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Louhosjärvimallinnus

BOLIDEN KEVITSA OY

KEVITSA MINE

PIT LAKE WATER QUALITY MODELLING

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B.0	Draft for client comment
A.0	Client comments addressed and translations added

Please note: this report was originally prepared in English and contains subsequent translation to Finnish. Where any discrepancy in understanding is identified between the English version and the Finnish translation, the English language version should be relied upon.

Huomio: Tämän raportti on alun perin laadittu englanniksi ja suomenkielinen käännös on lisätty jälkikäteen. Jos englanninkielisen ja suomenkielisen version välillä on havaittavissa ristiriitaa, tulee luottaa englanninkieliseen versioon.

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Executive Summary

WSP Finland Oy (WSP) have been commissioned by Boliden Kevitsa Mining Oy (Boliden) to provide studies which support an Environmental Impact Assessment (EIA) for the proposed expansion and subsequent closure of Kevitsa mine, located approximately 30 km northeast of Sodanklyä, Finland. This report focusses on the pit lake modelling which relates to two other completed studies including groundwater modelling and contaminant transport modelling (WSP, 2025a & WSP 2025B).

Four EIA scenarios provided by AFRY represent alternative versions of the proposed life of mine design, referred to as Scenario VE0, VE0+, VE1.1 and VE1.3. Scenarios VE0 and VE0+ are very similar to the currently permitted design, whilst VE1.1 and VE1.3 include consideration of a larger pit, larger waste rock storage facility (WRSF), additional tailings storage facilities (TSFs), and the Iso Hanhilehto quarry. Scenario VE0 was assessed under a previous study (Golder, 2022). Scenarios VE0+, and VE1.3 have been modelled as part of this pit lake study.

The formation of a pit lake following mine closure, when water begins to rebound and fill the pit, was developed and simulated through hydrodynamic and thermodynamic modelling approaches. Conceptual models were developed in line with previous modelling efforts, to include pumping of the contact water inflow at 40 m below the surface to induce stratification of the pit lake and maintain a fresher water surface layer thus reducing the chemical loading at the spillway.

For Scenario VE0+, the Stage 4 pit shell designs were used with incorporation of the starter pit area. Pit lake modelling of both scenarios is across a 200-year period, starting in 2034 for Scenario VE0+. For Scenario VE1.3, a larger pit volume is

WSP Finland Oy (WSP) on saanut toimeksiannon Boliden Kevitsa Mining Oy:ltä (Boliden) laatia selvityksiä, jotka tukevat ympäristövaikutusten arviointia (YVA) Kevitsan kaivoksen suunnitellun laajennuksen ja myöhemmän sulkemisen osalta. Kaivos sijaitsee noin 30 km koilliseen Sodankylästä. Tämä raportti keskittyy louhosjärven mallinnukseen, joka liittyy kahteen jo valmistuneeseen selvitykseen: pohjavesimallinnukseen ja haitta-aineiden kulkeutumismallinnukseen (WSP, 2025a & WSP, 2025b).

YVA-menettelyssä on esitetty neljä vaihtoehtoa (VE0, VE0+, VE1.1 ja VE1.3) Kevitsan kaivoksen kehittämiseksi. Vaihtoehdot VE0 ja VE0+ vastaavat hyvin pitkälti nykyisen ympäristöluvan mukaista toimintaa, kun taas vaihtoehdot VE1.1 ja VE1.3 sisältävät mm. Iso-Hanhilehdon tarvekivilouhoksen, laajennetun avo-louhoksen, suuremman sivukivialueen sekä uusia rikastushiekka-altaita. Vaihtoehtoa VE0 on arvioitu aikaisem-massa selvityksessä. (Golder, 2022).

Sulkemisen jälkeen muodostuvaa louhos-järveä mallinnettiin hydrodynaamisilla ja termodynaamisilla menetelmillä. Konseptuaaliset mallien määrittämisessä huomioitiin aikaisemmat mallit. Malleihin sisällytettiin kontaktivesien pumppaus järveen 40 metrin syvyydeltä, jotta louhosjärveen muodostuisi kerrostu-neisuutta ja pintaosaan jäisi makeampi vesikerros, mikä vähentäisi kemiallista kuormitusta ylivuotokohdassa.

Vaihtoehdossa VE0+ käytettiin avolouhoksen vaiheen 4 suunnitelmaa, johon sisältyi myös aloituslouhos. Molempien vaihtoehtojen louhosjärven mallinnus kattaa 200 vuoden ajanjakson, alkaen vuodesta 2034 vaihtoehdossa VE0+. Vaihtoehdossa VE1.3 louhos on suurempi, ja siinä käytetään avolouhoksen

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expected using the Stage 5 pit shell design given a later closure start date of 2045.	vaiheen 5 suunnitelmaa. Täten myös sulkemisvaihe alkaa myöhemmin, vuonna 2045.
The pit lake for each scenario is expected to have 6 primary sources of chemical loading, including the contact water (recoverable WRSF seepage and contact water reservoir combined), precipitation, unrecoverable seepage from the WRSF, natural groundwater, non-contact water (WRSF runoff and catchment runoff combined), and pit wall runoff.	Kussakin vaihtoehdossa louhosjärven kemiallisella kuormituksella on kuusi pääasiallista lähdettä: kontaktivedet (sivukiven läjitysalueelta kerättävät suotovedet ja kontaktivesialtaan vesi), sadevedet, sivukiven läjitysalueelta pohjaveteen suotautuva vesi, luonnollinen pohjavesi, ei-kontaktivedet (sivukiven läjitysalueen ja valuma-alueen pinta-valunta) sekä louhoksen seinämien pintavalunta.
Thermodynamic modelling was completed in PHREEQC (and Excel) to calculate the expected water qualities at the spillway. Hydrodynamic modelling was completed in CE-QUAL-W2 to model the lake circulation based on water densities across the 200-year modelling periods for both VE0+ and VE1.3.	Termodynaaminen mallinnus tehtiin PHREEQC-ohjelmalla (ja Excelillä) ylivuotavan veden laadun arvioimiseksi. Hydrodynaaminen mallinnus tehtiin CE-QUAL-W2-ohjelmalla, jossa mallinnettiin järven vedenkiertoa veden tiheyksien perusteella 200 vuoden ajanjaksoilla. Mallinnus tehtiin vaihtoehdoille VE0+ ja VE1.3.
Pumping contact water at depth of 40 m indicates that the pit lakes, for both VE0+ and VE1.3 scenarios, in the hydrodynamic modelling will be stratified for both TDS and temperature. Higher concentrations are maintained at the base of the pit lake and a fresher surface layer is maintained at the spillway. Temperatures at the surface of the lake indicate seasonal mixing, while the bottom layers remain at a stable temperature.	Kontaktiveden pumppaus 40 metrin syvyydelle osoittaa, että molemmissa vaihtoehdoissa VE0+ ja VE1.3 järvi kerrostuu sekä veteen liuenneiden aineiden kokonaispitoisuuden (TDS) että lämpötilan mukaisesti. Korkeammat pitoisuudet jäävät järven pohjalla, ja järven pinnalla ylivuotokohdassa pysyy makeampi vesikerros. Pintakerroksien lämpötiloissa tapahtuu vuodenaikojen mukaista sekoittumista, kun taas pohjimmaisissa kerroksissa lämpötilat pysyvät vakaana.
The expected filling times to reach the spillway elevation at 225 masl are approximately 90 years for the VE0+ scenario, and 114 years for the VE1.3 scenario in both the water balance and also the hydrodynamic modelling.	Sekä vesitase- että hydrodynaamisten mallien mukaan arvioidut täyttymisajat ylivuotokorkeuteen 225 mmpy ovat noin 90 vuotta vaihtoehdossa VE0+ ja 114 vuotta vaihtoehdossa VE1.3.
The results of the thermodynamic water quality models in PHREEQC, indicate lower concentrations of dissolved metals in the upper layer which will discharge via the spillway. Higher concentrations of dissolved metals will remain in the bottom layer. This stratification of better quality at	PHREEQC-mallinnuksen tulokset osoittavat, että metallien pitoisuudet ovat alhaisempia järven pintaosan vedessä, joka purkautuu ylivuotona. Korkeammat pitoisuudet jäävät järven pohjakerrokseen. Tämä kerrostuneisuus ja pinnan lähellä oleva parempi vedenlaatu on riippuvainen

the surface of the lake is dependent on the placement of the contact water at the 40 m depth to maintain the stratified layers. This is also dependent on the planned WRSF cover systems leading to reduced chemical loadings and inflow volumes over time, for which robust water monitoring and planning should be implemented.

The results of the pit lake water quality at the spillway presented in this study were used in the separate contaminant transport modelling undertaken. Results were screened against the EIA criteria and the SSAC (site-specific assessment criteria) only in the contaminant transport modelling (WSP, 2025b).

siitä, että kontaktivesi johdetaan järveen 40 metrin syvyyteen. Lisäksi riippuvuutta on sivukiven läjitysalueelle suunniteltuihin peittorakenteisiin, jotka johtavat kemiallisen kuormituksen ja sisäänvirtaamien vähenemiseen ajan myötä. Tämän vuoksi vesienhallinta on suunniteltava hyvin ja vedenlaatua on seurattava.

Tässä selvityksessä esitettyjä louhosjärvestä ylivuotavan veden vedenlaadun tuloksia käytettiin erillisessä haitta-aineiden kulkeutumismallinnuksessa. Tuloksia on verrattu YVA-kriteereihin ja kohdekohtaisiin arviointikriteereihin (SSAC-arvoihin) on esitetty haitta-aineiden kulkeutumismallinnuksessa yhteydessä (WSP, 2025b).

1. Introduction

1.1. Overview

WSP Finland Oy (WSP) have been commissioned by Boliden Kevitsa Mining Oy (Boliden) to support with the preparation of an Environmental Impact Assessment (EIA) for the proposed expansion and subsequent closure of Kevitsa mine, located approximately 30 km northeast of Sodankylä, Finland. Boliden's EIA consultant AFRY Management Consulting ("AFRY") are completing the EIA report separately.

The studies that WSP are conducting include (1) groundwater flow modelling, and (2) pit lake modelling, and (3) downgradient groundwater contaminant transport modelling. These studies aim to address the following key outcomes required for the EIA:

- An assessment of the extent and impact of dewatering on the Natura 2000 area and the Satojärvi;
- An assessment of the contaminant concentrations and loads to the Mataraoja, Saiveljärvi and Viivajoki as a result of seepage from the tailings storage facilities (TSF) and the waste rock storage facility (WRSF); and
- An assessment of the quality of the discharge from the pit lake on closure and the need for water treatment.

This report focusses on modelling of the pit lake expected to form on closure, with focus on the expected hydrodynamics of the lake circulation, and on the thermodynamically modelled water quality which feeds into the contaminant transport modelling (WSP, 2025b).

1.2. EIA Scenarios

The hydrogeochemical modelling detailed in this report has been carried out following several EIA scenarios which correspond to various mine layout options. The options which have been considered as part of this assessment are referred to as the EIA scenarios.

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Four separate EIA scenarios have been identified by AFRY: VE0, VE0+, VE1.1, and VE1.3. The proposed activities for each scenario are summarised in Table 1-1. The mine layout plan for each scenario is presented in Figure 1-1 through to Figure 1-4. For the pit lake modelling (hydrodynamic and thermodynamic), only two scenarios are quantitatively considered in the pit lake modelling, VE0+ (Stage 4 pit shell design with starter pit) and VE1.3 (Stage 5 pit shell design).The Stage 5 pit for Scenario VE1.3 is larger, by both width and depth, than the Stage 4 pit (Scenario VE0+). Scenario VE1.3 incorporates a longer operational mine life with closure starting in 2045, compared with 2034 for the VE0+.

The designs in VE0, listed in Table 1-1, remain largely the same as the existing studies already completed for this scenario (formally Scenario 1, (Golder, 2022)). As such, no additional modelling has been undertaken for scenario VE0. Comment has been made to explain whether the proposed design changes affect the validity of the existing studies for this scenario as part of the wider studies.

Modelling has been undertaken to determine the impacts of the design changes in scenarios VE0+ and VE1.3. However, for scenario VE1.1, only contaminant transport modelling has been undertaken, as it is considered that the variation in design between VE0+, VE1.1, and VE1.3 can be considered qualitatively for the groundwater flow and pit lake models.

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Table 1-1. Summary of EIA Scenarios

Mine Aspect	Scenario VE0	Scenario VE0+	Scenario VE1.1	Scenario VE1.3
Production Timescales	2012- 2029 (inclusive)	2030 – 2033 (inclusive)	2034 – 2044 (inclusive)	2034 - 2044 (inclusive)
Closure Start	January 2034		January 2045	
TSF A	Raised to 270 masl using centerline design	Raised to 280 masl using centerline design	Raised to 310 masl using centerline design	Raised to 280 masl using centerline design
TSF A2	*Not included*	*Not included*	*Not included*	Included
TSF B	Raised to max. permitted height (251 masl)	Raised to max. permitted height (251 masl)	Raised to max. permitted height (251 masl)	Raised to max. permitted height (251 masl)
TSF B2	*Not included*	*Not included*	Included	*Not included*
Process Water Reservoir Raise	*Not included*	Included	Included	Included
Open Pit	Current design (Stage 4 pit)	Current design (Stage 4 pit)	Extends 55 ha (Stage 5 pit)	Extends 55 ha (Stage 5 pit)
USW Starter Pit	*Not included*	Included	Included	Included
WRSF	Current height (310 masl) and footprint (322 ha)	Current height (310 masl) and footprint (322 ha)	Height raised (350masl) and footprint increased (445 ha)	Current height (310 masl) and footprint increased (568 ha)
Iso Hanhilehto USW Quarry F	*Not included*	*Not included*	Included	Included
EW Usage	*Not included*	Included (WRSF+TSF)	Included (WRSF+TSF)	Included (WRSF+TSF)

Notes:
Scenario VE0 was formally named Scenario 1.
The operational periods are outlined under 'Production Timescales'.
Closure is defined as 200 years post-production.
WRSF = waste rock storage facility
TSF = tailings storage facility
USW = material classified as useable waste rock
EW = material classified as environmental waste rock

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1.3. Related Studies

As outlined in Section 1.1, WSP have been engaged to complete the following related assessments in addition to the pit lake modelling:

1. Numerical groundwater flow modelling for groundwater flows and levels, including pit lake recovery modelling for operational and closure phases; and
2. Contaminant transport modelling for assessment of the surface water qualities, along contaminant pathways, in the operational and closure phases.

The groundwater flow modelling has been completed for scenarios VE0+ and VE1.3. The flow modelling simulates how the proposed mining activities influence groundwater levels and flows during active operations, and how the groundwater system evolves post-closure (WSP, 2025a). The results of this modelling were also incorporated from a groundwater and groundwater rebound perspective with the site wide water balance provided by SRK, the consultancy tasked with this component of the EIA models.

The pit lake water quality modelling assesses the evolution of water quality as the pit lake develops during closure for scenarios VE0+ and VE1.3, as discussed in this report. The outputs of the groundwater flow and pit lake modelling completed have been used to support the wider contaminant transport assessment (WSP, 2025b).

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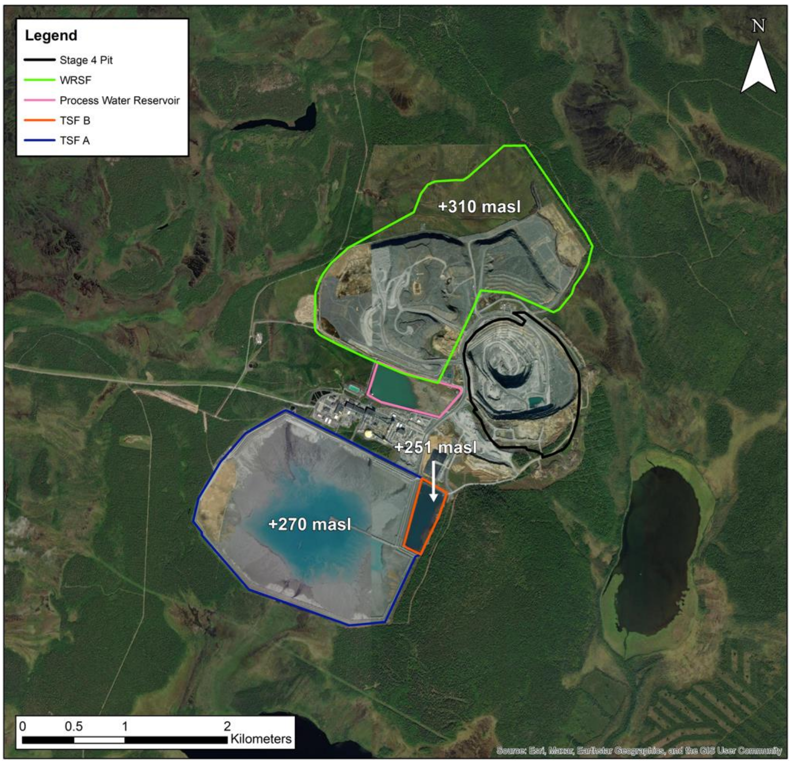

Figure 1-1. Plan view of Scenario VE0 mine site layout

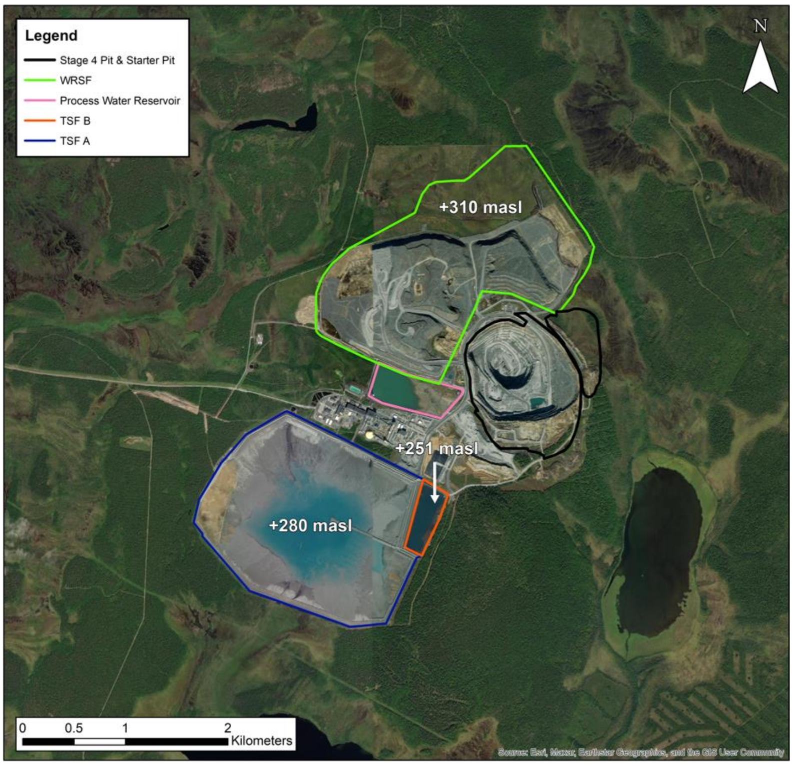

Figure 1-2. Plan view of Scenario VE0+ mine site layout

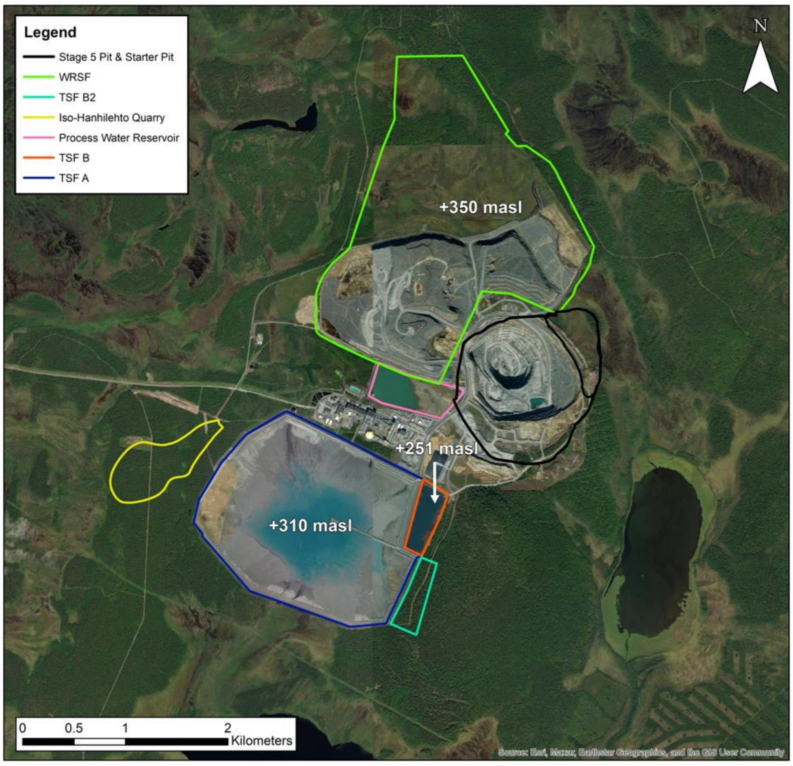

Figure 1-3. Plan view of Scenario VE1.1 mine site layout

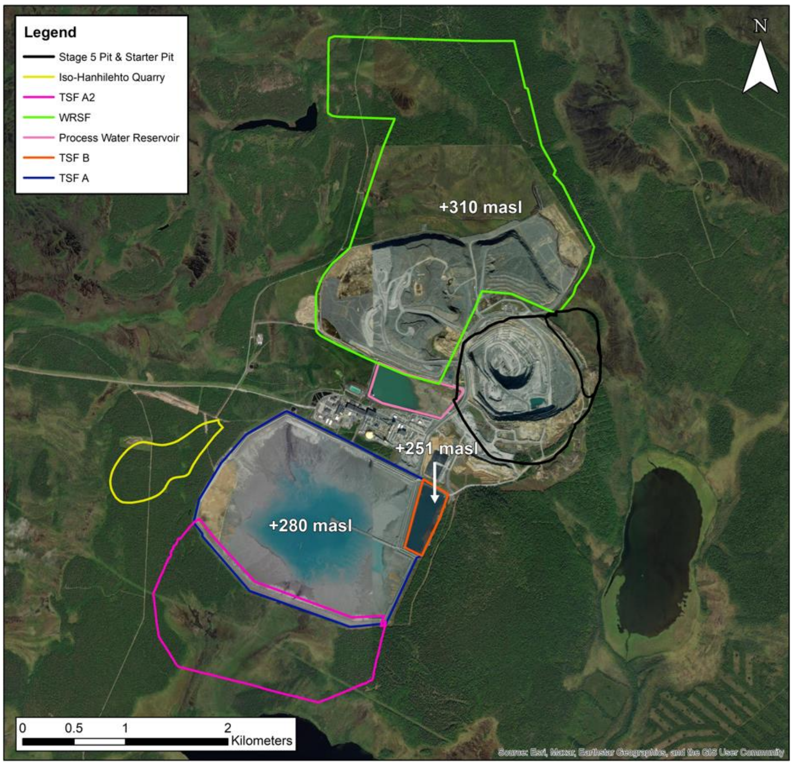

Figure 1-4. Plan view of Scenario VE1.3 mine site layout

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1.4. Data Sources

The main sources of information used in this study are presented in Appendix A. Key documents and/or datasets used in this study include reports and data for the closure modelling of water balances, input water qualities, pit shell designs, and pit shell lithologies.

This study builds on previous studies conducted by Lorax (2019) to characterise the expected pit lake circulation and water qualities on closure of the Kevitsa open pit mine. The conceptualisation of the pit lake modelling was based on the findings of this reporting, including most notably the placement of contact water at a depth of 40 m via floating platform which will rise along with the water levels in the pit.

Data provided by SRK (2025), include the water balance and associated water qualities modelled in GoldSim. These datasets were used for the water balance to inform the pit lake modelling, in addition to selected chemistries used in the thermodynamic and hydrodynamic modelling in this study.

Datasets on the lithological waste coding and associated geochemical testing were provided by Mine Environment Management (MEM, 2024). WSP used the lithological codes (i.e., Capsulated Waste, Environmental Waste, Ore, Unusable Waste and Usable Waste) and the associated data to calculate pit wall runoff water quality. Hydrogeochemical datasets for the recoverable seepage from the waste rock storage facility (WRSF) were additionally provided from MEM (2024).

Boliden provided all pit design datasets including the pit shell designs, pit shells for each EIA scenarios, and the lithological components of the pits. The lithological components of the pit were based on the waste coding conducted by MEM (2024), combined with the pit shell design.

2. Conceptualisation

2.1. Overall Modelling Approach

The Kevitsa mine operates a single open pit which, upon closure, is predicted to form a pit lake. After the end of operations, pit dewatering will cease, and the pit will begin to rebound with water from various sources to form the pit lake over time.

The two scenarios modelled for the pit lake are the VE0+ scenario, and the VE1.3 scenario which relate to an expansion of pit geometry (Table 1-1). The VE0+ scenario uses the Stage 4 pit design, for which closure begins in January 2034. For the VE1.3 scenario, which uses the larger Stage 5 pit design, for which closure will begin from January 2045. Both scenarios are modelled across a 200-year time period.

This report details modelling to evaluate the hydrodynamic and thermodynamic conditions of the expected pit lake. Hydrodynamic modelling is used to indicate the expected pit lake circulation based on the densities and movements of the pit lake water over time, including meteorological influences. Thermodynamic modelling is used to indicate the expected water quality and chemistry of the pit lake. A combination of two modelling softwares was used to evaluate the pit lake:

1. Thermodynamic modelling (Section 2.2) for detailed water quality predictions informed by the expected hydrodynamics of the lake using PHREEQC; and
2. Hydrodynamic modelling (Section 2.3) to investigate the expected lake circulation and stratification using CE-QUAL-W2.

Thermodynamic modelling was completed first to predict concentrations of TDS for the pit wall runoff source term used in the hydrodynamic modelling, and to also calculate the overall lake water quality via mass balance calculations in Excel, followed by thermodynamic modelling in PHREEQC.

Hydrodynamic modelling was subsequently completed to predict lake density and mixing vs. stratified conditions, using the same TDS concentrations as used in the inflows of the thermodynamic model. Higher density water, due to higher chemical loading, will be inclined to sink compared to lower density water. The density of water will also drive the changes in circulation, with the highest density of water occurring at approximately 4°C. At temperatures below the 4°C maximum, water is less dense until its freezing point and is also less dense with increasing temperature towards its boiling point.

2.1.1. Pit Lake Conceptual Model

The conceptual models for the pit lake scenarios are described in Figure 2-1 for the VE0+ scenario with Stage 4 pit design, and in Figure 2-2 for the VE1.3 scenario with Stage 5 pit design.

Both scenarios have the same inflows entering the pit to form the pit lake as shown in Table 2-1, informed by the SRK GoldSim water balance and groundwater modelling (WSP, 2025a). The only two outflows from the pit lake are via the overflow spillway at 225 masl, and via evaporation. No outflows to groundwater are expected within the modelling time periods as indicated by the groundwater modelling conducted (WSP, 2024a).

The pit in the VE1.3 scenario is larger as more material is expected to be mined in the Stage 5 pit design, with a base elevation of -402 masl. The base of the Stage 4 pit (VE0+ scenario) is at -252 masl. The surface lithologies exposed on the pit shells therefore differ slightly and leads to differing chemistry leaching from and on the surface of the pit walls (pit wall runoff).

Table 2-1. Summary of conceptual flows used in the models

Description	Chemistry(s)	Flow(s)
1. **Contact Water** To be pumped 40 m below surface	Mixed water quality for: 1. WRSF recoverable seepage (MEM, 2024) 2. Contact water reservoir (SRK GoldSim, 2025)	Combined flows of: 1. WRSF recoverable seepage (SRK GoldSim, 2025) 2. Contact water reservoir (SRK GoldSim, 2025)
2. **Precipitation** Surface flow	Representative public dataset on rainfall chemistry (QA/SAC, 2025)	Direct precipitation on the pit lake (SRK GoldSim, 2025)
3. **Unrecoverable WRSF Seepage** Shallow groundwater flow	Recoverable seepage diluted by groundwater SRK GoldSim (2025) / WSP (2025b)	WRSF unrecoverable seepage (SRK GoldSim, 2025)
4. **Groundwater** Deep groundwater flow	Site monitoring data (See Section 3.2.1.3)	Natural groundwater (SRK GoldSim, 2025)
5. **Non-Contact Water** Surface flow	Non-contact waters of same chemistry SRK (2025) GoldSim	Combined Flows of: 1. Catchment runoff 2. WRSF runoff (SRK GoldSim, 2025)
6. **Pit Wall Runoff** Surface flow	Calculated/modelled in this report	Combined Flows of: 1. Pit wall runoff 2. Snowmelt on pit walls (SRK GoldSim, 2025)

2.1.2. Pit Lake Inflows

Inflows into the pit, as outlined in the conceptual model in Section 2.1.1, are described in the following sub-sections. A summary of the expected chemistry and flow terms for each inflow to the pit is also included in Table 2-1.

2.1.2.1. Contact Water

Lorax (2019) modelled pit lake stratification by simulating the injection of contact water at a constant depth of 40 m below the lake surface using a floating platform, as the pit fills and once full. Stratification was driven by the higher density of the contact water relative to the lake water, due to higher chemical loading. In the predicted stratified system (Lorax 2019), the upper mixolimnion layer is generally well-mixed and oxygenated due to wind action and surface exchange, while the deeper monimolimnion remains relatively isolated and more stable. Over time, chemical and biological processes in the monimolimnion may lead to oxygen depletion and the accumulation of solutes, resulting in distinct water quality differences between surface and bottom layers. This stratification is important to consider in predictive modelling, as it influences nutrient cycling, redox conditions, and the mobility of metals within the pit lake as shown in Figure 2-1 and Figure 2-2.

The term contact water refers to the water resulting from interactions with mine rock or facilities which contribute chemical loading. In this study, the contact water consists of two inflows as provided by the SRK GoldSim (2025) water balance:

1. Water collected in the contact water reservoir/pond; and
2. Recoverable seepage from the waste rock storage facility (WRSF), as identified in the SRK water balance.

Together, the contact water reservoir and recoverable seepage flows are referred to as ‘contact water’. The chemistries of these two flows were mixed based on the proportions of their flows in the SRK GoldSim water balance. The recoverable seepage flow uses the geochemical source term from MEM (2024), whilst the contact water reservoir uses the contact water reservoir source term from the SRK (2025) GoldSim modelling.

The MEM geochemical data were used for recoverable seepage to reduce the conservatism of the modelling, as the SRK (2025) GoldSim data only extend to 2049 after which unrealistic and conservative approaches would need to be applied to repeat the data. It is expected with a cover system the WRSF seepage chemistry would reduce in concentration over time due decreased reactivity of the mass of waste rock, which is represented by the MEM (2024) data.

2.1.2.2. Precipitation

Precipitation is added to the pit as direct rainfall onto the lake, as informed by the water balance (SRK, 2025). There is minimal chemical loading from the precipitation, representative rainfall chemistry for Finland was applied.

2.1.2.3. Unrecoverable WRSF Seepage

The pit lake will capture a proportion of the unrecoverable seepage from the WRSF that infiltrates to groundwater and which cannot be recovered. This flow differs from the recoverable WRSF seepage which is the seepage collected surrounding the WRSF and recovered. This flow enters the pit via groundwater flow pathways in the sub-surface.

The geochemical source term for this term is sourced from the SRK (2025) GoldSim recoverable WRSF seepage term, but was diluted with the groundwater (WSP, 2025b). The inflow volume is informed by the SRK (2025) GoldSim modelling.

2.1.2.4. Groundwater

The rate of groundwater inflow changes as a function of the water level within the pit; as the pit water level rises, the hydraulic gradient between the pit lake and the surrounding groundwater elevation decreases.

The natural groundwater is distinct from the unrecoverable WRSF seepage groundwater inflow and represents the natural background groundwater from the surrounding areas which is drawn towards the pit in the sub-surface and to deeper levels. The inflow volume is informed by the SRK (2025) GoldSim modelling, and the chemistry is based on on-site monitoring wells described further in Section 3.2.

2.1.2.5. Non-contact Water

Non-contact water is a combination of two flows which will enter the pit from runoff across the covered WRSF facility, and from the surrounding catchment area of the pit. Both of these flows have minimal interaction with mine-affected materials and are therefore considered as non-contact water.

The chemistry for both of these inflows is the same using the SRK (2025) GoldSim modelling data. The inflow volumes of these flows, as informed by the SRK GoldSim modelling, were summed to a single flow as non-contact water.

2.1.2.6. Pit Wall Runoff

Pit wall runoff changes as a function of water level within the pit. As the water level increases in the lake, the area of exposed pit wall decreases. The pit wall is comprised of a range of lithologies which contribute differing chemical loadings, and which leads to varying pit wall runoff concentrations over time. The pit wall runoff was modelled as part of this study, based on the flow data from the SRK (2025) GoldSim water balance.

The water balance indicates two flows which contribute to the pit wall runoff volume including pit wall runoff and snowpack release on the pit walls. The geochemical source terms (VE0+ and VE1.3) for the pit wall runoff were calculated based on the humidity cell data testing, discussed in MEM (2024), which are mapped to the lithological components of the pit shells for both modelling scenarios. The pit shell designs and lithological proportions for both pit shell designs (Stage 4 and Stage 5) were provided by Boliden. The pit wall runoff geochemistry is discussed further in Section 3.3.1.

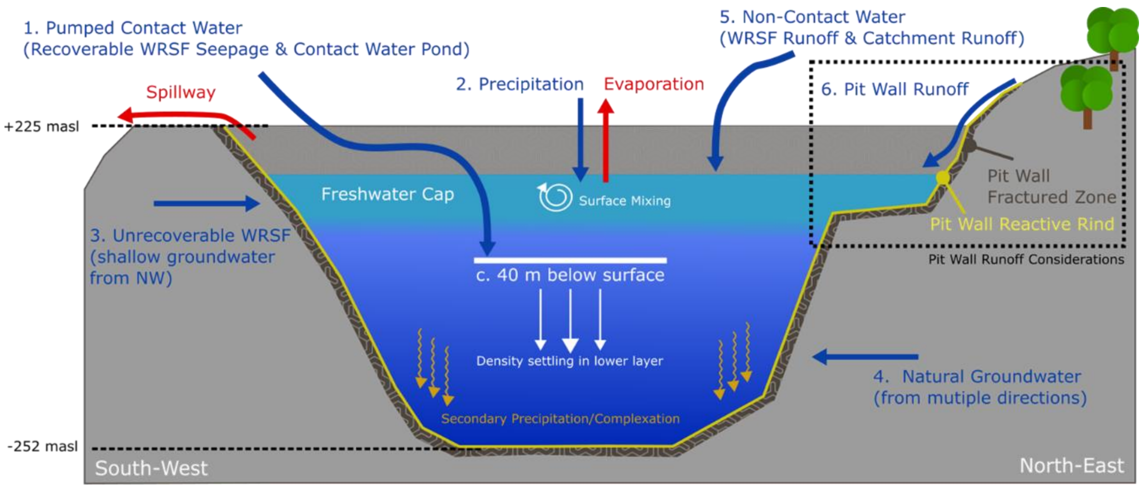

Figure 2-1. Conceptual model for Scenario VE0+ (Stage 4 with Starter pit)

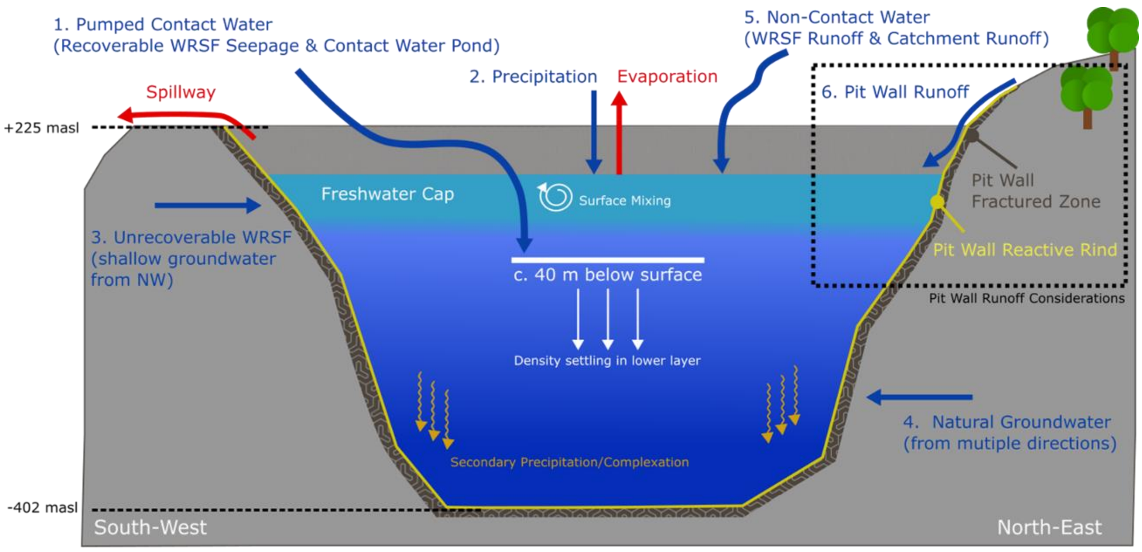

Figure 2-2. Conceptual model for the larger pit in Scenario VE1.3 (Stage 5)

2.2. Thermodynamic Modelling Approach

The pit lake thermodynamic modelling was developed using a combination of mass balance calculations in Microsoft Excel in addition to thermodynamic modelling using PHREEQC Version 3.8.6-17100 from the United States Geological Survey (USGS; Parkhurst and Appelo, 2013).

PHREEQC is an aqueous thermodynamic and geochemical modelling code developed by the United States Geological Survey (USGS), which is widely accepted by the regulatory and scientific community. PHREEQC simulates chemical reactions in aqueous solutions such as mineral dissolution, ion exchange and redox processes to calculate elemental speciation and saturation indices. The 'minteq.v4' thermodynamic database provided with PHREEQC was used.

Thermodynamic modelling was completed in PHREEQC to develop the mass loadings expected from the pit wall runoff for each of the scenarios (VE0+ and VE1.3), in addition to developing the source terms for pit wall runoff to be input into the hydrodynamic modelling. The geochemical source terms listed in Table 2-1 were combined along with their inflow volumes to evaluate the resulting pit lake water quality using PHREEQC.

2.2.1. Model Scenarios

The base-case model is intended to give the most likely output in terms of future pit lake quality based on the most likely input parameters and hydrodynamics of the lake. Two pit scenarios have been modelled (VE0+ and VE1.3) as shown in Table 2-2. Each scenario was evaluated under base-case conditions of a stratified lake (upper layer and lower layer), in addition to simulating the conditions of a fully mixed lake (a more conservative scenario). This approach provides insight into how water quality may vary depending on whether the pit lake remains stratified as expected, based on the placement of the contact water at 40 m depth, or as a worst-case sensitivity check whereby the lake fully mixes from top to bottom.

The modelled time steps presented for the thermodynamic modelling include individual years up to Year 10, followed by Years 25, 50, 75, 100, 150, and 200. This is intended to provide snapshots of the modelling across the 200 years modelling periods for each scenario.

Table 2-2. Summary of modelled scenarios with description of the hydrodynamics

Model Number	Pit Scenario	Description
1	VE0+ (Stage 4 + Starter Pit)	Upper Layer
2		Lower Layer
3		Fully Mixed lake
4	VE1.3 (Stage 5)	Upper Layer
5		Lower Layer
6		Fully Mixed lake

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2.2.2. Conceptual Flows

WSP used the latest water balance model completed by SRK (2025), in addition to the flow diagrams provided by Boliden. Based on the available water balance data, WSP developed conceptual thermodynamic mixing models, presented in Figure 2-3 to Figure 2-8.

A conservative, fully mixed pit lake scenario was developed, with results (e.g., TDS) used to inform the hydrodynamic modelling. The hydrodynamic results were then applied to define when stratification of the pit lake occurs and at what stage of rebound it begins.

The stratified pit lake scenario assumes that from year 90 in Scenario VE0+ and year 115 in Scenario VE1.3, corresponding to rebound to water level 225 m in both scenarios, the lake transitions into a stratified system. The base-case mixing models are therefore structured in two stages:

- Filling period: The lake is represented as fully mixed.
- Post-filling period: Once the lake is full, it is considered stratified, as confirmed by hydrodynamic modelling.

It is only after the pit lake reaches full capacity that water begins to spill via the spillway; therefore, the filling period is not representative of spillway chemistry. The two stages of the thermodynamic base-case modelling considered for each scenario are outlined below.

1. Pit lake filling period with mixed inflows in a single ‘layer’. Scenario VE0+ (2034 to 2124) and Scenario VE1.3 (2045 to 2159); and
2. Stratified pit lake: In a stratified pit lake, the recoverable seepage/contact and groundwater are modelled in a distinct lower layer, whilst all other inflows are modelled in a separate upper layer. Scenario VE0+ (2125 to 2235) and Scenario VE1.3 (2160 to 2246).

In the fully mixed lake scenario, as the conservative-case, the inflows are mixed in a single layer together across the modelling periods for both Scenarios VE0+ and VE1.3.

The key source-pathway-receptor features of the conceptual model are:

1. Recoverable seepage and pumped contact water as the main sources of flow and chemistry entering the pits throughout the modelled years;
2. Water from snowmelt on the pit walls and pit runoff represent the pit wall runoff total flow;
3. Water from precipitation, the natural catchment, unrecoverable seepage and groundwater report to the pits in smaller quantities (see Section 3.1); and
4. The remaining pit lake volume represents the water chemistry carried over from the previous year, which is then mixed with new inputs to define the water chemistry in the subsequent year.

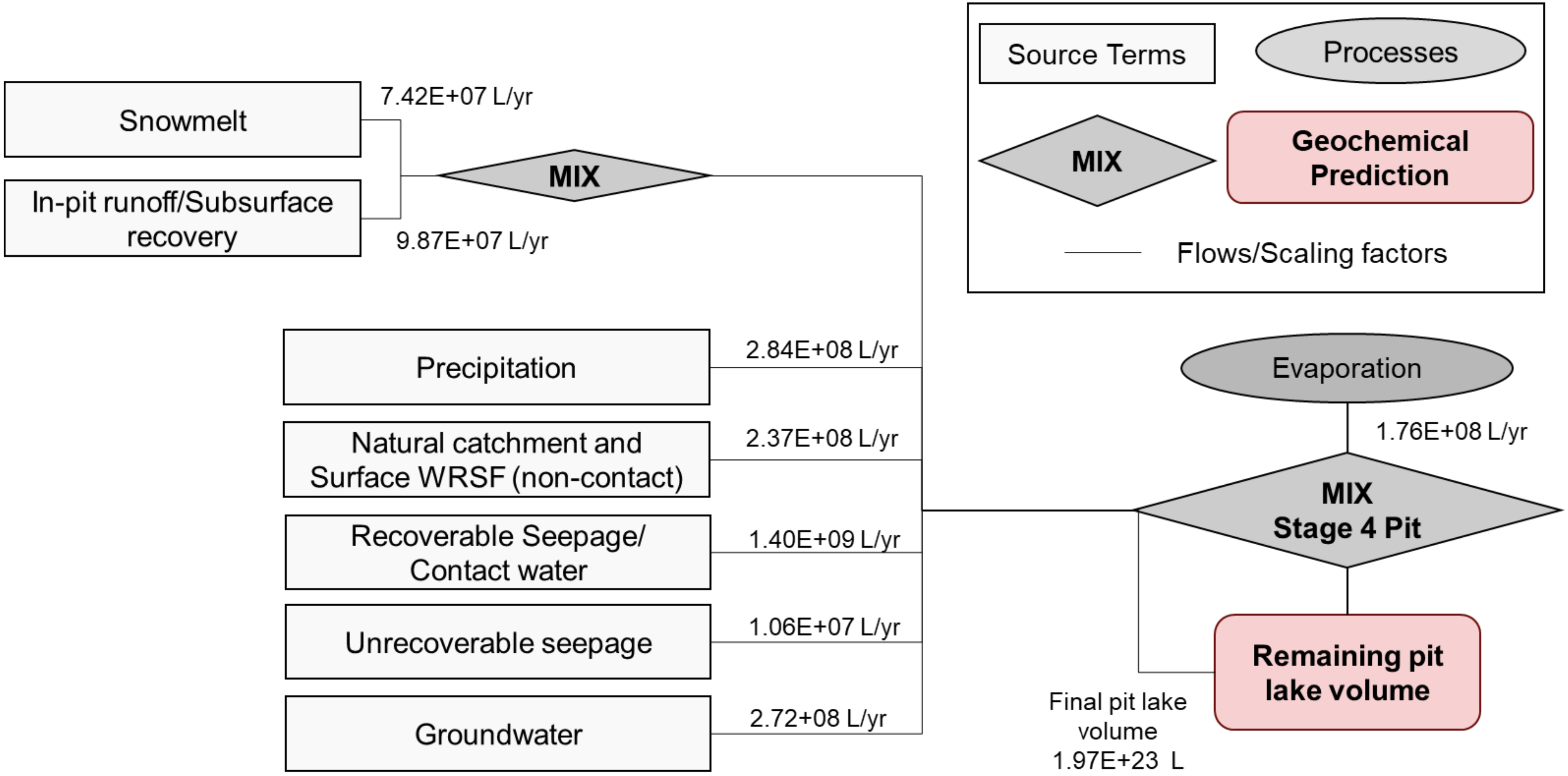

Figure 2-3. VE0+ conceptual flow diagram – filling period (Year 0–89), showing average flow rates

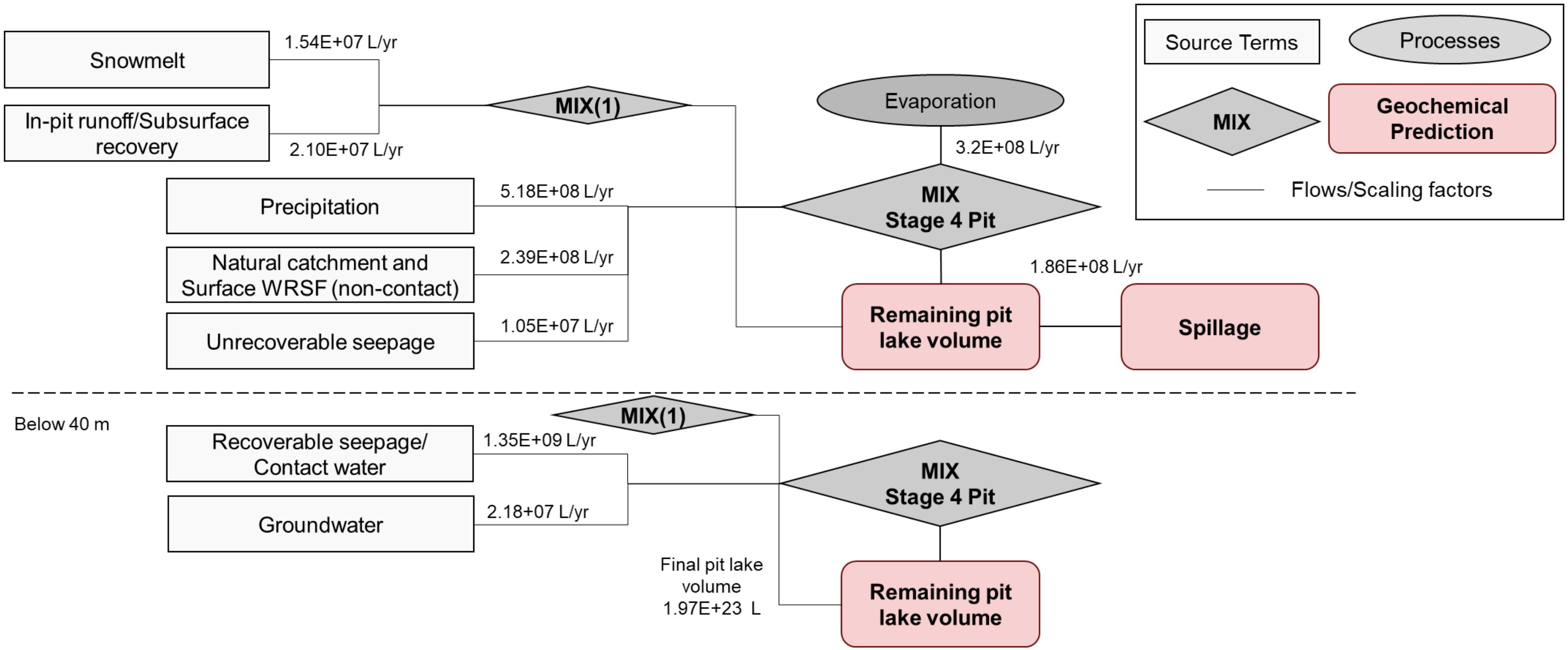

Figure 2-4. VE0+ Conceptual Flow Diagram – Stratified pit lake (Year 90 onwards), showing average flow rates

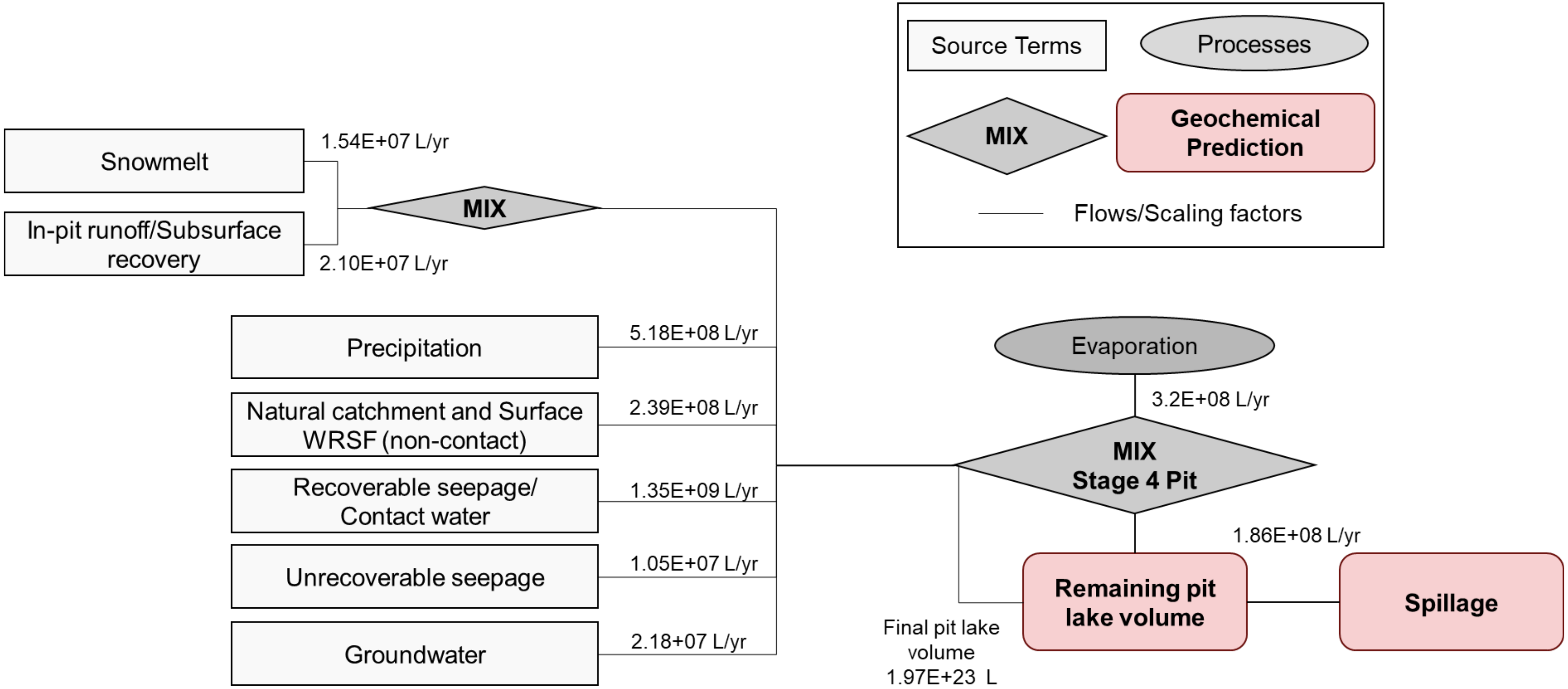

Figure 2-5. VE0+ Conceptual Flow Diagram – Fully Mixed Pit Lake (Year 90 onwards), showing average flow rates

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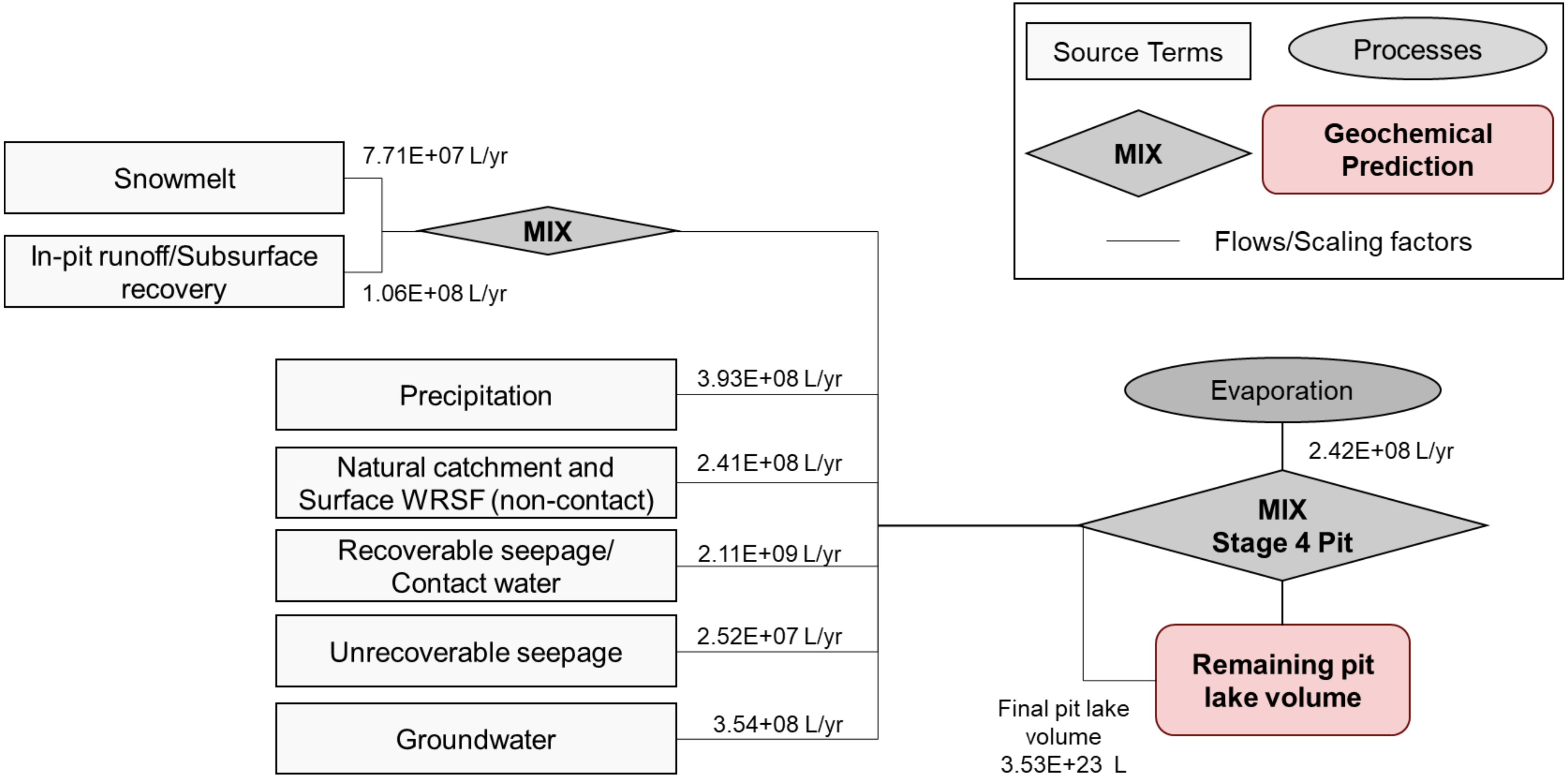

Figure 2-6. VE1.3 Conceptual Flow Diagram – Filling Period (Year 0–114), showing average flow rates

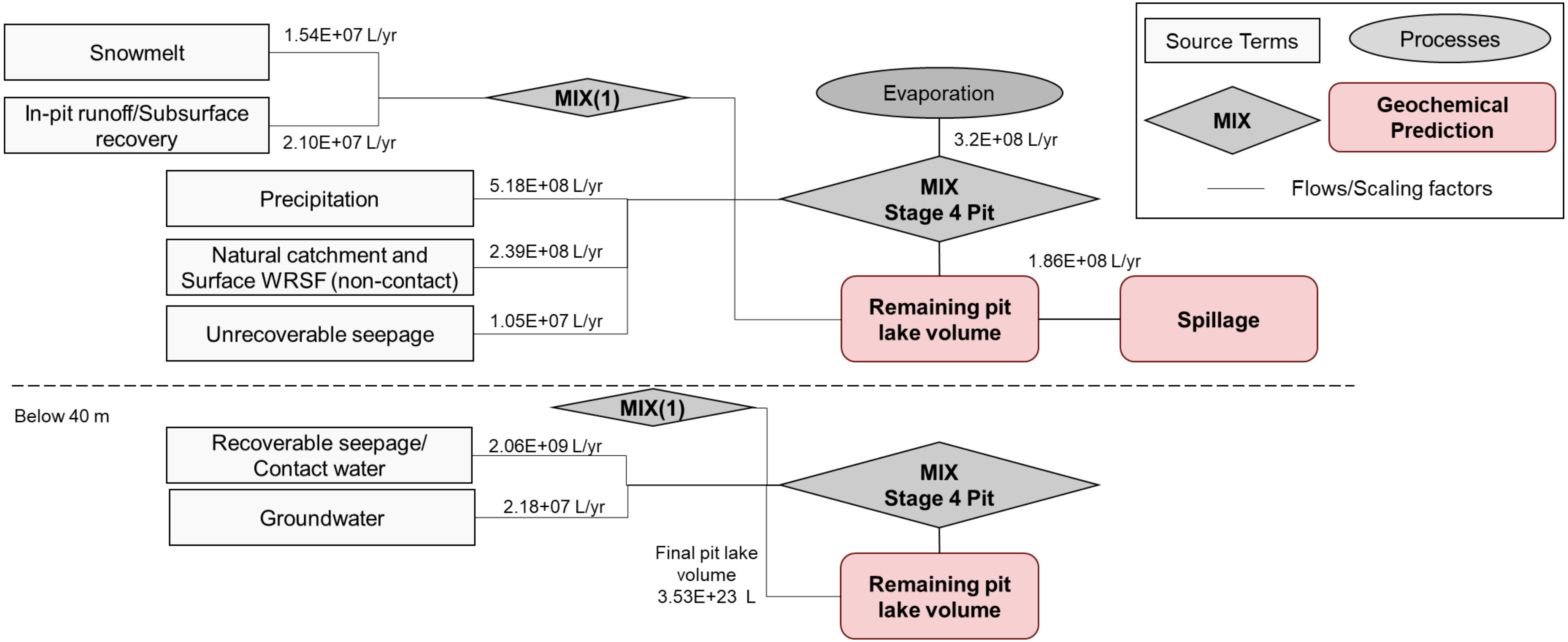

Figure 2-7. VE1.3 Conceptual Flow Diagram – Stratified Pit Lake (Year 115 onwards), showing average flow rates

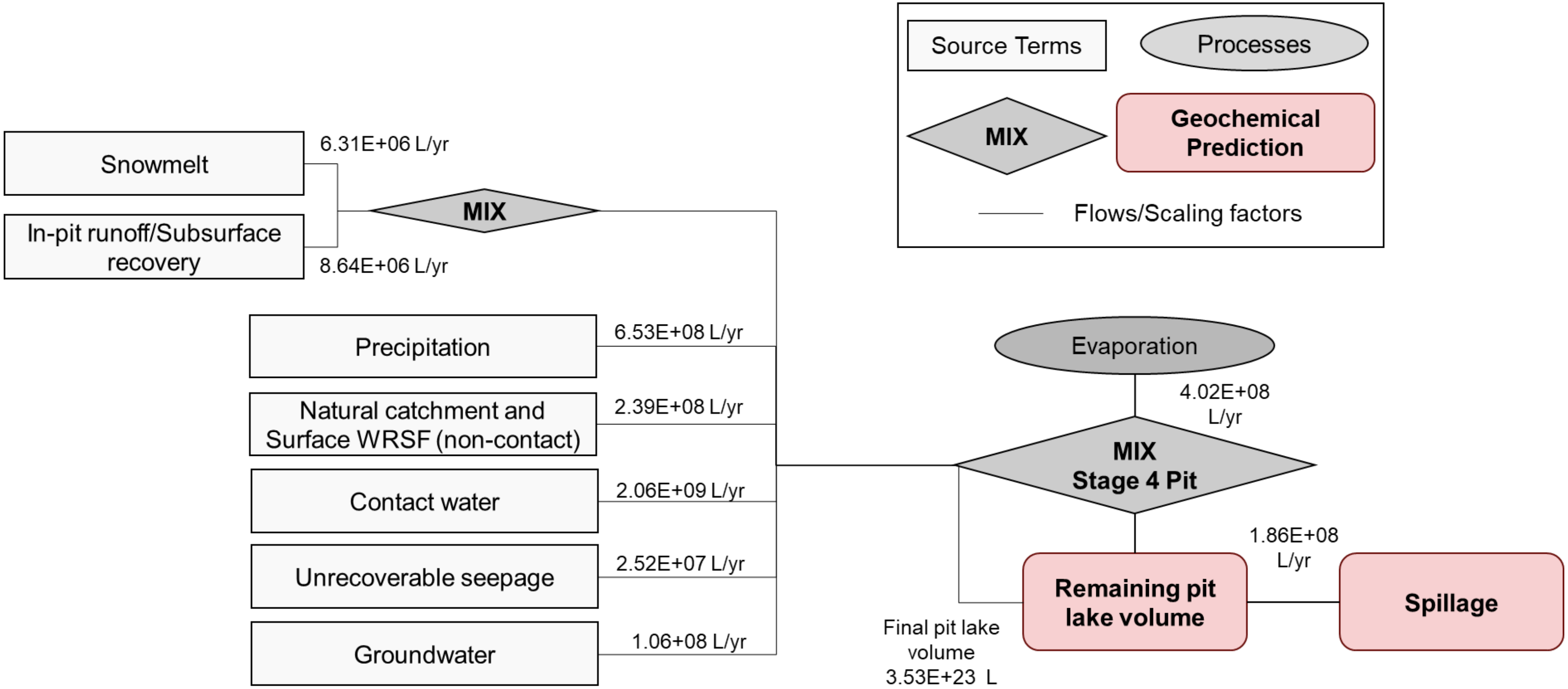

Figure 2-8. VE1.3 Conceptual Flow Diagram – Fully Mixed Pit Lake (Year 115 onwards), showing average flow rates

2.3. Hydrodynamic Modelling Approach

To simulate the pit lake circulation over time, as a function of the total dissolved solids concentration (TDS) and density of each source term, hydrodynamic models were developed in the CE-QUAL-W2 (W2) software package. CE-QUAL-W2 was developed by the U.S. Army Corps of Engineers (Cole and Wells 2017) and Version 4.5 of the CE-QUAL-W2 software version was used in the modelling.

The CE-QUAL-W2 program is a two-dimensional (2-D, profile-view: horizontal distance vs depth), laterally-averaged, fluid mechanics, and water quality model that has been widely used to evaluate the likelihood of complete mixing within natural lakes, reservoirs, and mine pit lakes worldwide. The program provides 2-D flow fields from which the distribution of heat, momentum and mass can be simulated. The theoretical basis for CE-QUAL-W2 was the 2-D longitudinal-vertical transport model written by Buchak and Edinger (1984) which formed the hydrodynamic and transport basis of the first version (i.e., W1) of the water quality model (US Army of Engineer Waterways Experiment Station, 1986).

2.3.1. Model Scenarios

For both modelling scenarios, the models were run for a period of 200 years. For scenario VE0+, the modelling period begins on 1st January 2034, ending on 1st January 2235. For scenario VE1.3, the modelling period begins on 1st January 2045, ending on 1st January 2246. The model timesteps are input as Julian days, with a total of 73,414 Julian days across the 200-year modelling period for each of the scenarios.

Inputs to the model include lake bathymetry, meteorological data, hydrological data, and water quality data, as described in the following sections. The temperature, flow volumes, and concentration of each input were specified in the model on daily time steps. Total dissolved solids (TDS) and temperature were used to indicate the frequency and depth of annual circulation events, the development of meromictic (perennially stratified) conditions, and the depth of the chemocline separating the surface (mixolimnion) and deep (monimolimnion) layers in the modelled pit lakes.

A base case, most likely scenario, model was constructed in line with the conceptual models (Figure 2-1 and Figure 2-2) and assumed pumping of contact water to 40 m below the surface, as previously modelled by Lorax (2019). Two sensitivity checks were also completed by pumping the contact water to the base of the pit and by pumping it at the surface of the lake in order to test the sensitivity of the contact water placement within the pit lake.

2.3.2. Model Segmentation

Model segmentation is the discretisation of a physical domain into individual grid cells that can be used by the CE-QUAL-W2 software to iteratively calculate state variables (i.e., properties such as velocity and concentration) at all locations within the lake within each time step.

A 2-D grid was developed for each of the pit shell designs:

1. Stage 4 pit with starter pit for scenario VE0+; and
2. Stage 5 pit for scenario VE1.3.

Each scenario is comprised of a single pit lake, forming one individual branch within the modelling software. The segmentation details are included in Table 2-3 for both scenarios. Plan views of the segmentation are included in Figure 2-9 for Stage 4 (VE0+) and in Figure 2-10 for Stage 5 (VE1.3). The upstream segment is Segment 1. Water and mass were removed via a spillway at elevation 225 masl in Segment 10, the downstream segment in both scenarios.

Equal length (x-axis) horizontal grid spacings were used to discretize the pit into segments (x-direction), each at 170 m in length for Stage 4 and at 182 m in length for Stage 5. Each segment is split into 10-m-thick layers (z-direction). CE-QUAL-W2 assumes that processes occurring perpendicular to the x-axis (i.e., the y-direction) have a negligible affect relative to processes occurring in either the x- or z-directions. The vertical profile view sections are included in Figure 2-11 for Stage 4 (VE0+) and in Figure 2-12 for Stage 5 (VE1.3).

The starter pit extension is conceptually viewed as merged with the main Stage 4 pit, without a ridge separating the two basins (Figure 2-1 and Figure 2-9). The deepest point in the Stage 4 pit is modelled at an elevation of -252 masl. The Stage 5 pit is a single pit design, with the deepest point modelled at an elevation of -402 masl.

Table 2-3. Model segmentation of the CE-QUAL-W2 models

Scenario	Pit Shell Design	Vertical Spacing	Number of Layers	Horizontal Spacing	Active Segments
VE0+	Stage 4 with starter pit	10 m	50	170 m	9
VE1.3	Stage 5	10 m	65	182.2 m	9

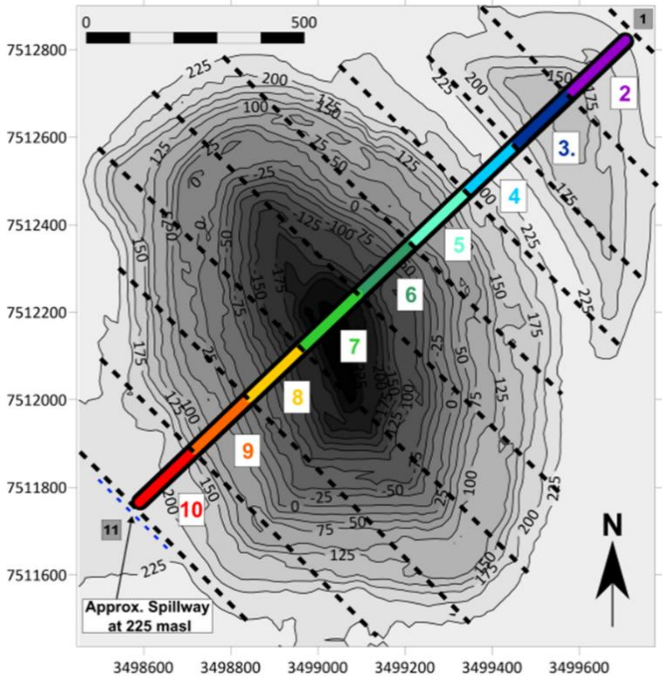

Figure 2-9. Model segmentation plan view for the Stage 4 Pit with Starter Pit (VE0+)

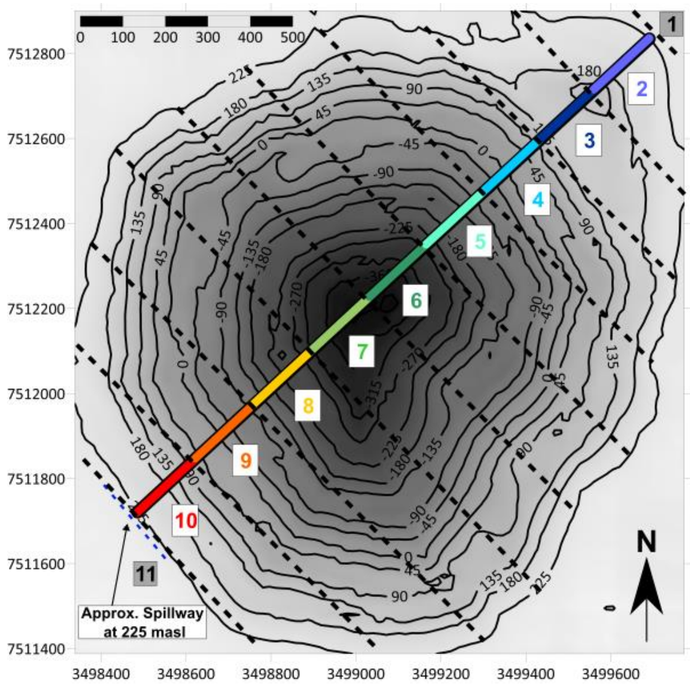

Figure 2-10. Model segmentation plan view for the Stage 5 Pit (VE1.3)

Segment No.		1	2	3	4	5	6	7	8	9	10	11	Row No.
Elevation above pit base (m)	492	0	0	0	0	0	0	0	0	0	0	0	1
	482	0	1512	2288	3043	3421	4178	5394	4963	3450	2243	0	2
	472	0	1233	1996	2703	3071	4056	5300	4778	3133	1871	0	3
	462	0	732	1797	2545	2824	3929	5273	4580	2837	1225	0	4
	452	0	465	1480	2363	2644	3793	5242	4259	2651	907	0	5
	442	0	351	1252	2224	2569	3552	5138	3973	2579	736	0	6
	432	0	312	1134	2149	2468	3355	5043	3734	2465	655	0	7
	422	0	258	1009	2018	2340	3231	5009	3603	2329	537	0	8
	412	0	191	925	1681	2245	3165	4925	3490	2235	314	0	9
	402	0	127	725	1234	2116	3082	4885	3276	2179	175	0	10
	392	0	61	600	1135	2060	2980	4839	3200	2118	135	0	11
	382	0	0	486	1066	1983	2855	4816	3097	2050	120	0	12
	372	0	0	0	1024	1949	2806	4764	3058	2016	0	0	13
	362	0	0	0	889	1845	2712	4635	3010	1874	0	0	14
	352	0	0	0	507	1656	2681	4570	2951	1775	0	0	15
	342	0	0	0	368	1540	2534	4488	2909	1703	0	0	16
	332	0	0	0	162	1441	2321	4432	2876	1567	0	0	17
	322	0	0	0	0	1349	2157	4334	2769	1430	0	0	18
	312	0	0	0	0	1247	1953	4222	2688	1213	0	0	19
	302	0	0	0	0	1046	1905	4173	2566	1002	0	0	20
	292	0	0	0	0	959	1771	4130	2473	816	0	0	21
	282	0	0	0	0	839	1675	4074	2380	683	0	0	22
	272	0	0	0	0	488	1607	4003	2307	604	0	0	23
	262	0	0	0	0	312	1543	3938	2229	477	0	0	24
	252	0	0	0	0	0	1492	3877	2149	402	0	0	25
	242	0	0	0	0	0	1381	3805	2083	323	0	0	26
	232	0	0	0	0	0	1143	3770	1966	259	0	0	27
	222	0	0	0	0	0	958	3655	1876	188	0	0	28
	212	0	0	0	0	0	839	3537	1764	0	0	0	29
	202	0	0	0	0	0	701	3354	1657	0	0	0	30
	192	0	0	0	0	0	665	3073	1462	0	0	0	31
	182	0	0	0	0	0	539	2872	1308	0	0	0	32
	172	0	0	0	0	0	390	2671	1142	0	0	0	33
	162	0	0	0	0	0	340	2477	857	0	0	0	34
	152	0	0	0	0	0	264	2392	684	0	0	0	35
	142	0	0	0	0	0	218	2284	555	0	0	0	36
	132	0	0	0	0	0	146	2157	485	0	0	0	37
	122	0	0	0	0	0	0	2067	391	0	0	0	38
	112	0	0	0	0	0	0	1958	277	0	0	0	39
	102	0	0	0	0	0	0	1785	209	0	0	0	40
	92	0	0	0	0	0	0	1638	106	0	0	0	41
	82	0	0	0	0	0	0	1457	0	0	0	0	42
	72	0	0	0	0	0	0	1212	0	0	0	0	43
	62	0	0	0	0	0	0	958	0	0	0	0	44
	52	0	0	0	0	0	0	779	0	0	0	0	45
	42	0	0	0	0	0	0	634	0	0	0	0	46
	32	0	0	0	0	0	0	489	0	0	0	0	47
	22	0	0	0	0	0	0	344	0	0	0	0	48
	12	0	0	0	0	0	0	201	0	0	0	0	49
	2	0	0	0	0	0	0	0	0	0	0	0	50

Figure 2-11. Profile view of vertical layers in the Stage 4 and starter pit , VE0+ Scenario, for CE-QUAL-W2 (cell values represent the y distance)

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Segment No.		1	2	3	4	5	6	7	8	9	10	11	Row No.
Elevation above pit base (m)	640	0	0	0	0	0	0	0	0	0	0	0	1
	630	0	450	650	1050	1200	1300	1340	1290	1050	840	0	2
	620	0	410	618	990	1131	1270	1313	1270	1000	748	0	3
	610	0	355	597	956	1103	1258	1284	1258	972	619	0	4
	600	0	318	562	912	1066	1226	1263	1181	921	549	0	5
	590	0	292	540	875	1026	1154	1217	1132	908	508	0	6
	580	0	254	510	854	1010	1139	1198	1104	894	471	0	7
	570	0	240	483	814	999	1099	1165	1078	853	450	0	8
	560	0	225	428	758	991	1086	1139	1065	796	396	0	9
	550	0	207	405	733	980	1068	1124	1055	781	376	0	10
	540	0	151	363	687	966	1042	1103	1035	767	328	0	11
	530	0	72	356	672	956	1031	1091	1024	761	278	0	12
	520	0	0	344	651	934	1012	1077	996	726	265	0	13
	510	0	0	335	619	925	995	1027	960	676	249	0	14
	500	0	0	328	607	916	964	1005	940	662	240	0	15
	490	0	0	290	565	821	925	992	930	647	214	0	16
	480	0	0	245	535	770	867	979	922	638	187	0	17
	470	0	0	216	514	753	833	959	911	629	169	0	18
	460	0	0	75	493	728	806	946	894	612	146	0	19
	450	0	0	0	481	719	798	936	882	604	131	0	20
	440	0	0	0	468	712	792	918	870	587	0	0	21
	430	0	0	0	464	705	788	911	861	581	0	0	22
	420	0	0	0	453	695	759	871	816	572	0	0	23
	410	0	0	0	434	674	733	836	793	557	0	0	24
	400	0	0	0	414	656	688	775	766	522	0	0	25
	390	0	0	0	384	584	680	748	729	442	0	0	26
	380	0	0	0	369	567	673	724	721	423	0	0	27
	370	0	0	0	326	553	656	711	708	355	0	0	28
	360	0	0	0	274	543	644	699	694	243	0	0	29
	350	0	0	0	239	533	629	694	683	196	0	0	30
	340	0	0	0	170	522	619	687	669	131	0	0	31
	330	0	0	0	138	514	611	681	660	78	0	0	32
	320	0	0	0	90	496	600	659	647	0	0	0	33
	310	0	0	0	82	477	591	648	631	0	0	0	34
	300	0	0	0	0	457	574	633	622	0	0	0	35
	290	0	0	0	0	442	495	576	573	0	0	0	36
	280	0	0	0	0	434	470	520	526	0	0	0	37
	270	0	0	0	0	389	426	467	473	0	0	0	38
	260	0	0	0	0	379	419	461	467	0	0	0	39
	250	0	0	0	0	376	359	438	447	0	0	0	40
	240	0	0	0	0	357	333	413	411	0	0	0	41
	230	0	0	0	0	331	315	383	386	0	0	0	42
	220	0	0	0	0	299	304	366	345	0	0	0	43
	210	0	0	0	0	241	295	340	318	0	0	0	44
	200	0	0	0	0	157	280	323	278	0	0	0	45
	190	0	0	0	0	150	271	319	267	0	0	0	46
	180	0	0	0	0	128	256	299	252	0	0	0	47
	170	0	0	0	0	94	247	269	235	0	0	0	48
	160	0	0	0	0	69	237	246	226	0	0	0	49
	150	0	0	0	0	38	216	235	200	0	0	0	50
	140	0	0	0	0	38	209	231	193	0	0	0	51
	130	0	0	0	0	0	190	220	172	0	0	0	52
	120	0	0	0	0	0	156	206	155	0	0	0	53
	110	0	0	0	0	0	130	191	140	0	0	0	54
	100	0	0	0	0	0	98	178	127	0	0	0	55
	90	0	0	0	0	0	82	157	115	0	0	0	56
	80	0	0	0	0	0	56	139	99	0	0	0	57
	70	0	0	0	0	0	48	131	91	0	0	0	58
	60	0	0	0	0	0	39	115	69	0	0	0	59
	50	0	0	0	0	0	28	105	38	0	0	0	60
	40	0	0	0	0	0	16	100	19	0	0	0	61
	30	0	0	0	0	0	0	84	0	0	0	0	62
	20	0	0	0	0	0	0	63	0	0	0	0	63
	10	0	0	0	0	0	0	42	0	0	0	0	64
	0	0	0	0	0	0	0	0	0	0	0	0	65

Figure 2-12. Profile view of vertical layers in the Stage 5 , VE1.3 Scenario, for CE-QUAL-W2 (cell values represent the y distance)

2.4. Assumptions

This study models the hydrodynamic and thermodynamic conditions of the Kevitsa pit lake expected to develop under EIA Scenarios VE0+ and VE1.3. These models are subject to limitations and uncertainties due to the inherent uncertainties in input data, model assumptions, and the required hypotheses necessary to carry out the predictions. The following section outlines key limitations and their potential implications.

For modelling purposes, the following assumptions are applicable:

1. Processes are homogenized within a given hydrodynamic model cell. CE-QUAL-W2 assumes the processes occurring perpendicular to the long-axis of the lake (illustrated in Figure 2-11 and Figure 2-12) have a negligible impact on lake circulation relative to processes occurring parallel to the long-axis or vertical processes;
2. Using a vertical layer thickness of 10 m in CE-QUAL-W2 hydrodynamic modelling may oversimplify processes happening immediately below the surface of the lake, such as seasonal thermal structure;
3. Flow volumes for both thermodynamic and hydrodynamic modelling were based solely on the water balance produced by the SRK (2025) GoldSim water balance provided, one of the other consultancies involved in the development of the EIA with Boliden. The flow volumes of WRSF recoverable seepage have been identified to be higher than expected given that the WRSF will be covered at closure, therefore, the seepage volumes used in CE-QUAL-W2 are more conservative;
4. WRSF seepage chemical inputs were sourced from the Mine Environment Management (MEM;2024) hydrogeochemical datasets provided, and in the contaminant transport modelling (WSP, 2025b), see Appendix B for data sources.;
5. The hydrogeochemical inputs for the non-contact water and contact water reservoir are source solely from the SRK (2025) GoldSim dataset provided;
6. Pit wall runoff water quality was estimated using humidity cell test (HCT) and other geochemical characterisation results for representative lithologies data provided by MEM (MEM, 2025);
7. Pit wall runoff chemistry was expressed as a load (mass per time) and scaled to the changing pit wall surface area over time in the overall thermodynamic pit lake models; and
8. The nitrate leaching from explosive residues has been neglected in the hydrogeological and thermodynamic modelling as it is considered that the majority of the explosive residues will have been leached during the life of mine.
9. The removal of solutes by thermodynamically controlled processes such as secondary precipitations and surface complexation are assumed to be permanent. However, these mechanisms are reversible if the environmental conditions which could lead to the release total or partial of the solutes.

3. Methodology

3.1. Water Balance

The simulated water balance components used in the thermodynamic and hydrodynamic modelling are presented in Figure 3-1 and Figure 3-2, along with pit lake volume development for Scenarios VE0+ and VE1.3, respectively.

The water balance was computed using GoldSim on a monthly timestep by SRK (2025) (See Section 1.4, Appendix A). These data were used along the groundwater modelling (WSP, 2025) to inform the overall water balance. As each pit lake fills, the water level was computed in GoldSim based on the storage curve, which has been analysed using GIS base on the pit geometries for both scenarios. The groundwater rebound curves are included in Figure 3-3 for the Stage 4 Pit (VE0+) and in Figure 3-4 for the Stage 5 Pit (VE1.3). The results highlight the relative contributions of inflows and outflows over the 200-year model period.

In both scenarios, the contact water inflow represents the dominant source of water to the pit. Total overall volumes of the inflows, outlined in Section 2.1.2, are dominated by the contact water comprising 60% of the overall flows for Scenario VE0+ (Figure 3-5) and 65% of the overall flows for Scenario VE1.3 (Figure 3-6). This inflow drives the long-term rise in pit lake volume and chemical loading.

Total contributions from precipitation (<18%), non-contact water (<10%), and natural groundwater (<8%) are the next highest inflows after contact water. The unrecoverable seepage (<0.8%) contributes the lowest total flow to the pit. The total inflows of pit wall runoff (<4%) are comparatively minor to the contact water, with runoff also decreasing after the first few decades. The total volume of the pit lake water at each time step is also mixed with the inflows, with a dynamic model integrating previous time steps into each new mixing step.

The total pit lake volume differs between the two scenarios. Under Scenario VE0+ (Figure 3-1), the final pit lake volume is at approximately 6,500 ML, whereas under Scenario VE1.3 (Figure 3-2), the final volume is roughly double, reaching approximately 12,000 ML. The rebound curves for the two scenarios are shown in Figure 3-3 and Figure 3-4. Both have a rapid initial rebound in the early 20 modelled years and become steady after the pit lake reaches the spillway elevation.

Outflows are limited primarily to evapotranspiration, which remains consistent at low levels. Overflow is projected to occur once the pit lake reaches capacity at 225 masl, at approximately 90 years in scenario VE0+ and 114 years in scenario VE1.3. After this point, pit volume stabilises, balancing ongoing inflows and outflows.

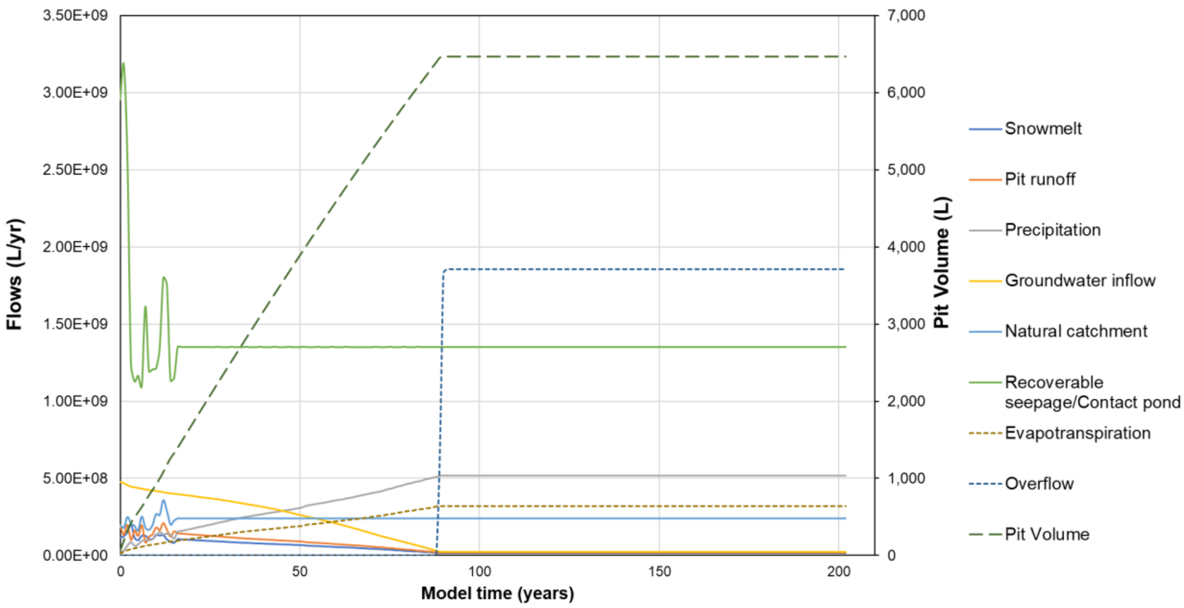

Figure 3-1. Water Balance for Scenario VE0+

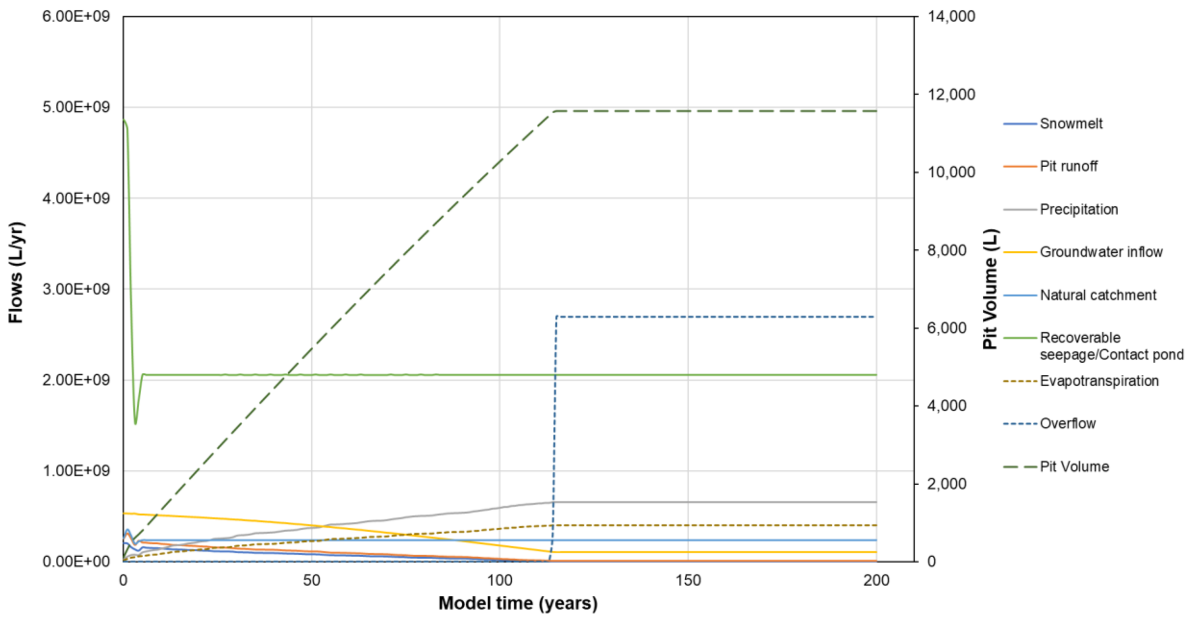

Figure 3-2. Water Balance for Scenario VE1.3

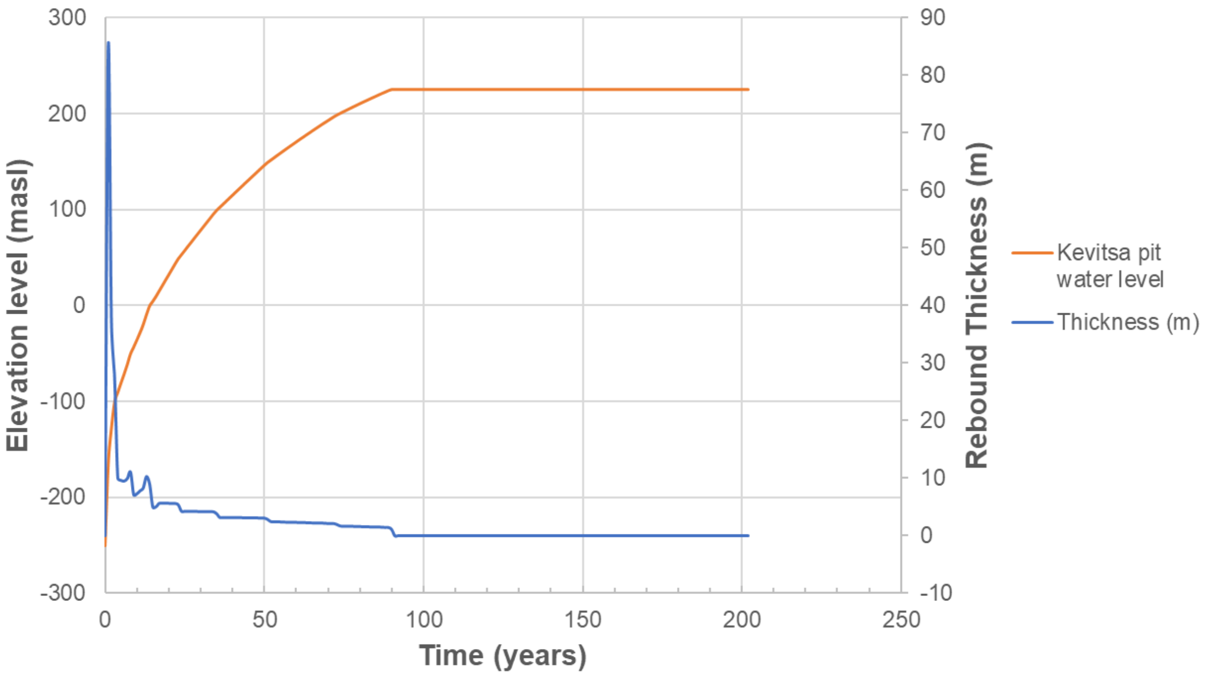

Figure 3-3. Rebound curve for Scenario VE0+

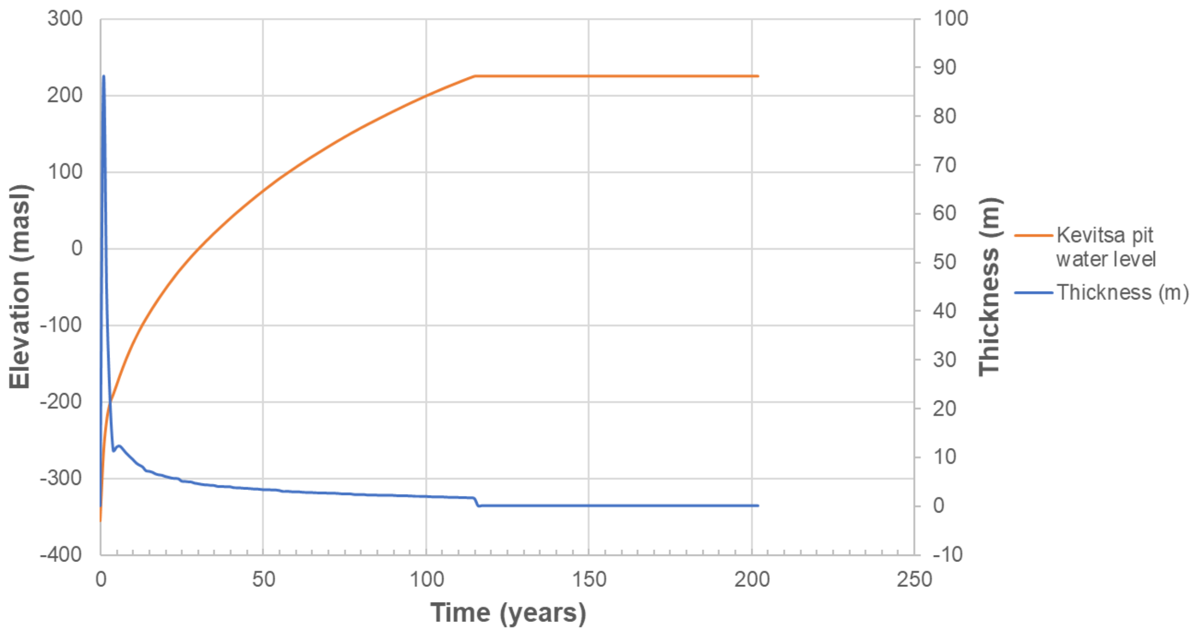

Figure 3-4. Rebound curve for Scenario VE1.3

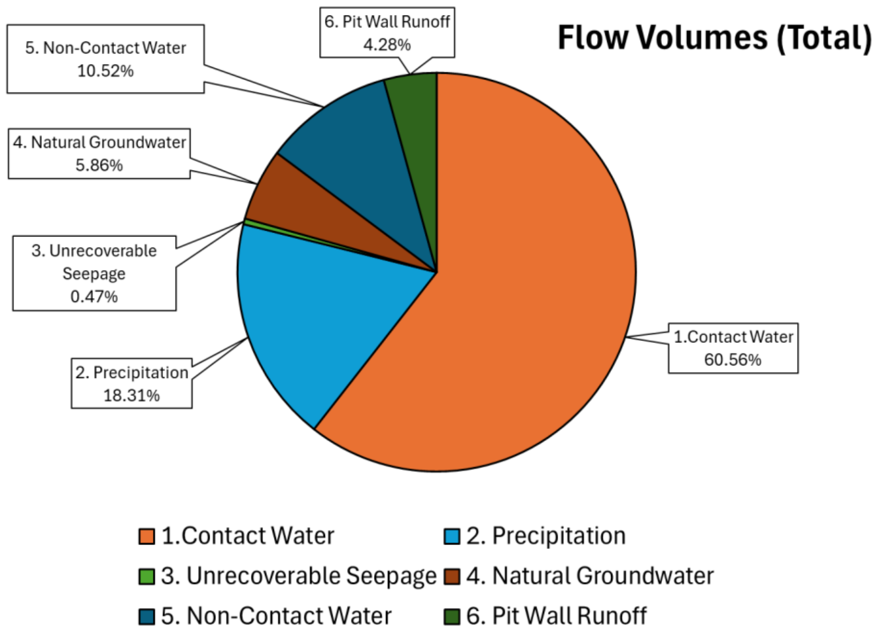

Figure 3-5. Contribution of total inflows in Scenario VE0+ pit

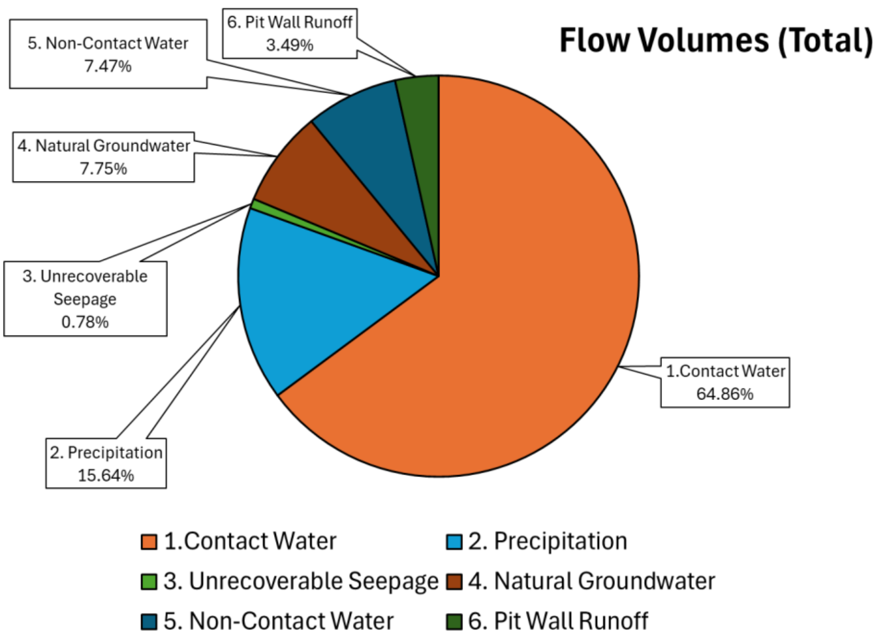

Figure 3-6. Contribution of total inflows in Scenario VE1.3 pit

3.2. Water Quality Inputs

The water qualities and input chemistries for each inflow are described in the following sub-sections.

Overall, the water qualities are dominated by the contact water comprising approximately 60% of the overall loading for Scenario VE0+ (Figure 3-7), and over 50% of the total loading for Scenario VE1.3 (Figure 3-8). Overall contributions of TDS from each of the inflows across the modelling periods are included in Figure 3-7 for Scenario VE0+, and in Figure 3-8 for Scenario VE1.3.

3.2.1.1. Contact Water Chemistry

The contact water is a mix of the contact water reservoir flows and recoverable WRSF seepage outlined in the SRK (2025) GoldSim water balance. The chemistries of each flow were mixed according to their flow proportions at each time step.

The input water chemistry for the contact water pond is sourced from the SRK (2025) GoldSim model, whilst the input chemistry for recoverable WRSF seepage is sourced from the MEM (2024) geochemical dataset (See Data Sources, Appendix A). The MEM dataset indicates an expected decrease in the contact water chemical loading, due to reduction in reactivity resulting from the placement of a cover systems on the WRSF. The variation over time for the contact water is shown for Scenario VE0+ in Figure 3-9 to Figure 3-11, and for Scenario VE1.3 in Figure 3-12 to Figure 3-14, for a range of parameters including total nitrogen, sulphate, and TDS. The average contact water input chemistry is included in Table 3-2 for Scenario VE0+, and in Table 3-3 for Scenario VE1.3.

3.2.1.2. Precipitation Chemistry

Precipitation chemical data were obtained from freely available public data at the Quality Assurance/Science Activity Centre (https://qasac-americas.org). Representative results were obtained from Lab 700014 Finland, and Study 70.

The rainfall chemistry (and snowmelt on the pit wall) remains at a constant geochemical concentration throughout the modelling period, with a TDS of 7.0 mg/l. The inputs are included in Table 3-2 for Scenario VE0+, and in Table 3-3 for Scenario VE1.3.

3.2.1.3. Groundwater Chemistry

Groundwater baseline monitoring data for the mine site were provided by Boliden. The locations of the groundwater monitoring wells can be found in WSP (2024). The groundwater monitoring wells included in

Table 3-1 were used to calculate average concentrations. The groundwater inflow has a single input water quality and does not vary with time. The concentration of TDS is 66.7 mg/l for both scenarios.

The inflow chemistry for groundwater is available in Table 3-2 for Scenario VE0+, and in Table 3-3 for Scenario VE1.3.

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Table 3-1. Groundwater monitoring wells

Well ID	No.
GTK_PV	1-94, 2-94, 3-94, 4-94
KevG	-1, -2, -3, -4, -5, -6. -7, -10, -11, -12, -14, -15, -16, -19, -20, -23
PVP	04-04, 14-04, 10-10, 32-04, 37-04
YPVP	1-10, 2-10, 3-10, 4-10, 5-10, 6-10

3.2.1.4. Non-contact Water Chemistry

The WRSF runoff and natural catchment terms included in the water balance have identical water chemistry in the SRK (2025) GoldSim dataset. These flows have therefore been grouped as a combined flow volume with the same chemistry as ‘non-contact water’. Data after 01/12/2049 were not provided. As there are no data beyond this time, the data have been conservatively repeated on a yearly seasonal basis after 2049.

The average inflow chemistry for the non-contact water chemistry is available in Table 3-2 for Scenario VE0+, and in Table 3-3 for Scenario VE1.3.

3.2.1.5. Unrecoverable Seepage Chemistry

The unrecoverable seepage chemistry has the same seepage chemistry as the recoverable seepage, however, as an inflow it will be diluted by groundwater at the point of entry into the pit. Values for diluted constituents of concern were provided by the contaminant transport modelling (WSP, 2025b) team after modelling a dilution factor. Other input constituents were conservatively assumed at a dilution factor of 2.

The unrecoverable seepage has a single input chemistry which does not vary with time across the modelling period, available in Table 3-2 for Scenario VE0+, and in Table 3-3 for Scenario VE1.3.

3.2.1.6. Pit Wall Runoff

The pit wall runoff input is a calculated input for the hydrodynamic modelling in CE-QUAL-W2, as presented in Section 4.1.1. The pit wall runoff chemistry is calculated relative to the groundwater rebound and mass balance calculations for the overall PHREEQC pit lake water quality modelling. Further description of the development of the pit wall runoff and pit wall runoff source term for the hydrodynamic modelling is included in Section 3.3.1.

Table 3-2. Inflow chemistries used in the Scenario VE0+ models

Parameters	Units	Precipitation	Contact Water	Unrecoverable WRSF Seepage	Non-Contact Water	Groundwater
		Input	Average	Input	Average	Input
pH	pH Unit	5.01	7.50	6.50	6.50	5.88
TDS	mg/L	7.00	1,929	106	3.56	66.7
Alkalinity	mg/L as $CaCO_3$	-	106	95.0	73.9	24.2
Sulphate	mg/L	1.97	1,194	97.9	1.96	7.83
Chloride	mg/L	1.55	92.5	6.50	1.37	1.25
Cadmium	mg/L	-	0.0002	0.0002	4.13E-05	0.0006
Cobalt	mg/L	-	0.0844	0.0100	0.0003	0.0072
Copper	mg/L	-	0.0478	0.0076	0.0008	0.0102
Lead	mg/L	-	0.0012	0.0004	0.0001	0.0011
Mercury	mg/L	-	1.25E-05	1.94E-05	1.04E-05	5.00E-05
Nickel	mg/L	-	1.61	0.156	0.0033	0.0197
Zinc	mg/L	-	0.0034	0.0055	0.0007	0.0140
Total Nitrogen	mg/L	1.90	16.5	1.00	0.222	0.607
Phosphorus	mg/L	-	0.0405	0.0304	0.0046	0.0743

Table 3-3. Inflow chemistries used in the Scenario VE1.3 models

Parameters	Units	Precipitation	Contact Water	Unrecoverable WRSF Seepage	Non-Contact Water	Ground-water
		Input	Average	Calculated	Average	Input
pH	pH Unit	5.01	7.50	6.50	6.50	5.88
TDS	mg/L	7.01	1,211	877	102	66.7
Alkalinity	mg/L as $CaCO_3$	-	80.4	95.0	73.9	24.2
Sulphate	mg/L	1.97	716	97.5	1.98	7.83
Chloride	mg/L	1.55	73.5	7.00	1.37	1.25
Cadmium	mg/L	-	0.0002	0.0002	3.96E-05	0.0005
Cobalt	mg/L	-	0.0575	0.0100	0.0003	0.0072
Copper	mg/L	-	0.0331	0.0077	0.0009	0.0102
Lead	mg/L	-	0.0004	0.000459	0.000101	0.0011
Mercury	mg/L	-	1.07E-05	2.02E-05	1.0385E-05	5.00E-05
Nickel	mg/L	-	1.08	0.156	0.0033	0.0197
Zinc	mg/L	-	0.0025	0.0057	0.00070	0.0140
Total Nitrogen	mg/L	1.90	12.5	1.00	0.230	0.607
Phosphorus	mg/L	-	0.0300	0.0315	0.00472	0.0743

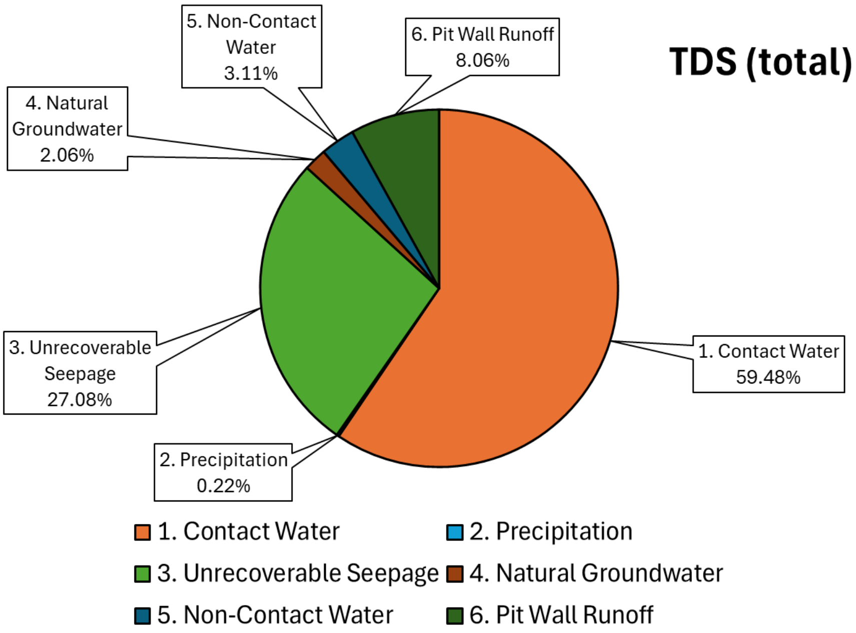

Figure 3-7. Contribution of TDS in the Scenario VE0+ Stage 4 pit

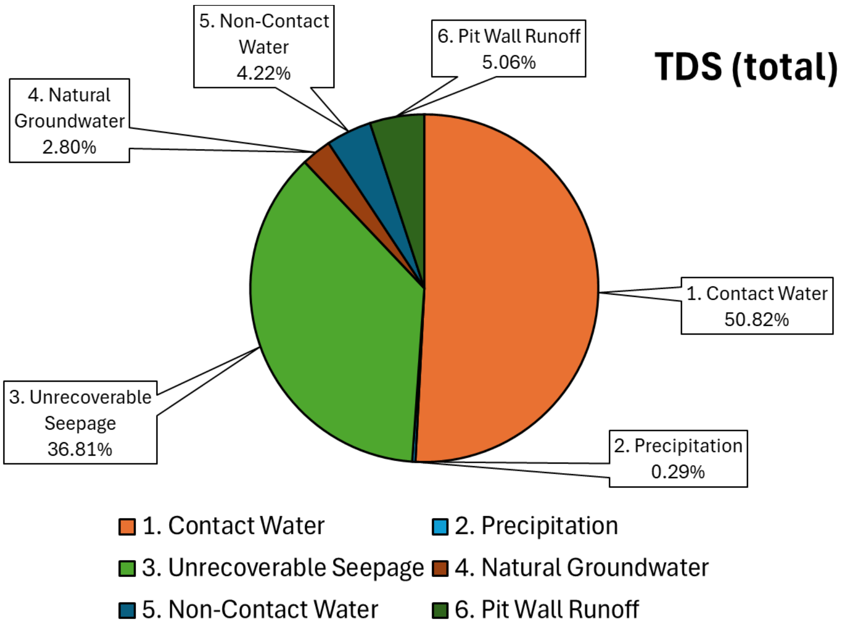

Figure 3-8. Contribution of TDS in the Scenario VE1.3 Stage 5 pit

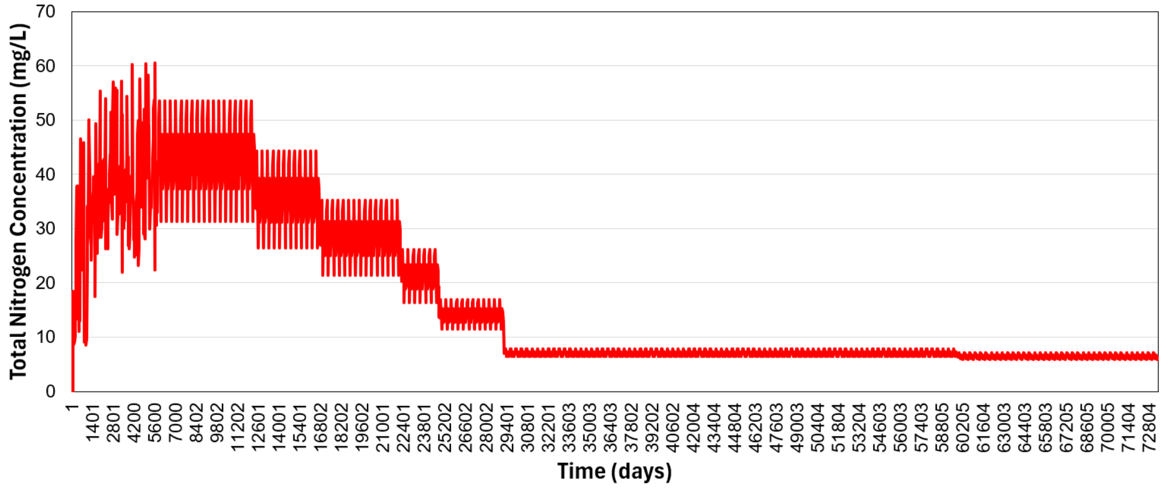

Figure 3-9. Total Nitrogen concentration (mg/l) of the contact water for Scenario VE0+

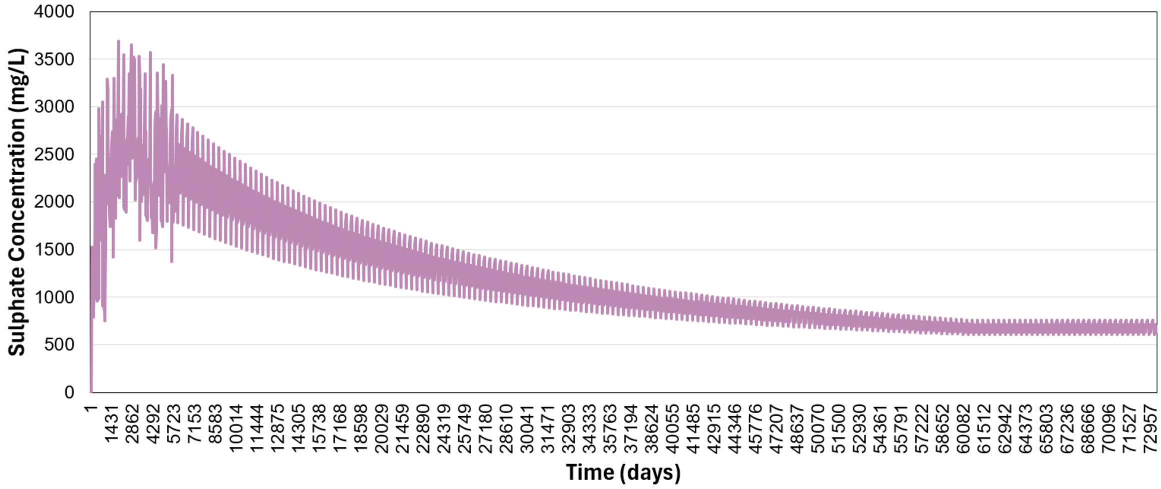

Figure 3-10. Sulphate concentration (mg/l) of the contact water for Scenario VE0+

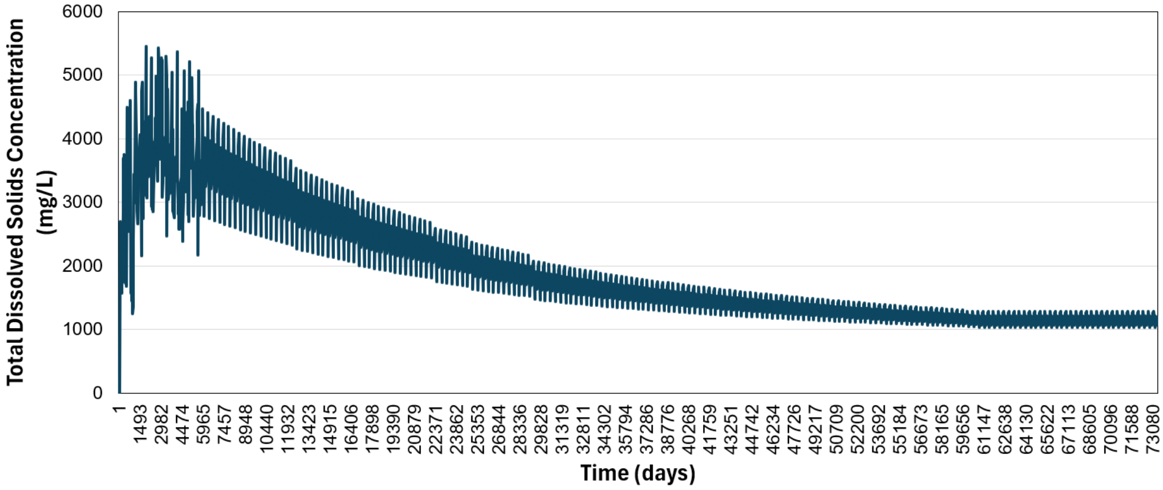

Figure 3-11. Total Dissolved Solids (TDS) concentration (mg/l) of the contact water for Scenario VE0+

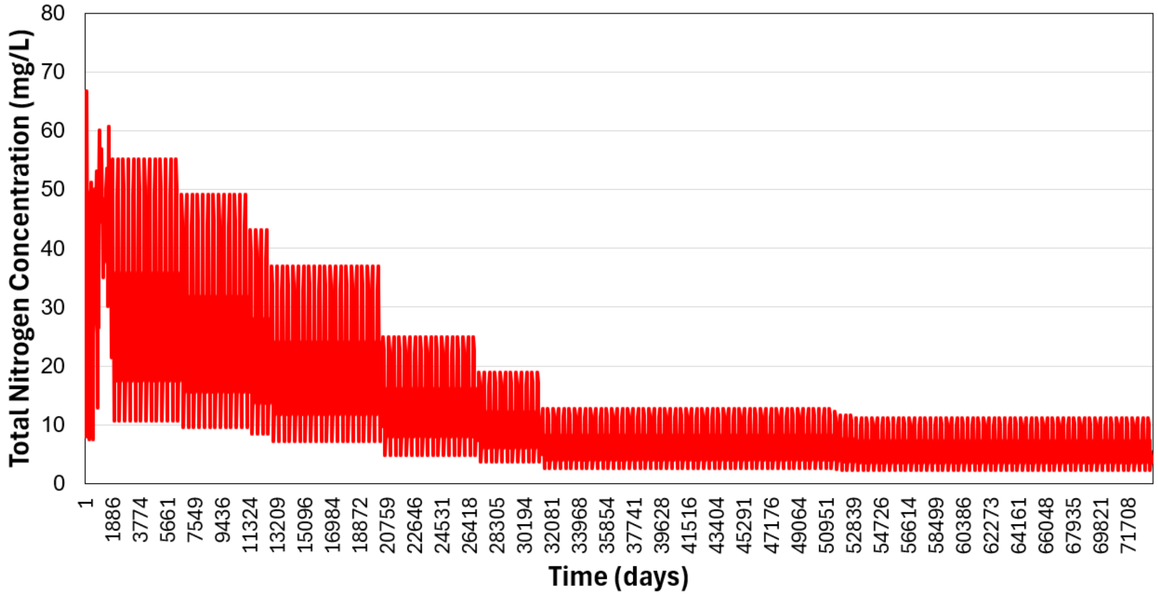

Figure 3-12. Total Nitrogen concentration (mg/l) of the contact water for Scenario VE1.3.

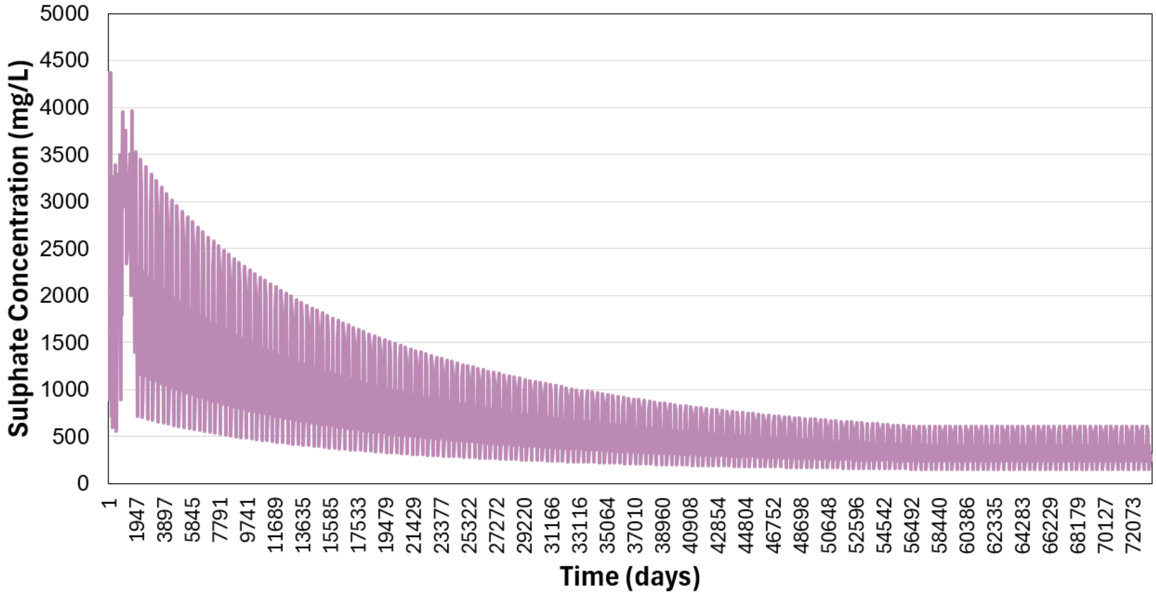

Figure 3-13. Sulphate concentration (mg/l) of the contact water for Scenario VE1.3

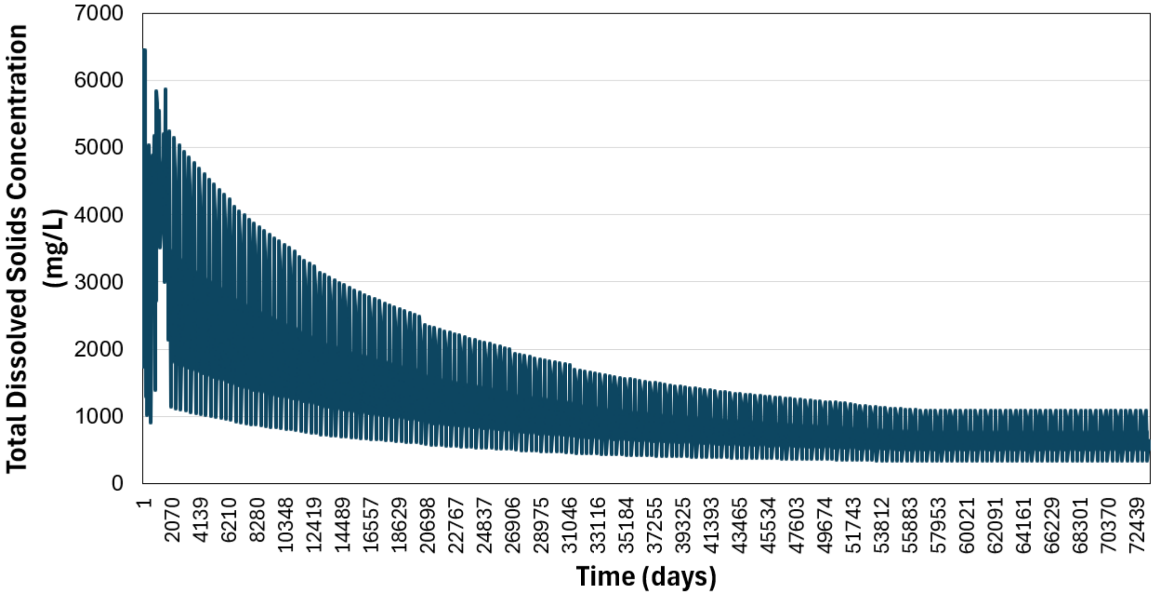

Figure 3-14. Total Dissolved Solids (TDS) concentration (mg/l) of the contact water for Scenario VE1.3

3.3. Thermodynamic Modelling Methodology

3.3.1. Pit Wall Runoff

3.3.1.1. Pit Wall Runoff Modelling Approach

The pit wall runoff is a direct inflow to the pit lake and is generated as precipitation falls on the exposed pit walls and flows toward the open pit. Direct precipitation reacts with a reactive rind of weathered and oxidised materials exposed on the walls of the pit which will readily react with the runoff across it, in addition to the highly zone extending into the walls from blasting of the pit (Figure 3-15).

This inflow source term is calculated initially within Excel followed by modelling in PHREEQC, to provide an updated water quality (i.e., TDS) for the hydrodynamic modelling. Within the thermodynamic modelling, the pit wall runoff chemical loads are calculated along with the other inflows in Excel, and the overall pit lake water quality is modelled in PHREEQC. The quantity and quality of the runoff is influenced by several factors, including rainfall volumes, surface area of exposed walls, and the lithological composition of the pit walls.

3.3.1.2. Pit Wall Runoff

As the pit lake fills over time, the water level within the pit will progressively submerge portions of the pit wall. This results in a dynamic process, shown in Figure 3-18, and described here:

- The exposed surface area decreases as more of the pit wall becomes submerged with the rebound of the water in the lake (as shown in Figure 3-3 (VE0+) and Figure 3-4 (VE1.3);
- Runoff quantity decreases as the catchment area decreases;
- Runoff quality changes as the proportion of a given exposed lithology changes as the pit fills. For example, lithologies with higher sulphide content may contribute more acidity and dissolved metals to the runoff load; and
- Runoff loads (the product of quantity and quality) vary temporally, being higher during wetter periods and lower during dry seasons, consistent with climatic inputs as discussed in Section 3.1.

While the pit wall runoff is an important source term in the water balance and load calculations, its contribution is generally small compared to other inflows, in particular contact water and as can be seen in the total volume contributions included in Figure 3-5 for Stage 4 (VE0+) and in Figure 3-6 for Stage 5 (VE1.3).

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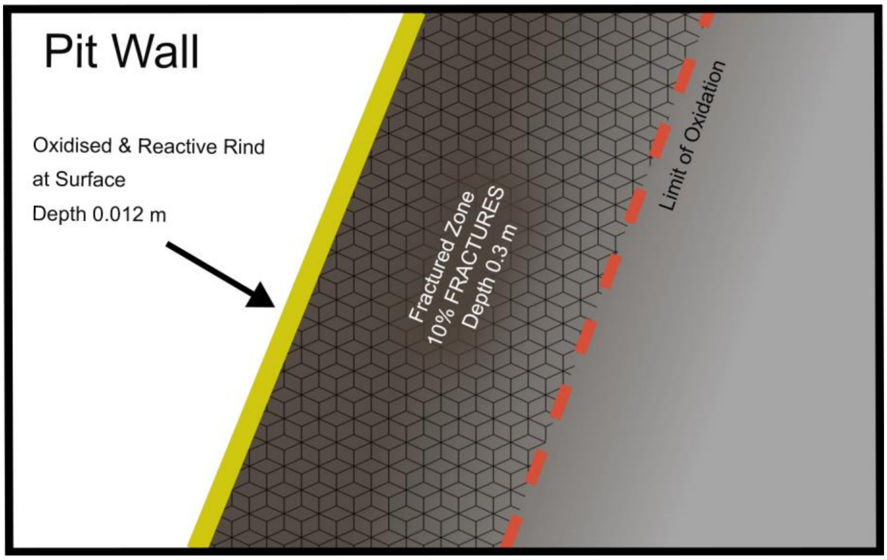

Figure 3-15. Conceptualisation of the pit wall runoff reactive mass and scaling

3.3.1.3. Pit Wall Surface Areas

The block model for the open pit and waste code mapping provided by Boliden were used to calculate the areas of exposure lithologies in the pit wall using Leapfrog. The analysis was based on five waste material classifications Usable Waste (USW), Unusable Waste (UNW), Capsulated Waste (CW), Environmental Waste (EW) and Ore as developed and analysed by MEM (2024). These waste materials have been defined by their sulphur grades alongside other parameters (Table 3-4).

Table 3-4. Waste Material Classification System

Lithologies or Waste type	Sulphur grade	Other parameter
Usable Waste - USW	0.3%	Ni <0.1% NIS
Unusable Waste - UNW	0.3-0.8%	N/A
Capsulated Waste - CW	>0.8%	N/A
Ore - HG	N/A	NSR >=15=< (65.3*NiS) + (43.4*Cu) + (7.1*Pt) + (7.2*Pd) + (8.2*Au) + (83.4*CoS)
Environmental Waste - EW	0.3-0.8%	Ni <0.1% NIS

The block model was used to quantify the surface area and proportion of each lithology at 12m depth intervals within the pit lake, as shown in Figure 3-16 and Figure 3-17.

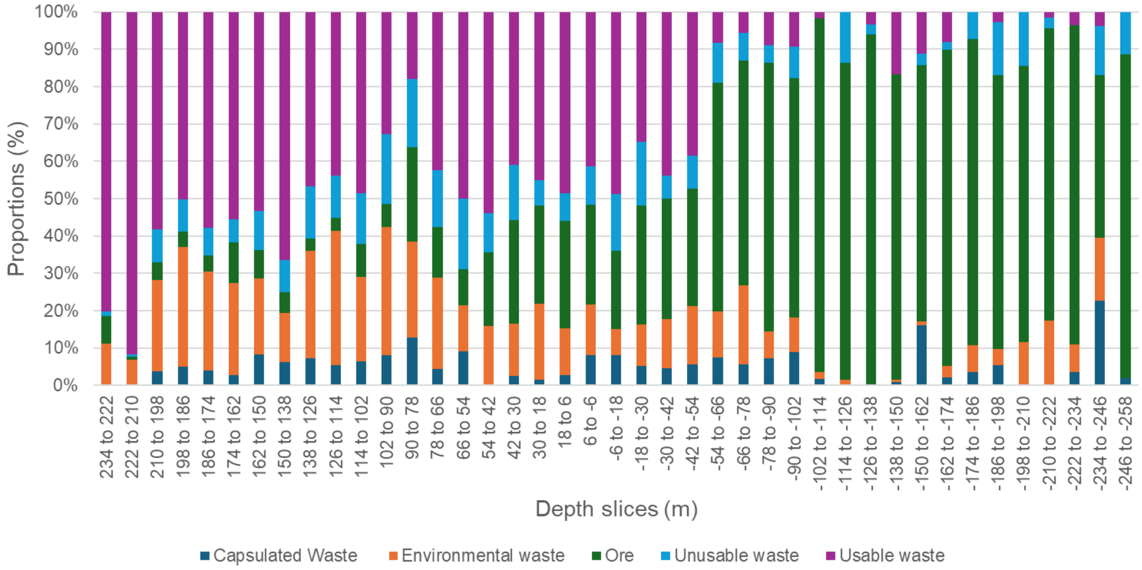

Figure 3-16: Proportion of the lithologies at each depth interval (Scenario VE0+)

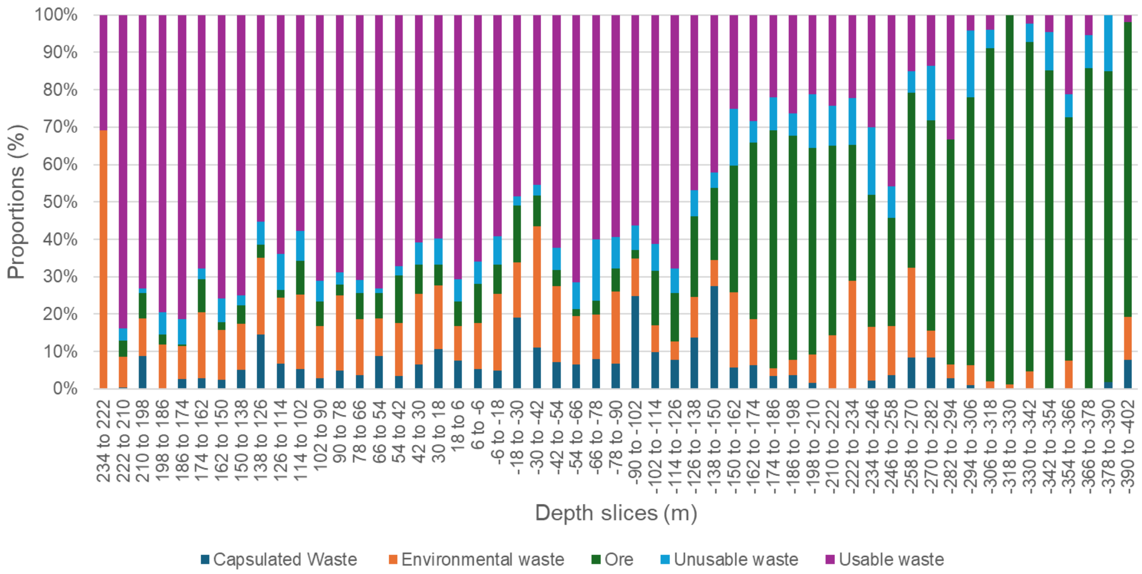

Figure 3-17: Proportion of the lithologies at each depth interval (Scenario VE1.3)

The rebound curve from the water balance was used to calculate the exposed pit wall area above the water level at each model time step (i.e., one year intervals). This value is used in combination with the waste class surface areas to define the reactive area for runoff at each time interval as well as the rebound surface area.

3.3.1.4. Geochemical Inputs

The chemical mass release rate from the pit wall was scaled from HCT data of the various waste categories. Over 150 weeks of HCT data was available for the USW (<22 mm), UNW (<22 mm), UNW (22-50mm) and CW lithologies as described in MEM (2024) and provided in the geochemical datasets from MEM (2024). An average of the long-term seepage after 20 weeks was calculated for each cell and is shown in Table 3-5.

The categories developed by MEM for the HCT data were used as follows:

1. The USW cell average was used to represent the USW waste class release rate;
2. The combined average of two UNW cells was used to represent chemical release rate from the UNW waste category;
3. The UNW (<22mm) cell was used to represent from the release rate of the ore class given this is waste category has most metals as expected from a more ore-like waste;
4. The CW cell was used to represent the release rate from exposed capsulated waste class; and
5. The release rate from the exposed surface area of the EW waste category was calculated from the UNW average with the exception of nickel rich material. This is because the EW is the most "useable" waste of the UNW and has a distinctly lower nickel concentration that reflects the values of the USW.

Table 3-5. Average HCT data used in the PHREEQC Calculations

Parameters	HCT	HCT 1	HCT 2	HCT 3	HCT 4
	Lithology	USW	UNW	CW	UNW
	Units	Average	Average	Average	Average
pH		8.21	8.09	8.05	7.56
Alkalinity	mg/kg/yr as $CaCO_3$	40.0	34.4	95.4	10.4
Sulphate (as SO_4)	mg/kg/yr	135	412	447	54.4
Chloride	mg/kg/yr	3.47	3.39	8.21	1.75
Cadmium	mg/kg/yr	2.67E-05	2.19E-05	1.11E-04	2.58E-05
Cobalt	mg/kg/yr	0.0003	0.0109	0.0088	0.0214
Copper	mg/kg/yr	0.0006	0.0017	0.0052	0.0009
Lead	mg/kg/yr	0.0001	0.0001	0.0003	0.0001
Mercury	mg/kg/yr	3.02E-06	2.37E-06	1.29E-05	3.36E-06
Nickel	mg/kg/yr	0.0162	0.281	0.260	0.314
Zinc	mg/kg/yr	0.0009	0.0009	0.0038	0.0011
Total Nitrogen	mg/kg/yr	0.342	0.132	0.584	0.159
Phosphorous	mg/kg/yr	0.0050	0.0055	0.0227	0.0057

3.3.1.5. Pit Wall Runoff Calculation

PHREEQC was used to model the water quality of pit wall runoff solutions in both VE0+ and VE1.3 to develop a separate source term for the hydrodynamic modelling. For the the overall pit lake thermodynamic modelling the pit wall runoff was calculated as mass loading in Excel and modelled along with the other inflows in PHREEQC.

The total load from the pit wall runoff is proportional to the sum of the chemical loading from each lithology exposed, in addition to the load from the precipitation water quality interacting with the pit walls.

The reactive mass of each lithology was calculated using the following scaling factors:

1. Fracture zone thickness;
2. Rind thickness; and
3. Fracture density.

The reactive mass of each lithology was calculated from the total surface area and scaled using these scaling factors. An approximate rock density, for an olivine pyroxenite or gabbro dominant lithology as is the case at Kevitsa, of 3,000kg/m^3 was used to calculate the reactive mass of each lithology at each model time step.

For each model step the following equation was used to calculate the load:

$$Release\ load = \left(\sum lithology\ reactive\ mass\ \times lithology\ release\ rate\right) + snowpack\ melt\ volume\ \times snowpack\ melt\ water\ quality$$

The input concentration to PHREEQC for the pit wall runoff was then calculated by dividing the release load by the combined inflow volumes provided in the SRK GoldSim dataset, for pit wall runoff plus the volume of snowpack release on the pit wall.

3.3.1.6. Groundwater Rebound

The pit lake rebound calculation predicts the geochemical and hydrological processes occurring as the pit fills. This calculation focuses on how oxidation products formed in fractures and exposed surfaces during mining are mobilized as groundwater rebounds and the pit lake forms. The conceptual diagram shown in Figure 3-18 shows the progressive evolution of pit lake conditions.

During the life of mine, the pit walls are exposed to atmospheric oxygen and highly fractured zones are created from blasting. Oxidation occurs on the surface and within these fractures, producing readily reactive zones, during operations. At the start of closure (t = n), groundwater rebound begins as pumping ceases. The rising water in the pit lake along with the rebounding groundwater will flush through the oxidised and fractured zones, mobilising the accumulated oxidation products, which then enter the developing pit lake as a chemical loading. This is in addition to the pit wall runoff across the surface of the pit walls. Flushing of these oxidised zones persists but at decreased rates as the pit lake fills and submerges the pit walls.

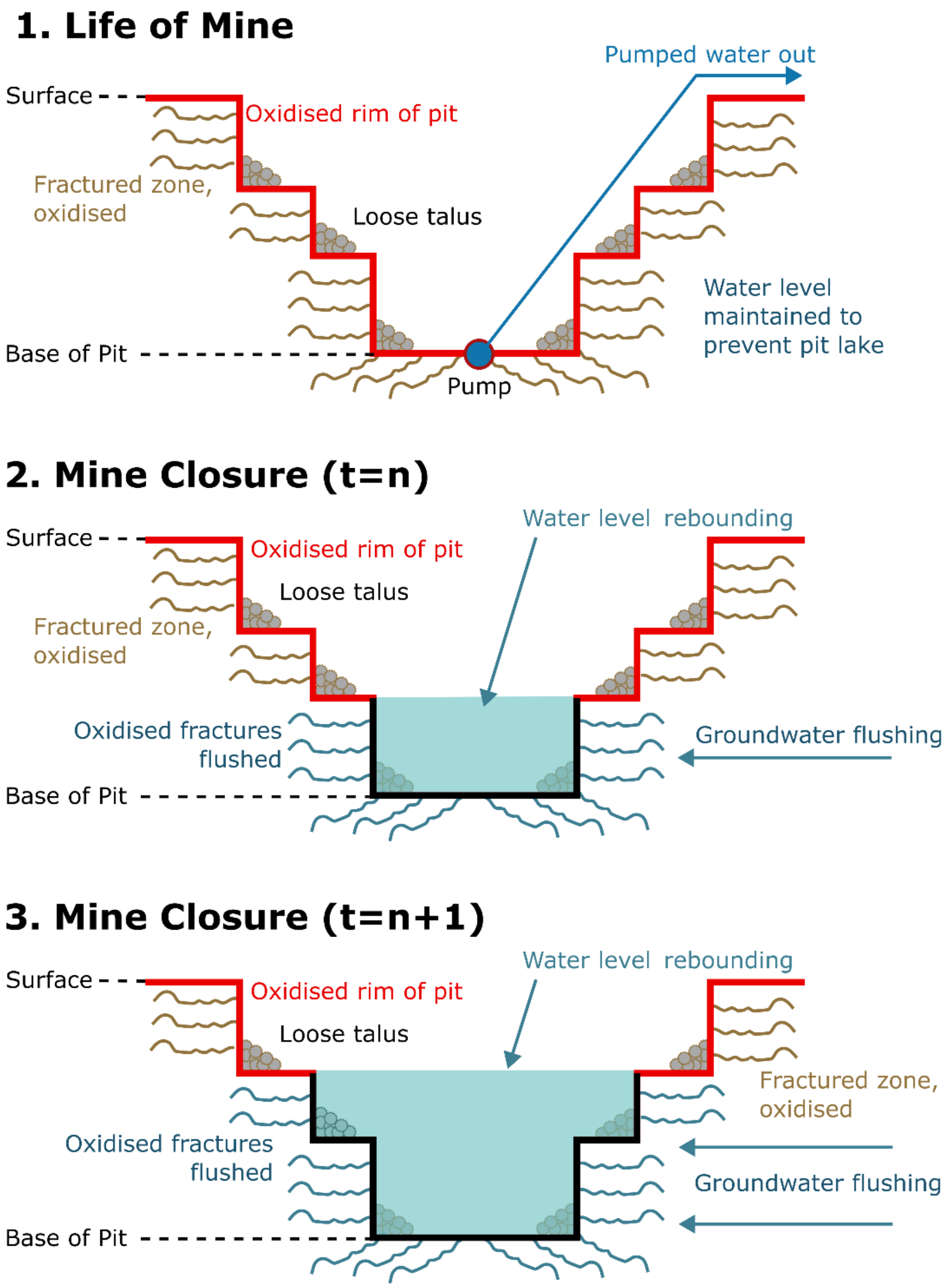

Figure 3-18. Conceptual diagram of groundwater rebound and the geochemical interactions with the pit wall

3.3.1.7. Groundwater Rebound Calculation

Following pit closure, active dewatering ceases, and groundwater levels gradually recover toward pre-mining conditions. This rebound process generates a net inflow of groundwater into the developing pit lake. The calculation of groundwater rebound loads is a key component of the pit lake water balance and geochemical modelling, as it represents a continuous, long-term source of inflow.

The groundwater rebound rate is estimated using the SRK GoldSim water balance to determine inflow rates for each modelled time step (as shown in the rebound curves in Figure 3-3 and Figure 3-4). After each time step, the change in pit lake depth is calculated and apportioned across the relevant lithologies.

Groundwater loads are then calculated as the product of inflow volume and the representative concentration for each lithological unit. These loads are subsequently integrated into the overall pit lake load balance.

3.3.2. Pit Lake Calculation

The pit lake chemistry is calculated using a mass balance approach, which accounts for all sources of inflow to the pit lake. For each chemical parameter, the contribution from each inflow source is determined by multiplying the inflow volume by the concentration of the parameter in that source, as described in the conceptual flow charts (Section 2.2.2).

The total geochemical contributions are summed to give the total mass of each chemical entering the lake. The resulting total mass is divided by the total inflow volume to calculate the average concentration in the pit lake. Evaporation losses and outflows as spillage, as determined from the water balance, are subsequently subtracted to account for concentration effects due to water loss.

The final calculated solutions are modelled in PHREEQC to provide the thermodynamic modelling. This approach allows the model to capture the combined effects of groundwater rebound, surface runoff, and pit wall contributions on the evolving pit lake chemistry over time.

3.3.3. Solubility Controls and Trace Element Adsorption

The calculated solutions were brought to thermodynamic equilibrium with the aqueous species, mineral phases, and atmospheric pO_2 and pCO_2 in PHREEQC. In the fully mixed scenario and in the upper-layer of the stratified scenario, thermodynamic processes that consume O_2 and CO_2 were allowed to proceed while equilibrium with atmospheric gases was maintained. In contrast, for the stratified lower layer, equilibrium with the atmosphere was not maintained; instead, pO_2 and pCO_2 were allowed to drift as a result of these processes, reflecting the potentially reducing conditions that can be observed in monimolimnion waters.

This assumption also accounts for carbonate equilibrium shifts under low-gas exchange environments. The MINTEQ version 4 (minteq.V4) thermodynamic database (Allison et al. 1990), as provided with PHREEQC, was selected for the simulations as it includes the full suite of metals relevant to the project geochemistry. Mineral phases which can be reasonably expected to precipitate under the geochemical conditions present at the mine site are outlined in Table 3-6. These minerals were allowed to precipitate if their saturation index was greater than zero.

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For the pit lake components, including the pit wall runoff, an initial PHREEQC model was run to determine alkalinity. Alkalinity was controlled based on equilibration with atmospheric CO_2 and the speciated solution was charge balanced against pH. This allowed for the correction of the scaled up alkalinity values obtained by mass balance.

The model uses the properties of ferrihydrite published by Dzombak and Morel (1990) with a surface site density of 0.2 moles of weak sites (HFO_w) and 0.005 moles of strong sites (HFO_s) per mole of ferrihydrite. Any HFO/ferrihydrite will therefore originate from the precipitation of oversaturated mineral phases that develop upon solution mixing. The Donnan approach was used to calculate the composition of the ferrihydrite diffuse layer. A default thickness of 10-8 m was used (Parkhurst and Appelo, 2013).

Table 3-6. Equilibrium Phases considered in the PHREEQC models

Mineral Name	Formula present in Minteq.v4
Barite	$BaSO_4$
Calcite	$CaCO_3$
Ferrihydrite	$Fe(OH)_3$
Gibbsite	$Al(OH)_3$
Gypsum	$CaSO_4 \cdot 2H_2O$
Magnesite	$MgCO_3$
Quartz	SiO_2

Equilibrium Phase in the fully mixed pit lake and the upper layer of the stratified pit lake	Partial Pressure
CO_2	$10^{-3.5}$
O_2	$10^{-0.67}$

Equilibrium Phase in the lower layer of the stratified pit lake	Partial Pressure
CO_2	$10^{-2.4}$
O_2	$10^{-20.8}$

3.4. Hydrodynamic Model Methodology

3.4.1. Meteorological Inputs

Meteorological input data required for the hydrodynamic pit lake modelling include:

- Air temperature (°C);
- Dew point temperature (°C);
- Wind speed and direction (m/sec; radians, measured east of north); and
- Cloud cover (% of sky area).

Hourly data are required to better model the changes across a day within the pit lake using CE-QUAL-W2. An hourly time-series was constructed for each of these inputs during the 200-year modelling time periods based on climate forecast data from the RCP4.5 climate dataset, and the Finnish Meteorological Institute. The data and sources are included in Table 3-7.

The RCP4.5 dataset incorporates climate forecasts as per Representation Concentration Pathway (RCP) 4.5, provided by Boliden. This dataset was used for air temperature, and dew point temperature (calculated from the air temperature and relative humidity) and provides changing temperature forecasts. For scenario VE1.3, the final two years of data repeat from the beginning of the data as the data extends only until 2244. The dataset is provided as daily timesteps, for the construction of an hourly dataset in CE-QUAL-W2, the data for any given day are used for all time steps of that day.

All other meteorological inputs (wind speed, wind direction, cloud cover, solar radiation) were based on historical data from the Finnish Meteorological Institute, Sodankylä Tähtelä weather station, located approximately 40 km southwest from the Kevitsa pit lake. The Finnish Meteorological Institute has freely available meteorological data to download (https://en.ilmatieteenlaitos.fi/download-observations). The data were downloaded using an hourly time interval from 2004 to 2023 (20 years inclusive) which are repeated across the 200-year time steps of each modelling scenario. Data gaps were treated by using the values of the previous time step.

Solar radiation values were not added as an input into the model. Precipitation was added as a separate inflow based on the water balance calculations as indicated in Section 3.1.

Table 3-7. Meteorological data and sources for CE-QUAL-W2

Input	Data Source
Air Temperature (°C)	Daily RCP4.5 (until 2244).
Dew Point (°C)	Calculated from daily relative humidity and temperature in RCP4.5 (until 2244)
Wind (m/sec)	Sodankylä Tähtelä hourly monitoring (2004-2023)
Wind Direction (radians)	Sodankylä Tähtelä hourly monitoring (2004-2023)
Cloud Cover (value/10)	Sodankylä Tähtelä hourly monitoring (2004-2023)

3.4.2. Hydrological Inputs

The hydrological inputs for the CE-QUAL-W2 modelling are the same as those used in the thermodynamic modelling, based on the water balance discussed in Section 3.1.

The model starts at the point of closure, as such there is no initial water volume stored. Inflows were placed with in the upstream segments of the waterbody according to their approximate pathway into the pit. The flows were also vertically placed at the depths they will enter the pit, i.e. surface components at the surface and sub-surface placed at depth.

As discussed in Section 2.1.2, the contact water was placed at 40 m below the water surface, as previously modelled by Lorax (2019) for the base-case model. This flow was added in Segment 7, the centre and deepest segment of the pit lake. The pit segmentation can be seen in Figure 2-9 for Stage 4 (VE0+) and Figure 2-10 for Stage 5 (VE1.3).

In CE-QUAL-W2, contact water placement was achieved by adding separate tributaries based on 40 m increments as the pit lake fills, informed by the rebound curve of the water balance. For every 40 m increment, a new tributary was placed at the relevant timing, and once the pit was full, the contact water was placed at 40 m below the 225 masl spillway elevation.

Precipitation was added to the CE-QUAL-W2 modelling as a distributed tributary which is spread across the lake on the surface, and across the segments. Non-contact water is added to the surface, entering in the north/north-east of the pit in segment 4. Pit wall runoff is placed upstream in segment 4 and allowed to fill across the entire depth of the pit.

Unrecoverable seepage reports to the pit in the upper 40 m, as informed by the groundwater modelling. This is considered as a shallow groundwater flow, separated from the natural background groundwater flow which is placed from the base of the pit to 40 m below the pit surface. These sub-surface flows were added to segment 6 upstream. No groundwater losses are modelled for the pit over the modelling period.

3.4.3. Chemical Inputs

The water quality inputs for the CE-QUAL-W2 modelling are the same as those used in the PHREEQC modelling, available in Section 3.2. Only TDS is simulated for the CE-QUAL-W2 modelling, and is used to predict water density, lake circulation, and stratification.

3.4.4. Temperature Inputs

Each inflow to the pit was assigned a temperature for the W2 modelling. A summary of the data and flows is included in Table 3-8.

Surface water flows were assigned monthly average air temperatures, using the RCP4.5 meteorological data (discussed in Section 3.4.1). This allowed for variations in temperatures across the years in the modelling period.

Sub-surface flows were assigned temperatures based on groundwater monitoring data provided by Boliden. Median values were calculated for shallower groundwater where the unrecoverable seepage reports to the pit (above a depth of 40 m), and for the overall groundwater median value used for the background natural groundwater. These values remained at a constant temperature over the modelling period. Temperatures below 0.5°C in the datasets were limited at 0.5°C.

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Table 3-8. Temperature inputs to CE-QUAL-W2

Flow	Data Source	Data Range
1. Contact Water To be pumped 40 m below surface	Monthly average, RCP4.5 data	0.5 to 16.7°C
2. Precipitation Surface flow	Monthly average, RCP4.5 data	0.5 to 16.7°C
3. Unrecoverable WRSF Seepage Shallow groundwater flow	Shallow groundwater monitoring data, median	3.05°C
4. Groundwater Deep groundwater flow	Groundwater (total depth) monitoring data, median	3.65°C
5. Non-Contact Water Surface flow	Monthly average, RCP4.5 data	0.5 to 16.7°C
6. Pit Wall Runoff Surface flow	Monthly average, RCP4.5 data	0.5 to 16.7°C

3.4.5. Model Co-efficients

Default coefficient values in the CE-QUAL-W2 control file were generally used for hydrodynamic and energy terms. Specific coefficients, mainly in the ice and heat exchange modules, were modified to reflect a northern environment based on previous WSP experience, including:

1. Water-ice heat exchange (HWICE): set to 15 W/m^2/°C.
2. Temperature above which ice formation is not allowed (ICET2): set to 4°C.
3. Ratio of reflection to incident radiation of ice (ALBEDO): set to 0.9.
4. Sediment temperature (TSED): set to 2°C.
5. Interfacial friction factor (FI) set to 0.15.
6. Wind shelter coefficient: 0.8.
7. Shade: 0.9.

4. Results

4.1. PHREEQC Geochemical Model

4.1.1. Pit Wall Runoff Results

The predicted pit wall runoff chemistry for scenarios VE0+ (Stage 4) and VE1.3 (Stage 5) over a 200-year simulation period can be seen in Figure 4-1. Key parameters shown below include pH, total dissolved solids (TDS), sulphate, and total nitrogen. Full results are available in Appendix B. Result summaries are included in Table 4-1 for Stage 4 (VE0+) and Table 4-2 for Stage 5 (VE1.3).

Both scenarios predict near-neutral to slightly alkaline conditions throughout the modelled time steps. pH stabilises at approximately 8.0 to 8.2 in scenario VE0+, whereas scenario VE1.3 remains slightly lower, stabilising around 7.5.

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TDS in scenario VE0+ gradually increases, peaking at 320 mg/L after 100 years, before stabilising. In contrast, scenario VE1.3 shows a progressive decline in TDS, reducing from initial concentrations above 250 mg/L to 100 mg/L at long-term equilibrium. These differences reflect variations in solute loading and dilution processes between the two scenarios.

Sulphate concentrations diverge between scenarios. In scenario VE0+, sulphate increases steadily, stabilising around 150–160 mg/L after 100 years. Conversely, scenario VE1.3 exhibits a consistent decline from 140 mg/L initially to 21 mg/L after 150 years.

Total nitrogen trends also vary significantly. Scenario VE0+ shows stable concentrations around 2 to 3 mg/L after an initial equilibration period. In Scenario VE1.3, nitrogen decreases progressively from between 4 and 5 mg/L to 1 mg/L by year 200.

Nitrogen was included in the mass balance source terms (based on HCT data, runoff, and contact water inputs) and carried through to PHREEQC for speciation and mixing. However, nitrogen was not subject to geochemical reaction modelling in PHREEQC, so the trends primarily reflect inflow concentrations rather than pit wall leaching, geochemical reactions, or biological processes (that consume nitrate).

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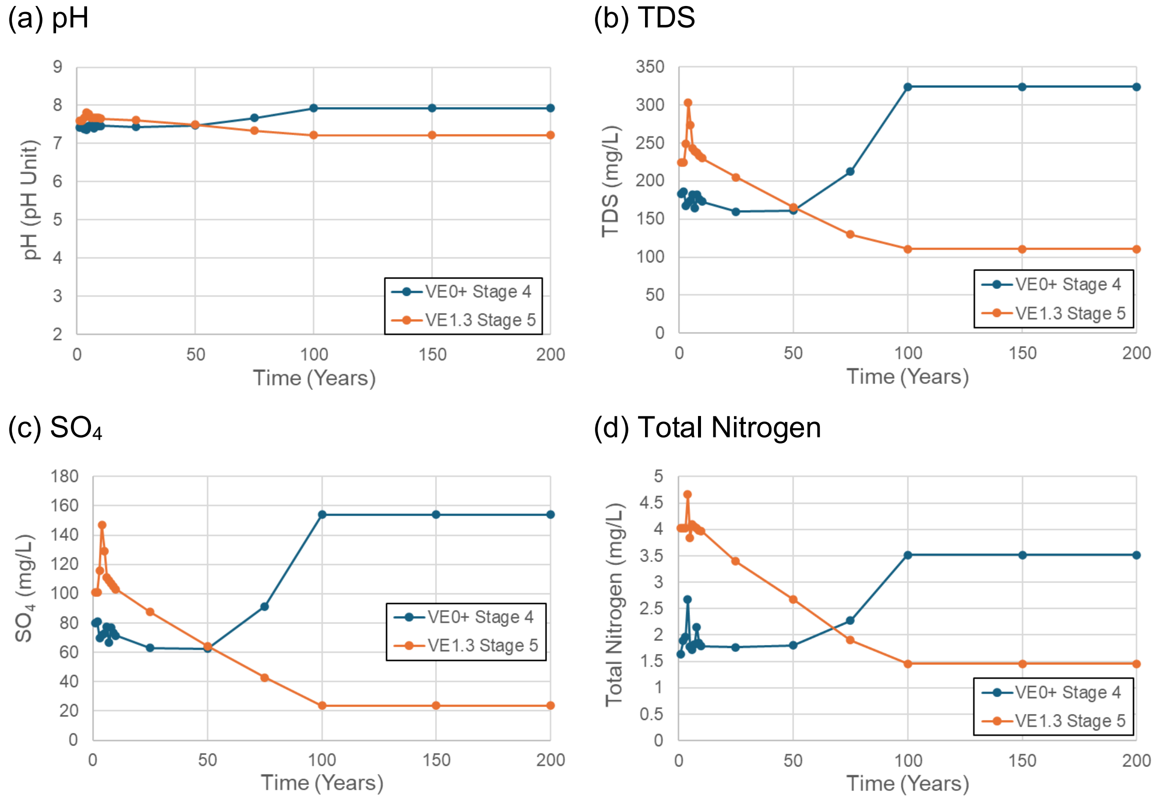

Figure 4-1. Predicted Pit Wall VE0+ and VE1.3. Chemistry – (a) pH; (b) TDS; (c) SO_4; (d) Total Nitrogen

Table 4-1. Summary of modelling results for Pit Wall Runoff for Scenario VE0+

Parameters	Units	Time (Years)															
		1	2	3	4	5	6	7	8	9	10	25	50	75	100	150	200
pH	pH Unit	7.42	7.45	7.37	7.36	7.45	7.48	7.41	7.48	7.47	7.47	7.43	7.47	7.67	7.93	7.93	7.93
Total Dissolved Solids	mg/L	183	186	168	171	174	182	164	182	176	173	160	161	212	324	324	324
Alkalinity	mg/L as $CaCO_3$	8.52	9.06	7.55	7.38	9.05	9.68	8.18	9.59	9.41	9.33	8.64	9.48	15.3	27.9	27.9	27.9
Sulphate	mg/L	80.2	81	69.9	71.7	72.9	77.5	66.7	77.1	73.6	71.4	62.9	62.5	91.4	154	154	154
Chloride	mg/L	1.44	1.53	1.40	1.58	1.44	1.51	1.37	1.60	1.51	1.47	1.37	1.44	2.11	3.60	3.60	3.60
Cadmium	mg/L	1.01E-05	1.05E-05	9.23E-06	9.71E-06	1.00E-05	1.07E-05	9.29E-06	1.08E-05	1.05E-05	1.02E-05	9.46E-06	9.77E-06	1.46E-05	2.48E-05	2.48E-05	2.48E-05
Cobalt	mg/L	0.0023	0.0023	0.0020	0.0021	0.0021	0.0022	0.0019	0.0022	0.0021	0.0020	0.0018	0.0015	0.0020	0.0025	0.0025	0.0025
Copper	mg/L	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004	0.0003	0.0003	0.0004	0.0006	0.0006	0.0006
Lead	mg/L	2.56E-05	2.64E-05	2.44E-05	2.57E-05	2.56E-05	2.71E-05	2.45E-05	2.75E-05	2.68E-05	2.63E-05	2.52E-05	2.69E-05	3.84E-05	6.68E-05	6.68E-05	6.68E-05
Mercury	mg/L	1.15E-06	1.20E-06	1.06E-06	1.11E-06	1.15E-06	1.23E-06	1.07E-06	1.24E-06	1.20E-06	1.17E-06	1.09E-06	1.12E-06	1.67E-06	2.82E-06	2.82E-06	2.82E-06
Nickel	mg/L	0.0351	0.0342	0.0286	0.0283	0.0285	0.0299	0.0254	0.0290	0.0272	0.0261	0.0205	0.0169	0.0218	0.0330	0.0330	0.0330
Zinc	mg/L	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0009	0.009	0.0009
Total Nitrogen	mg/L	1.64	1.89	1.96	2.68	1.77	1.72	1.82	2.15	1.85	1.79	1.77	1.81	2.27	3.52	3.52	3.52
Total Phosphorus	mg/L	0.0021	0.0022	0.0019	0.0020	0.0021	0.0022	0.0019	0.0022	0.0021	0.0021	0.0019	0.0020	0.0029	0.0048	0.0048	0.0048

Table 4-2. Summary of modelling results for Pit Wall Runoff for Scenario VE1.3

Parameters	Units	Time (Years)															
		1	2	3	4	5	6	7	8	9	10	25	50	75	100	150	200
pH	pH Unit	7.60	7.60	7.68	7.81	7.77	7.68	7.67	7.68	7.67	7.66	7.61	7.49	7.34	7.11	6.93	6.93
Total Dissolved Solids	mg/L	224	224	249	303	274	243	240	237	234	230	205	166	130	96.2	80.7	80.7
Alkalinity	mg/L as $CaCO_3$	13.0	13.0	15.5	21.3	19.4	15.5	15.3	15.5	15.2	14.7	13.1	9.84	6.84	3.97	2.61	2.61
Sulphate	mg/L	101	101	116	147	129	111	109	107	105	103	87.6	64.2	42.9	23.6	23.6	23.6
Chloride	mg/L	2.39	2.39	2.67	3.34	2.91	2.66	2.63	2.61	2.58	2.54	2.20	1.68	1.17	0.645	0.396	0.396
Cadmium	mg/L	1.51E-05	1.51E-05	1.76E-05	2.28E-05	2.02E-05	1.75E-05	1.74E-05	1.73E-05	1.70E-05	1.66E-05	1.42E-05	1.05E-05	7.10E-06	3.96E-06	2.44E-06	2.44E-06
Cobalt	mg/L	0.0025	0.0025	0.0028	0.0035	0.0031	0.0026	0.0026	0.0025	0.0025	0.0024	0.0020	0.0014	0.0008	0.0004	0.0002	0.0002
Copper	mg/L	0.0005	0.0005	0.0006	0.0007	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005	0.0004	0.0003	0.0002	0.0001	6.84E-05	6.84E-05
Lead	mg/L	3.75E-05	3.75E-05	4.31E-05	5.49E-05	4.90E-05	4.29E-05	4.26E-05	4.24E-05	4.19E-05	4.14E-05	3.70E-05	3.02E-05	2.39E-05	1.68E-05	1.16E-05	1.16E-05
Mercury	mg/L	1.70E-06	1.70E-06	1.99E-06	2.58E-06	2.29E-06	1.98E-06	1.97E-06	1.95E-06	1.92E-06	1.88E-06	1.60E-06	1.19E-06	7.95E-07	4.42E-07	2.71E-07	2.71E-07
Nickel	mg/L	0.0383	0.0383	0.0429	0.0532	0.0460	0.0386	0.0370	0.0358	0.0346	0.0335	0.0270	0.0184	0.0113	0.0061	0.0035	0.0035
Zinc	mg/L	0.0005	0.0005	0.0006	0.0008	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0004	0.0003	0.0001	8.69E-05	8.69E-05
Total Nitrogen	mg/L	4.02	4.02	4.03	4.67	3.84	4.10	4.06	4.02	3.99	3.97	3.40	2.68	1.90	1.01	0.557	0.557
Total Phosphorus	mg/L	0.0031	0.0031	0.0036	0.0046	0.0041	0.0035	0.0035	0.0035	0.0034	0.0033	0.0028	0.0021	0.0014	0.0008	0.0005	0.0005

4.1.2. Pit Lake Scenario VE0+

4.1.2.1. Stratified Pit Lake

Predicted pit lake chemistry for the VE0+ scenario is presented in Figure 4-2 and summarised in Table 4-3. The results indicate the predicted water quality of the Stage 4 pit under base-case stratified conditions over the 200-year modelled period. During the lake filling period from year 0 to 90, the model results are presented as mixed. Once the lake fills, the lake was assumed to be stratified from this point, as a forced condition for the thermodynamic modelling.

The pH remains circum-neutral throughout the modelling period, with values ranging from pH 6.0 to 7.0. During the early years, minor fluctuations occur, particularly between years 2 and 10. Thereafter, pH stabilises at approximately 6.7–6.8 in both the upper and lower lake layers.

TDS concentrations increase sharply in the first two years, rising from 1,275 mg/L in year 1 to 2,695 mg/L in year 2. After peaking at 3,101 mg/L in year 8, concentrations decline steadily, reaching 1,300 mg/L at year 50 and 1,000 mg/L at year 75. Following stratification, TDS concentrations in the upper layer stabilise at approximately 23 mg/L by year 100, whereas TDS concentrations in the lower layer remain high, with concentrations decreasing gradually from 959 mg/L at year 100 to 696 mg/L by year 200. This reduction in the TDS is driven by the decrease in metal(loid)s in the recoverable seepage and contact water, as described in Section 3.2.1.1 (Figure 3-9 to Figure 3-11). Sulphate and other major ions show a similar trend to the TDS.

Sulphate exhibits a similar pattern to TDS, with an early peak of 1,864 mg/L in year 3 before declining progressively. By year 75, sulphate concentrations decrease to 650 mg/L. This reduction is driven by the decrease in the recoverable seepage and contact water. Under stratified conditions, upper-layer concentrations stabilise at 7 mg/L, while the lower layer remains high, declining from 628 mg/L at year 100 to 436 mg/L at year 200. The upper layer is influenced only by snowmelt and pit wall runoff, diluting the upper layer concentration from 750 mg/L initially to 7 mg/L after year 90. the majority of sulphate is retained in the lower layer, where recoverable seepage and contact water remain the dominant sources.

Total nitrogen increases in the early years, rising from 10.2 mg/L in year 1 to a peak of 26.2 mg/L in year 2 from the inflow of contact water. Concentrations then fluctuate before declining steadily, reaching 15.1 mg/L at year 7 and 8.0 mg/L at year 75. Long-term predictions show stabilisation at approximately 4.2 mg/L in the lower layer after year 100. This trend suggests that nitrogen inputs are largely flushed from contact water during the initial years, with concentrations stabilising in the long term once nitrogen generation ceases after operations.

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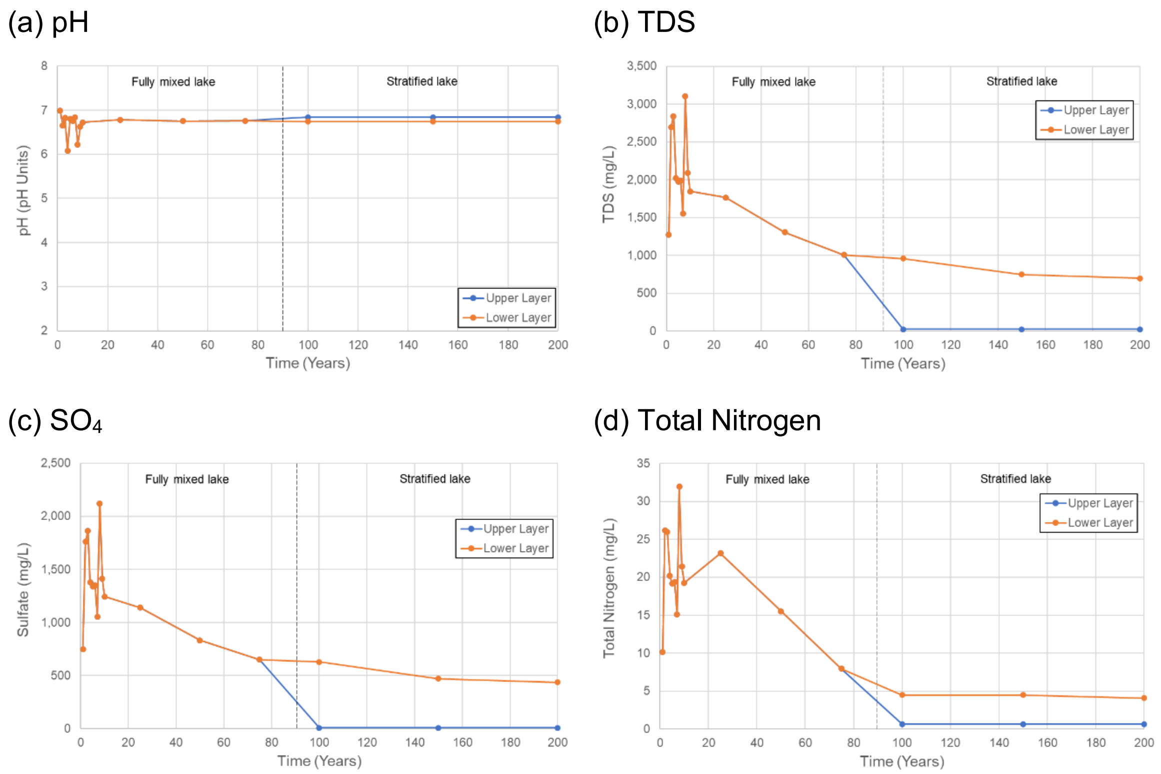

Figure 4-2. Predicted stratified pit VE0+ chemistry – (a) pH; (b) TDS; (c) SO_4; (d) Total Nitrogen

Table 4-3. Predicted stratified pit lake chemistry, Scenario VE0+

Parameters	Units	Time (Years)																		
		Mixed pit lake													Stratified Upper Layer			Stratified Lower Layer		
		1	2	3	4	5	6	7	8	9	10	25	50	75	100	150	200	100	150	200
pH	pH Unit	6.98	6.65	6.83	6.08	6.81	6.75	6.84	6.22	6.62	6.72	6.78	6.75	6.76	6.84	6.84	6.84	6.74	6.74	6.74
Total Dissolved Solids	mg/L	1,275	2,695	2,839	2,021	1,977	1,990	1,554	3,101	2,090	1,846	1,764	1,307	1,007	23	23	23	959	747	696
Alkalinity	mg/L as $CaCO_3$	19.0	32.2	32.3	14.3	28.5	26.7	22.9	24.8	25.6	24.6	29.8	26.3	23.5	3.4	3.4	3.4	24.6	24.5	23.6
Sulphate	mg/L	750	1,761	1,864	1,377	1,342	1,351	1,052	2,122	1,412	1,245	1,141	831	650	7.0	7.0	7.0	628	470	436
Chloride	mg/L	162	200	206	109	102	102	80	158	110	97	115	79	43	0.9	0.9	0.9	29.2	29.2	28.4
Cadmium	mg/L	0.0001	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.00001	0.00001	0.00001	0.0001	0.0001	0.0001
Cobalt	mg/L	0.05	0.13	0.13	0.10	0.10	0.10	0.08	0.16	0.10	0.09	0.09	0.06	0.05	0.0002	0.0002	0.0002	0.04	0.03	0.03
Copper	mg/L	0.002	0.01	0.01	0.005	0.008	0.008	0.01	0.02	0.009	0.008	0.009	0.006	0.006	0.00002	0.00002	0.00002	0.02	0.01	0.01
Lead	mg/L	0.00002	0.0001	0.0001	0.0000	0.0001	0.0001	0.00004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	9.4E-08	9.4E-08	9.4E-08	0.0006	0.0006	0.0006
Mercury	mg/L	1.E-05	1.53E-05	2.32E-05	1.84E-05	1.81E-05	1.70E-05	1.46E-05	1.99E-05	1.73E-05	1.56E-05	1.54E-05	1.32E-05	1.01E-05	1.64E-06	1.64E-06	1.64E-06	8.45E-06	8.44E-06	8.44E-06
Nickel	mg/L	0.886	2.42	2.47	1.93	1.86	1.89	1.44	3.07	1.93	1.74	1.60	1.12	0.857	0.0026	0.0026	0.0026	0.820	0.572	0.518
Zinc	mg/L	0.002	0.004	0.005	0.005	0.004	0.004	0.004	0.005	0.004	0.004	0.004	0.003	0.003	0.0002	0.0002	0.0002	0.0023	0.0023	0.0023
Total Nitrogen	mg/L	10.2	26.2	26.0	20.2	19.2	19.4	15.1	32.0	21.4	19.3	23.2	15.5	7.96	0.664	0.664	0.664	4.49	4.49	4.09
Total Phosphorus	mg/L	0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.001	0.001	0.001	0.03	0.03	0.03

4.1.2.2. Fully Mixed Pit Lake

Results for a fully mixed pit lake across the modelling period are included in Table 4-4 under the VE0+ scenario. The predicted pH, TDS, SO_4 and Cu for this sensitivity are included in Figure 4-3 for Scenario VE0+.

Initial pH is predicted at approximately 6.98 in Year 1, decreasing slightly and stabilising between pH 6.75 and 6.84 over the long term similar to the stratified pit lake scenario. Alkalinity is predicted to increase from 19 mg/L to 32.5 mg/L in the initial year of pit filling then declines to a steady range of 22–23 mg/L after 100 years.

TDS shows an initial increase from 1,300 mg/L to 2,900 mg/L after 3 years, then declines to 640 mg/L in year 150 and remaining stable thereafter. This coincides with the decrease in metal(loid)s through time in the recoverable seepage/contact water chemistry as described in Section 3.2.1.1 (Figure 3-9 to Figure 3-11). Sulphate and other major ions show a similar trend to the TDS.

Most trace metal concentrations (e.g., cadmium, cobalt, copper, lead, mercury, nickel, zinc) are predicted to remain stable, with a small increase in concentration over the initial 20 years followed by a decrease and stabilising after year 100 when the pit lake reaches equilibrium. This reduction is driven by the decrease in metal(loid)s in the recoverable seepage and contact water, as described in Section 3.2.1.1 (Figure 3-9 to Figure 3-11). Total nitrogen increases from 10.2 mg/L in year one to 26.2 mg/L in year two, before gradually decreasing and stabilising at approximately 4.2 mg/L in the long term, after year 100. This trend suggests that nitrogen inputs are largely flushed from contact water during the initial years, with concentrations stabilising in the long term once nitrogen generation ceases after operations.

Overall, the modelling indicates that while initial water quality is strongly influenced by the contact water inflows, the pit lake is expected to stabilise over time, with gradual dilution and geochemical attenuation processes leading to a stable water chemistry. Additionally, the decrease in contact water concentrations, which is the main driver of chemistry and flow volumes, leads to better water quality over time.

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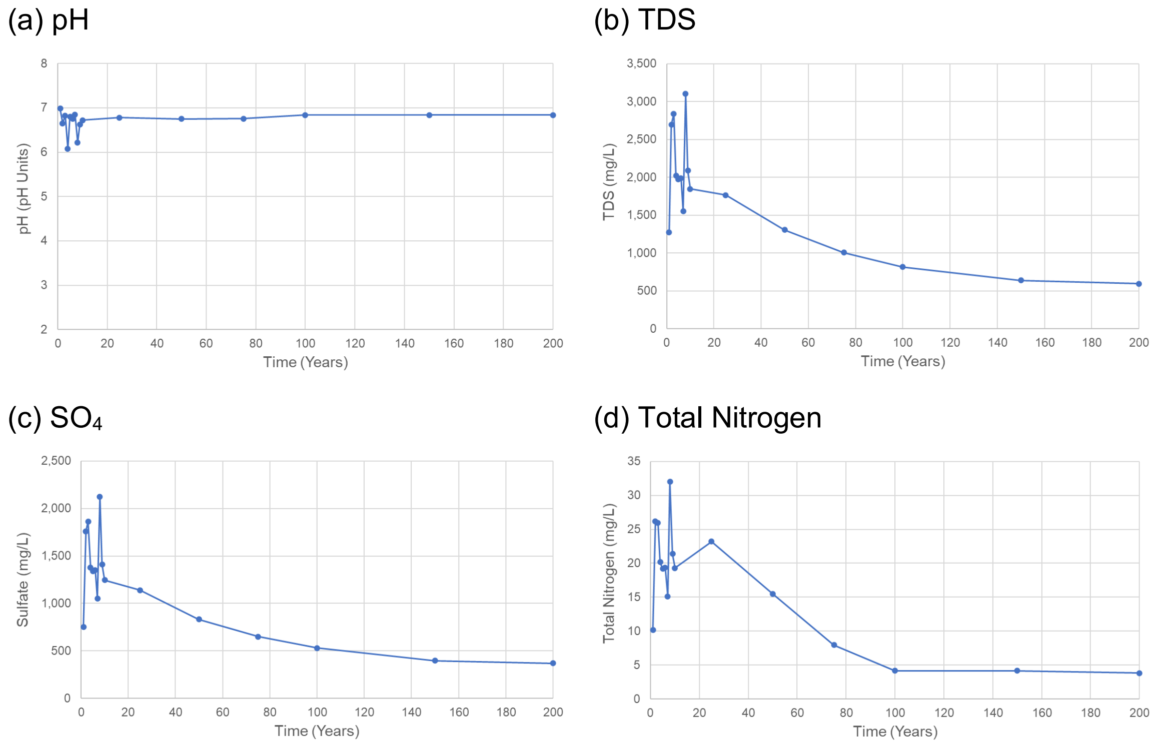

Figure 4-3. Predicted Fully Mixed Pit VE0+ Chemistry – (a) pH; (b) TDS; (c) SO_4; (d) Total Nitrogen

Table 4-4. Predicted Fully Mixed Pit Lake Chemistry, Scenario VE0+

Parameters	Units	Time (Years)															
		1	2	3	4	5	6	7	8	9	10	25	50	75	100	150	200
pH	pH Unit	6.98	6.65	6.83	6.08	6.81	6.75	6.84	6.22	6.62	6.72	6.78	6.75	6.76	6.84	6.84	6.84
Total Dissolved Solids	mg/L	1,275	2,695	2,839	2,021	1,977	1,990	1,554	3,101	2,090	1,846	1,764	1,307	1,007	816	639	597
Alkalinity	mg/L as $CaCO_3$	19.0	32.2	32.3	14.3	28.5	26.7	22.9	24.8	25.6	24.6	29.8	26.3	23.5	22.7	22.6	21.9
Sulphate	mg/L	750	1,761	1,864	1,377	1,342	1,351	1,052	2,122	1,412	1,245	1,141	831	650	530	398	369
Chloride	mg/L	162	200	206	109	102	102	79.9	158	110	97.5	115	78.6	42.9	24.9	24.9	24.3
Cadmium	mg/L	0.0001	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
Cobalt	mg/L	0.05	0.13	0.14	0.1	0.1	0.1	0.08	0.16	0.1	0.09	0.09	0.06	0.05	0.04	0.03	0.02
Copper	mg/L	0.0019	0.0139	0.0123	0.0049	0.0085	0.0087	0.0056	0.0165	0.0092	0.0077	0.0090	0.0059	0.0063	0.0082	0.0054	0.0047
Lead	mg/L	2.06E-05	0.0001	0.0001	0.0000	0.0001	0.0001	4.00E-05	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mercury	mg/L	1.02E-05	1.53E-05	2.32E-05	1.84E-05	1.81E-05	1.70E-05	1.46E-05	1.99E-05	1.73E-05	1.56E-05	1.54E-05	1.32E-05	1.01E-05	8.20E-06	8.20E-06	8.19E-06
Nickel	mg/L	0.89	2.42	2.47	1.93	1.86	1.89	1.44	3.07	1.93	1.74	1.60	1.12	0.86	0.68	0.48	0.43
Zinc	mg/L	0.0024	0.0040	0.0051	0.0045	0.0044	0.0042	0.0035	0.0053	0.0043	0.0039	0.0038	0.0032	0.0025	0.0020	0.0020	0.0020
Total Nitrogen	mg/L	10.2	26.2	26.0	20.2	19.2	19.4	15.1	32.0	21.4	19.3	23.2	15.5	7.96	4.18	4.18	3.85
Total Phosphorus	mg/L	0.0196	0.0346	0.0437	0.0343	0.0348	0.0338	0.0279	0.0441	0.0358	0.0322	0.0334	0.0300	0.0256	0.0228	0.0228	0.0227

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4.1.3. Pit Lake Scenario VE1.3

4.1.3.1. Stratified Pit Lake

Predicted pit lake chemistry for the VE1.3 scenario is presented in Figure 4-4 and summarised in Table 4-5. The results indicate the predicted water quality of the Stage 5 pit under base-case stratified conditions over the 200-year modelled period, during the lake filling period the model results are presented as mixed. Once the lake fills, the lake was assumed to be stratified from this point, as a forced condition for the thermodynamic modelling.

During the initial decades, the pH declines gradually from circumneutral conditions (pH 6.6 to 6.2 in the first 10 years) to a minimum of 5.8 by year 80. After stratification, pH diverges between layers: the upper layer stabilises near pH 5.5, while the lower layer gradually increases, reaching 7.3 by year 200.

TDS concentrations rise in the first two years, peaking above 4,000 mg/L, before declining sharply as inflows become more dilute and solute loads decrease. By year 100, concentrations fall below 500 mg/L, with further reductions to around 350 mg/L by year 200. Both lake layers show similar behaviour, although the upper layer consistently trends toward lower concentrations. The TDS is largely controlled by the chemistry of the recoverable seepage/contact water chemistry as described in Section 3.2.1.1 (Figure 3-12 to Figure 3-14). Sulphate and other major ions show a similar trend to the TDS due to contact water.

Total nitrogen increases sharply in the first two years, peaking near 45 mg/L, before declining rapidly to below 20 mg/L by year 10. Concentrations continue to decrease steadily thereafter, approaching 5 mg/L by year 75 and stabilising around 2–3 mg/L after year 150 in the lower layer and 0.8 mg/L in the upper layer. This trend suggests that nitrogen inputs are largely flushed from contact water during the initial years (see Section 3.2.1.1), with concentrations stabilising in the long term once nitrogen generation ceases after operations.

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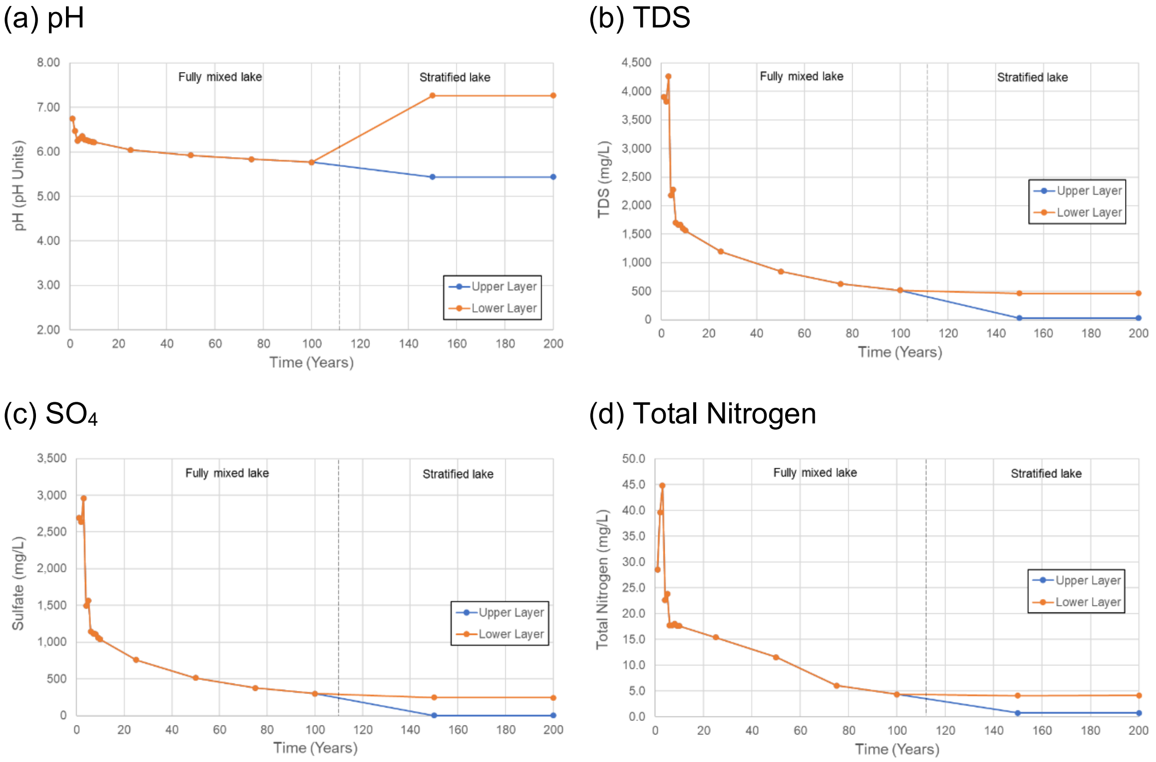

Figure 4-4. Predicted Stratified Pit VE1.3 Chemistry – (a) pH; (b) TDS; (c) SO4; (d) Total Nitrogen

Table 4-5. Predicted Stratified Pit lake Chemistry, Scenario VE1.3.

Parameters	Units	Time (Years)																	
		Mixed pit														Stratified Upper		Stratified Lower	
		1	2	3	4	5	6	7	8	9	10	25	50	75	100	150	200	150	200
pH	pH Unit	6.75	6.47	6.25	6.30	6.36	6.28	6.26	6.24	6.22	6.22	6.04	5.92	5.84	5.77	5.44	5.44	7.26	7.26
Total Dissolved Solids	mg/L	3,905	3,820	4,264	2,182	2,278	1,702	1,665	1,662	1,600	1,566	1,195	847	629	519	29.6	29.6	466	463
Alkalinity	mg/L as $CaCO_3$	30.4	33.4	32.9	36.2	35.9	36.9	36.7	36.4	36.3	36.1	34.4	34.6	36.2	38.2	10.1	10.1	49.3	50.0
Sulphate	mg/L	2,695	2,634	2,959	1,494	1,562	1,143	1,115	1,110	1,063	1,038	760	512	376	301	3.8	3.8	248	245
Chloride	mg/L	190	207	217	108	113	91.2	91.0	92.4	90.8	90.5	79.8	61.5	35.3	27.0	0.889	0.889	30.6	30.8
Cadmium	mg/L	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.00001	0.00001	0.0001	0.0001
Cobalt	mg/L	0.18	0.21	0.24	0.12	0.13	0.09	0.09	0.09	0.09	0.09	0.06	0.04	0.03	0.02	0.0002	0.0002	0.02	0.02
Copper	mg/L	0.02	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.006	0.004	0.003	0.004	2.01E-05	2.01E-05	0.003	0.003
Lead	mg/L	0.0002	0.0001	0.0001	0.0001	0.0001	4.12E-05	4.02E-05	4.01E-05	3.83E-05	3.75E-05	2.84E-05	2.25E-05	2.13E-05	2.43E-05	8.26E-08	8.26E-08	4.46E-05	4.55E-05
Mercury	mg/L	2.68E-05	2.06E-05	2.38E-05	1.59E-05	1.51E-05	1.52E-05	1.51E-05	1.51E-05	1.50E-05	1.49E-05	1.41E-05	1.27E-05	1.12E-05	9.54E-06	1.67E-06	1.67E-06	8.87E-06	8.93E-06
Nickel	mg/L	3.30	4.02	4.54	2.27	2.39	1.72	1.67	1.66	1.59	1.55	1.12	0.740	0.536	0.428	0.0028	0.0028	0.358	0.352
Zinc	mg/L	0.0077	0.0051	0.0063	0.0042	0.0040	0.0036	0.0035	0.0036	0.0035	0.0035	0.0032	0.0028	0.0024	0.0020	0.0001	0.0001	0.0021	0.0022
Total Nitrogen	mg/L	28.5	39.6	44.8	22.6	23.8	17.7	17.7	18.0	17.7	17.6	15.4	11.6	6.03	4.32	0.758	0.758	4.08	4.17
Total Phosphorus	mg/L	0.0558	0.0456	0.0536	0.0332	0.0327	0.0300	0.0299	0.0301	0.0297	0.0296	0.0280	0.0258	0.0234	0.0213	0.0011	0.0011	0.0216	0.0219

4.1.3.2. Fully Mixed Pit Lake

Results for a fully mixed pit lake across the modelling period are included in Table 4-6 under the VE1.3 scenario. The predicted pH, TDS, sulphate, and copper concentrations for this sensitivity are included in Figure 4-5 for Scenario VE1.3. Initial pH is predicted to be approximately pH 6.75 in Year 1, decreasing and stabilising at pH 5.73 over the long term after year 100. Alkalinity concentration is predicted to steadily increase from 30 to 42 mg/L throughout the modelled years.

TDS concentration shows an increase from 3,900 mg/L to 4,300 mg/L after 3 years, then decreases and stabilises to 400 mg/L in year 150 and remaining stable thereafter. This coincides with the decrease in metal(loid)s through time in the recoverable seepage/contact water chemistry. The TDS is largely controlled by the chemistry of the recoverable seepage/contact water chemistry as described in Section 3.2.1.1 (Figure 3-12 to Figure 3-14). Sulphate and other major ions show a similar trend to the TDS.

Concentrations of most trace metals are predicted to show a small increase in concentration over time and stabilising after year 100 when the pit lake reaches equilibrium. This is controlled by the chemistry of the recoverable seepage/contact water.

Total nitrogen increases from 28.5 mg/L to 45 mg/L in year 3, followed by a continue decrease and stabilises at 3.8 mg/L in the long term. This trend suggests that nitrogen inputs are largely flushed from contact water during the initial years, with concentrations stabilising in the long term once nitrogen generation ceases after operations.

Overall, the modelling indicates that while initial water quality is strongly influenced by higher concentrations from contact water inflows, the pit lake is expected to stabilise over time, with gradual dilution and geochemical attenuation processes leading to more stable water chemistry. Additionally, the decrease in contact water concentrations, which is the main driver of chemistry and flow volumes, leads to better water quality over time.

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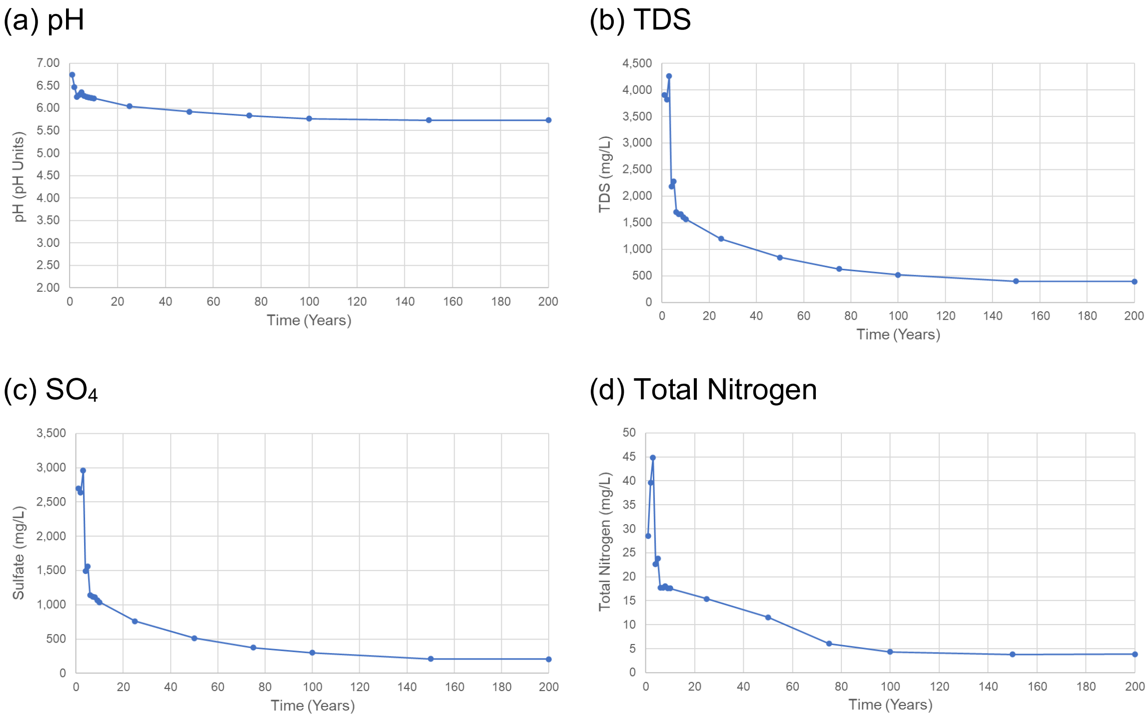

Figure 4-5. Predicted Fully Mixed Pit VE1.3 Chemistry – (a) pH; (b) TDS; (c) SO_4; (d) Total Nitrogen.

Table 4-6: Predicted Fully Mixed Pit Lake Chemistry, Scenario VE1.3.

Parameters	Units	Time (Years)															
		1	2	3	4	5	6	7	8	9	10	25	50	75	100	150	200
pH	pH Unit	6.75	6.47	6.25	6.30	6.36	6.28	6.26	6.24	6.22	6.22	6.04	5.92	5.84	5.77	5.73	5.73
Total Dissolved Solids	mg/L	3,905	3,820	4,264	2,182	2,278	1,702	1,665	1,662	1,600	1,566	1,195	847	629	519	396	393
Alkalinity	mg/L as $CaCO_3$	30.4	33.4	32.9	36.2	35.9	36.9	36.7	36.4	36.3	36.1	34.4	34.6	36.2	38.2	41.5	41.7
Sulphate	mg/L	2,695	2,634	2,959	1,494	1,562	1,143	1,115	1,110	1,063	1,038	760	512	376	301	208	205
Chloride	mg/L	190	207	217	108	113	91.2	91.0	92.4	90.8	90.5	79.8	61.5	35.3	27.0	25.8	26.1
Cadmium	mg/L	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
Cobalt	mg/L	0.18	0.21	0.24	0.12	0.13	0.09	0.09	0.09	0.09	0.09	0.06	0.04	0.03	0.02	0.02	0.02
Copper	mg/L	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.006	0.004	0.003	0.003	0.003	0.003
Lead	mg/L	0.0002	0.0001	0.0001	0.0001	0.0001	4.12E-05	4.02E-05	4.01E-05	3.83E-05	3.75E-05	2.84E-05	2.25E-05	2.13E-05	2.43E-05	2.48E-05	2.52E-05
Mercury	mg/L	2.68E-05	2.06E-05	2.38E-05	1.59E-05	1.51E-05	1.52E-05	1.51E-05	1.51E-05	1.50E-05	1.49E-05	1.41E-05	1.27E-05	1.12E-05	9.54E-06	8.40E-06	8.44E-06
Nickel	mg/L	3.3	4.0	4.5	2.3	2.1	1.7	1.7	1.7	1.6	1.6	1.1	0.74	0.54	0.43	0.29	0.29
Zinc	mg/L	0.0077	0.0051	0.0063	0.0042	0.0040	0.0036	0.0035	0.0036	0.0035	0.0035	0.0032	0.0028	0.0024	0.0020	0.0017	0.0017
Total Nitrogen	mg/L	28.5	39.6	44.8	22.6	23.8	17.7	17.7	18.0	17.7	17.6	15.4	11.6	6.03	4.32	3.77	3.84
Total Phosphorus	mg/L	0.0558	0.0456	0.0536	0.0332	0.0327	0.0300	0.0299	0.0301	0.0297	0.0296	0.0280	0.0258	0.0234	0.0213	0.0195	0.0197

4.2. CE-QUAL-W2 Hydrodynamic Model

4.2.1. Scenario VE0+

4.2.1.1. Pit Lake Rebound

Based on the storage capacity of the Stage 4 pit (with starter pit) and the water balance, it is predicted that the water level in the pit will rise steadily to the spillway elevation at 225 masl. Once the spillway elevation is reached, a constant lake level is maintained with water spilling (and evaporating) to remove additional volumes added.

The CE-QUAL-W2 models for the VE0+ scenario have similar filling times for the pit when compared with the water balance. The CE-QUAL-W2 models have approximate filling times of 90 years compared with 89 years modelled in the water balance data. The list of filling times for Scenario VE0+ is available in Table 4-7, and plotted in Figure 4-6.

Table 4-7. Lake rebound and filling times for the Stage 4 Pit, VE0+ Scenario

Model Version	Water Balance	Mixed Lake (VE0+ v3.1.3)	Pumping to 40 m (VE0+ v3.2.3)	Pumping to Base (VE0+ v3.3.3)
Julian Days to spillway	33097	33062	33181	33188
Years to spillway	89.8	90.5	90.8	90.9

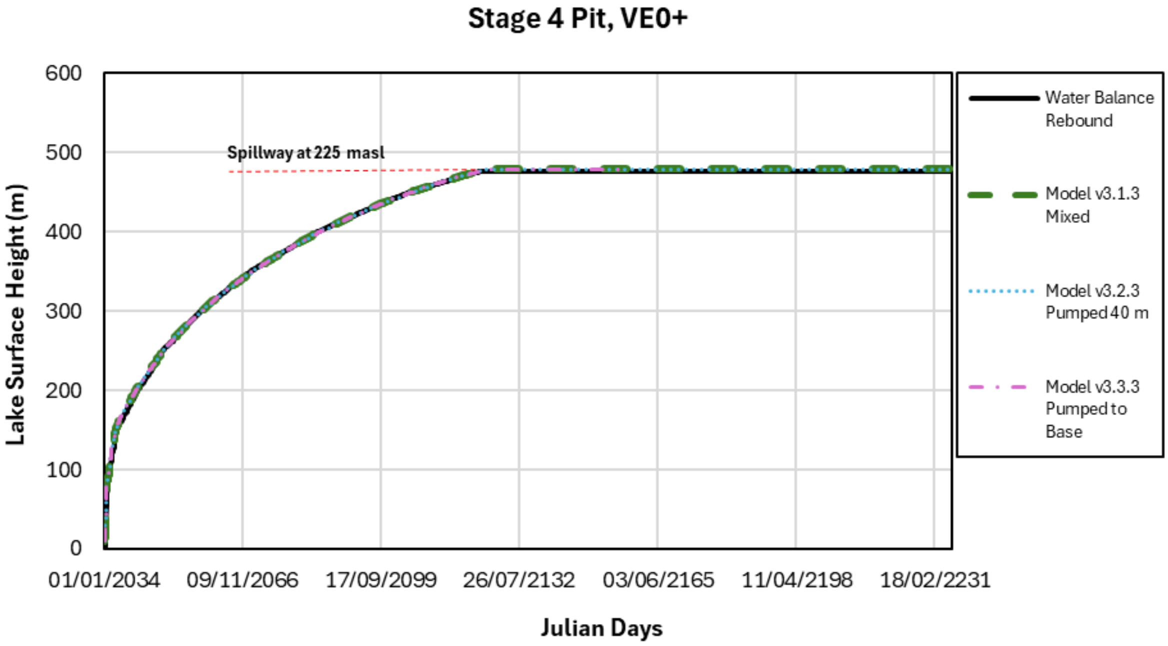

Figure 4-6. Lake rebound and filling times for the Stage 4 Pit, VE0+ Scenario

4.2.1.2. Ice Thickness

For Scenario VE0+, there is seasonal ice formation during the winter months in the pit lake. The variation across the modelling period of 200 years is included in Figure 4-7. After the initial filling period, the ice thickness remains relatively stable across the subsequent years. The overall average annual ice thickness is 0.72 m, with an annual maximum ice thickness is 1.04 m.

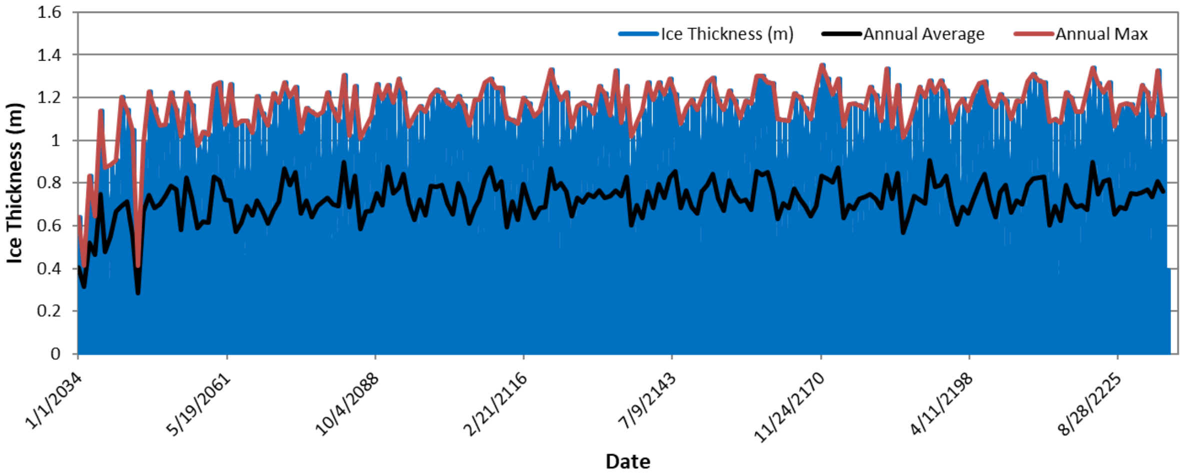

Figure 4-7. Ice Thickness of CE-QUAL-W2 Modelling for Scenario VE0+

4.2.1.3. Model Results

Modelled profiles of temperature and TDS were used to evaluate the circulation in the VE0+ pit lake for the base-case model of pumping contact water to 40 m below the lake surface.

Note that the PHREEQC models have informed the water quality for the pit lake modelling, notably TDS concentrations which influenced water density, whilst the CE-QUAL-W2 results indicate the stratification and lake circulation.

4.2.1.3.1. TDS

For the VE0+ Scenario, the TDS concentrations indicate a sustained stratification of upper and lower layers from the start of the pit lake filling. A gradual stratification and chemocline is indicated with lower concentrations towards the surface of the lake and higher concentrations towards the base (Figure 4-8). Whilst there is some instability within each of the upper and lower layers in the initial filling period, the higher concentrations of the lower layer remain at depth below a fresher surface layer.

There is no mixing between the upper and lower layers across the modelling period of 200 years (Figure 4-9). In the bottom layer of the model (-252 masl), there is a sharp increase in concentrations from the initial period before a gradual decrease in concentrations to the point at which the pit is full. The bottom layer remains relatively stable after the pit has filled. Concentrations decrease gradually towards the surface as indicated in Figure 4-9. The average concentration in the bottom layer is 2310 mg/L, with a maximum of 2522 mg/L across the modelling period.

Once the pit lake is full after 90 years, the TDS concentrations in the upper layer at the spillway (225 masl) show a small and gradual increase, due to an increase pit wall runoff concentrations during this period, however, ultimately concentrations decrease over time. The final concentration modelled for the spillway elevation indicates a TDS concentration of 969 mg/L, compared to a concentration of 2282 mg/L at the bottom layer of the pit lake. The concentrations in the upper layer range from 941 mg/L to 1120 mg/L, with an average concentration of 1046 mg/L across the modelling period. There is a difference of 1200 to 1300 mg/L between the concentrations in the surface and bottom of the lake based on the average and final concentrations.

4.2.1.3.2. Temperature

For the VE0+ Scenario, the temperature profiles indicate a continued stratification of upper and lower layers from the start of the pit filling. A thermocline is indicated with lower and more stable temperatures towards the bottom of the lake and seasonal fluctuations of temperature in the upper surface layer (Figure 4-10)Pit Lake Filling Time for Scenario VE0+. There is no seasonal fluctuation observed below a depth of approximately 30 to 40 m below the surface, with most fluctuations occurring in the uppermost 20 m.

There is no mixing between the upper and lower layers across the modelling period of 200 years (Figure 4-11). As the pit lake fills, and each layer of the model becomes increasingly submerged, the temperatures decrease to a stable average temperature of 2°C. The bottom layer remains stable after the pit has filled. The temperatures gradually increase to approximately 3°C below the stratified upper layer as indicated in Figure 4-11.

Once the pit lake is full after c. 90 years, the temperature in the stratified upper layer at the spillway (225 masl) fluctuates on a seasonal basis. Higher temperatures, up to a maximum of 17.8°C, are observed in the warmer summer months. In the colder winter months, a minimum of 0°C is observed, when ice also forms across the lake surface, as discussed in Section 4.2.1.2. The annual average temperature is 4.8°C across the modelling period.

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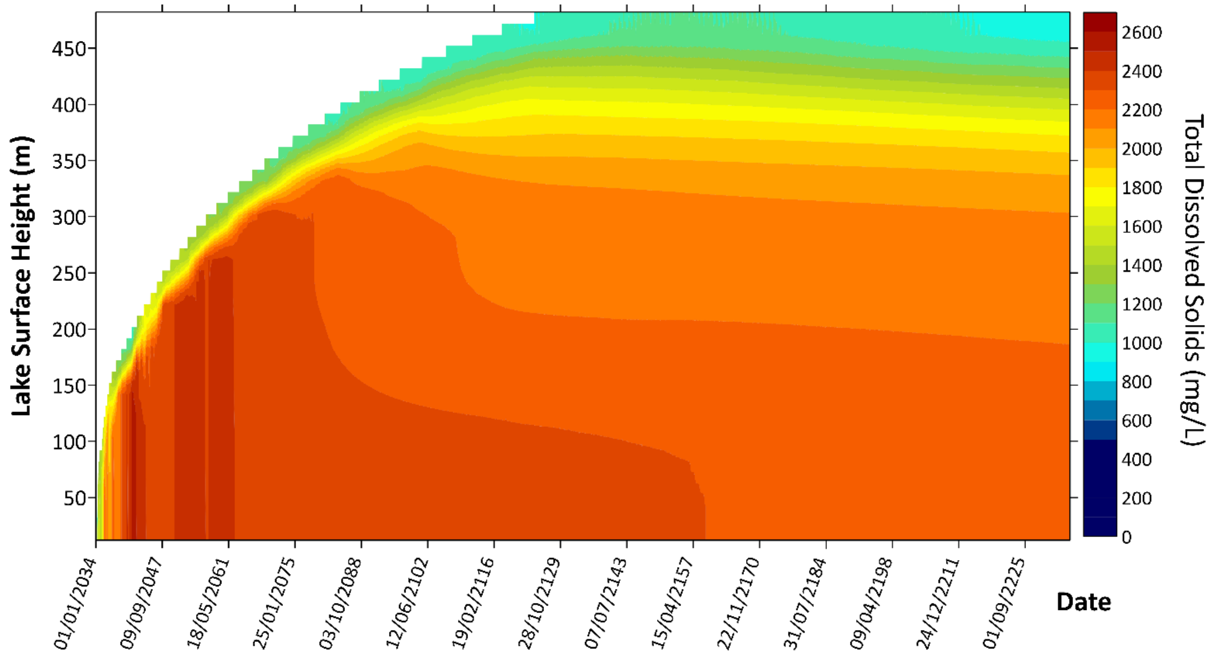

Figure 4-8. Total Dissolved Solids (TDS) Contour Plot with Pit Lake Filling Time for Scenario VE0+

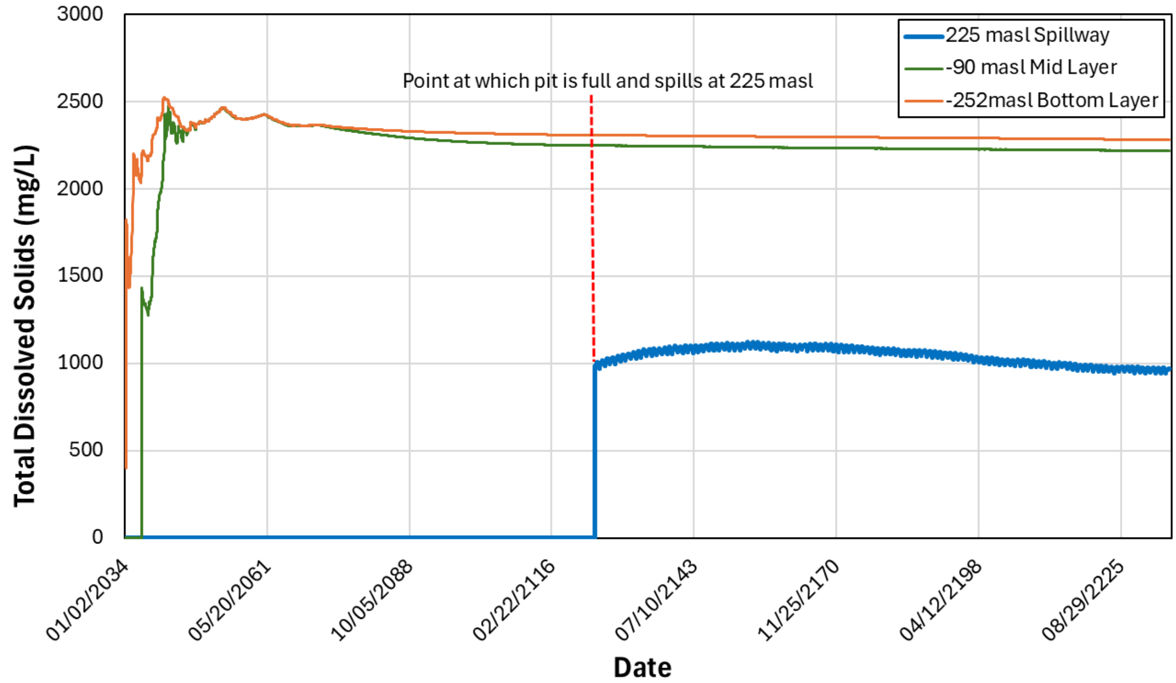

Figure 4-9. Total Dissolved Solids (TDS) Time Series for Scenario VE0+

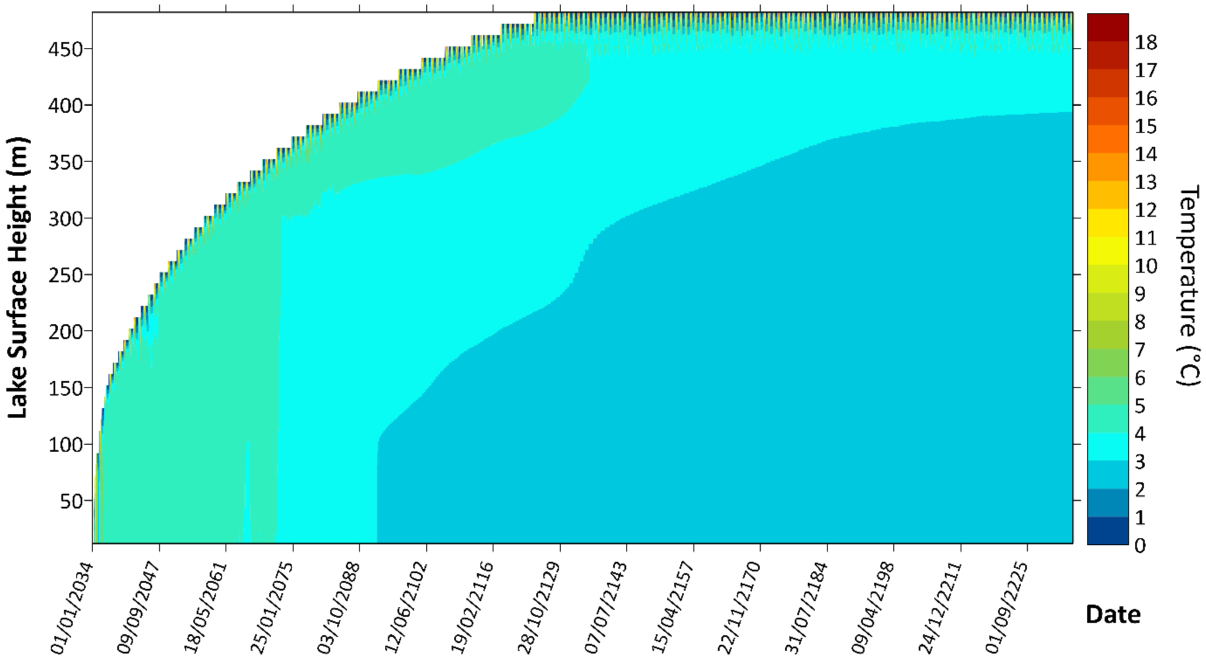

Figure 4-10. Temperature (°C) Contour Plot with Pit Lake Filling Time for Scenario VE0+

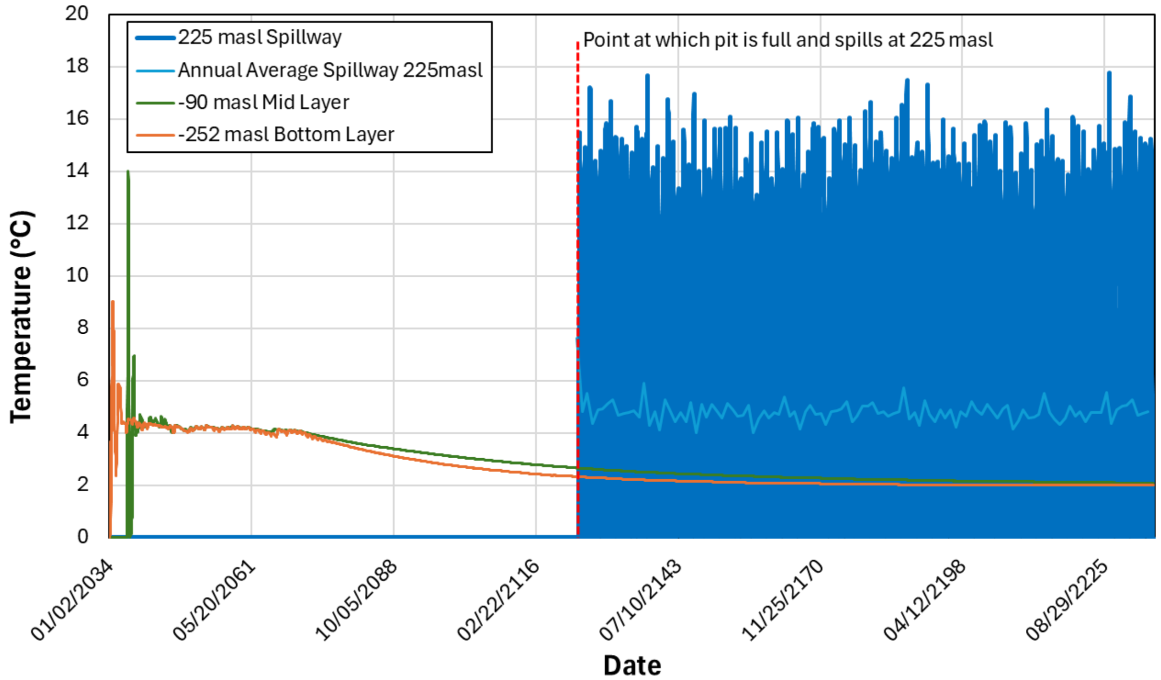

Figure 4-11. Temperature (°C) Time Series for Scenario VE0+

4.2.2. Scenario VE1.3

4.2.2.1. Pit Lake Rebound

Based on the storage capacity of the Stage 5 pit and the water balance, it is predicted that the water level in the pit will rise steadily to the spillway elevation at 225 masl. Once the spillway elevation is reached, a constant lake level is maintained with water spilling (and evaporating) to remove additional volumes added.

The CE-QUAL-W2 models for the VE1.3 scenario have similar filling times for the pit when compared with the water balance. The CE-QUAL-W2 models have approximate filling times of 114 years, the same as the 114 years modelled in the water balance data. The list of filling times for Scenario VE1.3 is available in Table 4-8, and plotted in Figure 4-12.

Table 4-8. Lake rebound and filling times for the Stage 5 pit, VE1.3 Scenario

Model Version	Water Balance	Mixed Lake (VE0+ v3.1.3)	Pumping to 40 m (VE0+ v3.2.3)	Pumping to Base (VE0+ v3.3.3)
Julian Days to spillway	41882	41812	41826	41805
Years to spillway	114.7	114.5	114.5	114.5

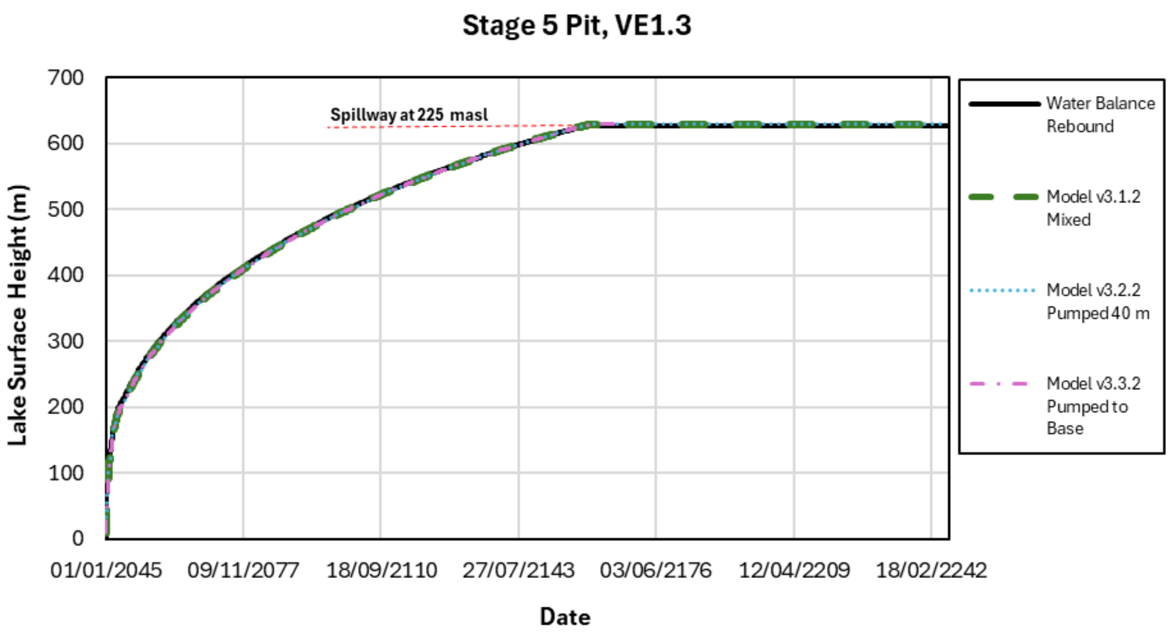

Figure 4-12. Lake rebound and filling times for the Stage 5 pit, VE1.3 Scenario

4.2.2.2. Ice Thickness

For Scenario VE1.3, there is seasonal ice formation during the winter months in the pit lake. The variation across the modelling period of 200 years is included in Figure 4-13 After the initial filling period, the ice thickness remains relatively stable across the subsequent years. The overall average annual ice thickness is 0.71 m, with an absolute maximum ice thickness of 1.14 m across the modelling period.

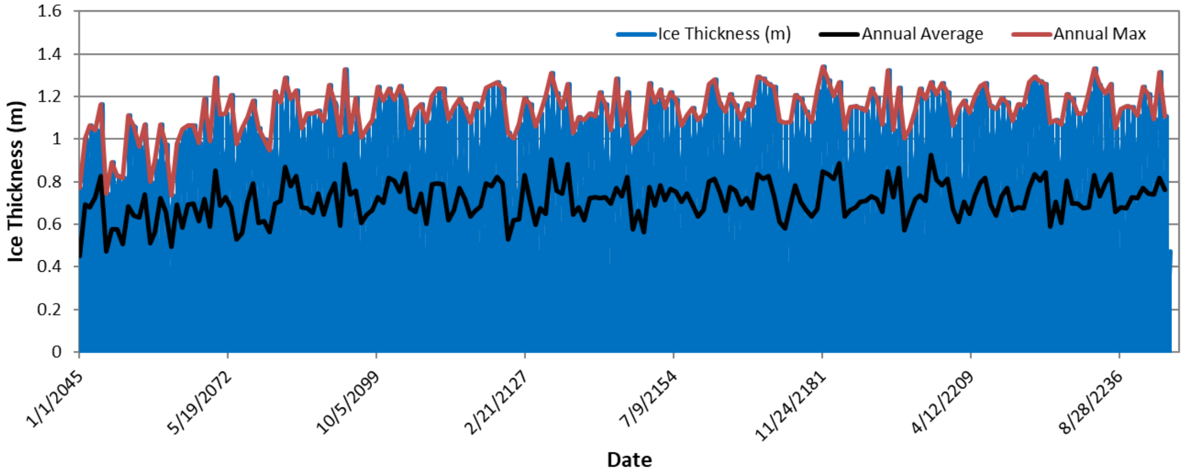

Figure 4-13. Ice Thickness of CE-QUAL-W2 Modelling for Scenario VE1.3

4.2.2.3. Model Results

Modelled profiles of temperature and TDS were used to evaluate the circulation in the VE1.3 pit lake for the base case model of pumping contact water to 40 m below the lake surface. Note that the PHREEQC models have informed the water quality for the pit lake modelling, whilst the CE-QUAL-W2 results indicate the stratification and lake circulation. TDS

For the VE1.3 Scenario, the TDS concentrations indicate a long-term sustained stratification between upper and lower layers. A gradual stratification and chemocline is indicated with lower concentrations towards the surface of the lake and higher concentrations towards the base (Figure 4-14). Whilst there is initial instability within the pit lake during the initial filling period, the higher concentrations remain at depth below the fresher surface layer into the long-term.

There is no mixing between the upper and lower layers across the modelling period of 200 years (Figure 4-15). In the bottom layer of the model (-402 masl), there is a sharp increase in concentrations from the initial period before a steep decrease in concentrations to the point at which the pit is full. The bottom layer remains relatively stable after the pit has filled. Concentrations reduce gradually towards the surface as indicated in Figure 4-15 by the mid-lake layer results. The average concentration in the bottom layer is 1673 mg/L, with a maximum of 6069 mg/L across the modelling period. The initial high concentrations are due to short-term higher TDS concentrations in the contact water inflows at this period.

Once the pit lake is full after 114 years, the TDS concentrations in the upper layer at the spillway (225 masl) remain relatively stable, with a slight decrease near the end of the modelling period. The final concentration modelled for the spillway elevation indicates a TDS concentration of 533 mg/L, compared to a concentration of 1405 mg/L at the bottom layer of the pit lake. The concentrations in the uppermost layer range from 517 mg/L to 661 mg/L, with an average concentration of 581mg/L across the modelling period. There is a 800 to 1000 mg/L difference between the concentrations in the surface layer and the concentrations in the bottom of the lake based on the average and final concentrations.

4.2.2.3.1. Temperature

For the VE1.3 Scenario, the temperature profiles indicate a continued stratification of upper and lower layers from the start of the pit filling. A thermocline is indicated with lower and more stable temperatures towards the bottom of the lake and seasonal fluctuations of temperature in the upper surface layer (Figure 4-16). There is no seasonal fluctuation observed below a depth of approximately 30 to 40 m below the surface, with most fluctuations occurring in the uppermost 20 m.

There is no mixing between the upper and lower layers across the modelling period of 200 years (Figure 4-17). As the pit lake fills, and each layer of the model becomes increasingly submerged, the temperatures decrease to a stable average temperature of 2°C. The bottom layer remains stable after the pit has filled. The temperatures gradually increase to approximately 3°C below the stratified upper layer as indicated in Figure 4-17.

Once the pit lake is full after 114 years, the temperature in the stratified upper layer at the spillway (225 masl) fluctuates on a seasonal basis. Higher temperatures, up to a maximum of 17.2°C, are observed in the warmer summer months. In the colder winter months, a minimum of 0°C is observed, when ice also forms across the lake surface, as discussed in Section 4.2.1.2. The annual average temperature is 4.7°C across the modelling period.

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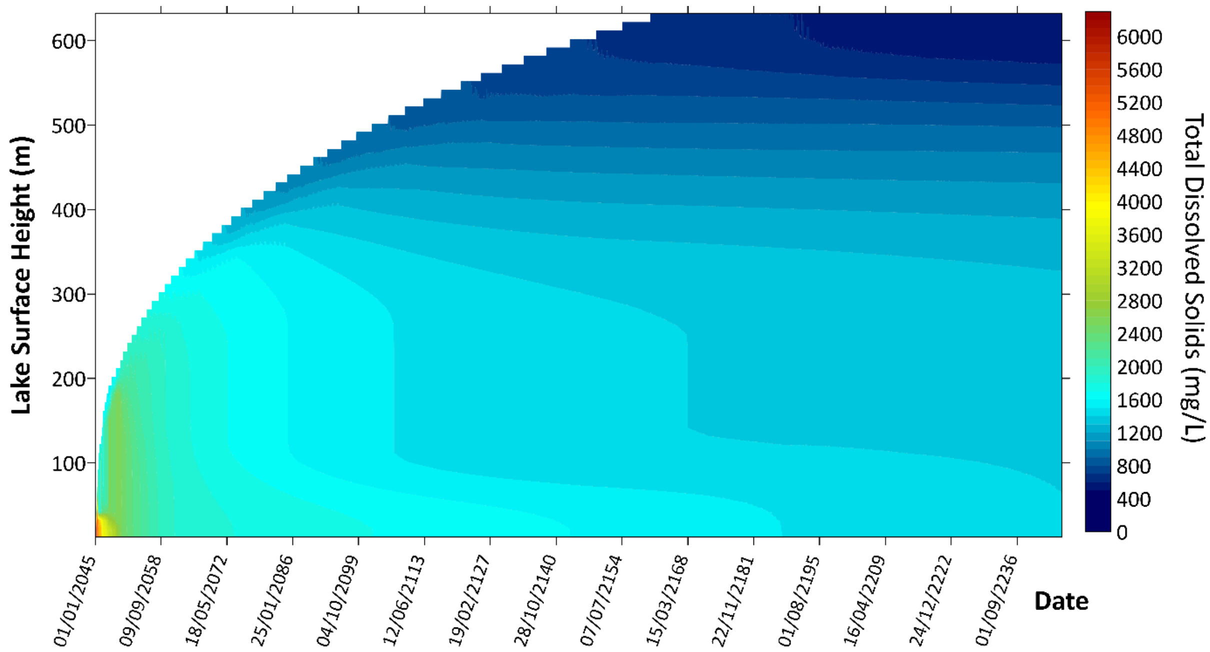

Figure 4-14. Total Dissolved Solids (TDS) with Pit Lake Filling Time for Scenario VE1.3

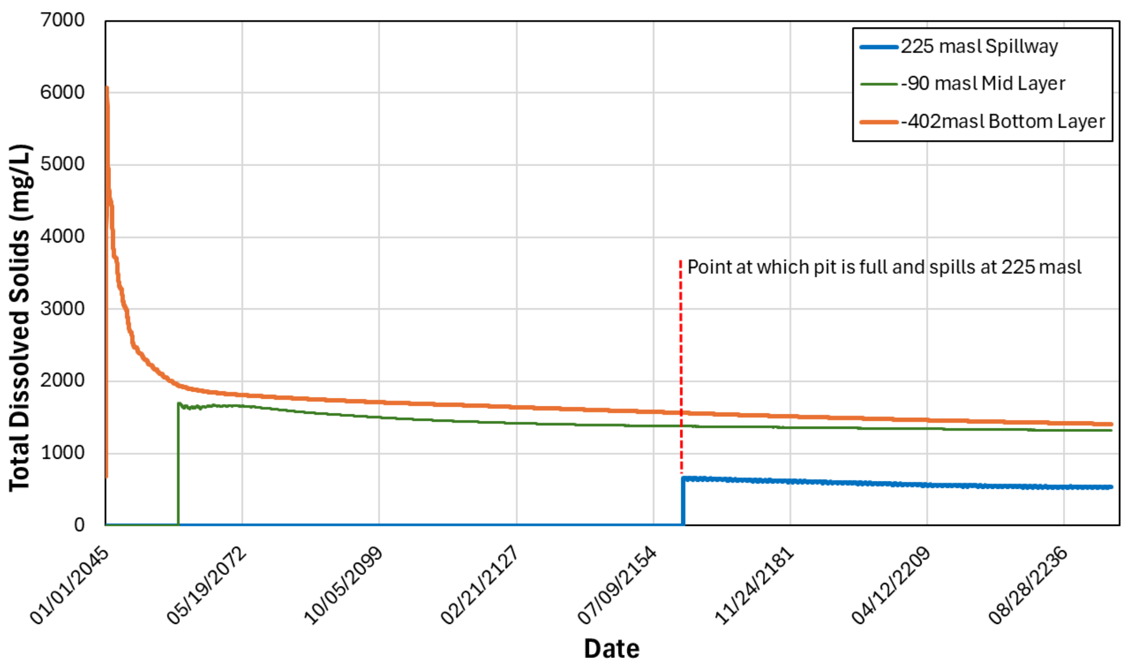

Figure 4-15. Total Dissolved Solids (TDS) with Pit Lake Filling Time for Scenario VE1.3

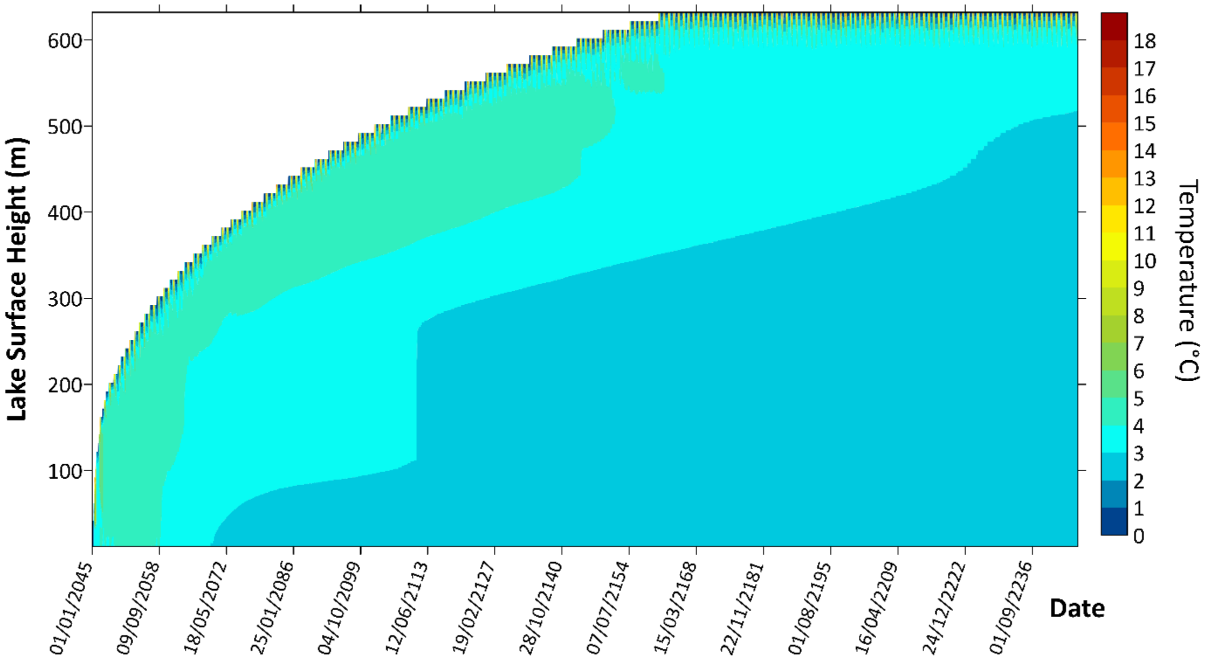

Figure 4-16. Temperature (°C) with pit lake Filling Time for Scenario VE1.3

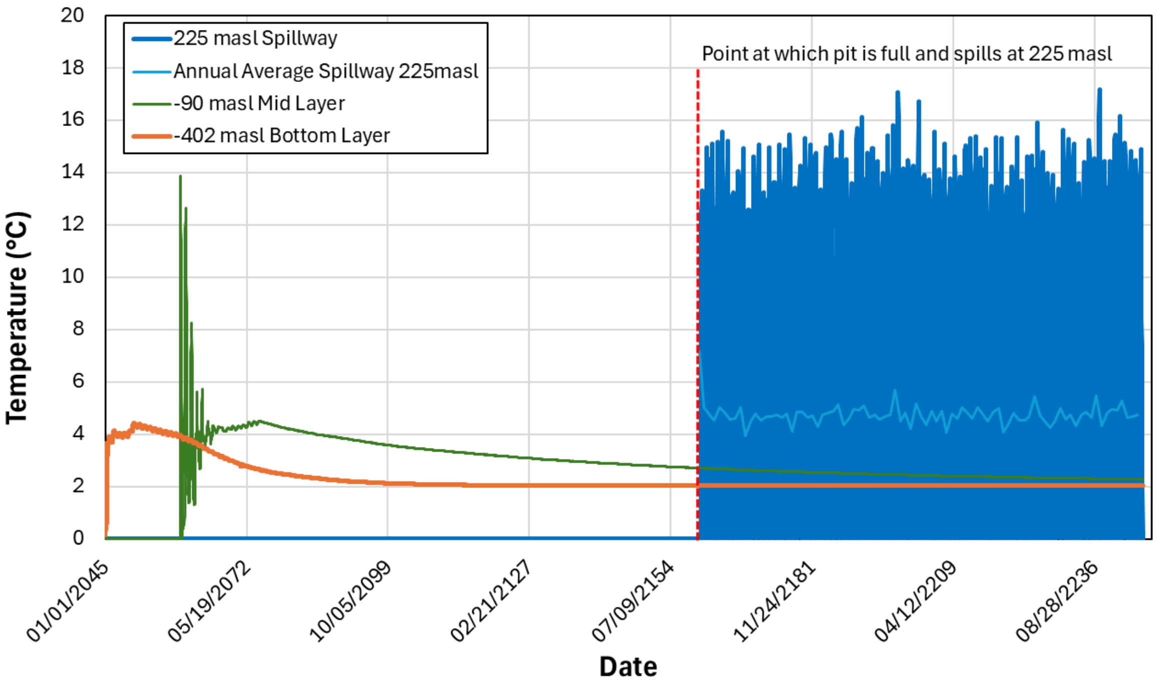

Figure 4-17. Temperature (°C) Time Series for Scenario VE1.3

4.2.3. Sensitivities & Assurance

Several sensitivity and assurance checks were conducted for both modelling scenarios of the pit lake, VE0+ and VE1.3. These checks include comparison of the temperatures and ice thickness of the modelled pit lakes with literature values for the region for model quality assurance. Sensitivity checks were completed in the modelling to investigate the sensitivity of the depth of contact water placement, to test the conceptual model of inducing better stratification by pumping water to approximately 40 m below the lake surface (after Lorax, 2019).

4.2.3.1. Temperature & Ice Thickness

The temperature in the upper surface layer of both of the pit lake scenarios modelled ranges from 0°C when there is ice formation during the winter, up to a maximum of 17°C. The Finland Environment Institute provides free access to publicly available data on surface water temperatures via their webpage (www.waterinfo.fi). Comparing with the maximum temperatures of the Lokan Tekojärvi surface water monitoring point, approximately 35 km to the north-east, the maximum temperature reached is 23.3°C with an average between 15 to 20°C in line with the modelled pit lake values.

Ice thickness in both of the pit lake scenarios, reaches and average annual thickness of 0.7 m with a maximum thickness of 1 m. This is comparable to literature values for ice thickness in northern Finland. Ice thickness, as presented in Korhonen (2002), varies from approximately 0.6 m in more southern regions to 0.7 m in northern regions with a maximum up to 1 m thickness. A more recent study of a lake in northern Finland, Lake Imandra, also indicates annual ice thicknesses between 0.6 to 0.7 m between 2021 to 2024 (Zdorovennova et al., 2025).

4.2.3.2. Contact Water Placement

Three sensitivities were completed for the placement of the contact water for each of the modelling scenarios. These sensitivities allow for comparison of how placement of the contact water, which is the dominant source of flow and chemical loading, can affect the predicted stratification of the pit lake. The sensitivity checks include:

1. Base-Case, pumped contact water to 40 m below pit lake surface;
2. Pumping the contact water to the base of the pit lake; and
3. Allowing for the contact water to fill from the surface of the lake.

Vertical profiles for the deepest segment (segment 7) are plotted for total dissolved solids (Figure 4-18) and temperature (Figure 4-19) for comparison of these sensitivity checks.

The base-case model provides the overall best stratification across the modelling periods for both pit lake scenarios. Pumping contact water to the base of the pit lake initially provides better stratification in the earlier years post-closure; however, the high volumes of contact water create mixing at the bottom of the pit leading to a reduction in the stratification over time compared with the base case model. Conversely, pumping the contact water to the surface of the lake initially leads to a more mixed lake particularly during the filling period but as concentrations in the contact water reduce over time the lake becomes more stratified. These results are similar to the Lorax (2019) modelling which indicated pumping below the surface at approximately 40 m would induce better stratification.

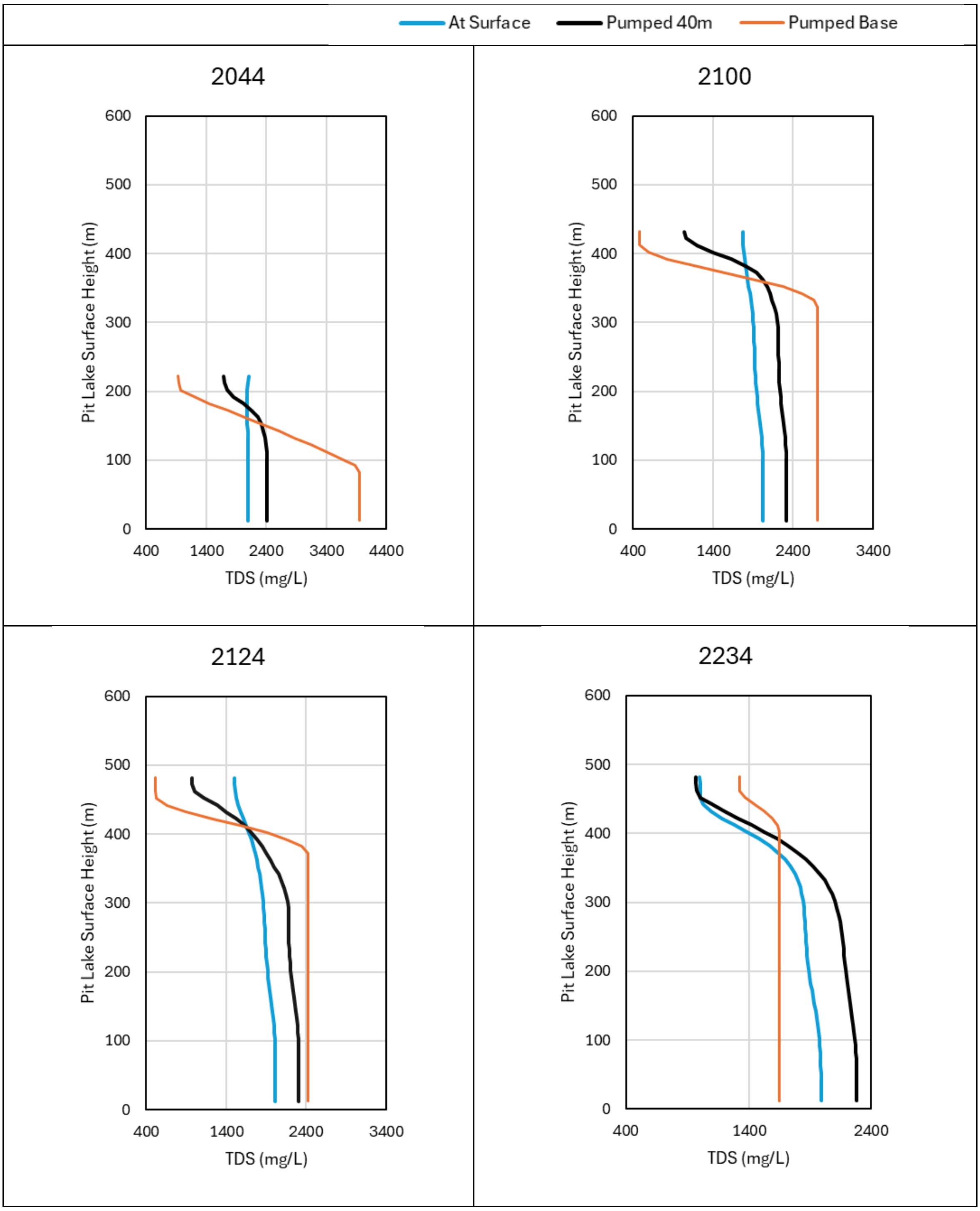

Figure 4-18. Profile plots for Scenario VE0+ contact water placement sensitivity checks

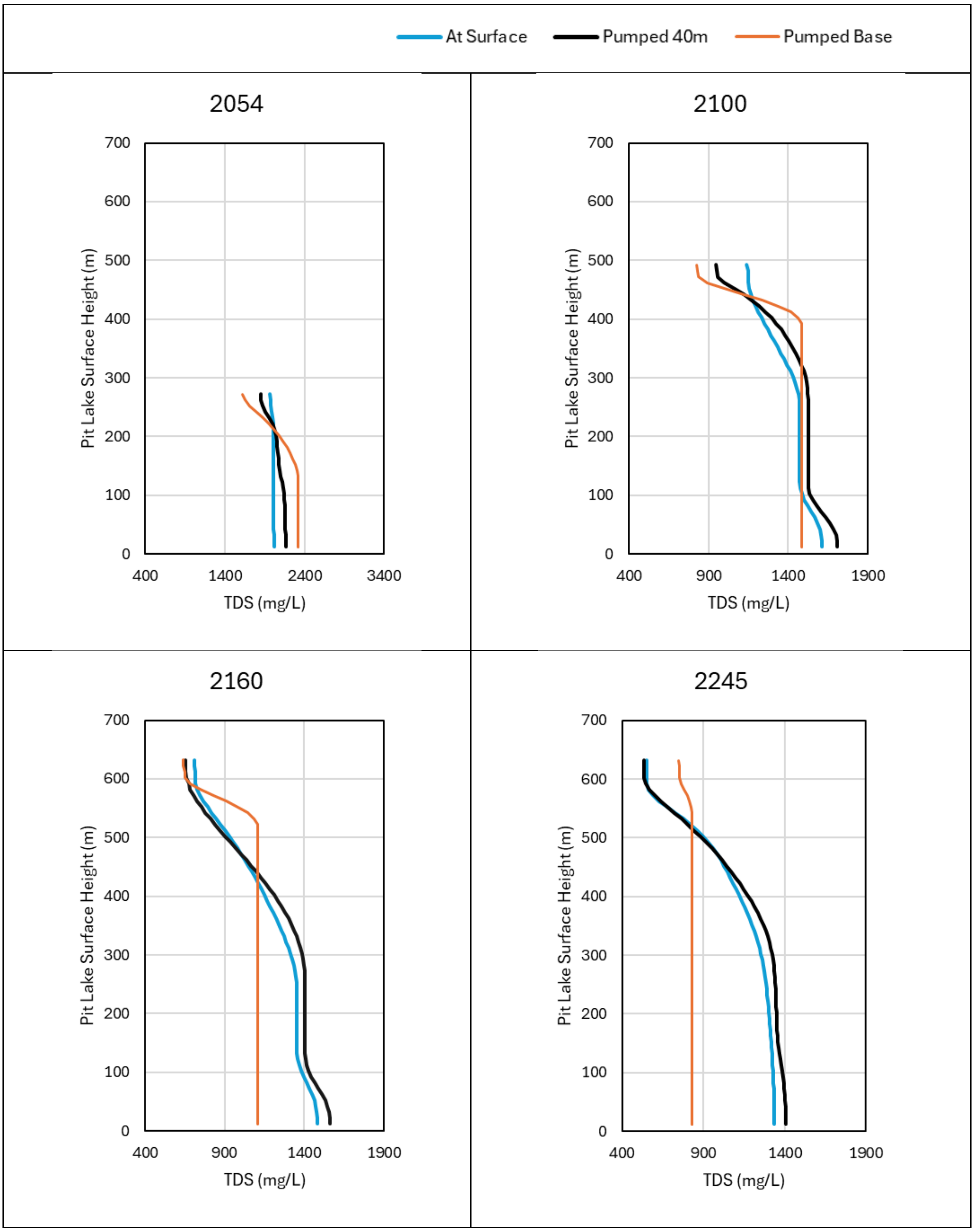

Figure 4-19. Profile plots for Scenario VE1.3 contact water placement sensitivity checks

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5. Discussion

Hydrodynamic CE-QUAL-W2 modelling indicates that formation of a pit lake will take approximately 90 years for the VE0+ scenario, and 114 years for the VE1.3 scenario. For both scenarios modelled, the lake will stratify using the conceptual model of pumping contact water to a depth of 40 m below the lake surface. The water balance and CE-QUAL-W2 modelling are well aligned in terms of rebound rates.

Sensitivity checks confirm the modelling completed by Lorax (2019), which indicates that the conceptual model of pumping contact to 40 m below the surface will induce a better stratified lake with the water quality in the upper surface at the spillway improved compared to a mixed lake. This is also dependent on the concentrations from the contact water decreasing over time, as would be expected from a covered waste rock storage facility. Management and monitoring of the contact water, which contributes the largest loading of chemistry and flow volumes, is crucial to the development of the modelled lake circulation and chemistry.

Stratification is stable throughout the modelling periods of 200 years, up to 2235 for the VE0+ scenario and up to 2246 for the VE1.3 scenario. The upper surface layer will seasonally mix, with increased summer temperatures and ice formation during the winter months.

The predicted base case water qualities using the thermodynamic modelling indicate that the pit lake will experience a progressive stabilisation of water chemistry. Early water quality is strongly influenced by the high loads of TDS, sulphate, and alkalinity in contact water. As the contact water concentrations decrease over time, the lake water quality improves. Stratification, as predicted to occur by the CE-QUAL-W2 modelling, leads to a better quality at the surface where water will spill via the spillway. Concentrations of TDS, and other constituents, are expected to be lower in the VE1.3 compared to the VE0+ scenario into the long-term. This is reflective of lower input chemistries.

From a management perspective, the results suggest that acidic conditions are unlikely, with pH expected to remain within a slightly neutral range (6.7–6.8) across the entire modelling period. Trace metals and nutrient levels are predicted to remain relatively low and do not lead to exceedances in the wider mine contaminant transport modelling (WSP, 2025b), though ongoing monitoring during closure and early post-closure phases would be recommended to validate these modelled trends.

It should also be noted that the modelled water qualities are based on geochemistry and do not account for reduction in concentrations (e.g. nitrogen) by biota, hence the concentrations are likely to be lower than modelled. Enhancements to the overall site water balance, and inflow chemistries, would further decrease the conservatism of the modelling approach and allow for better predictions of water quality.

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6. Conclusions & Recommendations

This report details the pit lake modelling to understand the lake circulation and resultant water qualities at and post-closure of the Kevitsa Mine facilities. Scenarios VE0+ and VE1.3 have been assessed.

Tässä raportissa kuvataan louhosjärven mallinnus, jonka kautta järven kiertoliikkeestä ja vedenlaadusta Kevitsan kaivoksen sulkemisvaiheen ja sen jälkeisen ajalta saadaan parempi ymmärrys. Mallinnetut vaihtoehdot ovat VE0+ ja VE1.3.

The hydrodynamic modelling indicates that there will be stratification in the lakes for both scenarios when contact water is pumped at depth. Fresher water mixes seasonally in the upper layer and the worst water qualities maintained at depth across the 200-year modelling periods.

Hydrodynaaminen mallinnus osoittaa, että molemmissa vaihtoehdoissa järveen muodostuu kerrostuneisuus, kun kontaktivesi johdetaan järveen 40 m syvyyteen. Pintaosan makeammassa vedessä tapahtuu sekoittumista vuodenaikojen mukaan, kun taas huonompilaatuinen vesi säilyy syvemmällä koko 200 vuoden mallinnusjakson ajan.

PHREEQC thermodynamic water quality modelling additionally indicates that once the pit is full and stratified, the water qualities at the spillway will continue to be lower in concentration compared to the waters in the lower layer or compared to a fully mixed lake.

PHREEQC-ohjelmalla tehty termodynaaminen vedenlaatumallinnus osoittaa lisäksi, että kun louhos on täyttynyt ja vesi kerrostunut, ylivuotokohdassa purkautuvan veden pitoisuudet pysyvät alhaisempina verrattuna syvempiin kerroksiin tai täysin sekoittuneeseen järveen.

It is recommended that a level of water management would be required, during closure, to ensure these site flows are discharged below the lake surface accordingly. Further updates to site-wide water balances and chemical inputs would provide for less conservative approaches in the modelling.

Suosituksena on, että sulkemisvaiheessa tarvitaan jotain vedenhallintatoimenpiteitä, jotta alueen vesien virtaamat voidaan johtaa järven pinnan alapuolelle. Lisäksi kaivosalueen vesitaseen ja kemiallisten lähtötietojen päivittäminen mahdollistaisi vähemmän konservatiivisen lähestymistavan mallinnuksessa.

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References

1) **Buchak E.M., and Edinger J.E., 1984.** Generalized, Longitudinal-Vertical Hydrodynamics and Transport: Development, Programming and Applications. Prepared for US Army Corps of Engineers Waterways, Experiment Station. Vicksburg, MS, USA.
2) **Cole, T.M., and Wells, S.A., 2017.** CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 4.1 User Manual. October 2017.
3) **Dzombak, D. A., & Morel, F. M. M., 1990.** Surface Complexation Modeling: Hydrous Ferric Oxide.
4) **Golder, 2022.** Kevitsa Mine Site, Finland. Groundwater Risk Assessment: Seepage Migration from TSFA and TSFB. Reference: 19131142_21451864.606/A.4. 7 April 2022.
5) **Korhonen J., 2002.** Ice and water temperature conditions in some Finnish lakes. Ice in the Environment: Proceedings of the 16th IAHR International Symposium on Ice. International Association of Hydraulic Engineering and Research.
6) **Lorax, 2019.** Predictive Modeling of Long-Term Pit lake Water Quality, Kevitsa Mine, Finland. Project No. A517-2.
7) **Mine Environnent Management Ltd (MEM), 2025.** Kinetic testing of Kevitsa waste rock and tailings material: update. Report No. 011-33 -0924.
8) **Parkhurst and Appelo, 2013.** Description of Input and Examples for PHREEQC Version 3—A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. U.S. Geological Survey Techniques and Methods, Book 6, Chapter A43, 497 p.
9) **QA/SAC - Americas., 2025**. Quality Assurance/Science Activity Centre – Americas. World Meteorological Organization Global Atmosphere Watch. NOAA Air Resources Laboratory. Retrieved from https://qasac-americas.org 26/07/2025
10) **SRK, 2025**. GoldSim model dataset for water balance and water quality.
11) **Stumm, W. and Morgan, J.J., 1996.** Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters.
12) **US Army Engineer Waterways Experiment Station, 1986.** CE-QUAL-W2: A Numerical Two-Dimensional, Laterally Averaged Model of Hydrodynamics and Water Quality; User's Manual. Defence Technical Information Center. Washington, DC, USA.
13) **WSP, 2024.** Boliden Kevitsa Mine – Baseline Water Quality and Derivation of Site-Specific Assessment Criteria. Reference No. 318559_70096006.014.
14) **WSP, 2025a**. Environmental Studies 2024-2025, Groundwater Flow and Drawdown Modelling. Reference G321132.UK0040343.01. 18th July 2025.
15) **WSP, 2025b**. Environmental Studies 2024-2025, Contaminant Transport Modelling. Reference G321132.UK0040343.01. 5th September 2025.
16) **Zdorovennova G., et al.** Contrasting Changes in Lake Ice Thickness and Quality Due to Global Warming in the Arctic, Temperate, and Arid Zones and Highlands of Eurasia. Water 2025, 17, 365. https://doi.org/10.3390/w17030365.

Appendices

Appendix A: Data Sources

Appendix B: Data Tables

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