Appendix 2

Murrawombie HLF Cover System and Landform Design

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Murrawombie HLF Cover System and Landform Design

28 August 2018

Aeris Resources

O'Kane Consultants




Integrated Mine Waste Management and Closure Services
Specialists in Geochemistry and Unsaturated Zone Hydrology

Murrawombie HLF Cover System and Landform Design

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Prepared for:

Aeris Resources Pty Ltd
Level 2, HQ South Towers
Box 14, 520 Wickham Street
Fortitude Valley, QLD, 4006

Prepared by:

Philippe Garneau
Senior Engineer
pgarneau@okc-sk.com

O'Kane Consultants Pty Ltd

193D Given Terrace
Paddington QLD 4064
Australia

Telephone: (07) 3367 8063
Facsimile: (07) 3367 8052
Web: www.okc-sk.com

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EXECUTIVE SUMMARY

O'Kane Consultants Pty Ltd (OKC) was retained by Aeris Resources Limited (Aeris) to develop a cover system and landform design for the Murrawombie heap leach facility (HLF), satisfying the conditions of the agreed closure plan. OKC's mandate was to design an engineered cover system and associated landform that will satisfy the following objectives:

- Permit non-contaminated surface runoff from the HLF landform;
- Limit the ingress of meteoric water (i.e. net percolation (NP)) to the underlying heap leach thereby reducing contaminant production and mobilization;
- Provide for a stable landform;
- Provide an adequate layer to support establishment of sustainable vegetation; and
- Facilitate recovery of the environment disturbed by mining over the long term.

OKC recommended a scope of work consisting of six major tasks to satisfy these objectives:

1) Project orientation and review of available information;
2) Material sampling campaign;
3) Laboratory testing program;
4) Development of cover system design;
5) Development of landform design and surface water management plan; and
6) Reporting to relay all information, findings, and recommendations to Aeris.

Murrawombie is located within a sub-tropical, semi-arid environment where yearly precipitation averages 477 mm based on a 100-year data set. With this information, OKC developed a store-and-release type cover system as part of closure planning for the Murrawombie HLF. Various monolithic cover designs were considered, however, a cover system comprising two layers covering the heap leach material offered the most promising performance. The layers comprised non-acid-forming material, sourced from local borrows and existing waste rock dump, and a final top layer to aid vegetation growth. Three thicknesses were considered for the store-and-release design; the thickest NAF layer design of 0.9m was the option retained, taking into consideration NP, oxygen ingress, constructability and other factors detailed in the body of the report.

A shallow sloped embankment design is retained to allow the store-and-release cover to be effective by managing potential erosion. Water channels and drains are constructed on the surface of the landform to direct surface runoff to the adjacent Murrawombie pit. In the event excess water is present in the cover and percolation into the heap leach material occurs, basal seepage management utilises the existing basal liner to direct impacted water to an evaporation system contained within a closed system.

The information OKC has gathered from Aeris' environmental and operational needs, from field material sampling, and lab and modelling results, has set confidence in the type of cover system chosen for this project. The store-and-release system is best suited for the climate type around the Murrawombie pit area. In terms of functionality, the landform profile proposed best suits the needs as understood by OKC. Uncontaminated runoff will flow into the open pit while excess water, during prolonged rainfall events overwhelming the storage capacity of the cover system and resulting in net percolation to the heap leach material, will be captured in evaporation ponds. OKC recommends the cover system design specifications, landform design, and water management plan presented in the report based on site findings, expertise acquired from other similar sites, and modelling conducted with data and samples collected specifically for this project. Also, for this cover system to be as effective as possible, OKC recommends grading the leach pile prior to commencing any material deposition onto the heap leach piles. OKC is confident that the information presented in this report will support the Aeris Resources closure plan.

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1 INTRODUCTION

Aeris Resources Limited (Aeris) retained the services of O'Kane Consultants Pty Ltd (OKC) to assist with further development of a cover system and landform design for the heap leach facilities (HLF) at the Murrawombie Project Site (Murrawombie) located in New South Wales (31°16'S, 146°52'E). The HLF is one of the most significant post-mining environmental risks identified at Murrawombie, and soil and groundwater contamination have been identified as potential environmental impacts associated with the HLF. The HLF's cover system and landform designs are the most important elements to mitigate this risk.

1.1 Project Objectives and Scope

The objectives of the required HLF cover system are to:

- Construct surface cover to permit "clean" surface runoff from the HLF landform;
- Limit the ingress of meteoric water (i.e. net percolation (NP)) to the underlying heap leach, thereby reducing contaminant production;
- Provide for a stable landform;
- Provide an adequate layer to support establishment of sustainable vegetation; and
- Facilitate recovery of the environment disturbed by mining over the long term.

As a first step to developing a cover system design for HLF that achieves these objectives, OKC previously completed a conceptual cover system and landform design for the Murrawombie HLF (OKC, 2016a). In order to validate some of the parameters assumed for the conceptual cover system design, and assess the HLF and locally available borrow materials for physical, geotechnical, and geochemical properties to improve the evaluation of potential cover system designs, OKC recommended a scope of work consisting of six major tasks (OKC, 2016b):

1) Project Orientation and Review of Available Information;
2) Material Sampling Campaign;
3) Laboratory Testing Program;
4) Development of Cover System Design;
5) Landform and Surface Water Management; and
6) Report Preparation.

This document represents completion of these project tasks.

1.2 Report Organisation

For convenient reference, this report has been subdivided into the following sections.

- Section 1 – Provides introduction.
- Section 2 – Provides pertinent background information to support the study.
- Section 3 – Summarises the material characterisation program, both physical and geochemical.
- Section 4 – Summarises the modelling program and input and present modelling results.
- Section 5 – Presents HLF surface water runoff assessment.
- Section 6 – Present the HLF closure design
- Section 7 – Provides reference material quoted throughout this document.
- Appendix A – Sampling locations maps
- Appendix B – Samples summary table
- Appendix C – Geotechnical Laboratory results
- Appendix D – Geochemical laboratory results
- Appendix E – Drawings

2 BACKGROUND

The following section provides:

- A brief history and description of Murrawombie;
- Definition and classification of net percolation (NP);
- Definition and classification of oxygen (O_2) ingress;
- Conceptual model for potential HLF cover systems; and
- Conceptual landform design.

2.1 Site History and Description

The Girilambone site, comprising both Murrawombie Project site and North East Project site, is located in the central western plains of New South Wales, in the Cobar Peneplain Bioregion (as shown in Figure 2.1). The site is located approximately 44 km northwest of Nyngan. During 2002, Australian miner Straits Resources (now Aeris Resources) bought a majority stake in the mine, buying the minorities in Tritton Resources to reach full ownership in 2005.

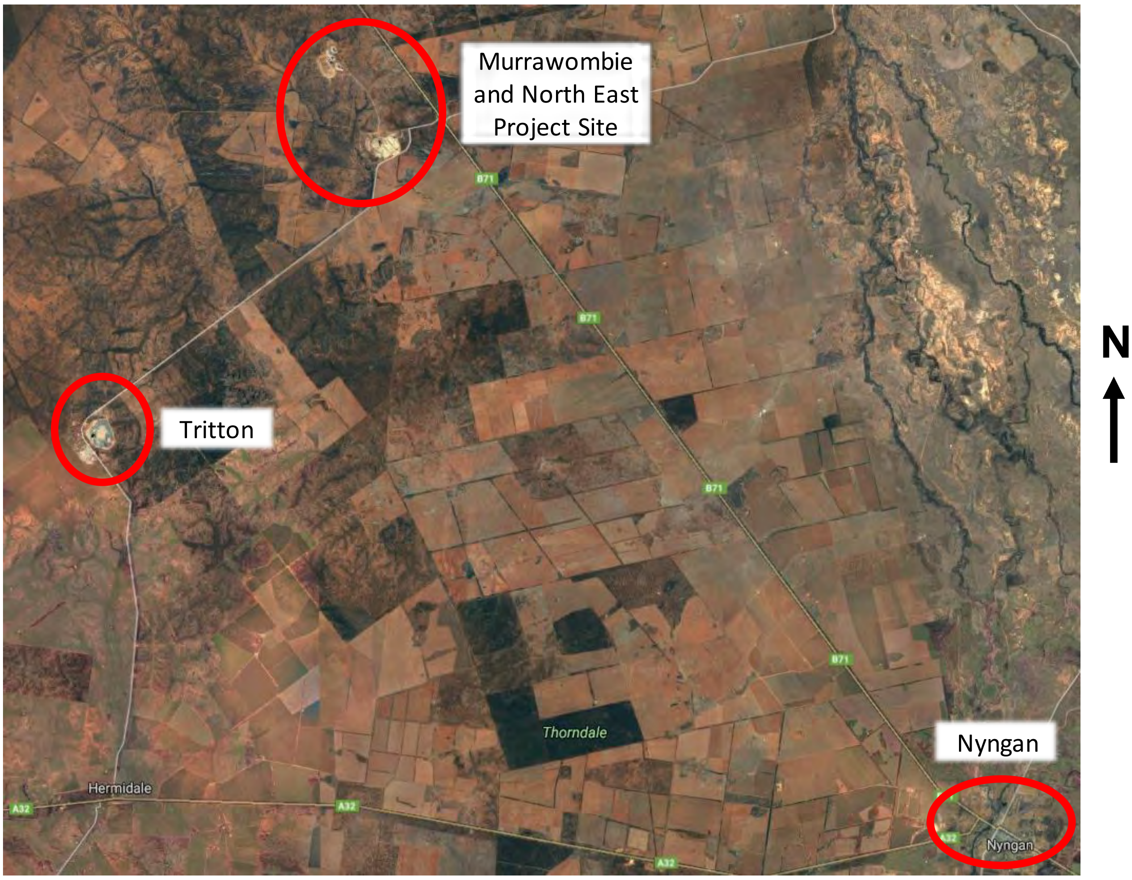

Figure 2.1: Site location map for Murrawombie Project site and North East Project site

Murrawombie is an active copper heap leach operation that produces copper cement for sale to the chemicals industry. Mining ceased at the Murrawombie pit in 2005 and rehabilitation of the waste rock dumps (WRDs) has been substantially completed. However, a pre-feasibility study was completed in FY17 for the Murrawombie open pit extension (Aeris, 2017). Waste rock extracted as part of this extension is planned to be used within rehabilitation of the HLF once all activities at the underground mine have ceased. This will eliminate interaction/s and potential risks between both operations (Aeris, 2017). Approximately 50 ha of the Murrawombie site comprises the HLF. Collectively these comprise three heap leach pads (HLPs) of crushed ore (approximately 10 million tonnes) and are 7 m to 20 m high (Figure 2.2). Materials have been loose-tipped and stand at angle of repose. The basic operation of the HLF has involved the percolation of acidic solution through the loose material for copper recovery.

The HLF was commissioned in 1993 as part of the Girilambone Copper Company (GCC) operations. It used a solvent extraction electrowinning (SX-EW) process to extract copper. After decommissioning the SX-EW plant in 2003 watering of the pads ceased. In an effort to recover remaining copper in the HLF, the copper cementation plant was commissioned in 2008. The cementation plant uses the same process as the SX-EW plant by watering the HLF with an acidic solution. Current operations use water instead of an acidic solution for copper recovery.

The HLF comprises the following infrastructure (Figure 2.2):

- Heap Leach Pads (HLP);
- Pregnant liquor solution ponds (PLS ponds);
- Raffinate ponds;
- Copper cementation plant; and
- Containment Dam (GSW01).

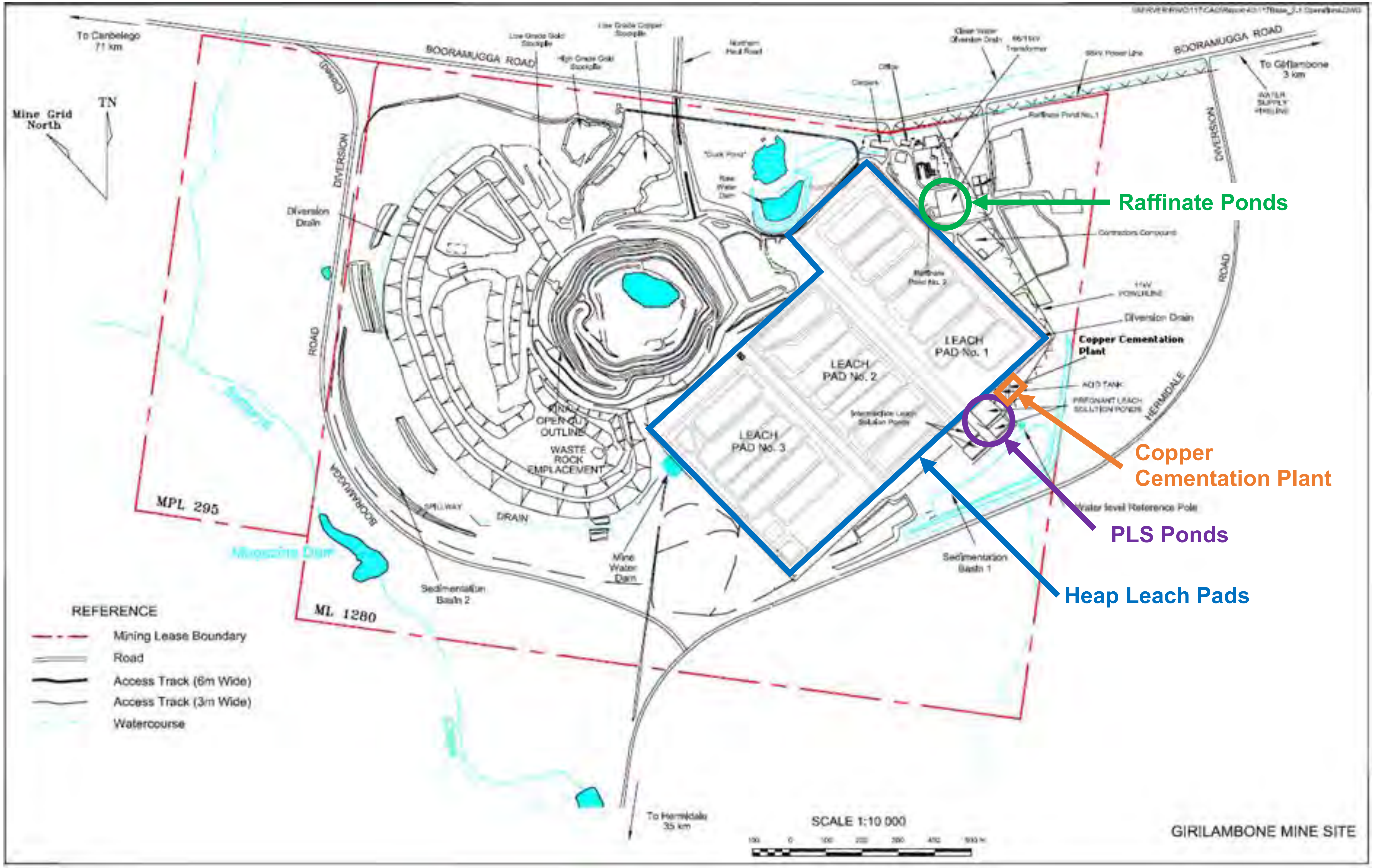

Figure 2.2: Girilambone Mine Site Layout (Straits Resources Ltd., 2012)

2.2 Definition and Classification of Net Percolation

The term NP is used throughout this report and is defined as presented in Figure 2.3. Rainfall (R) will either be intercepted by vegetation, runoff (RO), or infiltrate into the surface. A portion of the water that infiltrates will be stored in the 'active zone' (ΔS) and subsequently exfiltrate back to the surface and evaporate, or be removed by transpiration (ET). Infiltration can also move laterally downslope within and below the active zone (referred to as interflow). A percentage of the infiltrating water will migrate beyond the active zone as a result of gravity overcoming the influence of atmospheric forcing (i.e. evaporation) and result in NP to the underlying material.

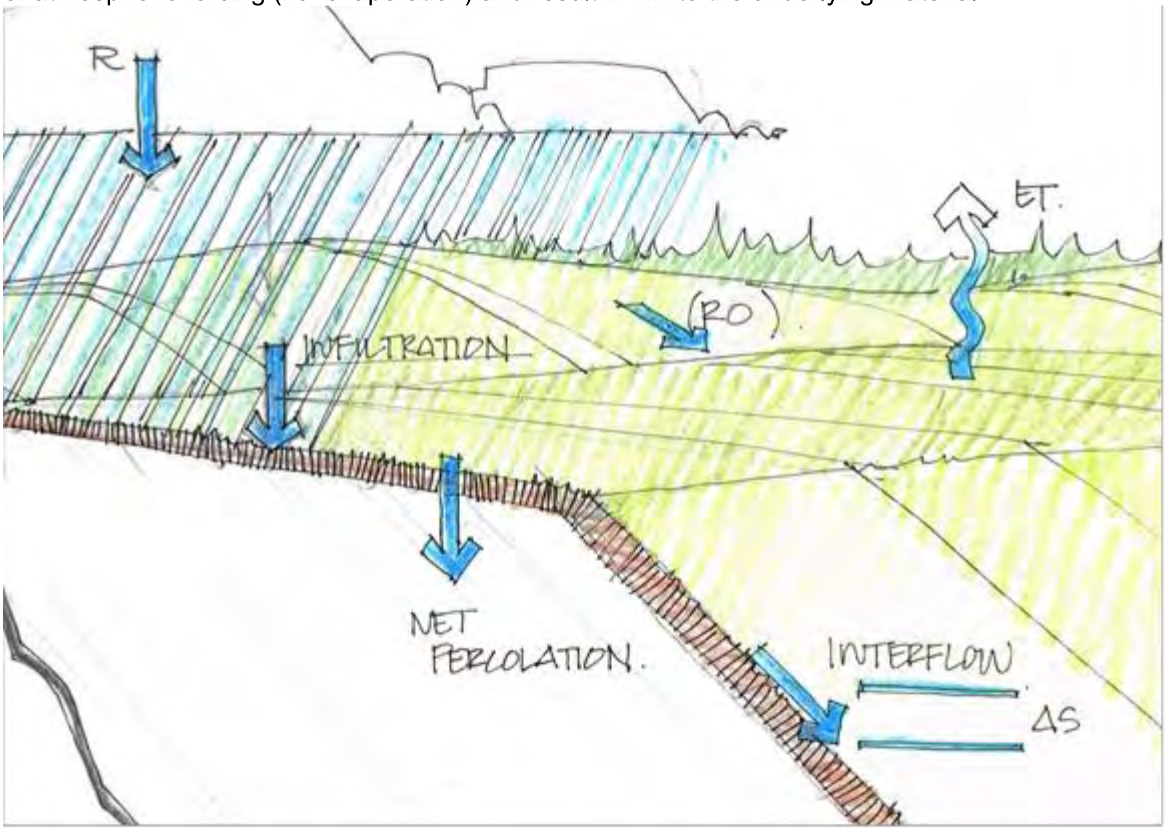

Figure 2.3: Schematic of hydrologic processes that influence performance of cover systems for HLF.

A range of performance in terms of NP rates exists for a cover system, which is highly dependent on the climate regime. The range of cover system performance for the HLF is presented conceptually in terms of "Very Low" (VL), "Low" (L), "Moderate" (Mod), "High" (H), and "Very High" (VH) NP rates, based on recommendations in the "Global Cover System Design – Technical Guidance Document (INAP, 2017). The following ranges were used to analyse the HLF cover system options:

- "Very High" NP is classified as greater than 20% of average annual rainfall (% R);
- "High" NP is between 10% R and 20% R;
- "Moderate" NP is between 5% R and 10% R;
- "Low" NP is between 1% R and 5% R; and

- "Very Low" NP is less than 1% R.

It must be noted that NP rates and resultant % R can be higher or lower for any given year. For example, a high rainfall year (or, more specifically, a number of successive wetter than average climate years) may result in a high NP rate for the year, even for a site classified, on average, as having a very low NP rate. Therefore, occasional exceedances of the target NP are not necessarily an indication of cover failure.

2.3 Definition and Classification of Oxygen Ingress

O_2 ingress to the underlying waste rock materials considered within this report occurs through diffusion transport and as dissolved O_2 in NP. The difference in O_2 concentration between the atmosphere (21% O_2 by volume) and the upper HLF profile produces a diffusion gradient driving the movement of O_2. The diffusion coefficient is influenced by the degree of saturation within the cover system; a high degree of saturation results in a low diffusion coefficient and low O_2 transport and vice versa. Aachib *et al*. (2004) reviewed the relationship between diffusion coefficient and degree of saturation, showing that as degree of saturation exceeds 80% the diffusion coefficient decreases by several orders of magnitude. In general, maintaining consistent saturation ≥ 85% within a cover system layer will substantially limit the amount of O_2 movement by diffusion.

A similar range of performance exists for O_2 ingress as does for NP. However, O_2 ingress is less challenging to limit in wetter environments where a tension-saturated layer is more easily maintained. Furthermore, finer-textured material, together with the tension saturated conditions, will lead to reduced air permeability and therefore lower potential advective gas transport. For the purposes of this project, OKC classified O_2 ingress as:

- "High" at a rate greater than 100 mol O_2 m^{-2} $year^{-1}$;
- "Moderate" (Mod) between 100 and 50 mol O_2 m^{-2} $year^{-1}$;
- "Low" between 50 and 5 mol O_2 m^{-2} $year^{-1}$; and
- "Very Low" (VL) at a rate less than 5 mol O_2 m^{-2} $year^{-1}$.

However, these ranges are a preliminary estimate. The static geochemical testing carried out on one HLF sample (Section 3.3) confirmed that the material has the capacity to generate acidity through reaction with oxygen. Kinetic testing of the underlying HLF material would be required to confirm where the site materials fall in this range with respect to oxygen consumption rates.

2.4 Conceptual Model for Potential HLF Cover Systems

The purpose of a cover system for the rehabilitation of the HLF is to provide a stable, reliable and sustainable engineered interface between the receiving environment and the mine waste (INAP, 2017). It supports agreed-upon land uses while minimising degradation of the surrounding environment. The purpose of a cover system for the HLF is to limit NP, O_2 ingress, and erosion while supporting preferred vegetation communities. Numerical modelling was undertaken to determine the most effective way of achieving these objectives.

Cover systems limit NP by one of two methods:

1) Diversion: a layer of the cover system may be constructed from materials with a sufficiently low permeability to limit downward percolation of rainfall, and "release" water as surface runoff or interflow.

2) Store-and-release: infiltrating water is stored within the rooting zone of the cover system, so it can be subsequently released via actual evapotranspiration (AET). In these types of cover systems, the objective is to minimise deep percolation by returning most of the infiltrating waters from storage to the atmosphere via transpiration.

The type of cover system being considered in the study at Murrawombie utilises the moisture store-and-release principle, as this cover system type best fits with the site's climate (Figure 2.4). The red marker indicates the designation for Murrawombie's climate.

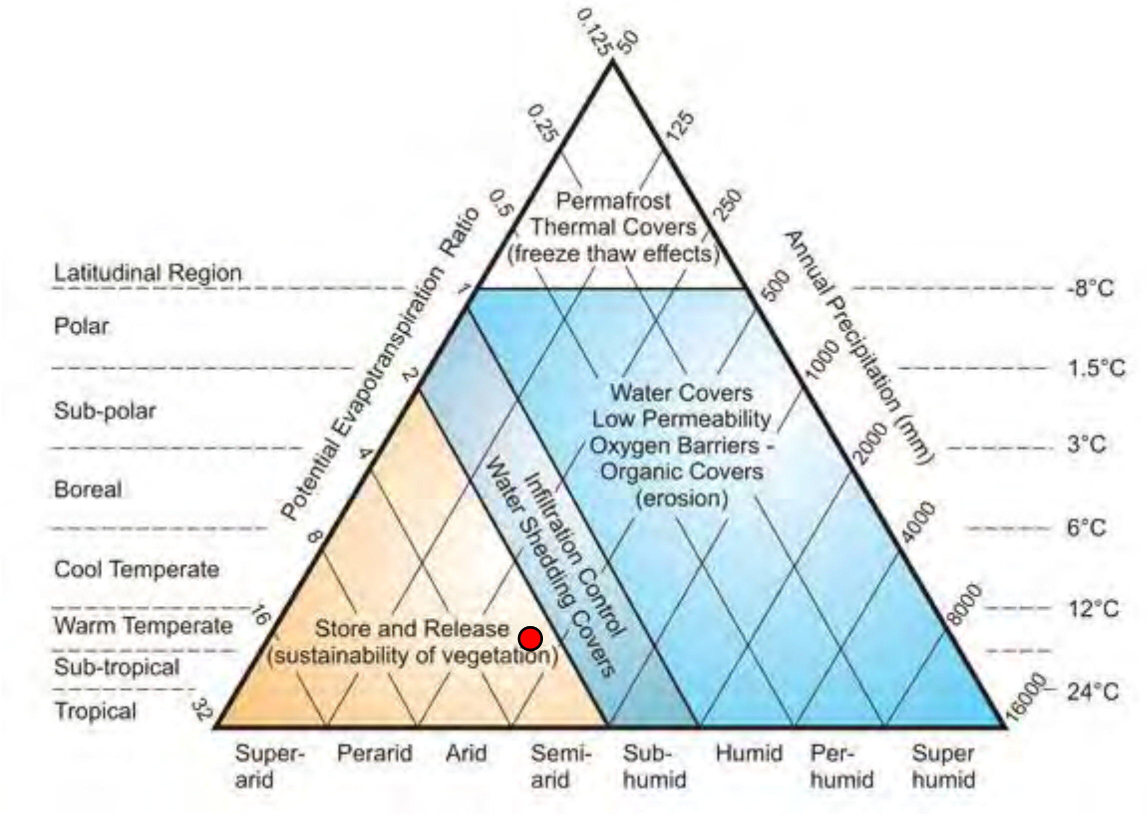

Figure 2.4: Cover systems and climate type (GARD Guide, 2011).

Cover systems that utilise moisture store-and-release principles can be simple or complex, ranging from a single layer of earthen material to several layers of different material types. For this study, simple, monolithic cover systems consisting of a thin topsoil layer overlying a layer of non-acid forming (NAF) waste rock were evaluated. This cover system is an attempt to increase the ability of the cover to reduce NP to the underlying waste by increasing the available moisture storage capacity. A relatively homogeneous layer of a well-graded earthen material is best suited for this type of cover system. For the previous conceptual cover system study (OKC, 2016a), three cover system design Options were evaluated (Figure 2.5):

- Option 1 – 0.1 m of topsoil overlying 0.1 m of waste rock;
- Option 2 – 0.1 m of topsoil overlying 0.4 m of waste rock; and
- Option 3 – 0.1 m of topsoil overlying 0.9 m of waste rock.

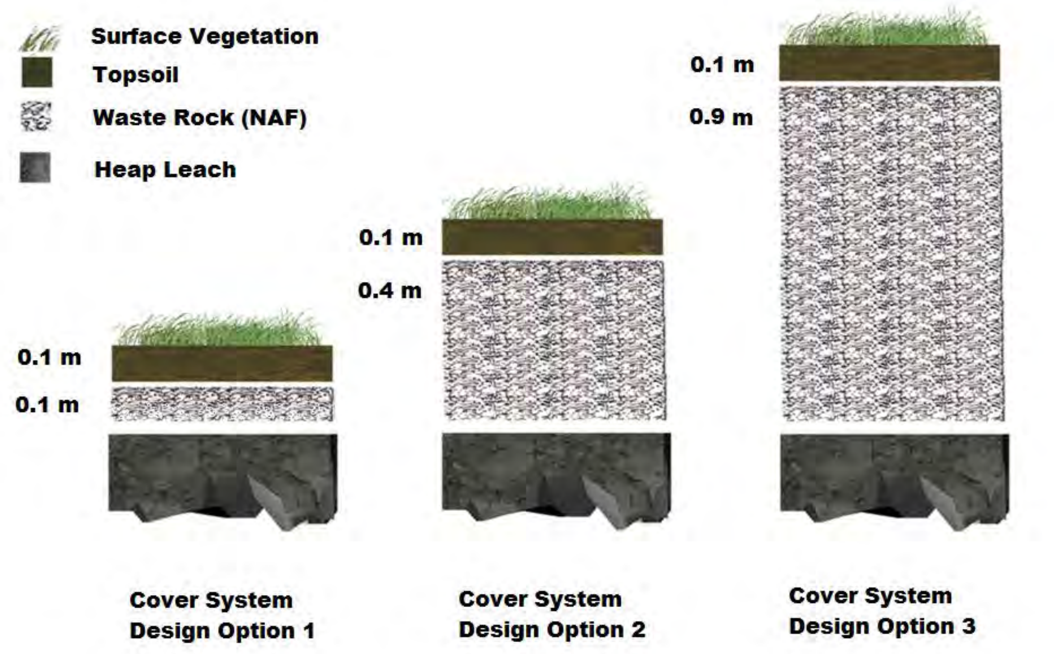

Figure 2.5: Cover system design options

As part of the conceptual cover system and landform design (OKC, 2016a), a conceptual model water balance was developed for each option. This was undertaken using an empirical approach and OKC's experience with similar cover system types utilised at several Australian sites. A summary of the results of this assessment are provided in Table 2.1.

Table 2.1: Conceptual water balance summary for Murrawombie cover system design options.

Parameter	Option 1	Option 2	Option 3
Rainfall	447 mm	447 mm	447 mm
Runoff	0 to 5% R	0 to 5% R	0 to 5% R
Actual Evapotranspiration	75 to 90% R	85 to 95%% R	90 to 95% R
Net Percolation	5 to 25% R	<10% R	<5% R
NP Classification	VH to Mod	Mod to Low	Low to VL

3 MATERIAL CHARACTERISATION

The HLF is one of the most significant post-mining environmental risks identified at Murrawombie. Soil and groundwater contamination have been identified as potential environmental impacts associated with the HLF. As such, rehabilitation of the HLF through appropriate cover system and landform designs are the most important elements to mitigate this risk.

OKC completed a materials sampling program in October 2016 to gain a more thorough understanding of the characterisation of the materials on site. As part of this sampling program twenty-two test pits were developed across Murrawombie. Samples were obtained from the test pits for laboratory testing, these included six non-acid forming (NAF) waste rock samples, six samples of oxidising material, four topsoil samples and six samples located on the heap leach. Additionally, six test pits were developed at the nearby Tritton Tailings Storage Facility, located approximately 20 km southwest of Murrawombie (Figure 2.1). Samples here comprised five topsoil and one tailings sample.

This section summarises the results from geotechnical and geochemical characterisation of samples taken from site, including acid risk classification.

3.1 Materials Sampling

Material sampling and laboratory testing of materials which may potentially be used within a cover system design at the Murrawombie HLF was conducted in late 20016 and early 2017. During this analysis various topsoil, subsoil, oxide, waste rock, heap leach and tailings materials were analysed. This included materials from both the Murrawombie and Tritton sites. The sample plans for Murrawombie and Tritton are provided in Appendix A.

Thirty-two samples, one from each test pit, were selected for geotechnical testing and sixteen samples for geochemical testing (Appendix B). Respective laboratory testing reports are provided in Appendix C and Appendix D.

3.2 Physical and Hydraulic Characterisation

There were three general material types defined for this project: topsoil, NAF waste rock and heap leach material. The University of Queensland completed particle size distribution (PSD) testing for all samples, with water retention curves (WRCs) and saturated hydraulic conductivities measured for select samples. The PSDs, WRC and hydraulic conductivity function (k-function) for the waste rock were adjusted based on the percentage of over-sized (OS) particles removed before the samples were tested. To remove the OS material a grizzly screen was employed during excavation with a diameter of 100 mm. The k-function for each material was estimated from its WRC and saturated hydraulic conductivity using the Fredlund *et al.* (1994) method.

Figure 3.1 and Figure 3.2 show texture triangles summarising the PSDs measured for the Murrawombie and Tritton samples, respectively. Using the texture ranges shown in these figures, in addition to laboratory measurements provided in Appendix C, the hydraulic properties for the topsoil, waste rock and heap leach materials were defined for the modelling program (Table 3.1).

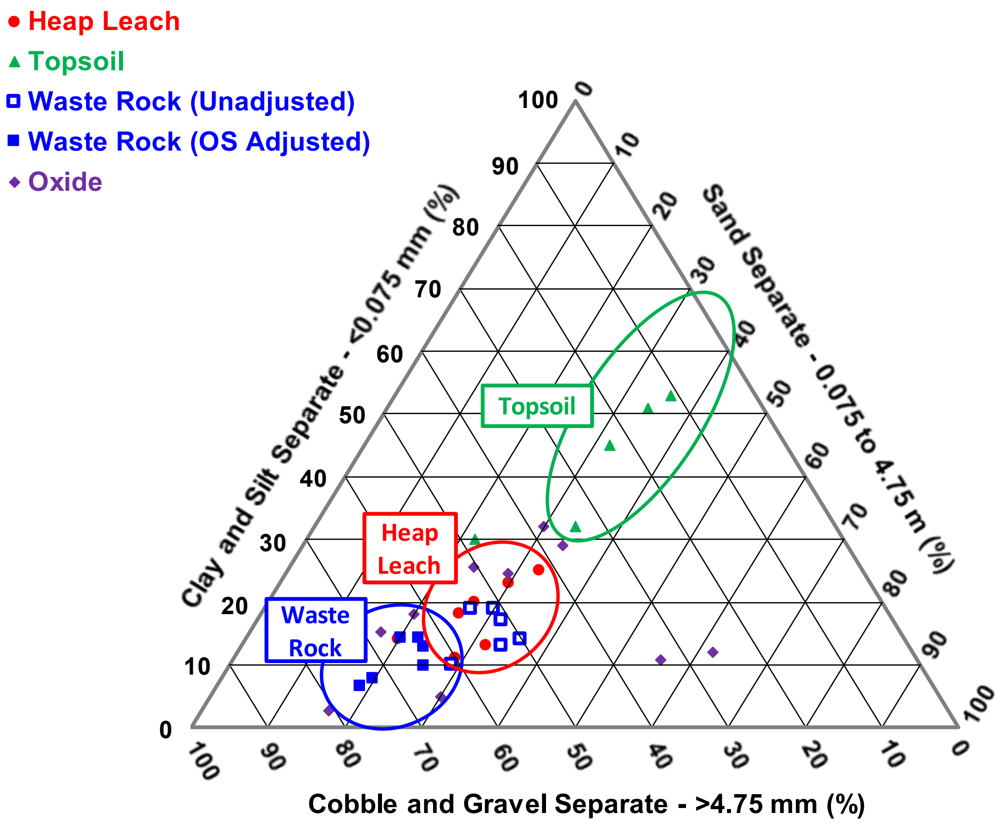

Figure 3.1: Texture triangle for Murrawombie samples.

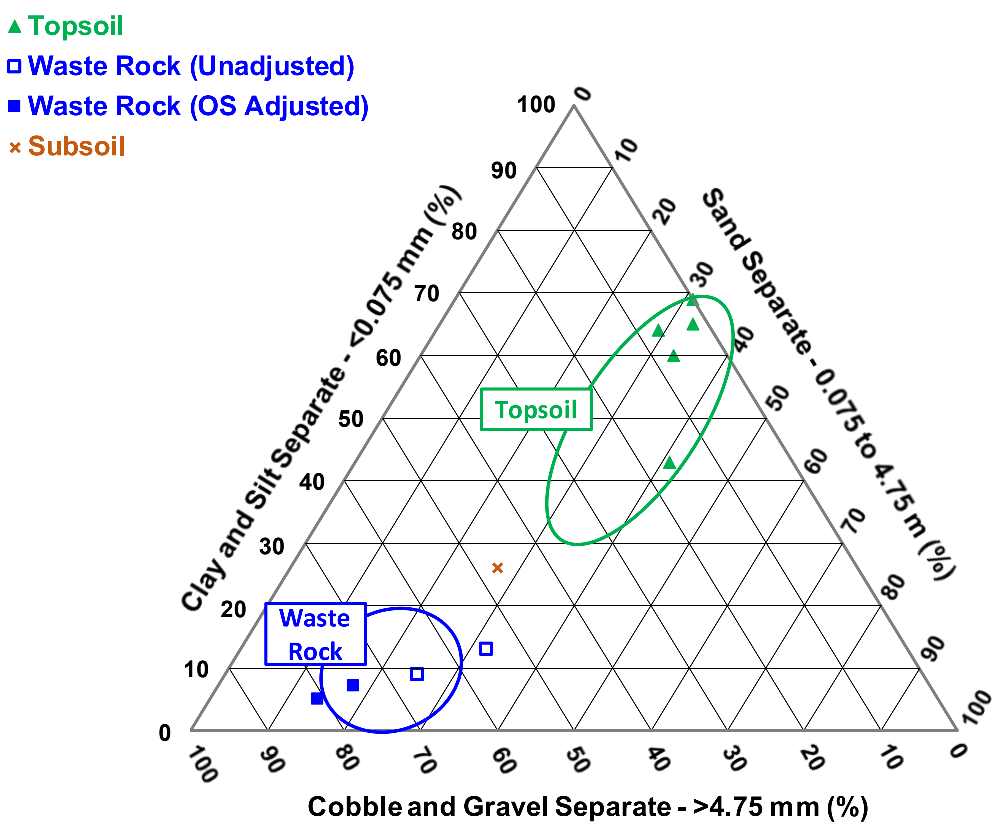

Figure 3.2: Texture triangle for Tritton samples.

In addition to the aforementioned testing, Atterberg limits (AL), Emerson class testing and standard compaction testing (Appendix C) was conducted on select samples to provide further insight on the soil type and dispersion characteristics (Table 3.1). The consistency of fine-textured materials can range from a dry solid to a liquid form with successive addition of water and mixing to expand the pore-space for acceptance of the water. The consistency passes from a solid, to semi-solid, to plastic, and finally to a liquid, as water is added and mixed with the material. The AL for a given material defines the water content at these limiting or critical stages of a fine-textured material's behaviour.

The characteristics of fine-textured materials can be developed through the relationship between liquid limit (LL) and plasticity index (PI). Figure 3.3 shows the relationship between the LL and PI of select samples from both Murrawombie and Tritton. In general, a sample that plots above the A-line near the U-line contains active clay minerals such as montmorillonite. Illites usually plot just above the A-line, while kaolinites are usually located just below the A-line.

Emerson class testing is used to classify the behaviour of soil aggregates, when immersed, on their coherence in water. Once aggregates are immersed in water, an osmotic stress arises between the negatively charged particles. This stress increases gradually as the soluble salts present in the aggregates diffuse out. The increase may be sufficient to cause dispersion. Soil are divided into seven classes based on their dispersion and slaking behaviour. Class 1 disperses completely, Class 2 partially. Classes 3 - 6 do not disperse initially but may so upon remoulding and may also exhibit flocculation or slaking behaviour and Class 7 involves no slaking or dispersion but swelling instead, typical of organic matter. All tested samples were placed in Class 3, meaning there was no dispersion initially, however upon remoulding at water content equivalent to field capacity there was dispersion.

Table 3.1: Results of AL and Emerson class tests.

Sample No.	LL	PI	Emerson class No.
TP12-OX	38	22	3
TP14-TS	21	8	3
TP26-T-TS	19	4	3
TP27-T-TS	41	19	3
TP32-T-BP	19	7	3

Table 3.2: Summary of hydraulic properties estimated for Murrawombie materials.

Material	Durner (1999) Parameters [1,2]										k_{sat} m/s
	θ_S	θ_r	ω_1	α_1	n_1	m_1	ω_2	α_2	n_2	m_2	
Topsoil	0.35	0	0.60	0.025	1.80	0.44	0.4	0.8	2.2	0.545	5E-5
Waste Rock	0.25	0	0.50	0.060	1.70	0.41	0.5	10.0	1.6	0.375	1E-5
Heap Leach	0.30	0	0.55	0.040	1.75	0.43	0.45	4.0	1.9	0.474	3E-5

1. Durner, W., E. Priesack, H.-J. Vogel, and T. Zurmühl, Determination of parameters for flexible hydraulic functions by inverse modeling. In: M.Th. van Genuchten, F.J. Leij, L. Wu (Editors), Characterization and Measurement of the Hydraulic Properties of Unsaturated Porous Media. University of California, Riverside, CA, pp. 817-829, 1999.

2. θ_S = saturated volumetric water content (m^3/m^3); θ_r = residual volumetric water content (m^3/m^3); ω_1 = weighting factor for region of curves defined by α_1, n_1, m_1; α_1 = inverse of air entry value for first part of curve (m^{-1}); n_1 = empirical parameter; m_1= 1-1/n1; ω_2 = weighting factor for region of curves defined by α_2, n_2, m_2; α_2 = inverse of air entry value for first part of curve (m^{-1}); n_2 = empirical parameter; $m_2 = 1-1/n_2$; k_{sat} = saturated hydraulic conductivity (cm/s)

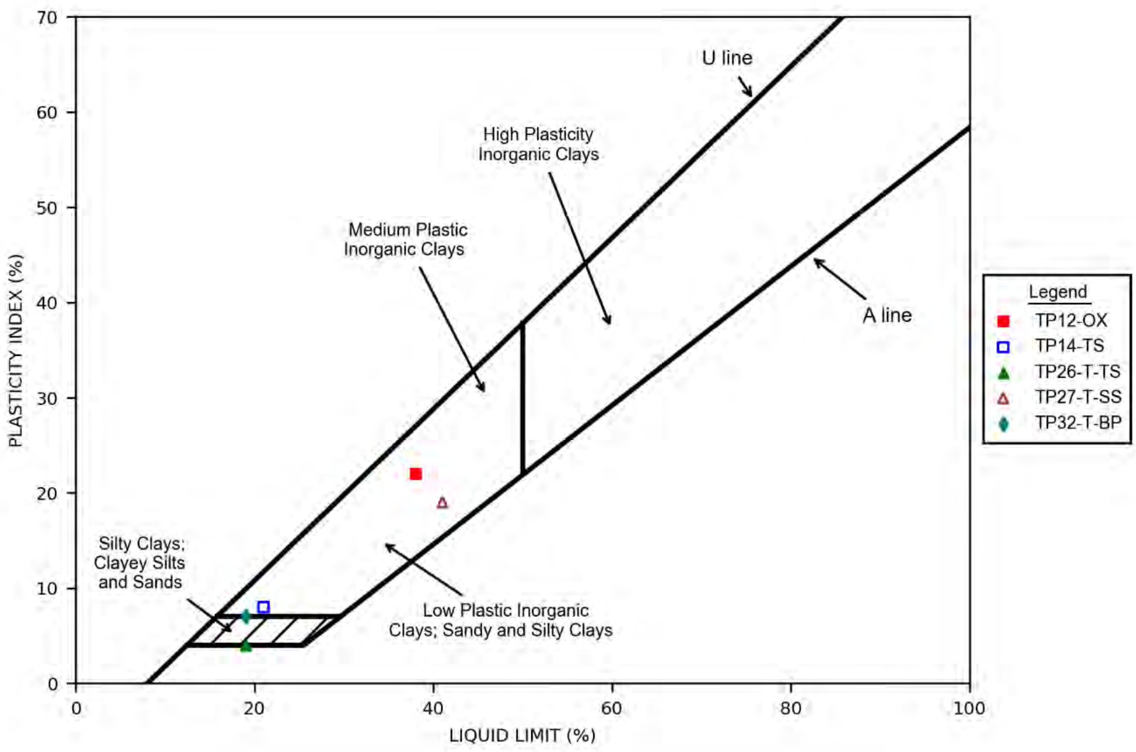

Figure 3.3: Relationship between the liquid limit and plasticity index for potential cover materials

3.3 Geochemical characterisation

This section summarises the results from geochemical characterisation of samples taken from site, including acid risk classification.

3.3.1 Phase 1 Analysis: Preliminary Acid Risk Classification

All sixteen samples selected for geochemical characterisation were analysed for total sulfur (S), acid neutralising capacity (ANC), paste pH and paste electrical conductivity (EC) (Appendix D). Using the total sulfur content and the ANC, samples can be subject to preliminary screening with respect to the risk of acid generation (Price, 2009; see also AMIRA, 2002). The total S content is used to calculate a maximum potential acidity (MPA). An ANC/MPA ratio less than one implies the material is PAF. A ratio greater than two is classified as NAF. Between one and two, the classification is “Uncertain” (UC).

Most samples were determined to be low risk with respect to acid generation (ANC/MPA >2, Figure 3.3). This included all samples of Murrawombie topsoil (three samples) and Tritton topsoil (four samples), which were associated with low total sulphur contents.

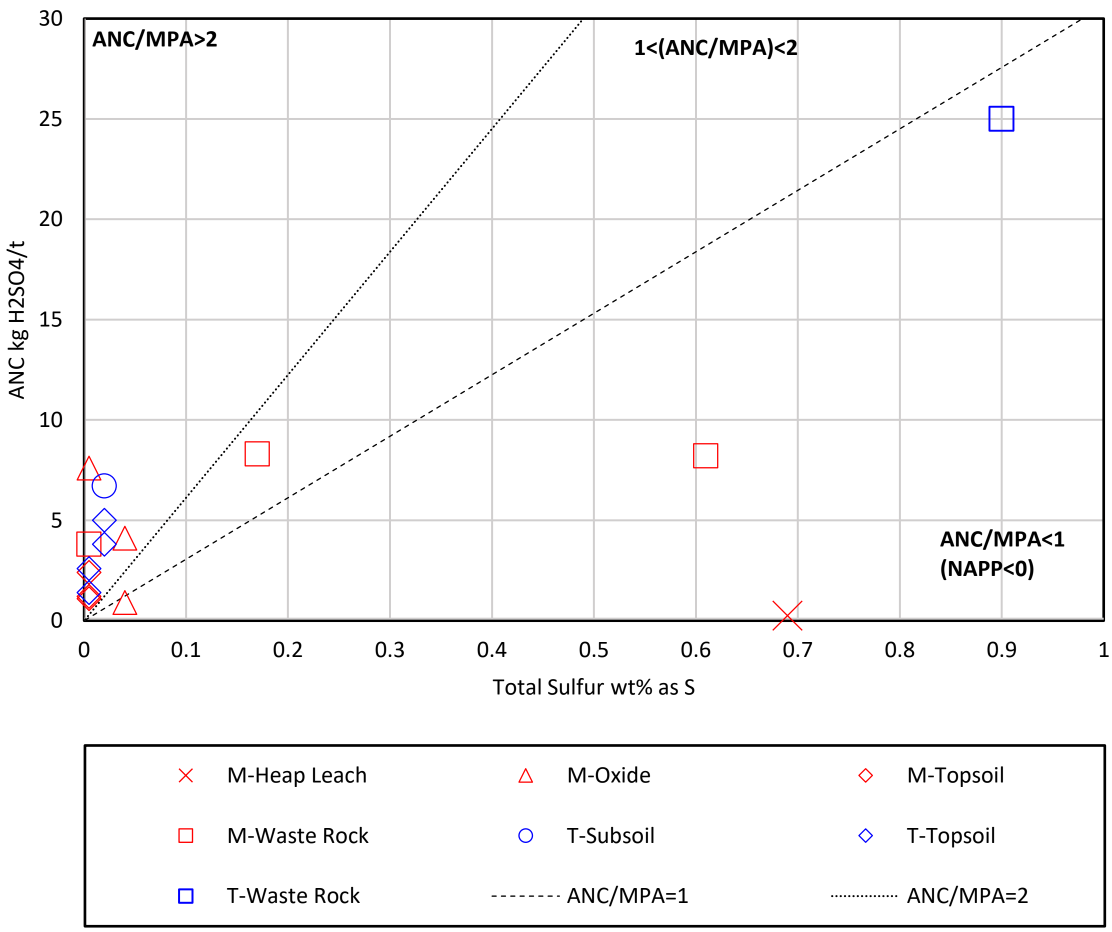

Figure 3.3: Acid neutralising capacity (ANC) vs. Total S content, and corresponding ANC/MPA ratio (M-Murrawombie; T-Tritton)

Based on this preliminary screening, four Murrawombie samples were classified as moderate to high risk with respect to acid generation:

- Two waste rock samples from Murrawombie (OKC 956/4-TP2-WR-A, OKC 956/4-TP5-WR-A);
- A Murrawombie heap leach sample (OKC 956/4-TP17-HL-A); and
- One Murrawombie oxide sample (OKC 956/4-TP10-OX-A).

The waste rock sample from Tritton (OKC 956/4-TP29-T-WR-A) was also classified as potentially acid-forming.

These samples were subjected to further testing in order to refine the risk classification, as described below.

3.3.2 Phase 2: Further Analysis and AMIRA (2002) Risk Classification

The total S minus the acid soluble sulfur is often assumed to reflect the sulfide mineral content of the sample. This represents a capacity to generate acid in future. The acid soluble sulfur may indicate that sulfide has already oxidised to sulfate, but sulfate may also be present due to other processes, such as evapoconcentration. The acid-soluble sulfate content of some samples was high, in some cases constituting over half the total S.

Accumulation of sulfate could indicate that sulfide oxidation has occurred, with associated acid generation. However, the paste pH was only acidic (low) for the heap leach sample implying that either the SO4 present in the other samples is unrelated to sulfide oxidation, or there is considerable ANC. ANC is also plotted in Figure 3.4 and is indeed high in some samples, indicating that overall, the material may not be acid-generating.

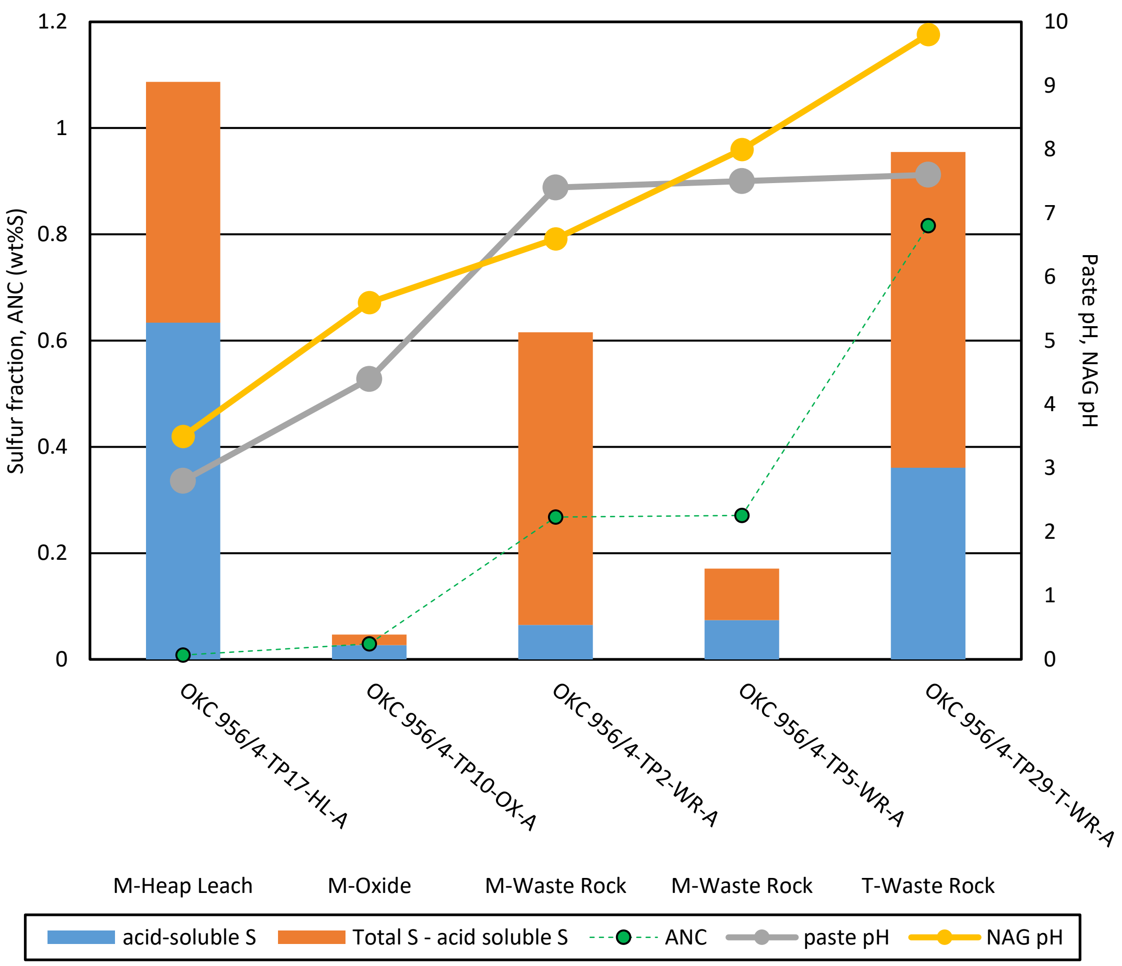

Figure 3.4: Sulfur species as stacked column chart (Acid soluble sulfate, and Total S minus acid soluble sulfate), as well as ANC, in units of wt%S. Secondary y-axis: paste pH and NAG pH. (M-Murrawombie; T-Tritton).

Net acid generation (NAG) testing involves rapid oxidation of the sample, to release all the acid generating potential. Determination of NAG pH allowed refinement of the acid risk classification, with respect to the AMIRA (2002) system. According to this classification, a Murrawombie waste rock sample from an older, rehabilitated waste dump was re-classified as NAF.

However, the Murrawombie waste rock sample from the newer dump with no rehabilitation, and the sample of Murrawombie oxide, were reclassified to “Uncertain”, indicating there still may be the risk of acid generation. The Tritton waste rock sample was also re-classified as low risk, likely due to high ANC (Figure 3.5).

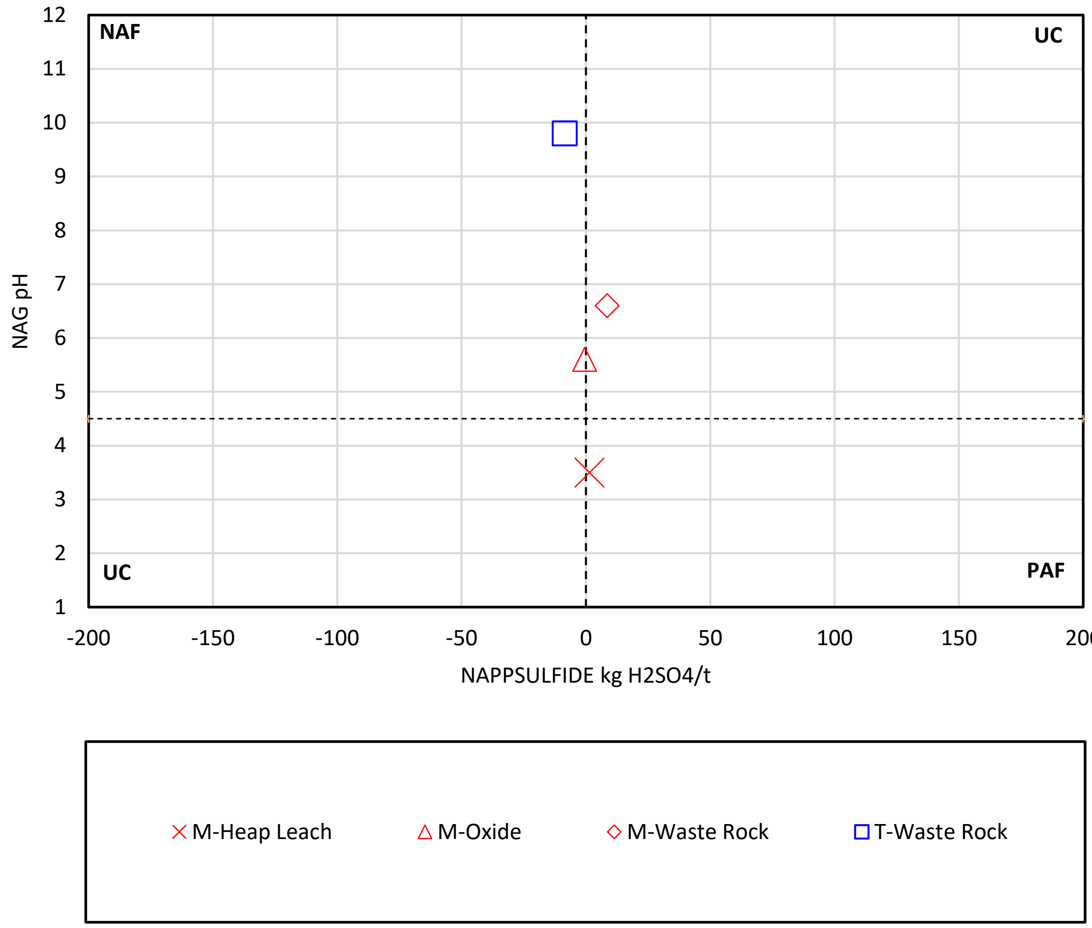

Figure 3.5: NAG pH vs NAPP sulfide and resulting AMIRA (2002) risk classification. (NAF- non-acid forming; UC-uncertain; PAF-potentially acid forming; M-Murrawombie; T-Tritton).

3.3.3 Phase 3: DI leachate composition

The four samples exhibiting high acid generation risk according to the preliminary classification system were sent for leach testing and analysis of the leachate composition. Two samples classified as NAF were also sent for testing, as leachability is not solely determined by the acid generation risk of the material.

The leach test was performed on the <2 mm fraction, with a 1:2 soil/deionised water leach solution (0.45 µm filter) and 12 h contact time (bottle roll). The leachate was analysed for pH, EC, acidity, major ions, nitrate and reactive P, and a suite of trace elements (Ag, Al, As, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, S, Sb, Se, Si, Sn, Sr, Tl, V, W, Zn, and Hg). It should be noted that soils assessments in Australia are usually performed at a solid:liquid ratio of 1:5, and for waste classification the ratio is usually 1:20; the concentrations resulting from this test may therefore be higher than if assessed by other methods.

To allow for a discussion on the water quality emanating from the materials assessed, results have been presented at levels ten times above the limit of laboratory reporting (LOR). A summary is provided in Table 3.3.

Note that exceeding 10x the LOR is not necessarily an indication of environmental concern and concentrations of some elements that are <10x the LOR, or below the LOR, may still be of environmental concern. Assessment of the relevance of these leach results with respect to possible environmental impacts would require comparison with any compliance criteria that may exist for water quality of any discharges at the site. The interpretation of the leach data with respect to environmental risk would also require the consideration of the difference between the leach test conditions (e.g., solid:water ratio, contact time, leach solution pH and composition) and the conditions the material would be exposed to in the field.

Table 3.3: Elements that exceeded 10x LOR for samples subject to DI leachate

OKC sample ID	Site	Material	Comment	AMIRA	Price	Leach pH	Leach EC (µS/cm)	Elements >10x LOR
OKC 956/4-TP17-HL-A	Murrawombie	Heap Leach	Heap Leach	PAF	PAF	3.6	5290	Acidity, SO4, Si, Cl, Ca, Mg, Na, **Al, B, Cd, Cr, Co, Cu, Fe, Mn, Ni, Zn, Ce**
OKC 956/4-TP10-OX-A	Murrawombie	Oxide	Expected cut back area	PAF	UC	5.4	1650	SO4, Si, Cl, Mg, Na, **Fe, Mn, Zn**
OKC 956/4-TP12-OX-A	Murrawombie	Oxide	Expected cut back area	NAF		7.6	1770	Alkalinity, SO4, Si, Cl, Ca, Mg, Na, **Sr**
OKC 956/4-TP2-WR-A	Murrawombie	Waste Rock	Newer Waste Dump (No Rehab)	PAF	UC	7.4	2610	Alkalinity, SO4, Si, Cl, Ca, Mg, Na, K, **Mn**
OKC 956/4-TP3-WR-A	Murrawombie	Waste Rock	Older Waste Dump with Rehab	NAF		7.5	641	Alkalinity, SO4, Si, Cl, Na, **Fe**
OKC 956/4-TP29-T-WR-A	Tritton	Waste Rock	Waste Dump	PAF	NAF	7.3	3120	Alkalinity, SO4, Si, Cl, Ca, Mg, Na, K, **Mn, Sr**

Note: AMIRA – acid risk classification according to AMIRA (2002). Price- acid risk classification according to Price (2009).

Trace elements in bold font.

The Murrawombie heap leach sample (PAF) exhibited the lowest leachate pH, highest salinity, acidity, and SO_4 concentration, and the greatest range of trace elements released at concentrations >10x the LOR.

The tested Murrawombie oxide samples, and waste rock samples from both Murrawombie and Tritton, also released some major ions: Mn, Fe, and Sr. The Murrawombie oxide sample classified as “Uncertain” according to AMIRA (2002), with moderately acidic leachate pH (5.4), also released Zn at >10x LOR.

3.3.4 Quality Assurance/Quality Control (QA/QC)

The QA/QC data provided by the laboratory was inspected and the geochemical data was considered of suitable quality for this assessment.

3.3.5 Summary

Based on static geochemical testing of a limited number of samples, Murrawombie topsoil (three samples) was classified as NAF and is therefore potentially suitable for cover material, based solely on its geochemical classification.

One of the three Murrawombie waste rock samples analysed (from a newer dump with no rehabilitation; OKC 956/4-TP2-WR-A) was “uncertain”, and therefore represents moderate risk. The two waste rock samples from older, rehabilitated dumps were classified as NAF.

One sample (OKC 956/4-TP10-OX-A) of the three Murrawombie oxide samples was classified as “uncertain”, and therefore represents moderate risk.

The Murrawombie heap leach sample (OKC 956/4-TP17-HL-A) was classified as high acid generation risk.

Samples of Tritton topsoil (all four samples) and subsoil (one sample tested) were classified as NAF. The Tritton waste rock sample was re-classified as NAF upon further testing; however, this material was associated with a high acid generating and neutralising capacity. As such, further testing to confirm the availability of the ANC for reaction would be required.

Note that the testing discussed provides an initial screening. Geological materials are associated with heterogeneity, and therefore extrapolation of these results to the bulk of each material type for the site is highly uncertain. Sampling and testing completed as part of this project can be considered preliminary in order to establish suitability of materials for use within a cover system. Further testing of additional samples of potential suitable cover system materials should be considered to confirm the overall material classification as the concept design progresses to construction. Recommendations of number of samples per material type are given in Leading Practice Sustainable Development Program for the Mining Industry handbook on Preventing Acid and Metalliferous Drainage (DFAT, 2016). In addition, for NAF classifications where the result depended upon reactivity of acid neutralising capacity, different types of tests to the static testing carried out here (e.g., kinetic testing, ABCC testing; AMIRA, 2002) would indicate whether the acid neutralising capacity of this material was available for reaction.

Short-term leach tests on samples classified as NAF or Uncertain resulted in the release of trace elements Mn, Fe, and/or Sr at concentrations >10 x LOR. In the case of the Murrawombie oxide sample classified as Uncertain, with moderately acidic pH, leaching also resulted in Zn concentrations >10x LOR. However, the concentrations may not be at levels of environmental concern. Assessment of this would require the environmental guideline levels to be specified, and consideration of the difference between the leach test conditions and those in the field.

4 COVER SYSTEM DESIGN MODELLING

4.1 Objectives

As previously stated, the HLF at Murrawombie represents one of the most significant post-mining environmental risks. Soil and groundwater contamination have been identified as potential environmental impacts, and as such, rehabilitation of the HLF through design and construction of an appropriate cover system, and landform design, are the most important elements to mitigate this risk. Cover system design modelling was completed to address the following objectives:

- Limit the ingress of meteoric water to the underlying heap leach, thereby reducing contaminant production;
- Provide adequate layer to support establishment of sustainable vegetation; and
- Facilitate recovery of the environment disturbed by mining over the long term.

4.2 Model Description and Inputs

SEEP/W (GEO-SLOPE, 2017) is a 2D finite element model (which can also perform 1D simulations) that predicts suction in the material profile in response to climatic forcing (such as evaporation) and lower boundary conditions (such as a water table). NP is predicted based on these calculations. A key feature of SEEP/W is the ability of the model to predict AET based on potential evaporation and predicted suction, as opposed to the user being required to input these surface flux boundary conditions. The AET rate is generally below the potential rate during prolonged dry periods because the suction, or negative water pressure, in the material profile increases as the surface desiccates.

SEEP/W version 9.0.0.14833 was used to solve the simulations presented in this report.

Soil-Plant-Atmosphere (SPA) numerical modelling inputs can be divided into five categories: geometry, material properties, upper boundary conditions, lower and boundary conditions, and initial conditions. Brief descriptions of these model inputs are presented in the following sections.

4.2.1 Geometry

The cover system design options were simulated with a mesh similar to that shown in Figure 4.1 which shows the mesh of Design Option 3, consisting of 151 nodes. The mesh for Design Option 1 and 2 differed from Design Option 3 in the thickness of the waste rock, as defined in Section 2.4 and consisted of 111 and 126 nodes, respectively.

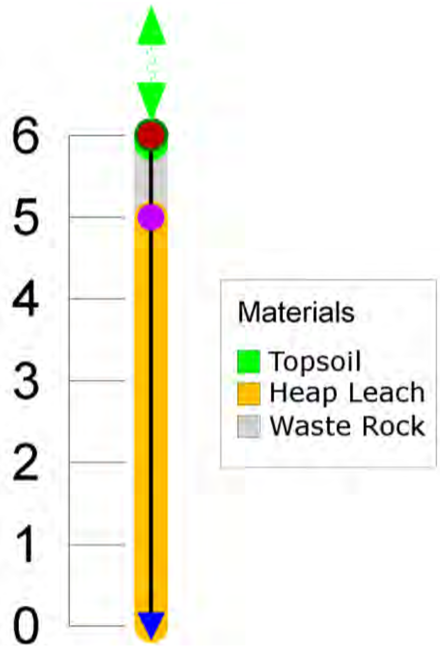

Figure 4.1: Mesh used to simulate Design Option 3

4.2.2 Upper Boundary Conditions

The upper boundary conditions required for the SPA models can be divided into two parts: climate and vegetation. Details regarding the model inputs developed for each are described below.

4.2.2.1 Climate

The Murrawombie site's dry continental climate is characterised by hot summers with high evaporation rates and low humidity, and mild winters. The hottest months are January and February, with July being the coldest month. The site lies in a region that is neither dominated strongly by winter nor summer rainfall with precipitation events distributed relatively evenly throughout the year.

As part of the conceptual modelling phase of the project (OKC, 2016a), historical climate data representative of site conditions at Murrawombie were obtained from a SILO (Scientific Information for Land Owners) data drill (State of Queensland, 2017). SILO is a database of historical climate records for Australia and provides estimated daily datasets for a range of climate variables for any location in Australia (referred to as 'data drills'). The database is reliant on climate data measured at stations reported by the BoM (2017); therefore, the accuracy of the SILO data drill is contingent on the proximity of climate stations to the site in question. Fortunately, BoM climate stations (namely, Girilambone prior to 2012 and Nyngan in recent years) have been active in the vicinity of Murrawombie for over 100 years. Therefore, a historical 100-year climate database was developed for the site beginning in 1915. Five-year averages of rainfall received on site are presented in Figure 4.2 displaying the historical distribution of rainfall on site. The figure indicates that annual rainfall received before the 1950s were lower compared to that recorded in later years. A series of above average rainfall years was received between 1970s to late 1990s.

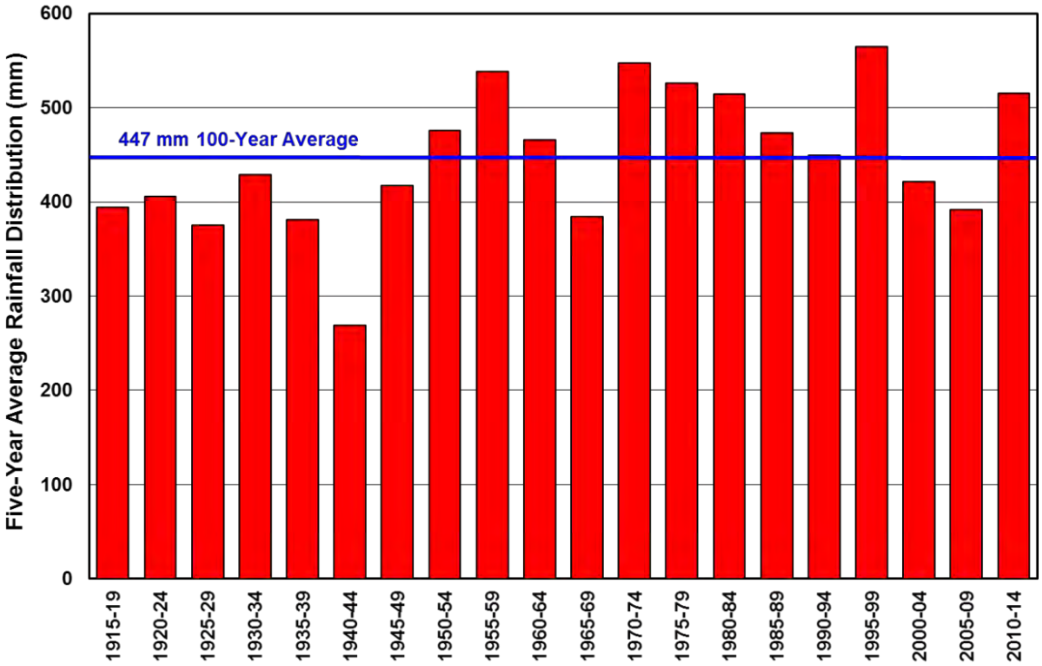

Figure 4.2: Murrawombie site 5-yearly average Rainfall, 1915-2014

The main drivers of cover system water dynamics are the amount and distribution of rainfall and potential evaporation (PE), which was provided by the SILO data drill and estimated using the Food and Agriculture Organisation (FAO) of the United Nations' method; referred to as FAO56 (FAO, 1998). Table 4.1 shows the average year climate parameters based on the 100-year climate database while monthly averages for rainfall and potential evaporation are presented in Figure 4.3. Average annual rainfall for the site is 447 mm, with fairly consistent monthly averages, and no distinct wet or dry season. As shown in Figure 4.3 average monthly PE is consistently higher than the average monthly rainfall, which is well-suited for a store-and-release cover system; however, during the winter months, monthly PE decreased close to the rainfall totals. The maximum monthly rainfall for an average year is 50 mm received in the summer months when PE values are at the higher end of the cycle.

Table 4.1: Summary of average annual climate parameters for the historical 100-year climate database

Parameter	
Mean Annual Rainfall	447 mm
Maximum Rainfall (Year)	1012 mm (1950)
Minimum Rainfall (Year)	170 mm (1929)
Average Daily Maximum Temperature	26°C
Average Daily Minimum Temperature	12°C
Average Daily Maximum Relative Humidity	84%
Average Daily Minimum Relative Humidity	34%
Mean Annual Potential Evaporation	1559 mm

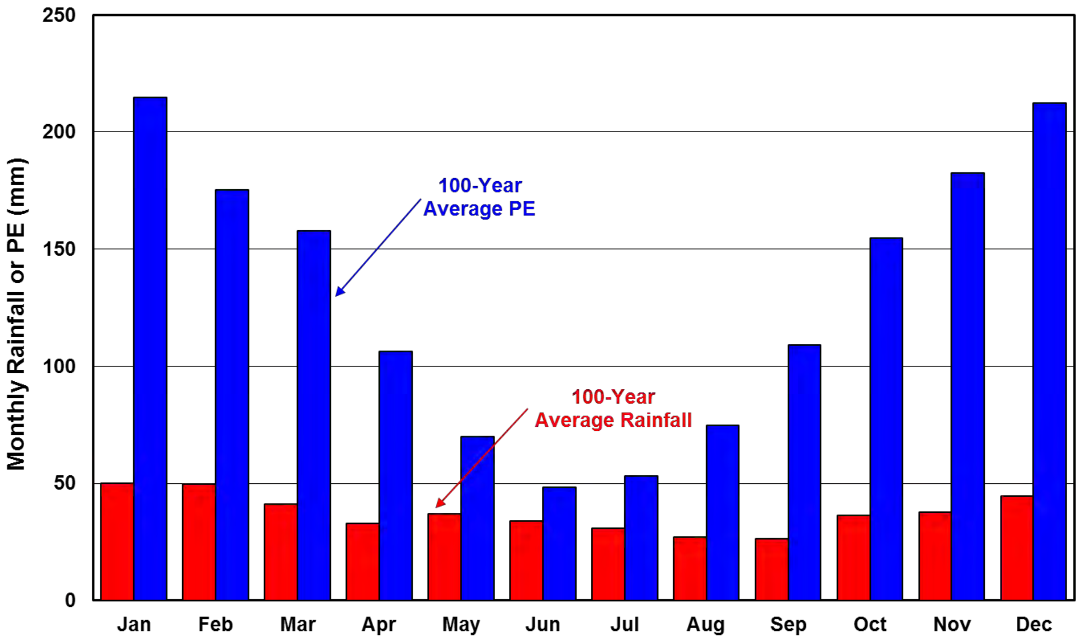

Figure 4.3: Murrawombie Site "Average Year" Rainfall and Potential Evaporation, 1915 to 2014 dataset

4.2.2.2 Vegetation

The vegetation biome for Murrawombie comprises temperate grasslands. The vegetation mix to be established on the HLF is anticipated to consist mainly of grasses to support the end land use of cattle grazing. As such, deep-rooted tree species are to be avoided over the area, further reducing the risk of ore material pore-water uptake from the rooting system. Therefore, the model inputs used to simulate temperate grasslands are summarised in Table 4.2, with additional description following the table.

Table 4.2: Vegetation model parameters

Model Parameter	Temperate Grasslands
Root Depth (m)	1.3
Root Distribution (Depth to 50%, m)	0.13
Soil Cover Fraction	0.5
Field Capacity (kPa)	10
Permanent Wilting Point (kPa)	3,000

Jackson *et al*. (1996) estimated a typical root distribution for temperate grasslands using the following formula first put forth by Gale and Grigal (1987):

$Y = 1\text{-}\beta^{d}$

Where Y is the cumulative root fraction from the soil surface to depth d (cm), and β is the fitted "extinction coefficient". β is the only parameter estimated in the model and provides a simple numerical index of rooting distribution. Jackson et al. (1996) estimated a β of 0.943 for temperate grasslands (Figure 4.4).

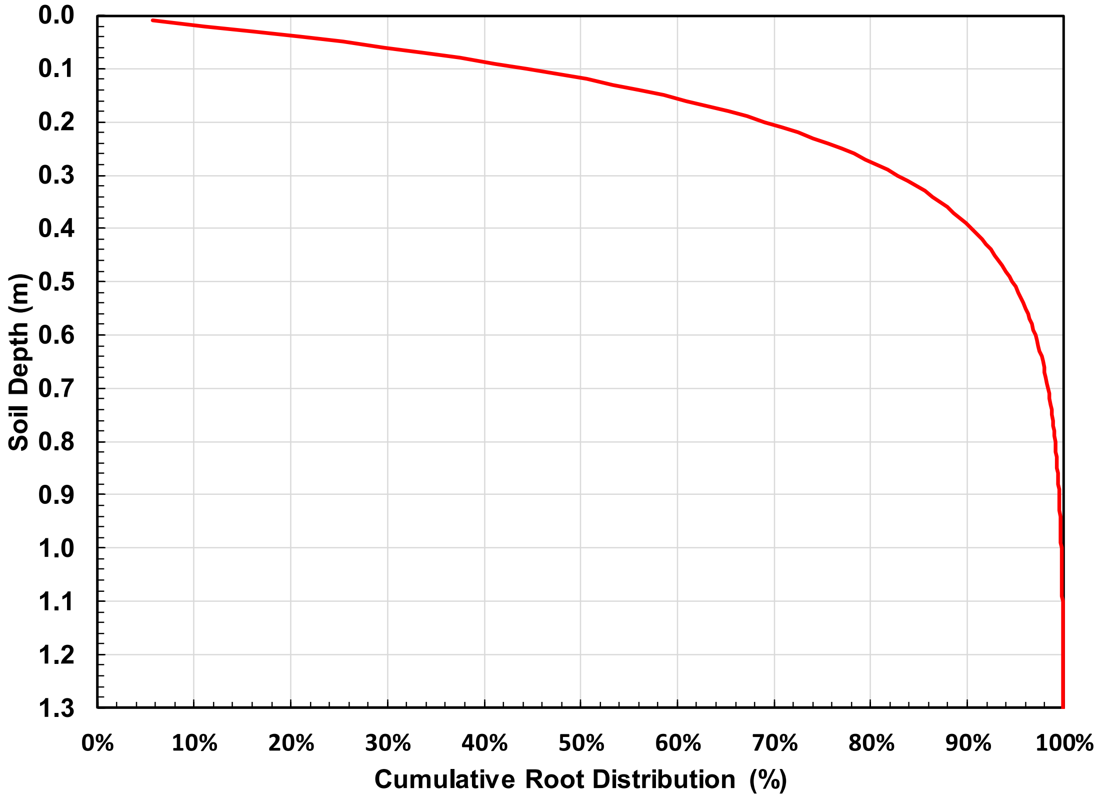

Figure 4.4: Cumulative root distribution estimated for temperate grasslands growing on the HLF cover system.

In general, field capacity (FC) is defined as the water content of soil at a suction of 33 kPa, and permanent wilting point (PWP) is defined as the minimum soil water required for a plant to resist wilting at a suction of 1,500 kPa. However, this range is very general and does not account for differences in soil and plant characteristics. Based on the estimated properties for the topsoil and the anticipated grassland vegetation, the FC and PWP for this project were defined at suctions of 10 kPa and 3,000 kPa, respectively. These values were also used to define the plant water limiting function (PWLF) shown in Figure 4.5 which determines the percentage decrease in a plants ability to draw water as suction increases in unsaturated ground.

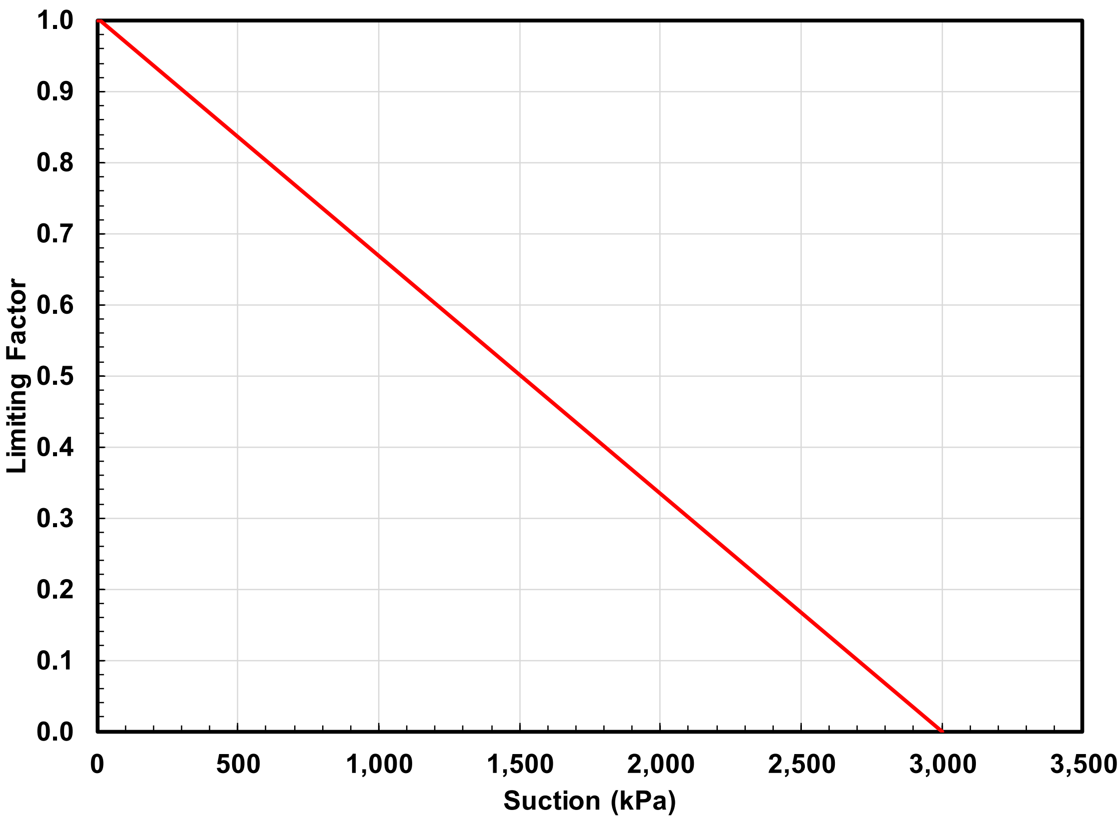

Figure 4.5: Plant water limiting function estimated for temperate grasslands at Murrawombie.

4.2.3 Lower Boundary Conditions

The lower boundary of the models was simulated as a unit hydraulic gradient. A unit hydraulic gradient boundary condition assumes that at the lower boundary the suction (and as a result, water content and hydraulic conductivity) are constant with depth. For this situation, the total head equals the gravitational head, which results in a unit hydraulic gradient. In other words, a unit hydraulic gradient represents a location in the material profile where water movement is controlled mainly by gravity.

A constant gas concentration of 0 Mg/m^3 was simulated at the boundary between the waste rock and the heap leach material. This extreme boundary condition, while not realistic, highlights the worst-case scenario for evaluating oxygen ingress via diffusion through the cover system.

4.2.4 Initial Conditions

All three materials were initially set to a pore-water pressure of -10 kPa and a gas concentration of 0 Mg/m^3. The model was not influenced by the initial conditions after a period of approximately one year.

4.3 Modelling Results

The results of the simulation can be evaluated based on NP and oxygen ingress performance. The following section provides the results of the simulations.

4.3.1 Net Percolation

The 100-year historical simulations of the cover system estimate the NP to be in the very high range for Design Option 1, in the low range for Design Option 2 and in the very low range for Design Option 3 (See Figure 2.5). Table 4.3 provides a summary of the 100-year historical model results for the three design options.

Table 4.3: Average annual performance of the cover system design options simulated with the 100-year historical climate database.

	Design Option 1	**Design Option 2**	**Design Option 3**
Potential Evapotranspiration	1559 mm	1559 mm	1559 mm
Precipitation	447 mm	447 mm	447 mm
Runoff	<1% R	<1% R	<1% R
Actual Evapotranspiration	76% R	97% R	97% R
Net Percolation	25% PPT (Very High)	4% PPT (Low)	3% PPT (Low)
O_2 Ingress via Diffusion (mol O_2 m^{-2} $year^{-1}$)	508 (High)	164 (High)	66 (Moderate)

NP varies with time, as shown in Figure 4.6. Approximately 53% of the years simulated for Design Option 1, 13% of the years simulated for Design Option 2 and 9% of the years simulated for Design Option 3, exceeded very high net percolation. Only approximately 30% of the years simulated for Design Option 1 were in the moderate or lower NP categories, compared to 70% and 85% for Design Option 2 and 3, respectively.

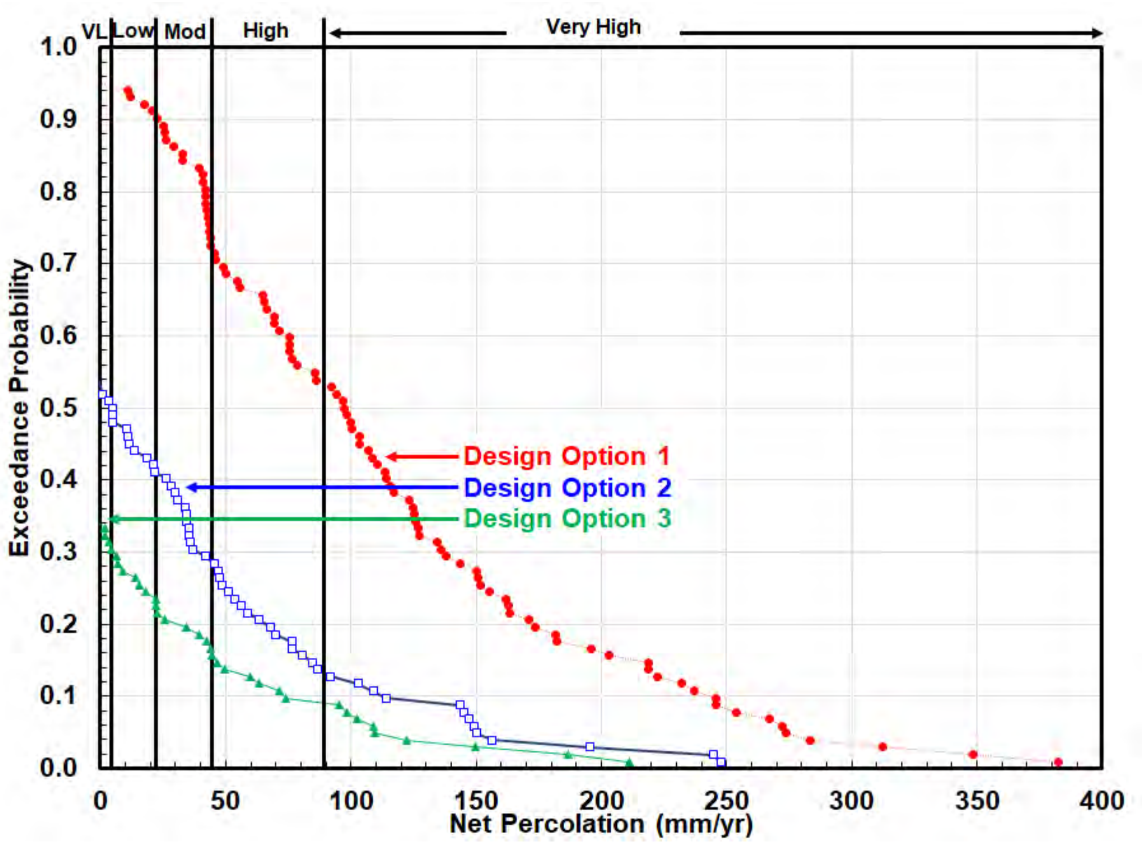

Figure 4.6: Exceedance probability graph for net percolation through the cover system during the 100-year historical simulations.

4.3.2 Oxygen Ingress via Diffusion

The 100-year historical simulations of the cover system estimate the O_2 ingress via diffusion to be in the high range for Design Option 1 and 2, and in the moderate range for Design Option 3.

Figure 4.7 shows the exceedance probability for O_2 ingress via diffusion for all three Design Options. All the years simulated for Design Option 1 and 95% of the years simulated for Design Option 2 were in the high range of O_2 ingress. Approximately 80% of the years simulated for Design Option 3 were in the moderate range, with the remaining 20% falling in the low range of O_2 ingress.

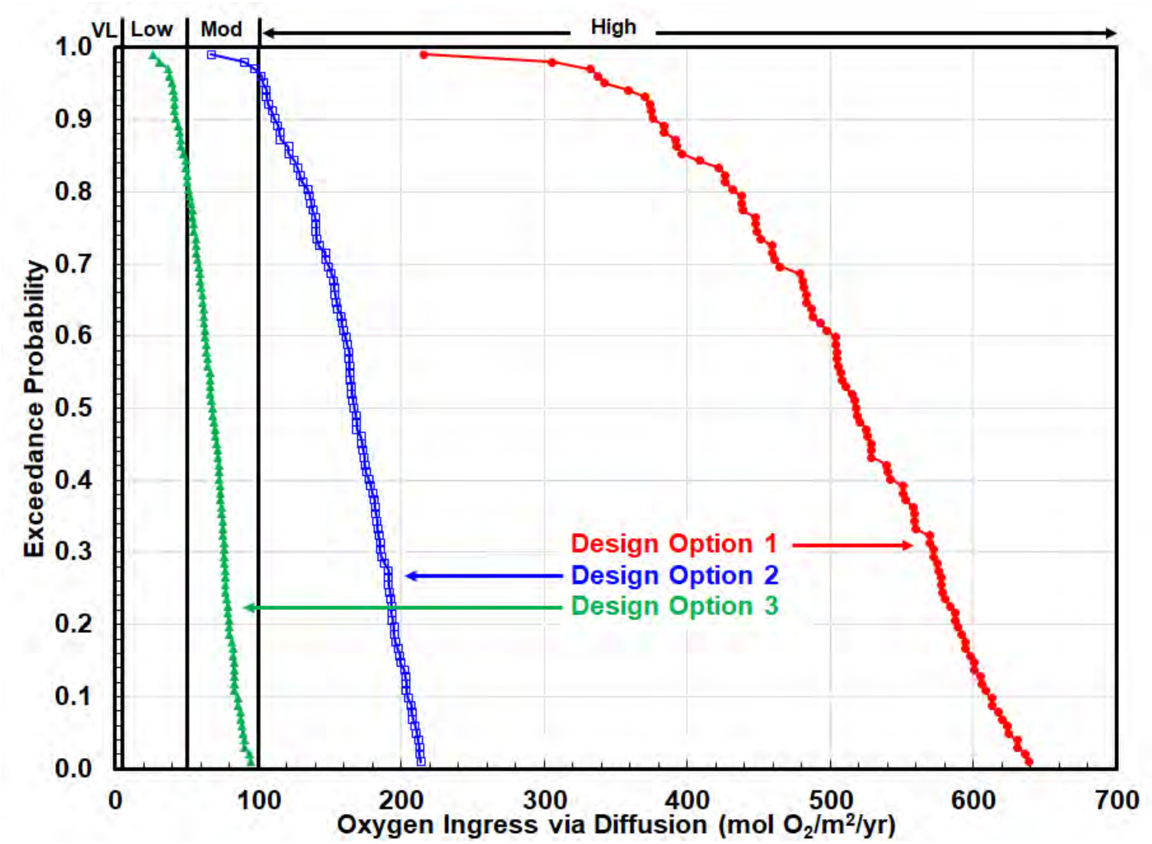

Figure 4.7: Exceedance probability graph for oxygen ingress via diffusion through the cover system during the 100-year historical simulation.

4.4 Model Limitations

The SPA models presented in this section are mathematical representations of water and oxygen transport within the waste rock and proposed cover system designs examined for the site. The complex hydrogeology of the site was simplified into conceptual models that could be represented by mathematical models.

The following limitations should be noted when interpreting the results of the model predictions for the SPA numerical modelling program.

- The model assumes that movement of water in the unsaturated zone can be represented as Darcian flow in a porous media. The model does not account for any potential non-Darcian flow in macropores and/or cracks within the simulated tailings and cover system profiles.
- The model assumes that the heap leach and cover system profiles can be represented by various material types with homogeneous material properties. The potential influence of local heterogeneity (within a given material type) was not investigated.
- The water movement within the cover systems is defined by the unsaturated hydraulic conductivity versus matric suction relationship. This relationship is extremely difficult to measure *in situ* in a field condition and consequently is derived by a theoretical algorithm based on the value input for saturated hydraulic conductivity and water retention curve. The

theoretical relationship defines the k-function over several orders of magnitude, while a single or half order of magnitude change can greatly affect the predicted NP results from a simulation.

- Vegetation development is subjectively defined by the model user and (other than the plant water limiting function) is not controlled by the material and water conditions estimated by the modelling program.

The key advantage to the numerical modelling results summarised herein is the ability to enhance judgment. Hence, rather than a focus on the absolute results predicted, it is recommended that the modelling results be viewed as a tool to understand key processes and characteristics that will influence performance of the cover system and develop engineering decisions based on this understanding.

5 HLF SURFACE WATER RUNOFF ASSESSMENT

A conceptual geometry, cover and surface water drainage design was developed by OKC to satisfy net zero site-discharge closure objectives for HLF surface water runoff and seepage (OKC, 2016b). The concept further assessed to predict anticipated surface water conditions on the HLF in larger, infrequent events. The assessment was conducted using the commercial hydrological/hydraulic model, DRAINS (http://www.watercom.com.au/), which supports Australian Rainfall and Runoff (2016) assessment methodologies (http://data.arr-software.org/).

The surface water network has been designed to:

- Provide zero off-site discharge from the HLF catchments. However, the cover system is expected to maintain water quality within the boundary of the HLF;
- Ensure the drainage system has capacity to convey surface runoff in events up to and including the 1% annual exceedance probability, equivalent to the 1-in-100-year average recurrence interval (ARI); and
- Predict surface water flow velocities in key locations, and potential requirement for scour protection.

DRAINS modelling was conducted for a range of 1% AEP storm events, with channel sizing adjusted iteratively until acceptable hydraulic results (i.e. freeboard, flow capacity and velocity) were predicted. Once acceptable performance was obtained in the 1% AEP, the 1-exceedence per year (1EY) storm was assessed to gauge performance in more common flow conditions i.e. expected to occur in any given year.

5.1 DRAINS MODEL INPUTS

Details of the DRAINS model input parameters are provided in Sections 5.1.1 to 5.1.5. The results of DRAINS modelling are provided in Section 5.2.

5.1.1 Design Rainfall

Design Intensity Frequency Duration (IFD) relationships (Figure 5.1), provided by BoM were used to produce design storm events for assessment of the HLF. The IFD relationships were used in DRAINS to generate site specific design rainfall events.

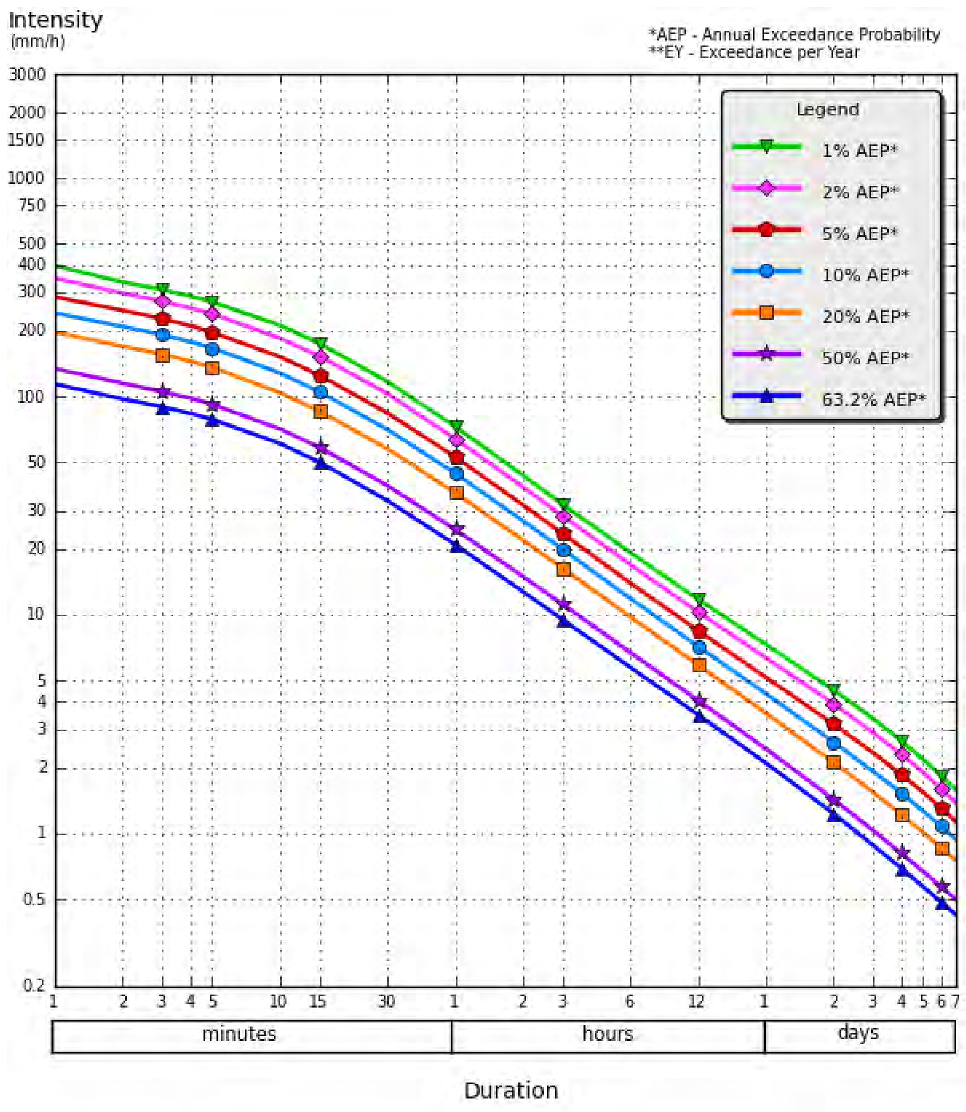

Figure 5.1: Murrawombie IFD

5.1.2 Rainfall Losses

The DRAINS model utilises a ‘loss model’ to determine the amount of rainfall not contributing to surface runoff. The specific loss model adopted for Murrawombie is based on infiltration characteristics of the waste and align most closely with a Type 2 (or B) soil (described by U.S. Soil Conservation Service). Type 2 soils are ‘moderately well drained’, i.e. moderate rates of infiltration. This Soil Type has been selected to approximate the expected performance of a cover system utilising the moisture store-and-release concept, using available site materials.

In addition to losses via infiltration, rainfall losses brought about by surface water retained in surface puddles has been allowed. This is referred to as depression storage. In the DRAINS model, 5 mm of rainfall is assumed to report to depression storage. This value has been adopted in accordance with suggested values in the DRAINS user manual for pervious catchments areas, and the propensity for mine waste landforms to differentially consolidate over time. Depression storage losses are accounted in DRAINS after infiltration losses have been applied.

5.1.3 Drainage and Catchment Layouts

The HLF drainage network layout used for assessment of surface water catchments and channels is illustrated in Figure 5.2. The sub-catchments of the HLF have been delineated based on the conceptual landform geometry and drainage design developed (OKC, 2016b).

HLF embankment catchments that do not shed directly to the arterial drainage network, such as the southern, eastern and western embankment catchments, are expected to be collected / retained by local drainage paths around the HLF and have not been specifically assessed in the model.

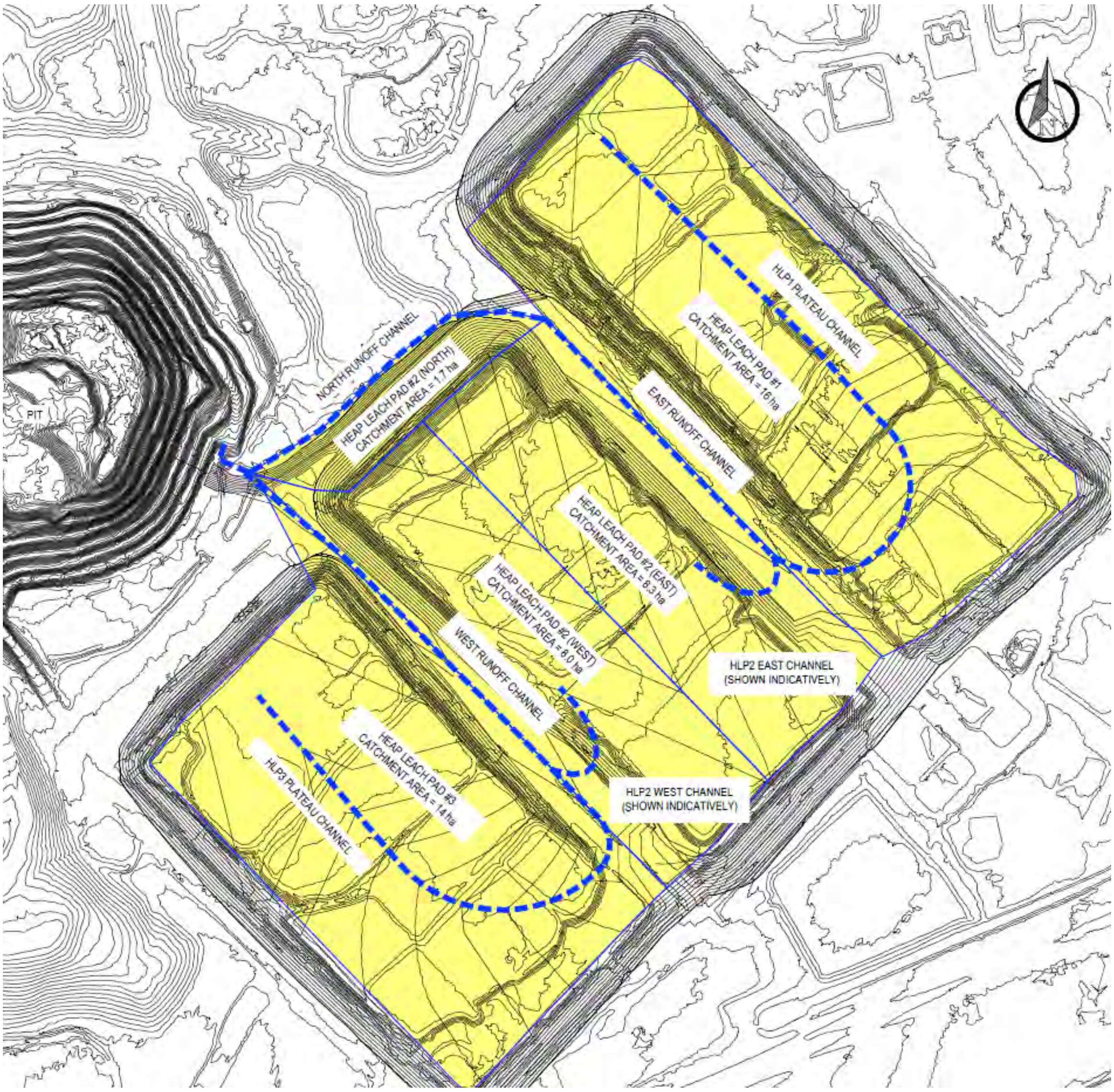

Figure 5.2: HLF Catchment Layout

5.1.4 Catchment Input Parameters

The key DRAINS catchment parameters modelled are listed in Table 5.1

Table 5.1: Catchment Parameters

Catchment	Area (ha)	Roughness (n*)	Flow Path Slope (%)
Heap leach pad 1	16	0.045	1
Heap leach pad 2 (east)	8.3	0.045	1
Heap leach pad 2 (west)	8.0	0.045	1
Heap leach pad 2 (north)	1.7	0.045	1
Heap leach pad 3	14	0.045	1

* HLF surfaces are assumed to have a retardance coefficient (n*) of 0.045 (QUDM, 2007). The retardance factor is based on Manning's equation but is applied to shallow flow over a plane, rather than channel flow.

5.1.5 Channel Input Geometry

The DRAINS-modelled channels are trapezoidal in cross section (Figure 5.3) with dimensions as listed in Table 5.2, this details the geometry for each component of the network. The geometry listed is intended as a guide to sizing for the 1% AEP event (inclusive of 0.3 m minimum average freeboard). However, this is not prescriptive and other cross sections may be considered to perform satisfactorily.

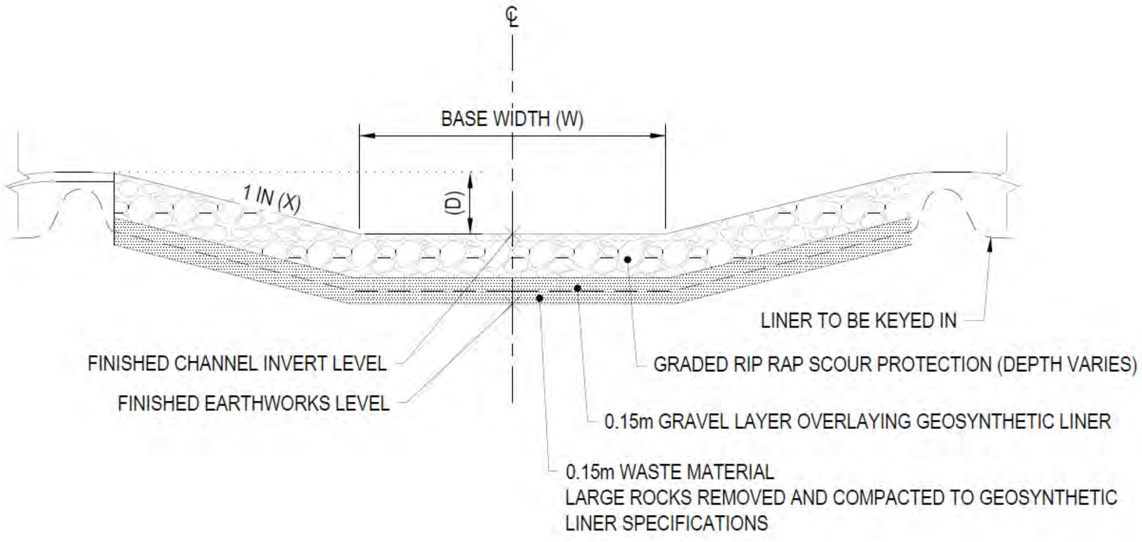

Figure 5.3: Cross section of drainage channel

Table 5.2: Channel Input Geometry

Channel	Length (m)	Channel Shape	Base Width (m)	Side Slopes (1 in X)	Average longitudinal Gradient (%)	Depth (m)	*Mannings n
HLP1 Plateau	665	Trapezoidal	3	6	2.0	1.0	0.035
HLP2 East Channel	118	Trapezoidal	3	4	6.8	1	0.035
HLP2 West Channel	132	Trapezoidal	3	4	5.3	0.8	0.035
HLP3 Plateau	451	Trapezoidal	3	6	1.7	1.0	0.035
East Runoff Channel	328	Trapezoidal	5	3	0.5	1.0	0.035
West Runoff Channel	546	Trapezoidal	5	3	1	1.0	0.035
North Runoff Channel	50	Trapezoidal	5	3	3.5	1.0	0.035
Pit Outlet Channel	50	Trapezoidal	5	6	3.5	1.0	0.035

*Sourced from DRAINS user manual,

5.2 DRAINS Modelling Results

5.2.1 Results for 1% AEP Storm Scenario

The channel sizes were developed iteratively within DRAINS to generate a functional drainage network. The channels listed meet all the performance requirements in terms of criteria for flow depth, freeboard and velocity. Key metrics are listed in Table 5.3.

Table 5.3: 1% AEP DRAINS model results

Channel	1% AEP Peak Flow Rate (m3/s)	1% AEP Peak Velocity (m/s)	1% AEP Average Freeboard (m)
HLP1 Plateau	5.6	1.9	0.51
HLP2 East Channel	3.0	2.7	0.60
HLP2 West Channel	2.9	2.4	0.48
HLP3 Plateau	5.0	1.7	0.51
East Runoff Channel	7.4	1.4	0.30
West Runoff Channel	7.2	2.0	0.47
North Runoff Channel	7.1	2.0	0.36
Pit Outlet Channel	13	2.9	0.27

5.2.2 Results for 1EY Storm Scenario

No runoff was predicted in the one exceedance per year (1 EY) storm scenario. This reflects the cover system modelling assessment that runoff is anticipated to be low in average rainfall years.

6 HLF CLOSURE DESIGN

6.1 Geometry

The geometrical design for the HLF is provided in the design drawings in Appendix E. OKC has previously provided an optimised earthworks design (OKC, 2016c) which detailed the material movements required to achieve the desired landform gradients. Equipment to be used for re-grading of the facility is to be determined by Aeris Resources and the chosen contractor (as required).

Prior to placement of the cover system materials, the plateau areas should be reshaped and regraded to create a surface that promotes surface runoff towards the runoff collection channels between the leach pads. This will eliminate depressions that may promote infiltration though the cover system and into the underlying heap leach material. Re-shaping the surface of the HLF prior to construction of the cover system enables construction of a uniform cover thickness over the entire facility (Drawing 956-4-003, Appendix E). The HLF plateau surfaces have been designed to create a minimum 1% slope towards the collection channels (Drawing 956-4-002 and 956-4-003, Appendix E). The two central channels between the leach pads have been designed to take collected 'clean' surface runoff down from the plateau and direct it towards the pit.

The embankments of the HLF are designed to approximately 33% gradient (1H:3V) using NAF material for fill. It is recommended that Aeris avoid pushing down the ore material to form the embankment to maintain the ore material over the installed collection liner. NAF material should be used between the HLF to create the runoff collection channels draining towards the open pit (refer to Drawings 956-4-003 and 956-4-004 for typical cross-sections of the landform, Appendix E).

6.2 Drainage

6.2.1 HLF Plateau Drains

Central HLF plateau drains are recommended on HLP1 and HLP3 to convey excess surface water off the landform in larger storm events and minimise surface runoff shedding distances. The modelled geometry of these plateau drains is provided in Section 5.1.5 and it is recommended that these be constructed with a low permeability liner and compacted gravel base underlying rip rap type scour protection, as indicated in Figure 6.1. This will reduce NP through the channel and resist erosion of the cover channel material over time.

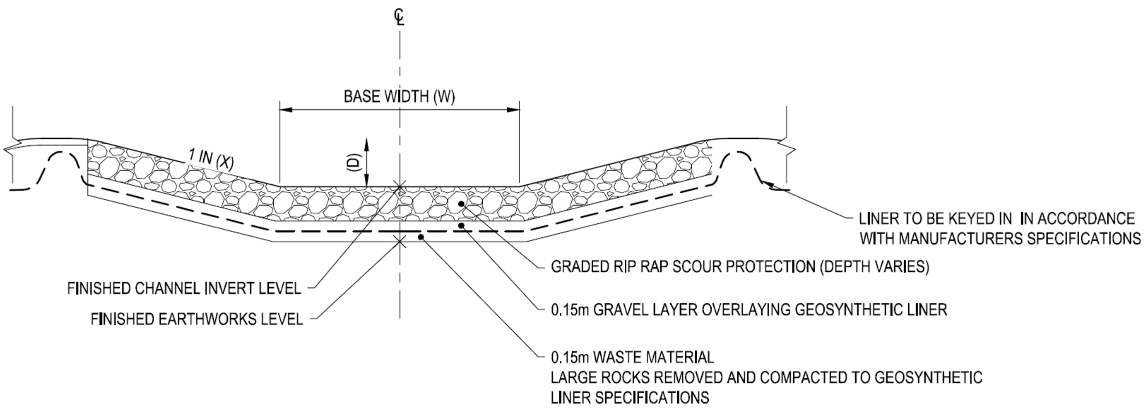

Figure 6.1 Channel Design

Rip rap material on steeper embankment drains (5-6%) should be minimum 0.25 m thick sized at least 150 mm in diameter. Should larger minimum stone size be used, than a layer thickness equivalent to at least 1.5 times the minimum stone size is recommended. Channel construction on shallower plateau drains (2% maximum gradient) should include a minimum rip rap stone size of ~100 mm, with minimum layer thickness of 150 mm.

Plateau drains should be constructed with generally uniform gradients. Where the plateau channel drains encroach into the HLF embankments, local reshaping may be required to accommodate the transition, or the spine drainage may be constructed to traverse the outside of embankment slopes from the crest to the toe of the embankment.

HLP2 has been designed with a central ridge that sheds surface runoff towards the northern and southern crests of the plateau. This eliminates the need to construct a central plateau drain on HLP2. The intent of the design is that surface water will be collected on the plateau and drained off the landform via dedicated drainage channels towards, though set back from the edge of the plateau. Surface runoff should be collected and discharged in a similar method to HLP1 and HLP3, avoiding discharge over the crest of the landform and down embankments due to the high risk over cover system erosion. This may be achieved by constructing either wide, well compacted crest bunds to divert surface water south and/or via channelised drainage.

6.2.2 HLF to Pit Drains

The two proposed channel drains between the three HLPs are designed to take collected 'clean' surface runoff from the HLF north to the pit. These drains will need to be constructed in areas of fill to provide sufficient fall such that the channels drain to the north-west. Infill should be well compacted (in ~0.3 m layers), and the drainage channels lined with a low permeability material to limit seepage through the channel bases. A 150 mm minimum rip rap layer should be placed on the channel surfaces, using a minimum stone size of approximately 50 mm for channel stability.

The two channels have been conceptually designed with a 0.5% (minimum) longitudinal gradient. QA/QC is recommended to ensure that the minimum gradient is met. Construction of flat or south draining channels would lead to surface water discharging at the south end of the landform and risk jeopardising the zero-discharge design criteria for HLF.

6.3 Seepage Management

NP through the constructed cover system is expected to report as seepage due to the high hydraulic conductivity of the ore material forming the HLF. This is typical of a heap leach material. The HLF has a synthetic liner underlying the entire facility. Provided the basal liner is in good condition, seepage from the HLF will be collected by the liner and report via the seepage collection system.

Following closure of the facility, it is proposed to retain the lined seepage collection channels, infilled with coarse NAF rock, to provide hydraulic conductivity for pore water relief. These channels will be covered with oxide and regraded to form the base of the final HLF to Pit channel drains.

The seepage volume reporting to the PLS ponds is expected to be low, or close to nil during average rainfall years. Cover system modelling indicates NP to be 5-10% of annual rainfall in wetter years. NP will attenuate within the HLF, slowing the discharge response relative to the rainfall duration, i.e. flowing into the PLS ponds.

Several engineering solutions can be implemented to manage the HLF seepage water, all respecting the “zero-discharge” concept. Some of the options considered are discussed in sections 6.3.1 to 6.3.3 below.

6.3.1 Option 1: Modify current containment dams to manage seepage volumes by evaporation

Evaporation may be a viable seepage management option given the climatic conditions. Preliminary inflow-outflow calculations were developed to assess if the areas occupied by the existing containment dams are potentially sufficient to manage all seepage from the HLF (following cover placement) as well as the direct rainfall.

The existing containment dams are immediately downgradient of the PLS ponds and in a good location for managing seepage flow into these areas. Existing containment dams are highlighted bright green and labelled as GSW1A, GSW1B and GSW1C, and the PLS Ponds are highlighted orange in Figure 6.2.

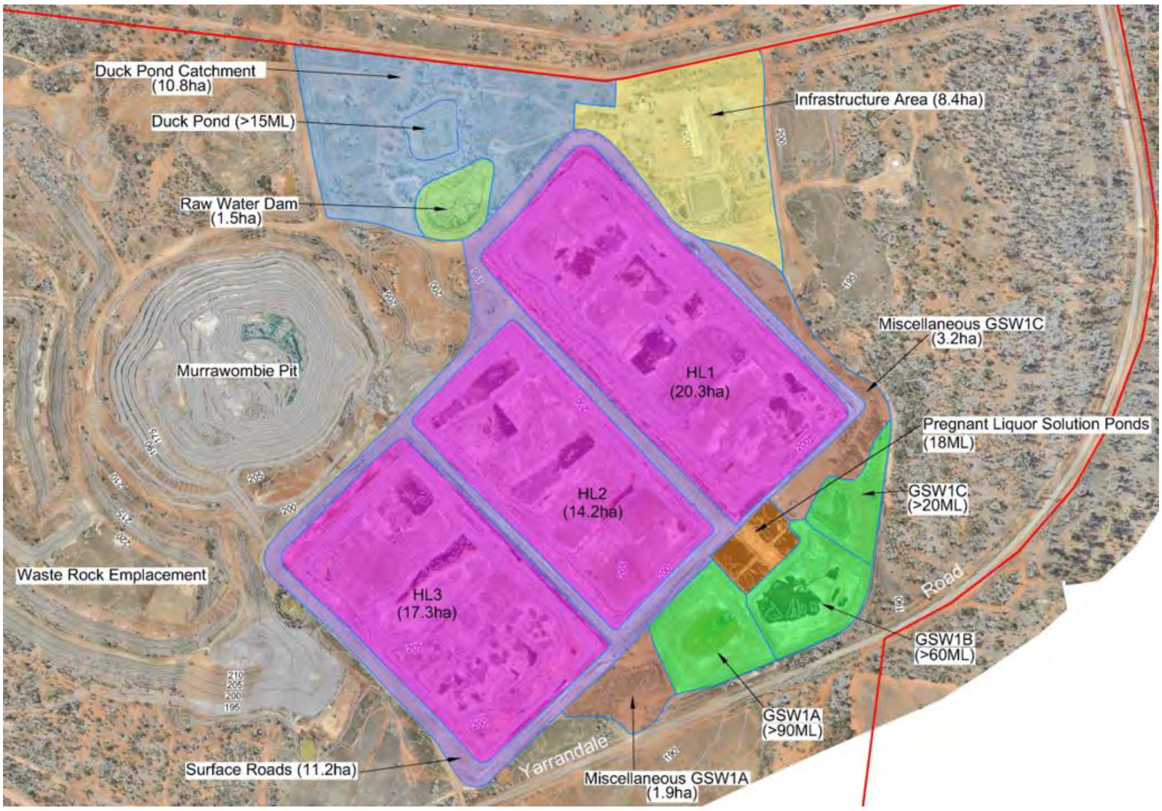

Figure 6.2: Existing Murrawombie Containment Dams (bright green) and PLS Ponds (orange). Figure has been reproduced from Corkey & Co., 2014.

The objective of the assessment was to determine whether the containment dams provide sufficient surface area to manage expected seepage by evaporation. The performance of the three dams were assessed separately by:

- Predicting the volume of overflow using the 100-year climatic sequence (refer to Section 4.2.2.1); and
- Predicting the number of overflow days in that assessment period.

Four scenarios were developed to assess the relative performance of each of the containment dam areas. The scenarios provide a range of results for different inflow and evaporation conditions, as follows:

- Scenario 1: high seepage inflows and low evaporation rates;
- Scenario 2: High seepage inflows and high evaporation rates;
- Scenario 3: Low seepage inflows and low evaporation rates; and
- Scenario 4: Low seepage inflows and high evaporations rates.

The assessment is considered preliminary given the evaporation potential of seepage has not been specifically investigated, and this will be impacted by the seepage quality. The calculations are sensitive to predicted seepage rates (inflows) and evaporation rates (outflows), therefore this assessment should be considered a qualitive level of assessment and not adopted for construction design. Key assumptions include:

- High seepage inflows are defined as 8% of annual precipitation, and low seepage inflows are defined as 3% of annual precipitation. This range was selected based on the cover system modelling (Section 4). No time for attenuation of seepages within the HLF is assumed.
- Selected 'High' evaporation rates used are the potential evaporation rates obtained from the 100-year SILO climate series used for cover system modelling. 'Low' evaporation rates used (in the absence of any specific evaporation studies) are 75% of the potential evaporation rates. This factor has been assumed and is not based on specific seepage quality or site conditions.
- No height-area storage relationships were developed for the containment dams; which may be used to better estimate effective evaporative areas at different depths of containment. Instead, the whole surface area of each containment dam is assumed to contribute to the evaporative potential. This is less conservative (i.e. produces more evaporation) than using a height-area relationship.

The key inputs and results of the assessment are summarised in Table 6.1.

Table 6.1: Results of preliminary assessment of evaporation

Metric	GSW1A[1]	GSW1B[1]	GSW1C[1]
Basin Area (ha)	2.0	2.2	1.7
Basin Volume (ML)	90	60	20
Predicted Overflow Volume in 100 Years (ML) (Scenario 1)	0	0	0
Predicted Number of Overflow days (Scenario 1)	0	0	0
Predicted Overflow Volume in 100 Years (ML) (Scenario 2)	0	0	24.5
Predicted No. Overflow days (Scenario 2)	0	0	49
Predicted Overflow Volume in 100 Years (ML) (Scenario 3)	0	0	0
Number of overflow days (Scenario 3)	0	0	0

[1] GSW1A, GSW1B and GSW1C are existing Murrawombie containment dams, refer to Figure 6.2 for locations.

The preliminary assessment indicates that:

1) GSW1 A & B, when considered separately are potentially able to manage the inflows via evaporation. Despite having less storage volume, GSW1B is the most robust alternative owing to its larger average basin area.

2) A sensitivity assessment was completed by increasing the maximum seepage inflow rate from 8% of annual precipitation to 10%. With this increased inflow rate, GSW1B overflows approximately 115 ML over 13 days and GSW1A overflows 49 ML over 81 days under scenario 1 conditions.

3) An increased seepage inflow rate also results in GSW1C overflowing on 243 days under Scenario 1 conditions and 49 days under Scenario 2 conditions. This corresponds to total overflow volumes of 106 ML and 24 ML respectively over the 100-year duration assessment.

4) GSW1A will overflow when minimum evaporation rates are reduced to <62% and GSW1B will overflow when minimum evaporation rates are reduced to <60% over the total 100-year assessment period.

When considering the containment dams as independent structures, and given the above performance, GSW1B provides the best potential geometry for the controlled evaporation of HLF seepage. However, in practice it would be relatively easy to combine at least two containment dams as well as the recently relined PLS Ponds to create a seepage evaporation system with significantly more capacity and evaporation potential than any one containment dam. A seepage evaporation system combining multiple structures would likely lead to a substantial improvement in performance when assessed against similar, and more extreme, scenarios

Should Aeris wish to explore these closure options further, it is recommended a more comprehensive assessment of water quality and its effects on actual evaporation be conducted.

6.3.2 Option 2: Construct an open channel from the current collection system to the open pit

As part of the March 2016 conceptual design OKC assessed the viability of an open channel HLF perimeter drain from the PLS ponds to the pit. Given the existing site terrain around the HLF, this option would require construction of a channel up to 20 m deep and ~1672 m length. The significant maximum depth of the channel is unlikely to provide an acceptably safe and stable landform for eventual closure and relinquishment.

6.3.3 Option 3: Construct a coarse aggregate seepage interception drain from the HLF to the open pit.

This option requires the construction of a seepage interception drain. Initially the open channel is constructed, as discussed in Option 2. Then a perforated pipe surrounded with a filter sock is installed at the base of the excavation. The excavation is progressively backfilled and compacted with porous media (gravel and sand) to provide a low permeability pathway to drain seepage to the pit. Existing ground levels are re-established around the HLF following backfilling. This alternative requires a very deep excavation and may block over the long-term.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Cover System

The high evaporative climate conditions at Murrawombie encourages the function of a cover system that utilises the store-and-release concept during ‘normal’ rainfall conditions. The cover system options investigated by OKC are shown in Figure 7.1. OKC recommends the 0.9 m thick cover system (Option 3). The cover system design modelling indicates that increasing the thickness of the NAF waste rock layer from 0.1 m (Option 1) to 0.4 m substantially reduced the anticipated amount of NP from ‘Very High’ to ‘Low’. Further increasing the thickness of the NAF waste rock to 0.9 m (Option 3) only slightly reduced NP in comparison to Option 2. However, the additional thickness provided in Option 3 has two significant advantages:

1) Additional growth medium for rooting depth. As shown in Figure 4.4, it is anticipated that almost 100% of plant roots will be within 1 m of the surface, and, therefore, within the thickness of the Option 3 cover system. Option 2 cover system has a higher risk of roots developing in the underlying heap leach; resulting in pore water uptake from the heap leach material.

2) A reduction in oxygen ingress via diffusion from High to Moderate. The geochemistry of the HLF sample indicated that the material has the capacity to continue oxidising and generate acidity; further (kinetic) testing would be required to confirm the rate at which the reactions will occur. However, assuming the reaction rate is faster than the rate at which oxygen can diffuse, which is a common situation in mine waste materials, the reduction in the oxygen transport rate will reduce the overall rate of reaction.

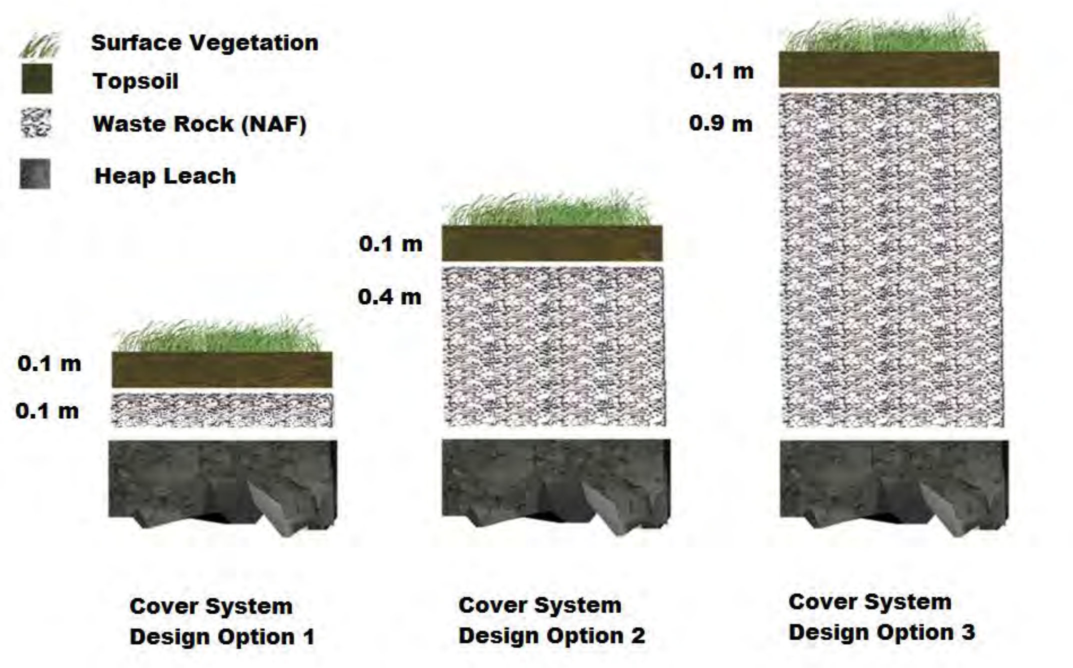

Figure 7.1: Cover System Design options

Prior to placement of the final cover system materials, it is recommended that the HLF be reshaped and graded to reflect the recommended final surface profile. Reshaping the subgrade prior to construction of the cover system allows for a uniform cover system thickness. It is recommended that a final inspection be undertaken to ensure surfaces are constructed at generally shallow gradients (1-3%) to support the store-and-release function of the cover system. QA/QC processes should also be implemented to ensure surfaces are free of depressions, which may increase NP through the cover system

7.2 Surface Grading and Drainage

Grading the HLF to drain excess rainfall to the two central surface runoff channels is recommended to separate clean surface water flows from seepage. Design drawings (956-4-002, 956-4-003 and 956-4-004, Appendix E) detail the new surface water drains constructed above the current drainage system, however the fall of the new surface water drains have been reversed to flow in a north-westerly direction (as described in Section 5). This minimises bulk re-shaping of the HLF.

The surface water modelling presented in Section 5 indicates channelised drainage is feasible. Surface water channels for drainage of the HLF would ideally be lined with a low permeability liner (synthetic or clay) to reduce NP through the HLF; limiting the generation of seepage. The channels should also include a coarse rip rap armour to prevent scouring of the channel over time, as detailed in Section 6.

7.3 Seepage

The approach to seepage management is constrained by surface levels around the HLF, with the low point located on the south-eastern side of the HLF. Various alternatives for seepage management were considered (Section 6.3). Whilst gravity drainage to the pit via either open channel or gravel drain is physically possible, these alternatives are unlikely to provide the most practical or cost-effective approach.

Preliminary calculations indicate management of seepage via an evaporation system constructed within the footprint of the existing containment dams and recently relined PLS Ponds presents as the most promising solution to maintaining zero discharge from the HLF post closure.

OKC’s assessment of the existing containment dams and the potential for an interconnected evaporation system is conceptual and requires further development and consideration of achievable evaporation rates over time. It should be noted that evaporation rates will be impacted by seepage quality, and the effectiveness of an evaporation system will be impacted by its geometry. Notably, the use of an evaporation system is a change in the seepage management strategy outlined in previous closure plans and would be subject to stakeholder support.

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Appendix A

Sampling Location Map

Appendix B

Sampling Summary

Appendix C

Geotechnical laboratory results

Appendix D

Geochemical laboratory results

Appendix E

Drawings

O'Kane Consultants

For further information contact:

Philippe Garneau
Senior Engineer
pgarneau@okc-sk.com

O'Kane Consultants Pty Ltd

193D Given Terrace
Paddington QLD 4064
Australia

Telephone: (07) 3367 8063
Facsimile: (07) 3367 8052
Web: www.okc-sk.com