Graphinex – Esmeralda Graphite Project

Environmental Impact Statement

Appendix R – Groundwater Impact Assessment Peer Review

GRAPHINEX

Our Ref: **HA2026/20**

HydroAlgorithmics Pty Ltd
ABN 25 163 284 991

PO Box 4282, Hawker ACT 2614
Phone +61 (0)404 001 780

info@hydroalgorithmics.com
www.hydroalgorithmics.com

Date: 24 September 2026

To: Justin Miller
AARC Environmental Solutions Pty Ltd
c/- Qld Aus Graphite Pty Ltd
Level 4, 10 Eagle Street
Brisbane QLD 4000

From: Claire Stephenson
Dr Noel Merrick

Re: **Esmeralda Graphite Project Groundwater Peer Review**

1 INTRODUCTION

This report provides a peer review of the groundwater impact assessment (**GIA**) and associated modelling for the Esmeralda Graphite Project (the **Project**). The GIA has been prepared by Hydrogeologist.com.au for the client Qld Aus Graphite Pty Ltd (**Graphinex**).

The Project is a critical minerals operation proposed 70 km south of Croydon, Queensland. The Project includes a proposed open cut natural graphite mine with extraction of up to 3.5 million tonnes per annum (Mtpa) of Run-of-Mine (ROM) ore over the life of operations. The main elements of the Project are shown in **Figure 1** (below) and include a range of aspects relevant to a groundwater assessment, including:

- Life of Project approximately 65 years, which includes two (2) years for construction, operation for 53 years and final rehabilitation for 10 years.
- One open cut pit covering 80 hectares and excavated to approximately 250 m depth (-157 mAHD).
- Mineral processing plant for stockpiling and concentration via conventional flotation methods, producing between 100 kilotonnes per annum (ktpa) to 200 ktpa graphite concentrate during operations.
- Establishment of a permanent creek diversion and levee bank on the northern side of the pit at an unnamed tributary of Warrigal Creek (3rd order creek).
- Out of pit waste rock emplacements adjacent to the mining void.
- Construction of four tailings storage facility (**TSF**) cells that will each have a high-density polyethylene (HDPE) liner to prevent seepage.

- Construction of three mine affected water (**MAW**) structures, which will be lined to prevent seepage.
- Post closure design with disposal of tailings material from three of the TSF cells into the base of the pit, filling up to an elevation of 42 mAHD. The in-pit tailings material will be capped with low-permeability material, and the remaining pit backfilled with waste rock material, and a rehabilitated landform established up to around 123 mAHD.

The peer review was undertaken in accordance with the *Australian Groundwater Modelling Guidelines* (AGMG) (Barnett *et al.* 2012[1]).

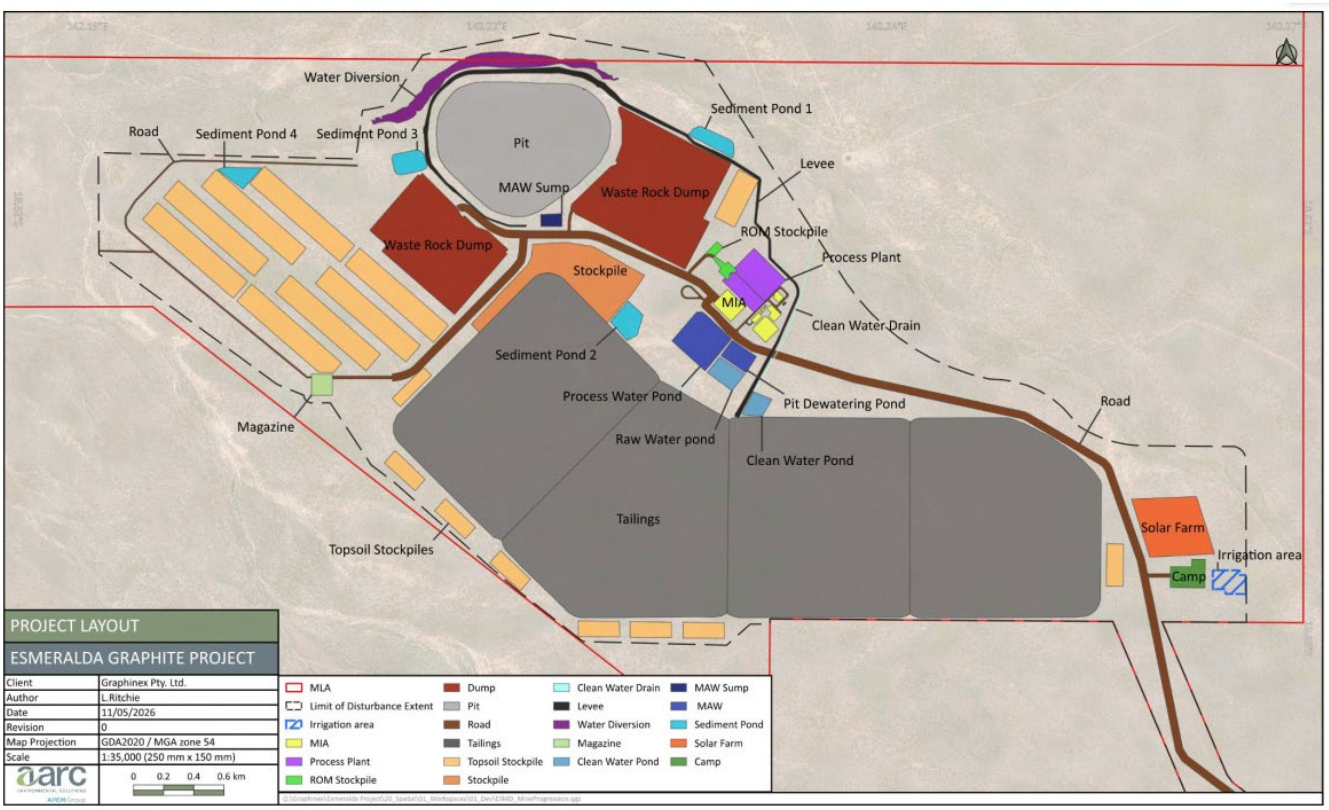


Figure 1 Project Infrastructure Layout (Source: AARC, 2026[2])

2 MODEL REVIEW

2.1 Documentation

The review is based on:

[1] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra

[2] AARC (2026). Esmeralda Graphite Project Environmental Impact Statement, prepared for Graphinex.

- Document #1 – Hydrogeologist.com.au, 2026. *Esmeralda Graphite Project Groundwater Impact Assessment*, prepared for Qld Aus Graphite Pty Ltd, dated 18/9/2026. [89p + 4 Appendices]

Document # 1 is structured as follows:

1 Introduction
2 Regulatory setting
3 Physical setting
4 Methodology and data analysis
5 Existing groundwater regime
6 Impact assessment
7 Groundwater monitoring and management
8 Conclusions
9 References

The included Appendices are:

- Appendix A Field investigation report
- Appendix B Details of registered bores within 10 km of the Project
- Appendix C Groundwater quality data
- Appendix D Numerical model report

Appendix D is structured as follows:

1 Introduction
2 Model design
3 Calibration
4 Predictions
5 Recovery model
6 Model confidence level assessment
7 Model limitations
8 References

A groundwater peer review report was also prepared by Whiting Groundwater.

Relevant additional reports from the Environmental Impact Statement (**EIS**) prepared by AARC include:

- WatermarkEco (2026) Groundwater Dependent Ecosystem Assessment – Esmeralda Graphite Project, prepared for Graphinex Pty Ltd, May 2026.
- EcoLogical Australia (2026) Esmeralda Graphite Project Stygofauna Assessment, prepared for Qld Aus Graphite Pty Ltd, February 2026.
- RGS (2026) Geochemistry assessment of mine materials and tailings: Esmeralda Project, prepared for Graphinex and AARC, April 2026.
- Engeny (2026) Esmeralda Graphite Project Surface Water Impact Assessment, prepared for Qld Aus Graphite Pty Ltd, May 2026.

- AARC (2026) Progressive Rehabilitation and Closure Plan, Esmeralda Graphite Project, May 2026.

The surface water assessment by Engeny (2026) describes the unnamed creek at the northern end of the proposed pit as ephemeral, with flow occurring immediately following rainfall events. The permanent flood levee is proposed to be designed to provide 0.1 % annual exceedance probability (AEP) flood immunity, minimising potential for surface water ingress to the pit.

The Groundwater Dependent Ecosystem (**GDE**) assessment by WatermarkEco (2026) included a field program to assess potential groundwater dependence at areas of mapped potential GDEs. The fieldwork included analysis of leaf water potential (**LWP**), stable isotopes, as well as soil augering and soil moisture. WatermarkEco (2026) presented conceptual ecohydrological models, and reported that there was a limited potential for groundwater dependence in the Project area.

EcoLogical Australia (2026) conducted stygofauna sampling of seven monitoring bores and four landholder bores between July and September 2025. The sampling event was conducted at bores within the Gilbert River Formation (**GRF**) and one bore (ESMB7D) in the Esmeralda Granite. At the time of sampling the shallow bores in the Tertiary sediments were dry. As reported by EcoLogical Australia (2026) the sampling events did not detect stygofauna.

As summarised in the AARC (2026) EIS, geochemical testing by RGS indicated that soil, overburden and waste rock materials are typically non-acid forming and generally have a low total sulphur content, slightly alkaline, low salinity and only contain slightly elevated concentrations of Aluminium (Al), Arsenic (As), and Zinc (Zn). As reported by RGS (2026), the tailings material is classified as potentially acid forming (**PAF**) and will require management. The Project description and the Progressive Rehabilitation and Closure Plan (**PRCP**) propose deposition of tailings material at the base of the open pit void where the Esmeralda Granite is intersected. The tailings material would be capped and backfilled to minimise potential acid generation and seepage to the overlying GRF.

2.2 Review Methodology

The peer review was undertaken based on the Australian Groundwater Modelling Guidelines (AGMG), issued by the National Water Commission in June 2012 (Barnett *et al.*, 2012). The AGMG includes a compliance checklist (refer **Table 1**) that covers essential aspects that a groundwater model needs to satisfy, in addition to the model objectives.

The Murray-Darling Basin Commission (**MDBC**) Groundwater Flow Modelling Guideline[3], issued in 2001, was also used to provide a more in-depth review covering the model. The checklist is provided in **Appendix A** and covers data analysis, conceptualisation, calibration, verification, prediction, sensitivity analysis and uncertainty analysis.

[3] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. Authors: H.Middlemis, N.Merrick, and J.Ross.

Hydrogeologist.com.au commenced the groundwater assessment scope of works in 2024, which included a gap analysis, site investigation, numerical modelling, assessment and reporting. Terms of Refence (**ToR**) were issued for the Project in September 2025. The Project is part of a new approach for approvals assessment led by the Office of the Coordinator-General (**OCG**), which involves a review process from the Cross-Agency Assessment Team (**CAAT**). As part of this process, initial feedback on the GIA was provided by the CAAT in August 2026.

HydroAlgorithmics was engaged in September 2026 to provide peer review advice on the GIA and numerical modelling completed by Hydrogeologist.com.au. As part of this review, model information and progressive versions of the GIA report were provided for comment. After each revision, a log of issues (**LoI**) was prepared and updated for consideration in the preparation of the final GIA report. Online meetings were held with Hydrogeologist.com.au on 1 September, 7 September and 16 September, with discussion on the model assumptions and reporting. All issues raised in the LoI and discussions have been addressed satisfactorily.

2.3 Compliance Checklist

The overall findings of the peer review are provided in the AGMG Compliance Checklist shown in **Table 1**, with further explanation of the findings provided for each question in **Section 2.3.1** to **Section 2.3.10.** Further details on the review, in accordance with the MDBC Groundwater Flow Modelling Guideline, are provided in **Appendix A**.

Overall, it has been concluded that the groundwater model is "*fit for purpose*", where the purpose is to provide quantitative predictions of groundwater take, drawdown and post closure recovery associated with the proposed open cut pit, which intersects the GRF aquifer.

Table 1 Compliance Checklist

QUESTION	YES/NO
1. Are the model objectives and model confidence level classification clearly stated?	Yes
2. Are the objectives satisfied?	Yes
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes
5. Does the model design conform to best practice?	Yes
6. Is the model calibration satisfactory?	Yes

QUESTION	YES/NO
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes
8. Do the model predictions conform to best practice?	Yes
9. Is the uncertainty associated with the predictions reported?	No
10. Is the model fit for purpose?	Usability - Yes Reliability - Yes Feasibility - Yes

2.3.1 Question 1: Are the model objectives and model confidence level classification clearly stated?

Findings

The model objectives and model confidence level classification are clearly reported in Document #1.

Discussion

The scope of work undertaken by Hydrogeologist.com.au is stated in Section 1.3 of Document #1, which includes construction of a "*numerical groundwater flow model suitable for assessing the Project's groundwater extraction, dewatering requirements, and potential drawdown impacts*". The objectives of the model are further documented in Section 1 of Appendix D in Document #1, as follows:

- *"Predicting changes to local and regional groundwater flow regimes;*
- *Predicting project-specific effects on groundwater resources, users and the environment;*
- *Estimating groundwater inflow into mining operations;*
- *Assessing potential for cumulative drawdown on groundwater resources, users and the environment; and*
- *Addressing regulatory requirements in relation to groundwater modelling."*

Section 6 of Appendix D in Document #1 presents the model confidence level assessment. Within this section, comparison to the AGMG classification criteria is provided. Strict application of the checklist results in a Class 1 classification, as one or more elements are Class 1, but the authors consider Class 2 a more appropriate overall level of confidence. The reviewers support Class 2 as the level of

attainment, as this coincides with the earlier more meaningful MDBC (2001) designation of an "impact assessment model". It should be noted that the latest Uncertainty Analysis Explanatory Note (Peeters and Middlemis, 2023)[4] recommends discontinuation of this scheme because it has been misapplied in the past by assigning Class 1 inappropriately.

2.3.2 Question 2: Are the objectives satisfied?

Findings

In our opinion the model objectives have been satisfied.

Discussion

Each of the modelling objectives and how they have been addressed is summarised below.

Predicting changes to local and regional groundwater flow regimes

Section 6.3 of Document #1 presents the groundwater model predictions. The predictions include maximum predicted groundwater drawdown and drawdown at the end of mining for the:

- GRF (Layer 3);
- Mesoproterozoic granite (Layer 5); and
- Water table.

Document #1 also presents the predicted water table levels for current conditions (Figure 5-2; main report), at the end of calibration (Figure 3-6; Appendix D) and at post closure equilibrium (Figure 5.2; Appendix D).

Predicting project-specific effects on groundwater resources, users and the environment

Section 6.4.1 of Document #1 includes discussion on impacts to groundwater resources. The modelling predicted between approximately 550 ML/year to an isolated peak of 5,024 ML/year of associated water take from the GRF during mining.

Section 6.4.2 of Document #1 includes discussion on third-party groundwater users. Groundwater drawdown is predicted at one registered bore on Esmeralda Station (RN157196), with approximately 1.6 m drawdown predicted. Bore RN157196 is reportedly constructed with screen from 42 to 54 metres below ground level (**mbgl**) within the GRF, with a groundwater level of 12.5 mbgl measured in 2013. The predicted drawdown presents a 5 % reduction in the available water column in the bore (based on the 2013 water level reading), which is unlikely to impair the capacity of the bore.

[4] Peeters LJM and Middlemis H (2023) *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia 2023.

Section 6.4.2 also provides discussion on post closure groundwater conditions, and potential for groundwater mixing with the backfilled spoil material within the GRF. Particle tracking undertaken by Hydrogeologist.com.au predicts limited migration of water from the mine area, with particles within the mine area taking approximately 12,000 years to migrate to the nearest downgradient bore (RN157437).

Section 6.4.3 of Document #1 includes discussion on impacts to springs, with no impacts predicted due to the distance of mapped springs from the Project area.

Section 6.4.4 of Document #1 includes discussion of impacts to GDEs. Figure 6-9 and Figure 6-10 in Document #1 present the maximum extent of drawdown in the GRF (layer 2 and 3) compared to mapped potential GDEs. The extent of maximum drawdown is largely within the mining lease. The model predicts no drawdown within layer 1 (Tertiary sediments), due to largely unsaturated conditions represented in the model layer. This corresponds with the available site observation data, which recorded unsaturated conditions to 10 to 12 m depth between 2024 and 2025. There is potential for the Tertiary sediments to be recharged following significant rainfall and flood events; however, this is likely to be a short-term response based on the current site observation data. The saturation status of the Tertiary sediments should be a focus for future assessment.

The WatermarkEco (2026) report indicates that there is limited potential for groundwater dependence, with estimated root depth thresholds for mapped vegetation ranging from 5 m to 10 m for most species. This corresponds with the depth of the Tertiary sediments. An exception to this is River Red Gum (*Eucalyptus camaldulensis*), which can have a maximum root depth of 8 to 15 m (WatermarkEco 2026). A single River Red Gum tree (E2_T1) was reported by WatermarkEco (2026) as having a 'Very High' LWP.

Estimating groundwater inflow into mining operations

Section 6.3.5 of Document #1 presents the predicted inflows to the pit over time. Inflows are predicted to be approximately 890 ML/year on average during mining, ranging between 536 ML/year and 5,024 ML/year. The highest inflows are predicted in year 5, which corresponds to a period in the mine plan where the largest area of the GRF is excavated into.

Assessing potential for cumulative drawdown on groundwater resources, users and the environment

There are no other mining operations in the region; therefore, no cumulative impacts from surrounding mining. The main groundwater use in the area is stock water supply. There are three private bores within 5 km of the proposed pit (Rowe3, RN157196 and RN157437). Therefore, it is unlikely that private water usage for stock water supply would contribute a measurable cumulative impact.

Addressing regulatory requirements in relation to groundwater modelling

The numerical groundwater model was developed in line with the AGMG. The Project specific ToR issued in September 2025 include requirements for numerical groundwater modelling, in accordance with the relevant guidelines (Australian Government, Australian groundwater modelling guidelines, 2012). The ToR also specifically state that the model:

- *"is consistent with the ecohydrological conceptual model*
- *predicts project-only and cumulative groundwater changes to:*
    - *groundwater drawdown or pressure changes in affected formations*
    - *groundwater flows, inter-aquifer connectivity, recharge and discharge*
    - *groundwater-surface water connectivity*
    - *groundwater uses and users*
- *simulates groundwater impacts for the life of project and post closure, with sufficient timeframe to assess long term impacts, and potential plume behaviour and aquifers recovery*
- *explicitly represents subsidence in a manner that is consistent with supporting subsidence studies, which should include temporal effects on hydraulic properties and inter-aquifer connectivity/connectivity to surface systems*
- *connects model outputs to groundwater monitoring design and defines adaptive management strategies (e.g. drawdown thresholds or contaminant concentrations)*
- *is peer reviewed by an independent third-party specialist, and accompanied by a peer review report*
- *is accompanied by a numerical model report that details all relevant parameters, conditions and assumptions used."*

In our opinion the ToR regarding numerical groundwater modelling have been addressed in the work presented by Hydrogeologist.com.au.

The ToR requirements for model predictions are consistent with the model objectives discussed above.

The model design is consistent with the conceptual model presented by Hydrogeologist.com.au. The model represents changes to groundwater conditions during mining and post closure. The model is developed in a way to represent excavation (hydraulic connection) through the Tertiary, GRF and Mesoproterozoic granite.

Section 7.3 of Document #1 includes an adaptive management strategy, utilizing the numerical groundwater model predictions to inform groundwater trigger levels and verify modelled and observed groundwater level trends on an annual basis.

This independent third-party Peer Review has been completed for the groundwater model.

Document #1 includes discussion on the model design, calibration, assumptions and predictions.

2.3.3 Question 3: Is the conceptual model consistent with objectives and confidence level classification?

Findings

In our opinion, the illustration and explanation of the conceptual groundwater model within Document #1 adequately discuss each key process (natural and imposed) relevant to the Project and model objectives.

Discussion

The main aspects of a conceptual groundwater model relate to the natural hydrogeological conditions and potential changes and impact pathways associated with the Project; these include:

- **Water In:** recharge processes (e.g. rainfall and streamflow) that result in changes in groundwater levels;.
- **Water Out:** natural discharge processes from evapotranspiration and potential baseflow contributions, as well as other water uses (i.e. landholder bores and surrounding activities) .
- **Hydraulic connection**: covering hydraulic connection within and between hydrogeological units and surface water-groundwater interactions.
- **Potential impact pathways associated with the Project**: reflecting interception of groundwater through mining, causing mine inflows and groundwater drawdown, as well as post closure groundwater conditions.

The conceptual groundwater model for the Project is presented visually in Figure 5-1 of Document #1 (refer **Figure 2**). The conceptual groundwater model shown in **Figure 2** provides a simple illustration of the Tertiary sediments, GRF and Mesoproterozoic basement unit within the Project area. The diagram depicts unsaturated conditions in the Tertiary sediments, with a groundwater table indicating the GRF is fully saturated. The proposed open cut pit is represented in the diagram, extending below the groundwater table. The figure also shows the indicated location of the out of pit waste rock dump and monitoring bore locations. Normally, arrows would be added that indicate recharge (rain) and discharge (ET) mechanisms, as well as natural and mine-induced groundwater flow directions.

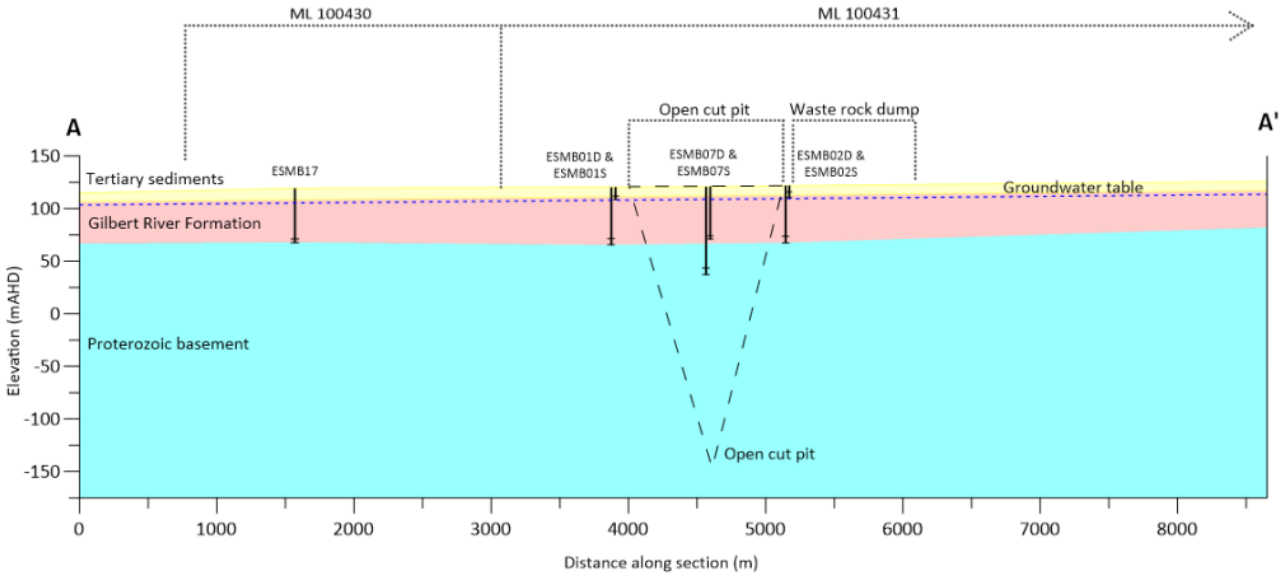


Figure 2 Conceptual Groundwater Model (Source: Hydrogeologist.com.au 2026, Figure 5-1)

Further information and explanation of the conceptual groundwater model is provided in Section 3 to Section 5 of Document #1.

As reported in Document #1, rainfall is the main source of recharge to the groundwater system. Recharge events would likely occur during the wet season (November to March). Streamflow is also influenced by seasonal rainfall events, with Warrigal Creek, Borer River and the unnamed tributary characterised as ephemeral, only flowing directly following rainfall events.

Natural discharge from the system is reported as being via evaporation and evapotranspiration (ET). Document #1 indicates low potential for surface water-groundwater interactions, with baseflow contributions to creeks considered unlikely within the Project area. This was informed by shallow bores installed in the Tertiary sediments in 2024 to 10 to 12 m depth that were recorded as dry between 2024 and the end of 2025, by reporting by Engeny (2026) regarding the ephemeral creeks, and the GDE assessment by Watermark Eco (2026). WatermarkEco (2026) undertook fieldwork to verify shallow water table conditions at GDEs, with auger holes and soil moisture readings taken between 0.3 m to 6.6 m depth. WatermarkEco (2026) reported that soil moisture generally increased below 0.5 m depth, but groundwater was not intersected in the auger holes. WatermarkEco (2026) reported that ecosystems are likely more reliant on soil moisture within the vadose zone, recharged by rainfall and flood events, with a low potential for groundwater usage. It is conceptualised that the surficial Tertiary sediments may receive episodic recharge from peak rainfall and streamflow events, but do not maintain a persistent or connected groundwater source. A shallow water table may develop locally within the Tertiary sediments following peak recharge events; however, these water levels are likely to decline and dissipate rapidly.

Groundwater occurrence is largely associated with the Triassic age sandstones of the Gilbert River Formation (GRF), which unconformably underlies the Tertiary sediments in the Project area. Groundwater heads for bores screened 46 to 55 mbgl range between 6 and 20 mbgl. Groundwater quality is generally fresh to brackish, with chloride mass balance (CMB) analysis indicating recharge to the GRF may range between 1.25 % to 2.5 % of rainfall.

To the south and west of the Project area the GRF is overlain by the low permeability Wallumbilla Formation, which acts as a confining unit for the GRF. Where the Wallumbilla Formation is present (see Figure 3-6), artesian groundwater heads have been recorded at registered bores to the south and west of the Project area. These conditions are discussed in Document #1, but not visually presented in the conceptual groundwater model in Figure 5-1 of Document #1. **Figure 3** is included here to illustrate the regional geological context.

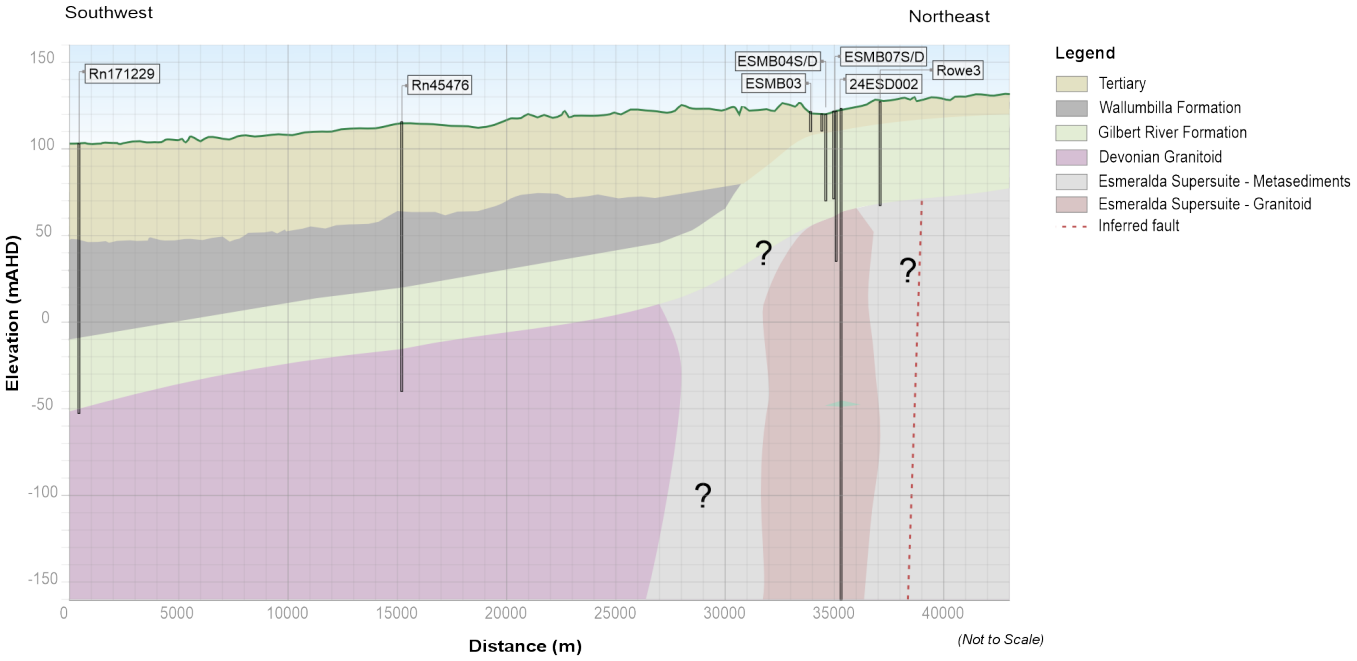


Figure 3 Regional conceptual geological cross section

The GRF is unconformably underlain by the Mesoproterozoic age granite unit, which is present from around 70 mAHD (50 mbgl) within the Project area. The granite is characterised as having a very low primary porosity, but has potential for secondary porosity associated with fractures and faults. An inferred fault, trending northwest, has been mapped approximately 3 km north of the Project area. The inferred fault location corresponds with an offset observed within the basement geology, based on geophysical studies (Mitre Geophysics, 2025)[5].

The Project involves excavation through the Tertiary sediments and GRF, into the Mesoproterozoic granite down to 250 mbgl (-157 mAHD). The open cut pit would result in groundwater inflows from the

[5] Mitre Geophysics (2025) *2025 Esmeralda VTEM Report*, prepared for Graphinex Pty Ltd

Tertiary sediments (where saturated), GRF and Mesoproterozoic granite. Groundwater drawdown would occur around the pit during operations, with gradual recovery within the final pit void.

Mine water and tailings material will be stored within lined regulated structures, reducing the potential for seepage to the surficial Tertiary sediments. At cessation of operations, the tailings material from three of the TSF cells will be deposited with a maximum fill level to 42 mAHD, and capped within the Mesoproterozoic granite. The pit would then be backfilled with spoil/waste rock across the GRF and Tertiary sediments. The in-pit storage and capping was proposed to minimise potential for impacts to groundwater quality in the GRF and Tertiary sediments that may impact on downgradient users.

2.3.4 Question 4: Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?

Findings

The conceptual groundwater model has been reviewed internally and by the lead reviewer whose opinion is that the conceptual groundwater model has utilised all data available to Hydrogeologist.com.au to characterise the groundwater conditions, with focus on the GRF. The information presented is considered suitable to characterise the main aquifer and potential impact pathway, associated with intersection of the GRF. However, an adaptive management approach should be followed that would incorporate new data as it becomes available. This includes review of recharge response in the Tertiary sediments, and the secondary porosity and groundwater conditions within the Mesoproterozoic granite.

Discussion

Information to support the conceptual groundwater model is presented in Section 3 to Section 5 of Document #1. This includes analysis of climate trends, topography, drainage, geology, hydraulic testing, groundwater level and groundwater quality analysis, including use of CMB for recharge estimates. The information is presented and reported clearly.

The conceptual groundwater model is informed by the site geological model and exploration drill holes across the Project area. A groundwater monitoring network was also installed within the Project area, which includes six bores within the Tertiary sediments, seven bores in the GRF and one bore within the Mesoproterozoic granite.

The assessment also draws on a range of publicly available information and data, including SILO climate data and registered bore information. The assessment also incorporates information from, and

is consistent with, previous hydrogeological assessments of the GAB, including AECOM (2025)[6], KCB (2016)[7], OGIA (2012)[8] and Smerdon *et al.* (2012)[9].

Four bores (ESMB01D/S and ESMB02D/S) were installed and equipped with groundwater level loggers around July 2024. An additional 10 bores were installed and equipped with groundwater level loggers around September 2025. Hydrogeologist.com.au utilised all groundwater level data available to them for the site bore network, and private landholder bores. However, the timeframe of available site groundwater level data is limited. Document #1 presents a combination of logger data and manual dipped water levels recorded for four of the bores over the 2024/2025 wet season, and data from 14 bores at the start (November and December) of the 2025/2026 wet season. The groundwater level loggers remain in place for ongoing groundwater level monitoring.

As reported in Document #1, the available groundwater level and hydraulic data for the deep bore ESMB07D indicate confined, low permeability conditions in the Mesoproterozoic granite. However, other available data reported in Document #1 contrasts to this. This includes the water quality results for ESMB07D that recorded fresh water quality, indicating high estimated recharge based on CMB analysis. Pumping test results for exploration hole 24ESD002 also indicate higher yields; however, this may relate to the construction of the bore and potential connection to the GRF. Therefore, as new data becomes available the conceptualisation of the basement unit should be checked and verified.

2.3.5 Question 5: Does the model design conform to best practice?

Findings

The mathematical model design follows best practice for the model objectives. The numerical groundwater model provides a useful tool that can be progressively refined and improved upon for quantifying and verifying groundwater take and impacts over the life of operations.

Discussion

The model was developed in MODFLOW-USG (Panday *et al.*, 2015), with Voronoi mesh refinement at key features using Algomesh (HydroAlgorithmics, 2016) software.

A regional model domain was established, extending over 62 km north to south and 89 km west to east. The large model domain enables the model predictions within the Project area to be not unduly affected by the assumed boundary conditions and enables representation of regional groundwater conditions.

[6] AECOM, 2025. Critical Minerals Queensland - Groundwater Baseline Project GEO2025_01184

[7] Klohn Crippen Berger. (2016). Hydrogeological Assessment of the Great Artesian Basin. Characterisation of Aquifer Groups, Carpentaria Basin. D09997A01.

[8] Queensland Office of Groundwater Impact Assessment (2012) MBC Groundwater model layer boundaries. Bioregional Assessment Source Dataset. Viewed 25 October 2017.

[9] Smerdon, Brian; Welsh, Wendy; Ransley, Tim. Water resource assessment for the Carpentaria region. A report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment. CSIRO; 2012. csiro:EP132679.

The model includes six layers that represent the main hydrogeological units, consistent with the conceptual groundwater model. These include:

- Layer 1: surficial Tertiary sediments
- Layer 2: Wallumbilla Formation and Gilbert River Formation, zoned based on the OGIA (2012) modelled extent of Wallumbilla Formation and bore log information
- Layer 3: Gilbert River Formation
- Layer 4: Upper Proterozoic basement
- Layer 5: Proterozoic basement to the base of the proposed pit
- Layer 6: Proterozoic basement.

The model uses a general head boundary (GHB) to represent flow across the model boundary. Artesian groundwater conditions have been observed to the west and south-west edges of the model domain, based on registered bore details. These conditions were represented in the model using the GHB head elevation.

The model includes steady state calibration and transient calibration from August 2024 to November 2025, represented with monthly stress periods. The model was calibrated using PESTPP- Iterative Ensemble Smoother (**IES**) software. The transient calibration period was aligned to the period of available site observation data, and the application of monthly stress periods helps maximise representation of trends in the available data. Future updates of the model should consider inclusion of a verification period. Ideally the verification period would be maintained with monthly stress periods, and used to verify the fit of the model as additional site observation data become available. The use of monthly stress periods would also enable representation of temporal variability in the shallow water table following recharge events.

In the predictive model, the 53 years of mine operations are represented with annual stress periods. This will provide an average annual estimate of inflows and impacts. The recovery period extends for 1000 years, with stress period duration ranging from 1 to 100 years.

The model timing for the predictive period is considered appropriate based on the available data and the objectives of the model to estimate inflows and predict maximum potential drawdown impacts. It is noted from climatic data that average rainfall is higher during the summer wet period. If the model is to be used for site operational purposes to inform the site water balance, future model updates should consider applying quarterly or six monthly stress periods.

2.3.6 Question 6: Is the model calibration satisfactory?

Findings

The model calibration is considered satisfactory for the objectives of the model and availability of data. The model shows a good fit to observed groundwater levels within the key aquifer, the GRF.

Discussion

The model was calibrated in two stages, with an initial PEST calibration undertaken to inform the parameter distributions, followed by PESTPP-IES for 300 trial realisations (of which 226 were retained).

The calibrated parameters included hydraulic properties (Kh, Kv, Ss, Sy), recharge rate, ET factor and extinction depth, GHB parameters (elevation correction and conductance) and riverbed conductance.

The calibration period was represented with monthly stress periods from August 2024 to November 2025 (a relatively short period).

The model was calibrated to observed groundwater levels (including dry bores) and groundwater head differences between monthly readings. The majority (approximately 95 %) of calibration targets were for the GRF (layer 3). This included groundwater levels for site monitoring bores and registered bores. Observation targets representing dry conditions measured at monitoring bores within the Tertiary sediments (layer 1) were included, and nine observation readings from bore ESMB07D were used for the shallow Mesoproterozoic granite (layer 4).

Available details for registered bores to the southwest and west of the Project area generally recorded artesian groundwater heads within the GRF. Available geological logs indicate these artesian conditions correspond to areas where the low permeability black shales of the Wallumbilla Formation are present overlying the GRF. These artesian conditions are not observed within the Project area, because the Wallumbilla Formation is absent in this area.

It is noted that the artesian groundwater levels for registered bores were measured between 1940 to 2015. Due to the timing of the model, observation data for registered bores measured prior to 2024 were assigned to a nominal stress period date of March 2025. Groundwater levels and flow gradients are known to have changed over time within the region (Smerdon *et al.* 2012)[9]. Therefore, while this approach enables a general fit to regional groundwater levels, the model would be unable to precisely fit to observation data prior to the calibration period.

Pilot point calibration was undertaken, with a total of 522 pilot points per layer. Kriging interpolation was used to assign parameters around the pilot points, with no zonation or constraints applied to reflect mapped geology. However, manual calibration was subsequently undertaken to more explicitly reflect the extent of the Wallumbilla Formation and GRF in model layer 2.

Section 3 of Appendix D presents the calibration results, which include statistical analysis of fit between modelled and observed data, spatial spread of residual error and hydrographs comparing modelled and observed water levels over time. The calibration statistics indicate a good fit, with a residual mean of 1.2 m, unweighted root mean square (**RMS**) error of 4.5 m and unweighted scaled RMS (**SRMS**) of 3.9 %.

The mapped residuals and hydrographs show a good fit between modelled and observed groundwater levels for the site groundwater monitoring bores within the Project area. The model shows a very good fit to groundwater elevations and trends for bores ESMB02D and ESMB17. The model slightly under-predicts groundwater levels in the GRF at site bores ESMB01D, ESMB04D, ESMB05D, ESMB06D and

ESMB07S. The model also slightly under-predicts groundwater levels in the Mesoproterozoic granite (layer 4) for ESMB07D. However, the modelled groundwater levels are all within about 4 m of observed levels, which is considered a good fit.

The model also records a good fit to observed groundwater levels at registered bores within 10 km of the Project (Rowe2, Rowe3 and Rowe4). For bores over 10 km east of the Project area (Pelican and Rowe1), the model over-predicts groundwater levels.

2.3.7 Question 7: Are the calibrated parameter values and estimated fluxes plausible?

Findings

The adopted model parameters are plausible. Being a greenfield situation, the estimated fluxes give sensible magnitudes and relativities for rainfall recharge and ET discharge.

Discussion

The calibrated hydraulic and storage parameters are listed in Table 3-3 and Table 3-4 of Appendix D. As the model was calibrated with pilot points to allow spatial variability, the range in hydraulic properties is listed. Horizontal hydraulic conductivity ranges appear reasonable for the represented geology, with Tertiary sediments in layer 1, Wallumbilla Formation in layer 2, GRF in layer 3 and the Mesoproterozoic basement in layer 4 to layer 6. The calibrated Kh:Kv anisotropy is logical for the geology modelled, with a ratio of 10:1 for the GRF and Tertiary sediments, and 100:1 or lower for the Wallumbilla Formation and Mesoproterozoic basement. The calibrated storage properties in Table 3-4 of Appendix D appear reasonable for the geology presented, with the highest specific yield (0.3) attributed to the GRF.

Subsequent to the automated calibration process, a manual calibration update was made to assign the calibrated parameters from layer 3 (GRF) to the GRF zone in layer 2. This adjustment improved the model fit to the site geology and conceptual groundwater model.

Calibrated recharge and ET parameters are listed in Table 3-5 of Appendix D. It is noted that the model calibration extended ET extinction depth to the maximum bound of 10 m. This assumption is within the range of vegetation root depth threshold presented by WatermarkEco (2026).

Average water budgets over the transient calibration period are presented in Table 3-8 of Appendix D. The values presented indicate:

- Slight net loss of stored groundwater during this period.
- Groundwater system recharge is primarily from boundary inflows over time.
- Groundwater system discharge is primarily from boundary outflows over time.
- No groundwater – surface water interaction.

2.3.8 Question 8: Do the model predictions conform to best practice?

The Project is within an area with no existing mining in the region. The predictive model includes a Null (no mining) scenario to represent current conditions, and a Project scenario that represents the open cut mining. The predictive model period extended for 53 years with annual stress periods, consistent with the mine design.

Two recovery scenarios were modelled, one assuming full backfill of the pit with spoil and one scenario with full backfill of the pit with low permeability material. The recovery model was run with variable stress period lengths (annual to 100 years) covering a period of 1000 years post mining.

Key outputs of interest are:

- Water budgets.
- Pit inflows over time.
- Groundwater levels at the end of mining: water table and layer 3 (GRF)
- Maximum groundwater drawdown at the end of mining, for all time and post closure: water table, layer 3 (GRF) and layer 5 (Mesoproterozoic basement)
- Incremental changes to alluvium fluxes.
- Post-closure equilibrium water levels: water table and layer 3 (GRF)

Predicted hydrographs to the end of mining, at bores in the monitoring network, are not included. However, most of the bores are situated within the proposed pit extent and would be mined out or removed with site infrastructure over time. It is expected that the groundwater monitoring network would be revised over the life of operations to maintain a suitable spread of monitoring bores, laterally and vertically, outside the area of disturbance. With future updates of the model and bore network, the predicted groundwater levels at monitoring points should be produced to help inform groundwater triggers.

The model predictions conform to best practice.

Average water budgets over the transient prediction period are presented in Table 4-1 of Appendix D for the Null Scenario and in Table 4-2 of Appendix D for the Project Scenario. The values presented for the Project Scenario indicate:

- Slight net loss of stored groundwater during this period.
- Groundwater system recharge is primarily from boundary inflows over time.
- Groundwater system discharge is primarily from boundary outflows over time.
- Mine inflows less than 2 % of groundwater system recharge.
- No groundwater – surface water interaction.

The recovery scenarios represent two extreme ranges in post closure landform that are unlikely to occur, fully backfilled with spoil and with low permeability material. A scenario was not run to represent

the input tailings deposition in the base of the pit that will be capped from 42 mAHD and backfilled with spoil.

The two scenarios run represent worst case conditions, one that would enhance seepage post closure (backfilled with spoil) and one that would impede natural groundwater flow (backfilled with low permeability material). Particle tracking was run for both scenarios to demonstrate that under these worst case conditions there is limited seepage from the mine area. This is relevant to understanding the potential risk to groundwater quality and use within the GRF aquifer. This is considered an appropriate approach to communicate the Project risk. The final void modelling could be further refined and improved upon over the life of operations to inform ongoing management and planning.

2.3.9 Question 9: Is the uncertainty associated with the predictions reported?

The limitations and qualitative uncertainty associated with the predictions are discussed in Section 7 of Appendix D. No quantitative uncertainty analysis has been undertaken.

Key limitations are:

- Absence of historical mining to ground-truth expected responses to mining stresses.
- Limited duration of (unstressed) groundwater level records.
- Reliance on a single model for predictions rather than the full set of ensemble models.

Key uncertain features are:

- Topographic elevations over the full model extent, affecting derived groundwater elevations.
- Saturation dynamics in Tertiary sediments (model layer 1)
- Characteristics of fault structures (e.g. throw, vertical extent, barrier/conduit status). It is noted that:
    - the model has a good fit to landholder bores on the eastern side of a fault, indicating GRF connection across the fault; and
    - predicted drawdown extends out to this fault;
- Degree of connective fracturing in the Mesoproterozoic granite .

2.3.10 Question 10: Is the model fit for purpose?

The latest IESC Explanatory Note on uncertainty analysis (Peeters and Middlemis, 2023[10]) advocates the use of three criteria in deciding fitness for purpose:

[10] Peeters LJM and Middlemis H., 2023. Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining

- Usability.
- Reliability.
- Feasibility.

Each aspect is further discussed below.

Usability

In our view, sufficient information has been conveyed to decision-makers about the uncertainty in conceptual processes and characterisation of the groundwater system based on model calibration and model simulation. The model can be regarded as a usable tool for making decisions.

Reliability

In our opinion the model provides a reliable tool for predicting potential impacts to groundwater resources and users. The main aquifer within the region is the GRF, which is well represented in the groundwater model and informed by site specific data and regional publicly available data.

By applying an adaptive management approach, the model can be further updated and refined as additional data become available to improve ongoing groundwater monitoring and management.

Feasibility

In our view, the developed model is a sufficient approximation to reality subject to computational constraints and data limitations. No model will ever be perfect. The model shows a good fit to the observed groundwater levels and trends within the GRF, which is the main aquifer relevant to the Project. The regional groundwater model is suitable for predicting groundwater take and drawdown impacts to the water table, GRF and basement geology.

The model has not been developed to assess short term, local scale changes to water availability for specific GDEs, such as soil moisture changes within the vadose zone (unsaturated zone above the water table). This type of process is not typically captured within a regional-scale numerical groundwater model. The conceptual ecohydrological model for the vadose zone is presented and discussed separately within the GDE assessment by WatermarkEco (2026). The reporting by WatermarkEco (2026) highlighted the influence of natural rainfall and surface water flow events in recharging the soil moisture conditions, with limited potential reliance on the water table.

Overall, we regard the model as *fit for purpose*, where ‘purpose’ is defined by the modelling objectives referenced above in Question 1.

Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia 2023.

3 CONCLUSION

This peer review has assessed the groundwater impact assessment and supporting numerical groundwater model prepared for the Esmeralda Graphite Project against the requirements and expectations of the Australian Groundwater Modelling Guidelines. On the basis of the information reviewed, the groundwater model is considered suitable for its stated assessment purpose, namely to provide quantitative predictions of groundwater take, pit inflows, groundwater drawdown and post-closure groundwater recovery associated with the proposed open cut pit.

The model objectives are clearly stated and have been addressed through simulation of changes to local and regional groundwater flow regimes, Project-specific effects on groundwater resources, users and the environment, groundwater inflows to mining operations, potential cumulative drawdown effects and regulatory requirements relevant to groundwater modelling.

The principal conclusions of the peer review are summarised below.

- The conceptual groundwater model provides an appropriate basis for the numerical model and adequately represents the principal hydrogeological units, groundwater processes and Project-related impact pathways, including groundwater interception by the pit, operational drawdown, mine inflows and post-closure recovery.
- The numerical model design is consistent with accepted industry practice for a regional-scale groundwater assessment. The model domain, boundary conditions, layering, calibration approach and predictive simulation framework are suitable for assessing groundwater take and drawdown impacts associated with the Project.
- Model calibration is considered satisfactory for the available dataset. The model demonstrates a good fit to observed groundwater levels and trends in the Gilbert River Formation, which is the key aquifer intercepted by the proposed pit and the primary unit relevant to the predicted groundwater impacts.
- Predicted groundwater impacts are primarily associated with excavation of the proposed pit through the Gilbert River Formation and into the underlying basement. Groundwater drawdown in the GRF is predicted to extend up to 3 km from the pit, with an average of approximately 890 ML/year in take from the GRF. Less than 2 m drawdown is predicted to occur at one registered landholder bore.
- The assessment appropriately recognises limitations and uncertainty in the model predictions, without actually undertaking quantitative uncertainty analysis. Key matters for ongoing verification include recharge response in the Tertiary sediments, hydraulic behaviour of the Mesoproterozoic basement, temporal groundwater level trends and comparison of observed monitoring data against model predictions.
- The proposed adaptive management approach is appropriate and should be maintained through ongoing groundwater monitoring, periodic review of model performance and progressive model refinement as operational and monitoring data become available.

Subject to implementation of the proposed monitoring, verification and adaptive management measures, the reviewers consider the groundwater model as *fit for purpose* and support the technical conclusions of the groundwater impact assessment for the stated modelling objectives.

Appendix A. MDBC (2001) Model Appraisal Checklist

MDBC (2001) Model Appraisal Checklist

NO.	QUESTION	N/A OR UNKNOWN	LOW	SCORE 1	SCORE 3	HIGH	SCORE	COMMENT
1.0	**THE REPORT**							
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good		
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes			
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good		
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good		
1.5	Are the model results of any practical use?		No	Maybe	Yes			
2.0	**DATA ANALYSIS**							
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good		Site groundwater bore network installed in 2024 to 2025, and site specific data collected and analysed.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good		Figure 4-11 for the GRF
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good		SILO climate data
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good		Hydrographs for bores near landholder bores indicate potential influence from private bore abstraction, but limited available details regarding bore usage. Likely low and can be ignored in the simulation.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good		Hydrographs compared with rainfall.

NO.	QUESTION	N/A OR UNKNOWN	LOW	SCORE 1	SCORE 3	HIGH	SCORE	COMMENT
2.6	Are groundwater hydrographs used for calibration?		No	Maybe	Yes			
2.7	Have consistent data units and standard geometrical datums been used?		No	Yes				
3.0	**CONCEPTUALISATION**							
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes		
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good		
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good		
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?		Yes	No				
4.0	**MODEL DESIGN**							
4.1	Is the spatial extent of the model appropriate?		No	Maybe	Yes			
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good		GHB applied
4.3	Is the software appropriate for the objectives of the study?		No	Maybe	Yes			MODFLOW-USG
5.0	**CALIBRATION**							
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good		
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good		

NO.	QUESTION	N/A OR UNKNOWN	LOW	SCORE 1	SCORE 3	HIGH	SCORE	COMMENT
5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good		Limited temporal range within the observation data
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes		
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good		
5.6	Are there good reasons for not meeting agreed performance criteria?		Missing	Deficient	Adequate	Very Good		
6.0	**VERIFICATION**							**Optional**
6.1	Is there sufficient evidence provided for model verification?		Missing	Deficient	Adequate	Very Good		Recommended applying an adaptive management approach to the model, with future verification against observation data.
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?		Unknown	No	Maybe	Yes		N/A
6.3	Are there good reasons for an unsatisfactory verification?		Missing	Deficient	Adequate	Very Good		N/A
7.0	**PREDICTION**							
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good		No climate change scenarios run. Not considered necessary at this stage.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good		Null, Project and two final landform scenarios.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes		Rarely possible for mining models. Steady state and transient calibration (Aug 2024 to Nov 2025) with monthly stress periods. Predictive model extends for 53 years (annual stress periods), plus 1000 year recovery period.

NO.	QUESTION	N/A OR UNKNOWN	LOW	SCORE 1	SCORE 3	HIGH	SCORE	COMMENT
7.4	Are the model predictions plausible?		No	Maybe	Yes			The model shows a good fit to observed groundwater levels within the GRF, the key aquifer intercepted with the Project. However, future improvements could be made as additional site data becomes available, including for the Tertiary sediments and Mesoproterozoic basement.
8.0	**SENSITIVITY ANALYSIS**							**Optional**
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good		Not essential at this stage.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good		Not essential at this stage.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good		Not essential at this stage.
9.0	**UNCERTAINTY ANALYSIS**							
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes		Qualitative statements are made. No quantitative UA. (Not in project brief) Scenario analysis (Type 1 UA) has been undertaken for closure: extreme backfill scenarios confine final void uncertainty.