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Date 16 March 2012

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Department of Planning & Infrastructure
GPO Box 39
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Our Ref 53/12

Attention Sara Wilson

Re: Additional Groundwater Submission on the Moolarben Coal Project Stage 2 Preferred Project Report

As noted in our initial submission, UCML commissioned Mackie Environmental Research (MER) to undertake a comprehensive technical review of the groundwater assessment to understand these differences and the interactions as noted by RPS Aquaterra. A summary of the key findings is provided below, with the full assessment report enclosed.

1. The Moolarben Coal Mine (MCM) groundwater model assumes that enhanced permeabilities arising from subsidence related cracking is limited to the Permian Strata. However, observed pore pressures above and adjacent to extracted longwall panels at a number of locations within Ulan Coal Mines (UCM) operations demonstrate cracking and drainage of both Permian and the overlying Triassic strata.

2. Calibration of the MCM groundwater model has been achieved by adjusting the model material properties and boundary conditions in order to achieve a 'calibrated' match between model predictions and measured regional depressurisation of strata and reported groundwater influx to UCM mining operations. The MCM model has been calibrated against observed impacts of mining at UCM before being used to predict impacts relating to MCM operations, and cumulative impacts.

3. Due to the manner in which the reported model influxes have been extracted from the UCM model output MER believes they may be under-estimated by 50% or more. Correction of this is likely to require a reduction in strata permeabilities which would then align the MCM model more closely with the existing UCM regional model.

4. Given the above issues MER believe that the reported mine water seepage rates for all operations may be incorrect. Implications relate largely to site water management (i.e. water balance – supply and demand requirements) (reduced volumes of influx) and potentially smaller predicted yields from any production bores. Regional pore pressure changes predicted by the MCM model may also be in error.

5. The groundwater assessment uses data which relates to UCML's 2008 operations. Since this time UCML has continued to further monitor, assess and refine its understanding of its impacts on the groundwater resource. Given the additional data and further understanding of

how UCM operations interaction with groundwater, the use of 2008 historical data raises questions as to the representativeness of the groundwater model to the infield conditions and experiences.

6. We note the base flow losses to the Goulburn River predicted by Aquaterra are up to approx 7.5ML/day, while the impact predicted by MER is 0.5ML/day. Without being able to interrogate the model it is assumed that this is due to the difference model assumptions and calibration methodology, which MER has questioned as noted above.

7. We note that UCML and MCM have been developing a data sharing agreement since September 2011. Consistent with the data sharing agreement, UCML are keen to cooperate with MCM and DP&I to provide relevant information that UCML holds which may assist in the MCM groundwater assessment being refined to address the attached data and modelling considerations.

In essence, MER has questioned the validity of the fundamental assumptions and method implement to calibrate the model. Given these aspects form the foundations upon which groundwater assessment is built, MER as such, questions the validity of the findings of the groundwater assessment.

It is critical for UCML to have a thorough understanding of the MCP groundwater model given the use of UCML groundwater data, potential interactions with groundwater recovery rates, end of mine life piezometric surfaces, offsetting base flow impacts, determining responsibility for providing compensatory water supply (i.e. apportioning impacts and responsibilities to address such impacts) as well as ensuring the UCML groundwater model reflects the infield conditions and experiences.

Without this level of detail and robustness of the predictions it is not possible to confidently reach agreement on a joint management strategy and / or commercial arrangements associated with apportioning costs associated with the implementation of mitigation measures or property acquisition costs, as required under UCML's 2010 Project Approval. Additionally without such information DP&I may not be able to condition the project appropriately.

Please do not hesitate to contact Jamie Lees (Environment & Community Manager) on Ph (02) 63725368 should you have any questions.

Yours Faithfully

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Enc

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12/03/2012

Att. R. Williams

Brief review of Moolarben Coal Complex Stage 2: Preferred Project Report

Further to your instructions, Mackie Environmental Research (MER) has conducted an overview of groundwater related impacts assessed as part of the Moolarben Coal Mines (MCM) Preferred Project Report (PPR). The impacts are described in Appendix E of the PPR entitled 'Moolarben Coal Complex Stage 2 Preferred Project Report: Groundwater Impact Assessment, November 2011' authored by RPS Aquaterra.

We have focused on parts of the project that are most likely to have significant impacts and in particular, any cumulative impacts that might be associated with Ulan Coal Mines (UCM). These issues are addressed in the PPR through the development of a regional groundwater flow model. We have therefore considered the PPR groundwater model with respect to our model developed for UCM.

Key PPR elements associated with groundwater are:

- The development and operation of open cut OC4 – noting that open cuts OC1, OC2 and OC3 were previously approved as part of Stage 1;
- The development and operation of two underground operations identified as UG1 and UG2. The most northerly underground operation (UG4) has been previously assessed as part of Stage 1;
- The cumulative impacts of MCM operations when associated with approved operations at UCM.

1. Review summary

Summary findings from our review are:

1. Extensive exploration drilling, testing and monitoring underpin an acceptable conceptual regional hydrogeological model generally consistent with the conceptual model that has evolved at UCM.
2. Computer based groundwater flow modelling of these systems is based on the Modflow-Surfact code which is also employed at UCM.
3. Treatment of the subsidence zone in the MCM calibration model differs from the existing UCM model in so far as enhanced permeabilities arising from subsidence related cracking of the strata have apparently been restricted to Permian strata. However, observed pore pressures above and adjacent to extracted longwall panels at a number of locations at UCM demonstrate cracking and drainage of both Permian and Triassic strata.

4. The MCM model has been calibrated against observed impacts of mining at UCM before being used to predict impacts relating to MCM operations, and cumulative impacts. Measured regional depressurisation of strata and reported groundwater influx to UCM mining operations have been used to adjust the model material properties and boundary conditions in order to achieve a 'calibrated' match between model predictions and measured responses. However, we believe the reported model influxes to UCM may be under-estimated by 50% or more due to the manner in which they have been extracted from the model output. Correction of this flaw is likely to require a reduction in strata permeabilities which would then align the MCM model more closely with the existing UCM regional model.
5. Given the above issues we believe that the reported mine water seepage rates for all operations may be incorrect. Implications relate largely to site water management (reduced volumes of influx) and potentially smaller predicted yields from any production bores. Regional pore pressure changes predicted by the MCM model may also be in error.

A more detailed assessment is provided below.

2. Hydrogeological background

The geology of the Moolarben Coal Complex (MCC) is similar to the geology prevailing over large parts of the UCM area insofar as Permian coal measures are underlain by the Shoalhaven Group comprising sedimentary, volcanic and granitic rocks, and overlain by Triassic sediments within the Narrabeen Group of rocks which dip gently to the north-east.

The hydrogeology of these rocks has been characterised by MCM using exploration drilling, piezometer installations and hydraulic testing to assess the permeability and storage characteristics of the strata. Monitoring of the water table at a large number of observation piezometers has also provided a significant database from which groundwater flow directions have been assessed. Most piezometer installations are standpipe completions whereby a particular section of the borehole has been screened using slotted casing and then isolated by grouting to ensure that the resulting standing water level is representive of the piezometric head at the installed depth.

Vertical pore pressure distributions are also monitored in the MCM area using vibrating wire transducers at four locations near planned underground operations UG1, UG2 and UG4, and at two other locations. These types of installations are especially useful in assessing the depressurisation within the subsidence zone associated with underground mining.

Hydraulic testing is reported to have been completed at all installed standpipe locations. These test were generally short duration (typically between 1 and 100 minutes) pumping tests or falling head (slug) tests and while providing site specific estimates of material properties, were too short to evaluate aquifer geometry or regional hydraulic continuity. In addition to standpipe testing, longer duration tests of between 48 and 72 hours have been conducted in a number of larger diameter boreholes specifically constructed as (test) production boreholes. Results have apparently confirmed that sustainable yields at these locations would be in the order of 300 to 400 kL/day[1]

Results of testing are summarised in Tables 2.2 and 2.3[2]. The reported permeabilities are generally higher than values considered to prevail in strata encountered in the UCM areas currently being mined (underground) and may reflect the shallower depths of cover and reduced effects of confinement.

Piezometric monitoring by MCM supports active rainfall recharge at many locations as evidenced by correlation of water level trends with the rainfall residual mass curve – rising water levels correlate to increased availability of rainfall recharge. At other locations where strata are too deep to support rainfall recharge, observed recovery of piezometric levels may be

[1] EA Appendix E, Groundwater impact assessment: page 10
[2] EA Appendix E, Groundwater impact assessment: pages 8 and 9

attributed to northwards migration of underground mining operations at UCM (UG3) away from monitoring locations, reduction in pumping from water supply bores close to UCM and/or increased storage of surplus mine water in UCM open cut voids[3]. These explanations are considered to be plausible.

Vertical array piezometric measurements in the MCM area often reflect large differences in heads with Ulan seam pore pressures often being lower than piezometric heads measured in the surficial aquifer systems[4]. Such differences in areas near UCM could reasonably be attributed to UCM historical mining operations. However in the southern part of the MCM area, it is reported that piezometric heads in the Ulan seam are up to 60m lower than in the overlying Permian strata and in the surficial aquifers. These areas are too distant from UCM operations for UCM to be the cause. Since the measured responses pre-date mining at Wilpinjong and Moolarben they are reported to be a 'natural feature'. We note that this is an unusual situation and in the absence of a plausible cause, we agree that the difference may indeed be a natural feature.

3. Groundwater flow model

The groundwater flow model employed by Aquaterra to assess mining related impacts utilises the Modflow-Surfact finite difference code. This code was used for MCM Stage 1 simulations and has also been used at UCM. The new model is identified as MC2.2 and comprises 8 layers. Material properties (permeability and storage parameters) distributed throughout the model were initially based upon prior Stage 1 modelling and subsequently adjusted as part of the calibration process.

3.1 Model calibration

Both a steady state calibration and a transient calibration are reported by Aquaterra. The steady state calibration was aimed at generating starting regional piezometric heads before the onset of significant impacts attributed to mining operations. The date adopted for steady state representation is reported to be July 1987. This approach is consistent with groundwater flow modelling conducted for UCM by MER (2009) except that steady state conditions were assumed to prevail at January 1986 in the UCM model.

Transient calibration was then undertaken by Aquaterra. This process has involved simulation of UCM mining operations from July 1987 to June 2008. Boundary conditions used to simulate these operations include constrained head (drain and river) type cells designed to remove groundwater from model areas representing streams, rivers, open cut and underground operations. Distributed flux conditions have also been applied across the model to represent rainfall recharge. It is understood that material properties (permeability and storage parameters), were adjusted during the calibration process with resulting values listed in the following Table 1. UCM model parameters are also listed for comparison.

Reference to Table 1 indicates the UCM model has 11 layers while the MCM model has 8 layers. The UCM model generally reflects lower horizontal hydraulic conductivities and higher vertical conductivities than the MCM model.

Enhanced conductivities in the subsidence zone in the MCM model have seemingly been restricted to Permian strata. This conflicts with observations from established piezometers adjacent to or above extracted longwall panels at UCM underground operations and UCM modelling (MER, 2009) which support cracking into the Triassic strata. The reason for apparently restricting the height of cracking in the MCM calibration model is unclear from the Aquaterra report, particularly since it is stated that the height '*was based on assessment of pressure responses .... within and near the Ulan Coal Mine footprint*'[5].

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[3] EA Appendix E, Groundwater impact assessment: page 12
[4] EA Appendix E, Groundwater impact assessment: page 13
[5] EA Appendix E, Groundwater impact assessment: page 39

Unusually, the MC2.2 model does not utilise a feature of the Modflow-Surfact code that facilitates changes to material properties during a single simulation. This feature is especially relevant for simulation of the subsidence zone above longwall extractions. Instead, Aquaterra have employed a cumbersome and inefficient methodology for changing hydraulic conductivities which involves a number of separate model simulations with manual changes to the conductivity of the subsidence zone at the conclusion of each model. Four separate stress periods or 'time slices' have apparently been employed[6] to represent the 21 year calibration period. This contrasts with the UCM model where individual panels were represented over 26 stress periods.

In addition, it is reported that the (model) calculated short term increases in the rates of inflow to UCM operations at the commencement of each time step '*reflect over-estimates of inflows, as the model adjusts to the new parameter distribution for that time slice.*'[7] This statement demonstrates a limited understanding of how the groundwater model (code) simulates flow systems. It is improbable that there are any over-estimates reported by the model assuming volumetric balances at the end of each model time step were satisfactory. Rather, the reported inflows are likely to be correct estimates (for the applied material properties and boundary conditions) which have been incorrectly extracted from the model. These inflows will invariably be very high at the start of a panel extraction where substantial piezometric heads prevail, and then decline as the model time steps proceed. The reported inflow rates used by Aquaterra in establishing the calibrated model, have been taken at '*the end of each model stress period, as this is considered to represent the likely long term inflow rate.*'[8]. Again this illustrates a limited understanding of groundwater flow modelling. The correct procedure requires inflow rates to be rigorously calculated using variable time-stepping within each stress period. In our estimation, the reported values could be in error by 50% or more.

Given the potential errors associated with influx predictions we believe that transient calibration has not been adequately demonstrated by Aquaterra. It is likely that conductivities derived from the calibration and applied across the model, would need to be adjusted to improve the calibration. This would probably result in closer alignment with the UCM model. Greatest error is associated with predictions of mine water influx to open cut and underground operations which are likely to be lower, and to production bore yields which are also likely to be lower than predicted.

4. Predicted impacts on regional groundwater systems

The predicted impacts on regional strata, are presented as a series of contour plots. Reference to these plots indicates large depressurisation areas in the Ulan seam and Permian strata associated with the extensive MCM operations across four open cut and three underground operations and the UCM operations across UG3 and Ulan West underground operations. Wilpinjong drawdowns are more subdued due to the shallower depths of cover in that area. The extent of drawdowns predicted in the Ulan seam are consistent with our estimates.

Triassic strata reflect reduced drawdowns probably as a result of a reduced height of cracking employed in the MC2.2 model.

[6] EA Appendix E, Groundwater impact assessment: page 43
[7] EA Appendix E, Groundwater impact assessment: page 45
[8] EA Appendix E, Groundwater impact assessment: page 45

Table 1: Comparison of Ulan (UCM) 2009 and Moolarben (MCM) 2011 groundwater flow model parameters

Ulan (UCM) model					Moolarben (MCM) model			
Layer	Lithology	Kh	Kv	Sy	Layer	Kh	Kv	Sy
1	alluvium-regolith	1.0E-2 to 5.0E+1	1.0E+1	5.0E-2 to 1.0E-1	1	5.0E-1 to 3.0E+0	1.0E-3 to 7.5E-2	5.0E-2 to 1.0E-1
2	Jurassic	8.0E-2	4.0E-2	3.0E-2	2	5.0E-1	1.0E-5	2.0E-2
3	Jurassic	8.0E-2	4.0E-2	3.0E-2	2	5.0E-1	1.0E-5	2.0E-2
4	Triassic quartzose	1.5E-01	8.0E-2	2.0E-2	2	5.0E-1	1.0E-5	2.0E-2
5	Triassic quartzose	1.5E-01	8.0E-2	2.0E-2	2	5.0E-1	1.0E-5	2.0E-2
6	Triassic lithic	4.0E-2	2.0E-4	1.5E-3	3	2.0E-1	5.0E-5	1.0E-2
7	Upper Permian	1.0E-4	5.0E-6	5.0E-3	4	1.0E-3 to 1.0E-1	2.5E-5	5.0E-3
8	Middle Permian	4.0E-4	8.0E-6	5.0E-3	5+6	1.0E-3 to 5.0E-2	1.0E-5	5.0E-3
9	Ulan seam	4.2E-1	3.0E-1	2.0E-2	7	1.0E0	5.0E-4	1.0E-1
10	Lower Permian	1.0E-4	5.0E-6	1.0E-3	8	1.0E-1	1.0E-5	1.0E-1
11	Granite+meta sediments	1.0E-5	1.0E-5	1.0E-2	8	5.0E-4	1.0E-5	5.0E-3

Notes: 1. Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity, Sy = drainable porosity
2. UCM 2009 model is 11 layers while MCM model is 8 layers. Lithologies are approximately aligned.
3. Jurassic strata are not represented as separate layers in the MCM model

Aquaterra have conducted groundwater recovery simulations for a period of 100 years. Within that time frame the model predicts that water levels in the Permian coal measures '*will recover to at least, and in many cases above, present day levels*'[9]. This rapid recovery contrasts with very long recovery times associated with UCM operations. The reason for such rapid recovery is unclear from the report but may be attributed to the open cut operations and the potential for emplaced spoils to facilitate rainfall recharge at relatively high rates.

The Drip is discussed in limited detail. A perched system above the deeper saturated Triassic strata, is identified and it is noted that MCC operations will not affect the Drip[10]. This is consistent with our observations.

Impacts on registered and identified bores, wells and springs are provided.

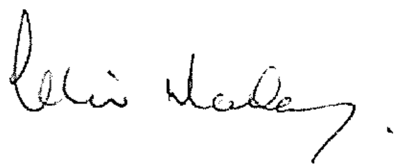
Impacts on baseflows to the larger streams and the Goulburn River have been assessed and are summarised in Table 5.12 and 5.13[11]. Many stream channels particularly on the southern side of the Goulburn River and in areas that would be expected to be influenced by MCM mining operations, seem to have been excluded from this assessment. It is also unclear from the documentation just how the baseflows have been calculated but for the stream reaches that have been assessed, the changes are generally small over the period of mining. However baseflow in the Goulburn River eastern extent (river reach R111 in Table 5.12) declines from 13.28 ML/day in 2011 to 5.75 ML/day in 2142. The reach immediately upstream (R105) exhibits a very small decline over the same period of just 0.048 ML/day. No discussion is provided for the significant decline in catchment R111 which seems unusually high for mining related impacts.

5. Longer term monitoring of groundwater impacts

The regional monitoring network appears to be extensive. We encourage data sharing between UCM and MCM in order to monitor individual and cumulative impacts.

Yours sincerely

Mackie Environmental Research



Dr. C. Mackie

References

Mackie Environmental Research, 2009. Ulan Coal Mines Limited, Continued Operations – Groundwater Assessment.

[9] EA Appendix E, Groundwater impact assessment: page 57
[10] EA Appendix E, Groundwater impact assessment: page 59
[11] EA Appendix E; Groundwater impact assessment: page 55