

CHAPTER 10 - Tailings and waste rock management

10.1 Introduction.....	286
10.2 Waste management legislation and regulations	286
10.3 Waste management principles	287
10.4 Waste management strategies	287
10.4.1 Existing facilities.....	290
10.4.1.1 Existing tailings dam	292
10.4.1.2 Existing waste rock dump.....	292
10.5 Proposed mining wastes	293
10.5.1 Operational wastes	293
10.6 Tailings characterisation and management.....	297
10.6.1 Tailings characterisation	297
10.6.2 Tailings processing	300
10.6.3 Conceptual tailings and concentrate residual dam risk assessment.....	303
10.6.4 Conceptual tailings dam design	305
10.6.5 Conceptual CRD design	309
10.6.6 Tailing deposition and water management.....	313
10.6.7 Conceptual tailings dam seepage analysis.....	313
10.6.8 Seepage management measures.....	314
10.6.9 Tailings dam and CRD monitoring.....	314
10.6.10 Tailings dam and CRD rehabilitation.....	315
10.6.11 Future work.....	315
10.7 Waste rock characterisation and management.....	316
10.7.1 Waste rock locational considerations.....	316
10.7.2 Waste rock characterisation chemical.....	316
10.7.3 Waste rock characterisation physical	319
10.7.4 Waste rock dump risk assessment.....	322
10.7.5 Waste rock dump design	323
10.7.6 Waste rock dump surface water management	328
10.7.7 Waste rock dump monitoring.....	328
10.7.8 Waste rock dump rehabilitation	329
10.8 Topsoil and rehabilitation stockpiles	330
10.9 Pit areas.....	330

10.1 Introduction

This chapter deals with the environmental values considered in relation to the management of processed tailings and excavated hard waste rock as a direct result of mining the Twin Bonanza project. This chapter identifies the mining and processing material streams and volumes, potential impacts of the material generation and the management measures used to mitigate and minimise impacts. Management of other wastes associated with the operation are detailed in Chapter 9 – Waste management.

The existing management system, for tailings and waste rock, will be significantly upgraded from the current bulk sample system.

10.2 Waste management legislation and regulations

The regulatory requirements governing waste management in the Northern Territory are contained within the following legislation:

- Waste Management and Pollution Control Act 1998 (NT)
- Waste Management and Pollution Control (Administration) Regulations 2001 (NT)
- Water Act 1992 (NT)
- Mining Management Act 2001 (NT)

Regulations and guidelines that are applicable and have been consulted are outlined below:

- ANCOLD Guidelines - Guidelines on tailings dams; planning, design, construction, operation and closure.
- AS 1726-1993 - Geotechnical site investigations
- LPSD - Tailings Management
- LPSD - Water Management
- LPSD - Managing Acid and Metalliferous Drainage 2007
- GARD Guide - best practices and technology to address AMD issues
- TEAM NT: Technologies for the Environmental Advancement of Mining in the Northern Territory, Toolkit.
- Mine Wastes. Characterisation, Treatment and Environmental Impacts (Lottermoser, B., 2007)

10.3 Waste management principles

ABM Resources NL (ABM) is committed to minimising the impact of tailing and waste rock on the environment and the community by adopting appropriate waste management principles. ABM in all practicable cases will endeavour to achieve the best possible environmental outcome by safely treating and disposing of tailings and waste rock.

Leading practice waste management principles are incorporated into ABM's waste management procedures (Section 10.2).

10.4 Waste management strategies

ABM has applied standard waste management principles to the tailings and waste rock these strategies include cleaner production, pollution prevention and waste minimisation. In addition, ABM has used leading practice guidelines, carried out waste and tailings characterisation, undertaken landscape evolution modelling and incorporated data from the current bulk sample. This information and data has been used to ensure advanced conceptual designs account for both short and long term physical and geochemical properties of the material to be mined. Table 10-1 summarises the decision making process and outcomes.

Table 10-1. Summary of aspects considered prior to tailings dam, concentrate residual dam and waste rock dump construction.

Issue	Issue addressed prior to waste rock Dump (WRD) construction	Issue addressed prior to tailings dam and concentrate residual dam (CRD) construction
Location	A balance has been achieved between haul distance and environmental considerations. The location achieves: • being outside the zone of instability • limits clearing of habitat where bilbies may be present • reduces the total area and number of localised surface water catchments affected positioned on mineralised soil elevated in arsenic to reduce effect of selective waste rock units that are elevated in arsenic.	Locating adjacent to the plant achieves the following environmental outcomes: • reduces pipeline distances thus reducing the potential for spills (i.e. long pipeline more potential) • limits number of localised surface water catchments affected • positioned on mineralised soil elevated in arsenic to reduce contrast with tailings • CRD located close to the process plant to discourage avian usage and to enable regular monitoring.
Rehabilitation options	• Using inert and competent sandstone for external batters. • Waste rock characterisation has determined selective waste rock handling strategy to position more erodible and trace sulphides containing units in the centre of the dump. To limit erosion and oxygen egress. • Design the top of the dump to be water harvesting.	• Flexible staged below ground starter cells with subsequent above ground embankment cells to allow immediate closure at any stage of project. • Mine site layout has incorporated selective sandstone, siltstone and pisolite stockpiles located adjacent for capping. • A store and release cover incorporating sandstone, siltstone and gravel layer from the pit to establish soil profile. • Multiple cell configuration to allow potential progressive rehabilitation.
Groundwater	• Located on a thin weathering profile with the underlying geology likely having low permeability and with limited fractured rock zones. • Overlying groundwater zone that has a high probability of having elevated arsenic similar to Corsair Bore (Arsenic values of 0.184 mg/L) which is located 2 to 3 kilometres to the north along geological trend.	• Bulk of tailings processed by minimal chemicals in gravity separation circuit. • 1 to 2 tonnes of daily tailings cyanide leach concentrate deposited in a purpose built lined CRD after detoxification of cyanide. • Located on a thin weathering profile with the underlying geology having low permeability and with limited fractured rock zones. • Overlying groundwater zone that has a high probability of having elevated arsenic similar to Corsair Bore (Arsenic values of 0.184 mg/L) which is located 2 kilometres to the north along geological trend. • Tailings dam base to be designed to attain 1×10^{-8} permeability to limit seepage.

Issue	Issue addressed prior to waste rock Dump (WRD) construction	Issue addressed prior to tailings dam and concentrate residual dam (CRD) construction
AMD and leachate potential	Testing has demonstrated all rocks units are unlikely to be potentially acid forming. Conservative approach of positioning selective units that have arsenopyrite, pyrite and galena present at low levels in the centre of the waste dump.	- Testing has demonstrated all ore unit are unlikely to be potentially acid forming. Established tailings dam base to have 10^{-8} permeability to limit seepage. - The capture of tails concentrate for fine gold recovery (cyanide leach material) is likely to also recover the majority of trace arsenopyrite, pyrite and galena from the bulk tailings reducing potential tailings reactivity. 1 to 2 tonnes of daily cyanide leach material (cyanide removed) reports to lined CRD.
Landform	- Erosion testing of selected waste rock unit to be used on outer batter angles. - Waste rock dump batter angles of 1V:3.7H (15°) adopted. This angle is below the landscape evolution modelling recommendation of $\leq 18^{\circ}$ (1V:3H). - Slope designed to contain the majority of eroded sediment within the landform footprint for at least 100 years post construction.	Designed outer batters at 1V:4H (14°) and cover with topsoil/rock mulch to limit embankment erosion and enhance revegetation.
Cost	Higher costs upfront for selective handling of material, anticipated will reduce final closure costs.	Higher costs for: 1V:4H embankment compared to traditionally steeper angles. - stockpiling capping material adjacent to tailings dam. However, this approach reduces double handling and rehabilitation resources are easily accessed.
Relinquishment	Where practicable progressive rehabilitation will be undertaken to limit the liability at closure. Proposed trials to refine rehabilitation design and strategies.	Positioning rehabilitation resources for ease of accessibility at closure.
Stakeholder Perceptions	Mining Agreement with the Traditional Owners of the region via the Central Land Council (CLC). CLC and Traditional Owners continuously informed of project developments via on ground meetings and review of mining documentation.	Mining Agreement with the Traditional Owners of the region via the CLC. CLC and Traditional Owners continuously informed of project developments via on ground meetings and review of mining documentation.

ABM's tailings and waste rock management strategy also reduces the level of risk associated with pollution generation, onsite and off-site. ABM's waste management objectives are to:

1. minimise the production of tailings and waste rock wherever possible
2. prevent waste rock and tailings from contaminating the surrounding environment
3. manage and control disposal of all tailings and waste rock
4. optimise the use of waste rock to ensure rehabilitation success.

10.4.1 Existing facilities

New tailings dams and waste rock dumps will be constructed, to encompass the increased wastes generated from the mine. The establishment of new facilities will be proximal to upgraded infrastructure and are displayed in Figure 10-1.

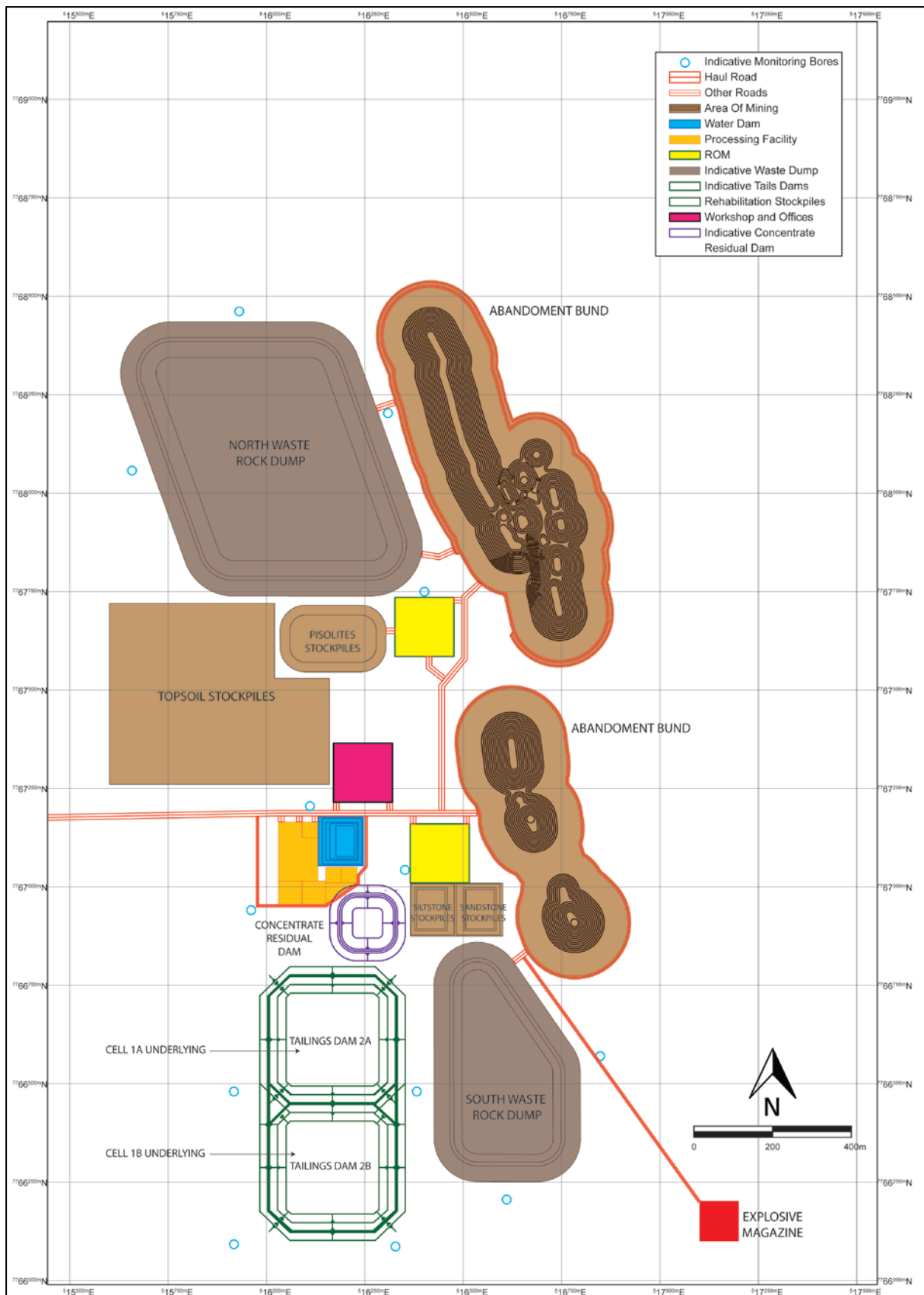


Figure 10-1. Indicative locations of tailings dam, CRD, NWRD, SWRD and stockpiles with proposed location of monitoring bores.

10.4.1.1 Existing tailings dam

As part of the bulk sampling program that was approved in 2013, a small high density polyethylene (HDPE) lined tailings dam of the dimensions 114 x 125 metres was constructed to contain the anticipated 10,000 tonnes of ore that would be sampled (Figure 10-2). Currently, the tailings dam for the bulk sample only receives gravity processed tailings without cyanide. The facility was constructed below ground with sufficient volume and freeboard to allow future conversion of the facility into a process water dam for the expanded project as the dam is unsuitable for continued tailings storage for the full scale mine.

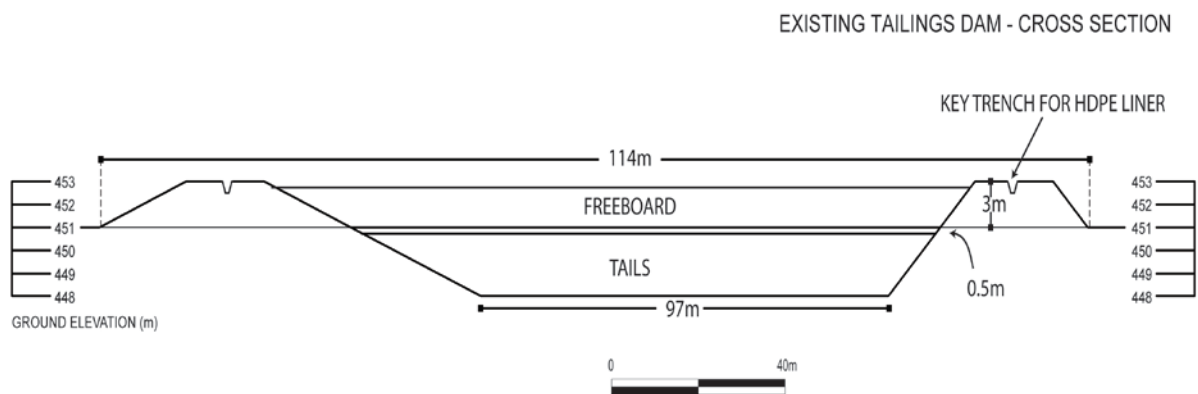


Figure 10-2. Cross section through existing tailings Dam. Proposed to be converted into water storage dam

10.4.1.2 Existing waste rock dump

There is no existing waste rock dump (WRD) for the bulk sample; the material is stockpiled along the trenches, available for progressive backfill of the trenches if the project does not proceed (Figure 10-3).

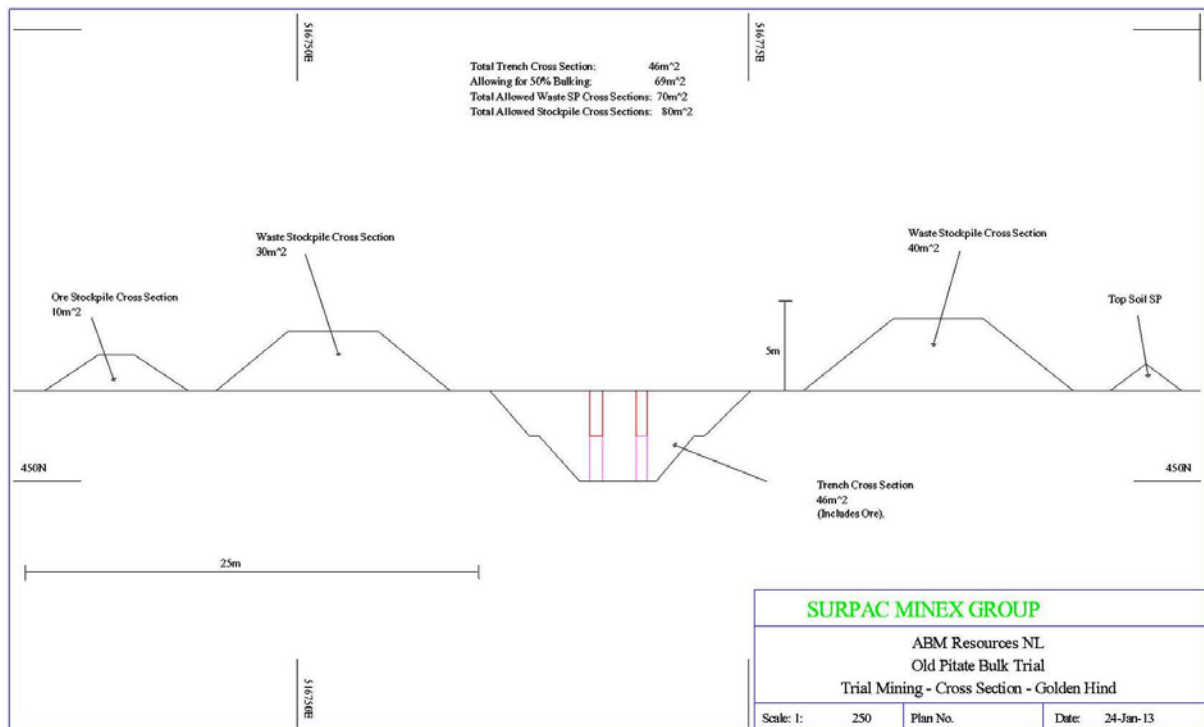


Figure 10-3. Cross section through existing waste rock and topsoil stockpile along the excavated bulk sample trenches.

10.5 Proposed mining wastes

10.5.1 Operational wastes

ABM is proposing two potential options for tailings management:

Either:

Option 1: Construct 2 new tailings dams/cells:

1. Tailings Dam, Cell TSF 1 – initial stage single below ground tailings cell TSF1. Gravity separation tailings only.
2. Tailings Dam, Cell TSF 2 – once initial stage cell TSF1 full, convert to one above ground impoundment cell with embankments TSF2. Gravity separation tailings only.
3. CRD – for concentrated tailings that has passed through the intensive leach reactor, undergoing cyanide leaching, with subsequent cyanide removal prior to deposition.

Or:

Option 2: construct 3 new tailings dams/cells:

1. Tailings Dam, Cell 1A/1B – initial stage two below ground tailings cells 1A and 1B. Gravity separation tailings only.

2. Tailings Dam, Cell 2A/2B - once initial stage cell 1A/1B full, converted to two above ground impoundment cells with embankments 2A and 2B. Gravity separation tailings only.
3. CRD – for concentrated tailings that has passed through the intensive leach reactor, undergoing cyanide leaching, with subsequent cyanide removal prior to deposition.

The dams will be constructed and managed in accordance with the ANCOLD Guidelines - Guidelines on tailings dams; planning, design, construction, operation and closure.

ABM proposes to construct two new waste rock dumps and three rehabilitation stockpiles (Figure 10-1):

1. Northern waste dump total height 20 metres; receiving waste from Old Pirate deposits/pits.
2. Southern waste dump total height 16.5 metres; receiving waste from Old Glory and Golden Hind deposits/pits.
3. Pisolite/gravel stockpile; during the mining of the pits the top 800mm to 1000mm will be stockpiled separately for use in establishing a soil profile over the tailings dams and WRDs at closure.
4. Sandstone stockpile for use as a component of the tailings dam cover design at closure.
5. Siltstone stockpile for use as a component of the rehabilitation tailings dam cover design at closure.

The estimated volume of tailings and waste rock produced during the project's operational phases are detailed in Table 10-2. Table 10-3 outlines the type, source and estimated volumes of wastes produced during the project's operational phases and initial construction. Indicative volumes of waste have been estimated based on current pit models and geological data for the stage 3 mining developments. It needs to be noted that there is a potential for further ore to be mined in the future via open pit and underground methods.

Prior to further expansion additional approvals will be sought through the Mining Management Plan (MMP) process. Nonetheless, to ensure integrated tailings management over the life of the project now and into the future, approval is being sought for either a single tailings cell with the embankment being lifted twice to a height of 10 metres (known as Option 1 (TSF 1 and 2)) or a two tailings cell configuration with an embankment height of 5 metres (known as Option 2 (Cell 1A/1B and 2A/2B)) as outlined above. Each of the two options are located in the same area and with details provided in Appendix I. Whichever option is implemented the management and mitigation measures will be the same and rehabilitation stockpiles volumes have been calculated to accommodate either option. Both the single and double tailings cell design allow for excess tailings storage capacity. Due to the design of each tailings storage option, with a below and above ground stage implemented

when tailings capacity is required, at any point of each developmental stage the facilities can be fully rehabilitated. Currently the preferred option is the dual cell configuration, allowing progressive rehabilitation, Option 2, and as such all plans and further discussion will reflect this (Figure 10-1).

Mitigation and management measures will be further detailed in this Chapter and Chapter 13 - Environmental Management Plan (EMP).

Table 10-3. Rock units within the proposed pit shell; indicative volumes, tonnage and specific gravity.

Unit type	Unit_name	Volume (m ³)	Tonnage	SG	Waste type
Ore	Quartz Veins - Ore	195,700	518,500	2.65	Tailings
Waste rock	Sandstone	773,200	1,951,500	2.50	Waste rock
	Siltstone	169,300	428,300	2.50	Waste rock
	Diorite	1,900	4,800	2.61	Waste rock
	Intercalated sandstones & siltstones	2,111,500	5,317,800	2.50	Waste rock
	Intercalated Anomalous Arsenic	1,277,900	3,228,100	2.50	Waste rock
Pit (total)	Stage 3	4,529,500	11,449,000	2.54	

Table 10-4. Waste management: Twin Bonanza project – Estimated quantity of waste rock and tailings projected forward for operational mine site.

Type	Waste description	Estimated quantity of waste	Source(s)	Management
MINING WASTES				
Waste rock	Waste rock-material surrounding the economic ore and below the topsoil and growth medium.	<i>4,333,800 m³ and an estimated 10,930,500 tonnes</i>	Mining	Any overburden material that is found to have elevated elements is encapsulated within the waste rock dump. Material that has the potential to generate small volumes of acid will be contained within non-acid forming material (NAF) material to reduce any negative effects on the environment through leaching. The final landform will be physically stable, safe, non-polluting and suitable for the agreed post mining land use so as not to affect the receiving environment. Specific measures to promote the stability of the WRDs are included in Chapter 11: Rehabilitation and mine closure.
MINING AND METALLURGICAL WASTES				
Tailings	Tailings will be produced by the processing of the ore	<i>195,700 m³ and an estimated 518,500 tonnes</i>	Processing plant	Tailings are removed from the processing plant as slurry and pumped to the tailings dam for disposal. Testing of the tailings water is to be conducted monthly. Surface and groundwater monitoring and sampling will also be conducted to determine the water quality around the tailings dam. As described in Appendix L: ABM Tailings Characterisation, tailings material generally exhibit NAF characterisations. The tailings dam will be monitored to ensure the facility is stable; adequate freeboard is available, seepage is controlled and storage capacity of tailings is sufficient during operations.
Residual Concentrate	Residual Concentrate in the volumes of 1 to 2 tonnes will be produced daily by the bulk leaching of selected batches of concentrate.	<i>50,000m³</i>	Acacia reactor – Processing plant	To recover fine gold from the tailings stream a centrifugal gravity concentrator or equivalent will be positioned on the tailings stream to recover heavy minerals. Approximately 1 to 2 tonnes of this material will be leached with cyanide to recover fine gold. Prior to deposition in the lined CRD, the cyanide will be recovered and detoxified.

10.6 Tailings characterisation and management

10.6.1 Tailings characterisation

ABM has undertaken geochemical and leachate assessments of the tailings, which are presented in Appendix L. These assessments have been peer reviewed by technical consultants, Soilwater Group (Appendix N: Geochemical characterisation memo).

The tailings evaluation focused on whether the tailings material, after processing, will pose a threat to the environment as a result of acid mine or metalliferous drainage, and to establish the most appropriate form of containment for the post processing waste materials and design parameters for the tailings dam construction and monitoring.

Analytical data used in the characterisation of these units includes:

- multi-element data
- petrography
- x-ray diffraction (XRD)
- x-ray fluorescence (XRF)
- acid base accounting (ABA)
- leachate quality – water quality

Specific geochemical testing/interpretation involved a series of methods to determine the acid producing and leaching potential of the rocks under non-acid forming conditions; these methods can be detailed as follows:

1. Geochemical characterisation (INAP, (2009), AMIRA (2002)) - to determine acid generation in samples;
 - a. ABA
 - b. net acid generation (NAG).
2. APR classification - to classify the leachate samples' potential to produce acidic drainage.
3. Element enrichment (GAI) - to analyse the geochemical abundance index (GAI, Förstner *et al.*, 1993) which assesses the enrichment of the samples by major elements.
4. Water quality prediction – to determine the risk of metalliferous drainage occurring under neutral conditions (ASLP INAP, 2009).

The ore material is considered a single unit for the purposes of characterisation (Appendix L), but can be further subdivided based on weathering characteristics into 3 main categories; oxidised, transition and fresh, of which the oxidised and transition are the only subdivisions to be mined at this stage.

Ore comprises over 518,500 tonnes of material or 4.53% of the total tonnage mined.

The ore material has been classified based on the 2012 and 2013 resource estimate models. The models are based on a wire-frame of the gold assays using quartz as a guide (quartz is the dominant lithology in which the gold occurs).

The findings of the characterisation program presented in Table 10-5 can be summarised as follows:

- The bulk tailings material is classified as benign, with minimal potential for acid mine drainage (AMD). The Risk of AMD has been found to be associated with the presence of pyrite and arsenopyrite. Increased levels of pyrite associated with mineralisation are predominantly found proximal to the gold mineralisation within the ore regardless of weathering phase.
- The ore is characterised by 75% quartz veins including banded, bucky, milky, smoky vein textures. Mineralisation occurs with variable sulphides including arsenopyrite, pyrite and galena but these minerals represent a small part of the ore. Even at depth the pyrite along fractures planes and shears appears strongly oxidised.
- The low % sulphur, and the extremely low Acid Neutralising Capacity (ANC), suggests that this material has a limited capacity to neutralise the acid generated from the oxidation of pyrite and arsenopyrite, however the arsenopyrite and pyrite content is small enough for acid generation to be minimal.
- An assessment of the elemental enrichment in the samples highlighted that all ore samples are enriched in arsenic (As) from between 8.5 to 9.1 times average-crustal-abundance. Processing of the ore material will reduce the ore to sand or silt sized particles (approximately 2 mm to 2µm) and expose the sulphides to oxidation. The use of a non-cyanide gravity circuit (with the exception of intensive leaching of a small volume of tailings concentrate) will result in no changes in pH and keep the pH of the tailings at pH ranges where As leaching is unlikely. The use of cyanide for a small volume of concentrates will increase the pH of the tailings to greater than 8. High pH conditions have the potential to leach As.

Table 10-5. Geochemical characterisation and leachate results summary for all waste rock units.

Unit Name	Phase	Lithology	Veins	Ore minerals	Alteration	APR	ABA	GAI enrichment	Leachability
Ore	Oxidised	75% quartz veins, 25% sandstones and siltstones	Banded, Bucky, Smoky and milky quartz veins	Gold, pyrite, arsenopyrite, scorodite	Moderate hematite alteration, kaolinite-limonite alteration, rare goethite (XRD analysis- 58% mass kaolinite)	Predominately non-acid producing, 1 outlier potential acid drainage	Predominately NAF, 1 outlier UC (uncertain)	As - up to 9.1 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
	Transition	75% quartz veins, 25% sandstones and siltstones	Banded, Bucky, Smoky and milky quartz veins	Pyrite, chalcopyrite, pyrrhotite, galena, and native gold	Moderate haematite alteration and weaker kaolinite-limonite alteration, with rare goethite (XRD analysis - 44% mass kaolinite)	Predominately non-acid producing, 1 outlier potential acid drainage	NAF	As - up to 8.5 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).

10.6.2 Tailings processing

The expected processing flow is detailed as follows with the process flow chart for the ore and subsequent tailings detailed in Figure 10-4.

1. ROM pad
2. crushing circuit
3. coarse gold gravity recovery
4. milling
5. fine gold gravity recovery
6. concentrate upgrade

Ore is planned to go through a crushing circuit with a jaw, cone and impact crusher; however, the crushing circuit will be modified as the scale of the operation changes. Crushed material will be fed into the jig with the table upgraded for coarse gold gravity recovery.

The remaining ore material that has not been previously captured for coarse gold recovery will be milled to liberate finer gold particles. Target final grind size is expected to be 100 - 150 micron. All material from the mill, subject to screening of oversize, will pass through a centrifugal gravity concentrator for fine gold gravity recovery.

The tails from the centrifugal gravity concentrator will then be passed through a cyclone, and underflow, being the larger and heavier particles, will be returned to the mill for further grinding. Cyclone overflow, being the finer and lighter particles, will be sent to the tailings dam. The final output of the tails is expected to be between 75 and 106 micron.

In addition to the gravity concentration, ABM will selectively recover a concentrate from the tailings stream reporting to the tailings dam, these small quantities of concentrate are to undergo intensive cyanide leaching to optimise gold recovery as it has been found during the bulk sampling that the gravity tailings retain a gold grade of 1.5 grams per tonne.

Final circuit configuration may vary depending on review of the bulk sample but will remain similar in principle.

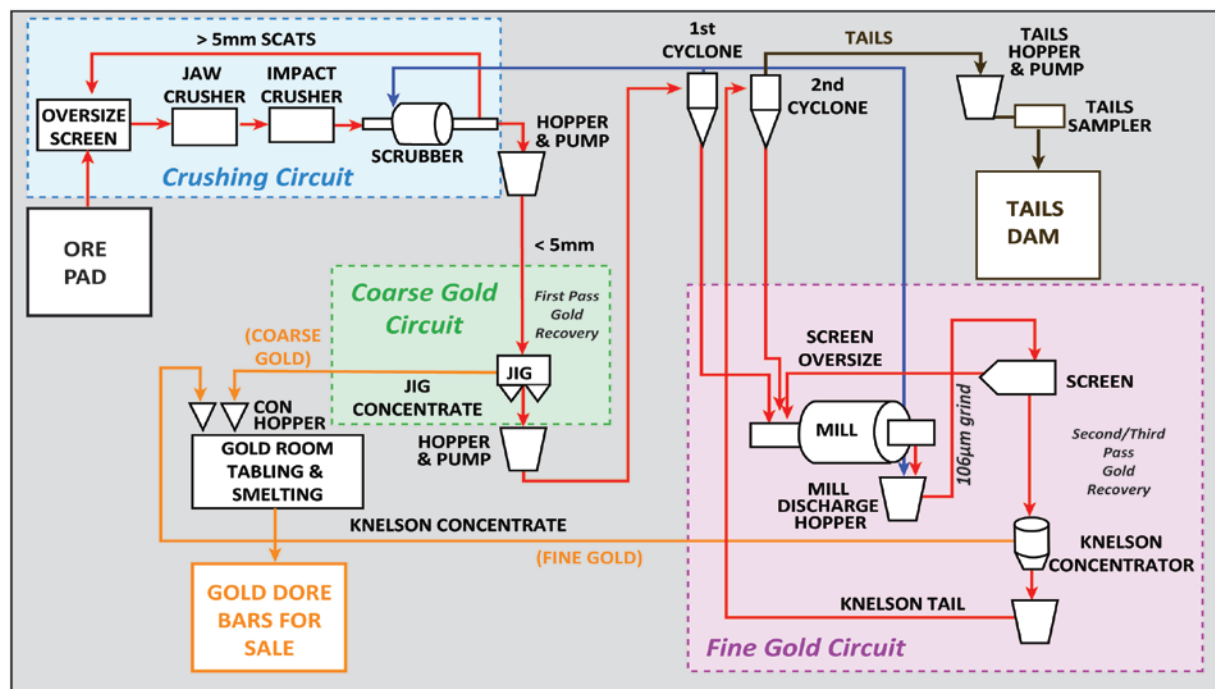


Figure 10-4. Grind and gravity circuit flowchart (Note: subject to change).

Intensive cyanide leaching would involve a small fraction of the total material with approximately 1 to 2 tonnes of concentrate recovered daily from tailings via a Knelson concentrator or similar expected to be leached. The concentrate will be leached in an intensive leach reactor, such as an Acacia reactor, a closed system that is isolated from the environment, which introduces cyanide to the concentrate material. ABM proposes to use additional modules in the system to eliminate the discharge of cyanide into the environment. Details of the process flow sheet are provided in Figure 10-5.

The modules include:

1. A recycling module to recover as much cyanide as possible from the spent leach, thereby minimising cyanide use and the amount of cyanide containing solution needing detoxification each day.
2. A detoxification module which controls the detoxification process by using sodium hypochlorite (swimming pool chlorine) as the active reagent to neutralise and break down cyanide.

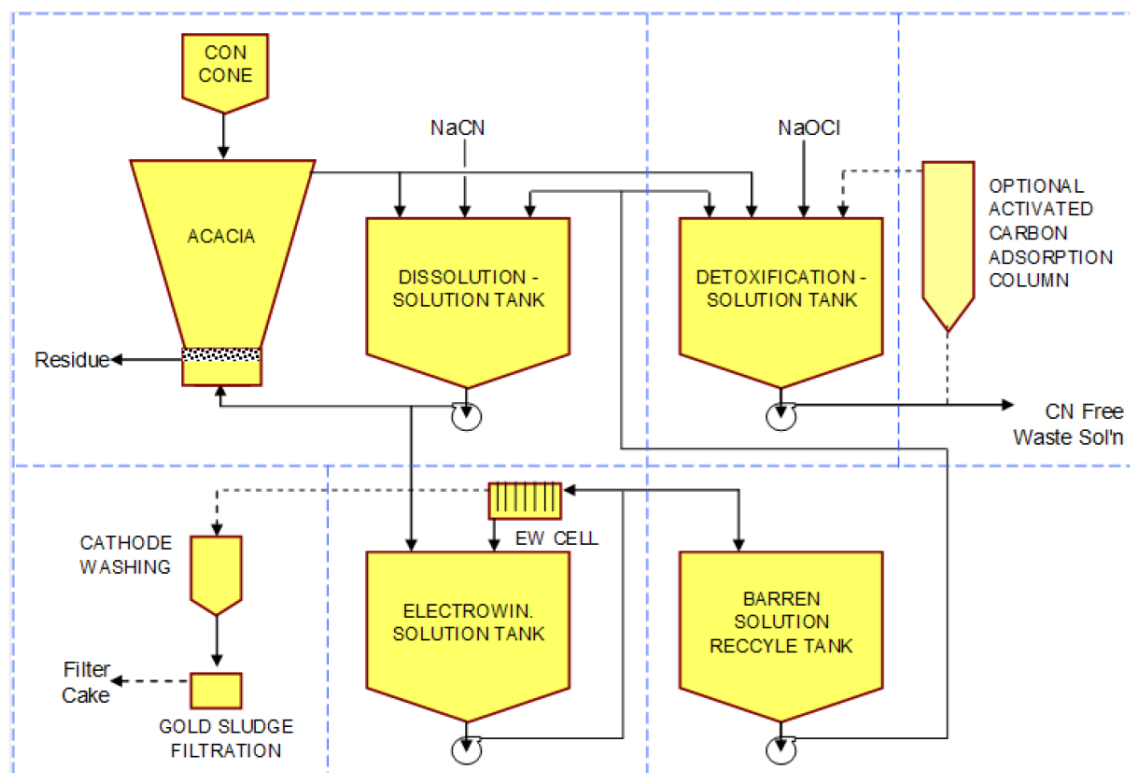


Figure 10-5. Simplified process flow diagram for a Concept Acacia Refinery System.

The waste at the end of this process will be known as the concentrate residual and will be disposed in the CRD.

To ensure the small volumes of cyanide do not have an effect on the environment, the following measures will be implemented:

- Storage and handling in accordance with recognised standards.
- Management by staff who are trained to be competent in the management of cyanide.
- Ensuring quarantine from the environment by the use of containment structures and exclusion of wildlife from cyanide solutions.
- Having secondary containment within the cyanide transfer system (including storage tanks, mixing systems and pipelines).
- Instigating preventative maintenance on storage facilities.
- Holding sufficient neutralising agent on site in the case of an accident.
- Removal of cyanide prior to deposition in the lined CRD.

In 2006, the International Cyanide Management Code was established to provide a risk based process to improve cyanide management. The code consists of nine principles relating to production, transportation, handling and storage, operations and decommissioning,

worker safety, emergency response, training and dialogue. Where practicable, ABM will align itself to the principles and related standards of the code.

10.6.3 Conceptual tailings and concentrate residual dam risk assessment.

A risk assessment and mitigation approach was utilised to ensure the design, operation and closure of the facilities will minimise the potential risk of impact to the receiving environs. The potential risks that were identified included (further detail of the risks are provided in Chapter 5: Risk assessment):

- failure of tailings dam wall and/or CRD
- tailings pipeline leak
- uncontrolled tailings dam seepage – leachates
- overtopping of tailings dam.

To minimise the identified risks a number of mitigation and management measures have been adopted with the intention of implementing them over the life of the facilities. The mitigation and management measures are detailed within Table 10-6.

Table 10-6. Risk assessment with related mitigation and management measures.

Risk/potential events	Management, mitigation and controls
Failure of tailings dam wall and/or concentrate residual dam.	• Appropriate design, construction and operation of facility to ensure structural integrity is maintained; in accordance to the principles of the ANCOLD Guidelines. • Regular independent inspections. Quality control during dam construction. • Manage the freeboard of the facility and ensure that the facility is not used for water storage, to prevent water ponding.
Tailings pipeline leak.	• Appropriate design, construction and operation of facility to ensure structural integrity is maintained; in accordance to the principles of the ANCOLD Guidelines. • Regular inspections of pipelines. Quality control during construction. • Pipelines located in earthen bunds.
Uncontrolled tailings dam seepage – leachates.	• Facility designed in accordance to the tailings characterisation work. • Leach residuals reporting to a separate Concentrate Residual Dam. • Position the tailings dam to limit seepage and construct a low permeability layer. Installation of monitoring bores and if required, recovery bores. • Position the facilities in mineralised soils with similar elevated elements.
Overtopping of tailings dam.	• Monitor the deposition of tails and freeboard to ensure available capacity and prevent subsequent overtopping; in

Risk/potential events	Management, mitigation and controls
	accordance to ANCOLD Guidelines. • Design the facilities with a spillway for a probable maximum flood event.

10.6.4 Conceptual tailings dam design

The proposed management and disposal of gravity processed tailings during mining operations will involve a multi-stage approach, comprising both below (in pit) and above ground tailings dam structures located to the south of the existing Bulk Sampling processing area. The design is based on tailings characteristics as follows:

- tailing slurry will be 30% solids
- particle size distribution (PSD) of tailings ranges below 250 microns (μm)
- specific gravity (SG) of the tailings is 1.23 t/m^3 (1.2 t/m^3 used for all calculations)
- 5% of tailings delivery will consist of leach material, to be stored separately.

Preliminary sub-surface data has indicated the expected ground conditions are that of a relatively flat surface profile consisting of shallow colluvium over residual saprolite ranging in depth from 2m to 5m and generally dipping north to south. Underlying this profile is granitic bedrock.

Stage - Cell 1A/1B will comprise two excavated pits to 5 m depth below the natural ground level, each with dimensions of 280m x 280m, capable of holding a minimum of $208,334 \text{ m}^3$ of tailings [enough for 250,000 tonnes at a nominal 1.2 t/m^3 Specific Gravity (SG)]. At completion of each pit, the tailings are to be no higher than 2 m below natural ground level. This will allow for the pits to be backfilled thus encapsulating the tailings below ground for rehabilitation or for two impoundment tailings dam cells 2A/2B to be built overlying and enclosing Cell 1A/1B. Cell 2A and 2B have the capacity to store $500,000 \text{ m}^3$ of tails each [enough for 600,000 tonnes at 1.2 t/m^3 SG] (Figure 10-6). Cell 2A/2B will comprise a 5.0m high embankment constructed in a single lift. All internal and external embankment batters will have 1V:4H batter angles and a flat crest 4m wide (Figure 10-6) this will allow for machinery access and reduce the erosion potential of the embankments. Further design details are provided in Appendix I.

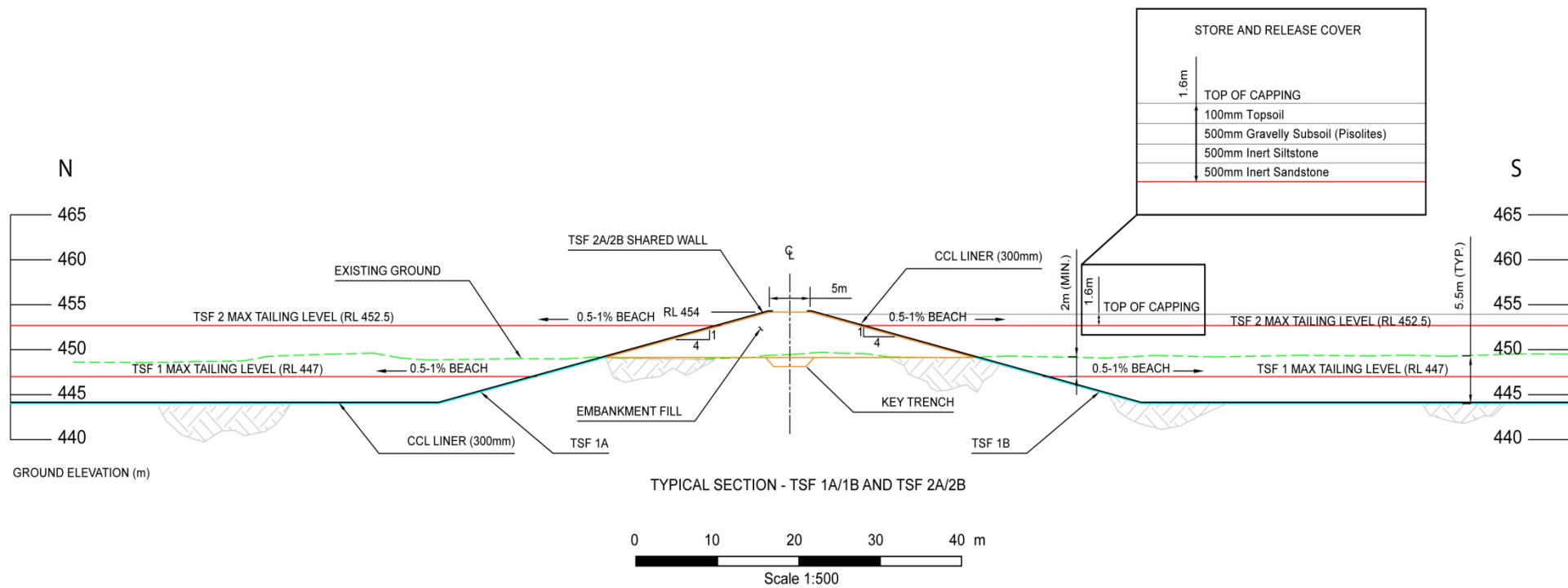


Figure 10-6. Cross Section detailing the shared wall between 2A and 2B and relationship to below ground cells 1A and 1B.

Stage - Cell 2A/2B will have the same configuration and dimensions of 370m x 370m. As with Cell 1A and 1B, Cell 2B is to be positioned to the south of Cell 2A. By adjoining Cell 2B with 2A, a common embankment will be shared. Included in each embankment design is a 0.5m deep, rip rap-lined, 20 m wide spillway to guard against uncontrolled spillage during unforeseen circumstances beyond the probable maximum flood (PMF) that could lead to overtopping of the tailings dam embankments. Depending on the suitability of the material, the embankments will be constructed from the material excavated from cell 1A and 2A or from waste mined from the pit. To limit potential seepage from the two cells either the insitu material at the tailing dam location will be conditioned and compacted or clay sourced from a borrow pit to the north of the project will be used to achieve a permeability of 1×10^{-8} . Details on the design specifications of cells 1A/1B and 2A/2B are presented in Table 10-6 and 10.7 respectively.

Table 10-6. Tailings dam cell 1A and 1B – design specifications

Proposed cell 1A and 1B characteristics	Design specific for each cell
Depth	5m
Footprint	280m x 280m (7.8ha)
Capacity	208,334m ³
Freeboard	Final tailings deposition level prior to the above ground construction of 2A and 2B embankments no higher than 2 m below existing grade (natural surface). Thus 2 metres of freeboard.
Spillway	NA
Capping Design	If project does not advance to the construction of cell 2A and 2B. Backfill the pit with excavated material leaving a 2m high elevated pad above the previous excavated cell location. Outer slopes would be battered to 1V:4H and topsoiled
Liner	Either insitu conditioning of material or clay layer to produce 1×10^{-8}
Seepage management	Maintain minimal supernatant pond. Establishment of monitoring bores along most likely seepage pathways capable of being fitted out for seepage recovery
Erosion protection	During construction a water cart will be used to suppress dust generation.
Sediment capture	Monitoring of the excavated material; if erosion is occurring construct a sediment capture drain
Engineering standard	ANCOLD Guidelines on Tailing Dam Design, Construction, Operation and Closure 2012
Monitoring	Regular visual inspections of excavation edges, stockpiled material, instrumentation and supernatant pond levels.

Proposed cell 1A and 1B characteristics	Design specific for each cell
	Monthly monitoring of groundwater.

Table 10-7. Tailings dam cell 2A and 2B – design specifications

Proposed cell 2A and 2B characteristics	Design specific for each cell
Height	5m
Footprint	370m x 370m (13.7ha)
Capacity	500,000m ³
Freeboard	The probable maximum precipitation will be approximately 820mm for a 5hr storm event. Using a coefficient of 1, the freeboard requirement is 1m with an additional 0.5m for wave run up.
Spillway	0.5m deep, rip rap-lined, 20.0m-wide spillway to guard against uncontrolled spillage during unforeseen circumstances. The spillway invert is located 0.5 m below the crest level and the supernatant pond to maintain at least 1 m below the spillway invert.
Capping design	At closure a store and release cover of 1.6m thickness will be placed over the surface. Further details are provided in the Conceptual Mine Closure Plan - Appendix O.
Liner	Either insitu conditioning of material or clay layer to produce 1×10^{-8}
Seepage management	Maintain minimal supernatant pond. Establishment of monitoring bores along most likely seepage pathways capable of being fitted out for seepage recovery
Erosion protection	All embankment batters have been designed to 1V:14H to limit water erosion. During construction a water cart will be used to suppress dust generation.
Sediment capture	Monitoring of the embankments; if erosion is occurring construct a sediment capture drain
Engineering standard	ANCOLD Guidelines on Tailing Dam Design, Construction, Operation and Closure 2012
Monitoring	Series of piezometers and inclinometers along the crest or toe of the tailings cell embankments to monitor distribution of pore water pressure. Regular visual inspections of embankment crests, embankment walls, instrumentation and supernatant pond levels.

Preliminary stability analysis of the conceptual tailings dam 2A/2B embankments was completed under the following static and seismic loading conditions:

- drained

- undrained
- pseudo-static
- post seismic.

Stability was modelled using the limit equilibrium computer program SLOPE/W with the Morgenstern Price Method of Slices adopted. For pseudo-static analysis the US Army Corp Engineers 1984 method was adopted as recommended by ANCOLD. Initial results of the pseudo-static and post-seismic stability analyses indicated that the dam will have a factor of safety of 1.2 and 1.6 respectively (Appendix I). As the analysis is conceptual in nature further fine tuning of the embankment configuration may occur as information becomes available from additional investigations of the in situ and physical properties of the material.

The tailings density of 1.23t/m^3 is based on preliminary metallurgical test work. This value will be reviewed once further tailings information becomes available from the bulk sample. With the majority of tailings composed of quartz with a low clay fraction, preliminary observations are that the bulk of the tailings settle quickly.

10.6.5 Conceptual CRD design

The proposed management and disposal of cyanide residual leach tailings during operations will involve a single CRD either lined with HDPE or clay. The design is based on tailings characteristics as follows:

- tailing slurry will be 30% solids
- PSD of tailings ranges below 250 microns (μm)
- specific gravity (SG) of the tailings is 1.23 t/m^3 (1.2 t/m^3 used for all calculations)
- 5% of tailings delivery will consist of leach material (equating to 1 to 2 tonnes daily) that will have cyanide removed (see section 10.6.2).

The sub-surface profile is similar to the tailings dams as the CRD is located directly to the north of tailings cell 2A.

The CRD is a precautionary measure designed to handle the leached concentrate. The facility will be excavated to a depth of two metres. Around the excavation an embankment of 5m will be formed from either the locally excavated material or mine waste. Once complete the facility will be located immediately to the south of the processing plant and cover an area of $190\text{m} \times 190\text{m}$ (Figure 10-1). Approximately $50,000\text{m}^3$ of material is to be deposited into the facility. With only 1 to 2 tonnes being deposited daily and annual pan evaporation in the range of 2400 to 2800mm, evaporation will remove a large component of the tailings water. All internal and external embankment batters will have 1V:4H batter angles with a flat crest

measuring 10 wide (Figure 10-7); this will allow for machinery access, room for a trench to key in the HDPE liner and reduce the erosion potential of the embankments. Further design details are provided in Appendix I.

Table 10-8. CRD – design specifications

Proposed CRD characteristics	Design specifics
Depth	2m
Height	5m
Footprint	190m x 190m (3.6ha)
Capacity	50,000m ³
Freeboard	The probable maximum precipitation will be approximately 820mm for a 5hr storm event. Using a coefficient of 1, the freeboard requirement is 1m with an additional 0.5m for wave run up.
Spillway	No spillway present.
Capping design	At closure a cover of 1.6m thickness will be placed over the surface with water shed off the rehabilitated dam. Further details are provided in the Conceptual Mine Closure Plan - Appendix O.
Liner	HDPE or clay liner.
Seepage management	Establishment of monitoring bores along most likely seepage pathways capable of being fitted out for seepage recovery
Erosion protection	All embankment batters have been designed to 1V:4H to limit water erosion. During construction a water cart will be used to suppress dust generation.
Sediment capture	Monitoring of the embankments; if erosion is occurring construct a sediment capture drain
Engineering standard	ANCOLD Guidelines on Tailing Dam Design, Construction, Operation and Closure 2012
Monitoring	Regular visual inspections of embankment crests, embankment walls, surrounding area, liner, instrumentation, supernatant pond levels and critical ancillary infrastructure.

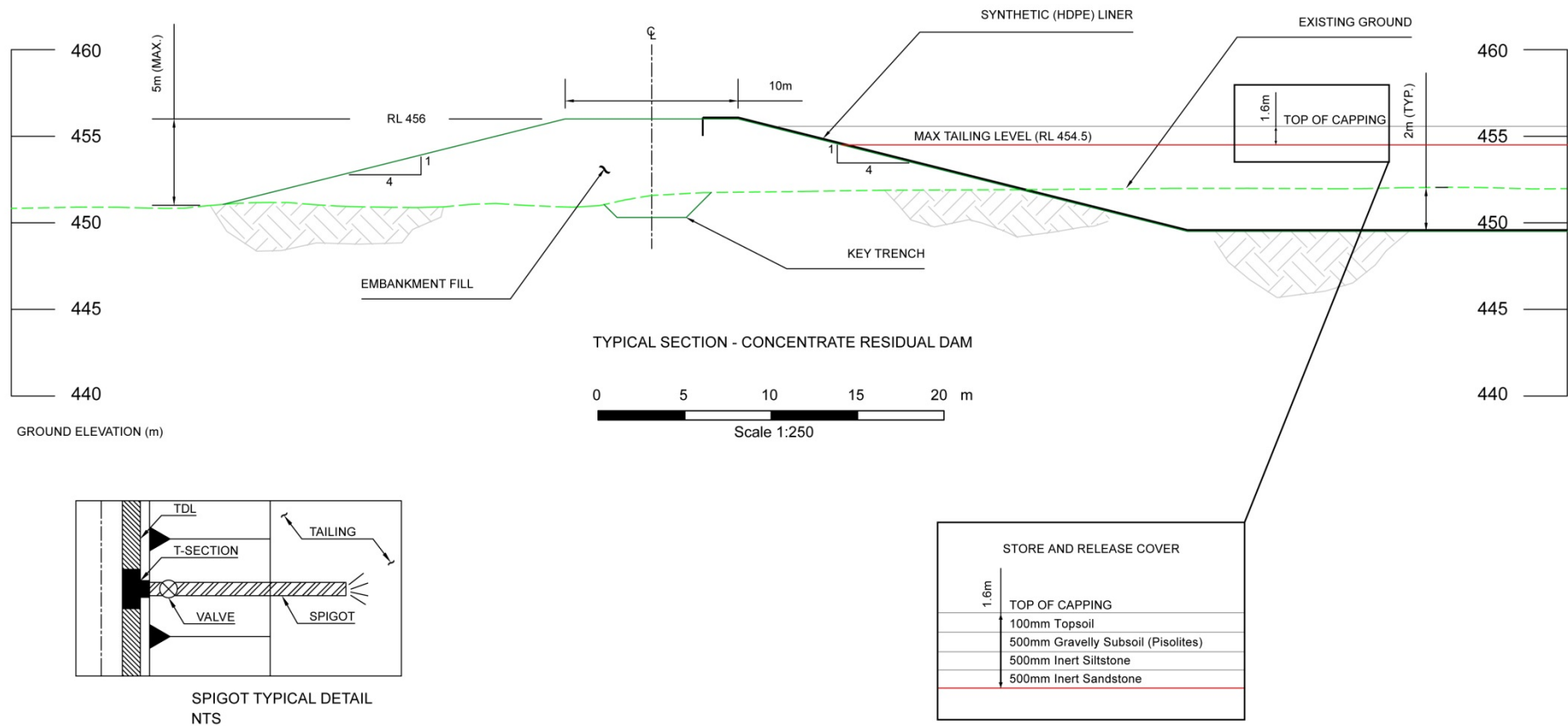


Figure 10-7. Cross section detailing the CRD embankment.

Stability was not modelled on the CRD as at this conceptual stage the wider embankment design with a significantly wider crest is considered more inherently stable than the tailings dams which had sufficient preliminary factors of safety. With the analysis being conceptual in nature further fine tuning of the embankment configuration may occur as information becomes available from additional investigations of the in situ and physical properties of the material. An analysis will be performed on the final design.

10.6.6 Tailing deposition and water management

Tailings will be pumped along a bunded pipeline from the mill to the tailings dam for sub aerial discharge via a spigotted system located at regular intervals along the embankment perimeter. The spigots will be operated in sequence around the facilities to develop a tailings beach which forces supernatant water to flow to the centre of the pond for recovery by a decant pump for re-use at the mill. This system will encourage a geometry of beached tailings to control the position of the decant pond away from the embankments to lower the risk of seepage whilst maximising freeboard for any unexpected rain events. Additionally, sequential spigotting will produce relatively thin layers of tailings allowing preferential drying to assist in the formation of high in-situ tailings density with low permeability close to embankment walls.

The tailings concentrate material will be pumped to the CRD once processed by the intensive leach reactor. As only 20 cubic metres will be deposited daily the water contained in the slurry will be allowed to evaporate given the dry climate and high evaporation rates of the Tanami Region.

10.6.7 Conceptual tailings dam seepage analysis

Conceptual seepage was modelled using SEEP/W a computer program used to analyse steady state and transient seepage under saturated and partially saturated conditions. Modelling evaluated the effect of no liner, a 300mm thick clay liner and a HDPE liner (only for the CRD). The analysis quantified potential seepage through the base of the tailings dams and CRD over a ten year period.

Adopting overburden horizontal hydraulic conductivity of 3×10^{-5} and a tailings value of 2×10^{-7} within the unlined tailings cells 2A and 2B, seepage increased the groundwater phreatic surface by 11.4 metres. The effect of reducing the conductivity to 1×10^{-8} either by a clay liner or insitu conditioning of the foundation material almost halved the seepage with a phreatic surface developing in the tailings cells. As this is a preliminary analysis, further work during the design stage is required to investigate insitu permeability and the possibilities of higher permeability zones that may affect localised seepage.

A clay and HDPE liner were modelled within the CRD. The clay liner over a ten year period produced minor infiltration into the foundation, while the HDPE liner (horizontal hydraulic conductivity of 1×10^{-14}) had almost no infiltration over the period. Further details on the analysis are provided in Appendix I.

10.6.8 Seepage management measures

A monitoring bore network will be established around the tailings dams and CRD to test both the up and down gradient water levels and quality. Each bore will be constructed with a capacity to be fitted out for seepage recovery if there is a requirement in the future. The indicative locations of the bore are detailed in Figure 10-1 and are subject to change based on further site investigations that may identify structural influences on water movement. Further details of groundwater and surface water monitoring are provided in Appendix F: Water Management Plan. As a minimum, provisions to be made during operations to minimise seepage will include:

- sequential spigotting to discharge tailings in thin layers to improve preferential drying and to attain high in situ densities
- maintaining an appropriate tailings deposition regime to keep the supernatant water pond in close proximity to the decant system
- where practicable, minimising the size of the supernatant water pond.

10.6.9 Tailings dam and CRD monitoring

Monitoring of the tailings dam and CRD is to include both geotechnical and geochemical monitoring. Geochemical monitoring will include surface water and groundwater to monitor for potential changes in water quality over time from the existing site conditions. ABM will perform monthly monitoring of:

- groundwater quality bores around and water within the tailings dam to detect changes in water quality
- groundwater levels around the tailings dam to detect excessive seepage migration.

The proposed operational monitoring will be extended to include the closure phase to ensure a continuous series of data is available to aid in demonstrating the trends in water quality and levels over time. Data will be assessed at regular intervals to monitor the presence of any developing trends so that management measures can be implemented if required. As part of the obligations under the MMP, monitoring data is submitted annually.

In addition, regular geotechnical monitoring of the tailings dam and CRD will take place. A network of piezometers and inclinometers will be established along the embankment crests or toes. The network will enable monitoring of the distribution of pore pressures in the dams

and allow for overall assessment of the facility stability during operations, and seismic or climatic events of significant magnitude. In conjunction regular inspections of the embankment crest, embankment walls, liner, instrumentation, supernatant pond level and other critical ancillary infrastructure will be undertaken in accordance with the operational and maintenance plan that will be produced during the final tailings dam and CRD design stage.

10.6.10 Tailings dam and CRD rehabilitation

Rehabilitation and decommissioning is detailed in Chapter 11 – Closure and rehabilitation. The closure objectives for the tailings dam and CRD are to produce landforms that are safe, stable and non-polluting which can be integrated into the surrounding environs and land management practices. To achieve the closure objectives the tailings dam and CRD design and planning has included the following elements:

- Formation of a low permeability layer in the tailings dam to limit seepage.
- Operation of the decant pond in the centre of tailings dam to limit seepage through the embankments.
- Geochemical testing of the tailings material indicating that it is unlikely to create acid mine drainage.
- Monitoring and if required water recovery along structural influences.
- The outer embankments designed with 14 degree (1V:4H) walls to limit erosion.
- Separation of tails into two dams:
 1. Residual cyanide leached material deposited in a lined evaporative dam (referred to as the CRD). Cyanide removed prior to deposition.
 2. Non cyanide tailings deposited in tailings dam cell 2A and 2B with insitu permeability barrier or clay lining.
- At closure the capping of the tailings dam with a store and release cover to limit water egress into the tailings. Capping of the CRD to shed water away from the facility.
- Locating the facilities on a mineralised soil with a similar geochemical signature (i.e. elevated in arsenic) to the tailings to reduce the effect of the tailings.

At closure the existing groundwater monitoring will be continued to provide detail on the water levels and water quality to assist in demonstrating closure completion criteria have been achieved.

10.6.11 Future work

A conceptual design for the tailings dam cells and CRD have been presented in Section 10.6. Prior to final design and construction the following ground breaking investigations are required to ensure the design reflects the natural variations within the proposed construction location:

- A site assessment and geological mapping to examine the in situ characteristics of rock and soil materials.
- Exploratory drilling and test pitting (for site characterization, material permeability and identification of potential borrow characteristics).
- In situ testing including water pressure (packer) testing and falling/constant head permeability testing, shear vane, dynamic cone penetrometer and SPT.
- Laboratory Testing (moisture content, particle size distribution, Atterberg limits, compaction, CBR, triaxial, point load, pinhole dispersion, emerson class and slake durability).
- Geotechnical analysis (seepage, slope stability, piping risk assessment).

Information and data from the above surveys will aid in refining the design to improve the operation and management of the facilities. Approvals for these further refinements will be sought under the MMP.

10.7 Waste rock characterisation and management

10.7.1 Waste rock locational considerations

At the Twin Bonanza project, ABM proposes to construct two waste rock dumps to store an estimated total of 10.9 Mt of overburden that is removed during the extraction of ore. The northern waste dump will receive waste material from the Old Pirate deposits. Once constructed the northern waste rock dump (NWRD) will attain a nominal height of 20 m with a footprint of 41.8 ha. The southern waste rock dump (SWRD) will receive waste from the Old Glory and Golden Hind deposits with a footprint of 18.8 ha and a nominal height of 16.5 m. The two WRDs have been located to the west of the pits based on a number of considerations:

- Limited surface water will intersect the dumps as the upstream catchment is reduced due the presence of the pits.
- The location avoids any Aboriginal heritage sites.
- Avoidance of an area of known bilby activity and preferred habitat.
- Close proximity to the pits.
- Positioned outside of the zone of instability.
- Positioned in a zone of mineralised soils similar to the chemical signature overlying the proposed pits.

ABM proposes using benign waste rock units (such as sandstone which are stable and chemically benign) for the purposes of constructing the outer batters of the WRD.

10.7.2 Waste rock characterisation chemical

The waste rock geochemical evaluation focused on whether the four defined rock units, after excavation, will pose a threat to the environment as a result of acid mine or metalliferous drainage. These investigations were also used to establish the most appropriate form of management and design parameters for the WRD constructed post excavation.

ABM has undertaken geochemical and leachate assessments of the waste rock units, which are characterised in a memo written for the purposes of this EIS and contained in Appendix M. The waste rock characterisation memo has been peer reviewed by technical consultants Soilwater Group (Appendix N).

The waste rock was split into four key rock units within the proposed pit shell, excluding the ore. Table 10-9 highlights the indicative volumes for each respective waste rock and ore component. Each of the five units have been further divided based on weathering characteristics and are grouped into 3 main categories; oxidised, transition and fresh (Table 10-9).

Ore and fresh rock highlighted in yellow are included within the table to provide context. However, ABM is not proposing to mine this material at this stage.

Table 10-9 Rock units within the proposed pit shells, broken into units for characterisation.

Unit type	Unit name	Phase	Volume (m ³)
Ore	Quartz veins - ore	OXIDISED	144,400
		TRANSITION	51,300
Waste rock	Sandstone	OXIDISED	588,300
		TRANSITION	185,000
	Siltstone	OXIDISED	116600
		TRANSITION	52700
	Intercalated sandstones & siltstones	OXIDISED	1,721,100
		TRANSITION	390,500
	Intercalated Anomalous Arsenic	OXIDISED	943,200
		TRANSITION	334,700
	Diorite	OXIDISED	1,900

The waste rock is characterised by metamorphosed sedimentary rocks that host the mineralisation in the Old Pirate area. The grade of metamorphism varies within the greater prospect area such that primary and sedimentary textures are better preserved in some areas relative to others. The sedimentary rocks are interpreted to comprise lithic quartz and quartz lithic feldspathic arenite and related siltstone, silty mudstones and mudstones.

The analysis of the waste rock included geological logging and analytical data sourced from:

- multi-element analysis
- petrography
- XRD
- XRF
- ABA
- leachate quality – water quality

Geochemical classification involved a series of methods to determine the acid producing and leach potential of the rocks, these are detailed below:

1. Geochemical Characterisation (INAP (2009), AMIRA (2002)) - to determine acid generation in samples:
 - a. ABA
 - b. NAG.
2. APR classification - to classify the leachate samples potential to produce acidic drainage.
3. Water quality prediction - determine the risk of metalliferous drainage occurring under neutral conditions (ASLP INAP, 2009).
4. Element enrichment (GAI) - to analyse the geochemical abundance index (GAI, Förstner *et al.*, 1993) which assesses the enrichment of the samples by major elements.

Table 10-10 highlights the main findings of the geochemical characterisation. The sandstone unit is likely to have sufficient buffering capacity to inhibit AMD. In addition, the non-carbonate matrix makes the unit relatively resistant to weathering. No sulphides were observed in the rock mass except along veins and fractures, the arsenic element enrichment results are representative of the background values for the Old Pirate deposit. These properties make this unit ideal for the construction of the outer external batters of the waste rock dump, encapsulating any adverse chemical or physical units.

The siltstone unit is lithologically similar to the sandstones but with a finer grain size and higher clay / silt component; making it more susceptible to erosion. The unit was classified as non-acid forming for both the ABA and NAG/APR classifications. There are no sulphides observed within the siltstone unit, therefore any potential acid formation can be attributed to the presence of pyrite and arsenopyrite within veins.

The intercalated unit comprises a mixture of the sandstone and siltstones with minor dolerite intrusives and quartz stringers. ABA classification suggests that the unit is generally neutral in nature, as all samples reported as NAF. The minor sulphides in the unit are likely

to be a combination of visually logged pyrite and arsenopyrite in isolated veins and vein selvages. The bulk of the unit has little sulphide content.

For the purposes of waste rock management, a unit known as the intercalated anomalous arsenic unit has been defined. This unit, regardless of rock type or weathering phase, is the zone in close proximity (within 5 metres) to the ore. This zone encompasses the stringer, shear zones and fracture planes that are mineralised but not captured within the ore model. Due to alteration this zone has the possibility to exhibit higher potential for AMD and arsenic enrichment than the other units. The intercalated anomalous arsenic unit, which includes the oxidised, transitional and fresh units of the sandstones, siltstones and intercalated units also, has the potential to contain gold which may represent low grade ore in the future. The presence of sulphides, coupled with a low ANC, suggests that the rock has little capacity to neutralise any acid generated from the oxidation of pyrite, however the pyrite content is sufficiently small that acid generation is likely to be minimal. The majority of samples fall within the acid drainage characterisation of APR but have a low ability to generate acid and a low ANC to characterise them as NAF in terms of the ABA classification.

Arsenic was found to be naturally enriched in the Old Pirate area with GAI that were well above 3 times average-crustal abundances. However, the majority of the As is found to be concentrated in narrow veins within or peripheral to the ore body, with relatively small amounts present in the waste rock. Leach testing highlighted one oxidised sample which produced arsenic in the leach solution above Guidelines for Freshwater and Marine Water Quality, Australia and New Zealand Environment and Conservation Council. The majority of the As is associated with arsenopyrite and is closely linked to areas of mineralisation. The waste rock units have circum-neutral pH (average 6.3) and the presence of iron oxides will likely limit the amount of arsenic that could be potentially liberated from the small amounts of arsenic containing minerals.

10.7.3 Waste rock characterisation physical

Based on geological logging and field observations the most resistant unit to erosion and potential weathering (i.e. breakdown of the rock structure over time) was the oxidised and transition sandstone unit. A 300kg sample of oxidised sandstone was collected during the bulk sampling program and sent for laboratory-scale erosion testing. A laboratory-scale rainfall simulator was used to measure the interrill (raindrop impact) erodibility (K_i) and effective hydraulic conductivity (K_{eff}) of each material, and a rill erosion test was conducted to measure the rill erodibility (K_r) and critical shear stress (T_c) of the materials under overland flow conditions. These parameters were then used within the Watershed Erosion Prediction Project (WEPP) model to determine expected average sediment yields on a range of land surface configurations. Predicted average erosion rate for near-flat surfaces (i.e. pads, roads, etc.) was negligible, at < 0.2 t/ha/yr, with approximately 90 % of the predicted erosion expected in the months of December, January, and February. In the case of waste

dump batters with a vertical height of 10 metres the erosion rate ranged between 5.1 t/ha/yr for a slope of 15° to 5.4 t/ha/yr for a slope of 21°. Erosion rate increased as the vertical batter height increased. Further details on the erosion testing can be sourced from Appendix AB.

Table 10-10. Geochemical characterisation and leachate results summary for all waste rock units.

Unit Name	Phase	Lithology	Veins	Ore minerals	Alteration	APR	ABA	GAI Enrichment	Leachability
Sandstone	Oxidised	Metamorphosed quartz feldspathic arenite	Limited amount of quartz veins	None	Moderate Goethite and hematite alteration (XRD analysis- 44.5% mass kaolinite and 3.5% goethite)	Acid/Neutral/Alkaline (could generate acid, alkaline or neutral drainage)	NAF	Arsenic - 5.8-6.6 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
	Transition	Metamorphosed quartz feldspathic arenite	Limited amount of quartz veins	None	Moderate Goethite and hematite alteration	Acid/Neutral/Alkaline predominately, one potential acid drainage sample	NAF	No Data	Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
	Fresh	Metamorphosed quartz feldspathic arenite	Limited amount of quartz veins	Disseminated pyrite <5% in isolated veins and vein selvages, isolated pyrite and arsenopyrite	None	No Data	No Data	No Data	No Data
Siltstone	Oxidised	Metamorphosed quartz feldspathic siltstones	Limited amount of quartz veins	None	None	No Data	No Data	No Data	No Data
	Transition	Metamorphosed quartz feldspathic siltstones	Limited amount of quartz veins	None	None	Acid/Neutral/Alkaline	NAF	No Data	Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
	Fresh	None in Pit boundaries							
Intercalated	Oxidised	Intercalated metamorphosed quartz feldspathic sandstones and siltstones with minor felsic intrusives	Mainly milky quartz veins (<50%) with lesser amounts of Bucky and Smokey veins	Disseminated pyrite <5% in isolated veins and vein selvages	12.5% goethite and 14.5% kaolinite	2 alkaline drainage and 4 acid drainage	4 NAF and 2 UC	Arsenic – 5.46 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
	Transition	Intercalated metamorphosed quartz feldspathic sandstones and siltstones with minor felsic intrusives	Mainly milky quartz veins (<50%)	Disseminated oxidised sulphides <5% in isolated veins and vein selvages	Goethite and hematite alteration, high proportion of clays	Acid/Neutral/Alkaline	NAF	Arsenic -4.2-8.8 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
	Fresh	Intercalated metamorphosed quartz feldspathic sandstones and siltstones with minor felsic intrusives	Mainly milky quartz veins (<50%) with lesser amounts of Bucky and Smokey veins	Disseminated pyrite and arsenopyrite <20% in isolated veins and vein selvages	None	Acid/Neutral/Alkaline or Acid drainage	NAF	Arsenic -4.2-8.8 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As).
Intercalated Anomalous Arsenic samples	ALL	Intercalated metamorphosed quartz feldspathic sandstones and siltstones (of the other two waste rock units), with minor felsic intrusives, with mineralised quartz vein stringers	Mainly milky quartz veins (<50%) with lesser amounts of Bucky and Smokey veins	Shear zones, fracture planes and stringers also host high quantities of pyrite (moderate intensity >20%) in isolated millimetre to centimetre scales	23.3mass% kaolinite, 9.6% goethite	Bulk of the samples had Acid/Neutral/Alkaline or alkaline APR's. Several samples were identified to potentially result in acid drainage	Bulk of samples NAF, 2 samples UC	Arsenic – 6.7-9.1 times average crustal abundance	High GAI for As. Water leachates at neutral pH's would indicate that there would be limited leaching of elements (As). A conservative approach would be to isolate this unit in centre of waste dump and manage oxidation of sulphides.
Diorite	Oxidised	N/A							
	Fresh	None in pit boundaries							

10.7.4 Waste rock dump risk assessment

A risk assessment and mitigation approach was utilised to ensure the design, operation and closure of the waste rock dumps will minimise the potential risk of impact to the receiving environs. The potential risks that were identified included (further detail of the risks are provided in Chapter 5 – Risk assessment):

- liberation of sediment from waste dump
- liberation of leachates from waste dump
- position of waste dump inhibits surface water flow
- reduction and/or fragmentation in threatened species habitat.

A number of mitigation and management measures have been adopted to minimise the identified risks. These measures will be implemented over the life of the waste rock dump. The mitigation and management measures are detailed in Table 10-11.

Table 10-11. Risk assessment with related mitigation and management measures.

Risk/potential events	Management, mitigation and controls
Liberation of sediment from waste dump	• Undertake erodability testing and design outer batters based on physical characteristics of the material. Assessment undertaken external batters covered by competent sandstone.
Liberation of leachates from waste dump	• Undertake AMD and water leach tests, and design the waste dump based on the chemical nature of the material. Testing has highlighted that it is unlikely that AMD or potential leaching will occur.
Position of waste dump inhibits surface water flow	• Complete surface water modelling and position waste dump according to results. Waste dumps positioned in areas with small catchments and limited surface water intersection.
Reduction and/or fragmentation in threatened species habitat	• Siting of infrastructure in areas that will least impact threatened species. • Adhere to agreed clearing boundaries as part of the EIS approval. • Manage clearing in accordance with the Biodiversity Management Plan.

10.7.5 Waste rock dump design

The objective of the NWRD and SWRD was to design landforms based on both the geochemical and physical characterisation of the rock units to be deposited. By designing the waste dumps based on waste rock volumes and characteristics the desired outcomes of stable, non-polluting landforms capable of rehabilitation could be achieved. Once the WRD locations were selected based on site specific criteria detailed in Section 10.7.1, WRD included considerations of the following aspects:

- geochemical characteristics of the rock unit
- physical properties of the rock unit
- indicative volumes of each respective rock unit
- climatic conditions
- haulage distances
- ability to cost effectively rehabilitate the landforms.

Figure 10-1 shows the location of the WRD and associated infrastructure.

No test pits have been excavated from the footprint of the proposed WRD locations, however historical drilling and a recent digital elevation model have highlighted that the terrain within the location of the WRD is gently sloping towards the west, characterised by sheet flow and colluvial cover up to 1.5 m in depth with minimal subcrop. Below the surficial cover the majority of the area is underlain by granitic rocks with a shallow weathering profile of 1 to 2 m.

As detailed in the waste rock characterisation memo (Appendix M), ABM proposes to selectively manage and position waste rock units in the WRD based on their characteristics as illustrated by Figure 10-8. The location is based on managing the less competent units with more variable chemical signatures being placed in the centre of the WRD. Compaction is limited to the wheel rolling of earthmoving equipment over the dump with the intention that the position of the rock units will limit the egress of oxygen to the trace sulphides and prevent the breakdown and subsequent erosion of more friable siltstone units. It needs to be noted that the intercalated anomalous arsenic maybe stored and processed as low grade ore due to the presence of gold. If defined as low grade ore the material will be stockpiled on the ROM pad or within the WRD footprint and managed to prevent runoff for later processing and disposal in the tailings dams and CRD as detailed in Section 10.6. If not processed as low grade material and, if not economically viable for potential processing, this unit will be placed as waste in the WRD and surrounded by more inert material (i.e. sandstone and siltstone) at closure to limit any reactivity or erosion.

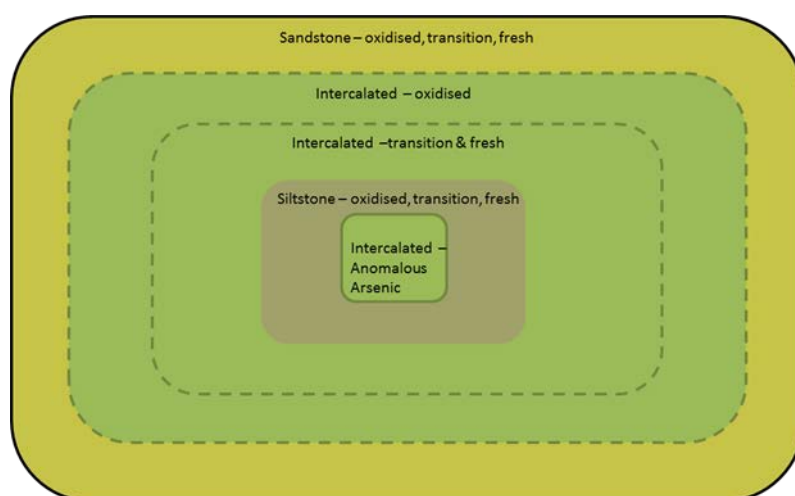


Figure 10-8. Schematic for WRD construction and proposed waste rock distribution.

From field observations of existing WRD at the Central Tanami mine (constructed of similar geological units) and the interlocking nature of the majority of the waste rock units, a detailed geotechnical stability analysis was not undertaken for the proposed WRD as the potential for stability problems is considered unlikely. Nonetheless the WRD heights have been limited to a nominal height of 20 m with the slopes consisting of two, 10 m high lifts with batters flattened off to 15°, with a 10 m wide back sloping berm between lifts (Figure 10-9). In the case of the SWRD, the first lift will attain a nominal height of 10.5 m with the second lift having a height of 6 m (Figure 10-10).

A SIBERIA landscape evolution model was developed to test and visualise long-term landform stability (Appendix AB). The model was run using the proposed WRD design over a 1,000 year period. The simulation represented a worst-case scenario, as the reduction in erosion due to surface armouring and vegetation establishment was not included in the model. Thus, the predicted erosion rates are expected to decrease to a steady-state rate, resembling background erosion rates in the region.

Visual output of this model showed:

- The waste rock dump designs do not contain any concave areas that can concentrate flow into large channels.
- The design of the berms is adequate to contain > 100 years' worth of eroded sediment from the upper portion of the landform. This means that the majority of eroded sediment is contained on the landform.
- The berms are predicted to fill only after >100 years, at which point some overtopping and more gully formation is possible. Overall, the current waste rock design is expected to perform well in terms of erosion resistance, with a safe, stable and sustainable WRD likely to be produced.

- Given the available materials for construction of the outer landform surface, the majority of sediment is expected to be contained within the landform footprint for at least 100 years post-construction. Thus, as long as adequate vegetation cover is re-established within a 100-year period, minimal sedimentation of the surrounding environment will occur, and a safe and stable landform will remain in the long-term.

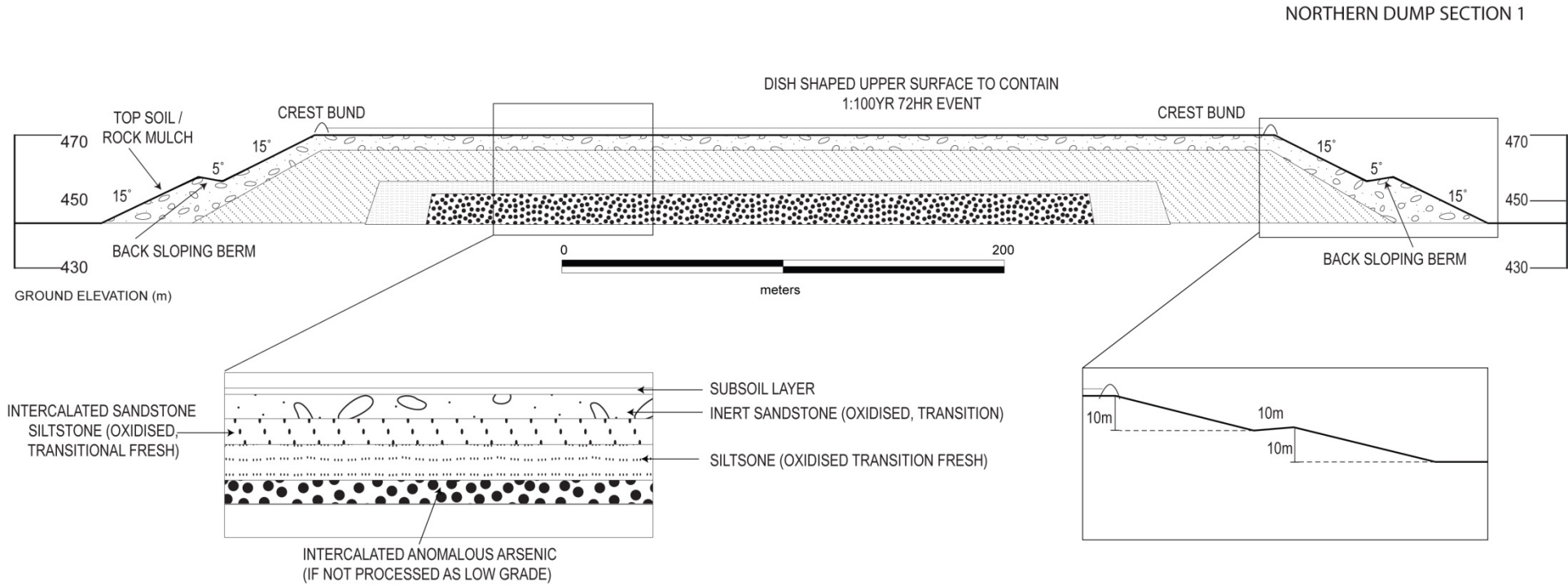


Figure 10-9. Cross section through the NWRD detailing the design and placement of the waste rock units.

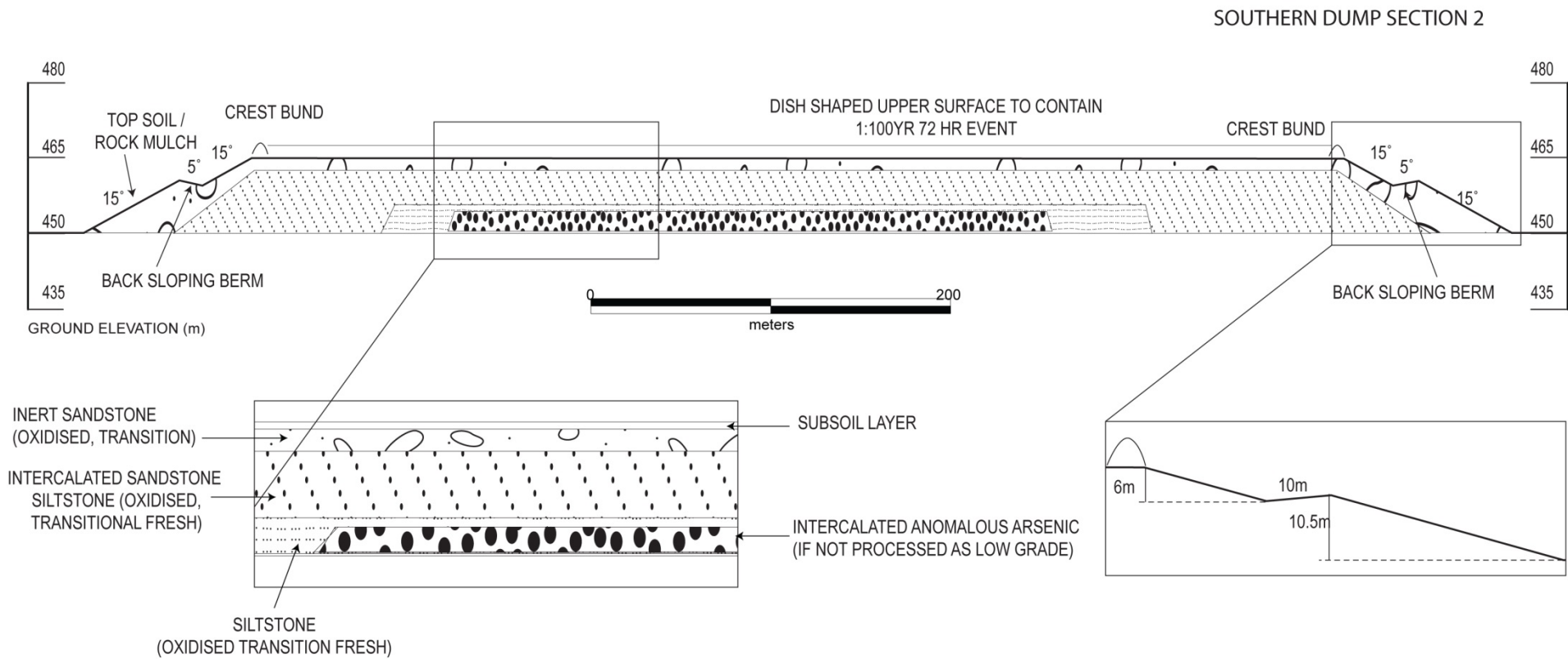


Figure 10-10. Cross section through the SWRD detailing the design and placement of the waste rock units.

ABM has proposed a NWRD and SWRD that uses the most benign and stable waste materials as the outer embankment of the waste dump and isolate, by covering with inert waste, those with the higher sulphide levels and potential for erosion. The circum-neutral pH, with the majority of the samples having ANC/MPA ratios greater than 2, suggests that the pH of the waste rock units should be well buffered; however, ongoing surface and ground water monitoring will be implemented.

10.7.6 Waste rock dump surface water management

The objectives of surface water management are to:

- limit erosion as a result of flow concentration
- limit sediment loads to the surrounding environment
- prevent sheet flow (unrelated to mining) mixing with water that has flowed across the site.

Surface water that has not come into contact with mining infrastructure or landforms will be diverted around the mine site including the waste rock dumps, CRD and tailings dams in order to minimise the potential water volumes that will need to be managed. Diversion structures will be designed for the expected peak surface water flow rate for a 1:100-yr event with all bunds and diversion drains constructed from compacted nature soils due to their high gravel content. Further details of surface water management are presented in Appendix E: Erosion and Sediment Control Plan. Where water has come into contact with disturbed areas and has the potential to transport sediment this water will be passed through sediment basins designed as flow through systems that remove $\geq 90\%$ of particles $\geq 0.045\text{mm}$ in diameter during a 1:100-yr peak flow event. The basins are designed with a settling zone depth of 0.6 m, sediment storage depth of 0.6 m and a freeboard of 0.3 m. Discharge from the basins will be via a rock armoured spillway. The upper surface of the waste rock dumps will be designed to be inward sloping to trap any rainfall during a 1:100yr 72hr event that falls on the upper surface and to prevent it from running down the slopes.

10.7.7 Waste rock dump monitoring

Monitoring of the waste dumps will include elements of sediment, erosion and geochemical monitoring. Geochemical monitoring will include surface water and groundwater to monitor for potential changes in water quality over time from the existing site conditions. Monitoring will encompass:

- monthly checks of groundwater quality from bores around the waste rock dumps to detect changes in water quality
- visual assessment of erosion after rainfall events
- monitoring of dust as part of air quality

- monitoring of surface water will only occur when surface water flows are present due to the distinct wet season and semi-arid Tanami climate.

Further details are provided in Appendix F: Water Management Plan. As the monitoring is reviewed, additional monitoring points may be added. ABM proposes doing this under the annual MMP process.

The proposed operational monitoring will be extended to include the closure phase to ensure a continuous series of data is available. This will aid in demonstrating the trends in water quality over time. Data will be assessed at regular intervals to monitor the presence of any developing trends so that management measures can be implemented if required. As part of the obligations under the MMP, monitoring data is submitted annually.

10.7.8 Waste rock dump rehabilitation

Rehabilitation and decommissioning is detailed in Chapter 11: Closure and rehabilitation. The closure objectives for the WRD are to produce landforms that are safe, stable and non-polluting that can be integrated into the surrounding environs and land management practices. To achieve the closure objectives the WRD design and planning has included the following elements:

- physical and geochemical characterisation of the waste rock units
- design of the WRD to manage each of the rock units
- monitoring and if required water recovery along structural influences
- the outer slopes composed of two lifts with 15 degree [(1V):(3.7H)] slope angles to limit erosion
- 10 m wide back sloping berm between lifts to catch sediment from the higher slopes
- at closure the integration of a rock mulch consisting of rock and topsoil to armour the waste dump slopes and promote vegetation establishment
- locating the dumps on a mineralised soil with a similar geochemical signature to the waste rock units to reduce the contrast.

At closure existing groundwater monitoring will be continued to provide detail on the water levels and water quality to assist in demonstrating closure completion criteria have been achieved. Additionally, erosion monitoring will be undertaken. Should any significant erosional areas develop repairs will be carried out as required.

10.8 Topsoil and rehabilitation stockpiles

The top 100mm of soil known to contain the nutrients and seed bank will be recovered for use as topsoil for soil profile establishment during rehabilitation. Recovered topsoil will be placed in a number of locations across the site. At each location topsoil is to be paddock dumped to improve water infiltration and maximise the surface to volume ratio thus improving natural vegetation establishment. This stockpiling technique is aimed at limiting erosion of the topsoil. Soil analysis has indicated the soils are reflective of the semi-arid Tanami region in that they are strongly acidic, non-saline, non-sodic, low in nutrients and organic carbon highlighting the arid conditions with low fertility and pedogenic development. The topsoils have the potential for dispersion once disturbed due to the lack of salts. Visual assessment indicated the soils are prone to slaking but do not disperse. It was also found that soils with higher fractions of clay are the most prone to breakdown. During rehabilitation it is proposed that topsoil will be blended with competent waste rock and integrated to the landform or surface; this will allow the layer to armour overtime thus reducing erosion. Further details on soil and erosion analysis are presented in Appendix AB.

Once topsoil has been removed, the top 800mm to 1000mm of the pits (representing the shallow gravel and saprolite horizon) will be selectively mined and stockpiled for later used in rehabilitation. This will ensure appropriate material is available for the capping of the tailings dam, CRD and top surface of the WRD. In addition, to enabling the construction of the 1.6 m thick tailings dam cover, a zone of inert siltstone and sandstone identified in the geological model will be separately stockpiled. The pisolite/gravel, siltstone and sandstone stockpiles will only attain a height of ≤ 10 m and are to be tiered with a trench excavated around the perimeter of each to limit sediment liberation.

10.9 Pit areas

The project will create two pits with a combined area of 22.5 ha. Soils disturbed in the open pits are colluvium sheet wash areas comprising mostly shallow loamy sands overlying gravel in a sandy loam matrix to a depth of between 500mm to 1000mm. This material will be selectively mined and stockpiled for used in constructing the covers over the tailings dams, CRD and top surface of the WRD.

Once excavated, the void will be bunded to prevent access and limit sheet flow from entering the pit. During operations potential opportunities to back fill the mining voids with tailings or waste rock will be explored. Backfilling will only occur provided:

- The process of backfilling does not sterilise a potentially viable mineral resource in the future.
- There is no possibility that the safety of future underground mining operations is jeopardised.