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Meeting date:	12 July 2018
To:	Milos Pavlovic; Alex Russo
From:	Cassie Turvey; Damien Janssen
Subject:	Mesa H Groundwater Modelling Review

Dear Milos,

RPS has undertaken a review of recent groundwater modelling for Mesa H completed by AQ2. Mesa H is an iron ore operation located immediately west of the existing Mesa J mine, 17 km south-west of Pannawonica. Mining at Mesa H is proposed from 2020 to 2037.

The following document was reviewed:

AQ2 ref – 182B_006c_FINAL / RTIO ref - RTIO-PDE-0161936 including associated figures and appendices.

The key objectives of the model were to:

- Assess the dewatering rates necessary to facilitate dry mining conditions at Mesa H and Mesa J; and
- Assess the impacts of dewatering and water supply abstraction (including cumulative impact of the Coastal Water Supply project at Bungaroo Valley) on regional groundwater levels and surface water pools along the Robe River and Jimmawurrada Creek.

Modelling Review Focus

It is understood that the model and the modelling report have been through several iterations over a number of years. The Mesa H Groundwater Modelling Report was reviewed by a third party in 2016. Minor changes to the 2016 model were made for this report with the majority of setups and results remaining consistent with the original 2016 model. However, for the purpose of documentation a review has been undertaken as per recommendations in the Australian Groundwater Modelling Guidelines (NWC, 2012). Results are presented in the following tables for (1) Overall Compliance, (2) Planning, (3) Conceptual Model, (4) Design and Construction, (5) Calibration and Sensitivity, (6) Prediction, (7) Uncertainty, (8) Surface Water-Groundwater Interaction.

In addition to the review from a numerical standpoint, we have also made some comment in terms of operational considerations in reference to the key objectives of the modelling exercise.

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Overall Compliance	Yes/No	Comment
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Dewatering requirements and impacts due to dewatering/water supply
2. Are the objectives satisfied?	Yes	
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes	Level 2 confidence level
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	Conceptual model details within separate report
5. Does the model design conform to best practice?	Yes	
6. Is the model calibration satisfactory?	Yes	No statistics presented, but hydrographs indicate good calibration in most locations
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	
8. Do the model predictions conform to best practice?	Yes	
9. Is the uncertainty associated with the predictions reported?	Yes	Only for impacts to water levels along rivers
10. Is the model fit for purpose?	Yes	

2. Planning	Yes/No
1.1 Are the project objectives stated?	yes
1.2 Are the model objectives stated?	yes
1.3 Is it clear how the model will contribute to meeting the project objectives?	yes
1.4 Is a groundwater model the best option to address the project and model objectives?	yes
1.5 Is the target model confidence-level classification stated and justified?	yes
1.6 Are the planned limitations and exclusions of the model stated?	yes

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3. Conceptualisation	Yes/No	Comment
2.1 Has a literature review been completed, including examination of prior investigations?	half	Very brief mention of previous AQT/RPS work, RTIO conceptual model. None by others - maybe isn't any.
2.2 Is the aquifer system adequately described?	yes	Separate conceptual report
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	yes	
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	yes	Separate conceptual report
2.2.3 aquifer geometry including layer elevations and thicknesses	yes	Separate conceptual report
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	yes	Separate conceptual report
2.3 Have data on groundwater stresses been collected and analysed?	yes	Separate conceptual report
2.3.1 recharge from rainfall, irrigation, floods, lakes	yes	Separate conceptual report
2.3.2 river or lake stage heights	unknown	
2.3.3 groundwater usage (pumping, returns etc)	yes	Separate conceptual report
2.3.4 evapotranspiration	yes	Separate conceptual report
2.3.5 other?	yes	TSF seepage
2.4 Have groundwater level observations been collected and analysed?	yes	
2.4.1 selection of representative bore hydrographs	no	Not discussed in modelling or conceptual report
2.4.2 comparison of hydrographs	no	Not discussed in modelling or conceptual report
2.4.3 effect of stresses on hydrographs	no	Not discussed in modelling or conceptual report
2.4.4 watertable maps/piezometric surfaces?	yes	Separate conceptual report
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of	unsure	Not discussed in modelling or conceptual

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3. Conceptualisation	Yes/No	Comment
groundwater head and flow data?		report
2.5 Have flow observations been collected and analysed?	yes	Robe River only at Ngalooin Pool
2.5.1 baseflow in rivers	no	Not discussed in modelling or conceptual report
2.5.2 discharge in springs	no	Not discussed in modelling or conceptual report
2.5.3 location of diffuse discharge areas?	no	Not discussed in modelling or conceptual report
2.6 Is the measurement error or data uncertainty reported?	no	Not discussed in modelling or conceptual report
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	no	Not discussed in modelling or conceptual report
2.6.2 spatial variability/heterogeneity of parameters	no	Not discussed in modelling or conceptual report
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	no	Not discussed in modelling or conceptual report
2.7 Have consistent data units and geometric datum been used?	yes	
2.8 Is there a clear description of the conceptual model?	yes	Separate conceptual report
2.8.1 Is there a graphical representation of the conceptual model?	half	Lithology and water table presented, no indication of recharge/discharge/flow directions or changes due to mining
2.8.2 Is the conceptual model based on all available, relevant data?	yes	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	yes	
2.9.1 Are the relevant processes identified?	yes	Separate conceptual report

3. Conceptualisation	Yes/No	Comment
2.9.2 Is justification provided for omission or simplification of processes?	yes	
2.10 Have alternative conceptual models been investigated?	unsure	

4. Design and Construction	Yes/No	Comment
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-Surfact
3.2.1 Are the numerical and discretisation methods appropriate?	yes	
3.2.2 Is the software reputable?	yes	
3.2.3 Is the software included in the archive or are references to the software provided?	yes	
3.3 Are the spatial domain and discretisation appropriate?	yes	
3.3.1 1D/2D/3D	3D	
3.3.2 lateral extent		
3.3.3 layer geometry?	half	Reasonable layer thicknesses, layer elevations could be improved
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	yes	
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	
3.4 Are the temporal domain and discretisation appropriate?	yes	
3.4.1 steady state or transient		Both
3.4.2 stress periods		Annual

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4. Design and Construction	Yes/No	Comment
3.4.3 time steps?		Not stated in report (monthly)
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	yes	
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	yes	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	yes	GHB and STR boundary conditions for river flow affect model outcomes (as intended and consistent with conceptual model). No flow at basement outcrop.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	yes	
3.5.4 Are lateral boundaries time-invariant?	yes	Except where lowered to simulate dewatering by CWS borefield
3.6 Are the initial conditions appropriate?	yes	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?		Steady state modelling to provide initial heads to transient calibration
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	NA	
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	
3.7 Is the numerical solution of the model adequate?	yes	
3.7.1 Solution method/solver	not stated	Milos old GWV: PCG5, pseudo soil with upstream weighting
3.7.2 Convergence criteria	not stated	Milos old GWV: head change 0.005
3.7.3 Numerical precision	not stated	Mass balance values imply ~0% error

5. Calibration and sensitivity	Yes/No	Comment

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5. Calibration and sensitivity	Yes/No	Comment
4.1 Are all available types of observations used for calibration?		
4.1.1 Groundwater head data	yes	
4.1.2 Flux observations	no	Should report obs v mod for dewatering volumes and pumped volumes to date.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc	no	
4.2 Does the calibration methodology conform to best practice?	yes	
4.2.1 Parameterisation	yes	
4.2.2 Objective function	yes	Comparison of obs v modelled (visual in hydrographs). Assume some statistical measure considered during calibration (e.g. minimising sum of squares, SRMS etc)
4.2.3 Identifiability of parameters	yes	
4.2.4 Which methodology is used for model calibration?	not stated	Assume only manual
4.3 Is a sensitivity of key model outcomes assessed against?	not stated	
4.3.1 parameters	not stated	Intrinsic sensitivity during calibration assumed but not reported
4.3.2 boundary conditions	not stated	Intrinsic sensitivity during calibration assumed but not reported
4.3.3 initial conditions	not stated	Intrinsic sensitivity during calibration assumed but not reported
4.3.4 stresses	not stated	Intrinsic sensitivity during calibration assumed but not reported
4.4 Have the calibration results been adequately reported?	half	Hydrographs, no stats

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5. Calibration and sensitivity	Yes/No	Comment
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	yes	Indicate good calibration
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	no	Multilevel VWP's or nested piezos should be plotted on single chart
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	no	Not reported, but likely good based on hydrographs
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	no	
4.5.1 spatially	no	Map of residuals to indicate any areas which perform less well
4.5.2 temporally	yes	Hydrographs
4.6 Are the calibrated parameters plausible?	yes	
4.7 Are the water volumes and fluxes in the water balance realistic?	yes	
4.8 has the model been verified?	no	Recommendation for verification and re-calibration was made in report

6. Prediction	Yes/No	Comment
5.1 Are the model predictions designed in a manner that meets the model objectives?	yes	
5.2 Is predictive uncertainty acknowledged and addressed?	yes	Particularly in relation to rivers and mine plan
5.3 Are the assumed climatic stresses appropriate?	yes	
5.4 Is a null scenario defined?	yes	
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	yes	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there	yes	

6. Prediction	Yes/No	Comment
reference to the associated reduction in model confidence?		
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	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	
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	yes	
5.6 Do the prediction results meet the stated objectives?	yes	
5.7 Are the components of the predicted mass balance realistic?	yes	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	unknown	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	no	
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	
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	yes	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	unknown	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	

7. Uncertainty	Yes/No	Comment
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	yes	Ranked by drawdown
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	no	No consideration of impact on calibration results
6.3 Are the sources of uncertainty discussed?	yes	

7. Uncertainty	Yes/No	Comment
6.3.1 measurement of uncertainty of observations and parameters	yes	
6.3.2 structural or model uncertainty	yes	
6.4 Is the approach to estimation of uncertainty described and appropriate?	yes	
6.5 Are there useful depictions of uncertainty?	yes	

8. Surface water–groundwater interaction	Yes/No	Comment
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	yes	Noted uncertainty due to limited data
8.2 Is the implementation of surface water–groundwater interaction appropriate?	yes	
8.3 Is the groundwater model coupled with a surface water model?	no	
8.3.1 Is the adopted approach appropriate?	na	
8.3.2 Have appropriate time steps and stress periods been adopted?	na	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	na	

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Guideline Model Review Discussion

The modelling has been undertaken to a high standard and is fit for its intended purpose, being the prediction of dewatering and water supply volumes, and the prediction of impacts to water levels along the Robe River and Jimmawurrada Creek. There are no areas of concern that would have a material effect on the predicted outputs of interest. General comments and minor corrections have been included as tracked changes in the report document.

It is understood that the model has been dramatically simplified in recent years in order to improve run-times. However, considerations for model improvements during future work may include the following:

- Verification of model predictions and re-calibration if required to recent monitoring along the Robe River (as indicated within the report)
- Representation of actual topographic surface as top of model Layer 1.
- Layer bottom elevations more indicative of key lithological horizons shown in conceptual models Figure 3 (assuming geological model for the site is readily available)
- Reduction of stress period length from annual to monthly in order to more accurately represent seasonal fluctuations in both calibration and prediction runs to end of mining. Refine recharge, EVT and stream flow volumes accordingly.
- Inclusion of recorded dewatering volumes from existing mining as a calibration target.
- Characterisation of hydrogeological properties of major faults mentioned in conceptual model for inclusion in the model. Due to the often uncertain nature of faults acting as barriers or conduits (typically both), uncertainty analyses on fault properties may be most appropriate. The conceptual model report notes Yeera Bluff Pool exists as a result of fault structures.
- Application of fill properties/recharge post completion of mining using the TMP package in predictive runs
- Depending on need for water management planning purposes, additional uncertainty analyses with focus on predicted ranges in results of dewatering/water supply volumes and resulting drawdowns may be warranted using standard conductivity/storage parameter perturbation (+/- inclusion of faults as above).

Operational / Planning Considerations

Reviewing the modelling work with regards to the key objectives, and with consideration of the implications of uncertainties for planning and operational management purposes, we make some comments below.

Assessment of Future Dewatering Requirements

In reviewing the model report, it is noted that the calibration and prediction runs focused on the hydrographs and water levels for a verification of calibration confidence. In terms of water balance, the various water balance components within the model seem to be at the lower end of ranges identified in the conceptual hydrogeology report for the area. It may be worth additional enquiry of the calibration model to better understand the modelled abstraction volumes simulated to achieve the drawdowns and cross-check those against the actual dewatering volumes historically. This will enable a greater degree of confidence in the predicted dewatering volumes – as you may gain an appreciation that the model has a tendency to over-predict or under-predict abstraction volumes required to achieve a target water level.

Confidence in the dewatering requirement predictions in terms of volumes will provide greater confidence in the planning and budgeting of required dewatering infrastructure (number of bores, sizing of sump pumps and transfer pipelines, etc).

Assessment of Drawdown Impacts – Particularly on Pools / GDE's

On review of the conceptual hydrogeology report, it is clear that groundwater-fed pools in the proximity of the mining operations are a particular focus – namely Yeera Bluff Pool and Japanese Pool. The modelling exercise was seeking to better understand the potential for dewatering operations to negatively impact upon groundwater levels in proximity to these pools. On that basis, there may be value in exploring a few of the modelling assumptions and key sensitivities to better understand the impact potential. The aspects in question are:

- ***The annual time step / creek recharge application*** – given the seasonality of groundwater levels, especially in the Robe River Alluvium, annual time steps has the potential to mask a drawdown trend in the vicinity of pools that may be more severe within a given year than is currently represented; and
- ***General Head Boundary on Robe River*** – given that the model outcomes were sensitive to this, there may be value in exploring the implications of a seasonal fluctuation on the boundary condition, and/or some piezometer validation to gain confidence in this modelled factor.

In the absence of high confidence in these predictions, there may need to be some consideration given to management approaches that will ensure groundwater levels can be maintained at acceptable limits in proximity to these Pools should operational data indicate unfavourable trends toward these receptors.

It was also noted that the predicted drawdown below the riparian vegetation aligned with Jimmawurrada Creek is significant and sustained, and it could be expected that there is potential for vegetation with a high level of groundwater dependence to be negatively impacted by these local dewatering influences – it is currently not clear if such an impact would be acceptable, or if irrigation measures might be required.

If you have any questions or comments regarding this review, please do not hesitate to get in touch.

Kind regards,

RPS

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