31 October 2024

Illawarra Coal Holdings Pty Ltd
Port Kembla Coal Terminal, Inner Harbour
Port Kembla Road, Port Kembla NSW 2505

Attention: Linda Zanotto
via email: Linda.Zanotto@gm-3.com.au

Dear Linda,

Dendrobium Mine Groundwater Flow Model Peer Review Findings

1 Introduction

This document summarises the findings of a peer review of the Dendrobium Mine groundwater flow model undertaken by Keith Phillipson. Peer review of this model is a condition of the Water Access Licence (WAL) associated with Dendrobium Mine. Condition DS8767-00001of the WAL states that:

> *By 31 October 2024, the licence holder must submit a peer review report of the model report in electronic form to the Department and the NRAR. The peer review report must:*
>
> - *A. comply with the requirements of section 9.1 and Appendix A (model review checklist) of the Modelling Requirements[1];*
> - *B. be prepared by a suitably qualified independent expert in groundwater modelling and include a statement of that expert's qualifications and experience, and a conflict of interest declaration by the expert.*

Partial review findings based on the work completed by August 2024 are provided below.

[1] Section 9.1 and Appendix A of the Groundwater Assessment Toolbox for SSD/SSI, Minimum Groundwater Modelling Requirements for SSD/SSI Projects (https://water.nsw.gov.au/__data/assets/pdf_file/0005/507614/Minimum-Groundwater-Modelling-Requirements-for-SSD-SSI-Projects.pdf).

2 My background

My technical expertise is as groundwater and surface water scientist specialising in hydrogeology and integrated groundwater and surface water modelling and I have been a consultant and public servant in these fields for over 29 years. I hold a BSc (Hons) in Geography and an MSc in Water Resource Systems Engineering. Both of these qualifications included modules in hydrological and hydrogeological sciences. Since completion of my MSc in late 1994 I have been continuously employed as a hydrogeologist acquiring extensive experience in assessing the impacts of large-scale groundwater extraction for water supply, coal mining and coal seam gas production purposes on groundwater and surface water systems. Between 2015 and 2019 I directed hydrogeological and modelling research activities at the Queensland Office of Groundwater Impact Assessment (OGIA). My experience includes:

- extensive experience in the development and management of numerical groundwater flow modelling studies including integrated surface water and groundwater simulations to assess the impacts of a variety of groundwater extraction activities;
- development of detailed local and regional scale conceptualisations to support subsequent numerical flow modelling and other studies;
- technical input to and management of groundwater impact assessment activities for EIS studies undertaken in a number of jurisdictions including Australia (Queensland, New South Wales and Victoria) and Europe;
- assessment and modelling of surface water groundwater interactions; and
- surface water runoff and recharge estimation.

As such I am suitably qualified to comment on the adequacy of the integrated surface water and groundwater numerical model developed by Watershed HydoGeo to assess the impacts of operation of the Dendrobium Mine and address the requirements of the WAL associated with this development. A copy of my CV is attached (Attachment A).

I have also previously undertaken an independent review of current and proposed pool water level, shallow groundwater and deep groundwater monitoring sites within Area 3C at Dendrobium Mine. Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) are also currently providing hydrogeological input at the nearby Metropolitan Mine. As such I have some prior knowledge of the hydrogeological setting of the Dendrobium Mine and Southern Coalfield area. I am not aware of any Conflicts of Interest that would be relevant to this Peer Review.

3 Basis for review

This report is based on a review of the following Watershed HydroGeo reports provided for review by Watershed HydroGeo and GM[3]:

- Watershed HydroGeo, 2024, Illawara Coal Holdings, Dendrobium Mine, Groundwater Model Update, August 2024. 436 pages including Appendices A to K.
- Watershed HydroGeo, 2023, History of Modelling at Dendrobium, Word document dated April 2023.

A meeting was also held on the 29 October 2024 with the lead modeller at Watershed HydroGeo (Will Minchin). It should be noted that the model report provided for review (Watershed HydroGeo, 2024) did not include complete model calibration or model prediction report sections as these components of the modelling work had not been completed at the time (August 2024). This review report therefore only documents peer review findings in relation to the planning, conceptualisation and design and construction stages of the modelling workflow. It is intended that this review document will be further updated once the remaining modelling work has been completed.

As required by the relevant WAL condition (Section 1) this review has been undertaken with reference to checklists provided in Appendix A of the Minimum Groundwater Modelling Requirements for SSD/SSI Projects, Technical Guideline (DPE, 2022). These checklists are based on similar checklists included in the current Australian Groundwater Modelling Guidelines (Barnett et al, 2012).

The current Dendrobium Mine groundwater flow model, as described in Watershed HydroGeo (2024), has evolved gradually over the period since 2012. During this time it has been subject to numerous independent peer reviews (including by Noel Merrick in 2012, Frans Kalf in 2017; 2019 and 2020 and by Brian Barnett [of Jacobs] in 2022). The model has also been subject to review on a number of occasions by both NSW state and federal regulators (primarily the NSW Department of Planning and Environment (DPE)) and advisory bodies including the Independent Expert Panel for Mining in the Catchment (IEPMC), the Independent Advisory Panel for Underground Mining (IAPUM) and the Independent Expert Scientific Committee (IESC). The majority of these peer and regulator reviews would have resulted in recommendations for improvements. A summary of recent advice received from various agencies is provided in Section 1.1.2 of the modelling report (Watershed Hydrogeo, 2024). Hence a key objective of the model update was to address this advice. Accordingly, this review includes an assessment of degree to which this advice has been addressed. However, the review does not seek to re-assess the overall model design (including the model domain, mesh, layering etc) unless these model characteristics are considered to represent a barrier to achieving the aims of the current modelling work.

4 Review findings

4.1 Checklist item 1 – Are the modelling objectives and model target confidence level class clearly stated?

The objectives of the model update are clearly stated in Section 1.2 of the modelling report (Watershed Hydrogeo, 2024). In addition to compliance with condition DS8767-00001 of the WAL the model update also attempts to address a range of agency advice received in relation to a number of recent groundwater assessments. This advice is summarised in Table 1.2 of the of the modelling report (Watershed Hydrogeo, 2024).

Model complexity (or confidence level class) is discussed in Section 4.2.2 of the modelling report (Watershed Hydrogeo, 2024). Consistent with the high environmental sensitivity of the area and the scale of the potential groundwater impacts a relatively complex 3D regional groundwater flow model has been developed. In many respects the model is considered to be highly complex, especially in its representation of fracture development above longwall mining areas. This complexity combined with the extensive model domain and the number of other mines represented in some detail has resulted in excessively long run times (over 10 hours) which are likely to limit the degree to which several of the stated modelling objectives of the modelling work can be achieved. This is discussed further in Section 4.5.

4.2 Checklist item 2 – Are the modelling objectives satisfied?

The majority of the stated objectives of the modelling work relate to calibration of the model, the inclusion of additional predictions and completion of a predictive uncertainty analysis. As mentioned above (Section 3) since only model construction activities have been completed at the time of reporting (August 2024) many of the modelling objectives have not been satisfied at this stage. However, the model has been updated and a number of improvements made to address agency advice summarised in Table 1.2 of the modelling report (Watershed Hydrogeo, 2024). Reported improvements to the model which had been completed by August 2024 include:

- The inclusion of geological structures (dykes and faults) in modelled hydraulic conductivity fields;
- Further clarification of quality assurance checks and weights applied to groundwater level and other data during calibration; and
- The inclusion of recharge, hydraulic conductivity in all units, and surface and sub-surface fracturing parameters in the model calibration (i.e. as adjustable parameters).

As mentioned above the very long model run times are likely to limit the degree to which a number of the remaining model objectives (particularly those relating to model calibration, sensitivity and predictive uncertainty analysis) are likely to be achievable.

4.3 Checklist item 3 – Is the conceptual model consistent with the model objectives and target confidence level class?

Longwall mining at Dendrobium commenced in Area 1 in 2005 and the response of the groundwater and surface water systems to mining have been extensively monitored and modelled since this time, consistent with the high environmental sensitivity of the area. Longwall panels have been developed in close proximity to Lake Cordeaux and Lake Avon and several water courses and upland swamp systems have been mined beneath. Accordingly, both the surface water and groundwater monitoring networks are extensive.

For instance the groundwater level data set used for model calibration includes data for around 1,200 deep groundwater level monitoring points. Data are also available for a further 120 shallow swamp piezometers and 32 surface water flow and level monitoring points, 16 of which are above historic longwall panels and have been used for calibration of modelled losses. The data from these monitoring networks is also complemented by extensive site characterisation activities which, for instance, includes data for some 3,400 pre-mining packer tests and further post mining packer testing above longwall panels 6, 7, 9 and 12 to 18. Based on this information a detailed conceptualisation of the area has been developed (Figure 4.1).

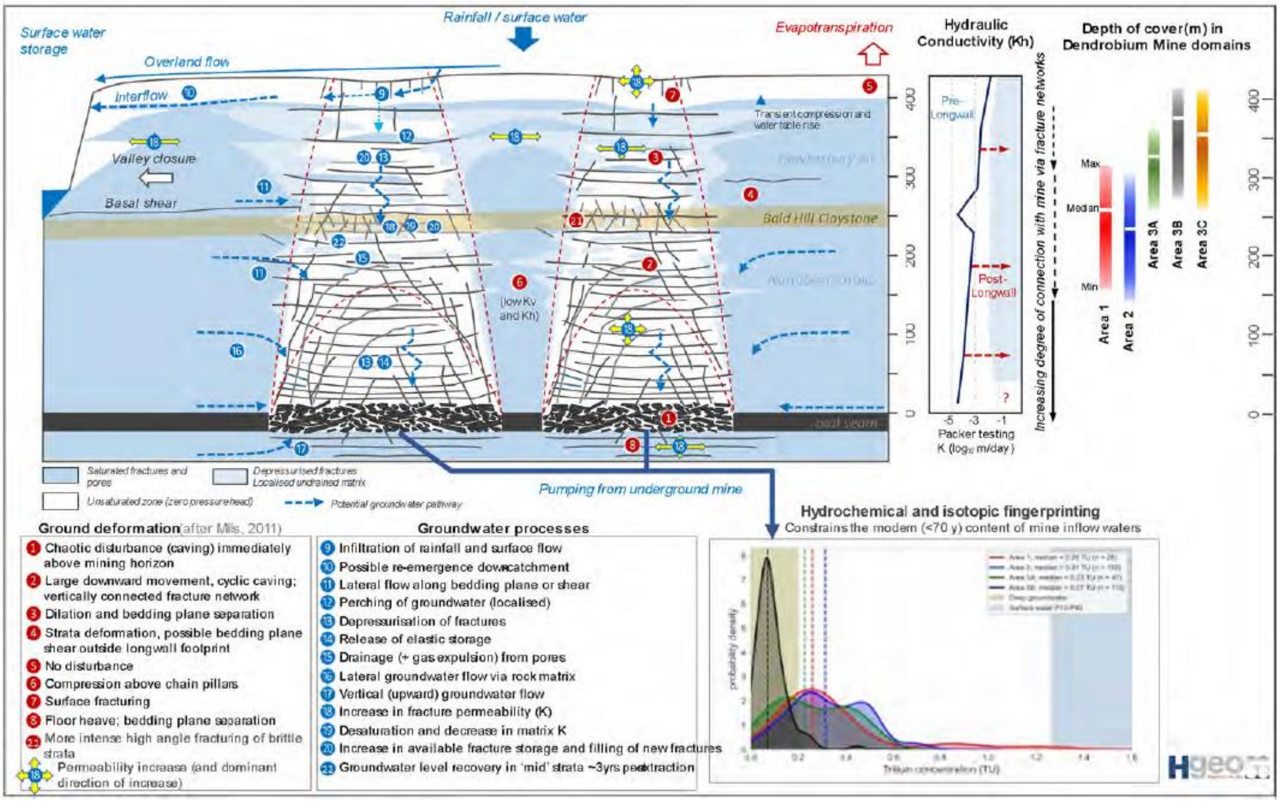

Figure 4.1 Conceptual model of groundwater and associated effects (Watershed Hydroeo, 2024)

Importantly many of the key components of this conceptual model have been validated and/or measured using site data. For example as shown in Figure 4.2 the availability of downhole geophysics, pre and post longwall mining packer testing profiles and data for nested VWP arrays has allowed detailed before and after vertical profiles of actual hydraulic parameter changes and groundwater pressure responses to be developed for multiple longwall panels. The conceptual model and mechanisms by which impacts occur at the site are therefore well understood and confirmed in most cases by field data collection. As such the conceptual model presented is considered to be consistent with the model objectives and target high model complexity (or confidence level class).

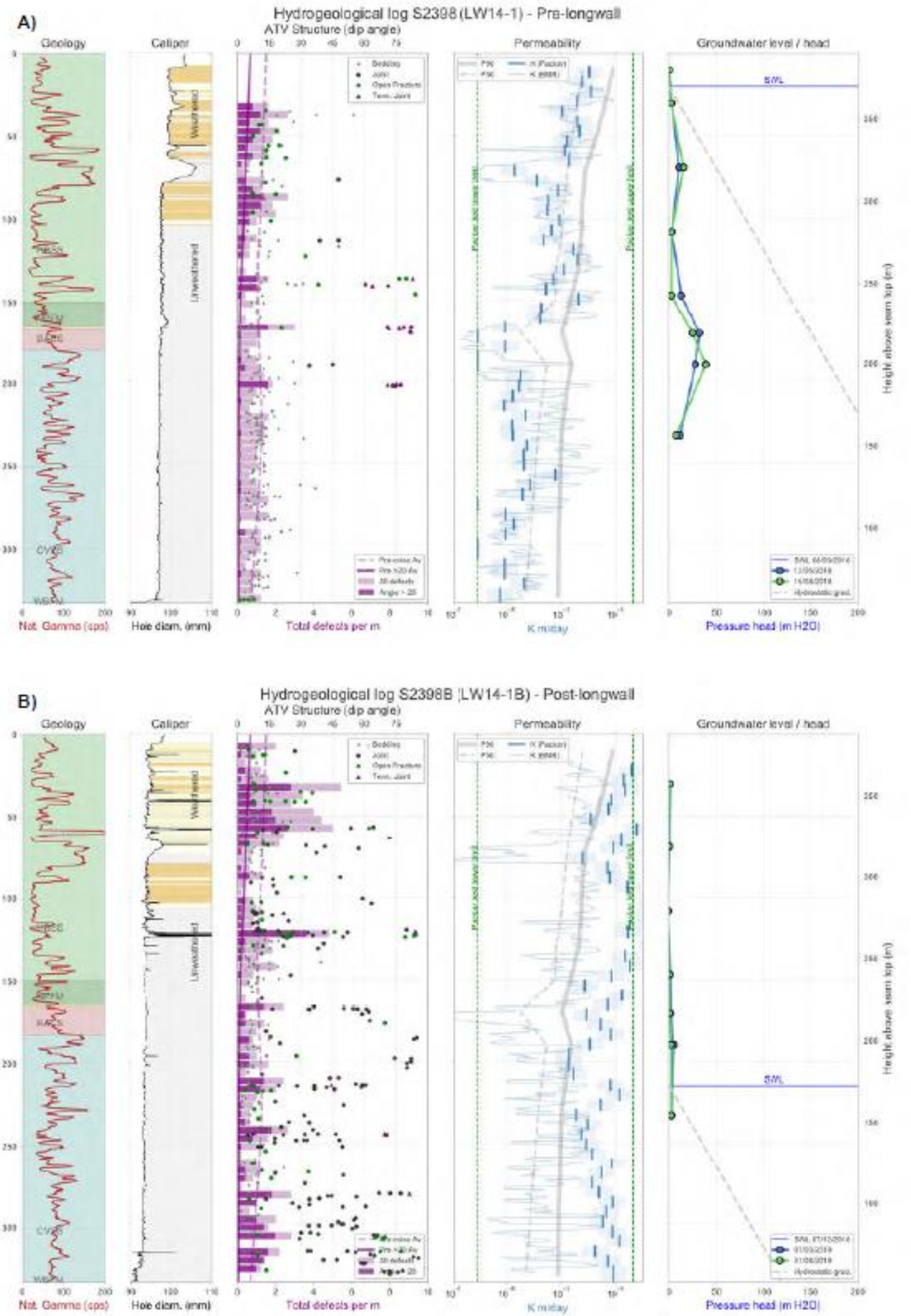

Figure 4.2 Pre and post-mining conditions above Longwall 14 (Watershed HydroGeo, 2024)

4.4 Checklist item 4 – Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?

As mentioned previously (Section 3) both the conceptual and numerical models presented in the modelling report (Watershed HydroGeo, 2024) have been presented and reviewed on multiple previous occasions. In particular, the conceptualisation of longwall induced effects on overlying strata provided is comprehensive and presented clearly with well thought out diagrams (including those shown in Figure 4.1 and Figure 4.2). As mentioned previously the conceptualisation and subsequent model parameterisation is also informed by extensive field data collation. Given that longwall mining induced fracturing and subsidence represent the main mechanisms by which impacts on surface receptors are likely this focus on this aspect of the conceptual and numerical models is considered to be entirely appropriate.

4.5 Checklist item 5 – does the mathematical model design conform to best practice

In almost all respects the numerical model design and modelling workflow (Figure 4.3) conforms with best practice. Modelling has been undertaken using MODFLOW-USG, using an appropriately designed mesh and calibration is to be undertaken through reference to both groundwater levels and flows and using software and approaches which are consistent with current industry standards. However, the overall size of the model and the associated very long run times are likely to represent a significant barrier to the degree to which: model parameters can be optimised during calibration (or history matching); or the sensitivity of key predictions to parametric uncertainty can be assessed.

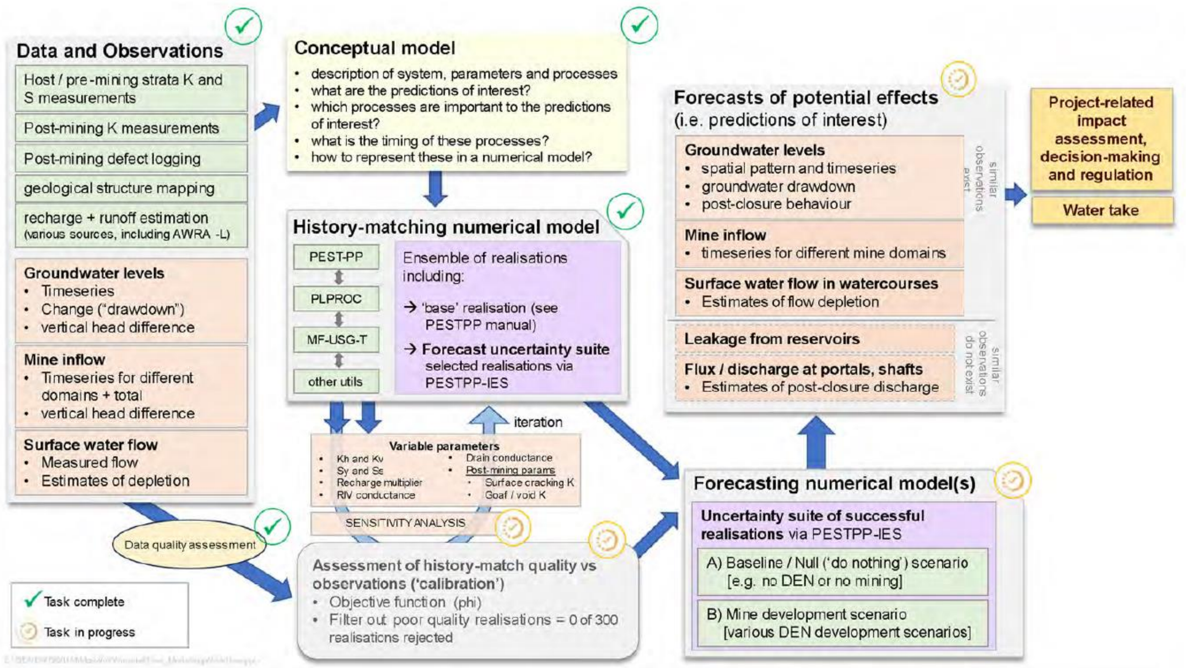

Figure 4.3 Workflow to integrate data and to achieve modelling objectives (Watershed HydroGeo, 2024)

Recent publications released as part of the Groundwater Modelling Decision Support Initiative (GMDSI) including Doherty and Moore (2021) stress that the primary task of a decision support groundwater flow model, such as the Dendrobium model, is the harvesting of information relating to highly complex sub-surface processes which can only be approximated in any numerical model. In this case the vast majority of this information relates to the Dendrobium Mine area and immediate surrounds (i.e. a small part of the current model domain). Furthermore, the primary potential impact pathways and receptors also occur in close proximity to the mine. It is recommended therefore that calibration is undertaken initially through the development of a smaller surrogate or nested model of the mining area itself. Such a model would run substantially quicker than the current regional model thereby improving the degree to which potentially spatial variability can be explored and parameters optimised (especially those representing subsidence fracturing processes). Once optimised, using the surrogate or nested model, parameters could be fed back into the current regional model in order to assess regional scale and cumulative impacts.

5 References

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A., Boronkay, A., 2012, Australian groundwater modelling guidelines, Waterlines Report Series. Canberra.

Doherty, J. and Moore C., 2021, Decision Support Modelling Viewed through the Lens of Model Complexity. A GMDSI Monograph. National Centre for Groundwater Research and Training, Flinders University, South Australia.

DPE, 2022, Minimum groundwater modelling requirements for Major Projects in NSW. Technical note prepared for the Water Division, NSW Department of Planning and Environment as part of the Groundwater Modelling Toolbox Project.

Watershed HydroGeo, 2023, History of Modelling at Dendrobium, Word document dated April 2023.

Watershed HydroGeo, 2024, Illawarra Coal Holdings, Dendrobium Mine, Groundwater Model Update, August 2024. 436 pages including Appendices A to K.

Yours faithfully,

Keith Phillipson
Senior Principal Hydrogeologist
Australasian Groundwater and Environmental Consultants Pty Ltd

ATLAS CERTIFICATION ISO 9001 | ATLAS CERTIFICATION ISO 45001 | ATLAS CERTIFICATION ISO 14001

Attachment A

AGE CV's