APPENDIX G

Groundwater Model Peer Review

PEER REVIEW

Our Ref: HC2013/8

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From: Dr Noel Merrick

Re: **Groundwater Peer Review – Drayton South Coal Project**

Introduction

This report provides a peer review of the groundwater assessment undertaken for open cut and highwall mining for the Drayton South Coal Project (the Project). The assessment has been done by Australasian Groundwater and Environmental (AGE) Consultants Pty Ltd for Anglo American Metallurgical Coal Pty Ltd. The Project is located about 10 km north-west of Jerrys Plains in the Upper Hunter Valley (NSW).

The groundwater assessment is based on field investigations and a regional numerical groundwater model. The groundwater modelling forms an important component of the environmental assessment for the project. The main purpose of the modelling is to assess potential impacts on groundwater levels on the Project Site and in the surrounding area, and also to quantify the incidental capture of streamflow and alluvial groundwater associated with the Hunter River and Saddlers Creek as required by the Aquifer Interference Policy (issued September 2012). The model also provides an assessment of likely groundwater inflow to the open cut pits as the mine progresses in time.

The scope of work was limited to a peer review of AGE's groundwater report and completed model.

Documentation

The review is based on:

> *Australasian Groundwater & Environmental Consultants Pty Ltd, 2012, Drayton South Coal Project Groundwater Impact Assessment. October 2012. 138p (Text) + 114p (Figures and Appendices).*

An interim review was conducted in June 2012 on a draft report. The reviewer did not hold any discussions prior to the delivery of this report for review. Comments made at that time have been accommodated in the final report as presented in the Environmental Assessment.

Guidelines

The review has been conducted in accordance with the principles of the Australian Groundwater Modelling Guidelines issued by the National Water Commission (NWC) in June 2012 (Barnett *et al*., 2012[1]) and structured according to the checklists in the Murray Darling Basin Commission Groundwater Flow Modelling Guideline (MDBC, 2001[2]).

In terms of the MDBC 2001 modelling guidelines, the Project model is categorised as an Impact Assessment Model of medium complexity, as distinct from an Aquifer Simulator of high complexity.

The Australian best practice guide (MDBC, 2001) describes the connection between model application and model complexity as follows:

- *Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies; and*
- *Aquifer Simulator - a high complexity model, suitable for predicting responses to arbitrary changes in hydrological conditions, and for developing sustainable resource management policies for aquifer systems under stress.*

An Impact Assessment model is the appropriate level of complexity for an Environmental Assessment.

The NWC 2012 guide has replaced the model complexity classification by a "model confidence level". The AGE report gives a thorough defence of the model's Class 2 classification (the middle category) in terms of data, calibration, prediction and key indicator checkpoints. A Class 2 model would be suitable for "prediction of impacts of proposed developments in medium value aquifers" and for "providing estimates of dewatering requirements for mines and excavations and the associated impacts".

The review checklists are presented in Table 1 (at the back of this letter report). The checklists address the following components of a groundwater assessment based primarily on modelling:

1. The Report;
2. Data Analysis;
3. Conceptualisation;
4. Model Design;

[1] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra.

[2] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: http://www.mdbc.gov.au/nrm/groundwater/groundwater_guides/

5. Calibration;
6. Verification;
7. Prediction;
8. Sensitivity Analysis; and
9. Uncertainty Analysis.

The review has been based entirely on a written report, with no reference to electronic model files.

Discussion

Comments on The Report

1. Comprehensive Executive Summary.
2. Good summary of the new Aquifer Interference Policy (released in September 2012).
3. Good report structure and high quality graphics.
4. Project objectives are articulated clearly.
5. The project objectives are considered in turn in the Conclusions section.
6. A full water balance is reported only for steady-state calibration; however, no evapotranspiration (ET) is included although this is part of the conceptual model and the ET parameters are discussed for the transient model.
7. There is no overall water balance for the transient verification model.
8. For the prediction model(s), a full water balance is not reported but component flows of interest are considered in detail.
9. "mAHD" should be used instead of "RL m".
10. In Section 6.3.5, it is not correct to use the term "pore pressure" when referencing heads in mAHD.

Comments on Data Analysis

1. Geology is well known except towards the corners of the model extent outside the Project Boundary.
2. Substantial previous field investigations undertaken since 1998 and sufficient new work installed and undertaken as part of the Environmental Assessment (10 standpipe piezometers; 5 vibrating wire piezometer nests with 4-6 piezometers in each).
3. Water level monitoring since 1998. Useful information on vertical hydraulic gradients.
4. Due to the length of various review stages, the hydrograph plots are not extended past 2011 (Figures 10-11, 15-26). To assist with Aquifer Interference Policy assessment, the average natural fluctuation in water levels should be stated.
5. An indicative regional groundwater head pattern (and associated flow direction) is given in Drawing 13. As this map is based in part on interpolation, the source data points should be shown so that the reader can assess the spatial reliability of the contours. It is not correct to call these "Predicted" heads in the legend - they are interpolated from observations.
6. Although there is a lack of stream gauge data for the Hunter River, this is not a critical factor for a groundwater assessment.
7. There is no comment on whether Hunter River floods might reach the Project Site or whether Saddlers Creek is prone to flooding. If so, this is another potential source of aquifer replenishment. Ignoring flooding is consistent with a conservative assessment of drawdown impacts.

8. Groundwater abstraction is not included as a stress on the aquifer system, due to lack of metering and difficulty in access to private records. This is not a critical factor in the assessment.

Comments on Conceptualisation

1. Valid and sufficient.
2. Excellent conceptual model graphic (Figure 35).
3. Includes ET but there is no evidence of ET quantification in any model run, or of impacts on ET which might be interpreted as impacts on GDEs.

Comments on Model Design

1. MODFLOW-SURFACT software is appropriate. It is unclear whether pseudo-soil or full unsaturated zone option has been used.
2. Cell size 50m to 500m.
3. 168 rows; 155 columns; 17km x 22km.
4. About 470,000 model cells.
5. 18 layers. 5 separate coal seam layers (thickness is the aggregate of the ply thicknesses). 5 deeper seams combined with overburden to form 5 model layers.
6. Southern boundary limited to the southern extent of the Hunter River Alluvium. Effects might propagate beyond this limit, but modelling supports the original decision.
7. Western boundary marked by Mt Ogilvie fault on assumption of significant throw associated with truncation. However, there is a possibility that the coal seams roll over the fault; in this case drawdowns could propagate farther to the west.
8. The full model grid could have been overlaid on a geology map to show how geology has been used to define no-flow borders. This is said to have been done on Drawing 14 but the geology is missing.
9. The model grid is said to be "directly north-west". It seems to be about 11 degrees west of north.

Comments on Calibration

1. Limited to steady-state but supported by transient verification over 14 years without time-varying rainfall recharge or stream stage.
2. Sufficient evidence for good steady-state calibration in the form of a scattergram, performance statistics, a table of residuals and groundwater head contours for comparison with interpolated field contours.
3. Steady-state performance: 7.0 %RMS; 12 mRMS. One of the 95 calibration targets could have been removed as it is impossibly low (56.3 mAHD). The performance has been affected by inclusion of lower-quality data from open holes.
4. Transient performance: 7.8 %RMS.
5. Adopted/calibrated hydraulic and storage properties are generally in accord with field measurements and expectations. The specific yield (Sy) value of 0.0005 is considered very low in layers 2, 4, 6, 8, 10, 12. If these layers are dewatered, inordinately large temporal changes in head would result during dewatering and recovery. The dewatering would be associated mostly with spoil, rather than host rock, but the increased value (0.01) is still low for spoil. (For highwall backfill, the report text has 0.25% instead of 25% but the value in Table 25 is correct.)
6. Storage properties are not well resolved due to lack of significant natural fluctuations in groundwater hydrographs.

Comments on Verification

1. Traditional verification has not been done. This is not an issue as it is not a compulsory step in the modelling process (Barnett *et al*., 2012).

Comments on Prediction

1. Proper procedures have been followed for transient tracking and representation of the mine plan. A time-slice approach has been followed.
2. The prediction model outputs have been interrogated thoroughly in accordance with the minimal impact considerations of the Aquifer Interference Policy.
3. Pit inflow estimates are considered overestimates, so that the predicted environmental impacts would be conservative.
4. The prediction outputs have been used to partition water takes between different water sources for licensing purposes.
5. It is likely that the impact on Saddlers Creek flows will be substantial, and that cumulative impacts from adjacent mines will exacerbate (or have exacerbated) this effect.
6. A very long recovery simulation (1000 years) has been conducted. This shows that the drawdown limit extents continue to propagate outwards for a very long time (400 years) and the final voids will remain as groundwater sinks and would not cause deleterious changes to groundwater or nearby river water quality.
7. The cumulative groundwater level and flux impacts of neighbouring mines have been assessed by discussion of the findings of previous (approved) modelling studies rather than independent simulation. This is a sufficient and sensible approach to the difficult and demanding requirements for cumulative impact assessment.
8. Although there is Biophysical Strategic Agricultural Land (BSAL) nearby, the mine lease and the Aquifer Interference activity do not impinge on it.
9. In Section 9.6.2, it would be helpful to give the definitions for Highly Productive and Less Productive groundwater sources. The foregoing assessment of groundwater salinity is sufficient to place Saddlers Creek Alluvium in the Less Productive category.
10. Three scenarios are examined for rejects and tailings disposal.

Comments on Sensitivity Analysis

1. Sensitivity analysis has been conducted for horizontal (Kh) and vertical (Kv) hydraulic conductivity, rainfall recharge fraction, and the two storage properties (Sy, Ss).
2. The perturbation of 50% for Kv is low, but it is understood that the latitude is limited for this parameter as it is tied to Kh as a ratio in the custom code used by AGE.
3. As the calibration performance varies from 7.9 to 10.3 %RMS for the sensitivity scenarios, none of them improves on the base case (7.0 %RMS).
4. Sensitivity is tested on pit inflow, rock-alluvium flux and drawdown extent.
5. Insight into the impact of the earlier criticism on the Sy value being too low in spoil (0.01) and host rock (0.0005) can be gained by viewing the +50% Sy simulation (e.g. Figure 50). This indicates that a higher Sy will cause less slower and less severe impacts after post-closure, and slower recovery to final equilibrium conditions.
6. There are two errors in Table 27 (Sensitivity Analysis Summary): (1) Baseline Steady State RCH should be 6.4 (not 3.6); (2) the Net RIV outflow row should not be identical to the Steady State RCH row.

Comments on Uncertainty Analysis

1. The uncertainty in the model findings is illustrated sufficiently through the outputs of the sensitivity simulations.
2. It is agreed that a conservative approach has been adopted in the case of uncertain assumptions.

Additional Comments

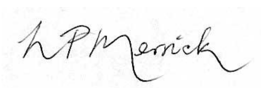
Table 30 lists the volumes of water that require licensing from different water sources. It is considered that the value in the bottom-right cell should be zero, as current licences are sufficient for the Hunter Regulated River Water Source.

In Section 12.6, it would be better to nominate likely locations for new monitoring bores for the tailings and rejects emplacements rather than cite general "strategic locations".

There are still some editorial corrections to be made in terms of spelling, use of singular/plural, and wrong legend entries in a few figures (e.g. Figure 49).

Overall, the groundwater assessment has been conducted to a very high level of competence and there has been a very thorough examination of the pertinent outputs and uncertainties of the modelling simulations. The stated project objectives have been addressed in full.

Yours sincerely,



Dr Noel Merrick

Table 1. MODEL APPRAISAL: **DRAYTON SOUTH**

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
1.0	THE REPORT								Good Executive Summary and very good AI Policy summary.
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Impact Assessment Model, medium complexity. Class 2 confidence.
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Steady-state calibration (but no ET). Not shown for transient verification. Prediction : inflow and river-aquifer components (no ET).
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			
1.5	Are the model results of any practical use?			No	Maybe	Yes			
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Substantial history plus new work. Geology well known except at model corners.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Interpolated contours are shown in Drawing 13. Source data points should be posted.
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Lack of stream gauge information. Estimated stages from DEM. No consideration of flooding as potential recharge source (conservative approach).
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			Gw abstraction is not included but should be minor. Could refer to BoM "actual ET". Main streams are included.

2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			Hydrographs compared with residual mass across several plot scales. No obvious pumping effects (not stated). Comments on vertical head gradients and flow directions.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			Used for verification rather than calibration.
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				
3.0	CONCEPTUALISATION								ET is in the conceptual model and is said to be in the numerical model but it does not appear in any water balance.
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes			
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good			Detailed flux pairs identified.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Figure 35.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Limited southern extent to far side of Hunter River alluvium. Limited western extent to fault line. Full model grid should be shown with geology underlay to define BCs.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Appear to be no-flow cells on boundaries. No GHB control.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			Modflow SURFACT & PMWIN & custom code. Not clear what variable saturation option has been used – seems to be pseudo-soil.

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
5.0	CALIBRATION								
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			Scattergram for 95 target water levels (median = steady-state). Table of observed, simulated and residual water levels.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			No spatial residual map to see where calibration is good or bad.
5.3	Is the model sufficiently calibrated against temporal observations?	N/A	Missing	Deficient	Adequate	Very Good			Done by verification using steady-state K. No time-varying RCH.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Some uniform, some distributed (PEST analysis). Min, max & median given. Spatial distributions are disclosed. Ss & Sy are not well resolved due to lack of natural variation. %Rain OK.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			7.0 %RMS , 12 mRMS. Some large residuals (>20 m). 7.8 %RMS transient.
5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good			Steady-state only – on median historical water levels. No rain or stream dynamics included in transient verification.
6.0	VERIFICATION								
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			Insufficient data . This is not a compulsory step (Barnett et al., 2012).
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes			
6.3	Are there good reasons for an unsatisfactory verification?	N/A	Missing	Deficient	Adequate	Very Good			
7.0	PREDICTION								
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			Average conditions. No climate change scenario but rain recharge sensitivity analysis could serve the same purpose.

7.2	Have multiple scenarios been run for operational /management alternatives?	N/A	Missing	Deficient	Adequate	Very Good			One mine plan. Final void. Recovery for 1000 years. No integrated modelling of cumulative impacts but results borrowed from two previous models. Three tailings/rejects scenarios.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			27 years projected from steady-state calibration and 14 years transient verification (June 1998 - June 2011).
7.4	Are the model predictions plausible?			No	Maybe	Yes			Consistent with earlier modelling and experience with neighbouring mines. Peak pit inflow seems somewhat high. Sy=0.01 is low for spoil - h(t) would be flatter with higher Sy.
8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			Done for Kh, Kv, recharge%, Sy, Ss. Kv has low range but locked to Kh/Kv ratio.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			Baseline 7.0 %RMS. Perturbations 7.9-10.3 %RMS.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			For pit inflow, drawdown extent and rock-alluvium fluxes.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			Conservative approach.
	TOTAL SCORE								PERFORMANCE: %