DATE: 20 March 2017

TO:  Mr Graham Chase  
    Environmental and Community Manager  
    Moolarben Coal Operations Pty Ltd  
    4250 Ulan Road  
    Ulan NSW 2850

FROM:  Dr Noel Merrick

RE:  Moolarben Extraction Plan Longwalls 101 to 103 – Groundwater Assessment Review

OUR REF: HS2017/08 [YAN014]

1. INTRODUCTION

The Moolarben Coal Complex is an open cut and underground coal mining operation located approximately 40 kilometres (km) north of Mudgee in the Western Coalfield of New South Wales (NSW) (Figure 1).

Moolarben Coal Operations Pty Ltd (MCO) has approval under Project Approval (08_0135) for the extraction of Longwalls 101-105 as part of the Underground Mine 1 (UG1) of the Moolarben Coal Complex. MCO is preparing the Extraction Plan covering Longwalls 101-103, which will outline the proposed management, mitigation, monitoring and reporting of potential subsidence impacts and environmental consequences from the secondary extraction of Longwalls 101-103. Additional information on the Moolarben Coal Complex and UG1 is provided in the main text of the Extraction Plan.

This report responds to a request from MCO for a groundwater assessment review of the Extraction Plan for UG1 Longwalls 101-103 of the Moolarben Coal Complex (Figure 1). The report will support the Water Management Plan component of the Longwalls 101-103 Extraction Plan and addresses relevant aspects of Project Approval (08_0135) Schedule 4 Condition 5 (h).
2. SCOPE OF WORK

This report pertains to Longwalls 101-103. It:

- provides a summary of outcomes of previous studies including hydrogeology, subsidence and potential groundwater impacts;
- proposes a monitoring program for monitoring the impacts of Longwalls 101-103 extraction;
- proposes trigger levels and management responses for the impacts of Longwalls 101-103 extraction;
- provides data analysis of key bores with respect to observed groundwater levels to date;
- confirms the location and saturated extent of the Tertiary Palaeochannel definition in the vicinity of Longwalls 101-103 following analysis of additional investigation bores; and
- provides conclusions in regard to how the analysis in this report supports the findings of previous groundwater modelling assessments.

3. PREVIOUS STUDIES

3.1 Background

Stage 1 at the Moolarben Coal Complex has been operating for several years and at full development will comprise three open cut mines (OC1, OC2 and OC3), a longwall underground mine (UG4), and mining related infrastructure (including coal processing and transport facilities) (Figure 2).

Stage 2 at the Moolarben Coal Complex has commenced and at full development will comprise one open cut mine (OC4), two longwall underground mines (UG1 and UG2) and mining related infrastructure (Figure 2).

The UG1 Underground Mine is a component of the approved Moolarben Coal Complex (Figure 2). The UG1 Underground Mine commenced first workings in April 2016 and is scheduled to commence secondary workings (longwall extraction) in October 2017 by longwall mining methods from the Ulan Seam within Mining Lease (ML) 1605, ML 1606, ML 1628, ML 1691 and ML 1715 (Figure 3).

The most recent assessment and approval for UG1 was the UG1 Optimisation Modification (Project Approval 08_0135 [Stage 2] Mod 2), which assessed the currently approved layout for UG1 (Longwalls 101-105) (Figure 3).

3.2 Hydrogeology

Several groundwater investigations, assessments and reviews have been undertaken since 2006 to assess the potential impacts of the approved Moolarben Coal Complex. Recent groundwater assessments undertaken for the approved Moolarben Coal Complex include:

- Moolarben Coal Complex Stage 2 PPR Groundwater Impact Assessment, November 2011 (RPS Aquaterra, 2011);
- Moolarben Coal Project Stage 1 Optimisation Modification Groundwater Assessment (AGE, 2013);
- Moolarben Coal Complex Stage 2 PPR Response to Submissions Additional Groundwater Impact Assessment (RPS Aquaterra, 2012); and
- Moolarben Coal Complex Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015).

RPS Aquaterra (2011) predicted that drawdown impacts on privately-owned bores from the approved Moolarben Coal Complex would not exceed 0.6 m and therefore would have negligible effect on groundwater users.

Groundwater monitoring and management at the Moolarben Coal Complex is conducted in accordance with the Water Management Plan, including the approved subcomponent Groundwater Management Plan (Appendix 3).
3.2.1 **Hydrogeological Regime**

The Moolarben Coal Complex area is located in the Western Coalfield on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks, including coal measures, of Permian and Triassic age. The dominant outcropping lithologies over the Moolarben Coal Complex are the Triassic Narrabeen Group (Wollar Sandstone) and the Permian Illawarra Coal Measures. The siltstones and sandstones of the Triassic Narrabeen Group form elevated, mesa-like incised plateaus associated with the Goulburn River National Park and the Munghorn Gap Nature Reserve.

3.2.2 **Alluvial Aquifers**

Quaternary alluvial deposits in the vicinity of the Moolarben Coal Complex are associated with Lagoon Creek, Goulburn River, Moolarben Creek and Wilpinjong Creek.

There is no ‘highly productive’ groundwater, as defined under the Aquifer Interference Policy (NSW Government, 2012), mapped in the vicinity of the Moolarben Coal Complex. The nearest ‘highly productive’ groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

3.2.3 **Tertiary Palaeochannel Deposits**

Tertiary palaeochannel deposits have been recognised in the Goulburn River diversion (at Ulan) and in the Murragamba and Wilpinjong creek valleys, with a maximum thickness of 40 m to 50 m. Palaeochannels are remnants of inactive river or stream channels that have been later filled in or buried by younger sediment. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix.

Transient Electro-Magnetic (TEM) and Direct Current (DC) electrical resistivity surveys have been conducted to better define the thickness and the extent of the palaeochannel to the north-east of UG1. Following a subsequent program of targeted drilling, HydroSimulations has determined that the modified UG1 mine layout for Longwalls 101-103 would not pass beneath any water bearing palaeochannel sediments, as was considered in HydroSimulations (2015). A summary of the recent investigation into further definition of the palaeochannel is provided in Section 7.

3.2.4 **Porous Rock Groundwater Systems**

The porous rock groundwater systems consist of the Narrabeen Group sandstones and the Illawarra Coal Measures, consisting of coal seams, conglomerate, mudstones and siltstones.

None of the identified groundwater systems is a significant aquifer. The most permeable units are the Ulan Seam and Marrangaroo Conglomerate, while the sandstones of the Narrabeen Group are of lower permeability and are elevated above the Moolarben Coal Complex. The Illawarra Coal Measures also include low permeability mudstones and siltstones.

Recharge to the groundwater systems would occur primarily from direct rainfall and runoff infiltration. The Permian and Triassic groundwater systems in the vicinity of the Moolarben Coal Complex are primarily recharged at outcrops and subcrops. Where the Triassic and/or Permian strata are overlain by alluvium, colluvium or highly weathered bedrock, additional recharge may occur from these unconsolidated surficial materials.

There are no high priority culturally significant sites listed in the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*. However, a spring known as The Drip is a groundwater dependent ecosystem (GDE) with local cultural significance. This water feature is likely to be fed from perched water in the Wollar Sandstone and is not considered relevant to this Extraction Plan as it is located more than 6 km to the north of the UG1 mine and there is no credible mechanism for impact from the extraction of Longwalls 101-103.
3.3 **Subsidence**

Potential subsidence impacts for the Approved Layout for the UG1 longwalls (Longwalls 101-105) were assessed by MSEC (2015), and subsequently approved (subject to conditions), as part of the approved UG1 Optimisation Modification.

During the preparation of the Extraction Plan, MCO introduced a barrier pillar separating Longwalls 102A and 102B with a total length of approximately 300 m along the alignment of Longwall 102. In addition, for operational reasons MCO has reduced the length of Longwalls 101-103 by approximately 70 m to maintain a safe operating distance between the end of the longwall panels and the infrastructure (e.g. conveyors and associated electrical infrastructure) within the Main Headings.

MSEC (2017) reviewed the layout for Longwalls 101-103 for the Extraction Plan (referred to as the Extraction Plan Layout) and concluded:

“...the overall impact assessments for the natural and built features based on the Extraction Plan Layout are unchanged, or reduce compared to those based on the Approved Layout.”

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 101-103, based on the Extraction Plan Layout, with those based on the Approved Layout is provided in **Table 1**. The values are the maxima anywhere above longwall layouts.

It can be seen that the maximum predicted total subsidence parameters based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101-103. Whilst the specific values of the maximum tilt and curvatures are not shown, due to these representing the localised irregular movements rather than the macro (i.e. overall) movements, these parameters do not change (MSEC, 2017).

**Table 1. Comparison of Maximum Predicted Conventional Subsidence Parameters based on the Approved Layout and the Extraction Plan Layout**

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103)</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Extraction Plan Layout</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

Source: MSEC (2017)

In regard to potential for subsidence-related surface cracking, MSEC (2017) states:

“The depths of cover over the underground mining areas vary from 47 m to 165 m. Where the depths of cover above Longwalls 101 to 103 are less than 100 m, surface cracking is expected to be typically in the order of 150 to 200 mm wide, but could be as large as 500 mm wide where the depths of cover are the shallowest. The surface crack widths are likely to be smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave. Where the depths of cover above Longwalls 101 to 103 are 100 to 150 m, the surface crack widths are expected to be typically in the order of 100 to 150 mm wide.”

The extent of potential cracking predicted by MSEC (2017) for the Extraction Plan Layout is consistent with the Approved Layout.
3.4 Summary of Potential Groundwater Impacts

HydroSimulations (2015) presents potential impacts associated with the Approved Layout. The Extraction Plan Layout would result in the same, or lower, potential impacts in comparison to the Approved Layout (as assessed and approved for the UG1 Optimisation Modification), given:

- The Longwalls 101-103 lengths have been reduced from those that were simulated by approximately 70 m.
- MSEC (2017) predicts potential subsidence impacts for the Extraction Plan Layout would be the same or lower than those for the Approved Layout.
- Additional drilling investigation has confirmed the assumptions of the HydroSimulations (2015) modelling with respect to the extent and saturation of the palaeochannel.

A summary of potential groundwater impacts is provided below, with focus on Longwalls 101-103 where possible (i.e. it is difficult to isolate impacts from the approved cumulative impacts of the Moolarben Coal Complex open cuts and Wilpinjong and Ulan Coal Mines).

3.4.1 Risk Assessment

On 8 December 2016, a team consisting of MCO operational, technical and environmental staff and specialist consultants participated in a facilitated risk assessment workshop on the UG1 Longwalls 101-103 inclusive.

No follow-up actions that were not already completed, relevant to groundwater, were identified. The risks identified by the Risk Assessment team were considered to be as low as reasonably practicable (ALARP).

3.4.2 Privately Owned Bores

A bore census has been undertaken to identify private groundwater use in the vicinity of the Moolarben Coal Complex.

Only three bores were identified during the census survey that are located on private property relevant to the assessment of Moolarben Coal Complex mining effects. Two of these bores (census points SP39 and SP42) are shallow low-yielding bores located more than 7 km up-dip and southwest of UG1 Longwalls 101-103 and as a result these bores would not be impacted. The remaining private bore (census point SP49) is located more than 6 km to the north of UG1 Longwalls 101-103 and is a relatively shallow bore (24 m) developed in Triassic strata. Negligible drawdown impact due to the Moolarben Coal Complex mining has been predicted at this bore.

A further private bore developed in Triassic strata is located over 12 km north of the UG1 (Work ID GW064580). A negligible drawdown is predicted at this bore from Moolarben Coal Complex mining related effects (i.e. all approved mining operations, not UG1 in isolation). This bore is 70 m deep and is predicted to have an additional drawdown impact of up to 5 m as a result of mining at the Ulan Mine Complex (Mackie Environmental Research, 2009).

Predicted drawdown impacts from the approved Moolarben Coal Complex on privately owned bores within 10 km of the Moolarben Coal Complex would not exceed 0.6 m and therefore the Moolarben Coal Complex would have negligible effect on groundwater users. The predicted maximum drawdown impact of 0.6 m is less than the 2 m minimal impact consideration for drawdown impacts at an existing bore specified in the NSW Aquifer Interference Policy.

The location and baseline condition of each of the privately owned bores are summarised in Table 2.

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1 This does not include bores located on private properties to the west of the Moolarben Coal Complex that are developed in the outcropping basement rocks or associated regolith that underlie the Sydney Basin and that are hydraulically disconnected from the hydrogeological regime of the Sydney Basin sedimentary strata and its associated alluvial sediments.
### Table 2. Baseline Condition of Privately Owned Bores

<table>
<thead>
<tr>
<th>Census Point ID</th>
<th>Easting</th>
<th>Northing</th>
<th>Bore Type</th>
<th>Licence No.</th>
<th>Work ID</th>
<th>Hydrogeological Unit</th>
<th>Water Level (m AHD)</th>
<th>EC (µS/cm)</th>
<th>pH</th>
<th>Yield (L/s)</th>
<th>Distance to LW101-103</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP39-40</td>
<td>760393</td>
<td>6414282</td>
<td>Stock</td>
<td>-</td>
<td>-</td>
<td>Permian coal measures</td>
<td>526</td>
<td>1020 – 1598</td>
<td>6.9 – 8.0</td>
<td>-</td>
<td>&gt; 7 km</td>
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<tr>
<td>SP42-43</td>
<td>761294</td>
<td>6414948</td>
<td>Stock</td>
<td>-</td>
<td>-</td>
<td>Permian coal measures</td>
<td>516</td>
<td>1450 – 1990</td>
<td>6.3 – 7.4</td>
<td>-</td>
<td>&gt; 7.9 km</td>
</tr>
<tr>
<td>SP49</td>
<td>765208</td>
<td>6431971</td>
<td>Domestic</td>
<td>80BL236762</td>
<td>GW800279</td>
<td>Triassic Narrabeen Group</td>
<td>375.1</td>
<td>730</td>
<td>6.0</td>
<td>-</td>
<td>&gt; 6 km</td>
</tr>
<tr>
<td>-</td>
<td>764120</td>
<td>6438504</td>
<td>Stock &amp; Domestic</td>
<td>20BL137225</td>
<td>GW064580</td>
<td>Triassic Narrabeen Group</td>
<td>-</td>
<td>-</td>
<td>0.63</td>
<td>&gt; 12 km</td>
<td></td>
</tr>
</tbody>
</table>

EC = electrical conductivity; µS/cm = microSiemens per centimetre; m AHD = metres Australian Height Datum

#### 3.4.3 Groundwater Modelling

The groundwater assessment by HydroSimulations (2015) used MODFLOW-SURFACT groundwater modelling software to assess the potential cumulative impacts on groundwater resources of Moolarben Coal Complex open cut mining and UG1 underground mining for Longwalls 101-105, as well as adjacent mining operations (Ulan Mine Complex and Wilpinjongs Coal Mine).

The model domain is discretised into 1,166,592 cells comprising 434 rows, 336 columns and 8 layers. The dimensions of the model cells are varied from 100 m in the mining areas to 500 m near the boundaries. The model extent is 49.8 km from west to east (Eastings 740000-789800) and 54.7 km from south to north (Northings 6405300-6460000), covering an area of approximately 2,725 km².

Based on the conceptual hydrogeology described in the PPR report (RPS Aquaterra, 2011), the following layers were defined for the model:

- Layer 1: Quaternary alluvium, Tertiary palaeochannel and Weathered bedrock/ regolith.
- Layer 2: Triassic (upper) or Permian where Triassic is eroded.
- Layer 3: Triassic (lower) or Permian where Triassic is eroded.
- Layer 4: Permian (upper).
- Layer 5: Permian (middle).
- Layer 6: Permian (lower).
- Layer 7: Ulan Seam.
- Layer 8: Marrangaroo Formation, Ulan Granite and Volcanics.

As determined by RPS Aquaterra (2011), Layers 5-7 for the mid-Permian, lower-Permian and the Ulan Seam were taken to be fractured in the model across UG1.

Calibration was carried out in a transient mode (using time slices) to achieve a history match to the reported observed groundwater levels during the period 1987 to 2008 (RPS Aquaterra, 2011). The calibration was done against 1,227 target water levels, using a combination of auto-sensitivity analysis and manual modification of zones and model parameters. These targets were distributed throughout the model layers in the form of 145 groundwater hydrographs. Calibration achieved a satisfactory Scaled Root Mean Square (SRMS) performance measure of about 8%, and the mass balance error was less than 0.1%.

The prediction period ran from July 2008 to June 2042 to simulate extraction for the full duration of approved Moolarben Coal Complex mining.

#### 3.4.4 Groundwater Modelling Results

A summary of groundwater impacts is provided below.

The groundwater model developed using MODFLOW-SURFACT software (HydroSimulations, 2015) has been used to predict responses to UG1 longwall extraction of coal from the Ulan Seam for Longwalls 101-105 over a period of nine years. Each model simulation included the cumulative effects of Moolarben open cut mining as well as Ulan and Wilpinjong operations.
Predicted drawdowns in model Layer 1 for the alluvium/regolith and the Tertiary palaeochannel at the end of Longwall 105 are shown in Figure 4. The model predicts less than 0.5 m drawdown in Layer 1 adjacent to the northern edge of the UG1 longwall panels. Given the drawdown minimal impact consideration of 2 m in the Aquifer Interference Policy, the effect on alluvial and regolith water levels due to UG1 mining is expected to be negligible. Drawdowns greater than 2 m are predicted in Layer 1 to the north-west of UG1, and to the east of UG1 in Murragamba Valley. However, these approved drawdowns are due to approved OC1 and OC4 mining and should not be attributed to UG1.

In summary, and consistent with previously approved impacts:

- No private bores are likely to be affected by 2 m drawdown or more.
- No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry.
- With the exception of drawdown at the level of the Ulan Seam in the north-eastern extents of UG1, there would be no discernible change in drawdown resulting from UG1 extraction.
- The Ulan Seam has no productive water use other than for mining purposes. No change to beneficial use category is anticipated.
4. MONITORING PROGRAM

4.1 Groundwater Monitoring

Groundwater monitoring at the Moolarben Coal Complex is currently undertaken in accordance with the complex-wide Groundwater Management Plan (GMP) (MCO, 2015). The objectives of the GMP are to establish baseline groundwater quality and water level data and to implement a program of data collection that can be utilised to assess potential impacts of mining activities on the groundwater resources of the area.

In October 2016 a revised version of the GMP was provided by MCO to DPI Water and the Department of Planning and Environment, which describes MCO’s proposed improvements to the current GMP. The description of monitoring and management below is consistent with the revised GMP dated October 2016.

The groundwater monitoring network currently consists of 51 monitoring sites distributed across all major hydrogeological units, comprising 41 standpipe (SP) sites and 10 multi-level vibrating wire piezometer (VWP) sites. The standpipe piezometers can be used for monitoring water level either manually or with an automated datalogger, as well as for collection of water samples for groundwater quality monitoring purposes. The VWPs are grouted and therefore can only be used for monitoring groundwater pressures.

A sub-set of the monitoring network which is most relevant to UG1 Longwalls 101-103 is detailed in Table 3, with bore locations provided in Figure 5. PZ156 and PZ157 will require grouting prior to mining and will be removed from the monitoring program.

The assessment of riparian vegetation undertaken by Ecovision Consulting for the Stage 2 EA did not indicate any specific riparian plant communities that could be considered groundwater dependent ecosystems (GDEs) and therefore no specific groundwater monitoring for riparian vegetation communities is required.

4.2 Groundwater Inflows

Since commencement of UG1 first workings in April 2016, groundwater inflows have been monitored by means of flowmeters on dewatering lines along the headings either side of Longwall 101 (Figure 5).

Water supply to the underground workings is also monitored and will be considered when quantifying groundwater inflows.

4.3 Groundwater Levels

Table 3 details the monitoring program for groundwater levels at monitoring bores relevant to UG1 Longwalls 101-103. The piezometers will be monitored manually on a monthly basis, or continuously by means of automatic dataloggers, as detailed in Table 3.

As monitoring sites PZ127 and PZ157 within the UG1 Longwalls 101-103 area have piezometers in the Ulan Seam, monitoring might be disrupted as mining progresses in these areas. The more elevated piezometers in P127 have more chance of survival.
<table>
<thead>
<tr>
<th>Bore</th>
<th>Type</th>
<th>Depth (m)</th>
<th>Screened Interval (mbgl)</th>
<th>Lithology Screened</th>
<th>Water Level Monitoring Frequency</th>
<th>Historical Water Level Range (mbgl)</th>
<th>Water Quality Monitoring Frequency</th>
<th>Date Established</th>
<th>Licence No.</th>
<th>Easting (m)</th>
<th>Northing (m)</th>
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</thead>
<tbody>
<tr>
<td>PZ 127</td>
<td>VWP</td>
<td>152</td>
<td>43</td>
<td>Triassic</td>
<td>Datalog Reported monthly</td>
<td>Dry</td>
<td>N/A</td>
<td>23/11/2007</td>
<td>20BL173935</td>
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<td>VWP</td>
<td>68</td>
<td>43</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>47.2 - 52.1</td>
<td>N/A</td>
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<td></td>
<td>VWP</td>
<td>112</td>
<td>43</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>84.7 - 101.3</td>
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<tr>
<td></td>
<td>VWP</td>
<td>141</td>
<td>43</td>
<td>Ulan seam</td>
<td>Datalog Reported monthly</td>
<td>103.4 - 126.1</td>
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<td>PZ 130</td>
<td>VWP</td>
<td>111</td>
<td>38.5</td>
<td>Permian overburden</td>
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<td>37.7 - 40.4</td>
<td>N/A</td>
<td>29/11/2007</td>
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<td>760 940</td>
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<td></td>
<td>VWP</td>
<td>64</td>
<td>38.5</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>51.6 - 58.9</td>
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<td></td>
<td>VWP</td>
<td>97</td>
<td>38.5</td>
<td>Ulan seam</td>
<td>Datalog Reported monthly</td>
<td>79.3 - 88.2</td>
<td>N/A</td>
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<td></td>
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<tr>
<td>PZ 186</td>
<td>SP</td>
<td>114</td>
<td>108 - 114</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>8.47 - 17.21</td>
<td>6 months</td>
<td>6/05/2009</td>
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<td>22</td>
<td>15 - 21</td>
<td>Palaeochannel</td>
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<td>0.78 - 2.88</td>
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<td>7/05/2009</td>
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<td>PZ 188</td>
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<td>18.5</td>
<td>12 - 18</td>
<td>Palaeochannel</td>
<td>Datalog Reported monthly</td>
<td>7.29 - 8.40</td>
<td>6 months</td>
<td>14/05/2009</td>
<td>20BL173935</td>
<td>764 478</td>
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<tr>
<td>PZ 189</td>
<td>SP</td>
<td>65</td>
<td>59 - 95</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>10.41 - 14.90</td>
<td>6 months</td>
<td>20/05/2009</td>
<td>20BL173935</td>
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</tr>
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<td>VWP</td>
<td>145</td>
<td>29</td>
<td>Triassic</td>
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<td>24.6 - 28.0</td>
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<td>4/07/2008</td>
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<td></td>
<td>VWP</td>
<td>33</td>
<td>29</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
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<tr>
<td></td>
<td>VWP</td>
<td>145</td>
<td>29</td>
<td>Ulan seam</td>
<td>Datalog Reported monthly</td>
<td>28.9 - 71.4</td>
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<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
4.4 Groundwater Quality

Table 4 details the monitoring program for groundwater quality at monitoring bores relevant to UG1 Longwalls 101-103. Samples are taken six-monthly and sent for laboratory analysis of key parameters (Table 4).

Field measurements of EC and pH are recorded at the time of water quality sampling conducted for relevant bores. No change is required for the Longwalls 101-103 Extraction Plan.

Table 4. Groundwater Quality Monitoring Program

<table>
<thead>
<tr>
<th>Class</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical parameters</td>
<td>EC, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and pH</td>
</tr>
<tr>
<td>Major cations</td>
<td>calcium, magnesium, sodium, potassium</td>
</tr>
<tr>
<td>Major anions</td>
<td>carbonate, bicarbonate, chloride and sulphate</td>
</tr>
<tr>
<td>Dissolved metals</td>
<td>aluminium, arsenic, boron, cobalt, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc</td>
</tr>
<tr>
<td>Nutrients</td>
<td>ammonia, nitrate, phosphorus, reactive phosphorus</td>
</tr>
<tr>
<td>Other</td>
<td>fluoride</td>
</tr>
</tbody>
</table>

4.5 Streamflow

Streamflow monitoring forms part of the surface water monitoring regime. A data sharing agreement has been established between MCO, Ulan Coal Mines Limited and Wilpinjong Coal Pty Limited. The streamflow data from this program will inform the monitoring of stream baseflows (i.e. net groundwater discharge to the stream system) throughout the life of the Moolarben Coal Complex. Streamflow monitoring is discussed further in the existing complex-wide Surface Water Management Plan.

4.6 Climate Monitoring

Climate monitoring data are collected from an automatic weather station on site.

The recorded rainfall data are used to differentiate between natural groundwater level variations caused by rainfall induced recharge, and abstraction induced variations due to mining or groundwater pumping\(^2\). For shallow unconfined aquifers there is a direct and often immediate relationship between rainfall and groundwater level. For deeper aquifers this relationship often holds but with a time-lagged and muted response.

\(^2\) By calculation of rainfall residual mass (cumulative deviation from the mean), and observation of abstraction timing.
5. TRIGGER LEVELS AND MANAGEMENT RESPONSES

MCO evaluates the environmental performance of the Moolarben Coal Complex against the predictions of impact made in the Stage 1 and Stage 2 Environmental Assessment documents and the performance measures described in the complex-wide GMP dated October 2016.

Periodic review of performance is undertaken by comparison of observed monitoring results against model predictions. The performance is assessed in terms of specific parameters by the application of trigger levels which are used to initiate a response action, as detailed in the following sections.

MCO has established trigger values to determine the need for investigation and possible response actions for potential impacts to groundwater levels and quality in the alluvial and Triassic groundwater systems.

The Permian strata are already extensively affected by past mining, are predicted to undergo significant further impact from ongoing mining at the Moolarben Coal Complex, the Ulan Mine Complex and the Wilpinjong Coal Mine, and contain groundwater of generally poor quality. Accordingly, trigger levels have not been set for the monitoring piezometers screened in the Permian.

5.1 Groundwater Quality Triggers

The ANZECC (2000) guidelines for Fresh and Marine Water Quality apply to the quality of both surface waters and groundwaters as they have been developed to protect environmental values relating to above-ground uses such as irrigation and stock use.

ANZECC (2000) recommends that wherever possible site-specific data be used to define trigger values for physical and chemical factors which can adversely impact the environment, rather than using ANZECC guideline values.

Groundwater monitoring results indicate that baseline values of pH and EC in the vicinity of the Moolarben Coal Complex vary across a wide range and can be outside the ANZECC (2000) guideline values for ecosystem protection. Therefore, site specific trigger levels based on the baseline data have been developed for monitoring the impact of the Moolarben Coal Complex.

5.1.1 Salinity Triggers

Table 1 of the NSW Aquifer Interference Policy sets out the minimal impact considerations for aquifer interference activities for less productive groundwater sources, including (inter alia):

- Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.

The Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 which regulates the alluvial water sources does not designate beneficial uses for the alluvial aquifers in the vicinity of the Moolarben Coal Complex. The Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources does not designate beneficial uses for the non-alluvial groundwater (i.e. groundwater within the porous rock water groundwater system) in the vicinity of the Moolarben Coal Complex.

The following beneficial uses were recommended by the National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia for major (or significant) aquifers and have been adopted by the DPI Water in its Groundwater Quality Protection Policy (Department of Land and Water Conservation, 1998):

- ecosystem protection;
- recreation and aesthetics;
- raw water for drinking water supply; and
- agricultural water and industrial water.
The National Land and Water Resources Audit (Murray Darling Basin Commission, 2005) specified groundwater quality ranges for beneficial use categories based on salinity (Table 5). These salinity-based categories generally align with the beneficial uses within the NSW Groundwater Quality Protection Policy.

Table 5. Groundwater Quality Categories: Electrical Conductivity

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>Quality Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable</td>
<td>Up to 800 µS/cm (500 mg/L TDS)*</td>
<td>Suitable for all drinking water and uses.</td>
</tr>
<tr>
<td>Marginal Potable</td>
<td>800-2,350 µS/cm (500-1,500 mg/L TDS)*</td>
<td>At the upper level this water is at the limit of potable water, but is suitable for watering of livestock, irrigation and other general uses.</td>
</tr>
<tr>
<td>Irrigation</td>
<td>2,350-7,800 µS/cm (1,500-5,000 mg/L TDS)*</td>
<td>At the upper level, this water requires shandying for use as irrigation water or to be suitable for selective irrigation and watering of livestock.</td>
</tr>
<tr>
<td>Saline</td>
<td>7,800-22,000 µS/cm (5,000-14,000 mg/L TDS)*</td>
<td>Generally unsuitable for most uses. It may be suitable for a diminishing range of salt-tolerant livestock up to about 6,500mg/L [~10,150 µS/cm] and some industrial uses.</td>
</tr>
<tr>
<td>Highly Saline</td>
<td>&gt; 22,000 µS/cm (14,000 mg/L TDS)*</td>
<td>Suitable for coarse industrial processes up to about 20,000 mg/L [~31,000 µS/cm].</td>
</tr>
</tbody>
</table>


Salinity triggers have been developed based on the 95th percentile baseline salinity level recorded at each relevant bore location. Should a measured salinity level exceed the trigger for two consecutive monitoring events, and the measured salinity is in a lower beneficial use category (Table 5) than the trigger level, then the groundwater investigation protocol described in the complex-wide GMP will be initiated.

The bores in Table 6 (a sub-set of those in the complex-wide GMP) are considered to be those relevant for investigating potential changes in groundwater quality due to longwall mining in Longwalls 101-103. The recommended salinity triggers (from the revised GMP dated October 2016) for each relevant bore are presented in Table 6. These values are lower than the current GMP (2015) trigger values.

Table 6. Salinity and pH Trigger levels

<table>
<thead>
<tr>
<th>Bore</th>
<th>Depth (m)</th>
<th>Lithology Screened</th>
<th>Salinity Triggers</th>
<th>pH Trigger Level (5th to 95th percentile)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Historical lab EC (5th to 95th percentile) (µS/cm)*</td>
<td>EC Trigger Level (µS/cm)</td>
<td>Beneficial Use Category Based on Lab EC 95th Percentile</td>
</tr>
<tr>
<td>PZ186</td>
<td>114</td>
<td>Permian Overburden</td>
<td>336-465 (370)</td>
<td>465</td>
</tr>
<tr>
<td>PZ187</td>
<td>22</td>
<td>Palaeochannel Alluvium</td>
<td>170-656 (201)</td>
<td>656</td>
</tr>
<tr>
<td>PZ188</td>
<td>18.5</td>
<td>Palaeochannel Alluvium</td>
<td>198-394 (245)</td>
<td>394</td>
</tr>
<tr>
<td>PZ189</td>
<td>65</td>
<td>Permian Overburden</td>
<td>311-408 (375)</td>
<td>408</td>
</tr>
</tbody>
</table>

*NB. Historical values in brackets are median values

5.1.2 pH Triggers

pH triggers have been developed from the 5th and 95th percentile baseline pH levels recorded at each bore location considered relevant to Longwalls 101-103. Should a measured pH level exceed the trigger for two consecutive monitoring events, then the groundwater investigation protocol described in the complex-wide GMP will be initiated. Recommended trigger values (from the revised GMP dated October 2016) are in Table 6.
5.2 Groundwater Level Triggers

Triggers for measured groundwater levels have been developed based on the minimal impact considerations in the NSW Aquifer Interference Policy.

There is no ‘highly productive’ groundwater, as defined under the Aquifer Interference Policy, mapped in the vicinity of the Moolarben Coal Complex. The nearest ‘highly productive’ groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

The NSW Aquifer Interference Policy describes the following minimal impact considerations for less productive groundwater sources:

Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:

- (a) high priority groundwater dependent ecosystem; or
- (b) high priority culturally significant site;

listed in the schedule of the relevant water sharing plan.

A maximum of a 2m decline cumulatively at any water supply work.

There are no high priority groundwater dependent ecosystems or high priority culturally significant sites identified in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 or Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources in the vicinity of the Moolarben Coal Complex.

The groundwater investigation protocol detailed in the complex-wide GMP would be initiated in cases where the groundwater monitoring program identifies the potential for a greater than 2 m reduction in the groundwater level at a private bore, determined against groundwater level hydrograph trends, so that a 2 m drawdown attributable to the cumulative impact of mining at the Moolarben Coal Complex, Ulan Mine Complex and/or Wilpinjong Coal Mine will be an effect superimposed on trends due to either climatic effects and/or other external cause.

Water level triggers have been developed for alluvium monitoring bores listed in Table 7. The bores in Table 7 (which are a sub-set of those in the complex-wide GMP) have been selected as investigation triggers for potential changes in groundwater levels due to underground mining in Longwalls 101-103. The investigation trigger levels (developed from an analysis of historical groundwater levels) are also provided in Table 7 and have been set at 2 m below the minimum water level reported during the baseline monitoring period.

### Table 7. Trigger Groundwater Levels – Alluvium Bores

<table>
<thead>
<tr>
<th>Alluvium Piezometer Number</th>
<th>Base of Alluvium/Tertiary Palaeochannel (m AHD)</th>
<th>Interval/Level Monitored (mbgl)</th>
<th>Minimum Observed Groundwater Level/Pressure (mbgl)</th>
<th>Trigger Level (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ187</td>
<td>&lt;396.5</td>
<td>15-21</td>
<td>2.9</td>
<td>413.7</td>
</tr>
<tr>
<td>PZ188</td>
<td>403.6</td>
<td>12-18</td>
<td>8.4</td>
<td>413.2</td>
</tr>
</tbody>
</table>

The above trigger levels are intended to trigger an investigation to determine whether the cause of the water level/pressure decline is caused by MCO’s mining activity, excluding borefield pumping, and to recommend an appropriate response action. Prior to initiating a response action, an exceedance of a trigger level will need to occur for at least two successive monthly monitoring rounds, to eliminate possible anomalous readings.
6. DATA ANALYSIS

6.1 Key Alluvial Bores

The key alluvium monitoring bores pertinent to Longwalls 101-103 are:

- PZ187 – 1.0 km from the takeoff line for Longwall 103; and
- PZ188 – 0.8 km from the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in Figure 6 and Figure 7.

PZ187 and PZ188 have similar groundwater level response which correlates well with the rainfall trend represented by the “Moolarben CRD” on the figures, without any significant time lag. This suggests that the water levels are controlled by direct vertical infiltration of rain water, with possible contributions from coincident streamflow down Wilpinjong Creek.

The groundwater quality is fresh at both sites.

6.2 Key Permian Overburden Bores

The key Permian overburden monitoring bores pertinent to Longwalls 101-103 are:

- PZ186 – 1.0 km from the takeoff line for Longwall 103;
- PZ189 – 0.8 km from the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in Figure 8 and Figure 9.

PZ186 and PZ189 have similar groundwater level patterns. The responses correlate well with the rainfall trend with a time lag of about 8 months. The peak water level at PZ186 is about 8 m lower than the peak in the overlying alluvium bore (PZ187). The peak water level at PZ189 is about 3 m lower than the peak in the overlying alluvium bore (PZ188). This suggests that the water levels are controlled by direct vertical infiltration of rain water through the alluvium.

In late 2016, there was an abrupt decline in groundwater level by about 1 m. This could be due to the UG1 first workings, but the event coincided with a similarly abrupt change in the rainfall trend.

The groundwater quality is fresh at both sites. At PZ186, the EC is about the same as in the overlying alluvium. At PZ189, the EC is about double that in the overlying alluvium.

6.2 Key Ulan Seam Bores

The key Ulan Seam monitoring bores pertinent to Longwalls 101-103 are:

- PZ156 – about 7 m north of the takeoff line for Longwall 101;
- PZ157 – about 115 m south of the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in Figure 10 and Figure 11.

PZ156 and PZ157 have almost identical groundwater level responses, with a head difference of only 1 m. The responses correlate very well with the rainfall trend with a time lag of about 12-18 months. This suggests that the water levels are controlled by vertical infiltration of rain water into the coal seam at outcrop/subcrop, with lateral migration of a pressure response through the seam.

In late 2016, there was an abrupt decline in groundwater level by about 5 m. This was due to the UG1 first workings, and preceded a smaller abrupt change in the rainfall trend.

The groundwater EC has tended to increase with rising groundwater level, with recent measurements at the boundary between “potable” and “marginal potable” quality (800 µS/cm).
Both these bores will be unserviceable following mining.

6.2 Key VWP Bores

The key multi-level VWP monitoring bores pertinent to Longwalls 101-103 are:

- PZ127 – over the pillar between Longwalls 102 and 103;
- PZ130 – over the pillar between Longwalls 104 and 105;
- PZ179 – 1.3 km from the takeoff line for Longwall 102.

Time-series graphs of groundwater level, EC and pH are provided in Figures 12-14.

At each site there is a fairly consistent vertical gradient indicative of downwards groundwater movement.

At PZ127, only the Ulan Seam VWP shows any correlation with rainfall trend, and it appears considerably lagged in time. A probable drawdown of about 1 m due to UG1 first workings is evident in the lower Permian in late 2016.

PZ130 ought to be affected by OC2 mining, but there is no evidence of a mining effect in the groundwater responses. In addition, the head in the Ulan Seam (about 450 mAHD) appears anomalously high.

PZ179 has a lagged rainfall response in the Ulan Seam, and has a probable UG1 mining effect of about 3 m drawdown in late 2016. A smaller drawdown at the same time is apparent in the upper Permian. The middle Permian sensor appears anomalous as its head is out of sequence with neighbouring sensors and should be removed from the monitoring program.
7. TERTIARY PALAEOCHANNEL DEFINITION

7.1 Objective

Further investigation into the extent and saturation status of the Tertiary palaeochannel has been undertaken to address an additional condition placed on the approval of the UG1 Extraction Plan Water Management Plan, which requires a program to:

1. confirm the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings, including drilling of additional investigation bores;
2. validate, and if necessary revise, the groundwater model for the palaeochannel; and
3. monitor and report on the groundwater impacts of underground 1 second workings on the palaeochannel; and a program to monitor and report on the predicted groundwater impacts on the palaeochannel adjacent to underground 1 boundary.

7.2 Field Investigations

The palaeochannel extent, sediment thickness and relative permeabilities in the UG1 Optimisation Modification groundwater model were inferred from a geophysical survey comprising transient electromagnetic (TEM) and direct current (DC) electrical resistivity profiling (Groundwater Imaging, 2014) and available exploration records. Both geophysical methods give estimates of the true electrical resistivity of the subsurface, generally to limiting depths of 50-70 m. The resistivity of a material is determined primarily by water content, water quality and lithology. High resistivity (>100 ohm metres) is indicative of freshwater sand, unsaturated sand or arenaceous rock (e.g. sandstone). Low resistivity (<10 ohm metres) is indicative of saltwater sand, clay, or argillaceous rock (e.g. shale). Accordingly, the interpretation of TEM or DC surveys is ambiguous in terms of the causative factors.

Figure 15 shows the TEM true resistivity pattern (at approximate depth 12 m) in relation to three DC resistivity survey lines (DC 1, DC 2 and DC 3) and Longwalls 101-105. The DC lines were located in areas of potential palaeochannel sediments at the northern ends of Longwalls 101-105.

The revised outline of the palaeochannel (HydroSimulations, 2015) at that time is shown in Figure 16 in relation to the 12 m depth TEM resistivity pattern and two pre-TEM key bores. Three discontinuous zones of potentially good quality palaeochannel sediments were interpreted. One of the isolated pockets of sediments occurs at the north-eastern end of Longwalls 101-102. No palaeochannel was detected at the north-eastern end of Longwall 103, but the palaeochannel was detected above the proposed mains at the north-eastern end of Longwalls 104-105 and in the vicinity of the takeoff lines there. Overall, HydroSimulations (2015) considered that the extended longwall panels would not pass beneath any water-bearing palaeochannel sediments.

To support the interpretation of the revised extent of the palaeochannel, a drilling program was undertaken at 7 sites at so-called post-TEM bores at the ends of Longwalls 101-103. The post-TEM bores relevant to Longwalls 101-103 are shown in Figure 16. The bores are aligned along Transects A and B as marked on Figure 16.

Figure 17 and Figure 18 show detailed comparisons of bore logs and downhole geophysical logs (primarily gamma and resistivity) for Transect A and Transect B, respectively. While there can be ambiguity in the physical description of cuttings, the geophysical logs are usually more diagnostic. Gamma logs, which indicate relative potassium content, show a consistent sharp increase from low to high counts at or near the base of the palaeochannel. This is marked by a green circle on each plot. Gamma counts are usually good indicators of relative sand/clay content, with higher counts for higher clay content. However, in these logs, the gamma counts are consistently low in palaeochannel sediments even though clay is often recorded as the dominant lithology, or the sands and gravels are recorded as being in a clayey matrix. This observation suggests that the type of clay is low in potassium (as is known to occur in the Namoi Valley).
Resistivity logs are particularly useful indicators of saturation, as no reading can be taken until the sensor is immersed in water. The commencement of each resistivity log, therefore, gives the groundwater level at the time of logging. In combination with gamma logs, the resistivity log can often be used to discriminate between saline water and clay as the causes of low resistivity readings. Taken together, the resistivity and gamma logs provide a reliable means of measuring the saturated thickness of palaeochannel sediments. Two holes on Transect B were found to be completely dry within the palaeochannel sediments: MCOL396 and MCOL398 (Figure 18).

Visual impressions of the subsurface geology (to a maximum depth of 40 m) are provided in Figure 19 and Figure 20, respectively, for Transect A and Transect B. The palaeochannel is interpreted to comprise gravel, coarse sand, sand and clay lithologies. On each figure is marked the saturated thickness derived from the resistivity log. The degree of saturation is variable, with several holes being almost or completely dry, and all with a low saturated thickness fraction\(^3\). On both sections is a superficial clay zone of about 10 m thickness.

The interpreted saturated thickness of palaeochannel sediments is given in Figure 21. Of particular interest are the values of zero and 2 m near the northern ends of Longwalls 101 and 102, in agreement with earlier conclusions by RPS Aquaterra (2011) and HydroSimulations (2015) that the palaeochannel here is essentially unsaturated. Near the takeoff line of Longwall 101, approximately 2 m of water has been recorded, which is about 7 percent of the palaeochannel thickness. For the seven sites near the end of Longwalls 101-102, the statistics for the saturated thickness fraction (i.e. percentage of water compared to total thickness of palaeochannel) are: range 0% to 31%; mean 9%; median 4%.

### 7.3 Summary of Findings – Palaeochannel Definition

With respect to Item [1] in Section 7.1 [Objectives], it is proposed that a reasonable definition of “saturated extent” be that volume of the palaeochannel where the Tertiary sediments are saturated to more than 10 percent of the alluvial thickness.

The additional investigation bores at the northern end of Longwalls 101-102 have confirmed the palaeochannel extent and the lack of saturation of the palaeochannel sediments, with saturated thickness fraction less than 10%. No palaeochannel deposits have been observed above Longwall 103.

No further drilling is required at Longwalls 101-103, as the additional drilling has successfully confirmed the location and saturated extent of the palaeochannel there.

With respect to Item [2] in Section 7.1 [Objectives], the additional drilling and downhole geophysics has successfully validated the assumptions in the groundwater model.

With respect to Item [3] in Section 7.1 [Objectives], it is recommended that a monitoring site (Site A) be established near bore MCOL394 to the north-east of Longwall 101, about 85 m from the takeoff line (Figure 22). At this location there is expected to be about 9 m of saturated gravel below about 16 m of dry clay and sand. An additional monitoring site (Site B) is recommended near MCOL406 in the axis of the palaeochannel about 200 m north of the Longwall 105 takeoff line, where the palaeochannel thickness is about 24 m (Figure 22).

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\(^3\) The ratio of water thickness to palaeochannel thickness
8. CONCLUSION

The key findings of this Longwalls 101-103 Extraction Plan groundwater assessment review are:

1. Since the publication of the Groundwater Modelling Assessment for the Moolarben Coal Complex UG1 Optimisation Modification (HydroSimulations, 2015), additional field investigations have been undertaken to confirm the location and saturated extent of the palaeochannel adjacent to the extents of UG1 second workings.

2. The additional investigation bores at the northern end of Longwalls 101-102 have confirmed the palaeochannel extent and the lack of saturation of the palaeochannel sediments. No palaeochannel sediments have been observed above Longwall 103.

3. The additional drilling and downhole geophysics have successfully validated the assumptions in the groundwater model.

4. Given the robustness of the model with respect to palaeochannel morphology adjacent to UG1, the model predictions remain applicable.

5. The model predicts negligible drawdown in alluvium and regolith for UG1 extraction.

6. No private bores are likely to be affected by 2 m drawdown or more. No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry. With the exception of drawdown at the level of the Ulan Seam in the north-eastern extents of UG1, there would be no discernible change in drawdown resulting from UG1 extraction.

7. Monitoring bores from the existing monitoring network located in close proximity to Longwalls 101-103 are suitable to monitor groundwater levels and quality and confirm potential impacts are consistent with those previously assessed and approved.

8. Groundwater level and quality trigger levels established for these bores (as per the GMP dated October 2016) with investigation protocols to be implemented should triggers be exceeded (as identified by monitoring) are suitable for the UG1 Longwalls 101-103 Extraction Plan.

9. Additional palaeochannel monitoring bores are recommended to be installed to the north-east of UG1 longwalls 101 and 105 prior to the commencement of secondary extraction of LW101 and LW104 respectively.

This review, based on currently available records, indicates no material groundwater impacts are expected from mining of Longwalls 101-103 beyond what was assessed and approved in the Moolarben Coal Complex UG1 Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015).
9. References


MSEC (2015) Moolarben Coal Project (Stage 2) Subsidence Predictions and Impact Assessments for Natural Features and Items of Surface Infrastructure due to Proposed Extraction of Mining Longwalls 1 to 13.


FIGURES
Figure 1

Source: NSW Land & Property Information (2015); NSW Department of Industry (2016); Office of Environment and Heritage NSW (2016)
Figure 2

Legend:
- Exploration Licence Boundary
- Mining Lease Boundary
- Haul Road
- Approved Road Realignment (not yet constructed)
- Existing/Approved Development
- Open Cut Mining Area
- Out-of-pit Emplacement
- Surface Infrastructure Area
- Underground Longwall Layout
- Direction of Longwall Mining
- Longwalls 101 to 103 Study Area

Source: MCO (June 2016); NSW Dept of Industry (2016)
Figure 4. Total Drawdown (m) in Alluvium / Regolith (model layer 1) at the end of UG1 Mining
Figure 5. Groundwater Monitoring Bores Most Relevant to UG1 Longwalls 101-103
Figure 6. Groundwater Hydrographs for Alluvium Monitoring Bore PZ187

Figure 7. Groundwater Hydrographs for Alluvium Monitoring Bore PZ188
Figure 8. Groundwater Hydrographs for Permian Overburden Monitoring Bore PZ186

Figure 9. Groundwater Hydrographs for Permian Overburden Monitoring Bore PZ189
Figure 10. Groundwater Hydrographs for Ulan Seam Monitoring Bore PZ156

Figure 11. Groundwater Hydrographs for Ulan Seam Monitoring Bore PZ157
Figure 12. Groundwater Hydrographs for VWP Bore PZ127

Figure 13. Groundwater Hydrographs for VWP Bore PZ130
Figure 14. Groundwater Hydrographs for VWP Bore PZ179
Figure 15. Longwall Locations, DC Resistivity Lines and TEM True Resistivity at 12m Depth
Figure 16. Post-TEM Investigation Bore Names and Locations with TEM Resistivity (at 12m Depth)
Figure 17. Transect A Geophysical and Lithological Logs

- Gamma marker at base of palaeochannel
Figure 18. Transect B Geophysical and Lithological Logs

- Gamma marker at base of palaeochannel
Figure 19. Transect A Geological Section Showing Tertiary Palaeochannel (Gravel and Sand) Profile and Degree of Saturation
Figure 21. Interpreted Saturated Thickness of Tertiary Palaeochannel Sediments (m)
Figure 22. Proposed Monitoring Bore Locations