BARALABA SOUTH

Baralaba South Project
Environmental Impact Statement

ATTACHMENT 7

Peer Review
Groundwater Modelling and Assessment

arc ENVIRONMENTAL SOLUTIONS

4 December 2023

Baralaba South Groundwater Peer Review

1 Introduction

Baralaba South Project (BSP) is a proposed open cut mine eight kilometres south of the township of Baralaba within the Mining Lease Application (MLA) area 700057. Approval of this proposed mine requires an Environmental Impact Statement (EIS) to be submitted. AARC Environmental Solutions Pty Ltd (AARC) are preparing the EIS on behalf of Baralaba South Pty Ltd for the BSP. A component of the EIS is the Groundwater Assessment (GA) that has been produced by Watershed HydroGeo (Watershed) with assistance from Groundwater Solutions.

AARC requested Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) undertake a peer review of the GA. AGE undertook a similar review for the previous EIS process.

2 Review methodology

In line with the provided scope, AGE have undertaken this peer review through a staged process through key milestones in the model development. This has allowed discussions to occur and feedback to be provided through the process. The review has focused on the groundwater assessment reporting, and the reviewer has not undertaken review of the model input files. This review also uses the checklists provided in the Australian groundwater modelling guidelines (AGMG)

3 Evidentiary basis

AGE have undertaken this review based on a review of the model generation and calibration approach / results during the model development phase, and a review of the GA report:

1. **Document 1**. Watershed HydroGeo, (2023), *Baralaba South Project – Groundwater Modelling and Assessment* for the Environmental Impact Statement.

The other ancillary documents not directly linked to the project that were used during this peer review are:

1. **Document 2**. Barnett, B, Townley, LR, Post, V, Evans, RE, Hunt, RJ, Peeters, L Richardson, S, Werner, AD, Knapton, A, & Boronkay, A (2012), *Australian groundwater modelling guidelines*. Waterlines report, National Water Commission, Canberra (herein referred to as the AGMG).
2. **Document 3**. Commonwealth of Australia (CoA), (2018), Information guidelines for proponents preparing coal seam gas and large coal mining development proposals, Commonwealth of Australia, May 2018.

3. **Document 4**. 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.
4. **Document 5** – Murray TA and Power WI (2021), *Information Guideline Explanatory Note: Characterisation and modelling of geological fault zones*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Agriculture, Water and the Environment, Commonwealth of Australia 2021.

The Terms of Reference (TOR) for the EIS were published in 2017. As previously determined, the project is a controlled action and it is expected the EIS, and specifically the groundwater assessment, will be subject to referral to the Independent Expert Scientific Committee (IESC) under the Water Trigger for their review and advice. The Watershed HydroGeo reporting directly addresses the guidelines provided by the IESC, identifying in Table 1-4 of the groundwater assessment report (Document 1) where the specific requirements of the IESC guidelines are addressed in the reporting.

4 Review discussion

The following sections provide a summary of key aspects of the various stages of the model development, following the process outlined in the Australian groundwater modelling guidelines (AGMG/Document 2).

4.1 Objectives

The objectives of the GA are presented Section 1.5 of the report. In summary, they are to provide an assessment of the potential impacts to the surrounding groundwater regime from the proposed mining. This is further divided into specific estimates for mine inflow, changes in groundwater levels around the BSP and at neighbouring bores, changes to baseflow and potential changes to groundwater at GDE locations.

At the start of the modelling section (Section 6.1), the specific objectives of the model to address the above project objectives are discussed by identifying the Quantities of Interest. These are the specific impact measures that the assessment tool (model) needs to show changes in due to BSP. It is the reviewer's opinion that the model design and approach has taken these requirements into consideration.

4.2 Conceptual model

The conceptual model is presented in Section 5 (Document 1) including diagrams that show bulk water movements pre and post mining. The conceptual model presented aligns with the data collection to date at the site, and with other similar studies throughout the Bowen Basin. The key components of the conceptual model are low recharge rates, high evapotranspiration and deep water tables. The dominant recharge mechanism to the alluvial aquifer appears to be leakage through the streams, as is the case in the Dawson River where the stream stage is somewhat regulated by the Neville Hewitt Weir.

No additional conceptual models were explored (not including the uncertainty analysis) as the system is largely well understood, its operation is simple, and there is no water level behaviour that the current conceptualisation cannot explain.

Section 5 also presents a discussion on causal (or impact) pathways and provides a flow diagram to display the pathways relevant to the BSP. The reviewer is aware that there is a consultation draft from the IESC regarding impact pathway diagrams based on ecohydrological conceptualisations so it is pleasing to see this diagram included.

4.3 Numerical model

The model uses the unstructured version of MODFLOW (MODFLOW-USG) as the basis for groundwater flow simulation. This model is considered industry standard, and has capabilities that are well suited to simulating dewatering from an excavation, where the surrounding strata layers become desaturated and then re-saturate post dewatering. The software has sufficient functionality through its boundary condition options to represent the conceptual model.

The BSP model extent is sufficiently large to minimise impacts from the assigned boundary conditions, and sufficiently large enough to include the nearest receptors / potential receptors, including the unlikely impacts on the Great Artesian Basin sediments.

The model domain has been discretised into a uniform grid of 200 m x 200 m cells. Given the model has been developed using MODFLOW USG, the option to utilise a variable mesh, such as one constructed from Voronoi polygons to add local refinement to the mesh was not utilised. With the orthogonal grid the active cell count is over 640,000 cells. This number of cells starts to make individual run times long and expansive uncertainty analysis efforts difficult. It is the reviewers experience that conversion from an orthogonal grid to a Voronoi mesh can yield a total cell count that is a quarter of the orthogonal count. This then expands the possibilities for increased calibration and uncertainty analysis where the model is run repeatedly. That being said, these comments do not indicate that the adopted approach of orthogonal uniform grid is wrong or limiting in terms of achieving the objectives.

4.4 Calibration

The calibration method adopted for this model makes use of some of the recent advances in calibration techniques, in particular the PESTPP-IES approach. This approach is an automated calibration method that does not necessarily narrow down on a single calibration parameter set, but rather at each iteration it seeks to find a range of parameter realisations that are similar to (varied minimally from) the initial values that also improve the level of match to an acceptable level.

This calibration technique has the advantage of creating a set of parameter realisations that can be utilised in the uncertainty analysis process. The parameters types chosen for calibration are considered appropriate and represent the typical parameters in groundwater models that are varied for improved history matching.

The calibration process produced a series of ensembles for each iteration of the calibration process that can be considered to calibrate the model to an acceptable level. The initial ensemble size starts at 100, but then declines to 95, 88, 47, 11, and then 2 for iterations 0 to 4 respectively. The reduction on the ensemble size is from the nonconvergence of the numerical solution. This can be due to oscillations, or could mean complete divergence, both of which are expected given the range of parameters being explored and combinations possible. There is a sharp drop off in the ensemble size after iteration 2, which would limit the uncertainty analysis for only a small increase in the level of fit. For this reason, and after a discussion with the modeller, it was decided that the 88 realisations in iteration 1, and the 47 realisations in iteration 2 should form the calibrated realisations for predictive and uncertainty analysis purposes. Beyond this the automated process was not likely to yield further information.

A statistical measure documented in the AGMG to describe the level of calibration is the Scaled Root Mean Square (SRMS). The initial SRMS for groundwater level match was 26.7%, but through the calibration process this was reduced to 15.2% and then 14.1% for iteration 1 and 2 respectively. These values are above the advocated 10% SRMS form the model guideline, but not significantly above. The modeller acknowledges that in a few places the match is poor, and that the calibration was also matching to a range of mine inflows at Baralaba North Mine. This is influenced by the necessary simplification of the mine plan at BNM within the model.

For previous modelling for Baralaba North and for previous modelling at BSP, the deterministic approaches employed for the calibration have performed better than the statistics achieved above, but that is when the calibration target dataset has been smaller, and with little acknowledgement of the non-unique nature of the calibrated dataset. Often the best calibration does not mean the best modelling tool for making informed decisions, and that is why this calibration is considered a better result.

The calibrated parameters are presented in Figure 6-27 for the initial and iterations 1 and 2. Most of these parameters are in expected ranges, however the values of horizontal hydraulic conductivity for Weathered Permian, Weathered Rewan, Weathered Gyranda, and colluvium are all tending towards upper bounds and possibly higher than what is typically observed in the field. This could be directly attributed to all these formations being shallow and possibly sitting above the water table, making them insensitive to the calibration target dataset. In this instance the automated calibration process has varied them to extreme values to explore the space to make them sensitive. Because these values have calibrated high in the range, they provide more opportunity for horizontal propagation of impacts where saturated conditions occur, adding an element of conservatism to the predictions.

4.5 Predictions and uncertainty analysis.

Representing the mining through the MODFLOW Drain boundary condition (DRN) and then representing the backfill through changes in parameters via the Time Variant Material properties package (TVM) is an appropriate approach to representing the BSP. The Baralaba North Mine is included in the model predictions allows for an assessment of cumulative impact to be made.

The predictions of drawdown are appropriately derived from the use of a 'null' model to determine the drawdown due to the proposed BSP. Three models are used for this, a 'no-mine' model run, a model run that only contains the approved BNM (to 2033), and then a cumulative prediction that includes the BNM and BSP mine dewatering and recovery, and examining the changes between various model runs will isolate and help derive the specific predictions required by the model objectives.

In addition to this, the predictions presented are not from a single model run, but rather are from a probabilistic distribution formed from the ensemble of parameter realisations that were derived from the calibration process. This means that the uncertainty analysis is integral to the presentation of the predictions rather than being an adjunct process reported on in addition to the predictions.

For the maximum drawdown the 50th and 95th percentile values on a cell-by-cell basis are derived from the various calibrated parameter realisations across the mining and post mining phases of BSP. These predicted maximum drawdowns were extensive for the presented lower coal measure drawdowns, but were reasonably limited for the shallower water table, with only areas to the south and southeast extending beyond the mining lease boundary by up to 4.5 km. At the other end of the probabilistic scale, the 5th percentile maximum water table drawdowns are contained within the mining lease boundary, and these are just as likely as the 95th percentile results. The most likely (50th percentile) predicted maximum drawdown for the mapped alluvium / colluvium is also presented and these show very limited impact within these formations.

Drawdown at private bores has also been assessed from the ensemble of parameter realisations with a base prediction presented along with the other realisations in hydrographs showing the change due to BSP in isolation (Scenario B minus Scenario C) and cumulatively (Scenario A minus Scenario C).

Mine inflow has also been presented as a probabilistic range of potential values throughout the proposed BSP mining period, with a most likely inflow represented by the median value, and the range defined by the 5th and 95th percentile. This range looks plausible and the daily inflow rates are typical of Bowen Basin coal mines.

Climate change has also been considered in the modelling, with an initial review of the climate modelling available, followed by a simplified approach of increasing and decreasing recharge by 20% as this encapsulates the predictions from the climate models, including the RCP8.5 scenario outputs for this area of Australia. The reporting on impacts of climate change were limited to only the predicted BSP inflows. Ideally climate change would also be a component of the long-term post mining conditions and changes in equilibrium drawdown due to climate change would also be presented. It is recommended that this be undertaken when the model is next updated.

The post mining predictions have been undertaken using an acceptable approach. Typically, groundwater recovery into a void represented in a groundwater model is limited by the time stepping. The bulk of the water balance input for a void lake is through direct rainfall and any runoff within the final landform catchment, with groundwater inflow generally a very small component. The rise in water levels is therefore heavily influenced by rainfall events, which are difficult to simulate in a groundwater model because stress periods and timesteps and usually decades long when simulating a long period of post mining. This means that the inputs are generally long-term averages, which makes the predicted void lake level recover very slowly.

For this reason the equilibrium water level in the void lake was provided by the surface water consultant and directly assigned within the model through the time variant constant head package of MODFLOW-USG. The representative groundwater inflow – void water level relationship was provided to the surface water consultant prior to their assessment. This approach is considered appropriate. The resulting groundwater recovery was predicted around the BSP and across the model domain. The interaction with the surface water consultant was only through one round or iteration. This is not seen as a significant limitation as subsequent iterations usually don't modify the predicted void water level from the surface water consultant too much.

The post mining prediction that the void remains a sink to the groundwater system is typical of the Bowen Basin, with evaporation significantly exceeding recharge in the area. The post mining prediction was run until year 2500 which is past the predicted time for equilibrium to be reached by the final void lake level (~325 years). The predicted long-term drawdown for the water table is provided and this demonstrates that there is predicted to be some residual drawdown remaining outside of the mining lease, and this is an expected result due to the stabilisation of the void water level below the pre-mining groundwater levels.

5 Does the model conform to Australian modelling guidelines?

The AGMG (Document 2) outlines a process of evaluating the appropriateness of various aspects of model development to determine if the model is adequate and 'fit for purpose'. It provides guidance on how particular aspects of model development should proceed and provides considerations for the modeller. The aim of the guidelines is to provide a more appropriate and consistent approach to model development across the industry.

The guidelines provide a review checklist (see Table 9-2, Document 3) that lists key areas of model development. The review checklist has been completed (where relevant) for the BSP groundwater model and is provided as Attachment A to this letter. The comments provide justification for the decisions made where required.

The confidence level class assessment has been determined by assessment to key indicators in Table 2-1 of the AGMG (Document 2). This assessment appears as Appendix G where a clear colour coding approach has been used to identify which class is achieved for each indicator. The model is assessed by Watershed HydroGeo as being a class 2 model, and the reviewer agrees with this assessment.

6 Is the numerical model consistent with the conceptual model?

There are a number of ways to indicate that the conceptual model has been appropriately represented in the numerical model. One such approach is to examine the overall water budget coming from the model (Table 7-3) . Firstly, this shows that the key bulk water movement into and out of the model domain is leakage from Dawson River (~27 ML/day) and inflow from the upstream boundary (~27 ML/day). Diffuse recharge (7.9-8.2 ML/day) is a smaller component than the other inflows, despite being applied across the model domain. The main outflow is through evapotranspiration (34.2 – 34.7 ML/day), followed by down valley flow (18.7 ML/day). Baseflow to surface drainages is predicted to be smaller than seepage from surface drainages (~11.5 ML/day) and this matches the conceptual model where groundwater levels are typically 12 m to 15 m below ground.

Groundwater flow directions in the conceptual and numerical models (as shown in water level contour plots) are similar enough to confirm consistency between the models.

The representation of the layering in the numerical model has captured the key hydrostratigraphic features identified in the conceptual model, including the segregation of coal seam and interburdens.

The reviewer considers the numerical model appropriately captures and represents the conceptual model.

7 Is the model 'fit for purpose'?

The purpose/scope of the GA is outlined in Section 1.5 as:

> *"The objectives of this report are to present an assessment of groundwater-related effects on the surrounding hydrogeological system and relevant environmental features of the Project during operation and following closure. ….*
>
> *….. The modelling to quantify the potential effects is consistent with the conceptual model and observational data to enable forecasting of effects from the project on groundwater and connected surface water systems.*
>
> *Specifically, the forecasts of groundwater and (connected) surface water effects from the Project, including estimates of uncertainty; would include:*
>
> - *Estimated groundwater inflow to mine workings ('groundwater take').*
> - *Estimates of the extent and rate of drawdown at specific locations including at private bores in the area.*
> - *Estimates of the magnitude and timing of changes to baseflow (groundwater discharge) to nearby watercourses.*
>
> *Review the likely groundwater dependence of wetland systems, and provide estimates of the potential for effects on Groundwater Dependent Ecosystems (GDEs) [in conjunction with the GDE Assessment report (3De, 2023) and Stygofauna report (Stygoecologia, 2019)]."*

Based on the reporting, it is considered that these objectives have been met.

With that in mind, it is the reviewer's opinion that the model has:

- represented the conceptualisation in an appropriate way;
- captured the key bulk water movements into and out of the model;
- been able to replicate water behaviour successfully in the model domain;
- function to be interrogated to provide required output listed in the model objectives; and
- met the requirements to be '**fit for purpose**'.

Yours faithfully,

Andrew Durick
Director / Principal Modeller
Australasian Groundwater and
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Attachment A Australian Groundwater Modelling Guideline Checklist

Attachment A

Australian Groundwater Modelling Guideline Checklist

Review questions	*Yes/ No*	*Comment*
1. Planning		
1.1 Are the project objectives stated?	Yes	Section 1.4 of the GA outlines the project objectives, and
1.2 Are the model objectives stated?	Yes	section 6.1 provides the model objectives
1.3 Is it clear how the model will contribute to meeting the project objectives?	Yes	Section 6.2 presents a figure showing the proposed model workflow achieves the modelling objectives
1.4 Is a groundwater model the best option to address the project and model objectives?	Yes	Assessment calls for determining the extent of impacts and to predict the water take (mine inflow).
1.5 Is the target model confidence-level classification stated and justified?	Yes	Section 7.9 - self assessed to be a Class 2 model. Appendix F recreates Table 2-1 from the modelling guidelines and provides justification for the assessment.
1.6 Are the planned limitations and exclusions of the model stated?	Yes	Section 7.12 discusses the limitations of the model.
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Yes	Literature review around hydraulic properties are presented and previous work at the site is referenced through the assessment.
2.2 Is the aquifer system adequately described?	Yes	All aquifers are identified and justified
2.2.1 Hydrostratigraphy including aquifer type (porous, fractured rock ...)	Yes	Sections 2.4 and 5.1.1 cover these descriptions
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Yes	Described in section 2.4
2.2.3 Aquifer geometry including layer elevations and thicknesses	Yes	Presented in Section 2.4 and 6.4.2
2.2.4 Confined or unconfined flow and the variation of these conditions in space and time?	Yes	Discussion about the deep water table and shallow sediments being unsaturated. Summarised through Section 3.6
2.3 Have data on groundwater stresses been collected and analysed?	NA	NA
2.3.1 Recharge from rainfall, irrigation, floods, lakes	Yes	Rainfall has been discussed in Section 3.7 Recharge rates are conceptualised as low (<1%). Flood periods were identified, and additional recharge applied.
2.3.2 River or lake stage heights	Yes	Section 2.2 provides river stages and flow rates and flow duration curves
2.3.3 Groundwater usage (pumping, returns etc)	Yes	local groundwater usage is described in Section 3.3
2.3.4 Evapotranspiration	Yes	Section 2.1.2 describes the evapotranspiration and the use of actual evapotranspiration estimates from BoM.
2.3.5 Other?	NA	NA
2.4 Have groundwater level observations been collected and analysed?	NA	See below

Review questions	Yes/ No	Comment
2.4.1 Selection of representative bore hydrographs	Yes	Section 3.7 summarises groundwater monitoring for each formation and provides representative hydrographs
2.4.2 comparison of hydrographs	Yes	Section 3.7 describes water levels and hydrograph behaviour on a formation by formation basis.
2.4.3 Effect of stresses on hydrographs	Yes	Previous mining identified in bores near Baralaba North – in Baralaba Coal Measures
2.4.4 Watertable maps/piezometric surfaces?	Yes	Available in Section 3.4
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	NA	NA
2.5 Have flow observations been collected and analysed?	Yes	NA
2.5.1 Baseflow in rivers	Yes and No	No baseflow analysed as surface drainage are losing streams due to depth to groundwater. Main water course is gauged and results from this are presented which can be compared with model predictions of leakages from flowing rivers.
2.5.2 Discharge in springs	NA	No springs identified in model area.
2.5.3 Location of diffuse discharge areas?	Yes	Wetlands identified have been conceptualised as surface water sourced wetlands.
2.6 Is the measurement error or data uncertainty reported?	NA	NA
2.6.1 Measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	Yes	Sources of measurement error is discussed in Section 7.12.
2.6.2 Spatial variability/heterogeneity of parameters	Yes	Variability in field measurements demonstrated in Section 3.6
2.6.3 Interpolation algorithm(s) and uncertainty of gridded data?	No	The approach taken is considered to be appropriate.
2.7 Have consistent data units and geometric datum been used?	Yes	It appears so, or at least the required conversions have been made as MODFLOW USG requires consistent units
2.8 Is there a clear description of the conceptual model?	Yes	See section 5.1 and cross sections showing pre and post mining conceptual models
2.8.1 Is there a graphical representation of the conceptual model?	Yes	Two cross section figures – one pre and one post mining.
2.8.2 Is the conceptual model based on all available, relevant data?	Yes	NA
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Yes	NA
2.9.1 Are the relevant processes identified?	Yes	The key components of the bulk groundwater movement at the Baralaba South site are captured in the conceptual model
2.9.2 Is justification provided for omission or simplification of processes?	Yes	Appropriate simplification to key components has taken place with evidence supporting the simplifications and omissions

Review questions	*Yes/ No*	*Comment*
2.10 Have alternative conceptual models been investigated?	Yes and No	Alternate conceptual models were explored and adopted through parameter ensembles in calibrated alternatives. These parameter realisations formed the basis of the uncertainty analysis and this is considered to be appropriate.
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Yes	
3.2 Is the choice of numerical method and software appropriate (Table 4-2)?	Yes	MODFLOW USG. Provides a more stable numerical scheme with the control volume finite difference method and is considered an industry standard.
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	Cell size is a uniform 200m by 200m. This is a relatively large cell size but is sufficiently small to show a good match the cone of depression at BCNOP.
3.2.2 Is the software reputable?	Yes	MODFLOW USG is distributed by the USGS and is now the industry standard software for modelling groundwater.
3.2.3 Is the software included in the archive or are references to the software provided?	Yes	Reference provided
3.3 Are the spatial domain and discretisation appropriate?	NA	NA
3.3.1 1D/2D/3D	Yes	3D - MODFLOW USG
3.3.2 Lateral extent	Yes	Model extent includes any identified potential receptors, including the GAB formations to the west. GHB boundaries have been used at the model extents. The details of how the reference level was determined has not been documented. The boundary conditions are far enough away not to influence the key predictions of the model. This is supported by the water budget summary where there is no change in inflow/outflow with and without the BSP.
3.3.3 Layer geometry?	Yes	The chosen vertical discretisation provides sufficient detail without being too simplified. The key coal seams are simulated discretely in separate model layers and coal seam thickness is cumulative for grouped seams
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Yes	Uniform 200m x 200m cell sizes. Ideally smaller cells should have been used in the proposed open cut pit area. Smaller cells sizes would allow more resolution to develop a sharper cone of depression around the mine. More refinement around surface drainage lines would also provide a more refined estimate of surface water and groundwater interaction and how this might change. The unstructured nature of MODFLOW USG is ideally suited to variable grids.
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Yes and No	Coal seams and aquitards are separated out, but the aquitards themselves are single layers. This approach is considered to be appropriate.
3.4 Are the temporal domain and discretisation appropriate?	NA	NA

Review questions	*Yes/ No*	*Comment*
3.4.1 Steady state or transient	Yes	Both - steady state to provide initial conditions, and transient simulation that represents historical and future mining at the Baralaba sites, as well as post mining.
3.4.2 Stress periods	Yes	Some large stress period representing pre-mining periods where the Weir was installed, then 4 monthly stress periods that were able to capture seasonality over the historical period. The stress period then moved to annual with a couple of smaller stress periods to represent the flooding in 2011
3.4.3 Time steps?	Yes	Stress period length and number of timesteps per stress period are appropriate, as indicated by successful convergence and low mass balance error.
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	NA	NA
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Yes	General head boundaries are assigned where significant flows are identified to be crossing, and no-flow boundaries are assigned where appropriate.
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Yes	The predicted impact from BSP to the leakage from streams is minimal - therefore not driving the predictions. Up and down gradient model domain outflows remain unchanged when BSP is added.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	Determined to be limited volumes from the outset. Zoned up based on outcrop geology.
3.5.4 Are lateral boundaries time-invariant?	Yes	The assigned general head boundary conditions are appropriate at fixed reference levels.
3.6 Are the initial conditions appropriate?		
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	Yes	Groundwater modelling - first stress period simulates steady state conditions, providing reliable initial conditions
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	Yes	Steady state results would be affected by the changes to hydraulic conductivity and recharge explored through the uncertainty analysis
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	NA
3.7 Is the numerical solution of the model adequate?	Yes	The overall percent discrepancy of the model is 0.04% for the historical calibration period, which increased to 0.08% in the forecast period. Some spikes in precent discrepancy were noted by the modeller, but these are in short timesteps and agree it could be removed with higher convergence criteria.
3.7.1 Solution method/solver	Yes	SMS solver is used for control volume finite difference solution scheme of MODFLOW USG

Review questions	*Yes/ No*	*Comment*
3.7.2 Convergence criteria	Yes	0.06 m (outer iteration) and 0.006 m (inner iteration)
3.7.3 Numerical precision	Yes	adequate for the predictions being made.
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	Yes	Some mine inflow is available at a neighbouring mine and has guided the calibration, groundwater and surface water interaction compared against streamflow for plausibility.
4.1.1 Groundwater head data	Yes	Model is calibrated to water level data (up to 2023)
4.1.2 Flux observations	Yes	The calibration was guided by mine inflow estimates.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	NA	NA
4.2 Does the calibration methodology conform to best practice?	NA	NA
4.2.1 Parameterisation	Yes	Geological extents are used, and pilot points (spatially distributed parameters) are used to define the heterogeneity.
4.2.2 Objective function	Yes	Yes – just above the advocated target in the AGMG, but this could be due to the calibration approach which focuses more on the ensemble rather than a specific, and likely non-unique, calibrated model
4.2.3 Identifiability of parameters	No	Not reported
4.2.4 Which methodology is used for model calibration?	NA	PESTPP-IES using advanced spatial parameterisation (pilot points).
4.3 Is a sensitivity of key model outcomes assessed against?	NA	NA
4.3.1 Parameters	Yes	Through adopting an ensemble of parameter values to represent the calibration data set and taking those through to produce the predictions, this has circumvented the need for sensitivity analysis.
4.3.2 Boundary conditions	No	This is seen as appropriate as the boundary flows are not impacted by the proposed mining
4.3.3 Initial conditions	Yes	The initial conditions are varied indirectly through the range of realisations in the ensemble for both recharge and hydraulic conductivities resulting in change to the predicted steady state conditions.
4.3.4 Stresses	Yes	The historical calibration includes mining / dewatering stresses on the system, variable recharge with time, and observations that show rises and falls in groundwater levels with time.
4.4 Have the calibration results been adequately reported?	NA	NA
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Yes	Some selected hydrographs are provided in Section 6.11.1, with all the hydrographs provided in Appendix E

Review questions	*Yes/ No*	*Comment*
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Yes	Hydrographs for all monitoring bores have been presented, but where there are multiple measurements at differing depths at the one location, these are generally around the BNM where the fit is considered poor. P-VWP5 is near BSP and while from a regional model perspective the match to the observed is sufficient, it is not following the reducing head with depth.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	NA
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Yes	scatter diagram and hydrographs are used in conjunction with statistical measures of the error. The SRMS for iteration 1 is 15.2%, and for Iteration 2 it reduces to 14.1% which is just above the target advocated by the guidelines.
4.5.1 Spatially	Yes	Figure showing average residual at each bore is provided in Section 6.11.2
4.5.2 Temporally	Yes	hydrographs are shown comparing observed and simulated water levels
4.6 Are the calibrated parameters plausible?	Yes	The ranges of hydraulic parameters are acceptable. It is noted that the weathered Permian strata went to the upper bound for the calibration data sets and could indicate that it is insensitive in the calibration, but because it is high it is conservative in terms of predicting impact extents. Storage properties in the shallow formations is indicative of the unconfined nature of these units with the deep water table across the site.
4.7 Are the water volumes and fluxes in the water balance realistic?	Yes	Volumes entering and leaving the model domain appear plausible for what they represent. Aerial recharge is generally lower than the river leakage conforming to the conceptual model where aquifers are recharged through the river. Baseflow is a small component of the budget due to the general depth top water table being 12 to 15 mbgl.
4.8 Has the model been verified?	No	Discussed in the recommendations once future datasets are available
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Yes	Boundary conditions representing the dewatering from the mines are applied and impacts are defined by comparison to a null model
5.2 Is predictive uncertainty acknowledged and addressed?	Yes	Uncertainty analysis is undertaken utilising the ensemble of model runs that calibrate the model.- see Section 7.3
5.3 Are the assumed climatic stresses appropriate?	Yes	Good discussion on the various models available and then adoption of some broader changes that encapsulate the modelling to date sourced from the Climate Futures website.

Review questions	*Yes/ No*	*Comment*
5.4 Is a null scenario defined?	Yes	Null scenarios include the other mines in the model domain as well as no mining.
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	NA	NA
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	Yes	Extraction due to mine dewatering is included in the calibration period, but away from the BSP
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	NA	NA
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	Yes	Calibration period is longer than the prediction (end of mining) period
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Yes	NA
5.6 Do the prediction results meet the stated objectives?	Yes	Predictions show impact extent and water take from mine
5.7 Are the components of the predicted mass balance realistic?	NA	NA
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	NA	NA
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	No	Predicted leakage is less than average flow
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	No	No evidence of 'short circuiting' of flows between boundary conditions
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	recharge generally below 1% of rainfall
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	No	NA
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	NA
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Yes	The calibrated ensemble of realisations used to generate model predictions and then these are processed on a cell by cell basis for maximum drawdown and this is presented for the 50th and 95th percentiles. Mine inflows are also shown as a distributed probability range rather than absolutes. This approach is considered appropriate.
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	No	Predictions are presented as probabilistic distributions from the ensemble of model runs that form the calibrated model. This is considered appropriate
6.3 Are the sources of uncertainty discussed?		
6.3.1 measurement of uncertainty of observations and parameters	Yes	Discussed in Section 7.12
6.3.2 structural or model uncertainty	Yes	Discussed in Section 7.12

Review questions	*Yes/ No*	*Comment*
6.4 Is the approach to estimation of uncertainty described and appropriate?	Yes	See Section 7.3, and throughout the reporting of predicted impacts.
6.5 Are there useful depictions of uncertainty?	Yes	The uncertainty shows that across a range of parameters that calibrate the model and a focus on the worst-case impacts, the impacts still remain manageable. The provided 95th percentile of maximum predicted drawdown in the water table shows that the impact to shallow formations will be limited to around the mining area, and the 50th percentile prediction indicates it is likely to be mostly contained within the mining lease area.
7. Solute transport		
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	NA	NA
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	NA	NA
7.3 Is the choice of numerical method and software appropriate?	NA	NA
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	NA	NA
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	NA	NA
7.6 Are the solver and its parameters appropriate for the problem under consideration?	NA	NA
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	NA	NA
7.8 Has an assessment been made of the need to consider variable density conditions?	NA	NA
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	NA	NA
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	NA	NA
7.11 Is the calibration based on meaningful metrics?	NA	NA
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	NA	NA
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	NA	NA
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	NA	NA
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	NA	NA

Review questions	*Yes/ No*	*Comment*
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	Appropriately represented such that impacts on surface water bodies can be predicted.
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Yes	steady river stages consistent with impounded water from weir supplying water for recharge, ephemeral streams and drainage lines are set up to simulate baseflow only
8.3 Is the groundwater model coupled with a surface water model?	No	Not a separate model, but the influence of the surface water system is adequately simulated by the RIV package within MODFLOW-USG
8.3.1 Is the adopted approach appropriate?	Yes	NA
8.3.2 Have appropriate time steps and stress periods been adopted?	Yes	Stage in the Dawson river is regulated by the weir so limited variation means longer stress periods are appropriate. Stress periods were varied to allow for additional recharge from historical flooding to be captured.
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	Yes	Budgets are appropriate and plausible given the flow gauged for Dawson River.