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DATE: 22 June 2014

TO: Dianne Munro
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FROM: Dr Noel Merrick

RE: **Peer Review – Russell Vale Colliery Groundwater Impact Assessment**

OUR REF: HS2014/12

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1. Introduction

GeoTerra Pty Ltd and Groundwater Exploration Services (GES) Pty Ltd have jointly undertaken the groundwater impact assessment for Russell Vale Colliery, which is located about 13 km to the north-west of Wollongong on the New South Wales South Coast. The subject of the assessment is the Russell Vale Colliery Underground Expansion Project. This is proposed to consist of Wongawilli Seam Longwalls 1, 2, 3, 6, 7, 9, 10 and 11. Longwalls 4 and 5 have already been mined. If approval is received, the next panel to be mined would be Longwall 6.

At the request of Hansen Bailey, acting on behalf of Wollongong Coal Ltd, Heritage Computing Pty Ltd (now trading as HydroSimulations) has undertaken a peer review of the supplied document that forms the assessment.

2. Documentation

The following report comprises the current documentation for the groundwater assessment:

1. GeoTerra and GES, 2014, Russell Vale Colliery Underground Expansion Project Preferred Project Report Wonga East Groundwater Assessment, Bellambi, NSW. Report NRE1 - R1C GW for Wollongong Coal Ltd., 19 June 2014.

Initial reviews were conducted on draft reports dated 20 May 2014 and 5 June 2014. No other documentation was relied upon as a basis for this review, and electronic model files were not examined. However, the reviewer met with the modeller (Andrew Fulton, GES) on a number of occasions during development of the model.

Document #1 has 17 sections:

1. Introduction

2. Relevant Legislation and Guidelines
3. Previous Groundwater Related Studies
4. Previous and Proposed Mining
5. Study Area Description
6. Previous Groundwater System Subsidence Effects
7. Potential Strata Deformation and Associated Groundwater Effects
8. Hydrogeological Investigations
9. Groundwater Modelling
10. Potential Subsidence Effects, Impacts and Consequences
11. Cumulative Groundwater Related Impacts
12. Modelling Uncertainty
13. Model Limitations
14. Water Licensing
15. NSW Aquifer Interference Policy Minimal Impact Considerations
16. Monitoring, Contingency Measures and Reporting
17. References.

The initial reviews advised restructuring the contents of the report without sacrificing content. This has been done.

The Appendices to Document #1 contain:

A. Piezometer Water Level Calibration Graphs
B. IESC Significance Guidelines Response

3. Review Methodology

There are two accepted guides to the review of groundwater models: (A) the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline[1], issued in 2001,and (B) newer guidelines issued by the National Water Commission at the end of 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 the 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 Russell Vale model type is Moderate Complexity (under the MDBC guidelines) and Class 2 Confidence Level (under the NWC guidelines). This is the appropriate level for a groundwater impact assessment for a mining development.

The review was conducted solely on several versions of a single submitted report and discussions with Mr Andrew Fulton. Electronic model files were not examined.

The groundwater guides include useful checklists for peer review. For the initial reviews, the Model Appraisal checklist[3] in MDBC (2001) was used for groundwater model review. 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 impact assessments are addressed by the first three sections of the checklist. The NWC checklist (which essentially has Yes/No rather than graded assessment) has been completed only for the final review.

The detailed assessment of the groundwater modelling, according to the MDBC checklist, is recorded in the model appraisal checklist in **Table 1**. The corresponding review according to the

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 new guidelines include a more detailed checklist but they do not offer the graded assessments of the 2001 checklist, which this reviewer regards as more informative for readers.

NWC checklist is included as **Table 2**, with a compliance checklist at **Table 3**. These tables contain the primary commentary for the peer review. Summary and supplementary commentary is offered in the following sections of this review.

4. Report Matters

Document #1 is a good quality document of 145 pages length plus two appendices that contain a comparison of observed and simulated hydrographs and a checklist that addresses Independent Expert Scientific Committee (IESC) requirements. Another Appendix could have been included that would show the calibrated hydraulic conductivity field for each model layer and the spatial rainfall recharge distribution. The report is well structured and the graphics are mostly of high quality.

The objective of the study is " to address any potential groundwater impacts relating to the proposed extraction and associated subsidence of the Wongawilli Seam in the Wonga East mining area". This objective has been met.

A full water balance summary is given only for the transient calibration period, and then only at the end date instead of an average over the period. No water balance is offered for steady-state conditions, and only selected water balance components (mine inflow, baseflows) are reported during prediction.

There had been modelling conducted previously in 2012 but only a cursory reference is made to it in Section 9. It is not clear how the previous and current models differ, other than the use of different software (FEFLOW and MODFLOW-SURFACT) and investigation of a different mine plan.

The report includes discussion on alternative representations of the fractured zone. The use of the Tammetta formula (adapted conservatively for multiple worked seams) implies fracturing to ground surface over already-mined Longwalls 4 and 5. A comment would be in order as to whether this assumption has field support. If not, the impact predictions are conservative. Monitoring of water level trends in piezometer NRE-A over the multi-seam mined area seems to lend support to fracturing reaching to the upper Hawkesbury Sandstone.

The report is missing a Summary or Conclusion section. In the first draft there was a very good summary of the scope of the study and its findings in an Executive Summary. While the Executive Summary is properly housed in the companion main report, much of this could have been retained as a concluding statement.

Over six pages of references are cited. However, many have incomplete citations, and "et al." attributions are not always spelled out as they should be.

5. Data Matters

The coverage of geology and hydrogeology is particularly good, with a brief section on field-derived permeabilities. However, the remaining aspects of the groundwater system are treated only briefly. The water table pattern in Figure 21, based on measurements and inferred levels, is sensible as it suggests logical groundwater flow from ridges to drainage lines. The water table pattern generated by the model is not subsequently compared with this figure.

Initial cross-sections of pressure heads (presented in the modelling section of the report) show substantial prior depressurisation due to neighbouring mining.

The rainfall residual mass (cumulative deviation from the mean) curve has been used effectively to show often strong correlation with groundwater hydrographs. This is a vital tool for investigating cause-and-effect where climate plays a role in groundwater responses. Where mining effects are observed, the timing of longwall panels is compared with the hydrograph responses to confirm mining as the probable cause.

Although there is good field evidence and conceptual discussion on the gaining/losing characteristics of the various watercourses, there is no substantiation with statistics for flow rates and durations of flow.

The adopted evapotranspiration (ET) rate (0.005 m/day = 1,825 m/year) is considered too high as it reflects evaporation rather than actual ET. The Bureau of Meteorology provides estimates of actual ET (limited by water availability) across Australia. Allowance should always be made for MODFLOW's weak linear representation of the ET process, which means that evaporation rates will always be too high as a surrogate for ET. However, this is not considered a serious issue, as the ET process will be activated in the model only where the water table comes within 4 m of ground surface. A depth to water map could have illustrated the locations where that might occur (along drainage lines).

The mine water balance in Figure 28 has detailed partitioning of components.

The conceptualisation based on the field investigations and data analysis is justified and well illustrated graphically in Figure 31 for a mining situation. The adopted conceptual model is consistent with other studies in the Southern Coalfield.

An important aspect of the conceptualisation is that geological faults and other structures have no significant role in the groundwater regime. Document #1 states that "faults encountered within the three levels of extraction have not encountered water make with any faults or dykes in the workings". The absence of water flows associated with faults is an important finding, as the role of faults in groundwater systems and their incorporation in models, is often a matter of contention.

6. Model Matters

The modelling section should commence with a brief summary of previous groundwater modelling, with reasons for what is assumed to be a substantial overhaul, given the adoption of a different software platform (MODFLOW-SURFACT instead of FEFLOW). It should be stated whether the current model is an enhancement or a replacement.

There is confusion as to the commencement year for transient simulation. Table 9 in Section 9.6 suggests 1993 but the introductory Section 9 states that 2003 is year zero.

There is also confusion over the meaning of Figure 33, as the caption (predicted height of depressurisation zone) is inconsistent with the legend (top of depressurisation to surface). It is likely that the legend is correct and the caption is wrong.

The most illustrative figures for the effects of past and future mining on the groundwater system are presented as Figures 37 to 42. All figures display pressure head (in metres), which can be considered as the height of water remaining above a mined seam. Figures 37 and 38 reveal substantial initial (presumably 1993) depressurisation due to neighbouring mining. Figures 39 and 40 show incremental depressurisation for current conditions (end of Longwall 5), while Figures 41 and 42 show continued depressurisation at the end of mining. In places, the zero pressure head at the water table has coalesced with the zero pressure head generated by mining.

Although monitoring of water level trends in piezometer NRE-A over the multi-seam mined area indicates an enhanced response to rainfall recharge in the upper Hawkesbury Sandstone down to the Upper Bulgo Sandstone, higher rainfall recharge has not been assumed in the model. While it is reasonable to maintain uniform recharge for the base case model, enhanced recharge could have been investigated in a sensitivity analysis.

Figures 67 to 69 show effectively the uncertainty associated with estimates for mine inflow and baseflow reductions. They show the results of 31 alternative model parameterisations, selected from the packer test database of horizontal hydraulic conductivities. However, there is an error in the text associated with Figure 67, which shows a probability distribution for mine inflow rates. Mean values have been recalculated just for the duration of Wongawilli Seam mining, rather than from the start of the simulation in 1993, but the text still says the mean is "influenced by the long period of model time where inflows are predominantly from the unmined areas of the Bulli Seam".

Estimation of fractured zone height above multi-seams is an open question. Here, the combined seam thicknesses are treated as the effective mined height. This would certainly be valid when the seams are contiguous, but a lower "effective thickness" would be more appropriate when there is intervening interburden. The adopted approach would be conservative.

Refer to **Table 1** for more detailed commentary.

7. Conclusion

The objective of the Russell Vale Groundwater Model is stated in Document #1 as the simulation of "the current and proposed mining activities within the Wongawilli Seam in the Wonga East area and to understand the effects to groundwater and surface water environment in a local and regional context". More broadly, the groundwater assessment in Document #1 is required to fulfil aspects of the Director General's Requirements, especially "the potential impacts of the project on the quantity, quality and long-term integrity of the groundwater resources in the project area".

The impacts of importance are stipulated in the Aquifer Interference Policy, especially drawdown impacts on GDEs and private bores, and water quality departures from beneficial use. In addition, the volumetric takes of water are to be determined (and partitioned where necessary) for licensing purposes.

The groundwater assessment includes a table (Table 16) that addresses the minimal harm considerations for less productive porous rock water sources. Each *consideration* is addressed in full. This reviewer concurs with the finding that no Level 2 impacts have been identified.

It is the reviewer's opinion that all objectives have been met satisfactorily.

Furthermore, it is the reviewer's opinion that the Russell Vale Groundwater Model has been developed competently and is “fit for purpose” for addressing the potential environmental impacts from the proposed underground mining operations and for estimating indicative dewatering rates.

The uncertainty in modelling predictions is assessed thoroughly by analysing the outputs of 31 models with parameterisations based on the statistical distribution of packer test permeabilities.

Due to the substantial depressurisation that has been caused by earlier mining at the subject mine, and at neighbouring historical mines, the additional effects of mining the Wongawilli Seam with eight more longwall panels are considered marginal.

Yours sincerely,

N P Merrick

Dr Noel Merrick

Table 1. Model Appraisal: Russell Vale Colliery Groundwater Model

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								145p text. 2 App.
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			Section 1.1 - Scope of Work (DGRs, regulator submissions on PPR).
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Reference to new national guidelines. Class 2 confidence classification. Equivalent to Impact Assessment Model, medium complexity.
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Not for Steady state. Transient calibration period - adequate (Table 11) - at end, not averaged. Prediction - missing summary (partial in Table 12, 13)
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			"...address any potential groundwater impacts relating to the proposed extraction and associated subsidence..."
1.5	Are the model results of any practical use?			No	Maybe	Yes			Quantitative impact assessment with uncertainty. Aquifer Interference Policy checked for minimal harm compliance.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Sections 5, 8. Good overviews of geology and hydrogeology. Brief section on field-derived permeability.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Includes map of observed water level contours (Figure 21) - but excludes Wonga West. (Simulated pattern not checked against this.) Figures 37, 38 give initial pore pressures on S-N and W-E sections.
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Rainfall in Section 5.2.1. Rainfall residual mass (CRD) in Figure 3. Stream flow in Section 5.8 - no statistics.

2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			Field assessment of gaining/losing. No abstraction by bores. Cataract Dam evaporation records. Could cite BoM actual ET estimate for region - model ET rate seems high. Expect a summary of stream baseflow or flow duration percentiles.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			Standpipe and VWP hydrographs are related to CRD (useful in discriminating climate effects - good correlation) and longwall dates. Mine water balance (Figure 28) has detailed partitioning of components - drop "rainfall" from caption.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			24 graphs. Standpipe and VWPs.
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				K in m/s and m/d.
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			Section 9.1.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Figure 31.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				Consistent with detail in other Southern Coalfield models. Fractured zone (goaf) handling via ramp function for K.
4.0	MODEL DESIGN								Minimal reference to previous 2012 model using FEFLOW.
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Dimensions unstated: probably 23 km x 23 km. Finite differences. 18 layers. Includes many mines. 25m to 250m cell size.

4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Mostly controlled by seam heads in mines around the boundary. Topo divide along open western boundary - could defend this with expanded Figure 21 (water level map) or reference to Appin model report. Cross-sections of initial conditions are given as pressure heads. Streams use RIV algorithm - RIV MODFLOW. Mines use DRN. ET maximum rate is quite high for MODFLOW linear decay. Variable stress periods. Strong argument for excluding faults.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			MODFLOW-SURFACT. Unsaturated properties not stated. Time-varying properties (TMP) for fractured zone.
5.0	CALIBRATION								**Jan.1993-Feb.2014**
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			**Steady-state**: missing. Should give RMS statistics and show watertable contours to compare with Figure 21. No scattergram. Steady-state = 1991: CRD (Figure 3) justifies "average" conditions. **Transient**: adequate. Two attributes: heads and mine inflow - no check on baseflow. Evidence = scattergram; mRMS and %RMS; hydrograph comparisons. Historical mine inflow matched in transient calibration. No spatial residual map to see where calibration is poor.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Steady state: ??%RMS, ??mRMS. 32 sites, unknown number of points. Cannot compare pattern with observed/inferred contours. Vertical head separation very good at VWPs. Transient scattergram centred on 45 degree line.

5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Marginally adequate, based on hydrograph comparisons. Trends generally OK. Fluctuations not reproduced. VWP matches as good as can be expected. Statistical performance is good: 2.6%RMS, 6mRMS. 2328 data points. (4.9mRMS if GW1 is excluded - could state %RMS also - expect ~4%RMS). Mine inflow well matched. Scattergram (Figure 36) reinforces lack of amplitude matching (horizontal lines at some sites).
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Table 10. Manual and PEST. Fractured Kz reasonable (consistent with other groundwater models).
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			<10 %RMS. Reasonable replication of hydrograph trends but not amplitudes.
5.6	Are there good reasons for not meeting agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Difficulties acknowledged and discussed briefly.
6.0	VERIFICATION								**No need**
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			
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								**Feb.2014-Feb.2018. Recovery for >200years.**
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			Average rain - normal practice. No climate change scenario.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good			One mine plan - normal practice. Impacts presented for Project (LW6 onwards) and for all Wongawilli longwalls (LW4 onwards).

7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			21 years calibration. 4 years prediction.
7.4	Are the model predictions plausible?			No	Maybe	Yes			Drawdown magnitudes and mine inflows seem reasonable. Maximum baseflow effect 7 ML/a (3 streams total). Maximum reservoir effect <0.01% of full storage. No third party bores of concern. Good pressure head sections. Zero pressure breaks through to surface above panels. Fracturing to surface not substantiated by observed water losses.
8.0	SENSITIVITY ANALYSIS								Replaced by uncertainty analysis.
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			31 Kx realisations. Although %rain is examined for its effect on calibration statistics, it is not clear whether hydrograph amplitudes improve. S not tested for improved hydrograph amplitudes.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			Only for %rain.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			Monte Carlo realisations (30 + base model).
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			31 Monte Carlo Kx realisations using packer test statistics. Tight mine inflow range. Broader baseflow range but still small. Good probability distributions - mean calculated from start of LW4.
	TOTAL SCORE								PERFORMANCE:

Table 2: Review checklist (2012 National Guidelines)

Review questions	*Yes/No*	*Comment*
1. Planning		
1.1 Are the project objectives stated?	Y	Section 1.1
1.2 Are the model objectives stated?	Y	P74
1.3 Is it clear how the model will contribute to meeting the project objectives?	Y	
1.4 Is a groundwater model the best option to address the project and model objectives?	Y	
1.5 Is the target model confidence-level classification stated and justified?	Y	Class 2
1.6 Are the planned limitations and exclusions of the model stated?	Y	Section 13
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Y	Southern Coalfield
2.2 Is the aquifer system adequately described?	Y	
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Y	
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Y	
2.2.3 aquifer geometry including layer elevations and thicknesses	Y	Isopachs not in Appendix
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Y	
2.3 Have data on groundwater stresses been collected and analysed?	Y	Climate & prior mining
2.3.1 recharge from rainfall, irrigation, floods, lakes	Y	Rain
2.3.2 river or lake stage heights	N	
2.3.3 groundwater usage (pumping, returns etc)	NA	No private bores nearby
2.3.4 evapotranspiration	N	Only evaporation
2.3.5 other?	-	
2.4 Have groundwater level observations been collected and analysed?	Y	
2.4.1 selection of representative bore hydrographs	Y	All
2.4.2 comparison of hydrographs	Y	
2.4.3 effect of stresses on hydrographs	Y	Compared CRD and LW periods
2.4.4 watertable maps/piezometric surfaces?	Y	Local watertable
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	NA	
2.5 Have flow observations been collected and analysed?	Y	Mine inflow
2.5.1 baseflow in rivers	N	Not shown
2.5.2 discharge in springs	NA	
2.5.3 location of diffuse discharge areas?	NA	
2.6 Is the measurement error or data uncertainty reported?	N	

Review questions	*Yes/No*	*Comment*
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N	
2.6.2 spatial variability/heterogeneity of parameters	NA	Uniform
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N	
2.7 Have consistent data units and geometric datum been used?	Y	
2.8 Is there a clear description of the conceptual model?	Y	
2.8.1 Is there a graphical representation of the conceptual model?	Y	
2.8.2 Is the conceptual model based on all available, relevant data?	Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Y	
2.9.1 Are the relevant processes identified?	Y	
2.9.2 Is justification provided for omission or simplification of processes?	Y	
2.10 Have alternative conceptual models been investigated?	N	
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Y	
3.2 Is the choice of numerical method and software appropriate?	Y	
3.2.1 Are the numerical and discretisation methods appropriate?	Y	
3.2.2 Is the software reputable?	Y	MODFLOW-SURFACT
3.2.3 Is the software included in the archive or are references to the software provided?	?	No archive submitted (nor should it be)
3.3 Are the spatial domain and discretisation appropriate?	Y	
3.3.1 1D/2D/3D	3D	
3.3.2 lateral extent	Y	23km x 23km
3.3.3 layer geometry?	Y	18 layers
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Y	25-250m cell size
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?	Y N	
3.4 Are the temporal domain and discretisation appropriate?	Y	
3.4.1 steady state or transient	T	
3.4.2 stress periods	Y	
3.4.3 time steps?	N	Missing (expect ATO)
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Y	
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Y	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Y	Far away
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Y	Aligned with neighbouring findings

Review questions	*Yes/No*	*Comment*
3.5.4 Are lateral boundaries time-invariant?	Y	
3.6 Are the initial conditions appropriate?	Y	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?		Steady-state modelling
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	N	
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	
3.7 Is the numerical solution of the model adequate?		Not stated
3.7.1 Solution method/solver		Not stated
3.7.2 Convergence criteria		Not stated
3.7.3 Numerical precision		Not stated
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	N	Not baseflow
4.1.1 Groundwater head data	Y	
4.1.2 Flux observations	Y	Mine inflow
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	-	
4.2 Does the calibration methodology conform to best practice?		Not stated - believed to be PEST
4.2.1 Parameterisation		
4.2.2 Objective function		
4.2.3 Identifiability of parameters		
4.2.4 Which methodology is used for model calibration?		Not stated - believed to be PEST
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Y	Monte Carlo Kx
4.3.2 boundary conditions	Y	Recharge
4.3.3 initial conditions	N	
4.3.4 stresses	N	
4.4 Have the calibration results been adequately reported?	Y	
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Y	
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Y	Multi-VWP hydrographs
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Y	
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Y Y	Scattergram; hydrographs. 2.5%RMS transient.
4.5.1 spatially	?	Missing simulated water table
4.5.2 temporally	Y	Hydrograph comparison
4.6 Are the calibrated parameters plausible?	Y	
4.7 Are the water volumes and fluxes in the water balance realistic?	Y	

Review questions	*Yes/No*	*Comment*
4.8 has the model been verified?	N	Transcient calibration 1993-2014
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Y	AIP impacts
5.2 Is predictive uncertainty acknowledged and addressed?	Y	
5.3 Are the assumed climatic stresses appropriate?	Y	Stable
5.4 Is a null scenario defined?		Not stated
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Y	
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?	NA	
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?	Y	4 yrs prediction vs. 22 yrs calibration
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Y	
5.6 Do the prediction results meet the stated objectives?	Y	
5.7 Are the components of the predicted mass balance realistic?	Y	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	NA	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?		Not stated
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)?		Unlikely
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Y	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?		Unlikely
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?	Y	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	N	
6.3 Are the sources of uncertainty discussed?	Y	
6.3.1 measurement of uncertainty of observations and parameters	N Y	
6.3.2 structural or model uncertainty	Y	Packer Kx statistics
6.4 Is the approach to estimation of uncertainty described and appropriate?	Y	Monte Carlo

Review questions	*Yes/No*	*Comment*
6.5 Are there useful depictions of uncertainty?	Y	Probability curves
7. Solute transport	NA	
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?		
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?		
7.3 Is the choice of numerical method and software appropriate?		
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?		
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?		
7.6 Are the solver and its parameters appropriate for the problem under consideration?		
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?		
7.8 Has an assessment been made of the need to consider variable density conditions?		
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?		
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?		
7.11 Is the calibration based on meaningful metrics?		
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?		
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?		
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?		
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?		
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Y	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Y	RIV
8.3 Is the groundwater model coupled with a surface water model?	N	
8.3.1 Is the adopted approach appropriate?	-	
8.3.2 Have appropriate time steps and stress periods been adopted?	-	
8.3.3 Are the interface fluxes consistent between the	-	

Review questions	*Yes/No*	*Comment*
groundwater and surface water models?		

Table 3: Compliance checklist

Question	*Yes/No*
1. Are the model objectives and model confidence level classification clearly stated?	Y
2. Are the objectives satisfied?	Y
3. Is the conceptual model consistent with objectives and confidence level classification?	Y
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Y
5. Does the model design conform to best practice?	Y
6. Is the model calibration satisfactory?	Y
7. Are the calibrated parameter values and estimated fluxes plausible?	Y
8. Do the model predictions conform to best practice?	Y
9. Is the uncertainty associated with the predictions reported?	Y
10. Is the model fit for purpose?	Y