Abel Mine SMP Area 1 Application-Written Report

APPENDIX C1

Review of the Abel Coal Groundwater Modelling Study

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Abel Underground Mine Part 3A Environmental Assessment

REPORT ON BEHALF OF

HERITAGE COMPUTING

REVIEW OF THE ABEL COAL GROUNDWATER MODELLING STUDY

FOR

PETER DUNDON & ASSOCIATES

ON BEHALF OF

DONALDSON COAL PTY LTD

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By

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EXECUTIVE SUMMARY

A groundwater model of the proposed Abel underground coal mine in the Hunter Valley of New South Wales has been developed by Aquaterra Simulations for Donaldson Coal Pty Ltd. The purpose of the modelling is to assess potential impacts on local aquifers and surface water bodies, and to make a preliminary assessment of mine dewatering requirements.

This report provides a peer review of the model according to Australian modelling guidelines. The review is based on a checklist of 36 questions across 9 model categories.

The review finds that the model has been developed competently, and is suitable as a first estimate of mine inflows and regional impact. However, the modelling results are sensitive to some features that are known poorly.

The study area has sufficient water level data for the Donaldson coal seams for a first-cut steady-state modelling exercise, but in other layers there is not much information. This will affect the reliability of mine inflow estimates. There is no time-varying water level record that would enable transient model calibration.

The spatial agreement in groundwater levels between those simulated and those inferred from observations is quite good.

The major uncertainties in the model parameterisation are in the values allocated to vertical permeability in the interburden, and mine drain conductance. Each has been explored by sensitivity analysis. The best estimate for mine inflows at the end of mining is 3 ML/day, with a likely upper limit of 5 ML/day.

The impact of mining on Hexham Swamp appears to be a drawdown of 10-15 cm at the western end of the swamp. However, this impact should be examined further for sensitivity to the assumed value for vertical permeability beneath the swamp.

Until there is enough time-series data, the current model parameterisation must be regarded as preliminary. Transient calibration (yet to be done) will provide more reliable aquifer properties because there is more information content in fluctuating water levels that are responding to stresses on the aquifer system.

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1.0 INTRODUCTION

This report provides a peer review of a groundwater model of proposed coal mining in the Abel Underground Project near Maitland in the Hunter Valley of New South Wales (NSW). The model has been developed by Aquaterra Simulations for Peter Dundon & Associates, who are undertaking the environmental impact hydrogeological investigations on behalf of Donaldson Coal Pty Ltd.

The Abel coal project is an underground extension of the existing Donaldson open cut mine. The modelling has been done as a component of the Part 3A Environmental Assessment for the project. The purpose of the modelling is to assess potential impacts on local aquifers and surface water bodies, and to make a preliminary assessment of mine dewatering requirements.

2.0 SCOPE OF WORK

The key tasks for this peer review are:

- Read and comment on progress and draft reports produced by Aquaterra Simulations;
- Review the model as documented against the guidelines developed for the Murray Darling Basin Commission;
- Provide the review in the form of a written report.

3.0 MODELLING GUIDELINES

The review has been structured according to the checklists in the Australian Flow Modelling Guideline (MDBC, 2001). This guide, sponsored by the Murray-Darling Basin Commission, has become a *de facto* Australian standard.

The modelling has been assessed according to the 2-page Model Appraisal checklist in MDBC (2001). This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Not all questions are pertinent to a site-specific model.

The effort put into a modelling study is very dependent on timing and budgetary constraints that are generally not known to a reviewer. Hence, reduced performance in one aspect of the modelling effort could be the result of a conscious decision by the modelling team to get the model finished on budget and/or on time, or to apply extra focus on specific issues arising during modelling.

4.0 EVIDENTIARY BASIS

The primary documentation on which this review is based is:

1. *Wallis, I. and Middlemis, HP., 2006, Groundwater Modelling of Impacts of Abel Underground Mining Operation. Aquaterra Simulations Report 022a [13 June 2006]*

In addition, the following document was provided during the course of the review:

2. *Wallis, I., 2006, Draft Report on Conceptual Hydrogeological Model and Numerical Modelling Approach for the Abel Mining Area. Aquaterra Simulations Memo Report 007a Job A28b [5 May 2006]*

No other documents were inspected by the reviewer. However, points of clarification were conveyed during one telephone discussion:

3. *June 23, 2006: Telephone (H.Middlemis, I.Wallis and N.Merrick).*

The objectives of the modelling study are stated in Document #1 as:

- "predict the potential impacts of the underground mining on groundwater levels in the area and on surface water resources including the Hexham Swamp; and
- assess the potential inflow into the mine workings during operation."

5.0 PEER REVIEW

In terms of the modelling guidelines, the Abel coal model is best categorised as an Impact Assessment Model of medium complexity.

The review was conducted progressively with checkpoints at the conceptualisation and model design stage (Document #2), and after calibration, sensitivity analysis, prediction and final reporting (Document #1). Comments were conveyed to the modelling team after reviewing Document #2.

The appraisal is presented in Tables 1 and 2.

Table 1. MODEL APPRAISAL: Abel Coal

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								
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
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Table for steady state calibration. Graph for transient prediction – table would be better.
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			There is considerable uncertainty given a lack of transient data and aquifer tests.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Provided by Peter Dundon.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Representative steady state contours are well defined near the Donaldson open cut, but are stylistic over the underground mine area. Very sparse for interburden and alluvium.
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Rainfall and stream stage are appropriate.
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			The important processes are evapotranspiration at Hexham Swamp and drainage to the Donaldson open cut. The latter is not quantified in the report.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?	N/A	Missing	Deficient	Adequate	Very Good			No hydrographs are available for analysing cause and effect.

2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			No hydrographs are available. Steady state calibration only.
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				
3.0	CONCEPTUALISATION								
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			
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			The nearest representation is Figure 3. This shows stratigraphy, but does not show recharge/discharge arrows or water bodies.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				Upper & Lower Donaldson seams are lumped – OK. Interburden is split into two to handle goaf effects – good idea.
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Out to limit of Donaldson seams. Arbitrary southern & eastern limits – to extent of data.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Creeks are handled appropriately as drains. Wallis Creek and Hexham Swamp as "river" features. Open cut as a "drain". Mined cells as "drains". Flow allowed through eastern and southern edges. Final head contours suggest that the eastern & southern boundaries are too close.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			Modflow (which version?). GUI is either PMWIN or Vistas. Both are mentioned.

Table 2. MODEL APPRAISAL – Abel Coal

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			Multiple lines of evidence: scattergram; 6 statistics, visual comparison of contours.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Calibration based on 16 measurements. The raw data do not give full coverage of the area, particularly for layers other than coal. Hence, very little to calibrate on. Open cut inflow is an important calibration target, but this has not been quantified or discussed in the report
5.3	Is the model sufficiently calibrated against temporal observations?	N/A	Missing	Deficient	Adequate	Very Good			Steady-state only.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Lower rain recharge (0.2-0.3%) than expected. Lower coal Kh than expected (0.1 m/d). Sensible Kv. Storage values cannot be calibrated.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Quite good - 6% scaled RMS.
5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good			
6.0	VERIFICATION								
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			Insufficient data.
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?	N/A	Missing	Deficient	Adequate	Very Good			Long term simulation requires average rain.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good			For one mine plan.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			This is a weakness, as no transient data are available. Hence, storage parameters are uncalibrated and K values are preliminary.
7.4	Are the model predictions plausible?			No	Maybe	Yes			There will be an overestimation of inflows due to instant activation of each panel. There will be an underestimation of inflows due to reporting at annual intervals rather then sub-yearly.
8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			Reported graphically for prediction. Done for higher Kh and Kv. Done for 5 values of mine drain conductance. Not done for %rain or storage parameters.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			Sensitivity not done for model calibration.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			Inflow range established for uncertain mine drain conductance.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			Uncertainty is explored in part by sensitivity analysis, and is discussed under model limitations.
	TOTAL SCORE								PERFORMANCE:

6.0 DISCUSSION

6.1 THE REPORT

The Draft Final Report (Document #1) is a good quality document of 40 pages text, including 12 figures, and 13 pages of appendices. To an external reader with no prior knowledge of the study area, the report serves well as a standalone document without need of supporting documents.

The report has sufficient description of the modelling process and modelling results, but it addresses the project objectives to different degrees. Potential inflows into the mine workings are addressed with sufficient detail, but more could be said of the potential impacts to surface water bodies. The sensitivity analysis should be used to give the likely range in drawdown at Hexham Swamp (10-15 cm), and the likely range in fluxes.

The report is missing an Executive Summary and a Conclusion section, which should focus on the modelling findings in terms of the project objectives.

A water balance for the steady-state model is given in Table 8, but there is no discussion on the water balance components in the text of the report. In particular, there should be a statement on whether the simulated flow to the open cut is supported by field magnitudes. A tabulation of water balance components for the transient dewatering simulation would be instructive. The provided Figure 21 does not tell the whole story as minor components are not discernible.

In the early stages of the report, future tense is often used when present or past tense is appropriate.

Minor typographical corrections and suggested additions are listed in the Appendix.

6.2 DATA ANALYSIS

The study is disadvantaged by a lack of aquifer test data, which leads to uncertainty in chosen hydraulic conductivity and rainfall infiltration factors, which usually are resolvable only as a ratio without supporting information (e.g. flux measurements or estimates).

There is a reasonable spread of representative groundwater level data for the Donaldson seams, but other layers are lacking severely in data. There are a few instances of measured vertical head gradients at the one location. The latter are critical for estimation of vertical hydraulic conductivity and mine drain conductance, which controls mine inflow estimates.

The contours of observed head for the coal seams over the proposed mine area are stylistic, but reasonable as an indicator of trends. There is field evidence for an extension of the 30 mAHD contour to the north.

6.3 CONCEPTUALISATION

The modelling team's conceptualisation is discussed in detail, but would benefit from a simplified graphical illustration of the conceptual model. Figure 3 gives a stratigraphic section, but does not show interactions with surface water bodies.

A conceptual model diagram is a simplified 2D or 3D summary picture (without stratigraphic detail) that conveys the essential features of the hydrological system, denoting all recharge/discharge processes that are likely to be significant. The diagram can serve a dual purpose for displaying the magnitudes of the water budget components derived from data sources or from simulation.

The two Donaldson seams are lumped as one layer, with an intervening thickness of interburden. This is a reasonable approach, given the lack of any evidence that they are not hydraulically equivalent. The effective hydraulic conductivity of the lumped unit will be lower than the value for coal itself. This lends some support to the lower than expected value used for the "coal" layer in the model (0.1 m/d).

The interburden layers are split into two layers to allow testing of different aquifer properties in the goaf zone immediately above a mined area. This is a sensible precaution.

6.4 MODEL DESIGN

The model has been built with PMWIN software and Modflow. Versions are not stated. There is also mention of Groundwater Vistas, but it is not clear if this was used in practice.

Discretisation in space is appropriate. Model cells are 100 m square, but the numbers of rows and columns are not stated. Most of the model edge is placed at the Lower Donaldson seam outcrop, which is a natural boundary. The southern and eastern edges are arbitrary, but are dictated by the extent of available data. Modelling results subsequently show that the edges are a little close, as drawdown impacts extend out to the edges. This compromise is unlikely to have a material effect on the magnitude of the predicted mine inflows, or on the drawdown predicted at Hexham Swamp. The applied external boundary conditions are sensible and uncertainty in them is unlikely to affect the modelling results.

Creeks and the swamp are handled with appropriate Modflow features ("drain" and "river" cells). Open cut and mined panels are represented appropriately as permanent drain cells.

Given the absence of time-varying water levels or fluxes, calibration has been limited to steady-state. However, for prediction purposes, transient simulation has been done. For transient simulation, storage properties are best estimates without calibration support.

6.5 CALIBRATION

The spatial agreement in groundwater levels between those simulated and those inferred from observations is illustrated by visual inspection of Figures 11 and 14. The agreement is quite good. In fact, the model has the 30 mAHD contour extending to the outcrop boundary, which is more in keeping with spot water level observations that the stylistic contours in Figure 11.

Figure 15 shows the simulated water level contours for the interburden above the Donaldson seams. There are no comparative observed contours, but there are two spot points which agree very well. This suggests that, at least in the areas with vertical gradient data (along easting 370000), the vertical hydraulic gradient should be well resolved.

Some very high observed water levels (about 65 mAHD) are reported in the northeast (easting 367000) in the upper part of Layer 4 where it outcrops. The model is not able to replicate these. As the head difference with the coal seams is about 40 m, the water table in that area is likely to be perched and would be very difficult to replicate in a model. Such a large head difference would suggest immunity of the shallow aquifer from impacts due to mining.

Layer 3 hosts the alluvium and surface water bodies. These zones communicate with the other aquifers vertically but not horizontally, as adjacent material is deactivated. The impact of mining at Hexham Swamp, therefore, is controlled by the model estimate for vertical hydraulic conductivity beneath the swamp. There is no easy way to assess this, other than assume a value similar to the calibrated interburden value. There is one head measurement at the western end of the swamp that is a little above sea level. The report does not indicate whether this is replicated well, or if the simulated elevation is sensitive to the underlying vertical hydraulic conductivity.

Steady-state calibration is based on 16 target measurements. Of the 23 measurements in Tables 5 and 6, it is not clear which 7 sites have been discarded. This action should be justified.

The Donaldson Mine open cut inflow is essentially another calibration target. A field estimate of this should be reported along with the simulated magnitude.

6.6 PREDICTION

Predictions are based on transient simulation for 21 years of mining followed by 60 years of recovery as a separate simulation, using enhanced properties in the goaf layer.

The stress period is generally two years, and mining panels are assumed to be excavated instantly at the start of each period. This will cause an overestimation of inflows, as the model cells are "mined" in advance of what will occur in reality. The seepage rate curve in Figure 20 would be more accurate if it were translated one year to the right.

On the other hand, inflows are reported (graphically) only at the end of each year when they tend to stabilise. More detailed reporting of modelling results, near the start of each stress period, would show much higher inflows initially, with exponential decay to the sampled values at the end of each stress period. It is probable that the decay curve will be oscillatory due to numerical shock caused by a very sudden drop in water levels at the mine face. Therefore, the values reported annually are underestimates of the rates that occur earlier.

The two preceding issues are compensating, but it is not known if they are balancing. The cumulative water budget for the mine drains at the end of 21 years should be compared with the water volumes calculated from annual rates. This will give an indication of the size of the error.

Water balance graphs (Figures 21, 22) show separate reporting of replenishment and release from aquifer storage, as determined by Modflow. Only net change in storage is meaningful physically, as the values include artificial additions and subtractions of "water" from model cells due to numerical fluctuations as Modflow seeks a solution.

6.7 SENSITIVITY ANALYSIS

Sensitivity analysis is illustrated for the transient prediction model in terms of mine inflow rates and drawdowns for varying mine drain conductance. Another sensitivity run was done for much higher horizontal and vertical hydraulic conductivity. The results are reported graphically in Figure 24 for inflows and Figure 25 for drawdowns.

Conductance variations by a factor in 5 in either direction suggest an end-of-mining range in inflow from 1.5 ML/day to 4.5 ML/day.

It is possible that the conductance could be higher than the explored limits. However, Figure 1 (in this report) shows a "saturation effect" whereby increase in conductance by an order of magnitude or more will cause minimal increases in inflows. As an increase in permeabilities by two orders of magnitude causes about 10% increase in inflows, an upper limit of 5 ML/day seems likely at the end of mining.

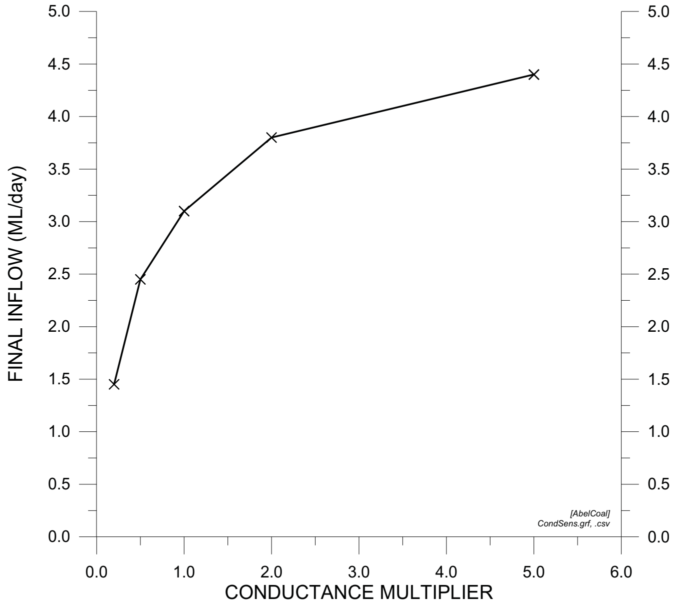

Figure 1. Sensitivity of final mine inflows to varying mine drain conductance.

Sensitivity analysis has not been reported for the steady-state calibration. This process can identify alternative combinations of aquifer property values that could match the observations just as well.

6.8 UNCERTAINTY ANALYSIS

No formal uncertainty analysis has been undertaken, but this is not unusual. This activity should not be expected unless it is called for in the project brief and is funded accordingly.

Uncertainty in predicted fluxes has been handled by sensitivity analysis.

Model limitations are discussed at length in a special section of the report. The main issues are:

- Absence of groundwater hydrographs for better calibration;
- Absence of data beyond the mining area, thus limiting the extension of the model domain;
- Absence of water levels in layers other than the coal seams;

- No calibration of aquifer storage properties.

7.0 CONCLUSION

The Abel Coal groundwater model has been developed competently, and is as good a model as could be expected with the current state of knowledge.

The report would benefit from the following actions:

- Addition of a Conclusion that summarises the modelling findings in terms of the project objectives;
- More discussion on the model's predictions of impacts at Hexham Swamp, and their sensitivity to underlying vertical hydraulic conductivity;
- Inclusion of a schematic conceptual model graphic;
- A statement on the order of magnitude of current inflows to the Donaldson open cut, and comparison with the model prediction;
- Comparison of the cumulative water volume at the mine drains at the end of mining, with the volume anticipated from annually sampled rates. This will indicate if the high simulated inflows at the start of each stress period can be excluded.

The model must be considered preliminary, and improved estimates of inflows will have to await the acquisition of a water level monitoring record, and analysis of cause and effect between stresses (rainfall recharge, dewatering) and responses (water level fluctuations, drawdown, inflow) established through transient calibration of the model.

The report states that the "predicted seepage rates and drawdowns should be regarded as rough, order-of-magnitude estimates". I concur with this.

8.0 REFERENCES

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

APPENDIX – Corrections and Suggestions

Table of Contents: Inconsistent case.
Figure 3: BOUDARY → BOUNDARY
Page 11: water course → water courses
Page 12, last paragraph: state that the assumed interburden permeability is 0.0001 m/d associated with seepage of 0.0024 m^3/day. This appears too late on the next page.
Page 13: on the to → on the.
Page 14 etc.: will be → has been; will → has; (similar tense errors).
Page 14: N3 Freeway → F3 Freeway
Page 15, paragraph 2: state number of rows, number of columns, at least as a footnote.
Page 17, paragraph 3: remove second "directly".
Page 17, 4.2, paragraph 1: summarises → summarise.
Page 18, Table 5: error in DPZ7 (water level lower than base of piezo).
Figures 11 & 12: swap the order.
Page 22, Table 8: clarify that "River flows" pertain to Wallis Creek and Hexham Swamp.
Page 24, Table 10: mention the number of time steps as a footnote (to placate reviewers who have to check numerical accuracy).
Page 26, paragraph 1: describe the rough locations for "selected hydrographs".
Page 26, paragraph 2, line 3: drawdown of 60 metres is not correct; the head is –60 mAHD.
Figure 18: a drawdown map for Layer 3 would be useful to see the impact on Hexham Swamp; not necessarily for the report, but for the modeller's appreciation.
Figure 23: misspelling of Donaldson.
Figure 25: poor choice of interpolation between points, as curves go backwards in time.
Page 34: Godman → Goodman.
Page 38, dot point 6: 6 → Six.
References: add Goodman et al. (1965)