VICKERY EXENSION GROUNDWATER ASSESSMENT INDEPENDENT REVIEW

Prepared for:	**NSW Department of Planning and Environment**	9 November 2018

hydrogeologic

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Version 2	9 November 2018	Updated re cumulative impacts and borefield

THIS REPORT SHOULD BE CITED/ATTRIBUTED AS:

Middlemis H (2018). Vickery Extension Groundwater Assessment Independent Review. Prepared by Hydrogeologic for NSW Department of Planning and Environment. 9 November 2018.

1. Introduction

1.1 Vickery Coal Project and Extension

An approval for the Vickery Coal Project was granted to Whitehaven Coal Pty Ltd by the New South Wales Government in September 2014, for an open cut mine to produce coal at a maximum rate of 4.5 Mtpa. There has been no construction or production to date following the 2014 approval (DRG, 2018). Whitehaven is now seeking Development Consent for the Vickery Extension Project, which would replace the existing Approved Mine Development Consent (SSD-5000), with a maximum production rate of 10 Mtpa. Essentially, the Extension project encompasses and expands the 2014 approved project, although post-mining would involve only one final void lake.

The Vickery Project is about 25 km north of Gunnedah (Figure 1), in the Maules Creek sub-basin of the Gunnedah Basin, which has a long history of coal mining. The former Vickery Coal Mine operated sporadically until about 1998. Open cut and underground mining by Whitehaven at the former Canyon Coal Mine ceased operations in 2009 and was rehabilitated. Whitehaven has also operated the Rocglen mine east of Vickery since 2008, and the Maules Creek and Tarrawonga coal mines north of Vickery since 2014 and 2006, while the Boggabri mine has been operated by Idemitsu since 2006.

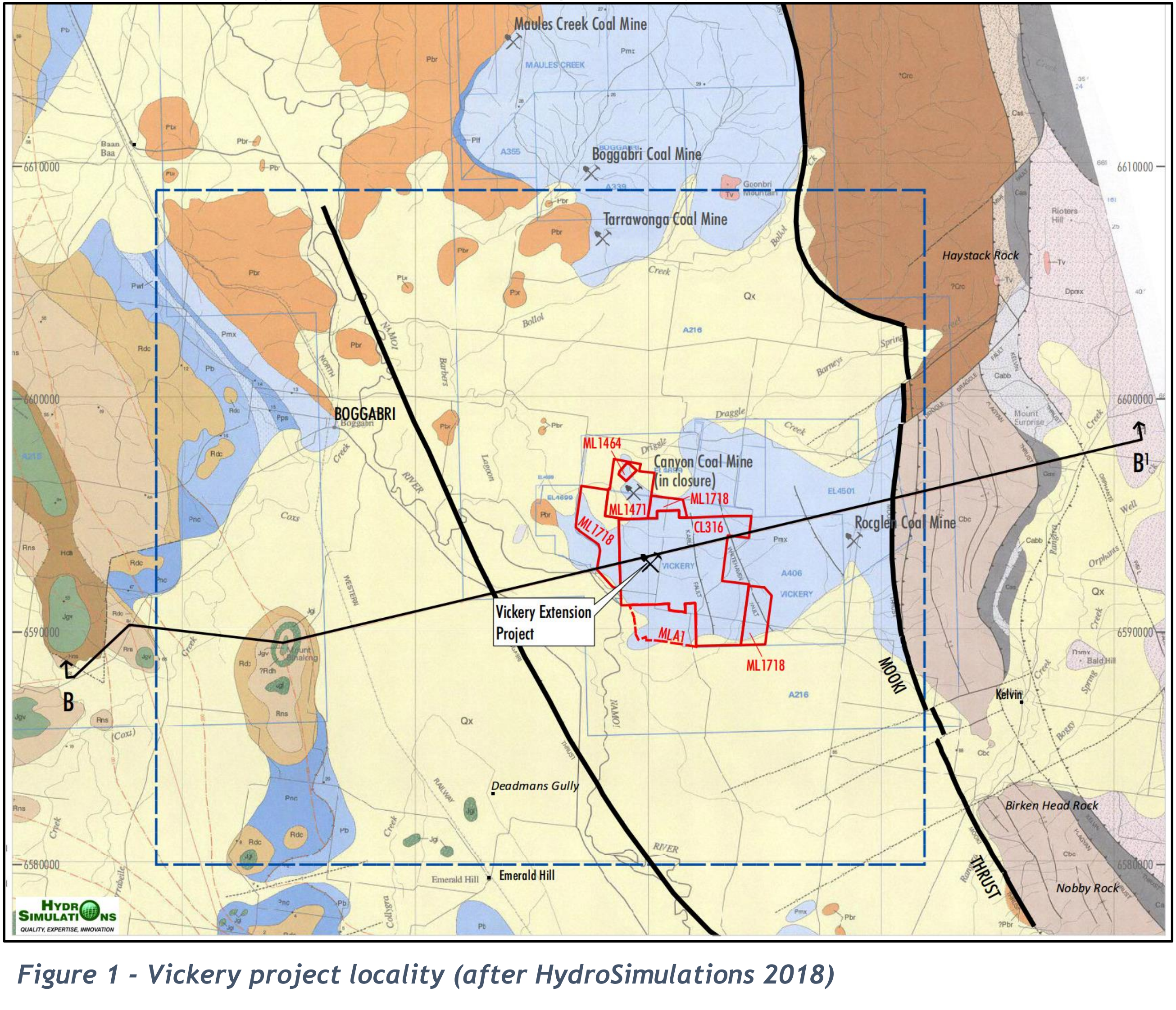

Figure 1 - Vickery project locality (after HydroSimulations 2018)

1.2 Peer Review

This report summarises the outcomes of an independent peer review of the Vickery Extension hydrogeological and groundwater modelling assessment conducted by HydroSimulations (2018). This desktop review was conducted by Hugh Middlemis (HydroGeoLogic), in accordance with the best practice principles and procedures of the Australian Groundwater Modelling Guideline (Barnett et al. 2012).

The review outcomes are summarised in section 2, including the guideline compliance summary checklist (Table 1).

1.3 Evidentiary Basis

The main evidentiary basis for this peer review is the groundwater assessment report:

- HydroSimulations (2018). Vickery Extension Project Groundwater Assessment. Prepared for Whitehaven Coal. August 2018. Presented as Appendix A to the Vickery Extension Project Environmental Impact Statement. Report referred to herein as 'HS'.

Several other reports from the Vickery Extension Project Environmental Impact Statement were considered:

- Section 5 Rehabilitation Strategy and Section 6 Planning Framework and Project Justification, mainly in relation to the post-mining final void lake scenario.
- Appendix B Surface Water Assessment, mainly in relation to the water balance modelling of the post-mining final void lake scenario.
- Attachment 4 Peer Review Letters (noting that this review concurs with their findings):
  - Kalf Associates Peer Review of HydroSimulations Groundwater Assessment.
  - Prof. Tom McMahon review of the Surface Water Assessment.

Two reports prepared by the NSW Department of Planning and Environment (DPE) were also considered in relation to the post-mining final void lake scenario:

- DPE (2017). Improving Mine Rehabilitation in NSW Discussion Paper. November 2017. Department of Planning and Environment.
- DRG (2018). Vickery Coal Extension Project, Resource and Economic Assessment. Prepared by Department of Planning and Environment Division of Resources and Geoscience. Version 1.1, October 2018.

2. Review Outcome Summary

My professional opinion is that the Vickery Extension hydrogeological and groundwater modelling assessment is fit for the purpose of mine dewatering environmental impact assessment (including cumulative impacts) and informing management strategies and licensing. A few sensitivity and uncertainty scenarios have been conducted but improved assessment is warranted. The post-mining final void water balance assessment is adequate, but the application of the groundwater model to investigate closure options and related uncertainties is less than one would expect in terms of best practice.

It is noted that the EIS reports include brief reports on peer reviews of the groundwater and surface water assessments (EIS Attachment 4), and this peer review concurs with those findings. As a summary of the findings of this peer review, the compliance checklist from the best practice guidelines is presented below in Table 1.

Table 1 - Groundwater Model Compliance: 10-point essential summary – Vickery Extension

Question	Y/N	Comments re Vickery Extension groundwater model
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Class 2-3 model confidence level is claimed (HS s4.1). Independent analysis for this review indicates that a Class 2-3 level is justified (see Table 2 below).
2. Are the objectives satisfied?	Yes	Competent model design and calibration to groundwater levels, demonstrating fitness for purpose. Sound application to mine dewatering scenarios, and input to post-mining final void water balance. Basic sensitivity analysis conducted.
3. Is the conceptual model consistent with objectives and confidence level?	Yes	Conceptualisation is sound, consistent with data, objectives and Class 2-3 confidence level for mining impact assessment and licensing purposes. Conceptual model does not include post-mining final void processes, but the water balance modelling (Appendix B Surface Water Assessment) did account for those processes and used the groundwater model inflow estimates.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	HS report lists studies since 1980s, including on many mines in the area, which have been carefully considered and combined with the available data to develop a sound conceptual model. Competent hydrogeologists and modellers have evaluated the data, conceptualisation, model design, execution & outcomes.
5. Does the model design conform to best practice?	Yes	The model software, design, extent, layers, grid, boundaries and parameters are consistent with best practice design and execution. Modelling approach accounts for Boggabri and Maules mine drawdown zone of influence, and includes effects of nearby Tarrawonga, Rocglen & Canyon projects.
6. Is the model calibration satisfactory?	Yes	Model calibration performance is acceptable (SRMS error 6.3% for steady state, 5% for transient 2006-2011 and 7.1% for verification 2012-2017). Time series matches mostly good, some isolated poor performances, but not close to Vickery area. Sensitivity and selected uncertainty analysis ok (bare minimum).
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Model parameter values are consistent with drilling & testing information. Inflow rates at nearby RocGlen and Tarrawonga mines in Maules Creek Formation (0.2-0.5 ML/day) help constrain potential model flux non-uniqueness. Predicted inflow rates (0.7-1.4 ML/d) higher than observed rates, attributed to model conservatism, appropriate for impact assessment.
8. Do the model predictions conform to best practice?	Adequate except for post-mining final void issues	Overall methodology is consistent with best practice and suitable for guiding dewatering impact assessment and management plans and licensing decision making. Cumulative impacts adequately considered, including due to water supply borefield, and due to nearby mines at Rocglen, Canyon, Tarrawonga, Boggabri and Maules. See section 3.4. Post-mining final void predictions are based largely on water balance modelling, informed by inflow-level relationship from groundwater model results (Figure 59). There has been no use of the groundwater model to explore mine closure options or to justify the final void arrangement, simply an application of the Approved Mine 'Condition 50' principle that final voids should act as a groundwater sink. But some Approved Mine final voids will be backfilled under the Extension project. Discussed further in section 3.5 below.

9. Is the uncertainty associated with the simulations/predictions reported?	Yes	Key sensitive parameter identified as vertical hydraulic conductivity (Kv), typical for most models. A conservative case climate change uncertainty scenario was run, along with two scenarios for higher and lower Kv, indicating limited effects.
10. Is the model fit for purpose?	Yes	My professional opinion is that the Vickery Extension hydrogeological and groundwater modelling assessment is fit for the purpose of mine dewatering environmental impact assessment (including cumulative impacts) and informing management strategies and licensing. A few sensitivity and uncertainty scenarios have been conducted but improved assessment is warranted. The post-mining final void water balance assessment is adequate, but the application of the groundwater model to investigate closure options and related uncertainties is less than one would expect in terms of best practice.

3. Discussion

The report (HydroSimulations 2018) is well-written and provides adequate explanations of the conceptual model, and the numerical model design and execution.

The 3D MODFLOW-USG model domain, layer setup, grid design, boundary conditions and parameters applied are consistent with the available information and conceptualisation, with a bias towards conservative assumptions where warranted (such as over-estimating mine dewatering).

The conceptualisation is sound, based on a range of investigations over many years, and has been implemented aptly in the model. The model calibration performance is adequate statistically, the time series matches to bore data is mostly good, and the simulated groundwater flow patterns reflect the hydrogeological conceptualisation.

The impact assessments and interpretations are largely supported by the data available and the evidence presented, and the ongoing monitoring and other investigations will provide additional data for future model refinements and improvements in performance and for comprehensive uncertainty analysis that should, in turn, be used to guide future monitoring and management programs.

3.1 Model Confidence Level Classification

Although the “model confidence level classification” is identified as a key issue in the latest groundwater modelling guidelines, there are identified limitations with the concept, as outlined in the draft IESC report on groundwater modelling uncertainty, along with methods to address its limitations (Middlemis and Peeters, 2018, in review).

The groundwater assessment report claims a Class 2-3 model confidence level classification, as expected for the study purpose of impact assessment and management, and related licensing.

This review conducted an independent assessment of the model confidence level classification, consistent with the guidelines but based on the method outlined in Middlemis and Peeters (2018). This review finds that a Class 2-3 model confidence level is indeed justified (Table 2), confirming the Vickery Extension model as suitable for impact assessment scenario modelling purposes.

Table 2 - Vickery Extension groundwater model confidence level

Model Confidence Class characteristics: Vickery Extension

Class	Data		Calibration		Prediction		Quantitative Indicators	
1 **(simple)**		Not much / Sparse coverage		Not possible.		Timeframe >> Calibration		Timeframe >10x
		No metered usage.		Large error statistic.		Large stresses/periods.		Stresses >5x
		Low resolution topo DEM.		Inadequate data spread.		Poor/no validation.		Mass balance > 1% (or one-off 5%)
		Poor aquifer geometry.		Targets incompatible with model purpose.		Transient prediction but steady-state calibration.		Properties <> field values.
		Basic/Initial conceptualisation.						No review by Hydro/Modeller.
2 **(impact assessment)**		Some data / OK coverage.		Weak seasonal match.		Timeframe > Calibration		Timeframe = 3-10x
	~	Some usage data/low volumes.	~	Some long term trends wrong.		Long stress periods.		Stresses = 2-5x
	~	Baseflow estimates. Some K & S measurements.		Partial performance (e.g. some stats / part record / model-measure offsets).	~	OK validation.		Mass balance < 1%
	~	Some high res. topo DEM &/or some aquifer geometry.	√	Head & Flux targets used to constrain calibration.	√	Calib. & prediction consistent (transient or steady-state).		Some properties <> field values. Review by Hydrogeologist.
	√	Sound conceptualisation, reviewed & stress-tested.	√	Non-uniqueness and qualitative uncertainty partially addressed.	√	Significant new stresses not in calibration.		Some coarse discretisation in key areas of grid or at key times.
3 **(complex simulator)**	~	Plenty data, good coverage.	~	Good performance stats.	~	Timeframe ~ Calibration	√	Timeframe < 3x
	~	Good metered usage info.	√	Most long term trends matched.	√	Similar stresses & periods.	√	Stresses < 2x
	√	Local climate data.	√	Most seasonal matches OK.	~	Good validation.	√	Mass balance < 0.5%
	~	Kh, Kv & Sy measurements from range of tests.	√	Present day head/flux targets, with good model validation.	√	Transient calibration and prediction.	√~	Properties ~ field measurements.
		High res. topo DEM all areas & good aquifer geometry.	√	Non-uniqueness minimised, qualitative uncertainty justified.	√	Similar stresses to those in calibration.	√	No coarse discretisation in key areas (grid or time).
	√	Mature conceptualisation.					√	Review by experienced Modeller.

(after Table 2-1 of Barnett et al (2012) Australian Groundwater Modelling Guideline)

3.2 Calibration and Prediction

The model has a good history match calibration in steady state and transient modes to the data record 2006-2011, with subsequent verification to 2012-2017. This is consistent with best practice and is well-executed to establish the validity of the model as a sound predictive tool.

Model calibration performance is acceptable in that is within the guideline 5-10% scaled RMS statistical criterion (SRMS is 6.3% for steady state, 5% for transient 2006-2011 and 7.1% for verification 2012-2017). The simulated groundwater flow system contours and time series matches to observation bore data is mostly good.

There are some isolated poor matches apparent in the time series plots (Appendix D to groundwater assessment) that are not well-explained, especially for those bores in other key areas near Canyon, Rocglen and Tarrawonga, although there are usually other bores nearby that show good matches; for example:

- the poor match at VNW223 in the Canyon lease area (Figure 45) is not explained, although there is a good match to the nearby VNW221 (Figure 24).
- a cluster of bores more than 3km southeast of Vickery show poor matches (WB-10, WB-12, GW036484, GW036462), although there are other bores nearby with good matches (WB9, WB11).
- some bores near Rocglen show poor matches (MP-2, WB-7, WB-5, WB-3), although there are good matches nearby (MP-3, MP5, WB-2).
- some bores near Tarrawonga (GW031856, MW-3, MW-6, MW-1), although there are good matches nearby (GW052266, MW-8, MW-2).

The overall prediction scenario methodology (apart from the final void scenarios, which are discussed in section 3.5) and results presentations are consistent with best practice and suitable for guiding dewatering impact assessment and management plans and licensing decision making. The modelling assessments provide good detail on water balance issues and drawdown impacts on third party bores, with consideration of impacts on potential groundwater dependent ecosystems. The analysis quantifies volumes affected in terms of the Aquifer Interference Policy and groundwater management zones, including interactions with the important Namoi alluvium, such that the results should be adequate for licensing purposes.

3.3 Sensitivity and Uncertainty

A basic sensitivity analysis has been conducted, identifying vertical hydraulic conductivity (Kv) as a key parameter, often the case in groundwater models of this type. Usually, there is more than one sensitive parameter identified, and the groundwater assessment has not clearly demonstrated best practice via the bare minimum effort that has been applied to consider and investigate sensitivities and uncertainties.

For example, the simple and practical method of conducting a relative composite sensitivity (RCS) analysis using PEST routines has not been attempted. A high RCS value indicates that the model calibration is sensitive to that parameter, but that the measurements have provided enough information to adequately constrain the uncertainty. A low RCS value indicates that the model calibration is not sensitive to the parameter because the measurements do not inform/constrain the calibration, and thus the effect on predictive uncertainty should be evaluated.

In this case, only one parameter uncertainty scenario has been run, concluding that prediction results are not highly sensitive to Kv. A conservative climate change uncertainty scenario was run, also showing relatively low impacts.

The methodology applied does not clearly demonstrate that even a bare minimum assessment has been conducted in terms of consistency with best practice guidance (Barnett et al. 2012; Middlemis and Peeters, 2018). While it could be argued that the risk context is fairly low in this case, given its setting in the low permeability Maules Creek Formation and benchmarking to low dewatering rates and lack of widespread drawdown impacts from nearby mines, the assessment does not highlight the use of such arguments to justify the minimum effort approach to uncertainty assessment.

Significant improvements are warranted in the uncertainty assessment, as a minimum to consider the risk management context and conduct a qualitative uncertainty analysis (Middlemis and Peeters, 2018), along with a relative composite sensitivity (RCS) analysis. Depending on the results of that assessment, a comprehensive/quantitative uncertainty assessment may be required, including into post-mining final void closure scenarios.

Even after improved uncertainty assessments, uncertainties will remain, and the ongoing monitoring program is well-designed to provide the data in due course for model improvements and assessment of uncertainties. In its current form, the groundwater assessment provides information that is suitable for impact assessments and management plan development, and for licensing decisions.

3.4 Cumulative Impacts

Cumulative impacts have been adequately considered for the Vickery Extension, by also including dewatering at the nearby mines at Rocglen and Tarrawonga that lie within the Vickery model domain. A separate simulation also considered the cumulative effects of all mines and the water supply borefield north of Vickery (Figure 62).

This also includes the cumulative effects of dewatering at the Boggabri mine immediately north of Tarrawonga. The Boggabri mine groundwater assessment showed that the cumulative (Boggabri plus Tarrawonga) drawdown zone of influence extends only as far as the southern side of the Tarrawonga lease (AGE 2010, Drawing 17). This is similar to that conservatively predicted by the Vickery Extension model, confirming that cumulative drawdown impacts have been adequately considered.

Furthermore, the available groundwater monitoring data in the area south of Tarrawonga effectively verifies the extent and magnitude of the mine dewatering effects in this area.

Having said that, there is no contour plan of modelled groundwater levels post-mining that confirm that the final pit void lake is indeed acting as a long term sink. The 100-tear post mining run results shown in Figures 50 and 51 are for drawdown only, and the post-mining water balance concluded that it would take at least 300 years for the pit lake levels to start approaching a long term dynamic equilibrium.

3.5 Post-Mining Final Void

According to DRG (2018), it is a requirement of Condition 50, Schedule 3 of the Development Consent for the Approved Mine (SSD-5000) for the Approved Mine final voids to act as groundwater sinks, due to the benefit of the sinks preventing the migration of poorer quality groundwater to surrounding aquifers. While this position may have been established on the basis of some groundwater modelling scenarios as part of the Approved Mine, the Extension EIS provides no details. It is also not known whether this principle should or must be carried forward in relation to the Vickery Extension project.

It can be said that there has been no use of the groundwater model to explore mine closure options or to justify the final void arrangement. It seems that the guiding principle was an application of the Approved Mine 'Condition 50' principle that final voids should act as a groundwater sink, without consideration of the fact that some Approved Mine final voids will be backfilled under the Extension project.

Based on a brief consideration of the final landforms (EIS Figure 5.4), the waste rock emplacement of up to 370 mAHD exceeds the pre-mining topography by around 100 metres (DRG, 2018). There appears to be adequate and suitable waste rock material available to fill the relatively small residual final void to at least the pre-mining groundwater level (around 250 mAHD). Subject to careful evaluation of potential leachate risks, best practice suggests that reduced long term risks to water resources could be achieved by backfilling to the pre-mining water level (Younger and Wolkersdorfer, 2004) to minimise final void lake evaporation and salinisation impacts. The Boggabri mine groundwater assessment (AGE 2010) was based on the backfilling of the final void to the pre-mining water table, although the Maules Coal Project further north will involve a final void pit lake sink, as will the Tarrawonga mine to the south.

There appears to be little exploration of final void closure options or justification of the final arrangement in these terms, simply an application of the ‘Condition 50’ principle for the Approved Mine to the Vickery Extension.

The Vickery Extension EIS (section 6.1.10) does indicate that final void infill options were ’considered’, but little detail is provided. It cites cost as major factor to justify not backfilling completely (in addition to the ‘Condition 50’ issue outlined above), without highlighting the benefit of any long term environmental impacts of a backfilled alternative, or the other costs of the adopted approach. For example, the final void lake salinity is predicted to be equivalent to seawater, but this is not stated clearly anywhere, although the EIS Figure 8.22 does show the result. The assessment is also deficient in not considering the potential for longer term density-driven flow effects. While the assessment is otherwise adequate in terms of consistency with ‘Condition 50’, best practice would involve application of the groundwater model to investigate a range of options for post-mining to demonstrate that the optimum closure arrangement is adopted with minimum long term impacts.

The post-mining final void prediction and assessments reported are based largely on the water balance model (details are outlined in section 8.10 of the surface water assessment; EIS Appendix B). This uses output from the groundwater model on the post-mining final void inflow-level relationship (Figure 59). The groundwater inputs were combined with synthetic 1000-year climate change datasets that were created to account for existing and rainfall and evaporation and related runoff from catchments contributing to the final void lake, along with projected changes due to climate variability. In summary, the final void water balance and lake level was estimated on a monthly basis under a suitably wide range of conditions and assumptions, consistent with best practice principles. The results indicate that it would take about 300 years to effectively achieve a new dynamic equilibrium lake level of between about 60 and 124 mAHD (depending on the scenario), all well below the potential spill level of 265 mAHD.

The results are reportedly more sensitive to rainfall changes than to evaporation. This implies that the results may be materially different if the analysis was conducted on a daily rather than monthly basis, as shorter timeframes would involve consideration of more intense events that could surcharge (but not spill) the pit lake and recharge the aquifer. A daily water balance analysis would provide a means of investigating uncertainties affecting the final void water balance.

The salinity of the final void after 1000 years post-mining is estimated to have increased to at least 11,000 to 14,000 mg/L (higher rainfall cases), and up to 37,000 to 46,000 mg/L (lower rainfall cases) (EIS Appendix B, Figure 8.22). All cases result in the salinity continuing to increase with time, beyond the current beneficial use for agricultural purposes to eventually be suitable only for industrial purposes (unsustainable trajectory).

The Condition 50 position assumes minimum groundwater quality risks to the surrounding groundwater regime if the final void forms a terminal sink. However, terminal pit void lake sinks do pose water quality risks, typically via salinity increases due to evapo-concentration (Johnson and Wright, 2003; Younger and Wolkersdorfer, 2004), as shown in this case. If this process results in hyper-saline pit void lakes, there is the potential for density-driven plumes to move away from the lake (McCullough and Schultze, 2015), but that typically takes many hundreds or thousands of years (if at all). In comparison, while a through-flow pit void lake could also have water quality impacts (Johnson and Wright, 2003), the impacts are dependent on potential leachate characteristics. Similarly, while significant reductions in risks to groundwater quality could be achieved by backfilling the pit void to the pre-mining groundwater level to minimise final void lake evaporation and salinisation impacts, leachate potential must again also be considered. These issues, and related uncertainties, do not appear to have been adequately explored in the EIS to identify minimum impact closure options.

The groundwater assessment report provides some very basic information on the final void model setup and results, but the details are unclear/inadequate. It could be presumed that modelling procedure involved running the model via a series of steady state runs with a range of fixed head levels applied to the pit lake to quantify the relationship for lake elevation versus groundwater inflow for input to the water balance. However, the groundwater model does not include evaporation on the pit void lake, so the results could also derive from a very simple transient simulation that does not represent all processes (as appears to be the case). While results are presented for a 100-year post-mining scenario, the figures need significant improvement (Figure 60 to show contour labels and Figure 61 to expand the Y-axis to show the time series properly). It is worth noting that the 100-year scenario does not provide an estimate of the long term effect of the terminal pit lake sink on the groundwater system as the recovery takes in excess of 300 years. Again, the reporting is deficient, and the uncertainties have not been investigated.

The application of best practice could avoid many of these problems by running the model in steady state for the post-mining scenario (Barnett et al, 2012), with a fixed head to represent the final lake level estimated from the pit void water balance assessment (and with appropriate parameters applied to represent the backfill and the lakes). It is noted that the model was calibrated to pre-mining conditions in steady state, and predictions in steady state do not involve aquifer storage parameters, so a steady state post-mining approach would reduce uncertainties in the post-mining predictions. A steady state post-mining run would not allow analysis of the time taken for recovery (the water balance already provides an estimate), but it would provide a conservative estimate of the long term extent and magnitude of aquifer depressurisation (i.e. improving confidence in the predicted impacts on third parties or environmental receptors). Such an approach could also allow investigation of options and uncertainties for the final pit void treatment (e.g. to test assumptions on backfill configurations, or on evaporation rates, provided an evaporation function is applied to the pit void lake).

The model is suitable for investigation of a range of closure options for the final void (from partial to total backfilling to none), to identify an optimum scenario to minimise risks to groundwater, and to evaluate how those predictions are affected by uncertainties. It is recommended that the model be applied to investigate closure options in order to provide quantitative information to justify the closure plans and to support decisions on licensing.

3.6 Report Documentation Issues

While the report is generally well-written, there are some matters where the report is deficient in its explanation or justification, as outlined above, or where the graphical figures require some improvement, including the points below:

- Section 2.10.1 does not explain how 'the effects of mining and pumping were removed' from selected groundwater level monitoring data.
- Figure 13 – appears to have reversed the bubble plot symbol size.
- Figure 36 – on the western boundary, appears to show GHB boundary condition cells overlying recharge cells; also, there is no explanation of why there is a zone 5 recharge rate of 1.8×10^{-4} m/day (higher than the maximum rate that is applied to zone 1 of 1.5×10^{-5} m/day) applied to the boundaries of the zone 2, 3 and 4 recharge zones that are specified at 1.5×10^{-7} m/day.
- Figure 50 & 51 – need explanation of why the drawdown contours at the end of mining are very closely spaced on the east and the south of Vickery, but not on the west and north, even though the contours appear to be all contained within the low permeability Maules Creek formation; also need explanation of why there is 1-2m cumulative drawdown (Figure 50) over an extensive area between Vickery and Rocglen, underlying the Vickery State Forest, and a very small area at Rocglen with 1m drawdown that is attributed to Vickery (Figure 51); and Figure 50 needs an update to show the deep contour levels at the end of mining (similar to the 150m and 200m contours in Figure 51).
- Figure 54-56 – needs explanation of what positive and negative flux values mean.
- Figure 59 – cognitive strain issue; should have level (mAHD) shown on y-axis.
- Figure 60 – no contour labels at all for levels after 100 years post-mining recovery.
- Figure 61 – y-axis on time series too small to show entire range of plot.
- Figure 62 – no explanation of why there are purple drawdown contours (associated with borefield drawdown) within the area of drawdown due to mine dewatering at Tarrawonga, Rocglen and Vickery.
- Figure 63 - no contour labels are shown.
- Appendix D Transient Calibration Hydrographs – the y-axis for the VKY series bores is 200m, when it should be much less to show the variations in detail.

4. Conclusion

My professional opinion is that the Vickery Extension hydrogeological and groundwater modelling assessment is fit for the purpose of mine dewatering environmental impact assessment (including cumulative impacts) and informing management strategies and licensing.

A few sensitivity and uncertainty scenarios have been conducted but improved assessment is warranted, consistent with best practice.

The post-mining final void water balance assessment is adequate, but the application of the groundwater model to investigate closure options and related uncertainties is less than one would expect in terms of best practice.

The recommended monitoring program and ongoing hydrogeological investigations are well-designed and will provide additional data for future model refinements and improvements in performance, and for comprehensive uncertainty analysis.

5. Declarations

For the record, the peer reviewer, Hugh Middlemis, is an independent consultant specialising in groundwater modelling. He is a civil engineer with a masters degree in hydrology and hydrogeology and more than 37 years' experience. Hugh was principal author of the first Australian groundwater modelling guidelines (Middlemis et al. 2001) that formed the basis for the latest guidelines (Barnett et al. 2012) and was awarded a Churchill Fellowship in 2004 to benchmark groundwater modelling best practice. He is currently working with Flinders University and Commonwealth agencies on guidance for modelling uncertainty that will soon be published (Middlemis and Peeters, 2018).

Hugh Middlemis has not worked on the Vickery Extension project or for Whitehaven Coal, and we assert no conflict of interest issues in relation to this work.

We note the following in relation to previous interactions with Dr Noel Merrick (principal of HydroSimulations, the consultant acting for Vickery):

- Mr Middlemis has conducted peer reviews of investigations led by Dr Merrick:
  - peer review of Hume Coal Project groundwater assessment (2018; DPE).
  - peer review of the Wambo longwall panel 10A expansion studies (2015, DPE).
  - review of the Mulgrave River model report (2016).
- Dr Merrick has completed peer reviews of groundwater models developed for catchment and salinity management purposes in South Australia and Victoria by Aquaterra when Mr Middlemis was Technical Director at Aquaterra:
  - Adelaide Plains solute transport model (2011);
  - Padthaway solute transport model (2008);
  - Eastern Mallee models EM2.1 (2008) and EM2.3 (2009).

- Previously, Mr Middlemis has worked directly with Noel Merrick, notably:
    - to write the 2001 guidelines on groundwater modelling and prepare and deliver some related conference papers (Middlemis et al, 2001, 2004);
    - for a few semesters across about 1996-2005, Mr Middlemis worked as the distance education tutor for Dr Merrick's Groundwater Modelling subject at UTS (i.e. marking assignments and helping students via email and telephone);
    - during about half of the period 1986-1989 when Mr Middlemis was at an early/mid-career stage at the Department of Water Resources, he was seconded from the Hydrology unit to work in the Hydrogeology Unit on groundwater modelling projects, supervised directly by Mr Merrick.

6. References

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