



Attachment 7

Groundwater Peer Review



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TO: **MACH Energy Australia Pty Ltd**
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FROM: Dr Noel Merrick

RE: **Mount Pleasant Operation Modification 8 – Groundwater Peer Review**

OUR REF: HA2025/19b

1. Introduction

This report provides a peer review of the Groundwater Impact Assessment (**GIA**) for Modification 8 (**MOD 8**) of Development Consent DA 92/97 for the Mount Pleasant Operation (**MPO**) in the Upper Hunter Valley, New South Wales (**NSW**). The GIA has been prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (**AGE**) for MACH Mount Pleasant Operations Pty Ltd.

Mining operations commenced at the MPO in Quarter 4, 2017. MOD 8 is for a smaller scale project than what was approved in 2022, which has necessitated only minor changes to the groundwater model that underpins the GIA. The numerical groundwater model has undergone development since 2016, originally by HydroSimulations, and subsequently by SLR Consulting Australia (**SLR**) and AGE. It has been peer reviewed in the past by specialists Frans Kalf, Brian Barnett and Hugh Middlemis.

The main elements of MOD 8 for the MPO that are relevant to groundwater assessment are:

- a six year extension of permitted (run-of-mine [**ROM**] coal) mining operations to 31 December 2032; and
- an increase in the approved ROM coal extraction rate from 10.5 Mtpa to 12.5 Mtpa.

2. Documentation

This review is based on the following report:

1. AGE, 2025. Mount Pleasant Operation Modification 8 Groundwater Impact Assessment. Report 20250079.MPO5009.001 prepared for Mount Pleasant Operations Pty Ltd, Version 5.01, 4 December 2025. 105p + 2 Appendices.

Appendix A to this report documents the groundwater modelling:

2. AGE, 2025. Numerical Modelling Report. Appendix A to Mount Pleasant Operation Modification 8 Groundwater Impact Assessment. Report 20250079.MPO5009.001 prepared for Mount Pleasant Operations Pty Ltd, Version 5.01, 4 December 2025. 45p + 3 Appendices.

Document #1 has the following major sections:

1. Introduction
2. Regulatory framework
3. Environmental setting
4. Geological setting
5. Hydrogeology
6. Numerical groundwater model
7. Groundwater model predictions
8. Groundwater impact assessment
9. Uncertainty analysis
10. Groundwater monitoring and management
11. Summary and conclusions
12. References
13. Glossary and acronyms

The Appendices for Document #1 are:

- A. Numerical modelling report (Document #2)
- B. Compliance with government policy

Document #2 has the following major sections:

1. Model objectives
2. Model details
3. Model calibration
4. Predictive and recovery simulations
5. Uncertainty analysis
6. Climate sensitivity analysis
7. Groundwater model validation
8. References

The Appendices for Document #2 are:

- A. Calibration details and hydrographs
- B. Spatial distribution of hydraulic parameters: Layers 1 to 3
- C. Verification hydrographs

3. Assessment Approach

This peer review is cognisant of the following guidelines issued by the NSW Government [DPE Water] in January 2022:

- A. Groundwater assessment toolbox for major projects in NSW – Overview document [Technical guideline]. 60p.
- B. Guidelines for Groundwater Documentation for SSD/SSI Projects [Technical guideline]. 237p.
- C. Minimum Groundwater Modelling Requirements for SSD/SSI Projects [Technical guideline]. 69p.
- D. Cumulative Groundwater Impact Assessment Approaches [Information Paper]. 69p.

These documents build upon the long-standing Aquifer Interference Policy (**AIP**) released in 2012, and nationally accepted guides to the review of groundwater models: the Murray-Darling Basin Commission (**MDBC**) Groundwater Flow Modelling Guideline¹, issued in 2001, and guidelines issued by the National Water Commission (**NWC**) in June 2012 (Barnett *et al.*, 2012²). Both guides also offer techniques for reviewing the non-modelling components of a groundwater impact assessment.

The NWC national guidelines were built upon the original MDBC guide, with substantial consistency in the model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details.

In the NWC groundwater modelling guideline, one of the checklist questions is:

- *Is a groundwater model the best option to address the project and model objectives?*

In this case, 3D groundwater modelling is an essential methodology for estimation of the likely future groundwater-related impacts of the development.

This peer review is structured according to the Compliance Checklist in Guideline C. It consists of the following questions:

1. Are the modelling objectives and model target confidence level class clearly stated?
2. Are the modelling objectives satisfied?
3. Is the conceptual model consistent with the modelling objectives and target confidence level class?
4. Is the conceptual model based on all available data, presented clearly, and reviewed by an appropriate reviewer?
5. Does the mathematical model design conform to best practice?
6. Is the model calibration satisfactorily addressed, including appropriate sensitivity analysis?
7. Are the calibrated parameter values and estimated fluxes plausible?
8. Do the model predictions conform to best practice?
9. Is the uncertainty associated with the predictions reported?
10. Is the model fit for purpose?

The peer review has been staged according to the following activities:

1. Review of Sections 1 to 5 of the draft GIA prepared by AGE and setup of a Log of Issues spreadsheet.
2. Provision of peer review comments on data analysis, model conceptualisation, key model assumptions, and editorial matters.
3. Checking how the review comments were considered and addressed by AGE.
4. Review of Sections 6 to 10 and Appendix A of the draft GIA prepared by AGE with additions to the Log of Issues spreadsheet.
5. Provision of peer review comments on model construction, calibration, prediction, etc., and editorial matters.
6. Review of the draft final GIA prepared by AGE and closure of the Log of Issues spreadsheet.
7. Review of Section 11 conclusions.
8. Preparation of a Peer Review letter for inclusion in MOD 8 documentation.

¹ MDBC (2001). *Groundwater flow modelling guideline*. Murray-Darling Basin Commission. Authors: Middlemis, H., Merrick, N. and Ross, J.

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.

The peer review has been done solely by Dr Noel Merrick who has had both groundwater assessment and/or peer review involvement in many approval applications for coal projects in the region; namely: MPO, Mt Arthur, Spur Hill Project, Mangoola, Drayton and Maxwell Mines.

4. Question 1: Are the modelling objectives and model target confidence level class clearly stated?

In addition to the objectives for complying with regulatory requirements for MOD 8 (listed in Section 2 of the GIA), the associated modelling objectives are stated clearly in Appendix A (Section A1):

- replicate the historical behaviour of the groundwater regime;
- predict the changes in groundwater levels and flows due to the proposed mining at the modified MPO;
- predict the cumulative changes to groundwater levels and flows due to the modified MPO and surrounding mining operations;
- predict potential impacts of the modified MPO to existing users including groundwater dependent ecosystems (**GDEs**); and
- predict take from various water sources for estimating licence requirements.

The confidence level class is Level 2, based on six stated key indicators in Section A2.1. This is the appropriate level for a mining model. The latest Uncertainty Analysis Explanatory Note (Peeters and Middlemis, 2023)³ recommends discontinuation of this scheme as it has been misapplied in the past. However, it is still included in Guideline C.

5. Question 2: Are the modelling objectives satisfied?

Each of the objectives (listed in Section 4 above) has been investigated systematically and assessed satisfactorily in my opinion.

6. Question 3: Is the conceptual model consistent with the modelling objectives and target confidence level class?

The hydrogeological conceptual model (**HCM**) is reported in Section 5.9 of the GIA in the form of description of key processes and one west-to-east cross section illustration (Figure 5.21) at the end of mining.

To be consistent with modelling objectives, the HCM has to include:

- recharge processes (e.g. rainfall) that result in changes in groundwater levels;
- discharge processes (e.g. evapotranspiration [**ET**]) that could result in local and regional drawdown at landholder bores, springs and ecosystems (e.g. GDEs);
- mechanisms that allow seepage to open cut pits and neighbouring longwall panels; and
- an approach that informs potential water quality impacts.

The Mount Ogilvie Fault is simulated as a barrier (using a no-flow boundary condition) because the throw is sufficient to fully offset the coal seams so they abut low-permeability interburden in the vicinity of the MPO. Farther south, in the Mt Arthur-Maxwell Mines area, the coal seams tend to flex along the fault line without rupturing.

³ Peeters LJM and Middlemis H (2023) *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia 2023.

The schematic (Figure 5.21) in the GIA gives an adequate picture of the key processes acting on the groundwater system. It gives a visual impression of the likely future post-mining interactions between the groundwater system and topography, prior to recovery, compared with a notional pre-mining groundwater table.

In my opinion, the HCM is sufficiently characterised to allow resolution of each modelling objective.

Confidence Level 2 is the appropriate target level for investigation, as a model in this class used to be called an 'Impact Assessment' model in the original MDBC (2001) guide.

7. Question 4: Is the conceptual model based on all available data, presented clearly, and reviewed by an appropriate reviewer?

The HCM is summarised in the GIA after a thorough analysis of the environmental setting (climate, topography, drainage, streamflow, land use), geological setting (local and regional geology), hydrogeology (groundwater level monitoring, water quality monitoring, groundwater flow patterns, borelogs, previous investigations including hydraulic property measurements), and identification of groundwater dependent assets (private users, GDEs, stygofauna).

Neighbouring stresses expected to have a cumulative effect on the groundwater system near the MPO include the Bengalla Mine (to the south) and Dartbrook Mine (to the north). More distant mines that might not contribute to cumulative effects near the MPO are Mangoola, Mt Arthur and Muswellbrook Mines.

Given a long history of coal mining in the Upper Hunter Valley, the stratigraphy of the area is well understood and there would be little uncertainty in the 3D geometry of the strata hosting the groundwater system. Geological maps, sections and photographs, together with conceptual diagrams, provide an adequate illustration of the regional geological strata and the natural and external recharge and discharge processes.

The groundwater monitoring network is well established, with most records covering a period of 20 years, and monitoring bores are distributed between alluvium, regolith and Permian formations. There is a total of 33 monitoring sites with five more planned for the MPO groundwater monitoring network.

Many bores have an identification (ID) name formed from the number of metres from the western boundary; for example bore 6000C000S (and /L) was originally positioned about 6,000 m from the western boundary. I understand this bore was destroyed by open cut pit progression and had to be replaced. As shown in **Figure 1**, the replacement bore is about 2.4 km to the south-west. However, the ID has not been changed. It is strongly recommended the naming for this replacement bore is updated as adopting the same name is likely to lead to confusion and errors in interpretation, in the future, if data from these separate bores are inadvertently combined.

A contour map of the likely water table in 2023, with all mines active, is presented in Figure 5.9.

The cause-and-effect analysis is done by comparing groundwater hydrographs in each of three domains with climatic trends represented by the CRD (cumulative rainfall departure) curve (Figure 3.1), and Hunter River stage for alluvial bores. These are reliable techniques for inferring sensitivity to rainfall recharge and groundwater-river interaction. Correlations, however, are hard to discern due to the wide ranges on the y-axis (Figures 5.5 to 5.8) and the number of plots on Figure 5.8. It is not clear which hydrographs show mining effects. The commencement dates of each relevant mine have been marked on each chart.

The conceptual model and numerical model have undergone several peer reviews in the past by recognised specialists: namely Dr Frans Kalf, Brian Barnett and Hugh Middlemis.



Figure 1. Location of replacement bore 6000C000S

8. Question 5: Does the mathematical model design conform to best practice?

The GIA relies on a numerical groundwater model that has undergone development since 2016, originally by HydroSimulations and subsequently by SLR and AGE. This model has been peer reviewed on several occasions (by Dr Frans Kalf, Brian Barnett and Hugh Middlemis). Due to its long period of evolution, it is a mature and robust model.

The model has been updated progressively for alignment with the latest software and best practice techniques. The model is currently in the form of an unstructured grid using AlgoMesh software and model execution uses the MODFLOW-USG code. The inputs and instructions to MODFLOW-USG are probably scripted rather than embedded in a graphical user interface, but this is not stated.

The modelled area is large, being approximately 19 km (east-west) by 30 km (north-south), with at least 9 km between the MPO and any model boundary. Laterally, there are approximately 33,000 Voronoi cells per layer with an expected total of about 658,000 cells (assuming the pinch-out feature of MODFLOW-USG has not been applied, which seems to be the case). Vertically, there are 20 model layers providing sufficient differentiation between major geological strata.

9. Question 6: Is the model calibration satisfactorily addressed, including appropriate sensitivity analysis?

For this GIA, a verification approach has been followed rather than a re-calibration of the model. This means that the parameters determined by calibration in 2020 are retained, and model-simulated groundwater levels are compared with recent measurements to check if the model still performs sufficiently well. This approach is normal practice as a first step when a model is upgraded. Time-consuming and expensive re-calibration should be done only if warranted when a model's performance is clearly deteriorating.

Using PEST software, the previous calibration (AGE, 2020) was performed on 5,604 groundwater level measurements at 114 monitoring sites up to September 2018. As the MPO commenced approximately 11 months earlier (Quarter 4, 2017), it is unlikely that the calibration dataset included any bores affected by early MPO mining, but the effects of other mines would be included. The calibration to mine inflow estimates was very good (Figures A3.10 to A3.13).

Depth-dependent functions were applied separately in coal and interburden layers to account for spatial variability. Better spatial resolution was obtained in the top three layers by means of pilot points.

Calibration performance is demonstrated by statistical measures and a scatter plot (Figure A3.3) showing performance separately for four mining areas and highlighting points added during the verification stage. There are more outliers during the verification stage, but overall the agreement between observed and modelled heads is very good. Another scatter plot is shown in Figure A7.1 for MPO alone.

The statistical measures show some deterioration in performance:

- 9.5 mRMS (verification) compared with 5.4 mRMS (calibration).
- 5.4% SRMS (verification) compared with 2.8% SRMS (calibration).

Inclusion of newly drilled bores into the validation dataset, and extension of time for existing bores, are the likely reasons for deterioration in performance. However, the statistics still indicate acceptable overall performance. Apart from the verification exercise, the uncertainty analysis accepts only those model realisations which remain sufficiently calibrated for the full extent of calibration and verification data.

Sensitivity analysis is reported only for climate change, based on three scenarios defined by recognised climate models. When a rigorous uncertainty analysis is done, there is really no need to perform traditional sensitivity analysis by perturbation.

10. Question 7: Are the calibrated parameter values and estimated fluxes plausible?

The calibrated hydraulic parameters are displayed effectively as cumulative distribution functions (**CDFs**) in Figure A3.8 (Kx) and Figure A3.9 (Kz). These figures show the spatial variability around the median which can be read from the plots at 50% on the x-axis. At the median, Kx and Kz values range across 6 and 8 orders of magnitude, respectively. Within an individual layer, the ranges of Kx and Kz values are generally across 8 orders of magnitude, as is to be expected.

Visual representations for Layer 1 to 3 (pilot point results) are included in Appendix A2. There are no apparent inconsistencies with measured or conceptualised values.

Uniformity is assumed for storage properties in each layer. A specific yield of 7% in alluvium and regolith is plausible, while the specific storage range of 2×10^{-7} to $1.3 \times 10^{-5} \text{ m}^{-1}$ is consistent with the normal range for this property.

Simulated fluxes have been demonstrated to match estimated mine inflows better than order of magnitude.

Recharge rates also have been determined by use of pilot points within three lithological zones (Figure A2.2). In addition to minimum and maximum rates, mean values are listed in Table A2.2; namely:

- Alluvium: 3.2% of annual rainfall.
- Triassic Sandstone 2.8% of annual rainfall.
- Permian 0.5% of annual rainfall.

These values are plausible and are consistent with other studies in the Upper Hunter Valley. A recharge rate of 2% has been adopted (not calibrated) for spoil; this lies within typical expected rates of 1-10%.

11. Question 8: Do the model predictions conform to best practice?

Model predictions are focused on the following metrics (quantities of interest):

1. Mine inflow to the pits at MPO up to December 2032.
2. Maximum drawdown per layer at any time during mining for:
 - a. cumulative approved mining; and
 - b. MOD 8 mining only.
3. Recovery of groundwater levels (out to 1,000 years) assuming two interconnected final voids without any backfilling other than normal in-pit waste emplacement.
4. Long-term residual drawdown.
5. Groundwater flowpaths from out-of-pit waste emplacements and consequent water quality effects.
6. Incidental water takes from alluvium and surface water and consequent water licensing requirements.
7. Identification of private bores with more than 2 m predicted drawdown.
8. Identification of GDEs at risk of impact.

The range of examined metrics is considered best practice, as is the methodology applied to quantify each metric.

12. Question 9: Is the uncertainty associated with the predictions reported?

Guidelines on Uncertainty Analysis (**UA**) for groundwater models were issued by the Independent Expert Scientific Committee (**IESC**) on Coal Seam Gas and Large Coal Mining Development in February 2018 in draft form and finalised in December 2018. A revision was issued in July 2023 with less emphasis on checklists and more emphasis on *fitness for purpose* based on usability, reliability and feasibility (Peeters and Middlemis, 2023).

The quantities of interest (**QoIs**) investigated by uncertainty analysis are items 1, 6 and 7 in the list of metrics in Section 11 (above).

A rigorous Monte Carlo UA has been applied that found 196 calibrated realisations out of a set of 300 trial models. Models were considered “calibrated” if a score of less than 10% SRMS was achieved. A convergence analysis on the mine inflow QoI demonstrated that 196 models were sufficient for stable results.

13. Question 10: Is the model fit for purpose?

The GIA prepared by AGE (2025) is based on historical data assessment, development of a conceptual hydrogeological model and a fully three-dimensional (**3D**) numerical model of groundwater flow.

The latest IESC Explanatory Note on uncertainty analysis (Peeters and Middlemis, 2023) advocates the use of three criteria in deciding *fitness for purpose*:

- Usability.
- Reliability.
- Feasibility.

Usability: In my view, sufficient information has been conveyed to decision-makers about the uncertainty in conceptual processes and characterisation of the groundwater system based on model simulation. The model can be regarded as a usable tool for making decisions.

Reliability: In my view, the modelling process has no inherent bias that would prejudice the reliability of predicted impacts of importance. Model outcomes are consistent with knowledge of the groundwater system in the Upper Hunter Valley.

Feasibility: In my view, the developed model provides a sufficient approximation to reality subject to computational constraints and data limitations. No model will ever be perfect. Ongoing tweaks, in my opinion, would take the model along a path of diminishing returns with the likelihood of little if any material improvement in predictions or reduction of risk.

Overall, I regard the model as *fit for purpose*, where ‘purpose’ is defined by the modelling objectives referenced above in Question 1.

14. References

AGE, 2020. Report on Mount Pleasant Optimisation Project Groundwater Impact Assessment. Prepared for Mach Energy Australia Pty Ltd, Project G1970A, December 2020.

AGE, 2025. Mount Pleasant Operation Modification 8 Groundwater Impact Assessment. Report MPO5009.001 prepared for Mount Pleasant Operations Pty Ltd, Version 3.01, 18 November 2025. 105p + 2 Appendices.

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