South Walker Creek Mulgrave Resource Access: Stage 2C (MRA2C)

EPBC 2017-7957

Appendix I:
Groundwater Supplementary Memo

Level 4, 56 William Street
Perth WA 6000

Tel +61 8 9322 9733
www.aq2.com.au

AQ2 Pty Ltd
ABN 38 164 858 075

Memo

To	John Kennedy	**Company**	BHP
From	Kathryn Rozlapa	**Job No.**	187C
Date	30/1/2019	**Doc No.**	021c
Subject	Response to IESC Review, Groundwater Modelling		

As outlined in the model peer review (AQ2, 2018) and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC comments), some of the documentation of the Groundwater Impact Assessment for the South Walker Creek Mine MR2AC Project (Golder, 2018) was unclear or not presented. Additional detail on the groundwater model is provided in the sections below. This information has been drawn from the report mentioned above, a previous modelling study in the area (CDM Smith, 2016) and inspection of groundwater modelling input files (for Groundwater Vistas) provided to AQ2.

The information below is provided to address points 37, 38 and 39 of the advice provided to the Australian Government Department of the Environment and Energy by the IESC and some further clarifications requested by the Department of Environment and the Office of Water Science.

1. GROUNDWATER LEVELS

Mining at South Walker Creek (SWC) commenced in 1996. There are six existing pits at the SWC mine (Kemmis I and II, Mulgrave, Carborough, Walker and Toolah) as shown in Figure 1. A recent topographic survey of the mine area suggests that mining (until the time of the survey) had progressed to pit base elevations of between approximately 95 mAHD and 200 mAHD.

The current life of mine plan for SWC includes mining until 2073. The total footprint of the final mine is around 3700 hectares, ranging in total depth from 40 to 130 mbgl. The proposed mining depths extend to similar depths as current mining at SWC. Future mining will result in reduction of piezometric levels in the confined coal seam aquifer and to a lesser extent, reduction of water levels in the water table aquifer, via downward leakage. The depressurisation of the coal seam aquifer and reduction of water levels in the overlying unconfined aquifers away from the mining areas, will be controlled by the horizontal and vertical hydraulic conductivity of the deeper confined aquifers and the degree of hydraulic connection between the deeper confined system and the overlying unconfined aquifers systems.

Monitoring at SWC is available since 2003, with the frequency of monitoring varying with location. Selected monitoring locations are shown in Figure 1 with monitoring at each location shown in Figure 2. While there is not sufficient monitoring to correlate all water level changes since the start of mining, the following trends are evident:

- Monitoring from the area west of Kemmis Pit is shown in Figure 2. Piezometric levels measured at CB01, located west of the Kemmis Pits, declined by almost 5 m between 2014 and 2018, to around 215 mAHD (CB01 is reported to be screened over the interval 100 to 105 mAHD). Mining at the Kemmis Pits has advanced to a minimum elevation of close to 180 mAHD, which is 35 m lower than measured water levels at CB01. At monitoring locations MB3A and MB3B, which are close to CB01 and monitor the shallower regolith, seasonal water level variations are observed over the same period, as well as a decrease in water level of 0.7 m (from May 2014 to June 2018). Water levels at MB3A and MB3B remain at close to 223 mAHD or 43 m higher than the minimum pit base elevation at Kemmis Pit, suggesting that, to date, the water level decline observed in the regolith at MB3A and MB3B is less than the observed depressurisation of the coal seam.

- Mining at the Toolah Pit has progressed to a minimum elevation of 95 mAHD. Monitoring of OBS1, which monitors the regolith and is located just south of Toolah Pit (Figure 2), shows a decline in water levels from 2005 to 2016 of close to 2 m, to around 209 mAHD or close to 115 m higher than the elevation of mining.
- MB13 and MB14 are located 5 km to the east and south east of the southern mining areas of SWC respectively (Figure 2) and monitor regolith water levels. Measured water levels at MB13 and MB14 respond to seasonal recharge and show an overall reduction of 1 m over the period December 2014 to June 2018. Mining at the closest pits, Walker and Toolah Pits, have reached minimum elevations of 125 and 95 mAHD respectively. Water levels at MB13 and MB14 are around 80 m higher than the minimum mining elevation reached at Toolah Pit.
- MB12 is located 1.5 km east of Carborough Pit and is screened in the alluvium. MB12 is located closer to mining than MB13 and MB14 and shows no decrease in measured water levels over the period 2014 to 2017, however mining at the Carborough Pit has reached a minimum elevation of 180 mAHD which is significantly higher than the elevation of the Toolah Pit (95 mAHD). Water levels at MB12 are around 15 m higher than the minimum mining elevation at Carborough Pit. Due to the proximity of MB13 and MB14 to active mining, compared to MB12, the measured drawdown at MB13 and MB14 may be attributable to mining operations.

Monitoring of the SWC area, close to the mine and at regional locations, will continue over the life of mine. This will allow resolution of both recharge driven and mining related water and piezometric level changes to be monitored.

2. GROUNDWATER MODEL

2.1 Model Construction

Prior to the construction of the numerical flow model, a 3D hydrostratigraphic model was built using Leapfrog Hydro™. This package uses geological data from boreholes (4,864 in total), maps and stratigraphic relationships to generate surfaces that represent stratigraphic layers. Volumes representing the hydrostratigraphic units (HSU's) of interest, are then created to provide a 3D representation of the hydrostratigraphy. These outputs are used to define the model geometry included in the Modflow Surfact finite difference grid and provide a high degree of consistency between the geological data, the hydrostratigraphic model and the numerical model.

The Leapfrog Hydro model mentioned above, was developed with 6 layers to represent the Alluvium, Overburden, Main Seam 1 (upper coal seam of the Rangal Coal Measures), Interburden (separating the main coal seams), Main Seam 2 (lower coal seam of the Rangal Coal Measures) and Underburden. An additional layer was added to the Modflow Surfact model to represent the regolith (i.e. the weathered zone where hydraulic conductivity has been enhanced through secondary processes). This involved dividing the Overburden into two layers.

As Modflow Surfact requires all model layers to be continuous (i.e. they cannot pinch out or have zero thickness), in areas where hydrostratigraphic units are absent the layer thickness is reduced to a minimum of 0.5 m. The resulting "thin" layer is then assigned the properties of the adjacent unit. Similarly, where HSUs are displaced by faults the hydrogeological properties of the adjacent units are assigned to simulate the impacts of the discontinuity.

The pinching out of layers means that more than one HSU maybe represented by a single model layer. The HSUs for model layer 4 (or the confined aquifer shown in the Golder report), are shown in Figure 3. In general, the main coal seams are represented in the western portions of layers 4 and 6 (and small areas of layers 3 and 5). When drawdown is presented for the confined aquifer (layer 4), it is shown for the coal seam on the western side of the model domain, and the other HSUs included in layer 4, located on the eastern side of the model domain. The assignment of HSUs, by layer, are summarised in Table 1 below.

The approach outlined above is a standard one and is taken to represent layers which pinch out. The approach should not impact the results predicted by the model. A simple approach to limit the presentation of the extent of the predicted drawdown impacts within a layer would be to crop the contours of predicted drawdown to the extent of the modelled aquifer(s) of interest.

Table 1: Assignment of HSUs by Layer

HSU	Layer Assignment
Alluvium	Parts of layer 1
Regolith	Parts of layer 1 and all of layer 2
Overburden	Eastern side of layer 3, small parts of layer 4, 5 and 6
Main Seam 1	Small parts of layer 3, western side of layer 4, small parts of layer 5
Interburden	Western part of layer 5
Main Seam 2	Western part of layer 6
Underburden	All of layer 7, eastern side of layer 3, 4, 5 and 6

The thickest model layers are layer 3 (Overburden) and layer 7 (Underburden). The Overburden is present only on the eastern side of the model, while the Underburden underlies the entire modelled area and is present over most of the eastern side of the model. The assignment of a uniform specific storage of 5e-5 m^{-1} means that the release of water from confined storage in these two units may be an over estimate. However, these volumes are low compared to the volumes of water removed from unconfined storage in the unconfined / upper layers.

As with any groundwater modelling approach there may be limitations associated with the hydrogeological conceptualisation and the subsequent representation using the adopted groundwater modelling code. The use of the Modflow Surfact groundwater modelling code, for the current project that simulates the regional impacts of a multiple pit mine development, is not believed to be influencing the impacts predicted to date.

Current model runs times have been around one to two hours These runs times are associated with the size of the model, the types of boundary conditions included (for example the ET package) and the length of the calibration and predictions periods and the associated discretisation of time, which uses stress periods or time increments of months to years rather than any issues with model construction.

2.2 Model Boundary Conditions

2.2.1 Flow Boundaries

The western model boundary is aligned with the Carborough Range. In the shallow aquifers (model layers 1 and 2 representing the alluvium and regolith) this is a no flow boundary, which is consistent with a no flow boundary that can be used to simulate the conditions of a catchment divide. In the deeper aquifers (layers 3 to 7, representing Overburden, Main Seams 1 and 2, Interburden and Underburden) this boundary is assigned as a General Head Boundary (GHB). This type of boundary allows flow across the boundary depending on an assigned conductance value and an assigned value of water level. The value of conductance at this boundary is calculated based on the cell size, the permeability of the aquifers along the boundary and the distance away from the water level the boundary is designed to simulate. The coal seams and lower permeability layers are assigned very low values of conductance, ranging from a minimum value of ~1e-8 m^2/d up to 1e-1 m^2/d. The head value assigned at these cells is set consistent with heads in deeper units located further upstream or down dip. The combination of these values results in little to no increase in groundwater inflow across this boundary during the model calibration and predictions. In fact, the changes in inflow are so low that this boundary almost acts like a no flow boundary and any drawdown impacts predicted at this boundary would be very conservative (i.e. a worst case).

The northern model boundaries are also assigned as the GHB type in layers 1 to 7. The elevation of the northern boundary is set at 247 mAHD consistent with water level measurements at registered bore RN162364 (5.5 km from the boundary). The southern model boundary is assigned a similar GHB in layers 1 to 7. The elevation of the southern boundary is set at 165 mAHD, consistent with water level measurements 4.7 km from boundary (at RN13040112). Similar to the western model boundary, very low conductance values are assigned (around 1 to 6 m^2/d in the alluvium and regolith and ~1e-6 m^2/d in the deeper units). This results in little to no inflow across the deeper units and most of the flow across these boundaries is in the Alluvium and Regolith. The assignment of these very low conductance values also means that there is little to no change in predicted groundwater inflow (or outflow) across these boundaries during the operational and closure predictions.

The assignment of the GHB conditions across the model domain reflect the inferred groundwater flow directions. The assignment of very low conductance values result in little to no change in groundwater inflow and outflow during model predictions and suggest that any predicted drawdown impacts represent conditions under constant groundwater inflow (i.e. there is no increase in groundwater inflow across model boundaries as water level decrease in response to mining or mine closure). If model boundaries were set further away than the currently assigned boundaries, there is the possibility that predicted groundwater flows towards the mine areas may increase. This may result in greater inflows predicted in the mining areas and it may also mean that less drawdown is predicted away from the immediate mine areas. For example, the drawdown predicted at the location of the current western model boundary may be less than currently predicted.

Any differences are however unlikely to be material to the overall assessment. The potential impacts of the assignment of model boundaries will be addressed as part of future work programmes, as outlined in Section 2.7 below.

2.2.2 River Boundaries

Recharge from ephemeral creek systems across the model domain is simulated using the River (RIV) package in Modflow Surfact. These boundary conditions are assigned along the course of major creek systems and are active only during periods when recharge is expected, based on responses observed in monitoring bores (i.e. a threshold value of rainfall would have had to occur to result in run off and subsequent flow along the creeks). The rate of leakage from the modelled river cells is controlled by the elevation of the river stage and base elevation and river conductance. This is shown schematically in Figure 4. River conductance (C) is calculated as shown in Equation 1 below:

$$C = K * L * W / m \qquad (1)$$

Where

C = River bed conductance (in m^2/d)

K = River bed hydraulic conductivity (in m/d)

L = length of river across model cell (in m)

m = thickness of river bed material (in m)

For each modelled river cell, the following conditions were applied:

- The modelled creeks are assumed to be disconnected from the underlying groundwater (when flowing and when dry) and act as losing streams. The assignment of the RIV boundary condition to reflect this is shown in Figure 4 (Case A). This is consistent with monitoring bores located in the vicinity of creek lines which show a depth to water of between approximately 2 and 15 mbgl.
- The river base elevation was set consistent with the ground surface (the top of layer 1). This surface accounts for the topographic surface, or incised profile of the river channel, which is lower than the surrounding areas.
- The river stage, when flowing, was set 0.5 m above the river base to simulate a depth of flow in South Walker Creek of 0.5 m (the average depth of flow in South Walker Creek during the wet season). When the creek is not flowing, the river stage is set consistent with the river base elevation (i.e. river stage = river base elevation).

- The river width was assumed to be 10 m, with a river bed thickness of 1 m and river bed hydraulic conductivity consistent with the vertical hydraulic conductivity of the regolith (0.06 m/d). These parameters are then used to calculate the river bed conductance, a coefficient which controls the amount of flow out of (or into) the modelled river cell as shown in Figure 4. River bed conductance varies with model cell size and length of river across modelled cells and is assigned values between 2.5 and 80 m^2/d.
- River bed conductance is assigned consistent with the parameters shown in Figure 4 (K, L, W and m). The RIV package in the current model set up does not account for a significant increase in the depth of unsaturated material underlying the modelled creek. As a result, the model may under predict the time taken for leakage to a deeper water table, or over predict the time taken for river leakage to reach a comparatively shallower underlying water table.
- If groundwater levels are predicted above the base of the river, the flux from the underlying aquifer to the river is calculated by the difference between the aquifer water level and the assigned river stage (or head in the modelled river cell) as shown in Figure 4 (Case B). In all model output files inspected by AQ2, there was no leakage from the aquifer to the river (i.e. there was only leakage from the river to the underlying aquifer).
- As the model calibration is simulated using a monthly stress period, the creek is assumed to flow or be dry over a minimum duration of a month to simulate episodic recharge.
- For long term predictions (operational and closure), recharge from the modelled creeks is averaged and assigned over the entire period as longer stress periods are used (one to tens of years). To account for this, river conductance values have been reduced, with river bed conductance values assigned at between 11 and 20 m^2/d. This means that the predictions do not include seasonal recharge, but do include an allowance for river derived recharge.
- For model predictions, the location and base elevations of river cells were modified based on the proposed alignment of the MR2AC diversion. As outlined above, recharge from modelled creeks is assigned over the entire prediction periods along with reduced river bed conductance.

2.2.3 Evapotranspiration

Groundwater outflow via evaporation from shallow water tables and evapotranspiration from vegetation is represented using the Evapotranspiration (ET) package in Modflow Surfact. The ET package uses a depth dependent relationship, such that if predicted aquifer water levels are at or above a specified elevation (represented by the ET surface), then ET occurs at the maximum specified rate. If predicted aquifer water levels decrease below the specified ET surface, the ET rate decreases linearly to zero as the predicted water level approaches an elevation equal to the ET surface minus a specified extinction depth. When aquifer water levels are below an elevation equal to the ET surface minus the extinction depth, the ET rate is zero. This relationship is shown schematically in Figure 4.

An ET rate of 2.19e-3 m/d is applied uniformly to the upper most model layer (~0.8 m/yr) in the model calibration and operational predictions, with an additional ET zone added to the closure models to simulate ET from the final voids (3.20e-3 m/d or 1.17 m/yr). The ET surface is assigned as the topographic or ground surface for the calibration, operational predictions and closure predictions. For the closure predictions only, the ET surface also includes the final topographic surface that will result after the end of mining and infilling of pits at SWC.

Review of Groundwater Vistas input files by AQ2, provided by Golder as part of the model review (AQ2, 2018), suggested that there was an inconsistency between the extinction depth assigned in the steady state calibration and the transient calibration and prediction models (12 m in the steady state model and 3 m in all other models). However, review of additional documentation (Golder, 2018[1]), suggests a 12 m extinction depth resulted in too much discharge via ET and that a smaller value is included in the current model. This suggests that the steady state model used for the current modelling study was not provided to AQ2 and a previous uncalibrated version was provided for review in July 2018 and that all models include the correct extinction depth of 3 m.

The use of ET package, is consistent with the intended outcomes - the specification of the ET rate, the ET surface, the extinction depth and the package, is used to simulate evapotranspiration from shallow water tables as part of all model calibration and prediction runs and account for inflows into pit voids during closure predictions. It is unlikely that the 12 m extinction depth is included in any final models and as a result will not have any impact on model predictions, however this should be investigated and resolved as part of future modelling work programs. This is discussed further in Section 2.7 below.

2.3 Model Calibration

Mining operations at SWC commenced over twenty years ago. The SWC groundwater model was calibrated to transient conditions that reflect mine development over the period 2000 to 2017. As such the model is not used to simulate a set of pre-development or pre mining conditions from the mid 1990's. Rather, the steady state model is used as the starting point for the transient calibration which commences in 2000.

Over the period 2000 to 2017, the groundwater model simulates:

- Seasonal variations in water levels in shallow bores resulting from applied rainfall recharge.
- An overall decreasing water level trend observed over part or all of the calibration period at MB7, OBS1, and MB6 (Regolith monitoring bores) and MB4 (Coal Seam monitoring bore) and a notable decrease in water level at CB01, (screened in the main seam), measured since 2014.
- A long term increase in water levels at OBS2 (Regolith monitoring bore).
- The measured water level magnitude. However in some areas, there is a difference in measured and modelled water levels of up to several metres.

As outlined above, the model uses seven model layers to replicate the hydrogeological conceptualisation. Each of these units is assigned one value for hydraulic conductivity (horizontal and vertical) and storage parameters. Within an HSU, no further zoning or division has been included to improve the match to measured water levels. Localised features or zones of hydraulic conductivity could have been added to change water level gradients across the model domain or restrict or enhance the measured response. Both approaches include further zonation within individual HSUs and may improve the appearance of calibration hydrographs and statistics close to the SWC mining area. However, further zonation would not improve the reliability of the prediction of impacts away from the mining area. To improve the reliability away from the mining area will require ongoing groundwater level monitoring and analysis of any responses measured and inclusion of this understanding in the conceptual hydrogeological model and the SWC groundwater model. This is discussed in Section 2.7 below.

2.4 Simulation of Mine Voids

The groundwater model was used to predict the regional drawdown and water balance impacts of mining and the final mine voids. As expected in this hydrogeological environment, low groundwater inflows predicted by the model over the operational period were of a such a small magnitude that they would be lost to evaporative losses from the pit walls and floor. Similarly, groundwater inflows to final voids (infilled or empty) would be low. Final voids were simulated in the model as local groundwater sinks, by holding water levels at the base of the pit or infill over the closure prediction period and removing any groundwater inflows to the mine area (or as stated in the report and observed during inspection of closure prediction input files, pit void lakes were not formed as a seepage condition using the Recharge Seepage Face Package (RSF) in Modflow Surfact and an evaporative flux using the ET package was implemented at the base of each mine void). As such, the model does not predict the development of a pit void lake that would result from a balance of groundwater inflow, surface water inflow and evaporative losses from the pit void lake. Instead it predicts the maximum drawdown in the mine area, as well as the maximum drawdown that would development across the catchment if water levels recovered to an elevation consistent with the base of each mine void (infilled with spoil or left empty). As such the pit void set up is not used as inputs to any water balance calculations for the final void.

Prediction of long term pit void lake behaviour was completed using a separate water balance model (Alluvium, 2018), which accounts for the variability of the surface water inflow, which has also been shown to be the major water balance component of the final mine voids. This approach has shown that the final pit void behaviour is most sensitive to the amount of surface water inflow to the final voids (via the adjustment of final pit catchment area), rather than groundwater inflows.

2.5 Drawdowns from Other Projects

2.5.1 Coppabella Mine

The current modelling includes an allowance for dewatering to date and future development from the Coppabella mine, located to the immediate south of the SWC Mine area and approximately 10 km south of the MR2AC project. The approach taken to date to include the cumulative impacts of Coppabella mine, includes reduction of water levels to maximum depth across the entire mine foot print, based on inspection of publicly available information. This reduction of water levels is assigned during calibration and prediction models and does not include any increase in the size of the mining footprint. As no agreements are in place between BHP and the operators of the Coppabella mine, this represents the best approximation to cumulative impacts of the two operations.

2.5.2 Arrow Energy Coal Seam Gas Project

The impacts of Arrow Energy's Coal Seam Gas (CSG) project are described in detail in reporting associated with the project Environmental Impact Study (EIS) (Arrow Energy, 2012). In particular the Groundwater Model Technical Report details the proposed development, including prediction of groundwater impacts during the CSG project. Key points of the study are outlined below:

- The CSG project will target the Rangal Coal Measures (Leichhardt and Vermont units)
- Over the Arrow Energy lease areas, CSG wells are planned for the Leichhardt seam, to the west, south and east of the SWC mine area.
- CSG wells are planned for the deeper Vermont seam more than 50 km away from the SWC mine area.
- Other deeper target seams (within the Moranbah Coal Measures) are targeted by the CSG project.
- Model predictions for Arrow's CSG project, using a regional groundwater model developed for the project, include operations for 50 years, followed by 50 years of recovery.
- Base case predictions for the CSG project suggest that drawdown of 2 m in the Liechhardt unit may extend to the south of the SWC mine area over the life of the CSG project.
- The plan for development of the CSG project is incremental. As a result, the exact development schedule of the CSG project is unknown. The drawdown impact of the CSG development on the SWC area (less than 2 m after 50 years of project life) and the unknown development schedule make incorporation of realistic impacts of the CSG project difficult.

Recently Arrow announced that they have experienced production challenges in the Bowen Basin and work is being undertaken to improve production from parts of the Bowen Basin that contain deeper and tighter coals than the Surat Basin. This has resulted in a delay to Arrow's Bowen Basin development. Once the timing and scale of the Arrow projects are known, the impacts of the development will be included in the SWC model. This will include implementation of appropriate flow conditions along the southern boundary of the existing SWC model, which is assigned as a no flow boundary in the current model setup (discussed in Section 2.7 below).

2.6 Model Sensitivity

The modelling study included a sensitivity analysis, to assess the potential impact on predicted drawdown over the life of the project. It included increases and decreases to assigned aquifer parameters over a range of values. The analysis included a total of 12 re-runs of the transient model calibration (2000 to 2017). The sensitivity analysis highlighted the model calibration runs /sets of parameters, that produced very similar results to the base case and these runs were chosen for the uncertainty analysis (i.e. sets of parameters that were not selected for the calibration, but produced very similar calibration results).

The subsequent uncertainty analysis was completed for 10 of the 12 sensitivity runs. The results of the uncertainty analysis suggested that:

- Drawdown of 2 m may extend up to a distance of 2 km further to the west of the SWC mine than the base case.
- There is very little difference in predicted impacts at land holder bores.
- There is some increase in downward leakage from the shallow aquifer for the ranges of parameters assessed.

The sensitivity and uncertainty analysis completed was consistent with the project aims and existing environment. A statistically based uncertainty analysis that includes quantification of ranges or bands of risk may not at this time provide greater certainty in model predictions due to the amount of available data.

As the project progresses, some of the areas of uncertainty will be addressed from the collection and analysis of additional monitoring data. The proposed work to address model uncertainty as part of future work programmes is outlined in Section 2.7 below.

2.7 Future Work Programs

As mining at SWC progresses, the groundwater system will be subjected to further changes, from both mining and variations in groundwater recharge and the construction of the creek diversion. A period of three years after commencement of the project will provide a data set of sufficient length and with sufficient climate stresses and water level changes, to allow a meaningful comparison of measured and modelled responses across the mine and surrounding areas. It is anticipated that the data sets that will be used include existing monitoring locations and monitoring associated with the MR2AC development. This includes higher frequency measurement of water levels across the site (11 boreholes in total) and the installation of three vibrating wire peizometers (VWPs) near Walker Creek, plus any further monitoring associated with the MR2AC project.

In addition to the analysis of measured and modelled responses, it is recommended that three years after the commencement of mining, the groundwater model calibration data set is extended to test the predictive capacity of the model once the creek diversion is constructed and mining has progressed. This will involve simulating the creek along the revised alignment and including the reduction of water levels consistent with the progress of mining.

It is also recommended that three years after commencement of mining the following areas are investigated:

- The assignment of extinction depth in the steady state model calibration.
- The assignment of specific storage in the model, in particular, the values assigned to the thicker HSUs (the Overburden and Underburden).
- Zonation (using different K values) or compartmentalisation of HSUs (via low permeability Features) to improve model calibration performance, if they are supported by observations of other data.
- The potential for the location of the western boundary of the model to impact model predictions. Review of available monitoring data and the overall model performance will be used to assess if the model boundary locations requires updating (ie moving the model boundary further to the west).
- The requirements for boundary conditions (reduction of water levels assigned to model boundaries), to accommodate drawdown impacts from Arrow's CSG project (once details and timing of the project are clear) and / or Coppabella mine. This reduction in inflow could be applied to the southern or western model boundaries (including a western model boundary that is located further to the west). It is unlikely that this impact will be measured over the period of interest (three years), however it could be included in predictions. A comparison between predictions with and without this condition would provide confidence in the potential for drawdown impacts from the CSG project to also be seen at SWC.

- Model sensitivity and uncertainty will be addressed via the relevant statistical analysis. The exact format of this will be guided by the analysis of monitoring data collected as part of the SWC mining operation as there may be some areas of uncertainty that are addressed as part of ongoing monitoring.

3. REFERENCES

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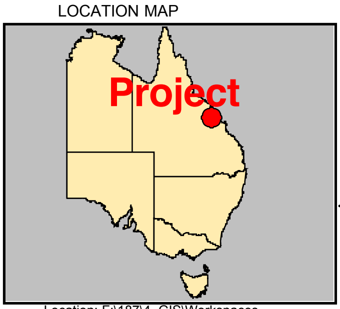
Regards

Kathryn

Consulting Modeller

Author: KLR (29/01/19)



KEY

Alluvium Monitoring Bores

Coal Seam Monitoring Bores

Regolith Monitoring Bores

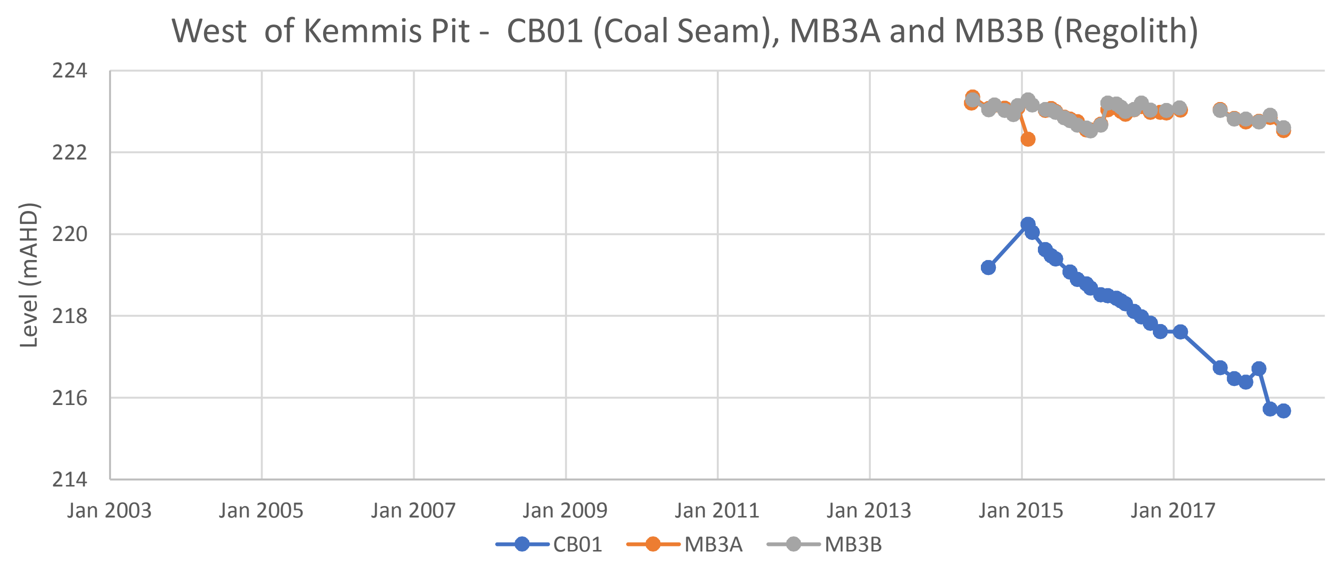
Pit Outline

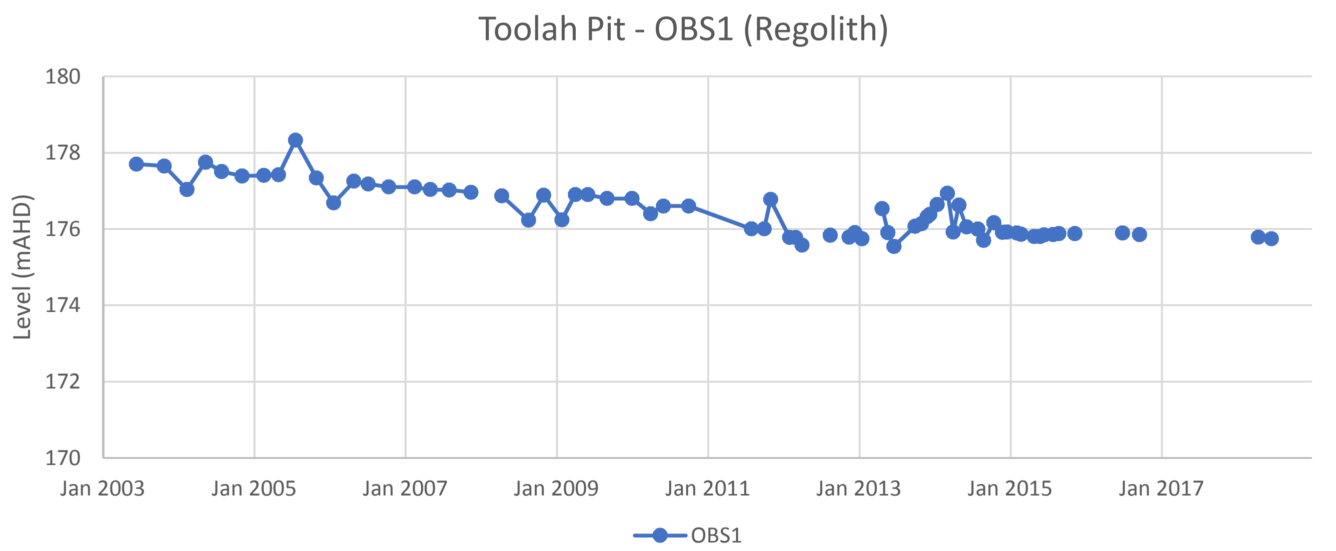
N

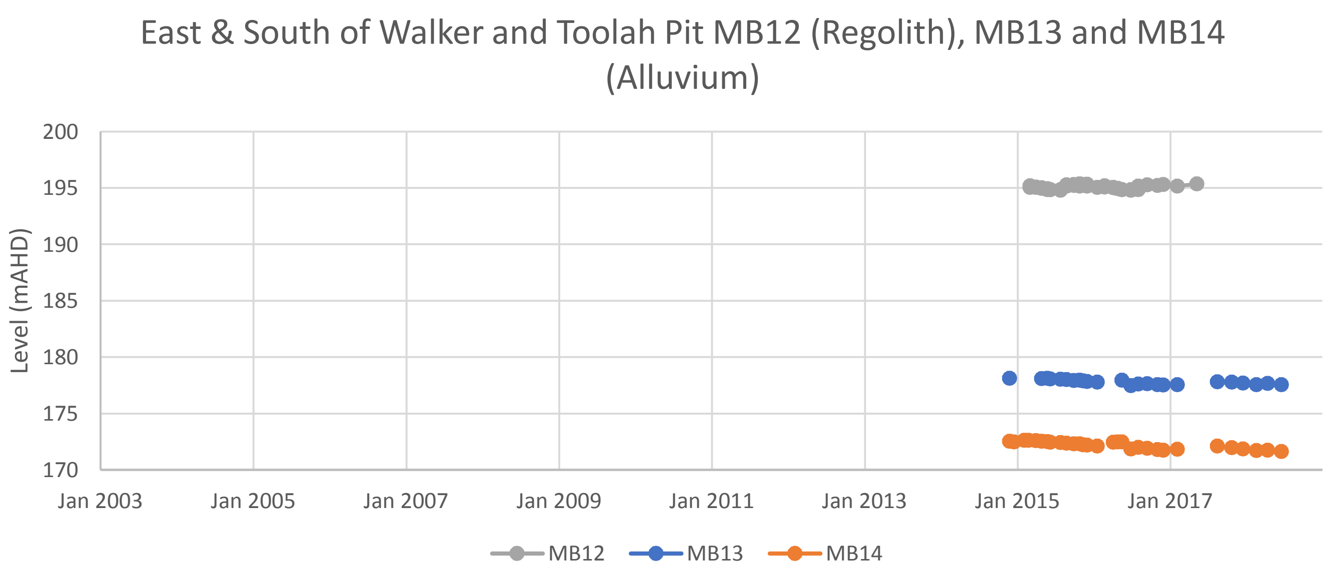
AUTHOR: KR	REPORT NO: 21C	**NOTES & DATA SOURCES:**
DRAWN: LDS	REVISION: a	
DATE: 24/01/19	JOB NO: 187C	

FIGURE 1

MONITORING SITES







Note: Different vertical scales

SWC Monitoring FIGURE 2

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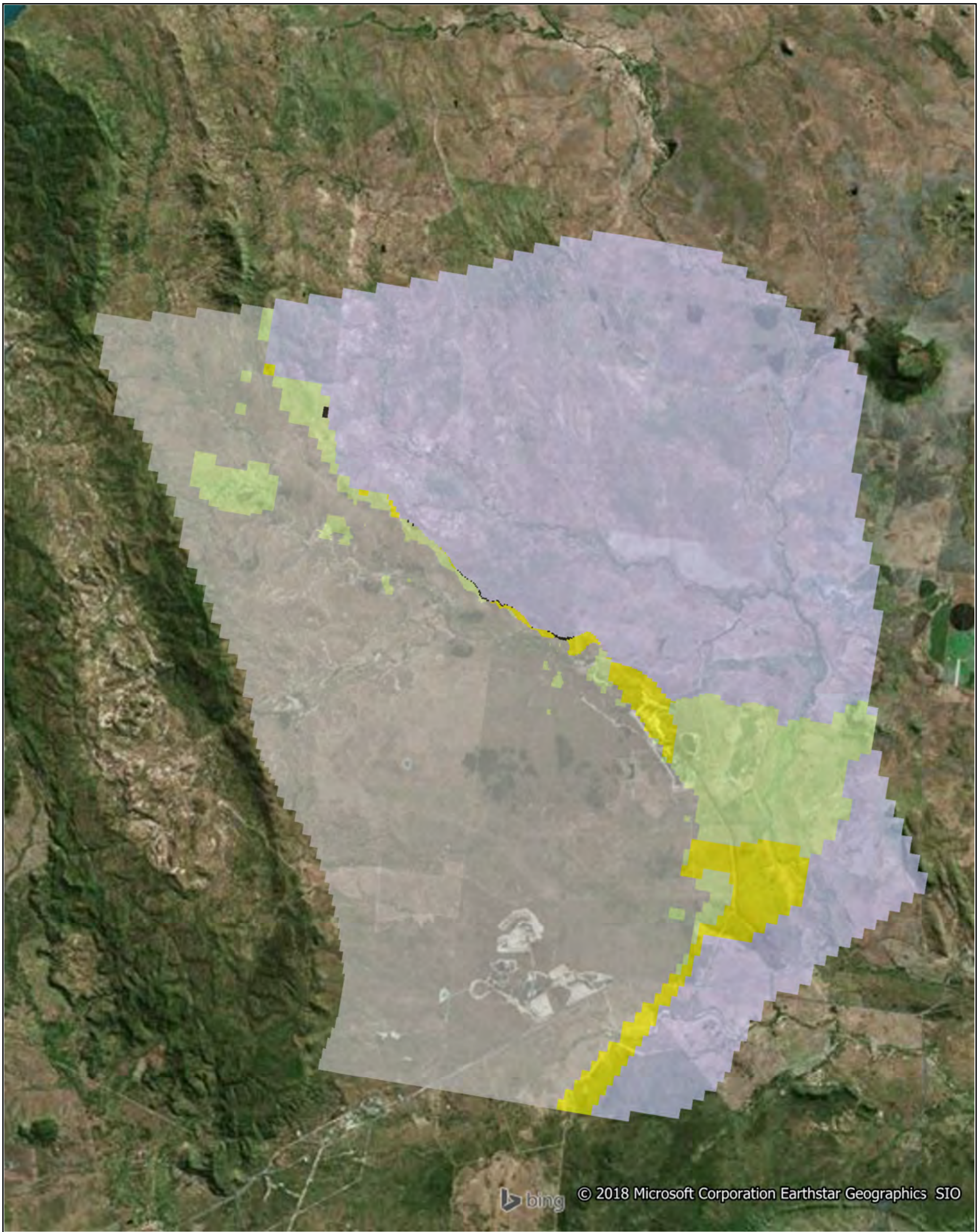
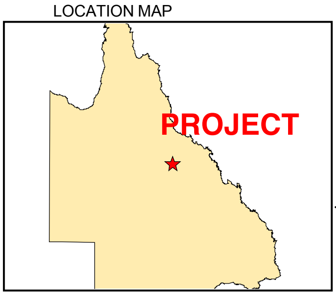


LOCATION MAP



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KEY

- Overburden
- Main Seam 1
- Interburden
- Main Seam 2
- Underburden

N

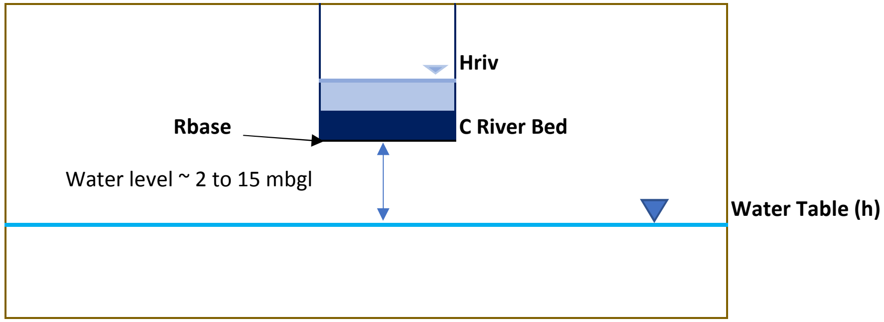
AQ2

FIGURE 3

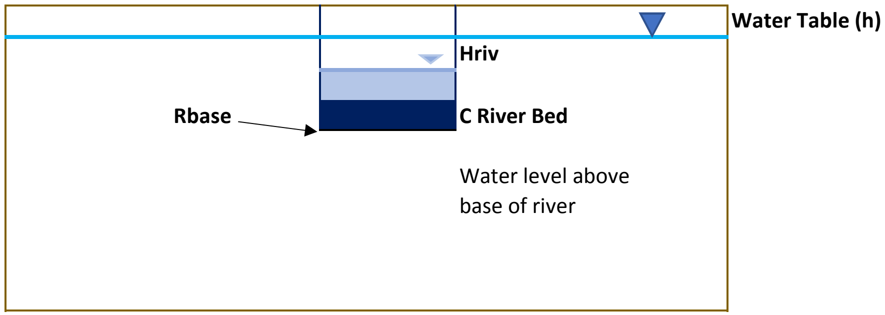
LAYER 4
HSU ZONES

AUTHOR: KR	REPORT NO: 21A	**NOTES & DATA SOURCES:** HSU distribution from layer 4 of SWC groundwater flow model
DRAWN: KR	REVISION: a	
DATE: 27/11/18	JOB NO: 187C	

SCHEMATIC OF RIVER PACKAGE



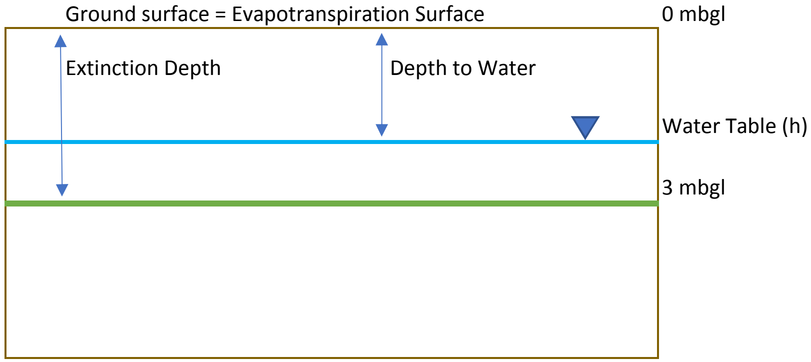
Case A **Water table elevation (h) < Rbase**
Qriver = C*(Hriv-Rbase)

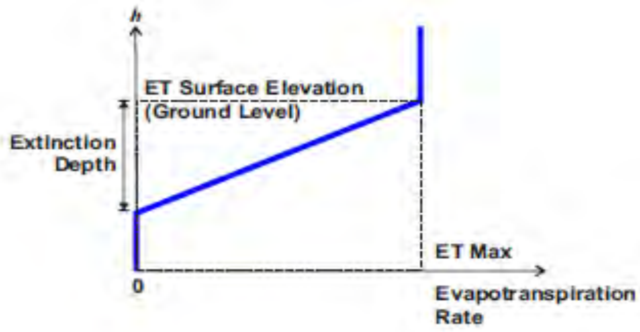


Case B **Water table elevation (h) >Rbase**
Qriver = C*(Hriv-h)

Where C River Bed = K * L * W/m (m^2/d)
where **K = hydraulic conductivity of river bed / regolith (m/d)**
L = length of river across modelled cell (m)
W = width of river (m)
m = thickness of river bed (m)

SCHEMATIC OF EVAPOTRANSPIRATION PACKAGE





NOT TO SCALE