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DATE: 5 December 2017

TO: Nathan Cooper
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FROM: Dr Noel Merrick

RE: Integra Underground MOD8 Project – Groundwater Peer Review

YOUR REF: Job 1702

OUR REF: HA2017/4

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1. Introduction

This report provides a peer review of the groundwater impact assessment (GIA) and associated modelling for the Integra Underground Mine Modification (MOD8) to the north-west of Singleton. The GIA has been prepared by Australasian Groundwater and Environmental Consultants (AGE) under the project management of Hansen Bailey, for the client HV Coking Coal Pty Ltd.

2. Documentation

The review is based on the following report:

1. AGE, 2017, Integra Underground Groundwater Impact Assessment. Project G1285A report prepared for HV Coking Coal Pty Limited, v4.03, 4 December 2017. 117p + 2 Appendices.

Appendix A of Document #1 is:

2. AGE, 2017, Numerical Modelling Report, 60p + 2 Appendices.

Document #1 has the following sections:

1. Introduction
2. Regulatory framework
3. Environmental setting
4. Geological setting
5. Hydrogeology
6. Numerical groundwater model
7. Model predictions and impact assessment
8. Groundwater monitoring and management plan
9. Summary and conclusions

10. References

The Appendices are:

A. Numerical modelling report
B. Compliance with government policy

Document #2 is structured as follows:

1. Introduction
2. Model construction and development
3. Model calibration
4. Recovery simulations
5. Uncertainty analysis
6. Sensitivity analysis
7. References.

The Appendices are:

1. Calibration details and hydrographs
2. Prior and posterior parameter confidence distributions
3. Predictive uncertainty hydrographs

3. Review Methodology

While there are no standard procedures for peer reviews of entire groundwater assessments, there are two accepted guides to the review of groundwater models: the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline[1], issued in 2001, and the newer guidelines issued by the National Water Commission in June 2012 (Barnett *et al.*, 2012[2]). Both guides also offer techniques for reviewing the non-modelling components of a groundwater impact assessment.

The 2012 national guidelines build on the 2001 MDBC guide, with substantial consistency in model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details. The new guide is almost silent on coal mine modelling and offers no direction on best practice methodology for such applications. There is, however, an expectation of more effort in uncertainty analysis, although the guide is not prescriptive as to which methodology should be adopted.

The groundwater impact assessment has been reviewed according to the 2-page Model Appraisal checklist[3] in MDBC (2001). This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Non-modelling components of the groundwater impact assessment are addressed by the first three sections of the checklist.

The review has also considered whether compliance with the minimal harm considerations of the NSW *Aquifer Interference Policy* (AIP) (NSW Government, 2012[4]) has been addressed adequately.

It should be recognised that the effort put into the modelling component of a groundwater impact assessment is very dependent on possible timing and budgetary constraints that are generally not known to a reviewer. However, this is less of an issue with a progressive review.

[1] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

[2] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). *Australian Groundwater Modelling Guidelines*. Waterlines report 82, National Water Commission, Canberra.

[3] The newer guidelines include a more detailed checklist with yes/no answers but without the graded assessments of the 2001 checklist, which this reviewer regards as more informative for readers.

[4] NSW Government, 2012, NSW Aquifer Interference Policy – NSW Government policy for the licensing and assessment of aquifer interference activities. Office of Water, NSW Department of Primary Industries, September 2012.

This review has been conducted progressively, with involvement of the peer reviewer at all stages of model development and application. The interaction was conducted through phone/email correspondence and a series of eight TeamViewer teleconferences. Early in the review process, a detailed review of the Model Study Plan, or Modelling Methodology, prepared by AGE as a memorandum (dated 6 June 2017), was conducted using 16 questions from the MDBC (2001) Peer Review checklist. The initial review at that time is recorded in **Table 1**.

4. Modelling Methodology

The sections in the Modelling Methodology memorandum were:

1. Introduction
2. Model grid and layers
3. Boundary conditions
4. Mining
5. Model calibration
6. Model predictions
7. Model uncertainty
8. References
   Integra mine plan modification slides

The reviewer was comfortable with the entire modelling methodology described at that time. It was noted that the model was being modified from an existing ("MOCO") model that had a number of shortcomings which have been recognised by AGE. They have been addressed adequately, although model geometry and boundary conditions were retained essentially unchanged. Of particular note are:

- conversion to Modflow-USG and AlgoMesh for better mass balance and better spatial resolution;
- replacement of Richards Equation by an equivalent pseudo-soil representation of unsaturated zones;
- division of Liddell Middle coal seam into two layers;
- a different approach to fracture zone height and equivalent porous medium enhanced permeabilities;
- a correction to calibration statistics when data points are weighted unevenly;
- inclusion of a more rigorous procedure for uncertainty analysis; and
- inclusion of development headings in the simulation.

Due to the large number of mines in the model for assessment of cumulative impacts, longwall mining is to occur in layers 9, 14, 15, 18 and 20. As there is multi-seam mining at Integra Underground and Ashton mines, the reviewer advised consideration of multi-seam effects on the height of fracturing. There is a correction procedure in the Ditton method for the extended height of the fracture zone[5], but there is no corresponding correction in any other algorithm in popular use. AGE adopted conservative elements of the single-seam formula to offset multi-seam effects, particularly adoption of the 95th percentile fracture height and application of enhanced properties to the entire layer hosting the top of the fracture zone.

5. Fracture Zone Methodology

AGE has used the Ditton algorithm for the height of the fracture zone and has introduced a new method for representing the enhanced transmissive properties of this zone.

Special mention of the adopted fracture zone methodology is warranted in this review, given the release by the Department of Planning and Environment (DP&E) in early September 2017 of four reviews that were critical of methods commonly adopted in groundwater models: Pells Sullivan

[5] This is implemented by increasing the effective mined thickness of the upper seam by a proportion of the additional land subsidence caused by mining a lower seam. The effective mining height is typically increased by about 70%. This revised height is then used in the standard Ditton formula.

Meynink (PSM) (Sullivan & Swarbrick, March 2017); Mackie (February 2017); Galvin (February 2017); and Galvin (June 2017). This release came too late for any consideration to be given to amendment of the procedure that had been agreed between AGE and the reviewer.

The reviews had a very limited scope, being restricted to Dendrobium Mine only and to algorithms developed by Tammetta (2013) for calculation of the height of "complete drainage" (*Tammetta's terminology*) and Ditton (Ditton and Merrick, 2014) for the height of "connective fracturing" (*Ditton's terminology*).

The restriction of the scope of the review to Dendrobium Mine was an unfair limitation on the assessment of two generic fracture height algorithms which agree well with each other and with monitoring holes over longwall goaf areas at other sites (e.g. Tahmoor, Metropolitan Mines). Dendrobium is an exception due to uncommonly high extraction heights. The two algorithms differ in their sensitivity to extraction height, but only the Ditton method conforms to laboratory evidence.

The primary review by geotechnical engineers at PSM had a fundamental flaw in conceptual understanding of groundwater mechanisms. PSM assumed that any reduction in groundwater pressure at a piezometer is a definitive indication of connectivity via fracturing. This is not a valid assumption, as depressurisation would occur even if the intervening rock is compact. For example, pumping from an irrigation bore at depth would cause widespread reduction in groundwater pressure within a "cone of depression" centred on the bore, but no fracturing is involved. As groundwater pressure reductions are widespread at Dendrobium, PSM seems to have assumed ubiquitous vertical connected fracturing from land surface to seam. They dismissed the Ditton method because it did not predict fracturing to land surface, and they dismissed the Tammetta method because zero pressures were not observed within their view of a "fractured zone".

Mackie and Galvin criticised the two algorithms because they were "empirical" and did not account for local geology. The first criticism is petty, as the mining industry has been operating successfully for decades on the strength of commonplace empirical formulas. For example, the MSEC *Incremental Profile Method* is used routinely for predicting land subsidence above longwall mines. It is a working alternative to full-blown geomechanical modelling which is, and will remain, impractical for 3D mining situations (due to limitations on processing capability and calibration). It is true that the methods do not, and cannot, account for the vagaries of local geology as they are designed to be best-fit generic models calibrated to databases where the height of fracturing has been measured or inferred. Only the Ditton method has introduced a geology compensating factor in the form of a notional effective beam thickness at the top of the fracture zone.

Galvin regards the Ditton approach as "*a considerable advance on that of Tammetta*", as the latter did not have built-in functional relationships with mechanistic properties or geometrical factors. The extraction height is a particular case in point.

The only practical alternatives to the two 3-parameter algorithms are "old-style" methods that calculate fracture height as simple multiples of longwall panel width (W) or extraction height (T), commonly 0.6 x W or 32 x T. These simpler methods have never received the level of criticism that the better methods have invited. The Ditton and Tammetta algorithms should not be discarded until an improvement is offered, and none is in sight, other than a reasonable evolution of the existing models for an expanded database. That is the normal evolutionary practice for empirical models.

The four reviews released by DP&E were remiss in making no mention of the equally contentious alternative methods for implementing the *permeability* of a fracture zone in a groundwater model (whatever the height). These approaches are reviewed by Merrick (2017) in the following words:

> *"There are several approaches in use for representing the properties of the connective fracture zone: (1) an equivalent porous medium, using either multipliers on the host properties, or a monotonic ramp function; (2) a connected linear network (CLN), using a few macro-fractures per model cell; (3) stacked drains along the edges of the fracture space, with flow controlled by drain conductance (either calibrated to mine inflow or estimated from CLN theory)."*

The review by Merrick (2017) did not include the practice of converting geotechnical (FLAC) model outputs to vastly enhanced permeabilities as they rely on inappropriate cubic law and constant aperture assumptions.

AGE has developed an original approach that can be considered a rational compromise of the other methods. While using the Ditton formula for fracture zone height, AGE uses the Tammetta technique of stacked drains but removes Tammetta's restrictive assumption of zero pressure within the entire fracture zone, by ramping the drain conductance using a modification of the CLN formula. This reviewer supports the new approach. It has performed well and seems very efficient numerically.

6. Other Matters

Table 2 and **Table 3** provide the detail for this review. **Table 2** addresses reporting, data analysis, conceptualisation and model design. **Table 3** addresses calibration, verification, prediction, sensitivity analysis and uncertainty analysis.

The main report (Document #1) and the modelling appendix (Document #2) are both high quality reports. Document #1 is sufficiently standalone in summarising the key predictive outputs of the more technical Document #2, but the latter document does not include any additional predictive outputs. A review of earlier drafts of these reports generated a number of questions and comments which have all been addressed in the final versions to the reviewer's satisfaction.

In terms of model confidence level classifications, Document #2 states:

> *"The model generally achieves aspects of Class 2 and Class 3 confidence level criteria."*

At the reviewer's suggestion, an annotated classification table of attributes from the guidelines has been included as Table A 12. This follows the simplification offered in **Table 4**, with ticks for achieved levels. The reviewer is in agreement with this classification.

Monitoring networks are substantial, with 24 alluvial sites and 58 piezometers at 27 Permian sites. The cause-and-effect analysis reveals mining effects at depth but not in alluvium. As no mine footprint groundwater hydrographs show zero pressure, there is no evidence of pronounced fracturing for existing mining. The model reproduces this behavior with zero pressure only to about 50 m above the mined coal seam, despite fracturing being considerably higher.

Considerable effort has been put into resolving different interpretations of alluvial extent. A transient electromagnetic method (TEM) survey has been deployed for better definition of the alluvium. Section 5.1.2 of Document #1 provides a very thorough assessment of alluvium in the district.

Baseflow analysis has been conducted on streamflow records for several streams using the Arnold-Allen method.

Barrier fault evidence is presented for one fault at the eastern limit of the Modification, given significant head differences either side of the fault. A sensitivity analysis is conducted for an assumed conduit fault running along the northern longwall extent.

Calibration performance statistics of 6.1 %RMS and 27 mRMS are acceptable for such a complex mining precinct. The scattergram (Figure A 11) is generally linear across a wide range, but there is some remaining bias due to underestimation at high heads and overestimation at low heads. This also is evident in the residuals diagram (Figure A 12). Replication of vertical head profiles (Figure A 13) is generally good.

The model predictions differ from those reported with the previous MOCO model, but more confidence should be placed in the current model as it is superior in design and application.

A substantial uncertainty analysis has been undertaken using a null-space Monte Carlo technique, using 179 alternative calibrated realisations.

7. Conclusion

The reviewer concludes that the model is *fit for purpose*, where the purpose is defined by the objectives stated in Document #2:

- *"assess the groundwater inflow to the mine workings as a function of mine position and timing;*
- *simulate and predict the extent and area of influence of dewatering and the level and rate of drawdown at specific locations;*
- *identify areas of potential risk where groundwater impact mitigation/control measures may be necessary; and*
- *simulate and predict the extent of influence of drawdown and potential impacts during the groundwater recovery phase, after mining activities and dewatering are ceased."*

The groundwater modelling has been conducted to a very high standard.

8. References

AGE, 2017, Integra Underground Groundwater Impact Assessment. Project G1285A report prepared for HV Coking Coal Pty Limited, v4.02, 23 November 2017. 117p + 2 Appendices

Ditton, S. and Merrick, N. 2014, *A new subsurface fracture height prediction model for longwall mines in the NSW coalfields*. Geological Society of Australia, 2014 Australian Earth Sciences Convention (AESC), Sustainable Australia. Abstract No 03EGE-03 of the 22nd Australian Geological Convention, Newcastle City Hall and Civic Theatre, Newcastle, New South Wales. July 7 - 10. Page 136.

Galvin, J. M. 2017. *Review of PSM Report on Height of Fracturing - Dendrobium Area 3B*. Galvin & Associated Pty Ltd. Advice to Department of Planning and Environment. 24/2/17.

Galvin, J. M. 2017. *Summary and Explanation of Height of Fracturing Issues at Dendrobium Mine.* Prepared for Department of Planning and Environment. 15/6/17.

Mackie, C. D. 2017. *Height of Fracturing at Dendrobium Mine – Peer Review of PSM Report*. Mackie Environmental Research Pty Ltd. Advice to Department of Planning and Environment. 18/2/17.

Merrick, N. P. 2017. *Recent Advances in Groundwater Modelling for Coal Mines*. Proceedings of the 10th Triennial Conference on Mine Subsidence "Adaptive Innovation for Managing Challenges", Mine Subsidence Technology Society, Pokolbin 5-7 November 2017, 29-35.

Sullivan, T. and Swarbrick, G. 2017. *Height of Cracking – Dendrobium Area 3B*. Prepared for Department of Planning and Environment. PSM Report No. PSM3021-002R. 16/3/17.

Tammetta, P. 2013. *Estimation of the height of complete groundwater drainage above mined longwall panels*. Groundwater, v51, no.5, 723-734.

NPMerrick

Dr Noel Merrick

Table 1. Model Review: Model Design

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
4.1	Is the choice of mathematical model appropriate (analytical / numerical)?			No	Maybe	Yes			Numerical
4.2	Is the spatial extent of the model appropriate?			No	Maybe	Yes			25km x 26km
4.3	Is the spatial discretisation scale appropriate?		Missing	No	Maybe	Yes			Unstructured mesh
4.4	Is the number of model layers justified?		Missing	No	Maybe	Yes			
4.5	Is steady state simulated?		Missing	Deficient	Adequate	Very Good			December 1979 assumed. Not really applicable due to complex mine interactions
4.6	Is transient behaviour simulated?		Missing	Deficient	Adequate	Very Good			97,000 targets
4.7	Is the stress period reasonable?		Missing	No	Maybe	Yes			Variable
4.8	Is the number of time steps per stress period justified?		Missing	Deficient	Adequate	Very Good			Expect use of ATS (automatic adjustment) but not stated
4.9	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Same as MOCO (previous model)
4.10	Are boundary condition locations consistent with the model grid configuration?		Missing	No	Maybe	Yes			
4.11	Are the initial conditions defensible?		Missing	Deficient	Adequate	Very Good			Provided by previous MOCO model
4.12	Is it clear what software has been selected?		Missing	No	Maybe	Yes			Modflow-USG + AlgoMesh
4.13	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			
4.14	Is the software reputable?			No	Maybe	Yes			
4.15	Is the software in common use and accessible to reviewers?			No	Maybe	Yes			AlgoMesh is fairly new
4.16	How detailed is the rainfall recharge algorithm?		Missing	Deficient	Adequate	Very Good			Soil moisture bucket algorithm
4.	TOTAL SCORE								

Table 2. Model Review (Part A)

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
1.0	THE REPORT								Main Report & Appendix A
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			Agency requirements. Modelling objectives at Appendix A, Section A1.
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Mixture of Class 2 and Class 3 - agreed
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Tables A10, A11.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			
1.5	Are the model results of any practical use?			No	Maybe	Yes			
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Alluvium definition (TEM). Weathering & alluvium photos. Structure and cover depth contours. Alluvium field Kh (Table 5-1) 79 packer tests. Water quality analysis violin plot (Fig.5-28).
2.2	Are groundwater contours or flow directions presented??		Missing	Deficient	Adequate	Very Good			Alluvium (Fig.5-5). Middle Liddell Seam (Fig.5-25).
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			SILO rainfall. Streamflow presented in graphical form.
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			Baseflow analysis S3.3 – Arnold & Allen (1979) method. Only 3 private bores.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			CRD comparison. Evident mining effects at depth but not in alluvium.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			Hydrographs: alluvium (Figs.5-6 to 5-12); Permian (Figs.5-14 to 5-24). Monitoring networks: alluvium (24 sites); Permian (58 @ 27 sites).
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				
3.0	CONCEPTUALISATION								

3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes			
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good			Inferences from dh/dx and water quality. Section 5.5. Observed fault barrier effect.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Geology X-Sections Fig.4-2, 4-3 with mine cutouts but no flow indicators.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				
4.0	MODEL DESIGN								Several prior models
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			25km x 26km. 21 layers. Max 32k cells/layer (less pinchouts). Total 0.54million cells. Confinement by fault not far from mining. Minimum cell size 20m. Many neighbouring mines included. Subdivided Liddell Seam.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Justified in Section A2.3.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			MF-USG unstructured + AlgoMesh Voronoi cells. Upstream weighting = pseudo-soil; CONSTANTCV. Ditton-Merrick fracture zone algorithm.

Table 3. Model Review (Part B)

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
5.0	CALIBRATION								Steady-state 1979. Transient 1980-April 2017 (38 years).
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			254 monitoring sites - good spread (x,z). Scattergram; residuals x-y plot; vertical profiles; hydrographs.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Scattergram generally linear across a wide range. Acceptable vertical head profiles (Fig.A13). Plausible head contours Figs.A14-A19.
5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Quarterly stress periods from 2009. Consistent bias: sim<obs (high head) and sim>obs (low head).
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			6.1%RMS, 27 mRMS.
5.6	Are there good reasons for not meeting agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Mining complexity; homogeneous K per layer (same depth); some thick layers (assumed single head); fracture height limited to discrete layer steps.
6.0	VERIFICATION								Optional for heads subset
6.1	Is there sufficient evidence provided for model verification?		Missing	Deficient	Adequate	Very Good			Baseflow verification Figs.A23, A24. Mine inflow Fig.A25
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	**N/A**	Unknown	No	Maybe	Yes			
6.3	Are there good reasons for an unsatisfactory verification?	**N/A**	Missing	Deficient	Adequate	Very Good			
7.0	PREDICTION								May 2017-2035 (18 years)
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			Understood to be long-term average during prediction and recovery, but not stated. Some reduction is assumed during rehab.

7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	**Adequate**	Very Good			Two mine plans.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	**Yes**			Calib:38 yrs, Pred:18yrs. Ratio Pred/Calib = 0.47 (implies high "confidence")
7.4	Are the model predictions plausible?			No	Maybe	**Yes**			Recovery hydrographs Fig.7-12 suggest slow recovery for >200 years. Alluvial drawdown increases post-mining (as expected).
8.0	SENSITIVITY ANALYSIS								GHB conductance; conduit fault
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	**Adequate**	Very Good			Usual sensitivity analysis on model properties done differently by uncertainty analysis.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		**Missing**	Deficient	Adequate	Very Good			
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	**Adequate**	Very Good			Output of interest: Main Creek alluvial flux change. Fault is sensitive; GH boundary is not.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	**Yes**			Substantial work. 275 realisations (Kx, Kz, Sy, Ss, RCH, RIV Kz, frac skin factor). Pseudo Null-space Monte Carlo. Prior and posterior distributions.
9.2	Are uncertainty results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	**Very Good**			65% calibrated.
9.3	Are uncertainty results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	**Very Good**			Uncertain outputs of interest: hydrographs; maximum drawdown (x,y); mine inflow (median close to base case); alluvium take; surface water take.
	TOTAL SCORE								PERFORMANCE: %

Table 4. Model Confidence Level Classification

CLASS	DATA	CALIBRATION	PREDICTION	INDICATORS
1	Not much. Sparse. No metered usage. Remote climate data.	Not possible. Large error statistic. Inadequate data spread. Targets incompatible with model purpose.	Timeframe >> calibration Long stress periods. Transient prediction but steady-state calibration. Bad verification.	Timeframe > 10x Stresses > 5x Mass balance > 1% (or single 5%) Properties <> field. Bad discretisation. No review.
2	Some. Poor coverage. Some usage info. Baseflow estimates.	Partial performance. Long-term trends wrong. Short time record. Weak seasonal replication. No use of targets compatible with model purpose.	Timeframe > calibration. Long stress periods. New stresses not in calibration. Poor verification.	Timeframe = 3-10x Stresses = 2-5x Mass balance < 1% Some properties <> field measurements. Some key coarse discretisation. Review by hydrogeo.
3	Lots. Good aquifer geometry. Good usage info. Local climate info. K measurements. Hi-res DEM.	Good performance stats. Long-term trends replicated. Seasonal fluctuations OK. Present day data targets. Head and flux targets.	Timeframe ~ calibration. Similar stress periods. Similar stresses to those in calibration. Steady-state prediction consistent with steady-state calibration. Good verification.	Timeframe < 3x Stresses < 2x Mass balance < 0.5% Properties ~ field measurements. Some key coarse discretisation. Review by modeller.