Appendix H Technical Report: Groundwater Modelling Assessment of Impact of Daunia Coal Mine on Regional Groundwater Aquifers

Introduction

BMA proposes to undertake mining activities within the Daunia and Daunia East Mining Leases. A predictive numerical groundwater model was constructed at a broad regional scale to simulate potential regional impacts on the groundwater system resulting from groundwater extraction from aquifers beneath the Project Site during mining of the Daunia and adjacent Poitrel and Millennium coal deposits. The model was specifically designed to assess groundwater for the purposes of the Daunia Project EIS. The model was built within Visual MODFLOW Version 4.2 (Waterloo Hydrogeologic Inc).

This appendix describes the process of construction, calibration, predictive runs and sensitivity analyses of the regional groundwater model built for the purpose of identifying environmental impacts relating to the Daunia Project.

Background Data

Information used in conceptual model design and numerical model construction was compiled from a variety of sources. These include:

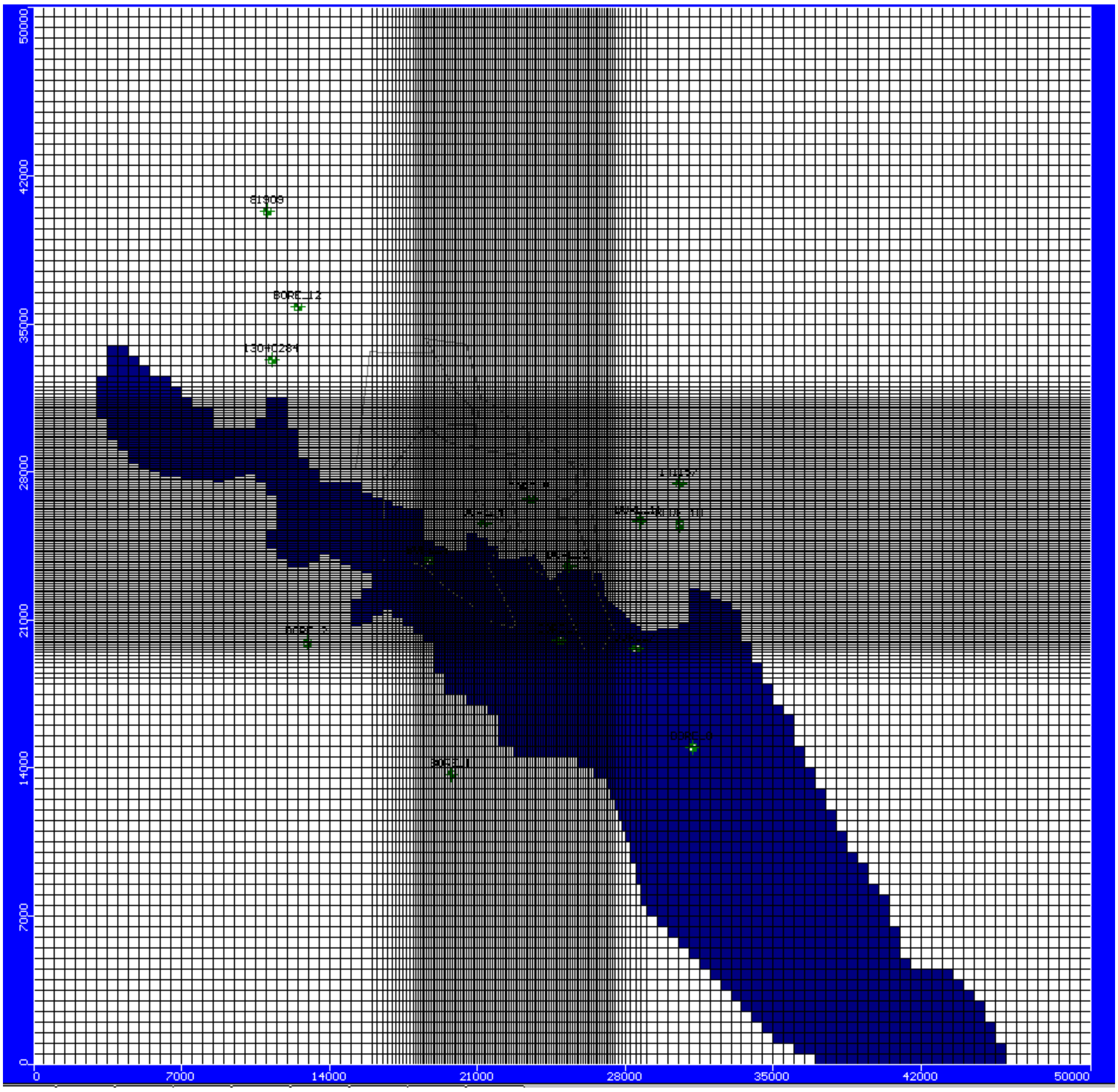
- Reports on geological, geotechnical and environmental investigations of the Project Site;
- Published regional geological maps;
- Department of Natural Resources and Water groundwater database;
- Digital terrain model for the Project Site and surrounds;
- EIS Poitrel reports.

Model construction

Model Extent

The model coordinate system is UTM Zone 55, AMG 84. The model domain covers the area of 609,000 mE, 7,533,000 mN to 659,000 mE, 7,583,000 mN. This is a spatial extent of 50 km east-west by 50 km north-south.

The model is split into grid cells including 203 rows, 186 columns and 7 layers. This represents a total of 264306 cells. Grid cells vary both in width and length from 100 by 100 m in the vicinity of the Daunia, Poitrel and Millennium coal mines to 500m by 500 m in the corners of the model.



Permian Triassic Rewan Group and Rangal Coal Measures

Quaternary Alluvial Sediments

Figure H-1 Model Extent

Geological / Hydrogeological Layers

The model consists of 7 layers as outlined below (**Table H-1**).

Table H-1 Geological/Hydrogeological layers used in model

Geological Unit	Model Layer	Aquifer Type	Modelled layer type	Modelled Layer Thickness
Quaternary age alluvium, soil	Layer 1	Unconfined	Confined/unconfined, variable S, T	10 m
Sandstone, siltstone, mudstones of the Permian Triassic Rewan Group and Rangal Coal Measures(Blackwater Group)	Layers 2,4,6,7	Aquitard	Confined/unconfined, variable S, T	10-200m
Coal seams within the Permian age Blackwater Group	Layers 3,5	Semi-confined to confined	Confined/unconfined, variable S, T	10 m

The digital terrain model (DTM) was generated from several DTMs including a 1 m, 5 m and 20 m contours.

Layer 1 represents the shallow alluvial aquifers south of the Project Site. The Alluvium sediments can be up to 20 m thick, however for the purpose of this assessment it is assumed to be 10 m thick.

In the vicinity of the Project Site all layers were assumed to be a constant thickness and the shape of the layer boundaries was extrapolated from the DTM. The depths and thickness of each layer was determined by the limited information available within geological reports and driller's logs from the nearby Poitrel Mine site. In the vicinity of the Project Site, the formations have been extensively faulted with throws up to 80 m. While the coal seams are likely to be disconnected across these faults, there could be some hydraulic connection between the disconnected coal seams. Consequently the coal seam aquifers were assumed to be continuous across the model. This assumption offers better model stability and a more conservative estimation of groundwater impacts.

Layers 6 and 7 represent the same geological unit (Permian sandstone, siltstone and mudstone) that underlies the coal seams. This unit has been divided into two layers to provide better model stability. The base of the 7^{th} layer is set at 0 mAHD, with vertical flows below this limit considered insignificant for the purpose of the assessment.

K values

Hydraulic conductivity (K) parameters used within the model are tabulated in **Table H-2**. No field measurements were available and published values are provided for reference.

Table H-2 Hydraulic conductivity values used in regional scale groundwater model

Geological Unit	Model Layer	K model	Sources
Quaternary age Alluvium Unit	Layer 1	10 m/day	No known pumping tests have been conducted in the Alluvium unit in the proximity of the site, and hence, measured hydraulic conductivity values are not available. The range of hydraulic conductivity values for silty sands of between 1 m/day and 90 m/day as reported by Freeze & Cherry (1979) has been adopted.
Sandstone/siltstone component of the Permian Triassic Rewan Group and Rangal Coal Measures (Blackwater Group)	Layer 2,4,5 and 6	0.1 m/day	No known pumping tests have been conducted in the sandstone unit in the proximity of the site, and hence, measured K values are not available. The absence of moisture in these units during drilling (D. McManus, pers.comm, January 6, 2005) indicates the sandstone to be largely impermeable. Freeze & Cherry (1979) reports the hydraulic conductivity of sandstone to range between 0.00001 m/day and 1 m/day. A number of 0.1 m/day has been assumed for the model after K sensitivity analysis during model calibration
Coal seam component of the Blackwater Group	Layer 3, 5	5 m/day	The representative and lower limit range of hydraulic conductivity results was sourced from BHP Billiton Mitsubishi Alliance pump tests conducted on similar coal seams at Goonyella. A conservative upper K value was selected from a range of pump test results conducted in Blackwater. Selected exploration holes at Poitrel were subject to yield testing. Typically, yields of less than 2 L/s were measured. Yields as low as 0.08 L/s and up to 15 L/s were however recorded. To this end, the range of K values adopted from the pump tests conducted in Blackwater are considered to be a satisfactory representation of the yields measured at Poitrel.

S values

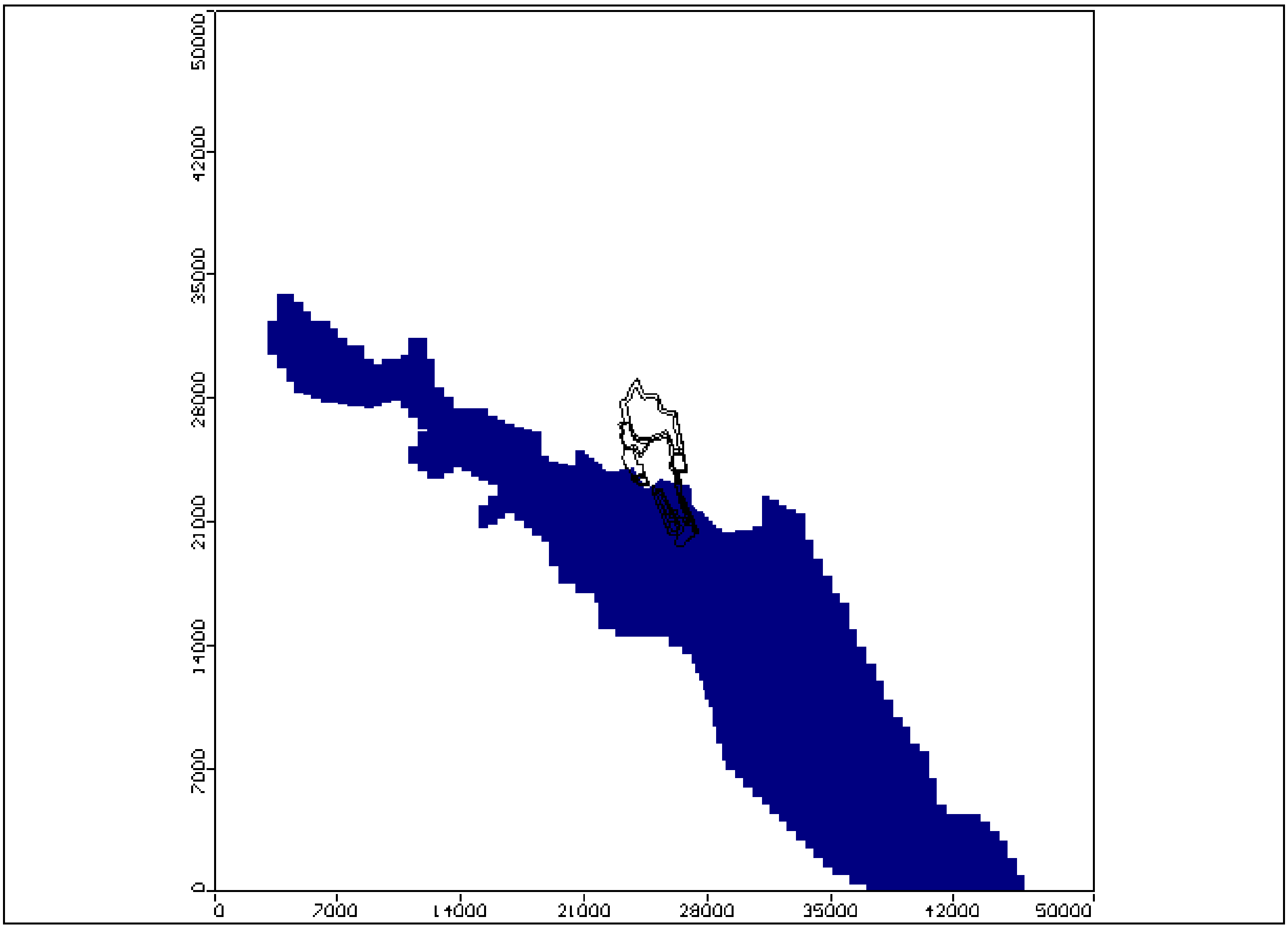
Specific storage and specific yield parameters used within the model are tabulated in **Table H-3**. No field measured data were available and published values are provided for reference.

Table H-3 Specific storage and specific yield values used in model

Geological Unit	Model Layer	Ss model (1/m)	Sy model	Sources
Quaternary age Alluvium Unit	Layer 1	N/A	0.26	No known pumping tests have been conducted in the Alluvium unit in the proximity of the site, and hence, storativity values are not available. The range of storativity values for a medium sand of between 0.15 and 0.26 as reported by Fetter (1994).
Sandstone/siltstone component of the Permian Triassic Rewan Group and Rangal Coal Measures (Blackwater Group)	Layers 2,4,5, 6 and 7	5E-6	0.05	This aquifer would typically be confined within the groundwater model and therefore the specific storage was assumed to be 0.000005.
Coal seam component of the Blackwater Group	Layer 3, 5	5E-6	0.05	Typical storativity value reported from BHP Billiton Mitsubishi Alliance pump tests conducted on similar coal seams at Goonyella and Blackwater

Recharge

Recharge was applied across the model domain as a percentage of average rainfall. Recharge zones were applied with respect to geological units and soil cover. A recharge of 5mm/year was applied along the alluvial deposit and 1 mm/yr in areas of the siltstone/sandstone unit outcrop. These values represent 0.8 per cent and 0.2 per cent of rainfall being applied as recharge to the uppermost active layer of the model at any point in time. The recharge rates were chosen with respect to regional geology, and site location within Queensland.



Permian Triassic Rewan Group and Rangal Coal Measures (Blackwater Group) – 1 mm/yr

Quaternary Alluvial Sediments – 5 mm/yr

Figure H-2 Recharge Zones within the Model

Boundary condition

The model domain includes a portion of the surface water catchment area of the Isaac River and other Creeks that converge and flow past the Project Site. General head boundaries are present within all layers along the four sides of the model domain. They mimic inflow and outflow of water into and from the model domain in order to generate a regional north north-west south south-east hydraulic gradient of 0.001.

Initial heads

Initial heads for the model are based on water levels within regional landholders bores collected during the 2004 regional bore survey and water levels recorded on the groundwater database. Groundwater flows from northwest to southeast.

Landholder Observation Bores

Landholder bores are represented in the model as observation points.

Isaac River

The Isaac River and its tributaries in the region are ephemeral and there are no permanent water bodies in the vicinity of the Project Site. The surface waterways have not been included in the model as under normal conditions they have no connection to the groundwater system.

Modelled Timeframe

Model stability was achieved in steady state mode, using average annual conditions (recharge, etc.). Once stability in steady state was achieved, the model was tested in transient state once again using average annual conditions.

Non Uniqueness, Sensitivity and Uncertainty analysis

Model construction was kept as simple as possible. The greatest hydrogeological data density was located in the immediate vicinity of the Daunia, Poitrel and Millennium Mine sites. In regions of limited information, parameters were averaged to provide a reasonable estimate of the likely values.

During model construction, sensitivity analysis was conducted on the hydraulic conductivity, storage, boundary conditions, recharge and ET to ensure the model was stable.

Significant uncertainty exists for aquifer geometry and hydraulic parameters in the model, due to the lack of information available on site. Average published values and site specific values were applied regionally. Conservative assumptions were made where relevant.

Model justification

The justification for the use of Visual MODFLOW modelling code is as follows:

- A block model is applicable for relatively shallow dipping strata;
- MODFLOW modelling code is the DNRW and industry standard finite difference code;
- The modelling code enables easy adaptation of the model to relatively orthogonal pit/strip advance rates;
- The modelling code is acceptable for confined/unconfined groundwater systems;
- The modelling environment is not subject to deformation of strata (e.g. underground mining); and
- The modelling code is able to model transient and steady state scenarios.

Model calibration and Sensitivity Analysis

Steady state calibration was undertaken using initial heads which represent the regional water table as information provided by the Department of Natural Resources and Water groundwater database and from the Poitrel Mine site.

During steady state calibration, a range of K values, recharge values, and boundaries conditions were applied to the domain to achieve close calibration with observed groundwater levels extracted the groundwater database.

Prediction and Sensitivity analysis

A series of model scenario runs were undertaken to depict different stages of mine life. These include:

- Steady state calibration to obtain initial conditions for the entire model domain;
- Transient model run to reflect the 8 years operational phase at the Poitrel Mine and Millennium Project prior to the first year of Daunia operational phase. This scenario assumes the Poitrel pit shape as it is at year 9 for the 9 years run and Daunia pit shape at year one just for the last year of the run. The Millennium pit shape is assumed remain the same for the all model runs.
- Transient model run to reflect operational phase of the project up until year 5. This scenario assumed the year 5 pit shape for 4 years;
- Transient model run to reflect operational phase of the project between year 5 and 10. This scenario assumed the year 10 pit shape for 5 years;
- Transient model run to reflect operational phase of the project between year 10 and 15. This scenario assumed the year 15 pit shape for 5 years;
- Transient model run to reflect operational phase of the project between year 15 and 20. T his scenario assumed the 20 year pit shape for 5 years;
- Transient model run to reflect groundwater re-equilibrium (or recovery) within the final void and regionally from end of mine life to year 500 post mine closure. Model used progressive time steps;
- Steady state model run to reflect recovery of model domain at time infinity post mine closure.

Model runs are outlined in **Table H-4**.

Table H-4 Model runs

Model run	Run Type	Duration (years)	Description
St-Daunia	Steady State	Infinity	Initial conditions, steady state calibration, pre-mining
Daunia-tr1	Transient	9	Aquifer dewatering from year -8 (beginning of Poitrel mining operation) to year 1.
Daunia-tr5	Transient	5	Aquifer dewatering from year 1 to year 5.
Daunia-tr10	Transient	5	Aquifer dewatering from year 5 to year 10.
Daunia-tr15	Transient	5	Aquifer dewatering from year 10 to year 15.
Daunia-tr20	Transient	5	Aquifer dewatering from year 15 to year 20.
Finalvoid-Daunia	Transient	500	Aquifer recovery modelling
ST-void recovery-Daunia	Steady State	Infinity	Recovery modelling – equilibrium conditions, post mining

Drains

Drains were assigned to cells within the Project Site during operational phase to mimic groundwater inflow into the base of the mine pit. The extent of mine progression at specific points in time was obtained from a series of progressive mine plans displaying the pit extent at specific points in time. Progressive mine plans were provided by BMA for year 5, 10, 15, 20 after beginning of extraction. Interim time steps were interpreted between these years to facilitate model stability.

Drain elevation was assigned according to the information available in the dxf images. Drain conductance was set at a very high value (10,000 m^2/d) in order to eliminate any flow resistance terms so that the potentiometric level is forced to match the appropriate pit floor level.

Drain cells within the pit were removed from post-mining recovery modelling scenarios to mimic cessation of pit groundwater inflow into the pit and aquifer re-equilibration.

Recharge

Recharge distribution over the model domain remained the same for all model runs (discussed in the Recharge section of this Technical Report).

Modelling outcomes

Outcomes of modelling are discussed in **Section 7** of the EIS.

Model sensitivity

A sensitivity analysis was conducted in two scenarios. A “worst case” scenario that assumed larger conductivities (by a factor 5) and specific yield (by a factor 2) for each unit, and a “best case” scenario that assumed lower permeability (by a factor 5) and specific yield (by a factor 2) for each unit. Outcomes are compared to the best estimate (representative) scenario which forms the most likely scenario according to current understanding of the regional groundwater system.

Outcomes of sensitivity analysis are discussed in **Section 7** of the EIS.

Model Limitations

The regional model is currently limited by the amount of regional geological and hydrogeological data available. As more information becomes available the model should be reviewed and adjusted to incorporate the new information. This will result in an increasingly accurate regional groundwater model that can more accurately predict regional impacts prior to their occurrence.

Limitations exist with respect to:

- Aquifer recharge rates and spatial distribution of aquifer recharge areas;
- Regional hydrogeological properties of rock units;
- Structural influence on groundwater flow (faults, fractures, joints);
- Regional geological/lithological unit boundaries (in three dimension); and
- Impacts of adjacent mining activities.