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Predictive draindown modelling for a copper heap leach facility

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Abstract

The moment irrigation of a heap leach facility (HLF) ends it begins its transition to closure. Its draindown in those first years will determine decades of environmental performance. At closure, the leached ore will be acidic, and draindown will require active management until seepage decreases to acceptable levels.

An innovative pseudo-3D numerical model was developed to estimate draindown from a proposed acid copper HLF after the final irrigation. In the modelling, the HLF was represented as individual cells that are sequentially constructed, irrigated and then allowed to drain. The overall model considered heap shape, stacking sequence, ore properties, liners, cover options and climate. A Python script was developed to integrate the results of multiple 1D simulations into a simplified 3D representation of the HLF.

Key inputs were obtained from material properties measured on leached ore generated in metallurgical column tests and from operational design parameters for the HLF. The soil-water characteristic curve (SWCC) for the heap material was estimated from particle size distribution and bulk density results using the HYDRUS Rosetta model as SWCC data were unavailable. The draindown model was validated by reproducing observed draindown curves from column tests under the applied irrigation regime, achieving close agreement with measured outflows. Heterogeneity was addressed through sensitivity analyses of key hydraulic properties.

The predicted changes in water content over time were used to estimate appropriate oxygen diffusion coefficients for modelling oxygen entry and oxidation, which then informed predictions of long-term water quality.

Results indicated that 4 years after closure, when the final cover is placed, drainage flow will decrease by up to 99%. Approximately 16–57% of the total drainable water would remain after 4 years, and draindown (excluding cover infiltration) could continue for 30–40 years, depending on evaporative losses. Initially, water quality would resemble the pregnant leach solution (pH ~1.2). After rapid draindown, ongoing pyrite oxidation will sustain acidic seepage.

The results highlighted the impact of evaporation on the HLF water balance, and the need to consider consolidation and deagglomeration on hydraulic conductivity. The model outcomes provided the basis for HLF design refinements.

Keywords: *heap leach facility, draindown, water management, long-term water quality, cover design*

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1 Introduction

Prior to construction, predictions of draindown volume, duration and composition are required to inform the design of a proposed acid copper heap leach facility (HLF) and to assess its potential post-closure environmental performance.

Modelling of draindown from HLFs differs from other subaerial mine waste facilities, such as waste rock dumps. At the end of the final irrigation cycle, the active portion of the HLF will be close to saturated. Water content will vary between cells because of its staged construction and irrigation. Drainage water will already be acidic, and the supply of oxygen will decrease sharply once aeration is stopped and oxygen supply transitions to diffusion from the HLF surface.

A series of modelling runs were undertaken to assess the post-closure water release from the HLF. Key management questions were:

- How long will draindown from the HLF occur following closure?
- What impact will the use of interlift liners and a cover have on draindown?
- Will management measures (active or passive) be required to reduce draindown volume and duration?

A pseudo-3D numerical model (described by Vega et al. 2025) was used to estimate how quickly the heap will drain after the last irrigation event. This paper emphasises the links between draindown with subsequent oxygen transport, sulphide mineral oxidation and solute release to forecast long-term seepage water quality.

2 Background

2.1 Facility construction, operation and closure

The stacking plan for the HLF consists of 9 lifts (layers), each 10 m in height, resulting in a total height of 90 m (Figure 1). The heap is divided into 3 groups of 3 lifts, each separated by a linear low-density polyethylene (LLDPE) liner. The construction sequence follows a symmetrical progression, with each lift subdivided into irrigation cells. Each cell will be constructed over 40 days and then irrigated for 200 days. The total construction time for the heap is 12 years. The HLF has a total footprint of 1,633,500 m².

Figure 1 Schematic representation of the proposed heap leach facility geometry

A drainage system consisting of high-density polyethylene (HDPE) pipes, sand and gravel will be placed above the base and interlift LLDPE liners (Figure 1). An irrigation system will consist of nozzles integrated with a geomembrane, which will be equivalent to having a temporary cover placed on top of each lift, following lift construction. The irrigation system will be removed prior to the construction of the subsequent lift. Aeration and a bacterial inoculum will be applied to optimise copper recovery.

At the end of active irrigation the irrigation system (temporary cover) will remain in place on lift 9 until closure. At closure, the batters will be recontoured and the leached ore covered with non-acid forming (NAF) waste rock. The blower pipes (used for aeration) will be sealed to prevent oxygen supply via the pipes.

2.2 Material properties

The ore will be crushed to <12.5 mm and agglomerated with sulphuric acid and raffinate prior to stacking in the HLF. The agglomerated ore will have a specific gravity of 2.9 t/m^3, and is expected to have a bulk density of 1.8 t/m^3.

Metallurgical and geochemical testing has shown that the resulting leached ore is likely to be acid forming with sulphide sulphur content ranging from 0.34–5.6 wt% and negligible carbonate acid neutralisation capacity (ANC). Sulphide sulphur is present as pyrite with trace (<0.1 wt%) amounts of chalcocite/digenite, covellite, chalcopyrite, sphalerite and molybdenite. Sulphate sulphur is present in acid-generating forms (jarosite and alunite) and non-acid-generating forms (gypsum and bassanite).

2.3 Climate

The HLF is to be located in an arid region where the potential evaporation rate (1,800 mm/year) is more than an order of magnitude greater than the precipitation rate (100 mm/year).

3 Draindown

3.1 Conceptual model

Construction and irrigation of the HLF will be sequenced as described in Section 2.1. Some flow to lower groups will occur due to LLDPE liner defects during irrigation. The agglomerates are expected to break down with increasing load (as consecutive lifts are placed) and with weathering over time. As a result, porosity and permeability are expected to decrease.

The irrigation system (temporary cover) will remain in place until the construction of the next lift, or – in the case of the final lift – until the final cover is constructed 4 years after the last irrigation event. The temporary cover will act as a temporary zero-flux top boundary condition. Following closure, recharge to HLF will be determined by net infiltration through the waste rock cover.

3.2 Method

Key inputs were obtained from material properties measured for leached ore generated from metallurgical column testing, and from operational design parameters for the HLF. The soil-water characteristic curve (SWCC) for the heap material was estimated using the Hydrus Rosetta model as laboratory testing data were unavailable. The Rosetta model uses particle size distribution data (percentages of sand, silt and clay) and bulk density to predict SWCC parameters.

The pseudo-3D numerical model used to estimate draindown integrates Hydrus-1D (Simunek et al. 2018) with Python scripting to automate large-scale simulations, capturing time-dependent spatial variability in material properties, stacking sequences and geometries (Noël et al. 2023; Vega et al. 2025). The top boundary conditions included irrigation rates, temporary covers and interlift liner leakage. The bottom boundary was set as a drainage system open to atmospheric pressure. Closure conditions incorporated net percolation rates as a top boundary condition, based on climatic data and cover performance.

Three scenarios were modelled: a main case and two sensitivity analyses with varying hydraulic properties. These scenarios evaluated the impact of material properties on seepage and saturation profiles.

3.3 Results

Initial draindown is rapid following the last irrigation event of the HLF. Flow is predicted to decrease from approximately 38,000–42,000 m^3/day to 530–1,200 m^3/day when the final cover is placed on the HLF after 4 years (equivalent to between 1% and 3% of the initial flow rate, Figure 2). Estimated flow rate and water inventory ranges considered scenarios where the leached ore has consolidated and/or de-agglomerated resulting in lower permeability (these were modelled as sensitivity cases 1 and 2). The water inventory in the

HLF when the final cover is placed is estimated to be between 16% and 57% of the total volume of water available for draindown at the end of leaching operations. The residual inventory will continue to slowly drain during the post-closure period.

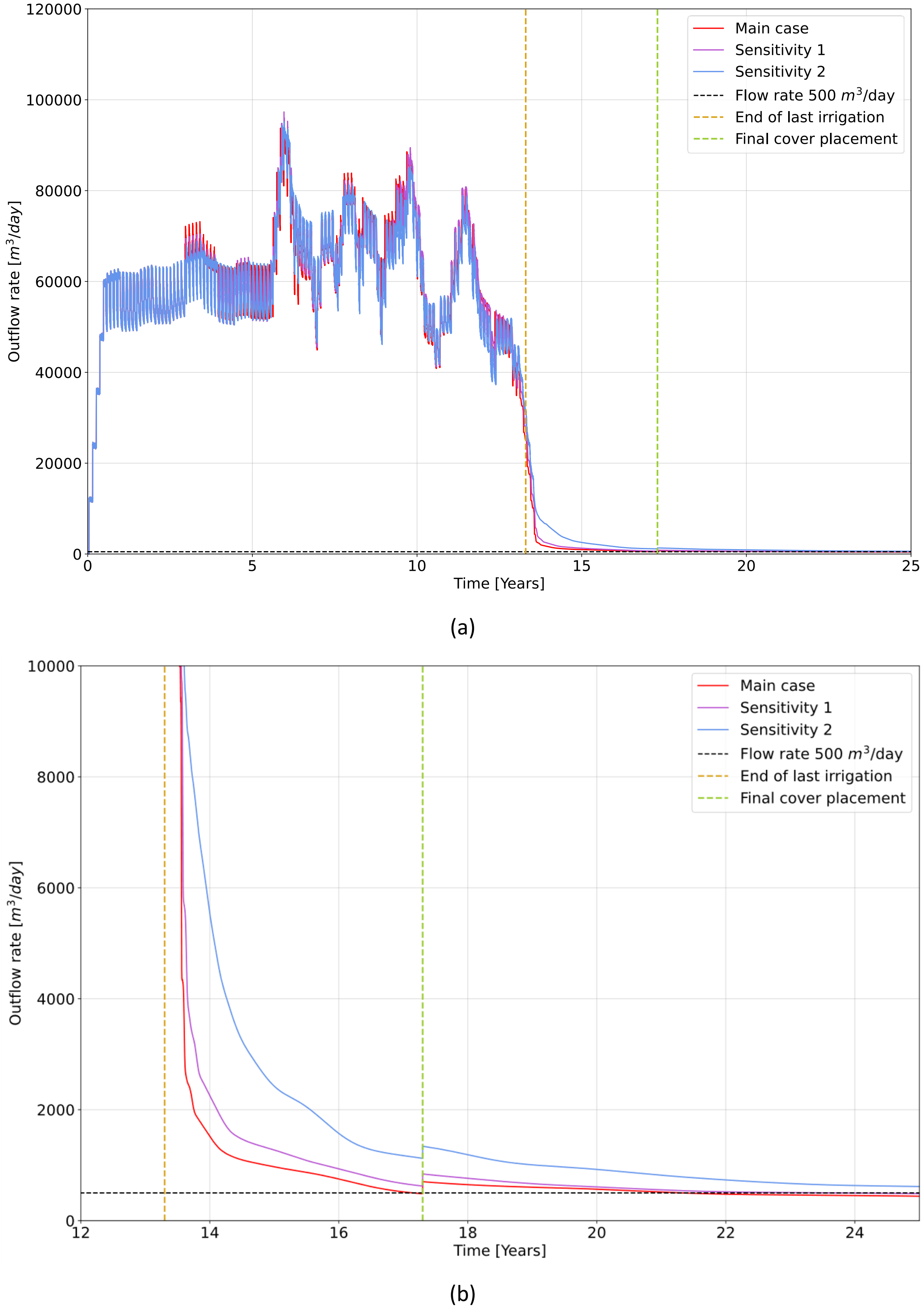


Figure 2 Estimated total outflow rate for the entire heap leach from main and sensitivity models for: (a) Entire outflow; (b) Draindown phase [a subset of (a)]

When considering only the drainage of residual water from irrigation (that is, excluding rainfall passing through the cover), small losses will occur through the liner at the base of the HLF and the outflow rate will eventually decrease to levels comparable to evaporative losses and become negligible. An estimate of the evaporation losses and observation at other HLFs indicate that evaporation could be sufficient to limit the draindown duration (excluding rainfall passing through the cover) to about 30–40 years following the last irrigation event.

Saturation profiles within the post-closure HLF were used as inputs to the oxygen transport and sulphide mineral oxidation model (Section 4). The profiles were modelled based on expected net percolation through the final cover (assessed by others). The results indicated that the HLF will remain unsaturated due to the site's very low precipitation rate, with saturation below 0.4 across the main and sensitivity cases (Figure 3 shows the main case saturation profile as an example). Given the arid site conditions, variations in climatic conditions, including dry and wet years, are expected to have negligible impact on saturation for different cover thicknesses.

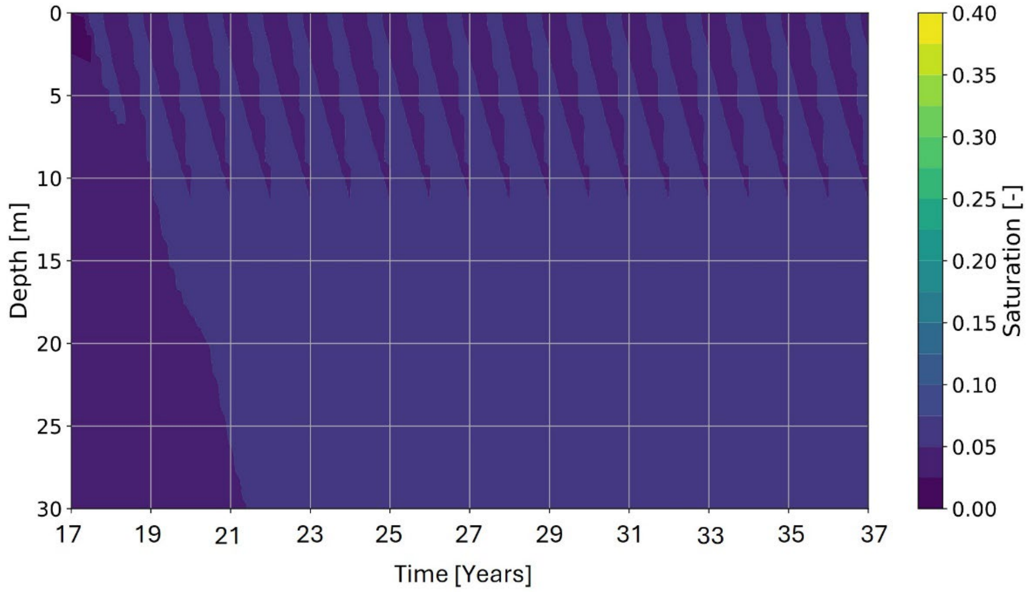


Figure 3 Saturation profile for group 3 lifts – main case assumptions

3.4 Model validation

Simulations were performed to compare the draindown model results (main case assumptions) with the observed metallurgical column test draindown (1.0 m in height, 0.14 m in diameter). The top boundary condition represented a constant inflow of 10 L/m²/hr in accordance with the irrigation rate used for the column tests. The model was used to simulate free draining after irrigation stopped, and the results are compared against the measured column test rates, as shown in Figure 4. The modelling results closely matched the measured draindown rates. This indicates that the hydraulic properties used in the modelling provide a reasonable representation of the heap leach material for water transport.

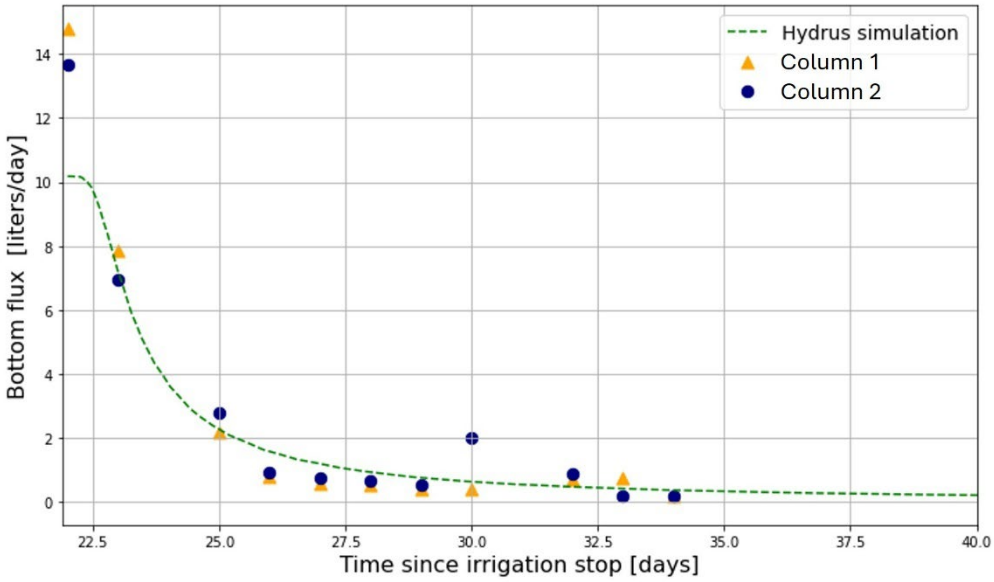


Figure 4 Column test draindown – measured versus simulated results

4 Oxygen transport and sulphide mineral oxidation

4.1 Conceptual model

Post closure, sulphide mineral oxidation (predominantly pyrite) will be expected to decrease, especially within the inner confines of the HLF. Conceptually, oxygen may be supplied to the interior of the oxidising heap by gas advection and oxygen diffusion.

Oxygen transport by advection is driven by pressure differences induced by differences in temperature which influence gas densities (often called convection) or by wind. Possible locations where advection could be the dominant gas transport mechanism are those near the face of the batter and along portions of the drainage layer (gravel and piping) of the interlift liner systems near the batter, unless this is prevented (e.g. by cover placement, U-bends in the drainage pipes). The paths of the advecting gas and the magnitude of the advecting gas velocities will be influenced by the intrinsic permeability and its spatial variability within the HLF.

Convection was excluded from the conceptual model on the basis of the intrinsic permeability measured for the ore (4.3×10^{-13} m^2 to 2.2×10^{-10} m^2) and proposed cover construction materials (5.4×10^{-16} m^2 to 1.0×10^{-11} m^2) being less than the theoretical values likely required to support convection. Numerical modelling for waste rock dumps completed by Pantelis & Ritchie (1991), Lefebvre et al. (2002), and Lahmira & Lefebvre (2008) suggest intrinsic permeabilities of less than 1×10^{-10} m^2 are unlikely to support convection. Furthermore, the intrinsic permeability of leached ore in the HLF is expected to be lower than laboratory measurements due to compaction from construction and will decrease over time as agglomerates break up and consolidate. Wind-driven advection was not explicitly assessed.

Oxygen supply by diffusion is driven by oxygen concentration gradients and is dependent on the saturation levels within the pore space. Sulphide mineral oxidation lowers the oxygen concentration in the heap pore spaces and resulting in oxygen concentration gradients. Over time, as sulphides are depleted in the near-surface layer, oxygen consumption decreases and oxygen diffuses deeper into the heap (i.e. the oxidation zone migrates downward). As the diffusion path length increases, the oxygen concentration gradient decreases and the oxygen supply rate consequently decreases, leading to lower rates of sulphide oxidation. The oxygen diffusion coefficient (D_{O2}) is the bulk material property that controls the oxygen flux by diffusion. The D_{O2} is dependent on the saturation of the leached ore.

4.2 Method

Oxygen diffusion was modelled to 100 years following the last HLF irrigation event. The model uses a 1D approach whereby a column of 1 m^2 surface area is represented, consisting of a cover layer of variable thickness (Table 1) and a 30 m layer of leached ore.

Table 1 lists the key input parameters to the model. Sulphide sulphur content reflects the conditions at the beginning of the modelling period. Intrinsic oxidation rate (IOR) values were calculated from oxygen consumption rate measurements on the leached ore.

Table 1 Key oxidation model input parameters

Parameter	Units	Value(s)
Sulphide sulphur	wt%	0.12 (cover material) 4.4 (leached ore)
Intrinsic oxidation rate (IOR)	kg(O_2)/kg/s	1.4×10^{-13} (cover material) 1.4×10^{-10} (leached ore)
Oxygen diffusion coefficient (D_{O2})	m^2/s	4.0×10^{-6} (cover material) 4.0×10^{-6} (leached ore)
Cover thickness	m	0, 0.5, 1.5, 3.0, 10

An upper D_{O2} estimate of 4×10^{-6} m^2/s was adopted for the leached ore and cover materials, based on the relationship between porosity, saturation and D_{O2} as proposed by Aachib et al. (2004) (Figure 5). The range of porosity values (0.3–0.5) represents compacted ripos (lower estimate) and the NAF waste rock cover (upper estimate). The range of saturation values represent the target saturation during HLF operation (upper estimate of 0.6) and the modelling results for draindown leached ore (lower estimate of 0.1).

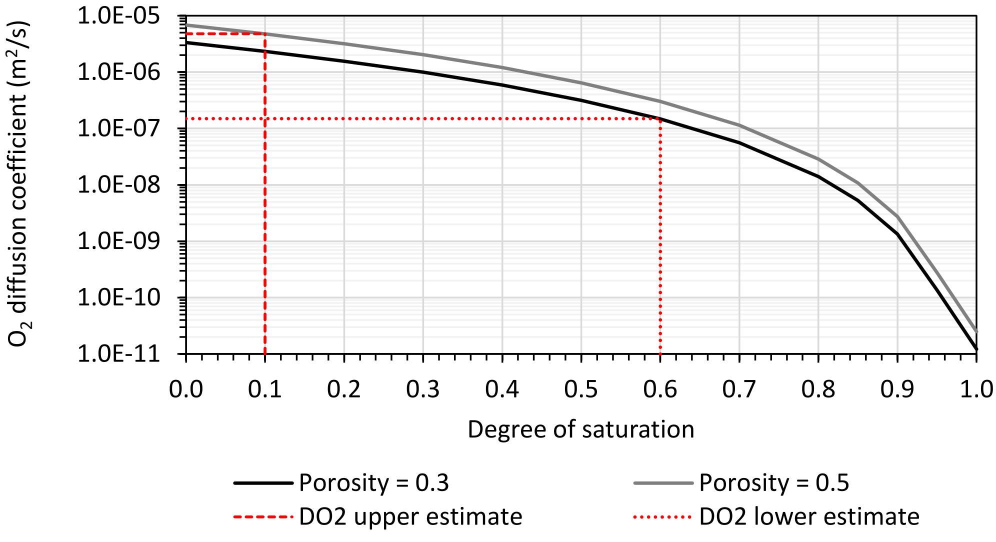


Figure 5 Diffusion coefficient (D_{O2}) estimated using the degree of saturation and porosity

The mathematical model developed to represent the time-dependent oxidation was based on the partial differential equations for conservation of mass and energy (e.g. Pantelis et al. 2002). These equations were solved using FlexPDE 7 (PDE Solutions Inc 2023), a finite element solutions environment for partial differential equations. The equations described:

- oxygen transport, simultaneous oxygen consumption and pyrite depletion
- heat production and transport

- constant atmospheric oxygen concentration and temperature at the HLF surface
- a 10 m-thick base layer to allow generated heat to be conducted through the base.

The oxidation rate calculations included a Monod dependence on reactant concentrations and an Arrhenius temperature dependence on chemical reactions.

4.3 Results

Without a cover, the depth of oxygen penetration is approximately 15 m for 100 years (Figure 6). The depth of penetration increases gradually. The slow rate of advancement is due to multiple factors including the increase in temperature in the top few metres of leached ore during the first 30 years, which increases oxidation rates and results in an increase in the oxygen consumption rates in this upper layer – therefore, less oxygen diffuses to depth. Furthermore, the rate of oxidation decreases with decreasing oxygen concentration (first order reaction kinetics) which means that the rate of sulphide depletion at depth is slow.

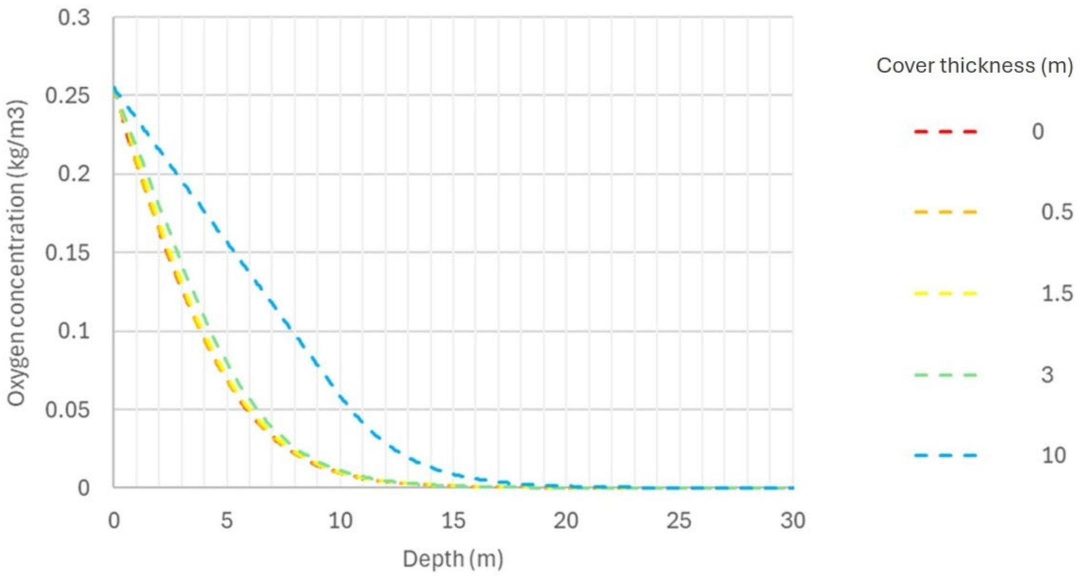


Figure 6 Oxygen concentration versus depth at 100 years for 5 cover thicknesses. Note the 0 m case appears overlaid with the 0.5 m case

Figure 7 presents calculated sulphate generation rates. The initial spikes in sulphate generation are associated with the assumed oxygen concentrations in the cover and leached ore. The subsequent results suggest that the 10 m-thick cover could reduce the maximum rate of sulphate generation (at about year 10, with no cover) from about 15 kg(SO_4)/m^2/year to less than 5 kg(SO_4)/m^2/year. At year 100, the rate for the 10 m cover remains approximately the same whereas the rate for the uncovered HLF would decrease to just above 10 kg(SO_4)/m^2/year.

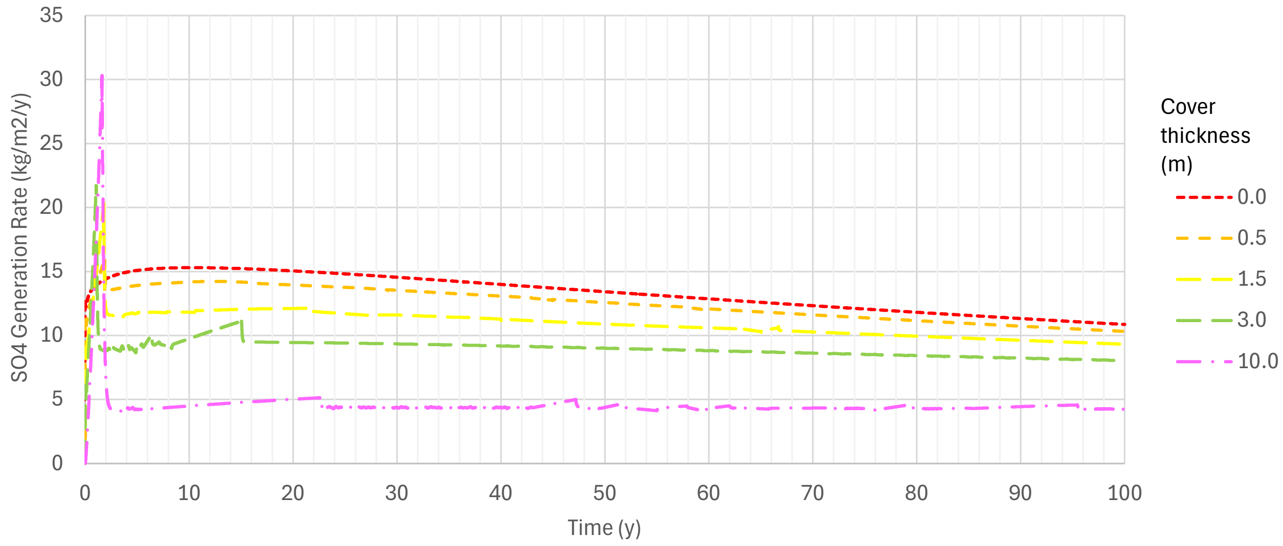


Figure 7 Sulphate generation rate over time for 5 cover thicknesses. Note year 0 commences when irrigation of the heap leach facility ceases

5 Solute release

5.1 Conceptual model

Seepage quality is expected to initially resemble the pregnant leach solution (PLS). It will be strongly acidic (pH 1.2) with up to 5 g/L dissolved copper and 120 g/L sulphate. As draindown progresses, seepage quality will transition to reflect mineralogical weathering of the leached ore subject to meteoric water percolation and oxidation of residual sulphides (predominantly pyrite). The leached ore will contain negligible ANC from carbonate minerals; however, silicate minerals such as plagioclase feldspar and chlorite, may provide some ANC in the long term once residual acid from the active HLF leaching has been removed.

Conceptually this transition will be gradual (in the order of decades), with draindown becoming progressively dictated by percolating rainfall and sulphide mineral oxidation. Due to the HLF design, much of this change will occur in the upper 30 m layer (group 3 lifts) following the removal of the temporary cover and in the batters (noting oxidising leached ore located under the interlift liners are unlikely to be flushed by percolate, Figure 8).

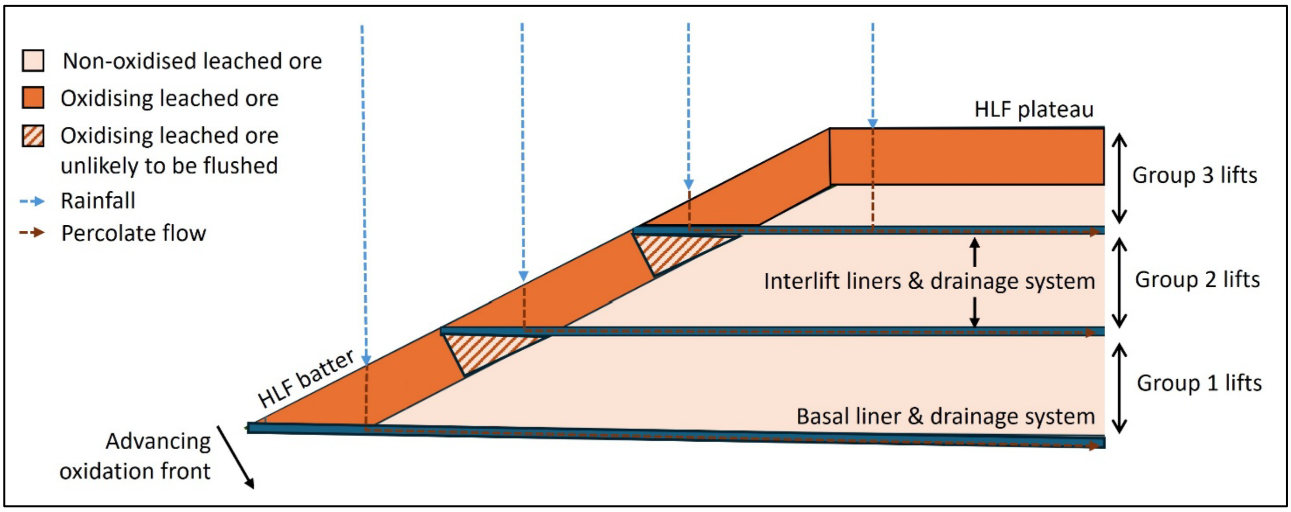


Figure 8 Conceptual diagram of heap leach facility (HLF) solute generation (no-cover scenario)

Cover placement at closure will result in lower concentrations of sulphate and dissolved elements in the post-draindown seepage due to a reduction in sulphide mineral oxidation rates as shown by oxygen transport modelling (Section 4).

5.2 Method

Seepage quality following the last HLF leach event was estimated using draindown test results from a metallurgical column leach test containing leached ore representative of the HLF material composition and grain size. The column (1 m in height and 0.14 m in diameter) contained 20 kg of agglomerated ore leached at 50°C for 50 days. The irrigation solution was conditioned (pH 1.2 ±0.1, <5 g/L Cu, <120 g/L SO_4) and recirculated, consistent with the HLF operation.

Concentrations of calcium, iron, silicon and sulphate in the column draindown were likely constrained by mineral solubility as inferred by mineral saturation indices calculated using PHREEQC software (Parkhurst & Appelo 2013). Concentrations of solutes not subject to leach solution conditioning and/or solubility constraints are expected to increase with increasing leached ore height (i.e. 1 m column to 30 m group height). This increase is not necessarily scalable due to differences in contact times (including recirculation) and oxygen availability between the column and HLF, and additional constraints such as co-precipitation with oxide and (oxy)hydroxide minerals, and adsorption to mineral surfaces. Therefore, the measured concentrations of unconstrained solutes in the column draindown represent lower bound estimates for the HLF initial draindown (Table 2).

Seepage water quality resulting from mineralogical weathering of the leached ore was based on sulphate generation rates from oxygen transport modelling (Section 4) and element-to-sulphate mass ratios calculated from kinetic test data. Annual sulphate production (kg/year) was calculated based on sulphate generation rates (kg/m^2/year) for the no-cover and 4-cover thickness options assessed as part of the oxygen transport modelling for the HLF. Three scenarios were evaluated:

- no cover
- cover A – 3 m cover on batters and 0.5 m cover on the plateau
- cover B – 10 m cover on batters and 1.5 m cover on the plateau.

The external surface areas of the HLF were calculated using its dimensions and a simplified trapezoidal geometry to account for batter exposure and oxidising leached ore located under the interlift liners that are unlikely to be flushed by percolate (Figure 8). The temporary cover on lift 9 during years 0 to 3 was assumed to be impervious to gas flux (i.e. no oxidation of the leached ore will take place below the temporary cover during this time). Solute contribution from the NAF waste rock cover was considered negligible.

The leachable mass generated from ongoing oxidation in the leached ore was assumed to be dissolved in porewater flux through the HLF. A factor of 0.3 was applied to annual solute production rates as an estimate of the portion of leached ore that would be contacted by percolating water.

Solute concentrations were adjusted for potential mineral and gas interactions under equilibrium conditions using PHREEQC (Parkhust & Appelo 2013). This included assessing the potential role of silicate ANC in moderating long-term seepage pH assuming an excess of kaolinite in the post-draindown leached ore. Kaolinite was used as an example of silicate ANC because it generally forms at the end of the silicate mineral weathering sequence (Plumlee 1999) and is unlikely to be depleted from the HLF. Kinetic mineral dissolution and depletion associated with faster reacting silicates was not considered at this stage.

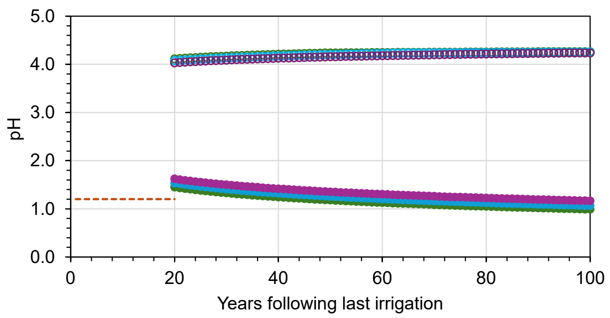
5.3 Results

Figure 9 shows percolate pH and concentrations of selected parameters as a function of post-draindown time, with concentrations in the initial draindown (PLS) shown for comparison (red dashed lines). Table 2 lists results for a greater number of parameters in the initial draindown and at 100 years following the last HLF irrigation event.

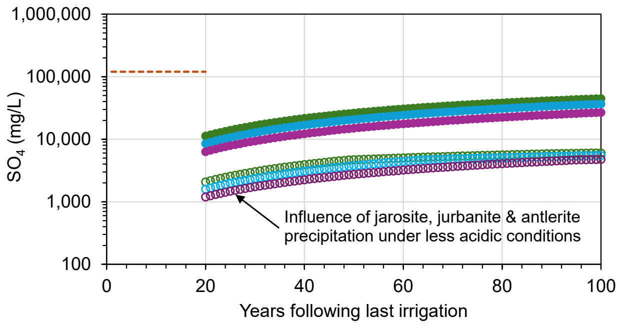
Without silicate ANC, the pH of the post-draindown seepage (pH 1.0–2.6) will be similar to the pH of initial draindown (pH 1.2) (Figure 9a). Assuming silicate ANC will react with the percolate, the pH of the post-draindown seepage is predicted to be less acidic (pH 3.6–4.2), resulting in lower sulphate (Figure 9b), dissolved copper (Figure 9c), aluminium and iron concentrations (due to the precipitation of jarosite, antlerite, jurbanite and ferrihydrite).

The change in pH had no effect on solutes not constrained by secondary mineral solubility, including arsenic (Figure 9d), molybdenum, nickel, selenium, uranium, vanadium and zinc. Processes that may constrain the concentrations of these solutes, including adsorption to oxides and hydroxides, and co-precipitation with sulphates and hydroxysulphates, were not assessed. Cover placement for closure resulted in lower concentrations of sulphate and dissolved elements in the post-draindown seepage due to a reduction in oxidation rates (Section 4).

Modelled solute concentrations in post-draindown seepage were either similar to or lower than the initial draindown water for most parameters (Table 2). By year 100, the portion of the total sulphide inventory estimated to have oxidised within the HLF ranged from 5.0% for the thicker cover scenario (cover B) to 8.4% for the no-cover scenario.



(a)



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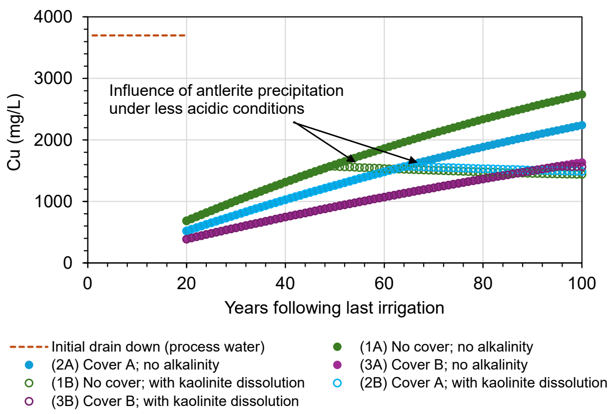
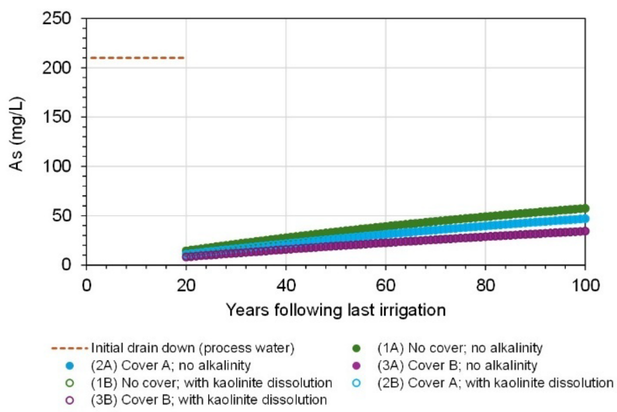


(d)



(d)

Figure 9 Estimated post-closure seepage concentrations as a function of time. (a) pH; (b) Sulphate; (c) Dissolved copper; (d) Dissolved arsenic

Table 2 Estimated heap leach facility seepage quality

Parameter [1]	Unit	Initial draindown (pregnant leach solution)	Long-term post-closure (100 years) seepage [4]		
			1 – No cover	2 – Cover A	3 – Cover B
pH	–	1.2 [2]	1.0–4.3	1.1–4.3	1.2–4.2
TDS	mg/L	190,000 [3]	9,500–54,000	8,700–44,000	7,600–32,000
SO_4	mg/L	120,000 [2]	6,000–45,000	5,500–37,000	4,800–27,000
Al	mg/L	2,600 [3]	73–2,100	62–1,700	48–1,200
As	mg/L	210 [3]	58	47	34
Ca	mg/L	420 [2]	340–410	360–370	270
Co	mg/L	520 [3]	94	77	56
Cu	mg/L	3,700 [2]	1,400–2,700	1,500–2,200	1,600
Fe	mg/L	30,000 [2]	0.17–2,700	0.12–2,200	0.12–1,600
Mg	mg/L	690 [3]	300	250	180
Mn	mg/L	130 [3]	39	32	23
K	mg/L	<1 [3]	0.000029–0.00067	0.000026–0.00068	0.000037–0.0007
Na	mg/L	16 [3]	0.066–1.5	0.06–1.5	0.084–1.6
Zn	mg/L	53 [3]	270	220	160

Notes: [1] Elements are dissolved concentrations; [2] High confidence estimate; the concentration is limited by leach solution conditioning and/or inferred mineral solubility limit; [3] Lower confidence estimate; the concentration is unconstrained; [4] Concentration ranges represent with and without silicate acid neutralisation capacity

5.4 Sensitivity analysis

The main sources of uncertainty in estimating solute release were:

1. the mixing of residual PLS and porewater solely characterised by sulphide mineral oxidation. This was not represented because it would require spatial discretisation of dilution, dispersion and mixing processes within the HLF, which was beyond this assessment scope. Instead, results were presented for the 2 water types as an indicative range of draindown water quality
2. the availability and reactivity of silicate ANC for buffering percolate in the long term. Depending on actual availability and reaction rates, silicate buffering could increase pH from 1.0 to 4.3 with concentrations of sulphate and dissolved aluminium, iron, sodium and potassium spanning one or more orders of magnitude (Table 2).

6 Conclusion

The key management questions posed at the study outset and the conclusions found are as follows:

- 'How long will draindown from the heap leach facility occur following closure?'

Results indicated that 4 years after the final cover is placed, drainage flow could decrease by up to 99%. Approximately 16–57% of the total drainable water would remain after 4 years, and draindown (excluding cover infiltration) could continue for 30–40 years, depending on evaporative losses.

The range in predicted outcomes reflects the propagation of uncertainty in the estimated SWCC and saturated hydraulic conductivity, for which laboratory measurements were not available. The sensitivity analyses varied both the SWCC shape and saturated hydraulic conductivity to reflect plausible ranges of consolidated and de-agglomerated leached ore. The draindown duration is also strongly influenced by the site's evaporation rate and the passive water management strategy ultimately adopted at closure. These predictions will be refined as site-specific laboratory data on hydraulic properties become available during subsequent design stages.

- 'What impact will the use of interlift liners and a final cover have on draindown?'

During HLF closure, the interlift liners and final cover will have negligible impact on draindown volume and duration, given the low rainfall (3.2×10^{-9} $m^3/m^2/s$) relative to active irrigation (1.7×10^{-6} $m^3/m^2/s$). Oxygen transport and associated sulphide mineral oxidation will not be impeded by the interlift liners. Oxygen ingress will occur in the batters and the group 3 lift to an approximate depth of 15 m. Greater oxidation depths are possible along drainage layers if they are not capped with low-permeability materials at closure.

Results showed that the final cover would regulate the rate of oxidation. Lower permeability cover materials will be required to reduce oxygen ingress into the leached ore, with modelling indicating a threefold reduction in sulphate production for a non-acid forming waste rock cover more than 10 m thick.

- 'Will management measures be required to reduce draindown volume and duration?'

Initially, water quality would resemble the pregnant leach solution (pH ~1.2). After rapid draindown, ongoing pyrite oxidation will sustain acidic seepage (pH 1.0–2.6) with solute concentrations in post-draindown seepage typically similar to or less than the initial draindown water.

Passive water management may be possible at the site, considering the high evaporation rates, and should be investigated for the management of drainage from the HLF post closure. The time needed to reach the point where passive management is possible will depend on the site configuration as well as environmental, operational and regulatory requirements.

At closure, measures can be undertaken to reduce oxygen ingress into the landform, including sealing blower pipes and adding U-bends in drains to limit oxygen entry. Lower permeability materials are being considered for the final cover design.

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