21 February 2023

EMM
Level 4, 74 Pirie Street
Adelaide, SA, 5000

Attention: Dr Doug Weatherill
via email: dweatherill@emmconsulting.com.au

Dear Doug,

Carmichael Coal Mine - Groundwater Model Peer Review

1 Introduction

Carmichael Coal Mine (CCM) is located in the Galilee Basin and is operated by Bravus Mining and Resources (Bravus). CCM is approved for open cut and underground mining and is approved to operate to 2075. The Queensland Department of Environment and Science (DES) granted Environmental Authority (EA) EPML01470513 to Bravus (then Adani) in 2019. Schedule E of the EA pertains to groundwater, with condition E9 requiring a peer review of the updated groundwater model for the mine.

Bravus engaged EMM to update the numerical model for the CCM. EMM, on behalf of their client Bravus, engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to provide a peer review of the updated numerical model which forms part of an updated Groundwater Monitoring and Management Program (GMMP).

2 Methodology

The peer review was undertaken in stages as the model was developed by EMM. EMM provided periodic slide packs of presentations they had provided to DES. No model files were viewed during the peer review process.

The peer review considers if the updated model addresses:

- available guidelines and regulatory requirements for numerical groundwater flow models;
- a compliance checklist of10 essential questions relating to the model; and
- Condition E9 of the EA.

3 Evidentiary basis of review

The reports supplied for review were:

- **Document 1**. EMM (2022), "RP1.6 Hydrogeological conceptualisation review and updated groundwater – Report No. 1 Data review and conceptualisation report", Prepared for Bravus Resources, June 2022.
- **Document 2**. EMM (2023), "Carmichael Coal Mine Report No. 2: Numerical groundwater flow model report". Prepared for Bravus Resources, February 2023.

After an initial review of the documents, a series of questions were posed to EMM. Those questions and the corresponding responses provided by EMM are attached (Attachment A) and referred to as:

- **Document 3**. EMM (2023) Carmichael Coal Mine numerical groundwater flow model report – additional information - Memorandum dated 20th February 2023

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

- **Document 4**. 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).
- **Document 5**. Commonwealth of Australia (CoA), (2018), *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*, Commonwealth of Australia, May 2018.
- **Document 6**. Middlemis H and Peeters LJM (2018), *Uncertainty Analysis – Guidance for groundwater modelling within a risk management framework*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2018.

I have not reviewed any other groundwater investigations that have been undertaken since the approval of the CCM, but rather have relied on the information as provided in Document 1.

4 Model Objectives

The model objectives are provided in Section 1.3 of Document 2. In summary, the objectives of the modelling exercise are to provide a revised / updated model that addresses the requirements outlined in the EA Condition E9, and incorporates the updated conceptual model that has been informed by studies and data collection undertaken since the Supplementary EIS (SEIS)[1].

[1] GHD, 2013, *Carmichael Coal Mine and Rail Project SEIS, Appendix K1: Mine Hydrogeology Report*, report prepared for Adani Mining Pty Ltd.

5 Response to Condition E9 of the Environmental Authority.

The following section lists the requirements of condition E9 of the EA, and my comments on how the documents provided have addressed these requirements.

a) *a review of the hydrogeological conceptualisation used in the previous model*

Document 1 provides this review and incorporates the studies undertaken post the SEIS into the current conceptual model. These studies provide more information on the source of water to the nearby springs including the Doogmabulla Springs complex which Bravus has committed to not impacting. The document compares the updated conceptual model with the understanding of the conceptual model at the time the SEIS was prepared. It includes a list of previous criticisms of the SEIS study and how the updated conceptual and numerical modelling addresses these comments (see Table 13.2 of Document 1).

b) *an update of the predicted impacts*

The groundwater model report (Document 2) provides basecase predictions of drawdown in the key hydrostratigraphic units including the Clematis Sandstone and the AB coal seam for three scenarios. The results of the first scenario that simulates only the open cut mining are further explored through uncertainty analysis. The uncertainty analysis explores the influence of different realisations of parameters on model predictions, and concludes that drawdown at the spring locations is less than the threshold of 0.2 m.

c) *a revised water balance model*

Section 10 of the conceptual report (Document 1) describes groundwater and surface water interaction and presents the data that is available and has been collected since the SEIS. There is a water balance provided with a focus on the springs (see Fig 10.34 of Document 1). A water balance is also provided in Section 5.2 of Document 2.

d) *a review of assumptions used in the previous model*

The numerical model assumptions associated with the model build are described in Section 3 of Document 2.

e) *predictions of changes in groundwater levels for a range of scenarios*

The numerical model was used to simulate three scenarios:

1. open cut only;
2. open cut and underground applying the SEIS fracture height; and
3. open cut and underground, with an updated estimate of fracture height applied.

Further to these, the uncertainty analysis explored 105 realisations of parameter distributions creating a range of predicted water levels and allowing for statistical summaries and probability distributions to be created.

f) *any changes made since the previous model review, including data changes*

This is covered in both Document 1, and in Section 3 of Document 2 where the model design is discussed.

g) *a justification for the refined model and the outputs of the refined model*

Changes in the conceptual model and the numerical model are supported by the additional studies and data collected since the SEIS. Document 1 describes the updated understanding of the groundwater regime resulting from the further data collection. Document 2 explains the updates to the conceptual model and associated changes to the model design.

h) *an evaluation of the accuracy of the predicted changes in groundwater levels, groundwater flow rates to surface water and recommended actions to improve the accuracy of the model predictions*

Document 2, Section 4 describes the history matching conducted for the updated model, which is a process intended to improve the accuracy of model predictions. Section 7 of Document 2 provides a series of recommendations for future data collection and updates to the model intended to improve the history matching ability of the model and reduce the range of uncertainty in future predictions. Ultimately the accuracy of predictions can only be assessed in hindsight once further data becomes available.

i) *an independent peer review and certification that the environmental authority holder has undertaken the review in accordance with all commitments in the GMMP*

This document is intended to address this condition.

6 General review comments

6.1 Model design

The following comments are provided on the updated model design:

- The model has been completely rebuilt using new software, and an improved understanding of how the groundwater systems within the main hydrostratigraphic formations may interact, including more information on the source for the Doongmabulla springs from studies undertaken by Bravus per the licence requirements.
- The model extent has been kept consistent with the previous SEIS modelling. This has been driven by the objective to make comparisons to the previous work.
- Conceptually the model domain is a flowthrough system from west, north and south, to the east. This process has been simulated with constant heads in the model. This approach can drive water levels within the model domain and can interrupt the ability to conduct water level history matching. Upon initial inspection the model boundaries appeared to be sufficiently distant to prevent this being a significant issue, however review of the maximum drawdown in the coal seams indicates drawdown does reach the model boundary in the west.
- The springs have been represented by assigning the drain return flow boundary condition to the Clematis Sandstone at the respective spring locations. This boundary condition allows for the distribution of water removed from the Clematis source formation to be returned as recharge to layer 1 in the model, thus replicating the spring flowing to the surface. This approach is considered appropriate.
- Faults have not been specifically modelled as there is little evidence of significant faults occurring in the mining area. This approach is considered acceptable as the model represents some spatial variability / heterogeneity in hydraulic properties that has the potential to capture the influence of any unknown faults if there is a differing water level response on either side.

6.2 Model history matching

The following comments are provided on the history matching process and outcomes:

- It is commendable to see the observation dataset used for history matching includes both absolute water level, as well as relative change / water level behaviour. This is good practice.
- It is not clear if there was an opportunity, and sufficient data, to utilise baseflow recorded at new surface water gauging sites on the local creeks in the history matching process, but this is recommended in further model iterations as the dataset available expands.
- The level of 'fit' achieved during the history matching process is considered acceptable, although there might be some systematic boundary condition influence in the lower discharge areas of the model, as evident in the pre-mining scatter diagram. Here the flattening of scatter and inability of predictions to fall below 215 mAHD indicates a structural influence, likely why the SRMS value for these absolute observations were higher at around 10%. More detail was requested from EMM on this aspect through Question 7 of Document 3 and they confirmed structural controls were likely influencing water level predictions in this area of the model.
- Reviewing the base case parameter distributions in Appendix B of Document 2, it is apparent that a number of the datasets, particularly for specific yield for deeper units have a basecase and the majority of realisations assigned to the upper bounds. In the case of specific yield this has numerous formations with a value of 0.1 (or 10%). This is potentially a higher value than typical and is resulting in predictions of relatively large groundwater inflows to the mining areas.
- The calibrated specific storage value distributions are biased towards low values for the deeper formations, particularly the coal seams, with values reaching their theoretically lowest plausible value, and potentially not representative of the coal seams even at depth. The outcome of this assumption is predicted drawdown within the coal seams will propagate further and at a quicker rate than would occur with less extreme values.
- Through the history matching process there will always be bores that don't match well, or have a poor match in favour of better matches at a numbering of neighbouring bores. Some of the hydrographs presented in Appendix C demonstrate this. However, where there is a mis-match in the starting water level, the model is generally still able to replicate the observed water level trend.

6.3 Model predictions

The following comments are provided on the model predictions:

- Three scenarios were developed which provide insight into the impact of underground mining over just open cut mining, and also the influence of the different fracture heigh estimates.
- The 'high-K' lake is approach to represent the residual void lake. This approach uses very high values of hydraulic conductivity and storage to represent the open void remaining post mining. The hydraulic conductivity value assigned is nominally high enough to readily connect water between model cells (as would be expected within a lake), and the specific yield value of 100% means that the entire volume of the cell is available to receive water and the unconfined water level changes linearly with added or removed water. Once the water level in the void cell gets high enough, the cell becomes confined (the water level moves above the top of the model cell and starts saturating the cell above). At this point the storage properties of the cell that is confined are described by the specific storage. EMM have assigned a specific storage value of 1.3×10^{-5} m^{-1} (note there is an error in Document 2 which records the units as m/d, rather than m^{-1}). The adopted value is at the theoretical upper limit of plausible specific storage values in confined media. This means that despite the cell being 'full', the high specific storage means that the cell can continue to receive water. When the cell is full, the value assigned to specific storage should approximate the compressibility of water, with a value of $5.0 \times 10^{-6} m^{-1}$. The implications for the model are that the final void water level will fill slower and ultimately be at a lower predicted level for the given inputs. I raised this with EMM and they acknowledged the error (see Question 4 in Document 3). I recognise the equilibrium water level in a void is a balance between the inputs (rainfall recharge and runoff, groundwater inflow) and outputs (evaporation), and in most cases groundwater inflow is significantly smaller than the other components. This means that the influence of this parameter is likely to be small. This issue could be overcome by adding a steady state stress period to the end of the transient post mining recovery to provide the equilibrium levels. Based on the hydrographs in Document 2 Appendix D it is not clear if a pseudo steady state in water levels has been reached at year 4000.
- Document 2 Figure 3.33 indicates the pit void depth which is assumed to be the final landform. I can appreciate that the detailed planning around what the final landform will look like may not be available at this point in time, but I would have expected the backfilling in the pit to bulk up and not be starting at 3 m or more below surface topography for areas along the eastern side of the pits.
- There are no equilibrium / long term drawdowns provided in the report. It would be helpful to visualise where the extent of the pit lake is within the pit extent.
- Water budgets indicate the dominant component is throughflow – water coming in from the west, north and south, and exiting the model domain as either evaporative losses or as throughflow in the east. This representation is supported by the conceptual model, and reflects the concept adopted in the original SEIS model. The assigned constant heads at the western boundary are influencing drawdown extents in the coal seams (and possibly other layers). This can be seen in Document 2 Figures 5.9 to 5.11, with the drawdown becoming zero right around the boundary. Given the dominant volume of throughflow in the model budget I posed Question 13 in Document 3. EMM confirmed that the budget does change in the predictive phase with an increase to the net inflow of 14 ML/day. The drawdown reaching this boundary is a function of the low coal seam specific storage. This will be a feature that needs review in future model updates, particularly as the specific storage values are refined through history matching to water levels influenced by nearby mining.

6.4 Uncertainty analysis

The following comments are provided on the uncertainty analysis:

- The uncertainty analysis has been undertaken on the scenario that simulates the 'open cut only' mining. The report does not treat the uncertainty analysis as a separate exercise, rather it is woven through the various prediction reporting. There is only one drawdown contour plot presented and this is for the Clematis Sandstone. This is an appropriate hydrostratigraphic unit to focus on as evidence to date suggests this is the likely water source for most of the springs in the area.
- The calibration results show not only the basecase model results, but also the results from the other 104 realisations that form the uncertainty analysis. This approach is helpful as it provide insights into the variability of predictions from each history matched model.
- Drawdown hydrographs are provided for observation bores and at spring locations in Document 2 Appendix D (for the open cut only scenario) and show all the realisations as well as the probabilities of the drawdown being less than the indicated hydrograph. These graphs all show the critical spring drawdown, however it is only necessary to show on hydrographs that represent spring predictions.

7 Confidence level classification

The Australian groundwater modelling guidelines provide a method of assessing a model's confidence level and infers typical uses for a model based on specific characteristics. Document 2 did not include a 'self-assessment' according to the modelling guidelines, and as such I have undertaken this as part of the peer review process.

Under the guidelines, this model would be classified as a Confidence Level 2 groundwater model, with the following key indicators (based on Table 2-1 of Barnett et al., 2012):

- rainfall and evaporation data are available for the site (Level 3);
- groundwater head observations and bore logs are available and with a good coverage around the Carmichael site, but without spatial coverage throughout the model domain (Level 2);
- some site and field properties are available, but missing some estimates of storage (Level 2);
- scaled RMS error and other calibration statistics, e.g. mean residual, are acceptable (Level 3); and
- Transient calibration and predictions are conducted (level 2).

The indicated use for the model based on this classification is for the assessments of impacts.

Table 7.1 Confidence Level Classification (After Table 2-1, Barnett et al, 2012)

Class		Data		Calibration		Prediction		Quantitative Indicators
1 (Simple) Count=0	×	Not much	×	Not possible	×	Timeframe >> Calibration	×	Timeframe > 10x
	×	Sparse coverage	×	Large error statistic	×	Long stress periods	×	Stresses < 5x
	×	No metered usage	×	Inadequate data spread	×	Poor/no validation	×	Mass balance > 1% (or one-off 5%)
	×	Low resolution	×	Targets incompatible with model purpose.	×	Transient prediction but steady-state calibration	×	Properties < > field values
	×	Poor aquifer geometry					×	No review by Hydro/Modeller
2 (Impact Assessment) Count=12	×	Some	✓	Partial performance	✓	Timeframe > Calibration	×	Time frame = 3-10x
	✓	Ok coverage	✓	Some long term trends wrong.	×	Long stress periods	×	Stresses = 2-5x
	~	Some usage data/ low volumes	✓	Short term record.	×	Ok validation	✓	Mass balance <1%
	×	Baseflow estimates. Some K & S measurements	~	Weak seasonal match.	✓	Transient calibration and prediction	✓	Some properties < > field values. Review by Hydrogeologist
	✓	Some high resolution topographic DEM &/or some aquifer geometry	✓	No use of targets compatible with model purpose (heads & fluxes)	✓	New stresses not in calibration	×	Some coarse discretisation in key areas of grid or at key times
3 (Complex Simulator) Count=9	~	Lots, with good coverage.	✓	Good performance stats	×	Timeframe ~ calibration	×	Timeframe < 3x
	~	Good metered usage info.	×	Most long term trends matched	×	Similar stress periods	×	Stresses < 2x
	✓	Local climate data	~	Most seasonal matches ok.	×	Good validation	✓	Mass balance < 0.5%
	~	Kh, Kv & Sy measurements from range of tests	✓	Present day data targets	×	Calibration & prediction consistent (transient or steady state).	~	Properties ~field measurements
	×	High resolution DEM all areas.	×	Head & Flux targets used to constrain calibration	×	Similar stresses to those in calibration.	✓	No coarse discretisation in key areas (grid or time)
	~	Good aquifer geometry.					✓	Review by experienced Modeller

Notes: Criteria met = ✓
Criteria partially met = ~
Criteria not met = ×

8 Compliance checklist

The Australian groundwater modelling guidelines provide a generic compliance checklist to assess a model at a high level. Because this assessment has relied on the reporting and not examined model files, nor the background reporting underpinning the conceptual model update, this is the most appropriate level to comment at. The 10 questions that form this checklist cover essential elements of a groundwater model.

The checklist is sourced from Table 9-1 of the Australian groundwater modelling guidelines (Document 4).

Table 8.1 Compliance Checklist

Question	Yes / No	Comment
1. Are the model objectives and model confidence level classification clearly stated?	Yes	The model objectives are outlined in Section 1.3 of the Document 2. The report does not provide a self assessment of the confidence level classification, but one has been carried out as part of this review.
2. Are the objectives satisfied?	Yes	The updates to the conceptual model presented in Document 1 have been amalgamated into the updated model (see Section 4 of this review).
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes	While there is no self-assessed confidence limit provided in the reporting, one has been undertaken for this review and assessed the model as having a confidence level classification of Level 2. This is supported by the additional data that underpins the conceptual model assumptions and the conceptual model
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	The conceptual model has been presented in Document 1. It was peer reviewed by Dr Noel Merrick who is appropriately qualified to review the document.
5. Does the model design conform to best practice?	Yes	The model uses the most up to date industry standard software (MODFLOW-USG) and applies features (such as adopting Voronoi cells in the mesh) that are best practice. The design has been a little constrained by needing to be comparable to the previous model in some places, such as model extent. The model utilises a transient pre-mining 'warm up' stage to help with solving the steady state model representing pre-mining conditions.
6. Is the model calibration satisfactory?	Yes	The calibration statistics satisfy targets, however the scatter diagram indicates some systematic mis-match – assumed to be due to boundary condition influence, and confirmed by EMM in response to Question 7 in Document 3. The calibration process has been thorough and has utilised emerging techniques with PESTPP-IES and ensemble smoothing to reduce the computational effort. The methodology and approach were sound and following the principles of the GMDSI, whereby after some initial range finding calibration with single values, the model was assigned a significant amount of pilot points totalling 30960 (7,740 per hydraulic parameter) to describe heterogeneity in the system and later explore parameter uncertainty.

Question	Yes / No	Comment
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Many parameters are matching to the conceptual model and field data that underpins it. However, some resulting hydraulic properties from the calibration, particularly the storage properties have calibrated to the predefined upper and lower bounds. This could be an indication of insensitivity in the parameter and the calibration process searching to make those parameters more sensitive and reaching the bounds. This aspect was explored in Question 9 of Document 3 (attached). It is noted that the calibrated steady state and transient water budgets are dominated by throughflow. This was a feature of the SEIS model and is part of the conceptual model.
8. Do the model predictions conform to best practice?	Yes	The predictive phase and the simulation of the mine dewatering through drains and applying property changes within the fracture zone, are aligned to best practice. The reporting is not clear on the exact details of how the mining progresses, but further information was provided by EMM in response to Question 1 in Document 3. Backfilling of spoil seems to be made at the end of mining. There is a tabulated schedule that indicates that mining remains active in the mining domains once it starts all the way through to the end of mining in 2075. The TVM package is used to make changes to hydraulic properties prior to the post mining phase of the predictions and this can be considered current best practice. Fracture height calculations using best practice have identified a significant change in a previous assumption for this value, thus the formulation of a number of prediction scenarios to explore the difference that this change creates. The presentation of drawdown within the model results comes from the maximum drawdown experienced at that location both during and after mining, which can be considered best practice. There has not been any climate change scenarios run. This included in the next model update.
9. Is the uncertainty associated with the predictions reported?	Yes	Hydrographs at bores and the critical 0.2 m drawdown in the Clematis Sandstone are presented with probabilistic measures. There is no uncertainty analysis provided for the mine inflow predictions, though EMM's response to Question 11 in Document 3 indicates that spot checks were carried out with some of the realisations which suggest variability of ±20% from the basecase prediction.
10. Is the model fit for purpose?	Yes	See Section 9 below.

9 Is the model 'fit for purpose'?

The purpose/scope of the model is outlined in Section 1.3 of the model report. In summary the purpose of the model is to provide predicted impacts on various groundwater 'receptors' utilising the updated data and conceptual understanding of the groundwater regime. This has been achieved.

While the review has identified some aspects of the model development that could be improved on in future versions, those aspects (such as low specific storage and high hydraulic conductivity in the coal seams) enhance the extent of predicted impacts on groundwater levels and are therefore conservative.

The model should be able to indicate the likelihood of an unacceptable impact occurring. In this case it would be drawdown at the Doongmabulla Springs complex exceeding 0.2 m. For the situation where only the open cut is mined, the basecase prediction indicates that the maximum drawdown at any time within the Clematis sandstone is below the threshold of 0.2 m. This is then further explored through uncertainty analysis where the impact at the springs for all the accepted parameter realisations is also less that 0.2 m during and post mining.

The 'SEIS B' basecase prediction for the combined opencut and underground mine plan, where the updated fracture height calculation is adopted, does indicate that there is a potential for the groundwater drawdown threshold at the springs is exceeded. The options for underground mining will need to be explored over the coming years as this may only occur if Bravus undertake certain parts of the underground mining.

Further data collection into the future and subsequent revisions of the model may change that prediction with time, however at this stage of development the is model is providing useful insight for both mine planners and regulators.

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

- provided an update and improvement over the previous SEIS modelling;
- represented the updated conceptualisation in an appropriate way;
- captured the key bulk water movements into and out of the model;
- applied appropriate best practice where possible;
- been able to replicate water behaviour successfully in the model domain; and
- meets the requirements to be considered '**fit for purpose**' at this stage of development.

10 Recommendations for future work

The following recommendations are offered:

- Undertake simulations that represent the potential impact of climate change on rainfall and evaporation.
- Calculate the fracture height on a cell by cell basis.
- Utilise observed flows (baseflow / mine inflow) in future model history matching.
- Ensure the bore network is sufficient to detect the outward propagation of impacts as this will assist calibration to storage properties.

Yours faithfully,

Andrew Durick
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Memorandum

20 February 2023

To: Andrew Durick

From: Tom Neill, Doug Weatherill & Joel Georgiou

Subject: Carmichael Coal Mine numerical groundwater flow model report - additional information

Dear Andrew,

See the below response to the queries from your email dated 20 February 2023.

1.1 Question 1

Q: How was the mining progressed within the pits? I know it was application of the DRN package, but looking at the Fig 3.31 I am wondering if these base of pit elevations were used to drop drain elevations across the footprint of the pit with time? Or alternatively, has there been a progression from east to west within each pit with a working area or window down to the floor of the pit and backfilled spoil behind (or drains left active), but slowly approaching the deepest points with time? There is an earlier mention of a "staged mine plan (refer Appendix D)" in Section 3.5.5 ii, but this might have been some earlier version of the report as I haven't been able to find the staged mine plan anywhere.

A: The mine plan was provided by Bravus in 5-year increments from 2024 to 2055, and then 10-year increments to 2075. These were implemented in the model using the DRN package at these corresponding footprints/elevations held constant from activation at the beginning of the stage through end of mining. For example, the '2034' mine geometry was activated in 2029 and held constant until the end of mining. Subsequent DRN boundary conditions with lower stage elevation then control the modelled in-pit groundwater elevation. Figure 3.31 presents an interpolation between the stages provided to EMM but does not represent how the mine was modelled. This is why we smooth drain inflow across multiple stress periods.

1.2 Question 2

Q: In 3.5.5 ii, in the last paragraph I think I follow the smoothing of drain inflow across stress periods (and possibly multiple stress periods), but I am not making the link between this and why this is conservative to predicting drawdown. Clarity around Q1 might help in this regard, but if not, I might need the line drawn.

A: As mentioned above, modelled in-pit groundwater levels show drawdown occurring up to 10 years earlier than is expected, due to the temporal discretisation of the available mine plan. This is conservative when predicting timing of impacts but is not expected to have significant impact on their total magnitude.

1.3 Question 3

Q: In regard to the ramp function for fracture zone changes (section 3.5.5 iii), my understanding is that this gets applied to each model cell in the fracture zone (within 230m above the caved zone), where the cell elevation (from centroid?) is applied to the log-linear relationship between to get a new K at that location. Initially, and based on the figure, I thought this could have been relying on whatever host K existed at the 230m above cave zone, and then the interpreted change using that host K for all the layers in that cell column. I think I understand it better now. With that in mind, is this applied to both Kh and Kv, using their respective host K values? As the 230 m was an average from the Merrick 2021 calcs, what was the range? Has Hmax been allowed to vary from location to location (possibly cell by cell)? I am asking because the fracture height calculation uses overburden thickness and I wonder how much this varies across the planned underground footprint.

A: Your understanding of elevation from centroid is correct, as is the modification to the in-situ hydraulic conductivity. This was applied to both Kh and Kv, with the assumption that Kh = Kv in the cave zone. Hmax was held constant for the full mine footprint, acknowledging the variance for the actual mine plan. This is a simplifying assumption that would have an impact on modelled property changes, but it was considered during model design that the uncertainty in estimated fracture height, cave zone properties, and ramp function did not justify the full detail being represented in the groundwater model.

1.4 Question 4

Q: In post mining recovery (Section 3.5.5 iv) the specific storage term for the void is reported to be "$1.3x10^{-5}$ m/d". Looking beyond the incorrect units, this value is very high. The usual approach in a 'high-k' lake is to apply a specific storage equivalent to the compressibility of water. Once the water level in a cell representing the void reaches the top of the cell, that cell becomes confined in the model and the water level moves above the top of the model cell and starts saturating the cell above. When this happens, any additional water received by the fully saturated (confined) void cells should be effectively passed to the partially saturated cell above as there should be no additional storage available in the confined cells. Applying a value at the upper bound of specific storage (like that reported) means that this cell will continue to store water that flows into it from surrounding strata, which will ultimately lead to an under prediction of the water level in the void with time, and result in a lower equilibrium water level. It is impossible to say if this will change the conclusion that the final void/s will act as a sink, I suspect not, but I can't be sure.

A: Acknowledged but given that the post-mining recovery period is run to pseudo steady-state, the values for storage do not influence final modelled groundwater elevations (it more so affects the rate of recovery). The mine is conceptualised to remain a sink because the voids are only backfilled to the coal seam elevations, yet the pre-mining watertable is much higher.

1.5 Question 5

Q: The use of the CLN package in the void is clever, but does it remove the influence of the pit geometry (i.e. lower evaporation due to limited wind, shade, etc), or is that accounted for in other ways?

A: That is accounted for by reducing the maximum 'evaporation' rate to 70% of pan evaporation. Again, this is a simplifying assumption but one we typically use to account for geometry impacts for pit void recovery problems. The CLN package was also chosen to promote numerical stability.

1.6 Question 6

Q:There is no presentation of post mining equilibrium groundwater conditions. Is this not required for the project? Water levels at some key bores are shown post mining, but that does not give the overall picture post mining.

A: No request has been made for post-mining groundwater conditions beyond simulated drawdown. However, we agree that a final modelled groundwater contour map would be useful from a readers perspective.

1.7 Question 7

Q: Looking at the scatter diagram (Fig 4.12) for pre-mining conditions, there seems to be a systematic flattening of predicted water levels. Is there something in the model (i.e. boundary condition elevation around 215 mAHD) that might have led to this? I noticed reasonable amount of alluvium and weathered hydrographs were over predicting around that 10 to 20m range. On the other hand, some were well under. Could the over predictions be the influence of stream recharge in the steady state? The hydrographs did seem tight across the range of realisations pointing to a boundary condition influence.

A: There are definite structural controls preventing improved history-matching performance and leading to tighter hydrographs in the uncertainty suite. This was observed through the history-matching process. An improvement we are happy to make is to add a spatial residual map with some supporting commentary. This would clearly show areas where the model over simulates modelled heads and, perhaps, underpredicts discharge processes.

1.8 Question 8

Q: In the hydraulic properties comparison (Table 4.5), does hydraulic conductivity refer to both Kh and Kv?

A: Yes. Comparisons are slightly 'fuzzy' due to the range of values in the updated model. We can add further clarity in Section 4.4.1 text.

1.9 Question 9

Q: Looking at the basecase parameter distributions in Appendix B, it is apparent that a lot of parameters have clustered around their upper and lower bounds. From memory this was a 'feature' of the ensemble smoothing process. Was there consideration given to that during the history matching phase?

A: Yes, and there was an apparent trade-off between history-matching performance and parameter clustering around the assigned bounds. The reported values were developed to provide as close a match as possible to measurements, acknowledging the influence this would have on clustering. Note that the presented histograms are not for an individual parameter at a single pilot point, but for all pilot point values across an HSU/model layer.

1.10 Question 10

Q: A number of the specific yield values for various deeper units (including the coal seams) have gone to 0.1 (10%), while the corresponding specific storage values are at the theorical lowest values. Is that result expected and in line with the conceptual model? These values will have an influence on the inflow volume to the mine.

A: The values are highly significant for modelled mine inflows; an increase in Sy compared to previous modelling resulted in a proportional increase in modelled inflow. As discussed in-text, these parameters should be prioritised for future modelling to improve predictive accuracy. In the next 5-year modelling phase, there will be a significant amount of drawdown data to support history-matching within the Permian and thus a tighter range on Sy should be achievable. It is acknowledged that, as it is, the model is likely overpredicting mine inflows. In terms of modelled vs measured aquifer properties, EMM is happy to add box-and-whisker plots within the history-matching chapter to assist with this comparison.

1.11 Question 11

Q: The uncertainty analysis has been presented for bore hydrographs and one set of drawdowns in the Clematis, but there is no summary of how the mine inflow changed for various realisations. Was this assessed?

A: Only nominally. A couple of spot checks were performed based on parameter values, which suggested a peak inflow range of ±20% relative to the base realisation, which is still significantly higher than the SEIS groundwater model. The focus of the project was on likelihood of drawdown at the DSC.

1.12 Question 12

Q: Was there any analysis on the 105 accepted realisations to confirm that this was a sufficient number of realisations – i.e. looking at statistical summaries which stabilise after each realisation is added in, such that adding additional realisations does not change the summary stats?

A: No, a formal ensemble size convergence study was not carried out. However, experience suggests that 100 accepted realisations is typically sufficient to achieve stabilised statistical predictive outcomes.

1.13 Question 13

Q: The drawdown in the coal seams reaches the boundaries through the mining period. The drawdown becomes zero at the boundary because of the constant head boundary condition. For this to occur the flow across the boundary must increase. The only reporting of these volumes are in Figures 5.1 to 5.3, but the scale makes it impossible to read. What were the increases for the boundary inflows? What changes were predicted to baseflow / stream leakage through the mining period? Did evaporation reduce with drawdown?

A: Net constant head boundary flux to the model increases by approximately 14 ML/d through the mining period (increase of 60%). Evapotranspiration reduces by around 1 ML/d (decrease of 9%), DSC seepage by around 0.1 ML/d (decrease of 9%), and river baseflow by around 0.05 ML/d (decrease of 3%).

1.14 Question 14

Q: Finally I noticed a few changes in some parameters from the Jan 10 presentation to the report (such as height of fracturing, recharge into Rewan and regional extinction depth). Were these changed in the model post that meeting, or does the report need to be updated to the presented values?

A: The parameters in the model report are the final values; not the parameters in the Jan 10 presentation. Those were superseded due to some detailed interim discussions with Noel Merrick.

Yours sincerely

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