Review of United Wambo Open Cut Coal Mine Project Environmental Impact Statement – groundwater impacts

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Introduction

This is the second expert report I have prepared in response to the proposed United Wambo Open Cut Coal Mine Project Environmental Impact Statement, on the topic of groundwater (and related surface water) impacts of the project. I was asked to prepare this report by EDO NSW acting on behalf of the Hunter Environment Lobby (HEL), addressing the following three questions:

a) In your opinion, are the groundwater and surface water assessments undertaken for the Project adequate?
b) In your opinion what, if any, are the groundwater/surface water impacts that would arise from the Project?
c) Provide any further observations or opinions which you consider to be relevant, having regard to the circumstances of this matter.

The brief from EDO NSW also requested I present orally to the Planning Assessment Commission in Singleton on the 8th of February. I was unable to physically attend the hearing due to other work commitments in Melbourne on that date; the request to present orally by phone to the PAC was unfortunately not granted.

This report is designed to be read in conjunction with the previous expert report I prepared on 21st September 2016 following the release of the EIS. Since that time, further work has been completed by the project proponent to address issues raised in this initial report (and many other submissions on groundwater, surface water and other topics), as outlined in the proponent's *Response to Submissions*. The content of this expert report relates predominantly to this *Response to Submissions* and related work that has been conducted.

a) In your opinion, are the groundwater and surface water assessments undertaken for the Project adequate?

In my initial expert report of 21st September 2016, I raised a number of issues with respect to the adequacy of the groundwater (and to a degree, surface water) assessments completed in the EIS. Below, the key areas where deficiencies were identified are re-visited and an assessment is made as to whether these deficiencies have been subsequently addressed in the *Response to Submissions* provided by the proponent in March 2017, and/or *Response to Request for Further Information* (provided in September 2017):

Groundwater levels, flow patterns and ground-surface water interaction (section 1.2 of first expert report):

My previous report raised issues with the presentation and interpretation of groundwater level data, and the analysis of the mechanism(s) and nature of ground-surface water interaction. Deficiencies included data missing in the presentation of water level contour maps, a relatively low number of groundwater hydrographs, a lack of clarity regarding the impacts of existing mining operations on groundwater levels and flow patterns, and the need for a dedicated section examining ground-surface water interaction (with supporting field data).

In the *Response to Submissions*, the proponent includes new maps (Figure 4.2 and 4.3 of the *Response to Submissions Part A*) showing specific data points of measured water levels in relation to the water level contours. These maps are useful, in that they allow a clearer identification of areas where there is greater density (e.g. immediately north and south of the project) and lesser density (east of the project) of water level baseline data. Some further assessment of where the monitoring network may be deficient for the purpose of ongoing groundwater level monitoring is however warranted on this basis (see below). While the *Response to Submissions* indicates that details of baseline and ongoing groundwater monitoring programs will be developed in consultation with the relevant authorities, it would be beneficial for these plans to be made public so that communities have an opportunity to scrutinise these and identify possible deficiencies in the monitoring plans.

No further hydrographs have been included to show the temporal variations in groundwater levels in the various aquifers and sub-regions of the study area. Inclusion of some further representative hydrographs from the different aquifers, to assess in conjunction with the water level contour maps (with appropriate cross-referencing), is an important aspect of delineating and describing groundwater flow patterns. It is important to allow assessment of the variability of water levels at particular points, their relationship to the overall groundwater flow directions, and factors such as changes in surface water levels, mining activity and climate. A more complete conceptual model should include such analysis, as there may be variability in the flow patterns and hydraulic gradients that could be revealed; and this may have implications for impact prediction.

The proponent has also not adopted the recommendation in my first report to include a dedicated section discussing ground-surface water interaction, and to include in this section further field data to better inform the conceptual model of ground-surface water interaction. Examples of field data which could be gathered to look at this specific issue are detailed groundwater and stream hydrograph analyses, calculation of Darcy fluxes, and/or collection of Radon-222 concentrations or electrical conductivity (EC) time series in the surface water bodies.

The lack of data of this kind creates uncertainty with respect to predictions of changes to baseflow and water fluxes to and from the Hunter River, Wollombi Brook and associated alluvial aquifers. Large scale fully saturated numerical groundwater flow models generally struggle to provide meaningful predictions of ground-surface water interaction, which involve complex flow processes at relatively small scales. The relatively thin and spatially discrete areas within which these ground-surface water interaction processes take place are generally not well captured and simulated by regional groundwater models (e.g., Rassam and Werner, 2008), such as the one developed for this project.

Most of the proponent's data used to define parameters and calibrate the numerical groundwater model are based on measurements of materials sampled during the progression of mining, and as a result there is considerably more data on appropriate hydraulic parameters (such as hydraulic conductivity) for the strata that are subject to mining in the region in comparison to the materials in the alluvium and streambeds of waterways. It is predominantly the hydraulic properties of these materials (e.g. streambed hydraulic conductivity, alluvial aquifer hydraulic conductivity and storage coefficients) which will regulate the inflow and outflow of groundwater from the alluvial aquifers, and their response to mining. As a result, the model will be better equipped to make predictions of mining impact for the material that will be subject to further mining, in comparison to the impacts on these alluvial systems.

If the impacts on baseflow and alluvial groundwater are considered to be important to stakeholders in the region, then further data collection and potentially, further modelling at a more appropriate scale using complementary techniques, would be beneficial. Rassam and Werner (2008), Barlow and Leake (2012) and others provide information about modelling techniques that are designed to look at changes to streamflow as a result of groundwater extraction; Brodie et al (2007) provide a comprehensive overview of field-based methods for the assessment of ground-surface water connectivity.

Groundwater quality (section 1.3 and 1.11 of first expert report):
In my first expert report I noted that the sections presenting and discussing groundwater quality data and potential impacts of the project on water quality also contained a number of deficiencies. These included a relatively small amount of groundwater quality baseline data, problems with the presentation of these data, a lack of critical analysis and interpretation with respect to hydrogeological and geochemical processes, lack of analysis of processes associated with mining that could impact water quality (such as mobilization of metals and salts, development of saline/poor quality water in areas of mining) and the key dynamics involved in these. These and other issues related to groundwater and surface water quality (such as the inadequacy of the baseline data) were also noted by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) in their advice in October 2016.

In response, the proponent has included a Geochemistry Assessment in their *Response to Submissions Part B*, and additional groundwater quality data in Appendix 2 of this document – namely maps of EC, pH and aluminium concentrations. The proponent also made corrections to Fig 4.4 – the scatterplot of Mg/Na and Na/SO_4 - which addressed an error pointed out in my first report, and a new figure (3.4) and table (Appendix 5) summarising aspects of the water quality data.

The proponent has collected limited further water quality data (particularly for groundwater), and the material contained in the *Response to Submissions* still lacks a thorough section discussing existing patterns and trends in groundwater quality, and their relationship to groundwater flow patterns, recharge/discharge, water-rock interaction and mining activity. The water quality summary in Appendix 5 includes new/updated information about the range, median and average values of particular analytes in the various aquifers (and surface water), while Fig 3.4 also shows locations of bores sampled for water quality monitoring. However, it is still not possible to link the results of Appendix 5 to specific locations in the study area, as the table only includes aggregated data for each analyte (not raw data showing each bore location and the associated concentrations). Spatial analysis of trends in water quality is important for characterising baseline groundwater quality and its relationship to different processes/factors, and assessment of potential issues such as build-up of salinity and/or heavy metals in the mine voids, mobilization of salinity or metals in areas of mine waste and areas de-watered by the mining and impacts of surface discharge of mine water.

A comprehensive groundwater quality section would typically begin by analysing the baseline groundwater chemistry data in terms of water 'types', and presenting these data using Piper and/or Schoeller plots. These are routine methods for providing a picture of major ion chemistry in groundwater, and assessing variability in chemistry with respect to different aquifers, regions, and processes in a study area (Appelo and Postma, 2005). The fact that these types of plots have still not been produced despite their absence being noted in the submissions (e.g. my first report) is concerning; this along with the general lack of detailed analysis of trends in water chemistry throughout the study area results in ongoing uncertainty regarding major hydrogeochemical processes. These may be important influences on groundwater and surface water in future should the project proceed, and they should be comprehensively resolved, either during the environmental impact assessment and/or as part of the baseline monitoring program.

The analysis of the data in the original groundwater impact assessment focussed almost exclusively on the total dissolved solids (TDS) of groundwater (e.g. overall groundwater salinity), which provides little information with respect to key influences on groundwater quality, particularly in areas of mining, where excavation and de-watering of the strata can lead to geochemical changes, such as exposure of reducing materials to oxygen, mixing of waters between different aquifers (and/or surface runoff) and physical disturbance of water and rock material, which may subsequently be leached by rainfall. The proponent argues in the *Response to Submissions* that there is no need to monitor redox conditions in the groundwater, stating that this has *"not been historically a standard measurement required by regulators at mine sites across the Hunter Valley"*. If this is true then it is surprising, given how important redox chemistry usually is at mine sites. The proponent suggests that because the groundwater in the region largely has neutral pH, that mobilisation of dissolved trace elements is not expected and thus redox conditions don't warrant monitoring. The range of pH values however span a relatively wide range – e.g. from approximately 5.4 to 9.7, over which sorption and mobilization of metals may vary. As is noted in my original report and below, there are instances of elevated concentrations of certain metals, particularly aluminium (but also others), which appear to warrant further investigation. The data in Appendix A of the *Groundwater Impact Assessment* shows that maximum concentrations of aluminium in groundwater from all of the sampled aquifers – including alluvium, inter-burden, coal are well above irrigation and stock watering guidelines (e.g., >5 mg/L and in some cases up to 410 mg/L). Concentrations of aluminium in the tens or hundreds of milligrams per litre range are highly unusual in undisturbed groundwater systems, and there is thus a significant possibility that these data relate to geochemical and/or physical processes which have mobilised aluminium into groundwater, e.g. due to mining activity. Any proper understanding of the behaviour of heavy metals and other potential inorganic contaminants in the aquifer system therefore requires characterisation of redox and pH conditions in the water, and discussion of these parameters in conjunction with detailed analysis of changes in metal concentrations through time and space.

The analysis of trends in EC, pH and aluminium through time (included in the *Response to Submissions Part B*) show that these characteristics are generally variable in time – pointing to potentially significant impacts from existing mining and/or responsiveness to seasonal changes in recharge sources/amount, flow and mixing. Most of these changes through time are explained in the text as localised effects, such as seasonal differences in the amount of water discharging from the Permian coal units to shallower aquifers, or influences from upstream mining activities. However a more in-depth analysis is warranted with respect to geochemical processes in the study area and their relationship to mining and hydrology. For instance, if indeed there are periodic increases in aluminium which relate to mining activity in upstream areas, what is the actual mechanism for these (e.g. when specifically has this been evident? does it relate to mobilisation through acidification? What type of geological material is involved?) Without more detailed characterisation of redox/pH conditions in water from the various aquifers, and their relationship to metal concentrations, explanations regarding localised causes of spikes in aluminium concentrations (for example) can't be fully understood. The explanation (for example) regarding 'solubilisation of metals from clays' following high rainfall events is not well substantiated and would require further detailed monitoring of particular regions where this may be occurring, including a full suite of water chemistry data.

The Geochemistry Assessment report included in the *Response to Submissions Part B* focusses on the acid forming / neutralisation potential of selected geological materials and mine tailings from the site; the study found limited acid generating capacity in much of the sampled material. In the response to the IESC advice regarding baseline groundwater quality data, the proponent argues that the existing monitoring network is adequate for characterising baseline groundwater quality in the region. While the further presentation of water quality data in Appendix 2 is an improvement on the original EIS, it still provides limited information regarding the key processes impacting on groundwater quality in the various aquifers of the site, and consequently results in uncertainty regarding predicted impacts. The maps of EC values and aluminium concentrations (Figures 1 and 3 of Appendix 2, respectively) contain a limited number of monitoring points – and nearly all of the points are to the south of the existing mining operations with almost no data near the major surface water bodies or areas of existing mining operations. Some discussion of the trends in groundwater quality is included in the text, but due to the relatively limited spatial coverage of the data, this analysis provides limited information about the governing processes controlling groundwater quality throughout the site (e.g. relationship with existing mining operations). The pH map (Figure 2) shows slightly better coverage and more data; however this alone is not able to assist much in elucidating the major controls on groundwater quality in the study area.

Understanding the dominant processes controlling the evolution of groundwater salinity, pH and metals concentrations, such as recharge, mixing, evaporation and water-rock interaction, including the influence of mining impacts (including those off-site /upstream), would therefore require significantly more data and analysis in my view.

In terms of the monitoring program for groundwater quality, the proponent argues that monitoring of EC, pH and total suspended solids (TSS) will be adequate in general to characterise groundwater quality, and does not propose monitoring redox condition of the water. The sampling for metals is also proposed to be at a relatively low frequency and/or only in response to changes in 'indicator' parameters EC and pH. Redox potential is a simple and routine parameter to monitor in groundwater, and in the case of a mine excavating to a significant depth below the water table, where heavy metals are locally elevated in groundwater already, it is an important parameter to monitor, report and analyse continuously. Nearly all metals are redox sensitive, and may behave differently under different redox environments; these settings will likely be modified during the progress of mining (Appelo and Postma, 2005). Ongoing, regular monitoring of elements which have historically shown elevated levels (above ANZECC criteria)– e.g. aluminium, manganese and arsenic is also justified in order to understand why these metals show periodic increases, and mitigate risks associated with them.

Both my original report and the IESC pointed out the lack of monitoring points to the north/northwest of the proposed pits. It is unclear whether it is proposed to address this through installation of additional monitoring points – the proponent states that the monitoring program design is ongoing, in consultation with the regulator. In the *Response to Submissions Part A* it is noted by the proponent that additional monitoring locations are now proposed covering the areas identified. The location of the sites is not immediately clear in Figures 3.3 and 3.4 however, and it appears there may still be a relative lack of monitoring proposed to the north of the proposed pits. If not addressed soon, this region will remain a gap in the monitoring network with little baseline data available with which to assess future impacts.

Groundwater dependent ecosystems (GDEs) (section 1.7)

Issues with the GDE assessment (including stygofauna) that were pointed out in my first report include areas where baseline data were missing (e.g. Hunter River Alluvium) and potential flaws in the risk assessment methodology for stygofauna. Some areas where drawdown impacts are likely to occur (based on the groundwater modelling) were not covered in the assessment meaning the 'low risk' rating given was based on incomplete data. The influence of dissolved oxygen levels on GDEs was also given minimal attention.

These issues have been addressed through additional work (a Stygofauna survey in the Hunter River Alluvium). It should be noted that there are some potential limitations with the survey:

1. The survey is representative of conditions only at one point in time (e.g., no repeat monitoring has been conducted to see if the detection of Stygofauna varies through time);
2. The number of sites sampled is relatively limited (5 bores);
3. I am not expert in Stygofauna survey techniques; however it would be beneficial to have the survey and results checked and peer-reviewed by an independent expert in the field.

Conceptual and numerical groundwater model (Section 1.9)

Issues identified with the conceptual and numerical model identified in my first report include the need to more carefully examine ground-surface water interaction, and improve the evidence base (in the form of field data) for predicting impacts in this regard. Collection of better field data to more accurately constrain the extent, mechanism and locations of ground-surface water interaction were recommended, to provide a stronger basis to make predictions of these specific impacts. My original report also questioned whether the regional-scale numerical groundwater model is an appropriate tool to make predictions about ground-surface water interaction, given the scale of the model, and the type of input data on which it is largely based. Additional modelling (e.g. using smaller scale numerical or analytical models) for ground-surface water interaction was recommended.

In the *Response to Submissions*, the proponent has offered justifications for many of the choices in the set-up of the numerical model, which are reasonable in many instances, given the current level of data/information for the site. However there has been no attempt to further address many of the data gaps that result in uncertainties in the modelling of ground-surface water processes and impacts, e.g., through collection of additional field data or testing of alternative hypotheses as to appropriate input parameters or system characteristics.

Regarding the appropriateness of the model for assessing ground-surface water interaction, the proponent makes the argument that the modelling is designed to give an overall, long-term estimate of impacts to baseflow, rather than details about the magnitudes of short-term responses, and that it is therefore still appropriate for the purpose. Ground-surface water interaction is typically variable on seasonal timescales, and impacts which are transient in nature (e.g. those which manifest particularly during low-flow periods of the year), can be vitally important for stream health; there are potential impacts which occur on a seasonal basis that could impact on stream health that may not be predicted using the current modelling approach. Careful consideration by regulator(s) and community is warranted regarding whether the proponent's approach here is satisfactory.

b) In your opinion what, if any, are the groundwater/surface water impacts that would arise from the Project?

These impacts have been discussed in my previous report (from September 21st 2016). In summary, the major potential impacts identified were:

- Interception of groundwater by mining operations, and drawdown in both the alluvium and coal measures, which may impact on some private bores and potential GDEs; and
- Reductions in baseflow and availability of water from the alluvial aquifer(s).

At that stage, it was difficult to assess what water quality impacts may occur as a result of the project, as very little baseline groundwater and surface water quality data was included or analysed in the EIS. However, impacts such as contamination of groundwater and surface water through a number of potential mechanisms (as are outlined in the IESC advice and in this report) should also be considered possible until more detailed assessment of relationships between water quality and key processes is completed.

The potential for one of the mine voids and/or tailings storage facilities (TSFs) to become contamination sources to groundwater (and possibly surface water) were additional potential impacts that were flagged by the IESC in their advice from October 2016, along with mobilization of metals, salt and acidity. In response, the proponent argues that based on the modelling it is unlikely the Wambo pit lake will become a recharge source to groundwater, and that the TSFs are generally well below the elevations at which this may be an issue. I have not interrogated this modelling in detail. The geochemical study also indicates that the acid-generating potential of much of the material that will be mined is limited, and so the proponent argues that the risk associated with acid mine drainage and associated mobilization of metals is low. However, based on the existing indications in the groundwater and surface water chemistry (see above), further analysis would be required to understand how these parameters vary through time, what are the key controls and how this might change under the proposed expansion of mining.

Declaration:

I declare that this report has been prepared in line with the requirements of an expert witness for the Land and Environment Court of NSW and that it contains my impartial expert opinion on matters relevant to my professional expertise.

[redacted]

13th February 2018

References

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