Appendix 3

AGE Groundwater Modelling Report

Australasian
Groundwater & Environmental
Consultants Pty Ltd

REPORT on

COLTON COAL PROJECT

GROUNDWATER MODELLING

prepared for
NORTHERN ENERGY CORPORATION LIMITED

Project No. G1451
April 2010

ABN:64 080 238 642

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REPORT ON
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1.0 INTRODUCTION

Northern Energy Corporation Limited (NEC) propose to develop an open cut coal mine north of Maryborough in South-East Queensland. The project referred to as the Colton Coal Project (the Project), proposes a production rate of approximately 0.5 Mtpa of export coking coal over a mine life of 8 years.

In order to obtain mining leases over the resource, an Environmental Authority (EA) is required under the Environmental Protection Act 1994, triggering the need for preparation of an Environmental Management Plan (EMP).

This report has been prepared as part of the EMP and describes a groundwater modelling study to assess the potential impact of the project on the groundwater resources and features related to the groundwater regime. The report describes the hydrogeological regime of the area and provides an assessment of the potential impact of the project on this regime.

This report should be read in conjunction with a report prepared by Streamline Hydro (2010)[1] that describes the hydrogeological field investigations, project impacts and proposed monitoring plan.

This report was prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of NEC.

2.0 PROJECT OVERVIEW

The intent of the Project is to develop an open cut coal mine to extract coking coal from the Burrum Coal Measures. The open cut pit will cover an area of approximately 40ha with a maximum depth of about 80m below ground level.

A coal handling and preparation plant (CHPP) with a capacity of up to 200tph (tonnes per hour) will be constructed within the lease. Water allocation for the CHPP and general industrial use will be sourced from site storages.

Coal will be transported by road to Bundaberg, or rail to Gladstone.

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[1] Streamline Hydro, (2010), *"Maryborough Project, Colton Mine, Hydrogeological Study"*, Report No. 2008010001-RPT-001, 2010.

3.0 SCOPE OF WORK

The groundwater investigation for the project included the following key tasks:

- *Task 1 - Data Review* – existing hydrogeological information was reviewed to determine data gaps and where additional information should be collected (documented in the Streamline Hydro 2010 report)[1].
- *Task 2 - Field Investigations* – an investigative program including installation of monitoring bores, permeability tests and water quality analysis was undertaken to address the data gaps (documented in the Streamline Hydro 2010 report)[1].
- *Task 3 - Data Analysis and Numerical Modelling* – The information collected in the desk top study and the field investigations was analysed and used to construct a numerical model of the groundwater regime, which was used to assess the impact of the proposed open cut mine (documented in this report).
- *Task 4 - Assessment Project Impact, Mitigation and Monitoring Plan* – The results of field investigations and modelling tasks were used to identify the impact of the project, the need for mitigation strategies and a long term monitoring plan (documented in the Streamline Hydro 2010 report)[1].

Task 3 undertaken by AGE is detailed under the headings below. Tasks 1, 2 and 4 are presented in Streamline Hydro (2010)[1] report.

4.0 DATA ANALYSIS

4.1 Falling Head Tests

In-situ hydraulic testing was undertaken in selected monitoring bores at the site. Testing was carried out using “falling head” test methods. The procedure used for each test was as follows:

- a “slug" of water was introduced to each bore as quickly as possible;
- the rate of recovery of the water level was then monitored using an electric water level tape and a pressure sensor and data logger set to record the water level at one-second intervals; and
- the test was terminated after the water level recovered close to the static water level.

The falling head data was analysed by the Hvorslev (1951)[2] method for confined aquifers using *Aquifer Test Version 2.5* software. The exception was the test undertaken on NMB-029 which recorded an oscillating water level and was therefore analysed in a spreadsheet using the method presented by Van der Kamp (1976)[3].

The results of the rising head permeability tests undertaken on the bores are summarised in Table **1** below, and the analysis details are included in Appendix 1.

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[2] Hvorslev, M.J., (1951), *“Time lag and soil permeability in ground-water observations”:* Vicksburg, Miss., U.S. Army Corps of Engineers, Waterways Experiment Station, Bulletin 36, 50 p. TIC#238956

[3] Van der Kamp, G., (1976), *“Determining aquifer transmissivity by means of well response tests: the underdamped case”,* Water Resources Res, 12(1), 71, 1976.

Table 1: SUMMARY OF FALLING HEAD TEST ANALYSIS

Bore ID	Gravel Pack Zone	Test Zone Geology	Hydraulic Conductivity	
			m/sec	m/day
NMb-026	27 - 48m	fine grained sandstone	1.6×10^{-7}	0.014
NMb-029	25.5 - 44.3m	fine grained sandstone	5.3×10^{-4}	45.7
NMb-043	29.5 - 49.5	clay, sandstone and mudstone	6.9×10^{-7}	0.059
NMb-044	17 - 25m	sandstone	7.3×10^{-6}	0.627
NMb-045	40 - 60m	claystone	4.2×10^{-6}	0.363
NMb-046	6.5 - 12m	clay and coal	5.1×10^{-8}	0.004
NMb-047	35.5 – 64m	claystone and minor coal	6.4×10^{-6}	0.553
NMb-048	24.5 - 33m	sandstone, mudstone and sandstone	5.5×10^{-7}	0.048
NMb-050	38 - 54m	clay and minor coal	3.5×10^{-5}	3.033
NMb-051	29.7 – 37	coal and clay	7.0×10^{-5}	6.074
NMb-052	12 - 22m	clay and sandstone	1.9×10^{-6}	0.164

The testing indicates a hydraulic conductivity ranging between 5.3×10^{-4}m/sec (45.7m/day) and 5.1×10^{-8}m/sec (0.004m/day) with a median value of 4.2×10^{-6}m/sec (0.363m/day).

The hydraulic testing indicates a wide range in permeability of four orders of magnitude. This is typical for fractured rock aquifers where the permeability at a particular site is controlled by a combination of primary porosity from the pore space matrix and secondary porosity created by features such as fractures, bedding planes and coal cleats.

Thomas (2002)[4] reports consolidated shale and mudstones from coal bearing sequences typically report a hydraulic conductivity in the range of 5×10^{-8}m/sec (0.00432m/day) to 5×10^{-4}m/sec (43.2m/day). The data collected at the Maryborough site falls within this range, but the median value of 0.36m/day is considered to be relatively high when compared to values typically reported for the Bowen Basin. Hydraulic conductivity values derived from a falling head test are only for a zone in close proximity to the monitoring bore. To assess the hydraulic properties of the coal measures across a larger area, a pumping test was undertaken as described below.

4.2 Pumping Test

4.2.1 Pumping Test Set-up

Test pumping was undertaken on NMb-049 using a grundfos submersible pump (SP14A-25). The pump suction was set at 38.8m, that is, 0.2m above the top of the slotted casing. Water level measurements were collected in the pumping bore NMb-049 and in observation bore NMb-050, NMb-051 and NMb-052 by integrated pressure sensors and data loggers (Diver type). The data

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[4] Thomas, (2002), *"Coal Geology",* Wiley.

loggers were programmed to record at 30-second intervals. Spot water levels were also recorded using an electronic whistle. Flow rates were measured using an ARAD 40mm water meter and cross checked with a bucket and stopwatch.

4.2.2 Data Analysis

A three-stage step test was undertaken on 16 December 2008; the pump was switched on at 07:30 hours and was turned off at 12:00 hours. Three, 90-minute steps of 1.5L/s and 3.0L/s and 4.5L/s were run. Based on the results of the step test, it was decided to undertake the constant rate pumping test at 4L/s.

The constant rate test commenced at 10:05 hours on 17 December 2008 and ceased on 18 December 2008 at 10:05 hours, at total of 24 hours continuous pumping.

Pumping was held at a relatively constant rate of 4.05L/s. This flow rate was regularly checked to ensure that the constant rate was maintained as the water level declined and the pumping head increased. The groundwater levels recorded in the pumping bore and observation bores are presented in Figure 1 below.

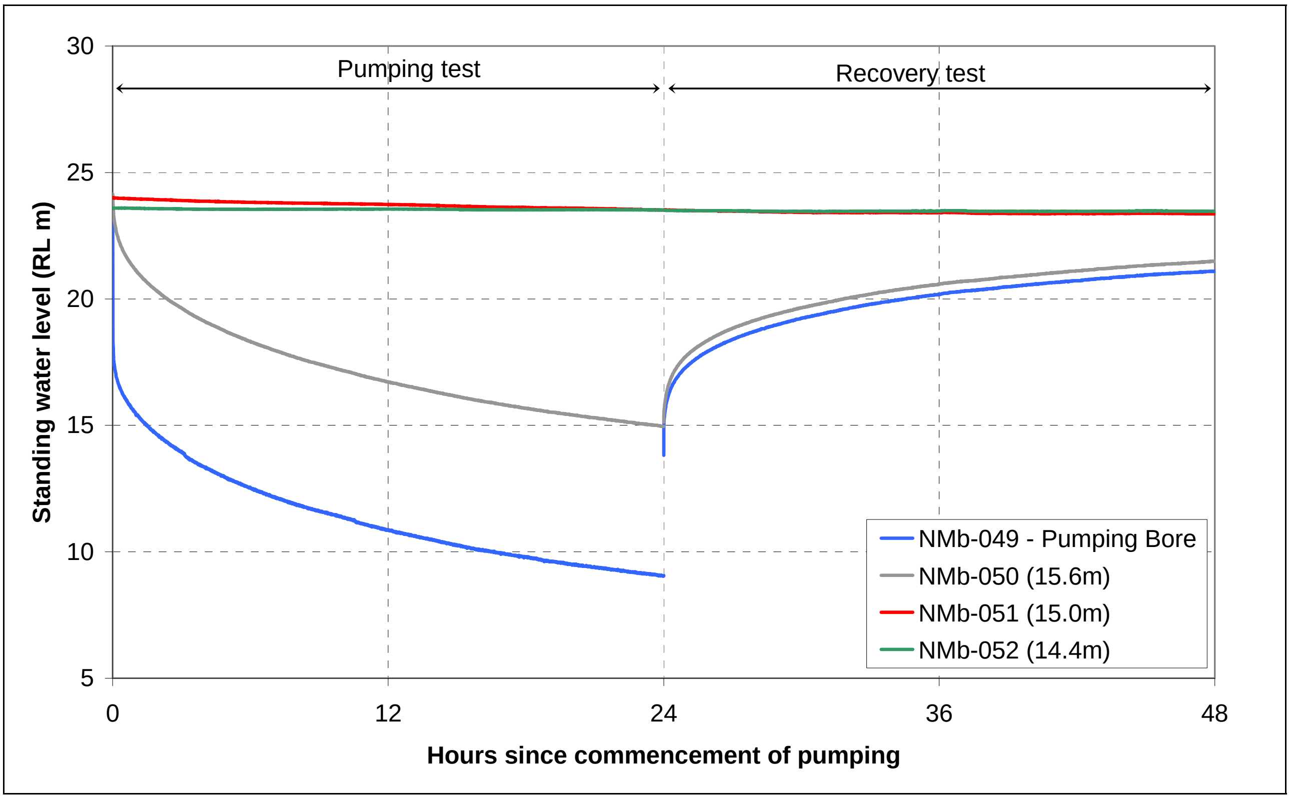

Figure 1: Pumping Test Groundwater Levels

Pumping bore NMb-049 recorded 14.7m drawdown after 24 hours of continuous pumping at a rate of 4.05L/s. Observation bore NMb-050, located at 15.6m from the pumping bore, recorded 9.2m drawdown at the end of the test. In contrast observation bores NMb-051 (0.5m) and NMb-052 (0.07m) showed only a very limited response to the pumping test.

The differing water level response in the bores is explained by the bore construction. The pumping bore NMb-049 is filter packed across coal seams from 37m to 60m, with the observation bore NMb-050 filter packed across a similar zone from 38m to 54m. The other observations bores were constructed at a shallower depth with NMb-051 having the filter pack from 29.7m to 37m and NMb-052 from 12m to 22m.

The limited drawdown in the observation bores constructed at shallower depth indicates a contrasting lower permeability of the overburden and a slower drainage from this material.

The recovery of water levels at the cessation of pumping in both the pumping bore and observation bores was relatively slow. After 24 hours monitoring, 2.7m residual drawdown remained in the pumping bore, with 2.66m recorded in observation bore NMb-050. The shallow observation bores NMb-051 and NMb-052 both continued to decline during the recovery phase by 0.16m and 0.04m respectively.

The poor recovery in the pumping and observation bores indicates an aquifer of limited extent with low recharge rates from overlying and underlying zones in the formation. This is demonstrated by the shallow observation bores that recorded a continual drainage of water from the overlying zones to the deeper aquifer to replace water removed during the pumping test.

The water levels recorded during the pumping test also indicate a limited aquifer extent with a gradual steepening of the drawdown curve shown in Figure 2, indicating a boundary condition in the aquifer gradually reducing the supply of water to the bore.

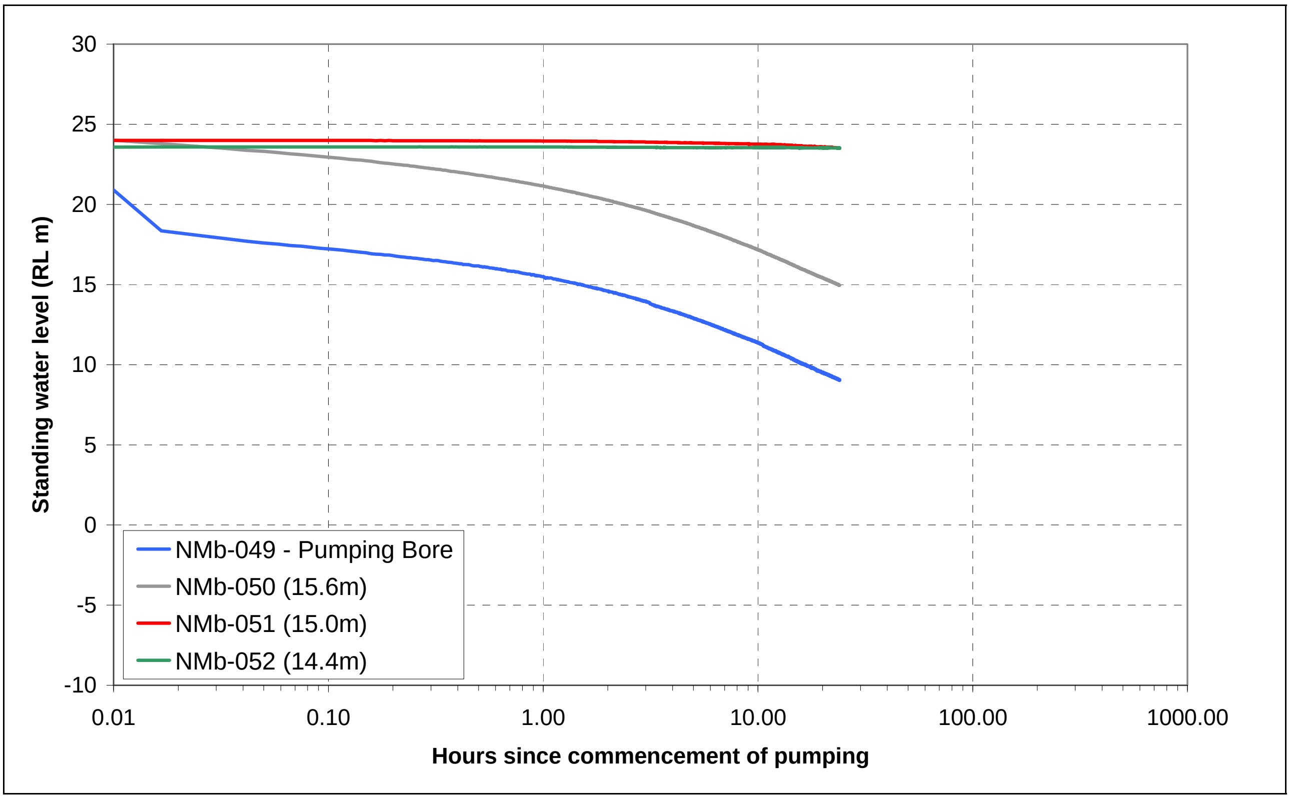

Figure 2: Pumping Test Groundwater Levels – Semilog Plot

The water level drawdown and recovery data from both the production bore and observation bore were analysed using the “Aquifer Test Version 2.5” software package and the analyses are presented in Appendix 2.

In order to assess the aquifer transmissivity, the Cooper Jacob (1946) straight-line analysis for a confined aquifer was used for the drawdown analysis with the Theis (1935) method used for the recovery data. The results of the analyses are summarised below Table 2 below.

The transmissivity was calculated based on the early water level data from the pumping test prior to the boundary conditions being evident in the data. The data from monitoring bores NMb-051 and NMb-052 was not amendable to analysis as these bores are constructed in an overlying section of the aquifer and did not respond significantly to the pumping test.

Table 2: SUMMARY OF ANALYSIS OF PUMPING TEST DATA

Bore	Maximum Drawdown (mbTOC)	Transmiss-ivity (m^2/sec)	Hydraulic Conductivity (m/day) [1]	Storage Coefficient (-)	Method of Analysis
NMb-049	14.7	3.78×10^{-4}	0.65	-	Cooper-Jacob
		5.28×10^{-4}	0.91	-	Theis Recovery
NMb-050	9.2	4.04×10^{-4}	0.70	3.49×10^{-4}	Cooper-Jacob
		6.0×10^{-4}	1.04		Theis Recovery

Notes: 1 - based on assumed aquifer thickness of 50m
2 - mbTOC: metres below top of casing

The analysis of the aquifer test data indicates a median hydraulic conductivity of about 0.8m/day, assuming an aquifer thickness of 50m.

Similar to the falling head test data, the pumping test results are considered to be an over-estimate of the aquifer hydraulic conductivity at a more regional scale. This is due to the boundary conditions evident, particularly in the Theis recovery plots (refer Appendix 2) that indicate full recovery in water levels will not intercept the x axis (t/t') at 1. This indicates an aquifer of limited extent that has been partially dewatered during the pumping test. Although the pumping bore had a moderate yield over the test period, as the zone of influence extends into less permeable rock over time, the drawdown would increase and the bore would eventually fail (go dry). This indicates that on a regional scale the aquifer has a lower hydraulic conductivity than that estimated from the 24-hour pumping test.

5.0 NUMERICAL MODELLING

5.1 Modelling Objectives

Predictive numerical modelling was undertaken to assess the impact of the Project on the groundwater regime. The objectives of the predictive modelling were to:

- estimate groundwater inflow to the open cut workings over the mine life;
- predict the zone of influence of dewatering and the level and rate of drawdown at specific locations;
- identify any areas of potential risk where groundwater impact mitigation/control measures may be necessary;

- predict the impact of mine dewatering on groundwater discharges and other groundwater users.

5.2 Conceptual Model

Every numerical groundwater model has its foundation in a conceptual model. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

Extensive information on the natural system is typically required to develop an equivalent and simplified conceptual groundwater model representative of the system. Development of the conceptual groundwater model of the project area is a crucial step in groundwater modelling and was based on:

- geological and topographical maps of the project area,
- geological information from coal exploration bores drilled across the project area,
- hydrogeological testing including falling head test and test pumping undertaken for the Project,
- previous hydrogeological investigations undertaken by the Laycock (1967)[5] in the region, and
- data from the NRW groundwater database.

The surface geology within the region is shown in Drawing No. 1. The project is located within the Mesozoic Burrum Coal Measures that form a synclinal basin elongated north-south with approximate dimensions of 20km x 6.5km. Hawthorne (1960)[6] reports the Burrum Coal Measures to be a 1,600m thick sequence of sandstones, siltstones, shale, carbonaceous shales and coal seams. A “productive sequence” approximately 150m thick is identified in the mid section of the Coal Measures where the bulk of the historic mining has been undertaken. The Burrum Coal Measures sit conformably on the Maryborough Formation and have an unconformable contact with the overlying Elliot Formation (refer Drawing No. 1).

NEC geologists report that the coal seams of the Burrum Coal Measures are thin and tend to be lenticular, wedging and pinching out over relatively short distances. The seams are patchy and thin with 1m thick developments considered typical. The historical underground workings mined coal down to around 300mm thick.

The only regional hydrogeological investigation undertaken in the area is reported in Laycock (1967)[5]. The investigation included drilling of ten bores in the Burrum Coal Measures. It was noted that *water was intersected at depths of between 15 and 30 feet and in all cases the water rose by more than 15 feet. Indicated yield by short term air-flow measurements were generally between 400 and 3000 gph (0.5 to 3.8L/s). Total dissolved solids in water samples ranged from 120ppm to 6321ppm with a mean of 2447ppm in 27 samples….Water within this unit is undoubtably contained in fissure openings, with the prospects of locating supplies of good quality water in excess of 1000 gph area are not high.*

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[5] Laycock, J.W., (1967*), “Mary Valley Groundwater Investigations – Hydrogeological report on the area between Tiaro and Pialba”.* Geological Survey of Queensland.

[6] Hawthorne, (1960), *“The Burrum Coal Field”,* Geological Survey of Queensland, Publication 296, 37pp.

The key conclusions of the Laycock (1967)[5] investigation were that:

- *The predominant sequence in the Mesozoic units is siltstone to fine sandstone or volcanics, and zones of significantly higher porosity and permeability are not likely to occur even though the units are between 1,400 and 10,000 feet thick.*
- *….all Mesozoic units are known to have low intergranular porosity and low permeability the water known to be present must occur in these units in fractures.*
- *No zones where intense faulting is likely to have increased the open space available for the flow of groundwater area expected to occur.*
- *Storage of those units in the area where water is contained in the joint openings, is expected to be low. The combination of the nature of occurrence and poor storage characteristics indicate that low yields of poor quality water would be anticipated, in the major rock units.*
- *The Takura beds and the Elliot Formation generally occur above the water table.*

The conclusions of the Laycock (1967)[5] investigation that the Burrum Coal Measures are a regionally relatively poor aquifer are in contrast to the results of the field investigations undertaken by Streamline Hydro (2010)[1] that indicate a moderate to high permeability in the formation. It is considered that locally high permeability features are present but on a wider scale the interconnection between these zones is poor, resulting in a low permeability on a regional scale. This is confirmed by the boundary conditions identified in the test pumping.

The three main water bearing zones present in the area are:

- Shallow lensiod type aquifers associated with gravelly zones in the overlying Elliot Formation;
- Aquifers associated with fractured zones in the weathered overburden material; and
- Confined aquifers associated with coal seams.

Recharge to the Burrum Coal Measures is expected to occur by direct infiltration into the Elliot Formation (where present) or directly where the formation is exposed in outcrop. Most of the project area is covered by open woodland that would be expected to intercept and transpire a significant amount of rainfall and therefore, the net groundwater recharge rates are expected to be relatively low.

Discharge from the aquifer is expected to be via local creeks and directly to the Mary River. Given the shallow groundwater levels and dense vegetation, evapotranspiration is also expected to occur.

The numerical model area encompasses the Burrum Coal Measures and overlying Elliot Formation within the Burrum Syncline and is bounded by:

- The eastern and western outcropping contact between the Burrum Coal Measures and the underlying Maryborough Formation; the boundaries are marked by roughly north-south trending ridgelines;
- The Mary River to the south; and
- An arbitrary distance of about 18km to the north of the proposed mine that was judged to be beyond the influence of potential mine dewatering.

The geology and extent of the groundwater model is shown in Drawing No. 1.

5.3 Model Development

5.3.1 Model Code

Numerical simulation of groundwater flows in the aquifers was undertaken using the MODFLOW SURFACT code Version 3. The MODFLOW pre- and post processor PMWIN (Chaing and Kinzelbach, 1996)[7] was used to generate some of the input files for the MODFLOW SURFACT model. SURFACT was chosen as it allows for simulation of unsaturated flow. It is also heavily based on the USGS MODFLOW code which is the industry standard for groundwater flow modelling.

5.3.2 Model Geometry

Due to the thin and discontinuous nature of the coal seams, and the limited information on the coal seam structure outside the proposed mining area it was decided not to model individual coal seams, but to represent the coal seams as a single layer in the model.

The model consisted of a four layers as follows:

- Layer 1 represented the weathered profile and Tertiary Elliot Formation from ground surface to a depth of 10m;
- Layer 2 represented overburden of the Burrum Coal Measures with a variable thickness;
- Layer 3 represented the coal seams to be mined and was set with a constant thickness of 5m;
- Layer 4 represented underburden sediments and was set with a floor level of RL -400m.

A northeast-southwest cross section view of the model domain and layers is shown in Figure 3 below. The model boundary and grid is overlain on the geology map as shown on Drawing No. 2.

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[7] Chaing W.H. and Kinzelbach W., (1996), *“Processing MODFLOW for Windows”.*

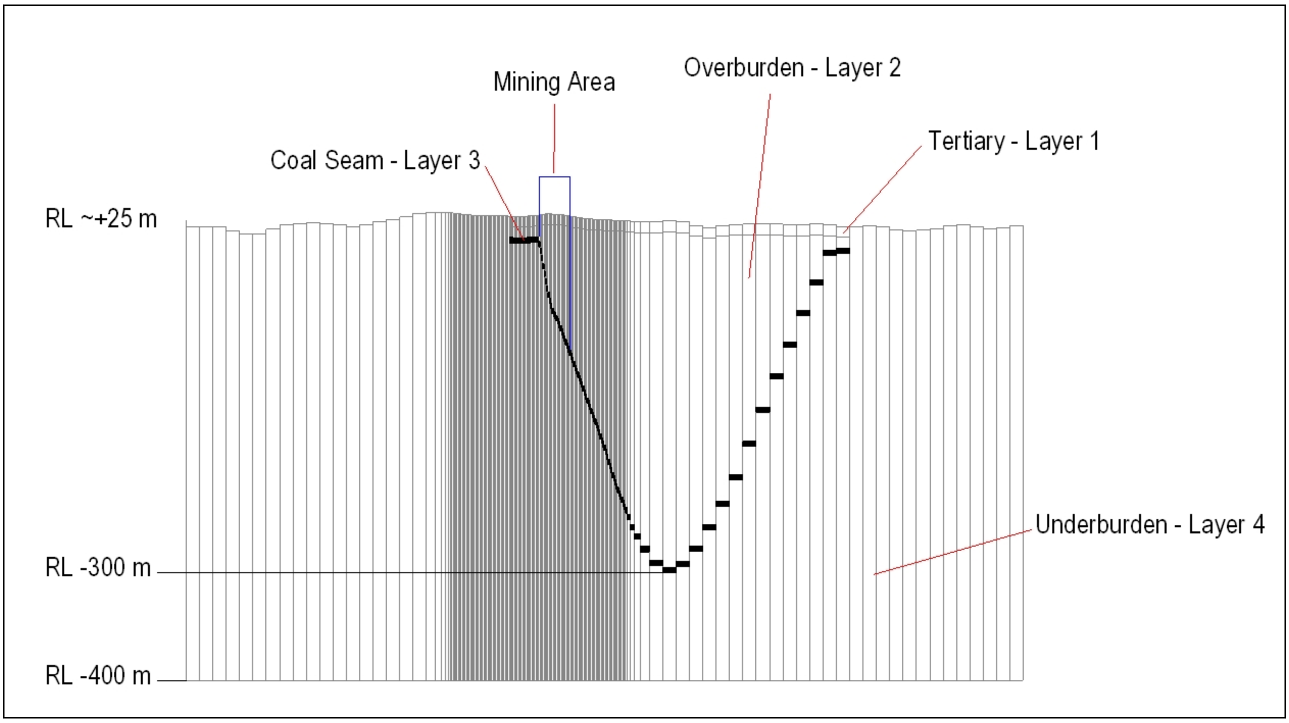

Figure 3: Cross Section of Model Domain

The model domain was discretized into 291 rows and 233 columns resulting in 67,803 rectangular cells per layer. The dimensions of the model cell size vary from 25m by 25m within the mining area and up to 250m by 250m outside the project area as shown on Drawing No. 2. The model grid was rotated at 45 degrees to align with the outcrop of the Burrum Coal Measures and the mine plan.

The active zone of the model is about 34km x 26km covering an area of approximately 884km^2. The cells located outside the extent of the Burrum Coal Measures were assigned ‘no flow’ status and therefore excluded from the simulation. Layers 1, 2 and 3 were set as inactive outside the known subcrop of the main economic seams with Layer 4 active across the entire model domain.

Publicly available digital elevation data (STRM data) with a 90m x 90m grid spacing was used to represent the ground surface in the model. The SRTM dataset was noted to generally record ground levels above surveyed levels, which was presumably due to interference from the tree cover at the site. To correct this inaccuracy the entire SRTM dataset was adjusted so ground levels at the proposed mine approximately matched levels surveyed at the monitoring bores. This related to a correction of about minus 6m over the entire dataset.

5.3.3 Hydraulic Parameters

Coal seams are known to reduce in permeability with depth as increasing stress results in closure of fractures and cleats in the coal (eg. Enever and Hennig [1997])[8]. In the model the hydraulic conductivity of the coal seams (Layer 3) was set at 0.22m/day from surface to a depth of 50m. Below 50m the hydraulic conductivity declined in accordance with the following formula which is based on the decline in permeability observed with depth in Australian coal basins:

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[8] Enever and Hennig (1997). “*The relationship between permeability and effective stress for Australian coals and its implications with respect to coalbed methane exploration and reservoir modelling*”, CSIRO Division of Petroleum, International Coalbed Methane Symposium 1997.

Hydraulic conductivity (m/day) = 30199 x $depth^{-3.0166}$

At 300m depth the coal seam permeability is reduced to 0.001m/day. The reduction in permeability with depth also has the effect of simulating the fact that coal seams at the site have been observed to be thin, lenticular and pinch out over relatively short distances.

The hydraulic parameters adopted for the model are as described in Table 3.

Table 3: HYDRAULIC PARAMETERS

Layer	Parameter	Value
Layer 1	Horizontal Hydraulic Conductivity kh	0.25m/day
	Vertical Hydraulic Conductivity kv	10% kh
	Specific Yield S_y	5%
	Specific Storage S_s	1×10^{-4}
Layer 2	Horizontal Hydraulic Conductivity kh	0.0075m/day
	Vertical Hydraulic Conductivity kv	10% kh
	Specific Yield Sy	1%
	Specific Storage Ss	1×10^{-5}
Layer 3	Horizontal Hydraulic Conductivity kh	Reducing with depth as above
	Vertical Hydraulic Conductivity kv	Reducing with depth as above
	Specific Yield Sy	1%
	Specific Storage Ss	5×10^{-4}
Layer 4	Horizontal Hydraulic Conductivity kh	0.005m/day
	Vertical Hydraulic Conductivity kv	10% kh
	Specific Yield Sy	0.1%
	Specific Storage Ss	1×10^{-5}

5.3.4 Boundary Conditions

The contact between the Burrum Coal Measures and the underlying Maryborough Formation was set as a “no flow” boundary. Layers 1, 2, and 3 were inactive outside the subcrop of the coal seams to simulate the outcrop of the major coal seams to be mined. The base of Layer 4 in the model was also assumed to be a “no flow” boundary. A “no flow” boundary does not allow any exchange of water between the model domain and the surrounding areas.

5.3.5 Recharge and Discharge

Recharge to the model domain was applied to the uppermost layer in the model that represented the topographic surface. The rate of recharge to the aquifers was unknown and was therefore obtained during model calibration.

No attempt has been made to directly measure groundwater recharge in the area; however, there are several indicators that suggest the recharge rate is relatively low. The groundwater is saline which indicates evaporative concentration of rainfall at the surface and a subsequently low rate of recharge. An approximate estimate of the rainfall recharge rate can be made by comparison of the chloride concentrations in rainfall with the concentration in the aquifers. Assuming a chloride concentration of 5mg/L in rainfall, and an average groundwater concentration of 4000mg/L this equates to a recharge rate of 0.125% of rainfall or about 1.5mm/year. It should be noted this estimate can be affected by minerals in the soil/aquifer and evapotranspiration of vegetation directly from the aquifer, and should be considered very approximate at best. However it does indicate the recharge rate is likely to be very low. This conclusion is supported by the lack of groundwater base flow in the local creeks, which would be expected to be flowing if the recharge was significant.

The calibrated rate of recharge to the surface layer of the steady state model was 2mm/year/m^2.

The Mary River and creeks in the model domain were represented in the model through MODFLOW SURFACT 'drain' package. A reference level (in this case 7m below ground surface) was specified for each confirmed drain cell in the model. When the groundwater level in the specified cells is higher than the reference level, water is removed from the cell based on the gradient between the cells and a conductance term. Setting the reference level for the creeks 7m below ground surface reflects the incised nature of the drainage features.

The MODFLOW SURFACT evapotranspiration package was used to represent evaporation and transpiration from the aquifer. The evapotranspiration rate was set at 1mm/day with an extinction depth of 5m to represent deep rooted vegetation.

5.4 Model Calibration

5.4.1 Steady State Calibration Targets

The recorded water levels in the newly installed groundwater monitoring bores and water levels recorded in exploration drill holes were adopted as calibration targets. A selection of groundwater bores installed during the Laycock (1967)[5] investigation in the 1960s was also used in the calibration to provide groundwater levels outside the area of the proposed mine. There was a considerable level of uncertainty in the Laycock (1967)[5] data, with the calibration focused on the newly installed bores.

The objective of model calibration was to reproduce the groundwater levels measured in the new monitoring bores. The accuracy of the model calibration depends on the number, quality and distribution of calibration parameters, and the data defining the model domain such as aquifer geometry, boundaries, hydraulic properties and stresses imposed on the aquifer.

The quality of the calibration target water levels was not optimal because the bores were clustered together in a small area in the model domain. Outside this area the only data available was old and of uncertain accuracy.

During the simulations, the value of hydraulic conductivity, the recharge rate and drain conductance were manually altered within representative ranges to obtain model calibration. The main objective of model calibration was to reproduce the general pattern of the groundwater contours and the direction of the groundwater flow.

5.4.2 Steady State Calibration Results

Comparison of observed and simulated groundwater levels in the model area are given in Table 4 and through a scattergram with observed and simulated groundwater levels as shown in Figure 4. The simulated steady state water levels in Layer 1 are presented in Drawing No. 3.

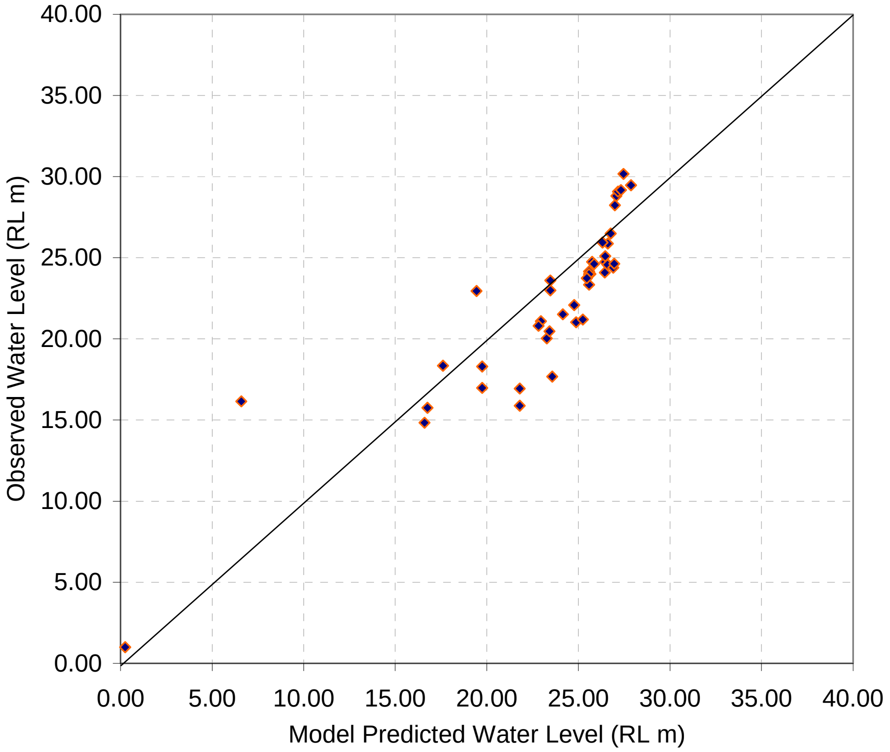

Figure 4: Observed vs Simulated Groundwater Levels – Steady State Model

Table 4: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL

Bore ID	Simulated Steady State Water Level (m AHD)	Observed Water Level (m AHD)	Difference (m)
110673	24.88	21.02	3.86
NMB-045	26.47	24.73	1.74
NMB-046	26.47	25.10	1.37
NMB-053	25.66	23.99	1.67
NMB-029	25.75	24.74	1.01
NMB-049	25.61	24.05	1.56
NMB-050	25.59	24.15	1.44
NMB-051	25.59	23.98	1.61
NMB-052	25.59	23.34	2.25
NMB-020	25.24	21.19	4.05
NMB-026	23.58	17.67	5.91

Table 4: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL

Bore ID	Simulated Steady State Water Level (m AHD)	Observed Water Level (m AHD)	Difference (m)
NMB-043	23.46	22.99	0.47
NMB-044	23.46	23.60	-0.14
NMB-047	21.80	15.87	5.93
NMB-048	21.80	16.93	4.87
NMB-041	19.75	18.29	1.46
NMB-042	19.75	16.98	2.77
110678	19.44	22.95	-3.51
110674	6.59	16.15	-9.56
110682	0.25	1.00	-0.75
NMB102C	25.86	24.62	1.24
NMB103C	25.46	23.74	1.72
NMB104C	22.95	21.09	1.86
NMB105C	22.83	20.80	2.03
NMB108R	24.16	21.51	2.65
NMB109R	24.78	22.08	2.70
NMB110R	23.27	20.03	3.24
NMB111R	27.88	29.46	-1.58
NMB113R	26.59	24.57	2.02
NMB114R	27.00	28.24	-1.24
NMB130R	23.43	20.46	2.97
NMB131R	27.07	28.81	-1.74
NMB132R	27.16	29.08	-1.92
NMB133R	27.47	30.16	-2.69
NMB134R	27.33	29.16	-1.83
NMB135R	26.90	24.38	2.52
NMB136R	26.77	26.49	0.28
NMB137R	26.61	25.87	0.74
NMB138R	26.96	24.63	2.33
NMB139R	26.32	25.94	0.38
NMB140R	26.45	24.09	2.36
NMB154R	16.61	14.83	1.78
NMB155R	16.75	15.75	1.00
NMB156R	17.61	18.35	-0.74

An objective method to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. One such method is by measurement of the error between the modelled and observed (measured) water levels. A root mean square (RMS) expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^{\;2}\right]^{0.5}$$

where:
n = number of measurements
h_o = observed water level
h_m = simulated water level

is considered to be the best measure of error, if errors are normally distributed.

The RMS error calculated for the calibrated model is 2.8m. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total change is small, the errors are only a small part of the overall model response, Anderson and Woessner (1992)[9]. The total observed head loss across the calibration points is a water level difference of about 29m. The ratio of RMS (2.8m) to the total head change across the calibration points (29.16m) is 10%. A target of 5% error is unusually considered best practice, however the calibration presented here is considered to be the best achievable based on the available data when the following points are taken into account:

- A simplified representation in the model of the a complex heterogeneous fractured rock system;
- The limited number of calibration points;
- The clustered nature of the calibration points and lack of points outside the mining area;
- The lack of time series water level data and the uncertainty about steady state water levels in historical data.

The mass balance error, that is, the difference between calculated model inflows and outflows at the completion of the calibration run expressed as percent of discrepancy, was <0.01% on both a cumulative and time step basis, indicating adequacy of the numerical solution and overall stability of the model.

6.0 PREDICTIVE SIMULATIONS

After the steady state and transient models were calibrated to the available data, the model was then used to undertake the predictive scenarios. The mine advancement was based on the mining schedule presented in Drawing No. 4.

The eight years of mining was subdivided into 32 stages, each of 3 months in length. Drain cells set at the proposed mine pit were used to simulate dewatering of the open cut pit. Similar to the steady state model the mass balance error, was <0.01% on both a cumulative and time step basis.

6.1 Inflow to Mined Void

The predicted inflows were obtained from analysing the water budget for the drain cells representing open pit dewatering in the model. The simulated inflow rates are shown in Figure 5.

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[9] Anderson, M. P. and Woessner, W. W., (1992), *"Applied Groundwater Modeling, Simulation of Flow and Advective Transport",* Academic Press.

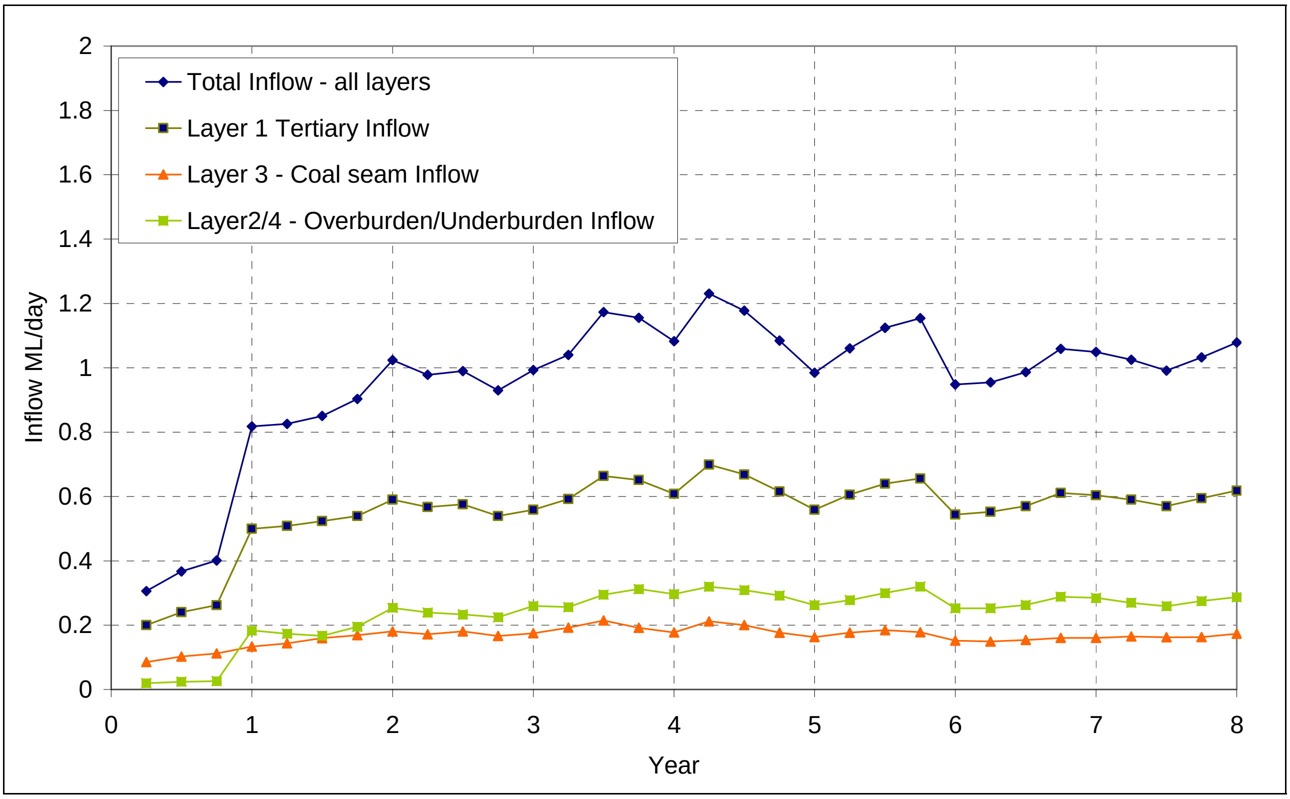

Figure 5: Simulated Groundwater Inflow to Mine

The model indicates that the inflow reaches 0.8ML/day in the second year of mining and then gradually increases to 1.2ML/day at Year 4 after which it is relatively constant over the remaining four years of mining. It is important to note that not all of the volume of groundwater inflow predicted by the model will report to the in-pit sumps for pumping for the following reasons:

- Some of the predicted water inflows will be removed as bound moisture in the coal,
- Some groundwater will evaporate directly from the pit face and floor, and
- The model assumes the mine pits stay open over the life of the mine; in reality the mine will be gradually backfilled as mining advances and this will allow groundwater levels in spoil areas to gradually recover, resulting in a lower inflow than reported by the model.

6.2 Piezometric Surface/Water Table Levels

Contours of piezometric surface for coal seam (Layer 3) and underburden (Layer 4) at the end of mining in Year 8 are presented in Drawing Nos. 5 and 6.

The modelling indicates the zone of influence, as indicated by the 1m drawdown contour, will extend about 2.9km from the open cut pit.

No registered water bores are within the simulated zone of influence. The closest bore, RN110673 is located about 3.6km north-east of the proposed pit. Information in the database indicates that this bore yielded 500gph for brackish water with a salinity of 10,400µS/cm. Given the low yield and poor water quality, it is considered unlikely that this bore is in use.

The modelling indicates the zone of influence does not expand to the major wetland areas mapped by the Department of Environment and Resource Management (DERM) but does encompass three small wetland areas. Inspections by AustralAsian Resource Consultants (AARC [2010])[10] have indicated that one of the DERM mapped wetlands does not classify as a wetland area by definition (refer Drawing No. 5). The groundwater modeling indicates the regional water table is about 6m to 8m below the ground surface in the wetland areas suggesting these ecosystems areas are unlikely to be dependent on groundwater. The conclusion is further supported by the fact that the regional groundwater quality is brackish to saline, meaning it is unlikely wetland vegetation is heavily dependent on this poor quality water, with overland flow of surface water being the likely source of water for these ecosystems.

6.3 Groundwater Level Recovery

Once mining operations cease, dewatering will not be required and a slow recovery in groundwater levels in the area will occur. A void will remain at the north-western and south-eastern extents of the mine footprint with an area of approximately 40ha each and will be up to about 90m deep.

Direct rainfall falling on the void and groundwater seepage will slowly fill the void forming a lake and eventually reaching an average stable water level which will be influenced by the balance of inflows from groundwater, and losses from evaporation. Surface water runoff will be directed away from the final void by bunding where practical.

The water level in the final void was estimated by running the groundwater model with the following modifications:

- a hydraulic conductivity of 10,000m/day and a specific yield/storativity of 1 were applied to the cells to represent the open void in Layers 1 to 3,
- inputs to the final void are direct rainfall (1.15m/year/m^2) minus open water evaporation (1.935m/year/m^2 x 0.7 pan factor) and therefore a net evaporation rate of 0.2m/year/m^2 was applied to the void surface - no allowance for surface water runoff was made as it was assumed the final void will be bunded,
- the spoil areas were represented with a hydraulic conductivity of 0.1m/day and specific yield of 1%,
- the recharge rate to the spoil was set at 10mm/year, a factor of 5 times the rate for the surrounding bedrock.

The recovery model reported a low mass balance error, was <0.01% on both a cumulative and time step basis. The simulated recovery in water levels in the final void and spoil zones aquifer is shown in Figure 6 below.

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[10] AustralAsian Resource Consultants, (2010), *"Colton Mine Project – Terrestrial Flora and Fauna Report".*

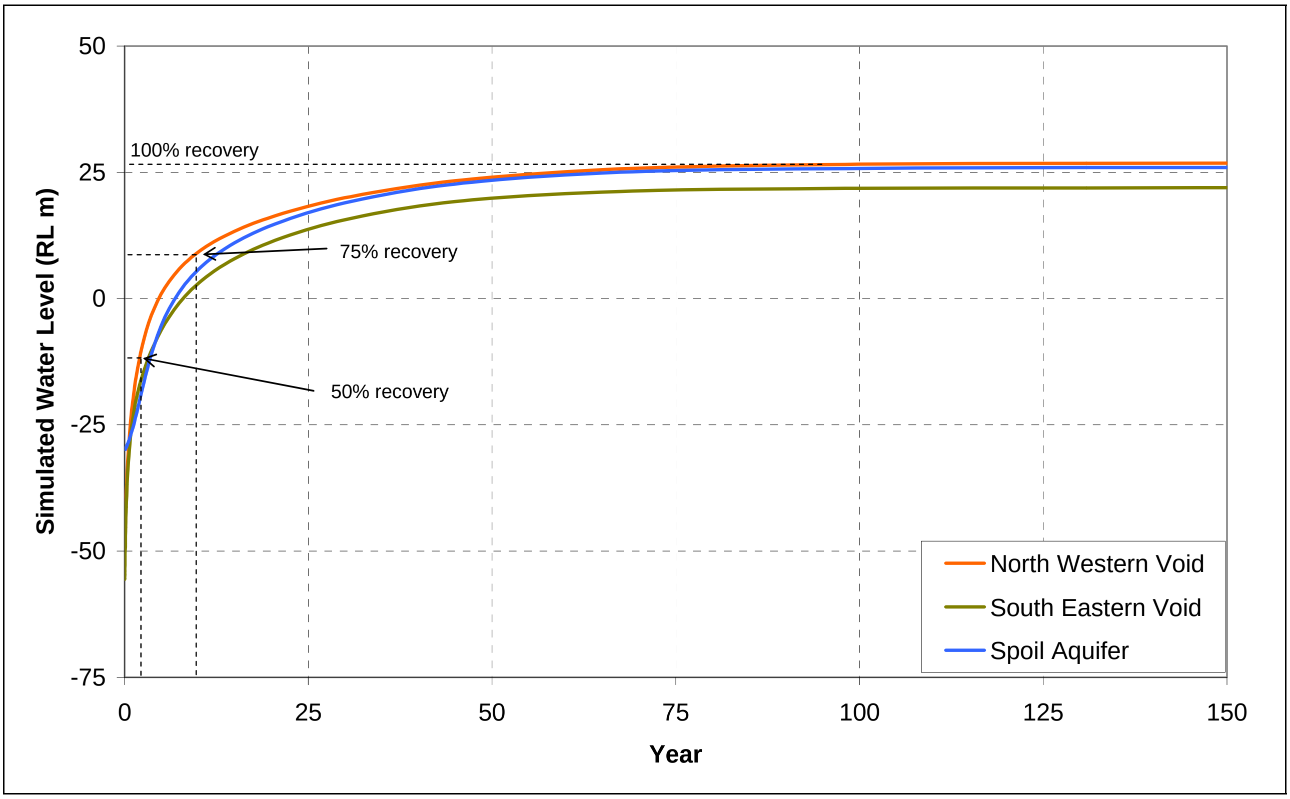

Figure 6: Water Level Recovery – Final Voids

The assessment indicates groundwater levels will stabilize at about RL 26m in the north-western void, about 12m below ground surface. The south-eastern void will stabilise at RL 22m, about 9m below ground surface, indicating that the neither of the voids will recover to ground level and overflow.

About 50% of the recovery will occur within the first 2 years and the void will be 75% recovered in about 9 years. The void will then slowly recover to an equilibrium level reached in about 100 to 150 years.

Both voids will recover to within 1m of the pre-mining groundwater level, and therefore the long term drawdown will be less than 1m. However as the water level in the void will be lower than the surrounding aquifers the void will act as an evaporative sink which will prevent water in the void from moving back into the aquifer. Full recovery back to the pre-mining groundwater levels will not occur as the rate of evaporation exceeds the direct rainfall input.

7.0 SENSITIVITY ANALYSIS

A sensitivity analysis was undertaken to demonstrate how the groundwater model responds to variations in modelling parameters. The analysis involved modifying the model parameters, re-running the model and examining the changes to the model predictions. A one sided sensitivity analysis was undertaken that would increase the drawdown in groundwater levels.

Hydraulic conductivity was increased by 10% in all layers and rainfall recharge reduced by 10%.

The impact of the modified parameters on drawdown at the end of Year 8 in the coal seam layer is presented in Drawing No. 7 and Drawing No. 8. The sensitivity analysis indicates that the zone of influence extends between about 100m and 300m further when the hydraulic conductivity is increased 10%, and less than 100m when the recharge rate is reduced by 10%.

8.0 SUMMARY AND RECOMMENDATIONS

The groundwater modelling indicates that the proposed mine will reduce groundwater levels up to about 3km from the open cut pit. No registered water bores are located within the predicted zone of influence. Two small wetland areas are located within the zone of influence, however the wetlands are not considered to be dependent on groundwater as the modeling indicates the water table is relatively deep at 6m to 8m below the surface in these areas and the water quality is brackish to saline, meaning it is unlikely to be suitable for vegetation, with overland flow being the likely source of water for these ecosystems. As the wetlands are not likely to be a groundwater discharge zone, they will not be impacted by the mine dewatering.

Monitoring of groundwater levels and quality within the predicted zone of influence and in the surrounding wetland areas is recommended so that the predictions of the groundwater modelling can be confirmed during the mining phase. At each monitoring site separate bores should be constructed in the overburden and coal seam aquifers. The recommended monitoring programme is detailed by Streamline Hydro (2010)[1].

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

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GLOSSARY

Alluvium - Sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquiclude - A low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.

Aquifer - Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, confined - An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, perched - A region in the unsaturated zone where the soil may be locally saturated because it overlies a low-permeability unit.

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

Aquifer, unconfined - An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water-table aquifer is a synonym.

Aquitard - A low-permeability unit than can store ground water and also transmit it slowly from one aquifer to another.

Colluvium - Sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Cone of Depression - The depression in the water table around a well or excavation defining the area of influence of the well. Also known as cone of influence.

Drawdown - A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or excavations.

Hydraulic Conductivity - A measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Hydraulic gradient - The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

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

Model calibration - The process by which the independent variables of a digital computer model are varied in order to calibrate a dependent variable such as a head against a known value such as a water-table map.

Packer test - An aquifer test performed in an open borehole; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.

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

Porosity - The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Pumping Test - A test made by pumping a well for a period of time and observing the response/change in hydraulic head in the aquifer.

Slug Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

Storativity - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in head.

Transmissivity - A measure of the rate at which water moves through an aquifer of unit width under a unit hydraulic gradient.

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

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

LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of Northern Energy Corporation Limited in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 4 December 2008.

The methodology adopted and sources of information used by AGE are outlined in this report. AGE has made no independent verification of this information beyond the agreed scope of works and AGE assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to AGE was false.

This study was undertaken between 19 December 2008 and 21 April 2010 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

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

This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our experience.

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

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