REPORT

DEPARTMENT OF MINES INDUSTRY REGULATIONS AND SAFETY

Bulong Tailings Storage Facility

Conceptual Closure Report

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TAILINGS.WATER.WASTE.

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1 INTRODUCTION

The Department of Mines, Industry Regulation and Safety (DMIRS) Abandoned Mines Program (AMP) has engaged ATC Williams (ATCW) to undertake a conceptual closure design for the Bulong TSF.

The Bulong TSF is located in Western Australia, approximately 40 km east of Kalgoorlie and adjacent to Lake Yindarlgooda. ATCW understand that the mine site has been abandoned since 2005 and the TSF has remained inactive since this time.

The scope of the conceptual closure design is summarised as follows:

- Define closure objectives;
- Identify and assess landform options;
- Identify and assess cover system options;
- Monitoring and instrumentation; and
- Define scope of works required for detailed design.

2 EXISTING SITE CONDITIONS

2.1 TSF Details

2.1.1 Physical Dimensions

The Bulong TSF starter embankment was constructed in 1998 to a crest height of RL 329 m. The embankment was subsequently centerline raised in 2001 to a crest height of RL 331 m. A third raise was designed to raise the embankment to RL 333 m, however this was never constructed. Throughout the operational life of the facility, tailings were discharged from the perimeter embankment to a central causeway decant structure.

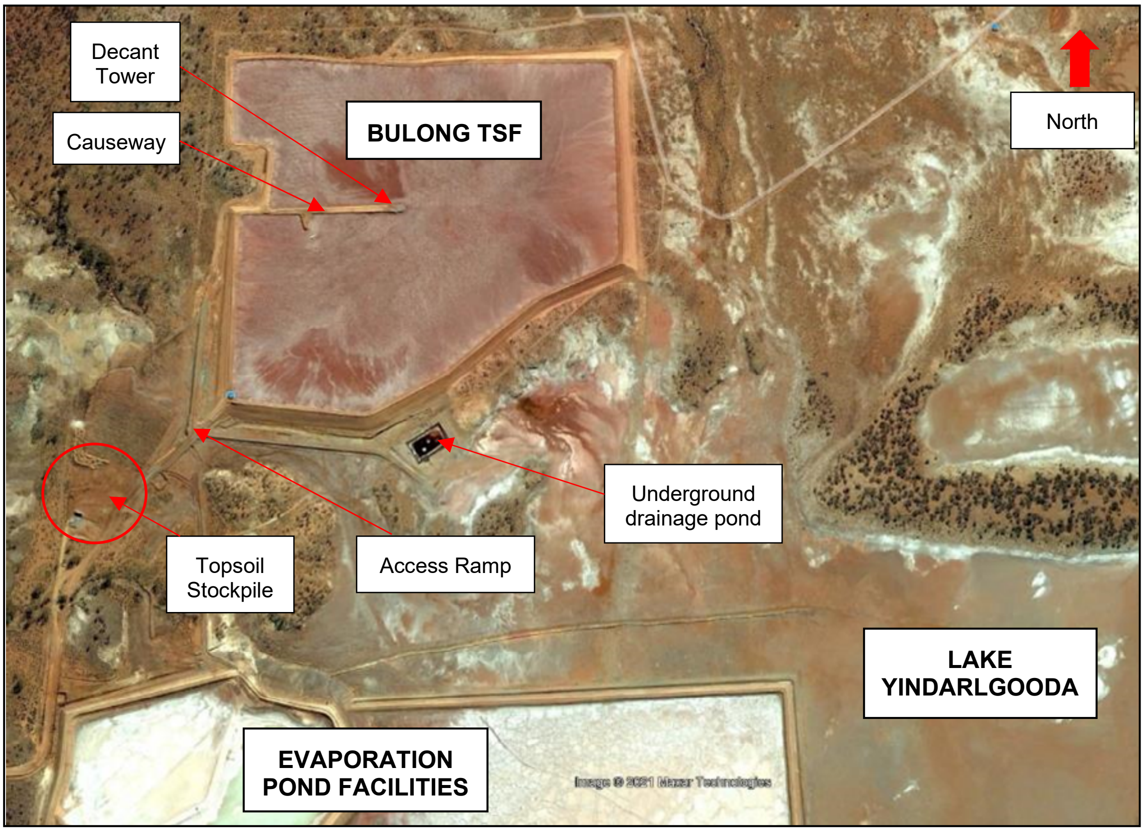
A summary of the design geometry for the Stage 2 raise of the Bulong TSF (existing condition) is presented in **Table 1**. It is noted that no as-constructed documentation is available, and as such, the data provided in the design reports has been relied upon.

TABLE 1 : BULONG TSF DESIGN GEOMETRY (STAGE 2 RAISE)

Criteria	Units	Value
Crest Length	m	2,800
Crest Width	m	8
Crest Elevation	m RL	331.0
Upstream Slope	H:V	2:1
Downstream Slope	H:V	2.75:1
TSF Stored Volume	m^3	2.3×10^6

The location of the Bulong TSF and general site layout is depicted in **Map 1**.

MAP 1: SITE LAYOUT



2.1.2 Embankment Materials & Strength Parameters

The Bulong TSF embankment is comprised of three zones:

1. Zone A low permeability facing
   Consisting of compacted clays and silts
2. Zone B downstream structural zone
   Consisting of compacted mine waste rock
3. Zone E toe drain
   Consisting of sand and gravel material. Cut into the foundations at the base of the Stage 2 raise.

The adopted design shear strength parameters for these zones are presented in **Table 2**.

TABLE 2: EMBANKMENT SHEAR STRENGTH PARAMETERS

Material	c' (kPa)	Degrees (°)	Bulk Density (t/m³)
Low Permeability Zone (Zone A)	5	25	18
Structural Fill (Zone B)	2	30	18
Downstream Toe Drain (Zone E)	5	40	22

2.1.3 Tailings Densities and Moisture Content

As the TSF has been non-operational since 2005, limited monitoring data is available for the structure. Current data gaps include the following:

- Consolidation of tailings
- In-situ densities
- Retained moisture in tailings
- Phreatic surface
- Seepage rates

2.2 Site Geology and Foundations

The site lithology is comprised of colluvium overlying siltstone. The colluvium and residual soils within the TSF footprint consist of high and low plasticity clays, silts and silty sands. Soil to the north of the facility consistently consisted of clays and silts and therefore was considered suitable for borrow material in the low permeability zones of the embankments. Residual siltstone consisting of gravelly silt or silty gravel was used for bulk fill in the embankments.

Foundation preparation under the starter embankment consisted of first stripping loose and/or granular material. This was followed by scarification to a depth of 200 mm, then moisture conditioned and recompacted to target a permeability of $1x10^{-8}$ m/s or less.

2.3 Hydrology

The catchment area for the Bulong TSF is stated to be 0.46 km^2 and is contained within the embankments. The TSF was designed to store a 1 in 100 year, 72 hour duration event plus operational and beach freeboards as per the DMIRS requirements. A such, a spillway was not designed for the facility.

A storm storage capacity estimate was performed as part of the 'Likelihood of Failure & Dam Break' report **[1]**. It was estimated that the TSF has capacity to store a 1 in 1,000,000 yr (PMP), 72-hr duration event.

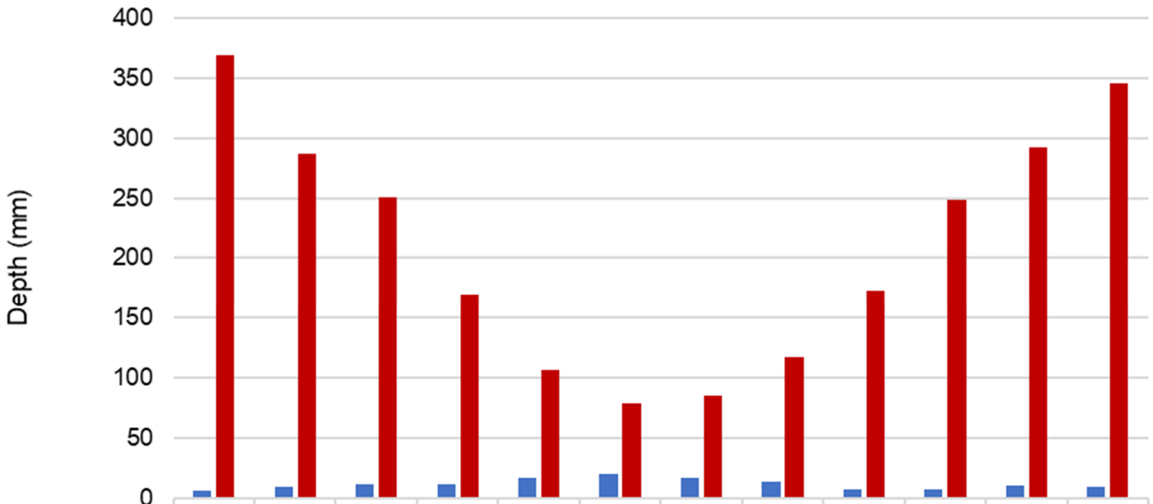
2.4 Climate

The regional climate is classified as Mid-Latitude Steppe and Desert Climate. The Department of Environment and Science (DES) provides an enhanced climate database SILO (Scientific Information for Land Owners) that holds Australian climate data from 1889. The interpolated climate data is stored on a regular 0.05° latitude x 0.05° longitude grid, which is approximately 5 km x 5 km. This database was used to obtain long-term geostatistically determined climate records at the nearest grid point to Bulong.

Chart 1 shows median monthly rainfall and pan evaporation. The monthly statistics of rainfall is shown in **Chart 2** and **3**. **Chart 4** and **5** display evaporation records and statistics.

Annual rainfall ranges from 65 mm to 500 mm, with long-term average annual rainfall in the order of 230 mm. The average annual evaporation (2,505 mm) exceeds mean annual rainfall by a factor of 10.9 and based on mean monthly rainfall and evaporation data, evaporation is more than triple for all months of the year (**Chart 1**).

CHART 1 : MONTHLY AVERAGE RAINFALL AND EVAPORATION



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	6.6	10	11.9	11.5	17.3	19.9	16.9	13.6	7.5	7.8	10.3	9.4
Evaporation	369.5	286.9	251.05	169.6	106.5	79	84.75	117	172.9	248.7	292.3	346

CHART 2: ANNUAL RAINFALL TOTALS (SILO DATA DRILL)

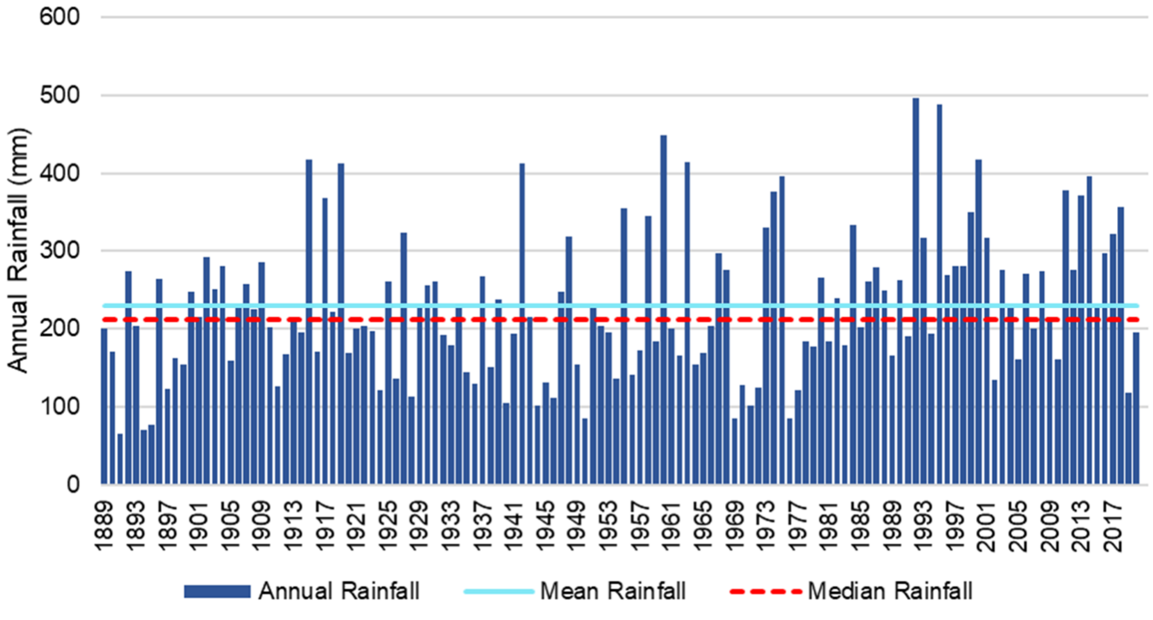


CHART 3: RAINFALL STATISTICS (SILO DATA DRILL)

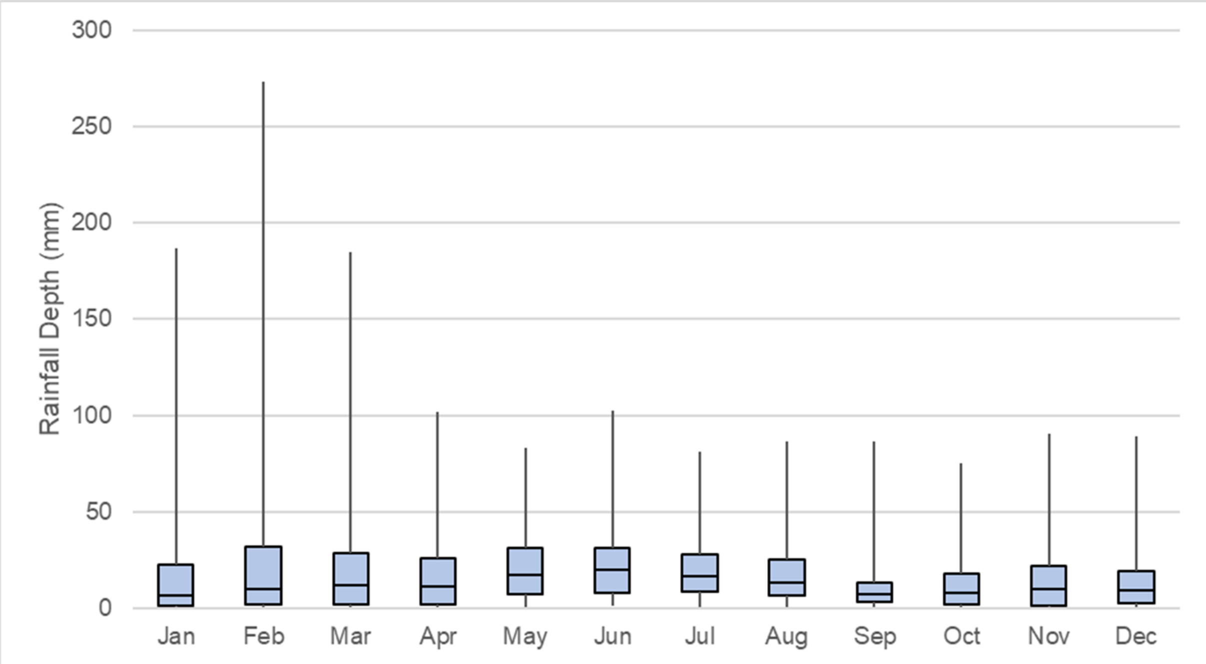


CHART 4: ANNUAL EVAPORATION TOTALS (SILO DATA DRILL)

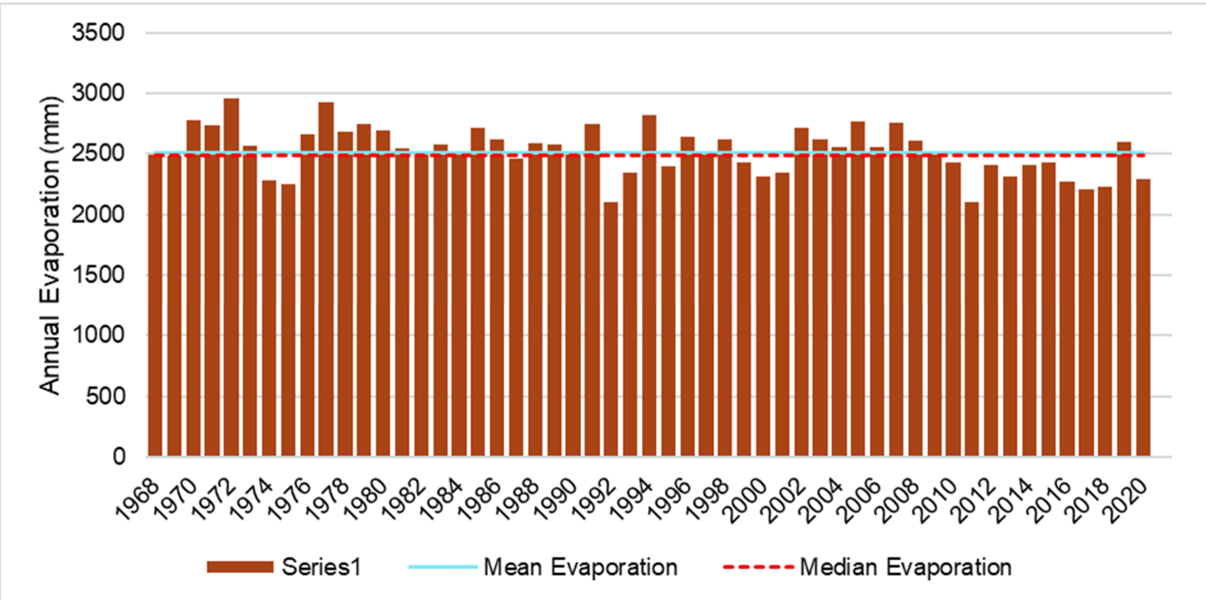


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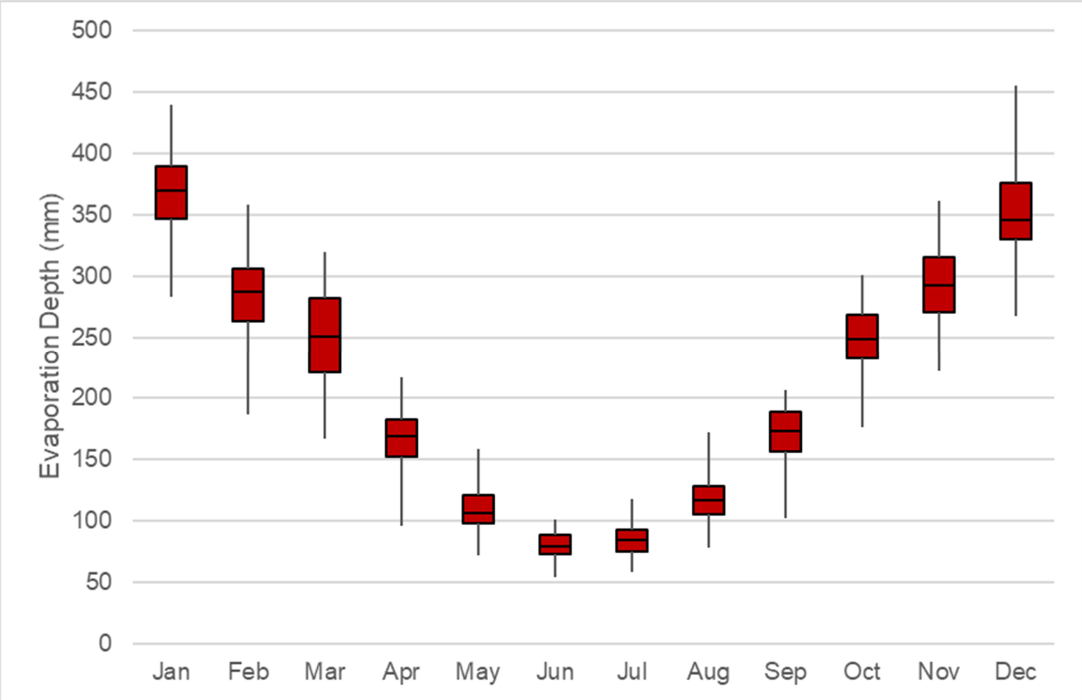
CHART 5: EVAPORATION STATISTICS (SILO DATA DRILL)



3 CLOSURE CONCEPT

3.1 Closure Objectives

In accordance with the requirements of *Guide to Departmental requirements for the management and closure of tailings storage facilities (2015)***[7]**, *Statutory Guidelines for Mine Closure Plans (2020)* and *Mine Closure Plan Guidance***[8]**, before closure of a TSF, the facility is to be decommissioned and rehabilitated such that the remaining structures are safe, stable, non-polluting, erosion-resistant and self-sustaining.

To achieve this, the following has been resolved (the below followed the structure set by DMIRS Guidelines **[7], [8]**):

1. **Set closure objectives, obligations, and commitments:**

   To date ATCW have found no record of any statutory obligations relevant to rehabilitation requirements for the Bulong site, and as such no Legal Obligations Register has been created. In reviewing the mine licence, again no reference to rehabilitation, obligations or commitments has been nominated.

   Table 3 below lists the current closure objectives, obligations and commitments to date.

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TABLE 3: CURRENT CLOSURE OBJECTIVES, OBLIGATIONS, AND COMMITMENTS

Closure Objectives, obligations, and commitments	Comment
Closure Obligation: Legal Compliance Register	No specific requirement identified
Closure Obligation: Ministerial Statement	No specific requirement identified
Closure Obligation: Works Approval	No specific requirement identified
Closure Obligation: EPA 1986	No specific requirement identified
Closure Obligation: Licence to Take Water	No approval provided
Closure Obligation: NOI / Mine Proposal	LRSF Stage 1 NIO 1997 page 58 to 59, no specific requirement identified
Closure Obligation: Non-Legally Binding Commitments and Promises	Final rehabilitation designs to be negotiated with Native Title Claimants
Closure Obligation: Safety	The decommissioned facility must achieve mitigation of safety risks to achieve As Low As Reasonably Practical (ALARP)
Closure Objective: Non-Polluting	The decommissioned facility must achieve mitigation of contamination risks and ensure the LRSF is non-polluting. In 2021 Senversa completed a Ecological Risk Assessment which concluded with the exception of a pathway of exposure to groundwater by the lake ecological system, the ecological risks associated with the LRSF have been assessed to be low and acceptable, further management of theses pathways is not considered warranted.
Closure Commitment: No additional disturbance	DMIRS have advised that the extent of disturbance across the site cannot be increase, this is particularly relevant in relation to sourcing of borrow materials and harvesting of local seed banks.

2. **Collate Baseline and Closure Data and Analysis:**

   In 2018, SLR completed a Preliminary Site Investigation (PSI), subsequentially in 2021 Senversa completed a Detailed Site Investigation (DSI) for the former mine site and an Ecological Risk Assessment (ERA). These reports provided a Conceptual Site Model CSM, details for risk assessment and inputs for ALARP as well as inputs to define criteria for monitoring. The DSI identified the following exposure pathways to potential contamination that must be managed through the mine closure process:

   - Wind-blown migration of particulates.
   - Migration of tailings material via wind-blown dust or erosion / surface water flow.
   - Leaching of COPC, saturated zone transport and discharge to water bodies.

   The Senversa ERA report provided baseline data analysis which established performance indicators and baseline conditions for a closure monitoring program. Review of these details is discussed further in Section 6.

3. **Post-Mining Land Use(s)**

   In consultation with DMIRS, functional closure objectives have been defined as follows:

- Prevent tailings becoming windblown
- Minimise infiltration into cover system to minimise seepage reporting from tailings

With respect to the post closure land use, the final landform would generally be considered as non-use management area. No target revegetation criteria (compared to background levels) have been defined. Notwithstanding, the surrounding environment generally comprises low vegetation density, due in part to the low rainfall conditions experienced in the region.

It is understood finalisation of closure criteria is subject to stakeholder discussion/acceptance.

4. **Identify and assess landform options**

Functional Objectives:

- Safe for Humans and Livestock
- Non-Polluting
  - Limited seepage due to low water flux into waste
  - No capillary rise
- Physically Stable
- Meets relevant minimum factors of safety (not assessed as part of this investigation)
- Sustains Agreed Land-use
- Refer Point 3.

Final landform concept:

Current shape of the LRSF surface is convex as a result of perimeter discharge during operations. For closure, following receipt of survey ATCW will provide DMIRS with up to three optimised free draining landform which minimises earthworks volumes.

3.2 Options Development

In consultation with DMIRS, ATCW developed a series of closure options with respect to the final landform, cover system and treatment of the batters. A discussion of options identified, and the risks/benefits are provided in the following sections.

3.2.1 Landform options

In reviewing the current TSF landform, aspects were identified for closure, summarised as follows:

- The landform is not free draining
- The TSF does not have an emergency spillway

The geometry of the existing tailings surface forms a bowl with the lowest point of the tailings beach approximately in the centre of the storage and adjacent to the decant causeway. Owing to this geometry, the TSF is not free draining. Drainage of ponded water on the TSF would be beneficial to minimise infiltration of rainfall into the tailings, potentially leading to seepage.

Additionally, the TSF does not currently have an emergency spillway. In accordance with ANCOLD (2019) Guidelines on Tailing Dams:

……..”it is good risk management practice to provide an emergency spillway. An emergency spillway is a strong preventative control against overtopping and hence against the potential for extreme consequences associated with catastrophic failure of the dam embankment”

It is recognised that the regional climate is characterised by very little rainfall (on average) and high evaporation. Notwithstanding, without having completed a water balance for the TSF, it is not known if successive wet years has the potential to fill the remaining storage capacity in the dam.

The consequences of water overtopping the embankment could be erosion of the embankment, leading to failure of the storage. On this basis, all cover options provide an emergency spillway channel.

To address landform aspects discussed above, three conceptual landforms were identified as shown in **Figures 1** to **3**. A summary of design concepts is summarised as follows:

Landform Option 1: Landform Option 1 comprises excavation of a spillway on the western embankment. No reshaping of the existing tailings beach would be undertaken and as such the tailings dam would not be free draining. During prolonged or extreme rainfall, ponding of water on the TSF surface would be expected, with subsequent loss of moisture though evaporation.

Water balance modelling would be required to confirm if a permanent pond would form on the TSF surface if the storage was not allowed to drain. Alternatively, the water balance model would determine the extents of such a pond and the time taken for the pond to evaporate following rainfall. Option 1 involves the least amount of earthworks, refer **Figure 1**.

Landform Option 2: Landform Option 2 requires excavation of a discharge channel from the invert of the tailing beach (adjacent to the decant riser) to the southeast embankment. The discharge channel would be constructed to convey peak flows from the PMP rainfall event. Option 2 requires significant earthworks to create the 400 m (approx.) long channel to the discharge point.

Stability analysis would be required to determine the maximum side slopes of the discharge channel. The channel dimensions shown in **Figure 2** assumes batter slopes of 1V:2H. This may need to be flattened (eg. 1V:5H) to address stability issues though geotechnical modelling. Flattening batter slopes could significantly increase the width of the channel.

Landform Option 3: Landform Option 3 requires reshaping of the south west corner of the tailings beach. Reshaping has been designed to achieve 0.25% longitudinal fall to the discharge point in the south west corner of the TSF. A crossfall of 0.5% into the drain has been included to direct flows to the invert of the cannel. Through reshaping the beach, the erosion risk present in Option 2 is reduced significantly however Option 3 requires the greatest amount of earthworks, refer **Figure 3**.

Based on discussions with DMIRS, it is understood Option 1 would be the preferred option to minimise the required earthworks.

FIGURE 1: LANDFORM OPTION 1

FIGURE 2: LANDFORM OPTION 2

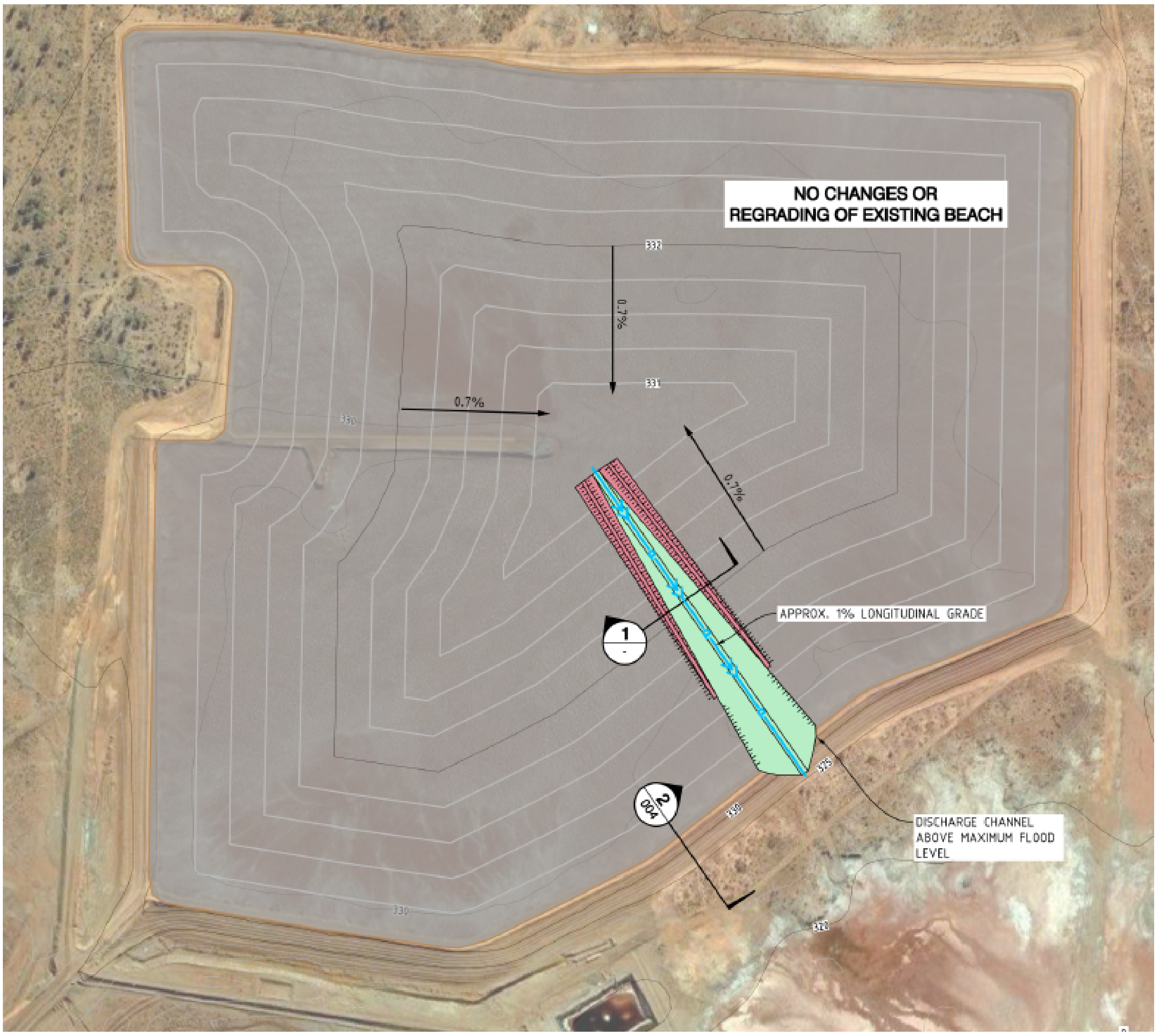

FIGURE 3: LANDFORM OPTION 3

3.2.2 Cover Systems

Four potential cover systems were identified as part of the options assessment as depicted in **Diagram 1**. As discussed in **Section 3.1**, the primary objective of the cover system is to prevent tailings becoming windblown. Ideally, the cover system would also minimise infiltration to the tailings thereby minimising seepage and groundwater recharge from the TSF. No closure objective has been defined with respect to vegetation establishment.

It is noted that proposed material depths are conceptual only and were based on cover systems developed for similar projects. The required material depths for each cover system would need to be assessed individually.

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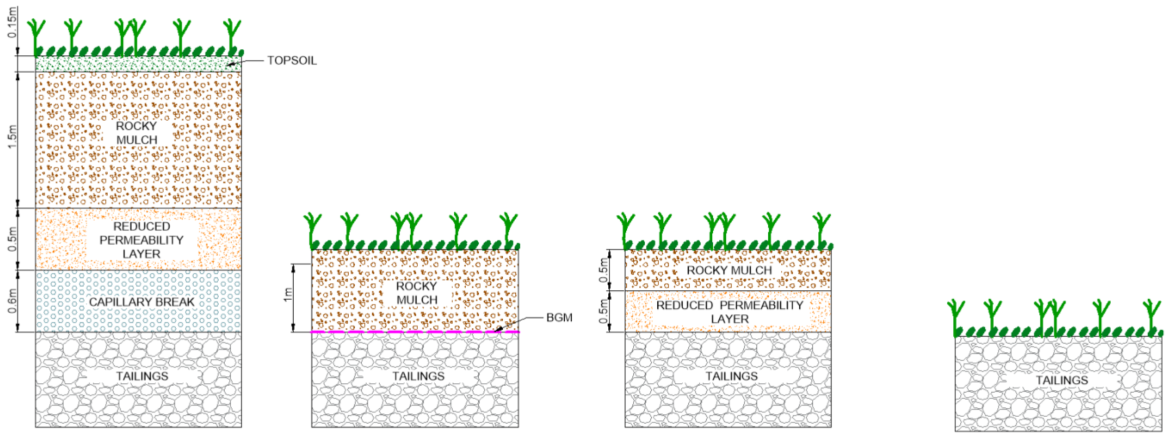
DIAGRAM 1: COVER OPTIONS



C1: DES DEFAULT

C2: BGM

C3: STORE AND RELEASE

C4: NO COVER SYSTEM

The properties of materials forming the cover systems identified are summarised in **Table 4**. It is noted that the source of these materials has not been established, which would be required for detailed design.

TABLE 4: PREFERRED QUALITIES OF COVER MATERIALS

Material	Preferred Qualities
Topsoil	• Be Non-Acid Forming, • Support vegetation growth • Exhibit suitable moisture holding capacity, and • Exhibit suitable nutrition characteristics. • Non dispersive
Rocky Mulch	• Be Non-Acid Forming, • Not prone to generating neutral/saline drainage, • Exhibit suitable moisture holding capacity, and • Exhibit suitable nutrition characteristics.
Reduced Permeability Layer	• Be Non-Acid Forming • High clay content • Form a low permeable layer when compacted to specification requirements
Capillary Break	• Well graded drainage aggregate material • Free draining • Be non acid forming
NAF Rock (NAF Rind)	• Be Non-Acid Forming • High strength, blasted rock • Mix of boulders and smaller particles

A description of cover systems identified is summarised as follows:

Cover 1 (Capillary Break):	Based on the default cover system for high risk facilities defined in the Queensland Government's Estimated Rehabilitation Cost Calculator. The capillary break prevents upward migration of moisture and contaminates through capillary action which can contaminate cover soils.
Cover 2 (BGM):	The BGM cover system is comprised of a vegetation growth layer (rocky mulch) and a bituminous geomembrane (BGM) as the hydraulic barrier preventing seepage though the cover soils into the tailings.
Cover 3 (Store and Release):	The objective of the store and release cover is to maximise plant available moisture within the cover system promoting infiltration into the cover system and minimising runoff. Functionally, storage of moisture should be confined to the infiltration storage layer (rocky mulch). A clay layer (reduced permeability layer) provides the hydraulic barrier to minimise seepage though the cover soils into the tailings.
Cover 4 (No Cover System):	Cover 4 would comprise direct seeding of the tailings surface without constructing a cover system.

Based on discussions with DMIRS, Cover 3, the store and release cover system was adopted. Cover 4 comprising direct seeding was discounted as this option is unlikely to meet closure criteria of preventing tailings becoming windblown as good vegetation cover is unlikely to establish, leaving the exposed tailings to be windswept. It is noted that windblown tailings were observed outside of the TSF beach extents during the site inspection. While the BGM and capillary break options have been demonstrated to be suitable cover systems on similar projects, these options were discounted due to high material and construction costs.

The performance of the adopted cover system was modelled as presented in **Section 4**.

3.2.3 Batter Treatment

The outer embankment shell is constructed with mine waste rock (refer **Section 2.1**). During the site inspection undertaken by a representative from ATCW, erosion of the embankment walls was observed as shown in **Photo 1**. Recognising that long term erosion of the TSF batters has the potential to impact embankment stability aspects through loss of material, two rehabilitation options were developed, summarised as follows:

Batter Option 1:	Do not reshape batters, with scheduled inspections to be undertaken to monitor erosion and scouring. Maintenance to be undertaken as required to replace material lost though erosion.
Batter Option 2:	Reshape batters with rock armouring to provide an erosion resistant surface as depicted in **Diagram 2**.

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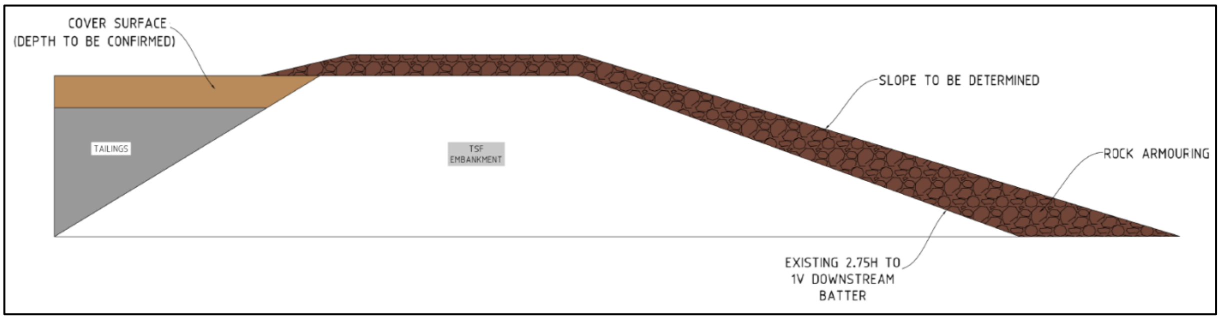
PHOTO 1: EROSION OF TSF EMBANKMENT

DIAGRAM 2: BATTER TREATMENT 2



A summary of risks and benefits for each of the options is identified in **Table 5**.

TABLE 5: BATTER TREATMENT – RISKS AND BENEFITS

Treatment Option	Risks	Benefits
Option 1 Leave batters as is	• Riling and erosion reducing geotechnical stability • Regular inspections and drone survey required to identify high risk erosion and to scope remediation works. Drone survey to be undertaken yearly at a set date so that erosion and embankment material losses can be measured and tracked over time. • Long term maintenance required	• Low cost • Minimal material required compared to option 2 • Material placed where embankment thinning and erosion is occurring
Option 2 Reshape batters with erosion resistant rocky mulch type materials	• High cost • Large quantity of rocky mulch type material required	• "long term" solution • Lower maintenance requirement • Reduced risk for loss of geotechnical stability

Based on discussions with DMIRS, limited rock is available and as such the preferred approach is currently Option 1. It is noted that this may be subject to change based on the next phase of design, including a materials investigation. If suitable quantities of rock material are found to be available, Option 2 may progress as the preferred design.

On this basis, ongoing inspections would be required to ensure the embankment stability is not compromised. A recommended monitoring schedule is discussed in **Section 5**.

3.3 Removal of Infrastructure

The closure works would also involve removal of TSF infrastructure, including:

- Removal of the decant causeway and riser and backfill with concrete or low permeability fill.
- Removal of any remaining pipework.

These works will be further defined as part of the next design phase.

3.4 Schedule of Quantities

A high-level schedule of quantities has been developed for the preferred cover system, being the store and release cover system. Quantities have been estimated based on the plan area of the tailings beach, with a 10% contingency included, noting that the design is preliminary only. The schedule of quantities is provided in **Table 6**.

TABLE 6: SCHEDULE OF QUANTITIES

Item	Description	Units	Quantity
1.0 Capping works			
1.1	Clear - remove vegetation established on tailings beach (as required). Stockpile of TSF footprint in designated area.	m^2	502,000
1.2	Remove decant causeway and riser - remove decant riser and backfill with concrete or low permeability fill with compaction to specification.	Item	Allow
1.2	Surface preparation - prepare existing tailings surface area, including grading of cracked or desiccated material, moisture conditioning and compaction, as required to achieve a suitable surface on which to place the cover system.	m^2	502,000
1.3	Reduced Permeability Layer - source, place, moisture condition, low permeability fill in accordance with specification. spread and compact in maximum 200mm (loose) layers to a total (compacted) thickness of 0.5m.	m^3	251,000
1.4	Rocky Mulch - source, place, moisture condition, Rocky Mulch in accordance with specification. Spread and compact in maximum 200mm (loose) layers to a total (compacted) thickness of 0.5m.	m^3	251,000
2.0 Miscellaneous works			
2.1	Excavate spillway channel	m^3	3000
2.2	Place rock armouring on embankment batters and spillway	m^3	1500
2.3	Install instrumentation	Item	Allow

4 VADOSE MODELLING

4.1 Overview

Modelling has been undertaken to assess the performance of the store and release cover system (preferred cover system). The model geometry comprised 6m of tailings overlain by a 1m cover system comprised of 0.5m of a low permeability layer and 0.5m of rocky mulch as depicted in **Diagram 1**.

The performance of each cover system has been assessed against the closure objectives discussed in **Section 3.1**, with key outputs and performance criteria summarized as follows:

Water Balance: The fate of rainfall being lost through surface water runoff, evaporation or infiltrating into the cover system.

Plant Available Moisture: Available moisture within the cover profile to support vegetation growth

Flux: the movement of moisture though the cover profile, in both directions:

- Downward flux: infiltration through the cover system into the waste rock, potentially reporting as seepage or to groundwater.
- Upward flux: upwards migration of moisture through drying of surface layers and capillary action. Potentially transporting contaminants upwards into cover soils.

Modelling was undertaken with SEEP/W, a computer-based, finite element package used for numerical modelling of saturated and unsaturated flow within soils. Model results include climatic inputs such as rainfall and evaporation, with the balance reporting as net infiltration through the model profile.

Modelling was undertaken using a one-dimensional column through the proposed cover system profile extending 5 m into the tailings. A daily time step was modelled for a 10-year period with climatic data sourced from a SILO data drill.

4.2 Model Development

4.2.1 Boundary Conditions

The geometric configuration of the model comprises a 1-dimensional column, with 5 m of tailings overlain by the cover system.

Other boundary conditions are outlined as follows:

Climatic Conditions: Applied to the surface of cover system. Further detail is provided in **Section 4.2.2**.

Initial Gradient (free drainage): Applied at the base of the model to allow seepage from the model. Seepage rates are calculated assuming the downward flux is equal to the hydraulic conductivity at that point.

Vegetation was not included in the modelling as the expected density of vegetation to establish on the rehabilitated TSF surface would not be expected to materially impact model results.

4.2.2 Climatic Conditions

Climatic data was adopted from a SILO data drill generated for the site location. A period of 10 years was adopted for the modelling period, with climatic data from 2010 to 2020 used. As shown in **Table 6**, this period includes dry (10th percentile in 2019) average (58th percentile in 2015) and wet (92nd percentile in 2014) rainfall years, allowing for assessment of the cover system under a variety of climatic conditions. Additional climatic data input to the Seep/W model, adopted from the SILO data drill includes humidity, temperature and radiation.

TABLE 7: RAINFALL ADOPTED

Rainfall Year	Rainfall Depth	Percentile
2010	160.6	0.23
2011	378.5	0.91
2012	275.9	0.74
2013	371.4	0.90
2014	395.5	0.92
2015	232.1	0.58
2016	296.5	0.79
2017	321.2	0.83
2018	356.4	0.88
2019	118.6	0.09
2020	195	0.40

4.2.3 Soil Properties

Model inputs for soil properties are the soil water characteristic curves and hydraulic conductivity curves. This information was not available for site material and as such, curves were generated using the limited geotechnical characteristic information available, target material properties discussed in **Section 3.2.2** and GeoStudio's inbuilt example curves. A summary of the information used for various soil types is summarised as follows:

Clay: Adopted based on GeoStudio default curve for Clay, assuming a saturated permeability of $1x10^{-8}$ m/s.

Rocky Mulch: Assumed material would be sourced onsite and would comprise similar material to the earthen fill embankments and generally comprise sandy silt to silty clay per material descriptions of provided in test pit logs described in the Stage 2 conceptual design report (Knight Piesold, 2000).

Tailings: Assumed sandy silt based on site observations.

Generated soil water characteristic curves and permeability curves are depicted in **Charts 6** and **7** respectively.

Prior to the construction of a cover system, sampling and laboratory testing of tailings and cover soils would be required to confirm material properties and validate model results.

CHART 6: SOIL WATER CHARACTERISTIC CURVES

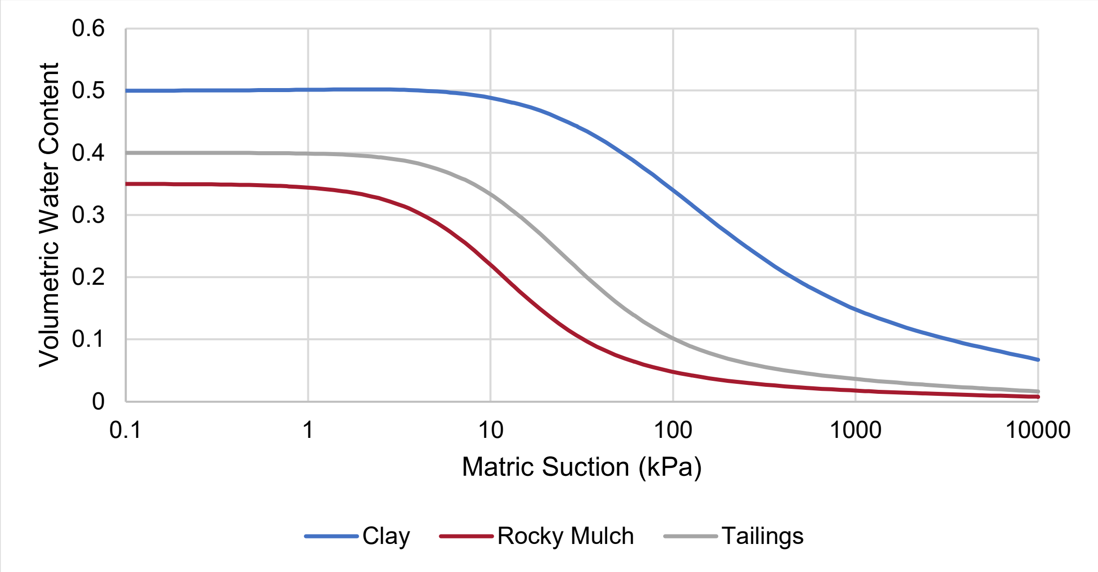
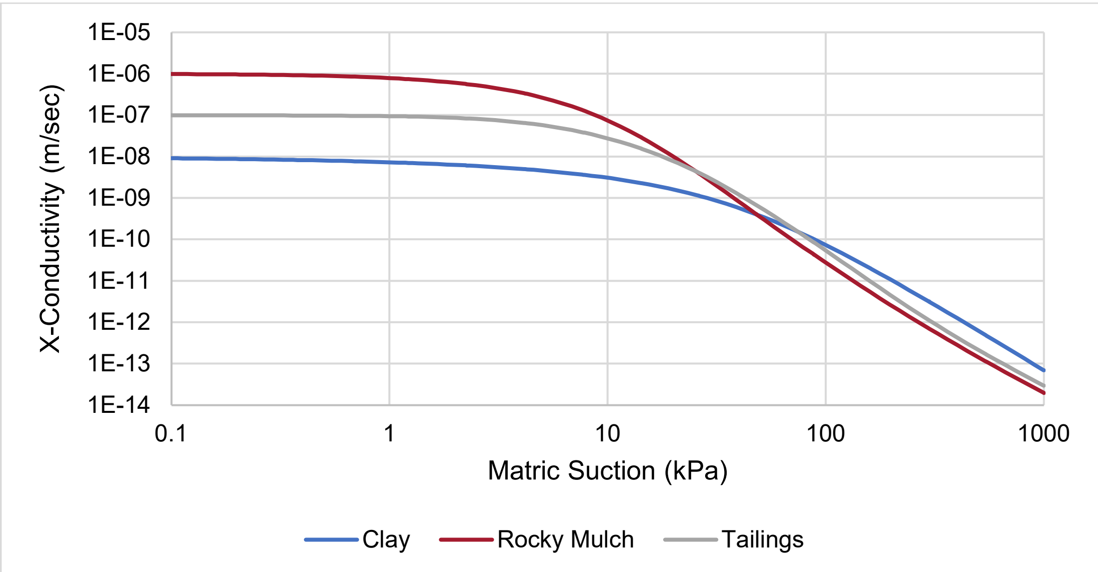


CHART 7: HYDRAULIC CONDUCTIVITY



4.3 Results

Modelled results are shown on **Charts 8** to **10**. Interpretation of results is as follows:

Water Balance

Modelled results for the cumulative water balance model are depicted in **Chart 8**. For the modelled period (10 years) some 2.9 m of rainfall occurs. A portion of this rainfall (around 0.3 m or 10%) reports as surface water runoff without infiltrating into the soil profile. Some 2.6 m (around 90%) initially infiltrates the surface layers but is lost though evaporation. The net infiltration rises after rainfall events however reduces in the following days due to evaporation. At the end of the modelled period, net evaporation is almost zero, indicating all moisture infiltrating the cover soils is lost through evaporation.

Volumetric Water Content

Modelled volumetric water content provides an indication of the likely plant available moisture. In the surface layer (0.1 m BGL) climatic influences are seen with saturation of soils following rainfall events. The volumetric water content subsequently reduces through evaporation.

The volumetric water content at greater depths is relatively stable. The rocky mulch does not saturate (measured at 0.3 m BGL) and maintains low moisture content, indicating rainfall infiltration is limited to <0.3 m, due to high evaporation losses and low rainfall. Moisture content in the clay layer (measured at 0.75 m BGL) and tailings (measured at 1.5 m BGL) reduces throughout the modelled period due to evaporative losses. Rainfall infiltration does not reach the Clay Layer or Tailings.

Flux

Modelled flux at the surface shows infiltration into the surface profile following rainfall events. Subsequent evaporation observed as positive flux rate occurs in the following days as infiltrated moisture is lost through evaporation.

Water flux 0.2m BGL is highly variable with influences from climatic conditions including rainfall and evaporation. Similar to the flux at surface, both negative flux (associated with infiltration following rainfall) and positive flux (caused by matric suction associated with evaporative losses at surface) are observed.

Flux within the clay layer and tailings is relatively stable and not impacted by climatic conditions. Model results indicate a constant, upward flux in the order of $1x10^{-10}$ m/s as moisture within the tailings is observed. This upward flux is a result of high matric suction (caused by evaporation) within the cover soils during dry periods.

Summary

A summary of observations from model results is as follows:

- The proposed cover system prevents rainfall infiltrating into tailings. As a result, issues related to excessive seepage and groundwater recharge would not be expected.
- Limited moisture would be available for plant growth although this is likely similar to background environmental conditions. It is also noted that no closure objectives have been set with respect to vegetation (refer **Section 3.1**).
- Capillary rise may occur, subject to initial moisture content of tailings which may result in migration of contaminates within the tailings into the cover soils including salts. It is recognised the receiving environment, and in particular Lake Yindarlgooda, is highly saline with salt scad visible on aerial imagery. The presence of salts would likely impact plant establishment and growth.

Based on model results, the proposed cover system would achieve the closure objectives discussed in **Section 3.1**.

CHART 8: WATER BALANCE

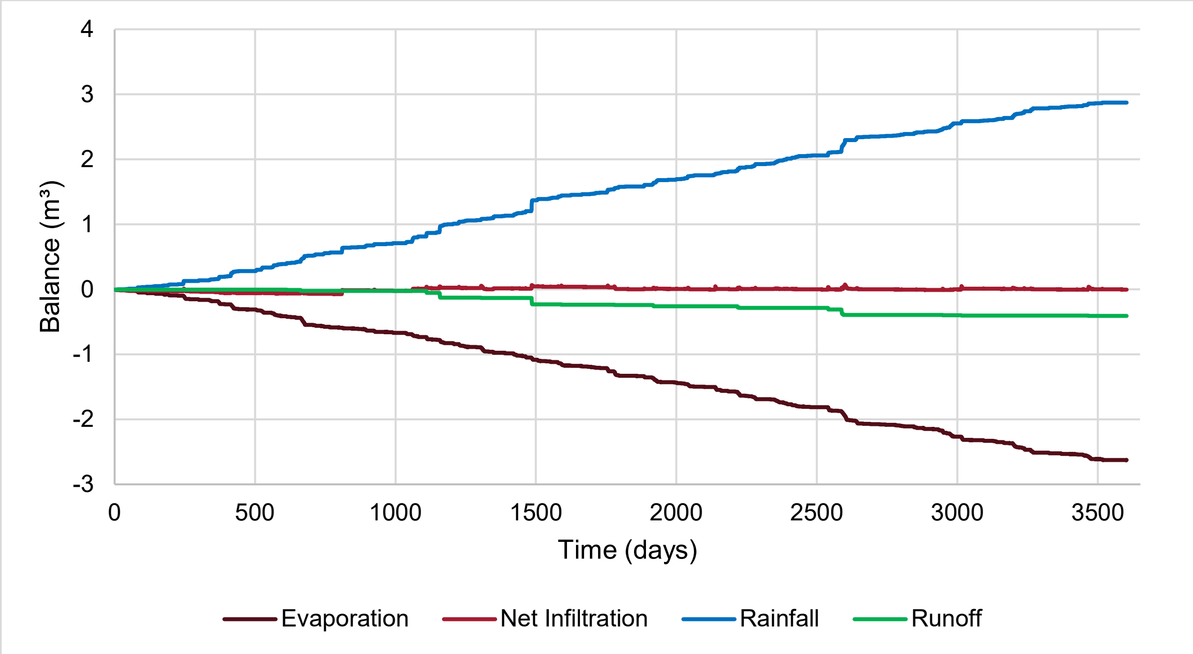


CHART 9: VOLUMETRIC WATER CONTENT

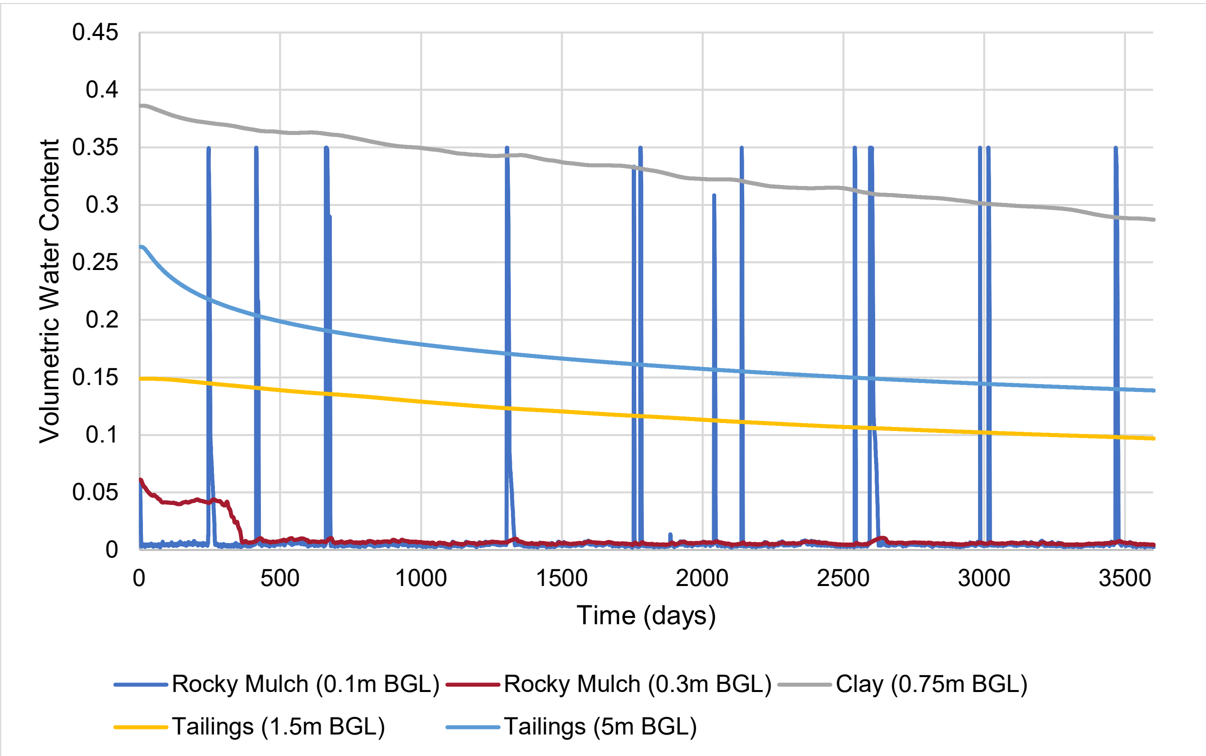


CHART 10: FLUX – AT SURFACE

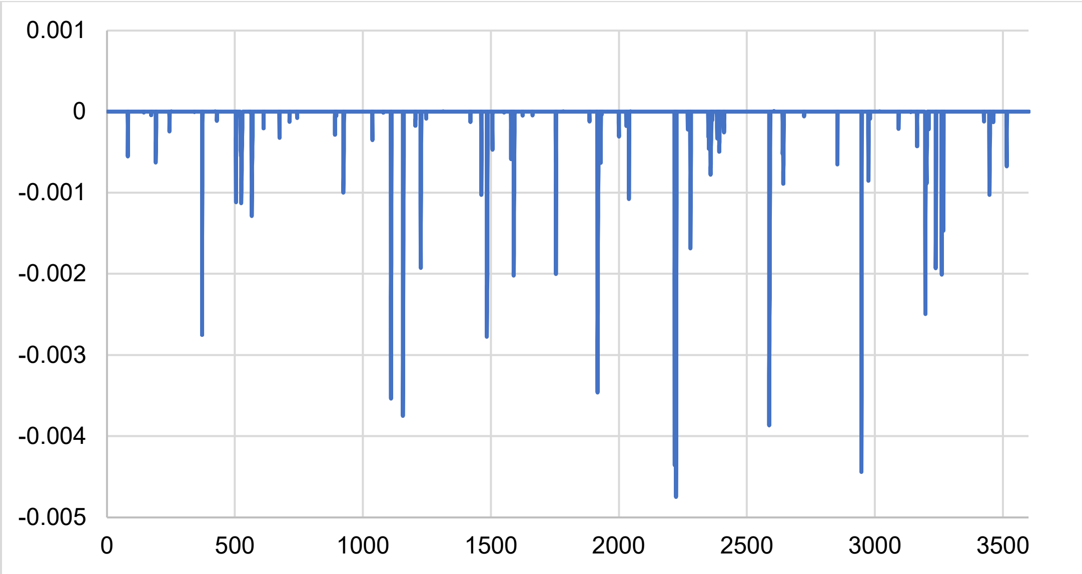
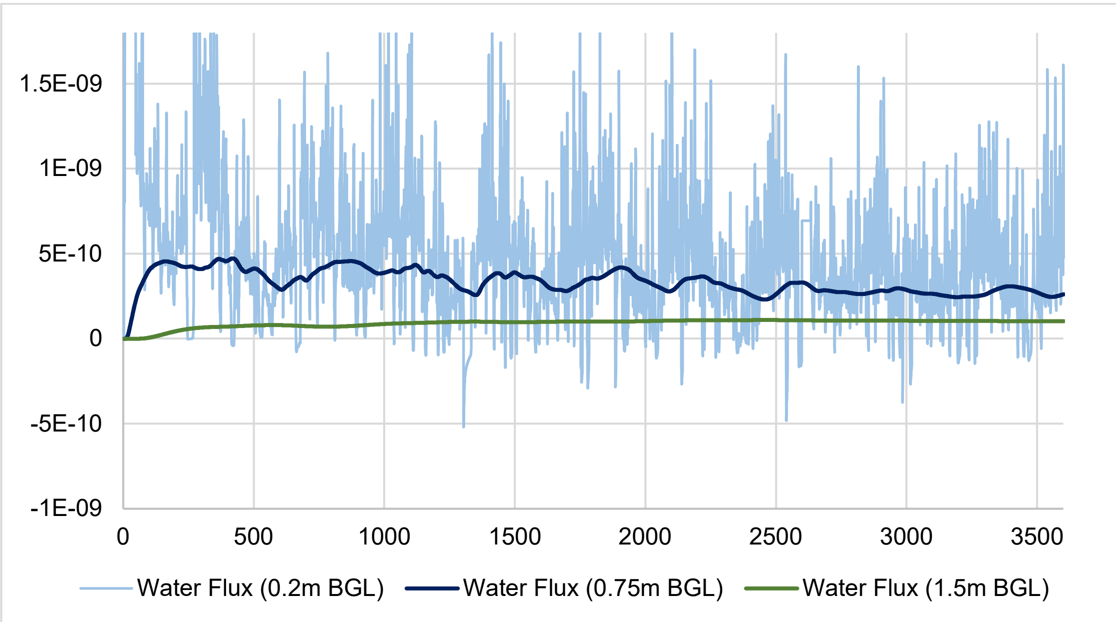


CHART 11: FLUX – COVER SYSTEM AND TAILINGS



TAILINGS.WATER.WASTE.

5 POST CLOSURE MONITORING AND INSTRUMENTATION

5.1 Background

A description of the proposed instrumentation, monitoring and maintenance program is provided in the proceeding sections. The monitoring program is required to assess the performance of the proposed cover system against the closure objectives.

Revision of the monitoring program may be required as new information becomes available or performance issues identified during regular inspections.

5.2 Instrumentation

Instrumentation is proposed for the tailings surface to monitor the performance of the cover system against rehabilitation objectives. Recommended instrumentation to be installed are as follows:

Weather station:	Climatic data will be useful for calibrating vadose models and for analysis of matric suction measurements. The following climatic data would be required: • Hourly rainfall • Temperature • Wind speed
Fredlund thermal conductivity sensor: (or similar sensor to measure matric suction)	A Fredlund thermal conductivity sensor measures matric suction. Measurement of matric suction in the cover system will provide an indication of the fate of moisture within the cover system. At each recommended location, 2 nodes will be required: 1. Base of cover soils 2. Surface of tailings
Settlement monitoring plates:	Settlement monitoring plates installed on the embankment and tailings beach will be used for monitoring tailings settlement and geotechnical stability of the embankment.

5.3 Monitoring

The typical post rehabilitation earthworks monitoring aspects would include:

- overall condition of the TSF;
- integrity of structures including spillway;
- presence (and cause) of surface settlement/displacement/erosion/disturbance;
- vegetation condition, including weeds.

Surface water monitoring should be conducted at a frequency consistent with other monitoring events conducted at the site. Samples must be collected by a suitably trained person, and the samples must be analysed by a NATA accredited laboratory.

Surface water samples should be retrieved from the internal drains (when flow is available), at points located immediately upstream of the outlet point. Field analysis of pH, temperature, electrical conductivity and dissolved oxygen is recommended, as well as laboratory analysis of surface water analytes.

5.4 Post-Closure Inspection Scope

The site inspections shall include assessment of the integrity of the following aspects:

- Cover material and batter slopes
  - Erosion/scour
  - Surface water ponding/ seeps
  - Vegetation establishment
  - Weed control
  - Settlement inspection
  - Condition & access
- Surface water drains
  - Sediment or debris build up in drainage lines
  - Erosion/scouring of drainage lines
  - Ponding of surface water

An inspection checklist should be completed during each inspection. This inspection checklist would form a record for tracking the condition and ongoing rehabilitation and maintenance requirements of the site.

In order to track and monitor scouring and material loss, it is recommended that drone survey is undertaken. This should occur at the same time of year, to allow the material loss and scour depth to be accurately measured. If there is consistency in losses recorded, upon review over a 5-year period, it is possible that the inspection and survey frequency could be reduced.

5.5 Maintenance

To ensure maintenance of the structural integrity of the final cover system, inspections would need to identify areas of settlement, erosion, scour or ponding of surface water. Settlement shall also be monitored on an ongoing basis in order to measure and assess any consolidation and effects on the surface drainage. Settled areas within the rehabilitated surface should be repaired by reprofiling and filling with cover soils to facilitate surface water run-off toward designed swales or drainage channels and ultimately to prevent ponding.

5.6 Post-Closure Inspection, Maintenance and Monitoring Summary

A preliminary post-closure inspection program is provided in **Table 8**. It is noted that the monitoring frequencies listed are indicative only at this time and are to be confirmed as part of the detailed design phase in consultation with DMIRS.

TABLE 8 : DETAILS OF POST-CLOSURE INSPECTION, MAINTENANCE AND MONITORING PROGRAM

Element	Inspection – Non-Conformance	Maintenance	Monitoring Type	Frequency
Erosion Control	Exposure of subsurface (tailings) profile/scour	Stabilise and repair cover system	Visual inspection	12 months after rehabilitation, then 5 years thereafter. Additionally, after a significant storm event
	Other indicators of erosion (see Vegetative Cover or Batters)	Stabilise, replace vegetation with seeding or hydromulch and establish Refer to Vegetative Cover	Visual inspection	
Damage to Batters	Evidence of scour or excessive erosion	Cover exposed subsurface In the case of a significant scour, obtain advice from a suitably qualified engineer and undertake recommended works	Visual inspection Annual Drone Survey as losses will not be obvious to the naked eye	
Differential Settlement / Consolidation	Surface depressions Rainfall pooling significantly	Restoration of cover system as required to prevent ponding	Visual inspection	
Seepage	High moisture in surface soil Evidence of seep through batters	Investigate source of seep and reinstatement cover system layer as required	Visual inspection	
	Vegetation dieback or inhibited growth	Collection and testing of seepage	Sample collection	
Surface Drainage	Accumulation of sediment and debris	Removal of accumulated sediment and debris	Visual inspection	
	Disrepair of drainage paths Localised inundation during rainfall Erosion and scouring of drainage	Repair of drainage paths		

Element	Inspection – Non-Conformance	Maintenance	Monitoring Type	Frequency
Surface Water Quality	Indication of contamination from assessment of water quality analysis results against published guidelines (ANZECC).	Identification of contaminant sources and remedial measures as required.	Visual Inspection Field Analysis Laboratory Analysis	Consistent with site contaminate release limits
Groundwater	Indication of contamination from assessment of water quality analysis results against relevant guidelines.	Identification of contaminant sources and remedial measures as required.	Visual Inspection Field Analysis Laboratory Analysis	Consistent with site contaminate release limits

6 PRE-CLOSURE MONITORING

It is recommended that prior to rehabilitation works, an annual walkover of the facility is conducted with particular focus on the condition of the embankments (progression of erosion). It is also recommended that a drone survey of the facility is conducted annually if possible.

7 CLOSURE AND FORWARD WORKS

7.1 Forward Works

The overall objective for the TSF rehabilitation is to create a landform that is non-polluting, environmentally sustainable and geotechnically stable in the long term. Based on the available information, vadose model results indicate the proposed Store and Release cover system to be feasible. Critical to the performance of the cover system will be the construction methodology and properties of material used in constructing the cover system.

A high-level scope of works to be undertaken as part of the next design phase is as follows:

- Seek stakeholder agreement on proposed post mine land use objectives, including (but not limited to) the following:
  - Relevant regulatory bodies
  - Indigenous communities/landholders
  - Other interested community stakeholders
- Undertake monitoring of conditions including:
  - Seepage rates
  - Downstream impacts
  - Geochemical characteristics of tailings
- Borrow investigation to identify source of cover materials (rock mulch, low permeability fill and rock armouring), including:
  - Investigation of the evaporation pond to determine if embankment material would be suitable for cover system. A preliminary estimate indicates that excavation of the embankments may yield up to 300,000 m^3 of earthfill, if deemed suitable.

This would include a study as to whether it is feasible to excavate the evaporation pond embankment considering the retained materials.

  - Undertake sampling program onsite to identify available materials and borrow areas
  - Laboratory testing of materials to confirm suitability
  - Identify potential off-lease sources such as waste rock dumps from nearby mines or potential rock quarries

- Undertake detailed embankment assessment to ensure that areas of deep scour and material loss are identified and repaired as part of the construction works (to be undertaken during borrow investigation). This will help to reduce maintenance costs and risks of failure.
- Water balance modelling to determine if a permanent pond would likely establish on the rehabilitated TSF or if the storage would be likely to overtop during extreme rainfall conditions
- Seepage modelling to assess the impacts of surface water infiltration through the tailings (if a pond is likely to form on the surface)
- Landform evolution modelling to determine if embankments are likely to erode long-term, potentially impacting geotechnical stability. This scope item may be provisional, dependant on the degree of erosion protection that is to be adopted.
- Engineering design of the stormwater system including hydraulic capacity for the spillway, drains and armouring requirements.
- Risk assessment for closure
- Development of a Design Report
- Development of Issued for Tender Drawings and Specifications

7.2 Preliminary Detailed Design Cost Estimate

ATCW has produced a preliminary cost estimate for detailed design of the Bulong TSF Closure, provided in **Table 9** below. The purpose of this cost estimate is solely for DMIRS budget planning.

The following is also noted:

- Stakeholder engagement aspects have been excluded from the ATCW scope.
- Costs are based on 2022 rates and as such would need to be escalated based on when the design work is to be performed.

TABLE 9: PRELIMINARY DETAILED DESIGN COST ESTIMATE

Tasks	Est. Cost
Project Management Incl. Meetings, Liaison	$7,000
Borrow Investigation & Embankment Inspection - Test pitting for borrow areas, supervision, reporting	$25,000
Laboratory Testing - Capping materials - Permeability, compaction, characterisation	$26,000
Water Balance Modelling	$7,000
Stormwater Design Spillway Routing and Armouring Requirements	$4,000
Seepage Modelling Modelling of runoff infiltration into tailings, groundwater	$6,000
Landform Evolution Modelling of Embankment Batters Provisional item - dependent on erosion protection design adopted	$30,000
Risk Assessment for Closure	$10,000
Design Report	$10,000
IFT Drawings & Specifications	$18,000
TOTAL	**$143,000**

REFERENCES

[1] ATCW (2021a), "Bulong Tailings Storage Facility, Likelihood of Failure Assessment & Dam Break Study", Rev 0, dated September 2021, Ref: 121085.01R01.

[2] ANCOLD (October 2003), "Guidelines on Risk Assessment", Australian National Committee on Large Dams.

[3] AS/NZS (2004), Australian/New Zealand Standard, Risk Management", AS/NZS 4360:2004.

[4] Australian Government Bureau of Meteorology Design Rainfall Data System (2016), http://www.bom.gov.au/water/designRainfalls/revised-ifd/ (accessed August 2021).

[5] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), 2019.

[6] Australian Government Bureau of Meteorology. "The Estimation of Probable Maximum Precipitation: Generalised Short Duration Method", June 2003.

[7] ATCW (2021b), "Bulong Tailings Storage Facility Condition Assessment – Site Investigation", ATCW Ref: 121085.01 L02, dated September 2021.

[8] Government of Western Australia Department of Mines and Petroleum (2015) Guide to Departmental Requirements for the management and closure of tailings storage facilities

[9] Government of Western Australia Department of Mines, Industry Regulation and Safety (2020). Statutory Guidelines for Mine Closure Plans.

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