JBS&G57612-125740 Rev0
L01Rev0_ReviewOfGroundwaterAssessment

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Review of Groundwater Assessment of EIS for McPhillamys Gold Project (SSD-9505)

Dear Mandana,

1. Introduction

JBS&G Australia Pty Ltd (JBS&G) have been engaged by the NSW Department of Planning, Industry and Environment (NSW DPIE) to undertake a comprehensive review of the following report:

- *McPhillamys Gold Project – Groundwater Assessment prepared by EMM (2019).*

The review presented in this letter has been prepared in accordance with JBS&G's proposal (Reference No. JBS&G-57612/P01Rev1, dated 10 October 2019) and agreed terms and conditions.

The following questions were required to be addressed:

1. *Undertake a comprehensive review of the groundwater assessment completed for the McPhillamys Gold Project EIS including:*
    a. *whether the assumptions used are reasonable, appropriate and suitably justified;*
    b. *the adequacy of the methodology, analysis and assessment presented in evaluating the groundwater impacts of the proposed development;*
    c. *the identification of any areas of deficiency and recommendations to improve or resolve these issues in the assessment;*
    d. *the significance of impacts, key environmental risks and issues for consideration during the assessment process;*
    e. *suitability of the proposed mitigation and/or management and/or protection measures; and*
    f. *any recommendations (if required) for additional information to inform the assessment of the project.*
2. *Consultation with relevant NSW Government personnel, the Applicant and its experts if required, to be co-ordinated through the Department.*

2. Review of Groundwater Assessment

The layout of the review is presented in accordance with the questions noted in **Section 1**.

Question 01a) *whether the assumptions used are reasonable, appropriate and suitably justified*

The Groundwater Assessment presented by EMM (2019) comprises a detailed discussion of the environmental setting for the McPhillamys Gold Project, with particular focus, as is appropriate, on regional geology, hydrogeology, geochemistry and groundwater quality. Of particular note, which is discussed in further detail below, is the distribution of geological structures presented in Figure 3.14 of EMM (2019). A numerical groundwater model is then presented, based on the United States Geological Survey (USGS) MODFLOW code, which is an industry standard software package.

The assessment presented in EMM (2019) is supported by a comprehensive groundwater investigation program, with groundwater level and quality data collected over a period of more than two years (from January 2017 through March 2019).

It is apparent in EMM (2019) that significant effort has been made to identify neighbouring groundwater users, potential groundwater dependent ecosystems, as well as the mechanism through which springs and seeps exist in the vicinity of the Project. As well, a comprehensive hydrogeochemical assessment is presented in EMM (2019).

Hydraulic testing of groundwater monitoring locations and laboratory testing of core samples (from exploration boreholes) has been undertaken. These data have been used by EMM (2019) to inform the choice of parameters selected for the numerical groundwater model developed for the Project. The numerical model was then used by EMM to predict changes to groundwater level, surface water/groundwater interaction as well as pit inflow rates due to the Project. Basic uncertainty analysis (refer IESC, 2018) was also undertaken on model predictions.

As will be presented below, there are, however, aspects of the groundwater model that are of concern to JBS&G; primarily that the adopted permeability of the 'metasediments' in the model are too low and that a Class 2 groundwater model is considered necessary to appropriately assess groundwater impact. Recommendations for improvement are provided in the following sections.

Question 01b) *the adequacy of the methodology, analysis and assessment presented in evaluating the groundwater impacts of the proposed development*

Based on the data and conceptual hydrogeological model presented in EMM (2019), groundwater use in the vicinity of the Project is spatially distributed and is not clustered in particular geologic units. i.e. the location of groundwater works corresponds more to landholding and proximity to road access than, necessarily, clustered within a particular geologic unit, such as the identified Quaternary alluvium (which is relatively shallow and is not classified by NSW DPIE: Division of Water as being highly productive). The implication of that distribution is that there are a lot of small, local groundwater users in the vicinity of the Project. Separate to this, there are a lot of small surface water dams, some of which are seep fed.

Figure 3.16 of EMM (2019) presents the estimated yield (which is low) of groundwater works in the vicinity of the Project. From Figure 3.16, these range between 0.5 and 8.8L/s, with most of the order of 2 to 5L/s (63ML/y to 158ML/y). Figure 3.16 also suggests that the distribution of hydraulic conductivity within the saprock (Layer 1 of the groundwater model) is probably reasonably uniform.

JBS&G concurs with EMM's conceptualisation that the hydraulic conductivity of the Cunningham Formation (Devonian age), Anson Formation (Silurian age), Blayney Volcanics and Byng Volcanics (Ordovician age) should, in general, decrease with increasing depth.

Most groundwater works in the vicinity of the Project are installed to less than 100m below ground level (mBGL), where the hydraulic conductivity of 'saprock' or partially weathered consolidated rock is such that reasonable, whilst low, yields from groundwater works can be obtained.

Of direct applicability to the Project, there is a cluster of groundwater users to the immediate south of the Open Pit, along the Mid-Western Highway. Those users are described in detail in EMM (2019) and most are currently part of the Project's groundwater monitoring program.

Whilst not of critical importance to the review, it is noted that data that JBS&G received from NSW DPIE: Division of Water, at the time, indicates that the Orange Basalt Groundwater Source is classified as a highly productive source. The Lachlan Fold Belt MDB Groundwater Source is classified as a less productive source. i.e. those designations supersede the criteria specified in the NSW Aquifer Interference Policy (AIP) (NOW, 2012).

Table 4.2 of EMM (2019) presents the results of slug testing at 23 groundwater monitoring locations. From Table 4.2, the hydraulic conductivity from monitoring locations screened in alluvium and saprock range between 0.1 and 1.3m/d (equivalent to $1x10^{-6}$ and $1.5x10^{-5}$m/s), which is considered reasonable. From Table 4.2, the measured hydraulic conductivity for rock (presumably fractured rock) ranges between $2x10^{-4}$ and 0.5m/d (equivalent to $2x10^{-9}$ and $6x10^{-6}$m/s), which again is considered reasonable.

Table 4.3 of EMM (2019) presents the results of laboratory testing of core sample specimens. From Table 4.3, the hydraulic conductivity and porosity of unweathered rock is very low to very very low.

In Table 4.3, the hydraulic conductivity ranges between $8.6x10^{-8}$ and $4.7x10^{-5}$m/d (equivalent to $1x10^{-12}$ to $5x10^{-10}$m/s), with the relatively higher values associated with sheared zones. For the purpose of comparison, the default value for hydraulic conductivity for the construction of clay liners in NSW for municipal landfills is $8.6x10^{-5}$m/d (equivalent to $1x10^{-9}$m/s). Accordingly, the values of hydraulic conductivity presented in Table 4.3 are such that the hydrogeologic unit, if the test values were representative of the whole unit, would be considered an aquiclude (impermeable rock). JBS&G notes that this may not be representative of the formation. From Table 4.3, total porosity ranges between 0.5% and 1.1% and is also very low.

EMM (2019) notes that there are no High Priority Groundwater Dependent Ecosystems listed in the Water Sharing Plan, as per the requirements of the NSW AIP (NOW, 2012).

Question 01c) *the identification of any areas of deficiency and recommendations to improve or resolve these issues in the assessment*

There are several aspects of the Groundwater Model that are considered to require improvement.

In general, and consistent with the findings of the 3rd party groundwater reviewer (Appendix H of EMM (2019)), JBS&G expects that the updated model will still demonstrate that the impact of the Project is relatively small on adjacent groundwater users, surface water/groundwater contribution and the identified facultative and opportunistically groundwater dependent ecosystem (PCT951 – Mountain Gum).

Transient Calibration

Currently, the calibration period is too close to the steady state period (refer Table 5.5 of EMM (2019)).

Due to a different form of the groundwater flow equation being solved in steady-state compared to transient conditions, JBS&G expects that the groundwater model was 'drifting'.

A work-around to this behaviour is to start the transient calibration period say 20 or 30 years previously, noting that observation data is only available for the last two (2) years.

The issue of 'drift' will have also been compounded by the very very low values of hydraulic conductivity adopted in the model (which are considered by JBS&G to be too low/non-physical).

An alternate strategy to resolving 'drift' can be to use a quasi steady-state approach to Stress Period 1, instead of a steady-state approach.

Groundwater Users

At present, it does not appear that 'take' from groundwater users in the vicinity of the Project, and in general, is included in the groundwater model.

JBS&G considers this to be an important aspect to include. Whilst the yield from groundwater users is low at 2 to 5L/s (equivalent to 63ML/y to 158ML/y), the take is of similar magnitude to the modelled 'take' from the Open Pit of up to 900ML/y (refer Figure 6.15 of EMM (2019)). EMM (2019) note also that some observation locations exhibit response to pumping, for example.

JBS&G accepts that the 'take' from each Water Access Licence will be estimated (presumably based on entitlement and then an assumed distribution through the water year).

Transient calibration, inclusive of groundwater users, will also provide 'anecdotal evidence' of the validity of the adopted values for hydraulic parameters in the model, with respect to the 'saprock'.

Evaporation or Evapotranspiration

EMM (2019) note that evaporation or evapotranspiration was held constant throughout the model simulation. This is not consistent with Figure 3.2 of EMM (2019) and should be made to be vary with time in the model.

Cumulative Departure from Mean Rainfall

EMM present a Cumulative Departure from Mean Rainfall (CRD) analysis in Figure 3.3 in EMM (2019). CRD analysis is helpful in groundwater studies due to the slow response of groundwater systems to changes in average climate.

JBS&G advises, however, that starting that analysis in 1900 is difficult to justify and it is recommended that the original paper on the CRD technique and critique of the CRD technique in the literature is reviewed and Figure 3.3 is updated to a closer starting date.

Springs and Seeps

Section 4.7.2 of EMM (2019) presents a comprehensive investigation program of springs and seeps in the vicinity of the Project. As noted above, there are no High Priority Groundwater Dependent Ecosystems in the vicinity of the Project however.

Whilst it is accepted that the majority of the identified springs and seeps are located within the 'Disturbance Footprint' and hence may be 'built over', JBS&G does not understand why springs and seeps were not included in the groundwater model, as the mechanism through which they occur was obviously considered important enough to warrant the substantial and thorough investigation as presented in EMM (2019).

As noted by EMM (2019) access to seeps as a potential water supply have been 'enhanced' through the use of farm dams.

JBS&G recommends that the mechanism through which springs and seeps exist is considered in the updated groundwater model. This may require consideration of variably saturated flow to account for the expected separated water table, as per Figure 4.27a and Figure 4.27b of EMM (2019).

Surface Watercourses

At present, only selected segments of surface watercourses in the vicinity of the Project are included in the groundwater model.

Whilst it is accepted that most of the upper reaches of the Belubula River catchment may be ephemeral, in particular when considering a saturated flow simulation, take from all of the watercourses is required to be calculated, else the total 'take' will be underestimated.

JBS&G recommends all surface watercourses mapped in the 1:25,000 scale hydrologic layer (as per Section 3.4.2 of EMM (2019)) are considered in the vicinity of the Project. At further distance from the Project, major watercourses only could be considered, depending on groundwater model behaviour (regional throughflow is discussed in further detail below). With the recommended change to evapotranspiration, it is expected that the licensable 'take' from surface water will change.

Geological Structures

From Section 4.3 of EMM (2019) and Figure 3.14 of EMM (2019), consideration of the influence of geological structures on bulk hydraulic conductivity is considered by JBS&G to be important.

JBS&G suggests that heterogeneity is introduced into the groundwater model via techniques such as Pilot Points, or, at a minimum, appropriate testing of higher hydraulic conductivity zones in the model is considered.

JBS&G also considers that the current approach in the groundwater model, whereby there is an instantaneous transition (vertically) from Layer 1 (saprock) to Layer 2 through 9 (fresh rock), is inconsistent with the conceptual model presented in EMM (2019), namely that there is a gradually decreasing hydraulic conductivity with depth. At present, the hydraulic conductivity in Layer 1 (saprock) compared to Layer 2 through 9 (fresh rock) is a difference by a factor of 600000 times (Anson Formation, Blayney Volcanics and Cunningham Formation) to 750000 times (Byng Volcanics). The configuration of the groundwater in this way is considered unrealistic when compared to the conceptual model and has impacted the validity of the modelling outputs, as discussed further below.

Groundwater Elevation in Layer 2 to Layer 9

At present, the groundwater elevation in the lower layers of the model is not presented in EMM (2019).

This is potentially of interest with respect to the approach to regional throughflow, discussed in the next section, as well as the influence of the GoDolphin Fault in the model.

Regional Throughflow

JBS&G has some concern as to the approach to regional throughflow via general head boundaries, as implemented.

Whilst it is not known if this aspect is important to the very very low value adopted for hydraulic conductivity in the model in Layer 2 to 9, JBS&G suggests that consideration is given to far field hydraulic head as a potential alternative to the current approach by EMM.

If all relevant surface watercourses are included in groundwater model, then the need for the '10m below ground level' approach will not be necessary, and there will be an opportunity to include a far field hydraulic head.

The value of hydraulic conductivity in Layer 2 to 9 used presently in the model by EMM (2019) has the effect that the lower part of the model is almost non-physical/not present. JBS&G suggests that this may be due to the adopted approach to regional throughflow and/or the extent of the model domain selected by EMM.

Sensitivity Analysis

The majority of the monitoring piezometers and wells in the vicinity of the Project are located in the 'saprock'. Accordingly, it is to be expected that changing the values of hydraulic conductivity for fresh rock units has, essentially, no impact on the Scaled Root Mean Square (SRMS) error.

This aspect is discussed in further detail below, with respect to uncertainty analysis.

Waste Rock Dump

Given the location of the Project at the 'top' of one of several catchments, JBS&G suggests that incorporating the Waste Rock Dump into the prediction simulation is worth consideration, as the Waste Rock Dump may lead to local waterlogging/enhanced discharge to surface watercourses to the east of the Project.

Climate Change Scenarios

JBS&G notes that the following dataset is also available for NSW and the ACT: NSW and ACT Regional Climate Modelling (NARCliM) Project (refer https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW). JBS&G's experience with climate change simulations is similar to the conclusion presented in EMM (2019).

Uncertainty Analysis

Section 6.4 of EMM (2019) presents the approach to uncertainty analysis in the groundwater model.

There are several methods available in IESC (2018) and it is accepted that the requirements of the IESC (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development) do not necessarily apply, because the Project is not an open cut coal mine; however, IESC (2018) does represent current best practice.

From Section 6.4, a limitation to the approach by EMM (2019) of changing a single parameter value at a time is that, because of the location of the Open Pit in the Anson Formation, and that surrounding groundwater users are in the Blayney Volcanics, because of the very very low value of hydraulic conductivity adopted in Layers 2 to 9, changes to the Anson Formation will not be 'seen' by those groundwater users. Conversely, changes to the Blayney Volcanics, because of the very very low value of hydraulic conductivity in the Anson Formation will not be 'seen' by the Open Pit.

If the 'subjective probability' method for uncertainty analysis is retained in the next version of the groundwater model (Method 1 of IESC (2018)), JBS&G recommends a 'scenario' analysis approach instead. This would entail changes to multiple parameters at once, representing a 'significant effect from structures' scenario, for example.

Question 01d) *the significance of impacts, key environmental risks and issues for consideration during the assessment process*

JBS&G considers that there is a potential that the impact to groundwater users located to the south of the Open Pit is underestimated. JBS&G also considers that the estimated take from surface watercourses may also be underestimated.

As noted above, JBS&G concurs with the 3rd party reviewer (Appendix H of EMM (2019)) that the expected impacts due to the Project should be small, however, the identified issues in the groundwater model need to be resolved as the implication to seepage from below the Tailings Storage Facility (TSF) depends on the hydraulic conductivity of the 'metasediments' (refer Figure 6.27 and 6.28 of EMM (2019)). Figure 3.14 of EMM (2019) implies, for example, that there are a plethora of structural features underlying the footprint of the TSF.

Question 01e) *suitability of the proposed mitigation and/or management and/or protection measures*

EMM (2019) outlines "make-good" provisions in Section 7.4, which are likely to be acceptable to potentially impacted landholders, if higher than predicted changes are realised.

JBS&G notes, however, that it is desirable to overpredict the potential impact than find, at a later stage of the Project, that the predicted change has been underestimated.

With respect to the Pit Lake, given the presented timeframe of 400 years, the proponent will not be present to resolve this issue. The design of the Pit Lake should be such that it is a groundwater sink and remain so. In that way, potential mobilisation of groundwater that has interacted with Potential Acid Forming (PAF) material as well as seepage through the clay liner of the TSF (refer Figure 6.27 and 6.28 of EMM (2019) for a conceptual diagram of the TSF) is avoided.

As noted in Section 3.5.4 of EMM (2019), leachability of tailings samples (and waste rock samples) will be greater under acidic conditions. JBS&G expects that the Pit Lake recovery calculation will change with the update to the groundwater model.

Post-mining, it is assumed that capping of the TSF will be sufficient to minimise seepage through the clay liner of the TSF. That aspect is outside of the scope of the Groundwater Assessment by EMM (2019).

Question 01f) *any recommendations (if required) for additional information to inform the assessment of the project.*

As noted above, a Class 2 Groundwater Model, with an amended representation of the vertical discretisation of hydraulic conductivity with depth, is considered necessary to appropriately assess the impacts due to the Project.

Also, the potential influence on all surface watercourses needs to be considered. In addition, the mechanism through which the springs and seeps exist in the vicinity of the Project also needs to be accounted for in the approach to the model.

As noted above, JBS&G speculates that a variably saturated flow approach to the groundwater model may be required to emulate the conceptual model presented in EMM (2019) as well as the anecdotal evidence referred to by EMM (2019) from the nearby Cadia Operation.

3. Summary of Findings

EMM (2019) presents a comprehensive hydrogeological assessment of the McPhillamys Gold Project. As is discussed above, and summarised below, whilst the data collection and hydraulic testing phase of the assessment are thorough, it is considered that a Class 2 Groundwater Model is necessary to appropriately consider the potential impact of the Project. This is primarily because of the close proximity of other groundwater users to the Project, plus also the expected underestimation of the change to surface water flow due to the Project. Suggestions for changes to the model to facilitate this level of analysis are provided in **Section 2** above.

The adopted hydraulic conductivity for fresh rock (applied to Layers 2 to 9 in the model) in the Open Pit area (Anson Formation) and in the vicinity of the Open Pit (Byng Volcanics, Blayney Volcanics and Cunningham Formation (further afield)) is considered to be very very low, which in turn significantly reduces the extent of the predicted drawdown due to mining.

Whilst it is acknowledged that permeability testing on core samples is presented in EMM (2019) in support of a calibrated hydraulic conductivity for the Byng Volcanics of $8x10^{-8}$m/d (equivalent to $9.1x10^{-13}$m/s) and Anson Formation/Cunningham Formation and Blayney Volcanics of $1x10^{-7}$m/d (equivalent to $1x10^{-12}$m/s), as per the description of regional hydrogeology presented in EMM (2019), Section 3.6.2, "*..HSU 3 – the Byng and Blayney Volcanics. These volcanics are comprised of fine siltstones and sandstones with low primary porosity and permeability. Groundwater flow is predominantly via secondary porosity (faulting and joints) and geological contacts…"* and "*…HSU 4 – the Silurian Anson Formation and Cunningham Formation. The Anson Formation underlies the mine development area and has low primary porosity and permeability. Groundwater flow is primarily along fault zones. Recorded bore yields are typically low (< 5 litres per second (L/sec))…*".

The presence of structures, as illustrated in Figure 3.14 of EMM (2019), will change the bulk hydraulic conductivity, potentially by several orders of magnitude. This is evident in the permeability testing on core samples presented in EMM (2019) where 'shear zone' segments had hydraulic conductivities of up to $1x10^{-5}$m/d (equivalent to $1x10^{-10}$m/s), which is still considered by JBS&G to be a very low value for saturated hydraulic conductivity.

In general, it is accepted that, depending on the vertical continuity of structures illustrated in Figure 3.14 of EMM (2019), that, at increasing depth, the hydraulic conductivity of the volcanics could 'reduce to zero', as per the reference in EMM (2019) to the Cadia Operation located 25km west of the Project; however, a value for saturated hydraulic conductivity of ~$1x10^{-12}$m/s, in a groundwater model, is almost non-physical and is not supported. JBS&G suggests that variably saturated flow may be required to be considered to match the conceptual model presented in EMM (2019).

As noted above, the selection of boundary conditions with respect to regional throughflow is potentially also contributing to the 'required' hydraulic conductivity needing to be adopted in the model to get it to match observations.

Uncertainty analysis presented in EMM (2019) involves manipulation of individual parameters, in isolation of one another. This is the most basic form of uncertainty analysis (refer IESC (2018)). Given that the Open Pit resides within the Anson Formation, adjustment of the hydraulic conductivity of that formation, whilst not changing the hydraulic conductivity of adjacent units, unsurprisingly, leads to limited change in the predicted drawdown extent. This is because the Open Pit is compartmentalised within the Anson Formation. Conversely, changes to the hydraulic conductivity of the Byng Volcanics, which lies adjacent to the Anson Formation, again, does not lead to significant change in the predicted drawdown extent, as would be expected.

If the 'subjective probability' approach to uncertainty analysis is retained in the next version of the groundwater model, a 'scenario' approach is recommended in place of changing individual parameters. i.e. a 'significant fracturing' scenario or a 'limited influence of Godophlin Fault' whereby multiple parameters are changed to represent that scenario.

4. References

Barnett B., Townley L.R., Post V., Evans R.E., Hunt R.J., Peeters L., Richardson S., Werner A.D., Knapton A. and A. Boronkay, 2012. *Australian Groundwater Modelling Guidelines - Waterlines Report Series No. 82*. National Water Commission, Canberra.

EMM, 2019. *McPhillamys Gold Project Groundwater Assessment*. Consultant report prepared by EMM Consulting Pty Ltd for Regis Resources Ltd. Reference No. J17064 RP2, dated 11 July 2019.

IESC, 2018. *Uncertainty Analysis – Guidance for groundwater modelling within a risk management framework*. A report prepared by Middlemis, H. and L.J.M. Peeters for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Environment and Energy, Commonwealth of Australia. Reference No. n/a, dated December 2018.

NSW Office of Water, 2012. *NSW Aquifer Interference Policy – NSW Government policy for the licensing and assessment of aquifer interference activities*. Policy prepared by the NSW Department of Primary Industries – Office of Water. Reference No. ISBN 978-1-74256-338-1, dated September 2012.

5. Closing

Should you require clarification, please contact the undersigned on 02 8245 0313 or by email jbell@jbsg.com.au.

Yours sincerely:

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Re: McPhillamys Gold Project - response to expert review of the EIS groundwater assessment

Dear Mandana,

1 Introduction

The following letter provides a summary of EMM Consulting Pty Limited (EMM) and Regis Resources Ltd (Regis) planned response to the JBS&G review of the Groundwater Assessment of the McPhillamys Project submitted as part of the Environmental Impact Study (EIS) (JBS&G 2019).

As stated above, the Groundwater Assessment prepared in support of the EIS included a numerical groundwater flow model, which has been independently reviewed by Hugh Middlemis of HydroGeoLogic Pty Ltd. The Department of Planning, Industry and Environment (DPIE) engaged Justin Bell of JBS&G to conduct a review of the Groundwater Assessment on behalf of DPIE. A meeting was held on 2 December 2019 between Justin Bell, EMM, Regis and DPIE personnel where JBS&G presented a summary of the review. Following receipt of the JBS&G review letter, a follow up meeting was held on 29 January 2020 with Dr Justin Bell, Hugh Middlemis, DPIE, EMM and Regis personnel to provide preliminary response to the review.

1.1 Response approach

As discussed during the 29 January 2020 meeting, responses to most of the review comments simply required additional information or documentation to better explain the Groundwater Assessment work.

The letter includes information presented and discussed during the 29 January meeting and also provides a breakdown of the review comments, followed by the response. To assist with the response to key review comments, three additional model scenarios have also been undertaken to comprehensively address certain issues raised by Dr Bell. These scenarios also complement the uncertainty analysis already completed and to provide additional confidence in the predictions presented in the Groundwater Assessment. These scenarios are intended to be considered in the context of the full uncertainty analysis, confirming that the range of parameter values and conceptualisations are sufficiently conservative for robust assessment of the potential impacts of the project on water resources.

2 Extracts from the Groundwater Assessment

The following subsections provide information previously presented in the Groundwater Assessment of the EIS to assist the reader.

2.1 Model objectives

The key objectives for the McPhillamys Groundwater Assessment numerical model are to:

- implement the conceptual hydrogeological model;
- assess the likely extent and magnitude of groundwater drawdown induced by mine dewatering and closure;
- predict changes to availability of groundwater for sensitive receptors surrounding the project;
- assess the potential changes to groundwater flow as a result of the TSF during operations and post-mining;
- provide information for the assessment of potential TSF impacts on groundwater quality; and
- inform the site wide water balance.

2.2 Water affecting activities

The main water affecting activities of the project are:

- mine dewatering;
- open cut mining;
- tailings storage;
- waste stockpiling;
- water storage facilities; and
- surface water diversions.

Each of the above activities has the potential to result in changes in groundwater quantity, groundwater quality and surface water-groundwater interaction.

2.3 Model layers

A summary of the model layers and zones is provided in Table 2.1.

Table 2.1 Model layer and zone summary

Layer	Zone [1]	Description
1	1	Alluvium
	2	Orange Basalt
	3	Carbonaceous alteration within the Anson Formation
	4	Byng Volcanics (saprock)
	5	Anson Formation (saprock)
	6	Cunningham Formation (saprock)
	7	Blayney Volcanics (saprock)
2-9	8	Byng Volcanics (fresh)
	9	Anson Formation (fresh)
	10	Cunningham Formation (fresh)
	11	Blayney Volcanics (fresh)

Note: 1. The zoning is generally based on HSU.

3 Comments and queries regarding adequacy of groundwater model

3.1 Model classification

JBS&G provide the following comment:

> "A Class 2 Groundwater Model, with an amended representation of the vertical discretisation of hydraulic conductivity with depth, is considered necessary to appropriately assess the impacts due to the project."

In the Groundwater Assessment (Section 5.4.2i), EMM presented the groundwater model as Class 1 in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). The guidelines suggest potential uses for a Class 1 model to include:

- predicting long-term impacts of proposed developments in low value aquifers;
- estimating impacts of low-risk developments; and
- understanding groundwater flow processes under various hypothetical conditions.

The third-party reviewer (HydroGeoLogic) determined that the groundwater model has a confidence level of Class 1 with elements of Class 2 (and Class 3) and that it is suitable for impact assessment scenario modelling purposes (see Appendix H of EMM (2019)).

We note that there is an initiative in progress that will result in a refinement of the modelling guidelines specifically in relation to the qualitative model confidence level classification. The guideline refinements reaffirm that the classification simply considers the level of data available to support model development, the conceptualisation and calibration process and model performance, and that it was intended for application to cases where a predictive uncertainty analysis has not been conducted. The guideline principles hold that the classification should not be used as an indicator of the confidence in the model results, because that should be based on predictive uncertainty assessments, as has been conducted in this case. The guideline revision is designed to correct its currently common misapplication of the 'target model confidence level' as erroneously 'the higher the better'. The revision reduces the importance of the qualitative confidence classification and raises the importance of a predictive uncertainty analysis in an assessment of the fitness for purpose of a model, commensurate with the risk context for the project. In this case, the predictive uncertainty scenarios demonstrate that there is a low risk of an unwanted outcome in terms of potentially unacceptable water-related impacts, consistent with guideline principles.

JBS&G also suggest that simulating a gradually reducing hydraulic conductivity with depth and adding more detail to simulated watercourses should be sufficient to achieve Class 2. Firstly, as discussed in Section 3, EMM have conducted additional uncertainty analysis where the hydraulic conductivity has been adjusted in the upper two fresh rock layers (layer 2 and 3) to assess the implications of a more gradual transition. Secondly, EMM consider the simulation of watercourses in the groundwater model appropriate, as the surface water assessment (see Chapter 9 of the EIS and Appendix J of the EIS) considered the reduction in catchment area as a result of the project and the changes in surface water flow. This is discussed further in Section 3.2.

The groundwater model is deemed fit for purpose by EMM and HydroGeoLogic, given the low productive aquifer and low risk context. As stated by JBS&G (2019) there are few groundwater users in the area, with locations of bores corresponding to landholdings and proximity to road access rather than clustered within a particular geological unit. This is consistent with the observations that the geology has low hydraulic conductivity and low potential for development as a groundwater resource. The uncertainty analysis (see Section 3.7) has been designed with a wide range of parameter values to account for the low coverage of calibration data and to assess potential impacts of the project.

With the overall Groundwater Assessment that included predictive uncertainty and with the additional scenarios completed following discussions with DPIE and JBS&G (see Section 4), EMM suggest that the model is demonstrably fit for purpose, consistent with the modelling guidelines and the findings of independent reviews.

3.2 Simulation of watercourses

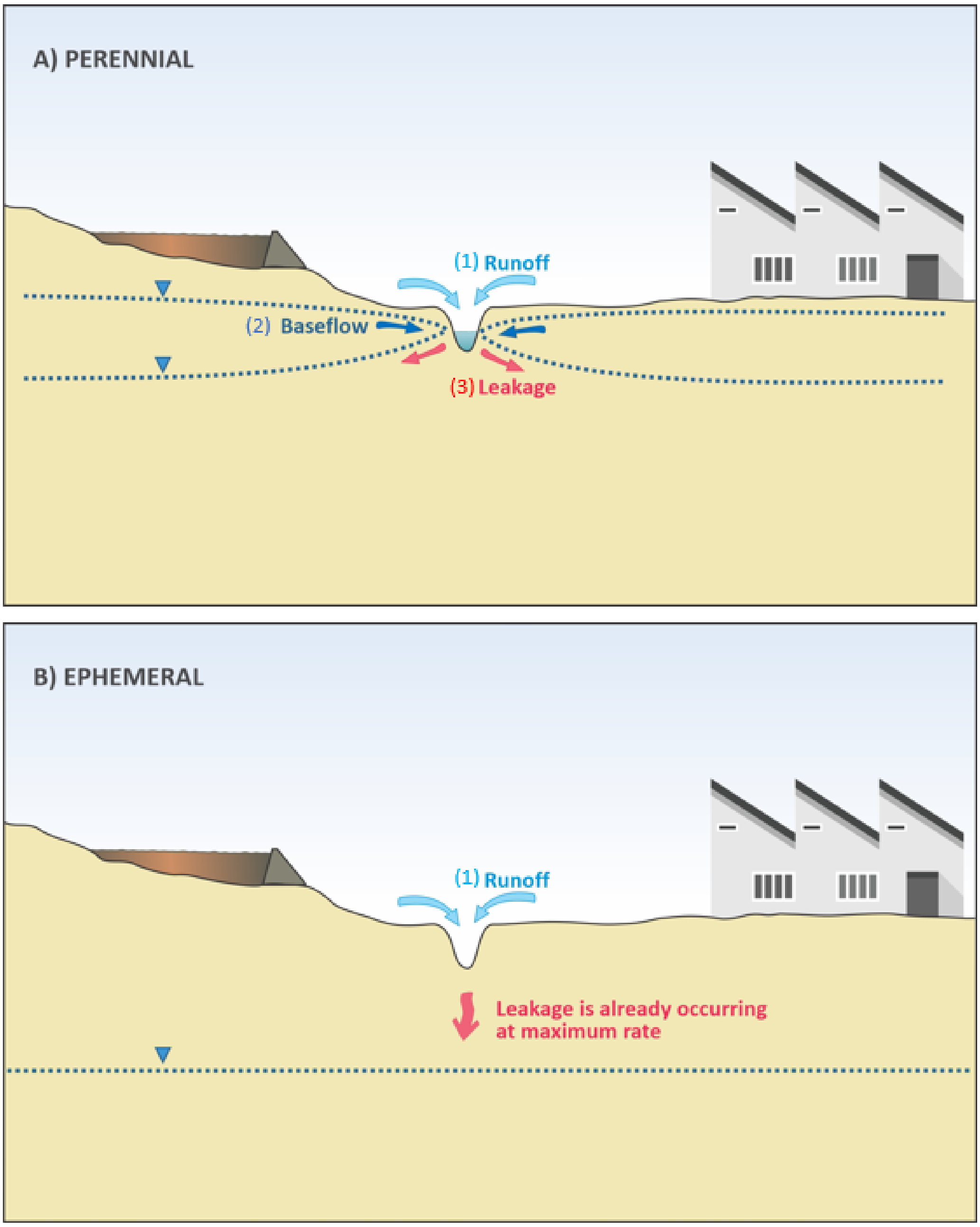
JBS&G provided the following comment:

> "At present, only selected segments of surface watercourses in the vicinity of the Project are included in the groundwater model. Whilst it is accepted that most of the upper reaches of the Belubula River catchment may be ephemeral, in particular when considering a saturated flow simulation, take from all of the watercourses is required to be calculated, else the total 'take' will be underestimated."

Surface water 'take' has been assessed primarily as part of the Surface Water Assessment (Appendix J of the EIS) and summarised in Chapter 9 of the EIS. The points below summarise how it has been assessed:

- changes in surface water flow as a result of a reduction in catchment area (due to project development) has been assessed in the Surface Water Assessment;
- predicted changes in groundwater discharge to watercourses (baseflow) and river leakage to groundwater has been assessed in the Groundwater Assessment;
- in the project area (area of influence), perennial and ephemeral watercourses have been simulated (see Section 5.4.2v of the Groundwater Assessment); and
- outside of the project area, only perennial watercourses are simulated, as when surface water flows in these watercourses, leakage from the (losing) watercourses is already occurring at the maximum rate (governed by the head of the water column in the watercourse).

Figure 3.1 provides a graphical representation of the components that were considered for surface water take.



Surface water take is estimated based on:
(1) Change in surface water flow from reduced catchment
(2) Reduction in baseflow
(3) Increase in leakage

Figure 3.1 Components considered for assessing surface water take

3.3 Simulation of springs

JBS&G provide the following comment:

> "Whilst it is accepted that the majority of the identified springs and seeps are located within the 'Disturbance Footprint' and hence may be 'built over', JBS&G does not understand why springs and seeps were not included in the groundwater model, as the mechanism through which they occur was obviously considered important enough to warrant the substantial and thorough investigation as presented by EMM (2019)."

The surface water-groundwater interaction assessment and hydrological characterisation of springs in the study area was undertaken as part of the EIS in order to address community concerns regarding the springs. There are many springs in the area.

As described in the Groundwater Assessment, most springs identified in the mine development area have been altered (excavated and converted into a dam) to allow cattle access for drinking water. Most identified springs are associated with the shallow, locally recharged, groundwater flow system (ie perched and short flow path groundwater systems) and are associated with changes in topography. The results of the Groundwater Assessment indicate that these springs do not contribute significant flows to the Belubula River. Construction of project infrastructure (including clearing, grubbing and preparing for construction) will change the local flow system in these areas, removing the groundwater discharge at the spring and seep locations. This groundwater resource will not be removed from the flow system. As flow gradients readjust, the groundwater will discharge at another location, which may be to a waterway or at another spring location. There is the potential for the predicted decline in groundwater levels to alter spring flows on the mine development boundary, however as these springs contribute minor flows to the Belubula River and do not provide habitat for sensitive fauna, the impact at a project scale is expected to be minor.

A conceptual diagram is provided in Figure 3.2.

The groundwater model is a regional scale impact assessment model and is not designed to simulate small-scale local flow. The springs were not simulated in the groundwater model based on the conceptualisation and objective and scale of the groundwater model. EMM and Regis believe that revisions to the groundwater model on this aspect are not required.

Due to community focus and other submissions received on the EIS, EMM and Regis will provide further detail on the conceptual understanding and additional data collected since the EIS, as part of the Response to Submissions report.

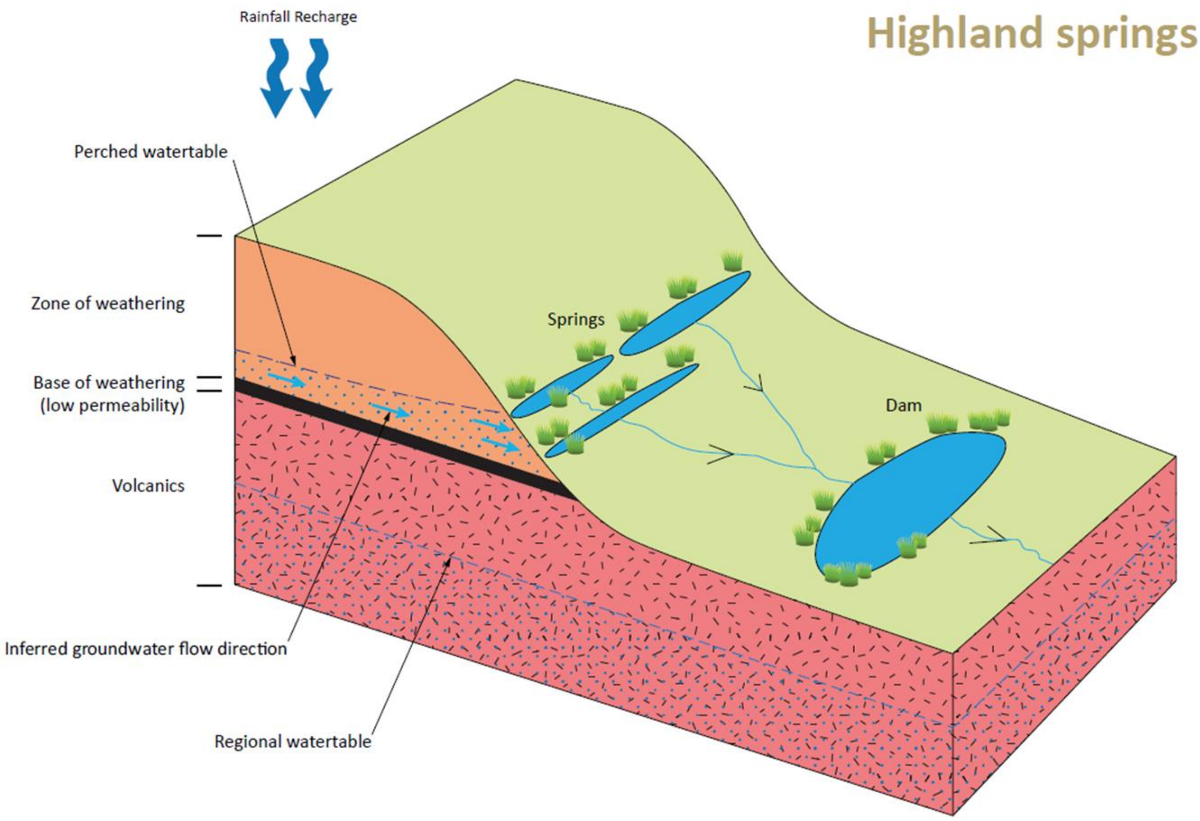


Figure 3.2 Conceptual diagram of perched highland springs

3.4 Geological structures and heterogeneity

JBS&G provide the following comment:

> "Consideration of the influence of geological structures on bulk hydraulic conductivity is considered by JBS&G to be important."

Of greatest significance to the project is the Godolphin Fault, which separates the Anson Formation in the east from the Byng Volcanics in the west. There have also been a number of smaller structures inferred by Regis within the proposed mine footprint. Extensive drilling has indicated faulted areas are highly weathered zones with high clay content and low hydraulic conductivity, and generally define the contacts between the lithological units. As discussed in Section 5.4.2iv of the Groundwater Assessment, geology is defined within each model layer as zones (or HSUs) and uniform properties are applied across each HSU. Heterogeneity and faulting are not specifically simulated but have been considered as follows:

- the geological units are vertically dipping and lateral changes in hydrogeological properties between units is captured via the zonation in the model;
- the separation of the Anson Formation from the Byng Volcanics is used to represent the influence of the Godolphin Fault;
- information available regarding faulting and associated fracturing indicates that fractures generally do not act as conduits for groundwater flow and are clay-filled; and
- heterogeneity associated with weathering is represented by the upper layer in the groundwater model.

The following points provide additional justification for not explicitly simulating structures in the groundwater model:

- regional scale groundwater flow systems are sensitive to and depend on average values of hydrogeological properties; and
- the equivalent porous medium approach has been adopted for this impact assessment model.

In addition, the uncertainty analysis conducted as part of the Groundwater Assessment analysed a wide range of hydraulic properties for the fresh rock units, individually and grouped. Further discussion on the uncertainty analysis is provided in Section 3.7.

EMM and Regis believe that no further modelling is necessary for this aspect of the current model. Future model improvements, as more data becomes available, may incorporate additional uncertainty analysis on the influence of structures. This will be documented in the Model Upgrade Plan that will be provided as part of the Response to Submissions.

3.5 Adopted hydraulic conductivity of fresh rock

JBS&G provide the following comments:

> "The values of hydraulic conductivity presented in Table 4.3 [of the Groundwater Assessment] are such that the hydrogeologic unit, if the test values were representative of the whole unit, would be considered an aquiclude (impermeable rock). JBS&G notes that this may not be representative of the formation."

> "JBS&G also considers that the current approach in the groundwater model, whereby there is an instantaneous transition (vertically) from Layer 1 (saprock) to Layer 2 through 9 (fresh rock), is inconsistent with the conceptual model presented in EMM (2019), namely that there is a gradually decreasing hydraulic conductivity with depth."

Core samples have been analysed to estimate hydraulic conductivity. A Box and Whisker plot of the measured hydraulic conductivity data is presented in Figure 3.3, grouped by geological unit. The majority of tests have been performed on the Anson Formation due to the project being located in this unit. Field testing has been conducted over varying depths. The uncertainty analysis covered the range of measured hydraulic conductivities and literature values, by simulating fresh rock hydraulic conductivity over a range of five orders of magnitude (up to 1 x 10^{-3} m/day).

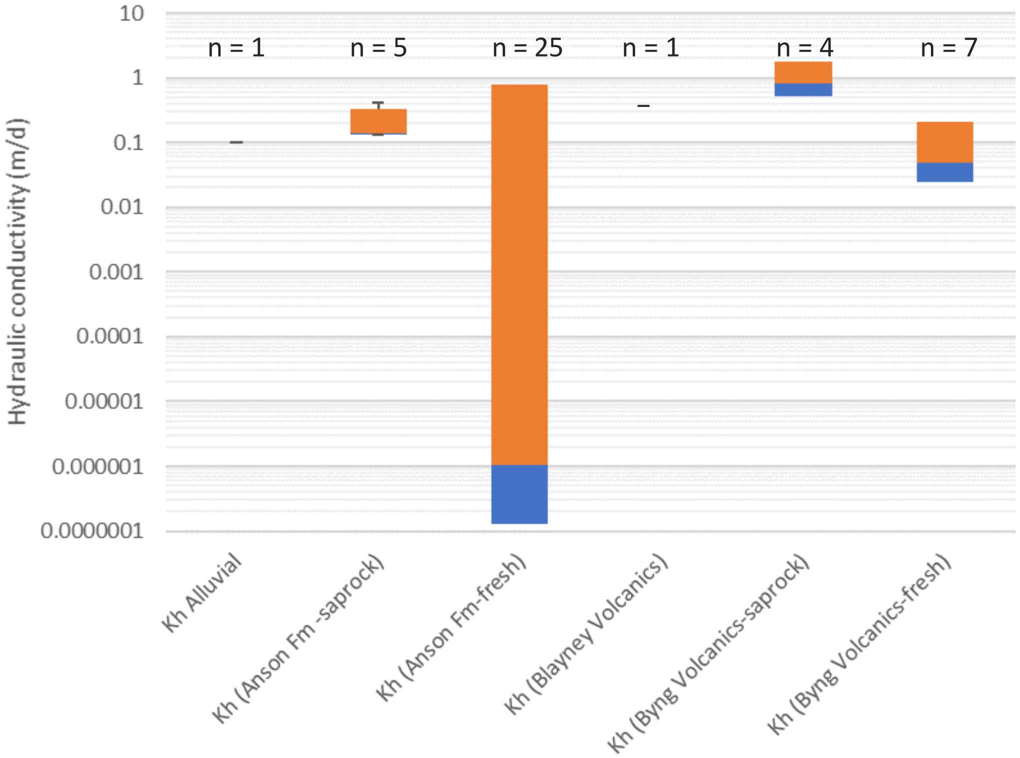


Figure 3.3 Box and whisker plot of field-measured hydraulic conductivity

The fresh rock layer elevation used in the model has been derived from the geological model which has been informed by Regis drilling data.

With a lack of detailed data to indicate various transition zones with depth, EMM adopted a simple two-layer (with depth) approach to the groundwater model. As mentioned above, regional scale groundwater flow systems are sensitive to and depend on average values of hydrogeological properties.

In order to respond to JBS&G's comment regarding the two-layer system, EMM have completed an additional uncertainty analysis scenario which included a more gradual vertical transition in hydraulic conductivity with depth. Information about this scenario is provided in Section 4. Increasing the hydraulic conductivity between saprock and fresh rock results in minimal change to calibration statistics and model predictions (when compared to the base case and reported uncertainty analysis). The results of the additional uncertainty analysis confirms that the modelling (including uncertainty analysis) completed as part of the Groundwater Assessment have adequately assessed the potential impacts of the project.

3.6 Sensitivity analysis and impact of metasediments on calibration

JBS&G provide the following comment:

> "The majority of the monitoring piezometers and wells in the vicinity of the Project are located in the 'saprock'. Accordingly, it is to be expected with changing the values of hydraulic conductivity for fresh rock units has, essentially, no impact on the Scaled Root Mean Square (SRMS) error."

EMM agree that most landholder bores are likely screened in the saprock, however Regis's groundwater monitoring network target locations in the fresh rock as well as the saprock (to obtain groundwater elevation, hydraulic properties and water quality information at different depths).

Table 3.1 below summarises the number of steady state observation points used in the model, broken down by layer and hydrostratigraphic unit. There are 15 monitoring points screened in fresh rock units, compared to 122 in the saprock.

The information presented here supports the discussion provided in the Groundwater Assessment that the model is not sensitive to hydraulic properties of fresh rock.

Table 3.1 Number of calibration observation points

Layer	Alluvium	Basalt	Anson Formation (saprock)	Anson Formation (fresh)	Byng Volcanics (saprock)	Byng Volcanics (fresh)	Blayney Volcanics (saprock)	Blayney Volcanics (fresh)
1	5	29	26	-	14	-	48	-
2	-	-	-	4	-	5	-	2
3	-	-	-	1	-	-	-	1
4	-	-	-	-	-	-	-	-
5	-	-	-	2	-	-	-	-
6	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-

3.6.1 Relative composite sensitivity analysis

Following the meeting on 2 December 2019, EMM performed a relative composite sensitivity (RCS) analysis on the base case model in order to quantify the sensitivity of the model calibration. The results are shown in Figure 3.4. The value of RCS is a unitless, scaled parameter corresponding to the sensitivity of the model calibration to changes in each parameter. Larger values mean that the model has a higher sensitivity to this parameter. The tested parameters are as follows:

- **kx**: horizontal hydraulic conductivity;
- **kz**: vertical hydraulic conductivity;
- **r**: recharge rate;
- **et**: evapotranspiration rate;
- **ed**: evapotranspiration extinction depth;
- **ghc**: conductance of general head boundary cells; and
- **rv**: conductance of river boundary cells.

The number following the parameter in Figure 3.4 represents the parameter zone or boundary reach. The zones and reaches are detailed in the Groundwater Assessment (EMM 2019). Storage parameters were not analysed, as storage is neglected in steady state groundwater flow conditions. Additionally, horizontal hydraulic conductivity and recharge are considered linked, as steady state groundwater flow is dependent on the ratio of recharge to transmissivity. It is for this reason that recharge was not varied in the model calibration; allowing recharge and hydraulic conductivity to both vary would allow for non-unique parameter values. However, recharge has been included in the RCS analysis.

Model layer 1 contains hydraulic conductivity parameter zones 1-7 (Table 2.1). As shown in Figure 3.4, the calibration is sensitive to horizontal hydraulic conductivity in this layer. The deeper layers representing fresh rock contain parameter zones 8-11 (Table 2.1). The calibration shows sensitivity to the parameter values in these zones higher than expected, with observable sensitivity to horizontal hydraulic conductivity and, to a lesser extent, vertical hydraulic conductivity. It is clear that despite the low number of measurements from the fresh rock, the properties of these units influence the overall groundwater conditions across the domain.

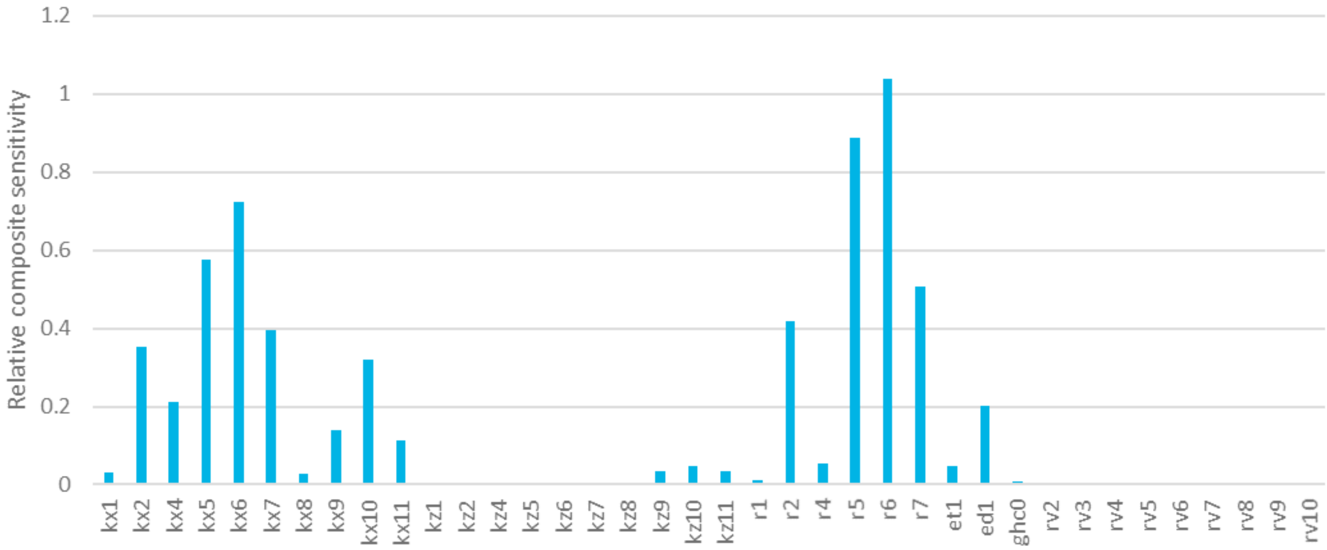


Figure 3.4 Relative composite sensitivity of model parameters against steady state SRMS

Parameters with greater RCS values indicate that the model calibration is sensitive to that parameter, but that the measurements have provided enough information to adequately constrain the calibration. Accordingly, the modeller can more easily determine reasonable upper and lower bounds for the more sensitive parameters. Noting the lower sensitivity of the model to fresh rock hydraulic conductivity, EMM applied a wider range of hydraulic conductivity in the sensitivity and uncertainty analyses for the deeper layers. In addition to this, the lack of calibration to storage parameters necessitated a wide range of values applied in the uncertainty analysis.

3.7 Uncertainty analysis

JBS&G provide the following comment:

> "A limitation to the approach by EMM (2019) of changing a single parameter value at a time is that, because of the location of the Open Pit in the Anson Formation, and that surrounding groundwater users are in the Blayney Volcanics, because of the very very low value of hydraulic conductivity adopted in Layers 2 to 9, changes to the Anson Formation will not be 'seen' by those groundwater users. Conversely, changes to the Blayney Volcanics, because of the very very low value of hydraulic conductivity in the Anson Formation will not be 'seen' by the Open Pit."

It is apparent that the Groundwater Assessment did not clearly communicate the work completed as part of the uncertainty analysis. As discussed on 29 January 2020, the uncertainty analysis completed as part of the Groundwater Assessment considered:

- hydraulic conductivity of the weathered Byng Volcanics (saprock) in isolation of other units (up and down);

- hydraulic conductivity of the fresh Byng Volcanics in isolation of other units (up and down);
- hydraulic conductivity of all the weathered rock units (up and down);
- hydraulic conductivity of all fresh rock units (up and down);
- specific yield of all weathered rock units (up and down);
- specific storage of all fresh rock units (up and down); and
- river stage elevation, 'dry watercourse' scenario and recent additional scenarios detailed in Section 4.

At the time of the expert review, JBS&G commented that there is residual risk of potential impacts to landholders to the south of the project (in Kings Plains). However, as presented on 29 January 2020 and in this document, the uncertainty analysis included changes in parameter values that have been applied to all fresh and all weathered units.

Uncertainty scenario S11 included increasing the hydraulic conductivity of the Byng Volcanics much higher than that presented in the base case model. This scenario allows assessment of the potential for greater impacts (drawdown) to be observed in the Kings Plains area. The results of the uncertainty analysis (presented in Section 4) demonstrate that the potential impacts have been adequately assessed and the groundwater model is fit for purpose.

Additional uncertainty analysis is proposed to be undertaken post-RTS, using the results of the RCS and incorporating the combination of multiple parameters simultaneously to simulate a total 'worst case' scenario. This will be documented in the Model Upgrade Plan which will be submitted as part of the Response to Submissions report.

3.8 Transition from steady state to transient calibration

JBS&G provide the following comment:

> "Currently, the calibration period is too close to the steady state period (refer Table 5.5 of EMM 2019 [Model stress periods]).
>
> Due to a different form of the groundwater flow equation being solved in steady-state compared to transient conditions, JBS&G expects that the groundwater model was 'drifting'."

As described in the Groundwater Assessment (Section 4.4.2) seasonal trends are not evident at most groundwater monitoring sites during the baseline monitoring period. There is an observable gradual groundwater level decline at most sites, correlating with below average rainfall following the wet year in 2016.

Calibration of the model was performed against single data points and assumed steady state flow conditions. Following calibration, validation was performed by comparing modelled groundwater elevations against measured time series data taken in the project area. Following the meeting on 29 January 2020, EMM have adopted the advice of Dr Justin Bell and Hugh Middlemis and developed an additional long-term transient model scenario, incorporating additional commentary from JBS&G regarding the modelled evaporation/evapotranspiration in the transient verification period.

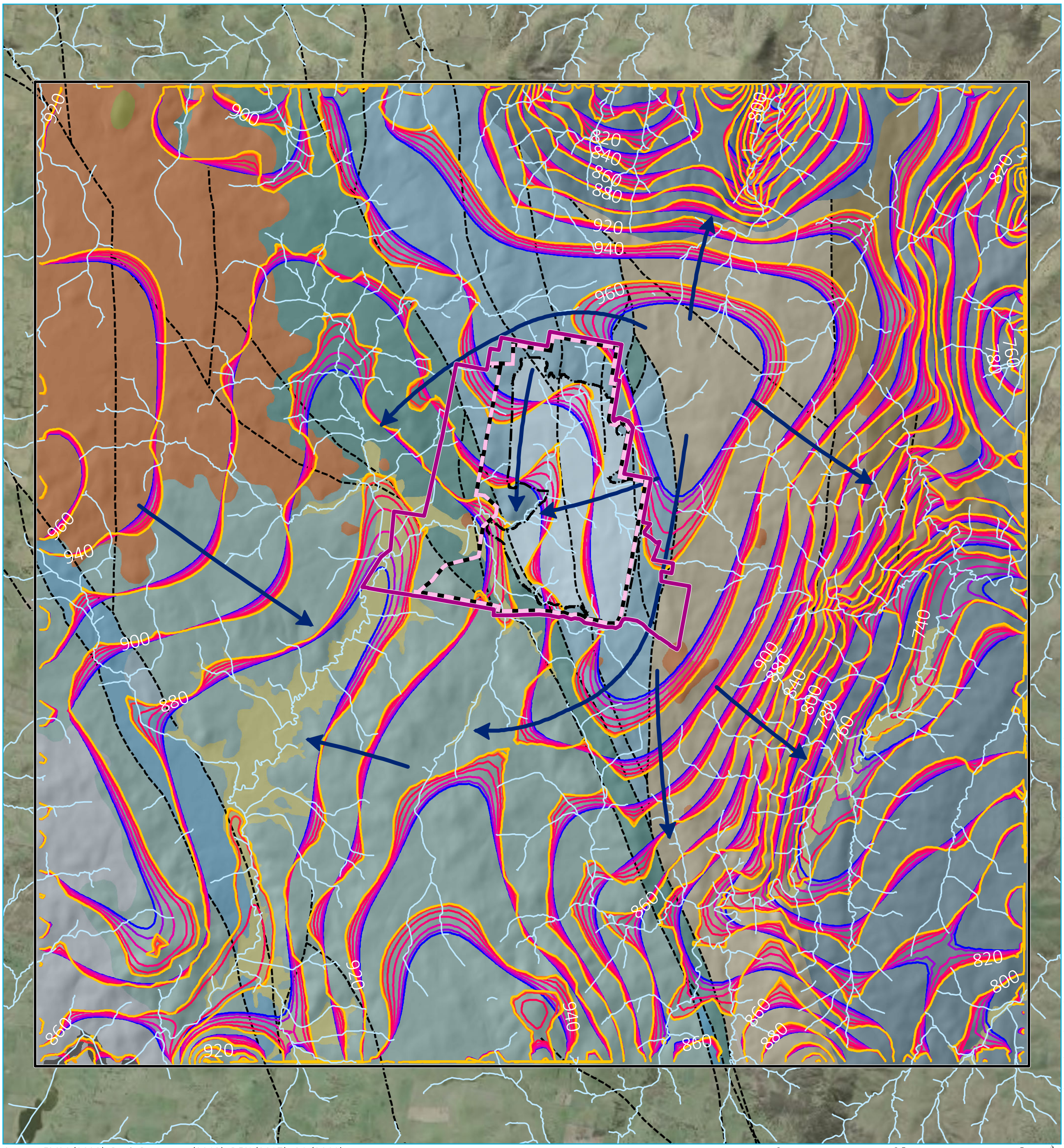
EMM conducted a model run with an extended transient calibration period to assess climate baseline variability. The model setup and results are described in detail in Section 4. In summary, the extended transient verification period, using monthly recharge and evapotranspiration from 1970 to mid-2018, result in a slightly greater response to climate stresses in the history match period. Transient calibration statistics from 2017 to 2018 improve slightly from 6.1% to 5.9%. Whilst the revised temporal setup improves the model response to climate variability, the improvements are minor and do not influence the model predictions. The results also show that the heads in the groundwater model are stable when it changes from steady state to transient and there is no observable drift at observation points.

3.9 Groundwater elevation in fresh rock

JBS&G provide the following comment:

> "At present, the groundwater elevation in the lower layers of the model is not presented in EMM (2019). This is potentially of interest with respect to the approach to regional throughflow […] as well as the influence of the Godolphin Fault in the model."

The model-derived watertable elevation and predicted change in the watertable as a result of proposed mine activities are presented in the Groundwater Assessment. Calibrated hydraulic head contours for model layers 1 to 9 are presented in Figure 3.5. Presenting the heads in this way allows the reader to observe a slight vertical gradient across most of the model domain. Regionally there is a downward gradient which reverses in low topographic areas (ie watercourses and valleys).



Source: EMM (2020); Regis Resources (2019); DFSI (2017); GA (2011)

0 2.5 5 km
GDA 1994 MGA Zone 55
N

\\emmsvr1\EMM\Jobs\2018\J180395 - Regis McPhillamys EIS\GIS\02_Maps_RTS_GW\RTSGW001_SteadyStateContours_20200217_02.mxd 17/02/2020

KEY

Watercourse/drainage line
Groundwater flow direction
Model boundary
Project application area
Mine development project area (2,513.47 ha)
Mining lease application area (1,812.99 ha)
(Note: boundary offset for clarity)
Disturbance footprint
Geology (Bathurst 250k, 2nd Edition)
Fault
Geology (Bathurst 250k, 2nd Edition)
Quaternary / Tertiary
Alluvium
Tertiary basalt
Trachyte
Carboniferous
Bathurst Batholith - Bathurst Granite
Bathurst Batholith - Dunkeld Granite
Bathurst Batholith - Gresham Granite
Bathurst Batholith - Icely Granite
Devonian
Other Carboniferous Intrusions
Ungrouped Devonian Formations
- Cunningham Formation
Crudine Group - Bushranger Volcanics
Crudine Group - Turondale Formation
Crudine Group - Waterbeach Formation
Silurian
Other Silurian Intrusions
- Carcoar Granodiorite
Other Silurian Intrusions
Mumbil Group (Northwest)
- Anson Formation
Mumbil Group (Northwest)
- Wombiana Formation
Mumbil Group (East) - Campbells Formation
Ordovician
Ordovician Intrusions
Cabonne Group - Blayney Volcanics
Cabonne Group - Oakdale Formation
Cabonne Group - Byng Volcanics
Other
Lake

Modelled groundwater level (by model layer)
L01
L02
L03
L04
L05
L06
L07
L08
L09

Steady state modelled groundwater level contours (all layers)

McPhillamys Gold Project
Groundwater assessment
Response to submissions
Figure 3.5

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3.10 Regional throughflow and use of general head boundary conditions

JBS&G provide the following comment:

> "JBS&G suggests that consideration is given to far field hydraulic head as a potential alternative to the current approach by EMM."

The mine development area is at a local topographic high, located at the headwaters of the Belubula River. The model domain is approximately 20 km in each direction, centred on the mine development, and the model boundaries are broadly at a lower elevation than the mine development area. Steady state calibration and the spatial distribution of observed groundwater elevations suggest that the model sufficiently represents pre-mining groundwater flow conditions. The comment raised by JBS&G refers to low lying areas outside of the model domain that appear to be major groundwater discharge locations. In order to capture these, either the model domain would need to be significantly expanded or the general head boundaries would need to be modified using stage elevation of the discharge features and calculated conductance based on distance to these features, hydraulic conductivity and model cell size. EMM agree that this could assist in refining the steady state calibration, but the additional modelling effort required would not be beneficial with respect to the model objectives. Increasing the model domain would also introduce additional uncertainty due to data gaps in the extended areas, which are well beyond the predicted extent of drawdown.

EMM believe that the groundwater model provides an adequate representation of the conceptual hydrogeological understanding and regional groundwater flow system. As such, alterations to the model domain or boundary conditions at the model extent are not proposed.

3.11 Waste rock emplacement

JBS&G provide the following comment:

> "Given the location of the Project at the 'top' of one of several catchments, JBS&G suggests that incorporating the Waste Rock Dump into the prediction simulation is worth consideration, as the Waste Rock Dump may lead to local waterlogging/enhanced discharge to surface watercourses to the east of the project."

The waste rock emplacement (WRE) has been considered as part of the Groundwater Assessment and Surface Water Assessment (Appendix J of the EIS). As described in the Groundwater Assessment (Section 5.2.4), the water storages capturing surface runoff from the WRE will be positioned downstream and will be engineered to capture any seepage reporting to the toe of the emplacement for recirculation in the operational water management system. In addition, the WRE will be undergoing compaction from heavy vehicle traffic, further reducing the risk of vertical migration of seepage.

As the main water affecting activities of the project are dewatering of the open cut and tailings storage, simulation of the WRE was not included in the model objectives (see Section 2.1). EMM and Regis maintain this view and do not consider that further modelling is required for this aspect.

3.12 Groundwater users

JBS&G provide the following comment:

> "It does not appear that 'take' from groundwater users in the vicinity of the Project, and in general, is included in the groundwater model. JBS&G considers this to be an important aspect to include."

Groundwater use in the vicinity of the Project is expected to be very low, due to the low productivity of the geology in the area, as evident in the minimal active groundwater licenses in the area. The majority of groundwater use in the study area is for stock and domestic purposes, with low, infrequent, and unmonitored extraction. There is minimal data available regarding pumping rates, bore lithology, screened interval for pumping bores and there is no observation data available to enhance model calibration. The predictive groundwater model calculates drawdown with respect to a 'null case' scenario without mining activities, a best practice method for quantifying dewatering effects whether or not other common and minor extraction is included or excluded (Barnett et al., 2012).

Inclusion of groundwater use in the model is not considered necessary due to these factors and the increased data uncertainty that would be included due to there being no records of extraction volumes.

3.13 Cumulative departure from mean rainfall

JBS&G provide the following comment:

> "CRD analysis is helpful in groundwater studies due to the slow response of groundwater systems to changes in average climate. JBS&G advises, however, that starting analysis in 1900 is difficult to justify and it is recommended that the original paper on the CRD technique and critique of the CRD technique in the literature is reviewed and Figure 3.3 is updated to a closer starting date."

JBS&G refer to Weber & Stewart (2004), who state that analyses based on the CRD method can be erroneously influenced by use on a long time scale. The Groundwater Assessment presented CRD back to 1900 to illustrate that the area has experienced large variations in rainfall trends since this time, including multiple droughts and very wet periods (see Section 3.2 of the Groundwater Assessment). Other than being used as a comparison to evaluate seasonal trends in groundwater level monitoring data, CRD was not used for further detailed analysis.

EMM propose to present an additional CRD plot in the RTS report calculated over a shorter time period. However, EMM consider that it has no influence on the groundwater modelling work completed.

4 Overview of additional model scenarios

As advised above, the three additional model scenarios have been performed to:

- complement the uncertainty analysis completed as part of the EIS;
- provide additional confidence in the groundwater model; and
- contribute towards responses in Section 3.

The scenarios do not present as new upper or lower bounds for the uncertainty analysis, thereby providing further justification that the results presented in the EIS appropriately assess the potential impacts.

The additional scenarios are as follows:

- **S64**: Increased hydraulic conductivity in model fresh rock layers 2 and 3, providing a more gradual reduction in hydraulic conductivity with depth. The adopted hydraulic conductivity values are presented in Table 4.1. Note that the anisotropy of horizontal to vertical hydraulic conductivity has been maintained as 10:1 for saprock (model layer 1) and 1:1 for fresh rock (model layers 2-9).
- **S65**: Extended transient verification period to assess climate baseline variability. JBS&G suggested that the direct change from steady state to transient formulations in MODFLOW may result in numerical drift and potentially contribute to difficulty in matching observed groundwater level trends. To test this, an additional scenario was run with a quasi-steady state stress period from 1900 to 1970, followed by a period of monthly transient stress periods applying recharge (using SILO rainfall records) and evapotranspiration from 1970 to mid-2018. As monthly evapotranspiration was applied through the

history match period (2017-2018), this scenario differs from the base case model which had annual average evapotranspiration applied across the model.

- **S66**: A combination of S64 and S65, with a gradual decrease of hydraulic conductivity with depth and an extended transient verification period.

Table 4.1 Modelled horizontal hydraulic conductivity (Kh) for base case and S64 (m/day)

Model layer/s	Base case		S64	
	Byng Volcanics	Other units[1]	Byng Volcanics	Other units [1]
1 (saprock)	6×10^{-3}	6×10^{-2}	6×10^{-3}	6×10^{-2}
2	8×10^{-8}	1×10^{-7}	8×10^{-4}	1×10^{-3}
3			8×10^{-6}	1×10^{-5}
4-9			8×10^{-8}	1×10^{-7}

1. Note: excludes areas of alluvium and basalt

4.1 Model design

4.1.1 S64 – change in K in layer 2 and 3

As stated above, scenario S64 simulated a more gradual reduction in hydraulic conductivity with depth. Figure 4.1 presents a chart of measured hydraulic conductivity with depth. As discussed in the Groundwater Assessment, slug test results tend to be biased to higher hydraulic conductivity areas and core tests can only be done on intact core and therefore tend to result in lower hydraulic conductivity values.

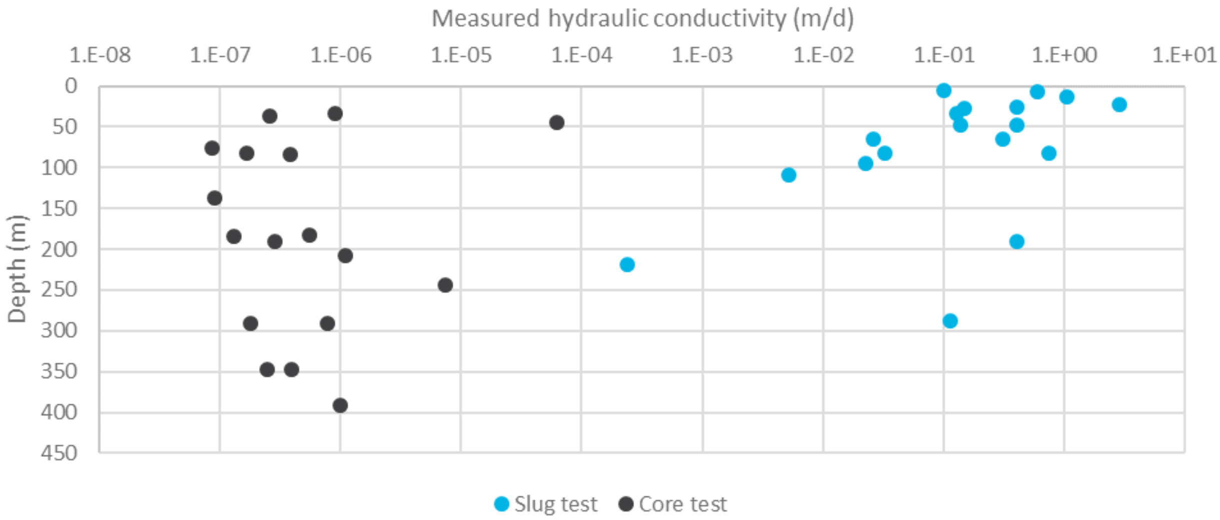


Figure 4.1 Measured hydraulic conductivity with depth

There is insufficient data available to provide estimates of the thickness of a transition layer (from saprock to fresh). Due to limited data availability to accurately support hydraulic conductivities with depth, an approximately linear relationship was used between layers 1 and 4 to derive the hydraulic conductivities for layer 2 and 3 for S64.

Aside from hydraulic conductivity, all other properties, stresses, and temporal setup were maintained from the base case model.

4.1.2 S65 – Base case model with extended transient verification period

Model scenario S65 incorporated an extended transient verification period to assess climate baseline variability. The base case history match model was run with a single steady state stress period at the start of the simulation, followed by monthly transient stress periods starting January 2017. The time series of measured groundwater level monitoring data have been used for validation of the calibration. The base case model showed little change in groundwater elevation in the transient verification period.

Review comments have suggested that this may be due to the temporal setup, and increasing the duration of the transient verification period may allow for better representation of temporal trends leading into the history match period.

In scenario S65, the steady state stress period was divided into two segments: a long-term (70 years) pseudo steady state stress period with annual average recharge and evapotranspiration, and then monthly stress periods from January 1970 using monthly recharge and evapotranspiration from 1970 to mid-2018. The stress period setup is shown in Table 4.2. The first stress period was converted from steady state to transient, to allow for consistent formulation of the groundwater flow equation throughout the model run. Initial heads were set as the calibrated steady state heads from the base case model. Through the history match period, evapotranspiration was converted from annual average to monthly in order to better represent conditions.

Recharge in the base case model was calculated based on rainfall from the AWRA model which only has data from 2005. For consistency through the pre-mining period, recharge and evapotranspiration were calculated from SILO data.

Table 4.2 S65 stress period setup

Detail	Stress period/s	Stress period length	From	To	Recharge applied	Evapotranspiration applied
Quasi-steady state warmup	1	70 years	1/01/1900	1/01/1970	Annual average	Annual average
Extended transient verification period	2−565	1 month	1/01/1970	1/01/2017	Monthly	Monthly
History match	566−583	1 month	1/01/2017	1/01/2020	Monthly	Monthly

4.1.3 S66 – combination of S64 and S65

Scenario S66 was run as a combination of S64 and S65. Hydraulic conductivities were applied consistent with Table 4.1, and the stress period setup, recharge and evapotranspiration outlined in Table 4.2 was used.

4.2 Assessment against calibration

Assessment of results from the three additional scenarios included:

- review of steady state SRMS and comparison to base case (4.3%);
- for S65, the measured data hydrographs were compared to model derived hydraulic heads from S65 and the base case model;
- review of pre-mining watertable elevation and groundwater flow directions; and

- review of mass balance results at the end of calibration, with a comparison to the base case.

4.2.1 SRMS and heads

Calibration statistics are presented in Table 4.3. The transient SRMS has been calculated against hydraulic heads.

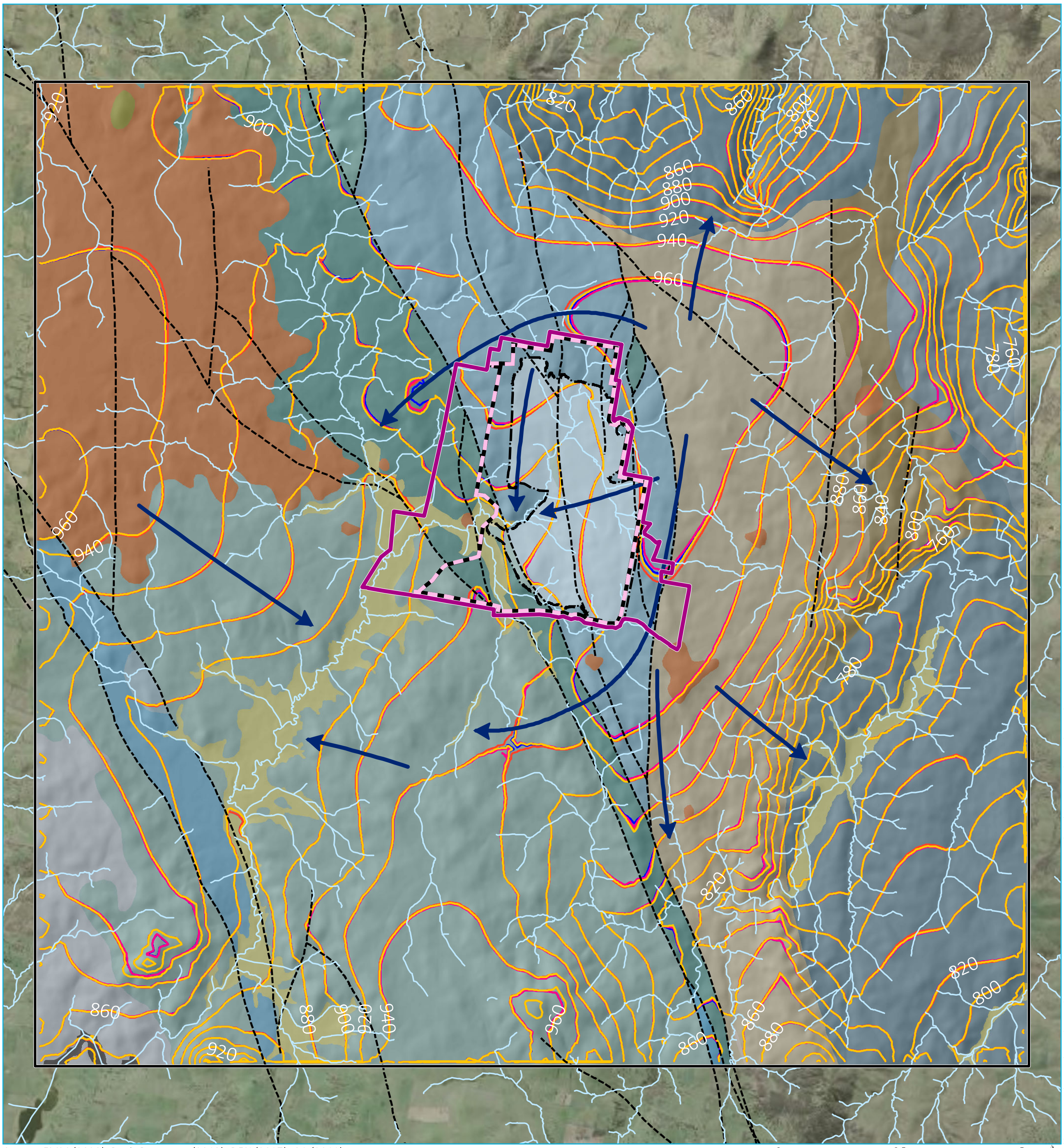
Table 4.3 Model calibration performance summary

Run name	Detail	Steady state SRMS	Transient SRMS
Base case	Base case	4.3%	6.1%
S64	Increased K in L2-3	4.3%	5.9%
S65	Transient RCH and ET from Jan 1970 to mid-2018	4.3%	5.9%
S66	Increased K in L2-3, transient RCH and ET from Jan 1970 to mid-2018	4.3%	5.9%

Each of the additional model scenarios show no change to steady state SRMS. These would all be accepted as part of the uncertainty analysis following the criteria of <5% SRMS. Modelled steady state watertable contours are shown in Figure 4.2. There are minimal changes across the model scenarios, consistent with the unchanged SRMS. The absolute average variance between the base case and the three additional scenarios is 0.5 m. Regional flow conditions are unchanged.

Transient SRMS has improved for each of the additional scenarios over the base case. Hydrographs showing the base case against S65 for the history match period are presented in Appendix A. S65 shows slightly changed starting conditions and a slightly greater response to climate stresses. This may be due to the addition of the extended verification period and/or the inclusion of monthly evapotranspiration rates.

Whilst the revised temporal setup improves the model response to climate variability, the improvements are minor and do not influence the model predictions. The results also show that the heads in the groundwater model are stable when it changes from steady state to transient and there is no observable drift at observation points that materially affects model performance.



Source: EMM (2020); Regis Resources (2019); DFSI (2017); GA (2011)

0 2.5 5 km

GDA 1994 MGA Zone 55

N

KEY

Watercourse/drainage line
Groundwater flow direction
Model boundary

Project application area
Mine development project area (2,513.47 ha)
Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
Disturbance footprint

Geology (Bathurst 250k, 2nd Edition)
Fault

Geology (Bathurst 250k, 2nd Edition)

Quaternary / Tertiary
Alluvium
Tertiary basalt
Trachyte

Carboniferous
Bathurst Batholith - Bathurst Granite
Bathurst Batholith - Dunkeld Granite
Bathurst Batholith - Gresham Granite
Bathurst Batholith - Icely Granite

Devonian
Other Carboniferous Intrusions
Ungrouped Devonian Formations - Cunningham Formation
Crudine Group - Bushranger Volcanics
Crudine Group - Turondale Formation
Crudine Group - Waterbeach Formation

Silurian
Other Silurian Intrusions - Carcoar Granodiorite
Other Silurian Intrusions
Mumbil Group (Northwest) - Anson Formation
Mumbil Group (Northwest) - Wombiana Formation
Mumbil Group (East) - Campbells Formation

Ordovician
Ordovician Intrusions
Cabonne Group - Blayney Volcanics
Cabonne Group - Oakdale Formation
Cabonne Group - Byng Volcanics

Other
Lake

Modelled pre-mining water table contours
Base case
S64
S65
S66

Modelled pre-mining water table contours for base case and additional scenarios

McPhillamys Gold Project
Groundwater assessment
Response to submissions
Figure 4.2

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4.2.2 Mass balance

Mass balance results at the end of calibration for the base case and additional scenarios are presented in Table 4.4 to Table 4.7. The following provides a discussion of the mass balance results:

- Smoothing the transition between saprock and fresh rock (S64) results in less river leakage and baseflow, and reduced evapotranspiration when compared to the base case model (see Table 4.5). This is thought to be due to lower groundwater elevations in areas that do not have monitoring bores and therefore are not captured by the SRMS.
- Extending the transient verification period, and altering the modelled evapotranspiration results in the following (see Table 4.6):
  - greater flux via storage;
  - decrease in modelled baseflow, recharge, and evapotranspiration; and
  - changes in recharge and evapotranspiration are a result of the changed calculation methodology (see Section 4.1).
- The calculated mass balance error is very low for all scenarios.

Table 4.4 Base case modelled water balance at the end of calibration (1/06/2018)

	Input (kL/day)	Output (kL/day)	Net (kL/day)
Storage	1,886	51	1,835
General head boundaries	14,353	11,247	3,106
Rivers	13,746	5,379	8,367
Recharge	17,852	-	17,852
Evapotranspiration	-	31,163	-31,163
Drains	-	0.0	0.0
TOTAL IN		47,836	
TOTAL OUT		47,839	
Error		-0.01%	

Table 4.5 S64 modelled water balance at the end of calibration (1/06/2018)

	Input (kL/day)	Output (kL/day)	Net (kL/day)
Storage	1,769	73	1,696
General head boundaries	12,824	10,728	2,096
Rivers	9,716	3,666	6,050
Recharge	17,852	-	17,852
Evapotranspiration	-	27,699	-27,699
Drains	-	0.0	0.0
TOTAL IN		42,161	
TOTAL OUT		42,165	
Error		-0.01%	

Table 4.6 S65 modelled water balance at the end of calibration (1/06/2018)

	Input (kL/day)	Output (kL/day)	Net (kL/day)
Storage	7,918	9,157	-1,239
General head boundaries	12,652	10,419	2,233
Rivers	7,384	4,674	2,710
Recharge	10,409	-	10,409
Evapotranspiration	-	14,113	-14,113
Drains	-	0.0	0.0
TOTAL IN		38,362	
TOTAL OUT		38,363	
Error		0.0%	

Table 4.7 S66 modelled water balance at the end of calibration (1/06/2018)

	Input (kL/day)	Output (kL/day)	Net (kL/day)
Storage	7,4301	9,165	-1,735
General head boundaries	12,948	10,535	2,413
Rivers	7,448	4,678	2,770
Recharge	10,409	-	10,409
Evapotranspiration	-	13,858	-13,858
Drains	-	0.0	0.0
TOTAL IN		38,235	
TOTAL OUT		38,236	
Error		0.0%	

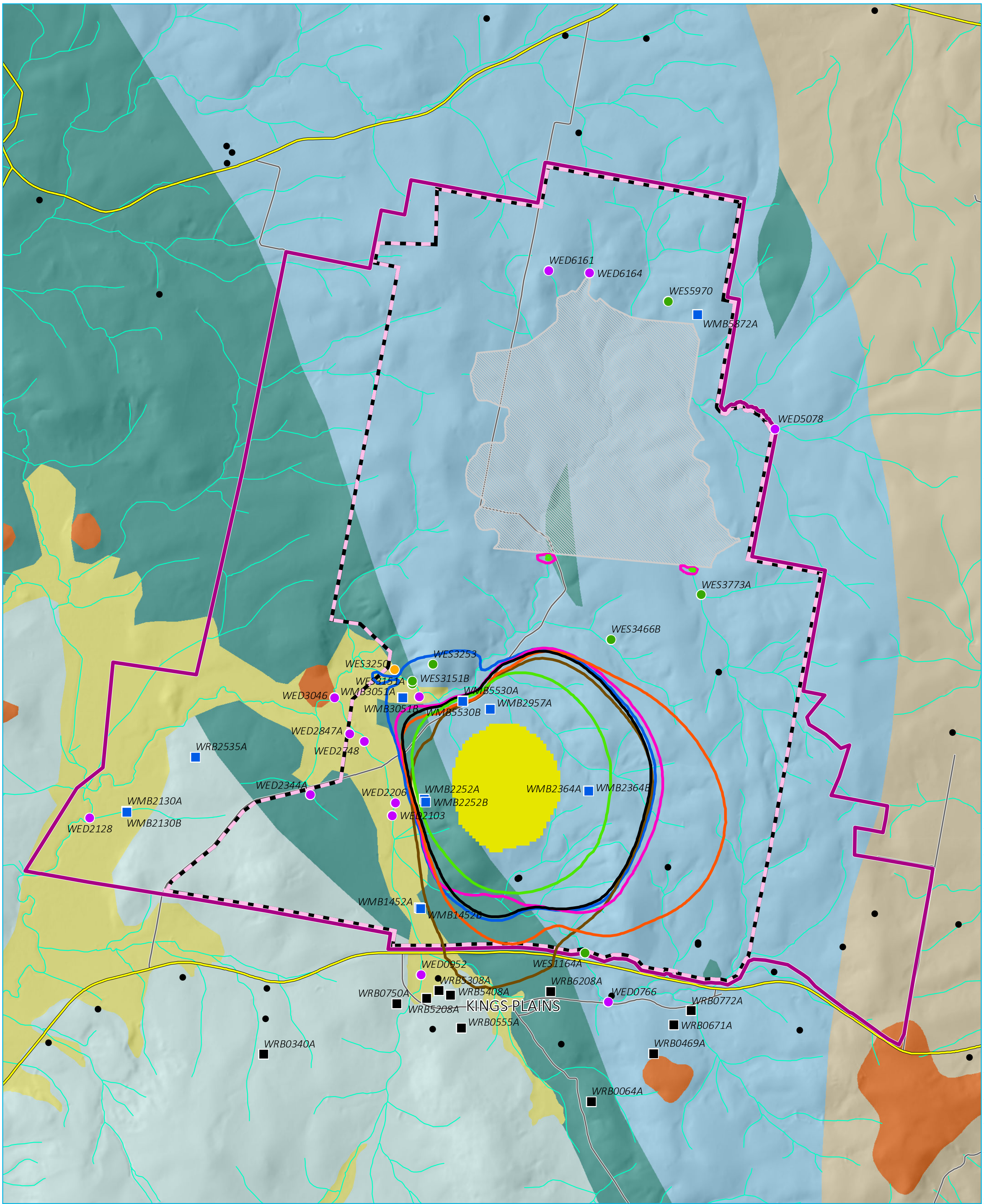
4.3 Model prediction results (S64)

Model scenario S64 (altered hydraulic conductivity in layers 2 and 3) is the primary focus for predictive modelling results, as the objective for scenario S65 and S66 was to assess model verification and climate baseline variability.

4.3.1 Watertable drawdown

The predicted 2 m drawdown contour at the end of mining in scenario S64 has been compared to the base case results and the results of the predictive uncertainty analysis completed as part of the Groundwater Assessment (see Figure 4.3). The figure shows that the S64 predicted 2 m drawdown contour is located within the extent of the best and worst case scenarios presented in the uncertainty analysis.

The results presented here and above demonstrate that the groundwater model calibration and predictions are not sensitive to increasing the hydraulic conductivity in layer 2 and 3, providing a smoother transition between saprock and fresh rock.



Source: EMM (2020); Regis Resources (2019); DFSI (2017); DPI (2015); ELVIS (2014)

0 1 2 km
GDA 1994 MGA Zone 55
N

KEY

- Best case 2 m drawdown
- Base case 2 m drawdown
- Worst case 2 m drawdown
- Dry watercourse scenario 2 m drawdown
- S64 2 m drawdown
- Byng Volcanics (saprock) high K
- PINEENA/Registered bore
- Groundwater monitoring site - Regis
- Groundwater monitoring site - other landholder
- Surface water monitoring site (dam)
- Surface water monitoring site (seepage area)
- Surface water monitoringsite (spring)

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- TSF Stage 3 (961 mAHD)
- Simulated pit (year 10)

Existing environment

- Main road
- Local road
- Watercourse/drainage line

Geology (Bathurst 250k, 2nd Edition)

Quaternary / Tertiary

- Alluvium
- Tertiary basalt

Devonian

- Ungrouped Devonian Formations - Cunningham Formation

Silurian

- Mumbil Group (Northwest) - Anson Formation

Ordovician

- Cabonne Group - Blayney Volcanics
- Cabonne Group - Byng Volcanics

Uncertainty analysis modelled drawdown at end of mining

McPhillamys Gold Project
Groundwater assessment
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Figure 4.3

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\\emmsvr1\EMM\Jobs\2018\J180395 - Regis McPhillamys EIS\GIS\02_Maps_RTS_GW\RTSGW003_DrawdownUncertaintyMiningEnd_20200217_02.mxd 17/02/2020

4.3.2 Mass balance

Mass balance results at the end of mining for the base case and scenario S64 are presented in Table 4.8 and Table 4.9. As observed at the end of calibration (Table 4.5 to Table 4.7), river leakage and baseflow and evapotranspiration are lower in S64 than in the base case. This is thought to be due to lower groundwater elevations in low lying areas around watercourses and in areas that do not have monitoring bores, ie away from the mine development area, and therefore are not captured by the SRMS.

Each of the models report a very low mass balance error.

Table 4.8 Base case modelled water balance at the end of mine year 10

	Input (kL/day)	Output (kL/day)	Net (kL/day)
Storage	150	343	-193
General head boundaries	14,307	11,308	2,999
Rivers	14,440	5,203	9,237
Recharge	20,037	-	20,037
Evapotranspiration	-	31,172	-31,172
Drains	-	913	-913
TOTAL IN		48,934	
TOTAL OUT		48,938	
Error		-0.01%	

Table 4.9 S64 modelled water balance at the end of mine year 10

	Input (kL/day)	Output (kL/day)	Net (kL/day)
Storage	136	313	-177
General head boundaries	12,779	10,795	1,984
Rivers	10,366	3,470	6,895
Recharge	20,037	-	20,037
Evapotranspiration	-	27,849	-27,849
Drains	-	896	-895
TOTAL IN		43,318	
TOTAL OUT		43,322	
Error		-0.01%	

5 Summary

The Groundwater Assessment considered the potential risk of the project on the local environment, including assessing the potential range in hydrogeological properties (uncertainty analysis). The following provides a summary of the key points of the McPhillamys Groundwater Assessment, including the groundwater model:

- the model is fit for purpose;

- the Groundwater Assessment is appropriate for the low risk context and low productive aquifer;
- uncertainty analysis has been completed to assess the potential risk of the project from a hydrogeological perspective;
- the additional modelling has been performed to extend the reported uncertainty analysis, and all results are within previously identified upper and lower bounds reported in the Groundwater Assessment;
- the recently completed additional uncertainty assessments confirm that the Groundwater Assessment has adequately assessed the potential risk of the project on landholders and other sensitive receptors; and
- the approach for future improvements and revisions of the groundwater model will be documented in a Model Upgrade Plan, as requested for DPIE Water

6 Closing

EMM trust that the responses and additional information provided in this letter are satisfactory for the queries raised by DPIE’s expert reviewer JBS&G.

Yours sincerely

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Yours sincerely

Kate Holder
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7 References

Barnett et al., 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra

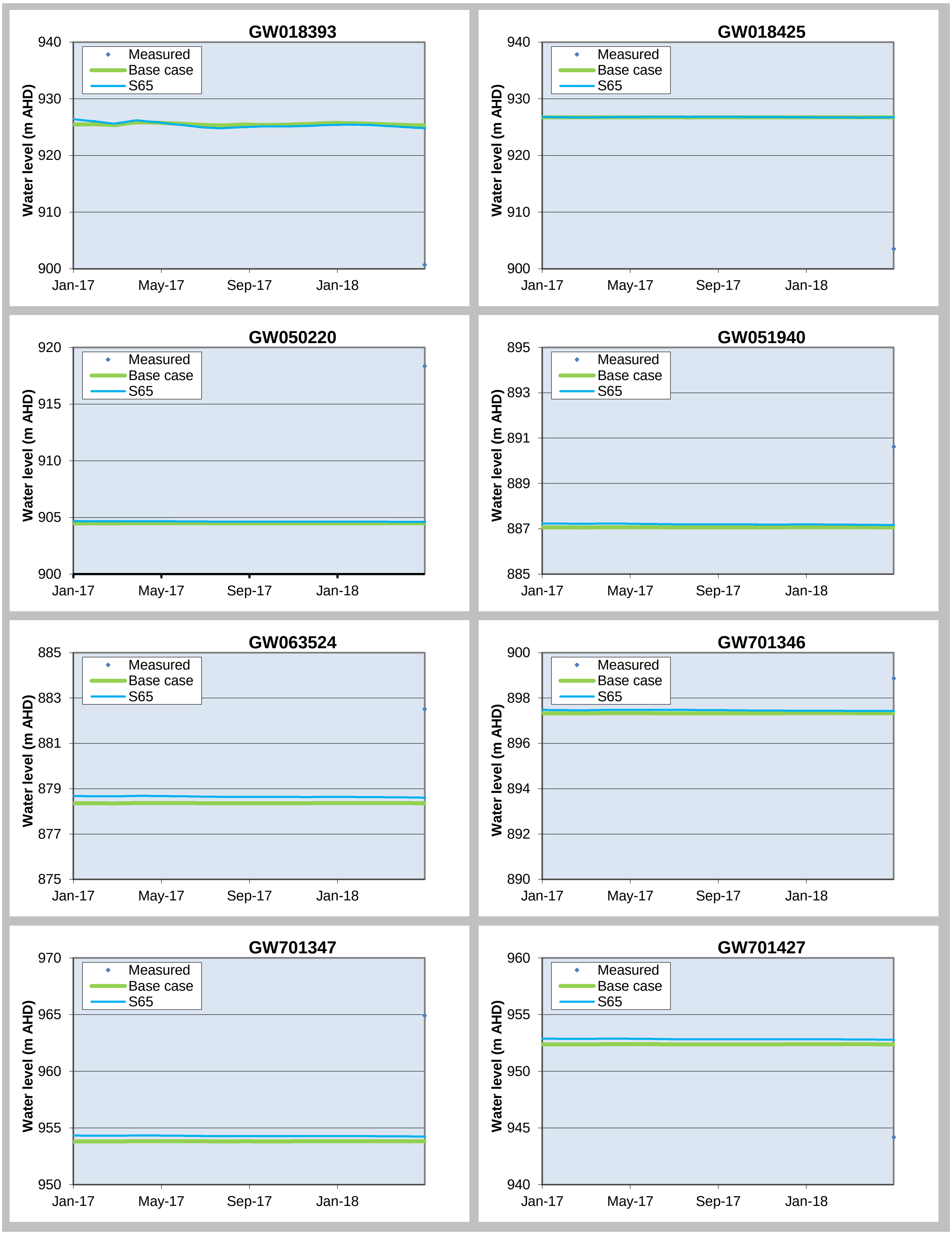
EMM 2019, McPhillamys Gold Project Environmental Impact Statement, prepared for LFB Resources NL, August 2019

JBS&G 2019, Review of Groundwater Assessment of EIS for McPhillamys Gold Project (SSD-9505), letter to NSW Department of Planning Industry and Environment, 5 December 2019

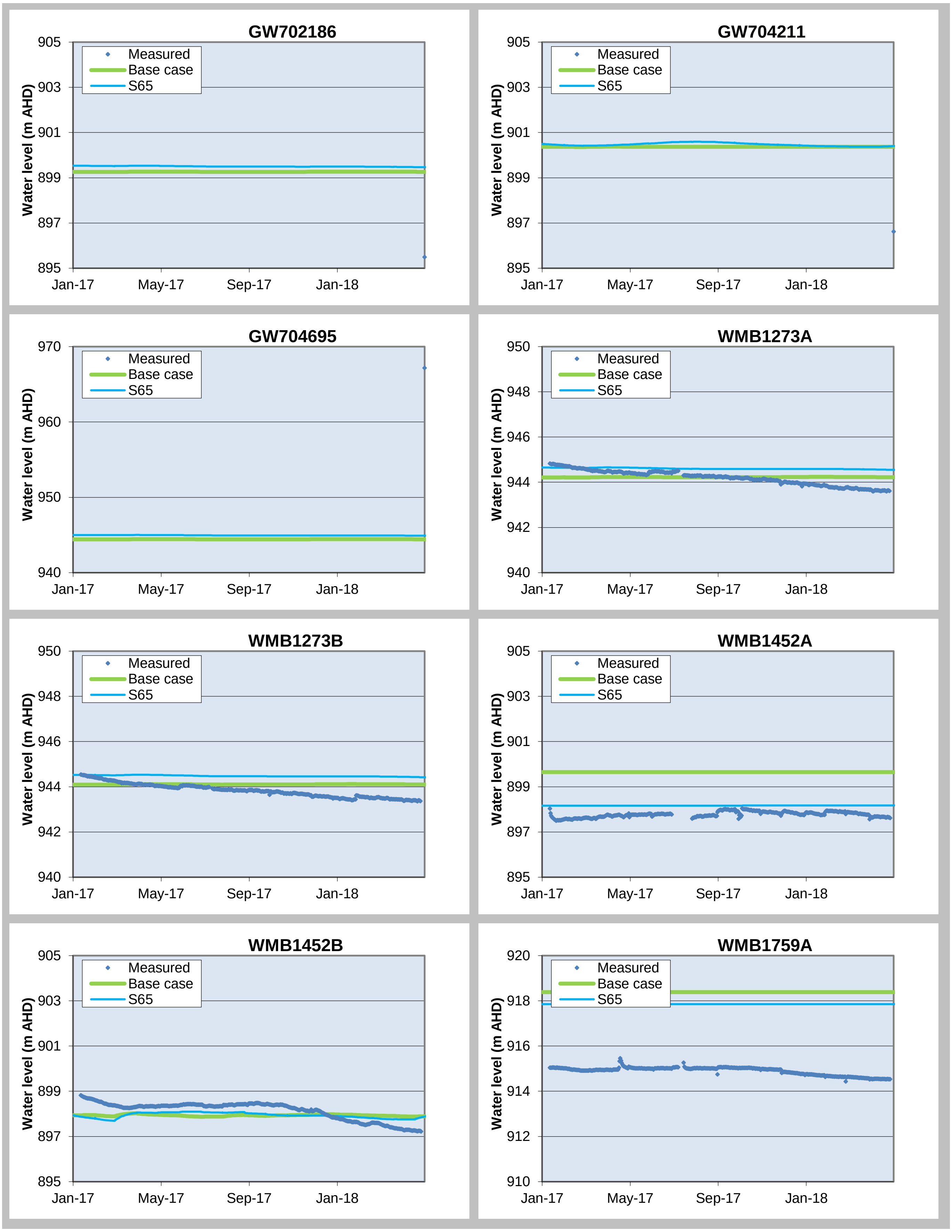
Weber, K., & Stewart, M. T. 2004, A Critical Analysis of the Cumulative Rainfall Departure Concept, Ground Water, vol 42 (6-7), pp 935-942

Appendix A

Base case and S65 modelled against measured hydrographs



Appendix A - Base case and S65 modelled against measured hydrographs



Appendix A - Base case and S65 modelled against measured hydrographs

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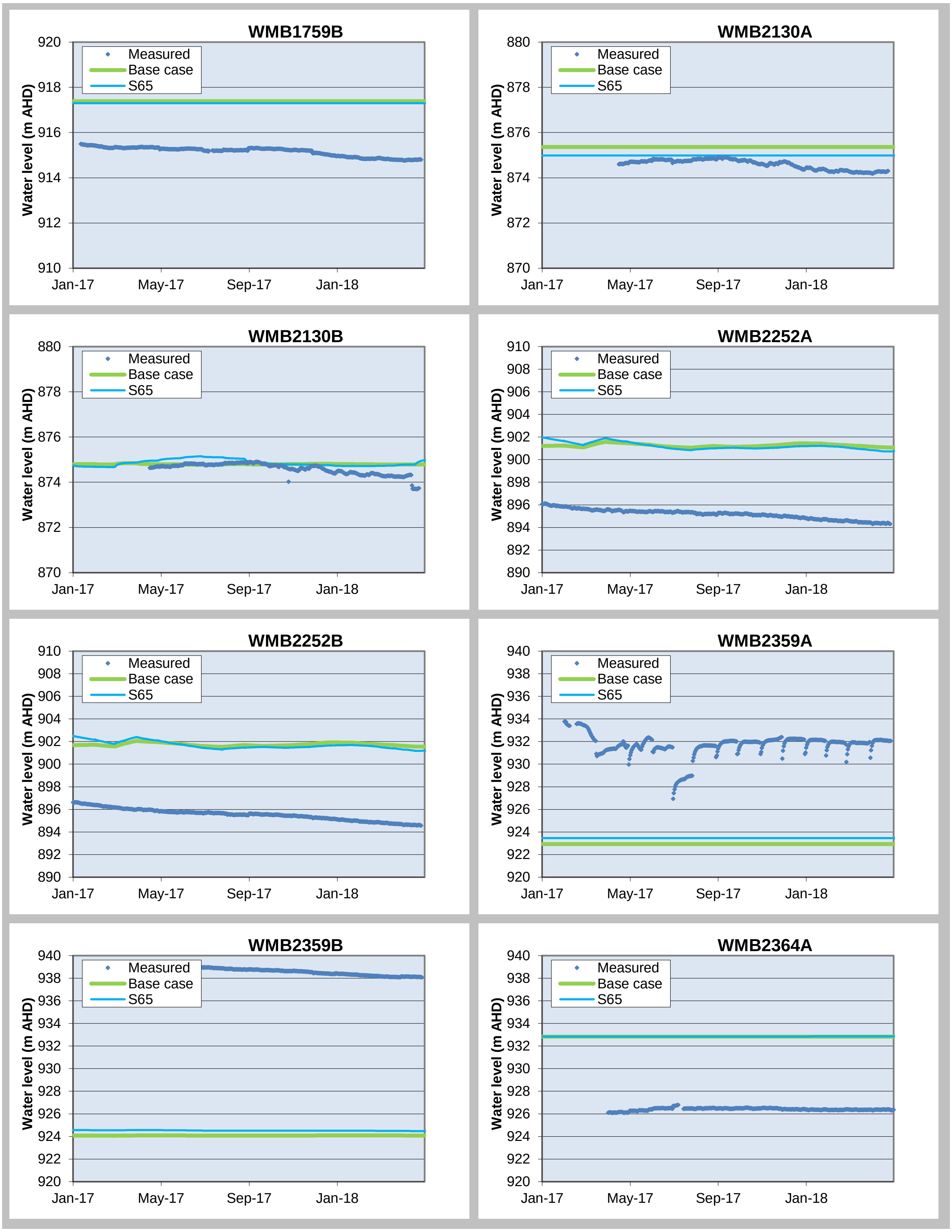
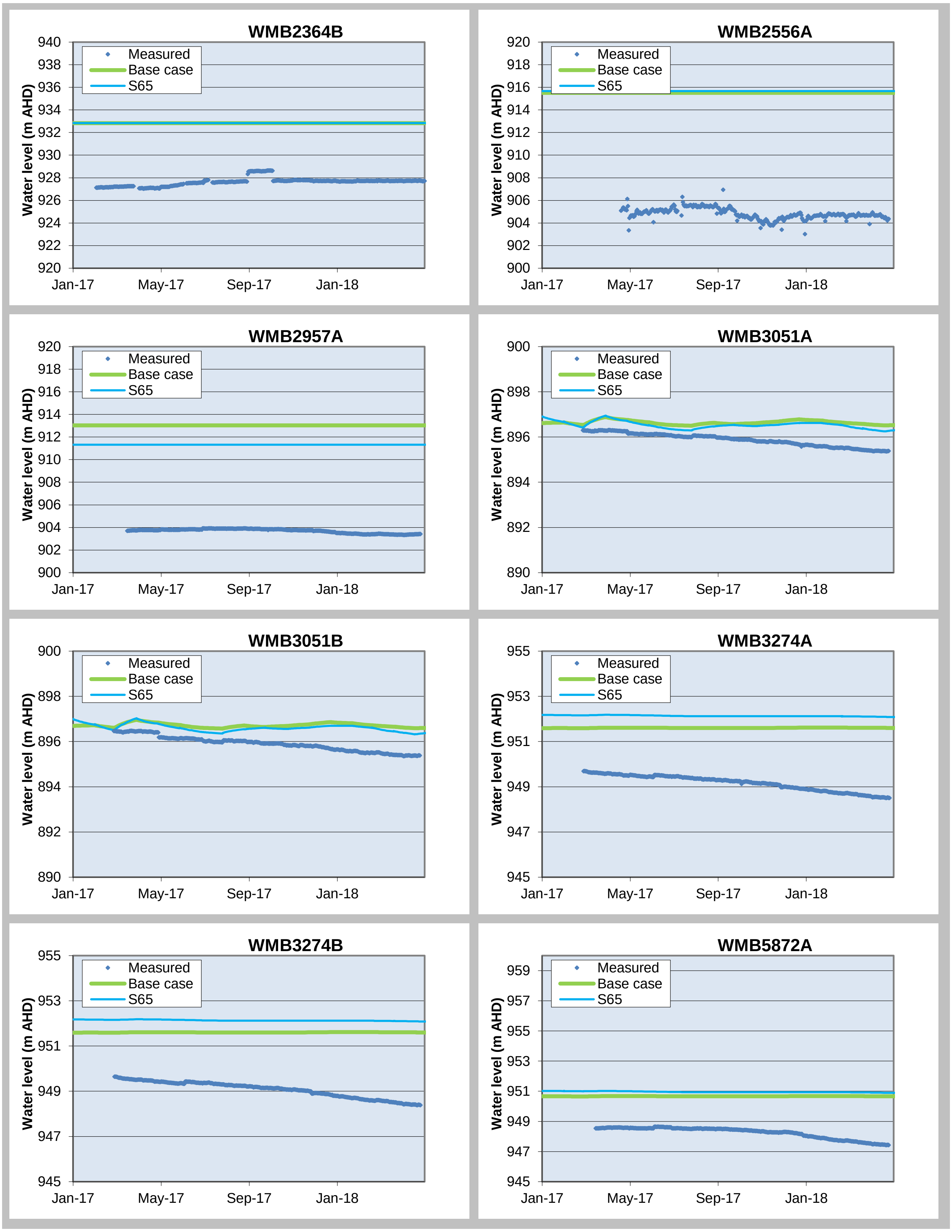


EMM

Appendix A - Base case and S65 modelled against measured hydrographs

T:\Jobs\2017\J17064 - McPhillamys water assessment\Technical studies\Groundwater\Modelling\Model output\MCPV1_tpred97\[MCPV1_tpred94_S65_hydrographs.xlsm]Fig3



Appendix A - Base case and S65 modelled against measured hydrographs

T:\Jobs\2017\J17064 - McPhillamys water assessment\Technical studies\Groundwater\Modelling\Model output\MCPV1_tpred97\[MCPV1_tpred94_S65_hydrographs.xlsm]Fig4

JBS&G57612-133875
L03Rev0_ReviewOfGroundwaterAssessment_AmendmentReport

9 December 2020

Mandana Mazaheri
Team Leader – Resources Assessments
NSW Department of Planning, Industry and Environment
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Via email: Mandana.Mazaheri@planning.nsw.gov.au

Review of Groundwater Assessment of McPhillamys Gold Project (SSD-9505) – Amendment Report

Dear Mandana,

1. Introduction

JBS&G Australia Pty Ltd (JBS&G) are currently engaged by the NSW Department of Planning, Industry and Environment (NSW DPIE) to provide expert review the Groundwater Assessment associated with the McPhillamys Gold Project (SSD-9505).

This letter presents JBS&G's review of the Groundwater Assessment Addendum prepared for the Amendment Report of the McPhillamys Gold Project (SSD-9505), namely:

- *McPhillamys Gold Project: Amendment Report - Groundwater Assessment Addendum by EMM (2020b)*.

JBS&G has also participated in a teleconference held on 9 December 2020 with the proponent, the proponent's hydrogeological consultant, the 3rd Party Groundwater Model Reviewer, Dr Hugh Middlemis as well as representatives from NSW DPIE.

JBS&G have previously provided review on the EIS for the McPhillamys Gold Project (SSD-9505) and that review was presented in JBS&G (2019, 2020).

The review presented in this letter has been prepared in accordance with JBS&G's proposal (Reference No. JBS&G57612-124871/P02Rev0, dated 19 October 2020) and agreed terms and conditions.

2. Review of Groundwater Assessment Addendum

Summary of Previous Work/Review

EMM (2019) concluded that groundwater impact due to the McPhillamys Gold Project (SSD-9505) were as follows (after EMM, 2019):

- Groundwater level drawdown extending to existing third-party users and impacting supply – minor
- Groundwater level drawdown affecting flow of the Belubula River – minor
- Reduced access to the water table for Mountain Gum – Manna Gum vegetation – minor
- Changes to spring flows as a result of the project – minor

- Seepage from the TSF migrating outside of the mine development area and affecting the water quality of the underlying groundwater and Belubula River – minor
- Changes in water quality at third-party bores – minor
- Seepage of leachate from the waste rock emplacement to the underlying water table – minor
- Water storages to lose water as seepage to the water table – minor
- Release of contaminants from storage of hazardous goods storage – minor.

JBS&G (2019) provided review of EMM (2019), and following several face-to-face responses as well as written responses from EMM (2020a), JBS&G finalised their review in JBS&G (2020).

Of note from JBS&G (2019, 2020) was a focus on transient calibration of the groundwater model, inclusion of groundwater users in the model, approach to springs and seeps in the model, investigation of the calibrated values of hydraulic properties adopted in the model including with respect to geologic structures, discussion of regional throughflow in the model, toe drainage in the waste rock dump as well as the approach to uncertainty analysis in the model.

As per JBS&G (2020), the matters raised were addressed or committed to a future revision of the groundwater model, as documented in EMM (2020a).

Summary of Project Amendments (Groundwater)

Since the time of the Environmental Impact Statement (EIS), there have been several amendments to the McPhillamys Gold Project (SSD-9505) to reduce the overall impact of the project. These amendments are presented in the following:

- *McPhillamys Gold Project: Amendment Report by EMM (2020b)*

From EMM (2020b), the amendments relate mainly to traffic and noise management. Of the water-related amendments (refer EMM, 2020b), there is a minor change in footprint of the Tailings Storage Facility (TSF), minor refinement to on-site water management infrastructure as well as refinement to the mine schedule.

Accordingly, JBS&G does not expect that the above amendments will lead to a substantial change to the conclusions of the Groundwater Assessment presented in EMM (2019, 2020a).

It is noted that JBS&G does not consider that the Pipeline component of the McPhillamys Gold Project (SSD-9505) is relevant with respect to groundwater impact and so has not been reviewed in detail.

Update to Groundwater Impacts

Mine Inflow and Pit Drawdown

As noted in EMM (2020b), the Amended Project will lead to a reduction in peak inflow to the open pit in Year 2 from 890ML/year (EIS) to 580ML/year (Amended Project).

EMM (2020b) present a summary of detailed outputs from the Groundwater Assessment Addendum (EMM, 2020c). From Figure 6.8 of EMM (2020b), the predicted drawdown in water table at the end of mining for the Amended Project is equivalent to that presented in the original EIS. From Figure 6.11 of EMM (2020b), the predicted water table elevation and groundwater flow direction post-mining for the Amended Project is equivalent to that presented in the original EIS.

Construction Water Supply

Construction water supply will be sourced from groundwater wells associated with the project rather than surface water supply. EMM (2020b) indicates that the extent of drawdown (analytical model) of the southern construction water supply (TPB4) is limited and should not lead to significant impact on Tributary E. For the northern construction water supply (TB05), whilst larger in terms of drawdown, it is in the vicinity of surface watercourses whose thalwegs are above the local water table level, hence the impact of that water supply on surface water flow should be minimal.

Surface Water / Groundwater Interaction

EMM (2020b) indicates that a surface water/groundwater interaction assessment was prepared. EMM indicate that the outcome of that assessment was that the Belubula River (from the top of the catchment to Blayney) receives the majority of its water from runoff, followed by direct rainfall on the watercourse and lastly from groundwater discharge (baseflow). EMM conclude that groundwater contribution is negligible at the very top of the catchment (surface water not connected to groundwater), to 5% contribution to flow and then 20% further downstream in the catchment. The above analysis is generally consistent with that put in the EIS (EMM, 2019).

As identified in JBS&G (2019,2020), and EMM (2019, 2020abc), surface water/groundwater is an important issue to the community and it is expected that surface water 'stream gauging' will be required as part of the conditions of project approval. JBS&G appreciates, however, that where watercourses are ephemeral, the water table level immediately adjacent the watercourse will need to be monitored as well, presumably as a nested piezometer pair (one piezometer in the alluvial/very near surface and another piezometer into the fractured rock immediately below).

As presented in EMM (2020b), the take from the Belubula River downstream of the confluence with Tributary A is negligible; however, there is a 5 to 15% change in groundwater contribution to surface water in various parts of the surface watercourse above that point. Modelling summarised in EMM (2020b) indicates that the Amended Project leads to a small reduction in impact to surface watercourses, with respect to reduction in groundwater contribution to surface water, compared to the EIS.

As noted in EMM (2020b), an approach has been developed to secure the surface water licenses for the project to proceed.

Pit Lake/Final Void

EMM (2020b) indicates that the final void will fill and become a groundwater sink. After 500 years, EMM (2020b) indicates that the 'pit lake' that is formed may transform into a throughflow pit, rather than a groundwater sink. EMM (2020b) indicates that predicted salinity in the pit lake will be 1600µS/cm after 1,000 years. As noted by EMM (2020b), a predicted salinity of that magnitude is within the range of current groundwater salinity.

Impact to Groundwater Users

EMM (2020b) indicates that groundwater levels at existing third-party water supply works will experience little to no change due to the project. As well, EMM indicate that the project is not anticipated to lead to a change in the beneficial use category of groundwater sources.

3. Recommendations

The Amended Project, as presented in EMM (2020b), is not significantly different from a groundwater point of view to that presented in the original EIS (EMM, 2019).

The following recommendations, as per JBS&G (2019, 2020), remain relevant for the Amended Project:

<u>Groundwater Model Class</u>

JBS&G notes EMM's (2020c) comment about an intention to refine the definition of model class. At present, the numerical groundwater model for the project is Class 1 in accordance with the Australian Groundwater Modelling Guidelines (Barnett et. al., 2012).

JBS&G acknowledges the comment in EMM (2020c) that the EMM and the third-party groundwater model reviewer both consider the project to be relatively low risk.

As per JBS&G (2019, 2020), it is recommended that the groundwater model continue to be developed to become a Class 2 equivalent model.

Given that a construction water supply is proposed to be now installed, an update to the calibration of the model from monitoring of the performance of that infrastructure is recommended.

As well, as per JBS&G (2020), "early pit inflow" is also recommended to be a trigger for a review of the calibration of the groundwater model.

Inclusion of Groundwater Users

As per JBS&G (2019, 2020), it is recommended that groundwater users be included in the groundwater model.

JBS&G accepts that groundwater extraction is limited in the vicinity of the project; however, as indicated by the analytical modelling undertaken in support of the construction water supply, it is considered helpful to confirm the parameterisation adopted in the numerical groundwater model is feasible.

This matter was discussed during the teleconference held on 9 December 2020.

Springs and Seeps

As noted in JBS&G (2020), JBS&G remain of the view that consideration should be given to a variably saturated flow approach to the groundwater model.

JBS&G accepts, however, that EMM (2020c) state that the numerical groundwater model is intended to only consider the impact to the regional water table due to the open cut pit. Given a single water table approach, the potential impacts to springs will need to be carefully monitored, as the model does not, by design, inform the expected impact to those springs.

This matter was discussed during the teleconference held on 9 December 2020.

4. References

Barnett B., Townley L.R., Post V., Evans R.E., Hunt R.J., Peeters L., Richardson S., Werner A.D., Knapton A. and A. Boronkay, 2012. *Australian Groundwater Modelling Guidelines - Waterlines Report Series No. 82*. National Water Commission, Canberra.

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EMM, 2020a. *McPhillamys Gold Project – response to expert review of the EIS groundwater assessment*. Consultant letter prepared by EMM Consulting Pty Ltd to the NSW Department of Planning, Industry and Environment. Reference No. J180395-RP1-v1, dated 21 February 2020.

EMM, 2020b. *McPhillamys Gold Project: Amendment Report – Groundwater Assessment Addendum*. Consultant report prepared by EMM Consulting Pty Ltd for LFB Resources NL. Reference No. J180395 GWA RP2, dated 24 August 2020.

EMM, 2020c. *McPhillamys Gold Project: Amendment Report*. Consultant report prepared by EMM Consulting Pty Ltd for LFB Resources NL. Reference No. J180395 RP10, dated 3 September 2020.

JBS&G, 2019. *Review of Groundwater Assessment of EIS for McPhillamys Gold Project (SSD-9505).* Consultant letter prepared by JBS&G Australia Pty Ltd for the NSW Department of Planning, Industry and Environment. Reference No. JBS&G57612-125740 Rev0, dated 5 December 2019.

JBS&G, 2020. *Review of Groundwater Assessment of EIS for McPhillamys Gold Project (SSD-9505).* Consultant letter prepared by JBS&G Australia Pty Ltd for the NSW Department of Planning, Industry and Environment. Reference No. JBS&G57612-127909 Rev0, dated 3 March 2020.

5. Closing

Should you require clarification, please contact the undersigned on 02 8245 0313 or by email jbell@jbsg.com.au.

Yours sincerely:

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21 December 2020

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NSW Department of Planning, Industry and Environment
Mandana.Mazaheri@planning.nsw.gov.au

Re: McPhillamys Gold Project (SSD-9505) – response to expert review of the Amendment Report Groundwater Assessment Addendum

Dear Mandana,

1 Introduction

EMM Consulting Pty Limited (EMM) was engaged by Regis Resources Limited (Regis) to assess the potential impacts of the proposed McPhillamys Gold Project (SSD-9505) (the project) on groundwater resources and associated receptors in the area of the project. An environmental impact statement (EIS) was prepared for the mine development (EMM 2019a), followed by a report responding to submissions on the EIS (Submissions Report; EMM 2020a) and a project amendment report (Amendment Report; EMM 2020b).

The EIS and Amendment Report include groundwater assessments also prepared by EMM (EMM 2019b and EMM 2020c). A numerical groundwater flow model was developed to assess the potential changes to groundwater flow and levels in the project area due to mining at the project open cut and tailings placement. The groundwater model (and assessment) was reviewed by Hugh Middlemis of HydroGeoLogic Pty Ltd who concluded that the model is "fit for the purpose of mine dewatering environmental impact assessment and informing management strategies and licensing". The NSW Department of Planning, Industry and Environment (DPIE) have engaged Dr Justin Bell of JBS&G Australia Pty Ltd (JBS&G) to provide an independent review of the groundwater assessments.

JBS&G provided a review of the groundwater assessment completed for the EIS (JBS&G 2019), which EMM responded to in 2020 (EMM 2020d). JBS&G conducted an additional review of the Groundwater Assessment Addendum completed for the Amendment Report (EMM 2020c). A meeting was held on 9 December 2020 between DPIE, JBS&G, EMM, Regis representatives and Mr Middlemis to discuss Dr Bell's review. This letter provides a response to the review completed by JBS&G (JBS&G 2020).

2 Response

2.1 Overview

The JBS&G (2020) review provided recommendations on the groundwater model under three headings:

1. **Groundwater model class** – recommendation that the groundwater model is developed into a Class 2 model by incorporating monitoring data from the operation of the construction water supply, as well as use of monitoring data collected during the early stages of mine dewatering ("early pit inflow") in the model history matching (calibration).

2. **Inclusion of groundwater users** – recommendation that third-party groundwater users are included in the groundwater model to confirm the parameterisation adopted in the groundwater model is feasible.

3. **Springs and seeps** – recommendation that consideration be given to a variably saturated flow approach to the groundwater model (to facilitate the inclusion of springs and seeps) and the monitoring program for the project include monitoring at identified springs (outside of the project disturbance area).

These recommendations have been considered with responses provided in the following sections.

2.2 Groundwater model class

As outlined in the Groundwater Assessment Addendum (EMM 2020c) and EMM's response to the 2019 review by JBS&G (EMM 2020d), the groundwater model has been assessed as meeting the requirements of a Class 1 confidence-level classification (with elements of Class 2 and 3) in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al 2012).

JBS&G (2020) recommended that:

- the groundwater model continues to be developed to a Class 2 equivalent model;
- monitoring of the performance of the construction water supply operation (pumping rates and groundwater level monitoring) be used in model history matching; and
- "early pit inflow" as a trigger for a review of the groundwater model history matching.

As outlined in the Submissions Report (2020a) and EMM 2020d, Regis has committed to reviewing and refining the model as additional baseline monitoring data becomes available, including data that illustrates groundwater responses to the development. As mining progresses, a need for further model updates will be assessed every two years based on evaluation of groundwater monitoring data and findings of impact verification. Regis will apply the adaptive management approach to all environmental related aspects of the project, including assessing groundwater-related impacts.

Upgrades to the model using additional data and measured responses to stresses will result in the model predictions becoming more accurate over time, and the model classification will increase accordingly, consistent with the modelling guidelines (Barnett et al 2012).

Whilst the Submissions Report (EMM 2020a) and Groundwater Assessment Addendum (EMM 2020c) did not explicitly refer to use of monitoring data collected during the operation of production bores used to meet construction water supply requirements in future history matching, Regis is committed to using all available monitoring data as part of future model reviews.

2.3 Inclusion of groundwater users

JBS&G (2020) recommended groundwater users are included in the groundwater model to confirm the parameterisation adopted in the groundwater model is feasible.

As discussed on 9 December 2020 and in Regis' response to JBS&G's 2019 review, groundwater use in the vicinity of the project is expected to be very low, due to the low productivity of the geology in the area, as evident in the minimal active groundwater licences in the area. The majority of groundwater use in the study area is for stock and domestic purposes, with low, infrequent, and unmonitored extraction. There is minimal data available regarding pumping rates, bore lithology, screened interval for pumping bores and there is no observation data available on the drawdown effects of any local pumping to enhance model calibration.

The predictive groundwater model calculates drawdown with respect to a 'null case' scenario without mining activities; a best practice method for quantifying dewatering effects whether or not other common and minor extraction is included or excluded (Barnett et al 2012). Therefore, inclusion of groundwater use in the model is not considered necessary due to these factors and increased data uncertainty would be invoked by the range of assumptions necessary to include local extraction.

As outlined in the Australian Groundwater Modelling Guidelines (Barnett et al 2012), it is never possible for one model to answer all questions on groundwater behaviour. Section 2.2 of the guidelines state:

> …a model designed to simulate regional-scale groundwater flow cannot be expected to predict local-scale groundwater processes… Similarly, a local-scale model of impacts of pumping at a single well cannot be extrapolated to predict the drawdown due to development of an extensive borefield in a heterogeneous aquifer.

The McPhillamys groundwater model is designed for regional scale impact assessment, not to simulate local-scale changes in hydrogeological properties such as fractures, faults or shear zones that govern stock and domestic bore yields. The equivalent porous medium approach has been adopted for the groundwater model. That is, at a regional scale and the scale of this project, groundwater flow in the fractured rock aquifer arising from project-scale activities can be represented using porous media methods, consistent with the modelling guidelines (Barnett et al. 2012). The model mesh was designed to allow simulation of project scale groundwater affecting activities (eg pit development and the tailings storage facility (TSF)) and watercourses. Model cell spacing is set at 200 m regionally and is refined to 25 m in the mine development area and at main watercourses.

In regard to the parameterisation used in the groundwater model, EMM completed predictive uncertainty analysis as part of the Groundwater Assessment (EMM 2019b). This analysis allowed assessment of the potential impacts of the project across a range of hydrogeological properties that are considered conceptually plausible for the project area. As discussed on 29 January 2020 and reported in EMM 2020d, the uncertainty analysis considered:

- hydraulic conductivity of the weathered Byng Volcanics (saprock) in isolation of other units (up and down);
- hydraulic conductivity of the fresh Byng Volcanics in isolation of other units (up and down);
- hydraulic conductivity of all the weathered rock units (up and down);
- hydraulic conductivity of all fresh rock units (up and down);
- specific yield of all weathered rock units (up and down);
- specific storage of all fresh rock units (up and down);
- river stage elevation, 'dry watercourse' scenario; and
- a gradual reduction in hydraulic conductivity with depth (ie rather than a change in hydraulic conductivity from layer 1 to 2, the reduction was simulated over layers 1, 2 and 3).

Based on the explanation above, inclusion of abstraction at third-party bores in the groundwater model is not considered necessary for the assessment of the project. The reasons for this include:

- identified groundwater users are local landholders who pump negligible volumes of groundwater intermittently;
- groundwater users access secondary porosity associated with local geological anomalies not simulated in the groundwater model (not significant for the assessment of potential groundwater impacts);

- the model grid (discretisation) is not suitably refined in the vicinity of groundwater users;
- predictive uncertainty analysis has been completed to assess the potential risk of the project from a hydrogeological perspective;
- the numerical model is designed to assess regional impacts; and
- abstraction rates and schedules for groundwater users are unknown and therefore inclusion would result in increased uncertainty.

2.4 Springs and seeps

JBS&G (2020) advises that consideration be given to a variably saturated flow approach to the groundwater model. JBS&G (2020) noted that under the current modelling approach, "the potential impacts to springs will need to be carefully monitored, as the model does not, by design, inform the expected impact to those springs."

As discussed on 9 December 2020, the topic of springs and seeps, and the potential impacts that the mine development may have was a common concern of community members, in particular neighbours downstream of the proposed development. Open days that were held prior to and after the submission of the EIS focussed on the potential impacts of the mine development on surface water and groundwater, in particular springs and seeps. There was a wide variation in terms of understanding of how springs originate and operate and what impacts them. Regis recognises the value of springs to the local landholders and to the local and regional environment. This is why Regis has undertaken several specialist studies prior to and since the submission of the EIS to specifically understand and explain the springs and seeps within the mine development and the greater catchment. The surface water – groundwater interaction assessment report (Appendix C to the Submissions Report; EMM 2020a) was developed specifically to provide an update and additional detail to the information presented in the EIS on the local groundwater and surface water environment.

As outlined above and in EMM's response to JBS&G (2019), the groundwater model is designed to assess potential groundwater impacts on a regional scale and is not designed to simulate small-scale local flow. The springs were not simulated in the groundwater model based on the conceptualisation and objective and scale of the groundwater model. EMM and Regis believe that revisions to the groundwater model on this aspect are not required.

As documented in the various approval documentation (eg Submissions Report and Amendment Report), Regis is committed to developing a water monitoring program that will allow the monitoring and early identification of potential impacts on groundwater receptors. This includes streamflow monitoring that will allow estimation of baseflow contribution to the Belubula River and groundwater level monitoring at targeted locations within the mine development area. Groundwater monitoring bores will be installed as part of the project development, with locations to be finalised based on access, health, safety and environmental considerations. Zones where monitoring bores will be installed have been identified and are categorised based on the typical Source-Pathway-Receptor approach:

- Monitoring near a source (eg open cut, TSF) - bores associated with potential sources of impact and will be used for diagnostic /information purposes to understand source water quality and levels (heads and flows) and potential for downgradient changes. Changes to groundwater quality and /or quantity (levels) will be observed at these locations in advance of other monitoring locations.
- Pathway monitoring - monitoring bores located downgradient of a source and within the pathway between the source and receptor. That is, for a water affecting activity to result in a change in quality or quantity at a receptor, there must be a pathway between the source and the receptor (eg hydraulic gradient driving the movement of water).

Monitoring will involve assessment of trends within the groundwater flow path and as the bore is located downgradient from the potential source, it acts as an early warning to identify unexpected changes that have the potential to affect receptors.

- Receptor monitoring - these monitoring bores are typically located within close proximity to identified receptors (eg third-party bores, springs/seeps, watercourses) and are outside of the predicted area of influence of mining activities. Groundwater monitoring data provides information on groundwater conditions at receptor locations and is used for compliance monitoring.

The planned monitoring locations will include nested monitoring bores in targeted areas, as described above. Existing nested monitoring bores will be utilised for monitoring where possible, including existing third-party bores that are currently included in Regis' monitoring program. Regis will identify seeps/springs outside of the disturbance area for monitoring purposes, including installation of nested monitoring bores in these areas. Final locations of the monitoring network will be determined in consultation with EPA, NRAR and DPIE-Water.

3 Closing

EMM appreciate the feedback and advice of DPIE's expert reviewer JBS&G; however, the groundwater model has been objectively assessed as fit for purpose by EMM and HydroGeoLogic for the assessment of potential impacts on groundwater resources, given the low productive aquifer and low risk context.

Regis has committed to reviewing and refining the model as additional baseline monitoring data becomes available. Regis will apply the adaptive management approach to all environmental related aspects of the project, including assessing groundwater-related impacts. Regis is also committed to developing a water monitoring program that will allow the monitoring and early identification of potential impacts on groundwater receptors.

EMM trust that the responses provided in this letter are satisfactory for the queries raised by DPIE's expert reviewer JBS&G.

Yours sincerely

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