ERIAS Group

Fountain Head Gold Project – EIS Comment Response: Pit Lake Water Quality

17 November 2021

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Section 1 Introduction

1.1 Background

CDM Smith Australia Pty Ltd (CDM Smith) was engaged by ERIAS Group (ERIAS) to address the comments received for the Fountain Head Gold Project Environmental Impact Statement (FHGP EIS). The FHGP EIS was submitted in July 2021 for review and comment. ERIAS is in the process of preparing a supplementary EIS, for which this report contributes to.

Specifically, the objectives of this report are to address the comments received on the FHGP EIS and in relation to Fountain Head pit water quality.

ERIAS has updated the project layout since the FHGP EIS submission (Figure 1):

- The footprint of the integrated waste landform (IWL) has increased in size and moved further east.
- The potential acid forming (PAF) stockpile, previously located at the southeast end of the pit, has been removed and all PAF waste rock will be stored in the pit during and post mining.

1.2 Scope of Work

The scope of work (SOW) for this report is documented in the ERIAS request for proposal dated 23 September 2021. The SOW formed two main components, an update of the groundwater monitoring plan (Section 3.1) and a pit lake water quality study (Section 3.2). This report documents the objectives listed in Section 3.2 of the SOW. The groundwater monitoring plan scope is documented in report number ERIAS-PNX-1001007-RPT-004-0.

1.2.1 Pit Lake Water Quality Study

1.2.1.1 Objectives

- Address comments made from the Department of Industry, Tourism and Trade (DITT) regarding pit lake water quality.
- Study and understand the long-term water quality of the Fountain Head open pit and the relevant contributions from:
  - Seepage water from the IWL.
  - Surface water runoff from the pit catchment.
  - Surface water runoff from the various rock units in the pit wall.
  - Surface water runoff from the PAF waste rock that has been backfilled into the pit.
- Assess the options to manage long term pit water quality, for example diverting water into the pit which may improve environmental outcomes by flushing the pit each year. As part of this, an assessment is required to determine if the pit will overflow and if the overflow water quality is acceptable to release off-lease.

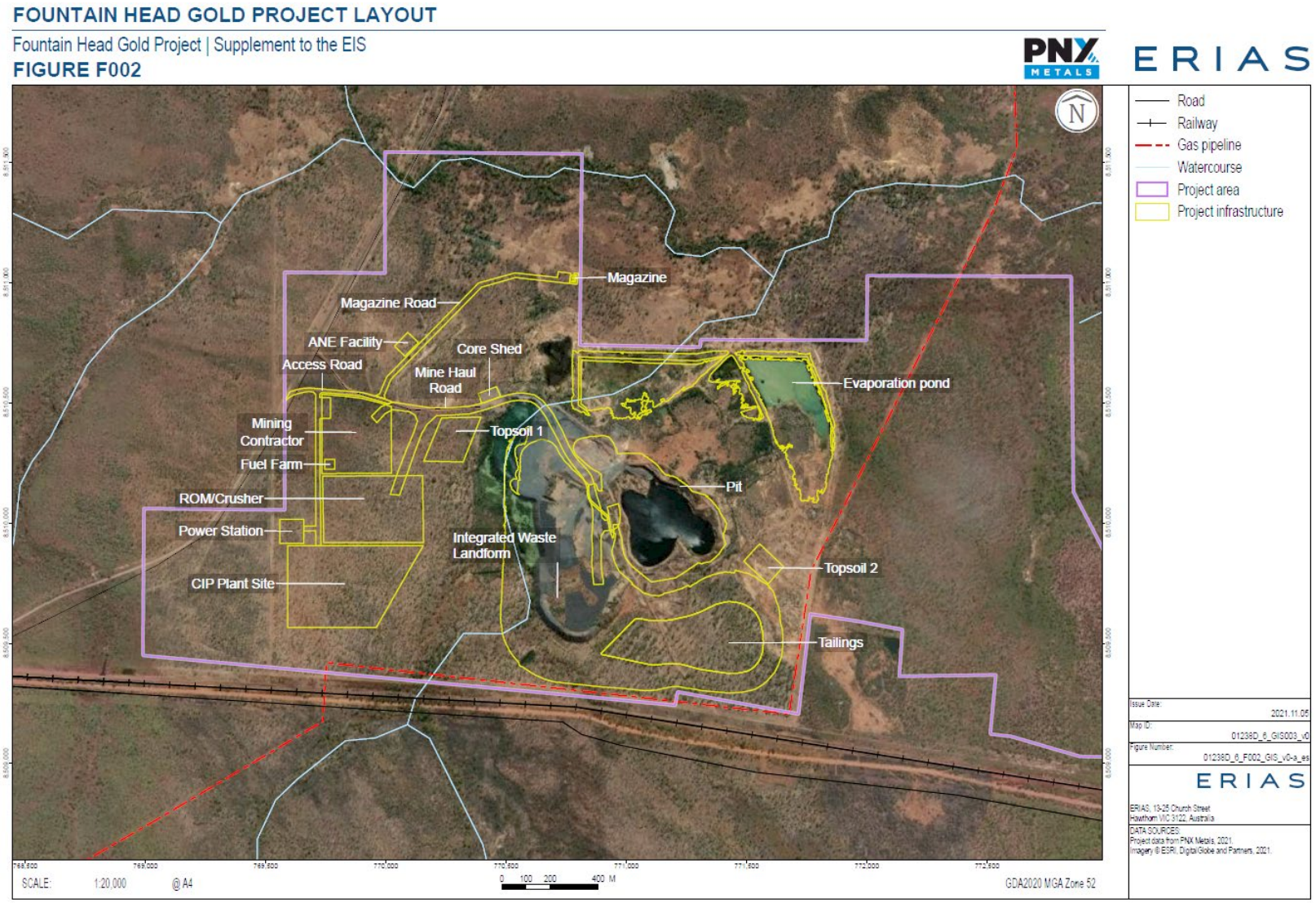

Figure 1-1 Proposed Fountain Head Gold Project Layout

Section 2 Conceptual Site Model

2.1 Overview

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.

A conceptual site model (CSM) has been developed by Land and Water Consulting Pty Ltd (LWC) to identify potential source(s), pathway(s) and receptor(s) associated with the geochemistry of storing PAF rock within the Fountain Head pit. The CSM contributes to an understanding of possible effects posed to environmental values (EVs) associated with in pit storage of acid generating waste materials.

The following sections summarise each of the source-pathway-receptor assessment components as well as providing context for the planned PAF storage and management within Fountain Head pit. The full source-pathway-receptor assessment is provided as Appendix A.

2.2 PAF Storage / Management Concept

The current proposed PAF management strategy is to dispose of the PAF rock within the pit, distributed in three 'pods' with a combined total in-pit storage of ~957,700 Loose Cubic Metres (LCM) (Figure 2-1). PNX consider the average waste density is 2.7 t/m^3 and the swell factor will be around 32% so recommend adopting a bulk density of 2.05 t/m3 – essentially 2 million tonnes (Mt) of PAF rock.

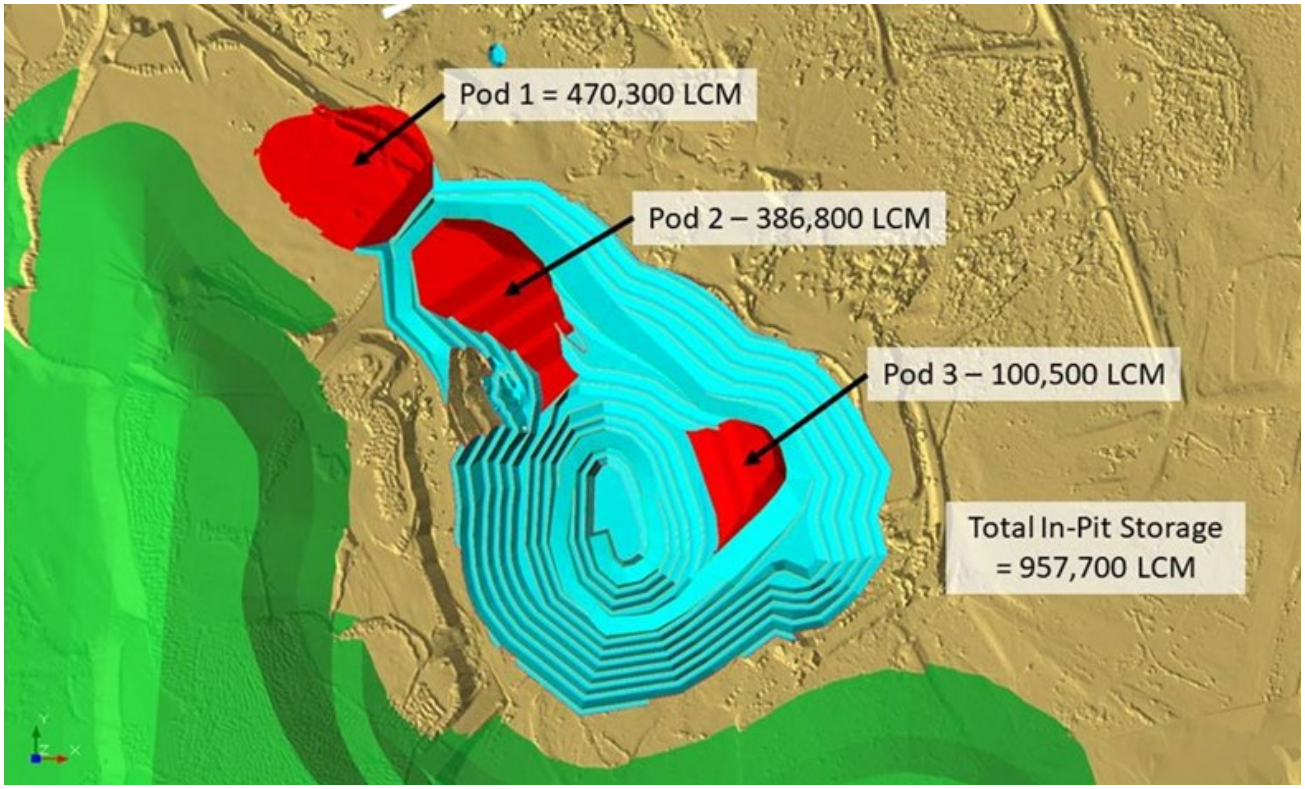

Figure 2-1 Proposed in pit storage of PAF

A key benefit of sub-aqueous disposal is the exclusion of oxygen in order to prevent oxidation (or ongoing oxidation) of sulfide in the rock. Water table elevation calculations indicate only PAF Pod 2 and PAF Pod 3 will be fully submerged (noting that PAF Pod 2 will take ~30 years to be fully submerged) following water level recovery post mining (Table 2-1), however, PAF Pod 1 will be at least partially above the pit lake water table and will be open to ongoing oxidation of sulfidic materials. PNX, however, have advised that any PAF rock exposed post mining will be pushed into the pit (submerged storage) should it be required. The distribution of the PAF pods with regard to the pit lake water level recovery is presented in Figure 2-2.

Table 2-1 PAF pod submergence calculations

Type	Min height (mAHD)	Max height (mAHD)	Loose cubic metres (LCM)	Approximate end of mine pit water level (mAHD)			Approximate end of mine submergence (mAHD)		
				5 years	25 years	50 years	5 years	25 years	50 years
FH pit	-54.6	106.7	-	61	89	92	-	-	-
Pod 1	60.5	105.9	470,300						
Pod 2	25.5	90.5	386,800						
Pod 3	10.5	40.5	100,500						

Notes: Red cells denote pod entirely above pit lake
Orange cells denote pod partially submerged by pit lake
Green cells denote pod fully submerged by pit lake

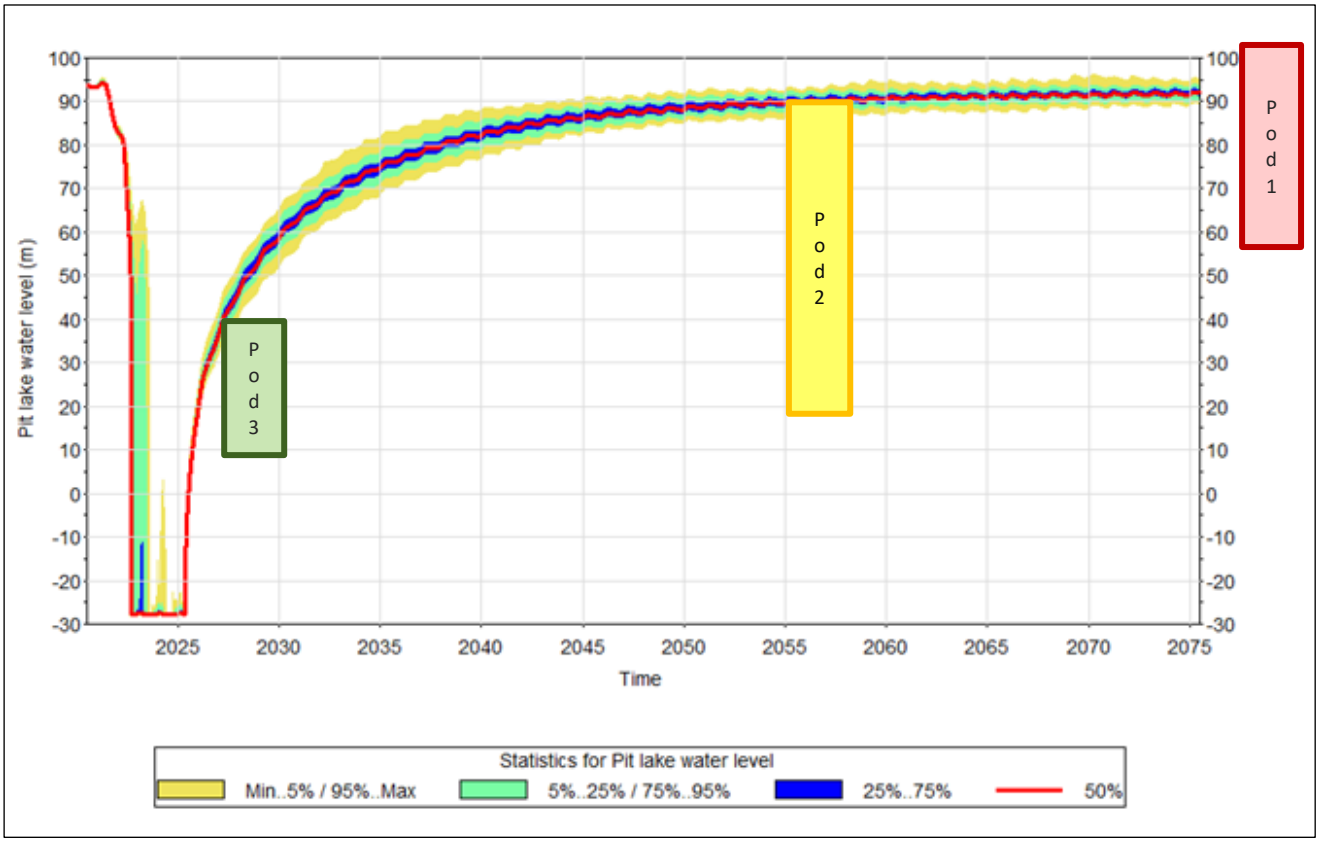

Figure 2-2 Predicted pit water level change during dewatering and recovery

2.3 Sources

The geology of the project site provides the sources of the chemical substances of potential environment concern (CPEC). These chemicals are naturally present in the environment. Based on the data provided in the geochemical

report generated for the site (EGI, 2020) natural enrichments of metals and metalloids are present in these geological materials. Table 2-2 presents the geochemical sources for pit-lake water quality impacts.

Table 2-2 Identified Sources

Geochemical Source (S)	Description	Discussion	Considered herein
S1	PAF rock in base of Pit as PODS 1 – 3 (refer Figure 2-1).	2 million tonnes of PAF rock with leach chemistry represented by kinetic sample 21363.	☑
S2	Open Pit – rock walls – as per Figure 2-3.	Sulfide oxidation in wall rock – dewatering and excavation exposes wall rock to atmospheric oxygen and solutes released by oxidation of sulfide minerals are flushed into the Pit by rainfall runoff or groundwater seepage through the rock wall. PNX provided an estimation of the PAF wall exposures in the pit (email ERIAS to CDM Smith 13 October 2021). As per Figure 2-3 there is approximately 18.8% of the 295,549 m^2 of pit wall which will be ore or PAF in nature (55,563 m^2).	☑

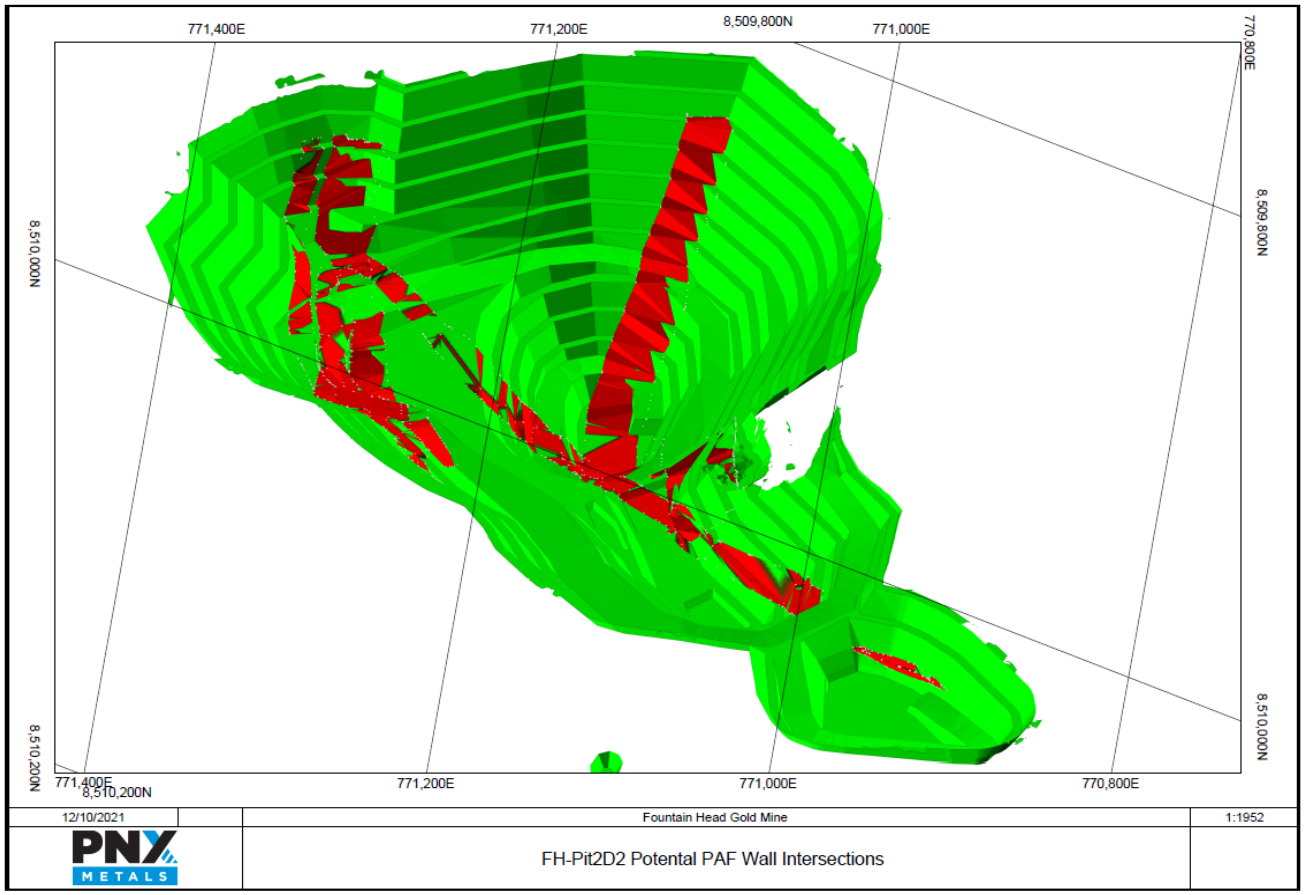

Figure 2-3 Fountain Head pit PAF wall intersection (red material denotes PAF rock and green material denotes remaining pit lithology)

2.4 Pathway

A pathway is the route along which a solute might move through the environment from its source to an EV. Potential pathways considered for the site are presented in Table 2-3.

Table 2-3 Identified pathways

Pathways (P)	Description	Relevant to this study?
P1	Groundwater inflow to the Pit and contact of water with exposed oxidised rock / materials	☑
P2	Direct biota uptake / contact of Pit water	☑
P3	Vertical or lateral migration of solutes from the Pit to the external groundwater	☑
P4	Abstraction and use (environmental values) of groundwater external to the Pit following P3 (now / future)	☑

Notes: ☒ Not identified or not relevant, not considered further in this assessment
☑ Potentially relevant, considered in this assessment

In summary, four pathways are considered relevant with respect to connection of the source (exposed waste rock and wall rock in the Pit) to receptors (ecology and identified environmental values of groundwater).

2.5 Receptors

For the source pathway receptor assessment, the receptor (R) represents the component, or receiving environment of an EV. These are summarised in Table 2-4.

Table 2-4 Identified Project area EVs

Environmental value[1]		Details
Ecosystem health	RAMSAR listed wetlands	☒ None identified
	Conservation category or Resource enhancement wetlands	☒ None identified
	Directory of Important Wetlands in Australia wetlands	☒ None identified
	Environmental Protection Policies wetlands	☒ None identified
	Wild rivers	☒ None identified
	Poorly represented wetlands in Conservation reserves system	☒ None identified
	Springs and pools	☒ None identified
	Ecosystems supporting significant flora, vegetation and fauna	☒ Stygofauna ☒ Troglofauna ☒ Terrestrial vegetation ☑ Migratory aquatic birds
	Ecosystems supporting significant amenity, recreation and cultural[4] values	☒ None identified
	Saline lakes, estuaries and near shore ecosystems	☒ None identified (Lake Eyre is ~200 km away)
	Downstream marine ecosystems	☒ None identified
Beneficial use	Drinking water supplies	☒ None identified
	Water supplies supporting significant commercial activities, e.g. mining and pastoral	☑ Livestock watering
	Inland waters with high levels of active and passive recreation including multiple use wetlands	☒ None identified
	Inland waters with significant cultural[4] or aesthetic values	☒ None identified

Key: ☒ Not identified or not relevant, not considered further in this assessment
☑ Relevant, considered in this assessment

Section 3 Source Term

3.1 Overview

The source term can be defined as the suite of elements with a propensity to leach from the source material. The source term is further refined by screening the concentrations measured in any leachate generated against generic water quality guideline concentrations.

The geochemical data made available to CDM Smith have been summarised by Environmental Geochemistry International (EGI) who have characterised the site geochemistry (waste rock and ore) (EGI, 2020). The results of the geochemistry characterisation are presented in the below subsections alongside the Project water quality.

3.2 Geochemical Characterisation

In order to obtain rock samples which would satisfactorily represent the distribution of waste rock types to be mined during the expansion of the existing Fountain Head pit, a number of drill holes were selected by EGI from the many drilled during resource definition drilling. Samples from these drill holes were selected to cover variation in lithology, oxidation and chemical composition of the waste rock, while also achieving appropriate spatial coverage of the proposed expanded pit. A value of 1 ppm Au (fire assay results) was used in most instances to delineate between ore (Au >1 ppm) and waste rock.

In total 111 drill hole samples, 18 waste rock samples (WRSs) samples and 3 ore and 3 cyanide leached samples were tested for the following:

- Total sulfur (S).
- Paste (1:2) pH and EC.
- Single addition net acid generation (NAG) test.
- Acid neutralising capacity (ANC).

3.2.1 Elemental Speciation

Multi element composition testing of Fountain Head pit waste rock and ore was undertaken by EGI (2020) and is presented as Table H1 in such document.

Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, reporting concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg). Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present at the Site. Arsenic has a calculated geochemical abundance indices of over 10. Anything of 3 or above is generally counted as being heavily mineralised. Other elements reporting with a Geochemical Abundance Index (GAI) at or >3 is (as per Table H2 of the EGI report):

- Silver (Ag).
- Beryllium (Be).
- Bismuth (Bi).
- Cobalt (Co) (in the ore only).
- Copper (in the ore only).
- Manganese (Mn).
- Lead (Pb).
- Sulfur (S).

- Selenium (Se).
- Uranium (U).
- Tungsten (W).

3.2.2 Static Testing

The EGI (2020) results of geochemical testing of samples obtained from drilling in the Fountain Head pit show:

- There is no immediately available acidity and low salinity in these samples when contacted with water, indicating that freshly mined rock is unlikely to provide low pH or saline drainage.
- Total S analysis showed a broad range up to 3%S, but with the vast majority (90%) having a relatively low S value of 0.5%S or less, suggesting the occurrence of pyritic rock is not widespread.
- ANC was relatively low, ranging up to 33 kg H_2SO_4/t, indicating a general lack of excess buffering.
- Carbon speciation analysis indicates carbonate content is negligible, with the total carbon content of these samples generally low. This is consistent with Acid Buffering Characteristic Curve test results which also suggest little carbonate content, and that the small amount of carbonate present in these samples is predominantly iron carbonates (ferroan dolomite, siderite), which will react relatively slowly.
- Most samples were net acid producing potential (NAPP) negative, with the majority of these having ANC/MPA ratios of 2 or more, indicating a high factor of safety.
- The majority (70%) of NAGpH values were 4.5 or greater, corroborating the Acid Base Accounting results which indicated most samples are likely to be non-acid forming (NAF).
- Chromium Reducible Sulfur measurements show that greater than 90% of Total S is contained in sulfide minerals, suggesting that Total S measurements can be used as suitable guide to the sulfide (pyrite) content of these materials.
- Test results were used to classify samples as NAF, PAF, PAF-LC or UC. Around 80% of samples tested were classified NAF (including UC equivalents), 15% PAF-LC (including UC equivalents) and 5% PAF. Overall results indicate most waste materials to be mined will be NAF, with a minor proportion of PAF.

Given the relatively low ANC and poor reactivity, criteria based on Total S was selected as the best potential option for routine classification of Acid Rock Drainage (ARD) rock types. Using the results from detailed geochemical testing, sulfur distributions were determined for each of NAF, PAF-LC (Low Capacity) or PAF ARD classifications. The results show:

- NAF samples can be differentiated from PAF/PAF-LC samples by applying a Total S cut-off of 0.2%S
- 95% of samples classified NAF have a Total S value of 0.2% or less, and all PAF samples and 60% of PAF-LC samples have a Total S value of greater than 0.2%S.
- Although using a ≤0.2%S criteria for NAF waste rock includes 40% PAF-LC material, these have low acid potential and operational blending with NAF materials would be expected to account for any minor acidity generated.

3.2.3 Single Addition Leach Testing

In addition to the above testing, water and peroxide extractions were conducted on selected samples to understand the likely quality of drainage from freshly mined and oxidised waste rock respectively. EGI (2020) reported the results of these tests show:

- All water extracts produced circum-neutral to mildly alkaline solutions with low salinity. Metal concentrations in water extracts were also very low to non-detectable.

- These results suggest leachates from freshly mined waste rock from the Fountain Head pit will, in general, be of reasonable quality. However, segregation of the PAF waste rock using a Total S value of 0.2% may improve leachate quality for the majority of fresh waste rock containing ≤0.2%S.
- Water extracts for WRS samples had neutral pH and low salinity. Metal/metalloid concentrations were also very low or non-detectable.
- Water extractions conducted on an ore sample and the same sample following cyanidation showed that cyanide leaching has significantly increased arsenic mobility in this sample.
- Arsenic is significantly enriched in the majority of samples tested relative to average crustal and soil abundance.
- Iron, copper, cobalt, nickel and arsenic concentrations in peroxide leachates correlated with Total S content of the samples, indicating that segregation of samples with significant sulfur content is likely to reduce the concentration of these heavy metals/ metalloids in drainage from oxidised waste rock in the WRS.
- Peroxide leachates suggest drainage from oxidised waste rock containing more than 0.2% sulfur may contain substantial concentrations of Al, Co, Mn, Ni, Pb, Zn and waste rock with Total S concentrations above this value should be managed to minimise oxidation and release of heavy metals.

The results summarised above suggest that further investigations are required to confirm the conclusions made to date and to provide more confidence in applying the results to the management of mine wastes during and post operations.

3.2.4 Kinetic Testing

Continuous column leach tests are typically conducted by filling a length of pipe or funnel with a solid sample and continuously passing water (or another leachate) through the sample for a specified period. Leachate samples can be collected at any desired frequency and analysed for any constituent of interest. There are many variables in column leach test design, including:

- Column length and diameter.
- Flow type (forced flow from bottom or gravity flow from top).
- Flow rate/residence time.
- Sample pre-treatment (particle size reduction, oxidation, bacterial inoculation).
- Leachate composition (water or another reagent, sparged to remove O_2, etc.).

Column tests are well-suited to determining the concentrations of constituents that can be released over a relatively small number of pore volumes, which corresponds to shorter time periods.

The column leach data provided to LWC spans weeks 0 – 12 (12 July 2021 to 5 October 2021). A total of five columns have been tested including the following material:

1. PAF Rock.
2. PAF-LC Rock.
3. NAF Rock.
4. Blend of PAF and NAF rock (10/90).
5. Tailings.

For the purposes of pit lake water quality prediction, the PAF data is of interest in the first instance. The kinetic test for PAF uses sample 21363. Sample characteristics are summarised in Table 3-1.

Table 3-1 Sample 21363 characteristics

Sulfur	ANC	NAPP	$NAG_{4.5}$	$NAG_{7.0}$	NAGpH	Weight	Start	Sample
%S	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t	pH Units	g	Date	Code
0.67	9	12	4	10	3.3	2001	09/01/21	FH/21363

General trends observable from sample 21363 in the duration of data available:

- In line with elemental speciation, arsenic is by far the predominant element in terms of metal/ metalloid magnitude.
- No alkalinity is recorded.
- Acidity has doubled in 12 weeks with a concomitant decrease in pH from 5.9 to 4.8.
- Sulfate has decreased three to four-fold.
- All metals are generally in a steady state other than copper which has ~doubled.

3.3 Project Water Quality

A piper diagram of various waters associated with the project is presented in Figure 3-1. The sulfate content within the mine water bodies present a strong distinction from surrounding surface and groundwater.

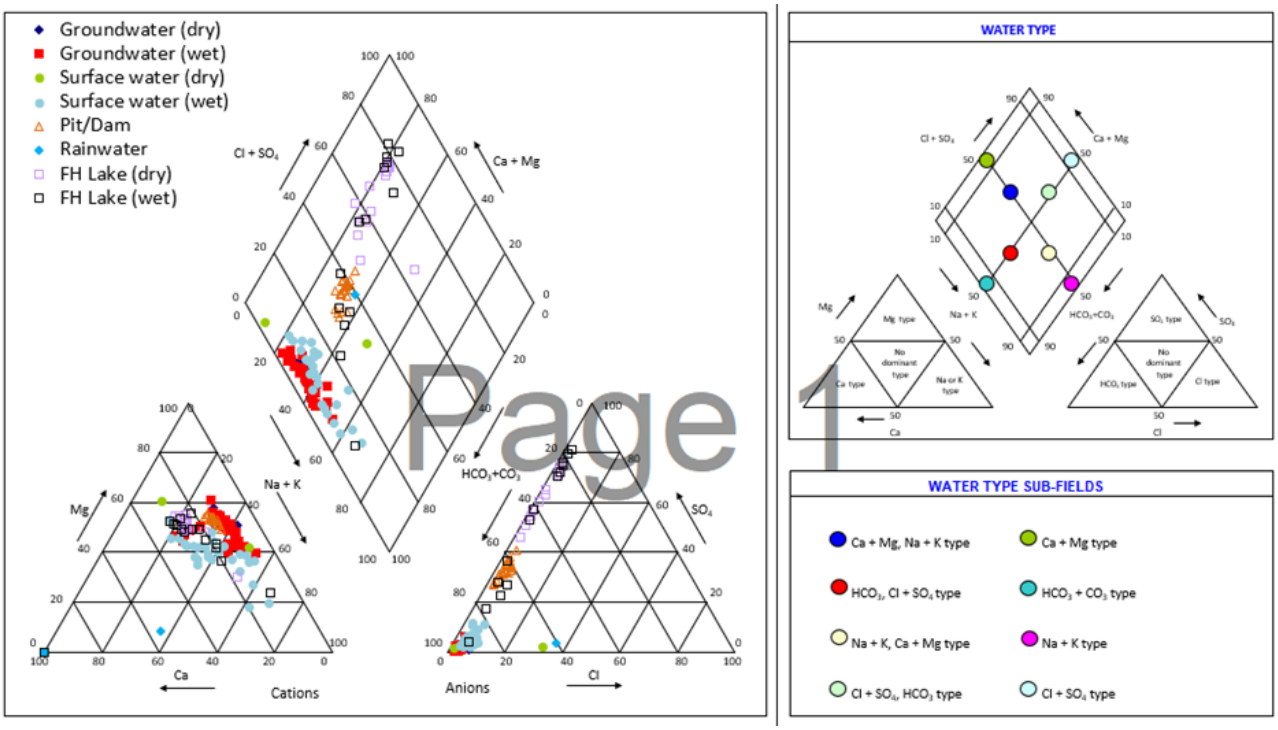

Figure 3-1 Piper diagram of project area water types (CDM Smith, 2021)

Groundwater monitoring wells 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.

Pit lake water currently has higher arsenic concentrations than the groundwater (Table 3-2 and Table 3-3) with lake arsenic concentrations noted to exceed stock water guidelines.

Table 3-2 Groundwater chemistry summary

		General Parameters				Major Ions (mg/L)						Total Metals (µg/L)										
	SWL (m below top of casing)	Conductivity (uS/cm)	pH	Hardness (mg $CaCO_3$/L)	Total Alkalinity as $CaCO_3$ (mg/L)	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulphate	Aluminium	Arsenic	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Nickel	Zinc
Long-term trigger value – Irrigation and General Water Use (ANZECC, 2000)		see below	6–8.5				see below			see below		5,000	100	10	100	50	200	200	2,000	1,000	200	2000
Short-term trigger value – Irrigation and General Water Use (ANZECC, 2000)												20,000	2,000	50	1000	100	5,000	10,000	5,000		2000	5000
Stock Drinking Water (ANZECC, 2000)		7460†	5–9			1000					1,000	5,000	500 (5000)	10	1,000	1,000	1,000		100	10000	1,000	20,000
Average		376	7	108	163	10	5	20	2	26	1131	655	101	0	5	2	6	5,316	6	171	3	10
Mean		335	7	89	140	7	4	17	2	24	5	87	50	0	2	1	3	650	4	113	2	6
s.d.		167	1	60	77	9	2	9	1	10	3707	2,074	115	0	12	1	9	7,595	7	152	6	13
Median		360	7	102	168	8	5	21	2	28	2	47	72	0	2	1	3	1,400	3	130	2	7
90%		648	7.521	209	290	28.7	7	34	3.5	34.9	3000	2,230	320	-	10	3	14.1	18,200	21.6	354	5	19.6
Max		**844**	**8.63**	**270**	**380**	**44**	**16**	**40**	**5**	**64**	**15000**	13,000	**450**	**0.3**	**53**	**3**	**40**	**32,000**	**26**	**860**	**35**	**86**
Count		72	72	70	69	70	69	70	69	70	39	46	69	3	19	16	22	67	21	67	33	55

Table 3-3 Pit Lake chemistry summary

	General Parameters				Major Ions (mg/L)						Total Metals (µg/L)																
	pH	Conductivity (uS/cm)	Hardness (mg $CaCO_3$/L)	Total Alkalinity as $CaCO_3$ (mg/L)	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulphate	Aluminium	Arsenic	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Molybdenum	Nickel	Selenium	Uranium	Vanadium	Zinc
Long-term trigger value – Irrigation and General Water Use (ANZECC, 2000)	6–9	see below				see below			see below		5,000	100	500	10	100	50	200	200	2,000	2500	1,000	10	200	20	10	100	2000
Short-term trigger value – Irrigation and General Water Use (ANZECC, 2000)											20,000	2,000	4000-6000 for sorghum	50	1000	100	5,000	10,000	5,000	2500		50	2000	50	100	500	5000
Stock Drinking Water (ANZECC, 2000)	5–9	7460†			1000					1,000	5,000	500 (5000)	5000	10	1,000	1,000	1000*		100		10000	150	1,000	20	200		20,000
Average	8.1	526		138	12.3	5.6	27.2	1.7	29.8	3549.3	50.4	618	15.6	0.0	0.9	0.2	2.8	82.2	1.4	18.0	124.5	7.3	0.8	0.2	5.0	0.5	8.2
Mean	8.0	433		137	12.2	5.5	27.2	1.7	29.7	99.0	15.0	547	15.5	0.0	0.9	0.1	0.6	35.3	0.3	18.0	30.0	6.9	0.4	0.2	4.6	0.4	4.5
s.d.	0.8	617		15	1.4	1.3	1.3	0.3	2.4	14351.9	169	156.1	1.6	-	-	0.1	9.5	175.3	2.8	0.0	172.8	2.9	1.2	0.0	2.1	0.3	10.3
Median	8.3	415		142	12.7	5.5	27.6	1.7	29.4	66.1	11.6	620	15.0	0.0	0.9	0.1	0.6	28.0	0.2	18.0	14.6	9.0	0.2	0.2	5.9	0.4	3.6
90%	9.0	509.5		154.6	14.1	7.7	28.8	2.0	33.3	84.0	55.0	770	18.6	-	-	0.4	2.0	239.0	7.5	-	426.0	-	2.5	-	-	1.1	28.4
Max	9.4	3991.4		170	14.9	7.9	29.1	2.4	34	62000	906	784	20	0.04	0.9	0.4	43	852	9.7	18	437	9	4.691	0.2	6.4	1.25	40
Count	34	34		32	36	33	36	36	36	35	28	35	13	1	1	13	20	26	13	2	32	3	17	2	4	12	26

Since there is uncertainty about the spatial extent and volume of groundwater with different chemical signatures, and because all of the groundwater is expected to be drawn into the pit and mixed together (CDM Smith, 2021), geometric mean concentrations were adopted to compare water composition (Table 3-4).

Table 3-4 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 (µS/cm)	184	-	70	378	409	357	38
TDS calc EC (mg/L)	119	7	45	246	266	232	25
Hardness ($mgCaCO_3/L$)	27	-	14	102	141	72	10
Total Alkalinity as $CaCO_3$ (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	-

Notes: 1. Darwin rainfall data from Crosbie et al. (2012)

Section 4 Pit Lake Water Quality Predictions

4.1 Overview

Two main strands of prediction have been used for calculating evolution of the PAF contact water:

1. Extrapolation of kinetic tests.
2. Extrapolation of kinetic tests scaled up for rock mass.

These approaches give vastly different results that are treated as "book-ends", i.e. upper and lower ranges. Both methods of kinetic extrapolation have been assessed for the two sources of PAF identified by the CSM (i.e. S1 PAF rock storages in pit and S2 exposed PAF material in the pit walls).

The parameters which the pit lake water quality predictions consider in this assessment are acidity and arsenic. These parameters have been identified by the source term analysis (Section 3) as having propensity to leach from the source (PAF) material resulting in change to the pit water quality and potential harm to receptors. The existence of arsenopyrite within the waste rock and ore and elevated concentrations of arsenic within Fountain Head pit lake is also well documented.

The following sub-sections describe the processes to predict the future pit lake water quality for these parameters assuming PAF material is stored within the pit during and post operations.

4.2 Source S1 – PAF Rock in Pit

4.2.1 Kinetic Testing Extrapolation

Four data points (weeks 0 – 12) are currently available for the kinetic testing of the PAF material. Using these data, a trend line was applied to the existing data points to formulate a regression equation. This was done for fitting through 0 intercept and also ignoring such intercept. The regression equations were used to extrapolate the potential concentration of the key parameters of acidity and arsenic over a 52-week period[1] and are shown in Figure 4-1 and Figure 4-2 respectively. Note the broad observations and assumptions made with respect to the available kinetic data in Section 4.5 of Appendix A.

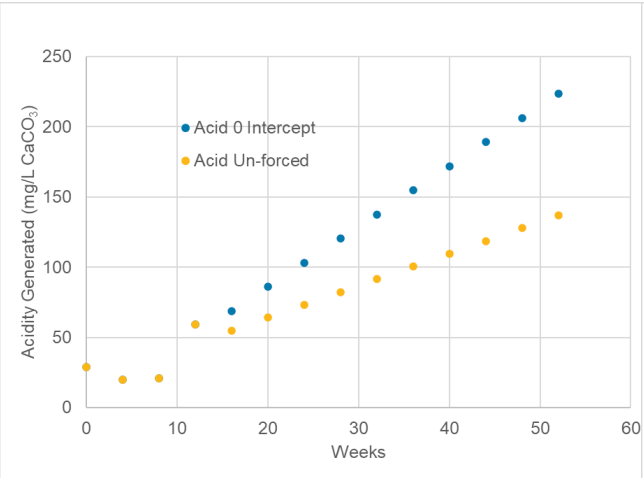

Figure 4-1 Acidity extrapolation

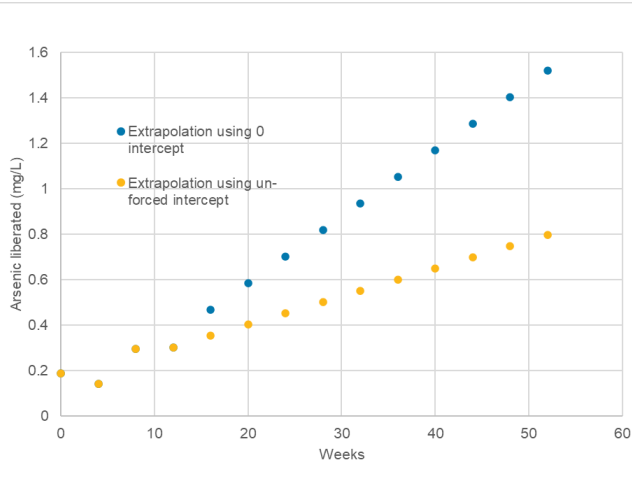

Figure 4-2 Arsenic extrapolation

[1] Points shown after 12 weeks denote extrapolated values; points shown prior to 12 weeks denote kinetic test concentrations.

4.2.2 Bulk Scale Drainage

As noted in Section 4.4 of Appendix A, a major challenge associated with the application of kinetic test results is the extrapolation of leachate chemistry to predict full-scale mine-site drainage chemistry even when waste rock compositions, tonnages and site water balance are constrained. A common approach is to convert laboratory kinetic test leachate concentrations into a geochemical loading rate (e.g., mg/kg rock/week) which is then upscaled to the tonnage of the waste dump to predict drainage quality as per equation 1 (Kirchner and Mattson, 2015):

$$Predicted\ Concentration = \frac{HC\ Load\ x\ Time\ x\ Mass\ of\ Rock\ in\ Dump}{Volume\ of\ Infiltrating\ Water}$$

Eq1

It has long been recognised that the predicted loads calculated from bulk scaling commonly overestimate actual geochemical loads seen in drainage from waste dumps (Morin & Hutt, 1994; Malmström et al., 2000). This is largely attributed to discrepancies in geochemical and physical conditions between laboratory kinetic reactors and full-scale waste dumps, including but not limited to, water-rock interaction, gas transport and oxygen content, reactive grain size distribution and temperature. Rather than using cumulative scaling factors[2] (CSF) which seek to account for the overestimation by lowering the concentrations based on the aforementioned discrepancies, use of bulk scaling alone (with no CSF) can be seen as a conservative method of leachate estimation.

The assumptions used to calculate the total scaled up predicted concentration are presented in Table 4-1, while the resulting values for both the 0-intercept and unforced extrapolations are presented as Table 4-3. Note that the milligrams of solute have been adjusted for an average leach column volume of 503 L.

Table 4-1 Scale up parameters

Parameter	Value	Source/ Reference/ Rationale
Time (weeks)	52 – refer value for 52 weeks in Appendix A, which mimics 1 year of oxidation, assuming	Arbitrary extrapolation – can be extended forward to any week value.
Mass of Rock	2 Mt	LCM of 957,700 x bulk density of 2.05 t/m^3.
Volume of infiltrating water	1,000 ML	Rainfall influx modelled reported in CDM Smith (2021)
HC Load	Kinetic data from sample 21363 using 0 intercept.	Kinetic data from sample 21363. The use of 0 intercept is more conservative currently when only 4 data points available.

4.2.3 Results / Rates

Calculations are summarised in Table 4-2 with BE1 being extrapolated from the kinetic testing results with no scaling, and BE2 being bulk scaled as per Section 4.3. The predicted leach at week 52 is summarised for the key parameters in Table 4-3.

[2] Refer to Section 6.1.2; Appendix A for further explanation

Table 4-2 Calculations for extrapolations of no scaling and bulk scaling using 0,0 intercept and un-forced intercept

Calculation Code	Calculation
BE1A – acidity	Book End 1A – extrapolation of acidity generation using kinetic testing, unscaled with linear trend drawn through 0,0
BE1B – acidity	Book End 1B – extrapolation of acidity generation using kinetic testing, unscaled, with linear trend not forced through 0,0
BE2A – acidity	(Upper) Book End 2A – extrapolation of acidity scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1A
BE2B – acidity	(Upper) Book End 2B – extrapolation of acidity scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1B
BE1A – arsenic	Book End 1A – extrapolation of arsenic generation using kinetic testing, unscaled, with linear trend drawn through 0,0
BE1B – arsenic	Book End 1B – extrapolation of arsenic generation using kinetic testing, unscaled, with linear trend not forced through 0,0
BE2A - arsenic	(Upper) Book End 2A– extrapolation of arsenic scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1A
BE2B - arsenic	(Upper) Book End 2B – extrapolation of arsenic scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1B

Table 4-3 Predicted 52 week and cumulative values for key parameters

Parameter	Week 0	Week 12	Week 52	Cumulative for 1 year
BE1A - 0 intercept				
acidity (mg/L $CaCO_3$)	29	59	224	1,591
arsenic (mg/L)	0.188	0.3	1.52	10.9
BE1B - Un-forced intercept				
acidity (mg/L $CaCO_3$)	29	59	137	1,089
arsenic (mg/L)	0.188	0.3	0.8	6.7
BE2A - 0 intercept				
acidity (mg/L $CaCO_3$)	175	356	1,350	9,608
arsenic (mg/L)	1.1	1.8	9.2	66
BE2B - Un-forced intercept				
acidity (mg/L $CaCO_3$)	175	356	827	6,573
arsenic (mg/L)	1.1	1.8	4.8	40

Notes: - This extrapolation method is not able to predict pH noting the logarithmic nature of pH, however an acidity of 224 mg/L $CaCO_3$ (assuming no buffering capacity) would equate to a pH of 2.3.
- Kinetic rates were calculated by mg/L*volume of rinse (fraction L)/ 4 weeks, using week 12 data. These rates are presented as Table 4-4.

Table 4-4 Calculated kinetic rates for key parameters

		Rate	Per week	Per month
BE1A	Acidity	mg/kg	0.0019	0.01
	Arsenic	mg/kg	0.0072	0.03
BE2A	Acidity	mg/kg	4.28	17.13
	Arsenic	mg/kg	7.81	31.22

4.2.4 Long-term Extrapolation

In the absence of oxygen consumption testing data or a full kinetic testing dataset, which may assist in predicting the duration for which material will oxidise and generate acidity, an estimate using the concentration of sulfate from the kinetic test data has been made to predict when the generation of acidity may plateau (Figure 4-3). The estimate attempts to infer the sulfide oxidation rate, a mechanism for the generation of acidity (as H_2SO_4) which in turn decreases pH.

The data suggests based on the current trend of sulfate consumption, acidity generation plateaus at around 52 weeks. Assuming arsenic dissolution coincides with an increase in acidity, a very loose assumption can be applied that after 52 weeks, the loading rate for arsenic and acidity will stabilise. Due to the paucity of kinetic testing data (noting only 4 data point exist) it is unknown for certain at what time generation of acidity and arsenic will completely cease. However, assuming the generation of acidity and arsenic will continue as steady state is a conservative assumption.

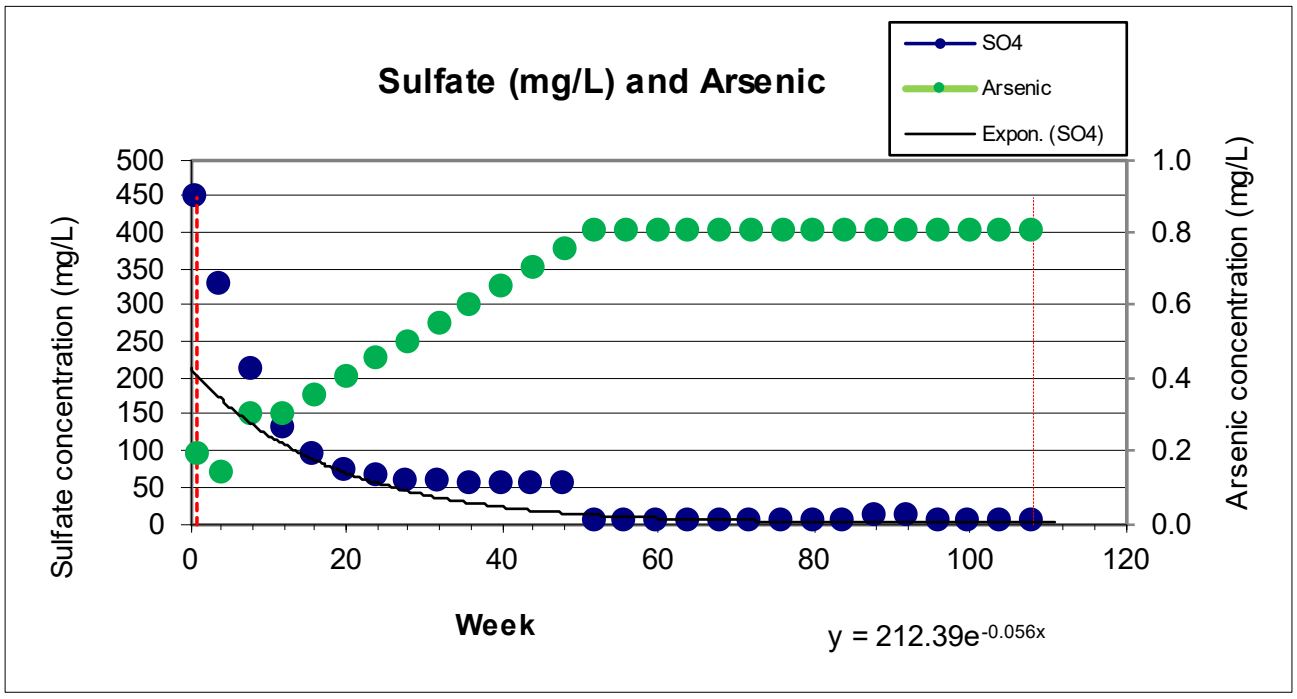

Figure 4-3 Estimated sulfate oxidation

4.3 Source S2 - Pit Wall

PAF rock will be exposed on the pit wall. A source term is required for the rinsing of sub-aerial pit wall by precipitation and inundation of exposed pit wall by the pit lake.

Both acidic and pH-neutral source terms have been developed for pit wall runoff. The proportion of acidic to pH-neutral loading from wall can be identified / revised based on the lag time calculated for the complete depletion of ANC from these units.

The surface area / particle size of rock used in column leach testing is not known and so a direct correlation between column leach rock mass and pit wall area is not achievable. The degree of geochemical loading from the pit wall is likely to be greatly influenced by the fracture intensity of the walls induced by blasting, for example:

- The blast effects in the pit wall can be subdivided into two zones; a blast influenced zone and a blast damaged zone.
- The blast damaged zone consists of highly fractured pit wall rock exposed on the pit wall face or ravel collected on benches.
- The blast influenced zone consists of more widely spaced fractures into the pit wall behind the blast damaged zone that will become progressively more fractured over time.
- The method for estimating the depth of blast damage in the transition zones was sourced from Hustrulid (1999). Each zone was calculated based on controlled blasting patterns and practices for medium strength rock and ANFO (ammonium nitrate and fuel oil) used as the blasting agent. Under these assumptions, blast fractured zone depth would be expected to range from a minimum of 0.85 m to maximum depth of 1.05 m. Blast influenced zone depth would typically range from 2.65 m to 3.15 m. Given these ranges, the blast damaged zone is estimated to extend 1.0 m into the final pit wall, and the blast influenced zone is estimated to extend another 2.9 m into the pit wall.
- The effective volume of material in a planar unit area of 1 m^2 (1 m^3) is increased by a factor of 1.41 to account for an assumed average pit wall slope of 45 degrees, i.e. 1.41 m^3. Finally, the mass of rock is determined by multiplying the effective volume by average waste density of 2.7 t/m^3 which gives 3.81 tonne (or 3,807 kg) for the blast fractured zone.
- Of note, the blast influenced zone would have a mass of 11,040 kg using the same logic but with a depth of 2.9 m.
- Accounting for both blast fractured and influenced zones, total mass of rock would be 14.8 tonne (14,800 kg).

The full parameters and values are presented in Table 4-5 with respect to arsenic. The mass of arsenic which may accumulate on PAF rock pit wall surfaces per year is 0.52 mg per kg of rock (no CSF). This represents:

- Single load transfer available once the pit wall is submerged.
- Ongoing loading from exposed rock now, during mining or post mining.

The proportion of exposed rock throughout the life or mine and post closure will be governed by the elevation of the water table. For simplicity, this calculation assumes that all PAF wall rock is exposed. When the water table rebounds the loading will decrease due to less exposed surface area. The final calculations carry a cumulative scaling factor of 0.4 (refer section 6.1.3 in Appendix A) to account for mass loading correction factors between laboratory and field scale calculations (e.g. grains size, seasonality, temperature, water contact etc.)

Note, acidities, not alkalinities, are associated with the sub-aqueous load; Pit-wall acidity is predominantly stored in sulfide mineralisation, which is released during oxidation. Acidity can then be stored on mineral surfaces in acidic oxide minerals (i.e. jarosite and alunite). This acidity stored in oxide minerals will be released upon pit wall submergence. Once the pit wall becomes submerged, oxidation and associated acidity release from primary sulfide minerals will largely be inhibited.

Unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerially exposure pit wall ANC will be consumed in response to acid production.

Table 4-5 Pit wall contribution of acidity and arsenic to lake water calculation

Parameter	Unit	Value
Area of exposed wall rock	m^2	1
Average assumes pit wall side slope angle	Degrees	45
Surface area of exposed unsubmerged pit wall rock	m^2	1.41
Density of pit wall rock	Tonne/m^3	2.7
Depth of blast fractured zone	m	1.0
Depth of blast influenced zone	m	3.0
Total volume of wall rock in the 4 m deep blast affected zone	m^3	5.64
Total mass of wall rock in the 4 m deep blast affected zone	kg	15,228
Mean annual precipitation	mm/year	1,245.2 (from section 4 of the EIS)
Mean annual precipitation volume (per 1m^2 of exposed unsubmerged wall rock)	m^3	1.25
Mass loading rates - arsenic		
Mass loading rate (arsenic, from Table 4-4)	mg/kg/wk	0.01
Mass loading rate (arsenic, from Table 4-4 – annual)	mg/kg/yr	0.52
Wall rock loading rate (arsenic, from Table 4-4)	mg/kg/yr (without CSF of 0.4)	0.52
Wall rock loading rate (arsenic, from Table 4-4)	mg/kg/yr (with CSF of 0.4)	0.21
Mass loading rates – acidity (as $CaCO_3$)		
Mass loading rate (from Table 4-4)	mg/kg/wk	14.5
Mass loading rate (from Table 4-4– annual)	mg/kg/yr	754
Wall rock loading rate (from Table 4-4)	mg/kg/yr (without CSF of 0.4)	754
Wall rock loading rate (from Table 4-4)	mg/kg/yr (with CSF of 0.4)	302
Mass loading predictions		
Total mass of rock in the blast damaged zones per m^2	Tonne / kg	15.2 / 15,200
Area of PAF rock	m^2	55,563
Total mass of PAF rock available	Mega-tonne	0.845
Total mass of PAF rock available	kg	845,000,000 (8.45 x 10^8)
Annual mass loading from the pit walls to the pit lake per 1m^2 of unsubmerged rock - **arsenic**	kg/yr / mg/yr	3.2 x10^{-3} / 3,200
Annual mass loading from the pit walls to the pit lake per 1m^2 of unsubmerged rock - **acidity**	kg/yr / mg/yr	4.6 / 4,590,400
Total annual contact water available per 1 m^2 of unsubmerged rock (per 1m^2)	m^3/yr / L/yr	1.25 / 1,250
Annual average wall rock runoff concentration (calculated/ predicted) per 1m^2 - **arsenic**	mg/L	2.6
Annual average wall rock runoff concentration (calculated/ predicted) per 1m^2 - **acidity**	mg/L $CaCO_3$/ as H^+ mg/L	3,672 / 73
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock - **arsenic**	kg/yr / mg/yr	178 / 1.77 x 10^8
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock - **acidity**	kg/yr / mg/yr	2.6 x 10^5 / 2.6 x 10^{11}
Total annual contact water available per PAF unsubmerged rock	m^3/yr / L per year / ML	69,454 / 6.95 x 10^7 / 69.5

Parameter	Unit	Value
Annual average wall rock runoff concentration (calculated/ predicted) for PAF rock - arsenic	mg/L	2.5
Annual average wall rock runoff concentration (calculated/ predicted) for PAF rock - acidity	mg/L $CaCO_3$ / as H^+ mg/L	1.0 / 0.02

4.4 Summary

The following summarises the prediction method results for the pit lake water quality:

- Arsenic and acidity are considered to be the key parameters.
- Current pit lake water reports arsenic above the stock watering guideline value of 0.5 mg/L. Arsenic concentrations in groundwater do not exceed this criterion.
- This assessment uses currently (limited) available kinetic data for PAF rock and extrapolated forward using linear trend analysis – the resulting arsenic concentrations in the leach exceed the stock watering value at week 52. It is understood the PAF rock would be left unmanaged for longer than this during life of mine (~3 – 4 years) and so further oxidation of sulfidic materials could likely occur, leading to a higher leach concentration of arsenic (and other metals) as the pH of the leach continues to decrease.
- The lowest predicted leach arsenic concentration at week 52 is 0.8 mg/L using an un-forced intercept linear trend (calculation BE1B). This concentration exceeds the stock criterion of 0.5 mg/L but is generally in line with current pit lake water (0.54 mg/L).
- Where forcing the intercept through zero, the arsenic leach concentration at 52 weeks is 1.5 mg/L, which is three times the stock watering criterion and double the current lake concentration.
- Using bulk scaling methods (BE2B), a rather blunt assessment that may overpredict concentrations associated with the total mass of rock, the resulting leach concentrations (accounting for 2 Mt of PAF rock) predicts an arsenic concentration of 4.8 mg/L, ~6 times the current pit lake water and result in a pit lake arsenic concentration ~9 times the stock watering criterion for arsenic.
- Based on the current trend of sulfate consumption, acidity generation has been roughly estimated to plateau at around 52 weeks. Assuming arsenic dissolution coincides with an increase in acidity, a very loose and conservative assumption can be applied that after 52 weeks, the loading rate for arsenic and acidity will stabilise and continue as steady state generation.
- Using a CSF adjusted loading, and ignoring the pit water level, the pit walls are considered to contribute around 2.5 mg/L of arsenic cumulatively, or around 2.6 mg/L per m^2 of PAF exposed rock. This would be diluted in a 'full' pit lake though evaporation and limited migration over time will increase the residual arsenic concentration. Note that the current pit lake arsenic concentration is higher than groundwater, possibly as a result of current or previous loading of arsenic from exposed fractured pit wall rock.
- Given the short-term status of the kinetic data and absence of other useful testing data such as oxygen consumption tests, there is considerable uncertainty in the magnitude of predicted concentrations of key parameters. Current (kinetic) and other lines of evidence (oxygen consumption) should be revisited where / when more data points are collected/ considered.
- The extrapolation method deemed most suitable for use in this assessment is BE2B (bulk scaling of kinetic testing results with an un-forced (not through 0,0) linear trend). This method is conservative in that it has no scaling factor applied and assumes a linear increase in acidity and arsenic concentrations.

Section 5 Water Balance Model Update

5.1 Model update

5.1.1 Approach

As part of a supporting scope for the FHGP EIS, CDM Smith (CDM Smith, 2021) developed a non-reactive solute balance which was paired with a water balance model (WBM) 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 3.3). Using the recent kinetic test data, the WBM and non-reactive solute balance function has been updated to provide estimates of the Fountain Head pit lake water quality assuming PAF material storage within the pit. 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. The modelling, however, does consider the kinetic results of arsenic and dissolution of this parameter from source material within the Fountain Head pit.

5.1.2 Model Structure

As reported by CDM Smith (2021), the WBM 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). Figure 5-1 presents a schematic of these stages noting the schedule has since been updated at the time of writing. The WBM assumes the dates and timeframes outlined in Figure 5-1, however, remains applicable to future scenarios provided similar operating stages are maintained.

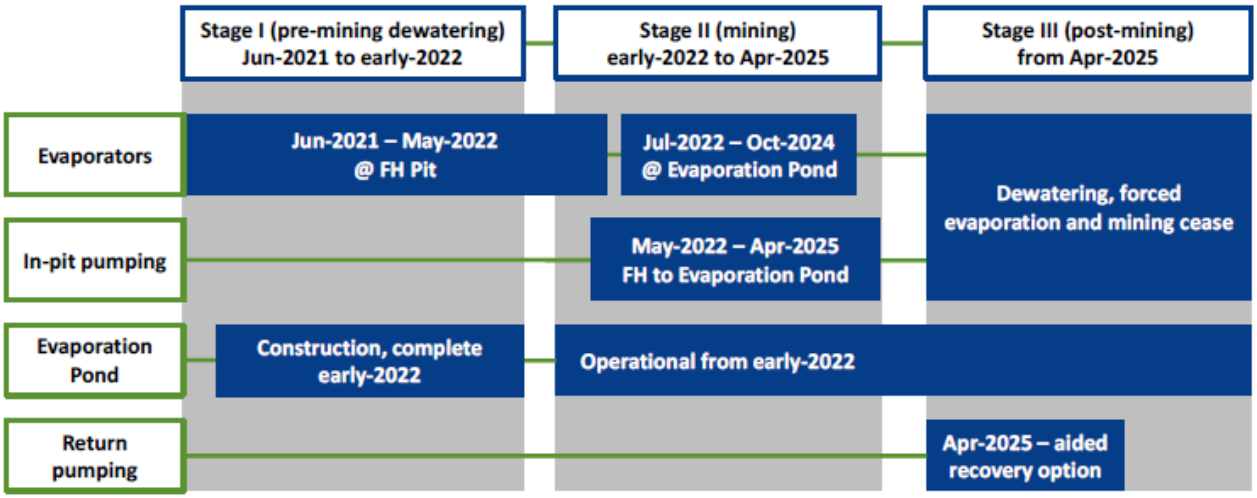

Figure 5-1 Overview of Fountain Head Pit and Evaporation Pond water balance Stages

The physical structure of the site comprises three main water balance components / sub-catchments which form part of the overall Fountain Head Lake catchment area (Figure 5-2):

- 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.
- The Fountain Head Lake – has bathymetry defined by the latest digital elevation models available and includes the proposed Carbon-in-Pulp (CIP) and other catchments related to proposed sedimentation dams.

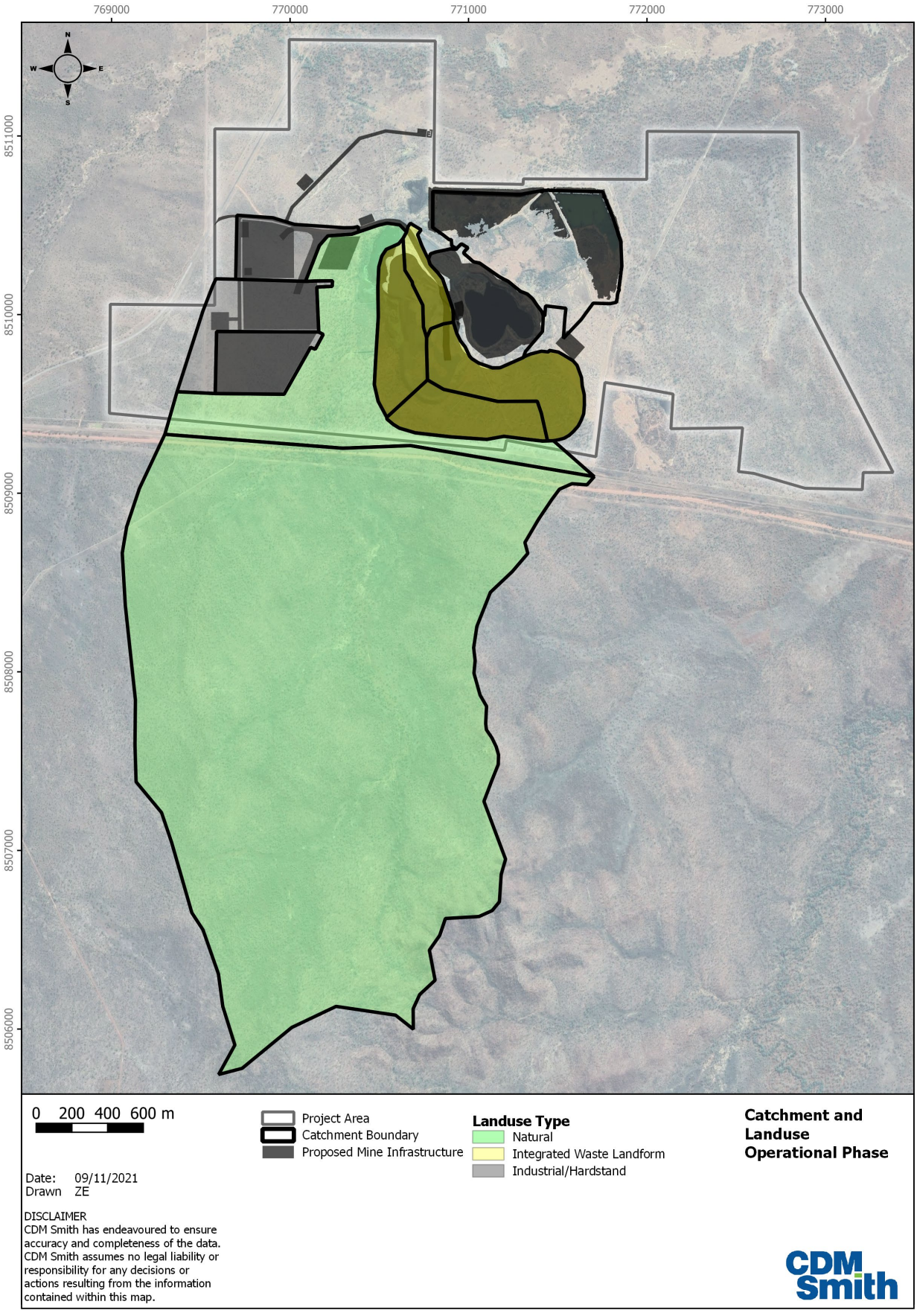

Figure 5-2 Fountain Head Lake catchment and land use

The WBM 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 5-3 while the model parameters are presented in Section 4.4.2.8 in CDM Smith (2021) and also as Appendix B.

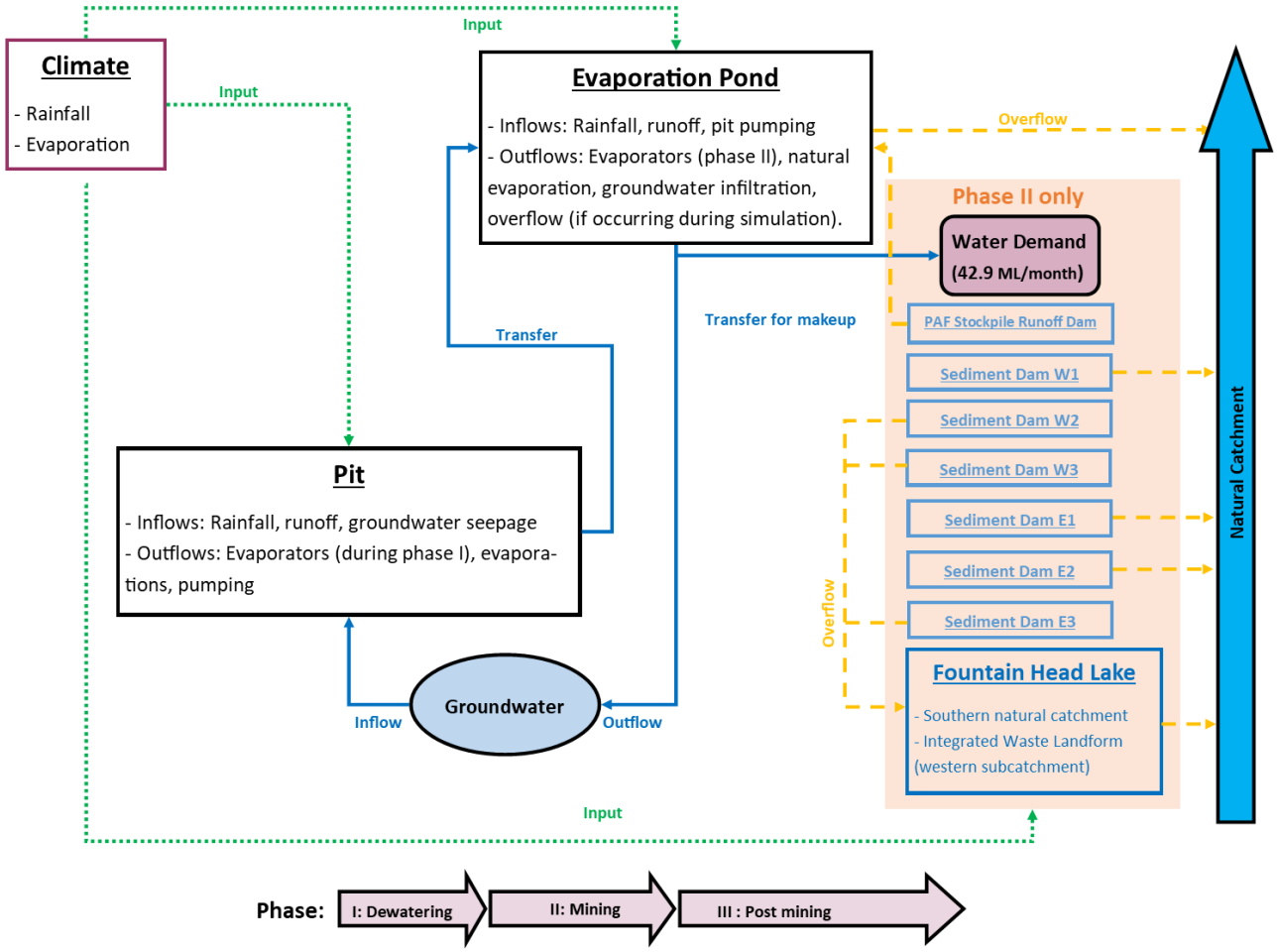

Figure 5-3 Fountain head site water balance schematic

5.1.3 Updated Model Inputs and Assumptions

To enable prediction of water quality associated with the in-pit PAF material storage scenario, the WBM has been updated with the kinetic test data of the key parameters. The updated parameters are listed in Table 5-1. Note, the addition of these data into the WBM assumes:

- Acidity and arsenic loading rates remain in steady state from 52 weeks post Stage I (dewatering) until the end of Stage III (500 years post mining) as per Table 5-1.
- All PAF material is of the equivalent geochemical make up as the PAF sample used in the column leach test and has the same reaction with water.
- Loading rates of S1 and S2 have been estimated based on full exposure to the atmosphere, i.e. that no submergence by water is occurring, during Stage II (mining stage). Furthermore, it is assumed the entire quantity of PAF rock (~2 Mt) will be exposed at the onset of mining. Given exposure of these materials during mining is likely to occur gradually, this approach is considered conservative.
- Key parameter loading rates are expressed in kg/d, which is assumed to mix with a combination of inflow water, rainwater and groundwater for which contain their own unique chemistry (as listed in Table 3-4).

- No changes to the surface water and/or groundwater model to those reported in CDM Smith (2021).
- PAF pod distributions as per Figure 5-2 and elevations as per Table 2-1.

Table 5-1 Key model inputs [1]

Source	Parameter	Unit	Value	Comments
S1 – PAF rock pods	Arsenic	kg/d	13.2 [2]	BE2B at 52 weeks. Assumes 2 Mt PAF rock and 1,000 ML rain refer Appendix C
	Acidity	kg/d	2,265 [2]	
S2 – PAF pit walls	Annual average wall rock runoff concentration - arsenic	mg/L	2.5	Rate assumed constant, refer Table 4-5
	Annual average wall rock runoff concentration - acidity	mg/L $CaCO_3$ / as H+ mg/L	1.0 / 0.02	

Notes: 1. Inputs represent steady state loading rates.
2. Refer Appendix C for S1 loading rates during first 52 weeks of PAF exposure.

To account for the PAF material storage within the Fountain Head pit, a number of model 'rule' changes have been incorporated into the WBM including:

- Adjustment of total mass loading to be a function of the percentage of source rock (both S1 and S2) exposed with regard to the pit water level. The loading rates (model inputs) presented in Table 5-1, apply only to exposed PAF rock, not submerged, i.e. if 100% of PAF rock is exposed, unit loading will apply to 100% of the source rock, however, if only 50% of PAF rock is exposed, then only half the rock mass will generate a release. Therefore, as pit levels recover over time, the rate at which acidity and arsenic are generated will also decrease as the PAF material becomes submerged. Note, some release is still expected post submergence, albeit at a slower rate.
- Implementation of maximum possible elemental concentrations as upper limits in the WMB. Should the cumulative concentrations for the key parameters be reached, generation will cease, and parameters considered completely exhausted.

5.1.4 Model Limitations

Although the key parameter kinetic test data has been incorporated into the WBM, the model itself does not allow for reactive modelling, i.e. decay or transformation of the source water components into other compounds, nor does it consider this effect when mixing waters of different chemistry. This is an important limitation to understand, as the extent to which certain parameters react within a solution differs greatly. For example, accumulation of arsenic within Fountain Head pit, is thought to occur relatively independent of other parameters. However, the accumulation of acidity, is both a function of sulfuric acid generated from the PAF rock, as well as the buffering capacity (alkalinity) of the solution. A non-reactive model such as the FHGP WBM, only considers the mixing of constituents independently. Therefore, acidity, which is co-dependant on the amount of available alkalinity, cannot be predicted by the WBM with the same accuracy as arsenic. For this reason, acidity has been excluded from this assessment.

Although a quantitative assessment of acidity cannot be completed using the WBM, a qualitative assessment can instead be made to assist in determining a rough estimate for which acidity may range.

Figure 5-4 presents the timeseries evolution of acidity within the Fountain Head pit until 2050 assuming no water management options are implemented. Acidity is expressed as H^+, which increases over time due to the ongoing oxidation of the PAF rock. However, despite the WBM showing an increase in acidity, it is likely the volumes of acid generated will be buffered by the groundwater when considering the total alkalinity ($CaCO_3$) of groundwater and the current Fountain Head pit water is around 158 and 136 mg/L respectively[3]. This observation would be consistent with

[3] Refer to Appendix A of LWC (2021) for calculations, the calculated acidity of Fountain Head pit lake is around 34 mg/L $CaCO_3$ compared with around 156 mg/L $CaCO_3$ alkalinity in the groundwater, leaving approximately 122 mg/L $CaCO_3$ buffering capacity within the pit water. The mean alkalinity of the Fountain Head pit lake is around 137 mg/L $CaCO_3$.

water quality currently observed within the Fountain Head pit, where despite elevated the arsenic concentration and existing exposed PAF material in the pit walls, the water remains relatively alkaline (mean pH of around 8).

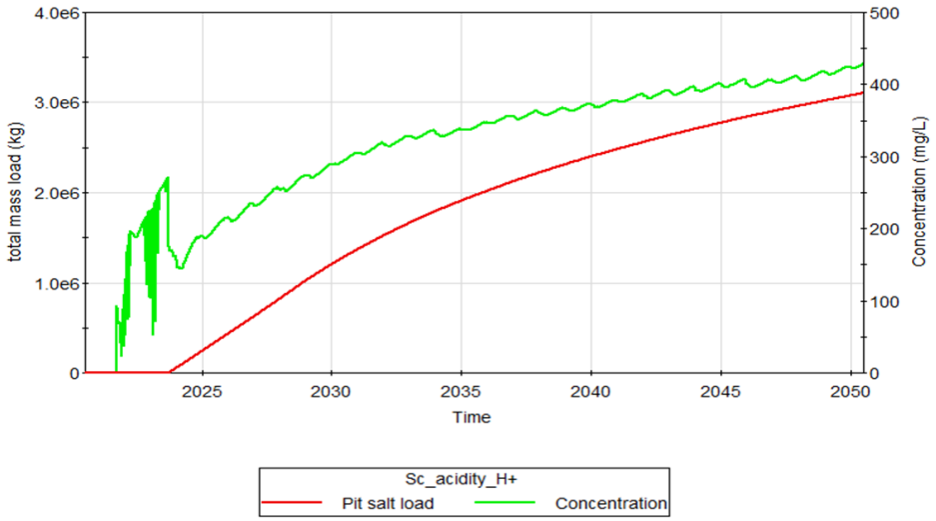

Figure 5-4 Timeseries evolution of acidity as H+ (non-reactive)

Other limitations of the WBM include:

- A paucity of kinetic test data for which this assessment is based upon. Current data has been inferred from the collection of 12-weeks (4 points) of column leach testing data of the PAF material. At a minimum, the WBM should be updated again once further collection of kinetic test data is made. Common practice, however, prefers the utilisation of kinetic data from the 28-week mark onwards.
- The WBM assumes uniform mixing of water storages. In a real-life scenario this is likely to be untrue, as stratification will naturally occur in deeper water bodies such as the Fountain Head pit lake. This may result in different layers (i.e. epilimnion – upper most layer, metalimnion – transition layer, hypolimnion – lower most layer which participates in mixing and monimolimnion – semi-permanent stratified bottom layer) that may not mix with one another. The implication of stratification on water quality is parameter concentrations will likely vary with depth rather than reporting as a single value as suggested by the WBM. As a generalisation the upper layers (epilimnion and hypolimnion) are often oxic resulting in lower concentrations of redox-sensitive metals and anions and higher concentrations of major ions like sodium and chloride. Conversely, the monimolimnion layer often has higher concentrations of calcium, magnesium and sulfate than the upper layers.

5.2 Model Results and Water Management Options

5.2.1 Overview

Two water management options have been considered as part of this assessment. Note, each option comprises two sub-options regarding PAF management, Option 1a/2a for partial PAF pod submergence (i.e. leave PAF pods as per Figure 2-1) and Option 1b/2b for full submergence of PAF pods post mining:

1. **No changes to water management** – This option assumes the Fountain Head pit is closed once mining ceases, the evaporation pond remains in place and no further pumping or water management activities are implemented. This scenario is consistent with that presented in CDM Smith (2021).
2. **Diversion of water and flushing of Fountain Head pit** – This option assumes diversion of 80% of the natural catchment water through the Fountain Head pit at end of mining. No back pumping of the evaporation pond occurs under this scenario, rather water level recovery within the pit will be assisted by the supplementary flows diverted from the catchment.

Predictions of the water quality evolution and comparison against guideline values for each of these options are made in the below sub-sections.

5.2.2 Option 1a – No Changes to Water Management | Partial PAF pod submersion

Option 1a assumes no change to the existing water management plan. Dewatering activities will occur from present till end of mining in April 2025 during which time the PAF pods will remain in the proposed locations (Figure 2-1), partially submerged with ongoing oxidation.

The WBM assumes the generation of leachate is instant once mining begins. During this time, the Fountain Head pit will be dewatered via the use of evaporators and dewatering to the evaporation pond. As a result, the dissolved arsenic concentration[4] with the evaporation pond quickly becomes elevated to over 40 mg/L from mid-2023, to around 75 mg/L by mid-2024 (Figure 5-5). However, at the onset of 2026, when mining ceases and pumping from the pit to the evaporation pond ends, the arsenic concentration within the evaporation pond quickly declines and falls below the stock water guideline for arsenic (0.5 mg/L) by the end of 2027 and the guideline for aquatic ecosystems (80% protection) (0.14 mg/L) shortly after in early 2028.

The arsenic concentration within the Fountain Head pit briefly spikes during mining before declining momentarily once mining ceases and groundwater inflow resumes to the pit. However, as much of the PAF rock remains exposed within the pit, arsenic continues to be generated post mining, which as illustrated in Figure 5-6, accumulates from less than around 8 mg/L post mining to around 50 mg/L at 500 years end of mine. As can be seen, stock water and aquatic ecosystems (80% protection) guidelines for arsenic are exceeded for almost the entirety of the period of record.

Under this option, pit water level recovery within the Fountain Head pit is expected to occur as shown earlier in Figure 2-2, where PAF Pod 3 will be fully submerged after around 2 years post mining and PAF Pod 2 after around 30 years post mining. PAF Pod 1 will remain partially submerged under this option contributing to the bulk of the arsenic load over the period of record both during and post mining.

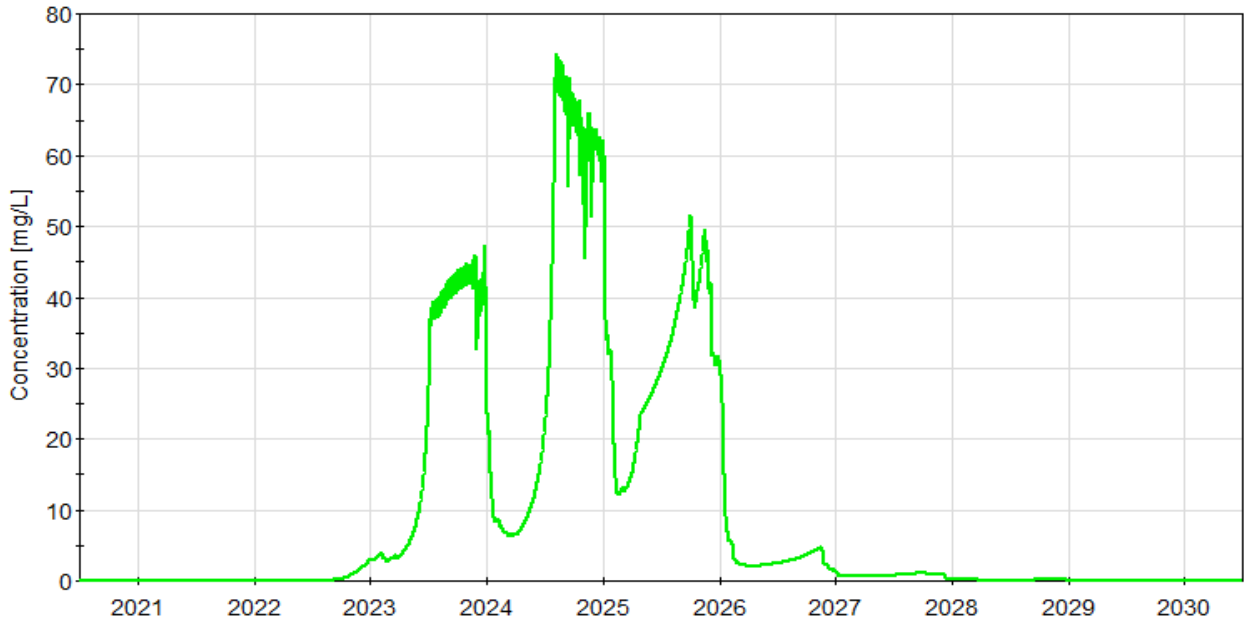

Figure 5-5 Option 1a - Predicted dissolved arsenic concentration of the evaporation pond over 10 years post mining

[4] All predicted concentrations referenced are as dissolved. Note in comparing predicted arsenic concentrations against stock water guidelines (as total species) caution should be considered, as it is likely total concentrations will be equal to or higher than dissolved concentrations.

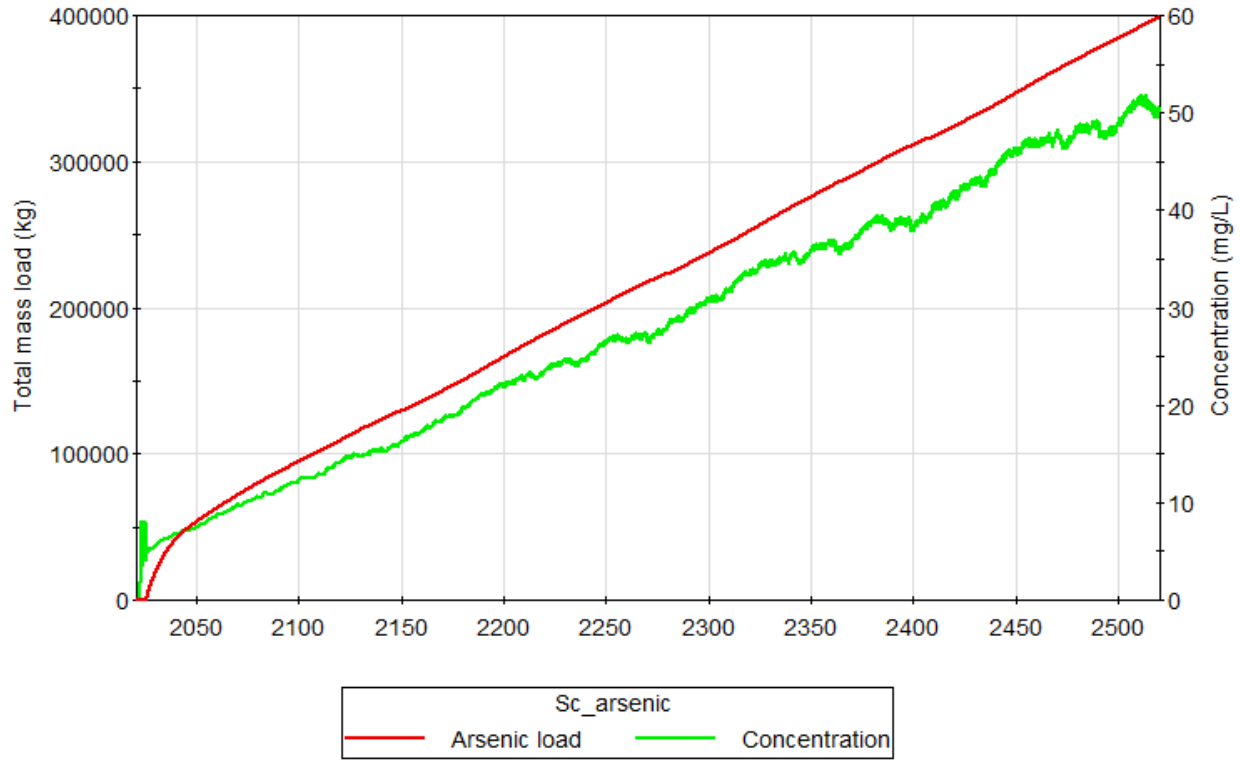

Figure 5-6 **Option 1a – Predicted dissolved arsenic concentration of the Fountain Head pit lake over 500 years post mining**

For other groundwater chemical components, a normalised approach[5] has been retained as per CDM Smith (2021) resulting in the concentration estimates for 30 years post-mining and 500 years post-mining presented in Table 5-2.

Table 5-2 **Current and predicted concentration of water chemical elements after 30 and 500 years in Fountain Head Pit (Option 1a and Option 1b)**

Parameter	ANZECC, 2000 Guideline – Aquatic Ecosystem (80% protection) [1]	ANZECC, 2000 Guideline – Stock Drinking Water [2]	Current [1]	30 years [1]	500 years [1]
EC (µS/cm)	20 or 250	-	409	407	1,083
TDS (mg/L)	-	5,000	266	265	704
Hardness ($mgCaCO_3/L$)	-	-	141	140	373
Total Alkalinity as $CaCO_3$ (mg/L)	-	-	136	135	360
Calcium (mg/L)	-	1,000	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)	-	1,000	68	68	180
Aluminium (µg/L)	150	5,000	5	5	13

[5] Assuming the sole source of contamination arises through pit runoff and groundwater inflow. To calculate the chemical concentration at a given time, the source concentration is adjusted in accordance with the relationship presented in Figure 4-28 of CDM Smith (2021) by multiplying the normalised concentration value at a future time by the estimate of the source concentration.

Parameter	ANZECC, 2000 Guideline – Aquatic Ecosystem (80% protection) [1]	ANZECC, 2000 Guideline – Stock Drinking Water [2]	Current [1]	30 years [1]	500 years [1]
Arsenic (µg/L) [3] (Option 1a)	140	500	567	6,000	50,000
Arsenic (µg/L) [3] (Option 1b)	140	500	567	2,200	2,500
Copper (µg/L)	2.5	400 or 5,000	0.6	0.6	2
Iron (µg/L)	-	-	26	26	69
Zinc (µg/L)	31	20,000	4.4	4.4	12

Notes: 1. Concentrations as dissolved species
2. Concentrations as total species
3. Inferred from column leach tests and assumed to be as dissolved species

5.2.3 Option 1b – No Changes to Water Management | Full PAF pod submersion

Option 1b simulates the same scenario as Option 1a, however, assumes PAF Pod 1 will be disposed of into the pit following mining, leading to full submersion of all PAF pods and only partial submersion of PAF rock associated with the exposed pit walls (similar to current conditions). The dissolved arsenic concentration within the evaporation pond remains unchanged to that presented in Option 1a (Figure 5-5).

Under this option, pit water level recovery within the Fountain Head pit is expected to occur as shown in Figure 5-7, which assumes the same water level recovery as Option 1a, although, with different PAF pod distributions. As shown, PAF Pod 1 will be submerged within 1 year post mining, PAF Pod 3 will be fully submerged after around 2 years post mining and PAF Pod 2 after around 30 years post mining. The WBM assumes PAF Pod 1 will be located between -20 and 24 mAHD (Figure 5-7) after disposal into the pit following mining which reduces the PAF oxidation and leachate generation.

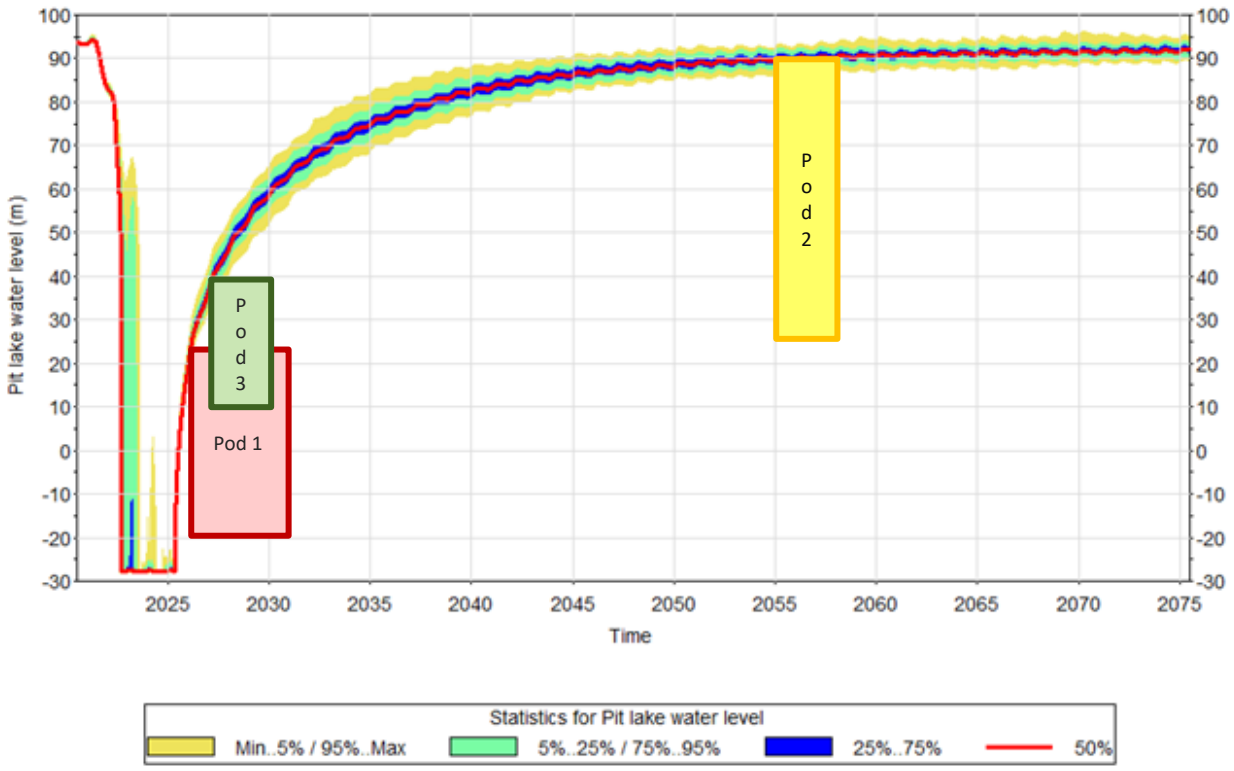

Figure 5-7 Option 1b - Predicted pit water level change during dewatering and recovery

The arsenic concentration within the Fountain Head pit briefly spikes during mining to around 8 mg/L before rapidly declining once mining ceases and groundwater inflow resumes to the pit providing dilution of the pit lake water and submersion of the PAF pods. The arsenic concentration gradually accumulates between 2050 to 2500 from around 2.2 mg/L to 2.5 mg/L driven mainly by the ongoing leachate contributions from the PAF rock exposed in the pit walls. As can be seen, stock water and aquatic ecosystems (80% protection) guidelines for arsenic are exceeded for almost the entirety of the period of record.

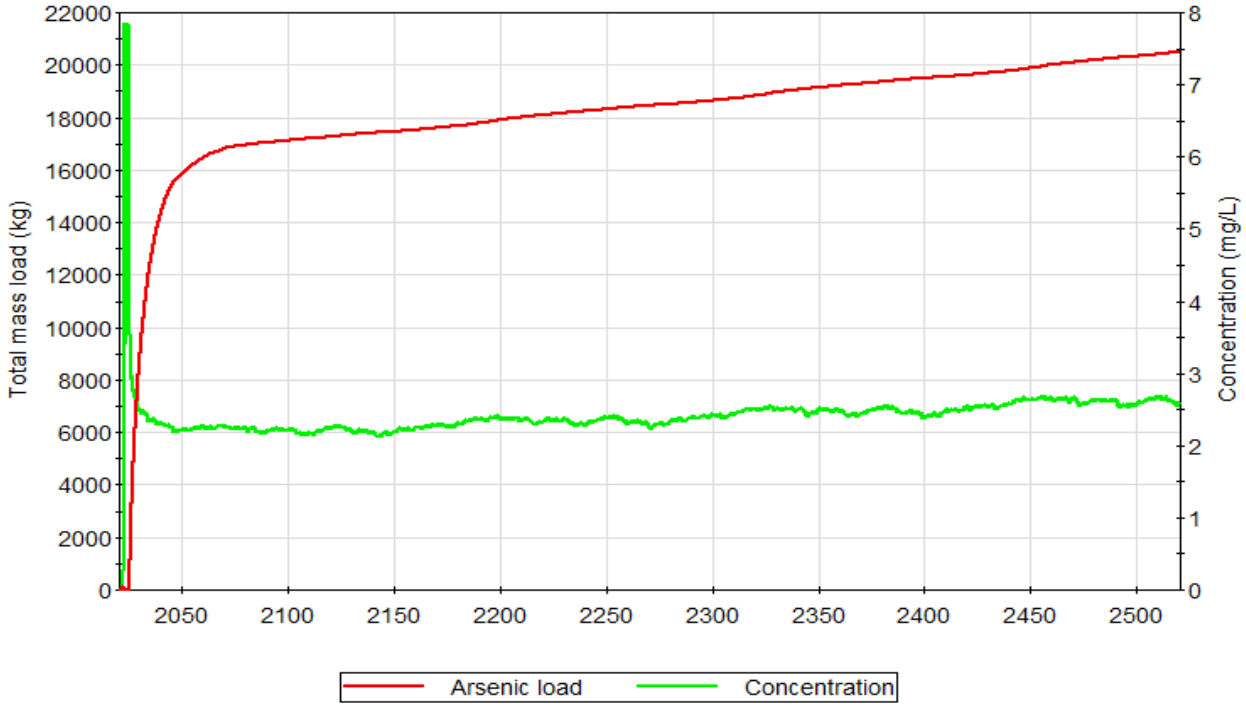

Figure 5-8 Option 1b - Predicted dissolved arsenic concentration of the Fountain Head pit lake over 500 years post mining

5.2.4 Option 2a – Water Diversion and Flushing of Fountain Head Pit | Partial PAF pod submergence

Option 2a assumes 80% of the natural catchment flow (Figure 5-2) will be diverted through the Fountain Head pit following mining. No other controls such as pumping between water storages, use of evaporators, preventing overtopping of water or logistics for managing such a diversion have been assumed. Mining will continue as per the assumed schedule until April 2025 during which the PAF pods will remain in the proposed locations (Figure 2-1), partially submerged with ongoing oxidation, however, submersion of this material will be aided by the inflow from the natural catchment. Under this option, the evaporation pond water quality, inflow and outflows remain unchanged to that shown in Option 1a.

Figure 5-9 illustrates the predicted arsenic concentration within Fountain Head pit. The arsenic concentration peaks at around 8 mg/L during mining operations, however, recovers to below the stock water guideline of 0.5 mg/L by 2033 once mining ceases and catchment water is diverted through the pit. The arsenic concentration momentarily recovers below the aquatic ecosystem (80% protection) guideline of 0.14 mg/L by 2046, however, increases and continues regular oscillation below and above the aquatic ecosystem (80% protection) guideline post mining, averaging a concentration of 0.15 mg/L between 2046 and 2500. However, it is noted this concentration is lower than the current pit lake water.

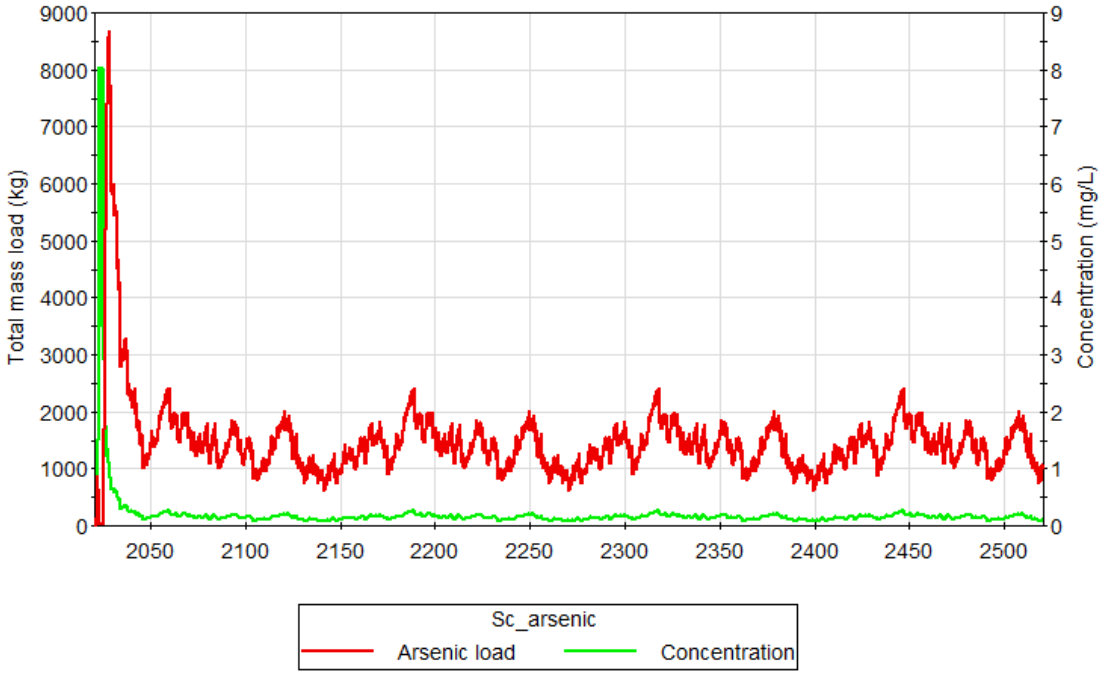

Figure 5-9 Option 2a - Predicted dissolved arsenic concentration of the Fountain Head pit lake over 500 years post mining

Diversion of the catchment causes regular (yearly) overtopping of the pit during the wet season. The predicted overtopping frequency and quantity is presented in Figure 5-10, while the Fountain Head pit inflow source quantities are shown in Figure 5-11. The modelling suggests overflow is likely to range between 50 and 1,000 ML/d while pit inflow is expected to amass around 3,500 ML/yr, with almost 80% of inflows being contributed by the catchment diversion.

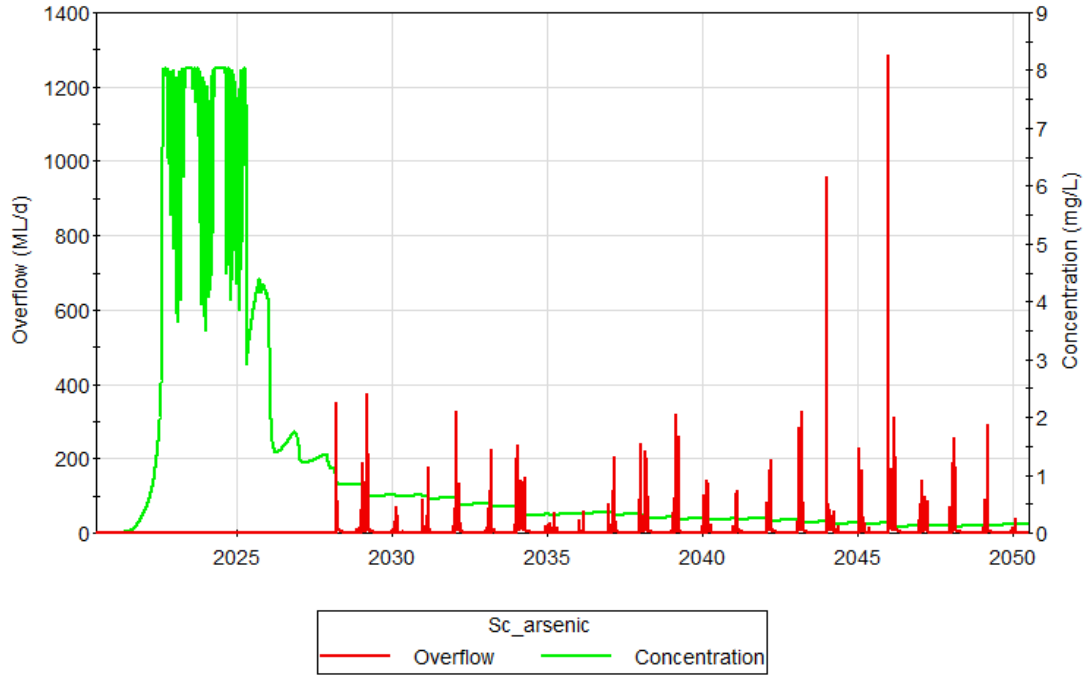

Figure 5-10 Option 2a - Predicted dissolved arsenic concentration and overflow occurrences of the Fountain Head pit lake up to 50 years post mining

Overtopping is first predicted to occur from the 2028 wet season before the arsenic concentration has decreased to below the stock water guidelines (2033) or aquatic ecosystem (80% protection) guidelines (2046). Consequently, it is predicted that for five (5) years post mining, overflow water will be above the stock guidelines with respective concentrations ranging between around 0.85 mg/L to 0.5 mg/L during this time. The arsenic concentration will likely alternate above and below the aquatic ecosystem guidelines (80% protection) of 0.14 mg/L in the years post 2046.

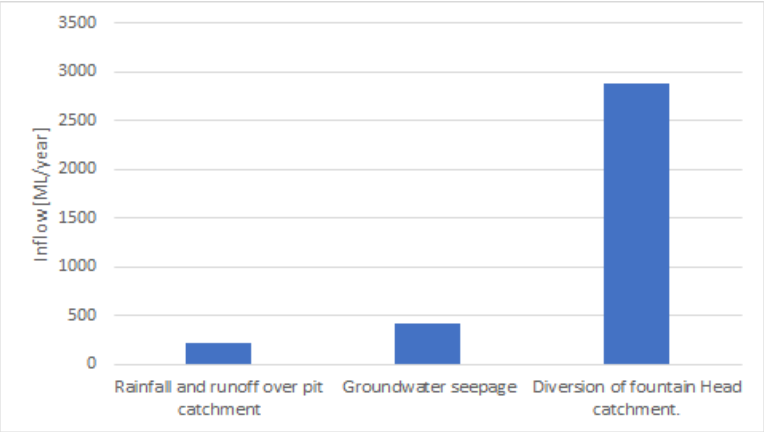

Figure 5-11 Option 2a – Predicted (mean) Fountain Head pit inflow source quantities

As shown in Figure 5-12, diversion of the catchment significantly improves the water level recovery within the pit, submerging PAF Pod 3 within 1 year post mining and PAF Pod 2 within 3 years post mining. The recovering water level has a duality of purpose by both diluting the Fountain Head pit lake water and submerging the PAF rock thus slowing the reactivity/release of arsenic. However, despite a significantly reduced load of arsenic following submersion of the PAF sources (estimated to be around 0.9 kg/d), the arsenic concentration within the pit lake after 2046 (Figure 5-9) oscillates below and above the aquatic ecosystem (80% protection) guideline (0.14mg/L) becoming diluted during periods of inflow and water level rise and concentrating in the pit during dry periods. The average arsenic concentration of Fountain Head pit post 2046 is 0.15 mg/L.

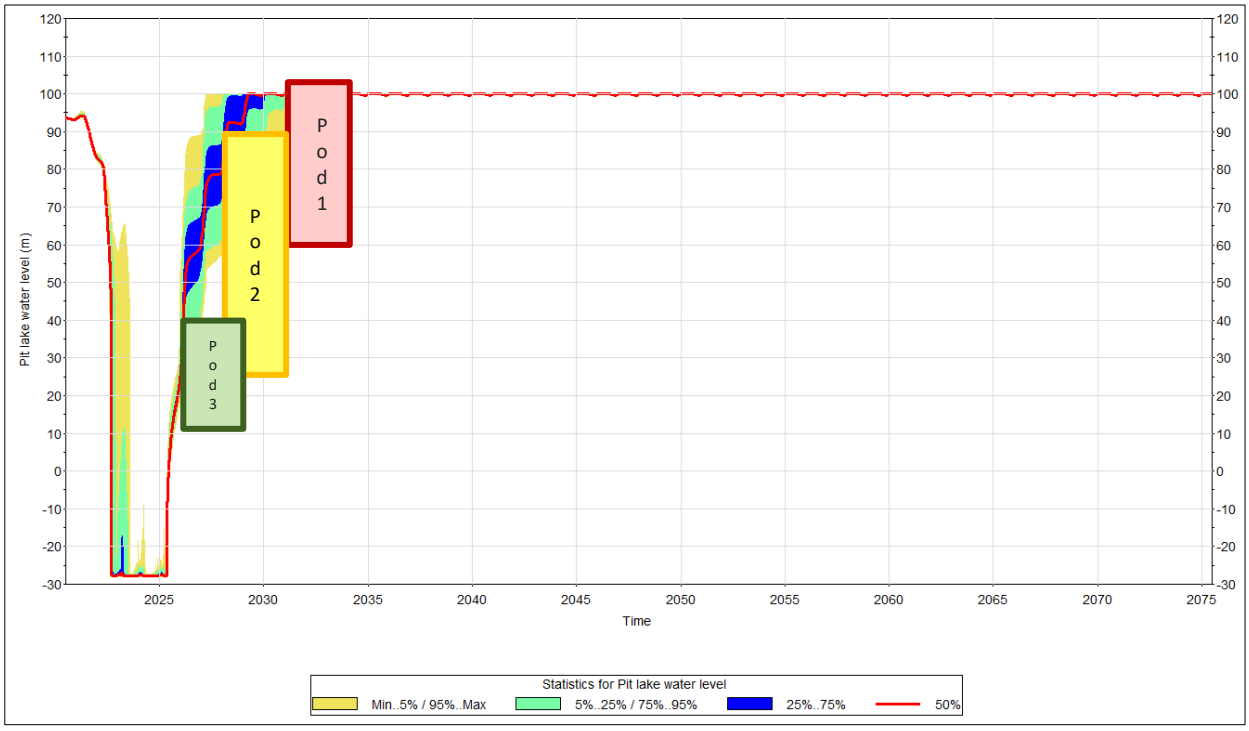

Figure 5-12 Option 2a - Predicted pit water level change during dewatering and recovery

5.2.5 Option 2b – Water Diversion and Flushing of Fountain Head Pit | Full PAF pod submergence

Option 2b simulates the same scenario as Option 2a, however, assumes PAF Pod 1 will be disposed of into the pit following mining, leading to full submersion of all PAF pods and only partial submersion of PAF rock associated with the exposed pit walls. The dissolved arsenic concentration within the evaporation pond remains unchanged to that presented in Option 1a (Figure 5-5).

Under this option, pit water level recovery within the Fountain Head pit is expected to occur as shown in Figure 5-12, which assumes the same water level recovery as Option 2a, although, with the PAF pod distributions shown in Figure 5-13. With the aided water level recovery from the catchment diversion, submersion of PAF Pod 1 and 3 occurs within 1 year post mining and PAF Pod 2 within 3 years post mining. As per Option 1a, the WBM assumes PAF Pod 1 will be located between -20 and 24 mAHD (Figure 5-13) after disposal into the pit following mining which reduces the PAF oxidation and leachate generation.

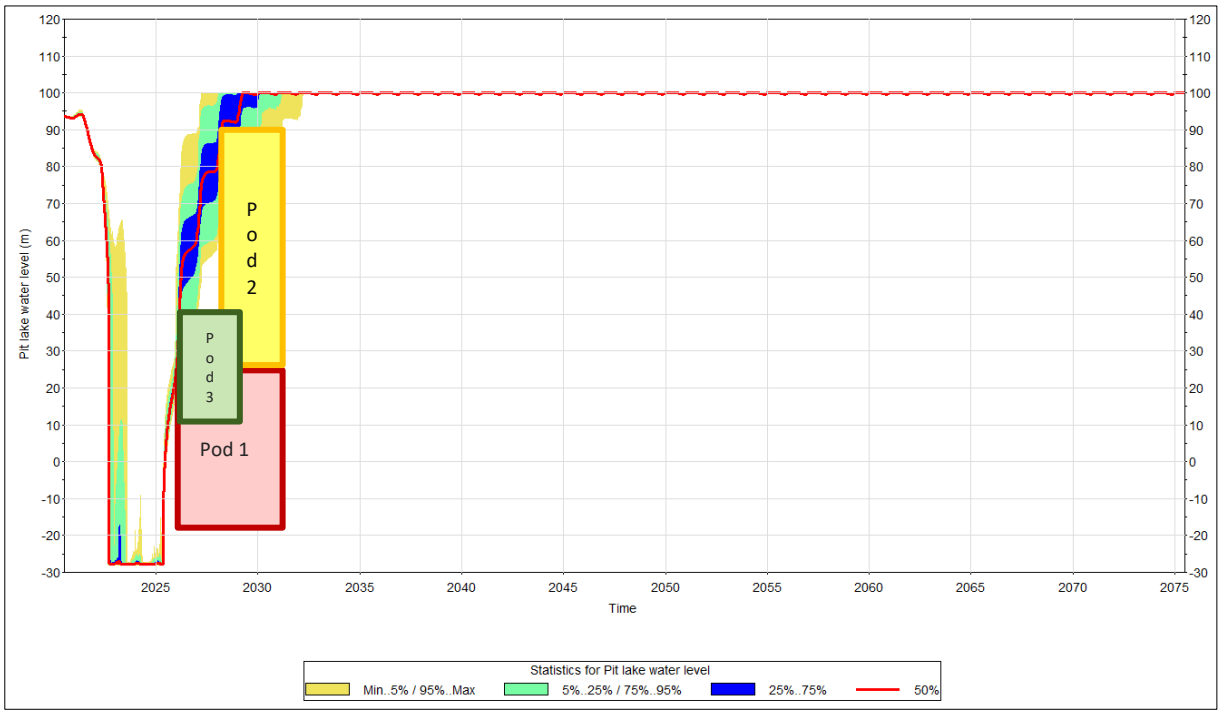

Figure 5-13 Option 2a - Predicted pit water level change during dewatering and recovery

Figure 5-14 illustrates the predicted arsenic concentration within Fountain Head pit. As per Option 2a, the arsenic concentration peaks at around 8 mg/L during mining operations, however, recovers to below the stock water guideline of 0.5 mg/L by 2028 once mining ceases and catchment water is diverted through the pit. The arsenic concentration recovers below the aquatic ecosystem (80% protection) guideline of 0.14 mg/L by 2033, where ongoing dilution from the diverted catchment water continues to reduce the arsenic concentration in the years post mining. Note, the WBM assumes an arsenic concentration of 0 mg/L for the catchment water diverted to the pit. Therefore, dilution of the pit lake water may be overpredicted in the long-term.

Overtopping is first predicted to occur from the 2028 wet season, in which time the arsenic concentration will measure around 0.33 mg/L, under the stock water guideline value of 0.5 mg/L, however above the aquatic ecosystem (80% protection) guideline of 0.14 mg/L. As stated, the arsenic concentration is expected to decrease below the aquatic ecosystem (80% protection) guideline by 2033, resulting in five (5) years where overtopping exceeds this value. Concentrations between the first overtopping event (2028) and 2033, ranges between around 0.33 mg/L and 0.14 mg/L.

Overtopping outflows and pit inflows remain the same as per Option 2a (Figure 5-10 and Figure 5-11 respectively).

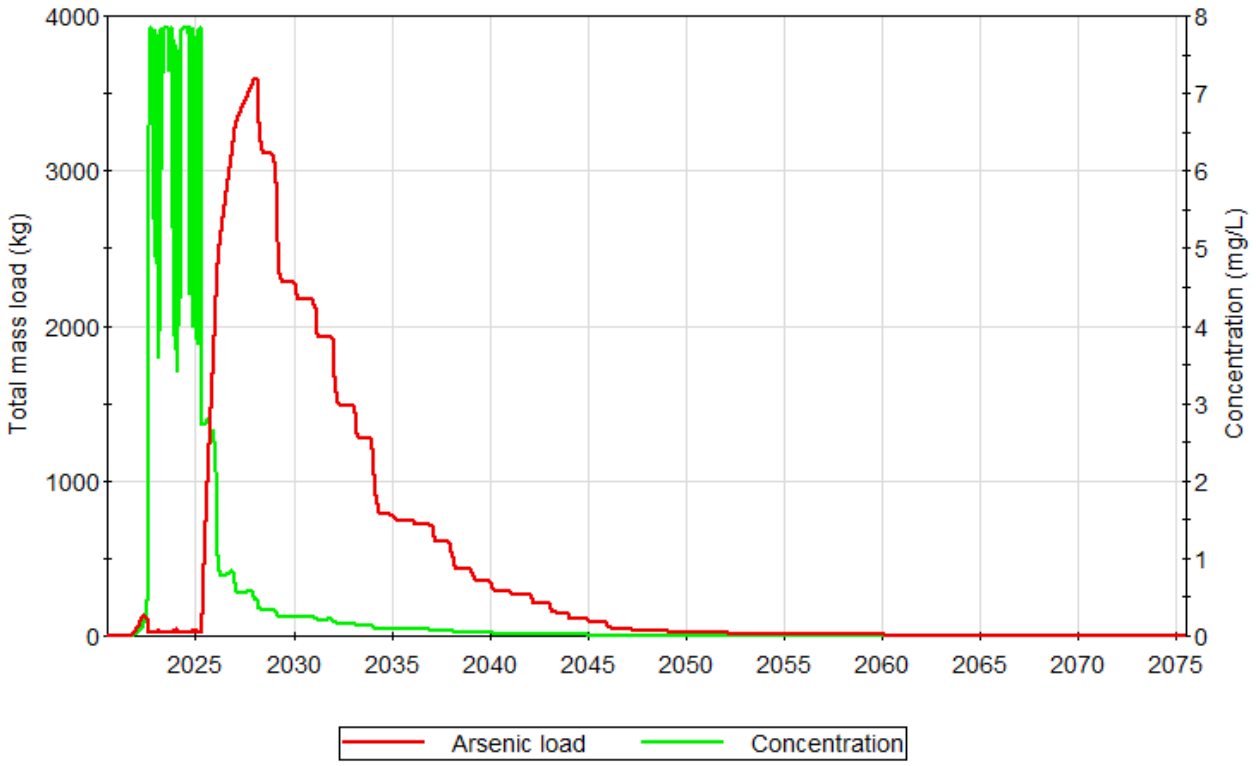

Figure 5-14 **Option 2a - Predicted dissolved arsenic concentration of the Fountain Head pit lake over 500 years post mining**

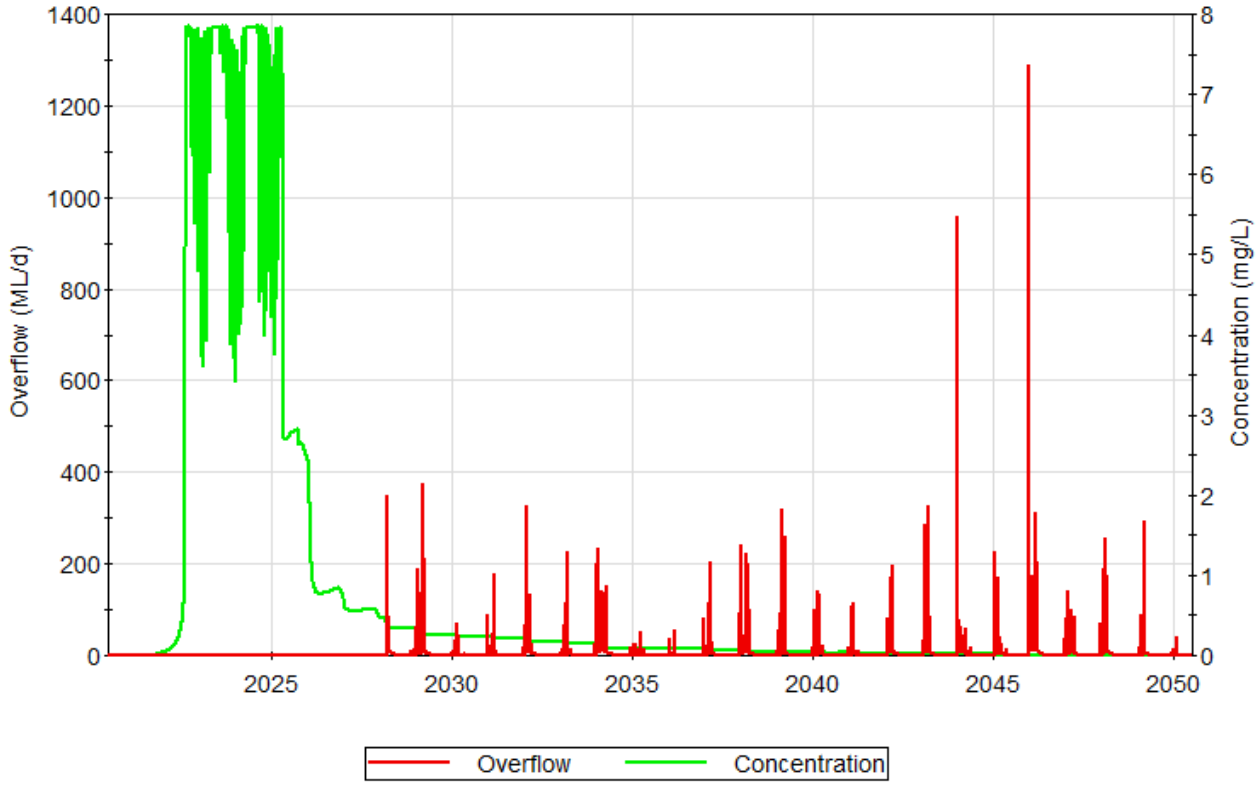

Figure 5-15 **Option 2a - Predicted dissolved arsenic concentration and overflow occurrences of the Fountain Head pit lake up to 50 years post mining**

Note, under Option 2a/2b, the normalised approach used for Option 1a/1b to estimate all other chemical components could not be applied with as much certainty as the catchment water inflow chemistry has not been defined (i.e. catchment arsenic concentrations assumed as 0 mg/L). Assuming all parameter increases and decreases are proportionate to the fluctuation of the arsenic concentration (a generalised and conservative assumption), pit water quality at 30 and 500 years post mining will be at levels significantly lower than those at present shown in Table 5-2. To increase the certainty of this approach, runoff water chemistry should be defined and added to the WBM and further extrapolations from the kinetic tests made for other parameters as further test data becomes available.

5.2.6 Discussion

Two water management options comprising each of two sub-options for assessing the effect of PAF material storage on the Fountain Head pit lake water quality have been completed as part of this assessment. The results indicate drastically different outcomes in managing the water quality associated with in-pit PAF rock storage.

Under Option 1a (partial PAF pod submersion), ongoing generation of arsenic can clearly be seen with a steady increase in arsenic concentration predicted to occur in the years following mining. The resulting arsenic concentration 500 years post mining of 50 mg/L exceeds both stock and aquatic ecosystem (80% protection) guidelines. Under Option 1b, whereby all PAF material is stored within the pit and fully submerged within 3 years post mining, the resulting arsenic concentration is predicted to be around 2.5 mg/L, significantly less than Option 1b, albeit still with an arsenic concentration above both the stock water and aquatic ecosystem (80% protection) guidelines.

Under Option 2a (partial PAF pod submersion), arsenic generation is significantly reduced by seasonal flushing of the pit with the diverted catchment water (i.e. pit water dilution and faster water level recovery leading to submergence of PAF rock). Under this option, the resulting arsenic concentration within the evaporation pond and Fountain Head pit are predicted to be below the stock water guidelines after 2028 and 2033 respectively. The arsenic concentration within the Fountain Head pit, however, never fully reduces to levels within the guideline for aquatic ecosystems (80% protection), although it is noted the average concentration (0.15 mg/L) between 2046 and 2500 is less than the current pit lake arsenic concentration. Under Option 2a, the arsenic concentration is further reduced recovering below the stock water guidelines by 2028 and the aquatic ecosystem (80% protection) guidelines by 2033.

Under the proposed PAF pod placement (Option 1a/2a), the water table is not predicted to fully cover PAF Pod 1 over the period of record. This indicates that a portion of PAF rock will be left open to above water oxidation, thereby generating acidity and concomitant metal solubilisation for an extended period until the PAF rock has been exhausted of its constituents. Although Option 2a suggests the concentration of arsenic may be managed through diversion of the natural catchment, the assumption is that all mixing will occur within the pit. However, due to the topography and positioning of PAF Pod 1 at the top of the pit, it is uncertain as to whether all contact water from this Pod will be captured within this water storage and may transport leachate with surface flow outside of the pit. Furthermore, at around 470,000 LCM, PAF Pod 1 is also the largest, contributing to around half of the leachate generated, the bulk of which is released post mining.

Under the submerged PAF pod placement options (Option 1b/2b), the water level recovers to above all PAF pods significantly reducing leachate generation with only minor arsenic contributions expected to occur from PAF material associated with the exposed pit walls. Implementation of this PAF management option significantly reduces the long-term arsenic contributions within the Fountain Head pit lake which has a number of benefits for future water management including lower pit lake arsenic concentrations, faster improvement in water quality with regard to environmental guideline values and less diversion water required to achieve dilution of the pit lake.

ERIAS have noted, PNX will dispose of all PAF rock into the pit following mining should the proposed PAF rock placement prove to have an unacceptable effect. Given the above observations, it is recommended PNX proceed with this action and remove the exposed PAF rock pods (PAF Pod 1) following mining and dispose of into the Fountain Head pit to allow full submergence below water (Option 1b or 2b). Should a post closure mine water management plan be adopted, focus should be on limiting PAF material exposure in the first instance and in the second instance, aiding the recovery of the pit lake water level as fast as possible, as this will slow the generation of acidity and metal solubilisation.

Section 6 Regulator Comment and Response

Comments on the FHGP EIS (ERIAS, 2021a) were received from two government agencies specific to pit lake water quality and groundwater. The comments and CDM Smith response related to pit lake water quality is shown Table 6-1.

Table 6-1 Comment and Response

Regulator	Comment	Recommendation	Response
Department of Industry, Tourism and Trade (DITT) – Mines Branch	The EIS states: 'Detailed assessment of the solute concentrations of the Pit Lake, once PAF material is added at the end of mining has not been conducted to date but is expected to be the primary driver of pit lake water chemistry with respect to contaminants of concern.'	Modelling of pit lake water quality should be undertaken to enable development of appropriate management systems.	Using the most recent column leach testing data (12 weeks - July to October 2021), the key parameter concentrations identified by the source term review as having a propensity to leach from the PAF rock (acidity and arsenic) has been used to estimate the likely loading rates which will enter the Fountain Head pit lake due to storage of PAF rock 'pods' within the pit. Extrapolation of the kinetic test data has been undertaken using an unforced 0,0 intercept, and bulk scaling the concentrations to account for the PAF rock mass (2 Mt). Using these concentrations, a long-term loading rate has been calculated and assumed to occur 52 weeks post oxidation for which the loading rate continues as steady state release. No cumulative scaling factor has been applied, and given the linear extrapolation of the kinetic test data, the key parameters loading rates are considered conservative. The existing water balance model, a goldsim model which links a surface and groundwater model together whilst simulating water movement around the Fountain Head site, has been updated to include the loading rates of the key parameters. Two water management options have been considered following the model update each with two sub-options for partial and full submergence of PAF material below the Fountain Head pit lake following mining. This includes: 1. No change to water management strategy 2. 80% diversion of the natural catchment through the Fountain Head pit. The modelling shows arsenic will likely accumulate within Fountain Head pit should no water or PAF management strategy be implemented post mining, however, with 80% catchment diversion, arsenic concentrations are expected to remain below the stock water guidelines from 2033, although never fully return to levels below aquatic ecosystem (80% protection) post mining. With below water storage PAF management implemented, the arsenic concentration is significantly reduced in both options slowing the accumulation within the Fountain Head pit with no water management option implemented. With 80% catchment diversion, arsenic concentrations decrease below the stock water guidelines from 2028, and return to below the aquatic ecosystem (80% protection) from 2033. Under both options, the evaporation pond water will increase in arsenic concentration to levels unsuitable for discharge during mining, however, the concentration will return to levels suitable for stock watering and aquatic ecosystem protection (80% protection) by 2028.

Section 7 Conclusions and Recommendations

7.1 Conclusions

The following conclusions present the key outcomes of this study:

- Estimated concentrations for the key parameters (acidity and arsenic) have been derived from the 12-week column leach testing data.
- Given the short-term status of the kinetic data, there is considerable uncertainty in the magnitude of predicted concentrations of the key parameters.
- Extrapolation of the current kinetic test data and bulk scaling method BE2B used in this assessment likely overpredicts the arsenic and acidity loading rates as the extrapolation assumes a linear trend of increasing PAF dissolution from only 4 data points of column leach testing results.
- Based on the current trend of sulfate consumption (assumed to expire at 52 weeks), and assuming arsenic dissolution coincides with an increase in acidity, the long-term loading rate of the key parameters is assumed to remain in steady state following 52 weeks of oxidation. Due to the paucity of kinetic testing data (noting only 4 data point exist) this should be considered as a loose estimate as it is unknown at what time generation of acidity and arsenic will completely cease. However, assuming the generation of acidity and arsenic will continue as steady state is conservative.
- Should no PAF rock management option be undertaken, a portion of PAF rock (PAF pod 1) will remain partially submerged by the recovered pit water level, thereby generating acidity and concomitant metal solubilisation for an extended period until the PAF rock has been exhausted of its constituents.
- The arsenic concentration within the evaporation pond remains the same between all water management and PAF rock management options (Option 1a/1b, 2a/2b) peaking at around 75 mg/L during mining and quickly declining and returning to levels below the respective stock water guideline (0.5 mg/L) by the end of 2027 and the guideline for aquatic ecosystems (80% protection) (0.14 mg/L) shortly after in early 2028.
- Option 1a assumes no change to the existing post mining water management plan and leaving the PAF pods partially exposed post mining, and:
  - The arsenic concentration within Fountain Head pit increases from around 8 mg/L post mining to around 50 mg/L at 500 years end of mine exceeding both stock water and aquatic ecosystem (80% protection) guidelines.
  - The main driver of arsenic accumulation within the Fountain Head pit is the partially submerged PAF rock, which continues to contribute loading of arsenic during and post mining.
- Option 1b assumes no change to the existing post mining water management plan and all PAF pods are disposed of in-pit and below the recovering water level post mining:
  - The arsenic concentration within Fountain Head pit decreases from around 8 mg/L post mining to around 2.2 mg/L in 2050 as a result of groundwater inflows after which the concentration increases to around 2.5 mg/L at 500 years end of mine exceeding both stock water and aquatic ecosystem (80% protection) guidelines.
  - All PAF pods become submerged after 30 years post mining after which arsenic generation significantly decreases and arsenic contribution is sourced primarily from the PAF rock within the exposed pit walls.
- Option 2a assumes 80% of the natural catchment is diverted through the Fountain Head pit and leaving the PAF pods partially exposed post mining, and:

  - The arsenic concentration peaks at around 8 mg/L during mining operations, however, recovers to below the stock water guideline of 0.5 mg/L by 2033 and momentarily below the aquatic ecosystems (80% protection) guideline of 0.14 mg/L by 2046.
  - The Fountain Head pit lake arsenic concentration never reduces to levels below the aquatic ecosystems (80% protection) guidelines post mining, averaging a concentration of 0.15 mg/L between 2046 and 2500. However, it is noted this concentration is lower than the current pit lake water.
  - Diversion of the catchment causes regular (yearly) overtopping of the pit during the wet season starting from the 2028 wet season, before the arsenic concentration has decreased to below the stock water guidelines (2033) or aquatic ecosystem (80% protection) guidelines (2046). Overflow concentrations range from less than 1 mg/L arsenic to as little as 0.1 mg/L.
  - Diversion of the catchment significantly improves the water level recovery within the pit, diluting the Fountain Head pit lake water, and submerging the PAF rock thus slowing the reactivity/release of arsenic into the water. However, the main driver of arsenic accumulation remains the partially submerged PAF rock, which continues to contribute loading of arsenic post mining.
- Option 2b assumes 80% of the natural catchment is diverted through the Fountain Head pit and all PAF pods are disposed of in-pit and below the recovering water level post mining:
  - The arsenic concentration peaks at around 8 mg/L during mining operations, however, recovers to below the stock water guideline of 0.5 mg/L by 2028 once mining ceases and catchment water is diverted through the pit. The arsenic concentration recovers below the aquatic ecosystem (80% protection) guideline of 0.14 mg/L by 2033, where ongoing dilution from the diverted catchment water continues to reduce the arsenic concentration in the years post mining.
  - Yearly overtopping of the pit occurs at the same frequency and magnitude as Option 2a, occurring first from 2028, however, the pit arsenic concentration remains below the stock water guideline during this time and reduces to below the aquatic ecosystem (80% protection) guideline by 2033. Overflow concentrations range from around 0.33 mg/L arsenic to less than 0.01 mg/L.
  - All PAF pods become submerged within 3 years post mining as a result of aided water level recovery from the diverted catchment water resulting in a significant decrease in arsenic generation and a heavily diluted concentration. The primary arsenic source following catchment diversion is the PAF rock within the exposed pit walls.
- Under options 1a and 2a, the biggest driver of the arsenic concentration within the Fountain Head pit is PAF Pod 1, which contributes to around half of the leachate generated from the PAF pods during mining and majority of leachate generated post mining.
- Under options 1b and 2b, the majority of leachate is generated during mining while the PAF pods are exposed (above water).
- Aided recovery of the pit dramatically decreases loading quantities of the key parameters from the PAF rock, however, submersion will only slow, not prevent ongoing generation and solubilisation of metals in the future.
- Implementation of below water storage of PAF material significantly reduces the long-term arsenic contributions within the Fountain Head pit lake which has a number of benefits for future water management including lower pit lake arsenic concentrations, faster improvement in water quality with regard to environmental guideline values and less diversion water required to achieve dilution of the pit lake.

7.2 Recommendations

The following recommendations are made regarding the further refinement of the pit lake water quality and PAF storage at FHGP:

- Update the kinetic testing extrapolation methods and bulk scaling calculations (expanding to include other parameters if necessary) once the full (52-week) kinetic test data becomes available or as more data points are collected. This will allow for more accurate extrapolation methods less likely to overpredict and give a non-linear extrapolation which accounts for any observed plateauing in the kinetic test results.
- Update and revise speciation and colloidal arsenic behaviour on receipt of the further kinetic data, to assess potential partition to sediment over time as lake volume progresses.
- Complete oxygen consumption tests to understand the duration in which the PAF materials will continue to generate acidity and dissolution of heavy metals. This will allow for:
  - Annual rate of acidity generation (per kg, per m2 and wt% FeS_2 – depending on material).
  - The reactive lifetime of the material.
  - Timing and magnitude of peak acidity.
  - Rate of ANC consumption.
  - 'Lag time' or onset to acid conditions.
- Adoption of either Option 1b or 2b ensuring submersion of the PAF material as soon as possible once disturbed.
- The adopted post closure water management strategy should focus on limiting partially submerged PAF material in the first instance and aiding the recovery of the pit lake water level as fast as possible, as this will slow the generation of acidity and metal solubilisation.
- Explore in greater detail enhanced pit flooding options, the feasibility of such options and the lowest acceptable flushing threshold to achieve pit water quality objectives.

Section 8 References

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Appendix A Fountain Head Pit Lake Water Quality Predictions

Land and Water Consulting

Fountain Head

Pit Lake Water Quality Predictions

CDM Smith

November 2021

Document Status

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Client	CDM Smith
Client Project Manager	Jakob Pretzsch-Kalsgaard
LWC Project Manager	James Fox
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1 INTRODUCTION

1.1 OVERVIEW

CDM Smith is currently supporting ERIAS to address the comments received on the Environmental Impact Statement (EIS) for PNX Metal's proposed Fountain Head Gold project in the Northern Territory, Australia. CDM Smith engaged Land & Water Consulting to provide technical support in predicting pit lake water quality in relation to acid rock drainage (ARD) associated with potentially acid forming (PAF) rock that is proposed to be stored in the pit.

CDM Smith had previously undertaken a pit lake water quality study using Goldsim. The previous modelling was prepared to understand the effect that storage of PAF materials may have on water quality within the pit during and post mining.

CDM Smith's previous work involved a non-reactive modelling approach and assumed that PAF storage would occur outside the pit area. ERIAS has since confirmed that PAF material storage will be within the Fountain Head pit comprising three "pods" of rock. The pit lake will be allowed to flood naturally (or be assisted in flooding) with a view to covering the waste PAF rock to exclude oxygen in order to prevent oxidation (or ongoing oxidation) of sulfide in the rock, and mitigate acid generation/ metals solubilisation.

1.2 CONTEXT

Acid mine drainage (AMD) (or Acid Rock Drainage, ARD) is the result of the combined chemical and biological oxidation of sulfide minerals and the concomitant release of associated metals, such as iron, aluminium, manganese, uranium and other toxic heavy metals/ metalloids. The oxidation of pyrite, the predominant sulfide mineral, can be expressed by the following stoichiometric equations:

Pyrite Oxidation:

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad \text{Eq. 1}$$

$$or, \quad 2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4 \quad \text{Eq. 2}$$

Ferrous iron (Fe^{2+}) is oxidized to its ferric state as follows.

$$2\,Fe^{2+} + \tfrac{1}{2}O_2 + 2H^+ \rightarrow 2\,Fe^{3+} + H_2O \quad \text{Eq. 3}$$

Thus, the exclusion of oxygen mitigates the initiation of sulfide oxidation and the concomitant release of associated metals/ metalloids. Noting that once oxidation is initiated it is a self perpetuating reaction. The lack of oxygen only slows the rate of the reactions it cannot stop them.

The reaction given by Equation 3 is dependent upon the pH of the solution and presence of catalysts such as *Thiobacillus ferroxidans* and other acidophilic bacteria. Under acidic conditions (pH 2 to 3), the biological oxidation rate is approximately 16 to 35 fold greater than the chemical rate.

Ferric iron does not remain in solution much above pH 2 to 3 where it is hydrolysed to $Fe(OH)_3$. Under more alkaline conditions $Fe(OH)_3$ is formed.

The placement of reactive waste under water cover has proven to be a highly effective method for AMD/ ARD control. Water cover is an effective barrier to the gaseous diffusion of oxygen.

The prime mechanism for oxygen entry into saturated reactive waste is by convective transport of dissolved oxygen in groundwater or infiltrating water. At the typical flows of water entering the submerged waste, oxidation rates are normally very low and of minor consequence. However, the flow of waters through the submerged wastes will slowly dissolve precipitates, buffering minerals and secondary minerals which will gradually release contaminants over time.

Open pit mines that have ceased production are increasingly being considered for the permanent and environmentally acceptable disposal of mine waste rock and tailings that are, or have the demonstrated potential to become, sources of acidic drainage.

There are four basic concepts for the placement of wastes in pits (refer MEND, 1995 for more detailed information):

1. Option 1 – Underwater disposal
2. Option 2 – Elevated water tables
3. Option 3 – Dry disposal
4. Option 4 – Perched water table within a cover system (to exclude oxygen)

Not all pits are suitable for the in-pit disposal of wastes. The success would depend on many technical factors, including:

- the acid generation potential of the wastes and pit walls;
- the degree of oxidation of the wastes (fresh or already oxidised)
- the geotechnical characteristics and properties of the wastes and the pit walls;
- predicted pore water, pit water, and groundwater quality;
- hydrogeology of the open pit; and
- the hydrology of the open pit.

Mine related constraints must also be taken into consideration. These include:

- limiting access to remaining mineralisation below the pit;
- wall stability and related safety concerns;
- available access; and
- the proximity of underground workings to the open pit.

Consideration must be given to both the short term and long term implications of the in-pit disposal concept; these include ecological and human health protection and closure planning perspectives.

1.3 OBJECTIVE

Assess acid generation, neutralisation and solute mineral release/ formation due to reactive processes associated with PAF rock to provide input to the CDM Smith Goldsim model used to simulate the pit lake water quality.

1.4 SCOPE

The following tasks were agreed as per the scope:

- Task 2.1 – Address comments from DITT regarding pit lake water quality.
- Task 2.2 – Gather information on the PAF rock deposit schedule and information from the geochemical characterisation of the PAF waste rock to be disposed of in the Fountain Head pit.
- Task 2.3 – Conceptualise the processes of acid generation, acid neutralisation and soluble minerals that would contribute to the water quality of the pit lake. Conceptualise the scenarios of saturated sediment (pit lake flooded) and unsaturated (in case the sediments remain above lake level for an extensive period).
- Task 2.4 – Design two (2) alternative feasible PAF management options:
    - Option 1 comprising no additional water transfer than existing plan.
    - Option 2 including back-pumping evaporation dam water and diversion of Fountain Head creek/ lake water to optimise reactivity of PAF deposit flood deposit and flushing of pit lake when concentration of CoPC builds-up to unacceptable levels.
- Task 2.5 – Develop a geochemical model (Geochemists Work Bench) to evaluate the kinetic of acid generation, neutralisation and solute mineral release/ formation to provide input to the Goldsim model used to simulate the water quality.

2 APPROACH

CDM Smith's requested proposed approach to the predictive assessment of pit lake water quality is as follows:

- Task 2.1 – Address comments from DITT regarding pit lake water quality.
- Task 2.2 – Gather information on the PAF rock deposit schedule and information from the geochemical characterisation of the PAF waste rock to be disposed of in the Fountain Head pit.
- Task 2.3 – Conceptualise the processes of acid generation, acid neutralisation and soluble minerals that would contribute to the water quality of the pit lake. Conceptualise the scenarios of saturated sediment (pit lake flooded) and unsaturated (in case the sediments remain above lake level for an extensive period).
- Task 2.4 – Design two (2) alternative feasible PAF management options:
    - Option 1 comprising no additional water transfer than existing plan.
    - Option 2 including back-pumping evaporation dam water and diversion of Fountain Head creek/ lake water to optimise reactivity of PAF deposit flood deposit and flushing of pit lake when concentration of CoPC builds-up to unacceptable levels.
- Task 2.5 – Develop a geochemical model (Geochemists Work Bench) to evaluate the kinetic of acid generation, neutralisation and solute mineral release/ formation to provide input to the Goldsim model used to simulate the water quality.
- Task 2.6 – Update the Goldsim model to represent the solute mineral concentration evolution in the pit lake for the options developed at task 2.3.

We understand that Task 2.6 will be completed by CDM Smith and Tasks 2.1-2.5 by LWC

The approach suggested by CDM Smith appears reasonable with respect to prediction of lake water quality as a function of PAF disposal to pit.

3 CONCEPTUAL SITE MODEL

3.1 GENERAL

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.

A conceptual site model (CSM) has been developed to identify potential source(s), pathway(s) and receptor(s) associated with the geochemistry of storing PAF rock within the Pit.

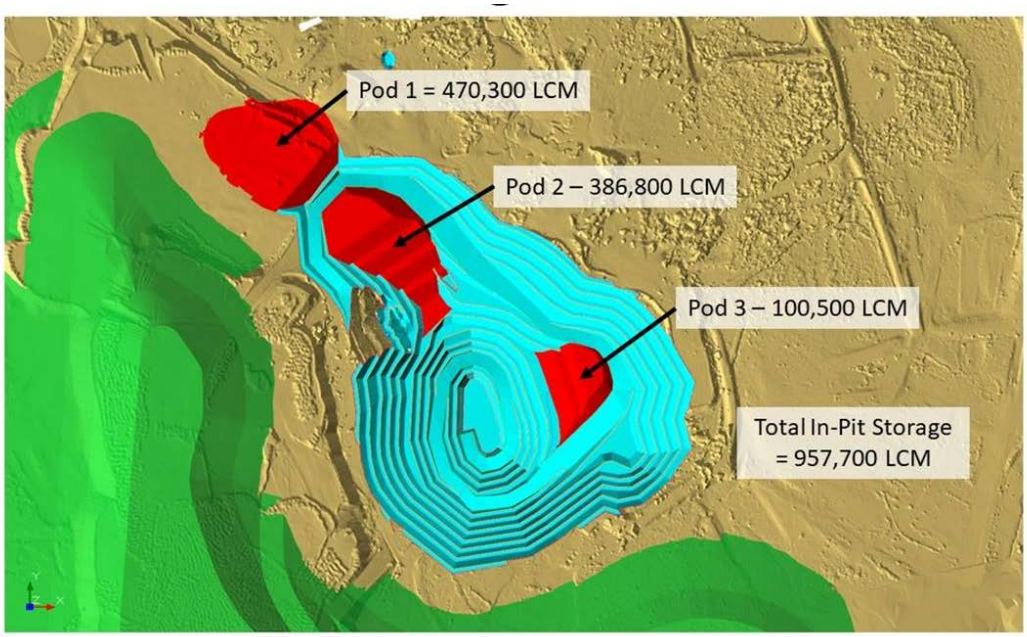
The CSM contributes to an understanding of possible effects posed to environmental values associated in pit storage of acid generating waste materials.

The following sections establish each of the source-pathway-receptor assessment components as well as the potential linkages formed where these three components are present.

3.2 PAF STORAGE/ MANAGEMENT CONCEPT

The current proposed PAF management strategy is to dispose of the PAF rock within the pit, distributed in three 'pods' with a combined total in-pit storage of ~957,700 Loose Cubic Metres (LCM). PNX Metals consider the average waste density is 2.7 t/m^3 and the swell factor will be around 32% so recommend adopting a bulk density of 2.05t/m^3 – essentially 2 million tonne of PAF rock.

Figure 3-1 Proposed in pit storage of PAF



A key benefit of sub-aqueous disposal is the exclusion of oxygen in order to prevent oxidation (or minimise ongoing oxidation) of sulfide in the rock.

Water table elevation calculations provided by CDM Smith indicate only POD 3 would be fully submerged (Table 3-1). This infers POD 1 and 2 would be at least partially above the pit lake water table and would be open to ongoing oxidation of sulfidic materials.

Table 3-1 POD submergence calculations (provided by CDM Smith)

Type	Min Z	Max Z	Approx Pit WL 1 year EOM	Approx Pit WL 5 years EOM	Approx Pit WL 10 years EOM	Approx submergence 1 year EOM	Approx submergence 5 years EOM	Approx submergence 10 years EOM
Pit	-54.6	106.7				-	-	-
PAF3	10.5	40.5				-40.5	20.5	30.5
PAF2	25.5	90.5				-90.5	-29.5	-19.5
PAF1	60.5	105.9	29	61	71	-105.9	-44.9	-34.9

3.3 GROUNDWATER AFFECTING ACTIVITIES

Mining related (ground)water affecting activities (WAA's), are those development activities that have the potential to interact with groundwater and alter groundwater conditions from the baseline, and hence are relevant as potential origins for environmental hazard(s).

An important component of this study is understanding its direct effect on the baseline groundwater regime and the effects this may cause to Environmental Values (EVs). There are three categories of direct groundwater effects potentially relevant to this study that may be realised as a result of PAF rock in pit potential WAAs:

- **Altered groundwater quantity**
  Seepage to the water table from the exposed rock face opened up by the in pit storage of waste rock (both NAF and PAF).
- **Altered groundwater quality**
  Seepage to the water table from the in pit waste rock (both NAF and PAF) – a function of the geochemistry of the waste materials. Solutes then have the capacity to be transported away from beneath these facilities towards EVs under newly established hydraulic gradients.
- **Physical disruption of aquifers**
  The development of pit voids below the water table will interfere with the baseline groundwater flow regime (drawing groundwater towards them during mining as well as after closure where a void will remain), this has the potential to mitigate transport of seepage impacted groundwater away from the mine site during mining and post-closure.

These potential direct effects and other mechanisms which may occur over the life of the mine and post closure have been linked to the hydrogeochemical processes occurring at the site to develop a (hydro)geochemical (CSM) (Table 3-1).

This hydrogeochemical CSM presented here is a representation of the physical and chemical processes that determine the way in which waste rock related elements may move from source areas containing the identified source materials through the environmental media (including soil, water and air, all of which have the capacity to transport contaminants) to affect potential receptors.

Table 3-2 Water Affecting Activity for the Pit

Water affecting activity		Potential direct effects			Potential water quality at closure
		Quantity	Quality	Aquifer disruption	
Mine pit at closure	Open pit	Groundwater will flow to the Pit void under gradients established by evaporative discharge from the void and any temporary water body formed within	Water collecting within open void will evapo-concentrate solutes arising from incident rainfall and groundwater discharge. No pit lake is expected to form and the solute will remain on the walls and/ or the base of the Pit.	Open pit will interrupt groundwater flow regimes within the different Hydrostratigraphic units (HSUs) that are intersected	• Exposure to PAF materials will increase the solute load to groundwater • Evapo-concentration of incidental water within the open Pit will increase the concentration of all solutes accumulated on the walls/ base of the Pit and within any temporarily present water. • Note there is a maximum value for total dissolved solutes at which evapo-concentration stops (around 400,000 mg/L), thus evapo-concentration is a finite process. • Water quality within the Pit at any point in time will be a function of the mass balance of water and solute; mass in (water and mass of solute) and mass out (dispersion and rate of evaporation)

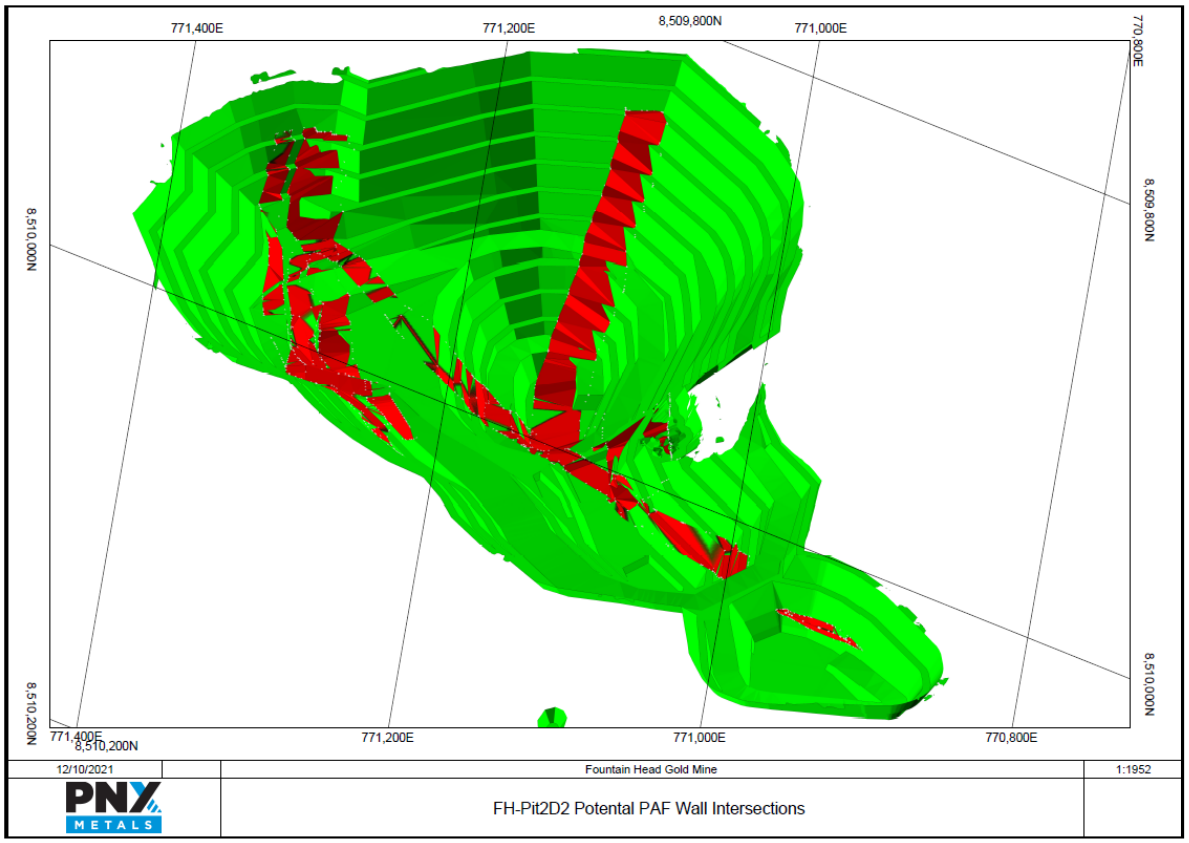
3.4 SOURCES

The geology of the project site provides the sources of the chemical substances of potential environment concern (CPEC). These chemicals are naturally present in the environment. Based on the data provided in the geochemical report generated for the site (EGi, 2020)) natural enrichments of metals and metalloids are present in these geological materials.

Table 3-3 Identified Sources

Geochemical Source (S)	Description	Discussion	Considered herein
S1	PAF rock in base of Pit as PODS 1 – 3 (refer Figure 3-1)	2 million tonnes of PAF rock with leach chemistry represented by kinetic sample 21363.	☑
S2	Open Pit – rock walls – as per Figure 3-2.	Sulfide oxidation in wall rock – dewatering and excavation exposes wall rock to atmospheric oxygen and solutes released by oxidation of sulfide minerals are flushed into the Pit by rainfall runoff or groundwater seepage through the rock wall. PNX provided an estimation of the PAF wall exposures in the pit (email ERIAS to CDM Smith 13 October 2021). As per Figure 3-2 there is approximately 18.8% of the 295,549 m^2 of pit wall which will be ore or PAF in nature (55,563 m^2).	X

Figure 3-2 PAF wall intersection



3.4.1 Source Term

The source term can be defined as the suite of elements with a propensity to leach from the source material. The source term is further refined by screening the concentrations measured in any leachate generated against generic water quality guideline concentrations. This process provides an assessment of the risk these concentrations may pose to EV's. The screening process is summarised in the process flow diagram in Figure 3-1. Refer to Section 4 for further detail.

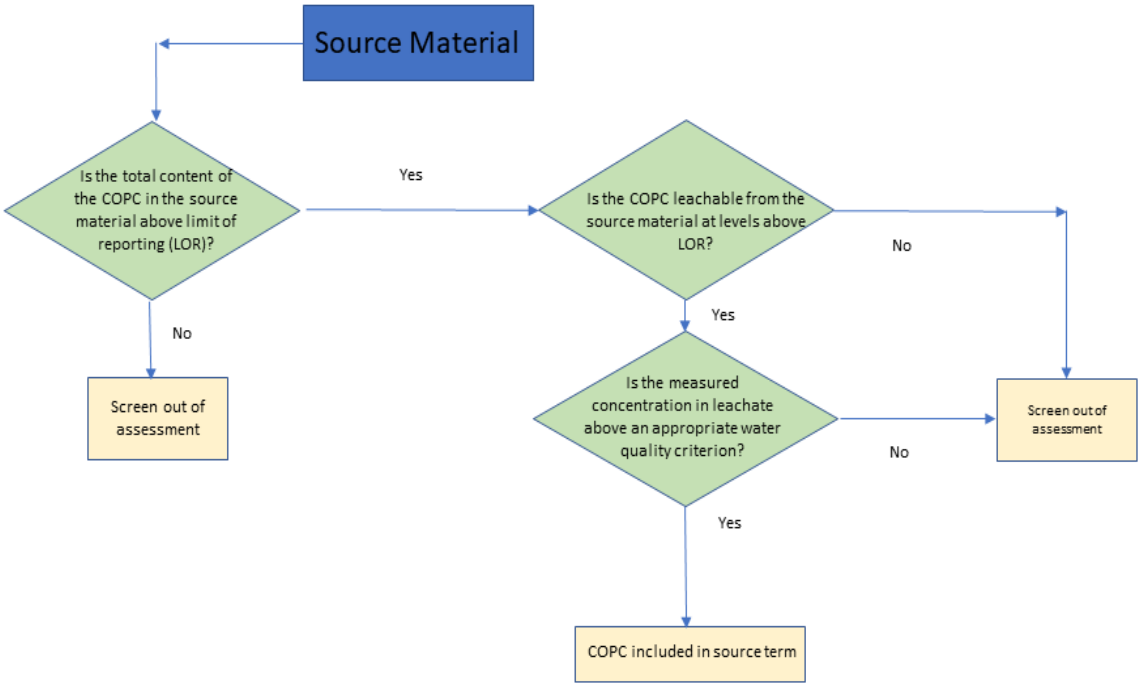


Figure 3-3 Source term screening process

3.5 Pathways

A pathway is the route along which a solute might move through the environment from its source to an EV. Potential pathways considered for the site are presented in Table 3-6.

Table 3-4 Identified pathways

Pathways (P)	Description	Relevant to this study?
P1	Groundwater inflow to the Pit and contact of water with exposed oxidised rock / materials	☑
P2	Direct biota uptake / contact of Pit water	☑
P3	Vertical or lateral migration of solutes from the Pit to the external groundwater	☑
P4	Abstraction and use (environmental values) of groundwater external to the Pit following P3 (now / future)	☑
Key: ☒ Not identified or not relevant, not considered further in this assessment ☑ Potentially relevant, considered in this assessment		

In summary, four pathways are considered relevant with respect to connection of the source (exposed waste rock and wall rock in the Pit) to receptors (ecology and identified environmental values of groundwater).

3.6 Receptors

3.6.1 Environment / Ecosystem Health

3.6.2 Beneficial use of groundwater

Potential future use of groundwater is understood to be restricted to stock watering supply

3.6.3 Summary of relevant receptors

For the source pathway receptor assessment, the receptor (R) represents the component, or receiving environment of an EV. These are summarised in Table 3-7.

Table 3-5 Identified Project area EVs

Environmental value[1]		Details
Ecosystem health	RAMSAR listed wetlands	☒ None identified
	Conservation category or Resource enhancement wetlands	☒ None identified
	Directory of Important Wetlands in Australia wetlands	☒ None identified
	Environmental Protection Policies wetlands	☒ None identified
	Wild rivers	☒ None identified
	Poorly represented wetlands in Conservation reserves system	☒ None identified
	Springs and pools	☒ None identified
	Ecosystems supporting significant flora, vegetation and fauna	☒ Stygofauna ☒ Troglofauna ☒ Terrestrial vegetation ☑ Migratory aquatic birds
	Ecosystems supporting significant amenity, recreation and cultural[4] values	☒ None identified
	Saline lakes, estuaries and near shore ecosystems	☒ None identified (Lake Eyre is ~200 km away)
	Downstream marine ecosystems	☒ None identified
Beneficial use	Drinking water supplies	☒ None identified

Environmental value[1]		Details
	Water supplies supporting significant commercial activities, e.g. mining and pastoral	☑ Livestock watering
	Inland waters with high levels of active and passive recreation including multiple use wetlands	☒ None identified
	Inland waters with significant cultural[4] or aesthetic values	☒ None identified

Key: ☒ Not identified or not relevant, not considered further in this assessment
☑ Relevant, considered in this assessment

These EVs can be summarised into a short list of potential receptors that can be easily linked to generic guideline concentrations for any identified COPC (Table 3-8).

Table 3-6 Potentially relevant receptors

Receptor (R)	Description
R1	**Migratory Birds** If a water body were to form such as a transient pit lake, it could potentially contain high levels of selenium (Se) in the water. One pit lake in Wyoming contains over 100 parts per million of selenium. Waterborne selenium concentrations greater than 0.45 mg/L are known to impair the reproduction and survival of aquatic birds due to the high potential for dietary toxicity through food chain bioaccumulation (Ramirez and Rogers, 2000). It is noted that the method of transfer was that lake water was used for irrigation onto grassland and the selenium was taken up via soil / flora accumulation rather than direct consumption (ingestion) of water. Acidic water can cause severe trauma to bird gastrointestinal tracts and eventual death. The acidic water also removes natural oils from the birds' feathers causing them to die by drowning or hypothermia. This has caused large scale bird deaths at the Berkeley Pit in Montana, United States in 1995 and 2016 (Guarino, 2016). With high selenium as total it is important to speciate the metalloid as the toxicity varies with oxidation state. Se release in acidic water may be to do with dissolution of calcite. Re-precipitation of carbonate can reduce Se content. Mo and Se both affect egg shell production (high concentrations cause softening of the shell) and thus can affect bird reproduction.
R2	**Future Human Use** Potential treatable water supply - Potential future abstraction for human use.
R3	**Stock Watering** Potential treatable water supply - Potential future abstraction for stock watering.

3.7 Potential Impact Linkages

The fundamental concept of the assessment is that first there should be an exposure pathway (which incorporates an exposure route) linking a source with a receptor. Where a linkage exists, an assessment of the nature and significance of the exposure pathway is required to determine the level of threat posed.

Assessment of proposed mine features and related hydrogeochemical processes and source terms (CPEC exceeding tier 1 criteria) indicates that there are relevant sources (S1 and S2). There are identified receptors. There are also potential pathways linking these sources and receptors. These three components (source-pathway-receptor) are assembled into individual linkages that require further (tier 2) assessment.

A total of 6 linkages are identified as being potentially relevant / significant (Table 3-9).

Table 3-7 Potential impact linkages

Source (S)	Primary Pathway (P) [2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)
S1 – PAF rock in the pit	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact	-	R1 Migratory Birds (contact)	L1
	P1 - Groundwater inflow (and/ or rainfall) and contact with exposed oxidised rock / materials	P3 - Lateral migration of solutes away from the Pit	P4 - Abstraction	R2 Future Human Use	L2
			P4 - Abstraction	R3 Stock watering	L3
S2 Pit wall rock	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact P3 - Lateral migration of solutes away from the Pit	-	R1 Migratory Birds (contact)	L4
			P4 - Abstraction	R2 Future Human Use	L5
			P4 - Abstraction	R3 Stock watering	L6

4 SOURCE TERM

4.1 CONTEXT

The geochemical data made available to LWC is summed in:

- Environmental Geochemistry International (Egi) (2020). Geochemical Characterisation of Waste Rock & Ore - FOUNTAIN HEAD. DOCUMENT NUMBER: 1316 / J000373 / REPORT # 1369 prepared for ERIAS Group Pty Ltd

Egi (2020) reports that the Project will involve a cutback of the existing pit. Approximately 15 Mt of waste rock and 3 Mt of ore will be mined over the 2.5 year operation. Waste rock will be placed in the existing waste rock stockpile (WRS). The existing WRS encroaches onto the proposed pit cutback and therefore a section of the waste stockpile will need to be relocated prior to cutting back in this region.

Egi (2020) reports that the geochemical testing included waste rock that will be removed from the pit during the cutback, waste rock from the existing WRS, including material that will be removed to allow pit development, and ore samples.

In order to obtain rock samples which would satisfactorily represent the distribution of waste rock types to be mined during the expansion of the existing Fountain Head pit, a number of drill holes were selected by Egi from the many drilled during resource definition drilling. Samples from these drill holes were selected to cover variation in lithology, oxidation and chemical composition of the waste rock, while also achieving appropriate spatial coverage of the proposed expanded pit. A value of 1 ppm Au (fire assay results) was used in most instances to delineate between ore (Au >1 ppm) and waste rock.

In total 111 drill hole samples, 18 WRS samples and 3 ore and 3 cyanide leached samples were tested for the following:

- Total sulphur (S);
- Paste (1:2) pH and EC;
- single addition net acid generation (NAG) test; and
- acid neutralising capacity (ANC)

For a number of samples, additional geochemical testing was conducted to provide better definition of their geochemical properties including:

- acid buffering characteristic curve (ABCC) testing to define the relative availability of the measured ANC;
- carbon speciation analysis (Total C, organic C and inorganic C) to determine carbonate content; and
- chromium reducible sulphur (CRS) to quantify the amount of sulphide sulphur.

In addition to the above tests, leach tests were conducted on a number of samples to provide information on the leaching characteristics of various metals and other elements of concern. Testing included:

- Multi-element testing of the sample solid (19 drill hole samples, multi-element assay results were available for WRS and metallurgical samples)

- Peroxide extraction testing including multi-element assay of the extract (9 drill hole samples)
- Water extraction testing including multi-element assay of the extract (19 drill hole samples, 3 WRS samples and 2 metallurgical samples)

4.2 ELEMENTAL SPECIATION

Multi element composition of Fountain Head pit waste rock and ore was undertaken by EGI (2020) and is presented as Table H1 in their document.

Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, reporting concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg). Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present at the Site. Arsenic has a calculated geochemical abundance indices of over 10. Anything of 3 or above is generally counted as being heavily mineralised. Other elements reporting with a GAI at or >3 are (as per Table H2 of the Egi report):

- Silver (Ag)
- Beryllium (Be)
- Bismuth (Bi)
- Cobalt (Co) (in the ore only)
- Copper (in the ore only)
- Manganese (Mn)
- Lead (Pb)
- Sulfur (S)
- Selenium (Se)
- Uranium (U)
- Tungsten (W)

4.3 STATIC TESTING

The Egi (2020) results of geochemical testing of samples obtained from drilling in the Fountain Head pit show:

- There is no immediately available acidity and low salinity in these samples when contacted with water, indicating that freshly mined rock is unlikely to provide low pH or saline drainage.
- Total S analysis showed a broad range up to 3%S, but with the vast majority (90%) having a relatively low S value of 0.5%S or less, suggesting the occurrence of pyritic rock is not widespread.
- ANC was relatively low, ranging up to 33 kg H_2SO_4/t, indicating a general lack of excess buffering.

- Carbon speciation analysis indicates carbonate content is negligible, with the total carbon content of these samples generally low. This is consistent with ABCC test results which also suggest little carbonate content, and that the small amount of carbonate present in these samples is predominantly iron carbonates (ferroan dolomite, siderite), which will react relatively slowly.
- Most samples were NAPP negative, with the majority of these having ANC/MPA ratios of 2 or more, indicating a high factor of safety.
- The majority (70%) of NAGpH values were 4.5 or greater, corroborating the ABA results which indicated most samples are likely to be NAF.
- CRS measurements show that greater than 90% of Total S is contained in sulphide minerals, suggesting that Total S measurements can be used as suitable guide to the sulphide (pyrite) content of these materials.
- Test results were used to classify samples as NAF, PAF, PAF-LC or UC. Around 80% of samples tested were classified NAF (including UC equivalents), 15% PAF-LC (including UC equivalents) and 5% PAF. Overall results indicate most waste materials to be mined will be NAF, with a minor proportion of PAF.

Given the relatively low ANC and poor reactivity, criteria based on Total S was selected as the best potential option for routine classification of ARD rock types. Using the results from detailed geochemical testing, sulphur distributions were determined for each of NAF, PAF-LC or PAF ARD classifications. The results show:

- NAF samples can be differentiated from PAF/PAF-LC samples by applying a Total S cut-off of 0.2%S
- 95% of samples classified NAF have a Total S value of 0.2% or less, and all PAF samples and 60% of PAF-LC samples have a Total S value of greater than 0.2%S.
- Although using a ≤0.2%S criteria for NAF waste rock includes 40% PAF-LC material, these have low acid potential and operational blending with NAF materials would be expected to account for any minor acidity generated.

4.4 SINGLE ADDITION LEACH TESTING

In addition to the above testing, water and peroxide extractions were conducted on selected samples to understand the likely quality of drainage from freshly mined and oxidised waste rock respectively. EGI (2020) reported the results of these tests show:

- All water extracts produced circum-neutral to mildly alkaline solutions with low salinity. Metal concentrations in water extracts were also very low to non-detectable.
- These results suggest leachates from freshly mined waste rock from the Fountain Head pit will, in general, be of reasonable quality. However, segregation of the PAF waste rock using a Total S value of 0.2% may improve leachate quality for the majority of fresh waste rock containing ≤0.2%S.
- Water extracts for WRS samples had neutral pH and low salinity. Metal/metalloid concentrations were also very low or non-detectable.

- Water extractions conducted on an ore sample and the same sample following cyanidation showed that cyanide leaching has significantly increased arsenic mobility in this sample.
- Arsenic is significantly enriched in the majority of samples tested relative to average crustal and soil abundance.
- Iron, copper, cobalt, nickel and arsenic concentrations in peroxide leachates correlated with Total S content of the samples, indicating that segregation of samples with significant sulphur content is likely to reduce the concentration of these heavy metals/ metalloids in drainage from oxidised waste rock in the WRS.
- Peroxide leachates suggest drainage from oxidised waste rock containing more than 0.2% sulphur may contain substantial concentrations of Al, Co, Mn, Ni, Pb, Zn and waste rock with Total S concentrations above this value should be managed to minimise oxidation and release of heavy metals.

The results summarised above suggest that further investigations are required to confirm the conclusions made to date and to provide more confidence in applying the results to the management of mine wastes during and post operations.

Consequently, the following are recommended as future geochemical investigations:

1. Although the proportion of PAF materials is likely to be minor, quantification of the distribution of PAF materials will be required ahead of mining and selective handling and management carried out during mining to ensure PAF materials are not a source of ARD during operations and at closure. Quantifying the proportion of PAF will require more extensive testing and it is recommended that any further drilling for resource definition, should include Total S analysis (high temperature combustion method e.g. LECO method, or ICP MS analysis) as a part of the suite of analyses conducted on the samples tested.
2. Only a limited number of WRS samples were tested, and more widespread follow up testing (S only required initially) is recommended for rock from the WRS.
3. It is expected that some ore processed at Fountain Head may have higher sulphide content associated with pyrite than the samples tested during this study. Such materials could potentially generate ARD, depending on the balance between the acid generating potential of the sulphide and the ANC in the material and the alkalinity added through lime addition. It is therefore recommended that ore samples with higher sulphur content should be tested for ARD generating potential.
4. Currently available geological information is not sufficient to calibrate reliable geological criteria for waste handling and management. Definition of geological criteria would require inspection of representative drill core through the deposit to better understand controls on sulphide and carbonate distribution, including the oxidation profile to check for the presences of residual sulphides in oxide and transition zones. It is recommended that this inspection should be undertaken as a part of a site visit.
5. If a ≤0.2%S criteria for NAF waste rock is to be utilised as a waste segregation and handling criterium, it is recognised that the NAF rock will likely contain a small portion of PAF-LC rock. While these materials have low acid potential and operational blending with NAF materials could be expected to account for any minor acidity generated, this assumption should be validated. It is recommended that kinetic leach column testing be undertaken on samples of PAF-LC material and mixtures of NAF and PAF-LC materials to determine the likely nature of drainage of such materials stored permanently in the WRS.

6. Because of the elevated concentrations of several metals (Al, Co, Mn, Ni, Pb, Zn) in peroxide extracts of samples containing relatively low Total S (<0.35%), it is recommended that further testing of the leaching behaviour of these types of samples should be investigated further.

4.5 COLUMN LEACH TESTING

Continuous column leach tests are typically conducted by filling a length of pipe or funnel with a solid sample and continuously passing water (or another leachant) through the sample for a specified period. Leachate samples can be collected at any desired frequency and analyzed for any constituent of interest. There are many variables in column leach test design, including:

- Column length and diameter
- Flow type (forced flow from bottom or gravity flow from top)
- Flow rate/residence time
- Sample pre-treatment (particle size reduction, oxidation, bacterial inoculation)
- Leachant composition (water or other reagent, sparged to remove O_2, etc.)

Column tests are well-suited to determining the concentrations of constituents that can be released over a relatively small number of pore volumes, which corresponds to shorter time periods.

The column leach data provided to LWC spans weeks 0 – 12 (12 July 2021 to 5 October 2021). A total of five columns are understood to be in progress:

1. PAF Rock
2. PAF (low confidence (LC)) Rock
3. NAF Rock
4. Blend of PAF and NAF rock (10/90)
5. Tailings

For the purposes of pit lake water quality prediction, the PAF data is of interest in the first instance The kinetic test for PAF uses sample 21363. Sample characteristics are summed in Table 4-1.

Table 4-1 Sample 21363 characteristics

Sulphur	ANC	NAPP	$NAG_{4.5}$	$NAG_{7.0}$	NAGpH	Weight	Start	Sample
%S	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t		g	Date	Code
0.67	9	12	4	10	3.3	2001	09/01/21	FH/21363

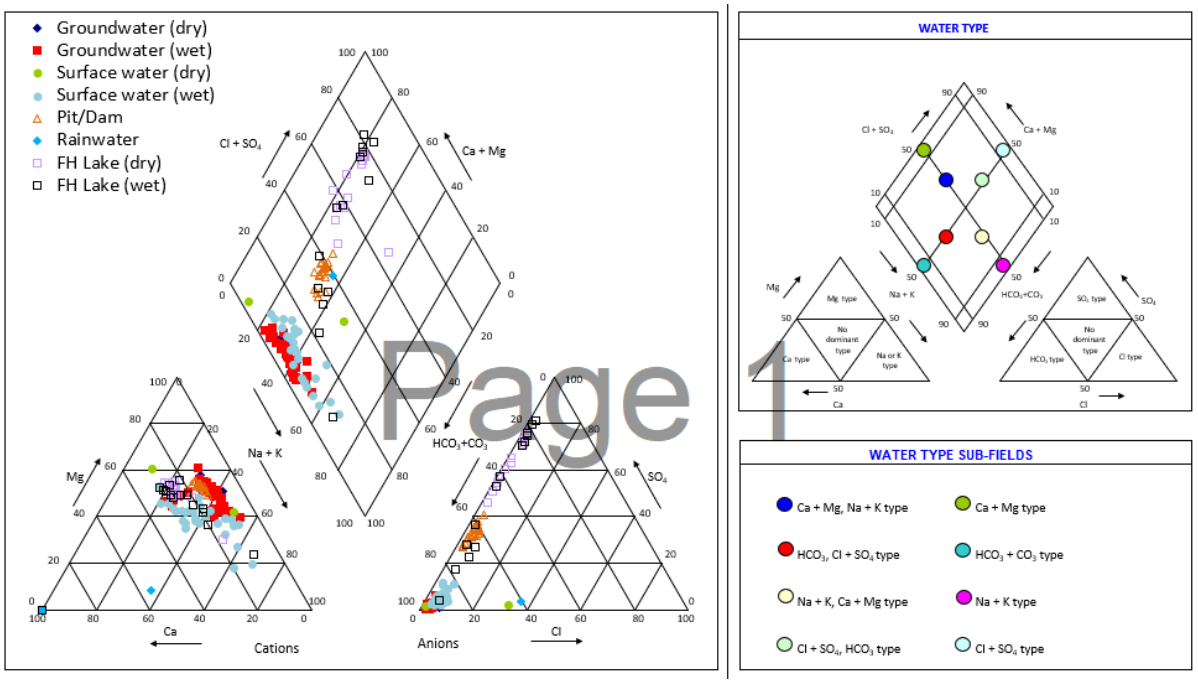
General trends observable from sample 21363 in the duration of data available:

- In line with elemental speciation, arsenic is by far the predominant element (metalloid) in terms of metal/ metalloid magnitude.
- No alkalinity is recorded.
- Acidity has doubled in 12 weeks with a concomitant decrease in pH from 5.9 to 4.8.
- Sulfate has decreased three to four-fold.
- All metals generally in steady state other than copper which has ~doubled.

4.6 PROJECT WATER QUALITY

Piper diagram of various waters associated with the project is presented as Figure 3-2 Piper diagram of project area water types (CDM Smith 2021).

Figure 4-1 Piper diagram of project area water types (CDM Smith 2021)



Groundwater monitoring wells 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.

Pit lake water currently has higher arsenic concentrations than the groundwater (Table 4-2 and Table 4-3), and the lake arsenic concentrations exceed the stock watering guideline value.

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 (CDM Smith, 2021), geometric mean concentrations were adopted to compare water composition (Table 4-4).

Table 4-2 Groundwater chemistry summary

		General Parameters				Major Ions (mg/L)						Total Metals (µg/L)										
	SWL (m below top of casing)	Conductivity (uS/cm)	pH	Hardness (mg $CaCO_3$/L)	Total Alkalinity as $CaCO_3$ (mg/L)	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulphate	Aluminium	Arsenic	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Nickel	Zinc
Long-term trigger value – Irrigation and General Water Use (ANZECC, 2000)		see below	6–8.5				see below			see below		5,000	100	10	100	50	200	200	2,000	1,000	200	2000
Short-term trigger value – Irrigation and General Water Use (ANZECC, 2000)												20,000	2,000	50	1000	100	5,000	10,000	5,000		2000	5000
Stock Drinking Water (ANZECC, 2000)		7460†	5–9			1000					1,000	5,000	500 (5000)	10	1,000	1,000	1,000		100	10000	1,000	20,000
Average		376	7	108	163	10	5	20	2	26	1131	655	101	0	5	2	6	5,316	6	171	3	10
Mean		335	7	89	140	7	4	17	2	24	5	87	50	0	2	1	3	650	4	113	2	6
s.d.		167	1	60	77	9	2	9	1	10	3707	2,074	115	0	12	1	9	7,595	7	152	6	13
Median		360	7	102	168	8	5	21	2	28	2	47	72	0	2	1	3	1,400	3	130	2	7
90%		648	7.521	209	290	28.7	7	34	3.5	34.9	3000	2,230	320	-	10	3	14.1	18,200	21.6	354	5	19.6
Max		**844**	**8.63**	**270**	**380**	**44**	**16**	**40**	**5**	**64**	**15000**	13,000	**450**	**0.3**	**53**	**3**	**40**	**32,000**	**26**	**860**	**35**	**86**
Count		72	72	70	69	70	69	70	69	70	39	46	69	3	19	16	22	67	21	67	33	55

Table 4-3 Pit lake chemistry summary

	General Parameters				Major Ions (mg/L)						Total Metals (µg/L)																
	pH	Conductivity (uS/cm)	Hardness (mg $CaCO_3$/L)	Total Alkalinity as $CaCO_3$ (mg/L)	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulphate	Aluminium	Arsenic	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Molybdenum	Nickel	Selenium	Uranium	Vanadium	Zinc
Long-term trigger value – Irrigation and General Water Use (ANZECC, 2000)	6–9	see below				see below			see below		5,000	100	500	10	100	50	200	200	2,000	2500	1,000	10	200	20	10	100	2000
Short-term trigger value – Irrigation and General Water Use (ANZECC, 2000)											20,000	2,000	4000-6000 for sorghum	50	1000	100	5,000	10,000	5,000	2500		50	2000	50	100	500	5000
Stock Drinking Water (ANZECC, 2000)	5–9	7460†			1000					1,000	5,000	500 (5000)	5000	10	1,000	1,000	1000*		100		10000	150	1,000	20	200		20,000
Average	8.1	526		138	12.3	5.6	27.2	1.7	29.8	3549.3	50.4	618	15.6	0.0	0.9	0.2	2.8	82.2	1.4	18.0	124.5	7.3	0.8	0.2	5.0	0.5	8.2
Mean	8.0	433		137	12.2	5.5	27.2	1.7	29.7	99.0	15.0	547	15.5	0.0	0.9	0.1	0.6	35.3	0.3	18.0	30.0	6.9	0.4	0.2	4.6	0.4	4.5
s.d.	0.8	617		15	1.4	1.3	1.3	0.3	2.4	14351.9	169	156.1	1.6	-	-	0.1	9.5	175.3	2.8	0.0	172.8	2.9	1.2	0.0	2.1	0.3	10.3
Median	8.3	415		142	12.7	5.5	27.6	1.7	29.4	66.1	11.6	620	15.0	0.0	0.9	0.1	0.6	28.0	0.2	18.0	14.6	9.0	0.2	0.2	5.9	0.4	3.6
90%	9.0	509.5		154.6	14.1	7.7	28.8	2.0	33.3	84.0	55.0	770	18.6	-	-	0.4	2.0	239.0	7.5	-	426.0	-	2.5	-	-	1.1	28.4
Max	9.4	3991.4		170	14.9	7.9	29.1	2.4	34	62000	906	784	20	0.04	0.9	0.4	43	852	9.7	18	437	9	4.691	0.2	6.4	1.25	40
Count	34	34		32	36	33	36	36	36	35	28	35	13	1	1	13	20	26	13	2	32	3	17	2	4	12	26

Table 4-4 Geometric mean parameters for Fountain Head water sources (CDM Smith (2021))

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)

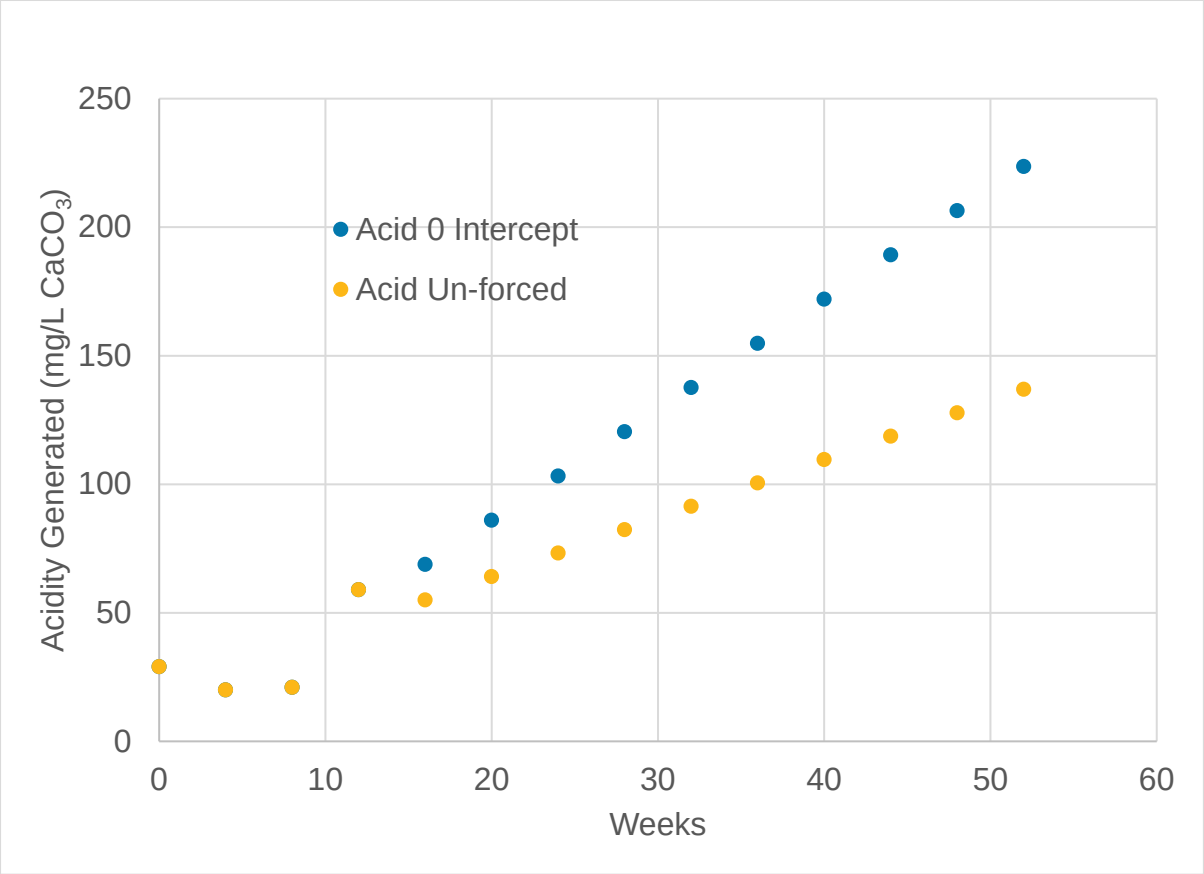
5 PIT LAKE WATER QUALITY PREDICTIONS

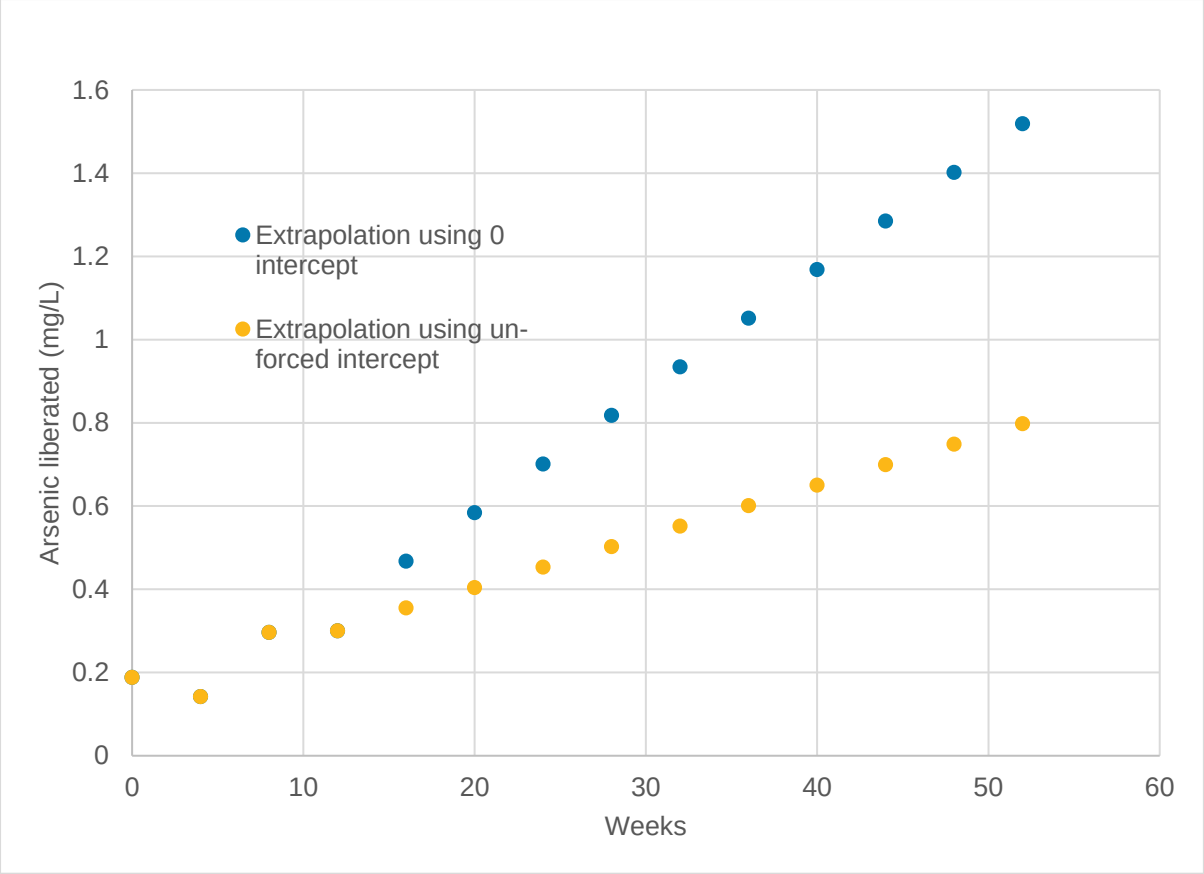
5.1 SOURCE S1 – PAF ROCK IN PIT

5.1.1 COLUMN LEACH TESTING EXTRAPOLATION

Noting four data points from the 0 – 12 week kinetic test of PAF material, a trend line was applied to the existing data points to formulate a regression equation. This was done for fitting through 0 intercept and also ignoring such intercept. The regression equations were used to extrapolate the potential concentration of the key parameters of acidity and arsenic over a 52 week period (note the broad observations and assumptions made with respect to the available kinetic data in Section 4.5).

Figure 5-1 Acidity extrapolation





5.1.2 ALKALINITY

Non-acid forming (NAF) sample 21365 was submitted for column leaching. The sample is currently producing alkalinity (as mg/L $CaCO_3$) of 97 mg/L as per the 12 week data point (four data points only). A rate was calculated for alkalinity release and is presented in Section 5.1.4.

Note that in terms of pit wall loading (Section 5.2), unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerially exposure pit wall ANC will be consumed in response to acid production.

5.1.3 BULK SCALE DRAINAGE

As noted in Section 4.4, a major challenge associated with the application of kinetic test results is the extrapolation of leachate chemistry to predict full-scale mine-site drainage chemistry even when waste rock compositions, tonnages and site water balance are constrained.

A common approach is to convert laboratory kinetic test leachate concentrations into a geochemical loading rate (e.g., mg/kg_{rock}/week) which is then upscaled to the tonnage of the waste dump to predict

drainage quality (Kirchner and Mattson, 2015):

$$Predicted\ Concentration = \frac{HC\ Load\ x\ Time\ x\ Mass\ of\ Rock\ in\ Dump}{Volume\ of\ Infiltrating\ Water}$$

The assumptions used to calculate the total scaled up predicted concentration are presented in Table 5-2. The resulting values are presented as Table 5-3 based on the calculations in Appendix A. Note that mg of solute was adjusted for an average leach column volume of 0.503L.

Table 5-1 Scale up parameters

Parameter	Value	Source/ Reference/ Rationale
Time (weeks)	52 – refer value for 52 weeks in Appendix A, which mimics 1 year of oxidation, assuming	Arbitrary extrapolation – can be extended forward to any week value.
Mass of Rock	2 million tonnes	LCM of 957,700 x bulk density of 2.05 t/m^3.
Volume of infiltrating water	1000 ML	Rainfall influx modelled reported in CDM Smith (2021)
HC Load	Kinetic data from sample 21363 using 0 intercept.	Kinetic data from sample 21363. The use of 0 intercept is more conservative currently when only 4 data points available.

A similar approach was undertaken for alkalinity in NAF wall rock - assumed to be primary source of alkalinity - noting however unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces.

Rationale for wall rock surface area is presented in Section 5.2. Assuming ~81.2% of the surface area is NAF rock (3.6 mega tonne), then assuming a 2000 ML lake the resulting concentration (ignoring groundwater, which is an average alkalinity of 163 mg/L (Table 4-2 Groundwater chemistry summary), then resulting alkalinity from wall rock could be ~30 mg/L (Appendix B), for a cumulative of close to 200 mg/L.

Assuming a total mass of acidity as mg/L $CaCO_3$ is 6.89 x 10^{10} (Appendix A), divided by lake volume of 2000 ML, this would result in an acidity of ~34 mg/L $CaCO_3$. Therefore depending on groundwater throughflow and NAF rock kinetics, alkalinity (based on data to date) would appear to be buffered to around 15 – 160 mg/L, which is around the current alkalinity (assuming some PAF from previous mining has influenced the water chemistry to a similar degree).

Using sample 21363 net acid producing potential of 12 kg H_2SO_4 per tonne of rock, this would equate to 0.24 kg of H^+ per tonne of rock, or a total of 480 tonne of acidity (as H^+) for 2 million tonne of PAF rock.

Total S in the same sample is given as 6,700 mg/kg. Harries et al., 1981 report a median weathering rate of 0.26 g S per kg rock per year (mixed rock ~3wt% Rum Jungle NT). Using the Total S concentration, this would assume an exhaustion of S oxidation in 25 years.

5.1.4 RESULTS / RATES

Calculations are presented in Appendix A and are summarised in Table 5-2 with BE1 being extrapolation of kinetic testing results, no scaling, and BE2 being bulk scaled as per Section 5.2.

Table 5-2 Calculations for extrapolations of no scaling and bulk scaling using 0,0 intercept and un-forced intercept.

Calculation Code	Calculation
BE1A – acidity	Book End 1A – extrapolation of acidity generation using kinetic testing, unscaled with linear trend drawn through 0,0
BE1B – acidity	Book End 1B – extrapolation of acidity generation using kinetic testing, unscaled, with linear trend not forced through 0,0
BE2A – acidity	(Upper) Book End 2 – extrapolation of acidity scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall , as per BE1A
BE2B – acidity	(Upper) Book End 2 – extrapolation of acidity scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1B
BE1A – arsenic	Book End 1A – extrapolation of arsenic generation using kinetic testing, unscaled, with linear trend drawn through 0,0
BE1B – arsenic	Book End 1B – extrapolation of arsenic generation using kinetic testing, unscaled, with linear trend not forced through 0,0
BE2A - arsenic	(Upper) Book End 2 – extrapolation of arsenic scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1A
BE2B - arsenic	(Upper) Book End 2 – extrapolation of arsenic scaled up to 2 million tonnes of rock and assuming 1000 ML inflow of rainfall, as per BE1B

The predicted leach at week 52 using BE1A is summarised for the key parameters in Table 5-3.

Table 5-3 Predicted 52 week and cumulative values for key parameters (BE1A)

Parameter	Week 0	Week 12	Week 52	Cumulative for 1 year
BE1A - 0 intercept				
acidity (mg/L $CaCO_3$)	29	59	224	1,591
arsenic (mg/L)	0.188	0.3	1.52	10.9
BE1B - Un-forced intercept				
acidity (mg/L $CaCO_3$)	29	59	137	1,089
arsenic (mg/L)	0.188	0.3	0.8	6.7
BE2A - 0 intercept				
acidity (mg/L $CaCO_3$)	175	356	1,350	9,608
arsenic (mg/L)	1.1	1.8	9.2	66
BE2B - Un-forced intercept				
acidity (mg/L $CaCO_3$)	175	356	827	6,573
arsenic (mg/L)	1.1	1.8	4.8	40

This extrapolation method is not able to predict pH noting the logarithmic nature of pH, however an acidity of 224 mg/L $CaCO_3$ (assuming no buffering capacity) would equate to a pH of 2.3.

Kinetic rates were calculated by mg/L*volume of rinse (fraction L)/ 4 weeks, using week 12 data. These rates are presented as Table 5-4.

Table 5-4 Calculated kinetic rates for key parameters using week 0 – 12 data

		Rate	per week	per month
BE1A	*Acidity*	*mg/kg/wk*	*0.0019*	*0.01*
	Arsenic	*mg/kg/wk*	*0.0072*	*0.03*
BE1A	*Alkalinity*	*mg/kg/wk*	*4.28*	*17.13*
BE2A	*Alkalinity*	*mg/kg/wk*	*7.81*	*31.22*

In terms of acidity and alkalinity, the column testing indicates the generation of alkalinity outstrips acidity generation based on the data available to week 12, however, unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerially exposure pit wall ANC will be consumed in response to acid production.

5.1.5 SOURCE S1 MIXING

Where rock leaching occurs as a result of penetration of lake water into the rock pore space and also flushing / leaching due to rainfall, the leach from the rock will mix with the volume of lake water available, which is understood to be ~2,000 ML.

A mixing model was created using Geochemists Work Bench GSS App where representative rock leachate from 52 weeks (both kinetic extrapolated and scaled up solution) was mixed with existing lake water at a ratio of 2:1 lake to leach solution.

Note that this assessment ignores Source S2 and any contribution of acidity and metals/ metalloids therefrom.

Table 5-5 Result of mixing using GSS for key parameters (BE1A)

Parameter	Lake Water	Leach	Resulting 2:1 Mix
Acidity (mg/L $CaCO_3$)	<1	224	112
Arsenic (mg/L)	0.76	1.52	1.14

Table 5-6 Result of mixing using GSS for key parameters (BE2A)

Parameter	Lake Water	Scaled Up Leach	Resulting 2:1 Mix
Acidity (mg/L $CaCO_3$)	<1	1,350	450
Arsenic (mg/L)	0.76	9.2	3.6

5.2 PIT WALL

PAF rock will be exposed on the pit wall. A source term is required for the rinsing of sub-aerial pit wall by precipitation and inundation of exposed pit wall by the pit lake.

Both acidic and pH-neutral source terms were developed for pit wall runoff. The proportion of acidic to pH-neutral loading from wall can be identified/ revised based on the lag time calculated for the complete depletion of ANC from these units.

The surface area / particle size of rock used in column leach testing is not known and so a direct correlation between column leach rock mass and pit wall area is not achievable.

The degree of geochemical loading from the pit wall is likely to be greatly influenced by the fracture intensity of the walls induced by blasting:

- The blast effects in the pit wall can be subdivided into two zones; a blast influenced zone and a blast damaged zone.
- The blast damaged zone consists of highly fractured pit wall rock exposed on the pit wall face or ravel collected on benches.
- The blast influenced zone consists of more widely spaced fractures into the pit wall behind the blast damaged zone that will become progressively more fractured over time.
- The method for estimating the depth of blast damage in the transition zones was sourced from Hustrulid (1999). Each zone was calculated based on controlled blasting patterns and practices for medium strength rock and ANFO (ammonium nitrate and fuel oil) used as the blasting agent. Under these assumptions, blast fractured zone depth would be expected to range from a minimum of 0.85 m to maximum depth of 1.05 m. Blast influenced zone depth would typically range from 2.65 m to 3.15 m. Given these ranges, the blast damaged zone is estimated to extend 1.0 m into the final pit wall, and the blast influenced zone is estimated to extend another 2.9 m into the pit wall.
- The effective volume of material in a planar unit area of 1 m^2 (1 m^3) is increased by a factor of 1.41 to account for an assumed average pit wall slope of 45 degrees, i.e. 1.41 m^3. Finally, the mass of rock is determined by multiplying the effective volume by average waste density of 2.7 t/m^3 which gives 3.81 tonne (or 3,807 kg) for the blast fractured zone.
- Of note, the blast influenced zone would have a mass of 11,040 kg using the same logic but with a depth of 2.9 m.
- Accounting for both blast fractured and influenced zones, total mass of rock would be 15.2 tonne (15,200 kg).

The full parameters and values are presented in Table 5-7 with respect to arsenic.

The mass of arsenic which may accumulate on PAF rock pit wall surfaces per year is 0.52 mg per kg of rock (no CSF).

This represents:

1. Single load transfer available once the pit wall is submerged; and
2. Ongoing loading from exposed rock now, during mining or post mining.

The proportion of exposed rock throughout the life or mine and post closure will be governed by the elevation of the water table.

For simplicity, this calculation assumes that all PAF wall rock is exposed. When the water table rebounds the loading will decrease due to less exposed surface area.

The final calculations carry a cumulative scaling factor of 0.4 (refer section 6.1.3) to account for mass loading correction factors between laboratory and field scale calculations (e.g. grains size, seasonality, temperature, water contact etc.)

Note that acidities but not alkalinities are associated with the sub-aqueous load - Pit wall acidity is predominantly stored in sulfide mineralisation, which is released during oxidation. Acidity can then be stored on mineral surfaces in acidic oxide minerals (i.e. jarosite and alunite). This acidity stored in oxide

minerals will be released upon pit wall submergence. Once the pit wall becomes submerged, oxidation and associated acidity release from primary sulphide minerals will largely be inhibited.

Unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerially exposure pit wall ANC will be consumed in response to acid production.

Table 5-7 Pit wall contribution of arsenic and acidity to lake water calculation

Parameter	Unit	Value
Area of exposed wall rock	m^2	1
average assumes pit wall side slope angle	Degrees	45
Surface area of exposed unsubmerged pit wall rock	m^2	1.41
Density of pit wall rock	Tonne/m^3	2.7
Depth of blast fractured zone	m	1.0
Depth of blast influenced zone	m	3.0
Total volume of wall rock in the 4 m deep blast affected zone	m^3	5.64
Total mass of wall rock in the 4 m deep blast affected zone	kg	15,228
Mean annual precipitation	mm/year	1,245.2 (from section 4 of the EIS)
Mean annual precipitation volume (per 1m^2 of exposed unsubmerged wall rock)	m^3	1.25
Mass loading rates - arsenic		
Mass loading rate (arsenic, from Table 5-4)	mg/kg/wk	0.01
Mass loading rate (arsenic, from Table 5-4 – annual)	mg/kg/yr	0.52
Wall rock loading rate (arsenic, from Table 5-4)	mg/kg/yr (without CSF of 0.4)	0.52
Wall rock loading rate (arsenic, from Table 5-4)	mg/kg/yr (with CSF of 0.4)	0.21
Mass loading rates – acidity (as $CaCO_3$)		

Parameter	Unit	Value
Mass loading rate (from Table 5-4)	mg/kg/wk	14.5
Mass loading rate (from Table 5-4 – annual)	mg/kg/yr	754
Wall rock loading rate (from Table 5-4)	mg/kg/yr (without CSF of 0.4)	754
Wall rock loading rate (from Table 5-4)	mg/kg/yr (with CSF of 0.4)	302
Mass loading predictions		
Total mass of rock in the blast damaged zones per 1 m^2	Tonne / kg	15.2 / 15,200
Area of PAF rock	m^2	55,563
Total mass of PAF rock available	Mega-tonne	0.845
Total mass of PAF rock available	kg	845000000 (8.45 x 10^8)
Annual mass loading from the pit walls to the pit lake per 1m^2 of unsubmerged rock - **arsenic**	kg/yr / mg/yr	3.2 x10^{-3} / 3,200
Annual mass loading from the pit walls to the pit lake per 1m^2 of unsubmerged rock - **acidity**	kg/yr / mg/yr	4.6 / 4590400
Total annual contact water available per 1 m^2 of unsubmerged rock (per 1m^2)	m^3/yr / L per year	1.25 / 1,250
Annual average wall rock runoff concentration (calculated/ predicted) per 1m^2 - **arsenic**	mg/L	2.6
Annual average wall rock runoff concentration (calculated/ predicted) per 1m^2 - **acidity**	mg/L $CaCO_3$ / as H^+ mg/L	3,672 / 73
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock - **arsenic**	kg/yr / mg/yr	178 / 1.77 x 10^8
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock - **acidity**	kg/yr / mg/yr	2.6 x 10^5 / 2.6 x 10^{11}

Parameter	Unit	Value
Total annual contact water available per PAF unsubmerged rock	m^3/yr / L per year / ML	69,454 / 6.95 x 10^7 / 69.5
Annual average wall rock runoff concentration (calculated/ predicted) for PAF rock - arsenic	mg/L	2.5
Annual average wall rock runoff concentration (calculated/ predicted) for PAF rock - acidity	mg/L $CaCO_3$ / as H^+ mg/L	1.0 / 0.02
Lake Volume	ML	2000
Dilution factor	(Total annual contact water available per PAF unsubmerged rock / Lake Volume, fraction)	0.034
Predicted lake water arsenic concentration from PAF rock post dilution in lake volume.	mg/L	0.086
Predicted lake water acidity concentration from PAF rock post dilution in lake volume.	mg/L $CaCO_3$ / as H^+ mg/L	0.034 / 6.8 x 10^{-4}

6 DISCUSSION

6.1 SOURCE S1 – PAF ROCK IN PIT

6.1.1 PREDICTION OUTCOMES

Two main strands of prediction were pursued:

1. Extrapolation of kinetic tests (BE1 A/B)
2. Extrapolation of kinetic tests scaled up for rock mass (BE2 A/B)

These approaches give vastly different results that are treated as “book-ends” - It has long been recognised that the predicted loads calculated from bulk scaling up commonly overestimate actual geochemical loads seen in drainage from waste dumps (Morin & Hutt, 1994; Malmström et al., 2000). The issues associated with scaling up are discussed in Section 6.2.

Both of these approaches are assessed in context of the volume and existing quality of the pit lake water, noting arsenic already exceeds the stock watering criterion.

6.1.2 SCALING FACTORS

This is largely attributed to discrepancies in geochemical and physical conditions between laboratory kinetic reactors and full-scale waste dumps, including but not limited to:

- water-rock interaction (contact);
- gas transport and oxygen content;
- reactive grain size distribution (and associated occlusion of reactive minerals);
- temperature (both sulfide and carbonate dissolution reactions are temperature-dependent).

Kirchner and Mattson (2015) report that direct scaling of geochemical loads measured by laboratory kinetic tests such as humidity cells relative to the mass of a full-scale mine waste facility will lead to concentration predictions for mine drainage that are unrealistically high for many dissolved constituents.

As a result, “scaling factors” are applied to account for discrepancies in parameters such as grain size, temperature and water/ rock ratio between the laboratory experiments and the field scale waste rock facilities.

Lapakko and Olsen (2015) consider that there is little agreement on scaling factors to be used for extrapolating laboratory dissolution test results for predicting solute release rates from proposed waste rock piles in the field.

The scaling factor for a given solute is the ratio of its release rate in the field to that observed in the laboratory, and its magnitude is dependent on both the solute and site-specific variables. Such research concluded that modelling should use cumulative probability distribution as recommended by the National Academy of Sciences (National Research Council, 2007) as opposed to a single value. Lapakko and Olsen (2015) concluded that they are deemed more appropriate for assessment of risk by

regulatory agencies, an assessment that is essential to environmental review of proposed mining operations.

The Lapakko and Olsen (2015) laboratory rates were calculated based on sulfate release during weeks 6 to 71 observed for 17 blast hole samples with sulfur contents of 0.18 to 1.64 percent. The samples were collected from the mine site from which comparative field data were generated. Annual field rates were determined over a period of 3 to 13 years for five waste rock piles, ranging in mass from 2,000,000 to 15,000,000 tons, with estimated sulfur contents of 0.24 to 0.97 percent. Laboratory and field rates were expressed per unit mass sulfur. Comparison of 17 laboratory rates and 42 annual field rates yielded in 714 distinct calculated scaling factors. These values were fit to a beta distribution for which the mean and standard deviation were 0.127 (~13%) and 0.083, respectively, with cumulative probability 1 being a CSF of 0.4 (40%).

It should be noted that the results were generated based on dissolution of a specific rock type in the laboratory and under specific conditions of climate and waste rock stockpile design in the field. Consequently, care must be taken when applying these results to other conditions.

Kirchner and Mattson (2015) observed that geochemical loads for major ions from two test sites are commonly more than two orders of magnitude lower than those predicted by direct scaling of laboratory kinetic test loads, yielding bulk scaling factors of <1%. In these models, many dissolved trace ions that may be of concern in mine drainage (e.g., As, Cu, Cd, Se, etc.) may still be significantly overpredicted if the model is calibrated to major ions, likely as a result of solubility limits and other attenuation mechanisms. Unlike loading rates, concentrations in field bin and waste dump drainage were commonly found to be on the same order of magnitude for both neutral and acidic sites suggesting that geochemical equilibrium may be attained at relatively small scales in waste piles.

In an attempt to account for the variable geochemical regimes, many authors have begun introducing scaling factors based on theoretical assumptions and field observations (Malmström et al., 2000; Neuner et al., 2009; Kempton, 2012). In theory, a scaling factor (generally <100%) is assigned to each of the lab-to-field discrepancies identified and multiplied by the upscaled load.

Understandably, depending on the type of waste material and the climatic conditions at a mine site, the sometimes inter-related individual scaling factors vary widely in practice (Kempton, 2012). A so-called cumulative scaling factor (CSF), defined as the product of all individual scaling factors can be calculated empirically where laboratory kinetic and waste drainage chemistry data are available, however a comprehensive database for different deposit types and climate conditions is missing.

Nevertheless, several studies have addressed this topic and CSF on the order of 5 to 60% have been reported (e.g., Andrina et al., 2012; Hanna & Lapakko, 2012; Morin & Hutt, 1994).

Kirchner and Mattso (2015) reported a range of 0.01% to 4% and concluded that many species appear to be solubility-limited at a scale of field bin experiments (150-200 kg), which is a factor that should be accounted for in water quality prediction modelling.

Of note when considering scaling factors, a detailed examination of kinetic testing by Maest and Nordstrom (2017), including speciation and inverse modelling, of HCTs from three projects with different geology and mineralisation showed that rapid sulfide oxidation dominates over a limited period of time that starts between 40 and 200 weeks of testing.

The kinetic data available currently spans 0-12 weeks, and may therefore underestimate sulfide oxidation. In addition, factors that complicate the use of HCTs include: sample representation, time for microbial oxidisers to grow, sample storage before testing, geochemical reactions that add or remove constituents, and the HCT results chosen for use in modelling the environmental performance at mine sites.

6.1.3 CSF PREDICTION OUTCOMES

If considering a cumulative scaling factor for this data, this must be sourced from the literature and this is not ideal, noting CSF is related to the many variables set out in Section 6.2. We present the calculations for consideration using the cumulative probability 1 CSF of 0.4 from Lapakko and Olsen (2015) - Table 6-1 and Table 6-2, noting the mean of such study was 0.127 and the upper value sits comfortably within the 5 to 60% range commonly observed in the literature, noting the far lower CSF reported by Kirchner and Mattso (2015). Obviously this CSF is an illustrative guesstimate but is considered reasonably conservative.

Table 6-1 Calculated kinetic rates for key parameters

		Rate	*per week*	*CSF*	*CSF adjusted rate*
BE1A	*Acidity*	*mg/kg/wk*	*14.45*	*0.4*	*5.8*
	Arsenic	*mg/kg/wk*	*0.01*	*0.4*	*0.004*
BE2A	*Acidity*	*mg/kg/wk*	*23.38*	*0.4*	*9.4*
	Arsenic	*mg/kg/wk*	*0.09*	*0.4*	*0.04*

Table 6-2 Predicted 52 week and cumulative values for key parameters (BE1A and BE2A) with 0.4 CSF applied

Parameter	Week 0	Week 12	Week 52	Cumulative for 1 year
BE1A - 0 intercept				
acidity (mg/L $CaCO_3$)	29	59	90	636
arsenic (mg/L)	0.188	0.3	***0.61***	4.4
BE1B - Un-forced intercept				
acidity (mg/L $CaCO_3$)	29	59	55	436
arsenic (mg/L)	0.188	0.3	0.32	2.7
BE2A - 0 intercept				
acidity (mg/L $CaCO_3$)	70	142	540	3,843
arsenic (mg/L)	0.44	0.72	3.7	26
BE2B - Un-forced intercept				

acidity (mg/L $CaCO_3$)	70	142	331	2,629
arsenic (mg/L)	0.44	0.72	1.9	16

The mixing assessment reported in Section 5.4 can be reviewed in light of CSF application to predict potential lake concentrations/ quality noting a lake volume of ~2000 ML.

Table 6-3 Result of mixing using GSS for key parameters (BE1A) – CSF adjusted

Parameter	Lake Water	CSF adjusted Leach week 52	Resulting 2:1 Mix	Stock Watering Criterion
Acidity (mg/L $CaCO_3$)	<1	90	45	
Arsenic (mg/L)	0.76	0.61	0.46	0.5

Table 6-4 Result of mixing using GSS for key parameters (BE2A) – CSF adjusted

Parameter	Lake Water	CSF adjusted scaled up Leach week 52	Resulting 2:1 Mix	Stock Watering Criterion
Acidity (mg/L $CaCO_3$)	<1	540	180	
Arsenic (mg/L)	0.76	3.7	1.4	0.5

Scaled up leach (accounting for 2 million tonne of rock) adjusted for a literature based CSF would be predicted to yield an arsenic concentration ~3 – 4 times the current lake water and result in a lake water arsenic concentration ~3 times the stock watering criterion for arsenic.

6.2 SOURCE S2 PIT WALL ROCK

The calculations set out on Section 5.2 necessarily make several assumptions around rock mass, water contact, loading rates etc and do not carry a low CSF. A factor of 0.4 was used as explained in section 6.1.3. As also explained, the proportion of exposed PAF rock is subject to water table level, and so the cumulative loading figure to the Lake will likely be less than that displayed.

In addition, concomitant submergence of neutral (NAF) sections of pit wall will make available some of the remaining carbonate mineral acid neutralising capacity (ANC) to the pit lake, providing a subaqueous source of alkalinity. Unlike submerged loading of other parameters, alkalinity will not be stored in oxides that accumulate on the pit wall. The amount of alkalinity contained in carbonate minerals on the pit wall that is available on the submerged sections of the pit wall depends on the quantity consumed to buffer acid generation while subaerially exposed.

Rationale for wall rock surface area is presented in Section 5.2. Assuming ~81.2% of the surface area is NAF rock (3.6 mega tonne), then assuming a 2000 ML lake the resulting concentration (ignoring

groundwater, which is an average alkalinity of 163 mg/L (Table 4-2 Groundwater chemistry summary), then resulting alkalinity from wall rock could be ~30 mg/L (Appendix B), for a cumulative of close to 200 mg/L.

Assuming a total mass of acidity as mg/L $CaCO_3$ is 6.89 x 10^{10} (Appendix A), divided by lake volume of 2000 ML, this would result in an acidity of ~34 mg/L $CaCO_3$. Therefore depending on groundwater throughflow and NAF rock kinetics, alkalinity (based on data to date) would appear to be buffered to around 15 – 160 mg/L, which is around the current alkalinity (assuming some PAF from previous mining has influenced the water chemistry to a similar degree).

Using the CSF adjusted loading, and ignoring water level, the pit walls are considered to contribute around 2.5 mg/L of arsenic cumulatively, or around 2.6 mg/L per m^2 of PAF exposed rock. This would be diluted in 'full' pit lake though evaporation and limited migration over time would overall increase the residual arsenic concentration.

Note that the current pit lake arsenic concentration is higher than groundwater, possibly as a result of current or previous loading of arsenic from exposed fractured pit wall rock.

6.3 ARSENIC

It is possible that arsenic may bind with available ferric oxyhydroxides (FeOH) and therefore have colloidal behaviour. This may result in the arsenic becoming enriched in sediment rather than water column over time – Appendix C shows oversaturation of several Fe phases.

Further partition and speciation modelling should be undertaken on receipt of further kinetic data.

6.4 PIT CHARACTERISTICS

Not all pits are suited for waste disposal and especially disposal of reactive waste. MEND (1995) lists some of the key considerations regarding suitability include:

1. mining constraints - future access to remaining ore reserves; other nearby mining activities; - stability; - safety of workers during placement of wastes;
2. mineralisation of exposed pit walls; and
3. hydrogeology/hydrology.

Other factors that also need to be considered include morphology, depth of overburden and potential benefits (e.g. future lake uses i.e. recreation etc.).

Mining Related Constraints

Few pits are ever "mined-out". Residual mineralisation often remains and may prove to be economically recoverable at a future date. In addition, concern is often raised regarding creation of flooded pits above existing or potential future mine workings. Other factors which may impact on the use of the pit include interconnection with other nearby mine workings, and concerns regarding the stability of underground workings located under the pit.

Mine owners/operators have generally opposed backfilling of pits for one or more of the above reasons; however, it has recently been clearly demonstrated that there can be a net positive benefit to using an open pit for mine waste disposal.

There is also concern over the safety aspects of working in old pits. Pit walls may be unstable or degraded to the point where the risk of entry into the pit may preclude its use. For example, at several sites, it was indicated that helicopters had to be used for safe access to pit waters for sampling water quality. On the other hand, backfilling may well be a cost effective technique for stabilising pit walls.

Pit Walls

Acid production from exposed mineralisation on the pit walls may be a factor. Leachates draining into the pit from joints, fractures, faults and exposed walls may be acidic and could seriously impact on the utility of using pits for waste deposition. In these cases, concepts can generally be adapted to address this concern (e.g. grouting); however, cost effective solutions may not always be available.

Hydrogeology

MEND (1995) observes that the hydrogeology of the pit is by far the most critical factor in assessing the applicability of any pit for waste disposal.

The hydrogeology of the site will often dictate what engineered controls are necessary to develop an acceptable disposal option. Key factors regarding the pit include:

1. presence of faults and major flow pathways;
2. bulk permeability of the surrounding rock around the pit;
3. hydraulic connections to other mining areas;
4. groundwater flow path and potential downstream receptors (e.g. potable groundwater supplies, surface water streams);
5. location and gradient of the groundwater table; and
6. stratigraphy/permeability of overburden and bedrock.

According to MEND (1995), the ideal pit for reactive wastes producing contaminated leachate would have the following characteristics:

1. minimal to no groundwater gradient across the pit to ensure that no release of contaminants occurs as a result of groundwater transport;
2. low permeability bedrock with few faults such that the pit effectively acts as a bathtub with no drain (i.e., a terminal lake). All flows to the pit enter and discharge at the top resulting in no infiltration or groundwater discharge.

The hydrology of the surface region surrounding the pit may be a very important factor, as the surface flow conditions will affect:

1. the flooding of the pit;
2. the final water table elevation;
3. the concentrations of contaminants leached from the wastes;
4. the dilution provided for contaminated seepage/ drainages from the pit which reach receiving water bodies; and
5. the possible connection of a flooded pit with other surface water bodies.

For reactive waste disposal, assurance that the water cover will be maintained is critical for most applications. Predicted water table elevations at this pit do not adequately cover the waste rock.

6.5 PREDICTIONS & CSM

The CSM set out in Section 3 is revisited with the outcomes of the predictive calculations. Six linkages were identified, and these are considered.

Source (S)	Primary Pathway (P) [2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)	Discussion
S1 – PAF rock in the pit	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact	-	R1 Migratory Birds (contact)	L1	Bioaccumulation of heavy metals becomes a concern for fauna when the capacity of species to regulate the internal concentration of metals is lost. This can occur through direct ingestion of heavy metals or ingestion of contaminated organisms. This results in the impairment of physiological functions required for normal growth and survival, with documented effects on development and survival of species. Accumulation of heavy metals can seriously alter the aquatic environment, affecting the survival of some fauna. The bioaccumulation of toxic chemicals could occur if waters within the Pit are considered productive enough to support algal growth, aquatic vegetation, and associated organisms such as zooplankton which could provide foraging opportunities for visiting fauna. The acidity generated and arsenic generated and metals may be significant and indicate this is a potentially significant linkage. Estimations of alkalinity from wall rock coupled to groundwater inflow suggest however that there is a potential for an excess of alkalinity in the lake water, with calculations indicating an alkalinity close to existing depending on groundwater dynamics and wall rock kinetics.
	P1 - Groundwater inflow (and/ or rainfall) and contact with exposed oxidised rock / materials	P3 - Lateral migration of solutes away from the Pit	P4 - Abstraction	R2 Future Human Use	L2	Abstraction of groundwater along the flow path away from the Pit – arsenic is currently above drinking water criteria in groundwater but is not above stock watering criterion. If lake water migrates to groundwater there is chance that groundwater arsenic concentrations could exceed stock watering criterion.
			P4 - Abstraction	R3 Stock watering	L3	

Source (S)	Primary Pathway (P) [2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)	Discussion
S2 Pit wall rock	P1 - Ground water inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact P3 - Lateral migration of solutes away from the Pit	-	R1 Migratory Birds (contact)	L4	Refer Section 6.2 The wall rock alkalinity may outstrip the acidity generated from the 18.8% of wall rock that is PAF (based on current data and several assumptions). There will be an interim loading of arsenic from the PAF wall sections.
			P4 - Abstraction	R2 Future Human Use	L5	
			P4 - Abstraction	R3 Stock watering	L6	

6.6 PROPOSED DISPOSAL

As noted in Section 1, there are four basic concepts for placement of wastes in pits:

1. Option 1 – Underwater disposal
2. Option 2 – Elevated water tables
3. Option 3 – Dry disposal
4. Option 4 – Perched water tables

The proposed approach of partial submergence does not fit any of these standard options. As the water table is not predicted to cover POD 1 nor 2, this would infer that a portion of PAF rock would be left 'open' to above water oxidation, thereby generating acidity and concomitant metal solubilisation for an extended period.

This is in addition to oxidation occurring in the interim period prior to partial submergence and any contribution from pit wall rock.

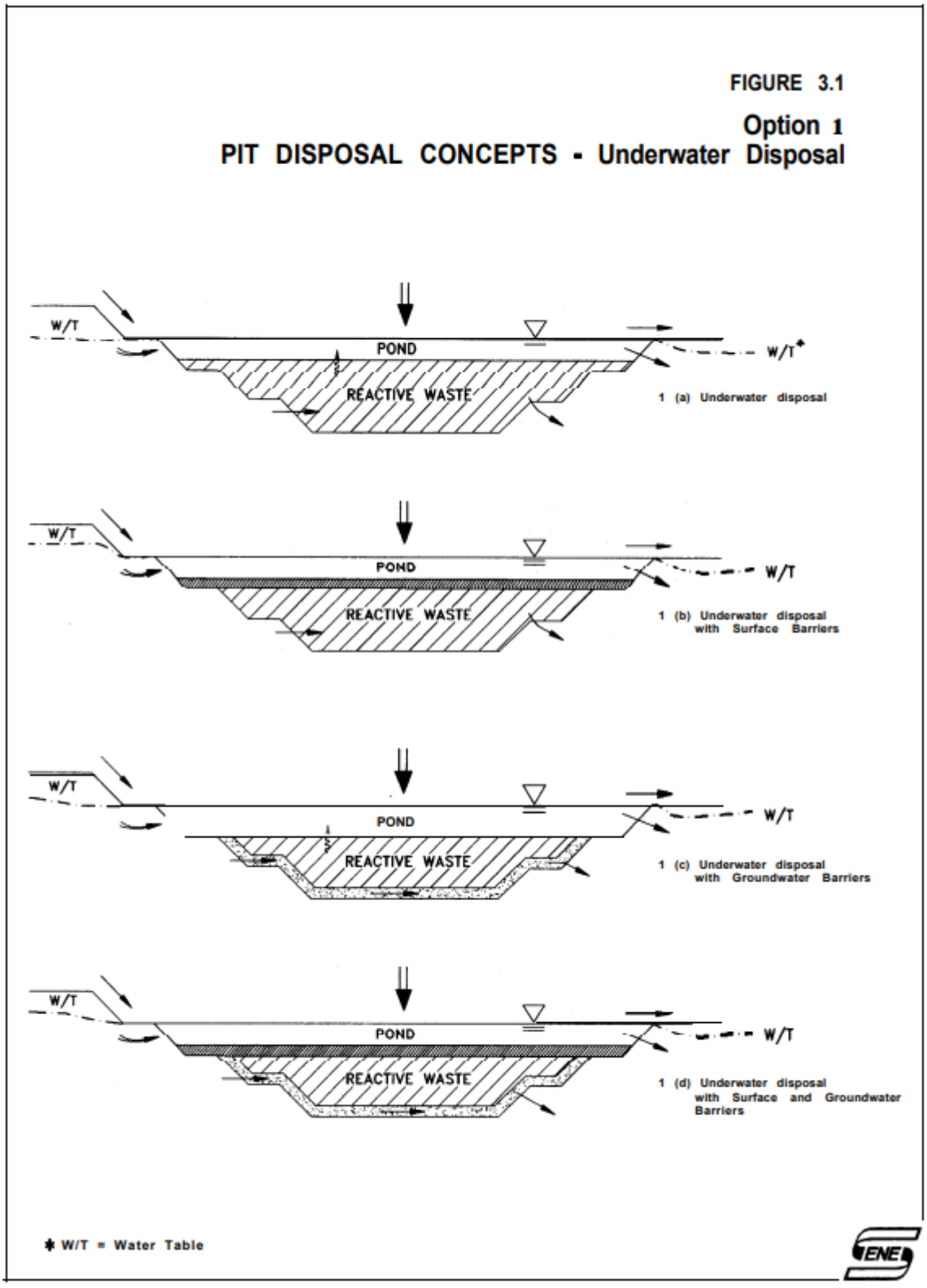
Noting only four data points of kinetic testing, extrapolation has been undertaken and the data available is not yet advanced enough to further predict (accurately) the overall kinetic rate, noting sulfide oxidation may yet peak.

The current proposed approach does therefore not reflect best practise for PAF storage. There are variations of in pit submerged storage options:

- Option 1a - Simple Underwater Disposal
- Option 1b - Underwater Disposal with a Surface Barrier
- Option 1c - Underwater Disposal with Groundwater Barriers
- Option 1d - Underwater Disposal with Surface and Groundwater Barriers.

These are shown in Figure 6-1 Underwater disposal of PAF in pit (MEND, 1995).

Figure 6-1 Underwater disposal of PAF in pit (MEND, 1995)



6.7 ADDRESSING SCOPE

With respect to scope in Section 1.4:

Task 2.1 – We have provided commentary on potential future pit lake water quality.

Task 2.2 – We have reviewed information on the PAF rock deposit schedule (PODS) and information from the geochemical characterisation of the PAF waste rock (Section 4) to be disposed of in the Fountain Head pit.

Task 2.3 – We have assessed potential acid generation, acid neutralisation and soluble minerals that may contribute to the water quality of the pit lake. The assessment broadly covers both of the following scenarios and comments (conclusions) are provided accordingly: Conceptualise the scenarios of saturated sediment (pit lake flooded) and unsaturated (in case the sediments remain above lake level for an extensive period).

Task 2.4 – We have not provided specific input to the required two (2) alternative feasible PAF management options noting the issues associated with the predicted water level and only partial submergence of PAF rock.

Task 2.5 – We have used empirical approaches and Geochemists Work Bench mixing applications to evaluate potential water quality, noting the limitations/ absence of kinetic or oxygen consumption based data.

7 CONCLUSIONS

The following conclusions are drawn in relation to this assessment in the context of the proposed partial submergence of PAF rock in the pit as a storage/ disposal option post mining.

Note that the predictions made are done so on the basis of four kinetic testing time points (weeks 0, 4, 8 and 12) which is insufficient for reasonable prediction of acid metal generation/ leaching from the given material (and only one kinetic column of PAF is established). Several factors of conservatism have been built in, although predictive rates are also presented using a <100% literature sourced cumulative scaling factor.

1. The key parameters based on geochemical abundance indices (GAI) as per previous geochemical testing (GAI of 3 or greater) are:
    a. Arsenic (As)
    b. Silver (Ag)
    c. Beryllium (Be)
    d. Bismuth (Bi)
    e. Cobalt (Co) (in the ore only)
    f. Copper (in the ore only)
    g. Manganese (Mn)
    h. Lead (Pb)
    i. Sulfur (S)
    j. Selenium (Se)
    k. Uranium (U)
    l. Tungsten (W)
2. Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, where concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg) have bene reported. Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present in project rock. Arsenic has a calculated geochemical abundance indices of over 10.
3. Arsenic and acidity are considered to be the key parameters.
4. Current pit lake water reports arsenic above the stock watering guideline value of 0.5 mg/L. Arsenic concentrations in groundwater do not exceed this criterion.
5. This assessment used currently (limited) available kinetic data for PAF rock and extrapolated forward using liner trend analysis – the resulted in arsenic concentrations in the leach exceeding the stock watering value at week 52. It is understood the PAF rock would be left unmanaged for longer than this during life of mine (~3 – 4 years) and so further oxidation of sulfidic materials could likely occur, leading to a higher leach concentration of arsenic (and other metals) as the pH of the leach continues to decreases.

6. The lowest predicted arsenic concentration at week 52 was 0.8 mg/L using an un-forced intercept linear trend (calculation BE1B). This concentration exceeds the stock criterion of 0.5 mg/L but is generally in line with current pit lake water (0.76 mg/L).

7. Where forcing the intercept through zero, the arsenic concentration at 52 weeks is 1.5 mg/L, which is three times the stock watering criterion and double the current lake concentration.

8. A cumulative scaling factor (CSF) was adopted for consideration from literature, and this reduces the predicted rates and leach concentrations, though scaling factors that are not site specific are problematic. The CSF reduced the week 52 predicted concentration to 0.6 mg/L (~lake concentration) and 0.5 mg/L when mixed with lake water (also within stock criterion).

9. Bulk scaling assessed, which is a rather blunt assessment that may overpredict concentrations associated with the total mass of rock. These resulting leach concentrations (accounting for 2 million tonne of PAF rock) adjusted for a literature based CSF would be predicted to yield an arsenic concentration ~3 – 4 times the current Lake water and result in a lake water arsenic concentration ~3 times the stock watering criterion for arsenic.

10. It is possible that arsenic may bind with available ferric oxyhydroxides (FeOH) and therefore have colloidal behaviour. This may result in the arsenic becoming enriched in sediment rather than water column over time – Appendix C shows oversaturation of several Fe phases. Further partition and speciation modelling should be undertaken on receipt of further kinetic data.

11. With respect to contribution of pit wall rock, the calculations set out on Section 5.2 necessarily make several assumptions around rock mass, water contact, loading rates etc and do not carry a low CSF. A factor of 0.4 was used as explained in section 6.1.3. As also explained, the proportion of exposed PAF rock is subject to water table level, and so the cumulative loading figure to the Lake will likely be less than that displayed. In addition, concomitant submergence of neutral (NAF) sections of pit wall will make available some of the remaining carbonate mineral acid neutralising capacity (ANC) to the pit lake, providing a subaqueous source of alkalinity. Unlike submerged loading of other parameters, alkalinity will not be stored in oxides that accumulate on the pit wall. The amount of alkalinity contained in carbonate minerals on the pit wall that is available on the submerged sections of the pit wall depends on the quantity consumed to buffer acid generation while subaerially exposed. Using the CSF adjusted loading, and ignoring water level, the pit walls are considered to contribute around 2.5 mg/L of arsenic cumulatively, or around 2.6 mg/L per m^2 of PAF exposed rock. This would be diluted in 'full' pit lake though evaporation and limited migration over time would overall increase the residual arsenic concentration. Note that the current pit lake arsenic concentration is higher than groundwater, possibly as a result of current or previous loading of arsenic from exposed fractured pit wall rock.

12. Assuming ~81.2% of the surface area is NAF rock (3.6 mega tonne), then assuming a 2000 ML lake the resulting concentration (ignoring groundwater, which is an average alkalinity of 163 mg/L (Table 4-2 Groundwater chemistry summary), then resulting alkalinity from wall rock could be ~30 mg/L (Appendix B), for a cumulative of close to 200 mg/L. Assuming a total mass of acidity as mg/L $CaCO_3$ is 6.89 x 10^{10} (Appendix A), divided by lake volume of 2000 ML, this would result in an acidity of ~34 mg/L $CaCO_3$. Therefore depending on groundwater throughflow and NAF rock kinetics, alkalinity (based on data to date) would appear to be buffered to around 15 – 160 mg/L, which is around the current alkalinity (assuming some PAF from previous mining has influenced the water chemistry to a similar degree).

13. Using sample 21363 net acid producing potential of 12 kg H_2SO_4 per tonne of rock, this would equate to 0.24 kg of H^+ per tonne of rock, or a total of 480 tonne of acidity (as H^+) for 2 million tonne of PAF rock. Total S in the same sample is given as 6,700 mg/kg. Harries et al., 1981

report a median weathering rate of 0.26 g S per kg rock per year (mixed rock ~3wt% Rum Jungle NT). Using the Total S concentration, this would assume an exhaustion of S oxidation in 25 years.

14. Given the short term status of the kinetic data and absence of other useful testing data such as oxygen consumption tests, there is considerable uncertainty in the magnitude of predicted concentrations of key parameters. Current (kinetic) and other lines of evidence (oxygen consumption) should be revisited where / when more data points are collected/ considered.

15. The interim storage (no management) of PAF rock may lead to notable generation of acidity and mobile metals/ metalloids during life of mine – when the pit is allowed to flood and contacts the PAF rock, this may cause a 'super' flush of acidity and metals/ metalloids to groundwater where lake water flows outwards from the pit.

16. Where the proposed partial submergence of PAF rock is adopted, generation of acidity and mobile metals/ metalloids may occur in the portion of rock that is not submerged beneath the lake water level, leading to ongoing flushing events to the pit lake water. Inputs from the aerial portion of the waste pile may provide solutes which will increase the rate of oxidation of the submerged portion of that waste pile and other submerged pods.

17. The proposed PAF rock management approach is not a standard best practise approach, as reactive rock should be entirely submerged to prevent ongoing oxidation of sulfidic materials. And also should be managed in the interim (life of mine) prior to final disposal.

18. The proposed PAF rock management strategy should, accounting for the above, be reconsidered.

Please note the statement of limitations as Appendix B.

8 RECOMMENDATIONS

We provide the following recommendations:

1. Continue current kinetic testing and revise leach quality predictions when more data is available (i.e. >week 28).
2. Update and revise speciation and colloidal arsenic behaviour on receipt of the further kinetic data, to assess potential partition to sediment over time as lake volume progresses.
3. Consider oxygen consumption tests on PAF and PAF-LC rock to assess:
    a. Annual rate of acidity generation (per kg, per m^2 and wt% FeS_2 – depending on material)
    b. The reactive lifetime of the material
    c. Timing and magnitude of peak acidity
    d. Rate of ANC consumption
    e. 'Lag time' or onset to acid conditions

    Oxygen consumption tests can be used to directly measure the sulfide oxidation rate of a material, supplementing yet overcoming the limitations of column leach and humidity cell tests (note that these are tests have not been approved for use by any regulator):

    a. OxCon Rapid Oxygen Consumption Cell Test:
        i. Determination of intrinsic sulfide oxidation rate, reactive lifetime of materials and the rate of ANC consumption under simulated site conditions.
    b. OxCon Wallrock Oxygen Consumption:
        ii. Determination of intrinsic sulfide oxidation rate, reactive lifetime of materials and the rate of ANC consumption.
        iii. Sulfide oxidation rate as a function of surface area (m^2) under simulated site conditions.
4. Formulation of a Site / project specific PAF rock management plan.

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APPENDIX A

Appendix A - Calculations

					Sample Characteristics									Arsenic mg/kg	mg As this sample (assumed)	Rainfall Inflow (L)	rock (tonne)	Average leach test vol.	*Arsenic kg/tonne*
					Sulphur	ANC	NAPP	$NAG_{4.5}$	$NAG_{7.0}$	NAGpH	Weight	Start	Sample						
		Rate	*per week*	*per month*	%S	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t		g	Date	Code	500	1001	1.00E+09	2.00E+06	*503*	*4*
BE1A	*Acidity*	*mg/kg/wk*	*0.0019*	*0.01*	0.67	9	12	4	10	3.3	2001	09/01/21	FH/21363			8.33E+07		*0.503*	
	Arsenic	*mg/kg/wk*	*0.0072*	*0.03*			2.30E+07						kg per tonne	*0.500*		*(monthly)*			
BE1A	*Alkalinity*	*mg/kg/wk*	*4.28*	*17.13*															
BE2A	*Alkalinity*	*mg/kg/wk*	*7.81*	*31.22*			368 mol per tonne						*% above wat*	*0*	*#REF!*				

Calculation Code	Parameters			Week														Cumulative
				0	4	8	12	16	20	24	28	32	36	40	44	48	52	
				12-Jul-21	9-Aug-21	6-Sep-21	5-Oct-21											
				21363-Initial	**21363-1**	**21363-2**	**21363-3**	**21363-4**	**21363-5**	**21363-6**	**21363-7**	**21363-8**	**21363-9**	**21363-10**	**21363-11**	**21363-12**	**21363-13**	
	Volume		ml	463	522	512	516											
	Volume		L	0.463	0.522	0.512	0.516											
	pH		-	5.9	5.9	5.1	4.8											
	EC		dS/m	0.816	0.74	0.62	0.43											
	Rate			-	2.5	2.6	7.4	8.7	10.8	13.0	15.2	17.3	19.5	21.6	23.8	26.0	28.1	15
BE1A - Acidity	Acidity	Extrapolation using 0 intercept	mg/l	29	20	21	59	69	86	103	120	138	155	172	189	206	224	1591
BE1B - Acidity		Extrapolation using un-forced intercept	mg/l	29	20	21	59	55	64	73	82	91	101	110	119	128	137	1089
BE1A - Acidity			mg in solution given volume	14.6	10.1	10.6	29.7	34.6	43.3	52.0	60.6	69.3	77.9	86.6	95.3	103.9	112.6	801
BE1B - Acidity			mg in solution given volume	14.6	10.1	10.6	29.7	27.7	32.3	36.9	41.4	46.0	50.6	55.2	59.8	64.3	68.9	548
BE1A - Acidity			mg per kg sample	7.3	5.0	5.3	14.8	17.3	21.6	26.0	30.3	34.6	38.9	43.3	47.6	51.9	56.3	400
BE1B - Acidity			mg per kg sample	7.3	5.0	5.3	14.8	13.8	16.1	18.4	20.7	23.0	25.3	27.6	29.9	32.2	34.4	274
BE1A - Acidity			mg per tonne of rock	7297	5032	5284	14845	17311	21639	25966	30294	34622	38949	43277	47605	51933	56260	400314
BE1B - Acidity			mg per tonne of rock	7297	5032	5284	14845	13839	16128	18418	20708	22997	25287	27577	29866	32156	34446	273879
BE2A - Acidity			mg total (2 million tonne)	1.46E+10	1.01E+10	1.06E+10	2.97E+10	3.46E+10	4.33E+10	5.19E+10	6.06E+10	6.92E+10	7.79E+10	8.66E+10	9.52E+10	1.04E+11	1.13E+11	800628410795
BE2B - Acidity			mg total (2 million tonne)	1.46E+10	1.01E+10	1.06E+10	**2.97E+10**	2.77E+10	3.23E+10	3.68E+10	4.14E+10	4.60E+10	5.06E+10	5.52E+10	5.97E+10	6.43E+10	6.89E+10	547758658171
BE2A - Acidity		Assuming 2 million tonne rock and 1000 ML rain	**mg/L**	1.75E+02	1.21E+02	1.27E+02	3.56E+02	4.15E+02	5.19E+02	6.23E+02	7.27E+02	8.31E+02	9.35E+02	1.04E+03	1.14E+03	1.25E+03	1.35E+03	**9608**
BE2B - Acidity		Assuming 2 million tonne rock and 1000 ML rain	**mg/L**	1.75E+02	1.21E+02	1.27E+02	3.56E+02	3.32E+02	3.87E+02	4.42E+02	4.97E+02	5.52E+02	6.07E+02	6.62E+02	7.17E+02	7.72E+02	8.27E+02	**6573**
BE1A - Arsenic	As	Extrapolation using 0 intercept	mg/l	0.188	0.142	0.296	0.300	0.47	0.58	0.70	0.82	0.93	1.05	1.17	1.28	1.40	1.52	**11**
BE1B - Arsenic		Extrapolation using un-forced intercept	mg/l	0.188	0.142	0.296	0.300	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	**7**
BE1A - Arsenic			mg in solution given volume	0.095	0.071	0.149	0.151	0.235	0.294	0.353	0.412	0.470	0.529	0.588	0.647	0.706	0.764	**5**
BE1A - Arsenic			mg per kg of sample	0.047	0.036	0.074	0.075	0.118	0.147	0.176	0.206	0.235	0.264	0.294	0.323	0.353	0.382	**3**
BE1A - Arsenic			mg per tonne of rock	47	36	74	75	118	147	176	206	235	264	294	323	353	382	**2731**
BE1B - Arsenic			mg per tonne of rock	47	36	74	75	89	102	114	126	139	151	164	176	188	201	**1683**
BE2A - Arsenic			mg total (2 million tonne)	9.46E+07	7.15E+07	1.49E+08	1.51E+08	2.35E+08	2.94E+08	3.53E+08	4.11E+08	4.70E+08	5.29E+08	5.88E+08	6.47E+08	7.05E+08	7.64E+08	**5461986657**
BE2B - Arsenic			mg total (2 million tonne)	9.46E+07	7.15E+07	1.49E+08	1.51E+08	1.79E+08	2.03E+08	2.28E+08	2.53E+08	2.78E+08	3.02E+08	3.27E+08	3.52E+08	3.77E+08	4.01E+08	**3365558021**
BE2A - Arsenic		Assuming 2 million tonne rock and 1000 ML rain	mg/L	1.14	0.86	1.79	1.81	2.82	3.53	4.23	4.94	5.64	6.35	7.05	7.76	8.46	9.17	**66**
BE2B - Arsenic		Assuming 2 million tonne rock and 1000 ML rain	mg/L	1.14	0.86	1.79	1.81	2.14	2.44	2.74	3.03	3.33	3.63	3.93	4.22	4.52	4.82	**40**
		Ca	mg/l	31	22	16	15	15	15	15	15	15	15	15	15	15	15	
		Cl	mg/l	13	4	2	1	1	1	1	1	1	1	1	1	1	1	
		Cu	mg/l	0.325	0.202	0.350	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	
		Fe	mg/l	0.24	0.08	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.3	0.30	0.30	0.30	0.30	
		K	mg/l	25	17	13	14	14	14	14	14	14	14	14	14	14	14	
		Mg	mg/l	88	73	42	27	27	27	27	27	27	27	27	27	27	27	
		Mn	mg/l	2.37	6.84	5.26	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	
		Na	mg/l	16	8	5	4	4	4	4	4	4	4	4	4	4	4	
		Ni	mg/l	0.61	0.35	0.35	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	
		Si	mg/l	1.4	2.7	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	
		SO_4	mg/l	448	327	209	131	131	131	131	131	131	131	131	131	131	131	
		Zn	mg/l	1.01	0.50	0.64	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	

APPENDIX B

Appendix B - Alkalinity Calculations

Table 1: Leach column test results: Fountain Head NAF Waste

Sample Characteristics								
Sulphur	ANC	NAPP	$NAG_{4.5}$	$NAG_{7.0}$	NAGpH	Weight	Start	Sample
%S	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t		g	Date	Code
0.07	6	-4	0	2	5.9	2000	09/07/21	FH/21365

Parameters		Week									
		0	4	8	12	16	20	24	28	32	36
		12-Jul-21	9-Aug-21	6-Sep-21	5-Oct-21						
		21365-Initial	**21365-1**	**21365-2**	**21365-3**	**21365-4**	**21365-5**	**21365-6**	**21365-7**	**21365-8**	**21365-9**
Volume	L	0.35	0.65	0.75	0.75						
pH	-	7.8	8.0	7.9	8.0						
EC	dS/m	0.339	0.15	0.13	0.14						
Alkalinity	mg/l	99	84	92	97						
	Lake Volume	2.00E+09	2.00E+09	2.00E+09	2.00E+09						
	Lake Alkalinity	1.40E+02									
BE1A	mg in solution given volume	34	55	69	73						
BE1A	mg per kg sample	17	27	34	36						
BE1A	mg per tonne of rock	17,118	27,286	34,483	36,357						
	Tonne of rock per 1m2	15.2	15.2	15.2	15.2						
	Area of wall rock (m2)	295,549	295,549	295,549	295,549						
	m2 of NAF rock	239,986	239,986	239,986	239,986						
	tonnes of NAF rock in the pit wall	3,647,784	3,647,784	3,647,784	3,647,784						
BE2A	mg total for pit wall	6.24E+10	5.46E+10	6.90E+10	7.27E+10						
	kg	6.24E+04	5.46E+04	6.90E+04	7.27E+04						
	mg/L	31.22	27.29	34.48	36.36						
Cumulative	mg/l	1.71E+02	2.73E+01	3.45E+01	3.64E+01						

APPENDIX C

SpecE8_output_GSS_Predicted 21363-13 Week 52

Temperature = 25.0 C Pressure = 1.013 bars
pH = 4.800

Ionic strength	=	0.006160
Activity of water	=	0.999999
Solvent mass	=	1.0000 kg
Solution mass	=	1.0002 kg
Mineral mass	=	0.00000 kg
Solution density	=	1.013 g/cm3
Solution viscosity	=	0.009 poise
Chlorinity	=	0.000028 molal
Dissolved solids	=	240 mg/kg sol'n
Elect. conductivity	=	389.73 uS/cm (or umho/cm)
Hardness	=	146.75 mg/kg sol'n as CaCO3
carbonate	=	0.00 mg/kg sol'n as CaCO3
non-carbonate	=	146.75 mg/kg sol'n as CaCO3
Carbonate alkalinity	=	0.00 mg/kg sol'n as CaCO3
Water type	=	Mg-SO4
Bulk volume	=	987. cm3
Fluid volume	=	987. cm3
Mineral volume	=	0.000 cm3
Inert volume	=	0.000 cm3
Porosity	=	100. %
Permeability	=	98.7 cm2

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
SO4--	0.001595	153.2	0.7167	-2.9418
Mg++	0.0009602	23.33	0.7374	-3.1499
K+	0.0003507	13.71	0.9187	-3.4919
Ca++	0.0003148	12.62	0.7274	-3.6401
Na+	0.0001708	3.927	0.9205	-3.8034
MgSO4	0.0001367	16.45	1.0000	-3.8642
CaSO4	5.470e-05	7.444	1.0000	-4.2620
Mn++	4.955e-05	2.722	0.7274	-4.4431
Cl-	2.779e-05	0.9851	0.9187	-4.5929
As(OH)3	2.003e-05	2.522	1.0000	-4.6983
H+	1.707e-05	0.01720	0.9286	-4.8000
Cu++	1.076e-05	0.6836	0.7274	-5.1064
MnSO4	7.966e-06	1.203	1.0000	-5.0988
Fe(OH)2+	4.871e-06	0.4376	0.9205	-5.3483
Ni++	4.556e-06	0.2674	0.7274	-5.4796
KSO4-	2.850e-06	0.3851	0.9205	-5.5812
HSO4-	1.937e-06	0.1880	0.9205	-5.7488
CO2(aq)	1.571e-06	0.06914	1.0000	-5.8037
NaSO4-	9.651e-07	0.1149	0.9205	-6.0514

NiSO4	4.893e-07	0.07572	1.0000	-6.3104
FeOH++	2.968e-07	0.02162	0.7222	-6.6688
Fe(OH)3	1.266e-07	0.01353	1.0000	-6.8974
CuOH+	1.174e-07	0.009453	0.9205	-6.9664
HCO3-	4.633e-08	0.002826	0.9214	-7.3697
CaCl+	3.184e-08	0.002404	0.9205	-7.5330
MgCl+	2.776e-08	0.001659	0.9205	-7.5925
Zn++	9.226e-09	0.0006031	0.7274	-8.1732
FeSO4+	8.434e-09	0.001281	0.9205	-8.1099
ZnSO4	1.799e-09	0.0002903	1.0000	-8.7450
Fe+++	1.029e-09	5.744e-05	0.5108	-9.2794
As(OH)4-	8.036e-10	0.0001148	0.9205	-9.1310
OH-	7.073e-10	1.203e-05	0.9196	-9.1868
MnCl+	6.339e-10	5.728e-05	0.9205	-9.2340
MgHCO3+	3.361e-10	2.867e-05	0.9205	-9.5095
CuCl+	2.222e-10	2.199e-05	0.9205	-9.6893
KCl	2.126e-10	1.585e-05	1.0000	-9.6724
Fe(SO4)2-	1.812e-10	4.491e-05	0.9205	-9.7779
CaHCO3+	1.767e-10	1.786e-05	0.9226	-9.7878
NaCl	1.010e-10	5.901e-06	1.0000	-9.9957
MgOH+	7.857e-11	3.245e-06	0.9205	-10.1407
MnOH+	6.370e-11	4.582e-06	0.9205	-10.2318
CuSO4	4.918e-11	7.847e-06	1.0000	-10.3082
NiOH+	4.904e-11	3.712e-06	0.9205	-10.3455
MnHCO3+	3.088e-11	3.580e-06	0.9205	-10.5462
NaHCO3	9.035e-12	7.588e-07	1.0000	-11.0441
Fe2(OH)2++++	3.887e-12	5.662e-07	0.3177	-11.9083
CaOH+	3.215e-12	1.835e-07	0.9205	-11.5288
Fe(OH)4-	2.045e-12	2.533e-07	0.9205	-11.7252
FeCl++	5.609e-13	5.120e-08	0.7222	-12.3924
ZnCl+	5.011e-13	5.051e-08	0.9205	-12.3361
FeCO3+	3.645e-13	4.222e-08	0.9205	-12.4743
CO3--	1.696e-13	1.017e-08	0.7195	-12.9136
MgCO3	7.142e-14	6.020e-09	1.0000	-13.1462
FeHSO4++	6.654e-14	1.017e-08	0.7222	-13.3182
KOH	6.652e-14	3.731e-09	1.0000	-13.1771
NaOH	6.420e-14	2.567e-09	1.0000	-13.1925
CaCO3	4.594e-14	4.597e-09	1.0000	-13.3378
MnCl2	4.206e-14	5.292e-09	1.0000	-13.3761
H2SO4	2.792e-14	2.738e-09	1.0000	-13.5540
MnCO3	1.451e-14	1.667e-09	1.0000	-13.8383
Fe3(OH)4(5+)	6.928e-15	1.632e-09	0.1666	-14.9376
Mn2OH+++	4.536e-15	5.754e-10	0.5036	-14.6413
Mg2OH+++	2.710e-15	1.778e-10	0.5036	-14.8650
CuCl2	1.042e-15	1.400e-10	1.0000	-14.9822
AsO2OH--	6.330e-16	7.843e-11	0.7167	-15.3433
Ni(OH)2	3.510e-16	3.254e-11	1.0000	-15.4547
HCl	3.214e-16	1.172e-11	1.0000	-15.4929

Mg2CO3++	2.442e-16	2.651e-11	0.7222	-15.7537
NaCO3-	6.657e-17	5.524e-12	0.9205	-16.2127
FeCl2+	5.021e-17	6.363e-12	0.9205	-16.3352
Ni2OH+++	2.760e-17	3.709e-12	0.5036	-16.8570
ZnCl2	1.782e-17	2.428e-12	1.0000	-16.7490
Mn(OH)2	9.134e-18	8.123e-13	1.0000	-17.0393
Mn2(OH)3+	4.512e-19	7.258e-14	0.9205	-18.3816
MnCl3-	3.154e-19	5.086e-14	0.9205	-18.5371
CuCl3-	7.258e-22	1.233e-16	0.9205	-21.1751
ZnCl3-	4.112e-22	7.060e-17	0.9205	-21.4219
FeCl3	1.178e-22	1.911e-17	1.0000	-21.9287
Ni(OH)3-	9.856e-23	1.081e-17	0.9205	-22.0423
Mn(OH)3-	6.007e-25	6.363e-20	0.9205	-24.2573
ZnCl4--	6.307e-27	1.306e-21	0.7167	-26.3449
CuCl4--	1.193e-28	2.449e-23	0.7167	-28.0681
FeCl4-	3.933e-29	7.771e-24	0.9205	-28.4413
Ni(OH)4--	7.487e-31	9.486e-26	0.7167	-30.2704
Ni4(OH)4++++	2.010e-31	6.087e-26	0.3177	-31.1947
Mg4(OH)4++++	2.808e-33	4.639e-28	0.3177	-33.0496
Mn(OH)4--	4.069e-34	5.003e-29	0.7167	-33.5351

Mineral saturation states

	log Q/K		log Q/K
Hematite	10.1979s/sat	Kainite	-14.0687
NiFe2O4	4.6415s/sat	Bloedite	-14.3769
Goethite	4.6207s/sat	Dolomite-ord	-14.4501
Ferrite-Cu	4.4693s/sat	Dolomite	-14.4501
Jarosite-K	0.4751s/sat	Dolomite-dis	-15.9945
Fe(OH)3(ppd)	0.2316s/sat	MnCl2^4H2O	-16.3440
Ferrite-Zn	0.0099s/sat	Ca(OH)2(c)	-16.6175
Gypsum	-2.1386	Portlandite	-16.6175
Anhydrite	-2.3167	Bischofite	-16.8648
Bassanite	-2.9456	Antarcticite	-16.9388
CaSO4^1/2H2O(bet	-3.1142	MnCl2^2H2O	-17.6106
Tenorite	-3.1790	CaCl2^4H2O	-17.7180
Jarosite-Na	-3.8539	NiCl2^6H2O	-17.8268
Epsomite	-4.2791	NiCl2^4H2O	-18.5172
Ferrite-Mg	-4.4232	NiCl2^2H2O	-18.5964
Hexahydrite	-4.5158	MgOHCl	-18.9902
Pentahydrite	-4.8566	MnCl2^H2O	-19.1601
Leonhardtite	-5.2451	Artinite	-19.2045
Ferrite-Ca	-5.3488	MgCl2^4H2O	-19.7931
Kieserite	-5.9818	Azurite	-20.0698
NiSO4^7H2O	-6.4137	KNaCO3^6H2O	-20.1875
NiSO4^6H2O	-6.4211	CaCl2^2H2O	-20.9222
Rhodochrosite	-6.7724	CaCl2^H2O	-21.0570
Claudetite	-7.8456	Na3H(SO4)2	-21.3022

Calcite	-7.9228	Scacchite	-22.4028
Arsenolite	-7.9760	Mg2Cl(OH)3^4H2O	-22.6016
Aragonite	-8.0877	K2CO3^3/2H2O	-23.0264
Magnesite	-8.1561	NiCl2	-23.2772
Arcanite	-8.2367	Hydrophilite	-24.6447
NiO	-8.3308	Carnallite	-24.8785
Ni(OH)2(s)	-8.6614	MgCl2^2H2O	-25.2304
Monohydrocalcite	-8.9167	Lime	-26.7341
Sylvite	-9.0443	Gaylussite	-27.6149
Malachite	-9.1554	Pirssonite	-27.7776
Mirabilite	-9.4572	Fe2(SO4)3(c)	-28.1972
Mercallite	-9.8586	MgCl2^H2O	-28.5830
Brucite	-9.9887	Ca2Cl2(OH)2^H2O	-33.2044
Halite	-9.9891	Huntite	-34.1237
MnSO4(c)	-10.0568	Chloromagnesite	-34.3399
Mn(OH)2(am)	-10.1420	KMgCl3^2H2O	-34.5634
Thenardite	-10.3126	Ferrite-2-Ca	-34.6278
Nesquehonite	-10.8548	Molysite	-36.5378
MgSO4(c)	-11.1134	Burkeite	-40.9270
Kalicinite	-11.1936	KMgCl3	-41.8696
Smithsonite	-11.1974	Hydromagnesite	-47.9885
NiCO3	-11.5537	Tachyhydrite	-54.9418
MHSH(Mg1.5)	-12.0327	Ca4Cl2(OH)6^13H2	-63.3528
Manganosite	-12.7690	Misenite	-66.7470
NiSO4(s)	-13.7553	K8H4(CO3)6^3H2O	-90.6455
NaFeO2(c)	-13.7613		

Gases	fugacity	log fug.
Steam	0.03131	-1.504
CO2(g)	4.454e-05	-4.351

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
As(OH)4-	2.00e-05	2.00e-05	2.86			
Ca++	0.000370	0.000370	14.8			
Cl-	2.79e-05	2.79e-05	0.987			
Cu++	1.09e-05	1.09e-05	0.691			
Fe+++	5.30e-06	5.30e-06	0.296			
H+	3.01e-05	3.01e-05	0.0303			
H2O	55.5	55.5	1.00e+06			
HCO3-	1.62e-06	1.62e-06	0.0987			
K+	0.000354	0.000354	13.8			
Mg++	0.00110	0.00110	26.7			
Mn++	5.75e-05	5.75e-05	3.16			
Na+	0.000172	0.000172	3.95			
Ni++	5.05e-06	5.05e-06	0.296			

SO4--	0.00180	0.00180	173.
Zn++	1.10e-08	1.10e-08	0.000721

Elemental composition	In fluid			Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Arsenic	2.003e-05	2.003e-05	1.501		
Calcium	0.0003696	0.0003696	14.81		
Carbon	1.618e-06	1.618e-06	0.01943		
Chlorine	2.785e-05	2.785e-05	0.9872		
Copper	1.088e-05	1.088e-05	0.6911		
Hydrogen	111.0	111.0	1.119e+05		
Iron	5.305e-06	5.305e-06	0.2962		
Magnesium	0.001097	0.001097	26.66		
Manganese	5.752e-05	5.752e-05	3.159		
Nickel	5.046e-06	5.046e-06	0.2962		
Oxygen	55.52	55.52	8.880e+05		
Potassium	0.0003536	0.0003536	13.82		
Sodium	0.0001718	0.0001718	3.949		
Sulfur	0.001801	0.001801	57.72		
Zinc	1.103e-08	1.103e-08	0.0007207		

SpecE8_output_GSS_Pit Lake 26 March 2020

Temperature = 25.0 C Pressure = 1.013 bars
pH = 8.430

Ionic strength	=	0.005602	
Charge imbalance	=	0.000246	eq/kg (3.274% error)
Activity of water	=	0.999994	
Solvent mass	=	1.0000	kg
Solution mass	=	1.0003	kg
Mineral mass	=	0.00000	kg
Solution density	=	1.013	g/cm3
Solution viscosity	=	0.009	poise
Chlorinity	=	0.000167	molal
Dissolved solids	=	280	mg/kg sol'n
Elect. conductivity	=	377.38	uS/cm (or umho/cm)
Hardness	=	134.42	mg/kg sol'n as CaCO3
carbonate	=	116.63	mg/kg sol'n as CaCO3
non-carbonate	=	17.79	mg/kg sol'n as CaCO3
Carbonate alkalinity	=	116.63	mg/kg sol'n as CaCO3
Water type	=	Mg-HCO3	
Bulk volume	=	987.	cm3
Fluid volume	=	987.	cm3
Mineral volume	=	0.000	cm3
Inert volume	=	0.000	cm3
Porosity	=	100.	%
Permeability	=	98.7	cm2

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.002214	135.0	0.9245	-2.6890
Na+	0.001368	31.44	0.9237	-2.8984
Mg++	0.001010	24.53	0.7462	-3.1231
SO4--	0.0005864	56.31	0.7268	-3.3704
Ca++	0.0002193	8.786	0.7368	-3.7916
Cl-	0.0001668	5.912	0.9220	-3.8131
MgSO4	5.421e-05	6.523	1.0000	-4.2659
CO3--	3.421e-05	2.052	0.7294	-4.6029
K+	2.518e-05	0.9842	0.9220	-4.6342
CO2(aq)	1.766e-05	0.7770	1.0000	-4.7530
MgHCO3+	1.708e-05	1.457	0.9237	-4.8019
MgCO3	1.554e-05	1.310	1.0000	-4.8086
CaSO4	1.438e-05	1.958	1.0000	-4.8421
As(OH)3	8.542e-06	1.076	1.0000	-5.0684
CaCO3	6.628e-06	0.6632	1.0000	-5.1786
CaHCO3+	5.956e-06	0.6019	0.9256	-5.2586
NaHCO3	3.480e-06	0.2923	1.0000	-5.4584
OH-	3.006e-06	0.05112	0.9229	-5.5568

NaSO4-	2.881e-06	0.3429	0.9237	-5.5750
As(OH)4-	1.457e-06	0.2082	0.9237	-5.8711
Fe(OH)3	8.204e-07	0.08765	1.0000	-6.0860
MgOH+	3.553e-07	0.01467	0.9237	-6.4839
MgCl+	1.773e-07	0.01059	0.9237	-6.7858
CaCl+	1.348e-07	0.01018	0.9237	-6.9047
NaCO3-	1.090e-07	0.009046	0.9237	-6.9970
KSO4-	7.627e-08	0.01031	0.9237	-7.1521
Zn++	7.032e-08	0.004596	0.7368	-7.2855
Fe(OH)4-	5.632e-08	0.006975	0.9237	-7.2838
Mg2CO3++	5.575e-08	0.006054	0.7319	-7.3893
Mn++	1.553e-08	0.0008532	0.7368	-7.9413
Ni++	1.546e-08	0.0009071	0.7368	-7.9436
CuOH+	1.522e-08	0.001225	0.9237	-7.8522
CaOH+	9.641e-09	0.0005502	0.9237	-8.0503
Fe(OH)2+	7.372e-09	0.0006623	0.9237	-8.1669
ZnSO4	5.177e-09	0.0008355	1.0000	-8.2859
NaCl	4.888e-09	0.0002856	1.0000	-8.3108
AsO2OH--	4.843e-09	0.0006001	0.7268	-8.4534
H+	3.990e-09	4.020e-06	0.9312	-8.4300
NaOH	2.201e-09	8.799e-05	1.0000	-8.6575
MnSO4	9.429e-10	0.0001423	1.0000	-9.0255
MnCO3	9.422e-10	0.0001083	1.0000	-9.0258
NiOH+	7.162e-10	5.421e-05	0.9237	-9.1795
NiSO4	6.267e-10	9.696e-05	1.0000	-9.2029
MnHCO3+	4.685e-10	5.431e-05	0.9237	-9.3637
Cu++	3.239e-10	2.058e-05	0.7368	-9.6222
HSO4-	1.687e-10	1.637e-05	0.9237	-9.8074
KCl	9.229e-11	6.878e-06	1.0000	-10.0349
MnOH+	8.598e-11	6.184e-06	0.9237	-10.1000
ZnCl+	2.322e-11	2.341e-06	0.9237	-10.6686
Ni(OH)2	2.195e-11	2.034e-06	1.0000	-10.6587
KOH	2.045e-11	1.147e-06	1.0000	-10.6894
Mg2OH+++	1.274e-11	8.356e-07	0.5171	-11.1813
MnCl+	1.208e-12	1.092e-07	0.9237	-11.9523
FeOH++	1.043e-13	7.595e-09	0.7319	-13.1174
Mn(OH)2	5.278e-14	4.693e-09	1.0000	-13.2776
CuCl+	4.067e-14	4.025e-09	0.9237	-13.4252
Ni(OH)3-	2.619e-14	2.874e-09	0.9237	-13.6163
FeCO3+	6.199e-15	7.180e-10	0.9237	-14.2422
ZnCl2	4.993e-15	6.803e-10	1.0000	-14.3017
Mn2(OH)3+	3.519e-15	5.661e-10	0.9237	-14.4880
CuSO4	5.590e-16	8.920e-11	1.0000	-15.2526
MnCl2	4.847e-16	6.098e-11	1.0000	-15.3146
Mn(OH)3-	1.475e-17	1.563e-12	0.9237	-16.8656
Mn2OH+++	1.900e-18	2.410e-13	0.5171	-18.0077
Ni2OH+++	1.353e-18	1.819e-13	0.5171	-18.1550
CuCl2	1.153e-18	1.549e-13	1.0000	-17.9383

Mg4(OH)4++++	1.142e-18	1.886e-13	0.3313	-18.4222
Ni(OH)4--	8.399e-19	1.064e-13	0.7268	-18.2144
ZnCl3-	6.914e-19	1.187e-13	0.9237	-18.1947
HCl	4.539e-19	1.654e-14	1.0000	-18.3431
FeSO4+	2.615e-19	3.971e-14	0.9237	-18.6171
Fe+++	8.369e-20	4.673e-15	0.5240	-19.3580
MnCl3-	2.182e-20	3.518e-15	0.9237	-19.6957
Fe(SO4)2-	2.094e-21	5.190e-16	0.9237	-20.7135
H2SO4	5.720e-22	5.608e-17	1.0000	-21.2426
FeCl++	2.782e-22	2.540e-17	0.7319	-21.6911
ZnCl4--	6.321e-23	1.309e-17	0.7268	-22.3378
Mn(OH)4--	4.219e-23	5.187e-18	0.7268	-22.5134
CuCl3-	4.821e-24	8.189e-19	0.9237	-23.3513
Fe2(OH)2++++	4.725e-25	6.882e-20	0.3313	-24.8054
FeCl2+	1.515e-25	1.920e-20	0.9237	-24.8540
Ni4(OH)4++++	8.895e-27	2.693e-21	0.3313	-26.5306
FeHSO4++	4.788e-28	7.320e-23	0.7319	-27.4554
CuCl4--	4.723e-30	9.695e-25	0.7268	-29.4644
FeCl3	2.150e-30	3.486e-25	1.0000	-29.6676
Fe3(OH)4(5+)	1.249e-30	2.942e-25	0.1779	-30.6532
FeCl4-	4.306e-36	8.509e-31	0.9237	-35.4004

Mineral saturation states

	log Q/K		log Q/K
Hematite	11.8208s/sat	Pirssonite	-9.4977
NiFe2O4	11.0604s/sat	Ca(OH)2(c)	-9.5091
Ferrite-Zn	9.7804s/sat	Portlandite	-9.5091
Ferrite-Cu	8.8364s/sat	Azurite	-9.7358
Goethite	5.4321s/sat	Jarosite-K	-9.9800
Ferrite-Mg	4.4866s/sat	Mg2Cl(OH)3^4H2O	-10.8781
Ferrite-Ca	3.3826s/sat	Arcanite	-10.9500
Dolomite	2.0466s/sat	MgSO4(c)	-11.5151
Dolomite-ord	2.0466s/sat	KNaCO3^6H2O	-12.1142
Fe(OH)3(ppd)	1.0430s/sat	Jarosite-Na	-12.2616
Dolomite-dis	0.5022s/sat	Bloedite	-13.3972
Calcite	0.2364s/sat	MnSO4(c)	-13.9835
Magnesite	0.1815s/sat	MgOHCl	-14.5535
Aragonite	0.0715s/sat	Kainite	-14.8329
Tenorite	-0.4348	Mercallite	-15.0595
Monohydrocalcite	-0.7575	Bischofite	-15.2783
Huntite	-0.9519	Antarcticite	-15.5306
Rhodochrosite	-1.9599	CaCl2^4H2O	-16.3098
Smithsonite	-1.9990	NiSO4(s)	-16.6478
Nesquehonite	-2.5173	K2CO3^3/2H2O	-17.0004
Malachite	-2.6162	MgCl2^4H2O	-18.2066
Brucite	-2.7019	MnCl2^4H2O	-18.2825
Gypsum	-2.7187	NiCl2^6H2O	-18.7311

Anhydrite	-2.8968	Ferrite-2-Ca	-18.7879
Bassanite	-3.5257	NiCl2^4H2O	-19.4215
NiO	-3.5348	NiCl2^2H2O	-19.5007
Artinite	-3.5801	CaCl2^2H2O	-19.5140
CaSO4^1/2H2O(bet	-3.6943	MnCl2^2H2O	-19.5491
Ni(OH)2(s)	-3.8654	Lime	-19.6256
Epsomite	-4.6809	CaCl2^H2O	-19.6488
Hexahydrite	-4.9176	MnCl2^H2O	-21.0986
Pentahydrite	-5.2584	Na3H(SO4)2	-23.0743
Leonhardtite	-5.6469	Hydrophilite	-23.2365
NiCO3	-5.7069	MgCl2^2H2O	-23.6439
Mn(OH)2(am)	-6.3803	Carnallite	-23.6544
Kieserite	-6.3835	NiCl2	-24.1815
Hydromagnesite	-7.3514	Scacchite	-24.3413
Kalicinite	-7.6552	Ca2Cl2(OH)2^H2O	-24.6877
Mirabilite	-8.0758	MgCl2^H2O	-26.9965
Halite	-8.3042	Burkeite	-28.0434
NaFeO2(c)	-8.4148	Chloromagnesite	-32.7534
Claudetite	-8.5859	KMgCl3^2H2O	-33.3393
Arsenolite	-8.7163	Ca4Cl2(OH)6^13H2	-40.6192
MHSH(Mg1.5)	-8.7910	KMgCl3	-40.6455
Thenardite	-8.9311	Molysite	-44.2767
Manganosite	-9.0072	Fe2(SO4)3(c)	-49.6400
NiSO4^7H2O	-9.3063	Tachyhydrite	-50.3605
NiSO4^6H2O	-9.3137	K8H4(CO3)6^3H2O	-64.4400
Gaylussite	-9.3350	Misenite	-100.6656
Sylvite	-9.4068		

Gases	fugacity	log fug.
Steam	0.03131	-1.504
CO2(g)	0.0005005	-3.301

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
As(OH)4-	1.00e-05	1.00e-05	1.43			
Ca++	0.000246	0.000246	9.87			
Cl-	0.000167	0.000167	5.92			
Cu++	1.55e-08	1.55e-08	0.000987			
Fe+++	8.84e-07	8.84e-07	0.0494			
H+	-3.64e-05	-3.64e-05	-0.0367			
H2O	55.5	55.5	1.00e+06			
HCO3-	0.00231	0.00231	141.			
K+	2.53e-05	2.53e-05	0.987			
Mg++	0.00110	0.00110	26.7			
Mn++	1.80e-08	1.80e-08	0.000987			
Na+	0.00137	0.00137	31.6			

Ni++	1.68e-08	1.68e-08	0.000987
SO4--	0.000658	0.000658	63.2
Zn++	7.55e-08	7.55e-08	0.00494

Elemental composition	In fluid			Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Arsenic	1.000e-05	1.000e-05	0.7493		
Calcium	0.0002464	0.0002464	9.872		
Carbon	0.002314	0.002314	27.79		
Chlorine	0.0001671	0.0001671	5.923		
Copper	1.554e-08	1.554e-08	0.0009872		
Hydrogen	111.0	111.0	1.119e+05		
Iron	8.841e-07	8.841e-07	0.04936		
Magnesium	0.001097	0.001097	26.65		
Manganese	1.797e-08	1.797e-08	0.0009872		
Nickel	1.682e-08	1.682e-08	0.0009872		
Oxygen	55.52	55.52	8.880e+05		
Potassium	2.526e-05	2.526e-05	0.9872		
Sodium	0.001375	0.001375	31.59		
Sulfur	0.0006579	0.0006579	21.09		
Zinc	7.552e-08	7.552e-08	0.004936		

APPENDIX D – STATEMENT OF LIMITATIONS

STATEMENT OF LIMITATIONS & IMPORTANT INFORMATION REGARDING YOUR REPORT

INTRODUCTION

This report has been prepared by Land & Water Consulting for you, as Land & Water Consulting's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice.

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Land & Water Consulting may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Land & Water Consulting has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

No warranty or guarantee of the site conditions is intended.

This report was prepared for the sole use of you, the Client and may not contain sufficient information for purposes of other parties or for other uses. Any reliance on this report by third parties shall be at such parties sole risk. This report shall only be presented in full and may not be used to support any other objectives than those set out in the report, except where written approval with comments are provided by Land & Water Consulting.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

LIMITATIONS OF THE REPORT

The scope of works undertaken and the report prepared to complete the assessment was in accordance with the information provided by the client and the specifications for works required under the contract. As such, works undertaken and statements made are based on those specifications (such as levels of risks and significance of any contamination) and should be considered and interpreted within this context. The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

Your environmental report should not be used without reference to Land & Water Consulting in the first instance:

- When the nature of the proposed development is changed, for example if a residential development is proposed instead of a commercial one;
- When the size or configuration of the proposed development is altered;
- When the location or orientation of the proposed structures are modified;
- When there is a change in ownership;
- For application to an adjacent site.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

ENVIRONMENTAL ASSESSMENT "FINDINGS" ARE PROFESSIONAL ESTIMATES

The information in this report is considered to be accurate with respect to conditions encountered at the site at the time of investigation and considering the inherent limitations associated with extrapolating information from a sample set. Note however that site assessment identifies actual subsurface conditions only at those specific points where samples are taken, when they are taken. Environmental data derived through sampling and analysis are interpreted by consultants who then render an opinion about overall subsurface conditions, the nature and extent of contamination and potential impacts on the use of the land. Actual conditions may differ from those inferred to exist as no professional and no subsurface assessment program can reveal every detail within the ground across a site. Subsurface conditions can vary across a particular site and no practical degree of sampling can ever eliminate the possibility that conditions may be present at a site that have not been represented though sampling.

SUBSURFACE CONDITIONS CAN CHANGE

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Land & Water Consulting should be kept appraised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions. Since subsurface conditions (including contamination concentrations) can change within a limited period of time and space, this inherent limitation to the representation of site conditions provided by this report should always be taken into consideration particularly if the report is used after a delay in time.

DATA SHOULD NOT BE SEPARATED FROM THE REPORT

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

RESPONSIBILITY

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.

Appendix B Goldsim Water Balance Model Parameters

Table 8-1 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: 0.134; A2: 0.433; A3: 0.433; C1: 3; C2: 27; C3: 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						
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: 0.27; Feb: 0.24; Mar: 0.33; Apr: 0.42; May: 0.48; Jun: 0.5; Jul: 0.52; Aug: 0.55; Sep: 0.54; Oct: 0.5; Nov: 0.42; Dec: 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.

Model component / Parameter	unit	Value (median value for Monte Carlo parameter)	Standard Deviation	Minimum value	Maximum value	note
			For the Monte Carlo parameters only			
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.
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 (CDM Smith, 2021)	-	-	-	-
Runoff. AWBM	-	Cf. Table 4-1 (CDM Smith, 2021)	-	-	-	-
Pan to lake	-	0.75	-	-	-	To account for vapour saturation over the lake.

Appendix C Calculated PAF loading rates

Table 1: Leach column test results: Fountain Head PAF Waste

Sample Characteristics														
Sulphur	ANC	NAPP	$NAG_{4.5}$	$NAG_{7.0}$	NAGpH	Weight	Start	Sample	Arsenic mg/kg	mg As this sample (assumed)	Rainfall Inflow (L)	rock (tonne)	Average leach test vol.	*Arsenic kg/tonne*	*Arsenic kg total (4 kg/tonne * 2 million tonne)*
%S	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t	kgH_2SO_4/t		g	Date	Code			1.00E+09	2.00E+06	*503*	*4*	
0.67	9	12	4	10	3.3	2001	09/01/21	FH/21363			8.33E+07		*0.503*		*8000000*
		2.30E+07 kg per 2 milion t									*(monthly) CRUCIAL*				

Calculation Code	Parameters			Week 0	4	8	12	16	20	24	28	32	36	40	44	48	52	Cumulative
				12-Jul-21	9-Aug-21	6-Sep-21	5-Oct-21											
				21363-Initial	**21363-1**	**21363-2**	**21363-3**	**21363-4**	**21363-5**	**21363-6**	**21363-7**	**21363-8**	**21363-9**	**21363-10**	**21363-11**	**21363-12**	**21363-13**	
	Volume		ml	463	522	512	516											
	Volume		L	0.463	0.522	0.512	0.516											
	pH		-	5.9	5.9	5.1	4.8											
	EC		dS/m	0.816	0.74	0.62	0.43											
	Alkalinity		mg/l	-	-	-	-											
BE1A - Acidity	Acidity	Extrapolation using 0 intercept	mg/l	29	20	21	59	69	86	103	120	138	155	172	189	206	224	1591
BE1B - Acidity		Extrapolation using un-forced intercept	mg/l	29	20	21	59	55	64	73	82	91	101	110	119	128	137	1089
BE1A - Acidity			mg in solution given volume	14.6	10.1	10.6	29.7	34.6	43.3	52.0	60.6	69.3	77.9	86.6	95.3	103.9	112.6	801
BE1B - Acidity			mg in solution given volume	14.6	10.1	10.6	29.7	27.7	32.3	36.9	41.4	46.0	50.6	55.2	59.8	64.3	68.9	548
BE1A - Acidity			mg per kg sample	7.3	5.0	5.3	14.8	17.3	21.6	26.0	30.3	34.6	38.9	43.3	47.6	51.9	56.3	400
BE1B - Acidity			mg per kg sample	7.3	5.0	5.3	14.8	13.8	16.1	18.4	20.7	23.0	25.3	27.6	29.9	32.2	34.4	274
BE1A - Acidity			mg per tonne of rock	7297	5032	5284	14845	17311	21639	25966	30294	34622	38949	43277	47605	51933	56260	400314
BE1B - Acidity			mg per tonne of rock	7297	5032	5284	14845	13839	16128	18418	20708	22997	25287	27577	29866	32156	34446	273879
BE2A - Acidity			mg total (2 million tonne)	1.46E+10	1.01E+10	1.06E+10	2.97E+10	3.46E+10	4.33E+10	5.19E+10	6.06E+10	6.92E+10	7.79E+10	8.66E+10	9.52E+10	1.04E+11	1.13E+11	800628410795
BE2B - Acidity			mg total (2 million tonne)	1.46E+10	1.01E+10	1.06E+10	2.97E+10	2.77E+10	3.23E+10	3.68E+10	4.14E+10	4.60E+10	5.06E+10	5.52E+10	5.97E+10	6.43E+10	6.89E+10	547758658171
BE2A - Acidity		Assuming 2 million tonne rock and 1000 ML rain	**mg/L**	1.75E+02	1.21E+02	1.27E+02	3.56E+02	4.15E+02	5.19E+02	6.23E+02	7.27E+02	8.31E+02	9.35E+02	1.04E+03	1.14E+03	1.25E+03	1.35E+03	**9608**
BE2B - Acidity		Assuming 2 million tonne rock and 1000 ML rain	**mg/L**	1.75E+02	1.21E+02	1.27E+02	3.56E+02	3.32E+02	3.87E+02	4.42E+02	4.97E+02	5.52E+02	6.07E+02	6.62E+02	7.17E+02	7.72E+02	8.27E+02	**6573**
BE1A - Arsenic	As	Extrapolation using 0 intercept	mg/l	0.188	0.142	0.296	0.300	0.47	0.58	0.70	0.82	0.93	1.05	1.17	1.28	1.40	1.52	**11**
BE1B - Arsenic		Extrapolation using un-forced interceot	mg/l	0.188	0.142	0.296	0.300	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	**7**
BE1A - Arsenic			mg in solution given volume	0.095	0.071	0.149	0.151	0.235	0.294	0.353	0.412	0.470	0.529	0.588	0.647	0.706	0.764	**5**
BE1A - Arsenic			mg per kg of sample	0.047	0.036	0.074	0.075	0.118	0.147	0.176	0.206	0.235	0.264	0.294	0.323	0.353	0.382	**3**
BE1A - Arsenic			mg per tonne of rock	47	36	74	75	118	147	176	206	235	264	294	323	353	382	**2731**
BE1B - Arsenic			mg per tonne of rock	47	36	74	75	89	102	114	126	139	151	164	176	188	201	**1683**
BE2A - Arsenic			mg total (2 million tonne)	9.46E+07	7.15E+07	1.49E+08	1.51E+08	2.35E+08	2.94E+08	3.53E+08	4.11E+08	4.70E+08	5.29E+08	5.88E+08	6.47E+08	7.05E+08	7.64E+08	**5461986657**
BE2B - Arsenic			mg total (2 million tonne)	9.46E+07	7.15E+07	1.49E+08	1.51E+08	1.79E+08	2.03E+08	2.28E+08	2.53E+08	2.78E+08	3.02E+08	3.27E+08	3.52E+08	3.77E+08	4.01E+08	**3365558021**
BE2A - Arsenic		Assuming 2 million tonne rock and 1000 ML rain	mg/L	1.14	0.86	1.79	1.81	2.82	3.53	4.23	4.94	5.64	6.35	7.05	7.76	8.46	9.17	**66**
BE2B - Arsenic		Assuming 2 million tonne rock and 1000 ML rain	mg/L	1.14	0.86	1.79	1.81	2.14	2.44	2.74	3.03	3.33	3.63	3.93	4.22	4.52	4.82	**40**
	Ca		mg/l	31	22	16	15	15	15	15	15	15	15	15	15	15	15	
	Cl		mg/l	13	4	2	1	1	1	1	1	1	1	1	1	1	1	
	Cu		mg/l	0.325	0.202	0.350	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	0.671	
	Fe		mg/l	0.24	0.08	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.3	0.30	0.30	0.30	0.30	
	K		mg/l	25	17	13	14	14	14	14	14	14	14	14	14	14	14	
	Mg		mg/l	88	73	42	27	27	27	27	27	27	27	27	27	27	27	
	Mn		mg/l	2.37	6.84	5.26	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	
	Na		mg/l	16	8	5	4	4	4	4	4	4	4	4	4	4	4	
	Ni		mg/l	0.61	0.35	0.35	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	
	Si		mg/l	1.4	2.7	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	
	SO_4		mg/l	448	327	209	131	131	131	131	131	131	131	131	131	131	131	
	Zn		mg/l	1.01	0.50	0.64	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	

Loading Rates

Acidity	*Weeks*	*Cumulative mg per tonne per year*	*Cumulative mg for 2 million tonne of rock*	*mg acidity per tonne of rock per week*	*mg acidity total rock per week*	*kg acidity per tonne of rock per week*	*total kg of acidity per week*	*weeks to exhaustion at kg per tonne*	*Years to ex. At kg per tonne*	*weeks to exhaustion at total kg*	*Years to ex. @total kg*
BE1A	*52*	*4.00E+05*		*7.70E+03*		*7.70E-03*		*1494*	*29*		
BE1B	*52*	*2.74E+05*		*5.27E+03*		*5.27E-03*		*2184*	*42*		
BE2A	*52*		*8.01E+11*		*1.54E+10*		*15397*			*1494*	*29*
BE2B	*52*		*5.48E+11*		*1.05E+10*		*10534*			*2184*	*42*

Arsenic	*Weeks*	*Cumulative mg per tonne per year*	*Cumulative mg for 2 million tonne of rock*	*mg As per tonne of rock per week*	*mg As total rock per week per 2 million tonne*	*kg As per tonne of rock per week*	*total kg of As per week*	*weeks to exhaustion at kg per tonne*	*Years to ex. At kg per tonne*	*weeks to exhaustion at total kg*	*Years to ex. @total kg*
BE1A	*52*	*2731*		*5.25E+01*		*5.25E-05*		*7.62E+04*	*1465*		
BE1B	*52*	*1683*		*3.24E+01*		*3.24E-05*		*1.24E+05*	*2377*		
BE2A	*52*		*5.46E+09*		*1.05E+08*		*105*			*76163*	*1465*
BE2B	*52*		*3.37E+09*		*6.47E+07*		*65*			*123605*	*2377*

Long term loading rates - Post 52 weeks

BE2B - Acidity	52	*8.27E+11*	*1.59E+10*	*15898*		*1447*	*28*
BE2B - Arsenic	52	*4.82E+09*	*9.26E+07*	*93*		*86371*	*1661*

	day		Acidity	Arenic
	Day (d)		PAF release [Kg/day]	PAF release [Kg/day]
		1	3	
	0	0	0	0
	272	0	0	0
0	273	0	479.79	3.11
4	301	0	330.89	2.35
8	357	0	347.43	4.90
12	441	0	976.12	4.96
16	553	0	909.94	5.87
20	693	0	1060.49	6.68
24	861	0	1211.04	7.50
28	1057	0	1361.60	8.31
32	1281	0	1512.15	9.13
36	1533	0	1662.71	9.94
40	1813	0	1813.26	10.75
44	2121	0	1963.81	11.57
48	2457	0	2114.37	12.38
52	2821	0	2264.92	13.20
1600	4421	0	2264.92	13.20
99999	104420	0	2264.92	13.20