Central Queensland Coal Project

Appendix 22 - Independent Groundwater Model Peer Review

Supplementary Environmental Impact Statement

20 December 2018

John Blanning
Central Queensland Coal Project Director
Central Queensland Coal Pty Ltd

Our ref: 41/32344
Your ref:

Dear John,

Central Queensland Coal Project, Groundwater Model Independent Third-Party Review

GHD Pty Ltd (GHD) was commissioned by Central Queensland Coal Pty Ltd (CQC) to undertake an independent third-party review of the Central Queensland Coal Project, Groundwater Model Report titled "Appendix A6 – Groundwater Technical Report, Draft" dated 30 November 2018 by CDM Smith. The groundwater model will be subject to Independent Expert Scientific Committee (IESC) review.

1 Overview

This report summarises the outcomes of an independent peer review by Rob Virtue of the Central Queensland Coal Project groundwater flow model developed by CDM Smith for CQC.

The groundwater model conclusions contribute to the Environmental Impact Statement (EIS) for the project, prepared under the Environmental Protection Act 1994 (EP Act) in support of an application for an Environmental Authority (EA), Mining Lease (ML) and approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The Project will be assessed under the bilateral agreement between the Queensland and Australian Governments.

For the record, the reviewer (Rob Virtue) meets the requirements of a suitably qualified independent expert: Robert Virtue is a Principal Hydrogeologist with over 30 years' experience in geological, hydrogeological and geochemical investigations for major mining companies; local, state and federal government; and commercial and industrial organisations. He has a Bachelor of Applied Sciences (Geology) from Queensland Institute of Technology and is a long term member of the International Association of Hydrogeologists, the Australian Institute of Geoscientists and the Association of Ground Water Scientists and Engineers. He has worked on groundwater resource, contamination, dewatering, dam seepage, acid and metalliferous drainage and acid sulfate soil projects throughout Australia and in West Papua, Papua New Guinea, the Philippines, New Zealand and the Middle East.

The review was conducted by Rob Virtue in accordance with the principles of the:

- *Australian Groundwater Modelling Guidelines* issued by the National Water Commission (NWC) in June 2012;
- *Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals*, issued by IESC in 2018; and
- *Explanatory Note, Uncertainty Analysis in Groundwater Modelling*, issued by IESC in 2018

The *Australian Groundwater Modelling Guidelines* suggests a compliance checklist suitable for high-level appraisals, which can also be used to summarise the outcomes of a review. The completed summary checklist is presented at Table 1, and justifications for the opinions indicated are summarised in the comments field, with key elements explored further in later sections.

Table 1 Groundwater Model Compliance Checklist: 10-point essential summary

Question	Yes / No	Comments regarding CQC Project groundwater model
1. Are the model objectives and model confidence level classification clearly stated?	Yes	The model meets the requirements of a Class 1 model. Class 2 is seldom achievable given length of monitoring required to the duration of required post-closure modelling.
2. Are the objectives satisfied?	Yes	The requirements for water level impact assessment during mining and recovery are met, but inflow predictions are less reliable due to the lack of flow data for calibration, other than qualitative observations that creeks do not flow in the dry season.
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes	
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	The use of isotropic hydraulic conductivity in the calibrated model is not consistent with general practice, but is addressed in sensitivity analyses as discussed below.
5. Does the model design conform to best practice?	Yes	Where there is uncertainty in calibration and some parameters, they are suitably covered by the "breaking-point" assessment.
6. Is the model calibration satisfactory?	Yes	It is generally satisfactory, although there is room for improvement in mid-elevation areas and matching of transient water levels. Calibration to flow would improve inflow confidence and limit non-uniqueness issues with K and recharge combinations. The large range of elevations over the model domain tends to give a misleadingly low scaled RMS, but it is still considered reasonable.
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Specific yields tend to be at the lower end of the observed range but this will more likely overestimate drawdown impact than underestimate, hence can be considered conservative for this aspect. Low drain flows to the creek are consistent with the general observation of lack of dry season baseflow, but measured flows would improve confidence.

8. Do the model predictions conform to best practice?	Yes	A wide range of combined parameters have been used to address calibration limitations.
9. Is the uncertainty associated with the predictions reported?	Yes	Uncertainty has been noted and has been addressed with sensitivity and breaking-point analyses.
10. Is the model fit for purpose?	Yes	The model is suitable for assessing risks of impact from water level changes and relative changes in stream flows, but inflow estimation confidence is lower.

The following independent peer review is structured around three key areas: hydrogeological conceptualisation, technical completeness and model parameters.

In addition to the comments below, feedback has been provided to CQC, as comments in the report.

2 Hydrogeological conceptualisation

The hydrogeological conceptual model (HCM) is generally consistent with the data reported in the groundwater section of the SEIS and is consistent with similar sedimentary basins with which I have experience. The exception is the use of vertically isotropic hydraulic conductivity (Kh/Kv = 1) in the coal measures. This is unusual, given that interbedding of sandstones and shales typically leads to significantly lower vertical hydraulic conductivity than hydraulic conductivity. The reference used in the report to justify isotropic conditions (Massarotto et al 2003) is related to individual coal seams rather than regional coal measures. This has, however, been addressed by introducing vertical anisotropy in the sensitivity analysis stage, which suggests isotropic conditions overestimate drawdown and are hence conservative.

Model internal and external boundary conditions are consistent with typical modelling practice. The use of external no-flow boundaries can constrain the model if they are too close, but they will tend to lead to overestimation of drawdown impacts and hence are conservative in this case. They can lead to underestimation of loss of groundwater from surrounding areas, however that is not an issue in this case as the model domain is mostly enclosed by low-permeability basement rock and the area of significant (>0.1 m) drawdown does not reach the model boundaries.

3 Completeness and model parameters

The model report and documentation is generally good. Feedback was provided on areas where clarification was required and is being address in the final draft. As noted in Table 1 specific yield values are relatively low for some materials but this is conservative/pessimistic for drawdown impacts. Parameter uncertainty has been addressed as part of the sensitivity analysis.

A key component of the model, recognising the limitation in calibration and parameterisation, is the use of a “breaking-point” approach. This assessment determines what parameter combination would be required to achieve a significant impact, in this case excessive drawdown in the Styx River and Broad Sound areas. This assessment demonstrates that unrealistically high hydraulic conductivities would be required for drawdown to result in either drainage and consequent oxidisation of lowland acid sulfate soils (ASS) or seawater intrusion.

4 Conclusions

Overall, the model has been prepared in a manner consistent with industry practice and, with the associated sensitivity and breaking-point analysis, is adequate for assessing the impacts of drawdown and changes in groundwater flow direction. However, given the absence of calibration against flow data such as creek baseflow data, the estimated inflow rates should be considered as order of magnitude estimates.

As with all models there is potential to improve the calibration and parameterisation as additional data become available, including groundwater level data in additional areas and over longer time periods, streamflow data and longer-term pumping tests, if practicable.

Sincerely
GHD Pty Ltd

Rob Virtue
Senior Technical Director – Hydrogeology
GHD Pty Ltd

Australian Groundwater Modelling Guidelines (2012) Review checklist

Review questions	*Yes/No*	*Comment*
1. Planning		
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	
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Yes	
2.2 Is the aquifer system adequately described?		
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	
2.2.3 aquifer geometry including layer elevations and thicknesses	Yes	
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Yes	
2.3 Have data on groundwater stresses been collected and analysed?		
2.3.1 recharge from rainfall, irrigation, floods, lakes	Yes	
2.3.2 river or lake stage heights	Yes	
2.3.3 groundwater usage (pumping, returns etc)	Yes	Only mine extraction in predictions
2.3.4 evapotranspiration	Yes	Extinction depth possibly shallow but unlikely to impact on model
2.3.5 other?	N/A	
2.4 Have groundwater level observations been collected and analysed?	Yes	
2.4.1 selection of representative bore hydrographs	Yes	
2.4.2 comparison of hydrographs	Yes	
2.4.3 effect of stresses on hydrographs	Yes	
2.4.4 watertable maps/piezometric surfaces?	Yes	
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	N/A	
2.5 Have flow observations been collected and analysed?		
2.5.1 baseflow in rivers	No	Not available
2.5.2 discharge in springs	N/A	
2.5.3 location of diffuse discharge areas?	Yes	
2.6 Is the measurement error or data uncertainty reported?	Yes	
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	Yes	

Review questions	*Yes/No*	*Comment*
2.6.2 spatial variability/heterogeneity of parameters	Yes	By layer only
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	Yes	Inverse distance weighted
2.7 Have consistent data units and geometric datum been used?	Yes	
2.8 Is there a clear description of the conceptual model?	Yes	
2.8.1 Is there a graphical representation of the conceptual model?	Yes	In main report. Does not indicate external boundary conditions
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	
2.9.2 Is justification provided for omission or simplification of processes?	Yes	
2.10 Have alternative conceptual models been investigated?	Yes	To some extent in sensitivity analysis
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?	Yes	
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	Yes	
3.3.3 layer geometry?	Yes	
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	Limited vertical discretisation but time lags are not critical given the model timescales
3.4 Are the temporal domain and discretisation appropriate?	Yes	
3.4.1 steady state or transient	Yes	Transient
3.4.2 stress periods	Yes	
3.4.3 time steps?	No	To be detailed in final draft
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Yes	No flow boundaries are in bedrock (except NE) and conservative for drawdown
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	Measurable drawdown does not intersect external boundary
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	

Review questions	*Yes/No*	*Comment*
3.5.4 Are lateral boundaries time-invariant?	No	Only internal ET and recharge.
3.6 Are the initial conditions appropriate?	Yes	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	Mod.	Calibrated quasi-steady-state (long transient) used for baseline starting heads.
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	No	Drawdown graphs show initial conditions were stable before mine impact. Not critical
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	Yes	
3.7.2 Convergence criteria	Yes	
3.7.3 Numerical precision	Yes	
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?		
4.1.1 Groundwater head data	Yes	
4.1.2 Flux observations	NA	Flow not available
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	NA	Not available
4.2 Does the calibration methodology conform to best practice?		
4.2.1 Parameterisation	Yes	Uniform by layer appropriate
4.2.2 Objective function	?	Not discussed
4.2.3 Identifiability of parameters	No	Recharge-K couple
4.2.4 Which methodology is used for model calibration?	Yes	Trial and error then PEST.
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Yes	
4.3.2 boundary conditions	Yes	Recharge only
4.3.3 initial conditions	No	Not critical given pre-mining conditions stable and the long mining and post-closure period modelled
4.3.4 stresses	Yes	Alternate mining schedule
4.4 Have the calibration results been adequately reported?		
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Yes	Some graphs need expanded y-axis
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Yes	
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Yes	Mid-elevation areas not as good but adequate
4.5.1 spatially	Yes	
4.5.2 temporally	Yes	

Review questions	*Yes/No*	*Comment*
4.6 Are the calibrated parameters plausible?	Yes	But at low end of K and Sy range
4.7 Are the water volumes and fluxes in the water balance realistic?	Yes	
4.8 has the model been verified?	Yes	
5. Prediction		
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	
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 reference to the associated reduction in model confidence?	No/Yes	Limitations discussed, hence Class 1.
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?	No/Yes	Limitations discussed, hence Class 1.
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?	?	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	No	Minor creek discharge consistent with observation of no dry season 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)?	Yes	Possible combination of drain and ET, but this is OK and both sinks.
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?	No	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Yes	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	Yes	
6.3 Are the sources of uncertainty discussed?	Yes	
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	

Review questions	*Yes/No*	*Comment*
6.5 Are there useful depictions of uncertainty?	Yes	
7. Solute transport	N/A	
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	
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	