Appendix C
RL 1150 m Project - Groundwater Impact Assessment Report (AGE 2023)

Australasian
Groundwater
& Environmental
Consultants

Report on

EHO Application for EA Amendment – Groundwater Assessment

Prepared for
Ernest Henry Mine Pty Ltd

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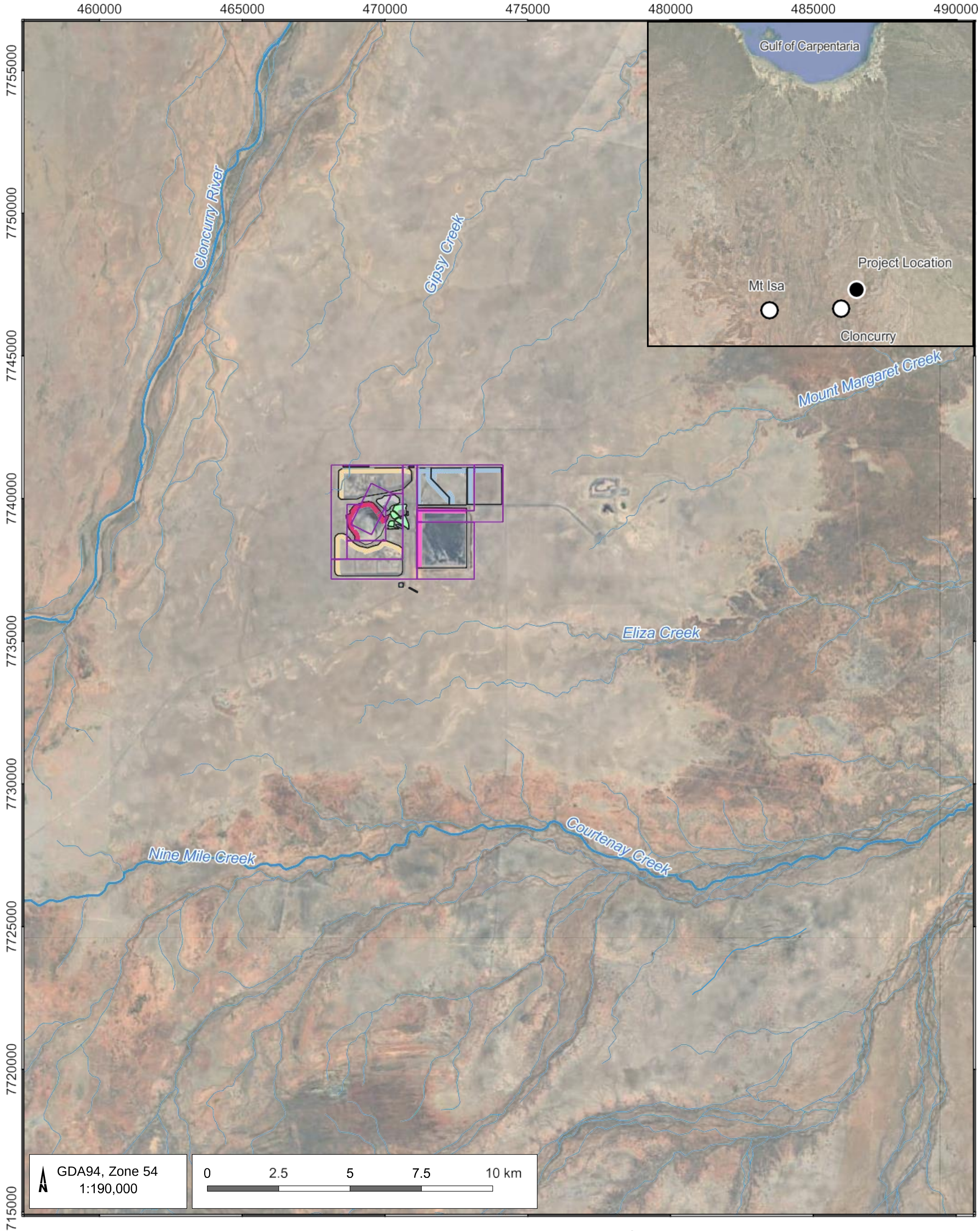
EHO Application for EA Amendment Groundwater Assessment

1 Introduction

Ernest Henry Mine Pty Ltd (EHMPL; an Evolution Mining company) operates Ernest Henry Operation (EHO). Surface site infrastructure at EHO includes two waste rock dumps (WRD) located to the north (NWRD) and south (SWRD) of an open-cut pit, which is connected to an underground mine (Figure 1.1). The transition from open cut mining to underground mining occurred in early 2011. In addition, there is a tailings evaporation dam (TED), tailings evaporation dam extension (TEDEX), and a production evaporation dam (PED) located northeast of the open-cut pit. There is also a Tailings Storage Facility (TSF) southeast of the pit (Figure 1.1). The operational strategy for the TSF is for the facility to be a free draining medium, which transfers the TSF supernatant that reports to the eastern TSF drain to the TED. The purpose of the TED is to collect and contain all tailings decant water and allow it to evaporate. The purpose of the PED is to collect and contain all runoff water from the industrial area and concentrator and allow this water to be recycled through the concentrator or to evaporate. The underground ore is excavated using the sublevel cave mining method, which causes caving and fracturing in the country rock overlying the orebody. Subsidence has occurred on the southern sideof the pit wall as a result of the advancement of the underground mine to the south.

Evolution plans to apply for an amendment to the Environmental Authority (EA), number EPML00899713, which was last amended on 05 June 2020. The changes to operations that are important for this application are: a proposed change to the total volume of tailings that can be stored within the currently approved TSF from 130 Mm^3 to 136 Mm^3, and the associated extension of underground workings from 1200 mRL to1150 mRL (mine datum). The current milling schedule predicts that the TSF will reach the current EA maximum volume (130 Mm^3) by August 2025. As such, an EA amendment is required to increase the TSF volume to 136Mm^3. This change aligns with production from the underground operation identifying an additional 50 m of resource beneath 1200 mRL level that is extractable within the current mine schedule. Therefore, the amended mine schedule would include production to the 1150 mRL level. In the Australian Height Datum (AHD), the 1200 and 1150 mine elevations are -800.158 mAHD and -850.158 mAHD, respectively. The proposedincrease in tailings volume can be stored within and does not alter the currently approved embankment heightof, the existing TSF. The deeper mining will cause further caving and fractures, and this is predicted to createadditional subsidence at the surface on the southern side of the pit. According to a recent study (Beck Engineering, 2023), the subsided area could include part of the SWRD. This subsidence would cause exposure of rock and waste material to the atmosphere; a change in the rock competency and permeability inthe subsided area; and a change in the shape of the pit void, as material falls into the pit.

This report provides a groundwater assessment for the change in TSF volume and the changes resulting from production to a deeper level of mining (1150 mRL).



EHM Application for EA Amendment (EHM5011.001)

Project location, infrastructure, and drainage

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08/06/2023

FIGURE No:
1.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;

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2 Objective and legislation conditions

The objective of this supporting document is to evaluate and report on the potential impacts to groundwater from the proposed changes to the operations and the mine plan (including impacts after mine closure). The application to amend the EA must adhere to the relevant regulatory requirements, including s226 and s226A of the Queensland Environmental Protection Act (the EP Act), which are provided below verbatim fromthe act. This supporting document mainly responds to items 1(f) and 1(g) of s226A.

226 Requirements for amendment applications generally

1) An amendment application must—
   a) be made to the administering authority; and
   b) be in the approved form; and
   c) be accompanied by the fee prescribed by regulation; and
   d) describe the proposed amendment; and
   e) describe the land that will be affected by the proposed amendment; and
   f) include any other document relating to the application prescribed by regulation.
2) However, subsection (1)(d) and (e) does not apply to an application for a condition conversion.

226A Requirements for amendment applications for environmental authorities

1) If the amendment application is for the amendment of an environmental authority, the application must also—
   a) describe any development permits in effect under the Planning Act for carrying out the relevant activity for the authority; and
   b) state whether each relevant activity will, if the amendment is made, comply with the eligibility criteria for the activity; and
   c) if the application states that each relevant activity will, if the amendment is made, comply with the eligibility criteria for the activity—include a declaration that the statement is correct; and
   d) state whether the application seeks to change a condition identified in the authority as a standard condition; and
   e) if the application relates to a new relevant resource tenure for the authority that is an exploration permit or GHG permit—state whether the applicant seeks an amended environmental authority that is subject to the standard conditions for the relevant activity or authority, to the extent it relates to the permit; and
   f) include an assessment of the likely impact of the proposed amendment on the environmental values, including—
      (i) a description of the environmental values likely to be affected by the proposed amendment; and
      (ii) details of emissions or releases likely to be generated by the proposed amendment; and
      (iii) a description of the risk and likely magnitude of impacts on the environmental values; and
      (iv) details of the management practices proposed to be implemented to prevent or minimise adverse impacts; and
      (v) if a PRCP schedule does not apply for each relevant activity—details of how the land the subject of the application will be rehabilitated after each relevant activity ends; and
   g) include a description of the proposed measures for minimising and managing waste generated by amendments to the relevant activity; and
   h) include details of any site management plan or environmental protection order that relates to the land the subject of the application.

2) Subsection (1)(f) does not apply for an amendment application for an environmental authority if—

    a) either—

        (i) the process under chapter 3 for an EIS for the proposed amendment has been completed; or

        (ii) the Coordinator-General has evaluated an EIS for the proposed amendment and there are Coordinator-General’s conditions that relate to the proposed amendment; and

    b) an assessment of the environmental risk of the proposed amendment would be the same as the assessment in the EIS mentioned in paragraph (a)(i) or the evaluation mentioned in paragraph (a)(ii).

3) Also, subsection (1)(a), (d), (e), (f), (g) and (h) does not apply to an application for a condition conversion.

4) Despite subsection (1)(f), (g) and (h), if the amendment application is for an environmental authority for the prescribed ERA mentioned in the Environmental Protection Regulation 2019, schedule 2, section 13A—

    a) it need only include the matters mentioned in subsection (1)(f)(i) to (iv), (g) and (h) to the extent the matters relate to fine sediment, or dissolved inorganic nitrogen, entering the water of the Great Barrier Reef or Great Barrier Reef catchment waters; and

    b) subsection (1)(f)(v) does not apply for the amendment application.

2.1 Report structure

The structure of this supporting document is simplified below:

1. Methods (Section 3).
2. Existing hydrogeological concept (Section 4).
3. Project summary (the changes relevant to the amendment; Section 5).
4. Effect of proposed changes to groundwater (s226A 1(f); Section 6).
5. Effect of proposed changes to water quality (226A 1(f); Section 7).
6. Control measures and mitigation (s226A 1(f) and 1(g); Section 8).
7. Residual impact of groundwater changes to environmental values (s226A 1(f); Section 9).

3 Methods

The conceptual hydrogeological model represented in this supporting document was developed through review of existing reports (HCID, 2009; AGE, 2022a; 2022b). The definition of environmental values (EVs) relies on public resources, such as state-based mapping or databases (sources further detailed in Section 4.7),and site observations of water levels and landholder bores. All relevant resources are cited in the text.The methods used to predict drawdown, inflows, and conduct the residual impact assessment are outlined inthe sections below.

3.1 Predicted drawdown

The predicted drawdown analysis included the following steps:

- the historical rate of change in mining depth over time was estimated using mining milestones (EHO advice);
- this rate of mining was correlated using time to known drawdown observed in bores of the Gilbert River Formation and the Wallumbilla Formation;
- thus, mining depth was correlated to drawdown using their mutual relationships to time;
- the proposed deeper mining was conceptualised as an extension of the duration of drawdown for the purposes of understanding groundwater impacts;
- linear extrapolation of recent drawdown rates (2017-2022) was used to estimate the extension of drawdown for the proposed mining depth (1150 mRL), noting that:
    - linear regression was conducted for RP-series bores on site due to their affiliation with landholder bore sites; their spatial distribution; and intersection of various hydrostratigraphic units;
    - both modelled and observed drawdown were extrapolated to assess prediction sensitivity;
    - drawdown data used for the extrapolation were from the period 2017 to 2022: as drawdown is not linear over the entire mine life (since 1996); therefore, it was important to avoid the trends of earlier data (prior to 2017; AGE, 2022b);
    - bores with no data in either 2017 or 2022 were excluded; and
    - bores that were dry in either 2017 or 2022 were excluded; and
- the difference between the total extrapolated drawdown (for proposed mining to 1150 mRL) and the currently predicted drawdown was taken ('predicted, additional drawdown') to determine the potential impact from the proposed changes to operations.

3.2 Predicted inflows

The predicted inflow analysis included the following steps:

- with the extended drawdown duration (calculated using the method outlined in Section 3.1), predicted inflows from the pit and underground were extrapolated from observed dewatering data (EHO advice) via linear regression, noting that:
    - the rate of inflows during the first 13 years (1996 – 2009) of mining operations differed from the rate of inflows during the latter 13 years (2009 – 2022). Inflow rates during the past 13 years have been significantly higher than those recorded in the first 13 years (pre-underground mining);
    - therefore, the rate of inflows for the period of 2009 – 2022 was considered representative and used to extrapolate potential inflow volume for this assessment.

3.3 Geochemistry

The geochemical assessment contained herein was completed by undertaking a comprehensive literature and data review, followed by geochemical reaction modelling using the numerical modelling code Geochemists Workbench (GWB) (www.gwb.com). The literature reviewed included:

- Ernest Henry Mining: Kinetic Leach Column Data - Project Review (URS, 2003).
- Illustrative Evaluation of Internal Seepage Characteristics for the Ernest Henry Copper-Gold Mine Waste Rock Dump (O'Kane Consultants, 2006).
- Briefing Note on Seepage Waters Emanating from the North Waste Rock Dump, Ernest Henry Mine (Lottermoser, 2009).
- EHM WRD Modelling – Stage 2 Assumptions (Deswik, 2020).
- Waste rock dump 3D digital terrain model, and waste rock dump design assessment (RGS, 2021).
- Waste Rock Management Plan 2022 (EHM, 2023).

The data that were considered include:

- acid-base accounting (ABA) results on 598 waste-rock samples;
- 744 leachate samples collected from 6 kinetic column experiments on waste-rock materials since 2004; and
- material volume estimates for the SWRD and subsided material under the 1150 mRL scenario.

The geochemical modelling has accounted for the reactions between rainwater and the subsided materials expected in the pit, with a focus on the resultant runoff quality. The models have considered a range in sulfur content based on the extensive ABA dataset. The models predict the acidity generated by oxidation of sulfide minerals and minor buffering by chemical weathering of silicate minerals expected to be present. Background information, results, and discussion are presented in Section 7.

3.4 Residual impact assessment

A source-pathway-receptor assessment was undertaken to assess residual impacts as a result of the proposed changes to operations. The assessment summarises the critical impacts by:

1. analysing all potential sources (and determining if they are a product of, or exacerbated by, the changes to operations);
2. identifying the associated receptor and likelihood that receptor is present (irrespective of changes);
3. identifying if a potential pathway exists between the source and receptor (and determining if the pathway is a product of, or exacerbated by, the changes to operations, or if the pathway is inhibited or precluded by control measures or mitigation actions); and
4. if a pathway is present, assessing the predicted impact, and determining if and how the impact differs from that predicted for the current mining schedule.

For this assessment, proposed and existing control measures and mitigation actions (including natural attenuation; Section 8) were considered to be undertaken; therefore, the residual risk to EVs was assessed (Section 9).

4 Existing hydrogeological concept

4.1 Climate, topography, and land use

The semi-arid climate of the EHO region is defined by a hot wet season (November to March) and a mild dry season (April to October). The Bureau of Meteorology (BoM) station located at Cloncurry (Station No. 29008) has the longest and most complete record of rainfall in the area (1884 to 2023) and provides an indication of long-term climatic trends in the region. Rainfall over the wet season is monsoon driven and therefore highly erratic in intensity from year to year. The average (50th percentile) of annual rainfall at EHO, as indicated by all records from Station No. 29008, is approximately 443 mm (complete annual records only). Potential evaporation is very high, with an annual average pan evaporation of 3,063 mm (DES, 2022). Average actual areal evapotranspiration is estimated regionally to be 435 mm/yr (BoM, 2005). Mild temperatures and low rainfall characterise the dry season.

To place rainfall rates into an historical context, the cumulative rainfall departure (CRD) was calculated for the data period 1884 to 2022 (years with incomplete data were omitted). This is a summation of the monthly departures of rainfall from the long-term average monthly rainfall. A rising slope in the CRD plot indicates periods of rainfall above the long-term average, as is the case for the 1950s, 1970s, and the period 2009 to 2013 at Cloncurry (Figure 4.1). A falling slope indicates periods when rainfall is below the long-term average (e.g., the 1920, 1930s, and 1960s, Figure 4.1).

EHO is situated between the catchments of two streams, Gypsy Creek and Eliza Creek. The northern portion of the site discharges to Gipsy Creek, which joins the Cloncurry River 42 km north of EHO (Figure 4.2). The southern portion of the site discharges to Eliza Creek, which is a tributary of the Williams River.The Williams River confluences with the Cloncurry River 80 km downstream of EHO (Figure 4.2). The Cloncurry River is a major tributary of the Flinders River; the confluence of the Cloncurry River with the Flinders River is located 250 km downstream (north) of EHO. The Flinders River drains into the Gulf of Carpentaria 350 km north of Cloncurry.

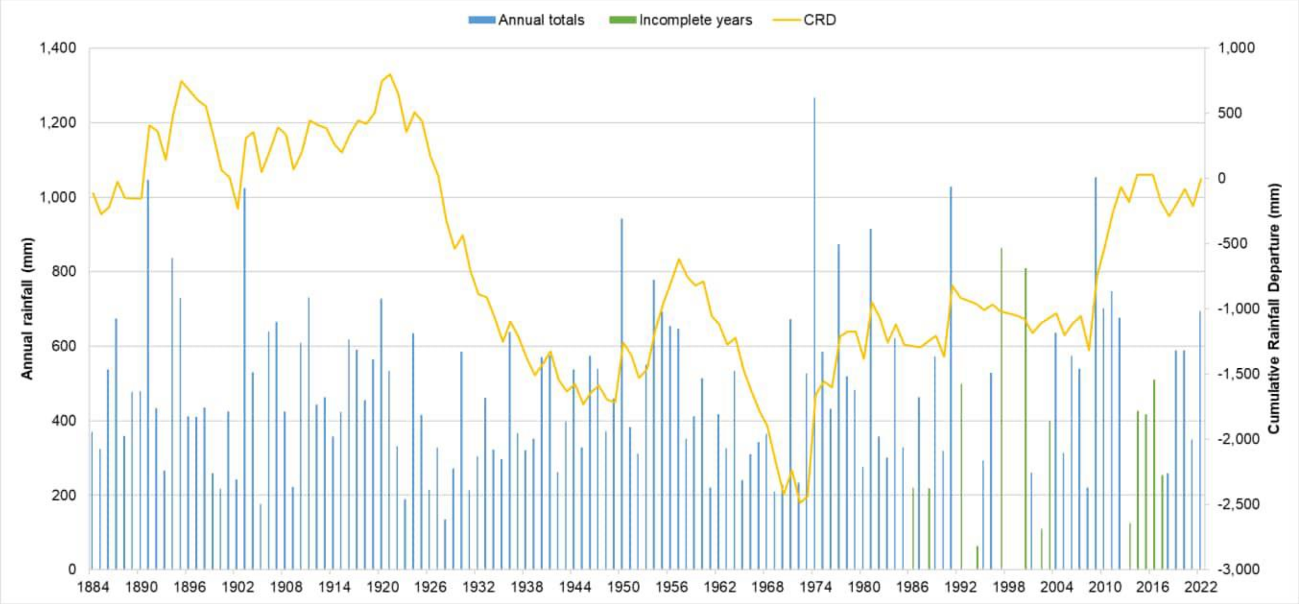
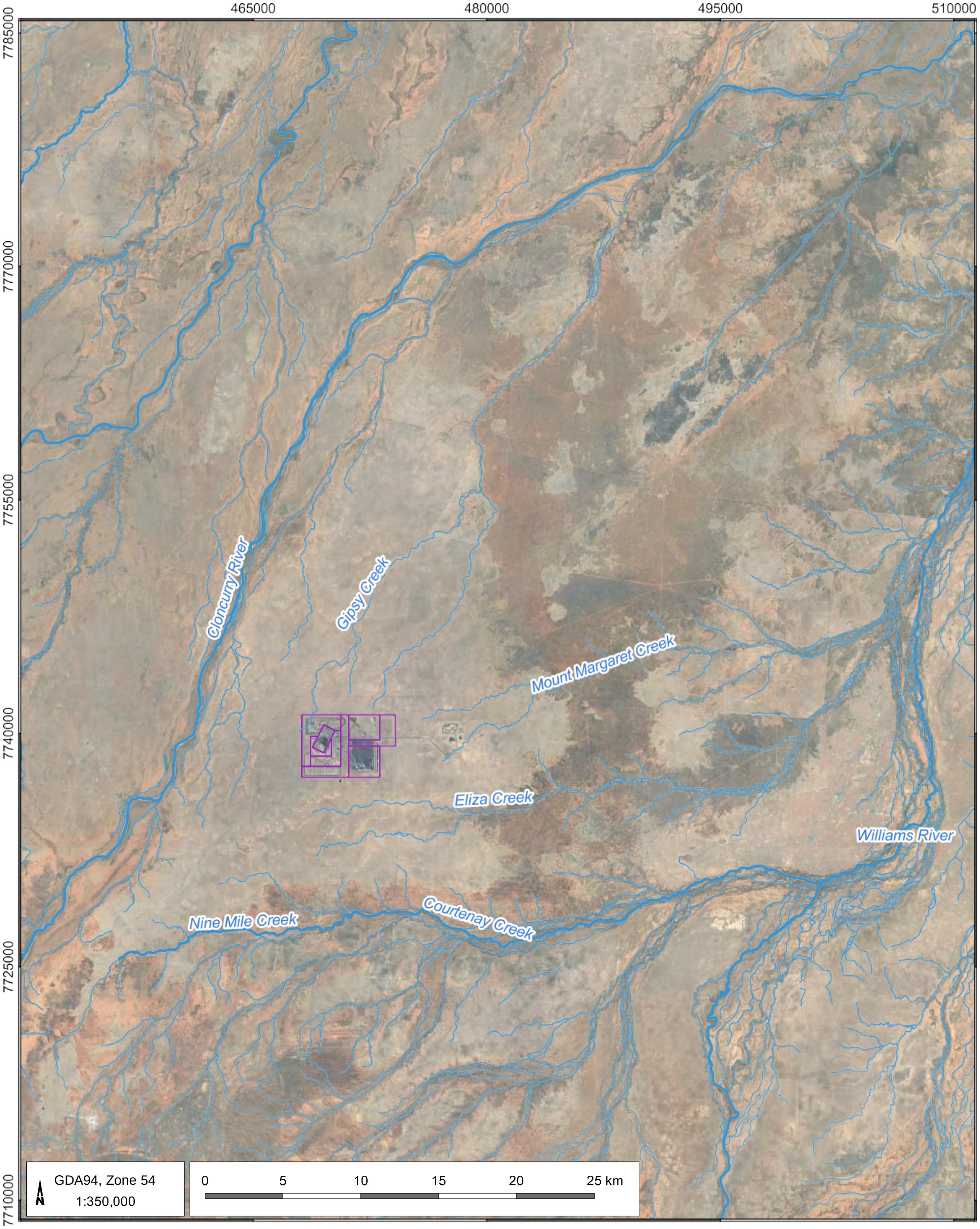


Figure 4.1 Long term record of rainfall and CRD at Cloncurry



LEGEND

Drainage

- ━ Major drainage
- ─ Minor drainage
- ☐ EHO mining lease

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Drainage

AGE

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08/06/2023

FIGURE No:

4.2

Source: Exploration and production permits - Queensland - © State of Queensland (Department of Natural Resources and Mines) 2015

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4.2 Geology and hydrology

The EHO copper and gold deposit is hosted within fault bounded and brecciated felsic volcanic rocks that are of Proterozoic age. These deposits are unconformably overlain by up to 40 m of Mesozoic sediments of the Carpentaria Basin, and up to 20 m of Cainozoic sediments of the Karumba Basin. The stratigraphy of the region is summarised in Table 4.1. The strata at EHO are at the south-western margin of the Carpentaria Basin. Thus, sediment cover thins to the south of EHO, and Proterozoic basement crops out at the surface approximately 20 km to the west and south-west of EHO (Figure 4.3). The Mesozoic and Cainozoic sediments thicken significantly towards the north and east, reaching up to 300 m in thickness approximately 30 km from the mine. Along modern drainages (e.g., the Cloncurry River), there is a thin and discontiguous layer of Quaternary alluvium. There are four hydrostratigraphic units described further below: Quaternary, Cainozoic, Mesozoic (comprising two formations), and Proterozoic.

Table 4.1 Stratigraphic units

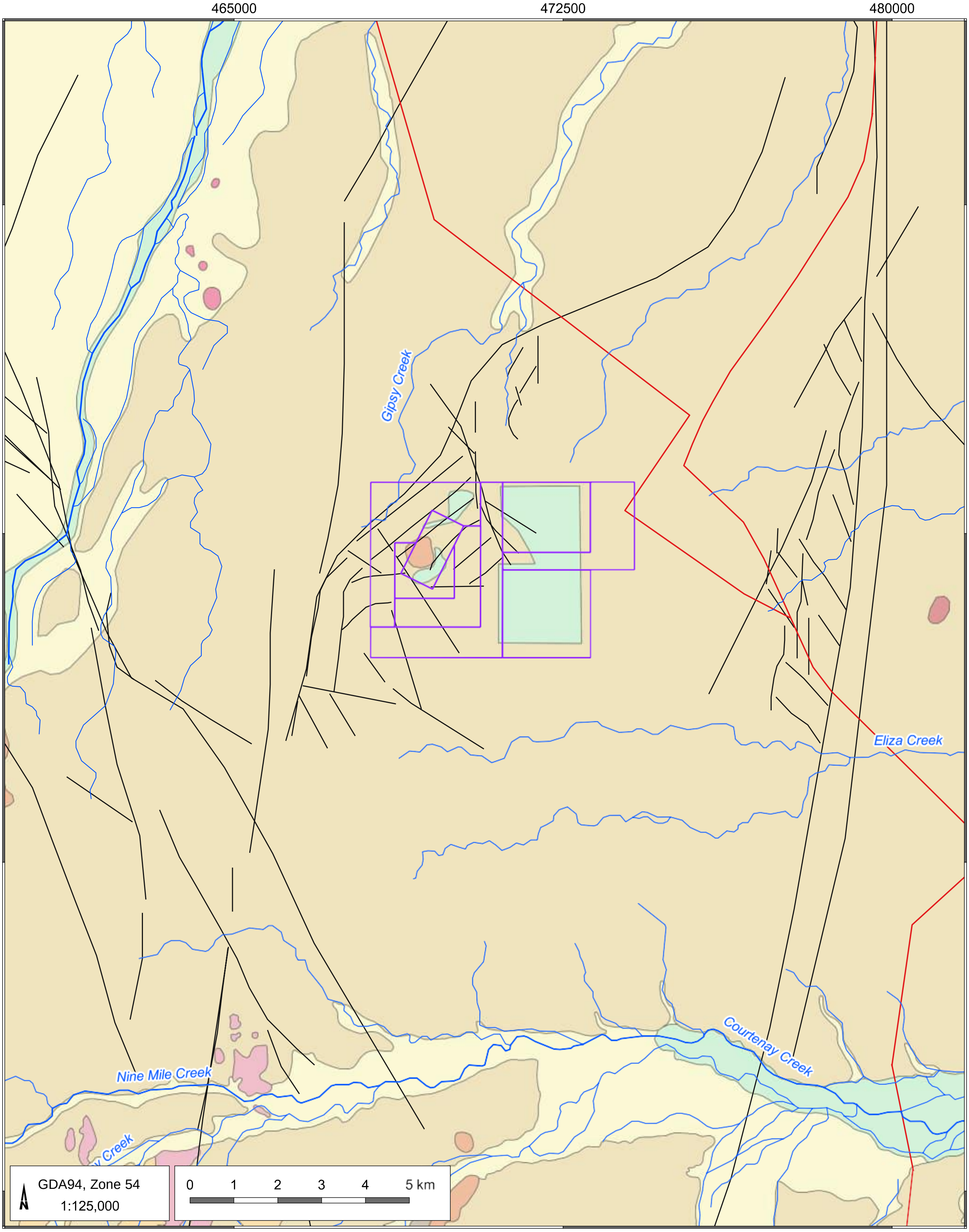
Age	Unit	Formation	Description	Thickness (m) [3]	Hydrogeology
Cainozoic (Quaternary and Tertiary)			Dominantly clayey facies (black soils): dissected high-level alluvial sheets.	0 – 20	Generally dry, heterogeneous
Mesozoic	Rolling Downs Group (Wilgunya Subgroup)	Wallumbilla Formation (Fm.)	Khaki/black shale, always present.	0 – 50	Aquitard[2]
			Clean to ferruginous, poorly indurated sandstone unit, occasionally contains conglomerate, not always present, and may be present as two distinct sandstone layers interbedded with shale.	0 – 21	Variable permeability but discontinuous aquifer[1]
			Black shale member, occasional minor sandy-silt layers.	0 – 24	Aquitard[2]
	-	Gilbert River Fm.[4]	A relatively clean quartz gravel that is not always present but tends to lie in the palaeo-topographic lows, where it occurs up to 30 m thick.	0 – 30	Permeable aquifer[1]
Proterozoic	Burstall Suite	Mt Fort Constantine Volcanics	Brecciated felsic to intermediate volcanic rocks (upper 5 m to 10 m distinctly weathered to clay).	-	Ore bearing unit

Notes: [1] An aquifer is defined as a formation, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to a bore or spring.

[2] An aquitard is defined as a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; that is, it is a leaky confining bed. It does not readily yield water to bores but may serve as a storage unit for groundwater.

[3] Details derived from Coates (1997).

[4] Formations as delineated by PPK (1998).



LEGEND

- Mining lease
- Major drainage
- Minor drainage
- Mt Margaret Fault
- Fault

State detailed geology

- Qa - Quaternary alluvium
- Qh - Quaternary (Holocene) sediments
- Ta - Tertiary regolith
- TQr - Tertiary sediments
- Tpf - Tertiary sediments (Ferricrete)
- PLgmm - Mount Margaret Granite
- PLgu - Naraku Granite
- PLgwm - Malakoff Granite
- PLkc - Corella Formation
- PLmfc - Mount Fort Constantine Volcanics

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Surface geology near the project

DATE
21/04/2023

FIGURE No:
4.3

© Commonwealth of Australia (Geoscience Australia) 2011.; Exploration and production permits - Queensland - © State of Queensland (Department of Natural Resources and Mines) 2015; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.; Geoldata - State of Queensland (Department of Employment, Economic Development and Innovation 2011). - merged 1:25,000 and 1:85,000 geology tiles
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4.2.1 Hydrostratigraphic units

4.2.1.1 Quaternary alluvium

Quaternary alluvium, comprising sand, silt, and clay sediments, is associated with the Cloncurry River (more than 10 km west of EHO), and Courtenay Creek, which lies south of EHO. The surface extent of Quaternary sediment distribution is mapped in Figure 4.3. Quaternary alluvium containing groundwater is not present within the mine area (AGE, 2015), and this unit is not discussed further in this report (except in Section 4.9.2).

4.2.1.2 Tertiary

The Tertiary sediments present in the region conformably overly the Wallumbilla Formation. The Tertiary strata comprise black clay soils overlying clay and sands. The upper part (typically 10 m thick) is comprised of soil and clay with minor sand. The lower part of the Tertiary unit (also approximately 10 m thick) is dominated by sands that may contain gravels or clay (AGE, 2017). There is increased sand, silt, and gravel content to the east of the Mt Margaret Fault, and along Courtenay Creek (AGE, 2015).

The thickness of the Tertiary sediments is typically about 20 m at EHO, although it is less extensive to the south, where basement rocks are closer to the surface. The shallow extent of the Tertiary sediments in the local area means that it was unsaturated around EHO in most areas prior to mining. As a result, hydraulic testing was not possible for this unit. The upper clay of the Tertiary is conceptualised as an aquitard, and cracking clays in this profile may allow the development of macropores that can allow water flow. The lower sand-rich layer of the Tertiary is conceptualised as a low or moderate permeability aquifer.

4.2.1.3 Wallumbilla Formation (Mesozoic)

The Wallumbilla Formation overlies the Gilbert River Formation, or the Proterozoic basement rocks, where the Gilbert River Formation is absent. The Wallumbilla Formation consists of fine quartz sandstones, irregularly interbedded with grey/green to black pyritic shale, siltstone, or mudstone. These lithologies have a distribution within the formation consisting of: a) an upper layer of mudstone/siltstone/shale (about 20 m thick), and b) a lower layer (about 15 m thick) of alternating shale and sandstone. In some areas, drilling results (AGE, 2017) indicate that the lower layer is simply a single sandstone layer interbedded within shaleor mudstone.

The upper clay-rich layers of the Wallumbilla Formation generally act as an aquitard with low hydraulic conductivity, impeding downward leakage from the overlying Tertiary (where saturated). The clay units have a low permeability (AGE, 2009), as evidenced by falling head tests conducted on monitoring bores and subsequent analysis using the Hvorslev Method (1951) for confined aquifers.

The thin sandstone layers (approximately 2 m to 4 m thick) present towards the base of the Wallumbilla Formation are known as the Wallumbilla sands. These units are moderate permeability aquifers (Table 4.1) and results from hydraulic conductivity tests indicate values between 0.001 m/day and 0.4 m/day (AGE, 2009).

4.2.1.4 Gilbert River Formation (Mesozoic)

The deepest Mesozoic unit at EHO is the Gilbert River Formation, which comprises fluvial, quartzose sands and gravels occurring within palaeo-channels. Where it is present, this unit directly and unconformably overlies the weathered top of the Proterozoic rocks. In a broad context, the Gilbert River Formation is a regional Great Artesian Basin (GAB) aquifer. However, on a local scale, the Gilbert River Formation was deposited within discrete palaeo-channels. Therefore, its presence and thickness vary across the mine area. The Gilbert River Formation is confirmed as absent to the north, northeast, and east of EHO (AGE, 2015; Clifford, 2012).

PPK (1998) reported that the Gilbert River Formation has a hydraulic conductivity of between 10 m/day and 13 m/day, and storativity (*S*) ranging between 2×10^{-5} and 1.5×10^{-4}, forming a productive aquifer. This is similar to data researched by HCID (2009) and AGE (2010).

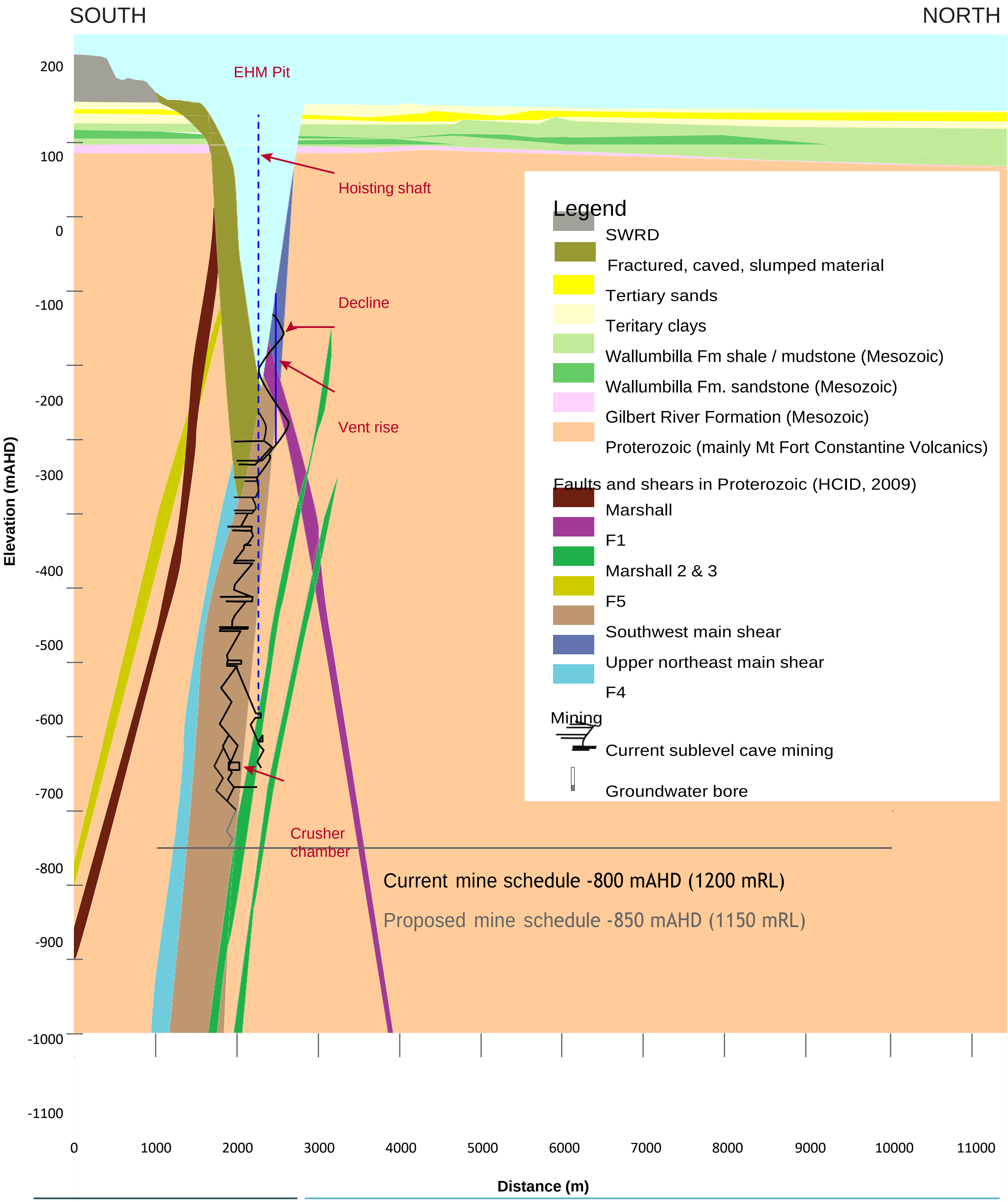
4.2.1.5 Proterozoic

The copper-gold deposits within the Mount Fort Constantine Volcanics were formed through the deformation (faulting and folding) and hydrothermal alteration of Proterozoic meta-volcanic rocks. Due to these geological processes, the host rock is highly heterogeneous, with mineralisation hosted in distinct faulted and altered zones. The ore-bearing assemblage dominantly comprises magnetite, pyrite, chalcopyrite, carbonate and quartz, with lesser apatite, barite, titanite, actinolite, biotite and fluorite (Porter GeoConsultancy, 2000).

The Proterozoic rocks are considered to have a low bulk permeability and porosity, with groundwater inflows during drilling only observed in the weathered zone, and where the Proterozoic rocks are fractured or faulted. Structural features such as faults, fractures, and joints provide secondary porosity within the Proterozoic rocks. The fault structures in the basement rock represent flow paths of high hydraulic conductivity (AGE, 2004). Aquifer hydraulic conductivity values determined for the fractured Proterozoic aquifer from in-situ permeability testing at EHO range from 0.81 m/day within fractured areas (e.g., ore body) to 3.46×10^{-6} m/day within more competent rock (e.g., distal from mineralisation; AGE, 2009). Collated data from other sources align with this range (e.g., AGE, 2010). Overall, the bulk permeability of the rock mass surrounding the ore bodies at EHO is very low, but it is locally higher around faulted zones.

4.2.2 Summary aquifer framework – conceptualisation

The descriptions above provide an outline of younger, alternating sedimentary aquifers and aquitards overlying an older, heterogeneous fractured rock basement. The Mesozoic and Tertiary layers are a thin cover in the EHO context, and the main faults and shears in the Proterozoic rocks are conceptualised as zones of relativelyhigher permeability within the greater rock mass (Figure 4.4; HCID, 2009).



Vertical exaggeration: 1:10

South (left) to north (right) cross section of aquifer framework

Figure 4.4

4.3 Mining activity history

Surface infrastructure at EHO includes two WRDs located to the north and south of the open-cut pit, the TED, TEDEX, and PED located north-east of the open-cut pit, the LADS dam, and a TSF south-east of the pit. Between the open-cut pit and the PED is the central processing area and mill, which includes a run of mine (ROM) Pad and sewage treatment plant (Figure 1.1). The underground mine extends to the south from a decline within the pit (Figure 4.5).

Mining at EHO commenced in 1996 with the removal of the Mesozoic overburden. The open-cut mine was completed in December 2011 and was transitioned into an underground mining operation. In the initial open-cut mine plan, mining comprised eight stages of pit development with each stage consisting of a pit expansion and deepening component to a depth of 530 m below original surface (~1627 mRL; Figure 4.4). Underground mining commenced in December 2011. The conceptual 3D model of the EHO pit and underground is displayed in Figure 4.5. With the sublevel caving mining method, ore is transported to the orepass system, reporting to the underground crusher chamber before it is crushed and conveyed for hoisting tothe surface (Figure 4.5).

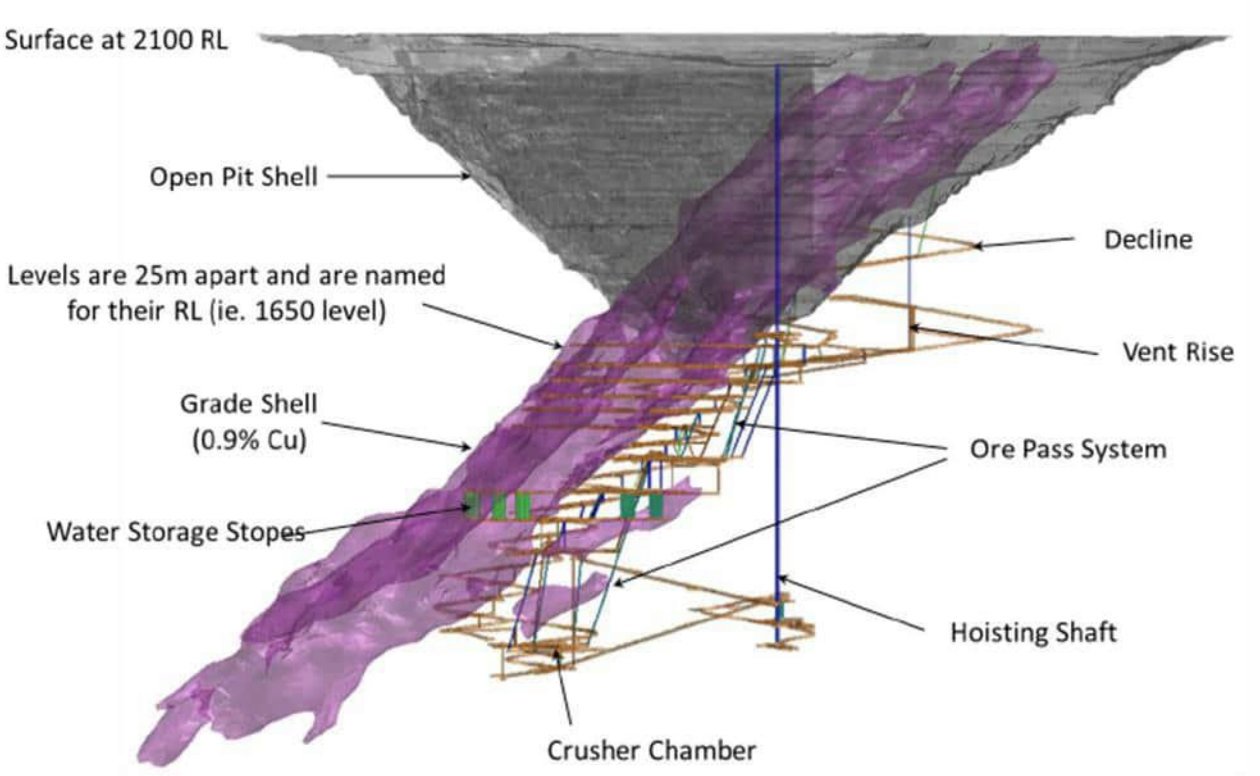


Figure 4.5 EHO ore body (grade shell), pit shell, and underground decline (looking west)

4.4 Dewatering

During early development of EHO, the rate of groundwater flow into the pit was anticipated to be manageable through the use of conventional sumps at low points in the pit. Unexpected volumes of water entering the pit at depth caused difficulties in the mining process, compromising wall stability and necessitating the use of water-resistant explosive emulsions for blasting (AGE, 2012). Inflows were from both the Mesozoic aquifers and from faulted Proterozoic rocks.

This early identification of the Proterozoic faults as a major water source in the deepening pit led to the construction of an out-of-pit pumping system, the local area dewatering system (LADS). The LADS was designed to intercept the groundwater water prior to its emergence into the pit. It consisted of four bores intersecting Proterozoic faults and four bores targeting palaeo-lows at the base of the Mesozoic sequence. Due to the progression of underground mining and dewatering in subsequent years, the LADS is no longer operational (Figure 4.6; EHM, 2009).

Currently, groundwater extraction on site occurs from sumps and pumping stations in the open pit and underground operations to maintain dry mining conditions. The development of the underground mine now has four stage in-pit pump systems for emergency dewatering during rain events. The majority of dewatering is now managed through the in-mine (underground) extractions (Figure 4.6). The Capture and Reuse Dam (CARD) is located within the PED (Figure 4.7) and receives the pumped water from underground and the pit sumps.

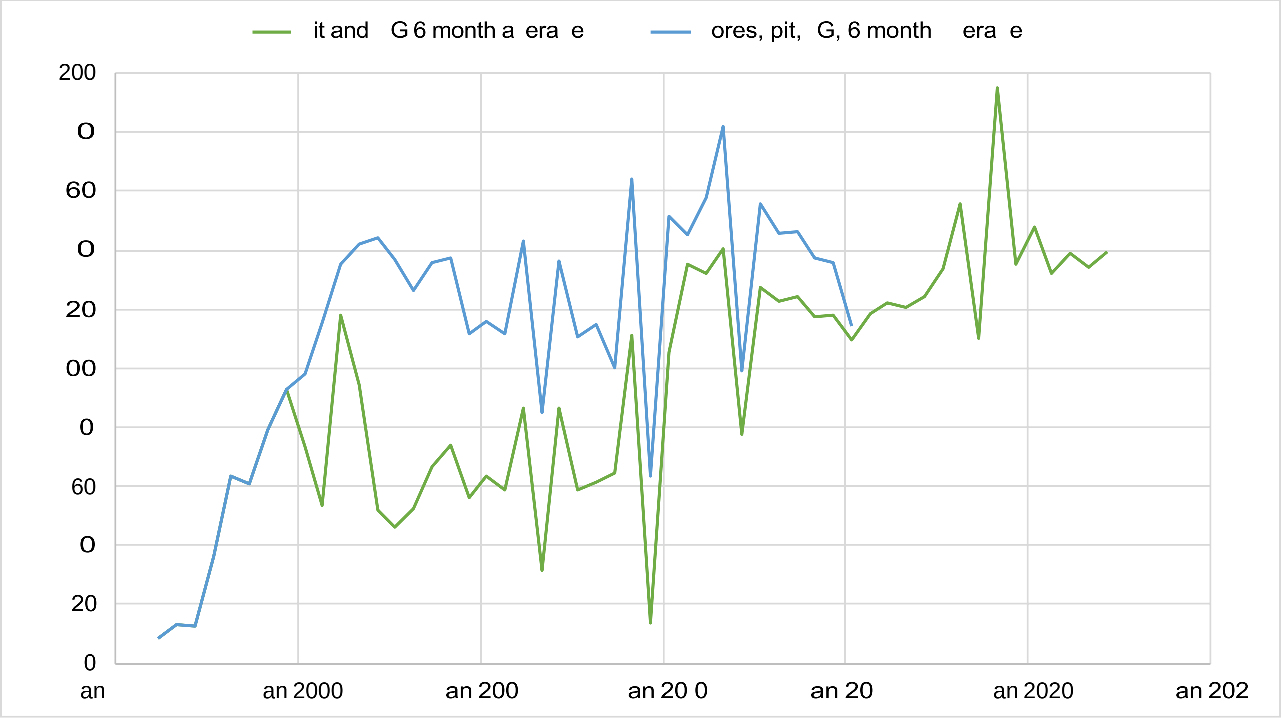


Figure 4.6 Six-monthly average rates of water withdrawal from: pit, underground (UG), and LADS (bores)

Figure 4.7 Catchments of the PED, TED, TEDEX, and TSF (EHO advice, 2018 LiDAR)

4.5 Pre-mining groundwater flow and quality conditions

4.5.1 Pre-mining groundwater flow system

Prior to mine development, observations show that the groundwater table was approximately 20 m below the ground surface (about 135 mAHD) at EHO, with a very weak horizontal hydraulic gradient toward the north-northeast (AGE, 2015). This flow system was consistent with the regional topography and drainage gradients, and with the regional groundwater flow within the Carpentaria Basin generally. Due to the depth of the groundwater table, most of the Tertiary sediments near the site infrastructure were typically unsaturated.

4.5.2 Pre-mining groundwater quality

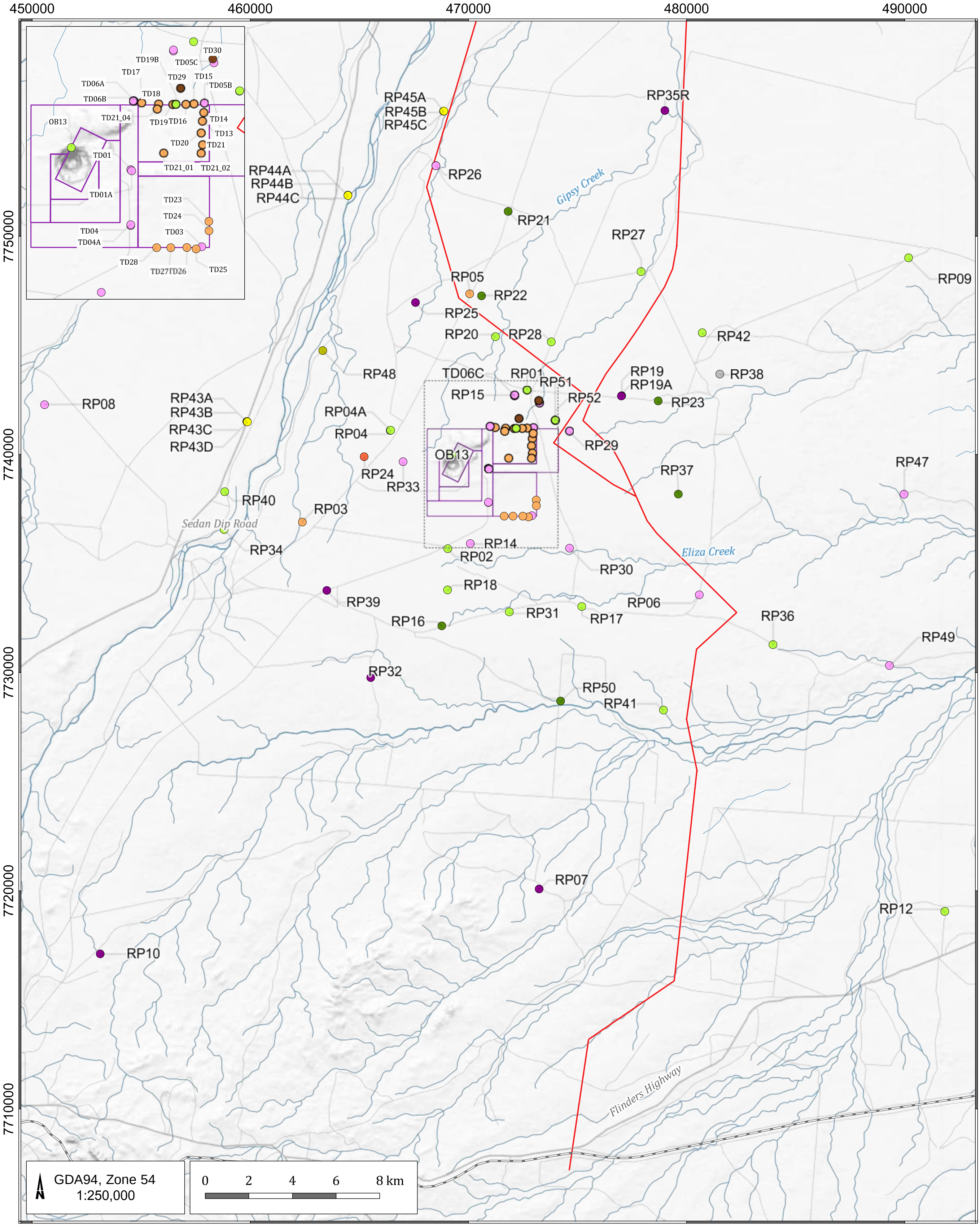
The hydrogeochemistry of the groundwater from the aquifers on and around EHO reveals variability through time and across hydrostratigraphic units. This is typical of the hydrogeological setting at EHO, which is characterised by:

- variable hydraulic conductivity aquifer/aquitard units, resulting in variable flow rates and a diverse range of connectivity between shallow and deep units;
- an arid climate with high evaporation rates, causing greater concentration of dissolved salts in the groundwater;
- mineralisation of the host rock, influencing the naturally occurring concentrations of dissolved metals in the groundwater; and
- a faulted geological setting, producing similar groundwater quality within fault-bounded blocks and variability across fault lines.

The groundwater quality prior to mining was diverse, depending on the combination of effects from the above factors at a particular location or depth/hydrostratigraphic unit. Generally, the groundwater from the Gilbert River Formation was sufficiently fresh for stock watering, although naturally elevated levels of fluoride meant that it did not meet all stock watering guidelines (AGE, 2022a). Broadly, the water encountered in the Wallumbilla shale or mudstone layers and the Proterozoic rocks was more saline and, in some areas, had naturally elevated sulfate concentration due to mineral interaction. As stated above, the Tertiary sediments were mainly unsaturated prior to mining; however, there are some bores distal from the mine with pre-mining baseline samples. The water from these sites indicated a similar composition to the shallow water of the Quaternary. Most groundwater encountered at EHO, regardless of hydrostratigraphic unit, has circum-neutral or mildly alkaline pH.

4.6 Monitoring network

The complete EHO groundwater monitoring network is displayed in Figure 4.8. The bores displayed include compliance bores (required for the EA conditions), water deeds bores (required for Water Licence reporting), and internal observation bores. Pore pressure is also recorded within the TSF using vibrating wire piezometers (VWPs). Groundwater monitoring (level and quality) is carried out at EHO to comply with the EAs, Water Deeds agreements between EHM Pty Ltd and landholders, to monitor seepage, to monitor borefield performance for water licence conditions, to verify model predictions, and to monitor progress of dewatering and depressurisation. Monitoring is carried out in accordance with the EHO Groundwater Monitoring Procedure (Ref: 710800).



LEGEND

Road

Major road

Minor road

Rail

Drainage

Major drainage

Minor drainage

Mining lease

Mt Margaret Fault

Monitoring bore network

- ● Alluvium
- ● Alluvium / Proterozoic
- ● Tertiary
- ● Tertiary / Wallumbilla Formation
- ● Tertiary / Proterozoic
- ● Wallumbilla Formation
- ● Wallumbilla Formation / Proterozoic
- ● Gilbert River Formation
- ● Gilbert River Formation / Proterozoic
- ● Proterozoic
- ● Unknown

EHM Application for EA Amendment (EHM5011.001)

Groundwater monitoring bores

AGE

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4.7 Existing groundwater drawdown

The purpose of this section is to outline the existing groundwater drawdown around the mine. The predicted drawdown relevant to this application is explored in Section 6.

The mining activities at EHO have caused changes to the groundwater system. Groundwater inflows to the mine voids have been withdrawn (Section 4.4), and this causes drawdown of the surrounding groundwater levels. As the cone of depression due to drawdown has developed, it caused some changes to groundwater flow directions. These processes are explained below.

Initial development of the open-cut pit at EHO necessitated dewatering and pumping from the Mesozoic sediments: the Wallumbilla Formation and the Gilbert River Formation. The depressurisation response was rapid, and the drawdown effects covered a large area (AGE, 2016). This was predominantly due to the relatively high hydraulic conductivity of the Gilbert River Formation, which forms the basal sequence of the Mesozoic sediments. As mining progressed from the overburden of the Mesozoic into the Proterozoic ore body, the open-cut pit and dewatering bores intersected zones of variable permeability that corresponded to large scale faulting (AGE, 2004). Subsequent dewatering resulted in further drawdown, with depressurisation continuing in the Mesozoic, and migrating into the Proterozoic. Details of dewatering are discussed in Section 4.4.

This depressurisation was modelled prior to approval of the mine (AGE, 1999), and predictions have been regularly updated for borefield performance reports since that time, incorporating several updates to the conceptual model (e.g., AGE, 2022a). The observed drawdown recorded from current monitoring is well simulated by the model outputs for the Proterozoic and Gilbert River Formation layers (AGE, 2022a). Therefore, the impacts to water levels and groundwater flow directions from the mine dewatering in those units is well understood.

Underground dewatering continued after the storages within the shallow faulted zones of the Proterozoic were depleted. This caused the ongoing depressurisation of the Gilbert River Formation adjacent to the EHO pit. In some areas (notably to the south of the TSF), the Gilbert River Formation has been only partially saturated for several years, as was expected from modelling predictions (AGE, 2016). The overlying Wallumbilla Formation is relatively less impacted by the dewatering, due to the lower permeability of that unit.

Many surrounding pastoral bores lie within the current or predicted cone of depression extent for the current mine schedule (AGE, 2022a), and will experience or have experienced drawdown. This impact was predicted (AGE, 1999; 2010) and approved by the administering authority. The water deeds were negotiated with graziers as part of the Water Licence, capturing make good arrangements to ensure continuity of water supply where drawdown was permitted. The most recent reporting against the Water Licence (AGE, 2022a) indicates that observed drawdown in most bores is similar to, or less than, the approved drawdown. Therefore, there is no unanticipated impact to groundwater levels that affect groundwater users that would warrant further revision of make good agreements at this point.

The four graziers’ bores closest to the EHO mine lease (Murphy Bore, Whitewood Bore, Harrington’s Bore and Angle Bore; further details in Section 4.9.4) are no longer in use, as their owners are being supplied with waterfrom Julius Dam by EHO under the water deeds.

4.8 Currently predicted groundwater flow conditions at closure

The most recent Water Licence Report (AGE, 2022a) updated the currently used MODFLOW-SURFACT model and ran the model forward to predict drawdown and groundwater elevation at the end of mining and for 100 years into the recovery phase. The predictions showed drawdown through to the conclusion of the current mining schedule (AGE, 2022a).

At the end of mining dewatering will cease; therefore, during the recovery phase (post-mining), the rise in groundwater levels will help form a lake in the open-cut void (AGE, 2022a). The equilibrium water level in the pit will be reached when there is a balance between the pit lake inputs (groundwater inflow from the formations, direct rainfall, and runoff from the site catchment) and outputs (evaporative losses from the pit, and outflow to groundwater, which is unlikely). The post-mining equilibrium groundwater levels predicted after 100 years of recovery (AGE, 2022a) indicate that a cone of depression will persist in the Gilbert River Formation, but only in the immediate area of the pit. Therefore, the groundwater sink effect is a local effect, and the regional groundwater levels are expected to eventually return to represent a hydraulic gradient towards the northeast, consistent with the pre-mining groundwater system.

Post-closure conditions relative to this application are discussed further in Sections 6, 7, and 8.

4.9 Groundwater environmental values

This section defines all groundwater environmental values (EVs) that are relevant to this application. Impacts to EVs that are relevant to this application are assessed in Section 9. If a groundwater EV is potentially present near EHO, but is not relevant to this application, it is discussed briefly below, and is not assessed in Section 9. An EV is defined in Section 9 of the Qld *Environmental Protection Act 1994* (EP Act) to be:

a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or

b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (Qld; EPP Water 2019) provides a framework to protect and/or enhance the suitability of Queensland waters for various beneficial uses. Groundwater resources in the vicinity of EHO are located within the Flinders River catchment. This area is not listed in Schedule 1 of the EPP Water 2019, therefore, all the EVs listed in Section 6(2) of the EPP Water 2019 may apply in an assessment of the area. These general EVs may be categorised as:

- biological integrity of ecosystems;
- beneficial use in production of foods;
- beneficial use in aquaculture;
- beneficial use in agriculture;
- suitability for primary, secondary or visual recreational use;
- suitability of the water for supply as drinking water;
- suitability of the water for industrial use; and
- cultural and spiritual values of the water.

All groundwater EV categories are discussed below.

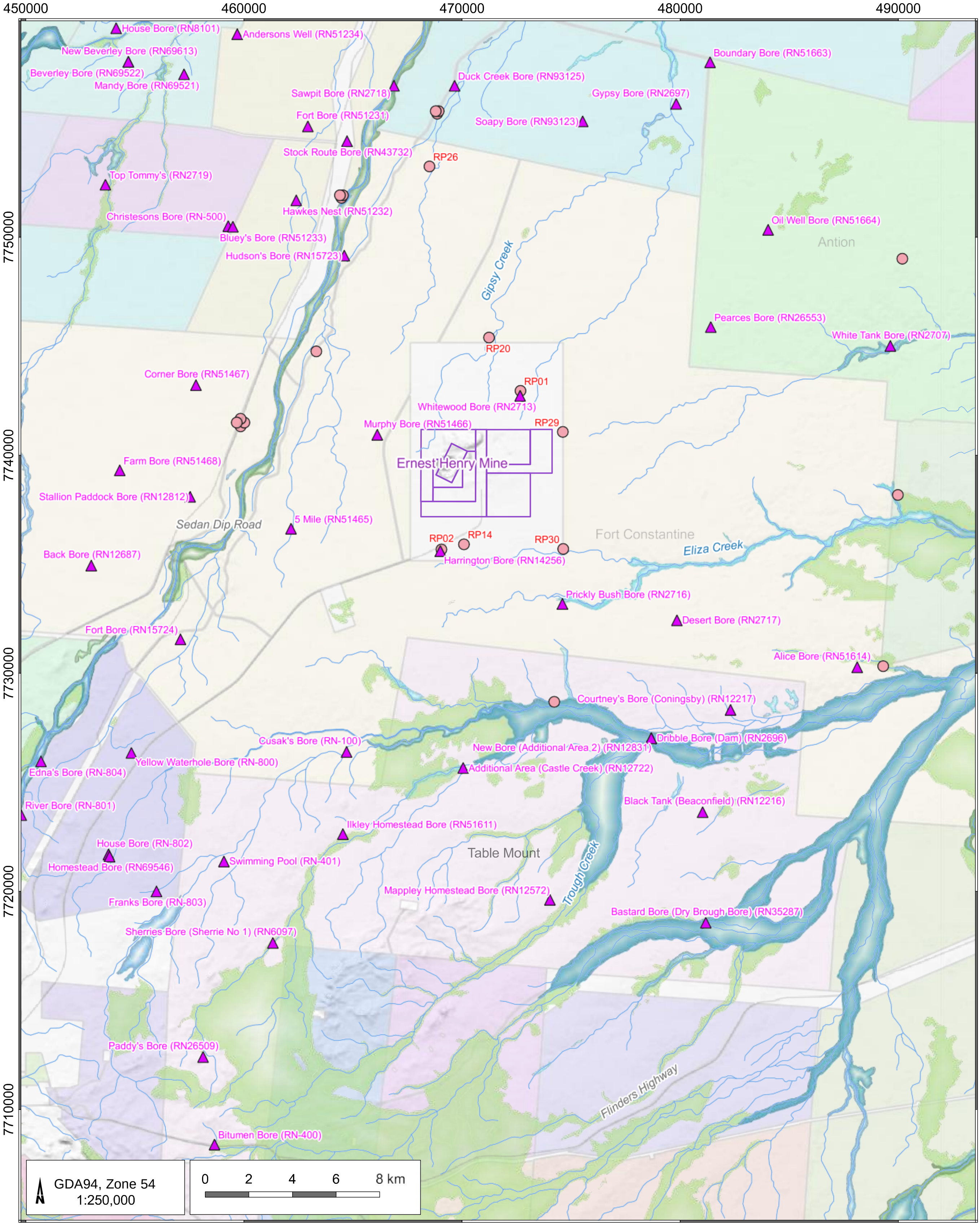
4.9.1 Biological integrity of ecosystems

The biological integrity of ecosystems may be supported by groundwater if they are a groundwater dependent ecosystem (GDE). The site groundwater data, public GDE data, and the conceptual hydrogeological understanding at EHO all indicate that there are no GDEs near the mine. As such, there are no GDEs relevant to this application, and they are not considered as receptors in Section 9. Further details documenting the absence of GDEs around the mine are provided below.

The GDE Atlas provides an indication of the potential groundwater dependence of ecosystems across the state and is obtained through application of a standardised method (DSITI, 2015). According to the GDE Atlas (BoM & DSITI, 2016), there are ecological areas in the wider region of EHO that are potentially dependent on groundwater to some degree for ecological function. These potential areas from the GDE Atlas are mapped in Figure 4.9. However, this map also shows there are no potential GDEs of any kind within approximately 4 km of the EHO mine lease boundary. Field surveys and site monitoring data at EHO (e.g. vegetation types, channel depths and groundwater levels) confirm the absence of GDEs in this area (details are expanded in the below sections).

4.9.1.1 Terrestrial GDEs

A terrestrial GDE is an ecosystem that is present above the ground surface and is reliant on groundwater below the ground surface (e.g., vegetation that can access groundwater for transpiration from the water table). There are no potential terrestrial GDEs mapped within 5 km of the EHO mine lease (Figure 4.9). The vegetation types within the area of EHO are dominated by open grassland and sparse woodland. As groundwater levels within the Mesozoic and Proterozoic aquifers were typically more than 18 m below surface prior to mining, and the maximum root depth for ecosystems in tropical savannah is approximately 15 m (Eamus, Hatton, Cook, & Colvin, 2006), vegetation at EHO is not expected to be dependent on groundwater. As such, terrestrial GDEs are not relevant to this application.



LEGEND

Drainage

- Major Drainage
- Minor Drainage
- Road
- ▭ Mining lease
- ▲ Graziers bore
- ● Water deeds bore

Aquatic

- 🟦 High potential for groundwater interaction
- 🟦 Moderate potential for groundwater interaction
- 🟦 Low potential for groundwater interaction

Terrestrial

- 🟩 High potential for groundwater interaction
- 🟩 Low potential for groundwater interaction

EHM Application for EA Amendment (EHM5011.001)

Pastoral groundwater users and potential GDEs in the vicinity of EHO

AGE

DATE
08/06/2023

FIGURE No:
4.9

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4.9.1.2 Aquatic GDEs

The definition of an aquatic GDE is an ecosystem (be it an aquatic, riparian or wetland ecosystem) that is dependent to some degree on the surface expression of groundwater. Therefore, for an aquatic GDE to be present, a surface expression of groundwater must be suspected or identified. There are no known locations of groundwater expression to the surface at EHO. Monitoring of shallow EHO groundwater bores near stream channels shows that the groundwater levels are always below the channel bed, precluding groundwater discharge to creeks. The potential existence of springs in the area was precluded following numerous discussions with landholders and extensive field surveys (EHM, 2009), and is supported by the results obtained through the Receiving Environment Monitoring Program (REMP). This is also supported by the pre-mining groundwater levels for the Mesozoic strata being approximately 18 m to 20 m below ground level. The Mesozoic units are therefore sub-artesian, and springs are highly unlikely to occur (EHM, 2009).As such, aquatic GDEs are not relevant to this application.

4.9.1.3 Subterranean GDEs

A subterranean GDE is an ecosystem that is dependent to some degree on the sub-surface expression of groundwater and exists within the subsurface. These types of GDEs mainly include stygofauna and cave ecosystems. There are no mapped subterranean GDE areas (Figure 4.9), and no known caves or sinkholes within the vicinity of EHO. Therefore, it is concluded that there are no subterranean GDEs present at the site, and they are not relevant to this application.

4.9.2 Beneficial use in production of foods

Groundwater in the vicinity of EHO is not used for production of foods for human consumption, as such, this EV is not relevant to this application.

4.9.3 Beneficial use in aquaculture

Groundwater in the vicinity of EHO is not used for aquaculture purposes, as such, this EV is not relevant to this application.

4.9.4 Beneficial use in agriculture

Groundwater in the wider region around EHO is used for livestock (cattle) drinking purposes (AGE, 2015). There are 11 established pastoral groundwater users neighbouring EHO who all hold Water Deeds with EHMPL (Table 4.2). The Water Deeds outline the terms of make-good conditions negotiated between the parties and EHMPL. Under these terms, Evolution supplies Lake Julius water to graziers whose groundwater bores have been affected by drawdown. The basis of the make-good supply was the current useable capacity (CUC) of the bores, which was devised at the outset of the deeds (Table 4.2). The raziers’ bores located bya previous audit, which included both registered and unregistered bores, are shown in Figure 4.9.

Based on the information from neighbouring pastoral properties, the main aquifers used for livestock (cattle) drinking purposes are the Gilbert River Formation and the Quaternary alluvium. A secondary aquifer used for this purpose is the sandstone layers of the Wallumbilla Formation.

The pastoral groundwater bores in the Gilbert River Formation and the Wallumbilla Formation are relevant to this application and are discussed further in Sections 6 and 9.

The pastoral groundwater bores in the Quaternary unit are not relevant to this application. The main controls on the groundwater quality and quantity within the Quaternary alluvium are the flows and water quality within the Cloncurry River, not the groundwater quality in the underlying Mesozoic or Proterozoic units. Therefore, there is no pathway between groundwater users of / receptors around the Quaternary aquifer and the potential sources of impact at EHO (AGE, 2015; discussed further in Section 9). Due to the distal nature of the Quaternary pastoral groundwater bores to the mine, there is no potential for the proposed mining change to impact this groundwater value.

Table 4.2 Pastoral users of groundwater in the area

Property	No. of bores in UniQuest survey[†]	CUC (ML/month)[†]	Water supply deed	
			Commencement	Superseded
Antion Holding	5	12.0	23/4/1996	-
Clonagh Station	No CUC survey undertaken		29/11/1996	-
Cotswold Station	8	12.0	17/5/1996	3/8/2010
Tablemount, Mapperly Park, Top Courtneys, Courtney, Dryburgh	13	19.4	23/4/1996	-
Ginburra Holding	No CUC survey undertaken		8/7/1996	-
Gipsy Plains	12	20.3	16/9/1996	3/8/2010
Mindie Station	7	5.8	5/6/1996	-
Tommy Creek Holding	2	4.0	23/4/1996	-
Tynndol Holding^	9	11.6	10/7/1996	-
Vee Isla*	1	3.0	16/9/1996	3/8/2010
Fort Constantine	-	-	1995	2/8/2010

Notes: CUC: current useable capacity.

[†] Data source Callow and Hawkins (2008).

*Vee Isla is included in the revised Gipsy Plains Water Deed.

^The Tynndol Holding Water Deed was never signed by the landholder.

4.9.5 Suitability for primary, secondary, or visual recreational use

Groundwater does not discharge to the surface and, therefore, is not used for primary, secondary, or visual recreational use in the region.

4.9.6 Suitability of the water for supply as drinking water

Groundwater is not used as drinking water supply in the vicinity of EHO, as such, this EV is not relevant to this application.

4.9.7 Suitability of the water for industrial use

The two existing water licences for conducting mining activities in the area relate to EHO and the neighbouring site of Mount Margaret Mine (MMM), which is approximately 7 km east of EHO. These licences cover mine dewatering activities from the Wallumbilla Formation (Carpentaria 1 Management Unit) and the Gilbert River Formation (Carpentaria 2 Management Unit) and are outlined in Table 4.3. As MMM, owned by Glencore, is in a phase of care and maintenance, there is currently no water use at that site. Licence number 93320J, which was previously active at EHO, was surrendered in December 2016.

Licence number 93189J is currently active at EHO, permitting the groundwater extracted from the pit and underground (Section 4.4). According to the *Water Resource (Great Artesian Basin) Plan 2006*, the Carpentaria 2 Management Unit relates to the Gilbert River Formation and the Eulo Queen Group. No volumetric limit is associated with the EHO water licences and pumping occurs as necessary to achieve the required dewatering to maintain mine operations.

Table 4.3 Industrial groundwater licence details near EHO

Licence number	Licence holder	Aquifer	Date of issue	Date of expiry
93189J	Ernest Henry Mining Pty Ltd	Mesozoic Gilbert River Formation (Carpentaria 2 Management Unit)	4 May 2006	31 July 2111
606852	Mount Margaret Mining Pty Ltd	Mesozoic Wallumbilla Formation (Carpentaria 1 Management Unit)	4 July 2012	30 June 2111

4.9.8 Cultural and spiritual values of the water

There are no documented cultural and spiritual values of groundwater at EHO, and there is no surface expression of groundwater in the area. As such, this EV is not relevant to this application.

5 Proposed operational changes

The proposed changes associated with the EA amendment are the increase in volume capacity of the TSF, and the extension of underground sublevel cave mining down to the 1150 mRL level. A recent sublevel caving (SLC) depth extension and subsidence assessment by Beck Engineering (2023) found mining to this depth will result in additional subsidence. This in turn will likely result in displacement of material of the SWRD. The additional subsidence that will result from mining to the proposed depth will change the shape and volumeof the pit void due to collapse of material. The proposed changes are summarised in the following points:

- the only waste from additional mining will be tailings, and it will be emplaced in the existing TSF, with no change to TSF embankment or spillway heights, but with a requirement to amend the EA-listed capacity from 130 Mm^3 to 136 Mm^3 (which is a volumetric increase of 4.6%);
- the depth of mining will increase to 1150 mRL, as stated above;
- groundwater inflows will be withdrawn from the underground mine as usual;
- any waste rock encountered in additional mining will be placed in underground void backfill or used as engineering material in the construction of the TSF, if suitable;
- the final landform of the WRDs will not increase in height or extent;
- further subsidence will occur at the surface, affecting the SWRD as a result of deeper and more extensive SLC mining (Beck Engineering, 2023), allowing more waste material to slump into the pit potentially resulting in Wallumbilla shale waste rock to be exposed
  - the exposed shale may result in additional, acidic, runoff draining to the pit; and
- there will be no material change in the nature of waste rock or tailings produced with increasing depth, due to the consistent geology.

5.1 Potential impacts to groundwater from changes

The proposed mining change associated with the EA amendment is expected to cause the following effects on groundwater:

- Additional storage of tailings in the TSF should not result in additional seepage from the TSF (consistent with current observations) due to the self-draining design of the TSF and the height of embankments remaining unchanged.
- Deeper mining could cause minor increases to the total expected groundwater inflows to the mine, and minor increases in the predictions of total drawdown.
- Groundwater recharge would change through the altered (subsided) medium, likely with higher rates of infiltration through the subsided material. Greater infiltration rates could lead to periods of higher groundwater pressures adjacent to the pit wall, or higher groundwater inflows reporting to the underground (Figure 5.3).
- The subsidence may expose potentially acid-forming (PAF) material from the SWRD that has the potential to generate acidic drainage (Figure 5.1). However, any such drainage would drain to groundwater (which would flow towards the pit) or directly to the pit.
- As the post-mining pit water was originally predicted to be of moderate salinity, and as, since commencement, disturbed areas are planned to drain to the pit there will be no retrograde outcome in relation to pit lake quality. During operations, any acidic drainage to groundwater from the SWRD will ultimately report to the pit or underground workings and would subsequently be extracted.

Subsidence processes and predictions are discussed further below, and the effects on groundwater are explored further in Section 6.

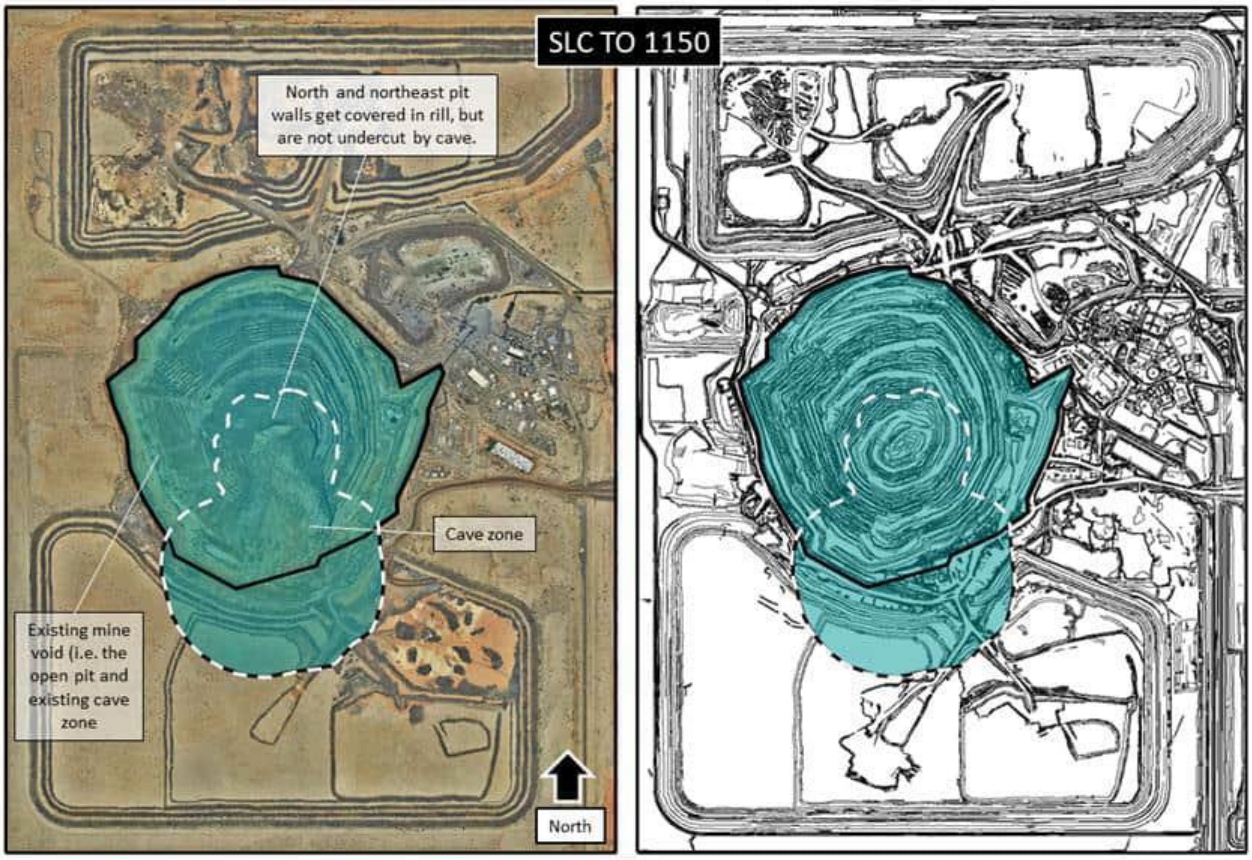


Figure 5.1 Predicted subsidence area and SWRD (Beck Engineering, 2023)

5.1.1 Subsidence

As previously described, the extension of mining activities to 1150 mRL is forecast to result in progressive subsidence of the southern pit wall, into the SWRD footprint (Figure 5.2; Beck Engineering, 2023). This subsidence is expected to change the pit geometry by decreasing pit depth (Figure 5.3), increasing pit footprint (Figure 5.1), and increasing the pit lake surface area available for evaporation (Beck Engineering, 2023). 6.3

The recent subsidence assessment (Beck Engineering, 2023) predicted approximately 31.5 million m^3 of caved rock would fill the bottom of the open pit by the end of mining to 1150 mRL. The additional mining wasalso predicted to cause subsidence of approximately 7 million m^3 of the SWRD; the majority of the subsided material is expected to enter the open pit (Figure 5.2; Figure 5.3). Beck Engineering (2023) forecast that, at the completion of the extended mining operations (1150 mRL), the caved and subsided material in the open pit would raise the pit floor by approximately 260 m. Beck Engineering (2023) also predicted that the subsidence would extend the pit surface area by approximately 370 m (Figure 5.3), equating to a change in the aerial extent enclosed by the pit rim from approximately 2.1 km^2 to approximately 2.5 km^2 (Figure 5.2; approximately a 20% increase in the pit rim circumference). This means that the potential surfacearea available for evaporative loss from the final void pit lake would be increased by the subsidence(11% increase in surface area).

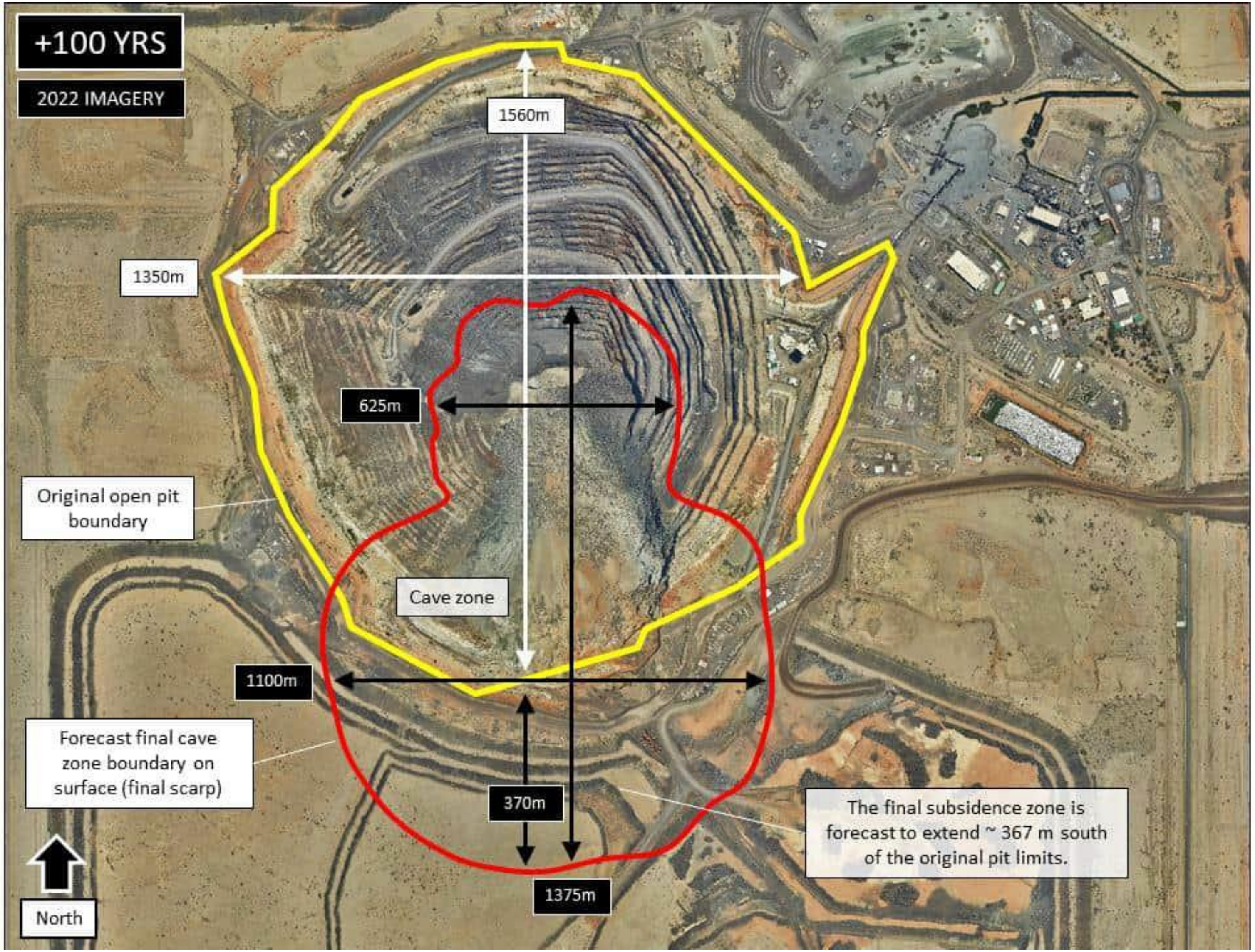


Figure 5.2 Final geometry of the open pit with the proposed subsistence dimensions (Beck Engineering, 2023)

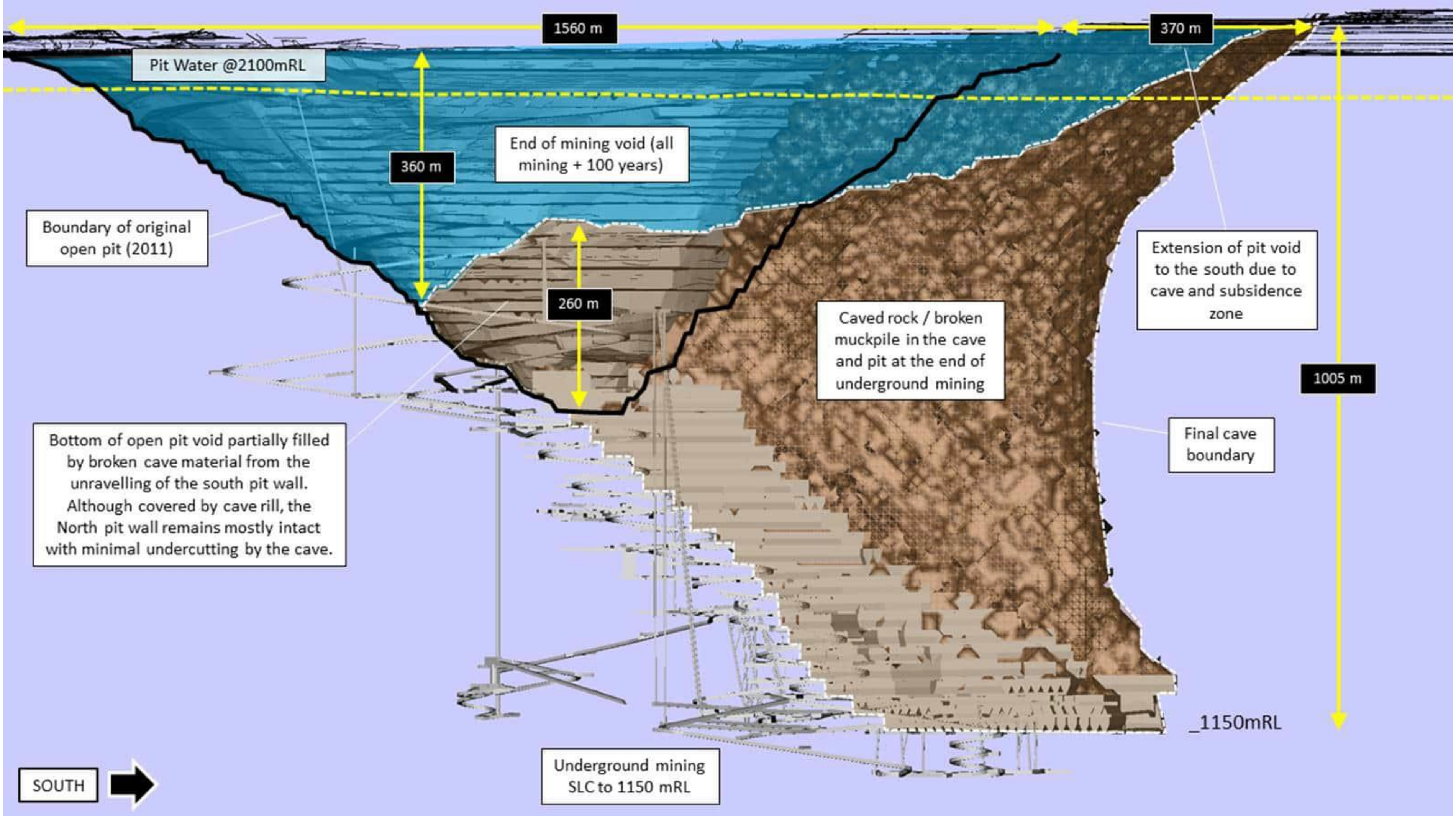


Figure 5.3 Final shape of excavated mine voids and SWRD subsidence (Beck Engineering, 2023)

6 Implications for groundwater conditions

The following sections outline the expected changes to groundwater flow conditions that are likely to result from the proposed extension to base of mining (1150 mRL), and the additional tailings production. All the changes to mine infrastructure and operation that are listed in Section 5 are considered. The processes relevant to groundwater include greater groundwater inflow during extended mining, greater drawdown, and post-mining groundwater-pit-lake interaction. The expected changes detailed below are not based on a new groundwater numerical flow model. Rather, they rely on detailed studies of the current mine schedule, new analysis and projection of historic numerical flow modelling predictions, and existing closure planning (methods are provided in Section 3).

6.1 Inflows

As the mine has developed from an open-cut pit to an underground SLC mine, progressive withdrawal of groundwater that inflows to the mine has been required to provide safe dry working conditions. Details of dewatering of mine inflows are discussed in Section 4.4. The impact of dewatering is the drawdown and depressurisation of the groundwater host units. The response of the aquifers to mining and dewatering, i.e., how much water flows into the voids, is critical for understanding the past and future impacts. Groundwater inflows change depending on the depth and extent of mining (including proximity to structures).

Deeper mining to the 1150 mRL level would expose deeper rocks to dewatering. The total expected, additional inflow volume due to the extended underground operations (from 1200 mRL to 1150 mRL) is approximately 365 ML. This volume constitutes 0.5% of the current total cumulative volume of inflows dewatered from the mine since 1996 under EHO's water licence (approximately 78,066 ML).

The subsidence that is predicted as a result of deeper mining to 1150 mRL level is expected to allow more rapid infiltration of rainfall and runoff, which may in turn increase the rate of groundwater recharge. Subsidence is expected to accelerate recharge due to the higher porosity and permeability (broken rock fragments) of the exposed waste rock material compared to the natural surface. Enhanced groundwater recharge over the existing subsided areas was simulated in the most recent update of the groundwater flow model (AGE, 2022a). This model provides a reliable resource from which to assess potential changes to mine groundwater inflow and drawdown for this supporting document.

The proposed operations extension could cause greater groundwater recharge adjacent to the pit wall and/or higher groundwater inflow rates reporting to the underground. Total predicted inflows from the recent groundwater modelling (AGE, 2022a, which included increased runoff to account for current subsidence of the pit), were compared to the total predicted inflows previously modelled (AGE, 2017, which made no account for subsidence). This comparison was undertaken to estimate the potential volume of additional groundwater recharge that was simulated by adding subsidence to the 2022 model. Subsidence was not the only boundary condition changed between the two model iterations; therefore, only a proportion of the difference in potential underground and pit inflows calculated is potentially related to the subsidence. However, it is conservative to assume that most of the difference in calculated inflows between the models is due to the additional recharge through subsided material.

The comparison of the 2017 and 2022 modelled monthly inflows showed predictions from the 2022 model were generally up to 0.5 ML greater than the total inflows per month from the 2017 model. The only occasionthe difference in inflows was significantly greater than 0.5 ML/month was during the anomalous 2019 rainfall event (1.58 ML in February 2019). For perspective, the average (50th percentile) inflow from the underground workings is typically 355 ML/month; therefore, the additional volume of inflow calculated (0.5 ML), only a portion of which is expected to be due to subsidence, is equivalent to just 0.1% of the monthly volume dewatered from the underground. The minor difference in predicted inflows to date indicates that increased runoff / groundwater recharge through subsided material of the SWRD in the 1150 mRL case is not likely to contribute a significant additional volume to operational inflows, or to the overall balance of the final void pit lake.

6.2 Drawdown

The deeper mining to 1150 mRL will cause further drawdown. The drawdown from the current mine is explained in detail in Section 4.7. A simple linear regression analysis was performed to extrapolate existing predictions of drawdown (modelled in AGE, 2022a and observed in water levels) to the proposed operations extension (methods outlined in Section 3.1). The results for the regional RP series bores are shown in Table 6.1 and Figure 6.1, detailing the difference between simulated and observed drawdown predictions for 2026.

The linear extrapolation used trend lines for predicted water levels since 2017 in each RP bore.The difference between currently predicted drawdown for 2026 and predicted drawdown for 2026 if mining extent is increased (to 1150 mRL) is presented as ‘predicted, additional drawdown’ in Table 6.1. Using this simplified approach, the calculated additional drawdown predicted for any bore in the RP bore series is less than 0.05 m (based on all simulated and observed data; Table 6.1; Figure 6.1). These estimates are not derived from an updated flow model and are not highly certain. However, good agreement between the predictions based on model results and those on observations (Table 6.1) provides confidence in the conclusion that additional drawdown from the proposed extension is minimal. The additional drawdown is negligible when compared to total, currently predicted drawdown, which was authorised in 2011.

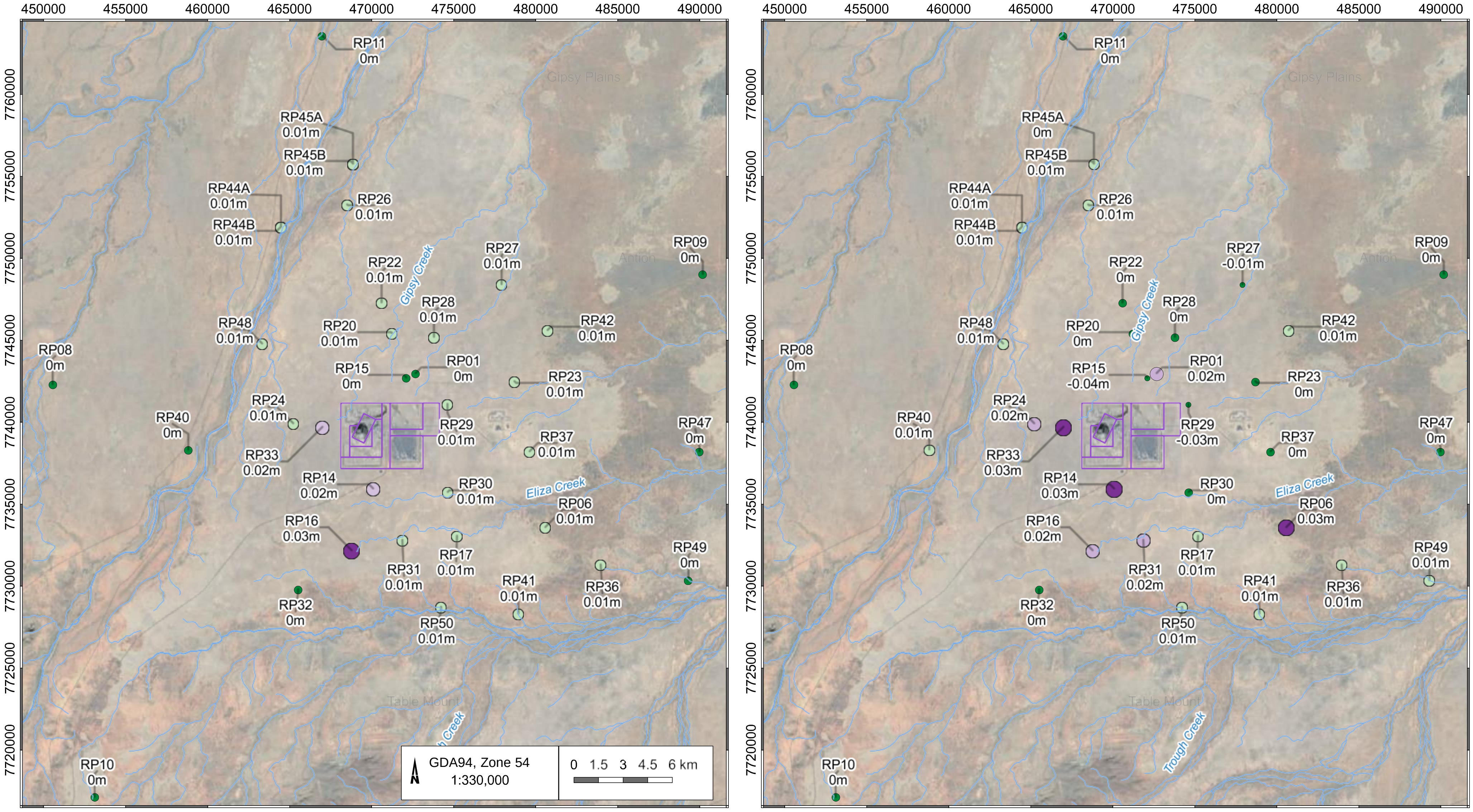
After dewatering during active mining ceases, groundwater level recovery (rise) will commence. Due to the lag times inherent in groundwater systems, the rate and timing of recovery will vary from bore to bore, according to the distance from the bore to the open pit. Further detail on total predicted drawdown from mining at EHO is provided in AGE (2022a).

Based on this assessment, the proposed operational extension to 1150 mRL level will cause negligible additional drawdown in Mesozoic and Proterozoic bores currently showing declining trends.

Table 6.1 Predicted drawdown in RP series bores for proposed operational depth (1150 mRL) and the additional drawdown predicted (proposed operational depth – current operational depth)

Bore ID	Aquifer	Predicted SWL (mAHD)	Drawdown since 2017* (m)	Predicted additional drawdown* (m)	Predicted SWL (mAHD)	Drawdown since 2017* (m)	Predicted additional drawdown* (m)
RP01	WF	119.46	-0.30	< 0.01	123.93	6.62	0.02
RP06	GRF	118.83	0.69	0.01	118.18	3.11	0.03
RP08	GRF	136.90	0.27	< 0.01	139.72	0.41	< 0.01
RP09	WF	107.64	0.26	< 0.01	133.21	0.01	< -0.01
RP10	Proterozoic	174.17	0.00	< 0.01	177.62	-0.76	< -0.01
RP11	WF	121.47	0.44	< 0.01	121.12	-0.04	< 0.01
RP14	GRF	112.89	1.67	0.02	116.34	4.76	0.03
RP15	GRF	119.96	0.27	< 0.01	134.29	-3.35	-0.04
RP16	WF / Proterozoic	123.43	3.24	0.03	126.69	2.21	0.02
RP17	WF	119.64	0.84	0.01	122.14	2.16	0.01
RP20	WF	123.86	0.82	0.01	128.19	1.10	< 0.01
RP22	WF / Proterozoic	120.40	0.96	0.01	128.98	-0.39	< 0.01
RP23	WF / Proterozoic	117.09	0.98	0.01	119.36	0.16	< 0.01
RP24	Tertiary / Proterozoic	127.39	1.28	0.01	130.92	1.39	0.02
RP26	GRF	124.65	1.03	0.01	127.75	0.97	0.01
RP27	WF	120.02	0.97	0.01	123.70	-1.57	-0.01
RP28	WF	120.39	1.04	0.01	129.83	-0.46	< -0.01
RP29	GRF	118.92	1.14	0.01	130.74	-3.22	-0.03
RP30	GRF	117.97	0.75	0.01	122.18	-0.45	< -0.01
RP31	WF	119.55	1.35	0.01	114.75	2.76	0.02
RP32	Proterozoic	139.78	0.07	< 0.01	141.21	-1.72	< -0.01
RP33	GRF	113.70	2.37	0.02	114.07	3.61	0.03
RP36	WF?	115.96	0.61	0.01	112.51	0.79	0.01
RP37	WF / Proterozoic	116.03	0.69	0.01	118.80	0.10	< 0.01
RP40	WF	136.57	0.24	< 0.01	139.06	0.41	0.01
RP41	WF	122.03	0.72	0.01	118.92	1.34	0.01
RP42	WF	114.94	0.74	0.01	113.75	2.25	0.01
RP44A	GRF	129.73	0.82	0.01	131.73	0.79	0.01
RP44B	WF	129.73	0.82	0.01	132.07	0.71	0.01
RP45A	GRF / Proterozoic	117.34	0.76	0.01	124.77	0.26	< 0.01
RP45B	WF	117.34	0.76	0.01	125.71	0.93	0.01
RP47	GRF	113.22	0.53	< 0.01	114.40	-0.04	< -0.01
RP48	Alluvium / Proterozoic	129.76	0.85	0.01	137.15	1.10	0.01
RP49	GRF	117.03	0.50	< 0.01	114.55	1.08	0.01
RP50	WF / Proterozoic	127.27	0.76	0.01	126.18	0.72	0.01

Notes: WF: Wallumbilla Formation; GRF: Gilbert River Formation.
*Negative drawdown indicates a groundwater level rise.



LEGEND

Road

Drainage

Major

Minor

▭ Mining lease

Predicted, additional drawdown from simulated data (m)

● 0
● 0.01
● 0.02
● 0.03

Predicted, additional drawdown from observed data (m)

● <0; GL rise
● 0
● 0.01
● 0.02
● 0.03

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Simulated and observed additional predicted drawdown

DATE
30/06/2023

FIGURE No:
6.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\EHM5011.001 EHM Application for Minor EA Amend\3_GIS\Workspaces\001_Deliverable1\06.01_EHM5011.001_Simulated and observed predicted additional drawdown.qgz

6.3 Pit lake levels

Current post-mine management planned for the pit predicts that the equilibrium pit lake be maintained as a sink to groundwater for potential contaminant management. Recent assessment of the final void lake indicated thata final void water level at approximately 100 mAHD would provide a local sink for groundwater, and a level of95 mAHD would provide a regional sink (AGE, 2022b). The catchment area draining to the pit after mining willbe controlled in such a way as to maintain a final void water level at about 100 mAHD.

There are five historical modelled scenarios that have assessed the behaviour of the EHO pit as a sink for groundwater post mining (AGE, Dobos, & WS, 2005; HCID, 2009; AGE, 2010). Only one of the five scenarios predicted that the pit will not behave as a sink for groundwater; this scenario used a low annual evaporation rate (300 mm/yr; HCID, 2009). The low evaporation scenario was used to simulate a post-mining setting where evaporative loss from the pit was actively minimised for management purposes. The second scenario by HCID (2009) of high evaporative loss (3,333 mm/yr; HCID, 2009), considered a more realistic representation given the hot arid climate at EHO, had comparable results to the other pit lake models (AGE, Dobos, & WS, 2005; AGE, 2010).

Previously modelled pit lake scenarios indicate that evaporation (being the main outflow from the pit) plays an important role in post-mining pit lake recovery and subsequent maintenance of the post-mining pit lake as a sink for groundwater. In Section 5.1.1, it was stated that the potential lake surface area available for evaporative loss from the final void pit lake would be increased due to the expected subsidence by approximately 11%. Therefore, the equilibrium final void pit lake level could be expected to be lower, as a result of increased evaporation, promoting the pit to act as a sink to groundwater after mining.

7 Implications for water quality

7.1 Introduction

The expected subsidence of the SWRD could lead to exposure of previously buried PAF material and may lead to the development of acidic and/or metalliferous drainage (AMD). Drainage from the SWRD will be captured by the pit and will potentially have an impact on pit lake water quality post-mining. As pit water was originally predicted to be of moderate salinity (discussed in Section 7.2), and disturbed areas are planned to drain to the pit, there will be no retrograde outcome in relation to pit lake quality (explained in Section 7.7).

For further detailed understanding within this application, AGE has undertaken geochemical modellingto predict the quality of runoff from the subsided materials (SWRD) into the final void and/or groundwater system. This runoff will interact with, but is not the sole component of, the final void pit lake water quality. The background, inputs, results, limitations, and uncertainty of the geochemical models are discussed below.

The following sections provide a summary of the previous assessments and existing geochemical data for the waste rock materials that are predicted to subside into the southern portion of the pit from the SWRD. Conceptualisation of the mechanisms was undertaken based on the existing waste rock geochemical dataset and material volumes in the SWRD. The modelling accounts for the chemical reactions between the rainfall runoff waters into the pit and acid forming materials associated with the subsided waste rock. Drainage and mixing with groundwater were not modelled with this runoff assessment, providing the most conservative assessment.

The quantity and mineralogy of acid forming materials was assumed from the acid-base accounting dataset, and from existing geologic information for the ore body and overlying units (e.g., some of the PAF material comes from sulfidic shales of the Wallumbilla Formation). The geochemical modelling has included consideration of the estimated volume of subsidence (Beck Engineering, 2023). The geochemical model predictions are representative of the chemical quality of the initial flux of runoff from the subsided materials into the pit (immediately post-mining). The modelling (Section 7.6) takes a conservative approach and has not accounted for changes in runoff quality over time or mixing between runoff and groundwater inflows.Rather, these interactions are described qualitatively in Section 7.7, with reference to relevant test datato predict impacts to the final void water quality.

7.2 Existing modelling of final void pit lake water quality

The existing geochemical models (AGE, Dobos, & WS, 2005; HCID, 2009) predict the post-mining pit lake water quality, based on the mine plans of the day. Both models predicted that the final void pit lake would be circum-neutral and moderately brackish (HCID, 2009). The exposure of PAF material in the SWRD was expected as part of the mining operations in one model (HCID, 2009). Therefore, this model is still broadly representative.

The existing models indicate that sulfides present in the ore and host rock that are PAF and can release trace metals to solution are: pyrite (FeS_2), chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S; and other copper sulfides), cobaltite ((Co / Fe)AsS), and molybdenite (MoS_2). Oxidation reactions of these minerals are possible in the pit water, and to a lesser extent in groundwater or seepage, prior to discharge to the pit. Oxidation will be sustained in the pit lake by the presence of dissolved oxygen (other electron acceptors are unlikely to be present).

AGE, Dobos & WS (2005) explained that the net acid production potential (NAPP) of the pit walls was, on balance, acid consuming, as most of the host rocks and country rocks contain carbonates (calcite and dolomite, which can neutralise acid), and most of the acid-forming sulfide minerals are removed with the ore. However, the results from leach tests did indicate that oxidation of the sulfide-containing black shales of the Wallumbilla Formation could produce acid and elevated salinity (HCID, 2009).

7.3 Review of geochemical waste rock assessments

A number of reports were supplied by EHO to assist with conceptualisation of the geochemical models. AGE reviewed these reports and selected a sub-set of these based on the datasets presented and associated interpretations. The objective of this undertaking was to obtain the key inputs to the models, specifically, mineralogical and/or geochemical data for the waste rock materials and waste rock material quantities. A summary of the previous reports considered by this assessment is presented in Table 7.1.

Table 7.1 Reports used to inform model conceptualisation

Report	Topic	Knowledge Gained
URS, 2003 *Ernest Henry Mining: Kinetic Leach Column Data - Project Review.* Report date 30/04/2003.	Kinetic Leach Column Testing (6 WRD samples)	• Bulk element data – enrichment in copper (n = 5), arsenic (n = 5) and manganese (n = 5) followed by nickel (n = 3) molybdenum (n = 2) and cobalt (n = 1). • column leachate collected on weekly basis for 3-4 years from “most of” the waste rock types. • high sulfur shale produced acidic leachate (pH 3 to 4 for 1st seven months and pH 2 to 3 for the remainder of the test period. • other waste rock materials retained generated neutral leachate (pH range of 6. to .). These samples “generate a significant amount of excess alkalinity under oxidising conditions”. • metal concentrations in leachate samples (not all) exceeded relevant ANZECC/NEPM water quality guideline concentrations- for Mo, Al, Fe, Ni, Mn, Se Cd, Co, Cu. • Study concluded that the alkalinity generated by waste rock materials (except for shale) was “more than adequate to neutralize any acidity generated by sulfide oxidation, through the first two or three years of exposure to oxidising conditions” and “the majority of waste rock materials are likely to continue to provide acid buffering for a significant period of time”.
O’Kane Consultants, 2006 *Illustrative Evaluation of Internal Seepage Characteristics for the Ernest Henry Copper-Gold Mine Waste Rock Dump.* Report dated July 2006.	Qualitative evaluation and modelling of seepage “characteristics”	"Reactive black shale” poses a risk leaching contaminants encapsulated in cells within the base two tiers of the WRD. At the time of reporting a third tier of reactive black shale tier was being planned including a WRD cover system" The study presented the following WRD concept design: 1) 15 m of high/low sulfur waste rock (tier 1); 2) 0.3 m of non-compacted orange clay (for tyre protection on trucks); 3) 15 m of high/low sulfur waste rock (tier 2); 4) 0.3 m of non-compacted orange clay (for tyre protection on trucks); 5) 15 m of high/low sulfur waste rock (tier 3) with the reactive black shale cell included; 6) 0.3 m of non-compacted orange clay (for tyre protection on trucks); 7) 15 m of high/low sulfur waste rock (tier 4); 8) 0.3 m of non-compacted orange clay (for tyre protection on trucks); 9) 5 m of high/low sulfur waste rock (tier 5); and 10) 0.5 m of blacksoil cover." The study also presents particle size distribution and hydraulic conductivity values for various materials.
Lottermoser, 2009 *Briefing Note on Seepage Waters Emanating from the North Waste Rock Dump, Ernest Henry Mine.*	Review of leachate data obtained from kinetic column tests	Study appears to infer, from the chemistry of leachate samples that the following minerals are present: arsenopyrite (As + S), pyrite (Fe + S), pyrrhotite (Fe + S), cobaltite (Co + S), siderite (Fe), cattierite (Co + S), molybdenite (Mo + S), pentlandite (Ni + S), chalcocite (Cu + S), coffinite (U), uraninite (U), native copper, chalcopyrite (Cu + Fe), sphalerite (Zn+ S), bornite (Cu + Fe). Leachates: five columns had circumneutral neutral pH values and evidence of “progressive dissolution of non-acid forming alkali sulfate phases”.

Report	Topic	Knowledge Gained
Report dated 17/02/2009.		The author proposed that dissolution of sulfate minerals gypsum, anhydrite and epsomite, were the primary influences in leachate chemistry at the time. In contrast, the leachate samples collected from one column containing “black shale” were acidic and exhibited elevated metal and elevated concentrations of metals/metalloids. The author proposed that these observations were the results of sulfide oxidation.
Deswik, 2020. EHM *WRD Modelling – Stage 2 Assumptions*. Report dated 27/05/2020. and RGS, 2021 *Waste rock dump 3D digital terrain model, and waste rock dump design assessment.* Report dated 20/01/2021	WRD design	Useful background information on geology of the deposit, WRD design and history of disposal. The Ernest Henry deposit is overlain by Tertiary and Mesozoic clays, sands, and shales. The upper portion of the mineralised sequence is oxidised and weathered, forming a supergene ore zone up to 150 above the primary ore zone. The supergene ore zone contains copper in the form of chalcocite, bornite and native copper with minor chalcopyrite ($CuFeS_2$). The primary ore zone contains chalcopyrite and gold occurs within the chalcopyrite crystal matrix. The cover sequence (from bottom to top) consists of Mesozoic sediment (0-40 m thick, average 16 m); quartz-pebble conglomerate (0-24 m thick; average 11 m); Tertiary orange clay sediments (1-27 m thick; average 10 m); and black soil (2-3 m thick; average 2.3 m). The uppermost unit comprises grey, clay rich soils, typically 2 to 3 thick. The quantity of materials in the SWRD as reported by RGS (2021) are as follows: • Area of 291 ha • Volume of 112 M loose cubic metres (LCM) • 2,232 mRL Maximum height • 5 tiers • 8 black shale cells • 19 M LCM Black Shale Column experiments have verified that the black shale within the cover sequence over the Proterozoic ore bearing rock is reactive and requires segregation within engineered cells inside the waste rock dump. Other waste rock types react very slowly as “verified” by long-term, on-site kinetic leach experiments. The study indicates that neutral pH, saline, and metalliferous drainage is one of the primary long-term environmental risks of EHO WRD design as apparent from NWRD and SWRD seeps that are moderately to highly saline and have elevated concentrations of molybdenum (Mo).
EHM, 2023. *Waste Rock Management Plan 2022.* Report dated February 2023.	WRMP is used to manage mining, characterisation, classification, and scheduling of waste rock placement into the N/SWRDs. The WRMP is limited to the management of waste rock that is placed into or removed from the NWRD or SWRD, and the management of environmental impacts from the NWRD and SWRD.	Report presents a conceptual model of the WRDs and the following high level description of the mineralogy of the ore units: (1) Lithophile elements (Al, Ba, Be, Cr, Li, Mn, Rb, Sr, V) are contained within aluminosilicate, sulfate and oxide minerals. (2) Chalcophile elements (As, Cd, Co, Cu, Mo, Ni, Pb, Sb, Se, Zn) occur within sulfide minerals. (3) Uranium is hosted by the uranium minerals uraninite, brannerite and coffinite. The report indicates that "reactive black shale” contains sulfide minerals and is highly reactive. The acid is neutralised by acid consuming minerals along the “flow path” and leads to neutral pH drainage that is elevated with salts (sulfate > calcium and magnesium > sodium, chloride and bi-carbonate ions), Cd, Mn and Zn. The seepage has the potential to become increasingly acidic over time as the acid neutralising minerals are consumed.

7.3.1 SWRD Material Volumes

According to Deswik (2020), RGS (2021), and EHM (2023) the approximate surface area and respective volumes of waste material contained at major site infrastructure, related to the operational changes, include:

- 1 open pit (approx. 154.7 ha and 240.0 Mm^3 void volume);
- 2 WRDs:
  - North WRD (approx. 223.4 ha and 90.9 Mm^3);
  - South WRD (approx. 291.6 ha and 104.5 Mm^3); and
- Tailings Storage Facility (TSF; approx. 425.4 ha and 122 Mm^3).

The volume of materials in the SWRD as reported by RGS (2021) and EHM (2023) are described below and are of primary relevance to the geochemical assessment contained herein (Table 7.2). Below is a summary of the material volumes including the volume of black shale in the SWRD (RGS, 2021). No other sources of information provided supporting or alternative estimates of the black shale volumes, which are critical inputs for the geochemical modelling as these are the primary acid forming materials.

SWRD details:

- Area of 291 ha.
- Volume of 112 M loose cubic metres (LCM).
- 2,232 mRL Maximum height.
- 5 tiers.
- 8 black shale cells.
- 19 M LCM black shale.

Table 7.2 Adopted Volumes and Assumptions (AGE)

Material	Volume M LCM	Geochem Assumptions	Subsidence Assumption
Total SWRD	112	Non-Acid Forming	Subsided material will contain the same volumetric proportions as within the greater SWRD
Black shale	19	Acid Forming – no other acid forming materials in SWRD	

7.3.2 SWRD Minerals

Geochemical modelling requires an understanding of the minerals that are present in the system in question. This is required so that reactions between water and minerals can be predicted. Importantly, the quantity of minerals is a required input to geochemical models so that the degree of water-mineral reactions can be predicted.

Reviews of EHO data and reports have not identified any quantitative mineralogical data. Various reports refer to the presence of minerals such as: arsenopyrite (As + S), pyrite (Fe + S), pyrrhotite (Fe + S), cobaltite (Co + S), siderite (Fe), cattierite (Co + S), molybdenite (Mo + S), pentlandite (Ni + S), chalcocite (Cu + S), coffinite (U), uraninite (U), native copper, chalcopyrite (Cu + Fe), sphalerite (Zn + S), bornite (Cu + Fe) (Lottermoser, 2009; RGS, 2021; EHM, 2023). The sources of this information are not provided and EHO are not aware of any mineralogical data. Review of the documents suggest that the minerals listed above have been assumed, based on leachate results and on mineral exploration information (e.g., assay data and visual identification).

7.3.3 Geochemical Testing Results

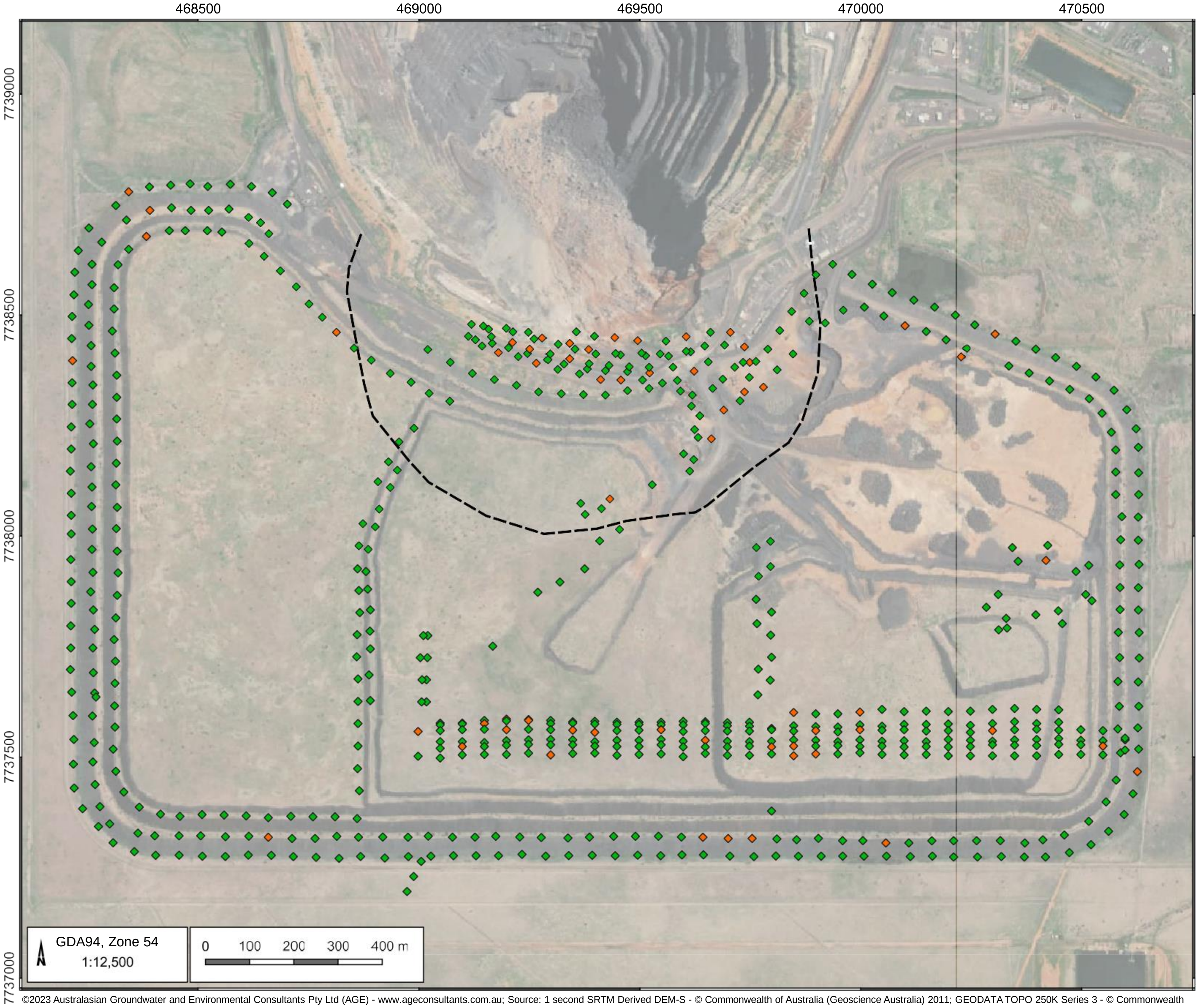
7.3.3.1 Static Testing Data

A total of 659 samples have been collected from the SWRD. The dates of sampling span 2003 to 2023 and the dataset appears to include leachate results. The method of collection is recorded in the EHO waste rock sampling procedure. Static testing data limitations were identified and communicated to EHO for future consideration regarding sample collection and analysis procedures. The dataset also suggests that the GARD Guide methods of mine waste characterisation were followed, specifically, measurement of total sulfur (%) calculation of NAPP, and AMD classifications of PAF, non-acid forming (NAF) or acid consuming materials (ACM). The dataset also has an EHO Classification as HSW or LSW. These acronyms stand for “high sulfur waste” and “low sulfur waste”, respectively.

The spatial distribution of sampling was largely confined to the outer perimeter of the SWRD (Figure 7.1; Figure 7.2). Exceptions are an east-west band of sampling that spans the southern portion of Shale Cell 4 andShale Cell 5. The vast majority of waste rock samples were classified NAF, ACM or LSW. Fifty-nine samples were classified as “high capacity” and “low capacity” PAF (PAF-HC and PAF-LC, respectively). Sixty-two samples were classified as “HSW”. Review of the dataset indicates that samples classified as PAF are also classified as HSW. Conversely, samples classified as NAF or AC have been designated the EHO classification of LSW. Total sulfur (weight %) results ranged from below detection (n = 2) to 5.1%. Percentile rank analysis of total sulfur yielded P_{20}, P_{50} and P_{80} values of 0.07%, 0.16%, and 0.32%,respectively. For samples classified as PAF (HC or LC), P_{20}, P_{50} and P_{80} values were 0.14%, 0.60% and 0.75%, respectively.

The spatial distribution of EHO classification results indicate that a higher density of HSW (Figure 7.1) or PAF-HC, PAF-LC and NAF-HS (Figure 7.2) have been identified within the zone of predicted subsidence relative to the zone outside the predicted subsidence. These AMD classifications, in addition to relatively highsulfur content (Figure 7.3) in a large proportion of samples (e.g., % S > 0.1), indicate a potential for acidic or metalliferous drainage/runoff from the subsided materials. This is tested by the predictive geochemical modelling.

The shale PAF cells within the SWRD are mapped along with the predicted subsidence zone in Figure 7.4.



EHM Application for EA Amendment
(EHM5011.001)

EHO static testing classification for waste rock materials collected from the SWRD

DATE
21/04/2023

FIGURE No:
7.1

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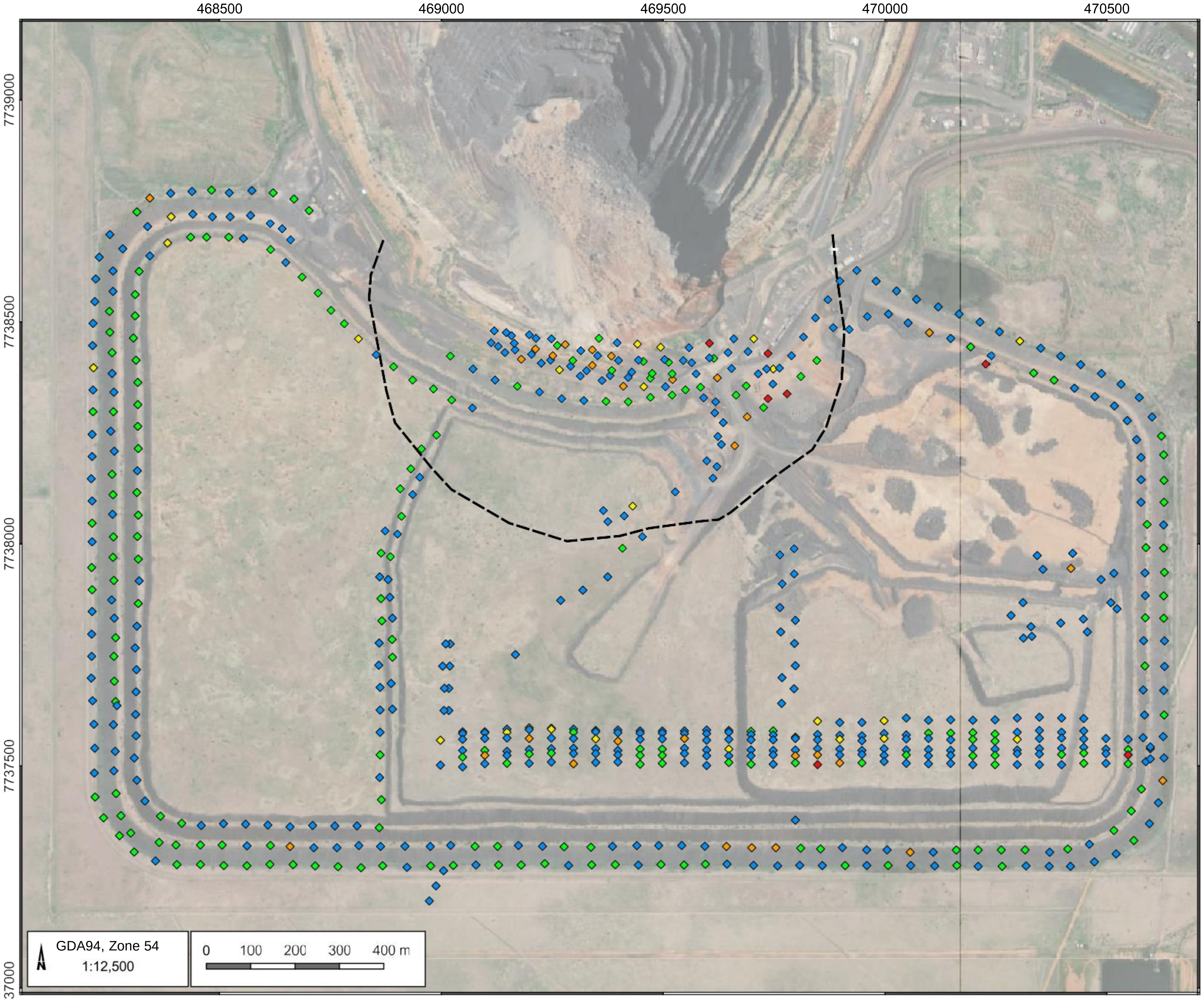

LEGEND

╌ Predicted zone of subsidence (Beck, 2023)

Leachate sample locations

- ◆ Acid Consuming Material (ACM)
- ◆ Non-Acid Forming - Low Sulfur Material (NAF-LS)
- ◆ Non-Acid Forming - High Sulfur Material (NAF-HS)
- ◆ Potentially Acid Forming - Low Capacity Material (PAF-LC)
- ◆ Potentially Acid Forming - High Capacity Material (PAF-HC)

EHM Application for EA Amendment
(EHM5011.001)

GARD guide static testing classification for waste rock materials collected from the SWRD

DATE
21/04/2023

FIGURE No:
7.2

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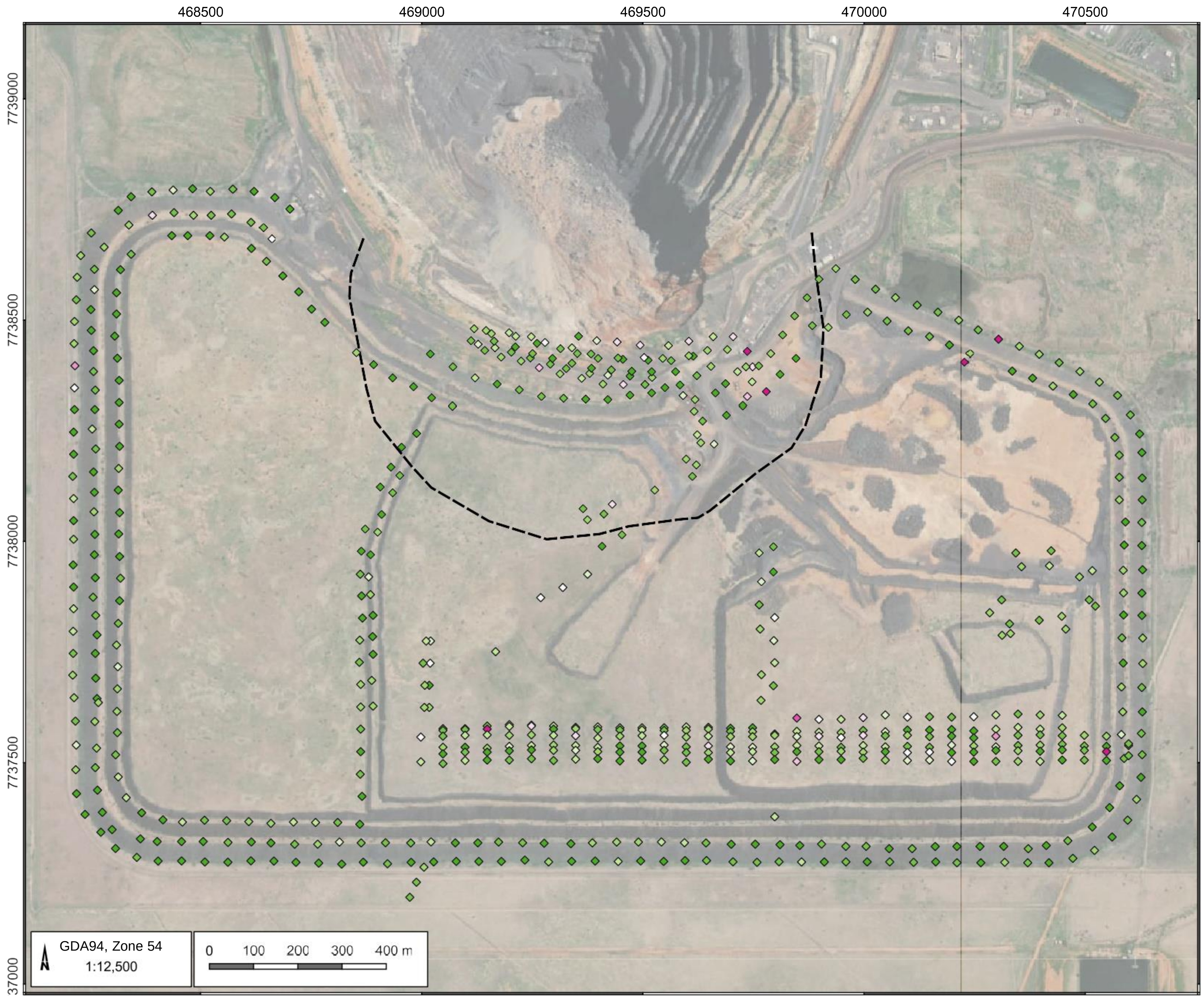

LEGEND

— — Predicted zone of subsidence (Beck, 2023)

Leachate samples - Sulfur %

- ◆ 0 - 0.10
- ◆ 0.10 - 0.20
- ◆ 0.20 - 0.30
- ◆ 0.30 - 0.40
- ◆ 0.40 - 0.50
- ◆ 0.50 - 0.60
- ◆ 0.60 - 0.70
- ◆ 0.70 - 0.80
- ◆ 0.80 - 0.90
- ◆ 0.90 - 1.00
- ◆ >1.00

EHM Application for EA Amendment (EHM5011.001)

Total sulfur results (weight %) for waste rock samples

DATE
21/04/2023

AGE

FIGURE No:
7.3

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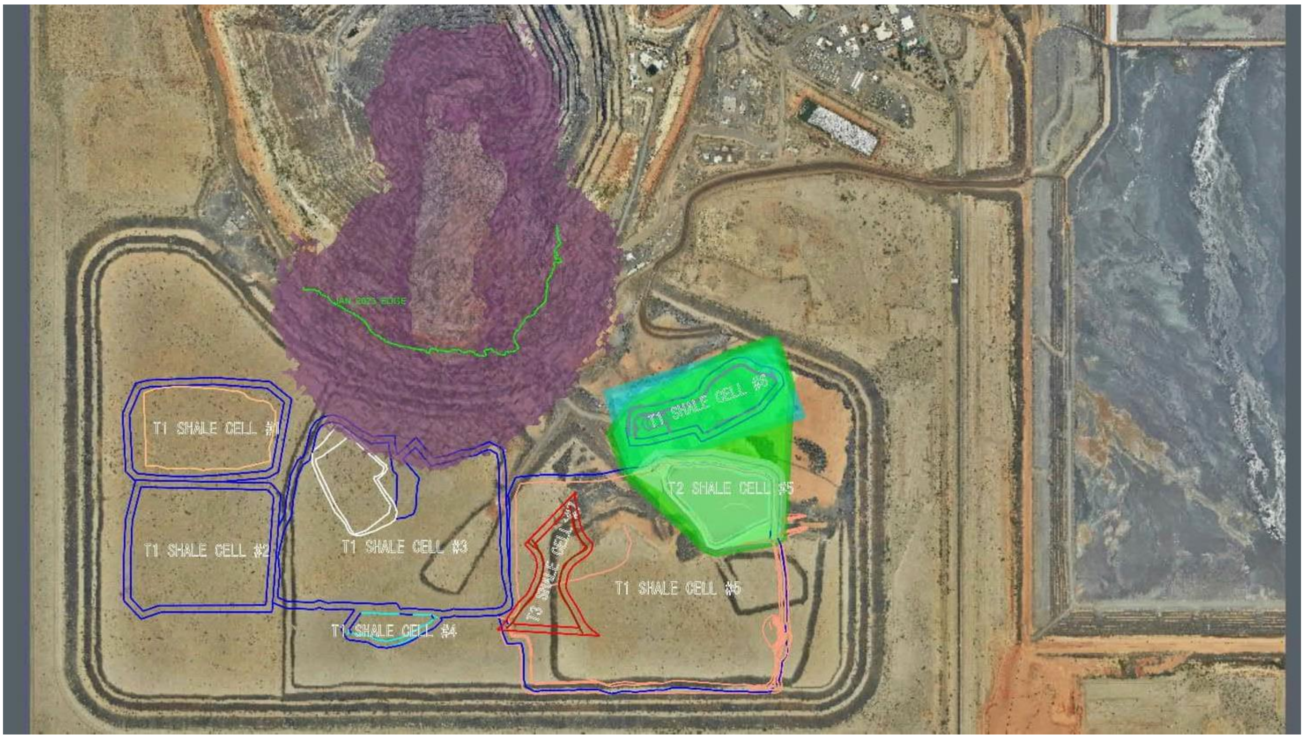

Figure 7.4 Predicted subsidence of SWRD and shale PAF cells (EHO advice)

7.3.3.2 Kinetic Testing Data

Column experiments were implemented in 2004 on six samples (labelled LC02 to LC07) of waste rock materials. The materials were described by URS (2003) but did not identify the geologic unit from which they were sampled (Table 7.3). Kinetic testing data limitations were identified and communicated to EHO for future consideration regarding sample collection and analysis procedures.

Table 7.3 Available description of column testing materials

Column ID	"Material Type"*
LC02	NAF Low Sulfur
LC03	NAF High Sulfur
LC04	PAF High Capacity
LC05	AF Shale
LC06	AF Shale/NAF Low Sulfur
LC07	PAF Low Capacity

Note: *Information from (URS, 2003).

Initial review of the data was undertaken by Lottermoser (2009). At that time, leachates of samples from LC02, LC03, LC04, LC06 and LC07 had circumneutral neutral pH values and evidence of "progressive dissolution of non-acid forming alkali sulfate phases". The author proposed that dissolution of sulfate minerals gypsum, anhydrite and epsomite, were the primary influences in leachate chemistry at the time. In contrast, the leachate samples collected from LC05 ("AF shale") were acidic and exhibited elevated concentrations of metals/metalloids. Lottermoser (2009) proposed that these observations in LC05 were the results of sulfide oxidation.

Review of the column leachate dataset from 2004 to 2022 was undertaken to assist with conceptualisation of the geochemical models. Temporal trends in ion concentrations have been relatively consistent over time and are similar to those discussed by Lottermoser (2009). Specifically, column LC05 (black shale) has yielded leachate solutions that are acidic and have elevated concentrations of metals/metalloids through the experimental period.

The other five columns have yielded leachate solutions over time that have circumneutral pH and relatively low concentrations of most metals/metalloids. The leachate samples from these columns have elevated sulfate concentrations and sulfate-chloride ratios that are several orders of magnitude greater than those expected in rainwater. Furthermore, samples from these columns have consistently exhibited elevated concentrations of molybdenum (P_{50} = 0.18 mg/L), zinc (P_{50} = 0.017 mg/L), and copper (P_{50} = 0.014 mg/L). These observations from LC02, LC03, LC04, LC06 and LC07 combined with their significantly elevated sulfate-chloride ratios indicate that sulfide oxidation has occurred throughout the experimental period in these leachate columns, which would have produced acid. However, the circumneutral pH indicates that the materials tested in these columns (all sample types except the AF shale) have sufficient buffering capacity to neutralise the acid. This finding is significant to the interpretation of modelling results below, and also has important environmental implications in terms of neutral mine drainage of metal-impacted waters. The concept of neutral mine drainage has been previously proposed by AGE, Dobos and Water Solutions (2005), HCID (2009), RGS (2021) and EHM (2023).

7.4 Model Conceptualisation

A key element of predictive geochemical modelling is the conceptualisation process. This begins with a review of existing information to gain an understanding of the hydrologic and geochemical conditions. This knowledge is used to identify the mechanisms that may occur due to future changes in the system being considered, or to assess the implications of past changes such as mine site development. In this case, the modelling objective is to provide an understanding of the effects of subsidence and exposure of PAF materials to atmospheric conditions and rainwater runoff, contributing to the final void water quality.

Detailed review of existing information regarding the SWRD was undertaken to inform the conceptualisation process (Table 7.2). The models were constructed to predict the chemical composition of runoff from SWRD materials following subsidence into the pit, which is predicted after underground mining extends to 1150 mRL (Beck Engineering, 2023). The models were conceptualised as follows:

- the materials that subside into the pit will have the same volumetric proportion of black shale as present within the greater SWRD (this is a conservative estimate of the shale proportion);
- the black shale is present within the delineated cells of the SWRD (shown in Figure 7.4);
- black shale is the primary source of acidic and metalliferous drainage (AMD);
- black shale represents 17% of the volume of materials in the SWRD;
- the volumetric fraction of the shale relative to other materials is equivalent to the mass fraction, assuming similar densities between the different rock types in the SWRD;
- all of the HSW material is associated with the black shale (while other lithologies may be classified as HSW material, it is conservative to make this assumption);
- the mineral within the black shale responsible for AMD generation is pyrite, and this mineral is present at the weight percentages listed in Table 7.4, adjusted to the equivalent percent as pyrite from the weight% sulfur dataset provided by EHO;
- all of the pyrite is exposed on the surface of the black shale at the time of subsidence;
- rainwater leaches the surface of the subsided materials during the wet season;
- rainwater has the median chemical composition observed at Mt Isa (Crosbie et al., 2012);
- rainwater is in equilibrium with atmospheric pressure with respect to carbon dioxide and oxygen;
    - this assumes that the water in contact with the subsided materials has a constant supply of oxygen (oxidizing agent) and carbon dioxide (source of alkalinity).
- the rainwater reacts with pyrite of the subsided material instantaneously until all of the pyrite is consumed;
- the reactivity of pyrite is not inhibited by changes in pH or “armouring” of the mineral surface due to secondary mineral precipitation; and
- other minerals in the WRD are relatively inert silicate minerals, quartz, albite and potassium feldspar.
    - These waste rock materials have limited to no buffering capacity; however, a small fraction of potassium feldspar was “allowed” to react in parallel with the pyrite oxidation reactions. This is considered justified based on the evidence of potassium-mineral weathering in groundwater samples beneath the site.

This conceptualisation leads to conservative predictions (worst case scenario) in terms of the acid generation from the black shale. The models have accounted for very minor pH buffering and have not accounted for metal/metalloid release (except for iron) or metal/metalloid attenuation.

As no quantitative mineralogic data are available, it is not possible to reliably account for metal/metalloid attenuation. These data are required to identify the sulfide minerals that are present, including abundances. The predicted pH of runoff from the subsided materials with only very minor effects of buffering is presented in Section 7.6. An understanding of the present buffering minerals and abundances would be required if this estimate were to be refined further. Qualitative discussion of buffering is included in Section 7.7.

7.5 Model Inputs

The inputs to the models have been based on the following:

- the quantity of materials in the SWRD in terms of million (M) loose cubic metres (LCM) and the extensive EHO dataset for weight percentage of total sulfur in SWRD materials (Table 7.4);
- estimated quantity of pyrite in the SWRD based on the quantity of materials in the SWRD and weight percentages of total sulfur (Table 7.5); and
- rainwater chemistry data published by CSIRO for the Mt Isa region (Crosbie et al., 2021) (Table 7.6).

Table 7.4 Modelling inputs and assumptions

Information	Value/Source
Volume of WRD (M LCM)	112
Volume of Black Shale (M LCM)	19
Mineral abundances in WRD materials	Unknown
Sulfur content (%) – all WRD materials	0.07_{P20} – 0.32_{P80}
Sulfur content (%) – HSW WRD materials	0.14_{P20} – 0.75_{P80}
Sulfur content (%) – HSW WRD materials	0.07_{P20} – 0.29_{P80}
Rainwater chemistry	CSIRO

Table 7.5 Estimated quantity of pyrite in SWRD

	All WRD Samples	LSW	HSW	Mixed LSW + HSW^	Mixed LSW + HSW
P_{20}	0.13	0.13	0.26	0.15	0.03
P_{50}	0.30	0.28	1.12	0.42	0.08
P_{80}	0.60	0.54	1.39	0.68	0.14

Notes: *wt % pyrite estimated from total sulfur results

^vol % pyrite estimated from total sulfur results & mass fraction of black shale (0.17)

$^{+}$vol % pyrite estimated from total sulfur results & mass fraction of black shale (0.17) and based on pyrite mineral density of 5.01 g/cm$^{3.}$

Table 7.6 Statistical analysis of rainwater chemistry results from Mt Isa (Crosbie, et al., 2012)

Analyte	P_{20}	P_{50}	P_{80}
pH	5.50	6.20	6.60
EC (µS/cm)	10	35	ID*
SO4 (mg/L)	1.10	3.05	6.00
Cl (mg/L)	0.256	0.630	1.46
Alkalinity (mg/L)	3.05	4.75	13.7
Na (mg/L)	0.219	0.642	2.19
K (mg/L)	0.30	0.52	1.22
Ca (mg/L)	0.207	1.15	3.24
Mg (mg/L)	0.237	0.366	1.34
Fe (mg/L)	BD	BD	BD
Al (mg/L)	BD	BD	BD
Si (mg/L)	0.33	0.55	2.39

Notes: BD: all values below detection.
*Insufficient data.

7.6 Modelling results and discussion

Three model simulations were completed based on the weight % sulfur results for WRD samples classified as HSW. Each model run had the same inputs for rainwater chemistry, which was the median (P_{50}) concentration values presented in Table 7.6. The variable input parameter to the three model runs and were the P_{20}, P_{50} and P_{80} weight % values for pyrite presented in Table 7.5 ("Mixed LSW + HSW").

The geochemical modelling predicts that the initial rainwater runoff (first flush) from the subsided materials will be acidic (pH 4 – 4.5) (see Figure 7.5) due to reactions with sulfide minerals on the waste rock material surfaces. In this case, the modelling assumes that pyrite is the primary mineral that is present, although other sulfide minerals are known to be associated with the ore body. The runoff from the subsided materials may also contain elevated concentrations of metals/metalloids, depending on the sulfide minerals that are present (not modelled). The predicted pH and concept of runoff having elevated concentrations of metals/metalloids is supported by the long-term column experiment on the black shale material (LC05). However, the other five columns have consistently exhibited characteristics of neutral mine drainage from the waste rock materials. Explanations for the discrepancies between the geochemical modelling results and column leachate results from LC02, LC03, LC04, LC06, LC07 are likely due to the limitations discussed below.

7.6.1 Limitations and interpretation

The geochemical modelling results were based on a number of assumptions that commonly need to be adopted in this field of numerical modelling. The primary limitation for all geochemical models is data availability and accuracy. The dataset provided by EHO has been collected on an extensive number of waste-rock samples (n = 598) that have been analysed for standard ABA. As such the range in weight % sulfur results used to inform the modelling is considered to be a best estimate of *in situ* conditions. The long-term leach column dataset provides significant insight into the potential mechanisms of water-rock interactions, includingbuffering capacity.

A critical limitation to the geochemical modelling results of acid generation is the limited buffering reactions incorporated into the model. This is due to a lack of mineralogical data needed to incorporate these reactions into the model. However, ABA accounting results indicate that the waste-rock materials of the SWRD have a high acid neutralisation capacity. Furthermore, the leachate results from five of the six columns indicate that the pH of mine drainage and runoff is likely to be circumneutral. As such, the geochemical modelling results contained herein are considered to be worst-case estimates of the pH of runoff waters into the pit, which after closure would mix with rainfall over the void, and groundwater inflows to the pit. It is possible that the acidity generated by sulfide oxidation is buffered by chemical weathering of non-sulfide minerals. A further limitation to the modellin is that it has not accounted for “armourin ” of the sulfide mineral surface. This process is caused by precipitation of iron-oxyhydroxide minerals, a product of pyrite oxidation. The armouring (or coating)of the sulfide mineral surfaces significantly decreases their reactive surface area and rate of acid generation.

The expected increase in pH due to buffering reactions (not modelled due to data limitations) will lead to metal attenuation via adsorption. This is particularly the case for the subsided materials as they are likely to contain a high abundance of iron-oxide minerals (RGS, 2021). Iron oxide minerals have a high affinity to attenuate metals via adsorption if the waters are circumneutral in pH. Potential exceptions are molybdenum, cadmium, and zinc. This concept is supported based on elevated molybdenum and zinc concentrations in leachate samples collected from columns LC02, LC03, LC04, LC06, LC07. Molybdenum can be mobile under circumneutral pH conditions and zinc can be mobile in the presence of elevated sulfate. These conditions have been observed in column leachate data.

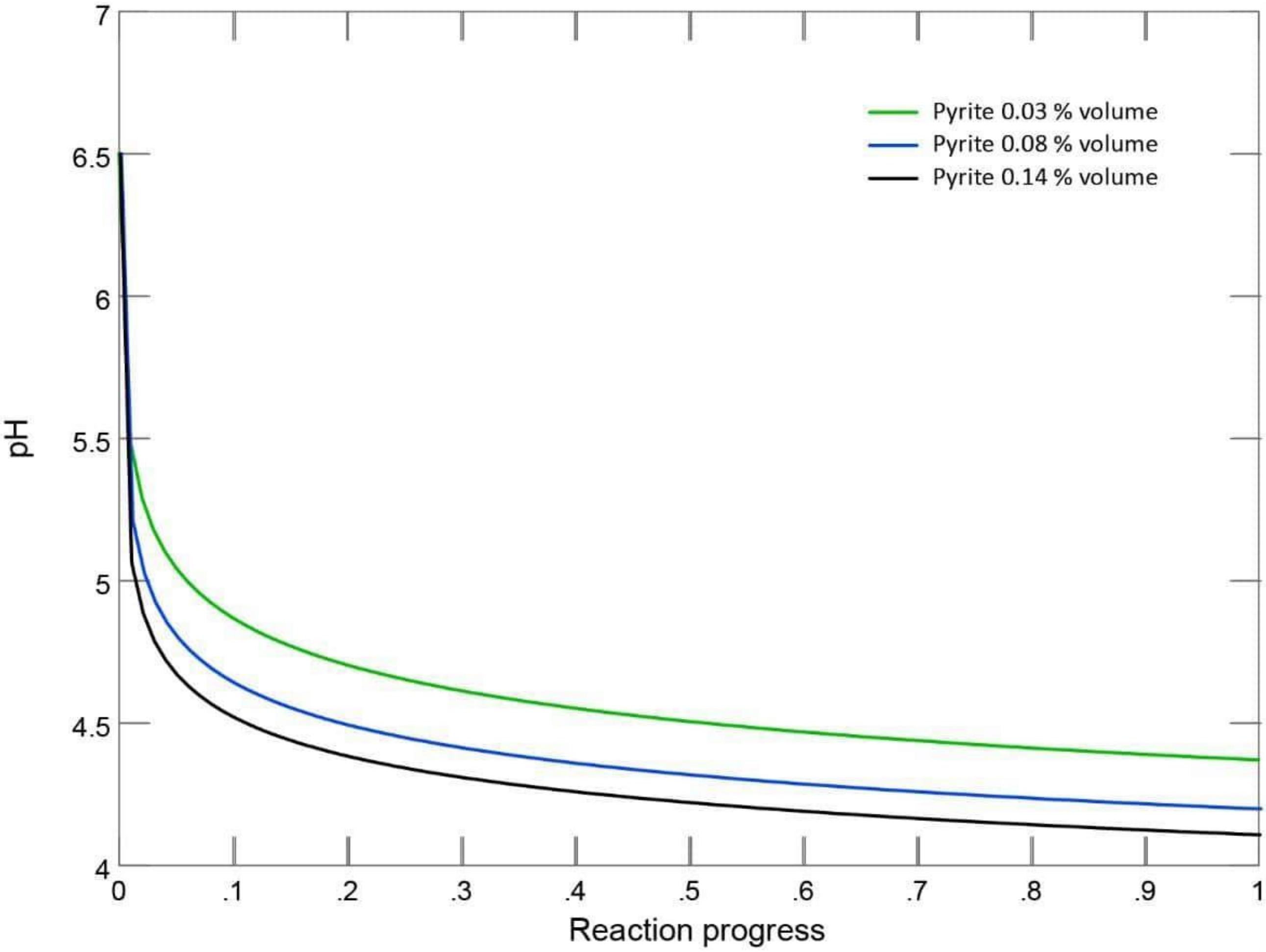

Figure 7.5 Geochemical modelling results for predicted pH due to oxidation of sulfide minerals by rainwater runoff from the subsided waste. The range in pyrite volumetric % are based on the weight % sulfur results for WRD samples classified as HSW

7.7 Updated discussion of final void water quality

As discussed above, expected subsidence of the SWRD may lead to exposure of previously buried, PAF material, including Wallumbilla shale material, and the development of acid drainage, which would potentially have an impact on pit lake water quality. The additional caved material predicted to fill the base of the pit, and subsided SWRD material, are initially expected to cause acid-producing reactions, resulting in acidic runoff (Figure 7.5). Although the pit wall material has buffering potential, the addition of PAF material to the pit lake may extend the period of time the pit lake will remain as a poor quality water repository (in an acidic state), due to the potentially slow rates of buffering reactions.

Over the long term, this acidity is not expected to persist, for the following reasons:

1. As the exposed PAF materials oxidise, the products of the reactions precipitate on the exterior of individual grains as rapidly formed oxide coatings (e.g., goethite, FeO(OH)). This in turn prevents dissolved oxygen access to the partially reacted sulfide minerals, thereby limiting acid generation.
2. Acid generation is also limited over time as the final void pit lake level rises and submerges the remnant PAF material and the pit walls. Full submergence of the sulfide minerals inhibits oxidation reactions, especially as all dissolved oxygen is slowly consumed in the deeper levels of the pit lake.
3. The acid generated rapidly in the early stages after material exposure will gradually be neutralised by the acid-consuming components of the wall rock, subsided waste rock (outlined above) and alkalinity of groundwater inflows.

Thus, there is a high likelihood that acidity will be neutralised over time, and the equilibrium pit lake will be circum-neutral, as predicted in the studies from 2005 and 2009. In addition, it is likely that some of the solutes produced by the oxidation reactions will remain in solution in the pit lake water. For example, most of the oxidation reactions would release sulfate to solution, and this is a conservative solute, meaning that it is likely to remain dissolved in the pit lake water. This means the pit lake will be saline and will not likely constitute a useable water supply for cattle or humans. No beneficial use of the pit lake was originally planned. Molybdenum and zinc may also remain in solution due to the expected circumneutral pH and elevated sulfate concentrations.

As long as the pit continues to act as a sink to groundwater post-closure (which is likely, due to the 11% increase in surface area available for pit lake evaporation), the reduced quality of water present in the pit lake is not expected to influence the surrounding groundwater systems.

8 Control measures and mitigation

Some of the changes to groundwater mentioned above may have the potential to impact groundwater. However, control measures and mitigation (including natural attenuation) are likely to change the impact assessment. The intended and existing measures are described in this section, based on existing infrastructure and processes, current plans, and information supplied by Evolution. This section satisfies the following points of s226A:

- *details of the management practices proposed to be implemented to prevent or minimise adverse impacts; and*
- *include a description of the proposed measures for minimising and managing waste generated by amendments to the relevant activity.*

EHO has developed land outcome documents including: a Post Mine Land Use Plan, a current EA, and the Estimated Rehabilitation Costs. In accordance with these documents, the following rehabilitation actions will be used to stabilise the post-closure mine environment (EHO advice):

- the TED, PED, and TEDEX will be removed (EHO has commenced a contaminated land assessment for the evaporation dams as part of closure planning);
- the soil horizons of the TED, PED, and TEDEX will be rehabilitated, removing contaminated portions from the upper layer and establishing a post-mining land use (PMLU) of grazing;
- the TSF will be capped;
- the ROM and processing area will be rehabilitated and graded to drain to the pit (instead of the PED, as it does during operation);
- the NWRD will be capped;
- the SWRD will be partially capped (the portion of SWRD that subsides to, and forms part of the pit, will be part of the residual void domain);
- there will be no pit backfilling apart from the partial subsidence of SWRD material into the pit (Figure 5.3);
- the underground mine will be allowed to flood with the natural recovery (rise) of groundwater levels (there will be no underground backfilling);
- the pit will be inundated with a pit lake due to rainfall runoff and the natural recovery (rise) of groundwater levels;
- the pit lake will be allowed to recover to a long-term equilibrium without adjustment or intervention (aside from the rehabilitation noted above); and
- through catchment management at the time of closure, the equilibrium pit lake is intended to remain a sink to groundwater, which is consistent with the existing predictions (Section 4.8).

The proposed control measures and rehabilitation actions for the TSF, NWRD, and SWRD are deemed suitable for minimising potential groundwater contamination from those features. Although seepage is expected to continue beneath infrastructure such as the TSF (by design), the volume will be significantly reduced by limiting the infiltration of rainfall through construction of the capping. Potential seepage beneath surface infrastructure (e.g. TSF) is expected to be captured by the pit (as long as it continues to act as a groundwater sink), due to the proximity of these features to the pit. However, in the case of the SWRD, where only partial capping is possible due to the expected subsidence, the potential runoff / seepage that may occur due to additional surface area being exposed to rainfall infiltration is expected to be captured by the pit. Residual impacts to groundwater, after the mitigation and control measures discussed above are implemented, are assessed in the next section.

9 Residual impact of groundwater changes to environmental values

This section provides a description of the risk and likely magnitude of impacts on relevant EVs, as a result of the changes to groundwater. The impact assessment takes mitigation actions and control measures into account; thus, residual impact is quantified or characterised.

Site infrastructure that has the potential to be a source of solutes to groundwater includes the: TED/PED/TEDEX, TSF, NWRD, SWRD, and the underground workings (Section 4.3). The TED/PED/TEDEX and the NWRD (and their potential as sources of impact to groundwater receptors) are not affected by any of the proposed changes relevant to this application. Therefore, the TED/PED/TEDEX and the NWRD are not assessed below.

The only pathway considered here is groundwater; groundwater is considered a potential pathway if changes in groundwater flow, level, or quality connects the source to the receptor.

The potential receptors are groundwater users (grazier bores or water deed bores; Section 4.9.4).

There is evidence of drawdown at grazier bores proximal to EHO, hence the implementation of Make Good agreements between EHMPL and related landholders (Section 4.9.4). However, the observation of drawdown at grazier bores is indicative of a transference of pressure due to mine dewatering, not the migration/movement of groundwater. Therefore, the changes in groundwater level observed at grazier bores is not indicative of a pathway for groundwater from EHO.

The impacts assessed below are focussed on those impacts that are due to the mining changes relevant to the EA amendment application. Discussion of known impacts is included as needed to provide context. The impact assessment concludes:

- drawdown:
  - compared to total permitted drawdown, there is negligible impact to groundwater users predicted in response to the proposed changes in drawdown;
- final void pit lake:
  - future impact to receptors is unlikely to occur as long as the pit remains a groundwater sink post-mining (this is likely considering that current models predict a groundwater sink and the proposed changes would result in an 11% increase in pit lake surface area available for evaporation);
- TSF:
  - no future impact is predicted as a result of the 4.6% increase in the TSF volume capacity due to the absence of pathways towards EVs, the low rate of observed leakage, and the fact that the height of tailings will not exceed that already authorised in the TSF;
  - this is concluded on the basis that the TSF is a free draining media (as evidenced by declining pore pressure monitored in TSF VWP sensors) and that it will be operationally maintained in accordance with its design intent;
- SWRD:
  - there is no future impact predicted for groundwater users regarding water quality from the SWRD due to the absence of pathways towards EVs; and
- underground workings:
  - there is no future impact predicted for groundwater users regarding water quality from this source due to the absence of pathways towards EVs.

In summary, there are no residual impacts to receptors predicted to occur as a direct result of the proposed changes.

10 Summary

In conclusion, the proposed mining change is predicted to affect groundwater in the following ways:

- subsidence and additional cave rock material:
  - the additional caved rock and subsided material is predicted to raise the pit floor by approximately 260 m (final pit void will be shallower);
  - subsidence of the SWRD will expand the pit surface area approximately 370 m into the SWRD;
- inflows to the underground workings:
  - are expected to increase;
  - however, the predicted increase in inflow is equivalent to approximately 0.5% of the current, cumulative volume of water removed from the underground and pit;
- increased recharge:
  - rainfall infiltration through subsided areas may increase and could report to sumps in the pit or underground;
  - however, the predicted increase is potentially 0.5 ML per month (0.1% of currently measured inflows), which is considered to be a negligible increase to the total expected inflows from the pit and underground;
- drawdown:
  - estimated to marginally increase;
  - however, the predicted increase is typically less than one centimetre; therefore, the proposed changes are considered to cause negligible additional drawdown;
- final void pit lake level:
  - the pit void is expected to widen (due to subsidence), which will cause an increase in evaporation;
  - therefore, the final void pit lake level is expected to be similar to, or slightly lower than, existing estimates, as a result of the proposed changes to operations;
  - existing estimates indicate the pit will remain a sink due to the planned catchment rehabilitation at closure, and as such, the pit lake with a reduced equilibrium level is also likely to act as a sink;
- increased tailings production:
  - the 4.6% increase in the TSF volume capacity will be accommodated within the existing height of TSF embankments authorised in the EA, therefore, there is no change in the maximum possible driving force of TSF leakage (which correlates to the height of the head pressure in the tailings);
  - TSF operation is expected to continue without material change after the TSF capacity increase;
  - potential of TSF seepage to groundwater would be diminished post-closure due to the construction of the capping;
- pit lake water quality:
  - due to the possible exposure of additional PAF material from subsidence; the pit lake water quality may initially have higher acidity (e.g. pH between 4 and 4.5);
  - however, due to the presence of acid-consuming components present in the pit wall rock and subsided materials, and due to alkalinity of groundwater inflows, this acidity is expected to be neutralised over time;
  - pit lake water will also have higher salinity than currently modelled due to the geochemical reactions that may lead to the initial acidic (pH < 4) pit lake water; however,
  - as long as the pit lake continues to act as a sink to groundwater after mine closure the lower quality pit lake water is not expected to influence the surrounding groundwater, and
  - no beneficial use of the pit lake was originally planned; therefore the change does not represent a nett deterioration.

The residual impact assessment analysed the SWRD, pit lake, and underground workings as potential sources; groundwater as the potential pathway; and groundwater users (bores) as the potential receptors. The assessment concluded that there were no significant residual impacts to groundwater EVs as a direct result of the proposed changes to operations.

11 References

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (1999). *Report on Development of a Sub-Regional Groundwater Model and Predictive Modelling – Ernest Henry Mine*. Project No. G1023. February 1999.

Australasian Groundwater and Environmental Consultants Pty Ltd. (2004). *Stages 6 & 7 Pit Dewatering: Ernest Henry Mine*. Prepared for Ernest Henry Mining Pty Ltd. Project G1150/B, December 2004.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2009). *Hydrogeological Assessment for Monakoff and Monakoff East Ore Bodies, Cloncurry Copper Project*. Prepared for Exco Resources Ltd, Project G1423/A, January 2009.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2010). *Borefield Performance Review and Groundwater Modelling, Ernest Henry Mine*. Prepared for Xstrata Copper, Ernest Henry Mining Pty Ltd. Project G1430, June 2010.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2012). *Borefield Performance Review 15th Water Year, Ernest Henry Mine*. Prepared for Xstrata Copper, Ernest Henry Mining Pty Ltd. Project G1604, September 2012.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2015). *Revised Groundwater Triggers Ernest Henry Mine and Mt Margaret Mining Project*. Project G1691.A4. January 2015.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2016). *Ernest Henry Mine, TD05B Contaminant Limit Exceedance*. Prepared for Ernest Henry Mining Pty Ltd. Project G1761. October 2016.

Australasian Groundwater and Environmental Consultants Pty Ltd (2017). *Report on Ernest Henry Mine, Factual report for Bore Installation*. Prepared for Ernest Henry Mining Pty Ltd Project No. G1761J.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2022a). *Ernest Henry Mine – 25th Year Performance Review Report & Model Update*. Produced for EHM Pty Ltd.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE). (2022b). *Ernest Henry Mine – Pre-Feasibility Groundwater Assessment*. Prepared for Ernest Henry Mining Pty Ltd. Project EHM5006.001, October 2022.

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE), Dobos, & Water Solutions (WS). (2005). *Report on Final Void Water Quality and Water Balance Ernest Henry Mine*. Project G1308, September 2005.

Beck Engineering. (2023). *Ernest Henry SLC to 1150 mRL Cave Propagation & Subsidence Assessment*. Prepared for Evolution Mining. Draft.

Bureau of Meteorology (BoM). (2005). *Average areal actual evapotranspiration – Annual* [dataset]. Commonwealth of Australia.

Bureau of Meteorology (BoM) & Queensland Department of Science, Information Technology and Innovation (DSITI). (2016). *Groundwater Dependent Ecosystems Atlas* [dataset]. http://www.bom.gov.au/water/groundwater/gde/map.shtml.

Clifford M. (2012). *Memorandum – Summary of 2012 Groundwater Investigation Drilling*. Ernest Henry Mining Pty Ltd. 17/04/2012.

Coates S. (1997). *Ernest Henry Sterilization Mesozoic Data Set*. Unpublished report.

Crosbie, R.S., Morrow, D., Cresswell, R.G., Leaney, F.W., Lamontagne, S. and Lefournour, M., (2012). Newinsights into the chemical and isotopic composition of rainfall across Australia. CSIRO Water for a Healthy Country Flagship, Australia.

Department of Environment and Science (DES). (2022). *SILO – Australian climate data from 1889 toyesterday* [dataset]. https://www.longpaddock.qld.gov.au/silo/point-data/#responseTab2.

Department of Science, Information Technology and Innovation (DSITI). (2015). *Potential Groundwater Dependent Ecosystem Aquifer Mapping Method: A method for providing baseline mapping of potentialaquifers supporting groundwater dependent ecosystems in Queensland* (Version 1.1) [dataset].
December 2015.

Deswik, (2020). *EHM WRD Modelling - Stage 2 Assumptions*. Report dated 27/05/2020.

Eamus A., Hatton T., Cook P., & Colvin C. (2006). *Ecohydrology: vegetation function, water and resourcemanagement*. CSIRO Publishing.

Ernest Henry Mining Pty Ltd (EHM). (2009). *EHM Monitoring Bore TD06 Non-Compliance Action PlanReport*. Prepared for Xstrata Copper. September 2009.

Ernest Henry Mining Pty Ltd (EHM), (2023). *Ernest Henry Mine Waste Rock Management Plan 2022*.
Management plan developed by RGS for EHM, dated February 2023.

HCI Tasca Denver (HCID). (2009). *Hydrologic and Geochemical Analyses in Support of the Feasibility Studyof Underground Mining at Ernest Henry Mine*. Prepared for Xsrata Copper and EHM Pty Ltd; HCI-1862;April 2009.

Hvorslev, M.J. (1951). Time Lag and Soil Permeability in Ground-Water Observations. *Waterways Exper.*
Sta. Corps of Engineers, U.S. Army. Vicksburg, Mississippi. Bull. No. 36, pp. 1-50.

Lottermoser, 2009. Briefing Note on Seepage Waters Emanating from the North Waste Rock Dump, ErnestHenry Mine. JCU Report dated 17/02/2009.

O'Kane Consultants, 2006. "Illustrative Evaluation of Internal Seepage Characteristics for the Ernest HenryCopper-Gold Mine Waste Rock Dump. Report dated July 2006.

Porter GeoConsultancy. (2000). *Ernest Henry* [dataset]. www.portergeo.com.au/database.

PPK Environment and Infrastructure Pty Ltd (PPK). (1998). *Ernest Henry Mine, Summary Report, RegionalHydrogeology*. Report 86K008A-PR001 Ach. June 1998.

RGS. (2021). *Waste rock dump 3D digital terrain model, and waste rock dump design assessment*. Report dated 20/01/2021.

URS. (2003). *Ernest Henry Mining: Kinetic Leach Column Data - Project Review*. Report dates 30/04/2003.