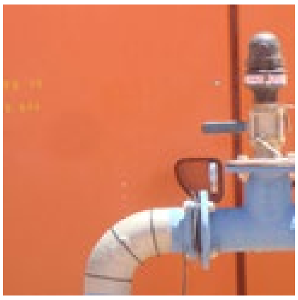
Appendix 3.

Fountain Head Gold Project Site Water and Solute Balance Modelling



ERIAS Group

Fountain Head Gold Project: Site water and solute balance modelling

25 May 2021

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Section 1 Introduction

1.1 Background

CDM Smith Australia Pty Ltd (CDM Smith) has been engaged by PNX Metals Limited (PNX), through ERIAS Group, to undertake water-related assessments in support of environmental approvals for the proposed Fountain Head Gold Project (the Project). The Project is located approximately 170 km south of Darwin (Figure 1-1) within the Pine Creek region of the Northern Territory.

The Project involves brownfield development of the Fountain Head deposit, where gold mining and exploration dates back to the late-1800's. Mining at Fountain Head was most recently undertaken from 2007 to 2009 by GBS Gold. PNX acquired the tenements in 2018, following further exploration and a mining scoping study completed in 2019. Recent exploration drilling intersected notable gold mineralisation in the vicinity of the existing open (but flooded) pit, prompting a renewed focus on the Fountain Head site. As outlined in the Notice of Intent (ERIAS Group, 2019), PNX proposes to use open pit mining methods and a carbon in pulp plant (CIP) at the Project site with the following related activities:

- Dewatering of the existing Pit Lake and expansion of the existing open pit
- Expansion of the waste rock storage (WRS) as an integrated waste landform (IWL)
- Construction of processing related areas, crushing facility and gold processing plant
- Construction of supporting infrastructure and expansion of the existing Evaporation Dam to an Evaporation Pond (EP) for water storage

Surface water and groundwater management are critical to the success of this project, which has prompted the need for more detailed assessment and water balance modelling. The CDM Smith scope of works has a number of components that will contribute to the development of a Mine Management Plan (MMP) and Environmental Impact Statement (EIS) related to the Project – these components include:

- Two short technical reports describing 1) a proposed shallow groundwater monitoring network, and 2) the soil infiltration testing and assessment of potential solute fate from tailings stored within the IWL and temporary PAF stockpile (CDM Smith 2021a)
- A technical report documenting the model predicted water fluxes and quality changes related to Fountain Head Pit dewatering and Evaporation Pond storage through to the mine closure Stage, and other site water balance components (this report)
- A technical report related to other scoped components including catchment, surface water and flood modelling (CDM Smith 2021b)

1.2 Objectives

The objectives of this report relate to the development of the Fountain Head Gold Project approval documents to:

- Estimate the life of mine (LOM) dewatering requirements for safe mining operations
- Estimate the seepage rates from the Evaporation Pond and conservative water quality evolution within the Pond
- Predict the Fountain Head Pit Lake recovery and conservative water quality evolution post-mining
- Generate maps showing the predicted groundwater contours during pre-mine, mining and closure stages
- Demonstrate that the planned water storage capacity and evaporators will be sufficient to enable dewatering of the pit for mining, and storage of water on site without uncontrolled discharge

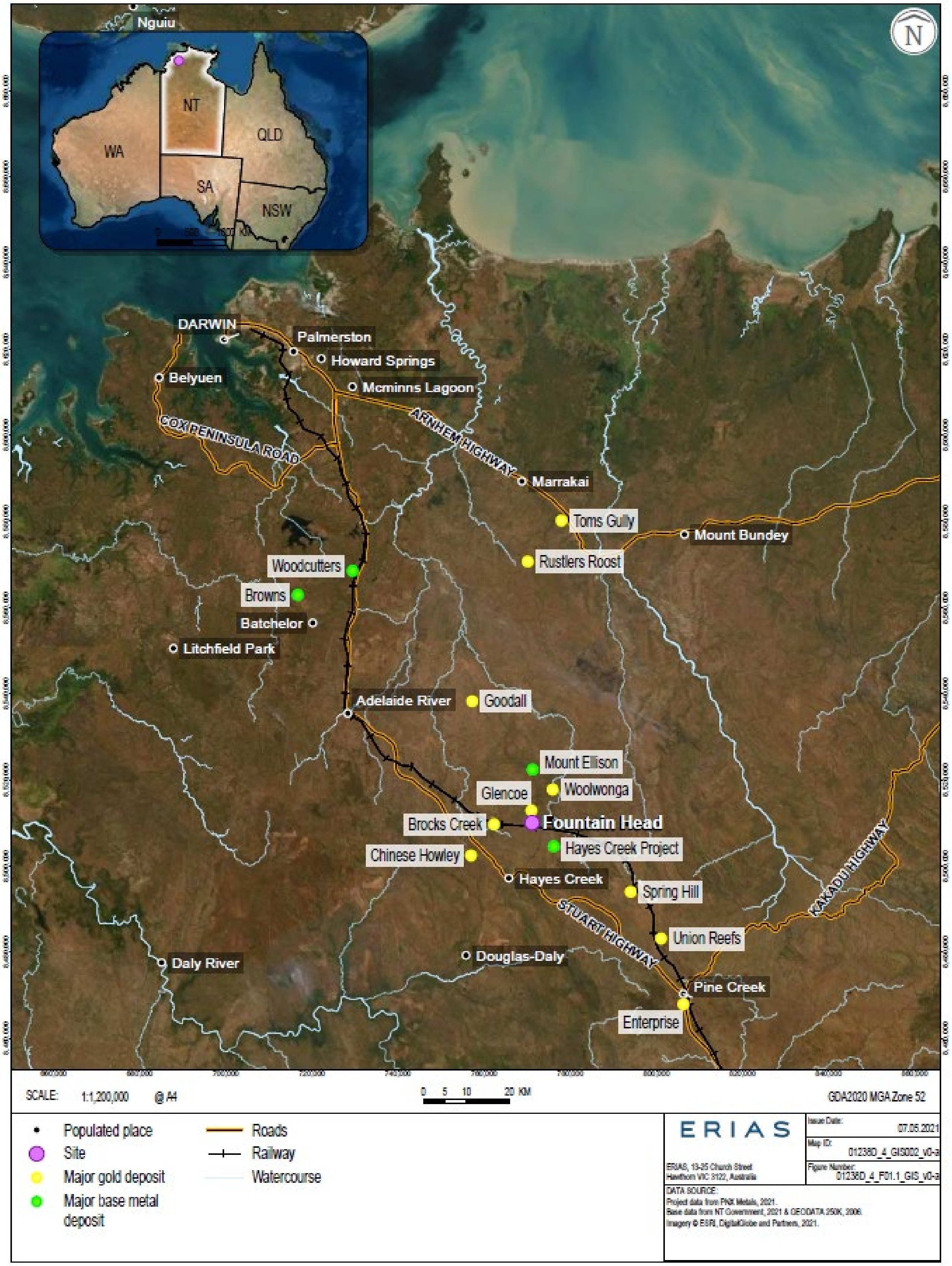


Figure 1-1 Project location map (source: ERIAS Group, 2021)

Section 2 Supporting data and information

All supporting data and information have been sourced either from publicly available data or from ERIAS Group. Data and information supplied to ERIAS Group by PNX includes the following:

- Historical water quality and climate information
- Proposed site layouts and mining plans
- Basemap spatial data (e.g. streams)
- Multiple digital elevation models and revised surface elevations of selected groundwater bores
- Various spreadsheets (e.g. historical hydrochemical data, proposed mine schedule and water balance)
- Historical reports and documentation related to the Project (e.g. Notice of Intent, referenced reports)

A listing of references used in this report is provided in Section 7.

Section 3 Physical setting

3.1 Climate

Two distinct seasons are experienced in the Project area - a wet season typically occurring from November to April and a dry season typically occurring from May to October. The wet season is characterised by warm to hot temperatures with high humidity and rainfall. The dry season is characterised by cooler temperatures, lower humidity and little to no rainfall (see Figure 3-1). The majority of rainfall typically occurs between November and March. Average annual rainfall is around 1200 mm (Douglas River).

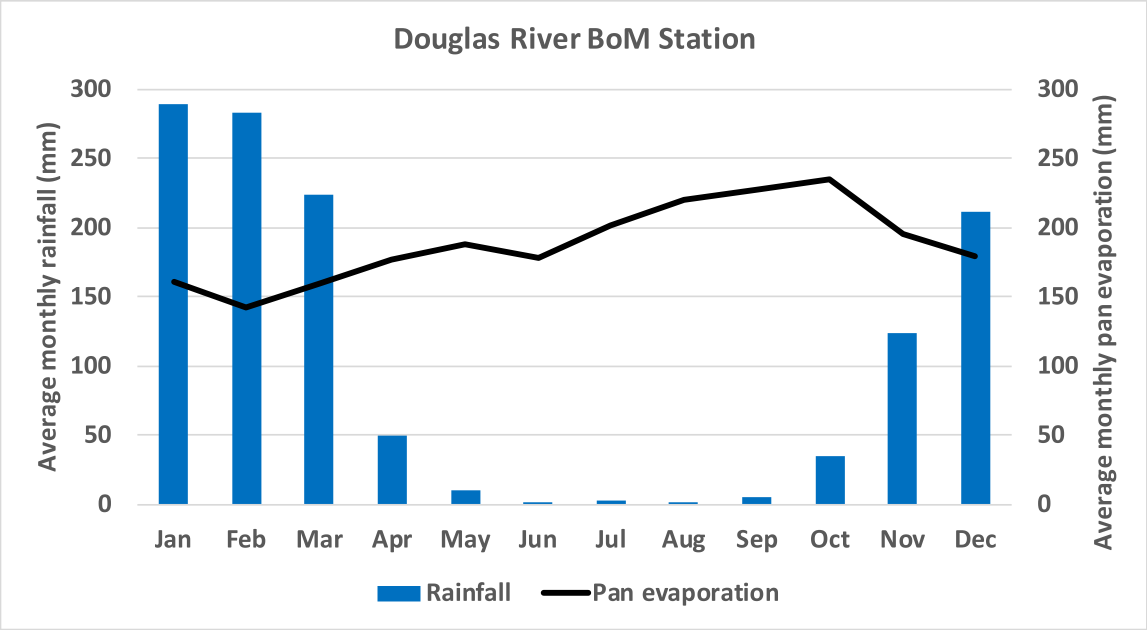


Figure 3-1 Mean monthly rainfall and daily pan evaporation at Douglas River (BOM station 14901)

Potential evapotranspiration (PET) (shown here as the pan evaporation rate) remains high throughout the year, peaking in the build-up to the wet season before humidity increases with net yearly evaporation exceeding net yearly rainfall (Figure 3-1).

3.2 Hydrology

Little is known about the hydrology of the Margaret River and its tributaries within the Project area (Figure 3-2). Anecdotally and from previous field observations, there have been end-of dry season pools along some watercourse reaches. Their presence in the dry season is likely dependent on the previous wet season’s rainfall and runoff, and subsequent groundwater recharge, baseflow and evaporation.

The nearest surface water gauge on the Margaret River is at Bobs Hill (G8170240; Figure 3-2) some 50 km downstream of the Fountain Head site. Figure 3-3 shows the measured ephemerality of the flow regime at this location with an incomplete data record from 1967 to 1986 after which there are no data. Flow duration is typically between three and six months.

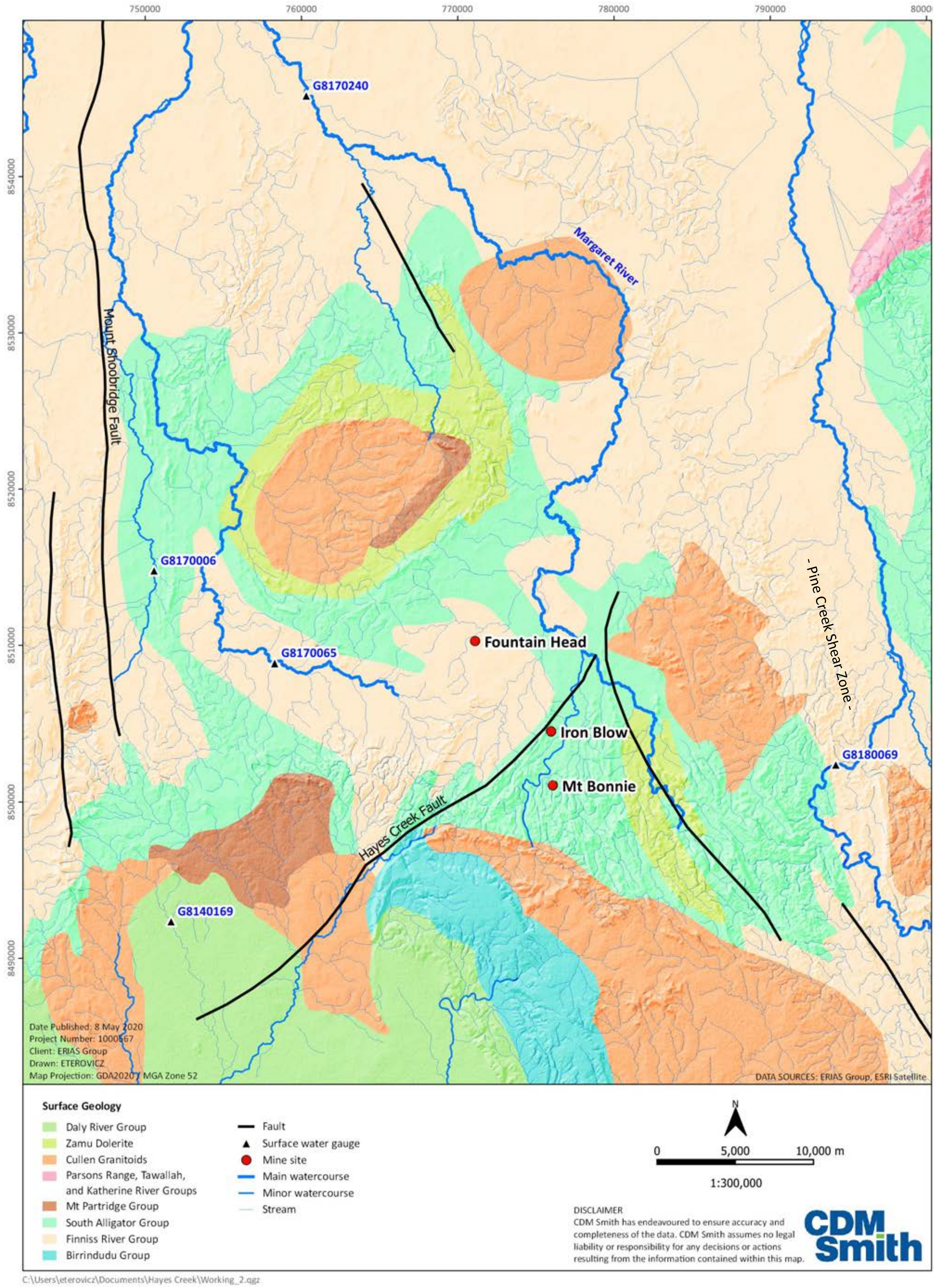


Figure 3-2 **Surface water and regional geology in the vicinity of Fountain Head**

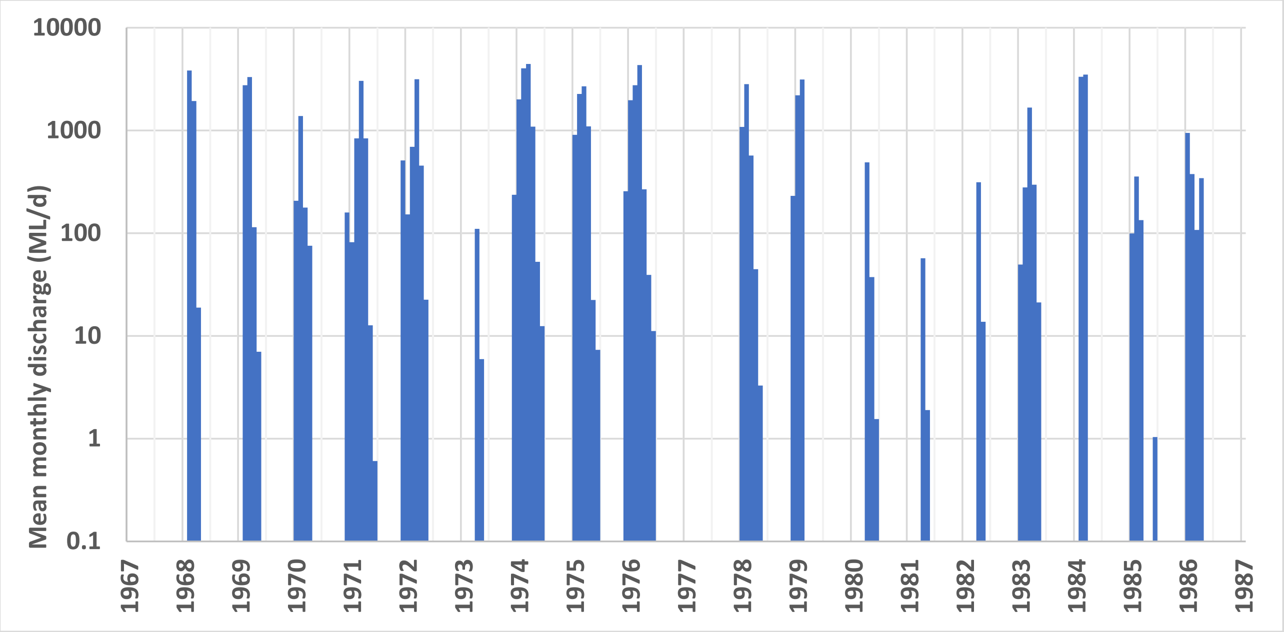


Figure 3-3 Mean monthly discharge from Margaret River at Bobs Hill (G8170240)

3.3 Hydrogeology

3.3.1 Hydrostratigraphy

The Project is located within the Pine Creek Geosyncline geological province, within which McGowan (1989) has identified four Proterozoic hydrostratigraphic units (HSUs):

- Alluvial sediments – alluvial aquifer where saturated
  - Variably weathered mudstone with poorly sorted sandstone, gravel and cobbles containing pyritic veining; comprised of remnant fragments of the Mt Bonnie Formation.
  - Forms the alluvial cover of the Margaret River floodplain and tributaries.
  - Groundwater flow and storage controlled by primary porosity.
- Burrell Creek Formation – fractured rock aquifer
  - A fine to course-grained feldspathic meta-greywacke consisting of minor slate/phyllite, mudstone, schist and lenses of volcanilithic pebble conglomerate.
- Mt Bonnie Formation – fractured rock aquifer
  - An interbedded carbonaceous unit consisting of pyritic and/or chloritic slate, feldspathic metagreywacke and ferruginous phyllite (metasiltstone) with chert lenses and nodules.
  - Conformably overlies the Gerowie Tuff.
- Gerowie Tuff – fractured rock aquifer
  - A combination of cherty/feldspathic crystal tuff, lithic tuff with minor felsic ignimbrite, volcaniclastic shale and siliceous siltstone.

Figure 3-4 presents the stratigraphic relationships. The sub-regional geology in the vicinity of Fountain Head is bounded by the Hayes Creek Fault to the south, the Pine Creek Shear Zone to the east and the Shoobridge Fault to the west (Figure 3-2). The original geometry of these sedimentary units has undergone significant distortion while surface geology at Fountain Head is dominated by weathering products of the Burrell Creek Formation.

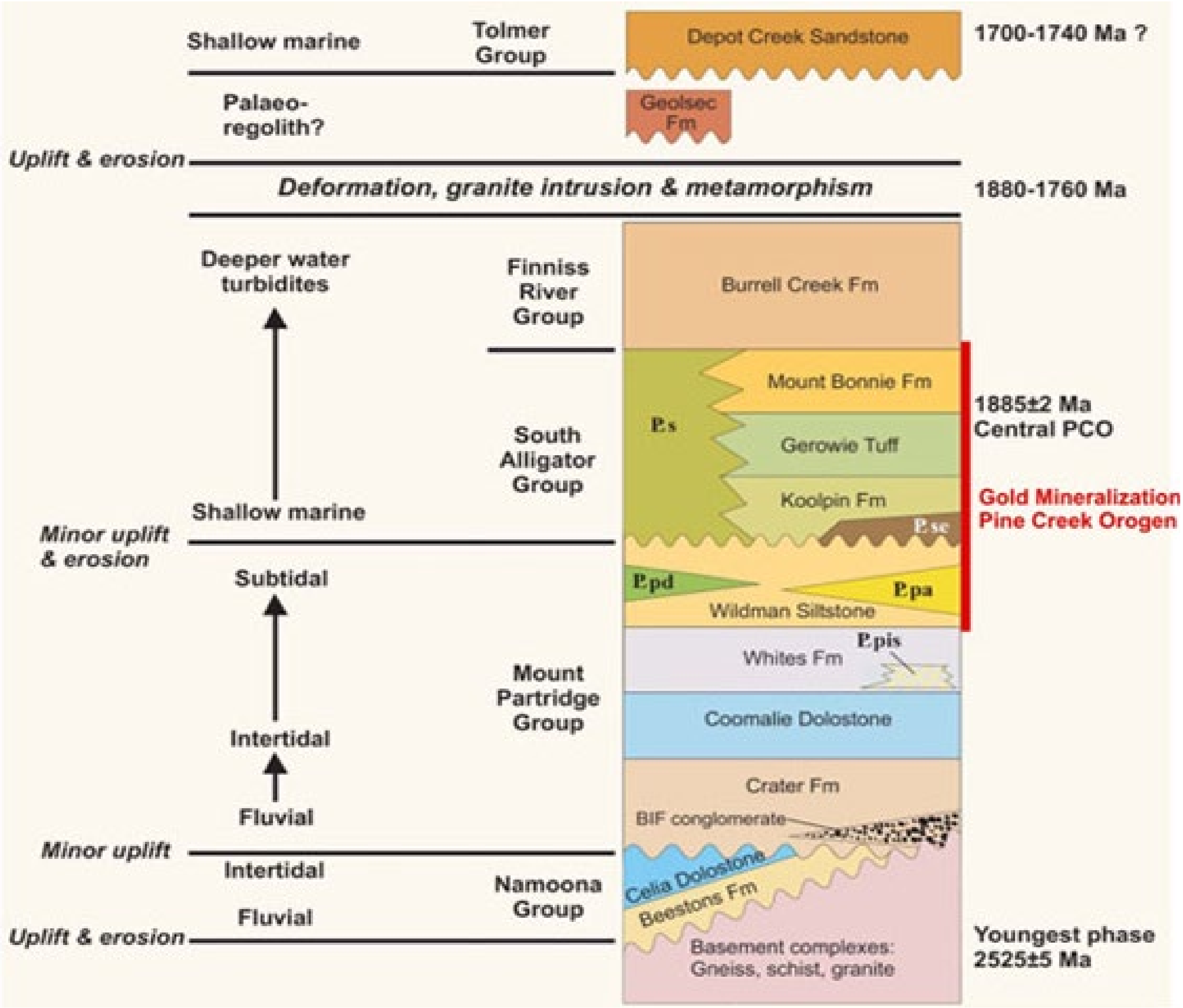
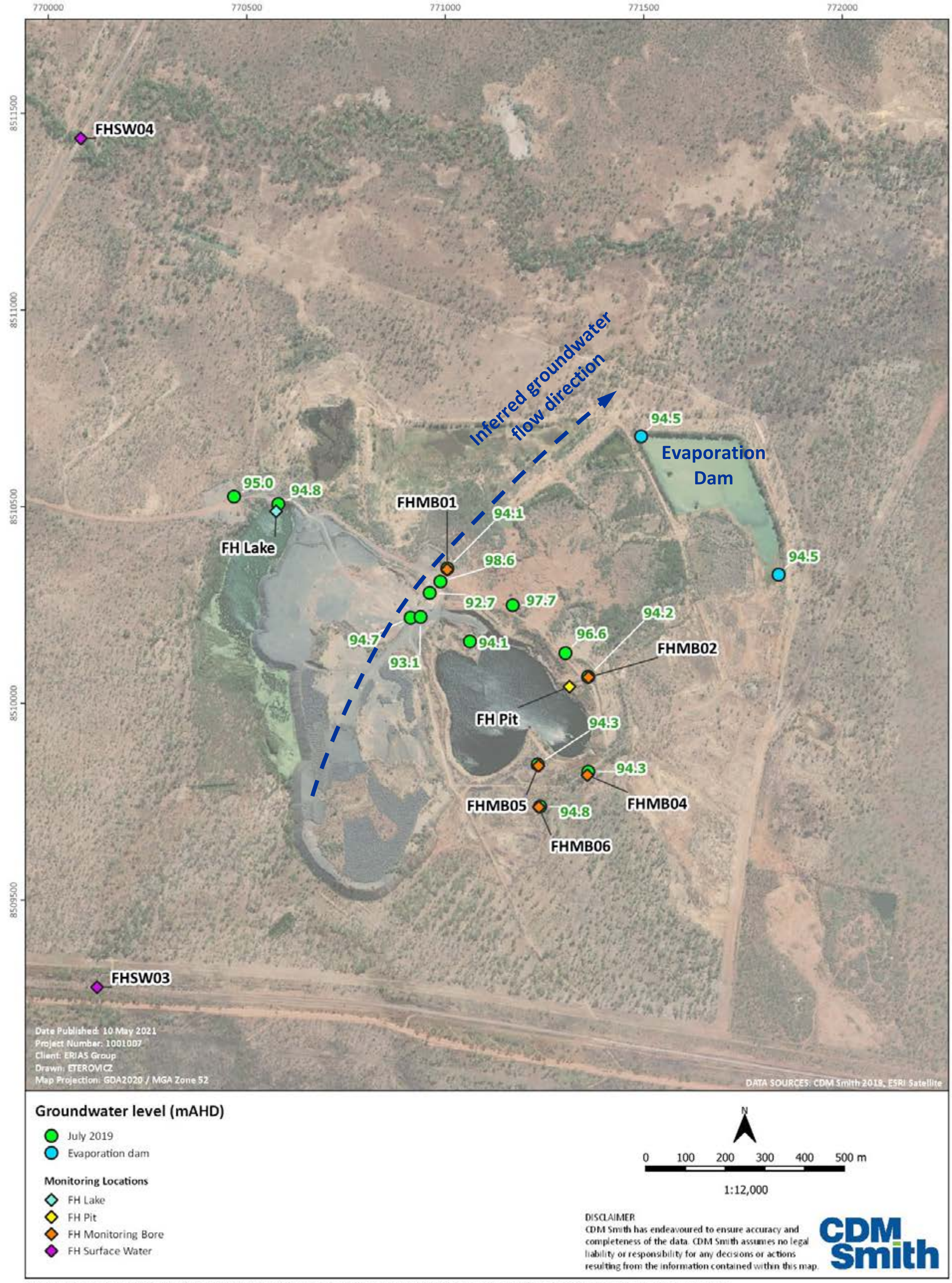


Figure 3-4 Stratigraphy of the Adelaide River – Pine Creek area (Coffey, 2012)

3.3.2 Groundwater levels and flow direction

Groundwater level monitoring and sampling was conducted by CDM Smith from the 15th to 19th of July 2019. The results of this field work are summarised in CDM Smith (2020a) and have been used where relevant in this report along with historical information provided by ERIAS Group. Figure 3-5 shows the most recent (July 2019) groundwater heads gauged at wells around the Fountain Head site. Given the uncertainty associated with screened/open intervals and reference elevations of some bores, combined with a near-flat hydraulic gradient, it is difficult to infer a clear groundwater flow direction from the data nor vertical head gradients within the HSUs. PNX staff collected refined reference elevations for some groundwater bores in early 2021, and these have been used where relevant to improve the accuracy of groundwater level data from the bores surveyed.



\\cdminc.internal.cdm.com\offices\AUST\Project\1001007 - ERIAS_FountainHead2021_WaterModelUpdates_Soil Sampling\7Work\3GIS\QGZ\ERIAS_groundwater levels.qgz

Figure 3-5 July 2019 groundwater levels (reference elevations estimated from recent DEM and differential GPS for some locations) and monitoring sites

Conceptually, the Fountain Head Pit is likely to be acting as a local groundwater discharge zone with minor throughflow due to the overall deficit between evaporation and rainfall (i.e. pit water levels may decline when evaporation exceeds rainfall, causing groundwater to flow from the aquifer into the pit). Given the Pit Lake is likely to have now fully recovered after previously being dewatered (CDM Smith, 2019) it is possible for there to be a throughflow component also. Regional groundwater flow is assumed, based on topography, to be in a north-easterly direction while site data does not resolve a clear flow direction given its proximity to the Pit Lake. Partly this is due to the uncertainty of the elevation (m AHD) of each monitoring point, and it is also possible the water table surface is quite flat in this area of relatively low relief (i.e. hydraulic gradients may be quite low). At the time of writing, there have been only a limited number of groundwater level measurements with accurate reference elevations from monitoring bores. Accurate reference elevations from all monitoring bores and additional time-series water level data (groundwater and surface water) will be needed to reduce uncertainty related to groundwater flow direction and potential connection between the shallow groundwater and surface water features (i.e. Fountain Head Lake and the Evaporation Pond), in addition to an expansion of groundwater monitoring at greater distances away from the Pit Lake.

Other on-site surface water features, including the Fountain Head (FH) Lake (to the west of the WRS) and the Evaporation Dam appear to have at least some of their extent permanently inundated based on historical satellite imagery (Figure 3-5). This implies they may be fed by groundwater discharge and their bed levels could be intersected by the water table.

3.3.3 Groundwater system hydraulic properties

Hydrogeological investigations by CDM Smith have been undertaken previously at the nearby Mt Bonnie and Iron Blow sites (Figure 3-2) (CDM Smith, 2018), where estimates of hydraulic conductivity derived for the Mt Bonnie Formation range from less than 0.5 m/d up to around 33 m/d (geometric mean of around 4 m/d), and estimates derived for storativity value around 7×10^{-5}.

A shallow geotechnical study by WANT Geotechnics (2020) at the Fountain Head site involved a series of falling head permeability tests on the silty clay soils / weathered basement. These tests were conducted in shallow test pits using MiniDisk Infiltrometers and in shallow dynamic cone penetrometer (DCP) holes using Falling Head Permeameters. The geometric mean of the hydraulic conductivity values derived from all nine tests was 3.4×10^{-2} m/d, with a minimum and maximum value of 2×10^{-3} and 5×10^{-1} m/d, respectively. These test results are considered to be relatively high for silty clays (but possibly representative of silty soils with sandy lenses) and may not be representative of the saturated hydraulic conductivity of the soils (noting that some tests were not sufficiently detailed or repeated to provide high confidence in their results). This may be a result of the influence of preferential pathways or disturbed ground, in combination with the nature of short-duration tests. Based on the soil descriptions, CDM Smith considers these estimates to be too high for meaningful application to the Evaporation Pond seepage assessment.

Recent field work by CDM Smith in early-2021, completed additional infiltration testing using Talsma Permeameters within the extent of the proposed Evaporation Pond (EP) area. Collecting water level measurements every 30 seconds until the infiltration rate became constant, these tests can be considered with greater confidence. Four tests were completed at each of two sites (western and south western segments) and intersected variable soils from silty clays with a median vertical hydraulic conductivity of 1.5×10^{-2} m/d with three tests indicating values $< 1 \times 10^{-3}$ m/d, which are captured within the Monte Carlo analysis for this parameter (Section 4.4). Three tests in silty sands and clayey silts with minor sand, had a median of 1.2 m/d but are not considered representative of the bulk characteristics of the proposed EP. It is clear from these tests that the vertical hydraulic conductivity of the soils within the proposed EP are highly variable, and larger scale infiltration tests may be needed to make more reliable estimates of potential infiltration rates. More detail on these and other sites can be found in CDM Smith (2021a).

Fountain Head water balance modelling completed by CDM Smith (2019) used an analytical solution to match groundwater inflow rates to the pit as it has recovered over time since last being dewatered. Through calibration to the historical pit water level (recovery) data, a fractured rock aquifer hydraulic conductivity value of 0.2 m/d produced a good fit to the observations, which is similar to the lower end of the range observed for the Mt Bonnie Formation around Mt Bonnie and Iron Blow. This hydraulic conductivity value is considered to be representative of bulk hydraulic conductivity of the aquifer hosting the Fountain Head Pit.

3.4 Hydrogeological conceptualisation

The water table surface is likely to follow a subdued form of the topography and also be structurally controlled due to the nature of fractured rock aquifers (i.e. flow through networks of connected fractures). Groundwater discharge is expected along ephemeral creek lines as groundwater evapotranspiration from riparian vegetation and as direct groundwater discharge (i.e. baseflow) when groundwater heads are higher than Stage / bed height of the ephemeral creeks. An unnamed ephemeral creek is located approximately 1 km north of the Fountain Head Pit and flows approximately 5 km towards the northeast before joining the Margaret River, consistent with the inferred groundwater flow field. End of wet season baseflow may occur but this is unclear due to a lack of flow information or groundwater measurements in the vicinity of the watercourses.

An indicative conceptual cross-section from the top of the surface water catchment (south of the site) through the Fountain Head Pit and to the Margaret River is shown in Figure 3-6.

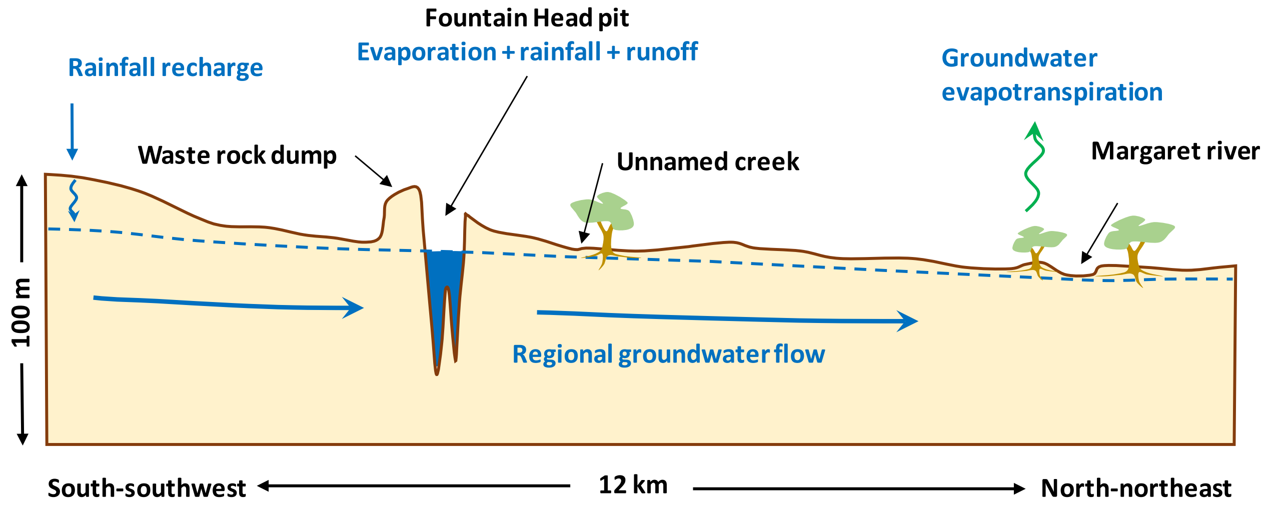


Figure 3-6 Simplified hydrogeological conceptual model

3.5 Water quality evolution and representative concentrations

3.5.1 Water quality and seasonal variability

The fractured rock aquifers of the Pine Creek Geosyncline are characterised by relatively fresh groundwater. Although groundwater salinity is generally low, some areas contain elevated concentrations of heavy metals, particularly in mineralised zones, with arsenic being the most commonly encountered. Typically, sulfide orebodies in the study area are potentially acid forming (PAF) and prone to generation of acidic and metalliferous drainage (AMD) when exposed to air or oxidised. AMD has the potential to alter surface and groundwater quality with subsequent potential for impacting Environmental Values. It should be noted that the groundwater and surface water at the Fountain Head site contain relatively elevated background concentrations of a range of metals. This is likely to be a result of natural water chemistry and/or in combination with legacy mining operations.

PNX is currently undertaking a further testing program to define the geochemical characteristics of existing and possible future ore and waste materials, and have indicated that large quantities of PAF material are not expected to require complex management based on 2020 results. Any PAF material identified during mining operations, will be stockpiled adjacent to the south-eastern corner of the Pit during operations. Once mining has ceased this will be backfilled into the pit and submerged below the recovering Pit Lake water levels.

Collection of historical and recent surface water and groundwater samples in the Project area (ERIAS 2020; CDM Smith 2020a) enable the interpretation of representative water types and inferences of potential mixing between them. The concentrations of major ions reported for these samples are presented in a Piper diagram (Figure 3-7) and are categorised into five groups (including “dry” and “wet” sub-groups for dry and wet season samples, respectively) to give an indication of the potential mixing of waters that could be occurring on site. It should be noted that FH Lake is a different site to FH pit (see Figure 3-5 for locations) and that both of these sampling locations are thought to be influenced by mine-related water-rock interaction processes (i.e. the source of altered chemical water composition as shown at the top of diamond section of Figure 3-7). Key observations relating to the hydrochemical data are:

- The Fountain Head Pit contains a considerable historical dataset including depth profiling in October 2016
- The groundwater and surface water types range from Mg- to Na-HCO_3 and are similarly grouped, suggesting these waters have undergone similar degrees of water-rock interaction (i.e. conceptually, shallow groundwater may be sourced from surface water as sheet-flow or creek flow, noting that surface water samples are from both wet and dry seasons)
- The groundwater samples have elevated Mg and HCO_3^- relative to surface water samples suggesting interaction with dolomitic rocks
- Fountain Head Lake is predominantly a Mg-SO_4 type water with some spread towards Mg-HCO_3 suggesting localised water-rock interaction (e.g. from adjacent WRS or waste rock within the pit)
- The Fountain Head Pit water samples are more tightly grouped as a Mg-HCO_3 type water
- The Fountain Head Pit grouping appears to be a mixture of the local source that contributes to the FH Lake samples (i.e. water type found at the top of diamond section of Figure 3-7) and a groundwater source from the near-vicinity of the Pit.

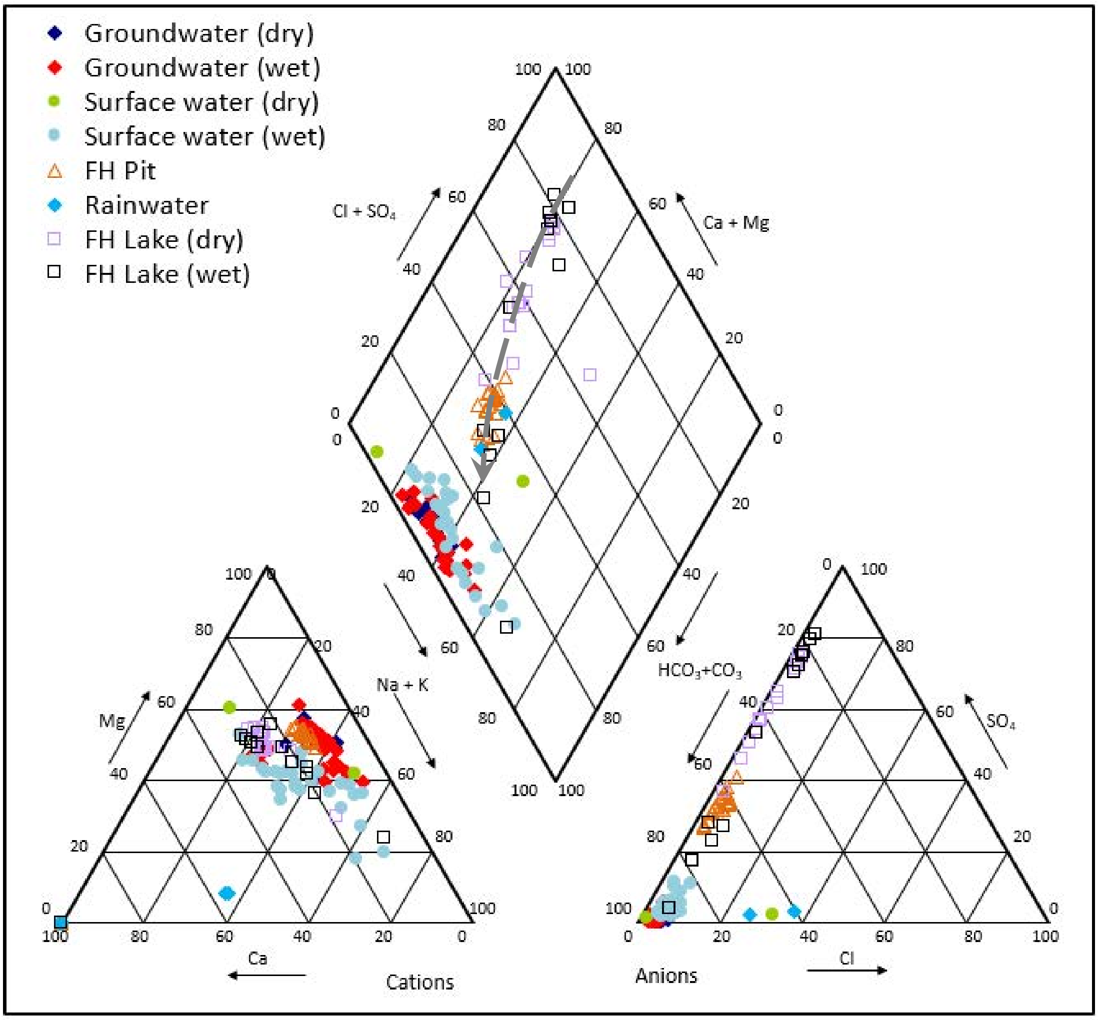


Figure 3-7 Fountain Head piper diagram (note “dry” & “wet” indicate Dry & Wet Season samples, respectively)

Analysis of historical time series water quality data shows that runoff originating in the southern part of the catchment (represented by FHSW03 shown in Figure 3-5) strongly influences the concentrations of water quality analytes in Fountain Head Lake. Effectively, the volume of water stored in the Lake is flushed each year during the wet season prior to returning to concentrations indicative of mine-drainage (see next section). This is represented in Figure 3-8 where hardness (as $CaCO_3$) and dissolved iron concentrations are shown for Fountain Head Lake and FHSW03 over time (other major ions and metals show similar changes). This flushing effect is most-easily seen following the 2014 dry season where increasing major ion concentrations suddenly drop at the onset of the 2014/15 wet season. This corresponds with a spike in dissolved iron and other metals (aluminium, copper and zinc), which are thought to be the result of dissolution from the relatively old and weathered soils in the region by rainfall-runoff.

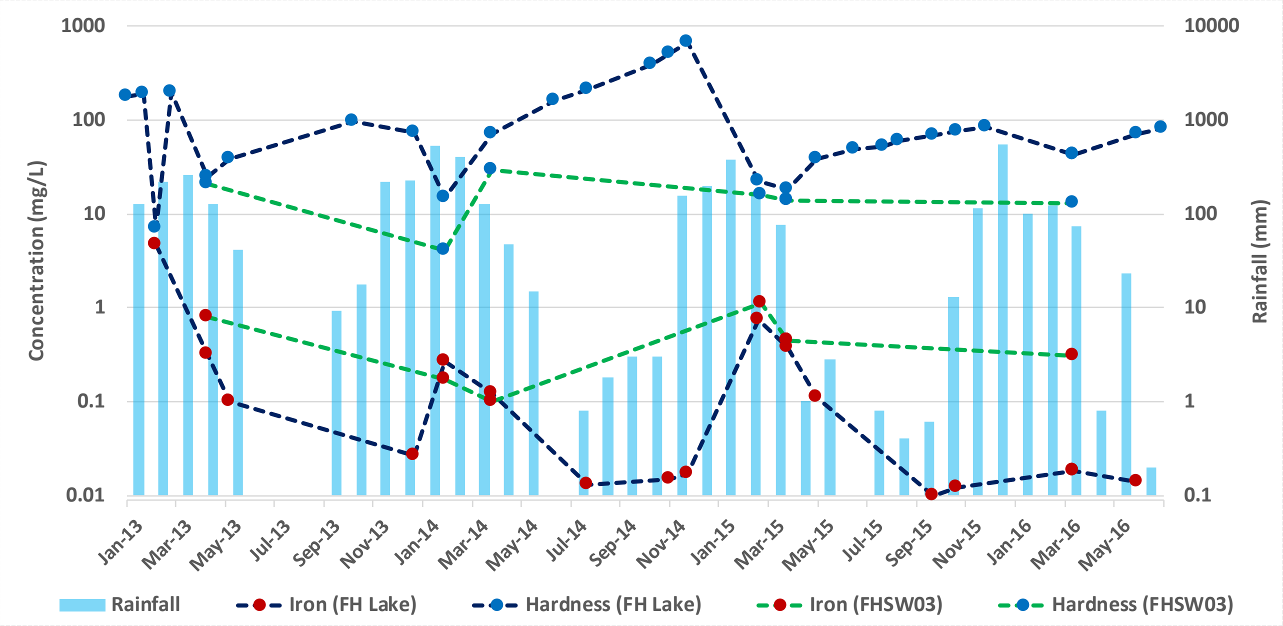


Figure 3-8 Fountain Head Lake and FHSW03 selected water quality analyte concentrations over time

3.5.2 Mine drainage water quality evolution

The generation, release, mobility and attenuation of mine drainage are complex processes governed by a combination of physical, chemical and biological factors (GARDGuide, 2015). The extent to which mine drainage enters and affects the environment depends largely on the characteristics of the sources, pathways and receptors which vary by commodity, climate, mine facility and phase. Ficklin Diagrams provide a method for illustrating the influence of these processes and can be used to interpret variations in mine drainage water chemistry between different deposits. Traditionally the diagram is populated by plotting the sum of base metals zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd), cobalt (Co), and nickel (Ni) against pH which allows for a diagnosis on different geological controls.

Figure 3-9 provides an overview for means of interpreting a Ficklin Diagram. The location in which data points plot on the diagram can provide an indicative diagnosis of the mine drainage type, i.e. whether the drainage type is acid mine drainage (AMD) or neutral mine drainage (NMD) / saline drainage. The locality of the data points, however, should not be construed as representing strict classifications as there are no formal guidelines for quantitative definitions of the mine drainage types mentioned (GARDGuide, 2015). Also depicted on the figure are the principles which govern the mine water quality that can explain increases/decreases in acidity and base metal concentrations.

The water groups at Fountain Head have been plotted on a Ficklin Diagram in Figure 3-10. Using the earlier figure as a diagnostic reference it can be observed that water groups at the Fountain Head site can be classified as NMD water due to their near-neutral pH and base metal concentrations. Using the principles outlined in the Ficklin Diagram it is likely that the water groups are influenced by the presence of carbonate minerals which provide a neutralising effect. Additionally surface water inflows are likely to increase dilution of the water’s pH and major ions although, conversely to the principles suggested by the Ficklin Diagram, the addition of surface water to the Lake increases the concentration of metals as a result of interaction with weathered soils in and around the mining area (as described in Section 3.5.1).

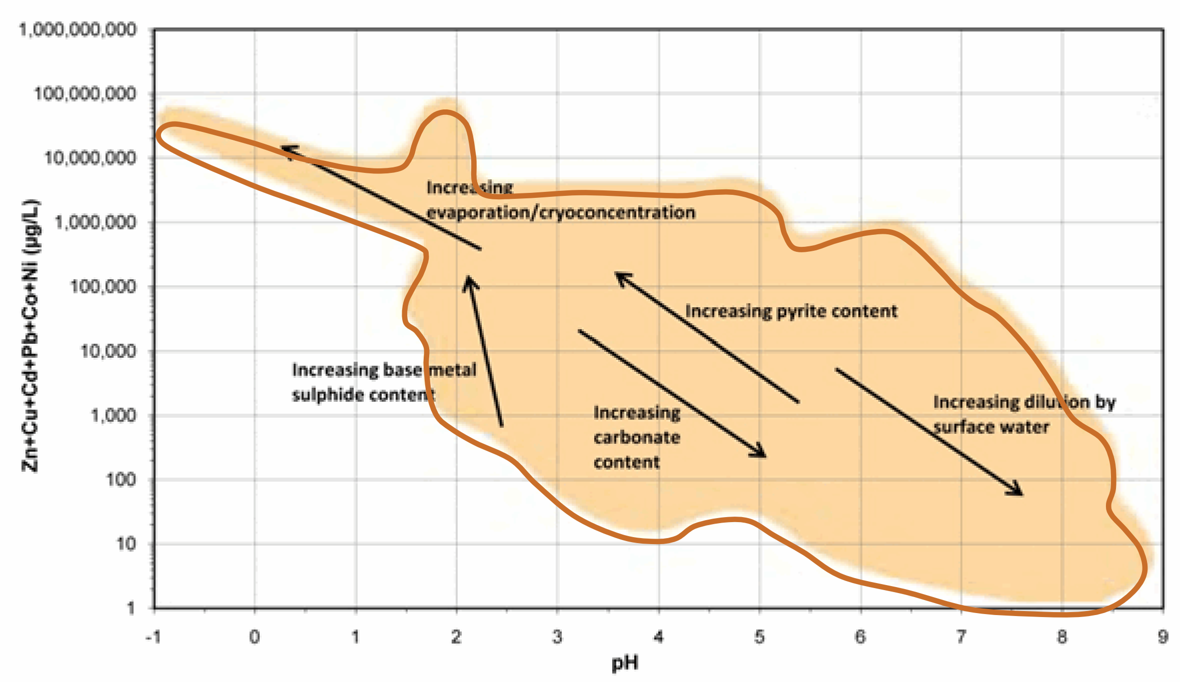


Figure 3-9 Ficklin Diagram showing selected principles that govern mine water quality (GARDGuide, 2015)

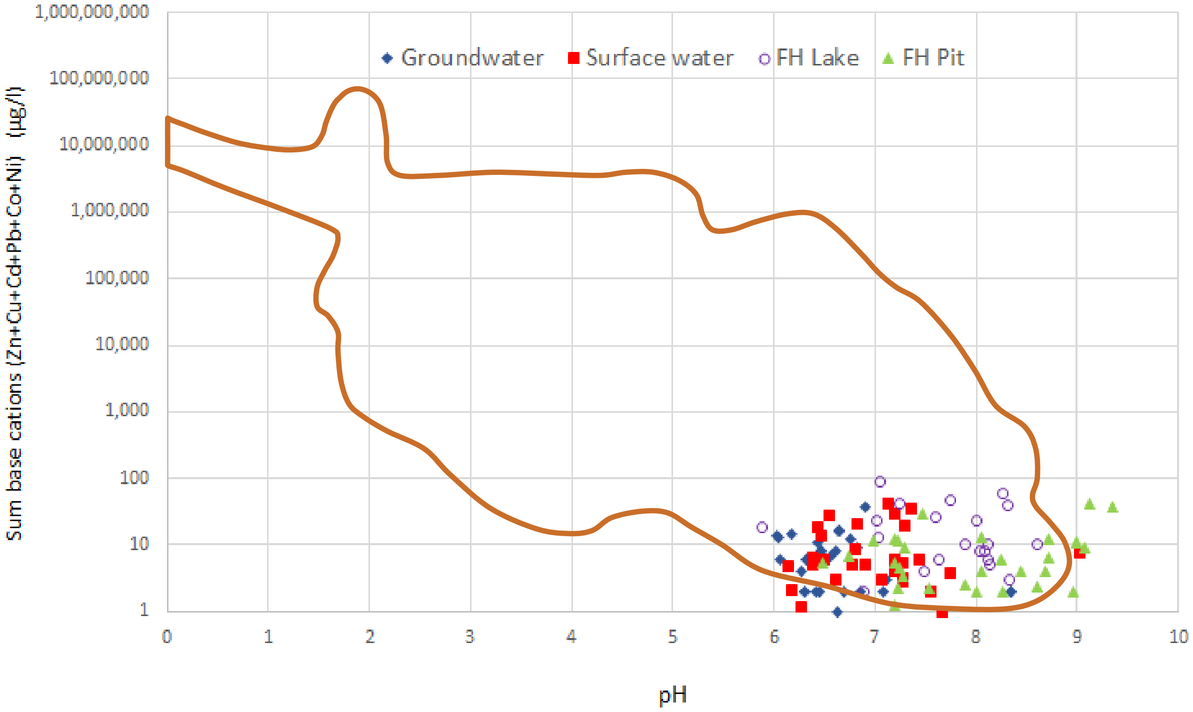


Figure 3-10 Ficklin Diagram of Fountain Head water groups relative to reference shape of GARDGuide (2015)

3.5.3 Representative concentrations for solute balance

Representative concentrations of selected key analytes based on historical and recent data from the site are presented in Table 3-1, with some groups separated to represent specific water bodies in more detail (e.g. FHSW03 is part of the surface water group). The representative groundwater chemistry is a combination of all data on site that includes the appearance of at least two groups of groundwater types. FHMB01, FHMB02 and FHMB03 generally have elevated metal concentrations compared to other groundwater samples and are located on the northern and eastern sides of the pit, while FHMB04, FHMB05 and FHMB06 for example, have lower metal concentrations and are located to the south of the pit. Since there is uncertainty about the spatial extent and volume of groundwater with different chemical signatures, and because all of this groundwater is expected to be drawn into the pit and mixed together, geometric mean concentrations have been adopted.

Table 3-1 Geometric mean parameters for Fountain Head water sources

Parameter	Surface water	Rainfall[1]	FHSW03	Groundwater	Fountain Head Pit	Fountain Head Lake	Evaporation Dam
FLS EC (uS/cm)	184	-	70	378	409	357	38
TDS calc EC (mg/L)	119	7	45	246	266	232	25
Hardness (mgCaCO3/L)	27	-	14	102	141	72	10
Total Alkalinity as CaCO3 (mg/L)	45.6	2.7	35	158	136	38	26
Calcium-Dissolved (mg/L)	3.9	1.2	1.5	8.6	13	9.4	-
Chloride (mg/L)	2.6	1.9	1.7	4.3	5.5	2.6	30
Magnesium-Dissolved (mg/L)	5.2	0.1	2.4	19	25	12	2.3
Potassium-Dissolved (mg/L)	1.4	0.1	1.0	1.9	1.8	1.6	0.6
Sodium - Dissolved (mg/L)	7.8	0.9	6.2	25	29	11	2.3
Sulfate (mg/L)	4	0.2	-	2.5	68	59	-
Aluminium-Dissolved (µg/L)	111	-	143	58	5.2	70	-
Arsenic-Dissolved (µg/L)	2.6	-	1.8	56	567	7.6	0
Copper-Dissolved (µg/L)	1.4	-	-	1.3	0.6	1.8	-
Iron-Dissolved (µg/L)	223	-	375	1272	26	74	-
Zinc-Dissolved (µg/L)	4.4	-	4.1	5.1	4.4	9.6	-

[1] Darwin rainfall data from Crosbie et al. (2012)

It should be noted, particularly for metal concentrations, that there will be a series of geochemical reactions occurring as dewatering of the Fountain Head Pit and disposal into the Evaporation Pond occurs because waters will be mixed and exposed to different oxidation, pH and temperature conditions. These interactions have not been modelled explicitly but salinity, which can be used as a proxy for conservative geochemical behaviour, has been tracked through the solute balance model components to demonstrate their changes over time (see section 4.9).

Section 4 Site operational water balance

4.1 Overview

The objective of this section is to describe the site water balance, which is assessed using GoldSim® software. The site conceptualisation, model construction methodology, data inputs and model results are presented in this section. The model was developed to estimate:

- The initial and ongoing dewatering rates, including groundwater inflows, to achieve dry conditions for mining in the Fountain Head Pit
- The Fountain Head Pit water level recovery rates after cessation of mining, under two scenarios (aided and unaided recovery)
- The recovered Pit Lake stabilisation level and the duration until full recovery is reached
- The ability of the proposed Evaporation Pond to contain the pit dewatering volume during dewatering and mining operations – a Monte Carlo analysis applied 200 realisations of historical rainfall data and model parameters to evaluate the likelihood of exceeding an upgraded Evaporation Pond storage capacity
- The feasibility of sourcing a non-potable water supply during construction and operational phases from the Fountain Head Pit
- The ongoing frequency and volume of flush/overflow at Fountain Head Lake
- The water salinity (and by extension the contaminant load) within the Fountain Head Pit, Evaporation Pond and Fountain Head Lake to assess the potential for exceedance of environmental water quality guideline values, and
- The overall site water balance

A number of features are not explicitly modelled, including seasonal groundwater recharge, seepage from the integrated waste landform or soil stockpiles, nor the return of processed or other water used on site sourced from Fountain Head Pit

4.2 Background and previous Fountain Head modelling

Dewatering of the Fountain Head Pit (which is known to envelope two smaller pits, the Tally Ho and Fountain Head Pits – the bridge between them occurs at around 80 m AHD) has been modelled previously by CDM Smith (2019) for a rapid dewatering scenario using GoldSim® software. Based on available historical information it is assumed that active dewatering of Fountain Head and Tally Ho pits during mining stopped on 15 September 2008, which is the date the previous operator (GBS Gold) was placed into Administration. The bottoms of the existing pits are at an elevation of 34.3 m AHD in Fountain Head and 44.4 m AHD in Tally Ho. The Pit Lake is assumed to have started recovering from an elevation of approximately 34.3 m AHD on 15 September 2008, reaching 93.9 m AHD by early August 2018. This equates to an increase in water level of 59.6 m in around 10 years, the result of groundwater and surface water inflow, balanced by evaporation.

For the CDM Smith (2019) study, the Pit Lake level was last measured on 2 August 2018 at an elevation of 93.9 m AHD (note the Pit Lake level was again measured in February 2021 at 93.2 m AHD). At this elevation, Fountain Head and Tally Ho pits are connected and form one Pit Lake with an estimated volume of 2064 ML, of which 991 ML is estimated to be stored above the bridge level, while 714 ML and 359 ML is estimated to be below the bridge separating Fountain Head and Tally Ho pits, respectively. For the work presented in this section, it is assumed both pits act as one (i.e. the Fountain Head Pit). This means the recovery is happening simultaneously and interaction between the two pits is ignored. The model simulates inflows to the Pit from direct rainfall, runoff and groundwater discharge, and outflows from evaporation. The calibration and structure of the CDM Smith (2019) model have been used as the basis for the current work. Calibration details are reported below, and only minor alterations have been made to the original model.

The Fountain Head GoldSim model has been calibrated based on recorded pit water levels to derive estimates of the groundwater and surface water inflow components (CDM Smith, 2019). The recorded water levels for the calibration period range between 90 and 94.4 m AHD, which means Fountain Head and Tally Ho were connected when recording started. A bund wall is present around the perimeter of the pit and no outside catchment is simulated, only the pit footprint. A good fit to the observations was achieved using an internal runoff coefficient of 0.6 (60% of rainfall becomes runoff while 40% is lost to evaporation or infiltration) and bulk aquifer hydraulic conductivity of 0.2 m/d. Groundwater inflows in the GoldSim model are simulated using the Dupuit-Forcheimer equation.

The observed and modelled levels are shown in Figure 4-1 and as an equivalent volume in Figure 4-2 (noting the black dashed line represents a stepwise function related to the bathymetry of the Pit Lake). The components of the water balance are shown over time in Figure 4-3 and Figure 4-4 for the Pit Lake inflows and outflows, respectively. Groundwater inflow is the major contribution to the water stored in the Pit Lake compared to runoff and direct rainfall.

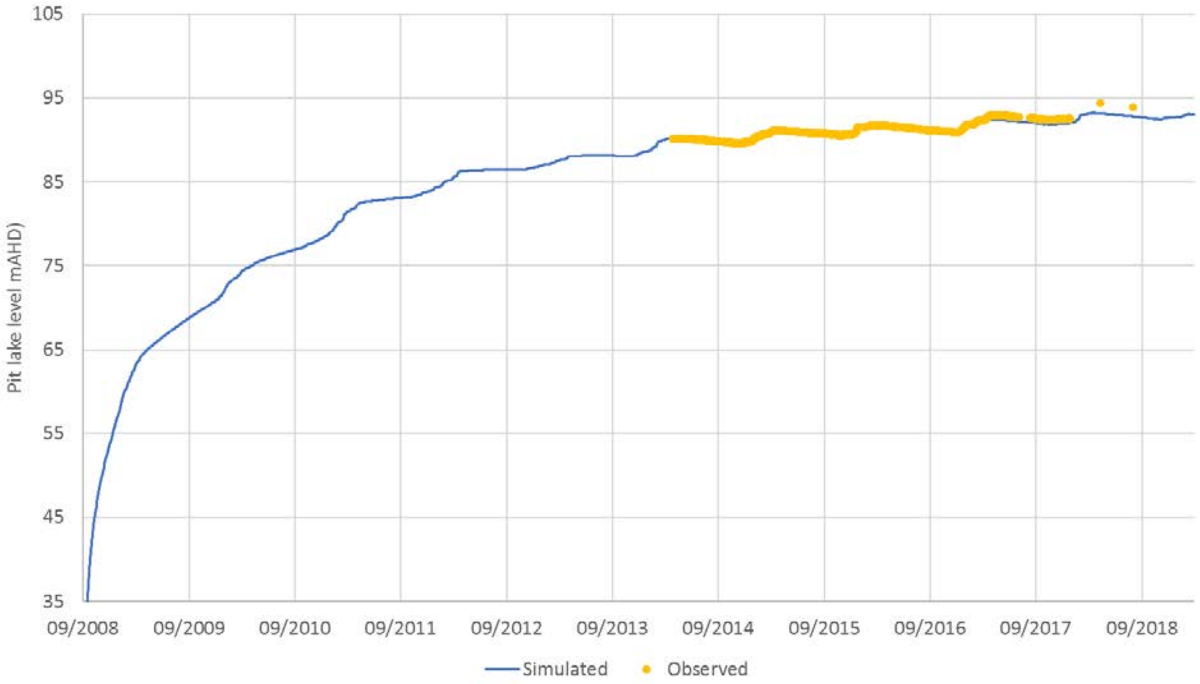


Figure 4-1 Observed and modelled Pit Lake level over time (CDM Smith, 2019)

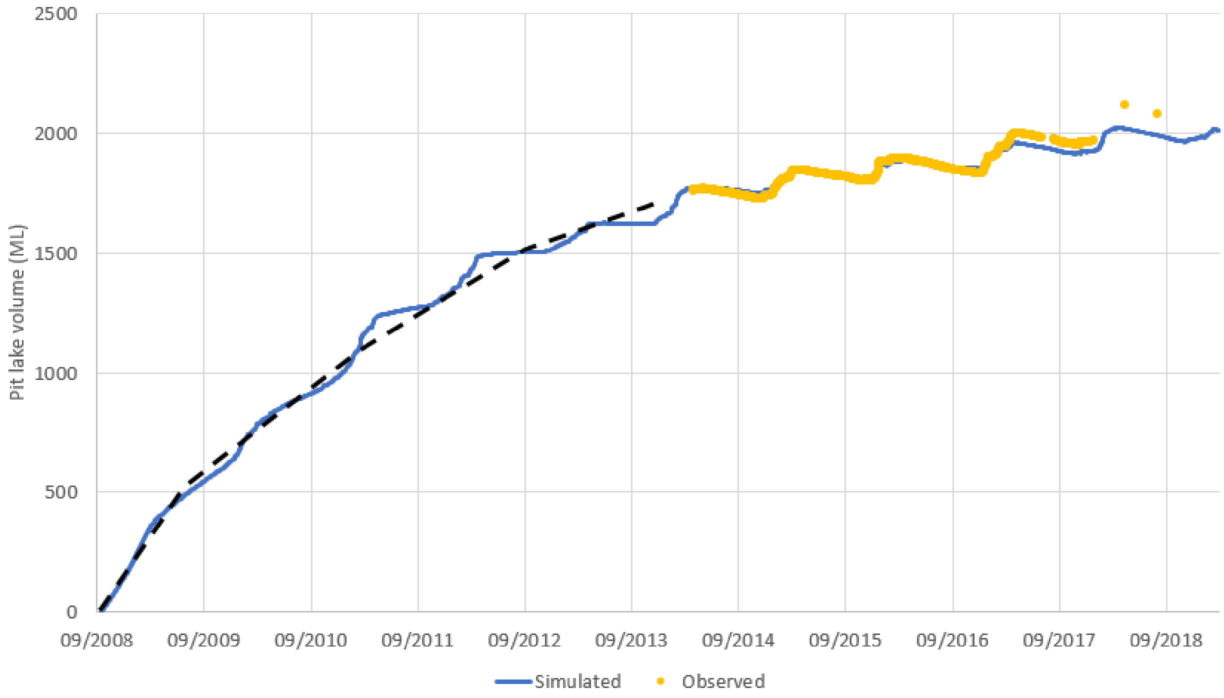


Figure 4-2 Observed and modelled Pit Lake volume over time (CDM Smith, 2019)

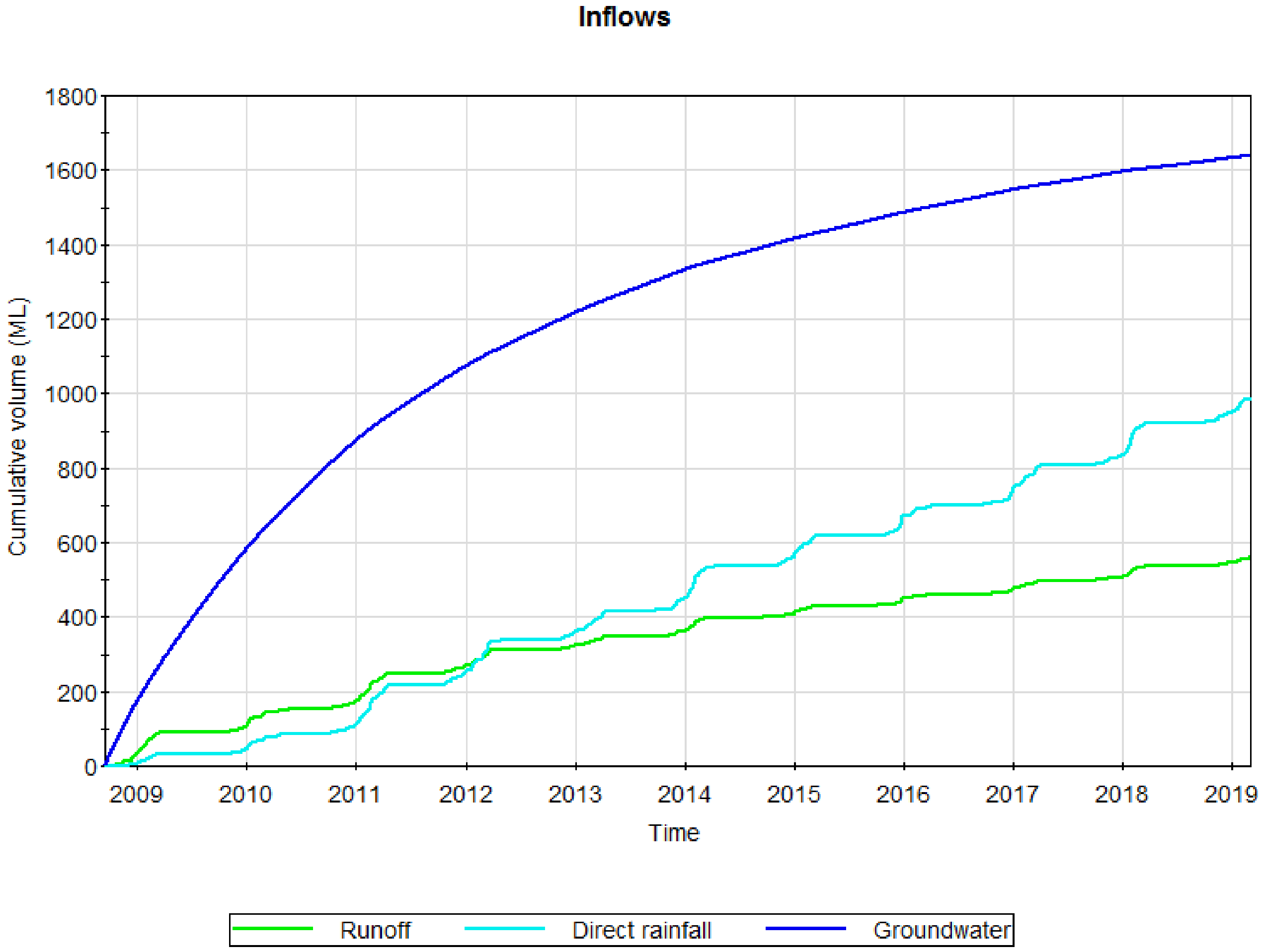


Figure 4-3 Modelled cumulative inflow volumes (CDM Smith, 2019)

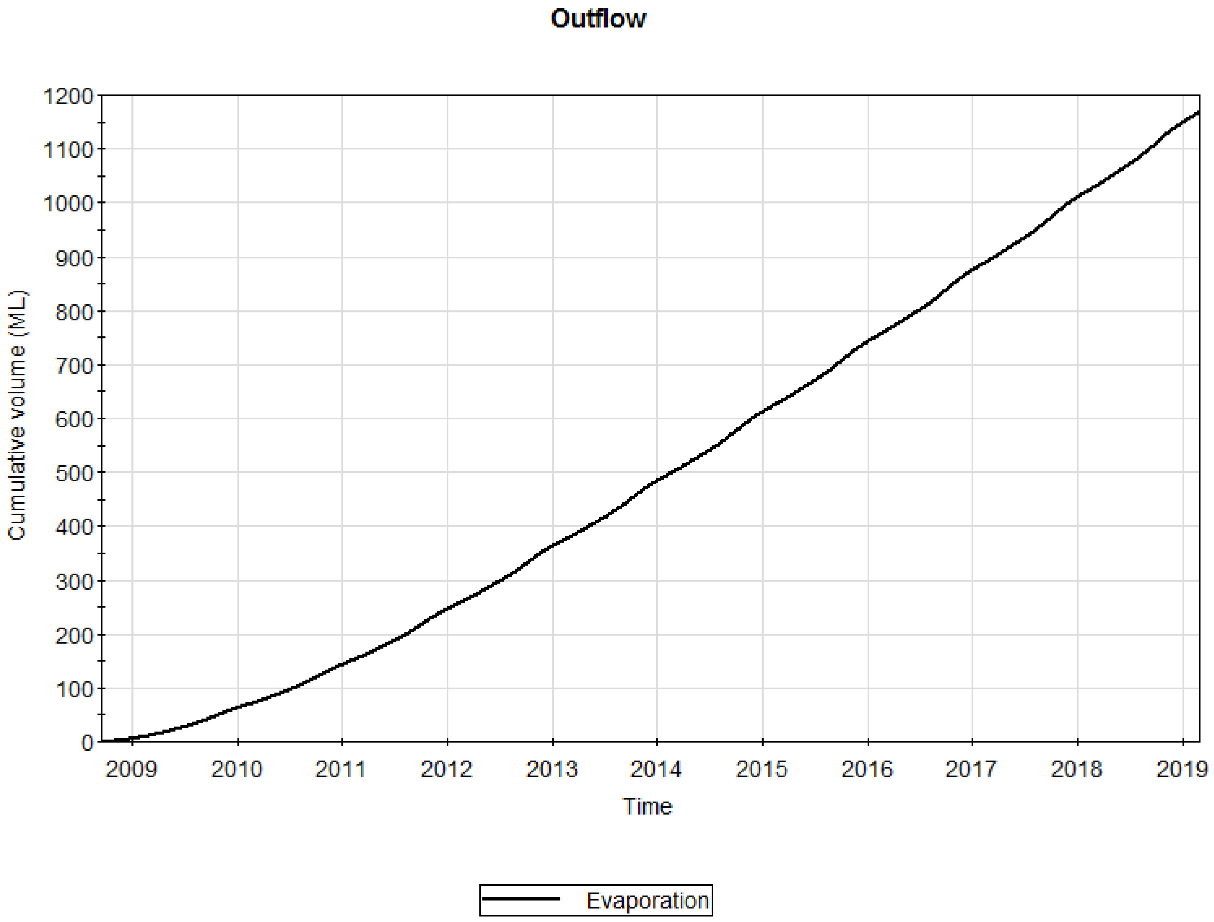


Figure 4-4 **Modelled cumulative volume removed due to evaporation (CDM Smith, 2019)**

4.3 Modelling conceptualisation overview

4.3.1 Overview

The stages of modelling work are outlined in Figure 4-5 and align with operational expectations that are subject to regulatory approval. In Stage I, PNX is planning to initially dewater the Fountain Head Pit using three evaporators located within the pit from approximately June 2021 to May 2022. The Evaporation Pond upgrade operations are planned to start in early-2022 and will take approximately three months to complete. Mining will also commence in early-2022 and the mining operations will work around the three in-pit evaporators (evaporation fans) until such time as they need to be removed and relocated to the Evaporation Pond. Once the Evaporation Pond is complete, pumps will be installed within the pit to assist with the pit dewatering, this water will be discharged to the Evaporation Pond.

Stage II – once the three evaporators are relocated to the Evaporation Pond the in-pit dewatering pumps will continue to draw the pit water down to maintain a water level in advance of the vertical mining rate. Once the pit is dewatered sump pumps will be required to maintain a dry floor for mining and this water will also be discharged in the Evaporation Pond. The three evaporators will be utilised on the Evaporation Pond to reduce the water volume stored in the Pond, which will aid in maintaining available storage capacity. Mining will be complete in April 2025 and all pumping will cease at that time.

Note the modelling assessment has not included the use of dewatering wells or considered the volume of in-pit sumps to achieve or buffer dewatering efforts, respectively. Pit inflows (groundwater, rainfall, runoff) will be balanced by natural evaporation and forced evaporation from the evaporators until they are re-positioned around the perimeter of the Evaporation Pond in July 2022. The modelling is described in three Stages as conventions, even though there will be some overlap in the timing of some operations in practice (e.g. mining would begin prior to full dewatering). The Stages are Stage I (dewatering), Stage II (mining), Stage III (post-mining).

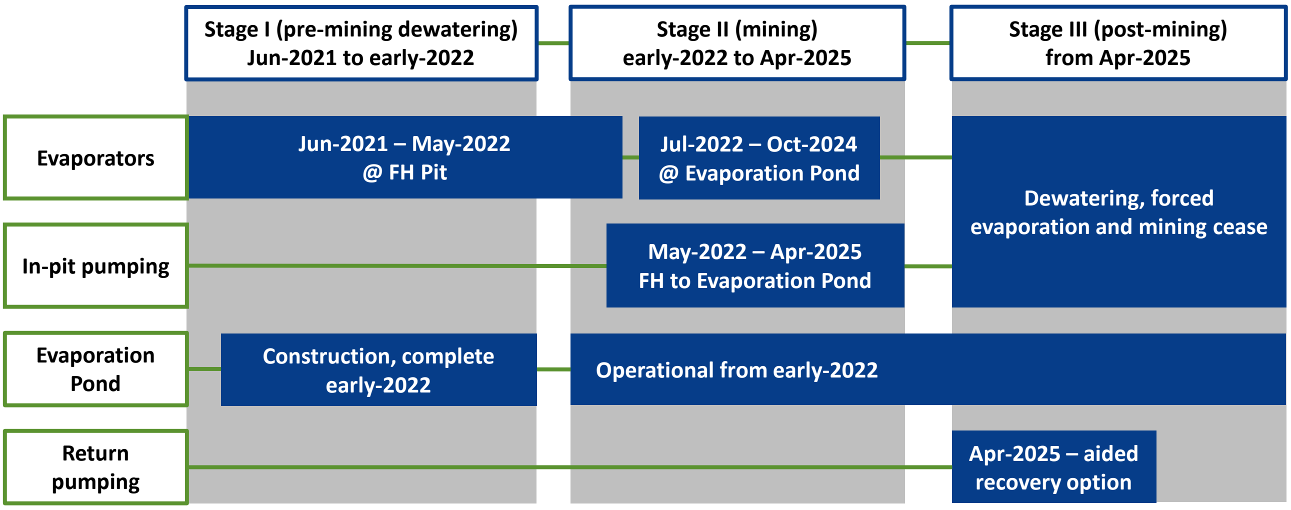


Figure 4-5 Overview of Fountain Head Pit and Evaporation Pond water balance Stages

This section of the report focuses on presenting the water balance model construction details, assumptions and the results based on current estimates of controlling parameters available to date. The uncertainty of the most critical parameters is also explored through a Monte Carlo analysis forming the basis of a quantitative uncertainty analysis.

4.3.2 Fountain Head Pit conceptualisation

The Fountain Head conceptualisation (CDM Smith, 2019) has been adopted and updated in regard to the transition from existing void dimensions to the final mined dimensions. For modelling purposes this occurs instantaneously and is considered conservative since the groundwater inflow rates will increase rapidly in following this transition – i.e. actual rates of pit development will be slower and result in lower rates of groundwater inflow compared to the modelled case. As described above, three evaporators will operate over the Pit from June 2021 until May 2022 when they are re-located to the Evaporation Pond. Direct pumping from the Pit to the Evaporation Pond will commence in May 2022 to first finalise the pit dewatering and then to maintain dry working conditions during mining.

Following the completion of mining activities there are two scenarios being considered for recovery of the pit water levels:

1. Unaided recovery (UR) – through groundwater inflow and rainfall sources
2. Aided recovery (AR) – by adding the volume of water remaining in the Evaporation Pond directly back to the pit void, in addition to groundwater inflow and rainfall sources

These two scenarios are expected to have a slightly different impact on the time needed for the pit water levels to recover toward a new dynamic equilibrium, mostly because the time required is dependent on the longer-term balance between rainfall, evaporation and the wider groundwater flow system.

Following full recovery, the groundwater model (Section 5) shows that the Pit Lake has a throughflow component, where the outflow flux to the groundwater system is approximately 20% of the inflow towards the end of the simulation (i.e. 2070 – 2075). This is expected to have implications for the post-closure solute balance of the Pit Lake, and so has been included in the water and solute balance within GoldSim when the Pit Lake level is > 90 m AHD.

4.3.3 Evaporation Pond conceptualisation

The Evaporation Pond balances the inflows (direct rainfall, runoff and contribution from the Fountain Head Pit dewatering) and outflows (evaporation, both natural and mechanically forced by evaporators, and groundwater infiltration / seepage). A residual water body is currently present in the Evaporation Pond most years, as shown in satellite imagery from at least 1987 to present. For modelling purposes, this residual volume is assumed to be permanent and therefore is not accounted for in the storage capacity of the Evaporation Pond (additionally it is currently disconnected from, and elevated above the base of the western part of the proposed Evaporation Pond). For modelling purposes, the existing water volume is considered as separate to the base of the Evaporation Pond, with the total additional capacity amounting to 1074 ML for a dam wall height of 98.8 m AHD (Figure 4-6). The proposed spillway level is 98.6 m AHD with a capacity of 1019 ML. However, the Evaporation Pond will mainly operate between a minimum level of 93 m AHD and a maximum operational level specified by PNX of 97.4 m AHD, which allows for approximately 1.2 m freeboard. The operational volume defined by these thresholds amount to 660 ML. The lower threshold aims at keeping a 50 ML reserve of water to meet site water demand. The upper threshold aims at keeping a sufficient storage capacity in the Evaporation Pond to prevent a 1% AEP 72-hour rainfall event from reaching the spillway level.

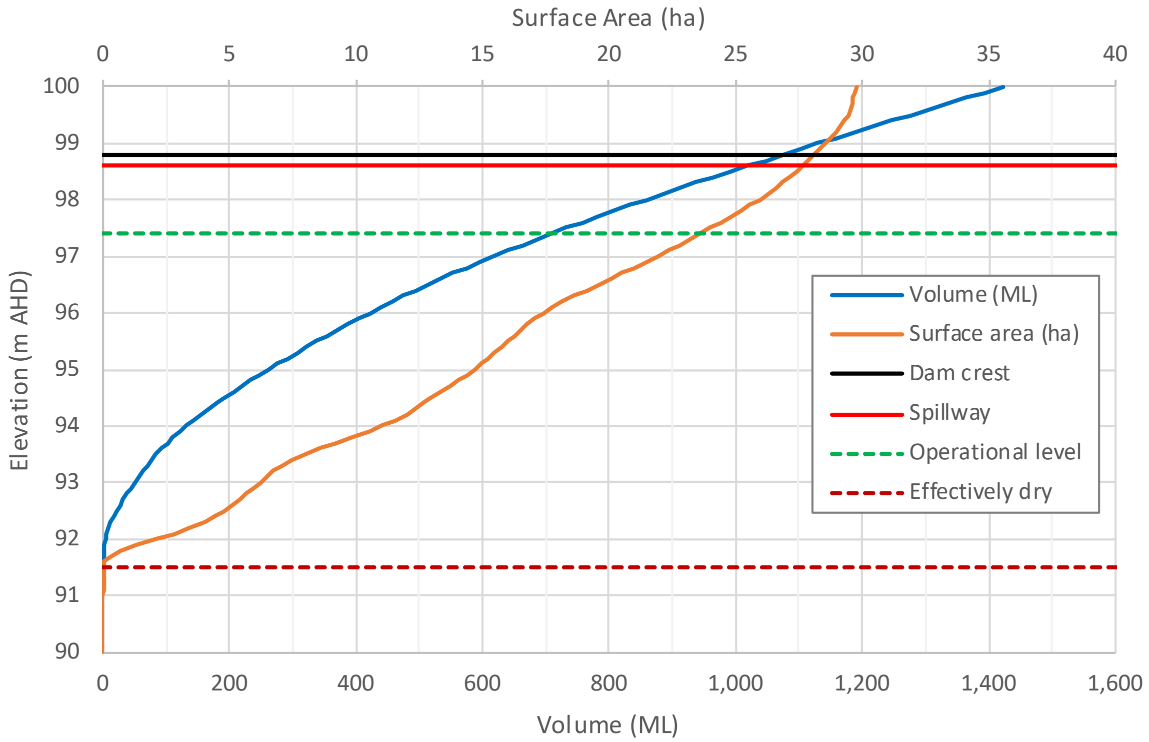


Figure 4-6 **Evaporation Pond level-volume-surface area relationship with operational and other levels**

Twelve months after the start of dewatering operations (i.e. the start of May 2022), pumps will be used to remove water from Fountain Head Pit directly to the Evaporation Pond at 9 ML/day until the pit is empty, after which lower pumping rates will be required to maintain dry pit conditions. Some months after the start of the mining operations (July 2022), the three evaporators will be moved from the pit to the Evaporation Pond to contribute to the Evaporation Pond volume reduction. The evaporators have a maximum pumping rate of 135 m^3/hr each, which typically equates to a daily removal of around 2–4.5 ML/d depending on evaporation efficiency and assuming they are operational for 20.3 hours per day. The evaporators are assumed to not interfere with natural evaporation from the Pond given its relatively large surface area. As the Evaporation Pond fills, groundwater infiltration (seepage) will progressively increase as the wetted area and the water level in the Pond increase.

At the end of mining, pumping from the Pit to the Evaporation Pond will cease along with the evaporators, and the Evaporation Pond storage will be allowed to transition back to its previous natural rainfall-runoff input, evaporation and groundwater infiltration dynamics.

4.3.4 Fountain Head Lake conceptualisation

The Fountain Head Lake is a surface water feature located in the middle of the site, between the locations of the proposed IWL to the east and CIP and other operation facilities (Crusher, Power Station, Mining contractor yard, processing plant and topsoil stockpile) to the west. Those features are, at least in part, within the Fountain Head Lake catchment as illustrated in Figure 4-7. However, the runoff from those features is proposed to be directed to six sediment dams (E1 ,E2, E3, W1, W2 and W3 – see Figure 4-7) before being released to the environment. Three of the sedimentary dams (W2, W3 and E3) will discharge directly in the Fountain Head Lake catchment and are included in the water balance. The three other evaporation dams discharge outside the Fountain Head Lake catchment and are not included in the Fountain Head water balance. Given any overflow from the sediment dams is only expected during high rainfall and surface water flow periods, any solutes picked up are unlikely to be at a high enough concentration to cause an exceedance of ANZEC guidelines once mixed with large floodwater volumes. This assumption is tested in section 4.7 using conservatively high solute concentrations and compared to relevant guidelines.

The overall water balance of the Fountain Head Lake accounts for water inflows from direct rainfall and from runoff, as well as losses of water to evaporation and through downstream overflow to the north. The Lake surface level is assumed to approximate the water table elevation (i.e. it is possibly a surface expression of the water table) based on nearby groundwater levels and satellite imagery showing the frequent presence of water in Lake. However, the available data are not sufficient to quantify the surface water and groundwater interaction status or changes over time. Hence, losses from the Lake to groundwater during high water levels and the potential groundwater inflow during low water levels have been neglected from the modelling.

4.4 GoldSim water balance model construction

4.4.1 Model structure

The water balance model simulates the water management of the mine site from the existing pit dewatering Stage (Stage I), the mining Stage (Stage II) and the post-mining period up to 500 years post-mining (Stage III). The physical structure of the site comprises three main water balance components, each with additional contributing sub-catchments:

- The Fountain Head Pit – during the dewatering period the pit shape used in the mass balance is the historical pit shape but, from the start of the proposed mining operation, the pit shape and associated bathymetry is swapped to the planned final pit shape at the end of mining
- The Evaporation Pond – has a volume to level relationship based on the upgrade works proposed for the site, and
- The Fountain Head Lake – has bathymetry defined by the latest digital elevation models available and includes the proposed CIP and other catchments related to proposed sedimentation dams

The water balance model concurrently simulates the Fountain Head Pit, the Evaporation Pond and the Fountain Head Lake to allow for a seamless transfer of water from the three sub-systems when applicable. The whole water management system and the structure of the GoldSim model is illustrated on Figure 4-8.

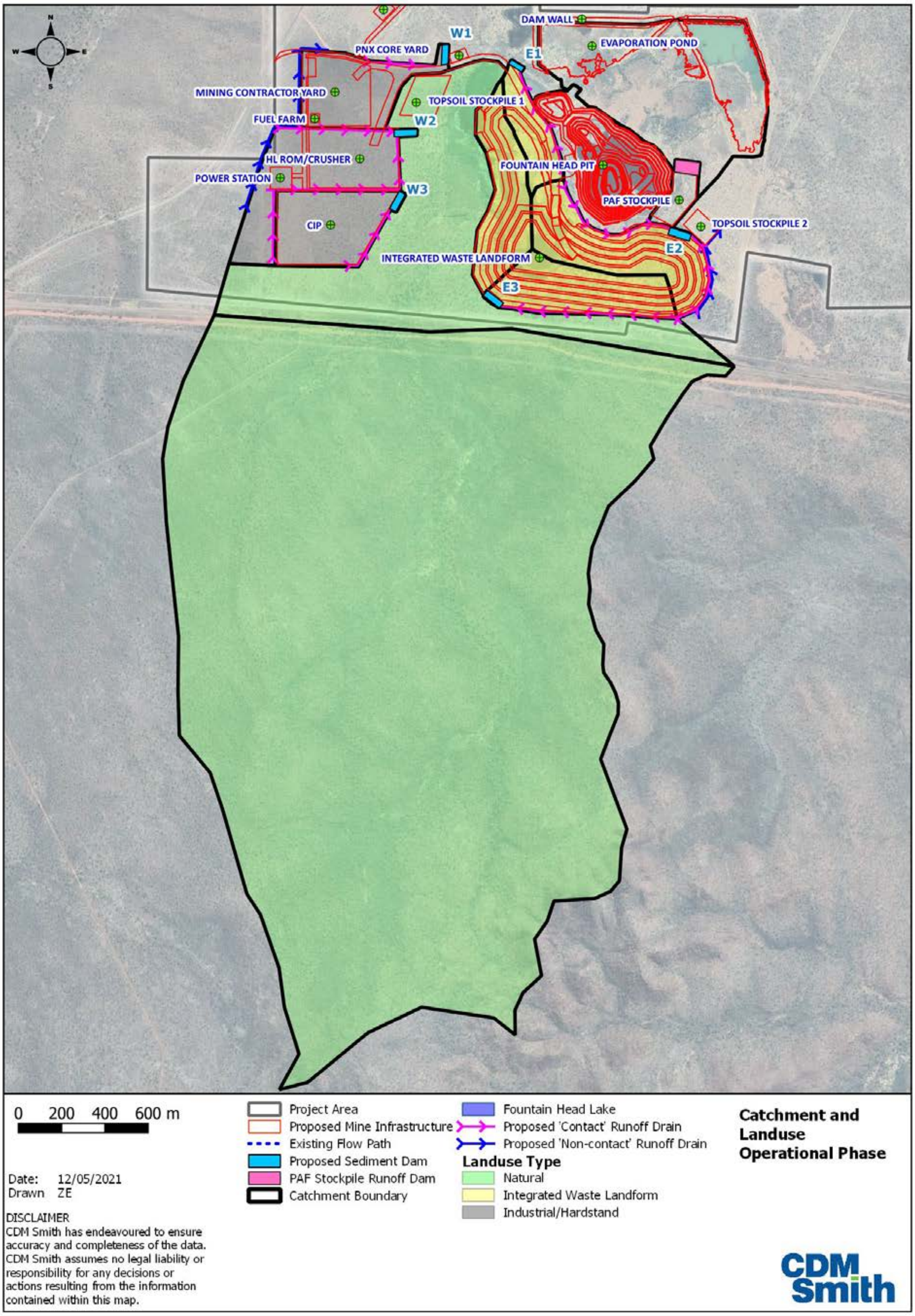


Figure 4-7 Fountain Head Lake catchment and land use

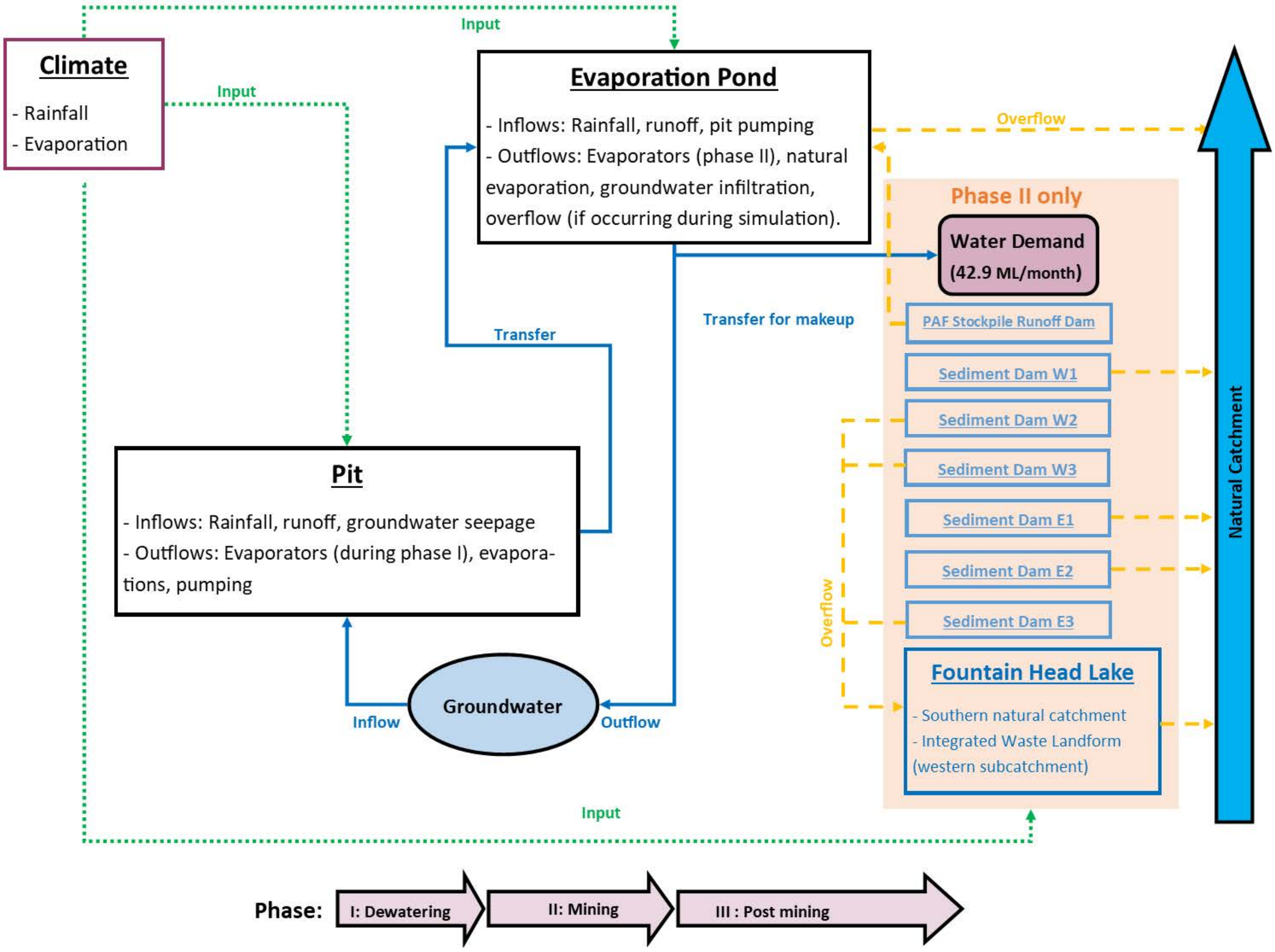


Figure 4-8 Fountain head site water balance schematic

4.4.2 Model approach

There are two main types of modelling approaches available in GoldSim, both of which have been used in this study:

- A deterministic approach
  With a deterministic approach, the model input parameters are determined exactly, and the outcome of the simulation is a unique set of results. This approach is appropriate if the input parameters are well known or for testing some definite condition.
- A probabilistic approach (Monte Carlo analysis)
  With a probabilistic approach, the uncertainty of the input parameters is accounted for to determine the likelihood of the outcome. A Monte Carlo analysis consists of describing the uncertainty of model predictions based on the quantification of the input parameter uncertainty (i.e. values selected within realistic parameter bounds). The methodology involves running the models a large number of times (realisations). For each realisation, inputs are sampled randomly and at the end of all model runs, the outputs are aggregated to determine their distribution. Many of the parameters of the model are not well constrained by field or other data assessment. This uncertainty in the model input parameters leads to an uncertainty of the model outputs. The modelling approach adopted here accounts for model parameter uncertainty through a Monte Carlo analysis. For the analysis, 200 realisations were generated by GoldSim.

Each of the model components and parameters included in this analysis are described in the following sub-sections. The parameter distributions used in the Monte Carlo analysis are summarised in Table 4-4.

4.4.2.1 Rainfall and runoff

Natural inflow to the Evaporation Pond consists of rainfall and runoff. The surface water catchment is estimated at 57 ha (Figure 4-9). At full capacity the Evaporation Pond covers about 30 ha or about 50% of the catchment. 100% of rainfall is accounted for over the wet surface of the Pond and over the rest of the catchment area runoff is estimated using the Australian Water Balance Model (AWBM).

For rainfall, the historical rainfall estimation from SILO (series for 1889 to 2020 downloaded from SILO point data for latitude -13.45 and longitude -131.50) was used as an estimation of future rainfall. To address rainfall uncertainty, a different starting point on the historical sequence is used for each model realisation. When the end of the sequence is reached, the historical data is recycled from the beginning of the sequence.

4.4.2.2 Pit dewatering volume

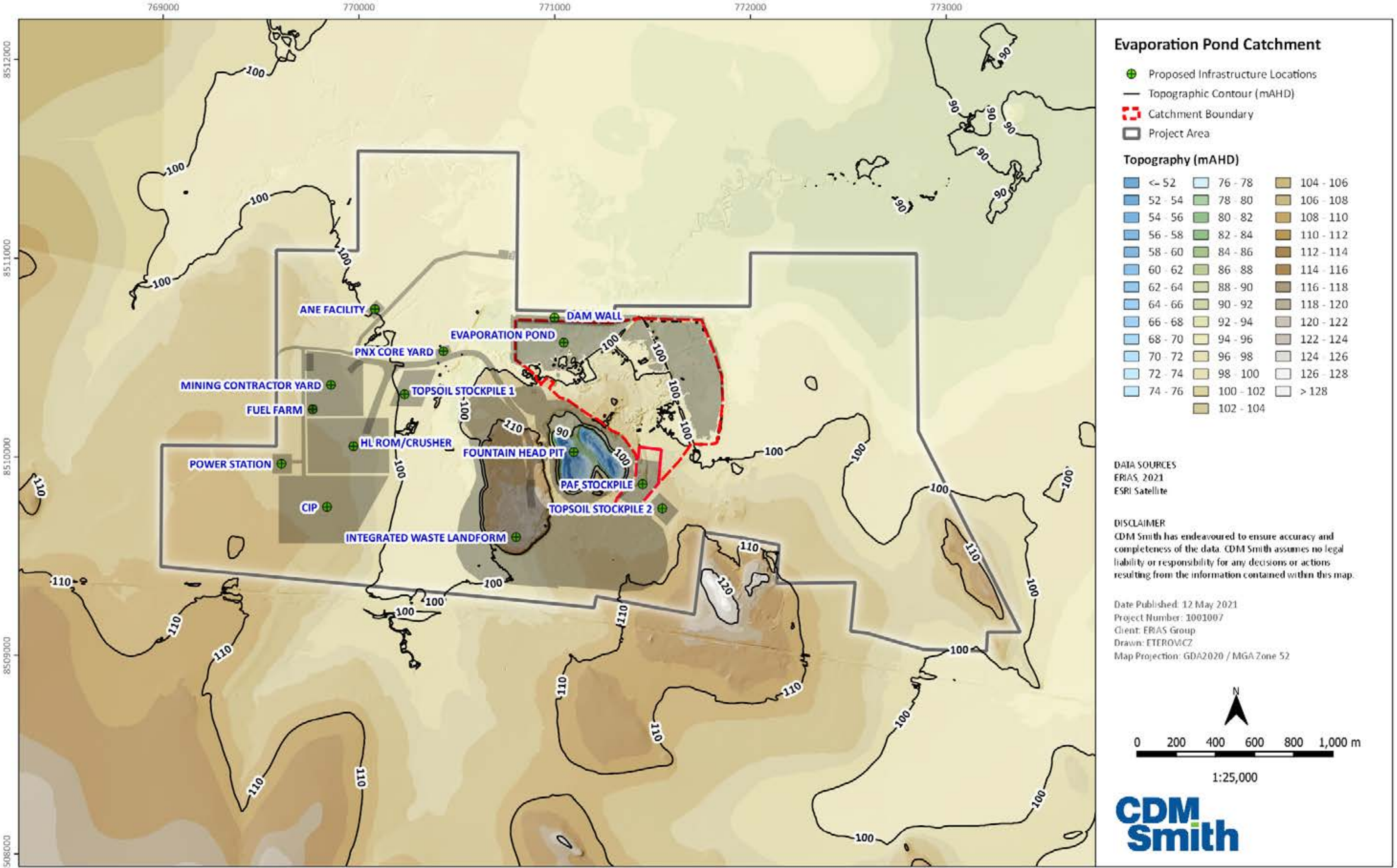
Stage I is planned to commence in June 2021 using evaporators (until the end of May 2022) and from May 2022 by direct pumping at a maximum rate of 9 ML/d (when construction of the Evaporation Pond retention walls is completed) with the intention of achieving dewatering as soon as possible.

During Stage II, dewatering maintains a dry environment in the pit at a maximum rate of 9 ML/d. The modelling also assumes that the final pit shape is reached on the first day of mining operations instead of a progressive deepening. This construction provides a conservative estimate of pit inflow and pumping requirements (i.e. maximum groundwater inflow rate that can be expected within the constraints of model parameter assumptions).

Various sources of uncertainty affect the estimation of the total dewatering volume and necessary rates. The main source is the estimation of groundwater inflow to the pit. The calibration of the pit recovery model (cf. Section 4.2) provides an estimate of pit groundwater inflow of 2 ML/d for an empty pit (at a depth of 30 m AHD). The inflow for the mining pit at a depth of -34 m AHD assumes the same uniform aquifer hydraulic properties and therefore doesn’t account for a likely reduction of hydraulic conductivity with depth that is commonly observed in fractured aquifers. To account for the new pit depth the original GoldSim model parameter defining the aquifer depth had to be modified. The base of the aquifer was moved from 0 m AHD to -80 m AHD and the hydraulic conductivity was changed from 0.2 m/d to 0.09 m/d. The modification of those two parameters allowed for a pit inflow of about 2 ML/d at the end of the previously modelled dewatering Stage (CDM Smith, 2019).

However, the hydraulic conductivity of the aquifer is an uncertain parameter representing the bulk characteristics of a heterogeneous fractured rock aquifer. For the Monte Carlo analysis, a log-normal distribution of hydraulic conductivity centred at the calibrated value of 0.09 m/d with a standard deviation of 0.01 m/d and truncated between 0.06 m/d and 0.12 m/d. was assumed. The hydraulic conductivity parameter is constrained by the calibration of the previous pit recovery where a maximum groundwater inflow of 2 ML/d was predicted prior to recovery (i.e. when hydraulic gradients toward the pit were their steepest). With an aquifer hydraulic conductivity ranging from 0.06 m/d to 0.12 m/d the existing pit inflow at the end of dewatering ranges from 1.2 ML/d to 2.5 ML/d, which is considered large enough to represent the uncertainty of groundwater inflow to the empty pit. It may be possible for short-duration inflow rates during mining to be higher than this rate however, if significant fracturing or fault zone structures are intersected by the deepened mine with steeper hydraulic gradients towards the pit.

Pit dewatering volume is also controlled by the capacity of the Evaporation Pond. During Stage I (the pit dewatering Stage) and Stage II (mining), the model adjusts the dewatering rate to maintain the Evaporation Pond beneath the operational trigger water level of 97.4 m AHD. The trigger level provides a 365 ML buffer prior to an Evaporation Pond spill event.



DATA SOURCES
ERIAS, 2021
ESRI Satellite

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Date Published: 12 May 2021
Project Number: 1001007
Client: ERIAS Group
Drawn: ETEROVICZ
Map Projection: GDA2020 / MGA Zone 52

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Figure 4-9 Evaporation Pond catchment at full capacity

4.4.2.3 Water demand

The Fountain Head Gold Project requires approximately 42.9 ML per month of non-potable water, which will be sourced from the Fountain Head Pit (predominantly) or Evaporation Pond. The water is assumed to be suitable for:

- The process plant and mill
- CIP start and make-up water
- Pit and road dust suppression.
- Office ablutions
- Vehicle washdown
- Core cutting and core shed ablutions.
- Crusher dust suppression
- Plant wash water

The non-potable water demand (42.9 ML per month) is included in the water balance model where it is sourced (as outflow) but does not return to the model as processed or infiltrated water (i.e. as inflow). Potable water that may be required on-site has not been included in the water balance model.

4.4.2.4 Fountain Head runoff

The Fountain Head Lake catchment areas were delineated based on topographic data and the provided mine plan (Figure 4-7). The land use of the Fountain Head catchment, for the purpose of the site water balance, was delineated based on aerial imagery. The catchment area and land use distributions for the two sediment dams discharging into the Fountain Head Lake catchment are summarised here and in Table 4-1:

1. Natural/undisturbed, representing natural or undisturbed areas
2. Waste rock, representing uncompacted overburden material
3. Roads, hardstand and mining infrastructure areas

Table 4-1 Adopted catchment areas and land use

Dam/Storage	Contributing catchment Area (ha)		
	Natural	Waste Rock	Industrial/Hardstand
SedDam_W2	-	-	24.1
SedDam_W3			17.0
SedDam_E3	-	17.5	-
Fountain Head Lake	688.8	16.1	-

The Australian Water Balance Model (AWBM) (Boughton, 2003) is incorporated in the GoldSim model to estimate runoff from rainfall to the sediment dams and Fountain Head Lake for the operational phase of the project to account for different types of land use. The AWBM has been widely used in Australia and has been verified to large amount of recorded streamflow data and used in many mining projects.

The AWBM catchment water balance model operates in daily timestep which allows for variable source areas of surface runoff. The AWBM contains three surface stores to simulate partial areas of runoff, a base flow store and a surface runoff routing store to represent a catchment. Water in the conceptual storages is replenished by rainfall and is reduced by evaporation and simulated surface runoff occurs when the conceptual storages fill and overflow.

The model uses daily rainfall and estimates of catchment evapotranspiration to calculate daily values of runoff using a daily water balance of soil moisture. The model has a baseflow component which simulates the recharge and discharge of a shallow subsurface store. Runoff depth calculated by the AWBM model is converted into runoff volume by multiplying the contributing catchment area.

The model parameters define the three conceptual storage capacities (C1, C2 and C3), the proportion of the catchment for each of the storages (A1, A2 and A3), and the rate of flux between them (K_b, K_s and BFI). The default parameter values are A1 = 0.134, A2 = 0.433 and A3 = 0.433 (see Table 4-2). In the absence of available calibration data, the adopted parameters are within the typical range for such land use types and are generally consistent with literature such as Boughton (2003) for ungauged catchments and other studies in the Northern Territory.

Table 4-2 Adopted AWBM parameters

Parameter	Natural	Waste Rock	Industrial/Hardstand
A1 (-)	0.134	0.134	0.134
A2 (-)	0.433	0.433	0.433
A3 (-)	0.433	0.433	0.433
C1 (mm)	9	8	3
C2 (mm)	91	76	27
C3 (mm)	183	152	53
BFI (-)	0.3	0.5	0
K_b (-)	0.98	0.8	0
K_s (-)	0	0	0

4.4.2.5 Groundwater infiltration (seepage) at the Evaporation Pond

The water table is estimated to sit within around 5 m below the ground surface in the vicinity of the Evaporation Pond (and is likely to be hydraulically connected). Water in the Pond will infiltrate when Pond water levels are higher than the adjacent groundwater levels and contribute enhanced recharge to the water table beneath it. For estimating the rate of infiltration, the primary control are the hydraulic properties of the sediments at the base of the EP.

Assessment of drilling logs in the vicinity of the site indicates an average soil thickness of 3 m and predominantly comprises of silty clays and clays, which are weathering products of the deeper more competent rock. The permeability testing by WANT Geotechnics (2020) indicates the vertical hydraulic conductivity (Kv) of the soil profile is around $3x10^{-2}$ m/d. Recent field work by CDM Smith (2021a) completed additional infiltration testing within the extent of the proposed EP area. Four tests were completed at each of two sites (western and south western segments) and intersected variable soils from silty clays with a median vertical hydraulic conductivity of $1.5x10^{-2}$ m/d with three tests indicating values < $1x10^{-3}$ m/d. Three tests in silty sands and clayey silts with minor sand, had a median of 1.2 m/d but are not considered representative of the bulk characteristics of the proposed EP. It is clear from these tests that the vertical hydraulic conductivity of the soils within the proposed EP are highly variable, and so the Monte Carlo analysis included in this modelling work is designed to capture this parameter uncertainty.

Preliminary water balance testing using a Kv value of $3x10^{-2}$ m/d (considered too high for silty clays and therefore unlikely) resulted in the relatively rapid infiltration of the EP volume (i.e. within around six months), and likely water logging of the soil profile local to the EP (to the north and northeast of the retention walls). One mitigation strategy for this potential threat pathway could be the construction of a groundwater interception drain along the perimeter of the EP but the requirements and modelling of such a structure is beyond the scope of this study.

For the analysis completed below, soil Kv was given a log-normal distribution with a median estimate of 0.0034 m/d (i.e. one order of magnitude lower than the field-based average that is considered high), a standard deviation of 0.002 m/d and truncated between 0.0005 m/d and 0.05 m/d. This value and distribution is considered more representative of the hydraulic properties of the soils (as described) on site.

4.4.2.6 Evaporation

Simulated evapotranspiration is based on pan evaporation and is applied over the whole wet area of the Evaporation Pond. No shading of the Evaporation Pond is considered given it is considerably larger and more open to wind than the Fountain Head Pit. A factor of 0.75 was applied to pan evaporation rates to account for water saturation (i.e. where relative humidity is 100% and no evaporation can occur) over the Pit as this was the applied value for the original GoldSim model (CDM Smith, 2019).

To allow access to Fountain Head Pit for mining (i.e. Stage II), the three evaporators will be relocated to the Evaporation Pond. Based on PNX estimations, the evaporator pumps are assumed to work at a rate of 135 m^3/hr each, working on average for 20.3 hr per day (around 85% of the time). To account for seasonal climatic conditions including rainfall, potential evaporation and wind, PNX calculated monthly evaporation efficiencies which are reproduced in Table 4-3, and these have been adopted in the model.

Table 4-3 Monthly evaporators efficiency

Month	Evaporation efficiency (%)
January	27%
February	24%
March	33%
April	42%
May	48%
June	50%
July	52%
August	55%
September	54%
October	50%
November	42%
December	33%

4.4.2.7 Initial condition

For the simulation, the Evaporation Pond is assumed to start empty. Note that the existing Pond has a relatively small volume, which is elevated above the base of the proposed Evaporation Pond and is currently disconnected from the western area.

4.4.2.8 Summary of model parameters

The model parameters, including the range of values used in the Monte Carlo analysis, are summarised in Table 4-4. The GoldSim model has not been re-calibrated with respect to groundwater inflows, but is developed to be consistent with the pit dewatering volume and the numerical groundwater model results (see Section 5) through the following control:

- The numerical model is calibrated to reach a similar estimate of pit inflow to the original GoldSim calibrated model (CDM Smith, 2019), which is strongly constrained by the pit recovery water level data (i.e. the pit inflow estimation of the GoldSim model is around 2 ML/d when dewatered to 30 m AHD)

.

Table 4-4 Summary of the model parameters

Model component / Parameter	unit	Value (median value for Monte Carlo parameter)	Standard Deviation	Minimum value	Maximum value	note
			For the Monte Carlo parameters only			
Climate data						
Rainfall		Time series of historical rainfall	Rainfall series is stochastically generated from historical rainfall data.			Rainfall is applied at 100% over the Pond wet surface
Natural evaporation		Use monthly average of pan ET	-	-	-	ET is applied over the wet surface of the Pond
Evaporation Pond						
Evaporation Pond catchment	m^2	570,400	-	-	-	-
Evaporation Pond spill level	m AHD	98.6	-	-	-	Any volume after the Evaporation Pond reaches 98.8 m AHD is reported as overflow
Evaporation Pond full capacity	ML	1,074	-	-	-	The full capacity is the total volume in the Evaporation Pond before the Pond overflow is triggered.
Evaporation Pond maximum wall elevation	m AHD	98.8	-	-	-	-
Evaporation Pond area at full capacity	m^2	281,000	-	-	-	-
Evaporation Pond maximum operational level	m AHD	97.4	-	-	-	Stop the dewatering to the Evaporation Pond when this elevation is reached to keep a reserve for large rainfall.
Evaporation Pond minimum level	m AHD	93	-	-	-	Stop the evaporators to keep a reserve of water in the Pond.
Evaporation Pond operational volume	ML	709	-	-	-	Volume between the minimum and maximum operational level.
AWBM Runoff coefficient over Evaporation Pond catchment	[]	A1 A2 A3 C1 C2 C3 0.134 0.433 0.433 3 27 53	-	-	-	Runoff is applied over the catchment (less the wet surface)
Pan to lake factor	[]	0.75	-	-	-	To account for vapour saturation over large lake
Groundwater seepage						

Model component / Parameter	unit	Value (median value for Monte Carlo parameter)	Standard Deviation	Minimum value	Maximum value	note
			For the Monte Carlo parameters only			
Soil thickness	m	3	-	-	-	-
Kv soil	m/d	0.0034	0.002	0.0005	0.05	This parameter has a large control on the amount of water infiltrating from the Evaporation Pond. Groundwater seepage is calculated by a Darcy flux equation applied over the wet surface area and the average depth of the Evaporation Pond.
Evaporators						
Quantity of evaporators	unit	3	-	-	-	The evaporators are initially installed over the Fountain Head Pit and then moved in June 2021 to the Evaporation Pond.
Pumping rate	m^3/h	135	-	-	-	-
Working period per day	h/d	20.3	-	-	-	-
Monthly evaporators efficiency	[]	Jan Feb Mar Apr May Jun 0.27 0.24 0.33 0.42 0.48 0.5 Jul Aug Sep Oct Nov Dec 0.52 0.55 0.54 0.5 0.42 0.33	-	-	-	Those factors provided by PNX accounts for average monthly climatic conditions (rainfall, pan evaporation and winds).
Fountain Head Pit parameters						
K aquifer	m/d	0.09	0.01	0.06	0.12	This parameter is relatively poorly characterised (and is a surrogate for the more complex hydrostratigraphy not represented in the model). However, this parameter is constrained by the historical pit water level recovery. The current Monte Carlo analysis does not assess the range of resulting groundwater inflows from this altered K value
Water table elevation near the pit	m AHD	95	0.5	93	97	This parameter accounts for the uncertainty in defining the average water level condition around the pit. It has some control over the long-term pit stabilisation water level.

Model component / Parameter	**unit**	**Value (median value for Monte Carlo parameter)**	**Standard Deviation**	**Minimum value**	**Maximum value**	**note**
			For the Monte Carlo parameters only			
Max pumping rate	ML/d	9	-	-	-	Pumping from the pit to maintain the pit dry during LOM
Base of pit diameter	m	175	-	-	-	From previous calibrated analytical solution of pit inflow
Initial Fountain Head Pit Lake volume	ML	2064	-	-	-	-
Fountain Head Lake parameter						
Catchment area	-	Cf. Table 4-1	-	-	-	-
Runoff. AWBM	-	Cf. Table 4-2	-	-	-	-
Pan to lake	-	0.75	-	-	-	To account for vapour saturation over the lake

4.5 Fountain Head Pit dewatering model results

4.5.1 Fountain Head Pit dewatering and recovery mass balance

4.5.1.1 Dewatering and unaided recovery scenario

The predicted water level decline and post-mining recovery in Fountain Head Pit is represented as a probability distribution for the medium-term in Figure 4-10 (2020 to 2075) and short-term in Figure 4-11 (2020 to 2030). The recovered pit water level is predicted to stabilise after around 50 years post-mining at an average level of 93.5 m AHD with seasonal amplitude of 2 m.

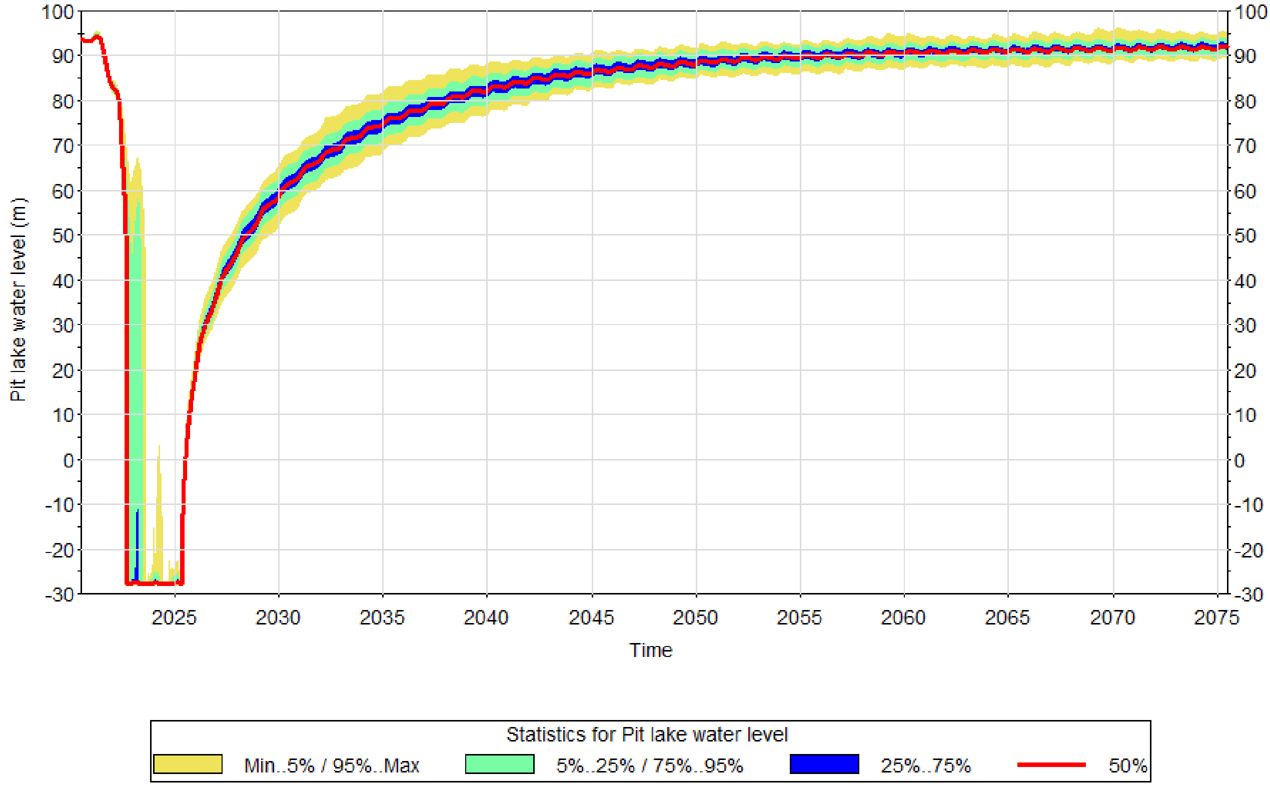

Figure 4-10 Predicted change in Fountain Head Pit water level during recovery for the first 50 years post-mining

The Monte Carlo analysis predicts the pit will be ‘empty’ on average by mid-September 2022. A continuous initial dewatering is successful for all but twenty-one of the 200 realisations between early-September and early-November 2022. In these twenty-one exceptional realisations (10.5%), the pit is not dewatered until after the 2022/23 wet season. This delay is due to the operational rule applied to the Evaporation Pond trigger level in combination with exceptionally high rainfall wet seasons.

There is a 59% likelihood the pit water levels will be maintained at dry conditions without interruption to in-pit dewatering pumps for the entire mining period under the existing model assumptions (Figure 4-11). Conversely, there is a 41% likelihood that the operational water level trigger in the Evaporation Pond will be exceeded during the mining period at some point in time, resulting in an interruption to the in-pit dewatering pumps. This causes a recovery of water levels in the pit, which will occur whenever the in-pit pumping rate slows to below the rates of inflow minus in-pit evaporation (e.g. see rising water levels in early-2022, Figure 4-11). The Evaporation Pond water level generally reaches the trigger for the model realisations that have larger groundwater inflow predictions to the pit (aquifer hydraulic conductivity value sampled from the upper end of the probability distribution). Following the wet season of 2022/23, full dewatering is then again achieved prior to the 2023/24 wet season when again the operational water level trigger in the Evaporation Pond is exceeded.

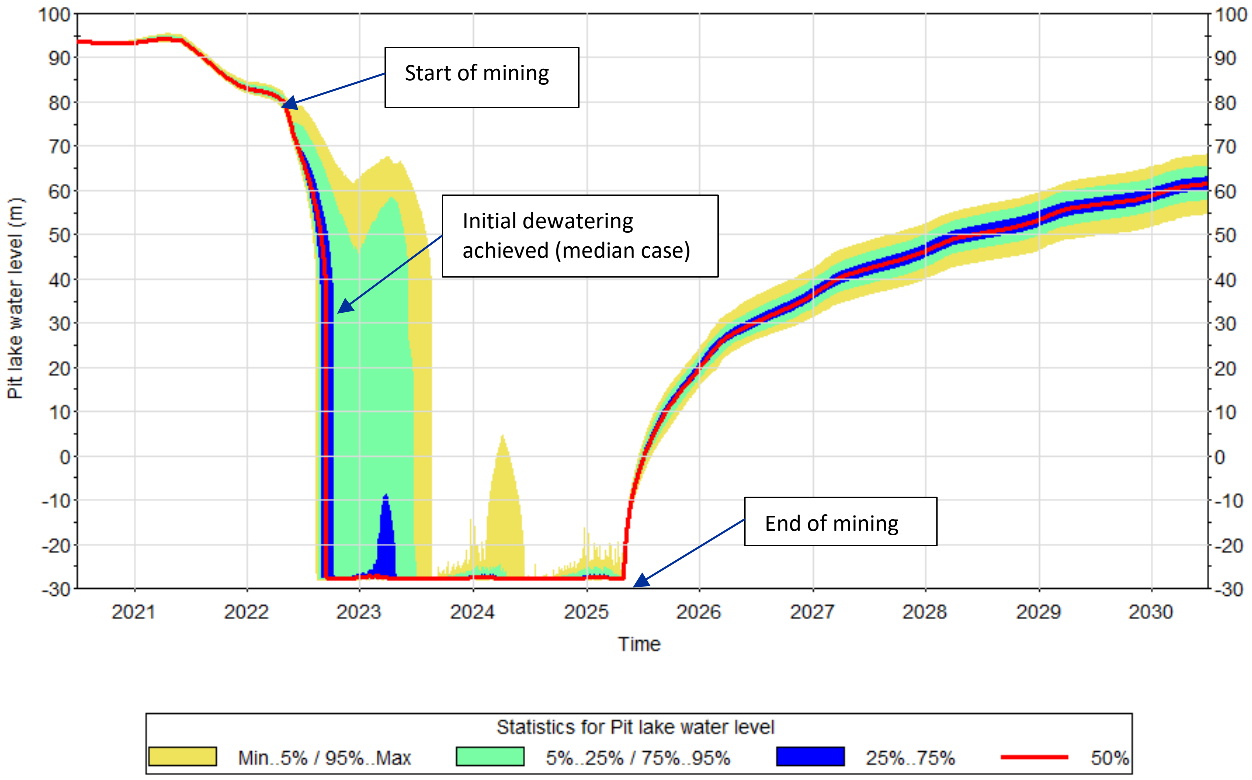

Figure 4-11 Predicted change in Fountain Head level during dewatering and recovery (modelling Stages indicated)

Sensitivity testing of the operational water level trigger shows that the likelihood of exceedances can be reduced if the trigger level is raised, as would be expected. Tests were performed at 97.9 m AHD and 98.4 m AHD and are summarised in Table 4-5. The probability distribution of predicted pit water levels for these two alternative operational water level triggers are shown in Figure 4-12 and Figure 4-13. For the initial dewatering by the end of 2022 all but twelve of the 200 realisations are predicted to be successful with an operational water level trigger of 97.9 m AHD and the likelihood of uninterrupted dewatering during the mining period increases to 72%. With an operational water level trigger of 98.4 m AHD the modelling predicts a 98% likelihood of reaching initial 2022 dewatering and 89.5% likelihood of maintaining uninterrupted dewatering during the entire mining period, within the assumptions of the modelling. However, the likelihood of exceeding the spillway level of 98.6 m AHD also increases to 1 and 6.5% for potential operational water level triggers of 97.9 and 98.4 m AHD, respectively.

Table 4-5 Sensitivity testing for Evaporation Pond water level operational trigger for life of mine period

Operational water level trigger (m AHD)	Likelihood of achieving initial 2021 dewatering (%)	Trigger exceedance likelihood over whole mining period (%)	Spill likelihood over LOM (spill level : 98.6mAHD)
97.4	89.5	41	0
97.9	94	28	1
98.4	98	11.5	6.5

Importantly, the sensitivity testing of operational level triggers does not take into consideration the 1% AEP rainfall event volume buffer accounted for by the 97.4 m AHD trigger. The proposed spillway level is 98.6 m AHD and the required buffer for a 72-hour 1% AEP rainfall event is 263 ML (for existing 57 ha Evaporation Pond catchment area) and potentially 187 ML (for an alternatively proposed 42.6 ha catchment area). The Evaporation Pond capacity below 98.6 m AHD is approximately 1019 ML (see Figure 4-6). Subtracting the 1% AEP 72-hr rainfall event volume reduces the Evaporation Pond level to approximately 97.6 m AHD and 97.9 m AHD for the 57 ha and 42.5 ha catchment area options respectively. This means that the sensitivity testing operational water levels of 97.9 m AHD may be possible with the current spillway level, noting that no consideration has been made for geotechnical or other dam design or safety requirements. The second sensitivity testing operational water level trigger of 98.4 m AHD would require the spillway to exist above the current dam crest elevation (98.8 m AHD) if the 1%AEP event is to be accounted for.

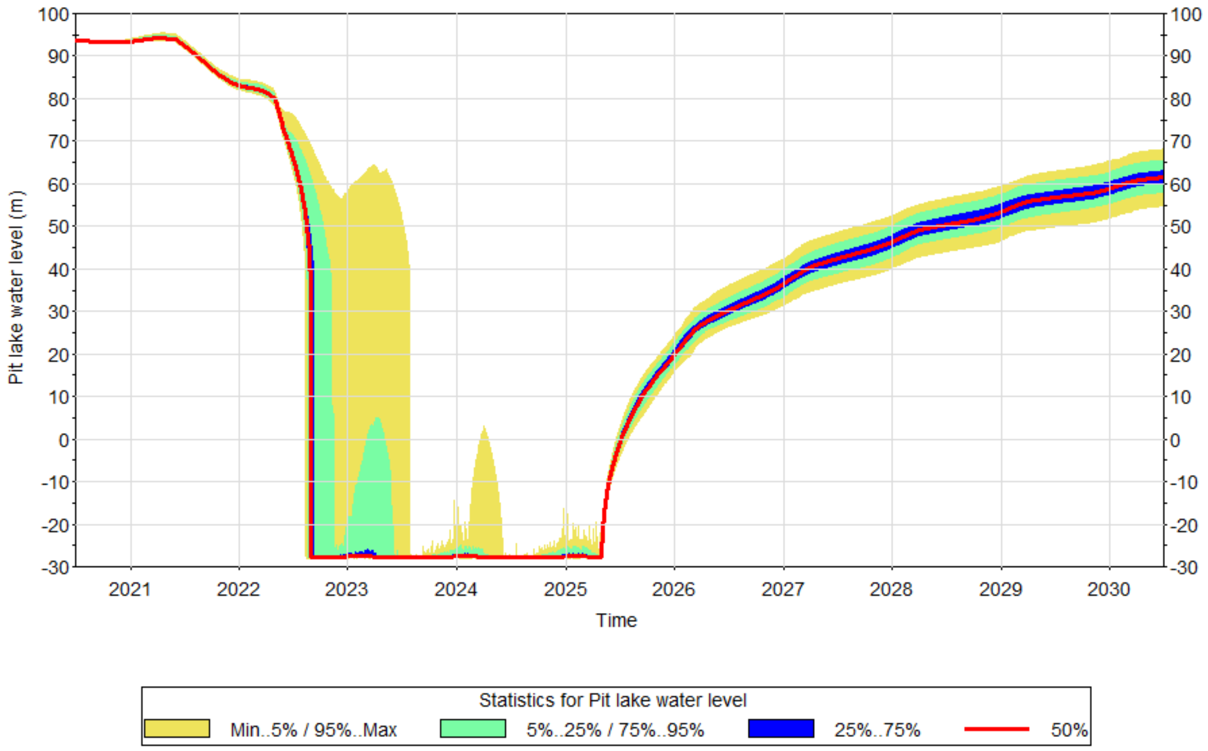

Figure 4-12 Predicted Fountain Head water levels (operational water level trigger sensitivity test at 97.9 m AHD)

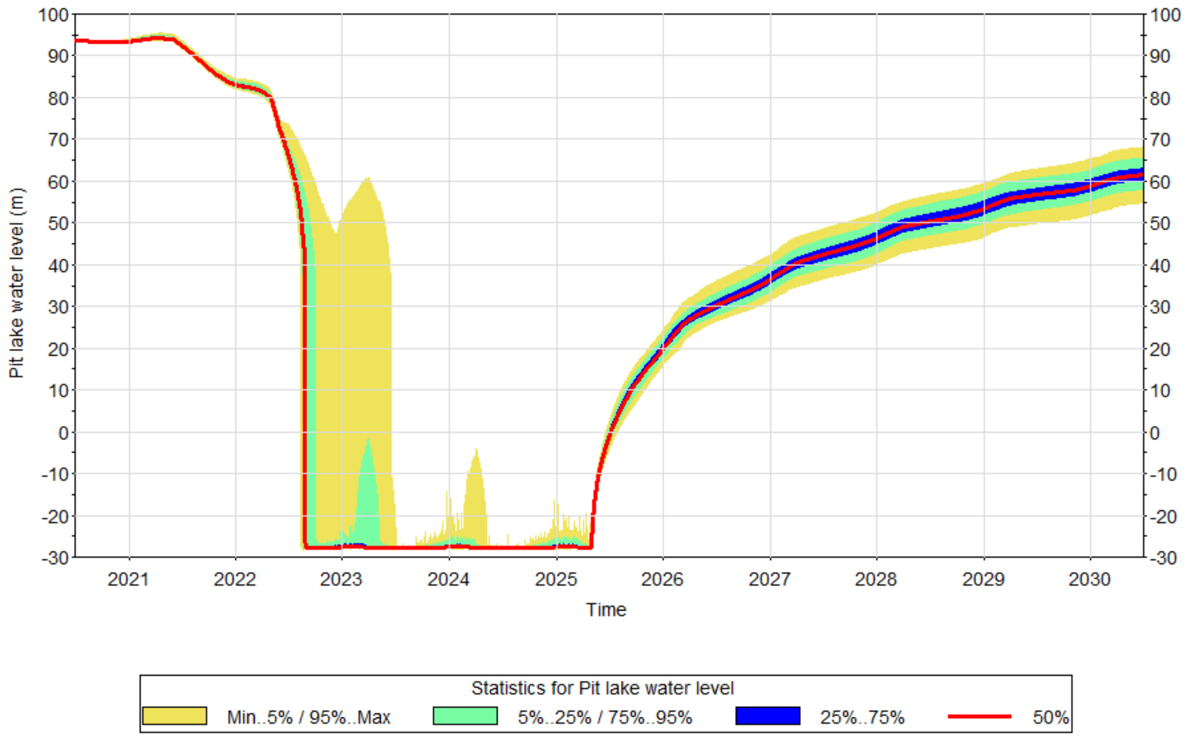

Figure 4-13 Predicted Fountain Head water levels (operational water level trigger sensitivity test at 98.4 m AHD)

During the dewatering Stage the groundwater inflow increases progressively to around 2 ML/d when the initial pit dewatering is complete (i.e. pit water level around 35 m AHD). At this point, groundwater inflow increases to around 3 ML/d on average as the pit bathymetry is swapped to the new pit shape (Figure 4-14). The change in pit bathymetry is modelled as instantaneous rather than as a progressive change, to maintain conservatism in groundwater inflow rates (i.e. maximum anticipated within model assumptions). The probability shading where groundwater inflows decrease for a few months in 2023 reflect the realisations where the pit water level recovers due to Evaporation Pond operational level triggers being exceeded and the in-pit pumps being stopped.

The average inflow components of the mass balance are illustrated over time in Figure 4-15. Pit inflows are dominated by the groundwater inflow but complemented by seasonal rainfall and runoff. The average outflow components of the mass balance are illustrated over time in Figure 4-16. The forced evaporation is the main outflow component until the pumps take over to complete the initial pit dewatering. During mining, the pumps operate at around 3 ML/d to maintain dry conditions in the pit (i.e. remove groundwater inflow) and up to 4 ML/d on average during the wet season.

The mass balance summary for the average condition is illustrated in Figure 4-17 and reported in Table 4-6. For Stage I (advance dewatering) and Stage II (mining), 55% of the pit water comes from groundwater inflow to the pit. Only 8% and 2% comes from runoff and direct rainfall, respectively. The pit is predicted to be maintained dry for most of the period with most of the rainfall contribution accounted as runoff (i.e. since the large pit void captures incident rainfall). The remaining 35% consists of the initial water storage in the Fountain Head Pit. For outflow, 76% is provided by the pit pumps while the evaporators account for 22% (only active during Stage I). The remaining 2% is due to natural evaporation, primarily occurring at the start of the dewatering Stage when the surface area is large.

Note that the total volume of water removed from the Fountain Head Pit to achieve dry conditions is almost 6 GL (Table 4-6).

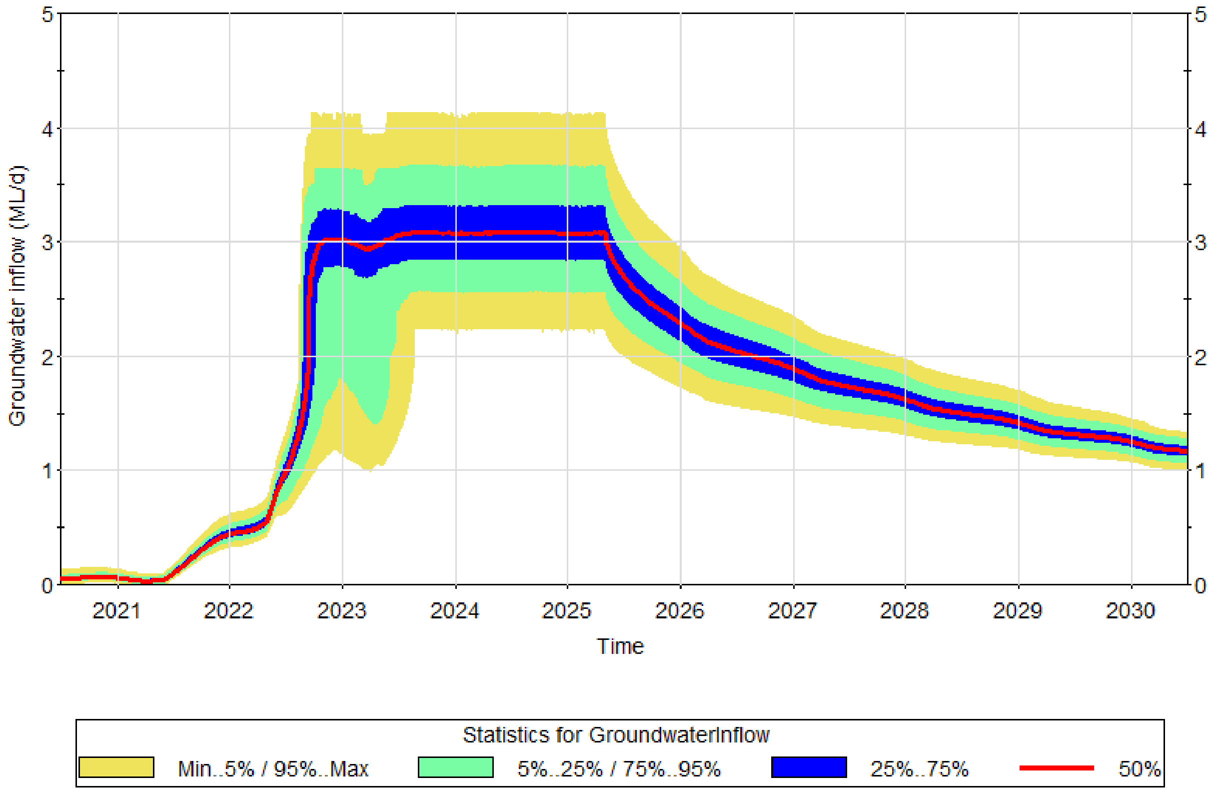

Figure 4-14 Predicted groundwater inflow rates during dewatering and recovery (ML/d)

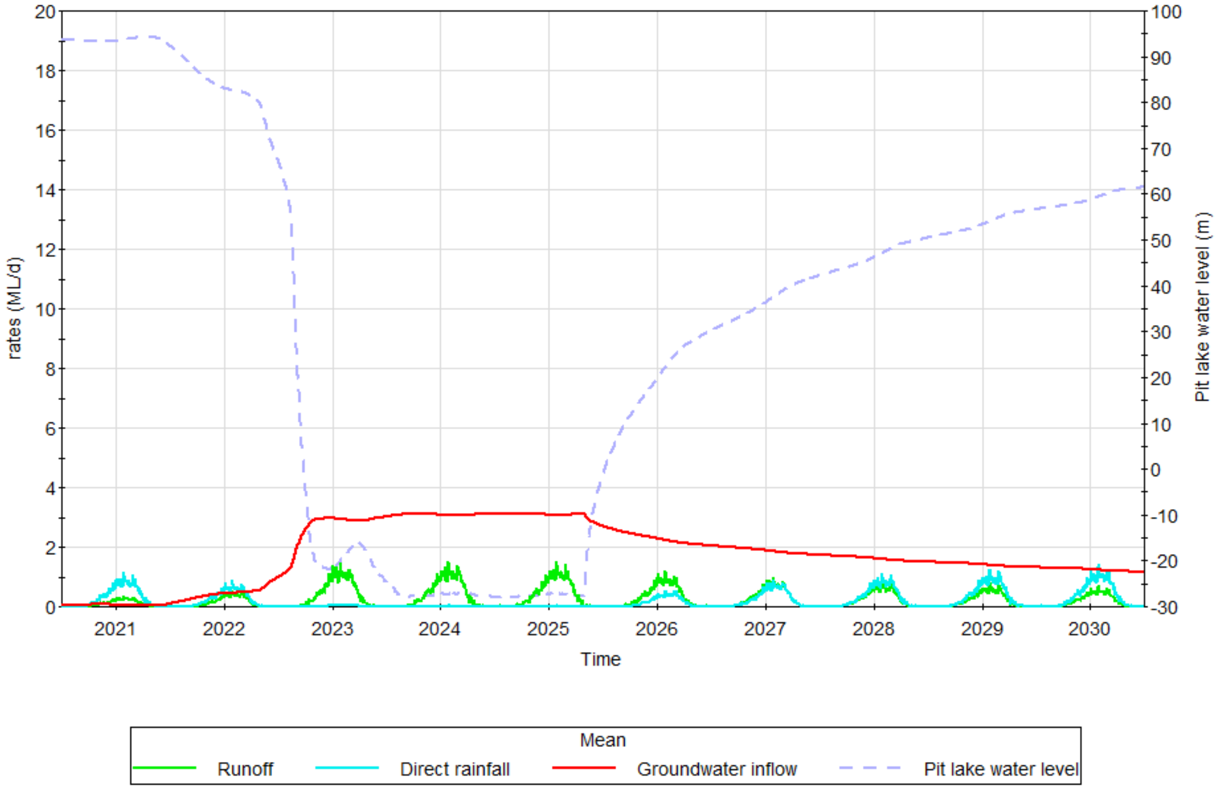

Figure 4-15 Predicted mean Fountain Head Pit Lake level and inflows during dewatering and recovery

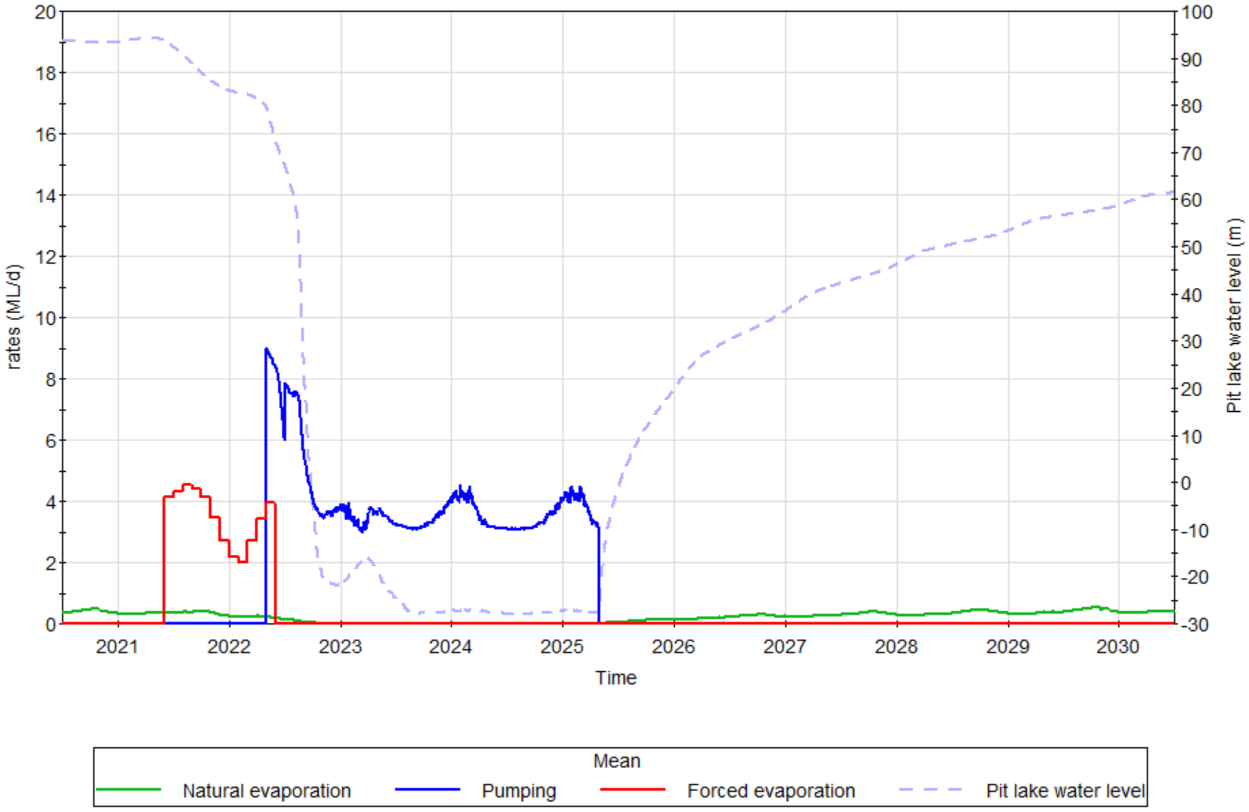

Figure 4-16 Predicted mean Fountain Head Pit Lake level and outflow during dewatering and recovery (mean)

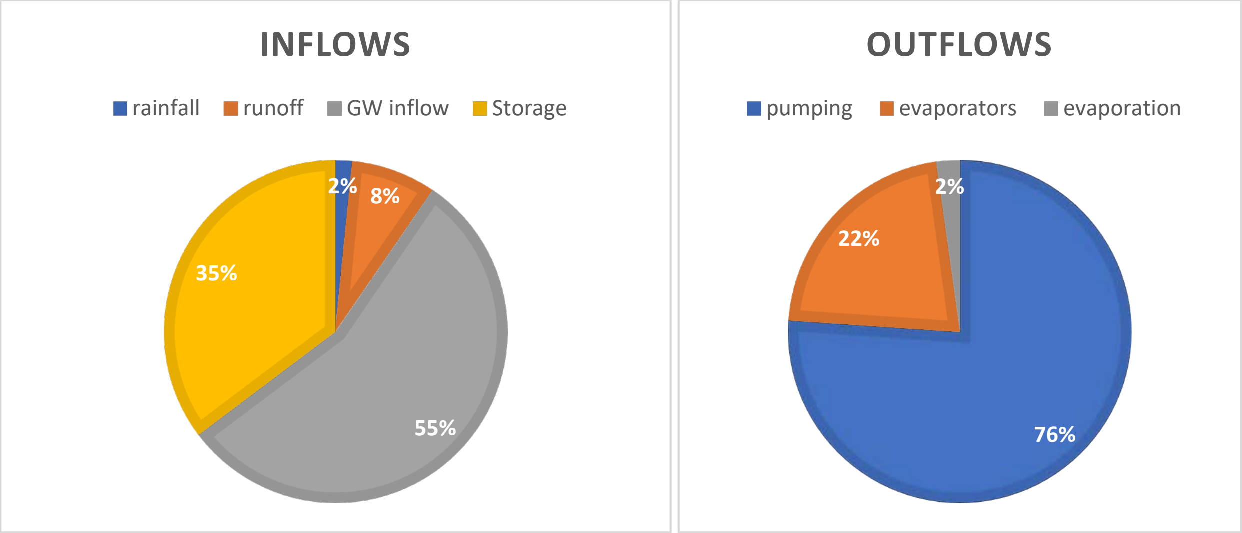

Figure 4-17 Summary of predicted median Fountain Head Pit mass balance for Stage I and II (pit dewatering and mining)

Table 4-6 Predicted Fountain Head Pit water balance summary from June 2021 to April 2025 (end of mining operations)

Component	Inflow [ML]
Rainfall	92
Runoff	465
Groundwater inflow	3222
Initial water storage	2060
Total	5840
Component	**Outflow [ML]**
Forced evaporation	1270
Natural evaporation	127
Pumping (incl. site water consumption)	4443
Total	5840

4.5.2 Aided recovery scenario

The aided recovery scenario consists of draining the Evaporation Pond back to the pit void after mining is completed. The return pumps are turned on at the end of the mining period at a rate of 9 ML/day (assumed to be the same as in-pit pumps used for dewatering). They are turned off as soon as the Evaporation Pond is empty. The Monte Carlo uncertainty analysis predicts that the return pumps would be operational for an average of five days to empty the Evaporation Pond (total volume is on average around 50 ML as this coincides with a low storage volume period). With the end of mining predicted to occur around April 2025, the Evaporation Pond is by then already mostly empty due to the action of the evaporators. The benefit of this option appears negligible under the assumed conditions as the volume in the Evaporation Pond is relatively small compared to the volume of the mine pit void. In practical terms, it is likely that the evaporators would be turned off towards the end of mining period, such that a larger volume of water would accumulate to be returned to the Pit. However, even if the Evaporation Pond were full at around 700 ML, this is unlikely to considerably reduce the number of years until stabilisation occurs, given this is more related on the groundwater system coming into a new equilibrium with the Pit Lake and the balance between evaporation and rainfall. It is likely that the PAF material to be backfilled into the Pit would be adequately submerged by groundwater inflowing at rates above 1 ML/day for the first five or more years post-mining (see Figure 4-14).

4.6 Evaporation Pond water balance and seepage results

4.6.1 Unaided recovery scenario

The predicted Evaporation Pond water level over Stages I and II is illustrated in Figure 4-18 and the equivalent volumes are illustrated in Figure 4-19. From all 200 Monte Carlo realisations, the Evaporation Pond has a 41% likelihood (i.e. 82 of 200 realisations) of exceeding the operational level trigger of 97.4 m AHD. When the maximum operational level is reached, the pit pumps are stopped to reduce the risk of the Evaporation Pond spilling, which delays dewatering pumping.

With this current management option in place, the Evaporation Pond does not reach the spill level in any of the Monte Carlo realisations (the model was tested with all the rainfall events that have occurred since 1890 as per the SILO database). In most realisations, the Evaporation Pond is maintained near the minimum operational volume toward the end of the mining Stage due to the forced evaporation.

The mass balance time series representing the average of all the Monte Carlo realisations is illustrated in Figure 4-20 (inflows) and Figure 4-21 (outflows). During Stage II (mining), the Evaporation Pond water balance is strongly dominated by the pumping from the Fountain Head Pit into the Pond and the action of the evaporators. The evaporators are simulated as being up to four times more efficient than natural evaporation. Groundwater infiltration is predicted to be about equal to natural evaporation, but this component is not well constrained and the resulting uncertainty contributes to the relatively wide probability colour bands shown in Figure 4-18 and Figure 4-19.

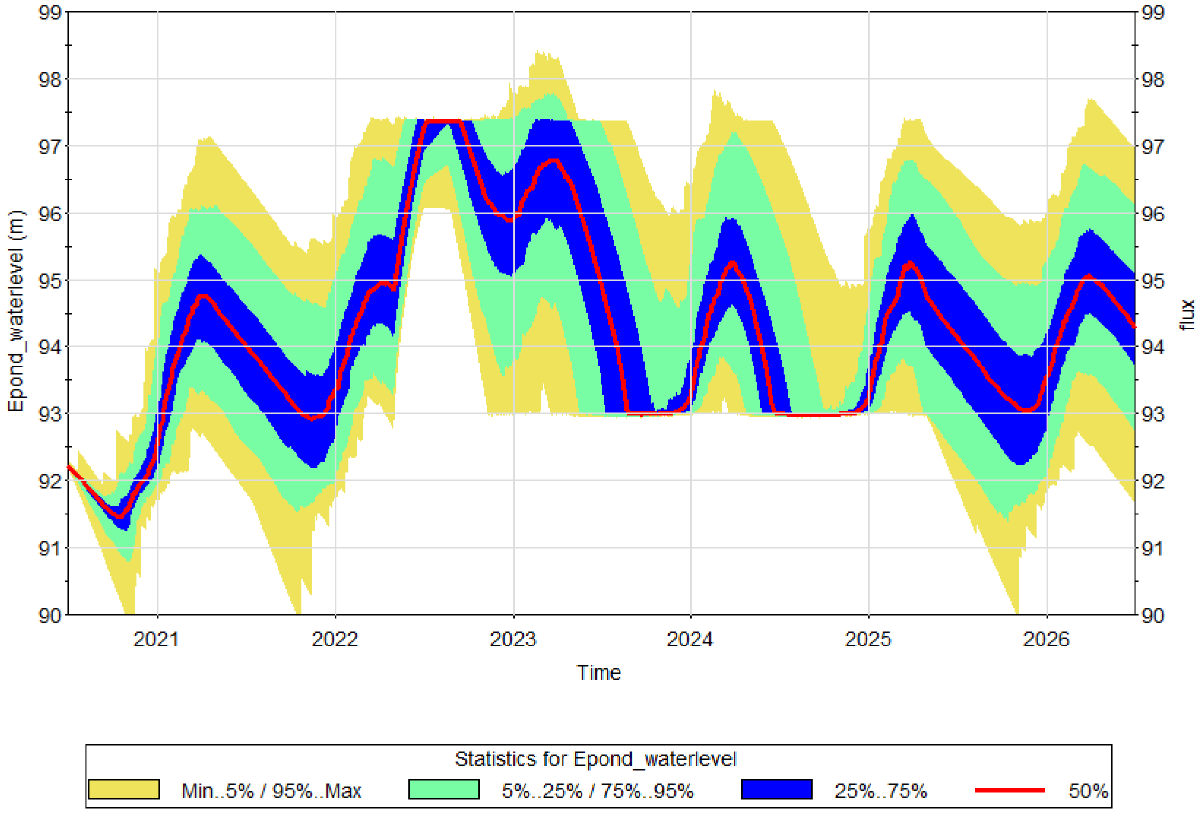

Figure 4-18 Predicted water level in the Evaporation Pond

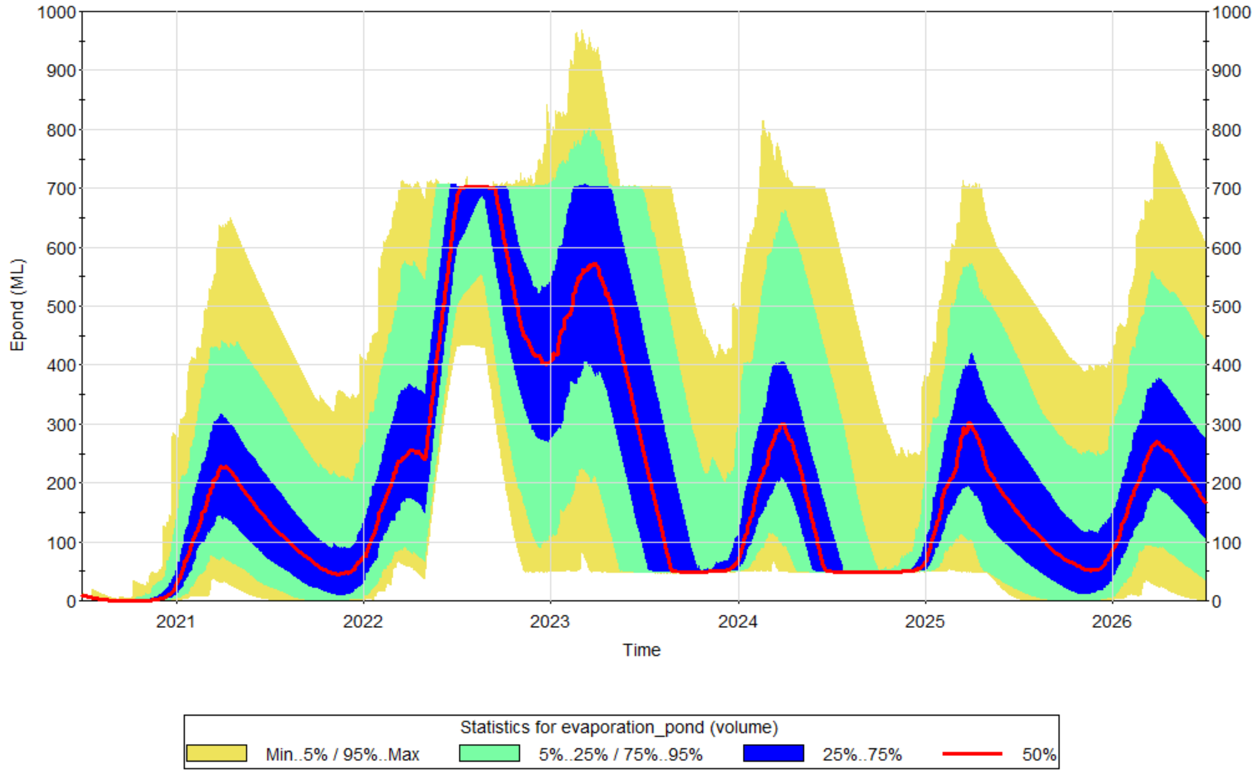

Figure 4-19 Predicted volume of water storage in the Evaporation Pond

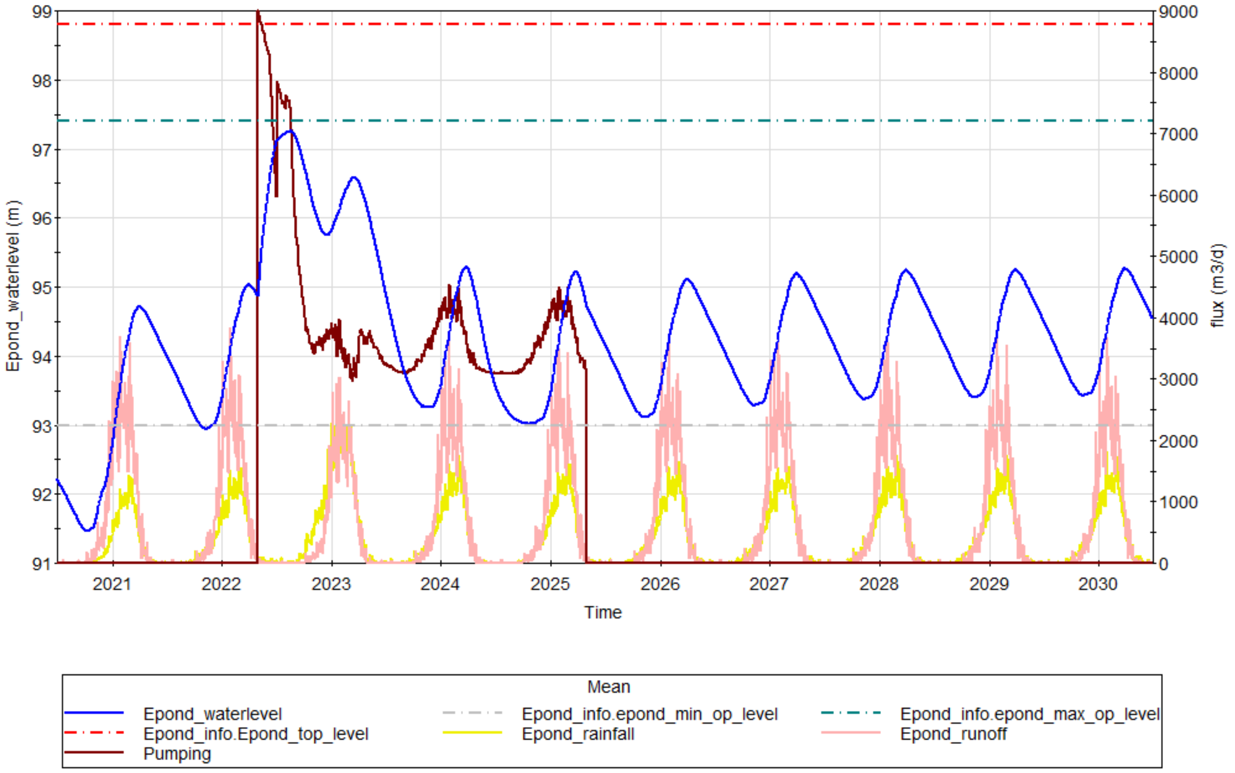

Figure 4-20 Predicted mean Evaporation Pond inflows time series

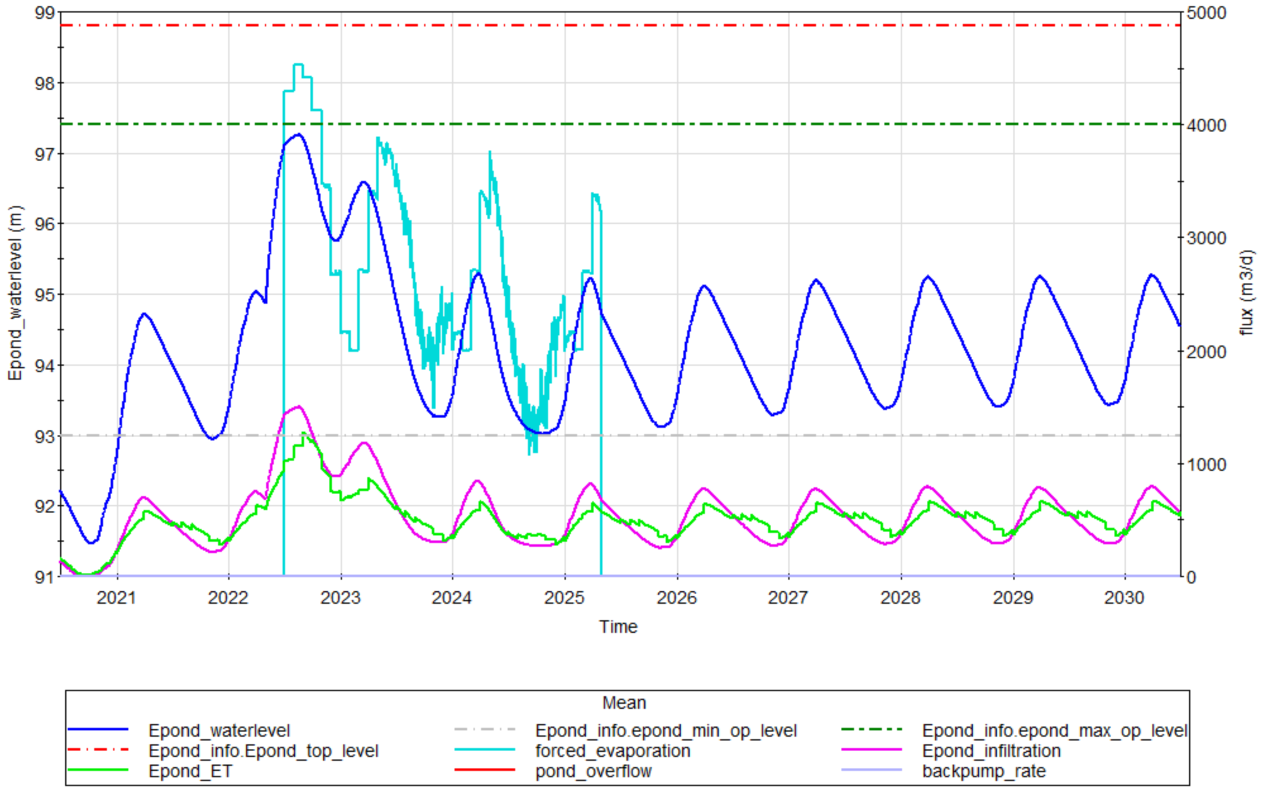

Figure 4-21 **Predicted mean Evaporation Pond outflows time series**

The mass balance summary for the average condition and for the Stage I and II is represented on Figure 4-22, and reported in Table 4-7.For the Stage I (dewatering) and Stage II (mining), 68% of the inflow to the Evaporation Pond is from pit dewatering, 13% comes from incident rainfall and 19% from runoff. The evaporators account for 61% of the outflows, followed by 19% for ground infiltration and 16% for natural evaporation. The remaining 4% is the volume stored in the Evaporation Pond at the end of mining operation.

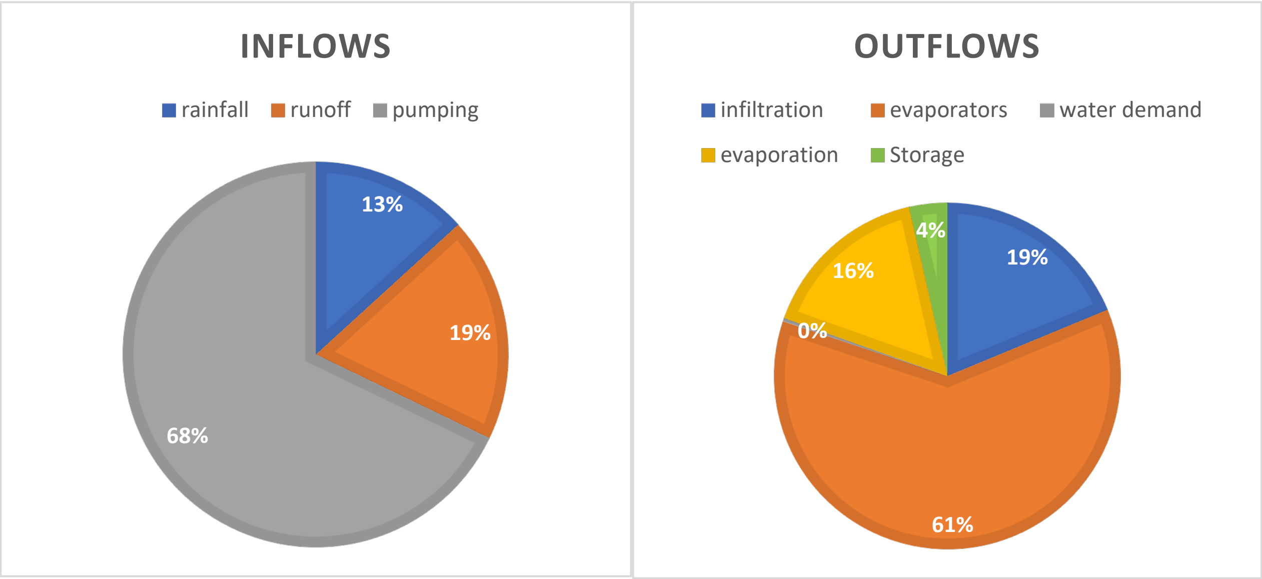

Figure 4-22 **Summary of predicted Evaporation Pond mass balance for Stage I and II (pit dewatering and LOM)**

Table 4-7 Predicted Evaporation Pond water balance summary from June 2021 to April 2025 (end of mining operations)

Component	Inflow [ML]
Rainfall	605
Runoff	886
Pumping	3106
Total	4578
Component	**Outflow [ML]**
Ground infiltration	858
Forced evaporation	2809
Natural evaporation	734
Supply to site water demand	161
Remaining water in Pond	15
Total	4578

4.6.2 Aided recovery scenario

As described in section 4.5.2, the recovery pumps are only active for about five days on average at the end of mining to assist pit water level recovery as only a limited amount of water is stored in the Evaporation Pond (around 45 ML, Figure 4-19). The benefit of returning water back into the Pit appears negligible under the assumed conditions. In practical terms, it is likely that the evaporators would be turned off towards the end of mining period, such that a larger volume of water would accumulate to be returned to the Pit. However, even if the Evaporation Pond were full at around 700 ML, this is unlikely to considerably reduce the number of years until stabilisation occurs, given this is more related on the groundwater system coming into a new equilibrium with the Pit Lake and the balance between evaporation and rainfall.

4.6.3 Operational water level triggers and potential mitigation options

The Evaporation Pond is operating between two operational water levels. The lower threshold set at 93 m AHD aims at keeping a reserve of water of 50 ML to meet site water demand. The upper threshold set at 97.4 m AHD aims at protecting the dam from a 1% AEP 72-hour rainfall event. This event (439 mm, see CDM Smith, 2020b) would conservatively raise the water level in the dam up to around 98.3 m AHD, or 0.3 m from the spillway elevation (98.6 m AHD).

As discussed in Section 4.5.1.1, there are twenty-one cases (i.e. 10.5% of 200 realisations) where the initial dewatering is not achieved by early-November 2022. Sensitivity testing shows that 6% of 200 realisations do not achieve initial dewatering if the operational level were raised to 97.9 m AHD and all but four realisations (2%) are eliminated with an operational level trigger at 98.4 m AHD (noting that these contain higher risk of reaching the spill level – see Section 4.5.1.1).

With the current estimation of uncertainty, there is a 59% likelihood the operational water level trigger will not be exceeded during the 2022/23 and subsequent wet seasons. For the other 41% of cases, pumping within the pit is interrupted for an average of 45 days (with individual cases ranging from 1 to 180 days). This essentially delays in-pit pumping to varying extents during the 2022/23 wet season to a lesser degree in the 2023/24 and 2024/25 wet seasons. While in-pit pumping is interrupted, the Evaporation Pond level is at the operational water level trigger, relying on forced evaporation and infiltration to reduce the water level to balance the inputs from the in-pit pumps.

Mitigation/design options that could be considered include:

- Raising the operational water level trigger (see sensitivity Table 4-5) and/or introduce a staged trigger management scheme, i.e. a series of two triggers, the first reducing pumping rates and the second delaying pumping
- Raising the spillway level to increase the Evaporation Pond capacity thereby allowing for a higher operational water level trigger to reduce the likelihood of pit dewatering interruption
- Divert a portion of the runoff away from the Evaporation Pond to reduce the 1% AEP rainfall event volume thereby allowing a higher operational water level trigger (see discussion at the end of Section 4.5.1)
- Reduce uncertainty in the predictions to better quantify the likelihood of operational trigger exceedances. The current analysis contains considerable uncertainty due to the limited understanding of hydraulic properties of the mined aquifer and the materials beneath the area inundated by the Evaporation Pond, and to a minor degree a lack of calibrated runoff coefficient values. A better understanding of groundwater infiltration and runoff through field investigations could help reduce future uncertainty.

4.7 Fountain Head Lake

With the current conceptualisation and adopted parameters, the GoldSim model predicts that Fountain Head Lake exceeds the spill level and discharges to the north of the site every-year during the wet season in alignment with PNX site experience (one Monte Carlo realisation is illustrated in Figure 4-23). The Lake water level has on average 30 cm of seasonal fluctuation between the dry and wet season (Figure 4-24), reflecting the limited range of elevations represented by the digital elevation model for that area (i.e. bathymetry data below the Lake water level at the time of the survey is not currently available). It should be noted that once the water level reaches the spill level (98 m AHD) it is instantaneously removed by the model. The median predicted flow rate out of Fountain Head Lake is 2850 ML/y with 5th – 95th percentile flows of 500 – 5900 ML/y.

The Fountain Head Lake water balance summary for the period covering Stages I and II is illustrated in Figure 4-25 and summarised in Table 4-8. The Lake inflows are dominated at 82% by runoff from the catchments to the south. Incident rainfall accounts for 7% of the inflow, while the runoff to the Lake from the IWL (including overflow of the sediment dam E3) and overflow from sediment dams W2 and W3 account for 4% and 7%, respectively. The outflows are dominated by the overflow downstream of the system (91%) while natural evaporation accounts for the remaining 9%.

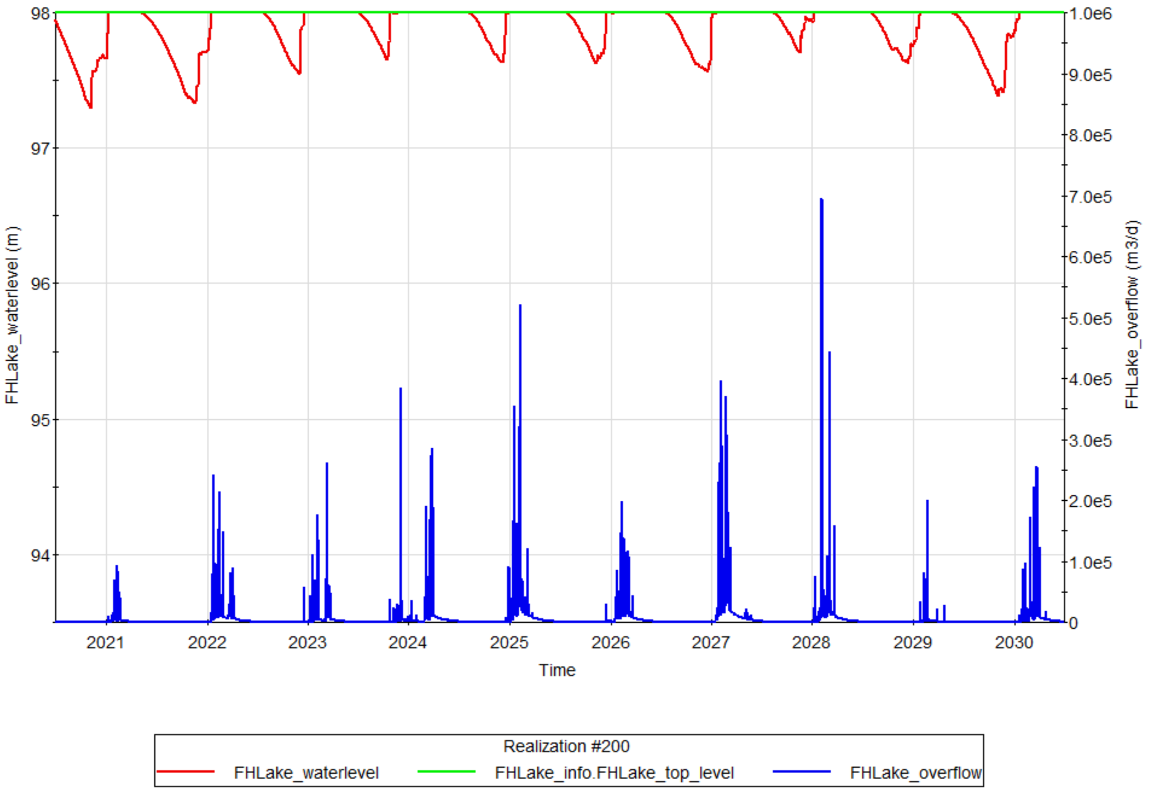

Figure 4-23 Example of predicted Fountain Head Lake water level and overflow rate

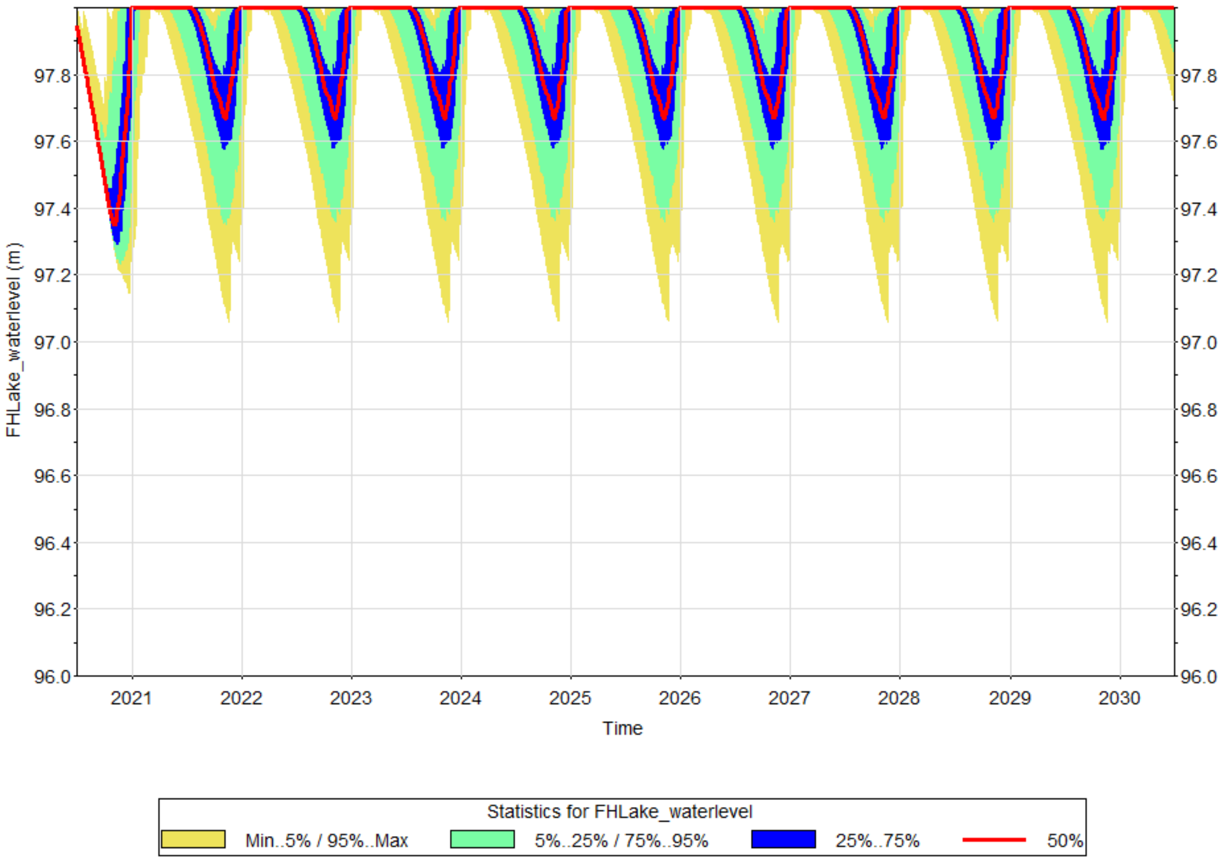

Figure 4-24 Probabilistic distribution of the predicted Fountain Head Lake water levels

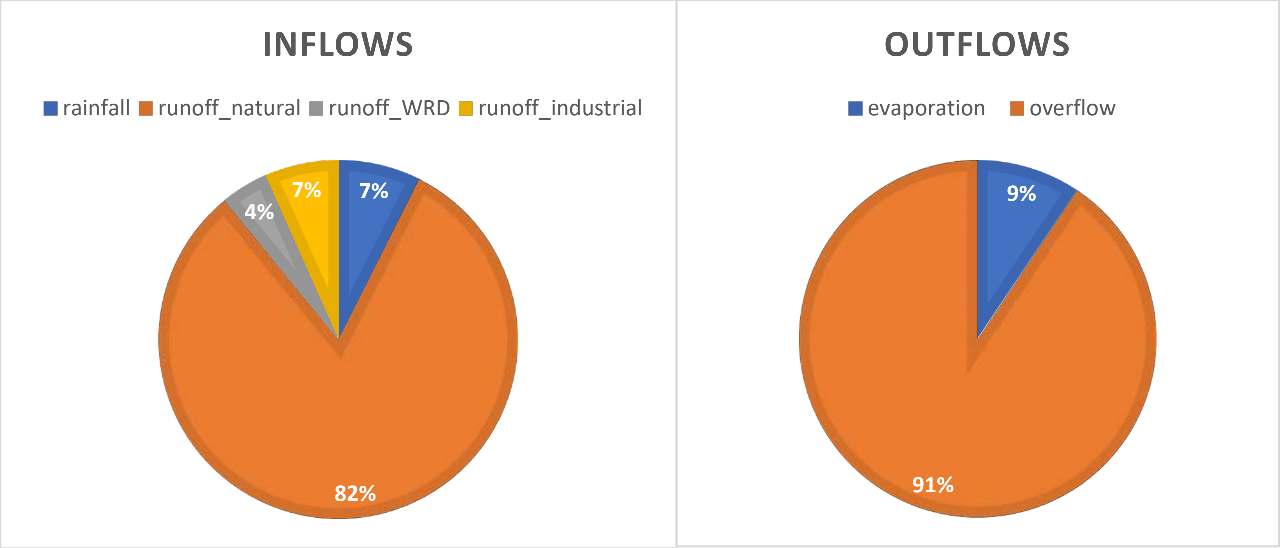

Figure 4-25 Summary of predicted median Fountain Head Lake mass balance for Stage I and II (pit dewatering and mining)

Table 4-8 Predicted Fountain Head Lake water balance summary from June 2021 to April 2025 (end of mining operations)

Component	Inflow [ML]
Runoff on Natural catchment	10 020
Direct rainfall	906
Waste rock runoff and sedimentation dam E3 overflow	523
Sedimentation dams W2 and W3 overflow	813
Total inflows	12 261
Component	**Outflow (ML)**
Lake overflow	11 107
Natural evaporation	1149
Total outflows	12 261

4.8 Water balance predictive uncertainty

The Monte Carlo analysis produces probabilistic predictions that reflect the current understanding of the uncertainty residing within each of the water balance input parameters. This approach is useful for considering the likelihood of certain metrics being exceeded (e.g. operational water level trigger in the Evaporation Pond). However there still remain a number of key aspects and parameter values that could be better constrained so that the predictive uncertainty is further reduced. These include, but are not limited to:

- The hydraulic conductivity value of the deeper part of the aquifer (i.e. below existing mine void) – it is not known whether the range of model parameters applied have adequately captured the actual properties of the aquifer, given the intersection of water-bearing fractures could be negligible at depth, or significant if faulted structures are intersected by mining operations
- Groundwater inflow predictions to the pit range from around 2.3–4.2 ML/d during the mining period and are simulated using a steady state analytical solution rather than transient model – this means that the model does not directly account for the storage properties of the aquifer

- The hydraulic properties of the materials beneath and adjacent to the Evaporation Pond are not well-constrained by field information and so the range applied in the Monte Carlo analysis predictions is large to cover a wide range of possible infiltration rates
- The efficiency of the evaporators is a critical assumption for managing water levels in the Evaporation Pond and the monthly values adopted by PNX are not varied in the Monte Carlo analysis – if in practice the evaporators do not perform as effectively as expected, the likelihood of trigger exceedance will increase

To reduce the predictive uncertainty of the water balance modelling, field investigations could be conducted to determine deep and adjacent aquifer properties around the pit and the hydraulic properties of the Evaporation Pond material in combination with frequent and spatially well-distributed environmental monitoring.

4.9 Water quality

4.9.1 Overview

A non-reactive solute balance has been paired with the water balance model to estimate the concentrations of potential contaminants in the Fountain Head Pit, Evaporation Pond and Fountain Head Lake (representative concentrations for each source water component are reported in Section 3.5 or in Table 4-10). The modelling is conservative, such that there is no decay or transformation of the source water components into other compounds and no precipitation due to geochemical reactions or dissolution from rock material. Two scenarios solute balance model are considered:

- The first scenario represents salinity as total dissolved solids (TDS) but is not calibrated to historical data and therefore the results should be considered in a relative sense rather than as absolute predictions
- The second scenario is a normalised approach that can be applied to any potential contaminant under the assumption that the natural surface water environment has effectively no background concentration of that contaminant (at least in a relative sense). The source is exclusively due to the mining and processing operation (e.g. through runoff from the waste rock area or though groundwater inflow into the mined pit). A prediction of the concentrations of a potential contaminant can be obtained by multiplying the normalised concentration value at a future time (assumptions described below) by the estimate of the source concentration.

4.9.2 Fountain Head Pit

As an initial assessment, for the TDS estimation (scenario 1), groundwater and rainfall are assumed to have salinities of 246 and 7 mg/L respectively (Table 3-1). Salinity is increased by direct evaporation from the pit water surface and the evaporators (assuming the airborne salts return to the water bodies). The predicted change in Fountain Head Pit water quality over time is shown in Figure 4-26 for the first seven years post-mining and in Figure 4-27 for 500 years post-mining. Modelling results show for the first seven years post mining the concentration of chemicals within the Pit Lake will remain within the range of existing concentrations, given groundwater inflow is initially the primary source of water. At 500 years post-mining solutes are predicted to concentrate due to the dominance of evaporation over rainfall, such that solutes in the Pit Lake are predicted to reach about two and a half times the current concentration.

Initially, direct evaporation of the Pit Lake is small at the end of the mining operation as the Pit Lake has a small area. As the water level rises in the pit, evaporation increases progressively and equilibrates with inflows (groundwater and rainfall) at the Pit Lake stabilisation level. Post-Pit Lake stabilisation, the Pit Lake acts largely as a groundwater sink (i.e. groundwater flows towards the lake due to the evaporative losses from the Pit Lake surface) but with a moderate throughflow component, as determined by the groundwater model (see Section 5). Once the Pit Lake water level reaches 90 m AHD, a throughflow flux is applied where outflow equals 20% of inflow and this moderates the evapotranspiration process.

Accurate groundwater level measurements with a broader spatial coverage across the site would be needed to assess the error introduced by these model assumptions. The solute balance model is designed to be conservative by assuming there is no dispersion of solutes away from the pit or mineral precipitation within the water body.

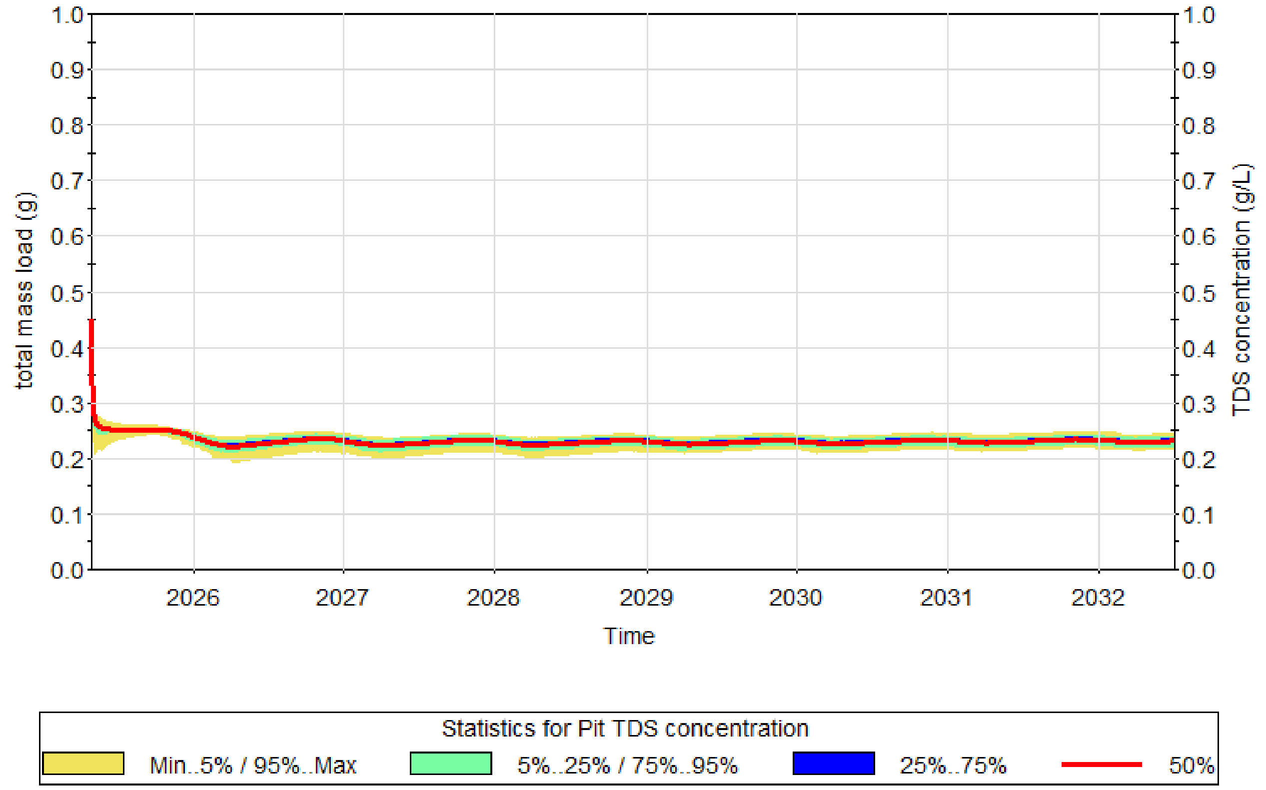

Figure 4-26 Predicted mass load and water TDS in the pit for the first seven years post-mining

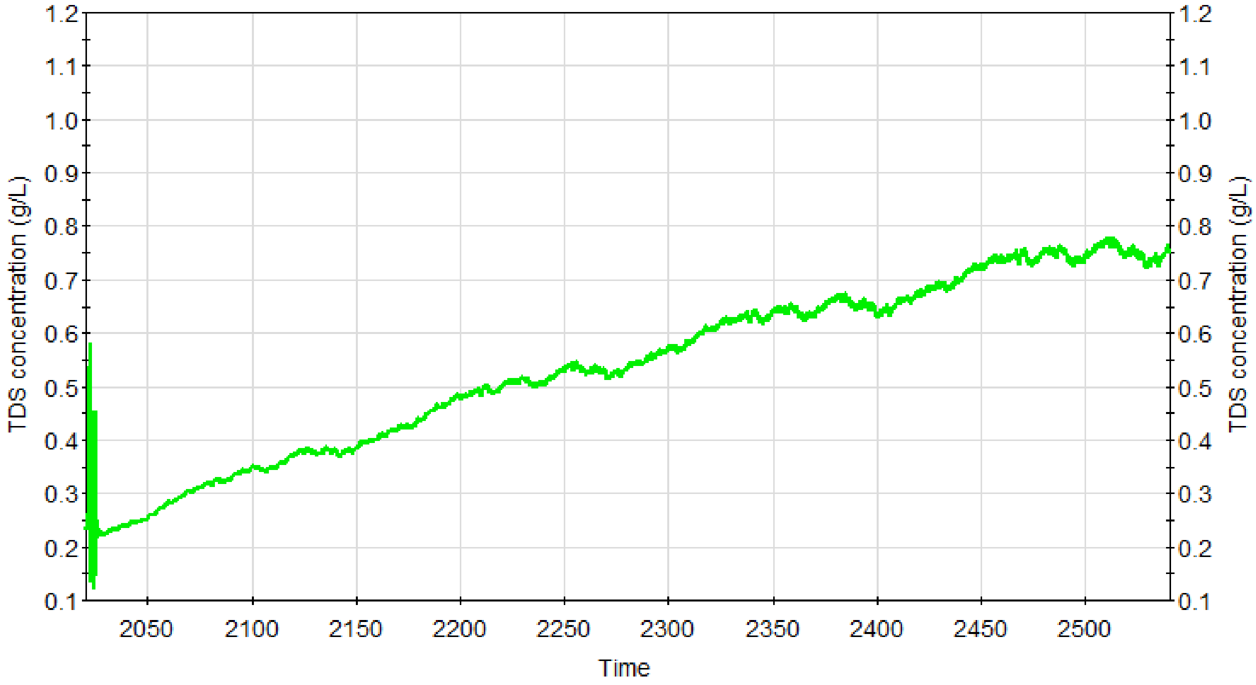

Figure 4-27 Predicted bulk TDS of the Pit Lake over 500 years post-mining (median case)

For other groundwater chemical components, a normalised approach has been derived by assuming the sole source of contamination (e.g. existing metal concentrations) arises from groundwater inflow (scenario 2). To calculate the chemical concentration at a given time, the source concentration from groundwater is adjusted in accordance with the relationship presented in Figure 4-28. The resulting concentration estimates 30 years post-mining and 500 years post-mining are summarised in Table 4-9.

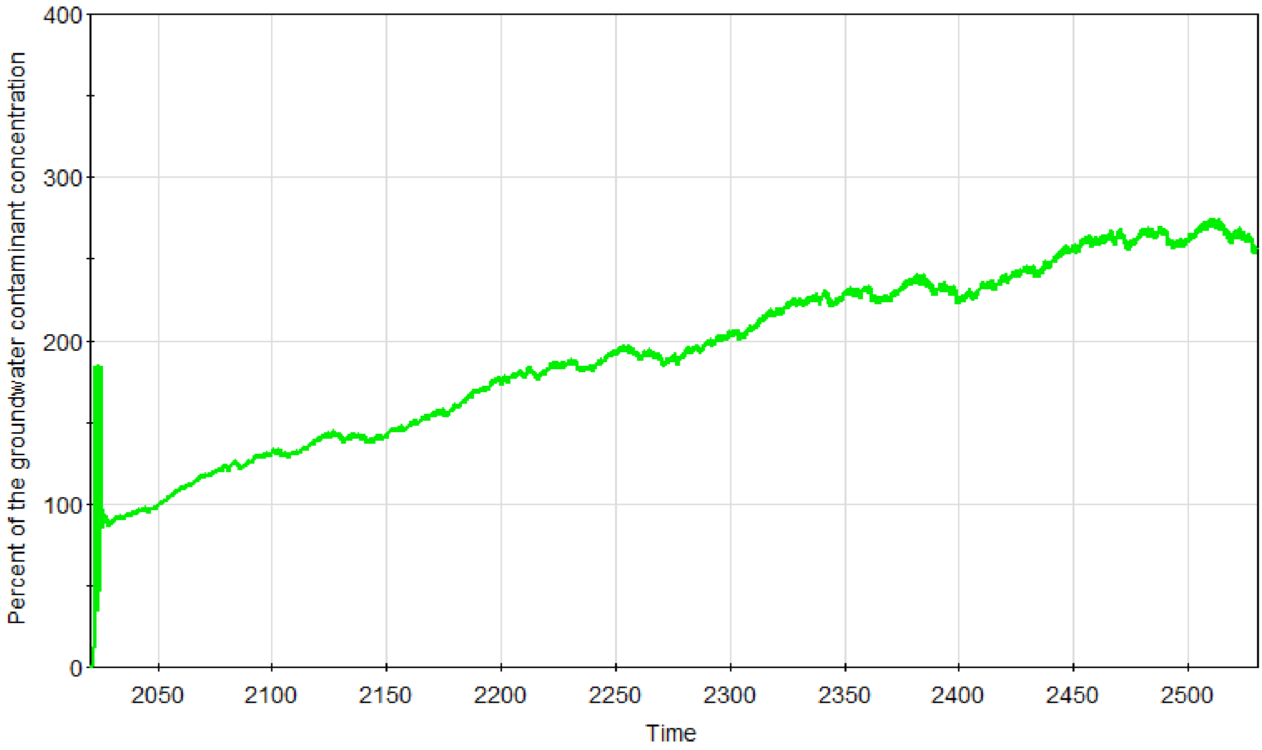

Figure 4-28 **Predicted normalised modelled pit water quality over time (median value), expressed as a percentage of the groundwater contaminant concentration**

Table 4-9 **Current and predicted concentration of water chemical elements after 30 and 500 years in Fountain Head Pit**

Parameter	ANZECC, 2000 Guideline – Aquatic Ecosystem (80% protection)	ANZECC, 2000 Guideline – Stock Drinking Water	Current[1]	30 years	500 years
EC (uS/cm)	20 or 250	-	409	407	1083
TDS (mg/L)	-	5000	266	265	704
Hardness (mgCaCO3/L)	-	-	141	140	373
Total Alkalinity as CaCO3 (mg/L)	-	-	136	135	360
Calcium (mg/L)	-	1000	13	13	34
Chloride (mg/L)	-	-	5.5	5.5	15
Magnesium (mg/L)	-	-	25	25	66
Potassium (mg/L)	-	-	2	2	5
Sodium (mg/L)	-	-	29	29	77
Sulfate (mg/L)	-	1000	68	68	180
Aluminium (µg/L)	150	5000	5	5	13
Arsenic (µg/L)	140	500	567	564	1501
Copper (µg/L)	2.5	400 or 5000	0.6	0.6	2
Iron (µg/L)	-	-	26	26	69
Zinc (µg/L)	31	20 000	4.4	4.4	12

[1] Current concentrations are for dissolved species not total concentrations

4.9.3 Evaporation Pond (unaided recovery scenario)

A non-reactive mass balance model has also been constructed to estimate the concentration of solutes in the Evaporation Pond as described for the Fountain Head Pit in the following Section. Similarly, groundwater and rainfall are assumed to have salinities of 246 and 7 mg/L respectively. The resulting predicted TDS concentration in the Evaporation Pond is illustrated in Figure 4-29. Maximum salinity in the Pond is predicted to be reached during the dry seasons of 2023 and 2024 when the Pond is essentially emptied via forced evaporation. After approximately five years post-mining the system resets to close to background salinity as the balance between inputs and outputs stabilises.

The normalised approach (Figure 4-30) shows that any contaminant present in the groundwater is on average likely to be found in higher concentrations during Stage II and then decrease to below groundwater concentrations after 2026, being then dominated by rainfall inputs.

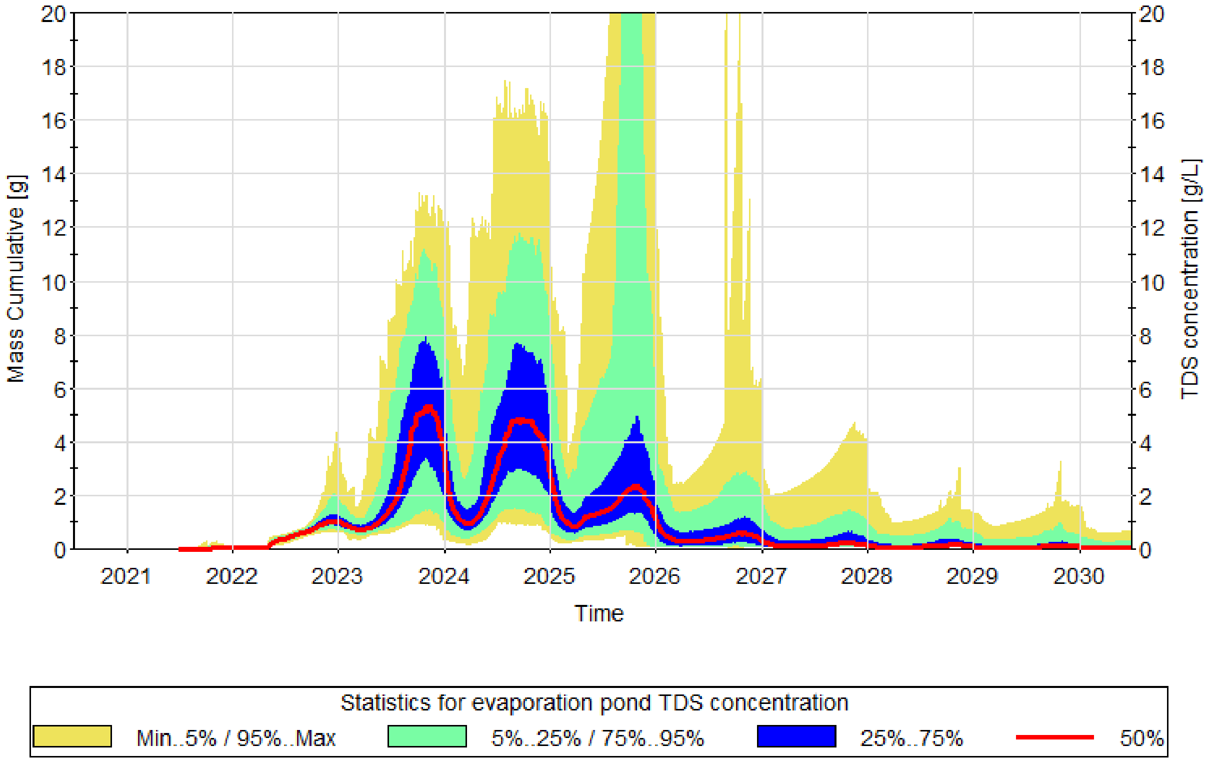

Figure 4-29 Predicated water salinity in the Evaporation Pond

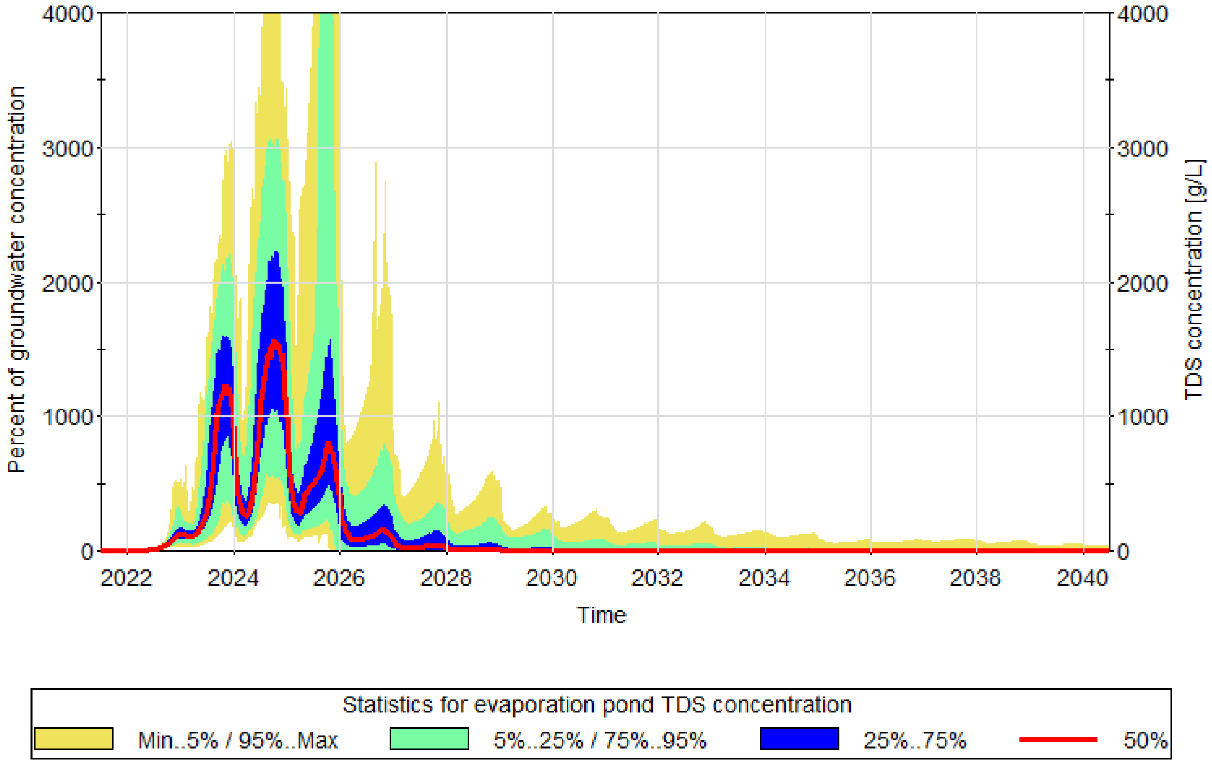

Figure 4-30 **Predicted normalised approach expressing Evaporation Pond concentration as a percent of the groundwater contaminant concentration**

4.9.4 Fountain Head Lake

Regarding the Fountain Head Lake salinity modelling, the TDS of rainfall is also set at 7 mg/L and the water from runoff attributed salinity values depending on the landuse within the catchment (see Table 4-10). For the waste rock area and industrial/hardstand, the source concentration is conservatively set at the maximum of on-site measured TDS (1000 mg/L) from historical records. The natural runoff of 105 mg/L is estimated at half the average historical TDS records in the Fountain Head Lake. The initial salinity is set at 200 mg/L. The water feeding into sediment dams carries the area weighted concentration of their runoff sources.

Table 4-10 **Fountain Head Lake catchment parameters**

Land-use	TDS [mg/L]	As-dissolved (µg/L)
IWL runoff (incl. E3 and direct)	1000	150[1]
Industrial/hardstand area runoff (incl. W2 &W3)	1000	150[1]
Natural area runoff	105	1.8
Fountain Head Lake initial concentration	200	7.6

Note: [1] Approximate highest water extract arsenic concentration from existing WRS and ore (from Figure 28; EGI 2020)

The results of TDS evolution (scenario 1) are illustrated in Figure 4-31. The TDS of the Fountain Head Lake is seasonal and rises during the dry season due to the dominance of evaporation and declines during the wet season due to the dilution and flushing related to the runoff from the natural catchment. The mine operations have only a limited and temporary effect on Lake salinity due to the annual flushing of the Lake by natural runoff.

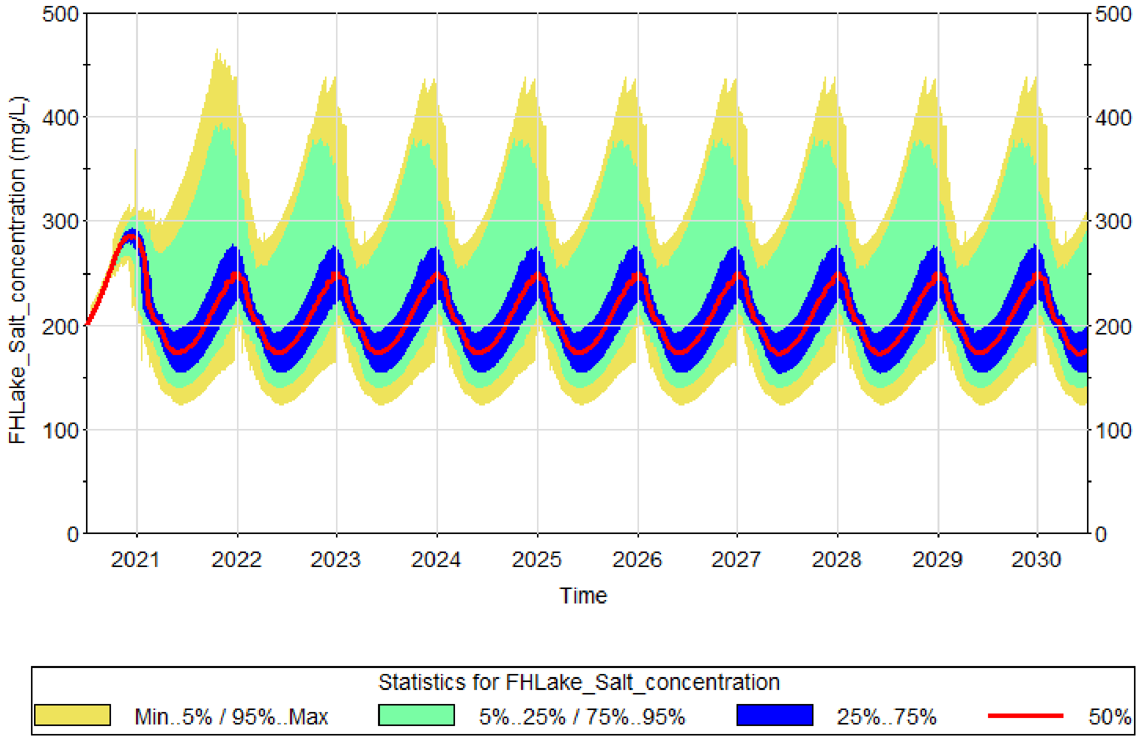

Figure 4-31 Predicted water salinity in the Fountain Head Lake

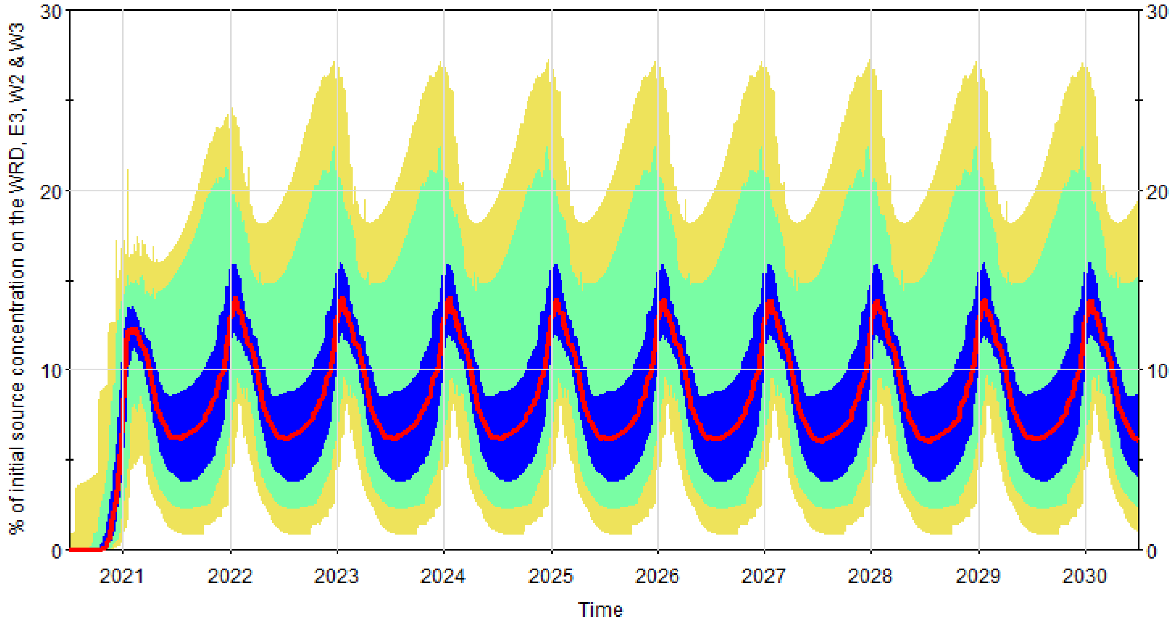

Figure 4-32 Predicted percentage concentration of a potential contaminant (compared to a waste rock runoff source) in FH Lake

The normalised TDS prediction (scenario 2) assumes that the source of solutes is provided by runoff from the IWL and overflow from sedimentation dams E3, W2 and W3 (with assumed concentrations of 1000 mg/L). Conservatively, the scenario assumes that no attenuation occurs post-mining and that the potential solutes of interest are still released post-mining. The result is illustrated in Figure 4-32, showing that solute concentrations in Fountain Head Lake are lower at only 26 percent the source concentration at the maximum and usually about 13% of the concentration that would be found in the IWL or in the sedimentation dams E3, W2 and W3. The annual flush shows that the concentration gets annually reset to a minimum of about 7% of the source concentration.

4.9.5 Comparison to water quality guidelines

A comparison of Fountain Head Lake and Fountain Head Pit Lake solute concentrations, specifically dissolved arsenic, to ANZECC guidelines (140 and 500 µg/L for Aquatic Ecosystem (80%) and Stock Drinking Water respectively) has been made using conservative assumptions, under a new model scenario. A representative arsenic concentration for runoff from the IWL and Industrial/hardstand areas was assumed to be the approximate highest water extract arsenic concentration value (150 µg/L) from existing WRS and ore (see Figure 28; EGI 2020). Importantly, this conservatively over-estimates the plausible runoff concentrations given these runoff areas are unlikely to have the maximum extracted concentration and the geochemical and other processes (e.g. dilution over time) that would result in lower arsenic concentrations are not included.

When combined with inflows and solute loads from each contributing source, the predicted arsenic concentration in Fountain Head Lake is shown in Figure 4-33 from 2020 – 2030. Predictions show that there are no instances where the arsenic concentrations exceed the ANZECC guidelines for Stock Drinking Water or Aquatic Ecosystems (80%). Using the total inflow volumes for the mining period in Table 4-8, the flow-weighted average arsenic concentration is well under the guideline at around 11 µg/L. It should be noted that all IWL and site infrastructure surfaces are attributed with a conservatively high arsenic concentration that are constant in time, and in reality, this not likely to be the case (i.e. significantly lower concentrations after the first large rainfall event).

Currently around 8% of the arsenic load comes from the natural catchment, 56% from the industrial hardstand areas and 36% from the IWL (representing 88, 7 and 5% of the inflows respectively). Under the modelled assumptions the exceedance of the Aquatic Ecosystem (80%) guideline is not predicted to occur unless the runoff arsenic concentration of these areas was > 500 µg/L. Further analysis and testing of likely runoff concentrations from each contributing area is recommended to reduce the uncertainty of this assessment. It should also be noted that there is currently no time-series water level or flow data from Fountain Head Lake to calibrate the rainfall-runoff model with more confidence.

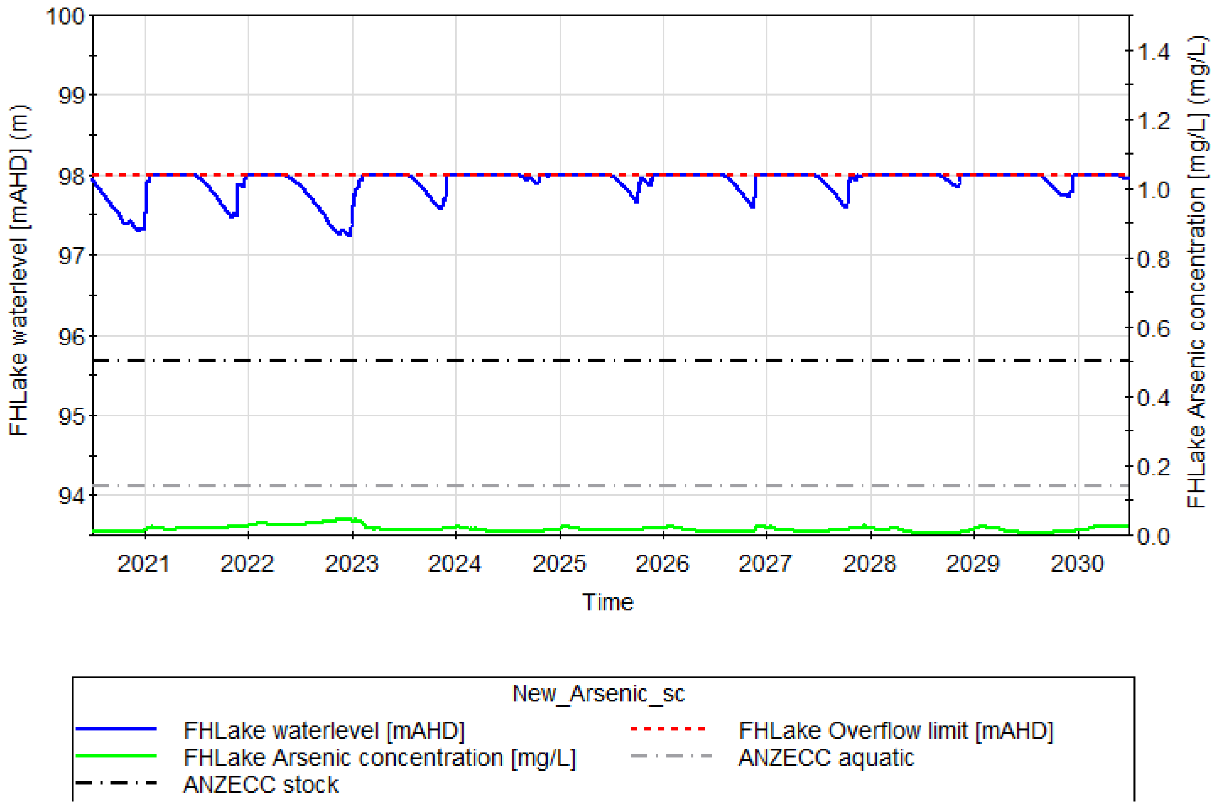

Figure 4-33 Predicted conservative arsenic concentration in Fountain Head Lake (median case)

When combined with inflows and solute loads from each contributing source, the predicted arsenic concentrations in Fountain Head Pit Lake are shown in Figure 4-34 from 2020 – 2030. The Fountain Head Pit Lake arsenic concentration is currently greater than the ANZECC criteria, likely due to the historical interaction with waste rock and/or processed material. As the evaporators reduce the volume of the Pit Lake, the concentration increases but then quickly declines as the mine is dewatered by in-pit pumping. The concentration reduces because groundwater has a relatively low arsenic concentration, and the Pit Lake inputs are additionally diluted by rainfall and runoff. When the Pit Lake recovers, these lower arsenic concentration waters then again dominate the water balance inputs and the Pit Lake arsenic concentration remains low. The post-mining Pit Lake water chemistry is likely to be altered when the PAF stockpile material is stored sub-aqueously and this has not yet been modelled or assessed in any detail.

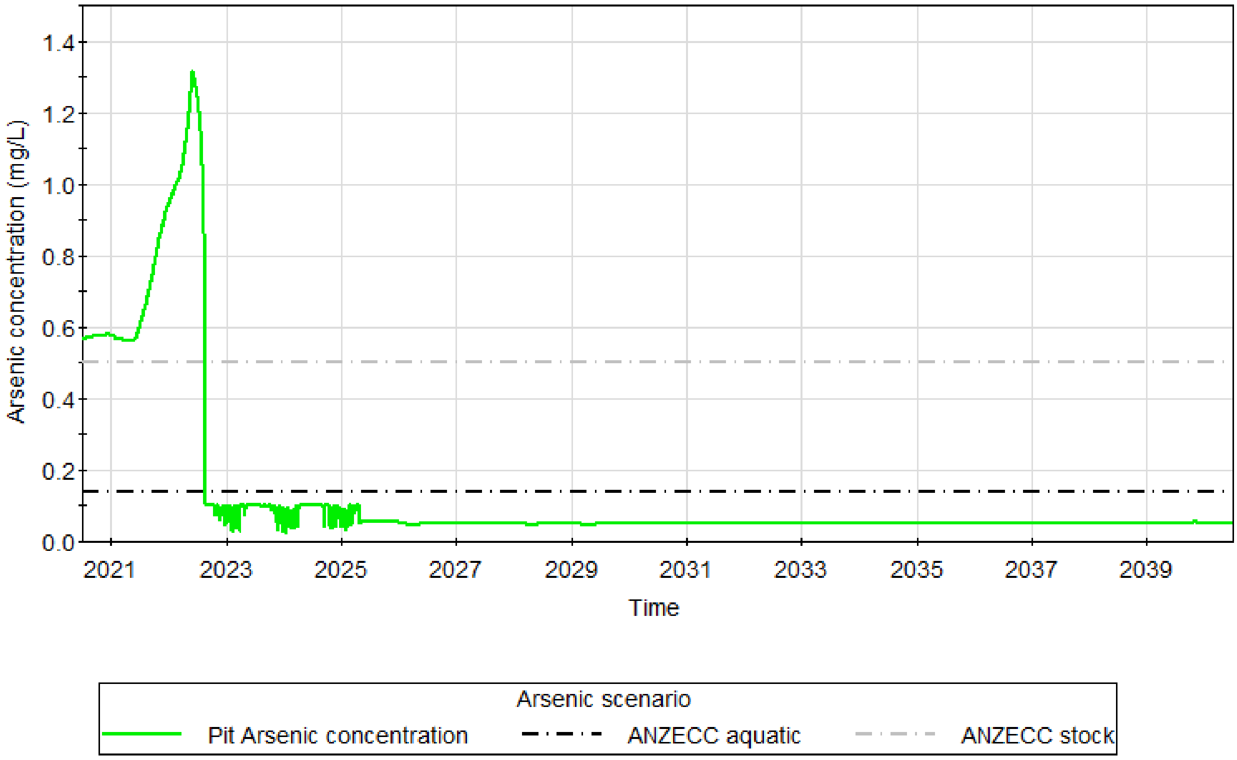

Figure 4-34 Predicted arsenic concentration in Fountain Head Pit Lake (median case)

4.10 Key findings

Key findings from the water and solute balance modelling include:

- Fountain Head Pit
    - Stage I (initial dewatering) should be completed on average by mid-September 2021 with significant delays to the initial 2021 dewatering phase in only 10.5% of realisations due to lack of storage capacity
    - Applying the Evaporation Pond operational water level trigger (97.4 m AHD), in-pit pumping has a 41% likelihood of being temporarily interrupted during the mining period due to lack of storage capacity
    - The likelihood of interruption to in-pit pumping due to lack of storage capacity can be reduced to 28 and 11.5% by raising the Evaporation Pond operational water level trigger to 97.9 and 98.4 m AHD, respectively (not accounting for any structural/safety dam design considerations that may be required or necessarily a 1% AEP rainfall event)
    - After mining, Fountain Head Pit Lake water levels are predicted to stabilise at around 93.5 m AHD by 2075 (50 years post-mining)

  - After 500 years, the TDS concentration in the Pit Lake is predicted to be around two and a half times the groundwater concentration if the Pit Lake functions as a localised sink for groundwater with a throughflow component that is approximately 20% of groundwater inflow as predicted in the groundwater model (Section 5) – this is expected to be similar to the condition if the brownfields mining operation does not occur even in the absence of the Project
  - Conservative representation of arsenic concentrations within Fountain Head Pit Lake and contributing sources, show the current exceedance of the ANZECC guideline for stock drinking water is continued until in-pit pumping dewatering stage where large groundwater inflows dilute and replace the existing water storage
- Evaporation Pond
  - The Evaporation Pond has 41% likelihood of temporarily reaching the operational water level trigger of 97.4 m AHD during the mining period (see above for sensitivity testing of this trigger)
  - Reaching the spill level (98.6 m AHD) is not predicted but there is a 10.5% likelihood of significant delay due to lack of storage capacity to achieving the initial Fountain Pit dewatering in 2021 (see finding above)
  - Predicted solute concentrations rise during mining due to forced evaporation but a concentration that is lower than groundwater is predicted within a few years post-mining
  - There remains considerable uncertainty in the groundwater seepage component of the Evaporation Pond water balance due to the uncertainty of the hydraulic parameters of the materials beneath the Pond – better characterisation of the spatial variability of on-site material saturated hydraulic conductivity (i.e. at steady state) would improve future constraints on Evaporation Pond infiltration rates and improve predictive uncertainty
- Fountain Head Lake
  - Modelling shows that runoff from the catchment to the south flushes the lake volume each wet season, with water regularly discharging to the north of the site
  - Conservative representation of potential arsenic runoff concentrations from site infrastructure and the IWL (150 µg/L) suggest the ANZECC guideline for Aquatic Ecosystems (80%) is unlikely to be exceeded under the current model assumptions – further testing of runoff concentrations from each contributing area is recommended to reduce the model uncertainty in addition to re-calibration using time-series flow and/or level data from Fountain Head Lake
  - No exceedances of the ANZECC guidelines discussed here are predicted under current model assumptions unless runoff sources had constant arsenic concentrations > 500 µg/L (considered highly unlikely)
  - It is likely that the Lake interacts with the local groundwater system but there is currently insufficient time-series Lake and groundwater level data to quantify this exchange

Section 5 Groundwater dynamics

5.1 Overview

A numerical groundwater model has been developed to interface with the GoldSim water balance model (Fountain Head Pit dewatering and Evaporation Pond components) to generate water table surfaces that can be used to interpret flow patterns and advective solute transport. At the current study Stage, the results of the groundwater model are considered preliminary because of a lack of relevant hydraulic property data that can be used for model refinement and model calibration. The development of the groundwater model is based on the following simplifications:

- The study site is cut by a series of faults (URS, 2006 and PNX, 2020)
  - Because of a lack of information on the orientation and dimensions of the fault zones, it is difficult to characterise the effects of the faults in the numerical model
  - The fault zones are not considered in this assessment
- The geological model is not available at the time of reporting
  - The HSUs in the study area is simplified to be homogeneous and isotropic
- The interaction between surface water bodies and groundwater is unclear
  - Only major watercourses are considered in this study

5.2 Numerical model

5.2.1 Model domain

A three-dimensional numerical groundwater model has been developed using the USGS MODFLOW code (NWT) and Groundwater Vistas graphical user interface. Figure 5-1 presents the outer boundary conditions of the model domain, which is approximately 10 km by 10 km and centred on the Fountain Head Pit. The model domain is of sufficient size to capture the key stresses imposed on the groundwater system and their area of influence without incurring significant boundary effects.

The model surface, representing the ground surface, has been sourced from high resolution survey data (provided by PNX), and a 25x25 m digital elevation model (ELVIS data) outside the high-resolution survey area. The model base is set at -80 m AHD, which is approximately 50 m below the pit bottom at the final mining Stage.

Figure 5-2 presents the model mesh using a structured grid. The size of relatively coarse grid is 50x50 m. The cells in the vicinity of the Pit Lake have been refined to be 25x25 m. The model has four layers with the same mesh refinement in plan. The thickness for each layer is approximately 15 m, except for the top layer, which is approximately 140 m in order to accommodate the time-varying pit water level that can drop down to approximately -28 m AHD.

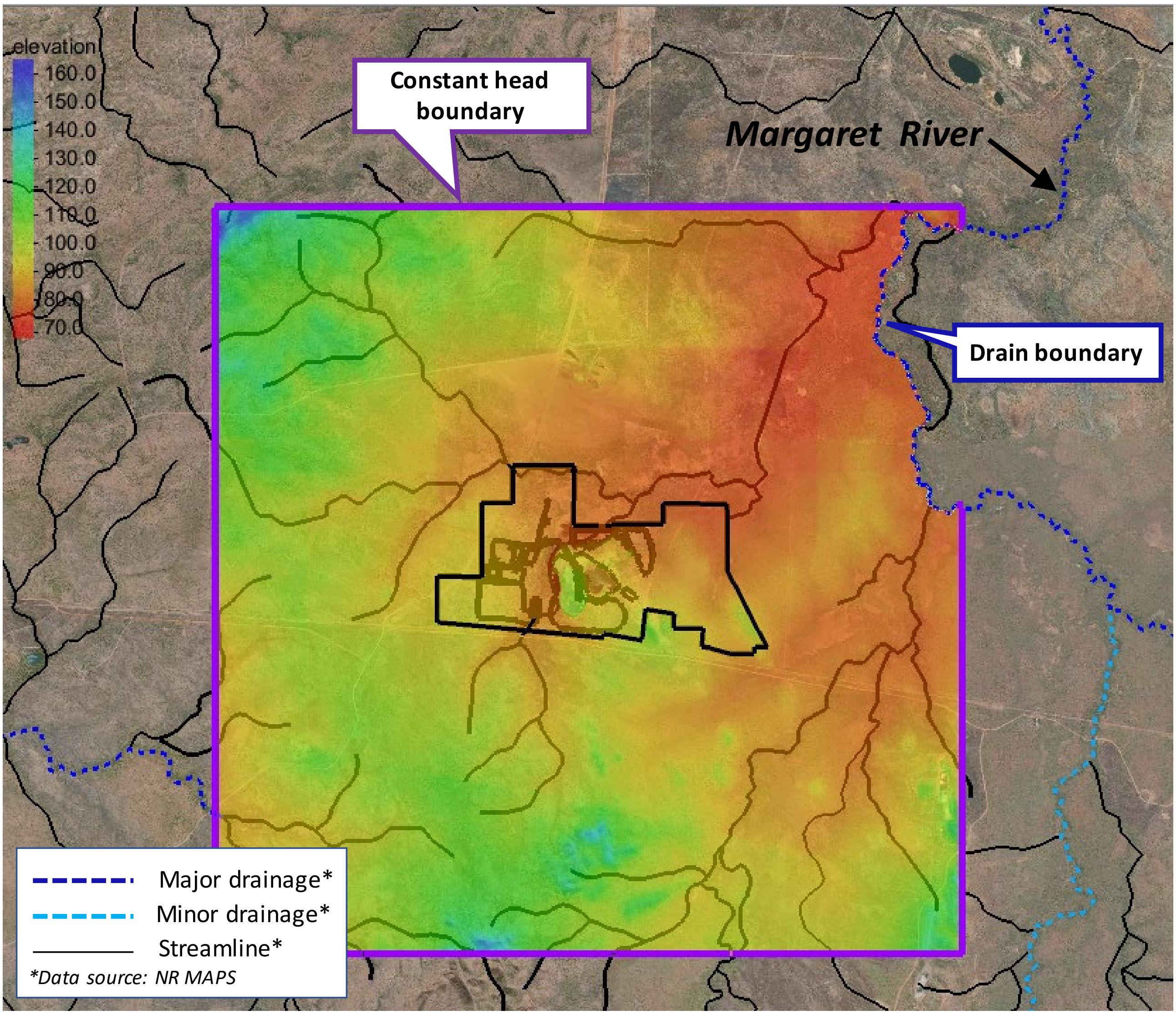

Figure 5-1 Groundwater model domain with surface elevation

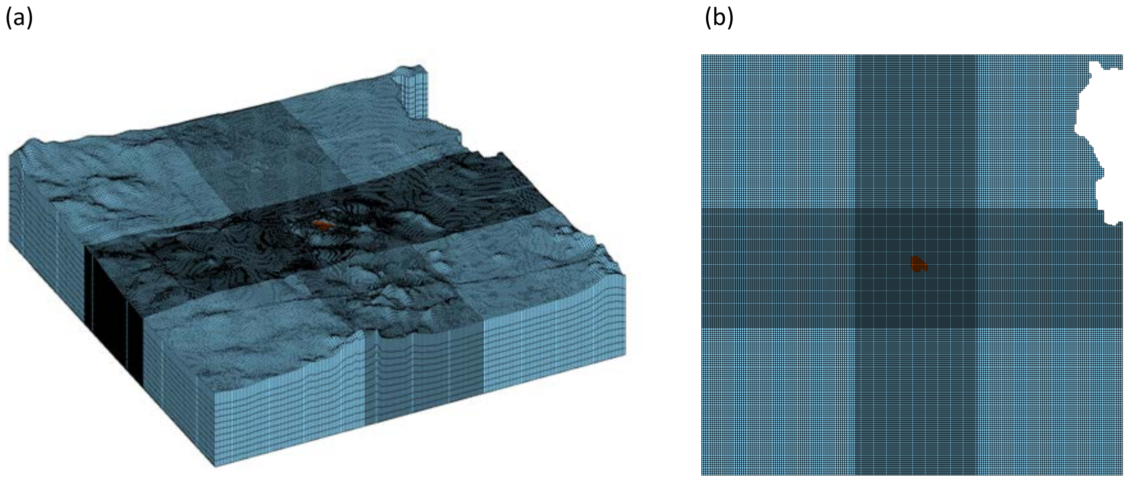

Figure 5-2 (a) 3D model view and (b) spatial discretization

5.2.2 Model boundary conditions and parameterisation

Boundary conditions and parameterisation in the model have been specified as:

- Constant head boundaries are applied around the perimeter of the model, with head values derived from correlation between topography and measured groundwater elevations.
- Although the Margaret River is ephemeral, it is conceptualised to be a groundwater discharge zone (either through groundwater ET or as baseflow for some parts of the year), simulated as a drain boundary with the head elevation specified as the surface elevation.
- Rainfall recharge is applied to the uppermost active cells of the whole domain using the MODFLOW Recharge (RCH) package, with the recharge rate adjusted during model calibration.
- Evapotranspiration is simulated using the EVT package, with the potential rate set to 6.5 mm/d based on the Douglas River Research Farm weather station (14901) and the extinction depth set to the standard value of 2 m.
- The HSUs are assumed to be isotropic and homogeneous, with hydraulic conductivity and specific yield of the bedrock aquifer estimated during model calibration. Storage coefficient is set to 7×10^{-5} (Section 3.3.3).
- The open pit is represented by a parameter zone with a high hydraulic conductivity of 100 m/d and specific yield of 1.
- The pit water level is represented using a constant head boundary. The constant head values are based on the water balance model outputs and change over time due to dewatering activities.
- When assessing the effect of the Evaporation Pond, the RCH package is used to simulate seepage from the Evaporation Pond at a rate predicted by the water balance model.
- Seepage from the CIP or other site infrastructure not specified above is not included in the model.
- Besides the Margaret River and Evaporation Pond, other surface water features (including Fountain Head Lake) are not explicitly represented in the model.
- A ‘no flow’ boundary is applied across the bottom of the model domain.

5.2.3 Steady-state and transient calibration

The historical model that was used for calibration comprises of a steady-state period that represents the current condition without any dewatering, followed by 76 transient periods that cover from 1 July 2020 to 29 Aug 2022.

The steady-state model was calibrated against 13 groundwater level observations from July 2019 and three observations with earlier unknown dates.

The transient model was calibrated against estimates of groundwater flux to the pit from the water balance model. Given the lack of groundwater level observations for the transient calibration, this approach is believed to provide valuable insights into how the groundwater system responds to temporal stresses. There is one flux target for each transient stress period, totalling 76 flux targets.

The combined steady-state and transient model was calibrated using PEST, an automated calibration technique. Due to the difference in scale between the head and flux targets, the weight for the flux targets was adjusted so that the two types of targets are equally visible in the objective function.

The observed and simulated groundwater levels are compared in Figure 5-3. With a root-mean square (RMS) error of 1.9 m, the match is considered reasonable given the homogeneous modelling approach. Similarly, the modelled fluxes from GoldSim and MODFLOW are compared in Figure 5-4. Despite the slight overestimation shown by the MODFLOW fluxes, the match is considered satisfactory given the good match in trend and a relatively small RMS error of 0.2 ML/d.

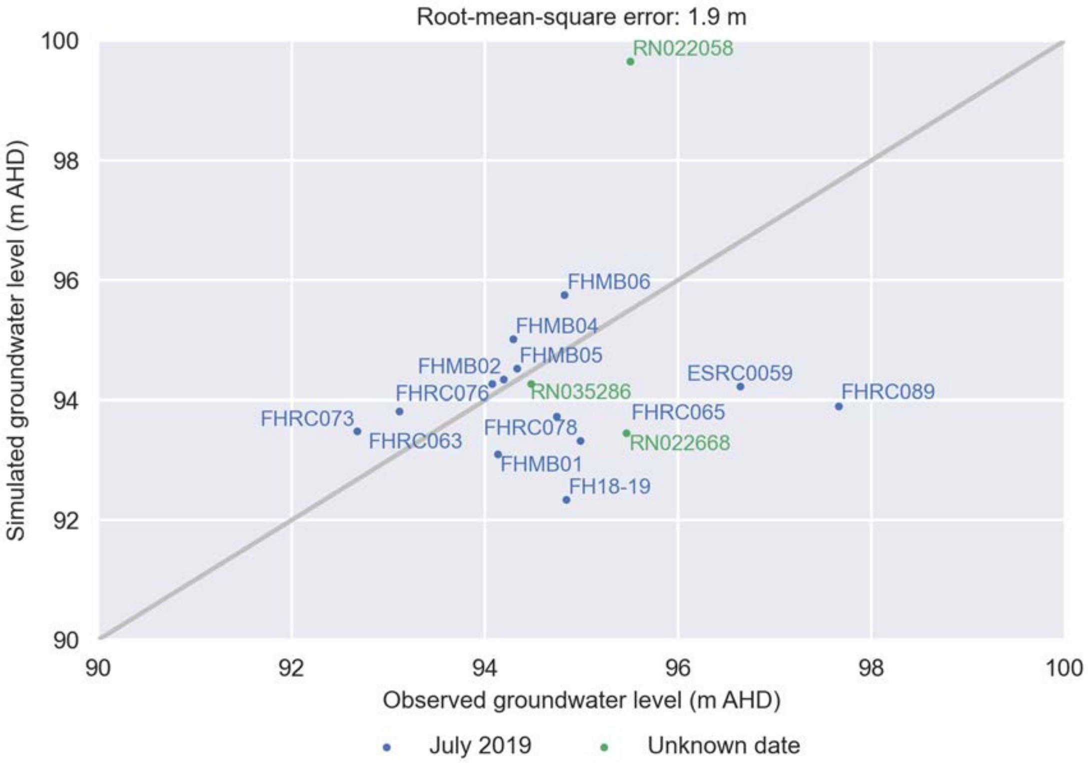

Figure 5-3 Comparison of observed and simulated groundwater levels

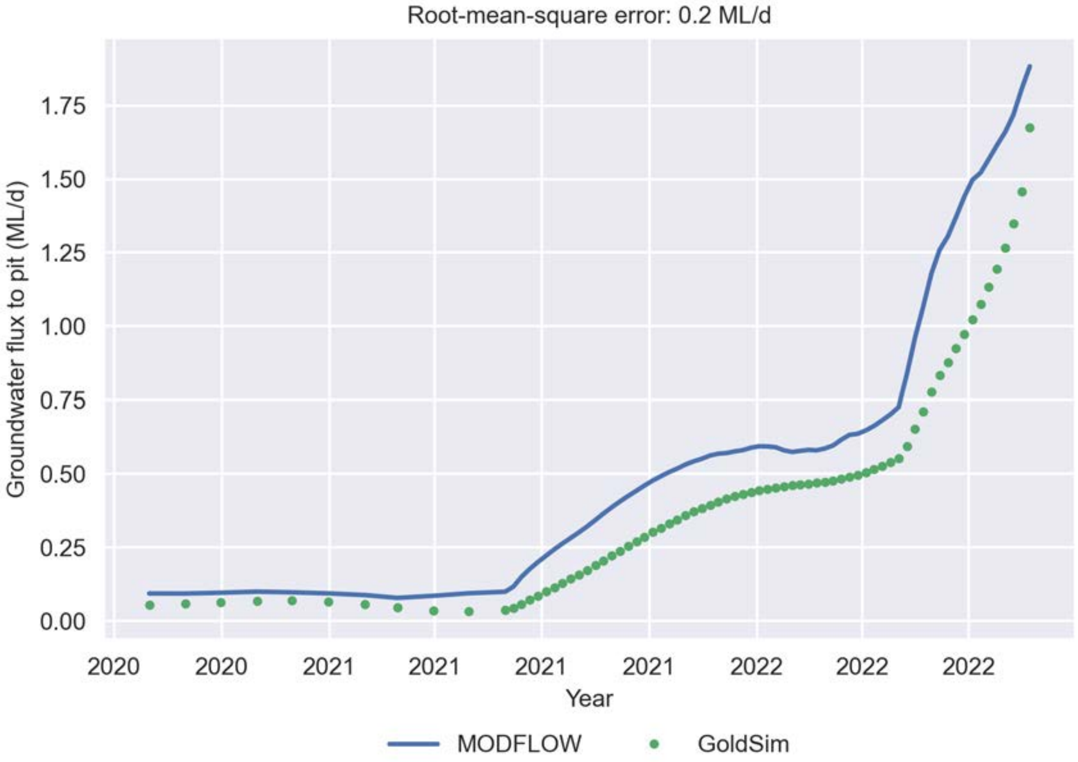

Figure 5-4 Comparison of groundwater flux to the pit between GoldSim and MODFLOW

The discrepancies in Figure 5-3 and Figure 5-4 could be due to errors in reference elevation, stand-pipe measurements and long open hole screen intervals. However, the error could also be due to complexity not represented in the model (e.g. aquifer heterogeneity, surface water – groundwater interactions). Improvements to the calibration may be possible in future by incorporating time series groundwater level data and refinement of the representation of the likely complexity of groundwater flow in a fractured rock aquifer (but there is insufficient information available at this time to support such refinement).

The calibrated parameters are shown in Table 5-1. The calibrated hydraulic conductivity shows a good agreement with the field estimates (Section 3.3.3). Similarly, the calibrated rainfall recharge rate is within the range of 30 – 100 mm/y estimated by CSIRO (2010). The calibrated specific yield is consistent with the literature, where Heath (1983) suggests that specific yield for basement aquifers can range from 0.001 to 0.1, while Healy and Cook (2002) suggest that fractured rock aquifers have specific yield values that are more commonly at the lower end of that range. However, due to the lack of field estimates for comparison, a sensitivity test was undertaken to examine the impact of different values of specific yield on the model results (Section 5.2.5).

Table 5-1 Calibrated model parameters

Parameter	Calibrated value
Hydraulic conductivity	0.053 m/day
Rainfall recharge rate	31 mm/year
Specific yield	0.0083

5.2.4 Scenario descriptions and results

The predictive groundwater numerical modelling is designed to interface with GoldSim water balance modelling to generate water table surfaces that represent the flow patterns at different Stages of the operation. Specifically, the modelling focuses on predicting the flow pattern at three time points: current status, end of mining and post-mining. Due to the change between the existing and future pit shell design, two simulations were undertaken as follows:

- Calibration model: a combined steady-state and transient model that was used for calibration (Section 5.2.3). The pit structure is based on the pre-mining conditions. The steady-state period of this model represents the current condition (i.e. prior to dewatering) and its groundwater level contours are shown Figure 5-5. The figure shows that the groundwater flow direction is generally towards the north-east.
- Prediction model: a transient model that covers from 30 August 2022 to 30 June 2075. The pit structure is expanded based on the post-mining conditions. Similar to the calibration model, time-varying pit water levels and seepage recharge from the Evaporation Pond were implemented in this model based on the water balance model outputs. The initial conditions of this model are based on the end of the calibration model simulation. The modelled groundwater level contours at the end of mining (April 2025) are shown in Figure 5-6. The figure indicates that the pit water level is at approximately -28 m AHD at the end of mining and considerable drawdown occurs in the immediate vicinity of the pit.
- After mining ceases in April 2025, the prediction model continues for approximately 50 years into the future, while Figure 5-7 shows the groundwater level contours 40 years after mining ceases (June 2065). The contours are similar to the current condition (Figure 5-5), with subtle differences that are likely to be caused by the expansion of the pit. The figure indicates that the expanded pit continues to act as a throughflow feature.

The model water balance is summarised in Table 5-2. The current condition shows that the system inflow and outflow are dominated by rainfall recharge and evapotranspiration respectively. At the end of mining, there is substantial groundwater outflow to the pit, which is balanced by a reduction in evapotranspiration. For the long-term recovery, groundwater outflow to the pit reduces significantly, albeit still being higher than the current condition, potentially reflecting the impact of the pit expansion.

Following full recovery (2070 – 2075) the groundwater flux out of the Pit Lake is approximately 20% of the groundwater flux into the Pit Lake (i.e. throughflow). This is likely to have implications for long term water quality by reducing the long-term salinity concentration in the Pit Lake (see Section 4). This also means that there will be an area of groundwater to the northeast of the Pit Lake with an initial concentration similar to that of the Pit Lake, before undergoing geochemical and mixing dilution processes along the groundwater flow path. The uncertainty associated with this throughflow flux could be reduced if more detailed timeseries groundwater data was collected from monitoring bores that have a wider spatial coverage across the site and regionally.

Table 5-2 Groundwater model balance for all scenarios

Model	Component	Net inflow (ML/y)	Net outflow (ML/y)
Current condition (Steady-state period of the calibration model)	Regional flow		768
	Pit Lake		19
	Rainfall recharge	2955	
	Evapotranspiration		2136
	Margaret River		33
	Total	**2955**	**2956**
End of mining (Apr 2025 of the prediction model)	Regional flow		767
	Pit Lake		1073
	Evaporation pond	237	
	Rainfall recharge	2953	
	Evapotranspiration		1394
	Margaret River		33
	Changes in storage	77	
	Total	**3267**	**3267**
Long-term recovery (Jun 2065 of the prediction model)	Regional flow		768
	Pit Lake		72
	Evaporation pond	186	
	Rainfall recharge	2953	
	Evapotranspiration		2239
	Margaret River		33
	Changes in storage		27
	Total	**3139**	**3139**

Predicted drawdown has been calculated for the end of mining and 40 years post-mining and is shown in Figure 5-8 and Figure 5-9 respectively. Drawdown of greater than 100 m is predicted at the end of dewatering but is relatively steep with the cone of depression largely restricted to the near vicinity of the pit. The groundwater drawdown extent of > 1 m is estimated to be within approximately 2.5 km from the pit. It is likely that this will capture much of the water that infiltrates through the IWL and as seepage from the Evaporation Pond while groundwater recovery takes place. A significant proportion of the seepage from the Evaporation Pond is likely to be lost as evapotranspiration due to the water table rising toward the ground-surface but this contains a considerable level of uncertainty due to the poorly constrained hydraulic characterisation of the material at the base of the Evaporation Pond, bund wall materials and the uncertainty in the distribution of groundwater levels across the site. It is possible that infiltration trenches may be required to capture this seepage water if solute concentrations are above relevant guidelines.

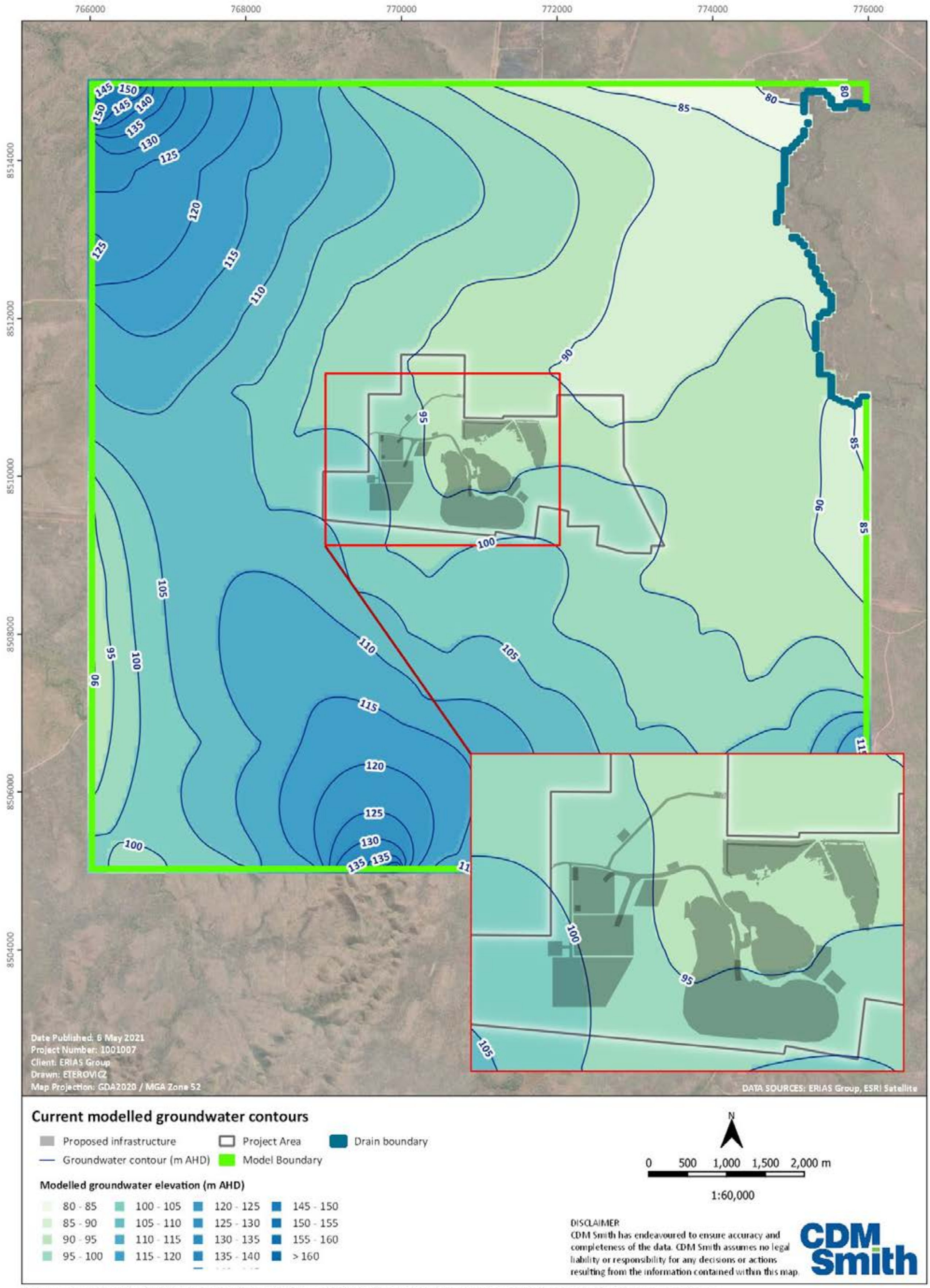

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Figure 5-5 Current conditions – predicted steady-state groundwater contours (m AHD)

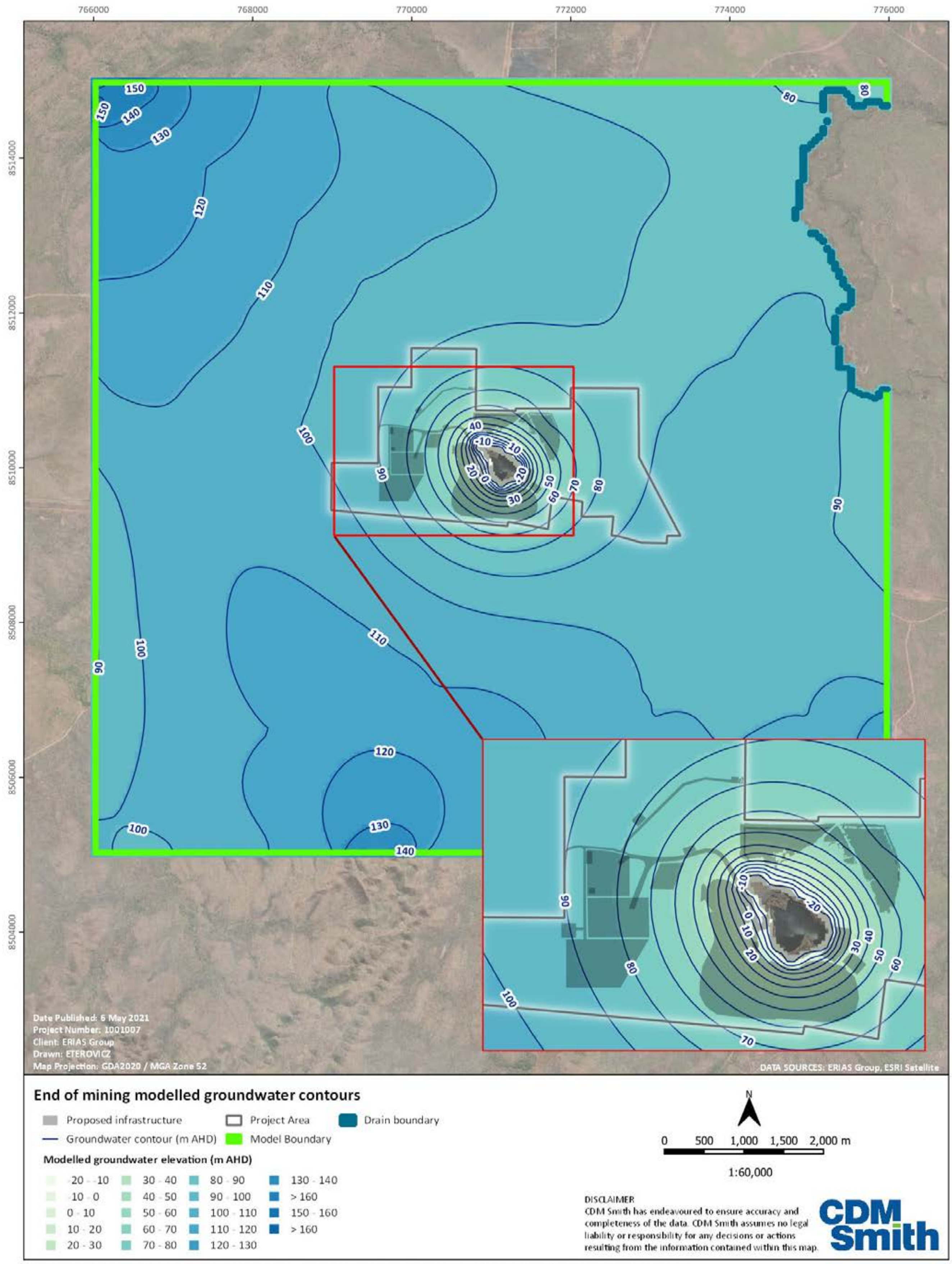

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Figure 5-6 Predicted groundwater contours at the end of mining – maximum dewatering (m AHD)

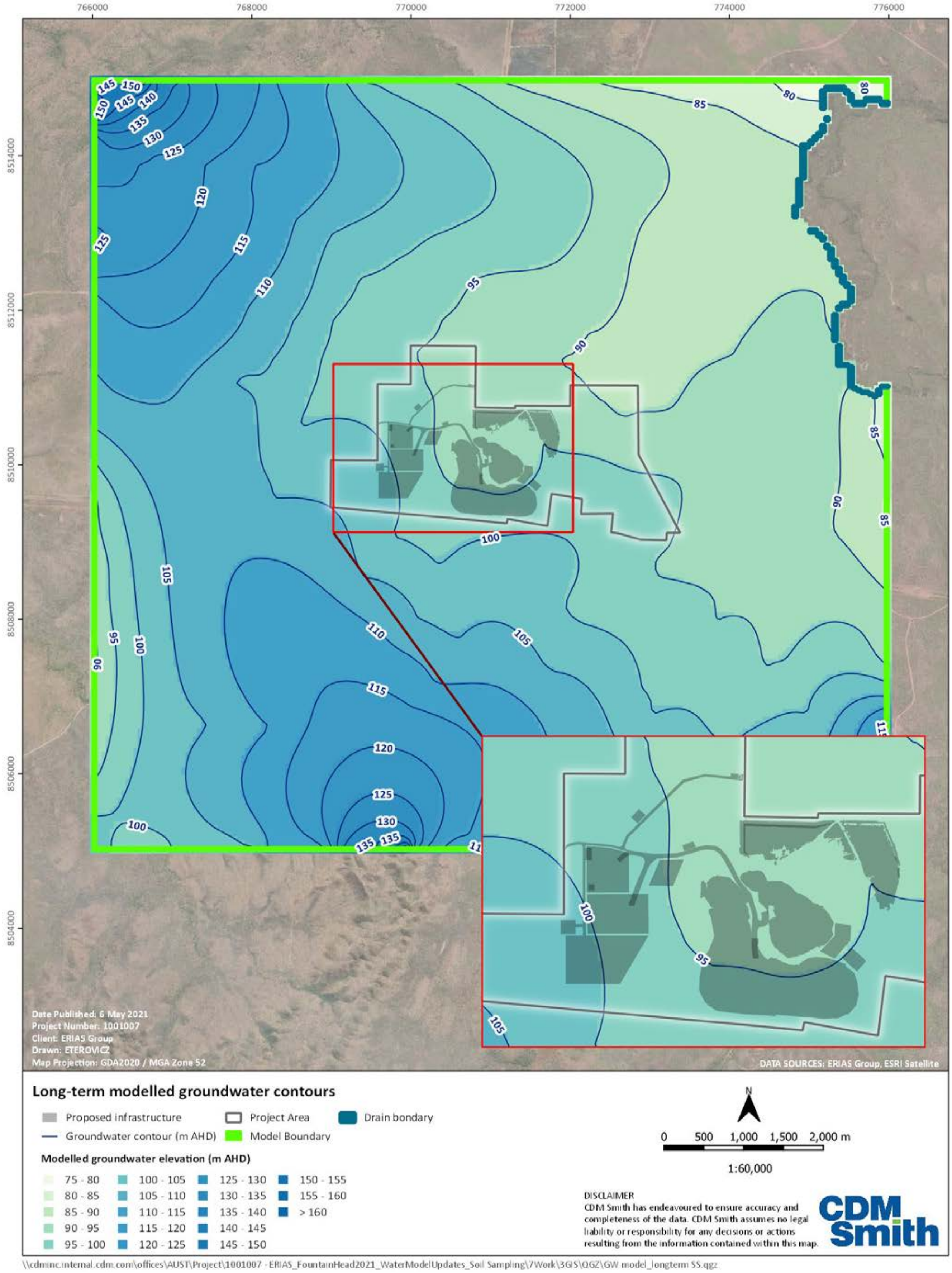

Figure 5-7 **Predicted steady state groundwater contours 40 years post-mining (m AHD)**

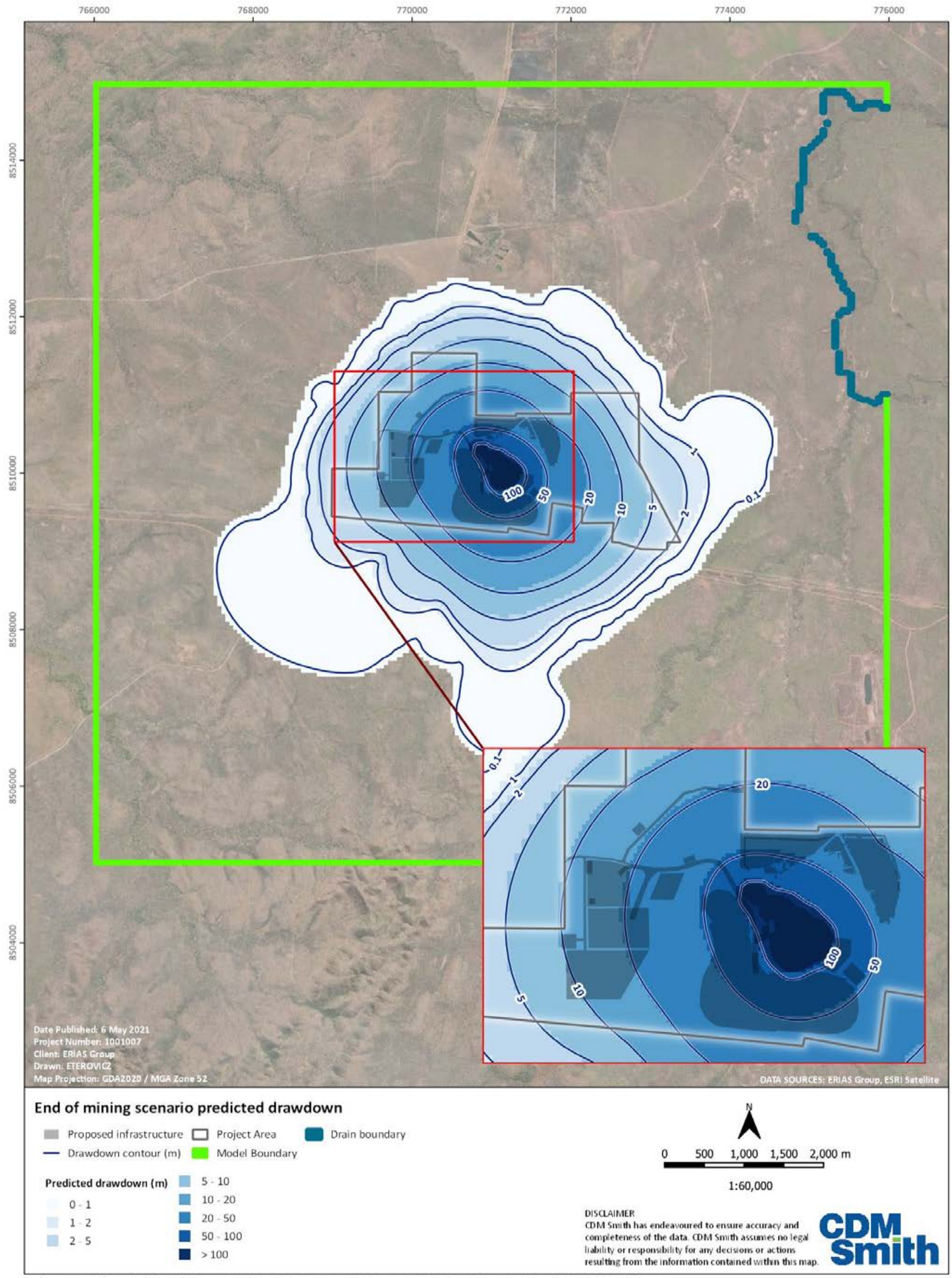

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Figure 5-8 Predicted drawdown at the end of mining – maximum dewatering (m)

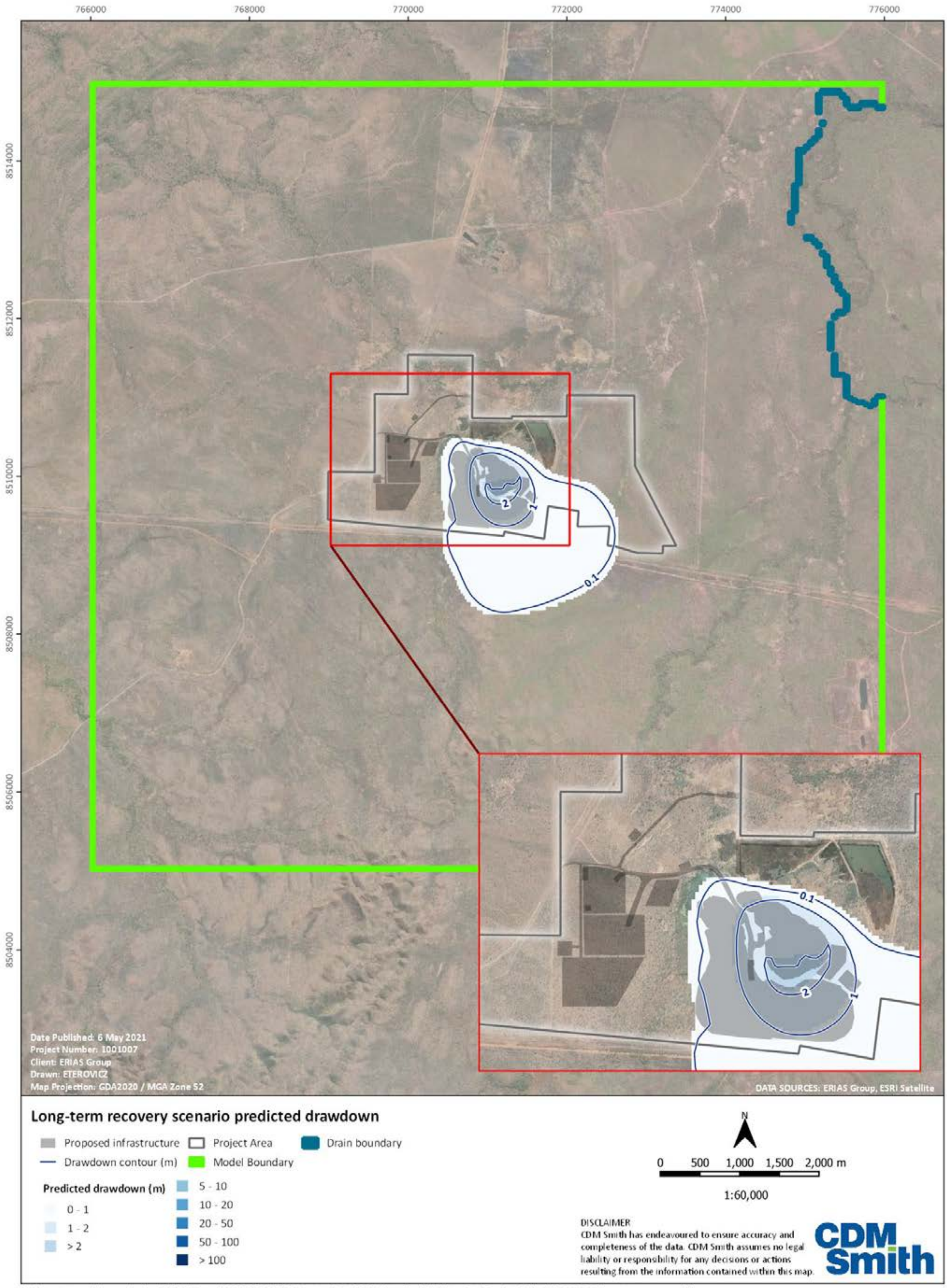

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Figure 5-9 Predicted drawdown 40 years post-mining compared to current conditions (m)

5.2.5 Sensitivity analysis

A sensitivity test was undertaken using the prediction model to examine the impact of different values of specific yield on the modelled groundwater flux to the pit (Figure 5-10). Specific yield was varied higher and lower by an order of magnitude from the calibrated value. The figure shows that the calibrated specific yield results in a flux that is near the lower end, and that any further reduction of specific yield from the calibrated value may only result in a relatively minor change in flux.

It is worth noting that the response of the groundwater system to pit dewatering depends on the particular combination of parameters rather than a single parameter in isolation. Different combinations of parameter values can be applied to develop many equally plausible realisations of the groundwater model – a situation referred to as non-uniqueness.

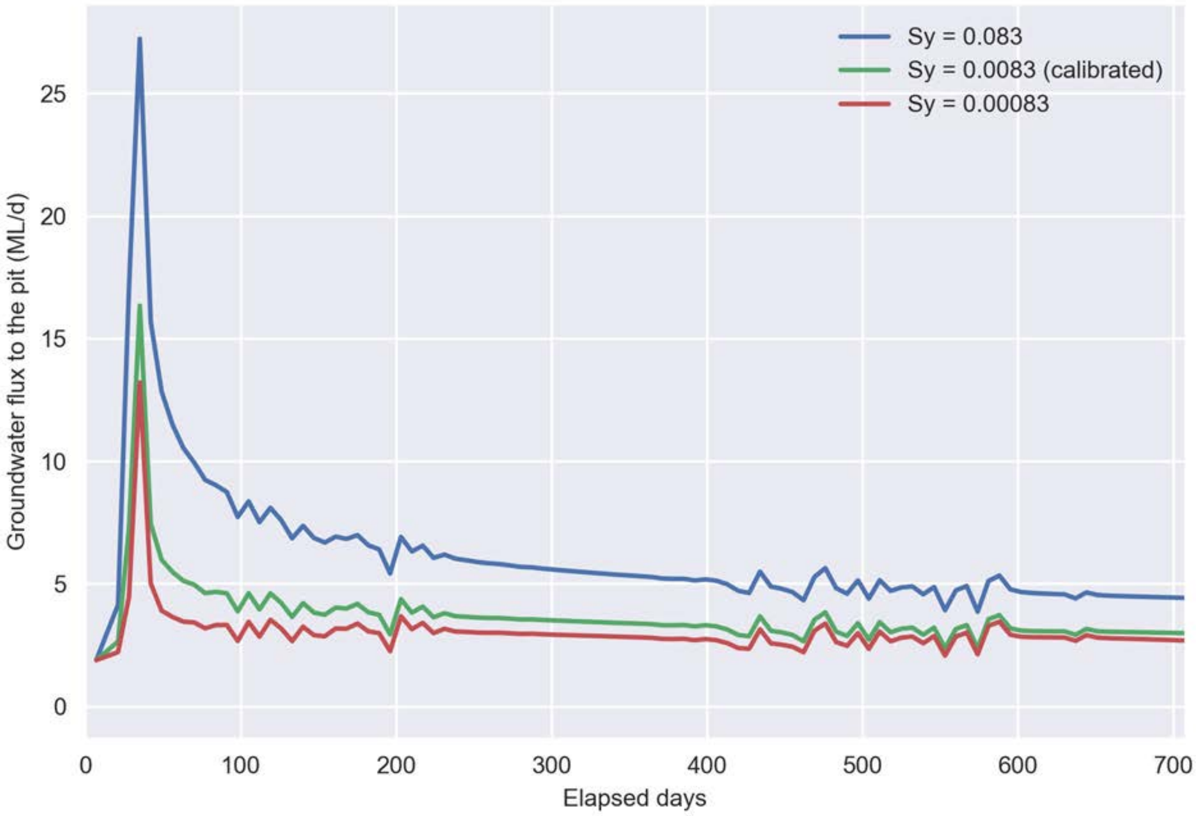

Figure 5-10 The effect of specific yield on the estimation of groundwater flux to the pit in the prediction model

5.2.6 Limitations

Limitations of the model include:

- The influence of faults or fault zones have not been considered in this assessment, and may have considerable control on local groundwater flow dynamics as they may act as recharge or discharge boundaries
- The model has not directly considered the influence of the unsaturated zone on recharge timing or other spatial variability
- The sensitivity analysis suggests groundwater inflow to the pit is highly sensitive to the value of specific yield and there is no field-based data from the site to provide constraints (information concerning aquifer hydraulic properties is very limited)
- The numerical groundwater model calibration is based on the outputs (i.e. pit water level, groundwater inflow and infiltration from the Evaporation Pond) of the GoldSim water balance model (Section 4) and a relatively limited number and spatial distribution of groundwater level data

5.3 Key findings

The groundwater model suggests that during the current and long-term recovery conditions the Pit Lake acts as a throughflow feature, where regional groundwater flows from the south-west towards the north-east. The groundwater level difference between the current and long-term recovery conditions suggests the expansion of Pit Lake will cause more groundwater discharge to the pit, but that it will remain as a throughflow feature to some degree (i.e. approximately 20% of groundwater discharge to the Pit Lake re-enters the groundwater system when fully recovered towards the end of the simulation period). The Pit Lake is likely to capture nearby groundwater (especially from the west, south-west and south due to the regional hydraulic gradients) including groundwater mixed with localised recharge through the IWL.

During active dewatering, the groundwater drawdown extent of 1 m or above is estimated to be approximately 2.5 km from the pit. It is likely that this will capture much of the water that infiltrates through the IWL and beneath the Evaporation Pond as seepage to the water table whilst groundwater recovery takes place. A significant proportion of the seepage from the Evaporation Pond may also be lost as evapotranspiration due to the water table rising toward the ground-surface but this contains a considerable level of uncertainty due to the poorly constrained hydraulic characterisation of the material at the base of the Evaporation Pond, bund wall materials and the uncertainty in the distribution of groundwater levels across the site. It is possible that infiltration trenches may be required to capture this seepage water if solute concentrations are above relevant guidelines.

Section 6 Conclusions

6.1 Water balance

The Fountain Head Pit, Evaporation Pond and Fountain Head Lake water balance modelling has estimated each of the inputs and outputs over the life of mine. Results suggest that initial dewatering of the Fountain Head Pit is 89.5% likely to be achieved prior to the 2022/23 wet season if dewatering commences in June 2021 as modelled. Over the mining period, there is a 41% likelihood of interruptions to the continuous in-pit pumping if the operational water level trigger of the Evaporation Pond is set to 97.4 m AHD. This likelihood of in-pit interruptions can be reduced to 28% or 11.5% if the trigger is raised to 97.9 m AHD 98.4 m AHD, respectively, noting these do not necessarily consider all dam wall design requirements and have greater likelihood of reaching the EP spill level.

The total volume of water to be removed from the pit leading up to and during the mining phase is estimated at around 5.7 GL. Of this volume, 1.3 GL is predicted to be evaporated (forced and natural) with 4.4 GL pumped to the Evaporation Pond. The majority of water removed from the Evaporation Pond is through forced evaporation (2.8 GL) with natural evaporation accounting for around 0.7 GL. Approximately 0.9 GL of seepage is likely to occur from the Evaporation Pond, depending on hydraulic properties of the basal material and soil profile, but it is likely that much of this will be captured as groundwater inflow to the dewatered pit during mining operations and recovery.

Modelling shows groundwater inflow to the Pit will vary considerably over time, reaching an average of around 3 ML/d during mining. The actual inflow rates will be highly dependent on the nature of the fractured rock aquifer intersected by the mine void (including heterogeneity and anisotropy), the connectedness of fractures to more distant aquifer storage and hydraulic gradients established. It is possible for large groundwater inflows to occur initially when fractures are intersected, which then slow as discrete parts of the aquifer are dewatered. This transience and heterogeneity in aquifer properties is highly challenging to quantify and a simplified approach has been taken in this work due to limited information to constrain a more complex approach. It should also be noted that the groundwater inflows and dewatering requirements are considered conservatively high apart from the uncertainty of aquifer parameters, due to the instantaneous change from the existing pit shell to the full future pit shell dimensions during the initial dewatering stage below the water level of -30 m AHD.

In the long-term, Fountain Head Pit Lake is predicted to recover to approximately 93.5 m AHD (+/-2 m) and is likely to act locally as a groundwater sink due to its large surface area (evaporation > rainfall) but with a considerable groundwater throughflow component. The groundwater model predicts that following full recovery (2070 – 2075), approximately 20% of groundwater discharge into the Pit Lake will flow through and re-enter the groundwater system.

The Fountain Head Lake modelling shows that it will normally be effectively flushed each wet season due to the large inflows from the catchments in the south, with natural discharge to the north of the site.

6.2 Solute balance

The primary driver of change to the salinity of both the Fountain Head Pit Lake and Evaporation Pond is evapo-concentration occurring due to the evaporators and seasonal freshening (rainfall and rainfall-runoff inputs). Modelling results for the Fountain Head Pit demonstrate an insignificant change to salinity over the first 30 years post-mining but at 500 years post-mining, salinity and solute concentrations are predicted to have steadily increased as evaporative effects exceed the freshening effect of rainfall and recharge events. As a result, salinity at 500 years post-mining is predicted to be around two and a half times the current salinity within the Fountain Head Pit, which is moderated by the groundwater throughflow component of the water balance (derived from the groundwater model). It should be noted that the process of evapo-concentration will occur over the existing Pit Lake (i.e. without further mining) and also result in increased solute concentrations of a similar magnitude. Evaporation Pond modelling predictions show that salinity will increase significantly if the Pond is allowed to dry due to forced evaporation and then reach similar concentrations to pre-mining conditions after approximately five years post-mining.

Under a conservative non-reactive mass balance model, the concentration of dissolved species increase or decrease proportionally to salinity over time from their starting values. It is likely that geochemical reactions between dissolved species will occur over time and result in lower solute concentrations than those predicted by this solute balance. For example, oxidation of dissolved metals within groundwater can be expected to occur following distribution to the Evaporation Pond and also as groundwater enters the Fountain Head Pit. This may cause flocculation and precipitation of dissolved metals out of solution thereby decreasing dissolved concentrations with respect to other solutes. However, a change in solute balance and environmental conditions (i.e. oxidation, pH, temperature) may also result in the dissolution of metals from the sediments or saturated rock to the water and in turn increase dissolved metal concentrations.

The extent to which geochemical reactions are likely to occur cannot be accurately modelled without more detailed geochemical characterisation of the Fountain Head Pit rock material and the Evaporation Pond sediments to combine with recent analysis of surface and groundwater samples. Bench-scale or field trial analysis would be required to better understand and quantify the likely fate of specific metals and other dissolved elements under controlled environmental changes. In the absence of this information, the predictions from the non-reactive mass balance estimates of the model, although conservative (i.e. non-reactive) are considered appropriate.

Comparison of Fountain Head Lake and Pit Lake predicted arsenic concentrations to ANZECC guidelines were made using conservative assumptions. For Fountain Head Lake, there were no predicted exceedances within the modelled assumptions for the Stock Drinking Water or the Aquatic Ecosystem (80%) guideline. Greater confidence could be placed on the rainfall-runoff model predictions if the model was re-calibrated using time-series site data, while additional testing of runoff arsenic concentrations is recommended for each contributing runoff area to reduce their uncertainty. For the Fountain Head Pit Lake, the arsenic concentration is currently similar to the Stock Drinking Water guideline (500 μg/L) and is predicted to exceed this guideline until in-pit pumping dewatering stage, where groundwater inflows dilute the remaining storage concentration to below both ANZECC guidelines under consideration.

The solute concentrations of the Pit Lake following closure and sub-aqueous storage of PAF material has not been assessed in combination with other potential solute pathways (see discussion in CDM Smith, 2021a). More detailed mixing, geochemical and reactive transport assessments would be required to better characterise the fate of in-pit water and the groundwater throughflow predicted to occur once the Pit Lake has fully recovered some 40–50 years after the end of mining.

6.3 Dewatering management

The water balance modelling predicts that there is an 89.5% likelihood that the initial pit dewatering will be achieved by late-2022 without interruption. Over the mining period ending in April 2025 there is a 41% likelihood of temporary interruption to Fountain Head in-pit pumping due to the Evaporation Pond operational level trigger being exceeded (set at 97.4 m AHD). If this operational level trigger is raised to 97.9 m AHD, there is a 94% likelihood that dewatering will be achieved prior to the 2022/23 wet season and the likelihood of in-pit pumping interruptions over the mining period is reduced to 28% but with a 1% chance of reaching the spill level of the Evaporation Pond. Currently there are no model predictions where the Evaporation Pond level reaches the spillway level (98.6 m AHD) when the operational trigger level is set at 97.4 m AHD, primarily due to the assumed efficiency of the evaporators in combination with the forced interruptions to in-pit pumping when the water level trigger is exceeded.

Interruptions to in-pit dewatering may impact mining operations, noting that the mining advancement is not explicit in the water balance assessment (change from the existing to future pit shell is instantaneous). Developing in-pit storage capacity (i.e. sumps) may mitigate such impacts and act as a buffer between operational water level triggers being exceeded and mining operation delays. In practical terms, the two largest sources of uncertainty related to the wet season storage volumes in the Evaporation Pond and Fountain Head pit dewatering requirements are:

- Actual rainfall and rainfall-derived runoff volumes into the Fountain Head Pit and Evaporation Pond

- Actual groundwater inflow rates as controlled by the vertical and lateral extent of connected fracture networks in relation to the:
  - Initial dewatering to the current pit bottom
  - Ongoing dewatering as the zone of dewatering influence expands during mining

In practice, frequent monitoring of water levels within the Evaporation Pond should be used to evaluate the remaining capacity as the dry season and build-up progresses. Evaporators should be used as planned throughout this period to minimise the Evaporation Pond volume prior to the onset of the wet season as the primary mitigation strategy to avoid operational water level triggers being exceeded during the wet season.

The uncertainty of groundwater inflow as the mine is deepened below the existing pit shell has been captured in the Monte Carlo analysis but not constrained by site specific aquifer property data. In concept, the currently assumed 9 ML/d pumping capacity should be able to keep pace with predicted groundwater inflows (range from 2.3–4.2 with an average of around 3 ML/d), but the timing and duration of any larger inflows are unknown and have the potential to be coincident with the wet season and a relatively high Evaporation Pond water level.

Section 7 References

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