MIDDLEMOUNT COAL MINE

SOUTHERN EXTENSION PROJECT

Original EPBC Referral Submission 18/03/2021
(EPBC 2021/8920)

Attachment 2
Groundwater Model
Peer Review Letter

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DATE: 4 May 2018

TO: Shane Flint
Middlemount Coal Pty Limited
PO Box 24
Middlemount QLD 4756

FROM: Dr Noel Merrick

RE: Middlemount Coal Mine Western Extension Project – Groundwater Assessment Peer Review

YOUR REF: Letter 00851920

OUR REF: HA2018/4

Introduction

This report is provided in response to a written request on 6 June 2017 from Resource Strategies Pty Ltd (RSPL), on behalf of Middlemount Coal Pty Ltd (MCPL), for conducting a peer review of the groundwater assessment (GA) for the Middlemount Coal Mine Western Extension Project in the Bowen Basin QLD. The GA has been done by Australasian Groundwater and Environmental Consultants (AGE) under the project management of RSPL

The review has been conducted by Dr Noel Merrick in accordance with national groundwater modelling guidelines, with a focus on compliance with Queensland government requirements and the likely expectations of the Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development.

The GA has been reviewed progressively:

1. After conceptualisation, software selection and model design planning.
2. After model calibration, prediction, and issue of the draft GA report (v01.02).
3. After issue of the draft GA report (v01.04).
4. After issue of the finalised GA report (v01.05).

HydroAlgorithmics Report HA2017/3 documented the review after Stage 1, issued 22 October 2017. Responses by AGE were received 9 November 2017.

Documentation

The peer review has been based on this report:

1. *AGE, 2018, Middlemount Coal Mine Western Extension Project: Groundwater Assessment. Project No. G1840D report prepared for Middlemount Coal Pty Ltd. 99p + 6 Appendices (v01.05).27 April 2018.*

Appendix F provides specific detail on the groundwater modelling component of the GA:

2. *AGE, 2018, Appendix F: Numerical Model Report. 41p.*

Other reports were provided, but these were not subject to review:

3. *WRM, 2017, Middlemount Mine - Estimate of Groundwater Inflows. Letter report for Middlemount Coal Pty Ltd. 5 October 2017, 3p.*

4. *4T Consultants Pty Ltd, 2017, Middlemount Coal Mine Western Extension Project: Groundwater Bore Census. Report prepared for Middlemount Coal Pty Ltd. 162p*

The major sections in Document #1 are:

1. Introduction
2. Mining history
3. Queensland regulatory framework for groundwater
4. Environmental setting
5. Geology within the study area
6. Conceptual groundwater model
7. Environmental value of groundwater
8. Numerical modelling
9. Groundwater monitoring strategy / program
10. Conclusions
11. References

The appendices are:

A. IESC Guidelines
B. DNRM groundwater data base bores
C. Bore census
D. Monitoring bores
E. Tertiary and Permian water quality data
F. Numerical model report

The major and minor sections in Document #2 (Appendix F) are:

1. Introduction and objectives
    - Model confidence level classification
2. Model background
    - Previous modelling for Middlemount Coal Mine
    - Other nearby sites
    - Conceptual model
3. Model software
    - Code selection
4. Model design
    - Time discretisation - stress periods
    - Boundary conditions
    - Initial conditions
    - Hydraulic parameters
    - Timing - proposed mining run
    - Timing - post-mining
    - Mine drainage
    - Recharge
    - Water budget
5. Model calibration and verification
    - Calibration heads
6. Groundwater fate modelling
7. Uncertainty analysis
    - Methodology

Parameter generation
Results
8. References

Review Methodology

While there are no standard procedures for peer reviews of entire groundwater assessments, there are two accepted guides to the review of groundwater models: the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline[1], issued in 2001, and the newer guidelines issued by the National Water Commission (NWC) in June 2012 (Barnett *et al*., 2012[2]). Both guides also offer techniques for reviewing the non-modelling components of a groundwater assessment. As yet there are no firm guidelines on uncertainty analysis for groundwater models; however, a draft guide was issued by the IESC in February 2018[3].

The 2012 NWC guide builds on the 2001 MDBC guide, with substantial consistency in model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details. The new guide is almost silent on coal mine modelling and offers no direction on best practice methodology for such applications. There is, however, an expectation of more effort in uncertainty analysis, although the guide is not prescriptive as to which methodology should be adopted.

The groundwater assessment has been reviewed according to the 2-page Model Appraisal checklist[4] 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. Non-modelling components of the groundwater impact assessment are addressed by the first three sections of the checklist.

It should be recognised that the effort put into the modelling component of a groundwater assessment is very dependent on possible timing and budgetary constraints that are generally not known to a reviewer.

A detailed assessment has been made in terms of the peer review checklists in **Table 1** and **Table 2**. Supplementary comments are offered in the following sections.

Report Matters

The GA report is a good quality document of about 200 pages length, including a number of appendices that contain more detail on Commonwealth requirements, field investigations, water quality, bore details, and numerical modelling. It is well structured, generally well written and the graphics are of high quality. The report serves well as a standalone document, with no undue dependence on earlier work.

Previous review comments after conceptualisation and model design stages have been addressed satisfactorily, except for a few instances that are explored further in following sections. Although some editorial corrections are warranted, they are not the focus of this review. Review comments on several draft reports have been addressed satisfactorily.

Overall, there are no significant matters of concern in the report as to structure or depth

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

[2] 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.

[3] IESC (2018). *Explanatory Note, Uncertainty Analysis in Groundwater Modelling.* Commonwealth of Australia, Draft February 2018.

[4] The NWC guide includes a more detailed checklist with yes/no answers but without the graded assessments of the 2001 checklist, which this reviewer regards as less academic and more informative for readers.

of coverage. There is a clear focus on regulatory requirements.

The objectives are stated clearly at the outset (Section 1.1), and the text of the report and its Conclusion sufficiently address those objectives.

In Section 8.1, the report should provide a map of numerical model extent, or at least refer to Figure F 4.1 (in Appendix F), before any modelling results are presented.

Data Matters

The groundwater monitoring network is substantial, consisting of 10 Tertiary bores, nine Permian bores, and two destroyed bores (MW1, MW1P). There are no bores in alluvium. According to the bore hydrographs in Figures 6.3 and 6.4, measurements commenced in 2008 for Tertiary bores, and in 2012 for Permian bores. Some bores are always dry, hence of little use. The hydrographs are compared with weather trends indicated by the CRD curve. There is no convincing correlation of groundwater levels with rainfall, but many of the Permian bores show definite mining effects. The magnitude and polarity of vertical head differences between paired Tertiary and Permian sites have been examined.

A thorough examination has been undertaken to identify neighbouring bores within 10 km, by means of database interrogation and a field bore census. All groundwater users appear to be located 5-10 km to the north of the mining lease. There are no off-lease monitoring bores in this area to track groundwater responses as mining moves to the north-west. The proposed additional monitoring bores (in Figure 9.1) are suitably positioned for the future mining extent.

Separate groundwater level contour maps for Tertiary and Permian support general groundwater flow direction to the south-east, although there is a strong sink effect near existing mining.

Stream flow data, presented for a gauging station on upstream Roper Creek, indicate very infrequent flows. Losing conditions would be expected during times of flow. Given long periods of zero flow, the creek is not likely to ever have a gaining status.

There is a clear description, and good justification, for hydrogeological conceptualisation, as summarised in the conceptual model of Figure 6.8, during mining. The reviewer endorses this conceptualisation. No significant stresses have been omitted in the transition from the conceptual model to the numerical model. It is noted that evapotranspiration is in the conceptualisation, but not in the numerical implementation, due to substantial depths to the water table that would negate this process.

Model Matters

The model extent is shown clearly in Figure F 4.1 of Appendix F, but does not appear in the main report. Compared to the earlier (Stage 2 EIS) model, it extends farther to the north (13 km from the ML), not as far to the south (6 km), and has more logical arcuate eastern (8 km) and western (9 km) boundaries controlled by geology. The presence of neighbouring mines has been the main determinant of the boundary locations.

The model extent is approximately 30 km x 21 km. The broad extent of the model should minimise potential boundary effects. The Project-only drawdowns (Figures 8.2-8.5) show no edge effects.

Modelling methodology

The modelling methodology, which was reviewed initially in October 2017, is endorsed by the reviewer.

The model has been built with 17 layers. Due to dislocation of layer continuity by the Jellinbah Fault, about 67% of model cells have been pinched out.

The use of MODFLOW-USG (Beta) coupled with AlgoMesh software has allowed extra stratigraphic detail and better spatial resolution of surface features without compromising memory requirements or simulation runtime. The minimum cell size is 100 m. The total number of model cells is only about 109,000 which is remarkably concise for a model with so many layers. This illustrates the advantage of modelling with MODFLOW-USG.

The Bowen Gas Project has been included for cumulative effects.

Model calibration

Model calibration is satisfactory for transient conditions. The calibration performance (for groundwater levels) is about 8.6 %RMS in relative terms and about 7 mRMS in absolute terms, both of which are acceptable for coal mining models. Semi-quantitative calibration would have been possible to current pit inflows inferred by WRM (2017). This has not been mentioned, but the results are in good agreement for low-rainfall conditions (1-2 ML/day).

It is not possible for a reviewer to readily discern whether vertical head gradients are reproduced well as the hydrographs in Appendix F1 are displayed one by one, rather than as stacked curves for paired sites. The hydrograph matches are reasonably good overall.

No spatial map of average residuals is provided to allow an appreciation of where calibration is good and where it is poor.

Calibrated formation properties appear consistent with previous studies and site tests, with appropriate use of a depth decay function for coal permeabilities. The adopted Kh/Kv anisotropies appear mild and could be much greater in reality; this should reduce the predicted effects.

Model prediction

Three scenarios are defined for predictive analysis, although only two are mentioned. Their definitions could be clearer. Essentially, they comprise a Null run, a Cumulative run (for all mines and CSG), and a Project-only run (obtained by deactivating the Project, and differencing from the Cumulative run).

Another scenario consisted of particle tracking post-mining. The reviewer considers this an unnecessary undertaking as the groundwater level contours are sufficient to determine that the final voids are permanent sinks and therefore must capture all "particles".

The drawdown extents (modified by faults and coal seam truncation) and drawdown magnitudes are plausible.

A rigorous "*monte carlo*" style uncertainty analysis has been undertaken, incorporating uncertainty in transmissive, storage and recharge properties, based on about 300 effectively calibrated realisations. Uncertainty has been reported for mine inflow, drawdown extents per formation, and hydrographic responses at every bore (for percentiles 5, 20, 80 and 95). This work is commendable.

Conclusion

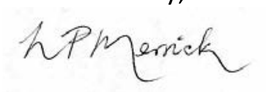
This reviewer finds that the model underpinning the groundwater assessment is "fit for purpose", where the primary purpose of the model is the prediction of potential environmental impacts as inferred from groundwater drawdown during mining.

The objectives have been addressed satisfactorily.

The proposed mitigation and monitoring measures are satisfactory. As all active landholder bores lie to the north, recommended monitoring between them and the mine extension is appropriate.

A very thorough and commendable analysis of the uncertainty in the estimates has been conducted.

Yours sincerely,



Dr Noel Merrick

Table 1. MODEL APPRAISAL: Middlemount Model Preparation

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			Section F1. Appendix F.
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Section F1.1, Table F 1.1. Reference to 2012 national guidelines. Class 2 confidence classification, partly Class 3. Evidence is substantiated by ticking guideline attribute list. Equivalent to Impact Assessment Model, medium complexity (2001 guide).
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Section F4.9: calibration & prediction periods. Mine inflow. No reported takes from alluvium and Roper Creek.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			Stated objectives are predicted mine inflows and drawdown impacts. DEHP guide requirements are addressed (except alluvial / stream takes)
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			Sections 5 & 6. Dipping geology truncated by major (Jellinbah) Fault. Detailed stratigraphy. Some historical measurements of physical properties - over-emphasis on textbook values. Good coverage of water quality in all formations.

2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Maps of flow directions should show locations of sample points – Figures 6.9, 6.10. There is sufficient data to infer flow towards the mine site from east and west, then regional flow to south-east, both in Tertiary and coal seams. Sections 6.5.3, 6.6.3 state alluvial and Tertiary groundwater flow to south-east. No steady-state head contours in modelling appendix F (other than particle tracking partial figure).
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Primarily diffuse rainfall recharge. Expected losses through streambeds. Potential flood recharge not mentioned.
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			Mine site drainages are ephemeral. Assessment of potential GDEs and stygofauna. Private groundwater usage estimated from bore census.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			Cumulative Rainfall Departure (residual mass) is compared with representative groundwater hydrographs to demonstrate active stresses - climate or mining effects. There is discussion on vertical head gradients. MW1 is said to be mining affected but the hydrograph shows rising heads before cessation - an explanation is offered.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			Sufficient monitoring network, and of long duration. Table 6.2 has 10 Tertiary sites and 9 Permian sites, with two destroyed (MW1, MW1P). Data from June 2008 (at most).

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			Section 6.12.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Figure 6-6 E-W cross-sections during mining.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				Major processes are included, including fault truncation. Evapotranspiration not significant due the water depth (~10m). Stratigraphy is sufficiently represented by layer aggregation.
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Dimensions 30 km x 21 km. Unstructured grid of Voronoi cells. Minimum cell size 100m. 17 layers, about 20,000 cells per layer. Total cell count 108,552; 67% pinchouts.

4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Distances of mine lease to boundaries: North ~13 km; South 6 km; East ~8 km; West ~9 km. Reasonable no-flow boundaries (north & east). Drain cells on three edges represent neighbouring mines. DRN elevation of 30m above seam has been used for CSG. RIV is suitable for streams. RCH algorithm is %rainfall - suitable. No WEL extraction assumed by private bores - suitable. Initial heads pattern not shown.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			MODFLOW-USG Beta + AlgoMesh and custom Fortran/Python software.

Table 2. MODEL APPRAISAL: Middlemount Model Implementation

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
5.0	CALIBRATION								2011-2017: 7 years. First mining 2011. Warm-up 1974-2010 (27 years).
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			Sufficient for performance against groundwater levels. No mention of historical mine inflow agreement (1-2 ML/day). No indication of spatial distribution of residuals. Scattergram and performance statistics are given. Entire set of observed vs. simulated hydrographs.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Scattergram suggests uniform performance over all elevations. No residuals spatial map.
5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Hydrographs for all bores are presented for comparison in App.F1. Full range from poor to very good matches. Mine inflows of correct magnitude. Multi-level bores not shown together to see if vertical gradients are reproduced.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Table F4.1. Consistent with previous studies and site tests. Depth decay functions used for coal seam K. Kh/Kv anisotropy is mild and could be much greater.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			8.6%RMS, 7mRMS at 26 calibration sites.

5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good			
6.0	VERIFICATION								*Not a necessary step.*
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			All data used for calibration.
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								2018-2038: 21 years. Equilibrium post-mining by steady-state, not long-term transient recovery.
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			A single average climate is assumed to have been used in accordance with standard practice.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good			One proposed mine plan. Three scenarios: Null, Cumulative, Project only. *("Null" not stated?)*. Particle tracking for final voids.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			Transient calibration 7 years from 2011 to 2017. Prediction period is 21 years from 2018 to 2038. Hence 3x.
7.4	Are the model predictions plausible?			No	Maybe	Yes			Plausible mining drawdown magnitudes and drawdown extent.
8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?	N/A	Missing	Deficient	Adequate	Very Good			Traditional perturbation analysis not done. Supplanted by thorough *monte carlo* uncertainty analysis.

8.2	Are sensitivity results used to qualify the reliability of model calibration?	N/A	Missing	Deficient	Adequate	Very Good			
8.3	Are sensitivity results used to qualify the accuracy of model prediction?	N/A	Missing	Deficient	Adequate	Very Good			
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			Rigorous null-space *monte carlo* uncertainty analysis on K, S and RCH parameters. 304 effectively calibrated realisations, with 40% rejection rate (on 500 model runs) using 20% tolerance on objective function (sum-of-squares). Examination of effect on mine inflow, drawdown extents per formation, and hydrographic responses at every bore.