Engineered Landform Water Quality Forecast Model Report

Bendigo-Ophir Gold Project

13 September 2025

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MINE WASTE MANAGEMENT
GREENROAD GROUP

MATAKANUI
GOLD LIMITED

Engineered Landform Water Quality Forecast Report

Bendigo-Ophir Gold Project

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EXECUTIVE SUMMARY

Mine Waste Management Limited (MWM) has prepared this report on the geochemical modelling of the proposed engineered landforms (ELFs) at the Bendigo-Ophir Gold Project (BOGP) for Matakanui Gold Limited (MGL) to understand potential effects on water quality from these mine domains. The modelling supports proactive source control and provides a foundation for sustainable waste rock management, aligning with INAP [1] (2024) principles for long-term environmental stewardship. Data are used in the water and load balance model (MWM, 2025b) to understand the effects on the receiving environment and provide improved management opportunities for ELF seepage.

Objectives of this Study

The purpose of this report is to present the geochemical modelling undertaken to estimate seepage water quality for the Shepherds ELF, SRX ELF, Come in Time (CIT) Backfill, West ELF, and Shepherds Creek (SCK) Fill during operations and during the active closure and post closure phases of the BOGP. The objectives of this report are as follows:

- Develop a conceptual geochemical model for each ELF.
- Estimate water quality seepage from the ELFs during operations and the active closure and post closure phases of the BOGP.
- Provide recommendations for management of ELF seepage based on model results.

Findings

MGL will place waste rock in ELFs to minimise long term risks associated with sulfide mineral oxidation and the release of potential constituents of concern (PCOC). Further details on the design philosophy for ELFs are provided in MWM (2025f)

The materials associated with the BOGP will generate neutral metalliferous drainage and may have elevated PCOC such as arsenic (As), sulfate, (SO_4), and trace metals. Nitrogenous compounds are also likely to be elevated. Collectively the waters are referred to as mine impacted waters (MIW).

If waste rock was managed by traditional waste rock stack construction methods that did not manage advective oxygen ingress along basal rubble zones created by high tipheads (>10 – 20 m in height) and grainsize segregation, then Shepherds WRS seepage water quality could be > 6,000 mg/L sulfate. By minimising oxygen ingress to the outer 20 m of the proposed ELFs, a significant reduction in sulfate (and other PCOC) are expected.

Modelling indicates that peak sulfate concentrations for the Shepherds ELF could be reduced by ~80% to approximately ~1,120 mg/L by using best practicable management methods for waste rock storage.

Management

This study has identified and recommends the following management opportunities that will minimise the long-term risks to water quality for waste rock storage at the BOGP:

[1] *International Network for Acid Prevention: https://www.inap.com.au/acid-drainage*

- Proceed with the proposed ELF design, ensuring low As TZ3 materials encapsulate high-sulfur materials (TZ4) to minimise oxygen ingress.
- Proceed with short lift heights at 5 m height and confirm that grainsize segregation is minimised and that oxygen is reduced to < 5% after 10-20 m horizontal distance into the ELF and that the oxygen profiles (from oxygen probe monitoring) demonstrate that oxygen ingress is diffusion controlled. Higher heights may be possible if advective oxygen ingress is prevented by engineering controls.
- Install cover systems to further mitigate risks as the final landform is created. Consider cover systems to minimise net percolation as this is a key driver of long term PCOC load.
- Establish a comprehensive monitoring program for water quality, oxidation rates, and cover system performance. Adapt management strategies based on observed trends and evolving conditions.
- Continue validating laboratory-to-field scaling factors using site-specific data, particularly for TZ3 and TZ4 materials, to refine long-term predictions.

General Background

MGL is proposing to establish the BOGP, which comprises a new gold mine, ancillary facilities and environmental mitigation measures on Bendigo and Ardgour Stations in the Dunstan Mountains of Central Otago. The project site is located approximately 20 km north of Cromwell and will have a maximum disturbance footprint of 550 hectares.

The total Mineral Resource Estimate for the BOGP using a 0.5 g/t cut-off for open pit and 1.5 g/t for underground is 34.3 Mt at 2.1 g/t for 2.34 M oz (MGL, 2025). The Bendigo-Ophir resources occur in four deposits: Come in Time (CIT), Rise and Shine (RAS), Srex (SRX), Srex East (SRE). The majority of identified mineral resources are located within the RAS deposit. Three primary geological units are recognised at site:

- RSSZ – Rise and Shine Shear Zone
- TZ3 – Lower Greenschist facies Textural Zone 3 rocks of the Otago Schist
- TZ4 – Upper Greenschist facies Textural Zone 4 rocks of the Otago Schist

The resources will be mined by open pit methods at each deposit within the project site, with underground mining methods also proposed to be utilised at RAS to access the deeper gold deposits. The majority of the mining activities, ancillary facilities and associated infrastructure will be located in the Shepherds Valley – which includes a conventional carbon-in-leach (CIL) gold processing plant and water treatment plant, a tailing storage facility, three engineered landforms, internal haul roads, topsoil stockpiles, water pipelines, underground utilities and electrical supply - with non-operational infrastructure located on the adjoining Ardgour Terrace. The BOGP also involves the taking of groundwater from the Bendigo Aquifer for use in mining-related activities and the realignment of Thomson Gorge Road via Ardgour Station.

The proposed BOGP will include the following components:

- Open pits targeting the RAS, SRX, SRE, and CIT deposits.

- An underground mine targeting the RAS deposit.
- Three ex-pit engineered landforms (ELFs) – Shepherds ELF, SRX ELF, and West ELF (WELF).
- Two in-pit landforms (backfill) – CIT and SRE [2].
- Plant and processing area, where CIL extraction technologies will be used as part of the ore recovery process. This includes ~ 5 m of TZ3 fill and is referred to as SCK Fill.
- A tailings storage facility (TSF) and TSF Embankment.
- Other ancillary support services / structures (e.g., roads, water management infrastructure, water treatment plants, etc).

Mine Impacted Water

A geochemical model is required to understand the effect on the receiving environment of the MIW and forecast the water quality from the proposed ELFs, as traditional waste rock stacks (WRS) generally represent the greatest source of contaminants for any mining project (e.g., INAP, 2020).

Model Development

The following modelling methods were used:

<u>Data and Methodology:</u> The geochemical model risks were informed by data from acid-base accounting (ABA), total sulfur analysis, and chemical assay of waste rock samples, as well as AMIRA (2002) column leach test (CLT) data. The geochemical behaviour was modelled under three scenarios:

1. A traditional WRS with high lift heights and complete oxidation of materials: This model was used to calibrate the model water quality estimates to empirical datasets.
2. An ELF constructed with limited oxygen ingress – 10 m horizontal oxidation shell.
3. An ELF constructed with limited oxygen ingress – 20 m horizontal oxidation shell.

<u>Sulfur Reservoir Estimation:</u> Reactive fractions of waste rock within the WRS and ELF models were defined, using a non-reactive fraction of 0.9 to account for field-scale mineral accessibility [3]. Sulfur reservoirs were split into stored oxidation products (SOP) and long-term sulfide sources that was based on CLT data.

<u>Oxidation and Release Rates:</u> Sulfate and metal release rates were calculated for the TZ3 and TZ4 lithological units from CLT data. CLT data showed that TZ4 was found to release sulfate at a rate six times higher than TZ3 due to its higher sulfur content and mineral reactivity.

<u>Time Lag to Peak Concentration:</u> A delay between waste rock placement and peak solute concentrations reporting as seepage from the structures is expected. Peak sulfate concentrations, a function of average ELF height, were determined for Shepherds ELF (~27 years), SRX ELF (~5 years),

[2] *Note: SRE Pit is backfilled by the SRX ELF.*

[3] *This non-reactive fraction is comparable to international literature (e.g., Linklater et al., 2017).*

CIT ELF (~4 years), WELF (~10 years), and SCK Fill (~3 years) based on analogue data from Macraes (e.g., MWM, 2024a).

Adjustment Factors: To align lab results with analogue data from Macraes, a release rate adjustment factor of 0.8575 was applied to oxidising materials (i.e., 10% of the materials in the WRS). These adjustments allowed the model to simulate realistic peak sulfate concentrations for a traditional WRS (e.g., ~6,200 mg/L for Shepherds WRS).

Mobilisation: Oxidation products are driven by net percolation, which has been estimated at 20% of rainfall (MWM, 2025c).

Solubility Controls: PHREEQC geochemical modelling (Parkhurst and Appelo, 2003) was used to apply mineral solubility limits and simulate precipitation of secondary minerals. Assumptions included dolomite buffering and elevated CO_2 in porewaters (due to carbonate dissolution within the WRS / ELF).

Summary

The study indicates that:

- Water quality is expected to be circum-neutral pH with low acidity. This is due to the abundance of carbonate minerals and a low sulfide content.
- When the results for the two scenarios overlap (e.g., 10 m and 20 m oxidation zones), it indicates that the solutes originate from short-term release, where oxidation has no impact on the results, and therefore, results are the same.
- The first 50 years are strongly influenced by the short-term release of SOP. This is particularly evident for nitrate-nitrogen (NO_3-N), boron (B), cobalt (Co), and zinc (Zn), which are generally elevated and are associated with SOP (see Table 14). Reducing water ingress would reduce the rate that these PCOC are mobilised.
- Sulfate concentrations are > 500 mg/L for the Shepherds ELF, SRX ELF, and WELF. Sulfate concentrations are < 500 mg/L in the CIT backfill and the SCK Fill.
- Nitrate-N concentrations are > 2.4 mg/L in seepage from all waste rock disposal areas. Duration of elevated nitrate in seepage is expected to range from 25 – 100 years but may be shorter due to biogeochemical processes that would remove the nitrate.
- Results indicate that the following trace metals: Co, Mo, Mn, Se, Sb, Sr, U, and Zn, are generally over the respective water quality reference limits.
- Results indicate that Al, B, Cd, Cr, Cu, Hg, and Pb, are below the respective water quality reference limits in all cases. These PCOC are not considered an issue for this mine domain.
- Constant concentrations are assumed for As (0.2 mg/L) and Fe (7.6 mg/L) based on empirical data for sub-oxic conditions (e.g., Globe Progress Waste Rock Stack, Hayton et al., 2022). These concentrations are above the proposed water quality reference limit (Ryder, 2025) and will require management. The SCK Fill assumes full oxidation, which results in low Fe concentrations.

Conclusions

- ELF construction to limit oxygen ingress significantly improve water quality outcomes over traditional WRS by limiting oxygen ingress and reducing the oxidation of higher sulfur materials.
- Net percolation rates drive the mobilisation of soluble contaminants.
- This modelling supports proactive source control and provides a foundation for sustainable waste rock management, aligning with INAP (2024) principles for long-term environmental stewardship.

Performance Monitoring

- Confirm the sulfur content of materials placed in the ELF ensuring that lower sulfur TZ3 materials are placed on the outside of the ELF. Testing should include shake-flask testing to validate the quantity of sulfate and nitrogenous compounds present in blasted rock.
- Confirm that oxygen ingress is excluded from the core of the ELF by the construction of oxygen probes into each lift during construction of the ELF.
- Confirm water quality for ELF seepage aligns with geochemical models including sulfate and nitrate. Update models where significant differences are observed.
- The geochemical model relies on laboratory data and analogue assumptions; field validation is required. The model requires updating once the CLT is complete as early data can bias results towards higher loads.
- If performance monitoring indicates unacceptable loads, then adaptive management options should be considered including additional source control actions (e.g., engineered cover systems), reducing oxidation depth to 10 m into the ELF, a longer period of active treatment and/or the development of passive treatment systems to manage the PCOC concentrations and loads.

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1 INTRODUCTION

Mine Waste Management Limited (MWM) has prepared this report on the geochemical modelling of the proposed engineered landforms (ELFs) at the Bendigo-Ophir Gold Project (BOGP) for Matakanui Gold Limited (MGL) to understand potential effects on water quality from these mine domains. The modelling supports proactive source control and provides a foundation for sustainable waste rock management, aligning with INAP[4] (2024) principles for long-term environmental stewardship. Data are used in the water and load balance model (MWM, 2025b) to understand the effects on the receiving environment and improved management opportunities for ELF seepage.

1.1 Project Description

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[4] *International Network for Acid Prevention: https://www.inap.com.au/acid-drainage*

[5] *Note: SRE Pit is backfilled by the SRX ELF.*

- Plant and processing area, where CIL extraction technologies will be used as part of the ore recovery process.
- A tailings storage facility (TSF) and TSF Embankment.
- Other ancillary support services / structures (e.g., roads, water management infrastructure, water treatment plants, etc).

These facilities will be placed in the catchment of Shepherds and Bendigo creeks (Figure 1).

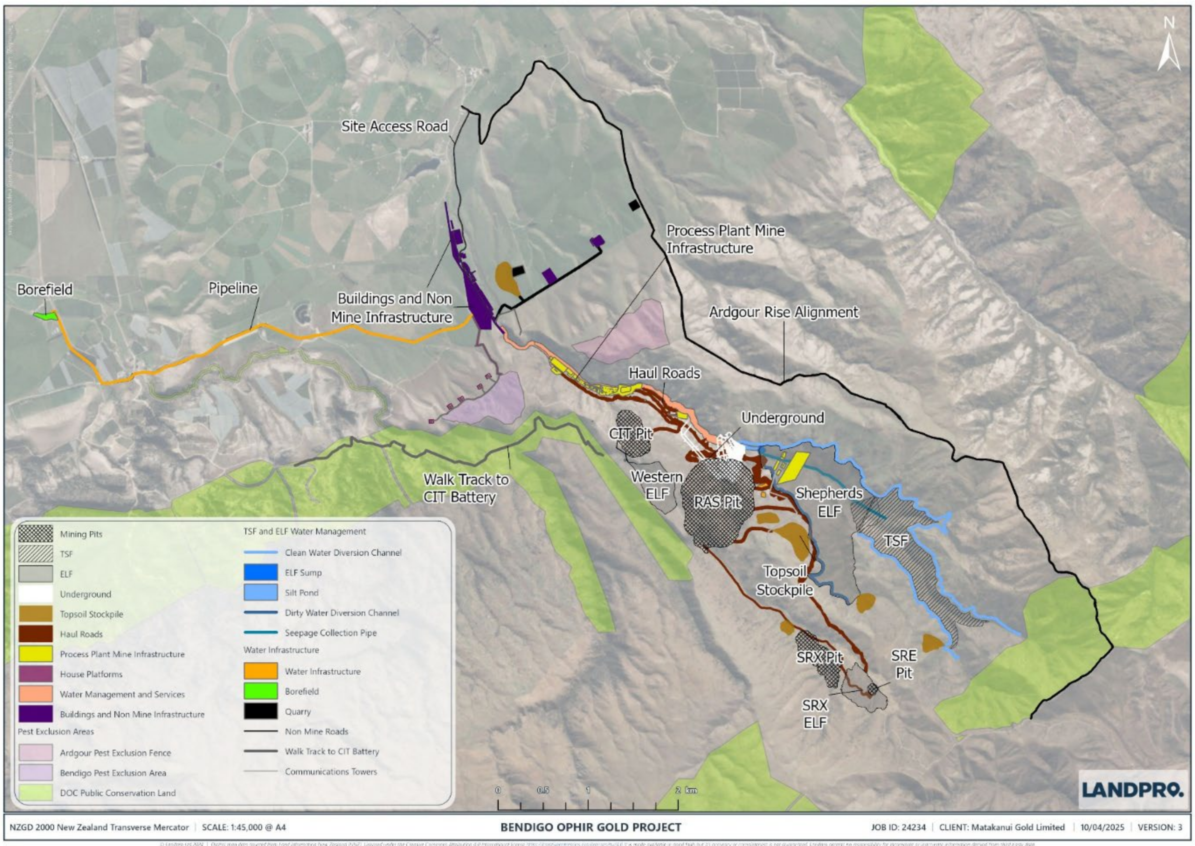

Figure 1. Bendigo-Ophir Gold Project Infrastructure

1.2 Geology

1.2.1 Regional Geology

The Dunstan Mountains are an uplifted block of the Otago Schist tilted to the northwest with remnants of a Cretaceous peneplain well preserved on its northern slopes. The Otago Schist is formed from sedimentary and minor intermediate volcanics and volcaniclastics of the Caples and Torlesse tectono-stratigraphic terranes. Greenschist facies rocks of the Otago schist are sub-divided into four textural zones based on mineralogy and mineral textures. Peak metamorphic grades in the Otago Schist occurred during the Jurassic when the Zealandia micro continent formed the outboard subduction complex of the Gondwana continental margin.

The regional geology of the Central Otago goldfields surrounding the BOGP consists of chlorite and biotite schists. The Rise & Shine Shear Zone (RSSZ), a late metamorphic deformation zone (Cox et al., 2006), runs through the project site dipping at 20-30 degrees northeast. The RSSZ occurs in the

Textural Zone 4 (TZ4) schist in close association with the Thomsons Gorge Fault, which cuts and truncates the RSSZ against the unmineralised TZ3 schist (Cox et al., 2006). There is no mineralisation associated with the TGF itself, and Au mineralisation had ceased by the time of formation of the TGF (c. 100 Ma) (Cox et al., 2006).

1.2.2 BOGP Geology

Gold mineralisation occurs along the Rise and Shine Shear Zone (RSSZ) within the Otago Schist. The Rise and Shine Shear Zone (RSSZ) has been traced for 1.7 km north-northeast beneath the unconforming TZ3 cover rocks with the bulk of the mineralisation sitting beneath 150-300 m of the lower sulfur cover rock (TZ3). The flat lying and flat plunging deposit sits within a zone up to 400 m wide and can be up to 90 m in thickness (typically 30 – 40 m).

The Thomson Gorge Fault is a post metamorphic, post mineralisation cataclastic fault zone developed primarily along the hanging wall of the RSSZ. It separates chlorite rich, TZ3 schists in the hanging wall from biotite rich TZ4 schists in the shear zone and foot wall. The main mineralisation at RAS is associated with silica-siderite/ankerite alteration with minor arsenopyrite sulfides associated with the gold. In some areas a cataclastite (brecciated) network of anastomosing, post-metamorphic quartz, occur with minor sulfide veins in a halo of the core mineralisation. Allibone (2023) also identified the presence of sphalerite ((Zn,Fe)S) and galena (PbS) at the BOGP.

Locally, a number of splay faults are interpreted coming off the main RSSZ structure which give a sense of structural control. These are also mineralised and are traceable for 10s to 100s of metres. Gold occurs as free gold particles, typically up to 400 µm but with some coarser visible gold. A minor gold component occurs associated with the arsenopyrite grains, but it is typically not in solid solution, giving rise to the free milling and highly gravity recoverable components expressed by metallurgical testing.

1.3 Environmental Geochemistry

The BOGP gold deposit is located within the Otago Schist, near Cromwell, New Zealand, and is associated with the mineralised Rise and Shine Shear Zone (RSSZ). Gold mineralisation within the RSSZ and TZ4 is dominated by elevated sulfur (S) and arsenic (As) (e.g., the mineral arsenopyrite) compared to TZ3 materials

The mineralisation associated with the BOGP and natural weathering of the gold deposit has contributed to baseline water quality being elevated in some metals, which has been acerbated by historical legacy mining activities, leading to streams in the project area being enriched in potential constituents of concern (PCOC) that include for instance, As, Co, Cu, Fe, U, and Zn that are elevated compared to proposed resource consent water quality limits (Ryder, 2025) and some others identified as being elevated on an infrequent basis such as Al, Cd, Mn, Pb, Sr, and Tl. Similarly, groundwaters are elevated in Sr.

Studies indicate that the rocks associated with the project (TZ3, TZ4, and RSSZ) will not generate acid rock drainage with >350 samples tested by industry accepted acid base accounting (ABA) techniques (e.g., AMIRA, 2002). This is a function of the high acid neutralisation capacity (ANC) of the rocks associated with carbonate minerals (e.g., dolomite) and a low sulfide mineral content (e.g., arsenopyrite, pyrite) that can generate lesser acidity. The overall ABA assessment indicates that the rocks are classified as non-acid forming (NAF).

Nitrogenous compounds such as nitrate are also expected to be elevated in seepage from blasted rock due to the use of ammonium-nitrate fuel oil (ANFO) based explosive. This is not an uncommon issue in the mining industry.

It is expected that mining of the BOGP could affect surface- and ground- waters within the project area and these effects will include:

- Elevated total suspended solids (TSS).
- Neutral metalliferous drainage with elevated sulfate (SO_4) and the certain PCOCs such as As, Fe, and trace metals.
- Nitrate-rich drainage due to the use of ANFO as a bulk explosive during blasting activities.

Collectively these waters are referred to as mine impacted water (MIW) to acknowledge the different contributions to poor water quality within the project area. This report assesses the effects of PCOC and nitrate-rich drainage.

1.4 Climate

The site is situated within the Otago semi-alpine region. As a result, the climate is strongly seasonal, comprising of frosts and snow between Autumn and Spring, and dry and hot summer months (with temperatures frequently exceeding 30º C). Rainfall in the region varies spatially, typically decreasing with increasing distance from the Southern Alps (KSL, 2025).

Site recorded data indicates a mean annual rainfall that ranges from 441 to 506 mm depending on elevation. Rainfall remains broadly constant throughout the year ranging from 30 – 50 mm per month except for the months of July and August in which rainfall is notably lower. Dry spells of up to two weeks are also common in these months. Evapotranspiration is strongly seasonal with the reported long-term average ranging from approximately 6 mm in July to 136 mm in January. Due to evapotranspiration exceeding rainfall in the summer months, with the exception of storm events, runoff typically only occurs in the winter months (Santana, 2024).

Rainfall water quality is required as an input to the water and load balance model (MWM, 2025b). Further climatic information is available in Rekker (2025).

1.5 Rehabilitation

The engineered landform will be progressively rehabilitated with compacted batter slopes, brown rock and soil to support the BOGP vegetation requirements. Previously work has indicated that net percolation (i.e., % of rainfall) into the various engineered landforms will be 20-50% (MWM, 2025c). The geochemical model uses 20% as a conservative estimate of net percolation rates.

1.6 Report Objectives

The purpose of this report is to present the geochemical modelling undertaken to estimate seepage water quality for the Shepherds ELF, SRX ELF, Come in Time (CIT) Backfill, West ELF, and Shepherds Creek (SCK) Fill during operations and into the active closure and post closure phases of the BOGP. The objectives of this report are as follows:

- Develop a conceptual geochemical model for each ELF.

- Estimate water quality seepage from the ELFs during operations and into the active closure and post closure phases of the BOGP.
- Provide recommendations for management of ELF seepage based on model results.

2 LITERATURE REVIEW AND MODEL ASSUMPTIONS

This section reviews previous studies to support the development of a conceptual geochemical modelling process for the proposed ELFs at the BOGP.

2.1 Analogue Site - Macraes

Analogue sites with comparable lithologies, mineralisation, and alteration styles are useful analogue sites to understand / identify potential geoenvironmental hazards and subsequent effects on water quality.

The Macraes Gold Mine (Macraes), near Macraes Flat, Otago has been operating for over 30 years and the gold deposit is also associated with the TZ3 / TZ4 boundary within the Otago Schist. A large quantity of publicly available information is available on Macraes.

Gold mineralisation is developed within TZ3 Otago Schist within the Hyde - Macraes Shear Zone. The Macraes Gold Project has mined portions of the HMSZ via open pit and underground methods for a period in excess of 30 years (since 1990) and continues to the present day. MWM consider the geochemistry of mineralised and unmineralised rock at the Macraes operation to be analogous to BOGP. The site therefore provides an appropriate analogue site to consider geoenvironmental hazards.

2.1.1 Sulfur Content

Sulfur content is a key consideration as to whether an analogue site is suitable as this represents the potential source hazard for acid and metalliferous drainage (AMD).

Analysis of total S data for tailings and waste rock at Macraes is comparable to BOGP with average waste rock being ~ 0.11 to 10.16 wt% S at Macraes (Figure 2) and ~ 0.094 wt% S at BOGP (Figure 3). Data presented by MWM (2024) as part of the MP4 resource consent application (RM24.184) for Macraes indicates that average sulfur for the waste rock samples ranged from 0.11 to 0.16 wt%, which agrees with Weightman (2020).

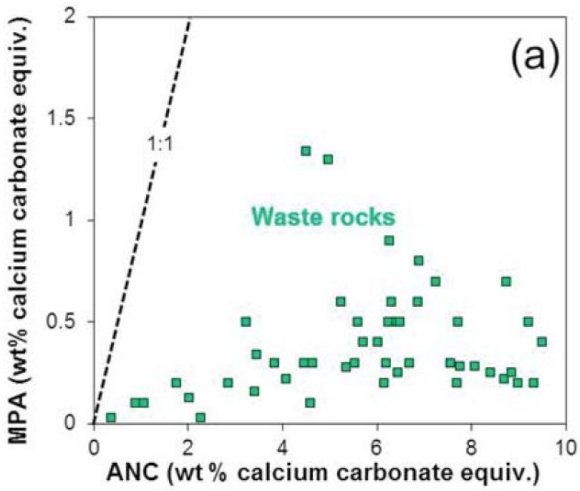

Figure 2. Sulfur content for Macraes waste rock.

Source: Weightman (2020). Note: Where Maximum Potential Acidity (MPA) = wt% S x 30.6 (units in kg H_2SO_4/t); wt% S can be determined by conversion from MPA (in wt% $CaCO_3$/t equivalence). Assumption that a MPA of 0.4 wt% $CaCO_3$ is the average of the data provided. ANC = acid neutralisation capacity. If the ANC > MPA then the rock is non-acid forming.

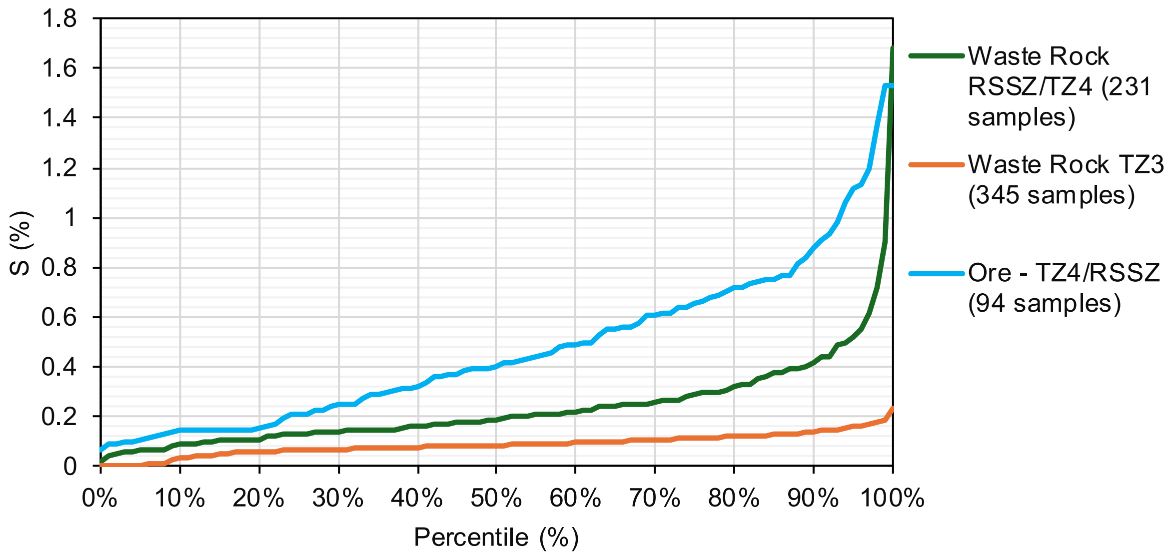

Figure 3. Total sulfur distribution curve for BOGP materials.

Source: MWM (2025a)

Assumption #1: Macraes is a suitable analogue site for potential water quality effects from waste rock at the BOGP due to similar sulfur content.

2.1.2 Waste Rock Stack Seepage

Data provided by Golder (2011a) for silt ponds, located at the toe of WRS at Macraes, indicates elevated sulfate in seepage waters (Table 1). Such data provides an indication of the risks to surface waters associated with this mine domain. The assessment by Golder in 2011 for Macraes did not consider the risks associated with nitrogenous compounds. Recent work in 2020 identified that nitrate can be elevated up to 10.5 mg/L in WRS seepage (OceanaGold, 2020).

Table 1. WRS silt pond seepage water quality from Macraes Gold Mine. From Golder (2011a).

PARAMETER (1)	DEEPDELL NORTH	DEEPDELL SOUTH	BATTERY CREEK	NORTHERN GULLY	FRASERS WEST (NBWR)	MURPHYS CREEK	BACK ROAD	AVERAGE
Arsenic	0.011	0.00001	0.00001	0.001	0.001	0.00001	0.00001	0.0016
Sulfate	38.6	15.4	1,200	2,300	1,500	1,320	2,200	1084
$Cyanide_{WAD}$	0.00001	0.00001	0.00001	0.013	0.00001	0.00001	0.00001	0.0016
Copper	0.001	0.00001	0.00001	0.003	0.001	0.001	0.002	0.0010
Iron	0.170	0.00001	0.00001	0.93	0.42	0.52	0.91	0.3734
Lead	0.001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0001
Sodium	16	10.8	36	57.7	26.2	33	56.4	29.81
Potassium	5.5	1.89	10	12	5.47	6.69	11.7	6.72
Calcium	68.5	40.2	290	434	199	250	425	215.5
Magnesium	14.5	7.7	200	360	165	204	352	164.7
Zinc	0.00001	0.00001	0.00001	0.032	0.015	0.018	0.032	0.012
Chloride	11.5	7.1	10	10.2	4.69	6.03	9.99	7.49

1. - All values presented in units of mg/L

2.2 Macraes WRS Seepage Water Quality: Height Relationship

Babbage (2019) completed an assessment of waste rock stack (WRS) seepage water quality at Macraes as part of the Oceana Gold (New Zealand) Limited Application RM20.024 to the Otago Regional Council (ORC).

Data are available for Ca, Mg, and SO_4 with SO_4 data being presented below in Figure 4. Babbage (2019) assessed various physical parameters of each WRS including WRS footprint, volume of waste rock, and height of the WRS. Analysis indicated there is a relationship between average height of the WRS, its age, and sulfate concentrations in WRS seepage (Figure 5).

Sulfate concentrations are a useful guide to other water quality effects and often very good correlations exist between sulfate, EC[6], and other potential constituents of concern (PCOC) such that PCOC concentrations can be forecast from sulfate concentration.

Figure 4. WRS seepage sulfate concentrations, Macraes Gold Mine.

Source: Babbage (2019): Available: https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/oceana-gold-new-zealand-limited-rm20024/

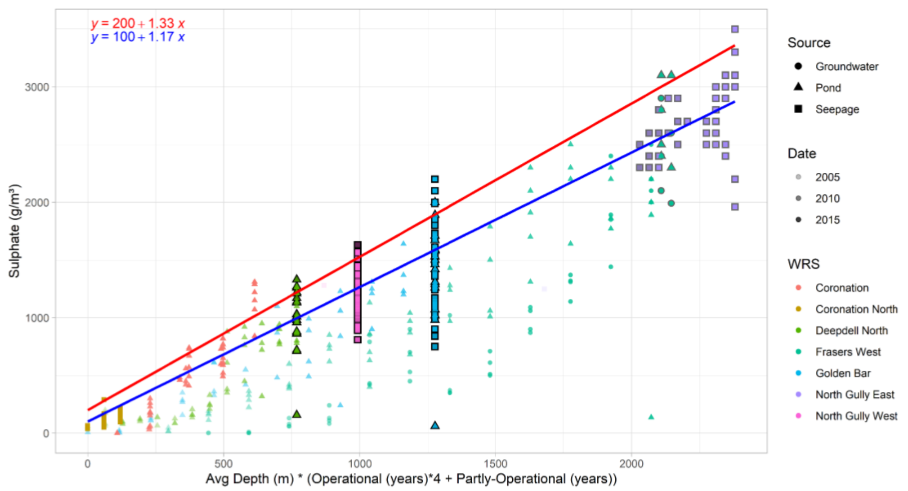

Figure 5. WRS seepage sulfate concentrations as a function of WRS age and average WRS height.

Source: Babbage (2019): Available: https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/oceana-gold-new-zealand-limited-rm20024/

[6] *Electrical conductivity*

Data presented in the Babbage (2019) report indicates that the average height of WRS at Macraes (in 2019) ranged from 15 m to 37 m with higher WRS generating higher sulfate concentrations. WRS at Macraes are mostly built using traditional WRS construction methods (e.g., tipheads > 10 - 20 m in height that can create grainsize segregation).

Recent work MWM (2024b) demonstrated a relationship between average WRS height and sulfate concentration using similar data sets to Babbage (2019).

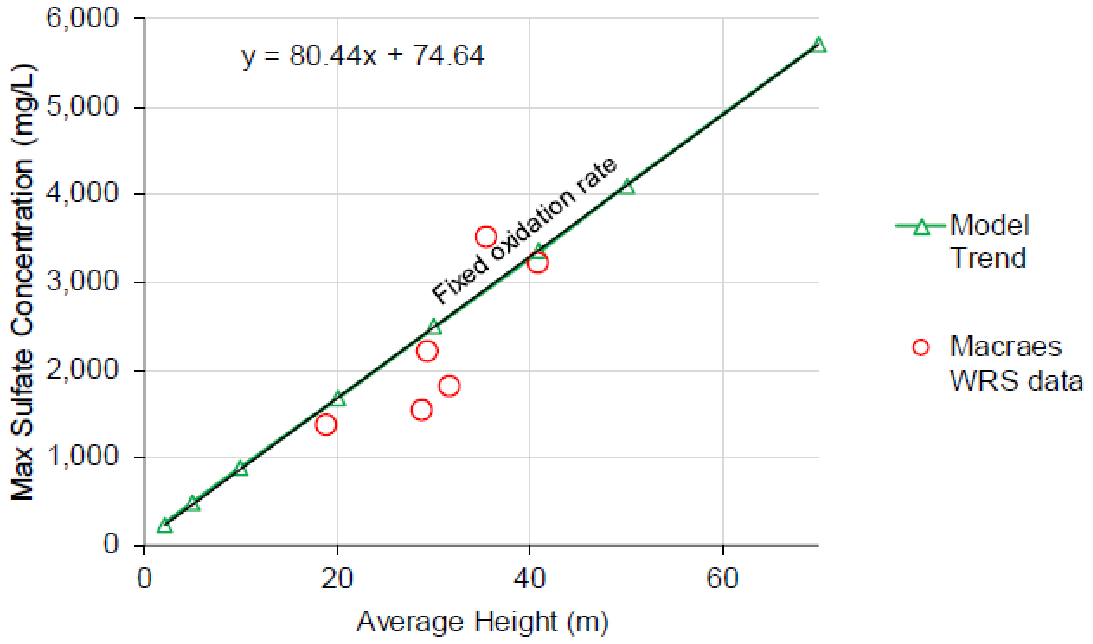

Figure 6. Average WRS height versus maximum sulfate concentrations at Macraes.

Source: Mine Waste Management (2024b): https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/oceana-gold-new-zealand-limited-rm24184/

Given that the source hazard (e.g., total sulfur content) at BOGP is comparable to Macraes, and rock properties are similar (non-acid forming) it is reasonable to assume that if waste rocks stacks are built at BOGP then sulfate concentrations would be a function of the WRS average height and have similar concentrations to those reported at Macraes (Figure 6). However, the BOGP propose to construct ELFs to minimise the advective flux of oxygen along coarse basal layers created by end-tipping and subsequent grainsize segregation.

Assumption #2: WRS seepage water quality at BOGP can be forecast as a function of WRS height using published empirical data from Macraes.

2.3 Concentration Versus Flow

Previous work (e.g., Mackenzie, 2010; Weber et al., 2015) has demonstrated that although contaminant concentration in seepage from waste rock stacks can remain approximately constant irrespective of flow rate, with increasing flow, the contaminant load increases proportional to flow rate (Figure 7, Figure 8). This demonstrates that the waste rock has a large reservoir of stored oxidation products that is mobilised by greater water flow through the materials driving an approximate constant concentration.

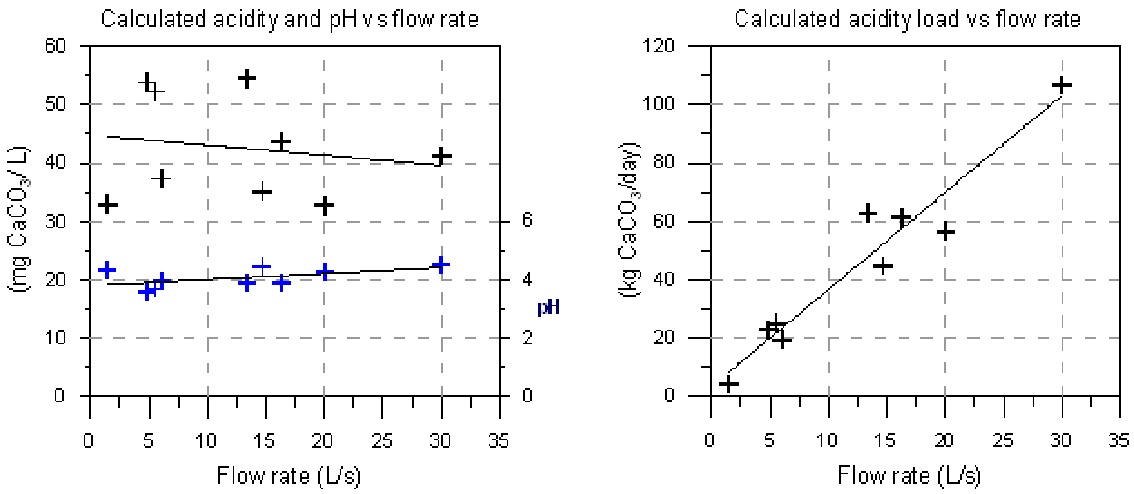

Figure 7. Fanny Creek Side Cast, Island Block Mine, West Coast

Source: Mackenzie (2010).

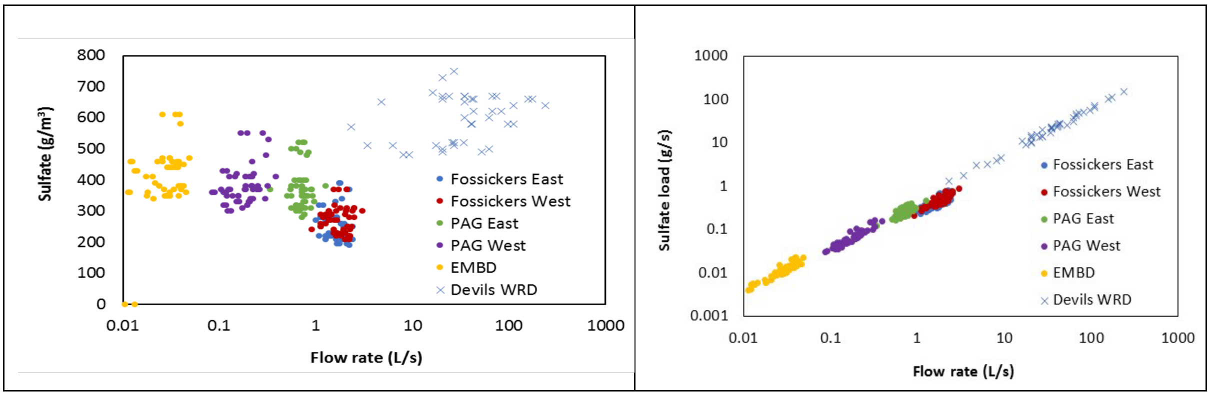

Figure 8. Globe Progress Mine, West Coast

Source: Weber et al. (2015)

Assessment of flow and quality data for the Frasers West WRS (FWWRS) at Macraes (MWM 6) indicates that the key driver of sulfate load is flow rate, with minor variance in sulfate concentrtaion (Figure 9). Again this supports modelling constant concentration (for daily time steps in any model).

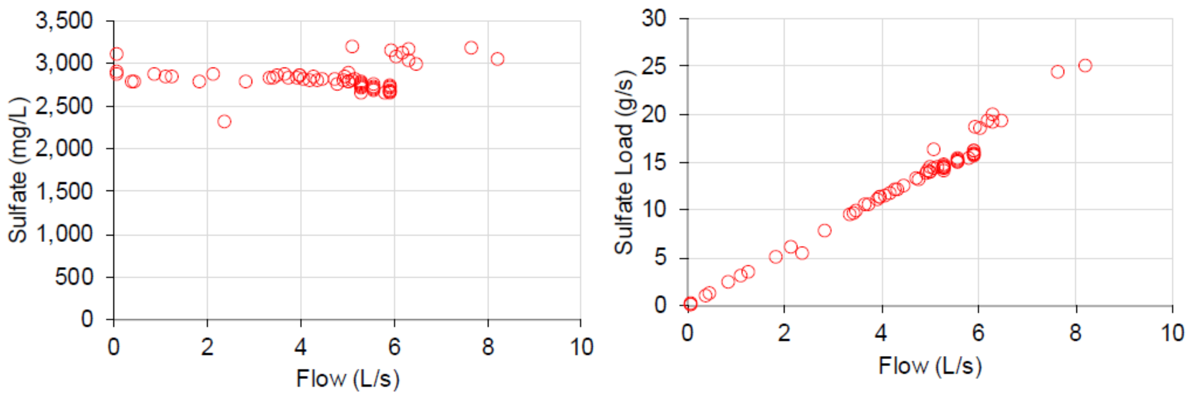

Figure 9. FWWRS seepage rates and interpolated sulfate concentration data.

Source: MWM (2024b).

Hence, numerical modelling of the proposed ELFs at the proposed BOGP will use constant concentration, with the assumption that each unit of waste rock contains a reservoir of stored oxidation products that will be mobilised by increasing flow. Decline in concentration is a function of the exhaustion of sulfides in any oxidising materials during the operational and active post closure phases of the project.

Assumption #3: WRS seepage water quality remains constant for daily time-step modelling.

2.4 Oxygen Ingress

Generally, WRS represent 60 - 80% of a site's AMD contaminant load (INAP, 2020; 2024) if the AMD source hazard is not managed appropriately. International case studies are available (e.g., Weber et al., 2017) to demonstrate the high proportion of AMD associated with waste rock domains. Hence there is a strong driver to incorporate waste rock into engineered landforms that address the key principles of AMD source control: Prevention and Minimisation.

2.4.1 Waste Rock Stacks

Waste rock that is end dumped in high lifts (>4-6 m in height) and the associated kinetic energy can result in grainsize segregation and the development of alternating coarse-textured and fine-textured bedding planes of poorly graded and well sorted material with high vertical airflow capacity (e.g., Fala et al., 2003; Wilson, 2008). This also results in an overall downward coarser grading providing higher airflow capacity deeper in the facility. In addition, the fall of rocks / cobbles from the end-tipped / dozer pushed material results in the development of a coarse basal layer with high lateral airflow capacity that provides oxygen ingress pathways into the core of the waste rock stack (WRS).

The dominant process for oxygen flux is by the advective and convective flow of oxygen (temperature differences, barometric pressure differences) along coarser waste rock layers that form within poorly constructed WRS. 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%.

Hence, a key control to prevent sulfide mineral oxidation and minimise the effects on seepage waters from WRS is to prevent the advective ingress of oxygen.

2.4.2 Engineered Landforms

International research (INAP, 2020; 2024) has demonstrated that one of the most effective methods to minimise advective ingress of oxygen into WRSs is to minimise the height of the tiphead to <4 - 6 m and ensure that each lift has a compacted engineered surface, which reduces the size of the advective cell (both vertically and horizontally into the WRS). Reducing oxygen ingress reduces sulfide mineral oxidation and hence the risks associated with AMD.

INAP (2024) note that an "Engineered Fill' approach "*allows for the ability to more accurately model and predict O2 ingress and the volume and quality of recoverable seepage requiring treatment over time*". This 'Engineered Fill' approach manages AMD "*risks through implementation of source control, progressive reclamation, and cover systems, which allows for opportunities to move from active to passive water treatment over time thereby reducing asset liability, and likelihood of in-perpetuity management*" (INAP, 2024).

Further details on ELF construction methods for BOGP are provided in MWM (2025f).

2.4.3 Model Development

For BOGP modelling purposes, it is assumed that oxygen flux will be limited horizontally through the ELF batter slopes by controlling the advective flux of oxygen using appropriate engineering controls (e.g., lifts heights < 5 m). For modelling purposes, the design assumptions are:

2.4.3.1 <u>20 m Wide ELF Oxidation Zones (ELF – 20 m Model)</u>

- 20 m horizontally into each ELF lift will be oxidising (aligns with previous New Zealand case studies that show 5 - 15 m can be achieved.
- Based on an angle of repose of 37°, the vertical oxidising distance is 15 m (with 20 m used horizontally for modelling purposes).
- On flat surfaces (e.g., running lifts) the depth is 15 m top account for better compaction of materials due to vehicle movements. A graphical representation of the outer oxidising zones is shown in Figure 10.

2.4.3.2 <u>10 m Wide ELF Oxidation Zones (ELF – 10 m Model)</u>

- 10 m horizontally into each ELF lift will be oxidising (aligns with previous New Zealand case studies that show 5-15 m can be achieved but is considered an optimistic lateral distance).
- Based on an angle of repose of 37°, the vertical oxidising distance is 8 m (with 10 m used horizontally for modelling purposes).
- On flat surfaces (e.g., running lifts) the depth is 8 m.
- This scenario would reduce the volume of material exposed to oxidation.

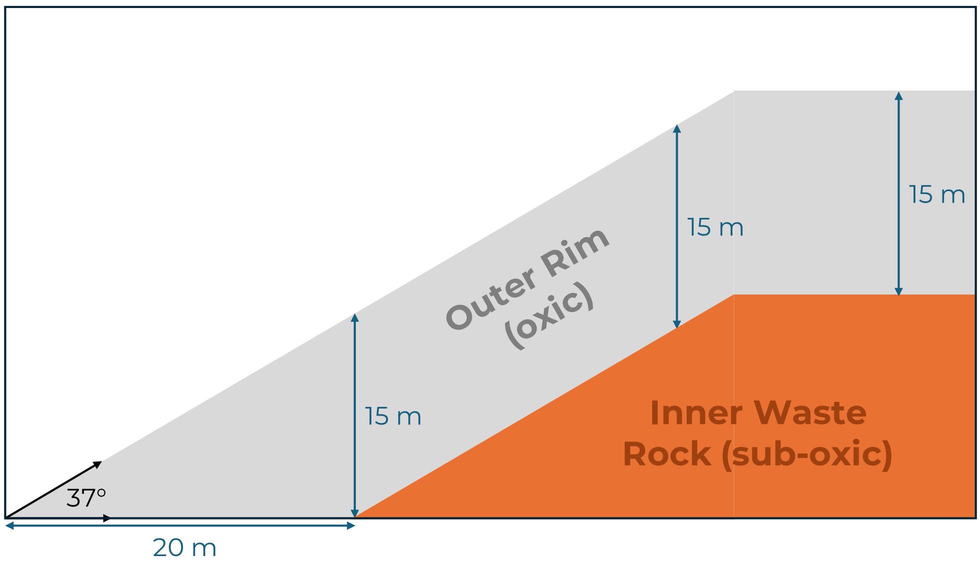

Figure 10. Graphic representation of the outer rim and horizontal ingress of oxygen at 20 m.

A nominal value of 20 m introduces a safety factor for batter slopes compared to data from other sites in New Zealand. This is a key design criterion for the project. However:

- Detailed design for the ELFs is required to demonstrate how this will be achieved.

- Performance monitoring during construction is required to confirm that these design criteria are being met.
- Geochemical models should be adjusted to the future measured oxidation depth and oxygen flux (through the cover system).

Assumption #4 – That ELF design and construction (including cover system) will limit oxygen ingress to a depth of 20 m horizontally and 15 m vertically once the ELF is constructed (and rehabilitation is completed).

2.5 Scaling Factors

Many projects rely on a first principles approach, scaling laboratory data to the field (e.g., Kempton, 2012; Linklater et al., 2017) to determine WRS water quality. Such analyses consider physicochemical issues such as moisture content, particle size, temperature, mobility of PCOC, oxygen concentrations, and solute attenuation (e.g., precipitation). Scaling lab data to the field can introduce several uncertainties that influence model results.

For the BOGP WRS / ELF geochemical models, the modelling process is simplified by relying on appropriate analogue empirical data from Macraes (e.g., Figure 6) with minor geochemical adjustments:

- It is expected that parts of the ELF contain materials that are effectively unreactive and do not contribute to the contaminant load or water chemistry. Price (1997) notes that >75% of the mass in a WRS occurs as coarse particles in which the mineralogy is almost entirely occluded from oxygen and water with drainage chemistry being controlled by a relatively small portion of the mass which is finer grained particles. Malmström et al. (2000) noted that ~65% of the water in a waste rock stack was mobile and 35% was immobile at the Aitik Copper mine, Sweden. At the Island Copper Mine (Vancouver), Lopez et al. (1997) notes that only 42% of the total area of the pile contributes to flow. Such studies indicate that 35 – 58% of water interacting in a waste rock stack may be immobile and will not contribute to drainage water chemistry.
- The assumed non-reactive portion of the waste rock used in the models presented in this report is 90%. This is assuming that coarser material will decrease the amount of minerals or sulfides reacting with water. The water passing through the reactive portion is assumed to fully react. Consequently, this 10% reactive fraction is considered fully available for the release of stored oxidation products and long-term solute generation.
- A scaling factor was applied for the long-term generation of solutes that were obtained from the column leach tests to calibrate using analogue empirical data.
- Scaling of sulfate for the reactive fraction (a key indicator of AMD and poor water quality) is derived from empirical data from Macraes, which provides the ability to scale other PCOC based on column leach test data correlations for the project area. This resulted in a general scaling factor (from laboratory to field)
- This general scaling factor affects sulfate and elements associated with the long-term release rates.
- To align lab results with analogue data from Macraes, a release rate adjustment factor of 0.8575 was applied to reactive oxidising materials (e.g., 10% of the materials in the WRS). These

adjustments allowed the model to simulate realistic peak sulfate concentrations for a traditional WRS (e.g., ~6,200 mg/L for Shepherds WRS).

- Linklater et al. (2017) applied several scaling factors to WRS materials, including surface area correction, fraction flushed by contact water, temperature correction, and oxygen availability. Combined, these factors result in an overall multiplier of 0.012, which is nearly two orders of magnitude lower than full reactivity. In our case, the adjustment is approximately one order of magnitude; 0.1 for short-term release, multiplied by an additional 0.8575 for long-term release, yielding an overall factor of 0.08575 for the long-term release.
- PHREEQC modelling (Parkhurst & Appelo, 2013) was conducted to consider solubility control for some solutes (e.g., precipitation).

Assumption #5 – The scaling approach using CLT data to forecast sulfate and other PCOC is appropriate to understand geochemical risks for the engineered landforms.

2.6 Nitrogenous Compounds

This section identifies the source hazards associated with the use of ANFO for blasting and the potential effects on ELF Seepage waters. Derivation of nitrate loads is complicated for modelling as geochemical test work is undertaken on drillcore that has not been blasted. Hence a reliance on literature is required.

2.6.1 Literature Review

Nitrogenous compounds from waste rock in mining operations are often a byproduct of blasting agents, such as ammonium nitrate-fuel oil (ANFO), used during extraction. These compounds can leach into surrounding water systems contributing to elevated levels of nitrate and ammonia in nearby groundwater and surface water. Data presented by OceanaGold (2020) indicates that nitrate can be 10.5 mg/L in WRS ponds at Macraes.

As noted by Navarro-Valdivia et al. (2023) pit lakes can also be elevated in nitrogenous compounds due to the presence of blasting residues, with nitrate nitrogen concentrations peaking in the Golden Bar Pit Lake at 30 mg/L due to an initial nitrate load of 400 kg yet steadily decreases at 20-30% per year due to biogeochemical processes. Navarro-Valdivia et al. (2023) noted that the quantity of nitrogen as NH_4NO_3 was estimated to be 5.35 g/m^2 once the pit lake started to fill.

Navarro-Valdivia et al. (2024) indicated that there was a poor relationship between sulfate and nitrate in WRS seepage at Macraes (R^2 = 0.43) and that the median nitrate nitrogen value was 12.6 mg/L (equivalent to a concentration of ~56 mg/L nitrate).

Dockrey et al. (2015) report nitrate nitrogen (NO_3-N) concentrations in coal waste rock seepages from 5 to over 100 mg/L depending on the size and age of the waste rock dump. Bailey et al. (2013) reports that measured NO_3 in seepage outflows at a diamond mine were 2,000 mg/L. Schmidt and Moffett (1979) report that concentrations of NO_3^- in mine effluent from uranium mines ranged from 60 to 80 mg/L.

Weber et al. (2021) report a range of nitrate concentrations (Figure 11) with nitrate concentrations of 68 mg/L for drainage from a waste rock dump (WRS) for an orogenic gold mine.

Mine Type	Mine Domain	Nitrate Concentrations mg/L as NO_3
Iron Ore	TSF	220
Diamond	WRD - test pile	2000
Diamond	WRD - test pile	4000
Orogenic Gold	WRD	68
Epithermal Gold	Low Grade Ore Stockpiles	0.14
Volcanic Massive Sulfide	Underground	285
Volcanic Massive Sulfide	Underground	5
Porphyry Copper	WRD	<2
Diamond	WRD	90 -230
Coal Mine	WRD Catchment Drainage	<1
Platinum	Pit	377
Platinum	WRD	440

Figure 11. Nitrate concentrations from various studies, mine type, and mine domains

Source: Weber et al. (2021).

MWM (2024a) assessed nitrate data for WRS at Macraes. Available data suggests maximum NO_3-N concentrations could be up to 35-40 mg/L (Figure 12) and that nitrate-N can be ~2.5 to ~22 mg/kg in blasted waste rock at Macraes (Figure 13).

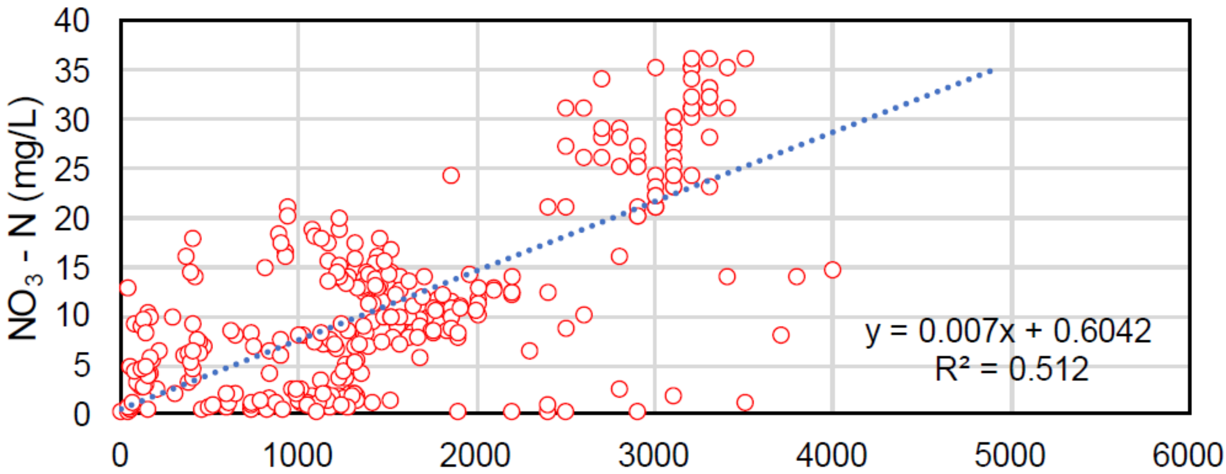

Figure 12. Sulfate versus nitrate-N concentrations for Macraes WRS.

Note: X axis is sulfate in mg/L

Source: MWM (2024a): Appendix I.

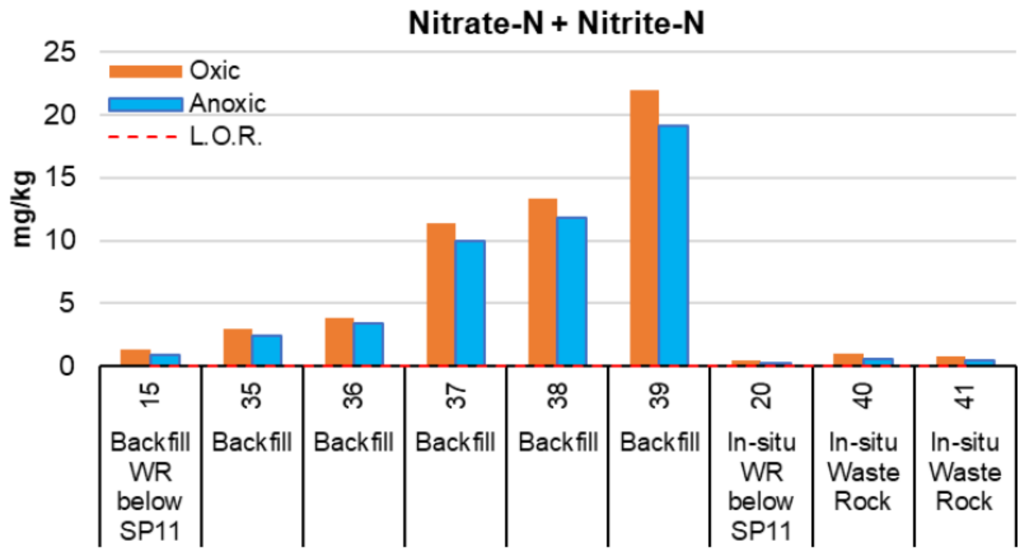

Figure 13. Shake flask extraction data for blasted backfill at Macraes.
Source: MWM (2024a).

Studies have been completed at the Argyle Diamond Mine, Western Australia on nitrate effects due to the use of ANFO (Borden et al., 2022) with nitrate concentrations in the ICI WRS seep reaching a mean peak of 300 mg/L in 2004 to 2007 declining to 170 mg/L between 2017 and 2020. The authors note that these mean values do not capture the full variability in nitrate concentration within each year, however a strong declining concentration was observed over the 20-year monitoring period. Data indicated that dry season nitrate concentrations were higher than wet season nitrate concentrations (Figure 14). Borden et al. (2022) note that:

- The higher concentrations and loads observed prior to 2015 (Figure 15) were a function of open pit mining and a greater quantity of ANFO being used with peak nitrate concentrations in WRS seeps coinciding with peak waste rock production in 1999 to 2005.
- Peaks nitrate loads during operations are a function of rapid flushing of high permeability zones.
- Long term nitrate loads are a function of finer grained low permeability zones that are not flushed by high rainfall events.
- Data for the WRS seeps suggests that toe seepage water quality will meet chronic nitrate guideline requirements (2.4 mg/L) in two to three decades.

These data suggest that for Argyle:

- Nitrate concentrations did not start to decrease till 2015, a decade after open pit operations ceased.
- Based on 20 years of monitoring data the effects of elevated nitrates are expected for another two to three decades. This suggests the effects of nitrate could last for 50 years once opencut mining ceases.

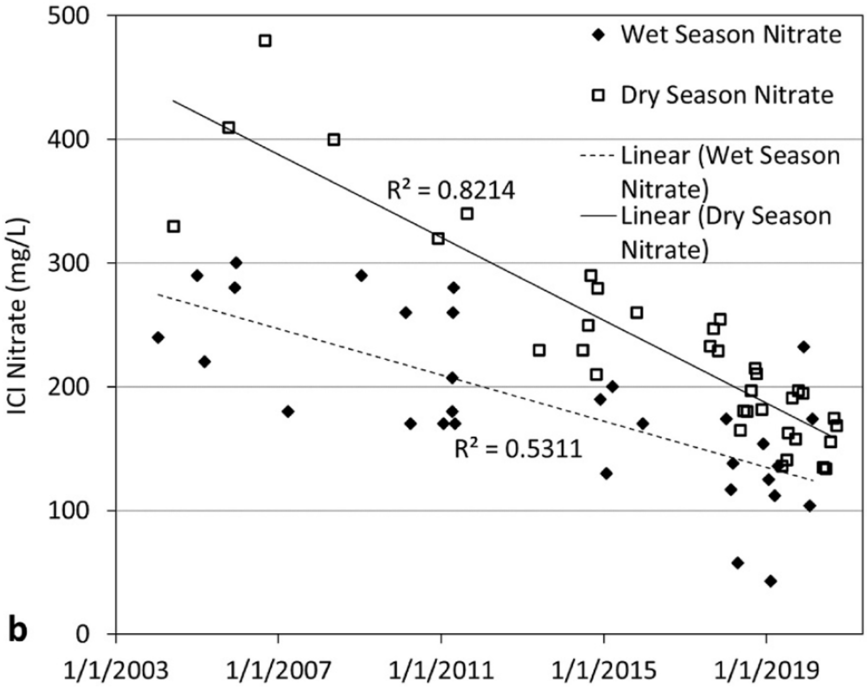

Figure 14. Nitrate concentrations for the ICI WRS seep (Argyle Diamond Mine).
Source: Borden et al. (2022).

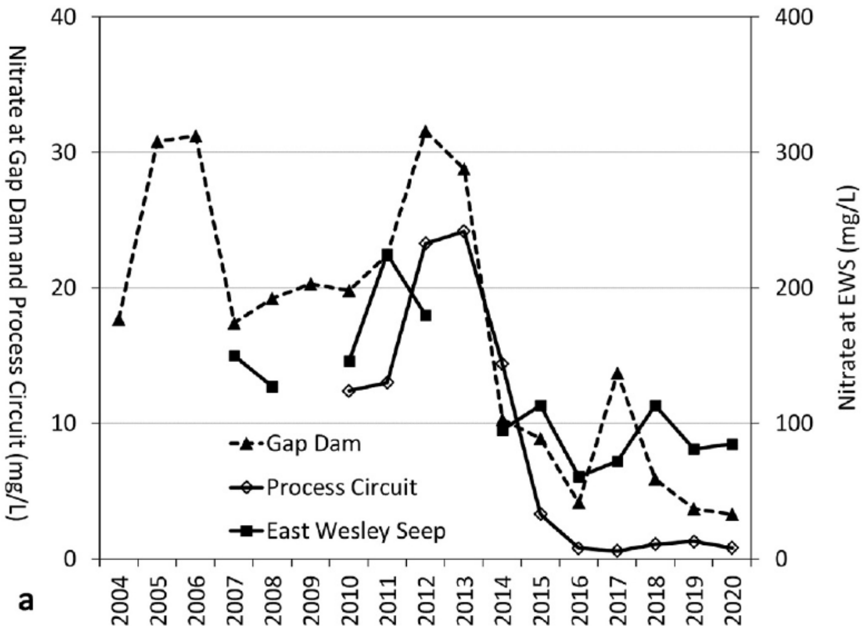

Figure 15. Nitrate concentrations for Gap Dam, the process circuit, and East Wesley Seep – Argyle Diamond Mine.
Source: Borden et al. (2022).

Elevated nitrate in ELF seepage is expected to last for decades, unlike the effects of AMD which are expected to last for centuries. For instance, (Mahmood et al. (2017) notes that, as an example, a 100 m high dump, placed at an average volumetric water content of 10% and flushed at a net percolation rate of 750 mm/year would take approximately 13 years to release most of the initial nitrate within the dump. Data for Argyle suggest that 50 years is a reasonable timeframe to meet water quality criteria (e.g., nitrate-N concentrations of 2.4 mg/L).

2.6.2 Model Inputs

Given that the average height of the Shepherds ELF is nearly twice that of the highest WRS at Macraes, it is assumed that the peak concentration will also be roughly double. Based on this assumption, a peak nitrate-N concentration of ~80 mg/L is expected for the Shepherds ELF. For modelling purposes, it is assumed that 90% of this nitrate-N is mobilised over ~50 years for all structures, although the time to peak concentration can extend this period once the tallest parts of the ELF are contributing load.

A nitrogen content (as NH_4NO_3) of 16.6 mg/kg was assigned to reactive waste rock within each ELF to enable the peak nitrate-N concentrations of 80 mg/L to occur. This load is comparable to the data available at Macraes (Figure 13).

Assumption #6 – That ELF seepage waters will be elevated in nitrate for many decades and that the peak concentration is expected to be ~ 80 mg NO_3-N/L in the Shepherds ELF seepage waters.

Assumption #7 – That model data suggests the initial load of nitrogen (NH_4NO_3) is 16.6 mg/kg.

Assumption #8 – That 90% of nitrogen is mobilised over ~50 years once the tallest part of the structure starts contributing load.

3 ELF CONCEPTUAL GEOCHEMICAL MODEL

This section explains the conceptual geochemical models for the proposed BOGP ELFs.

3.1 Engineered Landform Summary: RAS, SRX, and WELF

Overburden waste rock from the RAS deposit will be stored in the Shepherds ELF (Figure 16) and in the West ELF (WELF), and overburden from the SRX Pit will be stored in the SRX ELF (Figure 17):

- For the Shepherds ELF, the selected storage area, located downstream of the TSF, avoids terrain constraints, minimises the risk of sterilising nearby satellite deposits and will also act as a buttress to enhance TSF stability while accommodating 103.6 million loose cubic metres (LCM) of waste, including 3.2 million LCM from the TSF dam (MCL, 2024). The design includes a 12% contingency for changes in swell or compaction factors based on site-specific parameters.
- For the SRX ELF, the selected storage area is on top of the SRE Pit and is located upstream of the SRX pit to minimise the risk of sterilising nearby satellite deposits

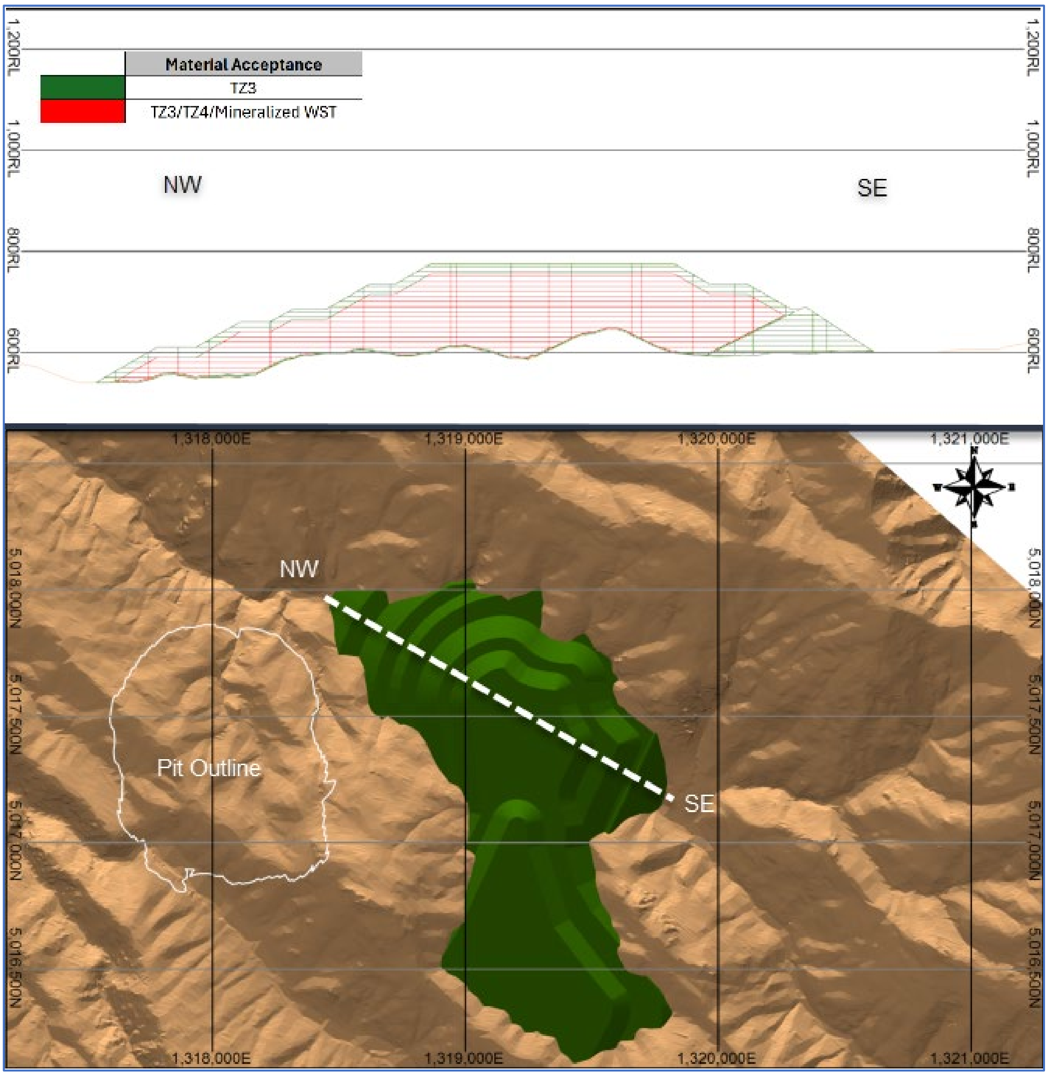

Figure 16. Shepherds ELF.

Reference: MGL (2024).

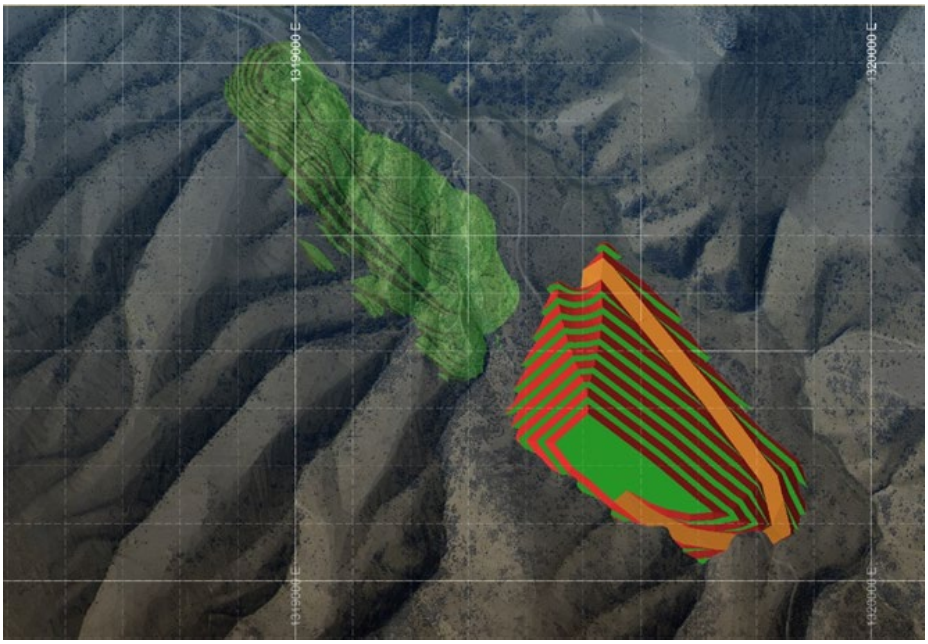

Figure 17. SRX Pit and SRX ELF

Source: MGL (2024).

Waste landform sequencing has been undertaken based on the assumption that arsenic concentrations are higher in the ore host rock (TZ4 and RSSZ) and for precautionary reasons it is planned to be encapsulated and capped with lower arsenic waste rock (TZ3). A base layer and encapsulating layer of inert material is typically required, with a core of non-inert material. For this reason, the ELF has a base layer of 3 metres of TZ3 material. The TSF dam embankment will also only consist of TZ3 material. Santana (2024) proposes that a 20 m thick low sulfur capping layer of TZ3 materials will encapsulate the ELF.

Mine schedules for RAS and SRX are shown in Table 2 and Table 3.

Table 2. RAS Pit mine schedule.

COMPONENT	TOTAL ROCK MINED	TOTAL WASTE	TZ3 TONNES	TZ4 TONNES	SOIL	ORE
Unit	(kt)	(kt)	(kt)	(kt)	(kt)	(kt)
Year						
-2	10,200	10,200	9,417	0	783	0
-1	30,572	30,363	29,967	149	247	209
1	25,859	24,437	20,456	3,139	842	1,422
2	24,612	21,438	16,804	4,344	291	3,173
3	24,493	22,680	19,717	2,815	148	1,813
4	24,300	23,060	20,939	1,613	508	1,240
5	24,300	24,007	22,636	1,339	33	293
6	24,267	21,880	19,530	2,184	166	2,387
7	23,112	21,575	19,401	2,171	3	1,537
8	2,258	1,355	1,019	336	0	902
Total	213,972	200,996	179,886	18,089	3,021	12,976

Reference: Santana, 2024

Table 3. SRX Pit mine schedule.

COMPONENT	TOTAL ROCK MINED	TOTAL WASTE	TOTAL TZ3	TOTAL TZ4	TOTAL SOIL MINED	ROM MINED (>0.30g/t Au)
Unit	(kt)		(kt)	(kt)	(kt)	(kt)
Months						
1	209	80	33	47	80	0
2	209	121	79	42	51	15
3	209	105	84	21	49	26
4	309	204	185	19	61	34
5	350	237	209	28	36	47
6	350	257	253	4	59	9
7	350	224	202	22	30	75
8	350	228	214	14	64	32
9	350	255	211	44	3	84
10	350	290	277	13	30	27
11	350	216	199	17	44	73
12	350	284	247	37	3	60
13	350	299	289	10	10	38
14	350	191	162	29	54	95
15	350	269	227	42	0	70
16	350	299	292	7	2	47
17	350	239	211	28	28	82
18	350	272	234	38	0	74
19	350	242	226	16	11	94
20	350	235	205	30	10	99
21	350	232	212	20	0	111
22	350	167	104	63	0	164
23	108	35	21	14	0	69
Total	7,344	4,981	4,377	606	625	1,428

Reference: Santana, 2024

3.2 Backfill

Two pit backfills will be created:

- Waste rock will be placed in the SRE pit as backfill as part of constructing the SRX ELF. It is assumed the quality of materials is negligible and the ELF seepage water quality will be dominated by the SRX ELF.
- Waste rock will be used to backfill the CIT Pit to provide a more natural surface for mine closure. This will create rock that will be saturated by groundwater and also an ELF that sits above this. The CIT ELF model addresses these components.

No mine plan was provided for CIT, however, total estimated quantities are provided in Table 4.

Table 4. CIT Pit material quantities.

ORE (kt)	SOIL (kt)	TZ3 (kt)	TZ4 (kt)	TOTAL ROCK MINED (kt)
700	475	2,550	850	4,575

3.3 Shepherds Creek Fill Area

A platform composed of TZ3 material will be placed in Shepherds Creek to serve as a foundation for the processing plant area. The volume of fill used is approximately 1.1 Mm^3, which is considered significant, as it is comparable to the volume of the Come in Time backfill (1.5 Mm^3). Given its scale, the fill is deemed geochemically relevant and is therefore included in the water and load balance model (WLBM) as an additional waste rock domain. The corresponding material volume, tonnage, and area are shown in Table 5.

Table 5. CIT Pit material quantities.

VOLUME (m3)	TONNAGE (kt)	AREA (kt)
1,109,758	2,264	2,550

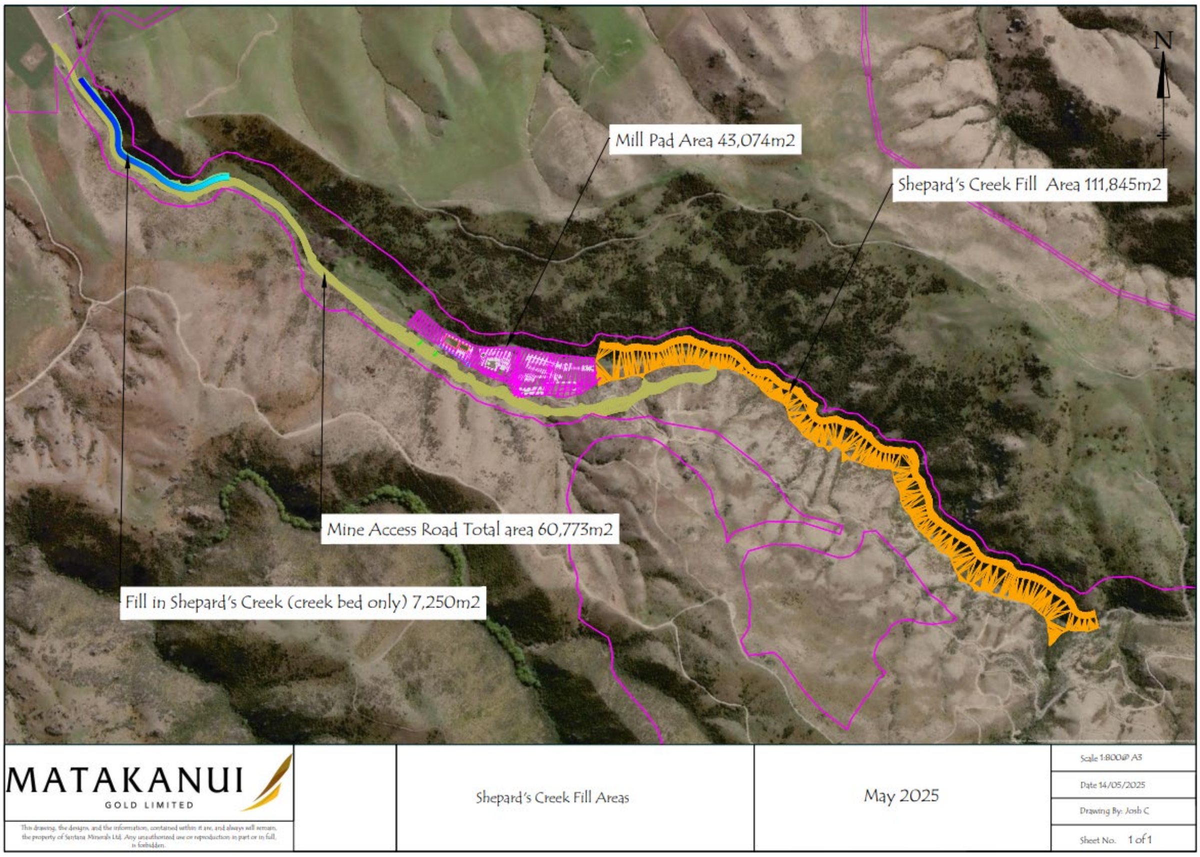

Figure 18. Shepherds Creek Fill Area Fill location.

Source: MGL (2025)

3.4 Cover System

The ELF will be progressively rehabilitated with compacted batter slopes, brown rock and soil to support the BOGP vegetation requirements. Previously work has indicated that net percolation (i.e., % of rainfall) into the various engineered landforms will be 20-50% (MWM, 2025c).

The impact of the landform, including the cover systems, on net percolation (NP) is expected to be minimal due to the high surface permeability of the materials. Both the ELF and TSF are predominantly flat or north-facing, which will result in similar potential evapotranspiration (PE). However, the steeper slopes of the ELF are likely to generate more runoff than the flatter TSF, potentially leading to slightly lower NP for the ELF. Nevertheless, this difference is not expected to be significant, as surface permeability is likely to remain high.

Based on the findings in the report, the estimated baseline NP post-closure of 20% is used for modelling purposes.

3.5 Water Soluble PCOC

Most rocks, following blasting contain stored water soluble PCOC that can be mobilised by the flow of water through these materials (e.g., net percolation). PCOC include nitrogenous compounds derived from blasting residues, and stored oxidation products (SOP) generated by sulfide mineral oxidation or due to a natural mineral dissolution by percolating waters (e.g., gypsum).

Two processes are considered in the model:

- **SOP Dissolution:** This process involves the release of solutes through the dissolution of readily available soluble minerals such as anglesite. The release of solutes occurs only in the short term due to flushing of these PCOC by net percolation through the ELF.
- **Oxidation:** This refers to the oxidation of sulfides in zones of the ELF that have oxygen available, resulting in the generation of sulfate and associated solutes over the long term.

3.6 Oxygen Ingress

The WRS base case scenario is modelled with no oxygen exclusion with the assumption that all materials generate a similar amount of sulfate from water soluble PCOC, which is then ongoing from sulfide mineral oxidation.

Scenarios are run for the three engineered landforms (Shepherds, SRX, WELF) where the depth of oxidation is limited to 10 m and 20 m depth into the ELF (as explained in Section 2.4.3), and for the CIT backfill as well. From a modelling perspective, this does not affect the presence of water soluble PCOC.

3.7 Conceptual Domain Models

Four key waste rock disposal domains are proposed for the BOGP: Shepherds ELF, SRX ELF, West ELF, and CIT backfill. While they share common characteristics, they differ in material quantities, dimensions, and area. Waste rock fill is also used within Shepherds Creek as fill for the BOGP infrastructure area (e.g., processing plant). Given the quantities of materials required this has also been modelled to understand seepage water quality.

Seepage is generated from rainfall infiltration, with net percolation assumed to be 20%. Consequently, average ELF seepage rates depend on the area of each ELF and the assumed net percolation. The toe seepage flow rate is calculated in the GoldSim water balance, based on the assumption that seepage flow rates drive the load, independent of concentration. That is, while seepage flow rates may vary, the concentration is expected to remain constant (see Section 2.3).

It is assumed that the ELFs will have an oxidising outer rim composed of the geological unit TZ3, while the inner core will consist of TZ3 and TZ4. The inner material will not oxidise but will release short-term SOP, which will be available for dissolution upon interaction with infiltrating rainfall. The outer rim undergoes both ongoing oxidation of minerals (or long-term release) and SOP dissolution. Quantification of the SOP are derived from column leach tests and are detailed in Section 4.2.

Since each ELF has different dimensions, the outer rim represents a different fraction of the total volume of each ELF. Given that the Shepherds ELF is the largest, its proportion differs accordingly. CIT is assumed to have similar proportions as SRX, as they both have similar material quantities.

The core of the ELF is assumed to experience SOP dissolution without oxidation (noting that the SOP is derived from ~20 weeks of data from the column leach test [7]), while the outer rim (i.e., the oxidising zone) undergoes both ongoing oxidation of sulfide minerals and SOP dissolution. For modelling purposes, it is also assumed that TZ4 is located within the core of the ELF, meaning only TZ3 is present and therefore oxidises in the outer rim.

Modelling was based on earlier material quantity estimates for SRX and Shepherds, as shown in Table 6. These estimates differ slightly from those provided in the pre-feasibility study (PFS) completed in late 2024 (MGL, 2024). However, these differences are not considered significant in assessing potential effects on water quality.

Table 6. Material quantities (excluding soil).

PIT/DOMAIN	MATERIAL	QUANTITY (KT)
SRX	TZ3	4,377
	TZ4	606
	TZ3+TZ4	4,983
Shepherds	TZ3	179,886
	TZ4	18,089
	TZ3+TZ4	197,975
CIT	TZ3	2,550
	TZ4	850
	TZ3+TZ4	3,400
West ELF	TZ3	10,732
SCK Fill	TZ3	2,264

Soil volumes were not included in the model, as the interaction of water with soils, which are essentially weathered rock, represents baseline conditions. Furthermore, soil is intended for use as a cover material for the ELFs. Consequently, the material quantity assessment includes only TZ3 and TZ4, explicitly excluding soil from the calculations.

3.7.1 Shepherds ELF

The Shepherds ELF contains 197,975 kt of waste rock, being primarily composed of TZ3 (179,886 kt, representing the 90.86% of the material), and a minor part of TZ4 (18,089 kt, or 9.14% of the material). Based on topographical differences between the designed ELF surface and the base topography, it was determined that the outer rim of the ELF accounts for:

- ~18.62% of the material for a 20-m oxidising rim (and 15 m vertically).
- ~9.60% for a 10-m oxidising rim (and 8 m vertically).

[7] *Ongoing data collection from the CLT that will be run for 12 months will validate these results.*

The area of the Shepherds ELF is approximately 115 Ha. Assuming a net percolation rate of 20%, the average seepage is estimated at ~3.7 L/s.

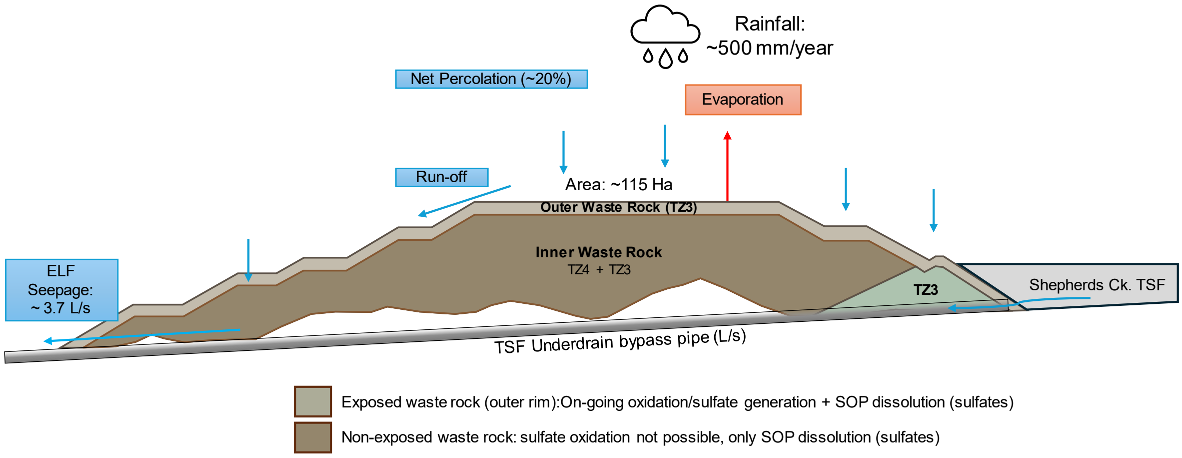

Figure 19. Conceptual (and schematic) water balance and material distribution for the Shepherds ELF.

A distinct feature of the Shepherds ELF is that it serves as the embankment for the TSF. However, seepage from the TSF will not interact with the waste rock in the Shepherds ELF, as it will be captured by an underdrain and will be passed through the ELF. It is expected that these seepage paths mix at the Shepherds Seepage Pond. This will reduce the PCOC load mobilised from the Shepherds ELF.

3.7.2 SRX ELF

The SRX ELF contains 4,984 kt of waste rock, being primarily composed of TZ3 (4,378 kt or 87.84% of the material) and a minor presence of TZ4 (606 kt or 12.15%). Based on topographical differences between the designed ELF surface and the base topography, it was determined that the outer rim of the ELF accounts for:

- ~58.98% of the material for a 20-m oxidising rim (and 15 m vertically).
- ~33.77% for a 10-m oxidising rim (and 8 m vertically).

The area of the SRX ELF is approximately 15.6 Ha. Assuming a net percolation rate of 20%, the average seepage is estimated at ~0.5 L/s.

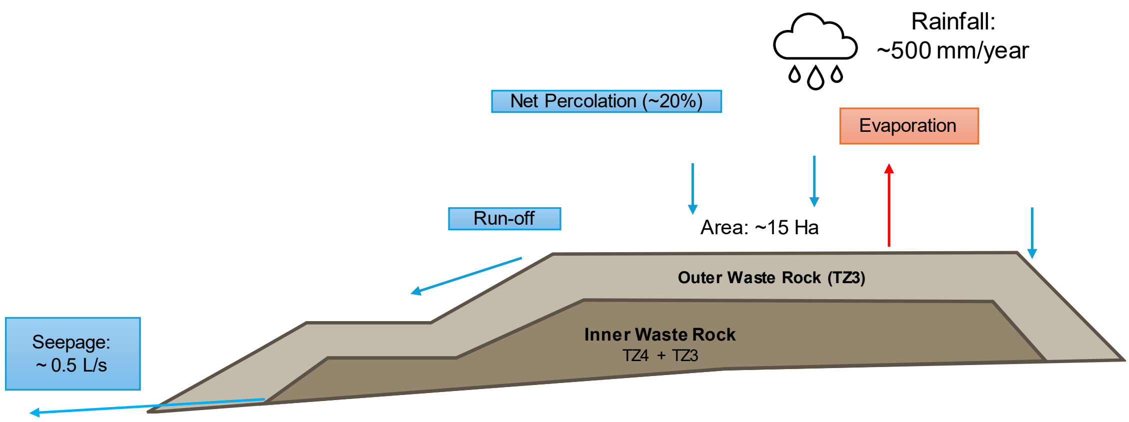

Figure 20. Conceptual (and schematic) water balance and material distribution for the SRX ELF.

3.7.3 West ELF

The WELF contains 10,732 kt of waste rock, composed entirely of TZ3 material. Assuming similar proportions between outer and inner waste rock as those calculated for SRX, the following distribution is estimated.

- ~58.98% of the material for a 20-m oxidising rim (and 15 m vertically), which represents 6,329 kt
- ~33.77% for a 10-m oxidising rim (and 8 m vertically), which represents 3,624 kt
- The area of the WELF is approximately 17.5 Ha. Assuming a net percolation rate of 20%, the average seepage is estimated at 0.56 L/s. The conceptual and schematic water balance and material distribution for this domain are shown in Figure 21.

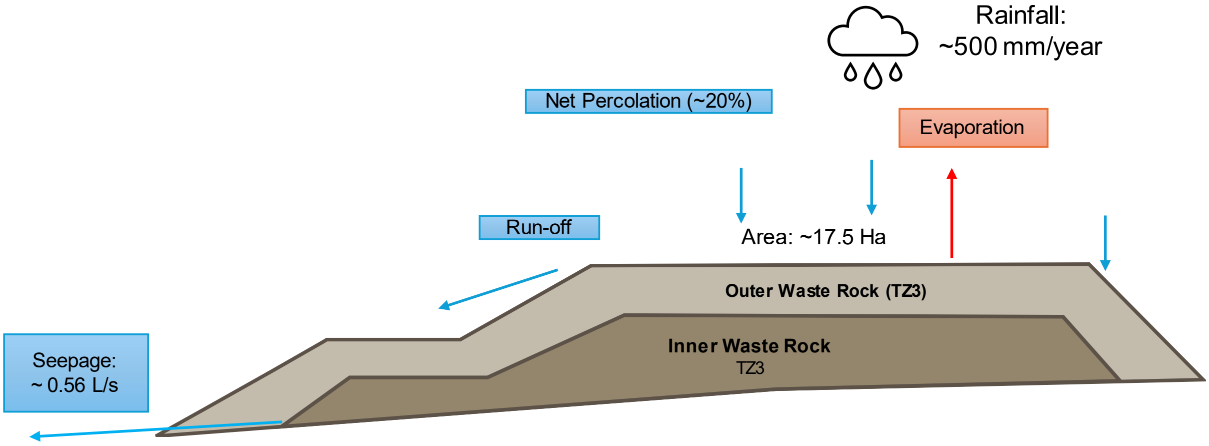

Figure 21. Conceptual (and schematic) water balance and material distribution for the WELF.

3.7.4 CIT Backfill

Unlike the ELFs, the CIT backfill consists of waste rock being backfilled into the CIT Pit void. It is assumed that once the material is backfilled, its pores will be filled by two water sources: infiltration from rainfall through the waste rock and groundwater inflow from the pit walls. When this pore water reaches the pit's overflow level (~503 mRL), it will emerge through the waste rock as seepage.

Below 510 mRL [8], the pit void has a volume of 922,930 m³. Assuming a backfill density of 2.16 t/m³, the total capacity is up to 1,993,529 t. The water volume capacity is estimated using a pore space fraction of 0.3, meaning 30% of the void volume is available for water.

Considering that the total waste rock mass (TZ3 and TZ4) in the CIT backfill of 3,400,000 t, approximately 58.6% of the material will be submerged. When this occurs, ongoing oxidation (or the long-term release of solutes) is assumed to cease. However, similar to the inner portions of the ELFs, the short-term release solutes (SOP) will remain available for dissolution.

A conceptual (and schematic) water balance is shown in Figure 22 for CIT Pit, while Figure 23 shows the amount of waste rock that is flooded with time (i.e., below the phreatic surface). This estimation is an output of the water balance model, due to its dependence on the current water level of the pore

[8] *Note: 510 mRL is used as a rounded value, as pit dimension staging is provided in 10 m increments.*

volume filling and is used in the model to quantify how much rock has ceased oxidising. This means that 42 months post closure the level of the pore water has reached the 510 mRL and no more material can be submerged.

The groundwater inflow rate is assumed to be 1 L/s when the pore volume is fully flooded at 510 mRL (Rekker and Dumont, 2025). Therefore, the total expected flow rate from the pit volume is approximately 1.88 L/s. However, the flow rates are calculated on the water balance and will vary day to day.

In this report, the estimated water quality corresponds exclusively to the 0.88 L/s component. However, in the water balance load model, the overall water quality from this backfill accounts for the mixing between seepage from the waste rock and groundwater inflow.

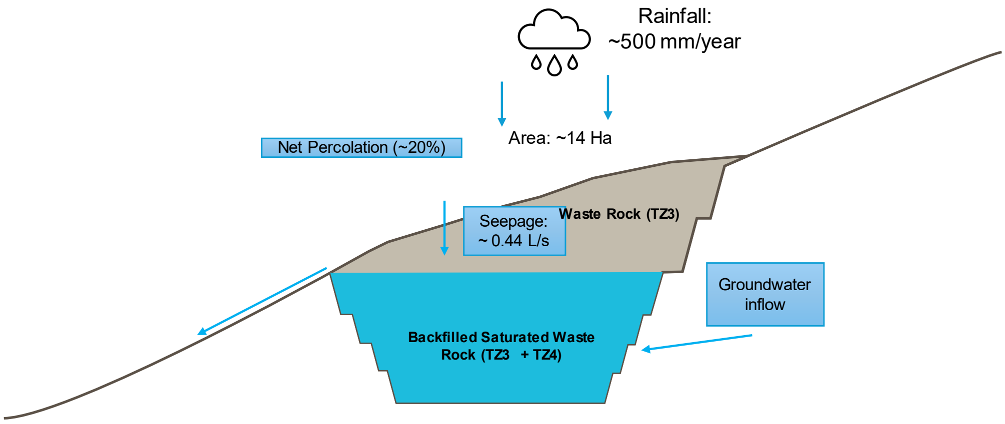

Figure 22. Conceptual (and schematic) water balance and material distribution for the Come in Time backfilled pit.

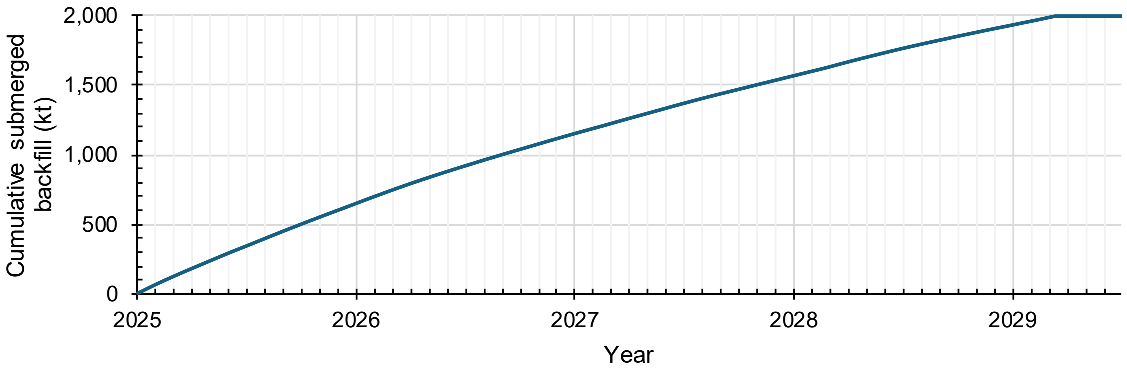

Figure 23. CIT cumulative backfill material below 510 mRL.

3.7.5 SCK Fill

The SCK Fill contains 2,264 kt of waste rock, composed entirely of TZ3 material. It is the smallest waste rock domain in terms of volume, area, and average height. Due to its elongated distribution along the creek, it is assumed that there will be no inner zone of low oxygen (e.g. sub-oxic conditions), and therefore the entire volume is expected to be reactive. The conceptual and schematic water balance and material distribution for this domain are shown in Figure 24.

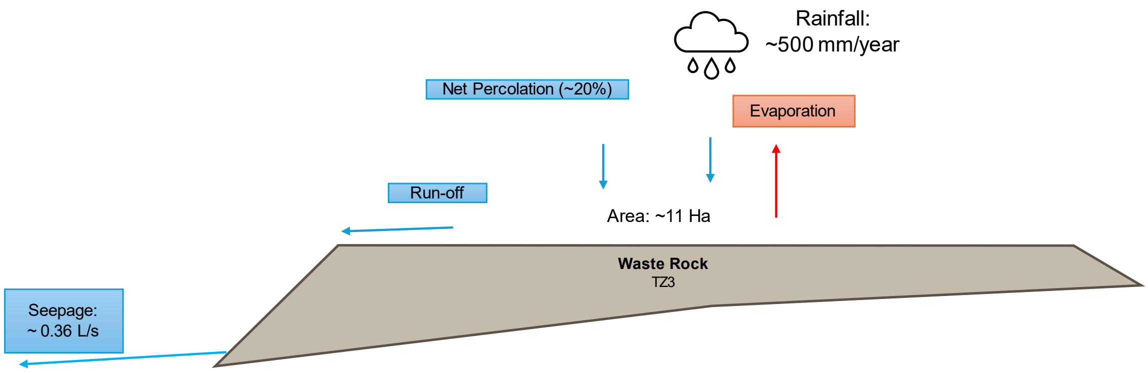

Figure 24. Conceptual (and schematic) water balance and material distribution for the SCK Fill.

Due to the presence of installations on top of the SCK Fill, the net percolation rate could potentially be lower than that assumed for the other waste rock domains. As a result, seepage may also be lower. However, the extent of this reduction is difficult to estimate. Therefore, for modelling purposes, it is assumed to behave similarly to the other domains. The average seepage flow rate is estimated at 0.36 L/s.

4 ELF GEOCHEMICAL MODELLING PROCESS

This section describes the geochemical modelling process utilised to estimate base case water quality for a WRS and the estimated water quality for the proposed ELFs at BOGP.

4.1 Data Sources

Data was obtained from MWM (2025a,d) including:

- 388 samples tested for ABA where total sulfur is used for sulfur reservoir calculations.
- 349 samples for chemical composition by 4-acid digestion and ICP-MS.
- 6 Column Leach Tests to quantify the initial stored oxidation products and long-term oxidation rates.

4.2 Modelling Approach

4.2.1 Scenarios Definition

Three scenarios are developed in this report. The first scenario corresponds to a scenario where a WRS is constructed (mine domain is fully oxidising) rather than an ELF. This scenario was developed to calibrate the modelled seepage water quality against empirical data from Macraes, assuming full oxidation of materials.

Two scenarios were then developed to estimate the expected seepage water quality under ELF-specific construction conditions. The BOGP ELFs will be built in short lifts to minimize oxygen ingress, meaning that only the outer rim of the ELF will be exposed to oxidation. This oxidation rim inherits the oxidation properties and assumptions from the WRS scenario, while the inner portion follows short-term release dynamics, where solute release is driven by water flow rather than oxidation.

For the ELFs, two oxygen ingress scenarios are considered: 20 meters and 10 meters of horizontal oxygen ingress as explained in Section 2.4.3.

4.2.2 Sulfur Reservoir Estimation

The following modelling approach was undertaken to define the initial SOP reservoirs

1. Define the quantities of TZ3 and TZ4 waste rock (Section 3), e.g., for the Shepherds ELF these amounts are 179,886 kt and 18,089 kt respectively.
2. Define the non-reactive fraction that represents the fraction of the material that is not part of the reaction due to the heterogeneous nature of waste rock (further details are provided in Section 4.2.5). This is set to 0.9 meaning that 10% of the material is available for interaction, hence, for the Shepherds ELF:
3. Reactive TZ3 waste rock: 179,886 kt x 0.1 = 17,989 kt
4. Reactive TZ4 waste rock: 18,089 kt x 0.1 = 1,809 kt
5. Determine how much sulfur is present that will be considered reactive. This is calculated by using the total sulfur content of the TZ3 and TZ4 material, which have been determined by

previous studies (MWM, 2025a) and is 0.088 wt% and 0.236 wt% respectively, therefore for the Shepherds ELF:

- Total sulfur reservoir in TZ3: 0.088% x 17,989 kt = 15,830 t.
- Total sulfur reservoir in TZ4: 0.236% x 1,809 kt x = 4,269 t.

6. The following calculation was undertaken to determine the quantities of sulfate and sulfide sulfur to understand the initial load of stored oxidation products (i.e., short-term sulfate load) and sulfide, associated with the long-term release due to oxidation of sulfides.
7. The amount of initial sulfate sulfur load is determined by the amount released in the AMIRA columns up to week 20 (further details are provided in Section 4.2.6).
8. For TZ3 it was determined that the initial load (sulfur as sulfate) is on average 2.19% of the total sulfur. For TZ4, this was calculated as 0.73%. The following calculations are provided for the Shepherds ELF:
9. Total sulfate sulfur reservoir for TZ3: 2.19 wt% x 15,830 t = 347 t.
10. Total sulfate sulfur reservoir for TZ4: 0.73 wt% x 4,269 t = 31 t.
11. Therefore, sulfide sulfur for TZ3 is 15,483 t and for the TZ4 it is 4,238 t.
12. Note: Due to the large quantity of rock, TZ3 has the largest SOP load, by an order of magnitude.
13. Reservoir calculations are then undertaken for all scenarios (Traditional WRS, ELF - 20 m model, ELF - 10 m model) for the Shepherds ELF, SRX ELF, WELF, and CIT backfill and data are provided in the following tables. For the SCK Fill (Table 11) only the WRS scenario is presented, as it was assumed to be fully oxic. Note that the SOP (or short-term sulfate load reservoir) remains the same across all scenarios, as it is not dependent on oxygen availability. Hence, only the sulfide reservoirs are affected.

Table 7. Sulfur reservoir calculations for the Shepherds ELF.

SCENARIO	COMPONENT	TZ3	TZ4	TZ3+TZ4
Total Waste Rock	Waste Rock Quantity (kt)	179,886	18,089	197,975
Waste Rock Stack Case	Reactive Waste Rock (kt)	17,989	1,809	19,798
	Sulfur reservoir (t)	15,830	4,269	20,099
	S as Sulfides (t)	15,483	4,238	19,721
	S as SOP (t)	347	31	378
ELF - 20 m model	Waste Rock in Outer Rim (20-m Ox) (kt)	36,866	0	36,866
	Reactive Outer Rim (kt)	3,687	0	3,687
	Sulfur Reservoir in Outer Rim (t)	3,244	0	3,244
	S as Sulfides (t)	3,173	0	3,173
	S as SOP (t)	347	31	378
ELF - 10 m model	Waste Rock in Outer Rim (10-m Ox) (kt)	19,011	0	19,011

SCENARIO	COMPONENT	TZ3	TZ4	TZ3+TZ4
	Reactive Outer Rim (kt)	1,901	0	1,901
	Sulfur Reservoir in Outer Rim (t)	1,673	0	1,673
	S as Sulfides (t)	1,636	0	1,636
	S as SOP (t)	347	31	378

Table 8. Sulfur reservoir calculations for the SRX ELF.

SCENARIO	COMPONENT	TZ3	TZ4	TZ3+TZ4
Total Waste Rock	Waste Rock Quantity (kt)	4,378	606	4,984
Waste Rock Stack Case	Reactive Waste Rock (kt)	438	61	498
	Sulfur reservoir (t)	385	143	528
	S as Sulfides (t)	377	142	519
	S as SOP (t)	8.4	1.0	9.5
ELF - 20 m model	Waste Rock in Outer Rim (20-m Ox) (kt)	2,939	0	2,939
	Reactive Outer Rim (kt)	294	0	294
	Sulfur Reservoir in Outer Rim (t)	259	0	259
	S as Sulfides (t)	253	0	253
	S as SOP (t)	8.4	1.0	9.5
ELF - 10 m model	Waste Rock in Outer Rim (10-m Ox) (kt)	1,683	0	1,683
	Reactive Outer Rim (kt)	168	0	168
	Sulfur Reservoir in Outer Rim (t)	148	0	148
	S as Sulfides (t)	145	0	145
	S as SOP (t)	8.4	1.0	9.5

Table 9. Sulfur reservoir calculations for the CIT ELF backfill.

SCENARIO	COMPONENT	TZ3	TZ4	TZ3+TZ4
Total Waste Rock	Waste Rock Quantity (kt)	2,550	850	3,400
Waste Rock Stack Case	Reactive Waste Rock (kt)	255	85	340
	Sulfur reservoir (t)	224	201	425
	S as Sulfides (t)	219	199	419
	S as SOP (t)	4.9	1.5	6.4
ELF - 20 m model	Waste Rock in Outer Rim (20-m Ox) (kt)	2,005	0	2,005
	Reactive Outer Rim (kt)	201	0	201
	Sulfur Reservoir in Outer Rim (t)	176	0	176
	S as Sulfides (t)	173	0	173

SCENARIO	COMPONENT	TZ3	TZ4	TZ3+TZ4
	S as SOP (t)	4.9	1.5	6.4
ELF - 10 m model	Waste Rock in Outer Rim (10-m Ox) (kt)	1,148	0	1,148
	Reactive Outer Rim (kt)	115	0	115
	Sulfur Reservoir in Outer Rim (t)	101	0	101
	S as Sulfides (t)	99	0	99
	S as SOP (t)	4.9	1.5	6.4

Table 10. Sulfur reservoir calculations for the WELF.

SCENARIO	WASTE ROCK UNIT	TZ3	TZ4	TZ3+TZ4
Total Waste Rock	Waste Rock Quantity (kt)	10,732	0	10,732
Waste Rock Stack Case	Reactive Waste Rock (kt)	1,073	0	1,073
	Sulfur reservoir (t)	944	0	944
	S as Sulfides (t)	924	0	924
	S as SOP (t)	21	0	21
ELF - 20 m model	Waste Rock in Outer Rim (20-m Ox) (kt)	6,330	0	6,330
	Reactive Outer Rim (kt)	633	0	633
	Sulfur Reservoir in Outer Rim (t)	557	0	557
	S as Sulfides (t)	545	0	545
	S as SOP (t)	21	0	21
ELF - 10 m model	Waste Rock in Outer Rim (10-m Ox) (kt)	3,624	0	3,624
	Reactive Outer Rim (kt)	362	0	362
	Sulfur Reservoir in Outer Rim (t)	319	0	319
	S as Sulfides (t)	312	0	312
	S as SOP (t)	21	0	21

Table 11. Sulfur reservoir calculations for the SCK Fill

SCENARIO	WASTE ROCK UNIT	TZ3	TZ4	TZ3+TZ4
Total Waste Rock	Waste Rock Quantity (kt)	2,264	0	2,264
Waste Rock Stack Case	Reactive Waste Rock (kt)	226	0	226
	Sulfur reservoir (t)	199	0	199
	S as Sulfides (t)	195	0	195
	S as SOP (t)	4.4	0.0	4.4

4.2.3 Release Rates

Release rates are obtained from CLT data. Since each sample in the CLTs has a different total sulfur value, sulfur loss is calculated as a percentage of sulfur per month. The following process was followed:

1. Convert the total sulfur content from percentage to mg/kg [9].
2. Estimate the total sulfate (SO_4) released from the CLT up to week 20 and convert it to sulfur [10], which indicated that the average SO_4-S production up to week 20 of the CLT is 20.97 mg/kg for TZ3 and 22.07 mg/kg for TZ4 [11].
3. Determine what percentage of the total sulfur that is represented by SO_4-S.
4. Calculate the amount of sulfide sulfur by subtracting SO_4-S from the total sulfur.
5. Determine the SO_4-S release rate by calculating the slope of cumulative SO_4 generation per week from week 20 onwards, converting it to mg/kg/month, and division by 2.996 to present data as SO_4-S.
6. Divide this value by the amount of sulfide-S to determine how much SO_4-S is released in the early stages of oxidation. Since sulfide-S will deplete over time, the release rate (and consequently the concentrations) will also decline with time, which is accounted for by the model.

These data (and the calculation process) are presented in Table 12. Results shown that TZ4 releases approximately 6 times the amount of sulfate released by TZ3, in part because the amount of total sulfur is higher (around 3 times higher), and also because the rock is more reactive (approximately 2 times higher). This supports the hypothesis that TZ4 materials should be placed in the core of the ELF away from oxygen.

Figure 25 shows the cumulative amounts of sulfate released over time. It is possible to see graphically that the amount of sulfate released in the first weeks is higher for TZ3, but after week 12, there is a clear change in the quantity of generated sulfate for this geological unit.

It is assumed a limit at week 20 for the initial amount of sulfate sulfur to account for on-going oxidation on field conditions before the material being placed on the ELFs

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[9] by multiplying by 10,000.

[10] Based on molecular weights (i.e., by dividing by 2.996)

[11] 20 weeks was considered a reasonable time-period as an inflection was identified in TZ3 cumulative sulfate plots indicating a change in rection kinetics (Figure 25) from short term kinetic rates to long term kinetic rates. 20 weeks was also considered a reasonable time frame for materials exposed in the field prior to being excluded from oxygen.

Table 12. Column leach test data for TZ3 and TZ4 oxidising materials.

Sample ID	TZ3 - S: 0.113% (MG19838)	TZ3 - S: 0.1025% (MG19875/76)	TZ3 - S: 0.0885% (MG43524/25)	TZ4/RSSZ - S: 0.488% (MG46045)	TZ4/RSSZ - S: 0.267% (MG40061)	TZ4/RSSZ - S: 0.226% (MG37922)	Average TZ3	Average TZ4
Total Sulfur (%)	0.113	0.1025	0.085	0.488	0.267	0.226	0.10017	0.327
Total Sulfur (mg/kg)	1130	1025	850	4880	2670	2260	1001.67	3270
SOP as Sulfur week 20 (mg/kg)	12.101	23.430	27.370	24.354	23.838	18.019	20.967	22.071
Sulfide-S (mg/kg)	1117.9	1001.6	822.6	4855.6	2646.2	2242.0	980.7	3247.9
SO_4-S as a percent of total S (%)	1.071	2.286	3.220	0.499	0.893	0.797	**2.192**	**0.730**
SO_4 release rate (mg/kg/week)	0.279	0.948	1.045	5.633	4.180	3.007	0.757	4.273
SO_4-S release rate (mg/kg/month) [1]	0.404	1.371	1.511	8.146	6.046	4.349	1.095	6.180
Release rate (%/month) [2]	0.036	0.137	0.184	0.168	0.228	0.194	**0.119**	**0.197**

1 – based on slope;

2 – normalised to wt% S

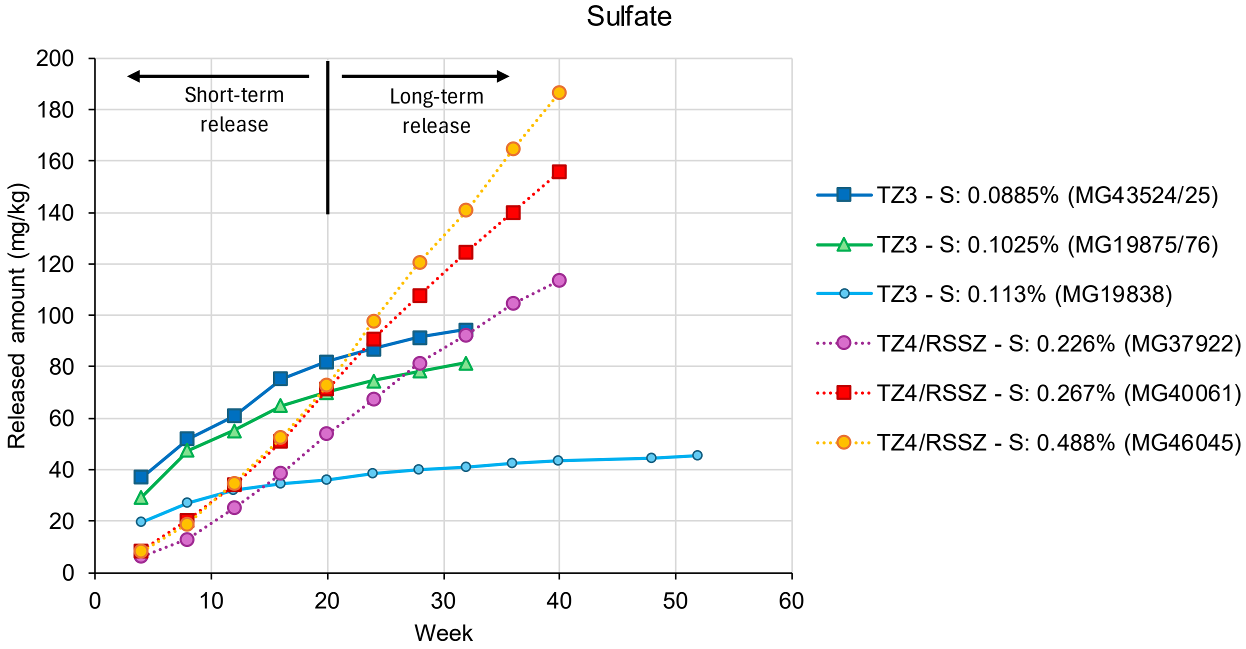

Figure 25. Cumulative released amount for sulfate based on the AMIRA CLT.

4.2.4 Time Lag to Peak Concentrations and Adjustments to Empirical Data

A time lag to peak PCOC concentration is expected for the proposed ELFs. Several physical and hydrological properties influence this behaviour including:

- The rate of WRS construction, its height, and geometry can affect water infiltration and residence time, with taller or more compacted WRS promoting longer contact times with reactive materials.
- Preferential flow paths, such as fractures or loosely compacted zones, can create localised areas of rapid transport, altering concentration trends.
- The hydraulic properties of the waste rock, including permeability and porosity, determine how water moves through the system and interacts with reactive minerals. Granulometry and particle size distribution also play a role, as finer materials can retain water longer, enhancing dissolution and sulfate release.

Given the complexity of how water moves through such materials and the time lag to peak concentrations, empirical data and analogue models were used to estimate both the time required to reach peak concentrations and the magnitude of those peaks.

Data from Macraes (e.g., Babbage, 2019) indicates that these peaks develop over several years. For the Frasers West WRS (an average height of ~ 40.9 m: Navarro et al., 2024), it took approximately 14 years to reach peak concentrations. Assuming this timing corresponds to when the tallest portion of the waste rock stack begins contributing to seepage quality, we estimate that the peak concentrations for Shepherds ELF will occur between 25 and 30 years after construction begins. This estimate is based on the fact that the average height of the Shepherds ELF is approximately twice that of the Frasers West WRS. Hence, using height data to scale to time lag to peak concentration, the time lag to peak sulfate concentration for SRX ELF is 5 years; CIT ELF backfill is 4 years; WELF is 10 years, and 3 years for the SCK fill.

In addition, based on the analysis of peak concentrations at Macraes (MWM, 2024a), the estimated sulfate peak concentrations have been calculated for a comparable WRS and are shown in Table 13 along physical characteristics of the ELFs.

Table 13. Summary of ELF physical characteristics and SO_4 (mg/L) if constructed as a WRS.

ELF PARAMETER	SHEPHERDS	SRX	CIT	WELF	SCK FILL
Volume (m^3)	91,655,093	2,306,944	1,574,074	5,260,808	1,109,758
Quantity (kt)	197,975	4,983	3,400	10,732	2,264
Area (m^2)	1,155,423	155,592	137,925	175,128	111,845
Average height (m)	79	15	11 (5)[2]	30	10
Estimated flow rate (L/s)	3.7	0.5	0.44	0.56	0.36
Years until peak concentration	27	5	4	10	3
Expected WRS sulfate peak concentration (mg/L) – no engineering controls[1]	6,206	1,160	861 (460)[2]	2,350	776

1. – Sulfate concentrations are for a traditional WRS with no engineered controls.

2. – Numbers in brackets represent the average height and sulfate concentration of the CIT WRS above the phreatic surface.

The time lag to peak concentrations is incorporated into the model by assuming a normal distribution for the material generating the loads. This means that solute release begins progressively from the start, with the majority of the material (99%) undergoing interaction by year 40 for the Shepherds ELF model. This is represented graphically on Figure 26. It is worth noting that this adjustment does not affect the total released load as a whole, it only affects when the load is released.

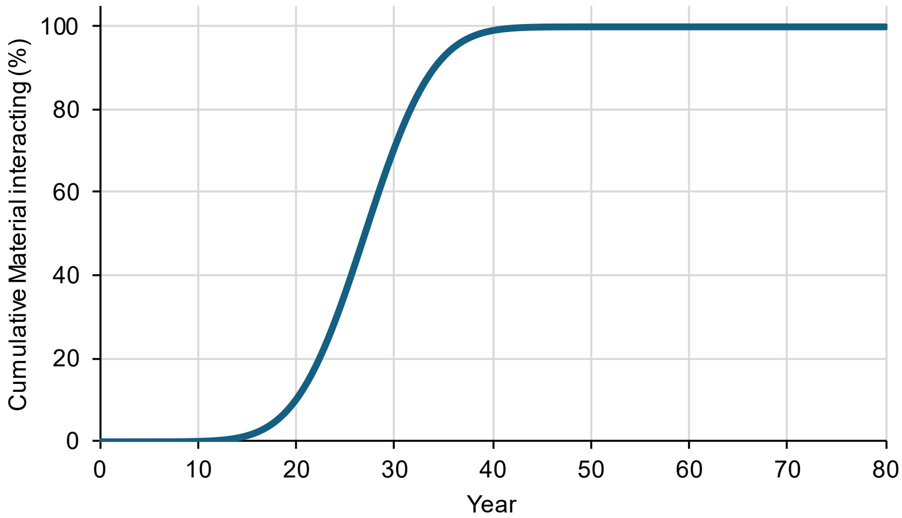

Figure 26. Cumulative percentage of waste rock material releasing solutes over time.

The effect on the sulfate concentration for the Shepherds WRS geochemical model is shown on Figure 27 where there is no scaling of data for any time lag to peak concentration. Without a time lag, all materials immediately release solutes from the start of the model and decays over time due to the exhaustion of available solutes, which is caused by both short-term and long-term sulfate release.

The introduction of a time lag to acid onset and an adjustment to the quantify of material contributing to solutes attenuates this peak concentration and generates the load later in the model. Note: these results are prior to the scaling of non-reactive material or column leach test concentrations to match empirical datasets (discussed in the next section).

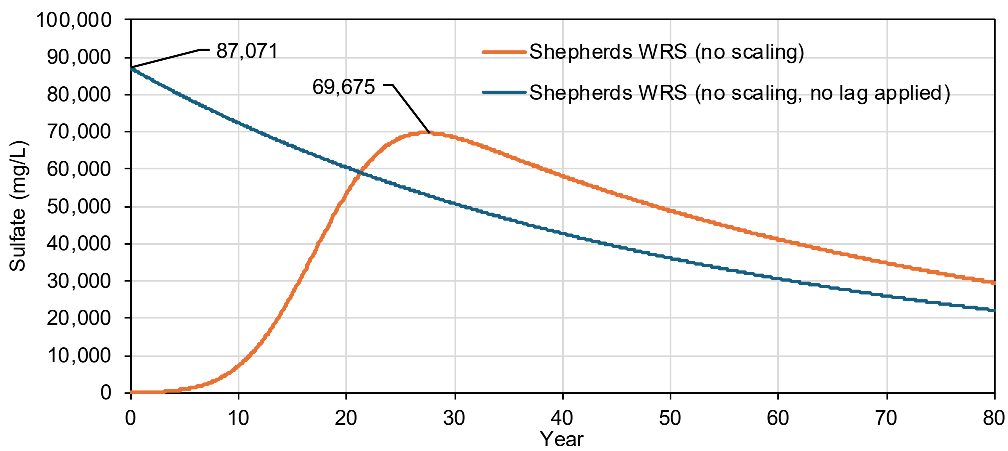

Figure 27. Comparison of model output for Shepherds WRS with no time lag to peak concentration and a time lag scenario.

4.2.5 Adjustments to Match Empirical Data: Waste Rock Stack Height

PCOC concentration is a function of WRS height. This process is based on analogue data from Macraes (Section 2.2), which shares similar geochemical characteristics and climatic conditions. The ELF model is based on the assumption that the expected average WRS sulfate concentrations peak correlates with the average height of the WRS. This approach is undertaken to develop the Traditional WRS model and assumes oxygen is freely available through the WRS.

The key driver for peak sulfate in the BOGP modelling is based on the height versus sulfate relationship (Navarro-Valdivia et al., 2024), which is shown in Table 13. Two adjustment factors are implemented to align the model:

1. The first factor to consider is the reactive material fraction. In laboratory conditions, such as those used in CLTs, a high percentage of minerals are available for reaction due to sample preparation, which often involves grinding the material to increase surface area. However, in the field, waste rock is coarser (e.g., boulders). Minerals within the inner parts of these boulders are not expected to be available for reaction in the short and long term. Additionally, preferential flow paths form during infiltration, and these paths will only interact with the minerals they come into direct contact with, further limiting the availability of reactive materials. The non-reactive material fraction was set to 0.9, which therefore decrease the peak sulfate concentration to ~7,000 mg/L (e.g., 10% of 70,000 mg SO_4/L).
2. The second factor to consider is an adjustment to the release rate of sulfate. The release rate adjustment factor specifically modifies the long-term release rates (e.g., derived from oxidation). This adjustment is made to align the release rates derived from CLT data with the expected sulfate peak from empirical data. The adjustment factor to the long-term release rates was set to 0.8575 to match the ~6,200 mg/L sulfate peak that is expected from the height versus peak sulfate concentration model (e.g., Figure 6).

The effect of the non-reactive fraction factor and the long-term release rates factor are shown in Figure 28.

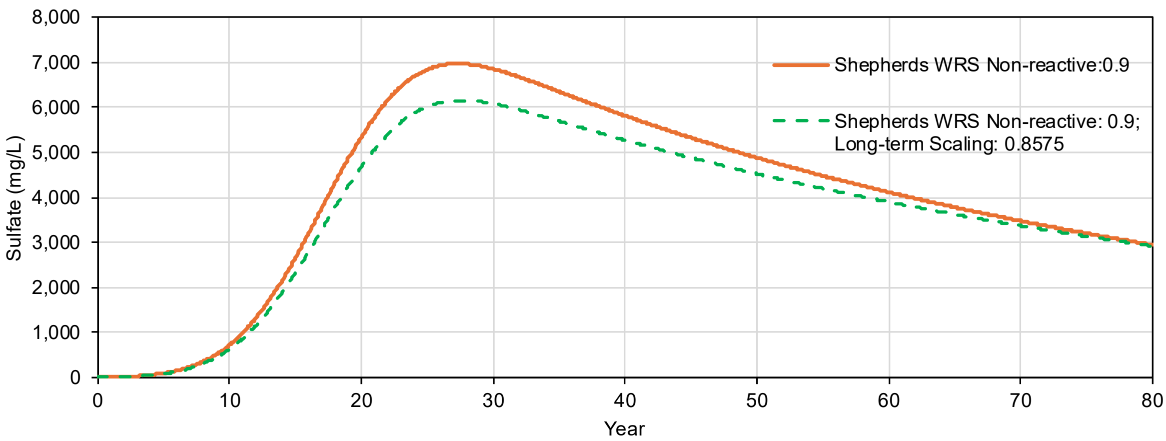

Figure 28. Adjustment Factors to match empirical data models: Traditional WRS.

Green line: Sulfate concentration for the non-reactive fraction set at 0.9.

Orange line: Sulfate concentration with non-reactive fraction set at 0.9 and long-term release rates adjusted with a factor of 0.8575 to match the ~6,200 mg/L expected sulfate peak.

4.2.6 Other Solute Release Calculations

Six AMIRA (2002) CLTs were conducted to quantify oxidation rates and solute release from TZ3 and TZ4 materials. Time series plots for sulfate are shown in Figure 25. The cumulative solute generation, expressed in milligrams of solute per kilogram (mg/kg) of rock, was calculated for each element.

The short-term release of contaminants was estimated using the intercept of the linear trend from the long-term decay. However, this approach differed for sulfate, where the total sulfate released up to week 20 was used instead. This exception was made because the TZ4 samples exhibited a negative intercept, suggesting an absence of initial sulfate load. Given that waste rock is expected to be exposed to the atmosphere (oxygen) before placement in the ELF and then will not be excluded from oxygen immediately, it was determined that sulfate generation would occur for up to 20 weeks prior to deposition, which also matched the SOP inflection point suggesting a change in kinetic rates (Figure 25), e.g., for example, a change from dissolution driven process to slower oxidation driven processes.

The long-term release rate was estimated by calculating solute generation from week 20 onward, with some exceptions. These exceptions were based on observed decay trends for specific solutes.

Since there is no empirical quantification of the total solute release over the long term for solutes other than sulfate, it was assumed that the solute decay follows the same pattern as sulfide decay. While this assumption may be conservative, implying that solute release persists for as long as sulfides, it provides a conservative estimate for long-term environmental impact assessments. This ensures that potential risks are not underestimated, even if the actual release duration may be shorter.

Three specific exceptions for solute behaviour are shown in Figure 29. Ongoing CLT will confirm whether the approaches presented below are appropriate:

- Molybdenum follows a similar pattern to sulfate; however, a slight decrease in CLT release rates is observed from week 32 onwards. The release rate for Mo was determined using the slope of the last three cycles to consider long term release rates.
- Uranium has a decreasing trend in CLT for TZ3 materials. The trend from week 28 onward is used for TZ3. TZ4 has very little U and all the released mass is assumed to be released in the short term.
- Boron release appears to cease in all CLT over time. Consequently, its long-term release rate is assumed to be zero, and the total amount released is attributed to short-term release.

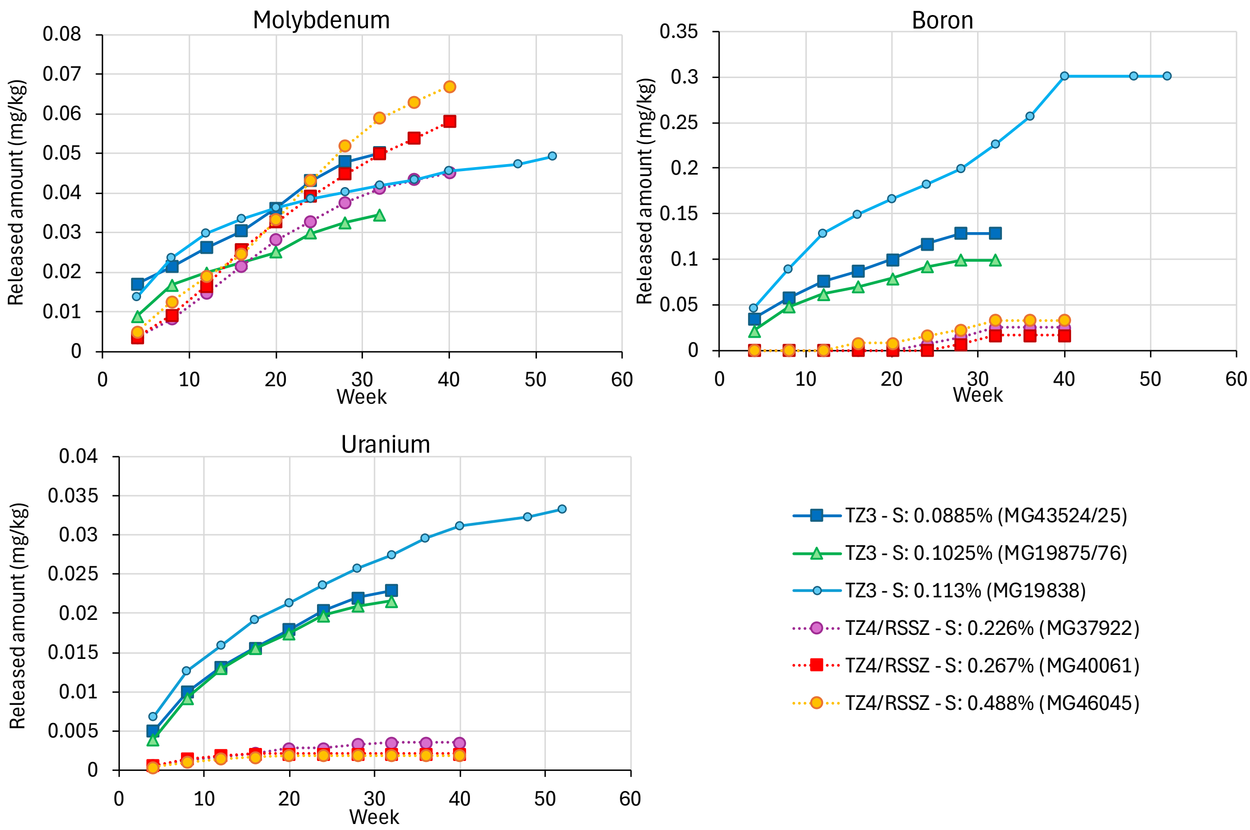

Figure 29. Cumulative CLT solute release rates for B, Mo, and U.

Table 14 summarises the average release rates for solute based on the CLT data for short and long terms for each lithological unit.

Table 14. Average short-term and long-term release rates for TZ3 and TZ4.

PARAMETER	SHORT-TERM RELEASE (mg/kg)[1]		LONG-TERM RELEASE (mg/kg/week)	
	TZ3	TZ4	TZ3	TZ4
Alkalinity	100.6841	8.457784	4.888945	1.100828
F	0.684865	0.064659	0.008621	0.00124
Cl	7.462766	0.842568	0.028704	0.020857
SO_4	58.28484	47.46398	0.757372	4.273423
P	0.240219	0	0.002427	0.004354
Al	0.341493	0.038954	0.005617	0.003156
SO_4	0.01508	0.00279	0.002833	0.0002
As	0.0283	0	0.016346	0.052076
Ba	0.006932	0.001595	0.001158	0.000722
B	0.176198	0.025042	0	0
Cd	0	0	0	0
Ca	0	0	1.354358	0.823776
Cr	0.000884	0.000432	0	0
Co	0.038286	0	0	3.7E-05
Cu	0.004143	0	0.000106	7.12E-06

PARAMETER	SHORT-TERM RELEASE (mg/kg)[1]		LONG-TERM RELEASE (mg/kg/week)	
	TZ3	TZ4	TZ3	TZ4
Fe	0.193134	0.00764	0.001586	0.000413
Pb	0.000246	0	0	0
Mg	0.094851	0	0.161223	0.620839
Mn	0.008974	0.006485	0.000678	0.000747
Hg	5.57E-05	0	0	0
Mo	0.024109	0.02288	0.00058	0.000844
Ni	0.001733	0.000484	0	6.38E-06
K	1.855408	4.621057	0.591858	0.558662
Se	0.00207	0	0.000144	0
Ag	0	0	0	0
Na	65.56925	7.088255	0.612655	0.182891
Sr	0.145743	0.110983	0.042898	0.058856
Tl	0	0	0	0
Sn	0	0	0	0
Ti	0.005641	0	1.86E-05	0
U	0.018802	0.0025	0.000186	0
V	0.006116	7.09E-05	9.87E-05	0
Zn	0.003452	0	0	0

For calculation purposes, any value below the limit of reporting was assumed to be zero.

Note: Nitrate-N cannot be determined from CLT as the materials have not been blasted. Nitrate-N loads of 16.6 mg/kg are used in the model (see Section 2.6.2).

1. - It is assumed that ~90% of the SOP load is mobilised over 50 years to align with the mobilisation of nitrate-N.

4.2.7 Solubility Controls (PHREEQC)

Once the solute concentration is estimated, the resulting concentrations are modelled using the geochemical modelling code PHREEQC version 3.7 (Parkhurst & Appelo, 2003) with the minteq.v4 database. The objective of this step is to apply solubility controls to the concentrations and precipitate supersaturated minerals, such as Fe, Al, and Cu hydroxides, as well as other hydroxysulfates and sulfates. This is achieved using the EQUILIBRIUM_PHASES keyword in PHREEQC simulations.

Certain assumptions are made, including the presence of excess dolomite in the reaction to help calculate and regulate pH. This assumption is possible, since mineralogical analyses (MWM, 2025a) identified dolomite as the main carbonate phase. Additionally, the ABA data indicates that the acid neutralisation capacity (ANC) exceeds the maximum potential acidity (MPA) by a ratio of 3 and higher, indicating a sufficient carbonate presence to neutralise the acid generated from sulfides.

Table 15. Equilibrium phases in the geochemical modelling for solubility controls.

PHASE	REACTIONS	LOG K
Dolomite(ordered)	CaMg(CO3)2 = Ca+2 + Mg+2 + 2CO3-2	-17.09
CO_2(g)	CO2 + H2O = 2H+ + CO3-2	-18.147
Ferrihydrite	Fe(OH)3 + 3H+ = Fe+3 + 3H2O	3.191
Basaluminite*	Al4(OH)10SO4 + 10H+ = 4Al+3 + SO4-2 + 10H2O	22.7

PHASE	REACTIONS	LOG K
Fluorite	CaF2 = Ca+2 + 2F-	-10.5
Al(OH)3(am)	Al(OH)3 + 3H+ = Al+3 + 3H2O	10.8
Gibbsite	Al(OH)3 + 3H+ = Al+3 + 3H2O	8.291
Celestite	SrSO4 = Sr+2 + SO4-2	-6.62
Gypsum	CaSO4:2H2O = Ca+2 + SO4-2 + 2H2O	-4.61
Strontianite	SrCO3 = Sr+2 + CO3-2	-9.27
Hydroxylapatite	Ca5(PO4)3OH + H+ = 5Ca+2 + 3PO4-3 + H2O	-44.333
Malachite	Cu2(OH)2CO3 + 2H+ = 2Cu+2 + 2H2O + CO3-2	-5.306
Barite	BaSO4 = Ba+2 + SO4-2	-9.98
Cupricferrite	CuFe2O4 + 8H+ = Cu+2 + 2Fe+3 + 4H2O	5.9882
Fluorapatite*	Ca5(PO4)3F + 3H+ = 5Ca+2 + 3HPO4-2 + F-	-17.6
Alunite	KAl3(SO4)2(OH)6 + 6H+ = K+ + 3Al+3 + 2SO4-2 + 6H2O	-1.4
K-Autunite	K2(UO2)2(PO4)2 = 2UO2+2 + 2K+ + 2PO4-3	-48.244
Na-Autunite	Na2(UO2)2(PO4)2 = 2UO2+2 + 2Na+ + 2PO4-3	-47.409
Calcite	CaCO3 = Ca+2 + CO3-2	-8.48
Quartz	SiO2 + 2H2O = H4SiO4	-4
Pyromorphite	Pb5(PO4)3Cl = 5Pb+2 + 3PO4-3 + Cl-	-84.43
PbMoO4	PbMoO4 = Pb+2 + MoO4-2	-15.62
Pb3(VO4)2	Pb3(VO4)2 + 8H+ = 3Pb+2 + 2VO2+ + 4H2O	6.14
Cr(OH)3(am)	Cr(OH)3 + H+ = Cr(OH)2+ + H2O	-0.75

**Added from WATEQ4F thermodynamic database.*

In addition, excess oxygen is assumed, meaning that Fe is assumed to be in the Fe^{3+} state and may precipitate as an iron hydroxide. Only phases that were at some point saturated in the WRS scenario are assumed to be in equilibrium, with initial amounts set to zero, allowing only precipitation to occur.

CO_2 equilibrium (fugacity) is set to -2.5, which is one order of magnitude higher than atmospheric conditions. This assumption is based on the expectation that the dissolution of carbonates, such as dolomite, enriches the waste rock pores with CO_2, leading to higher alkalinity concentrations.

Analogue empirical data for seepage from the Devils WRS at Globe Progress, where the waste rock was present under sub-oxic conditions, indicated elevated concentrations of As and Fe (Hayton et al., 2022). Therefore, these concentrations are used as constant outputs for ELF seepage. To represent the sub-oxic conditions of the ELF, Fe and As concentrations are set at 7.6 mg/L and 0.2 mg/L, respectively based on the Globe Progress waste rocks drains concentrations (Hayton et al., 2022). There is some uncertainty in these data, but any issues can be resolved by active and passive treatment processes that are proposed for the BOGP in the active and post closure phases (MWM, 2025e).

4.3 Summary of Model Inputs and Other Considerations

A process diagram is shown in Figure 30 and summarises the process to derive water quality estimates for the proposed BOGP ELFs. Summary inputs for model are shown in Table 16.

Table 16. Summary for ELF modelling inputs

PARAMETER	VALUE	UNIT
SULFUR RESERVOIR		
TZ3-S (%)	0.088	%
TZ4-S (%)	0.236	%
TZ3 (SO4-S)/S (%)	2.19223	%
TZ4 (SO4-S)/S (%)	0.72973	%
SULFATE RELEASE RATES		
Short-term rates	0.4	%/month
Long-term rate TZ3	0.118904	%/month
Long-term rate TZ4	0.196745	%/month
ADJUSTMENT FACTORS		
non-reactive fraction	0.1	
long-term rates factor	0.8575	
MATERIAL QUANTITIES		
SHEP-TZ3	179,886	kt
SHEP-TZ4	18,089	kt
SRX-TZ3	4,377	kt
SRX-TZ3	606	kt
CIT-TZ3	2,550	kt
CIT-TZ3	850	kt
WELF-TZ3	10,732	kt
SCK Fill-TZ3	2,264	kt
EXPECTED YEAR FOR PEAK CONCENTRATION		
SHEPHERDS	27	year
SRX	5	year
CIT	4	year
WELF	10	year
SCK Fill	3	year

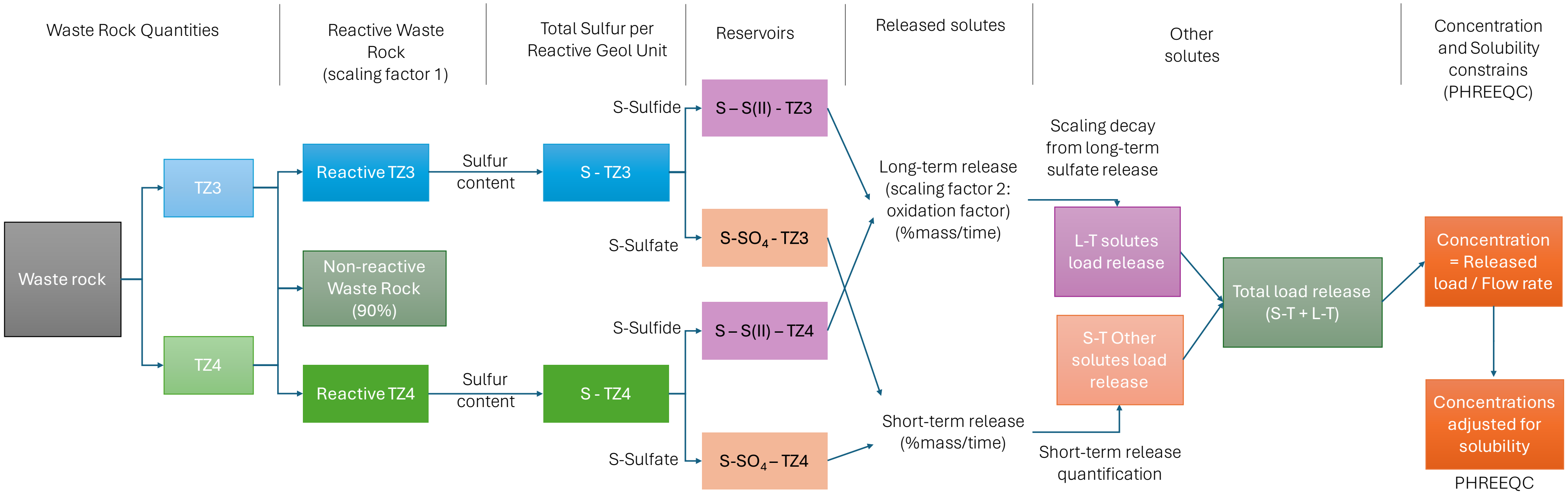

Figure 30. Process diagram for estimating the water quality seepage of the ELFs.

4.4 Model Limitations

The model has the following limitations:

- It is not possible to model the dynamics of nitrogen speciation accurately, as they are governed by sites-specific biochemical reactions and oxygen availability. It can be assumed that the majority of nitrogen will be speciated as nitrate, however, there could be a minor part as nitrite or ammoniacal nitrogen. The results are presented as nitrogen (total nitrogen).
- The estimated release rates for some elements may be overly conservative, as they are based on sulfide decay rates. Consequently, solute generation could be overestimated thereby maintaining high solute generation rates over time.
- The time lag to peak concentrations is influenced by the ELFs geometry, therefore the applied time lag to peak sulfate concentration is an approximate estimate based on analogue empirical data, and simplistic assumptions. However, the time frame is likely to be reasonable to estimate potential environmental risks for the BOGP.
- In-situ precipitation of ferric hydroxides is anticipated. Consequently, certain metals (e.g., As, Cu, Zn)) may be sorbed and captured by these minerals, particularly at neutral to alkaline pH where sorption capacities are elevated. While PHREEQC modelling can model this, significant uncertainty exists around the amount of available iron. Therefore, a conservative approach is adopted, and sorption is not modelled. Sorption may be higher in the outer oxidising zone of the ELF and lower in the core where oxygen is limited. Fixed Fe and As concentrations are provided to identify the risk to receiving waters and the need for management.

5 MODEL RESULTS AND ANALYSIS

This section presents the model results for Shepherds ELF, SRX ELF, WELF, CIT Backfill, and the SCK Fill.

5.1 Water Quality Reference Criteria

Model results are compared to the proposed compliance water quality limits for the BOGP (Ryder, 2025) for surface and groundwater to understand what PCOC may be elevated from these mine domains (Table 17).

- Sulfate limit is set at 500 mg/L as a guide to understand MIW with no modifications for SW (Ryder, 2025 recommends a variable limit between 500 and 1,000 mg/L based on hardness and chloride modifications)
- No modifications (e.g., hardness) were applied to the limits.
- Boron limit (ANZG, 2018 limits for 90% of freshwater level of protection) was used for reference purposes at 1.5 mg/L.

Table 17. Reference concentration limits for surface water and groundwater (mg/L).

PARAMETER	SURFACE WATER REFERENCE LIMIT	GROUNDWATER REFERENCE LIMIT
Al	0.08	1
Co	0.001	1
Cu	0.0018	0.5
Mn	-	0.4
Mo	0.034	0.01
NO3-N	2.4	11.3
Pb		0.01
Sb	0.074	0.02
Se	-	0.02
SO4	500	250
Sr	-	4
U	-	0.03
Zn	0.015	1.5
Cr	0.0033	0.05

Source: Ryder (2025); Units in mg/L

Results are displayed in time-series plots together with the GW and SW limits and a summary table of results.

5.2 General Observations

The following general observations are provided for the results:

- Water quality is expected to be circum-neutral pH with low acidity. This is due to the abundance of carbonate minerals and a low sulfide content.

- Peak sulfate concentrations, a function of average ELF height, were determined for Shepherds ELF (~27 years), SRX ELF (~5 years), CIT ELF (~4 years), WELF (~10 years), and SCK Fill (~3 years).
- When the results for the two scenarios overlap (e.g., 10 m and 20 m oxygen exclusion zones), it indicates that the solutes originate from short-term release, where oxidation has no impact on the results, and therefore, results are the same.
- The first 50 years are strongly influenced by the short-term release of SOP. This is particularly evident for nitrate-nitrogen (NO_3-N), boron (B), cobalt (Co), and zinc (Zn), which are generally elevated and are associated with SOP (see Table 14). Reducing water ingress would reduce the rate that these PCOC are mobilised.
- Sulfate concentrations are > 500 mg/L for the Shepherds ELF, SRX ELF, and WELF. Sulfate concentrations are < 500 mg/L in the CIT backfill and the SCK Fill.
- Nitrate-N concentrations are > 2.4 mg/L in seepage from all waste rock disposal areas. Duration of elevated nitrate in seepage is expected to range from 25 – 100 years but may be shorter due to biogeochemical processes that would remove the nitrate.
- Results indicate that the following trace metals: Sb, Co, Mo, Mn, Se, Sr, U, and Zn, are generally over the respective water quality reference limits.
- Results indicate that Al, B, Cd, Cr, Cu, Hg, and Pb, are below the respective water quality reference limits in all cases. These PCOC are not considered an issue for this mine domain.
- Constant concentrations are assumed for As (0.2 mg/L) and Fe (7.6 mg/L) based on empirical data for sub-oxic conditions (e.g., Globe Progress Waste Rock Stack, Hayton et al., 2022). These concentrations are above the proposed water quality reference limit (Ryder, 2025) and will require management. The SCK Fill assumes full oxidation, which results in low Fe concentrations.
- Zn is overall below both limits, however peak concentrations are slightly above the SW reference limit (0.0155 > 0.015 mg/L) for Shepherds ELF.

The following subsections present specific results and observations for each ELF.

5.3 Shepherds ELF

Results for the model scenarios for the Shepherds ELF are shown in Figure 31 and Figure 32 with selected outputs shown in Table 17.

The following observations are provided:

- In general, the highest concentrations of PCOC (especially SOP), can be found in Shepherds ELF, due to its higher material volume and higher height.
- Sulfate concentrations are similar across both scenarios (10 and 20 m oxygen exclusion) where oxygen is restricted to the outer rim of the ELF, peaking at approximately 1,100 mg/L. After year 50, sulfate concentrations declined to below 750 mg/L for both the 10 m and 20 m oxygen exclusion scenarios.

- NO_3-N concentration peaks at ~ 80 mg/L.
- Sb, U, and Mn behave similarly to sulfate, likely associated with oxidation of sulfides.

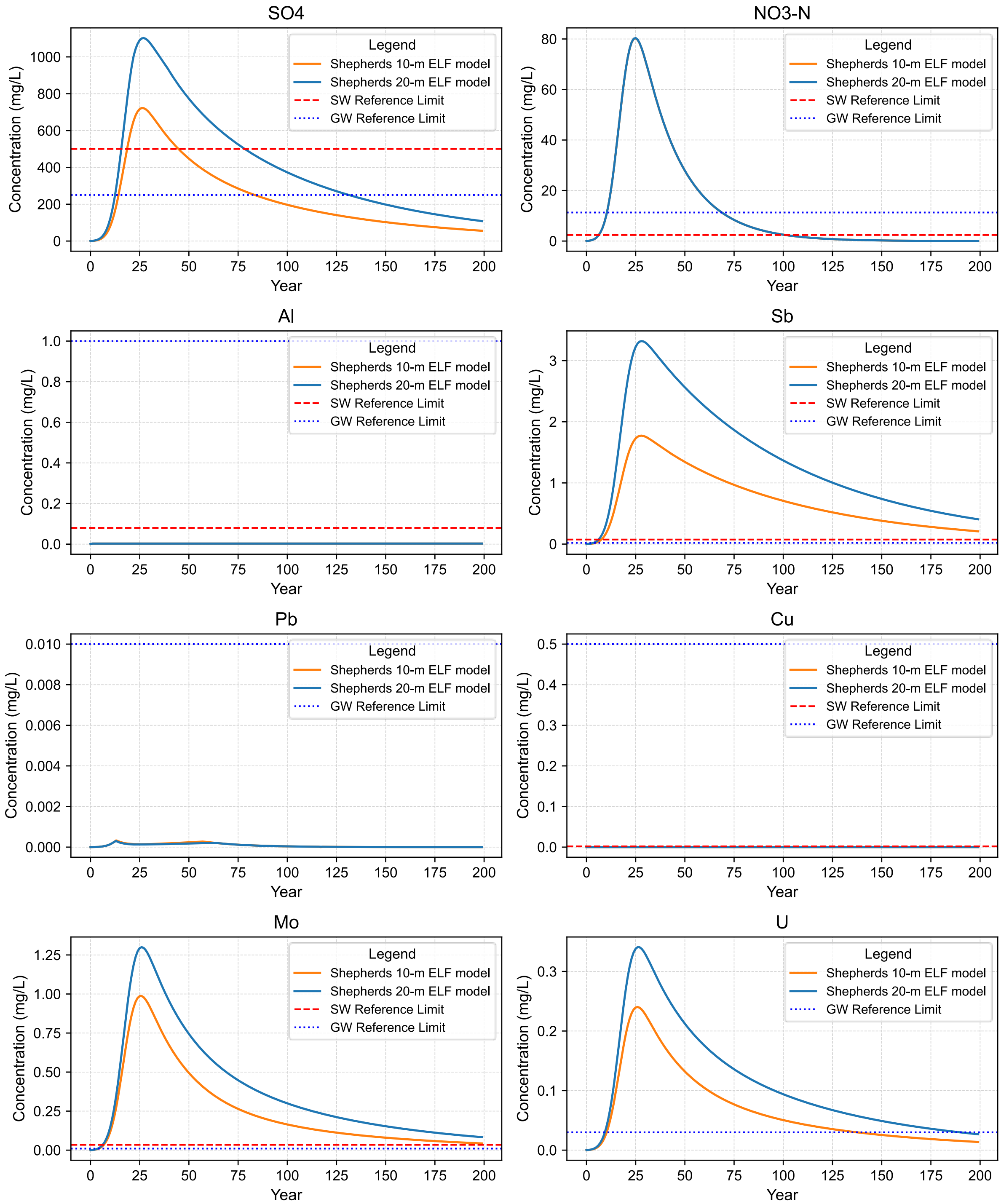

Figure 31. Model results part 1 for the Shepherds ELF.

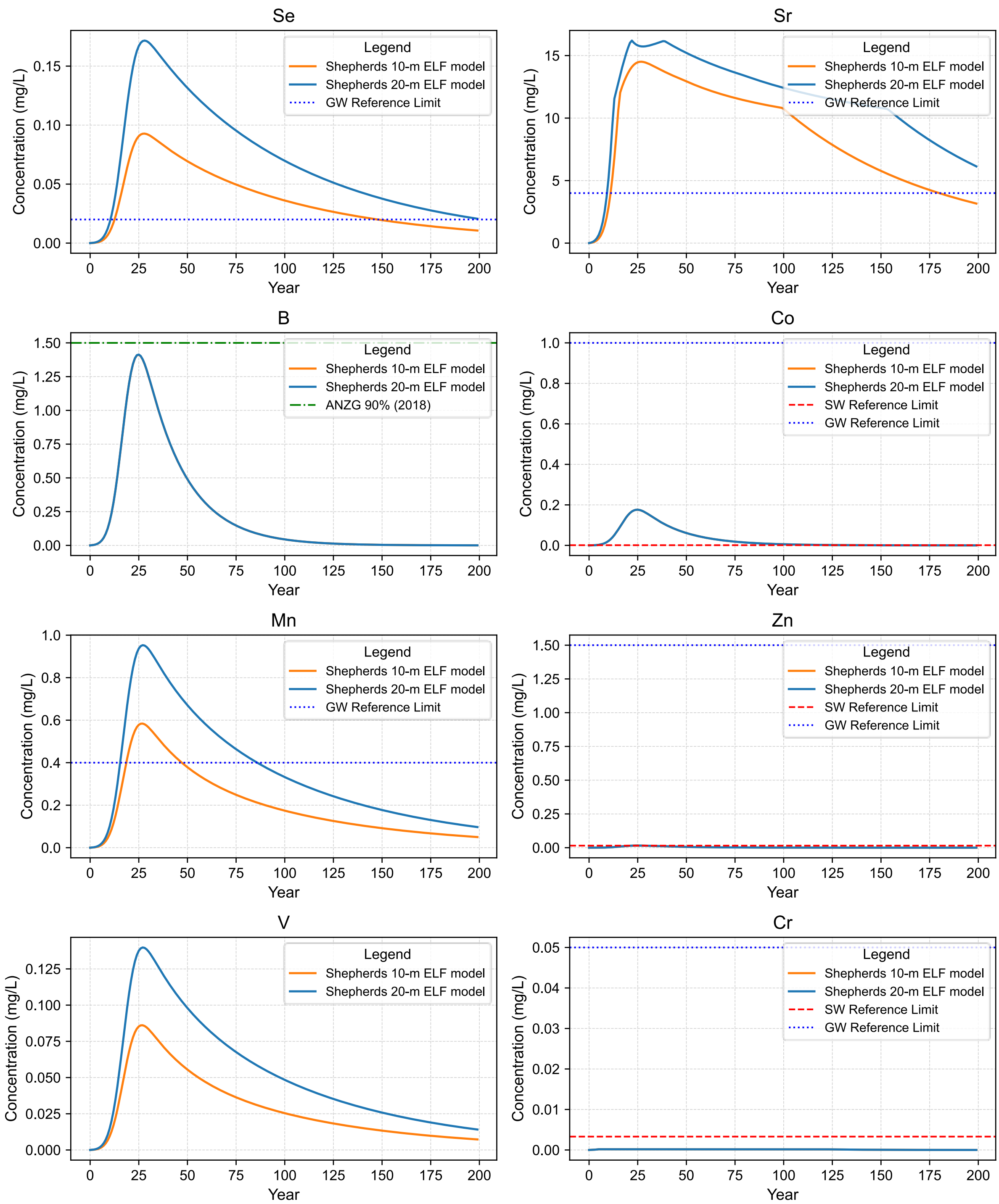

Figure 32. Model results part 2 for the Shepherds ELF.

Table 18. Selected model results for the Shepherds ELF Scenarios

SCENARIO	PARAMETER	Al	B	Co	Mn	Mo	NO3-N	Sb	Se	SO4	Sr	U	Zn	V	Cr
	SW REF LIMIT	0.08	-	0.001[a]	-	0.034	2.4[b]	0.074[a]	-	500	-	-	0.015		0.0033[c]
	GW REF LIMIT	1	-	1	0.4	0.01	11.3	0.02	0.02	250	4	0.03	1.5		0.05
	YEAR														
ELF - 20 m model	1	0.0028	0.001	0.0002	0.0008	0.0012	0.08	0.0026	0.0001	1	0.04	0.000	0.0000	0.0001	0.00002
ELF - 20 m model	5	0.0028	0.023	**0.0029**	0.0129	**0.0191**	1.32	**0.0426**	0.0022	16	0.67	0.005	0.0003	0.0019	0.00017
ELF - 20 m model	10	0.0030	0.175	**0.0218**	0.0997	**0.1464**	**9.96**	**0.3315**	0.0172	120	**5.18**	**0.037**	0.0020	0.0147	0.00017
ELF - 20 m model	27	0.0035	1.378	**0.1718**	**0.9529**	**1.2953**	**78.36**	**3.3105**	**0.1712**	**1102**	**15.73**	**0.341**	**0.0155**	0.1398	0.00019
ELF - 20 m model	50	0.0033	0.490	**0.0611**	**0.6704**	**0.7442**	**27.86**	**2.5623**	**0.1315**	**773**	**15.21**	**0.212**	0.0055	0.0980	0.00019
ELF - 20 m model	100	0.0031	0.044	**0.0055**	0.3322	**0.2996**	**2.51**	**1.3664**	**0.0697**	**373**	**12.41**	**0.094**	0.0005	0.0484	0.00018
ELF - 20 m model	150	0.0030	0.004	0.0005	0.1772	**0.1530**	0.23	**0.7386**	**0.0377**	198	**10.81**	**0.049**	0.0000	0.0258	0.00004
ELF - 20 m model	199	0.0029	0.000	0.0000	0.0970	**0.0831**	0.02	**0.4051**	**0.0206**	108	**6.14**	0.027	0.0000	0.0141	0.00000
ELF - 10 m model	1	0.0028	0.001	0.0002	0.0005	0.0010	0.08	0.0014	0.0001	1	0.02	0.000	0.0000	0.0001	0.00002
ELF - 10 m model	5	0.0028	0.023	**0.0029**	0.0082	**0.0151**	1.32	**0.0231**	0.0012	10	0.37	0.004	0.0003	0.0012	0.00017
ELF - 10 m model	10	0.0029	0.175	**0.0218**	0.0633	**0.1152**	**9.96**	**0.1791**	0.0094	80	2.87	0.027	0.0020	0.0093	0.00017
ELF - 10 m model	27	0.0034	1.377	**0.1716**	**0.5840**	**0.9791**	**78.27**	**1.7697**	**0.0927**	**722**	**14.51**	**0.239**	**0.0155**	0.0861	0.00019
ELF - 10 m model	50	0.0032	0.490	**0.0610**	0.3785	**0.4944**	**27.84**	**1.3431**	**0.0693**	**447**	**12.94**	**0.132**	0.0055	0.0555	0.00018
ELF - 10 m model	100	0.0030	0.044	**0.0055**	0.1742	**0.1644**	**2.51**	**0.7063**	**0.0361**	197	**10.74**	**0.050**	0.0005	0.0254	0.00017
ELF - 10 m model	150	0.0029	0.004	0.0005	0.0916	**0.0798**	0.23	**0.3810**	0.0194	102	**5.77**	0.025	0.0000	0.0133	0.00004
ELF - 10 m model	199	0.0029	0.000	0.0000	0.0500	**0.0429**	0.02	**0.2089**	0.0106	56	3.16	0.014	0.0000	0.0073	0.00000

Units in mg/L

a: Chronic value is used for reference.

b: Annual median used for NO_3-N

c: Cr(III) recommended compliance limit is used.

*Bold **red text** indicates values greater than the GW and SW reference limit.*

*Bold **orange text** indicates values greater than the SW reference limit.*

*Bold **purple text** indicates values greater than the GW reference limit.*

5.4 SRX ELF

Selected results for the model scenarios for the SRX ELF are shown in Figure 33 and Figure 34 and selected outputs for key years shown in Table 18.

The following observations are provided:

- Sulfate concentrations peak at 646 mg/L for the ELF (20 m oxygen exclusion model) and at 402 mg/L for the ELF (10 m oxygen exclusion model).

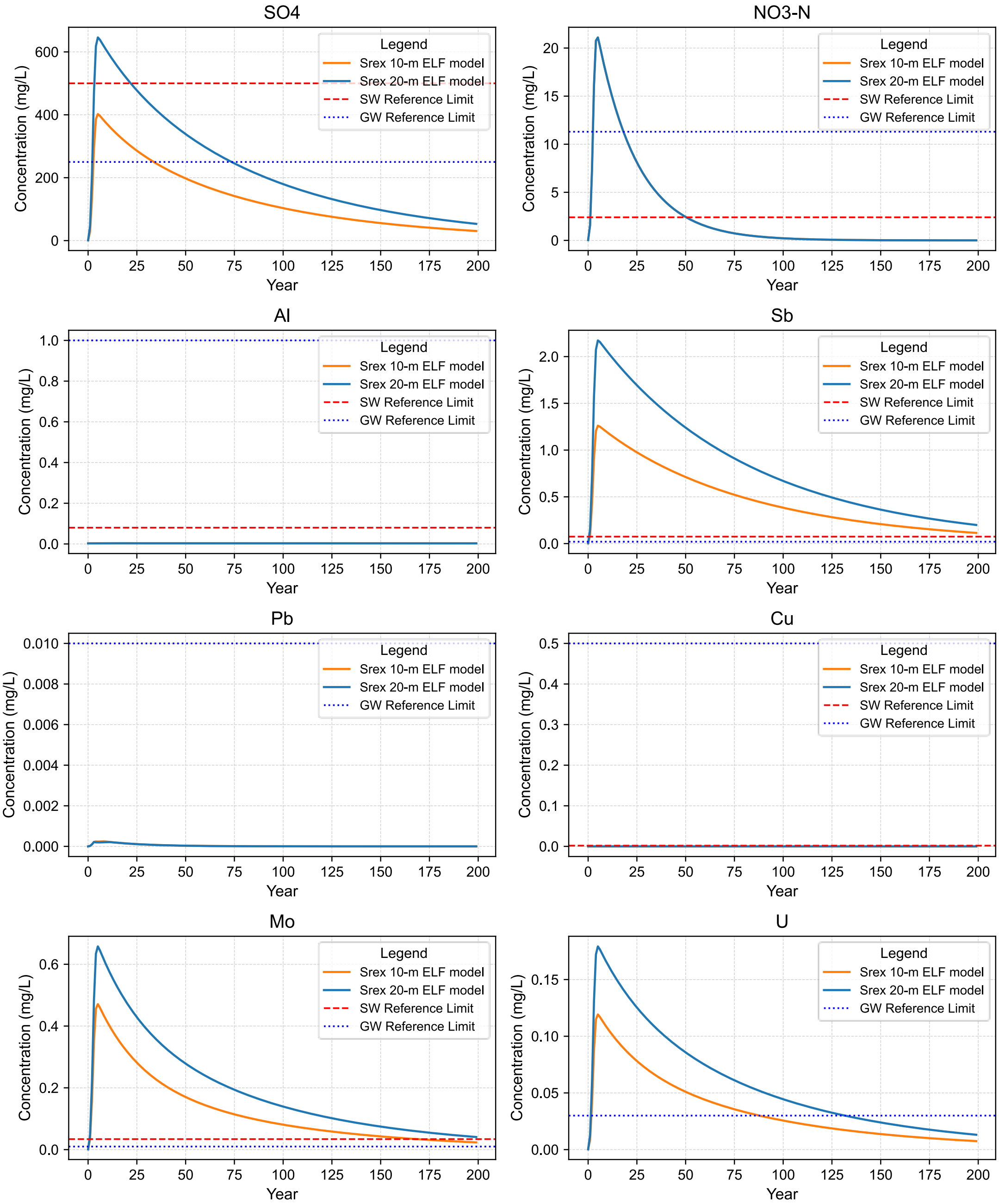

Figure 33. Model results part 1 for the SRX ELF.

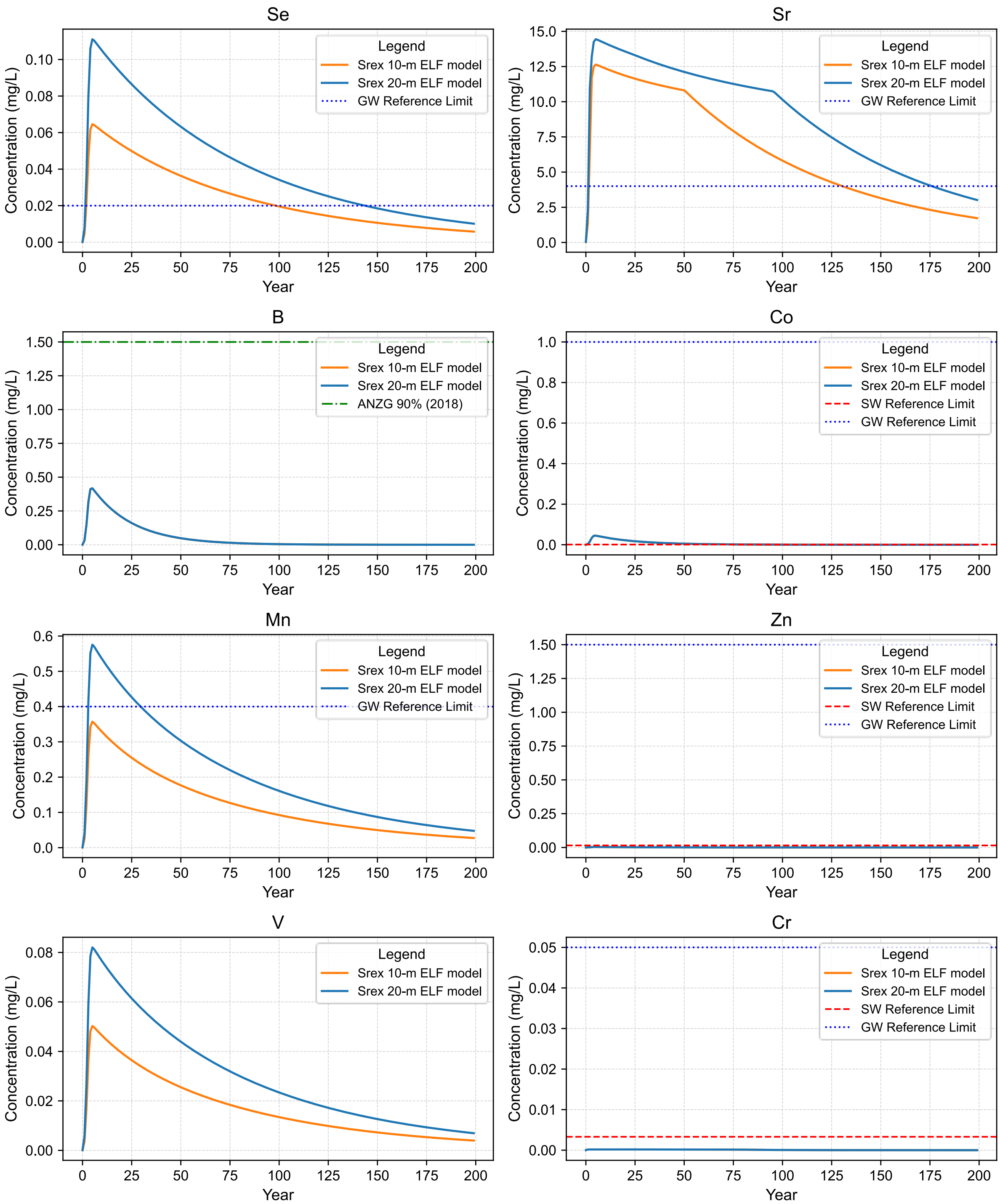

Figure 34. Model results part 2 for the SRX ELF.

Table 19. Selected model results for the SRX ELF Scenarios

SCENARIO	PARAMETER	Al	B	Co	Mn	Mo	NO3-N	Sb	Se	SO4	Sr	U	Zn	V	Cr
	SW REF LIMIT	0.08	-	0.001[a]	-	0.034	2.4[b]	0.074[a]	-	500	-	-	0.015	0	0.0033[c]
	GW REF LIMIT	1	-	1	0.4	0.01	11.3	0.02	0.02	250	4	0.03	1.5	0	0.05
	YEAR														
ELF - 20 m model	1	0.0028	0.031	**0.0034**	0.0402	**0.0468**	1.58	**0.151**	0.0077	45	2.32	0.013	0.0003	0.0057	0.00017
ELF - 20 m model	5	0.0033	0.418	**0.0449**	**0.5755**	**0.6579**	**21.11**	**2.173**	**0.1111**	**646**	**14.44**	**0.179**	0.0040	0.0820	0.00019
ELF - 20 m model	10	0.0032	0.331	**0.0355**	**0.5343**	**0.5880**	**16.70**	**2.049**	**0.1047**	**599**	**14.14**	**0.164**	0.0032	0.0764	0.00019
ELF - 20 m model	27	0.0032	0.146	**0.0157**	**0.4146**	**0.4125**	**7.37**	**1.651**	**0.0843**	**464**	**13.19**	**0.121**	0.0014	0.0597	0.00018
ELF - 20 m model	50	0.0031	0.048	**0.0052**	0.3031	**0.2784**	**2.44**	**1.239**	**0.0632**	**339**	**12.12**	**0.086**	0.0005	0.0439	0.00018
ELF - 20 m model	100	0.0030	0.004	0.0005	0.1609	**0.1393**	0.22	**0.669**	**0.0341**	180	**10.15**	**0.044**	0.0000	0.0234	0.00005
ELF - 20 m model	150	0.0029	0.000	0.0000	0.0869	**0.0745**	0.02	**0.363**	0.0185	97	**5.50**	0.024	0.0000	0.0126	0.00000
ELF - 20 m model	199	0.0029	0.000	0.0000	0.0477	**0.0408**	0.00	**0.199**	0.0101	53	3.02	0.013	0.0000	0.0069	0.00000
ELF - 10 m model	1	0.0028	0.031	**0.0034**	0.0251	**0.0339**	1.58	**0.088**	0.0045	28	1.36	0.008	0.0003	0.0035	0.00017
ELF - 10 m model	5	0.0032	0.418	**0.0448**	0.3572	**0.4710**	**21.09**	**1.261**	**0.0646**	**402**	**12.64**	**0.119**	0.0040	0.0503	0.00018
ELF - 10 m model	10	0.0032	0.330	**0.0355**	0.3278	**0.4113**	**16.69**	**1.186**	**0.0607**	**369**	**12.36**	**0.107**	0.0032	0.0463	0.00018
ELF - 10 m model	27	0.0031	0.146	**0.0157**	0.2470	**0.2691**	**7.36**	**0.951**	**0.0486**	**277**	**11.55**	**0.075**	0.0014	0.0353	0.00018
ELF - 10 m model	50	0.0030	0.048	**0.0052**	0.1767	**0.1702**	**2.44**	**0.712**	**0.0363**	198	**10.81**	**0.051**	0.0005	0.0255	0.00017
ELF - 10 m model	100	0.0029	0.004	0.0005	0.0924	**0.0807**	0.22	**0.384**	0.0196	103	**5.81**	0.026	0.0000	0.0134	0.00005
ELF - 10 m model	150	0.0029	0.000	0.0000	0.0498	**0.0427**	0.02	**0.208**	0.0106	56	3.15	0.014	0.0000	0.0072	0.00000
ELF - 10 m model	199	0.0028	0.000	0.0000	0.0273	**0.0234**	0.00	**0.114**	0.0058	30	1.73	0.008	0.0000	0.0040	0.00000

Units in mg/L

a: Chronic value is used for reference.

b: Annual median used for NO_3-N

c: Cr(III) recommended compliance limit is used.

*Bold **red text** indicates values greater than the GW and SW reference limit.*

*Bold **orange text** indicates values greater than the SW reference limit.*

*Bold **purple text** indicates values greater than the GW reference limit.*

5.5 West ELF

Results for the model scenarios for the West ELF are shown in Figure 35 and Figure 36, and selected outputs for key years are shown in Table 19.

The following observations are provided:

- Sulfate concentrations are peaking at around 1,300 mg/L in the 20 m oxygen exclusion model, which is higher than those estimated for Shepherds. This is primarily because a greater proportion of material is expected to be located in the outer rim (e.g., large surface area), which reduces the relative impact of short-lift construction compared to Shepherds. In addition, the peak at Shepherds is broader (due to its 79 m average height), meaning the load is distributed over several years, whereas the peak at WELF is sharper and more concentrated.

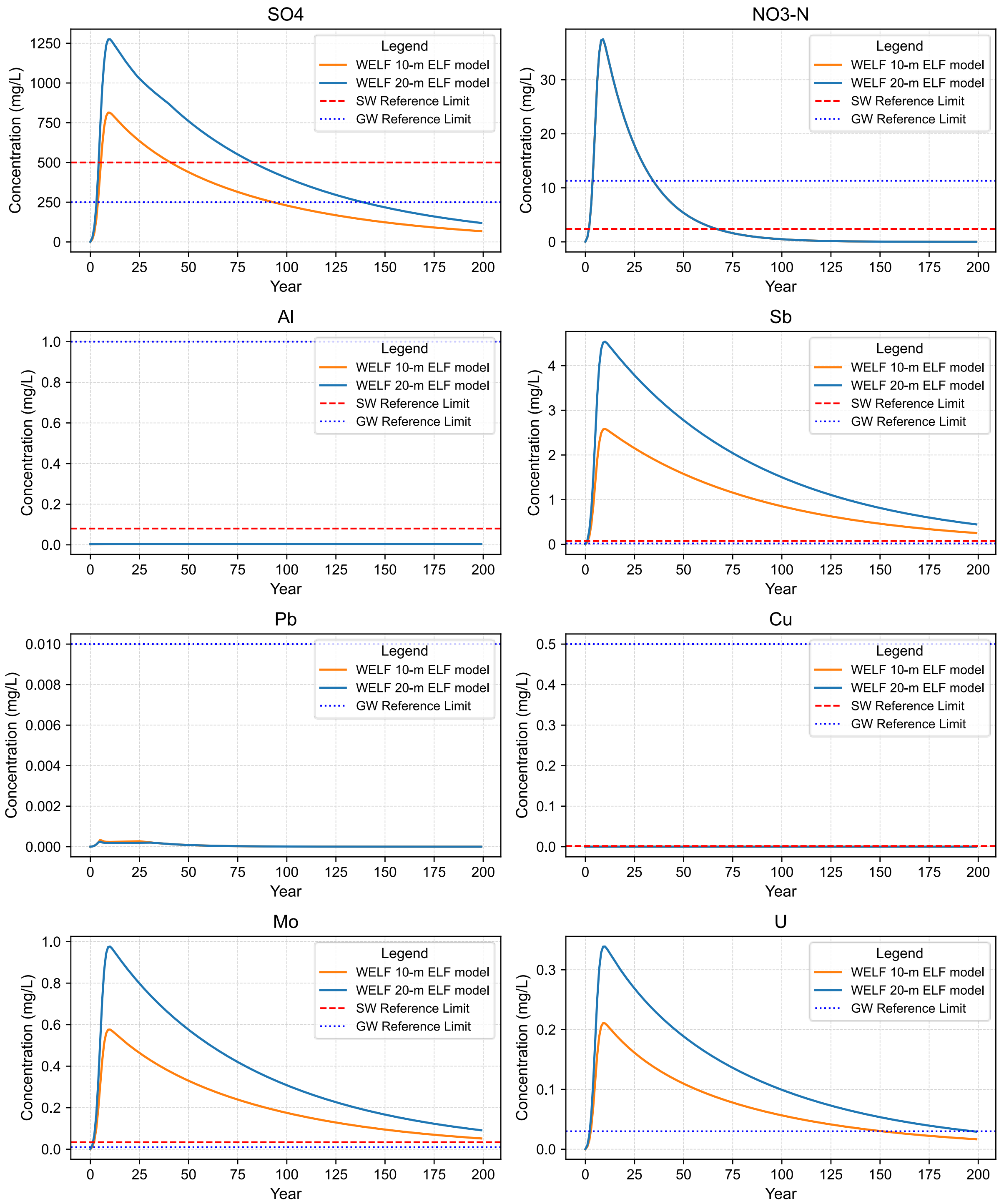

Figure 35. Model results part 1 for the West ELF.

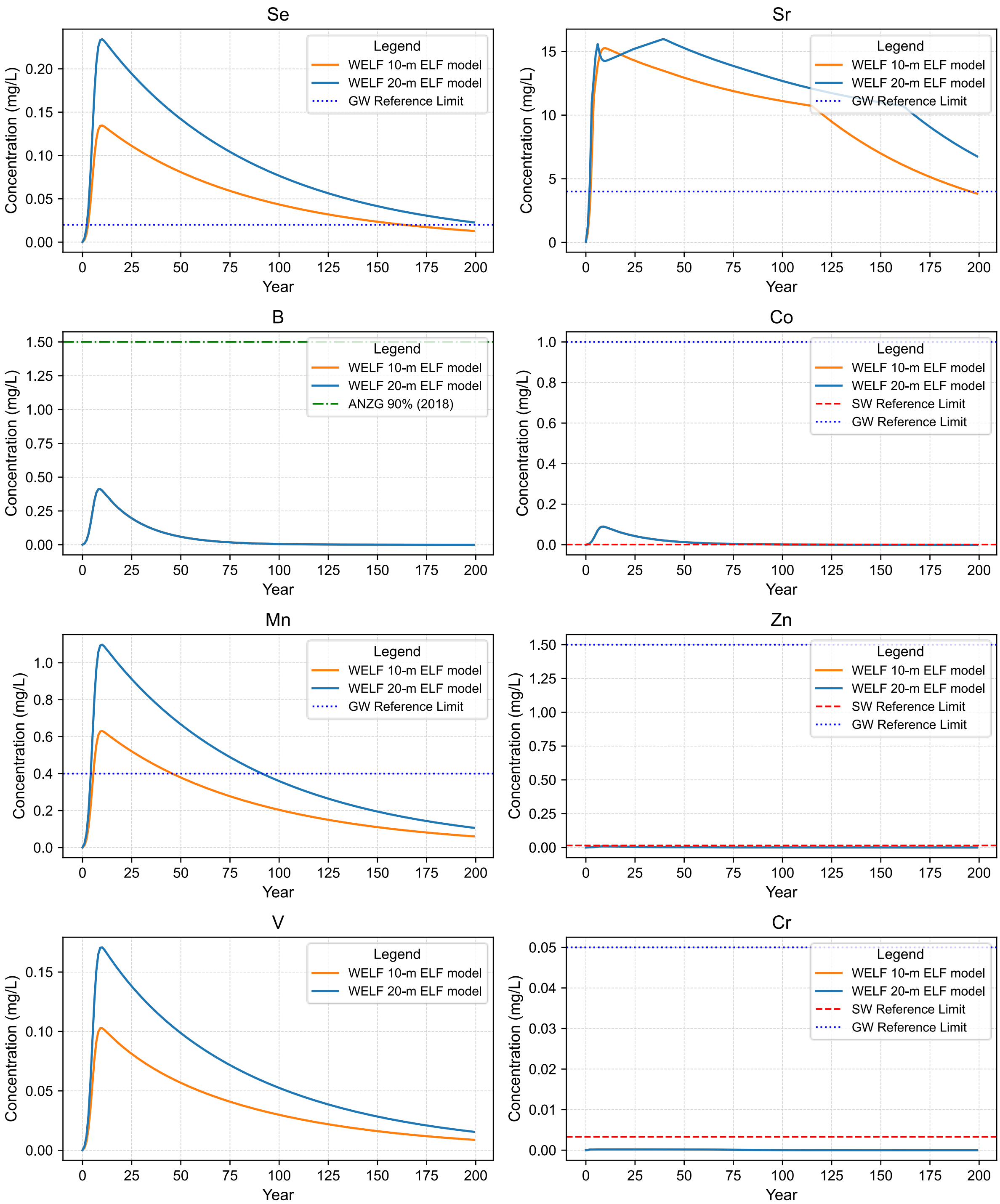

Figure 36. Model results part 2 for the West ELF.

Table 20. Selected model results for the WELF scenarios

SCENARIO	PARAMETER	Al	B	Co	Mn	Mo	NO3-N	Sb	Se	SO4	Sr	U	Zn	V	Cr
	SW REF LIMIT	0.08	-	0.001[a]	-	0.034	2.4[b]	0.074[a]	-	500	-	-	0.015	0	0.0033[c]
	GW REF LIMIT	1	-	1	0.4	0.01	11.3	0.02	0.02	250	4	0.03	1.5	0	0.05
	YEAR														
ELF - 20 m model	1	0.0028	0.009	**0.0020**	0.0212	**0.0190**	0.82	**0.087**	0.0045	26	1.32	0.007	0.0002	0.0033	0.00005
ELF - 20 m model	5	0.0033	0.240	**0.0521**	**0.5828**	**0.5208**	**21.81**	**2.404**	**0.1243**	**716**	**14.78**	**0.182**	0.0047	0.0914	0.00019
ELF - 20 m model	10	0.0036	0.401	**0.0871**	**1.0979**	**0.9763**	**36.45**	**4.536**	**0.2342**	**1275**	**14.26**	**0.339**	0.0079	0.1708	0.00019
ELF - 20 m model	27	0.0034	0.178	**0.0387**	**0.8889**	**0.7770**	**16.20**	**3.692**	**0.1895**	**1003**	**15.34**	**0.261**	0.0035	0.1343	0.00019
ELF - 20 m model	50	0.0033	0.059	**0.0128**	**0.6664**	**0.5756**	**5.36**	**2.777**	**0.1420**	**760**	**15.27**	**0.189**	0.0012	0.0986	0.00019
ELF - 20 m model	100	0.0031	0.005	**0.0012**	0.3597	**0.3082**	0.48	**1.502**	**0.0766**	**403**	**12.68**	**0.099**	0.0001	0.0525	0.00003
ELF - 20 m model	150	0.0030	0.000	0.0001	0.1948	**0.1667**	0.04	**0.819**	**0.0415**	217	**11.00**	**0.054**	0.0000	0.0284	0.00000
ELF - 20 m model	199	0.0029	0.000	0.0000	0.1069	**0.0914**	0.00	**0.447**	**0.0228**	119	**6.76**	0.029	0.0000	0.0156	0.00000
ELF - 10 m model	1	0.0028	0.009	**0.0020**	0.0122	**0.0113**	0.82	**0.049**	0.0026	16	0.75	0.004	0.0002	0.0020	0.00005
ELF - 10 m model	5	0.0032	0.240	**0.0521**	0.3356	**0.3094**	**21.79**	**1.372**	**0.0717**	**440**	**12.77**	**0.114**	0.0047	0.0554	0.00018
ELF - 10 m model	10	0.0033	0.400	**0.0869**	**0.6306**	**0.5766**	**36.40**	**2.584**	**0.1346**	**813**	**15.26**	**0.210**	0.0078	0.1027	0.00019
ELF - 10 m model	27	0.0032	0.178	**0.0387**	**0.5075**	**0.4507**	**16.19**	**2.098**	**0.1082**	**615**	**14.15**	**0.156**	0.0035	0.0787	0.00019
ELF - 10 m model	50	0.0032	0.059	**0.0128**	0.3790	**0.3297**	**5.35**	**1.576**	**0.0808**	**439**	**12.94**	**0.110**	0.0012	0.0568	0.00018
ELF - 10 m model	100	0.0030	0.005	**0.0012**	0.2040	**0.1750**	0.48	**0.852**	**0.0434**	229	**11.11**	**0.057**	0.0001	0.0298	0.00003
ELF - 10 m model	150	0.0029	0.000	0.0001	0.1105	**0.0945**	0.04	**0.462**	**0.0235**	123	**6.99**	**0.030**	0.0000	0.0161	0.00000
ELF - 10 m model	199	0.0029	0.000	0.0000	0.0606	**0.0519**	0.00	**0.253**	0.0129	68	3.83	0.017	0.0000	0.0088	0.00000

Units in mg/L

a: Chronic value is used for reference.

b: Annual median used for NO_3-N

c: Cr(III) recommended compliance limit is used.

*Bold **red text** indicates values greater than the GW and SW reference limit.*

*Bold **orange text** indicates values greater than the SW reference limit.*

*Bold **purple text** indicates values greater than the GW reference limit.*

5.6 CIT Backfill ELF

Results for the model scenarios for the CIT backfill ELF are shown in Figure 37 and Figure 38 with selected outputs for key years shown in Table 20.

The following observations are provided:

- Sulfate concentrations are similar across both scenarios where oxygen is restricted to the outer rim of the ELF, and in both scenarios remain below 500 mg/L.
- In general, the concentrations in the CIT backfill are low due to the following reasons:
    - The ELF has the least amount of waste rock, resulting in lower initial loads.
    - A significant portion of the ELF will be submerged during the first four years, preventing the material from undergoing ongoing oxidation.
    - It is assumed that a portion of the available material will remain inaccessible for oxidation due to the low-lift construction method.

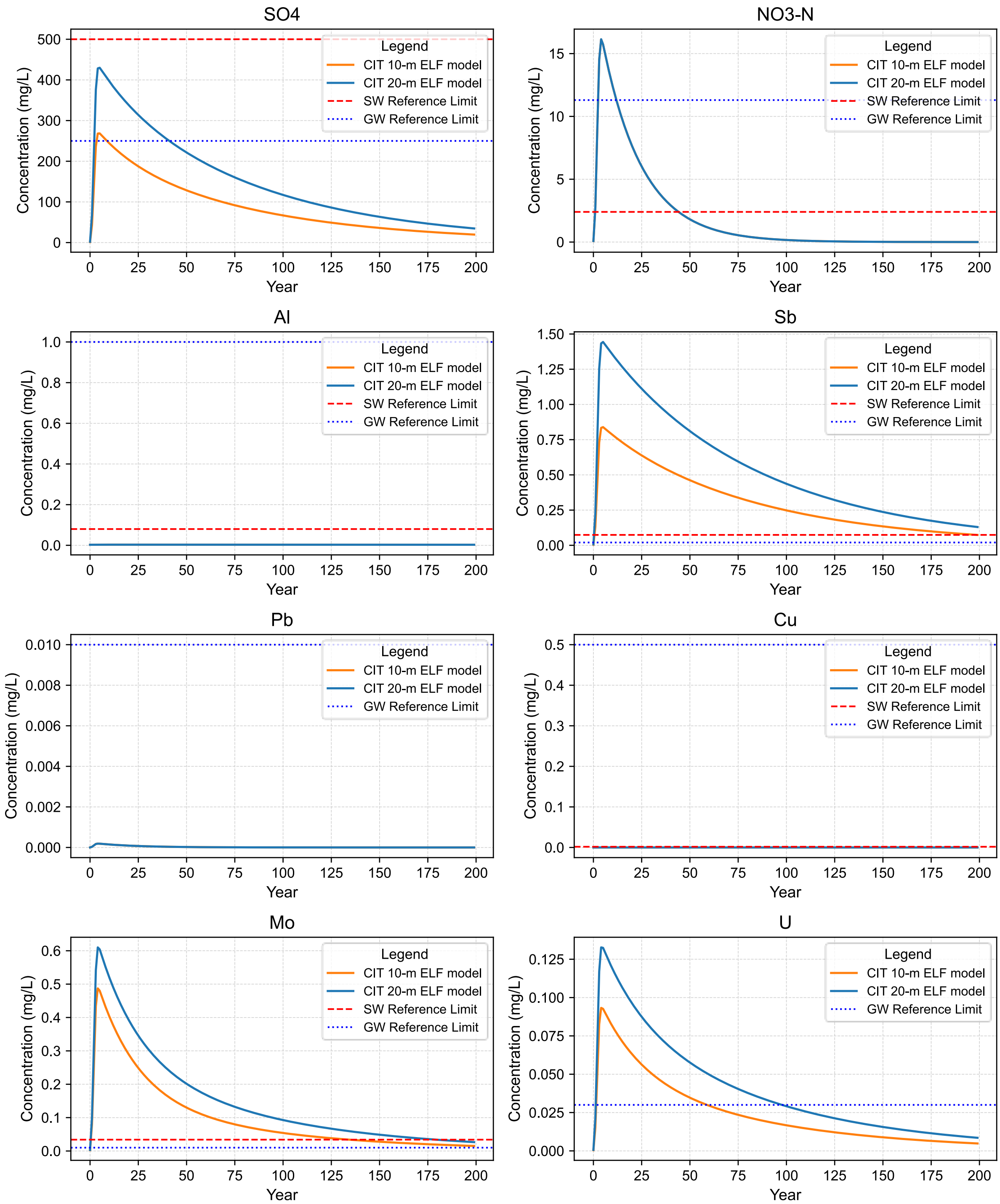

Figure 37. Model results part 1 for the CIT Backfilled ELF.

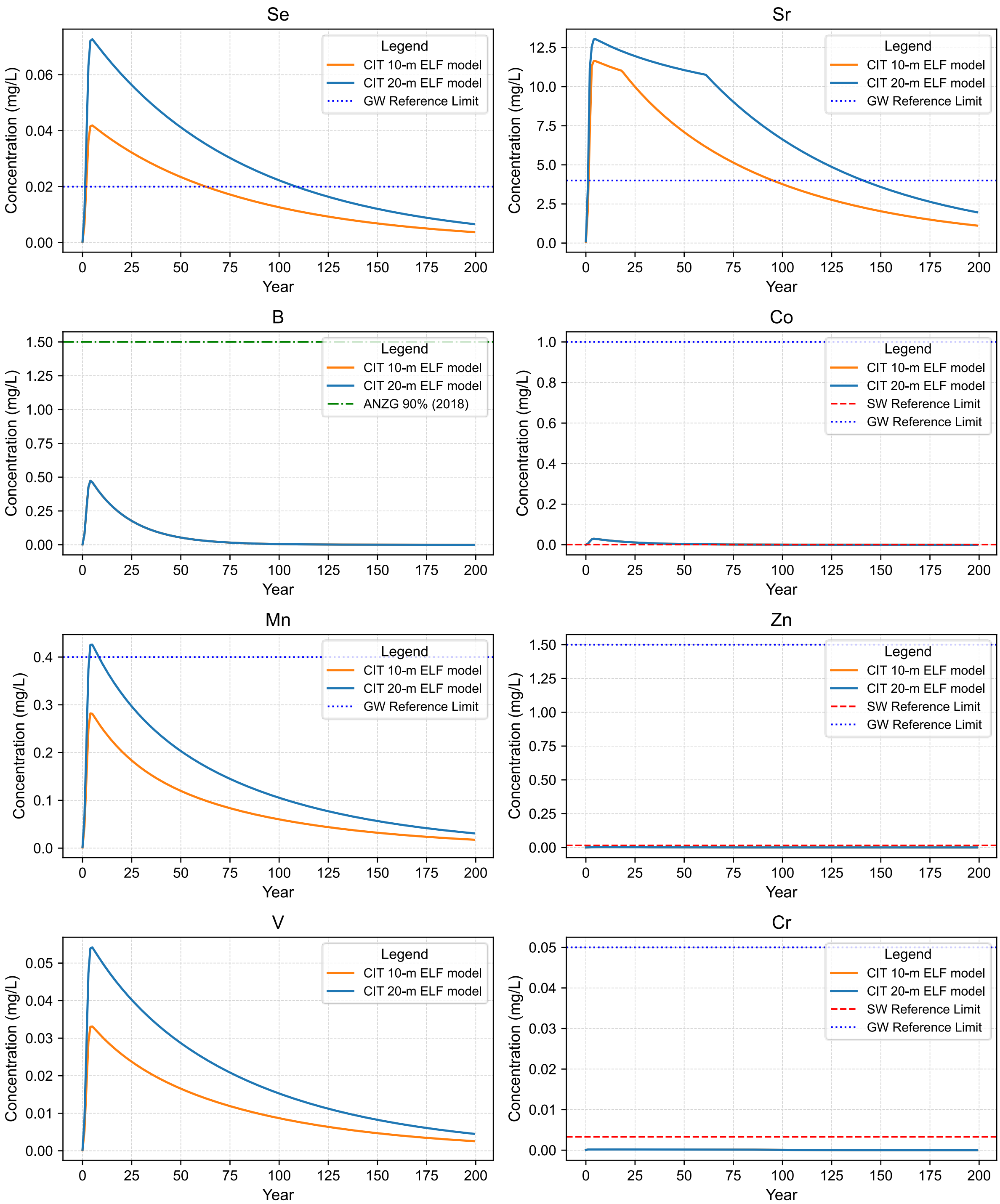

Figure 38. Model results part 2 for the CIT Backfilled ELF.

Table 21. Selected model results for the CIT Backfill scenarios.

SCENARIO	PARAMETER	Al	B	Co	Mn	Mo	NO3-N	Sb	Se	SO4	Sr	U	Zn	V	Cr
	SW REF LIMIT	0.08	-	0.001[a]	-	0.034	2.4[b]	0.074[a]	-	500	-	-	0.015	0	0.0033[c]
	GW REF LIMIT	1	-	1	0.4	0.01	11.3	0.02	0.02	250	4	0.03	1.5	0	0.05
	YEAR														
ELF - 20 m model	1	0.0029	0.079	**0.0050**	0.0680	**0.0992**	**2.70**	**0.226**	0.0114	68	3.57	0.021	0.0004	0.0086	0.00017
ELF - 20 m model	5	0.0032	0.462	**0.0290**	**0.4259**	**0.6041**	**15.73**	**1.444**	**0.0727**	**430**	**13.03**	**0.132**	0.0026	0.0542	0.00018
ELF - 20 m model	10	0.0032	0.364	**0.0228**	0.3869	**0.5197**	**12.39**	**1.352**	**0.0682**	**396**	**12.72**	**0.118**	0.0021	0.0502	0.00018
ELF - 20 m model	27	0.0031	0.160	**0.0101**	0.2873	**0.3291**	**5.47**	**1.084**	**0.0549**	**305**	**11.86**	**0.084**	0.0009	0.0391	0.00018
ELF - 20 m model	50	0.0030	0.053	**0.0033**	0.2032	**0.2014**	1.81	**0.811**	**0.0412**	222	**11.06**	**0.058**	0.0003	0.0287	0.00018
ELF - 20 m model	100	0.0029	0.005	0.0003	0.1054	**0.0926**	0.16	**0.437**	**0.0223**	117	**6.62**	0.029	0.0000	0.0153	0.00007
ELF - 20 m model	150	0.0029	0.000	0.0000	0.0567	**0.0487**	0.01	**0.237**	0.0121	63	3.58	0.016	0.0000	0.0082	0.00001
ELF - 20 m model	199	0.0028	0.000	0.0000	0.0311	**0.0266**	0.00	**0.129**	0.0066	35	1.97	0.009	0.0000	0.0045	0.00000
ELF - 10 m model	1	0.0029	0.079	**0.0050**	0.0454	**0.0799**	**2.70**	**0.132**	0.0066	43	2.14	0.015	0.0004	0.0053	0.00017
ELF - 10 m model	5	0.0031	0.462	**0.0289**	0.2812	**0.4802**	**15.73**	**0.839**	**0.0419**	**268**	**11.63**	**0.093**	0.0026	0.0331	0.00018
ELF - 10 m model	10	0.0031	0.363	**0.0228**	0.2506	**0.4031**	**12.38**	**0.783**	**0.0392**	244	**11.37**	**0.081**	0.0021	0.0303	0.00018
ELF - 10 m model	27	0.0030	0.160	**0.0101**	0.1767	**0.2344**	**5.46**	**0.622**	**0.0314**	181	**9.70**	**0.054**	0.0009	0.0230	0.00018
ELF - 10 m model	50	0.0030	0.053	**0.0033**	0.1198	**0.1300**	1.81	**0.462**	**0.0234**	128	**7.09**	**0.035**	0.0003	0.0165	0.00017
ELF - 10 m model	100	0.0029	0.005	0.0003	0.0602	**0.0540**	0.16	**0.248**	0.0126	67	3.76	0.017	0.0000	0.0087	0.00007
ELF - 10 m model	150	0.0028	0.000	0.0000	0.0322	**0.0278**	0.01	**0.134**	0.0068	36	2.03	0.009	0.0000	0.0047	0.00001
ELF - 10 m model	199	0.0028	0.000	0.0000	0.0176	**0.0151**	0.00	**0.073**	0.0038	20	1.12	0.005	0.0000	0.0026	0.00000

Units in mg/L

a: Chronic value is used for reference.

b: Annual median used for NO_3-N

c: Cr(III) recommended compliance limit is used.

*Bold **red text** indicates values greater than the GW and SW reference limit.*

*Bold **orange text** indicates values greater than the SW reference limit.*

*Bold **purple text** indicates values greater than the GW reference limit.*

5.7 SCK Fill

Results for the SCK Fill model are shown in Figure 39 and Figure 40 with selected outputs for key years shown in Table 21Figure 18.

The following observations are provided:

- Only the WRS scenario is presented, as it is assumed that all materials are oxidising.
- Sulfate concentrations peak at 327 mg/L.
- Arsenic concentrations are assumed to be 0.2 mg/L, consistent with the other waste rock facilities. Yet, as the system is assumed to be oxygenated, iron concentrations remain low according to PHREEQC modelling (due to precipitation as iron hydroxides). These hydroxides could potentially adsorb excess arsenic.

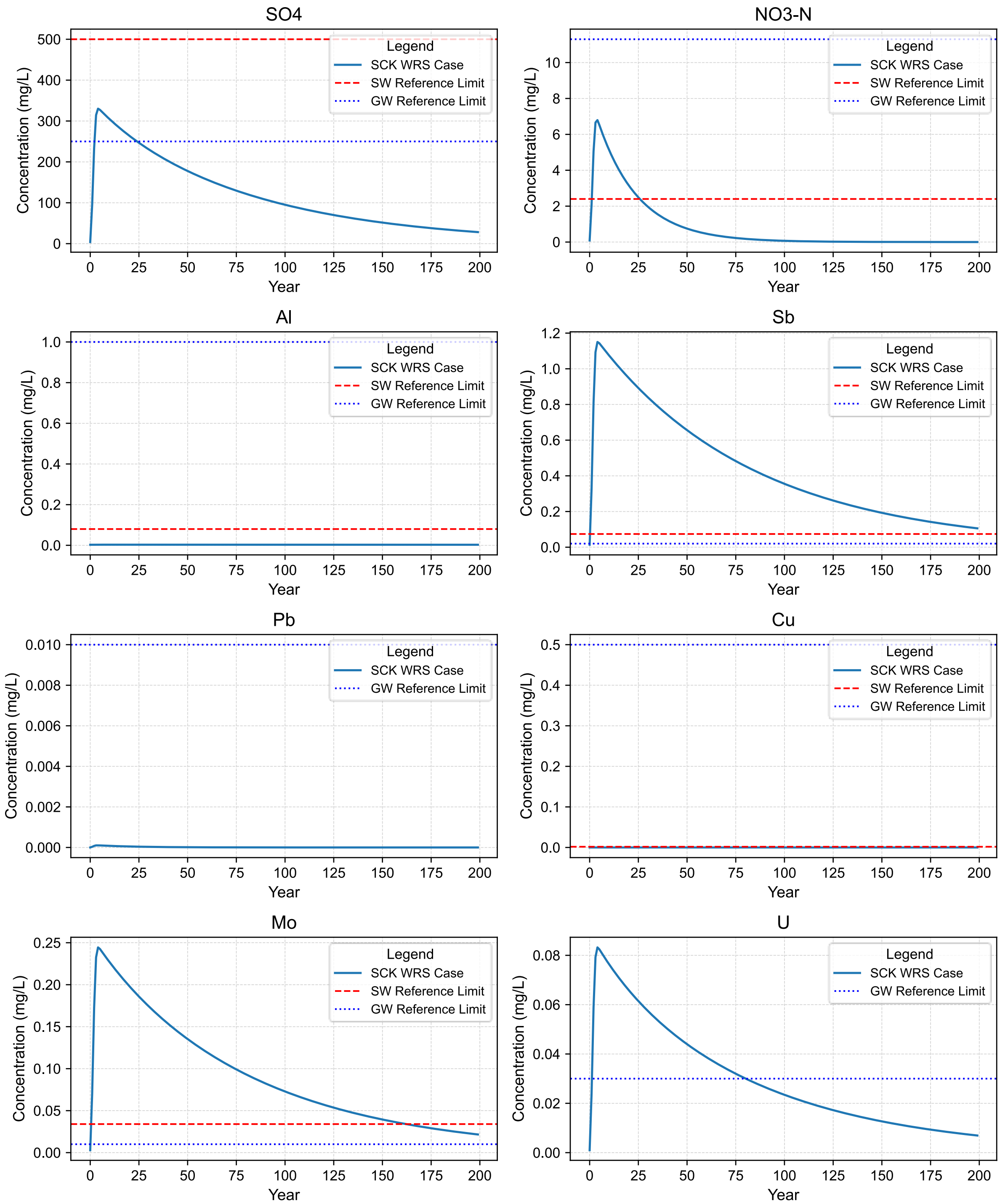

Figure 39. Model results part 1 for the SCK fill.

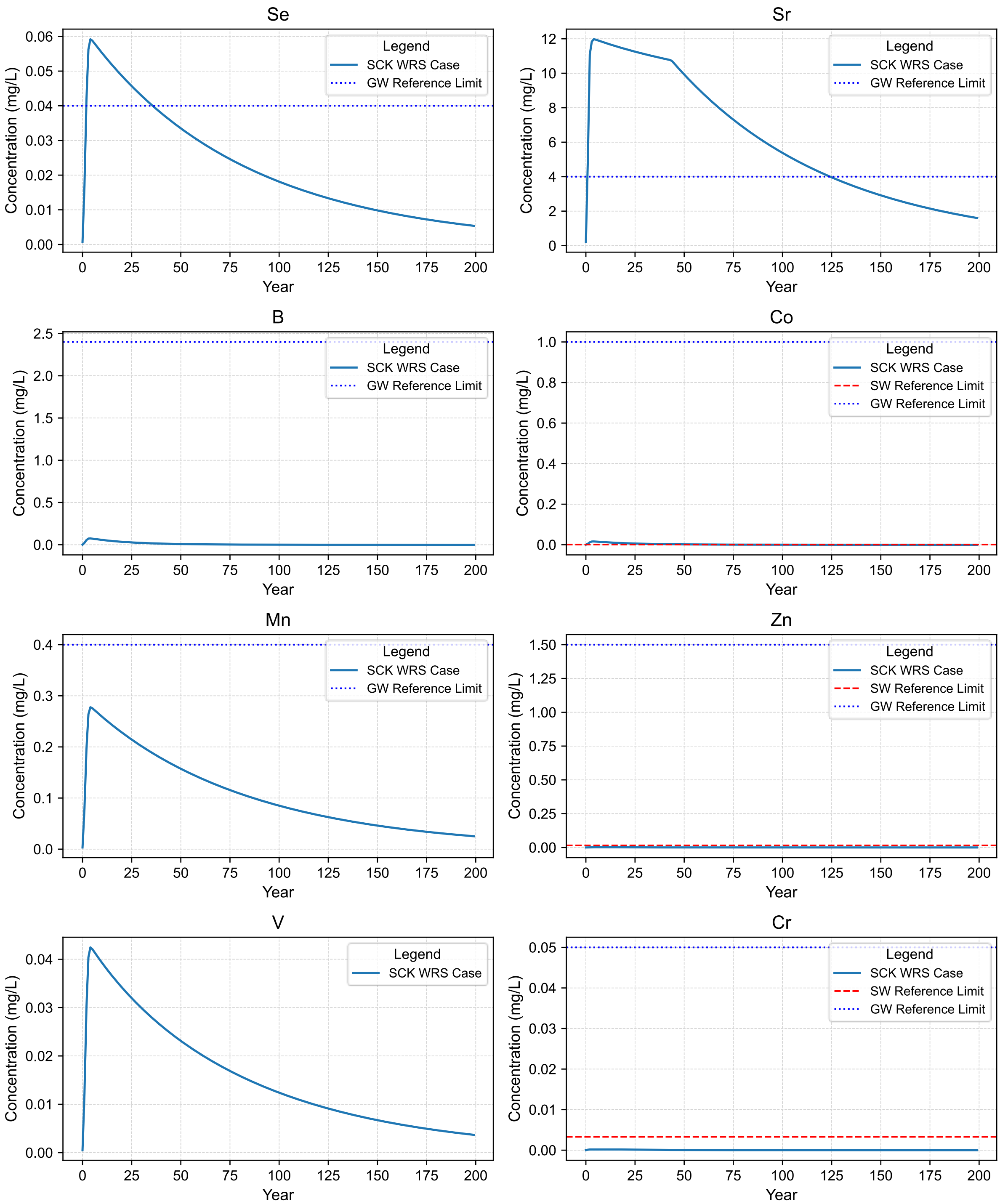

Figure 40. Model results part 2 for the SCK fill.

Table 22. Selected model results for the SCK Fill WRS scenario.

SCENARIO	PARAMETER	Al	B	Co	Mn	Mo	NO3-N	Sb	Se	SO4	Sr	U	Zn	V	Cr
	SW REF LIMIT	0.08	-	0.001	-	0.034	2.4	0.074[a]	-	500	-	-	0.015	0	0.0033
	GW REF LIMIT	1	-	1	0.4	0.01	11.3	0.02	0.02	250	4	0.03	1.5	0	0.05
	YEAR														
WRS	1	0.0029	0.023	**0.0050**	0.0798	**0.0704**	2.09	**0.331**	0.0170	95	**5.00**	0.024	0.0005	0.0122	0.00012
WRS	5	0.0031	0.072	**0.0156**	0.2757	**0.2425**	**6.52**	**1.143**	**0.0588**	**327**	**11.95**	**0.082**	0.0014	0.0421	0.00018
WRS	10	0.0031	0.056	**0.0122**	0.2588	**0.2267**	**5.13**	**1.074**	**0.0552**	**304**	**11.76**	**0.076**	0.0011	0.0392	0.00018
WRS	27	0.0031	0.025	**0.0054**	0.2091	**0.1812**	2.26	**0.871**	**0.0445**	240	**11.19**	**0.060**	0.0005	0.0311	0.00012
WRS	50	0.0030	0.008	**0.0018**	0.1572	**0.1353**	0.75	**0.656**	**0.0335**	178	**9.93**	**0.044**	0.0002	0.0231	0.00004
WRS	100	0.0029	0.001	0.0002	0.0850	**0.0728**	0.07	**0.355**	0.0181	95	**5.38**	0.023	0.0000	0.0124	0.00000
WRS	150	0.0029	0.000	0.0000	0.0461	**0.0394**	0.01	**0.193**	0.0098	51	2.92	0.013	0.0000	0.0067	0.00000
WRS	199	0.0028	0.000	0.0000	0.0253	**0.0216**	0.00	**0.106**	0.0054	28	1.60	0.007	0.0000	0.0037	0.00000

Units in mg/L

a: Chronic value is used for reference.

b: Annual median used for NO_3-N

c: Cr(III) recommended compliance limit is used.

*Bold **red text** indicates values greater than the GW and SW reference limit.*

*Bold **orange text** indicates values greater than the SW reference limit.*

*Bold **purple text** indicates values greater than the GW reference limit.*

6 SUMMARY

The following summary is provided to explain the modelling process, model outcomes, management requirements, and recommendations.

6.1 Overview

The geochemical modelling process for the proposed BOGP ELFs were designed to estimate mine-impacted water and evaluate best-practice construction methods to mitigate environmental risks. The study utilised site-specific data, predictive modelling, and analogue comparisons to develop an understanding of PCOC generation processes under varying conditions. Key components included

- **Quantifying sulfur reservoirs, oxidation rates, and contaminant release mechanisms**, as well as integrating field-based scaling factors.
- **Traditional WRS calibration modelling:** Representing a traditional WRS scenario with unrestricted oxygen ingress, leading to sulfide oxidation and relatively low arsenic and iron concentrations in seepage. Models were calibrated with analogue data.
- **ELF modelling:** Engineered scenarios incorporated reduced oxygen availability, resulting in lower PCOC concentrations yet higher arsenic and iron levels due to limited iron hydroxide formation (sub-oxic conditions).
- **Data Sources:** Laboratory testing (e.g., ABA, leachate, and kinetic tests) and empirical observations informed model parameters, with key sulfur contents and oxidation rates derived for TZ3 and TZ4 (RSSZ) lithological units.

6.2 Key Findings

The following key findings are presented:

- Sulfur content is a primary driver of poor water quality, with TZ4 and RSSZ materials presenting higher sulfur content, higher release rates, and AMD risks compared to TZ3.
- TZ4 was found to release sulfate at a rate six times higher than TZ3 due to its higher sulfur content and reactivity. Such data confirms the importance of placing these materials away from oxygen in the core of the ELF.
- Identified PCOCs are sulfate, As, Co, Fe, Nitrogen, Sr, Se, Sb, Mo, Mn, Se, Sr, and U.
- A traditional WRS construction process is likely to generate elevated PCOC and prolonged AMD generation. This should be avoided to reduce long-term reliance on water management activities by the construction of an ELF that minimises oxygen ingress.
- Engineered landforms provide notable improvements in water quality by limiting oxygen and water ingress, reducing sulfide oxidation rates, and capping high-sulfur material with non-reactive layers.
- Hydrogeochemical Processes: Short-term contaminant release from SOPs and long-term sulfide oxidation are critical considerations for modelling and management.

6.3 Recommendations

This study has identified and recommends the following management opportunities that will minimise the long-term risks to water quality for waste rock storage at the BOGP:

- Proceed with the proposed ELF design, ensuring TZ3 materials encapsulate high-sulfur materials (TZ4) to minimise oxygen ingress.
- Proceed with short lift heights at 5 m height and confirm that grainsize segregation is minimised and that oxygen is reduced to < 5% after 20 m horizontal distance into the ELF and that the oxygen profiles (from oxygen probe monitoring) demonstrate that oxygen ingress is diffusion controlled. Higher heights may be possible if advective oxygen ingress is prevented by engineering controls. Advective oxygen ingress is the driver for higher long term PCOC loads.
- Install cover systems to further mitigate risks as the final landform is created. Consider cover systems to minimise net percolation and oxygen flux as the key drivers of long term PCOC load.
- Establish a comprehensive monitoring program for water quality, oxidation rates, and cover system performance. Adapt management strategies based on observed trends and evolving conditions.
- Continue validating laboratory-to-field scaling factors using site-specific data, particularly for TZ3 and TZ4 materials, to refine long-term predictions.
- Confirm oxygen flux rates to further refine models.

By adopting these recommendations, the project can effectively manage geoenvironmental risks while aligning with best-practice approaches for sustainable waste rock management. As noted by INAP (2024): "*while it is true that designing and constructing a mine rock stockpile with a focus on source control can add upfront incremental costs to the project, a proactive approach allows for the ability to effectively understand, plan and reduce long term environmental risks and liabilities for a smaller range of anticipated outcomes*".

6.4 Limitations

The model is based on the results of laboratory tests, and on assumptions from analogue data. Performance monitoring is recommended to confirm model expectations. The following assumptions are noted:

- A net percolation rate of 20% is a reasonable estimate. Further work is needed to confirm the reliability of this assumption as flow is a key driver of contaminant load. Site-specific trials should be undertaken to validate net percolation rates.
- It is assumed that ELF design and construction will limit diffusive oxygen ingress to a depth of 20 m horizontally once the ELF is constructed (and the cover system and rehabilitation is completed). This needs to be managed by MGL to ensure the models are valid. Such details are provided in the ELF Management Plan.
- It is assumed that the scaling approach using column data to forecast sulfate and other PCOC is appropriate to understand geochemical risks for the engineered landforms.

- It is assumed that ELF seepage waters will be elevated in nitrate for many decades (> 50 years) and that this would equate to a load of 16.6 mg/kg of nitrogen as (NH_4NO_3).
- It is not possible to model the dynamics of nitrogen speciation accurately, as they are governed by site-specific biochemical reactions and oxygen availability. It is assumed that the majority of nitrogen will be speciated as nitrate, however, there could be a minor part as nitrite or ammoniacal nitrogen.
- The time lag to peak concentrations is influenced by the ELFs geometry, therefore the applied time lag to peak sulfate concentration is an approximate estimate based on analogue empirical data, and simplistic assumptions. However, the time frame is likely to be reasonable to estimate potential environmental risks for the BOGP.
- In-situ precipitation of ferric hydroxides is anticipated. Consequently, certain metals may be sorbed (e.g., As, Cu, Zn) and captured by these minerals, particularly at neutral to alkaline pH where sorption capacities are elevated. While PHREEQC modelling could model this for this case, uncertainty exists around the amount of available iron. Therefore, a conservative approach is adopted, and sorption is not modelled. Sorption may be higher in the outer oxidising zone of the ELF and lower in the core where oxygen is limited.

6.5 Performance Monitoring

The following performance monitoring activities are required to validate model inputs and ensure the effectiveness of the ELFs:

- Confirm the sulfur content of materials placed in the ELF ensuring that lower sulfur TZ3 materials are placed on the outside of the ELF. Testing should include shake-flask testing to validate the quantity of sulfate and nitrogenous compounds present in blasted rock to validate model inputs.
- Confirm that advective oxygen ingress is excluded from the core of the ELF by the construction of oxygen probes into each lift during construction of the ELF.
- Confirm water quality for ELF seepage aligns with geochemical models including sulfate and nitrate. Update models where significant differences are observed.
- The geochemical model relies on laboratory data and analogue assumptions; field validation is required.
- If performance monitoring indicates unacceptable loads, then adaptive management actions should be considered including additional source control actions (e.g., engineered cover systems), reducing oxidation depth to 10 m into the ELF, a longer period of active treatment and/or the development of passive treatment systems to manage the PCOC concentrations and loads.

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8 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix B 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
ANFO	Ammonium nitrate fuel oil (explosive)
ANC	Acid neutralisation capacity
BOGP	Bendigo-Ophir Gold Project
CIL	Carbon in Leach
CIT	Come in Time
CLT	Column Leach Test
CSM	Conceptual site model
DOC	Dissolved organic carbon
ELF	Engineered Landform
INAP	International Networks for Acid Prevention
LCM	Loose cubic metres
LOM	Life of mine
MIW	Mine impacted water
MPA	Maximum potential acidity
MGL	Matakanui Gold Limited
Mt	Million tonnes
MWM	Mine Waste Management Limited
NAF	Non-acid forming
NAPP	Net acid production potential
NP	Net percolation
PAF	Potentially acid forming
PCOC	Potential constituents of concern
PFS	Pre-feasibility study
QA/QC	Quality assurance and quality control
RAS	Rise and Shine
ROM	Run of mine
RSSZ	Rise and Shine Shear Zone
SCK Fill	Shepherds Creek Fill
SOP	Stored Oxidation Products
Srex	SRX
Srex East	SRE
TSF	Tailings storage facility

ABBREVIATION	DEFINITION
TSS	Total suspended solids
TZ3	Textural Zone 4 of the Otago Schist
TZ4	Textural Zone 4 of the Otago Schist
WELF	West ELF
WRS	Waste Rock Stack

APPENDIX B LIMITATIONS

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MINE WASTE MANAGEMENT

GREENROAD GROUP