal removal groundwater head condition. Accepted criteria to ensure a representative model calibration was adopted as follows.

- Simulated water table levels are within the water table measurement error of the bore field and/or the normalised Root Mean Squared (RMS) of calibration is less than 15% (as agreed with NOW).
- The simulated water balance error is less than 2%.

Two groundwater regimes were adopted as being representative of the groundwater condition at the Project Site. The first comprised of data collated from the NOW database and represents water levels measured following bore installation. The second represents water levels measured in 2008 in a selection of groundwater bores. Both data sets were assumed to represent steady state pre-coal removal conditions as well as representing the current site conditions. Water level gauging undertaken by GeoTerra since 2005 has not identified a response in groundwater levels from the existing approved operations. As such, the water levels are considered to be representative of pre-coal mining conditions.

Some groundwater bores utilised to generate these regimes were not surveyed and therefore the top of the bore was estimated from the relevant 1:25,000 topographic map with 10m contour intervals. For the Project Site and surrounds this methodology results in an uncertainty of about ±5m in the surface elevation and consequently there will be a similar error associated with the calculated water table level. This ± 5m error has been adopted as the water table measurement error for the purpose of calibration assessment.

For the NOW data set, there is considered to be a greater degree of error resulting from the recording of water table levels at the time of bore installation. In some instances it is possible that water levels had not stabilised and are therefore erroneous or of low reliability. This was considered when calibrating to the NOW data set.

8.2 CURRENT SITE CONDITIONS CALIBRATION METHODOLOGY

Model calibration under steady state conditions was achieved by systematically changing recharge and the hydraulic conductivity values. Initially, recharge was adopted as 1% of total rainfall in line with previous modelling with high recharge occurring along the ranges and creek systems.

During initial simulations, calculated heads were found to be elevated above observed site conditions throughout the lower topographic areas and the alluvium and lower than observed within the volcanic and sandstone strata. Initial normalised RMS errors were approximately 30%.

Noticeably, water levels in the southern portion of the Project Site were elevated in comparison to the northern section which indicated structural change in the basalt between the northern and southern areas. This same conclusion was reached during development of the 2009 model.

Additionally, regular variability was evident between bores in close proximity to each other that could not be discounted. This was considered likely due to aquifer anisotropy resulting from fracturing of the basalt, volcanic and conglomerates along fault lines, evident by creek lines and gully formations. Higher permeability zones were assigned along creek lines to represent zones of fracture and this produced an improved calibration. Further improved calibration was achieved by decreasing permeability in Layer 6 over the basalt domain to represent a lower occurrence of fractures with depth.

Adjustments in permeability values and locations were made within each layer until the hydrogeological condition was consistent with that observed. The normalised RMS determined for the final permeability combination is presented in **Figure 16** for the NOW data set.

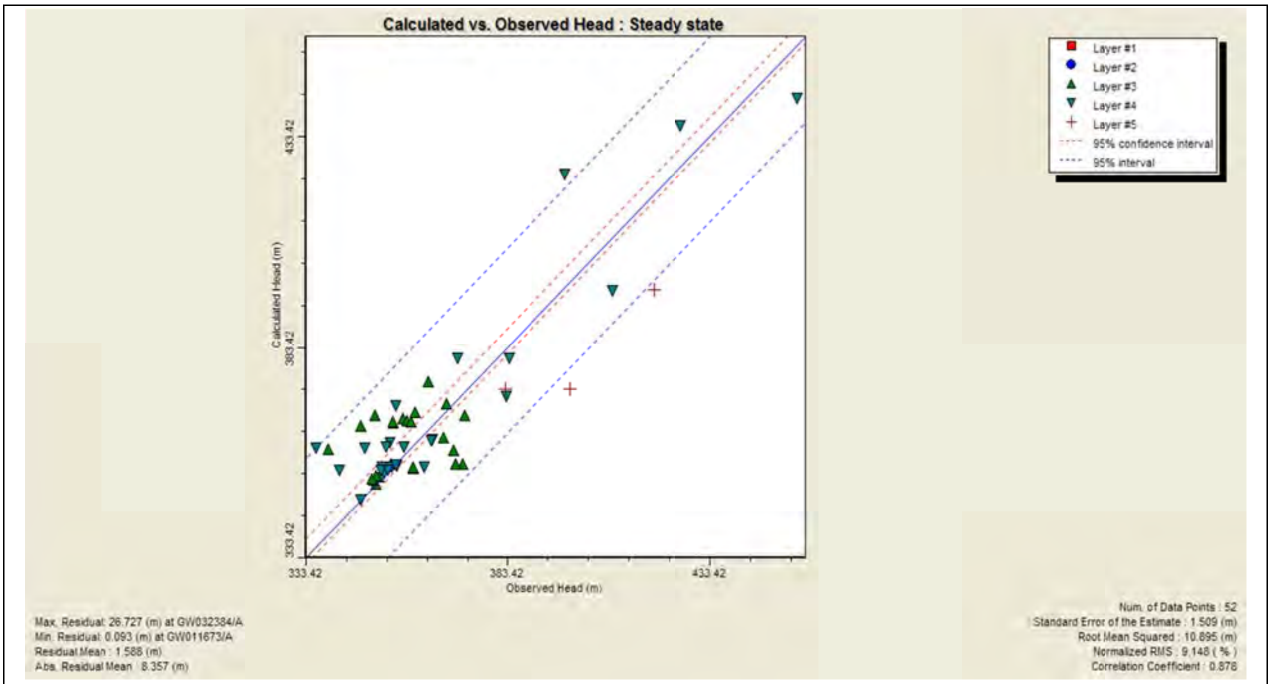


Figure 16 Calibration Output for Iterated Recharge and Permeability Combination in Comparison to the NOW Data Set

The normalised RMS is 9.1% and below the acceptable RMS of 10%. The maximum residual head is 27m and is considered acceptable for the NOW data set. This head value is considered reasonable when considering the complexity of the strata within the model domain, the length of time over which water levels have been measured and the potential for inaccuracy within that measurement.

Comparison with the 2008 data set is shown in **Figure 17** and indicates an RMS of less than 10% and a maximum residual head of -9.1m. This maximum residual head calculation is outside of the ±5m adopted variation however, given the model complexities and the good correlation with other observed head values is considered to be acceptable.

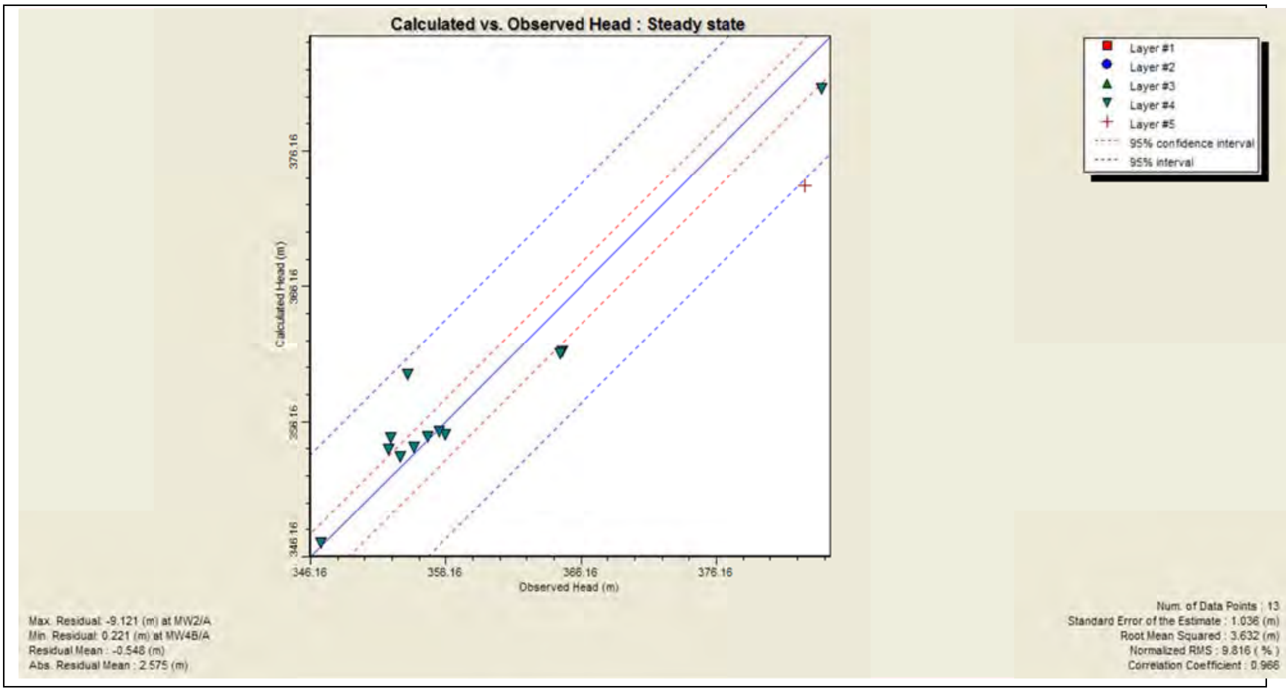


Figure 17 Calibration Output for Iterated Recharge and Permeability Combination in Comparison to the 2008 Data Set

The water balance error was also reviewed to assess model stability. The water balance error for the simulation is presented in **Figure 18** and shows an error of <1% in the water balance. This low water balance error indicates robustness and stability within the model.

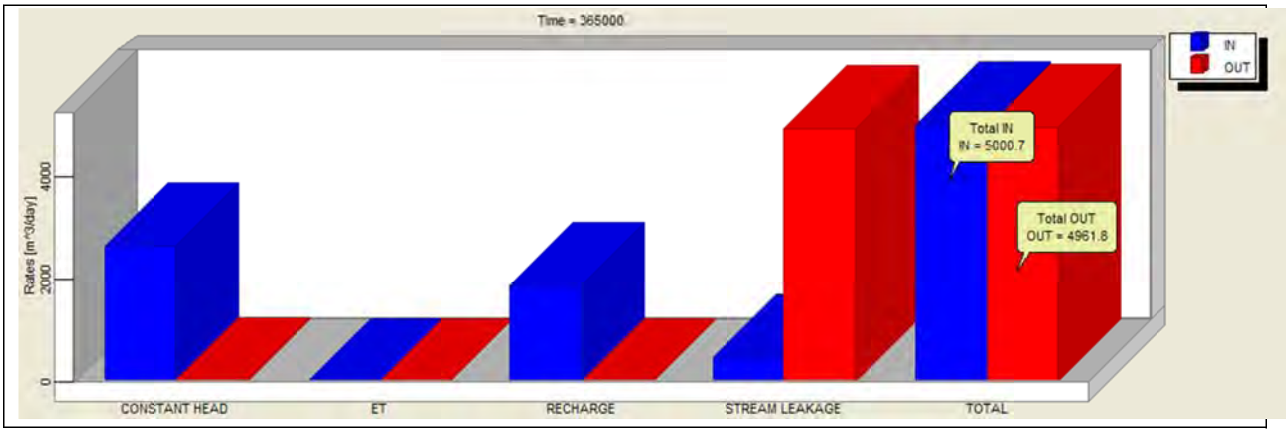


Figure 18 Water Balance Flux for Steady State Calibration

8.3 CALIBRATION SUMMARY

The steady state model calibration to simulate observed site conditions has identified that the groundwater system was best represented by areas of varying permeability and recharge as shown on **Figures 19** to **24**.

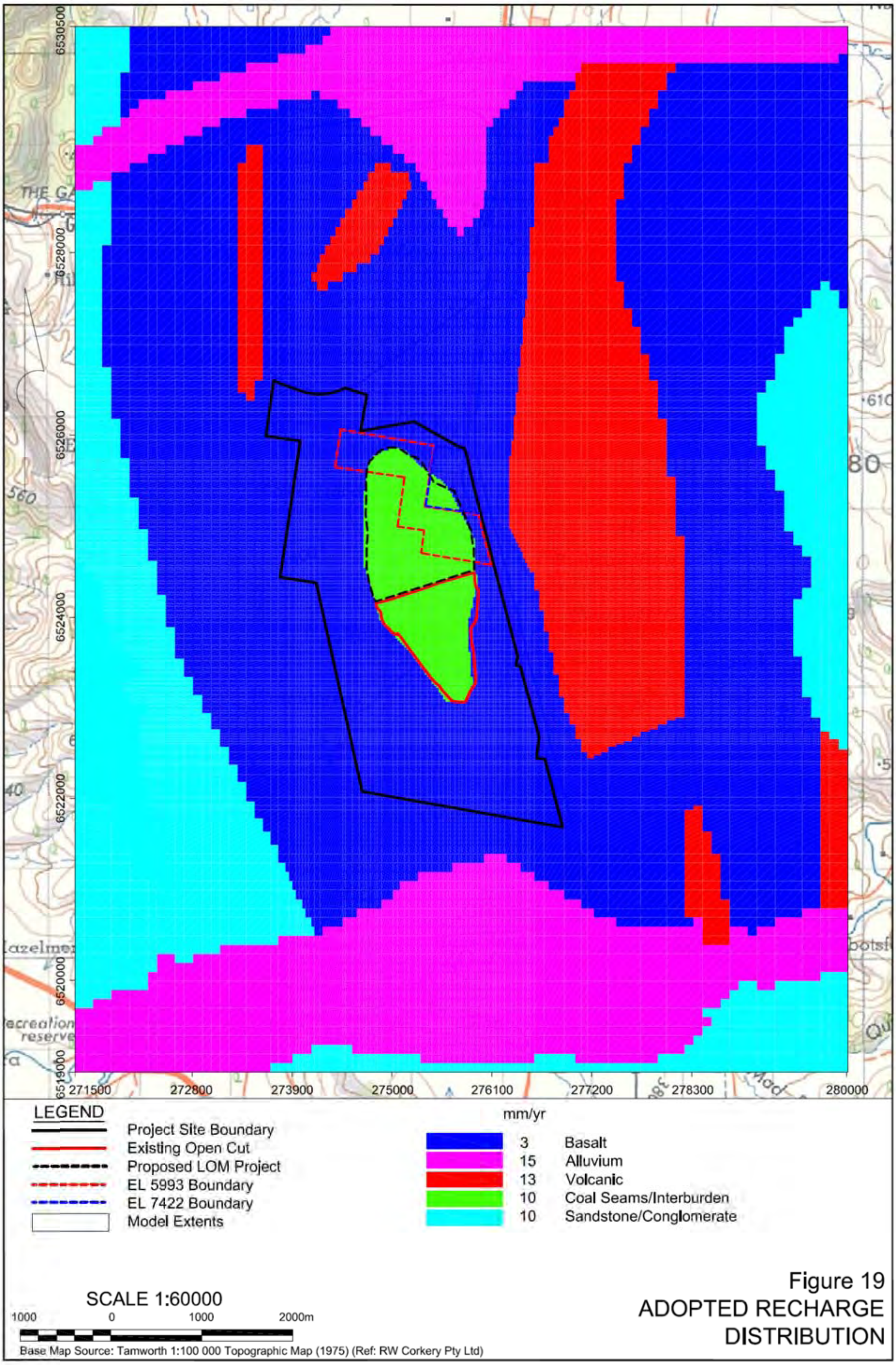


Figure 19
ADOPTED RECHARGE
DISTRIBUTION

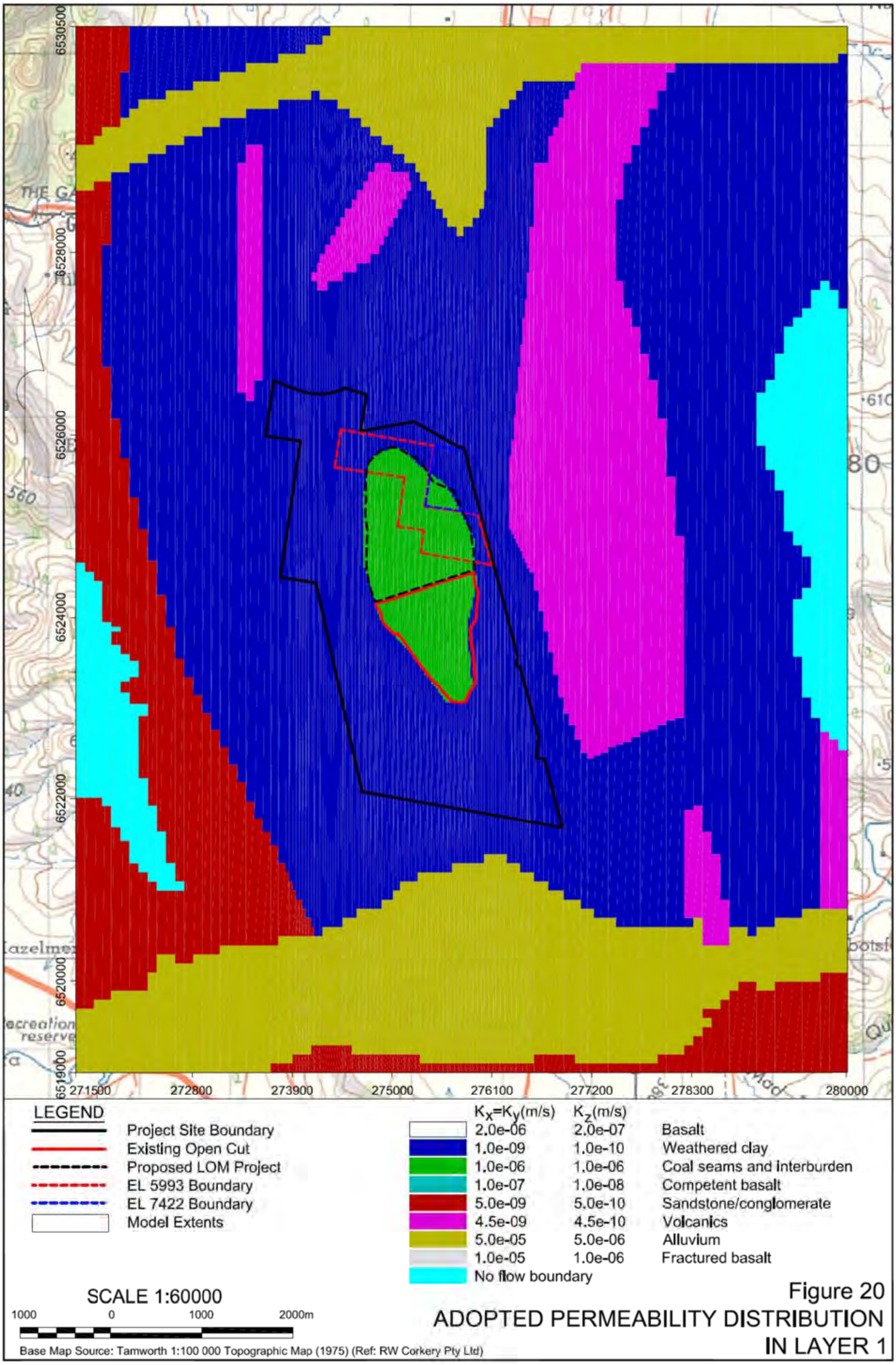


Figure 20
ADOPTED PERMEABILITY DISTRIBUTION IN LAYER 1

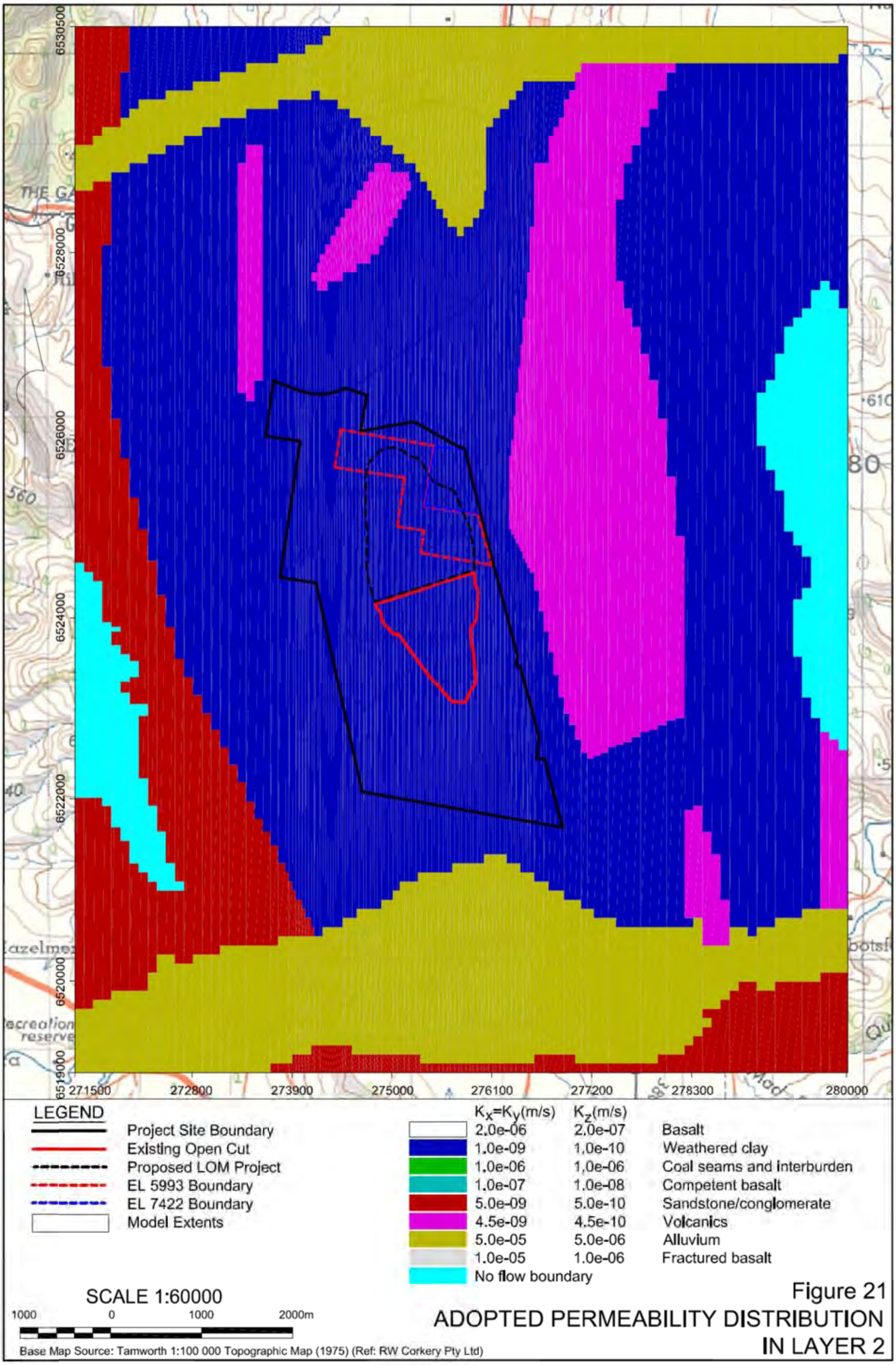


Figure 21
ADOPTED PERMEABILITY DISTRIBUTION IN LAYER 2

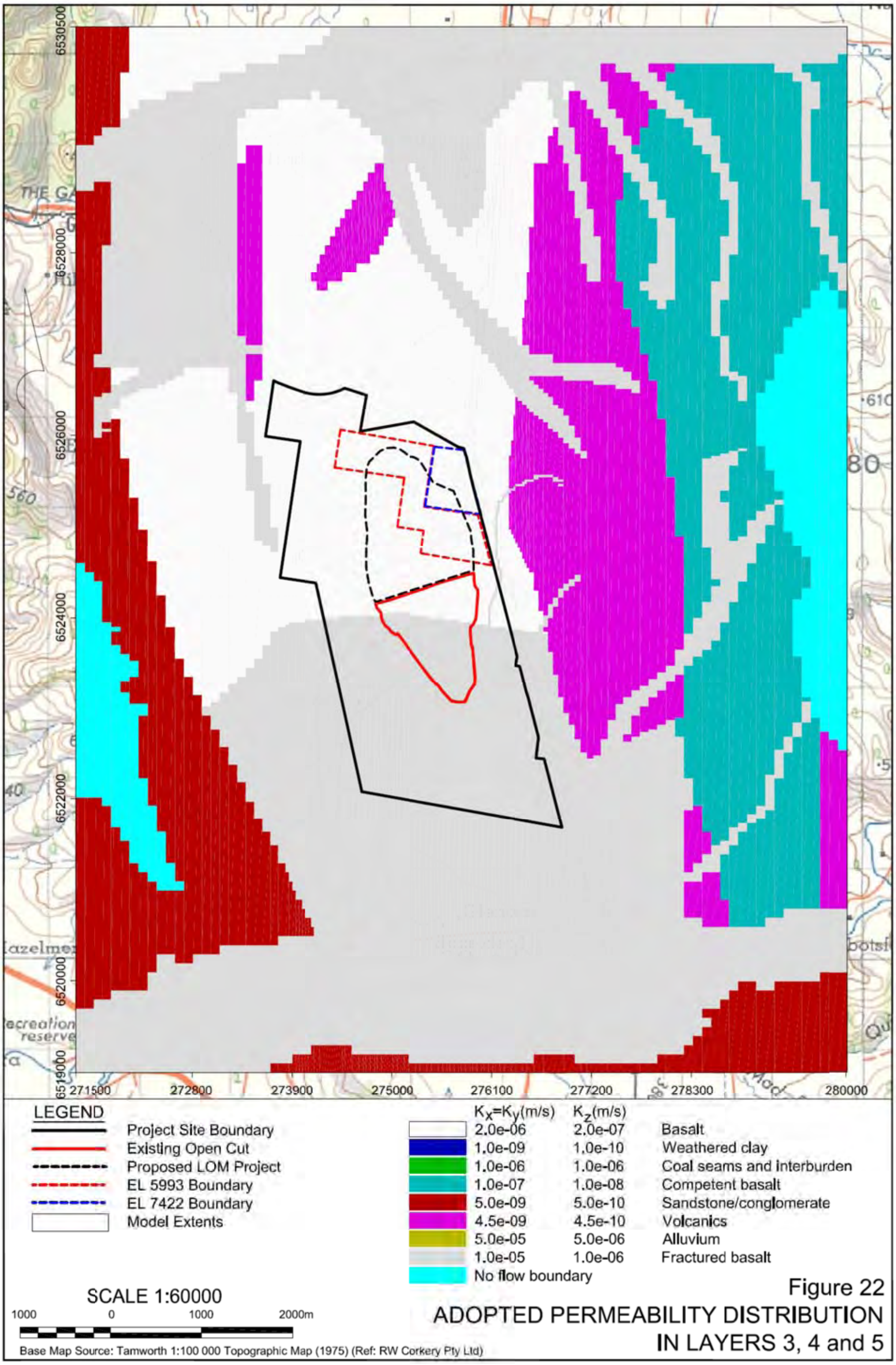


Figure 22
ADOPTED PERMEABILITY DISTRIBUTION IN LAYERS 3, 4 and 5

Figure 23
ADOPTED PERMEABILITY DISTRIBUTION IN LAYER 6

Figure 24
ADOPTED PERMEABILITY DISTRIBUTION IN LAYER 7

In summary, the recharge of 3mm/year was applied to the majority of the model domain and represents approximately 0.5% of the annual rainfall. This is consistent with modelling undertaken in 2009. Localised recharge of 13mm/year was applied to the higher regions and represents 1.9% of the annual rainfall. There is no obvious reason why higher recharge is required in this area to calibrate the model, but some increases could be attributed to the ephemeral drainage channels within the valley, a higher permeability within the unsaturated zone, lower runoff due to vegetation on the slopes or lower evapotranspiration resulting from a deeper water table in these areas. An increased infiltration along Quipolly Creek alluvium of 15mm/year was introduced to represent the increased recharge that would occur in this area due to increased surface permeability and reduced surface gradients. An increased recharge to the Greta Coal Measures outlier of 10mm/year was also introduced to represent the higher infiltration relative to the surrounding weathered basalt that would occur in this area as a result of coal seams close to the surface and a highly fractured subsurface. The recharge distribution adopted is presented in **Figure 19**.

The final permeability distributions for each layer are presented in **Table 9**.

Table 9
Adopted Permeability Distribution

Layer	**Permeability adopted (m/s)**		**Range of Field Measured Data (m/s)**
	$K_x = K_y$	K_z	$K_x = K_y$
Coal Seams and interburden	1.0E-06	1.0E-06	3.0E-07 to 2.0E-06
Weathered Clay	1.0E-09	1.0E-10	1.0E-09 to 3.0E-09
Basalt	2.0E-06	2.0E-07	2.0E-06 to 2.0E-05
Fractured Basalt	1.0E-05	1.0E-06	
Alluvium	5.0E-05	5.0E-06	2.0E-04 to 2.0E-03
Sandstone/conglomerate	5.0E-09	5.0E-10	No data
Volcanics	4.5E-09	4.5E-10	No data
K_x=K_y horizontal permeability. K_z = vertical permeability. K represents permeability in all directions.			

The permeability values adopted are within the ranges of permeability values measured at the LOM Project Site where measured data was available. The exception is for the alluvium where a lower than measured value was adopted. This was not considered consequential for the LOM Project Site where alluvium parameters are not a driver for groundwater flow.

This combination of recharge and permeability is considered plausible for the LOM Project Site and surrounds although is not likely to be a unique solution. It is possible that other combinations of recharge and permeability are available that can provide a similar approximation to the steady state condition.

The closest approximate solution resulted in a maximum and minimum residual of the water table after calibration of -9.1m and 0.2m at MW2 and MW4B, respectively. The absolute residual mean and RMS were determined to be -0.5m and 2.5m, respectively, with a normalised RMS of 9.8% and a correlation coefficient approaching 1. The calibration results indicate that the model is a good representation of the regional recharge and permeability distribution and is a suitable starting condition for transient analysis to determine drawdown created by the LOM Project.

Based on a low RMS value of <10% and the low water balance error of <1%, it can be concluded that the model has been calibrated.

8.4 INITIAL GROUNDWATER HEAD CONDITION

The initial steady state groundwater condition was determined for each layer. The groundwater condition for Layer 4 is presented in **Figure 25** and is representative of the groundwater condition outside of the syncline.

8.5 TRANSIENT CALIBRATION

Model validation was undertaken by modelling existing mining conditions at the LOM Project Site and comparing these against monitored water level change in monitoring bores P1 and P2. Water level change has not been observed within the monitoring bores and therefore any drawdown within the basalt strata underlying the coal measures should be negligible. Previous modelling undertaken by RCA in 2009 (RCA 2009) predicted drawdown in basalt underlying the coal measures to be up to 15m after Year 1 of the Northern Extension (**Figure 26**) and 20m following completion of Year 3 of the Northern Extension and dewatering of the underground workings. Monitoring in P1 and P2 indicates that this is not the case and that drawdown within the coal measures is not reflected in the basalt layers, which is most likely due to the presence of the weathered basalt/clay aquitard. These observations indicate that the permeability of the weathered basalt/clay aquitard is lower than the 5×10^{-9} m/s adopted for the 2009 model.

The model for this assessment has adopted a lower clay permeability of 1×10^{-9} m/s with modelling of the Year 1 scenario indicating drawdown in the underlying basalt of up to 0.4m. Drawdown of this magnitude is not expected to be observed within the monitoring bores, however, is considered a closer approximation to field conditions than previous modelling, which predicted approximately 10m of drawdown at P1 and P2. Evaluation of the sensitivity of the model to the permeability of the clay aquitard is undertaken in Section 9.2.

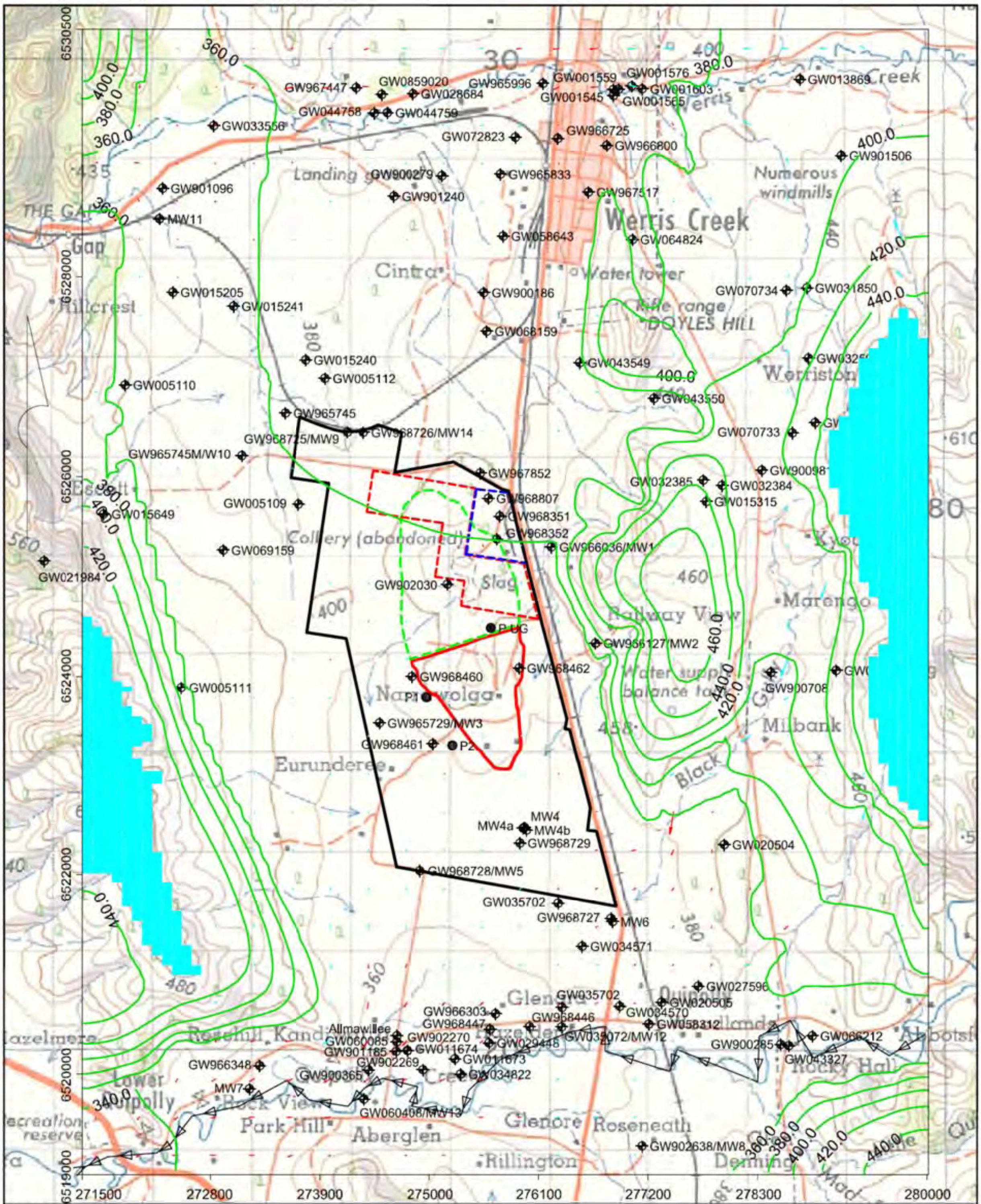
9. MODEL SIMULATION OF THE PROJECT

9.1 CALIBRATED/VALIDATED MODEL SIMULATION

Modelling the impact on groundwater of the LOM Project was undertaken to provide an indication of the likely groundwater table response to the LOM Project. The modelling considers existing data, local and regional site conditions, the proposed modification to mining operations and the resulting impacts surrounding the Project Site.

The initial water table condition for the transient modelling was simulated under steady state conditions, which are assumed to be representative of long-term climatic conditions but also representative of the current site conditions. To predict the drawdown affect created by the progressive open cut mining associated with the LOM Project, a transient simulation was necessary.

The limit of the open cut mining area was simulated by applying constant head values at the depth of the open cut. Simulations were undertaken for the conceptual mine plans in Years 3, 7, 12 and 15 of the LOM Project. At the completion of each mine scenario the constant head was removed and simulated spoil was placed within the void to the levels shown on the mine plans. This allows for recovery of the water table in backfilled areas and provides a closer approximation of mine inflow. The progressive mine stages also represents the progressive placement of mine spoil.



NOTE
Registered monitoring bore locations sourced from the NSW Natural Resource Atlas - www.nratlas.nsw.gov.au 2009 Copyright © 2009 New South Wales Government. Map has been compiled from various sources and may contain errors or omissions. No representation is made as to its accuracy or suitability.

LEGEND

- Project Site Boundary
- Existing Open Cut
- Proposed LOM Project
- EL 5993 Boundary
- EL 7422 Boundary
- Model Extents
- GW Registered Monitoring Bore
- MW Monitoring Well
- P Observation Bore
- Predicted water table equipotential (m, AHD)
- No flow cell

SCALE 1:60000

1000 0 1000 2000m

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

Figure 25
PREDICTED INITIAL GROUNDWATER CONDITION IN LAYER 4

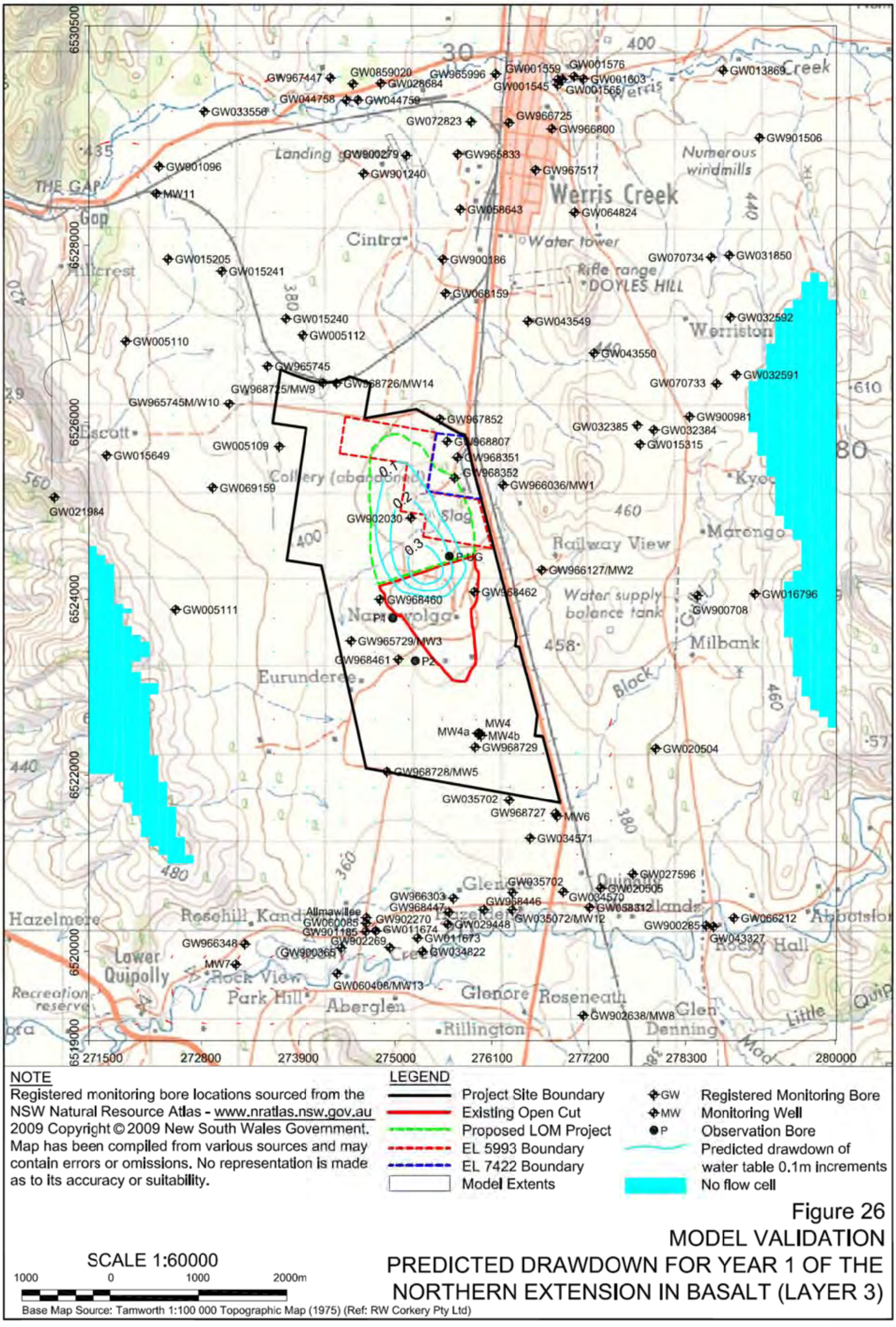


Figure 26
MODEL VALIDATION
PREDICTED DRAWDOWN FOR YEAR 1 OF THE NORTHERN EXTENSION IN BASALT (LAYER 3)

The proposed mine sequence of 2012 (Year 3 of the Northern Extension Project) was simulated to provide the current head condition for the purpose of modelling subsequent mine scenarios for the LOM Project. Dewatering of the underground mine workings was assumed to have been completed prior to commencement of the LOM Project (as determined to be required in the assessment for the Northern Extension). The proposed mine sequence of 2012 included dewatering of the existing underground workings. This dewatering was modelled by apply constant head cells to the mine voids to artificially reduce the water table. Once the water table was reduced the constant head cells were removed to all recovery and all for water from within the mine voids to drain to the open cut. This was considered to be a conservative model approximation and would over estimate mine inflow.

Output from mining scenarios was compared against the initial pre-mining groundwater condition represented in **Figure 25**.

The long-term groundwater condition following completion of the open cut LOM Project was simulated by removing the constant head boundary and varying the permeability of the layers within the void to represent backfilled overburden/interburden. The backfilled overburden/ interburden was modelled as a uniform mass with permeability of $1x10^{-5}$ and a specific yield of 0.01. This permeability was adopted on the assumption that the overburden would be backfilled above the equilibrium groundwater level to create the final landform. The mine plan simulations included a component of open cut and progressive placement of spoil within the mined areas. The depth of spoil placement was based on the mine plans for each scenario modelled.

9.1.1 Stress Periods

The stress periods modelled were the duration between each modelled mine plan. For example, the Year 3 mine plan was modelled for 3 years, the Year 7 mine plan was modelled for 4 years and so on. Ten time steps were adopted across each stress period and this was considered sufficiently small to capture the early time water table response.

Recovery was modelled for a period of 100 years with 50 time steps adopted across this duration. This number of time steps was also considered sufficiently small to capture the response in the water table. The time period of 100 years was shown to be sufficient, however was selected as a starting point to identify asymptotic conditions. Should sufficient recovery have not occurred over that period a longer timeframe would be adopted.

Increasing timestep durations were adopted for all simulations as changes in stress only occur at the commencement of modelling. This allowed for a concentration of small steps at the start of the model run to capture the water table response.

9.2 SENSITIVITY ANALYSIS

9.2.1 Introduction

A sensitivity analysis of the model was undertaken to determine the impact of chosen parameters on model behaviour. Recharge, permeability and specific storage are the main parameters that can impact on model predictions. The sensitivity of the model to recharge and permeability is addressed in the calibration process outlined in Section 8.2.

Previous modelling (RCA 2009) found the model to be sensitive to the storage coefficient adopted for the basalt aquifer. Field testing of storage parameters was undertaken to provide confidence in the value chosen. Field testing determined that values in the order of 0.002 1/m to be representative of the aquifer. This is lower than the range assessed for this parameter during the sensitivity analysis where values of 0.005 1/m were considered to be the low end of the range for this parameter. Lower specific storage values were found to provide greater levels of impacts and therefore the adoption of 0.002 is considered to provide a conservative evaluation of impacts.

Further sensitivity analysis was undertaken assessing the permeability of the clay layer underlying the coal measures. Impacts were evaluated in terms of maximum drawdown beneath the coal measures. These results are presented in **Table 10** for the variation in permeability assessed. The sensitivity analysis was undertaken by increasing the permeability as a reduced permeability would result in lower connectivity with the basalt aquifer and a lower impact. The evaluation was undertaken using the Year 1 scenario for the Northern Extension, the model used for validation. The maximum drawdown predicted in the underlying basalt strata is presented in **Table 10**.

Table 10
Model Sensitivity to Permeability of the Clay Aquitard

Permeability (m/s)	Maximum Drawdown Predicted in underlying Basalt strata (m)	Drawdown in Observation Wells	
		P1	**P2**
$1x10^{-9}$	0.3m	<0.1m	<0.1m
$5x10^{-9}$	2.0m	<0.1m	<0.1m
$1x10^{-8}$	21.7m	2m	1m

The results indicate that the model is sensitive to the permeability of the aquitard and that drawdown increases with decreasing permeability, which is expected. The analysis indicates that a permeability of $1x10^{-8}$m/s produced drawdown in the P1 and P2 observation wells greater than that observed by monitoring, thereby demonstrating that the aquitard permeability is less than $1x10^{-8}$ m/s. The drawdowns predicted from scenarios three and four, using lower permeabilities, could both produce the head conditions observed at P1 and P2. Measured permeability in the weathered clay found values of $1x10^{-9}$ m/s and $3x10^{-9}$ m/s, demonstrating that the likely permeability is less than $5x10^{-9}$ m/s. The adopted permeability of $1x10^{-9}$ m/s is therefore considered to be reasonable.

10. PREDICTED IMPACTS OF THE PROPOSED MODIFICATION

10.1 PREDICTED DRAWDOWN ON THE REGIONAL WATER TABLE

10.1.1 Calibrated Model Predictions

The drawdown in the regional water table predicted by the model at the completion of Year 3, Year 7, Year 12 and Year 15 are presented in **Figures 27** to **30**. These figures reflect drawdown in Layer 3 of the model which is representative of most groundwater bores in the local area. The predicted impact on groundwater bores surrounding the Project Site is tabulated in **Table 11**. Groundwater modelling has predicted a drawdown of up to 0.1m within the Project Site boundary with drawdown increasing to approximately 1.0m in the vicinity of LOM Project open cut area.

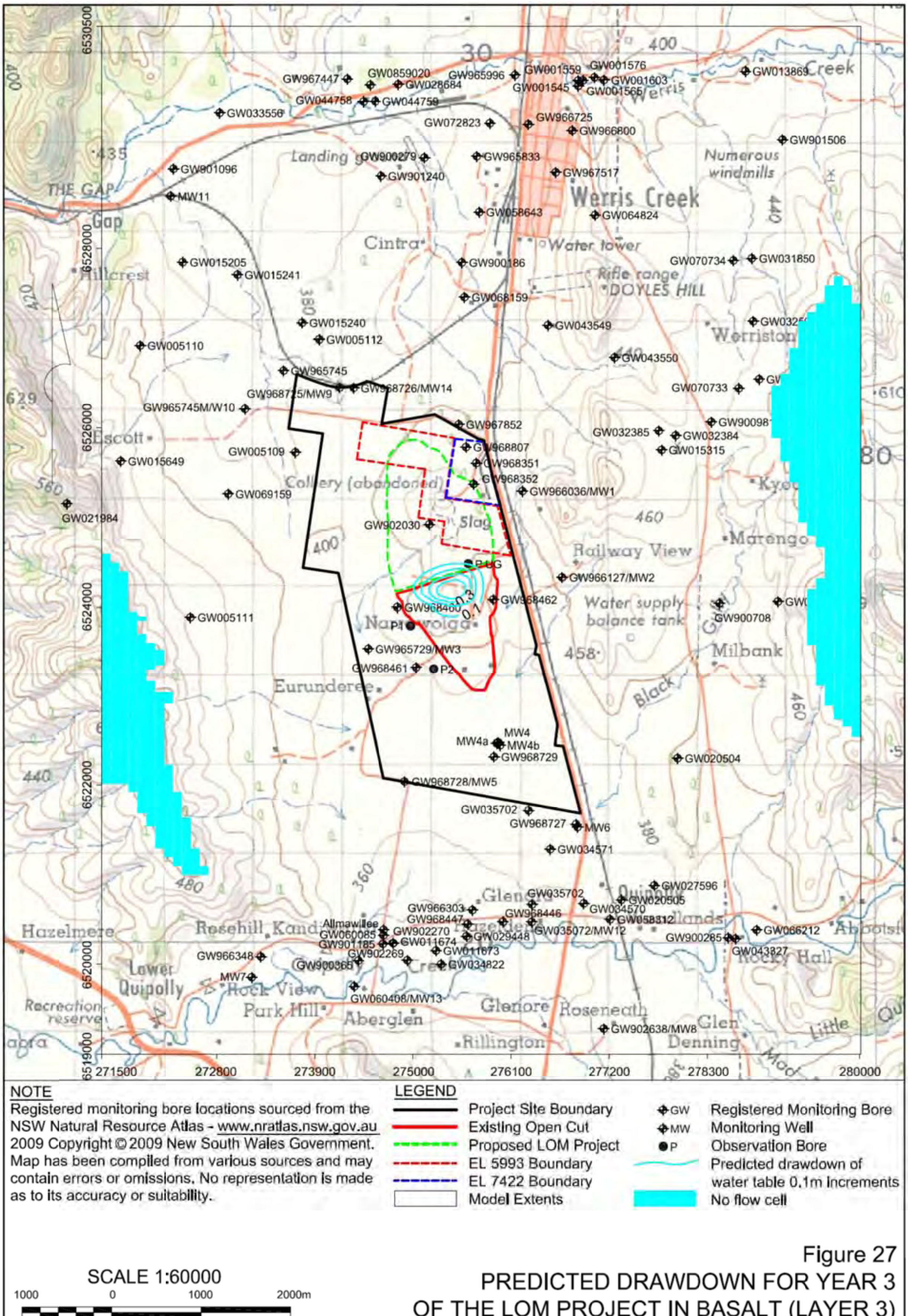
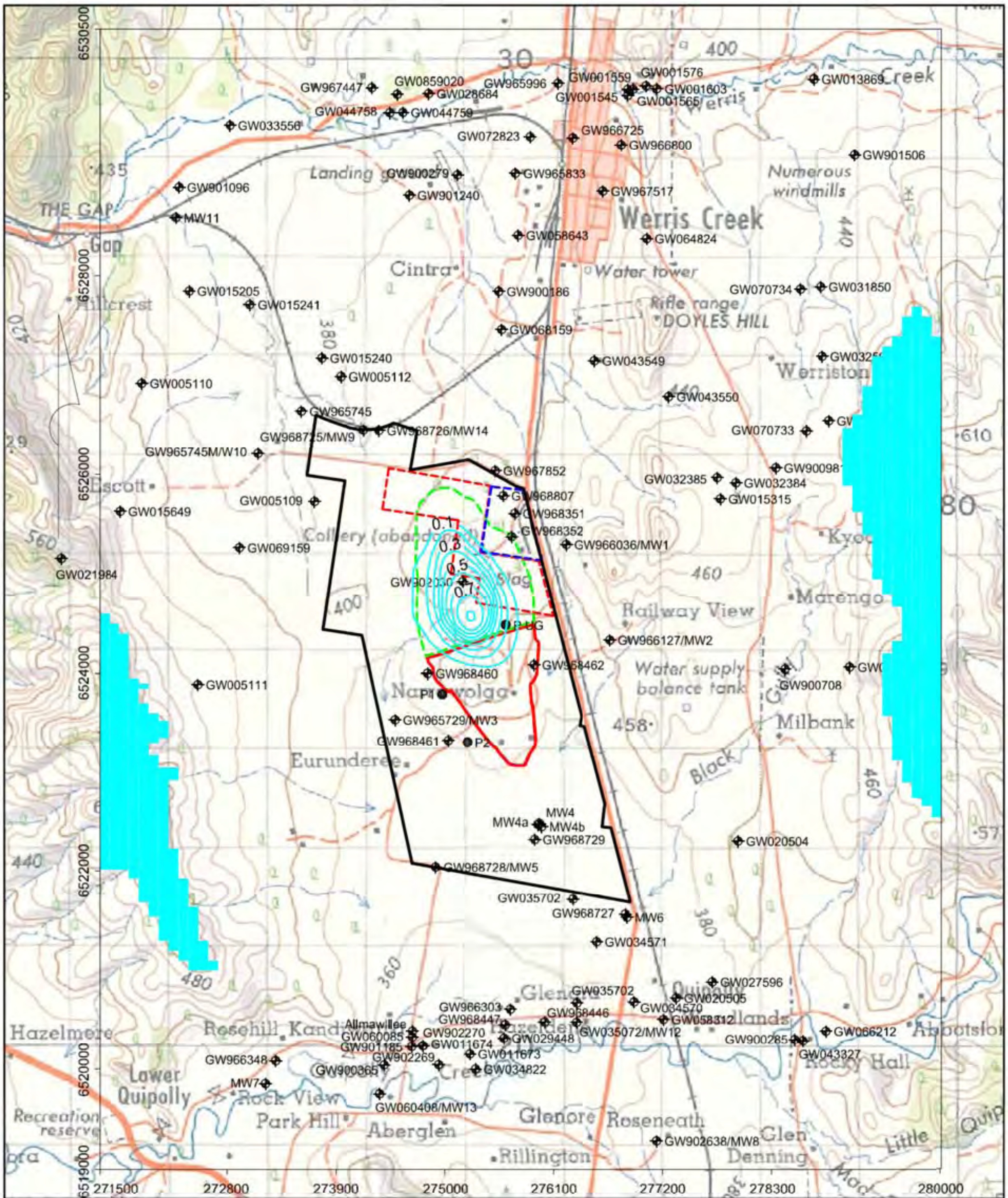


Figure 27
PREDICTED DRAWDOWN FOR YEAR 3 OF THE LOM PROJECT IN BASALT (LAYER 3)

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)



NOTE
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LEGEND

- Project Site Boundary
- Existing Open Cut
- Proposed LOM Project
- EL 5993 Boundary
- EL 7422 Boundary
- Model Extents
- GW Registered Monitoring Bore
- MW Monitoring Well
- P Observation Bore
- Predicted drawdown of water table 0.1m increments
- No flow cell

SCALE 1:60000
1000 0 1000 2000m

Figure 28
PREDICTED DRAWDOWN FOR YEAR 7 OF THE LOM PROJECT IN BASALT (LAYER 3)

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

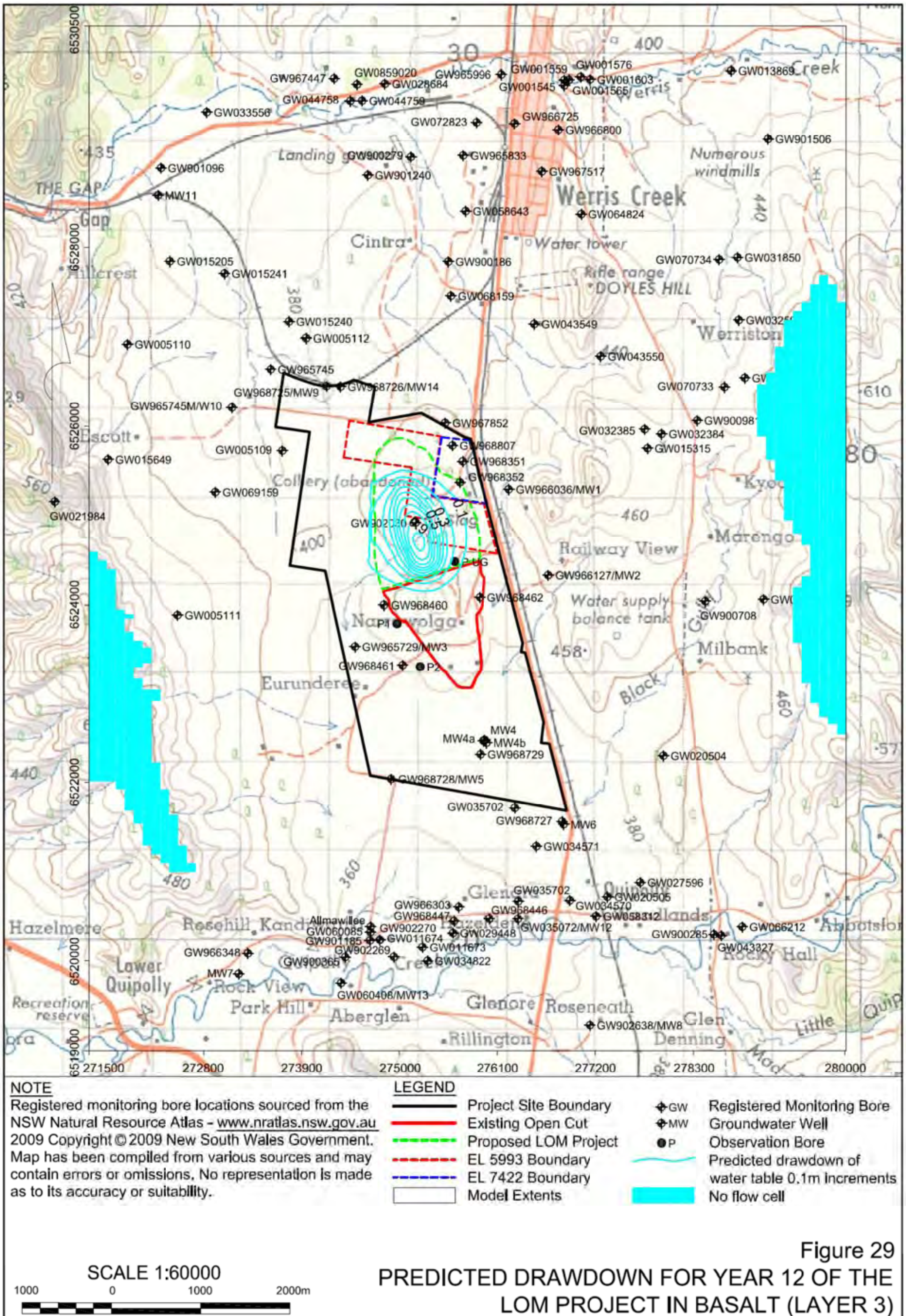
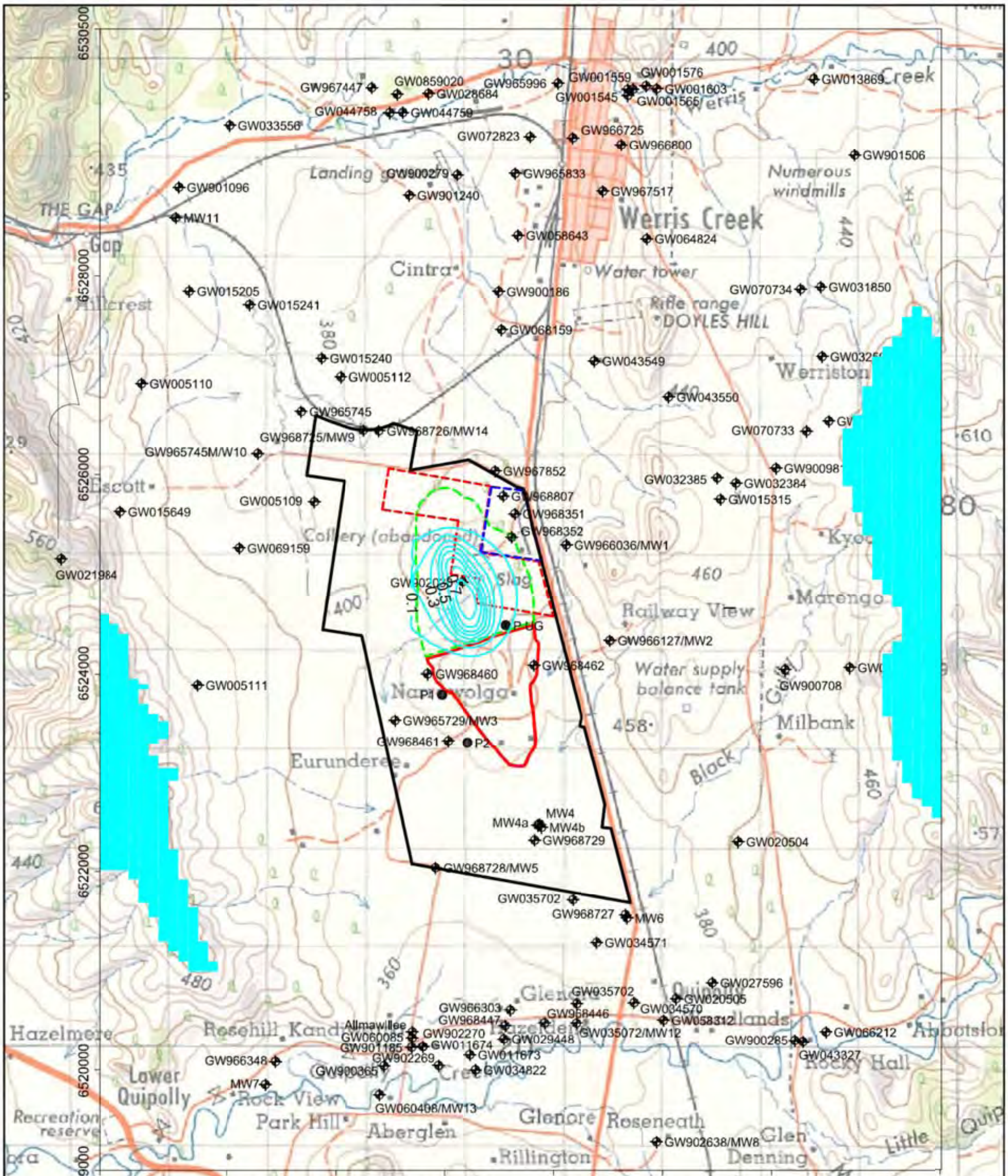


Figure 29
PREDICTED DRAWDOWN FOR YEAR 12 OF THE LOM PROJECT IN BASALT (LAYER 3)

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)



NOTE
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LEGEND

Black line	Project Site Boundary
Red line	Existing Open Cut
Green dashed line	Proposed LOM Project
Red dashed line	EL 5993 Boundary
Blue dashed line	EL 7422 Boundary
Open box	Model Extents
GW	Registered Monitoring Bore
MW	Monitoring Well
P	Observation Bore
Cyan line	Predicted drawdown of water table 0.1m increments
Cyan fill	No flow cell

SCALE 1:60000
1000 0 1000 2000m

Figure 30
PREDICTED DRAWDOWN FOR YEAR 15 OF THE LOM PROJECT IN BASALT (LAYER 3)

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

Table 11
Predicted Drawdown and Reduction in Saturated Thickness within 2km of proposed mining

Bore No	Property	AGM Easting	AGM Northing	Usage	Approx. Distance from limit of proposed mining (m)	Total Depth (m)	Water Bearing Zone Strata	Yield (L/sec)	SWL @ (m)	Saturated Thickness (m)	Predicted loss in head (m)	% Reduction in Saturated Thickness	Comments
GW902030	Old Colliery	275169	6524932	Domestic	0	96.6	Coal Measures	33.5	63.1	33.5	0.1	0.3%	Tested 2004
GW968352	Preston Park	275665	6525381	Domestic	10	48.80	Basalt/Water Bearing	1.26	35.3	13.5	<0.1	0.7%	Not Tested
GW968462	Narrawolga	275892	6524087	Monitoring	40	61	Basalt	NK	NK	NK	<0.1	NK	Not Tested
GW968460	Narrawolga	274815	6524004	Monitoring	60	42	Basalt	NK	NK	NK	<0.1	NK	Not Tested
GW968461	Narrawolga	275022	6523326	Monitoring	300	25	Basalt	NK	NK	NK	<0.1	NK	Not Tested
GW965729 (MW3)	Eurunderee	274599	6522941	Stock	600	39.6	Basalt	15.2	24.4	15.2	<0.1	0.7%	Tested 2008
GW966127 (MW2)	Railway View	276770	6524400	Domestic & Stock	820	65.5	Basalt	27.3	38.2	27.3	<0.1	0.4%	Tested 2008
GW968351	Preston Park	275696	6525612	Domestic & Stock	1080	76.2	Basalt	47.8	28.4	47.8	<0.1	0.2%	Not Tested#
MW5	Narrawolga	274900	6522046	Monitoring	1240	28	Basalt	8.2	19.8	8.2	<0.1	1.2%	Tested 2008
GW966036 (MW1)	Hillview	276380	6525100	Domestic & Stock	1250	68.7	Basalt	51.1	17.6	51.1	<0.1	0.2%	Tested 2008
GW967852	Cintra	275501	6526039	Domestic & Stock	1350	80	Shale	NK	NK	NK	<0.1	NK	Not Tested
GW005109	Lot 2, 802219	273671	6525732	Domestic & Stock	1640	79.2	Basalt	NK	NK	NK	<0.1	NK	Not Tested
GW034571	Lot 8 DP751017	276516	6521295	NK	1650	14.6	NK	NK	NK	NK	<0.1	NK	Not Tested
GW069159	Escott	272917	6525270	Domestic & Stock	1700	30.40	WB Basalt	1.26	11.9	18.5	<0.1	0.5%	Not Tested#
GW015240	Escott	273746	6527182	Stock	1800	20.70	Basalt	0.46	13.4	7.3	<0.1	1.4%	Not Tested#
MW6	Narrawolga	276810	6521544	Monitoring	1840	16	Basalt	11.1	4.9	11.1	<0.1	0.9%	Tested 2008
GW900708	Talavera	278418	6524040	Domestic & Stock	1935	192	Basalt	1.4	190.6	1.4	<0.1	7.1%	Tested 2004
GW968729 (MW4b)	Narrawolga	275896	6522327	Monitoring Bore	2000	NK	NK	NK	NK	NK	<0.1	NK	Not Tested
MW4a	Narrawolga	275940	6522469	Monitoring	2000	NK	Basalt	NK	8.9	NK	<0.1	NK	Not Tested
GW900186	NK	275534	6527859	Domestic & Stock	2000	24.30	W.B. Basalt/Basalt	1.26	16.6	7.7	<0.1	1.3%	Not Tested#
GW020505	Woodlands	277320	6520726	Stock	2050	23.8	Alluvial/Basalt	NK	NK	NK	<0.1	NK	Not Tested
GW032385	Hill View	277737	6525973	Stock	2100	97.50	Basalt Yellow Soak	0	28.7	68.8	<0.1	0.1%	Not Tested#
MW14	Cintra	274323	6526454	Monitoring	2240	26	Basalt	15.2	10.8	15.2	<0.1	0.7%	Tested 2008
GW020504	Woodlands	277947	6522311	Stock	2260	18.3	NK	NK	NK	NK	<0.1	NK	Not Tested
MW9	Cintra	274165	6526458	Monitoring	2280	28	Basalt	13.5	14.5	13.5	<0.1	0.7%	Tested 2008
GW005110	Escott	271927	6526927	NK	2300	18.3	Basalt	15.2	3.1	15.2	<0.1	0.7%	Not Tested#
GW005111	Escott	272495	6523889	NK	2400	88.4	Basalt	31.7	56.7	31.7	<0.1	0.3%	Tested 2004
GW015241	Escott	273020	6527721	Stock	2500	51.20	Basalt	0.19	9.1	42.1	<0.1	0.2%	Not Tested#
GW068159	Escott	275563	6527469	Domestic & Stock	2500	58.50	Shale	6.3	NK	NK	<0.1	NK	Not Tested
GW005112	NK	273935	6527001	NK	2650	48.8	Basalt	NK	NK	NK	<0.1	NK	Not Tested
GW965745 (MW10)	Turnbulls	273131	6526225	Domestic	2760	22	Basalt	18.2	3.8	18.2	<0.1	0.5%	Tested 2008
GW901240	Robynville	274631	6528826	Domestic & Stock	3000	28.90	Basalt	2.52	NK	NK	<0.1	NK	Not Tested

@ SWL (Standing Water Level); Not Tested - Testing not attempted, NK – not known # Taken from Department of Natural Resources. ^ Determined from modelling. * Based on field observations and discussions with owners (2004)

Drawdown at bores can be expressed as a reduction in saturated thickness which provides a useful relationship between the drawdown and the depth of water within the bore (saturated thickness). Reduction in saturated thickness can impact on bore yield by reducing the head of water available for pumping. A loss of saturated thickness has been calculated for bores within 2.5km of the proposed mining boundary.

At the completion of operations, the Project Site would be rehabilitated to a final landform (indicatively shown as **Figure 32**). To predict the final landform groundwater regime and the time taken to reach this regime, the model allowed re-saturation of the overburden. Evapotranspiration was also established for the mined footprint to accommodate the effects of evapotranspiration on near surface groundwater. Evapotranspiration does occur across the whole model domain, however, the depth to the groundwater table across the remainder of the model is in excess of the expected depth of evapotranspiration impact, and therefore this function has no consequence. In the mined footprint the presence of the aquitard, which acts to retain infiltration in the mined void and the reduced elevation of the landform are considered likely to result in a groundwater table that approaches or breaches the surface landform. As such, evapotranspiration will impact on the final groundwater table regime.

Evapotranspiration was set to an impact depth of 2m from the final landform. The value of evapotranspiration was taken from the Bureau of Meteorology. Three different rates for evapotranspiration are presented. The annual average point potential evapotranspiration was adopted as the most appropriate to the site conditions as this represents sites where the water supply is unlimited and surrounding land has a limited water supply. The adopted evapotranspiration was therefore 1600mm/yr with an effective depth of 2.0m.

The results indicate that the water table recovers to approximately 325m AHD. The predicted long-term groundwater condition is shown on **Figure 33**. A comparison of the final landform and the predicted final groundwater regime shows that the groundwater table would not breach the final surface. The rate of recovery of the final water table is shown in **Figure 31**. This graph shows that the full extent of recovery occurs within 10 years of the completion of mining. Groundwater recovery in the early years following the completion of mining is more rapid than as it reaches equilibrium. This is because as the water level reached equilibrium, there is less room for groundwater movement, thus recovery slows.

Variation of evapotranspiration was undertaken to assess the model sensitivity to this parameter. Adoption of a much lower evapotranspiration of 650mm/year predicted that the water level recovery would stabilise at approximately 327m AHD. Adoption of a much higher value of 2000mm/year which is the approximate pan evaporation, predicts a final water level of around 324m AHD. These results indicate that the model is not sensitive to evapotranspiration within the likely range of evapotranspiration values.

10.1.2 Predicted Groundwater Seepage to Operations Area

Based on the model simulations, the seepage to the void at the completion of mining stages is presented in **Table 12**.

Table 12
Total Seepage to the Void

Time Period	Year 3	Year 7	Year 12	Year 15
Flow Total (m^3/day)	36	137	129	60
Annual In-flow (ML/year)	13	50	47	22

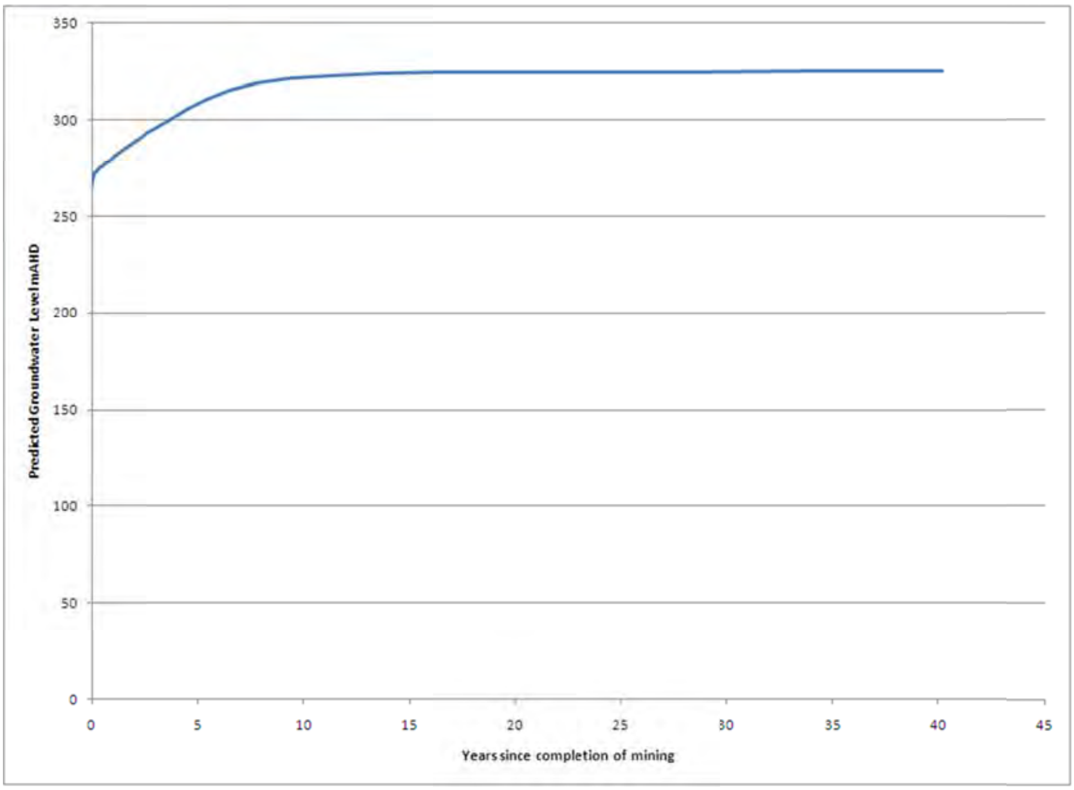


Figure 31 Predicted Rate of Recovery

The above inflow predictions have assumed that dewatering of the underground working has been completed prior to commencement of the LOM Project.

The annual inflow increases substantially in Year 7 and then decreases in Year 15 due to the synclinal nature of the coal seams and hence the depth of mining. In Years 7 and 12, the coal seams are at the deepest point and therefore there is more of the aquifer exposed to allow groundwater inflow. By Year 15, the coal seams are moving towards the surface which reduces the amount of groundwater inflow into the open cut void.

The above predictions are consistent with predictions from previous modelling. Due to evaporative rates in the area of approximately 1.9m/year (see Section 6.2) it is expected that evaporation would be greater than infiltration and that the mine would generally operate as a dry mine (assuming the underground workings are dewatered prior to the commencement of the LOM Project). In the current approved operations, water make in the open cut is anecdotally in the order of 130ML per year. This water make is largely considered to be from rainfall/surface water collection combined with the seepage of groundwater from within the adjacent underground mine workings. The seepage predictions presented in **Table 11** are lower than those currently observed and lower than the previous modelling predictions. This is consistent with the reduced infiltration from underground workings as they have been assumed to be dewatered prior to the commencement of the LOM Project.

A Water Access Licence (WAL) is required for the interception of the groundwater table during mining operations. The predicted maximum groundwater make during operations is 50ML/year (see **Table 11**). This groundwater make is termed incidental water make by NOW and an aquifer interference licence is required. NOW have identified that the Project Site is located in the Gunnedah Basin in an area administered by the *Water Act 1912*. The Proponent currently holds Water Access Licence No 90BL25258 which allows an allocation of 50ML/year.

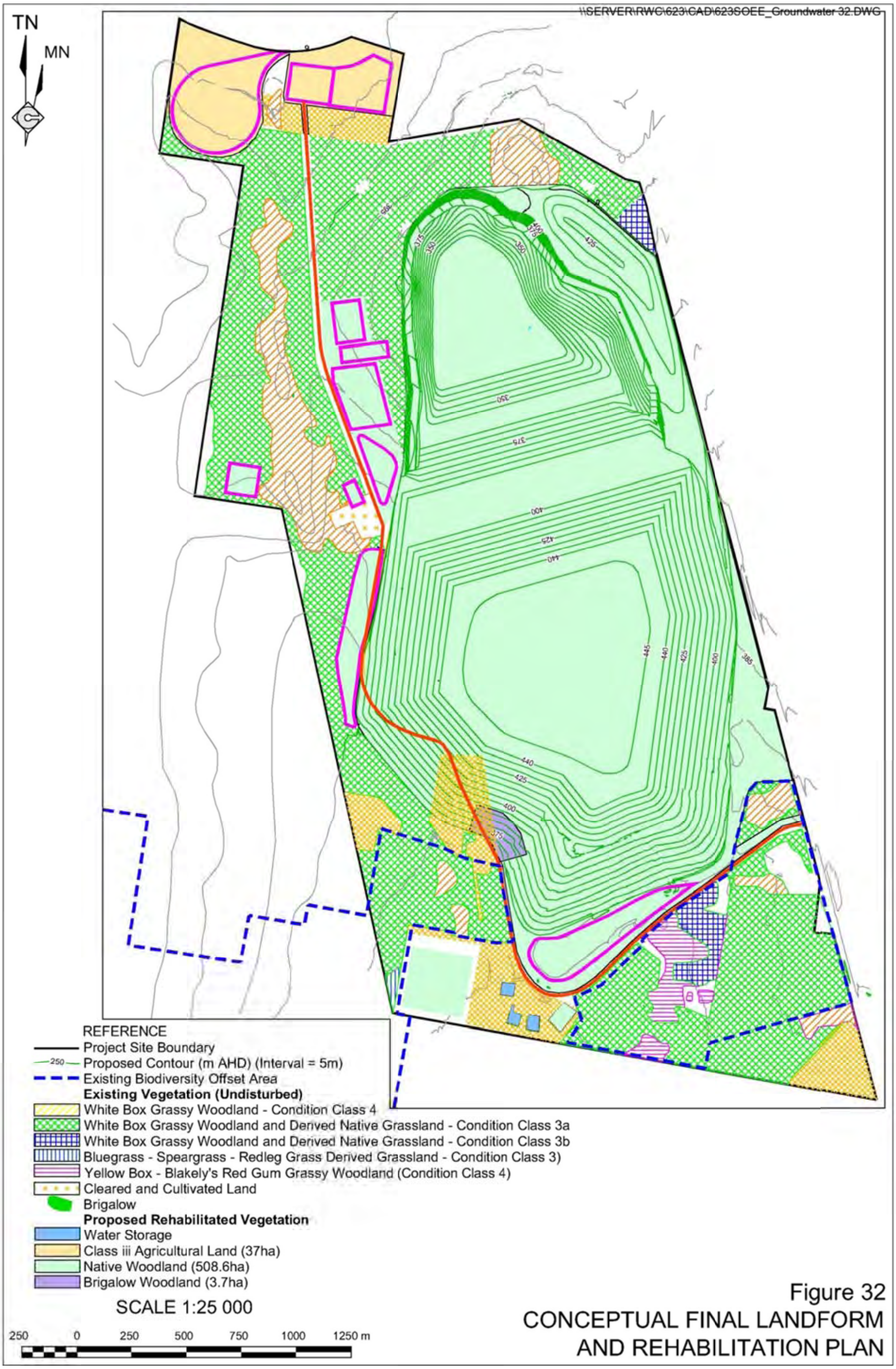
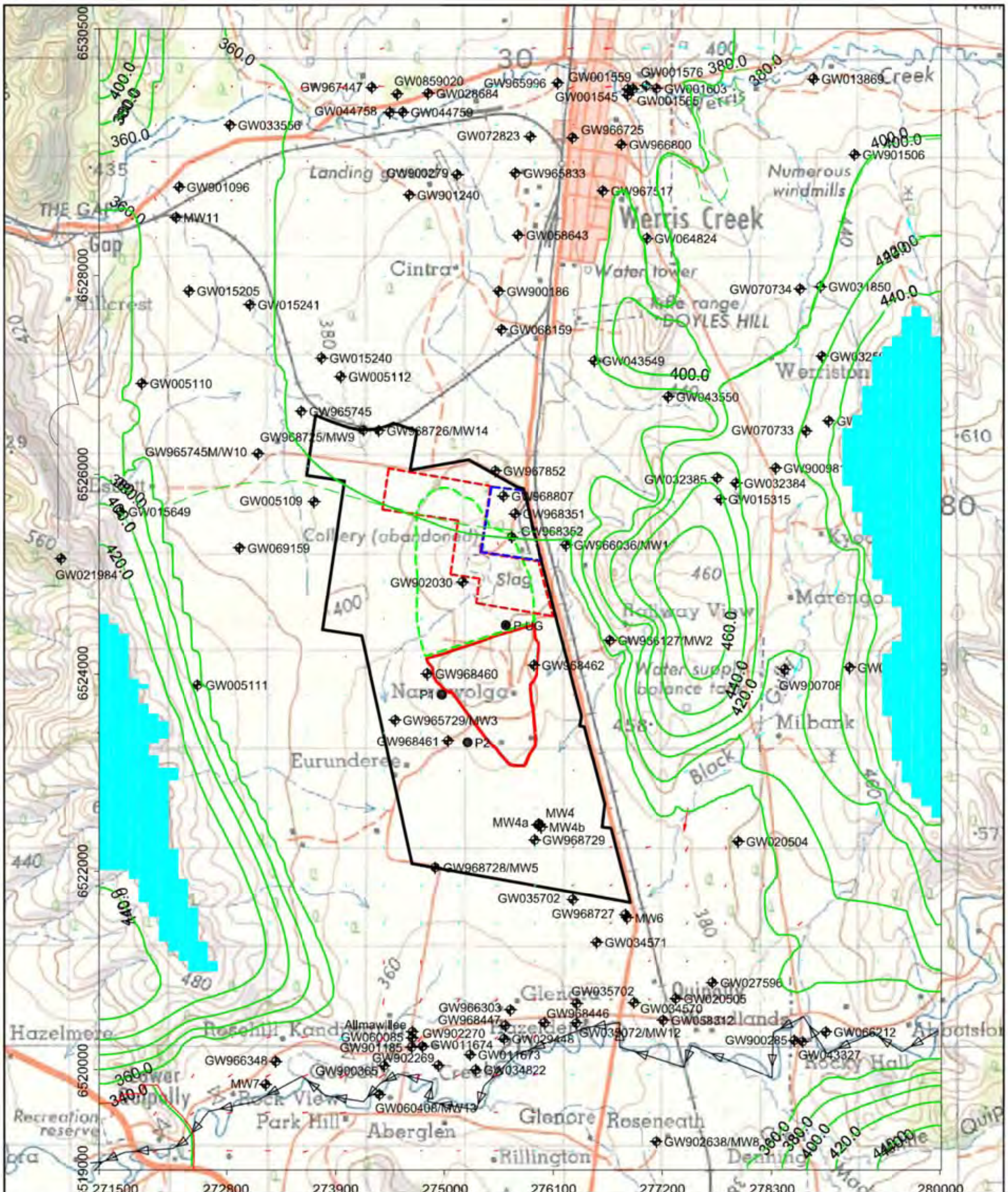


Figure 32
CONCEPTUAL FINAL LANDFORM AND REHABILITATION PLAN



NOTE

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LEGEND

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- EL 7422 Boundary
- Model Extents
- No flow cell
- GW Registered Monitoring Bore
- MW Groundwater Well
- P Observation Bore
- Predicted water table equipotential for the final landform(m, AHD)
- Predicted water table pre mining (m, AHD)

SCALE 1:60000

1000 0 1000 2000m

Figure 33

PREDICTED GROUNDWATER REGIME IN LAYER 4 FINAL LANDFORM

Base Map Source: Tamworth 1:100 000 Topographic Map (1975) (Ref: RW Corkery Pty Ltd)

10.2 CRITERIA FOR THE ASSESSMENT OF GROUNDWATER IMPACT

The parameter adopted to assess groundwater impact is the percentage reduction in saturated thickness predicted at bores surrounding the Project Site. This parameter represents the reduction of standing water within each monitoring or extraction bore. A typically accepted change in saturated thickness is 15%, which is an agreed trigger value with NOW.

Impacts on saturated thickness have been adopted to provide trigger levels to identify bores that are predicted to be impacted as a result of the LOM Project and for which further evaluation would then be undertaken. A trigger level of 15% reduction in saturated thickness has been adopted to represent variations that are outside naturally occurring seasonal fluctuations. Note that this evaluation does not consider the available drawdown within the bore as this can vary from saturated thickness depending on the location of the pump within the well. Therefore, evaluation of available drawdown for bores identified by the above trigger levels would be undertaken as part of the monitoring programme outlined in the groundwater component of the *Site Water Management Plan*.

10.3 ASSESSMENT OF IMPACTS

10.3.1 Groundwater Bores

The impacts on the groundwater regime surrounding the Project Site, as a result of the LOM Project were assessed using the calibrated and validated groundwater model.

Modelling predicts that up to a 1.0m drawdown in the water table would occur within the Project Site and that drawdown in the basalt outside the Project Site would be less than 0.1m.

The predicted reduction in saturated thickness was calculated for bores surrounding the Project Site (see **Table 12**). A variation in saturated thickness of 15% was considered to represent a variation outside of naturally occurring variations and is the adopted trigger criteria for the evaluation of bore impact. There were no reductions in saturated thickness predicted to occur within surrounding groundwater bores as a result of the Project.

10.3.2 Final Void

At the completion of the LOM Project, the Project Site would be rehabilitated to a final long term land use of predominantly native vegetation with some agricultural activities. Modelling predicts that groundwater recovery to approximately 325m AHD within the mine void footprint would occur within approximately 10 years from the completion of mining.

10.3.3 Impact on Alluvium of Quipolly Creek and Werris Creek

An evaluation of the reduction of groundwater flow to the alluvium of Quipolly Creek and Werris Creek was undertaken. Creeks were assigned a ‘stream’ function within the model and the reduction to this system was directly calculated. Modelling has indicated that there is no predicted impact to either creek systems associated with the LOM Project.

These model predictions vary from the 2009 model predictions due to the lower permeability adopted for the clay aquitard and the higher permeability and lower storativity adopted for the basalt strata. These parameters are considered to be a closer representation of the Project Site conditions and have been demonstrated to closely simulate the observed response in the water table to current mining operations.

10.3.4 Impact on Groundwater Dependent Ecosystems

No GDEs are identified within the *Water Sharing Plan for the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources 2004*. A study of GDEs undertaken for the Catchment Management Authority (SKM 2010) determined there to be a very low potential for GDEs to be present within the model domain. Eco Logical Australia in their Biodiversity Impact Assessment (Eco Logical 2010) determined that there were some GDE's present within Quipolly and Werris Creeks. Further information regarding the identification of these GDE's is presented in Eco Logical (2010).

Groundwater drawdown impacts were also determined not to be widespread across the domain and were limited to impacts that are considered to be within the range of seasonal variation. Due to the low likelihood for GDEs to be present and the absence of a predicted water table response, impact to GDEs is not expected to occur.

10.3.5 Impact on Water Quality

Groundwater is utilised at sites surrounding the Project Site for the purpose of irrigation and stock watering. Changes to water quality can occur as a result of significant movement in the water table resulting in oxidation of some compounds and changes to the chemical composition.

Oxidation of pyritic compounds within the coal seams may occur, although is unlikely. This could result in a decrease of groundwater pH and the subsequent release of metals. If this was to occur, there would be limited to no impact on the basalt layer due to the highly impermeable layer between the basalt layer and the coal seams. The interburden between these two layers may also act to neutralise the pH as it is composed of marine sediments and is fairly alkaline.

Groundwater quality monitoring undertaken and reported annually is presented in **Figure 34** for bores MW1, MW2, MW3, MW4 and MW4a (located in closest proximity to existing operations). This graph shows that pH values in monitored groundwater bores identified for the basalt aquifer in **Table 6** remain within the range of 6.5 to 8.5 pH units. A slight increase in pH is observed in MW1, MW2 and MW3. Further protection of water quality is discussed in Section 11.

10.4 PREDICTION OF WATER QUALITY IN REMAINING OPEN CUT VOID

It is proposed that the final surface would be shaped to a minimum surface level of 330m AHD to minimise the potential for groundwater storage. Whilst it is not expected to occur, an evaluation of water quality in a water storage in the final void would be undertaken in an ongoing monitoring regime.

As a worst case scenario, if water was to occur above the surface in the final void, water quality within the final void over time, would be determined by the chemistry of the overburden and interburden which would form the backfill spoil. Additionally, enhanced leaching and weathering following strata disturbance of interburden comprising sandstones, siltstones and shales laid down in marine conditions can potentially produce saline and possibly alkaline groundwater conditions. Groundwater quality is currently brackish and the direct rainfall recharge would freshen the water within the mined out basin.

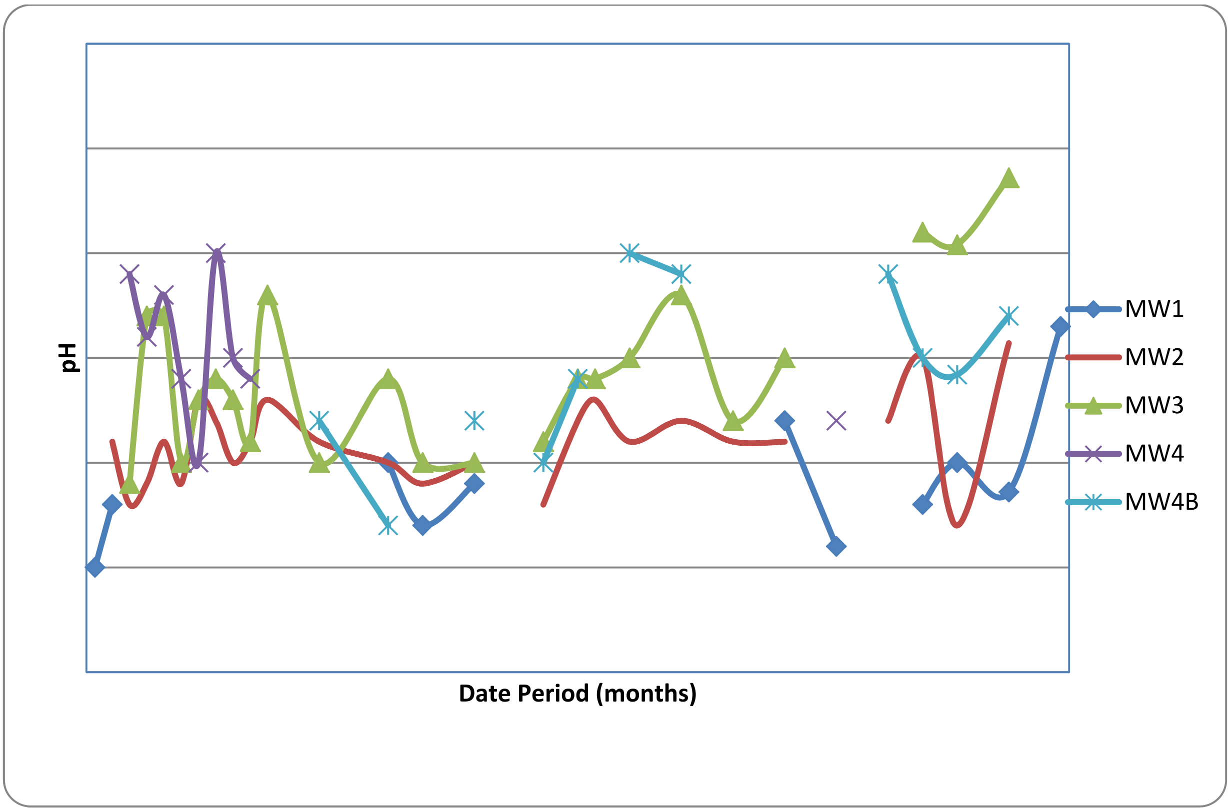

Figure 34 pH in Bores Monitoring the Basalt Aquifer Surrounding the Project Site

10.5 MITIGATION MEASURES

The focus on the mitigation measures relevant to the LOM Project relate principally to the replacement of the quantity of water that is predicted to be "lost" by a landowner as a result of groundwater drawdown caused by the Project.

The Groundwater Contingency Plan (2005) prepared for the site identified the trigger levels that have been determined in consultation with NOW as shown in **Table 13**.

Table 13
Trigger Levels and Benchmarks (WCCM 2005)

Parameter	Measure	Benchmark	Trigger Level
Standing Water Level	Saturated Thickness	Natural Conditions	15% Reduction
Water Chemistry	EC	Natural Conditions	15% Increase
	pH	Natural Conditions	15% Increase or Decrease

The plan states that:

In the event that monitoring identifies a reduction in the saturated thickness within any bore which is in excess of the identified trigger level and a consequence of mining, WCC will enter into negotiations with the affected landowners with the intent of formulating an agreement which provides for one or a combination of:

- *re-establishment of saturated thickness in the affected bore(s) through bore deepening;*
- *establishment of additional bores to provide a yield at least equivalent to the affected bore prior to mining;*
- *provision of access to alternative sources of water; and*
- *monetary compensation to reflect increased water extraction costs (if any), for example as a consequence of lowering pumps or installation of additional or alternative pumping equipment.*

In the event that routine monitoring indicates that a water quality parameter is triggered the Plan states that *an increase in the analytes monitored and/or frequency of sampling to confirm the magnitude and extent of the change in water chemistry and verify the change is a consequence of mining* would result. Should the change be a result of mining, the Groundwater Contingency Plan states that an appropriate solution would be sought in consultation with the NOW hydrogeologists.

10.6 SUMMARY OF RESIDUAL IMPACTS

The results of the modelling analysis indicates that predicted drawdown beyond the Project Site is less than 0.1m.

If drawdown impacts beyond the Project Site of greater than 15% are observed, and are identified to be as a consequence of mining activities, the Proponent would enter into negotiations with the affected landowner(s) with the intent of formulating an agreement which provides for one or a combination of the following.

- Re-establishment of saturated thickness in the affected bore(s) through bore deepening.
- Establishment of additional bores to provide a yield at least equivalent to the affected bore prior to mining.
- The provision of access to alternative sources of water.
- Monetary compensation to reflect increased water extraction costs.

Geological information for the Project Site and surrounds indicates that suitable aquifers occur within the fractured rock and are present at depths able to provide a supplementary water supply.

11. PROTECTION OF GROUNDWATER

11.1 GROUNDWATER MANAGEMENT PLAN

A *Groundwater Management Plan* has been prepared for the management of groundwater as part of a *Site Water Management Plan (2009)* for the existing approved operations. No change in the groundwater component of this management plan is considered necessary as a consequence of the LOM Project. The *Groundwater Management Plan* includes groundwater monitoring program, methodologies for sampling and analysis, trigger criteria, contingency and reporting requirements.

The contingency plans to be adopted if monitoring indicates that there have been impacts on groundwater associated with the LOM Project would be as follows.

- In the event that routine monitoring indicates that a trigger has been reached (refer Section 4B.1.5.1) or is being approached, the Proponent would commission a hydrogeologist to review the data, with the outcomes of that review, including any recommendations, being subject to discussion and agreement with hydrogeologists from NOW.
- If there is a trigger of pH or EC, the monitoring regime would initially be increased for analytes monitored and/or frequency of sampling to confirm the magnitude and extent of the change in water chemistry and verify the change is a consequence of operations associated with the LOM Project.
- Should the saturated thickness trigger level be achieved in any bore, the Proponent would notify the affected landowner(s) and, if the Proponent's and NOW's hydrogeologists are of the opinion that the reduction is a consequence of operations associated with the LOM Project, then the mitigation measures identified in Section 4B.1.2 would be initiated.
- An independent authority would also be used where a dispute arises as to the cause of the change, given that groundwater supply and quality can be affected by non-mining related factors.

11.2 GROUNDWATER MONITORING

Groundwater monitoring is currently being undertaken in accordance with the Site Water Management Plan (2009) by an independent monitoring consultant on behalf of the Proponent. No modification to the *Groundwater Management Plan* is recommended.

The approved plan includes monitoring of a network of nine groundwater monitoring bores that are monitored for total Nitrogen, nitrate, total phosphorus, EC, pH, total petroleum hydrocarbons, heavy metals, major cations and anions and standing water level. These bores have been selected to enable an assessment of impacts (if any) to local groundwater users from mining activities.

12. ASSESSMENT AGAINST NOW REQUIREMENTS AND STATE GROUNDWATER POLICY DOCUMENTS

The LOM Project Site is located within an embargoed groundwater resource area. **Table 14** identifies the key principles of the *Water Act 1912* and the *Water Management Act 2000*, and directs the reader to the relevant section within this document.

Table 14
Assessment of Proposal in Accordance with the Relevant Acts

Principle	Comments
Identification of the relevant groundwater system	**Section 10.3** details the groundwater system that would be encountered by the proposed modification.
Evaluation of the impact on the groundwater system	A hydrogeological study has been completed. The impact assessment is presented in **Section 10**.
Evaluation of the incidental water make by the proposal	The hydrogeological study undertaken included a prediction of incidental water make of 50ML/year. Refer to **Section 10.1.2**
Measures to ensure the protection of groundwater quality during operations	A Water Management Plan has been developed. Ongoing groundwater monitoring in accordance with this plan will continue
Evaluation of impact on groundwater dependent ecosystems	There are no groundwater dependent ecosystems identified at the mine site and surrounds. Further details are presented in **Section 10.3.4**

13. CONCLUSION

A three dimensional model domain has been developed to predict the extent of impact from the LOM Project. Modelling has predicted that drawdown of the basalt aquifer outside the LOM Project Site boundary is less than 0.1m.

A reduction in saturated thickness above the adopted trigger criteria of 15% was not exceeded at any bores surrounding the Project Site. These predictions are consistent with current observations in wells monitoring the response in the groundwater table of the basalt aquifer to current mining operations.

Whilst considered unlikely, should impacts occur that are greater than those predicted, and are identified to be as a consequence of the LOM Project, it would be possible for the Proponent to mitigate any reductions in saturated thickness through the installation of new and/or deeper groundwater bores. Available geological information for the Project Site and surrounds indicates that a suitable groundwater aquifer is present at depth within fractured rock.

There are no predicted impacts to Quipolly Creek or Werris Creek from the LOM Project.

The likelihood of occurrence of GDEs within the model domain were determined to be very low and, in combination with the absence of predicted impacts, there are no impacts to GDEs likely to occur as a result of the LOM Project.

The impacts of the LOM Project upon the groundwater resources in the area are predicted to be localised and within seasonal variation. These predictions are consistent with observations of the groundwater table in response to current mining conditions.

14. REFERENCES

ANZECC (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality, October 2000.

RCA Australia, Werris Creek Coal Mine, Groundwater Assessment, July 2004.

RCA Australia, Werris Creek Coal Mine, Modification Proposal Project, March 2009.

GeoTerra, Werris Creek Coal Pty Limited, Surface and Groundwater Monitoring, Annual Review 2006/2007, Werris Creek, May 2007.

GeoTerra, Werris Creek Coal Pty Limited, Surface and Groundwater Monitoring 2007/2008, Annual Review, Werris Creek, April 2008.

GeoTerra, Werris Creek Coal Pty Limited, Surface and Groundwater Monitoring 2008/2009, Annual Review, Werris Creek, May 2009.

GeoTerra, Werris Creek Coal Pty Limited, Surface and Groundwater Monitoring 2009/2010, Annual Review, Werris Creek, May 2010.

BOM (2005): Bureau of Meteorology website, www.bom.gov.au.

Department of Natural Resources (WSP 2003): Water Sharing Plan Phillips Creek, Mooki River, Quirindi Creek, Warrah Creek Water Sources July 2004.

Fetter (1994): Applied Hydrogeology, Third Edition, Prentice Hall.

Freeze, A, Cherry, J, (1979): Groundwater, Prentice Hall.

Eco Logical Australia Pty Limited, Biodiversity Impact Assessment, prepared for RW Corkery, Werris Creek Coal Mine LOM Project, September 2010.

NSW State Government: Water Act, 1912, last revised 1 July 2005.

NSW State Government: Water Management Act, 2000, last revised 15 January 2007.

US Geological Survey (2009): Modflow 2009.

Martin O'Rourke, Personal Correspondence, Department of Water and Energy, Tamworth.

Sinclair Knight Merz: Mapping Groundwater Dependent Ecosystems in the Namoi Catchment, undertaken for the Catchment Management Trust, May 2010.

Werris Creek Coal Mine, Groundwater Contingency Plan, August 2005

Appendices

(No. of pages excluding this page = 21)

Please Note a Colour Version of all Appendices is Available on the Project CD

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Appendix 1

Werris Creek Coal Mine, Groundwater Level Monitoring

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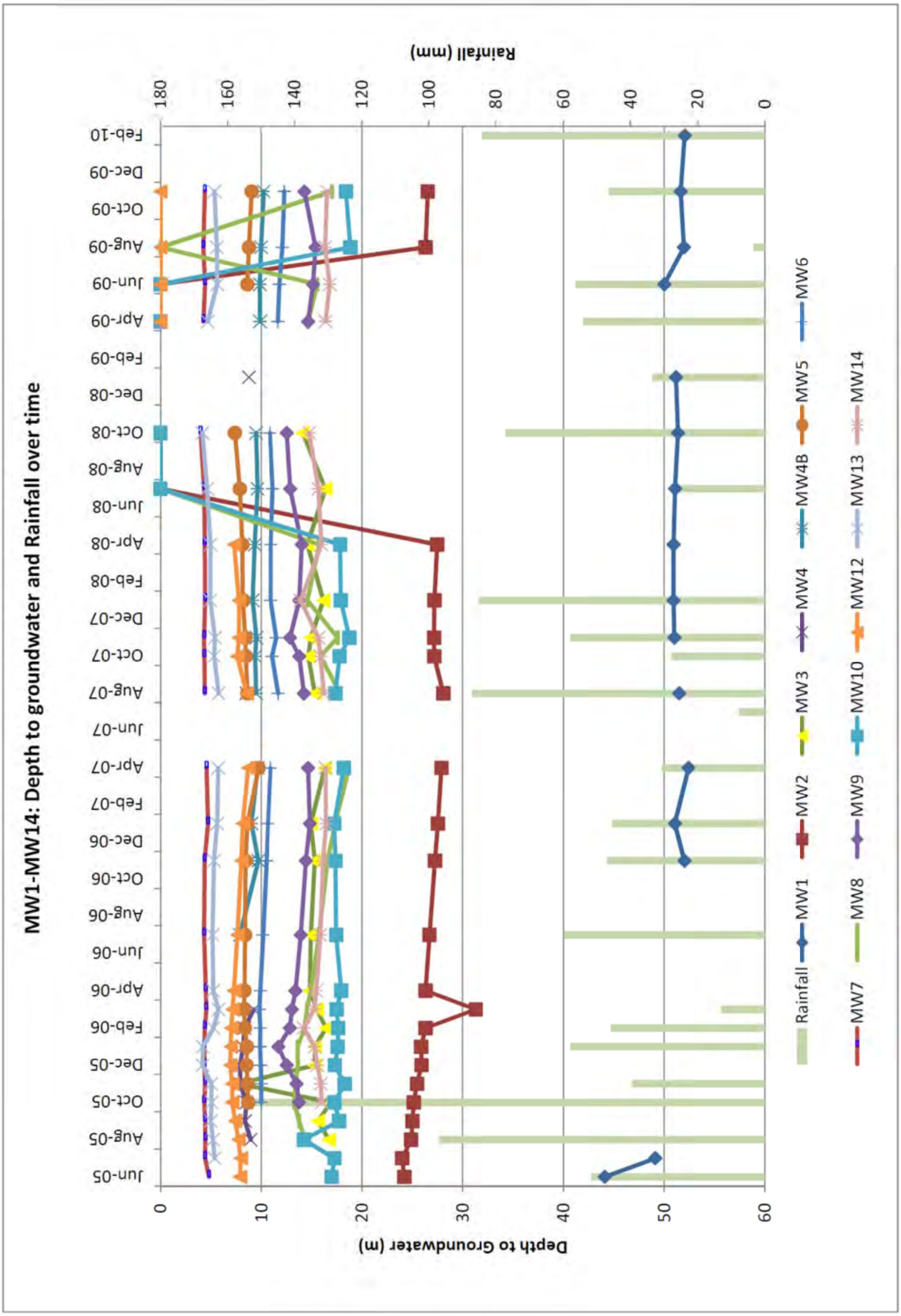
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Depth to Groundwater (m)
Rainfall (mm)
0
10
20
30
40
50
60
180
160
140
120
100
80
60
40
20
0
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Aug-08
Oct-08
Dec-08
Feb-09
Apr-09
Jun-09
Aug-09
Oct-09
Dec-09
Feb-10
Rainfall
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MW2
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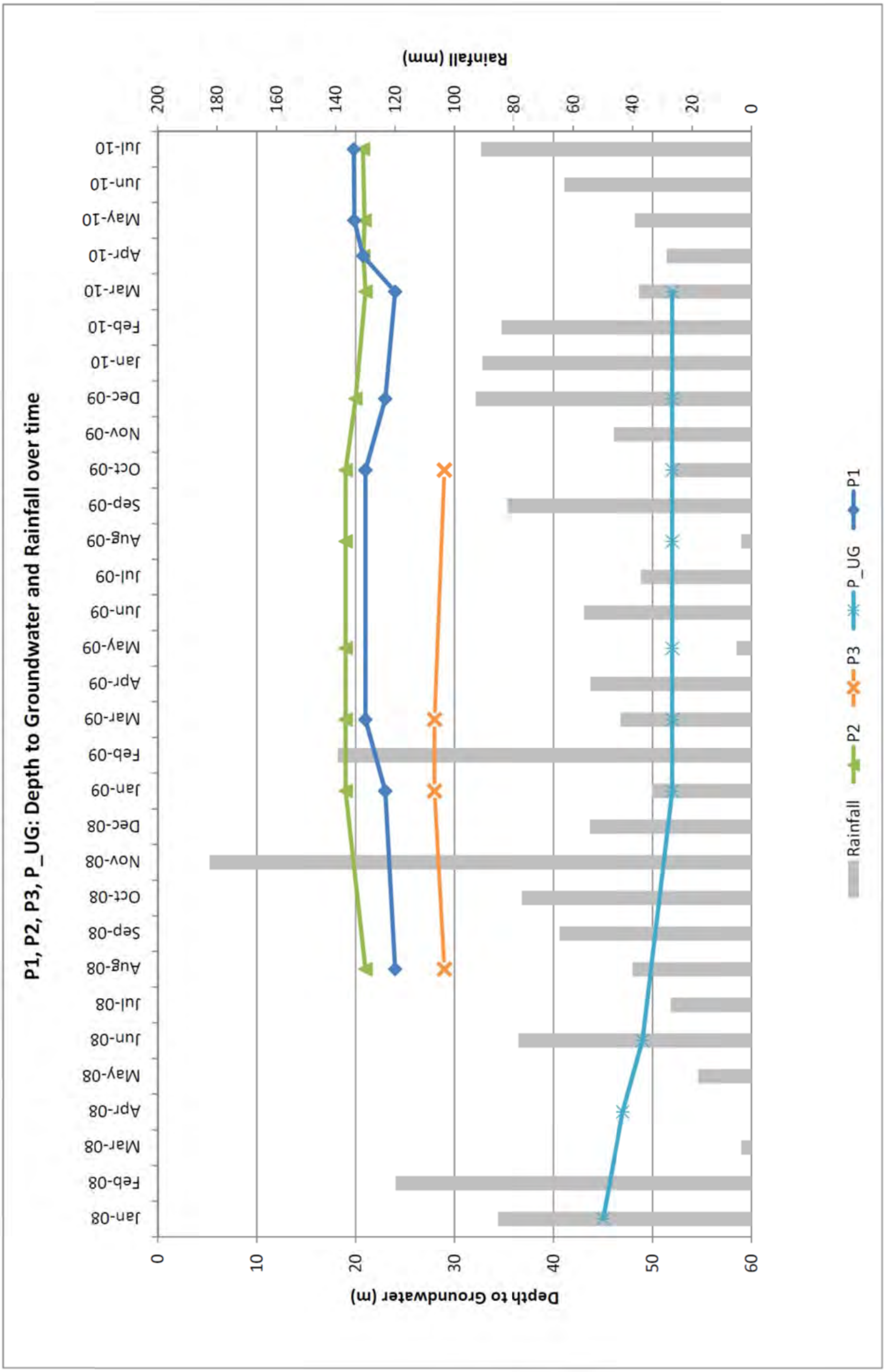
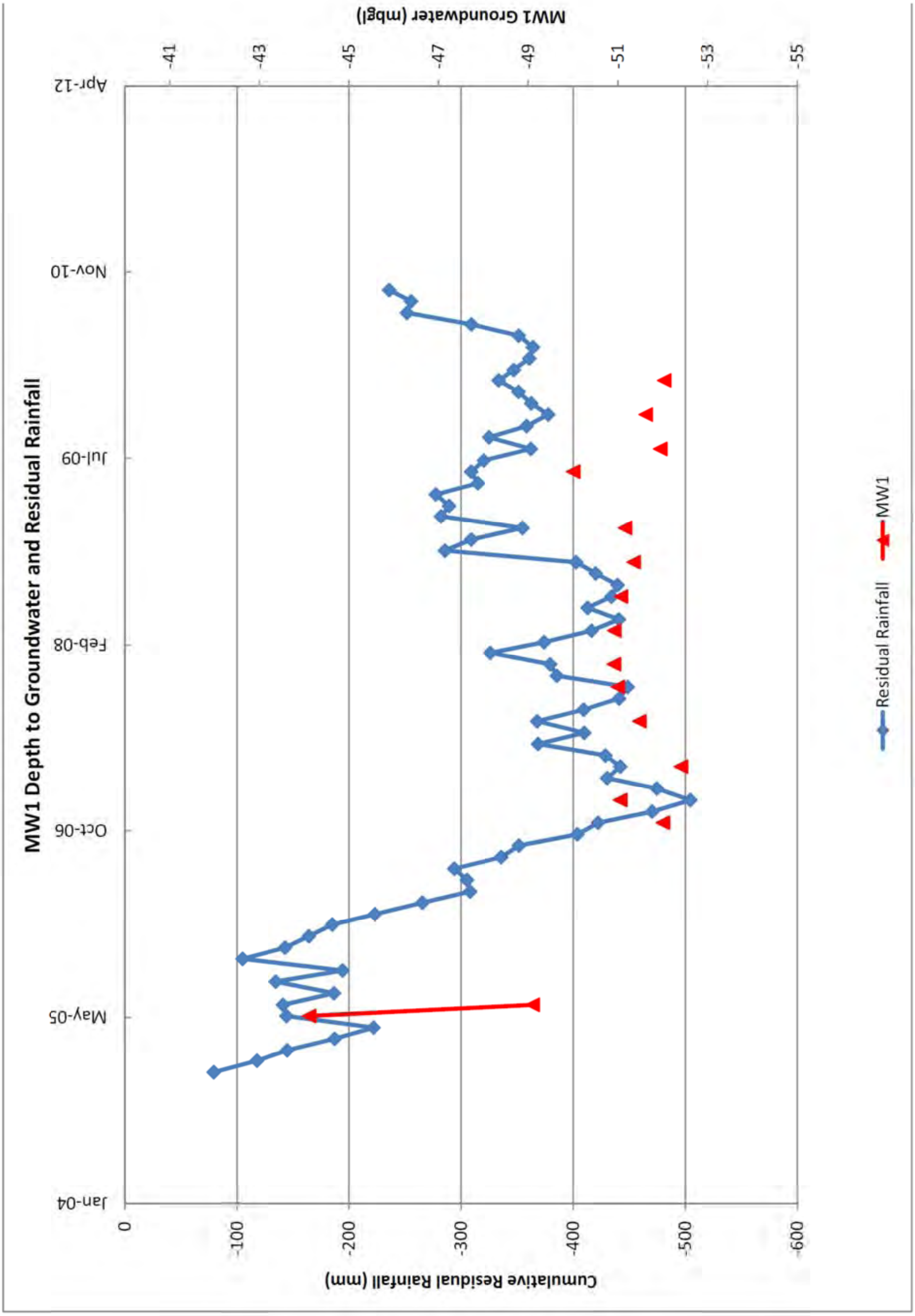
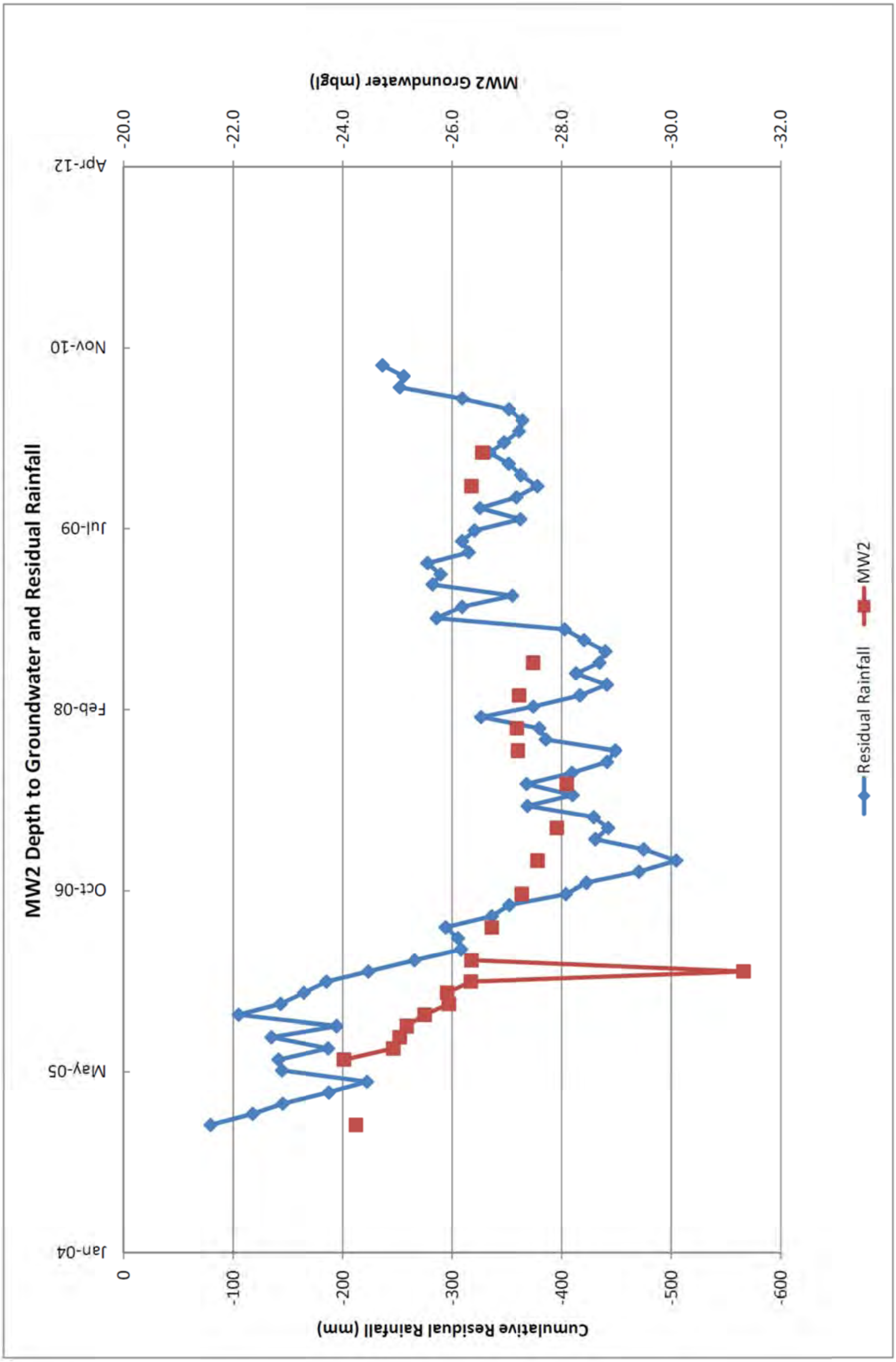
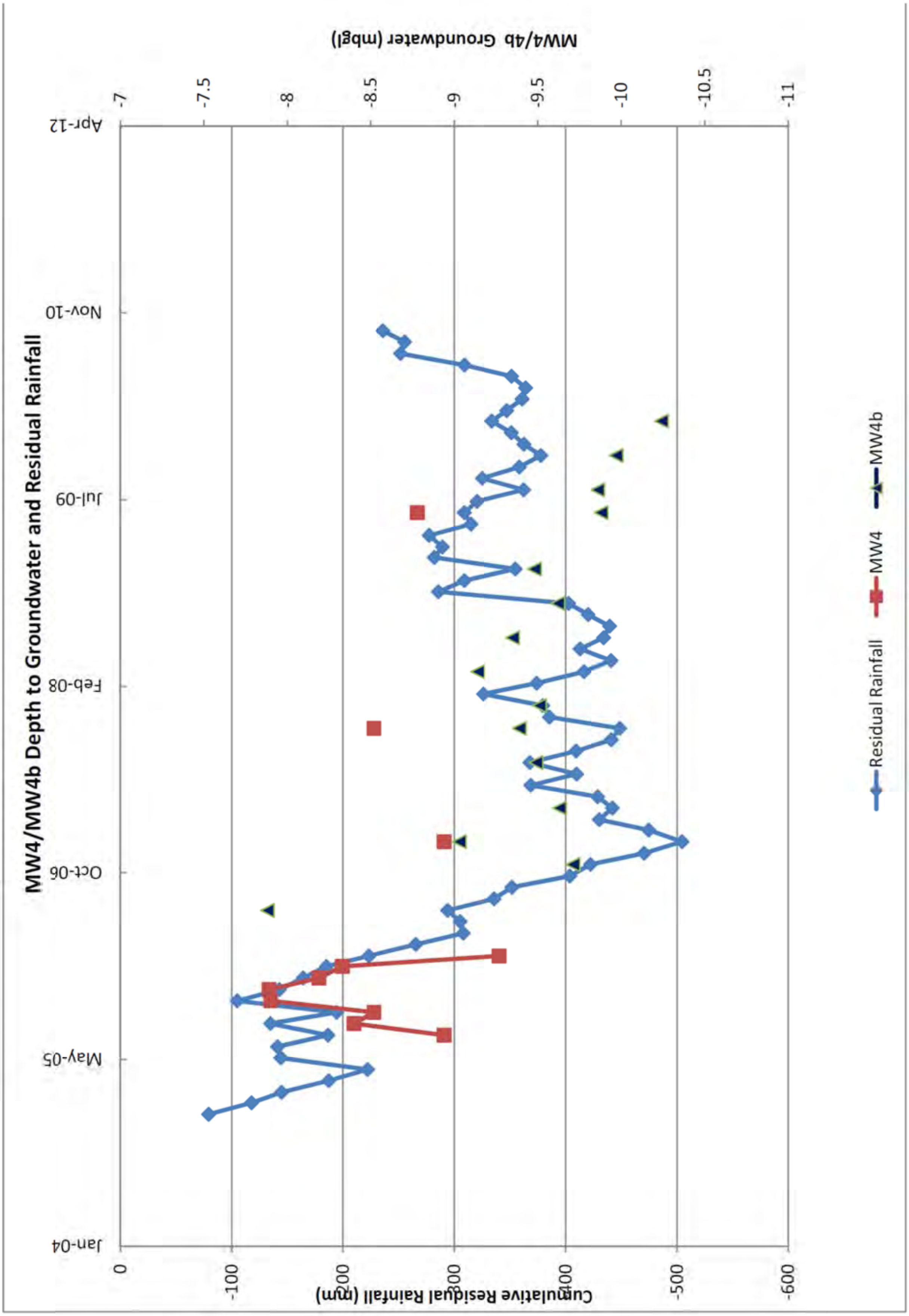
MW4
MW4B
MW5
MW6
MW7
MW8
MW9
MW10
MW12
MW13
MW14


P1, P2, P3, P_UG: Depth to Groundwater and Rainfall over time
Depth to Groundwater (m)
Rainfall (mm)
Rainfall
P2
P3
P_UG
P1


MW1 Depth to Groundwater and Residual Rainfall
MW1 Groundwater (mbgl)
-41
-43
-45
-47
-49
-51
-53
-55
Cumulative Residual Rainfall (mm)
0
-100
-200
-300
-400
-500
-600
Jan-04
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Residual Rainfall
MW1


MW2 Depth to Groundwater and Residual Rainfall
MW2 Groundwater (mbgl)
-20.0
-22.0
-24.0
-26.0
-28.0
-30.0
-32.0
Cumulative Residual Rainfall (mm)
0
-100
-200
-300
-400
-500
-600
Jan-04
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Residual Rainfall
MW2


MW4/MW4b Depth to Groundwater and Residual Rainfall
MW4/4b Groundwater (mbgl)
Cumulative Residual Rainfall (mm)
Residual Rainfall
MW4
MW4b
Jan-04
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
-7
-7.5
-8
-8.5
-9
-9.5
-10
-10.5
-11
0
-100
-200
-300
-400
-500
-600

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Appendix 2

Werris Creek Pump Testing Report

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APPENDIX 2

AQUIFER TESTING REPORT
WERRIS CREEK COAL MINE
WERRIS CREEK NSW

1 INTRODUCTION

1.1 BACKGROUND

RCA Australia Pty Ltd (RCA) was commissioned to extend a previous hydrogeological study of the area encompassing the Werris Creek Coal mine lease, (in the North-West Plains district of NSW), as part of a larger study assessing conditions over the projected life of the mine, supporting an application for alterations to the mining lease (and other conditions of operation).

As part of the study, groundwater modelling (MODFLOW) was used to assess regional groundwater conditions under a range of existing mining conditions and as a predicative tool to assess planned future mining operations (including post mining/rehabilitation activities).

A wide range of geological and hydrogeological/surface water hydrology data is required for input into the groundwater model.

A previous study identified aquifer parameters relating to the underlying bedrock volcanics (Werrie Basalts) as a key input into the model. The previous model had limited bedrock aquifer parameter data available, based on short-term single well slug testing, (potentially mis-representative of the fractured bedrock aquifer). It was proposed that, as part of the current works, a field investigation be conducted to obtain realistic values for transmissivity (T)/permeability (k) and storage coefficient (S) at two locations which may be indicative of two potential differing aquifer zones in the basalts.

1.2 SCOPE OF WORK

Previous groundwater modelling for Werris Creek used aquifer parameters obtained from short-term, single-well tests ("slug" tests). Typically, "slug" tests are undertaken by monitoring water level recovery following removal of a quantity of water from the well. Slug tests are considered not to be capable of providing accurate, reliable aquifer parameters (T, S and K), free from effects of well storage and/or representative of the aquifer on a larger scale due to their limited ability to stress the aquifer.

Pumping tests conducted for a significant length of time (sufficient to stress the aquifer by inducing a cone of depression to measure effects on an observation well (ie, not the pumping well) are more likely to provide a more representative characterisation of an aquifer. It is considered that this would also apply to the fractured rock (basalt) aquifer in this situation giving "averaged" (ie, more realistic) values for aquifer parameters from what can be very anisotropic conditions. In fractured rock aquifers, permeability is typically controlled by the occurrence and alignment of fracture sets rather than innate permeability of the rock mass itself (which can be very low).

In order to obtain reasonable, representative aquifer parameters from the fractured-rock Werrie basalt aquifer, the following scope of work was undertaken in June 2010:

- Conduct of a 24 hour pumping test at two monitoring well locations across the mine site, both of which had been installed into the Werrie basalts:
  - MW5 at the southern end of the mine lease (near Paynes Road); and
  - MW 14 adjacent to the coal load out facility, immediately south of the rail line which forms the northern boundary of the mining lease.

Prior to the pumping tests, Werris Creek Coal arranged for one new well to be drilled at each of the two sites (MW5A and MW14A[1]), within a few metres of the existing wells, to allow for the installation of a 100mm diameter submersible pump. The drilling was undertaken by Mannion Drilling in early June 2010.

The measured well offsets were:

- MW5 to MW5A = 11m;
- MW14 to MW14a = 5m.

During the testing the new wells were used as pumping wells and the existing wells as observation wells (recording water levels under the influence of discharge from the adjacent pumped well).

The following section details the scope of the pump testing.

2 METHODOLOGY

2.1 TESTING PROCEDURE

The aquifer (pumping) tests were undertaken in two weeks in June 2010.

A 24 hour pump test was conducted in MW5/MW5A over 23 to 24 June and in MW14/MW14A over 2 to 3 July.

Generally the testing was conducted as follows:

1. Static water levels (SWLs) were measured in all wells (pumped wells and observation wells), prior to disturbance from pumping.
2. A 100mm diameter electro-submersible pump was installed into the selected well (new wells MW5A and MW14A which had 125mm casing) with the pump intake set at a depth based on the pump performance curve and an allowance for drawdown (lowering of the water level as a result of pumping).
3. Due to the isolation of the well sites, it was necessary to use a portable generator with the ability to provide the required current load for the pump (approximately 5kVa) and be capable of running in excess of 24 hours.

[1] The two new (pumping) wells were designated with an "A" suffix by RCA for the purposes of this testing, however this may differ from the bore name assigned by Werris Creek Coal (unknown at the time of writing).

4. Water levels were measured in the pumped well and in the observation well using in situ "Level Troll" data loggers ("Level Troll 300") set to record levels at minute intervals over the testing period. Water levels were also manually recorded (in both pumped well and observation well) using an electric water level probe during the initial pumping stages and following pump shut-down (monitoring water level recovery).
5. The pump setup included a rising main (32 mm polyethylene pipe) with an in-line flow meter (to measure discharge) and valve to control flow.
6. All pumped water was discharged to the ground surface approximately 30m away from the pump and observation wells and conveyed, via surface drains, to waste water storage (at the MW14 site), or as casual surface water on mine property (at MW5). Given the depth to groundwater and the low permeability of surface soils, no recharge to the aquifer from this arrangement was anticipated.
7. The tests commenced with three stepped increases in discharge over 30 minute intervals to assess the most appropriate flow rate for the 24 hour test. In both cases the fully opened valve (maximum flow) was selected for the long-term test.
8. The pump was then allowed to discharge at the maximum rate for remainder of the 24 hour period.
9. After 24 hours the pump was shut off and water levels were allowed to recover (in pumped and observation wells) before the pump and ancillary equipment was removed and the data loggers recovered and water level information extracted.
10. All water level data (ie, record of water level/drawdown versus time per measured flow rate) in both the pumped wells and the observation wells were retained for analysis.

The table below presents the setup data for each of the pump tests.

	MW5	MW5A	MW14	MW14A
Well Type	observation	pumped	observation	pumped
Well separation distance (r)	11m		5m	
SWL (btoc*)	9.36m	9.06m	16.78m	16.53m
Pump Inlet Depth (btoc)	na	25m	na	25.2m
Data Logger Depth (btoc)	18.5m	19.7	25m	24.5m
Pump Rates (Duration)				
Q_1	na	0.6L/sec (30mins)	na	0.7 L/sec (30mins)
Q_2	na	0.91L/sec (30 mins)	na	1.2 L/sec (30mins)
Q_3	na	0.95 L/sec (1380 mins)	na	1.5 L/sec (1380 mins)

Notes SWL – standing water level, * below top of casing, na is not applicable, Q = discharge in units shown.

2.2 ACCURACY

The measured variables in the testing process included:

- water levels;
- time;
- flow (discharge) measurement (volume/time); and
- distance (between wells).

RCA estimates that the following accuracy in measurements was obtained during the test.

- Groundwater levels were accurate to within 1mm whether recorded on the data logger or using the electric water level probe.
- Time measurement was accurate to 0.5 sec, with implied discharge measurements accurate to 0.02 L/sec (1.73 m^3/day).
- Distance measurement (tape measure) was accurate to 2mm.

3 PUMP TEST ANALYSIS

Data recorded from the tests included the following:

- Water levels (as absolute levels and as a function of the difference between the static water level and the reduction in water level induced by discharge from the pumped well, ie, drawdown) over time of the test.
- Discharge from the pumped well.
- Distance between pumped well and observation well.
- Construction details of the pumped wells and observation wells.

Solutions to theoretical groundwater flow equations under a variety of conceptual aquifer conditions have been well documented. For example, Kruseman and De Ridder (1970 and revised editions) (Ref [1]) presents a summary of the solutions and approximations of the "well function" (describing groundwater flow in an aquifer), as applicable to a variety of aquifer conditions and well tests.

RCA has applied proprietary analysis software ("AquiferTest" version 2.55, Waterloo Hydrogeologic Inc) with a combination of manual check calculations to the observed pump test data for MW5 and MW14.

Specifically, the test data was analysed using:

- Jacob straight line method (confined aquifer unsteady state);
- Jacob-Cooper (adjusting for changing well discharge in step test);
- Thies Recovery method for drawdown recovery following pump shut down;
- "AquiferTest" programme using the Moench Method for fractured rock aquifers (partial penetration).

3.1 CONCEPTUAL AQUIFER/WELL CONDITIONS

The following conditions have been assumed to allow the calculation of aquifer parameters:

- the aquifer within the Werrie Basalts, in the areas under consideration, are confined by an overlying clayey sediments (or a clayey weathered zone);
- a single aquifer (at each location) is assumed;
- well storage effects can be neglected;
- water is instantaneously discharged from the well with a corresponding decline in head;
- the flow from the well is in an unsteady state; and
- the pumped wells are partially penetrating (ie, they are not screened across the full vertical extent of the aquifer). Although this is contrary to the basic assumptions inherent in the pump test analyses used, the use of a longer testing period is considered to minimise the effects of non-laminar/non-horizontal flow.

Well Data	Method	Transmissivity (m^2/sec)	Storage Coefficient (S)	Permeability (m/sec)	Comment
MW5A	Jacob Straight Line (Confined Aquifer)	5.80E-04	n/a	9.67E-06	Not Adjusted for Step Test
	Cooper Jacob (Step Adjusted)	7.00E-04	n/a	1.17E-05	Adjusted for multiple flow in pump test
	Thies Recovery	1.60E-03	n/a	2.67E-05	Limited data points

na is not applicable
k values (permeability) are based on a conceptual aquifer thickness of 60m

In summary, the following parameters were obtained from the mean of those results considered to most represent actual groundwater conditions.

Observation wells provide the following mean parameters excluding the unadjusted data and the early time data:

	Transmissivity (m2/sec)	Storage Coefficient (S)	Permeability (m/sec)
MW14	1.42E-03	1.33E-01	2.36E-05
MW5	1.54E-03	1.01E-01	2.92E-05

Pumped Wells provide the following mean parameters (excluding unadjusted data):

	Transmissivity (m2/sec)	Storage Coefficient (S)	Permeability (m/sec)
MW14A	1.02E-03	n/a	1.70E-05
MW5A	1.15E-03	n/a	1.92E-05

5 CONCLUSION

RCA has conducted pumping tests in two wells MW14 and MW5, installed into the Werrie basalts, underlying the coal resources (located at the northern and southern ends, respectively, of the Werris Creek Coal mine site).

Based on the analysis of pumping test results, RCA considers the following range of data provides representative aquifer parameters for input into groundwater modeling conducted for the site.

transmissivity	*1.02×10^{-3} to 1.54×10^{-3} m^2/sec*
storage coefficient	*0.101 to 0.133 (dimensionless)*
permeability	*1.70×10^{-5} to 1.92×10^{-5} m/sec (based on 60m aquifer thickness)*

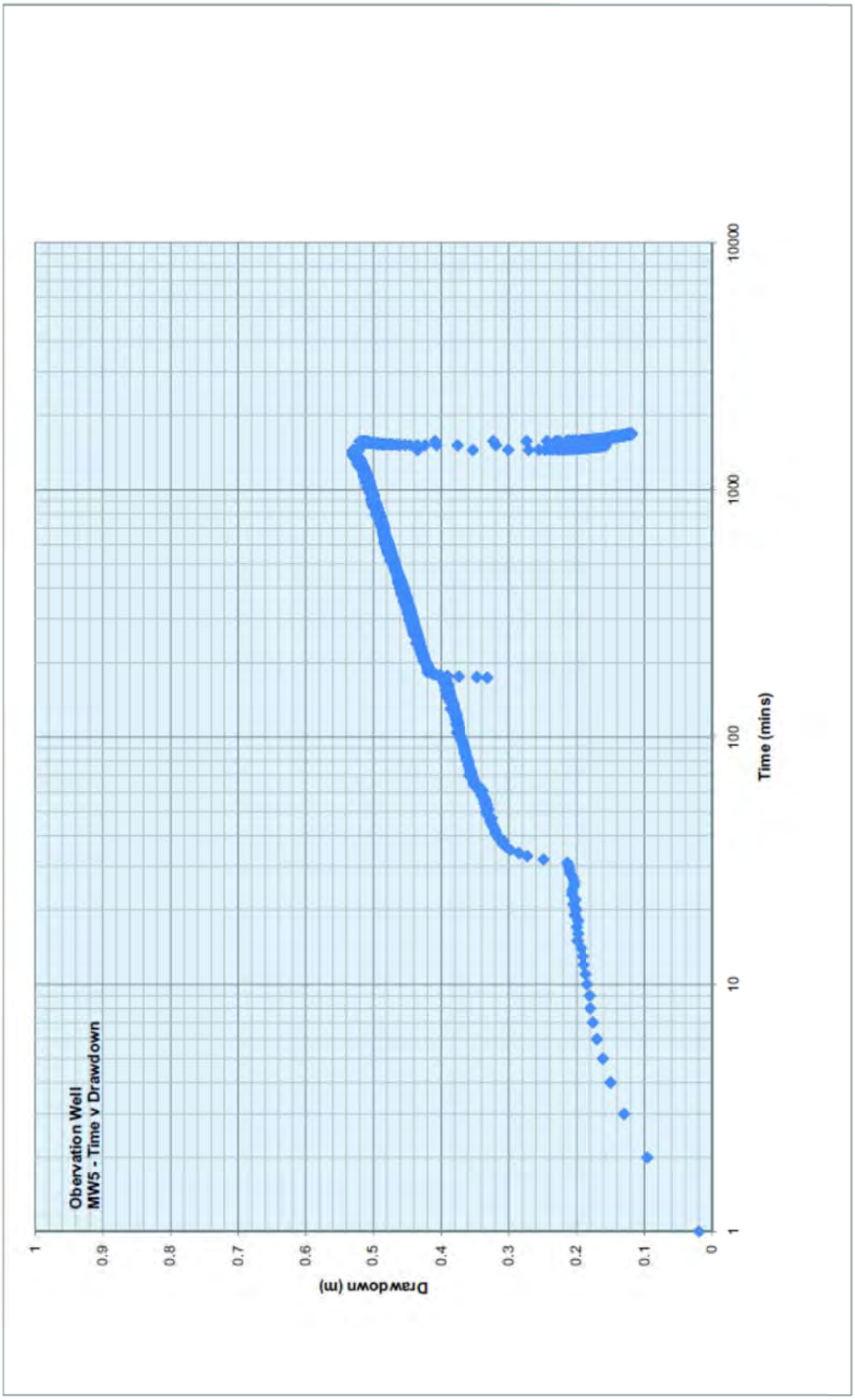
REFERENCES

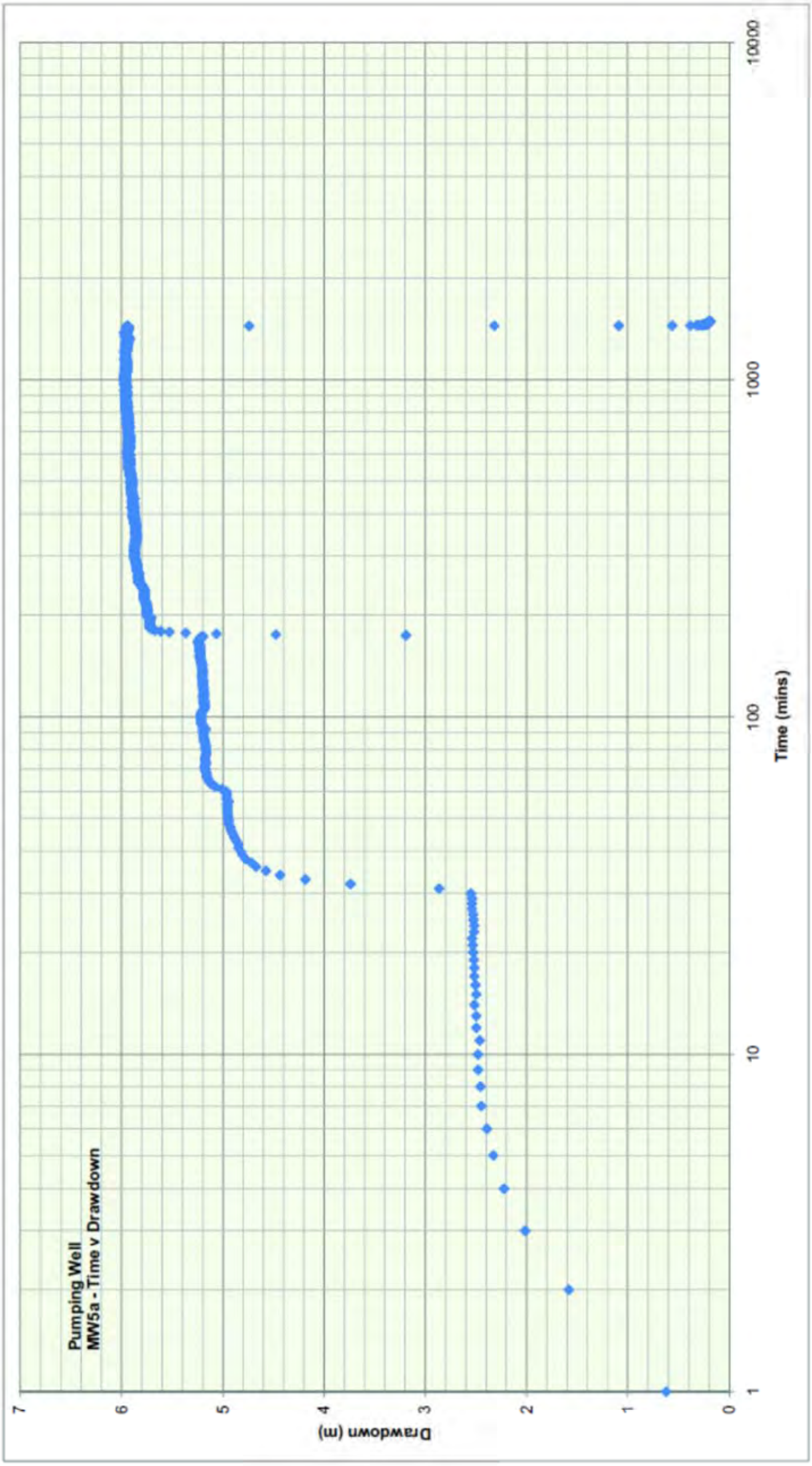
[1] Kruseman and De Ridder, *Analysis and Evaluation of Pump Test Data*, originally published 1970.

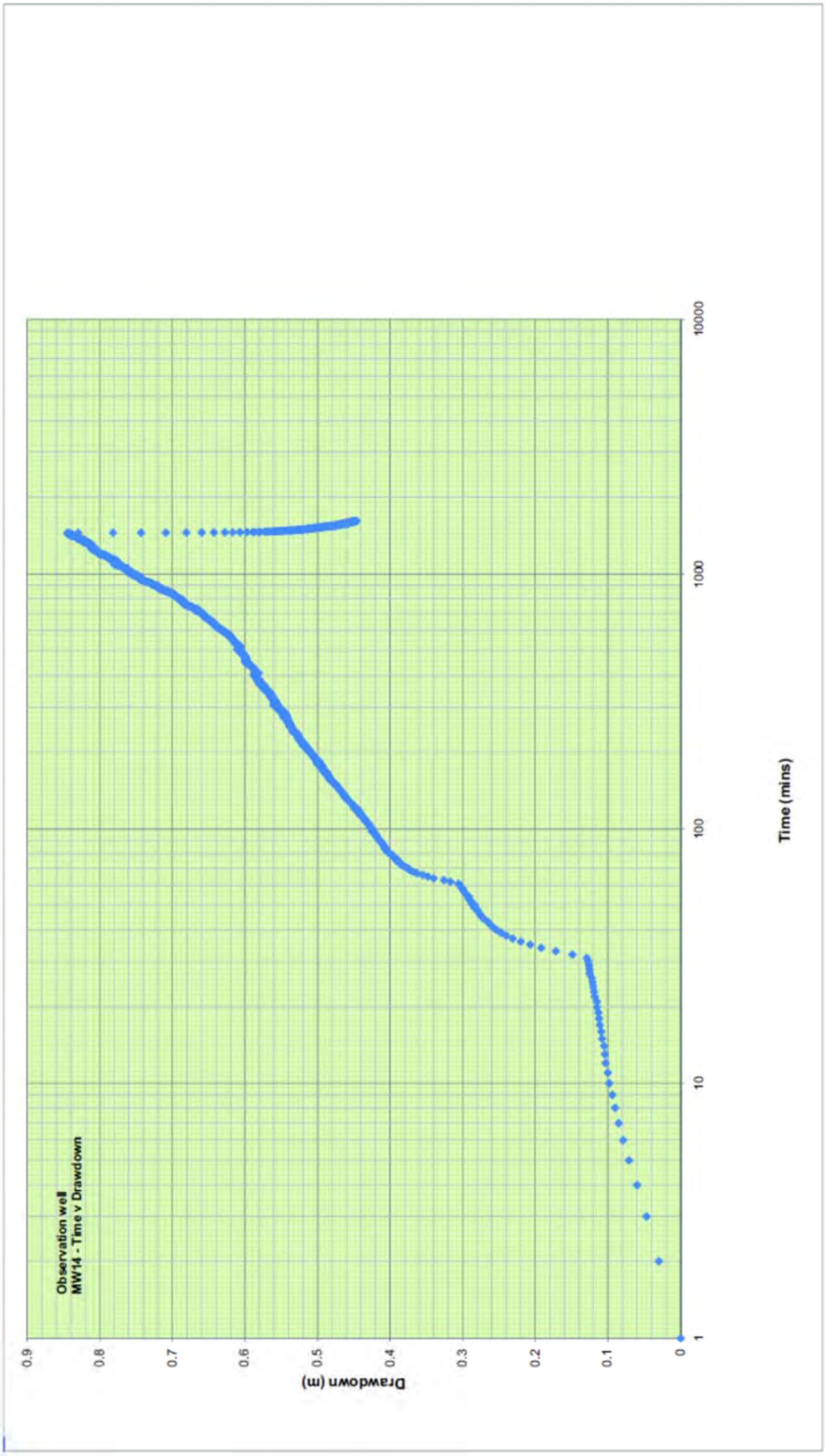
[2] CW Fetter, *Contaminant Hydrogeology*, 1993.

Attachment 1

Pump Test Calculation Graphs


Obervation Well
MW5 - Time v Drawdown
Drawdown (m)
Time (mins)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
1000
10000


Pumping Well
MW5a - Time v Drawdown
Drawdown (m)
Time (mins)
0
1
2
3
4
5
6
7
1
10
100
1000
10000


Observation well
MW14 - Time v Drawdown
Drawdown (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time (mins)
1
10
100
1000
10000


Pumping Well
MW14A - Time v Drawdown
Drawdown (m)
Time (mins)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1
10
100
1000
10000


Pumping Well
MW14A - Time v Drawdown
Drawdown (m)
Time (mins)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1
10
100
1000
10000

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