Macraes Mine Phase 4.3: Environmental Geochemistry Assessment

OceanaGold Macraes Mine Site

28 February 2024

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MINE WASTE MANAGEMENT
GREENROAD GROUP

OCEANAGOLD

Macraes Mine Phase 4.3: Environmental Geochemistry Assessment

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EXECUTIVE SUMMARY

Mine Waste Management Limited (MWM) has prepared this report for OceanaGold Limited (OceanaGold) to provide environmental geochemical support for the Macraes Gold Project (Macraes) Phase 4 (MP4) resource consenting process.

General Background

Macraes is a world-class orogenic gold deposit that has been in operation since 1990. Macraes is located approximately 30 km to the northwest of Palmerston in the Otago Region of the South Island, New Zealand. The ore is a combination of mineralised sheared graphitic schist and associated mineralised quartz veins. The gold is associated with pyrite (FeS_2) and arsenopyrite (FeAsS) within the Hyde-Macraes Shear Zone, which is the gold bearing structure.

Macraes was commissioned in 1990 with the development of open pits and the construction of a gold processing plant and tailings storage facility (TSF). The processing plant capacity has increased since 1990 through continual upgrades and now processes nearly 6 million tonnes of ore per annum. In 1999 an autoclave involving pressure oxidation was installed to treat refractory ore. From 2007 to 2016, additional ore concentrate was imported from the Globe-Progress Mine near Reefton for processing through the processing plant (OceanaGold, 2011). Mining operations continue using open pit methods combined with underground mining that has been operating since 2006.

Geochemical Investigations

The acid base accounting (ABA) data presented here supports previous investigations that waste rock at Macraes is generally non-acid forming, with low sulfide sulfur, and is unlikely to generate acid rock drainage with ANC values being significantly higher than MPA values leading to negative NAPP values. This is supported by circumneutral to alkaline NAG pH values and drainage waters at site that are circum-neutral.

Resource Consent requirements (RM10.351.10.V1 – Compliance Criteria iv) require all waste rock materials to be non-acid forming where the ratio of acid (e.g., the neutralisation potential ratio; NPR) neutralisation capacity (ANC) must be three times the maximum potential acidity (MPA) (i.e., ANC/MPA = 3:1), which provides a factor of safety for the risk associated with acid generation. Although not clarified in the resource consent conditions, it is generally acknowledged that a NPR of >2 is acceptable to account for alkalinity loss and that a NPR of 3 provides a factor of safety. The industry standard classification systems used in this report, as applied to the data (see Appendix E) indicate:

- The AMIRA (2002) classification process using NAG pH and NAPP (Figure 34) noted that 2 samples out of the 70 samples tested as part of this work were classified as uncertain in regards to the potential to generate acid drainage. However, the Price (2009) classification and Resource consent Classification indicated they were non-acid forming (NAF).
- The Price (2009) and Resource Consent conditions indicate 1 sample of ore was classified as uncertain (NPR = 1.13) and 1 sample of waste rock was uncertain (NPR = 1.7).

From an overall AMD hazards assessment perspective these materials, represented by samples that are classified as Uncertain, are unlikely to change the general geochemical nature of the bulk waste rock or the expected water quality for the project. It is recommended this consent condition should be reviewed and that a NPR is overly prescriptive given the low risk for acid rock drainage at the site.

Geochemical testwork and assessment of empirical data from site indicates that the key contaminants of concern for the project are arsenic, nitrogenous compounds (due to ammonium-nitrate-based blasting residues), and sulfate. Some data suggest that on occasion Fe, Zn, and Cu can also be elevated. Such data, supported by ABA results confirm that acid rock drainage is not expected at this site, rather lesser-risk neutral metalliferous drainage is expected, which is currently observed at the site (e.g., circum-neutral drainage elevated in sulfate and some contaminants of concern).

WRS Seepage Water Quality Model

A significant amount of empirical data are available for seepage from waste rock stacks (WRSs) at Macraes. The data was assessed, and a model was developed to forecast future water quality trends for WRS at Macraes based on previous work completed by Babbage (2019, 2022). A key driver for poor water quality was the average height of the WRS, with higher concentrations identified for taller WRS. A relationship was developed (Figure E1), which was used to forecast sulfate concentrations for the expansion of WRS associated with this project. Sulfate concentrations were then used to derive the concentrations of other contaminants to create source terms[1] for forecasting water quality through predictive modelling.

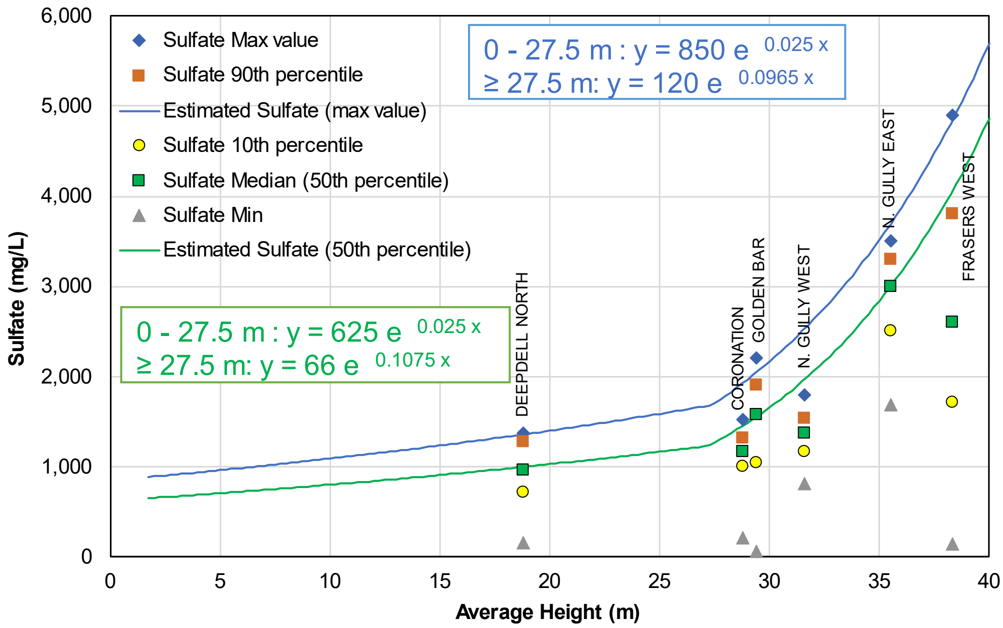

Figure E1: WRS average height versus sulfate concentrations.

Source: MWM (2023) Appendix I.

The relationship provided suitable source terms for WRS seepage for pit lake water quality modelling where the sulfate maximum data were used (blue line in Figure E1), which is considered conservative.

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[1] *Source terms refer to the derived water quality parameters that are used for modelling purposes. In this instance, the sulfate concentration algorithm (Figure E1) was used to develop relationships to other parameters based on empirical data to derive water quality data for modelling purposes (further details are provided in MWM, 2023).*

Median data have been used to compare current water quality trends (e.g., 2023 data) for Coronation WRS (Figure 50) demonstrating median data are a reasonable fit and that maximum data are a conservative approach for modelling.

Pit Lake Water Quality Modelling

Pit lake hydrogeochemical modelling was undertaken to understand the potential effects on groundwater and surface waters including during filling and then with overflow to the surrounding waterways. Source terms were developed for a variety of input to the hydrogeochemical model. These data were obtained from empirical field data and laboratory trials where applicable. Further details are provided in this report. A number of pit lake models were developed including:

- Golden Bar Pit Lake – Stage 1 Analogue Model (current pit lake).
- Golden Bar Stage 2 Pit Lake (proposed).
- Coronation Stage 5/6 Pit Lake (proposed).
- Frasers TSF and Innes Mills pit lakes (FRIM) (proposed).

Results are presented in Table E1 showing the water quality when overflow commences with discharge to nearby streams (noting that FRIM does not discharge).

Key contaminants of concern identified by the modelling processes include arsenic. Flow rates from these mine domains are low for Golden Bar Stage 2 Pit and Coronation Stage 6 Pit (<5 L/s). Modelling for FRIM indicates that it will not spill. Only minor seepage is expected from Coronation North once it is backfilled. Further details are provided by GHD (2024).

Table E1. Pit Lake Water Quality when overflow commences (spilling).

MINE DOMAIN	GOLDEN BAR STAGE 2	CORONATION STAGE 5/6	FRIM
Year post cessation of mining when overflow commences	35[2]	97[3]	No spill (data from Year 290)
Average discharge flow (L/s) to receiving environment when stable	3.3	1.46	-
pH	8.38	8.41	8.06
Dissolved solids	793	1,101	1,815
Alkalinity	182	238	108
Ca	60.9	80	181
Mg	92.7	131	167
Na	20.9	27	71
K	5.6	8	31
Fe	<0.001	<0.001	<0.001
Cl	12.9	14.2	4.7
NO_3-N	0.03	0.0036	0.09
Amm-N	0.00015	0.00005	0.0001
SO_4	373	545	1,209
Mn	0	-	0.05
Zn	0.0073	0.0034	0.0025
As	0.145	0.25	0.04

MINE DOMAIN	GOLDEN BAR STAGE 2	CORONATION STAGE 5/6	FRIM
Sb	0.0033	0.005	0.03
Cyanide	-	-	0.0057
Pb	0.00003	0.00004	0.000008

All units in mg/L except for pH and where indicated.

1. seepage water quality

2. Predicted by GHD (2023a) when discharge of the pit lake to a tributary of the North Branch of the Waikouati River occurs (with stable flow at Year 40).

3. Predicted by GHD (2023b) when the pit lake will discharge though the Trimbells WRS.

Red text indicates parameter values above the reference water quality reference value (see Section 2.6). No hardness modification was conducted.

There is evidence of seasonal stratification occurring in the Golden Bar Pit Lake that is resulting in a slight increase in As at depth from 0.12 to 0.17 mg/L during summer. The same trend was identified at the Globe Pit Lake in Reefton (Hayton, 2020). It is likely other pit lakes at Macraes will also be affected by thermal stratification causing slightly higher concentrations of As at depth in the summer months. Options are available for the management and treatment of As-rich waters if this is required (Section 8) and an appropriate management plan/process should be developed prior to dewatering activities commencing, which could be managed effectively by a Trigger Action Response Plan (TARP).

Engineering – Source Control

Source control technologies include methods to prevent the oxidation of sulfide minerals and methods to minimise the mobilisation of any oxidation products (derived from sulfide mineral oxidation). A key opportunity for the project is to reduce advective ingress into WRSs, which is acknowledged as the dominant transport mechanism for oxygen into a WRS. This can be achieved by

- Minimising the tiphead height to prevent grainsize segregation, which can create a rubble zone / oxygen pathway into the core of the WRS. OceanaGold have indicated this does not occur until the tiphead height is > 10 m.
- Limiting the height of the WRS to limit the sulfate concentration.
- Construction of advective barriers (i.e., a toe berm) to seal the basal rubble zone to prevent advective draw of air into the WRS.
- Progressive rehabilitation and capping of the WRS.

Other options include the management of interburden waste rock. OceanaGold note that interburden waste rock is blasted to create a finer material compared to overburden (to reduce milling costs) and is slightly higher in sulfur compared to overburden). A higher sulfur content and a finer grainsize suggests these materials should be placed in the core of a WRS away from advective oxygen flux.

Other source control options include methods to minimise water ingress and the mobilisation of oxidation products:

- Clean water diversion away from WRS.
- Avoidance of run-on water to a WRS (e.g., up-catchment drainage into a WRS).

- Encouraging clean-water run-off from the WRS surface (rather than ponding).
- Progressive rehabilitation and capping of the WRS.

Such source control technologies are recognised internationally as being appropriate for minimising the effects of sulfide mineral oxidation. These technologies should be integrated into the mine planning process.

Engineering – Management and Treatment of Mine Impacted Waters

There are two general options for the management of mine-impacted waters including management and treatment. Treatment options of mine impacted waters includes passive treatment and active treatment. Management and treatment options are viable for Macraes during the operational and closure phases of the project.

The following options are considered suitable for mine impacted waters at Macraes:

- Water management:
    - pumping to surface storage areas or pumping back to pit lakes;
    - dilution using dilution dams
    - controlled discharge; and
    - injection into underground workings.
- Passive treatment systems:
    - anaerobic systems;
    - enhanced passive treatment systems (E-PTS);
    - zero valent iron; and
    - vertical flow reactors (VFR).
- Active treatment (for arsenic and sulfate):
    - precipitation technologies; and
    - chemical addition.

Adaptive Management

Macraes is a mature operation (30+ years of operation) and the environmental geochemistry risks are well understood. The source hazards are unlikely to be different in the future. For this study, predictive models have been developed to forecast long term water quality from pit lakes and WRSs using empirical and laboratory data. Performance monitoring is required to confirm these models provide reasonable estimates of water quality in the future. Performance monitoring should be part of an adaptive management process.

Adaptive management is also proposed for the management of mine impacted waters associated with seepage from WRSs with a number of proven technologies available. Some new technologies such as enhanced passive treatment are also available but require further investigation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Mine Waste Management Limited (MWM) has prepared this report for OceanaGold Limited (OceanaGold) to provide environmental geochemical support for the Macraes Gold Project (Macraes) Phase 4.3 for the assessment of environmental effects (AEE) for the project. Specifically, MWM have provided advice on the potential acid and metalliferous drainage (AMD) source hazards for the materials that will be disturbed by the project and the effects of these materials on water quality.

1.1 Project Scope

OceanaGold requires environmental geochemistry support for the proposed Life of Mine (LOM) plan through to 2030, which includes open pit extensions and construction of the Frasers TSF. This includes:

- Golden Bar Pit – Stage 2.
- Coronation Pit – Stage 6.
- Backfilling of Coronation North Pit.
- Innes Mills Pit – Stages 7,8,9.
- Frasers TSF.

1.2 Objectives

The objectives of this report are to:

- Quantify the acidity generating and neutralising characteristics and likely geochemical nature of the waste rock associated with the MP4.3 phase of works.
- Determine the seepage water quality from waste rock stacks (WRSs).
- Determine the likely water quality for the following mine domains:
    - Golden Bar Stage 2 Pit Lake.
    - Coronation Stage 6 Pit Lake.
    - Coronation North Backfill seepage.
    - Frasers and Innes Mills Pit Lake (FRIM).
- Undertake a preliminary geochemical source hazard assessment.
- Assess conceptual engineering controls to minimise the potential environmental effects of mine-impacted water associated with the pit voids and WRS.

1.3 Approach

AMD is a general term used to describe waters impacted chemically by mining activities and can contain significant quantities of toxic metals, salts, and acidity. AMD is typically generated by the excavation of rocks that contain sulfide minerals, such as pyrite. When these minerals are exposed to oxygen and water, they undergo weathering processes and oxidise, generating acidity and releasing metals. International best practice guidance is available to manage the potential risks of AMD (e.g., INAP, 2014). Further details on AMD and how to predict AMD are provided in Appendix C.

2 PROJECT BACKGROUND

The following sections summarises relevant background information for the project.

2.1 Climate

The climate at Macraes is controlled predominantly by the Rock and Pillar Mountain ranges to the west of the site. These mountain ranges act as a barrier to incoming weather systems from the west, consequently leading to a fairly dry climate with limited precipitation (GHD, 2021).

OceanaGold record rainfall at three locations at Macraes including the Glendale, Deepdell, and Golden Point stations. Average annual rainfall for Glendale, Deepdell, and Golden Point was 628 mm, 518 mm, and 659 mm respectively (Golder, 2011a). Although recently the average annual rainfall for Glendale was reported as 634 mm (CDM Smith, 2016). Evaporation data are available from the national weather station in Middlemarch. This station is considered to be the most representative for the site, located 30 km south southwest at 200 mRL. Average monthly evaporation data for this station was reported as being 1.5 mm/day (June-July) to 4.75 mm/day (January) (CDM Smith, 2016).

A hydrometeorological water balance model (WBM) is a critical component of any modelling process to understand potential environmental effects of the project on the receiving environment. The WBM was developed by GHD (2024) and flow rates were provided by GHD as required for geochemical modelling purposes.

2.2 Geology

Macraes is a world-class orogenic deposit that has been in operation since 1990. It is hosted within a late metamorphic auriferous shear zone within the metamorphic greenschist facies Otago Schist. Several deformations and major discontinuities have been driven by the structural features; namely the Hyde-Macraes Shear Zone (HMSZ) and the Macraes Fault (GHD, 2021; OceanaGold, 2011). The Macraes Fault has offset the HMSZ by about 250 metres in a reverse sense (OceanaGold, 2011). This deformation has been accompanied by a number of faults, both parallel to foliation and cutting across foliation (OceanaGold, 2011). The mineralisation originally occurred in the brittle-ductile transition zone at about 300°C, creating a 120 m thick hydrothermally altered zone (Weightman et al., 2021); the zone is enriched in sulfides, primarily pyrite, and arsenopyrite.

The ore is a combination of mineralised sheared graphitic schist and associated mineralised quartz veins. The gold is associated with pyrite (FeS_2) and arsenopyrite (FeAsS) within the HMSZ, which is the gold bearing structure. Minor fine-grained chalcopyrite ($CuFeS_2$), sphalerite (ZnS) and galena (PbS) are also present (Golder, 2011a). Weightman et al. (2021) also report boulangerite ($Pb_5Sb_4S_{11}$) was present. Craw (2002) reports mineralised rocks have been variably enriched in As, Au, Sb, W, Mo and Bi, but not Co or Cd. The potential contaminants of concern (PCOC) associated with these minerals (As, Cu, Fe, Pb, SO_4, and Zn) are recognised by current resource consent conditions (e.g., S. Compliance monitoring is undertaken for these PCOC (along with others) to ensure that management processes are appropriate and that effects on the receiving environment are acceptable (Section 2.6).

A key indicator for environmental geochemistry risks associated with sulfide minerals is total sulfur content of the rock. At the Macraes there is a robust dataset for total sulfur, for instance there are approximately 3,000 assay data for sulfur in the Coronation Pit area (O'Kane Consultants, 2016). For the whole site this is likely to be a significant dataset.

A stylised cross section of the Coronation orebody, which shows both the overburden, interburden, and the hanging wall contact is shown in Figure 1 as an example of the site's geological structure. Sulfur data from the assay database for the Coronation orebody was split into interburden and overburden (Figure 2) and was compared to an ore cut-off grade of 0.4 g/t Au. O'Kane Consultants (2016) noted that (based on the sample population, not the waste rock block model) that the interburden waste having < 0.15 g/tonne Au had a slightly higher sulfur content compared to the overburden waste rock; and that low grade ore (LGO) being 0.15 – 0.4 g/t Au was comparable to the interburden waste. This suggests interburden is a slightly higher risk for AMD compared to the waste rock at site.

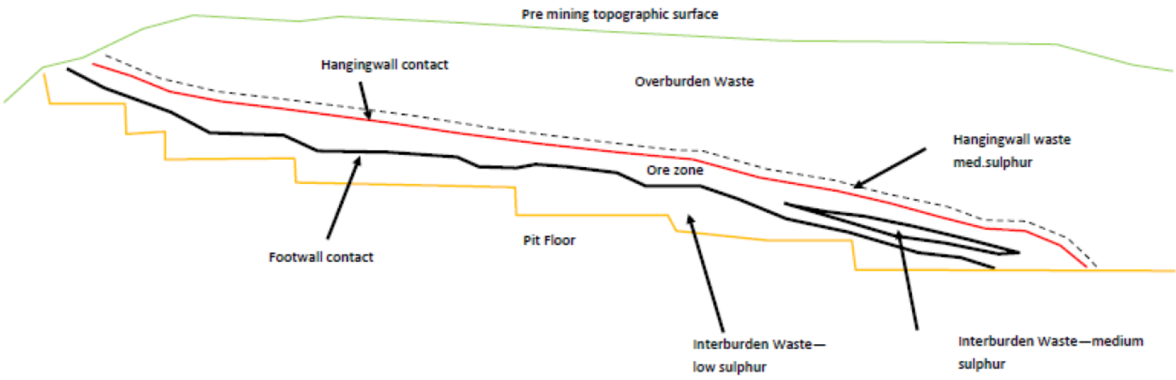

Figure 1. Coronation orebody stylised geological cross section.

Source: O'Kane Consultants (2016).

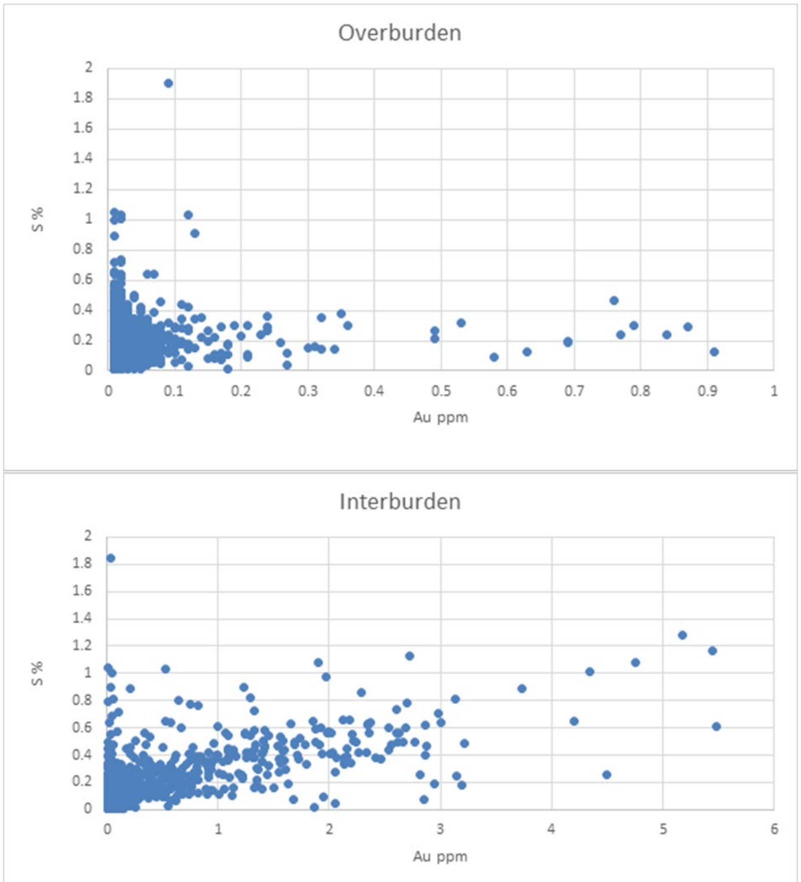

Figure 2. Au grade and sulfur content for overburden and interburden.

Source: O'Kane Consultants (2016).

2.3 Ore Processing

Processing of the ore involves production of a sulfide concentrate via flotation of crushed and ground ore. Historically this ore was processed via carbon-in-pulp cyanidation (~15 µm) with the result that historical tailings are elevated in sulfide minerals. Commencing in 1999, an autoclave was installed with the sulfide concentrate being fed through this pressure oxidation (POX) system (225 °C; Golder, 2011b) to oxidise the sulfide minerals to liberate the Au before carbon-in-pulp cyanidation. This has resulted in a lower sulfide content in the tailings yet a higher proportion of process mineral residues and the formation of secondary minerals such as gypsum +/- anhydrite, jarosite +/- alunite, and ferric sulfate (Weightman et al., 2021).

The process residues from the flotation and the gold extraction systems are discharged as mine tailings into purpose-built tailings storage facilities (TSFs). Between 1990 and 2013 the tailings were deposited in the Mixed Tailings Impoundment (MTI), and at a later stage, some tailings were periodically deposited in the adjacent disused open pit, termed the Southern Pit (post 2002) referred to as SP11 TSF. Eventually, these two impoundments merged behind an extended dam to form the combined MTI. From 2013, tailings disposal was transferred to the Top Tipperary Tailings storage facility (TTTSF).

2.4 Mine Plan

This section provides an overview of the Macraes Gold Mine and key developments proposed for the MP4.3 Project.

2.4.1 Overview

Macraes is located approximately 30 km to the northwest of Palmerston in the Otago Region of the South Island, New Zealand. The mine is located 1 to 2 km to the east of the Macraes township and is predominantly surrounded by farmland.

Macraes was commissioned in 1990 with the development of open pits and the construction of a gold processing plant and TSF. The processing plant capacity has increased since 1990 through continual upgrades and now processes nearly 6 million tonnes of ore per annum. The ore has been sourced from several open pits, the largest being Frasers Pit. In 1999 an autoclave was installed to treat refractory ore. Between 2007 and 2016, additional ore concentrate was imported from the Globe-Progress Mine near Reefton for processing through the processing plant (OceanaGold, 2011). Mining operations continue using open pit methods combined with an underground mine (Frasers Underground) that has been operating since 2006.

2.4.2 Golden Bar Stage 2

It is proposed that the current Golden Bar Pit will be expanded by ~ 200 m to the northeast and the current Golden Bar Waste Rock Stack (GB-WRS) will be expanded to accommodate the additional waste rock, increasing the height of GB-WRS by ~70 m providing ~30 Mt of additional storage capacity (OceanaGold, 2022b). The proposed Stage 2 Pit extension will be approximately 45 m deeper than the current pit and generate 1.3 Mt of ore and 27 Mt of waste rock (Figure 3).

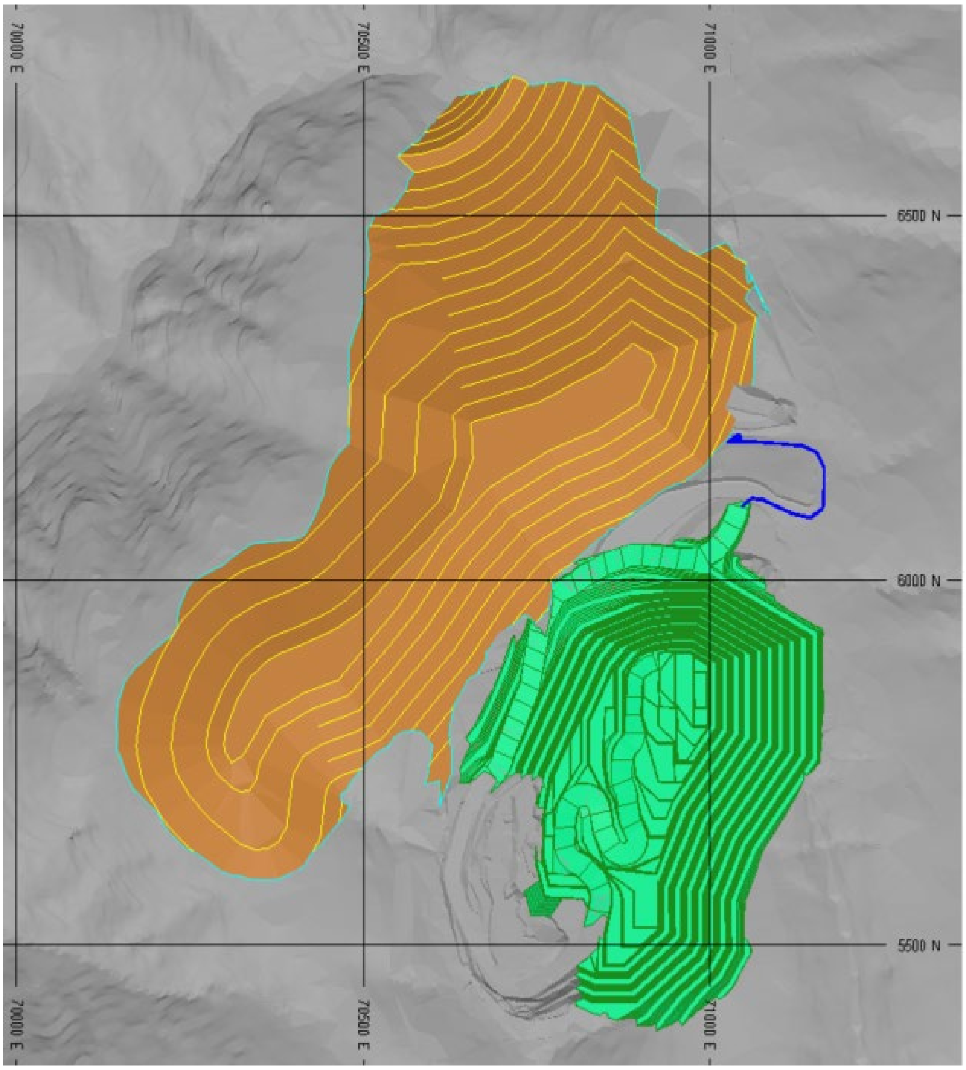

Figure 3. Golden Bar Stage 2 extension.
Source: OceanaGold (2023).

2.4.3 Coronation Stage 6

The proposed Coronation Stage 6 Pit (CO6) consists of a ~250 m expansion to the southeast and is expected to involve a total movement of approximately 2 Mt of ore and 31.5 Mt of waste (OceanaGold, 2022c, 2023). Waste rock will be transported to the Coronation North Pit, which has a capacity of 34.5 Mt and will be backfilled (Figure 4). No additional waste rock will be placed in the vicinity of the Coronation Pit. The average height of the Trimbells Waste Rock Stack (WRS) remains at a height of 35.2 m (pers. comm. Jeff Tuck, GHD – email 26 January 2023).

Water management will require the dewatering of the Coronation CO5 Pit to facilitate additional mining activities associated with Stage 6 expansion. The dewatering of Coronation CO5 is anticipated to take around 4 months with pit water being pumped back to main mining areas for final storage in Deepdell Pit, or for use in the processing plant. Pit dewatering will commence as soon as mining reaches 650 mRL in CO6, which is expected to start in October 2025.

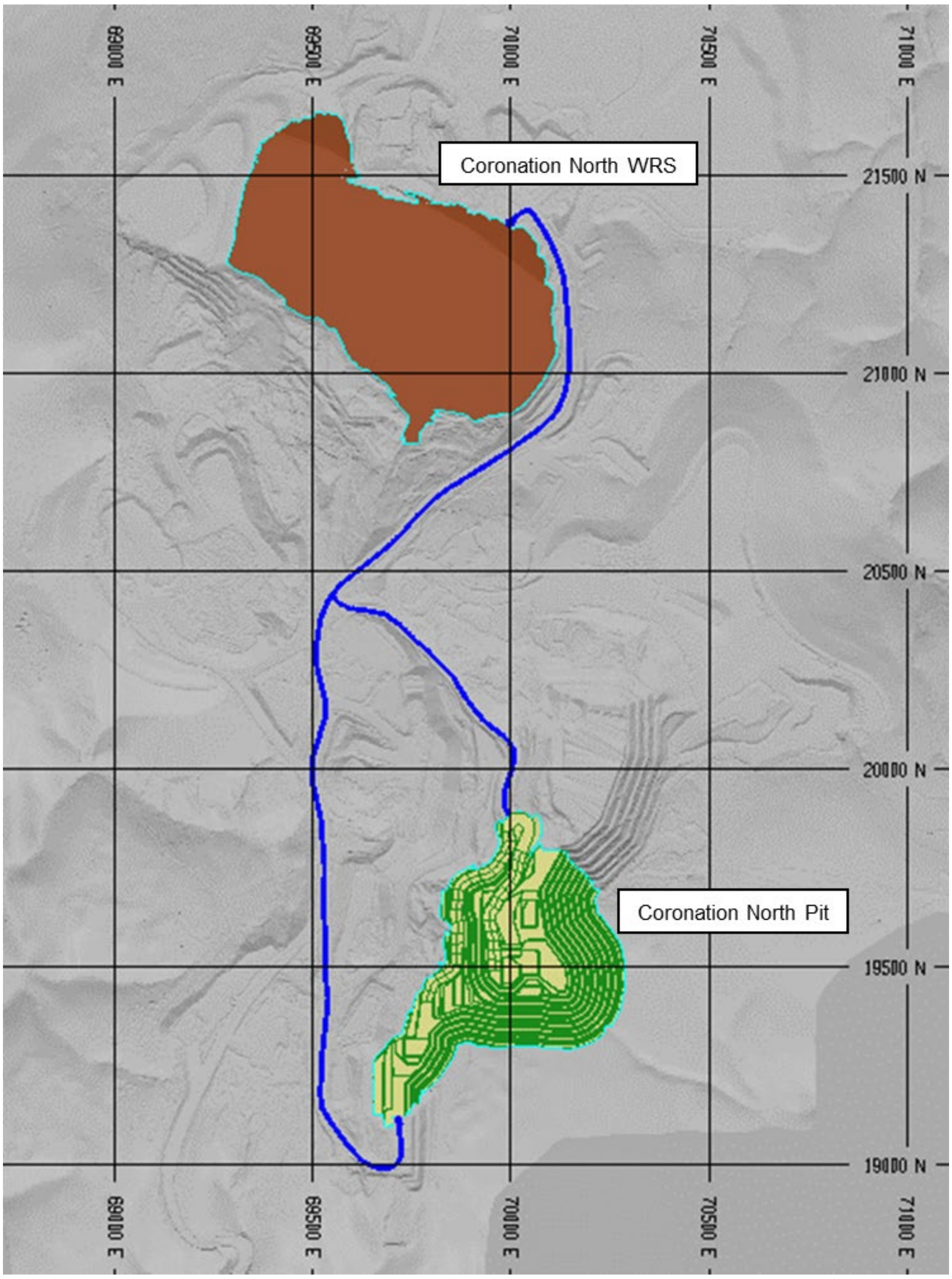

Figure 4. Coronation Stage 6 Pit design and waste rock placement in Coronation North Pit.
Source: OceanaGold (2022c): showing the Coronation Stage 6 pit area and the Coronation North backfill.

2.4.4 Frasers TSF and Innes Mills Pit Extensions

The proposed pit extensions for Innes Mills and the construction of the Frasers TSF (FTSF) consist of the following activities (OceanaGold, 2023) as shown in Figure 5:

- Construction of the Frasers (in-pit) TSF within the current Frasers Pit void.
- Mining of Innes Mill Pit – Stages 7,8,9.
- Placement of waste rock in the Frasers Backfill (FRBF), Frasers South Backfill (FSBF), Frasers East WRS (FEWD), and Golden Point Backfill (GPBF)
- Construction of the Frasers TSF

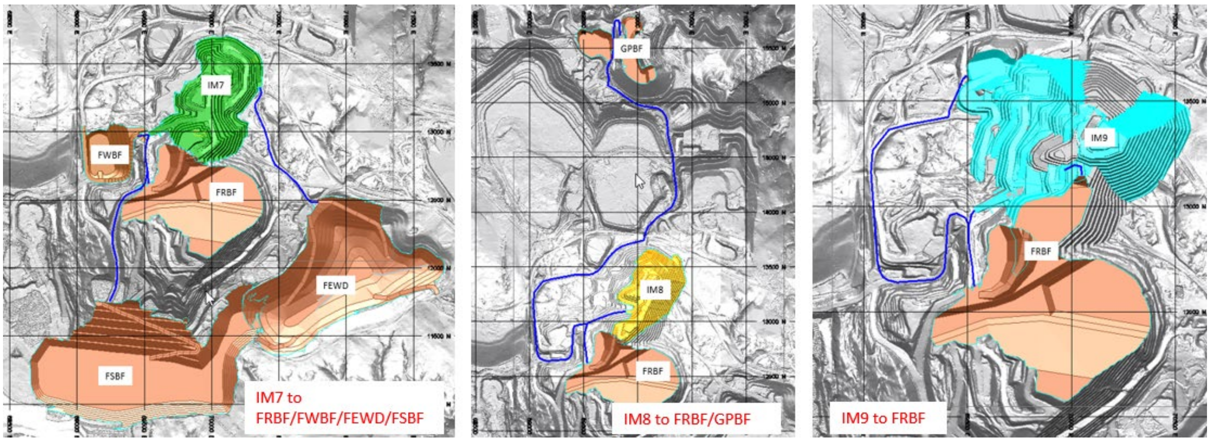

Figure 5. Innes Mills Pit Staging and FTSF

Source OceanaGold (2023) Project descriptions and haul routes (blue lines).

2.5 Previous Geochemical Investigations

The following section reviews previous relevant environmental geochemistry information for Macraes.

2.5.1 Waste Rock ABA Data

OceanaGold has been regularly collecting acid base accounting (ABA) data for waste rock at Macraes since 2007. Original ABA analysis was undertaken by Adrian Smith Consulting Inc (1992) and Woodward Clyde (1996) with a general conclusion that the site would not produce acid rock drainage (ARD). This expectation remains correct.

Previous investigations have indicated that waste rock at Macraes is generally non-acid forming (NAF) with a low potential to generate acidity. This is validated by recent ABA data (Table 1) obtained from the OceanaGold ABA database, which shows low maximum potential acidity (MPA) values and high acid neutralising capacity (ANC) values that nearly always generate NAF classifications by both the AMIRA (2002) and Price (2009) classification schemes.

The following observations are provided:

- Average ANC values ranged from 30.3 H_2SO_4/t (Coronation WRS) – 56.0 H_2SO_4/t (Frasers West WRS).
- Average MPA values ranged from 2.68 H_2SO_4/t (Coronation WRS) – 3.29 H_2SO_4/t (Frasers West WRS).
- All of the samples had negative net acid producing potential (NAPP) values indicating the materials are NAF:
    - Innes Mills having an average NAPP of -50.7 kg H_2SO_4/t.
    - Frasers West having an average of NAPP of -82.2 kg H_2SO_4/t.
    - Coronation having an average of NAPP of -27.6 kg H_2SO_4/t.
- The neutralisation potential ratio (NPR) values are > 3 as stipulated by resource consent RM10.351.10.V1 (Compliance Criteria iv).

- ABA data indicates a significant capacity to neutralise any acidity generated by the materials associated with the project.

Table 1. ABA summary data for WRS.

PARAMETER		TOTAL SULFUR	SULFIDE	SULFATE	ANC	MPA*	NAPP	NPR
		wt%	wt%	wt%	kg H_2SO_4/t			-
Innes Mills WRS (n=182)	Mean	0.15	0.10	0.05	53.7	2.96	-50.7	27.6
	Median	0.15	0.10	0.04	52.6	3.06	-50.1	18.7
	Stand. Dev.	0.07	0.04	0.06	11.7	1.37	11.6	37.4
Frasers West WRS (n=34)	Mean	0.15	0.11	0.04	56.0	3.29	-52.7	22.3
	Median	0.13	0.10	0.03	57.5	3.06	-54.0	18.5
	Stand. Dev.	0.08	0.06	0.04	11.4	1.91	51.3	43.3
Coronation WRS (n=34)	Mean	0.12	0.09	0.03	30.3	2.68	-27.6	34.4
	Median	0.10	0.07	0.02	25.5	2.10	-24.5	13.9
	Std Dev	0.10	0.07	0.05	30.1	2.29	30.1	54.5

** - MPA calculated from Sulfide S; ** - ANC is based on the 0.1 N HCl digestion rather than the 0.5 N HCl digestion to be conservative; Innes Mills WRS data from 2007 - 2021; Frasers West WRS data from 2018 – 2016; Coronation WRS data from 2015 – 2021.*

Note: A sample 23-1-2017 was excluded from the analysis as being anomalous (ANC was recorded as 729 kg/t H_2SO_4).

2.5.2 Tailings ABA Data

Since 1999 POX has been conducted on the ore to oxidise the sulfide minerals to enhance gold extraction resulting in a lower sulfide sulfur tailings. Weightman et al. (2021) report that POX tailings have nil sulfides present, although Golder (2011b) report this as being 0.05 - 0.06 wt% sulfide sulfur.

The current ABA data for tailings samples (between 2007 – 2021) are summarised below (Table 2) where samples were either collected from the tailings hopper or the tailings line on a monthly basis. The data indicates that the tailings material is NAF by both the AMIRA (2002) and Price (2009) classification schemes due to abundant ANC (Figure 6). Generally, the total sulfur and sulfide content is low decreasing with time (Figure 7). The mean and median NAPP values were negative (-36.2 kg H_2SO_4/t and -41.2 kg H_2SO_4/t respectively), and had an average NPR value > 3 (mean value of 26.1).

Table 2. ABA tailings data summary (2007 - 2021).

PARAMETER	TOTAL SULFUR	MPA*	SULFIDE	SULFATE	ANC**	NAPP	NPR
	wt%	kg H_2SO_4/t	wt%	wt%	kg H_2SO_4/t	kg H_2SO_4/t	-
Mean	0.71	4.30	0.16	0.55	40.5	-36.2	26.1
Median	0.16	2.14	0.07	0.08	43.7	-41.2	18.7
Standard deviation	1.36	6.2	0.37	1.19	16.3	20.1	-

** - MPA calculated from Sulfide S; ** - ANC is based on the 0.1 N HCl digestion rather than the 0.5 N HCl digestion to be conservative (i.e., a less aggressive acid will have a lower ANC). The total number of samples in the population was 382. Three samples were excluded as anomalous for ANC (01-01-2017, 01-04-2017, and 01-01-2021) – see Figure 6. One sample was excluded due to high sulfide sulfur (24-08-2007) with a value of 188.8 kg H_2SO_4/t.*

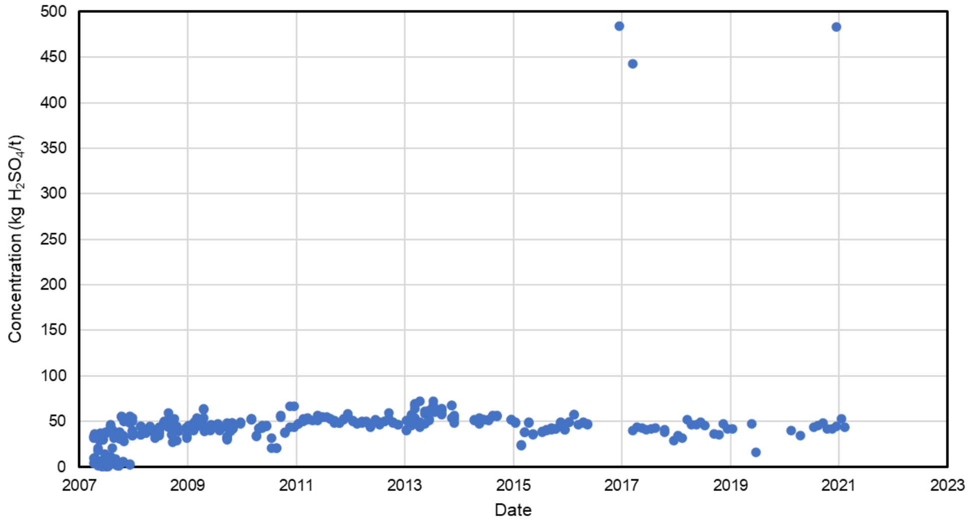

Figure 6. ANC results for tailings (2007 - 2021).

Source: Macraes ABA database.

Note: The three anomalous samples were excluded from the analysis provided in Table 2.

The data presented shows that across the project area, with ore materials being contributed from a variety of pits and underground workings, that the ANC is generally consistent and that the sulfur grade is decreasing with time. This also suggests that the source hazard for acid and metalliferous drainage is also decreasing.

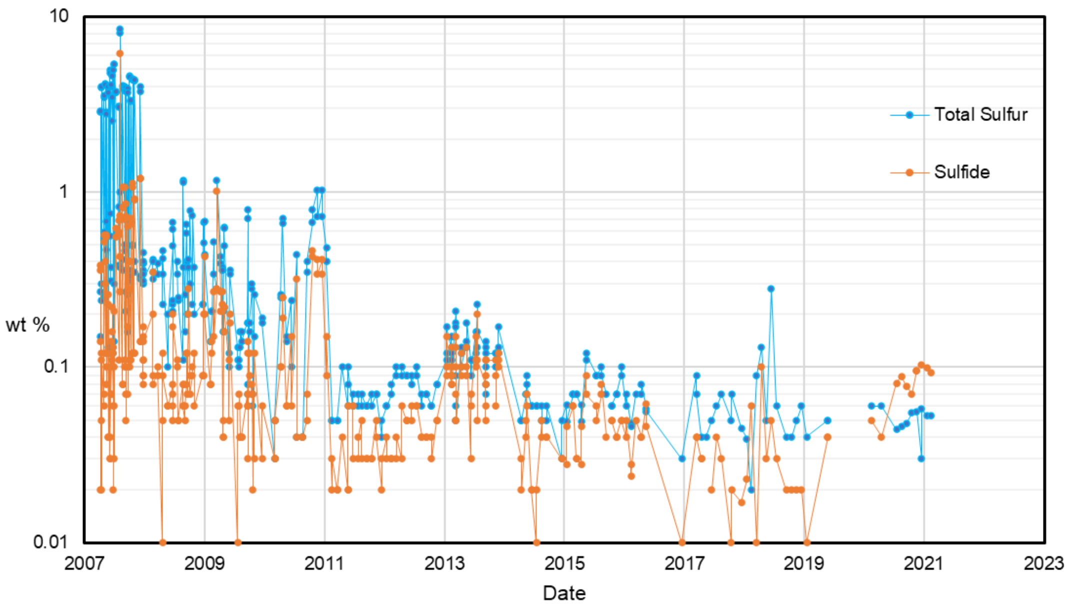

Figure 7. Total sulfur vs sulfide content for tailings (2007 - 2021).

Source: Macraes ABA database.

Notes:

1. *One anomalous sample was excluded from this graph and the analysis provided in Table 2 (high sulfide sulfur (24-08-2007) with a value of 188.8 kg H_2SO_4/t).*
2. *At times sulfide sulfur can be higher than total S measurements: SGS laboratories noted that "This happens whereby the species comes back higher than the total then it appears that all of that element is present as the species. i.e. if sulphide sulphur higher than total sulphur."*

2.6 Water Quality Resource Consents Conditions

OceanaGold has developed a water quality management plan (WQMP) to comply with their resource consent conditions. The objectives of the WQMP are to describe water quality management methods and procedures. Due to the size and complexity of Macraes, multiple resource consents exist around water quality involving key site features such as:

- Open pits.
- Frasers underground (FRUG).
- WRS and TSF.
- The ore processing plant.

For the purpose of completing the environmental geochemistry assessment that is contained within this report, the compliance limits from each consent were reviewed and compared to one another. A compliance limit for each PCOC was then selected (Table 3) as a reference for geochemical data to be compared against.

Data is then normalised to derive the metal ecotox quotient (MEQ). A MEQ is used to identify PCOC that are elevated with respect to compliance limits (Weber and Olds, 2016). The MEQ value for a PCOC is determined by dividing the measured concentration by the compliance limit. MEQ values greater than 1 indicate parameters which exceed water quality guidelines. Conversely, MEQ values less than 1 are below compliance limits and are unlikely to require routine monitoring if < 50% of the compliance limit.

Table 3. Compliance limits used for geochemical assessments.

PARAMETER	WATER QUALITY COMPLIANCE LIMIT	COMPLIANCE MONITORING LOCATION	RESOURCE CONSENT NUMBER
As	0.15	DC08	RM120.024.14
$CN_{(WAD)}$	0.1	MC01	RM10.351.10.V1
Cu[1]	0.009	DC08	RM120.024.14
Fe	1.0	DC08	RM120.024.14
Pb[1]	0.0025	DC08	RM120.024.14
Zn[1]	0.12	DC08	RM120.024.14
SO_4	1,000	DC08	RM120.024.14
pH (pH units)	6.0 – 9.5	DC08	RM120.024.14
NO_3-N	2.4 (median)	DC08	RM120.024.14
Amm-N[2]	0.24	DC08	RM120.024.14
Sb[3]	1.6	-	(see Note 3)

All compliance values are given in mg/L unless otherwise specified.

1 - Cu, Pb and Zn standards are hardness related limits in accordance with an assumed hardness value of 100 g/m³ $CaCO_3$ and will vary depending on actual hardness according to established calculation methodologies.

2 – Amm-N (Total Ammoniacal Nitrogen) is the total nitrogen as NH_3 and NH_4.

3 - Confirmation of Sb water quality limit was provided by Duncan Ross, source: pers. Comm. Duncan Ross, Consenting and Community Lead, OceanaGold Limited, email dated 30 June 2022.

2.7 Baseline Water Quality

2.7.1 Surface Water

Macraes surface drainage involves, often ephemeral tributaries of multiple rivers within and around the site (Figure 8), these are comprised of the following:

- Cranky Jims Creek (CJ01), which is to the north-east of the TTTSF and is a tributary of the Shag River.
- Murphy's Creek (MC01), which is a tributary of the North Branch Waikouaiti River.
- McCormicks Creek.
- North Branch Waikouaiti River where the southwestern third of Macraes intersects the catchment of this drainage system.
- Tipperary Creek.
- Deepdell Creek.

Baseline water quality data, which was originally used by Golder for mine development planning have been summarise by Weightman (2020) and are provided in Table 4. Table 4 shows that Murphys Creek had higher Ca and SO_4 background concentrations compared to the data summary for Tipperary, McCormicks, and Cranky Jims. It was suggested that elevated sulfate may be associated with mining.

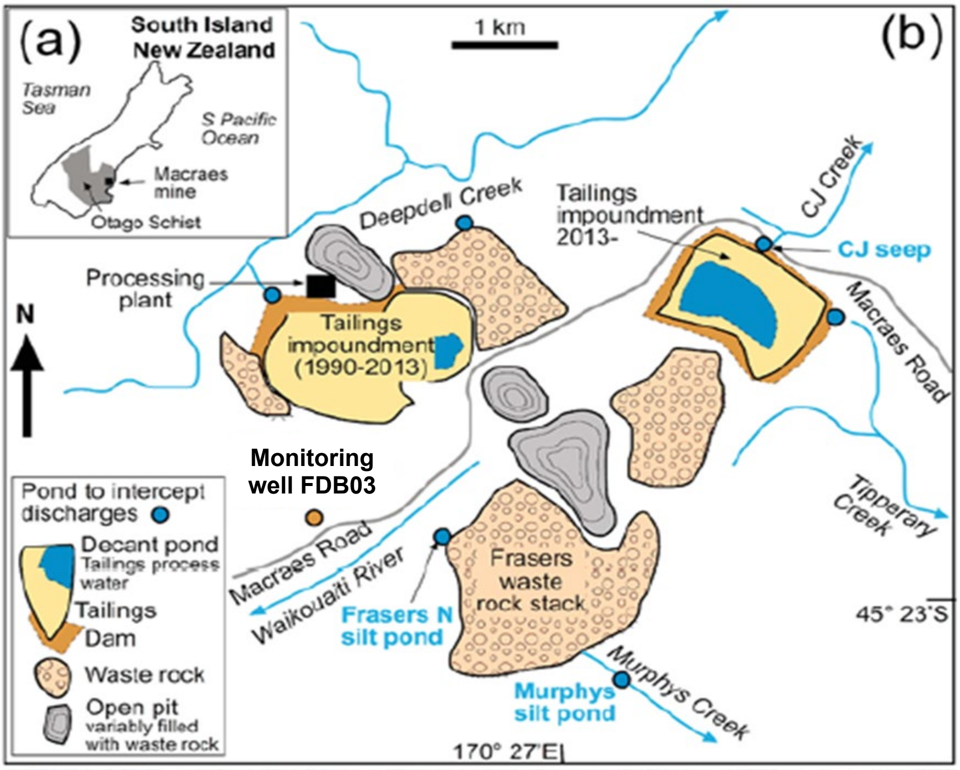

Figure 8. Conceptual site map showing the location of key surface water catchments.

Source: Modified from Weightman et al. (2020).

Table 4. Background water quality for local Macraes streams.

PARAMETER	TIPPERARY / MCCORMICKS / CRANKY JIMS	NBWR / MURPHYS
As	0.005	0.007
SO_4	4	47
CN	0.005	0.005
Cu	0.002	0.001
Fe	0.5	0.1
Pb	0.001	0.001
Zn	0.005	0.005
Na	11	13
K	2	2
Ca	10	36
Mg	4	12
Cl	11	10

Source: Weightman (2020): the Golder reference cited was absent from the Weightman (2020) reference list so could not be validated. All units are presented in mg/L - unless otherwise specified.

2.7.2 Groundwater

Groundwater bores are installed across the Macraes area to monitor the effects of mining on groundwater. Two types of monitoring wells are used including detection and compliance wells. Detection wells provide early warning of changes to groundwater quality (OceanaGold, 2011). Compliance wells are installed to detect changes in groundwater quality prior to reaching a designated freshwater catchment.

The shallow monitoring well FDB03 (Figure 8) with water depths between 0.39 and 2.31 m below ground level (bgl) was selected as a representative site for baseline groundwater quality due to its distance from mine impacted waters (pers. Comm. Duncan Ross, email dated 8 June 2022). Specifically, water quality data from September 2011 to December 2017 was chosen as it represented water quality for a period which not influenced by mining (comparative analysis to the surrounding monitoring wells). Key water quality data is shown in Table 5 and indicates that:

- Water quality typically exhibited circumneutral pH values ranging from 6.70 – 7.50.
- From 2011 to 2017 Ca, Mg, Na, and SO_4 were relatively stable.
- Concentrations for As, Cu, and Pb we typically below detection limits, and in all cases, below their respective compliance limits of 0.15 mg/L, 0.009 mg/L and 0.0025 mg/L.
- Fe concentrations were typically elevated above the compliance limits (mg/L) ranging between 0.02 and 6.20 mg/L with an average of 4.50 mg/L.

Table 5. Summary of groundwater quality for monitoring well FDB03 (2011 – 2017).

PARAMETER	COUNT	MIN	MAX	MEDIAN	AVERAGE
pH (pH units)	27	6.70	7.50	7.10	7.01
Total alkalinity (mg/L as $CaCO_3$)	27	43	63	51	51.8
Electrical conductivity (EC) (mS/m)	27	11.4	15.4	12.6	12.8
Total hardness (mg/L as $CaCO_3$)	37	20.0	341	36.0	35.7
Nitrate-N + Nitrite-N	3	0.01	0.07	0.02	0.03
Ammoniacal-N	2	0.09	0.21	0.15	0.15
Total Inorganic Nitrogen	3	0.16	3.30	0.22	1.23
As	7	0.001	0.01	0.001	0.002
Ca	27	4.90	127	5.50	10.0
Cl	27	5.00	6.90	6.20	6.13
Cu	7	0.0005	0.0005	0.0005	0.0005
$CN_{(WAD)}$	1	0.001	0.001	0.001	0.001
Fe	7	0.02	6.20	5.30	4.50
Pb	7	0.0001	0.0001	0.0001	0.0001
Mg	27	1.35	8.60	5.70	5.79
K	27	1.08	9.60	1.33	1.66
Na	27	5.90	11.0	9.40	9.44
SO_4	27	1.60	10.0	4.30	4.40
Sum of Anions (meq/L)	19	1.18	1.54	1.27	1.31
Sum of Cations (meq/L)	19	1.09	1.57	1.26	1.29

Source: OceanaGold groundwater quality (excel database).

All units are presented in mg/L - unless otherwise specified; metals and metalloids are dissolved fractions; pH presented is based on H+ concentration.

2.8 Mine Influenced Water - Pit Lakes

The following section summarises pit lake water qualities that are relevant to the project. This includes the Golden Bar, Coronation, Deepdell North, and Innes Mills. Water quality data are compared to the compliance limits (Table 3) to understand whether the parameter is elevated (i.e., MEQ > 1).

2.8.1 Golden Bar Pit Lake Water Quality

Full analysis of the current Golden Bar Pit Lake water quality can be found in the Appendix J. Key observations are:

- The water quality monitoring period ranged from 2004 to 2022.
- Water quality typically exhibited circumneutral pH levels ranging from 8.2 – 8.5.

- Sulfate concentration stabilises from 2013 onwards with a slight decrease in 2019 down to near 270 mg/L (as seen in Figure 9).
- Arsenic concentrations in the pit lake decrease over time with a concentration near 0.12 mg/L in the most recent sample.
- Nitrate nitrogen concentrations had a sharp increase in the first months up to 30.2 mg/L and then decreased with time down to 0.002 mg/L in the most recent samples. This is expected to be related to the flushing of ANFO[2] residues from the pit walls / remnant waste rock in the pit, followed by denitrification.

Sulfate concentration data and pH values are shown for the current Golden Bar Pit Lake in Figure 9.

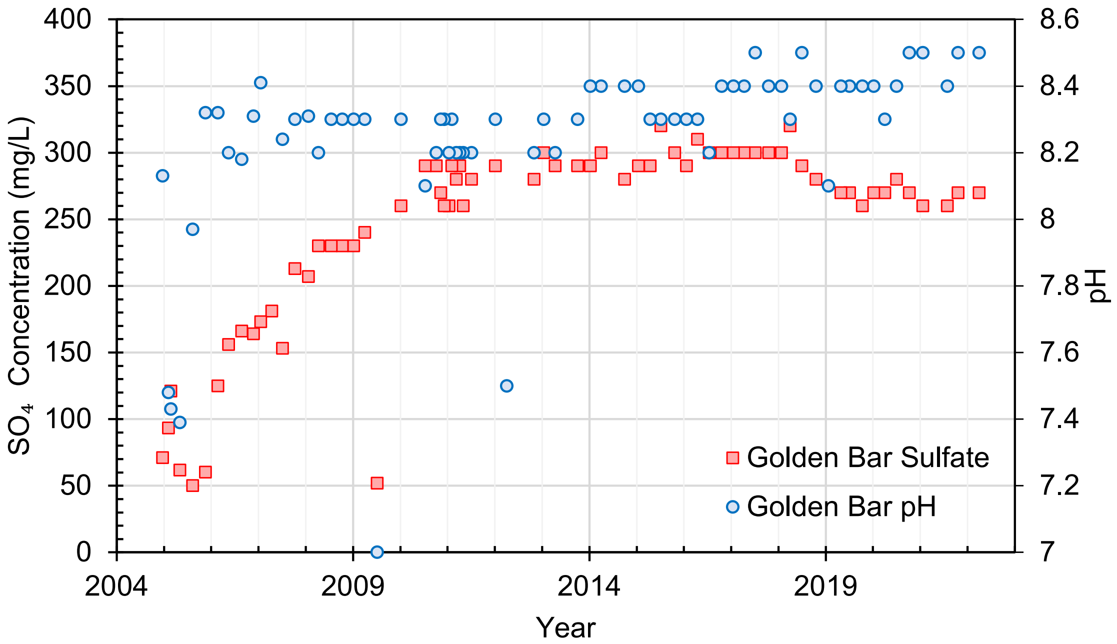

Figure 9. Golden Bar current pit lake water quality.

2.8.2 Coronation Pit Water Quality

Full analysis of the current Coronation Pit Lake (Stage 5) water quality can be found in the Appendix L. Key observations are:

- Monitoring period from 2015 to 2022.
- Water quality typically exhibited circumneutral pH levels ranging from 7.1 – 8.3.
- Sulfate data show an increase in concentration between 2016 and 2019 (from ~19 to 440 mg/L). From 2019 onwards sulfate declined down to 170 mg/L in the most recent sample.
- Arsenic concentrations have a decreasing trend from 2018 to 2021, and occasional increases up to 0.41 mg/L in recent data. The overall average As concentration is 0.13 mg/L.

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[2] *ANFO = Ammonium-nitrate fuel oil explosive using for blasting of rock*

- Nitrate nitrogen concentrations start at 20 mg/L with a decreasing trend down to 0.31 mg/L in April 2019, with peaks of 17.8 and 42 mg/L on two occasions (August 2018 and March 2021 respectively). The overall average is 6.99 mg/L. The average concentrations vary up and down due to the operational management of water being pumped between pits (e.g., Coronation North to Coronation) as mining continued during this period.

Sulfate concentration and pH values are shown for the current Coronation Pit Lake in Figure 10.

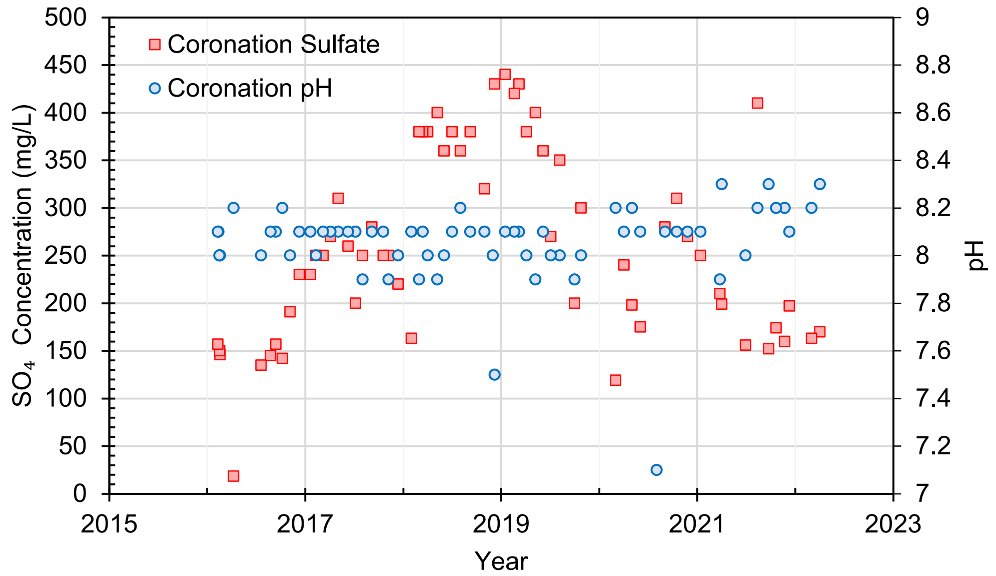


Figure 10. Coronation Stage 5 Pit Lake water quality (sulfate and pH).

2.8.3 Innes Mills Pit Lake Water Quality

Water quality samples from the Innes Mills Pit have been collected from 1996 to 2005. Data are provided in Table 6 and are presented graphically in Figure 11 to Figure 13.

The following observations are noted:

- Water quality typically exhibited circumneutral pH (7.21 – 8.46).
- Analysis of the data indicates that NO_3-N, Amm-N, and As are >1.0 MEQ indicating that these parameters are elevated.
- Nitrate-N concentrations ranged between 0.07 and 35.10 mg/L with an average concentration of 4.73 mg/L. Total ammoniacal nitrogen concentrations ranged from 0.01 to 2.68 mg/L with an average concentration 0.227 mg/L. The NO_3-N and Amm-N concentrations are likely to be derived from ammonium nitrate-based blasting reagents.
- Dissolved As concentrations ranged between 0.013 and 0.50 mg/L with an average of 0.16 mg/L.
- Sulfate concentrations were observed as having an increasing trend but remained below compliance limits (MEQ < 1.0).

Data for Innes Mills Pit Lake are limited between 1996 and 2005 with only some parameters (such as pH, $CN_{(WAD)}$, Fe, As, and SO_4) being monitored over the entire period. Data for parameters such as Cu, Zn, Na, Mg, K, and total alkalinity are limited. The data presented shows that the majority of parameters are relatively stable and below the water quality compliance limits with exception of the occasional outlier, which are interpreted to be analytical errors (e.g., as seen in Fe and Pb).

Table 6. Summary of water quality for the Innes Mills Pit Lake (1996 – 2004).

PARAMETER	COUNT	MIN	MAX	AVE	MED	COMPLIANCE LIMIT#	MEQ (MAX)
pH (pH units)	13	7.21	8.46	7.92	8.13	-	-
EC (mS/m)	14	53.8	184	103.6	89.05	-	-
Alkalinity - Bicarbonate (mg/L as $CaCO_3$)	7	109	457	249	209	-	-
Hardness-Total (mg/L as $CaCO_3$)	14	235	1,310	589	447	-	-
Nitrate-N	14	0.07	35.1	4.73	2.20	2.4	14.63
Nitrogen-Total	14	0.12	37.8	4.96	2.22	-	-
Nitrogen-Total Ammoniacal	14	0.01	2.68	0.227	0.025	0.24	11.17
As	13	0.013	0.50	0.162	0.06	0.15	3.33
Ca	10	47.3	351	181	188.5	-	-
Cl	7	2.5	13.7	8.56	9.70	-	-
$CN_{(WAD)}$	13	0.005	0.0100	0.005	0.0050	0.1	0.10
Cu	2	0.0008	0.0010	0.0009	0.0009	0.009	0.11
Fe	12	0.02	2.13	0.289	0.100	1	0.02
Hg	13	0.00001	0.0005	0.00017	0.0001	-	-
K	6	4.06	7.10	5.55	5.86	-	-
Mg	10	28	105	60.41	65.1	-	-
Na	6	11	28.5	20.90	23.4	-	-
Pb	13	0.0001	0.010	0.0018	0.001	0.0025	0.18
SO_4	14	87.5	975	407	305	1,000	0.98

Source: OceanaGold Mine Water Quality (excel database).

All units are presented in mg/L unless otherwise specified. Metals and metalloids dissolved. pH presented is based on H^+ concentration. # - Water Quality Limit obtained from Table 3. Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018). RED Text = MEQ values are >1.0 MEQ.

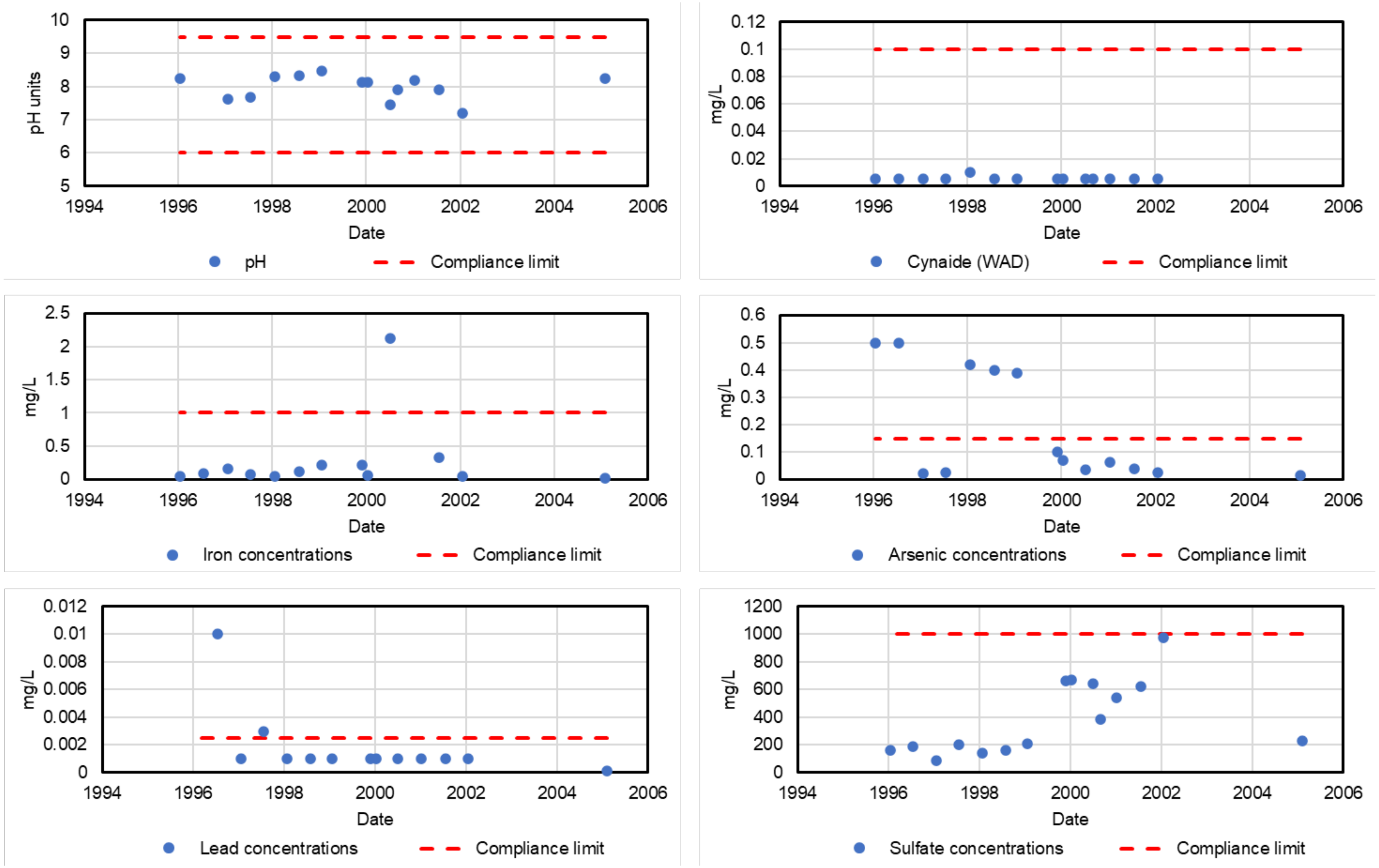


Figure 11. Water quality trends for the Innes Mills Pit.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are the dissolved fraction.

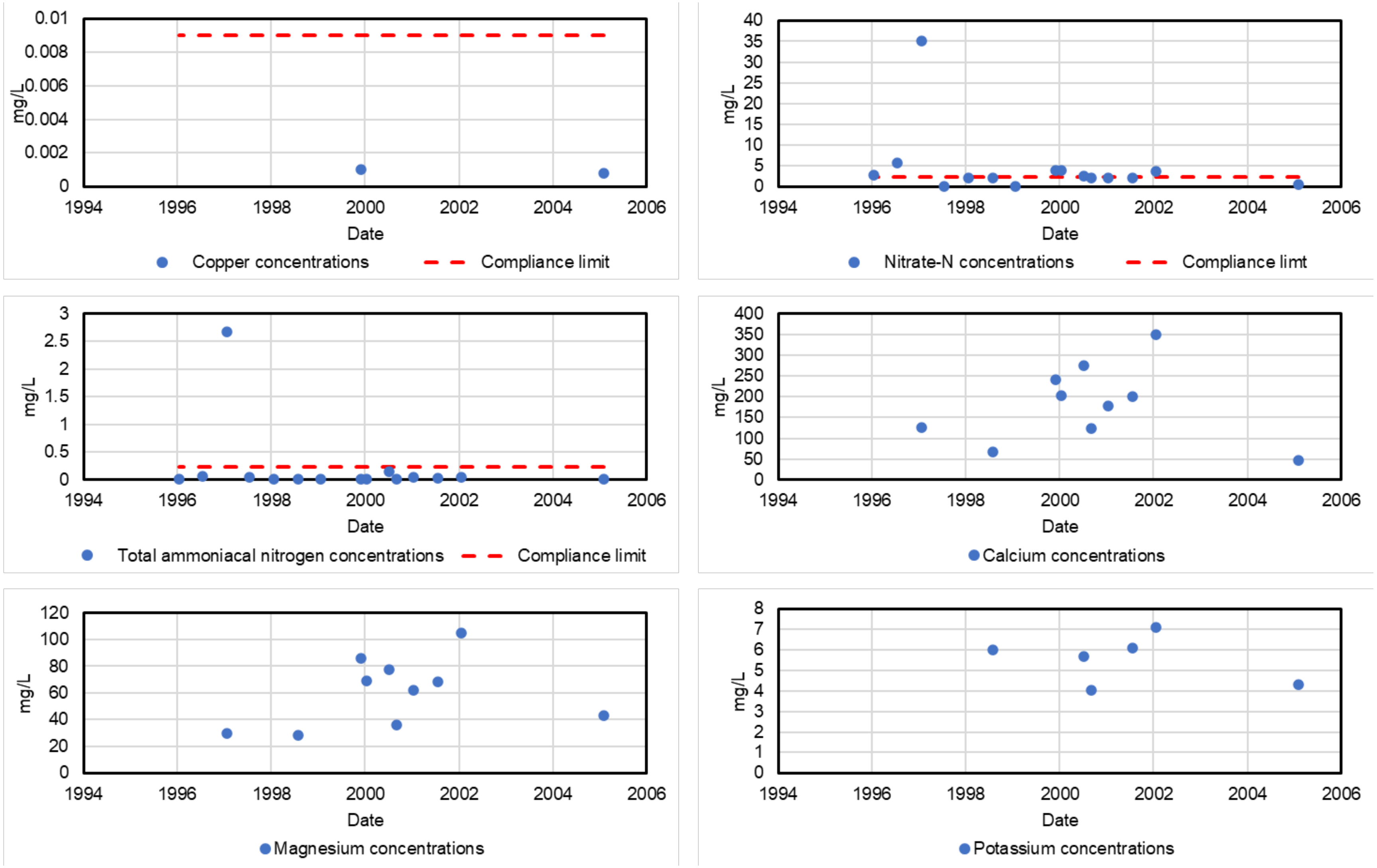


Figure 12. Water quality trends for the Innes Mills Pit continued.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are the dissolved fraction.

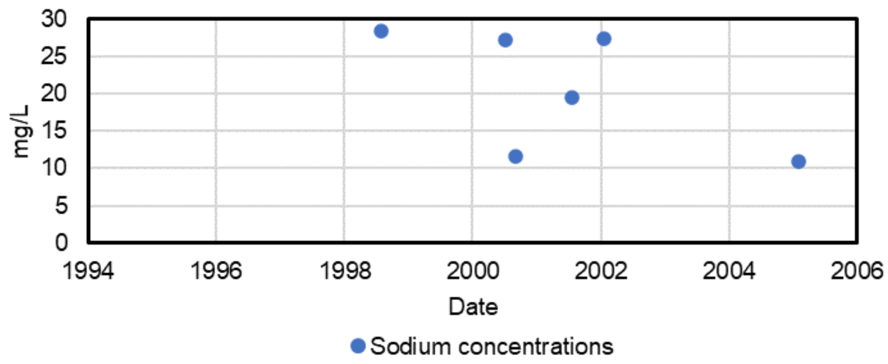


Figure 13. Water quality trends for the Innes Mills Pit continued.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are the dissolved fraction.

2.8.4 Deepdell North Backfill Water Quality

Water quality samples from the Deepdell North Backfill have been collected from 2001 to 2022 from a sump downgradient of the mine domain. MEQ analysis and a summary of the water quality data are presented in Table 7 from data collected between 2001 – 2022. Data are graphically presented in Figure 11 and Figure 16.

- Water quality typically exhibited circumneutral pH levels ranging from 7.50 – 8.58. pH values have remained relatively stable with no exceedances reported.
- The average total hardness was 1,112 mg $CaCO_3$/L. The average calculated hardness was 748.8 mg $CaCO_3$/L.
- The MEQ values for NO_3-N and SO_4 were >1.0 and thus above compliance limits.
- Nitrate concentrations ranged from 0.079 to 7.90 mg/L with an average concentration of 3.58 mg/L. Since 2021, NO_3-N concentrations have declined to below the compliance limit of 2.4 mg/L.
- Total ammoniacal nitrogen concentrations ranged from 0.01 to 0.16 mg/L with an average concentration of 0.03 mg/L. Two data points exceed the compliance limit (0.24 mg/L), however, these appear to be anomalous when compared to the rest of the dataset and were removed the analyses shown in Table 7.
- Dissolved As, Fe, and Pb concentrations have been relatively stable with average concentrations being 0.008, 0.11, and 0.0005 mg/L respectively; no exceedances were recorded over the ~21 years of monitoring.
- Sulfate concentrations have increased since monitoring began, reaching a semi steady state in 2015, with fluctuations. Data collected between 2015 – 2022 shows a SO_4 ceiling may be reached at ~1,400 mg/L.
- Since monitoring began Ca, Mg, and Na concentrations have followed similar trends, showing increases concentrations since 2009.

Table 7. Summary of water quality for the Deepdell North backfill (2001 – 2022).

PARAMETER	COUNT	MIN	MAX	AVE	MED	COMPLIANCE LIMIT#	MEQ (MAX)
pH (pH units)	92	7.50	8.58	8.07	8.10	-	
EC (µS/cm)	72	323	2,390	1,274	1,527	-	
Alkalinity - Total (mg/L as $CaCO_3$)	82	58	270	153.3	145.5	-	
Alkalinity - Bicarbonate (mg/L as $CaCO_3$)	92	57.0	270.0	167.9	172.0	-	
Carbonate Alkalinity (mg/L as $CaCO_3$)	50	1.00	212	37.3	2.25	-	
Total Suspended Solids	14	3.00	65.0	10.1	3.00	-	
Total Hardness (mg/L as $CaCO_3$)	40	210.0	1,600	1,112	1,140	-	

PARAMETER	COUNT	MIN	MAX	AVE	MED	COMPLIANCE LIMIT#	MEQ (MAX)
Calculated Total Hardness (mg/L as $CaCO_3$)	87	143.1	1,589	748.8	907.8	-	
Nitrate-N + Nitrite-N	33	0.098	8.80	3.66	3.60	-	
Nitrite-N	18	0.012	0.061	0.028	0.023	-	
Nitrogen-Total	14	0.310	9.80	3.67	2.73	-	
Total Inorganic Nitrogen	19	0.1030	8.40	3.72	3.60	-	
Nitrogen-Total Ammoniacal*	35	0.01	0.16 (1.57)	0.03	0.01	0.24	0.67
Nitrate-N	18	0.079	7.90	3.58	3.60	2.4	3.29
As - Dissolved	33	0.0028	0.023	0.008	0.006	0.15	0.15
As - Total	15	0.0023	0.0151	0.0057	0.0055	0.15	0.10
Ca	88	41.3	310.0	164.7	197.0	-	-
$CN_{(WAD)}$	13	0.001	0.005	0.0013	0.001	0.1	0.05
Cl	92	4.20	22.0	11.3	12.0	-	-
Cu - Dissolved	17	0.0005	0.002	0.0013	0.0014	0.009	0.22
Cu - Total	7	0.00053	0.0011	0.0007	0.0006	0.009	0.12
Fe - Dissolved	32	0.02	0.51	0.11	0.025	1	0.51
Fe - Total	15	0.022	0.430	0.096	0.057	1	0.43
Hg - Dissolved	1	0.00008	0.00008	0.00008	0.00008	-	-
K - Dissolved	93	2.02	11.5	5.27	5.30	-	-
Mg - Dissolved	92	9.70	198	78.0	89.0	-	-
Na - Dissolved	92	4.90	46.0	26.9	29.5	-	-
Pb - Dissolved	15	0.0001	0.001	0.0005	0.0002	0.0025	0.02
Pb - Total	7	0.00011	0.00021	0.00012	0.00011	0.0025	0.0007
Sb - Dissolved	1	0.0003	0.0003	0.0003	0.0003	-	-
Sb - Total	1	0.0002	0.0002	0.0002	0.0002	-	-
SO_4	93	38.6	1,370	599.0	720.0	1,000	1.37
Zn - Dissolved	1	0.0012	0.0012	0.0012	0.001	0.008	0.01
Sum of Anions (meq/L)	40	4.60	33.0	24.8	26.0	-	-
Sum of Cations (meq/L)	40	4.80	34.0	23.9	25.0	-	-

Source: OceanaGold Mine Water Quality (excel database).

All units are presented in mg/L unless otherwise specified. Metals and metalloids dissolved. pH presented is based on H^+ concentration. # - Water Quality Limit obtained from Table 3. Water quality limits were adjusted for hardness modifications where appropriate to derive the HMTV as per ANZG (2018). RED Text = MEQ values are >1.0 MEQ.

Brackets () denote the reported maximum value but ignored in the analysis due to being potentially erroneous.

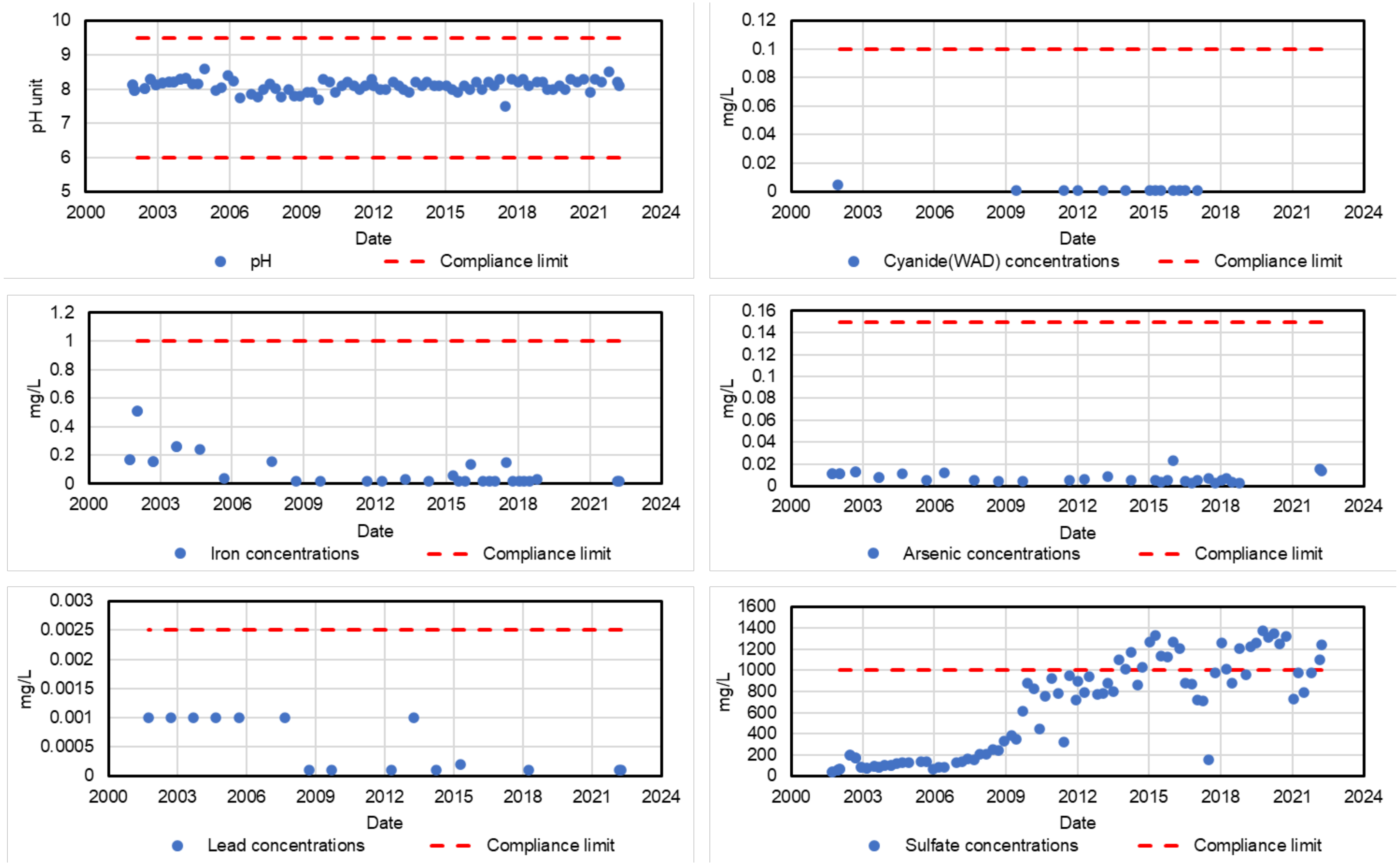


Figure 14. Water quality trends for the Deepdell North backfill.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are the dissolved fraction.

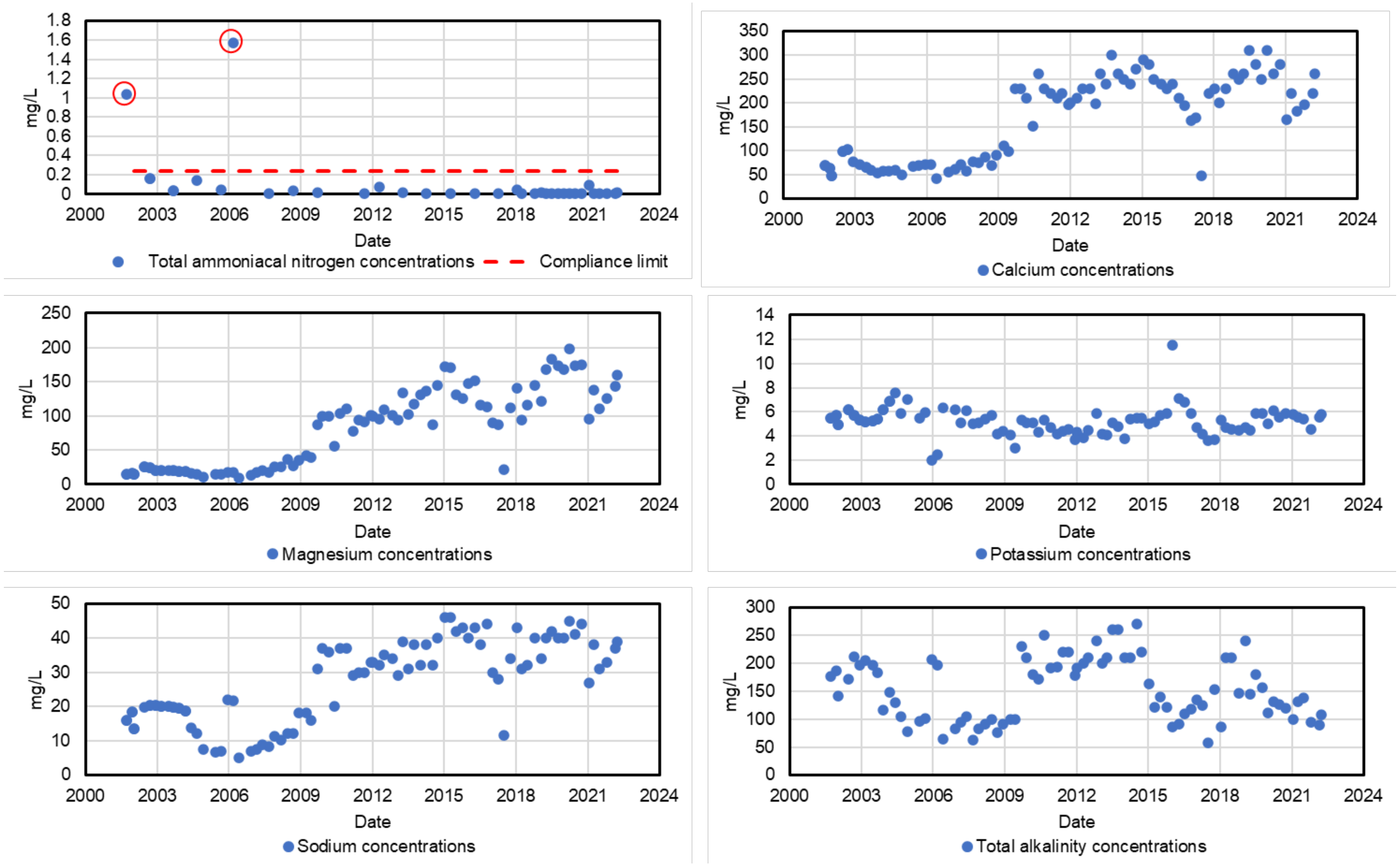
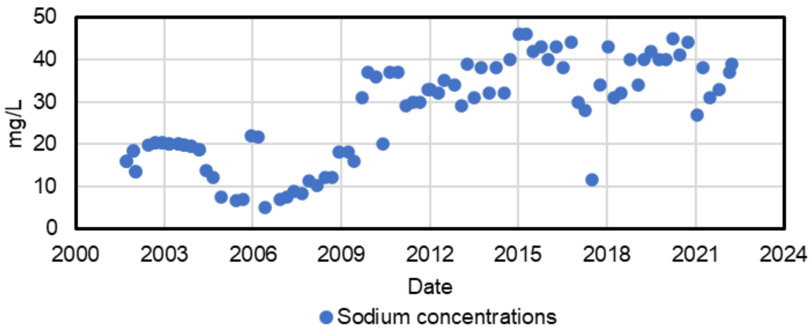


Figure 15. Water quality trends for the Deepdell North backfill continued.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are the dissolved fraction.

A red circle indicates potentially erroneous data.



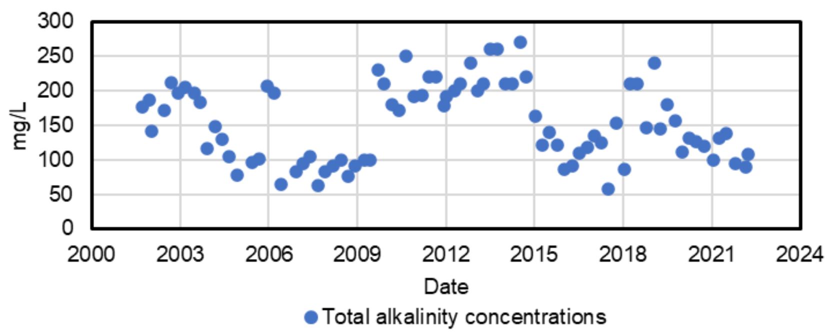


Figure 16. Water quality trends for the Deepdell North backfill continued.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are the dissolved fraction.

2.8.5 Pit Lake Stratification

Stratification in a pit lake (e.g., thermal stratification) can have significant impacts on the distribution of PCOC and other elements in the pit lake water column, which can mean that surficial sampling of the pit water may not be representative of the concentrations at greater depths. This is because during thermal stratification, the water column becomes divided into distinct layers with different temperatures, densities, and oxygen concentrations and potentially different chemical compositions. The warmer, less dense water forms a distinct layer at the surface, while the cooler, denser water forms a separate layer at the bottom of the lake with little mixing of the thermally stratified layers.

Lower oxygen in the bottom waters could potentially prevent the arsenic from oxidising and being removed from the water column through processes like adsorption onto hydrous ferric oxides. Other processes such as denitrification-nitrification and iron oxidation or reduction could also be affected. As a result, the deeper waters of a pit lake can have slightly higher concentrations of arsenic etc.

Previous work has demonstrated thermal stratification within the Globe Pit Lake near Reefton (Hayton et al., 2020) during warmer months with increased concentrations of As at depth (Figure 17) and full mixing of the water during the winter.

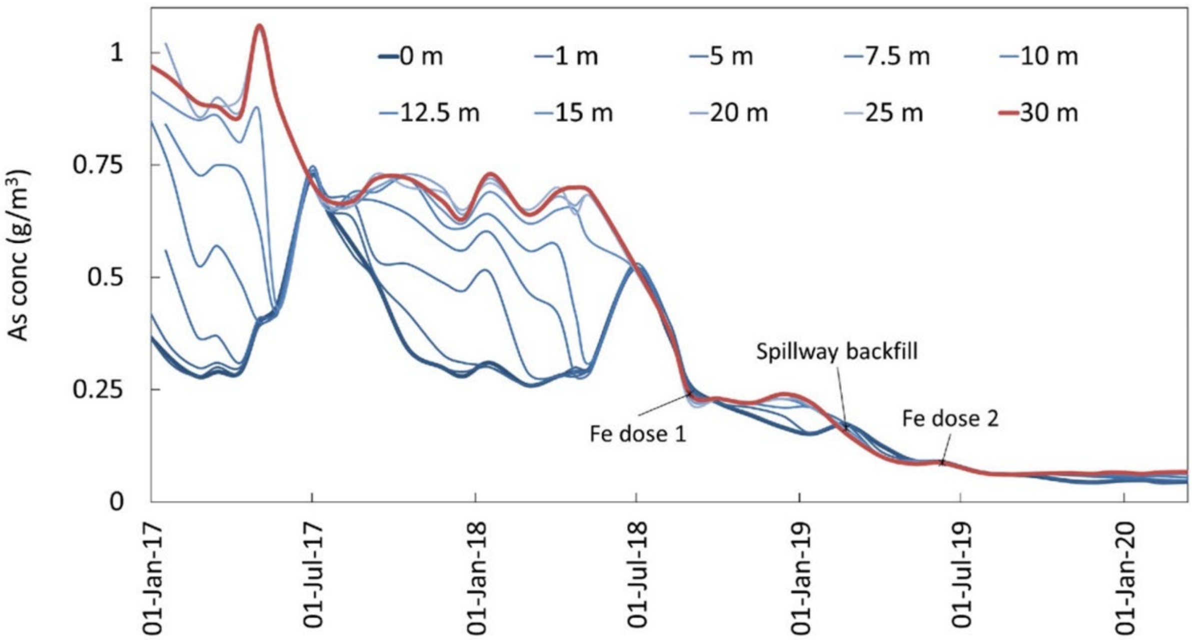


Figure 17. Globe Pit Lake As concentration stratification monitoring data.
Source: Hayton et al (2020).

Two field campaigns were conducted for the current Golden Bar Pit Lake to assess potential stratification effects (Figure 18). The current pit lake is reported to be 45 m deep (GHD, 2023b) and is currently spilling into an un-named tributary of the Golden Bar Creek. Key results include:

- Thermal stratification was identified in the pit lake.
- In the winter (25/10/2022: red line) there was a slight temperature decrease with depth from 11.2°C (at surface) down to 6.6°C (35 m deep), whereas in the summer (31/03/2023: green line) the decrease occurred between 10 - 20 m deep from 12.9°C at the surface down to ~7°C at 20 m depth.

- pH followed a similar trend in summer and winter decreasing at lower depths correlating with lower temperatures.
- EC increased with depth in both sample runs. However, it is more evident in the summer samples. This increase correlates positively with alkalinity and Ca.
- Sulfate concentrations remained constant at 260 – 270 mg/L independent of depth.
- The arsenic concentration was uniform at different depths in the winter (around 0.12 mg/L), but in the summer the concentration increased with depth up to 0.17 mg/L.

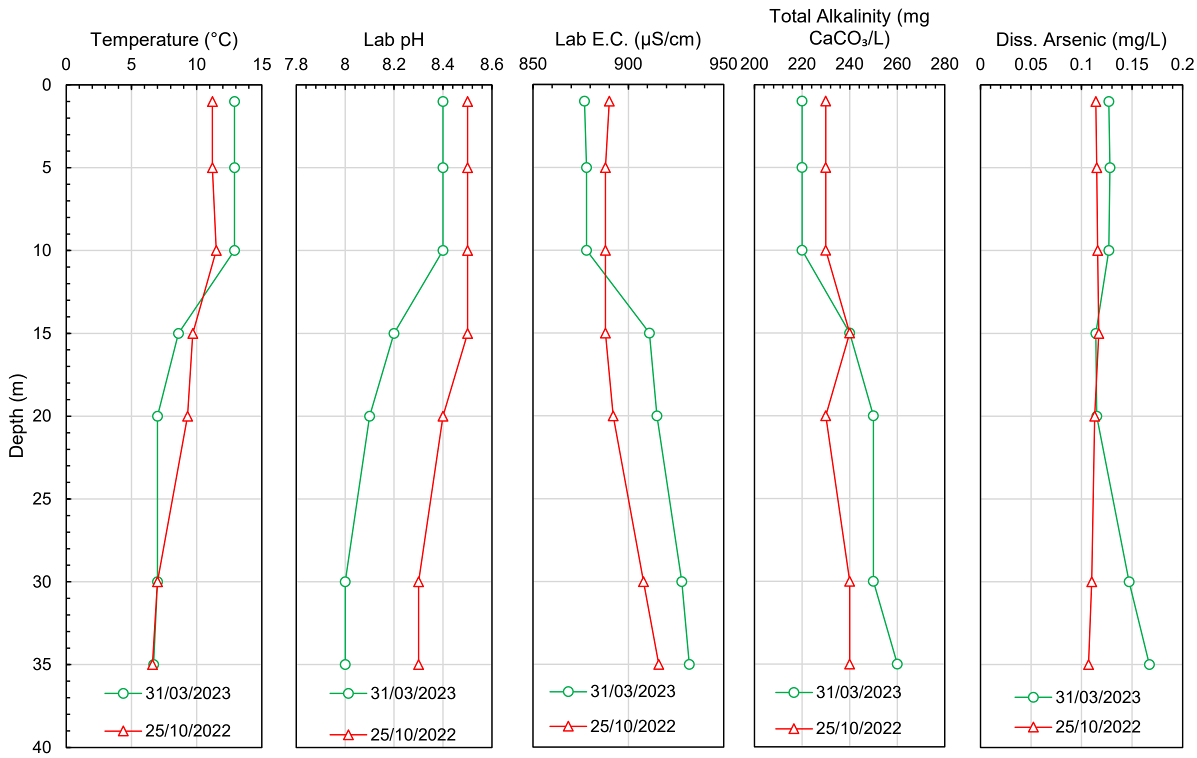


Figure 18. Golden Bar Pit Lake multi-depth analysis results.

It is likely other pit lakes at Macraes will also be affected by thermal stratification causing slightly higher concentrations of As at depth in the summer. Options are available for the treatment of As-rich waters (Section 8) and an appropriate management plan/process should be developed if these pit lakes require dewatering.

2.9 Mine Influenced Water - Tailings Underdrain Seepage

A summary of the average and median water quality data from each of the TSF underdrains are presented in Table 8 with key contaminants presented graphically in Figure 19. TSF underdrainage will be pumped to the final FRIM Pit Lake at closure for a period of 20 years. The following observations are provided:

- Data for each underdrain was only comprised of a single sampling location except for the MTI and the SP11 underdrains:
    - **MTI**: the Sump B – CDE, CDW, and SSF.

  - **SP11**: USCO Far Eastern Outlet, UD/USCO Western Outlet, UD/USCO Eastern Outlet, SP11, SP10 Combined Seepage Outlet, Far Eastern UD/USCO, CDBC Western Outlet, CDBC Eastern Outlet, Western UD/USCO, and the Middle Tailings Seepage.
- The SO_4 concentration ranges were fairly consistent in MTI with average concentrations being 1,571 mg/L respectively. TTTSF and SP11 were also consistent with average concentrations being 3,094 and 3,119 mg/L.
- Analysis indicated that the most variable parameters for each underdrain were SO_4, As, pH, and Fe (Figure 19).
- pH values within the MTI, TTTSF, and SP11 followed similar trends of slowly increasing from approximately pH 6 to >7.5.
- Weak acid dissociable cyanide concentrations were variable with across the sampling sites, but all showed a trend of decreasing with time.

Murphy's Creek Sediment Pond at the toe of the Frasers West WRS is also plotted in Figure 19 and Figure 20. This water will also be returned to the FRIM Pit Lake at closure. These data were used to develop a source term for hydrogeochemical pit lake modelling.

Table 8. Summary data for each TSF underdrain.

PARAMETER	MTI (1991 - 2022)		TTTSF (2014 - 2021)		SP11 (2006 - 2022)	
	AVE	MED	AVE	MED	AVE	MED
pH (pH units)	6.49	6.46	6.84	7.00	6.70	6.80
EC (µS/cm)	3,476	3,760	4,669	4,840	4,823	5,080
Alkalinity - Total (mg/L as $CaCO_3$)	268.3	196.0	226.8	250.0	414.2	400.0
Alkalinity - Bicarbonate (mg/L as $CaCO_3$)	248.2	166.0	227.4	260.0	395.6	390.0
Carbonate Alkalinity (mg/L as $CaCO_3$)	126.2	110.0	1.06	1.00	189.9	189.5
Hardness-Total (mg/L as $CaCO_3$)	1,532	1,420	2,432	2,500	2,462	2,600
Nitrate-N	1.20	0.10	1.385	1.245	0.108	0.02
Nitrate-N + Nitrite-N	0.59	0.05	1.378	1.290	0.079	0.02
Nitrite-N	0.05	0.02	0.075	0.064	0.03	0.02
Nitrogen-Total	7.03	7.25	-	-	24.26	0.135
Nitrogen-Total Ammoniacal	9.1	11.0	7.36	7.40	7.38	8.00
Total Inorganic Nitrogen	10.8	13.7	8.83	8.85	7.55	7.90
As	1.94	1.70	3.14	3.60	8.34	4.90
Ca	231.1	216.0	432.1	440.0	479.9	490.0
Cd	0.0001	0.0001	-	-	0.00014	0.00014
Cl	85.2	65.4	21.4	21.0	27.4	24.0
$CN_{(WAD)}$	0.66	0.47	0.055	0.02	0.046	0.012
Cu	0.029	0.01	-	-	0.00498	0.0027
Fe	9.33	8.00	28.8	27.0	36.8	34.0
K	27.5	25.5	50.2	52.0	57.1	54.0
Mg	117.2	101.0	328.8	340.0	321.0	330.0
Na	451.3	500.0	380.0	390.0	461.7	460.0

PARAMETER	MTI (1991 - 2022)		TTTSF (2014 - 2021)		SP11 (2006 - 2022)	
	AVE	MED	AVE	MED	AVE	MED
Pb	0.0027	0.00021	-	-	0.00058	0.00053
Sb	-	-	-	-	0.001	0.001
SO_4	1,571	1,750	3,094	3,200	3,119	3,200
Zn	0.004	0.004	-	-	0.01	0.01
Sum of Anions (meq/L)	55.2	54.0	69.6	71.0	75.3	76.0
Sum of Cations (meq/L)	54.0	53.0	66.8	69.0	71.7	73.0

Source: OceanaGold Mine Water Quality (excel database).

All units are presented in mg/L unless otherwise specified.

pH presented is based on H+ content to present equivalent geochemical data.

A hyphen (-) indicates no value is given.

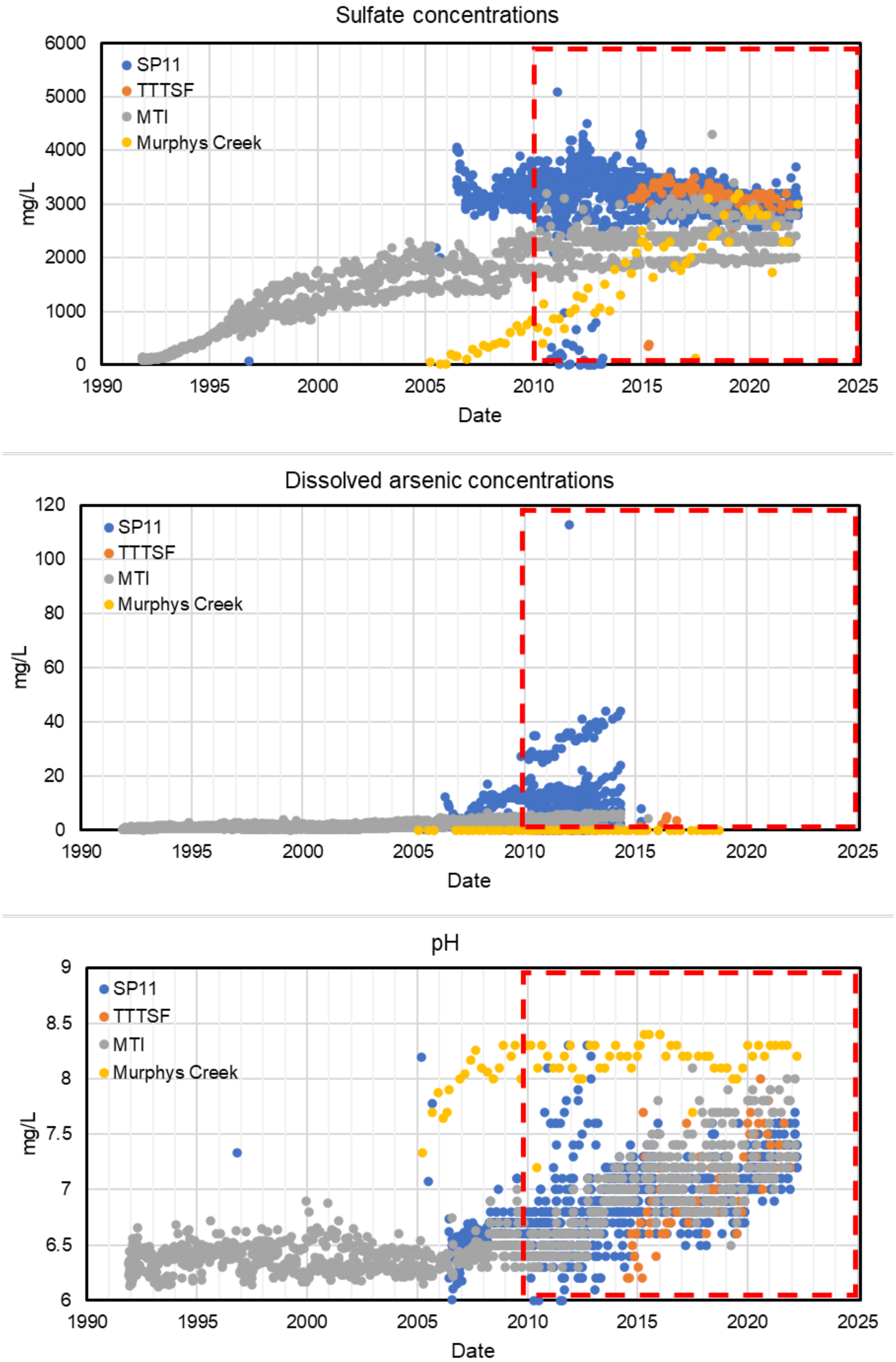


Figure 19. Tailings underdrain water quality and Murphy's water quality data.

Source: OceanaGold Mine Water Quality (excel database).

The red box (2010 data onwards) indicates the data used for the underdrains source term. Murphys Creek used data from 2015 onwards.

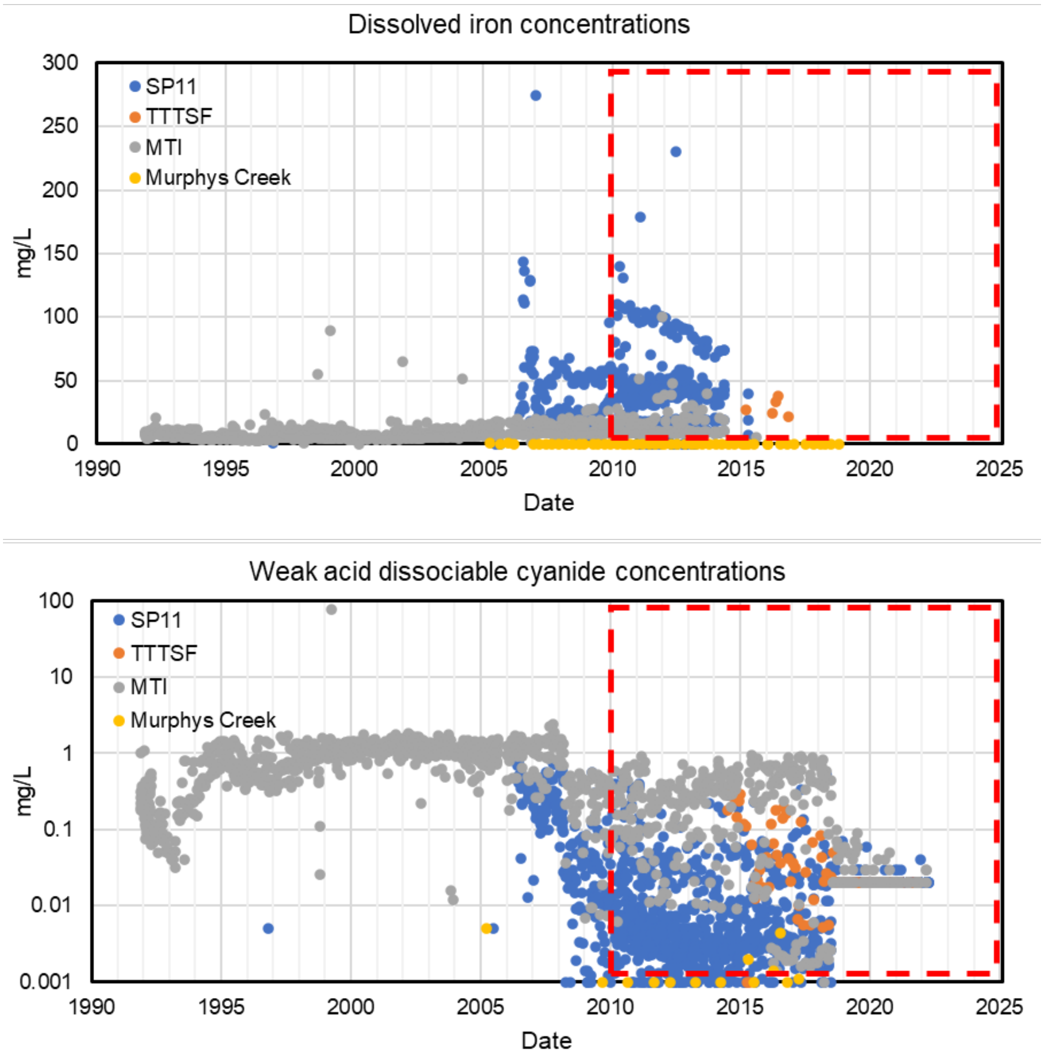


Figure 20. Tailings underdrain water quality and Murphy's water quality data continued.

Source: OceanaGold Mine Water Quality (excel database).

The red box (2010 data onwards) indicates the data used for the underdrains source term. Murphys Creek used data from 2015 onwards.

2.10 Mine Influenced Water - Waste Rock Stacks

The water quality from WRS seepage at Macraes has circum-neutral pH with elevated sulfate and nitrate. It was observed that taller WRSs have higher sulfate concentrations than lower height WRSs (Appendix H). Figure 21 provides a summary of these water quality data for several WRS at Macraes.

It was noted that the sulfate concentrations in seepage from WRSs can reach an approximate maximum concentration and then stabilise, although oscillations are observed. This phenomenon is likely attributed to the WRS reaching a state of geochemical maturity, where the hydraulic properties of the material, rainfall infiltration, oxygen flux, and geochemical reactions have achieved a balance but fluctuate, most likely as a function of rainfall effects.

Babbage (2022) developed a relationship (Eqn. 1) to forecast sulfate concentrations that considered age and average height (volume / area) but there was no limit to the maximum sulfate concentrations with time (i.e., age of the WRS).

$$(Eqn.1): Median\ Sulfate\left(\frac{mg}{L}\right) = 96.1 + 1.22 * \ Average\ Height\ (m) * (4 * Age1(year) + Age2(year))$$

Where Age 1 is the time the WRS is in full operation (not capped) and Age2 years when it was in partial operation (partially capped).

MWM (Appendix I) noted that this would create very high concentrations in any predictive models over the longer term (e.g., 100 years) due to the age multiplier. Instead, a sulfate ceiling limit was proposed, based on empirical data for WRS of differing height.

To determine the expected sulfate concentration for predictive modelling, a correlation between the maximum sulfate concentration and WRS height was used (Eqn. 2 and Eqn. 3):

$$(Eqn.2): Average\ Height < 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 850\exp\left(0.025\ \times\ Average\ Height\ (m)\right)$$

$$(Eqn.3): Average\ Height \geq 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 120\exp\ (0.0965\ \times\ Average\ Height\ (m))$$

The relationship provided suitable source terms for WRS seepage for pit lake water quality modelling where the maximum data were used, which is considered conservative. Median data were used to compare current water quality trends (e.g., 2023 data) for Coronation WRS (Figure 21) demonstrating median data are a reasonable fit and that maximum data are a conservative approach for modelling.

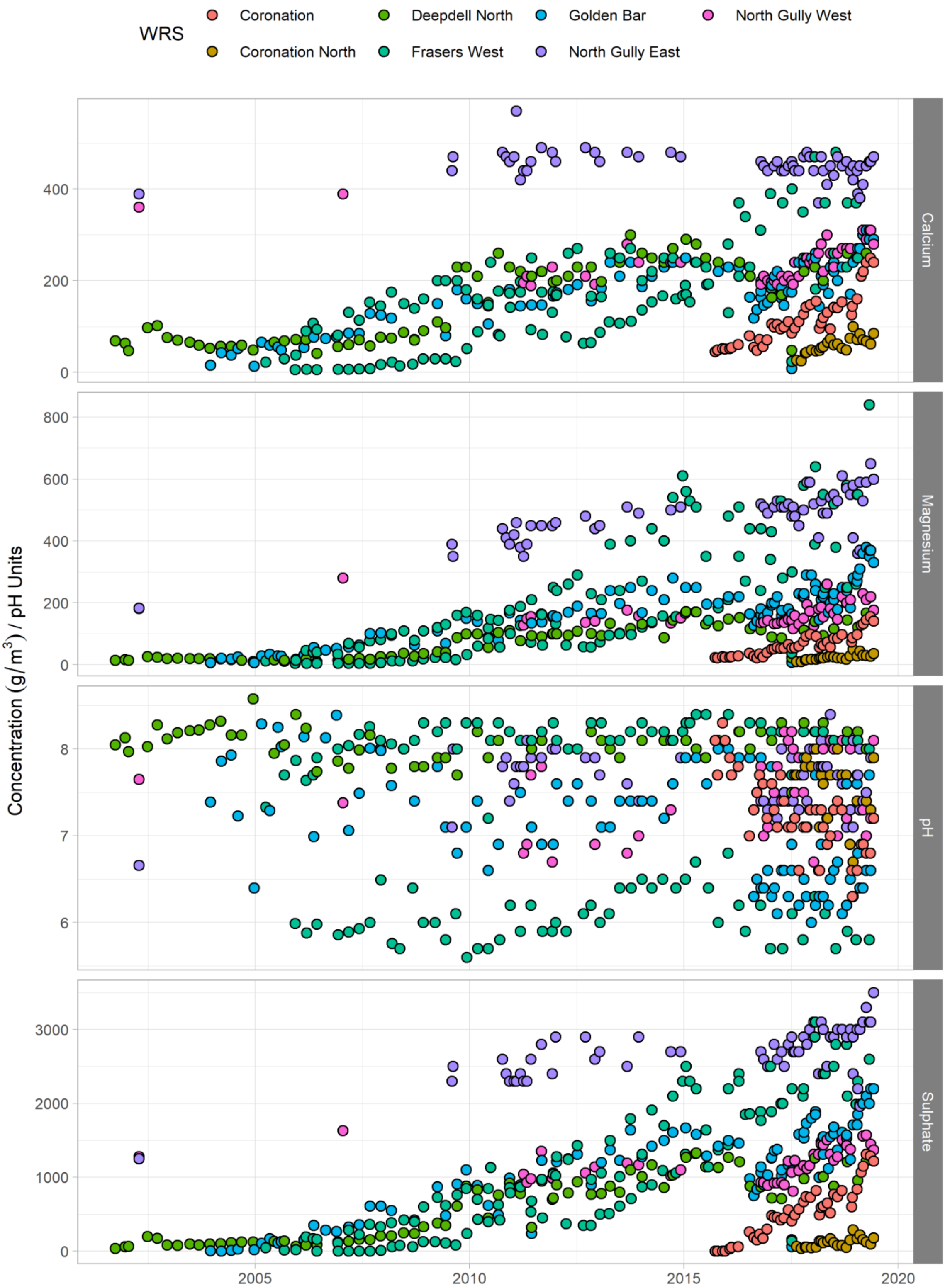


Figure 21: WRS seepage water quality trends.

Image Source: Babbage (2022).

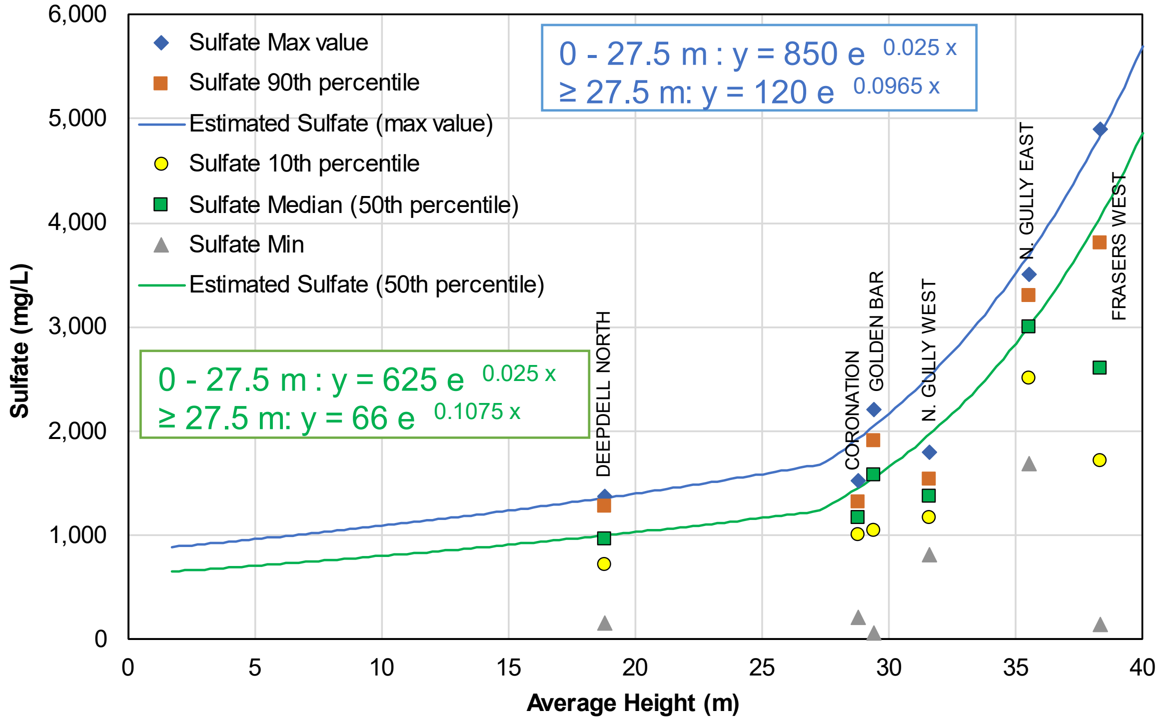


Figure 22. WRS average height versus sulfate concentrations.

Image Source: MWM (2023) Appendix I.

2.11 Conceptual Site Model

Several conceptual site models (CSMs) have been developed to facilitate the assessment of AMD risks for the project. The models are based on final closure plans for Macraes Phase 4.3 (OceanaGold, 2023). The following section presents each of the CSMs and the key components and processes associated with each pit lake model.

2.11.1 Golden Bar

Golden Bar Pit Lake (GPL) was separated into two CSM:

- Golden Bar Stage 1 (Current) Pit Lake where current water quality in GPL was used as an analogue for the future pit expansion; and
- Golden Bar Stage 2.

2.11.1.1 <u>Golden Bar Stage 1 Current Pit Lake</u>

A CSM was developed to facilitate the assessment of the potential environmental risks for the current GPL. The CSM (Figure 23) shows the current GPL with key features being discussed in Table 9. Further details of source derivation can be found in Appendix J.

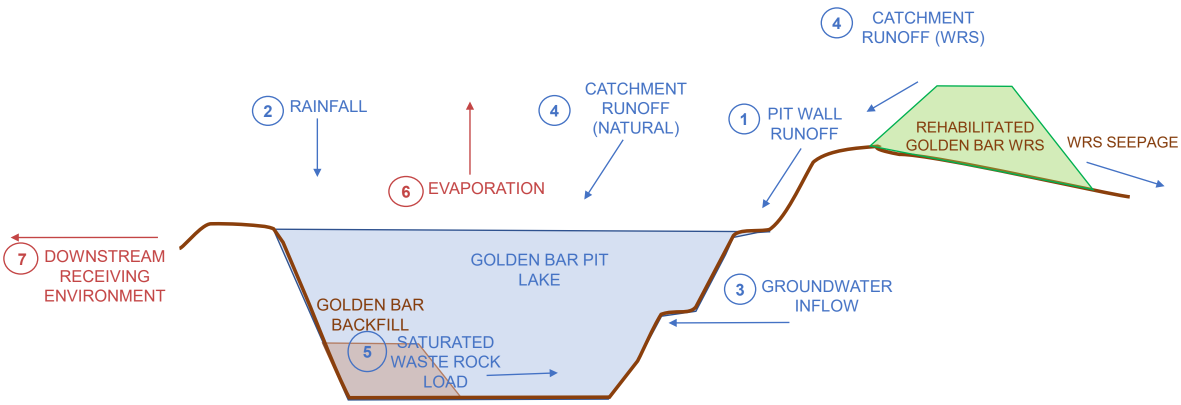


Figure 23. Conceptual Site Model for the Golden Bar Pit Lake Analogue Model.

Source: MWM (2023b), Appendix J.

Table 9. Key components and processes of the Golden Bar Pit Lake Analogue Model.

MODEL FEATURE	SUMMARY	DATA SOURCE
	MODEL INPUTS	
1	Pit wall run-off to GPL	Analogue Model: Water quality derived from the GPL water quality data (as discussed in proceeding sections)
2	Direct rainfall to the GPL.	Water quality derived from Nichol et al. (1997).
3	Groundwater inflow.	Groundwater inflow water quality data derived from monitoring wells MAC-RCH3004.
4	Catchment runoff for natural and rehabilitated WRS	Surface water quality data derived from the monitoring point GB02.
5	Saturated backfill load (below the water level).	The effect of the saturated backfill load solute release was conservatively allocated to the pit wall run-off source term.
	MODEL OUTPUTS	
6	Evaporation	Evaporation of water causes an increase in concentration of solutes. Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations (also known as evapoconcentration). Rates determined by GHD (2023).
7	Outflow (spill) to downstream environment.	Determined by GHD (2023).

2.11.1.2 Golden Bar Stage 2

A CSM was developed to facilitate the assessment of water quality risks for the Golden Bar Stage 2 Pit Lake (Figure 24) and is based on the proposed final closure design for the project. The key features of the CSM, as noted in Figure 24, are presented in Table 10. Further details of source derivation can be found in Appendix K.

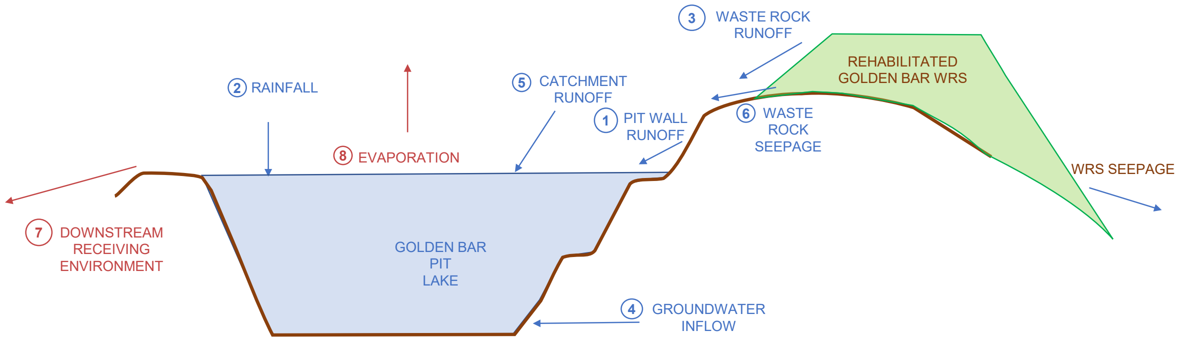


Figure 24. Conceptual Site Model for the Golden Bar Stage 2 Pit Lake.

Source: MWM (2023c), Appendix K.

Table 10. Key components and processes of the Golden Bar Stage 2 Pit Lake Model.

MODEL FEATURE	SUMMARY	DATA SOURCE
	MODEL INPUTS	
1	Pit wall run-off to the Pit Lake	Water quality derived from the Golden Bar Pit Lake Analogue Model (MWM, 2024a).
2	Direct rainfall to the Pit Lake.	Water quality was derived from Nichol et al. (1997).
3	WRS runoff to the Pit Lake.	Water quality derived from monitoring point GB02 before it was influenced by the pit lake discharge.
4	Groundwater inflow.	Groundwater inflow water quality data derived from monitoring wells MAC-RCH3004.
5	Catchment runoff.	Surface water quality data derived from the monitoring point GB02 before it was influenced by the pit lake discharge.
6	WRS seepage.	Derived from empirical correlations (Babbage, 2019, 2022 and MWM, 2024a).
	MODEL OUTPUTS	
7	Outflow (spill) to downstream environment.	Rates determined by GHD (2023) discharging to the NBWR tributary.
8	Evaporation	Evaporation of water causes an increase in concentration of solutes. Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations (also known as evapoconcentration). Rates determined by GHD (2023).

2.11.2 Coronation Stage 5/6

A CSM has been developed to facilitate the assessment of AMD (Figure 25) and is based on the proposed final closure design for the project. The key features of the CSM noted in Figure 25, are presented in Figure 12. Further details of source derivation can be found in Appendix L.

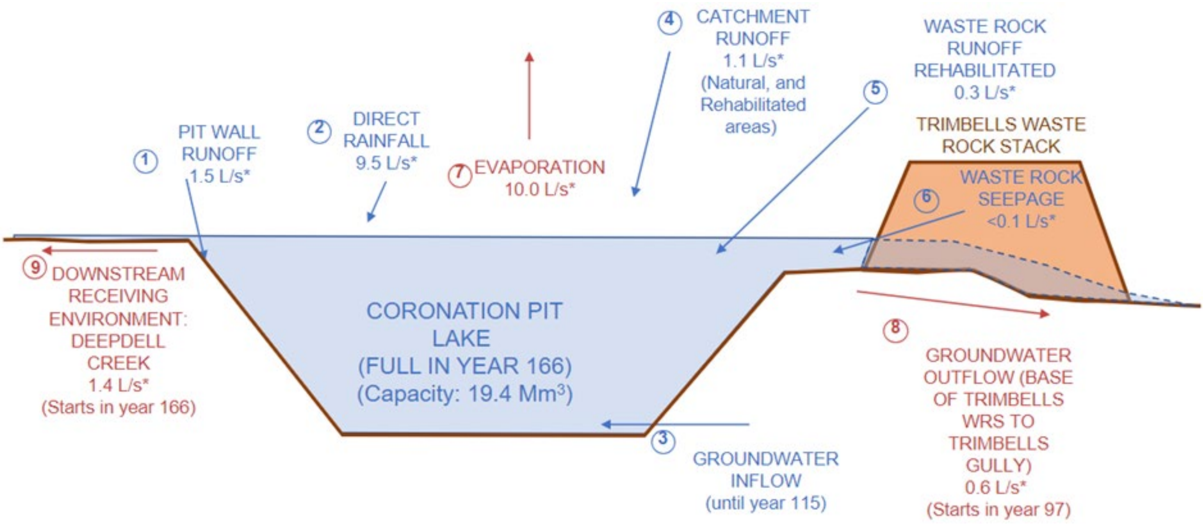


Figure 25. Conceptual Site Model for Coronation Stage 5/6 Pit Lake model.

Source: MWM (2023d).

Table 11. Key components and processes of the Coronation Stage 5/6 Pit Lake Model.

MODEL FEATURE	SUMMARY	DATA SOURCE
	MODEL INPUTS	
1	Pit wall run-off to the Pit Lake	Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
2	Direct rainfall to the Pit Lake.	Water quality derived from Nichol et al. (1997).
3	Groundwater inflow.	Groundwater inflow water quality data derived from monitoring wells MAC-CP02 and MAC-CP04.
4	Catchment runoff.	Surface water quality data derived from the monitoring point DC08. Includes impacted and non-impacted areas (natural catchment). It is assumed that impacted areas are rehabilitated.
5	Waste Rock Runoff (Rehabilitated)	Assumed to be rehabilitated and therefore has the same water quality as 4. Catchment runoff derived from the monitoring point DC08.
6	WRS seepage from Trimbells	Derived from empirical correlations (Babbage, 2019, 2022, and MWM, 2023).
	MODEL OUTPUTS	
7	Evaporation	Evaporation of water causes an increase in concentration of solutes. Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations (also known as evapoconcentration). Rates determined by GHD (2023).

MODEL FEATURE	SUMMARY	DATA SOURCE
8	Groundwater outflow.	Determined by GHD (2023) and represents the water that outflows through the Trimbells WRS due to the higher hydraulic conductivity of the waste rock compared to the bedrock.
9	Outflow (spill) to downstream environment.	Determined by GHD (2023) representing the water that discharges to Deepdell Creek.

2.11.3 Frasers TSF and FRIM Pit Lake

The CSM is presented to provide a visual schematic of the FTSF and FRIM to understand the components of the water balance model (Figure 26) and is based on the proposed final closure design. The key features of the CSM and the derivation of the source terms, noted in Figure 26, are presented in Table 12. Further details of source derivation can be found in Appendix M.

Table 12. Key components and processes of the FRIM Pit Lake Model.

MODEL FEATURE	WATER COMPONENT	SUB-DOMAIN WHERE WATER COMPONENT IS USED		DATA DESCRIPTION AND SOURCE
		FTSF	IM	
MODEL INPUTS				
1	Frasers TSF Pit Lake Initial Water Composition	X		Initial Frasers TSF water quality derived from the average of the TTTSF Impoundment water quality from Year 2016 onwards.
2	IM Initial Water Composition		X	This was determined from IM Pit Sump water quality (1996 - 2004).
3	Rainfall Direct (m^3)	X	X	Water quality derived from Nichol et al. (1997).
4	Runoff_Breakdown [Impacted Rehab]	X	X	Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
5	Runoff_Breakdown [Pit]	X	X	Pit Wall run-off water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
6	Runoff_Breakdown [WRS Nonrehab]	X		Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
7	Runoff_Breakdown [WRS Rehab]	X	X	Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
8	Frasers East Sump Inflow [Impacted]	X		Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
9	Frasers East Sump Inflow [Natural]	X		Natural source term, derived from monitoring point GB02, average values from 2007 – 2014.

MODEL FEATURE	WATER COMPONENT	SUB-DOMAIN WHERE WATER COMPONENT IS USED		DATA DESCRIPTION AND SOURCE
		FTSF	IM	
10	Frasers East Sump Inflow [Impacted Rehab]	X		Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
11	Frasers East Sump Inflow [WRS Non-Rehab]	X		Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
12	Frasers East Sump Inflow [WRS Rehab]	X		Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
13	Frasers East Sump Inflow [TTTSF Rehab]	X		Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
14	Flooded Waste Rock Solute Release	X	X	Solute release from waste rock once saturated by the rising pit lake as defined by the shake flask extraction (SFE) testing data for waste rock as mg/kg.
15	GW Inflow	X	X	Groundwater inflows: Groundwater inflow water quality data derived from groundwater monitoring well FDB03.
16	Inflow (overflow) from Frasers to IM and vice versa	X	X	Overflow from FTSF Pit Lake to IM Pit Lake and the other way around.
17	Waste Rock Stack Seepage	X	X	Drainage to FTSF Pit Lake: Assumed to be a water quality like the Frasers West WRS seepage. Drainage to Innes Mills Pit Lake: Assumed to be water quality like the North Gully East WRS seepage.
18	Murphy's Pond Seepage Return		X	Average water quality of Murphy's Silt Pond monitoring point from 2010 onwards.
19	TSF Underdrain Return	X		Average for the TTTSF, SP11 TSF, and MTI TSF underdrains as separate flow paths for selected periods of time (when stable).
20	Tailings Pore Water	X		Assumed to be similar to the TTTSF Underdrain water quality.
		MODEL OUTPUTS		
21	Evaporation	X	X	Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations.
22	Groundwater Loss	X	X	Groundwater loss to the aquifer including seepage flow through Frasers WRS
23	Groundwater to lower mRL	X		Groundwater from FR Pit through the rock or backfill to IM Pit
24	Overflow	X	X	Overflow from FTSF Pit Lake to IM Pit Lake and vice versa.

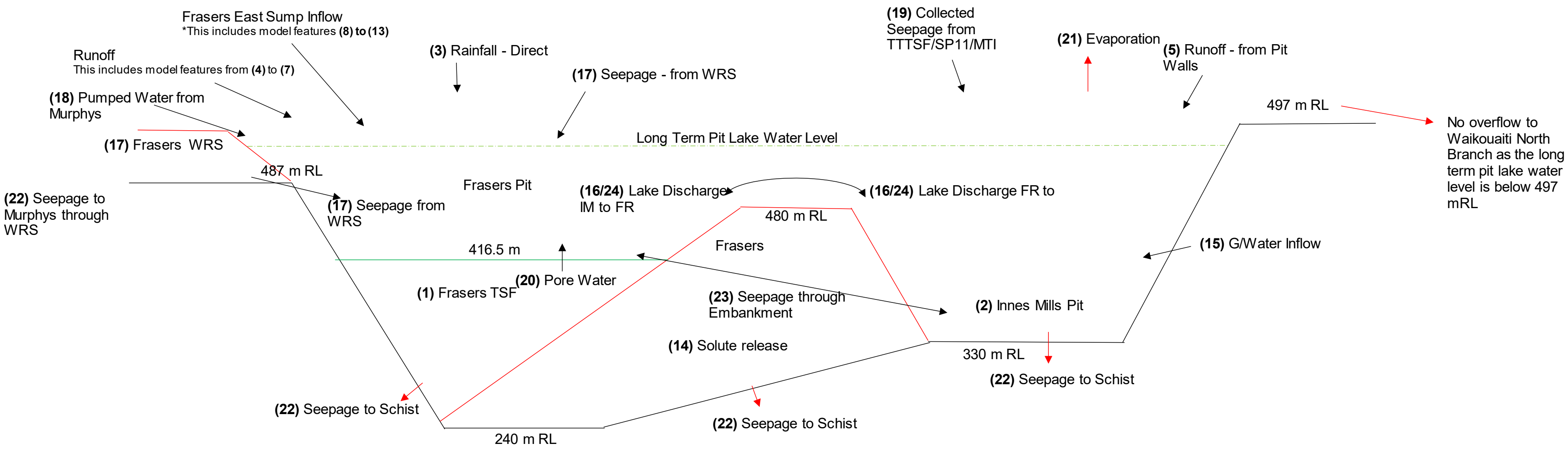


Figure 26. Conceptual site model for the FRIM Pit Lake.

Source: Modified from GHD (2023).

2.11.4 Coronation North Backfill

The CSM for Coronation North Backfill is presented in to provide a visual schematic to explain the water flow paths. No hydrogeochemical modelling was undertaken, however source terms were developed for:

- Toe seepage from the WRS to surface waters (water component 3)
- Backfill seepage water quality to groundwater (water component 6).

All other components of the model were assessed by GHD (2024) as part of the site-wide water balance model.

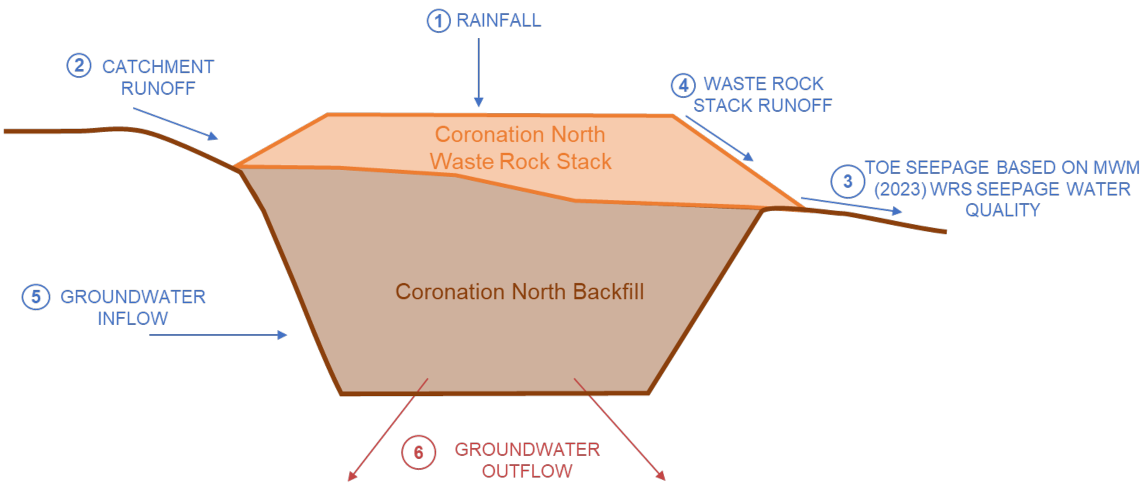


Figure 27. Conceptual site model for the Coronation North Backfill.

3 MATERIALS CHARACTERISATION RESULTS

In this section, results for the materials characterisation are presented and described. Characterisation methodologies are described in Appendix D, which also provides an explanation of the sample selection process and acronyms. ABA summary data are provided in Appendix E. Data for SPIM[3] and Round Hill have also been provided for context to demonstrate the general nature of the materials associated with the MP4.3 project.

Additional representative data have been presented here to confirm that the materials that will be excavated as part of this project are not different to previous materials (as discussed in Section 2.5) and that the environmental effects of the MP4.3 Project are likely to be similar to previous activities.

3.1 Waste Rock

3.1.1 Paste pH and EC

A summary of paste pH/EC data are provided for waste rock samples in Table 13 for each pit domain. with paste pH ranging from 7.53 to 9.44 (neutral to alkaline).

Table 13. Waste rock descriptive statistics for each pit domain.

PIT DOMAIN	PARAMETER	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
SPIM (n=19)	Paste pH	8.80	0.41	7.53	8.94	9.35
	EC (µS/cm)	236	143.7	142	190	699
Innes Mills (n=18)	Paste pH	9.10	0.18	8.69	9.11	9.44
	EC (µS/cm)	224	35.8	160	220	299
Round Hill (n=8)	Paste pH	9.26	0.11	9.11	9.22	9.44
	EC (µS/cm)	194	51.9	126	182	299
Golden Bar (n=8)	Paste pH	8.84	0.28	8.30	8.84	9.31
	EC (µS/cm)	283	46	252	265	396
Coronation (n=8)	Paste pH	8.73	0.50	7.89	8.75	9.32
	EC (µS/cm)	262	71.3	194	234	406
Total (n=61)	Paste pH	8.94	0.38	7.53	9.03	9.44
	EC (µS/cm)	237	94	126	216	699

Average pH values were reported rather than the log[H^+] as data are similar and of circumneutral nature.

Figure 28 shows graphically the results for paste pH and EC. It is observed that:

- Maximum paste pH values were generally consistent across all pit domains (9.31 – 9.44).
- Samples 13 and 14 (SPIM) had the highest values for EC (594 and 699 µS/cm respectively). These samples were near the waste rock/backfill interface in the SPIM area and may have undergone a higher degree of weathering compared to the insitu samples or may be affected by seepage through the backfill.

[3] *SPIM = Southern Pit / Innes Mills area*

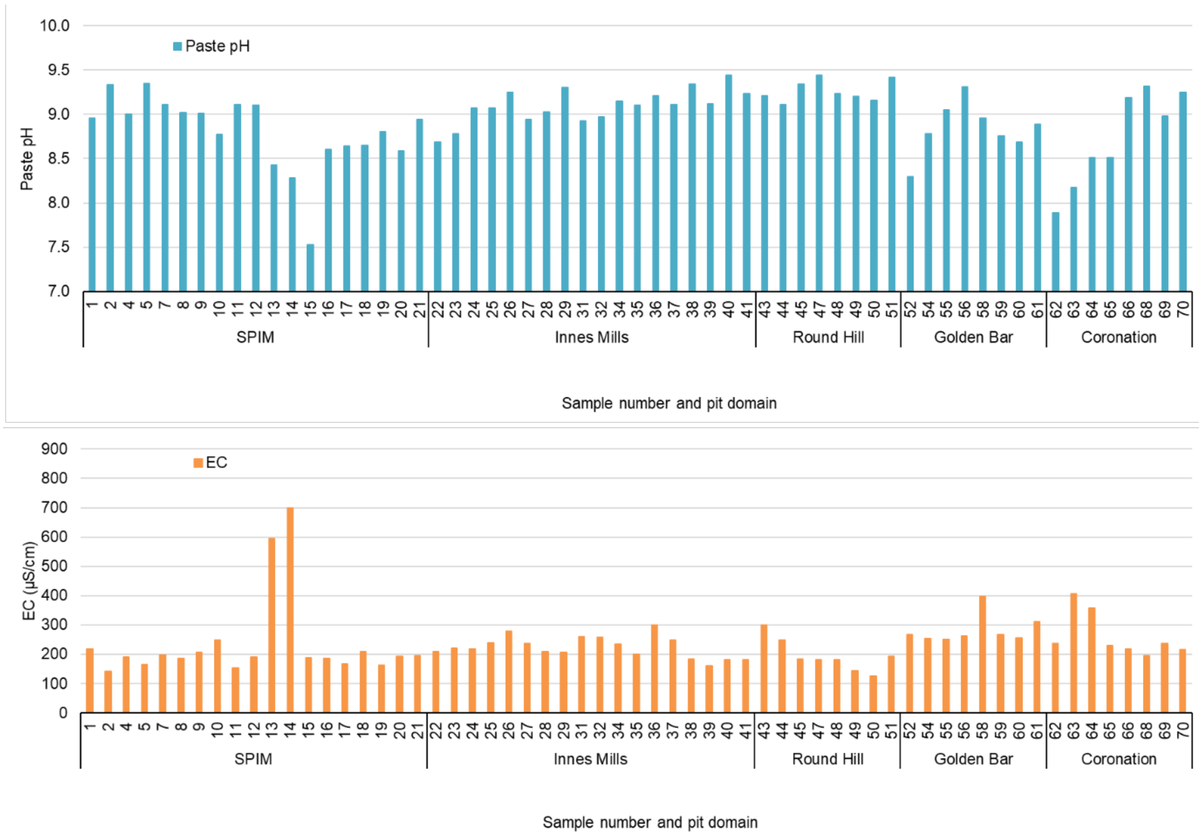


Figure 28. Waste rock paste pH and EC results.

3.1.2 Acid-Base Accounting

This section presents the results for sulfur (S), MPA, ANC, NAPP, and NAG test data for waste rock materials (Table 14).

Table 14. Waste rock ABA and NAG test data summary.

PARAMETER	PIT DOMAIN	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
S (wt. %)	SPIM (n=19)	0.11	0.06	0.007	0.12	0.20
	Innes Mills (n=18)	0.14	0.08	0.007	0.13	0.27
	Round Hill (n=8)	0.14	0.10	0.06	0.12	0.40
	Golden Bar (n=8)	0.16	0.08	0.05	0.15	0.29
	Coronation (n=8)	0.15	0.08	0.06	0.13	0.31
MPA ($kg\ H_2SO_4/t$)	SPIM (n=19)	3.4	1.8	0.2	3.6	6.1
	Innes Mills (n=18)	4.1	2.4	0.2	4.1	8.4
	Round Hill (n=8)	4.4	3.1	1.8	3.5	12.2
	Golden Bar (n=8)	4.8	2.5	1.6	4.7	8.8
	Coronation (n=8)	4.5	2.4	1.7	3.8	9.5
ANC ($kg\ H_2SO_4/t$)	SPIM (n=19)	57.8	26.0	13.4	59.2	98.7
	Innes Mills (n=18)	53.2	15.9	29.1	47.2	84.9
	Round Hill (n=8)	55.5	25.6	14.7	58.4	84.5
	Golden Bar (n=8)	39.6	7.4	29.4	41.0	49.0

PARAMETER	PIT DOMAIN	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
	Coronation (n=8)	48.1	21.3	25.7	41.7	93.5
NAG pH	SPIM (n=19)	9.2	2.4	4.2	10.6	11.4
	Innes Mills (n=18)	8.9	0.8	7.6	8.7	11.0
	Round Hill (n=8)	9.9	1.4	7.8	10.8	11.2
	Golden Bar (n=8)	9.0	0.8	7.6	9.1	10.2
	Coronation (n=8)	9.0	1.0	7.9	8.9	10.7
NAPP (kg H_2SO_4/t)	SPIM (n=19)	-54.4	25.4	-96.3	-54.3	-13.2
	Innes Mills (n=18)	-49.0	15.7	-81.2	-45.3	-25.3
	Round Hill (n=8)	-51.1	27.4	-81.0	-55.5	-8.6
	Golden Bar (n=8)	-34.8	7.1	-46.1	-34.9	-24.4
	Coronation (n=8)	-43.6	21.3	-86.9	-34.8	-20.2
NPR	SPIM (n=19)	24.5	17.9	6.6	19.9	64.1
	Innes Mills (n=18)	27.0	37.8	4.2	16.0	162.6
	Round Hill (n=8)	18.4	12.7	1.7	20.1	44.2
	Golden Bar (n=8)	11.2	6.2	4.3	8.8	21.7
	Coronation (n=8)	14.3	11.1	4.4	12.1	41.8

Red text indicates data that do not meet the Resource Consent Condition RM10.351.10.V1 (Compliance Criteria iv) where NPR must be > 3. Average pH values were reported rather than the log[H+] as data are similar and of circumneutral nature.

3.1.3 Sulfur and Maximum Potential Acidity

Average total sulfur ranged from 0.11 wt% (SPIM) to 0.16 wt% (Golden Bar) with some higher data observed (Figure 29). The SGS laboratory at Macraes ran a comparison of the total sulfur versus sulfide sulfur, based on their experience at Macraes they noted that all sulfur is present as sulfide sulfur in fresh waste rock. Hence, MPA values have been calculated using total sulfur data. Total sulfur data are plotted in Figure 29. Results (Table 14) indicate that average MPA ranges from 3.4 – 4.8 kg H_2SO_4/t. Such data suggest a low capacity to generate acid rock drainage (ARD).

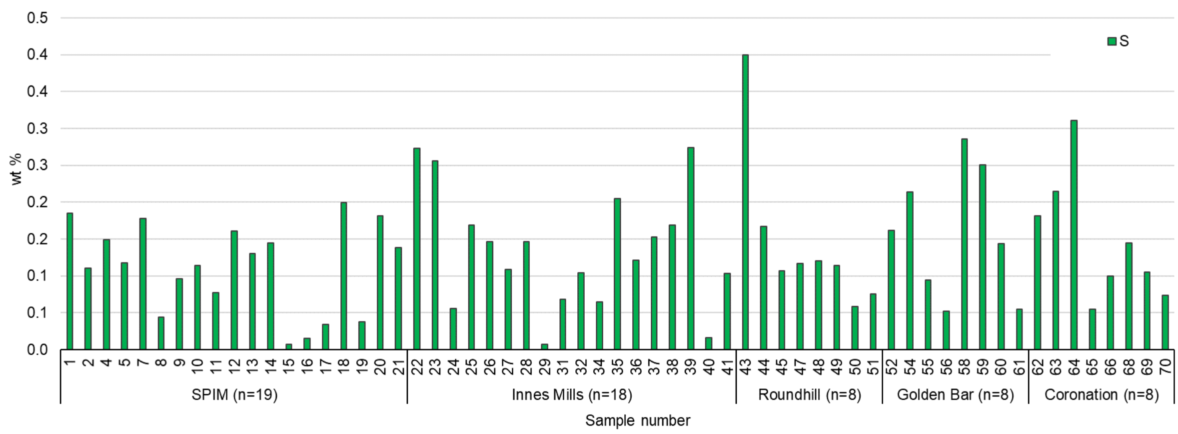


Figure 29. Waste rock total sulfur for each pit.

3.1.4 Acid Neutralisation Capacity – Waste Rock

ANC data are summarised in Table 14 with ANC content for each pit domain shown in Figure 30. The results indicate that samples taken from SPIM had higher average ANC content (57.8 kg H_2SO_4/t) comparatively; the average range for all samples was between 39.6 kg H_2SO_4/t (Golden Bar) to 57.8 kg H_2SO_4/t (SPIM). Some samples had very high ANC values (close to 100 kg H_2SO_4/t). The minimum measured ANC value was from SPIM (13.4 kg H_2SO_4/t) (sample number 15).

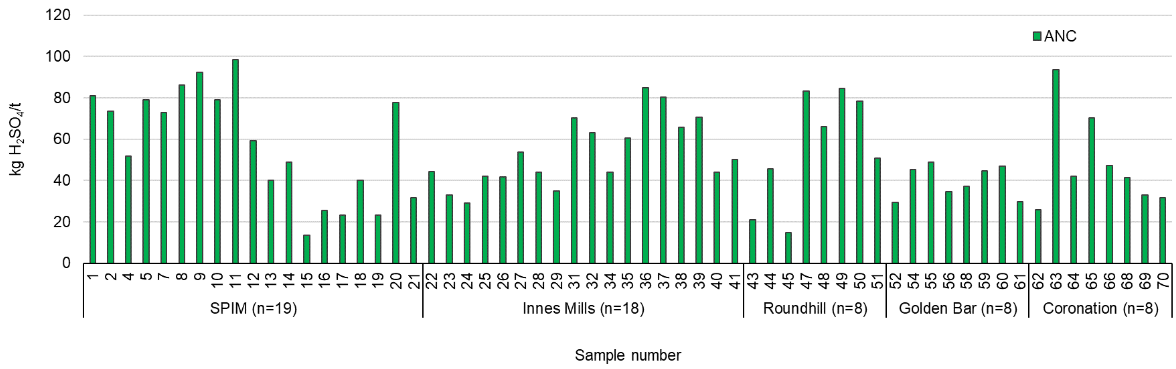


Figure 30. Waste rock ANC content for each pit.

3.2 Low-Grade Ore and Ore

3.2.1 Paste pH and EC

A summary of the results for low grade ore (LGO) and ore samples is provided in Table 15 and Figure 31. From the results it was observed that:

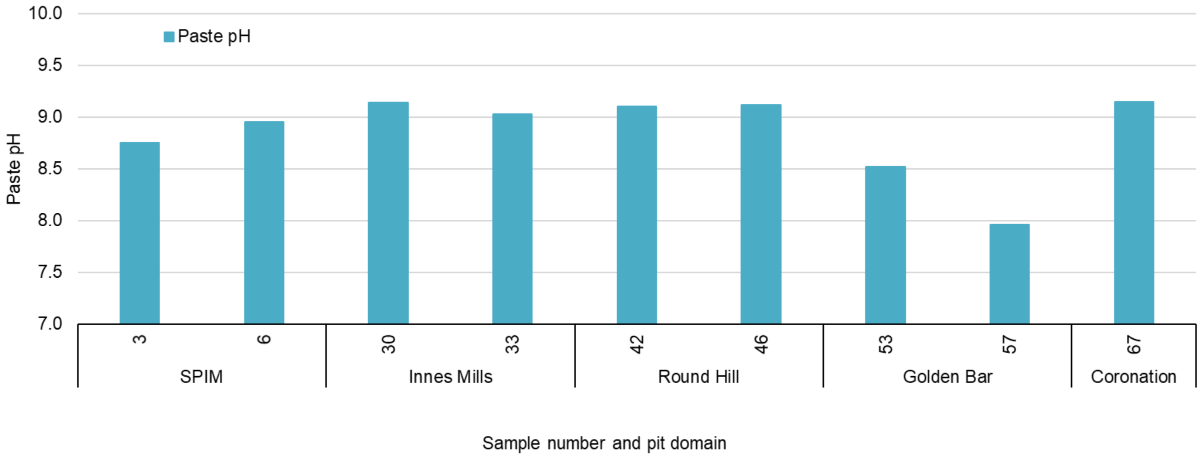
- Paste pH ranged from 7.96 to 9.15 (neutral to alkaline).
- EC ranged from 160 to 793 µS/cm with an average of 286 µS/cm.
- Paste pH and EC values from SPIM, Innes Mills, Round Hill, and Coronation areas were consistent. Sample 57 (Golden Bar) had the highest EC (793 µS/cm) and the lowest pH (7.96) values.

Table 15. LGO and ore descriptive statistics for each pit domain.

PIT DOMAIN	PARAMETER	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
SPIM (n=2)	Paste pH	8.85	0.10	8.75	8.85	8.95
	EC (µS/cm)	229	37.0	192	229	266
Innes Mills (n=2)	Paste pH	9.09	0.06	9.03	9.09	9.14
	EC (µS/cm)	240	22	218	240	262
Round Hill (n=2)	Paste pH	9.11	0.01	9.10	9.11	9.12
	EC (µS/cm)	180	20	160	180	199
Golden Bar (n=2)	Paste pH	8.24	0.28	7.96	8.24	8.52
	EC (µS/cm)	523	271	252	523	793
Coronation (n=1)	Paste pH	-	-	9.15	-	9.15
	EC (µS/cm)	-	-	230	-	230

PIT DOMAIN	PARAMETER	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
Total (n=9)	Paste pH	8.86	0.37	7.96	9.03	9.15
	EC (µS/cm)	286	182	160	230	793

Average pH values were reported rather than the log[H+] as data are similar and of circumneutral nature.



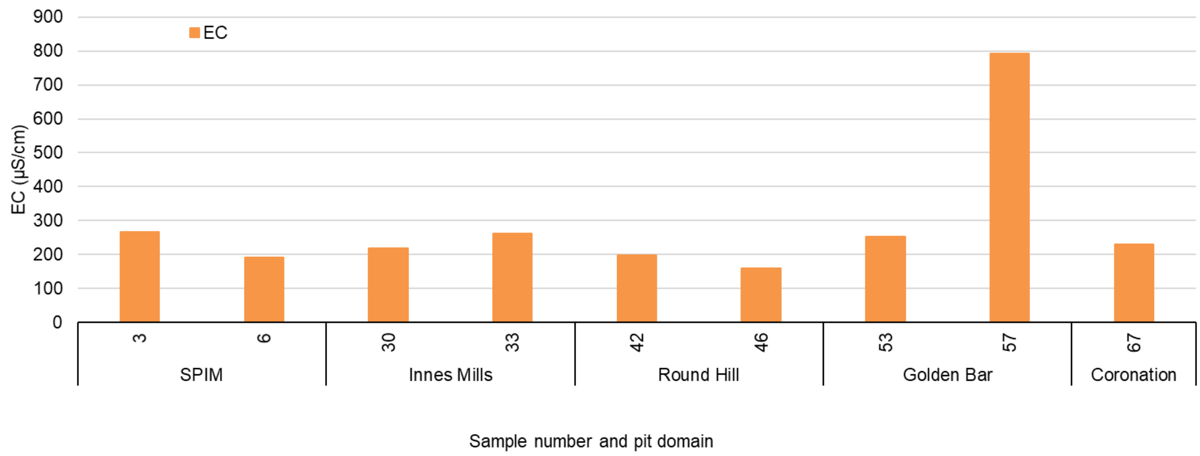


Figure 31. LGO and ore: paste pH and EC results.

3.2.2 Acid-Base Accounting (ABA)

This section presents the results for sulfur (S), MPA, ANC, and NAG test data for waste rock material (Table 16). Results are discussed in the subsequent sections.

Table 16. LGO and ore ABA and NAG test data summary.

PARAMETER	PIT DOMAIN	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
S (wt. %)	SPIM (n=2)	0.46	0.21	0.26	0.46	0.67
	Innes Mills (n=2)	0.25	0.10	0.16	0.25	0.35
	Round Hill (n=2)	0.22	0.06	0.16	0.22	0.27
	Golden Bar (n=2)	1.15	0.95	0.20	1.15	2.10
	Coronation (n=1)	0.16	-	0.16	0.16	0.16
	SPIM (n=2)	14.1	6.3	7.8	14.1	20.4

PARAMETER	PIT DOMAIN	AVERAGE	STANDARD DEVIATION	MINIMUM	MEDIAN	MAXIMUM
MPA (kg H_2SO_4/t)	Innes Mills (n=2)	7.8	3.0	4.7	7.8	10.8
	Round Hill (n=2)	6.7	1.7	5.0	6.7	8.4
	Golden Bar (n=2)	35.2	29.1	6.1	35.2	64.3
	Coronation (n=1)	5.0	-	5.0	5.0	5.0
ANC (kg H_2SO_4/t)	SPIM (n=2)	75.1	6.3	68.8	75.1	81.4
	Innes Mills (n=2)	39.9	6.7	33.2	39.9	46.6
	Round Hill (n=2)	54.5	16.5	38.0	54.5	71.1
	Golden Bar (n=2)	61.1	11.6	49.5	61.1	72.7
	Coronation (n=1)	51.0	-	51.0	51.0	51.0
NAG pH	SPIM (n=2)	10.7	0.04	10.7	10.7	10.8
	Innes Mills (n=2)	8.3	0.1	8.2	8.3	8.3
	Round Hill (n=2)	10.0	1.0	9.1	10.0	11.0
	Golden Bar (n=2)	8.3	0.3	8.0	8.3	8.6
	Coronation (n=1)	8.9	-	8.9	8.9	8.9
NAPP (kg H_2SO_4/t)	SPIM (n=2)	-61.0	12.6	-73.6	-61.0	-48.4
	Innes Mills (n=2)	-32.1	3.7	-35.8	-32.1	-28.4
	Round Hill (n=2)	-47.8	14.9	-62.7	-47.8	-33.0
	Golden Bar (n=2)	-26.0	17.5	-43.4	-26.0	-8.5
	Coronation (n=1)	-46.1	-	-46.1	-46.1	-46.1
NPR	SPIM (n=2)	6.9	3.5	3.4	6.9	10.4
	Innes Mills (n=2)	5.7	1.3	4.3	5.7	7.0
	Round Hill (n=2)	8.0	0.5	7.6	8.0	8.5
	Golden Bar (n=2)	4.6	3.5	1.1	4.6	8.1
	Coronation (n=1)	10.3	-	10.3	10.3	10.3

Red text indicates data that do not meet the Resource Consent Condition RM10.351.10.V1 (Compliance Criteria iv) where NPR must be > 3. Average pH values were reported rather than the log[H+] as data are similar and of circumneutral nature.

3.2.3 Sulfur and Maximum Potential Acidity – LGO and Ore

Average total sulfur ranged from 0.16 wt% (Coronation) to 2.1 wt% (Golden Bar). MPA values have been calculated using total sulfur data, total sulfur content is plotted in Figure 32. Results (Table 16) indicate that average MPA range from 5.0 – 35.2 kg H_2SO_4/t.

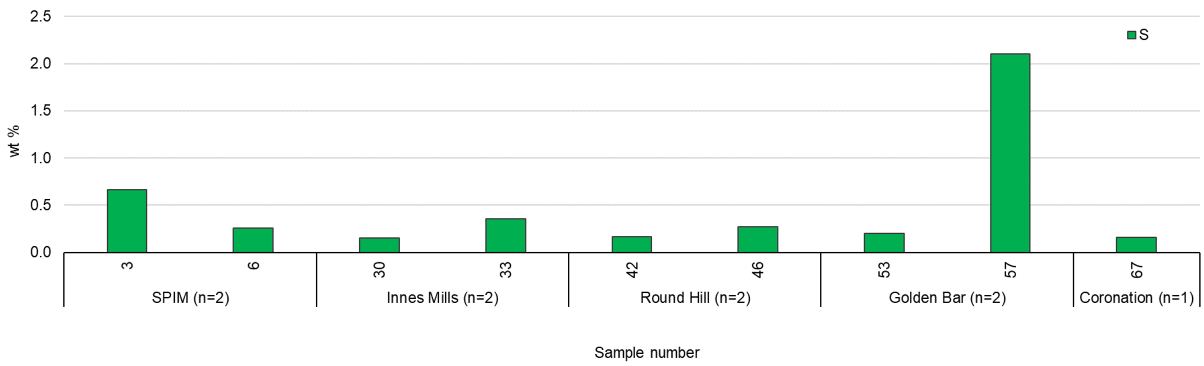


Figure 32. LGO and ore total sulfur content for each pit.

3.2.4 Acid Neutralisation Capacity – LGO and Ore

ANC data are summarised in Table 16 with ANC content for each pit domain shown in Figure 33. The results indicate that samples taken from SPIM had higher average ANC content (75.1 kg H_2SO_4/t) comparatively; the average range for all samples was between 39.9 kg H_2SO_4/t (Innes Mills) to 75.1 kg H_2SO_4/t (SPIM). The minimum ANC value was from Innes Mills (33.2 kg H_2SO_4/t) (sample numbers 30).

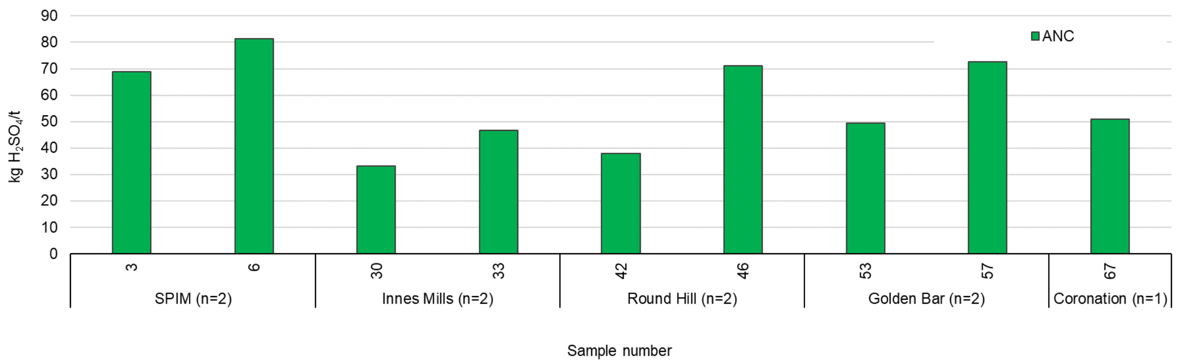


Figure 33. LGO and ore ANC content for each pit domain.

3.3 AMD Classification

The classification of waste rock, LGO, and ore are assessed by three classification methods.

3.3.1 AMIRA Classification Scheme

According to the AMIRA (2002) classification 68 out of the 70 samples are classified as NAF with the remaining two samples being classified as uncertain. The classification process using NAG pH and NAPP is shown in Figure 34. It is noted that:

- The two samples with low NAG pH (< 4.5) are NAPP negative demonstrating significant ANC in excess of the maximum potential acidity. It is noted that these samples are only slightly less than 4.5 but also relate to a grouping of other data that is lower NAG pH.

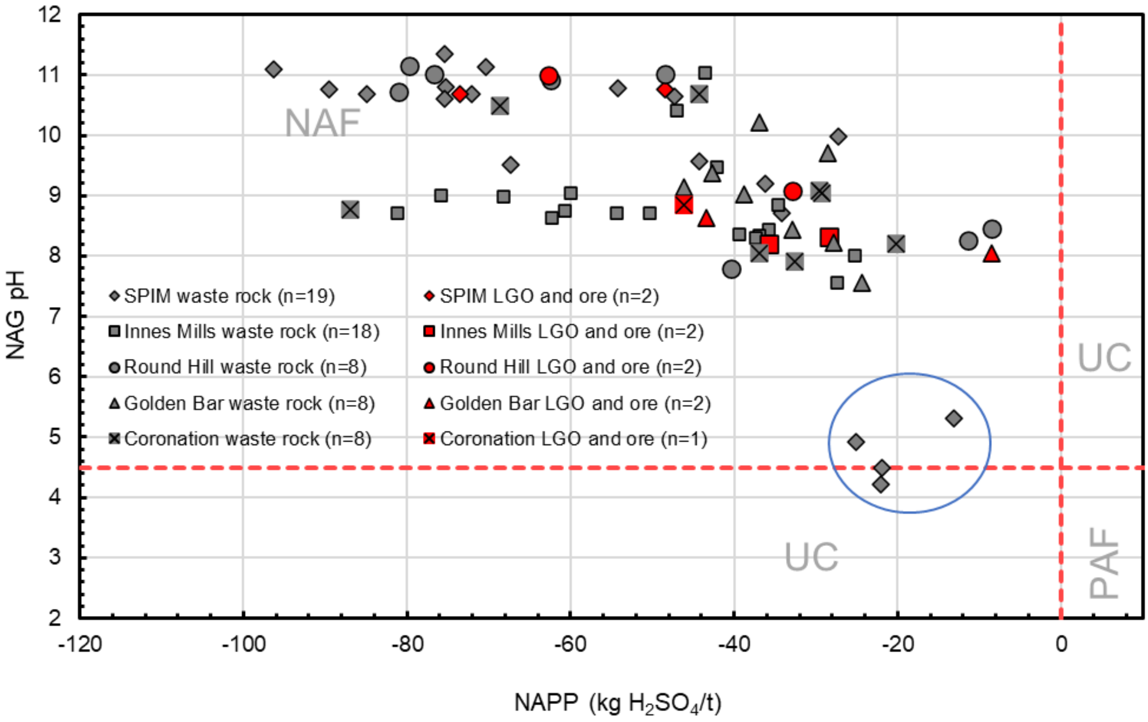


Figure 34. AMIRA (2002) classification based on NAPP and NAG pH data.

3.3.2 Resource Consent Classification System

Resource Consent (RM10.351.10.V1 – Compliance Criteria iv) requires all waste rock to have a neutralisation potential ratio (NPR) > 3. The NPR summary is provided in Figure 35 using the 3:1 ratio as the cut-off value for NAF materials.

Data shown in Figure 35 indicates that the majority of the materials tested are NAF and two samples having a NPR between 1-2, which can be considered uncertain by the Price (2009) methodology. The Price (2009) and Resource Consent classification processes do not consider NAG data, being reliant on one test methodology, which can also be problematic. NAG pH data for these two uncertain samples were > pH 8. One sample is ore and will be processed. The other sample is waste rock from Golden Bar.

Several samples were identified as being higher risk for AMD (Blue circle: Figure 34) being either classified as uncertain or had a lower NAG pH value (and were from SPIM). Such materials either require further work to quantify the AMD hazard, or as a precautionary approach the materials associated with these samples should be placed within the core of any WRS away from oxygen. These SPIM materials will not be mined as part of the proposed MP4.3 project, which means the effects do not need to be considered for this assessment of environmental effects for the project.

From an overall AMD hazards assessment perspective these materials, represented by samples that are classified as Uncertain, are unlikely to change the general geochemical nature of the bulk waste rock or the expected water quality for the project. It is recommended this consent condition should be reviewed and that the NPR (of 3) is overly prescriptive given the low risk for acid rock drainage at the site.

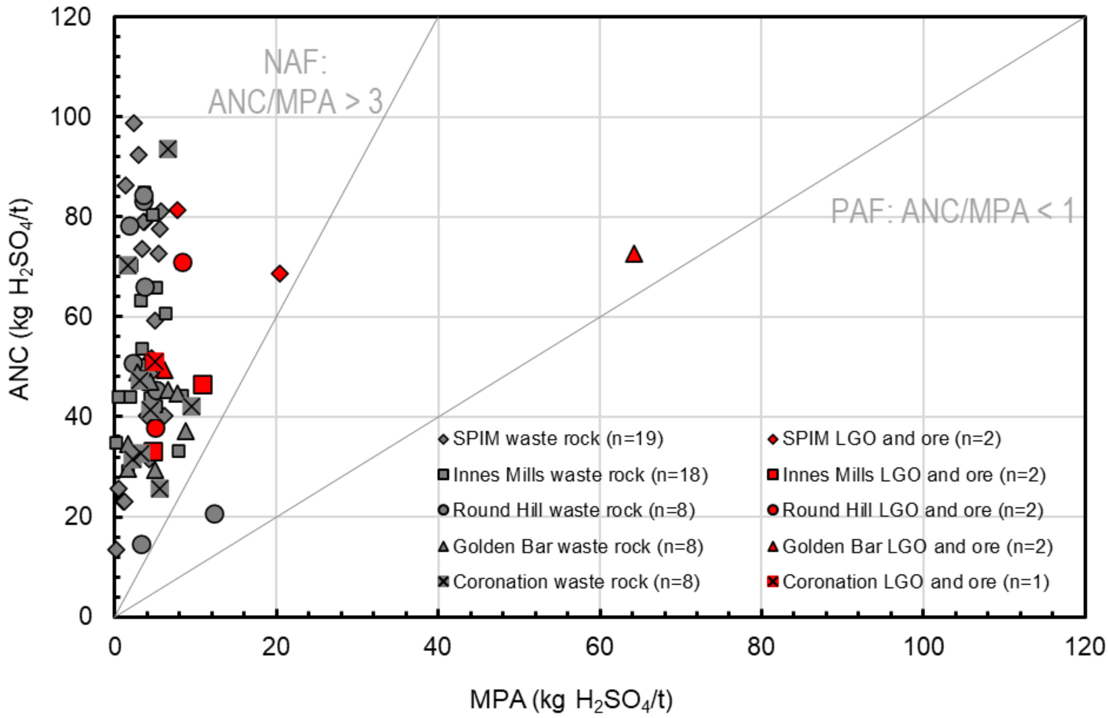


Figure 35. ANC/MPA ratio classification.

3:1 classification line based on resource consent RM10.351.10.V1 – Compliance Criteria iv.

Samples with 1> NPR < 3 are classified as uncertain classification and further work is required to validate whether acid drainage is an issue.

3.3.3 Paste pH versus NAG pH Classification

Paste pH versus NAG pH can be used to understand any time lag to acid onset (Weber et al., 2006) and data has been plotted in Figure 36. Two distinct grouping can be seen:

- Blue circle: largest group clustering across all domains (NAG pH 7.6 to 11.4).
- Red circle: SPIM with NAG pH values between 4.2 to 5.3.

Data indicates that generally all samples are NAF, although two waste rock samples from SPIM (sample numbers 17 and 19) were classified as PAF based on NAG pH values of 4.22 and 4.49, respectively. However, paste pH data suggests that there will be a time lag to the onset of acidity. SPIM samples will not be mined as part of this project. Data demonstrates that the project materials are NAF and are unlikely to generate acid drainage.

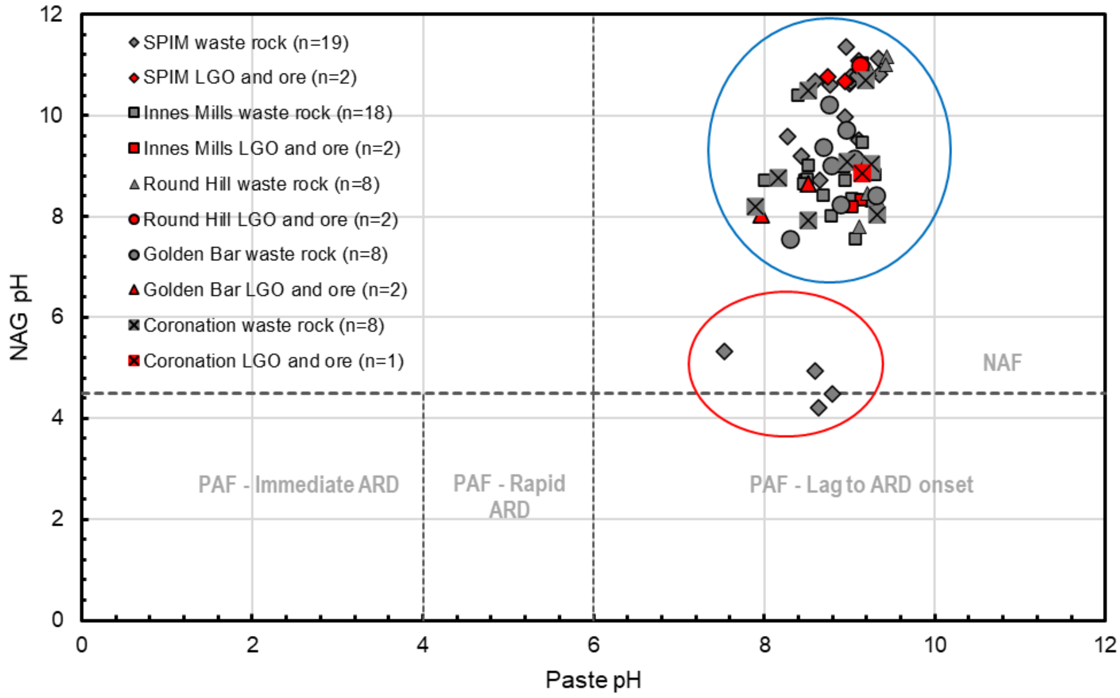


Figure 36. Paste pH NAG pH comparison.

3.3.4 AMD Waste Rock Classification Summary

Although two samples are classified as uncertain by the AMIRA (2002) classification process; two samples are classified as uncertain by the Price (2009) classification; and one sample does not comply with the resource consent classification, it is reasonable to assume that overall acid rock drainage is not expected from these materials. This is supported by field monitoring data that indicates no acid rock drainage has been observed on site.

3.4 Shake Flask Extraction

This section presents the data for the shake flask extractions (SFE) under oxic and reducing conditions to understand the mobility of PCOC from the materials. Shake flask data are available for materials from SPIM and Innes Mills. A limited number of samples were selected to provide a representative sample population for the schist. Key data are presented graphically in Figure 37 for pH, alkalinity, Mn, As, nitrate + nitrite, and sulfate. Full results are presented in the Appendix F. Further details are provided in Table 17. The following observations are provided:

- pH values for the oxic SFE are lower than the anoxic SFE, and at the same time, alkalinity was reported as being higher in the oxic samples.
- Arsenic concentrations are present above the limit of reporting (LOR) in the in-situ waste rock from Innes Mills (Sample 40 and 41)
- Mn is higher in the oxic samples for insitu waste rock from Innes Mills.
- The majority of the nitrate + nitrite concentrations are in the nitrate form (Table 17). Results indicate that nitrate is higher in the backfill waste rock (samples 35 to 39) compared to the in-situ waste rock. This nitrate is likely to be associated with blasting residues (ANFO).

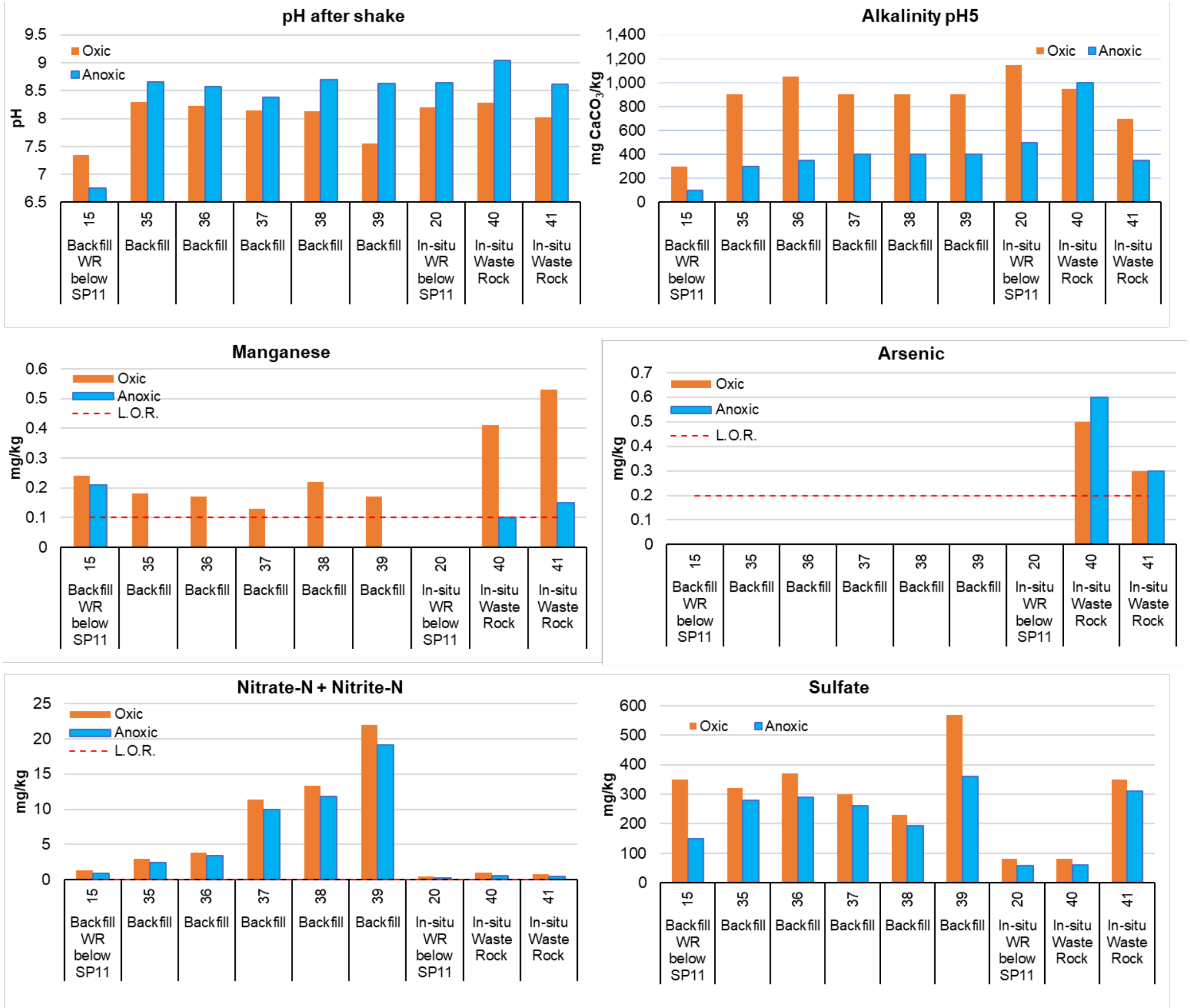


Figure 37. Selected SFE results (oxic and reducing conditions).

The SFE results are utilized to derive the waste rock source terms for pit lake modelling. The following data reduction steps were applied:

- Average values were calculated for the backfill and in-situ samples in both the oxic and anoxic tests. This provides four values per contaminant (Table 17).
- Average results were compared for the oxic and anoxic conditions, selecting the maximum value for each parameter (with the exception of pH, where the minimum was chosen).
- The average value of the two maximum's was selected. This resulting average was used as the source term for waste rock backfilled into the pit lakes (mg/kg).

These data are presented in Table 17.

Table 17. Average data for the oxidised and anoxic shake flask extraction tests.

PARAMETER	BACKFILL (n = 6)		IN SITU WASTE ROCK (n = 3)	
	OXIC	ANOXIC	OXIC	ANOXIC
pH (pH units)	7.9 ± 0.4	8.3 ± 0.7	8.2 ± 0.1	8.8 ± 0.2
Alkalinity to pH7 (mg $CaCO_3$/L)	19.2 ± 8.4	12.5 ± 6.3	18.3 ± 6.2	21.7 ± 6.2
Alkalinity to pH6 (mg $CaCO_3$/L)	50.8 ± 17.4	22.5 ± 8.5	51.7 ± 10.3	50 ± 21.6
Alkalinity to pH5 (mg $CaCO_3$/L)	82.5 ± 24.1	32.5 ± 10.7	93.3 ± 18.4	61.7 ± 27.8
Oxygen (DO) (%)	85.2 ± 3.2	30.8 ± 8.2	88 ± 2.2	< 30
Oxygen Reducing Potential (mV)	276.8 ± 32.4	162.2 ± 21.7	228 ± 36.8	143.8 ± 7.7
Electrical Conductivity (uS/cm)	217.7 ± 72.6	144.4 ± 40.4	183.9 ± 21.5	104.4 ± 25.9
Aluminium	0.093 ± 0.142	0.225 ± 0.151	< 0.06	0.2 ± 0.118
Antimony	0.014 ± 0.01	0.013 ± 0.009	0.014 ± 0.007	0.009 ± 0.004
Calcium	22.7 ± 7.4	10.7 ± 3.3	26 ± 3.7	10.8 ± 3.1
Cobalt	< 0.004	< 0.004	< 0.004	< 0.004
Iron	< 0.4	< 0.4	< 0.4	< 0.4
Magnesium	10.1 ± 4	5.7 ± 2.1	4.3 ± 1.1	2.1 ± 1
Manganese	0.019 ± 0.004	< 0.01	0.033 ± 0.02	< 0.01
Potassium	11.2 ± 5.2	9.9 ± 4.5	9.8 ± 1.8	8.2 ± 1.4
Selenium	< 0.02	< 0.02	< 0.02	< 0.02
Sodium	4.8 ± 1.4	4.3 ± 1.5	3.9 ± 0.9	3.5 ± 1
Thallium	< 0.001	< 0.001	< 0.001	< 0.001
Total Ammoniacal-N	0.179 ± 0.09	0.202 ± 0.103	0.246 ± 0.095	0.186 ± 0.092
Nitrite-N	0.026 ± 0.007	0.003 ± 0.001	0.026 ± 0	0.003 ± 0.001
Nitrate-N	0.876 ± 0.703	0.793 ± 0.639	0.051 ± 0.024	0.039 ± 0.012
Nitrate-N + Nitrite-N	0.913 ± 0.725	0.793 ± 0.638	0.078 ± 0.024	0.042 ± 0.013
Sulfate	35.7 ± 10.5	25.6 ± 6.8	17.1 ± 12.7	14.2 ± 11.9
Arsenic	< 0.02	< 0.02	0.03 ± 0.016	0.033 ± 0.021

PARAMETER	BACKFILL (n = 6)		IN SITU WASTE ROCK (n = 3)	
	OXIC	ANOXIC	OXIC	ANOXIC
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001
Chromium	< 0.01	< 0.01	< 0.01	< 0.01
Copper	< 0.01	< 0.01	< 0.01	< 0.01
Lead	< 0.002	< 0.002	< 0.002	< 0.002
Nickel	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	< 0.02	< 0.02	< 0.02	< 0.02

Units in mg/L unless indicated otherwise.

Alkalinity to pH4.5 (mg $CaCO_3$/L) was not undertaken.

3.5 pXRF Analysis

To understand the potential enrichment of PCOC within the different materials, pXRF was conducted for the 70 samples obtained from the sampling program. Full results are provided in Appendix E.

The geochemical abundance index (GAI) (Förstner et al., 1993) was calculated for all available data. Waste rock, LGO and ore samples that had a GAI of 3 or greater are summarised Table 18 and Table 19 respectively. From the analysis undertaken the following can be observed:

- Majority of the parameters fall below a GAI of 3 and were typically below the LOR. Often the LOR was higher than a GAI of 3 which meant only high GAI values are reported to avoid false positive values where the LOR is greater than a GAI of 3. For instance, ½ the LOR for Sb was a GAI value of 4.
- All pit domains had a reported GAI >3 for As for both the waste rock, LGO, and ore; all SPIM and Round Hill samples had a GAI >3.
- All samples that were > LOR for Sb had a GAI of 6.
- Sulfur concentrations in the LGO and ore samples were reported as having a GAI > 3 (SPIM and Golden Bar).
- Cd was identified as being elevated by the GAI analysis; however, this is a function of the LOR being equivalent to a GAI of 5. Several samples were detected at 20-30 ppm (GAI = 6), which is likely to be unreliable as the limit of quantification is 2-3 times greater than the Limit of Reporting (expected to be ~20 ppm for these samples). Work by Craw (2002) noted that "*cadmium contents of mineralised and unmineralised schists are near to the analytical detection limit (0.1 ppm), and there has been no enrichment of Cd during mineralisation.*" Cd is not expected to be an issue with available water quality data indicating that it is low. For instance:
    - Seepage water quality from SP11 and MTI tailings impoundments (Table 8) indicated that Cd ranged from 0.0001 – 0.0014 mg/L, which is less than the 95% ANZECC (2000) trigger value of 0.0002 mg/L.
    - SPLP test data (Golder 2011b) indicated Cd was < 0.0001 mg/L
- Only one sample was above the LOR for Sn, producing a GAI >3 within SPIM (LGO and ore sample).

Table 18. Waste rock samples with a GAI >3.

PARAMETER	SPIM	GOLDEN BAR	CORONATION	ROUND HILL	INNES MILLS
	(N=21)	(N=4)	(N=8)	(N=8)	(N=14)
As	16	3	6	7	13
Sb	1	0	2	0	0
Sn	1	0	0	0	0

All other analytes reported GAI < 3 for all samples and are not included in this table.

Table 19. LGO and ore samples with a GAI >3.

PARAMETER	SPIM	GOLDEN BAR	CORONATION	ROUND HILL	INNES MILLS
	(N=4)	(N=4)	(N=1)	(N=3)	(N=3)
As	2	2	1	2	2
S	1	1	0	0	0
Sb	0	1	0	0	1

All other analytes reported GAI < 3 for all samples and are not included in this table.

3.6 Environmental Geochemistry Testing Summary

The following summary is provided on the environmental geochemistry testing results.

3.6.1 Acid Base Accounting

The ABA data presented here supports previous investigations that waste rock at Macraes is non-acid forming, with low sulfide sulfur, and are unlikely to generate ARD with ANC values being significantly higher than MPA values leading to negative NAPP values. This is supported by circumneutral to alkaline NAG pH values.

Although the materials are unlikely to generate ARD, they have the capacity to generate neutral metalliferous drainage (NMD) due to the release of contaminants of concern. Contaminants include As, nitrogenous compounds (due to ammonium-nitrate-based blasting residues), and sulfate. Some data suggest that on occasion Fe, Zn and Cu can also be elevated.

3.6.2 Shake Flask Analysis

Leach tests were undertaken using shake flask extractions under oxic and reducing conditions. Analysis showed the following:

- pH values for the oxic SFE are lower than the anoxic SFE, and at the same time, alkalinity was reported as being higher in the oxic samples.
- Arsenic concentrations are present above the limit of reporting (LOR) in the in-situ waste rock from Innes Mills (Sample 40 and 41).
- Mn is higher in the oxic samples for insitu waste rock from Innes Mills.
- The majority of the nitrate + nitrite concentrations are in the nitrate nitrogen form. Results indicate that nitrate is higher in the backfill waste rock (samples 35 to 39) compared to the in-situ waste rock. This nitrate is likely to be associated with blasting residues (ANFO).

3.6.3 pXRF Analysis

The samples were analysed by pXRF to understand the source hazard associated with the different material types. Results were assessed using GAI. Of the parameters analysed, As, Cd, S, Sb and Sn were found to be above a GAI of 3; these parameters were more concentrated within the SPIM material. Enrichment does not necessarily mean that PCOC will be environmentally mobile and bioavailable because PXRF measures total concentrations and the enriched trace elements can be present in non-reactive minerals.

3.6.4 Overview

The environmental geochemistry data obtained as part of this study suggests the rocks are comparable to previous studies, as validated by site-based water quality monitoring programs. No new environmental geochemical hazards are expected.

4 DERIVATION OF SOURCE TERMS

This section provides a summary of the source terms used for the hydrogeochemical modelling of pit lakes associated with the project. The key features of the conceptual hydrogeochemical models are explained in Section 2.11. Source terms are discussed in detail in the appendices J, K, L, and M, for each of the pit lake models.

4.1 Run-off Water from Pit Walls and Waste Rock

Water quality for rainfall run-off interacting with the pit walls and the WRS surfaces was derived from the Golden Bar Stage 1 Pit Lake analogue model (Appendix J). This source term is assigned to the "Pit" runoff component of the water balances and provides a constant concentration (shown in Table 21) for flows from pit walls and run-off from the WRS.

4.2 Seepage from Waste Rock

The analysis of multiple datasets revealed consistent trends in sulfate concentrations as a function of the average height of each WRS. A relationship was developed to estimate the WRS seepage sulfate concentration, which has been described in Section 2.10. The relationship was used to forecast other parameters based on the sulfate relationship. Further details are provided in Appendix I.

4.3 Tailings Storage Facilities Underdrains and Frasers West WRS Seepage Return

The FRIM Pit Lake Model will receive water from the TSF underdrains for the first 20 years of the model (after closure of the site), and also water from the Murphys Creek Silt Pond located at the base of the Frasers West WRS. Water quality sources used for these source terms is obtained from the TSFs (TTTSF, MTI, and SP11) and the Frasers West WRS seepage are shown in Table 20.

Table 20. Key components and processes associated the underdrains.

FEATURE	SUMMARY	DATA SOURCE	TIME PERIOD
MTI	Sump B monitoring points	SUMP B-SSF, SUMP B-CDE and SUMP B-CDW	04/05/2015 to 01/03/2022.
TTTFS	TTTFS monitoring point	TTTSF Seepage Collection Sump	14/07/2014 to 02/12/2021.
SP11	SP10 monitoring point	SP10 Combined Seepage Outlet	06/01/2008 to 01/05/2016
Frasers West WRS	Murphys Creek Silt Pond that receives seepage from the Frasers West WRS (surface water)	Murphys Creek Silt Pond	19/01/2015 to 01/04/2022

4.4 Contaminant Load Derived from Saturated Waste Rock

As the level of the pit lake rises, it is assumed that soluble solutes will be released from the waste rock as the pit lake water saturates the rock. In the model this process is also assumed to prevent future sulfide mineral oxidation. This source term is derived from the SFE results (mg/kg) as described in Section 3.4. As a conservative modelling approach, it is assumed that there is a full release of these solutes upon saturation of the waste rock.

4.5 Natural waters

4.5.1 Rainfall

The source term for average rainfall water quality is obtained from Nichol et al. (1997) using the Lauder site collection (~70 km NE from Macraes, at 317 mRL), which includes rainfall water quality data from 1983 to 1994. Data are provided in Table 21.

4.5.2 Groundwater

Groundwater is derived from average values from groundwater samples in nearby monitoring points or points unaffected by the mining operation. Concentrations at these points are similar across the site. It is noted that there are impacts to groundwater from the current TSF facilities, which is discussed further in Section 5.4, although effects on the groundwater model are not considered material in that effects on the model are minor. Further details are provided in the appendices for each model. Data are provided in Table 22.

4.5.3 Run-off from natural catchment

The water quality of the runoff from natural catchments is derived by surface water monitoring points located in the area unaffected by the mining operation. Further details are provided in the appendices for each model.

4.6 Initial pit lakes water quality

The initial water quality for each pit lake is derived from previous water quality data. In the case of Frasers TSF, the water quality for the TTTSF impoundment is used to replicate the water quality that will be the starting pit lake composition. Data are provided in Table 21 to Table 23.

4.7 Source Terms Summary

Table 21, Table 22, and Table 23 present the source terms used for the FRIM, Golden Bar, and Coronation pit lake models.

Table 21. Source terms for pit lake water quality models.

SOURCE TERM	FTSF PIT LAKE (INITIAL) + TAILINGS PORE WATER RELEASE	INNES MILLS PIT LAKE (INITIAL)	GOLDEN BAR PIT LAKE (INITIAL	CORONATION PIT LAKE (INITIAL)	RAINFALL	NATURAL SURFACE WATER	RUNOFF FROM NATURAL CATCHMENT	SURFACE RUN-OFF WATER FROM WASTE ROCK AND PIT WALLS	REHABILITATE D WATER
DERIVATION FROM	TTTSF IMPOUNDMEN T	INNES MILLS PIT LAKE	GOLDEN BAR PIT WATER QUALITY	CORONATION PIT WATER QUALITY	NICHOL ET AL., 1997	MONITORING POINT GB02	MONITORING LOCATION DC08	GOLDEN BAR ANALOGUE MODEL (MWM, 2024A)	MONITORING POINT NBWRRF
MODEL DOMAIN	FRIM	FRIM	GB	COR	ALL	FRIM / GB	COR	ALL	FRIM
pH	7.94	7.92	8.37	8	5.2	7.44	7.83	8.37	7.67
Alkalinity Total	204.4	249	229	139.2	0.8	33.5	89	571.5	86
Al	n.a.	n. a.	n. a.	n. a.	n. a.	n.a.	n.a.	n. a.	n.a.
As	0.1685	0.16	0.16	0.13	n. a.	0.002	0.014	0.4087	0.0081
Ca	617.4	181	76.1	119.8	0.1	8.8	49.5	190.3	35.6
Cd	n.a.	n. a.	n. a.	n. a.	n. a.	n.a.	n.a.	n. a.	n.a.
Cl	21.53	8.6	6.25	7.11	0.6	10	10.03	15.6	8.9
Cu	n.a.	0.001	0.00057	0.00072	n. a.	0.003	0.00106	0.001	0.0008
Fe	n.a.	0.29	0.0259	0.037	n. a.	0.19	0.072	0.065	0.2706
K	94.52	5.55	4.47	5.04	0.09	0.72	1.95	11.18	5.55
Mg	343.3	60.4	74.5	24.6	0.1	3.2	29.6	186.4	38
Mn	n.a.	n. a.	n. a.	n. a.	n. a.	n.a.	n.a.	n. a.	n.a.
Na	365	20.9	13	16	0.3	8.7	17.7	32.4	17.68
NO_3-N	12.87	4.73	0.008	6.99	0	0.03	0.139	0.02	0.44
NO_2-N	0.754	n. a.	0.003	0.215	n. a.	0.002	0.0021	0.008	0.0027
Amm-N	14.04	0.23	0.015	1.564	n. a.	0.033	0.122	0.038	0.015
Pb	0.0012	0.0018	0.00011	0.00014	n. a.	0.0003	0.00014	0.0003	0.0002
Sb	n.a.	n. a.	0.003	0.037	n. a.	n.a.	n. a.	0.008	n.a.
SO_4	3,610	407	288	267	0	6.7	170	719	179
Zn	n.a.	n. a.	0.002	n. a.	n. a.	0.0026	0.0013	0.005	0.0019
$CN_{(WAD)}$	n.a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n.a.

All units n mg/L; alkalinity in mg/L equiv. ($CaCO_3$). n.a.: not applicable due to not being analysed or being below LOR. For modelling purposes, n.a. is equivalent to 0.

Table 22. Source terms (continued) for pit lake water quality models.

SOURCE TERM	GROUNDWATER	GROUNDWATER	GROUNDWATER	UNDERDRAIN FROM MTI	UNDERDRAIN FROM TTTSF	UNDERDRAIN FROM SP11	FRASER EAST WRS#
DERIVATION FROM	MONITORING WELL FDB03	MONITORING WELLS CP02 AND CP04	MONITORING WELL MAC-RCH3004	SUMP B MONITORING POINTS	TTTSF SEEPAGE COLLECTION SUMP	SP10 COMBINED SEEPAGE OUTLET	FRASER EAST WRS SEEPAGE (SEPTEMBER 2016 ONWARDS)
MODEL DOMAIN	FRIM	COR	GB	FRIM	FRIM	FRIM	FRIM
pH	7.01	7.44	6.04	6.79	6.84	6.81	7.59
Alkalinity Total	51.8	123.5	n. a.	268.3	226.8	363.8	461.1
Al	n.a.	n.a.	n. a.	n. a.	n. a.	n. a.	n.a.
As	0.0021	0.002	0.0014	3.3	3.86	11.87	0.005
Ca	10	33.1	8.18	310	432.1	329.9	326.7
Cd	n.a.	n.a.	n. a.	n. a.	n. a.	n. a.	n.a.
Cl	6.13	7.09	8.2	58.9	21.5	31.3	13.31
Cu	0.0005	0.00076	0.00248	0.003	n. a.	0.004	0.0043
Fe	4.5029	0.782	4.48	14.04	28.8	32.46	0.0622
K	1.66	1.04	0.974	37.24	50.15	63.74	16.53
Mg	5.8	8.6	7.6	169.4	328.8	329.9	445.8
Mn	n.a.	n.a.	n. a.	n. a.	n. a.	n. a.	n.a.
Na	9.44	10.1	9.38	505	380	481	85.1
NO_3-N	n.a.	0.173	0.407	1.2	1.38	0.064	36.05
NO_2-N	n.a.	0.011	0.012	0.05	0.075	0.055	0.0113
Amm-N	0.151	0.0182	0.047	10	7.4	11.8	0.061
Pb	0.0001	0.00021	0.0001	0.0004	n. a.	0.0005	0.0001
Sb	n.a.	n.a.	n. a.	n. a.	0.0011	0.0077	0.0032
SO_4	4.4	7.39	13.3	2280	3094	3426	2,282
Zn	n.a.	n.a.	0.045	0.0035	n. a.	n. a.	0.024
$CN_{(WAD)}$	n.a.	n.a.	n.a.	0.227	0.055	0.0039	n.a.

All units n mg/L; alkalinity in mg/L equiv. ($CaCO_3$). #- Empirical water quality data used rather than calculated (these flows make up 10% of the flow into Frasers TSF so differences in estimated versus empirical effects are minor (the waste rock also floods reducing the seepage flow path (less height)). n.a.: not applicable due to not being analysed or being below LOR. For modelling purposes, n.a. is equivalent to 0.

Table 23. Source terms (continued) for pit lake water quality models.

SOURCE TERM	FRASERS WEST AND SOUTH WRS#	NORTH GULLY EAST#	MURPHY'S SEEPAGE RETURN	SEEPAGE FROM EX-PIT WASTE ROCK	SEEPAGE FROM EX-PIT WASTE ROCK	BACKFILL SOLUTE RELEASE WHEN FLOODED
DERIVATION FROM	FRASER WEST SILT POND AND MURPHY'S CREEK SILT POND (2014 ONWARDS)	NORTH GULLY EAST	MURPHY'S CREEK SILT POND	EMPIRICAL CORRELATIONS*	EMPIRICAL CORRELATIONS*	WASTE ROCK SHAKE FLASK AVERAGE (IN mg/kg)
MODEL DOMAIN	FRIM	FRIM	FRIM	GB	COR	FRIM
pH	8.2	7.53	8.19	6.7	7.2	8.06
Alkalinity Total	526.3	640.6	601.1	129	39	879.2
Al	n.a.	n.a.	n.a.	n. a.	n. a.	2.13
As	0.0092	0.006	0.0041	0.001	0.001	0.22
Ca	206.7	462.7	206.9	241.8	545.2	243.25
Cd	n.a.	n.a.	n.a.	n. a.	n. a.	n. a.
Cl	17.35	12.52	11.45	11	8	n. a.
Cu	0.0028	0.002	0.0024	0	0.0005	0.05
Fe	0.2395	0.1033	0.0494	0.04	0.04	n. a.
K	13.69	13.55	15.51	7.2	5.8	105
Mg	693.2	649.4	561.1	262.9	384	72
Mn	n.a.	n.a.	n.a.	n. a.	n. a.	0.26
Na	61.1	68.1	51.7	49.3	46.5	43.08
NO_3-N	11.64	30.18	18.41	9.19	1.34	8.75
NO_2-N	0.0712	0.0049	0.0986	n. a.	n. a.	0.26
Amm-N	0.165	0.11	0.27	0.01	0.3	n. a.
Pb	0.0005	0.0002	0.0002	n. a.	n. a.	n. a.
Sb	0.0011	0.0076	n.a.	n. a.	n. a.	264
SO_4	3,014	3,200	2,328	1,645	3,319	0.143
Zn	0.01	0.025	n.a.	n. a.	n. a.	n. a.
$CN_{(WAD)}$	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.

Source: OceanaGold (2022b). n.a.: not applicable due to not being analysed or being below LOR. For modelling purposes, n.a. is equivalent to 0.

** - uses the empirical correlation derived for WRS seepage (Appendix I)..*

4.8 Modelling Processes and Software

Geochemical processes were modelled using PHREEQC (Parkhurst & Appelo, 2013), a widely used software distributed by the United States Geological Survey (USGS) to perform a variety of aqueous geochemical calculations, such as:

- Aqueous reactions.
- Mixing of solutions.
- Calculation of mineral saturation indices.
- Gas and mineral interaction.

Data inputs, modelled geochemical processes, and outputs produced by the hydrogeochemical model are shown schematically in Figure 38. For each timestep (1 year) represented in the pit lake water balance, the model simulated:

- Mixing volumes of each inflow, as represented by source terms in proportions predicted by the GHD (2023b) water balance.
- Concentration of the resulting mixed lake water by removal of pure water, representing evapoconcentration predicted by the water balance.
- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for geochemical processes including:
  - Equilibration with atmospheric gases (O_2 and CO_2).
  - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed lake water.
  - Adsorption of dissolved metals and metalloids to hydrous ferric oxides (HFO) as represented by precipitated iron (hydr)oxide minerals.

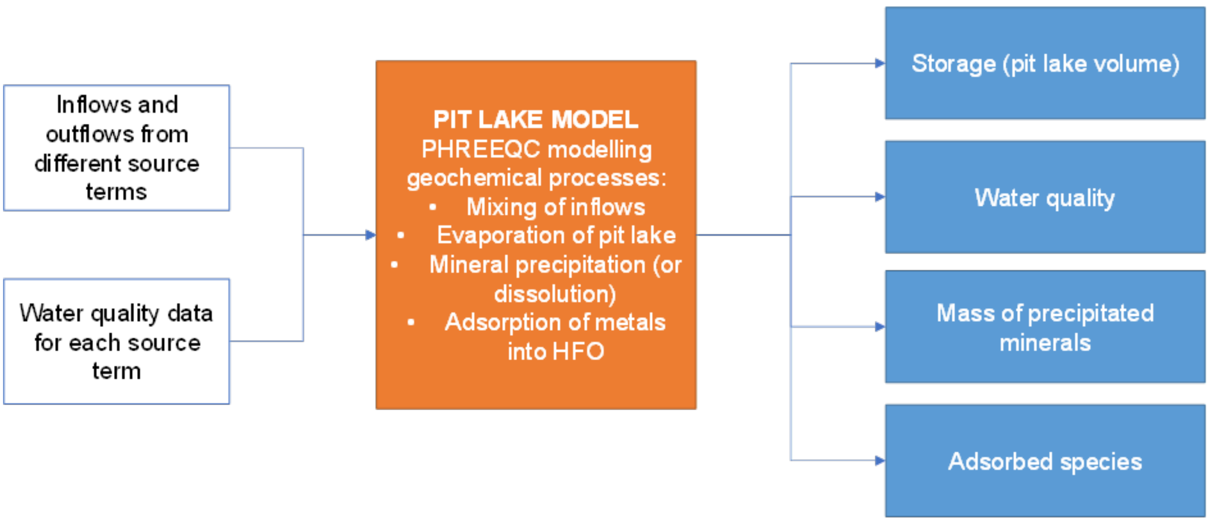


Figure 38. Hydrogeochemical model inputs, modelled processes, and outputs.

The WATEQ4F database was used for thermodynamic calculations, which included the derivation of mineral saturation indices. Mineral phases attaining a saturation index value equal to or greater than zero, which indicates that precipitation of that mineral from solution is thermodynamically favoured, were included as equilibrium phases if those minerals are known to, or are likely to, form under surface environmental conditions reflecting a pit lake. Adsorption of aqueous chemical species to hydrous ferric oxides was modelled using a diffuse double-layer surface complexation model (Dzombak & Morel, 1990), based on modelled precipitation of $Fe(OH)_3(a)$[4] from solution.

As per the Golden Bar Analogue Model (MWM, 2024a: Appendix J) the following was included:

- Two geochemical processes were included in the model to represent the nitrification and denitrification processes as modelled in the Golden Bar Analogue Model.
- Saturation index of $CO_2(g)$ was set to -3.1 and calcite to 0.85.
- Dolomite precipitation was included if the Saturation Index of 2.5 was exceeded. In other words, if enough magnesium is available, a Ca-Mg carbonate would precipitate instead of calcite.

4.8.1 Assumptions and Limitations

The following section discusses general model constraints, key assumptions and limitations relating to the hydrogeochemical model:

- All data provided by OceanaGold are assumed to be correct and no quality control / quality assurance (QAQC) has been undertaken on the datasets provided, except those identified as anomalous, which were discarded for the identification of PCOC in the MEQ analysis. No sample was discarded for the calculation of the source term.
- Data obtained from a variety of sources is assumed to be representative of the materials associated with the project, and data are representative of the key environmental geochemistry risks.
- Outputs from the water balance (as supplied by GHD) were assumed to be accurate and complete.
- The model assumes there is no stratification in terms of density (temperature or salinity stratification) or oxidation-reduction (redox) potential within the pits. It is acknowledged that recent data (Section 2.8.4) suggests that stratification may be occurring during summer months with slightly higher arsenic at depth (0.17 mg/L) compared to surface concentrations of 0.138 mg/L. Sulfate remains constant with depth and is not affected by stratification. Such effects are not considered in this model.
- Mineral reactions are modelled in equilibrium. If conditions are met, precipitation and dissolution occur instantly until mineral equilibrium is attained.
- Limited information was available for the chemical composition of some inflows. Where required, the composition was estimated using suitable analogues.

[4] (a) = amorphous.

- No redox state (such as pe, Eh or ORP) data were available for source term derivation. A pe value of 10 was applied for all source terms and equilibrium between the lake and the atmosphere (O_2 and CO_2) was assumed.
- The shake flask extraction (SFE) data used in the model is the maximum data observed for that sample, irrespective of whether it was an oxic or anoxic test. This does not apply for pH and minimum pH data was used to be conservative.
- All Fe introduced into the model is assumed to be in the Fe^{3+} form.
- Nitrification and denitrification processes were included to represent the process of ammoniacal nitrogen being converted to nitrate, and nitrate being converted to nitrogen gas, and therefore, degassing from the solution.
- Following the approach completed for the Golden Bar Analogue Model (MWM, 2024a), an initial nitrogen load (as NH_4NO_3) was added to account for the ANFO residues that flush into the pit lake. The initial nitrogen load was 5.35 g/m^2:
    - Golden Bar stage 2: (227,000 m^2), corresponding to 1,215 kg of nitrogen as NH_4NO_3.
    - Coronation Stage 6: (~136,000 m^2), corresponding to 728 kg of nitrogen as NH_4NO_3.
    - FRIM: (Innes Mills ~730,000 m^2), corresponding to 3,910 kg of nitrogen as NH_4NO_3. The Frasers pit area was not included in the calculation as it was considered to be already flushed out[5].
- The nitrogen loads were released over three years in the model as per empirical data trends found in the Golden Bar Analogue model (MWM, 2024a: Appendix J).
- The effects of cyanide are not considered in this geochemical model as it is anticipated that cyanide breaks down once exposed to the atmosphere in the pit lake. The only source of cyanide is associated with the Frasers in-pit tailings and the TSF underdrain water pumped into FRIM.
    - For modelling purposes all cyanide remains conservative and does not break down.
    - TTTSF impoundment water quality data (2016 – 2021) indicates that WAD cyanide ranges from 0.0176 – 0.35 mg/L with an average of 0.07 mg/L.
    - TTTSF underdrainage water quality data (2014 – 2021) indicates that WAD cyanide ranges from 0.001 – 0.35 mg/L with an average value of 0.05 mg/L. This is below the compliance limits of 0.1 mg/L at MC01 (Table 3).

[5] *It is noted that recent mining in the Gay Tan mining area of Frasers Pit could contribute to a residual nitrogen load, however, given the rapid nitrate decay (20-30% decrease per year) and the fact the pit lake does not spill (GHD, 2024) suggests the effects are not material and were not modelled.*

5 PIT LAKE WATER QUALITY MODELLING

This section discusses the results of hydrogeochemical pit lake modelling for the MP4.3 project. Further details are provided in:

- Appendix J – Golden Bar Pit Lake Analogue Model.
- Appendix K – Golden Bar Stage 2 Pit Lake Model.
- Appendix L – Coronation Stage 6 Pit Lake Model.
- Appendix M – FRIM Pit Lake Model.

5.1 Golden Bar Analogue Model

To estimate future pit lake water quality for Golden Bar Pit Lake (GPL), it was proposed that the current water quality in the current lake could be used as an analogue for Stage 2 using empirical site-specific data. MWM (2024a) provides a summary of this work (Appendix J). Results are summarised below:

- A calibrated water balance for GPL was provided by GHD (2023a), using in-situ lake level monitoring and hydrological data.
- The load for several parameters was estimated by multiplying the concentration by the estimated volume of the pit lake to compare to the modelled data.
- The pit wall source term (an average of the pit lake when it was stable (2013 – 2022), was adjusted by a factor of 2.5. This provided an adjustment factor to increase the load from the pit wall runoff to match the load in the pit lake. This became the source term for other pit walls (i.e., load per m^2).
- Nitrogen was not conservative, and data shows that it is naturally removed from the solution.
- Approximately 20-30% of the nitrate-N load is lost annually (after the peak load has developed). Although there is a gap in information between 2011 and 2018, nitrate load estimation approaches zero by 2018 with a clear decreasing trend.
- Ammoniacal nitrogen also exhibits a decaying trend, with concentrations and loads decreasing to zero within a year (from 2005 to 2006), from a peak of approximately 10 mg/L and 170 kg, respectively.
- The primary source of NO_3-N is assumed to be ANFO, where nitrogen comes from the NH_3NO_3 component.
- The model incorporates two essential kinetics processes to simulate the decay of nitrogen in the pit lake, nitrification, and denitrification, which are fitted to empirical data. These equations can be applied to other pit lake models at the Macraes Mine.
- Results indicate that ~5.38 g/m^2 of nitrogen as NH_3NO_3 can be sourced from pit walls. This initial load should be applied to any other pit lakes within the Macraes mining area.

5.2 Golden Bar Stage 2 Pit Lake Model

The long-term water quality of the Golden Bar Pit Lake (Stage 2) was completed by MWM (2024b). Further details can be found in Appendix K. Results are summarised below, and pH and sulfate concentrations are shown graphically in Figure 39. The following key observations are provided:

- pH remains constant at ~ 8.38.
- Sulfate concentrations reaches a peak of 434 mg/L in the first year and concentrations decrease steadily reaching a concentration of 372 mg/L by year 35 (when the discharge commences) and 370 mg/L by year 50. Concentrations are expected to be slightly higher than previous concentrations observed in the current pit lake (~290 mg/L when stable), even though there is less inflow coming from the pit walls (20% in the GPL-E vs 23% in the current pit lake).
- Antimony concentrations remains below 0.004 mg/L.
- Arsenic reaches a peak of 0.194 mg/L in year 1 when the pit wall runoff effect is greatest. In the long term, As concentration remain stable at 0.145 mg/L.
- Concentrations are relatively steady for Ca, Mg, and alkalinity. Calcite ($CaCO_3$) precipitation is over 500 tonnes by year 50.
- Nitrate nitrogen has an initial peak of 3.21 mg/L in year 1 due to the initial nitrogen load, and then decreases rapidly. By year 10, the concentration of NO_3-N decreased down to 0.16 mg/L.
- Ammoniacal nitrogen has an initial peak of 0.28 mg/L in year 1 and the concentrations are below 0.001 mg/L in year 10.
- Both nitrification and denitrification processes are included in the model as derived previously (MWM, 2024a) resulting in a decay in nitrogenous compound concentrations.

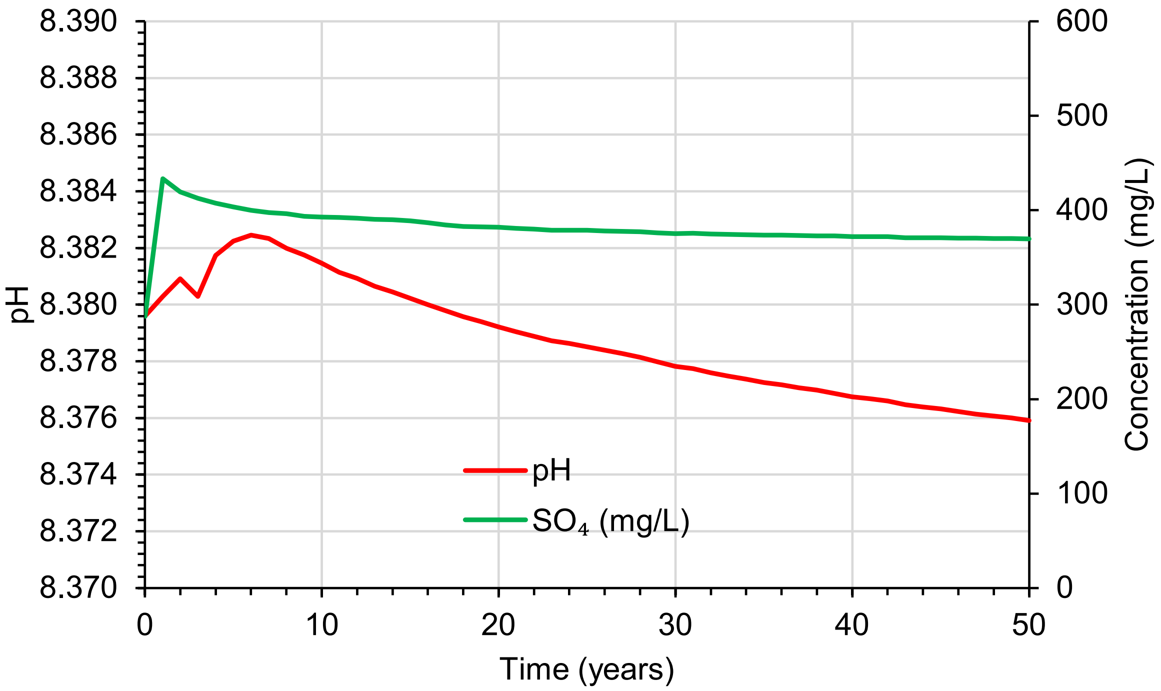


Figure 39. Predicted pH and sulfate for the Golden Bar Stage 2 pit lake.

Source: MWM (2024b) Appendix K.

5.3 Coronation Stage 5/6 Pit Lake Model

The long-term water quality of the proposed Coronation Stage 6 Pit Lake was completed by MWM (2023d). Further details can be found in Appendix L. Results are summarised below, and predicted values for pH and sulfate are shown graphically in Figure 40. The following key observations are provided from MWM (2024c):

- pH remains relatively constant and is in the range of 7.92 – 8.41, although pH mostly remains at pH 8.4 (which is comparable / slightly higher than the current pit water quality of pH 8.0).
- Sulfate concentrations are predicted to increase over time reaching a concentration of ~620 mg/L by year 277, although generally being relatively stable. Figure 40 also shows the concentrations at Years 97 (545 mg/L) and 166 (584 mg/L), when the groundwater loss and the surficial discharges commence, respectively.
- Nitrate nitrogen has an initial peak of 26.5 mg/L in year 0 due to the initial nitrogen load, and then decreases rapidly.
- Ammoniacal nitrogen has an initial peak of 2.08 mg/L in year 0 and decreases sharply to zero within the first year of the model.
- Both nitrification and denitrification processes are included in the model as derived previously (MWM, 2024a) resulting in a relatively rapid decay in nitrogenous compound concentrations.
- Year 15 is when the concentrations are stable for several parameters. It is predicted (by GHD) that the groundwater discharge of the pit lake will occur from Year 97 though Trimbells WRS and the discharge to Deepdell Creek will occur from Year 166. These data are also provided.

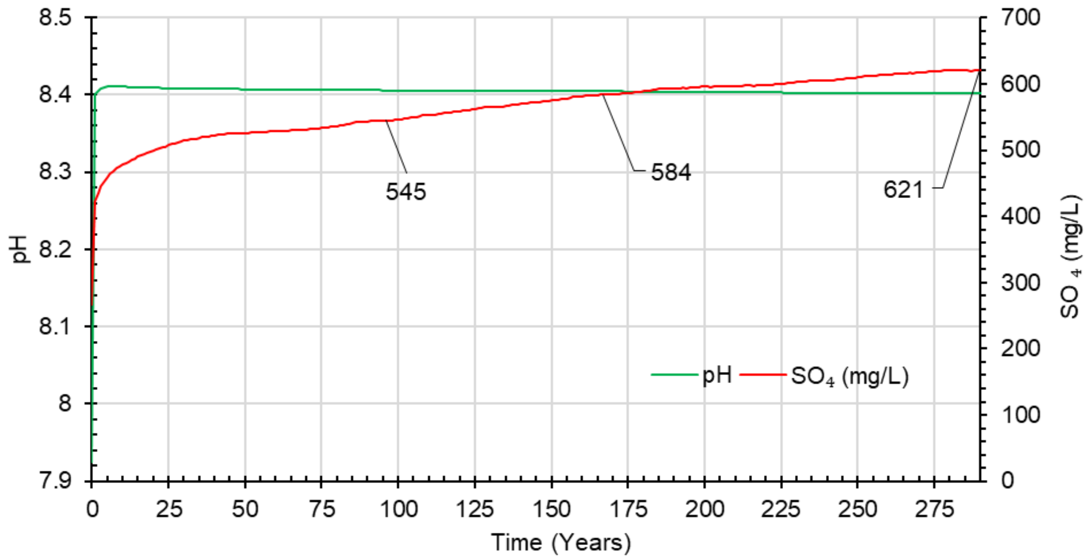


Figure 40. Predicted pH and sulfate for the Coronation Stage 6 Pit Lake Model.

Source: MWM (2024c) Appendix L.

5.4 FRIM Pit Lake Model

The long-term water quality of the FRIM pit was completed by MWM (2024d). Further details are provided in Appendix M. Results are summarised below, and predicted pH and sulfate are shown graphically in Figure 41 and Figure 42 respectively. The following key observations are provided:

- Modelling by GHD (2024) indicate that the pit lake will not spill, except for some minor seepage through backfill to Murphy's Pond, which is returned to the pit in the model (pumping).
- pH will remain neutral in the range of 8 to 8.2
- Sulfate exhibits a decreasing trend over time, decreasing from approximately 2,700 mg/L to below 1,500 mg/L after 140 years, as per the theoretical mixing approach.
- Arsenic has an increasing trend due to the effect of the waste rock backfill reaching a peak near 0.16 mg/L in Innes Mills in year ~90, and 0.04 in year 70 in Frasers.
- Nitrate nitrogen has an initial concentration of 12-13 mg/L in both pit lakes in year 0 due to the initial nitrogen load and then decreases rapidly to values below 2 mg/L by year 20, and close to zero by year 100.
- Ammoniacal nitrogen (Amm-N) results in an initial peak of 1 - 1.2 mg/L in both lakes with a decreasing trend. By year 10 Amm-N is below 0.1 mg/L for both pit lakes.
- Cyanide was included in the model as a conservative element, which means no decay and the results show what would be the maximum concentration. This is considered an unrealistic scenario but provides a potential value and remains below 0.05 mg/L.

Three lines are presented in the following plots to explain general water quality trends in the FRIM Pit Lake model:

- The red line represents the result of the Frasers TSF Pit Lake model.
- The blue line represents the result of the Innes Mills Pit Lake model.
- The orange line represents the theoretical mixing between the two lakes. Because Frasers TSF Pit Lake is larger than Innes Mills Pit Lake, the theoretical mixing line will be often closer to the Frasers TSF PL red line.

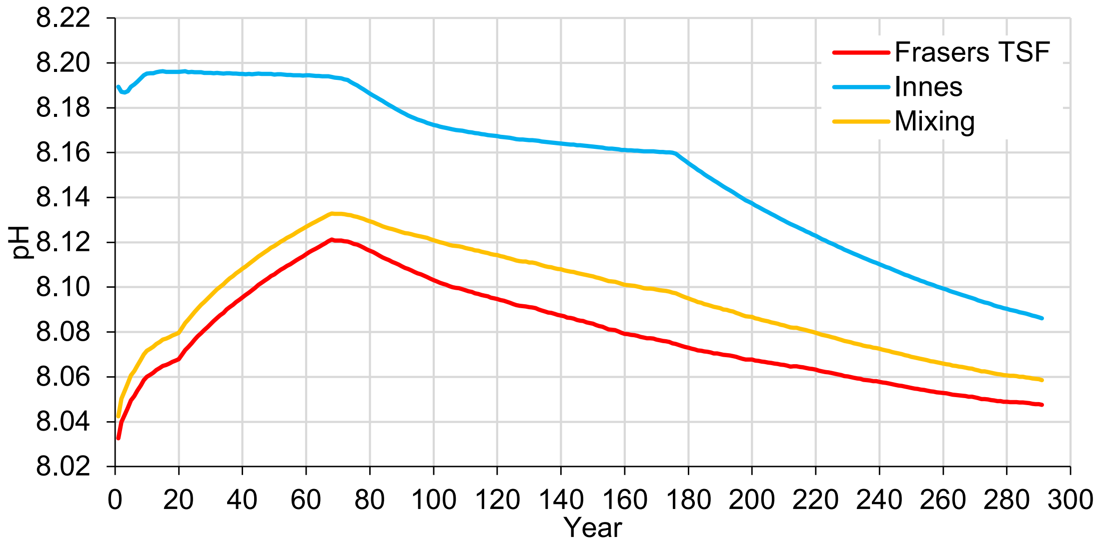


Figure 41. Predicted pH for FTSF, IM, and the mixed pit lakes.

Source: MWM (2024d) - Appendix M

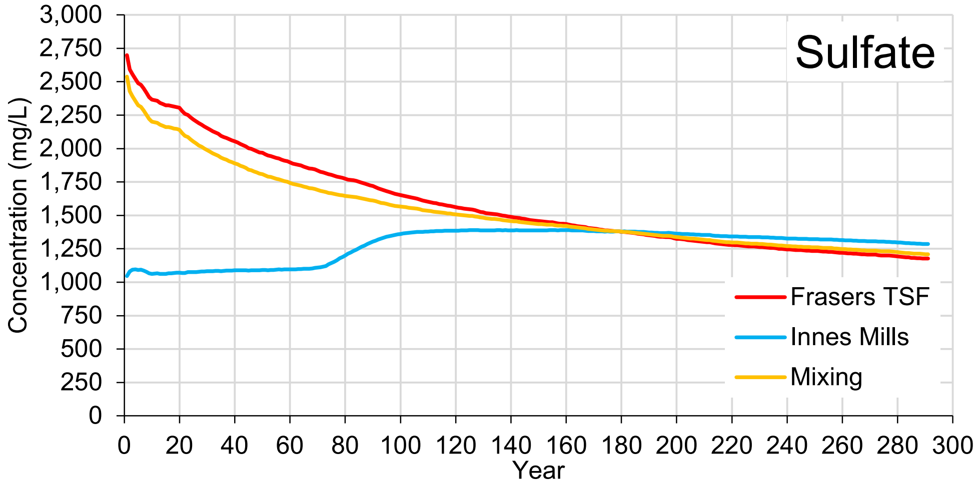


Figure 42. Predicted sulfate concentrations for FTSF, IM, and the mixed pit lakes

Source: MWM (2024d) - Appendix M

A scenario model was run to understand the potential effects of mine-impacted groundwater beneath the MTI and SP11 TSFs on the FRIM Pit Lake model. Two models were run looking at sulfate as a key indicator of risk where:

- Scenario 1: 10% of groundwater is affected by TSF impacted water until the pit lake is close to being full, after which the groundwater gradient reduces flow from the TSF area to the pit lake (reasonable model).
- Scenario 2: 50% of groundwater is affected by TSF impacted water until the pit lake is close to being full, after which the groundwater gradient reduces flow from the TSF area to the pit lake (conservative model).

A source term for impacted groundwater was developed (using TTTSF underdrain water mixed with baseline groundwater at 10 and 50%). This mixture was then compared with the groundwater quality near Frasers (SPMW3 and SPMW4) to evaluate the accuracy of this approach. Figure 43 shows sulfate concentrations and the input values for Scenario 1 and 2 modelling.

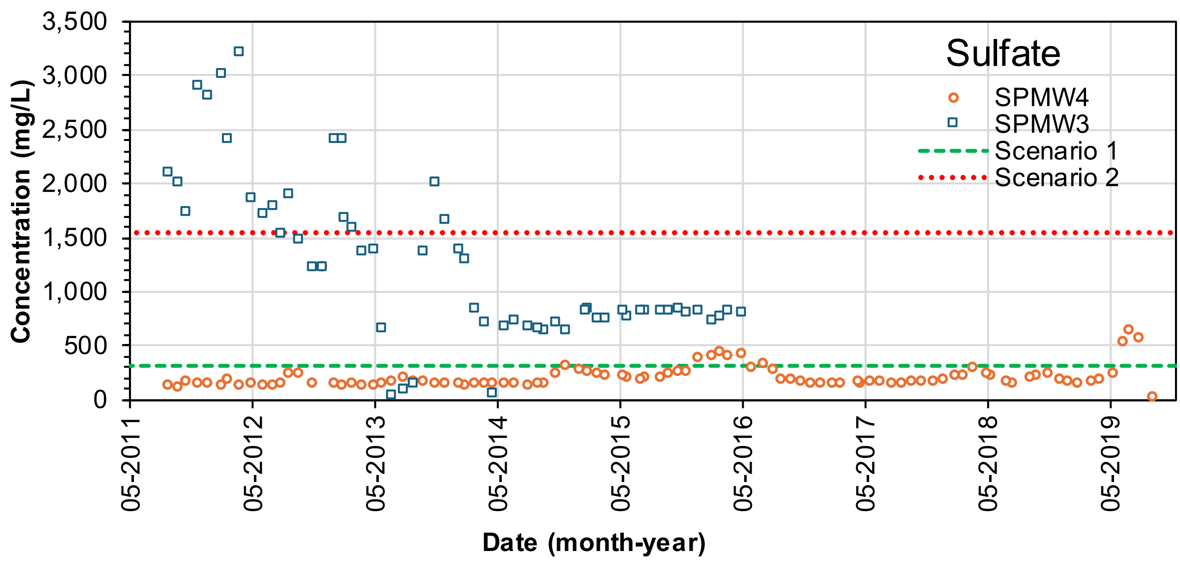


Figure 43. Sulfate concentrations for boreholes SPMW3 and SPMW4 near Frasers Pit.

Figure 44 shows the resulting concentrations for sulfate in the two scenarios (10%, 50%) and the base case (100% non-affected groundwater) for the theoretical mixing within the FRIM Pit Lake. Model results indicate negligible effect.

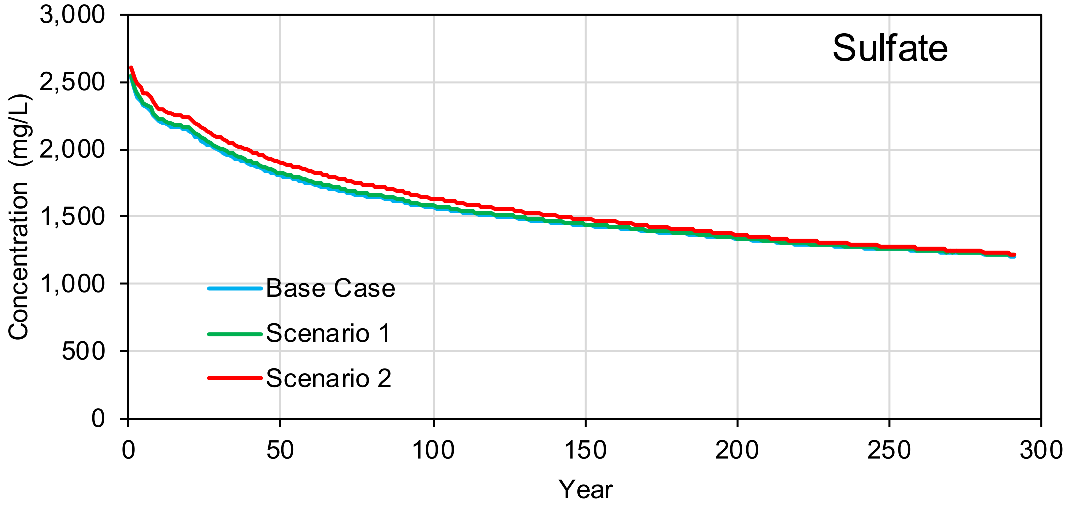


Figure 44. Results for Scenario 1 and 2 compared to the base case (FRIM).

The results suggest the following:

- The pit lake model shows no significant sensitivity to the groundwater quality, even in conservative scenarios (Scenario 2).
- Furthermore, considering the pit lake does not spill, it is reasonable to conclude that the effects on the receiving environment are negligible.

5.5 Coronation North Backfill Water Quality

The waste rock from the proposed Coronation Stage 6 Pit (CO6) will be transported to the Coronation North Pit, which has a capacity of 34.5 Mt and will be backfilled (Figure 4). The conceptual site model for Coronation North Backfill is shown in Figure 27.

No hydrogeochemical modelling was undertaken, however source terms were developed for:

- Toe seepage from the WRS to surface waters.
- Backfill seepage to groundwater.

5.5.1 WRS Toe Seepage

Toe seepage water quality was determined by GHD using the MWM (2023) model to forecast water quality as a function of WRS height. Further details are provided by GHD (2024).

5.5.2 Backfill Seepage to Groundwater

Water quality for seepage to groundwater was determined from shake-flask data (Table 17):

- Total volume of the pit is 8,929,575 m^3.
- A porosity of 0.15 was assumed, meaning that the available pore space is 1,339,436 m^3. A density of 2.19 t/m^3 was used for the calculations.

- Assuming a release of sulfate of 264 mg/kg (as per the shake-flask data), the estimated concentration of sulfate is 3,852 mg/L.
- Other parameters were based on the North Gully East WRS average water quality (see Table 25) as an analogue (3,017 mg/L of sulfate[6]), multiplied by a factor of 1.27 (i.e., 3,852/3,017). Results are shown in Table 24.

Table 24. Water quality for the Coronation North Backfill Seepage to groundwater.

PARAMETER	ESTIMATED CORONATION NORTH BACKFILL SEEPAGE
pH (pH units)	7.55
Alkalinity - Total (mg $CaCO_3$/L)	756.9
Nitrate-N	34.1
Amm-N	0.0958
Diss. As	0.0069
$CN_{(WAD)}$	0.0255
Diss. Cu	0.0031
Diss. Fe	0.12
Diss. Pb	0.0005
Diss. Sb	0.0093
SO_4	3,852
Diss. Zn	0.031

Units are in mg/L unless indicated otherwise.

Red text indicates parameter values above the reference water quality reference value (see Section 2.6). No hardness modification was conducted.

5.6 Summary - Pit Lake Water Quality Modelling

The modelling process provided a number of insights into pit lake water quality including:

- Acid pit lakes are not expected, rather circum-neutral waters are expected, which is similar to current pit lakes at Macraes. This means the risks associated with AMD are low.
- In the short-term nitrogenous compounds can be elevated due to the use of ANFO. In the pit lake environment these compounds decay quickly due to biogeochemical processes. Nitrogen decay rates are in the order of 20-30% per year. Navarro et al (2023) suggests that there is the potential to design pit lakes to act as natural reactors for nitrate treatment, promoting eco-friendly and sustainable mining practices.
- Pit lakes can be elevated in sulfate, which is a result of sulfide mineral oxidation. Sulfate is a key issue for water quality compliance. When the model pit lakes commence discharging:
    - Golden Bar Stage 2 Pit Lake has a sulfate concentration of 373 mg/L.

[6] *North Gully East was used as it conservatively represented WRS seepage having similar sulfate concentrations.*

  - Coronation Stage 5/6 Pit Lake has a sulfate concentration of 545 mg/L.
  - FRIM is not expected to spill / discharge to the surrounding waterways, however the sulfate concentration is elevated at 1,209 mg/L.

  The model suggests that where discharge occurs (Golden Bar, Coronation 5/6) the sulfate concentration is < 1,000 mg/L and treatment is not required.

- Arsenic is likely to be elevated in pit lakes. This is different to WRSs where arsenic is low (Table 25), likely a function of the oxidising environment where As is adsorbs onto Fe oxyhydroxide minerals within the WRS. In the pit lake Fe is low and this mechanism is limited. Management/treatment for As may be required. Options are available, if required, and these management/treatment processes are discussed in Section 8.

6 SOURCE HAZARD ASSESSMENT

6.1 Introduction

This section presents an overview of the AMD source hazard assessment for the MP4.3 Project for WRSs and pit lakes. This included:

- A review of PCOC, supported by the work completed here.
- An assessment of the source hazards for the WRS.
- An assessment of the source hazards for pit lakes.

This assessment assists in determining appropriate management strategies for the identified source hazards.

6.2 PCOCs criteria

As previously mentioned, the PCOCs in the Macraes area are established in the Water Quality Resource Consent Conditions presented in Section 2.6. This work has indicated the PCOC remain the same for this project (i.e., As, CN, Cu, Fe, Pb, Zn, SO_4) although nitrogenous compounds are also of importance.

6.3 Waste Rock Stacks

Analysis of data indicated that:

- Water quality typically exhibited circumneutral pH (6.56 – 8.46). No acid rock drainage is expected from the WRS, which is also in agreement with the overall NAF classification of the waste rock (Section 2.5 and Appendix I).
- Analysis of the data indicates that typically NO_3-N and SO_4 concentrations are elevated. Data (Appendix I) indicates that sulfate concentrations are a function of WRS height.
- Zinc concentrations can also be elevated.
- Arsenic concentrations are low.

Table 25. Average seepage water quality measured at individual WRS.

WASTE ROCK SEEPAGE	CORONATION NORTH WRS	CORONATION WRS	NORTH GULLY EAST WRS	NORTH GULLY WEST WRS	GOLDEN BAR WRS	DEEPDELL WRS	FRASER WEST WRS	REFERENCE WATER QUALITY LIMIT
Monitoring point	Maori Hen Gully Seepage	Coronation Silt Pond	N Gully Seep East	N Gully Seep West	Clydesdale Creek Silt Pond / Clydesdale WRS Seepage	Deepdell North Silt Pond	Murphy's Creek Silt Pond / FDB06 / FDB08	
Date (From - To)	Jan/22 – May/23	Feb/19 – May/23	Oct/16 – Jun/23	Jun/17 – Jun/23	Jan/13 – Jun/23	Mar/09 – May/23	Jul/14 – Jun/23	
pH (pH units)	7.74	6.99	7.55	7.40	6.68	8.10	6.56	6.0 – 9.5
EC (µS/cm)	-	1,920	4,413	2,694	2,419	1,744	3,781	-
Alkalinity - Total (mg $CaCO_3$/L)	264.4	36.5	592.8	302.7	128.7	149.3	463.3	-
Nitrate-N	9.50	1.32	26.71	15.57	8.57	2.83	8.06	2.4
Amm-N	0.025	0.329	0.075	0.059	0.143	0.023	0.148	0.24
Diss. As	0.0010	0.0042	0.0054	0.0044	0.0013	0.0071	0.0046	0.15
$CN_{(WAD)}$	0.0200	0.0200	0.0200	0.0200	0.0027	0.0010	0.0018	0.1
Diss. Cu	0.0006	0.0008	0.0024	0.0036	0.0012	0.0009	0.0041	0.009
Diss. Fe	0.06	0.05	0.09	0.08	0.05	0.03	0.19	1.0
Diss. Pb	0.00010	0.00013	0.00036	0.00061	0.00020	0.00016	0.00043	0.0025
Diss. Sb	0.00032	0.00020	0.00728	0.00270	0.00036	0.00054	-	1.6*
SO_4	797	1,248	3,017	1,753	1,568	1,019	2,840	1,000
Diss. Zn	-	0.5613	0.0243	0.0255	-	0.0045	0.0232	0.12

All units are presented as mg/L except as indicated.

Red text indicates parameter value is above the water quality reference limit. No hardness modification was conducted.

In brackets is shown a lower compliance limit used in some points of the WQMP.

An asterisk (*) denotes chronic levels of toxicity.

6.4 Pit Lakes

This report has assessed the water quality of two pit lakes that will spill to the surrounding environment once dewatering activities stop and the pits fill up. The modelled water quality results for these pits are summarised in Table 26. Several Pit Lakes also require dewatering.

6.4.1 Pit Lake Dewatering

The Golden Bar Stage 1 Pit and the Coronation Stage 5 Pit require dewatering prior to mining commencing.

6.4.1.1 <u>Gold Bar Stage 1 Pit Dewatering</u>

The pit lake is currently discharging into the receiving environment with an arsenic concentration of approximately 0.12 mg/L and a sulfate concentration of 270 mg/L. About 5 to 6 km downstream from the pit lake spill point, there is a compliance point (NB03), and arsenic concentrations there are below the compliance limit of 0.1 mg/L. If the discharge rate were to increase due to pit dewatering activities, it could potentially impact the concentrations at the compliance point (NB03).

Furthermore, thermal stratification has been observed in Golden Bar, with higher arsenic concentrations and lower dissolved oxygen levels (Figure 45) in the deeper parts of the lake during the warmer season (March 2023).

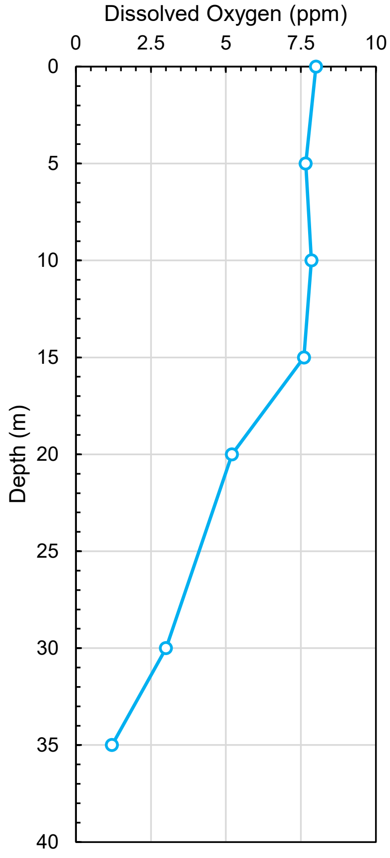


Figure 45. Dissolved oxygen profile at Golden Bar Stage 1 Pit Lake in March 2023.

An As load model was developed for the two available sampling events (as depicted in Figure 46) during stratification and with no stratification present. This model aimed to quantify the potential As concentrations that might be present within the lake due to thermal stratification. The following observations were made:

- A linear extrapolation for estimating As concentration at the bottom of the pit lake suggests concentrations could reach 0.21 mg/L. This trend aligns with a similar decreasing dissolved oxygen trend.
- An As-rich zone (>0.15 mg/L) can be identified at the bottom of the pit lake with a total volume of 47,156 m³ of water, and a weighted average of 0.17 mg/L of As.
- This As-rich zone represents 4.4% of the total volume of the pit lake and contains a load of 7.81 kg of As, which represents 5.7% of the total As load of the pit lake.

Management options are available to treat this As load during any proposed pit lake dewatering process in a relatively simple manner. Such options are discussed in Section 8.1.

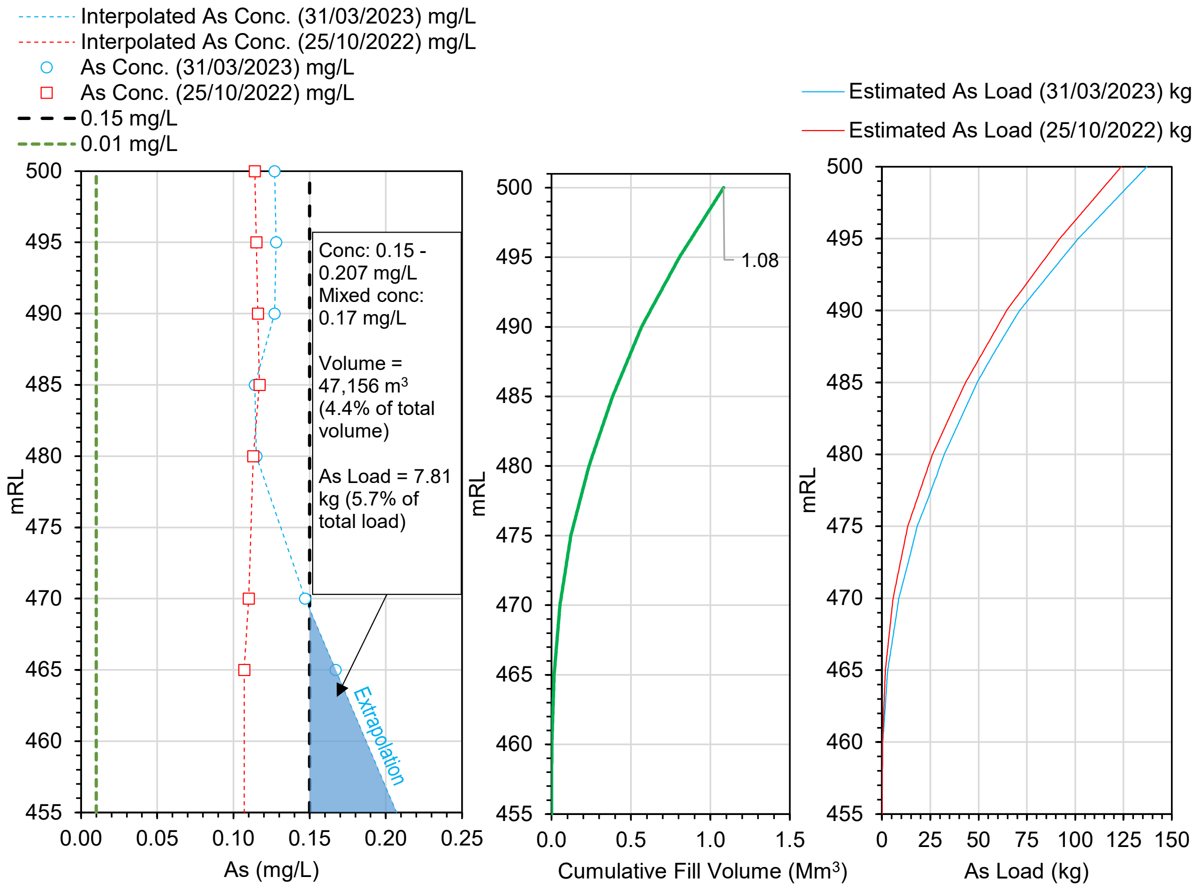


Figure 46. Arsenic Load and water volume at the current Golden Bar Pit Lake.

6.4.1.2 Coronation Stage 5 Pit Lake Dewatering

The sulfate concentration in the current Coronation Pit Lake is approximately 170 mg/L (recent data), and the average arsenic concentration between January 2021 and April 2022 was 0.11 mg/L with a peak of 0.41 mg/L in April 2022.

A multi-depth sampling programme in the Coronation Pit Lake has not been conducted, but it is reasonable to assume that same characteristics found in the Golden Bar Pit Lake could also be found in the Coronation Pit Lake (slightly higher As concentration at depth and lower dissolved oxygen).

As part of mining activities, the water with Coronation Stage 5 Pit will be pumped to Deepdell Pit for storage and reuse as required (e.g., processing).

6.4.2 Pit Lake Discharge Water Quality

A number of lake models were developed including:

- Golden Bar Pit Lake – Stage 1 (current pit lake).
- Golden Bar Stage 2 Pit Lake (proposed).
- Coronation Stage 5/6 Pit Lake 6 (proposed).
- Frasers TSF and Innes Mills pit lakes (FRIM) (proposed).

Pit lake hydrogeochemical modelling indicated key water quality hazards include arsenic (Table 26). Sulfate can also be elevated but not above 1,000 mg/L.

Table 26. Pit lake water qualities.

MINE DOMAIN	GOLDEN BAR STAGE 2	CORONATION STAGE 5/6	FRIM
Year post mining cessation when spill commences	35[a]	97[b]	No spill (Year 290 Water Quality Data)
Average discharge flow (L/s) to receiving environment when stable	3.3	1.46	-
pH	8.38	8.41	8.06
Dissolved solids	793	1,101	1,815
Alkalinity	182	238	108
Ca	60.9	80	181
Mg	92.7	131	167
Na	20.9	27	71
K	5.6	8	31
Fe	<0.001	<0.001	<0.001
Cl	12.9	14.2	4.7
NO_3-N	0.03	0.0036	0.09
Amm-N	0.00015	0.00005	0.0001
SO_4	373	545	1,209
Mn	0	-	0.05
Zn	0.0073	0.0034	0.0025
As	0.145	0.25	0.04
Cyanide	-	-	0.0057
Sb	0.0033	0.005	0.03
Pb	0.00003	0.00004	0.000008

All units in mg/L except for pH. Red text indicates parameter values above the reference compliance value (see Section 2.6).

No hardness modification was conducted.

a: Predicted by GHD (2023a) when discharge of the pit lake to the North Branch of the Waikouati River occurs (with stable flow at Year 40).
B: Predicted by GHD (2022) when the pit lake will discharge though the Trimbells WRS.

6.5 AMD Hazard Assessment Summary

The summary is provided for AMD source hazards associated with the project.

- Three primary AMD source hazards associated with this project are identified: pit lakes, waste rock stacks, and FTSF.
- Other sources of mine-impacted water (not assessed as part of this study, although are included in the pit lake model) are the TSF underdrains (e.g., MTI, SP11, TTTSF), which are pumped into the FRIM pit lake for 20 years as the TSF dewater. Following that dewatering process the seepage will be treated by passive technologies – e.g., see Section 8.2.
- PCOCs associated with each source hazard are identified to understand specific contaminants.
    - WRS have circumneutral pH, high concentrations of NO_3-N, SO_4, Amm-N, and Zn.
    - The height of waste rock stacks correlates with higher sulfate concentrations.
    - Pit lakes (Golden Bar Stage 2, Coronation Stage 5/6, and FRIM) are expected to have circumneutral pH, and relatively high concentrations of SO_4 and As compared to compliance limits.
    - Some pit lakes may also have elevated levels of NO_3-N, Amm-N in the early stages of pit lake development.
- Dewatering of Golden Bar and Coronation pit lakes requires assessment of As concentrations and dissolved oxygen levels if dewatering direct to local waterways is planned.

The environmental geochemistry hazards identified in this source hazard assessment are no different to those previously managed by OceanaGold during the first 30 years of operation. Management options are discussed in the following sections and include source control and management and treatment technologies.

7 ENGINEERING - SOURCE CONTROLS

The following section provides a high-level review of engineering source control options for the potential adverse effects that have been identified for the MP4.3 Project. Source control includes methods to prevent the oxidation of sulfide minerals and methods to minimise the mobilisation of any oxidation products (derived from sulfide mineral oxidation).

Where source control technologies are implemented, performance monitoring data is required before the impact of these technologies can be included in future water quality models and projections. This process is iterative and requires adaptive management principles (e.g., Leckie, 2017; Weber, 2020), which are described in further detail in Section 9.8.

7.1 Background: Waste Rock Management

Waste rock at Macraes is typically end dumped in high lifts. This results in grainsize segregation with coarse rock fragments at the base of each lift, which then acts as an underdrain beneath WRS. Often such 'French Drains' are designed for the management of water flow. EGL (2016) noted the use of such practices has resulted in greater infiltration of water and the ingress of oxygen through WRS (and hence transport of sulfate out of the WRS). Material on site is illustrated below in Figure 47, which shows the effects of grainsize segregation.

Figure 47. WRS lift and associated grainsize segregation, Macraes Gold Mine.

Source: Plate 8; EGL (2016).

Industry experience indicates that WRS are typically the principal mine domain associated with contaminant generation and typically can account for 60 – 80% of the site pollution load (e.g., Weber et al., 2017). Hence, if WRS are constructed to minimise oxygen ingress and avoid interactions with water there is the opportunity to significantly reduce the main source of contaminants reporting to the receiving environment.

Within a WRS the oxygen flux is usually driven by the advective flow of oxygen (temperature differences, barometric pressure differences) along coarser waste rock layers that form within poorly constructed WRSs. Often these advective oxygen pathways are associated with high tipheads (> 4-6 m in height) leading to grainsize segregation and the formation of basal rubble layers and chimney zones due to the process of end tipping (Figure 48). Work completed by Brown et al., (2014) has demonstrated that in a poorly constructed WRS, advection accounts for ~90% of oxygen ingress, and that diffusion of oxygen accounts for 10%.

A key control to prevent sulfide mineral oxidation and minimise the effects on seepage waters from waste rock stacks is to prevent the advective ingress of oxygen.

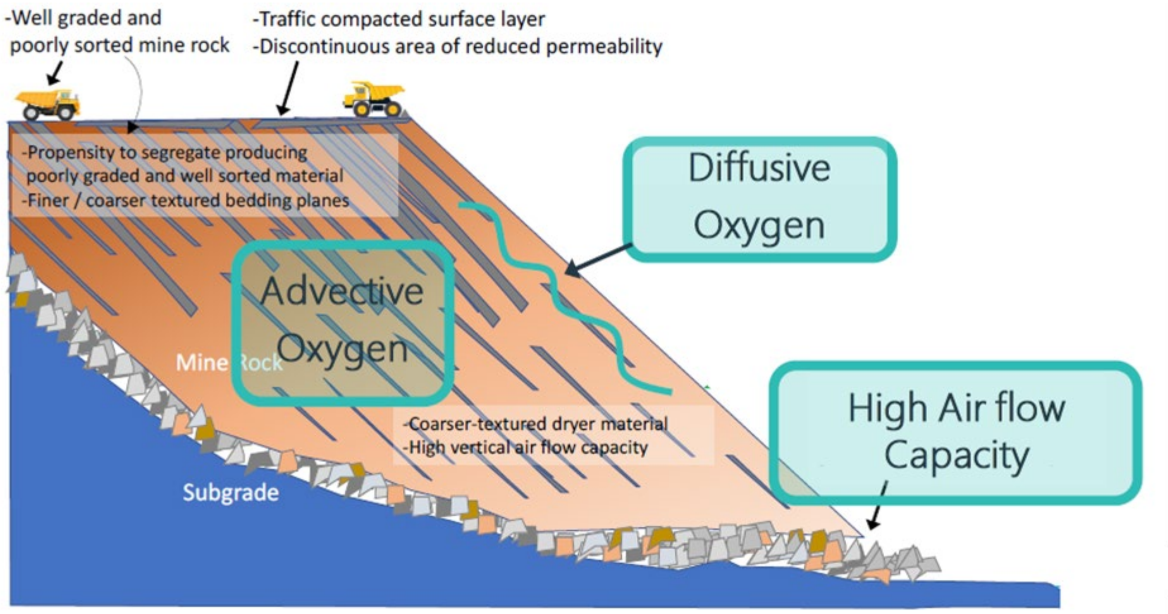


Figure 48. Advective air flow driven by grainsize segregation.
Source: Meiers (2020).

7.2 Literature Review - Source Control Options

The following section reviews source control opportunities for the Macraes MP4.3 Project.

7.2.1 Lift Height and WRS Height

OceanaGold notes that grainsize segregation at Macraes does not occur until tiphead heights are > 10 m (pers. comm. Mike Dodds, September 2023). For WRS that need to be constructed to minimise sulfate loads at Macraes, this height limit should be used, but requires validation. It is recommended that performance monitoring is undertaken to confirm this height is appropriate to precent advective ingress of oxygen.

Shorter lifts (<10 m) also enable the regular construction of running surface that are compacted by earthmoving equipment (using preferential trafficking), which can also contribute to reducing the advective oxygen flux. This can be achieved by creating a causeway around the outside of the WRS and then filling in the middle of the WRS.

Another option identified through this study is to limit the height of the WRS to limit the sulfate concentration.

7.2.2 Materials Management

The placement of higher sulfur materials within the core of the WRS is recommended. It is noted that interburden waste rock is blasted to create a finer material compared to overburden, which is generally coarser. Interburden is also higher in sulfide (O'Kane Consultants, 2016). A higher sulfide content and a finer particle size (i.e., larger surface area) will increase the AMD hazard for these materials. It is recommended that interburden waste rock should be placed in the core of the WRS away from advective ingress of oxygen. This materials management process should be included in the management plan and scheduling of waste rock at Macraes for this project.

7.2.3 WRS Progressive Rehabilitation and Capping

Golder (2011c) identified a range of mitigation options for PCOC that included progressive rehabilitation and capping. Golder (2011c) noted that current rehabilitation plans for the WRS incorporates the placement of a cover design.

Progressive rehabilitation is recommended for the project. Compaction of the final surface cap to encourage water shedding is also an option.

7.2.4 Advective Barriers

For historic WRS that have already been constructed, the ability to manage advective ingress of oxygen can be achieved by the construction of highly compacted low permeability advective barriers in front of any basal rubble layer formed by end-tipping of waste rock. The rubble layer height is site specific. At the Bingham Canyon Mine in Utah, the advective zone ranged from 9 m to 20 m, with a WRS height of 150 – 300 m (Brown et al., 2014). At Macraes Mine it is expected to be < 5 m as shown in Figure 47.

Brown et al., (2014) noted that the construction of an engineered zone around the WRS to prevent advective oxygen flux is expected to reduce the amount of oxidation to about one third of its current amount (e.g., a ~66% reduction), demonstrating significant advantages for advective barriers of historic WRS facilities.

Advective barriers could also be used to minimise the formation of oxidation products within WRS basal materials and/or French Drains at Macraes Mine by preventing the ingress of oxygen through these coarse materials. For instance, there would be benefit in the construction of an advective barrier at the toe of Trimbells WRS to prevent ongoing oxidation at the base of the WRS where oxidation products could be mobilised from any discharge/spill from the Coronation Stage 5/6 Pit Lake.

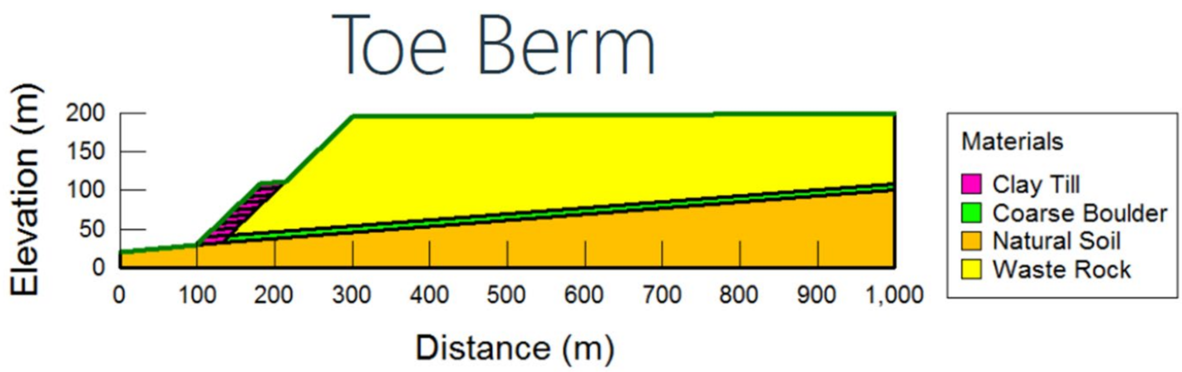


Figure 49. Diagram of an advective barrier.

Source: Meiers (2020).

7.2.5 Water Management

Other source control options include methods to minimise water ingress and the mobilisation of oxidation products (such as sulfate):

- Clean water diversion away from WRS.
- Avoidance of run-on water to a WRS (e.g., up-catchment drainage into a WRS).
- Encouraging clean-water run-off from the WRS surface (rather than ponding).
- Progressive rehabilitation and capping of the WRS.

7.3 Best Practicable WRS Construction Techniques - Coronation North

A review of the Coronation North WRS was undertaken to understand if there were any benefits from the best practicable WRS construction process used.

7.3.1 WRS Construction Approach – Coronation North

A workshop was conducted to examine sulfate management options for the Coronation North WRS (Okane Consultants, 2017) where the importance of managing air flux into the WRS was acknowledged to minimise sulfide oxidation and the accumulation of sulfate oxidation products. It was noted that the engineering controls implemented during WRS construction to prevent gas transfer have an additional advantage of reducing net percolation, which plays a crucial role in oxidation product transportation. Best practicable WRS construction processes considered were:

- Clean water diversion with run-on being diverted through a low sulfur basalt drain at the base of the WRS.
- Construction of an advective barrier above the basal drain using low permeability tuff to limit ingress of oxygen.
- Placement of higher sulfur materials in the core of the WRS away from the edge.
- Construction of the outside perimeter of the WRS using lower lift heights to minimise advective ingress of oxygen.
- Encouraging clean-water run-off from the WRS surface (rather than ponding).
- Progressive rehabilitation.

7.3.2 Review: Coronation North WRS Performance

To evaluate the benefits of the best practicable construction options applied to the Coronation North WRS (e.g., reduction of sulfate concentrations), a comparison was made between the sulfate concentrations of the Coronation North WRS and the Coronation WRS. The following approach was undertaken:

- Sulfate water quality data was plotted for Coronation North WRS and Coronation WRS (Figure 50) where the first water quality data was assumed to coincide with the start of the WRS construction.
- Average height for the WRSs at the completion of construction were confirmed by OceanaGold as being 25 m for Coronation WRS and 30 m for Coronation North WRS. Babbage (2022) completed a detailed assessment of average WRS height and concluded that the height of the Coronation WRS was 28.8 m. Hence the OceanaGold WRS height were adjusted by a factor of 1.152 (which increased the height of the Coronation North WRS slightly).
- The derived relationship for sulfate concentration in WRS seepage as a function of WRS height (as determined by MWM, 2023 – Appendix I) is shown in Figure 22 using median data. This was used to develop a sulfate concentration model for seepage from Coronation WRS and Coronation North WRS from the start of construction to the completion of construction (Figure 50). The model is a reasonable fit for long term water quality for Coronation WRS after construction is completed (as the MWM (2023) model is based on these data), however sulfate concentration in seepage is lower than expected for Coronation North WRS.
- The model overestimates sulfate concentrations during the early years of construction for the Coronation WRS as there is limited data available for WRS < 15 m in height (realistically the trend in Figure 22 should pass through 0 mg/L).

The model and empirical data indicates a significant difference between the expected model data and the observed data for the Coronation North WRS. It is possible this observed decrease in sulfate is attributable to best practicable WRS construction techniques. Data suggest up to a 60% reduction in sulfate concentrations. However, further work is required (multiple lines of evidence) to confirm this using contaminant load models based on flow and quality.

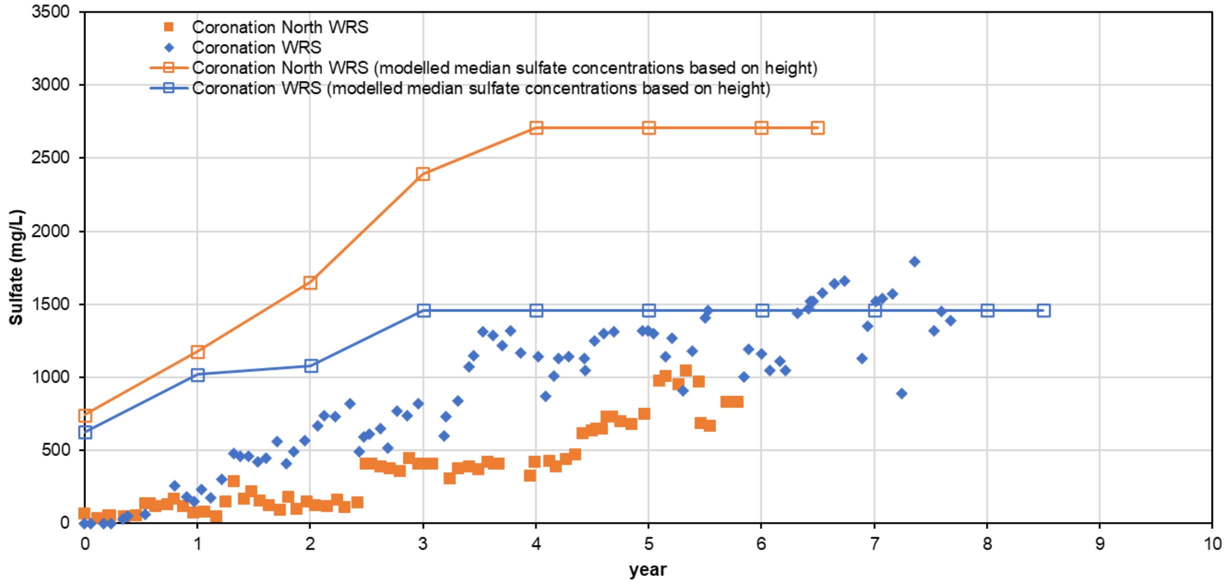


Figure 50. WRS average height versus sulfate concentrations.

Dates were shifted so all data starts at Year 0 (start date of WRS construction).

These results are encouraging; however, water quality data (concentration) is only one aspect of performance. The other important aspect to consider is flow rate, which is needed to understand the total sulfate load being generated per WRS. This would provide a stronger argument and indicate any benefits from source control. Flow data are not available at this point in time to validate whether source control technologies are working.

8 ENGINEERING - MANAGEMENT AND TREATMENT

The following section provides a high-level review of management and treatment options for the potential adverse water quality effects that have been identified for the MP4.3 Project. The purpose of the review is to indicate what options may be possible for the project. The review focuses on nitrate, sulfate, and As impacted waters, being the key project risks.

8.1 Pit Lake Dewatering

A number of pit lakes will require dewatering a part of the Macraes MP4.3 project. This section discusses dewatering options.

8.1.1 Golden Bar Current Pit Lake – Dewatering

The risks of low dissolved oxygen waters and elevated As at depth in the current Golden Bar Pit is a possibility due to stratification. Management options for poor water quality could include:

- Investigate aeration / mixing options for the pit lake prior to dewatering. Some aeration systems can be quite passive (e.g., Trompe's: see Leavitt and Danehy (2015); Leavitt et al. (2015)).
- Dosing with $FeCl_3$ to remove As (e.g., see Section 8.4.2).
- Pumping the deeper water, affected by elevated As to Frasers TSF.
- Discharge to the local tributary at rates than enable appropriate dilution.

8.1.2 Coronation Stage 5/6 Pit Lake

Pit Water from Coronation Stage 5 Pit Lake will not be discharged off site. It is proposed that any water present in Coronation Stage 5 Pit Lake will be pumped to Deepdell North Pit.

8.2 Management of Water

The following section provides a high-level summary of management options for mine-impacted waters (As, NO_3, SO_4) at Macraes.

8.2.1 Mine Impacted Water Management

Golder (2011c) noted that mine impacted seepage from WRSs and TSFs could be pumped back to the mine water management system. Golder (2011c) noted that pumping of TSF seepage to Frasers Pit for up to 20 years following closure of each facility would allow seepage rates to decrease to the point where passive treatment systems could be installed. Pumping of water remains a valid option for the project.

8.2.2 Injection into Underground Workings

Golder (2011c) noted that the use of passive injection of drainage water and captured groundwater seepage from the TTTSF to the FRUG could be viable.

8.2.3 Irrigation to Land

A study conducted at Macraes (Rufaut et al., 2022) looked at an irrigation programme for sulfate-rich waters to land for both pasture growth and SO_4 sequestration at Cranky Jim Culvert and Murphys Creek.

Results indicated that no substantial quantities of sulfate-bearing minerals were detected. It was also noted that the mixed pasture maintained a healthy appearance without any evident adverse effects on foliage colour, size, or shape (Rufaut et al., 2022). Specifically, there were no indications of pale or yellow leaves in new growth as long as aerobic conditions were maintained.

The absence of substantial amounts of sulfate-bearing minerals in the field trials implies that the observed changes in SO_4 concentrations from the source water to the soil profile are primarily attributed to dilution from soil pore water, rainfall, and leaching. At the conclusion of the 8-month trial, the topsoil SO_4 values were 35% to 40% of the input from the source water at the Cranky Jim Culvert site and 20 – 30% at Murphys (Figure 51) (Rufaut et al., 2022).

Topsoil samples exhibited a notable reduction in SO_4 concentrations, being 1500 – 2000 mg/kg lower than the levels in the source water. This reduction signifies a significant decrease in concentrations. The subsoil data was most robust at the Cranky Jim Culvert site, revealing a further decline of 350 – 600 mg/kg SO_4 at around the 60-cm depth, respectively (Rufaut et al., 2022).

It was found that there is a high potential for SO_4 contamination to extend beyond the topsoil layer, reaching subsoils and nearby creeks. The primary factors contributing to this risk include excessive irrigation leading to surface runoff and water percolation, the natural soil conditions with a high leaching potential, shallow or absent subsoils, and highly fractured surfaces on the bedrock. These combined factors create an environment that facilitates the movement of SO_4 beyond the intended irrigation zone (Rufaut et al., 2022). Data suggest irrigation has limited potential for Macraes.

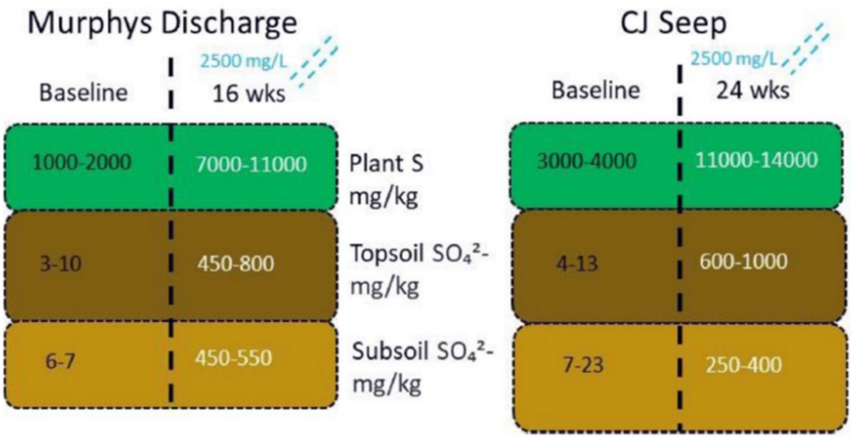


Figure 51. Irrigation trials schematic diagram.

Note: Schematic shows terrestrial partitioning of sulfate concentrations in samples collected during pilot mine water irrigation trials. N.B. Plant = pasture; top topsoil = 4–30-cm depth; subsoil = 40–60-cm depth, poorly developed at Murphys Creek and moderately at the Cranky Jim Culvert site, respectively.

Source: Rufaut et al. (2020).

8.2.4 Dilution Dams

Golder (2011c) noted that the construction of freshwater dams to augment base flows would provide improved downstream water quality by lowering the risk of occurrence of critical low flows through the water course during the summer season. Golder (2011c) noted the actual discharge regime needed to effectively mitigate effects needs to be determined on an adaptive management basis (e.g., once flow rates and quality are understood).

Two dams are consented at Macraes:

- Coal Creek (Mare Burn Catchment); and
- Camp Creek (Deepdell catchment).

These options remain viable for the project.

8.2.5 Controlled Discharge

Another option for the management of mine-impacted water such as WRS seepage is to contains these flows within an engineered pond at the toe of the WRS, releasing this water when catchment flows are suitably high. This is the same concept as a dilution dam, except it uses the capacity of the natural catchment to achieve compliance in regards to water quality. The construction of an engineered pond would also allow the space for the construction of a passive treatment system to attenuate part of the contaminant load from WRS seepage within this facility before discharge.

Further work is required to validate the opportunity for controlled discharge of mine-impacted waters and passive treatment.

8.3 Passive Treatment Systems

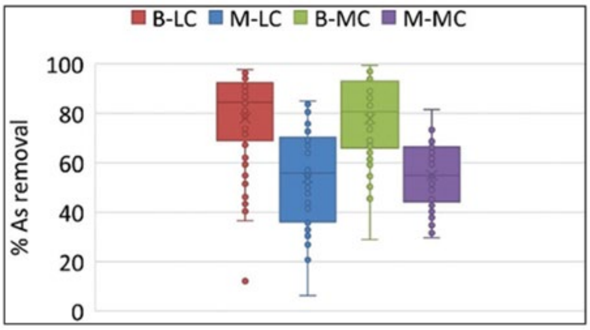
Passive water treatment of mine-impacted waters could be utilised to mitigate the effects of the downstream receiving environment. Passive treatment systems (PTS) were suggested by Golder (2011c) to either treat or pre-treat the combined drain and seepage water discharges from the TSF and WRSs. A number of options are possible.

8.3.1 Anaerobic Treatment Systems

A number of options for As-Fe-SO_4 impacted waters were assessed for OceanaGold's Globe Progress Mine (bioreactors and vertical flow reactors) (Hayton, 2022). The bioreactors included 4 different substrates:

- B-LC: Biosolids with less compost.
- M-LC: mussel shells with less compost.
- B-MC: biosolids with more compost.
- M-MC: mussel shells with more compost.

Data indicated that for a hydraulic residence time (HRT) of 50 hours there was a significant reduction in As in mine-impacted waters. The bioreactors were fed water from the sites combined underdrains (median chemistry: 28 mg Fe/L, 1.69 mg As/L and 430 mg SO_4/L). Results are shown graphically in Figure 52 and Figure 53.



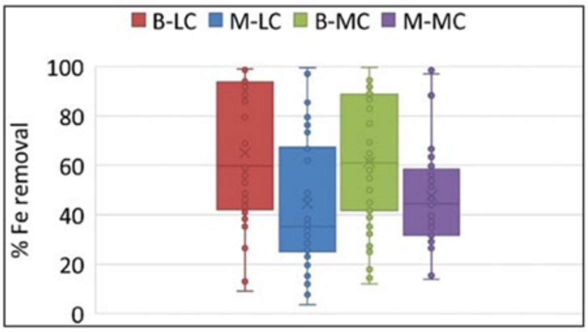


Figure 52. Globe Progress field trials

Percentage removal for sulfate. B-LC: Biosolids with less compost, M-LC: mussel shells with less compost, B-MC: biosolids with more compost, and M-MC: mussel shells with more compost.

Sources: Hayton (2022).

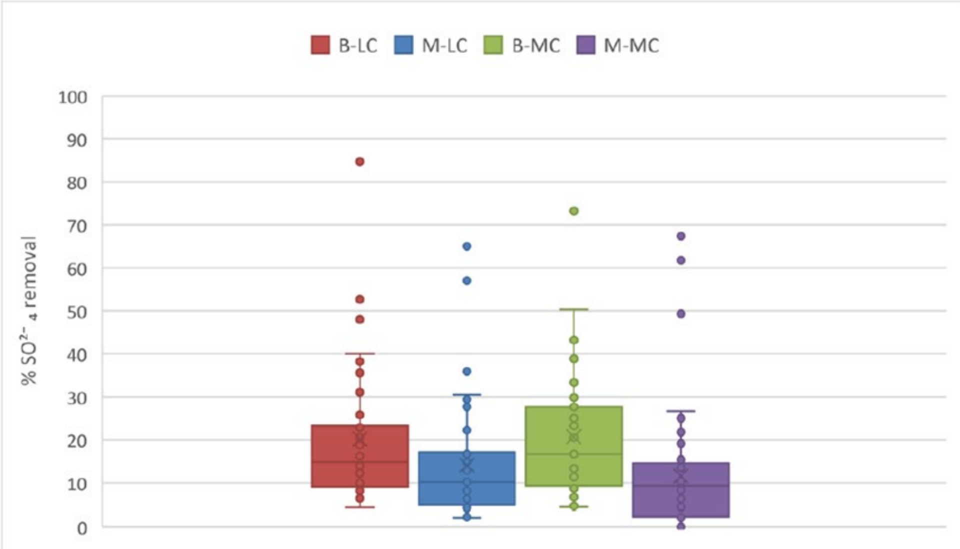


Figure 53. Globe Progress field trials

Percentage removal for sulfate. B-LC: Biosolids with less compost, M-LC: mussel shells with less compost, B-MC: biosolids with more compost, and M-MC: mussel shells with more compost. Source: Hayton (2020).

Data shows there was a positive correlation between SO_4 removal and HRT. Specifically, it was found that although the removal rates for As and Fe were higher than those for SO_4, the overall relationship between HRT and SO_4 removal was the strongest. Treatments incorporating biosolids demonstrated higher levels of SO_4 removal compared to those using mussel shells, achieving up to 40% removal in biosolid treatments at approximately a 75-hour HRT (Figure 54). Higher SO_4 removal resulted in higher sulfide concentrations in the effluent, which would require additional management (secondary treatment).

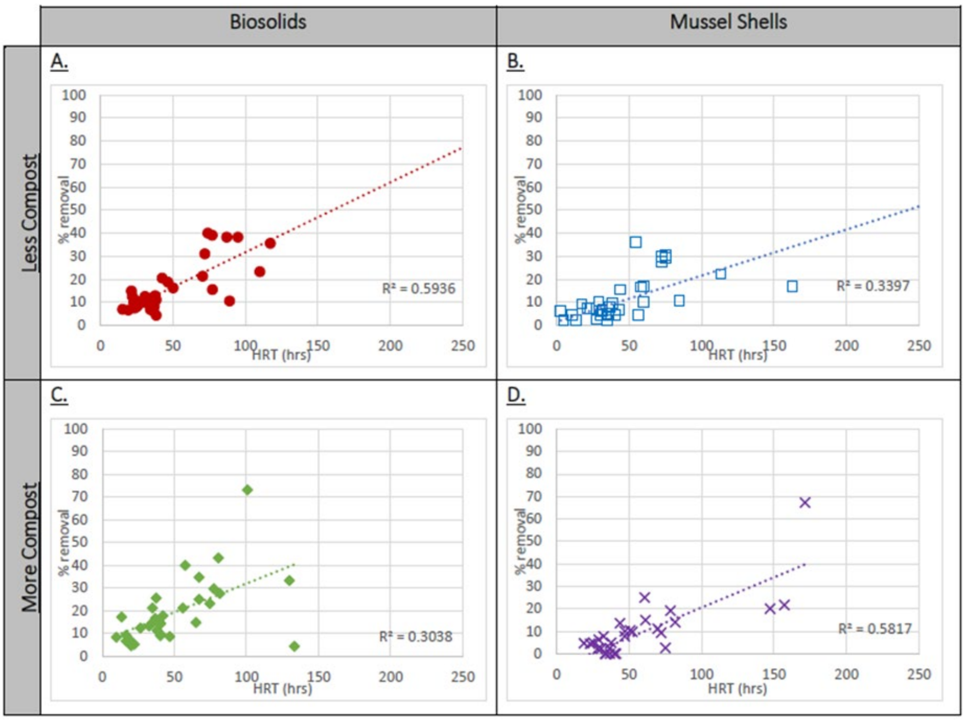


Figure 54. Graphs showing sulfate removal over HRT.

B-LC (Biosolids with less compost), B) M-LC (mussel shells with less compost), C) B-MC (biosolids with more compost) and D) M-LC (mussel shells with less compost). Source: Hayton (2020).

8.3.2 Enhanced Passive Treatment Systems

Verum Group (2021) was engaged by OceanaGold to set-up laboratory trials for enhanced passive treatment systems (E-PTS) with the aim of removing SO_4 and NO_3. EPTS are bioreactors that are enhanced by the addition of nutrients to passive bioreactors to increase the rates of water treatment (Christenson et al., 2022). Nutrient addition (e.g., liquid carbon) was undertaken on laboratory bioreactors, to test contaminant removal rates with varying substrates, temperatures, hydraulic residence time (HRT) and nutrient addition rates, in order to optimise parameter selection for field trials.

Trial results indicated that the treatment rates observed in the laboratory trials were more than 25 times higher than those of standard passive bioreactors, which typically remove 0.3 mol/m^3/day of SO_4 from mine water (Figure 55). The highest SO_4 removal rates observed were 15 mol/m^3/day and the SO_4 removal rates consistently exceeded 7 mol/m^3/day (Christenson et al., 2022). The consumption of dissolved organic carbon directly correlated with SO_4 removal. Out the seven bioreactors, the combination of mulch, bark, and compost proved to be the most effective substrate for SO_4 removal (Christenson et al., 2022). It was noted that sulfide, dissolve organic carbon, and ammoniacal nitrogen could be elevated.

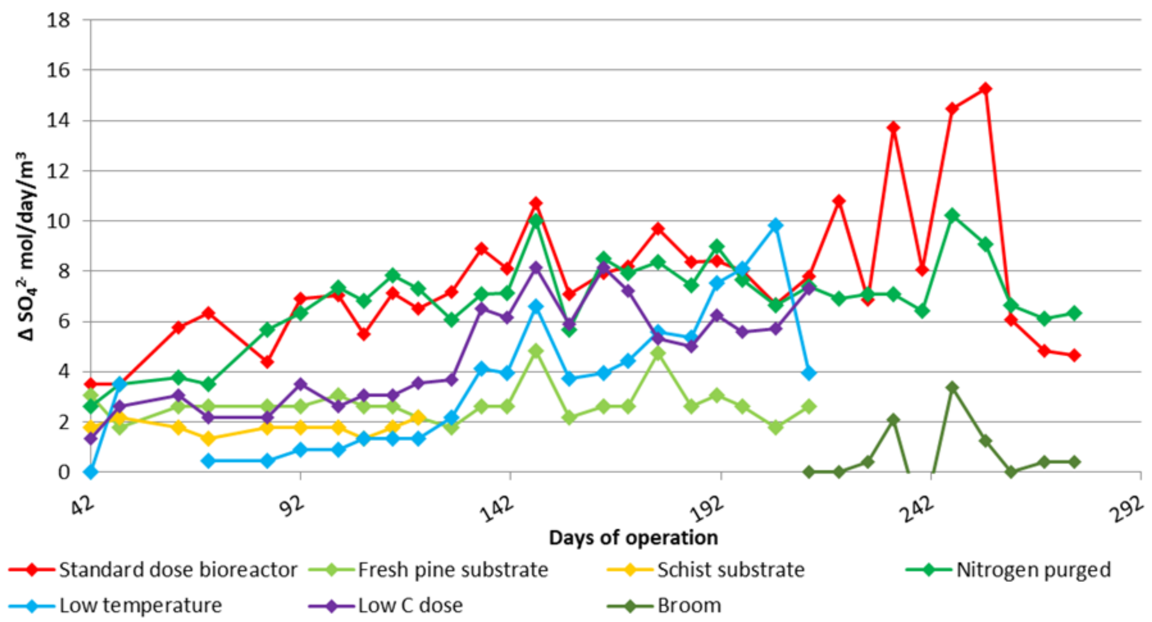


Figure 55. EPTS bioreactor effluent sulfate concentrations.

Source: Christenson et al (2022).

E-PTS have also been investigated as an option to treat nitrate-rich waters (e.g., Christenson et al., 2018) using nitrate-reducing bacteria (NRD) and water-soluble carbon compounds:

$4NO_3^- + 4H^+ + 5CH_2O \rightarrow 2N_2 + 7H_2O + 5CO_2$

NRB have been used in woodchip bioreactors to successfully reduce nitrate concentrations in agricultural and other enriched waters (Christianson et al., 2017). Similar systems could also be applied to nitrate rich MIW resulting from the use of nitrogen-based explosives. Results demonstrated a significant decrease in nitrate concentrations compared to the influent water quality (Figure 56).

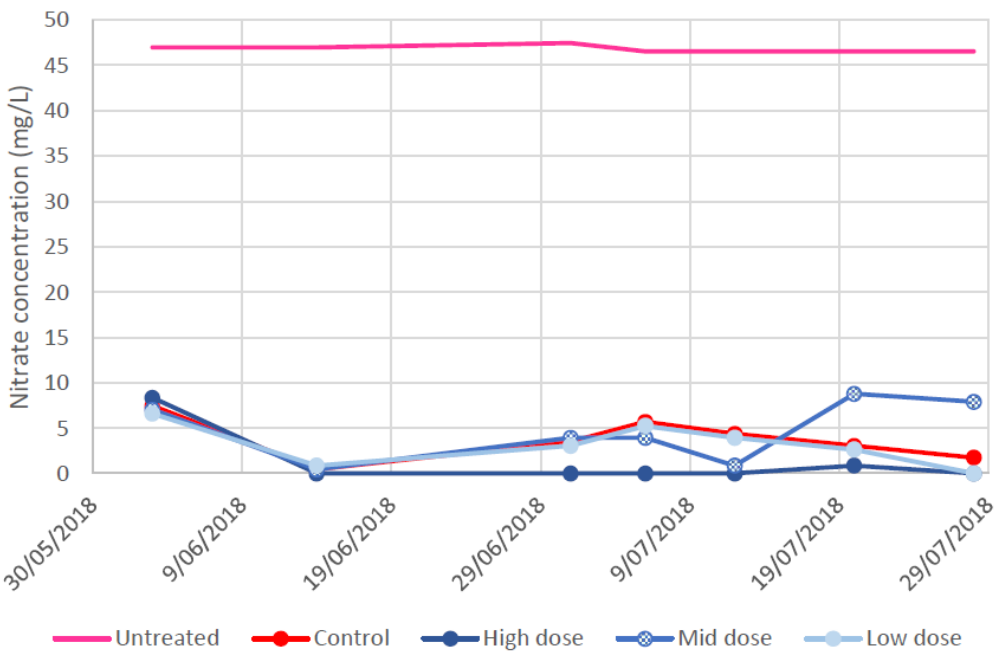


Figure 56. Nitrate treatment concentrations in the laboratory reactor effluent.

Source: Christenson et al. (2018).

Verum (2021) note, based on laboratory data, that "*sulfate removal in the standard dosed bioreactor removed more than half of the ~3,000 mg/L influent*" and "*nitrate removal was near complete in all reactors with influent concentrations reduced from ~17 mg/L to <0.5 mg/L NO_3-N*." Such data are encouraging and OceanaGold has engaged Verum to undertake field trials to validate the technology. Results are not available at the time of writing this report.

8.3.3 Zero Valent Iron

The chemical reduction of SO_4 within in anaerobic treatment system can result in elevated sulfide (H_2S) in the discharge water:

$$SO_4^{2-} + 2CH_2O \rightarrow 2HCO_3^- + H_2S$$

Elevated sulfide can create eco-tox issues. However, the hydrogen sulfide readily combines with metals (often Fe) to form acid volatile sulfides, precursors to the formation of pyrite / marcasite, which can remove the sulfide from solution:

$$Fe_2O_3(s) + 4SO_4^{2-} + 8CH_2O + \tfrac{1}{2}O_2 \rightarrow FeS_2(s) + 8HCO_3^- + 4H_2O$$

Iron-based compounds have been used previously for the removal of sulfide by precipitation, which can include zerovalent iron (ZVI) materials such as scrap iron. Robinson et al. (2022) used sulfide scrubber (SCR) technology that involved the use of magnetite, hematite, and iron filings:

$$Fe^{2+} + S^{2-} \rightarrow FeS$$

Results (Robinson et al., 2022) indicated that the effluent from the SCR systems contained concentrations of sulfide that were lower than the other passive treatment systems using organic matter and limestone by orders of magnitude (Figure 57).

Other research has noted that the use of ZVI led to minimal levels of toxic hydrogen sulfide in the treated effluent due to its efficient precipitation of sulfide as metal sulfides, which included Fe-sulfides generated by the anoxic corrosion of ZVI (Ayala-Parra et al., 2016; Gusek, 2009).

Liao et al. (2022) notes that metal sulfide precipitation is a common method to treat sulfide-containing wastewater that allows rapid precipitation of the sulfide salt and selective precipitation of heavy metals, and that zinc is commonly chosen as precipitation agent to recover sulfide due to its higher chemical stability compared to other transition metals.

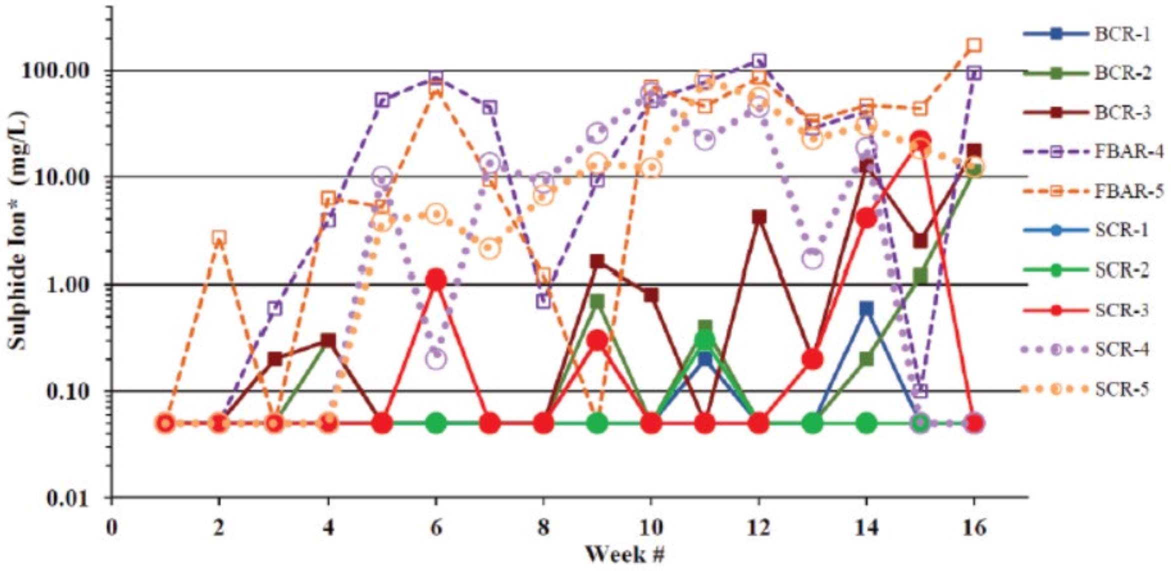


Figure 57. Sulfide concentrations following treatment.

Biochemical reactors (BCR); fixed-bed anaerobic bioreactors (FBAR) and Sulfide Scrubber (SCR) systems.

Source: Robinson et al (2022).

This sulfide precipitation approach could be applied to the effluent of a bioreactor. Ideally this would be undertaken prior to any oxidation step to encourage Fe-sulfide precipitation under reducing conditions. This could be incorporated as multi-step treatment approach whereby a scrubber system is used after an anaerobic treatment process. Materials could include iron fillings, waste galvanised steel, and possible Fe-rich sludge mixed with gravel to provide suitable permeability.

8.3.4 Vertical Flow Reactors

The work completed by Hayton (2022) demonstrated that a good option to treat arsenic and iron was a vertical flow reactor (VFR). A full-scale VFR has subsequently been constructed at the Globe-Progress Mine. The following link provides further information on the system:

- https://oceanagold.com/2021/01/27/delivering-innovative-passive-water-treatment-at-reefton/

The Globe-Progress Mine VFR aerates Fe- and As- rich waters from the waste rock stack seepage and tailings storage facility underdrains and then filters (downwards flow) the Fe-precipitates (with As adsorbed to the Fe-floc) through a gravel-bed. Treated waters are then discharged to Devils Creek.

The Fe-rich waters form a sludge on the base of the pond, which will require periodic removal and disposal. Having two ponds enables treatment to continue when one pond is off-line for desludging.

The use of Fe hydroxides to co-precipitate / adsorb and treat As-impacted mine waters is a proven technology for As treatment and could be applied at Macraes where required. This could include seepage from the WRSs, TSFs, and any pit lake overflow. If Fe is limited in the influent water stream, this could be added by a simple $FeCl_3$ dosing system.

Figure 58. Globe-Progress Mine Vertical Flow Reactor.

8.3.5 Summary – Passive Treatment Technologies

A number of viable passive treatment options are available for arsenic, sulfate, and nitrate mine-impacted waters that could be developed to mitigate any deleterious effects associated with the mining operation.

The following options are already used at Macraes or are easily utilised:

- Water management (pumping of water).
- Dilution of waters using dilution dams.
- Injection of mine-impacted waters into underground workings.

Passive treatment systems including anaerobic systems, enhanced passive treatment systems (E-PTS), zero valent iron, and vertical flow reactors (VFR) are also suitable options.

8.4 Active Treatment

The following section provides a high-level summary of potential active treatment options for As, Fe, and SO_4 mine impacted waters.

8.4.1 Precipitation to Remove Sulfate

Several minerals can be encouraged to precipitate thereby removing sulfate. Some examples are provided below.

8.4.1.1 <u>Precipitation of Gypsum</u>

The removal of sulfate by the addition of lime (CaO, $Ca(OH)_2$, $CaCO_3$) occurs through saturation of $CaSO_4$ (gypsum) and its precipitation. Given the simplicity of the process, it is a proven technology to remove elevated sulfate concentrations from mine-impacted waters. However, due to solubility constraints sulfate concentrations < 2,000 mg/L are unlikely. Competition for Ca ions is also likely with calcite precipitation anticipated.

Barium-based carbonates and hydroxides could also be used with similar effect. Table 27 shows the removal (%) of sulfate using Ba and Ca salt precipitation. A mechanical dosing system would be required together with sludge management procedures.

Table 27. Treatment of sulfate-rich effluents by Ba- and Ca-salt precipitation.

pH	LIME $Ca(OH)_2$	$BaCO_3$	$Ba(OH)_2$
		% removal	
2.9	62.3	24.2	107.7
7.9	80.5	101.6	137
12	51	90.1	134

Source: Bowell (2004).

8.4.1.2 Precipitation of Ettringite

The SAVMIN process, proposed by Smit (1999), involves the precipitation of Ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}$) to remove sulfate. The process consists of three mains stages (Figure 59). In the first stage, lime is added to raise the pH to 12, facilitating the removal of metals as hydroxides (Bowell, 2004). This is followed by the second stage, where gypsum is removed through seed crystallisation. In the third stage, aluminium hydroxide is added to form insoluble ettringite. Before discharge, CO_2 is introduced to lower the pH and precipitate $CaCO_3$ (Bowell, 2004). The ettringite can be disposed of or dissolved in sulfuric acid to recycle $Al(OH)_3$. The resulting effluent can be seeded with gypsum to generate more gypsum. A modified version of the SAVMIN process, known as the Cost-Effective Sulfate Removal (CESR) process, can also effectively remove metals and other contaminants, such as nitrate, during the ettringite precipitation step (Bowell, 2004).

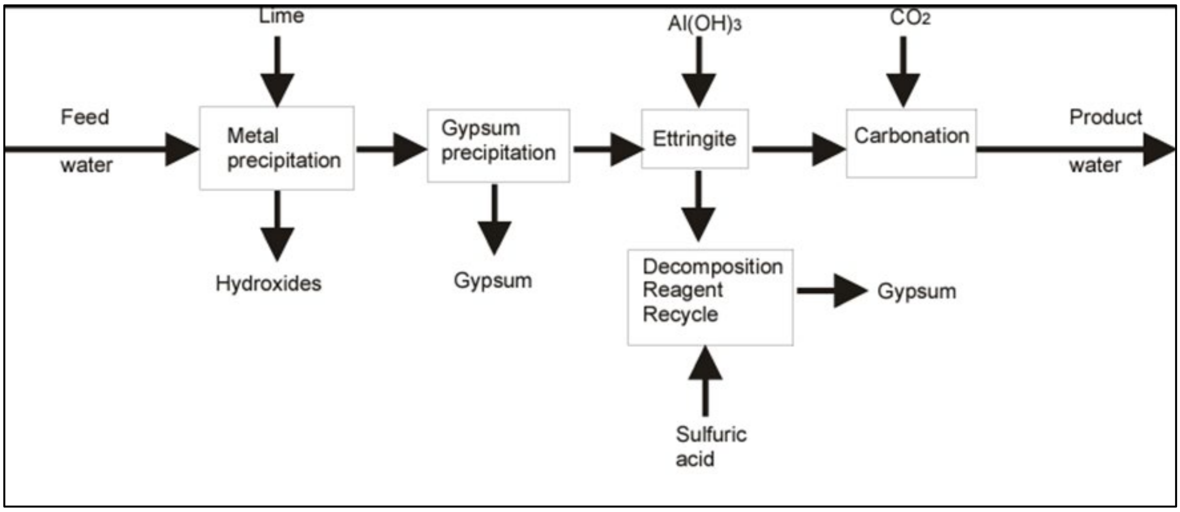


Figure 59. SAVMIN process flowsheet.

Source: Bowell (2004).

8.4.2 Active Treatment of Arsenic

Active treatment plants can be constructed where $FeCl_3$ is used to treat arsenic impacted waters. Often, these plants also require the addition of hydrated lime to maintain pH (as the hydrolysis of Fe(III) precipitation as $Fe(OH)_3$ is acid generating). The process forms a floc, which is then removed by large tank clarifiers +/- flocculants with clean water being discharged. These systems are common at mine sites throughout the world and a similar system operated at the Globe-Progress Mine to actively treat mine-impacted waters (elevated in As) during the operational phase of the mine.

An example of this includes the Globe Pit Lake (GPL), part of the Globe Progress Mine, located near Reefton New Zealand. As part of closure activities, the GPL was dosed with $FeCl_3$ to remove As (Navarro et al., 2022)). Results demonstrate a significant reduction in As loads for the GPL. Similar processes could be applied at Macraes (as pit lakes have been identified as being elevated in As).

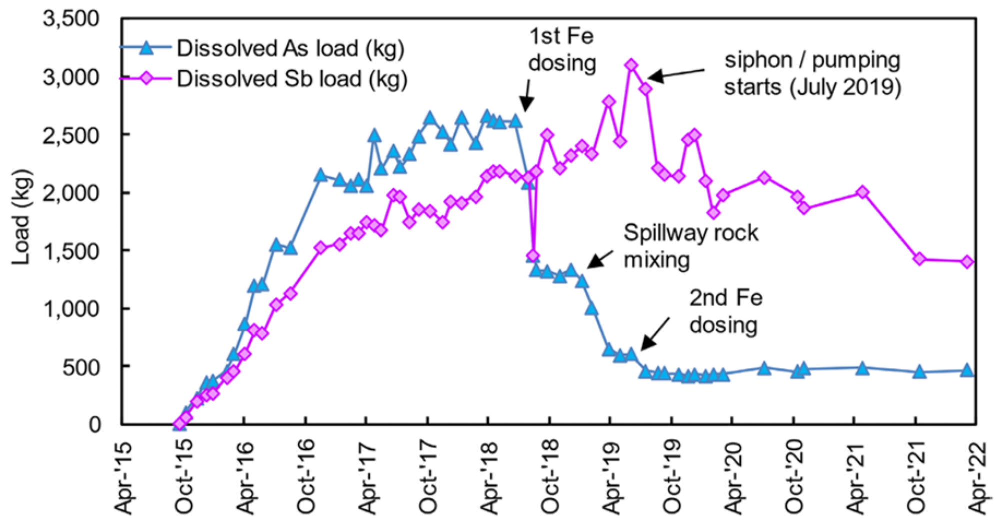


Figure 60. Arsenic removal in Globe-Progress Pit Lake following $FeCl_3$ addition.
Source: Navarro et al. (2022).

8.4.3 Summary

A number of viable active treatment options are available for arsenic and sulfate mine-impacted waters could be developed to mitigate any deleterious effects associated with the mining operation. Systems include:

- Precipitation.
- Chemical addition.

8.4.4 Sludge Management

Sludge produced from both passive and active treatment will require proper handling and disposal. Examples of sludge management include:

Operational Phase Management: During the mine operational phase, sludge can be placed back in the TSF. This is a common approach for the management of sludge.

Post Closure Phase Management: A number of options are possible including:

- Sludge could be placed within secure containment facilities on site. This would require consenting and ongoing management and performance monitoring.
- Sludge could be placed within a pit void / pit lake. Further studies would be needed to confirm the opportunities (e.g., additional adsorption of As) and risks (e.g., mobilisation of As – desorption of As from the Fe precipitate).

- Sludge could also be disposed off-site at a licensed landfill, treatment facility, or other approved disposal site. This will require the sludge to meet landfill acceptance criteria, which may require treatment or amendment of the sludge.

9 SUMMARY AND RECOMMENDATIONS

The objectives of this report were to provide the necessary environmental geochemistry technical studies to support the AEE for Macraes MP4.3. This included:

- Quantify the acidity generating characteristics and likely geochemical nature of the waste rock associated with the MP4.3 phase of works.
- Determine the seepage water quality from WRSs for predictive modelling.
- Determine the likely seepage/surface water for the following pit lakes:
  - Golden Bar Stage 2 Pit Lake.
  - Coronation Stage 5/6 Pit Lake.
  - Coronation North Backfill seepage.
  - Frasers and Innes Mills Pit Lake (FRIM).
- Undertake a preliminary geochemical risk assessment based on source hazard characterisation studies and pit lake modelling.
- Assess engineering controls for mine-impacted drainage associated with the pit voids and WRS.

The following section summarises the key findings for each of the subsequent sections and the recommendations.

9.1 Geochemical Characterisation

The acid base accounting (ABA) data presented here supports previous investigations that waste rock at Macraes is generally non-acid forming, with low sulfide sulfur, and is unlikely to generate acid rock drainage with ANC values being significantly higher than MPA values leading to negative NAPP values. This is supported by circumneutral to alkaline NAG pH values and drainage waters at site that are circum-neutral.

Geochemical testwork and assessment of monitoring data from site indicates that the **key contaminants of concern (PCOC) for the project are arsenic, nitrogenous compounds (due to ammonium-nitrate-based blasting residues), and sulfate**. Some data suggest that on occasion Fe, Zn and Cu can also be elevated.

Such data, supported by **ABA results confirm that acid rock drainage is not expected at this site**, rather neutral metalliferous drainage is expected, which is currently observed at site (e.g., circum-neutral drainage elevated in sulfate and some contaminants of concern).

9.2 WRS Water Quality

A model was developed to forecast waste rock seepage as a function of WRS height. The higher the WRS, the higher the sulfate concentrations. Sulfate concentrations were then used to derive the concentrations of other contaminants to create source terms for forecasting water quality.

The relationship provided suitable source terms for WRS seepage for pit lake water quality modelling where the sulfate maximum data were used, which is considered conservative.

9.3 Pit Lake Water Quality

Pit lake hydrogeochemical modelling was undertaken to understand the potential effects on groundwater and surface waters including during filling and then with overflow to the surrounding waterways. A number of pit lake models were developed including:

- Golden Bar Pit Lake – Stage 1 (current pit lake).
- Golden Bar Stage 2 Pit Lake (proposed).
- Coronation Stage 5/6 Pit Lake 6 (proposed).
- Frasers TSF and Innes Mills pit lakes (FRIM) (proposed).

Key contaminants of concern identified by the modelling processes includes arsenic and sulfate. Flow rates from these mine domains are low (GHD, 2024) for Golden Bar Stage 2 Pit and Coronation Stage 6 Pit (<5 L/s). Modelling for FRIM indicates that it will not spill.

9.4 AMD Hazards

Acid drainage is not considered a risk for the site, however neutral metalliferous drainage is a hazard for the site and a risk for the receiving waterways. The following is noted.

- WRS seepage is expected to be circumneutral pH, with high concentrations of NO_3-N, Amm-N, SO_4, and Zn.
- Pit lakes (Golden Bar Stage 2, Coronation Stage 5/6, and FRIM) are expected to have circumneutral pH, and relatively high concentrations of sulfate and arsenic with
  - As being above water quality reference values in Coronation Stage 5/6; and
  - SO_4 being above water quality reference values in FRIM.
- Some pit lakes may also have elevated levels of NO_3-N, Amm-N in the early stages of pit lake development before biogeochemical processes remove the nitrogenous compounds.

9.5 Source Control

Source control technologies include methods to prevent the oxidation of sulfide minerals and methods to minimise the mobilisation of any oxidation products (derived from sulfide mineral oxidation). A key opportunity for the project is to reduce advective ingress into WRSs. This can be achieved by

- Minimising the tiphead height to prevent grainsize segregation, which can create a rubble zone / oxygen pathway into the core of the WRS. OceanaGold have indicated this does not occur until the tiphead height is > 10m.
- Limiting the height of the WRS to limit the sulfate concentration.
- Construction of advective barriers (i.e., a toe berm) to seal the basal rubble zone.
- Progressive rehabilitation and capping of the WRS.

Other options include the management of interburden waste rock. Interburden waste rock is blasted to create a finer material compared to overburden (to reduce milling costs) and is slightly higher in sulfur compared to overburden). A higher sulfur content and a finer grainsize suggests these materials should be placed in the core of a WRS away from advective oxygen flux.

Other source control options include methods to minimise water ingress and the mobilisation of oxidation products:

- Clean water diversion away from WRS.
- Avoidance of run-on water to a WRS (e.g., up-catchment drainage into a WRS).
- Encouraging clean-water run-off from the WRS surface (rather than ponding).
- Progressive rehabilitation and capping of the WRS.

Such source control technologies are recognised internationally as being appropriate for minimising the effects of sulfide mineral oxidation. These technologies should be integrated into the mine planning process.

9.6 Management and Treatment

There two general options for mine-impacted waters including management and treatment. Treatment options of mine impacted waters including passive treatment and active treatment. Management and treatment options are both viable for Macraes during the operational and closure phases of the project.

The following options are considered suitable for the management on mine impacted waters at Macraes:

- Water management:
    - Pumping to surface storage areas.
    - Injection into underground workings.
    - Dilution using dilution dams.
    - Controlled discharge
- Passive treatment systems:
    - Anaerobic systems.
    - Enhanced passive treatment systems (E-PTS).
    - Zero valent iron.
    - Vertical flow reactors (VFR).
- Active Treatment (for arsenic and sulfate):
    - Precipitation technologies.
    - Chemical addition.

Sludge produced from both passive and active treatment will require proper handling and disposal. During operations sludge can be placed in the TSF. In the post closure phase, after rehabilitation of the TSF facilities, the sludge generated from ongoing treatment will require disposal in an appropriate facility.

9.7 Recommendations

The following general recommendations are provided to support a greater understanding of the environmental geochemistry effects of the project and options to mitigate those effects:

- The development of a contaminant load model for each WRS is recommended to understand the sulfate load (as a function of flow rate and water quality) as compared to the physical dimensions of the WRS. This will confirm the benefits of best practicable source control technologies.
- If advective barriers are required to minimise oxidation in WRSs, then trials should be undertaken to validate the approach required.
- Continue to assess water management and treatment options

9.8 Adaptive Management

This report models future geochemical hazards associated with waste rock stacks and pit lakes and appropriate technologies are available to manage these hazards. Long-term water quality forecasts require adaptive management processes to ensure the models remain valid. Adaptive Management should include:

9.8.1 Performance Monitoring

Performance monitoring and analysis is recommended to confirm the predicted water qualities for WRS and pit lakes are suitable. Specific performance monitoring includes:

- Ongoing ABA monitoring of waste rock and tailings associated with the project.
- Performance monitoring of WRS (flow and quality) to confirm the WRS seepage water quality algorithm remains correct.
- Performance monitoring of the pit lake as they fill against pit lake model forecasts.
- Monitoring of tipheads to confirm that grainsize segregation does not occur in WRS tip heads < 10 m high, which will support WRS design to minimise grainsize segregation[7].

9.8.2 Variance Planning

Variance from the expected case is likely, and there needs to be supporting management options to show how significant variance (or range) will be managed.

The range of management options can be referred to as the 'adaptive management regime' and needs to be acceptable to both internal and external stakeholders. Figure 61 provides an illustrative example of the adaptive management regime for AMD impacted waters.

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[7] *Drone based digital technologies are available to quantify the grainsize properties of tipheads.*

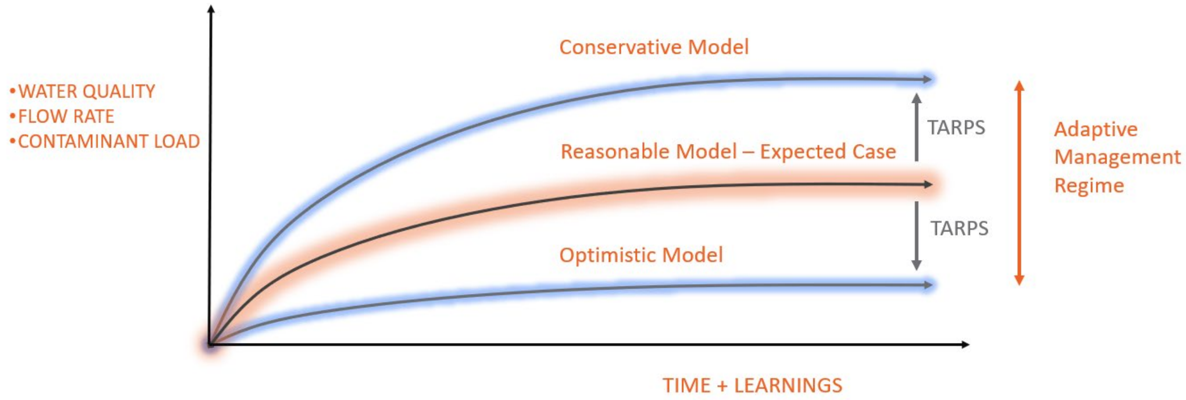

Figure 61. Adaptive Management Regime

Source: Weber (2020)

9.8.3 Trigger Action Response Plans

Variance from the expected case can be managed by Trigger Action Response Plans (TARPs) where appropriate. The number of TARPs is based on an AMD risk assessment process to ensure potential higher risk effects have management options in place. Generally, a TARP has set trigger limits to define what a significant change is, and then describes the actions to respond to the variance. TARPs need to be developed to cover the adaptive management regime to foster stakeholder confidence. Examples of this include:

- Waste rock placement verification to ensure design methodologies are achieved.
- Performance monitoring of WRSs for oxygen content and net percolation quality/quantity.
- Performance monitoring of pit lake water quality.

The use of TARPS provides the framework to manage uncertainty in a manner that makes stakeholders more comfortable that solutions are available and are ready to be implemented if there is variance from the expected case.

9.8.4 Adaptive Management for Macraes WRS Seepage

OceanaGold has undertaken a review of water management options, primarily for WRS seepage, to mitigate the effects of elevated contaminants in the downstream receiving environments. As shown in Sections 7 and 8 of this report there are a number of engineering controls and treatments ('management options') that are available to mitigate the risks of elevated sulfate (and other contaminants). Some of these management options have been implemented on site already or could be implemented in a relatively short time frame; others still require further development (and time to complete studies and trials). In view of this, an adaptive management approach is proposed for the management of WRS seepage elevated in sulfate and nitrate, in particular.

The following options form a potential base case approach to water management. Water models are being developed for each option to model a reasonable mix of practicable options and to estimate expected water quality improvement in the downstream receiving environments:

- Piping Frasers East Sump water to the North Branch Waikouaiti River (NBWR) on the west side of the Frasers Pit.

- Timely rehabilitation of all WRSs to ensure a subsequent decrease in infiltration rates to close to natural ground recharge levels as determined by GHD (2024).
- Implementation of Enhanced Passive Treatment (e.g., Section 8.3.2 of this report) to treat WRS seepage where, conservatively, 25% of the influent sulfate concentration is removed (Verum (2021) report 50% is acheivable).
- Return WRS seepage water from Murphys Silt Pond back to Frasers Pit (pumping) in perpetuity, which was deemed to have sufficient capacity to manage any additional load (flow and quality).

Subject to the modelling outcomes for the mix of base case management options, other options that could be investigated further include:

- Pumping of Clydesdale Sump Water to Frasers
- Controlled discharge of mine influenced waters (e.g., from Murphys Silt Pond) during higher catchment flows where natural dilution would be available.

Further work will be required to optimise the base case and other opportunities to result in a robust long term water management solution post closure. The base case should be supported by performance monitoring and appropriately designed TARPs.

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11 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix C of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A ABBREVIATIONS

ABBREVIATION	DEFINITION
ABA	Acid base accounting
AMD	Acid and metalliferous drainage, which can also include low metal saline drainage
AMDMP	Acid and metalliferous drainage management plan
ANC	Acid neutralisation capacity
ANFO	Ammonium-nitrate fuel oil explosive
ARD	Acid rock drainage
BRWRS	Back Road waste rock stack
CRS	Chromium reducible sulfur
CSM	Conceptual site model
DMIRS	Department of Mines, Industry Regulation and Safety
DO	Dissolve oxygen
DWER	Department of Water and Environmental Regulation
EC	Electrical Conductivity
EDS	Energy dispersive x-ray analysis
EPA	Environmental Protection Agency
FEWD	Frasers East waste rock stack
FRBF	Frasers backfill
FRUG	Frasers underground
FSBF	Frasers south backfill
FTSF	Frasers tailings storage facility
GAI	Geochemical abundance index
GB- WRS	Golden Bar waste rock stack
GPBF	Golden Point backfill
g/m^3	Grams per cubic metre
g/t	Grams per tonne
HMSZ	Hyde-macraes Shear zone
IMBF	Innes Mills Backfill
kg	Kilograms
LGO	Low grade ore
LOM	Life of mine
LOR	Limit of reporting
M	Moles
m	Metres
m bgl	Metres below ground level

ABBREVIATION	DEFINITION
MEQ	Metal ecotox quotient
mg/L	Milligrams per litre
MC	Murphy's Creek
mg/kg	Milligrams per kilogram
µm	Micrometre
MPA	Maximum potential acidity
m RL	Metres reduced level
mS/m	Millisiemens per metre
µS/cm	Microsiemens per centimetre
meq/L	Milliequivalents per litre
Mt	Million tonnes
MTI	Mixed tailings impoundment
MWM	Mine Waste Management Ltd
NAF	Non-acid forming
NAG	Net acid generation
NAPP	Net acid production potential
NBWR	North Branch Waikouaiti River
NMD	Neutral metalliferous drainage
NP	Net percolation
NPR	Neutralisation potential ratio
OceanaGold	OceanaGold Limited
ORC	Otago Regional Council
ORP	Oxidation-reduction potential
PAF	Potentially acid forming
PCOC	Potential contaminants of concern
POX	Pressure oxidation
PSD	Particle size distribution
QA/QC	Quality assurance and quality control
RHBF	Round Hill backfill
ROM	Run of mine
SD	Saline drainage
SEM	Scanning electron microscope
SFE	Shake flask extraction
SPLP	Synthetic precipitation leachate procedure

ABBREVIATION	DEFINITION
SPIMBF	SPIM backfill
SP11	Southern Pit 11
TAA	Titratable actual acidity
TSF	Tailings storage facility
TTTSF	Top Tipperary Tailings storage facility
UC	Uncertain
USGS	United States Geological Survey
WAD	Weak acid dissociable
WQMP	Water quality management plan
XRF	X-ray fluorescence
WRL	Waste rock landform
WRS	Waste rock stacks
W/S	Water/solid
wt%	Weight percentage

APPENDIX B DEFINITIONS

TERM	DEFINITION
Acid Base Accounting	Conducted to predict acid generation and neutralisation characteristics of a waste rock material.
Acid Neutralisation Capacity	This is a measure of the insitu neutralising potential of a sample. Expressed as kg H_2SO_4 equivalent per tonne.
Acid and Metalliferous Drainage	Includes both acidic drainage typically caused from the oxidation of exposed sulfides, and metalliferous drainage resulting from elevated levels of toxic metals and salinity. Saline drainage can also occur. In all instances sulfate is high.
Acidic Drainage	A form of AMD, characterised by low pH, elevated toxic metal concentrations, high sulfate concentrations and high salinity.
Maximum Potential Acidity	Is a measure of the insitu acid production of a sample. Expressed as kg H_2SO_4 equivalent per tonne.
Neutral Metalliferous Drainage	A form of AMD characterised by near-neutral pH, elevated heavy metal concentrations, and high sulfate salinity.
Net Acid Production Potential	Is a measure of the samples overall acid generating capacity and is calculated by subtracting the ANC from MPA. A negative NAPP indicates a net neutralising capacity and a positive NAPP indicates a net acid generating capacity. NAPP, MPA, and ANC are expressed in kg H_2SO_4 per tonne equivalent.
Non-Acid Forming	Appendix D has further information on the classification of The Project's waste rock classification scheme.
Potentially Acid Forming	Appendix D has further information on the classification of The Project's waste rock classification scheme.
Saline Drainage	Is a product of AMD, characterised by high sulfate salinity but near-neutral pH and low concentrations of heavy metals.

APPENDIX C AMD BACKGROUND INFORMATION

FACT SHEET 1 - WHAT IS AMD

AMD MANAGEMENT TRAINING SERIES

Acid and metalliferous drainage (AMD) is a general term used to describe waters impacted chemically by mining activities and can contain significant quantities of toxic metals, salts, and acidity.

AMD is typically generated by the excavation of rocks that contain sulfide minerals, such as pyrite. When these minerals are exposed to oxygen and water, they undergo weathering processes and oxidise, generating acidity and releasing toxic metals.

The oxidation of pyrite is explained by Equations 1-3 where the ferric (Fe^{3+}) iron precipitates in a goethite or ferrihydrite type form (iron-oxyhydroxide) such as the orange precipitate seen in the image.

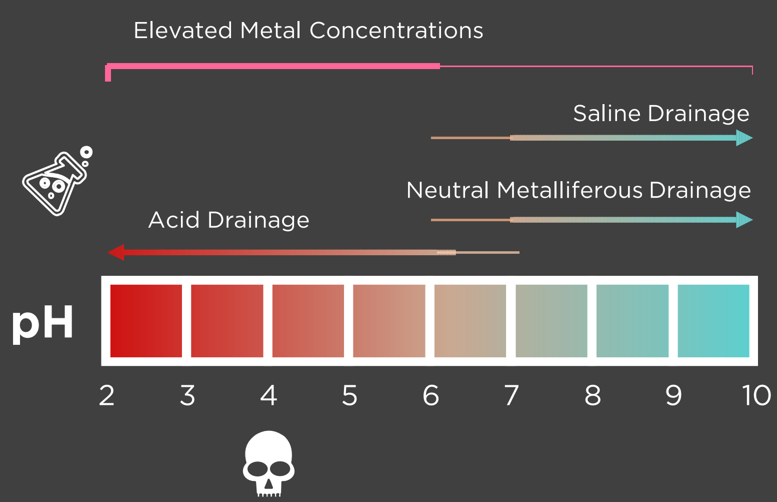
- **Equation 1:** $FeS_2 + {}^{7}/_{2}\ O_2 + H_2O \longrightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$
- **Equation 2:** $Fe^{2+} + {}^{1}/_{4}\ O_2 + H^+ \longrightarrow Fe^{3+} + {}^{1}/_{2}\ H_2O$
- **Equation 3:** $Fe^{3+} + 3H_2O \longrightarrow Fe(OH)_3 + 3H^+$

Microorganisims play an important part in the oxidation of sulfide minerals and the formation of AMD. Such bacteria can increase sulfide oxidation rates by many orders of magnitude.

Once acidity and metals are generated they can then be mobilised by any water sources, including rainfall, run-on water, water from dust suppression, or water added via processing. It is important to note that this can occur in both high rainfall and low rainfall environments.

TYPES OF AMD

AMD waters can be sub-divided into three general water types depending on their pH and concentration of sulfate and metals.



Acid Rock Drainage (ARD):
Has high acidity, low pH drainage, and has occurred due to the oxidation of acid producing sulfide minerals. ARD generally contains significant dissolved toxic metals.

Neutral Metalliferous Drainage (NMD):
Often referred to as metalliferous drainage where the acid produced by the oxidation of sulfide minerals has been neutralised by other minerals such as carbonates, with the resultant waters having high toxic metal concentrations but circum-neutral pH.

Saline Drainage (SD):
Which refers to waters that are close to neutral-to-alkaline in pH with elevated sulfate.

AMD EFFECTS

AMD can create a number of other health, safety, environmental, and community issues:

- Acute short term and chronic long term effects of interactions with acid waters and waters containing elevated metals where pathways include skin contact, ingestion, and inhalation.
- Metals derived from AMD entering the food chain (bio accumulation) causing health issues for animals, livestock, and humans.
- Sedimentation and smothering of drainage channels with metal-rich precipitates.
- Increased erosion rates for sulfidic materials.
- Interaction of AMD with concrete (acid- and sulfate- attack) leading to degradation of site infrastructure.
- Spontaneous combustion.
- Generation of gases such as carbon dioxide and hydrogen sulfide, which may be at fatal concentrations.
- Generation of low oxygen air, which can be fatal.
- Visual impacts and negative stakeholder perceptions.
- Impacts on business reputation and business sustainability including social licence / social value.
- Ability to close sites affected by AMD and long term treatment costs and risks.

AMD LEGACY EFFECTS

AMD MANAGEMENT TRAINING SERIES: FACT SHEET 1

Internationally, there are many examples of historical legacy sites where AMD has not been managed correctly resulting in significant impacts to the environment.

For instance:

- In Spain, the **Rio Tinto River** is coloured red due to iron, from sulfide mineral oxidation and is highly acidic. (see image)

  This is the result of AMD from thousands of years of base metal mining for gold, silver, and copper within the Iberian Pyrite Belt.

- **Iron Mountain**, a historical minesite in California, is another example. Untreated AMD from the site was causing fish kills in the river and the build-up of contaminated sediments in the downstream receiving environment.

- **Mount Lyell**, Tasmania is one of Australia's worst AMD sites where 100 million tonnes of sulfidic tailings were dumped into the Queen River resulting in low pH and elevated metals.

Modern mining companies must address the risks of AMD through sustainable best practicable management options to prevent the creation of future legacy sites

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FACT SHEET 4 - HOW TO PREDICT AMD

AMD MANAGEMENT TRAINING SERIES

Prediction of the potential for AMD, the type (being acidic, neutral metalliferous, or saline drainage), severity, time to onset, and subsequent longevity are determined by a process of materials characterisation.

Each project will have different AMD characterisation requirements to understand potential effects and risks for the project, which is specific to the deposit type, alteration styles, material quantities, weathering effects, physical setting, and regulatory setting.

Materials should be characterised so that material-specific AMD risks are understood, and hence also, the potential geochemical risks for mine domains containing these materials. Furthermore:

1. Understanding the potential AMD characteristics for various materials and subsequent mine domains enables a risk assessment based on scientific and engineering data to determine management options.
2. An **AMD risk assessment** is a fundamental step in AMD prediction and will be revisited many times over the project life.
3. The AMD risk assessment process determines the AMD management requirements for the project (e.g., prevention, minimisation, control and treat).
4. Hence, prediction drives AMD management options.

Prediction has several components, potentially requiring more detail as the mine matures through exploration, mine development, mine operation, and mine closure. The components of prediction can be simplified as follows:

1. Geoenvironmental Models
2. Material Characterisation
3. Material Geochemical Signature
4. Water Quality Predictions
5. AMD Risk Assessment

GEOENVIRONMENTAL MODELS (ANALOGUE MODELS)

Geoenvironmental models provide fundamental information on the type of deposit and the likely environmental risks associated with geochemistry (e.g., Plumlee, 1999). It has been suggested that deposit type can contribute to 30% of the maximum potential AMD risks for a site (Richards et al, 2006), which means that important information can be gained from understanding the deposit type.

Further information can be gained from analogue models, which include:

- Local mine operations that disturb similar geological materials;
- Other mine domains (e.g., waste rock dumps, pit voids); and
- Knowledge and data about specific problematic lithological materials.

Such analogue models can be used to provide evidence of similar geochemical effects and risks. Often such information is obtained from desktop investigations and provide initial guidance on the potential AMD risks for a project.

Visual Clues

- Are there any visual indicators of AMD generation such as iron oxide crusts on exposed rocks or iron oxide precipitates in nearby streams?

Analogue Models

- Are there any other mines in the area, which have targeted the same lithologies, minerals, ore type? Do these mines have issues with AMD?
- Globally, are these types of mines known to have AMD issues?

MATERIAL GEOCHEMICAL CHARACTERISATION

Material geochemical characterisation, or source hazard characterisation, is a fundamental step in the assessment of any project in regards to the potential risks for AMD. Materials should be characterised so that AMD risks are understood, and hence also, the potential geochemical risks for mine domains containing these materials.

Characterisation involves assessment of:

- **Geochemical Nature** (Acid Base Accounting), for instance, potentially acid forming (PAF); or non-acid forming (NAF).
- **Geochemical Signature** of water quality (potential effects), for instance acidic, metalliferous, or saline drainage.

Material Sampling Program

Several guidance documents are available to assist the development of a project specific sampling and analysis program (AMIRA, 2002; Price, 2009; INAP, 2010; DTIR, 2016), which all give consideration to the following:

- Project phase;
- Quantity of material to be disturbed through mining;
- Existing datasets;
- Variability of critical parameters (geology / alteration / mineralogy / degree of weathering); and
- Social value and regulatory requirements.

Where prior information is not available, a common guide to an initial sampling frequency is provided in the below table (variations presented in both Price, 2009, and DTIR, 2016).

Tonnage of Unit (metric)	Minimum Number of Samples
<10,000	3
<100,000	8
<1,000,000	26
<10,000,000	80
>10,000,000	Few hundred

Testing (chemical and physical) involves the use of geoenvironmental models, laboratory tests, field tests, and other observations. Further information on acid base accounting (ABA) to understand the geochemical nature of materials as well as test methodologies to understand the potential geochemical signature are provided in Fact Sheet 11 (Laboratory Test Methods).

*Although this fact sheet is focused on AMD characterisation, there are other environmental geochemical effects that might be identified during investigations including risks associated industrial diseases (asbestosis, silicious), carcinogenic compounds (e.g., As), radioactivity, spontaneous combustion, and greenhouse gas emissions, which all have potential receptors (environment, community, closure).

Geochemical Nature (Acid Base Accounting)

Acid base accounting (ABA) uses laboratory data to determine if the material is NAF or PAF, which is based on the difference or ratio between acid forming and acid neutralising minerals in the rock. Classification is typically based on either (or both) the AMIRA (2002) or Price (2009) classification schemes until site-specific classification systems are developed. Examples are available in the GARD Guide (INAP, 2010) and the Leading Practice Sustainable Development Program for the Mining Industry - Preventing Acid and Metalliferous Drainage (DTIR, 2016).

The acid generating potential of a rock is determined by measuring the sulfur (or sulfide) content and calculating the maximum potential acidity (MPA) that would be generated, assuming all the sulfur (or sulfide) is present as pyrite and completely oxidises.

The acid neutralisation capacity (ANC) is determined by laboratory testing (acid digestion), which is designed to assess neutralising minerals in the material. ANC can also be calculated from carbonate content where data are available and there is confidence in the approach.

$$\text{MPA} = \text{S (wt\%)} \times 30.63 \qquad \text{Units: kg } H_2SO_4/t$$

MPA and ANC data are fundamental data for ABA for determining the net acid producing potential (NAPP) where NAPP positive data suggests the sample is PAF and NAPP negative data suggests the sample is NAF.

$$\text{NAPP} = \text{MPA} - \text{ANC} \qquad \text{Units: kg } H_2SO_4/t$$

The net acid generating capacity (NAG) of a sample can also be determined to provide quantification of the overall acid generating capacity (kg H_2SO_4/t) of a sample where acidity generated reacts with any neutralising minerals to provide an overall final NAG pH.

ABA data can also provide guidance on the potential for neutral metalliferous drainage (NMD), for instance:

- Where elevated sulfide sulfur is present, yet the sample is NAPP negative due to abundant ANC; and
- Where NAG testing provides circum-neutral pH yet significant sulfide oxidation has occurred and metals of potential concern remain in solution.

Additional assessment is often required to understand and quantify the potential for NMD including kinetic testing and other wet laboratory techniques to understand the geochemical signature of the materials.

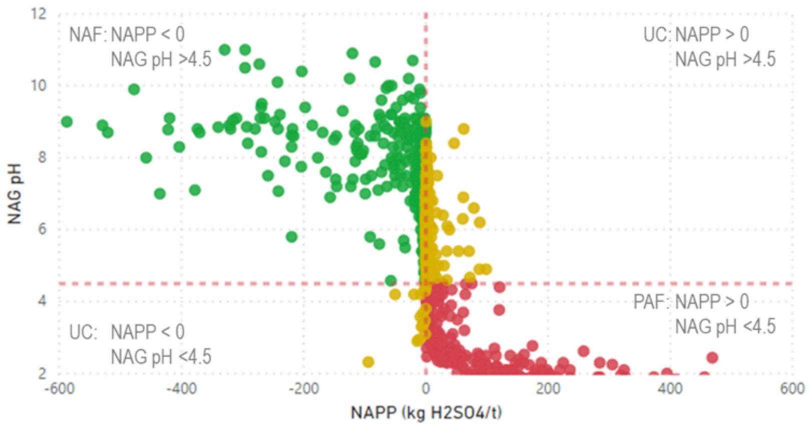
Further information on test methods is provided in Fact Sheet 11.

AMIRA Classification System

The AMIRA Classification system uses NAPP and NAG pH to classify samples as PAF, NAF or Uncertain (UC). Where NAPP is positive and NAG pH is less than 4.5, samples are classified as PAF. Where NAPP is negative and NAG pH is greater than 4.5, samples are classified as NAF. Samples with conflicting NAPP and NAG pH are classified as UC.

Note that although a sample may be classified as NAF it does not infer low geochemical risk.

High sulfide and high carbonate samples may present NMD or Saline Drainage (SD) risks requiring management.



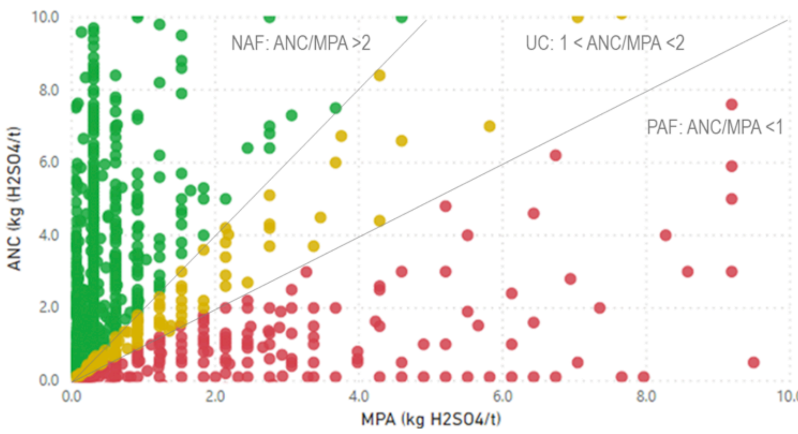
Areas within a plot of NAPP and NAG pH which are classified as NAF, PAF, and UC.

Price Classification System

The Price Classification system uses the ratio between ANC and MPA to classify samples as PAF, NAF or UC, where the Neutralisation Potential Ratio (NPR) = ANC/MPA. When ANC/MPA is less than 1, samples are classified as PAF.

When ANC/MPA is greater than 2, sufficient neutralising capacity is inferred to account for acid production and the samples are classified as NAF. When ANC/MPA is between 1 and 2, samples are classified as UC.

Areas within a plot of MPA and ANC which are classified as NAF, PAF and UC.

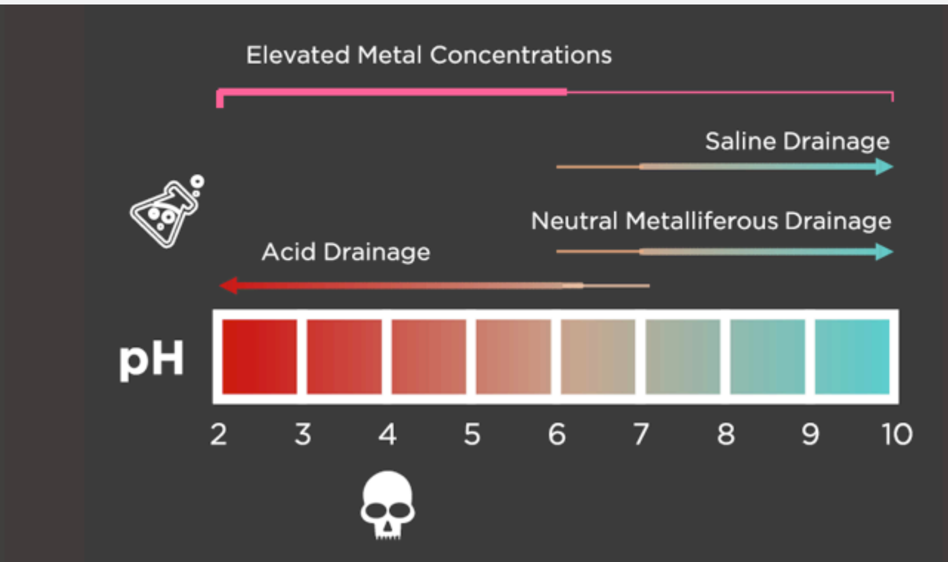


Geochemical Signature (Water Quality)

The geochemical signature or water quality from a material type can be inferred from ABA characterisation data. However, further information is required to determine the expected water quality, which can include data from geoenvironmental models, field data, and additional laboratory tests such as kinetic column leach testing.

Kinetic testing generally involves oxidising a material sample in the presence of water to understand trends in water quality and quantify oxidation rates, neutralisation rates and contaminant loads with respect to time. Such data is used to determine the potential for acid rock drainage, neutral metalliferous drainage, or saline drainage, which provides an indication of the potential geochemical signature of water quality and initial data for risk assessments.

Further information on test methods is provided in Fact Sheet 11.



Characterisation data, coupled with material schedules, and mine plans can be used to predict water quality from mine domains.

This is an essential step in prediction and such data should be used for risk assessments and can include:

- Numerical modelling;
- Geochemical modelling; and
- Groundwater and surface water modelling.

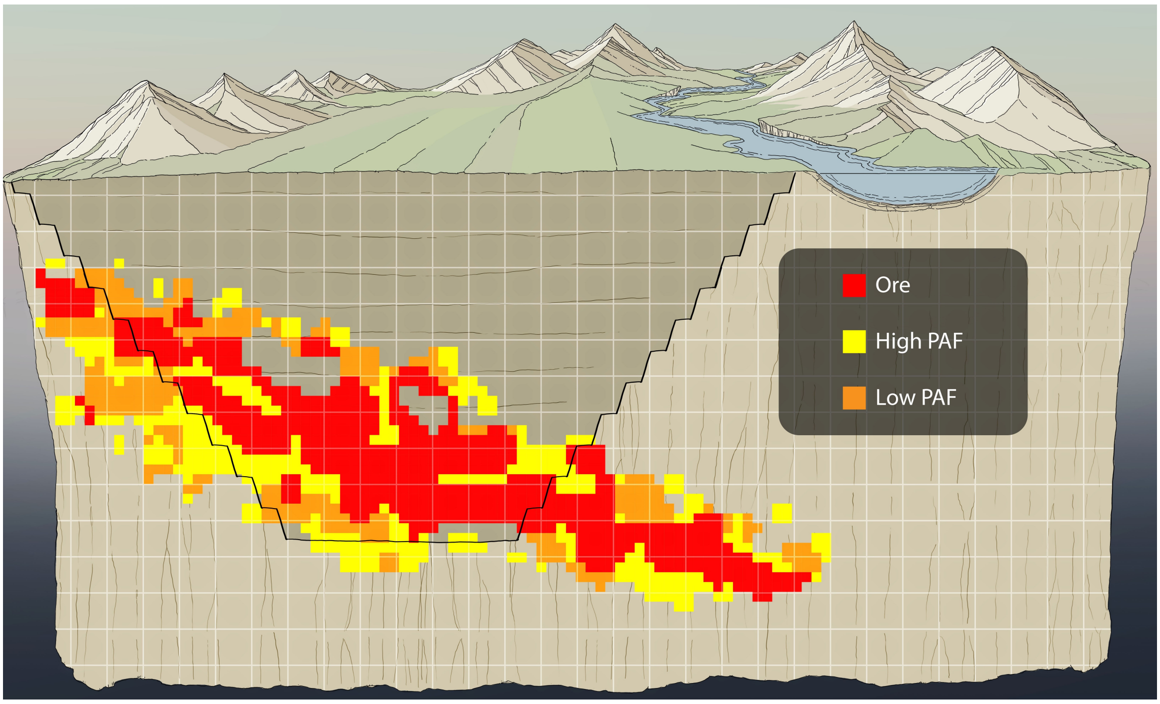
MATERIAL SCHEDULES

The data obtained from materials characterisation processes enables a classification system to be developed. Classification systems are often site-specific and can be used to develop a waste rock block model.

A block model is an essential step in AMD management as it is used to develop a materials schedule for the different material types over the project life cycle. This helps to quantify the potential risk from materials.

For instance, block modelling could indicate:

- That the risk for AMD is low as PAF materials represent a very small fraction of the materials schedule.
- Shortfalls in NAF materials later in the mine life, which could indicate stockpiling may be required.
- Identify higher risk materials that may require more intensive management options.



HOW TO PREDICT AMD

AMD MANAGEMENT TRAINING SERIES: FACT SHEET 4

AMD RISK ASSESSMENT

The data obtained from the geochemical characterisation of materials can be used to support AMD risk assessments, which will become increasing more detailed, coincidental with project development study phases. These risk assessments should be coupled with conceptual site models and an understanding of source-pathway-receptor analysis for informed risk-based decision making processes.

Geochemical characterisation investigations assess source materials to understand potential hazards. To understand possible effects on receptors requires an understanding of pathways, which can include for instance surface water, groundwater, and emissions to air.

NOMENCLATURE

This Fact Sheet, when describing key mine drainage terms, uses South Pacific nomenclature. The following North American synonyms have been summarised from Price (2009):

South Pacific Conventions		North American Conventions	
Potentially Acid Forming	PAF	Potentially Acid Generating	PAG
Non-Acid Forming	NAF	Non-Potentially Acid Generating	Non-PAG
Acid Neutralising Capacity	ANC (kg H_2SO_4/t)	Neutralisation Potential	NP (kg $CaCO_3$/t)
Maximum Potential Acidity	MPA (kg H_2SO_4/t)	Acid Potential[1]	AP (kg $CaCO_3$/t)
Net Acid Production Potential	NAPP (kg H_2SO_4/t)	Net Neutralisation Potential[2]	NNP (kg $CaCO_3$/t)
ANC to MPA Ratio	ANC/MPA	Net Potential Ratio	NPR

[1]AP = 31.25 × %S (kg $CaCO_3$/t)

[2]NNP = NP – AP (different to NAPP which subtracts the acid neutralising capacity from the maximum potential acidity)

Conversion Factors: ANC = 0.98 × NP; MPA = 0.98 × AP

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- Price, W., 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. Mine Environment Neutral Drainage (MEND) Program, Smithers, British Columbia.
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APPENDIX D MATERIAL CHARACTERISATION METHODOLOGY

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MEMORANDUM

Recipient:	Dean Fergusson – OceanaGold Limited
From:	Paul Weber – Mine Waste Management
Date:	24 September 2023
Cc:	Carlos Hillman – Mine Waste Management; Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0229-002-M-Rev1
Document Title:	J-NZ0229-002-M-Rev0 Macraes Mine Material Characterisation Methodology

Mine Waste Management Limited (MWM) has prepared this memorandum for OceanaGold Limited (OceanaGold) as part of the environmental geochemical support for the Macraes Mine (Macraes) Phase 4 (MP4.3) Project resource consenting process. The following memorandum summarises the sample and analysis plan (SAP) for the waste rock, ore, and low grade ore (LGO) materials. Samples were selected from Coronation, Golden Bar, Innes Mills, Round Hill, and SPIM[1] areas of the mine.

SAMPLE SELECTION

Industry guidance (Price, 2009) suggests that for > 10 Mt of mined materials there is a requirement for a few hundred samples to be collected for environmental geochemistry characterisation where prior information is not available. For this project, a significant acid base accounting (ABA) database is available for the project area, the geology of the deposit is understood, and the geochemical characteristics of the materials have been assessed over a number of years through studies and empirical datasets (e.g., drainage from mine domains). Therefore, it was proposed that a lesser characterisation programme was required, being supported by existing datasets.

Sample and Analysis Plan for Mining Extensions

A sample and analysis plan (SAP) was created to assist in the environmental geochemical support for the pit extensions associated with MP4.3 Project. OceanaGold provided representative cross sections for the pit extensions associated with MP4.3 Project and representative drillholes for the pit extensions (Table 1).

The basis for the sample selection was as follows:

- To provide representative samples of materials that will be excavated including waste rock, low grade ore, and ore.

[1] *SPIM= Southern Pit / Innes Mills area*

- Test all significant lithologies. It was acknowledged by OceanaGold that all materials in the proposed pit extensions are schistose in nature.
- Provide representative samples of the waste rock where Au grades are < 0.3 g/t.
- Assess the intra-shear zones where applicable, where the sulfur can be higher compared to the overburden.
- Assess the ore (> 0.5 g/t) and low-grade ore zones (0.3 – 0.5 g/t) to understand environmental geochemistry risks.
- Samples were only selected when OceanaGold sample IDs were available. If the sample IDs were not supplied these intervals were not selected as it was assumed these intervals had not been sampled.

Table 1. Sampling and analysis plan.

PIT DOMAIN EXTENSION	DRILLHOLE ID	FROM	TO	MWM SAMPLE ID	VERUM LAB ID	OCEANAGOLD SAMPLE ID	SAMPLE SELECTION RATIONAL
SPIM (n=21)	RCD5238	15	19	1	22/454 01	CN10004	Waste Rock
		39	40	2	22/454 02	CN12948	Waste Rock
		49	50	3	22/454 03	CN12954	Ore
		87	91	4	22/454 04	CN10022	Waste Rock
		103	104	5	22/454 05	CN12969	Waste Rock
		105	106	6	22/454 06	CN12971	Ore
		155	156	7	22/454 07	CN09010	Waste Rock
		170	171	8	22/454 08	CN09025	Waste Rock
		179	180	9	22/454 09	CN09037	Waste Rock
		192	193	10	22/454 10	CN09050	Waste Rock
		205	206	11	22/454 11	CN09065	Waste Rock
		215	216	12	22/454 12	CN09075	Waste Rock
	DDH7839	57.6	59.8	13	22/248-4	-	Waste Rock
		61.2	63.5	14	22/248-5	-	Waste Rock
		66.4	66.5	15	22/248-6	-	Waste Rock
		42.5	72.4	16	22/248-7	-	Waste Rock
		72.9	73.0	17	22/248-8	-	Waste Rock
		77.1	77.2	18	22/248-9	-	Waste Rock
		82.6	82.8	19	22/248-10	-	Waste Rock
		87.4	87.5	20	22/248-11	-	Waste Rock
		93.2	93.3	21	22/248-12	-	Waste Rock
Innes Mills (n=18)	DDH7917	34.5	35	22	22/454 13	CX66569	Waste Rock
		60	60.5	23	22/454 14	CX66624	Waste Rock
		80	80.5	24	22/454 15	CX66710	Waste Rock
		122	123	25	22/454 16	CX66728	Waste Rock

PIT DOMAIN EXTENSION	DRILLHOLE ID	FROM	TO	MWM SAMPLE ID	VERUM LAB ID	OCEANAGOLD SAMPLE ID	SAMPLE SELECTION RATIONAL
		145	146	26	22/454 17	CX66753	Waste Rock
		159.7	161	27	22/454 18	CX66769	Waste Rock
		175	176	28	22/454 19	CX66785	Waste Rock
		187	187.5	29	22/454 20	CX66797	Waste Rock
		189.5	190	30	22/454 21	CX66802	LGO
		194	195	31	22/454 22	CX66807	Waste Rock
		205	206.3	32	22/454 23	CX66819	Waste Rock
		220.25	221	33	22/454 24	CX66838	Ore
		225	226	34	22/454 25	CX66844	Waste Rock
	RCD7928	38	39	35	22/248-15	-	Backfill[1]
		42	43	36	22/248-19	-	Backfill[1]
		62	63	37	22/248-24	CX76002	Backfill[1]
		65	66	38	22/248-27	CX76005	Backfill[1]
		69	70	39	22/248-31	CX76009	Backfill[1]
		75	76	40	22/248-36	CX76015	Waste Rock
		79	80	41	22/248-40	CX76021	Waste Rock
Round Hill (n=10)	DDH7669	69	69.3	42	22/454 26	CX41413	Ore
		112.2	113	43	22/454 27	CX41417	Waste Rock
		118	118.5	44	22/454 28	CX41424	Waste Rock
		226.1	227	45	22/454 29	CX41425	Waste Rock
		240	241	46	22/454 30	CX41441	LGO
		249.6	250	47	22/454 31	CX41453	Waste Rock
		265	266	48	22/454 32	CX41470	Waste Rock
		276	277	49	22/454 33	CX41483	Waste Rock
		284	285	50	22/454 34	CX41492	Waste Rock
		291	292	51	22/454 35	CX41502	Waste Rock
Golden Bar (n=10)	RCH5452	15	16	52	22/454 36	CN25556	Waste Rock
		50	51	53	22/454 37	CN25593	LGO
		98	99	54	22/454 38	CN25642	Waste Rock
		143	144	55	22/454 39	CN25688	Waste Rock
		149	150	56	22/454 40	CN25695	Waste Rock
		194	195	57	22/454 41	CN25741	Ore
		202	203	58	22/454 42	CN25749	Waste Rock
		213	214	59	22/454 43	CN25761	Waste Rock
		249	250	60	22/454 44	CN25798	Waste Rock
		258	259	61	22/454 45	CN25807	Waste Rock
	RCD6230	90	91	62	22/454 46	CQ59694	Waste Rock

PIT DOMAIN EXTENSION	DRILLHOLE ID	FROM	TO	MWM SAMPLE ID	VERUM LAB ID	OCEANAGOLD SAMPLE ID	SAMPLE SELECTION RATIONAL
Coronation (n=9)		95	96	63	22/454 47	CQ59699	Waste Rock
		103	104	64	22/454 48	CQ59708	Waste Rock
		110	111	65	22/454 49	CQ59715	Waste Rock
		118.3	119	66	22/454 50	CQ65514	Waste Rock
		124	125	67	22/454 51	CQ65521	Ore
		127	128	68	22/454 52	CQ65526	Waste Rock
		129	130	69	22/454 53	CQ65528	Waste Rock
		130	131	70	22/454 54	CQ65529	Waste Rock

Cells shaded blue are samples that underwent shake flask testing.

1. Backfill relates to waste rock within an existing waste rock stack

Waste Rock Samples

Table 2 summarises the waste rock materials collected for geochemical analysis. Samples were collected from drillholes that were determined to be representative of the waste rock materials for the project by OceanaGold project geologist. Samples included waste rock samples collected from grab samples of waste rock stack (WRS) materials, reverse circulation drill core collected from a WRS, and samples from insitu rock that are within the proposed pit shell and will be classified as waste rock.

Table 2. Summary of waste rock materials used in the geochemical assessment.

PIT DOMAIN EXTENSION	DRILLHOLE ID	SAMPLE TYPE	MWM SAMPLE NUMBER	VERUM LAB ID	OCEANAGOLD SAMPLE ID	DATE COLLECTED
SPIM (N=19)	RCD5238	Waste rock	1	22/454 01	CN10004	14/03/2022
		Waste rock	2	22/454 02	CN12948	14/03/2022
		Waste rock	4	22/454 04	CN10022	14/03/2022
		Waste rock	5	22/454 05	CN12969	14/03/2022
		Waste rock	7	22/454 07	CN09010	14/03/2022
		Waste rock	8	22/454 08	CN09025	14/03/2022
		Waste rock	9	22/454 09	CN09037	14/03/2022
		Waste rock	10	22/454 10	CN09050	14/03/2022
		Waste rock	11	22/454 11	CN09065	14/03/2022
		Waste rock	12	22/454 12	CN09075	14/03/2022
	DDH7839	Waste rock	13	22/248-4	-	14/03/2022
		Waste rock	14	22/248-5	-	14/03/2022
		Waste rock	15	22/248-6	-	14/03/2022
		Waste rock	16	22/248-7	-	14/03/2022
		Waste rock	17	22/248-8	-	14/03/2022

		Waste rock	18	22/248-9	-	14/03/2022
		Waste rock	19	22/248-10	-	14/03/2022
		Waste rock	20	22/248-11	-	14/03/2022
		Waste rock	21	22/248-12	-	14/03/2022
Innes Mills (N=18)	DDH7917	Waste rock	22	22/454 13	CX66569	14/03/2022
		Waste rock	23	22/454 14	CX66624	14/03/2022
		Waste rock	24	22/454 15	CX66710	14/03/2022
		Waste rock	25	22/454 16	CX66728	14/03/2022
		Waste rock	26	22/454 17	CX66753	14/03/2022
		Waste rock	27	22/454 18	CX66769	14/03/2022
		Waste rock	28	22/454 19	CX66785	14/03/2022
		Waste rock	29	22/454 20	CX66797	14/03/2022
		Waste rock	31	22/454 22	CX66807	14/03/2022
		Waste rock	32	22/454 23	CX66819	8/03/2022
		Waste rock	34	22/454 25	CX66844	8/03/2022
	RCD7928	Backfill[1]	35	22/248-15	-	8/03/2022
		Backfill[1]	36	22/248-19	-	8/03/2022
		Backfill[1]	37	22/248-24	CX76002	8/03/2022
		Backfill[1]	38	22/248-27	CX76005	8/03/2022
		Backfill[1]	39	22/248-31	CX76009	8/03/2022
		Waste Rock	40	22/248-36	CX76015	8/03/2022
		Waste Rock	41	22/248-40	CX76021	8/03/2022
Round Hill (n=8)	DDH7669	Waste rock	43	22/454 27	CX41417	8/03/2022
		Waste rock	44	22/454 28	CX41424	8/03/2022
		Waste rock	45	22/454 29	CX41425	8/03/2022
		Waste rock	47	22/454 31	CX41453	8/03/2022
		Waste rock	48	22/454 32	CX41470	8/03/2022
		Waste rock	49	22/454 33	CX41483	8/03/2022
		Waste rock	50	22/454 34	CX41492	8/03/2022
		Waste rock	51	22/454 35	CX41502	8/03/2022
Golden Bar (N=8)	RCH5452	Waste rock	52	22/454 36	CN25556	8/03/2022
		Waste rock	54	22/454 38	CN25642	8/03/2022
		Waste rock	55	22/454 39	CN25688	8/03/2022
		Waste rock	56	22/454 40	CN25695	8/03/2022

		Waste rock	58	22/454 42	CN25749	8/03/2022
		Waste rock	59	22/454 43	CN25761	8/03/2022
		Waste rock	60	22/454 44	CN25798	8/03/2022
		Waste rock	61	22/454 45	CN25807	8/03/2022
Coronation (N=8)	RCD6230	Waste rock	62	22/454 46	CQ59694	8/03/2022
		Waste rock	63	22/454 47	CQ59699	8/03/2022
		Waste rock	64	22/454 48	CQ59708	8/03/2022
		Waste rock	65	22/454 49	CQ59715	8/03/2022
		Waste rock	66	22/454 50	CQ65514	8/03/2022
		Waste rock	68	22/454 52	CQ65526	8/03/2022
		Waste rock	69	22/454 53	CQ65528	8/03/2022
		Waste rock	70	22/454 54	CQ65529	8/03/2022

Cells shaded blue are samples that underwent shake flask testing.

1. Backfill relates to waste rock within an existing waste rock stack

Ore and Low-Grade Ore

Table 3 summarises the ore and low-grade ore (LGO) samples collected for geochemical analysis. Samples were collected from drillholes that were determined to be representative for the project by OceanaGold project geologist.

Table 3. Ore and LGO sample summary

PIT DOMAIN EXTENSION	DRILLHOLE ID	SAMPLE TYPE	MWM SAMPLE NUMBER	VERUM LAB ID	OCEANAGOLD SAMPLE ID	DATE COLLECTED
SPIM (n=2)	RCD5238	Ore	3	22/454 03	CN12954	14/03/2022
		Ore	6	22/454 06	CN12971	14/03/2022
Innes Mills (n=2)	DDH7917	Intra shear LGO	30	22/454 21	CX66802	14/03/2022
		Ore	33	22/454 24	CX66838	8/03/2022
Round Hill (n=2)	DDH7669	Ore	42	22/454 26	CX41413	8/03/2022
		LGO	46	22/454 30	CX41441	8/03/2022
Golden Bar (n=2)	RCD7928	LGO	53	22/454 37	CN25593	8/03/2022
		Ore	57	22/454 41	CN25741	8/03/2022
Coronation (n=1)	RCD6230	Ore	67	22/454 51	CQ65521	8/03/2022

ANALYSIS PROGRAMME

This section summarises the Acid Base Accounting (ABA) testing that was undertaken to understand the AMD geochemical nature of the materials. Shake flask testing was undertaken to understand the geochemical signature of water quality from the materials (Water Quality Analysis).

Acid Base Accounting

The geochemical samples were analysed by a typical ABA static testing suite. This included:

- Paste pH and electrical conductivity (EC).
- Total carbon and sulfur content (wt%).
- Maximum potential acidity (MPA).
- Acid neutralising capacity (ANC).
- Net acid producing potential (NAPP).
- Net acidity generation testing to determine net acid generation (NAG) pH and NAG acidity.

Paste pH and Paste EC

Paste pH was determined with electrochemical probes calibrated using certified buffers standards following the AMIRA (2002) methodology. Slurries are prepared at a 1:2 ratio of finely ground sample (typically < 75 µm) to deionised water. Paste pH is an industry standard test used to determine if the sample is already influenced by stored acidity / acid metalliferous drainage (e.g., AMIRA, 2002). Paste EC was also obtained during this test procedure.

Total Sulfur and Maximum Potential Acidity

The total sulfur of the samples was determined by high temperature combustion in a LECO furnace and sulfur dioxide detection by an infra-red cell (Eltra® 4000 CS Determinator). The infra-red cell output is calibrated against the value of a known standard sample to provide the total sulfur concentration of the sample.

The acid generation potential of a rock is determined by measuring the sulfur (or sulfide) content of the sample and calculating the MPA that would be generated, assuming all the sulfur (or sulfide) is present as pyrite and completely oxidises where:

MPA = S (wt%) x 30.6 Units: kg H_2SO_4/t

This approach follows industry standard methodologies (AMIRA, 2002).

Acid Neutralisation Capacity

The ANC of the sample was determined by the modified Sobek method (Sobek et al., 1978) where a known amount of standardised hydrochloric acid (HCl) is added to an accurately weighed sample, allowing the sample time to react, then back-titrating the mixture with standardised sodium hydroxide (NaOH) to determine the amount of unreacted HCl (AMIRA, 2002). The amount of acid consumed by reaction with the sample is then calculated. ANC is an industry standard test used to determine the acid neutralisation capacity of a sample.

Net Acid Producing Potential

The NAPP is a measure of the samples overall acid generating capacity and is calculated by subtracting the ANC from MPA. A negative NAPP indicates a net neutralisation capacity, and the sample can be classified as non-acid forming (NAF). A positive NAPP indicates a positive net acid producing potential and the sample can be classified as potentially acid forming (PAF). NAPP, MPA, and ANC are expressed in kg H_2SO_4 per tonne equivalent.

Neutralisation Potential Ratio

The neutralisation potential ratio (NPR) is another common method to assess the potential to generate acid rock drainage, which is based on the Price (2009) classification methodology. The Price classification system uses the ratio between ANC and MPA to classify samples as PAF, NAF or uncertain (UC), where the NPR = ANC/MPA. When ANC/MPA is less than 1, samples are classified as PAF. When ANC/MPA is greater than 2, sufficient neutralising capacity is inferred to account for acid production and the samples are classified as NAF. When ANC/MPA is between 1 and 2, samples are classified as UC.

NAG Test

The single addition NAG test was undertaken where a pulverised sample (2.5 g) is digested with 250 mL of 15% (unstabilised) hydrogen peroxide and allowed to react to completion before measuring the pH of the NAG liquor. The NAG liquor is then titrated with NaOH to pH 4.5 and pH 7.0. Acidity measured by the titration to pH 4.5 is due to free hydrogen ions as well as acidity from aluminium and iron (AMIRA, 2002). Additional acidity measured by the titration to pH 7 can be attributed to metal hydrolysis reactions such as Cu (AMIRA, 2002).

Elemental enrichment

Portable x-ray fluorescence (pXRF) was used to understand the enrichment of any potential contaminants of concern (PCOC).

Analysis Methodology

Samples were analysed using an Olympus Vanta VMR pXRF instrument with a 4W, 50kV rhodium anode tube and a large-area silicon-drift detector. The instrument was operated using a field test stand and a laptop with the Vanta PC Software. During the process of analysis, about 20 g of sample material was collected from the sample container using a spoon and poured into a 40 mm sample cup with one end covered by 4-µm polypropylene film. The sample cup was put in the test stand and analysed using 3-beam Geochem mode. An analysis time of 15 s for each beam was used. The following certified reference materials were analysed in the sample stream: OREAS232, OREAS235, OREAS239, OREAS24c, and OREAS501b. These methods are consistent with best industry practice (e.g., Gazley & Fisher, 2014; Fisher et al., 2014).

Geochemical Abundance Index

The pXRF results were assessed using the geochemical abundance index (GAI) methodology (Förstner et al., 1993) The GAI compares the actual concentration of an element in a sample with the median abundance for that element in the most relevant media (such as crustal abundance, soils, or a particular rock type). The main purpose of the GAI is to provide an indication of any elemental enrichments that may be of environmental importance. The GAI for an element is calculated as follows:

$$GAI = \log_2 [C / (1.5*S)]$$

where C is the concentration of the element in the sample and S is the median content for that element in the reference material (mean world soil, crustal abundance, etc). The GAI values are truncated to integer increments (0 through to 6, respectively) where a GAI of 0 indicates the element is present at a concentration similar to, or less than, median abundance and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above median abundance. The actual enrichment ranges for the GAI values are as follow:

- GAI=0 represents <3 times median soil content.
- GAI=1 represents 3 to 6 times median soil content.
- GAI=2 represents 6 to 12 times median soil content.
- GAI=3 represents 12 to 24 times median soil content.
- GAI=4 represents 24 to 48 times median soil content.
- GAI=5 represents 48 to 96 times median soil content.
- GAI=6 represents more than 96 times median soil content.

Generally, a GAI of 3 or greater signifies enrichment that warrants further examination such as leachate testing of rock samples. It is also important to note that elemental enrichment is not unexpected in samples from mineralised areas and that enrichment does not necessarily mean that specific elements will be environmentally mobile and bioavailable.

Water Quality Analysis

Shake Flask Tests

Shake flask extraction (SFE) test is a static leaching test procedure where a typically oxidised solid sample is leached with deionized water normally for about 18-24 hours contact time. Leachate from that interaction is then analysed to understand the concentration of dissolved parameters (mg/L) and then the quantity of dissolved constituents release from the material is determined (mg/kg).

For this project, the SFE involved an 18-hr extraction using 25 g of material with 250 mL of deionised water. Two variations of the SFE were undertaken to understand the effects of an oxidising environment (SFE 1) and a reduced environment (SFE 2). Once sample was left open to the atmosphere (unstoppered) to maintain oxidised conditions (SFE 1). The other sample was purged with N_2 gas to remove the O_2 gas from the sample and then was stoppered before the 18-hr extraction (SFE 2).

Both leachates are analysed for pH, EC, dissolved oxygen (DO), oxidation-reduction potential (ORP), SO_4, NO_3, NH_4, alkalinity, Ca, Mg, Na, K, Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, and Zn.

MATERIAL GEOCHEMICAL CLASSIFICATION

ABA determines if a sample is NAF or PAF, which is based on the difference or ratio between acid forming and acid neutralising minerals in the rock. Classification is typically based on either (or both) the AMIRA (2002) or Price (2009) classification schemes until site-specific classification systems are developed.

The AMIRA Classification system (Table 5) uses NAPP and NAG pH to classify samples as PAF, NAF or Uncertain (UC). Where NAPP is positive and NAG pH is less than 4.5, samples are classified as PAF. Where NAPP is negative and NAG pH is greater than 4.5, samples are classified as NAF. Samples with conflicting NAPP and NAG pH are classified as UC. Note that although a sample may be classified as NAF it does not infer low geochemical risk. High sulfide and high carbonate samples may present neutral metalliferous drainage (NMD) or Saline Drainage (SD) risks requiring management.

The Price Classification system (Table 6) uses the ratio between ANC and MPA to classify samples as PAF, NAF or UC, where the Neutralisation Potential Ratio (NPR) = ANC/MPA. Where ANC/MPA is less than 1, samples are classified as PAF. Where ANC/MPA is greater than 2, sufficient neutralising capacity is inferred to account for acid production and the samples are classified as NAF. Where ANC/MPA is between 1 and 2, samples are classified as UC.

For this project, as per resource consent RM10.351.10.V1 (Compliance Criteria iv) all NPR values must be greater than 3 in rock discharged into the waste rock stack. Based on industry standard classification approaches, uncertain classification rocks are classified as 1 ≤ ANC/MPA ≤ 3; PAF rocks are < 1.

Table 4. AMIRA (2002) acid base accounting classification system.

CLASSIFICATION	CRITERIA	COMMENTS
Potentially Acid Forming (PAF)	NAPP > 0 NAG pH < 4.5	Sample always has a significant sulfur content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material.
Non-Acid Forming (NAF)	NAPP < 0 NAG pH ≥4.5	Sample may, or may not, have a significant sulfur content but the ANC availability is more than adequate to neutralise the acid that theoretically could be produced.
Uncertain (UC)	NAPP > 0; NAG pH ≥4.5 NAPP < 0; NAG pH < 4.5	An uncertain classification is used when there is an apparent conflict between the NAPP and NAG results.

Table 5. Price, 2009 acid base accounting classification system.

CLASSIFICATION	CRITERIA	COMMENTS
Potentially Acid Generating (PAF)	ANC/MPA < 1	Potentially acid generating material, unless sulfide minerals are non-reactive, or ANC is preferentially exposed on surfaces.
Non-Acid Forming (NAF)	ANC/MPA > 2	Non-potentially acid generation material, unless ANC is insufficiently reactive, extremely reactive sulfides are present, or preferential exposure of sulfides is found in the material.
Uncertain (UC)	1 ≤ ANC/MPA ≤ 2	Possibly PAF if ANC is insufficiently reactive or is depleted at a faster rate than sulfides.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at +64 27 294 5181 or paul.weber@minewaste.com.au should you wish to discuss our memorandum in greater detail.

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APPENDIX E ENVIRONMENTAL GEOCHEMISTRY RESULTS

Mine Pit Extension Acid Base Accounting Results

Pit Domain	MWM Sample Number	Verum Laboratory ID	Material Description	S	C	S2-_S	Conductivity	Paste pH	NAG pH	NAG Acidity		MPA	ANC	NAPP	NPR	AMIRA 2002 Criteria	MEND (Price, 2009) Criteria	Resource Consent RM10.351.10.V1
				%	%	%	uS/cm	pH	pH	kg H_2SO_4/t (to pH 7.0)	kg H_2SO_4/t (to pH 4.5)	kg H_2SO_4/t	kg H2SO4/t	kg H_2SO_4/t				
	1	22/454 01	Waste Rock	0.185	0.967	-	219	8.96	11.35	-	-	5.7	81.05	-75.39	14.32	NAF	NAF	NAF
	2	22/454 02	Waste Rock	0.11	0.788	-	142	9.33	11.14	-	-	3.4	73.68	-70.32	21.89	NAF	NAF	NAF
	3	22/454 03	Ore	0.666	1.04	-	266	8.75	10.76	-	-	20.4	68.77	-48.39	3.37	NAF	NAF	NAF
	4	22/454 04	Waste Rock	0.149	0.602	-	190	9.00	10.64	-	-	4.6	51.80	-47.24	11.36	NAF	NAF	NAF
	5	22/454 05	Waste Rock	0.118	0.815	-	164	9.35	10.80	-	-	3.6	78.93	-75.32	21.86	NAF	NAF	NAF
	6	22/454 06	Ore	0.255	0.873	-	192	8.95	10.68	-	-	7.8	81.39	-73.59	10.43	NAF	NAF	NAF
	7	22/454 07	Waste Rock	0.178	1.84	-	198	9.11	9.51	-	-	5.4	72.76	-67.31	13.36	NAF	NAF	NAF
	8	22/454 08	Waste Rock	0.044	0.921	-	187	9.02	10.68	-	-	1.3	86.33	-84.98	64.12	NAF	NAF	NAF
	9	22/454 09	Waste Rock	0.096	1.02	-	207	9.01	10.77	-	-	2.9	92.49	-89.55	31.49	NAF	NAF	NAF
	10	22/454 10	Waste Rock	0.114	1.28	-	248	8.77	10.61	-	-	3.5	78.93	-75.44	22.63	NAF	NAF	NAF
SPIM (n=21)	11	22/454 11	Waste Rock	0.077	0.917	-	153	9.11	11.09	-	-	2.4	98.66	-96.30	41.87	NAF	NAF	NAF
	12	22/454 12	Waste Rock	0.161	0.705	-	190	9.10	10.78	-	-	4.9	59.19	-54.27	12.02	NAF	NAF	NAF
	13	22/248-4	Waste Rock	0.13	1.14	0.16	594	8.43	9.19	-	-	4.0	40.22	-36.25	10.11	NAF	NAF	NAF
	14	22/248-5	Waste Rock	0.145	1.08	0.18	699	8.28	9.58	-	-	4.4	48.76	-44.32	10.99	NAF	NAF	NAF
	15	22/248-6	Waste Rock	0.007	0.164	0.06	188	7.53	5.32	1.0	-	0.2	13.41	-13.19	62.60	NAF	NAF	NAF
	16	22/248-7	Waste Rock	0.015	0.17	0.01	185	8.60	4.93	1.2	-	0.5	25.60	-25.14	55.77	NAF	NAF	NAF
	17	22/248-8	Waste Rock	0.034	0.1	0.09	167	8.64	4.22	1.4	0.2	1.0	23.16	-22.12	22.26	UC	NAF	NAF
	18	22/248-9	Waste Rock	0.199	0.584	0.23	209	8.65	8.71	-	-	6.1	40.22	-34.13	6.61	NAF	NAF	NAF
	19	22/248-10	Waste Rock	0.038	0.289	0.13	162	8.80	4.49	1.2	0.1	1.2	23.16	-22.00	19.92	UC	NAF	NAF
	20	22/248-11	Waste Rock	0.181	1.29	0.21	192	8.59	10.68	-	-	5.5	77.62	-72.09	14.02	NAF	NAF	NAF
	21	22/248-12	Waste Rock	0.138	0.663	0.2	194	8.94	9.98	-	-	4.2	31.53	-27.31	7.47	NAF	NAF	NAF
	22	22/454 13	Waste Rock	0.273	0.657	-	209	8.69	8.43	-	-	8.4	44.18	-35.83	5.29	NAF	NAF	NAF
	23	22/454 14	Waste Rock	0.256	0.495	-	221	8.78	8.01	-	-	7.8	33.09	-25.25	4.22	NAF	NAF	NAF
	24	22/454 15	Waste Rock	0.056	0.282	-	219	9.07	7.56	-	-	1.7	29.11	-27.39	16.99	NAF	NAF	NAF
	25	22/454 16	Waste Rock	0.169	0.698	-	240	9.07	8.34	-	-	5.2	42.09	-36.92	8.14	NAF	NAF	NAF
	26	22/454 17	Waste Rock	0.146	0.466	-	279	9.25	8.31	-	-	4.5	41.88	-37.41	9.37	NAF	NAF	NAF
	27	22/454 18	Waste Rock	0.109	0.933	-	237	8.94	8.72	-	-	3.3	53.61	-50.27	16.07	NAF	NAF	NAF
	28	22/454 19	Waste Rock	0.146	0.675	-	210	9.03	8.36	-	-	4.5	43.86	-39.39	9.82	NAF	NAF	NAF
	29	22/454 20	Waste Rock	0.007	0.722	-	207	9.30	8.84	-	-	0.2	34.84	-34.62	162.63	NAF	NAF	NAF
	30	22/454 21	Low grade ore	0.155	0.602	-	218	9.14	8.33	-	-	4.7	33.16	-28.41	6.99	NAF	NAF	NAF
Innes Mills (n=18)	31	22/454 22	Waste Rock	0.068	1.36	-	260	8.93	8.99	-	-	2.1	70.30	-68.22	33.78	NAF	NAF	NAF
	32	22/454 23	Waste Rock	0.104	0.951	-	258	8.97	9.05	-	-	3.2	63.16	-59.98	19.85	NAF	NAF	NAF
	33	22/454 24	Ore	0.353	1.01	-	262	9.03	8.20	-	-	10.8	46.63	-35.83	4.32	NAF	NAF	NAF
	34	22/454 25	Waste Rock	0.065	1.37	-	234	9.15	9.47	-	-	2.0	44.10	-42.11	22.17	NAF	NAF	NAF
	35	22/248-15	Backfill	0.205	1.39	0.26	199	9.10	9.08	-	-	6.3	60.64	-54.37	9.67	NAF	NAF	NAF
	36	22/248-19	Backfill	0.121	1.88	0.15	299	9.21	8.46	-	-	3.7	84.90	-81.20	22.93	NAF	NAF	NAF
	37	22/248-24	Backfill	0.153	1.64	0.2	248	9.11	7.80	-	-	4.7	80.45	-75.77	17.18	NAF	NAF	NAF
	38	22/248-27	Backfill	0.169	1.85	0.15	183	9.34	8.27	-	-	5.2	65.82	-60.65	12.73	NAF	NAF	NAF
	39	22/248-31	Backfill	0.274	1.71	0.31	160	9.12	10.99	-	-	8.4	70.70	-62.31	8.43	NAF	NAF	NAF
	40	22/248-36	Waste Rock	0.016	1.42	0.08	181	9.44	11.16	-	-	0.5	44.10	-43.61	90.07	NAF	NAF	NAF
	41	22/248-40	Waste Rock	0.103	1.53	0.21	181	9.23	10.92	-	-	3.2	50.23	-47.07	15.94	NAF	NAF	NAF
	42	22/454 26	Ore	0.164	0.751	-	199	9.10	9.08	-	-	5.0	37.98	-32.96	7.57	NAF	NAF	NAF
	43	22/454 27	Waste Rock	0.4	0.691	-	299	9.21	8.46	-	-	12.2	20.83	-8.58	1.70	NAF	UC	UC
	44	22/454 28	Waste Rock	0.167	0.356	-	248	9.11	7.80	-	-	5.1	45.48	-40.37	8.90	NAF	NAF	NAF
	45	22/454 29	Waste Rock	0.107	0.77	-	183	9.34	8.27	-	-	3.3	14.70	-11.43	4.49	NAF	NAF	NAF
Round Hill (n=10)	46	22/454 30	Low grade ore	0.274	1.05	-	160	9.12	10.99	-	-	8.4	71.05	-62.67	8.47	NAF	NAF	NAF
	47	22/454 31	Waste Rock	0.117	1.14	-	181	9.44	11.16	-	-	3.6	83.30	-79.72	23.27	NAF	NAF	NAF
	48	22/454 32	Waste Rock	0.12	0.904	-	181	9.23	10.92	-	-	3.7	66.15	-62.48	18.01	NAF	NAF	NAF
	49	22/454 33	Waste Rock	0.114	1.3	-	144	9.20	10.73	-	-	3.5	84.53	-81.04	24.23	NAF	NAF	NAF
	50	22/454 34	Waste Rock	0.058	1.15	-	126	9.16	11.01	-	-	1.8	78.40	-76.63	44.17	NAF	NAF	NAF
	51	22/454 35	Waste Rock	0.075	0.971	-	192	9.42	11.01	-	-	2.3	50.74	-48.44	22.11	NAF	NAF	NAF
	52	22/454 36	Waste Rock	0.162	0.481	-	268	8.30	7.56	-	-	5.0	29.40	-24.44	5.93	NAF	NAF	NAF
	53	22/454 37	Low grade ore	0.199	0.645	-	252	8.52	8.64	-	-	6.1	49.51	-43.42	8.13	NAF	NAF	NAF
	54	22/454 38	Waste Rock	0.214	0.591	-	254	8.78	9.02	-	-	6.5	45.33	-38.78	6.92	NAF	NAF	NAF
	55	22/454 39	Waste Rock	0.094	0.509	-	252	9.05	9.15	-	-	2.9	49.00	-46.12	17.04	NAF	NAF	NAF
Golden Bar (n=10)	56	22/454 40	Waste Rock	0.052	0.334	-	263	9.31	8.43	-	-	1.6	34.53	-32.94	21.70	NAF	NAF	NAF
	57	22/454 41	Ore	2.1	1.61	-	793	7.96	8.04	-	-	64.3	72.74	-8.48	1.13	NAF	UC	UC
	58	22/454 42	Waste Rock	0.286	0.767	-	396	8.96	9.71	-	-	8.8	37.29	-28.54	4.26	NAF	NAF	NAF
	59	22/454 43	Waste Rock	0.251	0.845	-	267	8.76	10.21	-	-	7.7	44.62	-36.94	5.81	NAF	NAF	NAF
	60	22/454 44	Waste Rock	0.144	1.16	-	255	8.69	9.38	-	-	4.4	47.07	-42.66	10.68	NAF	NAF	NAF
	61	22/454 45	Waste Rock	0.055	0.77	-	312	8.89	8.23	-	-	1.7	29.60	-27.91	17.59	NAF	NAF	NAF
	62	22/454 46	Waste Rock	0.181	0.208	-	238	7.89	8.20	-	-	5.5	25.73	-20.19	4.64	NAF	NAF	NAF
	63	22/454 47	Waste Rock	0.215	1.15	-	406	8.17	8.76	-	-	6.6	93.53	-86.95	14.22	NAF	NAF	NAF
	64	22/454 48	Waste Rock	0.311	0.561	-	358	8.51	7.91	-	-	9.5	42.18	-32.66	4.43	NAF	NAF	NAF
	65	22/454 49	Waste Rock	0.055	0.705	-	230	8.51	10.49	-	-	1.7	70.30	-68.61	41.77	NAF	NAF	NAF
Coronation (n=9)	66	22/454 50	Waste Rock	0.1	0.565	-	219	9.19	10.69	-	-	3.1	47.40	-44.34	15.49	NAF	NAF	NAF
	67	22/454 51	Ore	0.162	0.78	-	230	9.15	8.85	-	-	5.0	51.04	-46.08	10.30	NAF	NAF	NAF
	68	22/454 52	Waste Rock	0.145	0.584	-	194	9.32	8.04	-	-	4.4	41.32	-36.88	9.31	NAF	NAF	NAF
	69	22/454 53	Waste Rock	0.105	0.484	-	238	8.98	9.09	-	-	3.2	32.81	-29.60	10.21	NAF	NAF	NAF
	70	22/454 54	Waste Rock	0.074	0.477	-	216	9.25	9.04	-	-	2.3	31.60	-29.33	13.95	NAF	NAF	NAF

Notes:

The resource consent uses a 3:1 classification (RM10.351.10.V1 – Compliance Criteria iv.)

NAG acidity was not titrated if pH >7.0. Results for titration to pH 4.5 and/or pH 7.0

Laboratory replicates were obtained for samples 229-49 and 229-54, measuring both total sulfur (S) and total carbon (C). The results indicated negligible differences.

Total C can be used to calculate ANC. Plotting ANC (calculated from Total C) versus ANC measured by digestion can provide a relationship that can be used to estimate ANC content. This is a useful process to determine ANC once the relationship is validated. Results indicated that there was no relationship between the reported total C and ANC results, however, this process can be improved by using inorganic C content (when available).

Cells shaded blue are samples that underwent shake flask testing

Mine Pit Extension pXRF Results

Location	Sample Description	MWM Sample ID	OGL Sample ID	Verum Laboratory ID	Mg	Al	Si	P	S	K	Ca	Ti	V	Cr	Mn	Fe
SPIM	Waste Rock	1	CN10004	22/454 01	7704	69,157	185,843	230	175	26,176	23,488	4,783	102	<LOD	581	44,797
SPIM	Waste Rock	2	CN10022	22/454 02	13867	68,566	190,238	252	183	23,889	19,253	4,678	133	56	692	47,105
SPIM	Ore	3	CN12948	22/454 03	<LOD	62,658	210,933	206	<LOD	23,708	20,419	4,043	117	<LOD	503	37,536
SPIM	Waste Rock	4	CN12954	22/454 04	10522	66,617	207,640	123	2,726	26,433	19,964	4,832	120	<LOD	537	43,563
SPIM	Waste Rock	5	CN12969	22/454 05	9809	57,736	199,095	211	<LOD	18,958	22,216	4,368	97	60	776	45,419
SPIM	Ore	6	CN12971	22/454 06	9349	62,325	188,847	<LOD	559	24,489	20,603	4,785	153	69	757	50,519
SPIM	Waste Rock	7	CN09010	22/454 07	7082	70,849	193,454	156	336	23,013	15,989	4,211	96	<LOD	476	42,153
SPIM	Waste Rock	8	CN09025	22/454 08	10963	65,522	178,593	242	<LOD	23,719	21,204	4,489	124	53	787	48,279
SPIM	Waste Rock	9	CN09037	22/454 09	11613	63,331	188,529	255	<LOD	24,069	23,239	4,858	118	47	733	44,317
SPIM	Waste Rock	10	CN09050	22/454 10	6912	67,648	195,112	191	<LOD	24,621	17,875	4,233	<LOD	<LOD	594	37,255
SPIM	Waste Rock	11	CN09065	22/454 11	13604	62,975	178,765	388	<LOD	17,017	25,401	5,383	<LOD	<LOD	816	49,835
SPIM	Waste Rock	12	CN09075	22/454 12	7465	68,757	204,279	106	100	26,626	13,049	4,290	114	49	538	39,077
SPIM	Waste Rock	13	-	22/248-4	10476	67,680	192,570	250	321	24,990	18,176	4,600	139	66	570	44,035
SPIM	Waste Rock	14	-	22/248-5	9699	69,848	192,311	180	332	27,016	20,010	4,870	<LOD	56	562	43,858
SPIM	Waste Rock	15	-	22/248-6	13154	72,156	192,434	<LOD	<LOD	23,198	7,803	5,035	120	<LOD	622	45,568
SPIM	Waste Rock	16	-	22/248-7	16793	65,146	200,837	483	<LOD	18,031	10,124	6,887	141	120	968	54,024
SPIM	Waste Rock	17	-	22/248-8	11806	60,294	206,946	280	<LOD	11,407	11,768	5,463	92	93	849	46,235
SPIM	Waste Rock	18	-	22/248-9	10613	67,795	191,869	291	175	23,009	13,367	5,540	<LOD	105	641	46,531
SPIM	Waste Rock	19	-	22/248-10	12861	76,107	185,271	144	<LOD	29,692	1,824	5,754	146	91	792	55,136
SPIM	Waste Rock	20	-	22/248-11	12826	59,159	181,794	122	<LOD	19,927	36,824	4,500	106	131	915	46,351
SPIM	Waste Rock	21	-	22/248-12	9140	70,777	196,379	179	97	26,065	13,301	5,281	91	56	474	46,256
Innes Mills	Waste Rock	22	CX66569	22/454 13	9150	62,417	201,558	241	657	19,898	22,546	4,749	131	<LOD	749	46,129
Innes Mills	Waste Rock	23	CX66624	22/454 14	10558	66,043	193,792	327	641	23,537	14,826	5,167	120	<LOD	629	48,684
Innes Mills	Waste Rock	24	CX66710	22/454 15	13404	67,253	192,951	392	<LOD	20,847	16,846	4,842	125	147	763	49,259
Innes Mills	Waste Rock	25	CX66728	22/454 16	7973	64,303	199,538	331	219	23,776	17,180	4,958	95	103	536	43,477
Innes Mills	Waste Rock	26	CX66753	22/454 17	11461	58,694	209,756	310	226	18,276	26,081	4,332	121	102	676	41,925
Innes Mills	Waste Rock	27	CX66769	22/454 18	9100	62,394	190,201	388	<LOD	22,044	20,648	4,884	156	119	579	43,266
Innes Mills	Waste Rock	28	CX66785	22/454 19	7336	63,775	196,605	237	<LOD	21,073	20,327	4,697	105	77	733	45,482
Innes Mills	Waste Rock	29	CX66797	22/454 20	5194	60,813	225,914	<LOD	<LOD	25,799	13,177	3,652	<LOD	113	487	33,198
Innes Mills	Low grade ore	30	CX66802	22/454 21	6869	71,065	199,908	226	345	29,145	9,537	4,414	185	86	714	47,187
Innes Mills	Waste Rock	31	CX66807	22/454 22	8119	58,650	194,655	240	<LOD	19,775	26,043	4,310	<LOD	109	792	44,394
Innes Mills	Waste Rock	32	CX66819	22/454 23	10436	59,609	190,759	197	<LOD	19,161	25,788	4,980	105	46	817	45,517
Innes Mills	Ore	33	CX66838	22/454 24	5381	62,705	226,797	99	1,263	25,875	12,249	3,426	93	105	391	30,724
Innes Mills	Waste Rock	34	CX66844	22/454 25	5933	59,978	215,220	99	<LOD	24,720	23,092	3,479	<LOD	111	466	31,900
Innes Mills	Backfill	35	-	22/248-15	10613	67,795	191,869	291	175	23,009	13,367	5,540	<LOD	105	641	46,531
Innes Mills	Backfill	36	-	22/248-19	7419	71,750	190,454	239	115	23,541	15,709	5,003	<LOD	78	813	47,930
Innes Mills	Backfill	37	-	22/248-24	4959	69,226	193,642	141	566	26,186	22,567	4,081	<LOD	86	664	38,136
Innes Mills	Backfill	38	-	22/248-27	12758	72,284	183,394	177	113	25,200	19,429	5,029	111	49	610	43,516
Innes Mills	Backfill	39	-	22/248-31	7258	75,740	186,118	165	<LOD	25,667	18,720	4,923	110	67	528	41,244
Innes Mills	Waste Rock	40	-	22/248-36	8152	78,398	181,041	213	352	26,996	15,510	4,689	119	59	598	43,557
Innes Mills	Waste Rock	41	-	22/248-40	7363	75,541	187,023	241	179	33,026	10,155	4,568	126	73	582	44,098
Round Hill	Ore	42	CX41413	22/454 26	6370	53,602	221,926	212	324	22,735	22,376	3,757	110	156	571	34,298
Round Hill	Waste Rock	43	CX41417	22/454 27	6157	64,705	202,560	206	1,452	23,477	14,369	4,441	109	75	513	41,038
Round Hill	Waste Rock	44	CX41424	22/454 28	12998	68,654	190,388	278	401	22,393	9,340	5,327	165	96	637	47,222
Round Hill	Waste Rock	45	CX41425	22/454 29	10620	68,191	189,832	204	<LOD	24,909	13,114	4,806	161	90	711	47,624
Round Hill	Low grade ore	46	CX41441	22/454 30	12910	70,183	192,525	173	732	26,989	18,453	4,774	109	<LOD	708	49,765
Round Hill	Waste Rock	47	CX41453	22/454 31	<LOD	53,103	219,441	<LOD	<LOD	19,333	30,178	3,155	<LOD	63	450	27,739
Round Hill	Waste Rock	48	CX41470	22/454 32	10491	60,468	204,504	180	<LOD	20,731	19,965	3,911	93	75	745	40,079
Round Hill	Waste Rock	49	CX41483	22/454 33	5798	60,784	201,397	172	<LOD	22,609	26,597	4,509	134	<LOD	742	39,462
Round Hill	Waste Rock	50	CX41492	22/454 34	6685	52,399	221,687	123	<LOD	16,899	27,880	3,551	<LOD	<LOD	775	34,905
Round Hill	Waste Rock	51	CX41502	22/454 35	<LOD	62,808	212,846	131	<LOD	25,919	13,869	3,597	85	52	511	36,003
Golden Bar	Waste Rock	52	CN25556	22/454 36	11581	65,871	190,543	175	449	25,558	11,596	5,178	153	<LOD	789	50,590
Golden Bar	Low grade ore	53	CN25593	22/454 37	7843	65,068	197,339	192	604	23,651	16,034	5,087	<LOD	45	708	50,497
Golden Bar	Waste Rock	54	CN25642	22/454 38	9449	66,579	202,149	283	773	24,537	17,463	4,964	151	<LOD	622	48,318
Golden Bar	Waste Rock	55	CN25688	22/454 39	9915	56,610	208,745	213	<LOD	16,102	17,513	4,017	<LOD	<LOD	1,324	47,789
Golden Bar	Waste Rock	56	CN25695	22/454 40	12351	57,950	221,404	305	<LOD	16,949	18,270	4,045	110	<LOD	907	45,998
Golden Bar	Ore	57	CN25741	22/454 41	<LOD	61,020	208,124	<LOD	9,676	23,653	24,080	3,651	<LOD	<LOD	581	49,882
Golden Bar	Waste Rock	58	CN25749	22/454 42	<LOD	51,603	262,940	<LOD	1,401	18,718	11,792	2,154	<LOD	<LOD	329	23,555
Golden Bar	Waste Rock	59	CN25761	22/454 43	5273	55,753	242,003	<LOD	825	19,953	13,624	3,166	<LOD	<LOD	468	29,795
Golden Bar	Waste Rock	60	CN25798	22/454 44	6303	65,576	206,818	104	215	24,329	11,926	4,706	<LOD	69	551	45,214
Golden Bar	Waste Rock	61	CN25807	22/454 45	<LOD	60,358	228,110	<LOD	<LOD	22,915	8,310	4,030	<LOD	<LOD	513	39,548
Coronation	Waste Rock	62	CQ59694	22/454 46	13869	66,339	202,814	344	481	16,271	3,352	5,176	139	80	739	45,453
Coronation	Waste Rock	63	CQ59699	22/454 47	11446	60,544	185,333	213	492	18,600	31,142	4,714	96	73	667	42,938
Coronation	Waste Rock	64	CQ59708	22/454 48	7663	68,662	209,089	216	953	25,779	15,241	4,826	<LOD	124	513	40,771
Coronation	Waste Rock	65	CQ59715	22/454 49	12433	59,932	190,192	216	<LOD	16,490	20,841	5,117	142	76	905	47,993
Coronation	Waste Rock	66	CQ65514	22/454 50	4656	53,808	237,079	121	<LOD	15,962	14,068	3,985	<LOD	110	482	34,656
Coronation	Ore	67	CQ65521	22/454 51	10587	66,099	209,841	<LOD	300	28,895	14,142	3,807	91	80	547	37,500
Coronation	Waste Rock	68	CQ65526	22/454 52	5276	62,085	220,974	<LOD	291	27,189	12,919	3,152	<LOD	81	449	31,518
Coronation	Waste Rock	69	CQ65528	22/454 53	6768	63,139	223,968	168	207	26,147	8,686	3,745	129	68	465	35,370
Coronation	Waste Rock	70	CQ65529	22/454 54	4863	63,530	224,177	193	<LOD	24,839	9,333	3,799	<LOD	80	456	34,797

Notes

Analysis date 18/07/2022

All units are shown in PPM

<LOD - less than of detection

Sample type was pulp

Project number: MWM

Cells shaded blue are samples that underwent shake flask testing

Mine Pit Extension pXRF Results

Location	Sample Description	MWM Sample ID	OGL Sample ID	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd
SPIM	Waste Rock	1	CN10004	<LOD	19	21	137	32	<LOD	117	279	28	167	4	<LOD	<LOD	<LOD
SPIM	Waste Rock	2	CN10022	92	27	36	139	14	<LOD	109	273	29	153	<LOD	<LOD	<LOD	21
SPIM	Ore	3	CN12948	114	17	21	106	32	<LOD	101	234	22	161	<LOD	6	<LOD	<LOD
SPIM	Waste Rock	4	CN12954	<LOD	29	26	123	553	<LOD	117	344	26	154	<LOD	<LOD	<LOD	<LOD
SPIM	Waste Rock	5	CN12969	<LOD	26	32	111	24	<LOD	93	331	26	138	<LOD	7	<LOD	<LOD
SPIM	Ore	6	CN12971	120	38	30	126	207	<LOD	121	289	29	137	<LOD	<LOD	<LOD	21
SPIM	Waste Rock	7	CN09010	<LOD	19	19	119	33	<LOD	102	275	25	159	<LOD	<LOD	<LOD	<LOD
SPIM	Waste Rock	8	CN09025	<LOD	39	18	121	100	<LOD	121	305	26	144	4	<LOD	<LOD	<LOD
SPIM	Waste Rock	9	CN09037	<LOD	26	21	103	35	<LOD	113	374	25	152	<LOD	<LOD	<LOD	<LOD
SPIM	Waste Rock	10	CN09050	<LOD	18	20	88	277	<LOD	120	318	28	161	<LOD	<LOD	<LOD	<LOD
SPIM	Waste Rock	11	CN09065	<LOD	26	15	116	20	<LOD	78	365	29	152	<LOD	<LOD	<LOD	25
SPIM	Waste Rock	12	CN09075	<LOD	25	25	107	37	<LOD	126	230	26	161	6	<LOD	<LOD	<LOD
SPIM	Waste Rock	13	-	<LOD	15	<LOD	120	25	<LOD	101	229	24	159	<LOD	8	<LOD	<LOD
SPIM	Waste Rock	14	-	<LOD	20	21	124	21	<LOD	106	216	26	158	<LOD	<LOD	<LOD	<LOD
SPIM	Waste Rock	15	-	94	31	33	111	19	<LOD	107	235	22	212	4	<LOD	<LOD	<LOD
SPIM	Waste Rock	16	-	<LOD	22	<LOD	119	18	<LOD	74	226	27	152	<LOD	<LOD	<LOD	18
SPIM	Waste Rock	17	-	<LOD	25	25	107	14	<LOD	47	263	31	120	<LOD	6	<LOD	<LOD
SPIM	Waste Rock	18	-	<LOD	29	22	125	6	<LOD	102	135	30	165	<LOD	8	<LOD	<LOD
SPIM	Waste Rock	19	-	<LOD	40	27	151	11	<LOD	146	36	26	143	6	8	<LOD	<LOD
SPIM	Waste Rock	20	-	121	36	24	111	13	<LOD	91	462	33	122	4	6	<LOD	<LOD
SPIM	Waste Rock	21	-	<LOD	15	18	130	11	<LOD	108	162	27	168	<LOD	9	<LOD	<LOD
Innes Mills	Waste Rock	22	CX66569	96	24	21	118	13	<LOD	88	305	34	156	<LOD	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	23	CX66624	113	23	25	148	7	<LOD	110	234	30	169	6	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	24	CX66710	<LOD	36	33	130	20	<LOD	103	337	27	160	<LOD	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	25	CX66728	<LOD	19	26	127	10	<LOD	108	163	28	158	5	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	26	CX66753	102	22	19	122	8	<LOD	83	436	34	163	5	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	27	CX66769	<LOD	20	27	130	12	<LOD	112	177	32	171	4	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	28	CX66785	97	29	27	125	15	<LOD	95	201	32	158	6	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	29	CX66797	<LOD	15	22	85	15	<LOD	121	238	22	160	<LOD	7	<LOD	<LOD
Innes Mills	Low grade ore	30	CX66802	<LOD	34	32	124	75	<LOD	155	165	26	169	5	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	31	CX66807	<LOD	32	19	98	38	<LOD	99	355	26	157	<LOD	7	<LOD	<LOD
Innes Mills	Waste Rock	32	CX66819	<LOD	28	33	105	75	<LOD	87	340	28	139	<LOD	<LOD	<LOD	20
Innes Mills	Ore	33	CX66838	80	17	22	78	840	<LOD	127	182	23	170	<LOD	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	34	CX66844	<LOD	19	21	90	47	<LOD	129	206	26	163	<LOD	<LOD	<LOD	<LOD
Innes Mills	Backfill	35	-	<LOD	29	22	125	6	<LOD	102	135	30	165	<LOD	8	<LOD	<LOD
Innes Mills	Backfill	36	-	<LOD	26	31	162	59	<LOD	98	247	32	161	<LOD	9	<LOD	<LOD
Innes Mills	Backfill	37	-	<LOD	16	17	84	525	<LOD	102	248	25	139	<LOD	8	<LOD	<LOD
Innes Mills	Backfill	38	-	<LOD	24	18	127	31	<LOD	101	270	26	144	<LOD	7	<LOD	<LOD
Innes Mills	Backfill	39	-	<LOD	17	15	112	14	<LOD	103	227	24	160	<LOD	<LOD	<LOD	<LOD
Innes Mills	Waste Rock	40	-	<LOD	24	22	131	20	<LOD	105	208	27	161	6	7	<LOD	<LOD
Innes Mills	Waste Rock	41	-	<LOD	22	19	116	38	<LOD	147	191	27	183	4	6	<LOD	<LOD
Round Hill	Ore	42	CX41413	82	23	<LOD	87	45	<LOD	106	300	17	119	4	<LOD	<LOD	<LOD
Round Hill	Waste Rock	43	CX41417	109	22	24	114	83	<LOD	110	278	21	162	<LOD	<LOD	<LOD	<LOD
Round Hill	Waste Rock	44	CX41424	92	27	26	128	10	<LOD	108	251	25	163	5	<LOD	<LOD	<LOD
Round Hill	Waste Rock	45	CX41425	<LOD	40	28	129	28	<LOD	128	171	26	145	5	<LOD	<LOD	<LOD
Round Hill	Low grade ore	46	CX41441	107	36	29	115	149	<LOD	132	340	31	146	6	5	<LOD	25
Round Hill	Waste Rock	47	CX41453	<LOD	17	20	80	47	<LOD	90	539	20	176	4	<LOD	<LOD	21
Round Hill	Waste Rock	48	CX41470	104	28	29	91	53	<LOD	104	281	26	137	<LOD	<LOD	<LOD	<LOD
Round Hill	Waste Rock	49	CX41483	<LOD	20	21	91	150	<LOD	105	440	25	142	<LOD	<LOD	<LOD	<LOD
Round Hill	Waste Rock	50	CX41492	<LOD	15	23	77	735	<LOD	81	483	18	105	<LOD	<LOD	<LOD	<LOD
Round Hill	Waste Rock	51	CX41502	89	24	20	101	85	<LOD	137	257	24	156	5	6	<LOD	<LOD
Golden Bar	Waste Rock	52	CN25556	<LOD	33	32	154	11	<LOD	111	265	31	158	5	7	<LOD	20
Golden Bar	Low grade ore	53	CN25593	119	34	43	149	19	<LOD	107	160	30	154	6	<LOD	<LOD	<LOD
Golden Bar	Waste Rock	54	CN25642	96	27	21	128	7	<LOD	111	270	29	164	<LOD	<LOD	<LOD	<LOD
Golden Bar	Waste Rock	55	CN25688	<LOD	18	38	116	11	<LOD	76	280	30	151	5	5	<LOD	<LOD
Golden Bar	Waste Rock	56	CN25695	<LOD	33	27	98	6	<LOD	75	316	27	146	<LOD	<LOD	<LOD	<LOD
Golden Bar	Ore	57	CN25741	140	26	17	75	787	<LOD	115	253	26	173	<LOD	<LOD	<LOD	<LOD
Golden Bar	Waste Rock	58	CN25749	<LOD	11	11	45	187	<LOD	92	187	12	95	<LOD	<LOD	<LOD	<LOD
Golden Bar	Waste Rock	59	CN25761	<LOD	18	26	76	9	<LOD	91	209	16	160	4	<LOD	<LOD	<LOD
Golden Bar	Waste Rock	60	CN25798	104	29	22	119	128	<LOD	123	226	27	172	7	5	<LOD	<LOD
Golden Bar	Waste Rock	61	CN25807	88	25	20	97	130	<LOD	111	161	25	166	<LOD	<LOD	<LOD	<LOD
Coronation	Waste Rock	62	CQ59694	108	20	30	129	19	<LOD	76	35	16	140	4	<LOD	<LOD	<LOD
Coronation	Waste Rock	63	CQ59699	<LOD	25	28	124	11	<LOD	88	140	21	146	<LOD	7	<LOD	<LOD
Coronation	Waste Rock	64	CQ59708	147	25	18	117	12	<LOD	111	214	23	163	4	6	<LOD	<LOD
Coronation	Waste Rock	65	CQ59715	100	34	26	111	23	<LOD	86	159	28	156	<LOD	<LOD	<LOD	<LOD
Coronation	Waste Rock	66	CQ65514	<LOD	23	31	87	233	<LOD	77	246	20	198	<LOD	<LOD	<LOD	<LOD
Coronation	Ore	67	CQ65521	89	23	22	106	67	<LOD	144	251	29	176	6	6	<LOD	<LOD
Coronation	Waste Rock	68	CQ65526	93	17	25	90	93	<LOD	139	216	23	176	<LOD	6	<LOD	<LOD
Coronation	Waste Rock	69	CQ65528	<LOD	20	25	101	15	<LOD	129	134	26	172	5	6	<LOD	<LOD
Coronation	Waste Rock	70	CQ65529	<LOD	17	24	96	16	<LOD	125	150	26	173	5	<LOD	<LOD	<LOD

Notes

Analysis date 18/07/2022
All units are shown in PPM
<LOD - less than of detection
Sample type was pulp
Project number: MWM
Cells shaded blue are samples that underwent shake flask testing

Mine Pit Extension pXRF Results

Location	Sample Description	MWM Sample ID	OGL Sample ID	Sn	Sb	Ba	La	Ce	Pr	Nd	W	Hg	Pb	Bi	Th	U	LE
SPIM	Waste Rock	1	CN10004	<LOD	39	681	138	181	<LOD	<LOD	142	<LOD	19	<LOD	18	<LOD	634,940
SPIM	Waste Rock	2	CN10022	<LOD	<LOD	604	<LOD	178	<LOD	<LOD	21	<LOD	18	<LOD	26	5	629,344
SPIM	Ore	3	CN12948	<LOD	<LOD	572	<LOD	155	181	<LOD	34	<LOD	13	<LOD	25	<LOD	638,082
SPIM	Waste Rock	4	CN12954	<LOD	<LOD	516	<LOD	110	<LOD	<LOD	47	<LOD	18	<LOD	25	<LOD	614,833
SPIM	Waste Rock	5	CN12969	<LOD	<LOD	571	108	<LOD	<LOD	<LOD	25	<LOD	15	<LOD	30	<LOD	639,718
SPIM	Ore	6	CN12971	<LOD	<LOD	625	<LOD	175	<LOD	<LOD	93	<LOD	16	<LOD	26	<LOD	635,490
SPIM	Waste Rock	7	CN09010	<LOD	<LOD	544	<LOD	152	<LOD	229	42	<LOD	15	<LOD	21	<LOD	640,432
SPIM	Waste Rock	8	CN09025	<LOD	<LOD	599	<LOD	<LOD	<LOD	<LOD	100	<LOD	13	<LOD	25	<LOD	644,411
SPIM	Waste Rock	9	CN09037	32	<LOD	469	<LOD	144	<LOD	<LOD	60	<LOD	10	<LOD	21	<LOD	637,308
SPIM	Waste Rock	10	CN09050	<LOD	<LOD	520	<LOD	121	<LOD	<LOD	66	<LOD	16	<LOD	30	5	643,772
SPIM	Waste Rock	11	CN09065	<LOD	<LOD	429	117	108	<LOD	<LOD	57	<LOD	12	<LOD	24	<LOD	644,243
SPIM	Waste Rock	12	CN09075	<LOD	<LOD	547	<LOD	<LOD	<LOD	277	31	<LOD	16	<LOD	22	<LOD	633,914
SPIM	Waste Rock	13	-	<LOD	<LOD	355	75	107	<LOD	<LOD	29	<LOD	18	<LOD	25	<LOD	634,837
SPIM	Waste Rock	14	-	<LOD	<LOD	410	94	87	<LOD	<LOD	18	<LOD	22	<LOD	28	<LOD	629,907
SPIM	Waste Rock	15	-	<LOD	<LOD	415	85	95	131	<LOD	17	<LOD	17	<LOD	30	<LOD	638,253
SPIM	Waste Rock	16	-	<LOD	<LOD	407	<LOD	116	142	166	13	<LOD	9	<LOD	28	<LOD	624,909
SPIM	Waste Rock	17	-	<LOD	<LOD	322	<LOD	<LOD	<LOD	<LOD	33	<LOD	10	<LOD	27	<LOD	643,739
SPIM	Waste Rock	18	-	<LOD	<LOD	512	117	99	<LOD	186	25	<LOD	14	<LOD	25	5	638,458
SPIM	Waste Rock	19	-	<LOD	<LOD	473	<LOD	137	134	<LOD	31	<LOD	17	<LOD	39	<LOD	630,759
SPIM	Waste Rock	20	-	<LOD	<LOD	342	<LOD	94	<LOD	<LOD	21	<LOD	13	<LOD	27	<LOD	635,827
SPIM	Waste Rock	21	-	<LOD	<LOD	371	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	13	<LOD	37	<LOD	630,834
Innes Mills	Waste Rock	22	CX66569	<LOD	<LOD	571	<LOD	<LOD	<LOD	<LOD	17	<LOD	14	<LOD	21	<LOD	630,298
Innes Mills	Waste Rock	23	CX66624	<LOD	<LOD	604	101	125	<LOD	<LOD	<LOD	<LOD	22	<LOD	25	<LOD	633,935
Innes Mills	Waste Rock	24	CX66710	<LOD	<LOD	560	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	18	<LOD	23	<LOD	631,724
Innes Mills	Waste Rock	25	CX66728	<LOD	<LOD	492	116	109	163	245	<LOD	<LOD	19	<LOD	20	4	635,699
Innes Mills	Waste Rock	26	CX66753	<LOD	<LOD	559	<LOD	105	<LOD	<LOD	<LOD	<LOD	15	<LOD	17	<LOD	626,350
Innes Mills	Waste Rock	27	CX66769	<LOD	<LOD	558	<LOD	<LOD	<LOD	197	<LOD	<LOD	16	<LOD	25	<LOD	644,740
Innes Mills	Waste Rock	28	CX66785	<LOD	<LOD	604	111	<LOD	<LOD	<LOD	<LOD	<LOD	15	<LOD	21	<LOD	638,018
Innes Mills	Waste Rock	29	CX66797	<LOD	<LOD	554	<LOD	<LOD	<LOD	<LOD	40	<LOD	16	<LOD	28	<LOD	630,331
Innes Mills	Low grade ore	30	CX66802	<LOD	46	754	<LOD	113	<LOD	<LOD	91	<LOD	18	<LOD	28	7	628,478
Innes Mills	Waste Rock	31	CX66807	<LOD	<LOD	526	125	157	<LOD	<LOD	58	<LOD	18	<LOD	32	<LOD	641,167
Innes Mills	Waste Rock	32	CX66819	<LOD	<LOD	415	<LOD	<LOD	<LOD	<LOD	78	<LOD	12	<LOD	17	<LOD	641,208
Innes Mills	Ore	33	CX66838	<LOD	<LOD	541	<LOD	98	<LOD	234	221	<LOD	26	<LOD	21	<LOD	628,211
Innes Mills	Waste Rock	34	CX66844	<LOD	<LOD	546	98	112	<LOD	<LOD	57	<LOD	13	<LOD	26	<LOD	633,446
Innes Mills	Backfill	35	-	<LOD	<LOD	512	117	99	<LOD	186	25	<LOD	14	<LOD	25	5	638,458
Innes Mills	Backfill	36	-	<LOD	<LOD	417	<LOD	<LOD	<LOD	<LOD	20	<LOD	14	<LOD	29	<LOD	635,644
Innes Mills	Backfill	37	-	<LOD	<LOD	343	<LOD	<LOD	<LOD	<LOD	88	<LOD	21	<LOD	29	<LOD	638,100
Innes Mills	Backfill	38	-	<LOD	<LOD	419	74	<LOD	<LOD	<LOD	30	<LOD	18	<LOD	30	<LOD	636,010
Innes Mills	Backfill	39	-	<LOD	<LOD	455	<LOD	<LOD	<LOD	<LOD	20	<LOD	15	<LOD	29	<LOD	638,271
Innes Mills	Waste Rock	40	-	<LOD	<LOD	453	<LOD	97	<LOD	<LOD	16	<LOD	17	<LOD	21	<LOD	639,002
Innes Mills	Waste Rock	41	-	<LOD	<LOD	534	<LOD	146	<LOD	<LOD	76	<LOD	15	<LOD	33	<LOD	635,467
Round Hill	Ore	42	CX41413	<LOD	<LOD	562	<LOD	122	<LOD	304	55	<LOD	14	<LOD	21	<LOD	631,703
Round Hill	Waste Rock	43	CX41417	<LOD	<LOD	543	142	125	<LOD	<LOD	51	<LOD	15	<LOD	31	<LOD	639,071
Round Hill	Waste Rock	44	CX41424	<LOD	<LOD	586	<LOD	<LOD	168	<LOD	<LOD	<LOD	20	<LOD	26	<LOD	640,465
Round Hill	Waste Rock	45	CX41425	<LOD	<LOD	589	<LOD	127	<LOD	<LOD	43	<LOD	18	<LOD	20	<LOD	638,239
Round Hill	Low grade ore	46	CX41441	<LOD	<LOD	485	<LOD	<LOD	<LOD	<LOD	78	<LOD	18	<LOD	24	<LOD	620,956
Round Hill	Waste Rock	47	CX41453	<LOD	<LOD	433	<LOD	102	<LOD	<LOD	58	<LOD	16	<LOD	24	<LOD	644,892
Round Hill	Waste Rock	48	CX41470	<LOD	<LOD	415	<LOD	<LOD	<LOD	<LOD	93	<LOD	13	<LOD	20	<LOD	637,365
Round Hill	Waste Rock	49	CX41483	<LOD	<LOD	438	<LOD	102	<LOD	<LOD	63	<LOD	14	<LOD	22	<LOD	636,160
Round Hill	Waste Rock	50	CX41492	<LOD	<LOD	355	<LOD	110	<LOD	<LOD	54	<LOD	21	<LOD	23	<LOD	632,994
Round Hill	Waste Rock	51	CX41502	<LOD	<LOD	539	101	139	<LOD	194	41	<LOD	20	<LOD	29	<LOD	642,213
Golden Bar	Waste Rock	52	CN25556	<LOD	<LOD	717	130	<LOD	<LOD	<LOD	<LOD	<LOD	22	<LOD	32	<LOD	635,787
Golden Bar	Low grade ore	53	CN25593	<LOD	<LOD	573	<LOD	110	<LOD	<LOD	<LOD	<LOD	15	<LOD	25	5	631,385
Golden Bar	Waste Rock	54	CN25642	<LOD	<LOD	566	<LOD	156	<LOD	<LOD	15	<LOD	17	<LOD	28	5	623,073
Golden Bar	Waste Rock	55	CN25688	<LOD	<LOD	563	<LOD	119	<LOD	<LOD	<LOD	<LOD	16	<LOD	27	<LOD	636,315
Golden Bar	Waste Rock	56	CN25695	<LOD	<LOD	442	130	124	<LOD	<LOD	15	<LOD	20	<LOD	27	<LOD	620,226
Golden Bar	Ore	57	CN25741	<LOD	57	463	163	<LOD	<LOD	<LOD	63	<LOD	20	<LOD	27	<LOD	616,927
Golden Bar	Waste Rock	58	CN25749	<LOD	<LOD	397	92	94	144	234	32	<LOD	16	<LOD	28	<LOD	625,830
Golden Bar	Waste Rock	59	CN25761	<LOD	<LOD	397	118	<LOD	156	<LOD	20	<LOD	19	<LOD	23	5	627,796
Golden Bar	Waste Rock	60	CN25798	<LOD	<LOD	483	109	117	<LOD	<LOD	35	<LOD	18	<LOD	24	<LOD	632,441
Golden Bar	Waste Rock	61	CN25807	<LOD	<LOD	482	89	125	<LOD	<LOD	20	<LOD	18	<LOD	26	<LOD	634,634
Coronation	Waste Rock	62	CQ59694	<LOD	<LOD	578	<LOD	<LOD	<LOD	258	56	<LOD	14	<LOD	22	<LOD	643,440
Coronation	Waste Rock	63	CQ59699	<LOD	<LOD	566	114	116	<LOD	209	30	<LOD	15	<LOD	25	<LOD	642,079
Coronation	Waste Rock	64	CQ59708	<LOD	<LOD	717	129	146	<LOD	<LOD	19	<LOD	15	<LOD	24	<LOD	624,270
Coronation	Waste Rock	65	CQ59715	<LOD	<LOD	464	<LOD	166	198	264	23	<LOD	19	<LOD	24	<LOD	643,782
Coronation	Waste Rock	66	CQ65514	<LOD	<LOD	322	<LOD	<LOD	<LOD	<LOD	65	<LOD	20	<LOD	23	5	633,725
Coronation	Ore	67	CQ65521	<LOD	<LOD	549	<LOD	125	<LOD	<LOD	21	<LOD	19	<LOD	28	<LOD	626,451
Coronation	Waste Rock	68	CQ65526	<LOD	33	559	140	108	150	<LOD	69	<LOD	18	<LOD	26	<LOD	634,086
Coronation	Waste Rock	69	CQ65528	<LOD	39	536	95	139	<LOD	247	23	<LOD	20	<LOD	20	6	629,382
Coronation	Waste Rock	70	CQ65529	<LOD	<LOD	491	<LOD	<LOD	<LOD	<LOD	32	<LOD	16	<LOD	31	6	632,724

Notes

Analysis date 18/07/2022

All units are shown in PPM

<LOD - less than of detection

Sample type was pulp

Project number: MWM

Cells shaded blue are samples that underwent shake flask testing

APPENDIX F SHAKE FLASK EXTRACTION DATA

Shake flask extraction 1 - oxic results

Sample Name:	SFE1/6 16-May-2022	SFE1/11 16-May-2022	SFE1/15 16-May-2022	SFE1/19 16-May-2022	SFE1/24 16-May-2022	SFE1/27 16-May-2022	SFE1/31 16-May-2022	SFE1/36 16-May-2022	SFE1/40 16-May-2022
Material Type	Backfill	In Situ Waste Rock	Backfill	Backfill	Backfill	Backfill	Backfill	In Situ Waste Rock	In Situ Waste Rock
Sample Number (MWM)	15	20	35	36	37	38	39	40	41
Verum Sample ID	22/248-6	22/248-11	22/248-15	22/248-19	22/248-24	22/248-27	22/248-31	22/248-36	22/248-40
Hill Laboratory ID	2992056.1	2992056.2	2992056.3	2992056.4	2992056.5	2992056.6	2992056.7	2992056.8	2992056.9
pH after shake (pH units)	7.34	8.2	8.3	8.23	8.14	8.13	7.55	8.28	8.02
Alkalinity pH7 (mg $CaCO_3$/L)	5	10	25	25	25	25	10	25	20
Alkalinity pH6 (mg $CaCO_3$/L)	15	65	50	60	70	60	50	50	40
Alkalinity pH5 (mg $CaCO_3$/L)	30	115	90	105	90	90	90	95	70
Alkalinity pH4.5 (mg $CaCO_3$/L)	0	0	0	0	0	0	0	0	0
Dissolved Oxygen (DO) (%)	85	85	80	88	85	90	83	90	89
Oxygen Reducing Potential (ORP) (mV)	325	280	294	289	260	220	273	203	201
Electrical Conductivity (EC) (uS/cm)	60.2	172.7	236	248	237	238	287	165	214
Dissolved Aluminium	0.41	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	0.07	< 0.06
Dissolved Antimony	< 0.004	0.006	0.011	0.016	0.005	0.024	0.029	0.014	0.023
Dissolved Calcium	6.9	21	25	23	25	26	30	27	30
Dissolved Cobalt	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Dissolved Iron	0.9	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	1.8	4	9.1	13	12.6	13.1	10.8	3.2	5.8
Dissolved Manganese	0.024	< 0.010	0.018	0.017	0.013	0.022	0.017	0.041	0.053
Dissolved Potassium	< 1.0	12.3	15.6	13	11.1	13.9	13.6	8.3	8.8
Dissolved Selenium	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	7.8	4.9	4.2	4	3.6	4.2	4.7	2.7	4
Dissolved Thallium	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	< 0.010	0.38	0.197	0.28	0.134	0.22	0.24	0.184	0.175
Nitrite-N	0.014	0.026	0.03	0.026	0.021	0.031	0.036	0.027	0.026
Nitrate-N	0.114	0.02	0.27	0.35	1.12	1.3	2.1	0.077	0.056
Nitrate-N + Nitrite-N	0.128	0.046	0.3	0.38	1.14	1.33	2.2	0.104	0.083
Sulfate	35	8.2	32	37	30	23	57	8.1	35
Dissolved Arsenic	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05	0.03
Dissolved Cadmium	< 0.0010	< 0.0010	0.0016	< 0.0010	0.0015	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Chromium	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.031	< 0.010	< 0.010
Dissolved Lead	0.005	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Zinc	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Notes
All units are expressed as mg/L unless otherwise stated

Shake flask extraction 2 - anoxic results

Sample Name:	SFE2/6 16-May-2022	SFE2/11 16-May-2022	SFE2/15 16-May-2022	SFE2/19 16-May-2022	SFE2/24 16-May-2022	SFE2/27 16-May-2022	SFE2/31 16-May-2022	SFE2/36 16-May-2022	SFE2/40 16-May-2022
Material Type	Backfill	In Situ Waste Rock	Backfill	Backfill	Backfill	Backfill	Backfill	In Situ Waste Rock	In Situ Waste Rock
Sample Number (MWM)	15	20	35	36	37	38	39	40	41
Verum Sample ID	22/248-6	22/248-11	22/248-15	22/248-19	22/248-24	22/248-27	22/248-31	22/248-36	22/248-40
Hill Laboratory ID	2992056.16	2992056.17	2992056.18	2992056.19	2992056.2	2992056.21	2992056.22	2992056.23	2992056.24
pH after shake (pH units)	6.76	8.64	8.65	8.57	8.38	8.69	8.63	9.04	8.61
Alkalinity pH7 (mg $CaCO_3$/L)	-	20	20	10	15	15	15	30	15
Alkalinity pH6 (mg $CaCO_3$/L)	5	40	25	30	20	30	25	80	30
Alkalinity pH5 (mg $CaCO_3$/L)	10	50	30	35	40	40	40	100	35
Alkalinity pH4.5 (mg $CaCO_3$/L)	0	0	0	0	0	0	0	0	0
Dissolved Oxygen (DO) (%)	42.5	39.8	34	30.6	29.8	33	<30	31.6	<30
Oxygen Reducing Potential (ORP) (mV)	193	145	191	153.1	140.7	141.8	153.6	133.8	152.5
Electrical Conductivity (EC) (uS/cm)	56	95.5	157.2	165.2	159.7	150.6	177.9	78.1	139.6
Dissolved Aluminium	0.56	0.08	0.16	0.13	0.15	0.2	0.15	0.36	0.16
Dissolved Antimony	< 0.004	0.005	0.01	0.013	0.005	0.022	0.027	0.008	0.015
Dissolved Calcium	4.1	7.7	11.1	11	13	10	14.8	9.8	15
Dissolved Cobalt	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Dissolved Iron	1	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	1.4	1.5	4.5	6.9	7.5	6.9	6.8	1.3	3.5
Dissolved Manganese	0.021	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.01	0.015
Dissolved Potassium	< 1.0	10.1	13.4	11.1	10	12.3	12.3	6.7	7.7
Dissolved Selenium	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	7.5	4.7	3.8	3.4	3.3	3.7	4.2	2.2	3.6
Dissolved Thallium	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	< 0.010	0.31	0.25	0.27	0.128	0.26	0.3	0.09	0.158
Nitrite-N	0.004	< 0.002	0.004	0.004	0.003	< 0.002	0.003	0.004	0.003
Nitrate-N	0.086	0.022	0.24	0.34	1	1.18	1.91	0.05	0.046
Nitrate-N + Nitrite-N	0.09	0.024	0.24	0.34	1	1.18	1.91	0.053	0.048
Sulfate	15	5.7	28	29	26	19.3	36	6	31
Dissolved Arsenic	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.06	0.03
Dissolved Cadmium	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Chromium	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Lead	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Zinc	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Notes
All units are expressed as mg/L unless otherwise stated

APPENDIX G LABORATORY CERTIFICATES

Verum Group

Data report for Frasers Open Pit

Prepared for Oceana Gold/Mine Waste Management

June 2022
22-248

Author M.Young

Verum Group reference 22/248

Client name Oceana Gold Limited

Client address

Distribution (other than client) Mine Waste Management

Date of Issue 21/06/2022

Reviewed by James Pope

Director – Business Development

Approved by Mike Young

National Laboratory Manager

Document tracking

Version	Date	Changes made	Reviewer(s)
2	21/06/22	Added detail and %w to KCl and HCl extracts. Corrected spelling	

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1. Method Notes

Sample prep	Samples 1-12 were dried at 30degC, crushed in a jaw mill and then ringmilled. All other samples were dried at 30degC and ring milled.	
1 - Paste pH/EC	AMIRA Handbook 2002 (2.2)	
2 - ANC	AMIRA Handbook 2002 (2.1)	
3 - NAG	AMIRA Handbook 2002 (2.1)	Not titrated if pH >7.0. Single results to pH 7.0. Result pairs to pH 4.5 and pH 7.0 respectively
4 - 1M KCL	Ahern et al 2004 (23A)	SO4, analysis completed by Hills - job 2971285 (As, Fe, Sb not tested due to lab error)
5 - TAA	Ahern et al 2004 (23F)	From 1M KCl extraction. Only completed if acidity <6.
6 - 4M HCl	Ahern et al 2004 (20B)	S, As, Fe, Sb analysis completed by Hills - job 2971286
7 - SFE 1		18 hr extraction (conical flask - unstoppered with shaker table providing mixing: 25g to 250 mL. Fe was below detection limits so speciation results are not reported. Ion analysis completed by Hills - job 2992056
8 - SFE 2		18 hr extraction (conical flask - stoppered with shaker table providing mixing; N2 purging: 25g to 250 mL. Fe was below detection limits so speciation results are not reported. Ion analysis completed by Hills - job 2992056

2. Analysis data

Verum Group Ltd Reference:	Sample type	Sample ID (Mine Waste Management)	Paste pH	Conductivity	ANC	ANC	NAG pH	NAG Acidity	NAG Acidity
			pH	uS/cm	kg H2SO4/t	%CaCO3	pH	kg H2SO4/t (to pH 7)	kg H2SO4/t (to pH 4.5)
Methods (see notes above)			1	1	2	2	3	3	3
22/248-1	Grab	Grab 1	8.26	369	60.3	6.2	8.19		
22/248-2	Grab	Grab 2	8.34	326	73.1	7.5	8.26		
22/248-3	Grab	Grab 3	8.58	282	56.1	5.7	8.57		
22/248-4	DDH7839	57.60 - 59.80	8.43	594	40.2	4.1	9.19		
22/248-5	DDH7839	61.2 - 63.5	8.28	699	48.8	5.0	9.58		
22/248-6	DDH7839	66.4 - 66.5	7.53	188	13.4	1.4	5.32	1.0	
22/248-7	DDH7839	72.4 - 42.5	8.60	185	25.6	2.6	4.93	1.2	
22/248-8	DDH7839	72.9 - 73.0	8.64	167	23.2	2.4	4.22	1.4	0.2
22/248-9	DDH7839	77.1 - 77.2	8.65	209	40.2	4.1	8.71		
22/248-10	DDH7839	82.6 - 82.8	8.80	162	23.2	2.4	4.49	1.2	0.1
22/248-11	DDH7839	87.4 - 87.5	8.59	192	77.6	7.9	10.68		
22/248-12	DDH7839	93.2 - 93.3	8.94	194	31.5	3.2	9.98		
22/248-13	RCH7934	1	8.08	339	41.2	4.2	8.96		
22/248-14	RCH7934	2	7.72	337	50.9	5.2	8.55		
22/248-15	RCH7934	3	8.00	331	60.6	6.2	8.72		
22/248-16	RCH7934	4	8.24	289	66.7	6.8	8.75		
22/248-17	RCH7934	5	8.20	508	78.8	8.0	9.76		
22/248-18	RCH7934	6	8.26	599	77.6	7.9	10.68		
22/248-19	RCH7934	7	8.48	397	84.9	8.7	8.71		
22/248-20	RCH7934	8	8.40	430	69.1	7.1	10.57		
22/248-21	RCH7934	9	8.42	464	67.0	6.8	10.67		
22/248-22	RCH7934	10.0	8.39	503	70.7	7.2	9.25		
22/248-23	RCD7928	62	8.49	375	70.7	7.2	10.09		
22/248-24	RCD7928	63.0	8.51	384	80.4	8.2	9.01		

22/248-25	RCD7928	64.0	8.37	337	71.9	7.3	8.63		
22/248-26	RCD7928	65.0	8.52	318	75.6	7.7	8.40		
22/248-27	RCD7928	66.0	8.50	343	65.8	6.7	8.75		
22/248-28	RCD7928	67.0	8.57	366	63.4	6.5	8.56		
22/248-29	RCD7928	68.0	8.69	312	63.4	6.5	8.64		
22/248-30	RCD7928	69.0	8.56	358	67.0	6.8	8.61		
22/248-31	RCD7928	70.0	8.46	457	70.7	7.2	8.64		
22/248-32	RCD7928	71.00	8.61	704	43.9	4.5	8.73		
22/248-33	RCD7928	72.00	8.03	1150	26.8	2.7	10.48		
22/248-34	RCD7928	73.0	8.39	673	35.3	3.6	10.80		
22/248-35	RCD7928	75	9.09	181	31.7	3.2	11.02		
22/248-36	RCD7928	76	9.15	160	44.1	4.5	11.04		
22/248-37	RCD7928	77	9.23	173	33.1	3.4	11.16		
22/248-38	RCD7928	78	9.03	194	42.9	4.4	11.05		
22/248-39	RCD7928	79.0	8.78	236	72.3	7.4	10.63		
22/248-40	RCD7928	80.0	8.40	373	50.2	5.1	10.41		
22/248-41	RCD7928	81.0	8.51	251	60.0	6.1	11.01		
22/248-42	RCD7928	82.0	8.47	210	110.5	11.3	11.13		
22/248-43	T1	7.8 - 8.5	7.59	2020	55.1	5.6	10.56		
22/248-44	T2	13.5 - 14.5	7.52	2150	36.8	3.8	9.85		
22/248-45	T3	25.5 - 26.5	7.56	2170	36.8	3.8	8.50		
22/248-46	T4	28.5 - 29.5	7.62	2160	34.3	3.5	9.08		
22/248-47	T5	34.5 - 35.5	7.91	2070	35.5	3.6	9.68		
22/248-48	T6	43.5 - 44.5	8.25	881	10.9	1.1	6.79	0.1	
22/248-49	T7	58.5 - 59.5	8.37	740	27.8	2.8	9.26		
22/248-50	T8	64.5 - 65.5	8.63	691	29.0	3.0	8.14		
22/248-51	T9	76.4 - 77.5	8.75	521	44.7	4.6	10.03		

KCl Extract

Verum Group Ltd Reference:	Sample type	KCl extraction pH (after initial rotation)			Sulphate	Sulphate	Titratable actual acidity (TAA)
		pH	Wt of sample (g)	Vol of liquor (mL)	g/m3	w%	mol H+/t
Methods (see notes above)		5					6
22/248-6	DDH7839	5.58	2.00	80	<50	<0.2	5
22/248-11	DDH7839	9.43	2.00	80	<50	<0.2	-
22/248-15	RCH7934	9.46	2.00	80	<50	<0.2	-
22/248-19	RCH7934	9.43	2.00	80	<50	<0.2	-
22/248-24	RCD7928	9.51	2.00	80	<50	<0.2	-
22/248-27	RCD7928	9.47	2.00	80	<50	<0.2	-
22/248-31	RCD7928	9.42	2.00	80	<50	<0.2	-
22/248-36	RCD7928	9.66	2.00	80	<50	<0.2	-
22/248-40	RCD7928	9.46	2.00	80	<50	<0.2	-
22/248-43	T1	9.20	2.00	80	117	0.468	-
22/248-44	T2	9.63	2.00	80	240	0.960	-
22/248-46	T4	8.55	2.00	80	380	1.520	-
22/248-47	T5	9.09	2.00	80	147	0.588	-

HCl Extract

Verum Group Ltd Reference:	Sample type	4M HCl extraction		Sulphate	Sulphate	Antimony	Antimony	Arsenic	Arsenic	Iron	Iron
		Wt of sample (g)	Vol of liquor (mL)	g/m3	w%	g/m3	w%	g/m3	w%	g/m3	w%
Methods (see notes above)		7									
22/248-6	DDH7839	2.00	80	<500	<2	0.034	0.00014	0.27	0.0011	630	2.52
22/248-11	DDH7839	2.00	80	<500	<2	<0.021	<0.00008	<0.11	<0.0004	590	2.36
22/248-15	RCH7934	2.00	80	<500	<2	0.09	0.00036	0.45	0.0018	690	2.76
22/248-19	RCH7934	2.00	80	<500	<2	0.144	0.00058	0.46	0.0018	790	3.16
22/248-24	RCD7928	2.00	80	<500	<2	0.058	0.00023	0.15	0.0006	760	3.04
22/248-27	RCD7928	2.00	80	<500	<2	0.156	0.00062	0.22	0.0009	850	3.40
22/248-31	RCD7928	2.00	80	<500	<2	0.183	0.00073	0.24	0.0010	750	3.00
22/248-36	RCD7928	2.00	80	<500	<2	0.049	0.00020	0.47	0.0019	600	2.40
22/248-40	RCD7928	2.00	80	<500	<2	0.058	0.00023	0.57	0.0023	710	2.84
22/248-43	T1	2.00	80	<500	<2	0.45	0.00180	17.2	0.0688	640	2.56
22/248-44	T2	2.00	80	<500	<2	1.93	0.00772	53	0.212	660	2.64
22/248-46	T4	2.00	80	570	2.28	0.33	0.00132	86	0.344	730	2.92
22/248-47	T5	2.00	80	<500	<2	0.177	0.00071	31	0.124	550	2.20

Shake Flask Extraction (SFE-1 Oxic)

Verum Group Ltd Reference:	Sample type	Sample ID (Mine Waste Management)	pH after shake	Alkalinity pH7	Alkalinity pH6	Alkalinity pH5	Dissolved Oxygen (DO)	Oxygen Reducing Potential (ORP)	Electrical Conductivity (EC)
			pH				%	mV	uS/m
22/248-6	DDH7839	66.4 - 66.5	7.34	5	15	30	85	325	60
22/248-11	DDH7839	87.4 - 87.5	8.20	10	65	115	85	280	173
22/248-15	RCH7934	3	8.30	25	50	90	80	294	236
22/248-19	RCH7934	7	8.23	25	60	105	88	289	248
22/248-24	RCD7928	63.0	8.14	25	70	90	85	260	237
22/248-27	RCD7928	66.0	8.13	25	60	90	90	220	238
22/248-31	RCD7928	70.0	7.55	10	50	90	83	273	287
22/248-36	RCD7928	76	8.28	25	50	95	90	203	165
22/248-40	RCD7928	80.0	8.02	20	40	70	89	201	214
22/248-43	T1	7.8 - 8.5	7.57	5	25	35	86	176	812
22/248-44	T2	13.5 - 14.5	7.56	5	15	25	85	192	1526
22/248-46	T4	28.5 - 29.5	7.50	5	10	20	86	178	2190
22/248-47	T5	34.5 - 35.5	7.65	5	10	30	87	176	1077

Shake Flask Extraction (SFE-2 Anoxic)

Verum Group Ltd Reference:	Sample type	Sample ID (Mine Waste Management)	pH after shake	Alkalinity pH7	Alkalinity pH6	Alkalinity pH5	Dissolved Oxygen (DO) *	Oxygen Reducing Potential (ORP)	Electrical Conductivity (EC)
			pH				%	mV	uS/m
22/248-6	DDH7839	66.4 - 66.5	6.76	-	5	10	43	193	56
22/248-11	DDH7839	87.4 - 87.5	8.64	20	40	50	40	145	96
22/248-15	RCH7934	3	8.65	20	25	30	34	191	157
22/248-19	RCH7934	7	8.57	10	30	35	31	153.1	165
22/248-24	RCD7928	63.0	8.38	15	20	40	30	140.7	160

22/248-27	RCD7928	66.0	8.69	15	30	40	33	141.8	151
22/248-31	RCD7928	70.0	8.63	15	25	40	<30	153.6	178
22/248-36	RCD7928	76	9.04	30	80	100	32	133.8	78
22/248-40	RCD7928	80.0	8.61	15	30	35	<30	152.5	140
22/248-43	T1	7.8 - 8.5	7.65	5	10	15	<30	184.3	776
22/248-44	T2	13.5 - 14.5	7.44	5	15	20	33	121.3	1595
22/248-46	T4	28.5 - 29.5	7.52	5	10	15	38	134.8	2090
22/248-47	T5	34.5 - 35.5	7.83	5	10	15	<30	101.1	1064

* Oxygen exclusion testing for the method adopted indicates that a maximum of 1.6E-5 moles of oxygen is included with these samples with potential to oxidise 0.5mg FeS_2.

MTI Tailing Samples

Depth	Moisture %
13.5 - 14.0	23.2
14.0 - 14.5	25.5
77.0 - 77.3	16.8

3. Quality Assurance duplicates

ANC

Sample ID	kg H2SO4/t	%CaCO3	RPD
22/248-10	23.16	2.36	5.2
22/248-10	21.94	2.24	
22/248-20	69.13	7.05	0.0
22/248-20	69.13	7.05	
22/248-30	67.04	6.84	0.9
22/248-30	67.65	6.90	
22/248-40	50.23	5.13	0.0
22/248-40	50.23	5.13	
22/248-51	44.66	4.56	1.3
22/248-51	45.26	4.62	

NAG

	pH	to pH 7	
SampleID		kgH2SO4/t	RPD
22/248-10	4.49	1.176	8.0
22/248-10	4.5	1.274	
22/248-22	9.25		
22/248-22	9.3		
22/248-34	10.8		
22/248-34	11		
22/248-44	9.85		
22/248-44	9.72		
22/248-51	10.03		
22/248-51	10.3		

Shake Flask Extraction

	pH after	Alkalinity pH 7		Alkalinity pH 6		Alkalinity pH 5		DO		ORP		EC	
Sample	18 hrs shake	mg CaCO3/L	RPD	mg CaCO3/L	RPD	mg CaCO3/L	RPD	%	RPD	mv	RPD	us/m	RPD
Oxic													
22-248-46A	7.50	5	0	10	0	20	22	86	3.4	178	2.8	2190	4.2
22-248-46B	7.50	5		10		25		89		173		2100	
Blank	7.60	0		0.5		0.5		88		115		3.6	
Anoxic													
22-248-47A	7.83	5	0	10	0	15	0	21.9	9.1	101.2	0.1	1075	1.0
22-248-47B	7.89	5		10		15		20		101.1		1064	
Blank	6.60	0		0		0.5		30.7		88.5		2	

4. Hill Laboratory reports

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Certificate of Analysis

SPv1

Client:	Verum Group Limited	**Lab No:**	2971285
Contact:	N Newman	**Date Received:**	29-Apr-2022
	C/- Verum Group Limited	**Date Reported:**	06-May-2022
	PO Box 29415	**Quote No:**	
	Riccarton	**Order No:**	
	Christchurch 8440	**Client Reference:**	22/248 KCl Leach
		Submitted By:	N Newman

Sample Type: Aqueous

Sample Name:		Blank KCl 28-Apr-2022	6 KCl 28-Apr-2022	11 KCl 28-Apr-2022	15 KCl 28-Apr-2022	19 KCl 28-Apr-2022
Lab Number:		2971285.1	2971285.2	2971285.3	2971285.4	2971285.5
Sulphate	g/m³	< 50 #1	< 50 #1	< 50 #1	< 50 #1	< 50 #1

Sample Name:		24 KCl 28-Apr-2022	27 KCl 28-Apr-2022	31 KCl 28-Apr-2022	36 KCl 28-Apr-2022	40 KCl 28-Apr-2022
Lab Number:		2971285.6	2971285.7	2971285.8	2971285.9	2971285.10
Sulphate	g/m³	< 50 #1	< 50 #1	< 50 #1	< 50 #1	< 50 #1

Sample Name:		43 KCl 28-Apr-2022	44 KCl 28-Apr-2022	46 KCl 28-Apr-2022	47a KCl 28-Apr-2022	47b KCl 28-Apr-2022
Lab Number:		2971285.11	2971285.12	2971285.13	2971285.14	2971285.15
Sulphate	g/m³	117 #1	240 #1	380 #1	147 #1	172 #1

Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the SO4 analysis.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-15
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-15

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed on 06-May-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Martin Cowell - BSc
Client Services Manager - Environmental

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

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Certificate of Analysis

Client:	Verum Group Limited	**Lab No:**	2971286 SPv2
Contact:	N Newman	**Date Received:**	29-Apr-2022
	C/- Verum Group Limited	**Date Reported:**	17-Jun-2022 **(Amended)**
	PO Box 29415	**Quote No:**	
	Riccarton	**Order No:**	
	Christchurch 8440	**Client Reference:**	22/248 4m HCL Leach
		Submitted By:	N Newman

Sample Type: Aqueous

Sample Name:		Blank HCl 28-Apr-2022	6 HCl 28-Apr-2022	11 HCl 28-Apr-2022	15 HCl 28-Apr-2022	19 HCl 28-Apr-2022
Lab Number:		2971286.1	2971286.2	2971286.3	2971286.4	2971286.5
Total Antimony	g/m³	< 0.0042	0.034	< 0.021	0.090	0.144
Total Arsenic	g/m³	< 0.021	0.27	< 0.11	0.45	0.46
Total Iron	g/m³	< 0.42	630	590	690	790
Sulphate	g/m³	< 500 #1	< 500 #1	< 500 #1	< 500 #1	< 500 #1

Sample Name:		24 HCl 28-Apr-2022	27 HCl 28-Apr-2022	31 HCl 28-Apr-2022	36 HCl 28-Apr-2022	40 HCl 28-Apr-2022
Lab Number:		2971286.6	2971286.7	2971286.8	2971286.9	2971286.10
Total Antimony	g/m³	0.058	0.156	0.183	0.049	0.058
Total Arsenic	g/m³	0.15	0.22	0.24	0.47	0.57
Total Iron	g/m³	760	850	750	600	710
Sulphate	g/m³	< 500 #1	< 500 #1	< 500 #1	< 500 #1	< 500 #1

Sample Name:		43 HCl 28-Apr-2022	44 HCl 28-Apr-2022	46 HCl 28-Apr-2022	47a HCl 28-Apr-2022	47b HCl 28-Apr-2022
Lab Number:		2971286.11	2971286.12	2971286.13	2971286.14	2971286.15
Total Antimony	g/m³	0.45	1.93	0.33	0.177	0.167
Total Arsenic	g/m³	17.2	53	86	31	28
Total Iron	g/m³	640	660	730	550	560
Sulphate	g/m³	< 500 #1	< 500 #1	570 #1	< 500 #1	< 500 #1

Analyst's Comments

#1 Due to the nature of this sample a dilution was performed prior to analysis, resulting in a detection limit higher than that normally achieved for the SO4 analysis.

Amended Report: This certificate of analysis replaces report '2971286-SPv1' issued on 11-May-2022 at 12:44 pm. Reason for amendment: Sulphate tests have been added, at the request of the client.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-15
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-15
Total Antimony	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.0042 g/m³	1-15
Total Arsenic	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.021 g/m³	1-15
Total Iron	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.42 g/m³	1-15

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1-15

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 10-May-2022 and 17-Jun-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental

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Certificate of Analysis

SPv2

Client:	Verum Group Limited	**Lab No:**	2992056
Contact:	N Newman	**Date Received:**	19-May-2022
	C/- Verum Group Limited	**Date Reported:**	31-May-2022 **(Amended)**
	PO Box 29415	**Quote No:**	117871
	Riccarton	**Order No:**	
	Christchurch 8440	**Client Reference:**	SFE set Weber
		Submitted By:	N Newman

Sample Type: Aqueous

Sample Name:		SFE1/6 16-May-2022	SFE1/11 16-May-2022	SFE1/15 16-May-2022	SFE1/19 16-May-2022	SFE1/24 16-May-2022
Lab Number:		2992056.1	2992056.2	2992056.3	2992056.4	2992056.5
Individual Tests						
Dissolved Aluminium	g/m³	0.41	< 0.06	< 0.06	< 0.06	< 0.06
Dissolved Antimony	g/m³	< 0.004	0.006	0.011	0.016	0.005
Dissolved Calcium	g/m³	6.9	21	25	23	25
Dissolved Cobalt	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Dissolved Iron	g/m³	0.9	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	g/m³	1.8	4.0	9.1	13.0	12.6
Dissolved Manganese	g/m³	0.024	< 0.010	0.018	0.017	0.013
Dissolved Potassium	g/m³	< 1.0	12.3	15.6	13.0	11.1
Dissolved Selenium	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	g/m³	7.8	4.9	4.2	4.0	3.6
Dissolved Thallium	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	g/m³	< 0.010	0.38	0.197	0.28	0.134
Nitrite-N	g/m³	0.014	0.026	0.030	0.026	0.021
Nitrate-N	g/m³	0.114	0.020	0.27	0.35	1.12
Nitrate-N + Nitrite-N	g/m³	0.128	0.046	0.30	0.38	1.14
Sulphate	g/m³	35	8.2	32	37	30
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Cadmium	g/m³	< 0.0010	< 0.0010	0.0016	< 0.0010	0.0015
Dissolved Chromium	g/m³	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	g/m³	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Lead	g/m³	0.005	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	g/m³	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Zinc	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample Name:		SFE1/27 16-May-2022	SFE1/31 16-May-2022	SFE1/36 16-May-2022	SFE1/40 16-May-2022	SFE1/43 16-May-2022
Lab Number:		2992056.6	2992056.7	2992056.8	2992056.9	2992056.10
Individual Tests						
Dissolved Aluminium	g/m³	< 0.06	< 0.06	0.07	< 0.06	< 0.06
Dissolved Antimony	g/m³	0.024	0.029	0.014	0.023	0.019
Dissolved Calcium	g/m³	26	30	27	30	167
Dissolved Cobalt	g/m³	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Dissolved Iron	g/m³	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	g/m³	13.1	10.8	3.2	5.8	12.6
Dissolved Manganese	g/m³	0.022	0.017	0.041	0.053	0.42
Dissolved Potassium	g/m³	13.9	13.6	8.3	8.8	4.6
Dissolved Selenium	g/m³	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	g/m³	4.2	4.7	2.7	4.0	6.6

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Sample Type: Aqueous						
Sample Name:		SFE1/27 16-May-2022	SFE1/31 16-May-2022	SFE1/36 16-May-2022	SFE1/40 16-May-2022	SFE1/43 16-May-2022
Lab Number:		2992056.6	2992056.7	2992056.8	2992056.9	2992056.10
Individual Tests						
Dissolved Thallium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	g/m^3	0.22	0.24	0.184	0.175	< 0.010
Nitrite-N	g/m^3	0.031	0.036	0.027	0.026	0.015
Nitrate-N	g/m^3	1.30	2.1	0.077	0.056	0.013
Nitrate-N + Nitrite-N	g/m^3	1.33	2.2	0.104	0.083	0.028
Sulphate	g/m^3	23	57	8.1	35	450
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	< 0.02	< 0.02	0.05	0.03	0.22
Dissolved Cadmium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0163
Dissolved Chromium	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	g/m^3	< 0.010	0.031	< 0.010	< 0.010	< 0.010
Dissolved Lead	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Zinc	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample Name:		SFE1/44 16-May-2022	SFE1/46A 16-May-2022	SFE1/46B 16-May-2022	SFE1/47 16-May-2022	SFE1/Blank 16-May-2022
Lab Number:		2992056.11	2992056.12	2992056.13	2992056.14	2992056.15
Individual Tests						
Dissolved Aluminium	g/m^3	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Dissolved Antimony	g/m^3	0.050	0.008	0.009	0.012	< 0.004
Dissolved Calcium	g/m^3	380	550	580	230	< 1.0
Dissolved Cobalt	g/m^3	0.006	0.006	0.006	0.014	< 0.004
Dissolved Iron	g/m^3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	g/m^3	21	27	29	18.2	< 0.4
Dissolved Manganese	g/m^3	0.41	0.32	0.36	0.58	< 0.010
Dissolved Potassium	g/m^3	9.4	10.1	10.9	6.0	< 1.0
Dissolved Selenium	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	g/m^3	16.2	18.9	19.0	13.3	0.8
Dissolved Thallium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	g/m^3	0.48	0.65	0.60	0.21	< 0.010
Nitrite-N	g/m^3	0.018	0.016	0.016	0.020	0.010
Nitrate-N	g/m^3	0.041	0.035	0.016	0.021	0.013
Nitrate-N + Nitrite-N	g/m^3	0.059	0.051	0.032	0.041	0.023
Sulphate	g/m^3	1,050	1,460	1,400	700	0.8
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	0.38	0.27	0.28	0.25	< 0.02
Dissolved Cadmium	g/m^3	< 0.0010	0.0016	0.0022	0.0021	< 0.0010
Dissolved Chromium	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Lead	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	g/m^3	0.011	0.012	0.012	0.012	< 0.010
Dissolved Zinc	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample Name:		SFE2/6 16-May-2022	SFE2/11 16-May-2022	SFE2/15 16-May-2022	SFE2/19 16-May-2022	SFE2/24 16-May-2022
Lab Number:		2992056.16	2992056.17	2992056.18	2992056.19	2992056.20
Individual Tests						
Dissolved Aluminium	g/m^3	0.56	0.08	0.16	0.13	0.15
Dissolved Antimony	g/m^3	< 0.004	0.005	0.010	0.013	0.005
Dissolved Calcium	g/m^3	4.1	7.7	11.1	11.0	13.0
Dissolved Cobalt	g/m^3	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Dissolved Iron	g/m^3	1.0	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	g/m^3	1.4	1.5	4.5	6.9	7.5
Dissolved Manganese	g/m^3	0.021	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Potassium	g/m^3	< 1.0	10.1	13.4	11.1	10.0
Dissolved Selenium	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample Type: Aqueous						
Sample Name:		SFE2/6 16-May-2022	SFE2/11 16-May-2022	SFE2/15 16-May-2022	SFE2/19 16-May-2022	SFE2/24 16-May-2022
Lab Number:		2992056.16	2992056.17	2992056.18	2992056.19	2992056.20
Individual Tests						
Dissolved Sodium	g/m^3	7.5	4.7	3.8	3.4	3.3
Dissolved Thallium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	g/m^3	< 0.010	0.31	0.25	0.27	0.128
Nitrite-N	g/m^3	0.004	< 0.002	0.004	0.004	0.003
Nitrate-N	g/m^3	0.086	0.022	0.24	0.34	1.00
Nitrate-N + Nitrite-N	g/m^3	0.090	0.024	0.24	0.34	1.00
Sulphate	g/m^3	15.0	5.7	28	29	26
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Cadmium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Chromium	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Lead	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Zinc	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample Name:		SFE2/27 16-May-2022	SFE2/31 16-May-2022	SFE2/36 16-May-2022	SFE2/40 16-May-2022	SFE2/43 16-May-2022
Lab Number:		2992056.21	2992056.22	2992056.23	2992056.24	2992056.25
Individual Tests						
Dissolved Aluminium	g/m^3	0.20	0.15	0.36	0.16	< 0.06
Dissolved Antimony	g/m^3	0.022	0.027	0.008	0.015	0.014
Dissolved Calcium	g/m^3	10.0	14.8	9.8	15.0	158
Dissolved Cobalt	g/m^3	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Dissolved Iron	g/m^3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	g/m^3	6.9	6.8	1.3	3.5	12.3
Dissolved Manganese	g/m^3	< 0.010	< 0.010	0.010	0.015	0.26
Dissolved Potassium	g/m^3	12.3	12.3	6.7	7.7	4.4
Dissolved Selenium	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	g/m^3	3.7	4.2	2.2	3.6	6.2
Dissolved Thallium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	g/m^3	0.26	0.30	0.090	0.158	0.031
Nitrite-N	g/m^3	< 0.002	0.003	0.004	0.003	< 0.002
Nitrate-N	g/m^3	1.18	1.91	0.050	0.046	0.011
Nitrate-N + Nitrite-N	g/m^3	1.18	1.91	0.053	0.048	0.012
Sulphate	g/m^3	19.3	36	6.0	31	400
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	< 0.02	< 0.02	0.06	0.03	0.17
Dissolved Cadmium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0025
Dissolved Chromium	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Lead	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Zinc	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Sample Name:		SFE2/44 16-May-2022	SFE2/46 16-May-2022	SFE2/47A 16-May-2022	SFE2/47B 16-May-2022	SFE2/Blank 16-May-2022
Lab Number:		2992056.26	2992056.27	2992056.28	2992056.29	2992056.30
Individual Tests						
Dissolved Aluminium	g/m^3	0.17	< 0.06	< 0.06	< 0.06	< 0.06
Dissolved Antimony	g/m^3	0.044	0.008	0.011	0.010	< 0.004
Dissolved Calcium	g/m^3	390	530	197	200	< 1.0
Dissolved Cobalt	g/m^3	0.006	0.004	0.013	0.012	< 0.004
Dissolved Iron	g/m^3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Dissolved Magnesium	g/m^3	20	27	15.8	15.8	< 0.4
Dissolved Manganese	g/m^3	0.35	0.26	0.31	0.32	< 0.010
Dissolved Potassium	g/m^3	9.6	10.3	5.5	5.8	< 1.0

Sample Type: Aqueous						
Sample Name:		SFE2/44 16-May-2022	SFE2/46 16-May-2022	SFE2/47A 16-May-2022	SFE2/47B 16-May-2022	SFE2/Blank 16-May-2022
Lab Number:		2992056.26	2992056.27	2992056.28	2992056.29	2992056.30
Individual Tests						
Dissolved Selenium	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Sodium	g/m^3	16.0	18.6	13.7	13.7	0.7
Dissolved Thallium	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Ammoniacal-N	g/m^3	0.47	0.63	0.28	0.26	< 0.010
Nitrite-N	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Nitrate-N	g/m^3	0.013	0.016	0.017	0.011	0.003
Nitrate-N + Nitrite-N	g/m^3	0.013	0.016	0.017	0.012	0.003
Sulphate	g/m^3	980	1,420	620	620	< 0.5
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	0.37	0.26	0.27	0.28	< 0.02
Dissolved Cadmium	g/m^3	0.0118	0.0126	0.023	0.0063	< 0.0010
Dissolved Chromium	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Copper	g/m^3	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Dissolved Lead	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dissolved Nickel	g/m^3	0.014	0.011	< 0.010	< 0.010	< 0.010
Dissolved Zinc	g/m^3	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Analyst's Comments

Amended Report: This certificate of analysis replaces report '2992056-SPv1' issued on 26-May-2022 at 3:18 pm.
Reason for amendment: Dissolved Thallium and Total Ammoniacal-N have been added to all samples.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Heavy metals, dissolved, screen As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm filtration, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.0010 - 0.02 g/m^3	1-30
Dissolved Aluminium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.06 g/m^3	1-30
Dissolved Antimony	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.004 g/m^3	1-30
Dissolved Calcium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	1.0 g/m^3	1-30
Dissolved Cobalt	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.004 g/m^3	1-30
Dissolved Iron	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.4 g/m^3	1-30
Dissolved Magnesium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.4 g/m^3	1-30
Dissolved Manganese	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.010 g/m^3	1-30
Dissolved Potassium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	1.0 g/m^3	1-30
Dissolved Selenium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.02 g/m^3	1-30
Dissolved Sodium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.4 g/m^3	1-30
Dissolved Thallium	Filtered sample, ICP-MS, screen level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-30
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-30
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-30
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-30
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-30
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1-30

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 23-May-2022 and 31-May-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Oceana Gold

PO Box 84
Palmerston
East Otago,
NEW ZEALAND

Lab Ref	MF137884
Client Ref	**Verum Group C/S job 1**
Project	MET
Cost Code	
Status	Internal
Received	11/07/22
Reported	12/07/22
Samples	54
First Sample	22/454 01
Last Sample	22/454 54
Pages	5

Copy

Notes

Authorised by

On behalf of: Andy Clare
Laboratory Manager

The results in this analytical report pertain to the samples provided to this laboratory for preparation and/or analysis as requested by the client. This document is issued by the company subject to its General Conditions of Services (www.sgs.com/generalconditions). Attention is drawn to the limitations of liability, indemnification and justifications issues established therein.

ANALYTICAL REPORT

Lab Ref	MF137884
Client Ref	**Verum Group C/S job 1**
Project	MET
Reported	12/07/22
Status	Internal
Page	Page 3 of 5

ANALYTICAL REPORT

Scheme **Units** **Detection Limit** **Upper Limit**	CSA06V % 0.01 40.00 S	CSA06V % 0.01 40.00 S(R)	CSA06V % 0.01 30.00 C	CSA06V % 0.01 30.00 C(R)
22/454 01	0.185		0.967	
22/454 02	0.110		0.788	
22/454 03	0.666		1.04	
22/454 04	0.149		0.602	
22/454 05	0.118		0.815	
22/454 06	0.255		0.873	
22/454 07	0.178		1.84	
22/454 08	0.044		0.921	
22/454 09	0.096		1.02	
22/454 10	0.114		1.28	
22/454 11	0.077		0.917	
22/454 12	0.161		0.705	
22/454 13	0.273		0.657	
22/454 14	0.256		0.495	
22/454 15	0.056		0.282	
22/454 16	0.169		0.698	
22/454 17	0.146		0.466	
22/454 18	0.109		0.933	
22/454 19	0.146		0.675	
22/454 20	0.007		0.722	
22/454 21	0.155		0.602	
22/454 22	0.068		1.36	
22/454 23	0.104		0.951	
22/454 24	0.353		1.01	
22/454 25	0.065		1.37	
22/454 26	0.164		0.751	
22/454 27	0.400		0.691	
22/454 28	0.167		0.356	
22/454 29	0.107		0.770	
22/454 30	0.274		1.05	
22/454 31	0.117		1.14	
22/454 32	0.120		0.904	
22/454 33	0.114		1.30	
22/454 34	0.058		1.15	
22/454 35	0.075		0.971	
22/454 36	0.162		0.481	
22/454 37	0.199		0.645	
22/454 38	0.214		0.591	

- not analysed | -- element not determined | I.S. insufficient sample | L.N.R. listed not received

Results are not intended for commercial settlement purposes.

Lab Ref	MF137884
Client Ref	**Verum Group C/S job 1**
Project	MET
Reported	12/07/22
Status	Internal
Page	Page 4 of 5

ANALYTICAL REPORT

	CSA06V % 0.01 40.00 S	CSA06V % 0.01 40.00 S(R)	CSA06V % 0.01 30.00 C	CSA06V % 0.01 30.00 C(R)
22/454 39	0.094		0.509	
22/454 40	0.052		0.334	
22/454 41	2.10		1.61	
22/454 42	0.286		0.767	
22/454 43	0.251		0.845	
22/454 44	0.144		1.16	
22/454 45	0.055		0.770	
22/454 46	0.181		0.208	
22/454 47	0.215		1.15	
22/454 48	0.311		0.561	
22/454 49	0.055	0.054	0.705	0.701
22/454 50	0.100		0.565	
22/454 51	0.162		0.780	
22/454 52	0.145		0.584	
22/454 53	0.105		0.484	
22/454 54	0.074	0.073	0.477	0.491

DESCRIPTION

CSA06V : Total Sulphur/Carbon, LECO Method

APPENDIX H BABBAGE CONSULTANTS REPORT

23 August 2019 Job No: 61130 eTrack No: 200028882

Gavin Lee
OceanaGold (New Zealand) Limited
RD3
Macraes Flat 9483

WASTE ROCK STACK SEEPAGE ASSESSMENT

Dear Gavin

OceanaGold (New Zealand) Limited (OGNZL) engaged Babbage Consultants Limited (Babbage) to find out whether seepage from the North Gully waste rock stack (WRS) (as measured at North Gully Seep East) is a suitable proxy for WRS seepage across the Macraes Gold Project (MGP, the Site). Previous water models have applied the chemistry measured at North Gully Seep East (over a limited period) to all WRS across the MGP with no consideration of WRS volumes, areas or geological characteristics.

In the event North Gully Seep East seepage is found to be an unsuitable proxy for WRS seepage across the MGP, we were asked to establish a set of relationships for median and 95%ile concentrations of sulphate, based on historical data, that could be used in the site wide water model. This letter presents the methodology and results of our assessments.

Approach

The initial scope of the work was to identify trends in the chemistry of water samples from different WRS at the Site and assess if the concentrations of certain parameters (in particular, sulphate) are at equilibrium (stable) or likely to increase over time. Babbage proposed to carry out this work by looking at the recent water chemistry from several WRS and creating a thermodynamic model in PHREEQC to assess whether the chemistry of the WRS was stabilising or might continue to increase.

After this initial analysis, possible correlations between the available data (physical properties of the WRS, time, age, and seepage quality) were considered to assess if there was a possible relationship and equations that could substitute the original value (for sulphate) used in the site-wide water model.

Available Data

In October 2018, Babbage carried out a site visit to familiarise itself with the location of the WRS and general geography, hydrology and layout of the Site.

OGNZL provided Babbage surface and groundwater chemistry data from locations in and around the Site. OGNZL also provided Babbage two sets of contour surveys covering the Site, one before mining

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(base contours) and one from a recent survey in 2018. Intermediary contours were provided for the Coronation WRS that were collected on an approximately three-monthly basis between January 2015 and March 2019. In summary, the data used for this assessment were:

- Site contours, base and recent (from OGNZL)
- Water chemistry from samples of surface water and groundwater taken at different locations around the Site since 1998 (from OGNZL)
- Aerial photography (from Google and LINZ)
- Rivers and road data (from LINZ)

There were no data available on the age of the WRS or intermediary contours (to assess increase in areas and depths over time), except for Coronation WRS.

Waste Rock Stack Seepage Quality

There were eight WRS for which seepage data were available, either directly or as measured in a silt pond downgradient (as was the case for Coronation WRS) or groundwater monitoring results. These WRS are listed below with the associated monitoring site in parenthesis:

- Coronation North (Maori Hen Gully Seepage)
- Coronation (Coronation Silt Pond)
- Frasers East (Frasers East WRS Seepage)
- Frasers West (Murphy's Creek Silt Pond, FDB06 and FDB08 groundwater)
- North Gully East (North Gully Seep East)
- North Gully West (North Gully Seep West)
- Golden Bar (Clydesdale WRS Seepage and Silt Pond)
- Deepdell North (Deepdell North Silt Pond)

The concentrations of sulphate and other analytes for Frasers East WRS were much higher than any other WRS data. OGNZL mentioned that it is likely that water from the tailings dam is percolating to the sampling location where samples for Frasers East WRS are taken. Therefore, the data for Frasers East WRS was not considered in this analysis.

The concentrations of calcium, magnesium and sulphate in the seepage from the WRS are summarised in Figure 1 along with pH. Sulphate is the principal element of concern, and calcium and magnesium are the principal controls on sulphate in groundwater. The results show the pH of WRS seepage is relatively stable (pH 6-8) over time and between WRS. In contrast, the concentrations of calcium, magnesium and sulphate are highest in the seepage from North Gully East and lowest in the seepage from Coronation North. Concentrations of all three parameters have, in general, increased over time in all five WRS.

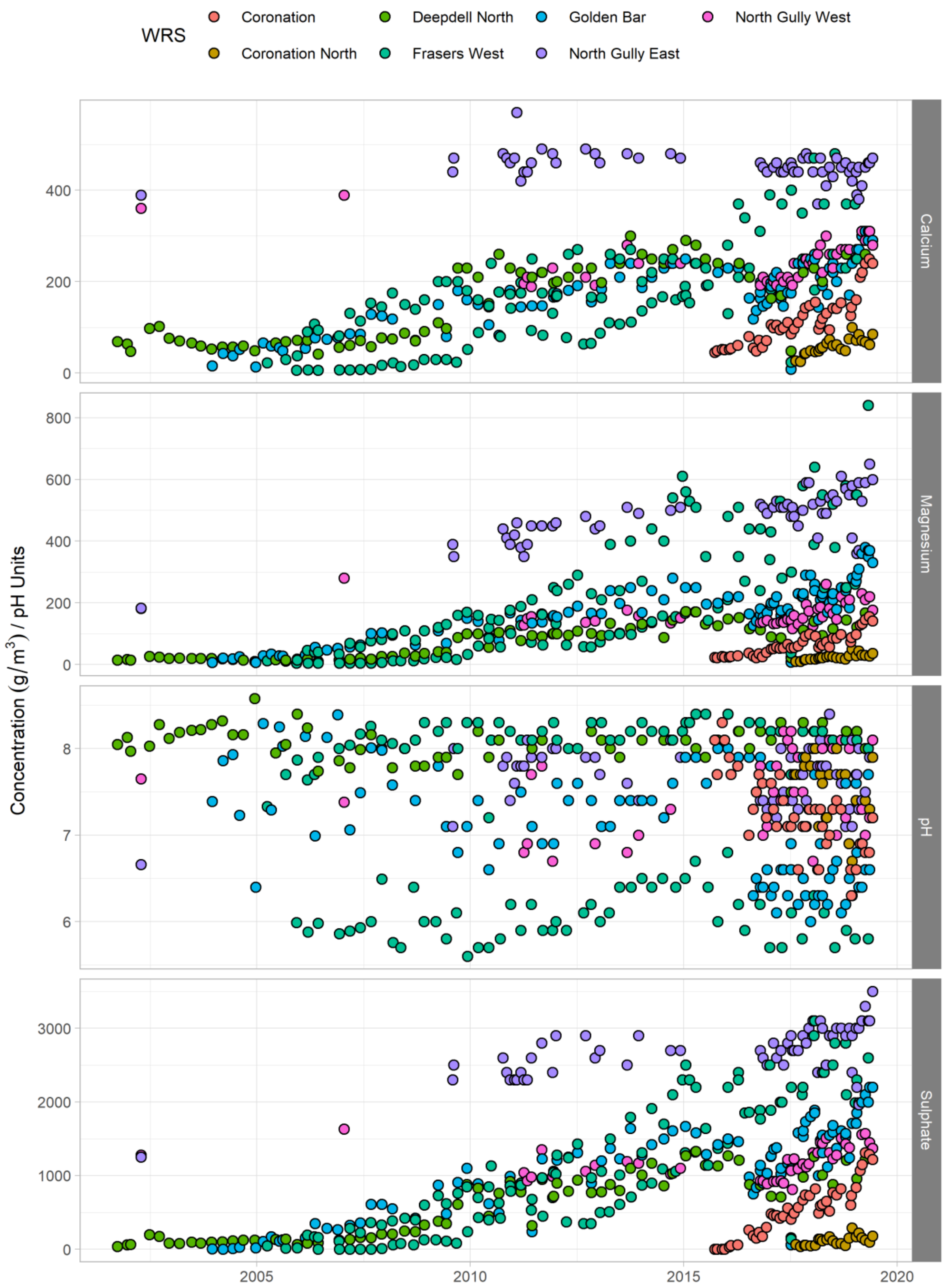


Figure 1. Waste rock stack seepage quality over time.

Thermodynamic Modelling

To assess whether WRS chemistry was stabilising, or might continue to increase, thermodynamical models for the North Gully East, Frasers East and Coronation WRS were developed in PHREEQCi, a geochemical modelling package. The results of modelling indicate the system is approximately at equilibrium for calcium-sulphate assemblages (e.g., calcite) but undersaturated with respect to epsomite, a magnesium-sulphate mineral. These results indicate that if there is epsomite in the WRS, then, especially for actively growing stacks, there is the potential for sulphate concentrations to continue to increase over time.

These results are broadly consistent with the WRS seepage quality data. As shown in Figure 2a, except for Frasers West, there is a linear correlation between calcium and magnesium at lower concentrations, but at high concentrations there is proportionately more magnesium than calcium in the solutions. In addition, as shown on Figure 2b, there is a correlation between magnesium and sulphate, especially at elevated magnesium concentrations (i.e., where calcium is less of an influence).

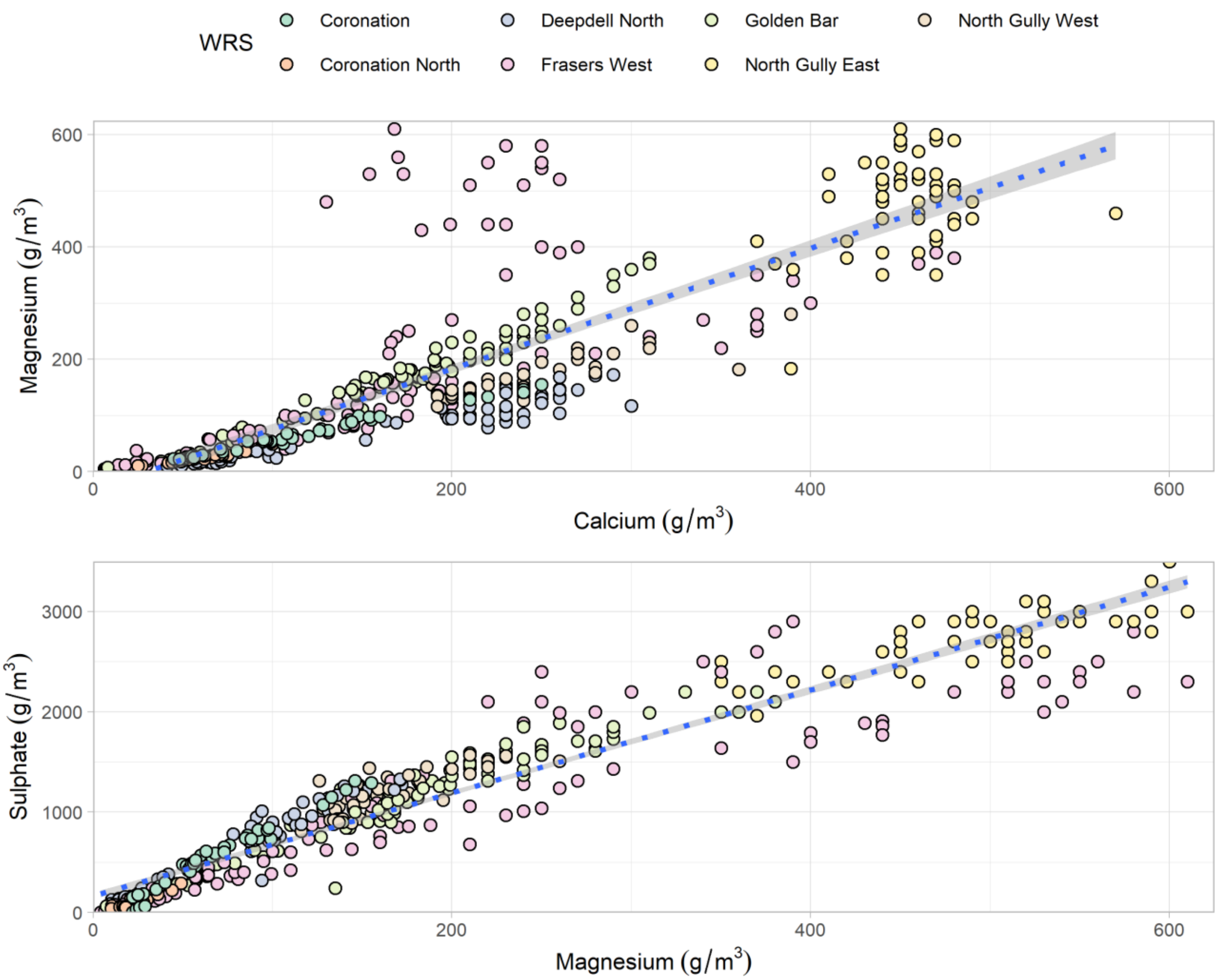


Figure 2. Correlation between a) magnesium and calcium WRS seepage concentrations (upper) and sulfate and magnesium WRS seepage concentrations (lower).

Waste Rock Stacks Areas and Volumes

A geographical information system was created with data provided by OGNZL (surface and groundwater monitoring locations and land contours) and publicly available aerial photography and river centrelines.

The contours were used to create two sets of digital elevation models (DEM), one using contours from before mining (base DEM) and one with contours from surveys done in 2018 (recent DEM). A raster analysis was done to identify elevation differences between the recent and base DEM. Areas where elevation had decreased indicated pits, while areas where elevation had increased indicated WRS.

Each WRS was delineated based on contour changes, topography files provided by OGNZL, aerial photos, and notes from the site visit. The volume, area and depth of each WRS (used in this assessment) were calculated using the data provided in a GIS environment. The location and average depth of each WRS are shown on Figure 3.

As more data was available for the Coronation WRS, including seasonal topography surveys, the changes of depth over time were calculated using each of the historical topography datasets.

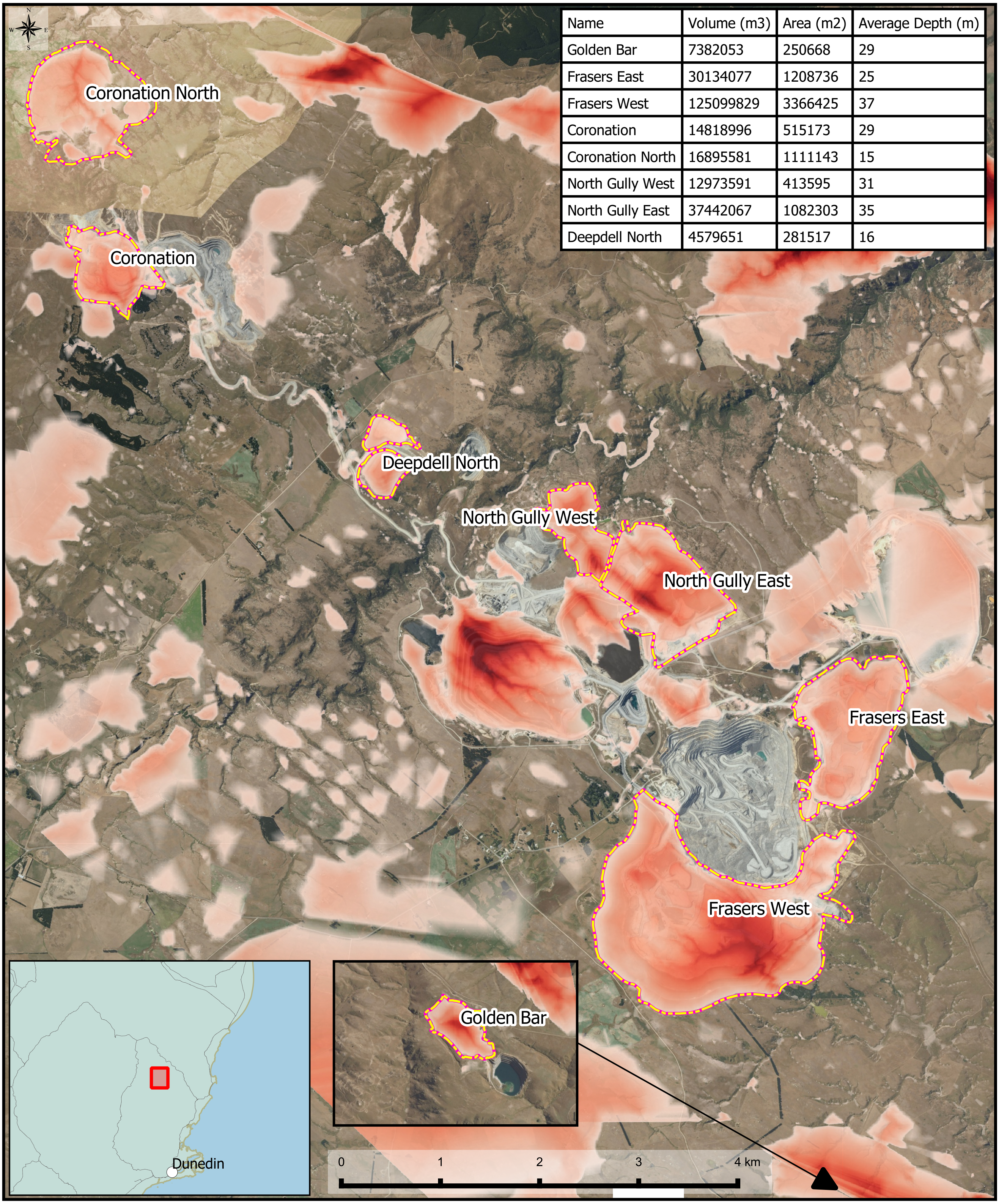
Correlations

Seepage (or silt pond) concentrations of sulphate were initially plotted against the age (in years) of the WRS. The results, in Figure 4, show that the increase in concentrations over time is not consistent between each WRS, and therefore further variables are needed for a good relationship.

It is evident from the plot (Figure 4) that sulphate concentrations in seepage from some WRS stop increasing when the WRS is capped (e.g., Deepdell North WRS) while others present a high degree of variation (e.g., Golden Bar WRS) or a slower rate of increase (e.g., North Gully East WRS). This seems to relate to whether the WRS is partially capped or fully capped. In any case, to establish a relationship between the age of a WRS and the seepage sulphate concentration, it is important to only consider the time during which the WRS was operational (i.e., age to partial capping, if relevant ,and age to full cap), otherwise the relationship will forecast ever-increasing concentrations.

The sulphate concentration was plotted against the results of the GIS analysis (i.e., area and volume), and the results and show that, individually, area(Figure 5) and volume (Figure 6) do not exhibit a good relationship with the resulting sulphate concentrations in the WRS seepage. However, when seepage concentrations are plotted against the average depth (volume/area) a strong relationship is observed (Figure 7). This is consistent with the idea that deeper stacks will increase the retention time of seepage water (as it takes longer to percolate through the WRS, staying longer in contact with the waste rock) and therefore increase the concentrations of the seepage.

The two correlations (age and average depth) were subsequently combined into one single correlation and different weight values were applied to each attribute to establish a linear relationship. The results are shown in Figure 8.



Name	Volume (m3)	Area (m2)	Average Depth (m)
Golden Bar	7382053	250668	29
Frasers East	30134077	1208736	25
Frasers West	125099829	3366425	37
Coronation	14818996	515173	29
Coronation North	16895581	1111143	15
North Gully West	12973591	413595	31
North Gully East	37442067	1082303	35
Deepdell North	4579651	281517	16

61130 Figure 3 - Oceana Gold

WRS and Positive DEM Changes

23/08/2019 by L.C.

SCALE **@ A4 1:50000**

Macraes WRS

NOTES
DEM calculated based on contour layers provided by the client.
WRS delimitation based on site visit and contours.

SOURCES
Aerial Photography: LINZ MapServices
Roads: LINZ MapServices
Topography: Client Provided

Legend
Waste Rock Stacks (WRS)
Otago Watercourses

DEM Changes (m)

0	55
5	70
20	80
40	95
	>110

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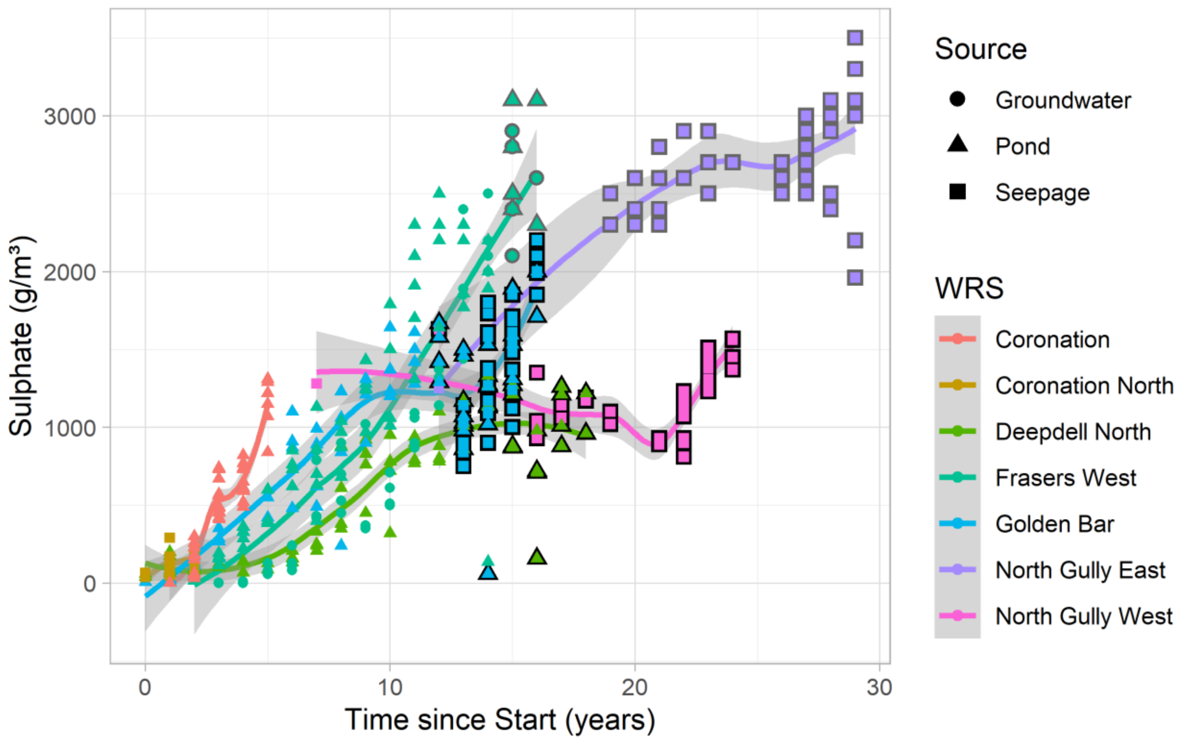

Figure 4. Sulphate concentrations in waste rock stack seepage over WRS age (in years). [1]

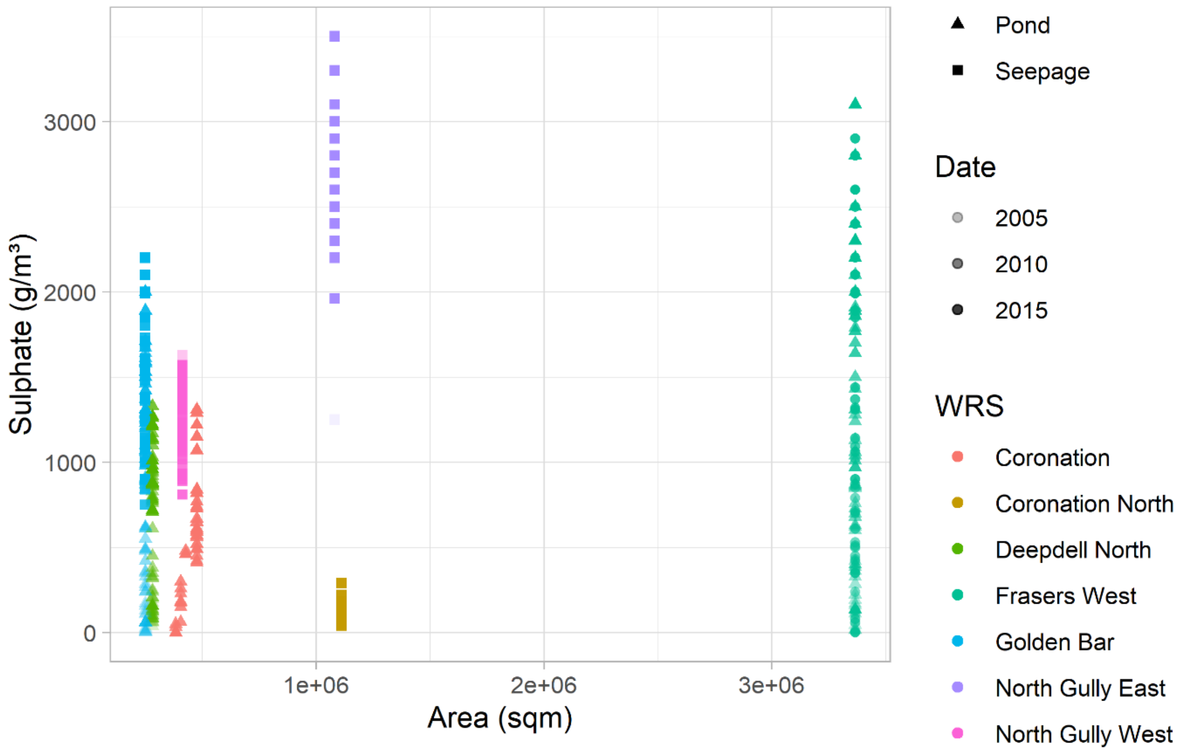

Figure 5. Sulphate concentrations in waste rock stack seepage over WRS area.

[1] In Figure 4, grey delineated data points are samples collected after partial capping, while the black delineated data points are samples collected after the WRS is fully capped.

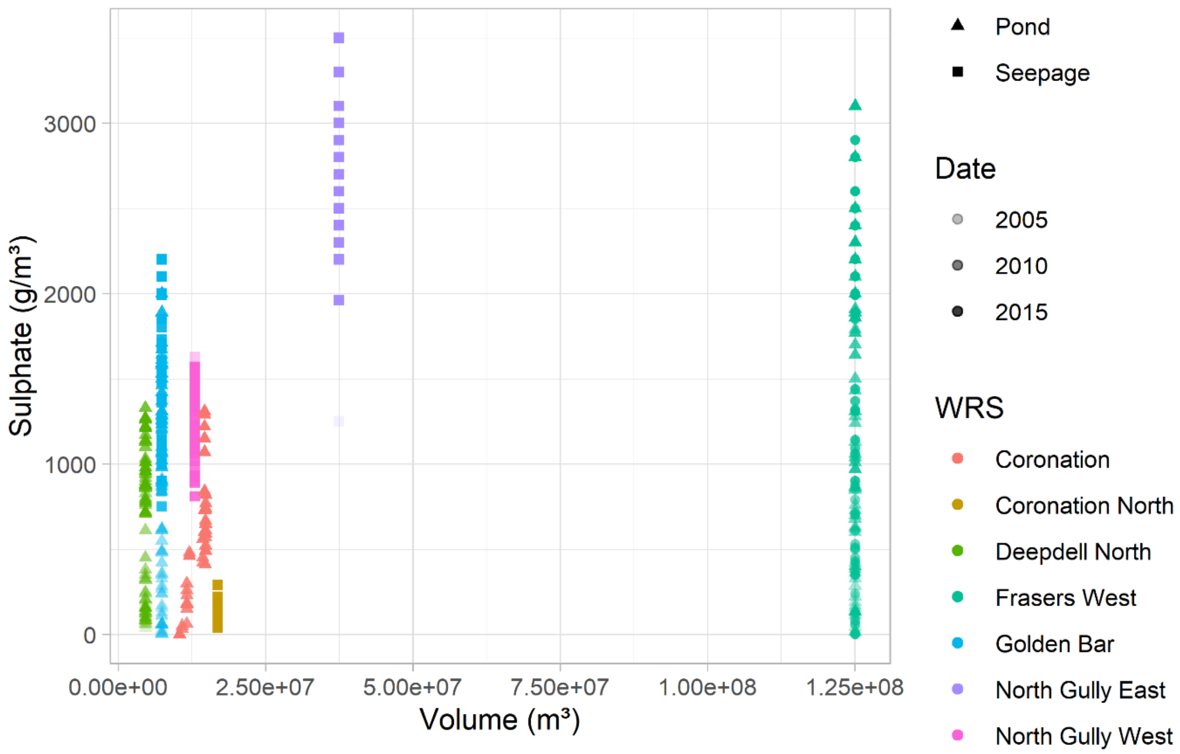

Figure 6. Sulphate concentrations in waste rock stack seepage over WRS volume.

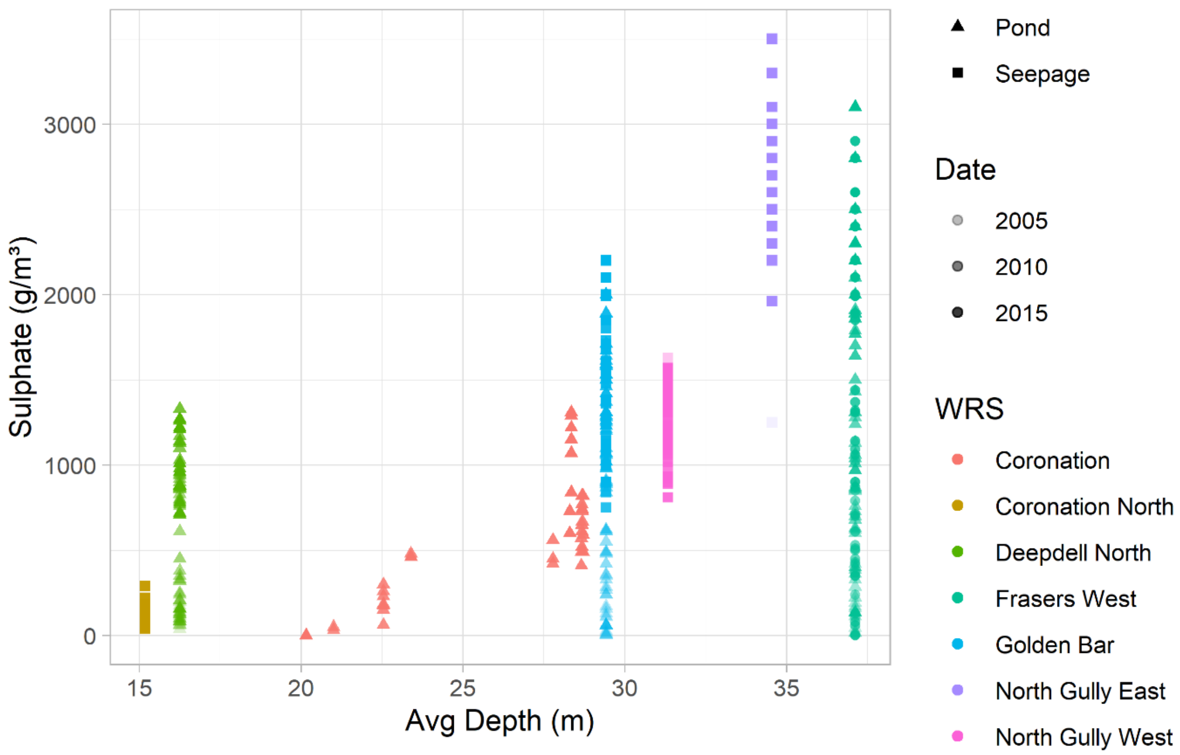

Figure 7. Sulphate concentrations in WRS seepage over WRS average depth (volume/area).

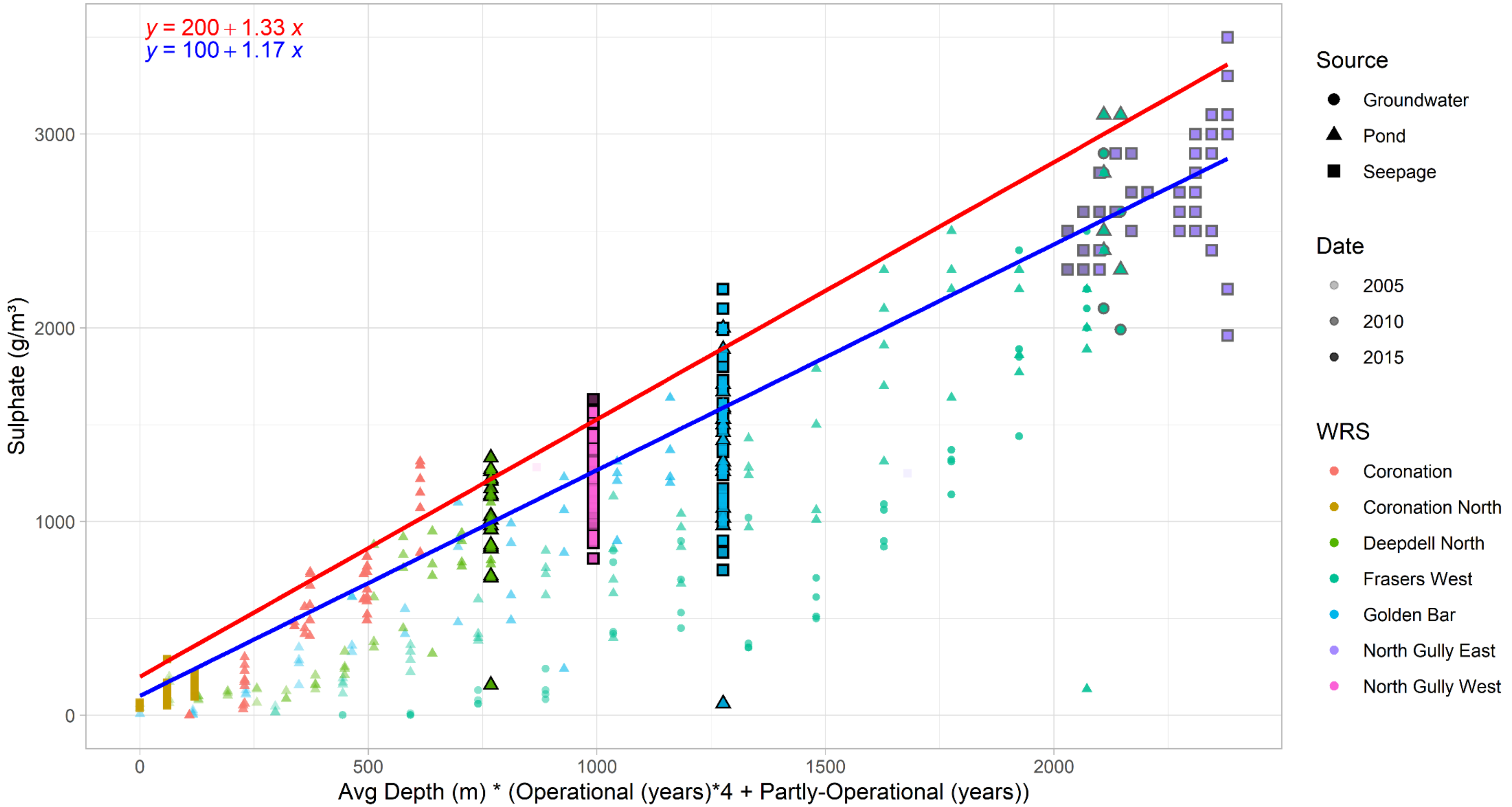

*Figure 8. Sulphate concentrations in waste rock stack seepage over (average depth) * [(full operation time * 4)+ partial operation time].[1]*

With the combined parameters (volume, area and age) and the adopted weights showing a linear relationship with the sulphate concentrations, we can establish a set of equations for the median and 95%ile values based on the data. The equations and linear relationship are shown in Figure 8, and can be written as:

$$95\%ile\ Sulphate = 200 + 1.33 * \frac{Volume}{Area} * [4 * Age1 + Age2]$$

$$Median\ Sulphate\ = 100 + 1.17 * \frac{Volume}{Area} * [4 * Age1 + Age2]$$

where:

- sulphate concentrations are in g/m^3
- Volume is the volume of the WRS, in m^3
- Area is the land footprint (not surface area) of the WRS, in m^2
- Age1 is the time the WRS was in full operation (i.e., not capped), in years
- Age2 is the time the WRS was in partial operation (i.e., partially capped), in years

Based on these data and the established relationship, the deeper and older (i.e., longer operating) WRS generally have higher concentrations of sulphate and a higher variation (as represented by the different coefficients for the median and 95%ile lines).

Observations

The plot in Figure 8 uses average depths as measured in 2018 by the GIS analysis. The exception for this is Coronation WRS, for which intermediary topography surveys were available, and therefore we can better see the evolution of the correlation.

Although North Gully East WRS has been capped (according to OGNZL) we considered it as partially capped, as the concentrations of sulphate in the seepage have been increasing (likely) due to the use of the WRS area for stockpiling low grade ore.

It is evident from the plot (Figure 8) that seepage quality from Coronation North WRS is below the median. This shows that the different methodology used in the construction of Coronation North (Mossman, pers. comm.) is working to reduce the concentration of minerals in the seepage.

In contrast, sulphate concentrations in Coronation silt pond (which was used as a proxy for Coronation WRS seepage) have recently (2019) increased above the median and 95%ile. This could be due to differences in operation or because of an increase in the average depth of the WRS subsequent to the latest available survey (March 2019).

Summary

Depending on the mineralogy of the WRS, the sulphate concentrations recently measured in the seepage from Northern Gully East may have reached a maximum. However, there is a risk sulfate concentrations will continue to increase. Accordingly, seepage from the North Gully East WRS (as measured at North Gully Seep East) is not considered a suitable proxy for WRS seepage across the Site.

Analysis of the available data shows that it is possible to establish a correlation between the age and size of the WRS and the sulphate concentration in the seepage (or silt pond when used as a proxy). The assessment resulted in two equations for expected median and 95%ile concentrations of sulphate in WRS seepage.

Recommendation

We recommend determining whether epsomite is present in the WRS to establish whether the sulphate concentrations in seepage are likely to stabilise or continue to increase. In either case, we recommend investigating sulphate remediation options and different ways to build the WRS (such as the one used in Coronation North WRS).

Closure

Thank you for providing Babbage with the opportunity to undertake this assessment. If you have any questions in relation to the contents of this letter, please contact the undersigned.

Yours sincerely

Lobo Coutinho
Environmental Engineer and Hydrogeologist

Dr Grant Allen
Senior Environmental Scientist

Babbage Consultants Ltd

Attachments: Applicability and limitations

APPLICABILITY AND LIMITATIONS

Restrictions of Intended Purpose

This report has been prepared solely for the benefit of OceanaGold (New Zealand) Limited as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such party's sole risk.

Legal Interpretation

Opinions and judgements expressed herein are based on our understanding and interpretation of current regulatory standards, and should not be construed as legal opinions. Where opinions or judgements are to be relied on they should be independently verified with appropriate legal advice.

Maps and Images

All maps, plans, and figures included in this report are indicative only and are not to be used or interpreted as engineering drafts. Do not scale any of the maps, plans or figures in this report. Any information shown here on maps, plans and figures should be independently verified on site before taking any action. Sources for map and plan compositions include LINZ Data and Map Services and local council GIS services. For further details regarding any maps, plans or figures in this report, please contact Babbage Consultants Limited.

30 June 2022

Job No: 61130

eTrack No: 200042622

Duncan Ross
OceanaGold (New Zealand) Limited
RD3
Macraes Flat 9483

WASTE ROCK STACK SEEPAGE CORRELATION ASSESSMENT – JUNE 2022

Dear Duncan

OceanaGold (New Zealand) Limited (OGNZL) engaged Babbage Consultants Limited (Babbage) to update the waste rock stack (WRS) seepage assessment Babbage prepared in 2019[1]. This previous assessment established a correlation between the age and size of the WRS and the concentration of sulphate in the WRS seepage (or silt pond or well when used as a proxy) that could be used in the site wide water model. OGNZL has requested the assessment is updated with the inclusion of data obtained between June 2019 and March 2022. The results of our updated assessment are provided below.

Available Data

The datasets employed in the earlier assessment were updated with the following data:

- Sulphate concentrations measured between June 2019 and March 2022 in seepage (or the applicable downgradient silt pond or groundwater well) from each of the following WRS:
  - Coronation North (Maori Hen Gully Seepage)
  - Coronation (Coronation Silt Pond)
  - Frasers West (Murphy's Creek Silt Pond, FDB06 and FDB08 groundwater)
  - North Gully East (North Gully Seep East)
  - North Gully West (North Gully Seep West)
  - Golden Bar (Clydesdale WRS Seepage and Silt Pond)
  - Deepdell North (Deepdell North Silt Pond)
- Contours for each of the WRS identified above that were obtained in December 2019, December 2020, and December 2021.

[1] Babbage 2021. Waste Rock Stack Assessment. A letter to OceanaGold (New Zealand) Limited (Gavin Lee) from Babbage Consultants Limited (Lobo Coutinho and Dr Grant Allen) dated 23 August 2019. eTrack: 200028882

Babbage Consultants Limited
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Draft

Waste Rock Stack Seepage Quality

The historical concentrations of calcium, magnesium and sulphate in the seepage from the assessed WRS are summarised in Figure 1 (attached) along with pH. Sulphate is the principal element of concern, and calcium and magnesium are the principal controls on sulphate in groundwater. The results show:

- The pH of WRS seepage remains relatively stable (pH 6-8) over time and between WRS with no significant change post 2020.
- Concentrations of calcium, magnesium and sulphate remain highest in the seepage from North Gully East and lowest in the seepage from Coronation North. The concentrations in the receiving waters downgradient of Frasers West WRS are also significant.
- Seepage concentrations of calcium, magnesium and sulphate have, in general, increased over time

Waste Rock Stacks Areas and Volumes

Following the method employed in the earlier assessment, the available topographical data were used to create five sets of digital elevation models (DEM), one using contours from before mining (base DEM) and four with contours from surveys completed in October 2018 (from Babbage 2019), December 2019, December 2020 and December 2021. The seasonal topography surveys of the Coronation WRS, which were obtained on an approximately three-monthly basis between January 2015 and March 2019 and included in the previous assessment, were retained in the current assessment.

A raster analysis using GIS software (QGIS) was undertaken to identify changes in elevation over time for each WRS (as delineated in the earlier assessment). The results are shown on Figure 2 (attached)[2] and summarised in Table 1 attached and show that the dimensions of most WRS have changed very little[3] between October 2018 and December 2021. The most notable exceptions include:

- A recent decrease in the volume of rock comprising Deepdell North WRS, reflecting the progress of the Deepdell North project which involves reworking this WRS.
- An increase in the volume of rock comprising Coronation North WRS between October 2018 and December 2021.

Updated Correlations

As observed in the previous assessment, there was a strong correlation between the concentrations of sulphate in WRS seepage (or, where applicable, the downgradient silt pond or well) and the weighted age[4] and average depth (volume/area) of the WRS age (Figure 3 attached).

Draft

[2] Figure 2 shows elevations (as recorded in December 2021) above the base DEM and not excavations (i.e., pits)

[3] Minor changes can be ascribed to the uncertainty of the method.

[4] Full operation time * 4 + partial operation time

The equations describing the linear correlations are provided below and remain similar to those reported previously. With the inclusion of the additional data, there has been a slight increase in the gradient for median sulphate concentrations (from 1.17 to 1.22) and some minor changes to the intercepts for both median and 95%ile concentrations (from 100 to 96.1 and from 200 to 189, respectively).

$$95\%ile\ Sulphate = 189 + 1.33 * \frac{Volume}{Area} * [4 * Age1 + Age2]$$

$$Median\ Sulphate\ = 96.1 + 1.22 * \frac{Volume}{Area} * [4 * Age1 + Age2]$$

where:

- Sulphate concentrations are in g/m^3
- Volume is the volume of the WRS, in m^3
- Area is the land footprint (not surface area) of the WRS, in m^2
- Age1 is the time the WRS was in full operation (i.e., not capped), in years
- Age2 is the time the WRS was in partial operation (i.e., partially capped), in years

Conclusion

The updated assessment confirms the correlation between the weighted age and size of the WRS and the sulphate concentration in the seepage (or silt pond when used as a proxy). The assessment resulted in two equations for expected median and 95%ile concentrations of sulphate in WRS seepage that are not dissimilar to the equations reported previously.

Closure

Thank you for providing Babbage with the opportunity to undertake this assessment. If you have any questions in relation to the contents of this letter, please contact the undersigned.

Yours sincerely

Tiago Teixeira
Environmental Engineer

Dr Grant Allen
Environmental Manager

Babbage Consultants Limited

Attachments: Applicability and limitations

Figures 1, 2 and 3 and Table 1

Draft

APPLICABILITY AND LIMITATIONS

Restrictions of Intended Purpose

This report has been prepared solely for the benefit of OceanaGold (New Zealand) Limited as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such party's sole risk.

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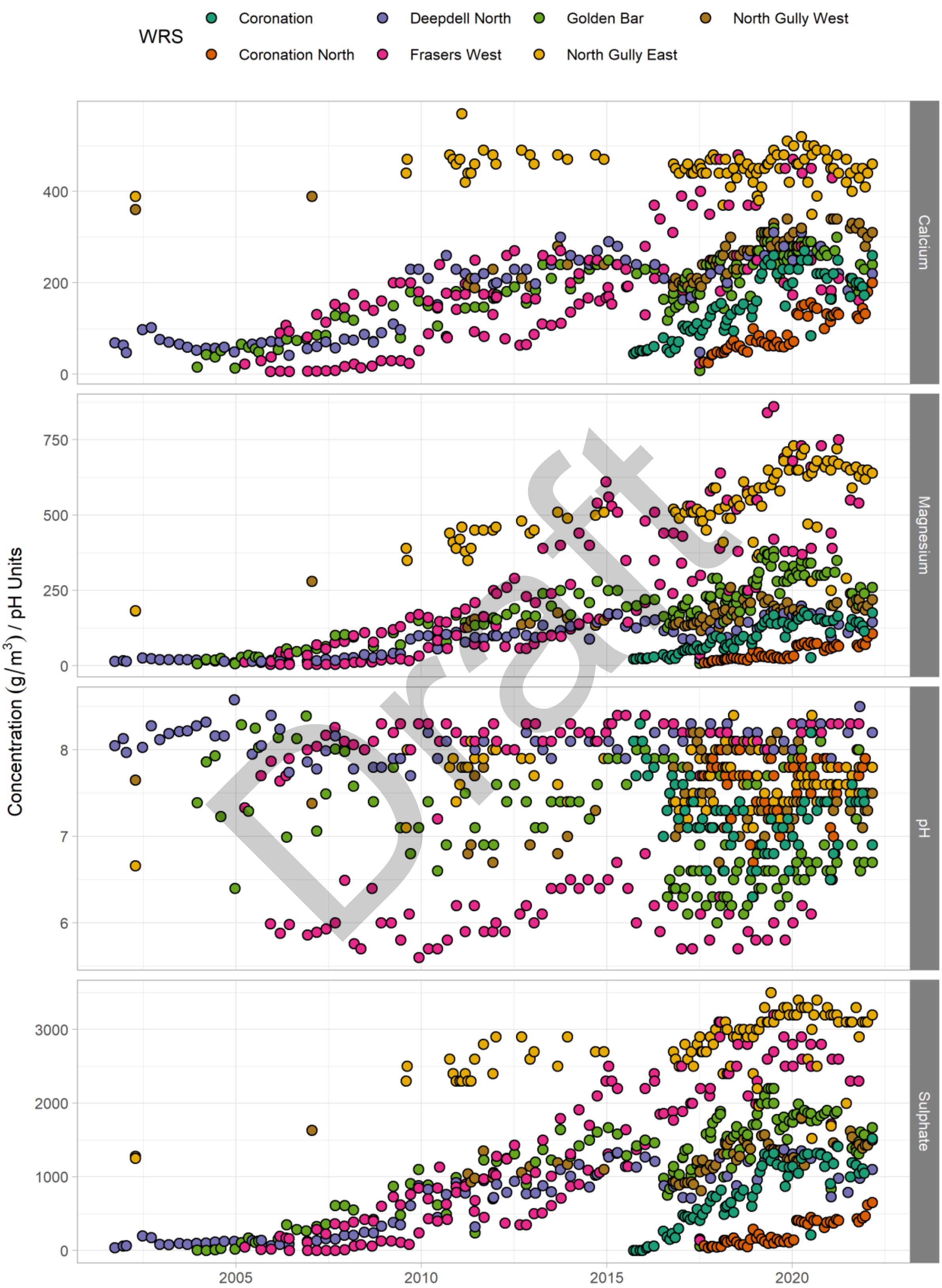
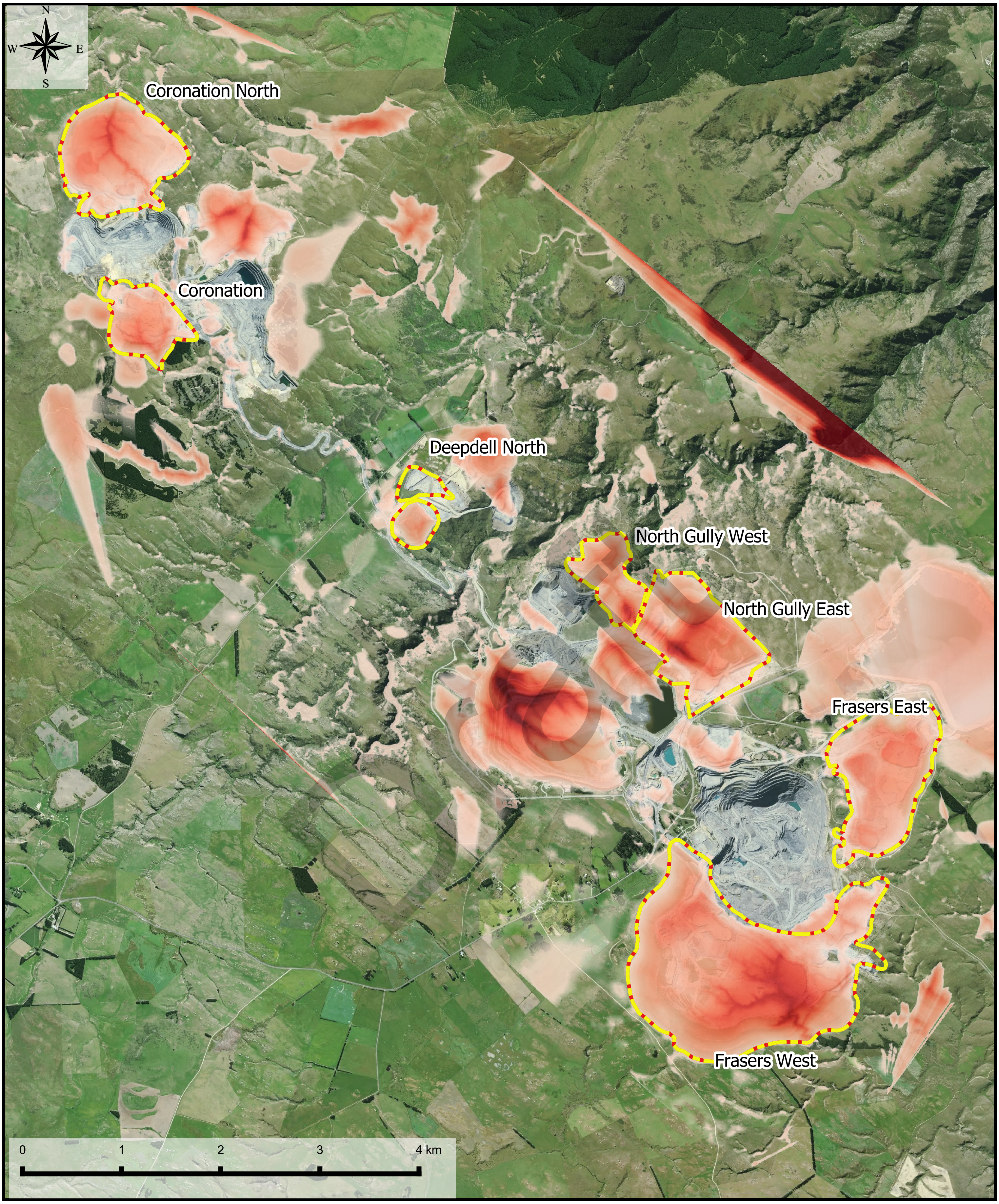


Figure 1. Waste rock stack seepage quality over time (up to March 2022).



61130 Figure 2 - Oceana Gold
WRS and Positive DEM Changes (2021/12 - Before Mining)
23/06/2022 by T.T.
SCALE @ A4 **1:50,000**
Macraes WRS

NOTES
DEM calculated based on countour layers provided by the cllient.
WRS delimitation based on site visit and contours - 03/2019

SOURCES
Road and Legal data: QuickMap v7.5.185
Aerial Photography: LINZ Online Database

Legend
Waste Rock Stacks (WRS)
DEM20211231-BaseDEM (m)
0
5
20
40
55
70
80
95
110

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Table 1. Estimated waste rock stack dimensions between October 2018 and December 2021

Waste rock stack	Date	Area (m^2)	Volume (m^3)	Average depth (m)
Frasers West	December 2021	3,260,854	125,019,422	37.0
	December 2020	3,271,108	124,823,637	37.0
	December 2019	3,272,830	124,682,535	37.0
	October 2018	3,366,425	125,687,081	37.3
Coronation	December 2021	502,690	13,728,966	26.6
	December 2020	510,425	14,422,671	28.0
	December 2019	512,379	14,730,109	28.6
	October 2018	515,173	14,827,870	28.8
Coronation North	December 2021	1,100,592	32,134,853	28.9
	December 2020	1,101,299	30,784,877	27.7
	December 2019	1,104,558	27,778,298	25.0
	October 2018	1,111,143	17,458,380	15.7
North Gully West	December 2021	409,477	12,884,558	31.1
	December 2020	409,332	12,748,276	30.8
	December 2019	409,504	12,949,925	31.3
	October 2018	413,595	12,886,436	31.1
North Gully East	December 2021	1,077,158	38,275,264	35.3
	December 2020	1,078,880	37,672,491	34.8
	December 2019	1,079,357	38,149,593	35.1
	October 2018	1,082,303	37,848,334	34.8
Deepdell North	December 2021	153,673	2,894,344	14.9
	December 2020	274,729	4,787,877	16.6
	December 2019	270,345	4,606,932	15.7
	October 2018	281,517	4,640,480	15.8
Golden Bar	October 2018	250,668	7,382,053	29.0

Draft

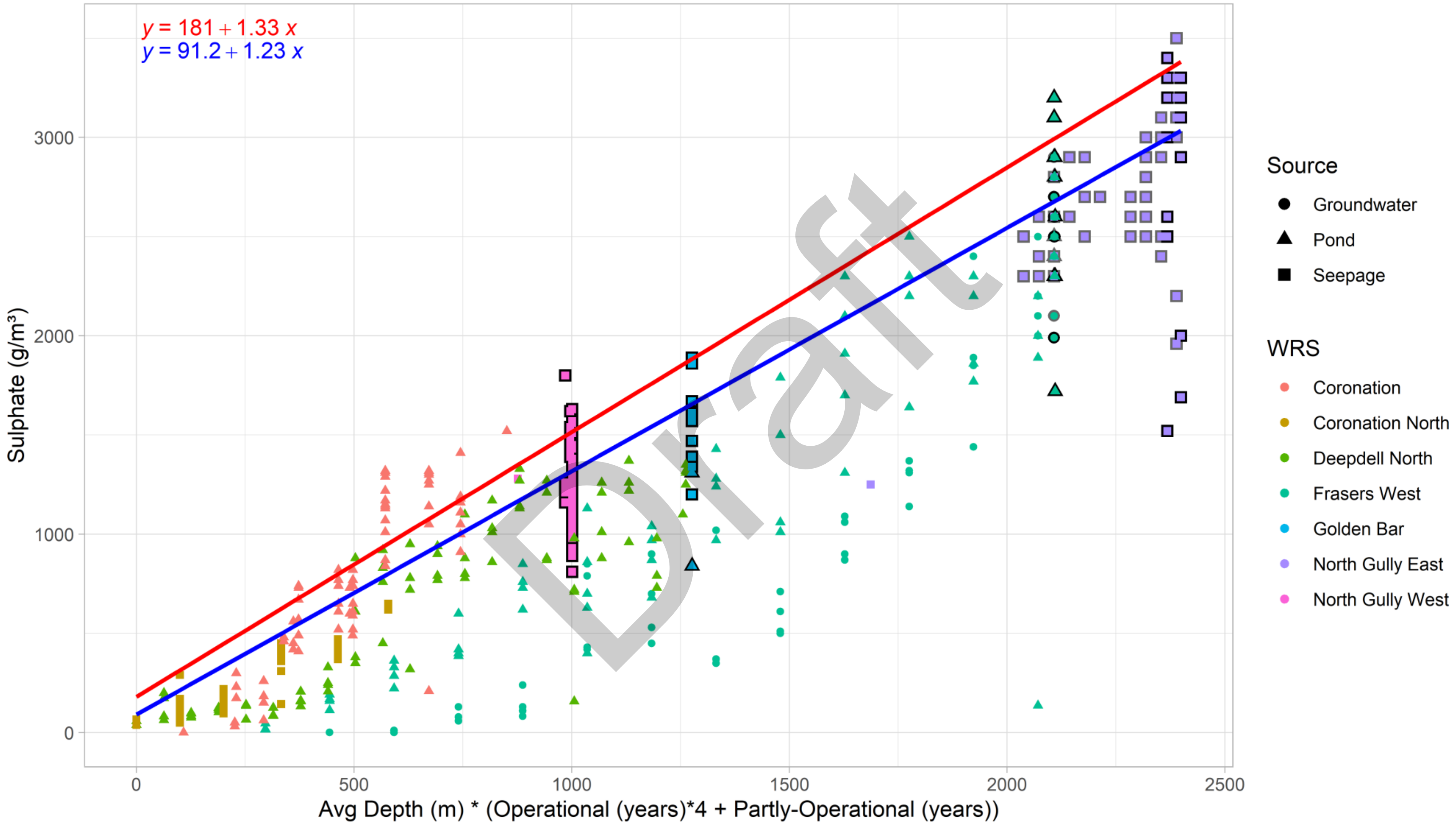

Figure 3. Sulphate concentrations in waste rock stack seepage over (average depth) * [(full operation time * 4)+ partial operation time].

APPENDIX I MWM WRS SEEPAGE MEMO

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Christchurch 8041, New Zealand

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MEMORANDUM

Recipient:	Duncan Ross - OceanaGold
From:	Paul Weber - MWM
Date:	23 February 2023
Cc:	Leonardo Navarro – MWM; Jeff Tuck – GHD; Dean Fergusson RARL; Gavin Lee (OceanaGold); Grant Allen (Babbage)
Document Number:	J-NZ0205-003-M-Rev1
Document Title:	Waste Rock Stack Seepage Water Quality

Mine Waste Management Limited (MWM) has been engaged by OceanaGold Limited (OceanaGold) to undertake geochemical characterisation of tailings and waste rock at the Macraes Gold Mine (Macraes) to understand the potential environmental geochemistry effects of co-disposal of these materials within the Frasers Opencast Pit (Frasers Pit) and subsequent water quality of the Fraser Pit Lake (and subsequent pit water interactions between Frasers Pit and Innes Mills Pit).

One of the tasks associated with this project was to determine the long term seepage water quality that could be generated by waste rock within a Waste Rock Stack (WRS). This memorandum explains the approach undertaken to estimate the water quality, which was determined to be a function of the average height of the WRS (e.g., Babbage, 2019; 2022).

SUPPLIED DOCUMENTS AND DATA

The documents supplied that were used to develop this memorandum included:

- Waste Rock Stack Seepage Assessment (Babbage; 2019, 2022); and
- OceanaGold water quality dataset (up to March 2022; being the same dataset that was used in Babbage (2022) for:
    - Coronation North (Maori Hen Gully Seepage);
    - Coronation (Coronation Silt Pond);
    - Frasers West (Murphy's Creek Silt Pond, FDB06 and FDB08 groundwater);
    - North Gully East (North Gully Seep East);
    - North Gully West (North Gully Seep West);
    - Golden Bar (Clydesdale WRS Seepage and Silt Pond); and
    - Deepdell North (Deepdell North Silt Pond).

METHODOLOGY

The following approach was undertaken to determine the long term WRS seepage water quality

WRS Sulfate Concentration - Seepage

Sulfate concentrations in WRS seepage were analysed and correlated with the age and average height of the WRS (Babbage, 2019; 2022). It was observed that the greater the average height of a WRS, the higher the measured sulfate concentration in toe seepage. Babbage (2019, 2022) developed a relationship to forecast sulfate concentrations that considered age and average height (volume / area). However, there was no limit to the maximum sulfate concentration and sulfate concentrations would continue to rise as a function of WRS age (e.g., Equation 1 and Equation 2; Babbage, 2022). This would create very high concentrations in any predictive models over the longer term (e.g., 100 years), which is not supported by the data provided; is unrealistic given the observed sulfate concentrations; and is not validated based on the current dataset and industry standard geochemical principles where concentration is a function of the amount of rock that percolating water interacts with.

$$(Eqn. 1): 95\%\ Sulfate = 189 + 1.33 \times \frac{Volume}{Area} \times [4 \times Age1 + Age2]$$

$$(Eqn. 2): Median\ Sulfate = 96.1 + 1.22 \times \frac{Volume}{Area} \times [4 \times Age1 + Age2]$$

Where:

- Sulfate concentrations are in g/m^3;
- Volume is the volume of the WRS in m^3;
- Area is the footprint (not surface area) of the WRS in m^2;
- Age1 is the time (in years) that the WRS was in full operation (i.e., not capped); and
- Age2 is the time (in years) that the WRS was in partial operation (i.e., partially capped).

From the water quality dataset (provided by OceanaGold) it was determined that the sulfate in seepage from some WRSs can reach a maximum concentration and then enter a period of quasi-stable but oscillating concentrations. This is likely due to the WRS reaching a state of geochemical maturity where the hydraulic properties of the material, rainfall infiltration, oxygen flux, and geochemical reactions have reached a ‘quasi-stable’ balance with oscillations in sulfate concentrations, but a distinctive maximum 'sulfate ceiling limit’. The number of years for the WRS to achieve this quasi-stable nature is variable, ranging from ~3.5 years (Coronation) to ~15 years (North Gully West).

The ‘sulfate ceiling limit’ for toe seepage from the Deepdell North WRS is shown in (Figure 1) from ~July 2013 onwards where sulfate concentrations oscillate in the range of ~600 to ~ 1,400 mg/L, but no more than ~1,400 mg/L.

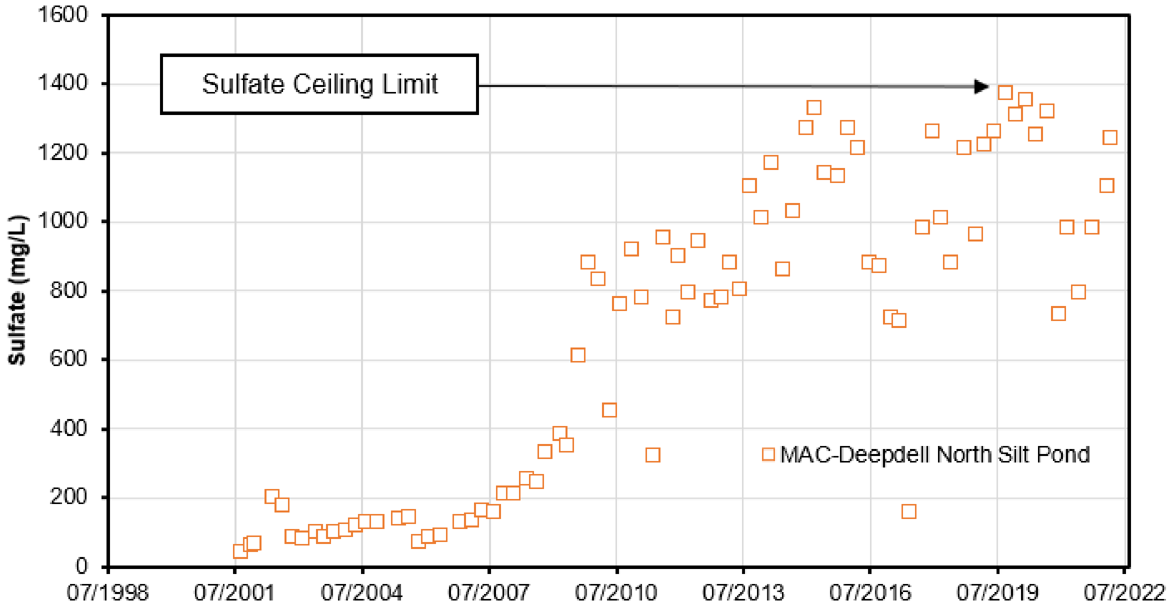

Figure 1: Sulfate concentrations: Deepdell North Silt Pond.

Other datasets were also available with similar trends being observed (see Attachment 1) and are presented below in Figure 2. Sulfate ceiling limits can also be determined for North Gully East (~3,500 mg/L), North Gully West (~3,200 mg/L), Frasers West (~4,900 mg/L), Coronation (~1,520 mg/L), and Golden Bar (~2,200 mg/L) where maximum concentration limits are observed together with a period of quasi-stable sulfate concentrations.

These sulfate ceiling limits are used to derive maximum sulfate concentrations for current and future WRSs at Macraes based on average WRS height. Maximum concentrations are used in predictive models as a conservative approach for WRS of different height.

Figure 2: WRS seepage sulfate concentrations in mg/L.

Image Source: Babbage (2022)

WRS Water Quality - Seepage

Sulfate, which is a key indicator of geochemical reactions (e.g., pyrite oxidation), was used to estimate the long term water quality of other parameters based on empirical water quality datasets. The following approach was undertaken:

- Sulfate and other parameters were analysed to determine if a relationship existed. If the correlation was reasonable (R^2 value ≥0.5) then the concentration of the parameter was based on sulfate concentration through linear regression finding the slope and the intercept.
- If the correlation between a parameter and sulfate was not reasonable (R^2 value < 0.5), then the median value was used instead (slope = 0 and intercept = median concentration) for the selected time period (i.e., where values for sulfate are no longer increasing, and are quasi-stable).

Individual water quality parameters for each WRS have been calculated and are included in Attachment B, for site-specific estimations.

SULFATE AND AVERAGE HEIGHT OF WRS CORRELATION

A relation between the maximum sulfate concentration and the average height of the WRS is shown in Figure 3. Average WRS height data was provided by Babbage (2022). Median (50th), 90th, and 10th percentile sulfate data are also shown. Results demonstrate there is a trend of increasing sulfate concentrations with increasing WRS height.

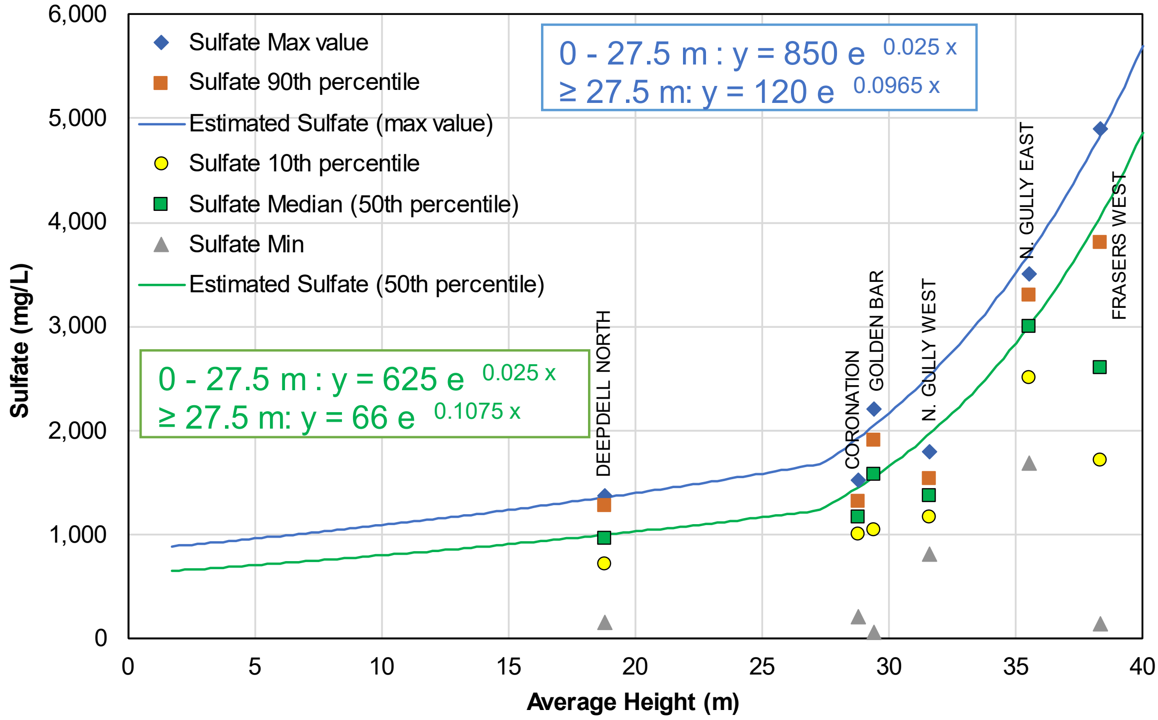

Figure 3: WRS average height versus sulfate concentrations.

Analysis indicated the relationship between sulfate and WRS height was more fairly represented by two equations when the WRS height was ≥27.5 m. Exponential equations are used to estimate the maximum and median sulfate concentrations as a function of the average WRS height:

$$(Eqn. 3): Average\ Height < 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 850\ \exp\big(0.025\ \times\ Average\ Height\ (m)\big)$$

$$(Eqn. 4): Average\ Height \geq 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 120\ \exp\ (0.0965\ \times\ Average\ Height\ (m))$$

$$(Eqn. 5): Average\ Height < 27.5\ m: Median\ Sulfate\ \left(\frac{mg}{L}\right) = 625\ \exp\ (0.025\ \times\ Average\ Height\ (m))$$

$$(Eqn. 6): Average\ Height \geq 27.5\ m: Median\ Sulfate\ \left(\frac{mg}{L}\right) = 66\ \exp\ (0.1075\ \times\ Average\ Height\ (m))$$

Based on the data presented in Figure 3, the Root Mean Square Error (RMSE) is 356 mg/L for maximum sulfate data, and the RMSE is 660 mg/L for the median sulfate data. This is an indication of how different the data are compared to trend lines presented in Figure 3 and Equations 3 – 6.

Data used to derive the relationship shown in Figure 3 are provided in Table 1 where the time interval selected represented the period where maximum quasi-stable sulfate concentrations are occurring.

Table 1: Sulfate Concentration Data#.

PARAMETER	DEEPDELL NORTH	FRASERS WEST	GOLDEN BAR	NORTH GULLY EAST	NORTH GULLY WEST	CORONATION
Selected start date	3/12/2009	14/07/2014	11/04/2013	18/10/2016	8/06/2017	18/02/2019
Selected final date	1/04/2022	1/04/2022	1/04/2022	1/04/2022	1/04/2022	1/03/2022
N of samples in time interval	50	179	94	70	47	30
Sulfate max value (mg/L)	1,370	4,900	2,200	3,500	1,800	1,520
Sulfate 90th percentile (mg/L)	1,270	3,800	1,900	3,300	1,530	1,320
Sulfate median (50th percentile) (mg/L)	960	2,600	1,580	3,000	1,370	1,160
Sulfate 10th percentile (mg/L)	720	1,710	1,046	2,500	1,160	1,000
Sulfate min value (mg/L)	157	136	60	1,690	810	210
Average height (m)	18.8	38.3	29.4	35.5	31.6	28.8

 # - for WRS that have achieved a quasi-stable sulfate concentration.

DERIVATION OF OTHER WATER QUALITY PARAMETERS

Water quality parameters for WRS seepage are derived from sulfate concentrations using the total water quality dataset for Deepdell North, North Gully East, North Gully West, Frasers West, Coronation, Coronation North, and Golden Bar.

Where there was a linear correlation (Figure 4) and $R^2 \geq 0.5$, the water quality parameter was determined from the equation "y = ax + b" where "a" is the slope and "b" is the intercept value (e.g., calcium, magnesium, and sodium) to estimate the parameter concentration as a function of the sulfate concentration.

For values of $R^2 < 0.5$, a median value of the parameter is used for a selected time period where the concentrations are quasi-stable (Figure 4) (e.g., alkalinity, potassium, nitrate-N, arsenic, iron, copper, and chloride).

Since every WRS has its own physicochemical characteristics such as location, surface area, height, shape, material type, etc, the seepage water quality is likely to be different. Hence, correlations for $R^2 \geq 0.5$ are more accurate for individual WRS if the individual water quality for that WRS is used (Attachment B). However, to simplify modelling processes (e.g., the Frasers Open Pit Co-Disposal Project), correlations were developed using the dataset for all the WRS to understand longer term WRS seepage water quality across the site.

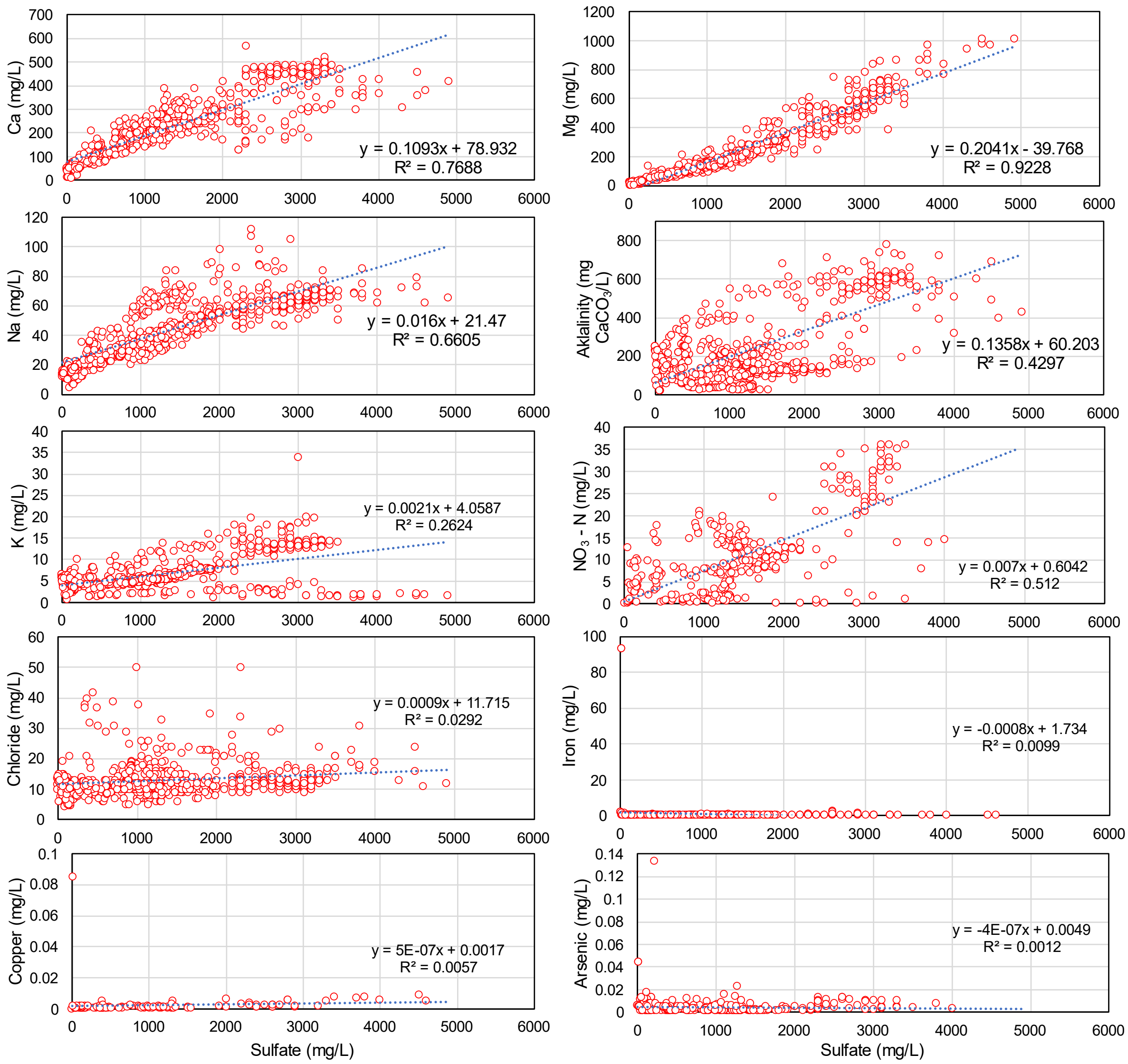

Figure 4. Sulfate versus other water quality parameters (Deepdell North, North Gully East, North Gully West, Frasers West, Coronation, Coronation North, and Golden Bar).

Table 2 summarises the derived water quality data (sulfate versus other water quality parameter) where sufficient data were available. As an example, if the sulfate concentration in WRS seepage was 2,000 mg/L, then:

- the Ca concentration would be 0.1053 x 2,000 + 87.93, which is 298 mg/L of Ca.
- For As, which has an R^2 close to 0, with no correlation with sulfate, it is estimated to be 0.004 mg/L based on median data.

Table 2: Water quality estimates for modelling as a function of sulfate.

PARAMETER#	SELECTED SLOPE (A)	SELECTED INTERCEPT (B)	MEDIAN	R^2
Alkalinity (mg $CaCO_3$/L)	0	193.0	193	0.43
As (mg/L)	0	0.004	0.004	0.01
Ca (mg/L)	0.1053	87.9	240	0.72
Cl (mg/L)	0	12	12	0.01
Cu (mg/L)	0	0.0017	0.0017	0.02
Fe (mg/L)	0	0.04	0.04	0.02
K (mg/L)	0	6.1	6.1	0.20
Mg (mg/L)	0.2083	-47.0	210	0.92
Na (mg/L)	0.0148	24.7	52	0.60
NO_3 – N (mg/L)	0	12.6	12.6	0.43

 # - when a slope is provided for the water quality parameter this indicates that R^2 ≥0.5; otherwise the median data is used as discussed.

SUMMARY

A sulfate ceiling limit was proposed for the Babbage (2022) relationship between sulfate and age and average height of a WRS at the Macraes Gold Mine. The analysis is based on empirical data and the assumption that WRS achieve a geochemical maturity after a number of years (ranging from ~3.5 to 15 years). If future sulfate concentrations are higher than the current empirical data, then the sulfate ceiling limit may also need to be increased to understand long term effects on the receiving environment.

Several other relationships were established to estimate other water quality parameters as a function of sulfate concentrations. These relationships as presented in Table 2 were used to support geochemical modelling processes associated with the Fraser Co-Disposal Project.

It is recommended ongoing performance monitoring is undertaken to evaluate this approach to deriving maximum sulfate limits for WRS based on average height.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at 027 294 5181 or paul.weber@minewaste.com.au should you wish to discuss this memorandum in greater detail.

Attachments: Attachment A – Sulfate ceiling limit analysis for individual WRS
Attachment B – Seepage water quality linear regression data for individual WRS

REFERENCES

Babbage, 2019. Waste Rock Stack Seepage Assessment. Memo provided to OceanaGold, 23 August 2019, 12 pp.

Babbage, 2022. Waste Rock Stack Seepage Correlation Assessment – June 2022. Memo provided to OceanaGold, 30 June 2022, 8 pp.

OceanaGold, 2022. Mine Water and Ground Water Database. Updated 2022. MW data.xlsx and GW data.xlsx.

ATTACHMENT A – SULFATE CEILING LIMIT ANALYSIS FOR INDIVIDUAL WRS

Figure 5 presents the sulfate ceiling limit for WRS (where applicable). Most WRS have achieved a sulfate ceiling limit except for Coronation North, which is a relatively young facility and has an increasing sulfate trend (and has not reached geochemical maturity).

The time required to achieve a quasi-stable sulfate concentration (QSSC) was estimated from the date that a QSSC was achieved compared to the first water quality monitoring data date. Hence, the estimated age is approximate as the start date for monitoring may not necessary correlate with the age of WRS construction. Key data and the estimated years to reach a QSSC for individual WRS are shown in Table 3.

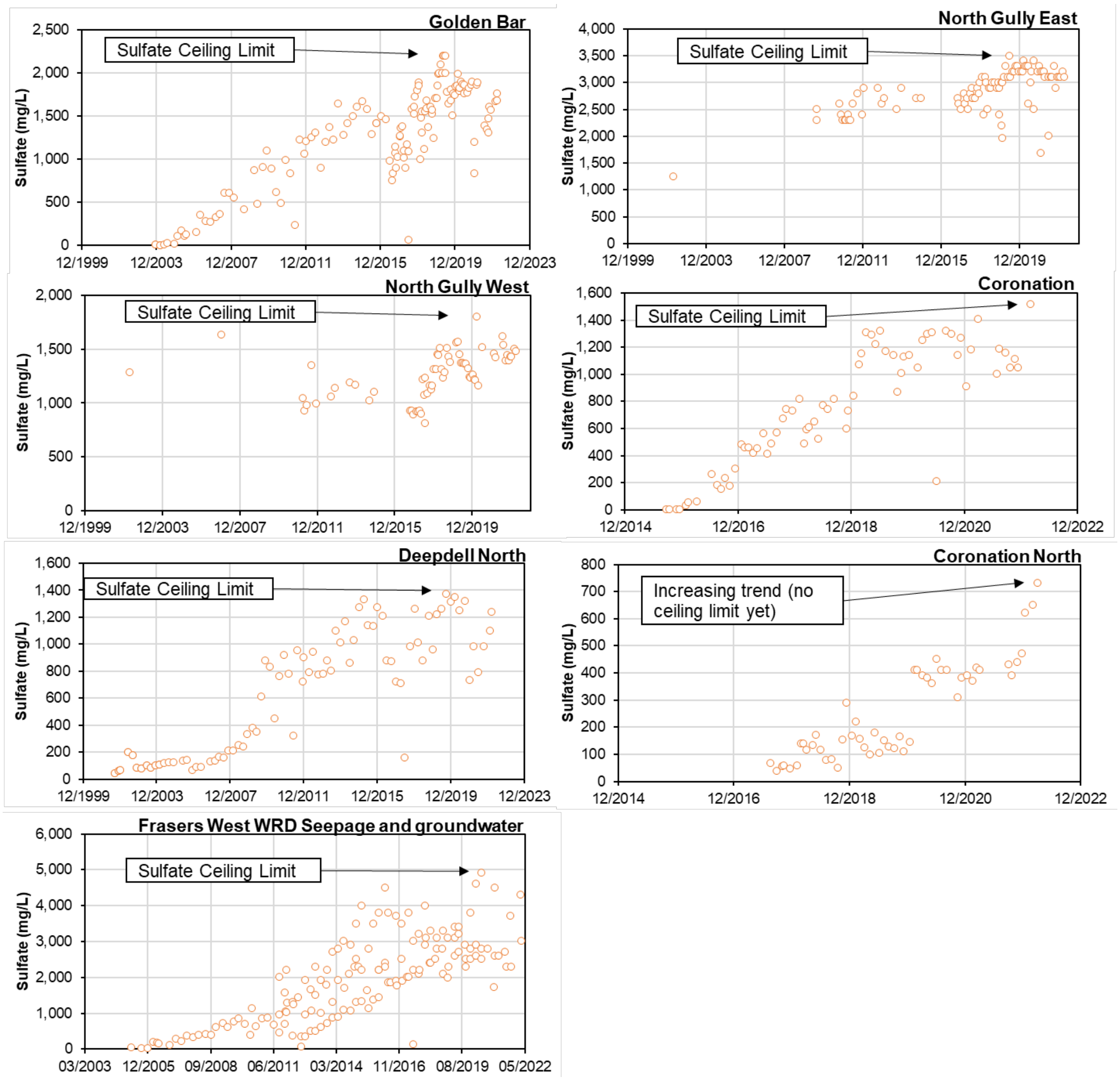

Figure 5: Sulfate ceiling limits for individual WRS.

Table 3: Key data and estimated years to achieve a quasi-stable sulfate concentration.

PARAMETER	DATE WHEN MONITORING STARTED	DATE WHEN QSSC* WAS ACHIEVED	YEARS TO REACH QSSC*
DEEPDELL NORTH	27/09/2001	3/12/2009	8.2
FRASERS WEST	29/03/2005	14/07/2014	9.3
GOLDEN BAR	16/12/2003	11/04/2013	9.3
NORTH GULLY EAST	16/04/2002	18/10/2016	14.5
NORTH GULLY WEST	16/04/2002	8/06/2017	15.1
CORONATION	23/09/2015	18/02/2019	3.4
CORONATION NORTH	23/09/2015	-	-

QSSC: Quasi–stable sulfate concentration.*

ATTACHMENT B – SEEPAGE WATER QUALITY LINEAR REGRESSION DATA FOR INDIVIDUAL WRS

Table 4. Seepage water quality linear regression data for individual WRS.

WASTE ROCK SEEPAGE	PARAMETER	SELECTED SLOPE (A)	SELECTED INTERCEPT (B)	MEDIAN	R^2	N*
Deepdell North	pH	0	8.10	8.1	0.014	92
Deepdell North	Alkalinity (mg $CaCO_3$/L)	0	163.0	163	0.027	82
Deepdell North	As (mg/L)	0	0.005	0.005	0.035	33
Deepdell North	Ca (mg/L)	0.180	51.4	230	0.911	88
Deepdell North	Cl (mg/L)	0	13.0	13	0.225	92
Deepdell North	Cu (mg/L)	0	0.0012	0.0012	0.215	17
Deepdell North	Fe (mg/L)	0	0.02	0.02	0.452	32
Deepdell North	K (mg/L)	0	5.10	5.1	0.001	93
Deepdell North	Mg (mg/L)	0.121	4.71	116	0.958	92
Deepdell North	Na (mg/L)	0.023	12.8	37	0.843	92
Deepdell North	NO_3-N (mg/L)	0	3.60	3.6	0.438	18
Deepdell North	Amm-N (mg/L)	0	0.01	0.01	0.202	35
Golden Bar	pH	0	6.70	6.7	0.096	131
Golden Bar	Alkalinity (mg $CaCO_3$/L)	0	129.0	129	0.053	130
Golden Bar	As (mg/L)	0	0.001	0.001	0.194	61
Golden Bar	Ca (mg/L)	0.126	34.6	240	0.958	133
Golden Bar	Cl (mg/L)	0	11.0	11	0.006	133
Golden Bar	Cu (mg/L)	-0.000057	0.08370	0.0008	0.968	4
Golden Bar	Fe (mg/L)	0	0.04	0.04	0.090	61
Golden Bar	K (mg/L)	0.00216	3.65	7.1	0.699	133
Golden Bar	Mg (mg/L)	0.158	3.06	240	0.943	133
Golden Bar	Na (mg/L)	0.021	14.8	47	0.925	133
Golden Bar	NO_3-N (mg/L)	0.00403	2.56	8.95	0.553	74
Golden Bar	Amm-N (mg/L)	0.00000	0.01	0.01	0.000	87
North Gully West	pH	0	7.40	7.4	0.000	66
North Gully West	Alkalinity (mg $CaCO_3$/L)	0.000	220.0	220	0.175	56
North Gully West	As (mg/L)	0	0.001	0.001	0.209	15

WASTE ROCK SEEPAGE	PARAMETER	SELECTED SLOPE (A)	SELECTED INTERCEPT (B)	MEDIAN	R^2	N*
North Gully West	Ca (mg/L)	0.182	35.8	280	0.622	66
North Gully West	Cl (mg/L)	0	15.0	15	0.165	66
North Gully West	Cu (mg/L)	-0.0000013	0.002755	0.0013	0.599	7
North Gully West	Fe (mg/L)	0	0.02	0.02	0.207	13
North Gully West	K (mg/L)	0.00000	5.85	5.85	0.385	66
North Gully West	Mg (mg/L)	0.135	7.6	187.5	0.643	66
North Gully West	Na (mg/L)	0	64.0	64	0.216	66
North Gully West	NO_3-N (mg/L)	0	13.9	13.85	0.377	52
North Gully West	Amm-N (mg/L)	0	0.0	0.01	0.006	53
North Gully East	pH	0	7.60	7.6	0.001	93
North Gully East	Alkalinity (mg $CaCO_3$/L)	0	590.0	590	0.142	74
North Gully East	As (mg/L)	0	0.008	0.0075	0.000	27
North Gully East	Ca (mg/L)	0	450.0	450	0.200	93
North Gully East	Cl (mg/L)	0	12.0	12	0.059	93
North Gully East	Cu (mg/L)	0	0.002	0.002	0.002	11
North Gully East	Fe (mg/L)	0	0.15	0.15	0.002	26
North Gully East	K (mg/L)	0	13.4	13.4	0.165	93
North Gully East	Mg (mg/L)	0.256	-188.0	590	0.829	93
North Gully East	Na (mg/L)	0	66.0	66	0.145	93
North Gully East	NO_3-N (mg/L)	0	27.0	27	0.477	70
North Gully East	Amm-N (mg/L)	0	0.1	0.1	0.058	76
Coronation	pH	0	7.20	7.2	0.244	68
Coronation	Alkalinity (mg $CaCO_3$/L)	$0^{\#}$	$39.0^{\#}$	39	0.566	67
Coronation	As (mg/L)	0	0.001	0.001	0.273	35
Coronation	Ca (mg/L)	0.154	34.0	220	0.961	68
Coronation	Cl (mg/L)	0	8.00	8	0.207	68
Coronation	Cu (mg/L)	0	0.0005	0.0005	0.092	13
Coronation	Fe (mg/L)	0	0.04	0.04	0.002	35

WASTE ROCK SEEPAGE	PARAMETER	SELECTED SLOPE (A)	SELECTED INTERCEPT (B)	MEDIAN	R^2	N*
Coronation	K (mg/L)	0	5.80	5.8	0.159	68
Coronation	Mg (mg/L)	0.113	8.87	145	0.965	68
Coronation	Na (mg/L)	0.014	13.8	30	0.886	68
Coronation	NO_3-N (mg/L)	0	1.34	1.335	0.144	44
Coronation	Amm-N (mg/L)	0	0.30	0.3	0.054	49
Coronation North	pH	0	7.65	7.65	0.001	51
Coronation North	Alkalinity (mg $CaCO_3$/L)	0.255	114.7	260	0.587	51
Coronation North	As (mg/L)	0	0.001	0.001	0.011	46
Coronation North	Ca (mg/L)	0.253	31.1	190	0.958	51
Coronation North	Cl (mg/L)	0	10.00	10	0.110	51
Coronation North	Cu (mg/L)	0	0.0006	0.0006	0.006	46
Coronation North	Fe (mg/L)	0	0.05	0.05	0.022	46
Coronation North	K (mg/L)	0.00347	2.69	4.4	0.589	51
Coronation North	Mg (mg/L)	0.148	7.63	101	0.977	51
Coronation North	Na (mg/L)	0.045	12.7	39.5	0.900	51
Coronation North	NO_3-N (mg/L)	0	8.00	8	0.235	51
Coronation North	Amm-N (mg/L)	0	0.02	0.0155	0.033	51
Frasers West	pH	0	7.10	7.1	0.019	150
Frasers West	Alkalinity (mg $CaCO_3$/L)	0	490	490	0.179	150
Frasers West	As (mg/L)	0	0.003	0.003	0.050	72
Frasers West	Ca (mg/L)	0.074	105.1	300	0.593	150
Frasers West	Cl (mg/L)	0	15	15	0.002	150
Frasers West	Cu (mg/L)	0.0000014	0.000341	0.0015	0.548	33
Frasers West	Fe (mg/L)	0	0.04	0.04	0.059	74
Frasers West	K (mg/L)	0	3	3	0.000	150
Frasers West	Mg (mg/L)	0.214	-24.8	540	0.878	150
Frasers West	Na (mg/L)	0	47.0	47	0.461	150
Frasers West	NO_3-N (mg/L)	0	9.20	9.2	0.018	44

WASTE ROCK SEEPAGE	PARAMETER	SELECTED SLOPE (A)	SELECTED INTERCEPT (B)	MEDIAN	R^2	N*
Frasers West	Amm-N (mg/L)	0	0.10	0.1	0.000	57

**Number of available values for the respective parameter*

#Data for alkalinity in Coronation shows R^2 > 0.5, but data suggests that for concentrations for sulfate higher than 400 mg/L, the concentration remains steady at 0.4 mg/L, therefore the median was used.

APPENDIX J GOLDEN BAR PIT LAKE ANALOGUE MODEL

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MEMORANDUM

Recipient:	Dean Fergusson – OceanaGold Limited
From:	Paul Weber – Mine Waste Management
Date:	15 January 2024
Cc:	Carlos Hillman – Mine Waste Management; Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0284-001-M-Rev1
Document Title:	Macraes Phase 4.3: Golden Bar Pit Lake Water Quality Analogue Model

Mine Waste Management Limited (MWM) has been engaged by OceanaGold Limited (OceanaGold) to undertake a geochemical assessment of the Golden Bar Pit Expansion at the Macraes Gold Mine (Macraes) to:

- Determine the current and future water quality trends for current Golden Bar Pit Lake (GPL).
- Determine pit lake dewatering options of the current pit lake.
- Determine water management options at mine closure for the Golden Bar Pit Lake extension (GPL-E).

To estimate future water quality, it was proposed that the current water quality in GPL could be used as an analogue for the GPL-E using empirical site-specific data. In addition, it was proposed that the GPL data could be used to develop a conservative estimate of pit wall run-off that could be used for other pit lake models such as the Coronation Pit, Frasers Pit, Innes Mils Pit, and Round Hill Pit.

This memorandum presents the results of the GPL analogue model and subsequent outputs and the applicability of results to other pits.

BACKGROUND

Previous work on the GPL was completed by Golder (2011) who noted that active water management in the Golden Bar Pit ceased in 2005 with the pit lake evolving thereafter. Golder (2011) noted the lowest elevation of the pit lake is 455 mRL, whereas the lowest portion of the pit rim is 500 RL, which is the spill point for the pit with around 1Mm^3 of storage capacity. There is also waste rock backfill within the pit containing nearly 160,000 m^3 of material, which provides an additional 32,000 m^3 of void capacity (based on 20% porosity). In 2018 the current GPL started to discharge (as per GHD, 2023; shown in Figure 5) having reached the spill level of 500 mRL.

OceanaGold (2022A) propose extending the current Golden Bar Pit ~ 200 m to the northeast and the current Golden Bar Waste Rock Stack GB-WRS will be expanded to accommodate the additional waste rock, increasing the height of GB-WRS by ~70 m providing ~30 Mt of additional storage capacity (Figure 1). The proposed Stage 2 Pit extension will be approximately 45 m deeper than the current pit and generate 1.3 Mt of ore and 27 Mt of waste rock.

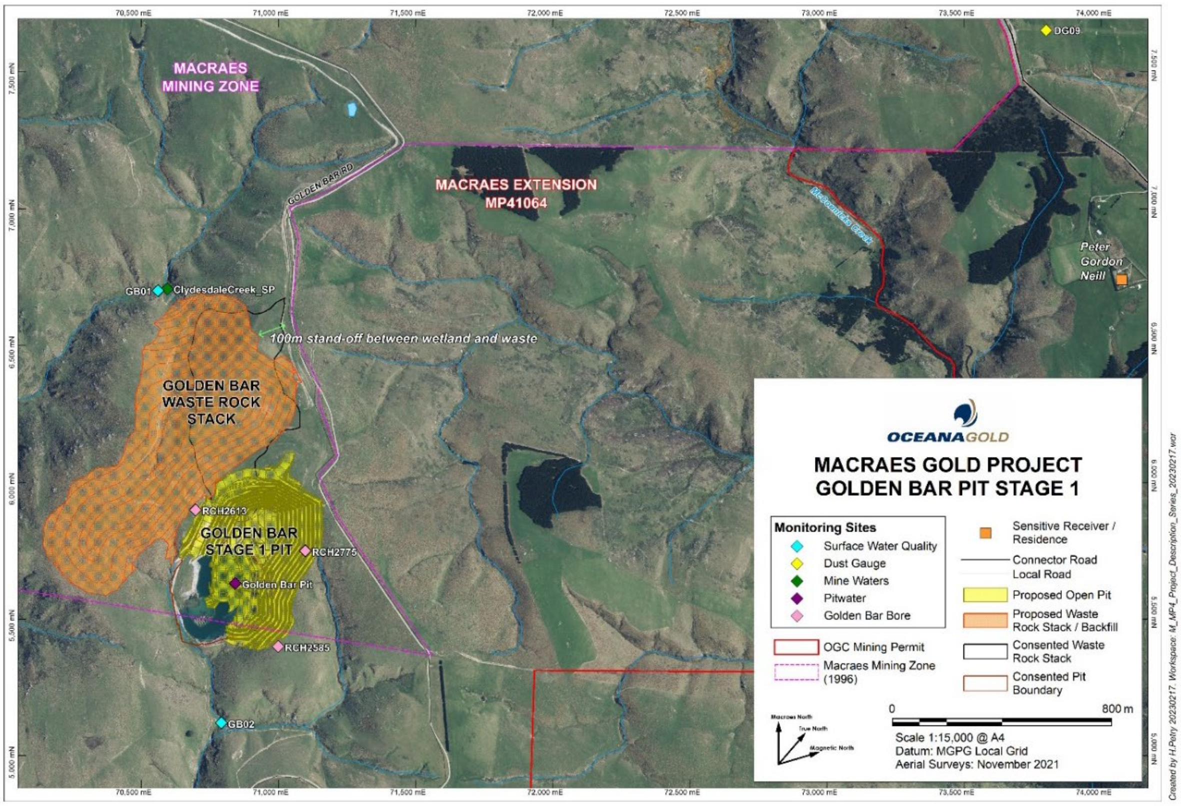


Figure 1. Golden Bar stage 2 open pit.

Source: OceanaGold (2022a).

GPL WATER QUALITY

Water quality data for GPL is available from 2004 to 2022. However, it was determined that data from 2013 onwards provided a better estimate of the stable water quality conditions. This stability in water chemistry is likely to be a function of a reduction in mineralised pit wall surfaces that are exposed to oxygen as the pit lake forms and a reduction in poor water quality from this source (which is considered the dominant source of poor water quality into the pit).

Analysis

To assess the water quality and understand potential contaminants of concern (PCOC), water quality data were normalised to derive the metal ecotox quotient (MEQ). MEQ is used to identify PCOC that are elevated with respect to water quality compliance limits or trigger values (Weber and Olds, 2016). The MEQ value for a PCOC was determined by dividing the reported maximum concentration by the consent compliance limit. MEQ values greater than 1 indicate parameters that exceed consent compliance limits. Conversely, MEQ values less than 1 are below consent compliance limits.

Table 1 provides the compliance limits used in the MEQ analysis where water quality sampling location NBWRRF (North Branch Waikouaiti River Compliance Point 1) was selected due to its relevance to the Golden Bar project area. Nitrate-N (NO_3-N) and total ammoniacal-N (Amm-N, which includes NH_3 and NH_4) were also included to understand the risk associated with nitrogen-based explosive compounds (ammonium nitrate).

Table 1. Water quality compliance limits used for geochemical analysis.

PARAMETER	WATER QUALITY LIMIT
As	0.15
$CN_{(WAD)}$	0.1
Cu[1]	0.009
Fe	1
Pb[1]	0.0025
Zn[1]	0.12
SO_4	1,000
pH (pH units)	6.0 – 9.5
NO_3-N[2]	2.4
Amm-N[2,3]	0.24

Source: OceanaGold (2020).

All values are given in mg/L unless otherwise specified. $CN_{(WAD)}$ is weak acid dissociable cyanide.

1 – Cu, Pb and Zn standards are hardness related limits in accordance with an assumed hardness value of 100 g/m³ $CaCO_3$ and will vary depending on actual hardness.

2 – Water quality limits taken from compliance point MB02 (OceanaGold, 2020).

3 – Amm-N (Total Ammoniacal Nitrogen) is nitrogen as NH_3 and NH_4.

Golden Bar Pit Lake water quality data (2013 - 2022) and MEQ analysis are presented in (Table 2). Data collected on the 21/01/2019 was excluded from the data presented (Table 2 and Figure 2 - Figure 4) due to appearing erroneous (e.g., SO_4 and NO_3-N concentrations were 2,100 mg/L and 5.9 mg/L respectively; these were significantly higher than data presented in Table 2). Time series graphs detailing water quality concentrations between 2004 and 2022 are presented Figure 2 to Figure 4[1].

The data presented in Table 2 are used to derive source terms for the GPL analogue model where data from 2013 to 2022 are used (green squares shown in Figure 2 to Figure 4)[2]. In this regard, the average data are used for the purpose of generating the source terms used in the water quality model that is presented in the following sections.

[1] Zinc is not shown in Figure 2 - Figure 4 due to only one data point being available.
[2] The GHD model indicates BPL spiling from 2018.

Table 2. Golden Bar Pit Lake water quality summary (2013 - 2022).

PARAMETER	MIN	MAX	AVE	MED	WATER QUALITY LIMIT	MEQ ANALYSIS
pH (pH units)	8.20	8.50	8.37	8.40	-	-
EC (µS/cm)	843	965	910	919	-	-
Alkalinity – Total (mg $CaCO_3$/L)	194	250	229	230	-	-
Alkalinity - Bicarbonate (mg $CaCO_3$/L)	190	240	222	230	-	-
Carbonate Alkalinity (mg $CaCO_3$/L)	3.70	6.70	5.15	5.00	-	-
Total hardness (mg $CaCO_3$/L)	450	550	498	500	-	-
Nitrate-N	0.002	0.023	0.008	0.005	2.4	0.01
Nitrate-N + Nitrite-N	0.002	0.118	0.017	0.010	-	-
Nitrite-N	0.002	0.010	0.003	0.002	-	-
Amm-N	0.010	0.100	0.015	0.010	0.24	0.42
Total Inorganic Nitrogen	0.011	0.139	0.026	0.015	-	-
As	0.121	0.210	0.163	0.171	0.15	1.40
Ca	61.0	88.0	76.1	76.0	-	-
Cl	5.00	9.00	6.25	6.00	-	-
$CN_{(WAD)}$	0.02	0.02	0.02	0.02	0.1	0.20
Cu	0.0005	0.0009	0.0006	0.0005	0.009	0.10
Fe	0.020	0.120	0.026	0.020	1	0.16
Hg	0.00008	0.00008	0.00008	0.00008	-	-
K	3.80	5.90	4.47	4.40	-	-
Mg	60.0	89.0	74.5	74	-	-
Na	11.4	15.0	13.0	12.9	-	-
Pb	0.0001	0.0002	0.0001	0.0001	0.0025	0.003
Sb	0.003	0.003	0.003	0.003	-	-
SO_4	260	320	288	290	1,000	0.32
Zn	0.002	0.002	0.002	0.002	0.12	0.002
Sum of Anions (meq/L)	9.60	11.5	10.7	10.7	-	-
Sum of Cations (meq/L)	9.60	11.8	10.6	10.6	-	-

Source: OceanaGold Mine Water Quality excel database (OceanaGold, 2022b).

All units are presented in mg/L unless otherwise specified.

Metals and metalloids are presented as dissolved.

A hyphen (-) indicates that no analysis was undertaken.

MEQ analysis was undertaken using the observed maximum concentrations, unless otherwise specified.

pH presented is based on average H^+ concentration converted to log equivalent.

Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018).

RED Text = MEQ values are >1.0 MEQ.

Data collected on the 21/01/2019 was not included in in the source term due to appearing erroneous (outlier). These outlier data are shown in Figure 2 - Figure 4.

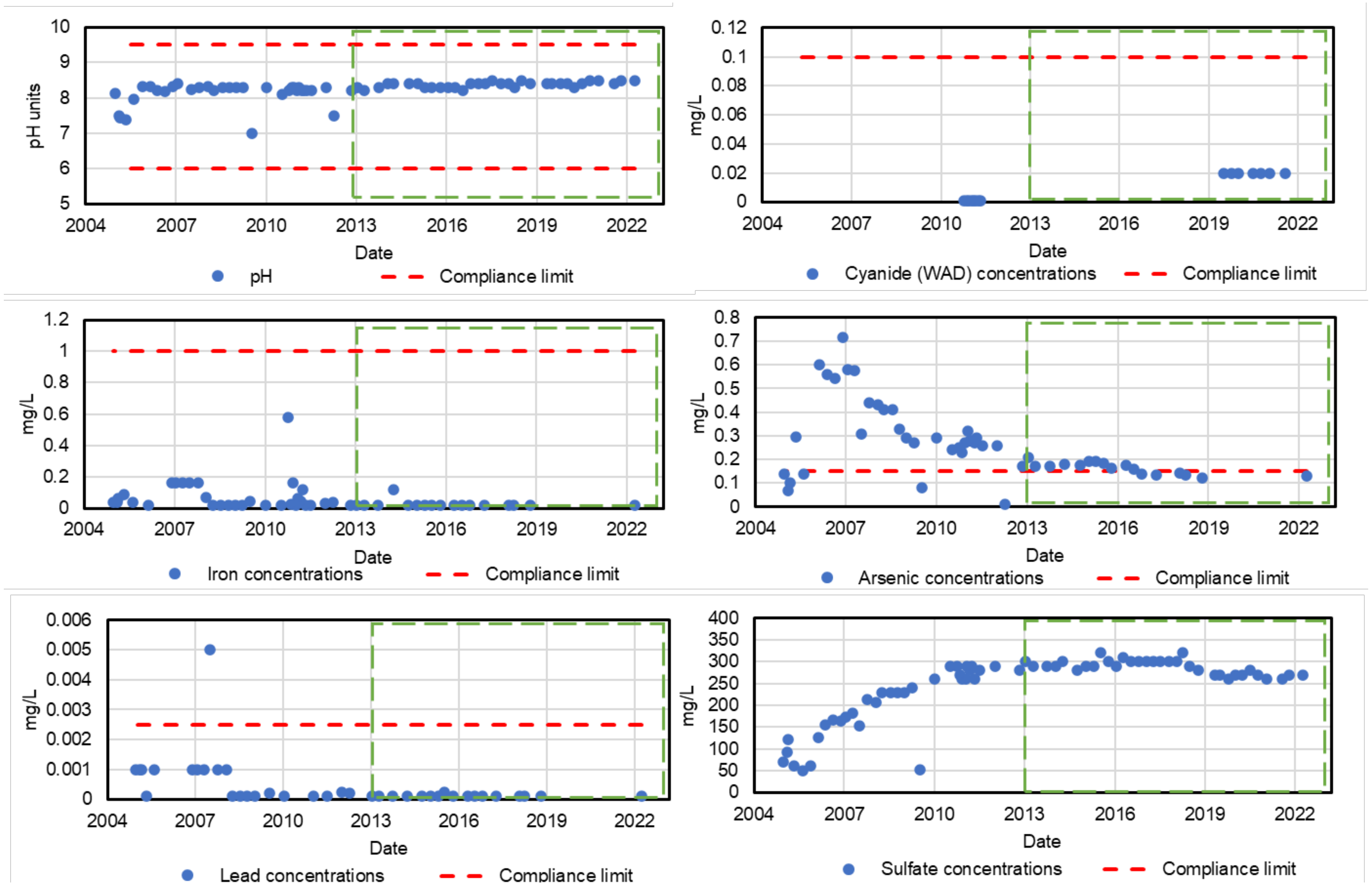


Figure 2. Water quality trends for the current Golden Bar Pit Lake.

Source: OceanaGold Mine Water Quality excel database (OceanaGold, 2022b).

The Green square indicates the data range used in Table 2.

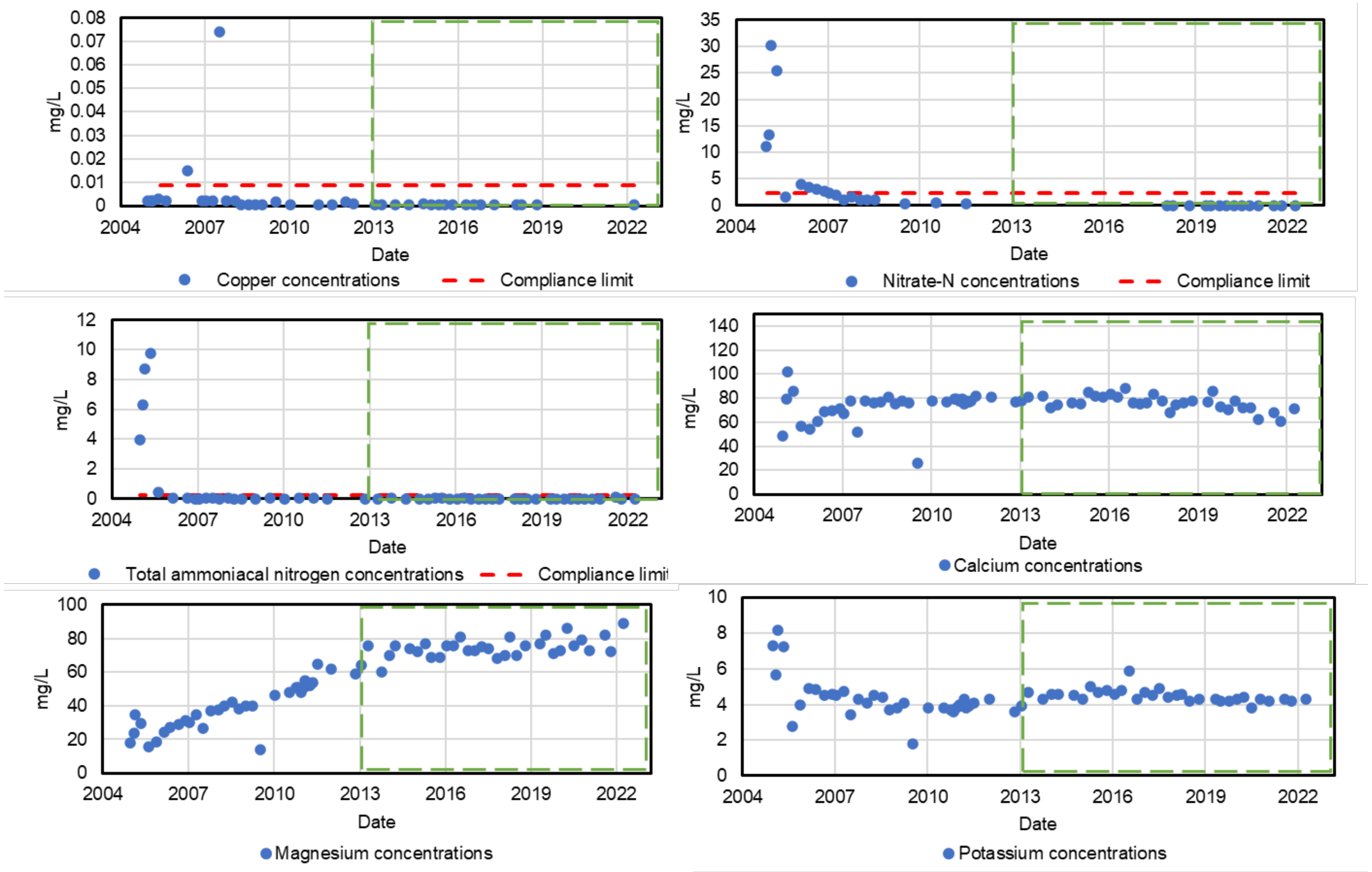
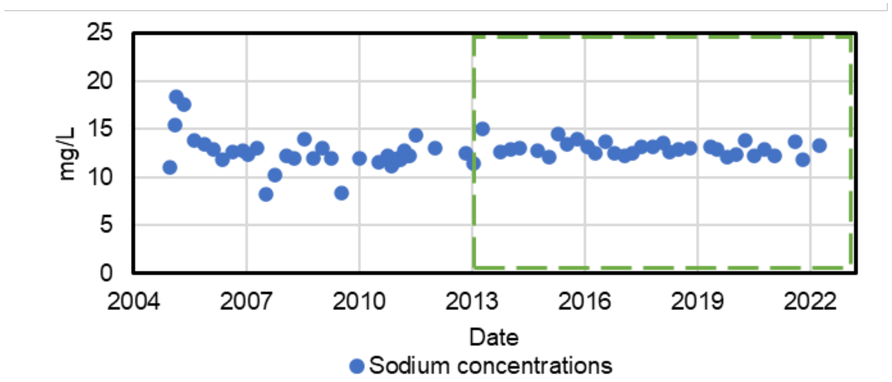


Figure 3. Water quality trends for the current Golden Bar Pit Lake continued.

Source: OceanaGold Mine Water Quality excel database (OceanaGold, 2022b).

The Green square indicates the data range used in Table 2.



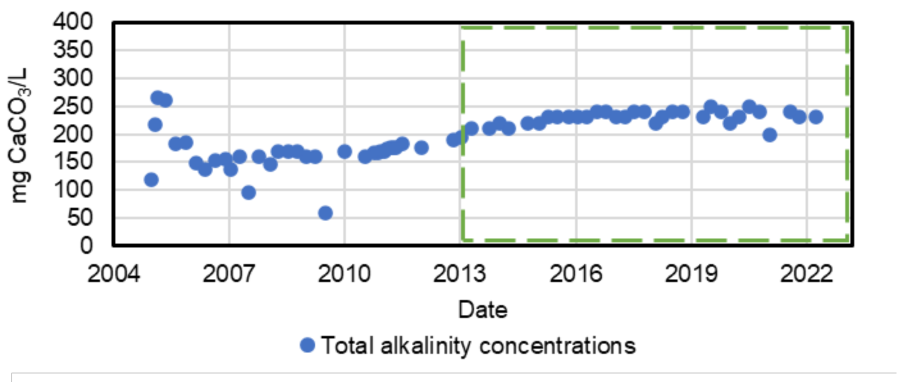


Figure 4. Water quality trends for the current Golden Bar Pit Lake continued.

Source: OceanaGold Mine Water Quality excel database (OceanaGold, 2022b).

The Green square indicates the data range used in Table 2.

Summary

From the data presented the following key observations were made:

- Water quality typically exhibited circumneutral pH levels ranging from 8.2 – 8.5.
- MEQ analysis conducted showed that As was >1.0 (i.e., above the compliance limit).
- Figure 2, Figure 3 and Figure 4 show SO_4 and other parameters concentrations began to stabilise from 2013 onwards. A slight decline in sulfate is noticeable, perhaps a function of pit lake discharge). Two outliers were discarded from the dataset due to their significant deviation from the overall data pattern.
- Analysis shows that As concentrations in the pit have continued to decrease. Between 2013 and 2022 concentrations ranged between 0.121 and 0.210 mg/L with an average of 0.163 mg/L.
- Cu remained consistent between 2013 and 2022. One outlier was noted during 2007 (0.074 mg/L) (Figure 3), and one other outlier taken during 2006 (0.015 mg/L). All other samples were reported as being below the compliance limit.
- NO_3-N concentrations ranged between 0.002 and 0.023 mg/L with an average concentration of 0.008 mg/L (Table 2). Figure 3 shows that NO_3-N concentrations have continued to decrease since 2005 (30.2 mg/L to 0.002 mg/L). The NO_3-N concentrations are likely a result of the ammonium nitrate-based blasting reagents. Data shows that from 2007 Amm-N concentrations ranged between 0.010 and 0.100 mg/L with concentrations typically reporting below the trigger value (0.24 mg/L).
- The source term shows Fe concentrations have been relatively stable with concentrations ranging between 0.02 – 0.12 mg/L between 2013 and 2022. One outlier is shown in Figure 2 (0.58 mg/L); all Fe concentrations were below the trigger value (1 mg/L).
- Since monitoring began, Ca, Mg, Na, and K concentrations have followed similar trends, showing slight increases in concentration in the first years following a stabilisation period. At the end of the monitored period, a slight decrease was observed in the concentrations of Ca and K, similarly to the decrease observed for sulfate.

WATER QUALITY MODELLING

This section explains the methodology use to develop an analogue model that can be used to forecast future water quality within the GPL-E and other pits at Macraes.

Water Balance and Pit Geometry

GHD (2023) developed a water balance model for the GPL, which models the filling of the pit lake. The model provides results from 2005 to 2024. This model indicates that once the overflow level was reached (500 mRL) in 2018, there is discharge to the environment (Waikouaiti River North Branch Tributary) with no groundwater loss. The evolution of the lake level and volume is shown in Figure 5.

Water quality data at water quality modelling location GB02 below the GPL discharge point suggest pit lake spilling could have occurred sporadically from 2015 onwards.

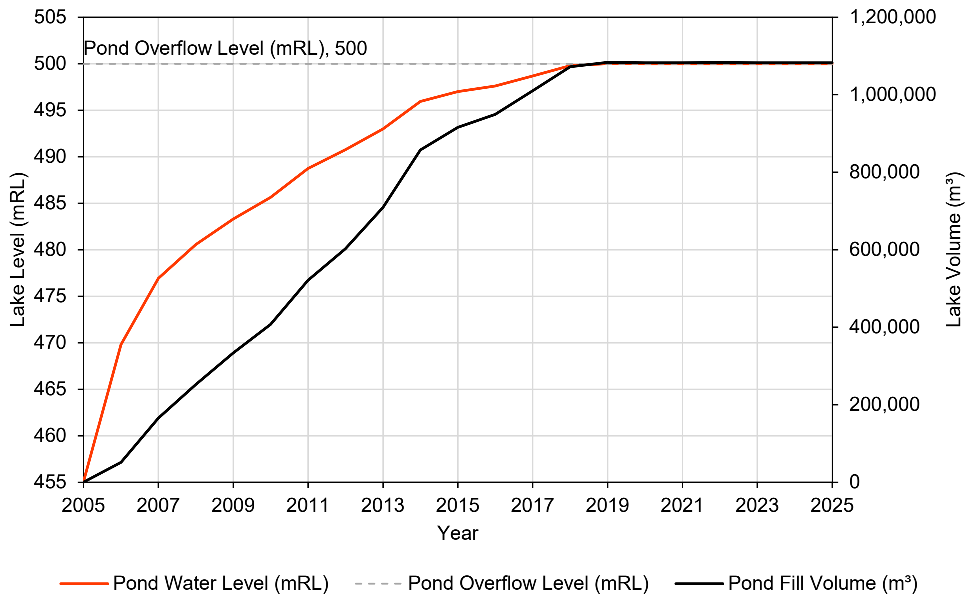


Figure 5. Golden Bar Current Pit Lake water balance model volume and height.

Data Source: GHD (2023).

The relative distribution of the average flow per year for the water balance components is shown in Figure 6 for the 2018-2021 period when the lake is overflowing, and flows are stable. The main inflow comes from the runoff (natural, pit, and GB-WRS) accounting for 62%, 36% comes from the direct rainfall, and the remaining 2% comes from the groundwater. The majority of outflow is to the downstream environment (river).

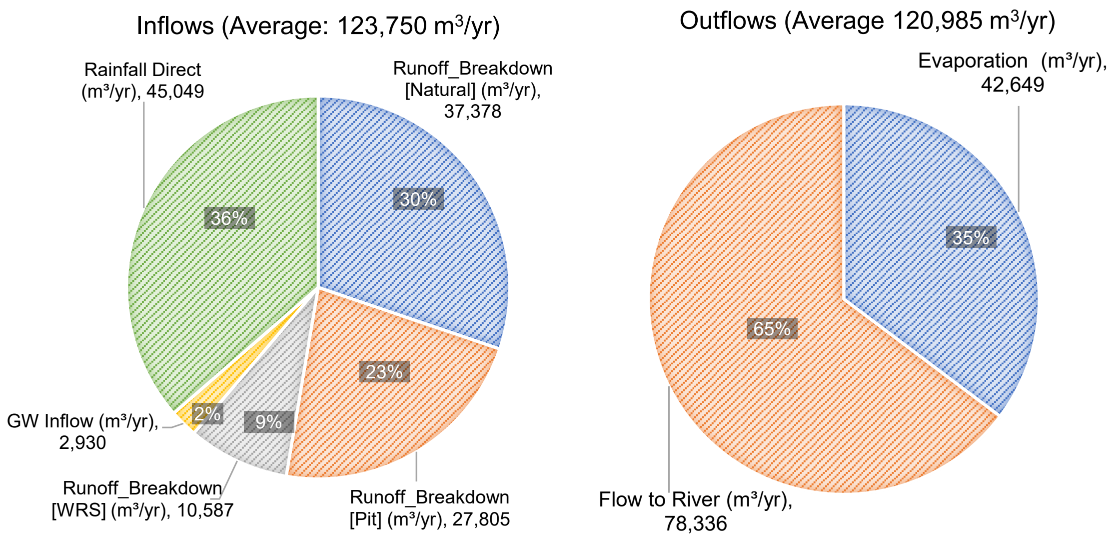


Figure 6. Pie chart of the distribution of inflows and outflows in the period 2018 to 2021.

Data Source: GHD (2023).

Conceptual Site Model

A conceptual site model (CSM) has been developed to facilitate the assessment of the potential environmental risks for the project. The CSM (Figure 7) shows the current GPL with key features being discussed in Table 3. Source terms are discussed in subsequent sections.

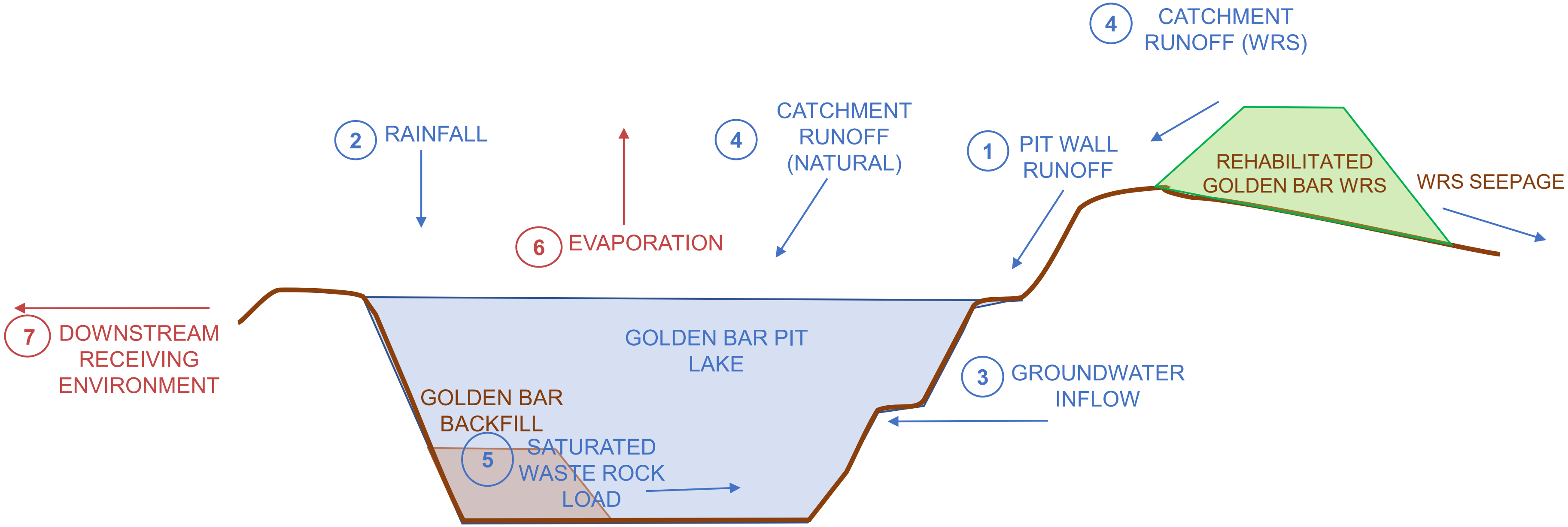


Figure 7. Conceptual site model for the GPL.

Table 3. Key components and processes associated with the current GPL model.

MODEL FEATURE	SUMMARY	DATA SOURCE
	MODEL INPUTS	
1	Pit wall run-off to GPL	Analogue Model: Water quality derived from the GPL water quality data (as discussed in subsequent sections of this memorandum)
2	Direct rainfall to the GPL.	Water quality derived from Nichol et al. (1997).
3	Groundwater inflow.	Groundwater inflow water quality data derived from monitoring well MAC-RCH3004.
4	Catchment runoff for natural and rehabilitated WRS	Surface water quality data derived from the surface water monitoring point GB02.
5	Saturated backfill load (below the water level).	The effect of the saturated backfill load solute release was conservatively allocated to the pit wall run-off source term (i.e., it is not accounted for and hence load is conservatively allocated to the pit wall source term)
	MODEL OUTPUTS	
6	Evaporation of water causes an increase in concentration of solutes. Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations (also known as evapoconcentration).	Rates determined by GHD (2023).
7	Outflow (spill) to downstream environment.	Determined by GHD (2023).

Derivation of Source Terms

This section provides additional notes on the source terms used for the hydrogeochemical model.

Pit Wall Runoff

Water quality for rainfall run-off interacting with the pit walls was derived from the average concentrations exhibited from the Golden Bar Current Pit Lake (Table 2) as discussed in subsequent sections of this memorandum. This source term is assigned to the “Pit” runoff component of the water balance. It is considered conservative as this also includes the effects of the 160,000 m^3 of backfill that would also contribute load to the pit lake.

Backfill

The effect of the backfill solutes being released into the pit lake was assumed to come from the pit wall runoff (this also accounts for other minor quantities of backfill material within the pit lake). This is a conservative approach for deriving the pit wall runoff.

Rainfall

The source term for average rainfall water quality is obtained from Nichol et al. (1997) using the Lauder site collection (~70 km NE from Macraes, at 317 mRL), which includes rainfall water quality data from 1983 to 1994.

Groundwater

Four monitoring wells (MAC-RCH2585, MAC-RCH2613, MAC-RCH2775, and MAC-RCH3004) exist for monitoring purposes around the Golden Bar Pit (Figure 8). The source term for groundwater was derived using the average data (2011 – 2022) from the monitoring well MAC-RCH3004 as this was the only monitoring well within the vicinity of the Golden Bar Pit that had water quality data available. Analysis showed that Amm-N, Cu, and Fe concentrations exceeded relevant guideline values across the monitoring period. Further data are provided in Attachment A.

Runoff from Natural Catchment and rehabilitated WRS

Two natural surface water monitoring points exist around the Golden Bar Pit (GB01 and GB02) (Figure 8). The source term for surface water used the monitoring site GB02 as it represents the closest and least impacted compliance point for the Golden Bar Pit. Average data was used from May 2007 to October 2014 as this data represented a period of time in which surface runoff from the natural catchment was the least affected by mining. Analysis showed that Cu concentrations can exceed relevant guideline values on occasion (average is below limits shown in Table 1).

The source term is assigned to the Runoff 'Natural' and 'WRS' water balance components with the assumption that natural catchments and the WRS are rehabilitated and hence water quality should resemble that of natural runoff. Further data are provided in Attachment A.

Figure 8. Golden Bar water quality monitoring locations.

Source (GHD, 2022a).

Source Terms Summary

Table 4 provides a summary of the source terms for the GPL analogue model.

Table 4. Source terms for GPL hydrogeochemical water quality model.

COMPONENT NAME	GOLDEN BAR PIT WATER QUALITY	RAINFALL	RUN-OFF FROM PIT WALLS TO GOLDEN BAR	GROUNDWATER	RUNOFF FROM NATURAL CATCHMENT AND REHABILITATED WRS
DERIVATION FROM	GOLDEN BAR PIT WATER QUALITY (2013-2022)	NICHOL ET AL., 1997	GOLDEN BAR PIT WATER QUALITY MULTIPLIED BY A FACTOR OF 2.5 (DERIVED PIT WALL RUN-OFF SOURCE TERM)	MONITORING WELL MAC-RCH3004	MONITORING LOCATION GB02 (2007 – 2014)
pH	8.37	5.20	8.37	6.04	7.44
Alkalinity – Total (mg $CaCO_3$/L)	229	0.810	572.5	*na*	32.0
Unit	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Al	*na*	*na*	*na*	*na*	*na*
As	0.16	*na*	0.409	0.0014	0.002
Ca	76.1	0.11	190.3	8.18	8.81
Cd	*na*	*na*	*na*	*na*	*na*
Cl	6.25	0.6	15.6	8.20	10.0
Cu	0.00057	*na*	0.001	0.00248	0.0031
Fe	0.0259	*na*	0.065	4.48	0.190
K	4.47	0.09	11.2	0.974	0.717
Mg	74.5	0.05	186.4	7.60	3.22
Mn	*na*	*na*	*na*	*na*	*na*
Na	13.0	0.32	32.4	9.38	8.74
NO_3-N*	0.008	0.0045	0.019	0.407	0.030
NO_2-N*	0.003	*na*	0.008	0.012	0.0020
Amm-N*	0.015	*na*	0.038	0.047	0.033
Pb	0.00011	*na*	0.0003	0.0001	0.00026
Sb	0.003	*na*	0.008	*na*	*na*
SO_4	287.6	0.18	718.9	13.3	6.72
Zn	0.002	*na*	0.005	0.045	0.0026

na -not applicable due not being analysed or being below LOR. For modelling purposes na is equivalent to 0.

**: In addition to the nitrogen from the source terms, an initial load of 700 kg of nitrogen as NH_3NO_3 is added to the first 3 years of the model representing the flushing of nitrogen from the pit walls*

Modelling Processes and Software

Geochemical processes were modelled using PHREEQC (Parkhurst & Appelo, 2013), a widely used software distributed by the United States Geological Survey (USGS) to perform a variety of aqueous geochemical calculations, such as:

- Aqueous reactions.
- Mixing of solutions.
- Calculation of mineral saturation indices.
- Gas and mineral interaction.

Data inputs, modelled geochemical processes, and outputs produced by the hydrogeochemical model are shown schematically in Figure 9. For each timestep (1 year) represented in the pit lake water balance, the model simulated:

- Mixing volumes of each inflow, as represented by source terms in proportions predicted by the GHD (2023) water balance.
- Concentration of the resulting mixed lake water by removal of pure water, representing evapoconcentration predicted by the water balance.
- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for geochemical processes including:
    - Equilibration with atmospheric gases (O_2 and CO_2).
    - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed lake water.
    - Adsorption of dissolved metals and metalloids to hydrous ferric oxides (HFO) as represented by precipitated iron (hydr)oxide minerals.

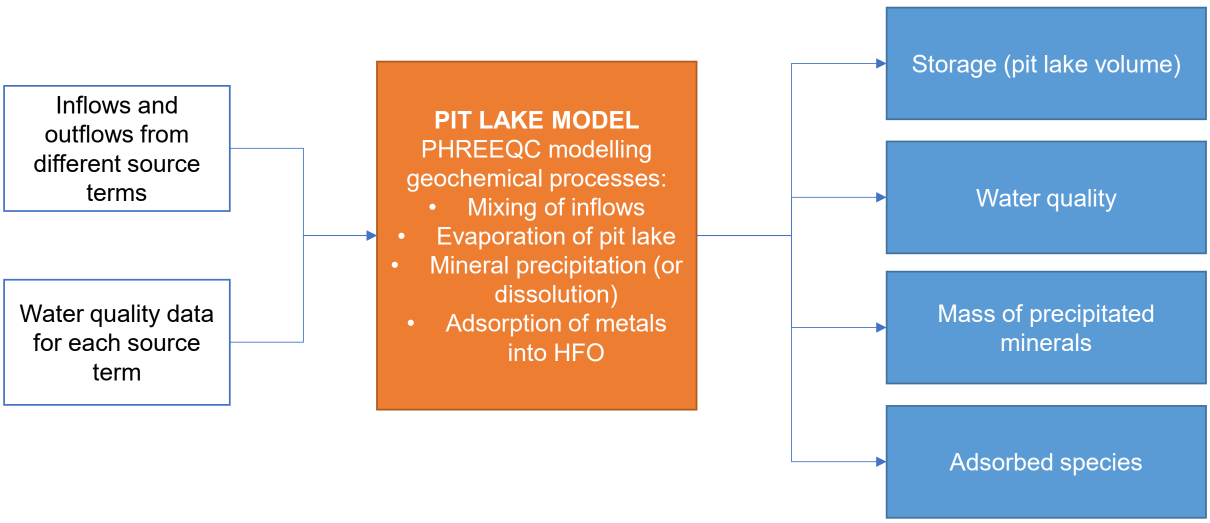


Figure 9. Hydrogeochemical model inputs, modelled processes, and outputs.

The WATEQ4F database was used for thermodynamic calculations, which included the derivation of mineral saturation indices. Mineral phases attaining a saturation index value equal to or greater than zero, which indicates that precipitation of that mineral from solution is thermodynamically favoured, were included as equilibrium phases if those minerals are known to, or likely to, form under surface environmental conditions reflecting a pit lake. Adsorption of aqueous chemical species to HFO was modelled using a diffuse double-layer surface complexation model (Dzombak & Morel, 1990), based on modelled precipitation of $Fe(OH)_3(a)$[3] from solution.

Assumptions and Limitations

The following section discusses general model constraints, key assumptions and limitations relating to the hydrogeochemical model:

- All data provided by OceanaGold are assumed to be correct and no quality control / quality assurance (QAQC) has been undertaken on the datasets provided unless specified.
- Data are obtained from a variety of sources and is assumed to be representative of the materials associated with the project, and the data are representative of the key environmental geochemistry risks.
- Outputs from the water balance (GHD, 2023) were assumed to be accurate and complete.
- It is assumed that continuous pit lake discharge commences at the start of 2018 as per the GHD (2023) model outputs. However, it is noted that sporadic spill from the lake is occurring from 2015 as observed at water quality monitoring location GB02. This could affect the average water quality, but the potential difference is amended through the load model (discussed below).
- The model assumes there is no stratification in terms of density (temperature or salinity stratification) or oxidation-reduction (redox) potential within the pits. It is acknowledged that recent data (MWM, 2023) suggest that stratification may be occurring during summer months with slightly higher arsenic at depth compared to surface concentrations. Sulfate remains constant with depth and is not affected by stratification. Such effects for arsenic are not considered in this model.
- Mineral reactions are modelled in equilibrium. If conditions are met, precipitation and dissolution occur instantly until mineral equilibrium, or target, saturation index is attained. Kinetically limited reactions were not accounted for mineral precipitation. However, kinetics for denitrification and nitrification were included based on empirical data.
- No redox state (such as pe, Eh or ORP) data were available for source term derivation. A pe value of 10 was applied for all source terms and equilibrium between the lake and the atmosphere (O_2 and CO_2) was assumed.
- All Fe introduced into the model is assumed to be in the Fe^{3+} form.

[3] (a) = amorphous.

- Data showed a decay in the ammoniacal and nitrate nitrogen load with time, and a kinetic equation (time dependent) was fitted to the data to model the nitrification (ammoniacal to nitrate conversion) and denitrification (nitrate to nitrogen gas conversion) processes.

CALIBRATION AND RESULTS OF THE ANALOGUE MODEL

Selected outcomes from the hydrogeochemical modelling are presented in this section for the current GPL. A spreadsheet of model outputs is provided as Attachment D to this memorandum.

Approach

GHD (2023) provided a water balance for the GPL, which they calibrated with insitu lake level monitoring, and hydrological data (Figure 5). Using this water balance model, the following comments are provided:

- The purpose of the analogue model was to develop a source term for the pit wall run-off and understand the decrease in nitrogenous compounds with time.
- The contaminant load for several elements was estimated by multiplying the measured pit lake concentration by the estimated volume of the pit lake.
  - Measure concentration data (mg/L) and calculated load (mg/L x GPL water volume) are provided.
  - Contaminant oad from all of the source terms were considered. However, the pit wall accounts for almost all of the incoming load (~95 – 98%) into the pit lake.
- Two models were developed including:
  - 1x Analogue Model where the concentration (and hence load) is the water volume multiplied by the GPL concentration.
  - 2.5x Analogue Model where the concentration (and hence load) is the water volume multiplied by 2.5 times the average concentration of the GPL (see Table 4). This provided an adjustment factor to increase the load from the pit wall runoff to match the load in the pit lake.
- Generally, the 1x Analogue Model did not compare well to the measured concentrations or contaminant loads in the GPL. Whereas the 2.5x Analogue Model was a good match to empirical data and provided a suitable basis to derive the pit wall runoff source term.

Sulfate

In the analogue model, it is assumed that the sulfate load nearly fully originates from the pit walls (~95 - 98%), which is a conservative approach for the development of model source terms. Results are shown in Figure 10 with analogue model sulfate loads shown by red lines; analogue sulfate concentrations shown by blue lines; and empirical pit lake data shown by red circles and blue dots. The 2.5x Analogue Model is clearly a better fit.

The 2.5x Analogue Model overestimates the load and concentration in the first 5 years of the model (2005 to 2010). However, the model accurately captures mid to long-term water quality trends, making it a valuable scaling factor for adjusting pit lake water quality to empirical data. Long term model validity is more important as this is when the pit lake will be spilling

This scaling factor of 2.5 is used to scale other data in the model to derive the pit wall runoff source term as shown in Table 4.

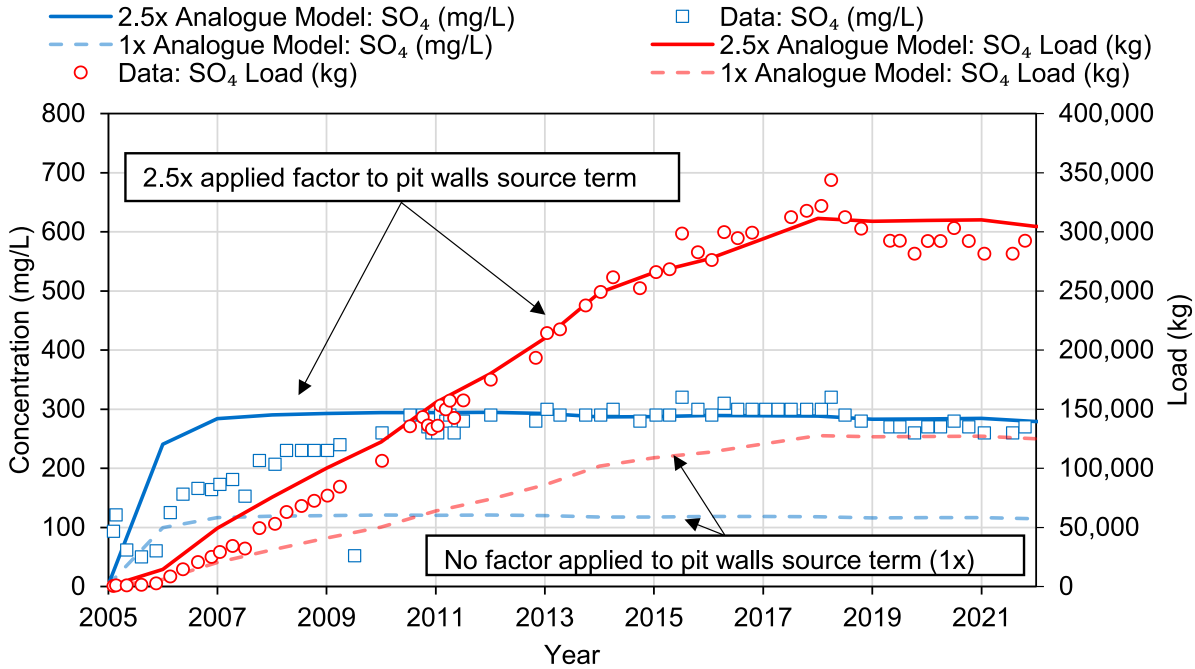


Figure 10. Sulfate concentrations and estimated load in the GPL analogue models.

Nitrogen

Nitrogenous data did not have a reasonable match to the 2.5x Analogue Model due to biochemical processes leading to the loss of load. Additional analysis was required.

The following observations are presented for current GPL load estimation and concentration data for nitrogenous compounds, which is presented in Figure 11:

- Nitrate-N loads and concentrations decrease significantly over several years from a peak of around 400 kg and 30 mg/L, respectively.
- Approximately 20-30% of the nitrate-N load is lost annually (after the peak load has developed).
- Although there is a gap in information between 2011 and 2018, nitrate load estimation approaches zero by 2018 with a clear decreasing trend.
- NH_3-N also exhibits a decaying trend, with concentrations and loads decreasing to zero within a year (from 2005 to 2006), from a peak of approximately 10 mg/L and 170 kg, respectively.

These findings suggest that nitrogen is not a conservative contaminant and is removed from solution (i.e., the pit lake), as evidenced by the decrease in load prior to the lake overtopping. This is most likely due to biochemical processes. This observation is important as it indicates that nitrate concentrations in pit lakes will decrease relatively quickly and are of lesser concern for effects on the receiving environment than for waste rock stacks.

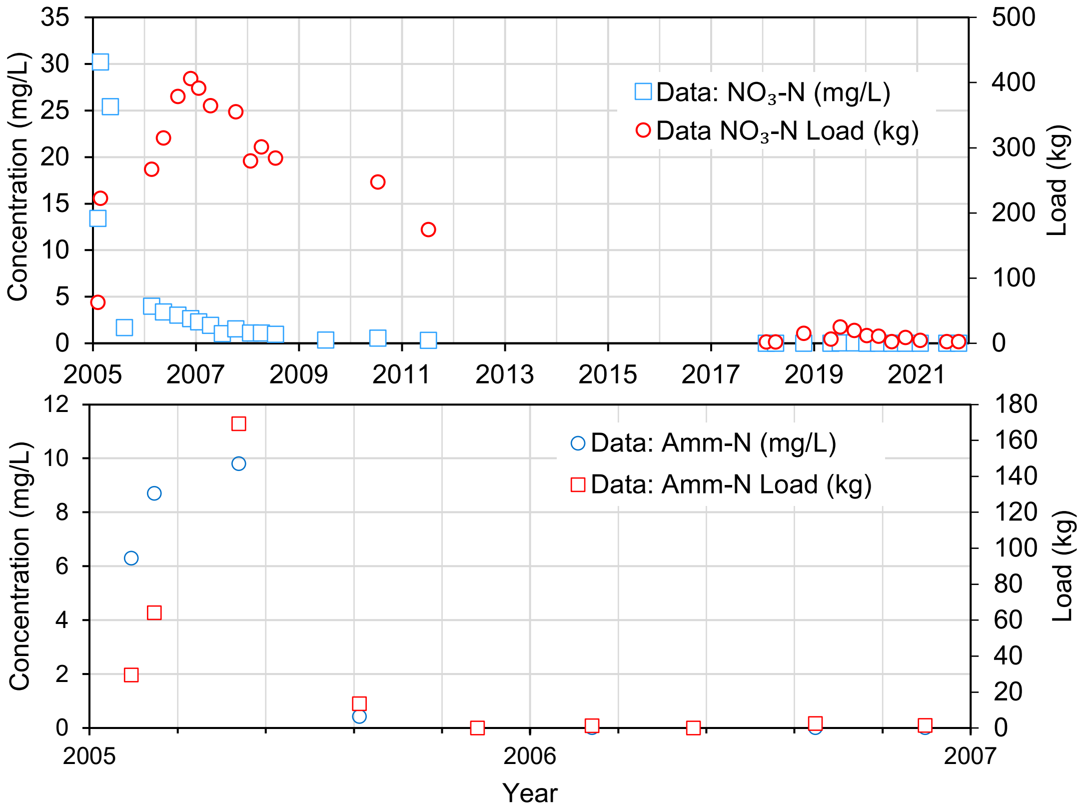


Figure 11. Concentrations and loads for NO_3-N and Amm-N in the GPL.

The primary source of nitrate and ammonia is assumed to be derived from ANFO[4] blasting residue. After mining ceases, water either runs off or runs through the waste rock, and rainfall interacts with the pit walls containing blasting residues, causing NH_3 and NO_3 to be flushed into the pit lake. A small fraction of the nitrogen is from groundwater, surface waters, and rainfall.

A nitrogen-decay model was constructed to determine the decay rates for nitrogenous compounds within the current GPL. The model incorporates nitrogenous decay processes based on the GPL empirical data:

- Nitrification, which involves the conversion of ammoniacal nitrogen into nitrate nitrogen. Conceptually, this process occurs naturally in the presence of oxygen and specific bacteria, which play a critical role in facilitating the reaction. It is assumed this process is occurring for modelling purposes.
- Denitrification involves the conversion of nitrate nitrogen to nitrogen gas. This process occurs under anaerobic conditions, where bacteria use nitrate as an electron acceptor in place of oxygen, resulting in the production of nitrogen gas. It is assumed this process is occurring for model purposes.

Both processes are fitted to empirical data. No assessment of redox state of the GPL is introduced to account for oxic or anoxic redox states and processes, and therefore, the only variable considered is time. Attachment B contains further details on the incorporation of nitrogenous reactions, speciation,

[4] Ammonium-nitrate and Fuel Oil

and kinetics in the PHREEQC code. It elaborates on how the model accounts for the various nitrogen species present in the system, their interactions, and transformations over time.

Since the source terms for pit walls is derived from 2013 to 2022 time period, this interval does not consider the earlier effects of elevated nitrogenous compounds. Hence, ~700 kg of nitrogen (as $NH_3.NO_3$) needs to be added in the first three years to match the empirical data to represent the flushing of nitrogenous compounds from the pit walls.

Based on ~700 kg being flushed off the pit walls having a plan surface area of ~131,000 m^2 provides a reasonable estimate of early nitrate flushing from pit walls. This was determined to be 5.35 g/m^2 of nitrogen as $NH_3.NO_3$. It is proposed this value can be used for other pit walls at the Macraes project. The resulting loads and concentration are shown in Figure 12 using the calibration process.

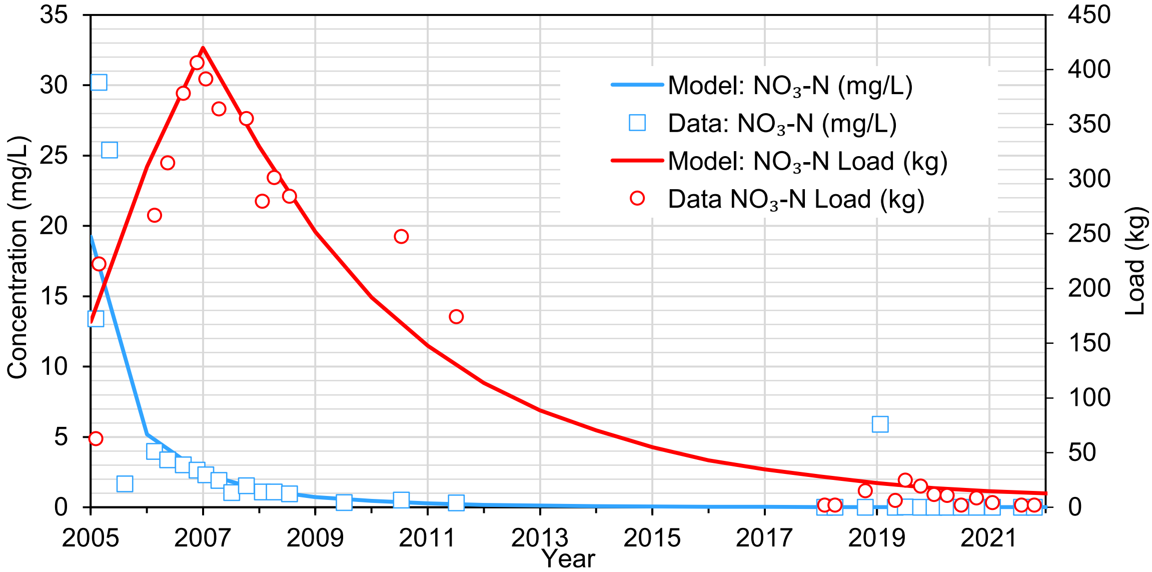


Figure 12. Concentrations (blue) and load estimations (red) for NO_3-N in the Golden Bar Pit Lake analogue model compared to data.

Alkalinity, Calcium, and Magnesium

Alkalinity, Ca, and Mg concentration data did not have a reasonable match to the 2.5x Analogue Model and additional analysis was required.

To calibrate calcium, magnesium, and alkalinity, a saturation index analysis in PHREEQC of relevant phases was conducted for the dataset of the current GPL, which is detailed in Attachment C. The outcome of that analysis is that the saturation of calcite and CO_2 are adjusted to empirically observed saturation values, and no dolomite is allowed to precipitate, improving the estimated concentrations of alkalinity, Ca, and Mg. Therefore, model results fit well with the data. Results for the mentioned parameters are show in Figure 13, Figure 14, and Figure 15, respectively.

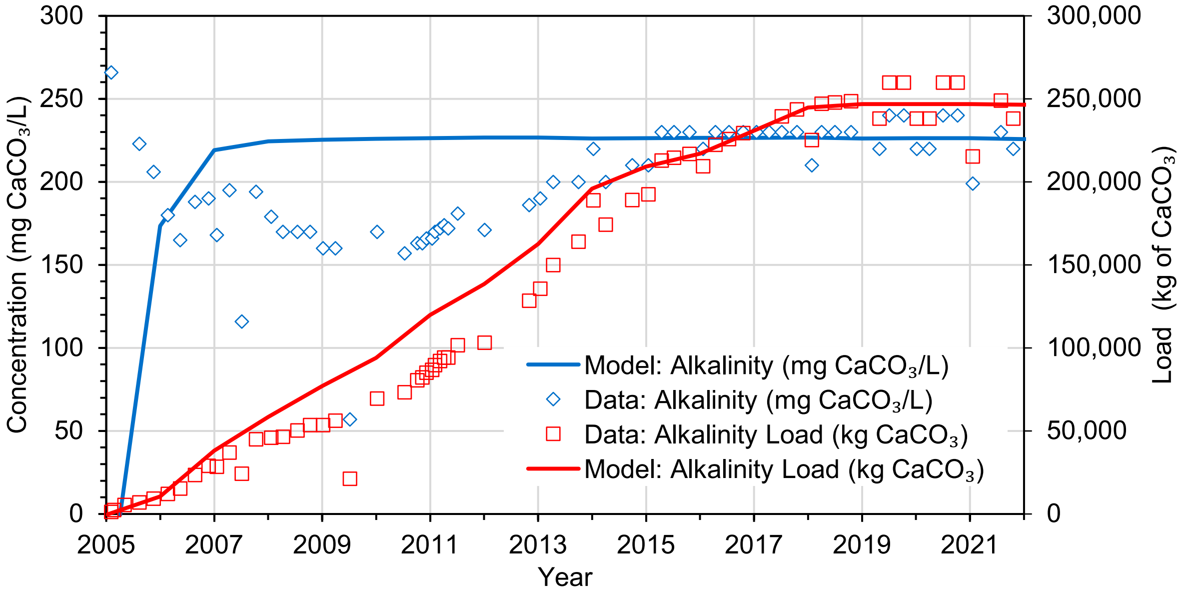


Figure 13. Alkalinity concentrations and load estimates for the GPL analogue model compared to data.

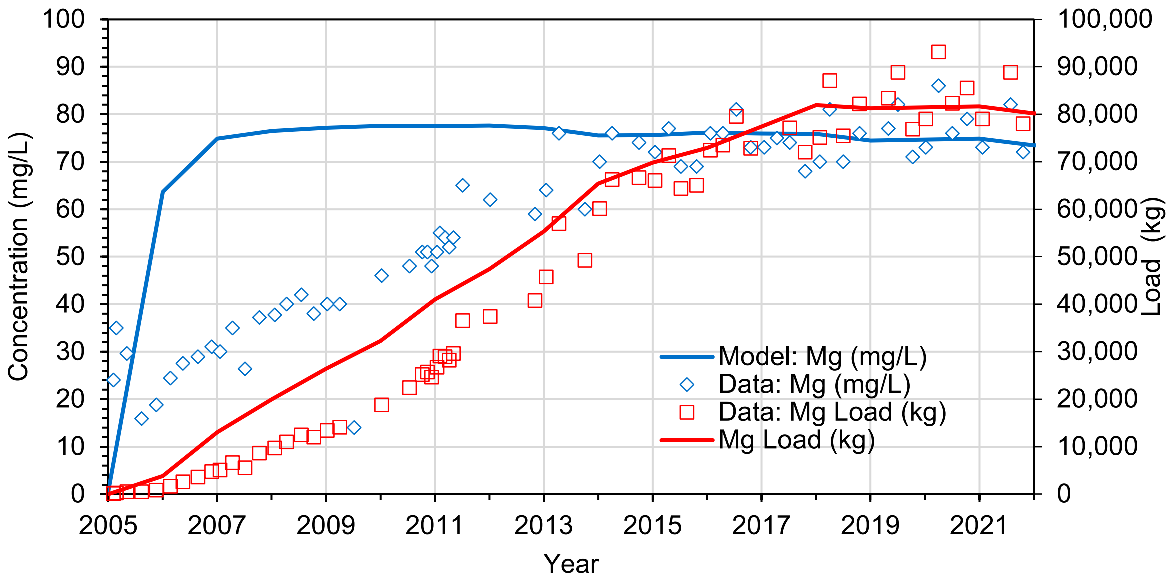


Figure 14. Magnesium concentrations and load estimates for the GPL analogue model compared to data.

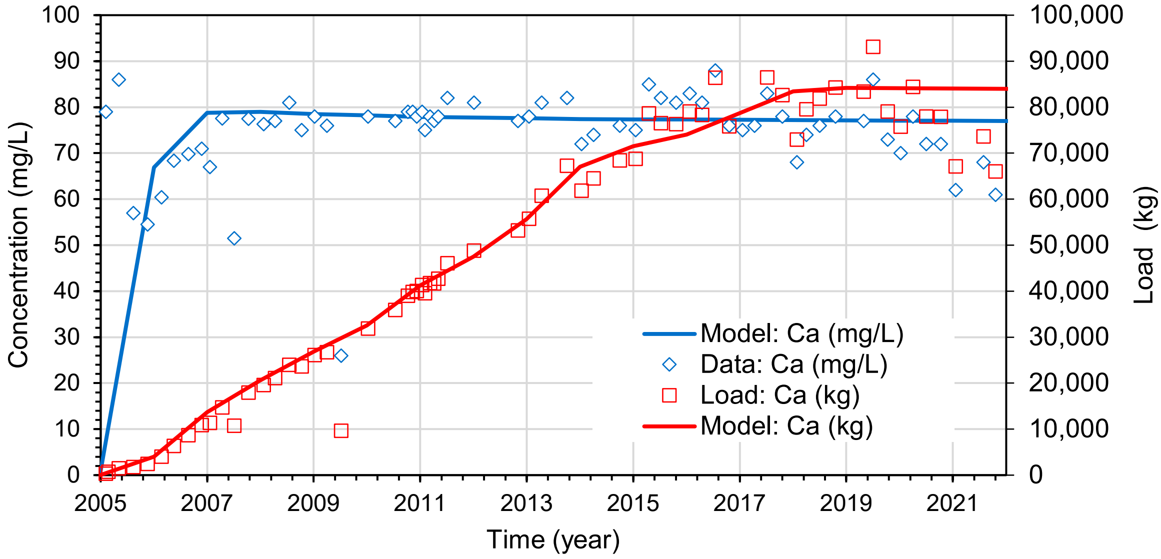


Figure 15. Calcium concentrations and load estimates for GPL analogue model compared to data.

Arsenic

The modelled arsenic concentrations have been plotted using the 2.5x Analogue Model adjustment factor (Figure 16), which shows arsenic concentrations and loads with respect to time. The following observations are made:

- Empirical data shows the concentration was ~0.6 mg/L in 2006 and has a decreasing trend over time and stabilises around ~0.13 mg/L.
- The model underestimates the concentration and load in the first years, but in the mid-term (after 13 years) fits the data for load and concentration.
- Data for load increases in the first years (2005 to 2007) from 0 to ~100 kg, and then increases to ~150 kg by year 2011 where it remains relatively stable, however a peak in the load of ~180 kg is reached by year 2015 but then decreases back to ~150 kg.

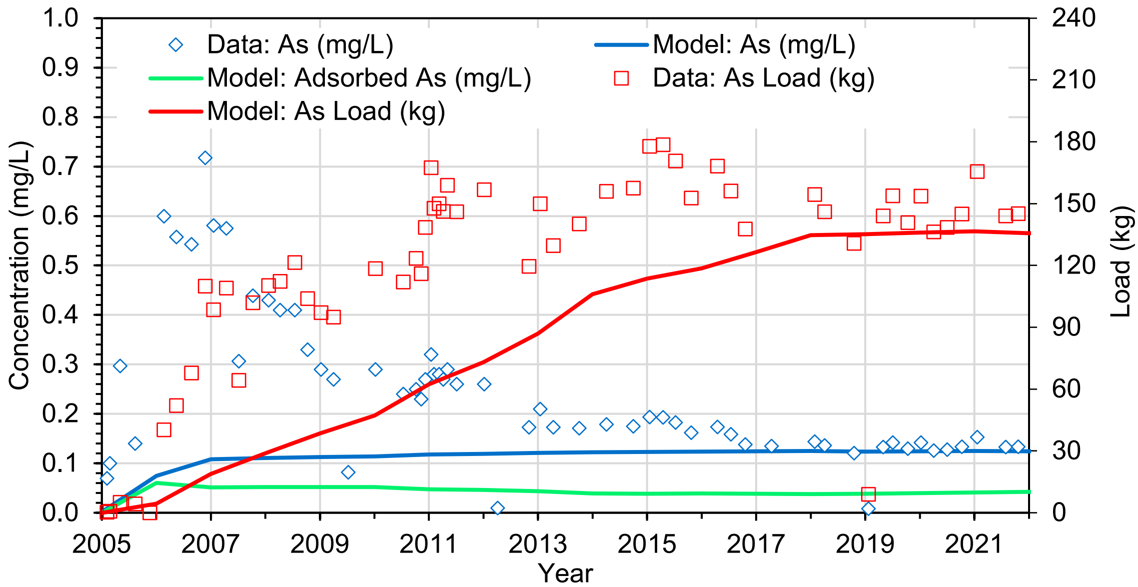


Figure 16. Arsenic concentrations and load estimates for As in the GPL analogue model compared to data.

A key observation of this arsenic analysis is that the data are reasonable in the longer term for the pit lake model, which is the reasonable as pit lake spilling at this project area will happen after several decades.

SUMMARY AND RECOMMENDATIONS

This memorandum presented the hydrogeochemical analogue model of the current GPL. The following summary and recommendations are provided:

- A calibrated water balance for GPL was provided by GHD (2023), using insitu lake level monitoring and hydrological data.
- The load for several parameters was estimated by multiplying the concentration by the estimated volume of the pit lake to compare to the modelled data.
- The pit wall source term (an average of the pit lake water quality when it was stable (2013 – 2022), was adjusted by a factor of 2.5 in the calibration process to best fit the data.
- Nitrogen was not conservative, and data shows that it is naturally removed from the solution. Approximately 20-30% of the NO_3-N load is lost annually, and the NO_3-N load estimation approaches zero by 2018. Amm-N also exhibits a decaying trend, with concentrations and loads decreasing to zero within a year.
- The primary source of nitrate is assumed to be ANFO, where nitrogen comes from the NH_3NO_3 component.
- The model incorporates two essential kinetic processes to simulate the decay of nitrogen in the pit lake, nitrification and denitrification, which are fitted to empirical data. These equations can be applied to other pit lakes at the Macraes Mine.
- Results indicate that ~5.35 g/m^2 of nitrogen as NH_3NO_3 can be sourced from pit walls. This initial load should be applied to any other pit lakes within the Macraes mining area.
- The derived pit wall run-off source term (Table 4) can be applied to other pit lake models as a reasonable estimate of water quality.

CLOSING REMARKS

Further information is provided in the following attachments:

Attachments: Attachment A – GW and SW Source Term Descriptions

Attachment B – Nitrogen Decay Rates added to PHREEQC

Attachment C – Saturation Index Calculations for Carbonates and Alkalinity

Attachment D – Digital Attachment Golden Bar Extension Pit Lake Analogue Model Results Excel File

REFERENCES

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ATTACHMENT A – SW AND GW SOURCE TERM DESCRIPTIONS

Surface Water Source Term (Monitoring Point GB02)

Parameter	Count	Min	Max	Ave	Med	Water Quality Limit#	MEQ Analysis
pH(pH units)	32	6.60	7.80	7.44	7.50	-	-
EC (µS/cm)	31	81.0	230.0	116.2	104.0	-	-
Alkalinity - Total (mg $CaCO_3$/L)	31	4.0	100.0	33.5	32.0	-	-
Alkalinity - Bicarbonate (mg $CaCO_3$/L)	32	10.0	100.0	34.7	32.0	-	-
Carbonate Alkalinity (mg $CaCO_3$/L)	8	1.00	11.0	2.25	1.00	-	-
Hardness-Total (mg $CaCO_3$/L)	27	17.0	93.0	35.4	29.0	-	-
Nitrate-N	1	0.030	0.030	0.030	0.030	2.4	0.01
Nitrate-N + Nitrite-N	2	0.005	0.011	0.008	0.008	-	-
Nitrite-N	1	0.002	0.002	0.002	0.002	-	-
Nitrogen-Total	4	0.002	0.870	0.313	0.190	-	-
Nitrogen-Total Ammoniacal	7	0.010	0.160	0.033	0.010	0.24	0.67
Total Inorganic Nitrogen	2	0.011	0.016	0.014	0.014	-	-
As	31	0.001	0.009	0.002	0.001	0.15	0.06
Ca	32	3.70	27.0	8.8	7.1	-	-
Cl	31	7.60	14.7	10.04	9.90	-	-
Cu	7	0.0007	0.016	0.0031	0.0009	0.009	1.78
Fe	31	0.04	0.63	0.19	0.17	1	0.63
K	32	0.10	2.40	0.72	0.69	-	-
Mg	32	1.90	6.1	3.2	2.75	-	-
Na	32	7.60	11.9	8.7	8.3	-	-
Pb	7	0.0001	0.001	0.0003	0.0001	0.0025	0.05
SO_4	32	2.20	17.2	6.7	6.3	1,000	0.02
Zn	2	0.0010	0.0042	0.0026	0.003	0.12	0.01
Sum of Anions (meq/L)	7	0.800	1.23	1.01	0.96	-	-
Sum of Cations (meq/L)	7	0.850	1.3	1.03	1.00	-	-

Notes:

- Water Quality Limits obtained from the OceanaGold water quality management plan (2020).

All units are presented in mg/L unless otherwise specified.

Metals and metalloids are presented as dissolved.

pH was determined from average H+ concentration converted to log scale

A hyphen (-) indicates that no data were available.

Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018).

RED Text = MEQ values are >1.0 MEQ where MEQ is based on maximum data.

Groundwater Source Term (Monitoring Well MAC-RCH3004)

Parameter	Count	Min	Max	Average	Median	Water Quality Limit[#]	MEQ Analysis
pH(pH units)	39	6.30	7.40	6.89	7.00	-	-
EC (µS/cm)	33	93.0	175.0	156.5	162.0	-	-
Alkalinity - Bicarbonate (mg $CaCO_3$/L)	40	14.0	67.0	50.1	53.5	-	-
Carbonate Alkalinity (mg $CaCO_3$/L)	33	1.00	1.00	1.00	1.00	-	-
Hardness-Total (mg $CaCO_3$/L)	40	26.0	69.0	51.7	53.0	-	-
Nitrate-N	14	0.002	1.700	0.407	0.079	2.4	0.71
Nitrate-N + Nitrite-N	16	0.002	1.730	0.365	0.051	-	-
Nitrite-N	14	0.002	0.069	0.0124	0.0055	-	-
Nitrogen-Total Ammoniacal	16	0.01	0.32	0.047	0.01	0.24	1.33
Total Inorganic Nitrogen	7	0.011	2.00	0.784	0.18	-	-
As	40	0.001	0.006	0.0014	0.001	0.15	0.04
Ca	40	4.70	11.2	8.18	8.65	-	-
Cl	40	5.00	12.0	8.20	8.35	-	-
$CN_{(WAD)}$	2	0.001	0.001	0.001	0.001	0.1	0.01
Cu	12	0.0005	0.0099	0.0025	0.0005	0.009	1.10
Fe	40	0.02	6.20	4.48	5.15	1	6.20
K	40	0.74	2.80	0.97	0.90	-	-
Mg	40	3.40	10.9	7.60	8.05	-	-
Na	40	6.70	11.0	9.38	9.40	-	-
Pb	12	0.0001	0.0001	0.0001	0.0001	0.0025	0.02
SO_4	40	5.00	24.0	13.3	13.0	1,000	0.02
Zn	4	0.020	0.065	0.045	0.048	0.12	0.61
Sum of Anions (meq/L)	33	0.690	1.86	1.48	1.56	-	-
Sum of Cations (meq/L)	33	0.850	1.90	1.59	1.67	-	-

Notes:

Source: OceanaGold Mine Water Quality (excel database).

- Water Quality Limits obtained from the OceanaGold water quality management plan (2020).

All units are presented in mg/L unless otherwise specified.

Metals and metalloids are presented as dissolved.

pH was determined from average H+ concentration converted to log scale

Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018).

RED Text = MEQ values are >1.0 MEQ where MEQ is based on maximum data.

ATTACHMENT B – NITROGEN DECAY RATES ADDED TO PHREEQC

Summary

Two processes are included in the PHREEQC code using Parkhurst's[5] approach, modifying rates to match the Golden Bar pit lake empirical data. For modelling purposes NH_3 is named Amm (from ammonia) following the Amm.dat database approach (Parkurst & Appelo, 2013) and is "uncoupled" from the NO_3 equations, and the key reactions that are modelled are listed below:

- **(Eq. 1)** $AmmH^+ = Amm + H^+$
- **(Eq. 2)** $NO_3^- + 2H^+ + 2e^- = NO_2^- + H_2O$
- **(Eq. 3)** $2\ NO_3^- + 12\ H^+ + 10\ e^- = N_2 + 6\ H_2O$

The first equation models the speciation between AmmH+ (NH_4 ammonium) and Amm (NH_3 ammonia). The second models the speciation of NO_3^- and NO_2^-. And the third one models the reaction/change between NO_3^- and aqueous N_2.

The first kinetic process to include is *Denitrification* which converts N_2 to Ntg (Nitrogen gas). By removing N_2 from solution, we are also converting NO_3^- to N_2 to compensate for the decrease in N_2 (due to equation 3). Conceptually this process would represent the change from NO_3^- to Nitrogen gas.

The second process is ammonia oxidation or nitrification, which converts Amm to NH_3. Due to NH_3 not being defined in the database, the NH_3 is assumed to be as the most stable species which would be NO_3^- (in an oxic environment). For denitrification, consumption of organic matter (CH_2O) is assumed, and specified in the RATES and KINETICS formula as defined by Parkhurst[3] as follows:

```
RATES
Denitrification
-start
10 NO3_load = MOL("NO3-")*TOT("water")
30 moles = NO3_load*0.0075*TIME/31557600 #seconds in a year
200 SAVE moles
-end

Amm_oxidation
-start
10 rate = 0.2/(31557600)#Seconds in a year
20 AmmLoad = TOT("Amm")*TOT("water")
40 moles = rate * TIME * AmmLoad
50 SAVE moles
60 END
-end

KINETICS 1
Denitrification
-formula  CH2O  5 N2  -2 Ntg  2
-m       1
-m0      1
 -tol    1e-08
```

[5] Denitrification and Nitrification processes: https://phreeqcusers.org/index.php?topic=465.0

```
Amm_oxidation
-formula  Amm  -1 NH3  1
-m        1
-m0       1
-tol      1e-08
```

ATTACHMENT C – SATURATION INDEX CALCULATIONS FOR CARBONATES AND CO2

The analysis of the saturation phases shows the following:

- The estimated saturation index of CO_2(g) was found to be close to -3.1, indicating that the pCO_2 level in the pit lake is higher than the ideal atmospheric value of -3.4. Therefore, a saturation index for $CO_{2(g)}$ of -3.1 was applied to the model.
- Dolomite ($CaMg(CO_3)_2$) is super saturated in the samples, but data at Macraes suggest that magnesium remains in solution with a good correlation with sulfate. Therefore, no dolomite precipitation should be expected which agrees with the literature (Weightmann, 2020).
- Calcite equilibrium (dissolution and precipitation) constrains the Ca and alkalinity concentrations. In the samples, calcite is supersaturated at a stable saturation index of ~0.85. The saturation index of calcite is set to 0.85, therefore, allowing a supersaturation before precipitation.

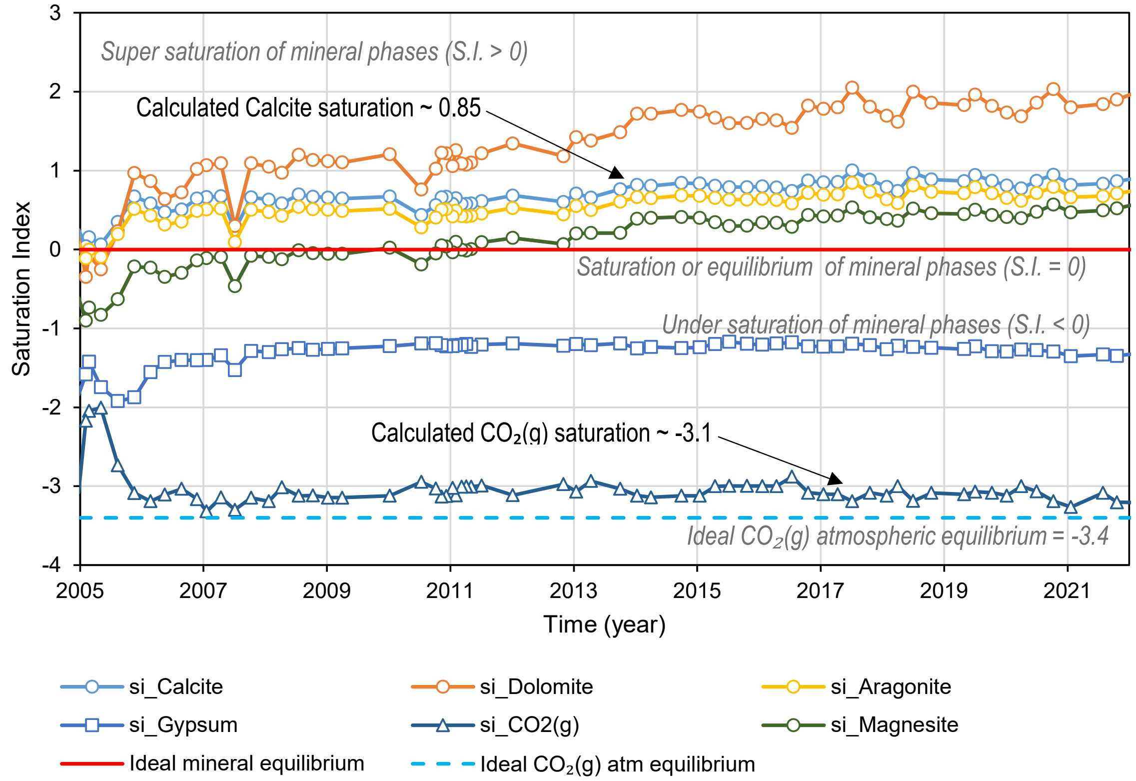

Figure 17. Calculated saturation indices (PHREEQC) for relevant phases in the Golden Bar Pit Lake dataset.

ATTACHMENT D – DIGITAL ATTACHMENT GOLDEN BAR CURRENT PIT LAKE ANALOGUE MODEL RESULTS EXCEL FILE

APPENDIX K GOLDEN BAR STAGE 2 PIT LAKE MODEL

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MEMORANDUM

Recipient:	Dean Fergusson – OceanaGold Limited
From:	Paul Weber – Mine Waste Management
Date:	16 January 2024
Cc:	Carlos Hillman – Mine Waste Management; Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0284-002-M-Rev2
Document Title:	Macraes Phase 4.3 Golden Bar Pit Stage 2 Pit Lake Model

Mine Waste Management Limited (MWM) has been engaged by OceanaGold Limited (OceanaGold) to undertake a geochemical assessment of the Golden Bar Pit Stage 2 Extension at the Macraes Gold Mine (Macraes) to:

- Determine the current and future water quality trends for current Golden Bar Pit Lake (GPL).
- Determine pit lake dewatering options of the current pit lake.
- Determine water management options at mine closure for the Golden Bar Pit (Stage 2) Lake extension (GPL-E).

To estimate future pit lake water quality, it was proposed that the current water quality in GPL could be used as an analogue for the GPL-E using empirical site-specific data. This has been successfully completed (MWM, 2024).

This memorandum presents the results of the GPL-E pit lake model for the Golden Bar Pit Stage 2 Extension.

BACKGROUND

Previous work on the GPL was completed by Golder (2011) who noted that active water management in the Golden Bar Pit ceased in 2005 with the pit lake filling passively thereafter via rainfall, run-off, and groundwater seepage. Golder (2011) noted the lowest elevation of the pit lake is 455 mRL, whereas the lowest portion of the pit rim is 500 RL, which is the spill point for the pit with 1,051,380 m^3 of storage capacity. There is also backfill within the pit containing approximately 160,000 m^3 of waste rock material, which provides an additional 32,000 m^3 of void capacity (based on 20% porosity). In 2018 the current GPL started discharging to a Waikouaiti River North Branch Tributary (as per GHD (2023) model) having reached a height of 500 mRL.

It is proposed that the current Golden Bar Pit will be expanded by ~ 200 m to the east and northeast and the current Golden Bar Waste Rock Stack (GB-WRS) will be expanded to accommodate the additional waste rock, increasing the height of GB-WRS by ~70 m providing ~30 Mt of additional storage capacity (Figure 1). The proposed Stage 2 Pit extension will be approximately 45 m deeper than the current pit and generate 1.3 Mt of ore and 27 Mt of waste rock (OceanaGold, 2022a).

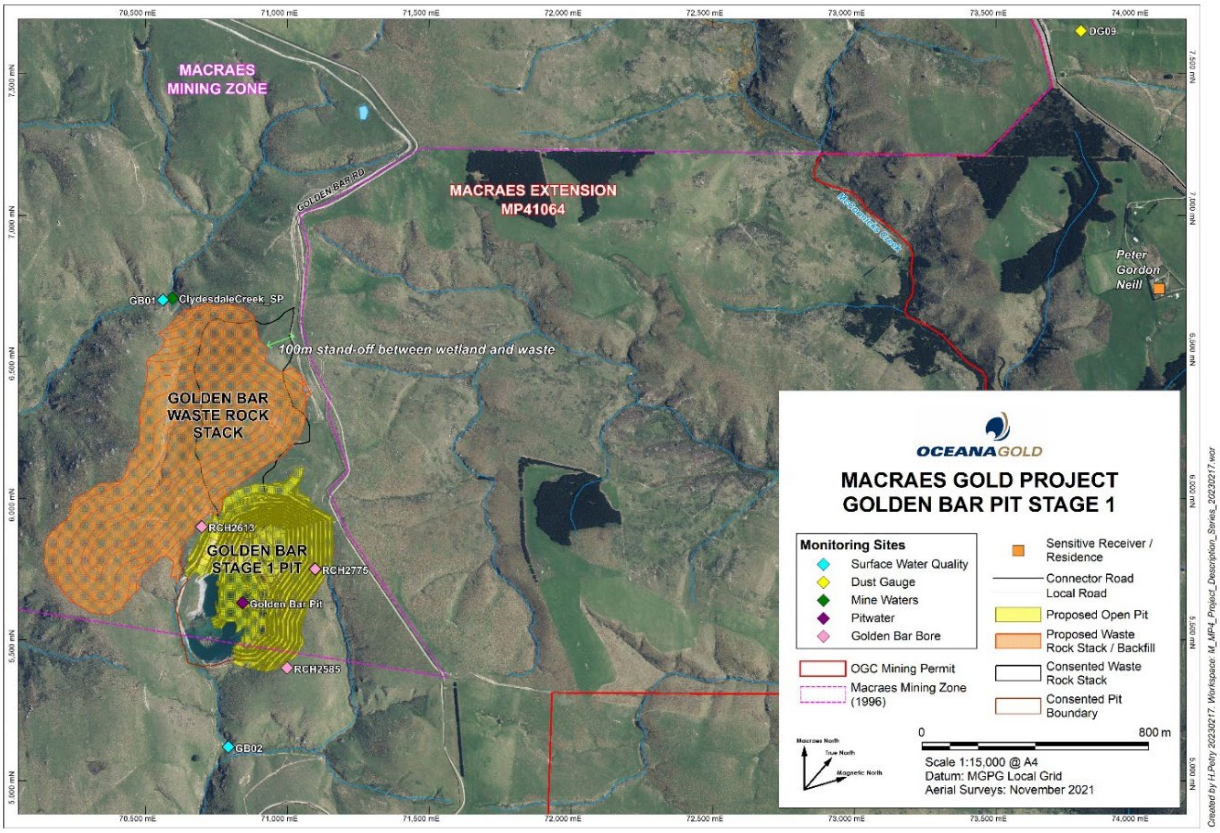

Figure 1. Golden Bar Pit Stage 2 Extension.

Source: OceanaGold

GPL WATER QUALITY

A detailed analysis on the water quality data for GPL was provided in the MWM (2024) memorandum. A summary of that analysis is provided in this section:

- There is available data for the Golden Bar Pit Lake from 2004 to 2022.
- It was determined that data from 2013 to 2022 provides a better representation of stable water quality conditions compared to the full data set that ranged from the 2004 to 2022, although pit lake discharge occurs from ~2015 onwards. During this period:
    - pH levels ranged from 8.10 – 8.50 and pH has remained relatively stable.
    - The average sulfate concentration was 288 mg/L, which is well below the compliance limit of set at 1,000 mg/L (NBWRT: North Branch Waikouati River Tributary Compliance Point 1).
    - Average As concentration was 0.163 mg/L, with a maximum concentration of 0.21 mg/L, which is elevated.
    - Other parameters are low e.g., cyanide-WAD, copper, iron, lead, zinc, sulfate, and pH).

- Nitrate nitrogen concentrations ranged between 0.002 and 0.023 mg/L with an average concentration of 0.008 mg/L.

WATER QUALITY MODELLING

This section explains the methodology and results for developing a long-term hydrogeochemical water quality model for the GPL-E. The purpose of the model is to understand potential environmental risks and provide a water quality source term (versus time) to understand potential effects on groundwater, surface water, and the subsequent downstream receiving environment.

Water Balance and Pit Geometry

GHD (2023) developed a water balance model for the current GPL, which modelled the filling of the current pit lake against measured levels. Using that as a calibration tool, GHD developed the water balance for the GPL-E for 50 years post-closure. The GPL-E model indicated that:

- First overflow (to Waikouaiti River North Branch Tributary) is estimated to occur at year 35 of the model.
- The pit lake overflows steadily (overflow level at 497.5 mRL for the GPL-E, which is 2.5 m lower than the current pit lake (500 mRL)) at year 40.
- There is no groundwater loss predicted, only groundwater inflow.

The evolution of the GPL-E lake level and water volume is shown in Figure 2.

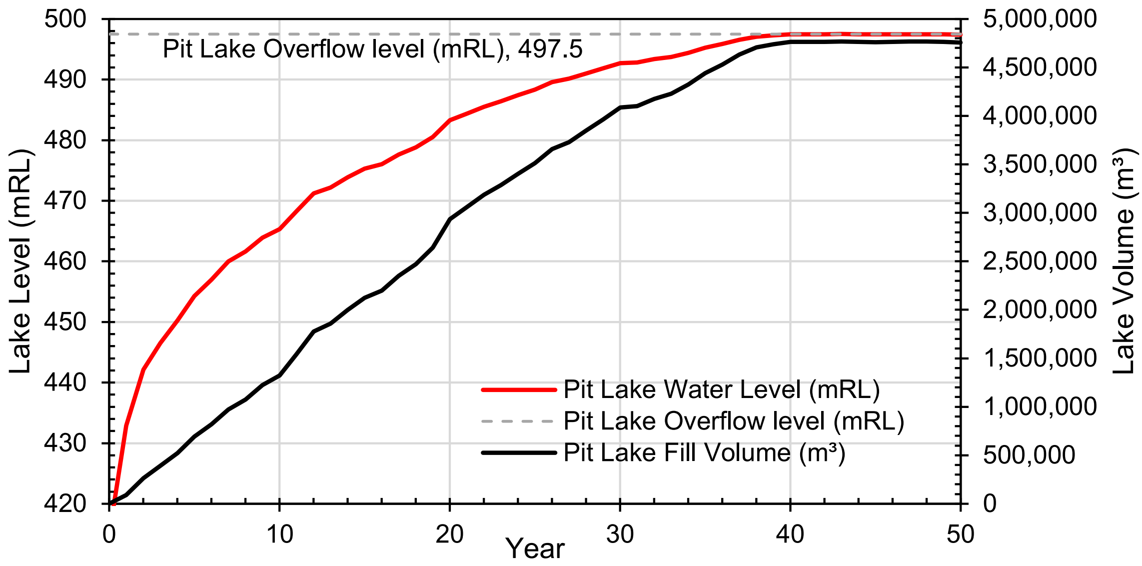

Figure 2. Golden Bar Pit Expansion Pit Lake water balance model.

Data Source: GHD (2023).

Steady discharge to the NBWRT occurs from year 40 with an average flow of 102,002 m^3/year. Figure 3 shows the relative average flows per year from years 40 to 50. The main inflow comes from the runoff (pit wall, natural catchment, and the Golden Bar WRS) accounting for 49% of the inflows, with direct rainfall being 47% and a small inflow (2%) from the WRS seepage and 2% from groundwater inflow.

Regarding the outflows, on average, 50% of the discharged water flows to the river, which is referred to as "Flow to River" (NRNBT) whilst the other 50% of the outflow is associated with evaporation.

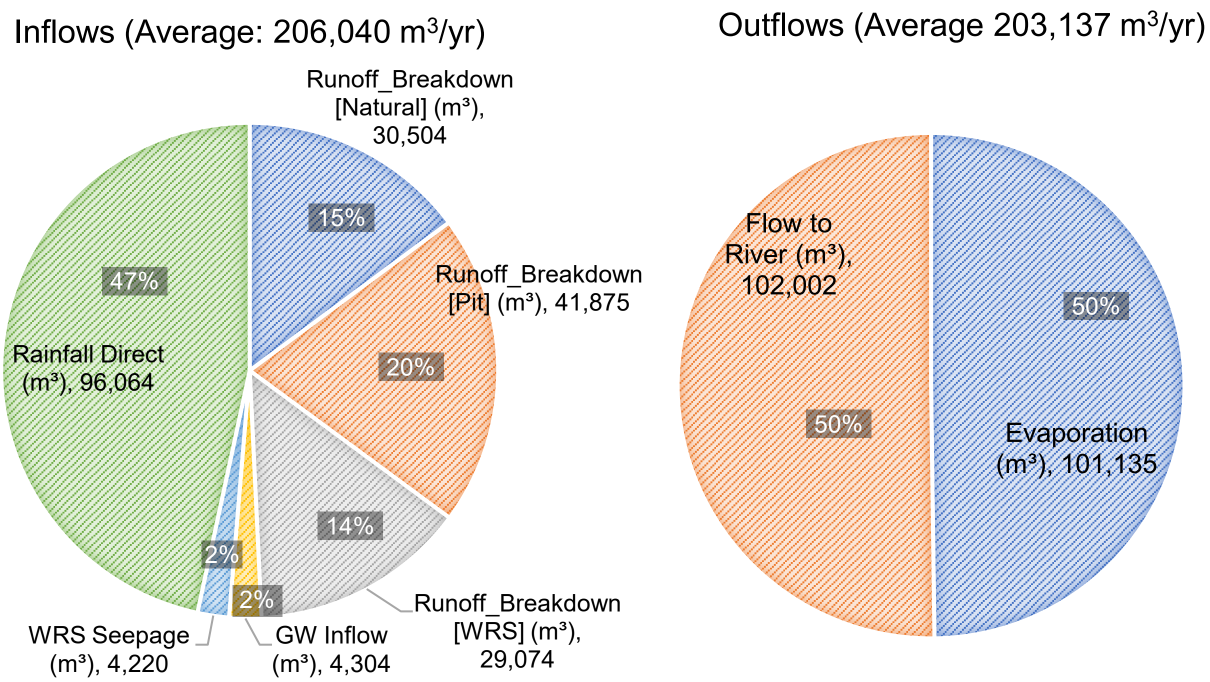

Figure 3. Pie chart of the distribution of average inflows and outflows from year 40 to 50.

Data Source: GHD (2023).

Conceptual Site Model

A conceptual site model (CSM) has been developed to facilitate the assessment of water quality risks for the project. The CSM (Figure 4) is based on a proposed final closure design for the project. The key features of the CSM, as noted in Figure 4, are presented in Table 1. Source terms are discussed in subsequent sections.

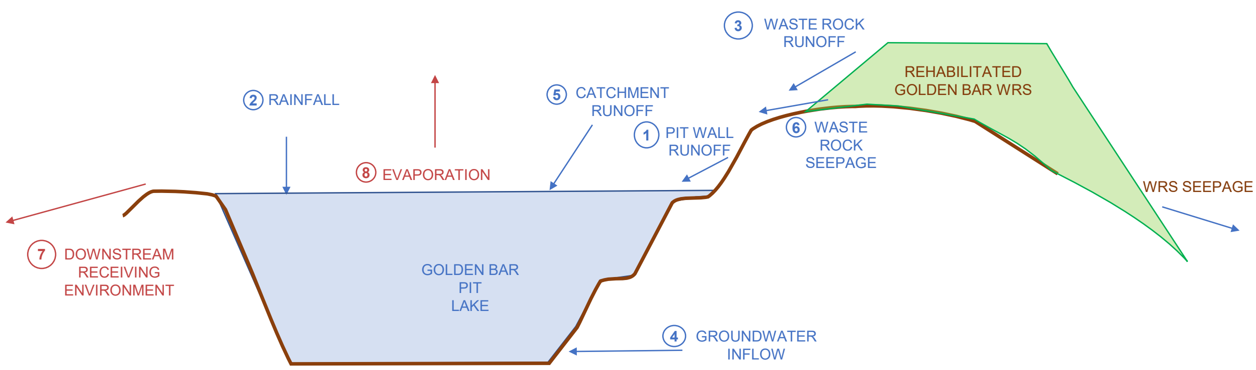

Figure 4. Conceptual site model for the GPL-E.

Table 1. Key components and processes associated with the hydrogeochemical pit lake model.

MODEL FEATURE	SUMMARY	DATA SOURCE
	MODEL INPUTS	
1	Pit wall run-off to the Pit Lake	Water quality derived from the Golden Bar Pit Lake Analogue Model (MWM, 2024).
2	Direct rainfall to the Pit Lake.	Water quality was derived from Nichol et al. (1997).
3	WRS runoff to the Pit Lake.	Water quality derived from monitoring point GB02 before it was influenced by the pit lake discharge.
4	Groundwater inflow.	Groundwater inflow water quality data derived from monitoring wells MAC-RCH3004.
5	Catchment runoff.	Surface water quality data derived from the monitoring point GB02 before it was influenced by the pit lake discharge.
6	WRS seepage.	Derived from empirical correlations (Babbage, 2019, 2022 and MWM, 2023).
	MODEL OUTPUTS	
7	Outflow (spill) to downstream environment.	Rates determined by GHD (2023) discharging to the NBWR tributary.
8	Evaporation of water causes an increase in concentration of solutes. Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations (also known as evapoconcentration).	Rates determined by GHD (2023).

Derivation of Source Terms

This section provides additional notes on the source terms used for the hydrogeochemical model.

Run-off Water from Pit Walls and Waste Rock

Water quality for rainfall run-off interacting with the pit walls and the WRS was derived from the current average Golden Bar Current Pit Lake water quality multiplied by a factor of 2.5 (MWM, 2024). This source term is assigned to the “Pit” runoff component of the water balance and provides a constant concentration (shown in Table 2) for flows from pit walls.

Golden Bar WRS – Seepage

Waste rock material situated above pit lake level will generate seepage due to rainfall infiltration. According to the GHD (2023) water balance, it is projected that a minor fraction of the Golden Bar WRS (GB-WRS) toe seepage will seep into the GPL, with most seepage reporting to the Clydesdale Creek (as is currently occurring). Thus, whilst some seepage from the GB-WRS will end up in the pit lake, it represents only a portion of the total seepage generated by the waste rock. Babbage (2022) developed a relationship (Eqn. 1) to forecast sulfate concentrations that considered age and average height (volume / area) but there was no limit to the maximum sulfate concentration or decay with time. MWM (2023) noted that this would create very high concentrations in any predictive models over the longer term (e.g., 100 years) due to the age multiplier.

Instead, a sulfate ceiling limit was proposed based on empirical data for WRS of differing height.

.

$$(Eqn.1): Median\ Sulfate\left(\frac{mg}{L}\right) = 96.1 + 1.22 * \ Average\ Height\ (m) * \left(4 * Age1(year) + Age2(year)\right)$$

Where Age 1 is the time the WRS is in full operation (not capped) and Age 2 years when it was in partial operation (partially capped).

To determine a sulfate concentration, MWM (2023) determined a correlation between the maximum sulfate concentration and WRS height based on site data:

$$(Eqn.2): Average\ Height < 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 850\exp\left(0.025\ \times\ Average\ Height\ (m)\right)$$

$$(Eqn.3): Average\ Height \geq 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 120\exp\left(0.0965\ \times\ Average\ Height\ (m)\right)$$

The average height of the portion of the GB-WRS that reports to the GPL-E is 26.4 (pers. comm. Jeff Tuck, GHD – email 22 March 2023), which in Equation (2) results in a concentration of 1,645 mg/L of sulfate. Using the correlations from the WRS water quality memo (MWM, 2023) other parameters are estimated as shown in Table 2.

<u>Rainfall, Groundwater, and Runoff from Natural Catchment and WRS</u>

These source terms are derived as per the Golden Bar Analogue Model (MWM, 2024). In summary:

- Rainfall water quality is derived from the study of Nichol et al. (1997) from a site 70 km from Macraes at 316 mRL with rainfall water quality data from 1983 to 1994.
- Groundwater is derived from the water quality data from 2011 to 2022 from the monitoring well MAC-RCH3004 as this was located 2.8 km to the northwest of the Golden Bar Pit.
- Run off from natural catchment and the rehabilitated WRS runoff are derived from the monitoring point GB-02 using the average data from May 2007 to October 2014.

Values used in the model are shown in Table 2.

<u>Source Term Summary</u>

Table 2 presents the source terms for the Golden Bar Pit Lake model.

Table 2. Source terms for Golden Bar Pit water quality model.

COMPONENT NAME	GOLDEN BAR PIT WATER QUALITY	RAINFALL	SEEPAGE FROM WASTE ROCK	RUN-OFF FROM PIT WALLS TO GOLDEN BAR	GROUNDWATER	RUNOFF FROM NATURAL CATCHMENT AND REHABILITATED WRS
DERIVATION FROM	GOLDEN BAR PIT WATER QUALITY	NICHOL ET AL., 1997	EMPIRICAL CORRELATIONS [(1)]	GOLDEN BAR PIT WALL SOURCE TERM (ANALOGUE MODEL)	MONITORING WELL MAC-RCH3004	MONITORING LOCATION GB02 (2007 – 2014)
pH	8.37	5.20	6.70	8.37	6.04	7.44
Alkalinity - Total (mg $CaCO_3$/L)	229	0.81	129.0	572.5	n. a.	32.0
Unit	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Al	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
As	0.16	n. a.	0.001	0.409	0.0014	0.002
Ca	76.1	0.11	241.8	190.3	8.18	8.81
Cd	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Cl	6.25	0.6	11	15.6	8.20	10.0
Cu	0.00057	n. a.	0	0.001	0.00248	0.0031
Fe	0.0259	n. a.	0.04	0.065	4.48	0.19
K	4.47	0.09	7.2	11.2	0.974	0.717
Mg	74.5	0.05	262.9	186.4	7.60	3.22
Mn	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Na	13.0	0.32	49.3	32.4	9.38	8.74
NO_3-N	0.008	0.0045	9.19	0.019	0.407	0.03
NO_2-N	0.003	n. a.	n. a.	0.008	0.012	0.002
Amm-N	0.015	n. a.	0.01	0.038	0.047	0.033
Pb	0.00011	n. a.	n. a.	0.0003	0.0001	0.00026
Sb	0.003	n. a.	n. a.	0.008	n. a.	n. a.
SO_4	287.6	0.18	1,645	718.9	13.3	6.72
Zn	0.002	n. a.	n. a.	0.005	0.045	0.0026

(1) Empirical correlations of Babbage (2019,2022) and MWM (2023, Appendix H).

n.a.: not applicable due not being analysed or being below LOR. For modelling purposes n.a. is equivalent to 0. Average values shown but vary according to equations in Babbage (2019, 2022) and MWM (2023, Appendix H).

Modelling Processes and Software

Geochemical processes were modelled using PHREEQC (Parkhurst & Appelo, 2013), a widely used software distributed by the United States Geological Survey (USGS) to perform a variety of aqueous geochemical calculations, such as:

- Aqueous reactions.
- Mixing of solutions.
- Calculation of mineral saturation indices.
- Gas and mineral interaction.

Data inputs modelled, geochemical processes, and outputs produced by the hydrogeochemical model are shown schematically in Figure 5. For each timestep (1 year) represented in the pit lake water balance, the model simulated:

- Mixing volumes of each inflow, as represented by source terms in proportions predicted by the GHD (2023) water balance.
- Concentration of the resulting mixed lake water by removal of pure water, representing evapoconcentration predicted by the water balance.
- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for geochemical processes including:
  - Equilibration with atmospheric gases (O_2 and CO_2).
  - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed lake water.
  - Adsorption of dissolved metals and metalloids to hydrous ferric oxides (HFO) as represented by precipitated iron (hydr)oxide minerals.

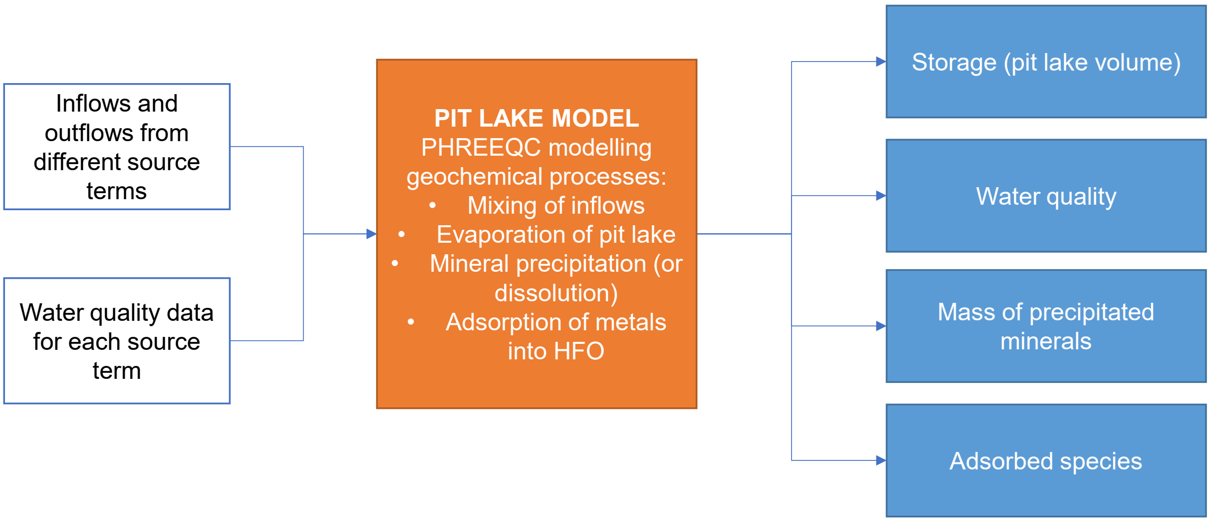

Figure 5. Hydrogeochemical model inputs, modelled processes, and outputs.

The WATEQ4F database was used for thermodynamic calculations, which included the derivation of mineral saturation indices. Mineral phases attaining a saturation index value equal to or greater than zero, which indicates that precipitation of that mineral from solution is thermodynamically favoured, were included as equilibrium phases if those minerals are known to, or likely to, form under surface conditions reflecting a pit lake environment. Adsorption of aqueous chemical species to HFO was modelled using a diffuse double-layer surface complexation model (Dzombak & Morel, 1990), based on modelled precipitation of $Fe(OH)_3(a)$[1] from solution.

As per the Golden Bar Analogue Model (MWM, 2024) the following was included:

- Two geochemical processes were included in the model to represent the nitrification and denitrification processes as modelled in the Golden Bar Analogue Model.
- Saturation index of $CO_2(g)$ was set to -3.1 and calcite to 0.85.

Assumptions and Limitations

The following section discusses general model constraints, key assumptions and limitations relating to the hydrogeochemical model:

- All data provided by OceanaGold are assumed to be correct and no quality control / quality assurance (QAQC) has been undertaken on the datasets provided.
- Data obtained from a variety of sources is assumed to be representative of the materials associated with the project, and data are representative of the key environmental geochemistry risks.
- Outputs from the water balance (GHD, 2023) were assumed to be accurate and complete.
- The model assumes there is no stratification in terms of density (temperature or salinity stratification) or oxidation-reduction (redox) potential within the pits. It is acknowledged that recent data (MWM, 2023) suggest that stratification may be occurring during summer months with slightly higher arsenic at depth compared to surface concentrations. Sulfate remains constant with depth and is not affected by stratification. Such effects for arsenic are not considered in this model.
- Mineral reactions are modelled in equilibrium. If conditions are met, precipitation and dissolution occur instantly until mineral equilibrium, or target, saturation index is attained. Kinetically limited reactions were not accounted for.
- Limited information was available for the chemical composition of some inflows. Where required, the composition was estimated using suitable analogues.
- No redox state (such as pe, Eh or ORP) data were available for source term derivation. A pe value of 10 was applied for all source terms and equilibrium between the lake and the atmosphere (O_2 and CO_2) was assumed.
- All Fe introduced into the model is assumed to be in the Fe^{3+} form.

[1] (a) = amorphous.

- Nitrification and denitrification processes were included to represent the process of ammoniacal nitrogen being converted to nitrate, and nitrate being converted to nitrogen gas, and therefore, leaving the solution. Both processes were empirically fitted in the Golden Bar Analogue Model (MWM, 2023) to provide a suitable model based on empirical data.
- Following the approach in the Golden Bar Analogue Model (MWM, 2024), an initial nitrogen load associated with the pit walls (as NH_3NO_3) was added to account for the ANFO residues that flush into the pit lake. The initial nitrogen load was 5.35 g/m^2 which for the GPL-E area (227,000 m^2), corresponds to 1,215 kg of nitrogen as NH_3NO_3. This load was released over three years in the model to fit previous empirical data trends (MWM, 2024)

RESULTS AND ANALYSIS

Selected outcomes from the hydrogeochemical modelling are presented in this section for the GPL-E pit lake model. A spreadsheet for the modelled parameters is provided as Attachment A to this memorandum.

Water Quality Results

pH and Sulfate

Predicted values for pH and sulfate are shown in Figure 6 where the following can be drawn from the data:

- pH remains constant at ~ 8.38.
- Sulfate concentration reaches a peak of 434 mg/L in the first year and concentrations decrease steadily reaching a concentration of 372 mg/L by year 35 (when the discharge commences) and 370 mg/L by year 50.
- Concentrations are expected to be slightly higher than previous concentrations observed in the current pit lake (~290 mg/L when stable), even though there is less inflow coming from the pit walls (20% in the GPL-E vs 23% in the current pit lake). The increase in concentration is due to the relative increase in evaporation (from 35% in the current lake to 50% in the GPL-E) and the additional of the GB-WRS seepage reporting to the pit lake.

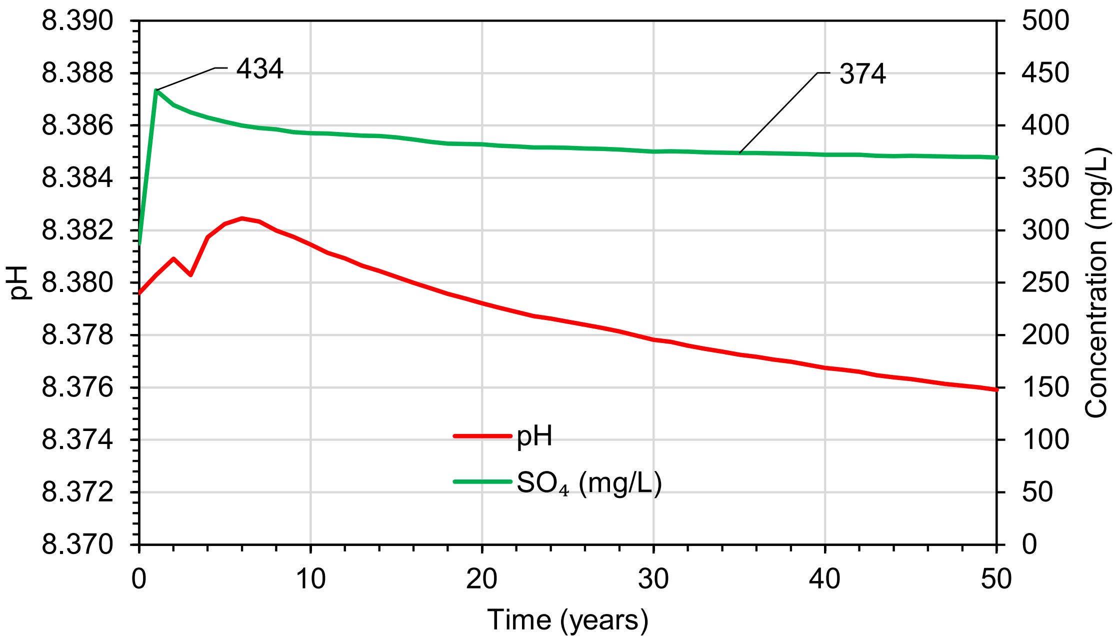

Figure 6. Predicted pH and sulfate for the Golden Bar Extension Pit Lake Model.

<u>Arsenic and Antimony</u>

Results for As and Sb concentrations are presented in Figure 7 and show:

- Sb concentrations remains below 0.004 mg/L.
- As reaches a peak of 0.194 mg/L in year 1 when the pit wall runoff effect is greatest. In the long term, As concentration remain stable at 0.145 mg/L, which is less than the water quality limit of 0.15 mg/L downstream in the WRNBT monitoring point.

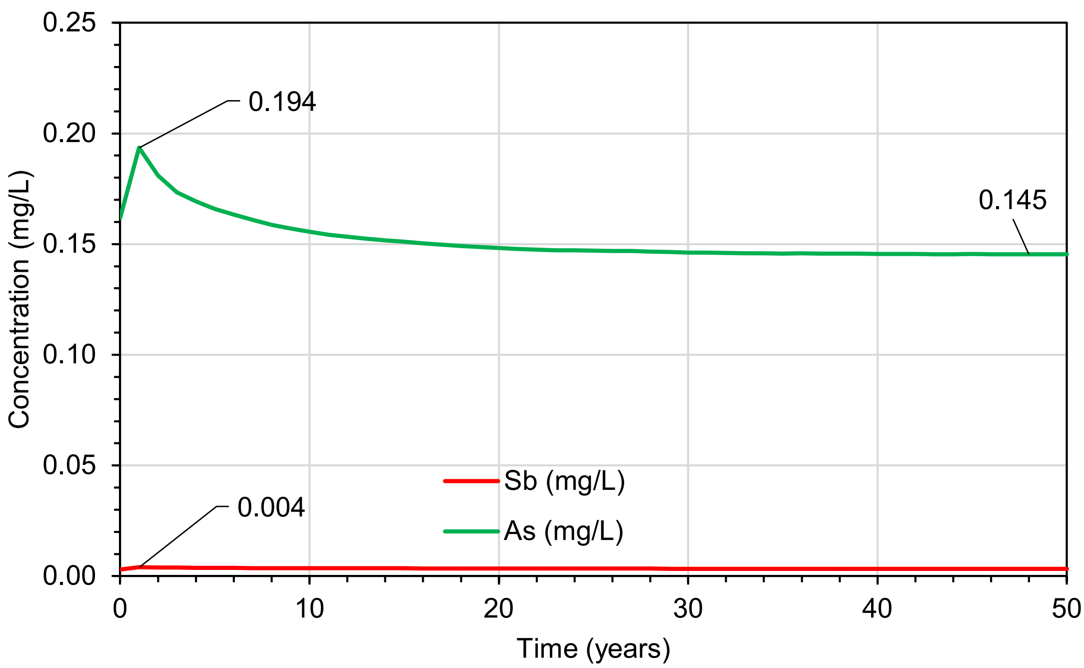

Figure 7. Predicted arsenic and antimony for the Golden Bar Extension Pit Lake Model.

Calcium, Magnesium, Alkalinity

Predicted concentrations for Ca, Mg, and alkalinity are shown in Figure 8. The following can be drawn from the data:

- Concentrations are relatively steady for Ca, Mg, and alkalinity.
- Magnesium reaches a peak in the first year near 110 mg/L and then decreases to ~90 mg/L in year 50.
- For Ca and alkalinity, the concentrations are controlled by calcite precipitation as shown in Figure 9 and remain at ~60 mg/L and ~185 mg $CaCO_3$/L respectively.
- Calcite ($CaCO_3$) precipitation is over 500 tonnes by year 50.

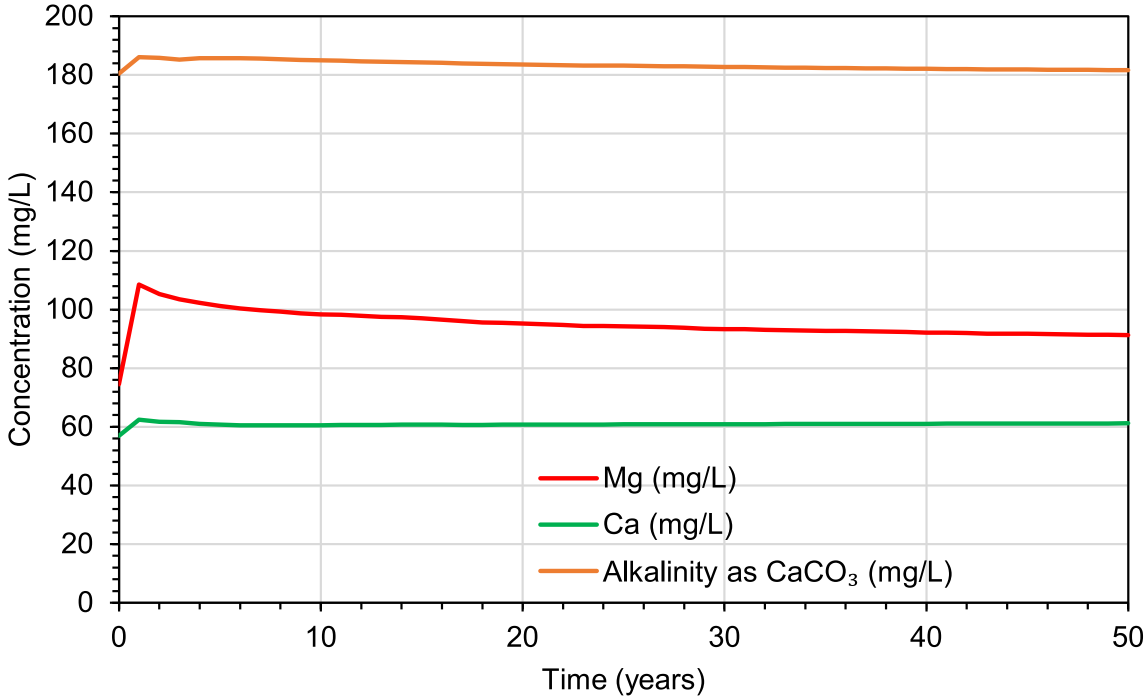

Figure 8. Predicted calcium, alkalinity, and magnesium concentrations, for the Golden Bar Extension Pit Lake Model.

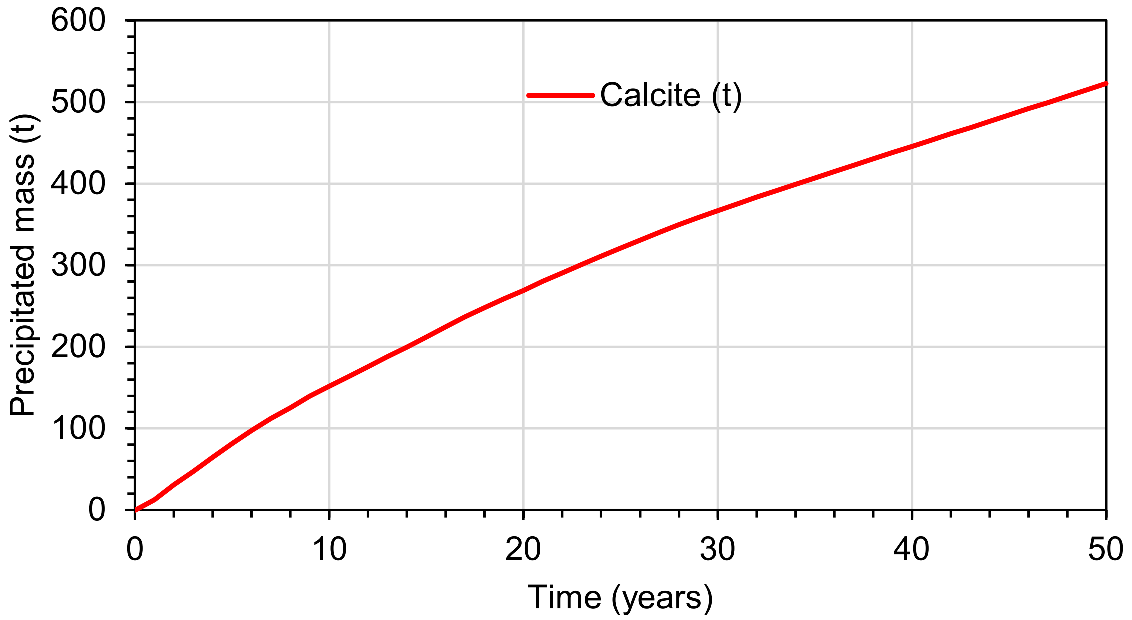

Figure 9. Predicted calcite precipitation for the Golden Bar Extension Pit Lake Model.

Nitrogenous Compounds

Predicted results for nitrate nitrogen (NO_3-N) and ammoniacal nitrogen (Amm-N) are shown in Figure 10. An initial load of 1,215 kg of nitrogen was added as NH_3NO_3 over the first 3 years of the model. From the results the following can be drawn:

- Nitrate nitrogen has an initial peak of 3.21 mg/L in year 1 due to the initial nitrogen load, and then decreases rapidly.
- By year 10, the concentration of NO_3-N decreased down to 0.16 mg/L.
- Ammoniacal nitrogen has an initial peak of 0.28 mg/L in year 1 and the concentrations are below 0.001 mg/L in year 10.
- Both nitrification and denitrification processes are included in the model as derived previously (MWM, 2024) resulting in a decay in nitrogenous compound concentrations.

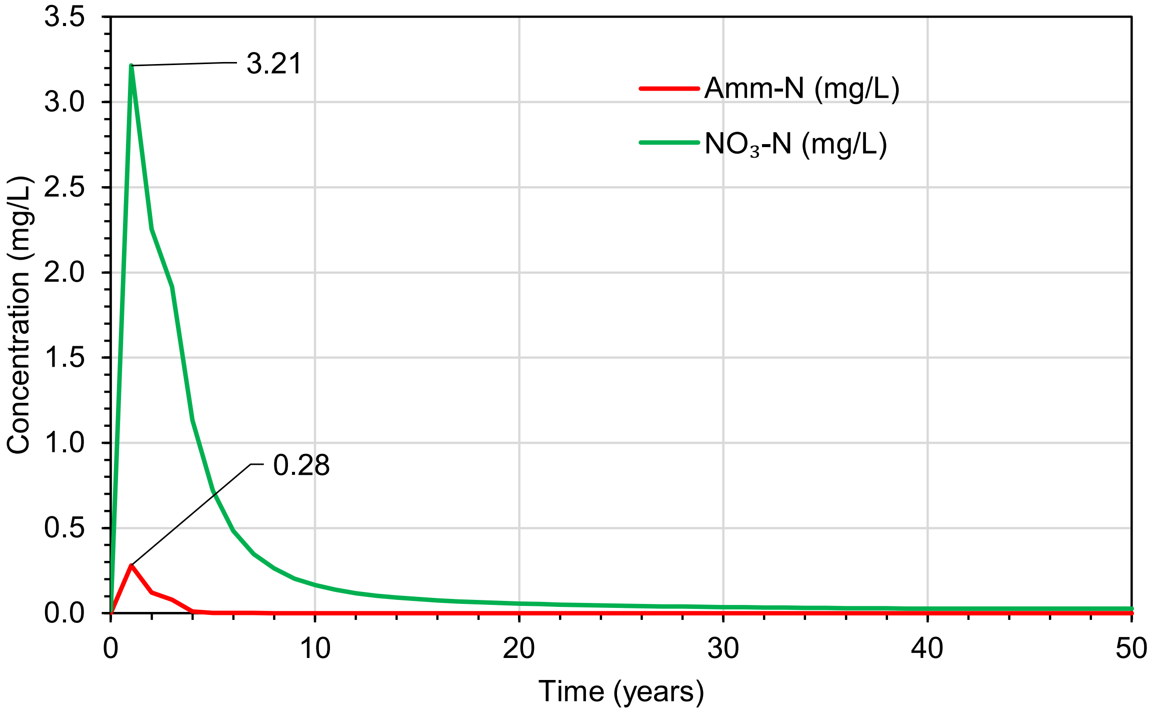

Figure 10. Predicted nitrate and ammoniacal nitrogen concentrations for the Golden Bar Extension Pit Lake Model.

<u>Other Parameters</u>

Other parameters were modelled such as Zn, Pb, but no relevant concentrations were predicted. Maximum concentration for those parameters were 8.1 µg/L and 0.084 µg/L respectively.

SUMMARY

A summary of the predicted water quality at 10 yearly intervals is presented in Table 3. Year 1 is when the peak concentration for several parameters is reached due to the greater effect of the pit walls, which was a function of the GHD (2023) mixing proportions. It is predicted by GHD (2023) that the groundwater discharge of GPL-E pit lake to the North Branch of the Waikouati River will occur from year 35 but will be steady from year 40 onwards.

Table 3. Summary of Golden Bar Extension Pit Lake water quality.

TIME (YEARS)	1	10	20	30	40*	50
pH	8.4	8.4	8.4	8.4	8.4	8.4
TDS (mg/L)	889	819	803	793	788	784
Alkalinity (mg $CaCO_3$/L)	186	185	184	183	182	182
Ca (mg/L)	62	61	61	61	61	61
Mg (mg/L)	109	98	95	93	92	91
Na (mg/L)	23	21	21	21	21	21
K (mg/L)	6.5	5.9	5.8	5.7	5.6	5.5
SO_4 (mg/L)	434	393	382	375	372	370
Cl (mg/L)	13.0	12.8	12.8	12.8	12.9	13.0
NO_3-N (mg/L)	3.21	0.16	0.06	0.04	0.03	0.03
Amm-N (mg/L)	0.3	0.0	0.0	0.0	0.0	0.0
Zn (mg/L)	0.0062	0.0081	0.0079	0.0075	0.0071	0.0067
As (mg/L)	0.194	0.156	0.148	0.146	0.146	0.145
Sb (mg/L)	0.004	0.004	0.003	0.003	0.003	0.003
Calcite (t)	12	152	269	367	446	523

**: The predicted year when discharge to NBWR is stable with an average flow of 102,002 m^3/year.*

CLOSING REMARKS

Further information is provided in the following attachment:

Attachments: Attachment A – Digital Attachment GPE-L Pit Lake Model Results Excel File

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ATTACHMENT A – DIGITAL ATTACHMENT GPL-E LAKE MODEL RESULTS EXCEL FILE

APPENDIX L CORONATION STAGE 5/6 PIT LAKE MODEL

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MEMORANDUM

Recipient:	Dean Fergusson – OceanaGold Limited
From:	Paul Weber – Mine Waste Management
Date:	16 January 2024
Cc:	Carlos Hillman – Mine Waste Management; Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0285-001-M-Rev3
Document Title:	Macraes Phase 4.3 Coronation Pit Stage 5/6 Pit Lake Model Geochemistry Assessment

Mine Waste Management Limited (MWM) has been engaged by OceanaGold (New Zealand) Limited (OceanaGold) to undertake a geochemical assessment of the Coronation Stage 6 Pit Expansion at the Macraes Gold Mine (Macraes). One of the tasks associated with this project was to determine the long-term water quality of the proposed Coronation Pit Lake after Stage 6 (CO6) mining has been completed. This memorandum explains how the long-term pit lake water quality was derived.

BACKGROUND

The proposed Coronation Stage 6 Pit (CO6) consists of a ~250 m expansion to the southeast and is expected to involve a total movement of approximately 2 Mt of ore and 31.5 Mt of waste (OceanaGold, 2023). Waste rock will be transported to Coronation North Pit, which has a capacity of 34.5 Mt and will be backfilled (Figure 1). No additional waste rock will be placed in the vicinity of the Coronation Pit. The average height of the Trimbells Waste Rock Stack (WRS) remains at a height of 35.2 m (pers. comm. Jeff Tuck, GHD – email 26 January 2023).

Water management will require the dewatering of the Coronation CO5 Pit to facilitate additional mining activities associated with Stage 6 expansion. During mining of Coronation Stage 6, pit water will be pumped back to main mining areas, either for final storage in Deepdell Pit, or for use in the processing plant.

The dewatering of Coronation CO5 is anticipated to take around 4 months. Pit dewatering will commence as soon as mining reaches 650 mRL in CO6, which is expected to start in October 2025. Stripping is projected to progress at a rate of 10 vertical meters per month. This memorandum assesses the water quality of the CO6 pit lake after mining activities are complete.

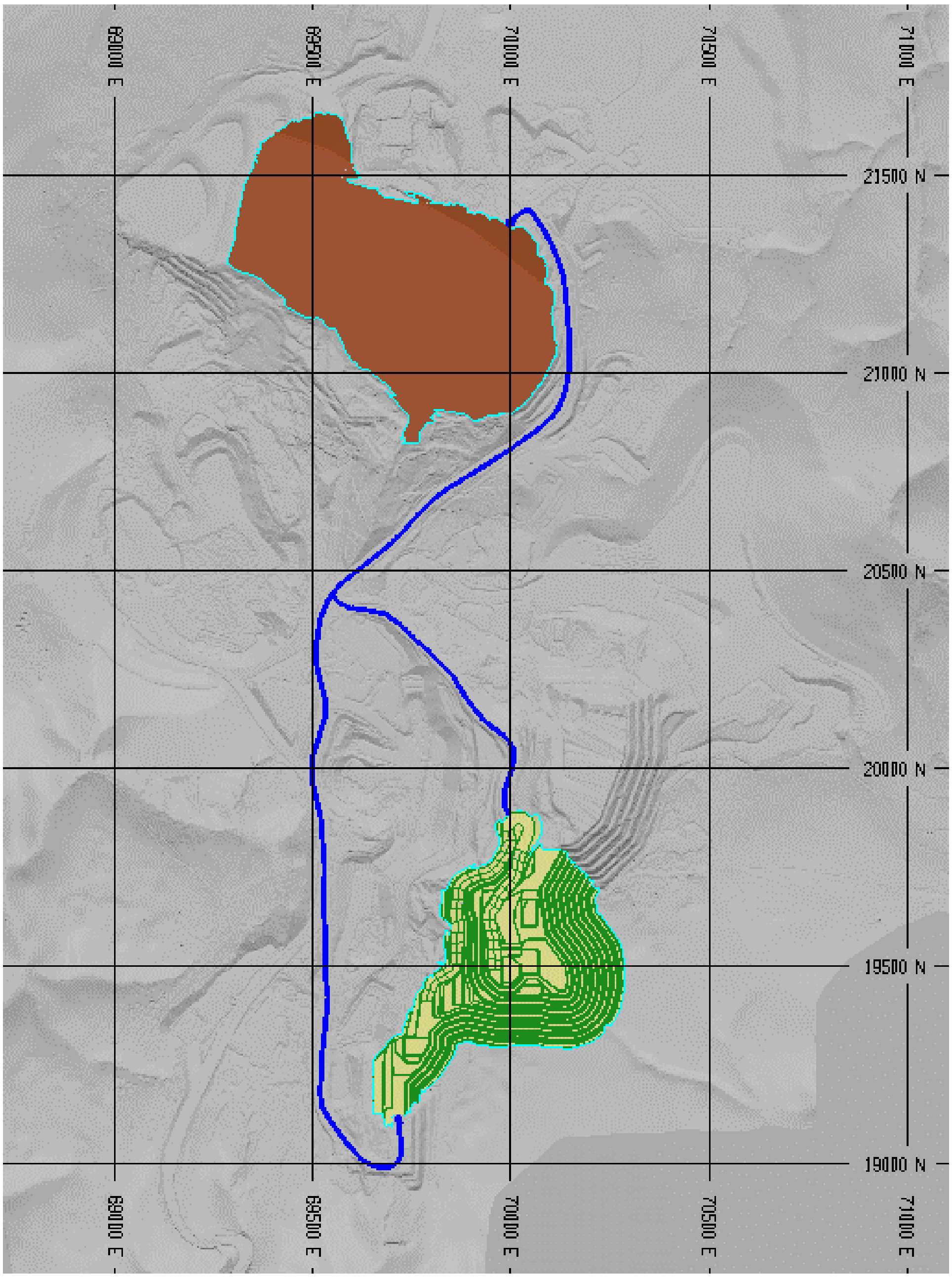


Figure 1. Coronation Stage 6 Pit design and waste rock placement in Coronation North Pit.

Source: OceanaGold (2023): showing the Coronation Stage 6 pit area and the Coronation North backfill.

MINE INFLUENCED WATER

The following section summaries the current water quality of the Coronation (CO5) Pit Sump.

To assess the water quality and understand potential contaminants of concern (PCOC), water quality data were normalised to derive the metal ecotox quotient (MEQ). MEQ is used to identify PCOC that are elevated with respect to water quality compliance limits or trigger values (Weber and Olds, 2016). The MEQ value for a PCOC was determined by dividing the reported maximum concentration by the compliance limit/trigger value. MEQ values greater than 1 indicate parameters that exceed water quality guidelines. Conversely, MEQ values less than 1 are below compliance limits or trigger values and are unlikely to require routine monitoring. For this assessment, some concentrations were ignored for the MEQ analysis as the data was not considered representative of the site.

Table 1 provides the compliance limits used in the MEQ analysis. The sampling location MB01 (Mare Burn compliance point) was selected due to its relevancy to the Coronation project area. These values were used to assess environmental geochemistry data to understand potential effects. Additional parameters were also included to understand other environmental risks including:

- Nitrate-N (NO_3-N) and Ammoniacal-N (Amm-N) were also included to understand the risk associated with nitrogen-based explosives.

Table 1. Water quality guideline limits for geochemical assessment.

PARAMETER	WATER QUALITY LIMIT
As	0.15
$CN_{(WAD)}$	0.1
Cu[1]	0.009
Fe	1.0
Pb[1]	0.0025
Zn[1]	0.12
SO_4	1,000
pH (pH units)	6.0 – 9.5
NO_3-N[2]	2.4
Amm-N[2,3]	0.24

Source: OceanaGold (2020).

All values are given in mg/L unless otherwise specified. CN_{WAD} is weak acid dissociable cyanide.

1 – Cu, Pb and Zn standards are hardness related limits in accordance with an assumed hardness value of 100 g/m³ $CaCO_3$ and will vary depending on actual hardness.

2 – Water quality limits taken from compliance point MB02 (OceanaGold, 2020).

3 – Amm-N (Total Ammoniacal Nitrogen) is the total nitrogen as NH_3 and NH_4.

Water quality samples have been collected from the Coronation Pit Sump since 2005. A summary of all available data (up until 2022) is provided (Table 2) with key parameters presented in Figure 2 – Figure 4.

The observed variability in water quality at the Coronation Pit Sump can be attributed to the inflow of water pumped from various areas within the mining operation. The introduction of water from these distinct areas contributes to the fluctuating concentrations of certain parameters, such as arsenic, total ammoniacal nitrogen, nitrates, and potassium. As a result, the water quality in the sump reflects the mixing of different water sources, each with its unique composition, ultimately influencing the overall variability in the observed concentrations of parameters.

Table 2. Summary of water quality for the Coronation Pit domain (2015 – 2022).

PARAMETER	MIN	MAX	AVE	MED	WATER QUALITY LIMIT#	MEQ (MAX VALUE)
pH (pH units)	7.10	8.30	8.00	8.10	-	-
EC (µS/cm)	262	1,267	771	745	-	-
Alkalinity - Total (mg $CaCO_3$/L)	46.0	260	139	129	-	-
Alkalinity - Bicarbonate (mg $CaCO_3$/L)	45.0	260	138	127	-	-
Carbonate Alkalinity (mg $CaCO_3$/L)	1.00	3.70	1.59	1.40	-	-
Hardness-Total (mg $CaCO_3$/L)	28.0	1,350	400	375	-	-
Total Inorganic Nitrogen	0.160	57.0	8.23	4.80	-	-
Nitrate-N	0.150	42.0	6.99	4.80	2.4	17.5
Nitrate-N + Nitrite-N	0.150	43.0	7.05	4.80	-	-
Nitrite-N	0.003	1.360	0.215	0.041	-	-
Amm-N	0.010	13.8 (6.10)	1.564	0.126	0.24	25.4*
As	0.001	0.430	0.130	0.101	0.001	2.87
Ca	10.2	260	120	114	-	-
Cl	3.50	35.0	7.11	5.00	-	-
$CN_{(WAD)}$	0.001	0.410 (0.115)	0.023	0.020	0.1	1.15*
Cu	0.0005	0.001	0.001	0.0006	0.009	0.11
Fe	0.020	0.200	0.037	0.020	1.0	0.20
K	0.52	10.8	5.04	4.25	-	-
Mg	0.66	172	24.6	23.0	-	-
Na	1.94	35.0	16.0	13.1	-	-
Pb	0.0001	0.0002	0.0001	0.0001	0.0025	0.003
Sb	0.037	0.037	0.037	0.037	-	-
SO_4	18.4	1,390 (590)	267	250	1,000	0.59*
Sum of Anions (meq/L)	2.70	30.0	9.06	8.60	-	-
Sum of Cations (meq/L)	2.80	28.0	9.10	8.55	-	-

Source: OceanaGold Mine Water Quality (excel database).

 # - Water quality limits obtained from the OceanaGold water quality management plan (2020).

All units are presented in mg/L unless otherwise specified.

Metals and metalloids are presented as dissolved.

A hyphen (-) indicates that no analysis was undertaken.

MEQ analysis was undertaken using the observed maximum concentrations, unless otherwise specified.

Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018).

RED Text = MEQ values are >1.0 MEQ.

** - $CN_{(WAD)}$, Amm-N and SO_4 maximum data values have been ignored due to potential erroneous data and instead the next highest value was used for the MEQ analysis (refer to Figure 2 – Figure 4). Brackets ( ) denote the maximum value concentrations used in determining the MEQ for these PCOC. All other statistical analysis (e.g., average values) included all available data.*

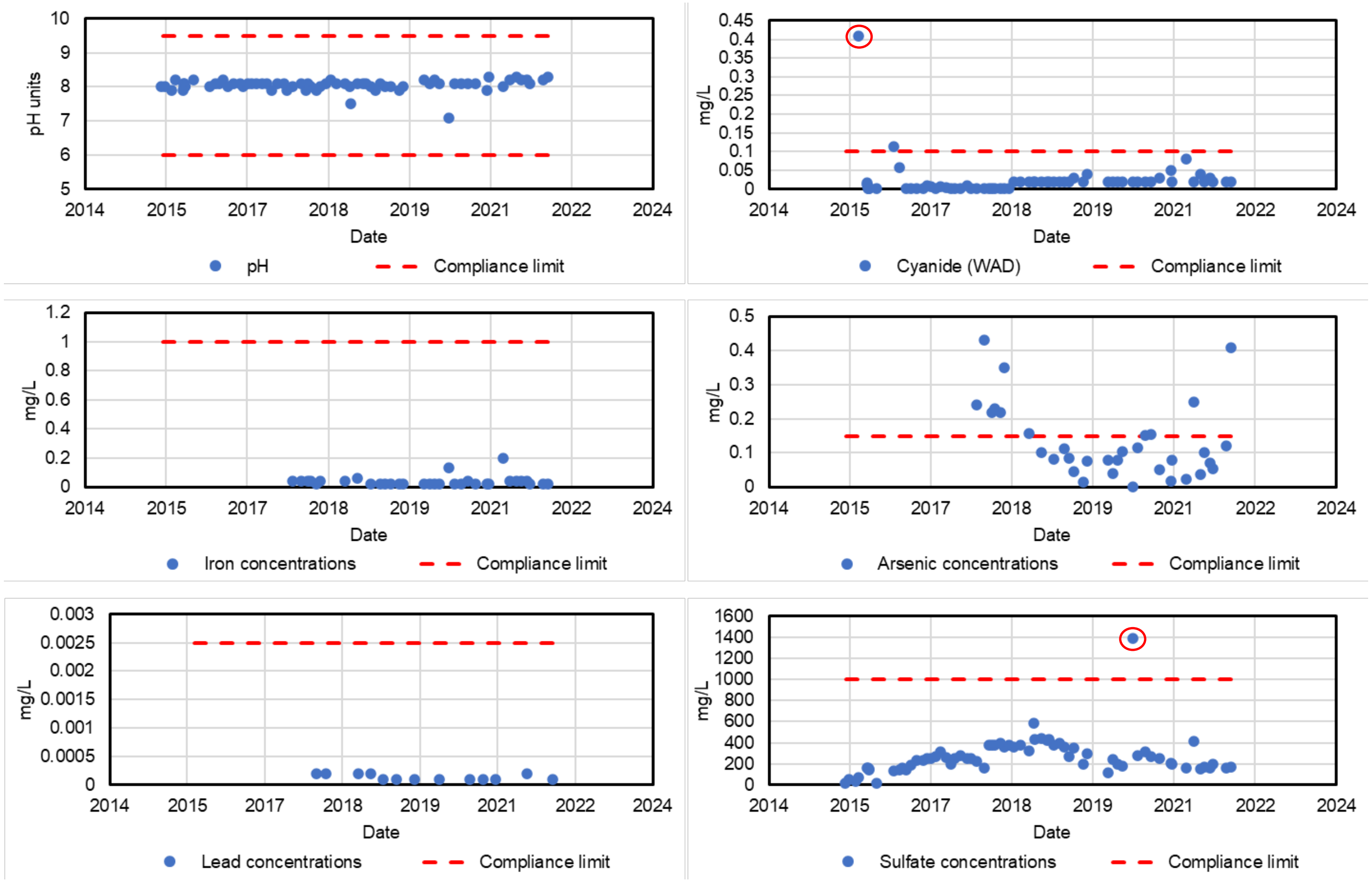


Figure 2. Water quality trends for the Coronation pit domain.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are presented as dissolved.

A red circle indicates a potential erroneous data point that was excluded from the MEQ analysis.

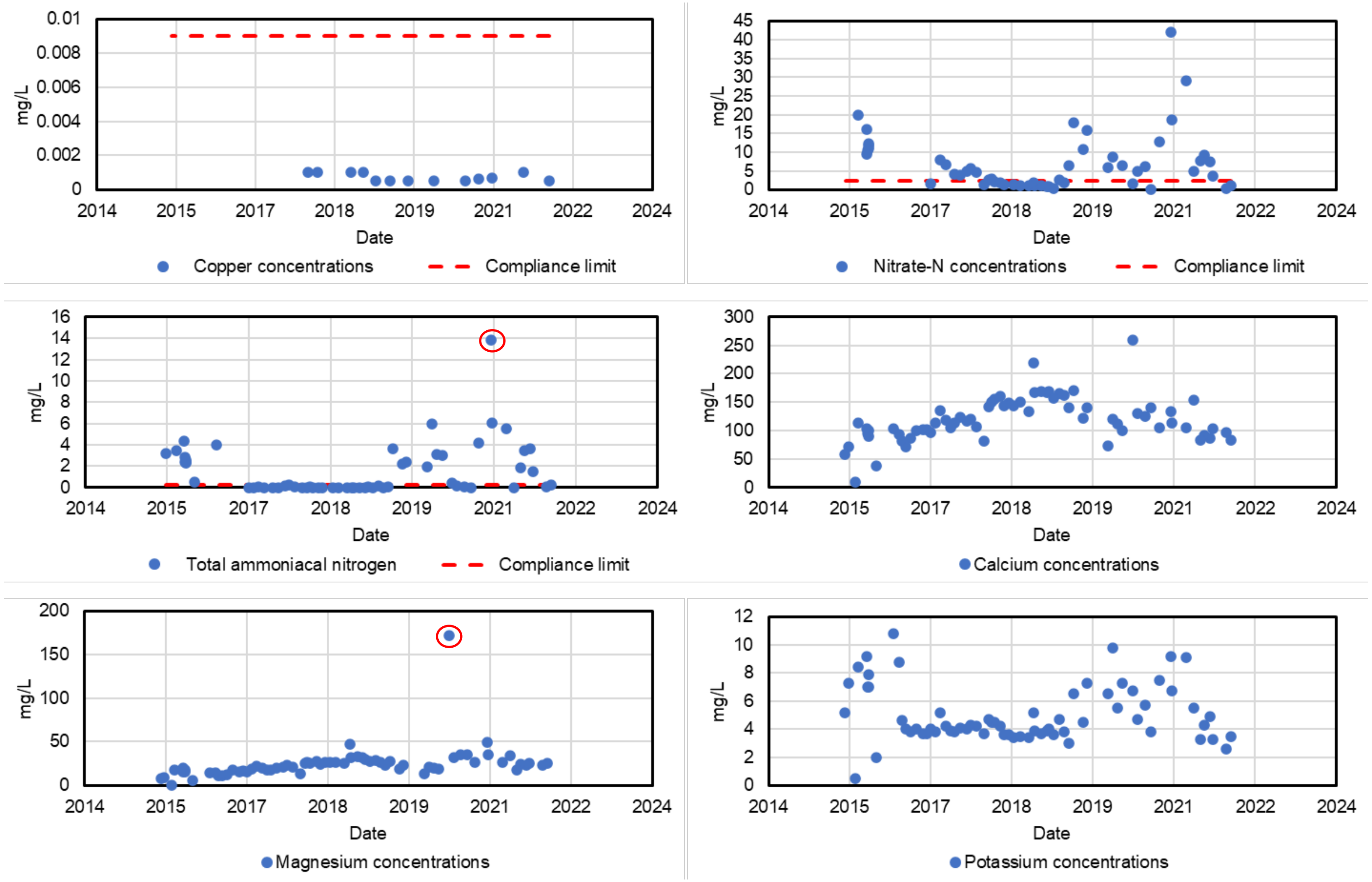
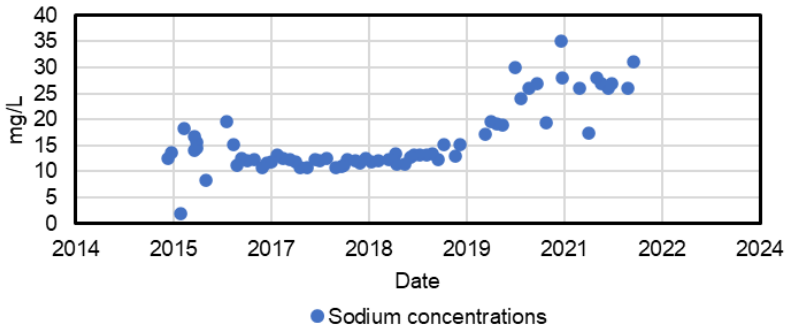


Figure 3. Water quality trends for the Coronation pit domain continued.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are presented as dissolved.

A red circle indicates a potential erroneous data point that was excluded from the MEQ analysis.



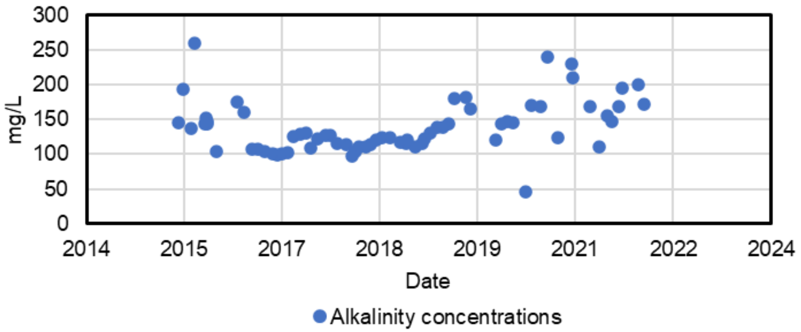


Figure 4. Water quality trends for the Coronation pit domain continued.

Source: OceanaGold Mine Water Quality Database (excel database).

Metals and metalloids are presented as dissolved.

Data Summary

Based on the data available, the following observations were made:

- pH ranged from 7.10 – 8.30 with the majority of pH values being approximately circumneutral (average pH 8.0).
- OceanaGold notes that Coronation Pit was used for water management with water being pumped from Coronation North Pit over the period 2015 -2020 and pit water transfer from Innes Mills West from ~ mid 2021, which presumably accounts for spikes in some contaminants, e.g., nitrate and ammoniacal nitrogen.
- Analysis of the data indicates $CN_{(WAD)}$, NO_3-N, Amm-N, and As are >1.0 MEQ indicating that these PCOC are potentially elevated at times. It should be noted that for $CN_{(WAD)}$, Amm-N, and SO_4 the maximum concentrations were ignored for the MEQ assessment, due the data points being potentially erroneous compared to the rest of the dataset (see Figure 2 to Figure 4). Instead, the next highest value (that was deemed appropriate within the provided data) was used for the MEQ analysis. Data was considered for the development of source terms
- NO_3-N and Amm-N were reported as having the highest MEQ values (17.5 and 25.4, respectively). The MEQ would be higher again for Amm-N if the elevated data point 13.9 mg/L was used). These high nitrogenous concentrations are likely to be derived from ammonium nitrate-based blasting reagents. Nitrate concentrations ranged between 0.15 and 42.0 mg/L with an average concentration of 6.99 mg/L. Total ammoniacal nitrogen concentrations were variable, ranging between 0.010 and 13.80 mg/L with an average concentration of 1.564 mg/L.
- Ca and SO_4 data show an increase in concentration between 2017 and 2020; the peak concentration occurs in 2018. This suggests sulfide mineral oxidation and neutralisation by Ca carbonates.
- Fe, Pb, and Cu concentrations have remained relatively stable, typically being reported as below the trigger values.

WATER QUALITY MODELLING

This section explains the methodology and results for developing a long-term hydrogeochemical water quality model for the Coronation Stage 5/6 Pit Lake. The purpose of the model is to understand potential environmental risks and provide a water quality source term to understand potential effects to groundwater, surface waters, and the subsequent downstream receiving environment (which will be addressed by GHD).

Water Balance and Pit Geometry

A water balance for the Coronation Stage 5/6 Pit Lake (Pit Lake) was provided by GHD (2023) and predicts that the Pit Lake will start discharging to Deepdell Creek in year 166 when the lake level is close to the pit lake overflow level (660 mRL). In addition, a groundwater loss (outflow) is expected to occur from model year 97, and mainly represents the outflow of the pit lake through the Trimbells WRS.

The final pit lake volume capacity is around 19.4 Mm^{3}, and the water level and volume over time are shown in Figure 5.

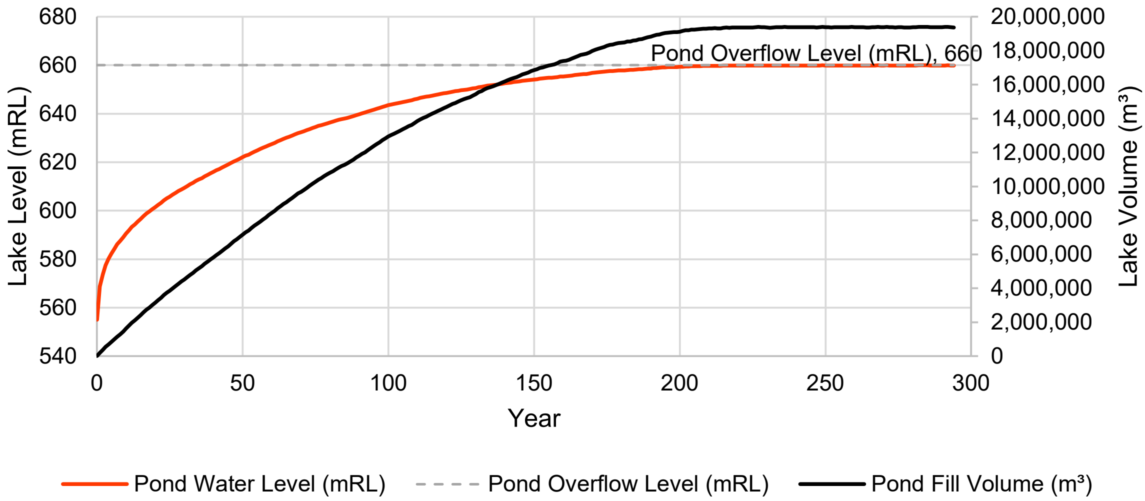


Figure 5. Coronation Stage 5/6 Pit Lake water volumes and height.

Data Source: GHD (2023).

The relative distribution of the water balance inflows and outflows are shown in Figure 7 for the last 80 years of the model (from year 215 to 294) when the flows are stable. Direct rainfall to the lake ("Rainfall Direct") is the main inflow for the water balance (78.2%), followed by Runoff from the pit walls ("Runoff_Breakdown [Pit]") representing 11.9% of the inflows. Evaporation represents 82.9% of the total outflow followed by Flow to River (12%), to Deepdell Creek, and Groundwater Loss (5.1%) to Trimbells Gully.

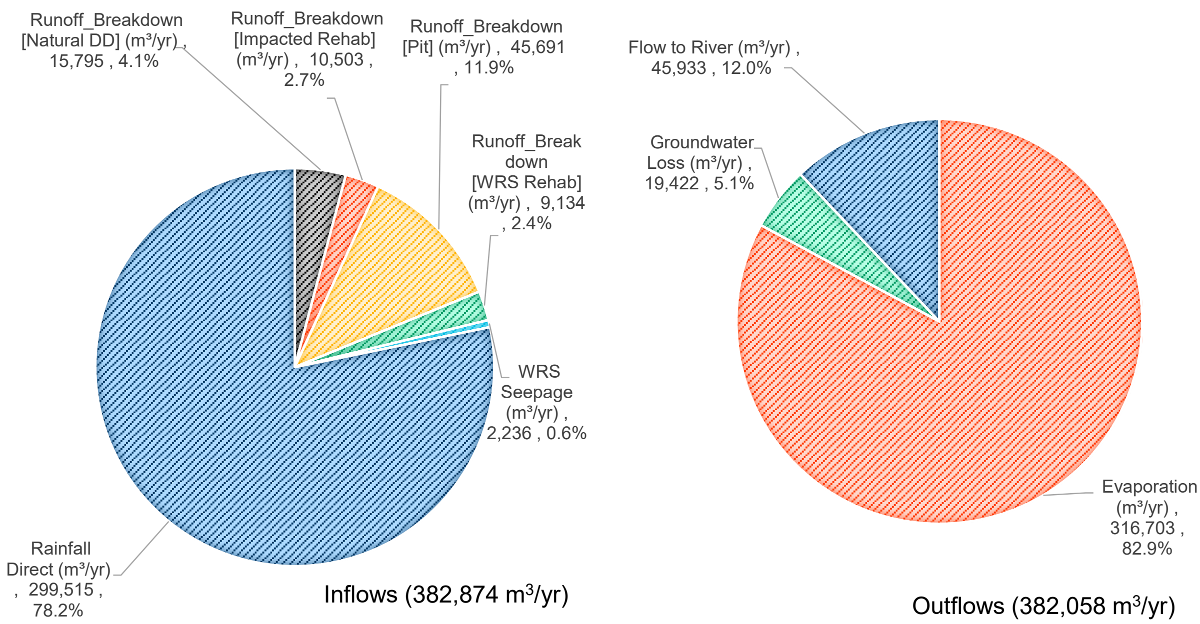


Figure 6. Water balance for the Coronation Stage 5/6 Pit Lake.

Data Source: GHD (2023).

Conceptual Site Model

A conceptual site model (CSM) has been developed to facilitate the assessment of acid and metalliferous drainage (AMD) risks for the project. The model (Figure 8) is based on a proposed final closure design for the project. The key features of the CSM noted in Figure 8, are presented in Table 3. Further details on how the source terms were derived are discussed in subsequent sections.

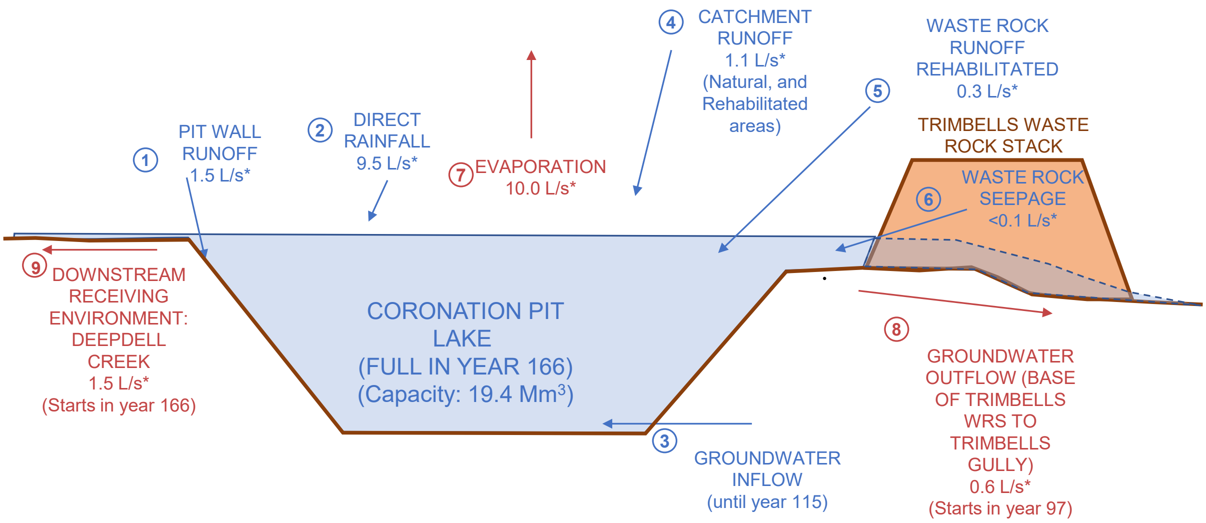


Figure 7. Conceptual site model for the Coronation Stage 5/6 Pit Lake.

**Flow rates shown are averages from year 215 of the model onwards.*

Table 3. Key components and processes associated with the hydrogeochemical pit lake model.

MODEL FEATURE	SUMMARY	DATA SOURCE
		MODEL INPUTS
1	Pit wall run-off to the Pit Lake	Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
2	Direct rainfall to the Pit Lake.	Water quality derived from Nichol et al. (1997).
3	Groundwater inflow.	Groundwater inflow water quality data derived from monitoring wells MAC-CP02 and MAC-CP04.
4	Catchment runoff.	Surface water quality data derived from the monitoring point DC08. Includes impacted and non-impacted areas (natural catchment). It is assumed that impacted areas are rehabilitated.
5	Waste Rock Runoff (Rehabilitated)	Assumed to be rehabilitated and therefore has the same water quality as 4. Catchment runoff derived from the monitoring point DC08.
6	WRS seepage from Trimbells	Derived from empirical correlations (Babbage, 2019, 2022, and MWM, 2023).
		MODEL OUTPUTS
7	Evaporation.	Rates determined by GHD (2023). Evaporation of water causes an increase in concentration of solutes. Evaporation is represented by removing pure water from the lake body, which

MODEL FEATURE	SUMMARY	DATA SOURCE
		causes an increase in solute concentrations (also known as evapoconcentration).
8	Groundwater outflow.	Determined by GHD (2023) and represents the water that outflows through the Trimbells WRS due to the higher hydraulic conductivity of the waste rock compared to the bedrock.
9	Outflow (spill) to downstream environment.	Determined by GHD (2023) representing the water that discharges to Deepdell Creek.

Derivation of Source Terms

This section provides additional details on the source terms used for the hydrogeochemical pit lake model. Full source term descriptions can be found in Attachment A.

Run-off Water from Pit Walls

Water quality for rainfall run-off interacting with the pit walls and the WRS was derived from the Golden Bar Analogue Model Pit Wall source term (MWM, 2024a). This source term is assigned to the pit wall runoff component of the water balance.

Trimbells WRS Seepage

Babbage (2022) developed a relationship (Eqn. 1) to forecast sulfate concentrations that considered age and average height (volume / area) but there was no limit to the maximum sulfate concentration with time. MWM (2023) noted that this would create very high concentrations in any predictive models over the longer term (e.g., 100 years) due to the age multiplier. Instead, a sulfate ceiling limit was proposed based on empirical data for WRS of differing height.

$$(Eqn. 1): Median\ Sulfate \left(\frac{mg}{L}\right) = 96.1 + 1.22 * \ Average\ Height\ (m) * (4 * Age1(year) + Age2(year))$$

Where Age 1 is the time the WRS is in full operation (not capped) and Age 2 years when it was in partial operation (partially capped).

To determine a sulfate concentration, MWM (2023) found a correlation between the maximum sulfate and WRS height based on site data:

$$(Eqn. 2): Average\ Height < 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 850 \exp\left(0.025\ \times\ Average\ Height\ (m)\right)$$

$$(Eqn. 3): Average\ Height \geq 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 120 \exp\left(0.0965\ \times\ Average\ Height\ (m)\right)$$

Figure 9-A shows the results for the predicted concentrations of SO_4 according to Eqn. (1), (2), and (3), and shows the SO_4 input into the model for waste rock from the Trimbells WRS (average height of 35.2 m) where:

- Up to year 20 is predicted by Eqn. (1) – Babbage Model.
- Then by Eqn. (2) and (3) (MWM, 2023) since sulfate has reached the estimated sulfate celing limit of 3,584 mg/L.

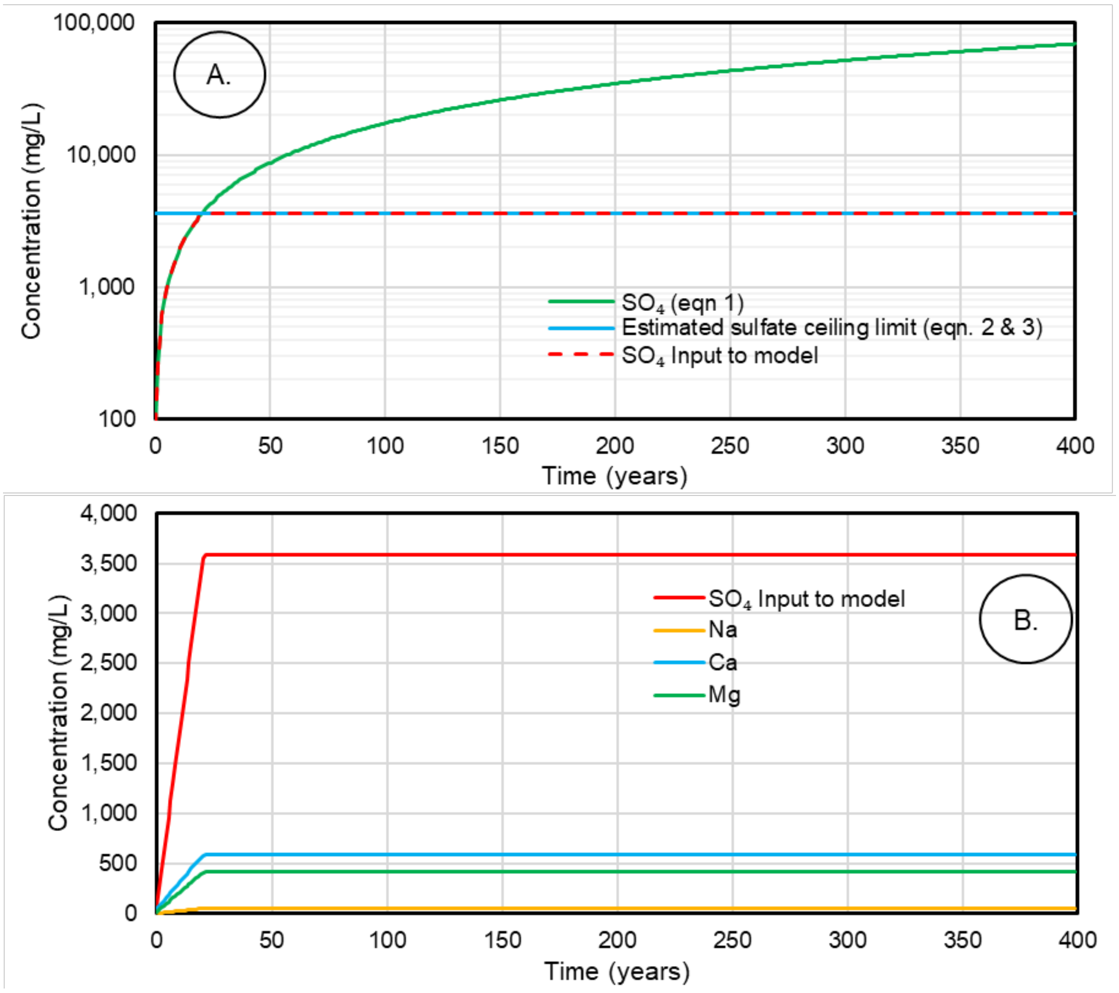


Figure 8. A: Model equations; B: Predicted values of SO_4, Ca, Mg, and Na in all WRS seepage.

Model parameters were also determined (MWM, 2023) for Ca, Mg, and Na as a function of SO_4, (positive correlation) as shown in Table 4 for Trimbells WRS. No correlation was determined between SO_4 and alkalinity, As, Cl, Cu, Fe, K, Amm-N, and NO_3-N for WRS seepage water quality data (only R^2 higher than 0.6 were classified as a good correlation), hence median values as defined in Table 4 (MWM, 2023) were used to derive water quality parameters for modelling purposes [1].

Cyanide (weak acid dissociable cyanide) is not included in Table 4 since all the values are below the last reported limited of reportability (<0.2 mg/L) and it is understood no tailings, that may contain cyanide, have been, or will be placed in this facility.

<u>Rainfall</u>

The source term for average rainfall water quality is obtained from Nichol et al. (1997) using the Lauder collection site (~70 km NE from Macraes, at 317 mRL), which includes rainfall water quality data from 1983 to 1994. This source term is assigned with the “Rainfall direct” water balance component.

[1] *Water quality parameters were derived using the following approach: For instance, using a sulfate concentration of 2,000 mg/L, the Ca concentration is calculated as 0.154 x 2,000 + 34 = 342 mg/L of Ca. The same method is used for Mg (0.113 x 2,000 + 8.87) and Na (0.014 x 2,000 + 13.8), resulting in concentrations of 235 and 42 mg/L, respectively. For the remaining elements, the median value is used regardless of the sulfate concentration.*

Table 4. Estimated water quality as a function of sulfate (Coronation WRS applied to Trimbells WRS).

PARAMETER	SELECTED SLOPE (A)	SELECTED INTERCEPT (B)	MEDIAN	R^2
pH	0	7.2	7.2	0.244
Alkalinity (mg $CaCO_3$/L)	0	39	39	0.566
As (mg/L)	0	0.001	0.001	0.273
Ca (mg/L)	0.154	34	34	**0.961**
Cl (mg/L)	0	8	8	0.207
Cu (mg/L)	0	0.0005	0.0005	0.092
Fe (mg/L)	0	0.04	0.04	0.002
K (mg/L)	0	5.8	5.8	0.159
Mg (mg/L)	0.113	8.87	8.87	**0.965**
Na (mg/L)	0.014	13.8	30	**0.886**
NO_3-N (mg/L)	0	1.34	1.34	0.144
Amm-N (mg/L)	0	0.3	0.3	0.054

Source: MWM (2023).

Groundwater

Four groundwater monitoring wells (MAC-CP01 to MAC-CP04) are present for the Coronation Pit. The source term for groundwater was derived using the average data from the compliance monitoring wells MAC-CP02 and MAC-CP04, as these wells were determined to be the least impacted of the four monitoring sites. All parameters were below relevant guideline limits except for Fe (guideline value of 1.0 mg/L), which had one exceedance (20 mg/L). This source term is assigned to the "Groundwater Inflow" water balance component.

Runoff from Natural Catchment and Rehabilitated Areas

The source term for the runoff from natural catchment and rehabilitated areas used the monitoring site DC08 (Deepdell Creek compliance point) as it represents the waters from a natural catchment and is the closest compliance point for the Coronation Pit. Average values were used of all the available data (from 2012 to 2022). All parameters were below relevant compliance limits (for DC08) with the exception of Cu (compliance limit value of 0.009 mg/L), which had one exceedance (0.0157 mg/L). This source term is assigned to the following runoff water balance components:

- "Natural DD": Natural catchment.
- "WRS Rehabilitated": Rehabilitated surface of the Trimbells WRS.
- "Runoff Impacted Rehabilitated": Rehabilitated mining impacted areas.

Source Terms Summary

Table 5 presents the summarised source terms for the Coronation Pit Lake model.

Table 5. Source terms for Coronation Pit water quality model.

COMPONENT NAME	CORONATION PIT WATER QUALITY	RAINFALL	SEEPAGE FROM WASTE ROCK	RUN-OFF WATER FROM PIT WALLS	GROUNDWATER	RUNOFF FROM NATURAL CATCHMENT AND REHABILITATED AREAS
DERIVATION FROM	CORONATION PIT WATER QUALITY	NICHOL ET AL., 1997	EMPIRICAL CORRELATIONS (1)	GOLDEN BAR ANALOGUE MODEL (MWM, 2024A)	MONITORING WELLS CP02 AND CP04	MONITORING LOCATION DC08
pH	8.00	5.20	7.20	8.37	7.44	7.83
Total alkalinity (mg $CaCO_3$/L)	139.2	0.81	0	572	123.5	89.0
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Al	n. a.	n. a.	n. a.	n. a.	n.a.	n.a.
As	0.130	n. a.	0.001	0.409	0.002	0.014
Ca	119.8	0.110	586.0	190.3	33.1	49.5
Cd	n. a.	n. a.	n. a.	n. a.	n.a.	n.a.
Cl	7.11	0.600	8	15.6	7.09	10.03
Cu	0.00072	n. a.	0.0005	0.001	0.00076	0.00106
Fe	0.037	n. a.	0.04	0.065	0.782	0.072
K	5.04	0.090	5.80	11.2	1.04	1.95
Mg	24.6	0.050	413.9	186.4	8.60	29.6
Mn	n. a.	n. a.	n. a.	n. a.	n.a.	n.a.
Na	16.0	0.320	50.2	32.4	10.1	17.7
NO_3-N	6.99	0.0045	1.34	0.019	0.173	0.139
NO_2-N	0.215	n. a.	n. a.	0.008	0.011	0.0021
Amm-N	1.564	n.a.	0.3	0.038	0.0182	0.122
Pb	0.00014	n. a.	n. a.	0.0003	0.00021	0.00014
Sb	0.037	n. a.	n. a.	0.008	n.a.	n. a.
SO_4	266.5	0.180	3,584	718.9	7.39	170.1
Zn	n. a.	n. a.	n. a.	0.005	n.a.	0.0013

(1) Empirical correlations of Babbage (2019,2022) and MWM (2023), shown values are for the estimated sulfate ceiling limit based on average height of 35.2 m of Trimbells WRS;
n.a.: not applicable due not being analysed or being below LOR. For modelling purposes n.a. is equivalent to 0. Run-off water from pit walls and waste rock are in mg/L

Modelling Processes and Software

Geochemical processes were modelled using PHREEQC (Parkhurst & Appelo, 2013), a widely used software distributed by the United States Geological Survey (USGS) to perform a variety of aqueous geochemical calculations, such as:

- Aqueous reactions.
- Mixing of solutions.
- Calculation of mineral saturation indices.
- Gas and mineral interaction.

Data inputs, modelled geochemical processes, and outputs produced by the hydrogeochemical model are shown schematically in Figure 11. For each timestep (1 year) represented in the pit lake water balance, the model simulated:

- Mixing volumes of each inflow, as represented by source terms in proportions predicted by the GHD (2022) water balance.
- Concentration of the resulting mixed lake water by removal of pure water, representing evapoconcentration predicted by the water balance.
- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for geochemical processes including:
    - Equilibration with atmospheric gases (O_2 and CO_2).
    - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed lake water.
    - Adsorption of dissolved metals and metalloids to hydrous ferric oxides (HFO) as represented by precipitated iron (hydr)oxide minerals.

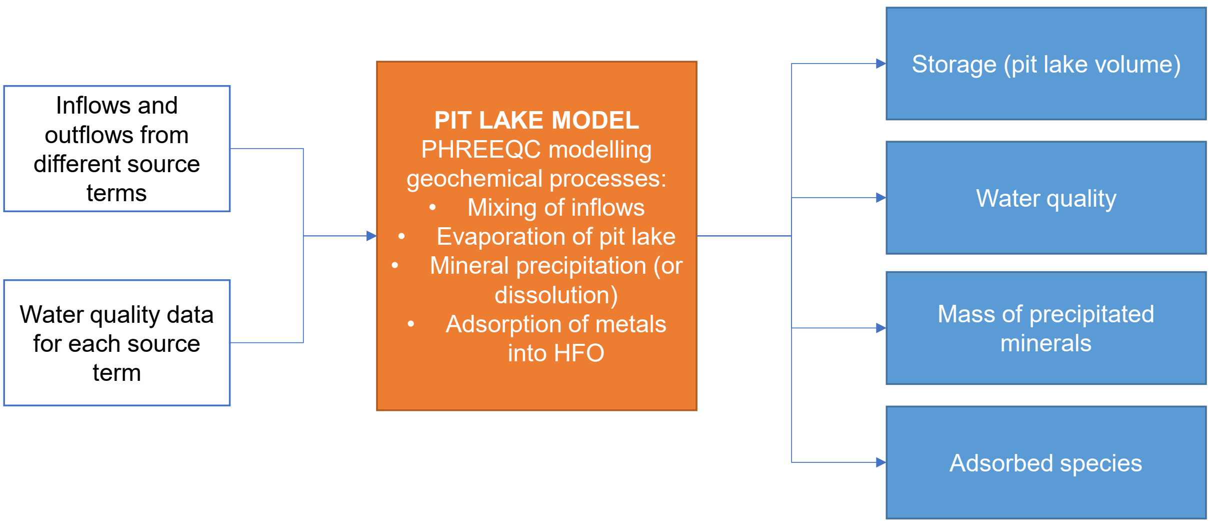


Figure 9. Hydrogeochemical model inputs, modelled processes, and outputs.

The WATEQ4F database was used for thermodynamic calculations, which included the derivation of mineral saturation indices. Mineral phases attaining a saturation index value equal to or greater than zero, which indicates that precipitation of that mineral from solution is thermodynamically favoured, were included as equilibrium phases if those minerals are known to, or are likely to, form under surface environmental conditions reflecting a pit lake. Adsorption of aqueous chemical species to hydrous ferric oxides was modelled using a diffuse double-layer surface complexation model (Dzombak & Morel, 1990), based on modelled precipitation of $Fe(OH)_3(a)$ [2] from solution.

As per the Golden Bar Pit Lake Analogue Model (MWM, 2024a) the following was included:

- Two geochemical processes were included in the model to represent the nitrification and denitrification processes as modelled in the Golden Bar Pit Lake Analogue Model (MWM, 2024a).
- Saturation index of $CO_2(g)$ was set to -3.1 and calcite to 0.85.

Assumptions and Limitations

The following section discusses general model constraints, key assumptions and limitations relating to the hydrogeochemical model:

- All data provided by OceanaGold are assumed to be correct and no quality control / quality assurance (QAQC) has been undertaken on the datasets provided, except those identified as anomalous, which were discarded for the identification of PCOC in the MEQ analysis. No sample was discarded for the calculation of the source term that used average data.
- There will be no placement of backfill within the Coronation Pit.
- Data obtained from a variety of sources is assumed to be representative of the materials associated with the project, and data are representative of the key environmental geochemistry risks.
- Outputs from the water balance (GHD, 2023) were assumed to be accurate and complete.
- The model assumes there is no stratification in terms of density (temperature or salinity stratification) or oxidation-reduction (redox) potential within the pits. It is acknowledged that recent data (MWM, 2024b) suggests that stratification may be occurring during summer months as seen in the Golden Bar Pit Lake.
- Mineral reactions are modelled in equilibrium. If conditions are met, precipitation and dissolution occur instantly until mineral equilibrium is attained.
- Limited information was available for the chemical composition of some inflows. Where required, the composition was estimated using suitable analogue data.
- No redox state (such as pe, Eh or ORP) data were available for source term derivation. A pe value of 10 was applied for all source terms and equilibrium between the lake and the atmosphere (O_2 and CO_2) was assumed.
- All Fe introduced into the model is assumed to be in the Fe^{3+} form.

[2] (a) = amorphous.

- Nitrification and denitrification processes were included to represent the process of ammoniacal nitrogen being converted to nitrate, and nitrate being converted to nitrogen gas, and thence degassing from the solution. Both processes were empirically fitted in the Golden Bar Analogue Pit Lake Model (MWM, 2024a) to provide a suitable model based on empirical data.
- Following the approach completed for the Golden Bar Pit Lake Analogue Model (MWM, 2024a), an initial nitrogen load (as NH_4NO_3) was added to account for the ANFO residues that flush into the pit lake from pit walls and associated minor waste rock. The initial nitrogen load was 5.35 g/m^2, which for the CO6 surface area (136,000 m^2), corresponds to 727.6 kg of nitrogen as NH_4NO_3. This load was released over three years in the model to fit previous empirical data trends (MWM, 2024a).
- The effects of cyanide are not considered in this geochemical model as it is anticipated that cyanide breaks down once exposed to the atmosphere in the pit lake; concentrations are low, and no tailings have been placed in this mine domain / catchment.

RESULTS AND ANALYSIS

Selected outcomes from the hydrogeochemical modelling are presented in this section for the Coronation Stage 5/6 Pit Lake model. Full water quality outputs are provided as a digital attachment (Attachment B).

pH and Sulfate

Predicted values for pH and sulfate concentrations are shown in Figure 12, where the following can be drawn:

- pH remains relatively constant and is in the range of 7.92 – 8.41, although mostly remains at pH 8.4 (which is comparable / slightly higher than the current pit water quality of pH 8.0).
- Sulfate concentrations are predicted to increase over time reaching a concentration of ~621 mg/L by year 277, although generally being relatively stable. Figure 12 also shows the concentrations at Years 97 (545 mg/L) and 166 (584 mg/L), when the groundwater loss and the surficial discharges commence, respectively.

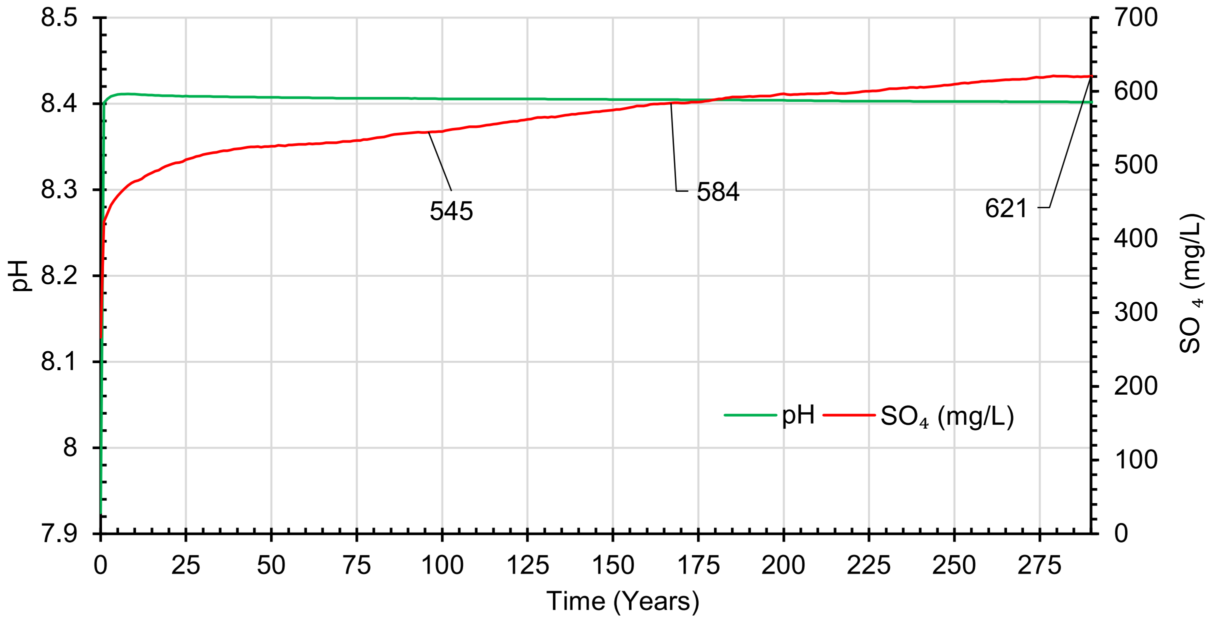


Figure 10. Predicted pH and sulfate concentrations for the Coronation Stage 5/6 Pit Lake Model.

Arsenic and Antimony

Results for predicted As and Sb concentrations are presented in Figure 13:

- Arsenic concentration reaches a value of 0.27 mg/L by year 252 of the model until the end of the simulated period.
- Antimony concentrations remained below 0.005 mg/L throughout the entire simulated period, except during the peak of 0.04 mg/L resulting from the initial conditions of the pit lake.

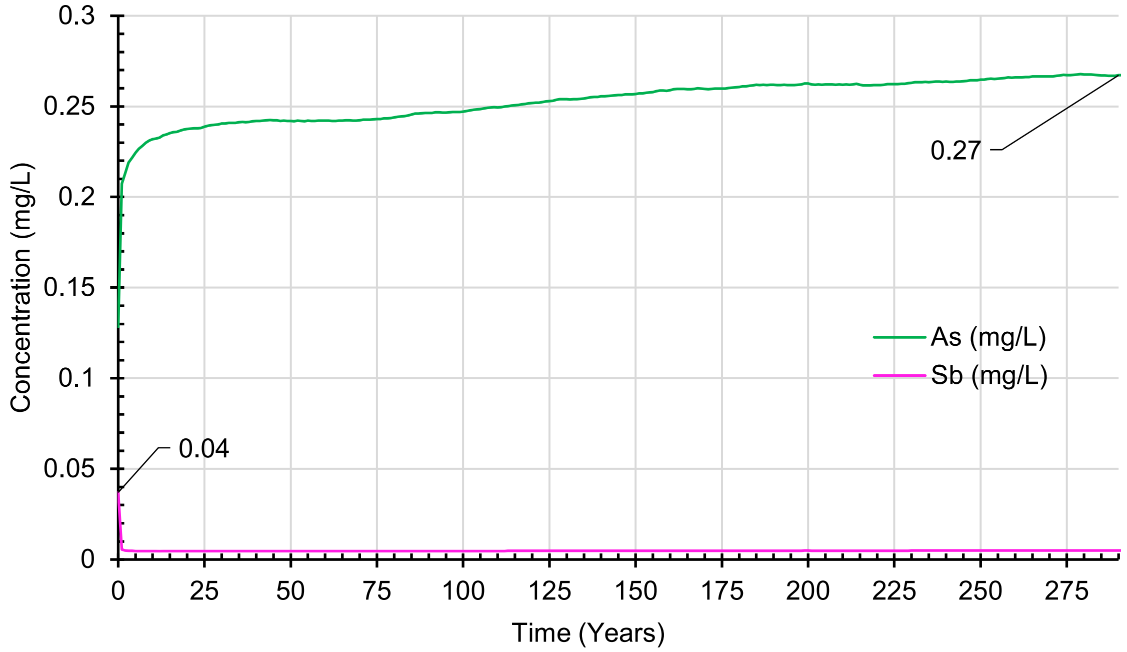


Figure 11. Predicted As and Sb concentrations for the Coronation Stage 5/6 Pit Lake Model.

Calcium, Magnesium, Alkalinity

Results for predicted Ca, Mg, and alkalinity concentrations are presented in Figure 14:

- The calcium concentration stabilizes at approximately 80 mg/L, showing a slight increase from 75 mg/L in year 10 to 84 mg/L by the end of the simulated period.
- The alkalinity concentration remains stable at around 239 mg $CaCO_3$/L throughout the simulated period.
- Magnesium shows a slight increase during the simulated period, reaching 145 mg/L.

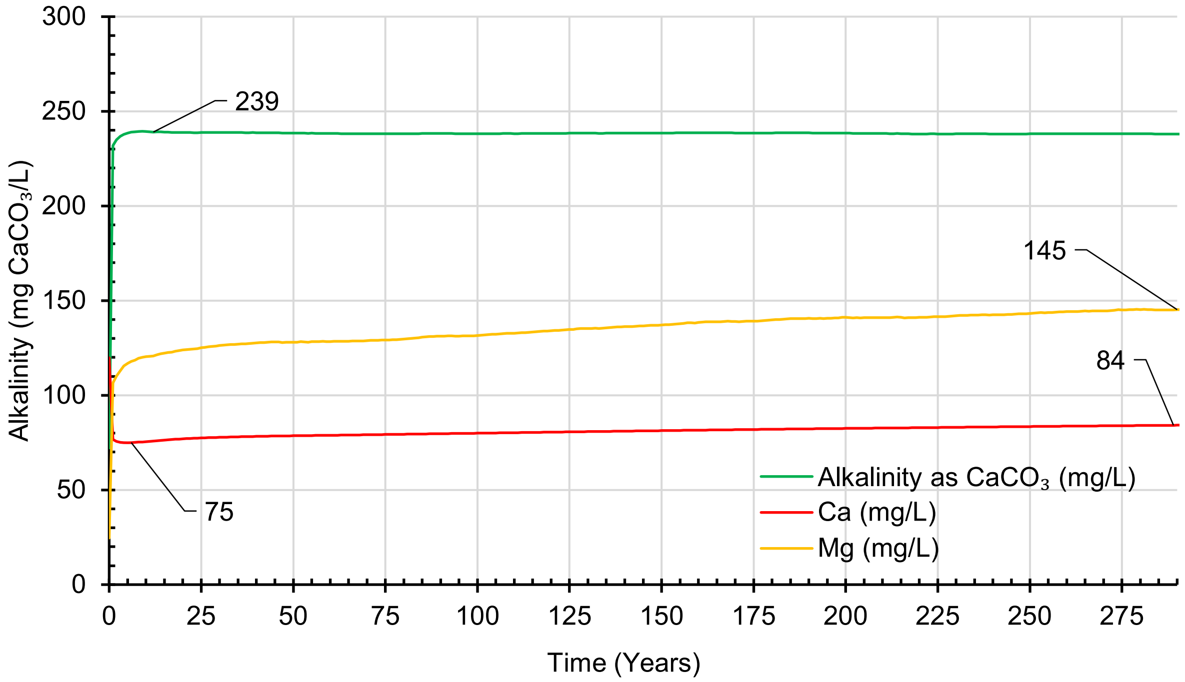


Figure 12. Predicted Ca, Mg, and alkalinity concentrations for the Coronation Stage 5/6 Pit Lake Model.

Alkalinity and calcium concentrations contribute to the precipitation of carbonate minerals. Calcite precipitation is predicted to total ~4.85 kt at the end of the 294-year model period, as depicted in Figure 15. No gypsum precipitation is predicted as it remains undersaturated.

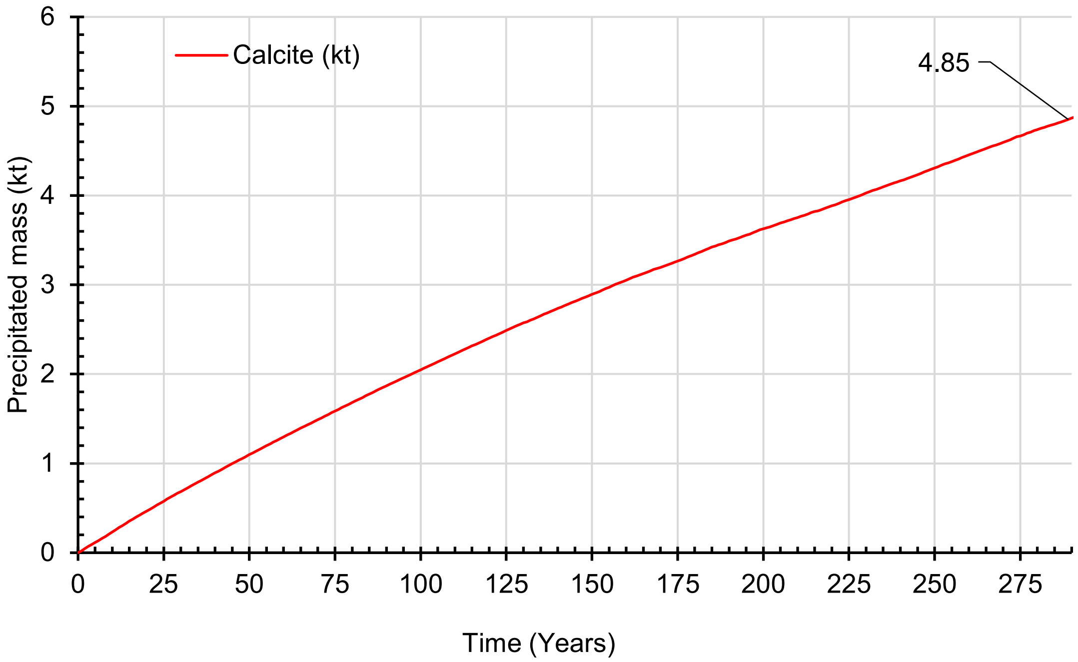


Figure 13. Predicted calcite precipitation for the Coronation Stage 5/6 Pit Lake Model.

Nitrogenous Compounds

Predicted results for nitrate nitrogen (NO_3-N) and ammoniacal nitrogen (Amm-N) are shown in Figure 16. An initial load of 727.6 kg of nitrogen was added as NH_4NO_3, distributed equally in the first 3 years of the model. From the results the following can be drawn:

- Nitrate nitrogen has an initial peak of 26.5 mg/L in year 0 due to the initial nitrogen load, and then decreases rapidly.
- By year 10, the nitrate concentration is near zero.
- Ammoniacal nitrogen has an initial peak of 2.08 mg/L in year 0 and decreases sharply to zero within the first year of the model (although load increases over the first 3 years due to more water in the pit).
- The nitrogen load increases in the first years (when the load is released). The concentration decreases from year zero due to the rapid increase in the volume of the pit lake.
- Both nitrification and denitrification processes are included in the model as derived previously (MWM, 2024a) resulting in a relatively rapid decay in nitrogenous compound concentrations.

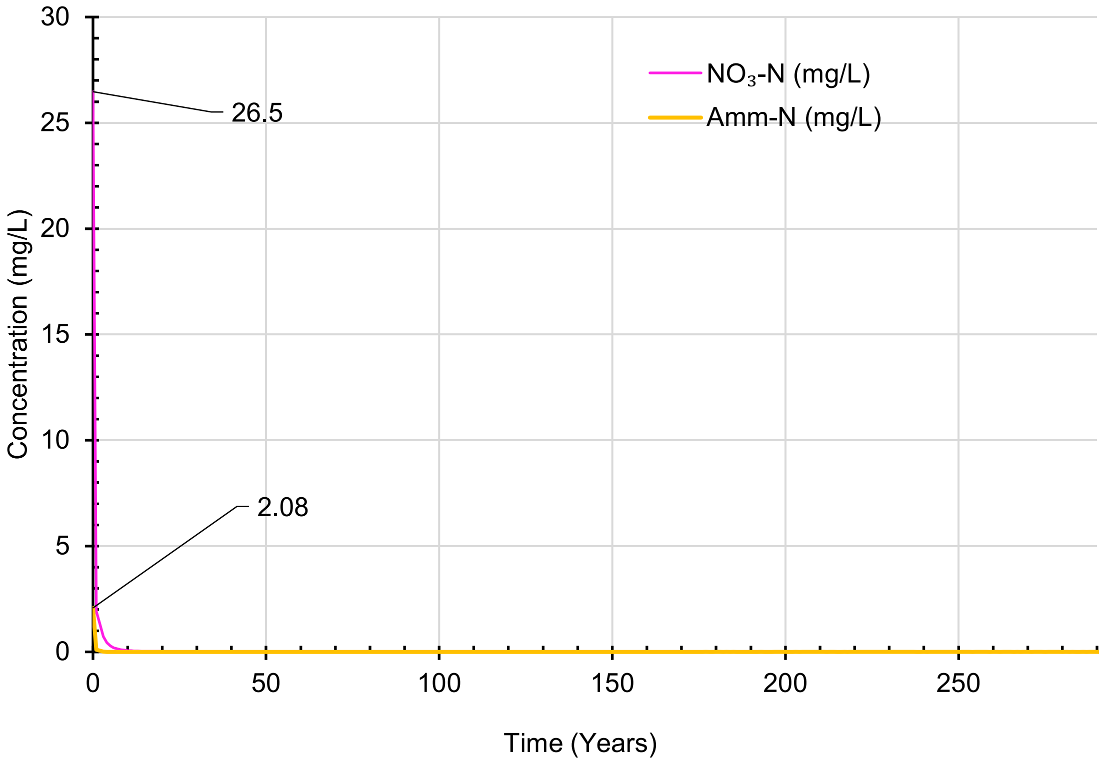


Figure 14. Predicted nitrate-nitrogen and ammoniacal nitrogen concentrations for the Coronation Stage 5/6 pit lake model.

<u>Other Parameters</u>

Other parameters modelled were Cu, Pb and Zn. However, the resulting concentrations were below 5 µg/L and are not considered of relevance for graphical analysis.

SUMMARY

A summary of the predicted water quality for selected years is presented in Table 6. Year 15 is when the concentrations are stable for several parameters. It is predicted (by GHD) that the groundwater discharge of the pit lake will occur from Year 97 though Trimbells WRS and the discharge to Deepdell Creek will occur from Year 166. These data are also provided.

Table 6. Summary: Coronation Stage 5/6 Pit Lake water quality.

TIME (YEARS)	0	15	97[a]	166[b]	250	290
pH	7.92	8.41	8.41	8.40	8.40	8.40
TDS (mg/L)	667	1,031	1,101	1,152	1,186	1,201
Alkalinity (mg $CaCO_3$/L)	72	239	238	239	238	238
Ca (mg/L)	120	76	80	82	83	84
Mg (mg/L)	25	122	131	139	143	145
Na (mg/L)	16	26	27	29	30	31
K (mg/L)	5	7	8	8	8	9
SO_4 (mg/L)	267	490	545	584	610	621
Cl (mg/L)	7.1	13.2	14.2	15.2	16.1	16.5
NO_3-N (mg/L)	26.5	0.0288	0.0036	0.0022	0.0019	0.0020
Amm-N (mg/L)	2.08	0.00037	0.00005	0.00003	0.00002	0.00002
Mn (mg/L)	na	na	na	na	na	na
Zn (mg/L)	0[c]	0.0032	0.0034	0.0036	0.0037	0.0037
Fe (mg/L)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
As (mg/L)	0.13	0.24	0.25	0.26	0.26	0.27
Sb (mg/L)	0.037	0.005	0.005	0.005	0.005	0.005
Pb (mg/L)	0.00006	0.00004	0.00004	0.00004	0.00005	0.00004
Calcite (kt)	0	0.35	1.99	3.14	4.31	4.87

a: Predicted year when groundwater loss commences.

b: Predicted year when surficial discharge commences.

c: Assigned zero in the model as the starting pit sump water quality had no data for Zn concentrations.

na – not available – no source terms contained Mn.

CLOSING REMARKS

Further information is provided in the following attachments:

Attachments: Attachment A – Source Term Descriptions
Attachment B – Digital Attachment Coronation Stage 5/6 Pit Lake Model Results Excel File

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ATTACHMENT A – SOURCE TERM DESCRIPTIONS (GROUNDWATER + SURFACE WATER)

Groundwater Source Term (Monitoring Wells MAC-CP02 and MAC-CP04 Combined)

Parameter	Count	Min	Max	Ave	Med	Water Quality Limits#	MEQ Analysis
pH (pH units)	42	6.50	8.20	7.44	7.80	-	-
EC (µS/cm)	35	159.0	359.0	256.4	280.0	-	-
Depth to Water (m)	99	0.0	17.99	4.57	0.290	-	-
Alkalinity - Total (mg $CaCO_3$/L)	42	67.0	177.0	123.5	141.5	-	-
Alkalinity - Bicarbonate (mg $CaCO_3$/L)	42	67.0	176.0	122.8	140.5	-	-
Carbonate Alkalinity (mg $CaCO_3$/L)	42	1.00	2.20	1.09	1.00	-	-
Hardness-Total (mg $CaCO_3$/L)	42	63.0	167.0	118.1	135.0	-	-
Nitrate-N	17	0.003	0.720	0.173	0.052	2.4	0.30
Nitrate-N + Nitrite-N	22	0.002	0.860	0.165	0.043	-	-
Nitrite-N	17	0.002	0.148	0.011	0.002	-	-
Nitrogen-Total Ammoniacal	22	0.010	0.099	0.018	0.01	0.24	0.41
Total Inorganic Nitrogen	11	0.011	0.690	0.152	0.029	-	-
As	34	0.001	0.019	0.002	0.0014	0.15	0.13
Ca	42	15.4	50.0	33.1	39.5	-	-
Cl	42	4.00	12.0	7.09	7.50	-	-
Cu	13	0.0005	0.0037	0.0008	0.0005	0.009	0.41
Fe	34	0.02	20.0	0.782	0.11	1	20.0
K	42	0.85	2.10	1.04	0.97	-	-
Mg	42	5.90	10.7	8.60	8.70	-	-
Na	42	6.00	14.8	10.06	11.7	-	-
Pb	13	0.0001	0.00155	0.00021	0.0001	0.0025	0.09
SO_4	42	5.00	14.0	7.39	7.00	1,000	0.01
Sum of Anions (meq/L)	42	1.63	4.00	2.82	3.20	-	-
Sum of Cations (meq/L)	42	1.56	4.60	2.844	3.25	-	-

Notes:

- Water Quality Limits obtained from the OceanaGold water quality management plan (2020).

All units are presented in mg/L unless otherwise specified.

Metals and metalloids are presented as dissolved.

pH presented is based on average H^+ concentration.

A hyphen (-) indicates that no data were available.

Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018).

RED Text = MEQ values are >1.0 MEQ.

Surface Water Source Term (Monitoring Point DC08)

Parameter	Count	Min	Max	Ave	Med	Water Quality Limits#	MEQ Analysis
pH (pH units)	91	6.60	8.80	7.83	7.90	-	-
EC (µS/cm)	72	138.0	1,755	500.1	443	-	-
Alkalinity - Total (mg $CaCO_3$/L)	91	29.0	168.0	89.0	81.0	-	-
Alkalinity - Bicarbonate (mg $CaCO_3$/L)	91	29.0	166.0	88.0	81.0	-	-
Carbonate Alkalinity (mg $CaCO_3$/L)	91	1.00	5.90	1.25	1.00	-	-
Hardness-Total (mg $CaCO_3$/L)	91	49.0	1,050	246.0	220.0	-	-
Nitrate-N	45	0.002	1.05	0.1388	0.076	2.4	0.44
Nitrate-N + Nitrite-N	48	0.002	1.06	0.134	0.073	-	-
Nitrite-N	45	0.002	0.004	0.002	0.002	-	-
Nitrogen-Total Ammoniacal	49	0.01	0.10	0.0122	0.01	0.24	0.42
Total Inorganic Nitrogen	36	0.01	1.06	0.16	0.089	-	-
Total Suspended Solids	4	3.00	3.00	3.00	3.00	-	-
Turbidity (NTU)	11	0.32	4.80	1.45	0.71	-	-
As	91	0.0015	0.037	0.014	0.0112	0.15	0.25
Ca	91	11.5	167.0	49.5	45.0	-	-
Cl	91	5.00	15.0	10.03	10.0	-	-
$CN_{(WAD)}$	89	0.001	0.020	0.0083	0.0010	0.1	0.20
Cu	90	0.0005	0.0157	0.001	0.0008	0.009	1.74
Fe	91	0.02	0.37	0.07	0.04	1	0.37
K	91	0.91	5.00	1.95	1.88	-	-
Mg	91	4.50	152	29.56	26.0	-	-
Na	91	8.40	53.0	17.7	15.7	-	-
Pb	90	0.0001	0.00105	0.000138	0.0001	0.0025	0.03
SO_4	91	13.0	950.0	170.1	151.0	1,000	0.95
Zn	87	0.001	0.01	0.0013	0.001	0.12	0.02
Sum of Anions (meq/L)	91	1.27	23.0	5.60	5.20	-	-
Sum of Cations (meq/L)	91	1.44	23.0	5.73	5.20	-	-

Notes:

- Water Quality Limits obtained from the OceanaGold water quality management plan (2020).

All units are presented in mg/L unless otherwise specified.

Metals and metalloids are presented as dissolved.

pH presented is based on average H^+ concentration.

A hyphen (-) indicates that no data were available.

Water quality limits were adjusted for hardness modifications where appropriate to derive the Hardness Modified Trigger Value (HMTV) as per ANZG (2018).

RED Text = MEQ values are >1.0 MEQ.

ATTACHMENT B – DIGITAL ATTACHMENT CORONATION STAGE 6 PIT LAKE MODEL RESULTS EXCEL FILE

APPENDIX M FRIM PIT LAKE MODEL

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MEMORANDUM

Recipient:	Dean Fergusson – OceanaGold Limited
From:	Paul Weber – Mine Waste Management
Date:	28 February 2024
Cc:	Carlos Hillman – Mine Waste Management; Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0229-005-M-Rev1
Document Title:	Macraes Phase FRIM Pit Lake Model

Mine Waste Management Limited (MWM) has been engaged by OceanaGold (New Zealand) Limited (OceanaGold) to undertake a geochemical assessment of the consented and proposed extension and subsequent pit lakes associated with the Innes Mills (IM) Pit, and the construction of the proposed Frasers (in-pit) tailings storage facility (FTSF) at the Macraes Gold Mine (Macraes). The tailings will be stored behind Frasers Backfill (FRBF) in the north of Frasers Pit constructed by disposal of IM waste rock. During the closure period, after mining activities have ceased, two pit lakes separated by FRBF will fill with water and will eventually combine once the FRBF crest is overtopped to form one pit lake, the Frasers – Innes Mills (FRIM) Pit Lake.

One of the tasks associated with this project was to determine the long-term water quality of the proposed FRIM Pit Lake. This memorandum explains how the water quality was derived and provides a summary of the pit lake model outputs.

BACKGROUND

The proposed mining extension for the IM Pit and formation of FTSF consist of the following activities:

- Mining of Innes Mills Pit.
- Formation of the FRBF to 480 mRL with IM waste rock placed in the northern end of Frasers Pit
- Filling of the in-pit FTSF with ~36 M tonnes of tailings within the current Frasers Pit void.
- Subsequent filling with surface and groundwater to form two pit lakes post-closure that then combine to form the FRIM Pit Lake.

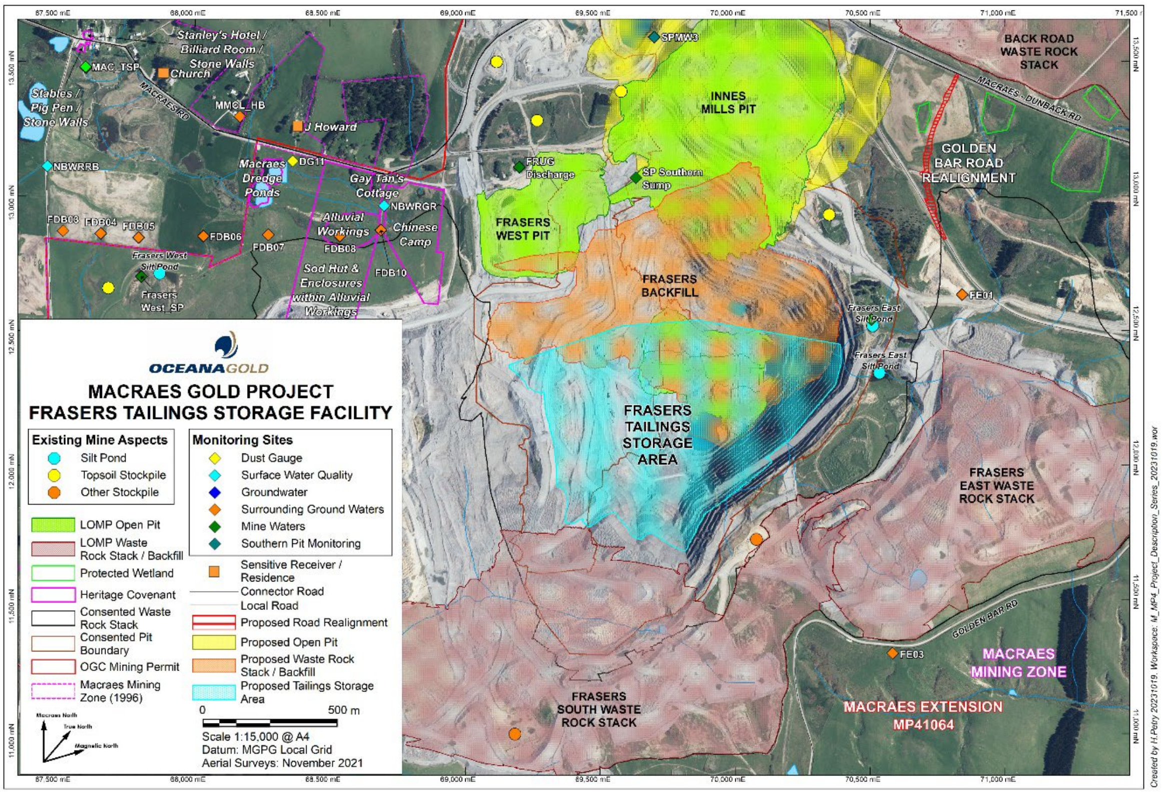

Figure 1. Frasers – Innes Mills pits showing the FTSF.

Source: OceanaGold (2023).

<u>WATER QUALITY MODELLING</u>

This section explains the methodology and results for developing a long-term hydrogeochemical water quality model for the FRIM Pit Lake. The objective is to provide a water quality source term to understand potential effects on groundwater, surface waters, and the subsequent downstream receiving environment. These effects are addressed by GHD (2024).

Water Balance

GHD (2023) provided a water balance model that simulates the water flows for ~300 years post-closure for two subdomains:

- FTSF Pit Lake has a total water capacity of approximately 58.8 Mm^3 at 480 mRL.
- The FTSF Pit Lake overflows into the proposed IM Pit Lake, which has a capacity of around 29.4 Mm^3 at 480 mRL.
- Above the FRBF crest (480 mRL) both lakes are connected in the surface and could hold up to 128.9 Mm^3 at 500 mRL.

Figure 2 shows the pit lake filling trends with time. After ~110 years, the IM pit lake reaches the crest of the FRBF (480 mRL) after which the pit lakes have joined and the lake level equilibrates and remains relatively stable at 487 mRL after year 150. The GHD (2023) model indicates there is no discharge to the environment through surface waters; outflow in the model occurs via evaporation losses and loss to groundwater. Groundwater loss from Innes Mills and from Frasers are shown in Figure 3 along with the two flows from Frasers to Innes Mills (surface overflow and groundwater flow).

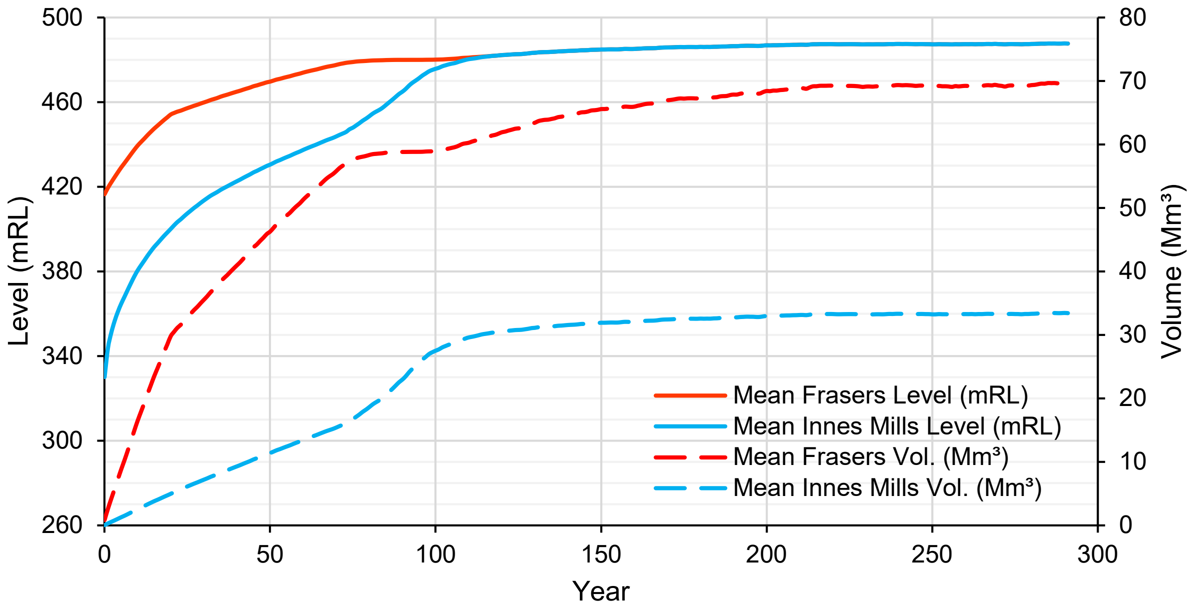

Figure 2. Pit lake water surface level and water volume during filling.

Data Source: GHD (2023).

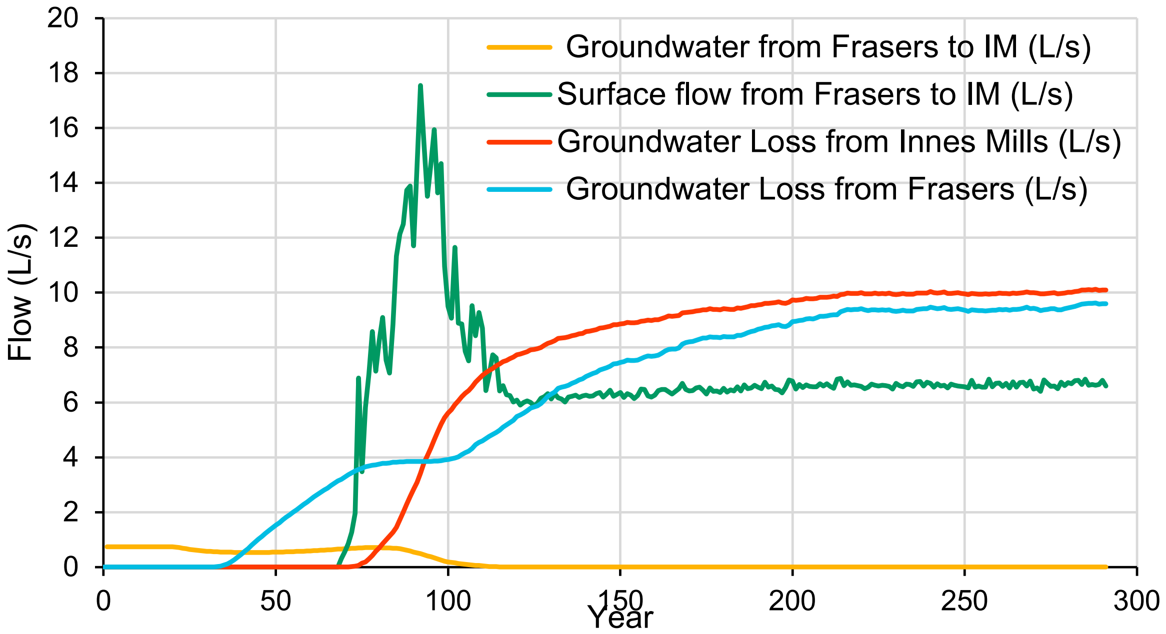

Figure 3. Overflow from Frasers Pit to Innes Mills Pit and groundwater flows.

Data Source: GHD (2023).

The relative distribution of the water balance components is shown in Figure 4 from year 150 onwards of the model. In general terms, the following can be drawn:

- IM Pit Lake:
  - Direct rainfall to the IM Pit Lake (‘Rainfall Direct (m^3)’) is the primary inflow for the water balance (50.92%).
  - 30.15% of the inflows are from the Frasers TSF Pit Lake when it reaches 480 mRL as surface discharge.
  - 3.5% of the inflows are from waste rock stack (WRS) seepage (Frasers WRS)
  - The remainder of the inflows correspond to run-off from rehabilitated or non-rehabilitated areas.
  - Evaporation (55%) is the primary outflow for the water balance. The remainder is groundwater loss.
- FTSF Pit Lake:
  - Primary inflow is direct rainfall (61.54%) followed by the Frasers East Sump Inflow (16.71%).
  - Approximately 11% of the inflows are coming from run-off from various areas (e.g., WRS, rehabilitated areas, non-impacted areas, etc) and non-rehabilitated areas such as pit walls and mining affected areas.
  - WRS seepage accounts for 6.2% of the inflows.
  - Evaporation is the main outflow representing 66.38%, followed by groundwater loss (19.39%).
  - Overflow to Innes Mills (FTSF Pit Lake discharge to IM) represent 14.23%.
- Regional:
  - Groundwater losses from the pit lakes is 589,381 m^3/yr
  - Overall evaporation of the pit lakes is 1,336,973 m^3/yr

Following the cessation of mining activities, it is expected that areas requiring rehabilitation (e.g., WRS surfaces and mine-impacted areas), will be restored within several years and water quality will be representative of a rehabilitated catchment (i.e., analogue water quality from the Ross Ford (monitoring site MAC-NBWRRF). Pit walls are assumed to be unrehabilitated at closure.

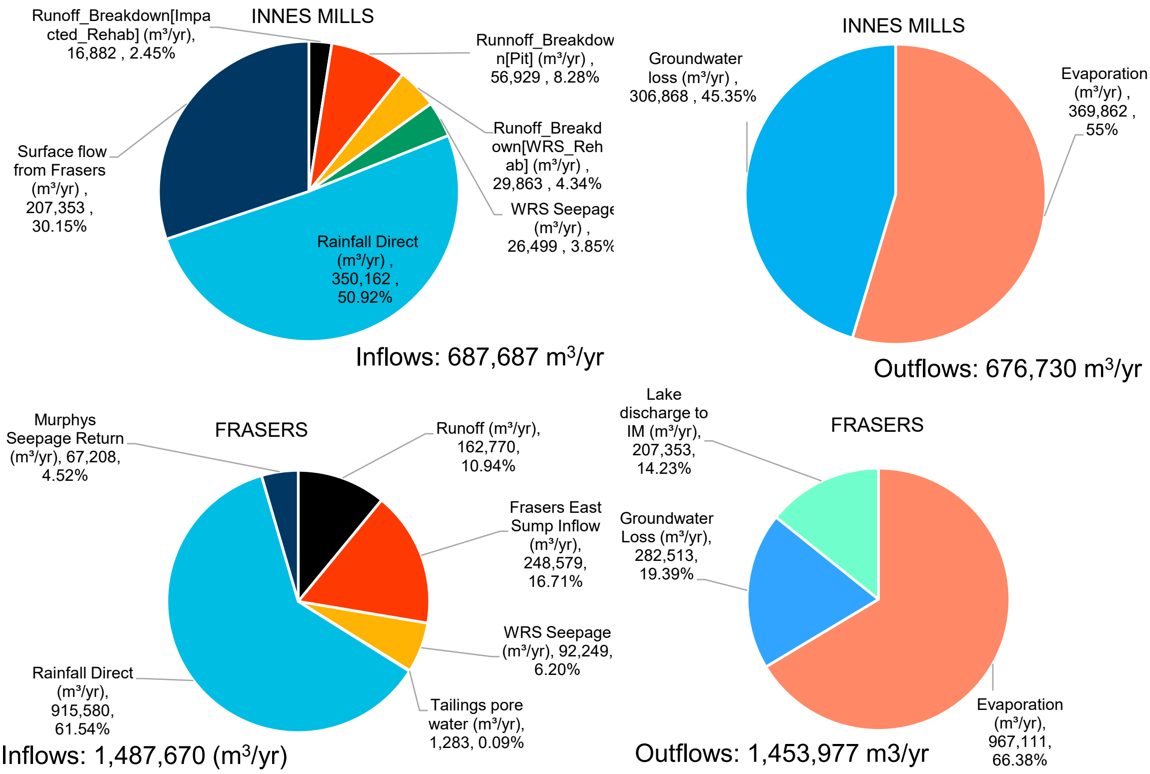

Figure 4. Average distribution of the water balance components for the FRIM pit lakes from year 150 onwards.

Data Source: GHD (2023).

Conceptual Site Model

The conceptual site model (CSM) developed by GHD (2023) is presented to provide a visual schematic of the FRIM mine domains to understand the components of the water balance model. The CSM (Figure 5) is based on the proposed final closure design. The key features of the CSM and the derivation of the source terms, noted in Figure 5, are presented in Table 1. Further detail on how the source terms were derived are discussed in subsequent sections.

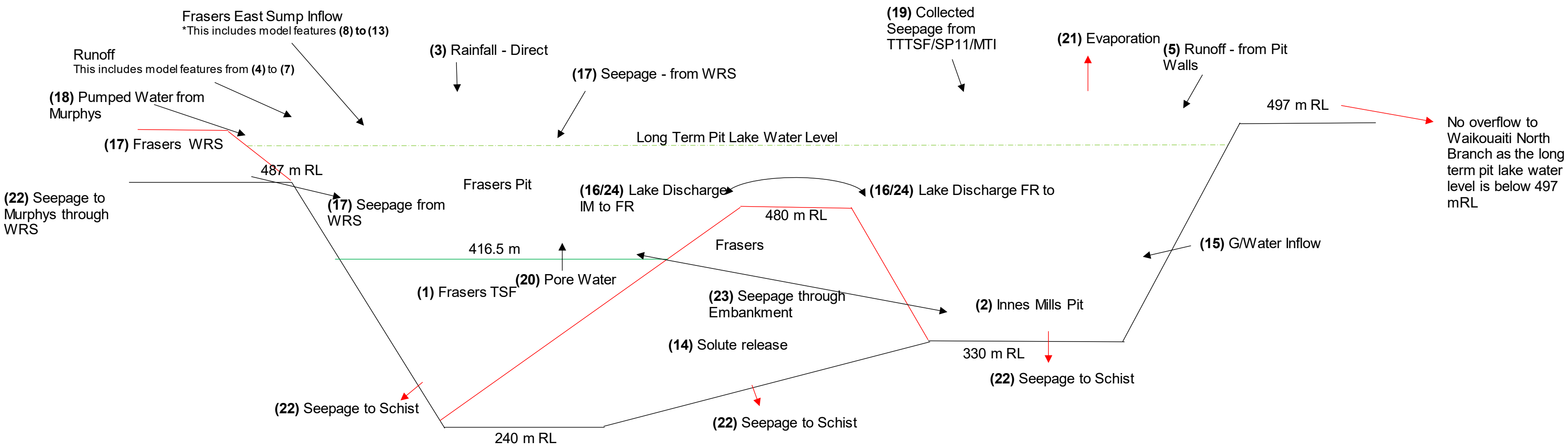

Figure 5. Conceptual site model for the FRIM pit lakes.

Source: Modified from GHD (2023).

Table 1. Key components and processes associated with the FRIM hydrogeochemical pit lake model.

MODEL FEATURE	WATER COMPONENT	SUB-DOMAIN WHERE WATER COMPONENT IS USED		DATA DESCRIPTION AND SOURCE
		FTSF	IM	
		MODEL INPUTS		
1	Frasers TSF Pit Lake Initial Water Composition	X		Initial Frasers TSF water quality derived from the average of the TTTSF Impoundment water quality from Year 2016 onwards.
2	IM Initial Water Composition		X	This was determined from SPIM Pit Sump water quality (1996 - 2004).[1]
3	Rainfall Direct (m^3)	X	X	Water quality derived from Nichol et al. (1997).
4	Runoff_Breakdown [Impacted Rehab]	X	X	Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
5	Runoff_Breakdown [Pit]	X	X	Pit Wall run-off water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
6	Runoff_Breakdown [WRS Nonrehab]	X		Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
7	Runoff_Breakdown [WRS Rehab]	X	X	Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
8	Frasers East Sump Inflow [Impacted]	X		Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
9	Frasers East Sump Inflow [Natural]	X		Natural source term, derived from monitoring point GB02, average values from 2007 – 2014.
10	Frasers East Sump Inflow [Impacted Rehab]	X		Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
11	Frasers East Sump Inflow [WRS Non-Rehab]	X		Water quality derived from the Golden Bar Analogue Model Pit Wall source term water quality data (MWM, 2024a)
12	Frasers East Sump Inflow [WRS Rehab]	X		Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
13	Frasers East Sump Inflow [TTTSF Rehab]	X		Rehabilitated water type (analogue water quality from Ross Ford (monitoring site MAC-NBWRRF).
14	Flooded Waste Rock Solute Release	X	X	Solute release from waste rock once saturated by the rising pit lake as defined by the shake flask extraction (SFE) testing data for waste rock as mg/kg.

MODEL FEATURE	WATER COMPONENT	SUB-DOMAIN WHERE WATER COMPONENT IS USED		DATA DESCRIPTION AND SOURCE
		FTSF	IM	
15	GW Inflow	X	X	Groundwater inflows: Groundwater inflow water quality data derived from groundwater monitoring well FDB03.
16	Inflow (overflow) from Frasers to IM and vice versa	X	X	Overflow from FTSF Pit Lake to IM Pit Lake and the other way around.
17	Waste Rock Stack Seepage	X	X	Drainage to FTSF Pit Lake: Assumed to be a water quality like the Frasers West WRS seepage. Drainage to Innes Mills Pit Lake: Assumed to be water quality like the North Gully East WRS seepage.
18	Murphy's Pond Seepage Return		X	Average water quality of Murphy's Silt Pond monitoring point from 2010 onwards.
19	TSF Underdrain Return	X		Average for the TTTSF, SP11 TSF, and MTI TSF underdrains as separate flow paths for selected periods of time (when stable).
20	Tailings Pore Water	X		Assumed to be similar to the TTTSF Underdrain water quality.
MODEL OUTPUTS				
21	Evaporation	X	X	Evaporation is represented by removing pure water from the lake body, which causes an increase in solute concentrations.
22	Groundwater Loss	X	X	Groundwater loss to the aquifer including seepage flow through Frasers WRS
23	Groundwater to lower mRL	X		Groundwater from FR Pit through the rock or backfill to IM Pit
24	Overflow	X	X	Overflow from FTSF Pit Lake to IM Pit Lake and vice versa.

1. Input data was derived from 22 samples including 19 samples rom Southern Pit from 1996 – 2001 and 3 samples from IM Pit South from 2003-2004 as a reasonable estimation of the starting pit sump.

Derivation of Source Terms – Additional Explanations

This section provides additional details on the source terms used for the hydrogeochemical pit lake modelling.

Run-off Water from Pit Walls and Waste Rock Stacks

Water quality for rainfall run-off from pit walls and the WRS surfaces was derived from the Golden Bar Analogue Model Pit Wall source term (MWM, 2024a). This source term is assigned to the following water model features:

- Runoff “Pit” (Model Feature #5).
- Runoff “WRS Non-Rehabilitated” (Model Feature #6).
- “Impacted” Frasers East Sump (Model Feature #8).

- "WRS_NonRehab" Frasers East Sump Inflow (Model Feature #11).

Run-off from Natural and Rehabilitated Areas

The source term for the runoff from the natural catchment used the monitoring site GB02 as it represents the waters from a natural catchment (using Golden Bar area before mining effects were observed). Average data were used from 2007 to 2014. This source term is assigned to:

- "Frasers East Sump Inflow [Natural]" (Model Feature #9).

The average water quality of the monitoring point Ross Ford Creek (NBWRRF) was used as an analogue for the "rehabilitated areas", with poorer water quality compared to natural catchments such as those represented by GB02 above. This source term was assigned to:

- Runoff_Breakdown Impacted rehabilitated (Model Feature #4).
- Runoff_Breakdown [WRS Nonrehab] (Model Feature #7)
- Frasers East Sump inflow [Impacted Rahab] (Model Feature #10).
- Frasers East Sump Inflow [TTTSF Rehab] (Model Feature #13)

Backfill and WRS Seepage - Background

Backfill above the water level of the pit lakes is expected to generate seepage as a result of rainfall infiltration. The model assumes no further seepage once the backfill is saturated by the rising pit lake level. The contribution of backfill above the water level to seepage will decrease over time as the pit lake fills. There is additional seepage (WRS seepage) originating from areas outside the lake.

Babbage (2022) developed a relationship (Eqn. 1) to forecast sulfate concentrations that considered age and average height (volume / area) but there was no limit to the maximum sulfate concentration or sulfate concentration decay with time. MWM (2023) noted that this would create very high concentrations in any predictive models over the longer term (e.g., 100 years) due to the age multiplier. This is not supported by the data provided; is unrealistic given the observed sulfate concentrations; and is not validated based on the current dataset and industry standard geochemical principles where concentration is a function of the amount of rock that percolating water interacts with.

$$(Eqn. 1): Median\ Sulfate\left(\frac{mg}{L}\right) = 96.1 + 1.22 *\ Average\ Height\ (m) * (4 * Age1(year) + Age2(year))$$

Where Age 1 is the time the WRS is in full operation (not capped) and Age 2 years when it was in partial operation (partially capped).

To determine a sulfate concentration, MWM (2023) found a statistically robust correlation between the maximum sulfate and WRS height based on site data:

$$(Eqn. 2): Average\ Height < 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 850 \exp\left(0.025\ \times\ Average\ Height\ (m)\right)$$

$$(Eqn. 3): Average\ Height \geq 27.5\ m: Maximum\ Sulfate\ \left(\frac{mg}{L}\right) = 120 \exp\left(0.0965\ \times\ Average\ Height\ (m)\right)$$

Innes Mills WRS Seepage

Figure 6 shows the results for the predicted concentrations of SO_4 according to Eqn. (1), (2), and (3), and shows the SO_4 input into the pit lake model for the FRBF, which seeps into the Innes Mills Pit Lake.

The sulfate concentration for the seepage flowing into the Innes Mills Pit Lake is predicted by Eqn. (1) up to year 22 when the maximum concentration (4,360 mg/L) is reached. After that, Eqn. (2) and (3) are used as the height difference between the top of the backfill and the Innes Mills Pit Lake level decreases (i.e., as the pit lake height increases to 480 mRL).

However, the water balance model did not separate WRS seepage rates into backfill seepage rates and ex-pit seepage rates for Innes Mills. Hence, a more conservative approach was undertaken, and seepage water quality from the North East Gully WRS was used as the source term (Model Feature #17 for IM Pit) (Figure 6: blue line). As shown in Figure 6, this provides conservative sulfate concentrations over the model period.

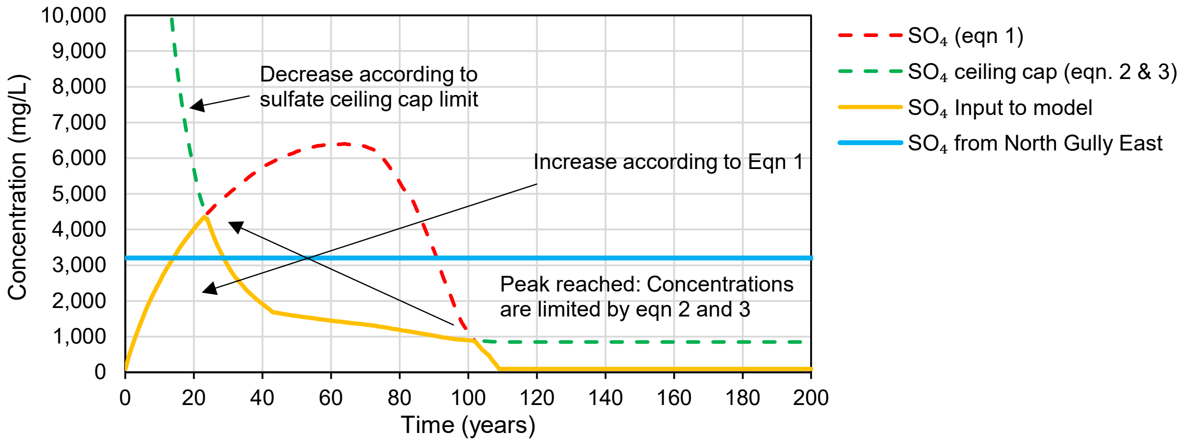

Figure 6. Calculated model sulfate concentrations for WRS seepage to Innes Mills Pit.

<u>Frasers WRS Seepage</u>

Waste rock seepage flowing into Frasers primarily comes from the Frasers WRS and is assigned a constant source term as the average of the Frasers West Silt Pond and Murphy's Creek Silt Pond from 2014 onwards (Model Feature #17 for FTSF Pit). No seepage from the FRBF to the Frasers TSF Pit Lake occurs in the water balance model, as water flows from the Frasers TSF lake to the Innes Mills pit lake due to the water gradient difference.

By year 110 of the model period, the water level in the Innes Mills Pit lake is above 480 mRL, rendering the embankment fully saturated and halting seepage generation from that area.

<u>Saturated Waste Rock</u>

As the water level of the pit lakes rise, it is assumed that soluble solute will be released from the waste rock as the rising pit lake saturates the waste rock. In the model, this process is also assumed to prevent future sulfide mineral oxidation. This source term is derived from the Shake Flask Extraction Test results (mg/kg), as shown in Table 2, which are discussed further in MWM (2024b). As a conservative modelling approach, it is assumed that there is a full release of these solutes upon saturation.

The amount of saturated waste rock is shown in Figure 7, where:

- A total of ~44.5 Mt (20.4 Mm^3) is saturated below the FTSF Pit Lake level by the end of the simulated period (blue line).
- A total of 17.8 Mt (8.2 Mm^3) is saturated below the Innes Mills Pit Lake level by the end of the simulated period (orange line).

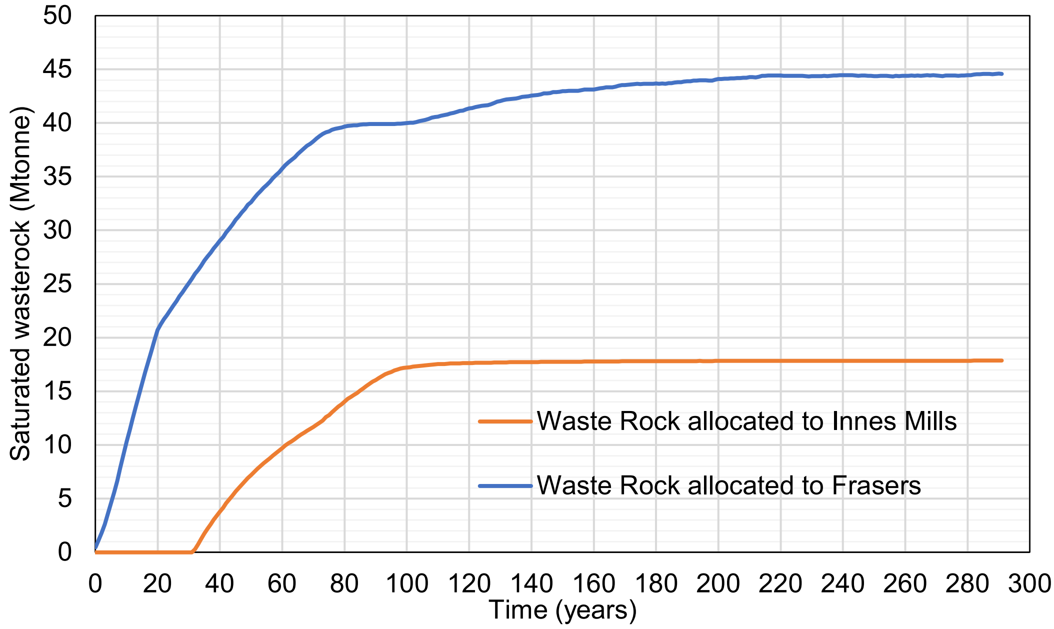

Figure 7. Flooded waste rock (Mt per annum).

This source term is not assigned to any water balance component. Instead, it provides solutes to solution (i.e., the pit lake) according to the amount of mass of waste rock that has been flooded. Once the waste rock is saturated, it releases a defined load (mg/kg) for that year. In the following years, the waste rock is considered non-reactive as it is assumed that there will be no further sulfide mineral oxidation (due to the rock being under water, e.g., excluding oxygen).

<u>Rainfall</u>

The source term for average rainfall water quality is obtained from Nichol et al. (1997) using the Lauder collection site (~70 km NE from Macraes, at 317 mRL), which includes rainfall water quality data from 1983 to 1994. This source term is assigned to the "Rainfall direct" water balance component (Model Feature #3).

<u>Groundwater</u>

Groundwater source term was derived using the average data from the monitoring point FDB03 from 2011 to 2017. This source term is assigned to the "Groundwater Inflow" water balance component (Water Model Feature #15)

<u>Source Terms Summary</u>

Table 2 and Table 5 present the summarised source terms for the FRIM lakes.

Table 2. Source terms for the FRIM water quality model.

SOURCE TERM	INITIAL FRASERS TSF	INITIAL INNES MILLS PIT SUMP	RAINFALL	NATURAL SURFACE WATER	LOAD FROM SATURATED WASTE ROCK	RUN-OFF WATER FROM WASTE ROCK AND PIT WALLS	REHABILITATED WATER	GROUNDWATER
DERIVATION FROM	TTTSF IMPOUNDMENT	PIT LAKE WATER QUALITY (1996 - 2004)	NICHOL et al., 1997	MONITORING POINT GB02	SHAKE FLASK EXTRACTION TEST	GOLDEN BAR ANALOGUE MODEL (MWM, 2024a)	MONITORING POINT NBWRRF	MONITORING WELL FDB03
pH	7.94	7.92	5.20	7.44	8.11	8.37	7.67	7.01
Alkalinity – Total (mg/L as $CaCO_3$)	204.4	249	0.8	33.5	877.5	571.5	86.0	51.8
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	mg/kg	**mg/L**	**mg/L**	**mg/L**
Al	n. a.	n. a.	n. a.	n. a.	2.13	n. a.	n. a.	n. a.
As	0.169	0.16	n. a.	0.002	0.22	0.4087	0.0081	0.0021
Ca	617.4	181	0.1	8.8	243.3	190.3	35.6	10.0
Cd	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Cl	21.53	8.6	0.6	10.0	n. a.	15.6	8.9	6.13
$CN_{(WAD)}$	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Cu	n. a.	0.001	n. a.	0.003	n. a.	0.001	0.0008	0.0005
Fe	n. a.	0.29	n. a.	0.190	n. a.	0.065	0.2706	4.5029
K	94.52	5.55	0.09	0.72	105	11.18	5.55	1.66
Mg	343.3	60.4	0.1	3.2	72	186.4	38.0	5.8
Mn	n. a.	n. a.	n. a.	n. a.	0.26	n. a.	n. a.	n. a.
Na	365.0	20.9	0.3	8.7	43.08	32.4	17.68	9.44
NO_3-N	12.87	4.73	0.00	0.03	8.75	0.02	0.44	n. a.
NO_2-N	0.754	n. a.	n. a.	0.002	0.26	0.008	0.0027	n. a.
Amm-N	14.04	0.23	n. a.	0.033	n. a.	0.038	0.015	0.151
Pb	0.0012	0.0018	n. a.	0.0003	n. a.	0.0003	0.0002	0.0001
Sb	n. a.	n. a.	n. a.	n. a.	0.143	0.0075	n. a.	n. a.
SO_4	3,610	407	0.0	6.7	264	719	179	4.4
Zn	n. a.	n. a.	n. a.	0.0026	n. a.	0.0153	0.0019	n. a.

Table 3. Source terms (continued) for the FRIM water quality model.

COMPONENT NAME	TSF UNDERDRAINS AND FRASERS WEST WRS RETURN TO FRASERS: MURPHY'S CREEK SILT POND RETURN	MTI	TTTSF	SP11	REHAB WATER	FRASER WEST	NATURAL SURFACE WATER	NORTH GULLY EAST
DERIVATION FROM	MURPHY'S CREEK SILT POND	SUMP B MONITORING POINTS	TTTSF SEEPAGE COLLECTION SUMP	SP10 COMBINED SEEPAGE OUTLET	REHAB WATER FROM ROSS FORD CK. (NBWRRF)	FRASER WEST SILT POND AND MURPHYS CREEK SILT POND (2014 ONWARDS)	MONITORING POINT GB02	NORTH GULLY EAST
pH	8.19	6.79	6.84	6.81	7.67	8.20	7.44	7.53
Alkalinity – Total (mg/L as $CaCO_3$)	601.1	268.3	226.8	363.8	86.0	526.3	33.5	599.7
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Al	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
As	0.0041	3.30	3.86	11.87	0.01	0.01	0.002	0.01
Ca	206.9	310.0	432.1	329.9	35.6	206.7	8.8	462.7
Cd	n. a.	0.00	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Cl	11.5	58.9	21.5	31.3	8.9	17.4	10.0	12.5
$CN_{(WAD)}$	0.0018	0.227	0.055	0.0039	n. a.	n. a.	n. a.	n. a.
Cu	0.002	0.003	n. a.	0.004	0.001	0.003	0.003	0.002
Fe	0.05	14.04	28.80	32.46	0.27	0.24	0.19	0.10
K	15.51	37.24	50.15	63.74	5.55	13.69	0.72	13.55
Mg	561.1	169.4	328.8	329.9	38.0	693.2	3.2	649.4
Mn	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Na	51.65	505.0	380.0	481.0	17.7	61.1	8.7	68.1
NO_3-N	18.41	1.20	1.38	0.064	0.436	11.6	0.030	30.2
NO_2-N	0.099	0.050	0.075	0.055	0.003	0.071	0.002	0.005
Amm-N	0.27	10.0	7.4	11.8	0.015	0.165	0.033	0.110
Pb	0.0002	0.0004	0.0	0.0005	0.0002	0.0005	0.0003	0.0002
Sb	n. a.	n. a.	0.0011	0.0077	n. a.	0.0011	n. a.	0.0076
SO_4	2,328	2,280	3,094	3,426	179	3,014	7	3,200
Zn	n. a.	0.0035	n. a.	n. a.	0.002	0.010	0.003	0.025

Source: OceanaGold (2022b).

n. a.: not applicable due to not being analysed or being below LOR. For modelling purposes, n. a. is equivalent to 0.

Modelling Processes and Software

Geochemical processes were modelled using PHREEQC (Parkhurst & Appelo, 2013), a widely used software distributed by the United States Geological Survey (USGS) to perform a variety of aqueous geochemical calculations, such as:

- Aqueous reactions.
- Mixing of solutions.
- Calculation of mineral saturation indices.
- Gas and mineral interaction.

Data inputs, modelled geochemical processes, and outputs produced by the hydrogeochemical model are shown schematically in Figure 8. For each timestep (1 year) represented in the pit lake water balance, the model simulated:

- Mixing volumes of each inflow, as represented by source terms in proportions predicted by the GHD (2023) water balance.
- Concentration of the resulting mixed pit lake water by removal of pure water, representing evapoconcentration predicted by the water balance.
- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for geochemical processes, including:
    - Equilibration with atmospheric gases (O_2 and CO_2).
    - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed pit lake water.
    - Adsorption of dissolved metals and metalloids to hydrous ferric oxides (HFO) as represented by precipitated iron (hydr)oxide minerals.

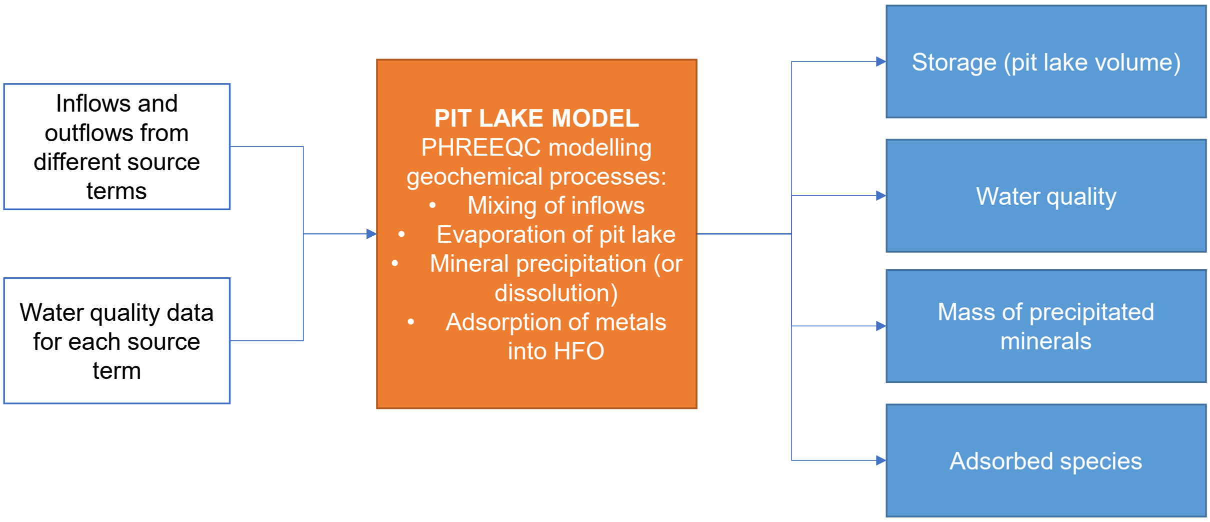

Figure 8. Hydrogeochemical model inputs, modelled processes, and outputs.

The WATEQ4F database was used for thermodynamic calculations, including mineral saturation indices' derivation. Mineral phases attaining a saturation index value equal to or greater than zero, which indicates that precipitation of that mineral from solution is thermodynamically favoured, were included as equilibrium phases if those minerals are known to, or are likely to, form under surface environmental conditions reflecting a pit lake. Adsorption of aqueous chemical species to hydrous ferric oxides was modelled using a diffuse double-layer surface complexation model (Dzombak & Morel, 1991), based on modelled precipitation of $Fe(OH)_3(a)$[1] from solution.

As per the Golden Bar Analogue Model (MWM, 2024a), the following was included:

- Two geochemical processes were included in the model to represent the nitrification and denitrification processes as modelled in the Golden Bar Analogue Model.
- Saturation index of $CO_2(g)$ was set to -3.1 and calcite to 0.85.

Dolomite precipitation was included if the Saturation Index of 2.5 was exceeded. In other words, if enough magnesium is available, a calcic-magnesic carbonate would precipitate instead of calcite.

Assumptions and Limitations

The following section discusses general model constraints, key assumptions, and limitations relating to the hydrogeochemical model:

- All data provided by OceanaGold are assumed to be correct, a high-level quality control / quality assurance (QAQC) has been undertaken on the datasets provided, to identify anomalous data.
- Data obtained from various sources is assumed to be representative of the materials associated with the project, and data represent the key environmental geochemistry risks.
- Outputs from the water balance (GHD, 2023) were assumed to be accurate and complete.
- The model assumes there is no stratification in terms of density (temperature or salinity stratification) or oxidation-reduction (redox) potential within the pits. It is acknowledged that recent data (MWM, 2024b) suggests that stratification may be occurring during summer months with slightly higher arsenic at depth (0.17 mg/L) compared to surface concentrations of 0.12 mg/L. Sulfate remains constant with depth and is not affected by stratification. Such effects are not considered in this model.
- Mineral reactions are modelled in equilibrium. If conditions are met, precipitation and dissolution occur instantly until mineral equilibrium is attained.
- Limited information was available for the chemical composition of some inflows. Where required, the composition was estimated using suitable analogues.
- No redox state (such as pe, Eh or ORP) data were available for source term derivation. A pe value of 10 was applied for all source terms, and equilibrium between the pit lakes and the atmosphere (O_2 and CO_2) was assumed.

[1] *(a) = amorphous.*

- The shake flask extraction (SFE) data used in the model are the maximum data observed for that sample, irrespective of whether it was an oxic or anoxic test[2]. This does not apply to pH and minimum pH data was used to be conservative.
- All Fe introduced into the model is assumed to be in the Fe^{3+} form.
- Nitrification and denitrification processes were included to represent the process of ammoniacal nitrogen being converted to nitrate, and nitrate being converted to nitrogen gas, and therefore, degassing from the solution. Both processes were empirically fitted in the Golden Bar Analogue Model (MWM, 2024a) to provide a suitable model based on empirical data.

  Following the approach completed for the Golden Bar Analogue Model (MWM, 2024a), an initial nitrogen load (as NH_4NO_3) was added to account for the ANFO residues that flush into the pit lake. The initial nitrogen load was 5.35 g/m^2, therefore, for the Innes Mills Pit (~731,000 m^2), corresponded to 3,910 kg of nitrogen as NH_4NO_3.This load was released over three years in the model to fit previous empirical data trends (MWM, 2024a). No nitrogen load was applied to the FTSF Pit Lake as it is assumed the nitrogen load present in the pit walls has already been flushed out (unlike the IM Pit where significant additional mining activities will occur.
- The effects of cyanide are considered in this geochemical model as a conservative compound, which means that the contaminant does not decay over time. However, this is an extremely conservative approach and will serve to estimate the maximum possible concentrations of cyanide. It is generally anticipated that cyanide breaks down once exposed to the atmosphere. Sources of cyanide are associated with the tailings placed in the FTSF, which flows to the Frasers Pit Lake from the pore space dewatering during consolidation, and the TSF underdrains water pumped into Frasers. TTTSF impoundment water quality data (2016 – 2021) indicates that WAD[3] cyanide ranges from 0.0176 – 0.35 mg/L with an average of 0.07 mg/L. TTTSF underdrainage water quality data (2014 – 2021) indicates that WAD cyanide ranges from 0.001 – 0.35 mg/L with an average value of 0.05 mg/L. Downstream compliance limits are 0.1 mg/L.

[2] *Further details of the anoxic and oxic test data are provided in MWM (2024b)*

[3] *Weak acid dissociable (WAD) cyanide.*

RESULTS AND ANALYSIS

Selected outcomes from the hydrogeochemical modelling are presented in this section for the Frasers-TSF Pit Lake and IM pit lake where year 0 represents the start of lake filling after mining activities have ceased in the pit.

Three lines are presented in the following plots:

- The red line represents the result of the Frasers TSF Pit Lake.
- The blue line represents the result of the Innes Mills Pit Lake.
- The orange line represents the theoretical mixing between the two lakes. Because Frasers TSF Pit Lake is larger than Innes Mills Pit Lake, the theoretical mixing line will be often closer to the Frasers TSF PL red line.

pH and Sulfate

Predicted values for pH are shown in Figure 9, and it can be observed that the expected pH is neutral to alkaline in the range of 8.0 to 8.2 for the modelled period.

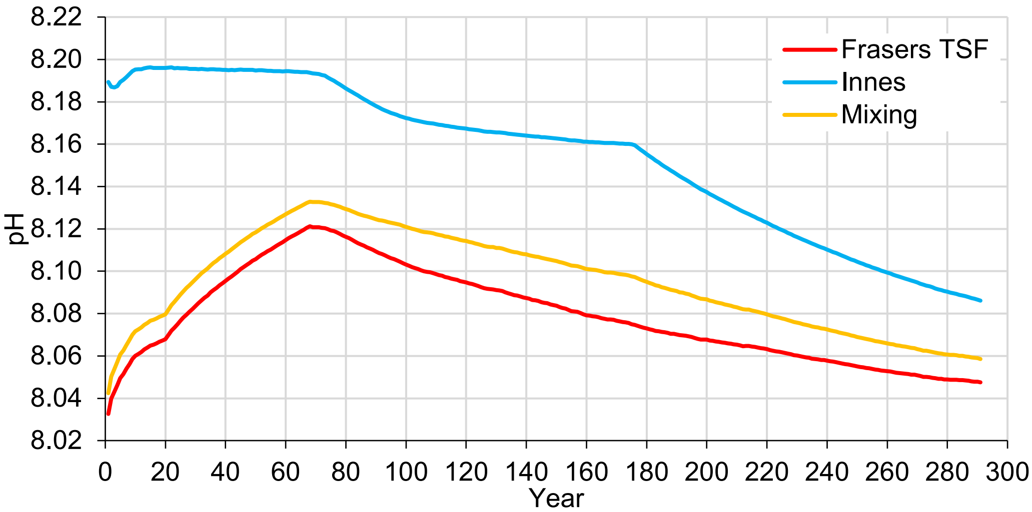

Figure 9. Predicted pH for FTSF and IM pit lakes.

Figure 10 shows the predicted sulfate concentrations, and Figure 11 shows predicted the sulfate load. The following can be noted:

- Frasers TSF Pit Lake sulfate concentrations are influenced by the composition of the tailings process water (underdrains) for the first 20 years with concentrations over 2,000 mg/L. However, sulfate concentrations decrease with time, reaching a concentration below 1,500 mg/L by year 140.
- The IM Pit Lake sulfate concentration has an increasing trend due to the inflow of groundwater and eventual overflow from FTSF Pit Lake into IM Pit Lake.
- After reaching similar values to FTSF Pit Lake, the long term combined pit lake trend resembles the behaviour of the FTSF Pit Lake.

- Sulfate load estimated in the FTSF Pit Lake is higher than the sulfate load estimated in the IM Pit Lake. The peak for IM Pit Lake is ~45 kt of sulfate, while the peak for FTSF is ~120 kt occurring in year 80 due to the solute release coming from the embankment backfill.

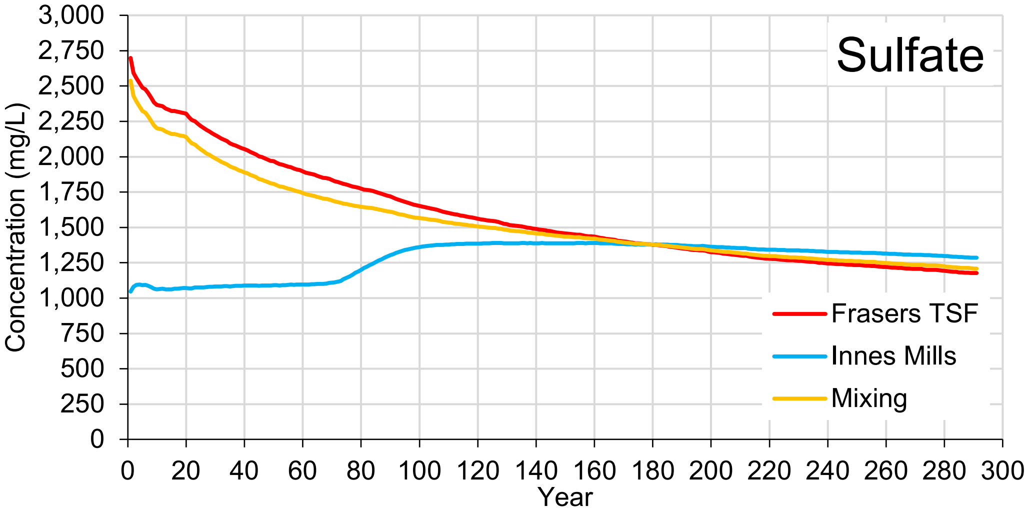

Figure 10. Predicted sulfate concentrations for FTSF and IM pit lakes.

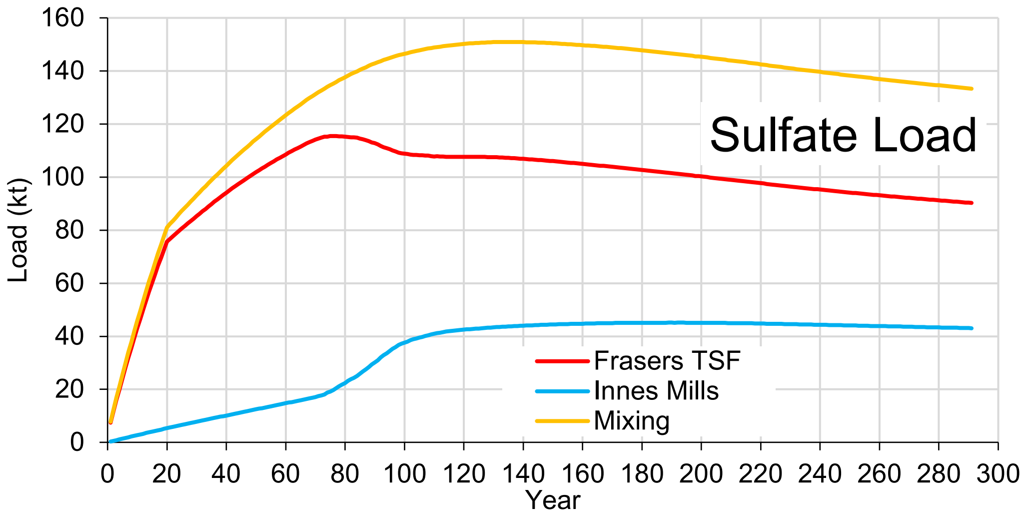

Figure 11. Predicted sulfate load for FTSF and IM pit lakes.

Arsenic and Antimony

Results for predicted As and Sb concentrations are presented in Figure 12 and Figure 13, respectively.

- The concentrations of As and Sb in the IM Pit Lake exhibit similar behaviour (increasing trends reaching a peak at ~0.16 mg/L and then decreasing), as both primarily result from the solute release caused by FRBF saturation as the pit lake level rises.
- Arsenic concentration peak in FTSF below 0.05 mg/L and is caused by the TSF Underdrain inflow.

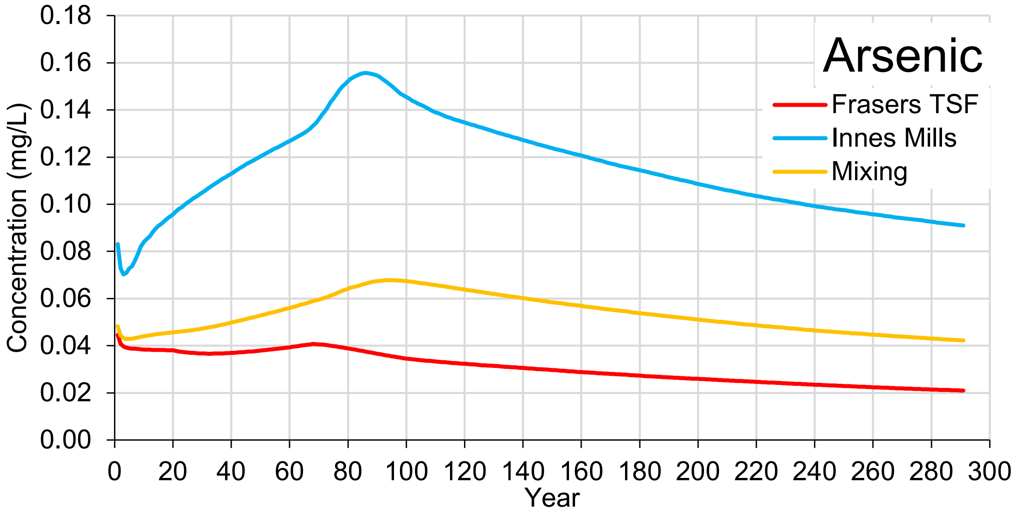

Figure 12. Predicted As concentration for FTSF and IM pit lakes.

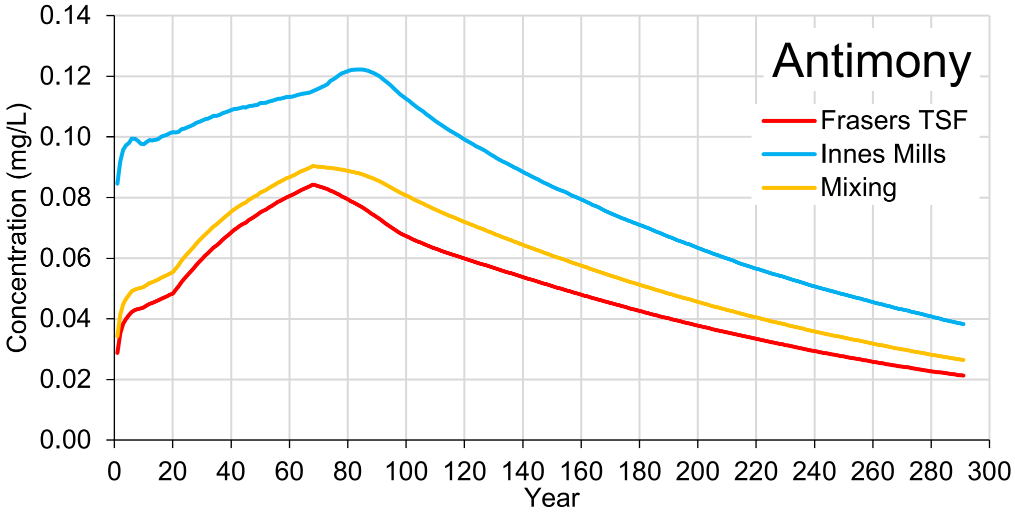

Figure 13. Predicted Sb concentration for FTSF and IM pit lakes.

Calcium, Magnesium, Alkalinity

Calcium, magnesium, and alkalinity are relevant parameters as they control the carbonate precipitation/dissolution, pH, and the interaction with atmospheric CO_2. If enough Ca and sulfate is available, gypsum (calcium sulfate) can precipitate decreasing concentrations of these elements.

Results for predicted Ca concentrations are presented in Figure 14:

- FTSF Pit Lake: Calcium has its maximum concentration of 450 mg/L at year 0 (set by initial conditions of the TTTSF impoundment water quality), then decreases to approximately 370 mg/L by year 10 and remains steady until year 70 when Ca starts decreasing overtime due to decreasing input loads once all FRBF materials have been flooded.
- IM Pit Lake: Ca increases from initial conditions to reach a peak of ~325 mg/L to later decrease with time reaching a concentration of ~250 mg/L.

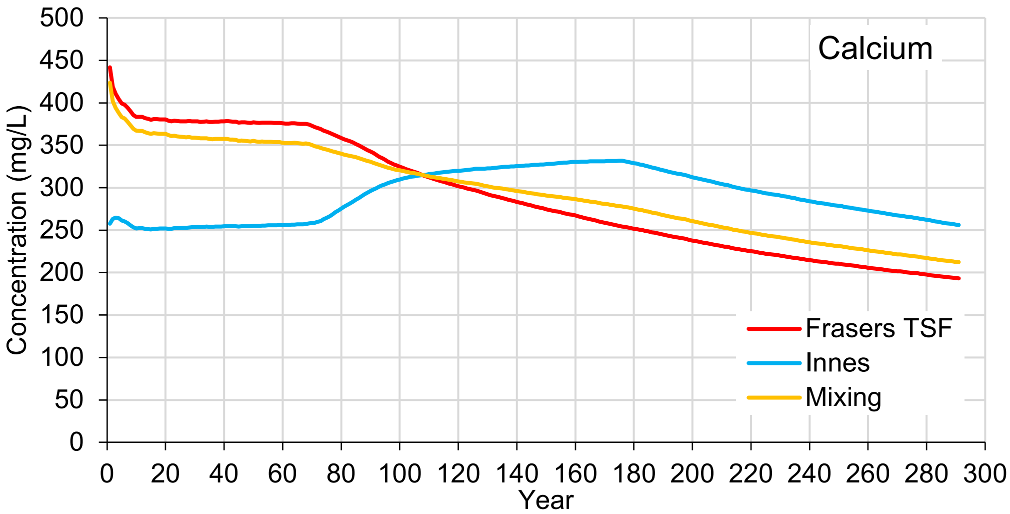

Figure 14. Predicted Ca concentrations for FTSF and IM pit lakes.

Results for predicted Mg concentrations are presented in Figure 15:

- FTSF Pit Lake: Mg concentration has its maximum concentration (~250 mg/L) in the first years decreasing to a concentration of nearly 150 mg/L. After that it is relatively stable (150 – 180 mg/L).
- IM Pit Lake: Mg increases from initial conditions (< 100 mg/L) and increase with time to resemble FTSF Pit Lake water quality.

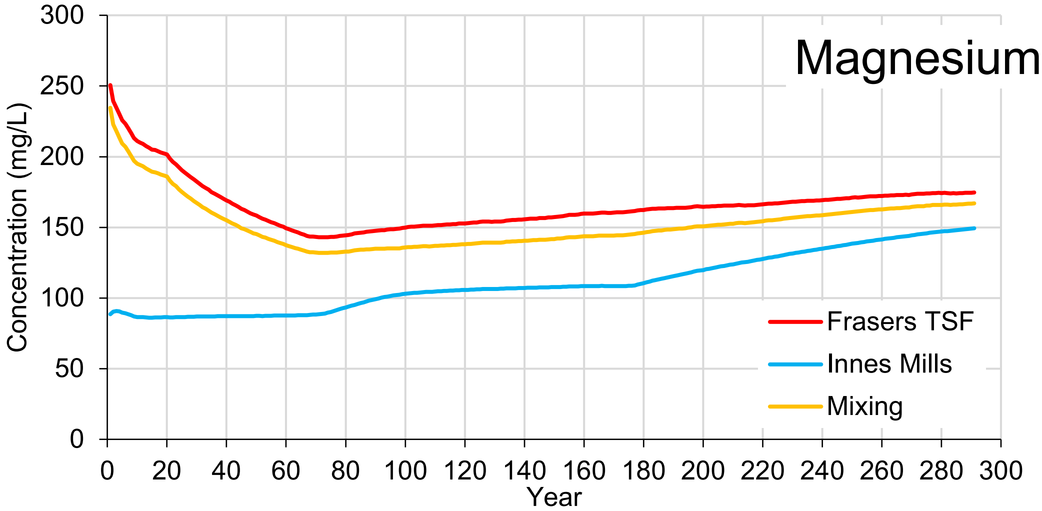

Figure 15. Predicted Mg concentrations for FTSF and IM pit lakes.

Alkalinity concentrations are heavily controlled by the CO_2(g) interaction and calcite precipitation resulting in concentrations between 110 to 150 mg of $CaCO_3$/L (Figure 16).

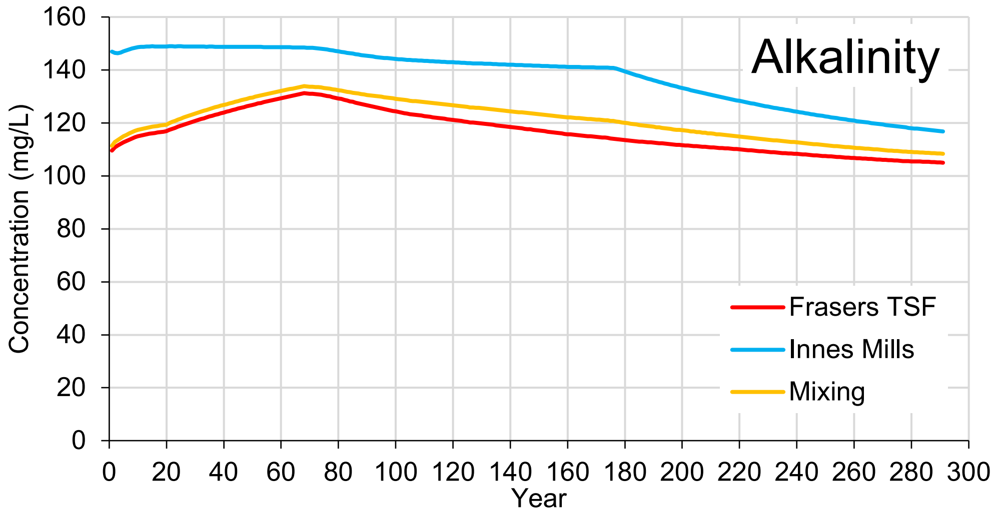

Figure 16. Predicted alkalinity concentrations for FTSF and IM pit lakes.

The elevated alkalinity and Ca inflows, contribute to carbonate mineral precipitation in IM Pit Lake. Calcite precipitation is expected, totalling approximately ~5 kt at its peak in year ~90, however, dissolution of calcite is expected afterwards (Figure 17). No calcite precipitation is expected for FTSF due to low alkalinity and Ca concentrations. No gypsum precipitation is expected as it remains undersaturated in the model.

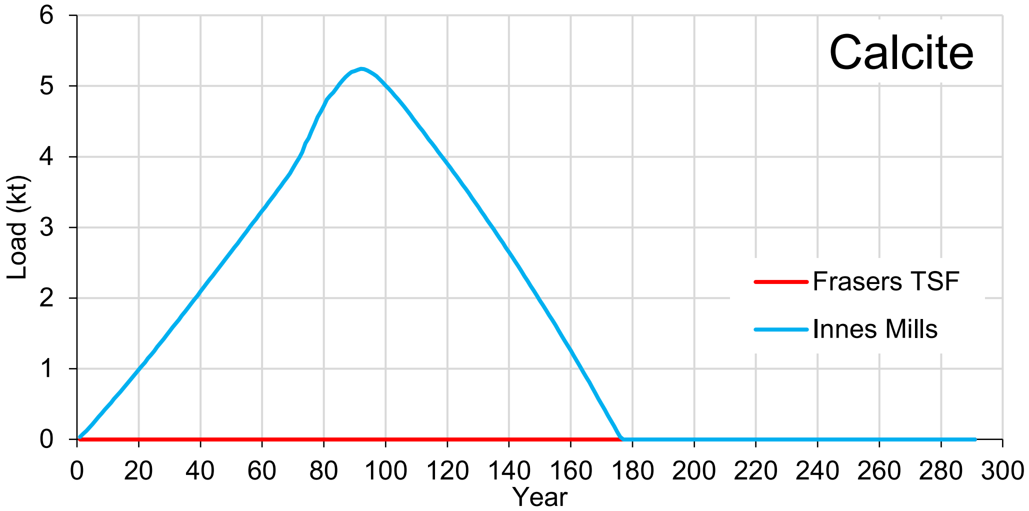

Figure 17. Predicted calcite precipitation for FTSF and IM pit lakes.

<u>Nitrogenous Compounds</u>

Predicted results for nitrate nitrogen (NO_3-N) and ammoniacal nitrogen (Amm-N) are shown in Figure 18 and in Figure 19. An initial nitrogen load was added as NH_4NO_3 to IM Pit Lake associated with the pit walls and/or impacted area, distributed equally in the first 3 years of the model. Data indicates most of the nitrate-N originates from waste rock backfill. From the results, the following can be observed:

- Nitrate nitrogen has an initial concentration of 12-13 mg/L in both pit lakes in year 0 due to the initial nitrogen load and then decreases rapidly to values below 2 mg/L by year 20.
- Ammoniacal nitrogen (Amm-N) results in an initial peak of 1 - 1.2 mg/L in both lakes with a decreasing trend. By year 10 Amm-N is below 0.1 mg/L for both pit lakes.
- Both nitrification and denitrification processes are included in the model as derived previously (MWM, 2024a), resulting in a fairly rapid decay in nitrogenous compound concentrations.

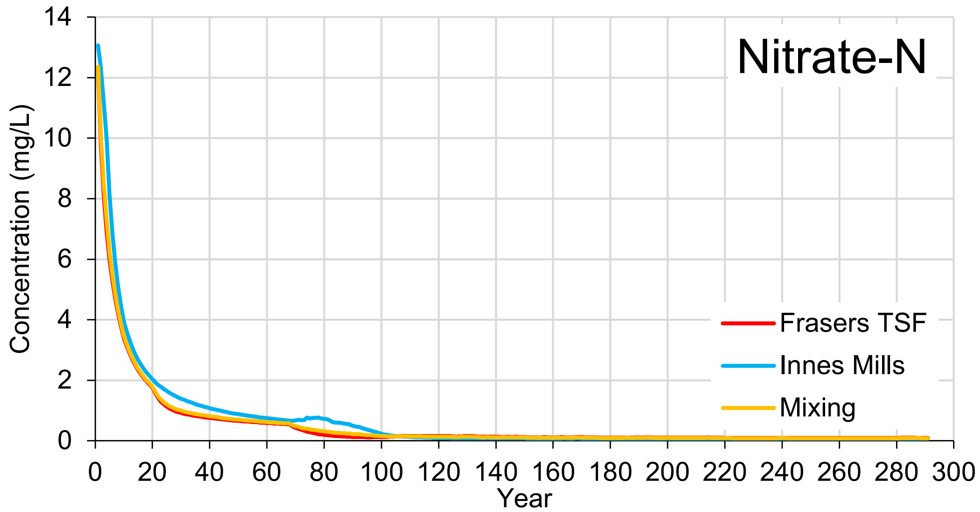

Figure 18. Predicted nitrate nitrogen concentrations for FTSF and IM pit lakes.

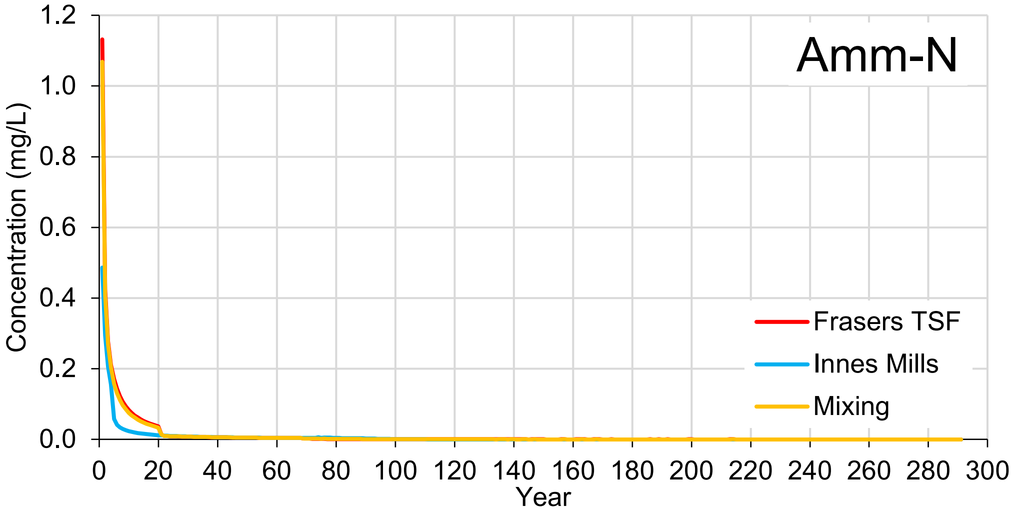

Figure 19. Predicted ammoniacal nitrogen (Amm-N) concentrations for FTSF and IM pit lakes.

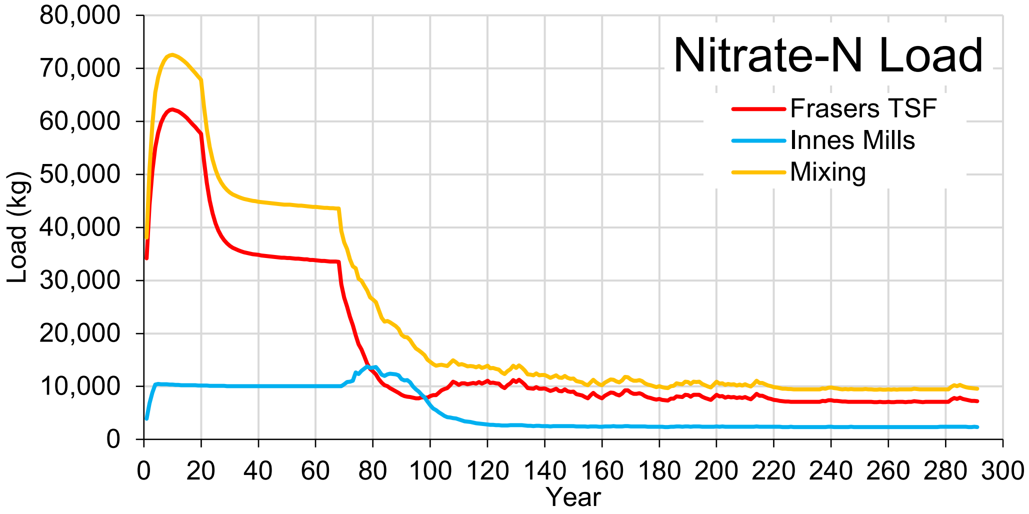

Figure 20. Predicted nitrate nitrogen loads for FTSF and IM pit lakes.

<u>Other Parameters</u>

Other parameters modelled were Cu, Pb, and Zn. However, the resulting concentrations were below 1 µg/L for Cu and Pb and below 6 µg/L for Zn.

Additionally, cyanide was included in the model as a conservative element, which means no decay and the results show what would be the maximum concentration. This is considered an unrealistic scenario but provides a potential value and remains low (< the resource consent limit of 0.1 mg/L).

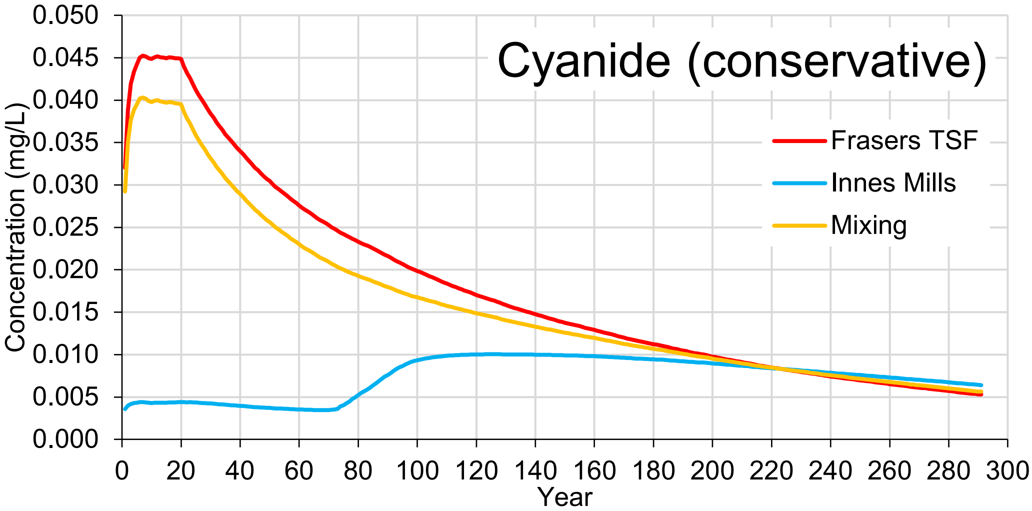

Figure 21. Predicted cyanide concentrations for FTSF and IM pit lakes (conservative).

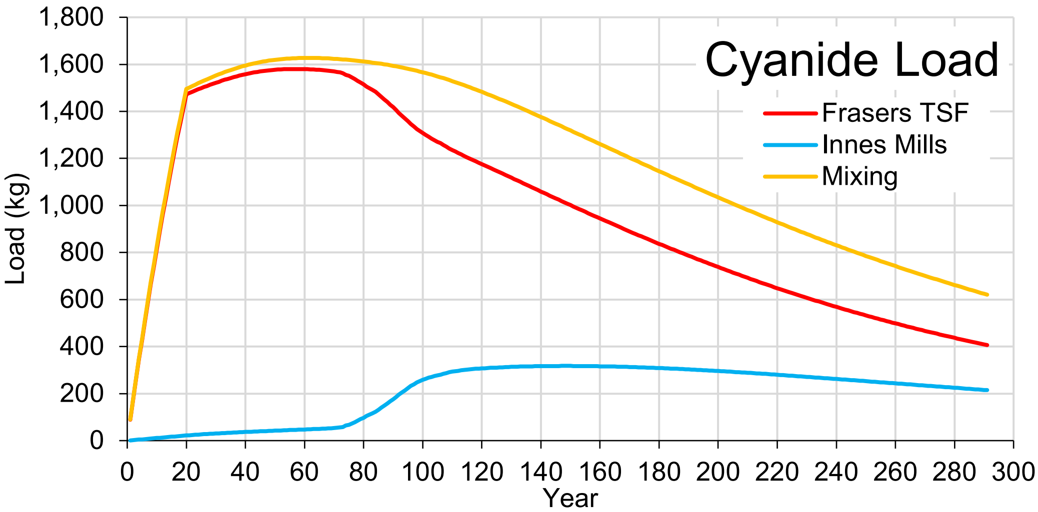

Figure 22. Predicted cyanide load for FTSF and IM pit lakes (conservative).

SUMMARY

A summary of the predicted water quality for selected years is presented in Table 4.

Table 4.Summary of predicted parameters/concentrations for Frasers TSF and Innes Mills pit lakes.

Sub-Domain	Frasers TSF				Innes Mills				Mixing			
Year	1	100	200	290	1	100	200	290	1	100	200	290
pH	8.03	8.11	8.07	8.05	8.19	8.18	8.14	8.09	8.04	8.13	8.09	8.06
Dissolved solids (mg/L)	3,974	2,509	1,993	1,753	1,802	2,182	2,129	1,959	3,760	2,411	2,033	1,815
Alkalinity (mg $CaCO_3$/L)	110	124	112	105	147	144	133	117	111	129	117	108
Ca (mg/L)	436	299	205	157	257	300	297	236	418	300	233	181
Mg (mg/L)	251	150	165	174	89	103	120	149	235	136	151	167
Na (mg/L)	306	158	95	67	82	114	100	80	284	145	97	71
K (mg/L)	73	70	42	27	73	95	60	40	73	77	47	31
Cl (mg/L)	6.9	5.2	4.6	4.4	3.9	4.6	4.8	4.8	6.6	5.0	4.7	4.5
NO_3-N (mg/L)	12.28	0.12	0.11	0.09	13.07	0.23	0.07	0.07	12.36	0.16	0.10	0.09
Amm-N (mg/L)	1.1317	0.0005	0.0004	0.0001	0.48	0.0006	0.0001	0.0000	1.07	0.0006	0.0003	0.0001
SO_4 (mg/L)	2,698	1,652	1,325	1,176	1,047	1,361	1,363	1,285	2,538	1,566	1,337	1,209
Mn (mg/L)	0.04	0.11	0.06	0.04	0.14	0.16	0.11	0.06	0.05	0.12	0.08	0.05
Zn (mg/L)	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
As (mg/L)	0.04	0.03	0.03	0.02	0.08	0.15	0.11	0.09	0.05	0.07	0.05	0.04
Sb (mg/L)	0.03	0.07	0.04	0.02	0.08	0.11	0.06	0.04	0.03	0.08	0.05	0.03
Cyanide (mg/L)	0.0320	0.0199	0.0098	0.0053	0.0036	0.0093	0.0090	0.0064	0.0292	0.0167	0.0095	0.0057
Pb (mg/L)	0.000002	0.000002	0.000002	0.000002	0.000027	0.000022	0.000026	0.000023	0.000005	0.000008	0.000009	0.000008

CLOSING REMARKS

Further information is provided in the following attachments:

Attachments: Attachment A – Digital Attachment FRIM Pit Lakes Model Results Excel File

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ATTACHMENT A – DIGITAL ATTACHMENT FRIM PIT LAKES MODEL RESULTS EXCEL FILE

APPENDIX N LIMITATIONS

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