Planning, Industry & Environment

Attachment B

Groundwater Model Assessment – Bowdens Silver Project

Comments on Chapter 5. Groundwater modelling in the report titled Bowdens Silver Part 5 Groundwater Assessment dated May 2020 by Jacobs Group (Australia) Pty Limited (pp 118–179).

Issue / matter	Report reference	Department
– Electronic file provided	– Entire document	– The Groundwater Assessment report is provided in protected pdf format, which makes it difficult for the reviewer to use, e.g. adding annotated comments and highlighting text. – The third-party model review presented in Annexure 10 (pp 305–38) is provided in scanned image format, which makes it difficult for the reviewer to mark up and highlight text for review purposes. – It is recommended to provide future versions of the report in a more user-friendly (unprotected) format.
– Report structure and table of contents	– pp 118–190	– There are five levels of sections. Levels sections 1-4 are numbered, but level 5 sections are not, making them difficult to reference. – The table of contents (pp 3–5) lists only the highest three section levels. Levels 4 and 5 are not listed in the table of contents, making it difficult to navigate the document. For example, there is cross-reference to Section 5.3.3.1 in page 174. However, this section is not shown in the table of contents. – Addition of all section levels in the table of contents will enable the report authors, the reviewers, and the readers to understand its structure and flow of thoughts. It will also help the authors deciding on the best way to present information about the groundwater system and the model.

Issue / matter	Report reference	Department
		– The numbering of level 4 section headers in the provided pdf is not provided in text format. So, it cannot be copied or searched for using standard methods (e.g. Section 5.3.3.1 in page 148, which is cross-referenced in page 174.). – The discussion of potential impacts (Section 5.1.6) is presented before the description of the project (Section 5.2). It is recommended to revise this order of information presentation. – The discussion of potential impacts (Section 5.1.6) does not fit well as a subsection in the conceptual model section (Section 5.1). Revision of the report structure in this part of the report is recommended. – It is recommended to reconsider the report section structuring, the format of section headers and the levels of sections included in the report's table of contents. – The level of subdivision of some sections is inappropriate. For example, the various types of boundary conditions are presented within a level four section (Section 5.3.2.4), which is very long (12 pages; pp 131–142, inclusive). As a result, boundary conditions are presented as fifth level subsections, which are not numbered, making them difficult to reference and find in both electronic and printed format of the report especially that level four and level five section headers are not included in the table of contents. It is recommended to promote the boundary conditions subsections from fifth level to at least level four, which will require re-consideration of the report structure. The report should be structured in a manner that enables easy navigation to information and helps the reader to understand the content and relationships between sections. – In Section 5.3.2.7, Table 32 is mentioned before Table 31. The order of cross-referencing these two tables in the text or their order of presentation should be changed

Issue / matter	Report reference	Department
– Follow up on review by Dr Noel Merrick	– pp 303–318	– There are some recommendations in the review by Dr Merrick that have not been implemented. For example, the Tailing Storage Facility (TSF) has not been shown on the conceptual groundwater model diagrams (Figures 40 and 41). – The model confidence level classification according to the Australian groundwater modelling guidelines (AGMG 2012) has not been provided in the report despite being noted as missing in the review (p 308). – A table like Table 1 (pp 5–27) is required to show how the proponent responded to the feedback from the third-party reviewer.
– Report matters	– Entire report	**There are various errors and inconsistencies in the report. Selected examples are listed below:** – There are nomenclature inconsistencies between the report text and figures. For example, the hydrostratigraphic units at the bottom of page 119 and the lithologic units in Figures 40 and 41 are not readily related. In addition, the order of units in the text at the bottom of page 119 is different than that in Figures 40 and 41, and there is apparent inconsistency between the information presented at these two locations and the text at the top of page 59. – There is inadequate cross-referencing to information in various parts of the report, e.g. cross-referencing to Section 3.6 and Annexure 3 is needed in Section 5.1.3. – The design of some tables require modification. For example, Tables 32 and 33 present Kx and Ky data separately in two different columns, but the system is conceptualised and modelled as being horizontally isotropic (i.e. Kx/Ky=1). Hence, a horizontal hydraulic conductivity (KH) column would have sufficed and the saved space could have been used to present vertical anisotropy (i.e. KH/KZ), which would be useful to the report readers and reviewers. – The last paragraph in Section 5.1.2.4 and Table 24 do not fit in their location. They are not related only to the Lachlan Fold Belt / Coomber Formation. – There are maps that are difficult to relate to features in the area and to information presented in the report. For example, Figures 46 and 47 are difficult to relate to surface waterways in the area and those listed in Tables 26 and 27. – Table 32 is unnecessarily split across two pages.

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		– Some figures need to be corrected. For example, the '*Ideal Fit*' line in Figure 57 is drawn incorrectly, suggesting that the model consistently overestimated head, whereas this is not the case (see Figure 4 below). – The scale (minimum, maximum and division of axes) in many figures is not user-friendly. For example, a more user-friendly scale will help the reader to understand the model performance more readily from the data presented in Figure 57. Also, the addition of overestimation and under estimation lines (e.g. ±10 m and ±20 m lines) will help the reader understand the level of fit between observed heads and model estimates. – There is inconstancy in the use of space between values and units throughout the report. For example, there values and units presented with and without space in the same line in the first paragraph on page (2 km… and 2.2km…). Values and units must be presented in consistent format, preferable with separating space but not before the percentage sign where it is used. – Numbers are presented with and without thousands separators (e.g. 1,000 m/d in page 165 and 1420 µS/cm in page 172). In addition, numbers are presented using space and comma as thousands separator (e.g. 2 746 in Table 37 on page 157 and 1,000 m/d in page 165). Consistency in number formatting is recommended, preferably using comma as thousands separator. – There are cross-referencing errors. For example, in the beginning of Section 5.3.2.2 (page 129) the reference to Figure 41 is incorrect. It should be changed to Figure 43. – There are grammatical errors and verb mismatches, e.g. '*Figure 54 and Figure 55 presents…*' at the bottom of page 143. – There are spelling errors, e.g. losses must be corrected to loses at the end of the first paragraph in Section 5.3.3.3 (p 157). – There is unhelpful/unspecific cross-referencing, e.g. '*Detail of the resultant hydraulic conductivity fields are presented further below*' on page 144, without citing the section, page, table, or figure. – There is inconsistency in the use of punctuation marks, e.g. comma/semi comma mix in the same bullet points set on page 164.

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		– There are illegible figures. For example, Figures 43 and 44 are low resolution (fuzzy/pixelated) and some of the colours used in them are indistinguishable (highway lines and mine site boundary). The inset map in the middle is difficult to relate to the larger map, especially that the solid greenish/yellowish colour is obscuring the map background. The same applies to Figure 44. It may be useful to make the colour denoting inactive cells in Figures 43 and 44 transparent to enable relating the inset map to the underlying larger map. In addition, Figures 43 and 44 are too small. It is recommended to reproduce them in A3 format. – There are data that are presented in the report text whereas they would be better presented in table format. For example, the data on different tests at the end of Section 4.5.10.1 would have been better presented in table format. Alternatively, they could be included in Tables 12 and 13. This also applies to other chapters in the Groundwater Assessment, e.g. the airlift tests summary on page 80. – There are formatting errors in the report. For example, m2/d in the paragraph before the last on page 135. The power should be superscript (i.e. m^2/d). Preferably, the power can be typed in using a symbol (e.g. ^{2}) to prevent accidental formatting changes. – Some section headers must be made clearer. For example, Section 5.3 header is '*Groundwater Modelling*', whereas the parent Chapter 5 is also titled '*Groundwater Modelling*'. It is recommended to change Section 5.3 header into 'Numerical groundwater modelling'. – The report is required to undergo rigorous proofreading and review to resolve shortcomings and inconsistencies, which if left uncorrected would degrade confidence in the model and groundwater assessment. The above examples are not exhaustive by any means.

Issue / matter	Report reference	Department
– Conceptual model	– pp 118–125	– The report lists guiding principles for the conceptualisation of groundwater systems from the AGMG (2012) but does not discuss whether they have been met, how, and if not, why. This self-assessment is required. – There is no evidence that the modelling exercise has complied with the listed principles for the groundwater system conceptualisation. For example, it seems that alternative conceptual models have not been considered (e.g. the use of drain (DRN) cells to represent most surface water features rather than river (RIV) cells without considering using RIV cells for all surface water features, and not considering alternative model domain extents). Similarly, there is no indication in the report that the conceptual and numerical models have been progressed through a process of iterative refinement. – The domain does not extend to incorporate the nearest mining operations. Although this seems reasonable in this specific case, the report must include a section that discusses the extent of effects from the other operations listed in Section 5.1.6.3 to demonstrate that their effects do not interfere with the effects expected from the proposed Bowdens Silver Mine. This information can be sourced from literature. – The sources of hydraulic property estimates in Section 5.1.2 are required to be provided (referencing of external sources and cross-referencing of sections in the report, as applicable). – In Figures 40 and 41, different line symbols (markers and/or colours) are recommended to differentiate water tables in different hydrostratigraphic units, and pre- and post-mining periods. – In Figure 41, the post mining shallow water table is the same as that presented in the pre mining conceptual diagram (Figure 40). Expected changes should be shown in Figure 41. If no change is conceptualised, this should be clearly stated and discussed. – TSF and Waste Rock Emplacement (WRE) must be shown on the conceptual drawings (Figures 40 and 41). The conceptual diagrams should also show potential groundwater mounding underneath such features. – The conceptual model should include third-party and mine dewatering bores.

Issue / matter	Report reference	Department
		– The Shoalhaven Group is suggested to be acting as an aquitard (Section 5.1.2.2). However, the drawings in Figures 40 and 41 show vertical infiltration and seepage from this unit in a manner that does not suggest that it is an aquitard as compared to the other units. Explanation or modification of figures is required. – Section 5.1.2.3 refers to lithologic units 4–6 from the top down as '*Rylstone Volcanics*', but this may not be readily clear to the reader from Figures 40 and 41 as the lithologic units are not grouped there, but only in the text at the bottom of page 119. The unit grouping in the text and figures should be consistent. – Alluvium deposits are limited in areal extent and thickness. Nevertheless, they are important in terms of their influence on the flow in rivers and streams like the Hawkins and Lawsons creeks. Special diagram/s are required to show the pre-mining, mining and post-mining hydrological situations in alluvium. – Figures 40 and 41 should show water users (other mines, Basic Landowner Right (BLR) bores, and bores associated with water access licences (WAL's). Section 5.1.6.3 states that bores have been identified in Sections 4.5.2 and 4.5.3 and incorporated into the numerical hydrogeological model for cumulative effects consideration. Figure 14 shows that most bores are located upgradient of the proposed mining operation. Therefore, they are at greater risk to be impacted by the proposed mining operation. – There seems to be conflicting information and lack of clarity with regards to horizontal groundwater flow direction and no discussion of vertical groundwater flow and inter-aquifer relationships: • Water level survey [by Jewell, 2003] indicated a general southerly groundwater flow direction (p 47). • Sydney Basins sediments dip gently to the northeast by approximately 0.5 degrees (p 59). • The geology of the Mine Site is heavily fractured, with six major fracture sets, two of which (a north-northwesterly trending set and an easterly trending set) primarily control the distribution of mineralisation (p 60). • The most dominant faulting in the area is associated with the north-northwesterly structures (p 60).

Issue / matter	**Report reference**	**Department**
		• Throughout the Macquarie-Bogan catchment, the dominant surface drainage direction is to the northwest toward the Darling River, and this will also be the case for shallow groundwater within the regolith profile. More locally shallow groundwater flow will mimic topography, initially to the south toward Hawkins and Lawsons Creeks and then in a northwesterly direction immediately north of Lue (p 63). • Deeper groundwater flow within the Ordovician basement is likely to be more structurally controlled with the dominant structures trending in a north-northwesterly direction, locally inducing groundwater flow to the south (p 63). • Regional groundwater flow will therefore be dominated by down-dip flow to the northeast, consistent with regional bedding dip on the western flank of the Sydney Basin. (p 63) • Localised flow towards the southwest and seepage faces at outcrop from the Sydney Basin sediments is also likely (p 63) • While the water strike map suggests a concentration of water strikes in the southeastern open cut pit area, anecdotal evidence suggests that the wettest part of the ore body is in the northern open cut pit area and to the west of the structure that runs along Maloneys Road (p 70). • The flow characteristics presented in page 96 based on Figure 28 (p 97) are not considered in the conceptual and numerical models. • On page 96, it is noted that Figure 28 show '*a general southeasterly flow direction*', which contradicts with other information presented in various sections of the report. • These geological provinces [Lachlan Fold Belt or Orogen and the Sydney Basin] also host two distinct regional groundwater systems with groundwater flow and discharge in the Lachlan Fold Belt system occurring to the northwest, whilst regional groundwater flow and discharge in the Sydney Basin system occurring to the northeast (p 119). • The flow directions shown in Figures 40 and 41 are to the north and south (pp 120–121). This indicates a groundwater divide to the north, which is not shown in the figures or discussed in the text.

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		• Cleavage planes [in the Lachlan Fold Belt / Coomber Formation] dip variably to the east and west. As groundwater flow in this unit will be controlled by fracture flow there is likely to be a preferred flow direction consistent with cleavage and fracturing. Shallower groundwater flow within the weathered zones of this unit (typically in the upper 20-30 m) will be more topographically controlled (p 123). Shallower groundwater flow direction/s must be discussed further and presented more clearly. • Regionally, groundwater discharge (throughflow) will be to the northwest in the Coomber Formation and wider Lachlan Fold Belt. Within the Sydney Basin sediments, regional groundwater discharge will be to the northeast, to the drainage features, the Totnes and Barigan Valleys, as well as the Bylong Valley, with minor vertical leakage to underlying formations (p 124). • Structure influences on the groundwater system are noted in different sections. However, they are not shown on Figure 28 and associated discussion, the conceptual model (Figures 40 and 41), and the numerical model. Some of these structures will act as groundwater flow conduits whereas some will act as barriers. • There is a possibility for enhanced hydraulic conductivity due to structure (e.g. Section 4.5.10.4). This aspect of the groundwater system has not been incorporated in the conceptual and numerical models. • The effects of mineralisation and veins (pp 60 and 62) on the groundwater heads and flow have not been included in the conceptual or numerical models. – Flow direction arrows should be added to all existing and additional maps and cross-sections representing observations, conceptualisation, and numerical modelling results (e.g. Figure 28). – A special section on groundwater flow direction is recommended to resolve apparent inconsistencies between various relevant parts in the report.

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		– It is clear that the proposed mine is situated within a complex groundwater flow system. Although it is understood and accepted that modelling entails simplification, there is a worry that the system has been oversimplified. For example, the report notes in page 67 that '*Within the Mine Site, a number of potential GDEs have been identified including springs and seeps, terrestrial vegetation, and river baseflow systems.*' However, the conceptual and numerical models fail to represent these features. The proponent should justify the exclusion of such features or include them in the conceptual and numerical models. – The model must demonstrate the ability to reproduce the modelled groundwater system nature and behaviour. As such, groundwater level contour maps are recommended for all model layer. These maps must also show contours derived from observations. If data availability is limiting, then observation points in each layer with the corresponding observed groundwater level must be shown on these maps. Horizontal flow direction vectors must be shown on all such maps. The agreement between the modelled groundwater level contour maps and observations must be discussed within the context of the assessment of the model goodness of calibration. These figures can replace, supplement or be supplemented by Figure 58. – Cross-sections along strategically selected transects are recommended to show modelled and observed groundwater levels at suitable horizontal scale and vertical exaggeration. Figure 73 shows only the modelled water table. Vertical flow direction vectors should be shown on all such cross sections. Inter-aquifer and groundwater-surface water relationships should be shown on the figures and discussed in the text. – The report indicates the possibility that some shallow groundwater and surface water features are perched above the regional groundwater table, i.e. possibility of unsaturated flow (e.g. first bullet point on p 95). The report should show this in the conceptual diagrams (e.g. Figures 40 and 41), discuss this matter in the modelling text (Chapter 5) and explain how they have been incorporated in the numerical model. If this characteristic of the groundwater system is not included in the model, justification for its exclusion is recommended alongside a discussion on how it has been compensated for and how it affects the model representativeness of the groundwater system, performance and predictions.

Issue / matter	Report reference	Department
		– In Section 5.1.2.3, clarification is requested on what ‘*pseudo-radial flow*’ mean and how this enables modelling the system as porous media. – Section 5.1.2.3 argues that although groundwater flow in the Rylstone Volcanics unit is dominated by fracture flow, on a meso-scale groundwater flow behaves in a pseudo-radial manner, similar to a porous aquifer. Clarification is requested on whether modelling of all other units using an equivalent porous medium approach (Section 5.3.2.7) is appropriate. - The source of information for the data presented in Table 24 should be provided. – The data in Tables 24 (representative hydraulic parameters) and Table 32 (initial values for hydraulic parameters) are different, particularly in terms of vertical isotropy ratios (KH/KV) and specific storage (Ss). Explanation is requested. In addition, the two tables present the data in inconsistent format (KV/KH in Table 24 vs Kx, Ky and Kz in Table 32), which may unnecessarily confuse the reader. – Section 5.1.3 discusses the influence of geological structure on groundwater flow. However, it does not specify which structures shown on Figure 11 are relevant and how the discussed structures impact on the groundwater flow pattern shown on Figure 28). Clarification is requested.
– Modelling objectives	– pp 128–129	– The model objectives should include: • Assessment of seepage into and mounding of groundwater due to seepage from the WRE and TSF. • Assessment of post-mining groundwater and surface water licencing requirements and environmental effects (not just dewatering during active mining). • Include springs in the first objective (the report notes that some springs occur in the proposed mine site). – Section 5.3.1 should list the criteria for the target model confidence level class (Class 2).

Issue / matter	Report reference	Department
– Model domain • Areal (horizontal) extent	– pp 129	– The description in Section 5.3.2.2 and Figure 43 are not clear. For example, it is not clear whether the catchments mentioned in the description are included in the model domain or border it. Specifically, it is not clear whether the Rylstone Dam is within or outside the model domain.
• Vertical discretisation	– pp 129–131	– The basis for vertical discretisation of the model domain into eight numerical layers corresponding to the eight hydrostratigraphic layers noted in Section 5.1.2 and Figures 40 and 41 is not provided. For example, the AGMG (2012) suggests that aquitard layers like the Shoalhaven Group can be subdivided into multiple numerical model layers to provide information about vertical flows. Also, hydrostratigraphic units can be lumped together in numerical model layers or split into supplementary numerical model layers. Model revision and/or appropriate discussion are recommended.
– Boundary conditions	– pp 131–142	– RIV & DRN boundary conditions (pp 131–136) • The conceptual differentiation between the RIV and DRN is incorrect (paragraph 1, p 135). It is made based on major versus minor watercourses. The main difference between the two MODFLOW packages is that RIV cells can exchange water with the groundwater system (add and remove) whereas DRN cells can only remove water from it. DRN cells cannot be used to represent surface water if some of that water may seep into the modelled groundwater system. So, representing seasonal or ephemeral runoff using DRN cells is inappropriate as these surface water features do not drain groundwater, but surface water and have the potential to recharge groundwater. This means they should be represented using RIV not DRN cells. • Surface water features modelled using MODFLOW RIV and DRN packages are not clear in Figures 46 and 47, especially at the periphery of the model domain. It is very difficult to relate them to the data presented in Tables 26 and 27. These figures would better be reproduced using an appropriate mapping or GIS software. They must show the features, their types, names and reach numbers as referenced in Tables 26 and 27 on a useful basemap.

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		• The basis for universally setting DRN and RIV cells bottom and water level (as applicable) relative to topographic elevation shold be explained. The universal approach may particularly be inappropriate/unrealistic for features like Lake Windamere and the Rylstone Dam. • Enhanced conceptual and numerical modelling of surface water is recommended, especially as Section 5.3.3.3 notes that '*The water balance indicates that, on average, the modelled groundwater system predominantly losses[1] water to water courses.*' Hence, surface water is considered an essential and integral constituent in the modelled hydrogeological system. • Varying depths of surface water stage and bottom below the surrounding land level should be considered. Sensitivity analysis of these parameters are also required to be undertaken followed by uncertainty analysis if found necessary. • The source of topographic elevation data is assumed to be Figure 8 or Figure 53. However, Section 5.3.2.6 (top of p 143) notes that the top of the model was based on LiDAR and 1:25,000 topographic dataset of NSW Lands and Property Information. Clarification of the used data source is recommended. In addition, a discussion of the similarity between Figures 8 and 53. Seepage faces, springs, seeps, and wetlands • Section 6.1.2 argues that Sydney Basin sediments bedding planes springs are unlikely to be impacted by drawdown from the proposed project. Explanation is requested of the apparent discrepancy between the above points. ○ Seepage faces (e.g. p 63), springs, seeps and wetlands (e.g. p 67) are not shown on a map or the conceptual cross-section diagrams. They are also not represented in the numerical model and the project effects on these features are not assessed despite that these features have been incorporated in water quality analysis (Section 4.5.12).

[1] Spelling error; correct to loses.

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		○ Some springs are deemed not to be connected to the groundwater system (i.e. perched) based on groundwater quality evidence, e.g. p 98. ○ Section 6.1.2 (p 180) suggests that there are springs that drain Sydney Basin sediments (model layers 2-4) through bedding planes. • It is recommended to provide an improved discussion of seepage faces, springs, seeps, and wetlands. They should be included in the conceptual model and where appropriate in the numerical model and reported water budgets. The discussion can be presented in a special 'groundwater-surface water interaction' section. • Effects on seepage faces, springs, seeps, and wetlands should be assessed. – Wells (pp 136–138) • Mine pit dewatering wells are not represented in the conceptual and numerical groundwater models. Clarification is requested. • In Table 28, either the headers or the data in the second and third columns should be swapped as they are inconsistent with the discussion under the header 'Wells (WEL)' (pp 136–138). The text articulates that BLR bores were assumed to be active throughout the year. However, the data in the table suggest they are assumed to be inactive from March to July. On the other hand, the data in Table 28 suggests that licenced bores (bores associated with WALs) are assumed to be active year-round whereas the text suggests these works are only active during the dry season (August–February) (See Figure 5 below). • The data in Table 28 suggest that the dry season extends from August to February. This assumption must be substantiated using data from Section 4.1 Climate (pp 50–52). • There is a risk that the error noticed in Table 28 has transpired into the numerical model. The proponent should check the model and clarify the situation.

Issue / matter	Report reference	Department
		• Bore labels (at least for bores associated with WAL) must be shown on the maps in Figure 48. A useful basemap is required for the maps in the figure. Also, it would be useful to use different symbols for BLR and production bores. – Climate (pp 50–52) • Add mean annual rainfall and potential/open water evaporation into Table 5. • Add rainfall–potential/open water evaporation balance into Table 5 as an indicator of wet/dry months and preliminary overall annual water balance. Alternatively, represent data monthly rainfall and potential evapotranspiration data in a single [bar] graph. – Atmosphere-aquifer water exchange, i.e. recharge and evapotranspiration from the water table (pp 138–142) • The reported basis for recharge and evapotranspiration zonation is the same. However, the report defines different zone systems for these two parameters (Figures 49 and 50 and Tables 29 and 30). It is noted that the there is an additional land-use/topography class ('Hilltops') in the recharge zonation. However, it is not clear why this land-use/topography class was not also included in evapotranspiration zonation. Explanation of these apparent areas of discrepancy is requested. • The effects of TSF and WRE on recharge and evapotranspiration are not discussed or represented in the numerical model. Explanation is requested. – Groundwater recharge (pp 138–140) • The modelled groundwater recharge is reported as a '*recharge factor*', which is a proportion of rainfall. A map showing initial recharge estimates for the steady-state model is recommended to be presented as a recharge depth rate (e.g. mm/year or m/year) to enable understanding the areal distribution of this parameter. Similar maps are required for the calibrated steady-state recharge and annual average recharge in the transient calibrated model. • In page 138, the report states that recharge was included as a calibration parameter, except for Lake Windamere, which was assigned a factor of 1.0 (equivalent to 100%). Conceptually, the area under Lake Windamere does not receive direct rainfall recharge, unless it is dry.

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		➢ If Lake Windamere was also modelled as RIV cells, correction or explanation is recommended as this constitutes double counting of water inputs. ➢ If Lake Windamere was not modelled as RIV cells, then there may be underestimation of the groundwater influx from the lake into the aquifer as it would be incorrectly limited in the model to the amount of rainfall whereas there is theoretically an infinite source of water that can seep into the aquifer. • The colours used in Figure 49 are not easy to differentiate. Also, it is difficult to relate the zones in the figure to features in the area due to the lack of a useful basemap. • The logic behind specifying recharge factors for different zones should be clarified. For example, it is noticed that the recharge factor for the foothills is 0.12, 0.06, 0.04, and 0.04 in Thiessen polygons for rain stations 62012, 62021, 62026 and 62032, respectively. The report does not explain why the recharge factor changed in these zones despite having the same 'land-use'. It is understandable that the topography in these different zones may be different, but the repot does not provide data that can be used to replicate the recharge zonation. • The report should clarify the topographic basis (classification system) that is used with land use for recharge zonation purposes. • The legend in Figure 49 shows 16 recharge zones, whereas there are only 15 recharge zones in Table 29. Zone 7 is missing in Table 29. Explanation or correction is requested. – Evapotranspiration (pp 141–142) • SILO potential evapotranspiration data is inappropriately referred to as '*FAO56 data*'. This must be corrected to 'Modified Penman-Monte evapotranspiration' or simply 'potential evapotranspiration'. • Explanation is requested with regards to why and how an '*evapotranspiration factor* [has been] *applied*' to calculate monthly totals from SILO daily potential evapotranspiration' data.

Issue / matter	**Report reference**	**Department**
		• The report argues that unreported earlier versions of the groundwater model showed that the numerical groundwater model is insensitive to evapotranspiration. The proponent is requested to explain the reasoning behind including evapotranspiration in the model where it is not affecting the model. To simplify the model and reduce uncertainty, could evapotranspiration have been left out and compensated for implicitly in the recharge values? • If there is evidence that evapotranspiration is not an important process in the Bowdens Silver Mine hydrogeological system, it should be clarified on the conceptual diagrams (Figures 40 and 41). • Hydrometeorological data analysis (e.g. Section 4.1 Climate) does not provide useful information on the relationship between evapotranspiration (combined evaporation and evapotranspiration). However, Section 4.5.12.4 Major Hydrogeochemical Processes articulates that '*a number of monitoring locations suggest an evaporative influence*'. This indicates that the groundwater system conceptual model (Section 5.1, including Figures 40 and 41) and numerical modelling (Section 5.3.2.4, specifically page 141) are incongruous to the hydrochemical evidence. Correction and/or explanation are recommended. • An evapotranspiration factor of 1 means that 'actual' evapotranspiration will occur at maximum possible level (i.e. at the potential evapotranspiration rate). Assignment of evapotranspiration factor of 1 to lake-covered areas may not be appropriate as MODFLOW EVT package removes water from the aquifer, not the overlying surface water like lakes. Hence, direct evapotranspiration from the water table underlying unvegetated lakes (plants not showing above the lake water level) is conceptually flawed. Clarification/correction is recommended. • The legend in Figure 50 shows 12 recharge zones, whereas there are only 10 recharge zones in Table 30. Zones 51 and 52 are missing in Table 30. Explanation is recommended.
– Model geometry	– pp 142–143	– Section 5.3.2.6 discusses only the model layers configuration. Hence, the section header '*model geometry*' is a misnomer. – The source of the geological data sould be clarified.

Issue / matter	Report reference	Department
		– There is a cross reference error to Table 32 at the end of the section. It must be corrected to Table 31. – All layers are continuous throughout the model domain. Commentary is required on how realistic this representation of the geology is. – The numerical model layers presented in Figures 51 and 52 cannot be readily related to the conceptualised hydrostratigraphic units listed in Section 5.1.2 and presented in Figures 40 and 41. This section is required to explain how the numerical layers overlap with the stratigraphic units to form hydraulic property zones as presented in the Section 5.3.27, particularly Table 32 and Figure 54. – It is recommended to reproduce Figures 51 and 52 in larger format with a suitable vertical exaggeration and show the different hydraulic property zones on them.
– Initial Hydraulic Parameters	– pp 143–147	– Although the basis for delineating hydraulic property zones (Figures 54 and 55, and Table 31) can be understood from the information provided in Section 5.3.2.7, it is not well described or explained. Clarification is requested. – The basis for assigning the initial hydraulic parameter values in Table 32 is not clear. It is difficult to relate them to the data in Section 4.5.7 Previous Hydraulic Testing, Section 4.5.8 Pumping Tests, Section 4.5.9 Extended Pumping, Section 4.5.10 Recent Investigations, and Section 4.5.10.1 Airlift Testing. It is recommended to combine and simplify Tables 12 and 13 to help understanding the hydraulic properties of various units. – Section 5.3.2.7 does not clarify the source of the initial estimates of hydraulic parameter values. However, apparently hydraulic conductivity estimates are obtained from Sections 4.5.7–4.5.10.4 and porosity and storage parameters values from Sections 4.5.10.5–4.5.10.6. The names of the geological units used in Chapter 4 are not readily translatable into the names of the hydrostratigraphic units or model layers used in Chapter 5, making it difficult for the reader to understand the model set up and parameterisation. The report should be adjusted to overcome this difficulty. – Section 5.1.3: drilling results suggest that relatively high groundwater yields can be obtained in the vicinity of the structures. However, these structures are apparently not represented in the numerical model. Explanation or correction is recommended.

Issue / matter	**Report reference**	**Department**
		– There is a note that two structures '*inhibit groundwater flow across them while enhancing groundwater flow parallel to their strike, both laterally and vertically.*' It is not clear whether these structures have been incorporated in the model. Clarification or correction is recommended. – Section 5.3.2.7 indicates that '*a zone of moderately elevated hydraulic conductivity has been introduced surrounding the orebody in Layers 4, 5 and 6 to account for the increased concentration of structural deformation.*' However, no information is presented about this zone in Tables 31 and 32 and Figures 54 and 55. This zone could be hydraulic conductivity zone 45, 46, 55 or 63. Clarification is recommended.
– Steady-state groundwater level calibration	– pp 148–154	– There are very few or no calibration targets in some model layers (e.g. layers 6–8). The report should make recommendations to enhance the monitoring network to enable better calibration of future model versions. – There are no multi-level monitoring wells or well pairs/clusters to enable conceptualisation and numerical model representation of vertical groundwater gradients. The report should utilise available data to address vertical groundwater gradients and, if necessary, recommend collecting additional data to do so. – The discussion of the use of Pilot Points to parameterise hydraulic conductivity in Layers 4, 5 and 6 is not useful. The Pilot Points are not shown on a map and the discussion does not provide the reader with adequate information about this part of the modelling process. – It is not understood why it has been attempted to use Pilot Points only in the vicinity of the mine site and how that was attempted (pages 144, 51 and 178). Pilot Point calibration could have been used with or without zones across the entire model domain. It seems that there has been an error applying this technique. This aspect should be explained further. – Some parameter values vary greatly between the initial estimates (Table 32) and the steady-state calibrated values (Table 33). Since the data in Table 32 are thought to be sourced from hydraulic testing (Chapter 4), an explanation is requested for the apparent occasional large discrepancy between field and model parameter values, (e.g. KH values for zones 51, 61 and 71).

Issue / matter	Report reference	Department
		– In Figure 58, the map legend colour ramp is not user-friendly. It does not enable instant understanding of close fit, over- and under-estimations of the head. It is recommended to use distinct intervals rather than a gradual colour scheme to represent agreement between observed and modelled heads. – Figure 58 is fuzzy, and the maps are too small to clearly show the data. It is recommended to provide the figures in larger and higher resolution format. – Commentary is recommended with regards to initial and calibrated hydraulic conductivity vertical anisotropy values and their agreement. – Conductance values for RIV cells (156.25–6,250 m²/d) and DRN cells (16.2–129.6 m²/d) have not been varied during calibration despite that these parameters are related to hydraulic conductivity, which has been adjusted during calibration. A discussion is recommended. These parameters should be included in the sensitivity and uncertainty analysis.
– Steady-state model sensitivity analysis	– pp 154–157	– Table 32 is presented in slightly different formats than Tables 33 and 38, which makes it difficult to compare initial and calibrated hydraulic property values. It is recommended to make these tables more similar. – It is not clear from the caption of Table 29 and the text on pages 139 and 151 whether the recharge factors presented in the table are for steady-state calibration only or also the transient model. Clarification is required. – Table 35 is redundant. It presents the same information presented in Tables 31, 32 and 33 and only adds info on the minimum and maximum used Kx value in the sensitivity analysis (order of magnitude either way of the calibrated model value). This information would have been ideally presented in the text. In addition, there is no mention of the Ky values noted in Table 32, which suggest that the report should not be discussing Kx and Ky separately, but combining them as KH. Confirmation/clarification is requested. – Like the previous point, Table 36 is redundant, virtually providing the same information as Table 29 and limited new information (range allowed for recharge variation in sensitivity runs, being 0.5–2 times the calibrated model values). This information is better included in the text rather than in a separate table. In addition, the report does not clarify whether the variation in the recharge parameter were made for the recharge factors or values.

Issue / matter	Report reference	Department
– Transient model groundwater calibration	– pp 158–162	– A map is recommended to show the locations of the bores included in Figures 61–66. – The vertical scale (axis min, max and interval) in Figures 61–66 is not user-friendly. – The history matching and calibration statistics are very good. – No transient model sensitivity analysis is reported. This is important as it means that the model sensitivity to storage parameters (Sy and Ss) and the model uncertainty in relation to these parameters have not been investigated. Clarification and/or additional work is required.
– Min pit representation	– pp 164–166 (Sections 5.3.4.1 and 5.3.4.3)	– Mine pit development is represented using DRN cells. – Information on the DRN cells conductance is requested to be provided, including whether it varied in area and/or with depth. – The representation of the mine pit during the mining and the post-mining periods is appropriate. However, it is recommended to consider the use of the LAK package for post-mining pit modelling. As clarified by Ünsal (2013)[2], the '*LAK3*[3] *package is superior to other lake simulation techniques. Its ability to simulate lake stage is an improvement over lake simulations using constant heads or head dependent flux boundaries because changes in lake stage can have appreciable effects on the groundwater system. Although High-K simulations and LAK3 results reported to compare well both at steady-state and transient stages, it is known that LAK3 simulations are more stable and require less computational time.*'. This recommendation is in line with the AGMG (2012) which encourages the consideration of alternative conceptual models. – The mine pits development is staged in six-monthly steps (stress-periods), whereas the model is built using monthly stress-periods. It is recommended to adopt monthly stress-periods for all model components to avoid abrupt changes as noted in Section 5.3.5.1.

[2] Ünsal, B (2013): Assessment of open pit dewatering requirements and pit lake formation for Kişladağ Gold Mine, Uşak-Turkey. PhD thesis. Middle East Technical University.
[3] The current version of this package is LAK7, which can be used in MODFLOW USG models.

Issue / matter	Report reference	Department
– Model predictions and uncertainty	– pp 164–178	– The approach and results are plausible. – In Figures 71 and 72, the drawdown contour lines labels have incorrect signs. Negative drawdown is an expression of groundwater mounding. Either signs must be reversed, or the figure captions changes to state ‘groundwater level change’ rather than ‘drawdown’.
– Conclusion		– The modelling chapter requires a conclusion, which effectively summarises the modelling outcomes, including recommendations for model validation and updating.
– Model review referencing errors.	– p 178 and pp 303–318	– Some referenced content in the report reviewed by Dr Noel Merrick has changed. For example, the Dr Merrick’s review references Tables 38 and 41 in point 1.3 (p 312), which are numbered 37 and 40 in the version provided to DPIE Water. Similarly, Figures referenced as 37 and 38 in Dr Merrick’s review are numbered 40 and 41 in the report reviewed by DPIE Water. – An erratum is required to be added in the report at the beginning of Annexure 10.

Figures

Figure 1 Mine site layout

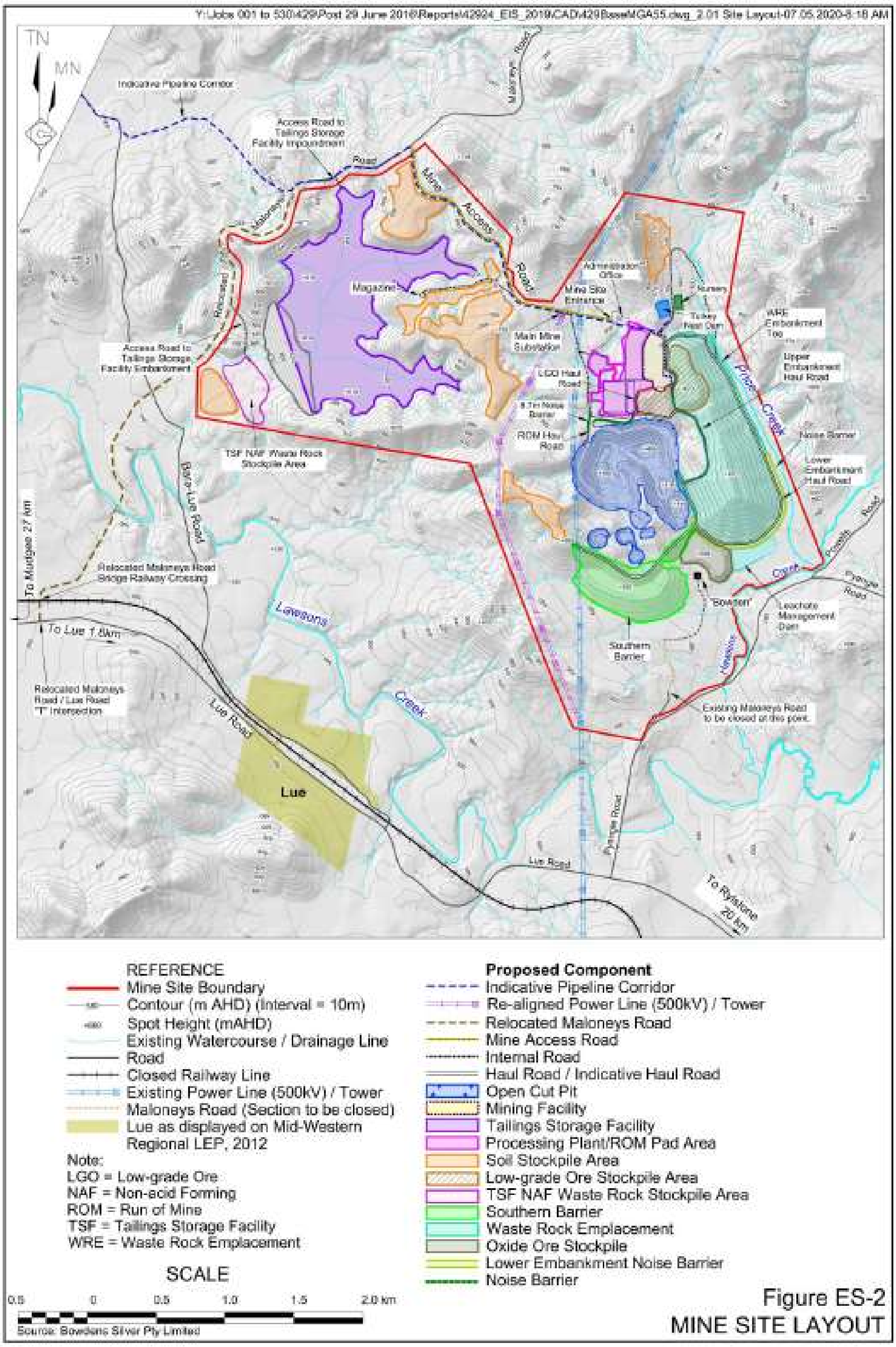

Figure 2 Open cut pit layout and cross sections

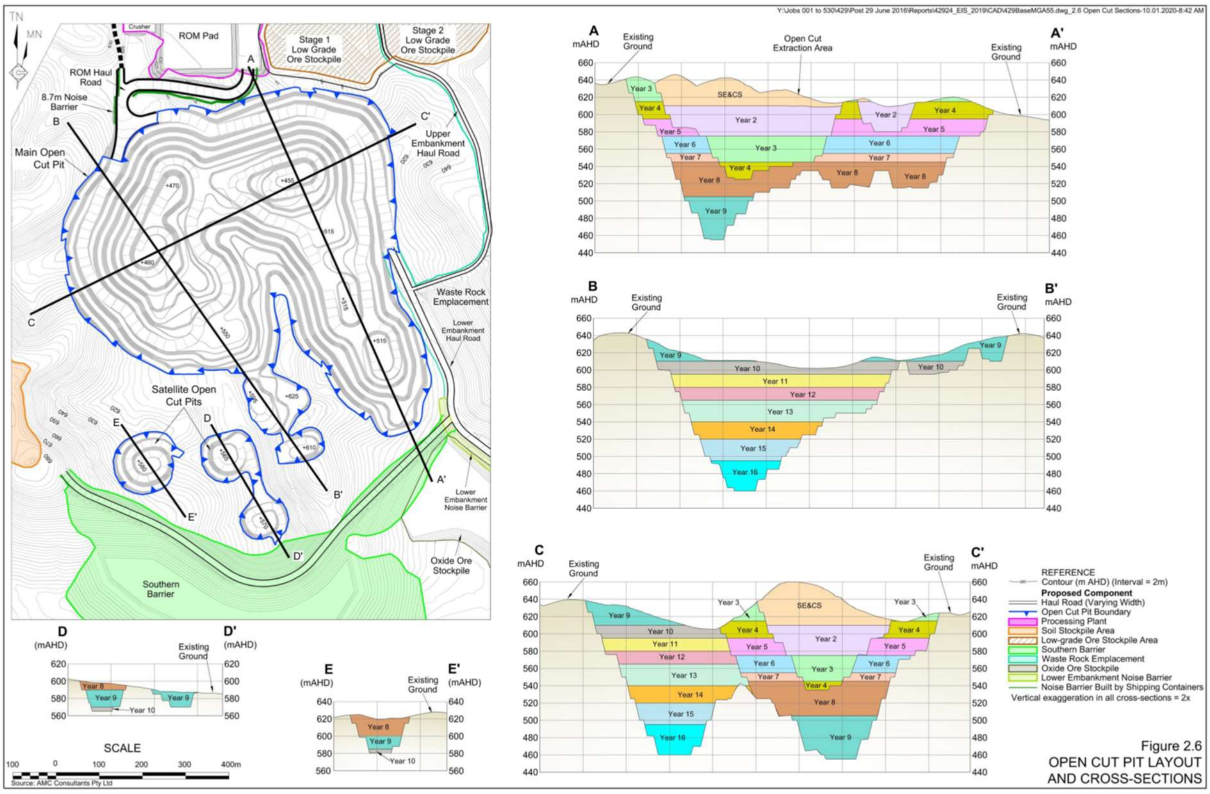

Figure 3 Composite groundwater level and monitoring bore locations

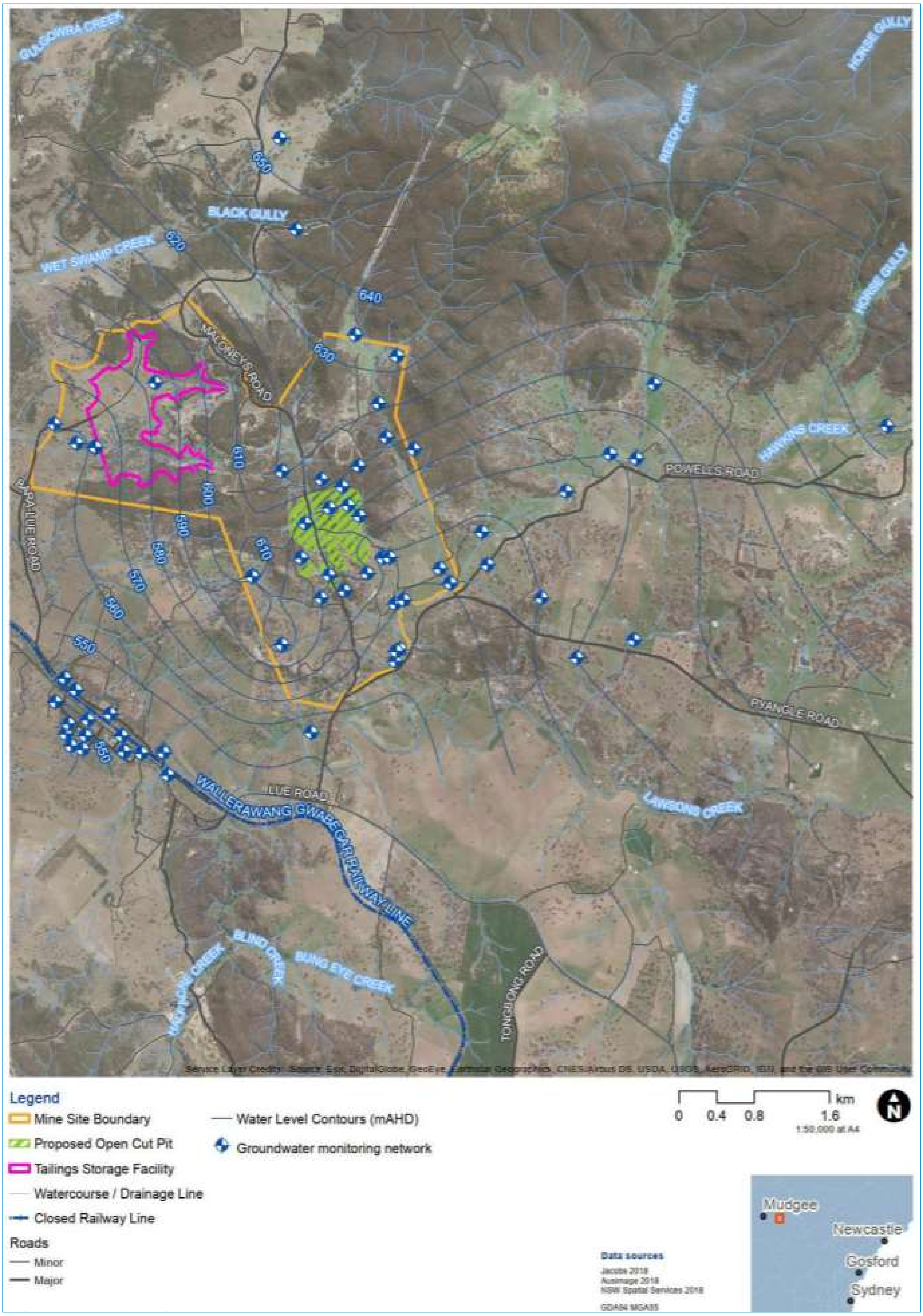

Figure 4: Example of model report error: Incorrect line of best fit

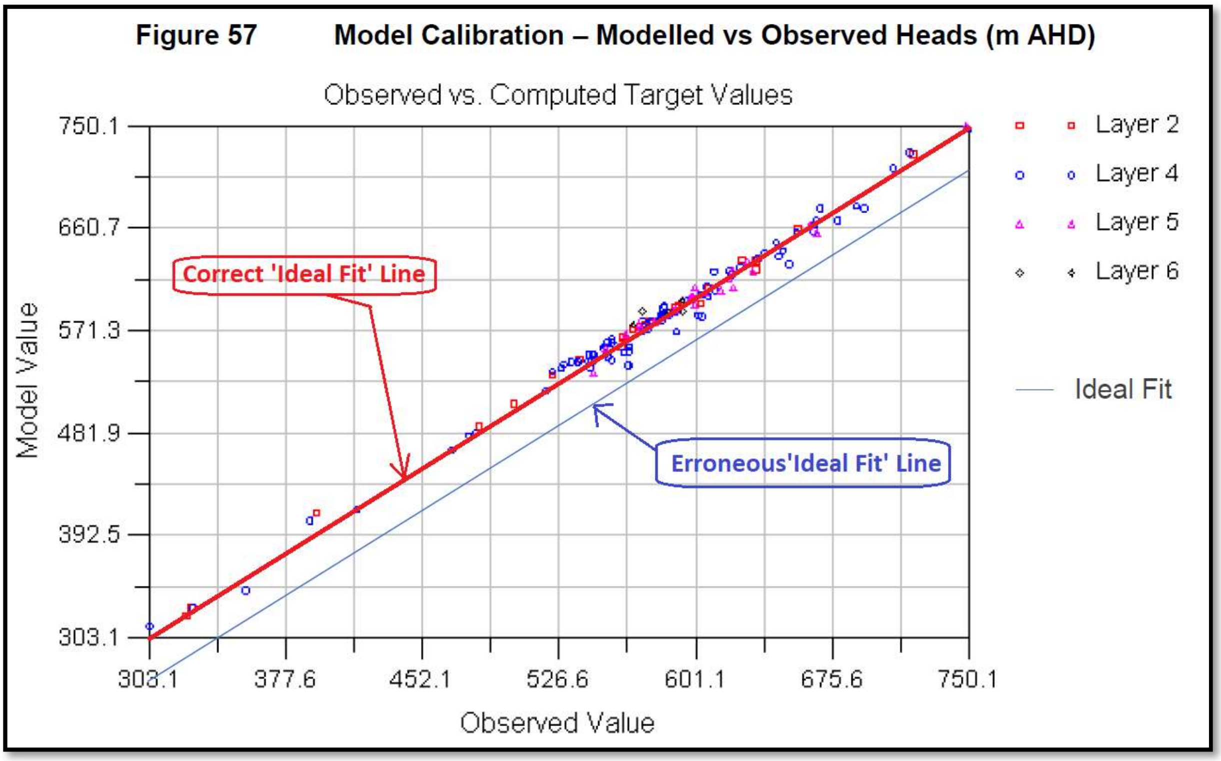

Figure 5: Example of model report error: Inconsistent distribution of water extraction, and contrary to discussions the text

Table 28
Groundwater Model Boundary Condition – Distribution of Pumping Rate (WEL)

Month	Basic Landholder Rights	Other Works
Jan	15.0%	12.0%
Feb	11.5%	10.0%
Mar	0.0%	8.0%
Apr	0.0%	7.0%
May	0.0%	6.0%
Jun	0.0%	5.0%
Jul	0.0%	5.0%
Aug	9.0%	7.0%
Sep	11.5%	8.0%
Oct	15.0%	9.0%
Nov	19.0%	11.0%
Dec	15.0%	12.0%