Jacobs

Memorandum

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Subject	**Response to HydroGeoLogic Groundwater Review**	**Project Name**	Bowdens Silver Project
Attention	Paul Ryal (RWC)	**Project No.**	IA132500
From	Greg Sheppard		
Date	15 December 2021		

1. Introduction

The following Memo provides a response to review comments provided by HydroGeoLogic on behalf of the NSW Department of Planning Industry and Environment, of the Bowdens Silver Updated Groundwater Assessment. The review is dated 12 July 2021.

Responses to the matters raised by HydroGeoLogic are provided in Section 2. In addition, the project groundwater assessment and modelling report has been updated to reflect review comments with a registry of these responses provided as Section 3.

Generally, it is noted that the review is mostly favourable, and with respect to the groundwater model compliance checklist of the Australian Groundwater Modelling Guidelines, the review found that:

- the model objectives and model confidence level classification are clearly stated, Class 2 model confidence level is justified, with some elements of Class 3, confirming its fitness for the investigative modelling purpose,
- the model objectives are satisfied,
- the conceptual model is consistent with the model objectives and confidence level,
- the conceptual model is based on all available data, presented clearly and reviewed by an appropriate reviewer,
- the model design conforms to best practice,
- the model calibration is largely satisfactory,
- the calibrated parameter values and estimated fluxes are plausible,
- the model predictions generally conform to best practice, however the reviewer did not agree with the interpretation of post mining final void results, which has potential flow-on effects of the assessment of Level 1 Minimal Impact Considerations of the Aquifer Interference Policy,
- the uncertainty associated with the simulations/predictions is reported, and
- most importantly, the model is fit for purpose.

Further discussion on model calibration and the interpretation of post mining final void results are provided in the following sections.

2. Response to issues raised

Issues raised in the review generally fall into one of two categories, these being either technical issues with the analysis, interpretation or presentation of data, or critique of the style, content or presentation of the report.

Issues of a technical nature are deemed to be of a higher priority to address and are discussed first in Section 2.1 and Section 2.2. Issues of lower priority are then addressed in Section 2.3.

2.1 Model calibration

Issue

The Bowdens model calibration performance is adequate (but not 'reasonably good' or 'very good' as is reported).

The TMR Figure 22 scatter plot shows that the range of heads in the Bowdens sub-area is much less at about 100m, which would result in a scaled RMS of around the nominal guideline value of 5% if the RMS was about 5m for this data subset (the RMS for this sub-area is not reported, but the overall standard deviation is stated as 8m).

The Bowdens sub-area is actually the key area where very good model performance is required for mine dewatering impact assessment purposes, and while the scatter plot (TMR Figure 22) shows most residuals within ±10m, residuals at two bores exceed 10m and one exceeds 20m. The question of whether the model performance is 'very good' where it needs to be, in the Bowdens mining area, is not comprehensively answered by the reports.

Response

This criticism is accepted. It is, however, maintained that the model calibration is at least "reasonably good" considering the regional nature of the model, the historical regional data sets, and lack of bore specific abstraction data. Descriptions of model calibration as being "good" have been modified and or qualified in the report. Additional discussion has also been provided in the reporting.

Stock and domestic bores, which comprise the bulk of the regional data set, are not required to report abstracted volumes. In the absence of reported abstraction rates, all stock and domestic bores within the model domain were assigned a nominal rate of 2ML/year. This annual volume was evenly distributed throughout the year in monthly increments. Similarly, those registered bores with relevant works approvals and a water access licence were assumed to abstract the full licenced volume over the course of the year. In this respect the model has potential to underpredict water levels when pumping is applied at a calibration target that is either not used or is pumping less than the stock and domestic entitlement, or conversely, may overpredict water level if a bore is being used at rates in excess of the entitlement.

It is noted that the magnitude of residuals and therefore the calibration statistics could have been significantly reduced if pumping rates had been varied individually rather than assigning uniform abstraction to all bores. However, this level of finessing was not considered warranted without site specific abstraction data to support it, and would have made negligible difference given the balanced nature of the calibration.

There are five water level calibration targets with calibration residuals in excess of 10m in the Bowdens mining area, these are summarised on **Table 2.1Error! Reference source not found.**.

Table 2.1: Mine site calibration residuals >10m

Bore	Residual[1]	Comment
BGW23	23.1	Private bore subject to basic landholder rights assumed to abstract 2 ML per year
BGW27	-16.4	Site monitoring bore
BGW31	10.2	Private bore subject to basic landholder rights assumed to abstract 2 ML per year
BGW33	23.9	Private bore subject to basic landholder rights assumed to abstract 2 ML per year
BGW42	12.8	Site monitoring bore
Note: [1] – Positive residual indicates model underpredicts water level, negative residual indicates model overpredicts water level		

It is noted that three of the calibration targets identified in **Table 2.1** (BGW23, BGW31 and BGW33) are privately owned bores, assumed to be subject to groundwater extraction under basic landholder rights and the discrepancy is likely due to the mismatch between modelled and actual extraction rates, and that a better fit would be obtained if the pumping was turned off.

The remaining two calibration targets with residuals in excess of 10 m are mine site monitoring bores BGW27 and BGW42 that were installed as part of the 2013 monitoring network installation (Section 4.5.7 of the Updated Groundwater Assessment).

BGW27 is located south of the pit, drilled to a depth of 90 m and screened from 58 to 70 m within the Coomber Formation. Groundwater elevations at BGW27 are over predicted by 16.4 m. This water level is more consistent with nearby alluvial monitoring bore BGW28. The model approach is conservative in that it assumes a continuous hydraulic connection at this location between the alluvial and hardrock aquifers, whereas monitoring data indicates that at this location they are disconnected.

BGW42 is located north of the pit, drilled to 120 m and screened over two intervals: from 36 to 42 m, and from 108 to 114 m within the Rylstone Volcanics. Water levels at BGW42 are underpredicted by 12.8m. The calibration target at BGW42 is solely assigned to layer 5, whereas the actual bore is screened over two intervals in an area of groundwater recharge (i.e. with a net downward gradient). Therefore, in reality the actual water levels in this bore represent a composite of the two screened intervals. In this context the underpredicted water level is considered to be reasonable.

While residuals associates with these bores may detract from the statistical performance of the calibration, they have no material effect on model reliability of predictive outcomes.

Issue

The question of whether the model performance is 'very good' where it needs to be, in the Bowdens mining area, is not comprehensively answered by the reports.

Response

Considerable time and effort was spent on achieving a good calibration in the mining area. A key component of this calibration effort was in matching the observed water level response at bore BGW108, which is situated in-pit, during a period of continuous pumping from late 2013 and early 2014.

Figure 26a of the Updated Groundwater Assessment, reproduced below as **Figure 1**, illustrates the observed drawdown and recovery response for this bore during the period of pumping. The response is also observed at BGW102, BGW106, and BGW107**. Figure 2** below presents the results of transient calibration for BGW108. This figure is included in the reporting and clearly shows a good match between the model results and the observed fluctuation at BGW108, demonstrating that the model is suitably calibrated in the Bowden mining area.

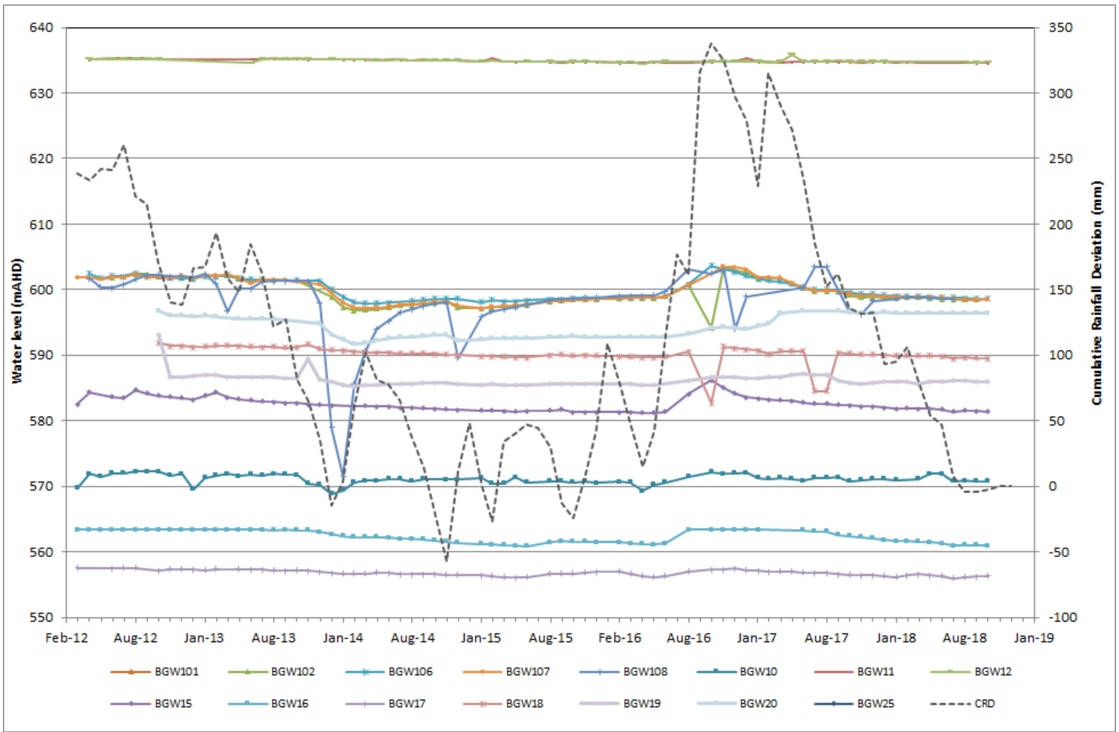

Figure 1: BGW108 pumping response (Figure 26a of the Amended Groundwater Report)

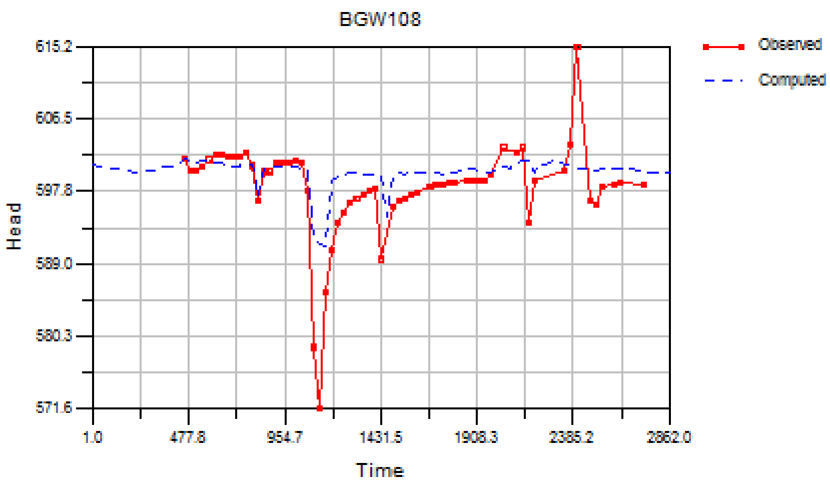

Figure 2: BGW108 head matching (from Figure 25 of the TMR)

Issue

Other measures of calibration performance assessment are presented, and this review considers them to indicate adequate but not good performance as such (i.e. adequate given the moderately low risk context; see section 3.2 above). For example, the scatter plot of residuals (TMR Figure 23 and related Table 10) show minimum and maximum residuals of -17m and +24m (standard deviation of about 8m) across the domain in a sparse pattern.

Response

The fact that there is no distinct patterning of residuals supports the assertion that the model is well calibrated. A lack of residual patterning indicates there is no systematic error or bias inherent in the modelling and is indicative of sound conceptualisation and representation of the groundwater system within the model. Random residual outliers are considered more indicative of the regional data sets utilised and the necessity to apply a compilation of water levels, potentially spanning across decades of groundwater measurements. Further, as noted above, there was also a necessity to incorporate regional groundwater extraction for basic landholder rights bores and licenced water use without knowing the rates or patterns of groundwater usage. This in itself can introduce potential for significant differences between simulated and observed water levels.

2.2 Final Void

Issue

The maximum extent of drawdown impact does not occur by 16 to 50 years post-mining (UGA section 6.2.4), as other results indicate that time frame should be about 150 years (UGA Figure 48);

Response

Section 6.2.4 of the Updated Groundwater Assessment discusses post mining water level recovery. As stated in this report, the cone of drawdown is predicted to approach its maximum extent 16 years post closure with further minor increases occurring until approximately 50 years post closure.

The assessment as presented in the Amended Groundwater Assessment still stands. The maximum extent of drawdown propagation and the equilibration of the final pit lake are not necessarily contemporary occurrences. The cone of drawdown will expand until the rate of groundwater inflow from the perimeter of the cone of drawdown, plus any recharge within the area of the cone of drawdown is equal to the rate of groundwater extraction. Depending on formation hydraulic properties and rate of recharge there is potential for this to occur during mining, at the end of mining or shortly after cessation of mining, as is the case for Bowdens.

The reviewer is suggesting that the maximum extent of drawdown would correspond with pit lake equilibrium, when in fact the cone of drawdown would diminish in area and volume at pit lake equilibrium.

Figure 3 shows the extent of drawdown propagation during and after mining and **Figure 4** presents the area encompassed by the 1m drawdown contour. It is noted that **Figure 4** is in Years from commencement of mining, so 50 years post mining is plotted at Year 66, and so on. As can be seen from **Figure 3**, the maximum extent of propagation is around 50 year post mining, with minor contraction of the 1m contour at 100 and 200 years post mining. Importantly, with respect to potential impacts to other groundwater users or sensitive environmental receptors, no additional impacts will occur post 50 years of mining that are not already captured by the impact assessment.

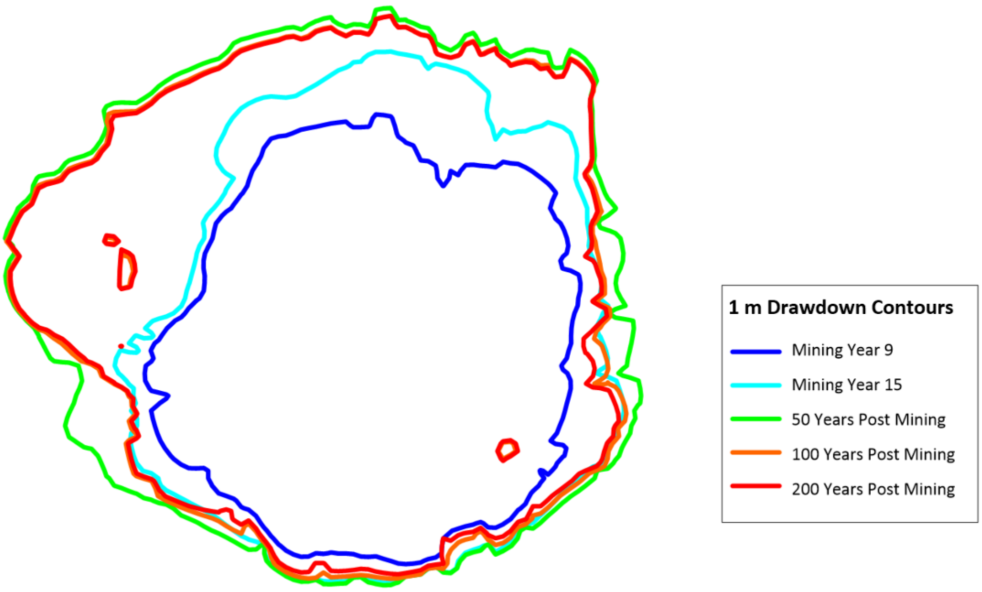

Figure 3: Extent of drawdown propagation (1m contour)

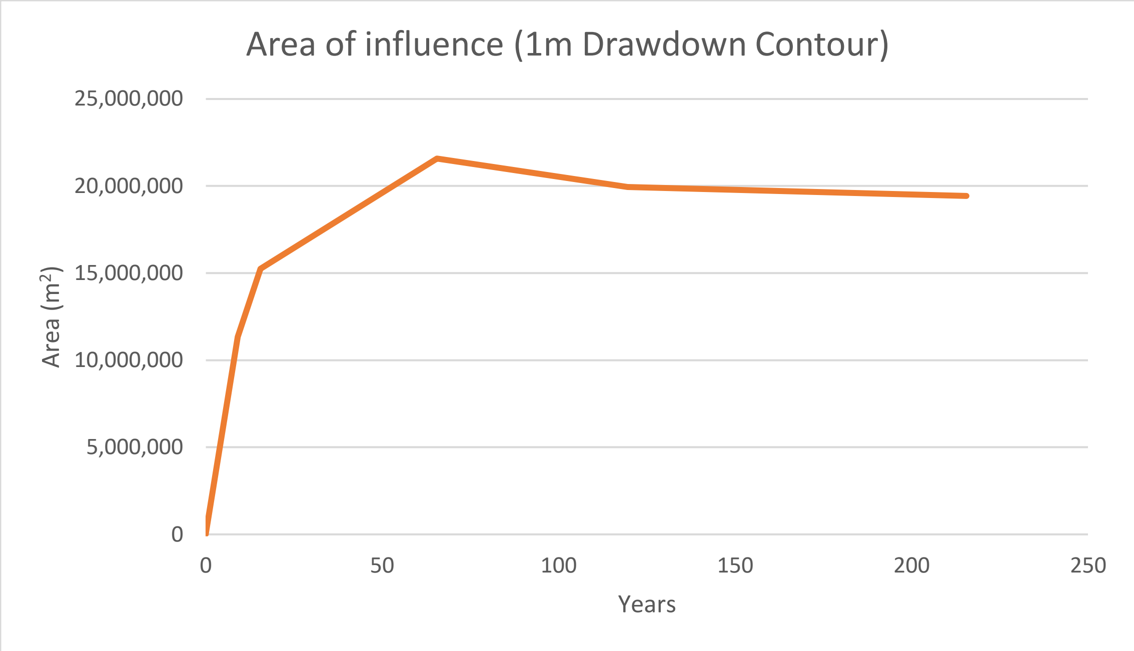

Figure 4: Area of influence (1m contour)

It is noted that the arguments and drawdowns presented above are for the mine dewatering scenario as presented in the Amended Groundwater Report as reviewed by HydroGeoLogic. The model and reporting has subsequently been updated to include advance dewatering via dewatering bores and presents revised extents of drawdown.

Issue

The final void lake is not a 'partial groundwater sink', as the evidence indicates that there is inflow and outflow, so it is a throughflow system, not a sink at all.

The water table contours (TMR Figure 39) show that the final void lake does not remain as a groundwater sink. The description of a 'partial groundwater sink' is nonsense, and is not consistent with the evidence presented.

Response

In groundwater terminology a feature that results in flux of water in-to or out-of a groundwater system is termed either a "source" (positive flux) or "sink" (negative flux). It is noted that the term "terminal sink", in the context of the references cited [McCullough and Schultze (2015), Johnson and Wright (2003), Commander, Mills and Waterhouse (1994)], refers to a mine void in which equilibrium water levels are below the surrounding water table and as such all local groundwater flow is towards the pit.

The term "partial groundwater sink" was used as qualifier to note that the final void it is not a "complete" or "terminal" groundwater sink. There is also no full post-mining recovery and residual drawdown remains due to pit evaporative losses. As such, there is a component of ongoing water take and continuous flux out of the system i.e. a "sink".

However, following from the review, the groundwater model has been revised to incorporate updates to the final void water balance modelling (WRM, 2021[1]) that incorporates updated modelling of inputs (rainfall runoff) and outputs (evaporation) to establish a new pit lake equilibrium level. The revised groundwater modelling now demonstrates that the final void will act as a terminal groundwater sink under the scenario of continuing average climatic conditions and under future climate change scenarios. This has been updated in the revised report.

It is noted that this confirmation of the final void as a terminal groundwater sink, negates comments regarding "*inadequate assessment of impacts that may arise from the final void throughflow conditions*", as being a terminal sink, there is no groundwater throughflow and therefore no potential impacts to downstream receptors such as Hawkins Creek.

2.3 Other issues

Issue - Geological layering at Bowdens site

These figures show considerable layer deviations at the mine site, but there is no commentary provided to justify this representation as reasonably representing the geological system.

The Submissions report and Updated Groundwater Assessment ('UGA'; Jacobs 2021a) does not present any additional explanation, despite this issue being raised by the initial review as requiring corrective action.

"The perturbations to regional geological layering are left over from the early construction of the groundwater model prior to confirmation of the final mine design. The layering was to allow for simplification and versatility if an expansion of the preliminary mine design was to be adopted. It is noted that due to the adopted parameter zonation in the mining area, the perturbations are of little consequence to predictions of mine dewatering or associated groundwater drawdown and impacts."

This is yet another example of the basic report documentation presented, in that the model report itself (which does not include the memo or its narrative) lacks an adequate explanation or justification for something as fundamental as the model layer structure in the mine area.

This reviewer is left to conclude that the proponent and/or its consultant is willing to risk an adverse peer review finding by not adequately addressing a specific issue \61.099.2\ Middlemis_2020_Bowdens_review_v2.docx 10 previously raised. This reviewer considers such an approach to be unprofessional, and notes that many such documentation issues were also raised by DPIE Water (these are set out in UGA Annexure 11). Having said that, it is not unreasonable to apply experienced judgement in this case and to speculate, for peer review purposes, and with an understanding of the moderately low risk context (see previous section), that if corrective action were taken to improve the melding of the regional data on aquifer layering with the local mine area data, it would probably not materially affect the model performance or predictions. Such speculation should not be needed in order to provide review advice to the DPIE or to evaluate the adequacy of the groundwater assessment.

[1] WRM, 2021. Bowdens Silver Final Void – Modelled void lake water levels under representative climate change conditions. Memorandum prepared for RW Corkery and Company by WRM Water and Environment. Reference 1356-05-C1. 24 September 2021.

Response

The groundwater assessment and groundwater modelling reports have been updated to reflect the response provided to the initial review comments.

It is further noted that the groundwater model is expected to be updated post approval and nominally 2 years after mining has progressed below the water table. This will allow for calibration of the model to observed inflows, and dewatering and depressurisation responses.

Future updates are likely to include revision to the model grid, most likely the adoption of nested grids with quadtree refinement. This would also allow an opportunity to refine model layering within the mining area to better reflect geological conditions. Bowdens Silver have now developed a Leapfrog three-dimensional geological model over the mining area and future model updates would utilise the geological model to refine model layering in the vicinity of the mine.

Issue - Evapotranspiration

ET rate was included in the uncertainty analysis, confirming low sensitivity in relation to mine inflows (Jacobs 2021a, Figure 42). Regarding Figure 42, only 8 scenarios are visible in the plot, whereas 10 scenarios are listed in the legend, which is further evidence of issues with report documentation and/or poor in-house review.

Response

It is noted that all 10 scenarios are plotted. The low and high RIV/DRN conductance, high and low ET and low recharge scenarios are all effectively over plotted and as such, present as one curve represented by the Low ET scenario. It is noted that these scenarios have little influence on mine inflows.

This is also discussed in the updated reporting.

3. Comments Register and Response

Issue #	Section	Page	Paragraph	Comment	Response
1	3.2	8	2	This review has not identified any material flaws in the AIP assessment for the mining conditions, except that the sensitivity analysis results for high and low aquifer storage appear erroneous (Figures A1-3 and A1-4 of Attachment 1 to the TMR Annexure 9; Jacobs 2021a)).	Figures for high and low aquifer storage were referencing incorrect shapefile and have been updated in the revised groundwater modelling report.
2	3.2	8	3	However, this review has identified flaws in the assessment of groundwater seepage impacts from the final void lake (see section 3.6 below for details), so some items in the AIP assessment (Annexure 1 to the UGA; Jacobs 2021a) should be reviewed/revised. In the AIP (Annexure 1), items 5 and 6 of Table 4, and item 3 of Table 5 and Table 6 (page 5-163 to 5-166 of Jacobs 2021a) rely on erroneous statements in the UGA at sections 6.2, 6.3, 6.4. They also rely on similar erroneous statements in the TMR (Annexure 9) at sections 5.4.5, 5.4.6, 5.4.7.	Revised final void water balance modelling has confirmed the final void would act as a terminal sink. This has been updated in the reporting. The AIP assessments stand as-is.
3	3.2	8	5	These variants appear to have been designed and executed consistent with best practice guidance, although there are some issues with interpretation of some results for the final void lake simulations (see section 3.6 for details).	As above.
4	3.3	9	1,2	These figures show considerable layer deviations at the mine site, but there is no commentary provided to justify this representation as reasonably representing the geological system. For example, the role of the mapped fault structures is not discussed, although that could justify the mismatch between the site data and the regional data.	Discussion of the layer perturbations, consistent with advice previously provided, has been updated in the reporting.

Issue #	Section	Page	Paragraph	Comment	Response
				The Submissions report and Updated Groundwater Assessment ('UGA'; Jacobs 2021a) does not present any additional explanation, despite this issue being raised by the initial review as requiring corrective action.	
5	3.4	10	2	The Bowdens model calibration performance is adequate (but not 'reasonably good' or 'very good' as is reported). The scaled RMS statistic of 1.7% for steady state and 1.4% for transient (TMR Tables 10 and 15) is used to claim 'very good' performance, which is not unreasonable where a criterion of 5% is often applied (Barnett et al. 2012). However, applying that metric to the Bowdens model involves dividing the RMS errors (7.74m and 6.26m, resp.) by what is a very wide range of heads across the entire model domain (446m).	Additional commentary and discussion is provided in the report. While it is maintained that the model calibration is at least "reasonably good" considering the regional nature of the model, the historical regional data sets, and lack of bore specific abstraction data, descriptions of model calibration as being "good" have been modified and or qualified in the report.
6	3.4	10	2	The question of whether the model performance is 'very good' where it needs to be, in the Bowdens mining area, is not comprehensively answered by the reports.	Discussion on calibration residuals in the mining area is proved in the Section 1. It is further noted that positive and negative residuals are well balanced throughout the model and demonstrate there is no bias in either over- or under-predicting water levels. As demonstrated by the history matching to prolonged abstraction from BGW108, located within the pit area, model calibration within the Bowdens mining area is considered to be more than adequate.
7	3.4	11	2	The match to estimated baseflow (TMR Figure 31) is adequate, as is typically achieved for most models, but it does not match 'well'.	Modified in reporting to "reasonable"

Issue #	Section	Page	Paragraph	Comment	Response
8	3.5	12	2	Regarding Figure 42, only 8 scenarios are visible in the plot, whereas 10 scenarios are listed in the legend, which is further evidence of issues with report documentation and/or poor in-house review.	It is noted that all 10 scenarios are plotted. The low and high RIV/DRN conductance, high and low ET and low recharge scenarios are all effectively over plotted as these have little influence on mine inflows. Reporting has been updated to reflect this.
9	3.6	12	6	the maximum extent of drawdown impact does not occur by 16 to 50 years post-mining (UGA section 6.2.4), as other results indicate that time frame should be about 150 years (UGA Figure 48);	As demonstrated in the supporting discussion - this assertion still stands.
10	3.6	12	6	the final void lake is not a 'partial groundwater sink', as the evidence indicates that there is inflow and outflow, so it is a throughflow system, not a sink at all.	As discussed in the updated reporting - revised water balance modelling has confirmed that the final void will remain a terminal groundwater sink.
11	3.6	13	1	Therefore, statements such as these that are made in the UGA and TMR reports are incorrect: 'residual drawdown, as predicted from Recovery Model A at 50 years post mining, is indicative of the long-term residual drawdown representing the predicted post-mining equilibrium with the final void acting as a groundwater sink.'	As above.
12	3.6	13	2	It is also important to note that the Submissions report long term throughflow result for Bowdens (Jacobs 2021a) differs fundamentally from the groundwater sink scenario promulgated in the EIS (Jacobs 2020, Figure 41 and section 5.3.5.5 and section 5.3.5.6 on page 5-172).	As above. Revised modelling has confirmed that the final void will remain a terminal groundwater sink.

Issue #	Section	Page	Paragraph	Comment	Response
13	3.6	13	4	The water table contours (TMR Figure 39) show that the final void lake does not remain as a groundwater sink. The description of a 'partial groundwater sink' is nonsense, and is not consistent with the evidence presented. The contours of Figure 39 indicate that there is inflow to and outflow from the final void lake (this is also shown in the cross-section in Figure 39), which would render it a groundwater throughflow lake, not a sink of any sort (eg. McCullough and Schultze 2015; see Figure 3c) below).	Revised long term water level contours, including supporting cross-section and discussion are presented in the revised reporting to demonstrate that the pit remains a terminal groundwater sink.
14	3.6	13	6	The statement in the UGA report at section 6.2.4 (page 5-130) that the equilibrium extent of the mining drawdown impacts (Figure 47) occurs by 16 to 50 years post-mining is not consistent with Figure 48, which shows that the groundwater inflows to the final void lake do not reach their dynamic equilibrium levels (571-577 mAHD) until about 150 years post-mining. The long term post-mining drawdown impacts can only be assessed once the long term final void lake level has been achieved.	As demonstrated in the supporting discussion - this assertion still stands. The extent of drawdown propagation as indicated by the 1m drawdown contour does not propagate any further than at 50 years post mining.
15	3.6	14	2	There is no other evidence presented (but there should be) that would allow a more detailed interpretation of the final void lake influence on the groundwater system. Such information could include sub-zone water balance data from the model, more detailed contouring of water table levels in the pit area, particle tracking simulations to allow assessment of any capture zones, etc. Such	As discussed in the updated reporting - revised water balance modelling has confirmed that the final void will remain a terminal groundwater sink. As such there will be no throughflow downgradient from the pit towards Hawkins Creek
16	3.6	14	3	There is inadequate assessment of impacts that may arise from the final void throughflow conditions.	As above.
17	3.7	15	4	that external review remains valid, although the 2019 review has not considered the latest final void throughflow prediction and implications.	As the revised water balance modelling has confirmed the final void to remain a groundwater sink (as per the EIS) Dr Merrick's review remains valid and complete.

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