

Six months of monitoring of a tailings storage facility barrier cover trial at Rosebery Mine, Tasmania

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Abstract

The rehabilitation of a potentially acid forming (PAF) tailings storage facility (TSF) to minimise potential contamination is site specific; being a function, among other factors, of TSF construction method, the tailings deposition and storage method used, and climate.

Two experimental barrier cover trials have been constructed at the Bobadil TSF at Rosebery Mine in the northwest of Tasmania to inform rehabilitation of the facility at the end of its operation.

The primary design objective of the Bobadil TSF barrier cover is to limit rainfall infiltration (referred hereon as seepage) and to a lesser extent limit the potential for oxygen to diffuse into the underlying PAF tailings.

One of the installed barrier cover trials at Bobadil TSF incorporates a geosynthetic clay liner (GCL) at the interface between the tailings and the overlying cover comprised of glacial till (450 mm) and Moorland peat (150 mm).

The Moorland peat provides a perched phreatic zone that is largely anoxic and limits the potential for deep-rooted trees to establish, that may potentially damage the GCL. Further, the peat provides the preferred environmental conditions for shallow-rooted native grasses that will enhance the water transpiration from the cover and create an ecological community that is sympathetic to the surrounding landscape.

As an alternative the barrier cover trials include a variant in which the GCL is removed.

Both cover trials have been highly instrumented to allow the assessment of their relative performance over the next 3–5 years.

This paper describes the first six months of performance monitoring, specifically reporting on the volumetric water content, matric suction and oxygen diffusion at various depths within the cover and tailings profile and the rates of seepage through the cover.

The monitoring to date indicates that the barrier cover variant incorporating the GCL liner achieves the design objectives and the variant without the GCL liner does not.

Keywords: *cover design, geochemistry, acid rock drainage*

1 Introduction and background

1.1 Location

The Rosebery Mine (the Mine) is an underground polymetallic mine (zinc, lead, copper, gold and silver) with some small-scale open cut workings on mining lease (ML) 28M/1993. The mine is owned and operated by MMG Australia Limited (MMG), approximately (~)125 km south of Burnie and ~300 km northwest of Hobart

on the west coast of Tasmania. The region surrounding the mine is heavily forested and has a wet climate. The Bobadil TSF (the TSF) is located approximately 3.5 km northwest of the mine adjacent to Lake Pieman, an operating hydroelectric reservoir.

1.2 The Bobadil TSF

Bobadil TSF has been in operation since 1974 and contains mine tailings that are potentially acid forming (PAF). In the absence of ongoing management, the tailings pose a risk of generating acidic and metalliferous drainage (AMD) that may not be acceptably assimilated within the receiving environment of Lake Pieman. MMG is currently conducting a closure prefeasibility study that includes identifying suitable decommissioning options for Bobadil TSF.

In 2021 the Bobadil TSF had a ‘stepped in’ upstream embankment lift to extend its operational life. A barrier cover was required to be installed on the 9 hectare ‘stepped in area’ in order to bring the embankment within acceptable geotechnical factors of safety. This situation provided an opportunity to trial different cover designs, prior to final decommissioning.

Investigations into closure cover designs suitable for Bobadil TSF were commenced in 2016. At that time a Phase A prefeasibility study (PFS-A) was completed by O’Kane Consulting Pty Limited (OKC). The preferred PFS-A closure design was a synthetically lined low permeability cover using a linear low-density polyethylene (LLDPE) and compacted clay layer (CCL). The objectives were to limit oxygen and seepage to the tailings and reduce the generation and transport of AMD.

SRK in 2020 built upon the PFS-A and completed a Phase B prefeasibility study (PFS-B). They identified that the construction of a CCL on tailings would be difficult to construct and the locally available glacial till soil materials may not be able to achieve the design objective of reducing seepage rates to below 1% of rainfall. SRK therefore recommended trialling two cover designs; one incorporating a compacted glacial till layer and the other glacial till incorporating a geosynthetic clay liner (GCL).

Due to Bobadil TSF being located within a heavily forested region with a wet climate, SRK and LMRS Pty Limited (LMRS) also recommended Moorland peat be used as the top layer of the cover to maintain near-saturated conditions that would inhibit the germination and growth of tall-growing and deep-rooting plants that would physically damage the glacial till and the GCL cover materials.

The resulting cover variants there were proposed by SRK and LMRS are given in Figure 1.

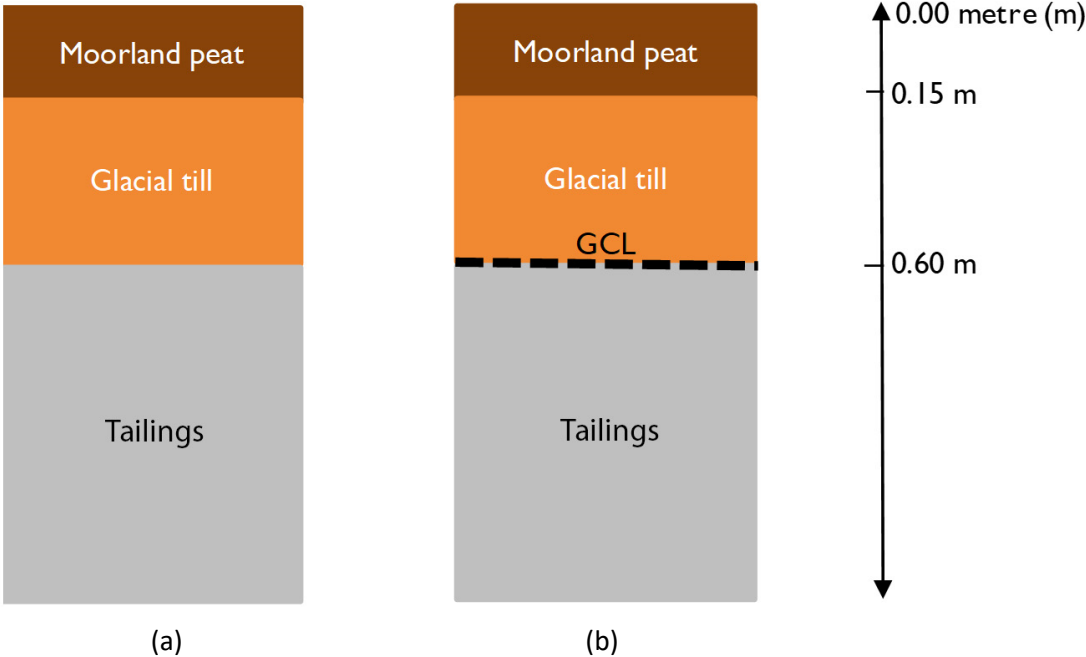


Figure 1 Proposed cover variants. (a) Glacial till cover; (b) GCL cover

In 2021, MMG commissioned two cover trials, (one cell (50 m × 50 m) for each cover option from PFS-B) on the Stage 10A embankment lift of the TSF and commenced monitoring of their performance (the cover trials) (Figure 2):



Figure 2 The cover trial area location at Bobadil TSF, Rosebery Mine, Tasmania

2 Method

The primary design objective of the Bobadil TSF barrier cover is to limit seepage and to a lesser extent limit the potential for oxygen to diffuse into the underlying PAF tailings. A secondary design objective is to identify a vegetation community that would minimise the risk of cover failure due to the establishment of deep-rooted plants species.

The two cover trial plots were highly instrumented so that their performance could be assessed over the next 3–5 years during which time the cover materials would be expected to settle, performance readings to stabilise, and vegetation to establish. The installed instrumentation included:

1. Two bulk lysimeters in each plot to measure seepage (Figure 1).
2. Two monitoring stations for each plot that monitor: volumetric water content (VWC), matric suction (the tenacity of the soil matrix to hold onto water in the absence of solute in the water and oxygen concentrations) (Figure 1).
3. Two clear acrylic root density tubes to 2 m in depth in each plot to allow periodic photographic recording of root activity (root density and depth).

2.1 The lysimeters

2.1.1 Design

Replication of in situ conditions within and around the lysimeters is important for correct function (Bews et al. 1997; O’Kane & Barbour 2003). The vertical wall height of the lysimeter must be greater than the potential

capillarity of the backfill. This condition will be satisfied where the applied flux (non-restricted percolation from the base of the cover trials) is equal to the hydraulic conductivity (measured as pressure head) internal and external to the lysimeter (Bews et al. 1997; O’Kane & Barbour 2003).

Because the lysimeters have been buried at depth, it is not possible to see and evaluate their function. Interpretation of function is dependent on understanding the processes that control unsaturated flow which was evaluated using SEEP/W (Geo-Slope International Limited 2012).

The SEEP/W model was set up to consider a lysimeter with a:

1. 2.38 m wall height.
2. Diameter of 3.67 m.
3. Buried 0.1 m below the cover trial.
4. Has a rock filter in the base of the lysimeter designed following Bertram and the US Army Corp of Engineers (reported in Cedegren (1977)).
5. The remaining volume within the lysimeter is backfilled with tailings at the same density as the tailings outside of the lysimeter.

The Soil Water Characteristic Curves (SWCCs) used in the SEEP/W model are given in Figure 3 and have been taken from the PFS-B, except for peat, which has come from Walczak et el. (2002).

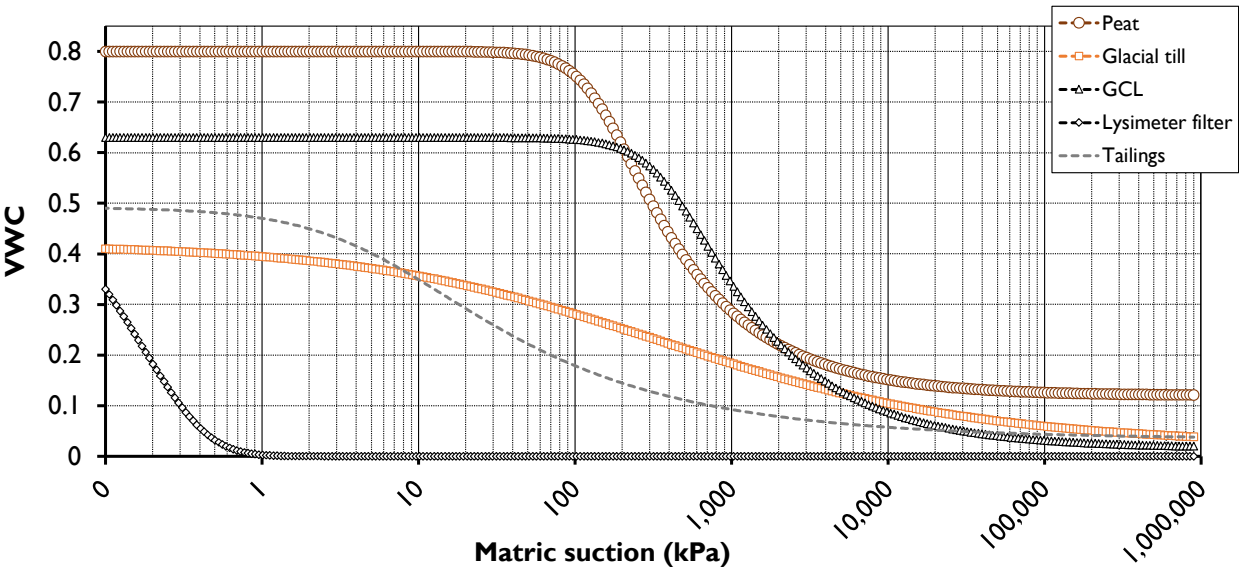


Figure 3 SWCCs used for lysimeter function modelling

The saturated hydraulic conductivities have also been taken from the PFS-B, with the exception of peat, which has been taken from Walczak et el. (2002) (Table 1).

Table 1 Saturated hydraulic conductivity used for lysimeter function modelling

Material	Saturated hydraulic conductivity (m/day)
Peat	8.64×10^{-03}
Glacial till	6.91×10^{-04}
GCL	1.73×10^{-06}
Tailings	8.64×10^{-02}

Because the lysimeters are buried at depth, it is not possible to observe and evaluate their function. Interpretation of their function is dependent on understanding the processes that control unsaturated flow which has been evaluated using SEEP/W (Geo-Slope International Limited 2012). Transient analysis (in SEEP/W) was done to assess lysimeter function using the wettest, driest and average years of rainfall selected from the ranked annual rainfall for the past 131 years from Queensland Government (2020) (Table 2).

Table 2 Transient rainfall analysis

Year	Description	Rainfall (mm)
2019	Wettest year	3,605
2015	Average year	2,453
1950	Driest year	1,653

The results of the analysis (Figures 4 and 5) show that the lysimeter wall height will stop percolation wicking towards/away from the lysimeters because the internal and external pressure heads are equal, meaning that the lysimeter results can be relied upon as giving a true measurement of percolation.

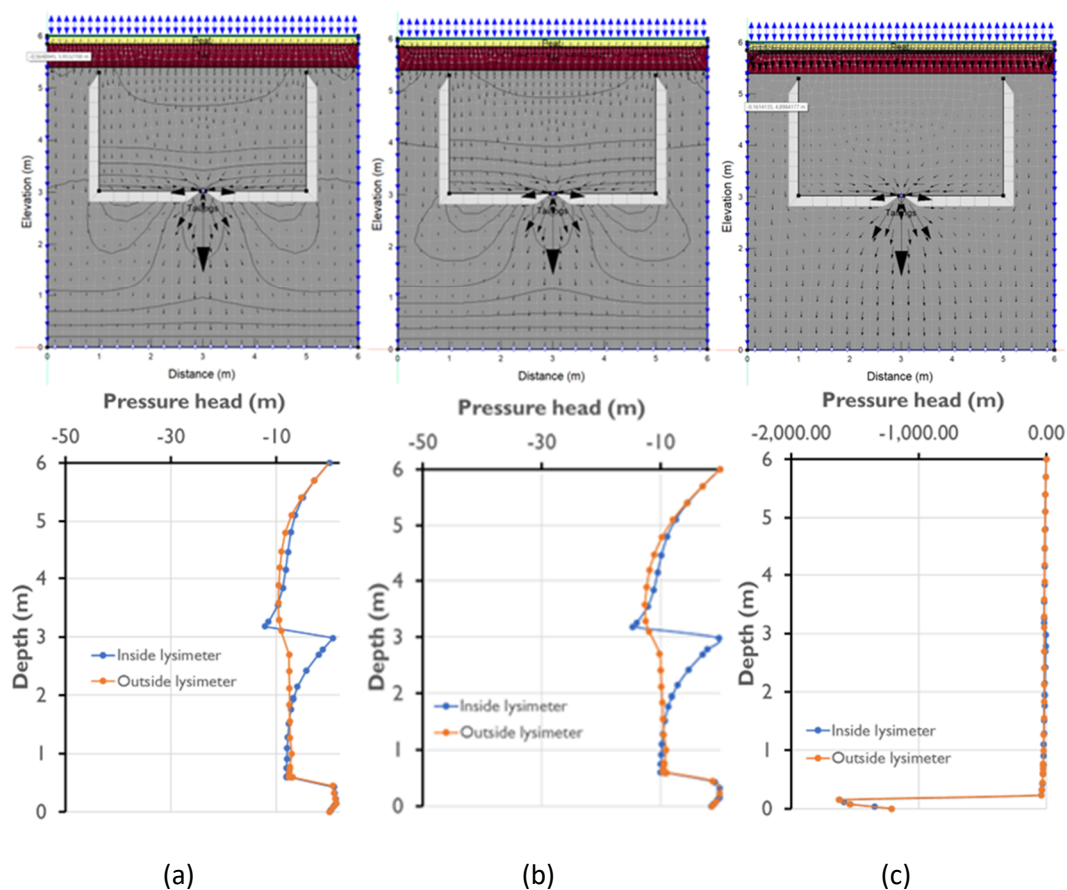


Figure 4 Lysimeter wall height performance for the GCL cover. (a) Wettest; (b) Average; (c) Driest year

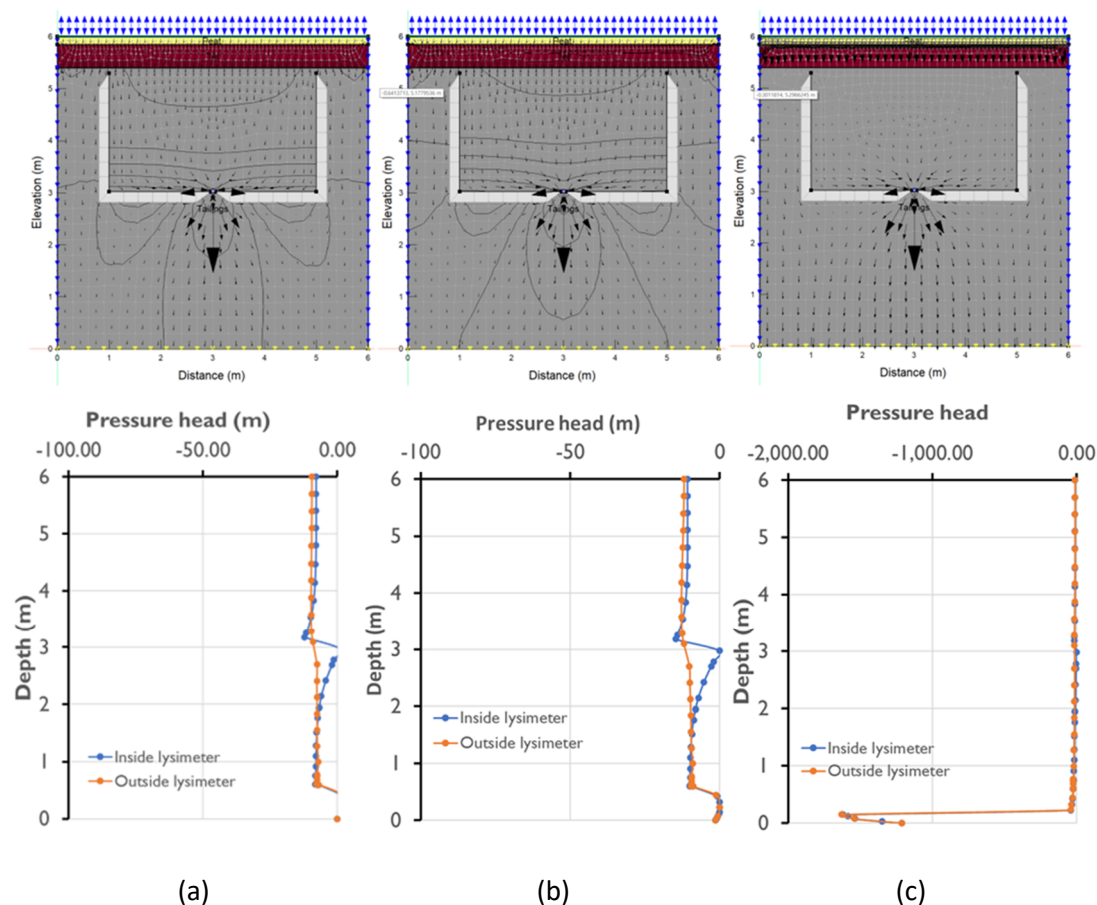


Figure 5 Lysimeter wall height performance for the no GCL cover. (a) Wettest; (b) Average; (c) Driest year

2.1.2 Installation

They lysimeters are an ‘off-the-shelf’ acid resistant and reinforced water tank that has its top cut off. They were installed in the field by first excavating an installation trench (Figure 6a), followed by lowering the lysimeter into place and attaching its 80 L seepage sump (Figure 6b) and then finally attaching the vertical stand-pipe (Figure 6c). The lysimeters are purged by automated groundwater pumps reporting to rain gauge tipping buckets. The automated system is triggered by floating switches in each sump (Figure 7).

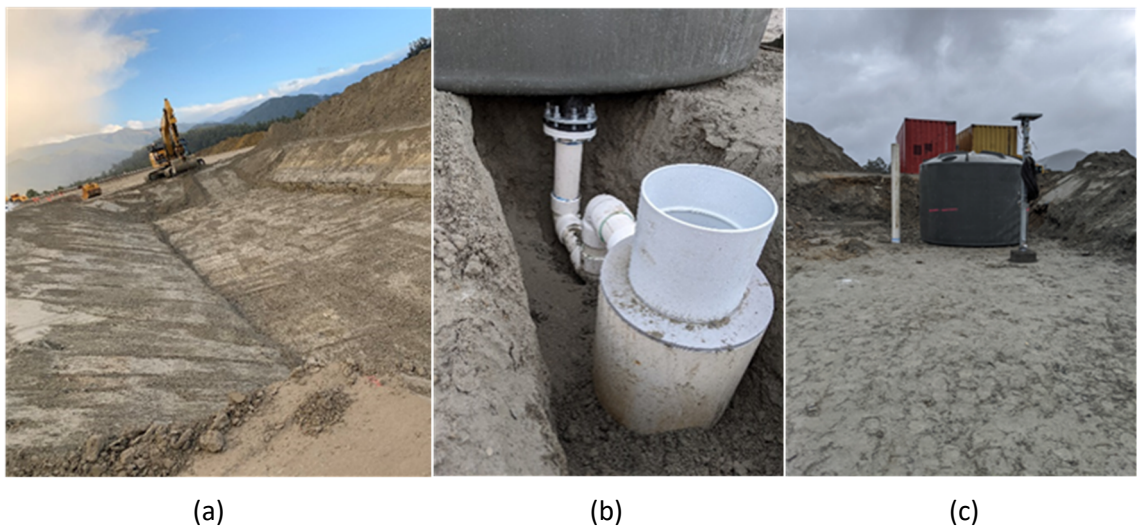


Figure 6 Lysimeter installation. (a) Installation trench; (b) Seepage sump; (c) Vertical stand-pipe

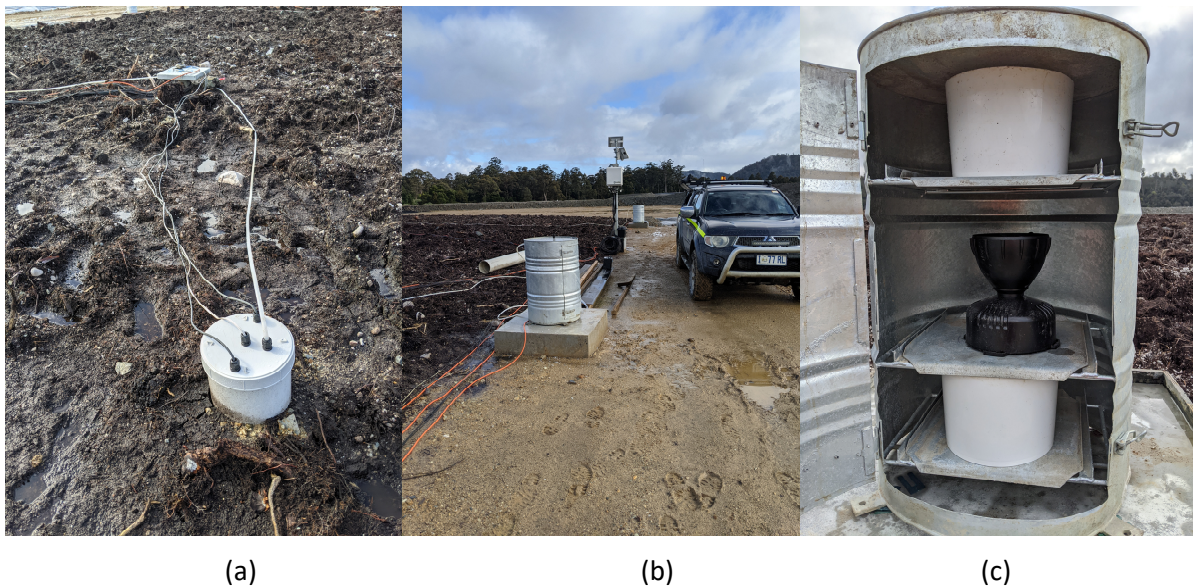


Figure 7 Lysimeter monitoring station. (a) Vertical stand-pipe at top of cover; (b) Monitoring station; (c) Rain gauging tipping bucket to measure seepage volume

2.2 The monitoring stations

2.2.1 Design

The cover trials and underlying tailings are monitored for VWC, matric suction and oxygen concentration (the sensors). They have been installed into the cover trials using a sensor tree, designed to protect the sensors and wires from the acidic conditions and damage during installation, prolonging their serviceability (Figure 8).

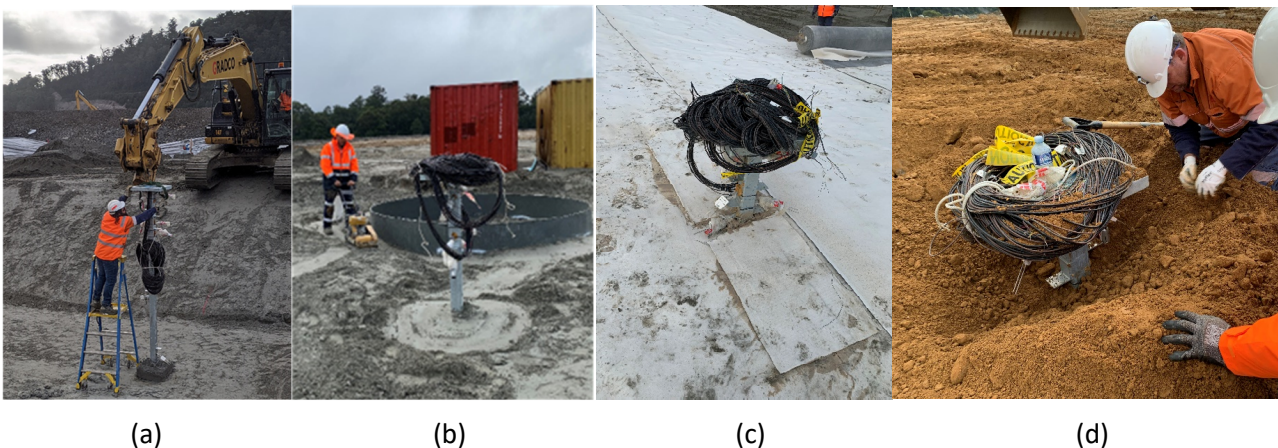


Figure 8 Sensor tree installation. (a) Mounting sensor tree in footing; (b) Backfilling tailings; (c) Placing GCL around sensor 'trees'; (d) 'Hand' backfilling glacial till around sensors

The matric suction sensors are recommended for use for matric suctions ranging from 10–1,000 kPa. The sensors have been calibrated for suctions greater than 1,000 kPa having regard for the technique used by Flint et al. (2002). The calibration functions presented extended up to 1,000,000 kPa (Figure 9); however, matric suctions of this magnitude are not expected in the field.

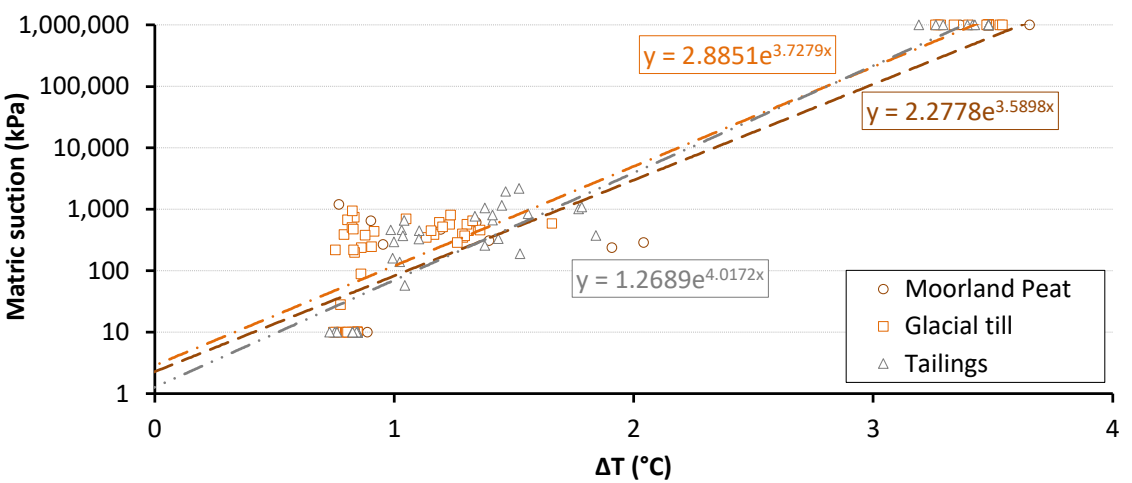


Figure 9 Matric suction sensor calibration functions

2.2.2 Installation

The buried sensors’ vertical position in the cover and underlying tailings when buried are given in Figure 10. The density of the tailings and cover material was achieved using a combination of vibrating drum roller, whacker packers and hand tools.

Depth of burial (mm)	Sensor	Material	Sensor	Material	Depth of burial (mm)	Sensor	Material	Sensor	Material
20	MS, VWC, Oxygen	Moorland peat	MS, VWC, Oxygen	Moorland peat	20	MS, VWC, Oxygen	Moorland peat	MS, VWC, Oxygen	Moorland peat
70	MS, VWC	Glacial till	MS, VWC	Glacial till	70	MS, VWC	Glacial till	MS, VWC	Glacial till
320	MS, VWC	Glacial till	MS, VWC	Glacial till	320	MS, VWC	Glacial till	MS, VWC	Glacial till
420	MS, VWC	Glacial till	MS, VWC	Glacial till	420	MS, VWC	Glacial till	MS, VWC	Glacial till
520	MS, VWC, Oxygen	Glacial till	MS, VWC, Oxygen	Glacial till	520	MS, VWC, Oxygen	Glacial till	MS, VWC, Oxygen	Glacial till
620	MS, VWC, Oxygen	Tailings	MS, VWC, Oxygen	Tailings	620	MS, VWC, Oxygen	Tailings	MS, VWC, Oxygen	Tailings
1,670	MS, VWC, Oxygen	Tailings	MS, VWC, Oxygen	Tailings	1,670	MS, VWC, Oxygen	Tailings	MS, VWC, Oxygen	Tailings
2,670	MS, VWC	Tailings	MS, VWC	Tailings	2,670	MS, VWC	Tailings	MS, VWC	Tailings

MS = matric suction

(a)

MS = matric suction

(b)

Figure 10 Sensor burial depth

3 Results and discussion

The following results and discussion are for the first six months of cover monitoring.

3.1 Volumetric water content and degree of saturation

The VWC and degree of saturation (S) versus depth results are given in Figures 11 to 14 for the non-GCL and the GCL cover. Generally, the VWC content has decreased in both covers since December 2021 from a VWC of ~ 0.4 and a S of 1.0 to a VWC of ~ 0.1 and a corresponding S of ~ 0.4 . The tailings below both covers have remained at near-saturation with a VWC of ~ 0.25 – 0.37 corresponding to a S of ~ 0.6 – 1.0 .

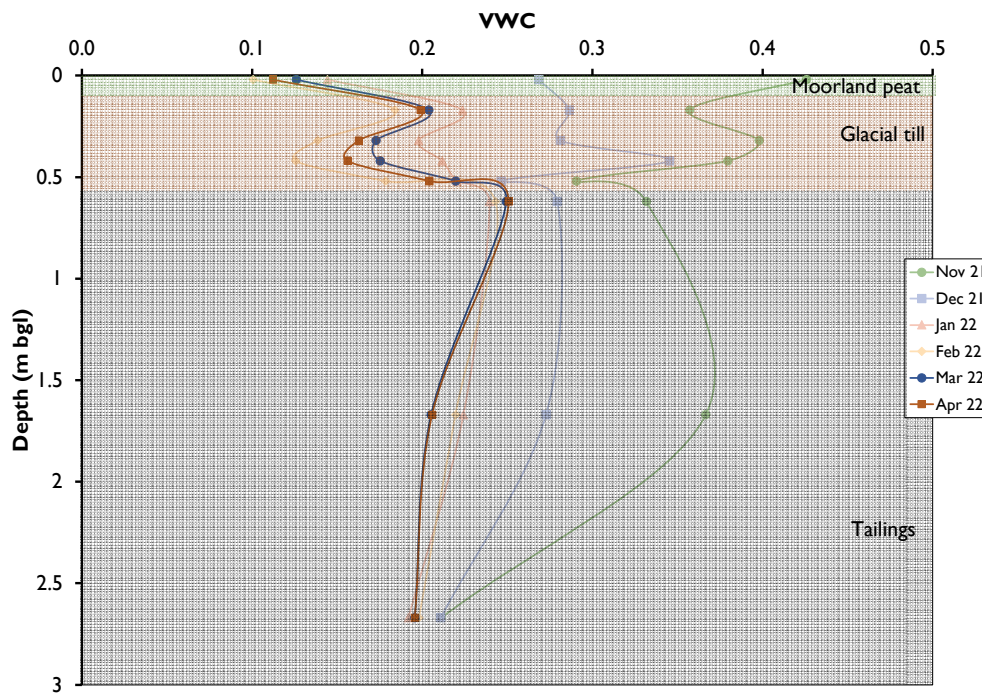


Figure 11 No GCL cover VWC versus depth

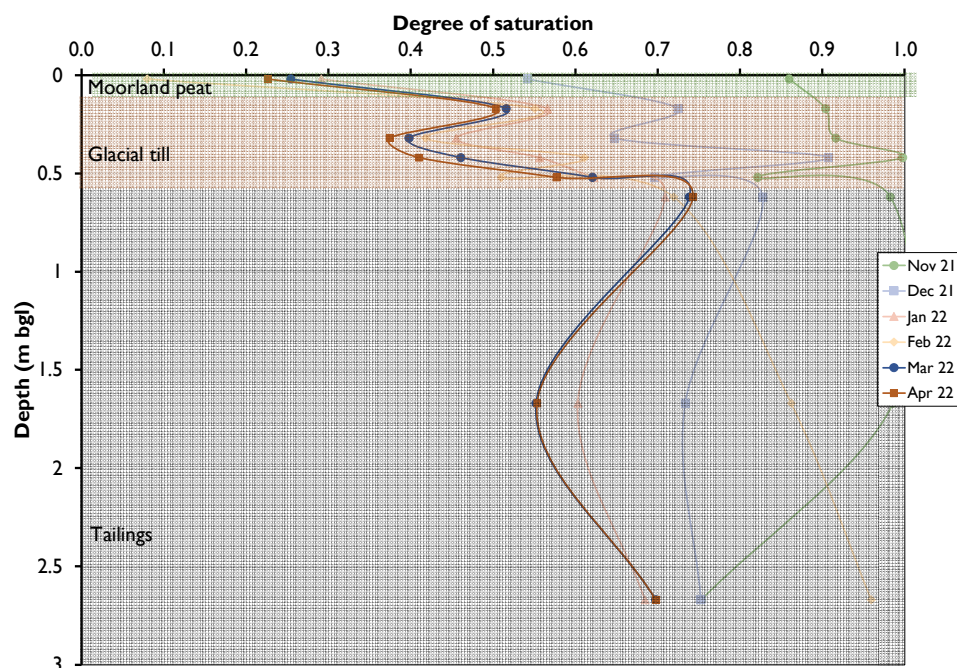


Figure 12 No GCL cover degree of saturation versus depth

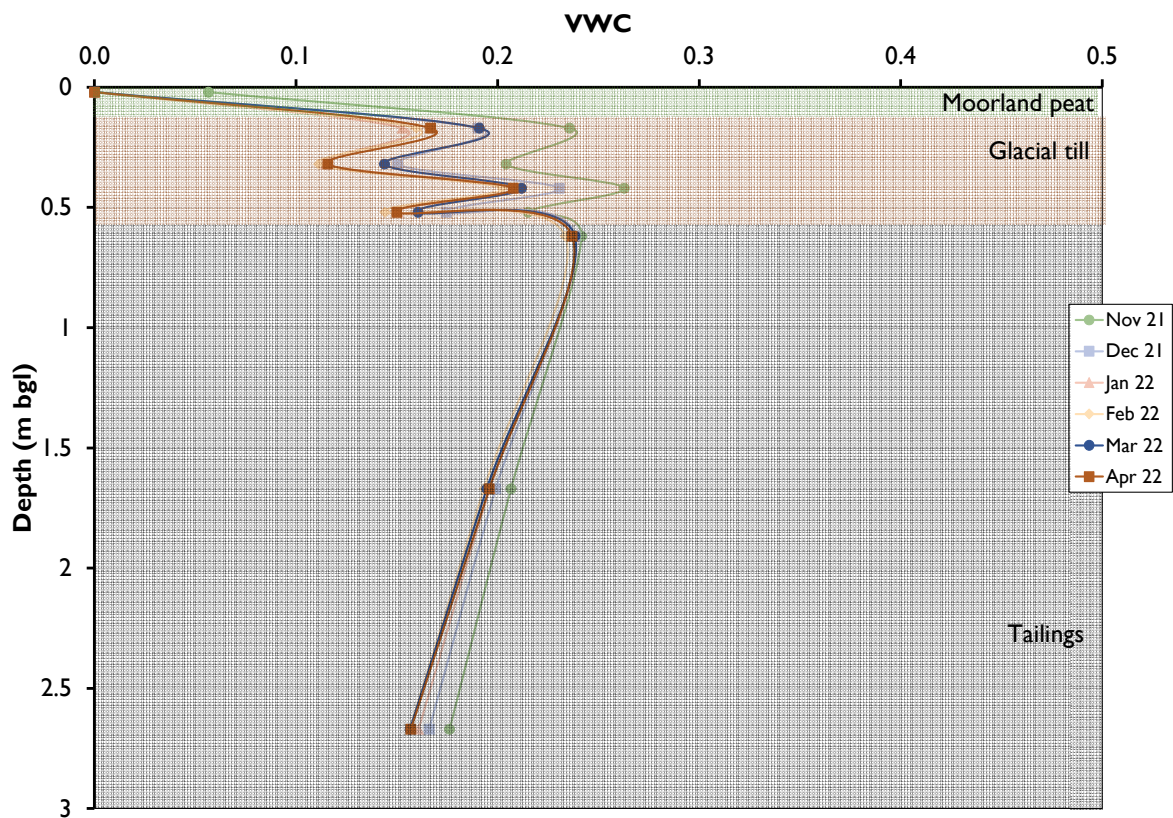


Figure 13 GCL cover VWC versus depth

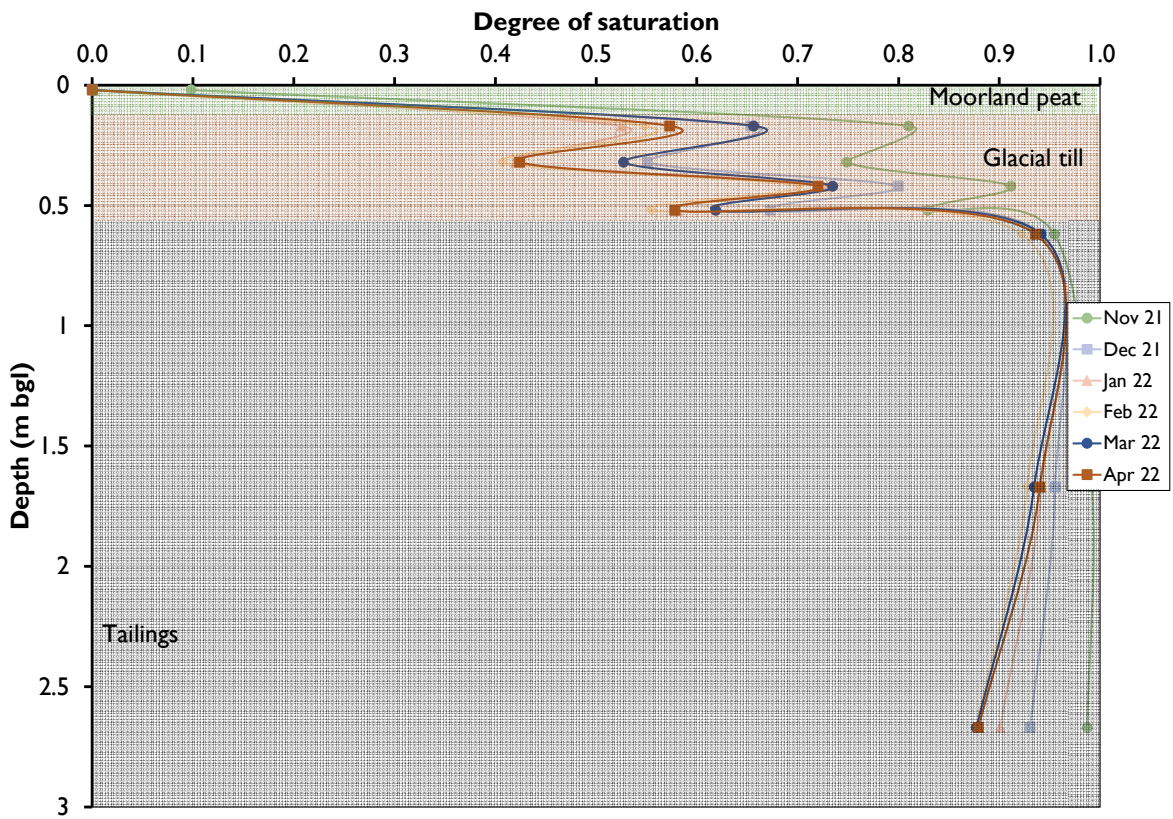


Figure 14 GCL cover degree of saturation versus depth

3.2 Matric suction

Matric suction results versus time for the no GCL cover and GCL cover are given in Figures 15 and 16. The results agree with the VWC results and show that the covers are generally drying out. The matric suction results do indicate that cover above the tailings is drying more quickly in the no GCL cover. The trend is likely in response to percolation into the underlying tailings. By comparison, the base of the cover in the GCL cover cannot percolate, maintaining wetter conditions (reflected by the low matric suction values).

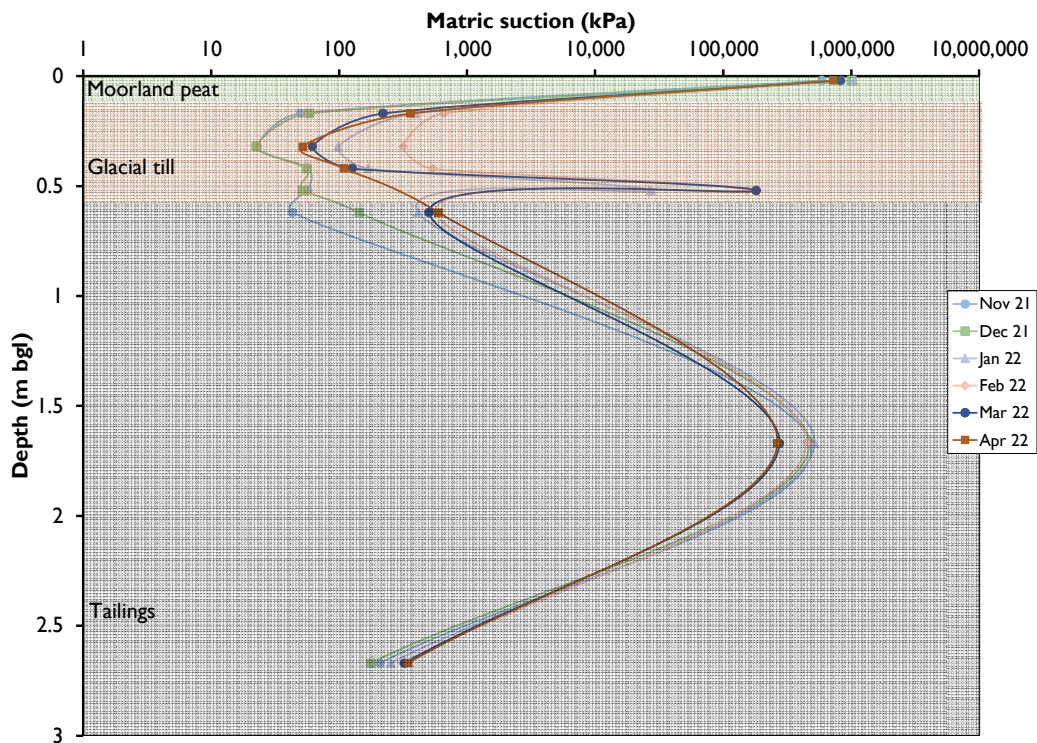


Figure 15 No GCL cover matric suction versus depth

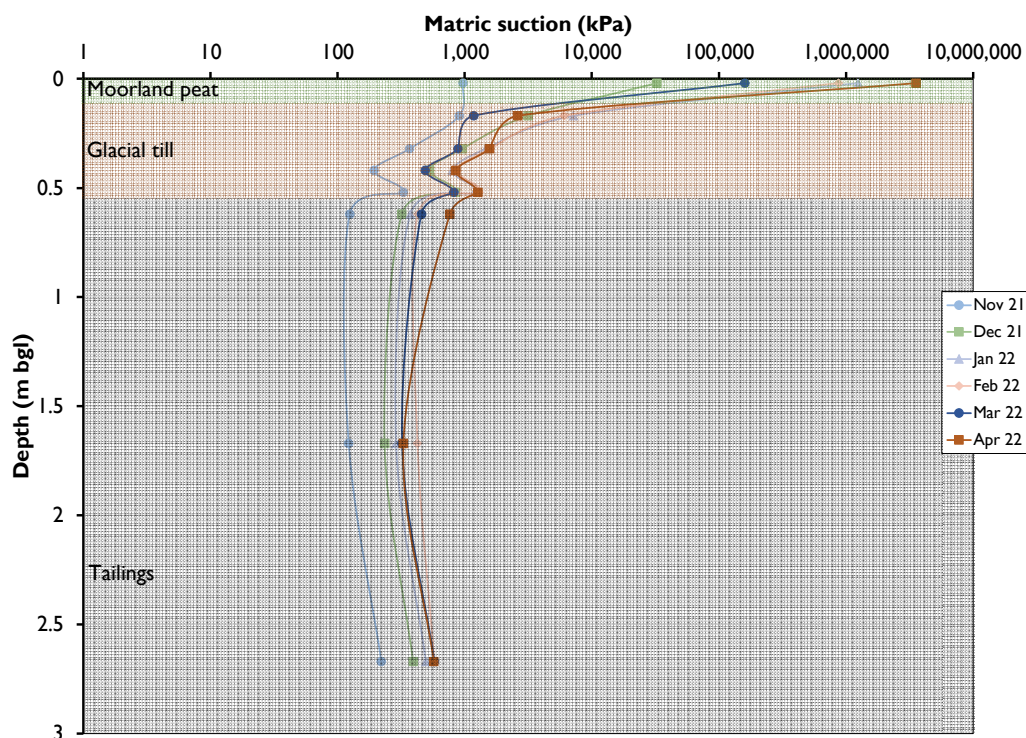


Figure 16 GCL cover matric suction versus depth

3.3 Oxygen concentration

Oxygen concentrations versus depth for the no GCL cover and GCL cover are given in Figures 17 and 18. Note that the results in Figure 17 are only for two months because of late commissioning and system malfunctions. The results show a decreasing oxygen gradient with depth. Trending from atmospheric in the Moorland peat (~21%) to near-residual oxygen concentrations (0-8%) at the base of the cover. Oxygen concentration in the near-saturated tailings is very low, with a decreasing concentration gradient from the top of the tailings to about 1.6 m below their surface (8–0%).

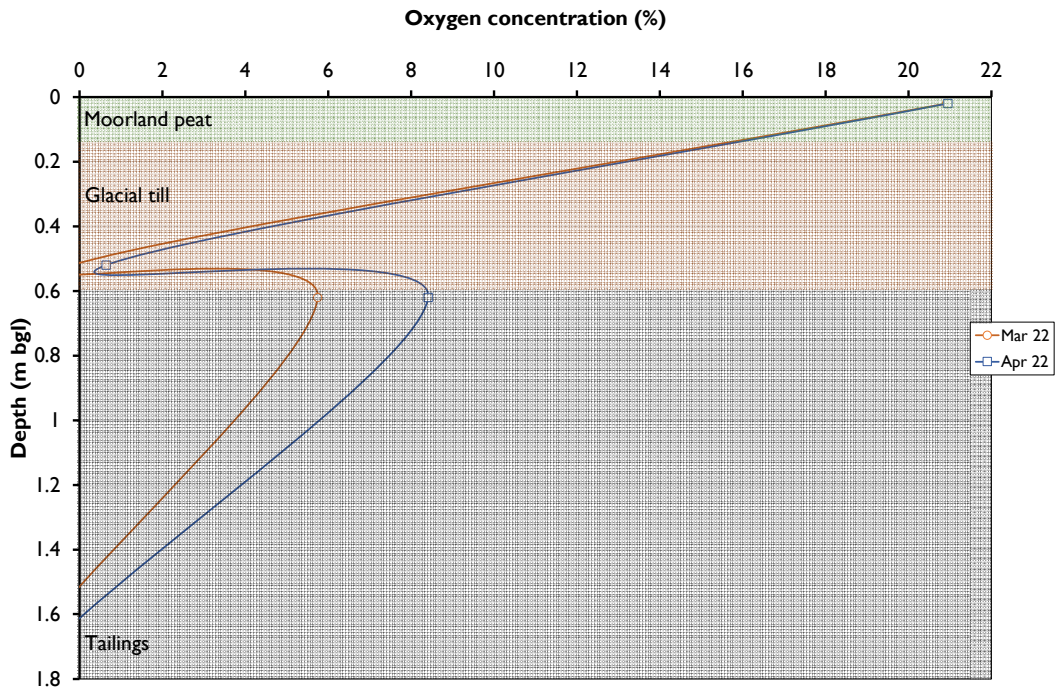


Figure 17 No GCL cover oxygen concentration versus depth

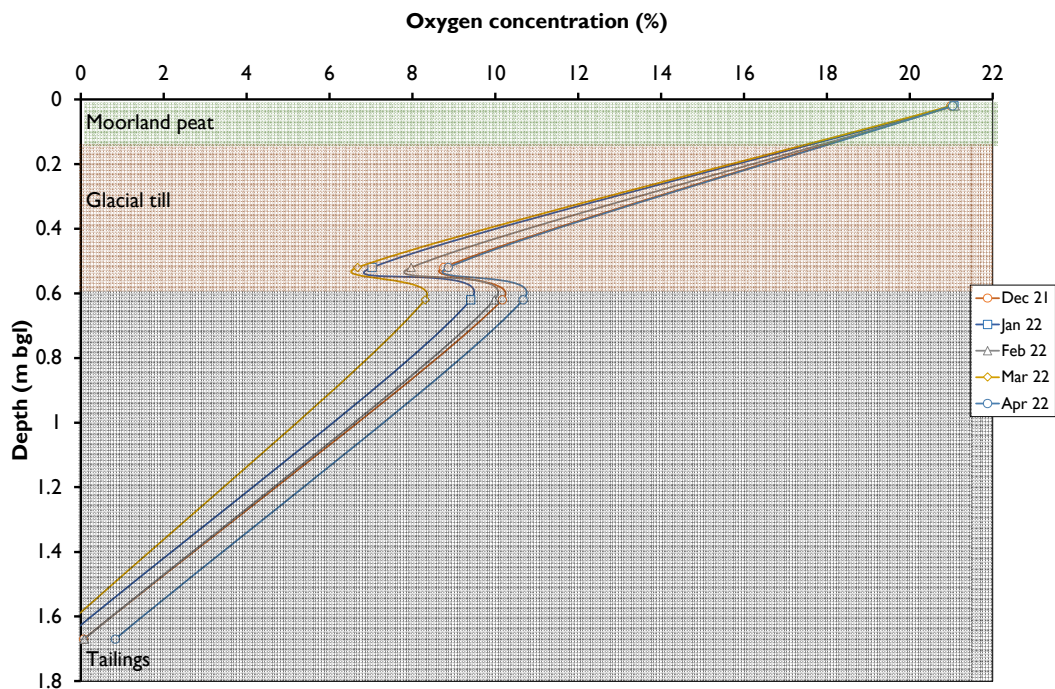
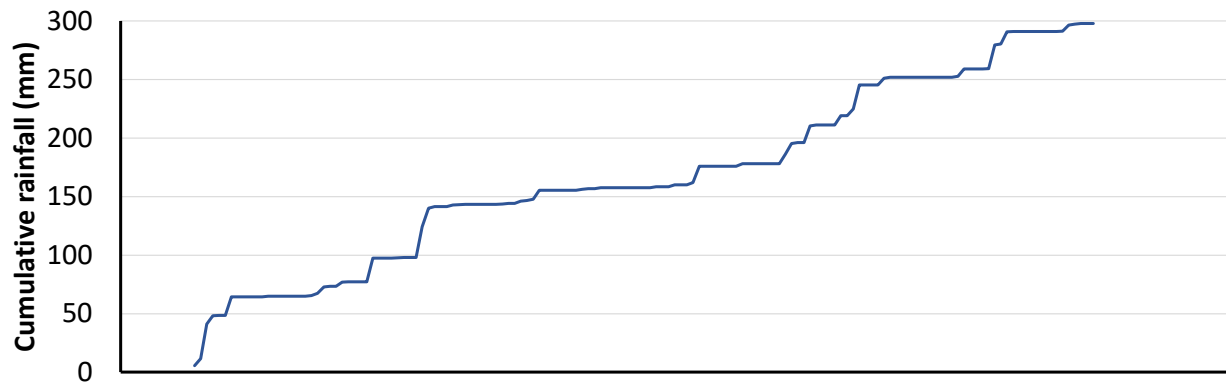


Figure 18 GCL cover oxygen concentration versus depth

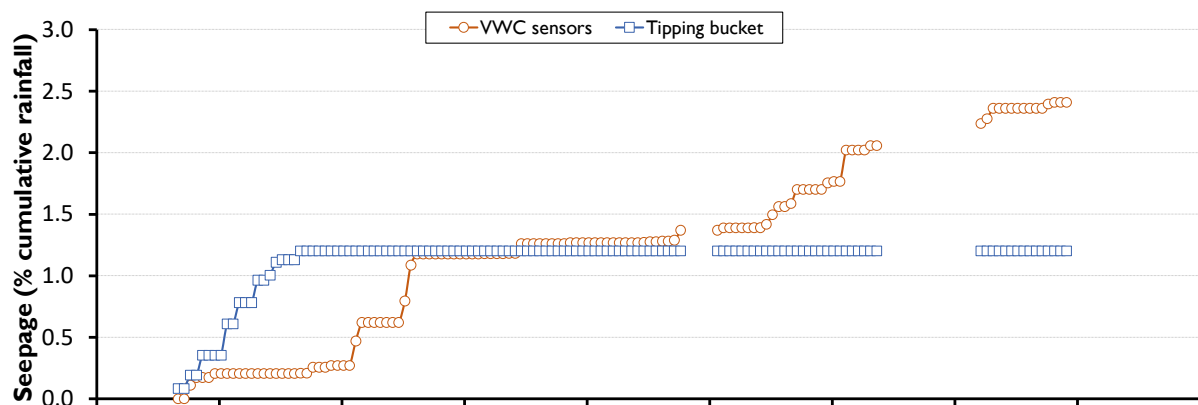
3.4 Cover seepage compared to rainfall

Cover seepage results, measured by the lysimeter monitoring station and calculated from the VWC sensors, are compared to rainfall as shown in Figure 19.

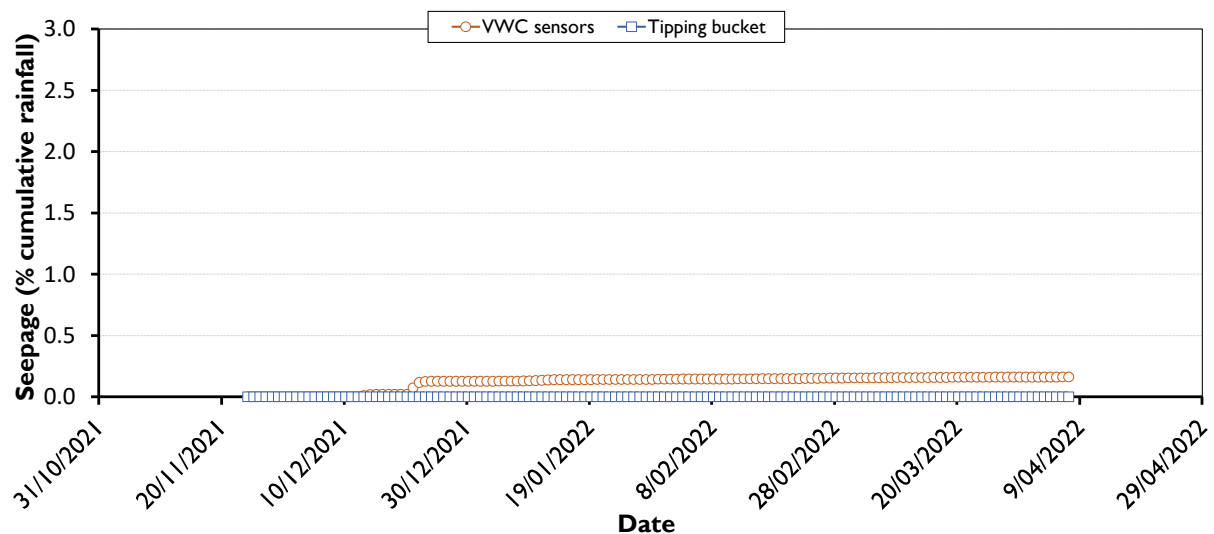
These results indicate that both cover options restrict seepage to less than 2.5% of cumulative rainfall, however the cover containing the GCL liner is performing better ($\sim 0.1\%$) than the non-GCL containing cover (seepage $\sim 2.4\%$).



(a)



(b)



(c)

Figure 19 (a) Rainfall; (b) Seepage through no GCL cover; (c) Seepage through GCL cover

4 Conclusion

Rosebery Mine has demonstrated through instrumentation that barrier cover systems have the potential to limit seepage to the receiving environment. It is anticipated that the performance of the barrier covers will improve as vegetation becomes established. After six months, seepage has remained below 2.5% of cumulative rainfall. At this early stage the GCL cover is the better performing cover option and does not show hydraulic connectivity between rainfall and seepage. By comparison, the no GCL cover has also performed well, but does show hydraulic connectivity to rainfall, which may result in increased seepage during the 2022/23 wet season.

Both barrier cover options have limited the diffusion of oxygen into the underlying PAF tailings as evidenced by the results.

Performance of the barrier covers will be dependent on establishing vegetation. It is anticipated that the near-saturated cover conditions will limit the potential for deep-rooted trees, which could compromise the barrier covers. There is a need, therefore, to maintain monitoring for the order of 5–10 years to assess the barrier covers at equilibrium under a range of climatic conditions.

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