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Our Ref: S6R/017e
Date: 30 July 2013

Mark Jacobs
Yancoal Australia Pty Ltd
Level 23, 363 George St
SYDNEY
NSW 2000

Dear Mark,

RE: Hydraulic Connection between Quaternary Alluvium and Tertiary Palaeochannel in the Moolarben Groundwater Model

1. Introduction

We have prepared this letter in response to correspondence from the NSW Office of Water (NOW – Reference No. ER20274, dated 1 July 2013) to provide clarification on the hydraulic connection between the Tertiary palaeochannel deposits, the Quaternary alluvium and modern-day drainage system in the numerical groundwater model for the Moolarben Coal Project.

2. Numerical Modelling

2.1 Hydraulic Connection between Quaternary Alluvium and Tertiary Palaeochannel

The numerical groundwater model is based on MODFLOW-SURFACT, which is a commonly used extension of the industry standard USGS MODFLOW modelling code. This has been described previously (refer for example RPS 2011).

The numerical model consists of layers representing various hydrogeological units, with each layer divided into discrete cells. (This is standard practice for three-dimensional numerical groundwater modelling and is consistent with the Australian Groundwater Modelling Guidelines). Model Layer 1 was constructed to represent all areas of unconsolidated material and includes (inter alia) Quaternary alluvium, Tertiary palaeochannel deposits, regolith and spoil filled mine voids. Layer 1 was further subdivided into zones each representative of constant hydrogeological properties.

As identified in Dundon (2013), hydrogeological field investigations imply that the Tertiary palaeochannel may not be hydraulically connected to the modern-day drainage system. However, in the numerical model, these units are constructed to be directly hydraulically connected (by virtue of the assigned parameters). This has been the case in each of the 2011 and 2012 versions[1] of the model (RPS, 2011 and 2012) and the recently completed sensitivity modelling (Dundon, 2013). That is, all Layer 1 is internally hydraulically connected in addition to being hydraulically connected to the modern-day drainage system, where they overlap. Further, where the palaeochannel has been identified to occur, all material in these areas (from the surface to the base of the palaeochannel) has been assigned the *same* hydraulic conductivity value.

The recent sensitivity modelling (Dundon 2013) examined two scenarios in response to the NOW's previous concerns:

- Scenario 1 – palaeochannel hydraulic conductivity increased to Kh = 10m/d.

[1] 2011 is the model version reported in Appendix E of the Moolarben Stage 2 Preferred Project Report – Environmental Assessment; 2012 is the model version reported in Appendix F of the Moolarben Stage 2 Project Preferred Project Report Response to Submissions.

- Scenario 2 – trunk palaeochannel hydraulic conductivity increased to Kh = 50m/d and tributary palaeochannel conductivity increased to Kh = 10m/d.

The representation of the connection between the varying zones of unconsolidated material (including Quaternary alluvium and the palaeochannel deposits) in the model is illustrated in Figures 1 and 2:

- Figure 1 shows the distribution of Layer 1 zones of hydraulic properties for the Scenario 1 sensitivity model run.
- Figure 2 shows the distribution of Layer 1 zones of hydraulic properties for the Scenario 2 model run.

It can be seen from the figures that the complete section of unconsolidated material within the extents of the identified palaeochannel have been assigned the *same* (higher) hydraulic conductivity value regardless of whether Quaternary alluvium exists in this area or not. That is, there is no separate representation in the model of Quaternary alluvium in areas where it exists within the extent of the palaeochannel alluvium. (Note however, as reported in Dundon (2013), the published 1:100,000 geological map of the area shows *no* Quaternary alluvium in the vicinity of the Stage 2 open cut mine).

The locations of creeks within the model are also shown in Figures 1 and 2. Creeks were represented in the model using the river (RIV) MODFLOW package. The riverbed conductance value assigned to the RIV cells representing the creeks was set at a value of 1000m^2/d, ensuring that there is no resistance to interconnection in the model. It is noted that not all creeks in the model occur in Layer 1. As indicated in the current geological map, some creeks, or parts thereof, flow over bed-rock rather than alluvium and as such were assigned in the model to the relevant layer based on the respective hydrogeologic unit. This was the upper Permian (Layer 4) of the model where the alluvium was absent. Where the RIV boundary was set in Layer 4, the thickness of overlying (dummy) layers in those areas was already minimised (minimum layer thickness is 1m) and, as such, the adopted approach does not affect the performance of that boundary condition.

These figures show Zone 3 (pale yellow – representing Quaternary alluvium) is directly connected to Zone 9 (purple – representing the interpreted Tertiary palaeochannel trunk), which is connected to Zone 10 (cyan – representing Murragamba and Eastern Creek tributaries). Each of these zones is connected to surrounding regolith, Quaternary alluvium (where it exists) and the overlying surface drainage (where applicable). The figures show a plan view of the model with the 100m x 100m model grid cells clearly visible. (Note the presented figures show the pre-Moolarben mine case).

The assigned hydraulic properties for each zone in Layer 1 (including a colour key) is summarised in Table 1. The assignment of values for each of the recent Scenario sensitivity models was discussed in Dundon 2013 and is not repeated here. Storage parameters were not adjusted for the sensitivity model runs, only the assigned values for hydraulic conductivity (Dundon, 2013).

Table 1: Modelled Values of Permeability (m/d) for Layer 1

Zone[2]	Description	Colour	2012 Model		Scenario 1 Model		Scenario 2 Model	
			Kh	Kv	Kh	Kv	Kh	Kv
1	Regolith		0.5	0.001	0.5	0.001	0.5	0.001
3	Quaternary Alluvium		3	0.01	3	0.01	3	0.01
9	Tertiary Palaeochannel		1	0.005	10	0.05	50	0.25
10	Tertiary Palaeochannel		1.5[1]	0.15[1]	10	1	50	5
22	Backfilled Mine Pit		1	0.1	1	0.1	1	0.1
27	Backfilled Mine Pit		1	0.1	1	0.1	1	0.1
33	Backfilled Mine Pit		1	0.1	1	0.1	1	0.1
35	Tertiary Palaeochannel		N/A	N/A	N/A	N/A	10	1

Note. 1. The value for Kh, horizontal permeability and Kv, vertical permeability presented in RPS 2011 were 0.4 and 0.005 respectively. Note these were adjusted to 1.5 and 0.15 in the RPS 2012 model;

2. Only those zones displayed in Figures 1 and 2 are tabulated here.

2.2 Approach to Modelling Creeks and Rivers

There are three creeks that are potentially directly impacted by the Moolarben Stage 2 project that lie in an area that is identified from geological mapping as being associated with unconsolidated Quaternary and or Tertiary palaeochannel deposits:

- Murragamba Creek (Model Reach, R107)
- Wilpinjong Creek North (Model Reach, R108)
- Wilpinjong Creek (Model Reach, R109A)

In the 2012 version of the model (RPS, 2012), Wilpinjong Creek (Reach 109) was split into two sections (109A and 109B). This was a change from that previously presented in RPS (2011). The reason for splitting Reach 109 into Reach 109A and Reach 109B in the 2012 version of the model was to separately quantify the potential impact of the Moolarben Stage 2 Project on Wilpinjong Creek in the vicinity of the proposed Project, as compared to the existing Wilpinjong mine. As presented in RPS (2012), comparison of the "with Moolarben Stage 2" and "without Moolarben Stage 2" model runs showed that Moolarben Stage 2 had no impact on baseflows in Reach 109B. All baseflow impacts in Reach 109B in the cumulative impact modelling were shown to be due to the Wilpinjong mine. Hence the Moolarben Stage 2 Project will have no impact on baseflow for this reach (Reach 109B) of Wilpinjong Creek.

3. Discussion and Conclusion

In summary, the model and choice of hydraulic parameters for each zone of Layer 1 facilitates effective hydraulic connection between the Tertiary palaeochannel deposits, the Quaternary alluvium and the modern-day surface drainage system at the Moolarben site.

While hydrogeological field investigations indicated that the Tertiary palaeochannel *may not* be hydraulically connected to the Quaternary alluvium and or the modern-day drainage system, each of these units is directly connected in the numerical groundwater model and they have been modelled in this manner in the 2011 and 2012 versions of the model, and more recent sensitivity analyses modelling.

The recent sensitivity modelling (Dundon 2013) included areas of increased hydraulic conductivity more representative of characteristic text book values for the Tertiary palaeochannel deposits, with the higher hydraulic conductivity values assigned to the complete section of alluvium (from the surface to the base of the palaeochannel), inclusive of any overlying Quaternary alluvium, even though the higher conductivity values were not consistent with the results of testing. That is, the higher hydraulic conductivity values have been applied to all alluvium in these areas in the sensitivity modelling. The model also included direct connection of these increased hydraulic conductivity zones with the modern-day drainage system where they adjoin.

Accordingly, the conceptualisation requested by the NOW (i.e. higher more textbook-consistent permeability for the Tertiary palaeochannel and Quaternary alluvium and in hydraulic connection) has been addressed and the sensitivity of higher hydraulic connectivity of the Tertiary palaeochannel to Quaternary alluvium and the overlying drainage system has been evaluated.

4. References

Dundon Consulting Pty Ltd, 2013. *Email from NOW to DoPI dated 19 April 2013, with attached internal NOW memo dated 9 April 2013*. Reference No. 0264b-L02_13-06-07 final draft.doc.

NSW Office of Water, 2013. *Moolarben Coal Project Stage 2 (08_0135)*. Reference No. ER20274, dated 1 July 2013.

RPS Aquaterra, 2011. *Moolarben Coal Complex Stage 2 Preferred Project Report Groundwater Impact Assessment*. Reference No. S6\S6N\019h, dated 30 November 2011. Appendix E to Moolarben Coal Project Stage 2 Preferred Project Report, July 2011.

RPS Aquaterra, 2012. *Moolarben Coal Complex Stage 2 – Additional Groundwater Impact Assessment*. Reference No. S6\S6P\020b, dated 14 June 2012. Appendix F to Moolarben Coal Project Stage 2 Preferred Project Report Response to Submissions, June 2012.

RPS Aquaterra, 2013. *Moolarben Stage 2 PPR: Response to Query on Alluvium Permeability*. Reference No. S6R/008b, dated 13 June 2013.

5. Closing

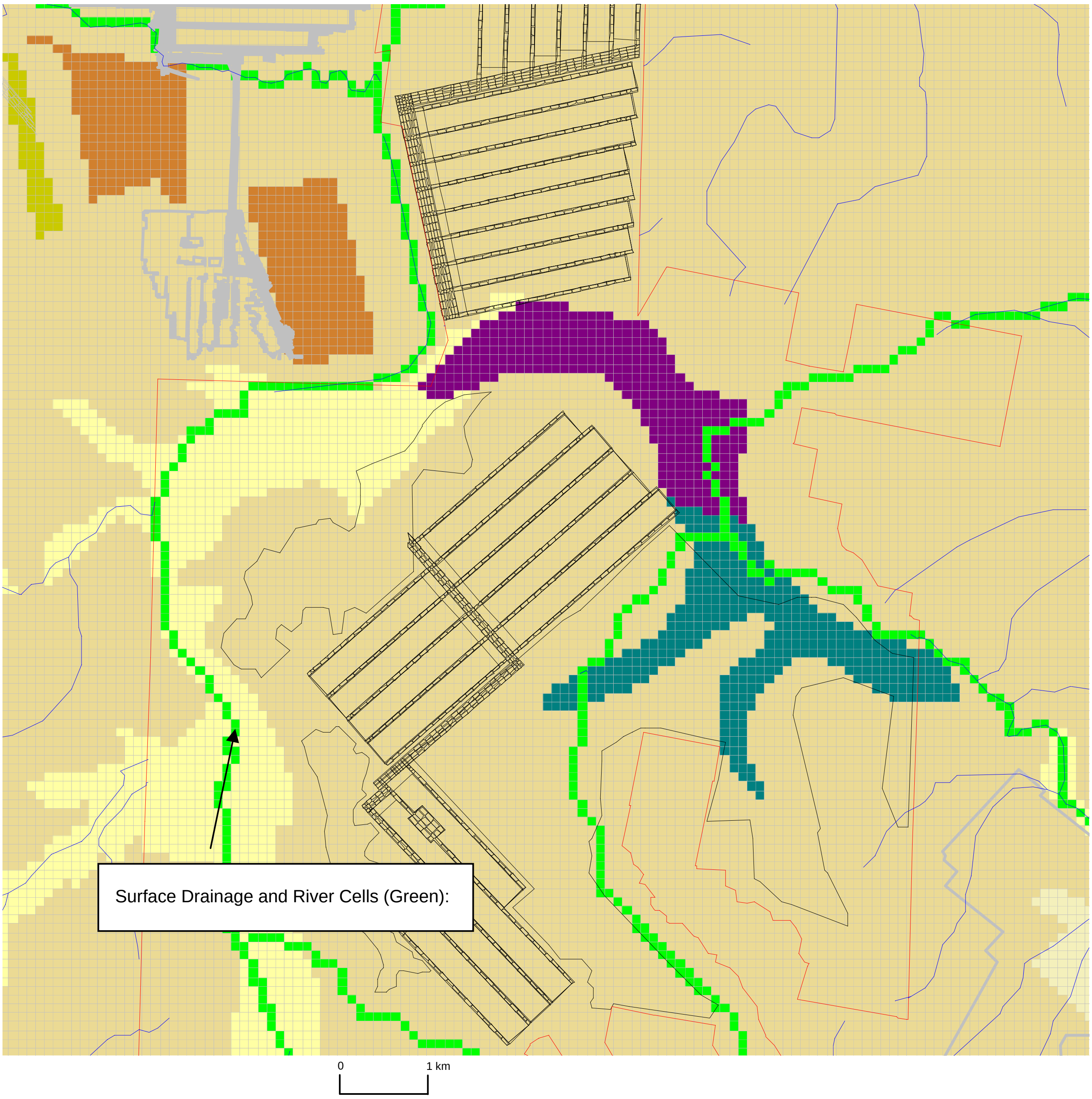
We trust this information is sufficient for your purposes, however should you require any further details or clarification, please do not hesitate to contact our office.

Yours sincerely
RPS Water

Justin	***Ray***
Dr Justin Bell Senior Modeller and Surface Water Engineer	Ray Hatley Senior Principal Hydrogeologist

enc: Figure 1 – Model Layer 1 – Hydraulic Property Zones (Mine Year 0) – Scenario 1
Figure 2 – Model Layer 1 – Hydraulic Property Zones (Mine Year 0) – Scenario 2

FIGURES



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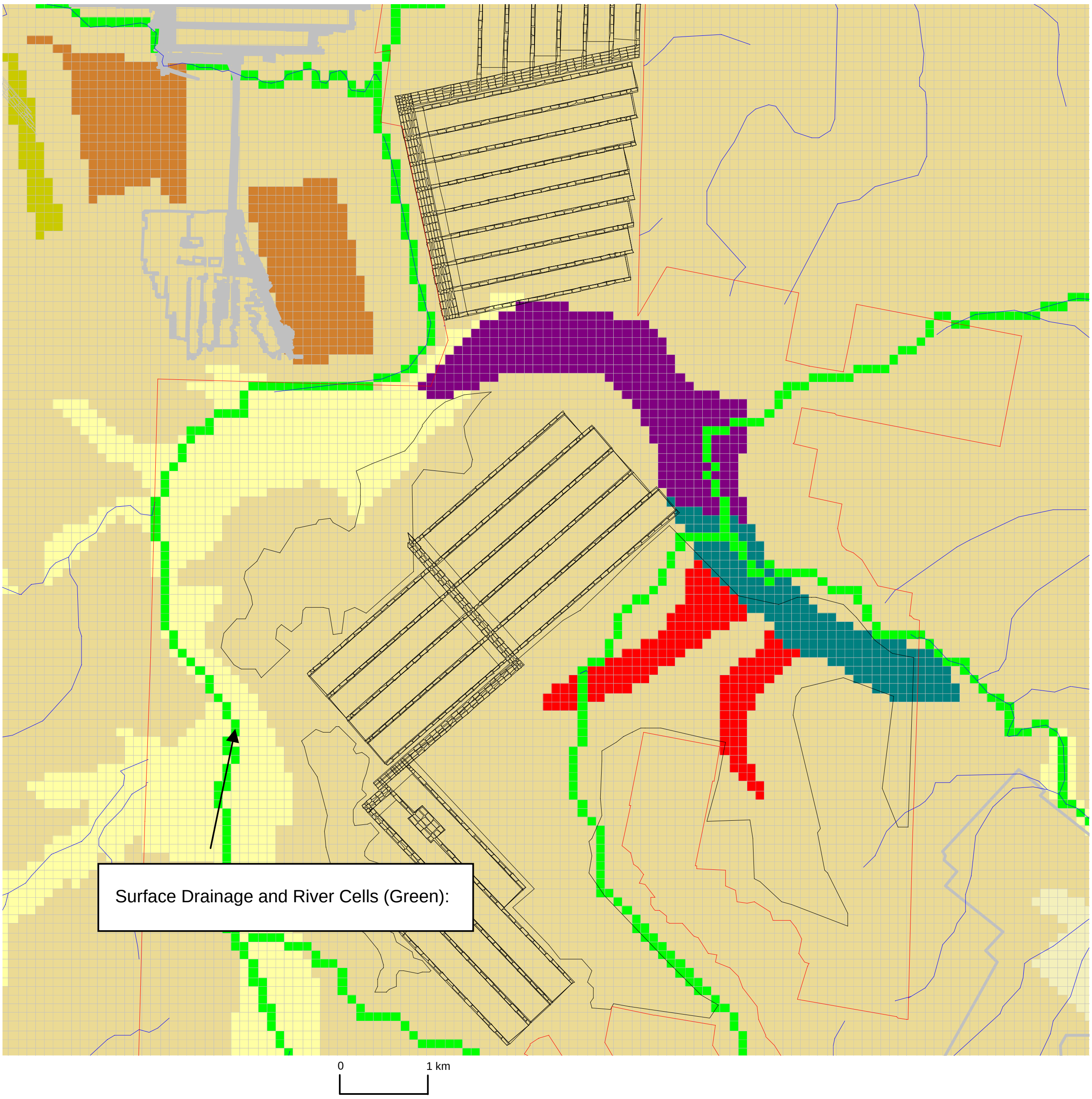
MODEL LAYER 1 – HYDRAULIC PROPERTY ZONES – SCENARIO 1 (MINE YEAR 0) FIGURE 1



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